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Scope of Study: In many high school and college physics courses, the units on radio and electronics have often been treated lightly or skipped entirely. With the field of radio and electronics becoming more important each day, the high school physics teacher should make a greater effort to present some of the important principles and applications of radio and electronics to the student. This report presents six demonstrations that cover the fundamental principles involved in radio transmission and reception. By the use of demonstrations to supplement the regular experiments, the principles and applications of electronics can be presented more effectively. Standard electronic circuits for the demonstration apparatus are drawn from basic texts in the field. Principles of rectification, oscillation, modulation and polarization of radio waves are demonstrated.

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A REPORT ON BASIC RADIO DEMONSTRATIONS
FOR HIGH SCHOOL PHYSICS

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CHAPTER I

INTRODUCTION

Radio and electronics have made tremendous progress in the last few decades and are becoming increasingly more important each day. The physics teacher finds the principles involved in radio transmission and reception interesting, but at the same time difficult to teach.

In most of the physics courses the writer has taken in high school and college, electronics was covered in the last few pages of the textbook. By the end of the course, the instructor very conveniently ran out of time or treated this subject very lightly. This, in the opinion of the writer, is an injustice to the student.

Basic radio theory is covered in the regular high school physics text, but most laboratory manuals list only two or three elementary experiments in electronics. These experiments are not adequate to get the complex ideas involved in radio across to the pupil. This report is an attempt to alleviate this condition by working out plans and demonstrations for a set of apparatus using low cost and readily available parts.

Six demonstrations have been selected which cover the fundamental principles involved in radio transmission and reception. The circuits used are standard, and some of the apparatus described is available commercially from scientific supply houses. The apparatus can be built as student projects from discarded radios and inexpensive materials. Ordinary radio sets are interesting, but of dubious value as teaching devices. They show very little of the nature of the electromagnetic wave which is fundamental to a knowledge of radio. In the demonstrations to be described, emphasis is placed on the nature of the electromagnetic wave. When properly presented these experiments should serve to: (1) motivate; (2) explain radio principles or applications; (3) provide for students with special interest in electronics.

The only additional equipment needed for the demonstrations is a cathode ray oscilloscope, microphone, four watt fluorescent tube, and tuning fork. The cathode ray oscilloscope has been overlooked by many physics teachers as a teaching aid. A cathode ray oscilloscope is a very useful instrument in the physics laboratory, not only in electricity and radio, but in sound also. Several oscilloscope kits are on the market at a cost of about fifty dollars which is in the range of most laboratory budgets.

Although semiconductors and transistor theory and applications are beyond the scope of this report, an attempt should be made to introduce these and other new advances being made in the field of electronics. Transistors are used in the receiving apparatus to be described in order to acquaint the student with the application of this new development. Numerous special experiments with these devices could be carried on by students interested in this phase of electronics.

Basic theory is kept to a minimum in this report. Circuit theory is covered in any good high school physics text. A bibliography of several references is given where further information may be obtained if desired.

CHAPTER II

CONSTRUCTION OF APPARATUS

The construction of the apparatus to be described requires no special skills other than an elementary knowledge of radio and soldering technique. The mechanical construction can vary and will depend on the materials on hand. Only the technical information necessary for proper operation of the equipment will be covered here. Figures one through four give the wiring diagrams and parts list.

The VHF oscillator-transmitter, modulator, and power supply should be mounted on separate chassis. Discarded radio chassis or aluminum cake pans will serve nicely.

The receiver-field strength meter[1] can be mounted in a small plastic utility box. By making the receiver compact, it can be conveniently moved about in the demonstrations. The receiving antenna is a simple dipole made of two pieces of small diameter welding rod soldered to terminal lugs and bolted to the top of the plastic case.

The power supply should present no difficulty. Wiring is not critical and some variation in components can be made without affecting its operation. Number twenty or larger

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[1] 28 Uses for Transistors. New York: Sylvania Electric Products Inc., 1955, p. 40.

insulated wire will be large enough to handle the current. The power supply furnishes power to both the modulator and the oscillator-transmitter.

