ANALYSIS OF SPEECH SOUNDS THROUGH DIGITAL COMPUTER SIMULATION OF THE COCHLEA

By

ORLEY LEON LAKE

Bachelor of Science
University of Kansas
Lawrence, Kansas
1961

Master of Science
University of Kansas
Lawrence, Kansas
1967

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
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Thesis Approved:

Victor W. Bolie
Thesis Adviser

Jack Allison

Rao Yarlagadda

Forest D. Whitfield

Charles M. Bacon

D. Durham
Dean of the Graduate College

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CHAPTER I

INTRODUCTION

A reliable scheme for real time pattern recognition of speech phonemes, speech syllables, or words would have considerable impact on advancing control technology, computer technology, communication technology, and business machine technology. Such a recognition scheme would make possible the ability to control servomechanism devices by voice. It would be possible to program and communicate with a computer by voice. A voice-input/teletype-output communication system would be possible. Voice-input typewriters, voice-input desk calculators, and voice-input accounting equipment would all come into the realm of possibility with a scheme for automatic speech recognition.

In anticipation of the great potential value of an effective automatic speech recognition methodology, much effort has been expended toward achieving machine recognition of human speech over the past three decades. However, machine recognition of human speech has not been achieved beyond the bounds of a very limited vocabulary. This fact is well illustrated by Lindgren (1).

1.1 Review of Previous Speech Recognition Research. Earnest efforts to analyze speech sounds and patterns were started in the 1940's and continue to be conducted. Varied techniques for speech analysis have been employed. Flanagan (2) categorizes these techniques for speech analysis chiefly into three categories: spectral analysis, formant analysis, and pitch analysis.

The spectral analysis technique was the first technique employed for analyzing speech phonemes and sounds. The prominence of this technique was brought about by the development of the sound spectrograph. As described by Koenig, Dunn and Lacy (3), the sound spectrograph is a wave analyzer which makes use of a variable-frequency local oscillator and a heterodyne circuit, together with recording equipment to provide a permanent visual record of the distribution of sound energy in terms of both frequency and time. Such records are commonly called sonographs. As indicated by Lindgren (1) voice pattern recognition schemes have been attempted by trying to identify speech sounds from the sonograph records; hence transforming the pattern recognition problem for sound into an optical pattern recognition problem. However, this scheme is basically limited to that of vowel recognition.

Another spectral analysis technique that has frequently been used is to provide a voiced sound input to a bank of parallel filters each tuned to a specific frequency within the voice sound spectrum. The outputs of the filters are sampled in time. This provides, for the duration of a particular voiced sound, a pattern which can be analyzed to obtain frequency characteristics peculiar to each particular voiced sound. This approach is described by Hughes (4,5,6) for some voiced phonetic sounds. Again, development of a pattern recognition scheme from this technique for speech analysis is limited since the frequency characteristics of several of the phonetic sounds are nearly alike.

Still another useful technique for spectral speech analysis makes use of the Fourier transform, from which the frequency amplitude-density spectrum of an aperiodic function of time may be obtained. Hence, phonetic sounds which are aperiodic can be analyzed by this technique. In order to accomodate speech signal segments of finite duration, the Fourier transform can be modified to provide a short-time transform. This technique is described by Flanagan (2). Noll (7) employed this technique for vocal pitch detection.

Formant analysis of speech sounds has in recent years been widely employed. Fant (8) defines a formant frequency as the position on the frequency scale of the peak of the spectrum envelope drawn to enclose the peaks of the harmonics. He also defines a formant level as the peak value of the spectrum envelope at the frequency of the formant. Formant analysis of speech sounds is a special case of spectral analysis, and involves the determination of the natural formant frequencies of the voiced sound and the tracking of these frequencies and their levels during the time period of sound utterance. Normally only the first three formant frequencies are tracked. The three-dimensional trajectory of each formant frequency (i.e. frequency and amplitude vs. time) as well as the frequency trajectories of the first formant frequency vs. the second or third formant frequency are tracked. The voiced sounds are thus analyzed to determine characteristics that will distinguish one voiced sound from another.

Holbrook and Fairbanks (9) have employed formant analysis to determine the characteristics of the diphthong phonetic formants and their transitional changes. A typical example of a diphthong phonetic is that of "ah-ee" in the voiced sound "eye". The Holbrook-Fairbanks technique of analysis has not led to a clearcut scheme for voice recognition, due to close similarities of formant characteristics of many of the voiced sounds.

Matthews, Miller, and David (10) have employed the technique of pitch-synchronous analysis of voiced sounds to analyze the vowels. Assuming the definition of pitch to be the fundamental frequency of vibration of the vocal cords during voiced sound emission, vowel waveforms were segmented into pitch periods for analysis by use of the Fourier transform. This procedure gives a spectrum which is approximated by resonance poles and antiresonance zeros. It is assumed that the prolonged sound extending over many pitch periods is adequately represented by the single pitch-period sample.

In terms of the complex frequency plane the vocal tract transfer function has been found to be characterized by an infinite number of poles located near the imaginary axis, by a zero at the origin, and by a pole on the negative real axis. Assuming complete closure of the vocal cords at the end of each glottal pulse, the transfer function for the glottal pulse can be characterized by an infinite number of zeros. These assumptions permitted Matthews, Miller, and David to obtain, from the Fourier spectrum of the voiced vowel, the transfer function for the vocal tract and the excitation spectrum of the glottal pulse. They showed that by normalizing the voice pitch of a speaker this technique produced uniformly interpretable spectra for each vowel sound over a wide range of voice pitches.

A more recent technique for speech analysis and recognition is that of feature abstraction. Falter (11) describes this technique as that of abstracting unique groups or combinations of spectral characteristics, formant structures, and time varying parameters which will selectively identify the various speech phonemes. These features can be obtained electronically for identification of each phoneme by use of appropriate decision logic circuits. Hughes (4,5,6) sought to use this technique to identify the stop consonants, with only minimal success.

Another more recent technique for speech analysis which seems promising for speech recognition involves that of using models of the cochlea of the ear and analyzing their responses to voiced sounds. This technique has emerged from the original neurological research of Von Bekesy (12), whose theory of hearing now appears in most textbooks on medical physiology.

In 1963 Glasser, Caldwell, and Stewart (13) reported the development of a preliminary electronic unit which approximates the cochlear functions identified by Von Bekesy (12). Bolie (14) developed improvements in the electronic hardware for simulating the cochlear functions, and also developed a digital computer program, which was used to aid in the design of his artificial cochlea.

1.2 Summary of Thesis Content. In this thesis a method is developed by which a normalized sample data set of voiced phonetic sounds of the English language may be obtained. The data set collected for this research is documented and catalogued to permit its use by others in future speech recognition work.

A combination of fast-Fourier transform techniques and a generalized model of the human cochlea based on the works of Von Bekesy (12), Glasser *et al*. (13), and Bolie (14), are used to generate a set of signals analogous to those encoded by the multiple fibers of the acoustic nerve. The responses of this model to each phonetic sound of the data set are presented and studied.

CHAPTER II

METHOD FOR OBTAINING A NORMALIZED SAMPLE DATA SET OF VOICED PHONEMES

2.1 Introduction. A review of the literature revealed the non-existence of documented phonetic sound data suitable for use in this research. Therefore, it was decided that the phonetic sound data obtained for this research should be documented and catalogued to permit its use by others in future related work. In this chapter the scheme employed to obtain a normalized sample data set of voiced phonetic sounds of the English language will be developed. The scheme may be divided into a three step process: (1) Collection of analog phonetic sound data; (2) Analog to digital conversion of the phonetic sound data; (3) Normalization of the digital phonetic sound data.

2.2 Collection of Analog Phonetic Sound Data. This section includes the description of the recording instrumentation, the acoustical facility and recording procedures employed for the collection of the analog phonetic sound data. Also, significant equipment characteristics and the properties of the acoustical facility are documented.

2.2.1 Instrumentation for Collection of Analog Phonetic Sound Data. The equipment used included a quality microphone located in an anechoic chamber, a broadband magnetic tape recording unit, an oscilloscope, and a two station intercommunication unit. Figure 2.1 illustrates the recording instrumentation.

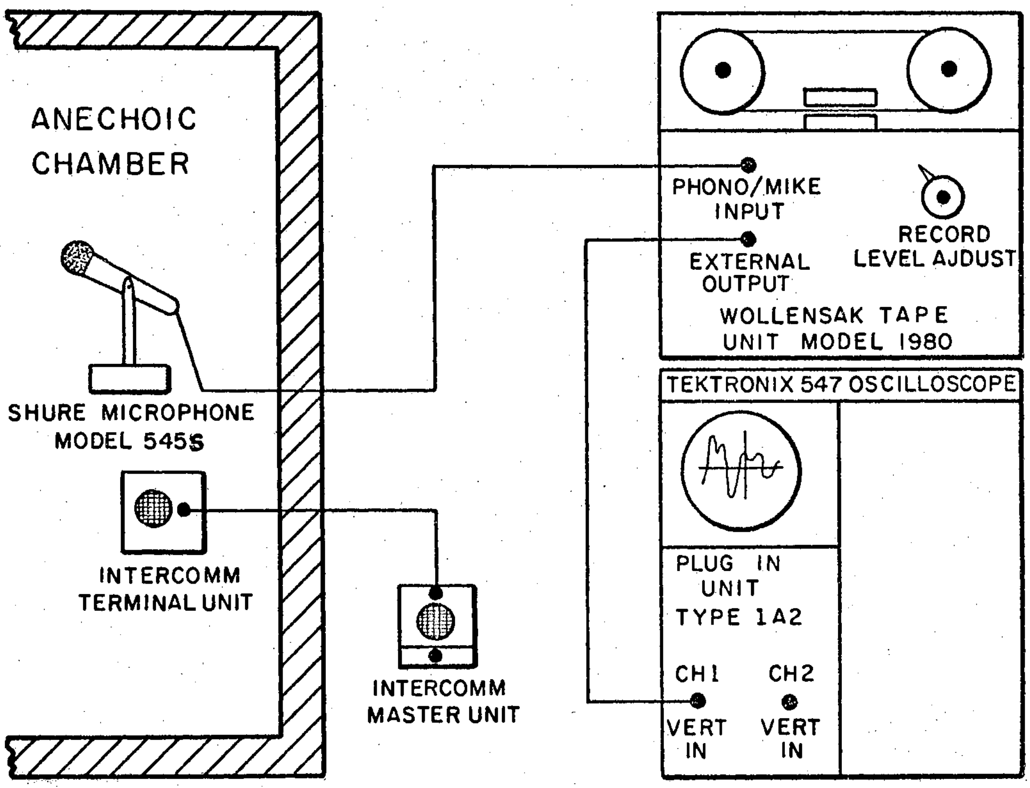

Figure 2.1. Block Diagram of Instrumentation for Phonetic Sound Recordings

2.2.1.1 Microphone Characteristics. The Shure model 545S microphone was used as the sound pickup device. It is a dynamic microphone having a frequency response range of 50 to 15,000 Hertz and a cardioid (Unidirectional) pickup pattern with a minimum front to back ratio of 15 db. Figure 2.2 shows a typical frequency response characteristic for the microphone.

The output level specifications of the microphone at 1000 Hz, assuming the microphone is wired to be compatible with a high input impedance interface, are given to be:

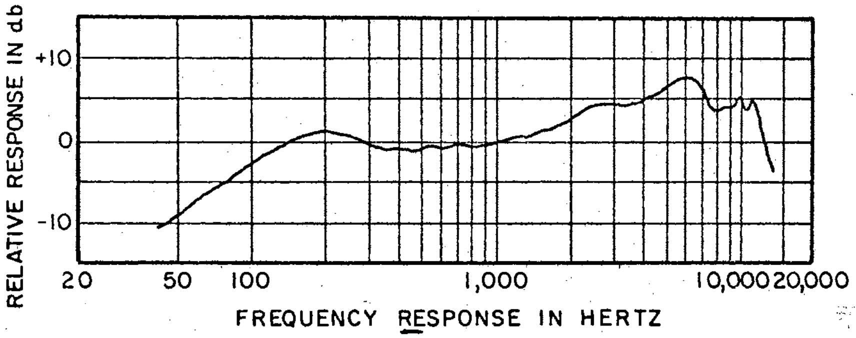

Figure 2.2. Shure Microphone Model 545S Frequency Response Characteristic

Open Circuit Voltage = -55 db[1] (1.76 mv); EIA Microphone Rating, Gm (sensitivity) = -151 db[2].

The specifications and characteristics of the microphone were compiled from Shure Brothers, Inc. (15). See Appendix D for additional information concerning the microphone.

2.2.1.2 Magnetic Tape Recorder Characteristics. Spoken phonetic sounds were recorded using the Wollensak Magnetic Tape Recorder Model 1980. The significant specifications of the tape recorder are given by Table I. To afford the highest quality recording possible, the tape recorder was operated in the monophonic mode (channel A only) at a tape speed of 7½ inches per second. To eliminate cross talk channel B record and playback amplifiers were off and the recording head was positioned to permit recording only on tape track A.

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[1] 0 db = 1 volt per microbar.

[2] 0 db = EIA Standard SE-10S, August, 1949.

TABLE I

WOLLENSAK MAGNETIC TAPE RECORDER MODEL 1980
CHARACTERISTIC SPECIFICATIONS

Characteristic	Specification
Record Speed	3 3/4 or 7 1/2 inches per second
Frequency Response	40-18,000 Hz ± 3 db @ 7 1/2 ips 40-13,000 Hz ± 3 db @ 3 3/4 ips
Wow and Flutter	Less than 0.3%
Signal to Noise Ratio	Greater than 48 db
Cross Talk	-50 db
Power Outputs	11 watts peak per channel 5 watts continuous at 5% harmonic distortion
Phono/Mike Input	High impedance input. Accepts high impedance dynamic, magnetic, ceramic or crystal microphones with -57 to -14 db output below 1 volt per microbar.
External Speaker Output	May be used with only slight power loss to drive 8 to 16 ohm loads. Output power rated 11 watts peak per channel.

2.2.1.3 Playback Editing and Communication Instrumentation. As shown by Figure 2.1 the Tektronix Oscilloscope Model 547 with Plug In Unit Type 1A2 was used to enable playback editing of recorded phonetic sounds. Communications between the speaker in the anechoic chamber and the recording operator were accommodated by a two station intercomm.

2.2.2 Anechoic Chamber. The anechoic chamber of the Acoustic Laboratory was used as the room in which the phonetic sounds were spoken by speakers for recording. "Anechoic" is an adjective meaning "echo-free". A sound chamber is said to be anechoic if a sound field can be established in it without objectionable interference from sound reflections at the boundaries. Acoustical Terminology, Standard No. S1. 1-1960 defines an anechoic room as one whose boundaries absorb effectively all the sound incident thereon, thereby affording essentially free-field conditions.

The dimensions of the anechoic chamber are 25 ft. by 19 ft. by 12 ft. Movement within the chamber is facilitated by a suspended wire mesh type of floor. The walls, floor, and ceiling of the chamber are lined with Gustin-Bacon type acoustic wedges as described by Martin and Su (16). These wedges are constructed from a fiber glass acoustic absorbing material. The design dimensions of the acoustic wedge, chiefly its length of 12 inches, eliminate reflections at the chamber boundaries of sound energy in the frequency range above 200 Hz.

In addition to the anechoic chamber's property of providing near free-field conditions from sound sources emitted within the chamber, it also provides the property of being an excellent facility for isolation and minimization of normal room background noise. Because of these properties the anechoic chamber was chosen as the facility from which the phonetic sounds would be spoken for recording.

<u>2.2.3 Phonetic Sound Recording Procedures</u>. The microphone was placed on a table located near the center of the anechoic chamber. The speaker was seated and the microphone was positioned so as to be approximately 12 to 15 inches from his mouth.

A listing of the phonetic sounds was provided to the speaker. See Table III in Chapter III for this listing. The phonetic sound to be spoken was denoted by capitalized and underlined letter or letters as they appear in a word which when spoken demonstrates the characteristic sound of the phoneme.

At a "ready to record" command, the speaker was instructed to start at his leisure, utterance of the phonetic sound, using the demonstrative word. The phonetic sound was stressed for 3 to 5 seconds. The sounds were spoken in a normal speaking voice; normal in volume and pitch, and unstrained. After each taping the recording was examined audibly. Using the oscilloscope the phonetic sound waveform was checked for distortion.

Each phonetic sound was recorded on a tape loop. Each tape loop was approximately 30 inches long, comprised of 22.5 inches of magnetic tape and 7.5 inches of leader tape. Use of the tape loops eliminated the need for post recording editing and tape splicing which would have been most time consuming and necessary had the normal method of continuous tape recording been employed. Each tape leader was labeled with speaker and phoneme identification.

2.2.4 Digital Sampling of the Analog Phonetic Sound Data. To enable digital computer simulation of cochlear responses to phonetic sounds it was necessary to convert the analog representation of the phonetic sound data into a digital representation. The cochlear simulation scheme imposes the requirement to have sample data corresponding to one period of a phonetic sound waveform. In this section the method employed to obtain sample data representative of one pitch period from the analog phonetic sound signal will be described.

2.2.4.1 Digital Sampling Instrumentation. The instrumentation employed for digital sampling of voiced phonetic sounds is illustrated by Figure 2.3. Figure 2.4 pictures the instrumentation in the laboratory. The instrumentation provided:

(1) The means by which N digital amplitude samples corresponding to one period of a voiced analog phonetic sound could be identified and recorded on a digital magnetic tape recorder.

(2) The means to permit selection, with respect to the voiced analog phonetic sound waveform, the approximate point on the waveform at which sampling was to start.

(3) The means to measure the pitch period of a voiced phoentic waveform.

(4) The means to vary the sampling rate of the sample clock.

(5) The means to vary the pulse width of the pulses from the sample clock.

Suppose that a tape loop on which a phonetic sound has been recorded is being played back. The output from the recorder's playback amplifier is connected to a 50-ohm dummy load, to the vertical input of channel A of the Tektronix 547 oscilloscope, and to the analog input of the EECO 761A analog to digital coverter. The trace provided by channel A presents a visual representation of the phonetic sound's waveform. The gating signal of time base A is supplied to the vertical input of channel B and to the scope input terminal of the sampling control unit. The trace provided by channel B is that of a marker pulse which is superimposed over the phonetic sound waveform trace of channel A. By adjustment of the delay-time multiplier potentiometer the marker pulse may be used to intensify the trace or "paint" any section of the phonetic sound waveform trace. Hence, by determining the difference between two potentiometer settings (each setting appropriately corresponds to marker pulse

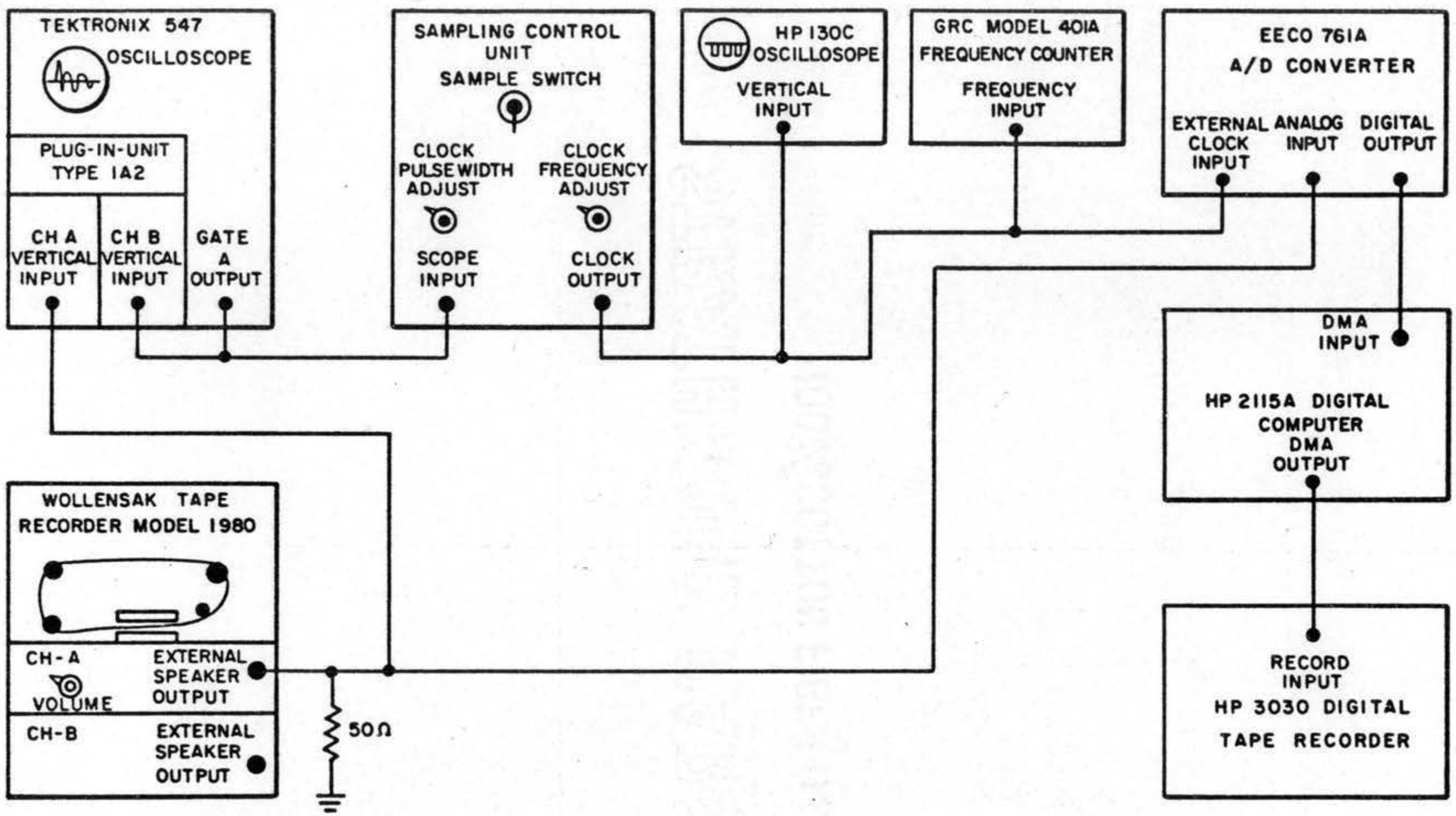


Figure 2.3 Block Diagram of Instrumentation for Digital Sampling

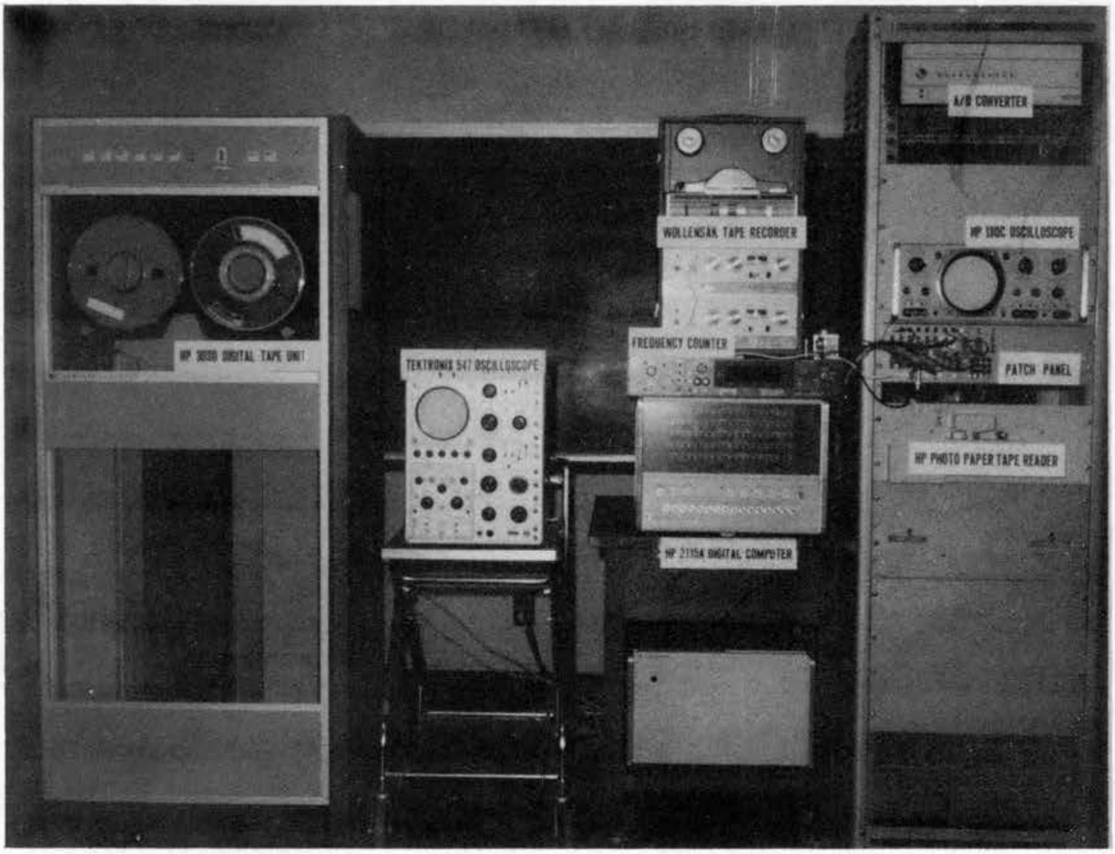


Figure 2.4. Picture of Digital Sampling Instrumentation

paintings of two repeated adjacent prominent points of the phonetic sound's waveform) the pitch period of the phonetic sound can be determined from Equation 2.1.

$$\text{Pitch Period} = (PS_2 - PS_1)S_B \qquad (2.1)$$

where

PS_2 and PS_1 are each potentiometer settings in cm.

S_B is the sweep time setting of time base B in sec/cm.

Coincidence of the marker pulse and the sample switch being on enables the sample clock to supply sampling pulses to the analog to digital converter. By this means digital sampling is started at approximately the point at which the marker pulse is painting the phonetic sound waveform. Adjustment of a potentiometer provides the means by which the frequency of the sample clock may be varied. The frequency counter is used for setting the sample clock to the desired sampling rate frequency. The width of the sample clock pulses may be varied by adjustment of a potentiometer. The HP 130C oscilloscope is used for monitoring the sample clock and for measuring the width of the clock's output pulses.

When the analog to digital converter receives the first clocking pulse, sampling is started. The digital output from the converter is in a 10 bit normal binary plus sign bit format. Using the DMA, direct memory access, feature of the HP 2115A computer, the digital data from the analog to digital converter is transferred into the computer's memory. The computer is programmed to accept the first NDATA digital samples from the analog to digital converter. By adjusting the sampling rate to correspond to NDATA samples per pitch period, sample data representative of one period of the voiced phonetic sound is obtained. After the NDATA samples have been read into the computer's memory the computer sequentially transfers these samples along with speaker and phoneme identification data to the HP 3030 digital magnetic tape recorder.

The identification data is read into the computer memory through the input switch register prior to instigation of the sampling. The identification data and sample data is recorded on magnetic tape by the HP 3030 digital recorder in a 16 bit natural binary plus sign bit format.

With this general understanding of how the instrumentation operates the details pertaining to how each equipment comprising the instrumentation functions will now be discussed.

2.2.4.1.1 Function of the Tape Recorder. The sole function of the tape recorder is to provide reproduction and amplification of the analog phonetic sounds recorded on the tape loops. To achieve this channel A of the tape recorder is operated in the playback mode at the 7½ ips speed. Channel A speaker select switch is positioned to external speaker. The output of the playback amplifier is thus connected across the 50-ohm dummy load. The amplitude of the analog voltage signal across the 50-ohm resistor is controllable by adjustment of the volume control of the tape recorder. The volume control is normally set to allow at most a ± 9 volt voltage swing of the phonetic sound signal. This assures that the voltage will not exceed the voltage conversion capability of the analog to digital converter while affording near full range utilization of the converter. The voltage signal across the 50-ohm resistor which is representative of a phonetic sound pressure wave is supplied to the Tektronix 547 oscilloscope for visual presentation of the phonetic sound signal and to the analog to digital converter for digital conversion.

2.2.4.1.2 Functions of the Tektronix 547 Oscilloscope. With respect to the digital sampling instrumentation the functions of the Tektronix 547 oscilloscope are varied. First it provides a visual presentation of the recorded phonetic sound signal. Secondly, the oscilloscope provides a marker pulse with adjustable delay. The pulse "paints" and enables sampling to start at any selected point on the phonetic sound waveform. Third, it is used to measure the pitch period of a phonetic sound signal. Last, the oscilloscope is used to assure that the peak output voltage from the tape recorder falls within the range of ± 9 volts.

Reference is made to Table II which lists the switch and control settings of the oscilloscope as required to permit proper operation of the digital sampling instrumentation.

With the HORIZONTAL DISPLAY switch set to B INTENS BY 'A' delayed trigger pulses are supplied to the time base A sweep generator. The pulses are generated by the delay-pickoff circuit. The delay is from the start of the B sweep and the amount determined by the settings of the MAIN TIME BASE B sweep switch and the DELAY-TIME MULTIPLIER potentiometer. This delayed trigger pulse is available from +GATE A of the oscilloscope. By supplying +GATE A to the vertical input of channel B and vertically aligning the ground reference lines of channels A and B the marker pulse super-imposed on the phonetic sound waveform is visually realized. That section of the phonetic sound waveform trace which corresponds with the variably delayable pulse is intensified or

TABLE II

TEKTRONIX 547 OSCILLOSCOPE SWITCH AND CONTROL SETTINGS AS REQUIRED FOR THE DIGITAL SAMPLING INSTRUMENTATION

Control of Switch	Setting
Horizontal Display	
Mode Control	B INTENS by 'A'
Sweep Magnifier	X1 (i.e. OFF)
Time Base A	
Triggering Switches	
Mode	AUTO
Slope	+
Coupling	AC
Source	NORM
Sweep Control	1 MSEC/CM
Time Base B	
Triggering Switches	
Mode	TRIG
Slope	+ or -
Coupling	AC
Source	PLUG-IN
Sweep Control	Optional (Normally 1 MILLISEC/CM)
Delay-Time Multiplier	Set as Desired
Type 1A2 Dual-Trace Plug-In Unit	
Vertical Display Mode	CHOP
Channel A	
Vertical Position	NORM and Ground Reference Line Aligned with Channel B Ground Reference Line
Vertical Voltage Control	5 VOLT/CM
Input Selector	DC
Vertical Input	Connected to Tape Recorder Output
Channel B	
Vertical Position	NORM and Ground Reference Line Aligned with Channel A Ground Reference Line
Vertical Voltage Control	10 VOLT/CM
Input Selector	DC
Vertical Input	Connected to the + GATE A of the Oscilloscope
Chopped Blanking Switch (rear panel)	ON

"painted" by the marker pulse. The marker pulse width is determined by the TIME BASE A horizontal sweep setting. The normal setting used was 1 millisec/cm. The pulse repetition rate is determined by the MAIN TIME BASE B horizontal sweep switch setting. The output from + GATE A is also connected to the sampling control unit. Coincidence of the first pulse from + GATE A after the sampling switch of the sampling control unit is switched on enables the sample clock. Thus, in this fashion the oscilloscope functions to generate a marker pulse with adjustable delay which is used to effect the commencement of sampling at any selected point on the phonetic sound waveform. The details pertaining to how the oscilloscope functions to provide the third and fourth mentioned functions are basic and will not be discussed. Further information concerning the operational functions of the oscilloscope can be found in the Type 547 Oscilloscope Instruction Manual (17).

2.2.4.1.3 Design and Function of the Sampling Control Unit. The Sampling Control Unit which was designed and fabricated for this research functions chiefly to generate sampling clock pulses which may be initiated by coincidence of an external marker pulse and a sample switch being in the "on" position. In addition the sampling control unit provides a means for adjustment of the pulse repetition frequency of the sample clock. Also provided is a means for adjustment of the width of the sample clock pulses. Appropriate level conversion is also provided to permit compatible operation of the control unit with the Tektronix 547 Oscilloscope and the analog-to-digital converter.

The design of the Sampling Control Unit is illustrated by Figure 2.5. Fabrication of the design was realized almost entirely by using R-series logic circuit boards manufactured by DEC, the Digital Equipment Corporation. The design specification and circuit schematic for each

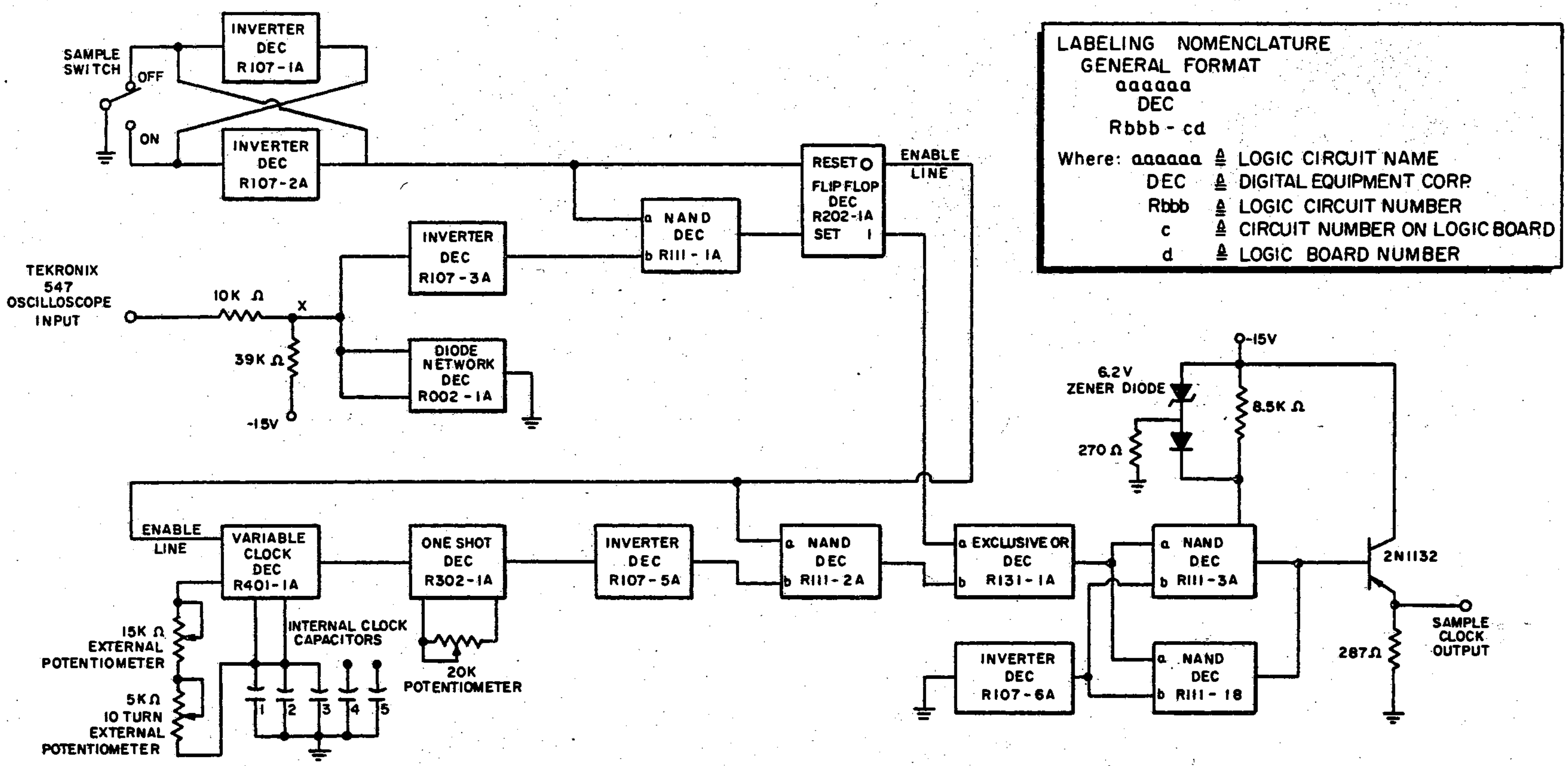


Figure 2.5 Diagram of the Sampling Control Unit

logic circuit board used are available in Appendix D. The standard logical levels of each input and output of the R-series logic circuitry are -3 volts and ground. Ground is assigned to be a logical zero while -3 volts is a logical one. Each R-series digital logic board is compatible for use with any other. The logic circuitry is capable of functioning to operational rates of 2 MHZ.

To provide interface compatibility of the Tektronix 547 oscilloscope + GATE A signal with the standard logic levels of the DEC boards the circuitry depicted in Figure 2.5 between the oscilloscope input and the input to logical NAND gate R111-1A was designed. The input signal from the oscilloscope is a repetitious positive pulse train. The amplitude of each pulse is +25 volts. Suppose the input to this circuitry is zero volts. The resistive 10K ohms and 39K ohms voltage divider establishes a voltage at X of approximately -3 volts. This implies that the output from inverter R107-3A is at ground. Now suppose the input from the oscilloscope is at 25 volts. The voltage at X is limited to approximately +0.5 volts by the shorting action of the diode network R002-1A. Thus, the output from inverter R107-3A is at ground. In this fashion the positive amplitude input pulses from the oscilloscope are converted to a 0 volt or -3 volt level.

The clock enable circuitry consists of inverters R107-1A and R107-2A, NAND R111-1A, and flip flop R202-1A. To start the clock a -3 volt input is required. With the sample switch in the off position the output of NAND R111-1A is latched at -3 volts. The outputs, 0 and 1, of flip-flop R202-1A are at 0 and -3 volts respectfully. Hence, the clock is disabled. When the sample switch is turned on NAND R111-1A becomes unlatched. Since flip flop R202-1A is set or reset by a positive level shift of -3 volts to ground the switching of the sample switch does not effects its state. However, the arrival of the first marker pulse at input b of NAND R111-1A when the sample switch is on creates a positive level shift at the output of NAND R111-1A. This level shift sets the flip flop R202-1A. The clock enable line is now set at -3 volts and the clock becomes functional and NAND R111-2A and exclusive OR R131-1A are unlatched. Switching the switch from on to off effects a positive level change on the reset line of the flip flop R202-1A which disables the clock.

Variable clock R401-1A and one shot R302-1A comprise the clock circuitry of the Sampling Control Unit. The clock produces standard 100-nsec pulses from a stable RC-coupled oscillator. The frequency of the clock is variable from 30 HZ to 2.0 MHZ. The internal capacitors provide frequency band control. Capacitors 1, 2, and 3 were used which permitted the frequency of the clock to be selected from 3.5 KHZ to 40 KHZ.

For adjustment within the frequency band two external potentiometers in series are utilized. A linear taper 15 K ohm potentiometer is used for coarse adjustment while a 10 turn 5 K ohm potentiometer is employed for fine adjustment.

The analog-to-digital converter requirements for external command clocking pulses are as follows:

(1) amplitude - Negative-going from 0 volts to -9 volts $\pm$ 3 volts

(2) width - 0.5 msec to 2.0 msec

(3) rise time - 0.1 msec maximum

(4) input impedance - 8,200 ohms to ground.

Since the nominal width of the clock pulses are 100 nano sec. the one shot R302-1A was used to provide a means to stretch the clock pulse to the desired width. Adjustment of the width of a clock pulse is provided by adjusting the external 20 K potentiometer associated with the one shot circuitry.

The remaining circuitry inverters R107-5A and R107-6A, NAND's R111-2A, R111-3A and R111-1B, exclusive OR R131-1A, the clamped biasing circuitry and the emitter follower output circuit perform varied and necessary functions. NAND R111-2A serves as a logical latch. When flip flop R202-1A is in its reset state (sample switch is off) NAND R111-2A permits no clocking pulses to pass. The NAND is unlatched when flip flop R202-1A is set and hence permits clocking pulses to pass. The combined effect of the exclusive OR R131-1A, inverter R107-6A and NAND's R111-3A and R111-1B is to provide the means by which the sample clock output signal is 0 volts when the clock is disabled. Associated with the NAND's R111-3A and R111-1B is clamped biasing circuitry. The components of this circuit connected in the fashion as illustrated in Figure 2.5 serve to convert the standard logic levels of the clock from 0 volts and -3 volts to nominal levels of 0 volts and -9 volts. Hence, the amplitudes of the sample clock pulses are compatible with the required external triggering characteristics of the analog to digital converter. NAND's R111-3A and R111-1B are operated in parallel to supply ample current for driving the external input triggering circuitry of the analog-to-digital converter. The emitter follower circuit serves as an isolation and impedance matching device between the parallel operated NAND gates and the input circuitry of the analog to digital converter having an input impedance of only 8.2 K ohms.

Associated with the operation of the Sampling Control Unit is the

HP 130C oscilloscope and the General Radio Corporation frequency counter. The HP 130C oscilloscope provides a visual representation of the clock signal from the sampling control unit. It also provides the means by which the pulse width of the clock signal can be measured. The frequency counter provides the means by which the sampling rate of the clock signal can be measured.

2.2.4.1.4 Function of the Analog-to-Digital Converter. The EECO 761A Analog-to-Digital Converter functions to convert the analog phonetic sound signals into an equivalent discrete time series representation. The conversion is performed by the method of successive approximation. This method is described by the EECO 761A Instruction Manual (18). Briefly, by this method the input voltage is compared with an analog voltage derived from a stored digital word. Comparison is made bit by bit. The results of the comparison is a corrected digital word representative of a discrete amplitude value of the analog signal. After correction each digital word is available for transfer into the HP 2115A computer memory via its DMA, direct memory access, register.

The converter operating mode, external trigger, is used to permit external sampling initiation and external sampling rate control. In this mode of operation a conversion cycle is begun each time a clock pulse is received from the sampling control unit.

Each digital amplitude sample of an analog input signal is represented in a 10 bit normal binary plus sign bit format. The accuracy of a conversion is $\pm$ 0.05% of full scale plus $\pm$ ½ LSB. The full scale voltage or maximum input voltage that can be effectively converted is $\pm$ 10.24 volts. The corresponding maximum rate of conversion is 33,000 words/sec.

2.2.4.1.5 Function of the HP 2115A Digital Computer. The HP 2115A Digital Computer is a small, 8 K memory, general purpose computer. It is well suited for on-line entry of data for subsequent handling and processing. This is provided by the computer feature called DMA, direct memory access. The DMA feature permits data to be read directly into the computer memory. Interfacing the HP 2115A with the analog-to-digital converter and the HP 3030 Digital Tape Recorder consists of inserting several standard microcircuit cards in the interface input/output slots of the computer. Computer instructions are entered from punched paper tape via a high-speed photoelectric paper tape reader. A switch register also permits a means for manual insertion of instructions or data into the computer. The HP manual entitled "A Pocket Guide to Hewlett-Packard Computers" (19) is referred to for detailed information concerning the computer.

With respect to the sampling instrumentation, the HP 2115A provides three functional tasks. These tasks are performed by the computer in accordance with an assembler language program which governs the computer's functional operations.

The chief function of the computer is to transfer sample data from the analog-to-digital converter into the computer memory for temporary storage and later transferral to the HP 3030 Digital Tape Recorder for recording. Secondly, the computer provides the means to manually insert digital identification words into its memory for later transferral along with the sample data to the digital tape recorder for recording. The third function provides the means for skipping over records previously recorded on the magnetic tape, to backspace the tape one record and to rewind the tape. To understand how the computer provides these functions can best be explained by discussing the concepts of the program used to govern its operations. An assembler language listing of the program about to be discussed may be found in Appendix C.

Suppose the computer has been loaded with the data handling program and all of the other instrumentation equipments are ready for instigation of sampling operations. To initiate computer operation the switch register switches are loaded with the address, OCTAL 100, at which the beginning instruction of the program is located in memory. The address is loaded into the computer's program register. The computer is next placed into the run mode. The computer executes the first instructions of the program. This causes the digital tape recorder to write a file mark on the magnetic tape after which the computer operations come to a halt. At this point NDATA, the number of data samples to be transferred from the analog-to-digital converter for temporary storage in the memory, is set in the switch register switches. Again the computer is placed in the run mode. The computer stores NDATA in its memory for future reference after which the computer halts. This time the switch register switches are set with the number NDATA + 5, which defines the length in digital words for a complete phonetic sound record. The run mode is initiated and the phonetic sound record length is inserted into the computer. Again the computer halts. If it is desirable to skip over K records previously recorded on the tape, the number K is entered into the switch register switches, where K may take on values 0,1,2,.... When the run mode is initiated the computer signals the tape recorder to step itself K records. After which the computer operation halts. The first of five identification words for the phonetic sound data samples to be recorded may now be set into the switch register. Having entered the word in the switch register the computer is placed in the run mode and the word is stored in the computer memory for later transferral along with the data samples to the tape recorder and then the computer operation halts. The second identification word may now be entered into the switch register for subsequent storage in memory. This sequence of operations is followed until all five identification words are in the computer memory. The first identification word designates the record number of the phoneme sample data. The second word is a number which corresponds to speaker identification. The sign bit of this word is used to denote the sex of the speaker. Word three is a number which corresponds to the phonetic sound identification. Indication as to whether the speaker was asked to speak the phonetic sound in a below normal, normal or above normal voice pitch is designated by word four. Finally, the fifth identification word directly corresponds to the measured pitch period of the speaker's voice. Assuming the fifth word is set in the switch register, initiation of the run mode allows the word to be stored in memory after which the computer goes into an operational hold loop. This is to say the computer is ready to accept data from the analog to digital converter and continually checks the status of the converter ready flag. The ready flag provides to the computer the cue as to whether it should wait a moment and check the status again or start accepting data from the converter. The ready flag is set shortly following the time a conversion command is received from the sample clock. While the computer is in the hold loop mode the marker pulse is set to paint that point on the phonetic sound waveform where sampling will approximately start. Sampling is now ready to take place. Initiation of the sampling is started by switching on the sample switch of the sampling control unit. Subsequently the computer senses that data is ready for transferral from the analog-to-digital converter into memory. The computer jumps out of the operational hold mode and starts storing in its memory the data coming from the converter. Upon the computer having stored NDATA data samples further data samples from the converter are ignored. The computer now transfers the identification words and the data samples to the digital tape recorder for recording. During the record operation the computer continually checks for digital word parity errors. When the recording is completed the computer operation halts and whether or not a parity error was found is indicated by the lights of register A. No lights imply no parity error, where as a light in the LSB position of the register indicates a parity error.

At this point the computer awaits an instruction as to whether the magnetic tape is to be rewound, backspaced one record or left in its present position. Which instruction is selected is a matter of choice. To cause the tape to be rewound to the load point the number 2 is set in the switch registers and the run mode initiated. The number 1 will cause the tape to be backspaced 1 record upon initiation of the run mode. Assuming additional sampling is desired all switches are placed off after which the computer is placed in the run mode. This action causes the computer to ready itself for the next sampling operation by branching back to that point where the first identification word is ready to be set into the switch register. These procedures may be followed until the completion of sampling. After the last record has been recorded the computer is branched manually to the beginning address of the program. The computer hence being placed in the run mode writes an end-of-file mark on the tape. The tape may then be rewound by manual operation of the tape record controls.

2.2.4.1.6 Function of the HP 3030 Digital Tape Recorder. Under the command and control of the HP 2115A computer the HP 3030 Digital Tape Recorder functions to record the identification words and the sample data that comprise a phonetic sound record. The HP 3030 Digital Tape Recorder is a nine track magnetic recorder. The recorder provides motion control, write clocks and facilities for reading and writing nine track IBM compatible magnetic tape. The computer communicates with the recorder via a command channel and a data channel. Each channel is accessible through registers A and B of the computer. Data transferral from the computer is accomplished by DMA and program control. The recorder provides three selectable read-write bit density formats of which the 800 bit per inch recording density is used. Each of the NDATA + 5 digital words is a 16 bit natural binary one bit of which is the sign. Further information concerning the tape record unit may be found in the "HP 3030 Digital Tape Recorder Manual" (20) and in the HP manual entitled "A Pocket Guide to Interfacing HP Computers" (21).

2.2.5 Normalization of the Phonetic Sound Sample Data. To provide an element of commonality between each phonetic sound record, the sample data of each was amplitude normalized. The task of normalizing the sample data was accomplished by using the IBM 360 digital computer. Using the digital tapes which were created during the sampling process as input data, two programs were used to govern the normalization of this data by the computer. To facilitate permanent records and further utilization of the sample data each normalized phonetic sound record was punched on IBM cards. To provide a graphical record each normalized phonetic sound record was plotted. The plotting of the phonetic sound waveforms was accomplished by employment of the IBM 1620 computer with its associated Calcomp Plotter. The details of these procedures will now be discussed.

2.2.5.1 Normalization Computation. Recall the digital word and record formats in which the phonetic sound data was recorded on the digital tape. A digital word is represented in a 15 bit natural binary plus sign bit format. A record format is comprised of NDATA + 5 digital words. These formats are not compatible with the standard IBM 360 FORTRAN IV word and record formats for tape input or output data. The FORTRAN IV word is comprised of 32 bits of which 7 bits represent the characteristic of the digital numbers, 24 bits represent the mantissa of the digital number, and 1 bit represents the sign of the mantissa. The sign of the characteristic is self deterministic by a convention. The FORTRAN IV record format requires two additional words per record. Hence, the first step of the normalization computations was to create a new tape on which the phonetic sound records are recorded in the standard FORTRAN IV word and record format. A conversion program, written in assembler language by Witz (22), was used to generate the FORTRAN IV compatible input data tape. A listing of this program may be found in Appendix C.

To achieve amplitude normalization of each phonetic sound record a FORTRAN IV program was written. In addition to its normalizing function the program provides the means by which the speaker and phoneme identification code numbers associated with each phonetic sound record may be interpreted and the means for producing punched card decks representative of each normalized phonetic sound record. A listing of this program may be found in Appendix C.

To accomplish amplitude normalization the computer was programmed to determine the maximum absolute sample value for a given phonetic sound record. Then this value was utilized to normalize the other sample values of the phoneme record. This is stated mathematically by Equation 2.2.

$$S_n(n\Delta t) = \frac{D_n(n\Delta t)}{\max\{|D_n(n\Delta t)|\}} NF \tag{2.2}$$

where

$\Delta t = \frac{1}{F_S}$

$S_n(n\Delta t)$ - the nth normalized amplitude-time sample of the phoentic sound data

$D_n(n\Delta t)$ - the nth amplitude-time sample of the phonetic sound data

$\mathrm{Max}\{|D_n(n\Delta t)|\}$ - the maximum of the sample data set, $\{|D_n(n\Delta t)|\}$

F_S - sampling frequency

NF - an arbitrary integer normalizing factor

NDATA - data samples per phonetic sound record

n = 1,2,3,...,NDATA.

After achieving normalization and identification correlation the computer was programmed to print on paper and punch on cards the phonetic sound record in a standard record format. Illustrations of this standard record format can be found in Appendix A.

The first card of a phonetic sound record provides the following information:

(1) Initials of speaker

(2) Sex of speaker

(3) Phoneme identification number

(4) The pitch at which the speaker spoke the phonetic sound

(5) The pitch classification, below normal, normal, or above normal

(6) The corresponding pitch period

(7) The phonetic sound record number and the associated card number.

The remaining cards contain the normalized sample data. Each data card of a phoneme record is sequentially numbered and labeled with its record number. Each data card may accommodate 24 sample values.

2.2.5.2 Plotting of the Phonetic Sound Records. From the punched normalized phonetic sound records plots of the phonetic sound waveforms were drawn. To accomplish this the IBM 1620 computer and the Calcomp Plotter were utilized. A FORTRAN II program was written which when executed by the computer plotted the normalized phonetic sound sample data and appropriately labeled the plots. Examples of such plots may be found in Appendix A. The FORTRAN II program is listed in Appendix C.

CHAPTER III

DOCUMENTATION OF A PHONETIC SOUND SAMPLE DATA SET

3.1 Introduction. Employing the method and the instrumentation described in Chapter II a normalized sample data set of phonetic sounds of the English language was compiled. In this chapter the data set compiled will be documented along with comments concerning the collection technique.

3.2 Data Set Documentation. The sample data set compiled is comprised of some 262 phonetic sound records. Each record is representative of one pitch period of a phoneme's characteristic waveform. The phonemes included in the data set are listed by Table III. These phonetic sounds were selected from the International Phonetic Alphabet of the English Language.

The data set may be found in Appendix A. Each record of the data set is represented by graphical plots and by a numerical listing of the sample data. The graphical plots were reconstructed from the normalized sample data using the IBM 1620 and the Calcomp Plotter. Each plot is a point-to-point reconstruction of the sample data.

Included in the data set are the 19 phonetic sounds as listed by Table III as spoken by 12 speakers of which 7 were adult males and 5 were adult females. In addition there are 4 subsets of phonetic sound records. Phonemes (e), (i), (O), and (u) each were selected to be

TABLE III

PHONETIC SOUND LISTINGS

1. The sound (ae) as in At	11. The sound (ʌ) as in bUck
2. The sound (e) as in Ape	12. The sound (ər) as in buRR
3. The sound (ɛ) as in mEt	13. The sound (l) as in buLL
4. The sound (i) as in mEEt	14. The sound (m) as in tiM
5. The sound (I) as in It	15. The sound (n) as in toN
6. The sound (ɑ) as in gOt	16. The sound (ŋ) as in sING
7. The sound (O) as in Obey	17. The sound (z) as in buZZ
8. The sound (ɔ) as in hORn	18. The sound (ʒ) as in Jour
9. The sound (u) as in bOOt	19. The sound (V) as in Vroom
10. The sound (U) as in bOOk	

spoken by a male speaker at 8 different pitch levels of his voice. The 8 pitch levels were equally spaced over a one-octave pitch range.

Each phonetic sound is classified as being voiced. A voiced phonetic sound is produced by glottal pulse excitation of the vocal tract. They have the characteristic of being quasi-periodic. Sounds 1-12 of table III are classified as the English vowel sounds. Sound 13 is classified as a voiced semivowel. While phonemes 14-16 are classified as nasal consonants. The remaining phonetic sounds are classified as voiced fricatives.

3.3 Sampling Rate Considerations. Phonetic sound records of all male speakers are comprised of 128 data samples/pitch period. Each female phoneme record consists of 64 data samples/pitch period. To permit N, the number of data samples, to be constant and representative of one period of a phonetic sound waveform regardless of speaker pitch, it was necessary to vary the sampling rate from phoneme record to record. Equation 3.1 defines the manner by which the sampling rate was determined to allow N data samples per pitch period. F_s denotes the sampling rate in samples/sec. and P_p denotes the pitch period in milli-sec.

$$F_s = \frac{N}{P_p} \quad . \tag{3.1}$$

To provide a comparative means to assure that the data samples were representative of a phonetic sound waveform, oscilloscope pictures were taken of several different phoneme waveforms. Figures 3.1, 3.2, 3.3, and 3.4 illustrate the oscilloscope pictures of the phonetic sounds (ae), (i), (O), and (u) with their graphical plots as reconstructed from the sample data. It is evident from these figures that the sample data does adequately represent the analog phonetic sound waveform. What deviation is noted is due to the fact that the time of sampling and the time of film exposure were not synchronized.

As noted previously phoneme records of male speakers consists of 128 data samples while those of female speakers consist of 64 data samples. The reason for this variation was due to the sampling rate limitation of the analog-to-digital converter. Recall the maximum sampling rate capability of the converter is 33,000 samples/second. From Equation 3.1 it may be determined, assuming N equals 128 and F_s equals the maximum rate, that any phonetic sound having a pitch period

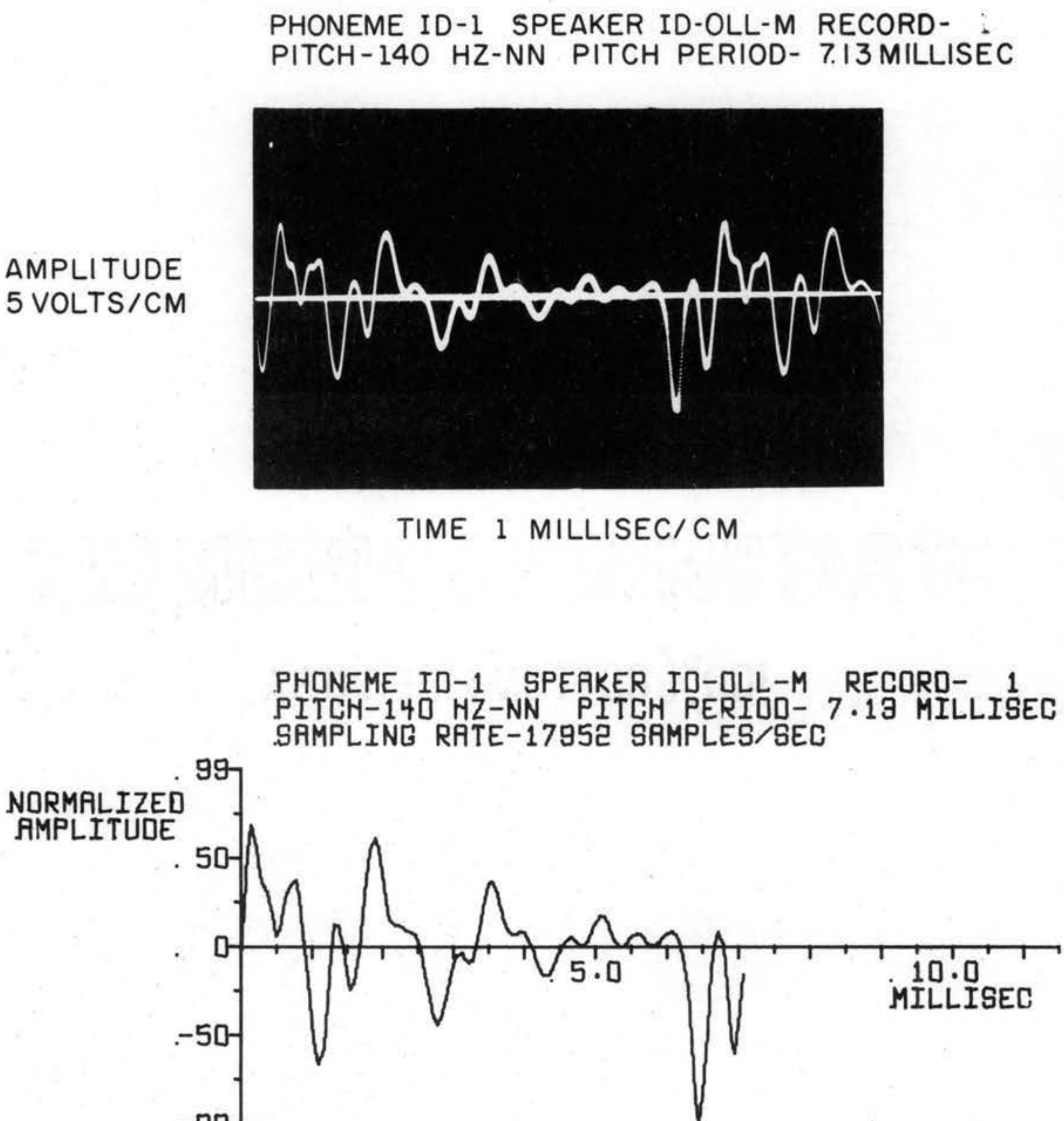
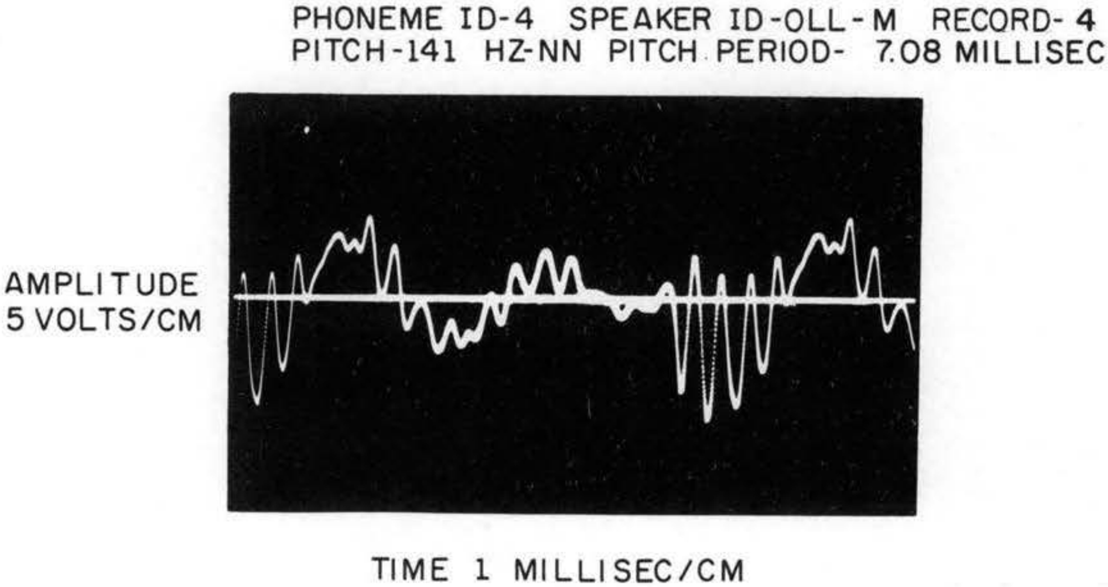


Figure 3.1. Oscilloscope Picture and the Corresponding Sample Data Plot of the Phonetic Sound (ae) as in "<u>A</u>t"



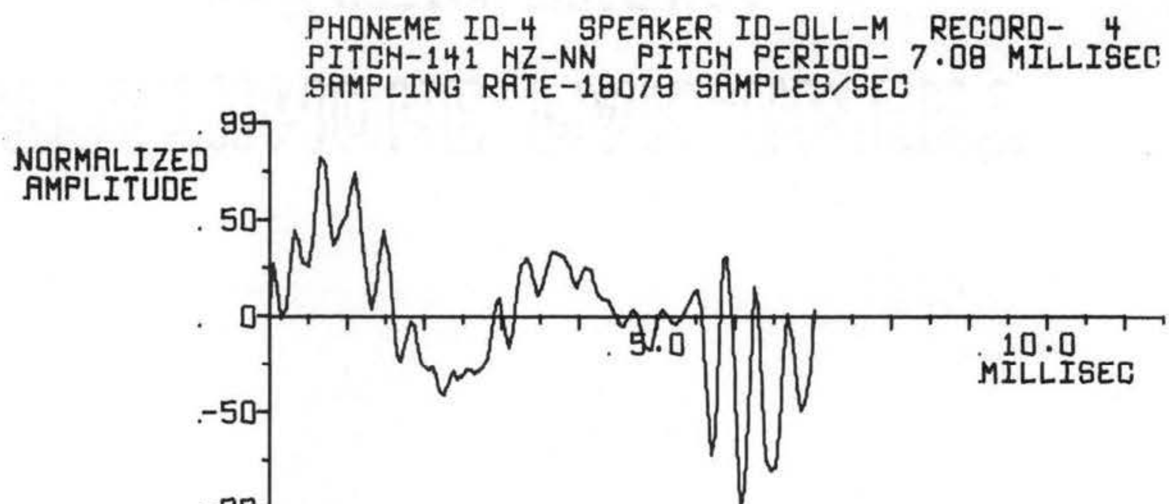


Figure 3.2. Oscilloscope Picture and the Corresponding Sample Data Plot of the Phonetic Sound (i) as in "m<u>EE</u>t"

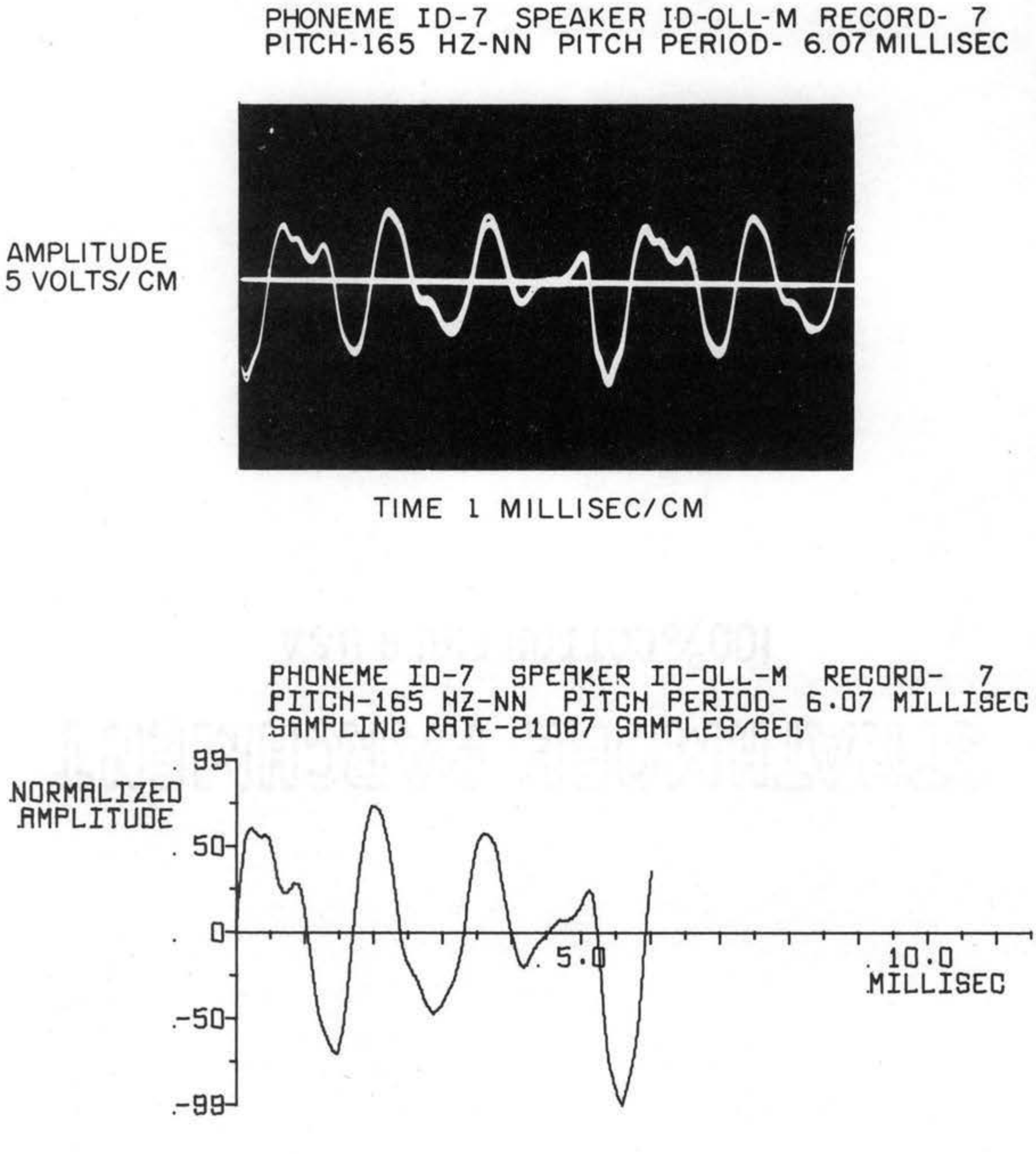


Figure 3.3. Oscilloscope Picture and the Corresponding Sample Data Plot of the Phonetic Sound (O) as in "Obey"

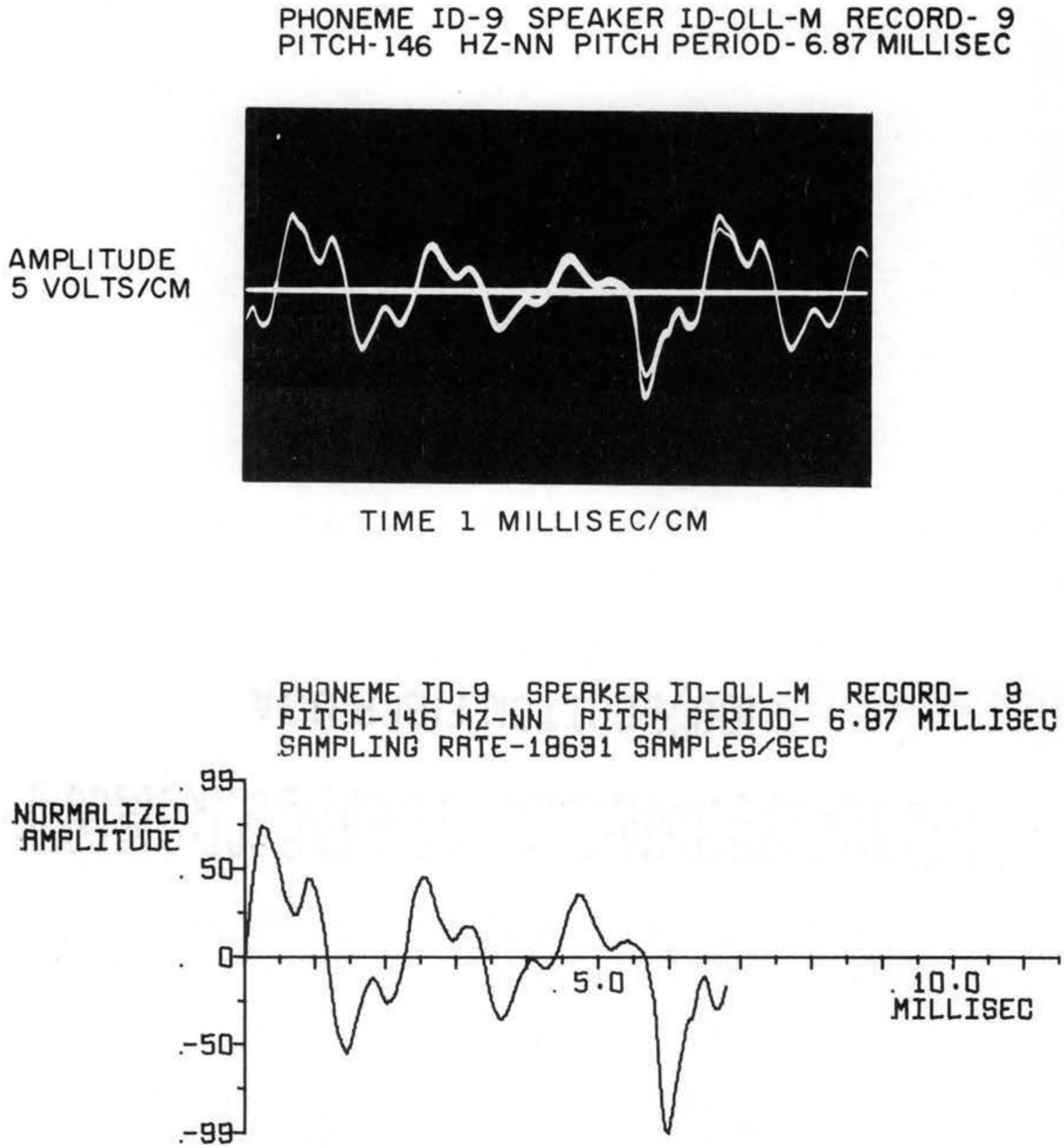


Figure 3.4. Oscilloscope Picture and the Corresponding Sample Data Plot of the Phonetic Sound (u) as in "bOOt"

less than 3.88 milliseconds cannot be sampled by the analog-to-digital converter rapid enough to provide 128 samples per pitch period. Numerous female phonetic sound records fell into this category. Therefore, to afford uniformality among the female phoneme records the value of 64 samples per pitch period was chosen.

Figures 3.5 and 3.6 illustrate graphical plots of the same phonetic sound record; Figure 3.5 having been reconstructed from 128 samples per pitch period while Figure 3.6 was reconstructed from 64 samples per pitch period. Graphically, little deviation can be noted between the two plots. This suggests that the sampling rate of 11,808 samples/sec which corresponds to 64 samples/pitch period is adequate. This seems reasonable since the spectral energy content of most voiced phonetic sounds falls within the 64 HZ to 5,000 HZ frequency band. To what degree sampling at half the desired frequency will effect the cochlear response simulations needs to be portrayed. The details of the cochlear response simulations to phonetic sounds are left for Chapter IV. However, to initiate a simulation an approximate Fourier series representation of the phonetic sound signal is obtained by determining the discrete Fourier transform from the sample data. The discrete terms of the transform are approximations to the Fourier series coefficients. Therefore, the discrete Fourier transform has been twice calculated. The first transform being calculated from a phoneme record of 64 samples and the second being determined from a record of the same phoneme having 128 samples. Table IV comparatively illustrates the results. The differences are observed to be slight. It should be noted that the times at which sampling was initiated in the process of obtaining each of these sample data records from the same tape loop do not correspond.

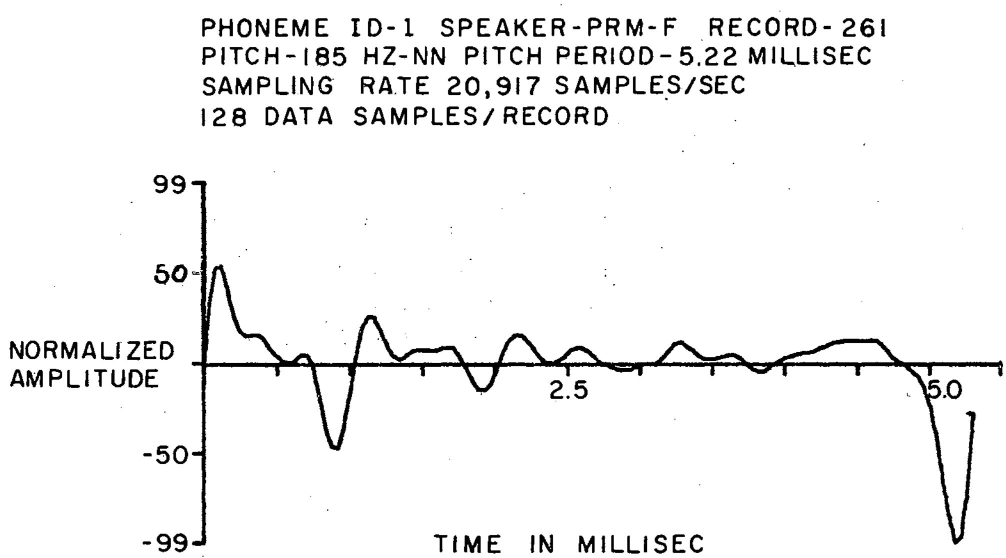


Figure 3.5 Plot of the Phonetic Sound Waveform (ae) as in "At" as Reconstructed from 128 Data Samples

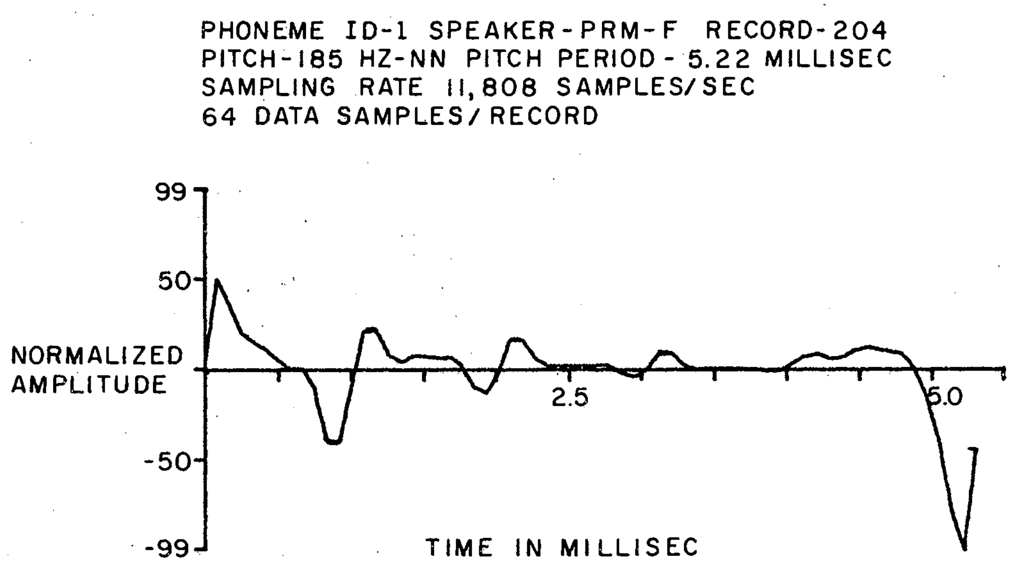


Figure 3.6 Plot of the Phonetic Sound Waveform (ae) as in "At" as Reconstructed from 64 Data Samples

TABLE IV

NORMALIZED DISCRETE FOURIER TRANSFORMS OF THE PHONEME (ae) AS IN AT AS BASED ON TWO SAMPLING RATES

Frequency vs Transform Terms		
Discrete Fourier Transform Frequency HZ	Normalized Transform Terms as Determined From 64 Data Samples[1]	Normalized Transform Terms as Determined From 128 Data Samples[2]
0	6	3
186	28	31
372	26	28
558	44	45
744	74	74
930	100	100
1116	50	51
1302	36	36
1488	41	39
1674	46	43
1860	66	64
2046	44	44
2232	11	7
2418	26	22
2604	24	20
2790	35	32
2976	12	11
3162	5	8
3348	8	7
3534	7	6
3720	7	7
3906	8	6
4092	6	6
4278	7	9
4464	8	8
4650	7	8
4836	8	6
5022	7	6
5208	7	5
5354	6	5
5580	6	6
5766	7	6

[1]Phonetic sound data samples used were those of Record - 204.

[2]Phonetic sound data samples used were those of Record - 261.

Hence, this accounts for some of the difference. However, it appears that sampling at half the desired rate should have but little effect on the cochlear response simulations. Figures 3.7 and 3.8 are simulated cochlear responses to the phonetic sounds depicted by Figures 3.5 and 3.6. These responses further illustrate the validity of the conjecture that sampling at half the desired frequency rate has only minor effect on the results of this research. An explanation of the meaning of these results is left for Chapters IV and V.

In passing it should be mentioned that if desired one could calculate intermediate sample values between each of the 64 data samples by using a computer interpolation routine. In this manner the female records could be made to consists of 128 data samples.

It is evident that the two values of N each correlate with 2^n. These values were purposely chosen to minimize the computation time associated with calculating the discrete Fourier transform from the phonetic sound sample data by employing the fast Fourier transform computer algorithm. The details of this point are provided by Brenner (23).

3.4 Representation Accuracy. By representation accuracy it is meant that accuracy with which the N data samples of a phonetic sound record correspond to one and only one pitch period. This is to say, do all N samples fall within a given pitch period, and if so are they properly incremented to represent the entire pitch period, or do some of the N samples fall outside the pitch period?

Representation accuracy is chiefly a function of the accuracy by which the instrumentation equipment can measure the pitch period of a

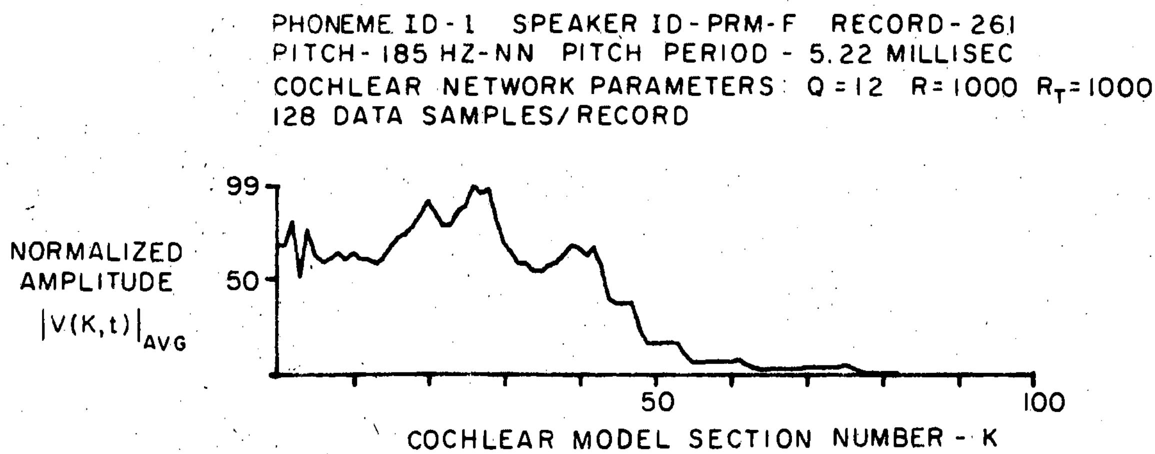


Figure 3.7. Simulated Cochlear Response to the Phonetic Sound (ae) as in "At" as Effected From 128 Data Samples

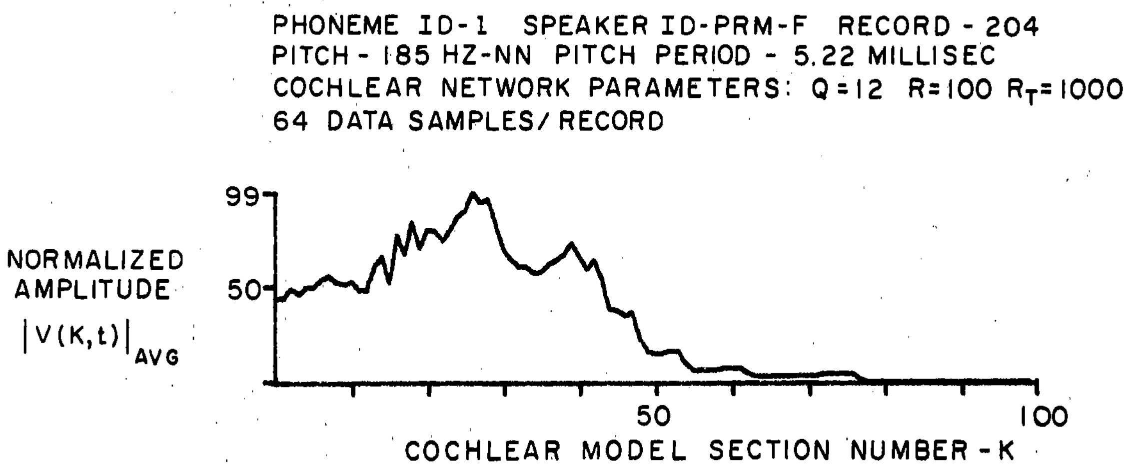


Figure 3.8. Simulated Cochlear Response to the Phonetic Sound (ae) as in "At" as Effected From 64 Data Samples

phonetic sound, the accuracy by which the sample clock of the instrumentation can be set, and the steadiness of the speaker's pitch. If it could be assumed that the speaker's pitch was invariant the representation accuracy could be determined from the time base resolution of the Tektronix 547 oscilloscope and the resolution of the frequency counter. However, this is not the case. In actuality the resolution capabilities of the equipments are overshadowed by the fact that the speaker's pitch is not invariant. Therefore, the accuracy of the pitch period measurement is a function of the periodicity of a speaker's pitch. Further, the sample clock setting is dependent upon the pitch period measurement. Therefore, the representation accuracy is principally only a function of the steadiness of the speaker's pitch. A mathematical model based on the sampling method and sampling instrumentation from which the representation accuracy could be predicted is beyond the scope of this research. However, each phonetic sound record has been examined in this regard and the findings are presented.

The examination revealed that the majority of the phonetic sound records were properly represented. At worst it revealed that none of the N data samples for any given record ever fell short or beyond a pitch period by more than two samples.

In order to conject the effect that worst case representation would have on the cochlear response simulations the discrete Fourier transform for phonetic sound records were calculated for the two worst case representations and the accurate representation. Table V illustrates in a comparative manner the calculated discrete Fourier transform terms for each representation case.

It is evident that the worst case representation of a phonetic

TABLE V

NORMALIZED DISCRETE FOURIER TRANSFORMS OF THE PHONEME (ae) AS IN AT FOR THREE CASES OF REPRESENTATION ACCURACY

Frequency vs Transform Terms											
Discrete Fourier Transform Frequency HZ	Transform Terms 128 Samples 2 Samples Over	Transform Terms 128 Samples	Transform Terms 128 Samples 2 Samples Under	Discrete Fourier Transform Frequency HZ	Transform Terms 128 Samples 2 Samples Over	Transform Terms 128 Samples	Transform Terms 128 Samples 2 Samples Under	Discrete Fourier Transform Frequency HZ	Transform Terms 128 Samples 2 Samples Over	Transform Terms 128 Samples	Transform Terms 128 Samples 2 Samples Under
0	1	1	1	4092	5	6	8	8184	0	0	0
186	33	33	33	4278	8	6	5	8370	0	0	0
372	29	29	30	4464	2	3	3	8556	0	0	0
558	37	38	38	4650	4	2	2	8742	0	0	0
744	65	67	72	4836	0	0	1	8928	0	0	0
930	100	100	100	5022	0	0	1	9114	0	0	0
1116	64	59	56	5208	0	0	1	9300	0	0	0
1302	40	40	42	5394	0	0	1	9486	0	0	0
1488	40	37	34	5580	0	0	0	9672	0	0	0
1674	36	40	48	5766	0	0	1	9858	0	0	0
1860	71	72	71	5952	0	0	0	10044	0	0	0
2046	65	61	58	6138	0	0	0	10230	0	0	0
2232	27	21	18	6324	0	0	0	10416	0	0	0
2418	23	24	25	6510	0	0	0	10602	0	0	0
2604	20	21	23	6696	0	0	0	10788	0	0	0
2790	38	45	48	6882	0	0	0	10974	0	0	0
2976	40	32	26	7068	0	0	0	11160	0	0	0
3162	19	16	13	7254	0	0	1	11346	0	0	0
3348	11	11	11	7440	0	0	0	11532	0	0	0
3534	9	9	6	7626	0	0	0	11718	0	0	0
3720	8	8	10	7812	0	0	0				
3906	8	7	5	7998	0	0	0				

sound has little effect on the corresponding discrete Fourier transform of the phonetic sound. This suggests that worst case representation of a phonetic sound should have negligible effect on the validity of the simulated cochlear responses. For each of the three phoneme representations, worst and normal representations, the corresponding simulated cochlear responses were found. Figures 3.9, 3.10, and 3.11 comparatively illustrate these responses. Note the negligilbe effect. Again it is mentioned that if desired, these phoneme records which are not adequately represented by the N data samples could be made more representative by interpolation and extrapolation techniques.

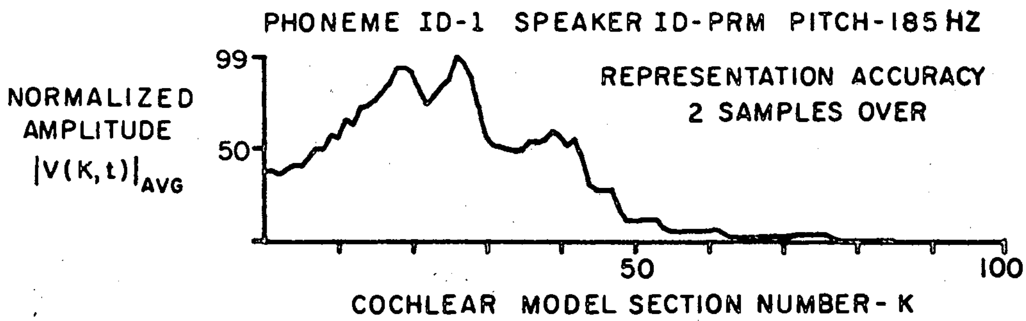


Figure 3.9. Simulated Cochlear Response to the Phonetic Sound (ae) as in "At" as Effected From 128 Data Samples Having a Representation Accuracy of 2 Samples Over

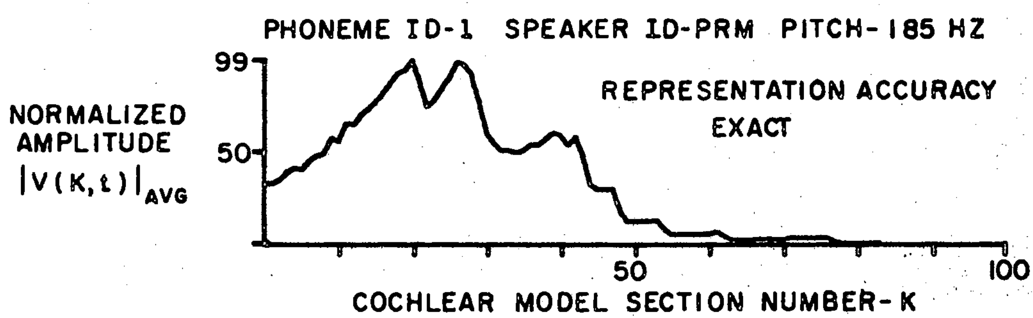


Figure 3.10. Simulated Cochlear Response to the Phonetic Sound (ae) as in "At" as Effected From 128 Data Samples Having an Exact Representation Accuracy

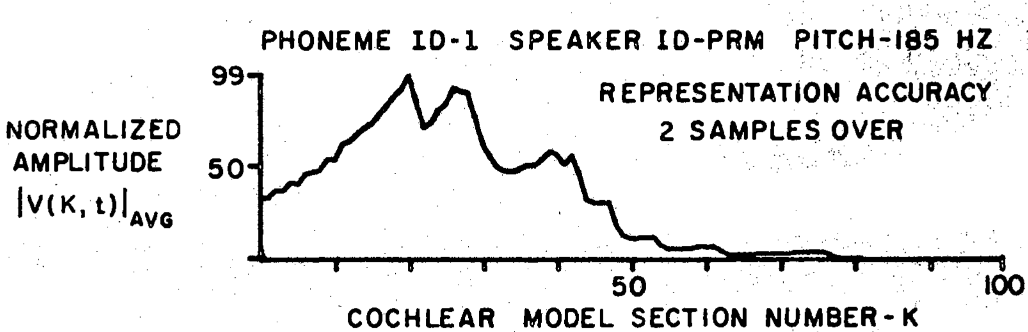


Figure 3.11. Simulated Cochlear Response to the Phonetic Sound (ae) as in "At" as Effected From 128 Data Samples Having a Representation Accuracy of 2 Samples Under

CHAPTER IV

DEVELOPMENT OF A DYNAMIC DIGITAL COMPUTER MODEL OF THE COCHLEA

4.1 Introduction. In recognition of his important research contributions directed toward comprehension of the physical mechanism of excitation in the cochlea of the ear, the neuro-physiologist, George von Bekesy, was awarded the 1961 Nobel Prize in medicine. Based on his research with mechanical models of the cochlea and with fresh and preserved human and animal cochleas Bekesy (12) noted that the locus of maximum disturbance of the basilar membrane of the cochlea was dependent upon the excitation frequency stimulating the cochlea. In 1963 Glasser, Caldwell, and Stewart (13) reported the development of a preliminary electronic unit which approximated the cochlear behavior and frequency response identified by Bekesy. Bolie (14) developed improvements in the electronic hardware for simulating the cochlear functions. In this chapter a digital computer model intended to dynamically simulate the cochlea response to voiced phonetic sound is developed.

4.2 Physiology of the Ear. The hearing mechanism consists of three divisions, the external, middle, and inner ears. The external ear and middle ear function to absorb and transform airborne acoustic energy into mechanical energy, while the innter ear functions to absorb and transduce the mechanical energy into a set of nerve-impulse signals which are characteristic of the original acoustic event. Studies have shown that the role of the external ear and middle ear is to provide a means to couple airborne sound signals to the sound detecting device of the hearing mechanism, i.e. the cochlea of the inner ear. Thus, it is thought that the external ear and middle ear play a negligible role in the recognition of sound signals. The essential transformations of the sound signals are those associated with the traveling-wave and filtering characteristics of the cochlea.

In physical form, the biological cochlea is a snail-like spiral of 2½ turns, inside of which there is a fluid-filled middle tube of triangular cross section which separates along most of its length the scala vestibuli and the scala tympani, a pair of fluid filled chambers. Figure 4.1 depicts the cochlea as it is found in the membranous labyrinth of the inner ear. A simplified cut-away schematic illustrating the overall relationship of the cochlea with the middle ear and external ear is shown by Figure 4.2. A cross section of the cochlea is illustrated by Figure 4.3. Both the scala vestibuli and the scala tympani chambers are filled with a fluid called perilymph. At the basal end of the scala vestibuli the oval window is located. The oval window is a "drum-like" membrane in which the stape of the middle ear is seated. The scala tympani is terminated at the basal end in the round window, another "drum like" membrane which serves as a pressure release mechanism. The middle channel of the cochlea is called the scala media. As depicted by Figure 4.3 it is triangular in form. Its upper boundary is called the Reissner or vestibular membrane. The lower boundary is a gelatinous membrane called the basilar membrane. A bony shelf comprises the third boundary of the scala media. This channel too is filled with a fluid called endolymph. The uncoiled scala media of an adult is

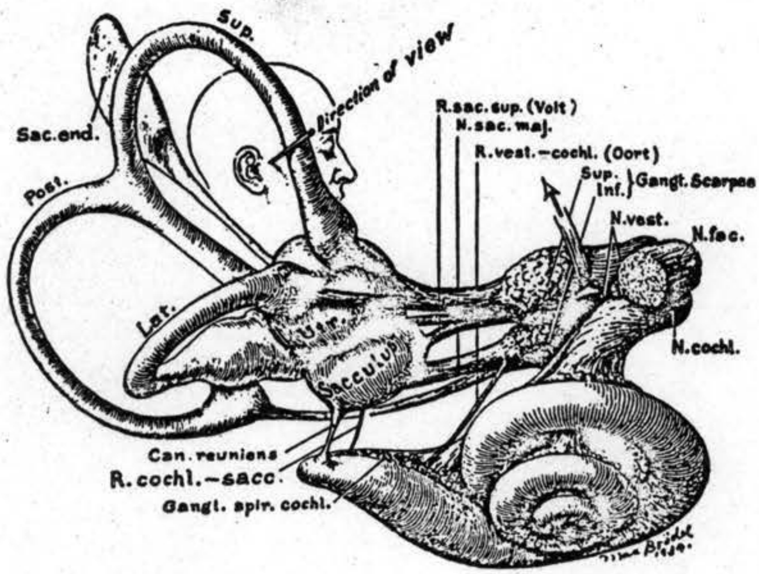


Figure 4.1. The Membranous Labyrinth of the Inner Ear (Reproduced from Zemlin (23))

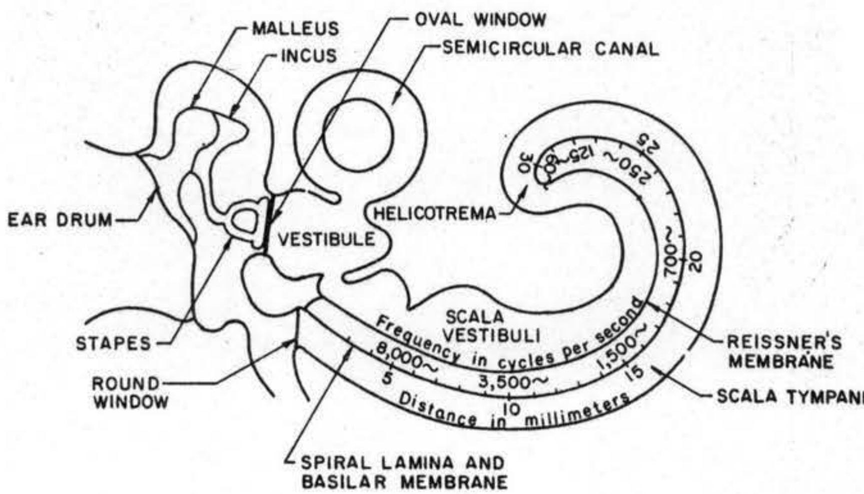


Figure 4.2. A Simplified Cut-Away of the Ear Depicting the Relationship Between the Outer, Middle and Inner Ear

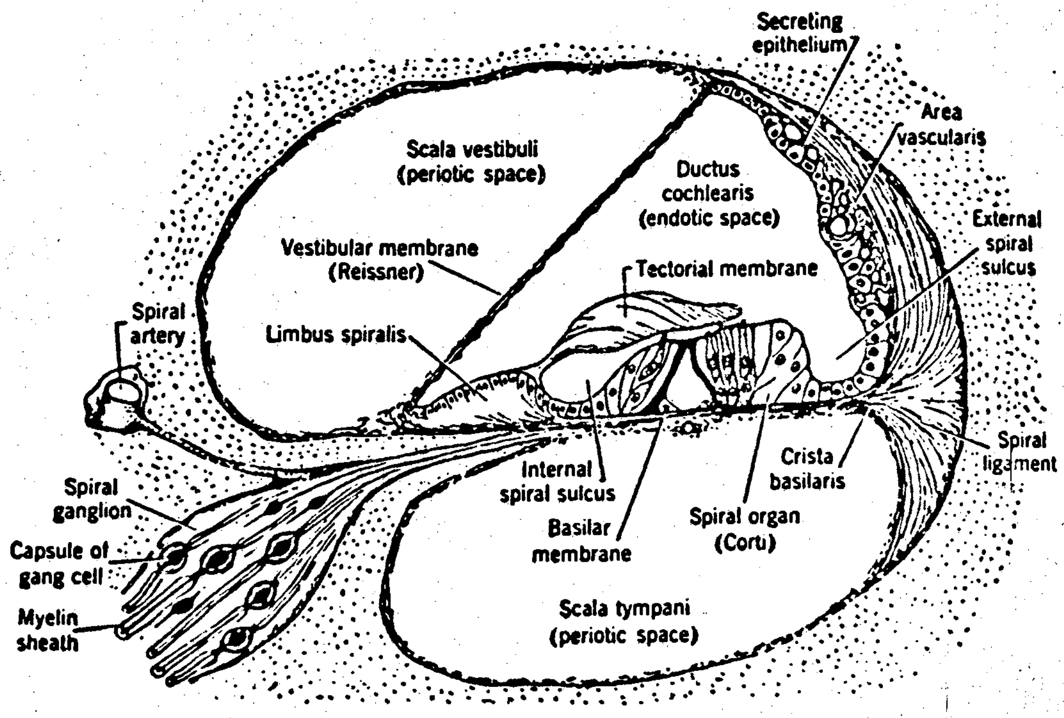


Figure 4.3. A Cross Section of the Cochlea (Reproduced From Zemlin (23))

approximately 36 mm in length. It terminates approximately 1 mm short of the apical end, which provides a point of commonality between the scali.