The VHF oscillator-transmitter, as described by Sutton,[2] is well suited for demonstration purposes. Wiring is somewhat critical and leads should be kept as short as possible. The plate inductor is a single turn of number ten bare copper wire about five centimeters in diameter. The plate inductor is supported directly by the plate leads, which come from the tops of the tubes. The grid inductor, which is similar but reversed in sense, as indicated in Figure 2, is supported in the same way. Mount the pickup loop of the transmitting antenna parallel to, and two centimeters from the plate inductor, on insulating supports. Coupling can be varied by bending the loop. The antenna is the same as for the receiver.

From Figure 3, it can be seen that the modulator is a contentional audio amplifier using a modulation transformer instead of the usual output transformer.[3] The unit can be tested by substituting a suitable output transformer and connecting to a loudspeaker.

The Lecher-wire system consists simply of two number 18 bare copper wires three meters long and five centimeters apart.

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[2] Sutton, Richard M., Demonstration Experiments in Physics. New York: McGraw-Hill Book Company, Inc., 1938, p. 454.

[3] Radio Amateur's Handbook. West Hartford, Connecticut: American Radio Relay League, 1953, p. 254.

Plastic spacers are used at each end. Two short stiff wires are soldered to the terminals of a small neon glow lamp so that it may be slid along the Lecher-wires.

The polarizing frame is a square wooden frame, 70 centimeters on a side. Parallel copper wires two centimeters apart are streched across the frame and nailed in place.

The complete set of apparatus is essentially a short range, amplitude modulated transmitter, operating in the VHF (very high frequency) band. The apparatus described here should operate on a frequency of around 220 megacycles. This frequency was selected in order to keep antenna dimensions small and enable measurements of length to be made easily.

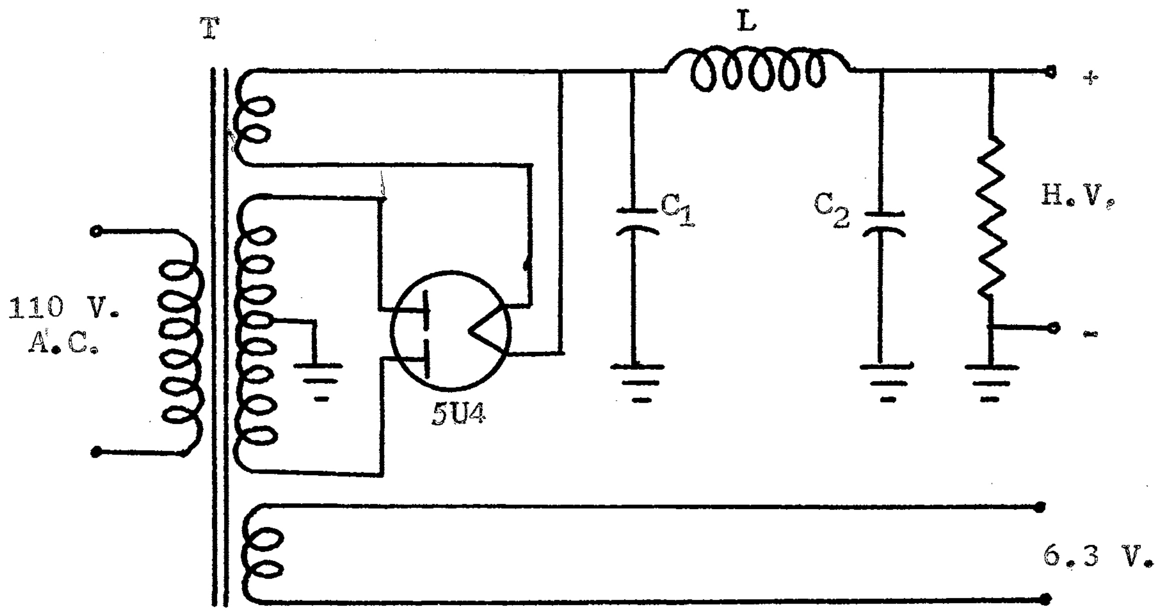

FIGURE 1

CIRCUIT DIAGRAM FOR POWER SUPPLY

C_1, C_2 -- 16 mfd. 450 volt electrolytic.
L -- 10-hy. 110-ma. filter choke
R -- 25,000 ohm, 10 watts.
T -- Power transformer: 600-0-600 volts, 200 ma; 5 volts, 2 amp.; 6.3 volts, 2.5 amp.

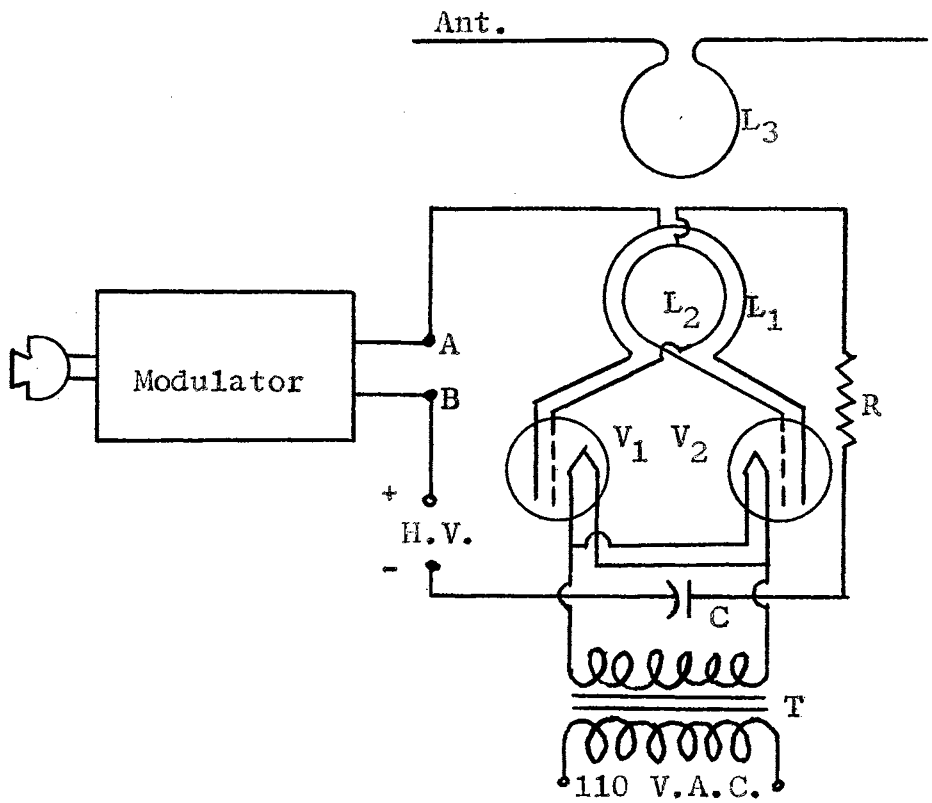

FIGURE 2

WIRING DIAGRAM FOR VHF OSCILLATOR SHOWING CONNECTION TO MODULATOR

Ant. -- See text for antenna construction.
C -- 0.001 mfd ceramic.
L_1, L_2, L_3 -- Inductors (see text).
R -- 15,000 ohm, two watts.
V_1, V_2-- RCA 834 tube.
T -- Filament transformer: 7.5 volts, 10 amp.