Resting on the basilar membrane is the organ of Corti. This organ contains some 30,000 sensory cells in which the auditory nerve endings interface with the cochlea. These sensory cells appropriately translate motion of the some 30,000 tiny hairs called cilia into neural impulses.

Whenever the tympanic membrane is excited by an acoustical signal the stape is placed into vibratory motion. This motion produces a volume displacement of the cochlear fluid. Since the perilymph is incompressible and the walls of the cochlea are rigid the volume displacement is relieved by the round window. To to-and-fro flow of the perilymph causes deflection of the basilar membrane. The cilia are disturbed by the flexure of the membrane and their disturbance sensed by the Organ of Corti. Thus, neural impulse patterns which characterize the acoustic event are conveyed to the brain for recognition. Zemlin (24) and Weiss (25) are referenced for more detailed discussion of the physiology of the ear.

In a sinusoidal fashion Bekesy vibrated the stapes of a fresh cadaver and noted along the basilar membrane the amplitude and phase of its flexure. He observed that it was characteristic of the basilar membrane to localize membrane vibration at a section as a function of frequency. Figure 4.4 illustrates the finding of his research. For a given frequency of excitation which corresponds to a particular point along the basilar membrane Bekesy's findings resemble the characteristics of a band-pass filter. For any given frequency of excitation the corresponding amplitude characteristics suggest a constant Q band pass filter. It is further observed that linear increments of distance along the basilar membrane seem to correlate logarithmically with frequency. Figure 4.2 depicts to an extent, physically, this correlation. Bekesy further noted that the excitation propagated a traveling wave of deflection along the basilar membrane with essentially no reflection at the helicotrema. The helicotrema is the apical end of the basilar membrane. The tapering property of the scala media and basilar membrane has been suggested to explain this characteristic. Since little reflection takes place no standing wave of displacement was observed.

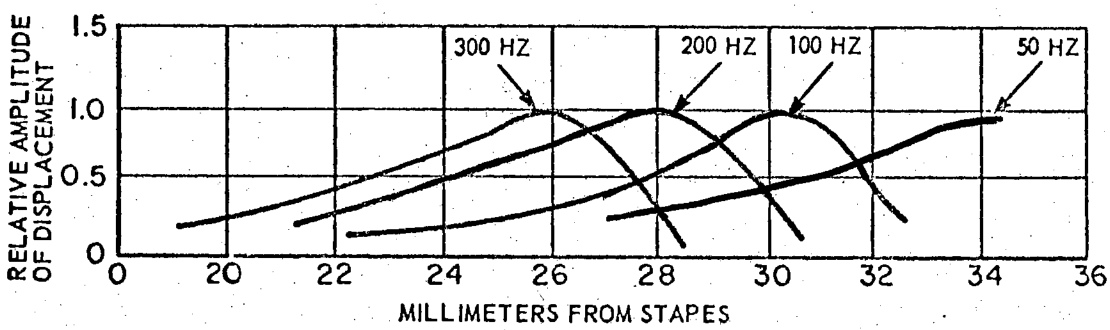


Figure 4.4. Experimental Findings of Bekesy Illustrating Basilar Membrane Displacement vs Frequency

4.3 Previous Cochlear Models. Based on the results of Bekesy, Glasser, et al. (13) developed an electrical analog model of the cochlea. Their model was a ladder network of tuned RLC circuits intended to effectively simulate the basilar membrane displacement resulting from volume displacement of the perilymph in the cochlear spiral. Each tuned circuit was of an L-type configuration. The series arm of each tuned circuit consisted of an inductor and resistor in series. The values of these components were a function of the position of that section from the input source. The shunt-arm consisted of an inductor, capacitor, and resistor connected in series. The values of the capacitor and inductor were chosen to be in accord with actual biological behavior of the human cochlea, that is, increasingly lower in frequency the greater the distance from the input source. To observe the response of their network a high-speed sample switch was used to sample the voltage across the shunt arms or the currents in the shunt arm. The sample values were displaced by the CRT of an oscilloscope.

This design was the first working electrical model which simulated the characteristic behavior of the cochlea. However, it had numerous inherent disadvantages. For example the parameter requirements for this design are most demanding. The most stringent being that the shunt-arm capacitor values must increase by a factor of 100,000-to-1 while the shunt-arm inductor values decrease by a factor of 4-to-1 from the input tuned circuit to the terminal circuit. Bolie points out the lack of provisioning in the sampling and display system to allow a sharply resolved response to a pure sinusoidal input. This is to say that the design provides a rather broad response which is incapable of resolving two pure tones nearly alike in frequency.

Using the basic design concept of Glasser, et al. (13), Bolie (14) utilized the computer to aid in the design of the cochlea model. This enabled him to realize a simpler but improved model which is physically easier to realize in practice. The general configuration of the ladder network to simulate the acoustical processing functions of the human cochlea is depicted by Figure 4.5. Assuming the value of NSECT, here meant to denote the number of tuned circuits of the network, is great enough, the ladder network will, in a discrete manner, closely approximate the near-continuum behavior of the basilar membrane in response to an acoustical event. Basically this is accomplished by each successive RLC shunt-arm, starting from the input terminals, being tuned in a

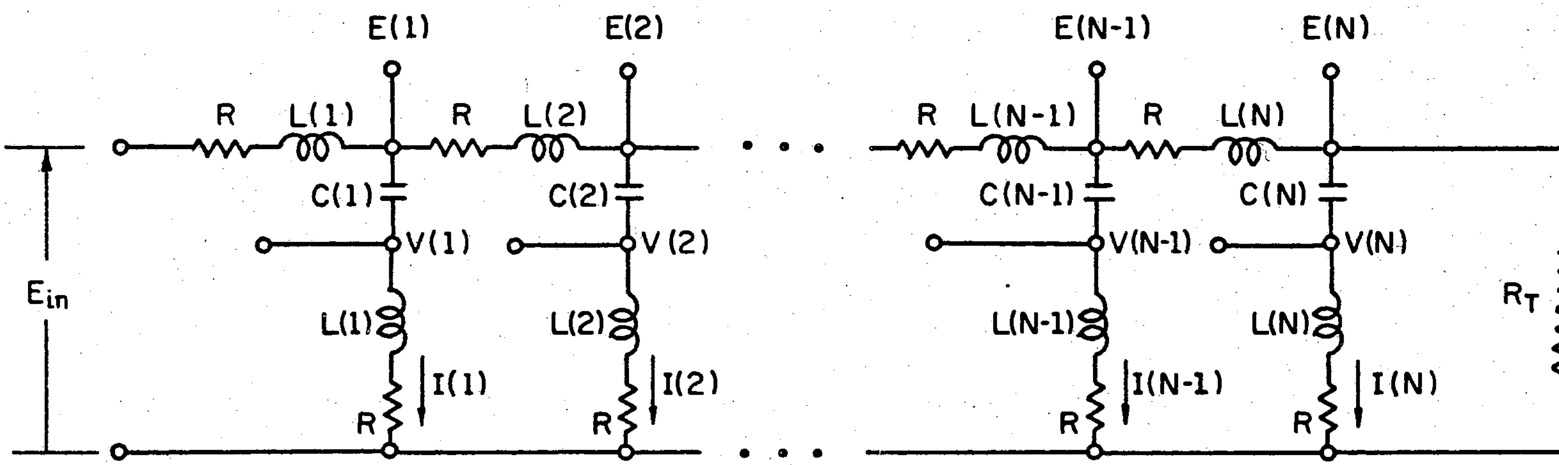


Figure 4.5. Configuration of the Ladder Network Whose Response Simulates the Cochlear Functions

logarithmic manner to progressively lower resonant frequencies while keeping the Q constant.

Based on numerous experiments and computer computations Bolie arrived at the following design conclusions.

(1) All inductors could have the same universally applicable Q-value.

(2) All resistors, except the terminal resistor, could have the same universally applicable value.

(3) The inductance in any given shunt-arm could have the same value as the inductance in its left-neighboring series arm.

(4) The resonant frequencies of the successive shunt-arms decrease exponentially from 8192 Hz at the input circuit to 64 Hz at the terminal tuned circuit.

Except for the terminal resistance, R_T, the design constraints for the network parameters may be expressed by Equations 4.1, 4.2, and 4.3.

$$L(K) = \frac{QR}{2\pi\, F_R(K)} \tag{4.1}$$

$$C(K) = \frac{1}{QR2\pi F_R(K)} \tag{4.2}$$

$$F_R(K) = \mathrm{Exp}[(13 - 7\,\frac{K-1}{N-1})\mathrm{Ln}2] \tag{4.3}$$

where

N = NSECT, the number of resonance sections of the cochlear network

K = 1,2,...,NSECT, denotes the number of a given resonance section

NSECT - the number of sections comprising the network

L(K) - the inductance value of the Kth section

C(K) - the capacitance value of the Kth section

$F_R(K)$ - the resonance frequency of the Kth section

Q and R - the respective universally applicable resistance value and coil Q-value.

To arrive at parameter values which would allow satisfactory portrayal of the cochlea functions Bolie wrote a FORTRAN II computer program to solve for the steady-state voltages and current E(K), V(K), and I(K) of the network in response to a sinusoidal input signal. Inherent in his analysis technique is that only four basic parameters along with the resonant frequencies of the tuned circuits need be defined to totally define the network in its entirity. These parameters are NSECT, Q, R, and R_T. Calculating the resonant frequencies from Equation 4.3 and by experimentally varying the values of NSECT, Q, R, and R_T he was able to converge to a set of network parameter values satisfactory to model the cochlea function.

It is the voltage V(K) which corresponds to the displacement motion of a discrete point along the basilar membrane. Assuming the network is excited by a pure sinusoidal voltage signal the composite $|V(K)|$ responses should approximate the behavior of the basilar membrane to a pure tone acoustical event as Bekesy observed. A typical set of results obtained by Bolie (14) are shown by Figure 4.6. The cochlear design parameters used to obtain these results were set at NSECT = 80, Q = 10, R = 100 ohms, and R_T = 1000 ohms. The input signal amplitude and frequency were 8.8 volts and 1024 Hz. The D(K) vs K plot represents the neighboring difference composite response of the network. A neighboring difference response is defined by Equation 4.4.

$$D(K) = |V(K)| - |V(K+1)| \quad . \qquad (4.4)$$

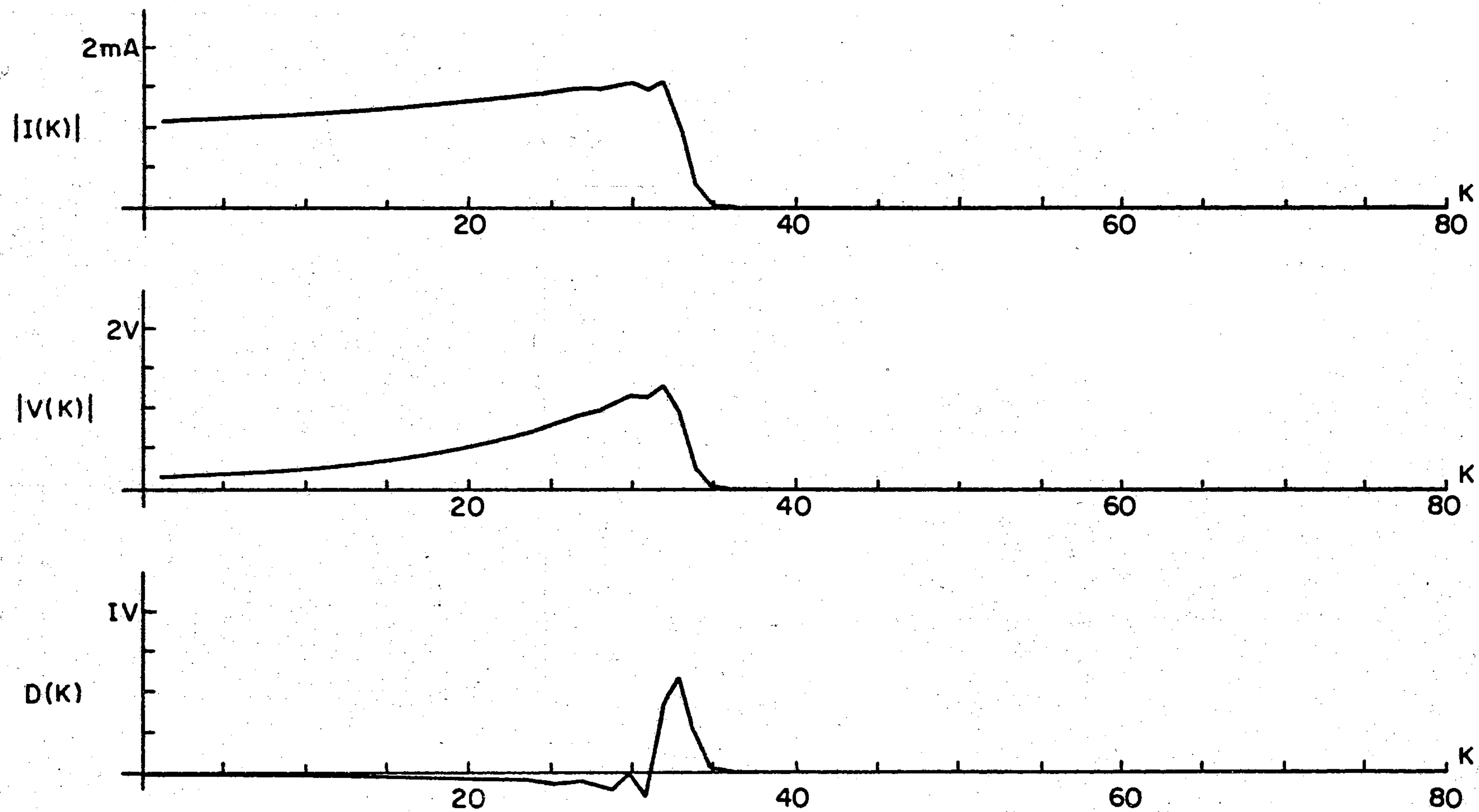


Figure 4.6. Response of 80 Section-Cochlear Network to a Sinusoidal Input Signal

From Figure 4.6 it is evident that the neighboring difference responses show selective discrimination of the frequency of the input signal. The degree of selectivity is noted to be chiefly a function of the universal Q-value of the network.

From a physiological viewpoint the neighboring difference is intended to simulate the well-known sharp selectivity that a human ear exhibits. Based on the information provided by Bekesy the conclusion can be reached that additional processing occurs in the cochlea, neural channels, or brain to provide this selectivity. Huggins (26) has suggested that mechanical processes interposed between the motion of the basilar membrane and the excitation of the auditory nerve may explain this capability and that neural mutual inhibition further enhances the selectivity. However, it should be mentioned that this has not been biologically confirmed.

Further results of the computer simulation are illustrated by Figure 4.7. The network parameters are the same as for the responses depicted by Figure 4.6. The input signal frequencies are successive half-tone responses having values 64, $64\sqrt{2}$, 128, $128\sqrt{2}$, 256, ..., $4096\sqrt{2}$, ..., and 8192 Hz. The corresponding amplitudes were calculated from Equation 4.5 to provide signals compatible with speech signal spectral content.

$$A(F) = \frac{141.4}{\sqrt{1.0 + (F/64)^2}} \qquad (4.5)$$

4.4 A Dynamic Computer Model of the Cochlea. Using as a basis the cochlear network model developed by Bolie a dynamic computer model of the cochlea has been developed. The combination schematic and

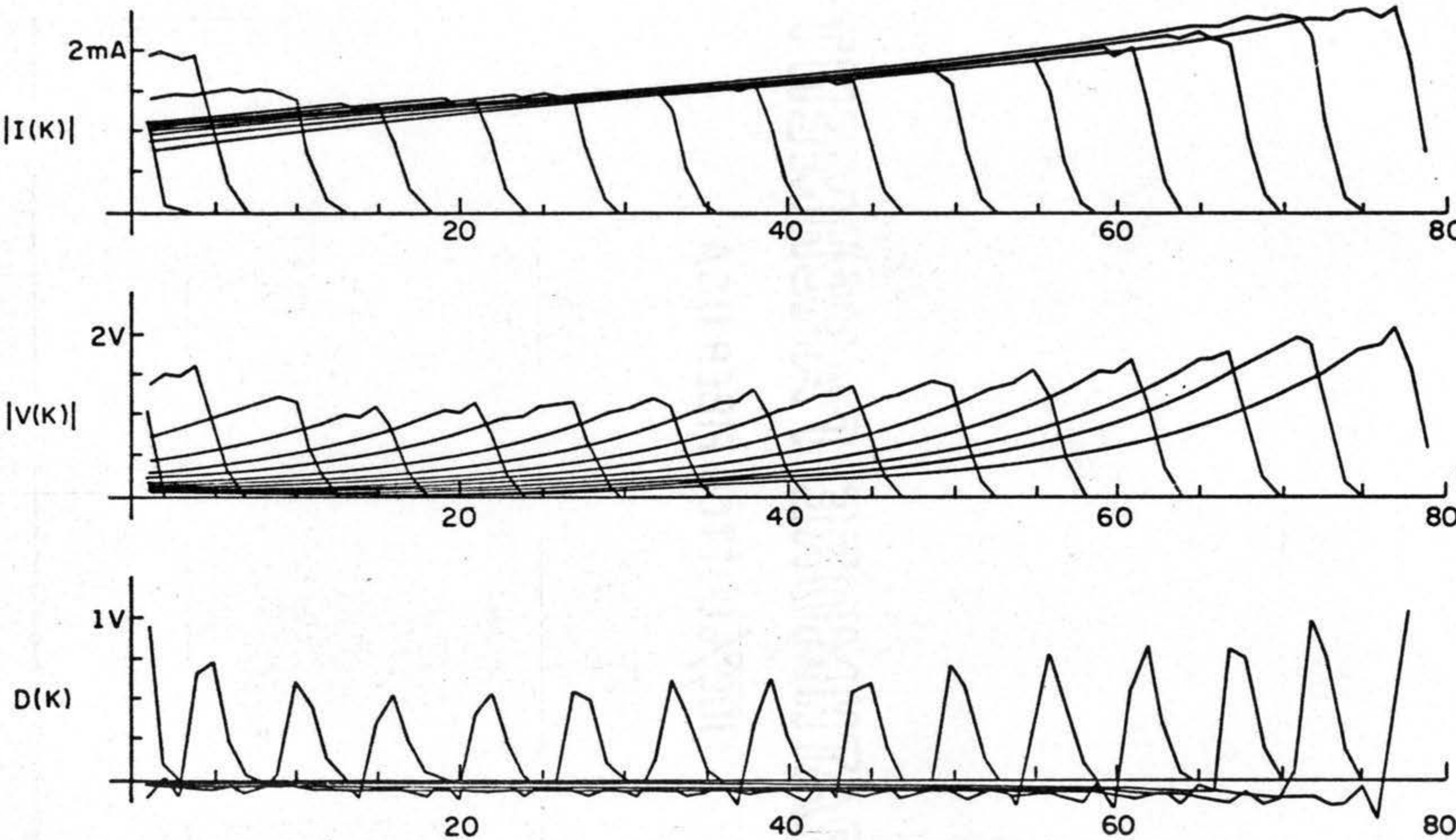


Figure 4.7. Response of 80 Section-Cochlear Network to Successive Half-Tone Sinusoidal Input Signals

process diagram, Figure 4.8, depicts the cochlear model. This model is intended to simulate the steady-state response of the cochlea to complex acoustic signals such as the voiced phonetic sounds. The simulation is achieved by employing the following concepts. Given a time series set of sample data which represents one period of a phonetic sound, an approximation of the Fourier series coefficients may be calculated by using the discrete fast Fourier transform computer algorithm. Thus the phonetic sound waveform may be represented by a finite complex Fourier series. Since the RLC network model of cochlea functions is linear the theory of superposition is applicable for analysis of the network. Based on this supposition the steady-state response of the network may be calculated for each term of the finite Fourier series. Applying the theory of superposition a sinusoidal series representative of the V(K,t) response for each section of the network may be derived. By summing each V(K,t) series at evenly spaced time intervals over one pitch period the steady-state amplitude-time response of each section may be computed. The inverse fast Fourier transform is conveniently used to calculate for each section a time series representative of the V(K,t) response. The quasi steady-state response of the network to a phonetic sound signal is determined by finding for each section the approximate average value of the time series representation of $|V(K,t)|$. It is then the composite set, $\{|V_{avg.}(K,t)|; K=1,2,\ldots,NSECT\}$, which represents the simulated steady-state response of the basilar membrane to an acoustical phonetic sound signal. To simulate the neighboring difference composite response of the network each of the NSECT-1 amplitude-time responses of D(K,t) is computed by Equation 4.6.

$$D(K,t) = |V(K,t)| - |V(K+1,t)| \qquad (4.6)$$

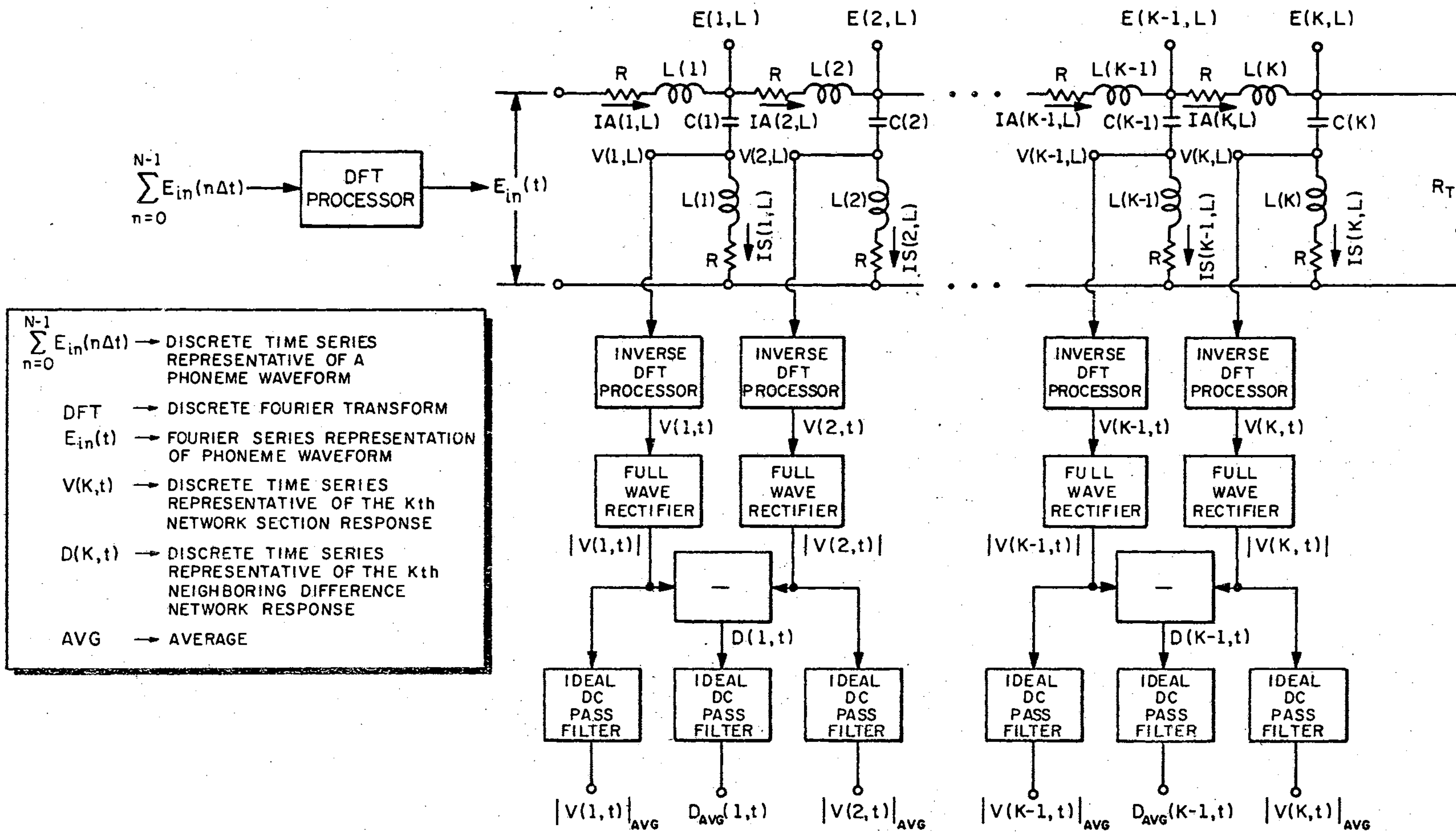


Figure 4.8. Combination Schematic and Process Diagram of the Dynamic Cochlear Model

where

$$t = 0, \Delta t, 2\Delta t, \ldots, N\Delta t.$$

Next the average value of each D(K,t) is computed. It is then the composite set of the average values $\{D_{avg}(K,t); K=1,2,\ldots,NSECT-1\}$ that represents the neighboring difference response of the network.

In order to simulate the response of the cochlear network model to phonetic sound signals a FORTRAN IV computer program was written for the IBM 360 Model 50 digital computer. A listing of this program with appropriate comments is given in Appendix C. The organization of the program follows the executive program/subprogram concept. Thus the program has the feature of being most versatile for research and most adaptable to further development and improvement. The executive program, hereafter referred to as the main program, may be sub-divided into four computational phases: (1) data definition, (2) computation of Fourier series coefficients, (3) network response calculations, and (4) data output. As the discussion to follow will frequently refer to the main program, a listing of it is provided in Table VI.

4.4.1 Data Definition Phase. The data definition phase is governed by subroutine programs READ1M and READ2. These subroutines effect the means by which data is conveyed to the computer from IBM cards. READ1M initiates the reading of the cards containing the network parameters NSECT, R, R_T, and Q. It also initiates the reading of the card which specifies computational options. These options are:

(1) Number of phoneme records to be processed

(2) The number of data sample per phonetic sound record

(3) The desired frequency number of coefficients of the Fourier

TABLE VI

PROGRAM LISTING OF THE MAIN PROGRAM WHICH SIMULATES THE COCHLEAR RESPONSE TO PHONETIC SOUNDS

```
//OLL1    JOB (10604,510-36-5956,40,36,360),'LEON LAKE',MSGLEVEL=1,      C
//              CLASS=L
// EXEC FORTGC
//FORT.SYSIN DD *
C     MAIN PROGRAM****MAIN PROGRAM****MAIN PROGRAM****MAIN PROGRAM
      COMPLEX V(100,128),DATA(256),WDATA(2048)
      COMPLEX ZA(128),ZS(128),Z(128),IA(128),VS(128),IS(128),WORK(10)
      COMPLEX CMPLX
      DIMENSION VDIFF0(100,128),VDIFF1(100,128)
      DIMENSION VDC0(100),VDC1(100)
      DIMENSION FFREQ(128),CFREQ(128)
      DIMENSION IVDC0(100),IVDC1(100)
      DIMENSION IDATA(128)
      COMMON /OUTEAR/V/DATAS/DATA/WDATAS/WDATA/IDATAS/IDATA
      COMMON /VDC/VDC0,VDC1
      COMMON /FREQ/FFREQ,CFREQ
      COMMON /IVDC/IVDC0,IVDC1
      COMMON /SPEC1/NREC,NDATA,KDATA
      COMMON /SPEC2/IDSPK,ISEX,IPHO,IPIT,IPCL,PERD,IREC
      COMMON /SPEC3/NSECT,NFREQ,R,RT,Q,FNORM1
      COMMON WORK,KM
      EQUIVALENCE (V(1),VDIFF0(1)),(V(6401),VDIFF1(1))
      CALL READ1M
      DO 999 KM=1,NREC
      CALL READ2
      CALL READY1
      CALL FOURT(DATA,KDATA,1,-1,1,WORK,10)
      CALL EAR
      CALL PRNTM1
      NSECT1=NSECT-1
      CALL FULREC(NSECT,NFREQ)
      CALL DCFLTR(NSECT,NFREQ)
      CALL NORM(NSECT)
      CALL WRITEM(NSECT)
      CALL PUNCHM(NSECT)
      CALL DCFLTR(NSECT1,NFREQ)
      CALL NORM(NSECT1)
      CALL WRITEM(NSECT1)
      CALL PUNCHM(NSECT1)
  999 CONTINUE
      STOP
      END
```

(3) series.

Subroutine READ2 effects conveyance of the sample data, representative of a phonetic sound, to the computer.

4.4.2 Fourier Series Coefficients Computation. Subroutines listed as READY1 and FOURT in the main program function to provide the means by which approximate Fourier series coefficients for a phonetic waveform may be computed from its sample data. As previously mentioned the Fourier series coefficients for the phonetic waveform may be approximated by utilizing the fast Fourier transform, FFT. At this point it is appropriate to digress and discuss in some detail the FFT.

Cooley, Lewis, and Welch (27) define the fast Fourier transform as a computational procedure for calculating the discrete Fourier transform of a time series represented by sample data. The FFT algorithm as developed by Cooley and Tukey (28) reduces the time required to compute the discrete Fourier transform by reducing the number of computer operations from N^2 (as required by a straightforward computational procedure) to $2N \log_2 N$. N here denotes the number of data samples. For large N the time savings by using the FFT algorithm is most significant.

Mathematically the discrete Fourier transform, DFT, may be expressed as

$$A_p(k\Delta f) = \sum_{n=0}^{N-1} X(n\Delta t)e^{-j\frac{2\pi kn}{N}} \qquad k=0,1,\ldots,N-1 \qquad (4.7)$$

where $A_p(k\Delta f)$ denotes the kth frequency coefficient term of the DFT and $X(n\Delta t)$ is the nth sample of the time series which is comprised of N data samples. The j is defined as the $\sqrt{-1}$. The term Δf is defined to be

$$\Delta f = \frac{1}{N\Delta t} \tag{4.8}$$

where Δt is the time interval between sample data points of x(t). In actuality Δf is defined as

$$\Delta f = \frac{F_s}{N} \tag{4.9}$$

where F_s denotes the sampling frequency. The inverse of the DFT is mathematically described as

$$X(n\Delta t) = \frac{1}{N} \sum_{k=0}^{N-1} A_p(k\Delta f) e^{j\frac{2\pi kn}{N}} \qquad n=0,1,\ldots,N \quad . \tag{4.10}$$

Mathematically the discrete Fourier transform has been defined; now its mathematical properties will be described. First it has mathematical properties that are entirely analogous to those of the Fourier integral transform. Essentially it then maps a time series of discrete data samples into a discrete frequency spectrum function. The mapping is reversible. Further, multiplication of the transform of two time series corresponds to convolving the time series. The DFT differs from the Fourier integral transform in that the transform function is a periodic function. Cooley, et al. (27) notes that a continuous version of this function may be formed from the non-periodic Fourier integral transform function by superposition of the non-periodic function shifted by all multiples of the fundamental period of the sampling rate, F_s. Equation 4.11 describes this mathematically as

$$A_p(f) = \sum_{k=-\infty}^{\infty} A(f + kF_s) \tag{4.11}$$

where $A_p(f)$ denotes the periodic continuous version of the DFT while $A(f)$ is the non-periodic function of the integral transform which is shifted to produce $A_p(f)$. $A_p(f)$ is said to be an "aliased" version of $A(f)$. Thus $A_p(k\Delta f)$ is the discrete "aliased" version of $A(f)$.

As is well known from sample data theory, if a time series of data samples is to accurately represent the continuous waveform then the waveform should be frequency band-limited and the sampling rate F_s be at least twice the highest frequency component present in the waveform. Therefore, when applying the DFT it is most important that the sampling rate F_s be at least twice the Nyquist frequency. This will assure minimum error in the aliased version of the integral transform over the frequency range of

$$-\frac{F_s}{2} \leq f \leq \frac{F_s}{2} \quad .$$

The relationship between the Fourier series and the discrete Fourier transform is given by Colley, et al. (27), and is given below in the form of a theorem:

Let there exist a periodic function $x(t)$ with period T which may be expressed in terms of a Fourier series expansion

$$x(t) = \sum_{n=-\infty}^{\infty} c(n) e^{j\frac{2\pi n}{T} t} \tag{4.12}$$

where $c(n)$ denotes the Fourier series coefficients which are complex and may be determined by

$$c(n) = \frac{1}{T} \int_0^T x(t) e^{-j\frac{2\pi n}{T} t} dt \quad . \tag{4.13}$$

Then the periodic sequence $x(n\Delta t)$ of period N, where $\Delta t = \frac{T}{N}$, has a discrete Fourier transform

$$c_p(n) = \sum_{k=0}^{N-1} X(k\Delta t)e^{-j\frac{2\pi nk}{N}} \qquad n=0,1,\ldots,N-1 \quad . \qquad (4.14)$$

(The subscript p denotes the periodic function formed by superposition of the non-periodic function c(n) shifted by all multiples of a fundamental period, N.) Assuming that N is such that the error due to aliasing in the approximation of c(n) by letting

$$c_p(n) = \sum_{i=-\infty}^{\infty} c(n + iN) \qquad (4.15)$$

is acceptable, then it may be said that

$$c_p(n) \approx c(n) \quad \text{for } n=0,\ldots,\frac{N}{2}$$

and

$$c_p(N-n) \approx c(-n) \quad \text{for } n=-1,\ldots,-\frac{N}{2} \quad .$$

The development of the Theorem by Cooley, <u>et al</u>. (27) may be found in the reference. However, further words are in order concerning the relationship between $c_p(n)$ and c(n) as related to the aliasing error.

From the theorem it is observed that the terms $c_p(n)$ are periodic and of period N. Also that $c_p(n)$ only approximates c(n) for $0 \le n \le \frac{N}{2}$. Hence, the error in approximating c(n) by $c_p(n)$ in the range $-\frac{N}{2} < n < \frac{N}{2}$ is the sum of the c(n + iN)'s for $i = \pm 1, \pm 2, \pm 3, \ldots$. Thus the proper choice of F_s must be made if acceptable approximations of the Fourier series coefficients of a waveform are to be determined by using the discrete Fourier transform.

It is well established that for voiced phonetic sound signals the spectral content of the signals lie within the 64 Hz to 6,000 Hz frequency range. This suggests that a sampling rate of at least 12,000 Hz should be adequate. Having chosen the sampling rate Cooley et al. (27) note that one has complete freedom in choosing the resolution interval Δf. One does this by selecting N. As pointed out by Brenner (23), N should be, if possible, preferably a power of 2 to permit minimal time for computing the DFT using the FFT algorithm.

In order to utilize the FFT to calculate the Fourier series coefficients for a voiced phonetic waveform the waveform is assumed to be periodic which is quite reasonable. It is well known that voiced phonetic sounds are quasi periodic. In fact for small time windows representing several periods of the waveform the phonetic sound signal is most periodic.

Having established the legitimacy and the related condition for using the FFT to determine Fourier series coefficients of phonetic sound waveforms the point has been reached at which the discussion of the computer program may be continued.

As the name suggests subroutine READY readys the phonetic sound sample data for subsequent use in the computation of its FFT. Recall the sample data is in an interger format. Subroutine FOURT requires the data passed to it be in a floating format.

The subroutine FOURT used was written by Brenner (23). From the phonetic sound data, subroutine FOURT computes the FFT whose discrete terms are approximations of Fourier series coefficients.

4.4.3 Network Response Computations. Using the Fourier series coefficients the response of the cochlear network model to a phonetic sound is determined by the computational procedures established by subroutines EAR, FULREC, DCFLTR, FOURT, and NORM. First consideration will be given to the analysis technique used to calculate the steady-state response of each V(K,L) and D(K,L) to each sinusoidal Fourier series coefficient. This analysis technique is the basis for the subroutine EAR.

To calculate each V(k,t) of the network it is first necessary to define the values of NSECT, the number of ladder sections, the universal values of R and Q and the terminal resistance R_T. In addition it is necessary to define the resonant frequency for each tuned ladder section and to establish the frequency value associated with each Fourier series coefficient. Recall the values of NSECT, R, R_T and Q are arbitrary and chosen to permit accurate portrayal of the basilar membrane functions. Employing the selected value of NSECT each resonant frequency, $F_R(K)$, of the network may be determined from Equation 4.3. The associated Fourier series coefficient frequencies may be calculated from the following equation,

$$F_S(L) = L\Delta f \qquad L=0,1,2,\ldots,NFREQ \quad . \qquad (4.16)$$

NFREQ denotes the number of Fourier series terms.

To determine each V(k,t) of the network a recursive computational procedure can be employed. The concept of this procedure will become evident. By starting at the terminal end of the ladder network in Figure 4.8 and working toward the input terminal the impedance terms necessary for calculating the series arm currents and voltages and shunt arm currents and voltages may be calculated. The impedance of any shunt arm, ZS(K,L), for any given Fourier series frequency may be expressed as

$$ZS(K,L) = R + j\ RQ \left[\frac{F_S(L)}{F_R(K)} - \frac{F_R(K)}{F_S(L)} \right] \qquad (4.17)$$

where K denotes the Kth shunt arm of the cochlear ladder network and L denotes the Lth Fourier series coefficient term. In similar fashion the impedance of any series arm, ZA(K,L) for any given Fourier series frequency may be expressed as

$$ZA(K,L) = R + j\ RQ \left[\frac{F_S(L)}{F_R(K)} \right] \quad . \qquad (4.18)$$

The term Z(K,L) denotes the impedance for any given Fourier series frequency as seen looking in at any one of the K nodes of the cochlear network which is common to the Kth K + 1 series arm and the Kth shunt arm. Now if K = NSECT then

$$Z(NSECT,L) = ZA(NSECT,L) + R_T \,||\, ZS(NSECT,L) \qquad (4.19)$$

where the symbol || denotes the parallel combination of the impedances R_T and ZS(NSECT,L). Now if K < NSECT

$$Z(K,L) = ZA(K,L) + Z(K+1,L) \,||\, ZS(K,L) \quad . \qquad (4.20)$$

By using Equation 4.19 and then Equations 4.17, 4.18 and 4.20 in a recursive fashion the impedance Z(K,L) for any K and any L may be readily calculated. Using the impedances Z(K,L), ZA(K,L) and ZS(K,L) and knowing the finite Fourier series approximation for the input voltage E_{in} the value of each V(K,L) may determine in following recursive manner.

$$E_{in}(t) = \sum_{L=0}^{\frac{N}{2}-1} c_p(L)e^{j2\pi L\Delta f t} = \sum_{L=0}^{\frac{N}{2}-1} E_{in}(L) \qquad (4.21)$$

V(K,L) of the cochlear network denotes the steady-state sinusoidal voltage across the series resistor-inductor combination of the kth shunt arm due to the Lth Fourier series term. For K = 1 the series arm current for any Fourier series input voltage is

$$IA(1,L) = \frac{E_{in}(L)}{Z(IN,L)} \quad . \qquad (4.22)$$

The voltage across the first shunt arm for the Lth Fourier series term is

$$E(1,L) = E_{in}(L) - ZA(1,L)\ IA(1,L) \quad . \qquad (4.23)$$

Continuing the shunt arm current is determined to be

$$IS(1,L) = \frac{E(1,L)}{ZS(1,L)} \quad . \qquad (4.24)$$

Knowing the shunt arm current and using the fact that the impedance of the series resistance and inductance of the series arm and the shunt arm are equivalent for every Fourier series frequency it is determined that

$$V(1,L) = ZA(1,L)\ IS(1,L) \quad . \qquad (4.25)$$

For $1 < K \leq NSECT$ it may be derived that

$$IA(K,L) = \frac{E(K-1,L)}{Z(K,L)} \tag{4.26}$$

from which it may be found that

$$E(K,L) = E(K-1,L) - ZA(K,L)\ IA(K,L) \quad . \tag{4.27}$$

Knowing E(K,L) it may be determined that

$$IS(K,L) = \frac{E(K,L)}{ZS(K,L)} \tag{4.28}$$

and hence it is derived that

$$V(K,L) = ZA(K,L)\ IS(K,L) \quad . \tag{4.29}$$

Thus by using Equations 4.21 through 4.28 in a recursive manner the value of V(K,L) for each section and for each value of L may be computed. For a given section there are $\frac{N}{2}$ V(K,L) terms. They may be regarded as the coefficients of a sinusoidal series representative of V(K,L). Hence, a discrete time series representative of V(K,t) of period $\frac{N}{2}$ may be computed using the inverse FFT algorithm. Having determined the discrete time series V(K,t) it is a simple matter to find each full wave rectified time series, $|V(K,t)|$, and the discrete time series representative of each D(K,t). For each time series representing $|V(K,t)|$ and D(K,t) the average value of each as would be obtained by passing their signal through a low pass filter having an upper cut-off frequency of 16-20 Hz can be approximated by conveniently using the FFT to find the average D.C. value. Here recall the first term of the DFT is the average value of the time series. Once the values of $|V(K,t)|_{AVG}$

are known for each section these values are normalized such that for any K, $0 \leq |V(K,t)|_{AVG} \leq 99$. In like fashion for the $D_{AVG}(K,t)$ composite response each value is normalized such that for any K, $-99 \leq D_{AVG}(K,t) \leq 99$. Mathematically the normalization of each composite $|V(K,t)|_{AVG}$ term and of each composite $D_{AVG}(K,t)$ term are defined by Equations 4.29 and 4.30.

$$[|V(K,t)|_{AVG}]_{NORM} = \frac{|V(K,t)|_{AVG}}{\max\{|V(K,t)|\}} 99 \qquad (4.29)$$

$$[D_{AVG}(K,t)]_{NORM} = \frac{D_{AVG}(K,t)}{\max\{|D_{AVG}(K,t)|\}} 99 \qquad (4.30)$$

Based on these computational procedures the subroutines EAR, FULREC, DCFLTR and NORM were written to simulate the cochlea behavior to complex acoustic signals.

4.4.4 Data Output. Having calculated a cochlea response the data output phase of computation provides the means to process this information out of the computer. Subroutine programs PRNTM1, WRITEM and PUNCHM define the necessary computer functions to accomplish this task. These subroutines properly identify the simulated responses with the phonetic sound sample data from which the response was effected. They also provide the instructions for listing and punching the responses on paper and cards respectfully. Hence, the composite responses $\{|V(K,t)|_{AVG};K=1,2,...,NSECT\}$ and $\{D_{AVG}(K,t);K=1,2,...,NSECT-1\}$ are in a format to permit further analysis and processing.

CHAPTER V

DIGITAL COMPUTER SIMULATIONS OF COCHLEAR RESPONSES TO VOICED PHONEMES

5.1 Introduction. Employing the digital computer simulation technique as described in Chapter IV the cochlear responses to each phonetic sound of the sample data set were determined. The IBM 360 computer was used in this endeavor.

5.2 Parameters Selected for the Cochlear Model. It was demonstrated in Chapter IV that the cochlear network model may be completely specified by the parameters NSECT, R, R_T, Q and the set of resonant frequencies $\{F_R(K);K=1,2,...,NSECT\}$. The value 100 was selected for NSECT. This value was selected since the results of others have conclusively shown that a ladder network of 100 sections adequately defines the cochlear function as effected by sinusoidal excitation. The parameters R, R_T, and Q were selected to be:

$$R = 100 \text{ ohms}$$

$$R_T = 1000 \text{ ohms}$$

$$Q = 12 \quad .$$

Each of the 100 resonant frequency values which together define the set $\{F_R(K);K=1,2,...,NSECT\}$ were determined from Equation 4.3. A listing of these resonance frequencies is shown in Table VII.

In order to assure that these specified network parameter values would effect proper simulation of the cochlear functions described

TABLE VII

RESONANT FREQUENCIES OF THE COCHLEAR NETWORK MODEL

Ladder Section Number K	Resonant Frequency HZ	Ladder Section Number K	Resonant Frequency HZ	Ladder Section Number K	Resonant Frequency HZ	Ladder Section Number K	Resonant Frequency HZ
1	8176	26	2402	51	706	76	207
2	7785	27	2287	52	672	77	197
3	7413	28	2178	53	640	78	188
4	7058	29	2073	54	609	79	179
5	6721	30	1974	55	580	80	170
6	6399	31	1880	56	552	81	162
7	6093	32	1790	57	526	82	155
8	5802	33	1704	58	501	83	147
9	5525	34	1623	59	477	84	140
10	5261	35	1545	60	454	85	133
11	5009	36	1471	61	432	86	127
12	4770	37	1401	62	412	87	121
13	4541	38	1334	63	392	88	115
14	4324	39	1270	64	373	89	110
15	4118	40	1210	65	355	90	104
16	3921	41	1152	66	338	91	99
17	3733	42	1097	67	322	92	95
18	3555	43	1044	68	307	93	90
19	3385	44	994	69	292	94	86
20	3223	45	947	70	278	95	82
21	3069	46	901	71	265	96	78
22	2922	47	858	72	252	97	74
23	2782	48	817	73	240	98	71
24	2649	49	778	74	229	99	67
25	2523	50	741	75	218	100	64

herein the model was excited at several discrete sinusoidal frequencies. Figures 5.1 and 5.2 illustrate the $|V(K,t)|_{AVG}$ vs K, the $D_{AVG}(K,t)$ vs K and $IS(K,t)_{AVG}$ vs K responses. Here K deontes a particular section of the cochlear network. The frequencies of the input signal are successive half-tones having values of 64, $64\sqrt{2}$, 128, ..., 8192 Hz. The amplitude values of the input signal were calculated from Equation 4.5. These responses correlate with those reported by Bolie (29) for a 100 section network. Although not graphically presented, similar responses of the cochlear network were determined assuming an 80-section model with a universal Q value of 10. These responses were in agreement with those illustrated by Figures 4.6 and 4.7 herein. Thus, it may be concluded that the dynamic computer model of the cochlear responds satisfactorily to discrete sinusoidal excitation in that its responses correspond to known physiological disclosures pertaining to the cochlea.

5.3 Cochlear Simulations. Using the specific cochlear model just defined, simulated responses of the model were determined for cases in which the excitation signals were actual phonetic sound signals. Simulated responses of the model to each phonetic sound record of the sample data set were calculated using the IBM 360 computer. In these determinations the finite Fourier series representation of each phonetic sound signal were calculated to have 64 terms for male phoneme signals and 32 terms for female phoneme signals. From Equation 3.1 it is seen that the sampling rate chosen for the collection of the sample data is directly related to the pitch frequency of the phoneme waveform. Thus, the corresponding frequency of each Fourier series term is a multiple of the voice pitch frequency.

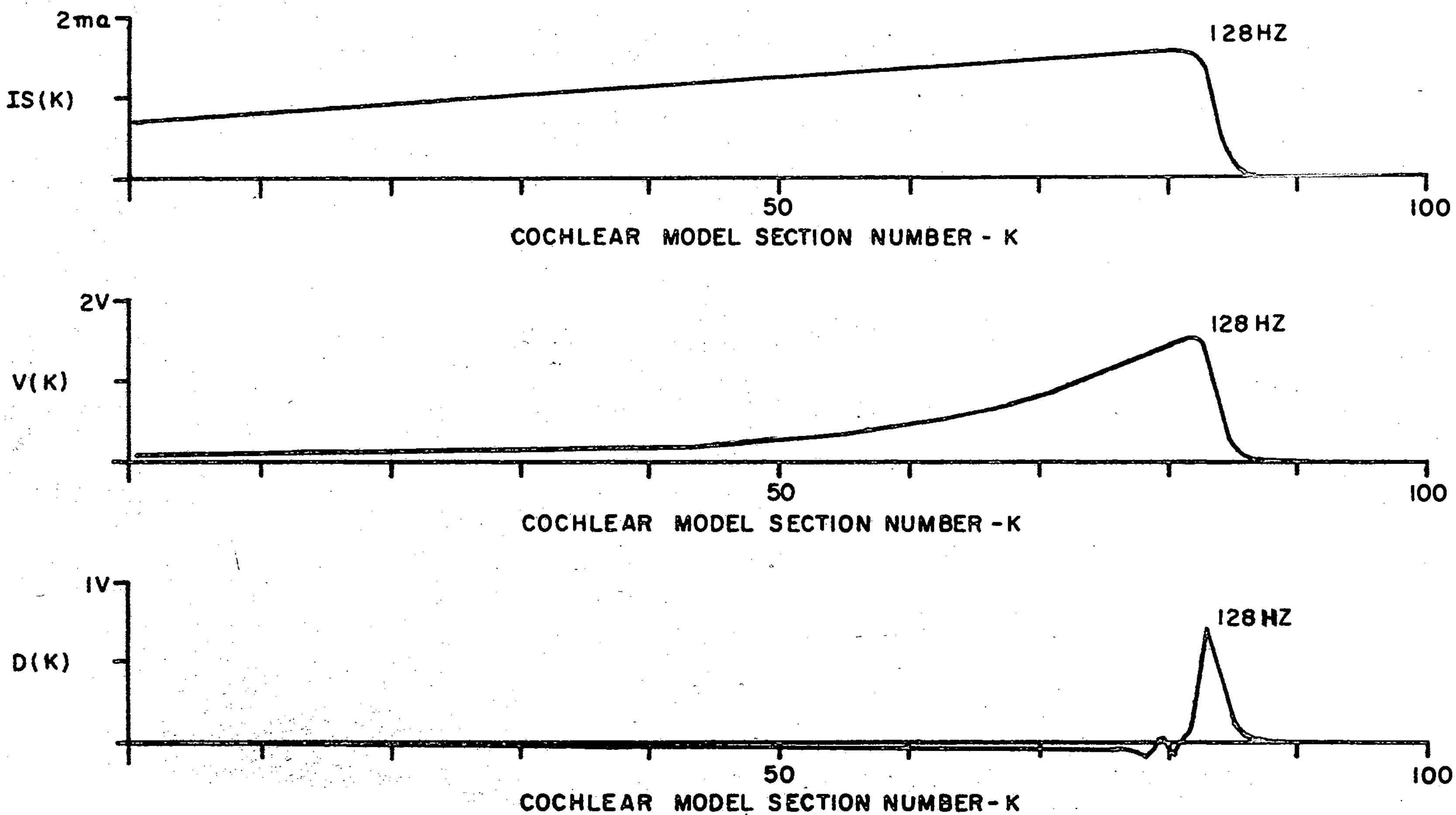


Figure 5.1. Response of 100 Section-Cochlear Model to a Sinusoidal Input Signal; Q of Network Resonant Shunt Arms, 12

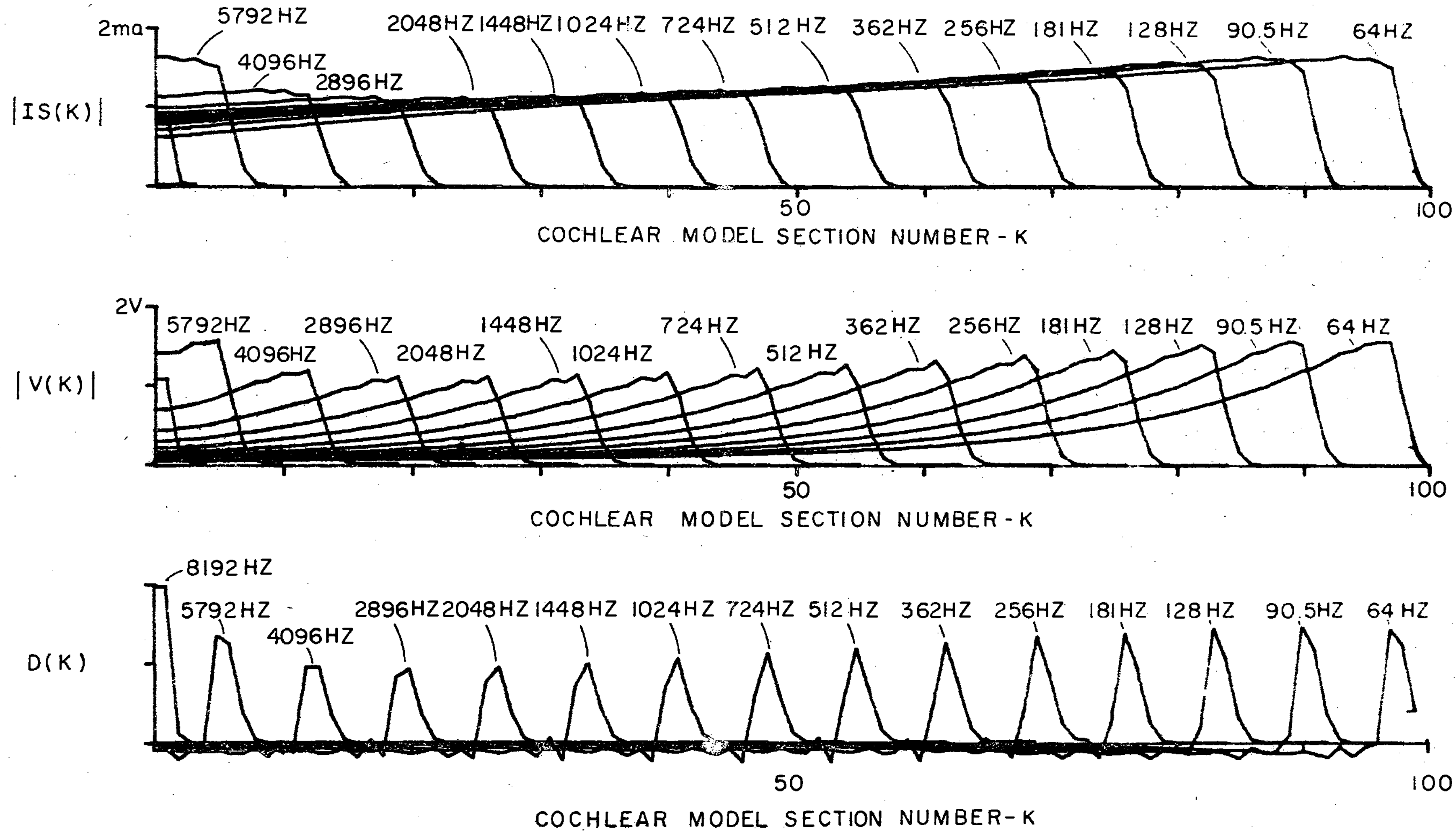


Figure 5.2. Response of 100 Section-Cochlear Model to Successive Half-Tone Sinusoidal Input Signals; Q of Network Resonant Shunt Arms, 12

In order to provide a convenient means for illustrating the simulated responses the IBM 1620 computer and associated Calcomp Plotter were employed. For each phonetic sound record graphical plots of each $|V(K,t)|_{AVG}$ vs K response and each $D_{AVG}(K,t)$ vs K response were drawn. A listing of the FORTRAN II program used for this endeavor is given in Appendix C. The graphical illustrations of the simulated cochlear responses are provided in total in Appendix B.

5.4 Analysis of the Simulated Cochlear Responses. The simulated cochlear responses as effected by the computer from actual phonetic sound sample data were examined for various characteristics. The simulated cochlear responses given in Appendix B are seen to be designated as "Zero-Order Difference Response of the Cochlear Network" and "First-Order Difference Response of the Cochlear Network". The former designation is synonymous with the designations of "simulated basilar membrane response", $|V(K)|$ vs K and $|V(K,t)|_{AVG}$ vs K, while the latter is synonymous with the designations of "simulated neighboring difference response", D(K) vs K and $D_{AVG}(K,t)$ vs K.

It is of interest to note the relationship between the zero-order difference response and the corresponding first-order difference response for a given phoneme. Typical simulated cochlear responses as effected by the phoneme (ae) as in "bAt" are illustrated by Figures 5.3 and 5.4. It is evident that the first-order difference response is predictable from the zero-order difference response. It can be seen that an abrupt change in the slope of the zero-order difference response profile correlates with a spike in the first-order difference response. A steep negative slope in the zero-order difference response profile gives

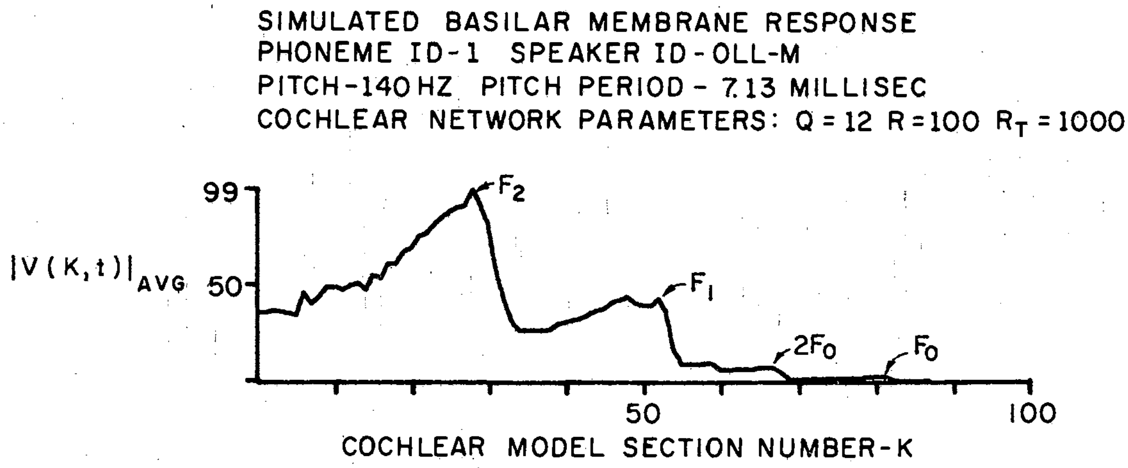


Figure 5.3. Simulated Basilar Membrane Response of the Cochlear Model to the Phoneme (ae) as in "bAt"

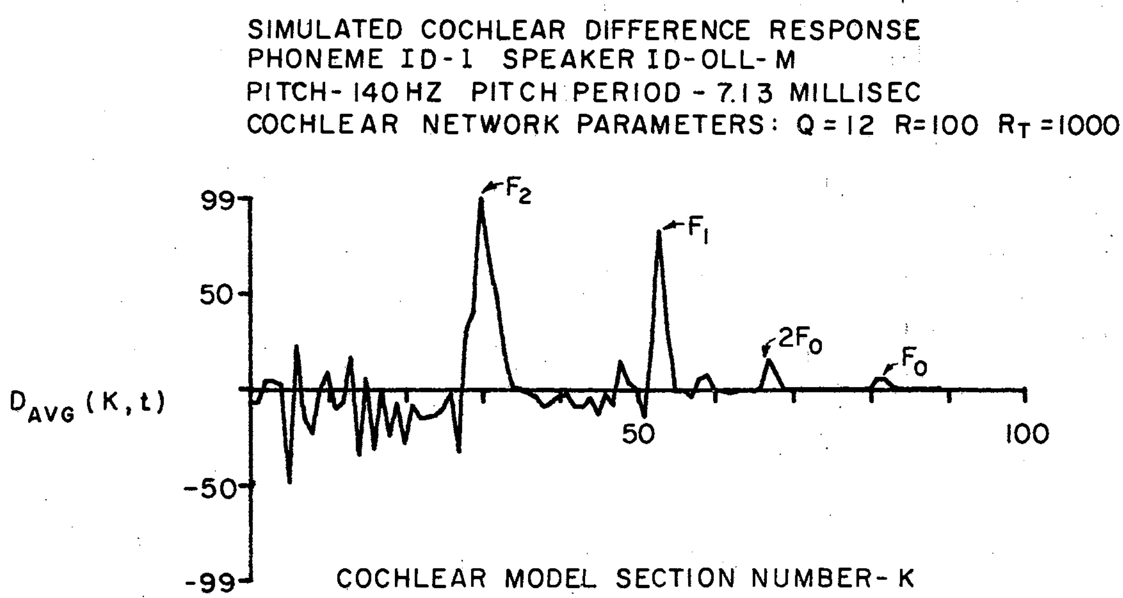


Figure 5.4. Simulated Neighboring Difference Response of the Cochlear Model to the Phoneme (ae) as in "bAt"

rise to a positive spike in the first-order difference response, while an abrupt positive slope effects a negative spike. If the profile gradient in the zero-order response is gradual the first-order difference response remains rather constant and no spikes are noted. This correlation is as expected, since the first-order difference response is an approximation of the derivative of the zero-order difference response profile.

A major observation which can be derived from the simulated cochlear responses shown in Appendix B is that the abrupt negative changes in the profile of the zero-order difference response and the corresponding positive peaks of the first-order difference response correlate rather well with the formant frequencies and the harmonics of the voice pitch for a given voiced phoneme. These frequencies are those which characterize and define the power spectrum of a voiced phoneme. The formant frequencies of a voiced phoneme are defined as those frequencies at which broad peaks (spanning harmonics of the glottal pulse frequency) occur in the power spectrum envelope. The power spectrum envelope is defined by a line drawn to profile the amplitudes of all of the harmonics of the voice pitch.

The above described results may be compared with the results reported by Peterson and Barney (30). They determined, by using a sound spectrograph, the formant frequencies of each of the vowel sounds (i), (I), (ɛ), (ae), (ʌ), (ɑ), (ɔ), (u), (ʊ), and (ɝ) as spoken by 76 speakers. Figure 5.5 is a reproduction of their results. It is a scatter plot illustrating the relationship between the first formant frequency, F_1, and the second formant frequency, F_2, of the vowel phonemes. Each F_1 vs F_2 domain into which a given phoneme may be

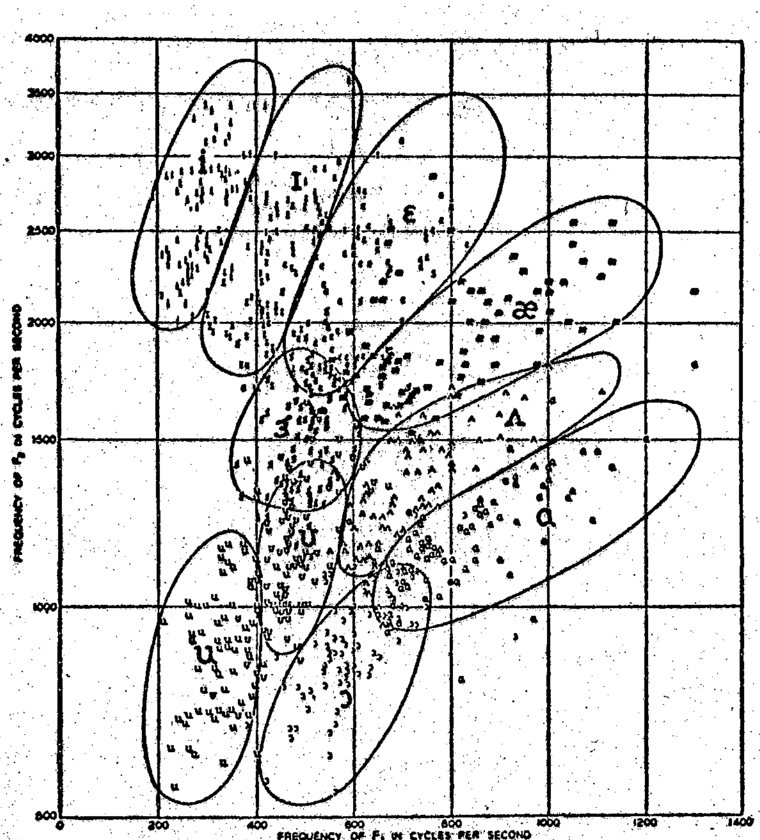


Figure 5.5. Frequency of Second Formant vs Frequency of First Formant for Ten Vowels by 76 Speakers as Compiled by Peterson and Barney (Reproduced From Peterson and Barney (30))

classified is defined by a closed contour line. From the simulated cochlear responses shown in Appendix B the values of F_1 and F_2 for each of the vowel sounds (i), (I), (ɛ), (ae), (ʌ), (ɑ), (ɔ), (u), (ʊ), and (O) were estimated. Figure 5.6 is the resultant scatter plot which indicates the F_1 vs F_2 relationship of the vowel phonemes for 12 speakers. It is evident by comparison of Figure 5.5 with Figure 5.6 that the results shown in Appendix B are in agreement with the results established by Peterson and Barney (30). Hence, it appears that the cochlear model

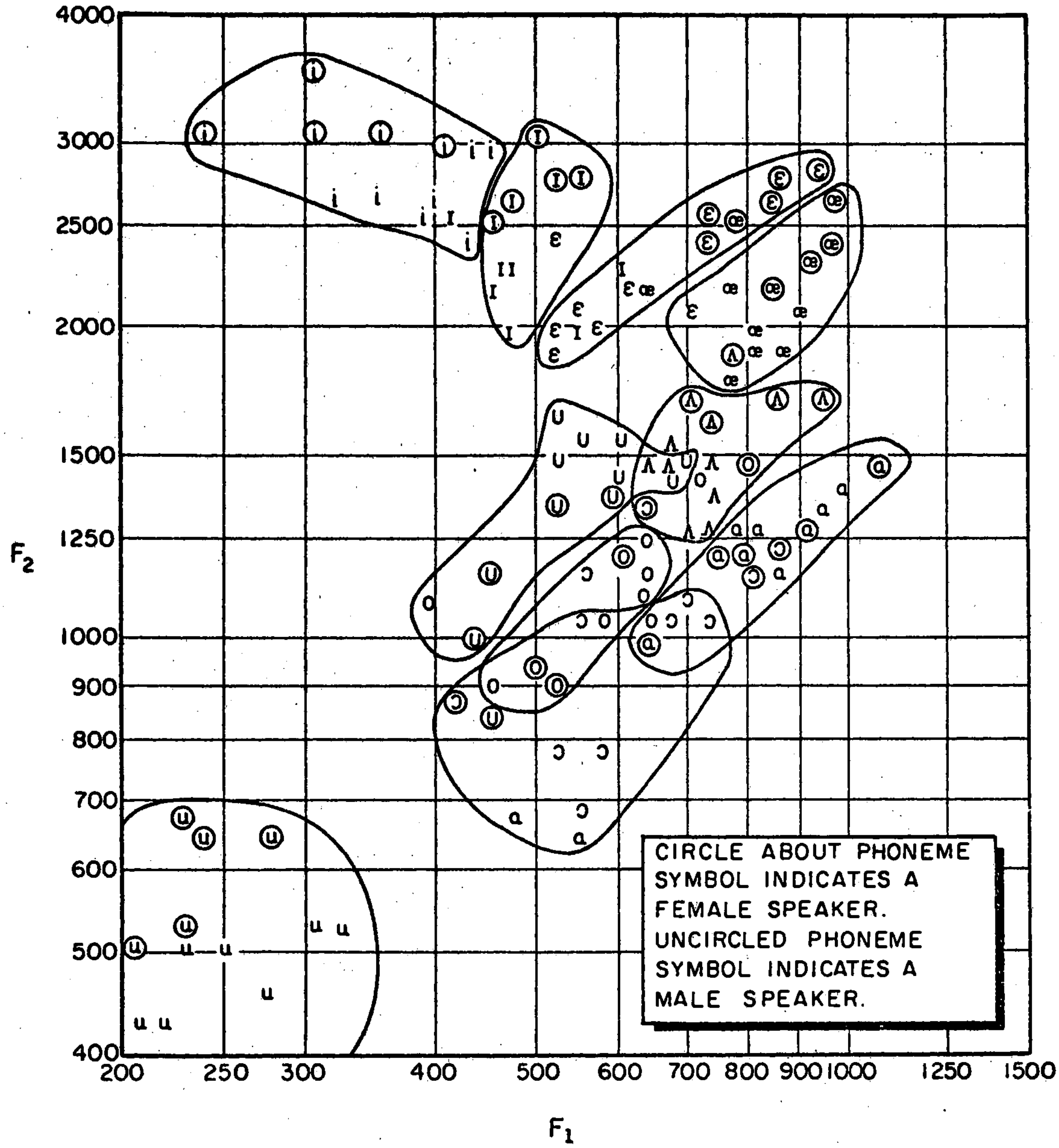


Figure 5.6. Second Formant Frequency vs First Formant Frequency for Nine Vowels by 12 Speakers as Compiled From Simulated Cochlea Responses Given in Appendix B

exhibits an inherent ability to perceive the formant frequencies, F_1 and F_2, of a given voiced phoneme.

Indirectly the agreement between the results of Peterson and Barney (30) and the results shown in Figure 5.6 suggests that the phonetic sound waveforms collected for this research are representative of the phonetic sound waveforms as they might occur in connected speech. As noted previously, a 3 second tape recording of a particular phonetic sound was made during which time the speaker maintained a near constant vocal tract configuration. The question arises as to whether the phonetic sound observed in this fashion is representative of how it would be observed in connected speech. Peterson and Barney (30) estimated the characteristic values of F_1 and F_2 for vowel phonemes extracted from spectrograph records of spoken words, i.e., the estimates of F_1 and F_2 were made from that segment of the spectrograph record which corresponded with the particular phoneme of interest. Thus, indirectly the fact that the two F_1 vs F_2 relationships are in good agreement, even though one F_1 vs F_2 relationship was determined from unconnected speech while the other was found from connected speech, suggests that the phonetic waveforms used in this research are representative of those found in connected speech.

The cochlear model also seems to exhibit the ability to perceive, in addition to F_1 and F_2, the fundamental formant frequency, F_0, and its associated harmonics, as well as the third formant frequency, F_3. As is apparent in Appendix B, the presence or effect of F_0 is evident in every response. Often the responses exhibit the presence of harmonics of F_0. In general, the responses show the effect of F_0 to be much less pronounced than F_1. Figures 5.7 through 5.10 illustrate typical

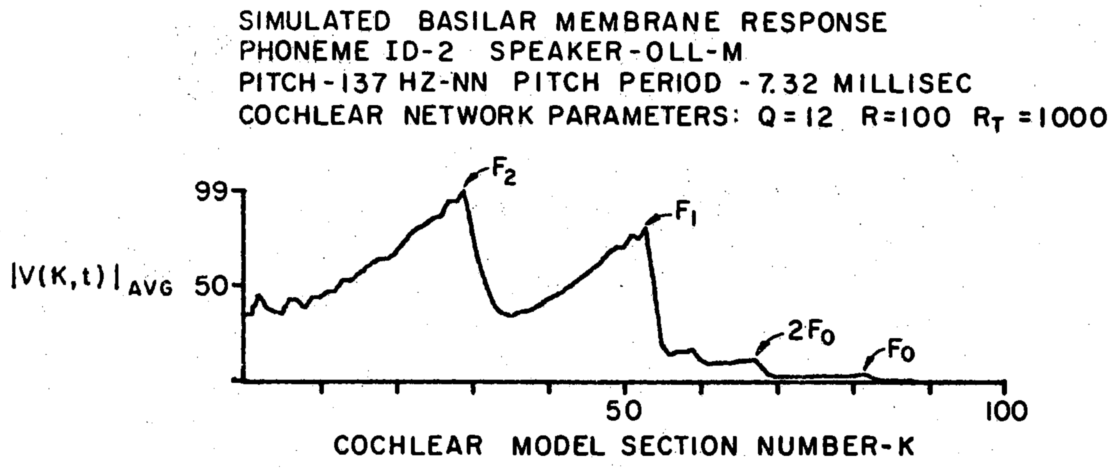


Figure 5.7. Simulated Basilar Membrane Response of the Cochlear Model to the Phoneme (e) as in "Ape" as Spoken by OLL

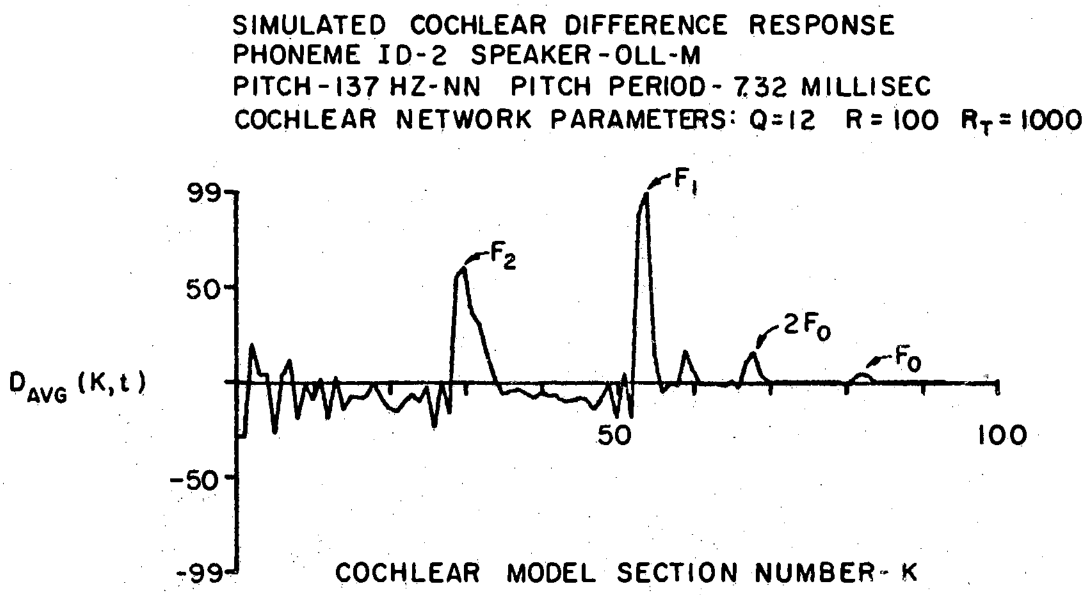


Figure 5.8. Simulated Neighboring Difference Response of the Cochlear Model to the Phoneme (e) as in "Ape" as Spoken by OLL

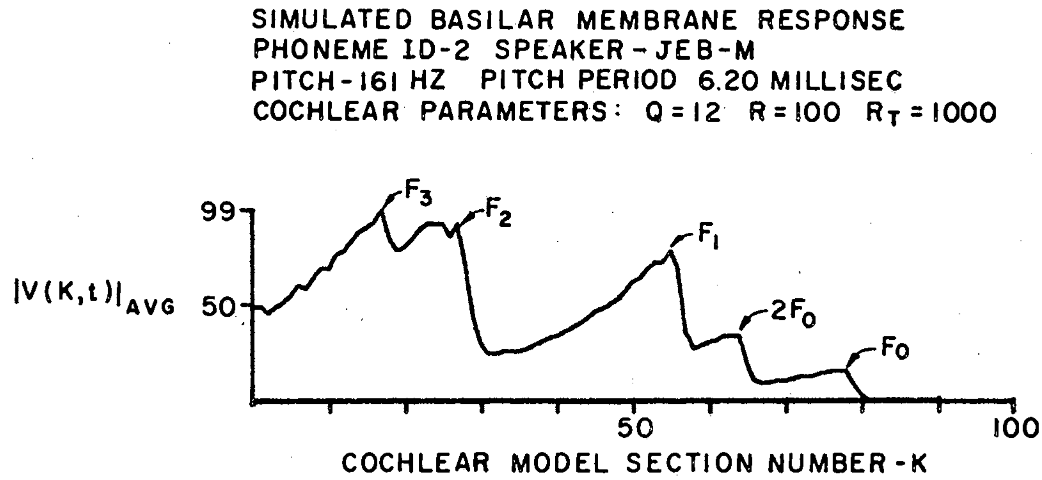


Figure 5.9. Simulated Basilar Membrane Response of the Cochlear Model to the Phoneme (e) as in "Ape" as Spoken by JEB

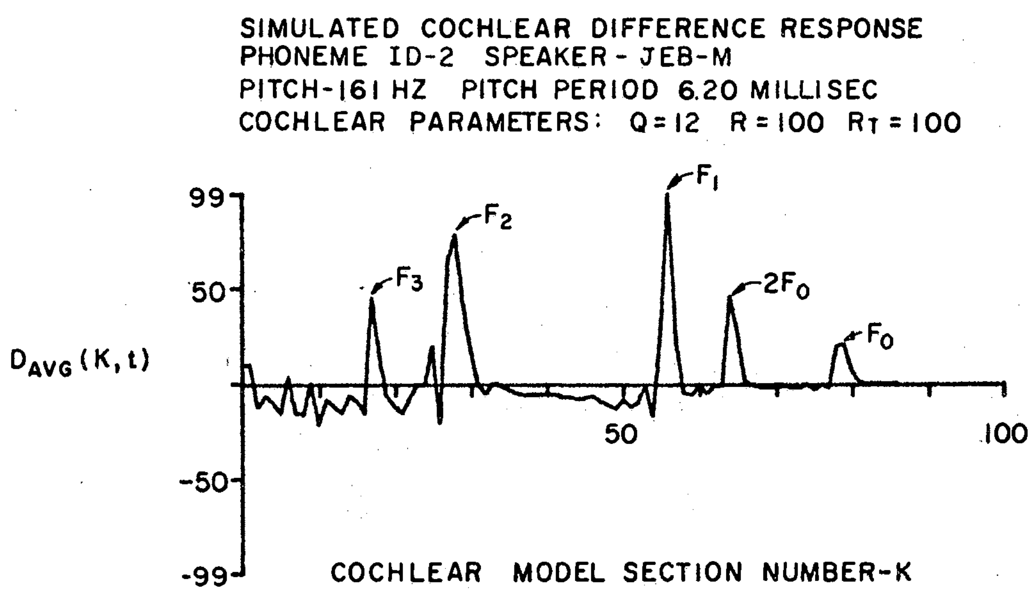


Figure 5.10. Simulated Neighboring Difference Response of the Cochlear Model to the Phoneme (e) as in "Ape" as Spoken by JEB

examples of this point. However, it is evident from some responses that this is not always the case. In these instances the first-order difference responses show the peak corresponding to F_1 and those effected by F_0 to be nearly equally pronounced. Figure B.10 is an illustration of this point. It was found that when this condition prevailed some difficulty was encountered when estimating F_1. In an analogous form, Peterson and Barney (30) also encountered a similar occurrence of this difficulty when estimating F_1 of a phoneme from a spectrograph recording. They attributed the difficulty to those cases in which the pitch frequency was high relative to F_1. This, they noted, caused a poor definition of F_1 in the spectrograph recording.

The responses shown in Appendix B suggest that the ability of the cochlear model to select F_3 is a function of the speaker, voice pitch, and, to a lesser extent, a function of the phoneme. Thus F_3 selection seems not to require a higher resolution of frequencies by the cochlear model. Figures 5.7 and 5.8 illustrate simulated responses of the cochlear model to the phoneme (e). It is noted that the humps and abrupt negative changes in the response profile shown in Figure 5.7, and the positive peaks of Figure 5.8, correspond to F_2, F_1, and F_0. Neither response, however, suggests perception of F_3. Figures 5.9 and 5.10 show the simulated responses to the phoneme (e), as effected by another speaker. Clearly both responses show the perception of F_3. This pattern is typical, and numerous examples of it may be found by examination of the responses. For those phonemes which have relatively low values of F_2 and F_1, namely, the phonemes (u) and (U), the perception of F_3 is more frequent. This point is made evident by comparing the (u) and (U) cochlear responses as depicted by Figures B.17 through

B.20 with those effected by other phonetic sounds. The responses depicted by Figures B.41 and B.42 suggest that the voice pitch at which a speaker utters a voiced phoneme relative to his normal pitch seems to relate to whether or not F_3 is perceived by the cochlear model.

An interesting implication may be derived from the zero-order difference responses of the cochlear model. These responses suggest that the displacement of the basilar membrane of the biological cochlea in response to a voiced phonetic sound is defined by the formant frequencies of the phoneme. The fact that the humps and abrupt negative changes in the profile of the zero-order difference responses have been shown to correlate with the formant frequencies of the vowel sounds substantiates this implication. Since the formant frequencies define those frequencies about which, for a given voiced phoneme, most of its spectral power is concentrated the implication seems reasonable in relation to Bekesy's observations concerning the frequency response behavior of the human cochlea. Figures 5.3, 5.7 and 5.9 are referenced to aid in illustrating this observation.

In general, the simulated basilar membrane responses suggest that the formants F_1 and F_2 of a voiced phoneme are the predominant frequencies which determine the displacement of the basilar membrane. This is particularly apparent in Figures 5.3, 5.7 and 5.9. Further, the responses suggest that the third formant frequency, F_3, seems to have less pronounced effect than F_1 and F_2 in giving definition to the displacement of the basilar membrane. In fact, the responses show that its influence is frequently not pronounced at all but obscured. Whether the effect of F_3 is pronounced or obscured in the basilar membrane displacement profile seems to be a function of the speaker, his pitch in relation to normality, and to some extent the voiced phoneme. Based on the simulated basilar membrane responses, it is suspected that the principal role of F_3 is that of giving definition to the displacement of the basilar (stapes) end of the basilar membrane. Reference is made to Figures 5.7 and 5.9 which partially portray the displacement influence of F_3. Additional examples illustrating the role formant F_3 plays in effecting displacement of the basilar membrane may be found in Appendix B, particularly in Figure B.41.

The zero-order difference responses suggest that the role of the fundamental formant F_0 is that of defining the displacement of the helicotrema end of the basilar membrane. However, being the fundamental frequency component of a voiced phoneme, F_0 also effects displacement along the entire length of the basilar membrane. This role of F_0 is obscured in the zero-order difference responses effected by the phonemes. However, the low frequency responses in Figure 5.2 which show the zero-order difference responses for pure tones demonstrates the displacement effect F_0 produces along the entire membrane.

The displacement effect F_0 has on giving definition to the helicotrema end of the basilar membrane is best demonstrated by the zero-order difference responses of Figures B.39 through B.44. These simulated basilar membrane responses were produced by the phonetic sound records which are representative of the phoneme waveforms for (i), (e), (O), and (u) as spoken by the same speaker over a one-octave pitch range of his voice. As the pitch of the speaker's voice increases there is a change in the amplitude of displacement of the simulated basilar membrane responses for $60 \leq K \leq 100$. This range of K corresponds to the 64 - 450 Hz frequency range. As the voice pitch increases the value of

K at which the simulated membrane displacement becomes zero decreases. From the referenced Figures this trend is vividly illustrated. Also the displacement effected by F_0 is considerably less than those displacements of the membrane effected by F_1 and F_2. This, in general, seems to be a prevailing factor.

As previously noted, the formant frequencies, F_1 and F_2 appear to play the leading role in prescribing the displacement of the basilar membrane. It is of interest to correlate this observation with the spectra of vowels as reported by Fairbanks and Holbrook (31). They determined the spectra for the vowel sounds (i), (I), (ɛ), (ae), (ɝ), (u), (U), (ɔ), (ɑ) and (ʌ). Their findings are shown in Figure 5.11, which show in graphical form the median frequencies vs relative spectral amplitudes of F_0, F_1, F_2 and F_3 of vowels. It is evident that the spectral amplitudes which correspond to F_0 and F_1 for each vowel are always greater than the spectral amplitudes corresponding to F_2 and F_3. Based on these findings, one might speculate that F_0 and F_1 of a phoneme would be the frequencies expected to give greatest definition to the basilar membrane displacement. However, the simulated basilar membrane responses of this research in contrast seem to suggest that it is F_1 and F_2 of a voiced phoneme that give the greatest definition to the membrane displacement. The obscure role that the fundamental formant F_0 plays in effecting displacement of the basilar membrane along its entire length is suggested to explain this phenomenon. In the results shown in Appendix B the displacement effected by F_2 is noted to be frequently greater than that effected by F_1. Examples of these cases are portrayed by Figures 5.12 and 5.7.

An interesting and perhaps significant implication can be derived

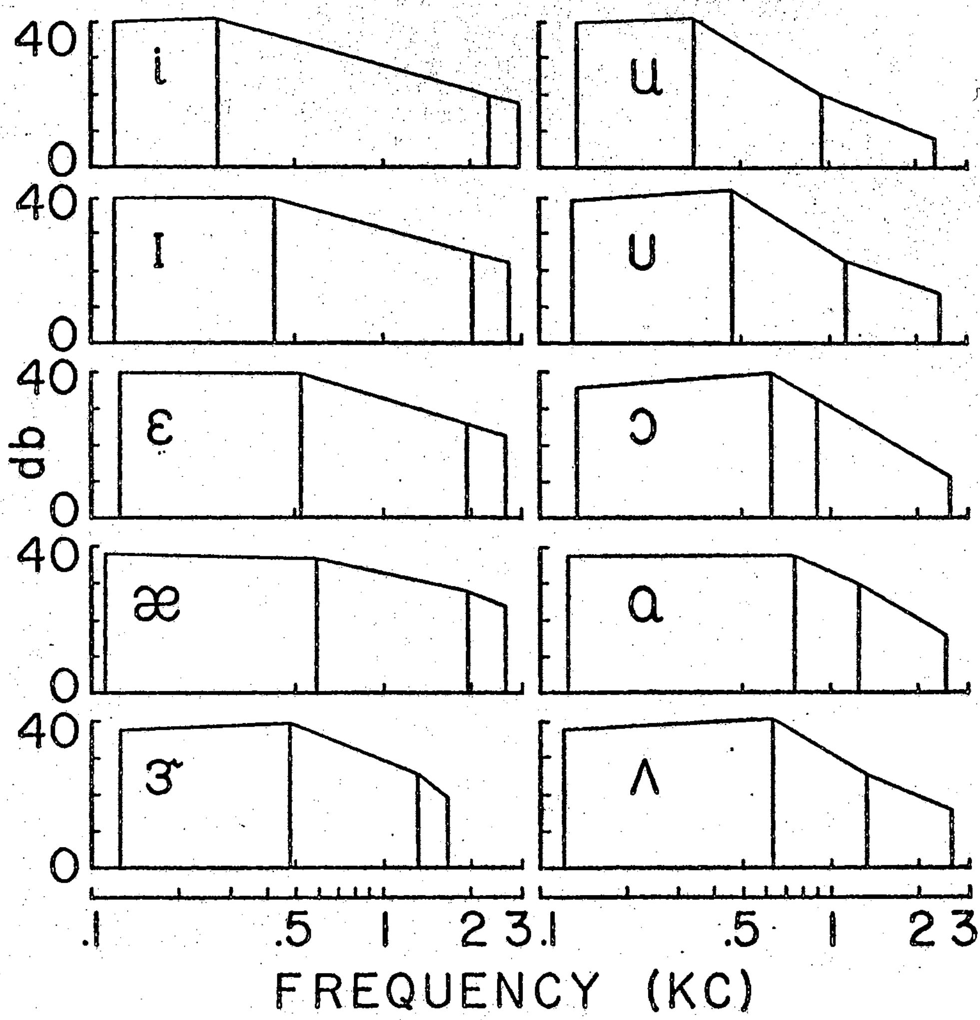


Figure 5.11. Spectra of Vowels, Median Frequencies vs Relative Amplitudes of the Fundamental and First Three Formants of Vowels as Reported by Holbrook and Fairbanks (Reproduced From Holbrook and Fairbanks (31)).

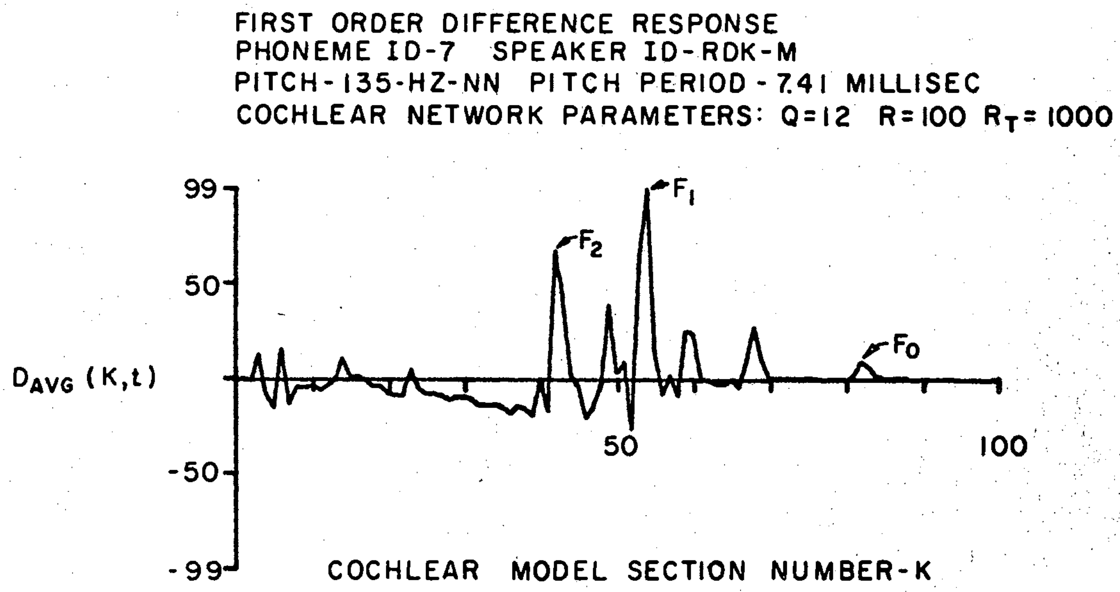


Figure 5.12 Simulated Basilar Membrane Response of the Cochlear Model to the Phoneme (i) as in "mEEt"

from the previous observations. The recognition of voiced phonetic sounds by an individual appears to be effected primarily by the apparent ability of the cochlea to perceive the formant frequencies. Further, since the perception of F_3 seems to be frequently obscured, as suggested by the profile shapes of the zero and first-order difference responses, its necessity for phoneme recognition is questionable. The simulated responses shown in Appendix B tend to support this conclusion, at least for the vowel sounds and the nasal consonants. For the voiced fricatives (z), (ξ), and (U) the response profiles tend to suggest that perception of F_3 is perhaps necessary for their recognition.

The basilar membrane responses tend to suggest that recognition of a phoneme is perhaps independent of F_0. The simulated responses demonstrate that the cochlear model has an apparent ability to place less emphasis on perception of F_0 while inherently placing emphasis on perception of F_1 and F_2. Thus, indirectly the necessity of F_0 for phoneme recognition is questionable.

Whether or not the conjectures concerning F_0 and F_3 as related to voiced phoneme recognition are valid needs to be persued through additional research. However, the simulated responses generated in this study strongly suggest that the recognition of a voiced phoneme by an individual seems to be primarily related to perception of F_2 and F_1 by the cochlea. From the simulated cochlear responses illustrated by Figures B.39 through B.44 the effect of a variation in F_0 has on F_1 and F_2 can be observed. These responses correspond to those generated from the phonetic sounds (i), (e), (O), and (u). The sounds were voiced by the same speaker at 8 incrementally spaced pitch intervals over a one-octave range of the speaker's voice. From the zero- and first-order difference responses the perceived values of F_1 and F_2 as related to the speaker's voice pitch have been found. Figure 5.13 is a scatter plot of F_1 vs F_2 which for each phoneme set illustrates the effect of variations in pitch (F_0) on F_1 vs F_2. Table VIII provides in tabular form the property of F_1 vs F_2 as it relates to F_0. The phoneme tab symbols of Table VIII correspond to the subscripted phoneme symbols plotted in Figure 5.13. In general, it is apparent from Figure 5.13 that variations in F_0 are manifested primarily in their effects on the values of F_1 perceived by the cochlear model. The above normal pitch frequencies of the speaker are noted to extend the F_1 vs F_2 domain of

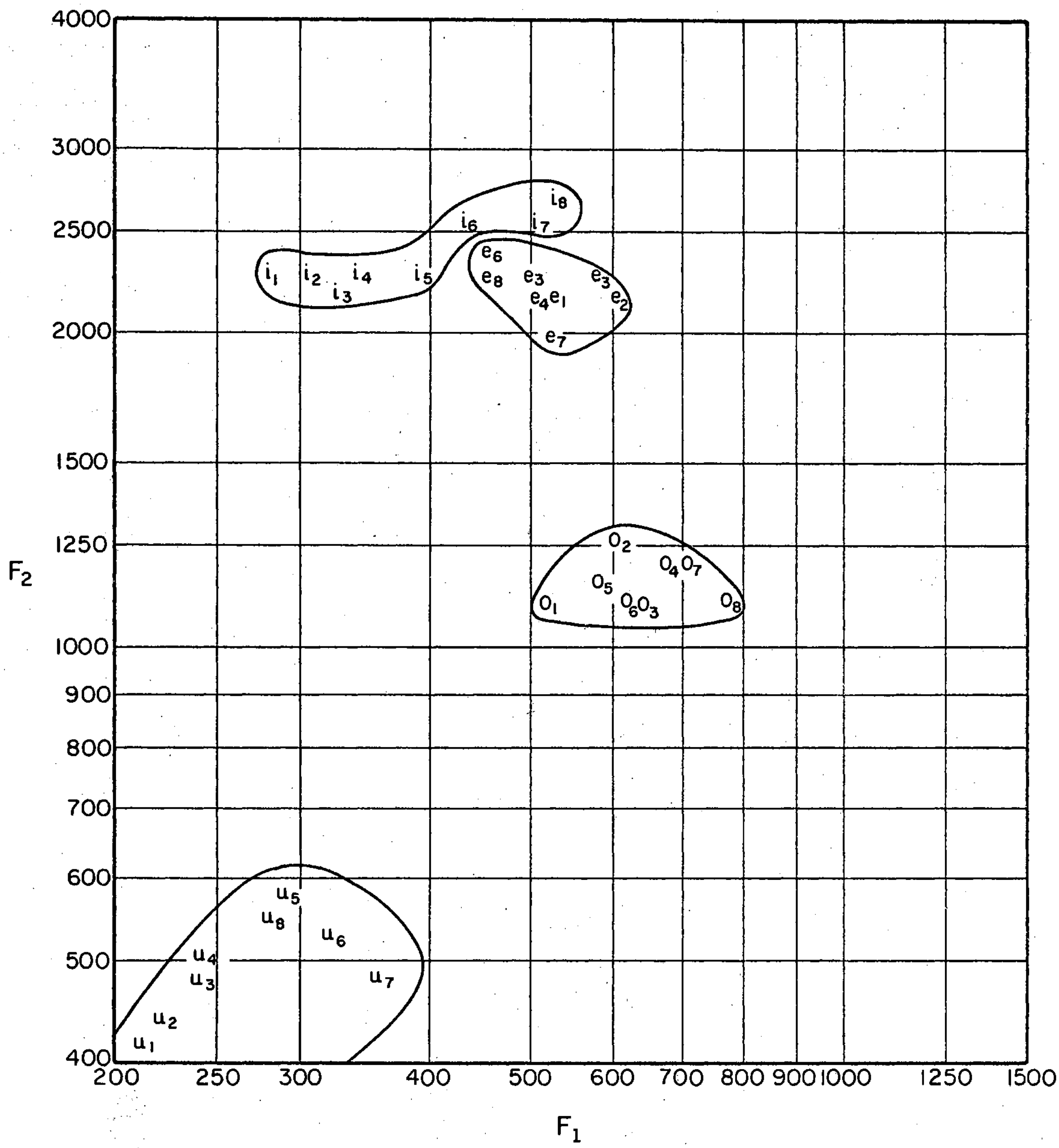


Figure 5.13. Second Formant Frequency vs First Formant Frequency for Four Vowels Showing the Effect of Pitch Variation of a Speaker on the First and Second Formant Frequencies.

TABLE VIII

F_0 VS F_1 VS F_2 ILLUSTRATING THE EFFECT F_0 HAS ON F_1 AND F_2 WHEN A SPEAKER INCREASES HIS VOICE PITCH OVER A ONE-OCTAVE RANGE

Phoneme Tab	F_0 HZ	F_1 HZ	F_2 HZ
i-1	122	2287	278
i-2	135	2287	307
i-3	143	2178	322
i-4	149	2287	338
i-5	167	2287	392
i-6	189	2523	432
i-7	215	2523	501
i-8	232	2649	526
e-1	114	2178	526
e-2	131	2178	609
e-3	140	2287	501
e-4	149	2178	526
e-5	169	2287	580
e-6	195	2402	454
e-7	217	1974	526
e-8	232	2287	454
O-1	118	1097	526
O-2	134	1270	609
O-3	141	1097	640
O-4	149	1210	672
O-5	168	1152	580
O-6	193	1097	640
O-7	219	1210	706
O-8	230	1097	778
u-1	118	412	207
u-2	127	432	218
u-3	139	477	240
u-4	146	501	240
u-5	170	580	292
u-6	181	526	322
u-7	211	477	355
u-8	242	552	278

the phonemes (i) and (u). Even so, mutual exclusiveness of the F_1 vs F_2 domains of (i) and (e) seems to prevail. These observations suggest that pitch normalization would be effective in reducing the F_1 vs F_2 domain of a phoneme and thus for an individual speaker, assure that the F_1 vs F_2 domains of the voiced phonemes are nearly mutually exclusive. The disclosures of Matthew, *et al.* (10) further suggest that pitch normalization would be effective in promoting mutual exclusiveness of the F_1 vs F_2 domain of phonemes among speakers.

CHAPTER VI

SUMMARY AND CONCLUSIONS

6.1 Summary. The method by which a quality microphone, a magnetic tape recorder and an anechoic chamber were used to collect a set of voiced phonetic sound recordings has been presented. A set of 262 phonetic sound recordings was compiled. The set contains recordings representing 19 different phonemes which are characteristic to each of 12 speakers.

Next a technique by which sample data representative of one period of a voiced phonetic sound signal could be obtained from analog phonetic sound tape recordings was developed. This technique was successfully instrumentated and employed to compile an amplitude-normalized sample data set of voiced phonetic sounds. The sample data set comprised of 262 phonetic sounds has been documented in both graphical and tabular formats to permit its use by others in future related research.

Based on the biological disclosures of Bekesy, modeling efforts by Bolie and utilization of the discrete Fourier transform a dynamic digital computer model of the cochlea has been developed. The model is intended to simulate the steady-state behavior of the cochlea to voiced phonetic sounds. Being a digital computer model it is most adaptable to redefinition. To redefine the RLC cochlear network, whose behavior simulates certain cochlear functions, only four network parameters, NSECT, R, R_T and Q, and a set of resonant frequencies need be specified.

This is accomplished by changing one data card.

The simulated cochlear responses are intended to be representative of the steady state displacement of the basilar membrane and the adjacent inhibition behavior of the neural fibers of the cochlea which has been suggested by Huggins and others as the possible biological mechanism which enables the acute frequency selectivity known to be fundamental in hearing. It has been demonstrated that the response of the cochlear model to pure sound frequencies is in concert with Bekesy's disclosures and Bolie's computer simulations. The simulated responses of the cochlear model to actual voiced phonemes seem representative of what one might expect based on the disclosures of Bekesy.