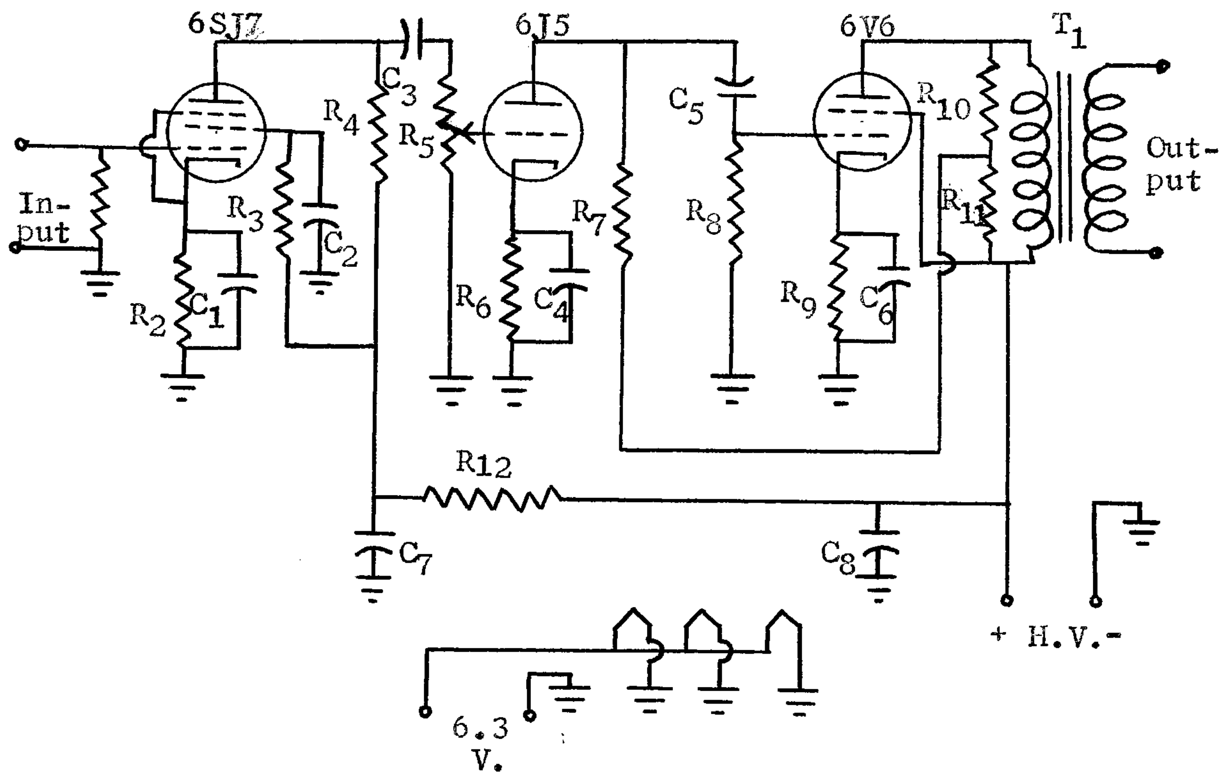

FIGURE 3

CIRCUIT DIAGRAM FOR MODULATOR

C_1, C_4, C_6 -- 20 mfd. 50-volt electrolytic.
C_2 -- 0.1 mfd. 400-volt paper.
C_3, C_5 -- 0.01 mfd. 400-volt paper.
C_7, C_8 -- 10 mfd. 450-volt electrolytic.
R_1 -- 2.2 megohms, one-half watt.
R_3 -- 1 megohm, one-half watt.
R_4 -- 0.22 megohm, one-half watt.
R_5 -- 1 megohm potentiometer.
R_7, R_8 -- 0.1 megohm, one-half watt.
R_9 -- 235 ohms, 2 watts.
R_{10}, R_{12} -- 47,000 ohms, 1 watt.
R_{11} -- 27,000 ohms, 1 watt.
T_1 -- Audio transformer, 1:1 turns ratio.