6.2 Suggested Refinements Related to the Cochlear Model. The digital computer model of the cochlea seems satisfactory for simulating cochlear responses to phonetic sounds. However, some responses suggest a need for better resolution in the 3,000 Hz to 8,000 Hz frequency range. The response characteristics which suggest this need are best portrayed by an illustration. In many of the simulated basilar membrane responses given in Appendix B there are ripples in that segment of the responses which correspond to the 3,000-8,000 Hz frequency range or in terms of K, $0 \leq K \leq 20$. From the viewpoint of depicting the general displacement of the membrane in response to a phoneme the ripple is not detrimental. However, it does effect undesirable and unmeaningful neighboring-difference-responses. Previously it was noted that the neighboring-difference-response is essentially the derivative of the basilar membrane response profile. Hence, the frequent steep changes in slope which accompany a small change in amplitude in the membrane response profile effect unmeaningful spikes in the neighboring difference response. Further, these undesirable response characteristics were noted to be more frequent in those responses effected by a phoneme spoken by a female speaker. Therefore it is though that some of the undesirable response characteristics can be attributed to errors in the high frequency coefficients terms of the finite Fourier series representation of the femalė phonetic sound waveforms. On the basis of these observations and the fact that little spectral energy content of a voiced phoneme is prevalent above 6,000 Hz the following refinements are suggested:

(1) The cochlear model should still consist of 100 resonant sections. The frequency range of the model is suggested to be 64 Hz to 6,400 Hz.

(2) Future female phonetic sound records should consist of 128 data samples. This would minimize the errors in the high frequency coefficients of the finite Fourier series which defines a given voiced phonetic sound signal.

6.3 Conclusions Concerning the Simulated Cochlear Responses. Basic to the conclusions reached is the assumption that the behavior of the cochlear model is representative of functions of an actual cochlea. It should be noted that the conclusions reached from the examination of the simulated cochlear responses given in Appendix B have not been biologically disclosed.

The simulated responses revealed that the cochlear model exhibits the inherent ability to perceive the formant frequencies of the voiced phonemes. This suggests that possibly the biological cochlea has a similar perception ability. From the simulated basilar membrane responses it was observed that the formant frequencies of a voiced phoneme seem to determine the steady state displacement of the membrane. Further the formant frequencies F_1 and F_2 seem to be the predominant frequencies which effect the membrane displacement. This is somewhat contrary to what one might expect on the basis of the power spectra of voiced phonemes. The overall displacement effect that F_0 has on the entire basilar membrane is suggested to explain the predominant displacement effect of F_1 and F_2. Hence inherent to the cochlear model and possibly the biogical cochlea is the ability to place less emphasis on the perception prominance of F_0 while emphasizing perception of F_1 and F_2. Thus, on the basis of this observation and the observation which suggests that perception of the third formant F_3 is frequently obscured, it is felt that recognition of a voiced phoneme by an individual is chiefly related to perception of F_2 and F_1 by the cochlea. The responses corresponding to variation of an individual's voice pitch over a one-octave range suggest that pitch normalization would be effective for enhancing mutual exclusiveness of the characteristic F_1 vs F_2 domains of the phonemes. This would in turn enhance the possibility of voiced phoneme recognition chiefly by formants F_1 and F_2.

6.4 Suggested Studies Using the Cochlear Model. It has been noted that the cochlear model has the inherent ability to perceive the formant frequencies of voiced phonemes and the ability to place less emphasis on the perception of F_0. Therefore, it is felt that further research directed toward optimizing these inherent abilities of the model would be meaningful. Since the universal Q of the cochlear network is the primary controlling factor it is suggested that studies of Q vs perception abilities of the model cochlea be undertaken.

It has also been noted that pitch normalization of the phonetic sound signals could possibly enhance mutual exclusiveness of the F_1 vs F_2 domains of voiced phonemes among speakers. Thus a study employing the cochlear model to obtain simulated responses to pitch-normalized phonetic sounds could prove to be promising with respect to development of a voiced phoneme recognition scheme.

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APPENDIX A

WAVEFORMS OF PHONETIC SOUNDS

The phonetic sound sample data set collected for this research is presented in this appendix. The phonetic sound data is documented in 2 forms, graphical and tabular. Figures A.1 through A.22 are graphical plots of the phonetic sound waveforms. The waveforms of each of 19 different phonemes each as spoken by 12 speakers are represented by these figures. In addition to identification of the phoneme waveform, the pitch, pitch period and sampling rate are also indicated for each waveform in each figure. These phoneme waveforms are graphical point to point reconstructions of the sample data which is representative of one glottal pulse period of a quasi-periodic phonetic sound waveform.

Table IX indicates the codes used for phoneme identification, speaker identification and pitch classification.

Table X illustrates the relationship among speaker's pitch vs the phonetic sound.

Table XI consists of a tabular listing of the normalized phonetic sound sample data set. The amplitude of the sample data is normalized such that each data sample is ≥ -99 but ≤ 99. This data is also available on IBM cards from the author.

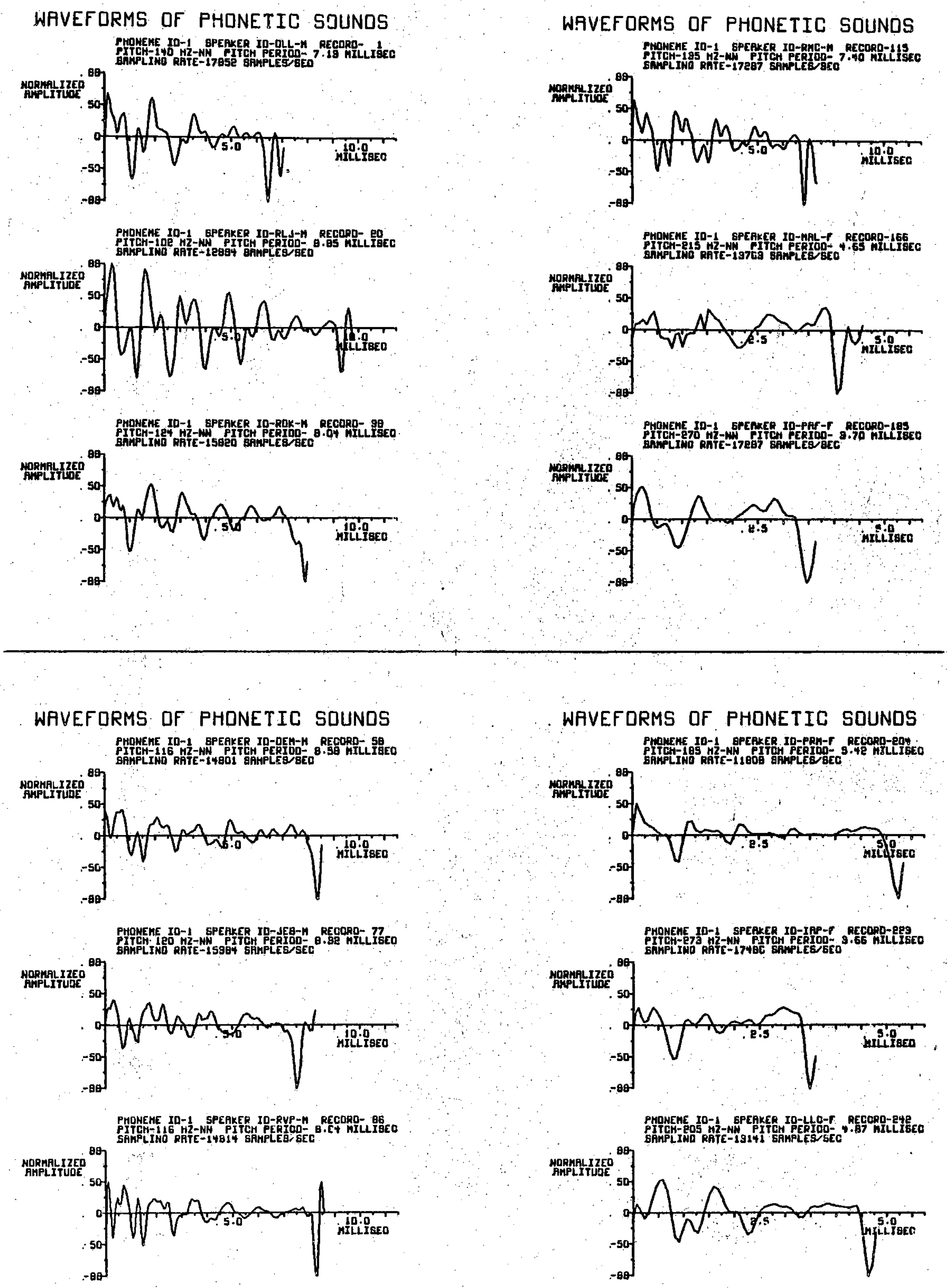


Figure A.1. Waveforms of the Phonetic Sound (ae) as in "At" for 12 Speakers.

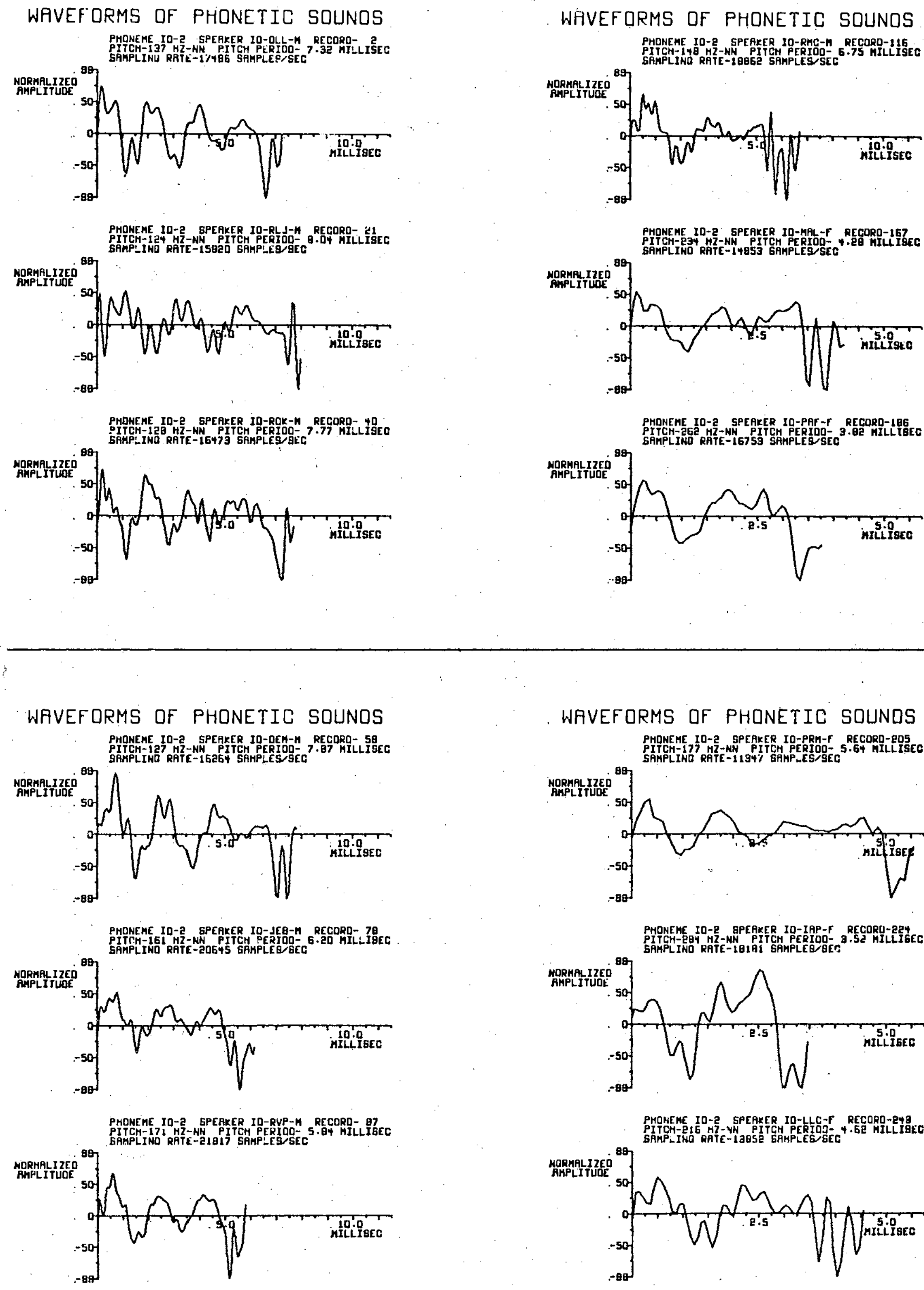


Figure A.2. Waveforms of the Phonetic Sound (e) as in "Ape" for 12 Speakers

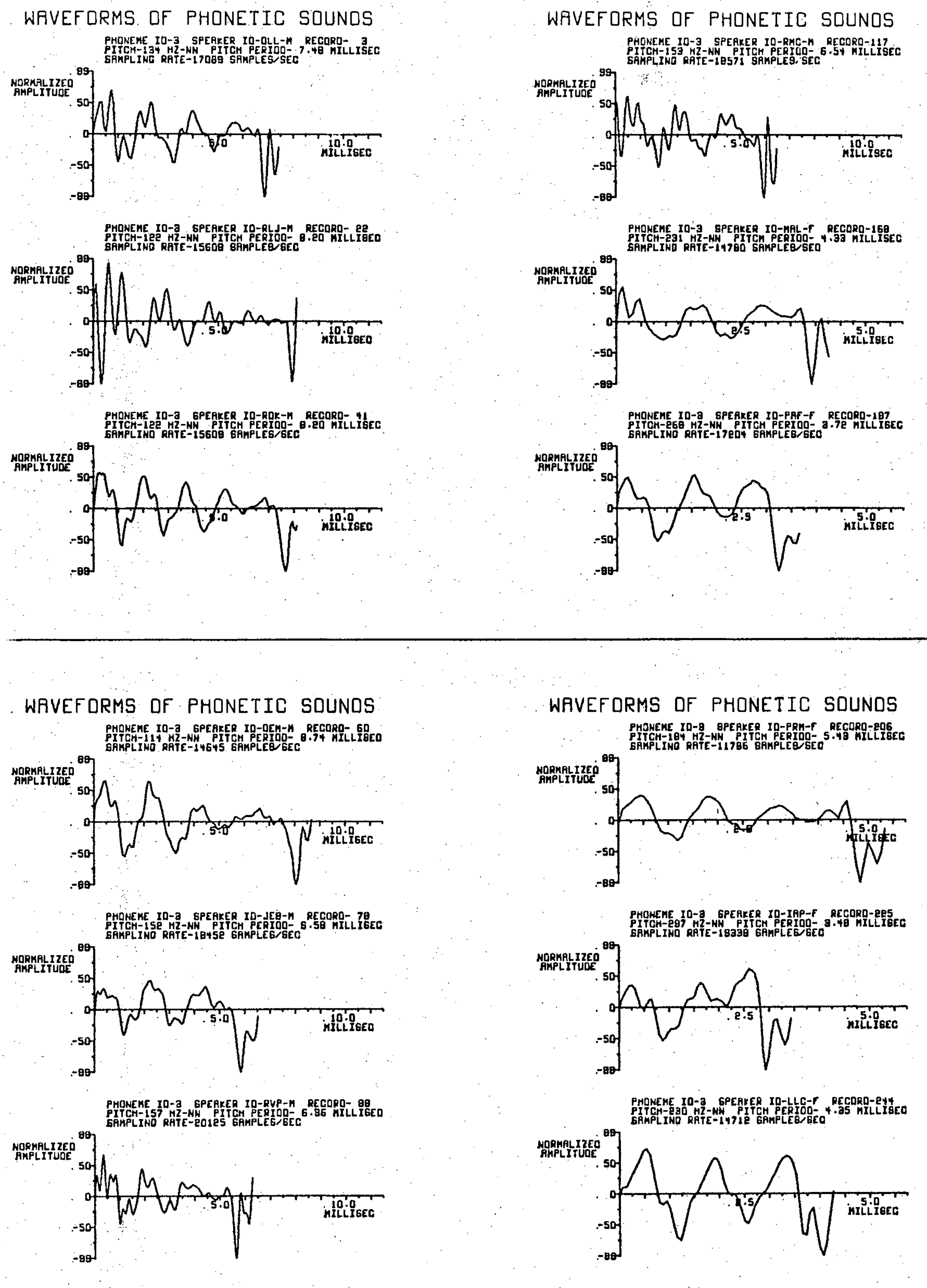


Figure A.3. Waveforms of the Phonetic Sound (ɛ) as in "mEt" for 12 Speakers

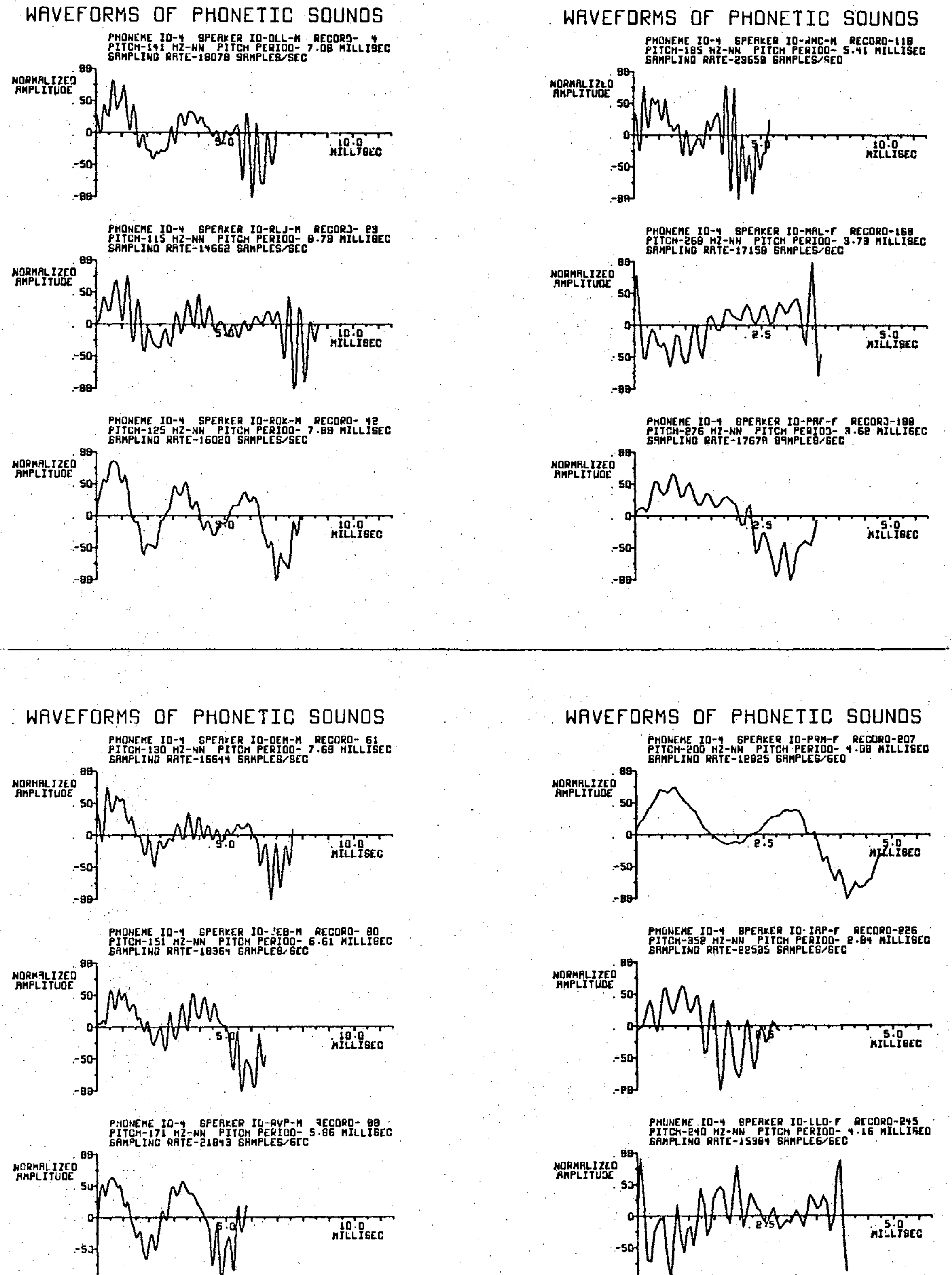
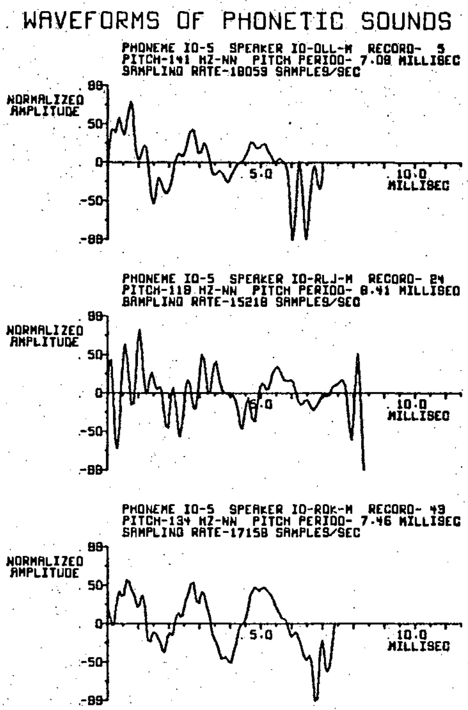
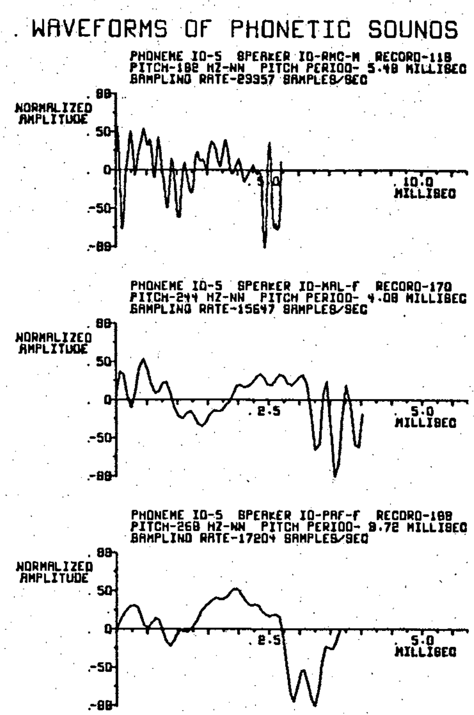
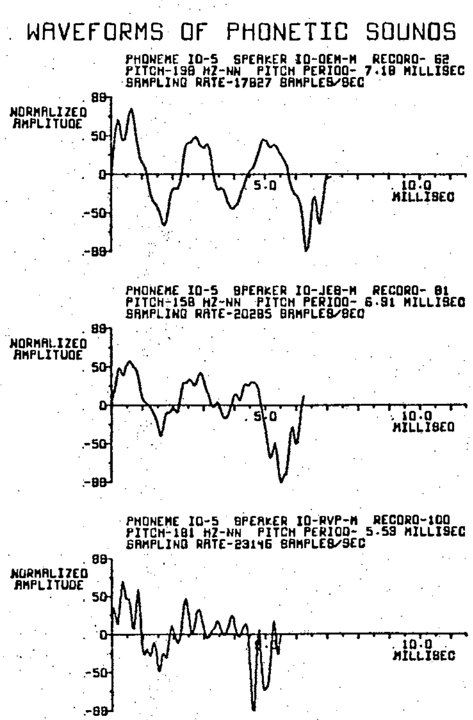


Figure A.4. Waveforms of the Phonetic Sound (i) as in "mEEt" for 12 Speakers







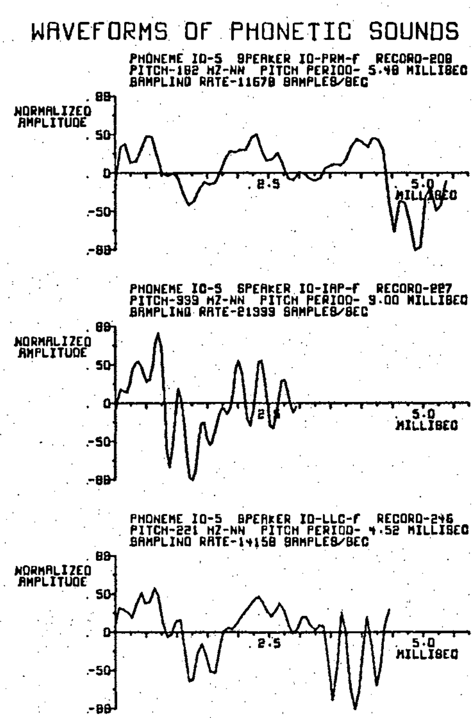
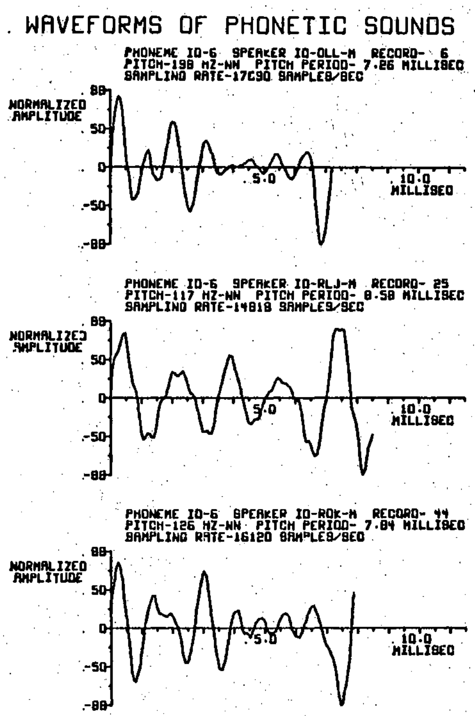
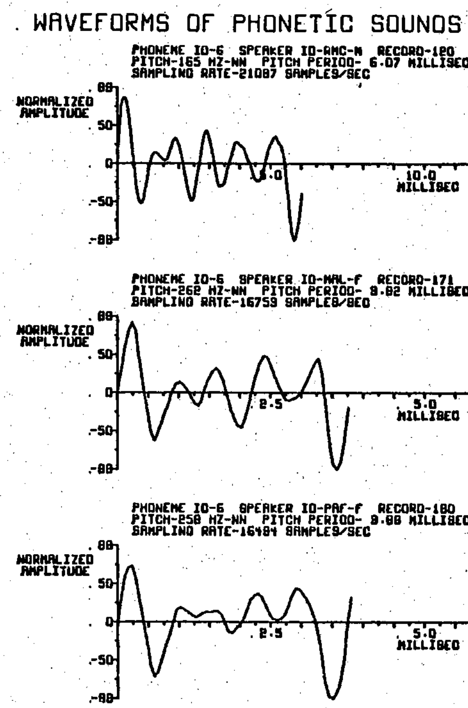
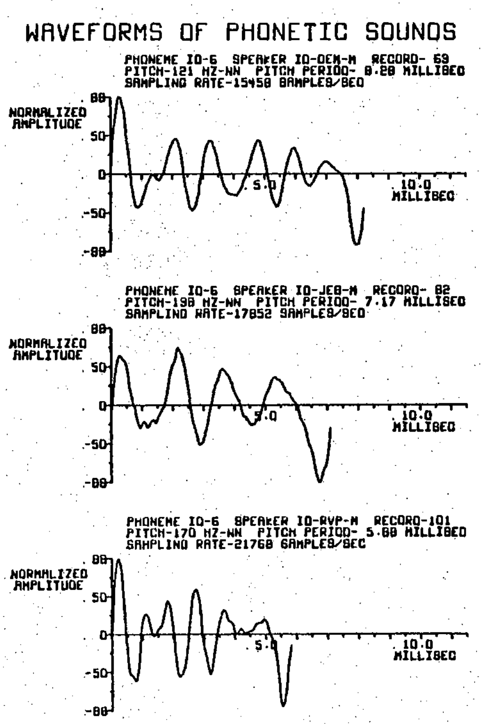


Figure A.5. Waveforms of the Phonetic Sound (I) as in "sIt" for 12 Speakers







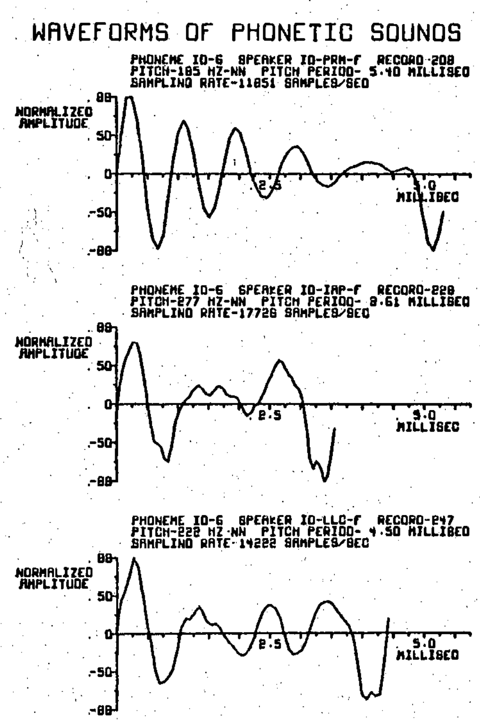


Figure A.6. Waveforms of the Phonetic Sound (ɑ) as in "gOt" for 12 Speakers

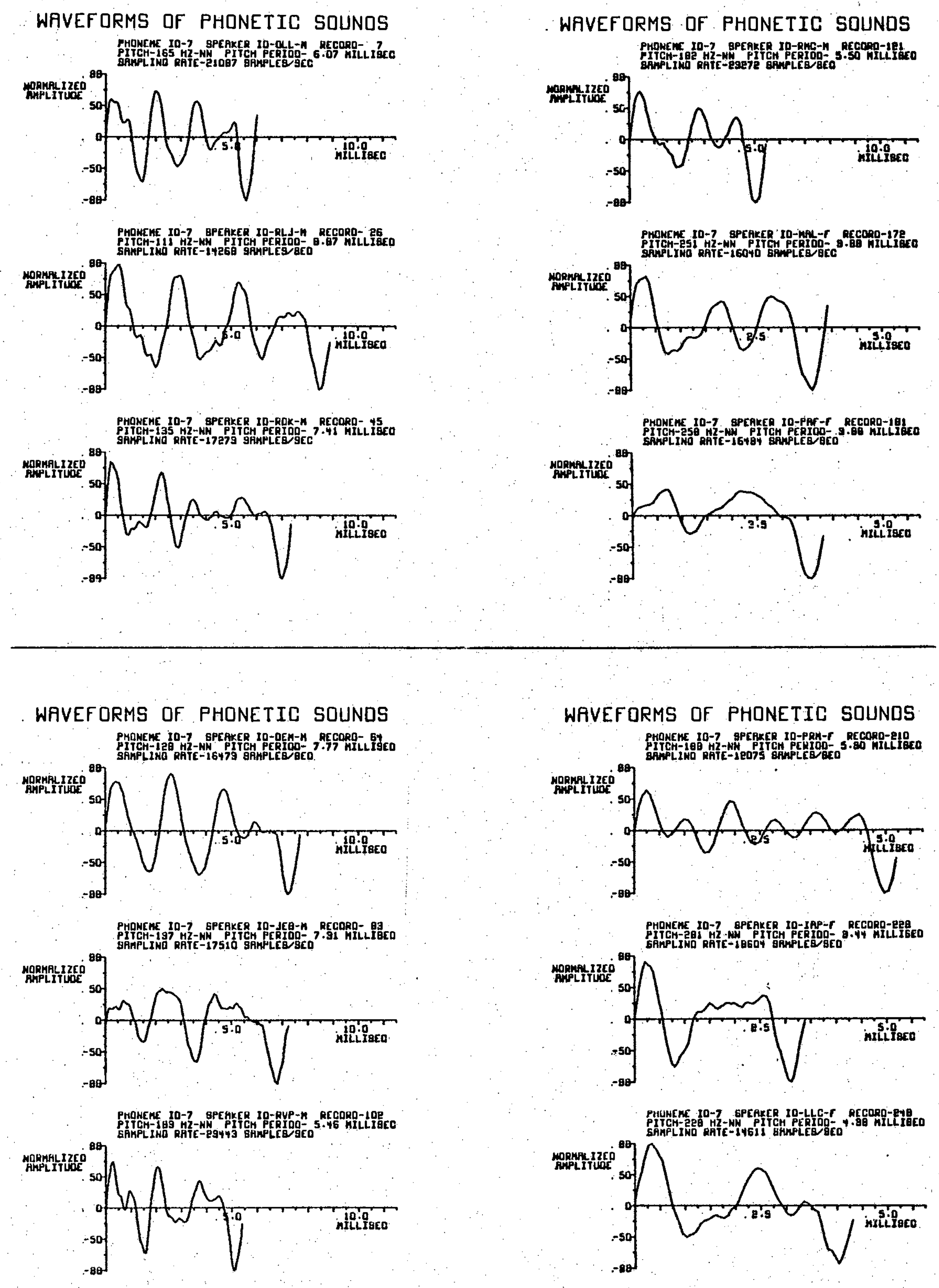
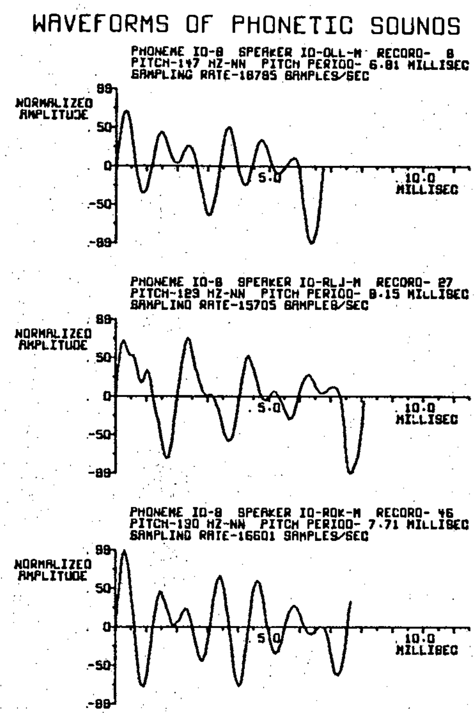
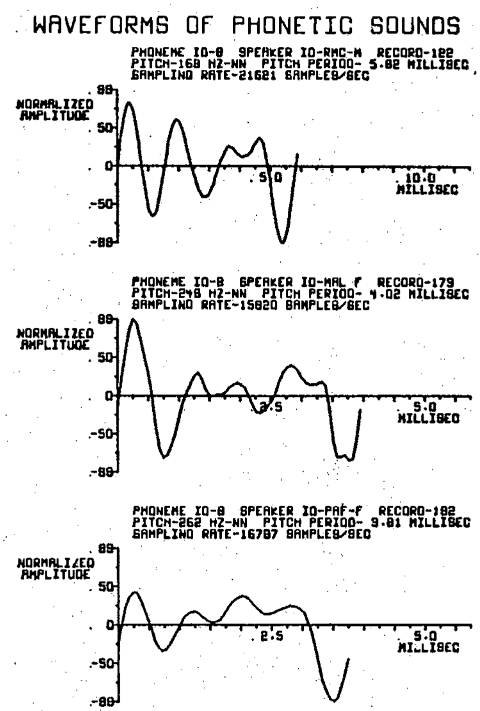
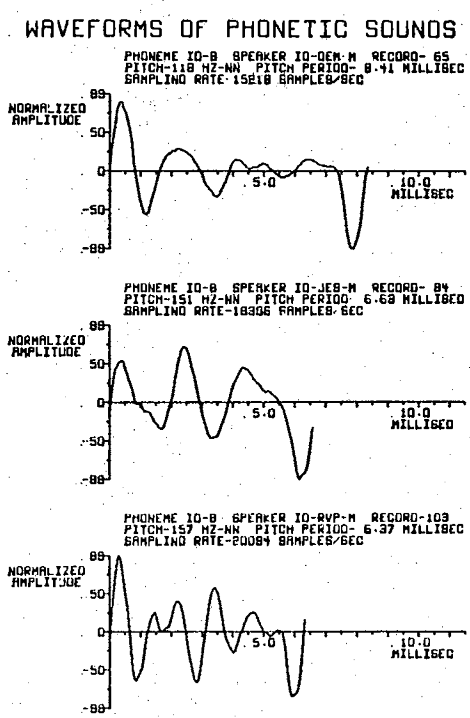


Figure A.7. Waveforms of the Phonetic Sound (O) as in "Obey" for 12 Speakers







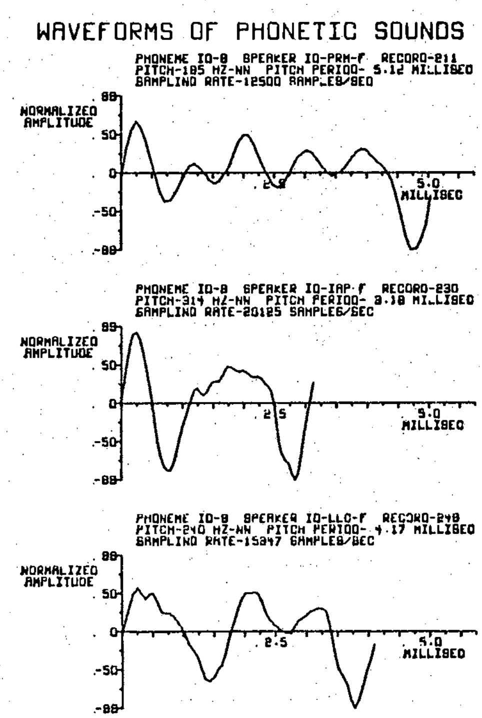


Figure A.8. Waveforms of the Phonetic Sound (ɔ) as in "hORn" for 12 Speakers

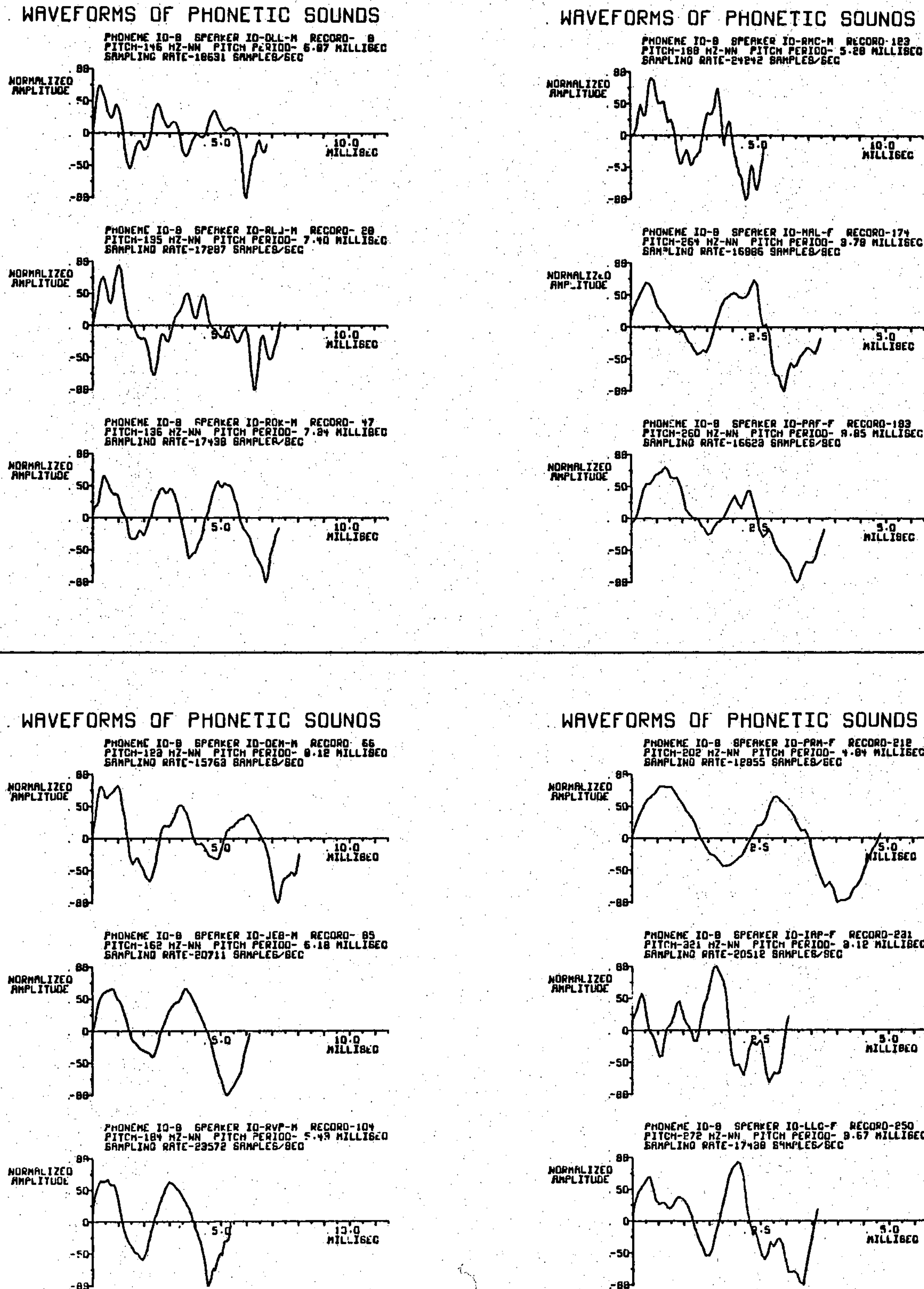
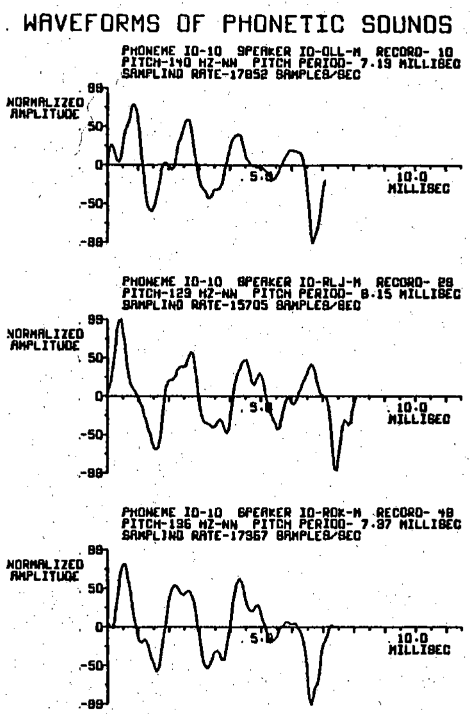
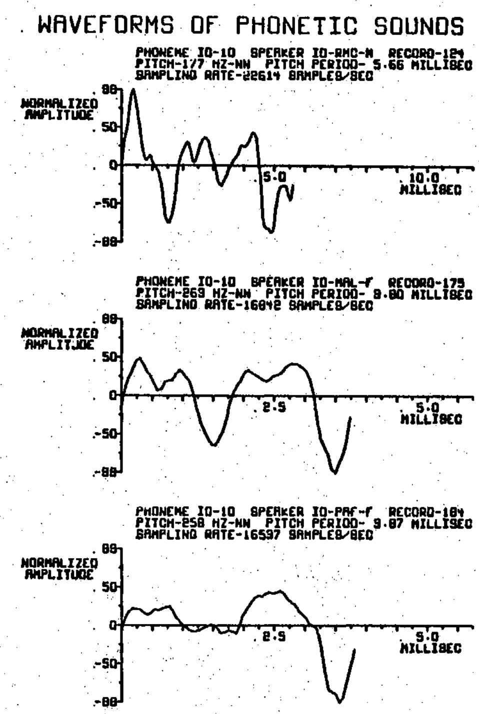
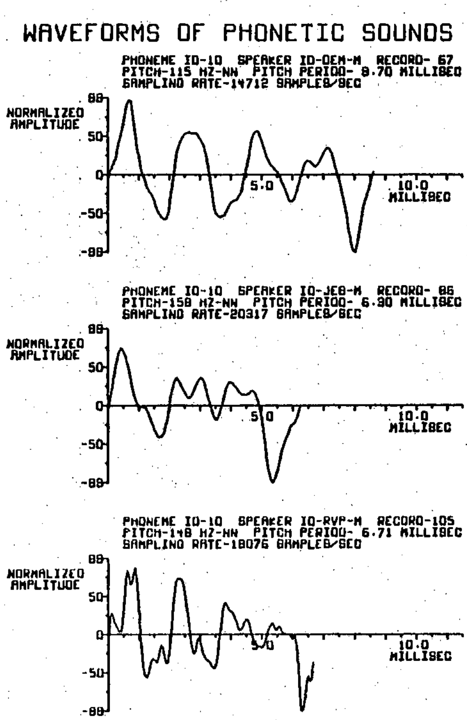


Figure A.9. Waveforms of the Phonetic Sound (u) as in "bOOt" for 12 Speakers







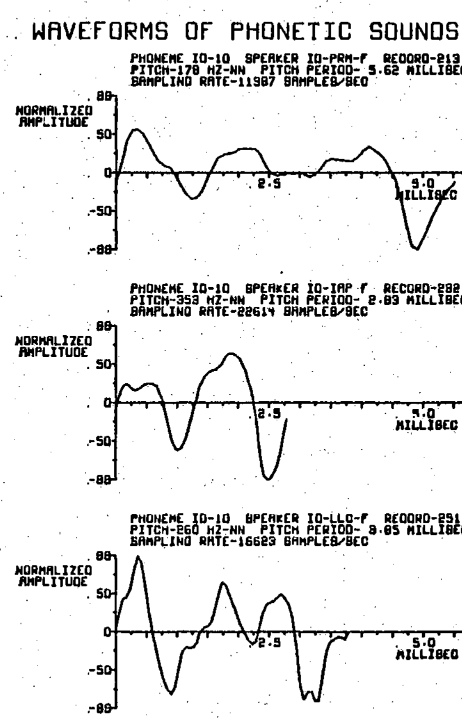
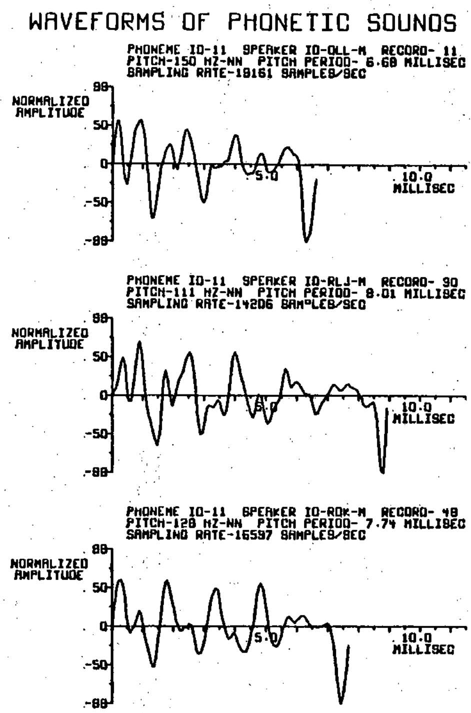
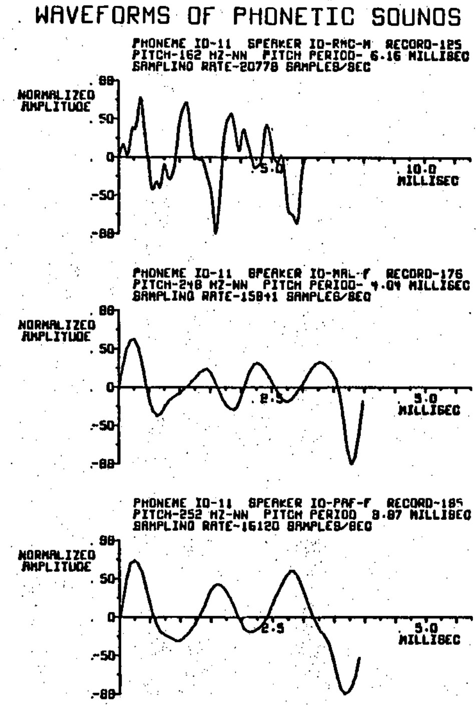
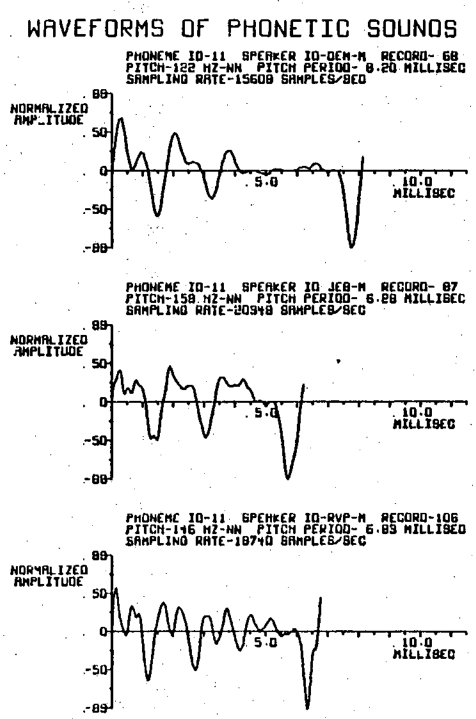


Figure A.10. Waveforms of the Phonetic Sound (U) as in "bOOk" for 12 Speakers







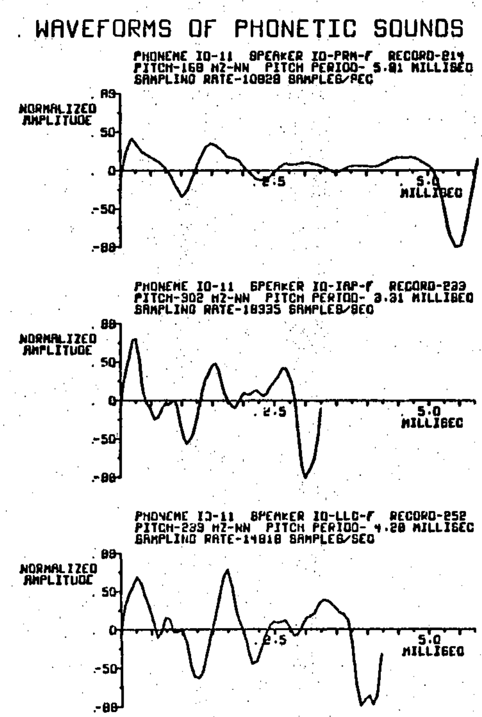
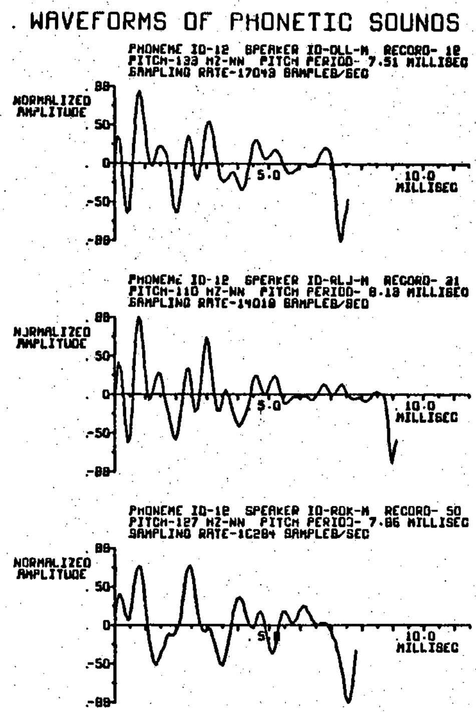
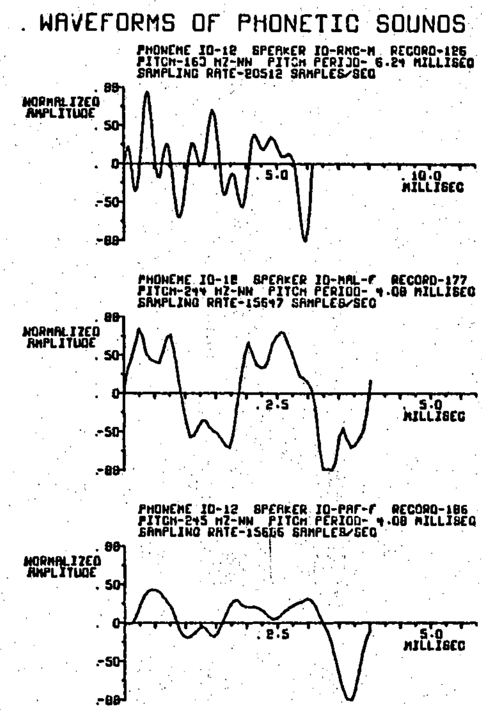
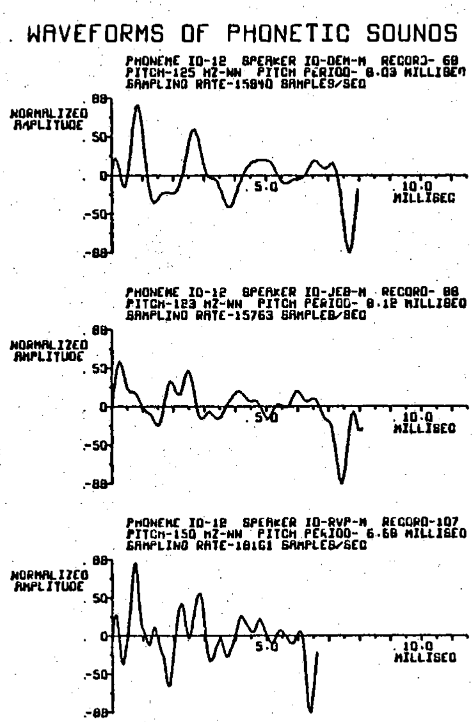


Figure A.11. Waveforms of the Phonetic Sound (Λ) as in "bUck" for 12 Speakers







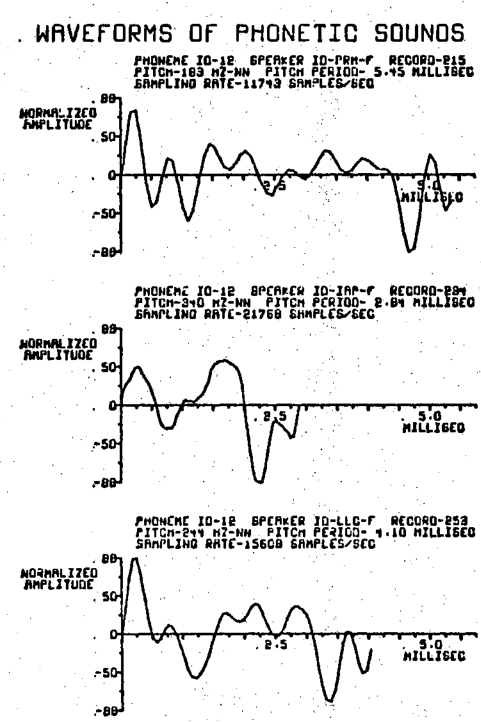


Figure A.12. Waveforms of the Phonetic Sound (ɝ) as in "buRR" for 12 Speakers

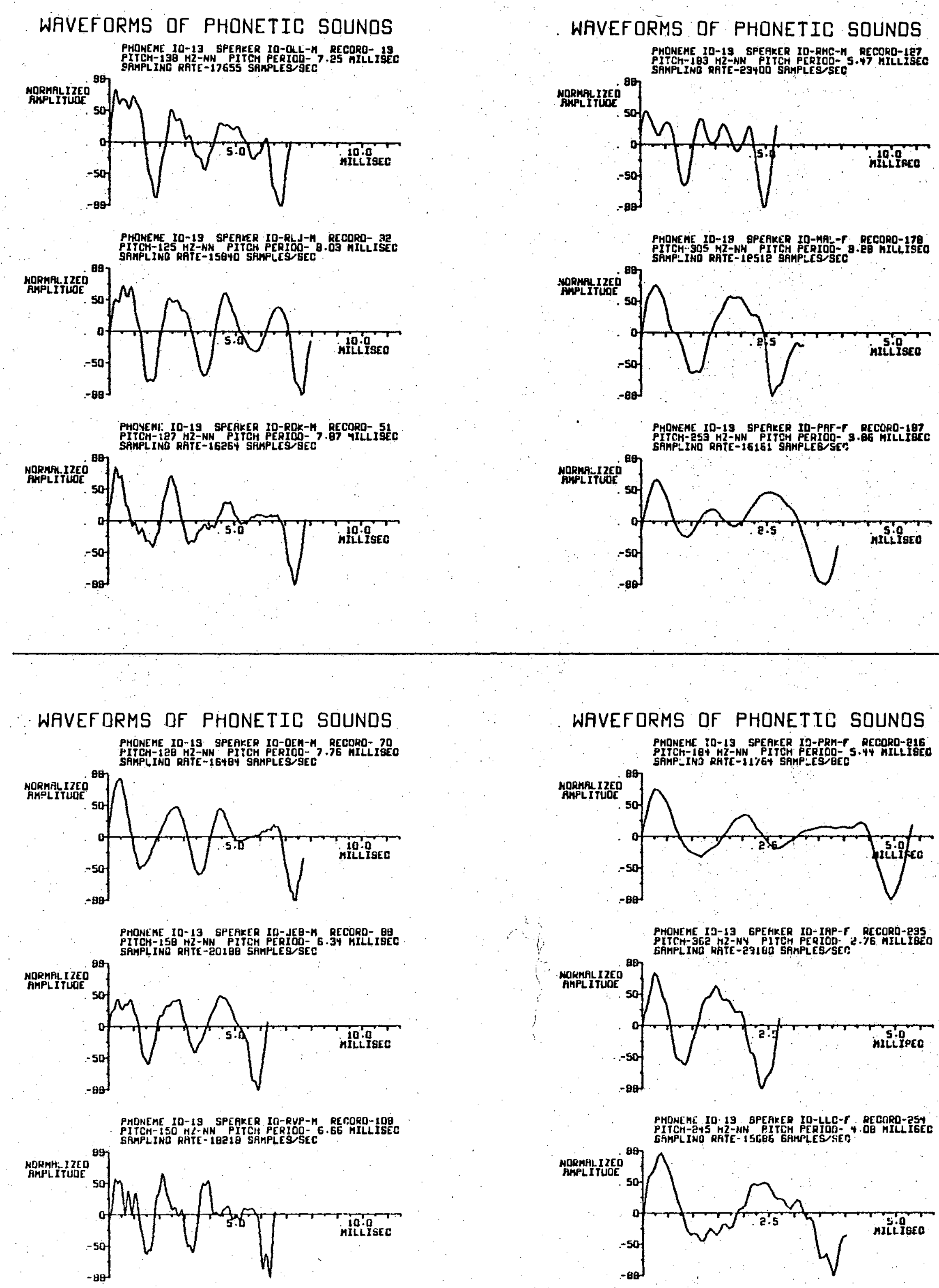


Figure A.13. Waveforms of the Phonetic Sound (l) as in "buLL" for 12 Speakers

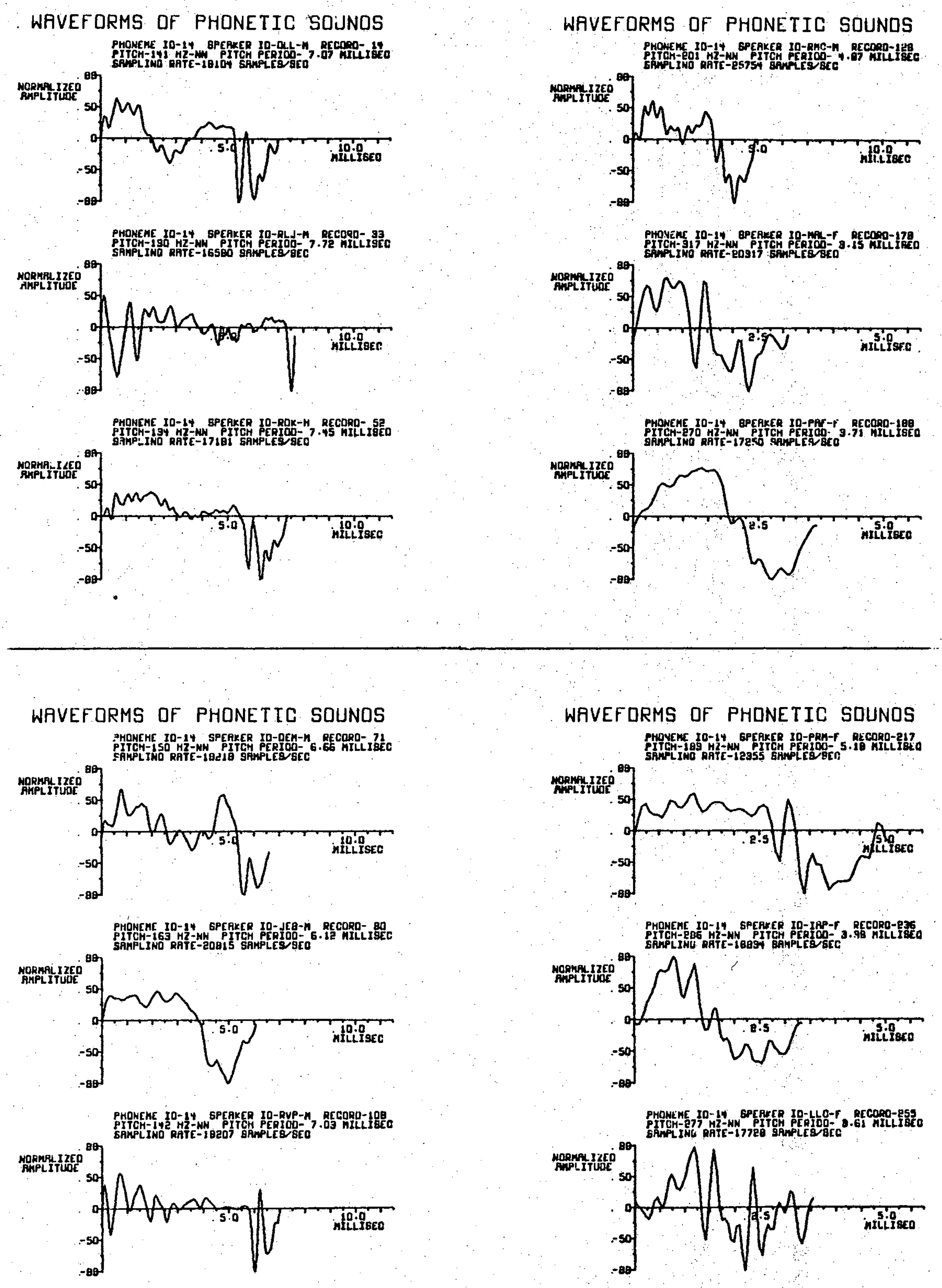
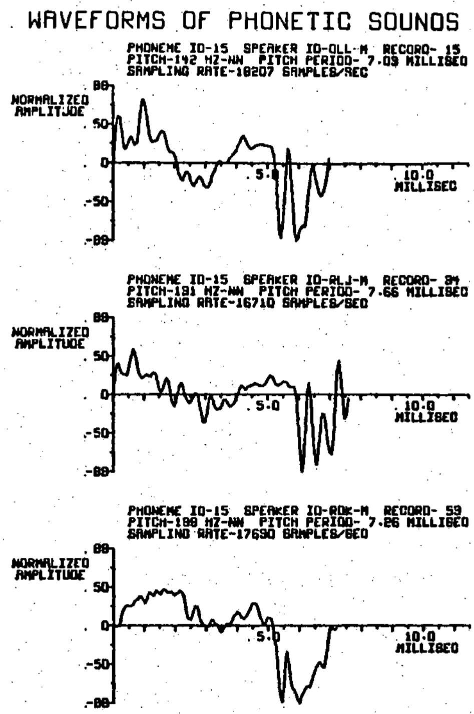
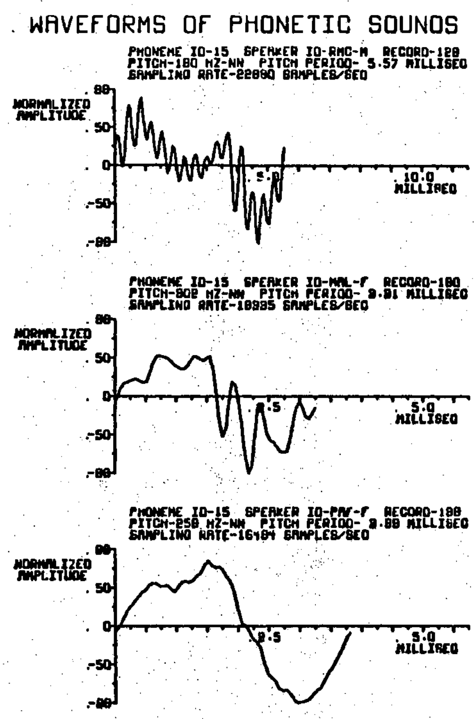
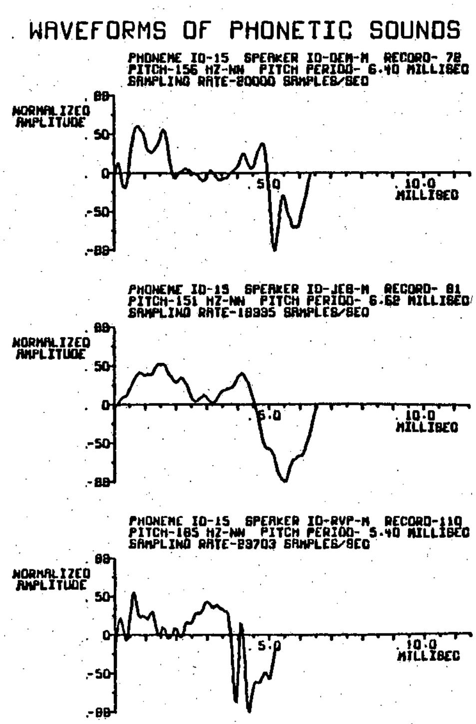


Figure A.14. Waveforms of the Phonetic Sound (m) as in "tiM" for 12 Speakers







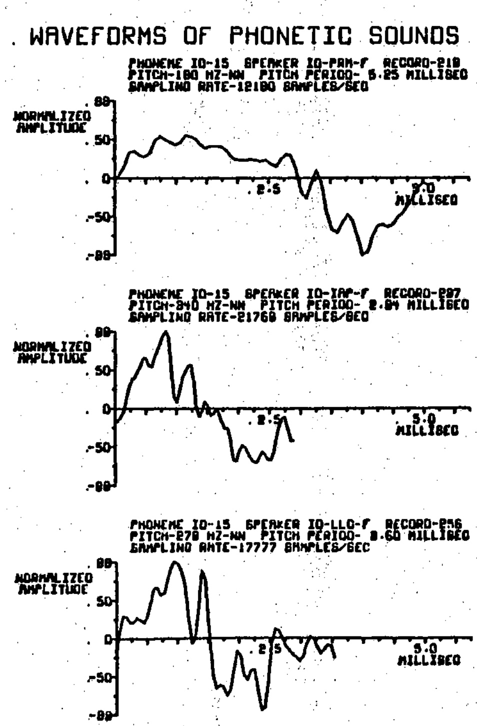
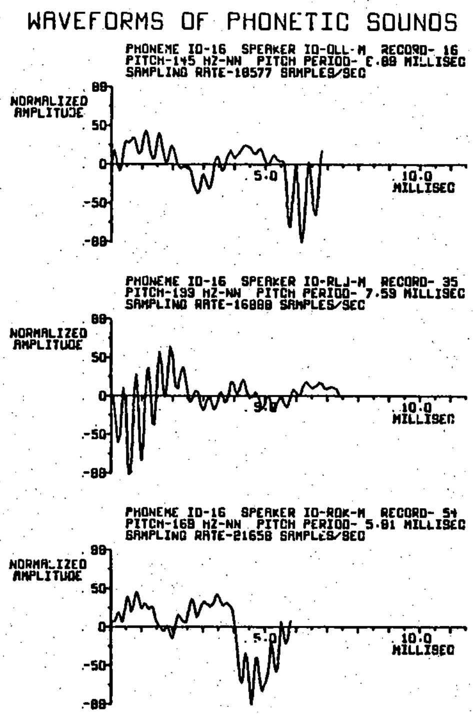
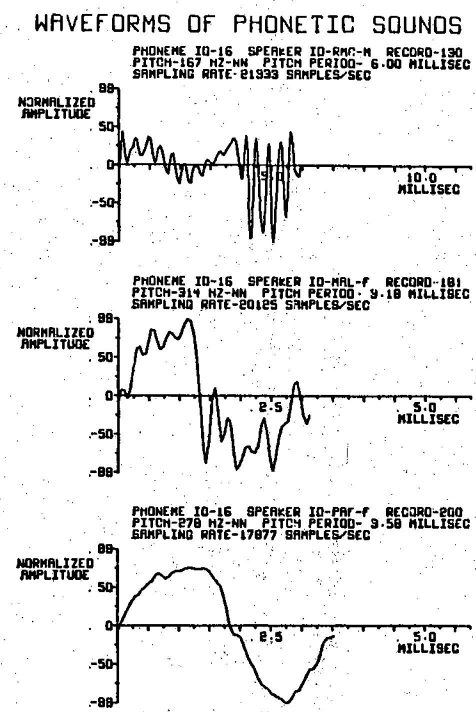
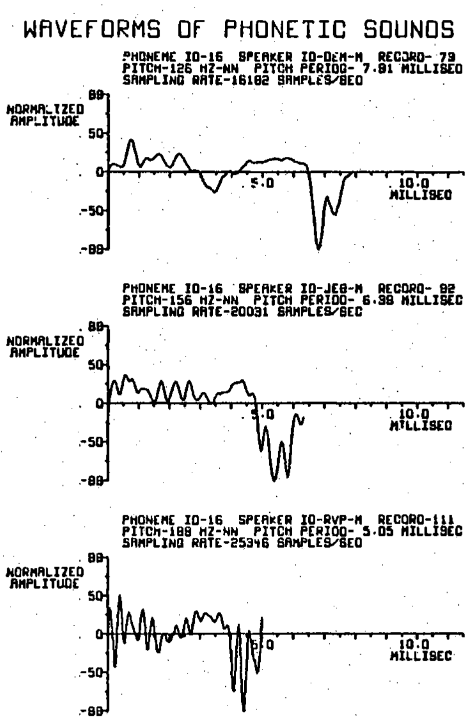


Figure A.15. Waveforms of the Phonetic Sound (n) as in "toN" for 12 Speakers







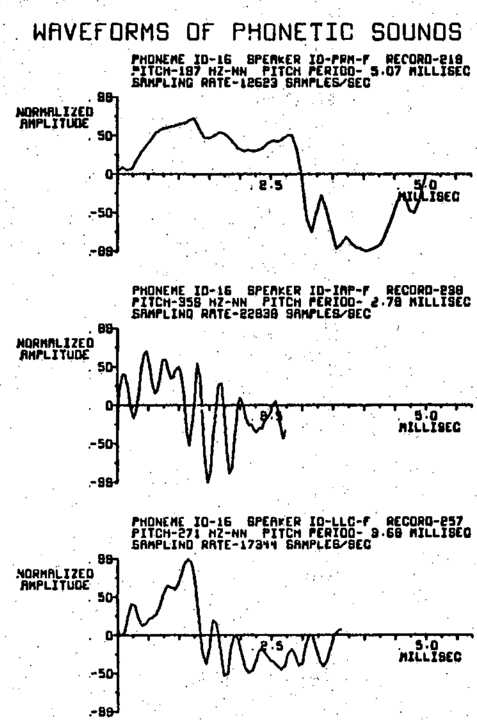


Figure A.16. Waveforms of the Phonetic Sound (ŋ) as in "sING" for 12 Speakers

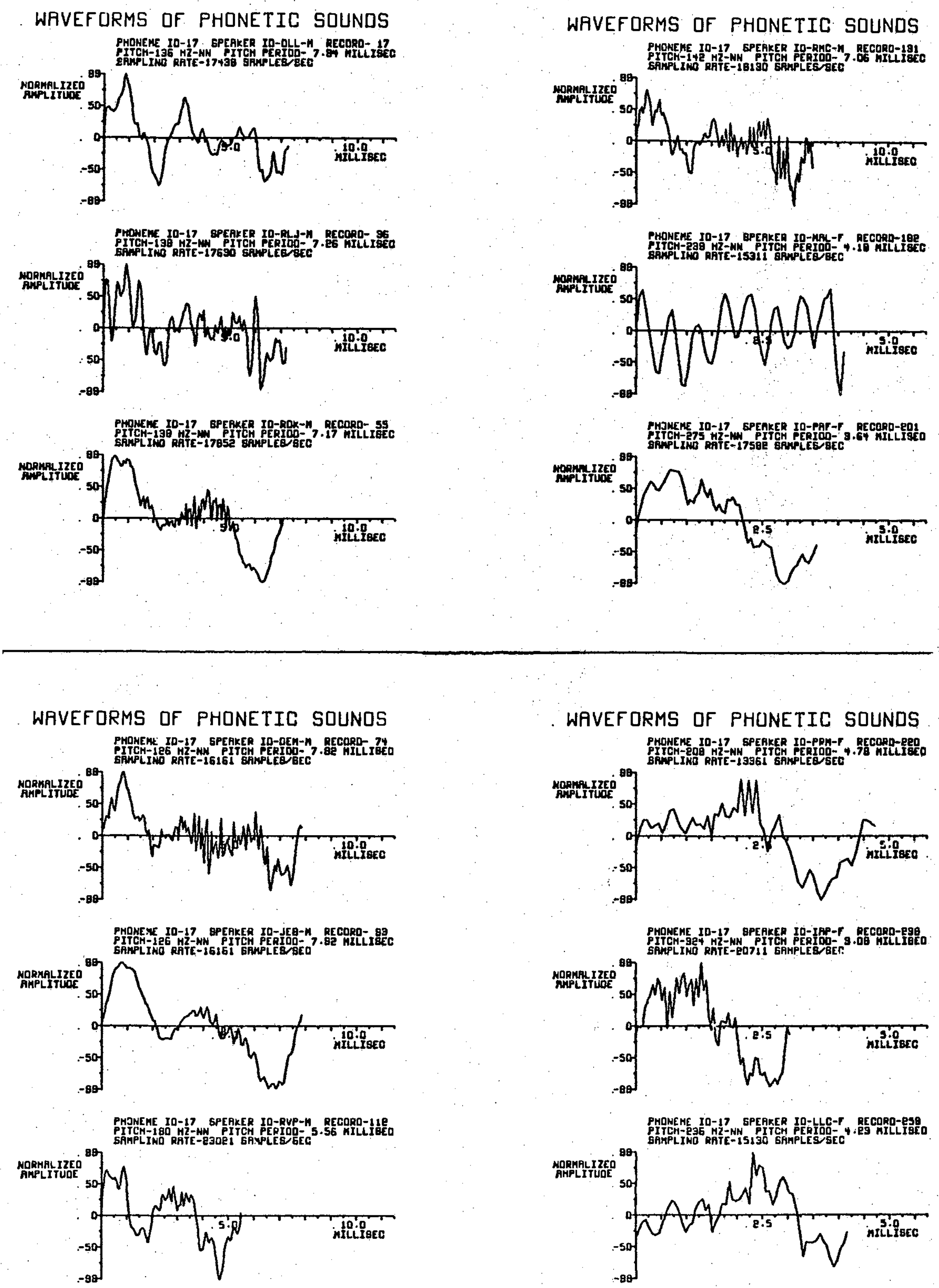


Figure A.17. Waveforms of the Phonetic Sound (z) as in "buZZ" for 12 Speakers

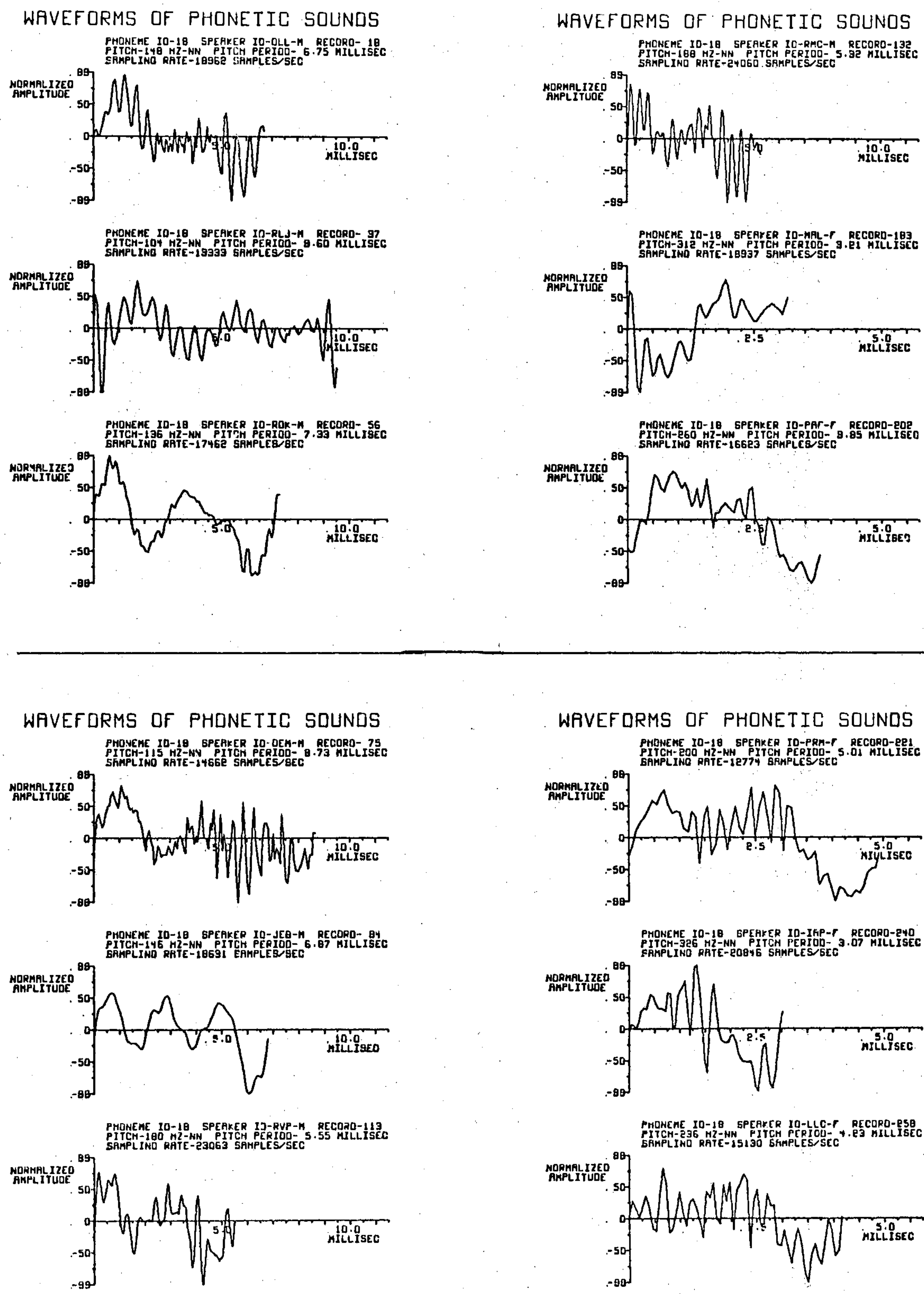


Figure A.18. Waveforms of the Phonetic Sound (ʒ) as in "Jour" for 12 Speakers

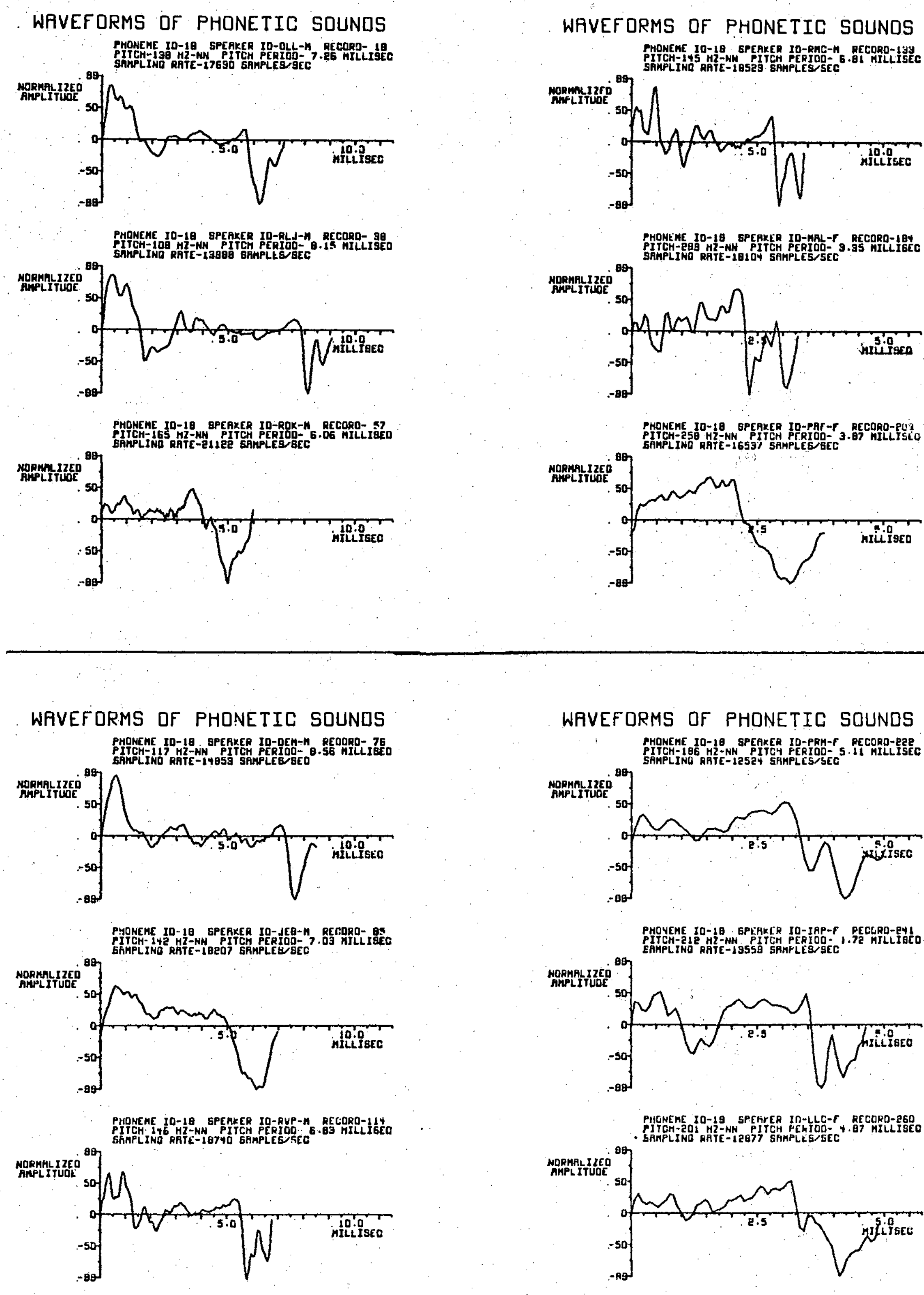


Figure A.19. Waveforms of the Phonetic Sound (V) as in "Vroom" for 12 Speakers

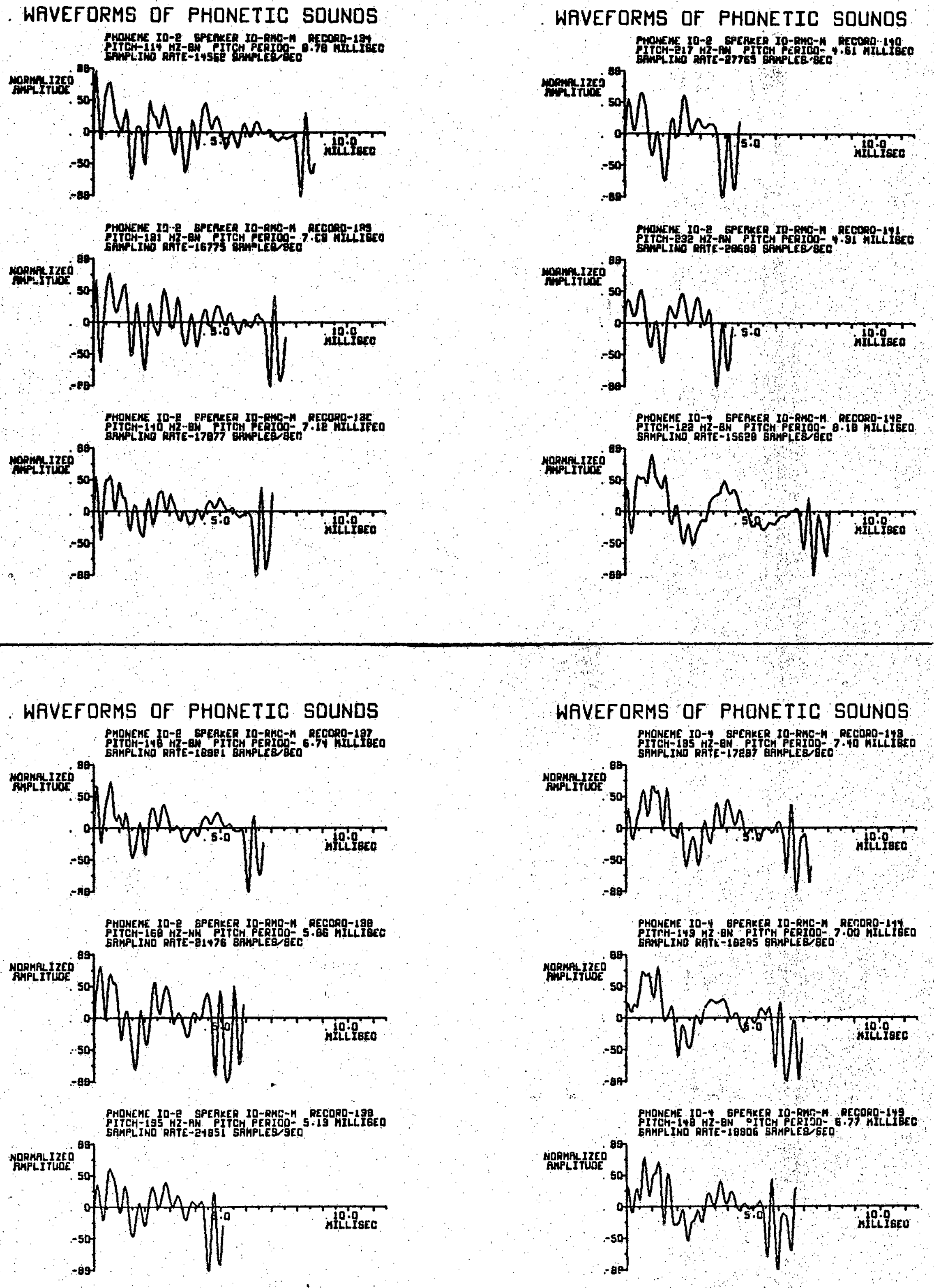


Figure A.20. Waveforms of the Phonetic Sounds (e) and (i) for a Speaker

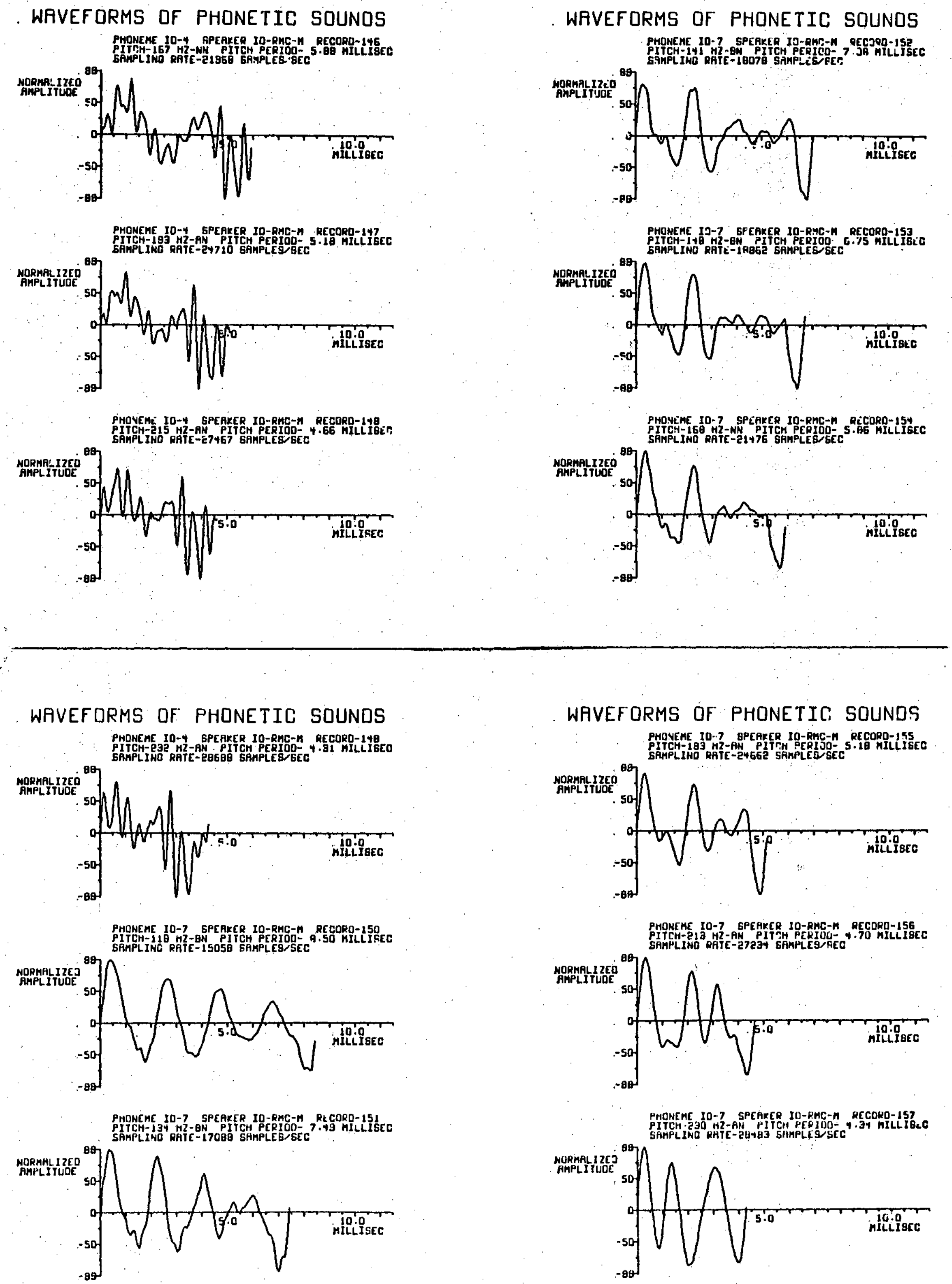
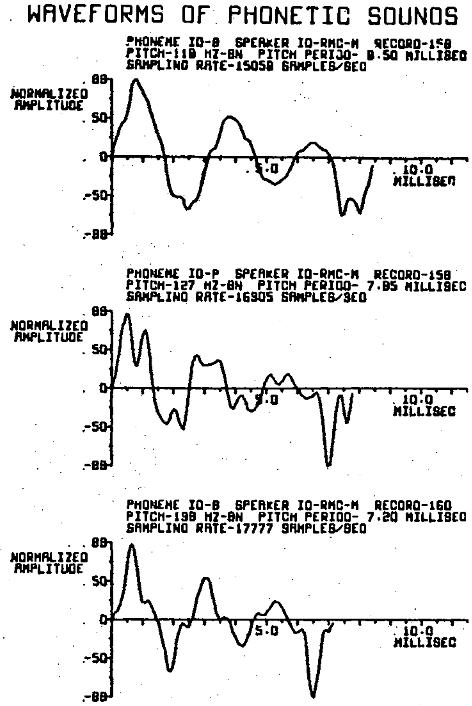
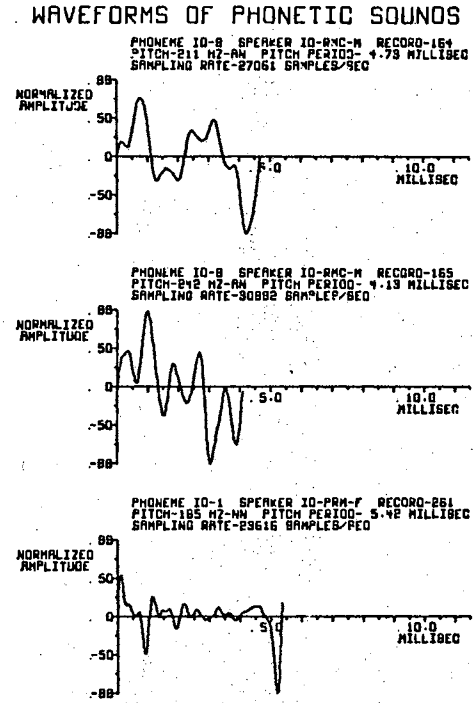
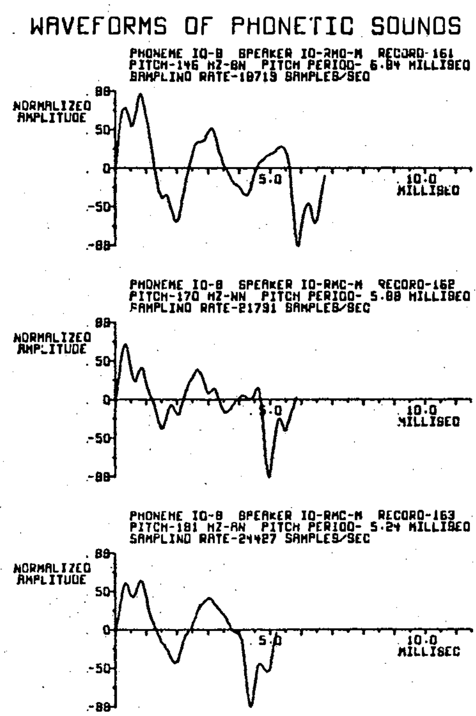


Figure A.21. Waveforms of the Phonetic Sounds (i) and (O) for a Speaker







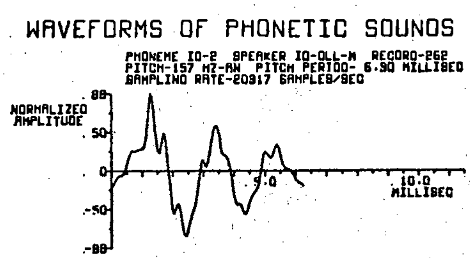


Figure A.22. Waveforms of the Phonetic Sound (u) for a Speaker

TABLE IX

PHONEME SAMPLE DATA SET IDENTIFICATION CODES

Phoneme ID Number	Phoneme	Phoneme Number	Phoneme
1	(ae) as in At	11	(ʌ) as in bUck
2	(e) as in Ape	12	(ɚ) as in buRR
3	(ɛ) as in mEt	13	(l) as in buLL
4	(i) as in mEEt	14	(m) as in tiM
5	(I) as in It	15	(n) as in toN
6	(ɑ) as in gOt	16	(ŋ) as in sING
7	(O) as in Obey	17	(z) as in buZZ
8	(ɔ) as in hORn	18	(ʒ) as in Jour
9	(u) as in bOOt	19	(V) as in Vroom
10	(U) as in bOOk		

Female Initials	Male Initials	Pitch Classification
MAL-F	OLL-M	BN - Below Normal
PAF-F	RLJ-M	NN - Normal
PRM-F	RDK-M	AN - Above Normal
IAP-F	DEM-M	
LLC-F	JEB-M	
	RVP-M	
	RMC-M	

TABLE X

SPEAKER PITCH VS PHONETIC SOUND

Speaker ID / Phoneme ID	OLL-M PITCH HZ	RLJ-M PITCH HZ	RDK-M PITCH HZ	DEM-M PITCH HZ	JEB-M PITCH HZ	RVP-M PITCH HZ	RMC-M PITCH HZ	MAL-F PITCH HZ	PAF-F PITCH HZ	PRM-F PITCH HZ	JAP-F PITCH HZ	LLC-F PITCH HZ
At	140	101	124	116	120	116	135	215	239	185	273	205
Ape	137	124	129	127	161	171	148	234	262	177	284	216
mEt	134	121	122	114	152	157	153	231	248	184	287	230
mEEt	141	114	125	130	151	171	185	268	265	200	352	240
sIt	141	119	134	139	158	181	182	244	258	182	333	221
gOt	137	117	126	121	139	170	165	262	270	185	277	222
Obey	164	111	135	129	136	183	182	251	262	189	291	228
hOrn	146	123	130	119	151	157	169	249	265	195	314	239
bOOt	145	135	136	123	162	184	189	264	269	202	321	272
bOOk	140	123	135	115	159	149	177	263	262	178	353	259
bUck	149	111	129	122	159	146	162	248	261	169	302	233
buRR	133	110	127	125	123	150	160	244	260	183	340	244
buLL	138	125	127	129	158	150	183	305	250	184	362	245
tiM	141	130	134	150	163	142	202	317	271	193	296	277
toN	142	131	138	156	151	185	180	302	260	190	340	278
sING	145	133	169	126	156	198	167	314	267	197	358	271
buZZ	136	138	139	127	126	179	142	239	275	201	324	236
Jour	148	104	136	115	145	180	188	312	275	200	326	236
Vroom	138	109	166	117	142	146	145	299	275	196	212	201

TABLE XI

TABULAR LISTING OF PHONETIC SOUND SAMPLE DATA RECORDS

```
SPEAKER ID-OLL-M/PHONEME ID- 1/PITCH-140-NN/PITCH PERIOD-  7.13 MS/      RC-  1-0
-11 22 53 67 56 40 34 31 18  6  9 21 30 35 37 29  8-18-41-58-65-57-32 -3RC-  1-1
 12 12  0-14-24-21 -4 17 38 54 61 56 42 26 15 12 12 11  9  8  7  3 -3-15RC-  1-2
-29-39-43-40-30-20-11 -5 -4 -7 -9 -8  0 14 27 35 36 30 21 14  9  7  7  8RC-  1-3
  8  4 -1 -8-13-16-16-13 -8 -3  1  4  5  3  1  1  3  8 13 17 17 14  8  3RC-  1-4
  0  0  2  5  7  7  5  2  1  1  2  5  7  8  7  3 -5-22-52-84-99-84-47-13RC-  1-5
  1  8  1-23-50-59-44-16                                                RC-  1-6
SPEAKER ID-RLJ-M/PHONEME ID- 1/PITCH-102-NN/PITCH PERIOD-  9.85 MS/     RC- 20-0
 -2 35 58 80 99 92 53  1-33-42-38-28-15 -1  0-24-62-78-51  8 64 90 84 63RC- 20-1
 37 13 -2 -3  9 20 15 -8-40-64-76-72-47 -6 32 49 39 18  7 12 26 37 44 43RC- 20-2
 29  0-36-61-64-50-28-10 -1 -1 -7-13 -9  8 33 52 55 45 26  2-20-41-56-48RC- 20-3
-19  0 -3-12-13 -8  3 21 34 39 42 38 18 -4-18-19-11 -4 -7-14-17-15 -8  0RC- 20-4
  8 14 18 18 11  1 -4 -4 -2  0 -3 -9-11 -9 -6 -1  3  5  8 11 10  8  5 -5RC- 20-5
-37-68-66-26 18 31 10-18                                                RC- 20-6
SPEAKER ID-RDK-M/PHONEME ID- 1/PITCH-124-NN/PITCH PERIOD-  8.04 MS/     RC- 39-0
  6 24 29 34 36 27 18 24 32 27 14 12 19 13-12-39-51-50-40-23 -2 12 12  4RC- 39-1
  2  9 22 35 45 52 52 45 32 16  0-10-15-15-12 -7 -6-12-20-22-16 -5  8 23RC- 39-2
 35 40 37 30 23 17 11  6  6  6  2 -5-16-26-33-34-27-15 -4  0  3  7 12 16RC- 39-3
 19 21 20 16 12  6  0 -8-15-19-17-13 -8 -4 -1  0  2  7 13 17 19 18 15 11RC- 39-4
  6  1 -1 -3 -4 -3 -2 -2 -1  0  3  6 11 17 17 11  6  3  0 -3-10-20-30-37RC- 39-5
-40-39-37-42-61-89-99-68                                                RC- 39-6
SPEAKER ID-DEM-M/PHONEME ID- 1/PITCH-116-NN/PITCH PERIOD-  8.59 MS/     RC- 58-0
  7 38 29  3 -3  4 23 37 37 37 41 40 29 12 -8-25-30-25-11  2  5 -6-27-39RC- 58-1
-32-10  8 17 18 19 24 29 25 18 14 13 15 16 13  5 -4-16-24-22-11  2  9  8RC- 58-2
  3  2  4  6  7  9 14 17 17 12  4 -2 -9-14-14-12-10 -7 -7-11-15-18-17 -5RC- 58-3
 11 23 25 21 13  7  4  4  6  6  3  0 -4 -7 -9-11 -9 -4  2  8  9  6  0 -2RC- 58-4
  0  3  8 10  7  4  1  0  0  2  4  8 13 17 16 12  6  2  1  5  8  5 -1-12RC- 58-5
-18-27-39-67-97-99-70-15                                                RC- 58-6
SPEAKER ID-JEB-M/PHONEME ID- 1/PITCH-120-NN/PITCH PERIOD-  8.32 MS/     RC- 77-0
  0 18 27 26 32 40 38 28 14 -5-25-36-32-15  4 11  4 -6-15-24-26-12  7 20RC- 77-1
 24 27 33 35 28 17  9  7  7 11 22 33 32 17  0 -9-13-12 -4  7 14 13  8  4RC- 77-2
  1 -5-13-18-18-15 -8 -1 10 19 16  9  9 10 11 17 22 21 17  9 -2 -7 -7-10RC- 77-3
-12-10-10-14-15-14-12 -8 -4  0  6 13 16 17 18 17 13 11 10 10 11 10  7  4RC- 77-4
  1 -2 -4 -2  0  1  0  1  3  1  1 -2 -9-11 -9-11-18-28-53-84-99-88-61-29RC- 77-5
 -3  4  0 -4 -9 -8  4 23                                                RC- 77-6
SPEAKER ID-RVP-M/PHONEME ID- 1/PITCH-116-NN/PITCH PERIOD-  8.64 MS/     RC- 96-0
-35 40 50  0-38-22 13 25 14 16 35 45 37 21  3-19-38-31  0 24  9-29-50-36RC- 96-1
 -6 11 16 19 23 22 18 18 20 15  7  8 17 16 -5-30-36-23-10 -5 -4 -2 -2 -2RC- 96-2
  2 13 22 22 19 20 20 13  0 -9-13-15-13-10 -9-11-11 -7 -1  3  8 11 14 16RC- 96-3
 16 13  8  3  0  0 -1 -4 -7 -9 -8 -5 -2  0  3  6  8  9  8  6  4  3  3  2RC- 96-4
  0 -4 -7 -8 -8 -6 -3 -2  0  0  1  2  3  4  6  6  4  4  7  8  2 -5 -6 -2RC- 96-5
 -4-41-90-99-38 38 49 -1                                                RC- 96-6
SPEAKER ID-RMC-M/PHONEME ID- 1/PITCH-135-NN/PITCH PERIOD-  7.40 MS/     RC-115-0
  0 49 62 48 34 27 19 12 18 34 43 37 27 22 16  0-22-43-47-34-15 -3 -1 -5RC-115-1
-18-34-39-19 14 39 46 42 36 27 16 14 24 34 32 23 15  9 -2-18-30-34-31-25RC-115-2
-17 -9 -7-15-28-34-25 -5 14 28 34 29 17  7  8 16 22 24 21 13  2 -7-14-15RC-115-3
-14-12-10 -6 -2 -3 -6 -8 -5  0  6 15 22 22 17 10  7  8 12 14 14 11  3 -4RC-115-4
 -8-10 -8 -6 -6 -6 -8-10-12-11 -7 -2  1  4  6  9 10  8  5  1-18-61-99-95RC-115-5
-48 -4  4 -2-12-33-62-65                                                RC-115-6
SPEAKER ID-MAL-F/PHONEME ID- 1/PITCH-215-NN/PITCH PERIOD-  4.65 MS/     RC-166-0
-13  9 10 16  9 21 29 11-11-14-14-28 -7 -6-26 -8 -5 -5  7 25  0 33 25 19RC-166-1
 15  6 -3-11-20-27-27-22-13 -2  4  7 17 25 25 23 17 13 12  6  0 -1  2  8RC-166-2
 12  8 10 23 34 36 24-32-99-89-27  6-16-21-14  8                        RC-166-3
SPEAKER ID-PAF-F/PHONEME ID- 1/PITCH-270-NN/PITCH PERIOD-  3.70 MS/     RC-185-0
 -9 22 41 50 51 42 23  3 -9-13-11 -7 -7-15-28-40-44-41-30-15  0 15 29 37RC-185-1
 34 23 11  2 -2 -1  0  0 -3 -5 -3  0  3  7 10 13 17 21 23 20 16 13 14 21RC-185-2
 28 33 30 22 13  7  5  6  3-14-48-82-99-91-67-35                        RC-185-3
SPEAKER ID-PRM-F/PHONEME ID- 1/PITCH-185-NN/PITCH PERIOD-  5.42 MS/     RC-204-0
  2 50 36 20 15 11  5  0  1-11-39-40 -8 21 22  8  4  8  7  6  7  2-10-13RC-204-1
  1 17 16  6  2  2  2  2  3  2 -2 -4  0  9 10  3  0  1  1  1  0  0 -1  0RC-204-2
  4  8  9  6  7 11 13 11 10  9  1-15-40-79-99-43                        RC-204-3
SPEAKER ID-IAP-F/PHONEME ID- 1/PITCH-273-NN/PITCH PERIOD-  3.66 MS/     RC-223-0
-13 20 28 14  5  8 19 28 24 16  6 -6-23-40-52-51-37-14  6  9  5  1  2  7RC-223-1
 14 18 15  7 -2-10-12-10 -4  1  5  6  5  3  4  6  8  7  1  0  4 10 15 16RC-223-2
 16 19 24 26 28 26 23 21 19 18 11-22-72-99-84-48                        RC-223-3
SPEAKER ID-LLC-F/PHONEME ID- 1/PITCH-205-NN/PITCH PERIOD-  4.87 MS/     RC-242-0
 -9 14  4 -9 -2 20 40 52 53 34 -4-38-45-28-10-13-28-32-16 10 32 42 39 28RC-242-1
 12  2  1  2 -6-24-35-30-12  3  9 11 13 14 11  9 10  7  0 -7 -7  1  8 10RC-242-2
  9 11 14 14 12 11 10  9  8 10 11 -7-57-99-84-31                        RC-242-3
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TABLE XI (Continued)

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SPEAKER ID-OLL-M/PHONEME ID- 2/PITCH-137-NN/PITCH PERIOD-  7.32 MS/      RC-  2-0
-13 24 57 73 70 56 41 32 32 35 40 44 49 52 47 33 11-14-41-57-61-53-36-18RC-  2-1
 -7-12-27-41-46-38-17  8 31 45 50 47 40 33 32 34 38 41 41 37 31 22 11 -3RC-  2-2
-18-30-36-38-35-33-35-42-49-52-47-34-15  2 14 18 18 17 19 25 33 41 46 46RC-  2-3
 41 32 22 12  3 -4 -9-11-11-11-11-14-19-24-25-23-16 -6  3  8 10 10  8  8RC-  2-4
 10 13 18 21 23 21 17 13 10  9  7  6  4  1 -3-14-29-47-69-90-99-90-63-30RC-  2-5
 -8 -8-24-42-50-46-31 -3                                                RC-  2-6
SPEAKER ID-RLJ-M/PHONEME ID- 2/PITCH-124-NN/PITCH PERIOD-  8.04 MS/      RC- 21-0
-21 37 48 11-33-48-29  8 35 43 36 28 23 18 15 19 32 47 53 46 29  8 -5 -6RC- 21-1
  4 21 27 15 -9-34-44-37-18 -3 -1-13-30-43-43-31-13  3 10  6 -6-15-14  0RC- 21-2
 22 38 40 28 13  6 10 22 34 38 34 22  8 -2 -5  0  8 11  3-14-32-41-37-22RC- 21-3
 -9 -8-21-38-44-33-14  1  5  0 -8 -9  0 15 27 30 26 20 17 20 25 30 30 25RC- 21-4
 18 12  8  7  6  5  2 -1 -6-11-13-14-11 -8 -8 -8-11-12-12-13-12-18-39-61RC- 21-5
-55-12 35 32-22-82-99-52                                                RC- 21-6
SPEAKER ID-RDK-M/PHONEME ID- 2/PITCH-129-NN/PITCH PERIOD-  7.77 MS/      RC- 40-0
-14  0 31 65 72 48 24 30 43 33 13  5 12 13  1 -9-17-30-52-67-56-28 -7 -3RC- 40-1
 -9-14-14 -7  7 28 50 63 62 55 50 49 46 37 28 27 29 25 11 -5-19-32-43-44RC- 40-2
-33-17-12-19-25-22-14 -6  5 22 36 40 34 24 20 16  4-11 -3 18 27 12 -8-19RC- 40-3
-32-39-24  1 11  4 -9-13-11 -3  4 16 24 23 19 21 23 21 11  9 14 22 27 27RC- 40-4
 24 16  1-10 -8  6 16 19 15  8 -5-17-19-19-22-25-30-34-42-57-67-78-92-99RC- 40-5
-97-47  6 12-22-40-31-17                                                RC- 40-6
SPEAKER ID-DEM-M/PHONEME ID- 2/PITCH-127-NN/PITCH PERIOD-  7.87 MS/      RC- 59-0
 -2 17 15 14 23 37 41 38 35 41 65 88 95 87 60 28  7  0  6 19 25 14-12-45RC- 59-1
-67-67-51-34-21-18-23-23-19-18-14 -6  9 30 50 61 58 47 33 26 30 42 53 55RC- 59-2
 44 24  3-11-16-19-18-18-21-24-32-41-49-52-47-38-23-11 -5  0  2  1  3 10RC- 59-3
 24 38 47 47 38 30 26 27 29 28 26 24 17  9  0 -6 -9 -9 -5  0  1  0 -1 -5RC- 59-4
 -5  0  5  8 11 13 12 12 11 11 10 13 14  9 -1-21-38-68-94-97-70-34-18-27RC- 59-5
-64-99-90-52 -9  3 11  9                                                RC- 59-6
SPEAKER ID-JEB-M/PHONEME ID- 2/PITCH-161-NN/PITCH PERIOD-  6.20 MS/      RC- 78-0
-13  8 24 30 29 25 22 24 31 39 43 42 39 38 43 49 52 45 32 19 11  9  8  4RC- 78-1
  0  0  4  9  7 -4-22-36-41-35-21 -9 -2 -2 -6-11-15-15-13 -9 -2  5 14 22RC- 78-2
 26 24 19 15 15 19 24 27 29 29 30 32 32 29 21 13  7  6  7  9 10  8  5  1RC- 78-3
 -2 -5 -9-13-14-10 -3  2  7  6  3  0  0  3  8 12 16 19 23 26 28 25 21 18RC- 78-4
 19 22 25 24 17  5 -4-11-17-27-43-59-61-50-32-23-35-60-85-99-92-76-60-51RC- 78-5
-45-38-31-28-33-41-43-34                                                RC- 78-6
SPEAKER ID-RVP-M/PHONEME ID- 2/PITCH-171-NN/PITCH PERIOD-  5.84 MS/      RC- 97-0
 -8 14 27 20  5  0  8 27 41 46 45 49 60 66 66 54 41 35 33 30 22 15 14 16RC- 97-1
 17 10 -3-19-29-36-40-42-41-36-29-25-26-30-33-33-30-25-16 -4  7 15 19 18RC- 97-2
 17 20 24 29 31 31 30 29 27 25 24 23 21 17 11  3 -4 -9-10 -8 -6 -8-14-21RC- 97-3
-25-25-23-19-15-11 -7 -3 -1  0  3  9 16 21 24 25 26 28 32 33 32 30 27 25RC- 97-4
 23 24 25 26 26 23 16 10  2 -3 -8-13-17-24-35-55-78-99-93-69-37-21-27-47RC- 97-5
-64-63-57-54-48-33 -7 17                                                RC- 97-6
SPEAKER ID-RMC-M/PHONEME ID- 2/PITCH-148-NN/PITCH PERIOD-  6.75 MS/      RC-116-0
-14 10 24 26 24 17  8  9 33 58 65 52 43 47 52 46 35 37 49 55 46 30 16  9RC-116-1
  7  6  5  5  4 -3-22-40-43-29-16-17-28-38-42-41-38-30-18-10-11-19-25-21RC-116-2
 -8  3 10 11 10 10  9  8 13 23 29 29 24 18 16 15 15 18 21 20 14  7  1  0RC-116-3
  0  4  8  5 -2 -7 -7 -6 -4 -3  0  1  0 -5 -4  0  5  9  8 10 13 15 14 15RC-116-4
 17 16 19 19 13 -3-35-53-27 16 38  3-62-90-67-36-25-21-20-28-67-99-89-39RC-116-5
  2  1-23-47-52-41-16  7                                                RC-116-6
SPEAKER ID-MAL-F/PHONEME ID- 2/PITCH-234-NN/PITCH PERIOD-  4.28 MS/      RC-167-0
 -6 35 54 44 24 24 34 33 31 25  5-13-21-23-23-26-36-39-31-19-11 -3  2 10RC-167-1
 18 21 24 30 28 16  3  0  8 14  1-12-11  3 15 12  7  9 16 23 25 24 25 28RC-167-2
 34 39 34 -5-83-92-17 13-37-96-99-39  8 -1-32-29                        RC-167-3
SPEAKER ID-PAF-F/PHONEME ID- 2/PITCH-262-NN/PITCH PERIOD-  3.82 MS/      RC-186-0
-17 11 29 45 56 54 42 34 37 40 38 31 15 -4-23-36-41-41-37-34-30-29-27-21RC-186-1
 -7  6 16 22 21 26 30 38 42 41 35 26 20 20 17 13 11 16 24 36 43 32 12  0RC-186-2
  5 11 17 13  3-23-64-92-99-81-61-49-47-47-49-44                        RC-186-3
SPEAKER ID-PRM-F/PHONEME ID- 2/PITCH-177-NN/PITCH PERIOD-  5.64 MS/      RC-205-0
 -9 20 33 50 55 27 23 20 -1-13-29-33-24-24-18 -1  6 19 32 34 37 31 26 17RC-205-1
  3  0 -5-17-16-12 -6 -1  0  9 19 18 16 14 12 12  8  5  5  5  3  6  7 13RC-205-2
 15 11 15 23 25 11  0 10  0-55-99-85-69-72-35-21                        RC-205-3
SPEAKER ID-IAP-F/PHONEME ID- 2/PITCH-284-NN/PITCH PERIOD-  3.52 MS/      RC-224-0
 10 24 22 21 20 26 36 39 39 36 27 12-10-34-48-48-37-26-30-49-71-85-77-42RC-224-1
 -1 18 18  8  4 16 38 58 65 56 38 25 19 22 28 34 37 41 45 53 65 77 84 82RC-224-2
 70 57 47 32 -4-56-95-99-80-63-62-77-96-99-72-28                        RC-224-3
SPEAKER ID-LLC-F/PHONEME ID- 2/PITCH-216-NN/PITCH PERIOD-  4.62 MS/      RC-243-0
-10 34 35 27 17 16 39 58 52 40 26  4  0 15 16 -8-35-48-38-15-12-37-52-36RC-243-1
 -6 13 11 -2  0 24 45 44 31 21 22 31 35 25 10  1  1  8 13  9  0  0 11 24RC-243-2
 30 17-34-76-41 26 16-61-99-75-22 11-12-64-54  4                        RC-243-3
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TABLE XI (Continued)

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SPEAKER ID-OLL-M/PHONEME ID- 3/PITCH-134-NN/PITCH PERIOD-  7.49 MS/      RC-  3-0
  0 10 22 32 42 51 51 34 12  4 17 41 64 69 47  6-28-43-38-22 -8 -3 -9-20RC-  3-1
-30-37-38-33-22 -7 10 25 35 36 27 16 11 17 31 45 51 45 30 13  0 -5 -6 -6RC-  3-2
 -7-10-14-18-23-29-37-44-44-35-20 -4  6  8  3  0  2 11 22 32 37 37 32 25RC-  3-3
 19 13  7  3  1  0  0 -3 -9-17-24-27-23-15 -8 -3 -2 -2 -2  0  4 10 14 17RC-  3-4
 18 18 19 18 15 11  6  5  6  9 10  8  4  0 -1  0  5  8 -1-31-72-99-94-57RC-  3-5
-12  8 -5-38-63-62-43-21                                                RC-  3-6
SPEAKER ID-RLJ-M/PHONEME ID- 3/PITCH-122-NN/PITCH PERIOD-  8.20 MS/      RC- 22-0
-17 42 59 15-53-99-92-38 32 82 92 61 18-12-21 -2 31 63 77 66 35 -1-27-34RC- 22-1
-28-19-13-13-18-21-24-28-36-40-36-20  4 27 37 31 17  3  1 11 30 46 52 46RC- 22-2
 29  7 -8-14-10 -1  3  0-11-24-34-38-35-27-18 -9 -2  1  1  0  0  4 12 23RC- 22-3
 31 31 21  5 -1  1  9 15 13  2 -9-17-18-14 -9 -2  0  0 -1 -2 -3 -2  2  9RC- 22-4
 15 17 14  8  2  0  0  4  8  9  5  0 -3 -4 -3  0  1  2  3  3  2  0 -2 -2RC- 22-5
  0 -2-25-67-95-78-24 37                                                RC- 22-6
SPEAKER ID-RDK-M/PHONEME ID- 3/PITCH-122-NN/PITCH PERIOD-  8.20 MS/      RC- 41-0
-10 14 40 55 57 54 56 54 42 26 19 25 30 25 10-11-36-55-58-44-26-16-17-21RC- 41-1
-21-15 -5  8 24 38 48 51 51 47 36 23 16 19 23 20  9 -6-23-37-42-36-26-19RC- 41-2
-16-15-12 -9 -5  1 12 24 33 39 42 38 29 17 10  7  4 -3-16-26-33-37-35-30RC- 41-3
-25-22-18-10 -1  6 12 18 24 28 31 31 27 20 12  7  6  4  2 -1 -5 -8 -8 -4RC- 41-4
 -1  1  2  3  3  4  5  8 10 12 16 17 11  4  2  4  4  2 -2-15-36-59-80-93RC- 41-5
-99-85-55-27-21-31-35-28                                                RC- 41-6
SPEAKER ID-DEM-M/PHONEME ID- 3/PITCH-114-NN/PITCH PERIOD-  8.74 MS/      RC- 60-0
  0 24 34 39 45 54 63 64 52 37 25 25 33 33 20 -3-31-51-54-47-39-36-39-39RC- 60-1
-28-13  0  3  4 12 30 50 63 62 52 43 39 38 38 32 21  6 -9-21-27-33-39-45RC- 60-2
-49-43-33-27-26-27-27-16  0 13 20 21 17 18 21 24 26 23 13  6  3  0 -2 -5RC- 60-3
-10-12-10 -9 -6 -5 -7 -9 -6 -2  4  8  7  5  4  4  7  9  9  9  9 10 13 16RC- 60-4
 18 21 18 10  6  6  7  8  2 -4 -2  0  0  5  4 -5-12-18-33-41-59-86-99-90RC- 60-5
-64-30 -9-16-28-30-19  3                                                RC- 60-6
SPEAKER ID-JEB-M/PHONEME ID- 3/PITCH-152-NN/PITCH PERIOD-  6.58 MS/      RC- 79-0
-14  8 26 30 26 25 28 33 33 28 22 19 20 21 22 21 19 19 15  6 -7-24-35-39RC- 79-1
-37-30-21-13 -8 -8-11-15-16-14-11 -4  4 16 27 33 36 39 43 46 46 42 36 32RC- 79-2
 31 32 33 31 28 26 20  9 -4-17-24-25-22-18-15-14-15-16-17-21-23-21-14 -5RC- 79-3
  1  6 12 18 22 24 24 23 23 23 23 26 29 33 36 36 31 25 17 10  5  3  4  8RC- 79-4
 11 12 13 11  8  4  1  0  2  3  1 -2-12-27-42-58-74-91-99-90-68-46-35-35RC- 79-5
-39-44-48-49-48-43-30-11                                                RC- 79-6
SPEAKER ID-RVP-M/PHONEME ID- 3/PITCH-157-NN/PITCH PERIOD-  6.36 MS/      RC- 98-0
 -8 26 35 20  9 22 52 66 47 15  0 14 32 36 28 24 31 34 17-16-41-42-29-20RC- 98-1
-23-28-23-10 -4-12-24-29-26-19-12 -1 16 35 44 41 31 22 16 14 17 23 28 29RC- 98-2
 25 17  9  3 -3-12-19-25-27-25-20-14 -9 -8-11-17-22-22-15 -4  8 18 22 21RC- 98-3
 18 15 13 12 13 14 16 18 18 16 15 13 11  8  4  0  0  1  3  5  5  2 -1 -4RC- 98-4
 -5 -6 -6 -3  0  0  0  0  1  6 12 14  9  3 -2-18-50-85-99-80-34  2  5-14RC- 98-5
-28-28-28-33-44-33 -1 29                                                RC- 98-6
SPEAKER ID-RMC-M/PHONEME ID- 3/PITCH-153-NN/PITCH PERIOD-  6.54 MS/      RC-117-0
 12 52 39 -3-33-34-19  8 39 59 61 46 30 20 14 15 30 49 51 37 23 19 19  9RC-117-1
 -8-18-16 -9 -4 -4 -7-14-25-41-51-46-27 -3 11  9 -4-18-24-17 -1 16 35 48RC-117-2
 44 27 11  8 18 31 36 37 35 25 11 -2-10-10 -9 -8-11-19-22-23-23-28-34-33RC-117-3
-23-14 -7 -1  0  0 -3 -5 -1  8 21 31 33 27 19 16 18 23 26 30 33 31 22 13RC-117-4
 10 10 10  9  5  2 -2 -6 -6 -7 -8-10-14-18-13  0  0 -9-33-61-92-99-77-12RC-117-5
 28 11-36-67-76-77-64-22                                                RC-117-6
SPEAKER ID-MAL-F/PHONEME ID- 3/PITCH-231-NN/PITCH PERIOD-  4.33 MS/      RC-168-0
-10 44 55 29  7 13 31 36 18 -1-12-18-23-27-29-26-23-24-21 -8  7 19 23 20RC-168-1
 20 24 26 21  9 -4-17-23-21-21-26-25-18-10  0  9 14 18 24 26 26 24 19 15RC-168-2
 12  9  9  8  7 11 19 21 -3-63-99-64 -6  5-27-55                        RC-168-3
SPEAKER ID-PAF-F/PHONEME ID- 3/PITCH-269-NN/PITCH PERIOD-  3.72 MS/      RC-187-0
  4 27 38 47 49 38 23 15 15 17 15  3-21-44-52-45-38-37-39-31-16 -3  5 14RC-187-1
 26 38 50 53 43 30 23 21 19 11  0 -8-13-14-14-13 -8  2 18 28 33 36 39 44RC-187-2
 43 39 33 31 23  0-42-84-99-83-58-44-46-55-56-40                        RC-187-3
SPEAKER ID-PRM-F/PHONEME ID- 3/PITCH-184-NN/PITCH PERIOD-  5.43 MS/      RC-206-0
 -9 17 23 28 35 39 39 31 19  0-16-21-21-25-32-27-11  4 12 19 31 37 37 33RC-206-1
 27 17  0 -6 -6-15-15-16 -8  3  8 13 19 20 23 22 16 11  3  0  0 -3 -3  0RC-206-2
  6 14 15 10  3 20 30 -3-66-99-69-37-50-69-51-14                        RC-206-3
SPEAKER ID-IAP-F/PHONEME ID- 3/PITCH-287-NN/PITCH PERIOD-  3.49 MS/      RC-225-0
 -7 12 20 30 35 35 29 17  1 -2  3 11 13  0-24-44-52-48-40-35-35-34-29-16RC-225-1
 -1 10 13 14 19 32 39 36 28 17 10 11 13 11  8  3  3 13 25 35 40 42 46 55RC-225-2
 61 58 54 40 -8-69-99-79-44-21-20-35-51-59-49-18                        RC-225-3
SPEAKER ID-LLC-F/PHONEME ID- 3/PITCH-230-NN/PITCH PERIOD-  4.35 MS/      RC-244-0
 -5 10 11 20 35 44 55 68 72 62 38  7-15-17-12-23-48-69-74-58-32-13 -4  2RC-244-1
 13 26 39 51 58 55 40 18  2 -1 -1 -9-27-43-47-36-20 -8 -1  4 13 24 36 48RC-244-2
 57 61 59 51 30-17-64-66-32-23-55-89-99-79-34  3                        RC-244-3
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TABLE XI (Continued)

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SPEAKER ID-OLL-M/PHONEME ID- 4/PITCH-141-NN/PITCH PERIOD-  7.08 MS/      RC-  4-0
  4 27 16 -1  4 29 44 39 28 26 36 60 81 77 51 37 40 47 53 65 73 62 37 14RC-  4-1
  4 13 32 44 31  2-20-23-11 -3 -5-16-25-28-27-30-38-40-34-29-33-32-28-28RC-  4-2
-30-29-27-22 -8  6  9 -3-16 -8 12 26 30 26 18 11 15 26 33 33 32 31 26 18RC-  4-3
 15 20 25 24 17 11  9  8  4  0 -4 -5  0  3  1 -7-16-17 -9  0  3  0 -3 -4RC-  4-4
 -2  2  8 12 13  4-31-71-61-14 29 30 -5-63-99-89-32 15  6-39-74-79-78-59RC-  4-5
-22  1-12-37-48-45-28  3                                                RC-  4-6
SPEAKER ID-RLJ-M/PHONEME ID- 4/PITCH-115-NN/PITCH PERIOD-  8.73 MS/      RC- 23-0
  0  2  7 23 41 42 31 21 23 34 50 65 67 52 24  6 18 52 74 57  9-27-22 13RC- 23-1
 39 29 -8-38-41-23 -8-10-21-30-34-35-37-35-25-13 -8-18-31-34-19  4 18 13RC- 23-2
 -3-14 -6 14 34 37 22  2 -4 11 38 47 26  0 -5  7 23 28 15 -2-10 -5  2  4RC- 23-3
  3 -1-11-18-16 -7  0  0 -8-19-20-10  3  6 -1 -9 -9 -2  7 12 11  5  2  3RC- 23-4
  8 16 20 18  8  2  8 17 20 10-17-52-49  0 43 25-43-99-92-29 26 18-41-88RC- 23-5
-77-30  4  2-17-26-17 -2                                                RC- 23-6
SPEAKER ID-RDK-M/PHONEME ID- 4/PITCH-125-NN/PITCH PERIOD-  7.99 MS/      RC- 42-0
 -3 18 30 40 52 57 53 54 64 79 84 84 83 82 74 59 51 55 62 57 38 17  3 -4RC- 42-1
 -9-11-10-17-36-55-60-51-44-44-46-46-47-50-46-31-15 -8 -7 -3  3  7 11 22RC- 42-2
 37 46 43 36 32 32 37 46 53 48 32 16 11 16 22 21 12 -2-16-22-17-10 -9-15RC- 42-3
-25-31-31-26-18-12-11-13-13-11 -7  0  8 14 16 16 16 17 23 29 35 37 32 25RC- 42-4
 22 24 29 28 24 17  3-12-26-33-38-49-48-40-44-70-99-95-73-58-65-72-73-78RC- 42-5
-81-65-31 -9-15-31-25 -3                                                RC- 42-6
SPEAKER ID-DEM-M/PHONEME ID- 4/PITCH-130-NN/PITCH PERIOD-  7.69 MS/      RC- 61-0
 13 34 23  0-10 11 50 74 67 48 37 39 51 61 59 53 54 57 52 38 23 19 24 29RC- 61-1
 22  9  0 -2 -1 -4-17-30-30-20 -8-10-25-43-48-36-19 -9-11-18-21-17-12 -7RC- 61-2
 -6 -8 -9  1 14 18 11  2 -6 -6  9 29 35 23  5 -6  0 16 28 26 11 -3 -4  6RC- 61-3
 15 13  2 -7 -7  1  9  5 -4-10-10 -3  6  9  5  1  1  6  9 15 17 13 10 11RC- 61-4
 11 14 19 16 11  3 -3 -3 -8-25-46-40-25-15-15-34-75-99-77-37-14-24-56-80RC- 61-5
-69-38-17-18-35-45-26  9                                                RC- 61-6
SPEAKER ID-JEB-M/PHONEME ID- 4/PITCH-151-NN/PITCH PERIOD-  6.61 MS/      RC- 80-0
 -1  5  5  5  6 11  9  6 15 35 51 58 50 32 28 36 51 58 49 43 48 53 50 41RC- 80-1
 30 26 29 34 35 31 20 12 15 14  6 -3 -7 -2  7  9  0-12-26-28-22-19-11 -5RC- 80-2
 -1 -4-15-30-36-32-12 13 23  8 -9-18-18 -9  0 16 33 37 27 13  0 -5  9 36RC- 80-3
 52 51 37 23 17 14 15 28 41 47 45 35 23 12  9 20 36 36 28 15 10  6  5  3RC- 80-4
  2  3 -3 -8-18-35-57-66-39-15 -7-36-85-99-90-70-51-51-55-59-62-77-93-93RC- 80-5
-74-38-11-21-42-58-60-44                                                RC- 80-6
SPEAKER ID-RVP-M/PHONEME ID- 4/PITCH-171-NN/PITCH PERIOD-  5.86 MS/      RC- 99-0
  0 11 24 40 51 52 44 35 37 46 56 61 62 61 62 60 55 49 47 51 51 44 31 19RC- 99-1
 17 22 25 19  6 -4-11-16-22-29-32-28-23-23-33-47-57-64-64-57-47-35-27-28RC- 99-2
-37-46-50-45-34-18 -3  7 10  6 -1 -4  0 12 26 40 48 48 45 39 35 36 41 48RC- 99-3
 54 57 56 51 46 42 38 37 38 37 35 31 27 24 20 17 14  9  5  1 -3 -5-11-20RC- 99-4
-35-57-75-66-42-18 -8-30-67-94-99-80-62-49-43-37-31-37-56-77-82-60-19 10RC- 99-5
 18  2-18-22-16 -5  6 19                                                RC- 99-6
SPEAKER ID-RMC-M/PHONEME ID- 4/PITCH-185-NN/PITCH PERIOD-  5.41 MS/      RC-118-0
 -3 20 35 24  0-20-24 -7 25 60 76 62 35 16 12 22 39 54 59 54 49 49 54 55RC-118-1
 48 32 24 24 32 48 57 49 29 16 13 15 13  8  7 10 12 16 16  7 -8-26-31-21RC-118-2
 -2  7  7 -3-20-31-30-24-19-16-13 -8 -6 -6 -6-10-17-20-13  1 16 22 19 11RC-118-3
  7 10 17 24 27 30 34 35 26  2-25-30  3 48 76 72 26-39-86-82-26 40 73 48RC-118-4
-16-77-99-76-29  0 -7-39-69-71-52-34-32-49-74-91-79-48-17-13-30-46-53-46RC-118-5
-36-29-29-27-15  0  6 24                                                RC-118-6
SPEAKER ID-MAL-F/PHONEME ID- 4/PITCH-268-NN/PITCH PERIOD-  3.73 MS/      RC-169-0
 25 77 13-50-51-21 -6-12-31-34-28-41-64-48-16-18-44-58-56-32 -1 -1-36-50RC-169-1
-20 10 15  4 -7 -8  6 25 25 16 13 10  8 21 33 25  9  2 11 27 31 17  2  6RC-169-2
 25 36 29 19 22 33 40 42 25-18-30 40 99 21-77-44                        RC-169-3
SPEAKER ID-PAF-F/PHONEME ID- 4/PITCH-276-NN/PITCH PERIOD-  3.62 MS/      RC-188-0
 -1  9 13 13  7 14 39 54 52 39 33 38 52 65 63 45 30 33 46 52 42 27 18 18RC-188-1
 26 35 33 22 14 16 23 29 30 26 21 19  3-14-13 11 17-20-57-52-29-26-39-53RC-188-2
-72-94-83-51-40-72-99-86-60-47-44-38-42-45-33 -7                        RC-188-3
SPEAKER ID-PRM-F/PHONEME ID- 4/PITCH-200-NN/PITCH PERIOD-  4.99 MS/      RC-207-0
  6 19 25 38 48 57 69 68 65 71 73 62 53 48 41 36 23 11  6  0 -5-10-14-15RC-207-1
-14-11-14-12 -4  0  2  5 12 21 27 28 29 37 38 37 38 37 24  2  0  4-22-41RC-207-2
-34-55-71-54-70-99-86-74-82-81-73-68-49-33-31-19                        RC-207-3
SPEAKER ID-IAP-F/PHONEME ID- 4/PITCH-352-NN/PITCH PERIOD-  2.84 MS/      RC-226-0
 -7 -5 -2  3 15 33 40 27  4 -8  5 36 58 59 44 28 20 26 41 54 62 60 44 27RC-226-1
 22 29 44 48 29 -5-42-39  0 33 39 -5-72-99-76-27  8  4-22-53-73-79-71-41RC-226-2
 -2  9-11-49-66-49-14  0-12-26-21 -5  6  3 -5 -7                        RC-226-3
SPEAKER ID-LLC-F/PHONEME ID- 4/PITCH-240-NN/PITCH PERIOD-  4.16 MS/      RC-245-0
  3 91 30-68-70-27-13 -4 -7-70-99-34 17-28-56-21-17-45-13 44 22-30-18 26RC-245-1
 41 46 39  1-11 42 79 31-17  4 35 27 13  8 -6-13  1 13 -5-21-13 -7-11 -1RC-245-2
  9 -4-17  4 34 26 11 16 32 23-23 -5 69 87-25-86                        RC-245-3
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TABLE XI (Continued)

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SPEAKER ID-OLL-M/PHONEME ID- 5/PITCH-141-NN/PITCH PERIOD-  7.09 MS/      RC-  5-0
 -6 13 33 43 42 39 48 58 53 41 36 43 58 72 78 67 41 16  4  4 10 17 22 18RC-  5-1
  0-23-43-52-46-32-20-21-29-35-38-39-36-30-22-12  0  8 12 10  8  9 15 23RC-  5-2
 32 39 43 41 32 21 12 13 18 25 24 18  7 -4-13-16-15-13-11-12-14-19-24-26RC-  5-3
-24-18-12 -8 -5 -2  0  1  3  6 11 17 24 27 26 22 19 19 20 23 24 24 20 15RC-  5-4
 12  7  2  0  2  5  5  3  1 -1-10-36-75-99-88-52-14  2 -9-47-83-98-83-53RC-  5-5
-26 -9 -4-10-27-34-27 -8                                                RC-  5-6
SPEAKER ID-RLJ-M/PHONEME ID- 5/PITCH-119-NN/PITCH PERIOD-  8.41 MS/      RC- 24-0
-17 41 43 -4-56-71-42  8 49 62 44 11-15-13 20 63 81 63 24  0  1 18 27 20RC- 24-1
  8  5  8  2-19-41-44-22  2  7-13-42-55-44-18  6 17 11 -5-20-20  0 29 50RC- 24-2
 45 21  0  0 17 37 41 30 14  4  1  0 -1 -3 -3 -4-11-24-40-45-33-14 -6-17RC- 24-3
-33-36-24 -6  8 13 10  5  6 15 25 31 34 33 28 22 17 16 16 17 15  8 -2-11RC- 24-4
-15-13-10 -9-13-18-22-20-16-11 -6 -4 -3 -4 -2  3  9 10 11 14 17 16  9 -9RC- 24-5
-42-59-36 17 51 25-43-99                                                RC- 24-6
SPEAKER ID-RDK-M/PHONEME ID- 5/PITCH-134-NN/PITCH PERIOD-  7.46 MS/      RC- 43-0
  3 16  9 -2  0 21 39 42 36 37 48 57 54 48 42 37 28 22 26 35 36 20 -4-22RC- 43-1
-23-15-11-13-17-20-27-35-37-27-16-12-15-11  1 13 14  9 11 21 30 38 45 52RC- 43-2
 53 41 29 27 35 41 38 29 20 12  0-13-21-25-30-39-45-44-43-45-49-50-44-36RC- 43-3
-27-16 -6 -1  0  3 12 25 36 43 46 47 44 43 45 47 47 44 41 39 35 29 23 19RC- 43-4
 14 10  7  6  4 -3-12-17-15-11-12-19-27-35-41-46-44-40-49-72-99-97-71-34RC- 43-5
-22-36-57-61-55-43-25  0                                                RC- 43-6
SPEAKER ID-DEM-M/PHONEME ID- 5/PITCH-139-NN/PITCH PERIOD-  7.18 MS/      RC- 62-0
 -4 14 37 56 70 67 54 44 45 54 67 79 84 76 62 47 31 20 16 13  7 -2-13-25RC- 62-1
-33-37-38-42-48-55-63-65-59-48-35-24-18-18-19-18-10  2 18 31 38 41 41 43RC- 62-2
 46 48 47 42 37 35 34 37 39 34 23  8 -4-15-20-20-18-20-24-30-37-42-44-44RC- 62-3
-41-38-34-29-22-15 -8 -2  2  5  8 11 17 23 32 40 45 45 43 39 36 35 38 38RC- 62-4
 36 32 27 24 20 16 10 -2-11-18-25-27-28-33-42-59-83-99-94-77-54-33-29-42RC- 62-5
-59-63-48-29-11 -2 -5 -4                                                RC- 62-6
SPEAKER ID-JEB-M/PHONEME ID- 5/PITCH-158-NN/PITCH PERIOD-  6.31 MS/      RC- 81-0
  0 11 17 27 40 49 47 41 39 42 49 54 57 57 54 50 48 45 38 26 15  8  5  3RC- 81-1
  1  0 -3 -7-11-15-20-28-36-38-31-20-11-10-10 -8 -5 -4 -6 -9 -8  0 11 22RC- 81-2
 29 29 29 32 33 32 29 26 27 33 39 42 40 34 26 20 15  9  2 -2 -2  2  4  2RC- 81-3
 -4-11-16-17-16-13 -7  0  5 11 14 14 10  7 10 19 26 28 26 26 29 30 30 29RC- 81-4
 27 22 11 -1-13-23-34-45-60-67-64-57-48-57-77-93-99-95-90-89-84-69-47-30RC- 81-5
-29-39-49-47-31-12  2 12                                                RC- 81-6
SPEAKER ID-RVP-M/PHONEME ID- 5/PITCH-181-NN/PITCH PERIOD-  5.53 MS/      RC-100-0
  2 26 36 27 14 14 29 54 69 68 56 47 47 47 39 24 10  8 25 48 59 45 17 -9RC-100-1
-25-26-20-19-25-28-23-14-10-17-32-44-47-38-28-25-28-31-26-11  3 11  9  3RC-100-2
 -4 -8-11 -8  0 12 28 42 47 43 30 16  5  0  6 16 26 31 32 28 21 13  4 -2RC-100-3
 -5 -4  0  2  5  7 10 15 17 14  9  4  0 -1  0  5 10 17 23 24 20 12  5 -1RC-100-4
 -3 -1  2  8 12 14 11 -3-29-66-97-99-75-37 -2  6-13-45-68-72-71-68-60-47RC-100-5
-27  0 17 14 -7-26-26 -6                                                RC-100-6
SPEAKER ID-RMC-M/PHONEME ID- 5/PITCH-182-NN/PITCH PERIOD-  5.48 MS/      RC-119-0
 -6 44 57 13-43-75-65-28 -5 10 27 45 50 34  8 -6  0 17 29 33 39 52 54 45RC-119-1
 34 33 40 37 18 -3 -9  9 35 42 29 10 -1-13-31-47-47-28 -1 15 10 -9-31-49RC-119-2
-60-59-41-15  4 10  3 -8-18-25-29-26-11  9 22 23 16 12 12 14 11  4  2 12RC-119-3
 26 34 37 35 31 26 19 10  5  9 19 31 39 38 28 14  2 -4 -4  0  4  8 13 14RC-119-4
  7 -2-12-15-11 -7 -5 -1  1  6  6  1 -4 -5 -2 -4-24-71-99-82-38 20 36 10RC-119-5
-39-71-74-69-76-73-41 11                                                RC-119-6
SPEAKER ID-MAL-F/PHONEME ID- 5/PITCH-244-NN/PITCH PERIOD-  4.09 MS/      RC-170-0
  2 37 33  5-10  9 42 53 40 21  9 11 22 23  9 -9-22-24-18-15-21-31-35-30RC-170-1
-20-14-15-14 -8 -3  6 18 19 16 18 23 30 34 29 20 19 26 33 31 22 19 24 30RC-170-2
 32 21-15-64-57  7 24-39-99-84-20 19 -7-57-61-19                        RC-170-3
SPEAKER ID-PAF-F/PHONEME ID- 5/PITCH-269-NN/PITCH PERIOD-  3.72 MS/      RC-189-0
 -5  8 19 26 30 31 28 17  4  2  8 14 11  0-15-22-17 -7 -1 -3 -4  0  6 14RC-189-1
 24 30 34 38 41 39 39 42 48 52 52 46 40 33 31 32 31 24 19 17 18 19 15 -5RC-189-2
-45-83-93-76-54-53-70-92-99-78-44-23-25-26-16 -1                        RC-189-3
SPEAKER ID-PRM-F/PHONEME ID- 5/PITCH-182-NN/PITCH PERIOD-  5.48 MS/      RC-208-0
-14 34 38 14 15 31 48 47 22  0 -4  0 -7-27-41-36-22-12-15-13  1 19 28 27RC-208-1
 30 30 46 51 29 16 18 26 12 -7 -9  1  0 -7-10 -7  6 10 11 10 18 35 44 40RC-208-2
 34 45 44 30-36-75-37-38-61-99-96-30-20-48-41-11                        RC-208-3
SPEAKER ID-IAP-F/PHONEME ID- 5/PITCH-333-NN/PITCH PERIOD-  3.00 MS/      RC-227-0
 -9  7 18 16 14 25 42 51 54 48 39 28 31 49 76 90 73 10-55-82-55 -9 19  6RC-227-1
-28-66-96-99-88-50-26-26-44-53-49-33-17 -7 -8-14 -7 15 44 55 42 10-19-29RC-227-2
-10 25 53 55 30 -5-30-32-14 12 29 30 14 -4-12 -5                        RC-227-3
SPEAKER ID-LLC-F/PHONEME ID- 5/PITCH-221-NN/PITCH PERIOD-  4.52 MS/      RC-246-0
  7 31 30 25 19 37 52 38 40 58 47 13 -6 -3 14 16-20-63-61-28-15-30-51-52RC-246-1
-25  2  6  4 11 20 27 35 43 47 40 27 21 29 38 29  8 -1  5 20 20  9  3  9RC-246-2
  7-41-87-45 26  3-70-99-77-19 20-18-69-45  9 29                        RC-246-3
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TABLE XI (Continued)

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SPEAKER ID-OLL-M/PHONEME ID- 6/PITCH-138-NN/PITCH PERIOD-  7.26 MS/     RC-  6-0
-10 21 52 74 85 91 89 73 46 21  3-13-32-41-40-37-33-21 -5  4 10 18 22 15RC-  6-1
  0-10-14-17-17-14 -5  4 16 32 46 55 59 57 51 37 18  0-16-31-44-53-56-52RC-  6-2
-44-31-16 -1 11 23 31 34 32 27 21 13  3 -4 -8 -9 -9 -7 -4 -2  0  1  3  2RC-  6-3
  0  0  1  2  2  4  6  8  9 10  9  5  2  0 -3 -6 -8 -6 -3  0  4 10 14 17RC-  6-4
 17 14 10  4 -1 -6-10-14-15-13 -9 -3  2  7 12 16 18 20 19 13  2-17-47-78RC-  6-5
-96-99-93-84-69-48-26  0                                                RC-  6-6
SPEAKER ID-RLJ-M/PHONEME ID- 6/PITCH-117-NN/PITCH PERIOD-  8.58 MS/     RC- 25-0
  2 34 52 57 60 70 82 83 70 49 30 19 12  0-22-44-53-50-45-46-50-50-40-23RC- 25-1
 -9 -2 -1  3 15 27 34 32 29 29 32 35 31 23 13  7  4  0 -9-23-36-43-43-42RC- 25-2
-45-45-37-21 -4  9 21 31 40 50 56 54 44 34 24 14  3 -8-21-31-34-31-28-28RC- 25-3
-26-19 -9  0  4  8 10 15 21 26 25 21 19 19 17 14  8  1 -2 -3 -6-26-47-56RC- 25-4
-55-59-70-74-72-60-41-21 -7  4 27 55 79 88 89 87 88 88 77 51 16-11-24-34RC- 25-5
-55-83-99-94-78-63-54-47                                                RC- 25-6
SPEAKER ID-RDK-M/PHONEME ID- 6/PITCH-126-NN/PITCH PERIOD-  7.94 MS/     RC- 44-0
 19 44 63 77 85 80 63 40 19 -1-27-53-67-68-61-52-37-16  3 17 26 35 42 42RC- 44-1
 32 23 18 18 16 15 16 19 18 13  7  2 -5-19-34-44-44-40-31-18  0 21 40 55RC- 44-2
 67 73 68 53 32 12 -6-25-42-52-53-48-39-25 -7  7 17 20 22 23 14 -2 -7 -6RC- 44-3
 -8-12 -7  1  7 11 12 13 12  6 -3 -7 -6 -6 -5  0  8 14 17 19 19 15  7 -2RC- 44-4
 -7-10-12-12 -5  2  9 16 23 28 29 25 18 10  1 -8-18-23-27-32-39-46-62-82RC- 44-5
-99-97-85-72-57-33  5 46                                                RC- 44-6
SPEAKER ID-DEM-M/PHONEME ID- 6/PITCH-121-NN/PITCH PERIOD-  8.28 MS/     RC- 63-0
  1 36 66 87 99 98 91 77 55 28  2-20-35-41-42-39-33-24-16 -9 -3 -1 -2 -5RC- 63-1
 -8 -7 -2  5 15 26 34 40 45 46 42 33 17 -1-19-33-42-46-44-38-26-11  5 21RC- 63-2
 34 41 44 42 36 27 16  5 -5-14-20-24-26-27-27-28-26-21-16 -9 -2  6 14 23RC- 63-3
 32 40 44 43 36 25 12 -1-15-27-36-41-41-34-23 -8  4 16 25 32 34 32 25 16RC- 63-4
  6 -2-10-14-15-13 -9 -4  2  8 12 15 16 15 13 10  8  5  3  2  0 -5-16-31RC- 63-5
-52-72-86-91-90-82-66-44                                                RC- 63-6
SPEAKER ID-JEB-M/PHONEME ID- 6/PITCH-139-NN/PITCH PERIOD-  7.17 MS/     RC- 82-0
-10  6 25 45 60 64 62 59 57 52 41 25 11  1 -4-15-24-29-25-21-23-28-28-23RC- 82-1
-19-20-23-20-14 -8 -5 -1  8 23 37 46 52 60 69 74 71 64 57 49 37 19  0-13RC- 82-2
-23-32-41-49-50-47-40-33-25-13  0 12 20 27 34 42 47 47 44 41 39 35 28 21RC- 82-3
 15 11  6  0 -8-14-16-18-22-25-26-24-21-19-15 -9  0  8 14 19 24 30 35 36RC- 82-4
 34 33 32 29 24 20 17 15 11  8  5  3 -1-10-18-22-27-35-44-51-58-67-79-90RC- 82-5
-99-99-92-84-78-70-53-30                                                RC- 82-6
SPEAKER ID-RVP-M/PHONEME ID- 6/PITCH-170-NN/PITCH PERIOD-  5.88 MS/     RC-101-0
 -2 24 55 80 95 99 93 82 66 41 10-19-41-51-52-53-57-60-56-42-20  2 17 25RC-101-1
 27 25 22 15  7  0 -2  0  3  6  8 10 16 26 36 43 44 39 29 15 -1-20-37-49RC-101-2
-54-53-51-48-43-31-13  8 29 43 53 58 59 54 42 23  4-10-21-29-39-47-51-47RC-101-3
-35-19 -5  4 12 20 27 32 31 27 21 18 17 15 11  4  0  0  3  6  7  4  2  1RC-101-4
  2  3  4  4  6  9 13 14 15 15 16 18 20 19 14  7  1 -3 -6-13-23-37-55-73RC-101-5
-88-93-89-76-59-44-30-15                                                RC-101-6
SPEAKER ID-RMC-M/PHONEME ID- 6/PITCH-165-NN/PITCH PERIOD-  6.07 MS/     RC-120-0
  4 31 56 73 83 86 85 77 63 44 25  5-11-25-37-47-51-50-45-36-25-13 -4  3RC-120-1
 10 13 14 14 13 10  8  6  5  4  5  8 14 20 27 32 33 31 28 23 15  5 -6-17RC-120-2
-27-36-43-47-47-42-32-19 -6  6 18 30 39 43 43 38 31 22 11 -1-12-23-29-30RC-120-3
-29-28-25-16 -6  1  7 13 19 25 28 28 26 24 23 21 17 11  6  2 -2 -8-15-20RC-120-4
-22-23-22-19-15 -8  0  9 16 22 27 31 34 36 34 29 26 24 18  6-10-31-50-65RC-120-5
-79-93-99-96-88-75-58-38                                                RC-120-6
SPEAKER ID-MAL-F/PHONEME ID- 6/PITCH-262-NN/PITCH PERIOD-  3.82 MS/     RC-171-0
 -2 30 54 77 91 80 49 14-17-47-61-54-39-25-13  0 11 14 10  5 -2-13-17 -9RC-171-1
  5 18 27 32 28 16 -2-22-34-42-44-33-14  4 23 39 48 47 37 23 11  0 -9-10RC-171-2
 -8 -6 -1  7 17 29 40 45 26-21-68-93-99-89-60-19                        RC-171-3
SPEAKER ID-PAF-F/PHONEME ID- 6/PITCH-258-NN/PITCH PERIOD-  3.88 MS/     RC-190-0
 -9 31 57 70 72 57 28 -1-29-55-70-63-46-31-17  1 16 19 16 13  9  6  8 12RC-190-1
 13 13 14 14  9 -1-13-14 -8 -3  5 18 29 35 37 32 21 10  4  3  4  9 21 35RC-190-2
 44 43 37 30 19  6-13-44-77-96-99-91-77-48 -5 32                        RC-190-3
SPEAKER ID-PRM-F/PHONEME ID- 6/PITCH-185-NN/PITCH PERIOD-  5.40 MS/     RC-209-0
 -6 56 98 99 69 17-43-84-96-78-32 20 56 68 57 24-17-46-55-43-13 21 48 60RC-209-1
 53 30  2-17-29-31-24 -7 15 28 34 36 28 14  0-10-15-16-12 -4  3  8 10 13RC-209-2
 16 15 14 12  7  3  4  7  8  4-13-50-88-98-80-48                        RC-209-3
SPEAKER ID-IAP-F/PHONEME ID- 6/PITCH-277-NN/PITCH PERIOD-  3.61 MS/     RC-228-0
-15 22 48 61 72 79 78 62 36  4-27-47-51-55-70-73-53-28-11 -2  5 10 17 22RC-228-1
 24 19 13 11 16 22 23 19 12 10 10  8  0-10-15-11 -3  1  8 19 29 39 49 57RC-228-2
 55 46 39 32 23 17  5-28-69-82-73-81-99-92-65-32                        RC-228-3
SPEAKER ID-LLC-F/PHONEME ID- 6/PITCH-222-NN/PITCH PERIOD-  4.50 MS/     RC-247-0
  2 43 57 77 99 86 49 16-13-46-64-62-56-47-21  8 20 19 27 36 29 15 11 13RC-247-1
  7 -3-11-17-24-29-27-19 -5 13 29 37 37 32 19 -1-21-28-27-22-11  7 25 36RC-247-2
 41 42 38 30 23 16  8 -7-43-80-86-77-82-80-36 19                        RC-247-3
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TABLE XI (Continued)

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SPEAKER ID-OLL-M/PHONEME ID- 7/PITCH-165-NN/PITCH PERIOD-  6.07 MS/      RC-  7-0
  2 25 40 52 58 60 58 56 55 56 55 49 40 32 26 23 23 25 28 28 24 14  3-10RC-  7-1
-25-39-49-55-60-65-68-69-65-57-42-23 -1 18 36 50 61 69 72 72 70 66 60 51RC-  7-2
 37 22  7 -4-12-18-22-25-29-34-39-42-45-46-44-42-38-35-31-27-20-11  0 13RC-  7-3
 27 40 50 55 57 57 55 52 46 38 27 16  5 -4-12-18-20-19-16-12 -9 -6 -4 -2RC-  7-4
  0  3  5  7  7  7  7  8 10 13 17 22 24 22 15 -2-28-53-72-81-88-95-99-96RC-  7-5
-88-80-70-56-33 -7 17 35                                                RC-  7-6
SPEAKER ID-RLJ-M/PHONEME ID- 7/PITCH-111-NN/PITCH PERIOD-  8.97 MS/     RC- 26-0
  3 32 60 78 85 88 93 96 97 89 71 50 35 30 26 14 -1-14-18-16-14-19-30-41RC- 26-1
-46-45-44-50-59-64-59-47-35-23-11  1 18 39 60 74 77 77 79 79 74 60 43 23RC- 26-2
  6 -5-15-26-39-49-52-49-45-41-40-39-37-32-26-23-27-31-29-18 -7  0  6 17RC- 26-3
 31 46 59 68 68 64 60 57 49 32 12 -4-17-28-35-42-48-51-45-34-25-20-15 -7RC- 26-4
  0  8 13 15 15 14 16 20 21 19 16 17 20 23 22 18 14 10  0-19-38-52-61-73RC- 26-5
-88-99-98-90-76-59-42-26                                                RC- 26-6
SPEAKER ID-RDK-M/PHONEME ID- 7/PITCH-135-NN/PITCH PERIOD-  7.41 MS/     RC- 45-0
  0 20 45 71 83 82 76 71 68 56 36 16  0-10-20-30-31-28-22-21-22-20-14-10RC- 45-1
-10-13-15-17-19-18-11 -2  7 15 25 38 48 58 64 67 65 55 41 26 12 -1-16-30RC- 45-2
-41-48-50-48-41-30-18 -8  0  8 16 22 25 25 22 17 10  3 -1 -3 -5 -6 -7 -7RC- 45-3
 -4 -2  1  4  6  6  3  0 -1 -2 -3 -4 -4 -3  0  3  8 15 22 26 27 27 28 27RC- 45-4
 24 20 16 12  7  3  0  0  2  3  3  3  5  6  6  3 -2 -7-16-27-40-55-68-86RC- 45-5
-97-99-95-85-79-66-42-14                                                RC- 45-6
SPEAKER ID-DEM-M/PHONEME ID- 7/PITCH-129-NN/PITCH PERIOD-  7.77 MS/     RC- 64-0
  0 20 40 56 67 72 76 77 76 75 71 65 58 46 34 24 15  8  2 -3 -9-17-25-33RC- 64-1
-42-49-55-60-62-63-62-58-51-41-26-10  7 26 45 60 73 81 87 89 88 83 75 63RC- 64-2
 51 37 21  7 -4-15-24-32-39-46-53-58-64-68-68-65-62-58-50-41-32-20 -5  9RC- 64-3
 25 37 50 58 62 65 65 62 58 50 41 31 19  9  2 -4 -8 -9-11-11-10 -7 -1  2RC- 64-4
  8 14 14 12  8  4  0 -2 -1 -1  0  0  1  0 -3 -3 -6-17-32-49-67-83-95-99RC- 64-5
-98-93-83-72-57-43-26 -6                                                RC- 64-6
SPEAKER ID-JEB-M/PHONEME ID- 7/PITCH-137-NN/PITCH PERIOD-  7.31 MS/     RC- 83-0
 -5  3 15 20 18 18 19 22 21 18 18 23 29 31 28 26 26 23 16  9  3 -2-13-24RC- 83-1
-30-32-34-34-30-21-12 -3  4 13 24 35 42 45 47 49 50 48 45 44 45 44 44 43RC- 83-2
 41 39 37 35 30 22 11 -1-17-30-39-45-53-59-63-65-63-57-46-32-16 -3  6 15RC- 83-3
 24 30 33 38 42 40 34 28 22 19 19 19 18 18 20 21 19 19 24 27 25 22 21 16RC- 83-4
 10  5  5  5  1  0 -1 -2 -3 -3 -3 -6 -7 -9-16-29-41-51-60-71-80-89-96-99RC- 83-5
-91-82-75-65-46-26-15 -9                                                RC- 83-6
SPEAKER ID-RVP-M/PHONEME ID- 7/PITCH-183-NN/PITCH PERIOD-  5.46 MS/     RC-102-0
-10 12 32 46 57 66 72 73 68 57 41 28 22 20 19 15  6  0 -3  1 11 21 27 27RC-102-1
 24 21 17 11  0-14-29-42-50-55-59-64-70-71-65-51-34-15  2 17 30 42 53 61RC-102-2
 65 65 63 58 50 40 28 15  3 -6-12-14-14-15-17-19-22-23-22-19-17-17-18-20RC-102-3
-22-23-23-21-19-14 -7  0  8 15 20 25 29 35 39 43 43 40 35 29 24 21 17 14RC-102-4
 12 11 11 11 12 13 14 15 17 19 19 16 12  7  0 -6-14-22-33-46-62-78-92-99RC-102-5
-98-93-84-75-68-58-44-26                                                RC-102-6
SPEAKER ID-RMC-M/PHONEME ID- 7/PITCH-182-NN/PITCH PERIOD-  5.50 MS/     RC-121-0
 -8  1 16 32 45 55 63 69 72 74 76 74 71 68 63 56 48 42 36 28 21 14 10  6RC-121-1
  4  1 -2 -6 -8 -8 -6 -6 -6 -9-13-15-17-20-22-24-26-31-37-41-43-43-43-42RC-121-2
-41-40-37-32-26-19-11 -3  4 12 19 25 31 38 43 47 49 50 49 48 45 41 37 33RC-121-3
 28 21 15  9  4  0 -3 -6 -9-11-12-13-13-12-10 -7 -2  1  4  6 10 15 20 24RC-121-4
 27 30 33 34 35 34 31 27 22 11 -2-12-19-29-43-57-69-82-92-95-97-99-98-95RC-121-5
-93-89-79-66-51-36-20 -8                                                RC-121-6
SPEAKER ID-MAL-F/PHONEME ID- 7/PITCH-251-NN/PITCH PERIOD-  3.99 MS/     RC-172-0
 10 48 70 76 78 81 72 46 17 -4-24-38-41-37-36-37-32-23-16-15-16-16-14 -8RC-172-1
  3 18 30 35 38 42 41 31 14 -1-18-32-36-34-29-22 -9  8 26 39 47 50 49 44RC-172-2
 42 40 34 24  6-24-56-74-82-92-99-88-65-37 -3 35                        RC-172-3
SPEAKER ID-PAF-F/PHONEME ID- 7/PITCH-258-NN/PITCH PERIOD-  3.88 MS/     RC-191-0
 -6  7 12 14 16 17 18 22 29 35 39 41 42 34 21  7 -5-17-26-29-27-24-18 -9RC-191-1
 -1  2  4  8 10 11 14 19 24 27 33 38 39 38 37 37 36 33 31 28 22 17 14  9RC-191-2
  2 -2 -2 -3 -6-16-34-57-77-92-98-99-93-79-57-33                        RC-191-3
SPEAKER ID-PRM-F/PHONEME ID- 7/PITCH-189-NN/PITCH PERIOD-  5.30 MS/     RC-210-0
 -6 33 56 63 56 36 14 -2-10 -6  2 12 18 17  7 -9-26-35-34-22 -2 19 37 47RC-210-1
 45 30 10 -6-18-22-18 -6  6 15 17 11  3 -5-11-11 -3  8 19 27 28 24 15  3RC-210-2
 -3 -2  2 10 17 22 25 18 -2-33-64-87-99-96-76-44                        RC-210-3
SPEAKER ID-IAP-F/PHONEME ID- 7/PITCH-291-NN/PITCH PERIOD-  3.44 MS/     RC-229-0
 -1 26 55 78 90 86 82 73 55 34 13-13-37-55-70-74-68-58-53-47-38-19  0 10RC-229-1
 11 11 15 20 25 23 18 16 19 22 25 25 24 25 23 20 19 24 26 25 24 27 31 35RC-229-2
 37 35 26  6-20-41-50-65-83-96-99-91-67-41-24 -3                        RC-229-3
SPEAKER ID-LLC-F/PHONEME ID- 7/PITCH-228-NN/PITCH PERIOD-  4.38 MS/     RC-248-0
  6 33 55 77 97 99 92 82 72 51 23  0-14-29-43-49-46-44-39-30-25-23-20-16RC-248-1
-16-19-20-16 -7 -2  5 18 33 43 52 59 60 58 53 43 29 17  6 -2-12-16-14 -8RC-248-2
  0  7  4  0 -7-10-28-54-69-72-81-92-83-64-47-23                        RC-248-3
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TABLE XI (Continued)

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SPEAKER ID-OLL-M/PHONEME ID- 8/PITCH-147-NN/PITCH PERIOD-  6.81 MS/      RC-  8-0
 -8 14 30 45 58 68 70 68 62 53 38 21  6 -7-20-30-35-35-33-29-21-11  0 11RC-  8-1
 22 32 39 43 44 43 38 32 26 20 14  9  6  4  4  6 10 15 20 23 26 26 24 21RC-  8-2
 16  8  0-11-22-33-44-53-60-63-62-58-50-39-26-12  2 17 31 42 48 51 50 44RC-  8-3
 35 25 14  3 -7-16-22-24-24-21-14 -5  4 14 22 29 33 34 34 31 26 20 14  7RC-  8-4
  1 -4 -7 -9 -9 -8 -6 -3  0  2  5  8 10 11 11  8  1-10-27-45-64-80-91-96RC-  8-5
-99-98-92-82-66-48-25 -1                                                RC-  8-6
SPEAKER ID-RLJ-M/PHONEME ID- 8/PITCH-123-NN/PITCH PERIOD-  8.15 MS/     RC- 27-0
 -1 27 50 66 72 69 61 54 53 53 48 37 25 18 19 27 34 31 19  2-12-22-31-45RC- 27-1
-60-72-79-78-69-54-33-11  7 25 42 57 69 75 71 61 48 37 29 21 13  6  2  1RC- 27-2
  2  2  0 -5-11-18-27-38-48-54-57-55-50-40-26 -9  6 22 36 48 53 49 41 34RC- 27-3
 25 15  5 -1 -4 -5 -3  1  5  7  6  3 -2 -7-13-19-25-29-28-24-16 -6  3 13RC- 27-4
 19 24 27 28 26 21 15 10  6  4  4  5  7 10 11 12 12 10  6  0-11-41-74-95RC- 27-5
-99-97-91-84-75-59-36 -6                                                RC- 27-6
SPEAKER ID-RDK-M/PHONEME ID- 8/PITCH-130-NN/PITCH PERIOD-  7.71 MS/     RC- 46-0
 -6 24 51 74 91 99 92 77 58 36 11-18-45-63-73-76-73-62-44-24 -5 10 25 38RC- 46-1
 46 45 39 31 24 16  8  3  2  5  8 11 16 21 24 22 16  7 -2-14-25-35-41-43RC- 46-2
-39-32-19 -3 14 32 47 58 64 65 60 48 31 12 -7-29-49-62-71-75-71-59-40-21RC- 46-3
 -2 19 37 50 58 60 57 48 35 19  4 -7-19-28-33-34-31-25-17 -7  3 12 19 24RC- 46-4
 27 28 25 21 15  8  1 -3 -7 -9 -9 -8 -5 -3  0  0  0 -1 -6-15-28-41-53-59RC- 46-5
-61-59-53-43-26 -7 14 33                                                RC- 46-6
SPEAKER ID-DEM-M/PHONEME ID- 8/PITCH-119-NN/PITCH PERIOD-  8.41 MS/     RC- 65-0
  6 26 46 65 80 88 88 81 74 66 55 35 13 -7-23-36-45-53-55-52-45-34-25-16RC- 65-1
 -6  2 10 16 20 22 24 26 26 28 29 28 27 26 24 22 20 16 12  8  4  0 -7-14RC- 65-2
-19-23-25-29-32-33-30-25-19-14 -8 -1  7 12 15 14 14 13 10  7  4  3  4  5RC- 65-3
  5  6  7  9 10  9  7  4  2  0 -3 -5 -7 -8 -8 -7 -6 -4 -2  0  3  6  9 12RC- 65-4
 14 15 15 15 14 13 11  9  8  7  7  6  6  6  6  5  1 -4-15-33-54-75-91-98RC- 65-5
-99-94-88-77-57-35 -8  5                                                RC- 65-6
SPEAKER ID-JEB-M/PHONEME ID- 8/PITCH-151-NN/PITCH PERIOD-  6.63 MS/     RC- 84-0
-14  2 20 35 44 48 51 53 54 53 46 37 30 25 19 11  1 -2 -2  0 -3 -8-12-12RC- 84-1
-12-13-16-21-25-27-29-32-34-34-32-26-19-12 -4  5 17 29 40 51 60 67 71 71RC- 84-2
 70 67 62 54 44 35 25 15  4 -4-13-20-27-34-40-44-45-45-44-43-40-36-30-25RC- 84-3
-19-13 -5  2 10 17 23 28 33 38 42 45 45 44 43 42 39 36 32 29 27 25 22 19RC- 84-4
 16 14 13 14 14 13 10  9  7  5  2 -2 -6-11-18-25-33-41-49-59-72-85-94-99RC- 84-5
-96-93-91-86-78-64-47-33                                                RC- 84-6
SPEAKER ID-RVP-M/PHONEME ID- 8/PITCH-157-NN/PITCH PERIOD-  6.37 MS/     RC-103-0
-10 16 39 58 75 90 99 96 84 68 53 40 23  1-25-48-60-63-59-55-51-46-34-19RC-103-1
 -5  4 10 15 20 24 25 19 10  2  0  1  3  5  5  7 13 21 30 36 39 39 37 33RC-103-2
 25 13  0-15-27-37-46-55-62-65-63-54-40-24-10  4 18 33 45 53 57 57 54 49RC-103-3
 39 27 14  1 -7-13-17-22-25-27-25-19-13 -6  0  4 10 15 20 22 24 24 25 24RC-103-4
 21 16 11  6  2  0 -1 -3 -5 -6 -5 -2  0  2  2  2  0 -4-14-29-49-67-79-83RC-103-5
-82-80-79-73-60-38-11 16                                                RC-103-6
SPEAKER ID-RMC-M/PHONEME ID- 8/PITCH-169-NN/PITCH PERIOD-  5.92 MS/     RC-122-0
 -3 12 28 42 54 64 73 79 82 82 79 74 67 56 44 31 18  4 -9-22-34-45-53-59RC-122-1
-63-64-63-60-54-47-38-27-16 -4  6 18 29 38 46 52 57 60 61 60 58 53 48 41RC-122-2
 34 27 19 11  3 -4-10-16-22-26-32-36-39-39-39-39-38-35-31-26-22-16-11 -5RC-122-3
  1  8 12 15 18 22 25 26 24 24 24 21 18 16 15 13 12 12 13 14 14 16 18 22RC-122-4
 25 28 31 35 37 36 34 31 24 14  3 -7-20-32-45-58-70-80-88-94-97-99-96-90RC-122-5
-82-72-60-47-31-16  0 16                                                RC-122-6
SPEAKER ID-MAL-F/PHONEME ID- 8/PITCH-249-NN/PITCH PERIOD-  4.02 MS/     RC-173-0
-16 22 56 84 99 93 74 52 31  0-40-69-80-76-64-49-29 -9  4 15 26 31 23  9RC-173-1
  1  0  2  2  4 10 15 17 15 11  1-11-21-22-19-13 -6  4 19 31 37 40 38 32RC-173-2
 23 17 15 15 16 19 14-14-56-79-79-76-83-82-58-18                        RC-173-3
SPEAKER ID-PAF-F/PHONEME ID- 8/PITCH-262-NN/PITCH PERIOD-  3.81 MS/     RC-192-0
-22  2 22 36 42 42 35 23  9 -4-18-29-34-32-27-18 -9  1  9 14 17 17 15 11RC-192-1
  7  4  3  4  7 14 22 28 33 36 38 37 33 27 22 18 14 14 15 17 19 21 23 25RC-192-2
 24 23 20 15  5 -9-30-52-71-84-95-99-94-82-65-43                        RC-192-3
SPEAKER ID-PRM-F/PHONEME ID- 8/PITCH-195-NN/PITCH PERIOD-  5.12 MS/     RC-211-0
 -7 29 54 66 60 42 20 -5-26-37-36-27-14 -1  9 12  7  0 -9-14-11 -2  8 24RC-211-1
 40 49 49 38 23  9 -4-16-19-15 -5  9 20 26 29 26 17  8  0 -4 -1  3 10 20RC-211-2
 27 31 29 22 15 10  3 -9-29-57-83-99-98-87-66-29                        RC-211-3
SPEAKER ID-IAP-F/PHONEME ID- 8/PITCH-314-NN/PITCH PERIOD-  3.18 MS/     RC-230-0
  5 29 55 77 89 91 84 69 50 27  3-22-47-67-80-86-87-80-67-49-33-21 -8  4RC-230-1
 16 19 14 10 14 22 27 28 28 34 42 48 47 44 42 41 42 40 37 34 34 34 32 26RC-230-2
 22 17  1-23-52-67-74-78-90-99-91-69-39-16  4 26                        RC-230-3
SPEAKER ID-LLC-F/PHONEME ID- 8/PITCH-240-NN/PITCH PERIOD-  4.17 MS/     RC-249-0
 -5 15 33 50 57 49 43 49 50 37 25 24 24 19 12  5 -6-18-26-34-49-62-64-58RC-249-1
-49-42-28 -7 12 28 42 50 50 51 50 41 26 15  9  5  1 -2 -2  5 13 17 21 26RC-249-2
 28 30 30 26  5-24-47-56-67-87-99-90-70-51-37-18                        RC-249-3
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TABLE XI (Continued)

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SPEAKER ID-OLL-M/PHONEME ID- 9/PITCH-146-NN/PITCH PERIOD-  6.87 MS/      RC-  9-0
 -3 16 36 53 66 73 71 65 60 55 46 35 28 24 24 29 37 44 44 37 28 18  3-14RC-  9-1
-30-42-50-54-51-43-35-28-20-14-12-14-18-23-26-25-21-14 -6  4 18 32 41 45RC-  9-2
 45 42 35 27 21 15 11  9 10 13 16 17 17 15 10  2 -7-18-27-34-35-33-29-24RC-  9-3
-18-12 -7 -3 -1 -2 -4 -6 -6 -4  0  4 11 19 26 32 35 35 32 27 22 17 11  7RC-  9-4
  5  4  5  7  8  9  8  7  5  3  0-10-25-53-81-97-99-88-73-56-44-36-35-27RC-  9-5
-16-11-15-24-29-29-26-17                                                RC-  9-6
SPEAKER ID-RLJ-M/PHONEME ID- 9/PITCH-135-NN/PITCH PERIOD-  7.40 MS/      RC- 28-0
 -2  8 21 35 50 63 71 75 72 62 50 39 35 40 52 68 82 92 93 86 72 53 35 22RC- 28-1
 12  7  4  0 -2 -8-13-18-20-21-20-20-23-30-41-54-68-76-76-68-52-36-22-14RC- 28-2
-14-18-23-25-21-13 -3  5 13 17 20 22 27 33 41 47 50 49 42 31 20 13 11 16RC- 28-3
 26 37 46 48 43 32 20  8  1 -3 -5 -6 -9-13-17-19-19-16-10 -5 -1 -1 -5-11RC- 28-4
-19-24-26-24-19-13 -8 -4 -6-15-34-61-83-99-98-83-60-37-20-16-20-32-43-50RC- 28-5
-52-49-43-35-26-17 -7  5                                                RC- 28-6
SPEAKER ID-RDK-M/PHONEME ID- 9/PITCH-136-NN/PITCH PERIOD-  7.34 MS/      RC- 47-0
  1 13 18 20 25 38 52 63 64 61 56 51 45 40 37 36 37 35 29 19 11  6  2 -4RC- 47-1
-15-26-32-33-33-33-30-24-20-21-25-27-23-15 -8 -2  2 11 20 27 33 38 43 46RC- 47-2
 46 42 39 39 42 45 44 40 35 28 20 10 -1-11-20-29-44-57-62-60-56-54-54-47RC- 47-3
-40-36-33-24 -9  1  5 10 21 33 40 44 51 57 56 50 48 51 54 53 51 51 50 44RC- 47-4
 36 28 22 13  3 -7-13-18-20-24-27-30-37-45-52-58-62-67-71-76-83-93-99-91RC- 47-5
-76-58-48-42-34-25-19-16                                                RC- 47-6
SPEAKER ID-DEM-M/PHONEME ID- 9/PITCH-123-NN/PITCH PERIOD-  8.12 MS/      RC- 66-0
 -6 15 34 54 72 79 79 73 63 62 65 68 70 73 76 80 81 75 61 45 29 10 -7-25RC- 66-1
-36-39-35-31-31-36-42-44-51-57-62-66-64-57-48-38-24 -9  4 14 19 20 19 19RC- 66-2
 21 26 31 37 44 50 52 52 49 44 40 34 25 12  2 -5 -9 -9 -9 -8-10-14-18-22RC- 66-3
-27-28-30-31-32-32-28-22-12 -2  6 12 14 17 18 20 23 25 28 30 31 31 35 37RC- 66-4
 37 35 31 26 21 18 11  6  0 -5 -9-16-26-41-52-69-86-94-99-91-76-65-62-60RC- 66-5
-58-56-52-53-57-53-42-24                                                RC- 66-6
SPEAKER ID-JEB-M/PHONEME ID- 9/PITCH-162-NN/PITCH PERIOD-  6.18 MS/      RC- 85-0
 -4  4 13 23 33 41 48 53 56 59 60 61 62 62 63 64 65 64 61 56 52 49 47 44RC- 85-1
 39 33 27 20 13  6  0 -8-13-16-17-19-21-23-26-28-29-30-31-32-33-34-35-37RC- 85-2
-39-39-38-34-28-21-12 -4  2  7 12 17 22 27 30 33 37 39 42 43 44 45 47 51RC- 85-3
 55 60 63 65 65 63 61 58 54 50 46 42 38 34 29 25 19 15 11  7  3  0 -5-12RC- 85-4
-19-28-36-43-51-58-65-71-75-82-88-94-98-99-97-94-90-87-84-81-77-73-69-66RC- 85-5
-60-53-44-34-26-19-12 -4                                                RC- 85-6
SPEAKER ID-RVP-M/PHONEME ID- 9/PITCH-184-NN/PITCH PERIOD-  5.43 MS/      RC-104-0
  5 22 35 44 50 55 59 63 64 63 62 62 63 65 66 64 60 58 58 59 58 56 50 43RC-104-1
 35 24 13  3 -5-13-18-23-27-31-33-36-39-41-44-47-48-48-50-53-55-57-58-56RC-104-2
-52-48-43-37-30-23-16-10 -4  1  7 12 18 24 29 34 38 42 46 51 55 58 61 62RC-104-3
 61 61 60 58 56 54 52 50 48 46 43 40 36 33 30 27 24 20 16 12  5  0 -6-12RC-104-4
-16-19-25-30-34-42-52-60-70-87-99-98-93-87-78-72-75-74-66-58-54-49-49-51RC-104-5
-45-33-30-31-30-27-19 -2                                                RC-104-6
SPEAKER ID-RMC-M/PHONEME ID- 9/PITCH-189-NN/PITCH PERIOD-  5.28 MS/      RC-123-0
-12 -2  2  1  3  9 16 24 35 46 49 43 34 32 32 40 51 65 78 87 90 89 87 83RC-123-1
 75 64 56 51 51 51 52 54 53 46 37 28 22 22 24 24 19 14  6 -6-20-30-36-42RC-123-2
-43-41-36-31-27-23-24-29-36-42-45-44-40-36-34-33-29-27-25-18 -7  5 13 20RC-123-3
 27 33 36 34 34 34 34 40 45 54 64 73 73 59 41 25 -2-15 -8  2 13 18 22 19RC-123-4
  7 -3-14-26-33-37-47-55-60-61-66-74-86-94-99-97-90-75-56-46-46-52-63-75RC-123-5
-82-83-76-67-56-45-36-21                                                RC-123-6
SPEAKER ID-MAL-F/PHONEME ID- 9/PITCH-264-NN/PITCH PERIOD-  3.79 MS/      RC-174-0
 13 28 39 50 61 68 67 60 45 32 25 19 10  4  0 -8 -7 -4-11-22-27-35-42-39RC-174-1
-36-38-30-14  2 17 33 43 46 50 54 52 47 46 47 53 63 73 65 25  1  5-12-55RC-174-2
-73-75-92-99-72-55-61-58-46-39-34-32-37-40-32-17                        RC-174-3
SPEAKER ID-PAF-F/PHONEME ID- 9/PITCH-260-NN/PITCH PERIOD-  3.85 MS/      RC-193-0
 -9 -2  6 24 46 54 54 59 67 70 73 80 74 63 62 63 52 34 13  7  1  1 -3-11RC-193-1
-16-25-23-14 -6 -5  0  9 20 29 36 24 17 29 43 43 26  7-19-29-24-16-26-40RC-193-2
-50-56-61-67-77-92-99-93-78-67-68-68-60-46-32-17                        RC-193-3
SPEAKER ID-PRM-F/PHONEME ID- 9/PITCH-202-NN/PITCH PERIOD-  4.94 MS/      RC-212-0
  2 21 38 50 60 65 71 80 80 79 79 70 61 53 42 35 24  6 -5-15-25-27-35-42RC-212-1
-42-41-37-32-26-14 -3  9 20 21 31 51 63 64 58 51 44 37 23 12 13  0-26-43RC-212-2
-61-75-68-77-99-96-96-93-79-73-63-46-31-18 -8  7                        RC-212-3
SPEAKER ID-IAP-F/PHONEME ID- 9/PITCH-321-NN/PITCH PERIOD-  3.12 MS/      RC-231-0
 15 26 34 47 58 48 19 -1 -7-15-29-40-39-16  3  7 13 25 42 46 32 17  9  6RC-231-1
 -3-17-17 -1 23 41 50 66 84 97 99 91 84 75 51  1-38-54-54-52-62-69-52-30RC-231-2
-19-21-23-17-19-38-65-80-73-65-67-66-49-17  9 22                        RC-231-3
SPEAKER ID-LLC-F/PHONEME ID- 9/PITCH-272-NN/PITCH PERIOD-  3.67 MS/      RC-250-0
  5 30 45 53 59 66 69 54 34 27 29 29 21 20 27 36 38 35 31 23  9 -7-21-33RC-250-1
-42-53-53-43-26 -8  8 29 50 69 81 86 92 89 68 21 -2-22-15-36-53-59-50-33RC-250-2
-39-30-27-36-56-80-79-78-83-95-99-76-49-25 -4 19                        RC-250-3
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TABLE XI (Continued)

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SPEAKER ID-OLL-M/PHONEME ID-10/PITCH-140-NN/PITCH PERIOD-  7.13 MS/      RC- 10-0
 -2 14 25 26 20 12  6  4 10 24 39 46 51 59 70 77 77 71 60 42 18 -6-29-45RC- 10-1
-53-57-58-55-50-41-29-16 -5  1  3  2  0 -3 -6 -3  5 17 28 35 42 49 56 59RC- 10-2
 58 51 38 21  4 -9-19-27-31-33-36-41-42-39-34-32-32-31-29-25-17 -6  4 14RC- 10-3
 22 31 36 38 39 40 38 31 22 14  8  4  1  0 -1 -2 -3 -3 -3 -4 -6 -8-10-14RC- 10-4
-18-19-17-13 -9 -3  0  4  9 14 18 20 20 19 19 18 17 16 11  3 -9-31-60-87RC- 10-5
-99-94-85-78-67-51-35-20                                                RC- 10-6
SPEAKER ID-RLJ-M/PHONEME ID-10/PITCH-123-NN/PITCH PERIOD-  8.15 MS/     RC- 29-0
  3 10 20 37 60 83 98 99 85 64 43 26 16 11  8  3 -3 -9-15-24-33-41-48-58RC- 29-1
-66-68-65-52-31 -7 11 19 21 21 23 27 34 38 39 38 40 46 54 58 54 40 19 -2RC- 29-2
-21-31-34-35-36-38-39-38-35-31-30-34-42-46-42-28 -8 11 24 31 37 43 47 47RC- 29-3
 41 30 19 15 19 26 30 26 16  2-10-18-25-31-37-41-39-30-18 -7 -2 -3 -7-10RC- 29-4
 -8 -2  4 11 17 24 31 37 42 40 32 21 11  4  1  0 -3-13-37-71-93-95-79-58RC- 29-5
-40-31-33-37-34-21 -8 -2                                                RC- 29-6
SPEAKER ID-RDK-M/PHONEME ID-10/PITCH-136-NN/PITCH PERIOD-  7.37 MS/     RC- 48-0
  0  4  0 -1  7 26 46 62 73 79 81 74 61 45 28 15  2 -8-17-20-18-16-18-24RC- 48-1
-31-38-46-53-56-51-39-26-11  5 22 37 47 52 54 53 50 46 43 42 44 46 47 45RC- 48-2
 40 32 19  3-12-27-40-48-52-51-47-41-35-32-31-33-37-41-41-32-19 -3 13 31RC- 48-3
 47 57 61 62 58 49 37 28 23 21 21 24 27 28 24 16  9  2 -5-12-17-18-17-14RC- 48-4
-10 -4  0  2  4  7  6  5  4  4  5  3 -2 -6-12-20-38-70-91-99-90-78-73-66RC- 48-5
-49-32-21-17-12 -2  2  2                                                RC- 48-6
SPEAKER ID-DEM-M/PHONEME ID-10/PITCH-115-NN/PITCH PERIOD-  8.70 MS/     RC- 67-0
 -5  3  9 16 24 36 47 61 75 88 96 95 81 58 36 20  8 -1 -9-16-22-26-31-38RC- 67-1
-46-51-54-57-56-49-34-13  8 25 35 44 49 53 54 55 54 54 54 52 48 44 38 27RC- 67-2
 13 -5-24-40-49-53-54-53-51-46-41-36-34-33-32-27-21-10  3 17 33 45 53 56RC- 67-3
 56 50 42 33 25 18 13 10  7  4  0 -6-13-20-28-34-35-32-26-16 -5  5 13 18RC- 67-4
 18 17 14 11 13 16 22 28 32 35 33 28 19  8 -3-13-24-36-50-65-84-97-99-92RC- 67-5
-76-58-44-34-24-14 -4  4                                                RC- 67-6
SPEAKER ID-JEB-M/PHONEME ID-10/PITCH-159-NN/PITCH PERIOD-  6.30 MS/     RC- 86-0
 -4  4 13 24 38 50 59 68 72 74 72 68 63 56 49 39 28 19 12  5  1 -1 -2 -2RC- 86-1
 -2 -3 -7-11-16-21-26-32-36-39-40-40-38-35-28-19 -8  2 12 21 29 34 36 33RC- 86-2
 29 25 22 18 14 11 10 11 15 19 24 29 33 35 36 34 29 21 13  5 -1 -8-14-18RC- 86-3
-18-16-11 -4  2 11 19 25 29 31 30 29 26 24 21 18 16 14 14 14 14 15 17 19RC- 86-4
 19 17 13  6 -2-11-23-38-52-64-78-87-94-99-96-92-85-77-68-58-52-46-40-37RC- 86-5
-31-26-25-23-19-14 -7  0                                                RC- 86-6
SPEAKER ID-RVP-M/PHONEME ID-10/PITCH-149-NN/PITCH PERIOD-  6.71 MS/     RC-105-0
-23 11 28 26 18 13 10  4  4 16 41 70 83 77 65 67 79 87 74 40  0-31-46-53RC-105-1
-55-50-42-34-31-34-36-31-21-14-17-28-37-37-25 -2 24 49 66 72 72 72 71 66RC-105-2
 57 40 20  0-16-25-23-14 -6 -5-13-23-30-33-34-36-39-42-43-40-29-11  8 28RC-105-3
 39 42 39 34 31 30 28 23 15  8  5  7 11 17 20 19 14  4 -4-10-14-16-16-17RC-105-4
-16-14 -8  0  7 13 15 11  6  6 11 10  4  2  1  0  0 -1 -4 -2 -2-14-41-76RC-105-5
-99-98-80-59-53-60-58-37                                                RC-105-6
SPEAKER ID-RMC-M/PHONEME ID-10/PITCH-177-NN/PITCH PERIOD-  5.66 MS/     RC-124-0
 -4 14 28 38 47 59 73 86 96 99 94 83 70 57 45 32 21 12  7  7 10 13 12  7RC-124-1
  1 -2 -5 -8-12-21-32-46-58-67-72-73-71-66-58-46-32-16 -3  6 13 17 21 25RC-124-2
 29 31 29 22 14  7  4  6 12 19 25 29 33 35 37 36 33 29 22 15  8  0 -8-16RC-124-3
-22-25-26-23-19-15-11 -7 -3  0  4  7  9 11 14 18 23 26 26 25 25 27 30 34RC-124-4
 39 42 43 41 36 25  7-17-44-64-76-80-81-81-83-86-85-78-65-50-38-30-28-27RC-124-5
-26-26-27-32-39-43-38-25                                                RC-124-6
SPEAKER ID-MAL-F/PHONEME ID-10/PITCH-263-NN/PITCH PERIOD-  3.80 MS/     RC-175-0
-15 10 22 33 45 49 42 32 25 16  7  9 18 20 20 28 34 29 23 17  1-20-36-45RC-175-1
-56-63-63-55-44-29-10  5 14 21 30 34 30 27 25 21 19 22 26 27 30 36 40 42RC-175-2
 42 40 37 32 21  1-30-56-66-77-94-99-86-74-58-28                        RC-175-3
SPEAKER ID-PAF-F/PHONEME ID-10/PITCH-258-NN/PITCH PERIOD-  3.87 MS/     RC-194-0
 -8 10 17 22 21 21 16 14 16 21 20 22 24 25 19 10  4 -1 -5 -8 -8 -7 -4 -2RC-194-1
  1  0 -5-10 -9 -7 -8-10  0 13 21 29 36 39 38 41 43 42 43 45 41 35 30 27RC-194-2
 19 14  9  2  0 -5-23-58-83-85-89-99-92-70-51-32                        RC-194-3
SPEAKER ID-PRM-F/PHONEME ID-10/PITCH-178-NN/PITCH PERIOD-  5.62 MS/     RC-213-0
-13 11 40 55 56 51 39 25 14  9  7 -2-16-27-34-33-25 -9  6 19 23 25 26 31RC-213-1
 31 31 31 23  8 -1 -4 -2 -1 -2  0 -2 -6 -2  5 15 18 17 16 15 15 21 29 34RC-213-2
 29 24 16  3-11-35-68-95-99-85-71-54-41-29-21-13                        RC-213-3
SPEAKER ID-IAP-F/PHONEME ID-10/PITCH-353-NN/PITCH PERIOD-  2.83 MS/     RC-232-0
 -7  4 15 22 24 22 18 16 17 19 22 24 25 25 24 22 16  6 -6-22-38-50-58-61RC-232-1
-59-54-45-34-21 -6  6 19 28 34 38 41 42 43 46 50 56 61 63 63 62 60 57 50RC-232-2
 41 29 18  0-25-54-80-95-99-98-93-88-77-60-41-22                        RC-232-3
SPEAKER ID-LLC-F/PHONEME ID-10/PITCH-260-NN/PITCH PERIOD-  3.85 MS/     RC-251-0
  0 26 42 46 57 81 99 90 62 28 -1-26-46-61-74-80-70-47-27-20-21-20-13 -1RC-251-1
  6  7 13 31 52 64 60 47 34 21  9 -1-11-16-12  4 24 36 38 41 46 49 43 35RC-251-2
 17-26-69-87-78-78-90-89-58-26-13-10 -7 -7-10  0                        RC-251-3
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TABLE XI (Continued)

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SPEAKER ID-OLL-M/PHONEME ID-11/PITCH-150-NN/PITCH PERIOD-  6.68 MS/      RC- 11-0
 -3 16 40 55 56 47 30  4-18-26-17 -2 10 23 38 47 51 55 57 53 39 19 -2-29RC- 11-1
-54-69-69-59-45-31-17 -4  5 13 19 23 25 24 17  6 -3 -7  0 11 26 37 44 44RC- 11-2
 39 33 25 16  5 -6-20-35-45-49-46-38-24-11 -2 -2 -5 -5 -3 -3 -3  0  3  4RC- 11-3
  4  8 17 26 34 38 36 26 12  1 -5-10-13-13-12-12-11 -5  2  9 13 14 13  6RC- 11-4
 -2 -9-10-10 -8 -6 -3  0  4  9 14 19 21 23 23 20 16 13 13 11  6 -8-34-67RC- 11-5
-90-99-95-88-75-54-32-19                                                RC- 11-6
SPEAKER ID-RLJ-M/PHONEME ID-11/PITCH-111-NN/PITCH PERIOD-  9.01 MS/      RC- 30-0
  1  6  9 22 40 49 39 13 -7 -7 13 41 64 69 52 19-10-26-34-44-57-63-50-16RC- 30-1
 18 32 19 -2-13 -7  7 19 26 32 41 50 56 50 29 -3-32-49-47-32-16-12-14-15RC- 30-2
-11 -6 -9-19-25-19  1 29 50 56 48 34 21 11  2 -9-22-28-22 -8  2 -1-15-30RC- 30-3
-36-32-24-16-10 -6  2 20 35 31 17 11 15 18 16 12  7  3  2  2 -3-16-24-23RC- 30-4
-16 -9 -5 -2  2  9 14 13 10  7  7 10 14 15 12 10  9  7  2 -3-11-14-14-11RC- 30-5
 -9 -9-23-59-96-99-59-16                                                RC- 30-6
SPEAKER ID-RDK-M/PHONEME ID-11/PITCH-129-NN/PITCH PERIOD-  7.74 MS/      RC- 49-0
-11 18 42 55 59 60 54 38 13 -3 -8 -4  0  5 14 20 16  1-12-23-32-43-51-51RC- 49-1
-38-19  1 23 43 57 59 50 38 28 18  7 -1 -6 -5 -2 -1  0  3  1 -7-21-32-35RC- 49-2
-34-29-18 -1 15 29 38 46 50 47 35 20  7 -2-11-16-14-10 -9-13-22-28-31-33RC- 49-3
-33-30-21 -9  2 18 38 51 56 51 39 22  5 -9-19-24-26-25-21-13 -3  4 10 13RC- 49-4
 11  8  5  7 10 12 14 14 12  7  3  1  0  0 -1 -1  0  0  2  3  4  0-10-24RC- 49-5
-44-67-88-99-89-72-49-24                                                RC- 49-6
SPEAKER ID-DEM-M/PHONEME ID-11/PITCH-122-NN/PITCH PERIOD-  8.20 MS/      RC- 68-0
 -3 19 41 57 66 67 58 42 25 11  3  3  9 15 21 25 22 16  7 -5-22-38-51-58RC- 68-1
-57-47-31-12  6 22 35 44 49 47 42 33 23 15 10  9 10 11 11 10  8  3 -2-10RC- 68-2
-20-29-34-36-32-24-13 -2  8 17 23 26 26 22 16  9  3 -1 -3 -3 -2 -1  0  0RC- 68-3
  0  0 -1 -3 -3 -4 -5 -5 -3  0  1  2  2  2  1  0  0  0  0  0  0  1  2  4RC- 68-4
  4  5  5  4  3  6  8  9  9  7  3  1  0 -2 -1  0  1  0  0 -2-11-25-41-63RC- 68-5
-87-99-97-86-65-36 -6 18                                                RC- 68-6
SPEAKER ID-JEB-M/PHONEME ID-11/PITCH-159-NN/PITCH PERIOD-  6.29 MS/      RC- 87-0
  2 18 25 28 36 41 40 28 16 11 15 18 17 12 12 20 27 28 23 21 20 17  8 -5RC- 87-1
-25-40-46-45-43-46-48-43-27-10  1  7 16 28 41 46 42 36 31 27 25 22 20 17RC- 87-2
 17 17 20 20 21 21 20 15  3 -7-18-26-32-40-45-43-38-31-23-15 -5  6 17 26RC- 87-3
 31 32 32 30 27 23 21 20 20 21 22 21 21 23 27 30 27 23 18 17 15 10  3  0RC- 87-4
  0  0  2  1  0 -3 -5 -3 -1  0  0  0 -2 -8-17-26-37-53-73-90-99-97-90-80RC- 87-5
-72-65-52-35-20 -3  8 22                                                RC- 87-6
SPEAKER ID-RVP-M/PHONEME ID-11/PITCH-146-NN/PITCH PERIOD-  6.83 MS/      RC-106-0
  0 31 55 57 41 24 10  4 -2 -5  1 18 31 34 26 19 21 24 17 -4-33-54-63-59RC-106-1
-46-30-14  0 14 24 32 36 38 35 24 10 -1 -4  1 13 24 32 31 27 22 15  6 -7RC-106-2
-22-35-44-49-46-34-16  2 15 20 20 20 19 13  0-10-16-13 -7  0  9 21 30 30RC-106-3
 22 12  3 -5-13-21-25-24-17 -5  5 14 20 22 20 14  7  3  2  3  3  4  7 12RC-106-4
 16 17 15 11  6  1 -3 -6 -6 -4 -3 -4 -3 -1  1  4  3  0 -5-14-28-53-84-99RC-106-5
-90-61-33-24-24-11 13 44                                                RC-106-6
SPEAKER ID-RMC-M/PHONEME ID-11/PITCH-162-NN/PITCH PERIOD-  6.16 MS/      RC-125-0
 -5  5 13 17 17 10  3  5 18 32 39 37 40 49 66 77 73 59 41 23  4-12-31-41RC-125-1
-40-34-32-35-39-33-20-10-10-19-27-29-27-21-13 -1 16 36 50 58 61 65 70 70RC-125-2
 61 43 24 10  2  0 -2 -3 -3 -3 -5-12-20-27-34-42-56-80-99-92-69-46-24  0RC-125-3
 20 35 47 51 55 57 54 44 31 17  9 12 24 35 37 29 20 14  6 -3-12-14-13-10RC-125-5
-10 -6  0 18 36 43 40 32 19  6 -2 -5 -8 -3  1  3 -2-19-42-62-71-72-73-77RC-125-5
-82-85-78-59-34-18 -5  0                                                RC-125-6
SPEAKER ID-MAL-F/PHONEME ID-11/PITCH-248-NN/PITCH PERIOD-  4.04 MS/      RC-176-0
 -6 26 49 61 62 54 36 10-14-31-37-34-26-19-14-10 -7 -2  2  8 13 19 23 24RC-176-1
 19  8 -3-15-23-28-29-23-10  5 20 30 32 28 21 13  4 -5-13-18-18-14 -7  0RC-176-2
  8 17 25 31 33 32 27 20 11 -8-43-81-99-89-58-18                        RC-176-3
SPEAKER ID-PAF-F/PHONEME ID-11/PITCH-252-NN/PITCH PERIOD-  3.97 MS/      RC-195-0
-10 23 52 69 73 69 59 44 23  4-10-19-23-26-28-31-31-27-22-16 -9  0  9 21RC-195-1
 34 41 43 41 35 27 17  5 -6-15-19-19-17-14 -8  0 12 24 35 45 54 60 60 53RC-195-2
 41 28 13  0-10-19-25-34-52-74-92-99-96-90-77-52                        RC-195-3
SPEAKER ID-PRM-F/PHONEME ID-11/PITCH-169-NN/PITCH PERIOD-  5.91 MS/      RC-214-0
-13 23 42 33 24 19 15 11  3 -7-22-34-26 -6 12 29 35 33 26 18 16 13  4 -4RC-214-1
-11-13-11 -4  4  9  8  8 10 10  9  7  4  0 -3  0  4  6  6  6  5  5  8 12RC-214-2
 16 17 17 17 16 12  7  2-14-46-82-99-97-69-26 15                        RC-214-3
SPEAKER ID-IAP-F/PHONEME ID-11/PITCH-302-NN/PITCH PERIOD-  3.31 MS/      RC-233-0
-13 21 43 59 78 79 53 18 -1 -7-15-24-22-11 -5 -6 -3  0 -8-28-48-55-50-42RC-233-1
-28 -8 12 26 37 46 48 40 24 10  0 -7 -9 -4  5 10  8  8 12 13  9  6  9 16RC-233-2
 22 27 35 42 42 33 23  0-42-84-99-92-84-74-49-11                        RC-233-3
SPEAKER ID-LLC-F/PHONEME ID-11/PITCH-233-NN/PITCH PERIOD-  4.29 MS/      RC-252-0
-11 30 45 58 68 60 44 31 10-10 -3 16 13 -3 -3  1-17-46-60-62-53-31 -5 15RC-252-1
 39 68 78 58 28 11 -4-28-44-41-27-11  3 10  9 10 12  3 -8 -7  6 15 17 22RC-252-2
 33 39 38 34 28 22 20 12-18-69-99-92-86-97-86-32                        RC-252-3
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TABLE XI (Continued)

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SPEAKER ID-OLL-M/PHONEME ID-12/PITCH-133-NN/PITCH PERIOD-  7.51 MS/     RC- 12-0
 -9 22 35 31  8-24-50-63-60-42 -7 32 67 87 93 85 69 47 26  9 -1 -3  1 11RC- 12-1
 18 22 22 21 17 11  0-18-37-54-62-62-52-35-14  8 27 36 34 21  3-13-20-15RC- 12-2
 -2 15 33 47 54 54 47 35 18  2-10-19-22-23-21-18-15-12-11-14-20-27-32-34RC- 12-3
-29-21 -9  3 15 26 31 31 26 19 11  7  6  8 11 14 17 18 17 14  9  2 -3 -8RC- 12-4
-11-12-12-11 -9 -7 -3  0  0  0  0 -2 -3 -3 -1  0  4  9 14 18 20 21 19 16RC- 12-5
  8 -9-35-67-89-99-91-70                                                RC- 12-6
SPEAKER ID-RLJ-M/PHONEME ID-12/PITCH-110-NN/PITCH PERIOD-  9.13 MS/     RC- 31-0
-13 24 41 34  4-35-61-57-21 30 75 99 94 66 29  2 -7 -3  7 20 28 26 13 -2RC- 31-1
-15-26-40-53-57-50-34-11 13 32 33 16 -7-22-19  0 31 59 73 67 43 15 -8-21RC- 31-2
-20 -9  2  6  0-11-22-31-38-40-37-31-23-13  0 15 24 24 16  7  0  0  6 15RC- 31-3
 21 24 20  9 -2-10-12-10 -7 -4 -3 -3 -4 -3 -2 -2 -4 -7 -7 -5 -1  4 10 13RC- 31-4
 11  6  2  0  1  5 10 13 11  5  0 -4 -6 -6 -5 -4 -5 -8 -9 -8 -5 -1  2  3RC- 31-5
  2  1  0-10-35-69-87-72                                                RC- 31-6
SPEAKER ID-RDK-M/PHONEME ID-12/PITCH-127-NN/PITCH PERIOD-  7.86 MS/     RC- 50-0
 -2 26 40 40 33 25 15  7  8 23 45 61 72 76 74 60 37 10 -9-24-38-47-50-45RC- 50-1
-39-34-29-21-13-11-13-13-11 -6 -1  9 28 49 65 74 76 72 60 39 19  5 -2 -7RC- 50-2
 -8 -6 -4 -6-13-23-32-41-48-50-45-35-24-11  2 16 27 34 36 35 30 20  9  1RC- 50-3
 -2 -1  1  8 15 18 15  5 -7-20-31-36-34-24-11  2 12 18 18 15  9  4  3  5RC- 50-4
  9 15 20 24 25 23 18 14  8  4  2  0  1  2  3  3  1 -2 -7-15-19-30-38-50RC- 50-5
-63-78-93-99-95-80-59-33                                                RC- 50-6
SPEAKER ID-DEM-M/PHONEME ID-12/PITCH-125-NN/PITCH PERIOD-  8.03 MS/     RC- 69-0
  0 17 23 20  9 -3-13-15 -6 10 32 57 77 89 90 80 62 38 15 -5-21-31-35-34RC- 69-1
-31-27-24-22-22-22-22-23-23-21-19-14 -6  3 15 28 42 52 58 60 56 48 36 24RC- 69-2
 13  4 -1 -3 -4 -4 -5 -8-14-21-28-35-39-40-39-34-27-20-12 -6  0  6 10 13RC- 69-3
 16 18 18 19 20 20 20 20 20 19 18 15 10  5  0 -4 -8-10-10-10 -8 -7 -5 -5RC- 69-4
 -4 -4 -3 -1  1  6 11 15 18 19 18 15 12 10  9 10 12 15 16 13  6 -4-21-43RC- 69-5
-66-84-96-99-88-68-43-18                                                RC- 69-6
SPEAKER ID-JEB-M/PHONEME ID-12/PITCH-123-NN/PITCH PERIOD-  8.12 MS/     RC- 88-0
 -5 17 38 52 59 56 46 33 24 20 19 19 18 15 10  5  0 -4 -7 -9-11-15-20-24RC- 88-1
-24-20-10  3 17 28 33 32 27 20 16 16 22 32 41 47 45 37 24  9 -4-13-16-15RC- 88-2
-11 -8 -7 -9-12-14-16-15-13 -8 -2  2  6 10 14 17 19 20 19 16 14 11  8  7RC- 88-3
  7  8  7  4  0 -6-11-14-15-12 -7 -2  1  3  3  1 -1 -1  0  4 10 16 20 20RC- 88-4
 18 14 10  7  7  8  9 10  9  5  0 -7-13-17-18-20-24-36-54-76-92-99-92-76RC- 88-5
-54-31-14 -7-10-21-30-31                                                RC- 88-6
SPEAKER ID-RVP-M/PHONEME ID-12/PITCH-150-NN/PITCH PERIOD-  6.68 MS/     RC-107-0
 -1 15 28 27 10-12-33-37-27-11  7 27 50 75 93 94 77 51 27 12  5 -1 -8-12RC-107-1
 -8  1 10 11  4 -5-13-19-28-40-55-64-63-50-31-12  4 21 35 42 41 31 16  3RC-107-2
 -1  2 12 25 37 47 54 56 48 30  7-13-27-33-32-29-23-16 -8 -4 -5-12-20-26RC-107-3
-27-24-19-14 -7  1 12 21 26 25 22 18 15 11  8  5  5  9 15 20 22 19 14  7RC-107-4
  2 -2 -7 -9 -8 -4  0  5  7  7  5  2  0 -2 -7-10-10 -8 -2  2  5  6  2-11RC-107-5
-38-68-92-99-85-64-44-22                                                RC-107-6
SPEAKER ID-RMC-M/PHONEME ID-12/PITCH-160-NN/PITCH PERIOD-  6.24 MS/     RC-126-0
-10  8 20 22 15  1-14-28-35-33-22 -2 21 48 71 87 93 89 74 53 29  7 -8-17RC-126-1
-17-11  0 10 20 26 25 17  3-13-32-48-61-68-68-63-52-37-19 -2 11 21 27 27RC-126-2
 24 17  9  2 -1 -1  4 14 29 44 57 66 69 64 53 36 15 -5-22-34-39-38-32-23RC-126-3
-16-13-14-18-29-39-48-54-55-48-37-21 -3 12 25 34 38 37 33 28 23 20 19 21RC-126-4
 25 29 32 35 34 32 28 23 18 14 11  9  9 10 11 13 12  9  4 -3-18-35-55-74RC-126-5
-89-98-99-89-72-49-24 -1                                                RC-126-6
SPEAKER ID-MAL-F/PHONEME ID-12/PITCH-244-NN/PITCH PERIOD-  4.09 MS/     RC-177-0
  0 33 46 65 84 73 51 44 41 40 53 72 76 56 24 -8-38-56-53-43-36-36-43-48RC-177-1
-51-59-67-70-53-16 18 49 66 53 37 34 34 45 64 73 79 78 66 53 37 23 20 15RC-177-2
  6-17-67-98-98-99-88-55-44-59-69-66-57-48-22 17                        RC-177-3
SPEAKER ID-PAF-F/PHONEME ID-12/PITCH-245-NN/PITCH PERIOD-  4.08 MS/     RC-196-0
 -2 -1  0  9 22 34 41 43 43 40 34 28 21  9 -5-16-19-18-13 -8 -5 -8-15-18RC-196-1
-13 -2  9 21 29 30 24 21 21 21 20 18 14  9  5  6 10 15 19 22 25 27 29 32RC-196-2
 29 21  9  0-11-25-44-66-85-98-99-85-61-37-19 -8                        RC-196-3
SPEAKER ID-PRM-F/PHONEME ID-12/PITCH-183-NN/PITCH PERIOD-  5.45 MS/     RC-215-0
-13 41 81 83 42-11-40-35 -5 21 18 -9-42-58-45-11 23 40 37 23 10  7 15 26RC-215-1
 31 24  7-12-24-26-15 -1  6  6  0 -5 -2  9 22 31 30 19  7  2  6 14 21 19RC-215-2
 14  8  7  6 -3-33-75-99-95-58 -2 26 16-15-45-36                        RC-215-3
SPEAKER ID-IAP-F/PHONEME ID-12/PITCH-340-NN/PITCH PERIOD-  2.94 MS/     RC-234-0
  2 19 29 33 41 48 50 48 39 33 27 19  8 -7-20-27-31-30-30-25-14 -5  4  7RC-234-1
  5  5  4  7 11 14 22 31 43 52 55 57 57 58 57 54 52 49 43 26 -1-35-62-83RC-234-2
-97-99-99-86-60-37-22-21-25-27-32-36-41-40-23 -2                        RC-234-3
SPEAKER ID-LLC-F/PHONEME ID-12/PITCH-244-NN/PITCH PERIOD-  4.10 MS/     RC-253-0
-11 31 72 98 99 77 46 16 -4-11 -6  5 12  9  0-15-31-46-55-57-52-44-30-13RC-253-1
  3 18 27 27 23 18 16 19 26 35 40 37 27 13  1 -4 -2  6 19 31 36 36 31 24RC-253-2
  9-14-45-70-86-88-73-43-13  3  2-15-37-51-47-21                        RC-253-3
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TABLE XI (Continued)

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SPEAKER ID-OLL-M/PHONEME ID-13/PITCH-138-NN/PITCH PERIOD-  7.25 MS/      RC- 13-0
  5 24 45 67 82 81 70 61 63 67 67 66 64 58 53 58 67 72 68 62 59 55 49 37RC- 13-1
 21  0-22-39-48-53-63-76-86-86-76-59-39-25-17-10  0 19 39 51 52 46 39 35RC- 13-2
 35 38 37 30 18  8  5  8 11  9  0-10-18-22-22-23-26-33-40-42-37-29-21-14RC- 13-3
 -9 -3  4 14 24 30 31 29 28 27 28 28 26 24 22 21 23 25 25 22 16 10  6  3RC- 13-4
  0 -6-13-21-25-26-23-20-17-16-13 -8  0  6  7 -2-25-50-66-71-76-85-92-97RC- 13-5
-99-94-76-51-31-18 -9  2                                                RC- 13-6
SPEAKER ID-RLJ-M/PHONEME ID-13/PITCH-125-NN/PITCH PERIOD-  8.03 MS/     RC- 32-0
 -6 11 31 46 51 48 47 55 67 72 65 56 55 63 70 64 47 27 15  8 -2-22-48-69RC- 32-1
-78-77-75-77-77-70-51-29-11  0 11 25 40 50 53 50 47 47 49 49 45 39 34 33RC- 32-2
 32 29 22 12  1 -8-18-29-40-52-61-67-69-67-63-56-48-35-17  0 16 28 40 50RC- 32-3
 58 61 60 55 48 41 34 27 19 11  3 -2 -6-10-15-20-25-27-29-30-31-31-29-25RC- 32-4
-19-13 -6  1  9 17 24 30 34 37 39 39 37 33 28 22 15  3-11-33-60-76-81-83RC- 32-5
-90-99-96-82-58-37-25-15                                                RC- 32-6
SPEAKER ID-RDK-M/PHONEME ID-13/PITCH-127-NN/PITCH PERIOD-  7.87 MS/     RC- 51-0
 -1 19 31 47 70 84 78 68 68 70 58 38 25 21 14  0 -8 -5 -3-11-20-18-12-15RC- 51-1
-25-32-32-32-37-40-36-29-22-16 -4 13 29 39 46 57 67 70 66 58 52 43 28 12RC- 51-2
  1 -7-18-30-36-34-31-32-33-27-19-15-14-11 -6 -6-11-13 -9 -7 -9-10 -3  5RC- 51-3
  9 13 21 28 30 28 28 30 25 16 10  7  3 -2 -5 -4 -3 -4 -2  1  5  6  6  8RC- 51-4
 10 10  9  9  8  7  6  7  8 10  7  8  8  9  5  0 -4-11-25-46-63-69-74-87RC- 51-5
-99-96-80-67-56-39-11  2                                                RC- 51-6
SPEAKER ID-DEM-M/PHONEME ID-13/PITCH-129-NN/PITCH PERIOD-  7.76 MS/     RC- 70-0
 -2 21 42 56 67 78 86 89 92 88 76 68 56 38 25 11 -3-16-25-34-44-49-46-44RC- 70-1
-44-41-37-33-26-19-14 -8 -2  2  7 13 18 22 28 34 38 41 44 45 46 48 47 41RC- 70-2
 34 28 20 12  2 -8-19-31-41-48-53-58-58-56-53-48-38-25-13  0 10 18 27 36RC- 70-3
 42 45 44 41 36 30 24 18 12  6  0 -4 -5 -7 -6 -6 -6 -5 -4 -3 -1  0  0  1RC- 70-4
  2  1  2  4  7  9  8  9 12 12 11 15 19 16 16 16  9 -2-19-39-48-55-74-85RC- 70-5
-87-99-99-84-71-64-51-34                                                RC- 70-6
SPEAKER ID-JEB-M/PHONEME ID-13/PITCH-158-NN/PITCH PERIOD-  6.34 MS/     RC- 89-0
-11  7 19 24 26 29 37 43 43 36 29 27 31 35 36 34 35 39 43 41 33 24 19 15RC- 89-1
  8 -4-22-37-45-48-51-56-59-56-47-38-33-27-18 -4  8 15 17 17 21 27 31 33RC- 89-2
 32 33 35 39 40 40 40 41 43 42 35 24 14  8  3 -4-14-24-29-32-36-40-40-36RC- 89-3
-30-26-25-22-17-11 -4  0  6 11 17 22 26 30 34 40 45 48 48 46 45 45 44 41RC- 89-4
 36 32 29 24 18 11  7  4  1 -1 -5 -8-12-16-21-27-41-60-77-85-85-86-92-99RC- 89-5
-96-84-70-57-46-32-13  7                                                RC- 89-6
SPEAKER ID-RVP-M/PHONEME ID-13/PITCH-150-NN/PITCH PERIOD-  6.66 MS/     RC-108-0
-10  0  4 19 42 57 54 50 53 55 48 24  3  7 26 38 30  9  1 15 32 34 16 -6RC-108-1
-20-26-37-50-60-62-57-55-56-47-24  4 25 30 32 41 55 65 63 50 39 32 24 16RC-108-2
  9  8 12 11  3 -2 -1  5  8 -3-25-44-50-48-49-56-59-52-38-24-10  9 32 47RC-108-3
 50 47 47 52 54 45 26  7  0  2  4  2 -2 -2  2  7  8 10 12 13  8 -1 -8 -7RC-108-4
 -2 -2 -5 -9 -8 -1  6 10  9  7  7  8  9  9  7  3  0 -3-14-41-73-86-74-62RC-108-5
-67-86-99-79-38 -8  3  3                                                RC-108-6
SPEAKER ID-RMC-M/PHONEME ID-13/PITCH-183-NN/PITCH PERIOD-  5.47 MS/     RC-127-0
 15 27 37 46 51 53 53 51 47 43 39 35 31 27 23 20 16 15 16 19 23 27 30 33RC-127-1
 34 35 35 33 31 28 22 15  6 -4-16-27-37-46-54-59-62-64-63-62-58-51-42-31RC-127-2
-18 -6  4 13 21 28 33 38 41 41 40 38 31 24 17 12  7  4  3  3  2  3  4  7RC-127-3
 11 15 21 26 30 32 32 31 28 24 20 17 12  8  3 -1 -5 -8-10-10 -9 -6 -3  0RC-127-4
  4  8 13 18 23 27 29 27 19 10  0-12-26-38-50-61-72-84-93-99-99-96-88-77RC-127-5
-66-54-40-26-10  4 17 30                                                RC-127-6
SPEAKER ID-MAL-F/PHONEME ID-13/PITCH-305-NN/PITCH PERIOD-  3.28 MS/     RC-178-0
-15 14 43 58 64 71 75 71 62 54 38 18  4  0 -1 -7-17-30-47-60-63-61-60-61RC-178-1
-54-38-20 -5  7 18 26 31 38 48 56 58 56 56 57 56 50 43 35 29 28 28 25 14RC-178-2
 -3-41-81-99-91-84-82-76-63-46-34-25-17-16-21-20                        RC-178-3
SPEAKER ID-PAF-F/PHONEME ID-13/PITCH-253-NN/PITCH PERIOD-  3.96 MS/     RC-197-0
-14 10 31 48 62 66 62 54 43 30 13 -2-13-20-24-25-21-14 -5  3 11 15 18 19RC-197-1
 18 13  6  1 -2 -6 -8 -6 -2  2 10 18 25 32 39 43 45 46 46 44 42 38 32 26RC-197-2
 22 17  9 -5-21-35-50-69-85-94-97-99-94-81-61-38                        RC-197-3
SPEAKER ID-PRM-F/PHONEME ID-13/PITCH-184-NN/PITCH PERIOD-  5.44 MS/     RC-216-0
  4 33 58 74 72 63 53 36 14 -1-15-23-26-29-32-25-20-17-11  0  9 20 27 31RC-216-1
 34 33 23 12  5 -5-14-18-19-16-10 -6 -1  5  9 10 12 14 15 15 15 13 14 15RC-216-2
 14 14 19 22 19  5-20-46-66-87-99-90-71-45-13 18                        RC-216-3
SPEAKER ID-IAP-F/PHONEME ID-13/PITCH-362-NN/PITCH PERIOD-  2.76 MS/     RC-235-0
 -6 15 27 41 58 75 83 78 67 55 45 35 23  4-19-41-51-53-55-59-61-53-41-27RC-235-1
-16 -7  4 20 34 42 44 45 50 58 62 59 50 42 40 41 39 34 27 21 21 22 21  9RC-235-2
-13-32-41-44-52-73-92-99-93-83-77-74-64-41-13 11                        RC-235-3
SPEAKER ID-LLC-F/PHONEME ID-13/PITCH-245-NN/PITCH PERIOD-  4.08 MS/     RC-254-0
-17 29 58 63 72 90 96 85 72 58 39 21  7-10-28-35-33-34-43-44-33-25-30-35RC-254-1
-29-19-18-25-22 -5  6  7 12 29 44 46 44 46 48 46 38 27 22 22 20 11  6 14RC-254-2
 21 17  0-10 -8-15-46-72-71-65-82-99-83-51-39-36                        RC-254-3
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TABLE XI (Continued)

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SPEAKER ID-OLL-M/PHONEME ID-14/PITCH-141-NN/PITCH PERIOD-  7.07 MS/      RC- 14-0
  0 14 28 35 33 24 17 19 29 40 50 58 63 60 52 45 42 44 49 54 56 54 48 41RC- 14-1
 38 41 47 52 52 45 34 22 13  8  5  5  5  2 -6-14-18-21-19-13-11-12-17-26RC- 14-2
-32-36-38-36-29-22-19-19-21-23-23-21-15 -8 -2  0  1  0  0  1  4  9 13 16RC- 14-3
 18 18 18 19 22 25 26 25 23 20 18 16 17 19 20 20 21 20 19 19 19 18 19 16RC- 14-4
  3-26-72-99-93-70-37 -5 11  8-13-47-75-91-94-90-76-59-55-61-65-60-50-36RC- 14-5
-19 -8 -9-16-21-22-18-10                                                RC- 14-6
SPEAKER ID-RLJ-M/PHONEME ID-14/PITCH-130-NN/PITCH PERIOD-  7.72 MS/     RC- 33-0
-11 36 50 46 27  7-13-27-38-54-69-77-70-56-40-28-13  6 25 39 38 19 -9-38RC- 33-1
-51-46-26  0 18 29 27 21 17 21 29 32 26 16 10  8  8  8 10 15 23 30 34 32RC- 33-2
 22 10  2  0  3  8 11 13 15 16 19 21 21 15  9  4  1 -2 -7 -9-10 -8 -5  0RC- 33-3
  4  5  1 -8-22-27-14  2  0-12-10 -1 -1-12-19-15-17-22-19 -4  5  4  0  1RC- 33-4
  6  6  6  2 -2 -6 -5 -1  0  1  5 12 16 14 13 15 16 12  9 10 12 12 10 11RC- 33-5
 10  5 -9-44-83-99-70-13                                                RC- 33-6
SPEAKER ID-RDK-M/PHONEME ID-14/PITCH-134-NN/PITCH PERIOD-  7.45 MS/     RC- 52-0
  0  0  1  7 13 12  1 -4  4 23 36 35 27 22 19 18 19 26 33 35 30 24 25 32RC- 52-1
 37 35 28 24 26 30 33 33 34 36 38 37 36 34 32 27 21 17 19 24 27 22 13 10RC- 52-2
 12 14 11  6  3  0 -2  0  3  6  6  4  0 -4 -4  0  1  0 -1  0  4  7  7  6RC- 52-3
  5  3  3  4  6  8 10  9  7  6  8  9  8  6  5  7 12 16 17 14 10  6  2 -2RC- 52-4
 -7-14-36-69-82-61-26 -7-16-30-49-79-99-97-74-54-54-65-69-66-50-38-38-45RC- 52-5
-47-41-36-33-26-12 -2  0                                                RC- 52-6
SPEAKER ID-DEM-M/PHONEME ID-14/PITCH-150-NN/PITCH PERIOD-  6.66 MS/     RC- 71-0
 -8  4 16 18 15 12 11 11  9  9 17 27 37 48 60 66 65 56 46 36 29 26 26 28RC- 71-1
 31 34 38 40 39 40 43 45 42 41 39 30 16  5  1  0  0  3 10 16 21 26 28 24RC- 71-2
 16  6 -4-14-19-19-17-14 -9 -4  0  2  1  0 -2 -7-11-15-19-24-28-30-28-23RC- 71-3
-17-11 -4 -1  0  0 -1 -3 -7-10-11 -9 -3  5 14 26 38 49 55 57 57 59 55 46RC- 71-4
 40 38 32 23 19 16  7 -7-28-58-86-98-99-93-76-52-41-45-54-63-72-82-88-88RC- 71-5
-83-79-72-65-56-46-40-33                                                RC- 71-6
SPEAKER ID-JEB-M/PHONEME ID-14/PITCH-163-NN/PITCH PERIOD-  6.12 MS/     RC- 90-0
  1  9 17 24 30 35 38 39 39 38 36 35 35 35 35 35 33 32 32 33 35 36 37 38RC- 90-1
 38 39 39 40 40 39 35 31 28 27 25 23 22 21 22 25 29 33 36 39 42 45 46 45RC- 90-2
 43 40 37 34 32 30 30 30 32 33 35 38 40 43 43 42 40 38 36 33 31 29 27 24RC- 90-3
 20 18 16 15 13 10  6  2 -1 -4 -8-14-25-40-52-62-68-70-71-71-71-67-64-62RC- 90-4
-65-70-76-80-83-86-91-96-99-98-95-90-84-77-70-64-58-53-47-40-34-33-34-36RC- 90-5
-36-35-31-28-25-21-15 -7                                                RC- 90-6
SPEAKER ID-RVP-M/PHONEME ID-14/PITCH-142-NN/PITCH PERIOD-  7.03 MS/     RC-109-0
  1 25 39 30  1-27-40-35-19  0 18 39 53 57 54 45 37 29 17  3 -3 -1  6 15RC-109-1
 21 26 32 37 38 32 23 14  7 -2-14-20-15  0 16 22 18 12  8  6  3 -5-16-21RC-109-2
-16 -4  5  8  8  6  3  0 -1 -1  1  4  7  9 10 11 13 14 15 14 11  6  2  2RC-109-3
  6 12 16 17 15 12 10  8  5  2  0  0  0  0  1  1  2  3  3  2  1  1  1  0RC-109-4
  0 -1 -1  0  2  4  4  4  4  2 -3-21-57-90-99-70-18 23 30  7-32-60-70-71RC-109-5
-69-63-52-36-25-23-23-10                                                RC-109-6
SPEAKER ID-RMC-M/PHONEME ID-14/PITCH-201-NN/PITCH PERIOD-  4.97 MS/     RC-128-0
-10  0  6 10  9  4  0 -1  4 15 29 42 51 52 47 42 39 41 46 53 59 61 57 48RC-128-1
 40 35 37 42 48 51 51 47 37 25 15  9  9 13 18 21 21 18 16 15 14 15 18 19RC-128-2
 17 11  3 -3 -5 -2  2  9 15 20 21 18 14 11 11 14 17 21 23 23 22 21 22 24RC-128-3
 27 33 39 44 44 42 39 37 34 31 24 11 -6-22-32-35-31-22-12 -3 -2-14-34-55RC-128-4
-66-64-59-55-54-57-67-79-91-99-98-88-75-63-57-56-58-61-64-65-65-62-56-51RC-128-5
-45-40-36-33-27-18 -7  1                                                RC-128-6
SPEAKER ID-MAL-F/PHONEME ID-14/PITCH-317-NN/PITCH PERIOD-  3.15 MS/     RC-179-0
-23 -6 14 34 50 61 67 63 49 32 27 38 60 77 79 72 64 63 69 74 72 64 49 24RC-179-1
-17-52-62-23 33 74 71 34 -8-35-40-42-42-50-57-66-68-58-39-19-21-47-82-99RC-179-2
-89-64-46-41-39-33-21-12-10-13-19-25-31-33-28-11                        RC-179-3
SPEAKER ID-PAF-F/PHONEME ID-14/PITCH-270-NN/PITCH PERIOD-  3.71 MS/     RC-198-0
-18-10  1  8 10 13 19 27 36 47 52 51 48 47 51 58 64 64 62 64 69 71 72 75RC-198-1
 76 72 71 72 73 69 61 47 22 -1-11 -9 -4 -3 -9-28-54-73-74-67-68-77-89-97RC-198-2
-99-93-85-81-86-91-91-85-73-57-46-38-31-22-16-14                        RC-198-3
SPEAKER ID-PRM-F/PHONEME ID-14/PITCH-193-NN/PITCH PERIOD-  5.18 MS/     RC-217-0
-10 15 39 43 30 26 25 21 32 48 46 38 37 45 56 59 42 30 33 42 45 45 44 35RC-217-1
 31 33 34 33 28 23 27 37 41 36 11-32-47  7 50 35 -6-74-99-53-37-53-54-73RC-217-2
-93-86-80-80-80-79-68-49-40-41-43-17 12  7-12-20                        RC-217-3
SPEAKER ID-IAP-F/PHONEME ID-14/PITCH-296-NN/PITCH PERIOD-  3.38 MS/     RC-236-0
 -4 -8 -7  2 15 28 35 44 58 72 78 76 75 79 90 99 93 64 39 35 49 62 74 87RC-236-1
 66 28 -5-17-16 -4 16 17 -1-28-34-30-36-50-62-61-57-52-40-40-48-63-67-66RC-236-2
-69-63-48-34-35-44-48-53-54-53-46-35-24-13 -6 -6                        RC-236-3
SPEAKER ID-LLC-F/PHONEME ID-14/PITCH-277-NN/PITCH PERIOD-  3.61 MS/     RC-255-0
 12  4 -1 -6-14-18 -8 11 17  7  0 15 43 54 45 32 29 38 52 69 86 96 81 31RC-255-1
-27-50 -8 60 92 58  2-20-18-26-50-54-31-29-71-99-55 30 62  8-61-75-44-28RC-255-2
-36-35-10  7  1 -9  2 25 21-11-47-57-39-12  8 14                        RC-255-3
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TABLE XI (Continued)

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SPEAKER ID-OLL-M/PHONEME ID-15/PITCH-142-NN/PITCH PERIOD-  7.03 MS/      RC- 15-0
 -4 22 46 60 59 44 28 18 19 26 32 33 28 23 26 40 61 76 81 75 61 44 33 28RC- 15-1
 27 28 29 34 38 41 39 33 25 18 14 14 12  7 -1-12-20-23-19-13-12-15-22-28RC- 15-2
-29-26-21-18-19-23-29-32-32-29-24-17-10 -4  0  2  1  0  0  0  2  6  9 11RC- 15-3
 13 16 22 28 33 35 32 27 22 19 19 20 22 23 24 24 24 24 23 23 22 22 20 11RC- 15-4
-11-49-82-95-82-47 -6 19 16-14-55-85-99-96-88-81-80-81-70-45-19 -4 -3-12RC- 15-5
-24-36-40-40-36-29-15  7                                                RC- 15-6
SPEAKER ID-RLJ-M/PHONEME ID-15/PITCH-131-NN/PITCH PERIOD-  7.66 MS/      RC- 34-0
 -5 24 40 40 32 26 26 25 28 38 52 59 54 41 28 22 22 24 26 25 23 26 28 27RC- 34-1
 19  8  3  6 15 21 17  4 -9-15-10  1 11 15  9  0 -7-11-10 -5 -1  2 -1-13RC- 34-2
-26-36-36-24 -7 -1 -6-14-19-19-18-13 -7 -7-11-15-15-13 -9 -2  4 10 11  8RC- 34-3
  7 10 11 12 13 15 14 12 11 11 13 16 21 25 23 18 14 12 13 15 17 17 15 11RC- 34-4
  9 10 10  0-31-76-99-86-40  2 15 -6-47-82-90-73-45-25-26-38-59-73-76-56RC- 34-5
-14 28 44 25 -8-31-28 -5                                                RC- 34-6
SPEAKER ID-RDK-M/PHONEME ID-15/PITCH-138-NN/PITCH PERIOD-  7.26 MS/      RC- 53-0
 -2  0 -1  0  5 14 20 25 26 25 25 27 31 33 35 38 38 34 30 33 40 43 40 39RC- 53-1
 43 45 42 41 44 47 46 43 43 44 42 40 41 43 45 44 39 29 16  9  8 12 19 25RC- 53-2
 25 16  6  2  0 -2 -2  2  7  7  3  1 -1 -7 -8 -3  1  2  1  3  8 12 15 18RC- 53-3
 16 12  9 10 12 16 21 27 29 29 26 20 11  3  1  5 10 10  9  0-14-34-60-86RC- 53-4
-97-79-47-34-51-72-80-82-88-94-99-90-86-82-79-77-78-70-63-56-51-48-47-52RC- 53-5
-53-42-22 -5 -1 -4 -5 -3                                                RC- 53-6
SPEAKER ID-DEM-M/PHONEME ID-15/PITCH-156-NN/PITCH PERIOD-  6.40 MS/      RC- 72-0
 -1  3 11 13  3 -8-17-19-17 -6 13 30 43 51 58 60 60 57 54 52 44 35 30 28RC- 72-1
 26 27 29 32 35 39 44 52 56 54 46 34 20  7 -1 -5 -5 -3  0  1  2  4  6  5RC- 72-2
  4  4  2  0 -1 -1 -2 -4 -7 -9-10 -9 -7 -1  2  3  0 -1 -4 -7 -9 -9 -8 -7RC- 72-3
 -7 -7 -4 -1  0  2  4  6  8 12 17 23 25 23 17 11  7  6  7 12 19 26 31 35RC- 72-4
 38 37 28  8-15-42-72-95-99-89-74-55-37-29-30-38-48-54-59-68-70-68-70-69RC- 72-5
-61-53-44-37-30-20 -9 -2                                                RC- 72-6
SPEAKER ID-JEB-M/PHONEME ID-15/PITCH-151-NN/PITCH PERIOD-  6.62 MS/      RC- 91-0
 -5 -1  0  3  6  8 10 10 12 16 21 26 31 34 37 40 41 41 39 38 38 40 39 38RC- 91-1
 39 43 48 51 52 51 52 52 50 46 41 38 36 33 30 29 30 33 34 33 30 27 23 17RC- 91-2
 12  7  5  4  4  6  8 10 12 11  9  6  4  3  3  3  5  9 13 15 17 18 19 20RC- 91-3
 21 21 22 24 29 33 36 38 40 39 37 32 26 20 14  7  0 -7-16-26-35-45-51-55RC- 91-4
-57-56-58-62-67-76-85-90-94-96-98-99-95-87-80-75-72-70-68-66-66-66-63-58RC- 91-5
-51-45-40-34-24-14 -7 -3                                                RC- 91-6
SPEAKER ID-RVP-M/PHONEME ID-15/PITCH-185-NN/PITCH PERIOD-  5.40 MS/      RC-110-0
-14 -5  5 16 22 21 14  4 -4 -7 -3  7 23 40 51 55 50 41 31 25 23 24 25 24RC-110-1
 23 21 22 25 28 30 28 20 10  2  0  1  6 10  9  5  0 -4 -4 -2  0  4  9  9RC-110-2
  7  2 -1 -3 -1  3 10 16 17 16 15 16 18 23 27 29 29 28 29 31 35 39 42 43RC-110-3
 43 41 39 37 36 37 38 39 37 36 35 34 32 31 31 29 21  5-21-55-81-86-71-41RC-110-4
 -7 15 14 -9-42-73-93-99-92-80-69-63-60-61-62-62-59-56-52-48-49-52-56-56RC-110-5
-49-39-29-21-19-19-18-13                                                RC-110-6
SPEAKER ID-RMC-M/PHONEME ID-15/PITCH-180-NN/PITCH PERIOD-  5.57 MS/      RC-129-0
 -1 25 39 38 25  6 -1  7 24 46 66 77 72 54 35 25 27 41 63 81 87 78 60 43RC-129-1
 34 37 47 56 56 45 27 13  9 16 29 41 44 33 14 -2-10 -5  7 20 25 20  6-10RC-129-2
-20-19 -9  3 11  9  0-11-19-19-10  2 12 13  5 -5-14-16-10  0  7 11 10  5RC-129-3
  2  4 11 20 28 30 26 17 10 10 17 28 37 42 40 23 -7-39-57-57-40-17  7 24RC-129-4
 21 -6-46-74-81-70-51-36-35-48-72-92-99-84-58-40-37-47-62-73-74-59-36-18RC-129-5
-14-23-37-45-41-23  1 23                                                RC-129-6
SPEAKER ID-MAL-F/PHONEME ID-15/PITCH-302-NN/PITCH PERIOD-  3.31 MS/      RC-180-0
 -7  2 12 17 18 20 22 22 20 18 19 29 42 51 53 52 51 49 45 41 38 36 36 40RC-180-1
 46 52 52 49 47 50 52 39  9-32-51-39 -1 19 15 -4-36-73-99-90-48-11 -9-29RC-180-2
-49-56-60-66-71-72-71-59-36-14 -7-15-26-29-24-15                        RC-180-3
SPEAKER ID-PAF-F/PHONEME ID-15/PITCH-258-NN/PITCH PERIOD-  3.88 MS/      RC-199-0
 -8 -1  6 17 24 30 37 43 47 52 56 56 52 52 53 48 45 51 58 58 57 60 64 68RC-199-1
 78 84 78 75 76 72 64 58 45 22  4  0 -6-16-21-28-46-62-66-71-80-83-82-88RC-199-2
-96-99-98-97-94-88-83-79-71-61-54-46-36-26-16 -9                        RC-199-3
SPEAKER ID-PRM-F/PHONEME ID-15/PITCH-190-NN/PITCH PERIOD-  5.25 MS/      RC-218-0
 -3  5 17 33 35 29 28 33 48 54 50 47 43 46 55 54 51 44 39 41 41 41 37 29RC-218-1
 24 23 23 24 23 22 23 18 15 24 31 29 10-20-26 -6 10 -7-43-66-70-57-47-54RC-218-2
-76-99-95-76-61-60-63-59-50-44-36-24-12 -6 -9 -8                        RC-218-3
SPEAKER ID-IAP-F/PHONEME ID-15/PITCH-340-NN/PITCH PERIOD-  2.94 MS/      RC-237-0
-17-17-11 -4  8 27 38 40 47 56 65 64 56 55 65 74 84 93 99 91 53 15  9 24RC-237-1
 40 49 55 56 34  0-10 -1  9  4 -9 -7 -1 -9-18-26-26-40-65-67-55-47-50-56RC-237-2
-63-68-69-64-55-59-65-66-56-37-23-12-11-25-41-41                        RC-237-3
SPEAKER ID-LLC-F/PHONEME ID-15/PITCH-278-NN/PITCH PERIOD-  3.60 MS/      RC-256-0
-23  9 30 28 21 21 27 25 21 28 47 64 65 57 59 74 91 99 96 88 70 31 -6 -1RC-256-1
 42 87 75 15-45-64-60-62-73-67-40-17-24-47-53-41-40-65-92-89-52 -9 12 10RC-256-2
  0-10-16-21-26-30-23 -9  2  0-12-20-15 -9-11-25                        RC-256-3
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TABLE XI (Continued)

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SPEAKER ID-OLL-M/PHONEME ID-16/PITCH-145-NN/PITCH PERIOD-  6.89 MS/      RC- 16-0
-11 12 18 10 -1 -8 -2 11 25 30 29 28 31 34 34 28 19 14 17 28 39 43 39 28RC- 16-1
 15  7  8 18 32 40 36 24 10  2  4 12 21 24 18  9  1 -3 -5 -4 -3 -3 -5 -5RC- 16-2
 -7-14-25-33-37-35-27-16-13-18-26-31-29-20 -6  5 10  6 -1 -8 -7  0  7 14RC- 16-3
 18 15 10  8 11 14 17 20 23 24 24 23 21 18 15 14 15 19 20 17 11  5  1  0RC- 16-4
  4 10 12 10  7  5  4  4  3-12-47-73-79-54-20 -2-13-51-85-99-80-43 -8  3RC- 16-5
 -8-33-56-64-51-21  6 17                                                 RC- 16-6
SPEAKER ID-RLJ-M/PHONEME ID-16/PITCH-133-NN/PITCH PERIOD-  7.53 MS/      RC- 35-0
  2  1-11-41-59-50-14 11 -5-55-99-98-50  7 28 -2-53-82-62 -8 34 36  0-35RC- 35-1
-37 -2 40 57 38  9 -1 16 46 63 55 32 13 10 21 34 38 29 12 -1 -7 -3  3  7RC- 35-2
  5 -2-12-18-15 -7 -1 -2-11-17-15 -6  3  5 -1 -8 -7  2 15 19 15  6  3  8RC- 35-3
 17 21 17  8  0 -1 -1  2  5  2 -5-15-16 -9 -1  0 -5-14-17-14 -8 -2  0 -5RC- 35-4
-12-14-10 -2  5  8  5  1  1  5 12 17 18 15 12 10 11 13 15 17 16 13 10  9RC- 35-5
 10 11 11 11  9  5  1 -1                                                 RC- 35-6
SPEAKER ID-RDK-M/PHONEME ID-16/PITCH-169-NN/PITCH PERIOD-  5.91 MS/      RC- 54-0
  1  8  7  7 11 17 18 13  7  8 19 32 39 34 25 20 26 37 45 44 35 27 24 27RC- 54-1
 30 29 25 23 24 26 25 19 10  5  2  0 -2 -5 -5 -2  1  0 -6-13-14 -6  5 13RC- 54-2
 16 14 11  8  6  6 10 18 29 36 35 27 18 14 16 22 28 32 33 32 30 29 27 28RC- 54-3
 30 34 39 42 40 36 31 28 29 30 31 29 27 25 19 12 -3-24-47-66-71-62-45-34RC- 54-4
-39-62-88-99-86-60-40-38-54-72-81-80-74-70-63-49-32-21-26-43-56-53-31 -5RC- 54-5
  7  1-12-21-18 -6  4  8                                                 RC- 54-6
SPEAKER ID-DEM-M/PHONEME ID-16/PITCH-126-NN/PITCH PERIOD-  7.91 MS/      RC- 73-0
  1  6 10 10  9  8  7  6  8 14 24 35 41 40 31 20 10  6  9 14 17 17 15 15RC- 73-1
 17 20 22 23 21 17 12  8  6  6 10 15 20 23 23 20 16 11  7  3  1  1  2  1RC- 73-2
  0 -4-10-15-19-20-21-24-26-24-19-13 -7 -5 -3  0  1  0 -3 -3 -1  1  4  6RC- 73-3
  9 12 14 14 12 12 12 13 13 12 13 14 15 16 16 17 17 17 16 15 16 18 18 17RC- 73-4
 17 15 13 13 12 11 11 11  8  0-13-33-60-86-99-95-77-52-35-32-38-45-52-54RC- 73-5
-49-40-29-17 -8 -6 -5 -2                                                 RC- 73-6
SPEAKER ID-JEB-M/PHONEME ID-16/PITCH-156-NN/PITCH PERIOD-  6.39 MS/      RC- 92-0
 -6  7 18 26 30 28 20 12 12 19 29 37 36 32 29 30 31 28 21 15 14 17 19 19RC- 92-1
 18 18 17 14  9  4  1  3  9 18 26 29 24 13  5  2  6 13 19 25 28 27 21 13RC- 92-2
  6  4  8 17 26 29 25 17  9  5  4  5  8 12 13 13 10  5  1  0  0  4  9 13RC- 92-3
 13 12 13 14 14 14 15 17 21 23 25 26 26 27 27 28 30 27 20 14 10 11 13 12RC- 92-4
  6-10-32-51-60-52-37-30-36-55-76-91-99-97-89-74-58-49-51-67-86-94-84-60RC- 92-5
-36-20-14-15-21-27-27-19                                                 RC- 92-6
SPEAKER ID-RVP-M/PHONEME ID-16/PITCH-198-NN/PITCH PERIOD-  5.05 MS/      RC-111-0
-15 14 34 28  3-27-41-28  1 35 51 41 16 -5-11 -1 15 27 29 23 14 10  6  1RC-111-1
 -5 -8 -3 10 25 32 27  8-10-20-15  0 14 21 17  3-11-22-24-20-11 -2  0  0RC-111-2
 -4 -9-10-10 -8 -4  0  4 10 11  8  0 -4 -4  0  9 17 21 17  9  3  2  8 17RC-111-3
 26 30 28 23 19 17 19 23 26 27 26 24 23 23 21 17 16 17 21 24 27 25 19 11RC-111-4
  7  7 10 11  4-12-42-68-73-57-24  4 12 -7-49-85-99-84-51-17  4  4 -9-23RC-111-5
-32-36-43-49-47-32 -7 21                                                 RC-111-6
SPEAKER ID-RMC-M/PHONEME ID-16/PITCH-167-NN/PITCH PERIOD-  6.00 MS/      RC-130-0
 -8 12 36 44 28  9  3 10 18 21 23 30 35 31 20 12 12 16 19 23 29 36 35 24RC-130-1
 10  3  6 14 21 24 20 12  0 -8-12 -6  4 14 14  4 -9-20-24-20-11 -1  1 -3RC-130-2
-14-23-23-16 -7 -1  0 -1 -6-12-14-11 -3  4  7  5  3  2  2  4  8 13 16 18RC-130-3
 15 13 15 18 21 24 27 31 34 34 29 22  9 -9-18 -6 22 38 16-44-94-92-41 17RC-130-4
 35 12-26-56-76-87-73-29 18 28-11-70-99-84-45 -8 17 31 23-11-53-66-35 16RC-130-5
 44 36 11 -5-10-14-14 -1                                                 RC-130-6
SPEAKER ID-MAL-F/PHONEME ID-16/PITCH-314-NN/PITCH PERIOD-  3.18 MS/      RC-181-0
 -8  8  7 -3  8 34 60 63 53 55 69 85 84 71 60 63 74 82 79 74 73 81 92 99RC-181-1
 96 81 47 -2-62-86-56 -4 10-24-58-48-29-35-69-95-89-78-66-65-72-73-64-38RC-181-2
-29-50-82-96-80-52-39-36-32 -9 15 19 -1-26-36-25                         RC-181-3
SPEAKER ID-PAF-F/PHONEME ID-16/PITCH-279-NN/PITCH PERIOD-  3.58 MS/      RC-200-0
 -7  3 12 22 31 37 41 46 51 55 59 64 67 64 61 63 68 70 70 71 74 75 74 73RC-200-1
 73 74 73 68 62 56 52 40 19 -2-12-12-16-27-40-48-56-67-75-79-82-87-90-92RC-200-2
-95-99-98-92-85-82-75-64-56-55-50-38-23-16-16-13                         RC-200-3
SPEAKER ID-PRM-F/PHONEME ID-16/PITCH-197-NN/PITCH PERIOD-  5.07 MS/      RC-219-0
  3  9  5  7 18 28 37 45 53 58 60 61 62 64 65 70 71 59 47 47 50 54 53 47RC-219-1
 40 33 30 31 30 31 34 40 44 42 45 51 50 32 -8-58-74-47-27-44-71-96-90-81RC-219-2
-88-94-96-99-97-94-90-78-61-44-28-28-46-49-34 -8                         RC-219-3
SPEAKER ID-IAP-F/PHONEME ID-16/PITCH-358-NN/PITCH PERIOD-  2.79 MS/      RC-238-0
-14 21 41 39 22 -3-16 -8 15 47 66 69 52 30 16 20 39 59 59 47 35 37 46 50RC-238-1
 42 13-30-50-28  8 55 37-19-74-99-83-41  0 27 28 -7-57-87-79-42  0 10  0RC-238-2
-16-26-25-32-35-30-30-20-16-11  0  6 -5-27-42-33                         RC-238-3
SPEAKER ID-LLC-F/PHONEME ID-16/PITCH-271-NN/PITCH PERIOD-  3.69 MS/      RC-257-0
 10 -1  4 26 41 38 23 12 16 21 24 27 38 54 63 62 60 64 78 92 99 93 69 22RC-257-1
-22-37-14 20 14-21-52-49-18  0 -6-24-43-48-45-33-20-20-26-32-36-39-44-39RC-257-2
-25-18-26-39-36-14  1 -1-19-36-40-32-15  0  6  7                         RC-257-3
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TABLE XI (Continued)

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SPEAKER ID-OLL-M/PHONEME ID-17/PITCH-136-NN/PITCH PERIOD-  7.34 MS/      RC- 17-0
  2 30 47 49 46 44 42 41 44 50 60 64 66 75 90 99 92 82 73 60 38 24 21 22RC- 17-1
 13  0  0  6  7  1 -6-15-29-44-54-57-60-68-73-70-58-44-28-15 -6 -1  3  8RC- 17-2
 14 19 22 22 26 36 51 62 62 56 48 39 24 10  5  2 -4 -8 -4  8 15  9  2 -4RC- 17-3
-11-20-24-27-26-25-26-19 -9 -3 -5 -9 -8-13-12-11 -7 -1  0  0  6 13 18  8RC- 17-4
  5  2  0  0  0  6 11 15 15  2-23-45-51-49-61-67-64-59-60-51-31-22-37-53RC- 17-5
-53-52-55-53-36-20-17-13                                                RC- 17-6
SPEAKER ID-RLJ-M/PHONEME ID-17/PITCH-138-NN/PITCH PERIOD-  7.26 MS/      RC- 36-0
 -4 43 76 73 44  4-20 -6 27 53 71 63 50 53 60 81 99 87 69 45 13  2 10 22RC- 36-1
 52 73 65 42  3-28-41-31-11  0 -4-20-36-40-34-23-22-38-55-57-52-25  5 13RC- 36-2
 18 10 -5 -3 -3 -1  6 17 26 29 39 38 32  9  4 -5-27-20 11 23 21 13 28-13RC- 36-3
 -8  2-13-18-16-16  5 -5 -7  7 18  1-15  2-17  0-12 -5 25 21  9  8 12 19RC- 36-4
  0  4 13  3-15-59-73-66-34 23 50 29 -5-62-93-87-67-48-38-46-50-48-46-27RC- 36-5
-16-21-19-24-42-54-53-31                                                RC- 36-6
SPEAKER ID-RDK-M/PHONEME ID-17/PITCH-139-NN/PITCH PERIOD-  7.17 MS/      RC- 55-0
 -6 12 29 44 59 72 81 92 96 97 93 89 85 81 82 89 86 92 91 90 80 79 72 59RC- 55-1
 47 39 32 20 26 34 16 29 33 16 17 21  9 -1 -1 -8-14-18-12-10-11 -8 -3-11RC- 55-2
 -6 -4-11-13 -1 -2-10 -3 10  4 -1 23 -9 15 15-11  3 35-15  0 20 -3 29 31RC- 55-3
 15 24 45 41 21 -2 28 28 32  2 21 22 -1 31 19-14 19 13-18-13 -5-17-30-35RC- 55-4
-49-56-58-68-70-76-73-71-75-80-76-78-82-85-90-96-99-97-97-92-83-77-70-59RC- 55-5
-52-43-34-28-22-16-10 -2                                                RC- 55-6
SPEAKER ID-DEM-M/PHONEME ID-17/PITCH-126-NN/PITCH PERIOD-  7.92 MS/      RC- 74-0
 12 11 25 31 28 44 59 47 39 53 72 81 85 98 99 83 74 69 57 47 35 26 28 29RC- 74-1
 23 27 32 26  7  2  9-11-32-14-15-16-18-12 10  0  0  2  0  2 -5 -7  4 14RC- 74-2
 13  0 31 29 11 24  6 14  5-11 -1 35-23 -6 31-20 13-41  3 26-58-35  7-28RC- 74-3
-14 -8-34-22 28-31-27-16 -5-18-26-30 22 -9 -9  1-13 -7 16  0-21 18 11 -9RC- 74-4
 -4  0 38 -6-20 16 -2-39-43-17-64-84-73-55-45-54-36-47-60-60-57-54-45-58RC- 74-5
-76-68-49-27 -3  9 17 13                                                RC- 74-6
SPEAKER ID-JEB-M/PHONEME ID-17/PITCH-126-NN/PITCH PERIOD-  7.92 MS/      RC- 93-0
  5 12 24 35 43 52 65 78 86 89 91 95 98 99 97 94 91 90 90 88 87 83 76 67RC- 93-1
 59 54 48 42 36 32 27 20 14  9  7  0-10-18-20-21-20-19-19-20-20-14 -6 -4RC- 93-2
 -5 -1  5  8 11 15 15 16 19 21 24 24 16 17 22 30 19 14 21 30 24  7  5  3RC- 93-3
  8 19  0-14-16 -1  0-14-11 -3 -1-10-27-21-11 -4-14-29-29-20-19-31-45-49RC- 93-4
-44-40-45-59-77-85-83-79-83-91-97-94-90-90-94-97-92-86-88-91-87-72-55-46RC- 93-5
-43-40-29-13 -2  2  7 17                                                RC- 93-6
SPEAKER ID-RVP-M/PHONEME ID-17/PITCH-180-NN/PITCH PERIOD-  5.56 MS/      RC-112-0
 -1 20 46 63 71 71 67 62 61 60 58 57 60 58 52 44 42 48 61 73 76 71 62 47RC-112-1
 28  9 -7-17-20-20-23-28-31-32-30-26-23-20-20-24-28-34-41-40-32-21 -9  2RC-112-2
 11 16 15 13 10  9 14 25 34 31 25 26 28 37 43 32 23 41 47 33 21  9 15 16RC-112-3
 17 38 34 16 25 36 33 27 22 27 33 30 24 18  4 -9-23-41-53-53-52-49-37-26RC-112-4
-29-38-41-37-35-37-41-50-59-73-89-99-98-91-85-71-54-44-38-33-34-38-36-26RC-112-5
-20-19-22-26-28-22-11  5                                                RC-112-6
SPEAKER ID-RMC-M/PHONEME ID-17/PITCH-142-NN/PITCH PERIOD-  7.06 MS/      RC-131-0
  1 21 25 48 54 44 53 72 80 68 59 45 25 34 48 46 56 64 47 41 45 36 30 25RC-131-1
  8-11-22-18 -9  1  8 -3-14-13-19-21-19-34-47-49-49-32-10 -3  0 -1 -5 -1RC-131-2
  4 11 13  7  6 10 21 32 36 31 17  3 -8  0 10 -6  0 20 -5-15 29 13-13 11RC-131-3
 -2-23 -9 -5  7-11  0  1-18 -8 23 -5 -8 22 -2 -8 26 32  9 19 32  5 12 37RC-131-4
 25  2-30-44-44-66-24  9-56-48-14-56-31  7-47-75-69-90-99-62-49-61-50-24RC-131-5
-32-32  6  5-17 -2-17-40                                                RC-131-6
SPEAKER ID-MAL-F/PHONEME ID-17/PITCH-239-NN/PITCH PERIOD-  4.18 MS/      RC-182-0
 -3 54 63 38 -3-36-65-66-31 -7 22 32  0-51-85-86-54 -9  6 10 -1-32-49-50RC-182-1
-31  0 43 59 46 21-10 -8 13 39 55 58 37 -1-32-52-27 12 35 39 10-17-27-23RC-182-2
 -4 37 56 50 39  0-26  5 22 51 55 66 -3-65-99-33                        RC-182-3
SPEAKER ID-PAF-F/PHONEME ID-17/PITCH-275-NN/PITCH PERIOD-  3.64 MS/      RC-201-0
-17  5 26 41 51 61 57 49 47 55 61 71 78 77 76 75 64 48 26 33 28 38 45 64RC-201-1
 48 37 50 26 17 26 16 12 33 32 37 25 25  7-15-35-28-41-40-40-31-37-39-42RC-201-2
-63-85-95-98-99-94-83-74-69-60-52-63-66-60-49-38                        RC-201-3
SPEAKER ID-PRM-F/PHONEME ID-17/PITCH-209-NN/PITCH PERIOD-  4.79 MS/      RC-220-0
-16  8 25 25 12 16 20  5 19 40 42 25 11  4 16 29 18 19 12 32  0 35 33 52RC-220-1
 31 30 45 39 89 33 87 37 87 21  8-24  6 17 34  0-10-26-46-72-80-68-52-62RC-220-2
-86-99-89-75-66-64-41-38-36-45-29 -4 25 25 21 16                        RC-220-3
SPEAKER ID-IAP-F/PHONEME ID-17/PITCH-324-NN/PITCH PERIOD-  3.09 MS/      RC-239-0
-13  0 -2  1 29 40 49 64 50 74 67 41 61 -3 55 14 48 75 52 75 82 47 64 72RC-239-1
 33 73 46 99 56 71 16 -4 28-22-29  8  8  5 21  0 -2 13-25-59-49-80-91-73RC-239-2
-77-49-50-74-76-72-86-94-89-82-90-79-71-42 -5-13                        RC-239-3
SPEAKER ID-LLC-F/PHONEME ID-17/PITCH-236-NN/PITCH PERIOD-  4.23 MS/      RC-258-0
-36-24-12 -7-20-30-32-28-14  0 15 23 17  7-13-27-17-12 11 20 26  8 17-27RC-258-1
-10 -1 18 17 53 25 22 25 33 43 18 99 62 79 73 37 38 17 30 53 61 48 35 32RC-258-2
  9-27-65-42-43-43-39-30-41-48-67-81-72-54-44-27                        RC-258-3
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TABLE XI (Continued)

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SPEAKER ID-OLL-M/PHONEME ID-18/PITCH-148-NN/PITCH PERIOD-  6.75 MS/      RC- 18-0
 -5  7 11  7  0  1 10 20 31 39 38 34 37 46 63 82 88 75 53 38 39 56 77 93RC- 18-1
 95 80 56 32 16 18 38 59 75 79 47 -1-19-18-10  9 37 41 20 -3-24-38-35 -4RC- 18-2
  5-13 -7  0-19-24 -5 -7-24-14-11-23 -9 11-13-25  2 -7-15-12-25 -7  7 -8RC- 18-3
  0 -6-41-30 -3-17  9 29  1-24-24-18 -5 16  1 -9  3  0 -2  2 -1-28-42-55RC- 18-4
-56-12 29 37  6-35-79-99-68-32 -7  4 -7-38-65-79-92-84-55-27 -3 -1-26-53RC- 18-5
-61-53-33 -4 10 16 17  9                                                RC- 18-6
SPEAKER ID-RLJ-M/PHONEME ID-18/PITCH-104-NN/PITCH PERIOD-  9.60 MS/      RC- 37-0
 -6 53 40-29-99-99-31 30 40 10-19-25-16  1 21 38 49 44 30 11  7 28 58 73RC- 37-1
 59 37 22 20 23 31 41 49 42 23 -2-19-11 15 37 27 -7-38-42-26 -8  2  2-10RC- 37-2
-33-47-48-27 -7  4 -1-25-44-49-30 -7 -1 -3 -8-16-27-26 -4 18 26 15  3 -4RC- 37-3
  0 14 32 44 30  8 -1 -5  9 27 30 25  1-14-22 -6 11 14  3-11-26-29-17 -1RC- 37-4
  1 -1-12-18-21 -8-10  1  0  4 -4 -9 -6 -1  6 11 15  9 -2 -5  2 16  1-34RC- 37-5
-49-16 33 46  2-64-91-61                                                RC- 37-6
SPEAKER ID-RDK-M/PHONEME ID-18/PITCH-136-NN/PITCH PERIOD-  7.33 MS/      RC- 56-0
  6 32 40 37 38 48 56 54 55 71 91 99 88 79 82 90 86 71 57 56 59 56 46 35RC- 56-1
 27 17  0-18-24-19-15-21-33-40-42-44-49-50-46-40-35-34-30-23-18-19-25-28RC- 56-2
-19 -7 -2  2  9 18 24 20 19 25 31 35 36 42 46 45 44 40 37 36 35 35 32 28RC- 56-3
 28 26 20 14 10 10 10  6  7  7  4 -1 -6 -8 -6 -5 -2 -2 -3  0 -1 -3 -8-11RC- 56-4
-15-24-28-33-41-58-79-81-60-46-46-68-87-86-83-81-86-83-68-56-55-56-48-28RC- 56-5
-15-22-28-21  5 31 39 39                                                RC- 56-6
SPEAKER ID-DEM-M/PHONEME ID-18/PITCH-115-NN/PITCH PERIOD-  8.73 MS/      RC- 75-0
-24 -1 32 38 25 17 23 40 50 51 66 72 64 55 48 65 82 71 62 65 52 45 47 40RC- 75-1
 44 42 26 26 14 -5-19  1 13 -4-13-39-32-12-17-29-26-26-26-12-19-26-20 -5RC- 75-2
-16 -1  4 -4-18-23 33  9 18 19 -8  4 -5 22 58  9  0 -1-16 24 13 45  2-61RC- 75-3
-15 37-19  7-11-60-28-12 28 17-49-99-40 -9 57  4-65-86-63  9 48  1-26-44RC- 75-4
-57 -4 24 24 15-36-33  7-32-15-23-38 38  2-63-69-53 -1 -1-32-50-51-46-41RC- 75-5
-33-16-35-46-26-26  9  7                                                RC- 75-6
SPEAKER ID-JEB-M/PHONEME ID-18/PITCH-146-NN/PITCH PERIOD-  6.87 MS/      RC- 94-0
-15  1 16 27 33 35 36 39 41 46 50 54 57 58 57 55 49 42 35 28 21 13  2 -5RC- 94-1
-13-18-20-21-21-21-21-22-24-27-30-30-27-20-10  0  9 18 26 30 32 30 28 27RC- 94-2
 29 33 39 45 50 53 53 49 42 33 24 16 10  6  4  2  1  0 -2 -6-12-19-25-29RC- 94-3
-30-29-26-21-14 -8 -2  0  1  2  3  5  8 13 19 25 32 37 41 42 42 40 38 35RC- 94-4
 32 29 27 24 21 17  9  0 -9-19-29-39-50-65-79-90-97-99-98-94-87-79-74-71RC- 94-5
-71-73-72-67-58-45-31-14                                                RC- 94-6
SPEAKER ID-RVP-M/PHONEME ID-18/PITCH-180-NN/PITCH PERIOD-  5.55 MS/      RC-113-0
-23  4 35 61 76 76 60 43 32 30 36 48 60 64 62 57 56 62 70 73 67 54 36 16RC-113-1
 -1-13-19-14 -1 10 12  7 -4-19-35-46-50-46-32-14 -1  5  6  4  2  0  0  0RC-113-2
  0  2  3  1  1  4 16 29 38 31 16  0 -7 -2  0 -1  5 22 48 60 44 26 14 11RC-113-3
 12 12 13 14 11 15 32 41 32 24 24 20  3-14-23-32-55-72-62-33  2 32 40 16RC-113-4
-29-73-99-99-77-51-33-28-35-45-48-48-50-54-53-53-58-62-59-58-54-39-16  5RC-113-5
 19 19  4-17-34-39-27 -3                                                RC-113-6
SPEAKER ID-RMC-M/PHONEME ID-18/PITCH-188-NN/PITCH PERIOD-  5.32 MS/      RC-132-0
-34 -9 31 68 84 76 47 12-10 -7 18 51 73 76 59 32 14 14 31 55 71 68 44 11RC-132-1
-14-24-19 -4  7 11 10  6  3  4  9  8 -4-22-37-43-37-17  8 27 30 18 -1-21RC-132-2
-32-27 -9  6 14 12  0 -8 -8  0  7 15 21 21 23 16 -3-22-11 22 45 48 45 26RC-132-3
 -4-14  5 22 18 14 31 52 38  9  0  0-23-52-61-52-29  1 30 45 37  6-35-78RC-132-4
-99-82-42 -8  7  5-21-61-89-90-66-25  7 15 -2-37-76-98-93-66-33 -5  8  6RC-132-5
 -3-13-13 -7 -6-12-19-24                                                RC-132-6
SPEAKER ID-MAL-F/PHONEME ID-18/PITCH-312-NN/PITCH PERIOD-  3.21 MS/      RC-183-0
 -8 60 54-21-89-99-60-18-14-47-73-67-46-39-53-70-75-68-55-38-23-19-26-39RC-183-1
-49-47-27  7 35 39 26 18 23 33 40 43 47 56 69 77 66 39 19 19 35 48 44 33RC-183-2
 27 20 13 13 19 24 30 34 37 41 38 34 30 24 37 50                        RC-183-3
SPEAKER ID-PAF-F/PHONEME ID-18/PITCH-260-NN/PITCH PERIOD-  3.85 MS/      RC-202-0
-45-51-49-27 -4 -1 -7  9 47 69 63 49 44 57 69 75 70 57 50 58 45 21 30 49RC-202-1
 19 32 63 31-13 11 11 20 26 20 16 11 31 33  8  2 46 51  1-10-39-38  4  0RC-202-2
-15-44-58-54-64-78-80-76-68-66-78-92-99-93-71-55                        RC-202-3
SPEAKER ID-PRM-F/PHONEME ID-18/PITCH-200-NN/PITCH PERIOD-  5.01 MS/      RC-221-0
-31-13 12 25 33 45 58 52 66 74 53 38 41 40 14  9 41 32-40 30 49-27-10 44RC-221-1
 22-19 22 49 16  5 42 78 -2 46 71 35 -8 81 69-21 50 46 -4-23-19-35-31-22RC-221-2
-73-59-56-78-99-77-81-91-92-83-87-77-54-48-47-25                        RC-221-3
SPEAKER ID-IAP-F/PHONEME ID-18/PITCH-326-NN/PITCH PERIOD-  3.07 MS/      RC-240-0
 -5  7  5  0 10 28 33 31 43 54 50 39 32 32 31 28 57 55  0  5 51 59 64 74RC-240-1
 36-10 29 95 99 64 18-46-68-14 48 69 30 -4-18-21-22-21-11-11-22-37-46-51RC-240-2
-51-52-50-61-88-97-69-28-24-55-85-93-74-34  8 27                        RC-240-3
SPEAKER ID-LLC-F/PHONEME ID-18/PITCH-236-NN/PITCH PERIOD-  4.23 MS/      RC-259-0
  3 28 16  2 20 36 18-16-20 29 79 52-22-16  9 42 11-12 26 31 15 -4-30 43RC-259-1
 33 56  1 -8 53 27 58-18 44 55 69 61-45 24 46 -9 -9 39 19 21-40-42-18-44RC-259-2
-69-38-16-34-85-99-57-39-62-71-38  0-18-58-49  3                        RC-259-3
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TABLE XI (Continued)

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SPEAKER ID-OLL-M/PHONEME ID-19/PITCH-138-NN/PITCH PERIOD-  7.26 MS/      RC- 19-0
 -3  7 23 43 62 77 84 84 79 71 64 61 63 66 65 58 51 49 49 51 52 51 44 34RC- 19-1
 23 12  3 -1 -2 -1 -2 -5-10-14-18-20-22-24-25-26-25-22-19-15 -9 -2  3  5RC- 19-2
  5  5  5  6  6  5  3  2  1  0  1  1  3  5  7  9 10 10 11 12 14 14 12 10RC- 19-3
  9  8  6  5  3  0 -1 -3 -5 -6 -7 -7 -6 -6 -5 -5 -4 -2  0  1  2  2  3  5RC- 19-4
  8 11 14 17 17  9 -7-29-47-59-66-73-83-93-99-96-89-78-65-48-34-28-31-37RC- 19-5
-39-39-34-28-22-17-12 -3                                                RC- 19-6
SPEAKER ID-RLJ-M/PHONEME ID-19/PITCH-109-NN/PITCH PERIOD-  9.15 MS/      RC- 38-0
 -1 20 47 66 77 84 86 83 72 61 54 54 60 68 71 64 52 40 32 26 18  6-14-35RC- 38-1
-48-47-40-31-28-29-33-35-34-31-29-28-26-24-19-11 -2  7 17 26 30 25 11  1RC- 38-2
  0 -3 -1  9 18 19 15 16 15 10  6  3  0 -5 -8 -3  1  5  7  9  7  3  0 -1RC- 38-3
 -2 -3 -4 -5 -3 -7 -7 -6 -6 -6 -6 -5 -9-14-15-14-12-10 -8 -5 -5 -3 -2 -2RC- 38-4
 -1 -1  0  1  3  5  7 11 13 15 17 16 14 10  5-19-58-91-99-89-65-34-16-16RC- 38-5
-33-48-54-51-40-29-19-13                                                RC- 38-6
SPEAKER ID-RDK-M/PHONEME ID-19/PITCH-165-NN/PITCH PERIOD-  6.06 MS/      RC- 57-0
  9 17 21 24 23 22 20 16 11 10 12 14 20 22 25 23 25 29 33 37 36 30 27 24RC- 57-1
 22 20 15  8  9 13 14 15 12  6  0  4  6  7  9 13 12 16 13 13 12 11 12 17RC- 57-2
 12 12 15  9 11  5  2 10  5 11 17 14 14  3  9  4 14 18 16 20 21 18 23 32RC- 57-3
 35 41 45 47 48 48 43 40 34 32 25 23 15  5 -1-12-14 -8 -2  2  3 -7-10-13RC- 57-4
-18-26-39-53-62-67-71-77-88-97-99-88-77-68-62-61-59-55-49-49-51-52-50-45RC- 57-5
-39-35-34-29-23 -8  4 15                                                RC- 57-6
SPEAKER ID-DEM-M/PHONEME ID-19/PITCH-117-NN/PITCH PERIOD-  8.56 MS/      RC- 76-0
 -6  7 25 42 54 62 73 84 91 94 90 84 73 57 44 33 23 19 13  9  8  9  6  4RC- 76-1
  6  5  0 -6-10-15-18-17-14-12 -8 -3  0  3  5  8 10 14 14 11 12 10 15 16RC- 76-2
 17 19 12  9  2 -2 -5-12-10-12-11-16-14-10 -4 -4 -1  2  4  8  8  6  2  5RC- 76-3
 10 11  7 -3 -5 -1  0  2  5  0 -2-10 -8 -5 -5-11-16-17-15-12 -7 -8 -9 -6RC- 76-4
 -8 -2 -1 -1  1  1  9 13 14 16 17 15  8  0-20-47-75-90-97-99-90-79-65-54RC- 76-5
-45-35-26-18-12-12-15-17                                                RC- 76-6
SPEAKER ID-JEB-M/PHONEME ID-19/PITCH-142-NN/PITCH PERIOD-  7.03 MS/      RC- 95-0
-11 -5  3 13 22 28 32 39 47 55 60 62 61 60 57 55 52 50 51 53 53 51 46 44RC- 95-1
 47 49 49 43 39 37 34 29 24 19 18 18 17 14 12 11 12 14 18 23 25 25 27 29RC- 95-2
 29 29 28 28 30 29 25 21 19 22 24 25 24 22 21 19 18 16 16 18 20 17 18 21RC- 95-3
 20 18 18 12 12 12 15 19 21 25 26 24 19 18 18 15 14 14 10  4  0 -2 -8-18RC- 95-4
-27-32-38-46-58-69-74-74-73-76-81-82-82-85-90-96-99-97-94-95-96-93-87-77RC- 95-5
-66-55-44-33-26-20-15-10                                                RC- 95-6
SPEAKER ID-RVP-M/PHONEME ID-19/PITCH-146-NN/PITCH PERIOD-  6.83 MS/      RC-114-0
-11 13 22 26 37 51 63 65 52 35 26 25 28 27 29 42 58 67 66 55 44 39 33 26RC-114-1
 11 -8-21-22-19-13 -9 -2  6 12 10  2 -6-12-13-12-16-23-26-21-15-11 -7 -3RC-114-2
  2  8  7  4  3  4  8 13 15 13 15 18 19 17 14 14 10  7  4  0 -1  0  1  2RC-114-3
  2  1  2  5  7  8  6  6  5  4  5  6  7  8 12 11 11 10 11 15 15 13 14 15RC-114-4
 16 21 23 24 24 24 23 17  5-13-42-73-93-99-86-67-60-65-65-57-38-24-27-39RC-114-5
-51-57-61-68-72-62-38 -8                                                RC-114-6
SPEAKER ID-RMC-M/PHONEME ID-19/PITCH-145-NN/PITCH PERIOD-  6.91 MS/      RC-133-0
 -8 24 39 51 55 50 48 50 36 21 16 14 12 19 31 47 66 83 86 71 46 20  1 -5RC-133-1
-10-18-18-14-12 -4  7 11 14 20 18  5-10-26-37-38-31-23-17 -9  0  8 14 22RC-133-2
 26 26 21 13 10  7  5 11 15 17 18 18 14  6  1 -2 -7-11-14-13-10 -7 -5 -3RC-133-3
 -1 -3 -2 -2 -4 -9 -7 -6 -9 -4  1  0  0  4  6  3  4  5  7  9  9 10 10 12RC-133-4
 14 15 18 24 28 32 37 41 41 21-25-61-82-99-90-66-58-52-38-26-22-18-17-23RC-133-5
-34-47-62-76-87-81-57-17                                                RC-133-6
SPEAKER ID-MAL-F/PHONEME ID-19/PITCH-299-NN/PITCH PERIOD-  3.35 MS/      RC-184-0
 -8 14 13  0 10 26 20 -8-22-28-33-32 -3 26 29  4  0 15 22 16 19 22 12 -2RC-184-1
  0 22 45 46 32 21 19 19 18 26 40 40 30 32 49 64 66 66 59 14-63-99-72-39RC-184-2
-44-45-22 -3-15-23 -6 16 -1-44-85-88-77-61-42 -7                        RC-184-3
SPEAKER ID-PAF-F/PHONEME ID-19/PITCH-258-NN/PITCH PERIOD-  3.87 MS/      RC-203-0
-21-13 13 25 22 26 31 32 31 36 40 32 32 43 46 39 35 37 42 47 44 43 53 58RC-203-1
 61 66 68 62 52 55 63 55 56 64 63 41 15 -3 -5 -7-22-34-40-41-45-48-55-75RC-203-2
-87-92-90-92-99-96-88-76-67-63-60-55-44-29-21-20                        RC-203-3
SPEAKER ID-PRM-F/PHONEME ID-19/PITCH-196-NN/PITCH PERIOD-  5.11 MS/      RC-222-0
-14 10 29 33 25 15  9  9 16 23 26 23 17 11  6 -1 -8 -6  4 11 11 12  9  6RC-222-1
  9 21 29 29 27 33 38 39 40 40 37 35 41 49 54 52 42 23 -4-35-54-54-38-21RC-222-2
-10-17-42-70-91-99-94-82-63-43-33-31-35-38-36-22                        RC-222-3
SPEAKER ID-IAP-F/PHONEME ID-19/PITCH-212-NN/PITCH PERIOD-  4.72 MS/      RC-241-0
 -3 36 34 24 21 29 45 49 52 36 14 20 26 15 -6-29-43-45-31-21-30-34-27-13RC-241-1
  6 22 29 31 36 41 35 28 27 28 34 39 40 36 31 31 30 28 26 19 19 25 35 49RC-241-2
 24-50-93-99-88-38-16-45-71-82-65-56-55-33-26 -4                        RC-241-3
SPEAKER ID-LLC-F/PHONEME ID-19/PITCH-201-NN/PITCH PERIOD-  4.97 MS/      RC-260-0
 -5 21 31 18 14 18 13  9 15 20 30 28 10 -1-12 -9 -1 13 16 22 16  1  5  7RC-260-1
 11 20 20 23 29 19 22 24 34 42 40 30 37 39 36 41 48 51 15-23-29 -6 -5-16RC-260-2
-20-30-41-52-80-99-89-71-63-60-58-47-37-45-41-19                        RC-260-3
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TABLE XI (Continued)

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SPEAKER ID-RMC-M/PHONEME ID- 2/PITCH-114-BN/PITCH PERIOD-  8.79 MS/      RC-134-0
-24 57 94 46-10-11 24 55 68 75 76 61 39 24 17  8  0  6 22 34 16-34-72-61RC-134-1
-19  6  9  7 -8-41-49-12 35 48 33 24 23 15  6 13 32 42 34 20  7 -9-29-34RC-134-2
-17  5  8-16-47-62-55-33 -2 18 14 -9-26-12 15 35 44 46 34 15  5 10 20 24RC-134-3
 20 12  0-15-25-21 -9  0  1 -5-15-23-19 -5  9 14  9  0 -6 -5  3 13 17 14RC-134-4
  7  0 -2 -1  0  4  3  0 -7-11-13-12 -9 -8 -8-10 -9 -8 -6 -4 -8-25-63-99RC-134-5
-86-17 30  1-46-63-62-49                                                RC-134-6
SPEAKER ID-RMC-M/PHONEME ID- 2/PITCH-131-BN/PITCH PERIOD-  7.63 MS/      RC-135-0
-17 47 65 18-41-61-36  1 33 55 72 76 64 44 25 16 19 28 37 47 57 59 44 13RC-135-1
-24-51-47-14 20 30 13-11-33-58-73-59-13 26 29  9 -5-10-14-20-13 12 40 52RC-135-2
 46 32 17  1 -9 -8  5 25 39 32  9-15-31-36-32-19  0 13  7-13-33-37-27-13RC-135-3
  0 13 20 18  5 -5 -7  0 12 21 25 25 21 14  4 -3 -4  3 12 14  9  2 -3-11RC-135-4
-17-17 -8  1  5  3 -2 -5 -7 -6 -2  4 11 13  9  6  4  1-11-42-83-99-62  4RC-135-5
 41 10-51-89-91-82-66-24                                                RC-135-6
SPEAKER ID-RMC-M/PHONEME ID- 2/PITCH-140-BN/PITCH PERIOD-  7.12 MS/      RC-136-0
-11 29 54 40 -6-43-38  0 37 50 49 51 56 49 24  3  5 28 45 44 31 23 21 15RC-136-1
  0-21-29-17  0 10  7 -5-20-30-36-38-29-10  9 20 13 -5-20-19 -4 12 23 29RC-136-2
 32 30 21  7  1  9 22 27 21 12  6  0 -6-13-14 -7  0  0 -7-15-20-19-18-15RC-136-3
 -9  0  3  0 -7-12 -8  0  8 12 15 16 13  8  5  7 13 19 21 18 13  8  4  1RC-136-4
  1  3  5  5  3 -2 -6 -8 -9 -7 -6 -4 -2 -2 -2 -5-10-27-65-99-97-50 11 37RC-136-5
  5-53-89-85-68-47-15 29                                                RC-136-6
SPEAKER ID-RMC-M/PHONEME ID- 2/PITCH-148-BN/PITCH PERIOD-  6.74 MS/      RC-137-0
 -9 33 65 62 27 -8-22 -7 18 36 46 54 64 71 63 39 17 12 17 20 15  5  1 11RC-137-1
 23 20  0-23-40-45-41-35-25-10  3  8 -2-22-38-40-26 -5 14 26 31 30 22 11RC-137-2
  3  3 12 25 35 37 32 23 14  5  0 -3 -3 -1  2  3  0 -5-12-18-21-21-19-14RC-137-3
 -9 -3 -1 -2 -6-10-12 -9 -2  5 12 17 18 16 12  8  7  9 14 19 23 24 21 16RC-137-4
 10  6  3  3  3  5  6  4  1 -1 -4 -5 -5 -5 -3 -3 -9-25-59-93-99-72-31  8RC-137-5
 19 -5-40-62-72-71-55-24                                                RC-137-6
SPEAKER ID-RMC-M/PHONEME ID- 2/PITCH-168-NN/PITCH PERIOD-  5.96 MS/      RC-138-0
-16 15 34 47 62 77 80 66 38  9  0 13 41 62 68 64 57 54 55 51 34  6-19-34RC-138-1
-32-16  0 10 10  2 -8-22-38-58-75-80-71-48-19  4 11  2-13-31-41-40-33-19RC-138-2
  0 22 44 56 55 42 23 10  6 13 26 37 45 49 49 44 35 22  6 -5 -9 -4  1  6RC-138-3
  7  4  0 -5-11-19-27-30-28-20 -9  0  6  8  6  3  0 -1 -3  0  6 18 28 36RC-138-4
 38 36 29 16-12-52-83-88-68-28 17 42 32 -2-42-75-93-99-96-88-63-20 25 49RC-138-5
 38  1-43-71-68-42 -7 20                                                RC-138-6
SPEAKER ID-RMC-M/PHONEME ID- 2/PITCH-195-AN/PITCH PERIOD-  5.13 MS/      RC-139-0
 -8  9 25 35 35 26 13  0-12-20-18 -4 16 36 50 59 61 58 52 48 45 39 28 14RC-139-1
  1 -6 -8 -4  7 21 31 33 27 14 -2-19-33-42-45-44-39-29-16 -3  4  6  2 -6RC-139-2
-16-25-29-27-19 -8  3 15 25 30 32 29 23 16  8  2  0  2  7 15 23 31 37 39RC-139-3
 37 31 23 14  7  2  1  3  8 13 17 18 17 12  6 -1 -8-16-20-20-17-10 -2  3RC-139-4
  7  9  8  6  4  2  1  2  4  6  9  8  3-12-40-72-94-99-86-60-26  5 23 18RC-139-5
 -7-41-70-88-90-78-54-29                                                RC-139-6
SPEAKER ID-RMC-M/PHONEME ID- 2/PITCH-217-AN/PITCH PERIOD-  4.61 MS/      RC-140-0
-13  9 28 42 52 55 51 40 25 13  7  6  9 16 26 38 50 58 63 64 62 60 54 46RC-140-1
 35 20  4-10-23-31-34-33-27-17 -6  1  3  0 -6-17-30-45-59-70-73-71-64-52RC-140-2
-35-14  4 17 23 25 21 12  3 -3 -4 -3  2 12 26 40 51 58 61 60 54 43 31 21RC-140-3
 13  7  4  4  6 11 16 20 22 24 23 21 18 15 12 11 10 10 10 12 14 15 15 15RC-140-4
 15 15 15 13 11  6  0-10-28-52-76-92-99-98-89-70-45-20 -3  1 -4-20-42-63RC-140-5
-79-86-84-73-54-28 -2 19                                                RC-140-6
SPEAKER ID-RMC-M/PHONEME ID- 2/PITCH-232-AN/PITCH PERIOD-  4.31 MS/      RC-141-0
  5 19 28 34 37 37 35 30 24 18 14 11 11 14 18 26 34 43 49 52 52 48 43 35RC-141-1
 24 13  0-11-22-31-36-37-33-25-15 -5  0  3  1 -6-18-31-44-54-61-61-54-42RC-141-2
-28-13  0 12 21 26 27 24 20 16 12 10  9 11 15 21 28 35 41 45 47 46 42 36RC-141-3
 29 21 13  6  2  0  0  2  7 13 20 27 33 38 40 40 35 27 18 11  5  1 -2 -2RC-141-4
  1  7 14 20 21 17  7 -7-27-52-74-90-99-97-87-71-51-29-11 -1 -2-12-28-46RC-141-5
-61-71-73-68-56-41-24 -7                                                RC-141-6
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TABLE XI (Continued)

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SPEAKER ID-RMC-M/PHONEME ID- 4/PITCH-122-BN/PITCH PERIOD-  8.19 MS/      RC-142-0
 -2 39 32 -9-34-19 14 46 56 54 52 54 54 46 46 63 83 89 73 57 50 45 39 38RC-142-1
 49 57 44 14-14-19 -5  8 10 -2-20-37-49-46-31-20-25-41-51-47-37-28-22-16RC-142-2
-13-15-14 -6  5 15 20 23 25 26 27 30 38 45 48 42 33 28 30 34 34 30 23 13RC-142-3
  3 -1  1  4  1 -8-20-24-23-20-18-20-22-27-29-28-24-18-18-19-20-20-16-14RC-142-4
-10 -8 -7 -7 -8 -6 -4  1  1  1  5  4  0-20-45-58-41  0 21 -4-63-99-77-31RC-142-5
 -5-11-27-44-61-69-45  1                                                RC-142-6
SPEAKER ID-RMC-M/PHONEME ID- 4/PITCH-135-BN/PITCH PERIOD-  7.40 MS/      RC-143-0
-14 26 30  6-15-17 -7  5 17 26 38 53 60 52 34 20 28 49 64 65 58 56 59 49RC-143-1
 24  3  9 39 62 54 24 -3-12-11-13-15 -6  6  8-11-42-59-56-43-28-18-14-18RC-143-2
-33-51-57-46-21  0 12  6 -8-20-24-15  3 24 38 39 25  6  0  8 25 40 45 40RC-143-3
 30 19  8  5 10 21 28 26 14  0 -8-10 -8 -3  0  0  0 -4-13-19-18-12 -5  0RC-143-4
  0 -1 -3 -4 -8 -7 -2  3  8 10  6  0-16-46-69-54 -9 36 36-20-81-99-74-36RC-143-5
-16-14-10-10-33-68-84-60                                                RC-143-6
SPEAKER ID-RMC-M/PHONEME ID- 4/PITCH-143-BN/PITCH PERIOD-  7.00 MS/      RC-144-0
  3 24 22 12 10 18 22 19 18 28 46 64 72 70 66 66 69 66 53 37 33 44 65 79RC-144-1
 74 50 21  1 -5 -3  1  8 15 19 12 -7-36-57-58-41-20-11-16-28-39-45-46-42RC-144-2
-31-14  0  4  0 -6 -9 -3  6 15 20 23 25 27 28 27 25 24 24 25 26 28 29 29RC-144-3
 26 19 11  3 -1  0  4  7  7  3 -5-14-20-22-17 -8 -1  1  0 -3 -7 -8 -5  0RC-144-4
  7 13 15 12  8  5  8 14 16  4-27-65-76-53 -9 24 22-18-68-96-99-86-70-48RC-144-5
-25 -5 -6-34-75-96-78-33                                                RC-144-6
SPEAKER ID-RMC-M/PHONEME ID- 4/PITCH-148-BN/PITCH PERIOD-  6.77 MS/      RC-145-0
  4 31 26  4 -9 -8  8 26 28 17 11 23 50 75 77 57 30 17 24 40 50 52 54 62RC-145-1
 70 60 26-12-27 -9 26 52 50 20-13-28-29-29-28-26-21-10 -5-15-34-50-53-43RC-145-2
-32-25-23-19-13 -6 -8-18-24-24-13  3 16 21 21 15  6  2  1  6 19 32 40 38RC-145-3
 28 14  6  4 10 18 23 23 20 12  4 -2 -6 -7 -2  2  4  4  0 -3 -4 -3 -2 -1RC-145-4
 -2  0  2  6  8  5 -4-32-68-79-61-15 33 43  0-57-96-99-65-30-15-12-13-16RC-145-5
-25-46-67-69-45 -9 27 29                                                RC-145-6
SPEAKER ID-RMC-M/PHONEME ID- 4/PITCH-167-NN/PITCH PERIOD-  5.99 MS/      RC-146-0
 -9  6 11 10 16 26 32 27 15  2  2 17 44 67 76 71 56 45 44 46 44 39 35 40RC-146-1
 57 77 87 74 45 18  4  7 22 34 36 33 29 24 18  4-12-27-31-21 -5  7  9 -1RC-146-2
-19-35-43-45-42-35-28-21-17-15-18-27-37-43-42-33-20 -9 -2 -2 -5 -9-10-10RC-146-3
 -9 -7 -2  6 16 24 28 25 18 12  9 12 17 23 29 34 36 35 32 26 18 10  0-16RC-146-4
-35-33-15 13 40 46 17-34-82-99-83-51-15  1 -4-21-36-52-68-84-95-89-58-20RC-146-5
 11 18 -3-39-66-68-47-20                                                RC-146-6
SPEAKER ID-RMC-M/PHONEME ID- 4/PITCH-193-AN/PITCH PERIOD-  5.18 MS/      RC-147-0
 -4  6 14 18 13  5  2 10 25 42 51 53 53 49 45 47 51 50 43 36 34 39 51 66RC-147-1
 80 82 69 46 25 14 14 25 38 44 43 41 36 29 23 16  5 -7-15-14 -5  9 20 22RC-147-2
 15 -2-20-29-29-26-19-13-10-10 -9 -8 -7 -9-14-21-26-25-19 -6  5 13 14 10RC-147-3
  3 -1  0  4  9 12 17 22 24 25 22 13 -4-33-56-46-14 17 45 62 54 14-38-82RC-147-4
-99-81-47-18  5 15  5-15-37-56-73-80-81-84-75-50-22 -3  0 -8-29-57-78-79RC-147-5
-58-27 -6  0  0 -5-12-11                                                RC-147-6
SPEAKER ID-RMC-M/PHONEME ID- 4/PITCH-215-AN/PITCH PERIOD-  4.66 MS/      RC-148-0
 -8  1 16 32 43 43 32 18  8  5  8 14 23 31 38 45 52 59 67 72 68 53 31 11RC-148-1
 -1 -2  7 26 47 64 70 62 46 29 14  2 -5 -9 -9 -5  0  7 15 24 28 25 14 -2RC-148-2
-19-30-33-28-19 -8  0  4  3  0 -4 -6 -6 -6 -8 -9 -9 -7 -4  1  9 15 19 20RC-148-3
 19 18 18 17 18 20 21 18 10 -6-29-46-46-30 -4 23 48 60 47 14-31-70-91-92RC-148-4
-77-54-27 -5  5  3 -5-18-32-45-61-80-95-99-85-59-27  0 14 12 -3-28-50-60RC-148-5
-53-35-17 -7 -5 -7 -8 -7                                                RC-148-6
SPEAKER ID-RMC-M/PHONEME ID- 4/PITCH-232-AN/PITCH PERIOD-  4.31 MS/      RC-149-0
 -6  8 28 48 61 63 57 43 30 18 11  9  9 12 19 31 47 61 73 79 77 64 45 25RC-149-1
  8 -1 -6 -3  6 21 37 50 56 54 44 28 10 -5-17-22-23-19-11 -2  5 11 14 12RC-149-2
  6 -1 -9-13-13 -9 -4  0  6 11 15 19 19 16 14 16 18 22 26 31 36 40 42 39RC-149-3
 31 16 -6-33-52-55-38-10 21 49 65 65 47 16-20-56-84-99-97-83-59-31 -9  2RC-149-4
  3 -6-22-39-56-70-82-91-95-89-76-57-37-21-13-14-20-29-35-37-35-27-18 -8RC-149-5
 -1  0 -3 -9-13-12 -2 14                                                RC-149-6
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TABLE XI (Continued)

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SPEAKER ID-RMC-M/PHONEME ID- 7/PITCH-118-BN/PITCH PERIOD-  8.50 MS/     RC-150-0
  4 17 37 62 83 96 99 97 93 85 77 67 54 41 25 11  2 -3 -6-13-25-35-41-40RC-150-1
-39-46-56-60-54-42-35-30-21 -5 12 28 42 56 63 67 69 68 66 58 45 30 14  4RC-150-2
 -2-12-26-39-46-46-46-48-51-52-49-43-37-29-21-12 -1 10 24 37 46 50 51 53RC-150-3
 54 49 40 28 17 10  3 -4-12-17-20-21-22-23-24-26-27-27-25-22-19-16-11 -4RC-150-4
  4 13 19 23 28 32 34 33 28 23 17 12  6  0 -8-13-18-20-22-25-29-36-46-59RC-150-5
-69-72-70-70-74-73-55-29                                                RC-150-6
SPEAKER ID-RMC-M/PHONEME ID- 7/PITCH-134-BN/PITCH PERIOD-  7.49 MS/     RC-151-0
-13 19 46 58 72 90 99 98 96 86 73 57 36 18  7  0 -5-11-23-31-35-33-28-29RC-151-1
-38-51-55-49-37-27-23-18 -2 20 41 58 71 80 88 87 77 68 60 46 26  2-21-35RC-151-2
-42-46-49-55-61-58-48-35-25-23-24-21-15 -8  0  6 14 21 28 35 46 57 61 54RC-151-3
 42 30 21 11 -1-14-27-36-40-37-29-19-12 -6  0  3  9 14 16 11  3  0  0  4RC-151-4
  7  9 11 15 19 22 25 27 24 17  9  1 -5 -8-14-21-27-33-36-37-43-57-76-88RC-151-5
-91-84-71-68-69-55-25  7                                                RC-151-6
SPEAKER ID-RMC-M/PHONEME ID- 7/PITCH-141-BN/PITCH PERIOD-  7.08 MS/     RC-152-0
  5 23 44 65 77 80 79 76 74 64 45 24  9  3  2  2 -2 -8-12-11 -7 -1  0 -5RC-152-1
-15-26-33-37-41-45-46-43-35-26-15 -1 18 41 61 70 71 70 73 75 69 53 30 10RC-152-2
 -5-18-31-43-51-54-55-55-51-44-32-20-12 -9 -7 -3  3  9 12 12 14 16 19 21RC-152-3
 22 24 26 25 20 13  7  5  3  0 -6-10-13-11 -8 -4  0  4  7  8  7  6  7  6RC-152-4
  2 -3 -9-11-11 -8 -6 -2  2  7 12 16 20 24 27 26 21 13  4-12-39-65-81-87RC-152-5
-87-90-98-99-83-56-26 -2                                                RC-152-6
SPEAKER ID-RMC-M/PHONEME ID- 7/PITCH-148-BN/PITCH PERIOD-  6.75 MS/     RC-153-0
 -8 16 39 58 73 85 94 97 93 83 71 53 30 14 10  5 -2 -7 -9-14-15 -6  0  1RC-153-1
 -1 -8-17-25-32-38-42-44-46-46-39-28-15  2 25 46 59 68 76 79 78 73 65 49RC-153-2
 27  5-13-28-40-48-51-52-52-47-36-23-11 -1  6 11 12 11 11 12 11  9  7  5RC-153-3
  3  4  8 13 16 16 15 12  7  3  1  0 -4 -9-12-12-10 -5  1  7 11 14 15 15RC-153-4
 14 13 12  7  1 -4 -9-12-13-11 -8 -5 -1  1  4  8 10  0-24-43-54-70-86-88RC-153-5
-90-99-97-84-64-38-11 14                                                RC-153-6
SPEAKER ID-RMC-M/PHONEME ID- 7/PITCH-168-NN/PITCH PERIOD-  5.96 MS/     RC-154-0
 -1 12 27 43 61 77 89 97 99 94 84 75 67 55 40 29 24 16  5 -4-12-19-21-19RC-154-1
-15-15-16-22-30-36-37-37-36-37-41-44-44-43-38-26-11  2 14 27 39 47 56 64RC-154-2
 72 76 74 68 57 42 28 14  2 -8-17-25-32-39-44-43-36-28-19-10 -3  0  3  6RC-154-3
  8 10 12 13 10  5  0 -4 -6 -5 -1  1  4  5  6  7  9 12 14 17 19 18 15 13RC-154-4
 10  8  7  7  6  5  3  0 -2 -4 -3 -3 -2 -1  0 -1 -5-18-37-50-54-59-67-71RC-154-5
-73-79-84-82-72-57-39-20                                                RC-154-6
SPEAKER ID-RMC-M/PHONEME ID- 7/PITCH-193-AN/PITCH PERIOD-  5.19 MS/     RC-155-0
 -2 14 29 42 56 69 80 88 90 87 80 71 61 49 38 28 19 11  3 -2 -8-13-16-15RC-155-1
-13-11 -8 -4 -2 -1 -2 -5 -8-12-18-23-28-33-38-43-48-52-53-51-45-35-25-13RC-155-2
  0 13 26 38 49 57 64 70 72 71 66 58 47 35 23 12  2 -7-16-23-28-31-32-30RC-155-3
-27-23-16 -8  0  5 10 14 16 17 18 18 16 13  9  4  0 -3 -5 -6 -7 -7 -5 -2RC-155-4
  1  5  8 11 15 20 26 30 32 33 33 32 29 20  7 -7-22-38-51-62-73-82-90-95RC-155-5
-98-99-95-85-71-54-35-16                                                RC-155-6
SPEAKER ID-RMC-M/PHONEME ID- 7/PITCH-213-AN/PITCH PERIOD-  4.70 MS/     RC-156-0
  0 14 29 44 58 73 84 92 95 98 99 96 91 83 73 61 49 36 24 14  5 -3-12-20RC-156-1
-27-33-38-40-40-39-37-34-31-30-31-33-34-35-35-36-38-38-39-40-41-38-34-29RC-156-2
-23-14 -3  8 21 35 47 57 65 71 75 77 76 72 67 60 51 40 27 14  1-11-21-29RC-156-3
-33-35-35-32-26-19-11 -3  6 16 26 36 45 53 57 57 54 48 40 30 21 12  3 -4RC-156-4
-11-17-21-25-27-27-26-24-23-24-24-27-33-41-46-49-53-58-63-68-74-81-84-84RC-156-5
-82-77-69-57-44-30-17 -2                                                RC-156-6
SPEAKER ID-RMC-M/PHONEME ID- 7/PITCH-230-AN/PITCH PERIOD-  4.34 MS/     RC-157-0
 17 32 46 59 72 83 91 96 99 98 94 87 78 65 51 37 22  8 -6-20-33-42-50-55RC-157-1
-58-59-55-49-41-32-20 -6  8 22 35 48 57 64 69 73 75 73 67 60 53 45 35 24RC-157-2
 13  2 -8-22-37-48-56-63-71-80-85-86-85-85-84-82-79-74-69-64-58-52-45-37RC-157-3
-27-19-13 -9 -2  5 13 18 23 28 35 41 47 52 57 60 63 65 66 67 65 63 61 60RC-157-4
 57 52 46 40 32 24 15  6 -2-11-20-29-37-44-51-58-64-70-74-78-81-82-82-79RC-157-5
-75-68-59-48-37-25-11  4                                                RC-157-6
```

TABLE XI (Continued)

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SPEAKER ID-RMC-M/PHONEME ID- 9/PITCH-118-BN/PITCH PERIOD-  8.50 MS/     RC-158-0
 -6 10 22 30 37 43 45 49 59 74 90 97 99 95 90 85 79 74 68 60 52 42 34 26RC-158-1
 20 14  1-15-33-44-48-50-51-51-51-54-62-67-66-61-57-56-53-45-34-23-11 -1RC-158-2
  6 10 11 14 23 34 43 48 51 52 52 51 49 47 44 38 31 25 23 21 17  9  0 -9RC-158-3
-17-24-28-29-30-31-33-35-35-33-31-29-27-24-20-14 -8 -2  3  7  8  9 11 14RC-158-4
 17 19 19 19 17 14 12 10 10  7  3 -2-10-22-40-62-73-72-62-53-52-53-55-59RC-158-5
-67-70-62-49-40-34-25-10                                                RC-158-6
SPEAKER ID-RMC-M/PHONEME ID- 9/PITCH-127-BN/PITCH PERIOD-  7.85 MS/     RC-159-0
 -2  7 16 33 48 66 79 87 95 94 80 56 36 29 34 48 62 70 75 67 48 24  0-16RC-159-1
-26-32-37-41-43-45-43-38-32-27-28-34-43-49-51-44-28 -6 15 33 41 43 41 35RC-159-2
 31 30 30 31 31 32 33 35 37 35 31 24 12 -2-15-24-26-22-17-12 -9 -9-13-19RC-159-3
-26-29-29-28-25-21-15 -8  0  7 13 17 18 15 11  7  5  7 10 14 17 19 17 13RC-159-4
  8  3  0 -4 -8-11-12-13-12-11-10 -7 -5 -8-18-34-59-85-99-98-84-59-38-22RC-159-5
 -9 -9-16-31-43-38-24 -7                                                RC-159-6
SPEAKER ID-RMC-M/PHONEME ID- 9/PITCH-139-BN/PITCH PERIOD-  7.20 MS/     RC-160-0
 -2  4  9 11 15 20 27 39 53 68 85 95 96 90 78 60 44 31 23 22 23 25 23 18RC-160-1
 13  8  1 -4-12-22-30-41-54-64-66-62-53-40-26-15 -8 -4 -6 -9-10 -8 -2  4RC-160-2
 13 23 32 40 47 52 54 54 51 43 32 22 11  5  1  1  2  3  2  0 -3-10-17-23RC-160-3
-27-31-33-34-33-30-25-18-10 -2  2  6  8  8  6  6  6  9 12 16 19 23 24 23RC-160-4
 23 20 17 12  6  2 -3 -9-12-16-17-16-15-13-13-20-39-62-82-96-99-89-78-62RC-160-5
-43-27-16-13-15-15 -9 -5                                                RC-160-6
SPEAKER ID-RMC-M/PHONEME ID- 9/PITCH-146-BN/PITCH PERIOD-  6.84 MS/     RC-161-0
 -4 11 34 54 67 75 77 73 68 62 55 56 63 75 87 94 95 89 78 67 56 42 29 17RC-161-1
  4 -8-18-29-36-38-37-35-35-40-49-57-65-68-67-63-53-42-30-17 -8  0  8 16RC-161-2
 23 30 33 34 34 35 36 40 45 49 52 51 47 41 32 23 16  8  3  0 -4 -8-12-17RC-161-3
-20-21-22-24-26-30-33-35-35-32-27-20-11 -4  1  6  8 10 11 14 16 17 19 19RC-161-4
 20 22 25 26 28 28 26 23 18 11 -3-32-61-83-98-99-86-73-61-50-46-45-48-57RC-161-5
-66-70-66-55-42-32-21-10                                                RC-161-6
SPEAKER ID-RMC-M/PHONEME ID- 9/PITCH-170-NN/PITCH PERIOD-  5.89 MS/     RC-162-0
  0  6 17 31 47 59 67 71 70 65 55 43 33 26 24 25 31 37 41 41 37 30 23 16RC-162-1
 11  5  1 -2 -7-14-22-29-34-37-37-33-26-19-12 -8 -7 -8-13-16-19-19-15 -8RC-162-2
 -2  4 11 15 20 23 26 30 34 38 39 38 35 31 25 19 13 10  8 10 12 14 14 12RC-162-3
  7  1 -5-11-15-17-17-16-14-12 -8 -6 -4 -1  0  1  4  5  6  5  4  2  1  0RC-162-4
  1  3  7 13 15 14  6 -8-31-57-79-93-99-94-80-65-50-38-29-25-25-29-34-39RC-162-5
-39-34-29-21-14-11 -2  3                                                RC-162-6
SPEAKER ID-RMC-M/PHONEME ID- 9/PITCH-191-AN/PITCH PERIOD-  5.24 MS/     RC-163-0
 -6  2 10 19 29 39 49 56 60 61 59 54 49 45 43 43 46 50 55 59 63 63 62 58RC-163-1
 52 43 34 26 20 15 11  7  3  0 -4 -9-13-16-18-20-22-25-27-31-34-37-39-42RC-163-2
-42-41-39-35-29-23-17-12 -8 -6 -3 -1  0  4  7 12 17 22 26 29 32 34 35 37RC-163-3
 39 40 41 41 40 38 36 33 31 29 27 25 23 21 19 17 15 11  8  4  0 -1 -3 -3RC-163-4
 -4 -5 -6 -9-14-23-37-54-70-85-95-99-95-86-73-60-50-45-43-44-46-48-51-53RC-163-5
-54-53-49-42-33-23-13 -4                                                RC-163-6
SPEAKER ID-RMC-M/PHONEME ID- 9/PITCH-211-AN/PITCH PERIOD-  4.73 MS/     RC-164-0
  0  7 13 17 19 19 18 16 14 13 13 14 19 26 35 43 52 60 67 72 74 75 74 72RC-164-1
 69 64 57 47 35 22  8 -3-14-23-29-31-31-30-27-24-22-20-18-16-15-16-17-18RC-164-2
-19-20-22-25-27-29-31-30-28-24-19-11 -2  6 14 22 28 32 33 34 33 31 29 27RC-164-3
 25 24 22 21 20 21 22 23 26 29 34 38 43 46 48 47 45 40 33 26 17  9  2 -4RC-164-4
 -9-12-13-15-16-15-14-13-12-12-15-22-34-46-59-71-83-92-97-99-97-93-89-83RC-164-5
-77-69-60-48-36-23-11  0                                                RC-164-6
SPEAKER ID-RMC-M/PHONEME ID- 9/PITCH-242-AN/PITCH PERIOD-  4.13 MS/     RC-165-0
 -9  4 17 27 35 39 40 41 43 44 46 47 46 42 37 31 24 17 10  6  5  7 13 21RC-165-1
 32 45 58 70 81 90 95 97 95 91 85 75 64 52 41 31 19  8 -1-12-21-28-34-37RC-165-2
-37-34-27-18 -8  1 12 21 27 30 29 27 23 18 13  8  2 -2 -8-12-15-18-20-21RC-165-3
-20-18-14 -9 -3  3 11 20 28 34 40 44 45 42 35 21  2-20-43-62-78-91-98-99RC-165-4
-94-87-80-73-66-59-53-47-41-33-24-16 -9 -4 -2 -4 -8-15-22-30-40-51-62-69RC-165-5
-73-74-71-65-54-39-22 -6                                                RC-165-6
SPEAKER ID-PRM-F/PHONEME ID- 1/PITCH-185-NN/PITCH PERIOD-  5.42 MS/     RC-261-0
-10 31 53 54 41 26 18 15 16 16 13  8  4  1  0  2  5  5 -1-17-35-46-47-35RC-261-1
-16  3 19 26 25 18 10  4  2  4  7  8  7  7  7  9  9  8  3 -3-10-15-15-11RC-261-2
 -3  6 13 16 16 12  8  3  0  0  2  4  8  9  8  6  3  0 -1 -3 -4 -4 -3 -1RC-261-3
  0  0  0  3  7 11 12  9  7  4  2  2  3  4  5  4  2 -1 -4 -5 -4 -1  1  3RC-261-4
  4  5  6  6  7  9 10 12 12 13 13 13 13 13 13 10  6  2  0 -2 -5 -8-14-25RC-261-5
-42-64-84-99-95-70-27 18                                                RC-261-6
SPEAKER ID-OLL-M/PHONEME ID- 2/PITCH-157-AN/PITCH PERIOD-  6.30 MS/     RC-262-0
-21-19-15-11 -8 -7 -6 -6 -4 -1  4 11 19 24 26 25 25 26 27 27 28 29 33 42RC-262-1
 60 83 99 95 76 55 37 26 24 34 46 49 37 17 -2-19-36-50-54-49-43-42-49-60RC-262-2
-73-82-83-78-69-61-54-48-42-31-15  1 12 14  9  6 11 22 35 47 55 59 58 52RC-262-3
 40 30 23 21 20 18 13  4 -8-23-35-42-43-42-43-48-53-55-52-44-38-34-31-28RC-262-4
-25-21-13  0 12 22 25 23 20 18 17 19 25 31 34 31 23 15  8  4  3  2  2  0RC-262-5
 -3 -7-11-13-15-16-17-19                                                RC-262-6
```

APPENDIX B

SIMULATED RESPONSES OF COCHLEAR MODEL TO PHONEMES

In this appendix the simulated responses of the cochlear model as effected by each phonetic sound of the phoneme sample data set are documented and presented in a graphical format by Figures B.1 through B.44.

Each simulated cochlear response denoted as "Zero-Order Difference Response" is intended to represent the steady-state basilar membrane response of the biological cochlea to a voiced phonetic sound. The ordinate designation, $|V(K)|$, of the zero-order difference response is equivalent to the output voltage of the cochlear model denoted as $|V(K,t)|_{AVG}$ in Figure 4.8. The correspondence of K with a resonant frequency of the cochlear model can be found through use of Table VII in Chapter V. A given resonant frequency value may in turn be related with distance along the basilar membrane through Figure 4.2.

To the right of each zero-order difference response is the corresponding simulated cochlear response denoted as "First-Order Difference Response". This response is intended to represent the seemingly adjacent inhibition behavior of the neural fibers of the cochlea which has been suggested as the mechanism which enables acute frequency perception by the ear. The ordinate designation, D(K), of the first-order difference response is synonomous with the output designation of the cochlear model denoted as $D_{AVG}(K,t)$ in Figure 4.8. The designation "First-Order

Difference Response" is also synonomous with the phrase "neighboring difference response" frequently used in the text of this thesis.

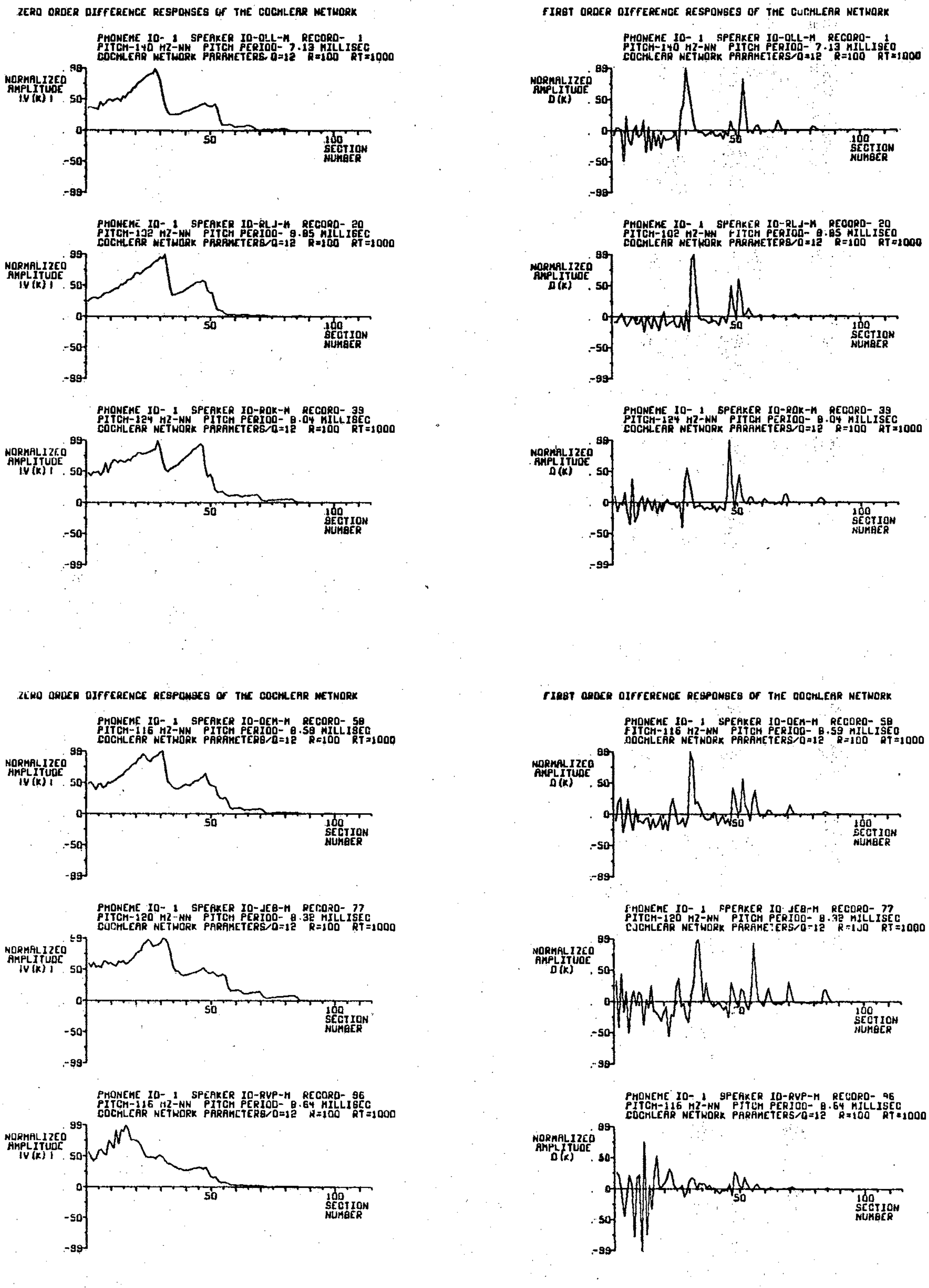


Figure B.1. Corresponding Zero and First Order Difference Responses as Effected by Phoneme (ae) of the First 6 Speakers

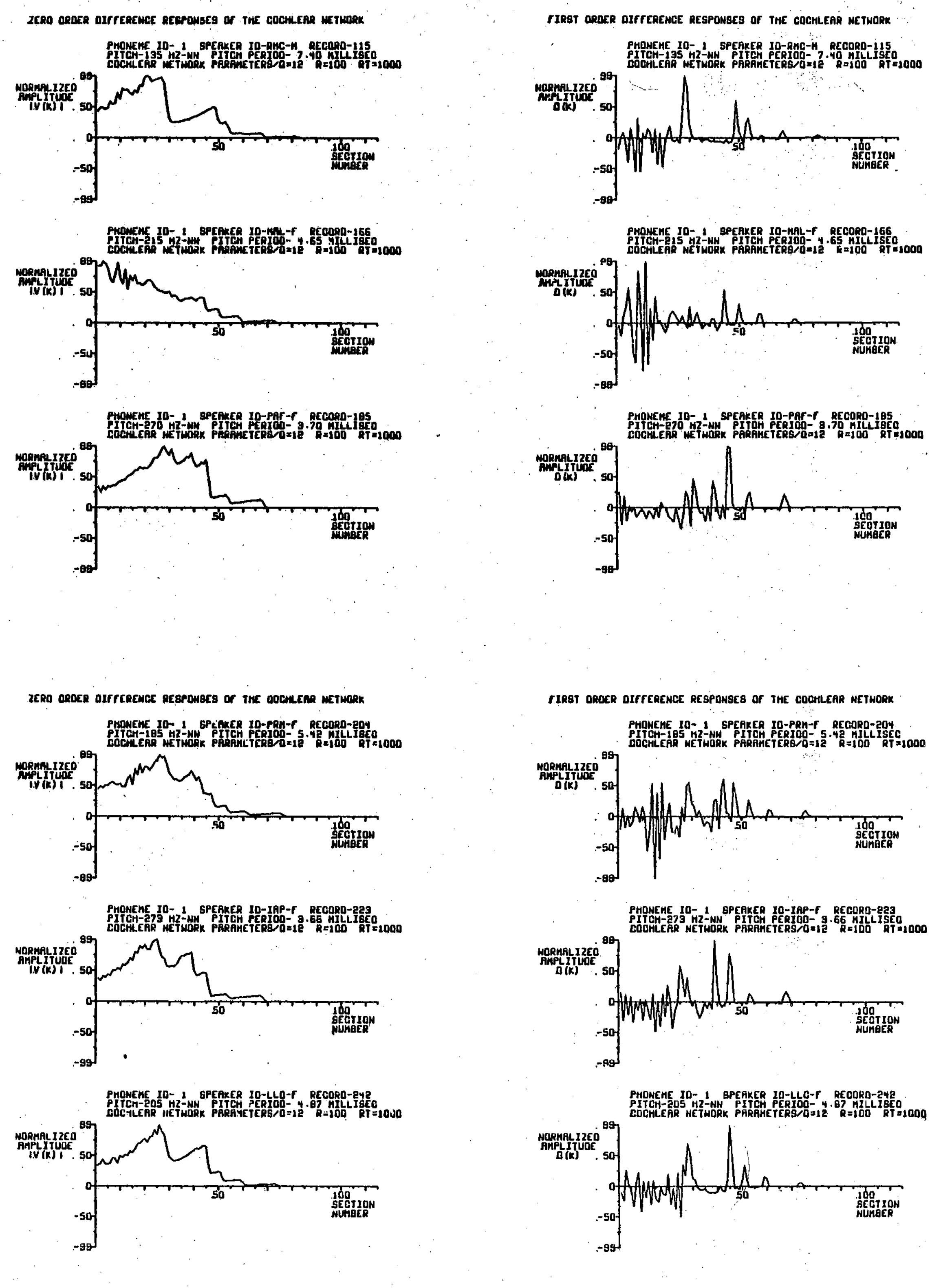


Figure B.2. Corresponding Zero and First Order Difference Responses as Effected by Phoneme (ae) of the Last 6 Speakers

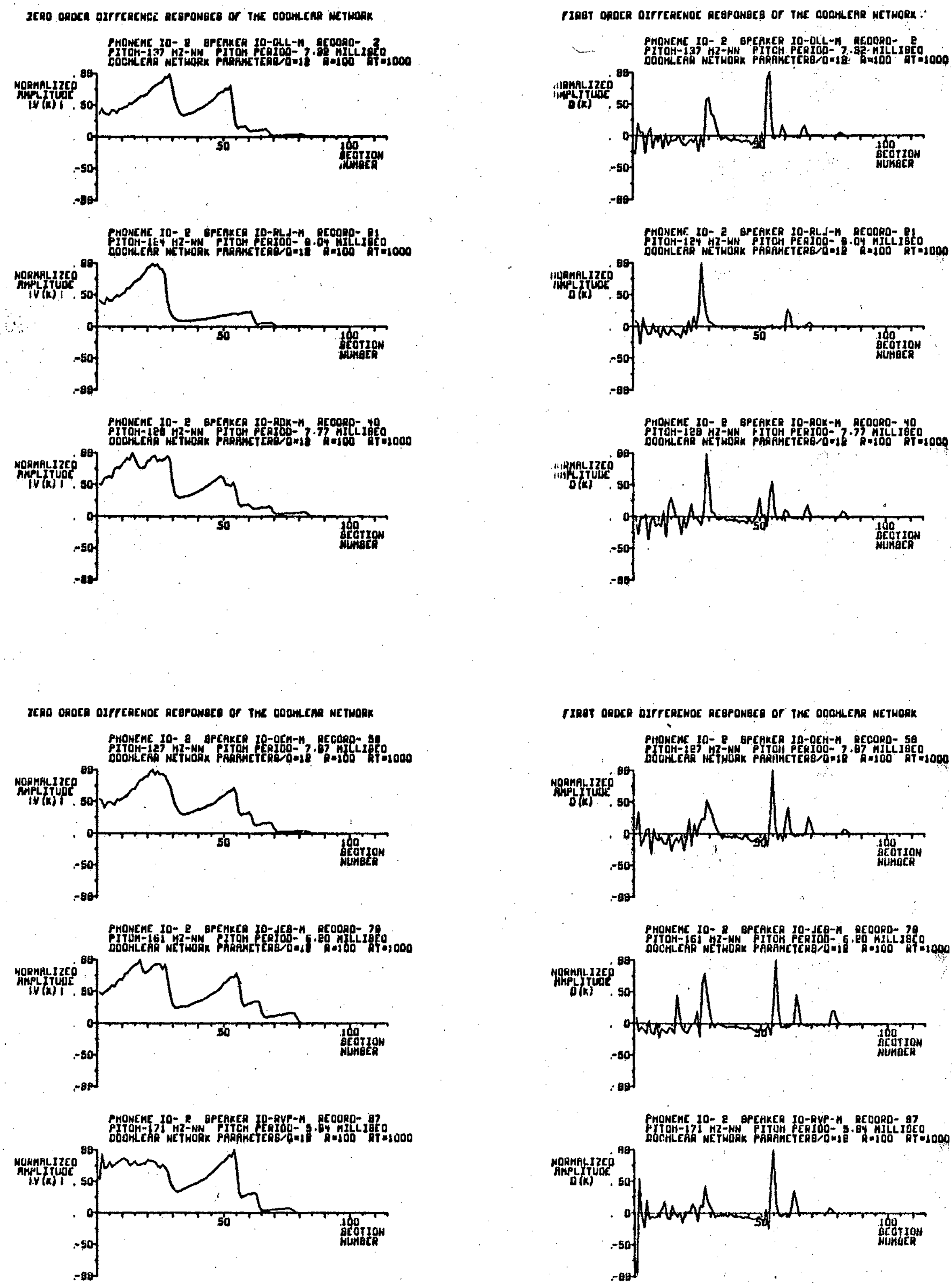


Figure B.3. Corresponding Zero and First Order Difference Responses as Effected by Phoneme (e) of the First 6 Speakers

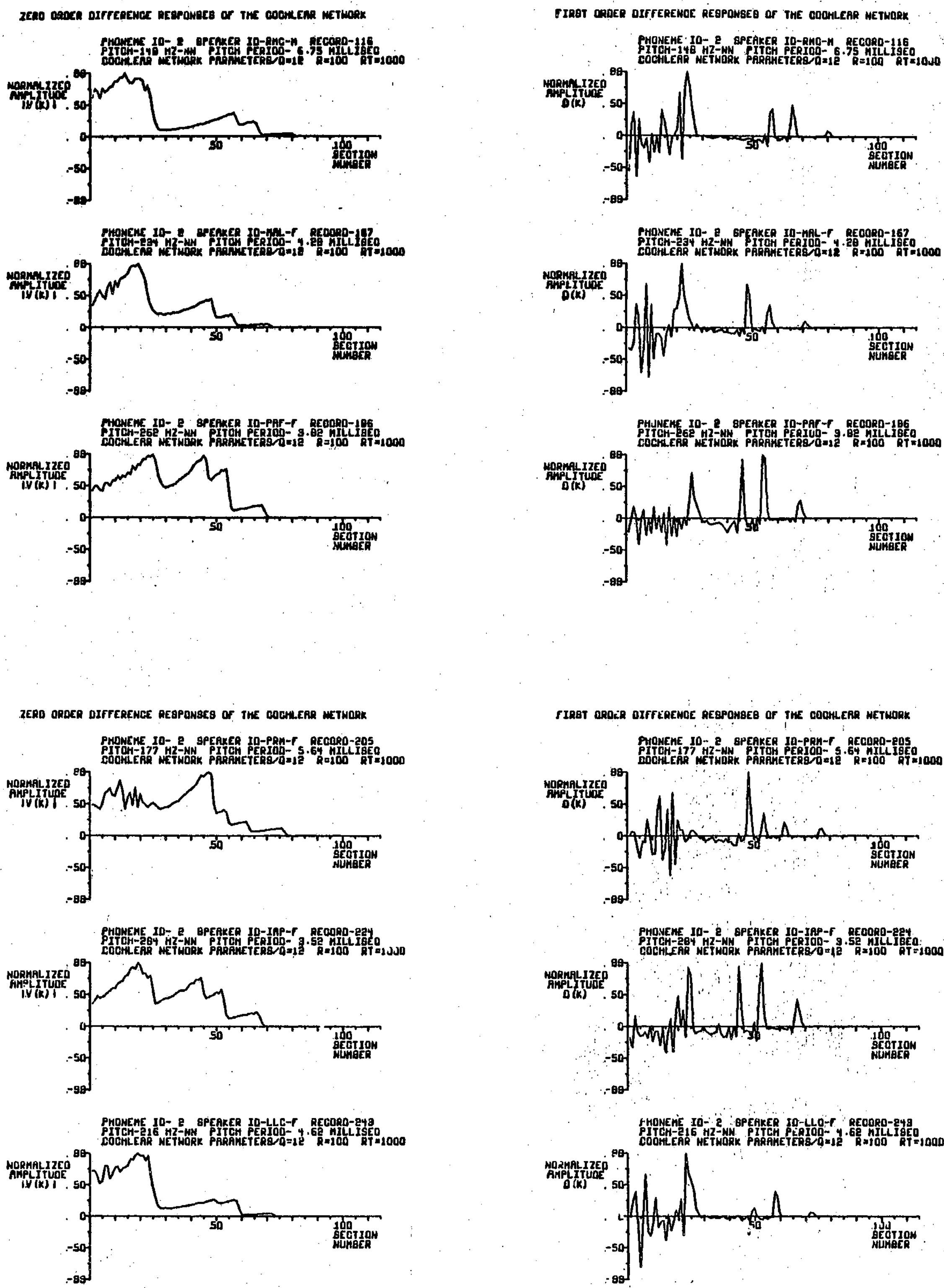


Figure B.4. Corresponding Zero and First Order Difference Responses as Effected by Phoneme (e) of the Last 6 Speakers

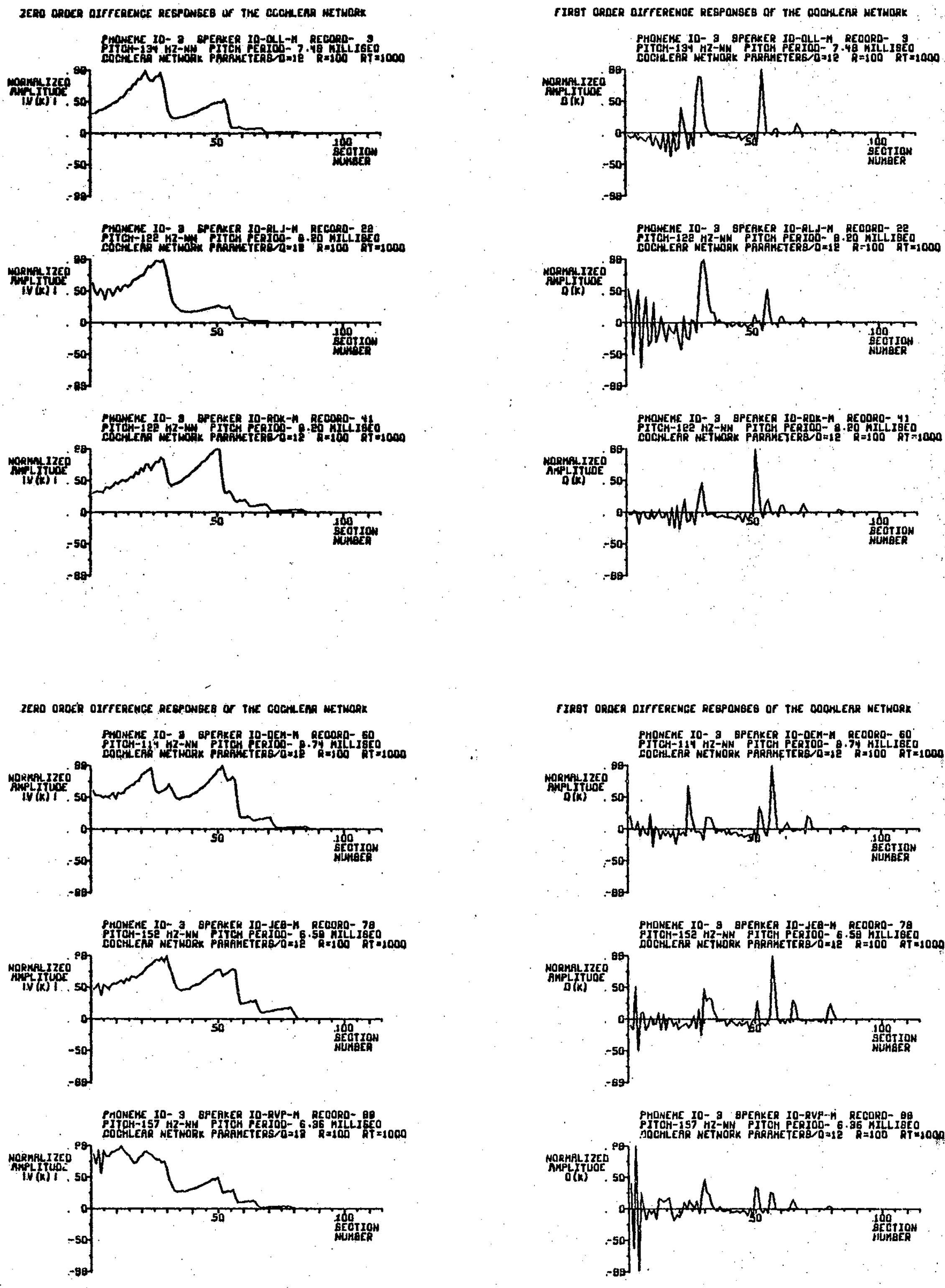


Figure B.5. Corresponding Zero and First Order Difference Responses as Effected by Phoneme (ɛ) of the First 6 Speakers

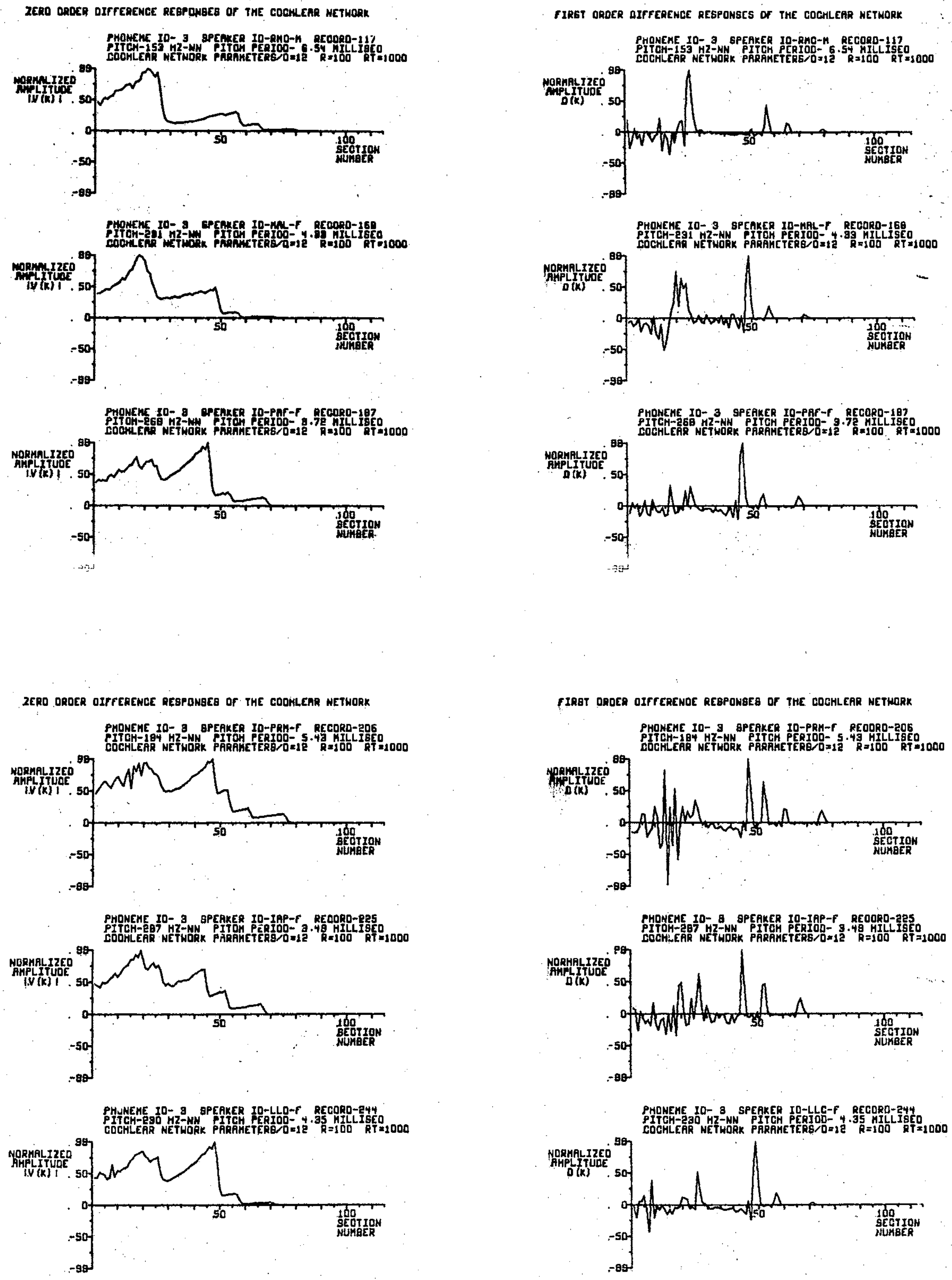


Figure B.6. Corresponding Zero and First Order Difference Responses as Effected by Phoneme (ɛ) of the Last 6 Speakers

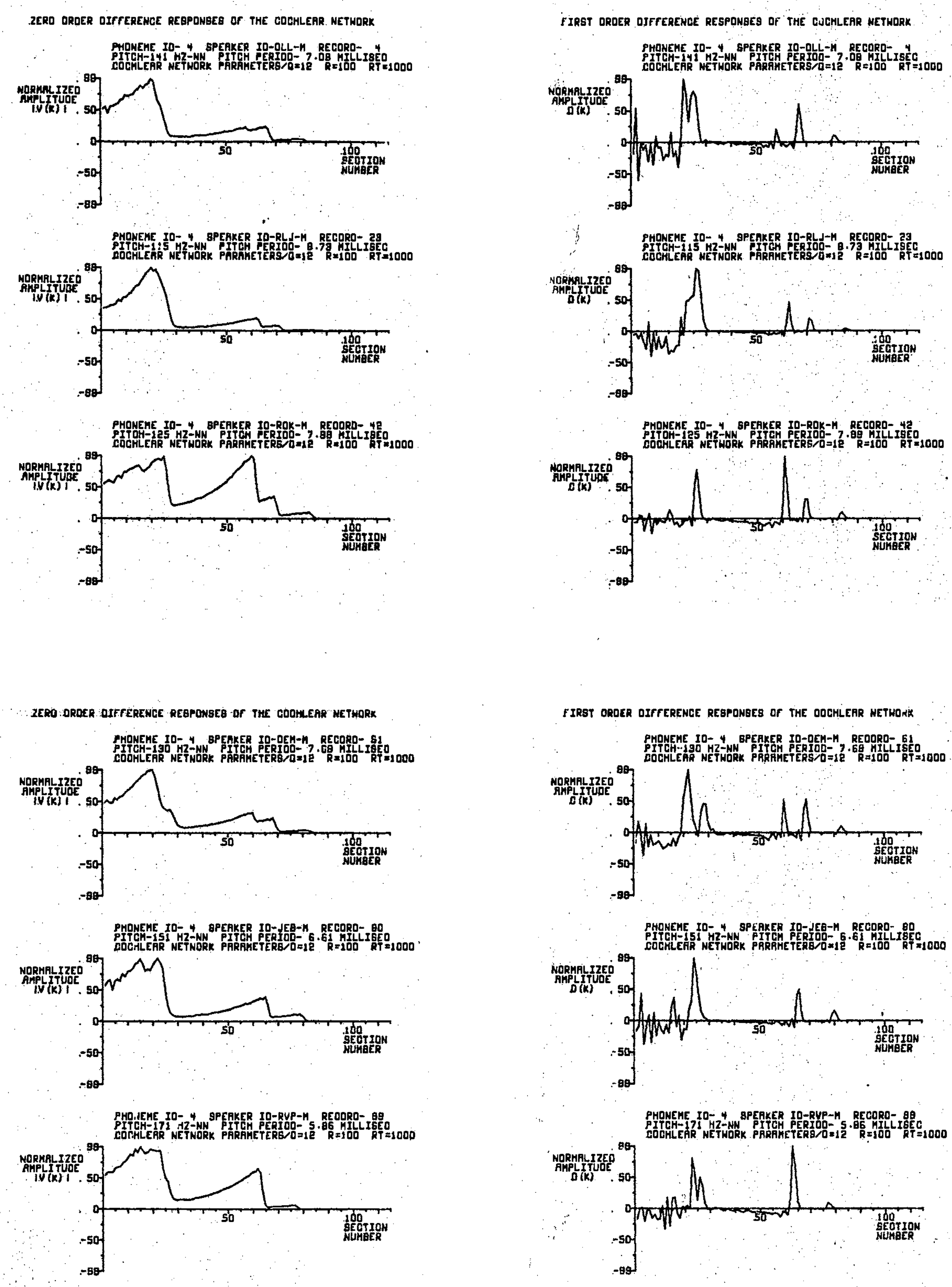


Figure B.7. Corresponding Zero and First Order Difference Responses as Effected by Phoneme (i) of the First 6 Speakers

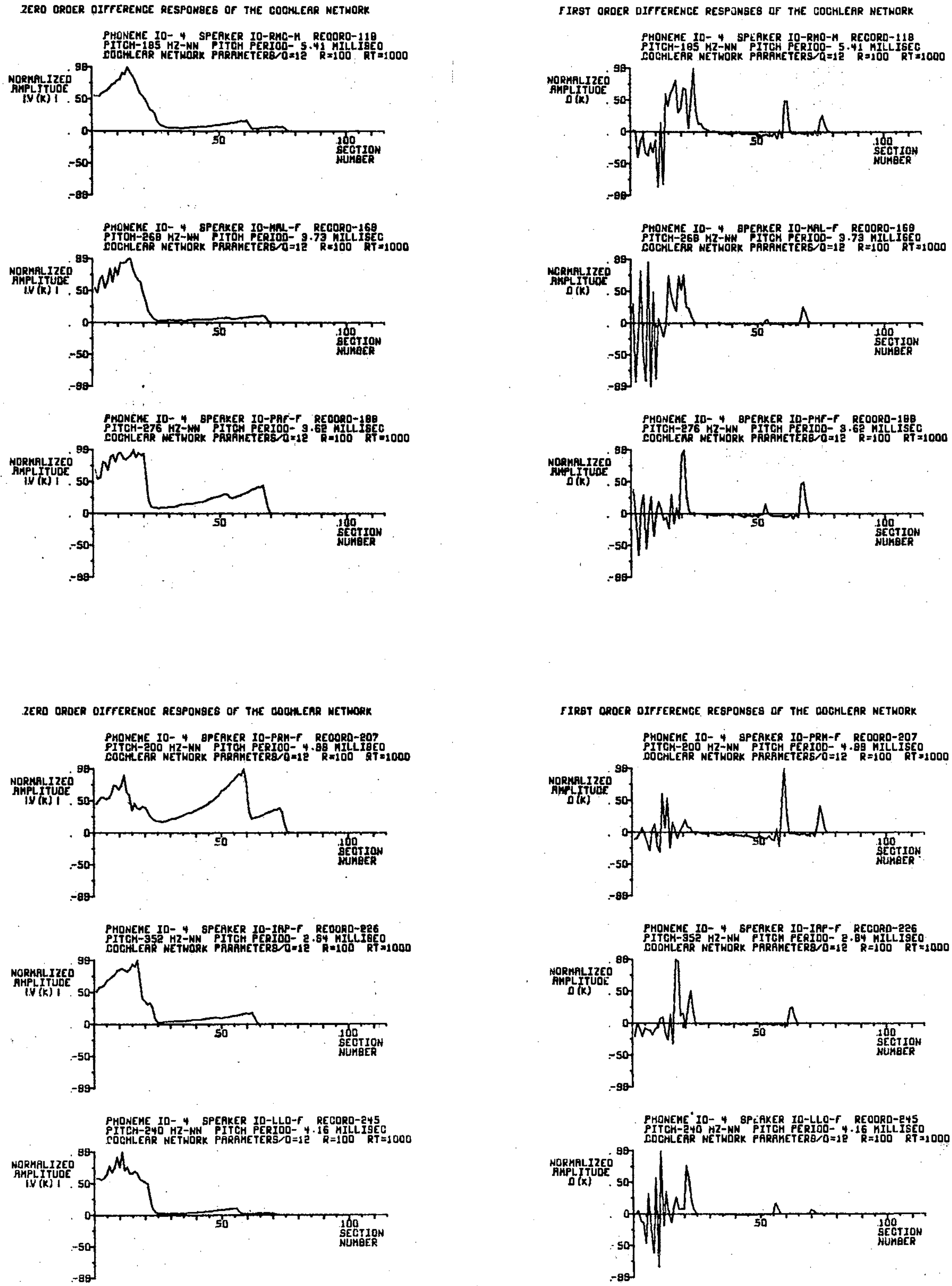


Figure B.8. Corresponding Zero and First Order Difference Responses as Effected by Phoneme (i) of the Last 6 Speakers

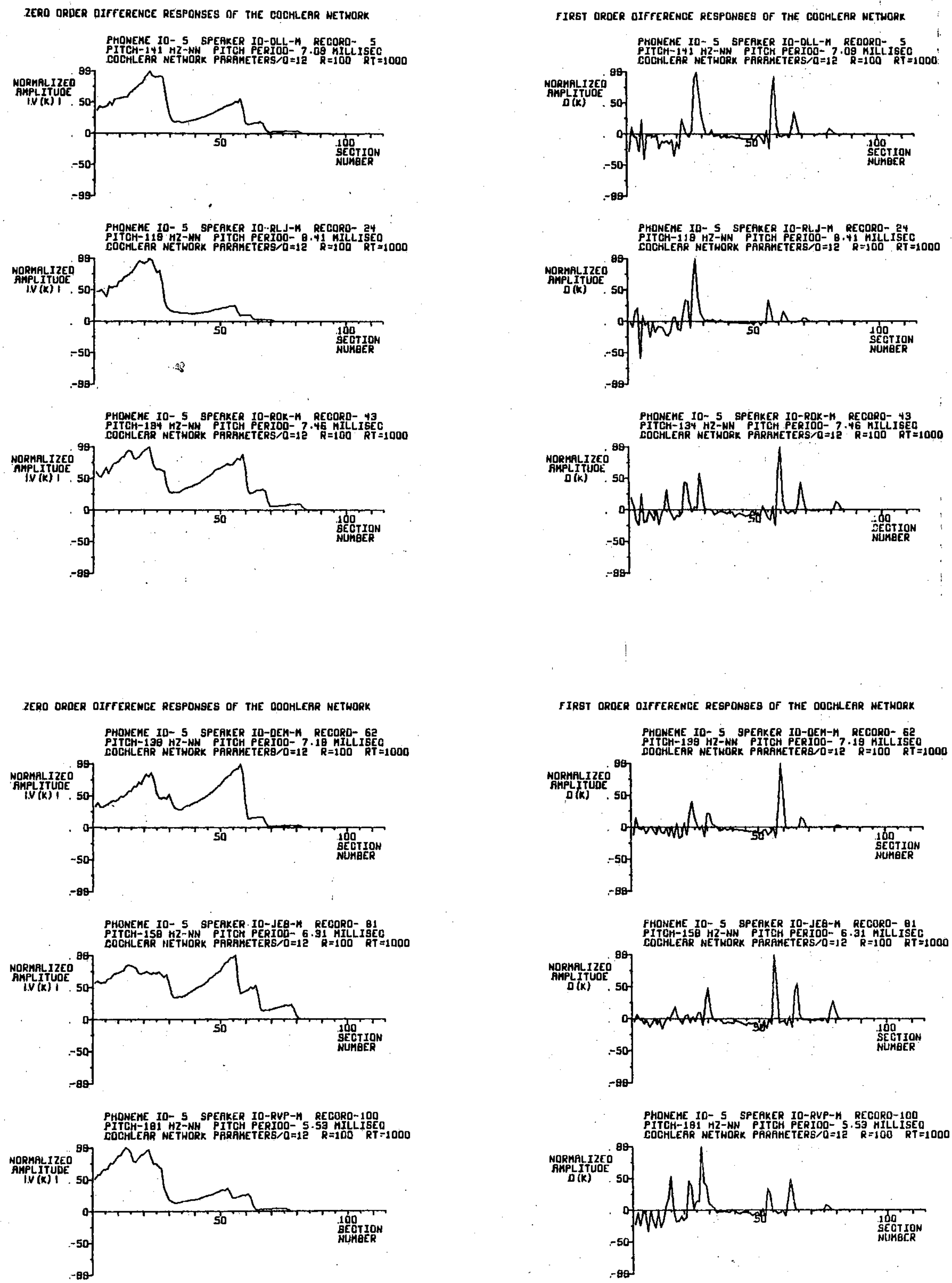


Figure B.9. Corresponding Zero and First Order Difference Responses as Effected by Phoneme (I) of the First 6 Speakers

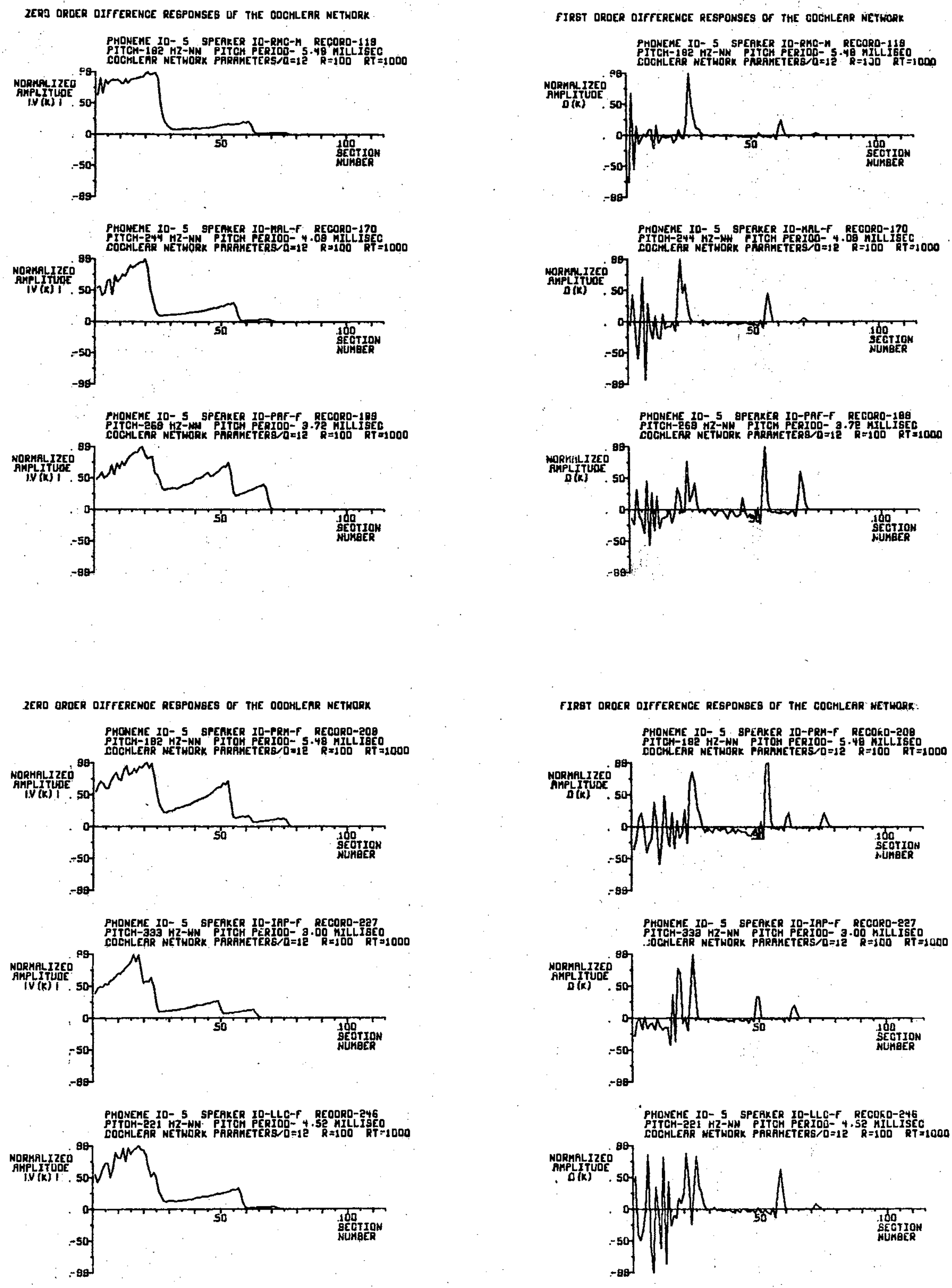


Figure B.10. Corresponding Zero and First Order Difference Responses as Effected by Phoneme (I) of the Last 6 Speakers

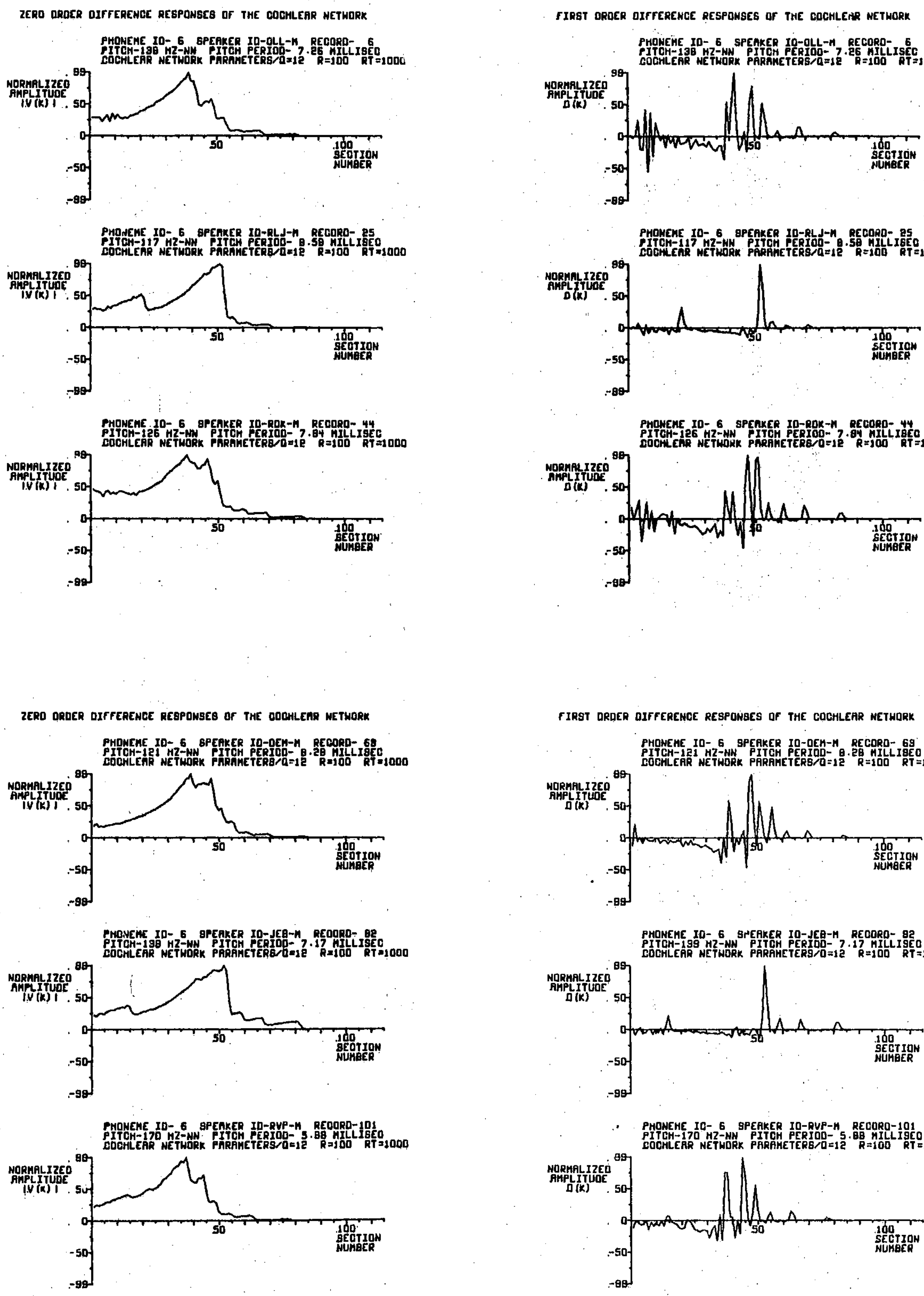


Figure B.11. Corresponding Zero and First Order Difference Responses as Effected by Phoneme (@) of the First 6 Speakers

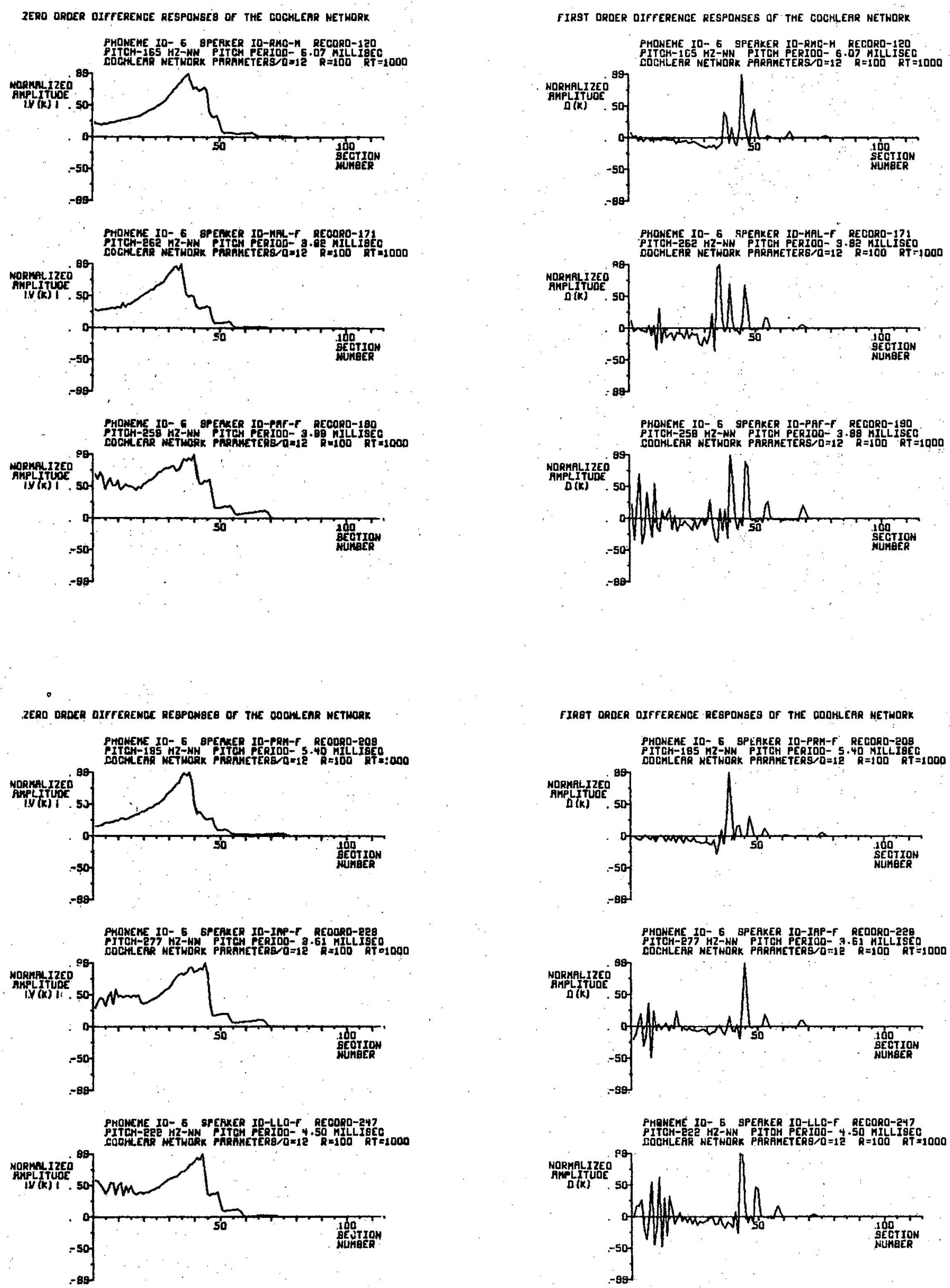


Figure B.12. Corresponding Zero and First Order Difference Responses as Effected by Phoneme (@) of the Last 6 Speakers

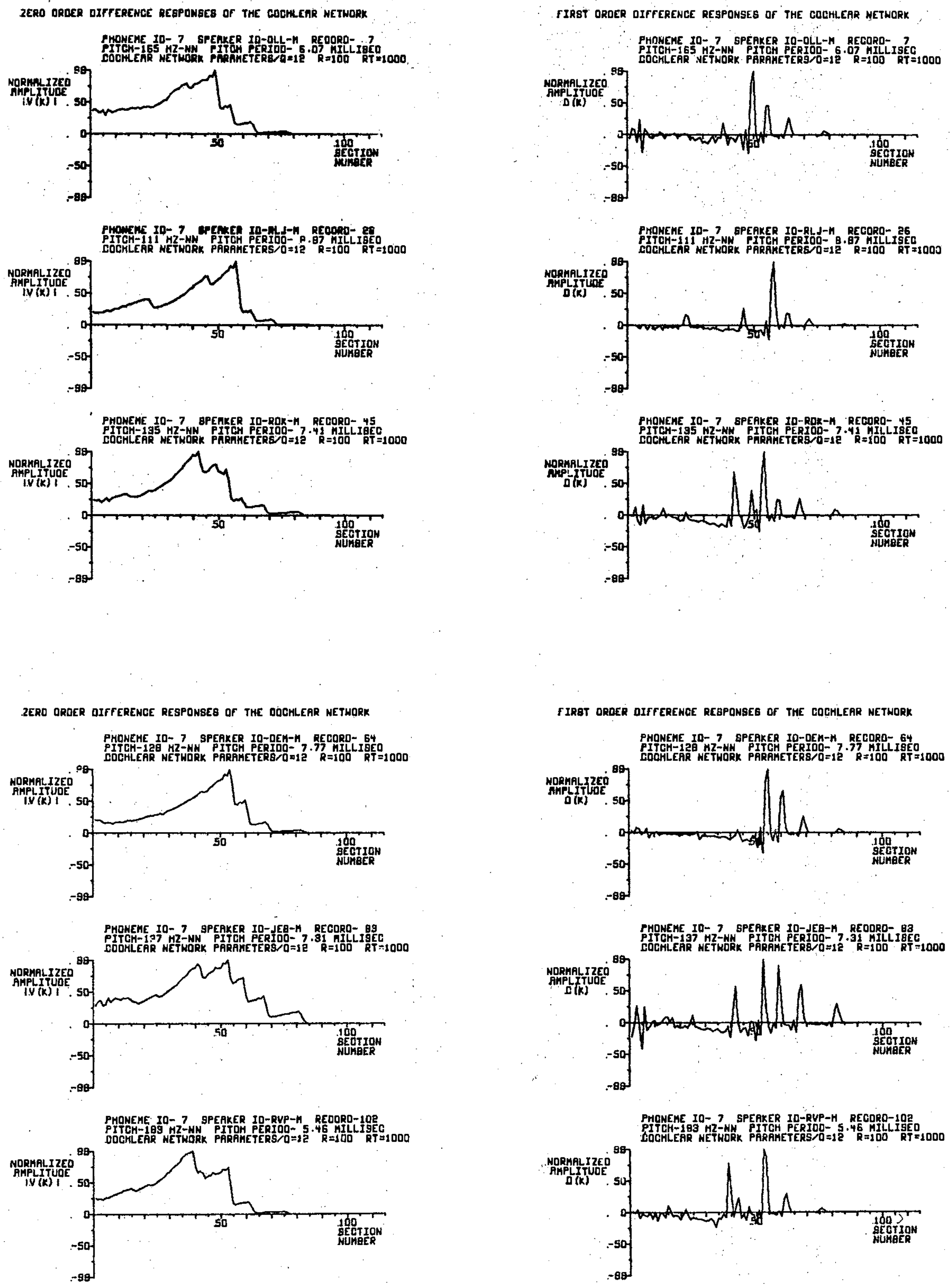


Figure B.13. Corresponding Zero and First Order Difference Responses as Effected by Phoneme (O) of the First 6 Speakers

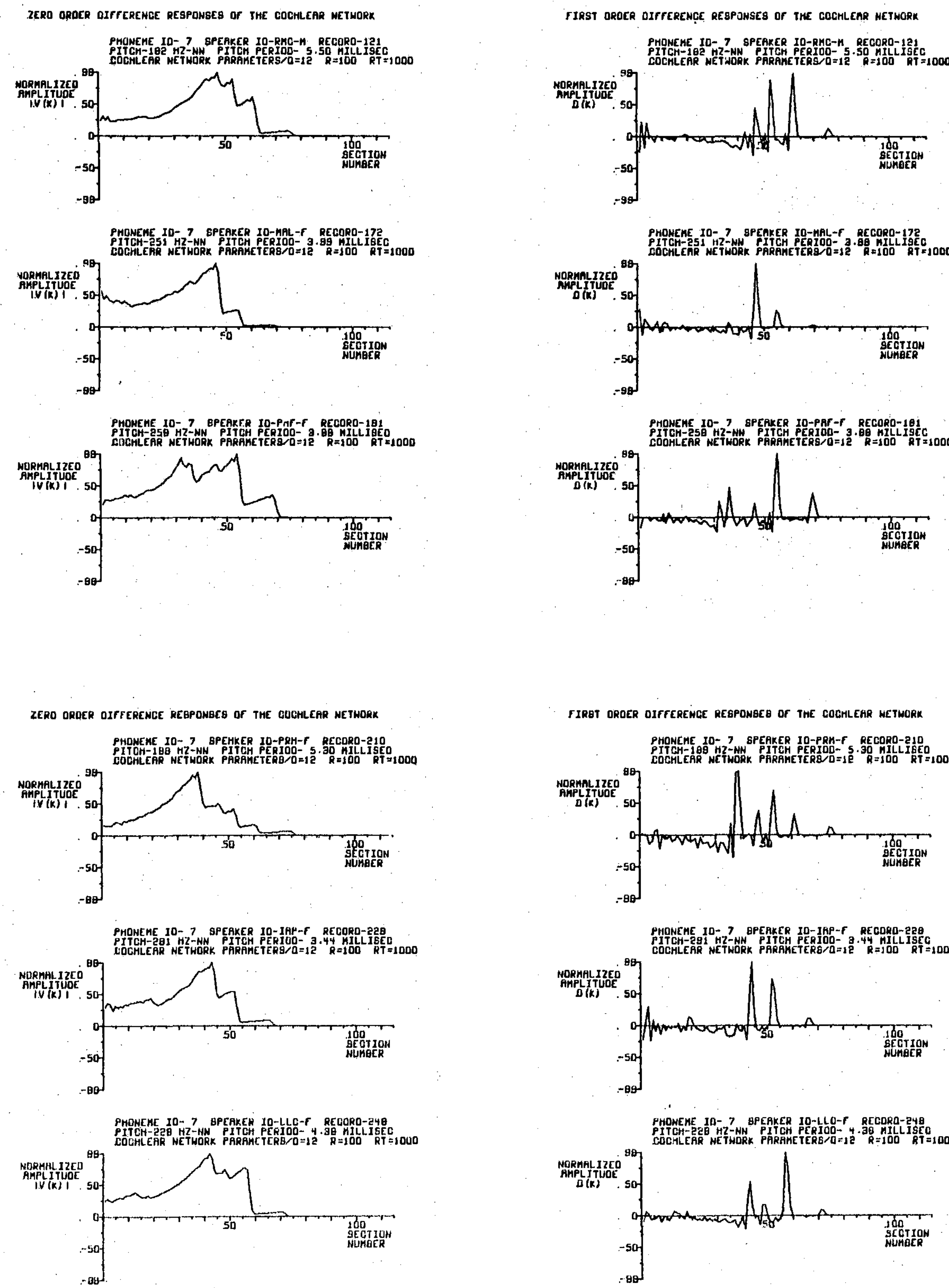


Figure B.14. Corresponding Zero and First Order Difference Responses as Effected by Phoneme (O) of the Last 6 Speakers

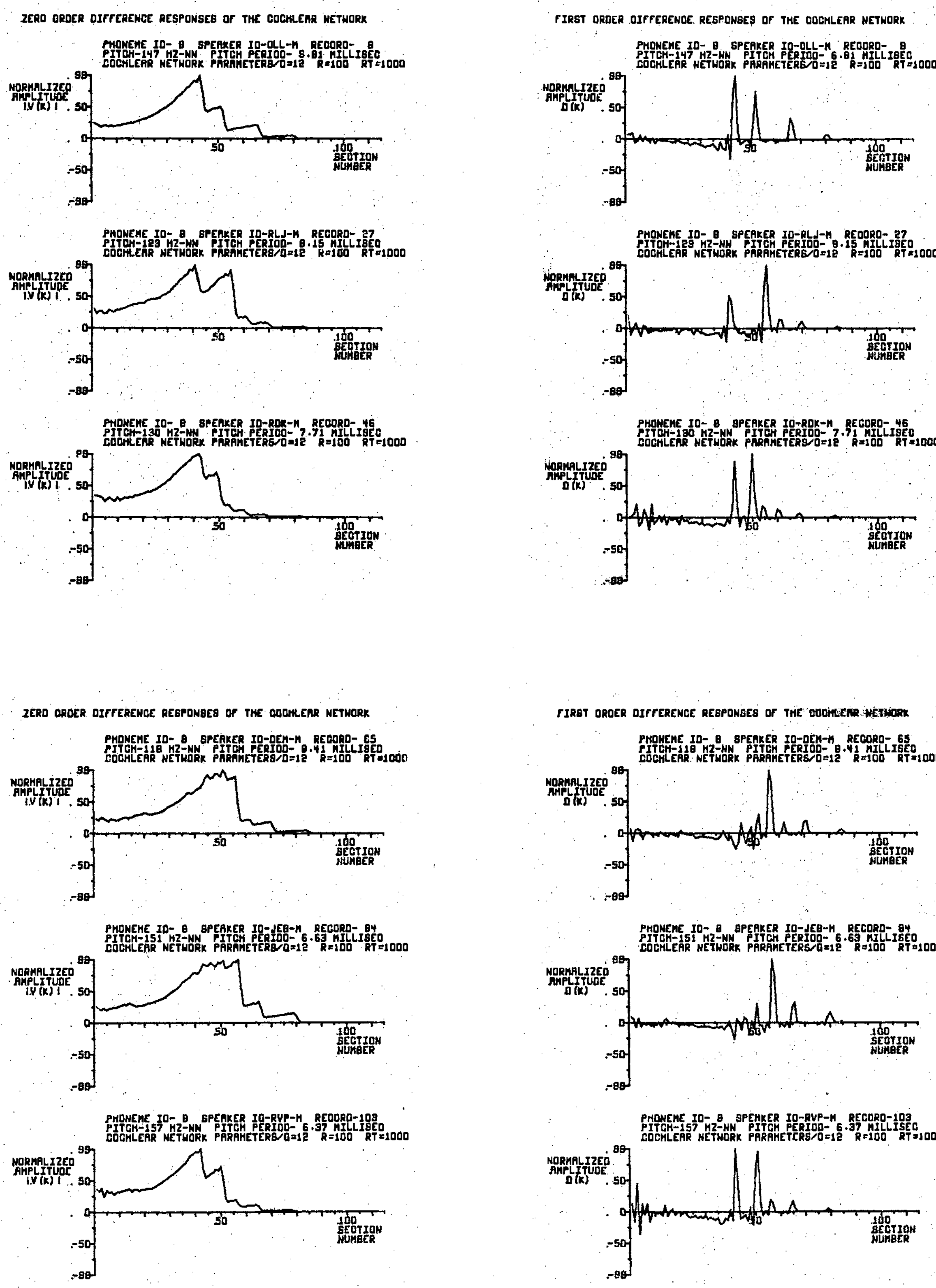


Figure B.15. Corresponding Zero and First Order Difference Responses as Effected by Phoneme (ɔ) of the First 6 Speakers

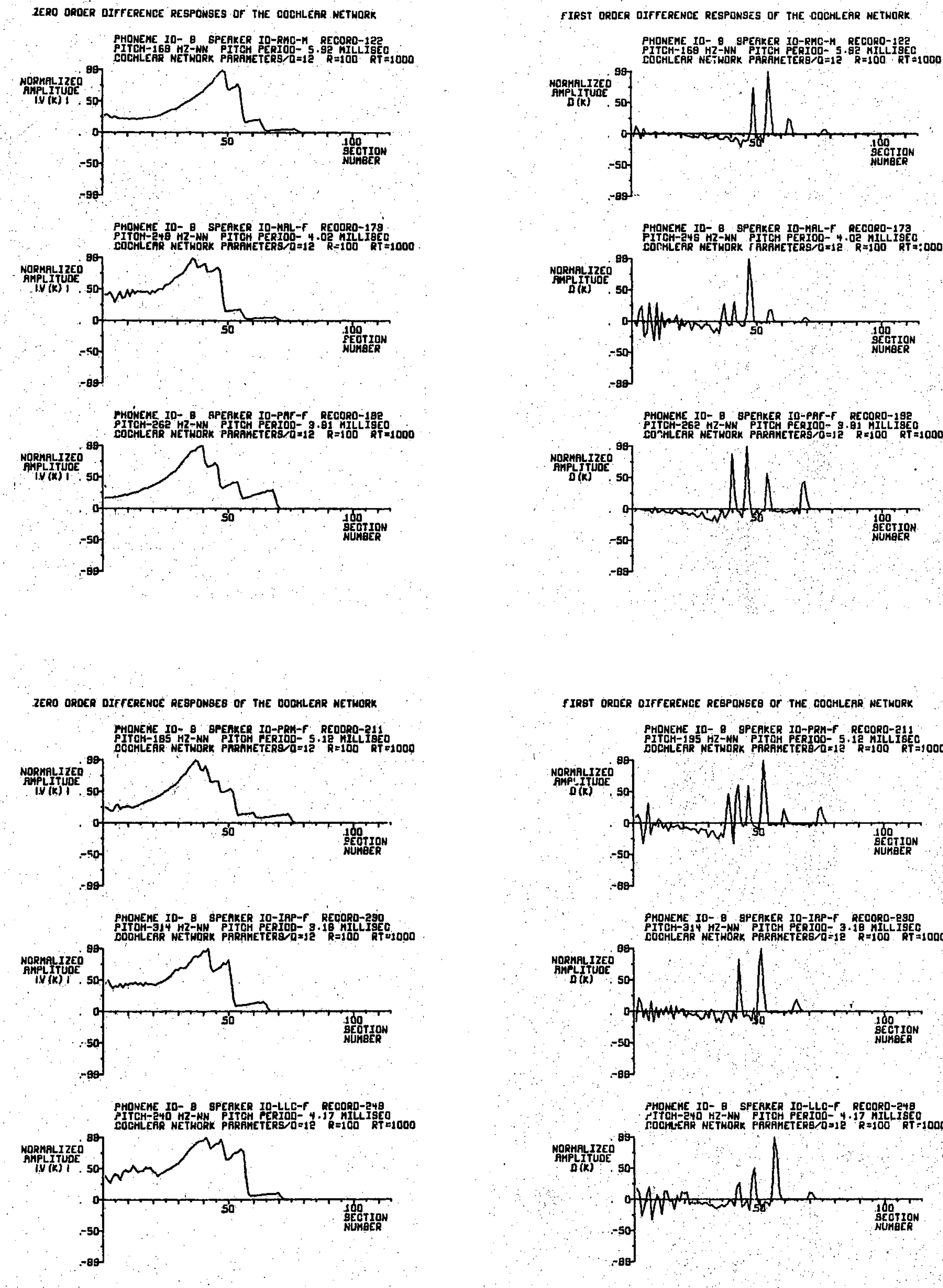


Figure B.16. Corresponding Zero and First Order Difference Responses as Effected by Phoneme (ɔ) of the Last 6 Speakers

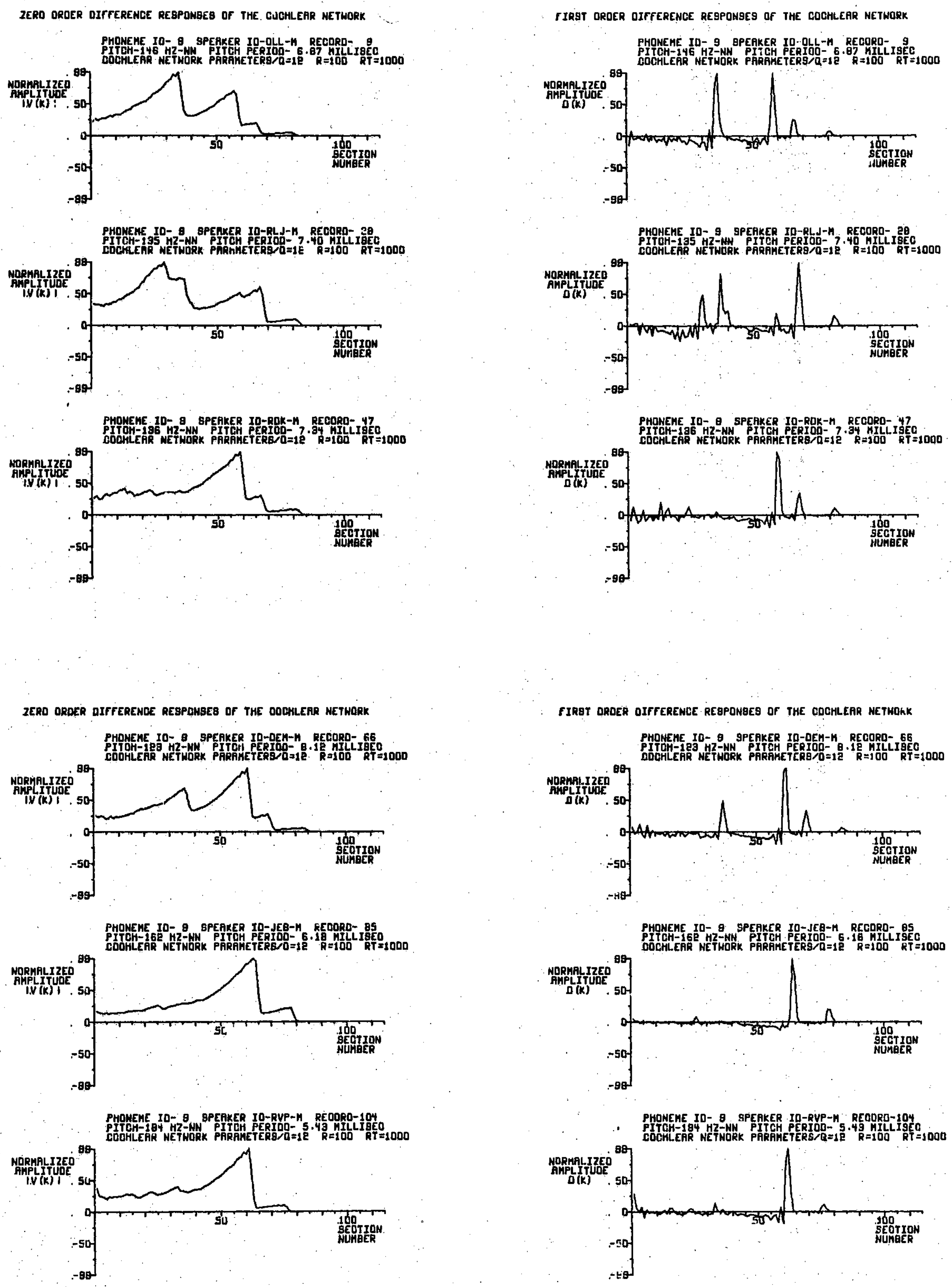


Figure B. 17. Corresponding Zero and First Order Difference Responses as Effected by Phoneme (u) of the First 6 Speakers

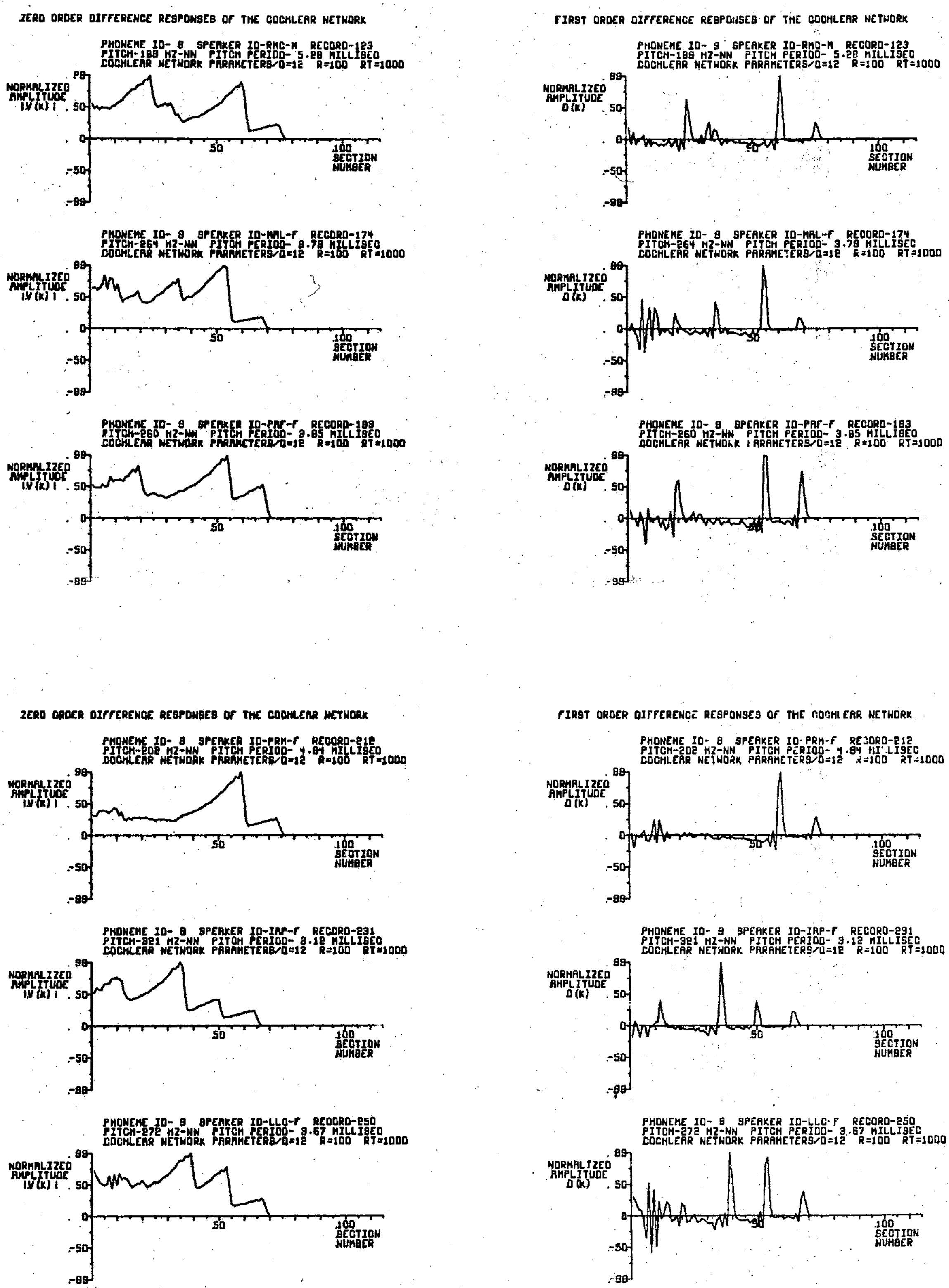


Figure B.18. Corresponding Zero and First Order Difference Responses as Effected by Phoneme (u) of the Last 6 Speakers

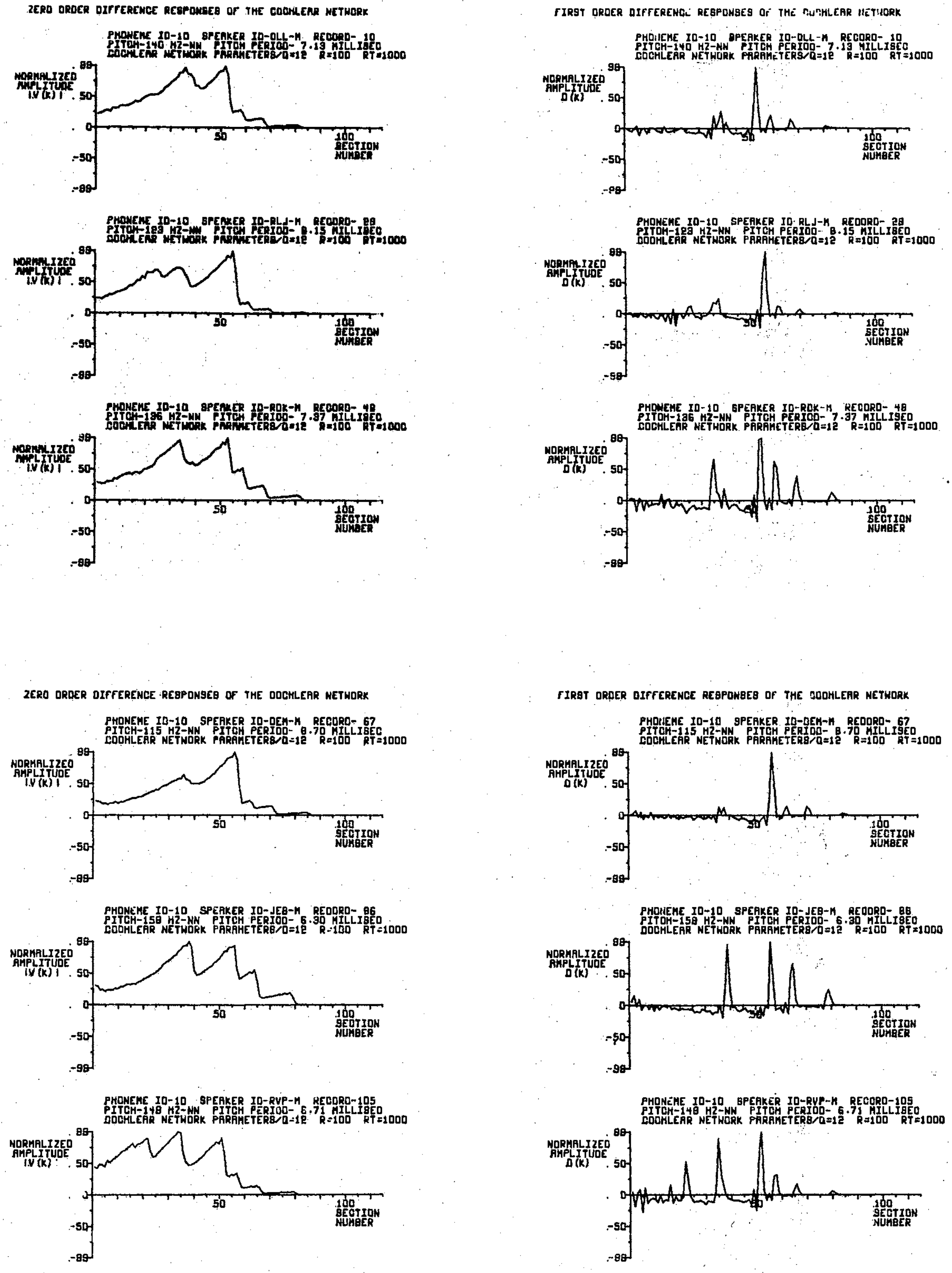


Figure B.19. Corresponding Zero and First Order Difference Responses as Effected by Phoneme (U) of the First 6 Speakers

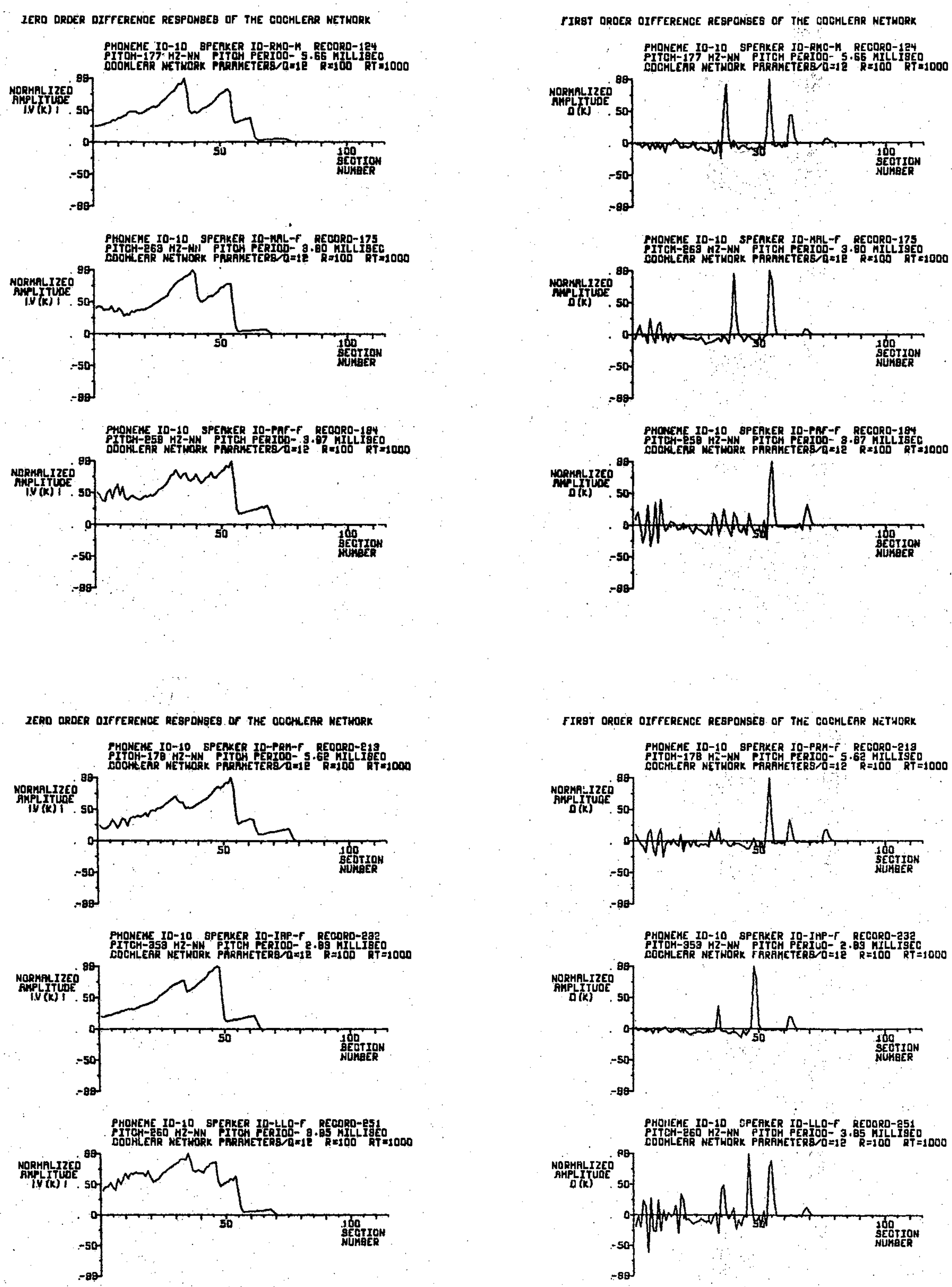
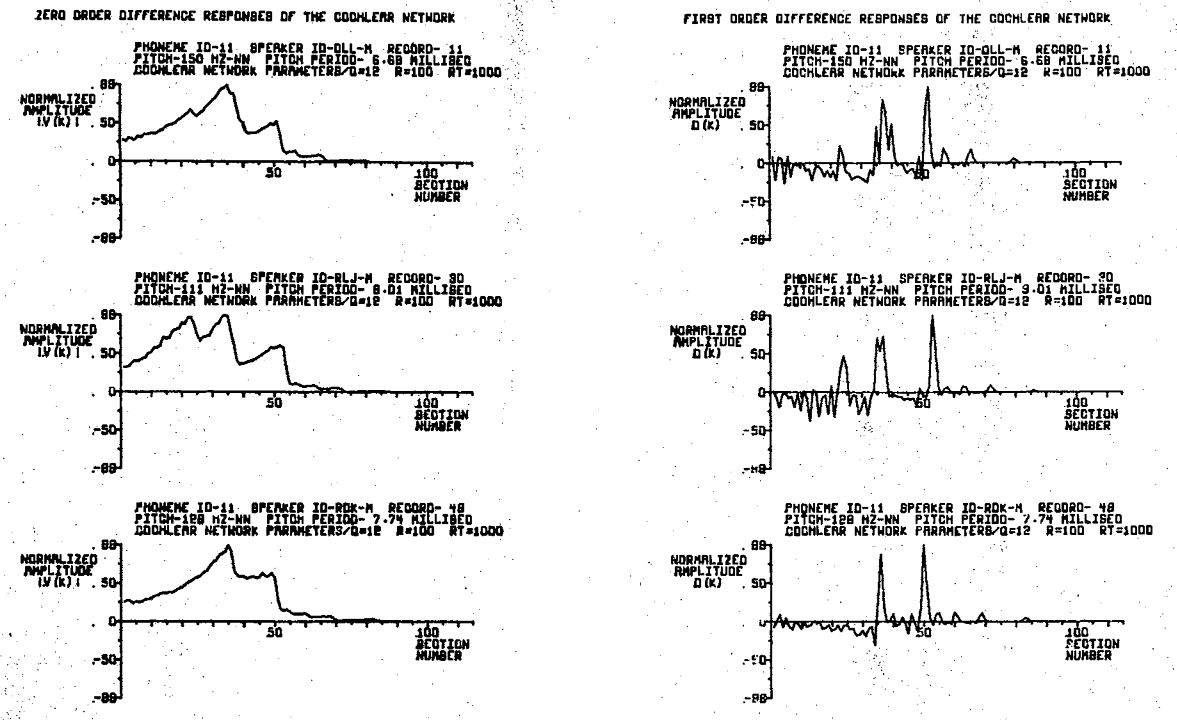


Figure B.20. Corresponding Zero and First Order Difference Responses as Effected by Phoneme (U) of the Last 6 Speakers



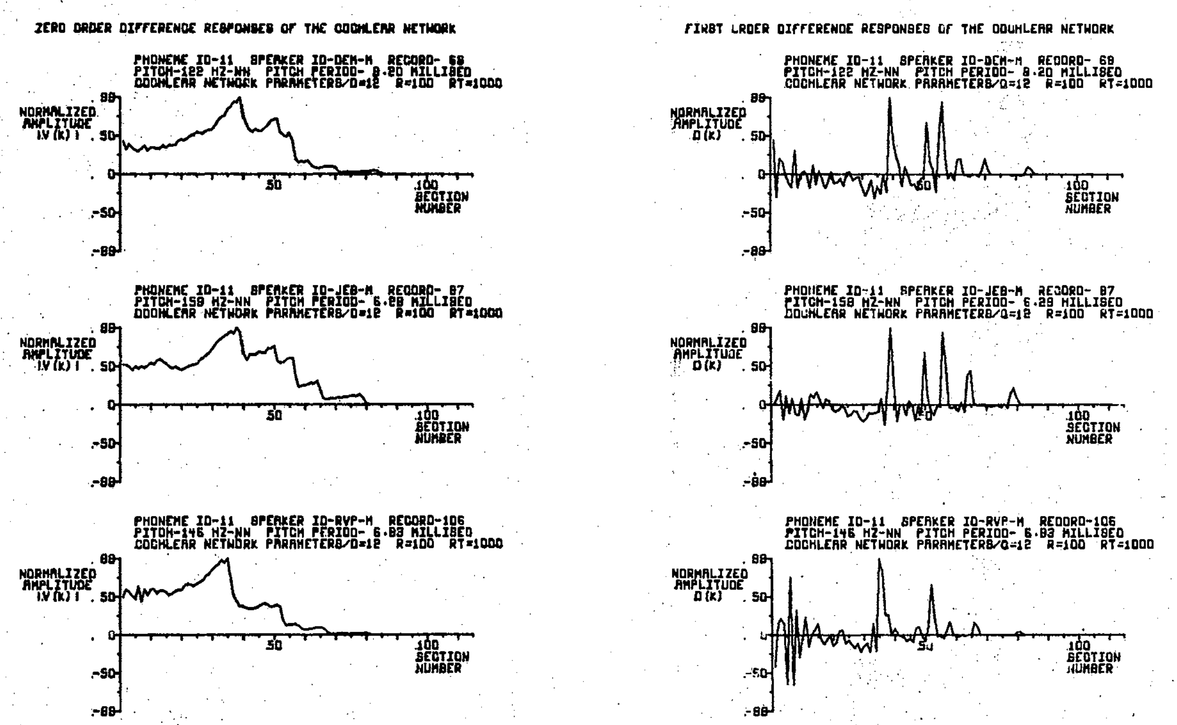


Figure B.21. Corresponding Zero and First Order Difference Responses as Effected by Phoneme (ʌ) of the First 6 Speakers

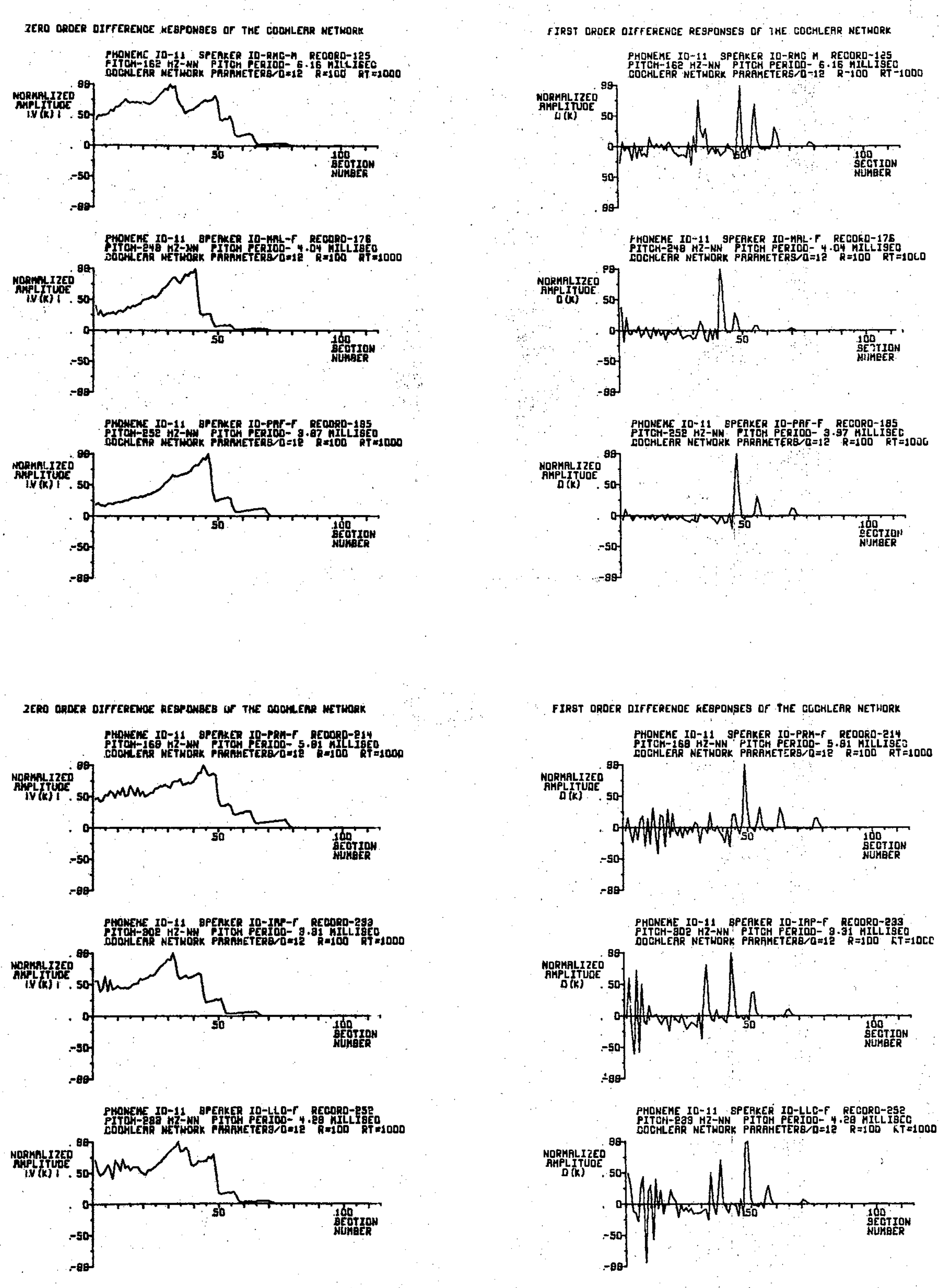


Figure B.22. Corresponding Zero and First Order Difference Responses as Effected by Phoneme (Λ) of the Last 6 Speakers

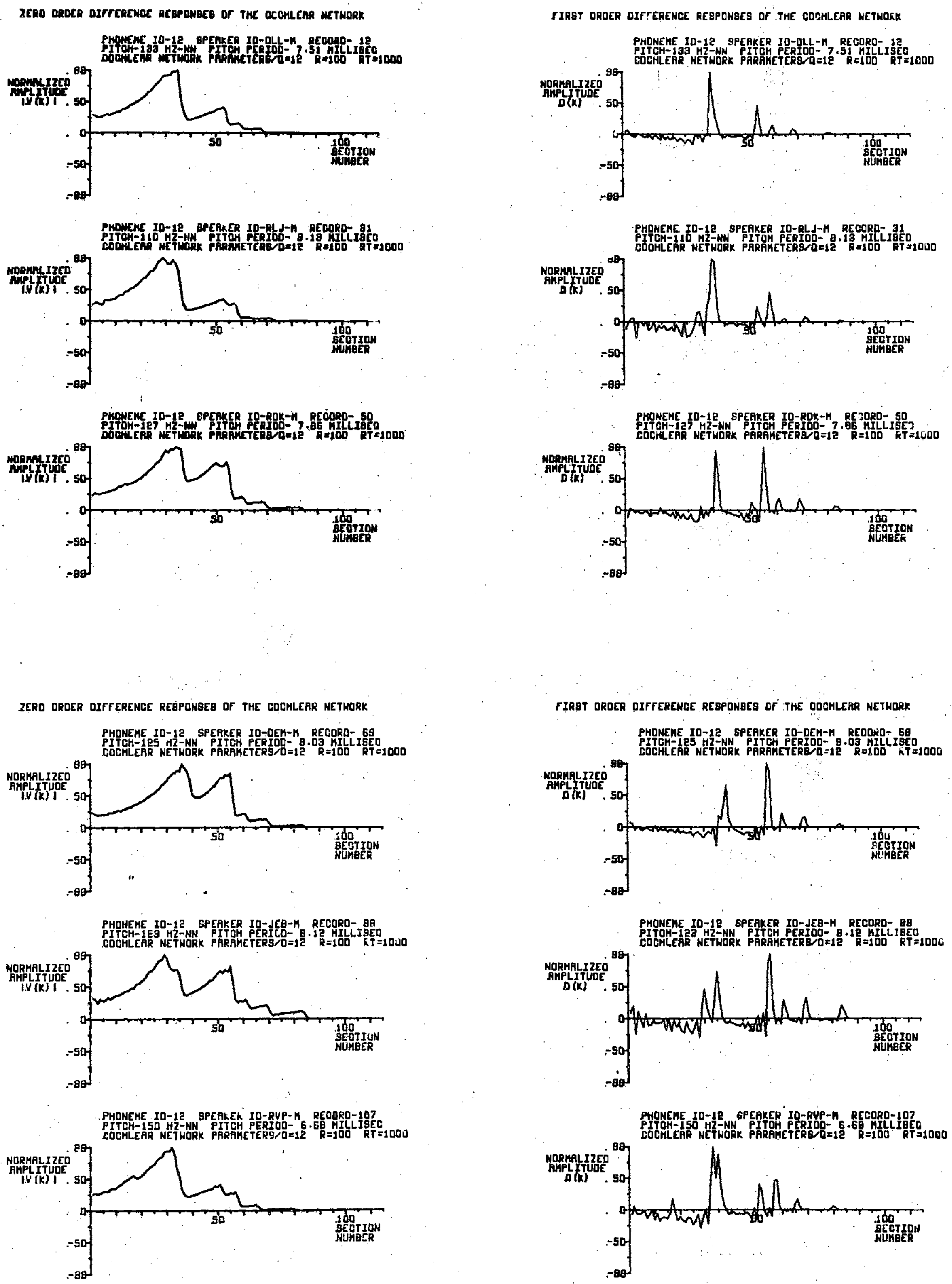


Figure B.23. Corresponding Zero and First Order Difference Responses as Effected by Phoneme (ər) of the First 6 Speakers

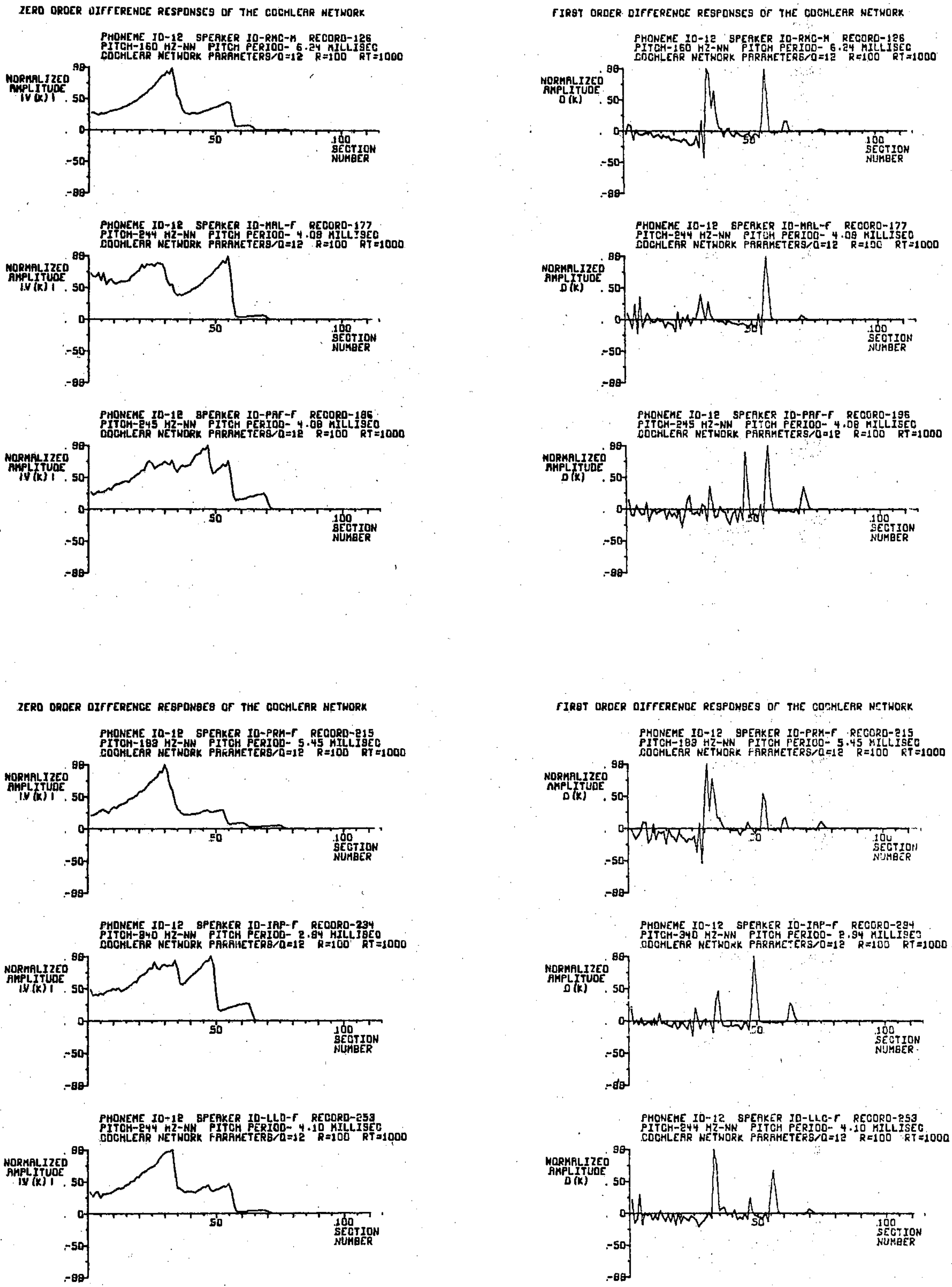


Figure B.24. Corresponding Zero and First Order Difference Responses as Effected by Phoneme (ər) of the Last 6 Speakers

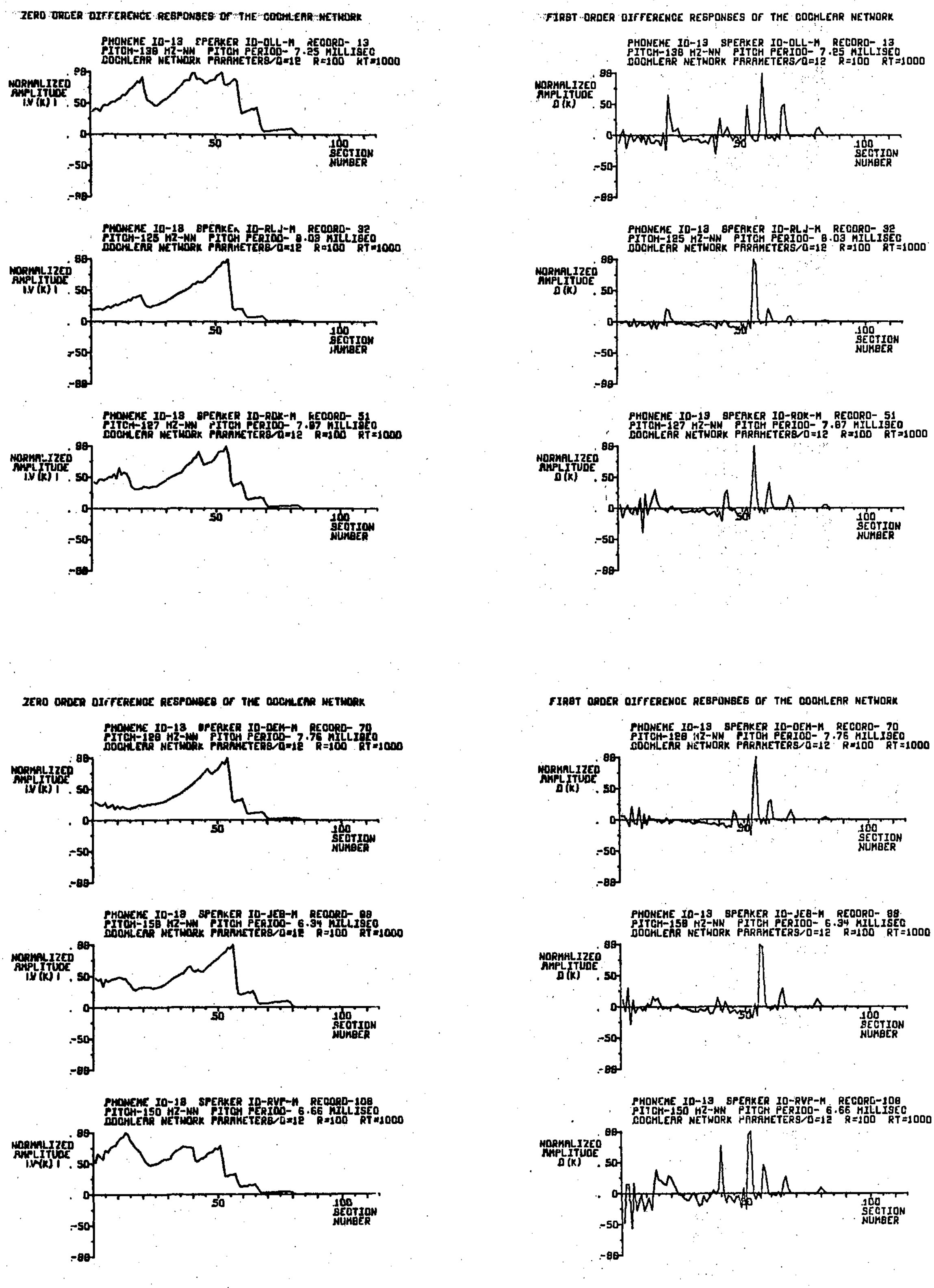


Figure B.25. Corresponding Zero and First Order Difference Responses as Effected by Phoneme (1) of the First 6 Speakers

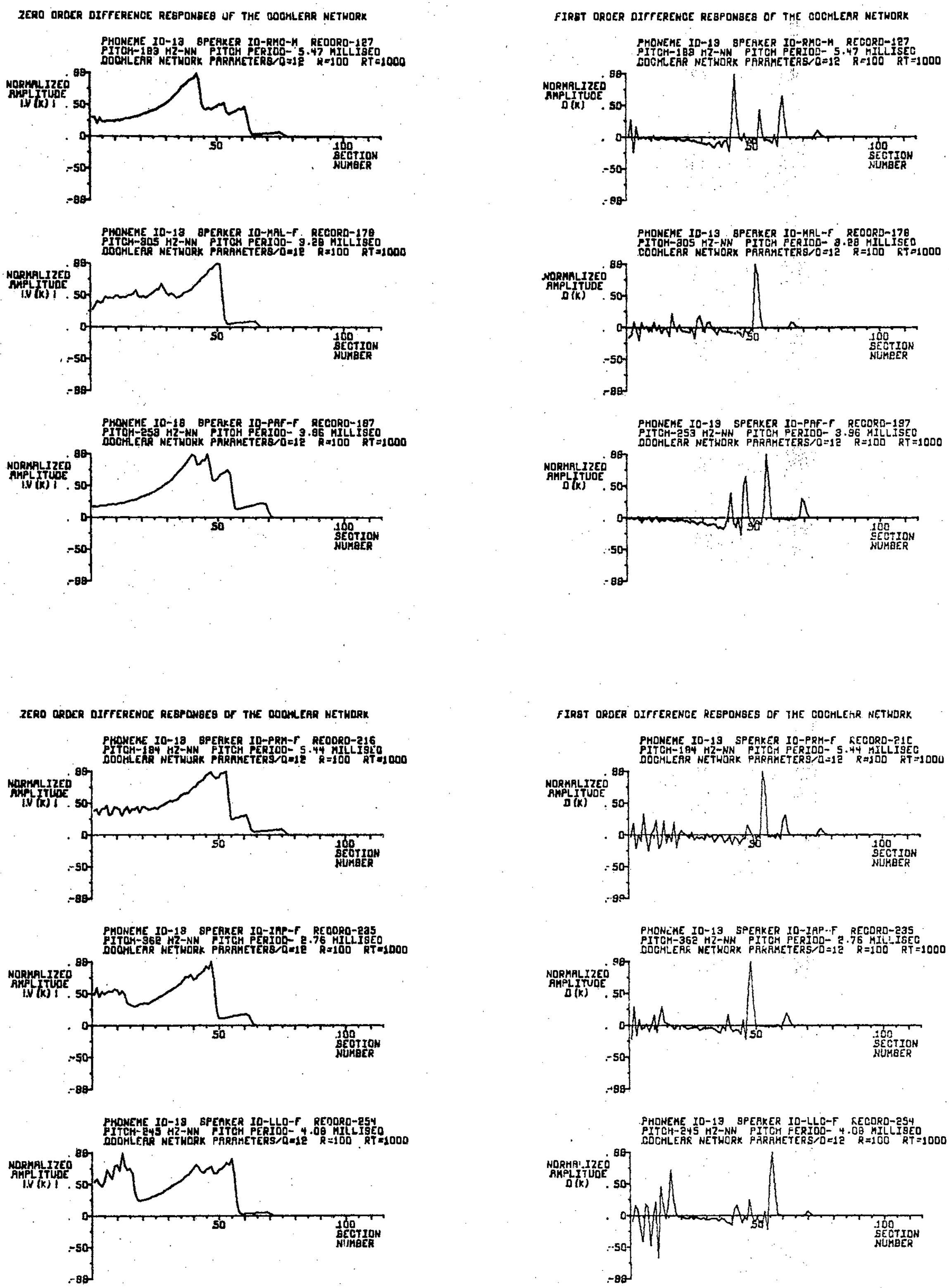


Figure B.26. Corresponding Zero and First Order Difference Responses as Effected by Phoneme (1) of the Last 6 Speakers

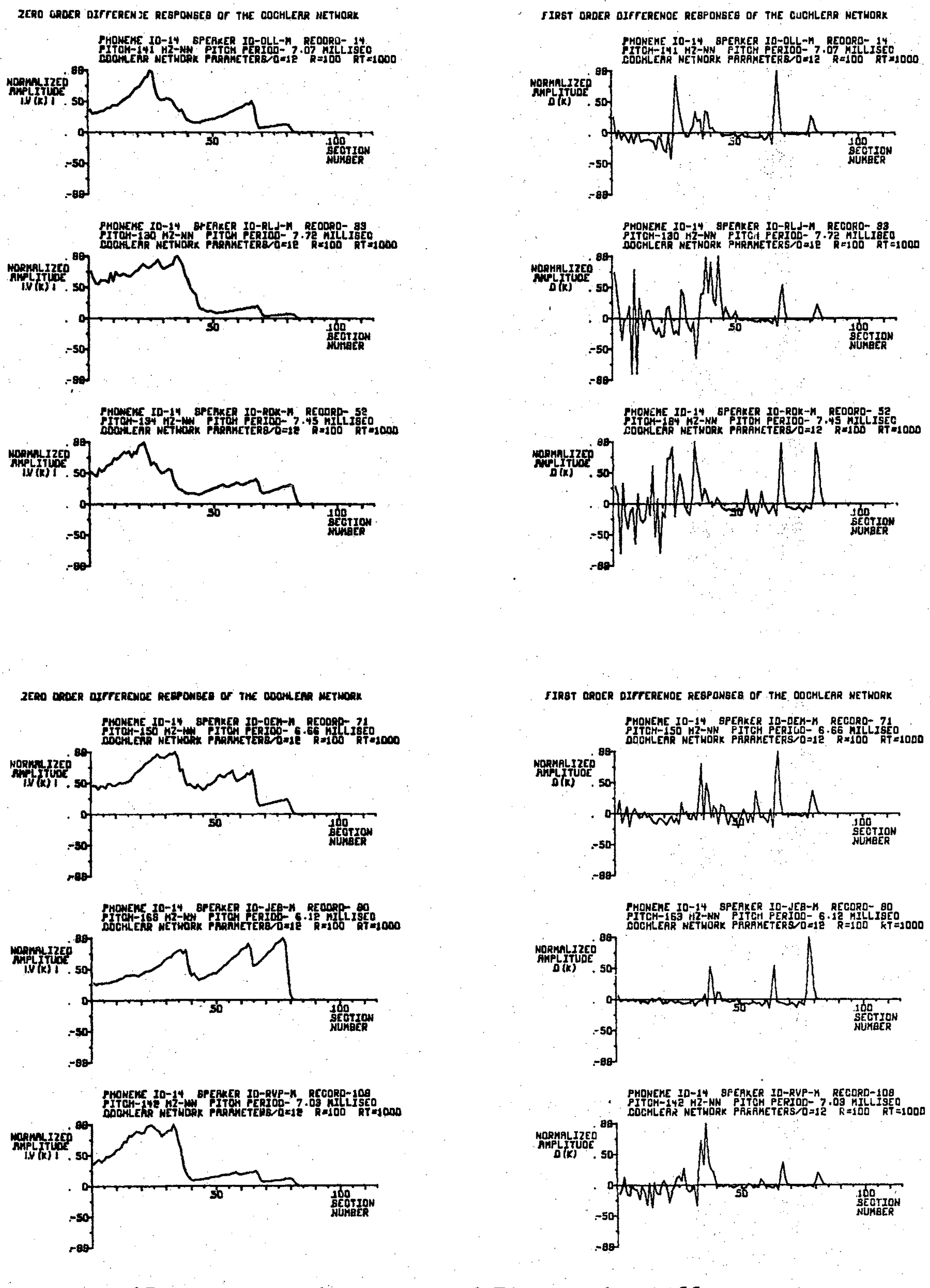


Figure B.27. Corresponding Zero and First Order Difference Responses as Effected by Phoneme (m) of the First 6 Speakers

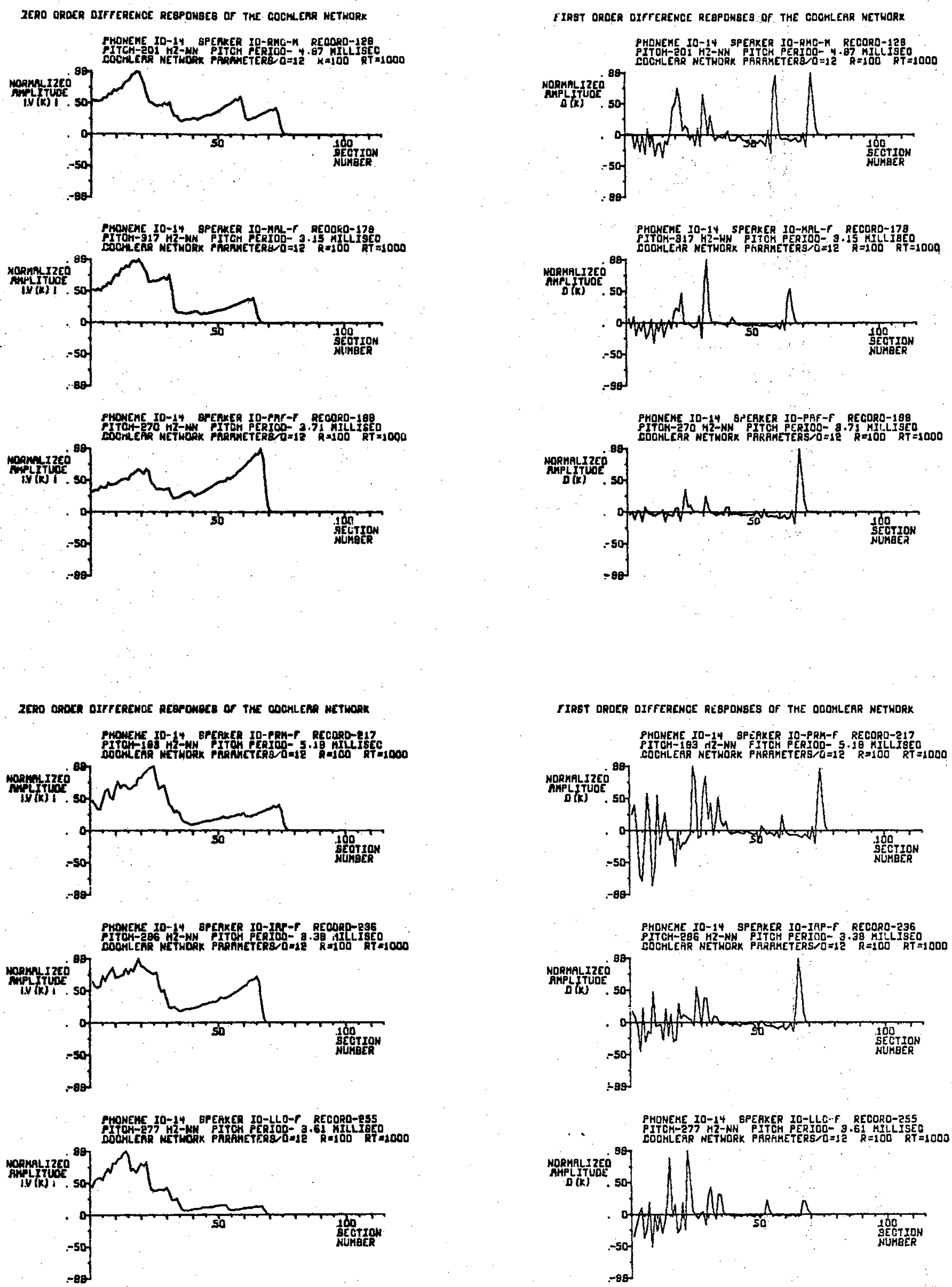


Figure B.28. Corresponding Zero and First Order Difference Responses as Effected by Phoneme (m) of the Last 6 Speakers

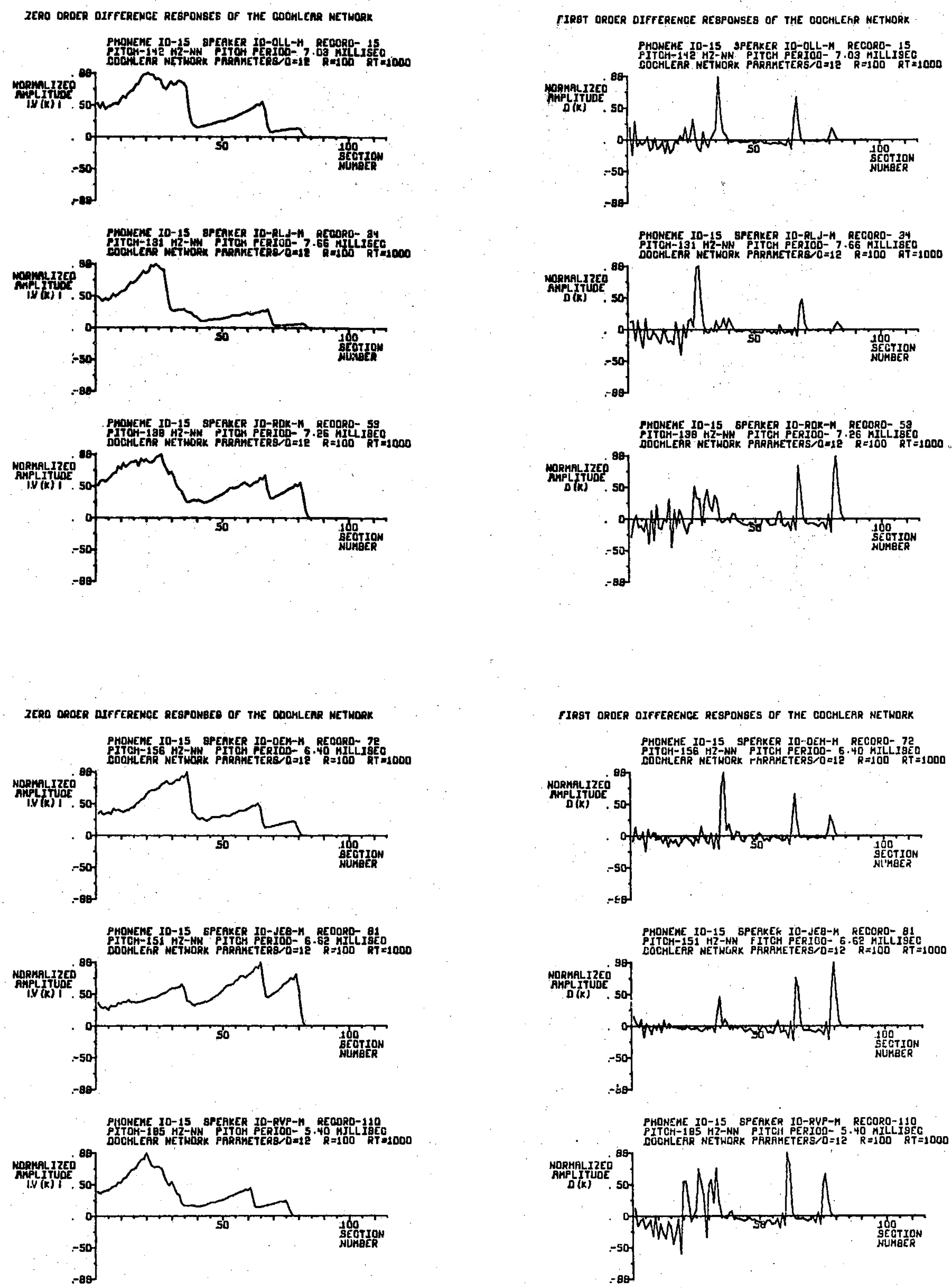


Figure B.29. Corresponding Zero and First Order Difference Responses as Effected by Phoneme (n) of the First 6 Speakers

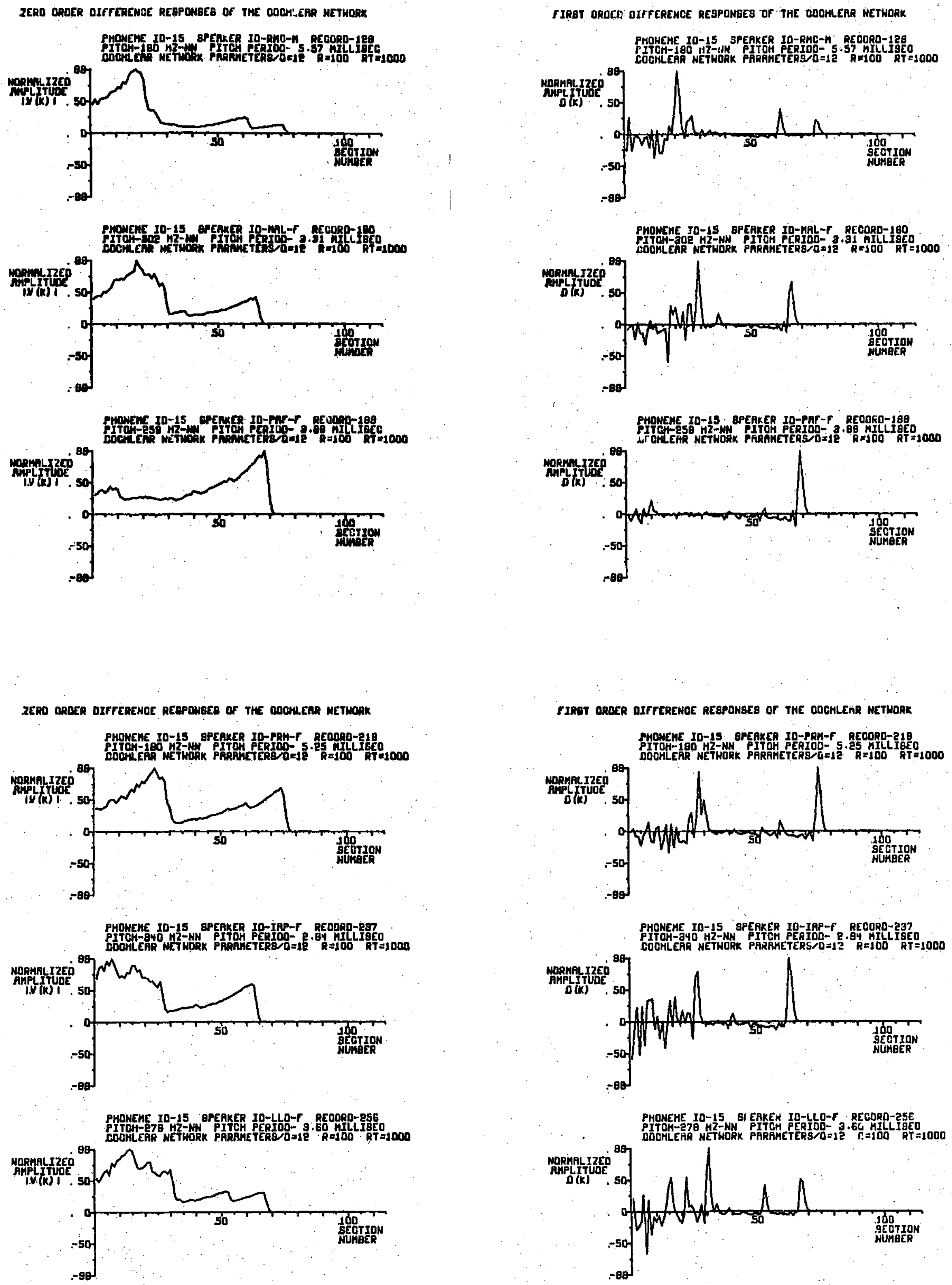


Figure B.30. Corresponding Zero and First Order Difference Responses as Effected by Phoneme (n) of the Last 6 Speakers

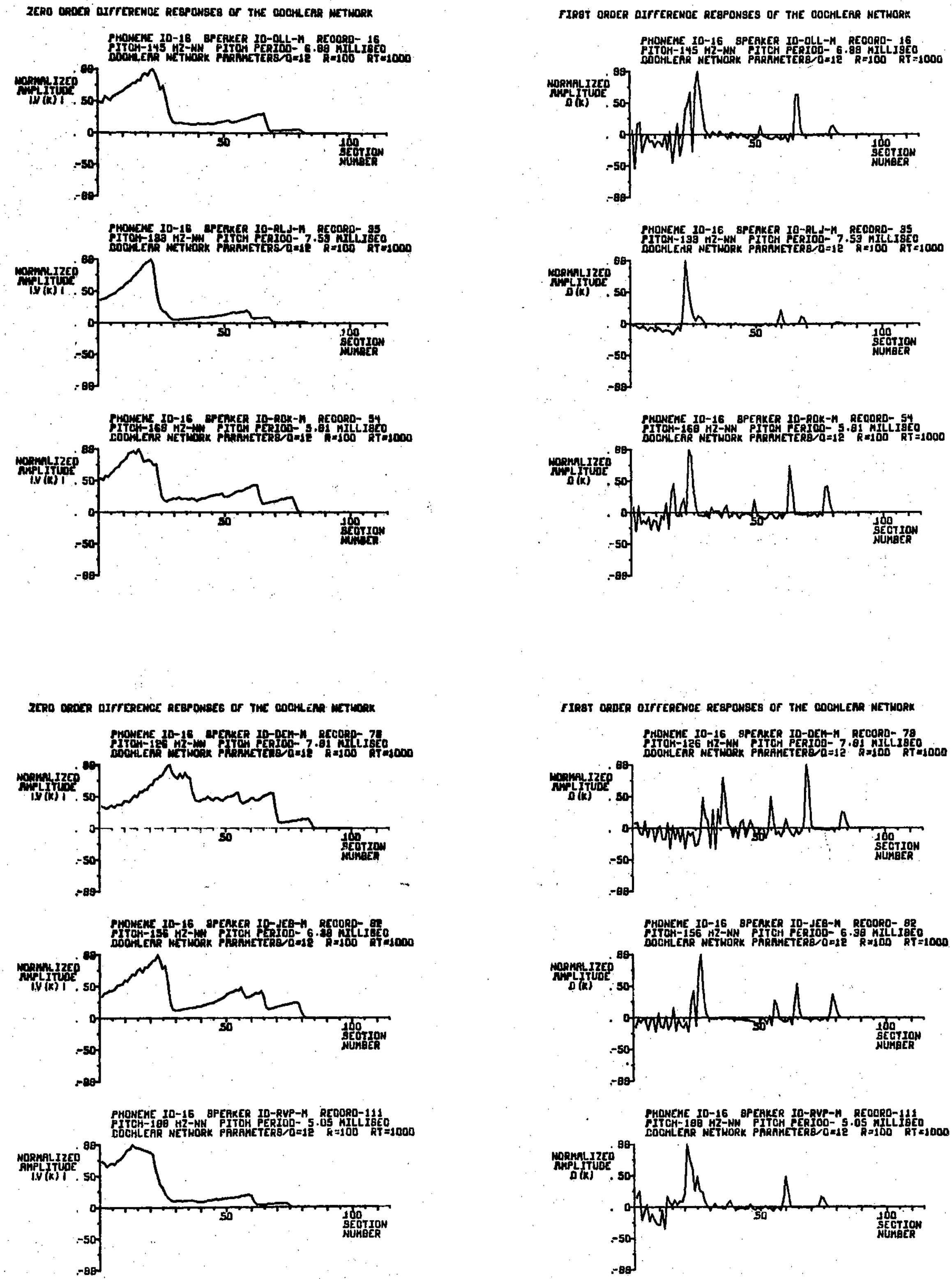


Figure B.31. Corresponding Zero and First Order Difference Responses as Effected by Phoneme (ƞ) of the First 6 Speakers

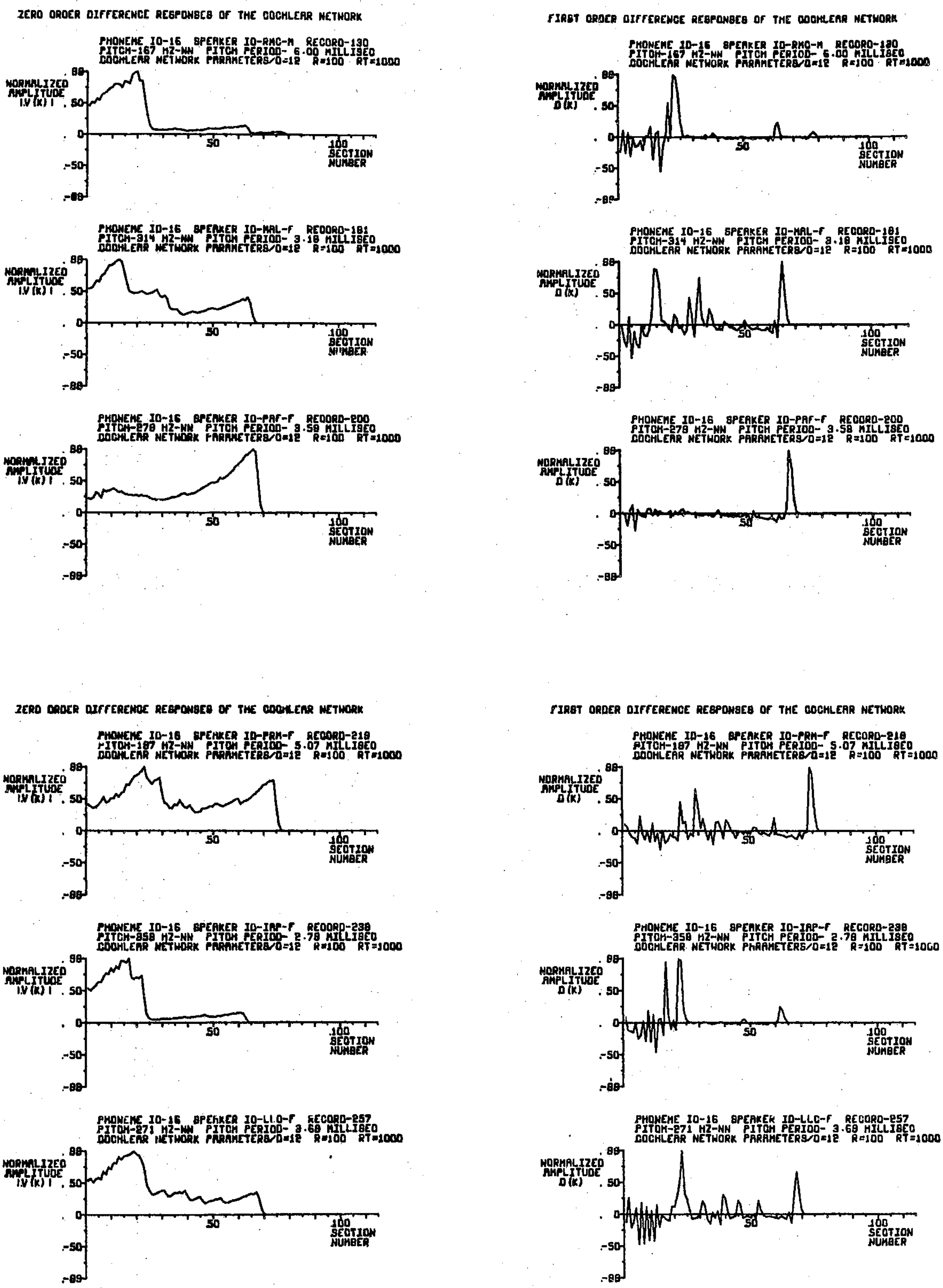


Figure B.32. Corresponding Zero and First Order Difference Responses as Effected by Phoneme (ŋ) of the Last 6 Speakers

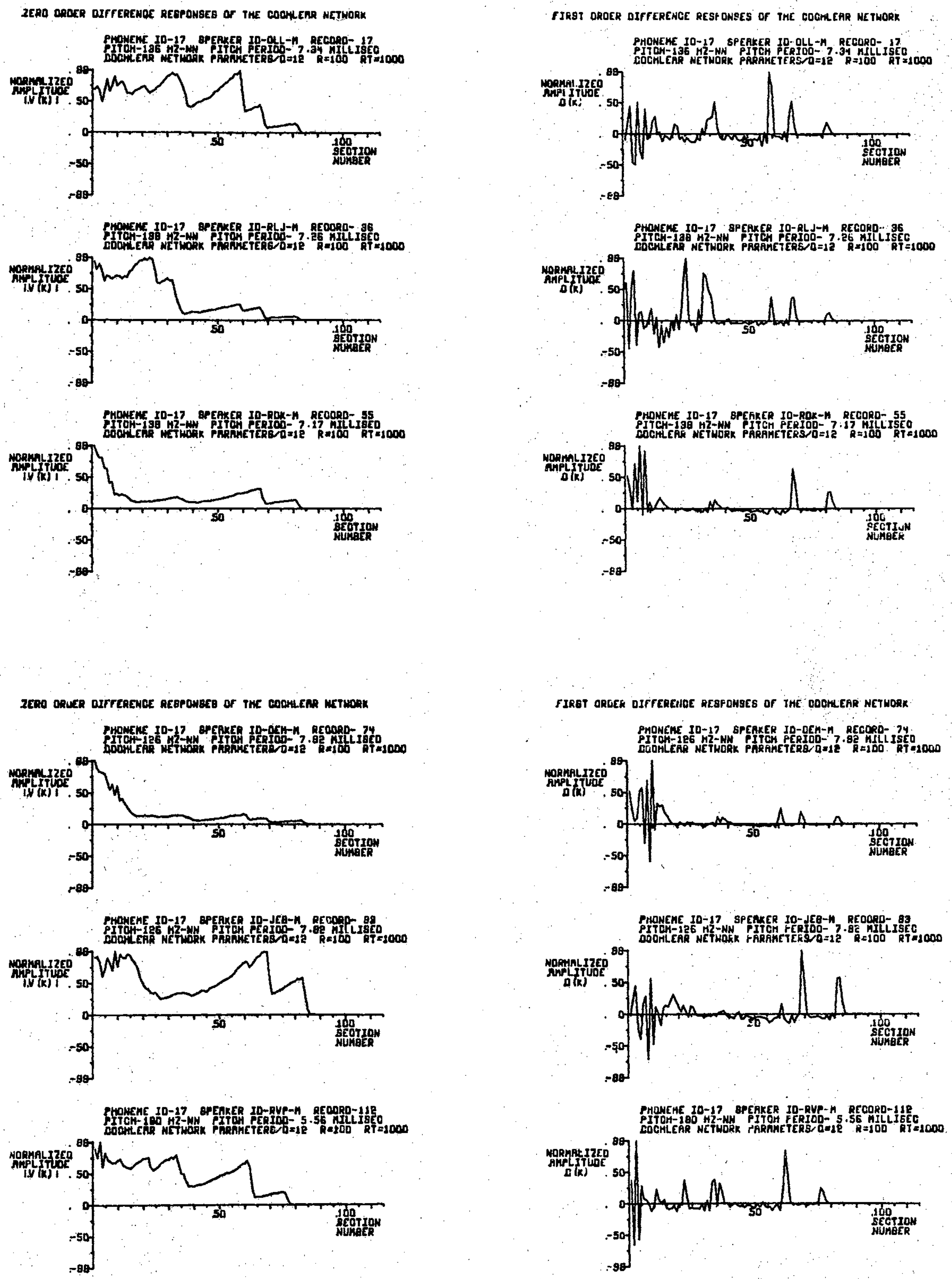


Figure B.33. Corresponding Zero and First Order Difference Responses as Effected by Phoneme (z) of the First 6 Speakers

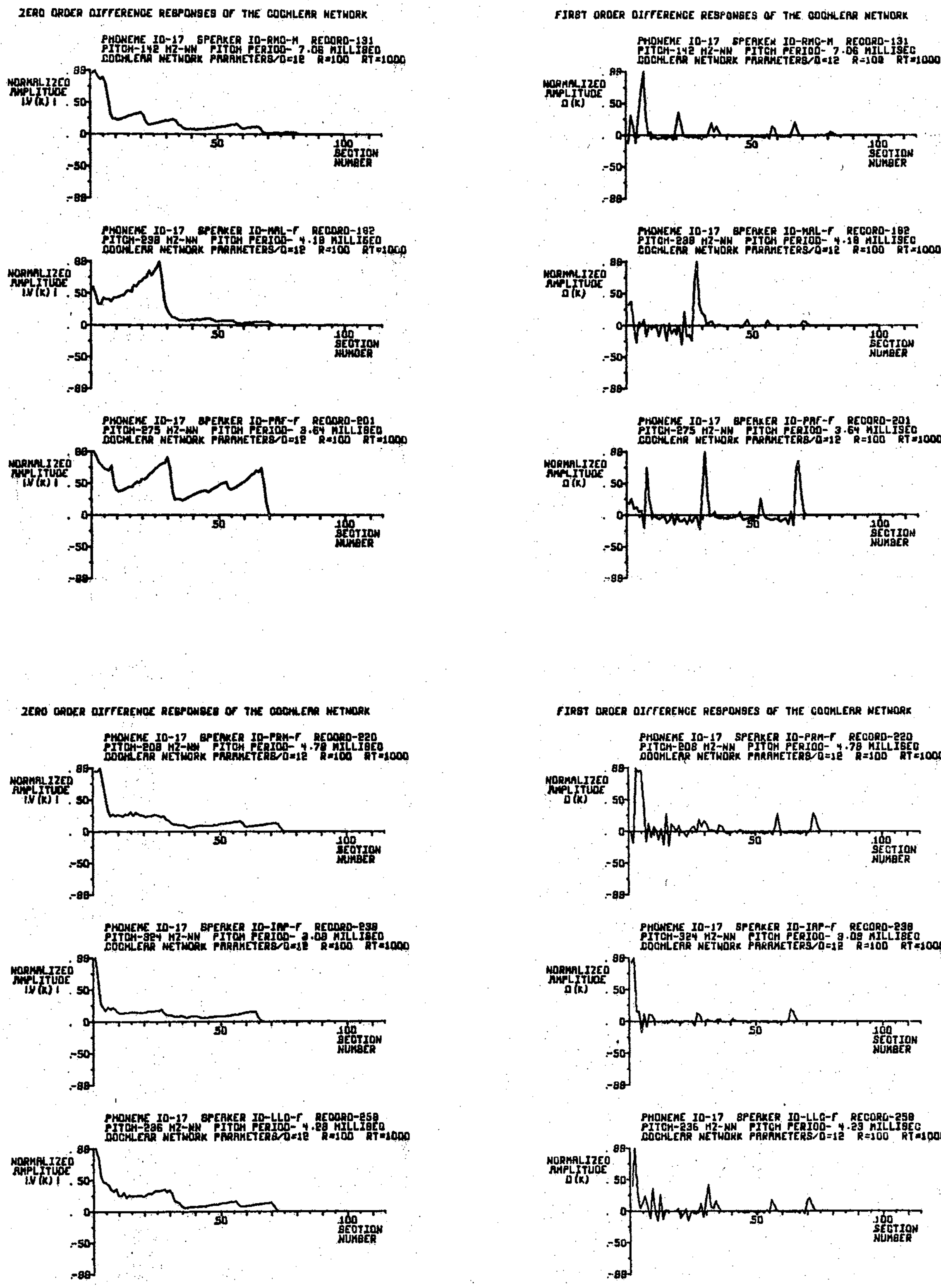


Figure B.34. Corresponding Zero and First Order Difference Responses as Effected by Phoneme (z) of the Last 6 Speakers

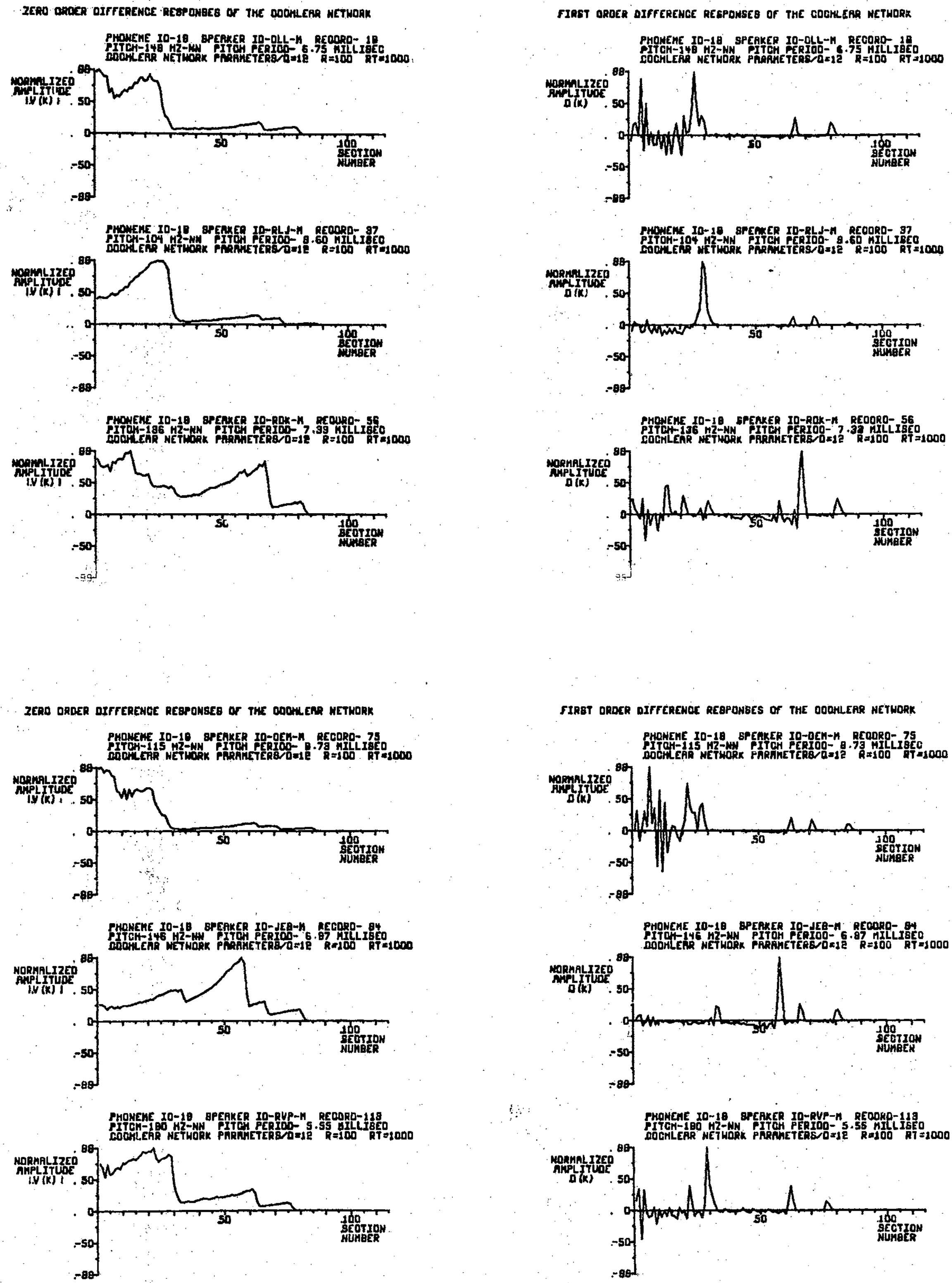


Figure B.35. Corresponding Zero and First Order Difference Responses as Effected by Phoneme (ξ) of the First 6 Speakers

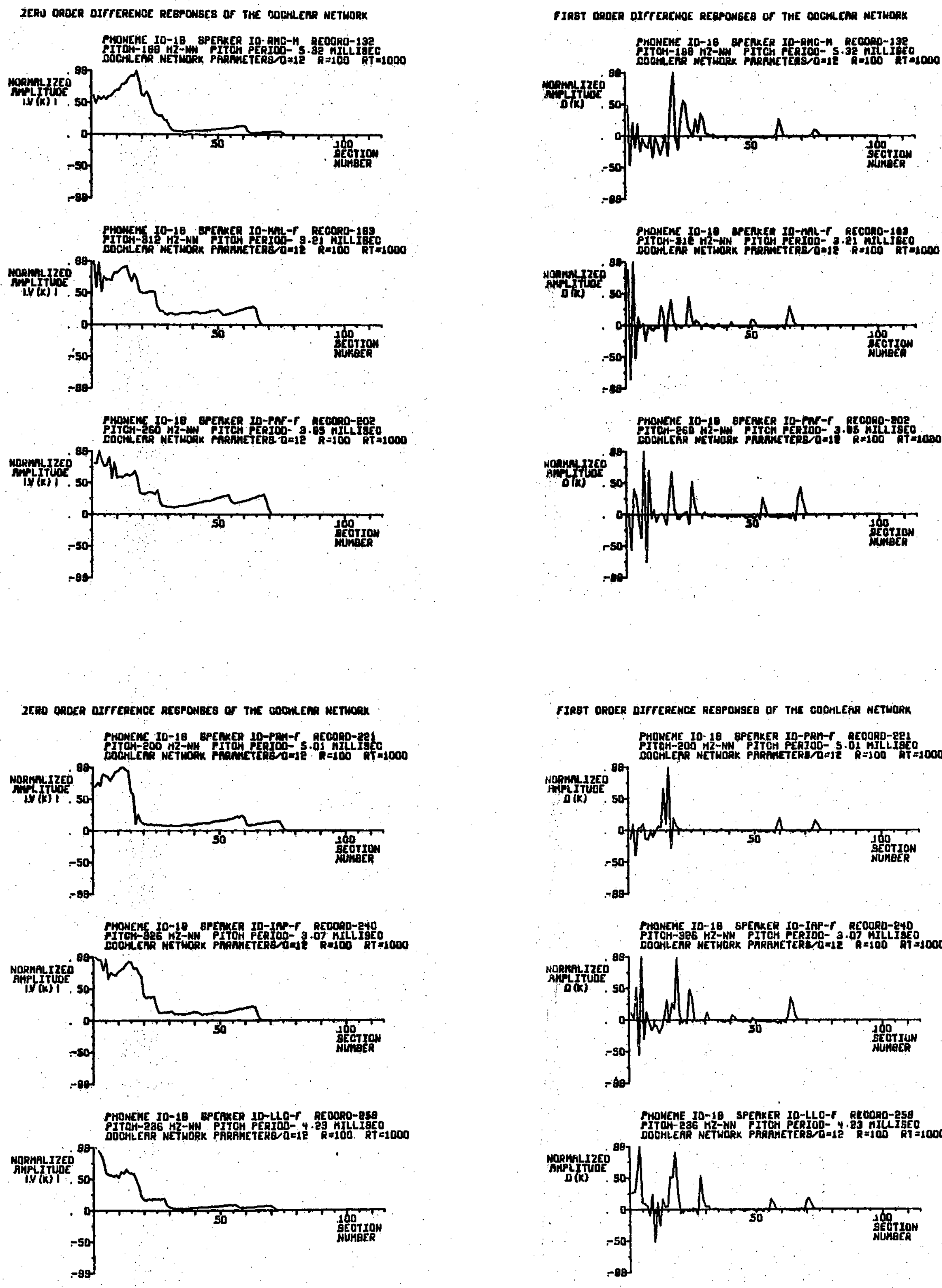


Figure B.36. Corresponding Zero and First Order Difference Responses as Effected by Phoneme (ξ) of the Last 6 Speakers

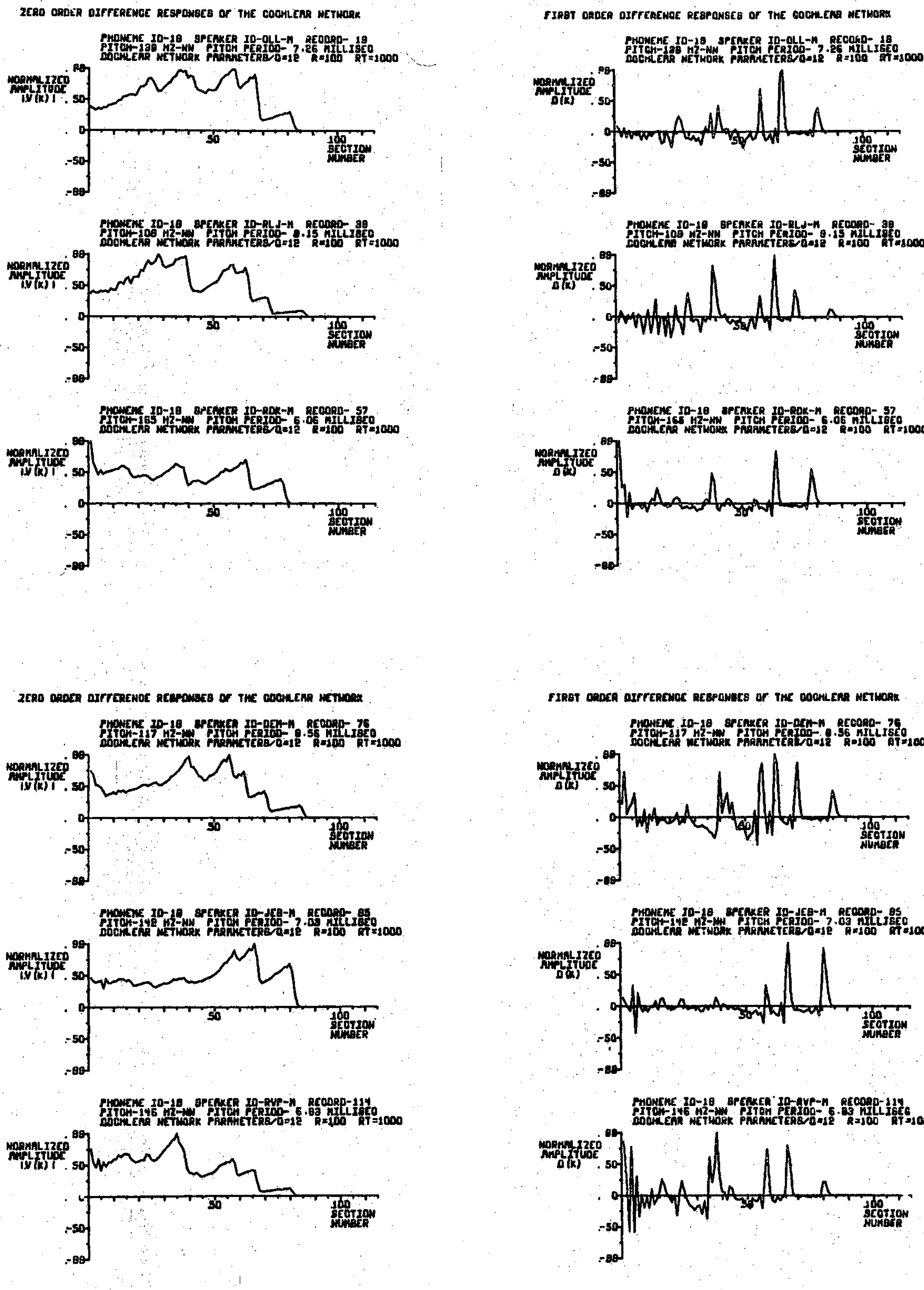


Figure B.37. Corresponding Zero and First Order Difference Responses as Effected by Phoneme (V) of the First 6 Speakers

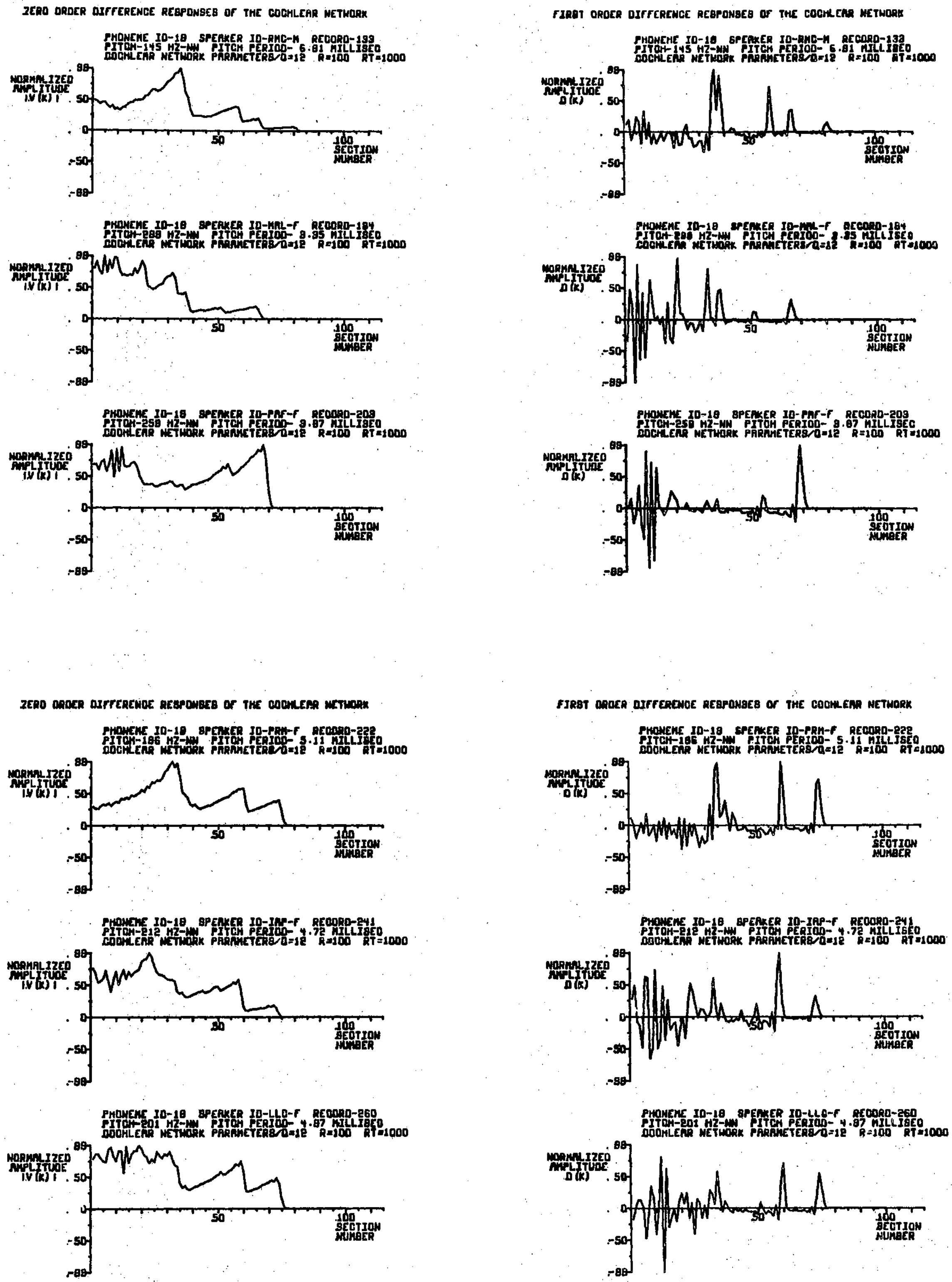


Figure B.38. Corresponding Zero and First Order Difference Responses as Effected by Phoneme (V) of the Last 6 Speakers

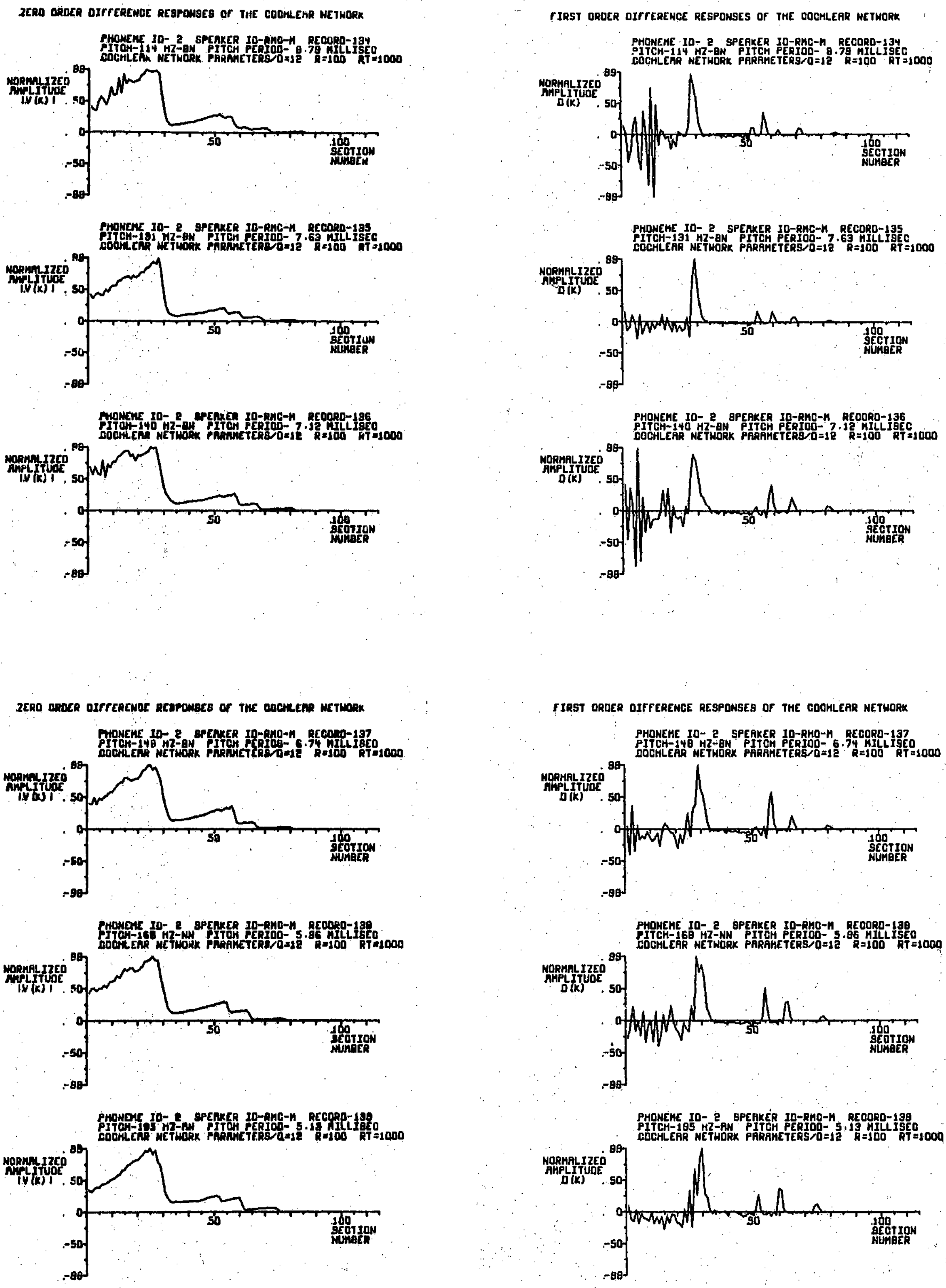


Figure B.39. Corresponding Zero and First Order Difference Responses as Effected by Phoneme (e) as Spoken by Speaker RMC

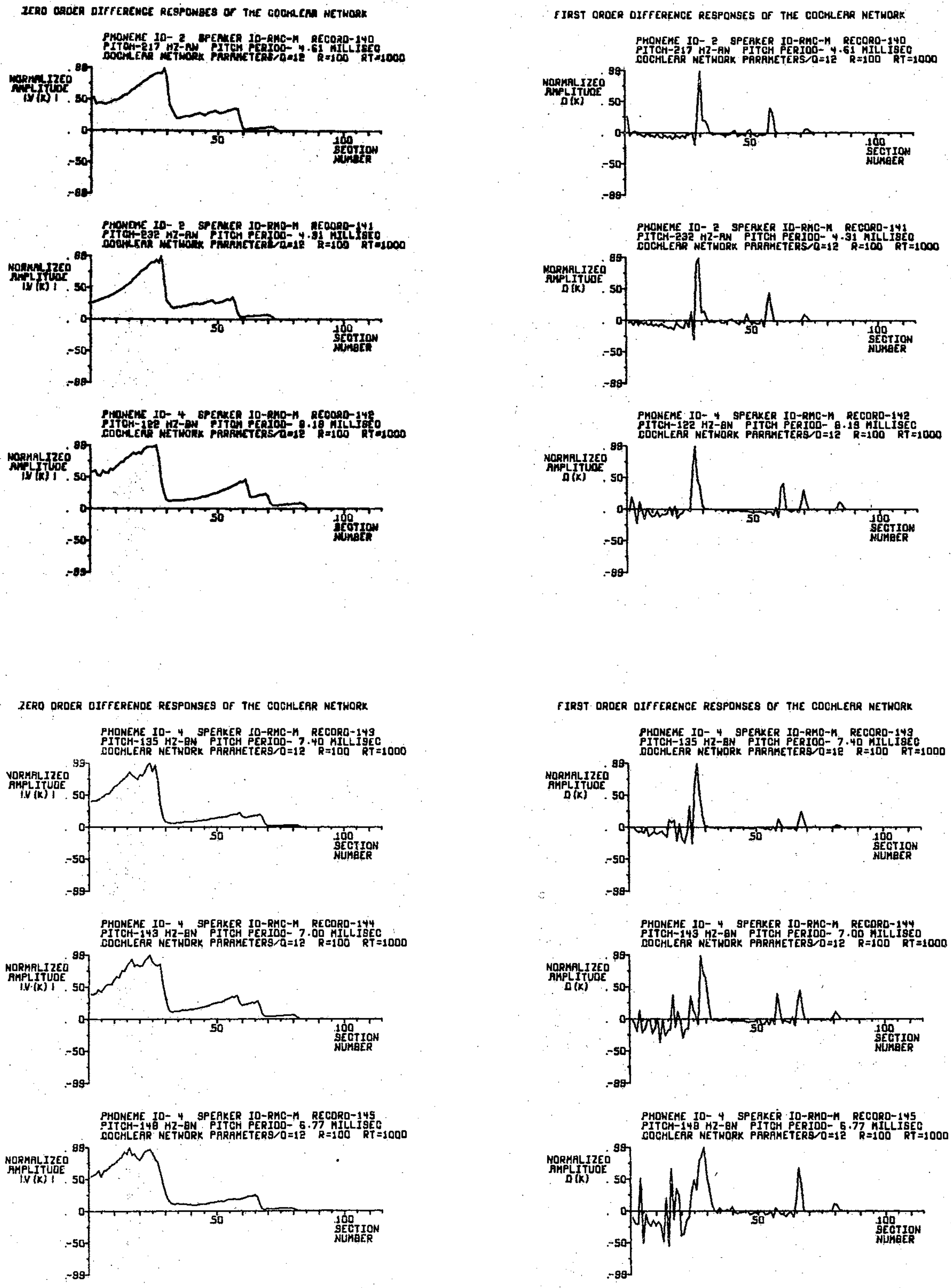


Figure B.40. Corresponding Zero and First Order Difference Responses as Effected by Phonemes (e) and (i) as Spoken by Speaker RMC

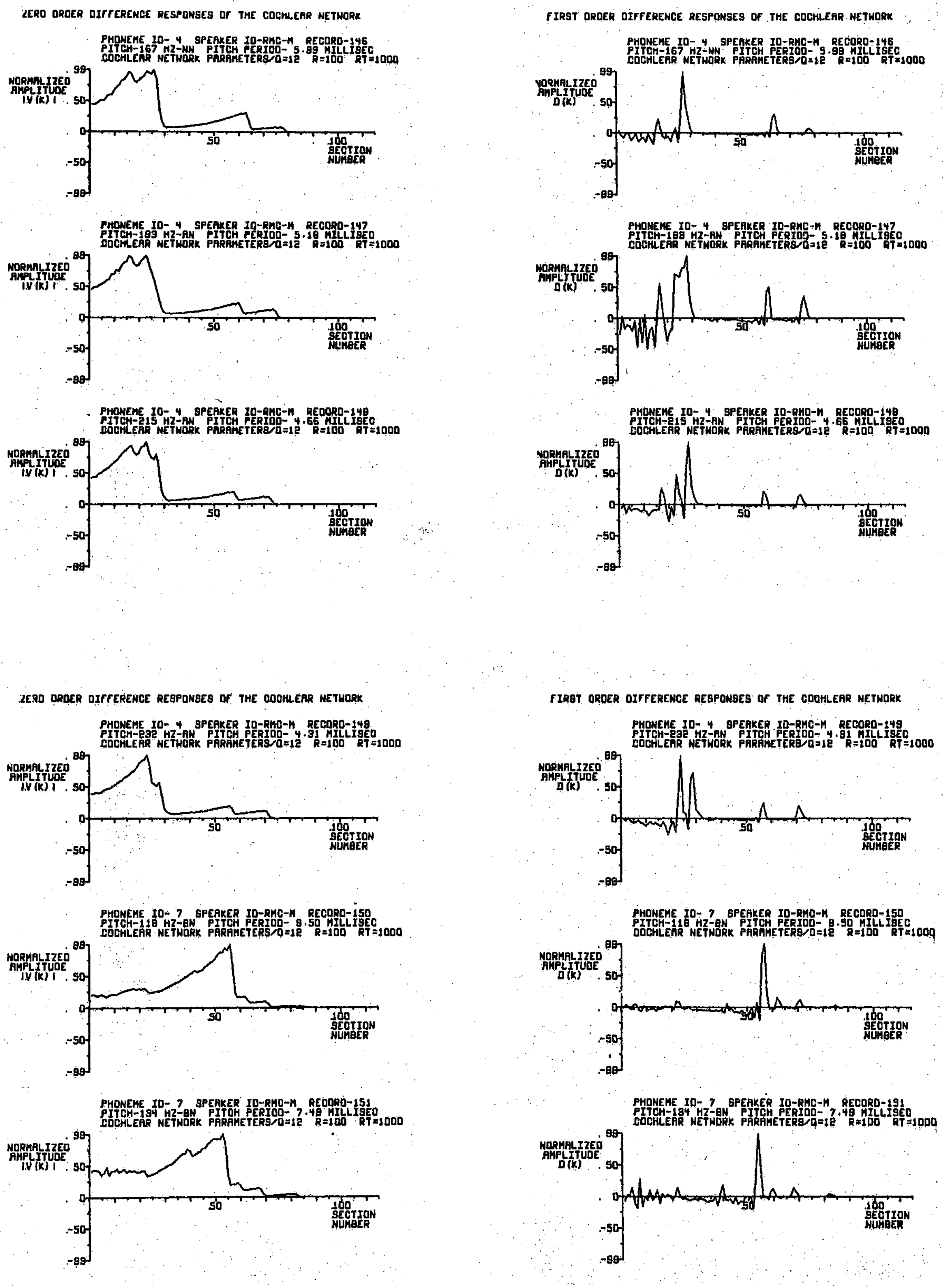


Figure B.41. Corresponding Zero and First Order Difference Responses as Effected by Phonemes (i) and (O) as Spoken by Speaker RMC

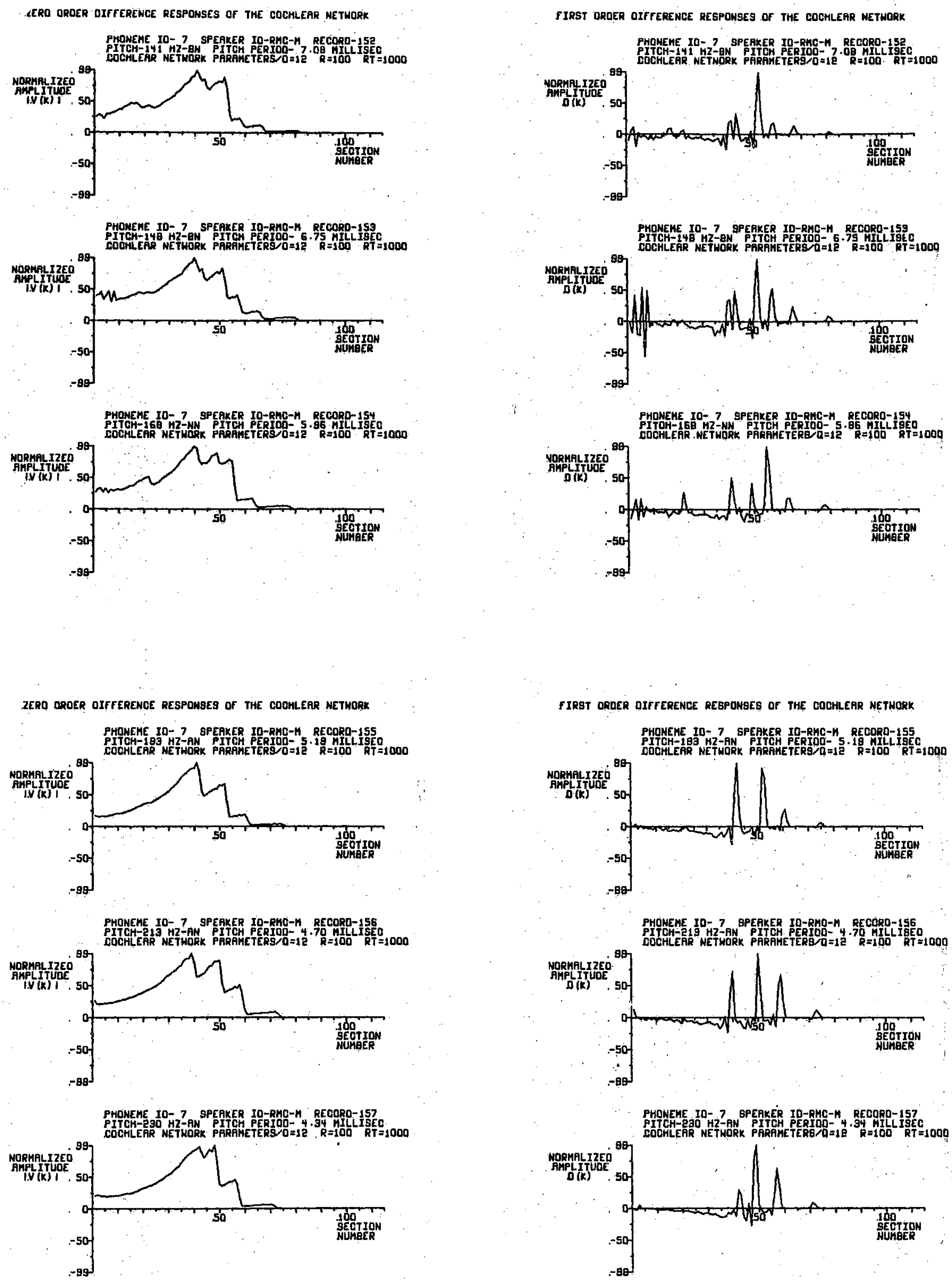


Figure B.42. Corresponding Zero and First Order Difference Responses as Effected by Phoneme (O) as Spoken by Speaker RMC

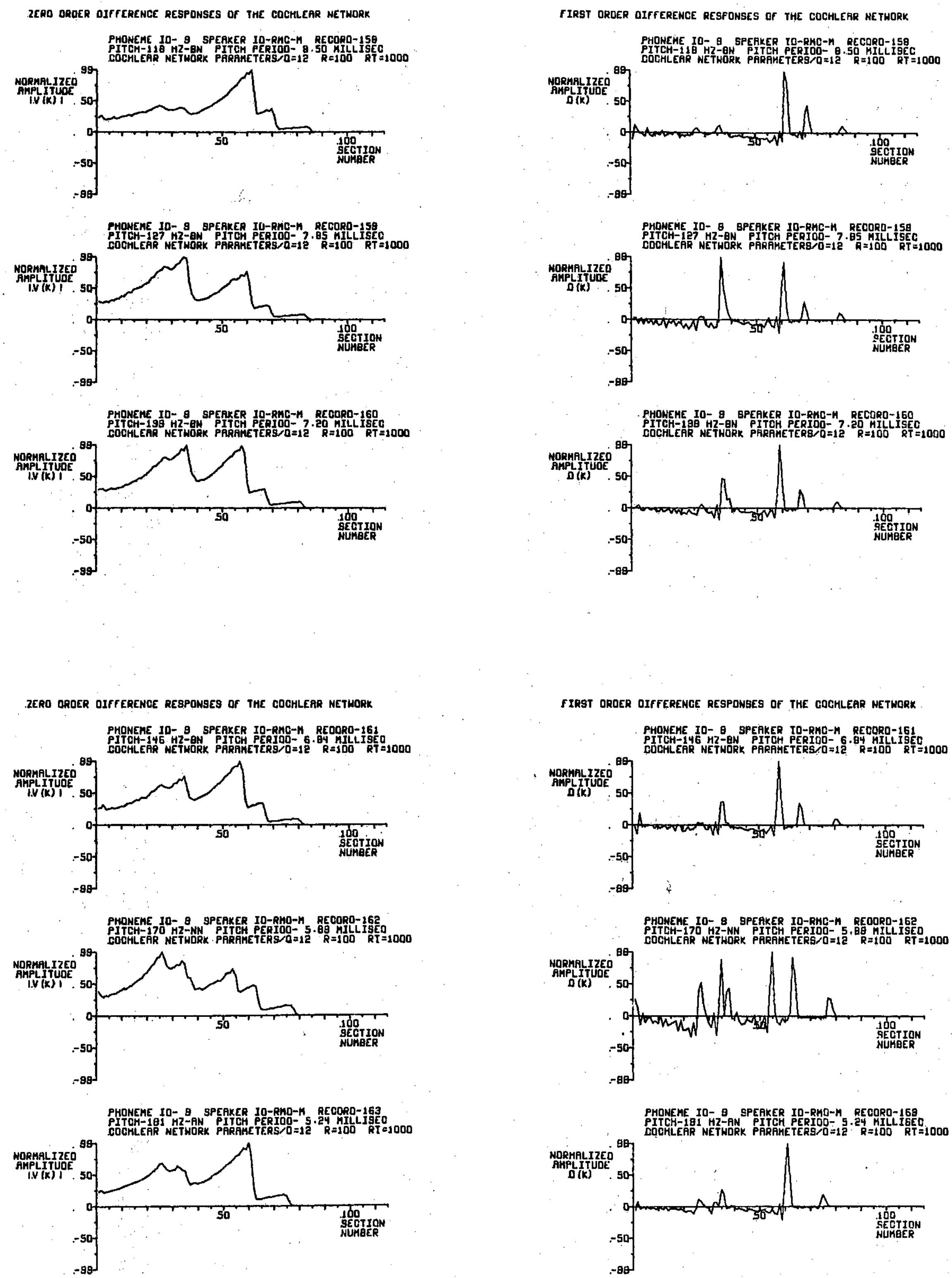
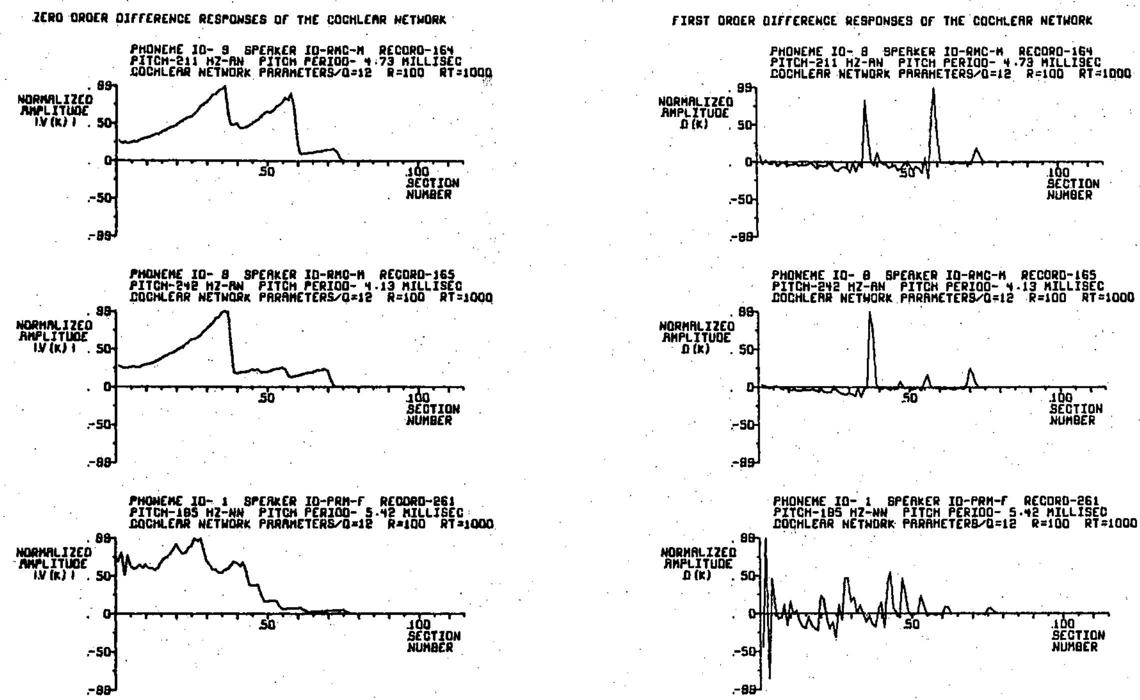


Figure B.43. Corresponding Zero and First Order Difference Responses as Effected by Phoneme (u) as Spoken by Speaker RMC



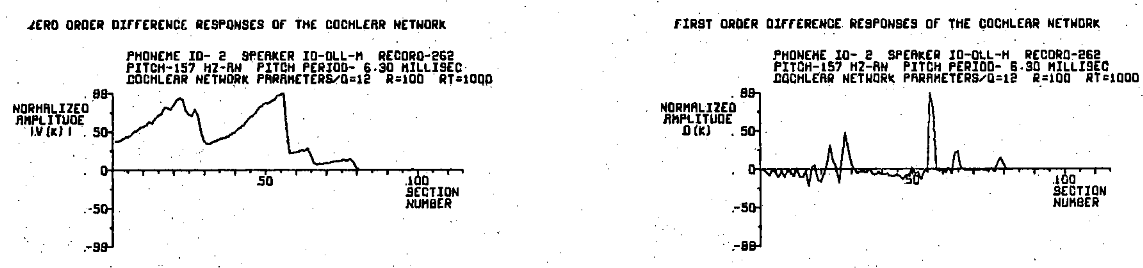


Figure B.44. Corresponding Zero and First Order Difference Responses as Effected by Phoneme (u) as Spoken by Speaker RMC

APPENDIX C

COMPUTER PROGRAMS

C.1 HP 2115A Computer Assembler Program. An assembler program written for the HP 2115A digital computer is listed by Table XII. This program was used in conjunction with the operation of the data sampling instrumentation used to collect phonetic sound data. Its functional relationship with the operation of the data sampling instrumentation equipments is varied as discussed in Chapter II.

The program is written such that the record length in words of a phonetic sound is a variable which can be specified as desired. Prior to initiation of a sampling operation the program provides the means by which numeric coded information can be manually set into the switch register of the computer for subsequent storage in memory. This information identifies the phonetic sound sample data to be collected and recorded. Upon initiation of sampling action the computer program controls the transfer of sample data from the analog-to-digital convert into the computer memory. Subsequent to this operation the program effects control of the transfer of the phonetic sound sample data and corresponding identification data from the computer memory to the HP 3030 digital magnetic tape recorder. Other program features are the means by which phoneme records previously recorded on the tape can be jumped over, the means by which the tape can be backspaced one record and the means to initiate rewinding of the tape.

A glossary listing and defining abbreviations used in the writting of the comment statements corresponding to a program instruction is provided. The comments associated with each program instruction in Table XII are detailed to enhance comprehension of the program and its functional relationships with the equipments whose operations it effects.

Glossary of Abbreviations for Program Listing of Table XII

```
A/D   ***** ANALOG/DIGITAL CONVERTER
ADDR  ***** ADDRESS
BLK   ***** BLOCK
CH    ***** CHANNEL
CLASS ***** CLASSIFICATION
COMM  ***** COMMAND
COMPL ***** COMPLIMENT
CONT  ***** CONTINUE
CW1   ***** CONTROL WORD 1
CW2   ***** CONTROL WORD 2
CW3   ***** CONTROL WORD 3
DEF   ***** DEFINES
DMA   ***** DIRECT MEMORY ADDRESS
ID    ***** IDENTIFICATION OR IDENTIFY
I/O   ***** INPUT/OUTPUT
INCR  ***** INCREMENT
INFO  ***** INFORMATION
INSTR ***** INSTRUCTION
JMP   ***** JUMP
LD    ***** LOAD
LOC   ***** LOCATION
MEM   ***** MEMORY
NUM   ***** NUMBER
OCT   ***** OCTAL
ORG   ***** ORIGINATE
PROG  ***** PROGRAM
RDY   ***** READY
REC   ***** RECORD
REG   ***** REGISTER
SW    ***** SWITCH
TRANS ***** TRANSFER
WRT   ***** WRITE

***************************************
```

TABLE XII

LISTING OF HP 2115A COMPUTER ASSEMBLER PROGRAM

```
                       ASMB,A,B,L,T
00100                        ORG 100B     OCT ADDR WHERE PROG ORG'S
00100 000000   BEGIN NOP                  CONT
00101 060267         LDA FL               LD FILE MARK WRT COMM IN REG A
00102 102611         OTA 11B              COMM RECORDER TO WRT FILE MARK ON TAPE
00103 102000   LOAD1 HLT                  LD N, NUM OF DATA SAMPLES/REC, IN SW REG
00104 102501         LIA 1                LD SW REG CONTENTS INTO REG A
00105 003000         CMA                  COMPL REG A CONTENTS
00106 002004         INA                  INCR REG A BY 1
00107 070260         STA NBUF1            STORE 2'S COMPL OF N IN NBUF1
00110 102000   LOAD2 HLT                  LD N+5 INTO SW REG
00111 102501         LIA 1                LD SW REG CONTENTS INTO REG A
00112 003000         CMA                  COMPL REG A CONTENTS
00113 002004         INA                  INCR REG A BY 1
00114 070261         STA NBUF2            STORE 2'S COMPL OF N+5 IN NBUF2
00115 102000   HALT1 HLT                  LD NUM OF TAPE REC'S TO BE SKIPPED IN SW REG
00116 102501         LIA 1                LD SW REG CONTENTS INTO REG A
00117 050245         CPA ZERO             JMP TO NEXT INSTR IF REG A IS ZERO
00120 024132         JMP START            JMP TO START
00121 003000         CMA                  COMPL REG A CONTENTS
00122 002004         INA                  INCR REG A BY 1
00123 070272         STA CNT              STORE 2'S COMPL OF NUM OF REC'S TO BE SKIPPED
00124 060264   LOOP1 LDA SPC1             LD FRWD SPACE REC COMM IN REG A
00125 102611         OTA 11B              COMM RECORDER TO FRWD SPACE
00126 102311         SFS 11B              SKIP NEXT INSTR IF RECORDER FLAG IS SET
00127 024126         JMP *-1              JMP BACK 1 INSTR
00130 034272         ISZ CNT              INCR CNT AND SKIP NEXT INSTR IF REG A IS 0
00131 024124         JMP LOOP1            JMP BACK TO LOOP1
00132 000000   START NOP                  CONT
00133 102000   HALT2 HLT                  LD PHONEME REC NUM INTO SW REG
00134 102501         LIA 1                LD CONTENTS OF SW REG INTO REG A
00135 170252         STA ADR1,I           STORE PHONEME REC NUM
00136 102000   HALT3 HLT                  LD SPEAKER ID CODE NUM INTO SW REG
00137 102501         LIA 1                LD CONTENTS OF SW REG INTO REG A
00140 170253         STA ADR2,I           STORE SPEAKER ID CODE NUM
00141 102000   HALT4 HLT                  LD PHONEME ID CODE NUM INTO SW REG
00142 102501         LIA 1                LD CONTENTS OF SW REG INTO REG A
00143 170254         STA ADR3,I           STORE PHONEME ID CODE NUM
00144 102000   HALT5 HLT                  LD PITCH CLASS CODE NUM INTO SW REG
00145 102501         LIA 1                LD CONTENTS OF SW REG INTO REG A
00146 170255         STA ADR4,I           STORE PITCH CLASS CODE NUM
00147 102000   HALT6 HLT                  LD PITCH PERIOD INTO SW REG
00150 102501         LIA 1                LD CONTENTS OF SW REG INTO REG A
00151 170256         STA ADR5,I           STORE PITCH PERIOD
00152 106700         CLC 0                CLEAR ALL I/O CONTROL BITS
00153 006400         CLB                  CLEAR REG B
00154 103100         CLF 0                CLEAR ALL I/O FLAGS
00155 060251         LDA CNTL1            LD CW1, CNTL1, INTO REG A
00156 102606         OTA 6                ID TO DMA A/D INPUT CH
00157 106702         CLC 2                RDY MEM ADDR REG TO RECEIVE CW2
00160 060257         LDA ADR6             LD CW2, START MEM ADDR FOR BLK TRANS
00161 102602         OTA 2                OUTPUT CW2 TO DMA CH 1
00162 102702         STC 2                RDY WORD COUNT REG FOR CW3
00163 060260         LDA NBUF1            LD CW3, 2'S COMPL OF NUM OF WORDS TO BE TRANS
00164 102602         OTA 2                OUTPUT CW3 TO DMA CH 1
00165 103714         STC 14B,C            START A/D INPUT CH
00166 103706         STC 6,C              START DMA OPERATION
00167 102306         SFS 6                WAIT FOR DATA TRANS AND JMP TO NEXT INSTR WHEN DONE
```

TABLE XII (Continued)

```
00170 024167         JMP *-1     JMP BACK 1 INSTR
00171 060262         LDA CNTL2   LD CW1, CNTL2 INTO REG A
00172 102606         OTA 6       ID TO DMA TAPE RECORDER AS OUTPUT CH
00173 106702         CLC 2       RDY MEM ADDR REG TO RECEIVE CW2
00174 060263         LDA ADR10   LD CW2, START MEM ADDR FOR BLK DATA TRANS
00175 102602         OTA 2       OUTPUT CW2, TO DMA CH 1
00176 102702         STC 2       RDY WORD COUNT REG TO RECEIVE CW3
00177 060261         LDA NBUF2   LD CW3, 2'S COMPL OF NUM OF WORDS TO BE TRANS
00200 102602         OTA 2       OUTPUT CW3 TO DMA CH 1
00201 102311         SFS 11B     SKIP NEXT INSTR WHEN RECORDER IS RDY
00202 024201         JMP *-1     JMP BACK 1 INSTR TO SEE IF RECORDER IS RDY
00203 060265         LDA OUT     LD REG A WITH RECORDER WRT CHARACTERS COMM
00204 103611         OTA 11B,C   OUTPUT WRT CHARACTERS COMM TO RECORDER
00205 103706         STC 6,C     SET I/O CONTROL BIT OF DMA CH 1,START DMA TRANS
00206 102306         SFS 6       SKIP NEXT INSTR IF DATA TRANS IS DONE
00207 024206         JMP *-1     JMP BACK 1 INSTR TO SEE IF DATA TRANS IS DONE
00210 102511         LIA 11B     LD REG A WITH PARITY INFO FROM RECORDER COMM CH
00211 010270         AND MASK1   AND REG A WITH PARITY CK WORD, MASK1
00212 002002         SZA         CK REG A FOR 0.  IF 0 SKIP NEXT INSTR.
00213 024216         JMP ERROR   JMP TO PARITY ERROR ID ROUTINE
00214 060245         LDA ZERO    LD REG A WITH ZERO
00215 024217         JMP *+2     JMP NEXT 2 INSTR
00216 060246  ERROR  LDA ONE     LD 1 INTO REG A TO INDICATE PARITY ERROR
00217 102000  HALT7  HLT         LD SW REG TAPE POSITIONING OPTION CODE
00220 102501         LIA 1       LD CONTENTS OF SW REG INTO REG A
00221 050245         CPA ZERO    CK REG A FOR 0. IF 0 CONT. IF NOT 0 SKIP NEXT INSTR.
00222 024132         JMP START   JMP TO START. RDY THEN FOR RECORDING NEXT REC.
00223 050247         CPA BACK    CK REG A FOR 1. IF 1 CONT. IF NOT 1 SKIP NEXT INSTR.
00224 024227         JMP BACK1   JMP TO BACK1, BACKSPACE TAPE 1 REC ROUTINE
00225 050250         CPA ENDX    CK REG A FOR 2. IF 2 CONT. IF NOT 2 SKIP NEXT INSTR.
00226 024234         JMP REW     JMP TO REW, REWIND ROUTINE
00227 060266  BACK1  LDA SPC2    LD TAPE BACKSPACE COMM WORD INTO REG A
00230 102611         OTA 11B     COMM RECORDER TO BACKSPACE TAPE 1 REC
00231 102311         SFS 11B     SKIP NEXT INSTR IF TAPE BACKSPACING IS DONE
00232 024231         JMP *-1     JMP BACK 1 INSTR TO SEE IF BACKSPACING IS DONE
00233 024132         JMP START   JMP TO START
00234 000000  REW    NOP         REWIND ROUTINE
00235 102311         SFS 11B     SKIP NEXT INSTR IF TAPE IS RDY
00236 024235         JMP *-1     JMP BACK 1 INSTR TO SEE IF TAPE IS RDY
00237 060271         LDA REW1    LD REWIND COMM WORD IN REG A
00240 103611         OTA 11B,C   COMM RECORDER TO REWIND TAPE
00241 102311         SFS 11B     SKIP NEXT INSTR IF TAPE IS REWOUND
00242 024241         JMP *-1     JMP BACK 1 INSTR TO SEE IF TAPE IS REWOUND
00243 106700         CLC 0       TURN OFF ALL I/O UNITS
00244 102000         HLT         HALT
00245 000000  ZERO   OCT 0       DEF ZERO TO BE OCT 0
00246 000001  ONE    OCT 1       DEF ONE TO BE OCT 1
00247 000001  BACK   OCT 1       DEF BACK TO BE OCT 1
00250 000002  ENDX   OCT 2       DEF ENDX TO BE OCT 2
00251 120014  CNTL1  OCT 120014  CW1, ID TO DMA A/D INPUT CH
00252 002000  ADR1   OCT 2000    OCT MEM ADDR WHERE BLK DATA STORAGE ORG
00253 002001  ADR2   OCT 2001    OCT MEM ADDR OF 2ND BLK DATA ID WORD
00254 002002  ADR3   OCT 2002    OCT MEM ADDR OF 3RD BLK DATA ID WORD
00255 002003  ADR4   OCT 2003    OCT MEM ADDR OF 4TH BLK DATA ID WORD
00256 002004  ADR5   OCT 2004    OCT MEM ADDR OF 5TH BLK DATA ID WORD
00257 102005  ADR6   OCT 102005  OCT MEM ADDR DESIGNATING ORG LOC FOR DATA FROM A/D
00260 001000  NBUF1  OCT 1000    SETS NBUF1 TO BE OCT 1000
00261 001001  NBUF2  OCT 1001    SETS NBUF2 TO BE OCT 1001
```

TABLE XII (Continued)

```
0117  00262 160010  CNTL2 OCT 160010   CW1 WHICH ID'S TO DMA TAPE RECORDER AS OUTPUT CH
0118  00263 002000  ADR10 OCT 002000   OCT MEM ADDR FOR BLK DATA TRANS VIA DMA TO RECORDER
0119  00264 000003  SPC1  OCT 3        RECORDER FRWD ADVANCE 1 REC COMM, OCT 3
0120  00265 000031  OUT   OCT 31       RECORDER WRT CHARACTERS COMM, OCT 31
0121  00266 000041  SPC2  OCT 41       RECORDER BACKSPACE 1 REC COMM, OCT 41
0122  00267 000035  FL    OCT 35       RECORDER WRT FILE MARK COMM, OCT 35
0123  00270 000002  MASK1 OCT 2        PARITY ERROR CK WORD, OCT 2
0124  00271 000201  REW1  OCT 201      RECORDER REWIND COMM WORD, OCT 201
0125  00272 000000  CNT   NOP          DEF CNT AS NOP OR OCT 0
0126                      END          END OF PROG
**  NO ERRORS*                         ***************************************************
```

C.2 Witz's Sign Magnitude to FORTRAN IV Data Conversion Program. The program listed by Table XIII is an assembler program written by Witz (22) for the IBM 360 computer. This program converts the data format of magnetic tape record files which are created by the sampling instrumentation system (depicted by Figure 2.3) to a FORTRAN IV tape input format. The converted data is recorded on a second magnetic tape.

To accomplish the format conversion two major changes are necessary. First each fixed record length of the original sample data tape must be converted to a variable record length format. Second it is necessary to convert each 16 bit sign magnitude word of a data record to 32 bit floating point words. The variable record length format is required by FORTRAN "unformatted" read statements. The change consists of adding 2 (32 bit) words to the beginning of each record. These two words define the "block length" and the "record length" of the record. Since all data records on the input tape are assumed to be equal in length, the added words to each record converted are constant.

The 32 bit floating point data format is the standard for the IBM 360 computer system. It is directly useable as a FORTRAN floating point variable.

The program is general in that any record length can be converted. This is accomplished by appropriate JCL specifications which define the tape data set to be converted and the tape data set to be created as the result of the conversion. Typical JCL required for execution of the program is included in the proper sequence in the program listing of Table XIII. This JCL is that necessary to permit data format conversion and subsequent normalization of the phoneme data by the program listed in Table XIV in one job step.

TABLE XIII

LISTING OF WITZ'S SIGN MAGNITUDE TO FORTRAN IV DATA CONVERSION PROGRAM

```
//OLL5    JOB (10604,510-36-5956,15,4,2000),'ORLEY L LAKE',MSGLEVEL=1
//ALRUN   EXEC     ASMFCLG
//ASM.SYSIN        DD     *
          TITLE    ' THEMIS TAPE CONVERSION '
          LCLA     &SCALE
          LCLC     &TYPE
CONV2     CSECT
*                            INSERT HERE THE SCALE USING TWO CARDS
*                            OF THE FORM (START IN COLUMN 1):
*                            &TYPE     SETC    'X'
*                                WHERE X IS N FOR NO SCALE,
*                                           M FOR MULTIPLY
*                                           D FOR DIVIDE
*                            &SCALE     SETA    #
*                                WHERE # IS THE SCALE FACTOR
&SCALE    SETA     1
&TYPE     SETC     'N'
*
*                            NEARLY ALL WORK IS DONE IN REGISTERS
*
*                            ALL NAMES BEGIN WITH A CODE
*                            TO INDICATE THEIR FORM AND USE
*                            R - REGISTER
*                            C   CONSTANT
*                            W    WORKSPACE
*
*                            THE PRECEDING ARE USUALLY FOLLOWED
*                            BY FURTHER TYPE CODE
*
*                            V    VARIABLE
*                            A    ADDRESS CONSTANT
*                            L    LOCATION LABEL
*
*                            E    FLOATING FULLWORD
*                            F    FULLWORD INTEGER
*                            C    CHARACTER STRING
          EJECT
*                        REGISTER NAME DEFINITIONS
RAY       EQU      1         LOCATION TO PUT OUTPUT DATA:  MUST BE 1
RAX       EQU      2         LOCATION OF INPUT DATA
RVN       EQU      8         COUNTS BLOCKS
RVI       EQU      3         COUNTS HALFWORDS WITHIN BLOCK
*
RC2       EQU      4         =2, INCR FOR I:  MUST BE EVEN
RVMAX     EQU      5         MAX FOR I:  MUST FOLLOW RC2
RW        EQU      0         WORKSPACE
RW2       EQU      6         WORKSPACE
RCFCLEAR  EQU      7         CLEARS THE EXTRA SIGN BITS PRODUCED
*                                BY LH (WHEN NUMBER IS NOT 2'S COMP.)
RCEXP     EQU      9         SOURCE OF EXPONENT
RADCB1    EQU      11        ADDR OF DCB FOR INTAPE
RADCB2    EQU      12        ADDR OF DCB FOR OUTAPE
RABASE    EQU      10        BASE REGISTER FOR THE WHOLE PGM
*                            FLOAT REGS
RECSCALE  EQU      0         SCALE FACTOR
REW       EQU      2         WORK
*
NLRECL    EQU      82        OFFSET FOR LRECL IN DCB
NBLKSI    EQU      62        OFFSET FOR BLKSIZE IN DCB
```

TABLE XIII (Continued)

```
*
         AIF      ('&TYPE' NE 'N').SKIP1
&SCALE   SETA     1
.SKIP1   ANOP
         EJECT
*                                 ACTUAL BEGINNING OF PROGRAM
         USING    *,15
         BAL      RABASE,SAVE+72
         USING    *,RABASE
SAVE     DS       18F
         STM      14,12,12(13)
         ST       13,SAVE+4
         LA       1,SAVE
         ST       1,8(13)
         LR       13,1
*                                 BEGINNING OF ACTUAL PGM
*
*                                 USE LRECL OF INPUT TAPE FOR MAX
         OPEN     (INTAPE,(INPUT))
         LH       RVMAX,INTAPE+NLRECL
*                                 SET OUTPUT TAPE LENGTH TO 2*MAX
*                                 (THE ACTUAL #'S INCLUDE CONTROL WORDS)
         LA       RW2,2(RVMAX)
         SLL      RW2,1
         STH      RW2,OUTAPE+NLRECL     LRECL = 2*MAX + 4
         LA       RW2,4(RW2)
         STH      RW2,OUTAPE+NBLKSI     BLKSIZE = LRECL + 4
         OPEN     (OUTAPE,(OUTPUT),SYSOUT,(OUTPUT))
         PUT      SYSOUT,CCOPEN
*
*                                 INIT REGS
         L        RC2,=F'2'
         L        RCFCLEAR,=X'80007FFF'
         L        RCEXP,=X'C6000000'
         L        RECSCALE,=E'&SCALE'
*
         LA       RADCB1,INTAPE
         LA       RADCB2,OUTAPE
*                                 LAST NUMBER IS AT 0 + LRECL -2
         BCTR     RVMAX,0         MAX = MAX - 1
         EJECT
*                                 DO N = -1 TO -4294967296 BY -1
         LA       RVN,1
         LNR      RVN,RVN         N = -N
LOOPN    EQU      *
         LR       1,RADCB1
         GET      (1)             RETURNS ADDR OF NEXT RECORD
         LR       RAX,1
         LR       1,RADCB2
         PUT      (1)             RETURNS A GOOD PLACE TO PUT OUTPUT
*                                 WHICH WILL BE WRITTEN AUTOMATICALLY
*                                 (RESULT IS IN REG 1 WHICH IS RAY)
*
*                                 SET OUTPUT CONTROL WORD
         LA       RW2,3(RVMAX)
         SLL      RW2,17          W2 = 2*MAX + 4   IN LEFT HALFWORD
         ST       RW2,0(RAY)
         LA       RAY,4(RAY)
*                                 DO I = 0 TO MAX BY 2
         SR       RVI,RVI
```

TABLE XIII (Continued)

```
LOOPI    EQU      *
*                         THE NITTY GRITTY:
         LH       RW,0(RVI,RAX)         LOAD NEXT DATA - X(I)
         NR       RW,RCFCLEAR           CLEAR EXTRA SIGN BITS
*                         N IS FOR AND, NR IS AND REGISTER
         XR       RW,RCEXP        FLOAT (.OR. IN AN EXPONENT)
*                         AND INVERT SIGN (USES EXCLUSIVE OR)
*
         AIF      ('&TYPE' EQ 'N').SKIP2
*                         SCALE
         ST       RW,WE
         LE       REW,WE          MOVE TO FLOAT REG
         AIF      ('&TYPE' EQ 'M').MULT
*                         DIVIDE
         DER      REW,RECSCALE
         AGO      .SKIP3
.MULT    ANOP
*                         MULT
         MER      REW,RECSCALE
.SKIP3   ANOP
         LR       RW2,RVI
         SLL      RW2,1                W2 = I*2
         STE      REW,0(RW2,RAY)       STORE DATA IN Y(W2)
*                                      I IS COUNTING BY 2'S
*                                      Y IS IN WORDS OR 4'S
         AGO      .SKIP4
*                         THIS SECTION IS USED IF NO SCALE NEEDED
.SKIP2   ANOP
         LR       RW2,RVI
         SLL      RW2,1          W2 = I*2
         ST       RW,0(RW2,RAY)     STORE DATA IN Y(W2)
*                                      I IS COUNTING BY 2'S
*                                      Y IS IN WORDS OR 4'S
.SKIP4   ANOP
         BXLE     RVI,RC2,LOOPI      I = I + 2
*                         IF(I <= MAX)GO TO LOOPI
*                         MAX IS ASSUMED TO BE IN RC2 + 1
         BCT      RVN,LOOPN       N = N - 1
*                         IF( N ¬= 0) GO TO LOOPN
*                         THE SUBTRACTION DISREGARDS OFLO:
*                         +MAX IS ONE LESS THAN -MAX
*                         THIS GIVES THE RANGE OF ABOUT 4E9
*                         ABS(N) IS PRINTED
         EJECT
*                         STANDARD EXIT IS TO ONE OF THE FOLLOWING
*                         ROUTINES ON END OF DATA OR ERROR
*
LERRIN   EQU      *
         CVD      RVN,WD          CONVERT N TO DECIMAL
         UNPK     V#FLD1,WD       MOVE TO OUTPUT FIELD
         MVZ      V#FLD1+15(1),=X'FF'    REMOVE SIGN
         PUT      SYSOUT,CCERR
         B        LCLOSE
*
LEOD     EQU      *
         CVD      RVN,WD          CONVERT N TO DECIMAL
         UNPK     V#FLD2,WD       MOVE TO OUTPUT FIELD
         MVZ      V#FLD2+15(1),=X'FF'    REMOVE SIGN
         PUT      SYSOUT,CCEOD
LCLOSE   EQU      *
```

TABLE XIII (Continued)

```
         CLOSE   (INTAPE,,OUTAPE,,SYSOUT)
         L       13,SAVE+4
         LM      14,12,12(13)
         LA      15,1
         BR      14
         EJECT
*                         CONSTANTS AND WORKSPACES
WD       DS      D
WE       DS      E
*
CCOPEN   DC      CL51'1 THEMIS TAPE CONVERSION PROGRAM'
CCERR    DS      0CL51
         DC      C'-INPUT (TAPE) ERROR IN BLOCK '
V#FLD1   DS      CL16
         DC      CL18' '
*
CCEOD    DS      0CL51
         DC      CL1'-'
V#FLD2   DS      CL16
         DC      C' BLOCKS CONVERTED'
         DC      CL30' '
*
*                         DATA CONTROL BLOCKS
INTAPE   DCB   DDNAME=INTAPE,                                         CONTINUE
               MACRF=GL,                                              CONTINUE
               DSORG=PS,RECFM=FS,                                     CONTINUE
               EODAD=LEOD,SYNAD=LERRIN
OUTAPE   DCB   DDNAME=OUTAPE,                                         CONTINUE
               MACRF=PL,                                              CONTINUE
               DSORG=PS,RECFM=V
SYSOUT   DCB   DDNAME=SYSOUT,                                         CONTINUE
               MACRF=PM,                                              CONTINUE
               DSORG=PS,RECFM=FA,                                     CONTINUE
               LRECL=51,BLKSIZE=51
         END
*
//GO.INTAPE DD DISP=(OLD,KEEP,KEEP),
//       UNIT=(TAPE9,,DEFER),
//       VOL=(PRIVATE,SER=T905),
//       LABEL=(1,NL),                 1 IS FOR FIRST DATA ON TAPE
//       DCB=(DEN=2,                   2 IS FOR 800BPI
//       LRECL=138,BLKSIZE=138)        69 16 BIT #'S
//GO.OUTAPE DD DISP=(NEW,PASS,DELETE), CREATE AND KEEP
//*                                    UNLESS PROGRAM ABENDS
//       DSNAME=SDATA921,              ANY 8 CHARACTERS
//*                                    THIS NAME MUST BE USED BY ANY PGM
//*                                    WHICH USES THE OUTPUT TAPE
//       UNIT=(TAPE9,,DEFER),
//       VOL=(PRIVATE,SER=T921),       THIS SER MUST BE USED BY ANY PGM
//*                                    WHICH USES THE OUTPUT TAPE
//       LABEL=(2,SL),
//       DCB=DEN=2                     2 IS FOR 800BPI
//*                                    THE OUTPUT TAPE WILL HAVE THE
//*                                    SAME # OF #'S PER BLOCK
//*                                    LRECL=(INTAPE-LRECL*2)+4
//*                                    BLKSIZE=(INTAPE-LRECL*2)+8
//*                                    OR BLKSIZE=LRECL+4
//*
//GO.SYSOUT DD SYSOUT=A
//
```

C.3 Phonetic Sound Normalization Program. The program listed by Table XIV is a FORTRAN IV program written for the IBM 360 computer. This program is designed to normalize the magnitudes of phonetic sound sample data such that any sample value of a phoneme record, S_n, will be an integer within the range of $-99 \leq S_n \leq 99$. The normalization method is stated mathematically by Equation C.1.

$$S_n(n*\Delta t) = \{(D_n(n*\Delta t)/\max\{|D_n(n*\Delta t)|\}*NF \qquad (C.1)$$

where

$S_n(n*\Delta t) \triangleq$ the nth normalized amplitude-time sample of the phonetic sound data

$D_n(n*\Delta t) \triangleq$ the nth amplitude-time sample of the phonetic sound data

$\max\{|D_n(n*\Delta t)|\} \triangleq$ the maximum of the sample data set $\{|D_n(n*\Delta t)|\}$

$NF \triangleq$ an arbitrary integer normalizing factor

$n = 1,2,3,...,N$

$N \triangleq$ data samples per phonetic sound record.

The phonetic sound input data is assumed to be file recorded on magnetic tape. Each phonetic sound record of a file consists of five numerical record identification words and N numerical words which are representative of the phoneme sample data. The identification words specify the following information.

ID-Word 1-Phonetic sound record number

ID-Word 2-Speaker identification

ID-Word 3-Phonetic sound identification

ID-Word 4-Speaker pitch classification

ID-Word 5-Pitch period.

A FORTRAN IV "unformatted" read statement is used to initiate the reading of a phonetic sound record.

In addition to the phonetic sound input data the program variables NREC, NDATA, NSPK and the array SPKID must be specified. NREC denotes the number of phonetic sound records to be normalized. NDATA specifies the word length of a phonetic sound record, N + 5. The variable NSPK denotes the dimension of the speaker initial vs speaker code number identification table. The array named SPKID is the program designation of this identification table.

The first data card must specify NREC, NDATA and NSPK in this order in a 3I3 format.

The next data cards (the number of cards is dependent upon the number of speakers) must specify the speaker initial vs speaker code number identification table. Speaker initials must be punched on a data card in an 26A3 format. Their order is important. The code number assigned to a speaker must be in agreement with the subscript integer of the SPKID array element which specifies the speaker's initials.

The documented and normalized phonetic sound records produced by the program are listed by the line printer and also punched on IBM cards. Table XI of Appendix A illustrates the output format of the normalized phonetic sound records which are the resultant product of this program.

To execute the program, the FORTRAN IV program card deck with associated JCL cards and data cards must be sequenced as follows and processed into the computer.

(1) JCL Card - Job Card

(2) JCL Card - // EXEC FORTGCLG

(3) JCL Card - //FORT.SYSIN DD *

(4) FORTRAN IV Program Deck

(5) JCL Cards - Specifications for Tape Data Set

(6) JCL Card - //GO.SYSIN DD *

(7) Program Data Cards

(8) //GO.SYSPUNCH DD SYSOUT=B

(9) //

TABLE XIV

LISTING OF PHONETIC SOUND NORMALIZATION PROGRAM

```
//OLL1   JOB (10604,510-36-5956,20,36,360),'LEON LAKE',MSGLEVEL=1,      C
//               CLASS=A
// EXEC FORTGCLG
//FORT.SYSIN DD *
      DIMENSION DATA(517),IDATA(517),SPKID(99),PCLASS(3),SEX(2)
      DIMENSION IMT(9),NUM(24)
      COMMON DATA,NDATA,SCALE
      DATA PCLASS(1)/'BN'/,PCLASS(2)/'NN'/,PCLASS(3)/'AN'/,SEX(1)/'M'/,
     1SEX(2)/'F'/
      DATA IMT(1)/'(   '/,IMT(2)/' '/,IMT(3)/'24'/,IMT(4)/'I3,T'/,
     1 IMT(5)/'73,3'/,IMT(6)/'HRC-'/,IMT(7)/',I3,'/,IMT(8)/'1H-,'/,
     2 IMT(9)/'I1)'/
      DATA NUM(1)/'1'/,NUM(2)/'2'/,NUM(3)/'3'/,NUM(4)/'4'/,NUM(5)/'5'/,
     1 NUM(6)/'6'/,NUM(7)/'7'/,NUM(8)/'8'/,NUM(9)/'9'/,NUM(10)/'10'/,
     2 NUM(11)/'11'/,NUM(12)/'12'/,NUM(13)/'13'/,NUM(14)/'14'/,
     3 NUM(15)/'15'/,NUM(16)/'16'/,NUM(17)/'17'/,NUM(18)/'18'/,
     4 NUM(19)/'19'/,NUM(20)/'20'/,NUM(21)/'21'/,NUM(22)/'22'/,
     5 NUM(23)/'23'/,NUM(24)/'24'/
      EQUIVALENCE (DATA(1),IDATA(1))
      READ(5,100) NREC,NDATA,NSPK
  100 FORMAT(3I3)
      READ(5,102) (SPKID(K),K=1,NSPK)
  102 FORMAT(26A3,2X)
      WRITE(6,136)
  136 FORMAT(1H1)
      DO 104 I=1,NREC
      READ(99) (DATA(J),J=1,NDATA)
      SCALE=99.0
      CALL NORM
      IREC=DATA(1)
      ISPK=DATA(2)
      IF(ISPK) 106,108,108
  106 ISEX=1
      GO TO 110
  108 ISEX=2
  110 ISPK=IABS(ISPK)
      IPHO=DATA(3)
      IPCL=DATA(4)
      PERD=DATA(5)/100.0
      PITCH=(1.0/PERD)*1000.0
      IPIT=PITCH
      FPIT=IPIT
      ROFF=PITCH-FPIT
      IF(ROFF-0.5) 138,140,140
  140 IPIT=IPIT+1
  138 NSAM=NDATA-5
      FNSAM=NSAM
      SAMRT=FNSAM*PITCH
      ISAMRT=SAMRT
      FSAMRT=ISAMRT
      RROFF=SAMRT-FSAMRT
      IF(RROFF-0.5) 142,144,144
  144 ISAMRT=ISAMRT+1
  142 WRITE(6,134)
  134 FORMAT(1H ,131('*'))
      WRITE(6,112) SPKID(ISPK),SEX(ISEX),IPHO,IPIT,PCLASS(IPCL),PERD,
     1ISAMRT,IREC
  112 FORMAT(1H ,'SPEAKER ID-',A3,'-',A1,'/PHONEME ID-',I2,'/PITCH-',I3,
     1'-',A2,'/PITCH PERIOD=',F6.2,' MS','/SAMPLE RATE-'I5,'/',13X,
```

TABLE XIV (Continued)

```
     2' RECORD-',I3,'-0')
      WRITE(7,114) SPKID(ISPK),SEX(ISEX),IPHO,IPIT,PCLASS(IPCL),PERD,
     1IREC
  114 FORMAT( 'SPEAKER ID-',A3,'-',A1,'/PHONEME ID-',I2,'/PITCH-',I3,
     1'-',A2,'/PITCH PERIOD-',F6.2,' MS/',T73,'RC-',I3,'-0')
      ICNT=1
      IFLAG=0
      NBEGIN=6
      IF(NDATA.GT.29) GO TO 116
      NSTOP=NDATA
  124 IFLAG=1
      GO TO 118
  116 NSTOP=29
  118 WRITE(6,120) (IDATA(J),J=NBEGIN,NSTOP)
  120 FORMAT(1H ,24I4)
      WRITE(6,132) IREC,ICNT
  132 FORMAT(1H+,102X,'"',3X,I3,'-',I1)
      IMT(3)=NUM(NSTOP-NBEGIN+1)
      WRITE(7,IMT) (IDATA(J),J=NBEGIN,NSTOP),IREC,ICNT
      IF(IFLAG) 104,126,104
  126 ICNT=ICNT+1
      NBEGIN=NSTOP+1
      NSTOP=NSTOP+24
      IF(NSTOP.LT.NDATA) GO TO 118
      NSTOP=NDATA
      GO TO 124
  104 CONTINUE
      WRITE(6,134)
      WRITE(6,136)
      CALL EXIT
      END


      SUBROUTINE NORM
      DIMENSION IDATA(517)
      COMMON DATA(517),NDATA,SCALE
      EQUIVALENCE (DATA(1),IDATA(1))
      SAMAX=ABS(DATA(6))
      DO 128 K=6,NDATA
      IF(SAMAX.LT.ABS(DATA(K))) SAMAX=ABS(DATA(K))
  128 CONTINUE
      DO 130 K=6,NDATA
      IDATA(K)=(DATA(K)/SAMAX)*SCALE
  130 CONTINUE
      RETURN
      END
//GO.FT99F001 DD DISP=(OLD,KEEP,KEEP),
//        DSNAME=SDATA921,
//        UNIT=(TAPE9,,DEFER),
//        VOL=(PRIVATE,SER=T921),
//        LABEL=(2,SL),
//        DCB=(DEN=2,
//        RECFM=V,
//        LRECL=280,BLKSIZE=284,
//        DSORG=PS)
//GO.SYSIN DD *
 35 69 12
OLLRLJRDKDEMJEBRVPRMCMALPAFPRMIAPLLC
//GO.SYSPUNCH DD SYSOUT=B
//
```

C.4 Cochlear Model Simulation Program. The program employed to simulate the response behavior of the cochlear model to phonetic sound signals is listed by Table XV. It is a FORTRAN IV program written for the IBM 360 computer. The simulation technique on which the program is based has been presented in detail in Chapter IV.

The resultant products of the program are responses which are intended to represent the steady-state displacement of the basilar membrane of the cochlea and the neighboring inhibition effect of neural fiber of the cochlea in response to a phonetic sound. These resultant responses are listed by the line printer of the IBM 360 computer system and also punched on IBM cards.

To initiate simulations by the computer model of the cochlea the FORTRAN IV program card deck with associated JCL cards and data cards must be sequenced as follows and processed into the computer.

(1) JCL Card - Job Card

(2) JCL Card - // EXEC FORTGCLG

(3) JCL Card - //FORT.SYSIN DD *

(4) FORTRAN IV Program Deck

(5) JCL Card - //GO.SYSIN DD *

(6) Data Card 1 - Used to specify the program variables NREC, NDATA and KDATA in a 3I4 format. Where NREC specifies the number of phonetic sound records to be processed. NDATA specifies the number of data samples which together are representative of a phonetic sound signal. KDATA is a model parameter which must always equal the value of NDATA.

Further NDATA and KDATA must be even integers.

(7) Data Card 2 - Used to specify the cochlear model parameter NSECT, NFREQ, R, R_T, Q and FNORM1 in a 2I4, 4F10.1 format. Where NSECT specifies the number of section of the cochlear model and must not exceed 100. NFREQ specifies the number of Fourier series coefficients to be calculated. NFREQ must not exceed 128 and must be one-half of NDATA. The parameter R specifies the universal resistance value of the cochlear model. RT denotes the terminal resistance value of the cochlear model. The variable Q designates the universal Q value of the cochlear model. FNORM1 specifies a normalizing factor.

(8) Phonetic Sound Data Cards

(9) JCL Cards - //GO.SYSPUNCH DD SYSOUT=B

(10) JCL Card - //

TABLE XV

LISTING OF COCHLEAR MODEL SIMULATION PROGRAM

```
//OLL1    JOB (10604,510-36-5956,40,36,360),'LEON LAKE',MSGLEVEL=1,       C
//              CLASS=L
// EXEC FORTGC
//FORT.SYSIN DD *
C      MAIN PROGRAM****MAIN PROGRAM****MAIN PROGRAM****MAIN PROGRAM
       COMPLEX V(100,128),DATA(256),WDATA(2048)
       COMPLEX ZA(128),ZS(128),Z(128),IA(128),VS(128),IS(128),WORK(10)
       COMPLEX CMPLX
       DIMENSION VDIFF0(100,128),VDIFF1(100,128)
       DIMENSION VDC0(100),VDC1(100)
       DIMENSION FFREQ(128),CFREQ(128)
       DIMENSION IVDC0(100),IVDC1(100)
       DIMENSION IDATA(128)
       COMMON /OUTEAR/V/DATAS/DATA/WDATAS/WDATA/IDATAS/IDATA
       COMMON /VDC/VDC0,VDC1
       COMMON /FREQ/FFREQ,CFREQ
       COMMON /IVDC/IVDC0,IVDC1
       COMMON /SPEC1/NREC,NDATA,KDATA
       COMMON /SPEC2/IDSPK,ISEX,IPHO,IPIT,IPCL,PERD,IREC
       COMMON /SPEC3/NSECT,NFREQ,R,RT,Q,FNORM1
       COMMON WORK,KM
       EQUIVALENCE (V(1),VDIFF0(1)),(V(6401),VDIFF1(1))
       CALL READ1M
       DO 999 KM=1,NREC
       CALL READ2
       CALL READY1
       CALL FOURT(DATA,KDATA,1,-1,1,WORK,10)
       CALL EAR
       CALL PRNTM1
       NSECT1=NSECT-1
       CALL FULREC(NSECT,NFREQ)
       CALL DCFLTR(NSECT,NFREQ)
       CALL NORM(NSECT)
       CALL WRITEM(NSECT)
       CALL PUNCHM(NSECT)
       CALL DCFLTR(NSECT1,NFREQ)
       CALL NORM(NSECT1)
       CALL WRITEM(NSECT1)
       CALL PUNCHM(NSECT1)
   999 CONTINUE
       STOP
       END
```

TABLE XV (Continued)

```
      SUBROUTINE READ1M
      COMMON /SPEC1/NREC,NDATA,KDATA
      COMMON /SPEC3/NSECT,NFREQ,R,RT,Q,FNORM1
C     READ DATA SPECIFICATIONS FOR PHONETIC SOUND SAMPLE DATA SETS.
      READ(5,1) NREC,NDATA,KDATA
    1 FORMAT(3I4)
C     READ PARAMETERS FOR COCHLEAR MODEL.
      READ(5,2) NSECT,NFREQ,R,RT,Q,FNORM1
    2 FORMAT(2I4,4F10.1)
      RETURN
      END


      SUBROUTINE READ2
      COMMON /IDATAS/IDATA(128)
      COMMON /SPEC1/NREC,NDATA,KDATA
      COMMON /SPEC2/IDSPK,ISEX,IPHO,IPIT,IPCL,PERD,IREC
C     READ ID CARD FOR PHONETIC SOUND DATA SET.
      READ(5,4) IDSPK,ISEX,IPHO,IPIT,IPCL,PERD,IREC
    4 FORMAT(11X,A3,1X,A1,12X,I2,7X,I3,1X,A2,14X,F6.2,12X,I3,2X)
C     READ PHONETIC SOUND NORMALIZED SAMPLE VALUES.
      READ(5,5) (IDATA(K),K=1,NDATA)
    5 FORMAT(24I3,8X)
      RETURN
      END


      SUBROUTINE READY1
      COMPLEX DATA(256)
      COMPLEX CMPLX
      DIMENSION IDATA(128)
      COMMON /DATAS/DATA/IDATAS/IDATA
      COMMON /SPEC1/NREC,NDATA,KDATA
C     FLOAT NORMALIZED SAMPLE VALUES INTO COMPLEX FORM.
      DO 700 K=1,KDATA
      IF(K-NDATA) 701,701,702
  701 XDATA=IDATA(K)
      DATA(K)=CMPLX(XDATA,0.0)
      GO TO 700
  702 DATA(K)=CMPLX(0.0,0.0)
  700 CONTINUE
      RETURN
      END
```

TABLE XV (Continued)

```
      SUBROUTINE EAR
C     SUBROUTINE EAR SIMULATES THE RESPONSE OF THE COCHLEA OF THE EAR
C     TO SOUND WAVES.
      COMPLEX V(100,128),DATA(256),WDATA(2048)
      COMPLEX ZA(128),ZS(128),Z(128),IA(128),VS(128),IS(128),WORK(10)
      COMPLEX CMPLX
      COMPLEX PLEX
      DIMENSION VDIFF0(100,128),VDIFF1(100,128)
      DIMENSION FFREQ(128),CFREQ(128)
      COMMON /OUTEAR/V/DATAS/DATA/WDATAS/WDATA
      COMMON /SPEC1/NREC,NDATA,KDATA
      COMMON /SPEC2/IDSPK,ISEX,IPHO,IPIT,IPCL,PERD,IREC
      COMMON /SPEC3/NSECT,NFREQ,R,RT,Q,FNORM1
      COMMON /FREQ/FFREQ,CFREQ
      COMMON WORK,KM
      EQUIVALENCE (V(1),VDIFF0(1)),(V(6401),VDIFF1(1))
C     CALCULATION OF FREQUENCIES WHICH CORRESPOND TO THE FOURIER SERIES
C     COEFFICIENTS.  ALSO CALCULATION OF CHARACTERISTIC FREQUENCIES FOR
C     EACH SECTION OF THE R-L-C NETWORK WHICH SIMULATES THE COCHLEAR
C     BEHAVIOR OF THE EAR TO SOUND.
      SDATA=NDATA
      FSAMRT=(SDATA/PERD)*1000.0
      FDATA=KDATA
      FCON=FSAMRT/FDATA
      XN=NSECT
      DO 100 K=1,NFREQ
      XK=K
      FFREQ(K)=(XK-1.0)*FCON
  100 CONTINUE
C     DETERMINE IF NECESSARY TO CALCULATE THE CHARACTERISTIC FREQUENCIES.
      IF(KM-1) 101,101,113
  101 DO 102 K=1,NSECT
      XK=K
      CFREQ(K)=EXP((13.0-7.0*((XK-1.0)/(XN-1.0)))*0.693)
  102 CONTINUE
C     CALCULATION OF RESPONSE OF THE COCHLEAR MODEL TO A SOUND WAVEFORM.
  113 M=NSECT+1
      DO 112 L=1,NFREQ
      DO 103 K=1,NSECT
C     CALCULATION OF ZA(K),ZS(K),Z(K).  WHERE K=1,2,3,...,NSECT
      I=M-K
      XA=Q*R*FFREQ(L)/CFREQ(I)
      ZA(I)=CMPLX(R,XA)
      IF(FFREQ(L)) 114,114,115
  114 FFREQ(1)=0.000001
  115 XS=Q*R*((FFREQ(L)/CFREQ(I))-(CFREQ(I)/FFREQ(L)))
      ZS(I)=CMPLX(R,XS)
C     CALCULATION OF Z(K) STARTING WITH K=NSECT AND L=1.
C     CHECK IF I IS LESS THAN NSECT.
      IF(I.NE.NSECT) GO TO 104
      Z(I)=ZA(I)+RT/(1.0+(RT/ZS(I)))
      GO TO 103
  104 Z(I)=ZA(I)+Z(I+1)/(1.0+(Z(I+1)/ZS(I)))
  103 CONTINUE
C     CALCULATION OF IA(K),VS(K),IS(K),V(K,L).
      DO 105 K=1,NSECT
      IF(K.NE.1) GO TO 106
      IA(K)=DATA(L)/Z(K)
      VS(K)=DATA(L)-ZA(K)*IA(K)
      IS(K)=VS(K)/ZS(K)
```

TABLE XV (Continued)

```
      V(K,L)=ZA(K)*IS(K)
      GO TO 105
  106 IA(K)=VS(K-1)/Z(K)
      VS(K)=VS(K-1)-ZA(K)*IA(K)
      IS(K)=VS(K)/ZS(K)
      V(K,L)=ZA(K)*IS(K)
  105 CONTINUE
  112 CONTINUE
C     CALCULATION OF THE TIME RESPONSE OF THE COCHLEAR MODEL FROM THE
C     FOURIER SERIES REPRESENTATION OF THE TIME RESPONSE.
      FDATA=NFREQ
      DO 107 K=1,NSECT
      DO 108 L=1,NFREQ
      WDATA(L)=V(K,L)
  108 CONTINUE
      CALL FOURT(WDATA,NFREQ,1,1,1,WORK,10)
      PLEX=CMPLX(FDATA/2.0,0.0)
      DO 109 L=1,NFREQ
      V(K,L)=WDATA(L)/PLEX
  109 CONTINUE
  107 CONTINUE
      DO 110 L=1,NFREQ
      DO 110 K=1,NSECT
      VDIFFO(K,L)=REAL(V(K,L))
  110 CONTINUE
      NSEC=NSECT-1
      DO 111 K=1,NSEC
      DO 111 L=1,NFREQ
      VDIFF1(K,L)=ABS(VDIFFO(K,L))-ABS(VDIFFO(K+1,L))
  111 CONTINUE
      CALL NORMO(NSECT,NFREQ)
      CALL NORM1(NSEC,NFREQ)
      RETURN
      END


      SUBROUTINE NORM(NS)
      DIMENSION VDCO(100),VDC1(100)
      DIMENSION IVDCO(100),IVDC1(100)
      COMMON /VDC/VDCO,VDC1
      COMMON /IVDC/IVDCO,IVDC1
      COMMON /SPEC3/NSECT,NFREQ,R,RT,Q,FNORM1
      IF(NSECT-NS) 100,100,101
  100 SAMAX=ABS(VDCO(1))
      DO 102 K=1,NS
      IF(SAMAX.LT.ABS(VDCO(K))) SAMAX=ABS(VDCO(K))
  102 CONTINUE
      DO 103 K=1,NS
      IVDCO(K)=(VDCO(K)/SAMAX)*99.0
  103 CONTINUE
      RETURN
  101 SAMAX=ABS(VDC1(1))
      DO 104 K=1,NS
      IF(SAMAX.LT.ABS(VDC1(K))) SAMAX=ABS(VDC1(K))
  104 CONTINUE
      DO 105 K=1,NS
      IVDC1(K)=(VDC1(K)/SAMAX)*99.0
  105 CONTINUE
      RETURN
      END
```

TABLE XV (Continued)

```
      SUBROUTINE NORMO(NS,ND)
      COMPLEX V(100,128)
      DIMENSION VDIFFO(100,128),VDIFF1(100,128)
      COMMON /OUTEAR/V
      COMMON /SPEC3/NSECT,NFREQ,R,RT,Q,FNORM1
      EQUIVALENCE (V(1),VDIFFO(1)),(V(6401),VDIFF1(1))
      VMAX=ABS(VDIFFO(1,1))
      DO 499 I=1,NS
      DO 499 J=1,ND
      IF(VMAX-ABS(VDIFFO(I,J))) 401,499,499
  401 VMAX=ABS(VDIFFO(I,J))
  499 CONTINUE
      DO 498 I=1,NS
      DO 498 J=1,ND
      VDIFFO(I,J)=(VDIFFO(I,J)/VMAX)*FNORM1
  498 CONTINUE
      RETURN
      END


      SUBROUTINE NORM1(NS,ND)
      COMPLEX V(100,128)
      DIMENSION VDIFFO(100,128),VDIFF1(100,128)
      COMMON /OUTEAR/V
      COMMON /SPEC3/NSECT,NFREQ,R,RT,Q,FNORM1
      EQUIVALENCE (V(1),VDIFFO(1)),(V(6401),VDIFF1(1))
      VMAX=ABS(VDIFF1(1,1))
      DO 497 I=1,NS
      DO 497 J=1,ND
      IF(VMAX-ABS(VDIFF1(I,J))) 402,497,497
  402 VMAX=ABS(VDIFF1(I,J))
  497 CONTINUE
      DO 496 I=1,NS
      DO 496 J=1,ND
      VDIFF1(I,J)=(VDIFF1(I,J)/VMAX)*FNORM1
  496 CONTINUE
      RETURN
      END


      SUBROUTINE FULREC(NS,ND)
      COMPLEX V(100,128)
      COMPLEX CMPLX
      DIMENSION VDIFFO(100,128),VDIFF1(100,128)
      COMMON /OUTEAR/V
      EQUIVALENCE (V(1),VDIFFO(1)),(V(6401),VDIFF1(1))
      DO 810 K=1,NS
      DO 810 L=1,ND
      VDIFFO(K,L)=ABS(VDIFFO(K,L))
  810 CONTINUE
      RETURN
      END
```

TABLE XV (Continued)

```
      SUBROUTINE DCFLTR(NS,ND)
      COMPLEX V(100,128)
      COMPLEX WDATA(2048),WORK(10)
      COMPLEX CMPLX
      DIMENSION VDIFF0(100,128),VDIFF1(100,128)
      DIMENSION VDC0(100),VDC1(100)
      COMMON /OUTEAR/V
      COMMON /VDC/VDC0,VDC1
      COMMON /WDATAS/WDATA
      COMMON /SPEC1/NREC,NDATA,KDATA
      COMMON /SPEC2/IDSPK,ISEX,IPHO,IPIT,IPCL,PERD,IREC
      COMMON /SPEC3/NSECT,NFREQ,R,RT,Q,FNORM1
      COMMON WORK,KM
      EQUIVALENCE (V(1),VDIFF0(1)),(V(6401),VDIFF1(1))
      FD=ND
      FX=FD/2.0
      IF(NSECT-NS) 700,700,701
  700 DO 702 K=1,NS
      DO 703 L=1,ND
      WDATA(L)=CMPLX(VDIFF0(K,L),0.0)
  703 CONTINUE
      CALL FOURT(WDATA,ND,1,-1,1,WORK,10)
      VDC0(K)=REAL(WDATA(1))/FX
  702 CONTINUE
      RETURN
  701 DO 704 K=1,NS
      DO 705 L=1,ND
      WDATA(L)=CMPLX(VDIFF1(K,L),0.0)
  705 CONTINUE
      CALL FOURT(WDATA,ND,1,-1,1,WORK,10)
      VDC1(K)=REAL(WDATA(1))/FX
  704 CONTINUE
      RETURN
      END


      SUBROUTINE WRITEM(NS)
      DIMENSION IVDC0(100),IVDC1(100)
      COMMON /IVDC/IVDC0,IVDC1
      COMMON /SPEC2/IDSPK,ISEX,IPHO,IPIT,IPCL,PERD,IREC
      COMMON /SPEC3/NSECT,NFREQ,R,RT,Q,FNORM1
      WRITE(6,650) IREC
  650 FORMAT(1H1,57X,'***RECORD-',I3,'****')
      WRITE(6,651)
  651 FORMAT(1H0,131('*'))
      IF(NS-NSECT) 652,653,653
  653 WRITE(6,660)
  660 FORMAT(1H0,'THE AVERAGE DC COMPONENTS OF THE FULL WAVE RECTIFIED Z
     1ERO ORDER DIFFERENCE RESPONSES ARE:'//)
      WRITE(6,661) (IVDC0(K),K=1,NS)
  661 FORMAT(24I4)
      WRITE(6,651)
      RETURN
  652 WRITE(6,662)
  662 FORMAT(1H0,'THE AVERAGE DC COMPONENTS OF THE FIRST ORDER DIFFERENC
     1E RESPONSES ARE:'//)
      WRITE(6,661) (IVDC1(K),K=1,NS)
      WRITE(6,651)
      RETURN
      END
```

TABLE XV (Continued)

```
      SUBROUTINE PUNCHM(NS)
      DIMENSION IVDCO(100),IVDC1(100)
      DIMENSION IMT(9),NUM(24)
      COMMON /IVDC/IVDCO,IVDC1
      COMMON /SPEC2/IDSPK,ISEX,IPHO,IPIT,IPCL,PERD,IREC
      COMMON /SPEC3/NSECT,NFREQ,R,RT,Q,FNORM1
      DATA IMT(1)/'(    '/,IMT(2)/' '/,IMT(3)/'24'/,IMT(4)/'I3,T'/,
     1 IMT(5)/'73,3'/,IMT(6)/'HRC-'/,IMT(7)/',I3,'/,IMT(8)/'1H-,'/,
     2 IMT(9)/'I1)'/
      DATA NUM(1)/'1'/,NUM(2)/'2'/,NUM(3)/'3'/,NUM(4)/'4'/,NUM(5)/'5'/,
     1 NUM(6)/'6'/,NUM(7)/'7'/,NUM(8)/'8'/,NUM(9)/'9'/,NUM(10)/'10'/,
     2 NUM(11)/'11'/,NUM(12)/'12'/,NUM(13)/'13'/,NUM(14)/'14'/,
     3 NUM(15)/'15'/,NUM(16)/'16'/,NUM(17)/'17'/,NUM(18)/'18'/,
     4 NUM(19)/'19'/,NUM(20)/'20'/,NUM(21)/'21'/,NUM(22)/'22'/,
     5 NUM(23)/'23'/,NUM(24)/'24'/
      WRITE(7,700) IDSPK,ISEX,IPHO,IPIT,IPCL,PERD,IREC
  700 FORMAT('SPEAKER ID-',A3,'-',A1,'/PHONEME ID-',I2,'/PITCH-',I3,
      '-',A2,'/PITCH PERIOD-',F6.2,' MS/',T73,'RC-',I3,'-0')
      IF(NSECT-NS)701,701,702
  701 ICNT=1
      IFLAG=0
      NBEGIN=1
      IF(NS.GT.24) GO TO 703
      NSTOP=NS
  704 IFLAG=1
      GO TO 705
  703 NSTOP=24
  705 IMT(3)=NUM(NSTOP-NBEGIN+1)
      WRITE(7,IMT)(IVDCO(K),K=NBEGIN,NSTOP),IREC,ICNT
      IF(IFLAG)706,707,706
  707 ICNT=ICNT+1
      NBEGIN=NSTOP+1
      NSTOP=NSTOP+24
      IF(NSTOP.LT.NS) GO TO 705
      NSTOP=NS
      GO TO 704
  706 CONTINUE
      RETURN
  702 ICNT=1
      IFLAG=0
      NBEGIN=1
      IF(NS.GT.24) GO TO 708
      NSTOP=NS
  709 IFLAG=1
      GO TO 710
  708 NSTOP=24
  710 IMT(3)=NUM(NSTOP-NBEGIN+1)
      WRITE(7,IMT) (IVDC1(K),K=NBEGIN,NSTOP),IREC,ICNT
      IF(IFLAG) 711,712,711
  712 ICNT=ICNT+1
      NBEGIN=NSTOP+1
      NSTOP=NSTOP+24
      IF(NSTOP.LT.NS) GO TO 710
      NSTOP=NS
      GO TO 709
  711 CONTINUE
      RETURN
      END
```

TABLE XV (Continued)

```
      SUBROUTINE PRNTM1
      DIMENSION FFREQ(128),CFREQ(128)
      DIMENSION IDATA(128)
      COMMON /IDATAS/IDATA
      COMMON /SPEC1/NREC,NDATA,KDATA
      COMMON /SPEC2/IDSPK,ISEX,IPHO,IPIT,IPCL,PERD,IREC
      COMMON /SPEC3/NSECT,NFREQ,R,RT,Q,FNORM1
      COMMON /FREQ/FFREQ,CFREQ
      DATA KCPS/' CPS'/
      WRITE(6,600) IREC
  600 FORMAT(1H1,57X,'***RECORD-',I3,'****')
      WRITE(6,601)
  601 FORMAT(1H0,131('*'))
C     WRITE PHONETIC SOUND ID INFORMATION.
      SDATA=NDATA
      SAMRT=(SDATA/PERD)*1000.0
      ISAMRT=SAMRT
      WRITE(6,602) IDSPK,ISEX,IPHO,IPIT,IPCL,PERD,ISAMRT,IREC
  602 FORMAT(1H0,'SPEAKER ID ',A3,'-',A1,'****PHONEME ID ',I2,
     1 '****PITCH ',I3,' CPS-',A2,'****PITCH PERIOD ',F6.2,
     2' MS****SAMPLING RATE ',I5,' SPS',T113,'RECORD-',I3,'-0')
C     WRITE THE NORMALIZED PHONETIC SOUND VALUES.
      ICNT=1
      IFLAG=0
      NBEGIN=1
      IF(NDATA.GT.24) GO TO 603
      NSTOP=NDATA
  604 IFLAG=1
      GO TO 605
  603 NSTOP=24
  605 WRITE(6,606) (IDATA(J),J=NBEGIN,NSTOP)
  606 FORMAT(1H ,24I4)
      WRITE(6,607) IREC,ICNT
  607 FORMAT(1H+,114X,'"',3X,I3,'-',I1)
      IF(IFLAG) 608,609,608
  609 ICNT=ICNT+1
      NBEGIN=NSTOP+1
      NSTOP=NSTOP+24
      IF(NSTOP.LT.NDATA) GO TO 605
      NSTOP=NDATA
      GO TO 604
  608 WRITE(6,601)
C     WRITE THE PARAMETERS FOR THE COCHLEAR MODEL.
      WRITE(6,610)
  610 FORMAT(1H0,'PARAMETERS FOR COCHLEAR MODEL ARE:')
      WRITE(6,611) NSECT,NFREQ,R,RT,Q,FNORM1
  611 FORMAT(1H0,'NSECT=',I3,' SECTIONS'/1X,'NFREQ=',I3,' NUMBER OF FOUR
     1IER SERIES TERMS'/1X,'R=',F9.1,' OHMS'/1X,'RT=',F9.1,' OHMS'/1X,
     2 'Q=',F5.1/1X,'NORM1=',F9.1,' NORMALIZING FACTOR')
      WRITE(6,601)
      WRITE(6,619)
  619 FORMAT(1H0,'THE CHARACTERISTIC FREQUENCIES OF THE LADDER NETWORK W
     1HICH SIMULATES THE COCHLEA ARE:')
      WRITE(6,629) (K,CFREQ(K),KCPS,K=1,NSECT)
  629 FORMAT(4(1X,'CF(',I3,')=',F8.1,A4))
      WRITE(6,601)
      RETURN
      END
```

TABLE XV (Continued)

```
//GO.SYSIN DD *
  42 128 128
 100  64      100.0     1000.0      12.0   99999.0
SPEAKER ID-OLL-M/PHONEME ID-14/PITCH-141-NN/PITCH PERIOD-  7.07 MS/     RC- 14-0
  0 14 28 35 33 24 17 19 29 40 50 58 63 60 52 45 42 44 49 54 56 54 48 41RC- 14-1
 38 41 47 52 52 45 34 22 13  8  5  5  5  2 -6-14-18-21-19-13-11-12-17-26RC- 14-2
-32-36-38-36-29-22-19-19-21-23-23-21-15 -8 -2  0  1  0  0  1  4  9 13 16RC- 14-3
 18 18 18 19 22 25 26 25 23 20 18 16 17 19 20 20 21 20 19 19 19 18 19 16RC- 14-4
  3-26-72-99-93-70-37 -5 11  8-13-47-75-91-94-90-76-59-55-61-65-60-50-36RC- 14-5
-19 -8 -9-16-21-22-18-10                                                RC- 14-6
//GO.SYSPUNCH DD SYSOUT=B
//
```

C.5 Phonetic Sound Plotting Program. The program listed by Table XVI is a FORTRAN II program written for the IBM 1620 computer with an auxiliary disk memory unit and a Calcomp Plotter. This program is designed to produce a point-to-point reconstruction of the normalized sample data records which are representative of a phonetic sound signal. In addition the program is designed to label the graphical plot of the phonetic sound signal.

The limited memory capacity of the IBM 1620 computer required that this program be written as three subprograms. The names given to these subprograms are START1, PLOT1, and CHAR1. The overall program effect is accomplished by storing each compiled subprogram on the disk memory unit and link editing the subprograms together by FORTRAN II "CALL LINK (xxxx)" statements.

Assuming each subprogram has been compiled and is stored on the disk memory unit the following instructions and data cards are necessary to initiate plotting.

Instruction Cards

(1) Cold Start

(2) ‡‡JOB

(3) ‡‡XEQSSTART1

Data Cards

(1) Used to specify parameters NREC, NDATA, TSCALE and ICNT in a 2I4, F6.2,I4 format. Where NREC specifies the number of plots to be drawn. NDATA specifies the number of data samples of a phonetic sound record. TSCALE specifies the scale factor for the time axis of the plots. ICNT defines the number of plots per page and must not

exceed 3.

(2) The remaining data cards are the normalized phonetic sound records. The format must be like that defined by the phonetic sound record listings of Table XI.

TABLE XVI

PHONETIC SOUND PLOTTING PROGRAM

```
3400032007013600032007024902402511963611300102
ZZJOB
ZZFOR
*LDISKSTART1
C       PROGRAM START1
        DIMENSION XX(8),YY(8),XXS(8)
        COMMON XX,YY,XXS,SPACE,ICNT,NREC,NDATA,XIDSPK,ISEX,IPHO,IPIT,IPCL,
       1 IREC,KREC,PERD,XMIN,XMAX,TSCALE
        READ 2,NREC,NDATA,TSCALE,ICNT
      2 FORMAT(2I4,F6.2,I4)
        XX(1)=1.15625
        YY(1)=1.5
        XX(2)=2.90625
        YY(2)=7.4125
        XX(3)=1.90625
        YY(3)=2.8125
        XX(4)=1.46875
        YY(4)=3.0
        XX(5)=1.95625
        YY(5)=2.45
        XX(6)=2.140625
        YY(6)=1.5
        XX(7)=3.09375
        YY(7)=4.5625
        XX(8)=3.09375
        YY(8)=6.4625
        XMIN=0.0
        XMAX=11.0
        SPACE=3.0
        KREC=1
        IF(ICNT) 71,72,71
     71 DO 73 K=1,8
        XXS(K)=XX(K)
     73 CONTINUE
        IF(ICNT-1) 72,72,74
     74 DO 75 K=1,8
        XXS(K)=XX(K)+SPACE
     75 CONTINUE
     72 CALL LINK(PLOT1)
        END
```

TABLE XVI (Continued)

```
3400032007013600032007024902402511963611300102
ZZJOB
ZZFOR
*LDISKPLOT1
C      PROGRAM PLOT1
       DIMENSION DATA(256),XX(8),YY(8),XXS(8),IDATA(256),IDSPK(3)
       COMMON XX,YY,XXS,SPACE,ICNT,NREC,NDATA,XIDSPK,ISEX,IPHO,IPIT,IPCL,
     1 IREC,KREC,PERD,XMIN,XMAX,TSCALE
       IF(KREC-NREC) 32,32,999
  999 CALL EXIT
   32 KREC=KREC+1
       READ 4, XIDSPK,ISEX,IPHO,IPIT,IPCL,PERD,IREC
    4 FORMAT(11X, A3,1X,A1,12X,I2,7X,I3,1X,A2,14X,F6.2,12X,I3,2X)
       READ 6,(IDATA(K),K=1,NDATA)
    6 FORMAT(24I3,8X)
       IF(ICNT) 5,3,5
    5 IF(ICNT-3) 7,9,9
    3 CALL PLOT(201,XMIN,XMAX,11.0,11.0,0.0,8.5,8.5,8.5)
       CALL PLOT(90,XMIN,0.0)
       CALL PLOT(90,XMIN,8.5)
       CALL PLOT(90,XMAX,8.5)
       CALL PLOT(90,XMAX,0.0)
       CALL PLOT(90,XMIN,0.0)
       CALL PLOT(99)
       DO 31 K=1,8
       XXS(K)=XX(K)
   31 CONTINUE
       GO TO 11
    7 CALL PLOT(201,XMIN,XMAX,11.0,11.0,0.0,8.5,8.5,8.5)
       DO 13 K=1,8
       XXS(K)=XXS(K)+SPACE
   13 CONTINUE
       GO TO 11
    9 ICNT=0
       GO TO 3
   11 CALL PLOT(99)
       CALL PLOT(90,XXS(2),YY(2))
       IFLAG=1
       X2=XXS(2)
       Y2=YY(2)
       DO 10 K=1,23
       IF(IFLAG) 12,12,14
   12 X2=XXS(2)+0.0625
       CALL PLOT(90,X2,Y2)
       CALL PLOT(90,XXS(2),Y2)
       Y2=Y2-0.2
       IFLAG=1
       GO TO 16
   14 X2=XXS(2)+0.03125
       CALL PLOT(90,X2,Y2)
       CALL PLOT(90,XXS(2),Y2)
       Y2=Y2-0.2
       IFLAG=0
   16 CALL PLOT(90,XXS(2),Y2)
   10 CONTINUE
       IFLAG=0
       X3=XXS(3)
       Y3=YY(3)
       CALL PLOT(99)
       CALL PLOT(90,X3,Y3)
       DO 18 K=1,8
       IF(IFLAG) 20,20,22
   20 Y3=YY(3)-0.0625
```

TABLE XVI (Continued)

```
      CALL PLOT(90,X3,Y3)
      CALL PLOT(90,X3,YY(3))
      X3=X3+0.25
      IFLAG=1
      GO TO 17
   22 Y3=YY(3)-0.03125
      CALL PLOT(90,X3,Y3)
      CALL PLOT(90,X3,YY(3))
      X3=X3+0.25
      IFLAG=0
   17 CALL PLOT(90,X3,YY(3))
   18 CONTINUE
      Y3=YY(3)-0.0625
      CALL PLOT(90,X3,Y3)
      CALL PLOT(90,X3,YY(3))
      CALL PLOT(99)
      CALL PLOT(90,XXS(2),YY(3))
      FNDATA=NDATA
      SCALE=(PERD)/(TSCALE*FNDATA)
      DO 30 K=1,NDATA
      DATA(K)=IDATA(K)
      X=XXS(2)-(DATA(K)/99.0)
      YJ=K-1
      Y=YY(3)+YJ*SCALE
      CALL PLOT(90,X,Y)
   30 CONTINUE
      CALL PLOT(99)
      CALL PLOT(90,XMIN,0.0)
      CALL PLOT(99)
      CALL LINK(CHAR1)
      END
```

TABLE XVI (Continued)

```
340003200701360003200702490240251196361130O1O2
ZZFOR
*LDISKCHAR1
C     PROGRAM CHAR1
      DIMENSION IWORK(5),XX(8),YY(8),XXS(8),IDSPK(3)
      COMMON XX,YY,XXS,SPACE,ICNT,NREC,NDATA,XIDSPK,ISEX,IPHO,IPIT,IPCL,
     1 IREC,KREC,PERD,XMIN,XMAX,TSCALE
      IF(ICNT) 34,33,34
   33 CALL PLOT(201,XMIN,XMAX,11.0,11.0,0.0,8.5,8.5,8.5)
      CALL PLOT(99)
      CALL PLOT(90,XX(1),YY(1))
      CALL CHAR(0,0.2,1)
    8 FORMAT(29H WAVEFORMS OF PHONETIC SOUNDS)
      CALL PLOT(99)
      GO TO 35
   34 CALL PLOT(201,XMIN,XMAX,11.0,11.0,0.0,8.5,8.5,8.5)
   35 CALL PLOT(99)
      CALL PLOT(90,XXS(4),YY(4))
      IF(IPHO-10) 48,49,49
   49 CALL CHAR(4,0.1,1,IPHO,XIDSPK,ISEX,IREC)
   19 FORMAT(11HPHONEME ID-,I2,13H  SPEAKER ID-,A3,1H-,A1,9H  RECORD-,
     1 I3)
      CALL PLOT(99)
      GO TO 51
   48 CALL CHAR(4,0.1,1,IPHO,XIDSPK,ISEX,IREC)
   50 FORMAT(11HPHONEME ID-,I1,13H  SPEAKER ID-,A3,1H-,A1,9H  RECORD-,
     1 I3)
      CALL PLOT(99)
   51 X4=XXS(4)+0.15
      CALL PLOT(90,X4,YY(4))
      IF(PERD-10.0) 52,53,53
   52 CALL CHAR(3,0.1,1,IPIT,IPCL,PERD)
   21 FORMAT(6HPITCH-,I3,4H HZ-,A2,15H  PITCH PERIOD-,F5.2,9H MILLISEC)
      CALL PLOT(99)
      GO TO 54
   53 CALL CHAR(3,0.1,1,IPIT,IPCL,PERD)
   55 FORMAT(6HPITCH-,I3,4H HZ-,A2,15H  PITCH PERIOD-,F6.2,9H MILLISEC)
      CALL PLOT(99)
   54 X4=X4+0.15
      FNDATA=NDATA
      SAMRT=((1.0/PERD)*1000.0)*FNDATA
      SAM=SAMRT/10.0
      ISRT1=SAM
      FISRT1=ISRT1
      FISRT1=10.0*FISRT1
      FISRT2=SAMRT-FISRT1
      ISRT2=FISRT2
      CALL PLOT(90,X4,YY(4))
   36 CALL CHAR(2,0.1,1,ISRT1,ISRT2)
   40 FORMAT(14HSAMPLING RATE-,I4,I1,12H SAMPLES/SEC)
      CALL PLOT(99)
      CALL PLOT(90,XXS(6),YY(6))
      CALL CHAR(0,0.1,1)
   24 FORMAT(10HNORMALIZED)
      CALL PLOT(99)
      X6=XXS(6)+0.15
      Y6=1.55
      CALL PLOT(90,X6,Y6)
      CALL CHAR(0,0.1,1)
   25 FORMAT(9HAMPLITUDE)
      CALL PLOT(99)
      IWORK(1)=99
      IWORK(2)=50
```

TABLE XVI (Continued)

```
      IWORK(3)=0
      IWORK(4)=-50
      IWORK(5)=-99
      X5=XXS(5)
      Y5=YY(5)
      DO 26 K=1,5
      CALL PLOT(90,X5,Y5)
      CALL CHAR(1,0.1,1,IWORK(K))
   27 FORMAT(I3)
      CALL PLOT(99)
      X5=X5+0.5
   26 CONTINUE
      TIME1=TSCALE*2.0
      CALL PLOT(90,XXS(7),YY(7))
      CALL CHAR(1,0.1,1,TIME1)
   28 FORMAT(F4.1)
      CALL PLOT(99)
      TIME2=TIME1*2.0
      CALL PLOT(90,XXS(8),YY(8))
      CALL CHAR(1,0.1,1,TIME2)
   29 FORMAT(F5.1)
      CALL PLOT(99)
      X8=XXS(8)+0.15
      CALL PLOT(90,X8,YY(8))
      CALL CHAR(0,0.1,1)
   47 FORMAT(8HMILLISEC)
      CALL PLOT(99)
      IF(ICNT-2) 43,44,44
   43 CALL PLOT(90,XMIN,0.0)
      CALL PLOT(99)
      GO TO 45
   44 CALL PLOT(90,XMAX,0.0)
      CALL PLOT(99)
   45 ICNT=ICNT+1
      CALL LINK(PLOT1)
      END
```

C.6 Cochlear Response Plotting Program. The program listed by Table XVII is a FORTRAN II program written for the IBM 1620 computer with an auxiliary disk memory unit and a Calcomp Plotter. This program is designed to produce point-to-point plots of the simulated cochlear responses to phonetic sounds. In addition the program is designed to label the plotted responses.

The limited memory capacity of the IBM 1620 computer required that this program be written as three subprograms having the names START2, PLOT2, and CHAR2. The overall program effect is accomplished by storing each compiled subprogram on the disk memory unit and link editing the subprograms together by FORTRAN II "CALL LINK (xxxx)" statements.

Assuming each subprogram has been compiled and is stored on the disk memory unit the following instructions and data cards are necessary to execute plotting.

Instruction Cards

(1) Cold Start

(2) ‡‡JOB

(3) ‡‡XEQSSTART2

Data Cards

(1) Used to specify parameters NREC, NDATA, TSCALE, IR, IRT, IQ, and KFLAG in a 2I4, F6.2, 4I4 format. Where NREC specifies the number of plots to be drawn. NDATA specifies the number of data samples of a cochlear response to be plotted. TSCALE specifies the scale factor for the axis of the plot which corresponds to the cochlear model section number K. IR defines the cochlear model parameter denoted as the universal resistance value. The

cochlear model parameter which corresponds to the terminal resistance is denoted by IRT; IQ defines the universal Q value of the cochlear model. KFLAG must be either 0 or 1. The value of 0 for KFLAG designates that a zero-order difference response of the cochlear model is to be plotted and labeled. If KFLAG is set equal to 1 then it is assumed by the program that a first-order difference response of the cochlear model is to be plotted and labeled.

(2) The remaining data cards are either a set of zero-order or first-order difference responses of the cochlear model. The format of each response is equivalent to the format of the phonetic sound records as listed in Table XI.

TABLE XVII

COCHLEAR RESPONSE PLOTTING PROGRAM

```
340003200701360003200702490240251196361130O102
ZZJOB
ZZFOR
*LDISKSTART2
C     PROGRAM START2
      DIMENSION XX(8),YY(8),XXS(8),XIDSPK(3),ISEX(3),IPHO(3),IPIT(3),
     1 IPCL(3),PERD(3),IREC(3)
      COMMON XX,YY,XXS,XIDSPK,ISEX,IPHO,IPIT,IPCL,PERD,IREC,SPACE,NREC,
     1 NDATA,XMIN,XMAX,TSCALE,IR,IRT,IQ,KFLAG
      READ 2,NREC,NDATA,TSCALE,IR,IRT,IQ,KFLAG
    2 FORMAT(2I4,F6.2,4I4)
      XX(1)=1.05625
      YY(1)=1.70
      XX(2)=2.90625
      YY(2)=7.4125
      XX(3)=1.90625
      YY(3)=2.8125
      XX(4)=1.46875
      YY(4)=3.0
      XX(5)=1.95625
      YY(5)=2.45
      XX(6)=2.140625
      YY(6)=1.5
      XX(7)=3.09375
      YY(7)=4.7125
      XX(8)=3.09375
      YY(8)=6.6625
      XMIN=0.0
      XMAX=11.0
      SPACE=3.0
      CALL LINK(PLOT2)
      END
```

TABLE XVII (Continued)

```
340003200701360003200702490240251196361130O102
ZZJOB
ZZFOR
*LDISKPLOT2
C      PROGRAM PLOT2
       DIMENSION DATA(128),XX(8),YY(8),XXS(8),IDATA(128),XIDSPK(3),
      1 ISEX(3),IPHO(3),IPIT(3),IPCL(3),PERD(3),IREC(3)
       COMMON XX,YY,XXS,XIDSPK,ISEX,IPHO,IPIT,IPCL,PERD,IREC,SPACE,NREC,
      1 NDATA,XMIN,XMAX,TSCALE,IR,IRT,IQ,KFLAG
       CALL PLOT(201,XMIN,XMAX,11.0,11.0,0.0,8.5,8.5,8.5)
       DO 80 J=1,NREC
       READ 4, XIDSPK(J),ISEX(J),IPHO(J),IPIT(J),IPCL(J),PERD(J),IREC(J)
     4 FORMAT(11X, A3,1X,A1,12X,I2,7X,I3,1X,A2,14X,F6.2,12X,I3,2X)
       READ 6,(IDATA(K),K=1,NDATA)
     6 FORMAT(24I3,8X)
       IF(J-1) 5,3,5
     3 CALL PLOT(90,XMIN,0.0)
       CALL PLOT(90,XMIN,8.5)
       CALL PLOT(90,XMAX,8.5)
       CALL PLOT(90,XMAX,0.0)
       CALL PLOT(90,XMIN,0.0)
       CALL PLOT(99)
       DO 31 K=1,8
       XXS(K)=XX(K)
    31 CONTINUE
       GO TO 11
     5 DO 13 K=1,8
       XXS(K)=XXS(K)+SPACE
    13 CONTINUE
    11 CALL PLOT(99)
       CALL PLOT(90,XXS(2),YY(2))
       IFLAG=1
       X2=XXS(2)
       Y2=YY(2)
       DO 10 K=1,23
       IF(IFLAG) 12,12,14
    12 X2=XXS(2)+0.0625
       CALL PLOT(90,X2,Y2)
       CALL PLOT(90,XXS(2),Y2)
       Y2=Y2-0.2
       IFLAG=1
       GO TO 16
    14 X2=XXS(2)+0.03125
       CALL PLOT(90,X2,Y2)
       CALL PLOT(90,XXS(2),Y2)
       Y2=Y2-0.2
       IFLAG=0
    16 CALL PLOT(90,XXS(2),Y2)
    10 CONTINUE
       IFLAG=0
       X3=XXS(3)
       Y3=YY(3)
       CALL PLOT(99)
       CALL PLOT(90,X3,Y3)
       DO 18 K=1,8
       IF(IFLAG) 20,20,22
    20 Y3=YY(3)-0.0625
       CALL PLOT(90,X3,Y3)
       CALL PLOT(90,X3,YY(3))
       X3=X3+0.25
       IFLAG=1
       GO TO 17
    22 Y3=YY(3)-0.03125
```

TABLE XVII (Continued)

```
      CALL PLOT(90,X3,Y3)
      CALL PLOT(90,X3,YY(3))
      X3=X3+0.25
      IFLAG=0
   17 CALL PLOT(90,X3,YY(3))
   18 CONTINUE
      Y3=YY(3)-0.0625
      CALL PLOT(90,X3,Y3)
      CALL PLOT(90,X3,YY(3))
      CALL PLOT(99)
      IF(KFLAG) 62,62,63
   62 X6=XXS(6)+0.30
      XX6=X6-0.10
      CALL PLOT(90,X6,1.75)
      CALL PLOT(90,XX6,1.75)
      CALL PLOT(99)
      CALL PLOT(90,X6,2.25)
      CALL PLOT(90,XX6,2.25)
      CALL PLOT(99)
   63 CALL PLOT(90,XXS(2),YY(3))
      CALL PLOT(99)
      DO 30 K=1,NDATA
      DATA(K)=IDATA(K)
      X=XXS(2)-(DATA(K)/99.0)
      YJ=K
      Y=YY(3)+YJ*TSCALE
      CALL PLOT(90,X,Y)
   30 CONTINUE
   80 CONTINUE
      CALL PLOT(99)
      CALL PLOT(90,XMIN,0.0)
      CALL PLOT(99)
      CALL LINK(CHAR2)
      END
```

TABLE XVII (Continued)

```
3400032007013600032007024902402511963611300102
ZZJOB
ZZFOR
*LDISKCHAR2
C     PROGRAM CHAR2
      DIMENSION XX(8),YY(8),XXS(8),XIDSPK(3),ISEX(3),IPHO(3),IPIT(3),
     1 IPCL(3),PERD(3),IREC(3),IWORK(5)
      COMMON XX,YY,XXS,XIDSPK,ISEX,IPHO,IPIT,IPCL,PERD,IREC,SPACE,NREC,
     1 NDATA,XMIN,XMAX,TSCALE,IR,IRT,IQ,KFLAG
      CALL PLOT(201,XMIN,XMAX,11.0,11.0,0.0,8.5,8.5,8.5)
      DO 91 K=1,8
      XXS(K)=XX(K)
   91 CONTINUE
      DO 90 J=1,NREC
      IF(J-1) 33,33,34
   33 CALL PLOT(90,XX(1),YY(1))
      IF(KFLAG) 60,60,61
   60 CALL CHAR(0,0.1,1)
    8 FORMAT(55HZERO ORDER DIFFERENCE RESPONSES OF THE COCHLEAR NETWORK)
      CALL PLOT(99)
      GO TO 34
   61 CALL CHAR(0,0.1,1)
   88 FORMAT(56HFIRST ORDER DIFFERENCE RESPONSES OF THE COCHLEAR NETWORK
     1)
      CALL PLOT(99)
   34 CALL PLOT(90,XXS(4),YY(4))
   49 CALL CHAR(4,0.1,1,IPHO(J),XIDSPK(J),ISEX(J),IREC(J))
   19 FORMAT(11HPHONEME ID-,I2,13H  SPEAKER ID-, A3,1H-,A1,2X,7HRECORD-,
     1 I3)
      CALL PLOT(99)
   51 X4=XXS(4)+0.15
      CALL PLOT(90,X4,YY(4))
   52 CALL CHAR(3,0.1,1,IPIT(J),IPCL(J),PERD(J))
   21 FORMAT(6HPITCH-,I3,4H HZ-,A2,15H  PITCH PERIOD-,F5.2,9H MILLISEC)
      CALL PLOT(99)
   54 X4=X4+0.15
      CALL PLOT(90,X4,YY(4))
      CALL CHAR(3,0.1,1,IQ,IR,IRT)
   40 FORMAT(30HCOCHLEAR NETWORK PARAMETERS/Q=,I2,2X,2HR=,I3,2X,3HRT=,
     1 I4)
      CALL PLOT(90,XXS(6),YY(6))
      CALL CHAR(0,0.1,1)
   24 FORMAT(10HNORMALIZED)
      CALL PLOT(99)
      X6=XXS(6)+0.15
      Y6=1.55
      CALL PLOT(90,X6,Y6)
      CALL CHAR(0,0.1,1)
   25 FORMAT(9HAMPLITUDE)
      CALL PLOT(99)
      X6=X6+0.15
      CALL PLOT(90,X6,1.80)
      IF(KFLAG) 62,62,63
   62 CALL CHAR(0,0.1,1)
   64 FORMAT(4HV(K))
      CALL PLOT(99)
      GO TO 66
   63 CALL CHAR(0,0.1,1)
   65 FORMAT(4HD(K))
      CALL PLOT(99)
   66 IWORK(1)=99
      IWORK(2)=50
      IWORK(3)=0
```

TABLE XVII (Continued)

```
      IWORK(4)=-50
      IWORK(5)=-99
      X5=XXS(5)
      Y5=YY(5)
      DO 26 K=1,5
      CALL PLOT(90,X5,Y5)
      CALL CHAR(1,0.1,1,IWORK(K))
   27 FORMAT(I3)
      CALL PLOT(99)
      X5=X5+0.5
   26 CONTINUE
      CALL PLOT(90,XXS(7),YY(7))
      CALL CHAR(0,0.1,1)
   28 FORMAT(2H50)
      CALL PLOT(99)
      CALL PLOT(90,XXS(8),YY(8))
      CALL CHAR(0,0.1,1)
   29 FORMAT(3H100)
      CALL PLOT(99)
      X8=XXS(8)+0.15
      CALL PLOT(90,X8,YY(8))
      CALL CHAR(0,0.1,1)
   47 FORMAT(7HSECTION)
      CALL PLOT(99)
      X8=X8+0.15
      CALL PLOT(90,X8,YY(8))
      CALL CHAR(0,0.1,1)
   46 FORMAT(6HNUMBER)
      CALL PLOT(99)
      DO 92 K=1,8
      XXS(K)=XXS(K)+SPACE
   92 CONTINUE
   90 CONTINUE
      CALL PLOT(90,XMAX,0.0)
      CALL LINK(PLOT2)
      END
```

APPENDIX D

EQUIPMENT SPECIFICATIONS

This appendix contains the specifications for the Shure Microphone used in collection of the analog phonetic sound data. Also provided are specifications pertaining to the R-series DEC logic circuitry used in the design and fabrication of the sampling control unit which is an integral part of the sampling instrumentation depicted by Figure 2.3. The DEC logic circuitry specifications contained herein are those for:

(1) Diode Networks - Type R002

(2) Inverter - Type R107

(3) NAND Gate - Type R111

(4) Exclusive OR - Type R131

(5) Dual Flip-Flop - Type R202

(6) Delay (One Shot) - Type R302

(7) Variable Clock - Type R401.

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SHURE

MICROPHONES AND ELECTRONIC COMPONENTS

AREA CODE 312/328-9000 • CABLE SHUREMICRO

MODELS 545 AND 545S UNIDYNE III

UNIDIRECTIONAL DYNAMIC MICROPHONES

The Model 545 Series Unidyne III Microphones are slender dynamic microphones built to provide wide range reproduction of music and voice, and have an exceptionally uniform and effective unidirectional pickup pattern.

The Models 545-Gold and 545S-Gold are identical to Models 545 and 545S respectively except Models 545-Gold and 545S-Gold have gold finish.

These microphones are particularly suitable for high quality theatre-stage sound systems, recording, cathedrals and churches, and other critical public address systems such as those used in political conventions and legislatures, hotels, stadiums, and public auditoriums.

The microphones feature:

- Unusually effective cardioid pickup pattern. Eliminates feedback (annoying loudspeaker "squeals"). In addition, they prevent echoing (boominess) that sometimes occurs in partially-filled halls. These microphones can also be used closer to loudspeakers than usual, without creating feedback problems.
- Response especially effective for announcing, narration, vocal music, and combo groups.
- Cartridge shock mounted for quiet operation.
- A strong detachable cable especially selected for good shielding from "hum" pickup.
- Dependability and ruggedness under all operating conditions.

The Model 545 Series Microphones are dual impedance for connection into a 50 to 250 ohm line or a high impedance input.

The low impedance connection is recommended where long cable lengths are required or under conditions of severe hum disturbance. The permissible cable length is practically unlimited, since neither response nor level is appreciably affected. For use with high impedance amplifiers, Shure Model A95A Line Matching Transformer is available for coupling the low impedance line to the amplifier input. The Shure Model A95A transformer permits coupling a 50-250 ohm line to the high impedance input.

Furnished Accessories

Swivel Adapter
(for Model 545) A25B

Optional Accessories

Line Matching Transformer...... A95A
Vibration-Isolation Stand............ S39A
Desk Stand
(for Model 545) S33B
(for Model 545S) S36A
Quick Disconnect Isolation Unit
(for Model 545) A45
(for Model 545S) A47
Windscreen Assembly................ A2WS

GUARANTEE:

Each microphone is guaranteed to be free from electrical and mechanical defects for a period of one year from date of shipment from factory, provided all instructions are complied with fully. In case of damage, return the microphone to the factory for repairs. Our guarantee is voided if the microphone is subjected to accident or abuse.

Replacement Components

Model R45 Dynamic Replacement CARTRIDGE
Model C56 Cable and Plug Assembly
Model 55A38 Replacement SWITCH (545S only)

Important: Shure Microphone Cables are selected after exhaustive tests to insure superior performance in microphones because of low capacities, superior shielding properties and unusually long life under severe use.

Cables with plastic insulation should not be subjected to excessive soldering-iron heat. Carefully clean and tin the conductors and the connections to which the conductors are to be soldered. The soldering operation can then be done with a minimum of heat, thereby avoiding any possibility of damage to the cable.

INSTALLATION AND CONNECTIONS OF SWITCH

A. To install the 55A38 Replacement Switch in the Shure Model 545S (see Figure A) proceed as follows:

1. Remove the two No. 2-56 screws holding the nameplate and cover to the connector assembly.
2. Remove the nameplate and take the switch out of the switch cover on the connector assembly.
3. Unsolder leads from old switch terminals.
4. Connect the leads to the new replacement switch. Observe lead color and terminal arrangement as in Figure A.
5. Re-assemble switch and nameplate back into the connector assembly and fasten the No. 2-56 screws securely.

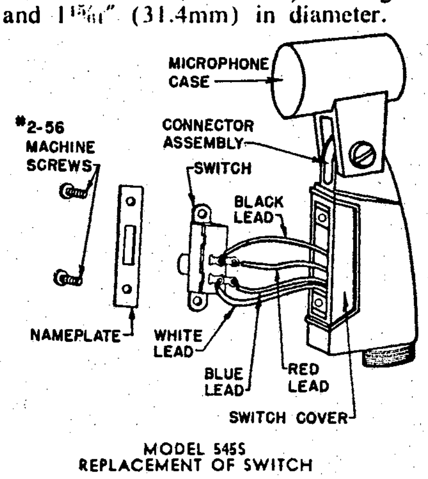
MODEL 545

Architect's Specifications

The microphone shall be the Shure Model 545 or equivalent. The microphone shall be a moving coil type microphone with a frequency range of 50 to 15,000 Hz. This unit shall have a "cardioid" polar characteristic. The cancellation at the sides shall be approximately 6 db and the cancellation at the rear shall be 15 to 20 db. The microphone shall be a dual-impedance microphone with rated impedance of 150 ohms and 40,000 ohms. The microphone rating GM (sensitivity) at 1000 Hz shall be within ±3 db of the following levels.

Low impedance............ —149 db
High impedance .... —151 db

The microphone shall be provided with a swivel adapter adjustable through 90° from vertical to horizontal and a receptacle equivalent to the Amphenol 91-MC4F capable of connecting to a three-conductor shielded cable plug. The microphone swivel adapter will mount on a stand having $\frac{5}{8}$"-27 thread. The overall dimensions shall be 5$\frac{13}{16}$" (147.6mm) in length and 1$\frac{15}{64}$" (31.4mm) in diameter.



MODEL 545S
REPLACEMENT OF SWITCH
FIGURE A

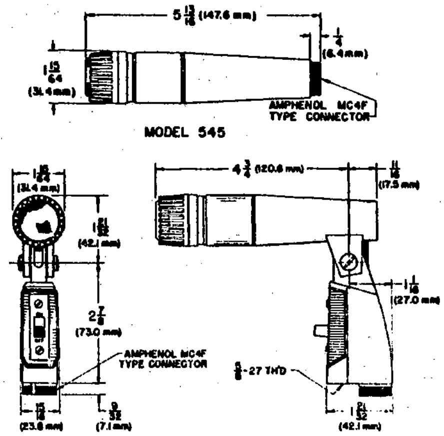
MODEL 545S
Architect's Specifications

The microphone shall be Shure Model 545S or equivalent. The microphone shall be a moving coil type microphone with a frequency range of 50 to 15,000 Hz. This unit shall have a "cardioid" polar characteristic. The cancellation at the sides shall be approximately 6 db and the cancellation at the rear shall be 15 to 20 db. The microphone shall be a dual-impedance microphone with rated impedance of 150 ohms and 40,000 ohms. The microphone rating GM (sensitivity) at 1000 Hz shall be within ±3 db of the following levels.

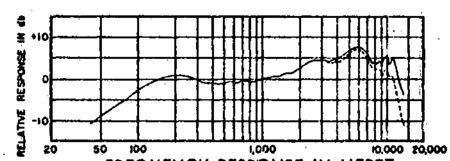
Low impedance ....—149 db

High impedance ....—151 db

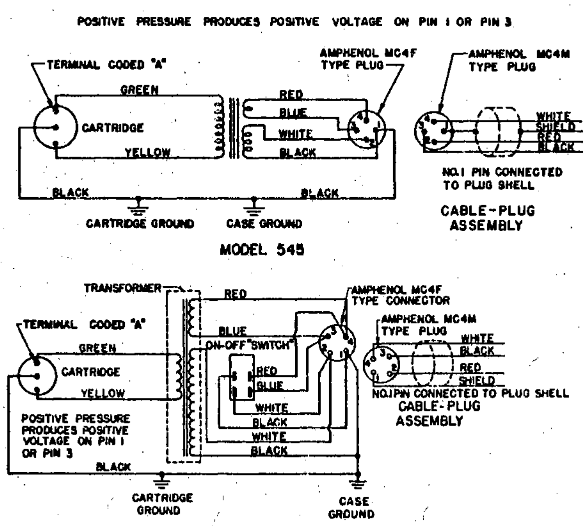
The microphone shall be provided with a swivel, a built in on-off switch and a receptacle equivalent to the Amphenol 91-MC4F capable of connecting to a three-conductor shielded cable plug. The microphone shall mount on a stand having ⅝"-27 thread. The overall dimensions shall be 4¹³⁄₁₆" (122.2mm) in height, 5¹³⁄₁₆" (147.6mm) in depth and 1¹⁵⁄₆₄" (31.4mm) in width.



MODEL 545S
OVERALL DIMENSIONS
FIGURE B



FREQUENCY RESPONSE IN HERTZ
FIGURE C



MODEL 545S
INTERNAL CONNECTIONS
FIGURE D

SPECIFICATIONS

Type: Dynamic

Frequency Response: 50 to 15,000 Hz (See Figure C)

Polar Pattern: Cardioid (Unidirectional) pattern—Effective rejection of sound at the rear of the microphone is uniform at all frequencies, while front pickup characteristics are uniform about the axis. (See Figure E)

Impedance: Dual. Connect to cable shield and red conductor for high impedance amplifier inputs. Connect to black and white conductors for balanced line low or medium impedance amplifier input. The shield is connected to the metal parts of the microphone. (See Figure D).

Output Level: 1,000 Hz response.

Model 545 Series Low Impedance
- Open Circuit Voltage.......—78 db* (.125 mv)
- Power Level.......—57 db**

EIA Microphone Rating
- Gm (sensitivity).......—149 db***

Model 545 Series High Impedance
- Open Circuit Voltage.......—55 db* (1.76 mv)
- EIA Microphone Rating
  - Gm (sensitivity).......—151 db***

*0 db = 1 volt per microbar.
**0 db = 1 milliwatt with 10 microbars
***0 db = EIA Standard SE-105, August 1949.

Cable: 15-foot (4.6 mm) three-conductor shielded with Amphenol MC4M type microphone plug on the microphone end.

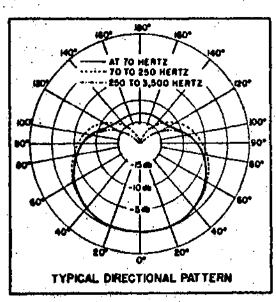
Case: Chrome-plated die-cast case and "Armo-Dur."

Dimensions: See Figure B

Switch: Model 545 None
Model 545S Built in "ON-OFF" switch to control microphone circuit. The switch is an integral part of the receptacle assembly and is a slide-to-talk locking type switch.

Net Weight: Model 545 - 9 ounces (255 grams)
Model 545S - 15 ounces (425 grams)

Packaged Weight: Model 545 - 2 pounds, 3 ounces (992 grams)
Model 545S - 2 pounds, 5 ounces (1049 grams)



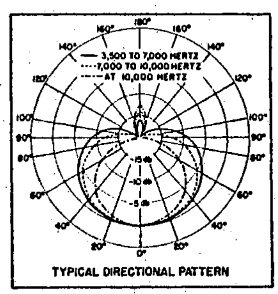
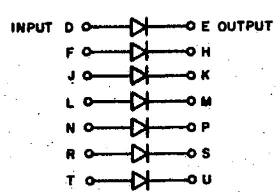


FIGURE E

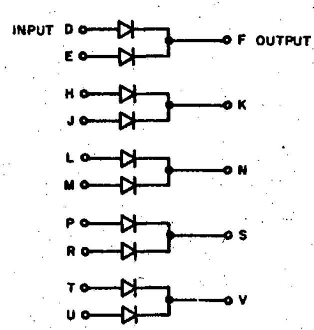
27A443 (11-68)
U.S. Patents 3,132,713 and D190,864
Printed in U.S.A.

R
SERIES

DIODE NETWORKS
TYPES R001, R002
2 MEGACYCLES



R001 DIODE NETWORK



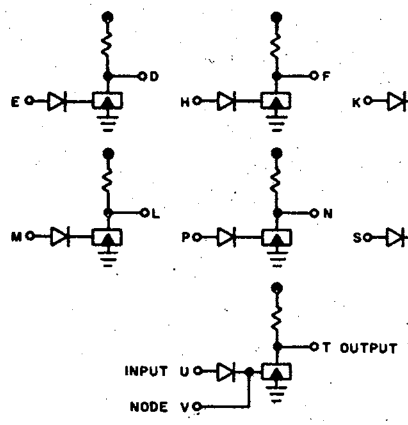
R002 DIODE NETWORK

The R001 Diode Network consists of seven diodes used to add inputs to the R107 Inverter or the R111 Diode Gate, or to provide OR inputs at flip-flop outputs. Diodes cannot be cascaded to perform other logic operations.

The R002 Diode Network consists of five diode networks used to add inputs to the R107 Inverter or the R111 Diode Gate, or to provide OR inputs to flip-flop outputs. Diode networks cannot be cascaded to perform other logic operations. The diodes are similar to type 1N3606.

INVERTER
TYPE R107
2 MEGACYCLES

R SERIES



R107 INVERTER

The R107 Inverter contains seven inverter circuits with single-input diode gates. Six of the circuits are used for single-input inversion; the seventh circuit can be used for gating by tying additional diode input networks to its node terminal. Clamped load resistors of 2 ma are a permanent part of each inverter. Typical output total transition times are 60 nsec for rise and 50 nsec for fall.

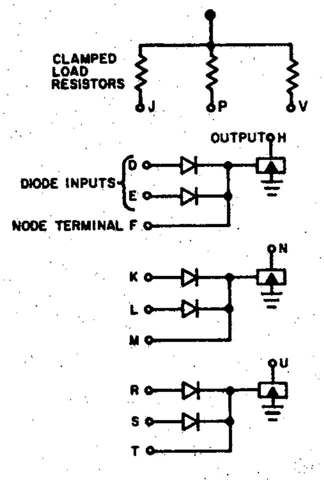
INPUT: Diode — Standard levels of —3v and ground, 100-nsec minimum duration. Input load is 1 ma, shared among the inputs that are at ground. **Node Terminal** — Accepts only R001 or R002 Diode Networks or their equivalent. The combined length of all leads attached to the node terminal must not exceed 6 in. Input signal and load characteristics for diode networks are the same as those given for the diode input above.

OUTPUT: Standard levels of —3v and ground. Each inverter can drive 18 ma of load at ground. Output terminals of inverters may be connected in parallel. Only one clamped load resistor is needed at the output when less than 2 ft of wire is used. If the wire exceeds this length, additional clamped load resistors may be necessary for a fast enough fall time in high frequency applications.

POWER: + 10 v(A)/0.7 ma; —15 v(B)/30 ma.

R SERIES

DIODE GATE
TYPE R111
2 MEGACYCLES



R111 DIODE GATE

The R111 Diode Gate contains three diode gates, each connected to a transistor inverter. The gate operates as a NAND for negative inputs and as a NOR for ground inputs. Each gate has three input terminals: two are connected to diodes; a third is connected directly to the node point of the diode gate. The third terminal allows the number of input diodes to be increased by adding external diode networks such as the R001 or R002. External diodes must be connected in the same direction as the diodes in the R111. Typical output total transition times are 60 nsec for rise and 50 nsec for fall.

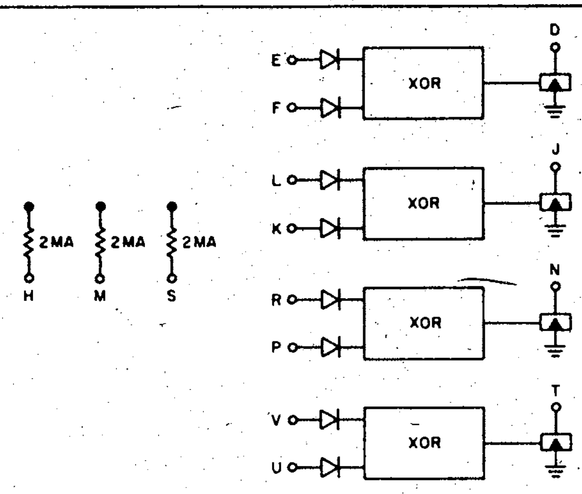
INPUT: Diodes — Standard levels of —3v and ground, 100 nsec minimum duration. Input load is 1 ma shared among the inputs that are at ground. **Node Terminal** — Accepts only R001 or R002 networks or their equivalent. The combined length of all leads attached to the node terminal must not be greater than 6 in. Input signal and load characteristics for the diode networks are the same as those given for the diode above.

OUTPUT: Standard levels of —3v and ground. Each output can drive 20 ma of load at ground. Clamped load resistors are included in the module. Each clamped load resistor represents 2 ma of load. The output terminals of diode gates may be connected in parallel. Only one clamped load is needed for parallel outputs when less than 2 ft of wire is used. If the wire exceeds this length, additional clamped loads may be necessary for a fast enough fall time in higher frequency applications. Two gates in parallel (driven by the same signal) can drive 38 ma at ground (20 ma each, less the 2-ma clamped load). If they are not driven by the same signal, gates in parallel drive 20 ma at ground minus 2 ma for each clamped load used.

POWER: +10 v(A)/0.3 ma; —15 v(B)/18 ma.

EXCLUSIVE OR
TYPE R131

R SERIES



R131 EXCLUSIVE OR

This module provides a convenient way to compare two binary numbers or patterns. The output of each circuit is negative if its inputs are the same, and ground if they are different. If the outputs of several circuits are tied together, the common output line will be negative if every input pair matches, ground if any pair doesn't match.

During the transition from one input pattern to another with the same output, there is an interval during which the R131 output may be wrong for both patterns. Transitions between unequal inputs have a relatively short settling time, but transitions between equal inputs may produce transients to ground lasting 250 nsec or more.

INPUTS: Standard levels of —3v and ground. Each input is a 2 ma load at ground.

OUTPUTS: Standard levels of —3v and ground. Each output can drive 18 ma at ground. Propagation delay for output rise is similar to R111 delay. Propagation delay for output fall is typically 300 nsec longer than R111 delay.

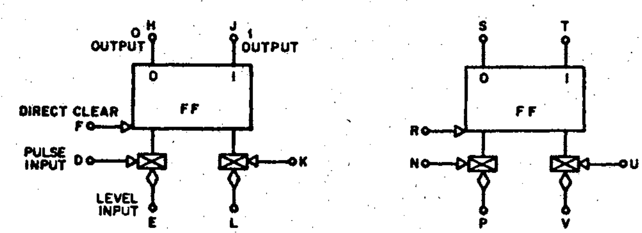
POWER: +10v(A)/0.8 ma; —15v(B)/36 ma.

TRUTH TABLE

Input E(K, P, U)	Output D(J, N, T)	Input F(L, R, V)
0v	0v	—3v
—3v	0v	0v
0v	—3v	0v
—3v	—3v	—3v

DUAL FLIP-FLOP
TYPE R202
2 MEGACYCLES

R SERIES



R202 DUAL FLIP-FLOP

The R202 Dual Flip-Flop contains two identical flip-flops. Each has a direct clear input and two DCD gates. The R202 can perform in any one of the following applications without additional gating: up counter, down counter, shift register, ring counter, jam transfer buffer, and switch tail ring counter.

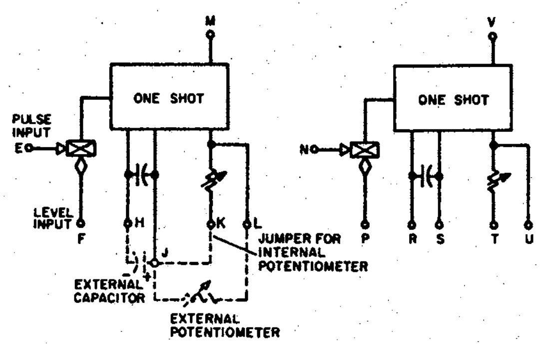
INPUT: Direct Clear—A standard 100-nsec pulse or a ground level of 100 nsec minimum duration activates the input; the load at ground is 1 ma. When not in use, the direct clear terminal must be at —3v. If the flip-flop is in an up counter with carry gates enabled, direct clear pulses must be at least 400 nsec long to suppress carry propagation. **DCD Gates, Level**—Standard levels of —3v and ground. Because DCD gates are internally conditioned by the state of the flip-flop, a complement input may be formed by tying the 1 and 0 DCD gate inputs together. A DCD gate is enabled by a ground level and disabled by a —3v level. The conditioning level must be present for at least 400 nsec before the gate is pulsed. The level input represents 2 ma of load at ground. When 1 and 0 DCD gates are connected in parallel to form a complement input, the total level load is 3 ma at ground. **Pulse**—Standard 100-nsec pulses (—3v to ground) at any frequency up to 2 mc. It can also be driven by positive-going level changes (—3v to ground) with rise times of 60 nsec max and duration of 100 nsec min. Prior to operation the input must have been at —3v for at least 400 nsec. The pulse input represents 3 ma of load at ground. When a pair of 1 and 0 DCD gates have a common pulse input, as in complementing or shifting, the total pulse load is 4 ma at ground. **Collector Triggering**—The flip-flop can also be set or cleared through its outputs by a diode gate circuit or a diode network. The triggering circuit load is the external load on the terminal being driven by the circuit plus the internal load on that terminal (5 ma each).

OUTPUT: Standard levels. The carry propagate time is 70 nsec. Each terminal can drive 15 ma of external load at ground and has an internal load of 5 ma. If more than 18 in. of wire is attached to an output, additional clamped loads (see the W002, W005) should be connected to decrease the output fall time. The load is sufficient if the positive transition at the opposite terminal reaches —1 v within 80 nsec after the flip-flop is pulsed. See note, p. 47

POWER: +10 v(A)/0.5 ma; —15 v(B)/30 ma.

DELAY (ONE SHOT)
TYPE R302
2 MEGACYCLES

R SERIES



R302 DELAY (ONE SHOT)

The R302 contains two delays (one-shot multivibrators) which are triggered by DCD gates. Each delay is independent and can be externally or internally controlled. When the input is triggered, the output changes from its normal ground level to —3v for a predetermined, adjustable period of time and then returns to ground. The length of the delay is determined by the capacitor and potentiometer. The delay range for typical capacitors used with the internal potentiometer is given in the table that follows.

DELAY RANGES

Total Capacitance Used (External +220 pf internal)	Minimum Delay Range	Recovery Time
None	400-4000 nsec	800 nsec
2000 pf	4-40 μsec	8 μsec
20,000 pf	40-400 μsec	80 μsec

The expected delay of any combination (with more than a 500-pf capacitance) can be estimated by the following formula:

$$\text{Delay} = 0.7\ RC \pm 10\%$$

where the delay time is in nsec, R in kilohm and C in pf. The total capacitance, C, equals 220 pf of internal capacitance plus any external capacitance used. External capacitors can be attached between terminals H and J (or R and S), J (S) being the more positive terminal. The resistance, R, is equal to the resistance of the potentiometer plus 1 kilohm of internal resistance. The 20-kilohm internal potentiometer can be used by putting a jumper between terminals J and K (or S and T). External potentiometers can be attached between terminals J and L (S and U). The total resistance between these terminals must not exceed 20 kilohm. The minimum delay is 400 nsec. The minimum delay in nsec for a given external capacitor is 0.7 C where C is equal to the external capacitance in pf plus a 220-pf internal capacitance. The recovery time is twice the minimum delay, or about 1.4 C nsec. A 20% change in power supply voltage will change the delay less than 2%. Delay jitter due to power supply ripple is less than 0.2%.

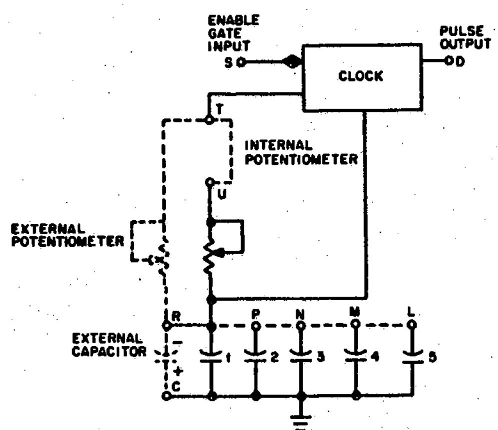
INPUT: Level — Standard levels of —3v and ground. A DCD gate is enabled by ground level and disabled by a —3v level. The conditioning level must be present for at least 400 nsec before the gate is pulsed. The level input represents 2 ma of load at ground. **Pulse** — Standard 100-nsec pulses (—3v to ground). It can also be driven by positive-going level changes (—3v to ground) with rise times of 60 nsec max and duration of 100 nsec min. Prior to operation the input must have been at —3v for at least 400 nsec. The pulse input represents 3 ma of load at ground. The delay cannot be set from its output terminal.

OUTPUT: Standard Level of —3v for the duration of the delay time. The output can drive 18 ma of external load at ground. The internal load is 2 ma.

POWER: +10 v(A)/0.6 ma; —15 v(B)/88 ma.

VARIABLE CLOCK
TYPE R401
2 MEGACYCLES

R SERIES



R401 VARIABLE CLOCK

The R401 Variable Clock is a gateable clock that produces standard 100-nsec pulses from a stable RC-coupled oscillator. The variable clock is often used as a primary source of timing for large systems.

The frequency of the R401 Clock is variable from 30 cps to 2.0 mc. Five capacitors provide coarse frequency control, and a built-in 20,000-ohm potentiometer permits fine adjustment. Terminals for an external potentiometer or capacitor are available. The maximum size of the external potentiometer to be used is 20,000 ohms.

FREQUENCY SELECTION

Select Pin R	Capacitor 1.	300 kc to 2.0 mc
Pin P	Capacitor 2.	30 kc to 375 kc
Pin N	Capacitor 3.	3.5 kc to 40 kc
Pin M	Capacitor 4.	300 cps to 4.5 kc
Pin L	Capacitor 5.	30 cps to 340 cps

Lower frequencies may be obtained by adding an external capacitor between pins R and C. A 20% change in power supply voltage will change the prf less than 1%. The pulse-to-pulse jitter is less than 0.2%.

INPUT: The clock is enabled by a −3 v level or an open circuit at its enable gate input. The total transition time from the time the gate is enabled until the first pulse reaches 90% of its amplitude is approximately 45 nsec. The pulses that follow appear at the frequency selected. The clock may be disabled by applying a ground level at the enable gate pin S. The enable gate loading is 4 ma at ground. Disable duration must exceed the period to which the clock is set.

OUTPUT: Same as R601 100-nsec output.

POWER: +10 v(A)/1.3 ma; −15 v(B)/19 ma.

VITA

Orley Leon Lake

Candidate for the Degree of

Doctor of Philosophy

Thesis: ANALYSIS OF SPEECH SOUNDS THROUGH DIGITAL COMPUTER SIMULATION OF THE COCHLEA

Major Field: Electrical Engineering

Biographical:

Personal Data: Born in Wichita, Kansas, January 1, 1939, the son of John A. and Arlie W. Lake.

Education: Attended high school in Haven, Kansas, and graduated from Haven High School in May, 1956; received the Bachelor of Science degree in Electrical Engineering from the University of Kansas in January, 1961. Commissioned as a regular officer in the United States Air Force in January, 1961. Continuous active duty in the United States Air Force from January, 1961 to the present. Current rank is Captain. Received the Master of Science degree in Electrical Engineering from the University of Kansas in May, 1967; completed requirements for the Doctor of Philosophy at Oklahoma State University in July, 1970.

Professional Experience: Served as Project Officer for the Survivable Low Frequency Communication System at the Electronic System Division of the Air Force System Command from January, 1962 until March, 1965. Assigned as a Project Officer for the instrumentation ships of the National Range Division of the Air Force System Command from March, 1965 until September, 1967.

Professional Organizations: Member of Tau Beta Pi, Sigma Tau, and Eta Kappa Nu.