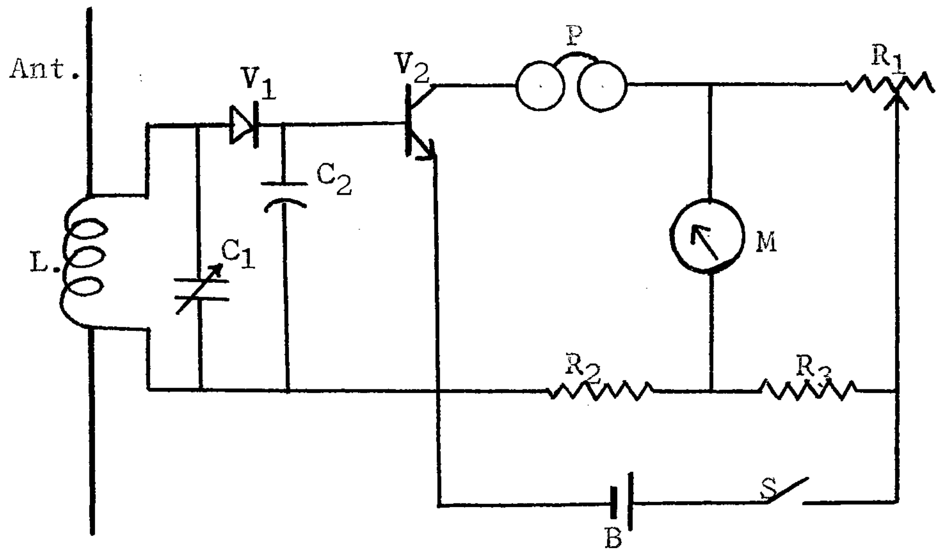

FIGURE 4

WIRING DIAGRAM FOR RECEIVER AND
FIELD STRENGTH METER

Ant.	--	Antenna (see text), each rod 70 cm. long.
B	--	One -one-half volt dry cell.
C_1	--	50 mmfd. variable.
C_2	--	0.002 mfd. mica.
L	--	two turns No. 20 enamelled wire airwound one-fourth inch diameter space one-fourth inch.
M	--	0-1 DC MA meter.
P	--	2000 ohm magnetic head phones.
R_1	--	5000 ohm potentiometer.
S	--	Single pole, single throw switch.
V_1	--	1N34A crystal diode.
V_2	--	2N35 transistor.

CHAPTER III

BASIC RADIO DEMONSTRATIONS

Rectifier and filter action. The purpose of a rectifier is to change alternating current to pulsating direct current, while the filter is to smooth out and fill in pulsating direct current to produce pure direct current. It would be well to aquaint the students with the applications of direct currents to radio and television as a means of opening the discussion of rectifiers.

It may be necessary to remind the students ofthe meaning of the sine wave as it appears on the oscilloscope screen. The part of the curve above a horizontal axis on the screen represents current flow in one direction while that part of the curve below the line represents current flow in the opposite direction. To change alternating current to direct current, the rectifier must cause current to flow in only one direction. After rectification, the only part of the sine curve which will remain will be that which was above the horizontal mid-line or that which was below.

To show alternating current before rectification connect two wires from the 6.3 volt terminals of the power supply to the vertical input terminals on the oscilloscope. With the horizontal and vertical gain controls on the oscilloscope set at low readings, the horizontal selector set at sixty cycles, the synchronizing selector switch set at internal, a typical sine wave curve should appear on the screen.

To show pulsating direct current, connect one of the vertical input leads from the oscilloscope to point A shown in Figure 1, and the other lead to the power supply chassis. Follow the same procedure in operating the oscilloscope as above with the exception that the horizontal selector is set at one hundred twenty cycles. A series of pulsating direct current curves should now appear on the screen. The student should note that the curves are all on one side of the horizontal axis of the screen indicating that current is flowing in one direction only.

As the student observes pulsating direct current curves on the oscilloscope screen, it should be pointed out that although the current is always in one direction, the voltage is continuously varying from zero to peak value. In radio this continual voltage variation will cause an undesirable hum in the receiver.

The filter action can now be shown by connecting the vertical input leads of the oscilloscope to the power supply high voltage output terminals. The oscilloscope controls should have the same settings as above. A smooth line should now appear to one side of the mid-axis of the screen, indicating pure direct current suitable for most radio and television purposes.

VHF oscillator-transmitter. Connect the power supply to the high voltage and filament terminals of the oscillator-transmitter. Connect a shorting wire across the modulator terminals A and B. With the oscillator working, a fluorescent tube can be lighted by holding it close to one end and bringing the pin terminals on that end in contact with the plate inductor. After the gas in the lamp has ionized, the lamp may be moved about the oscillator without touching any part of the circuit, and it will remain lighted. This demonstrates clearly the presence ofa radio frequency energy field.

Audio amplifier and modulator. As mentioned previously, the modulator is simply an audio amplifier with a suitable output transformer for modulation. Set up the modulator and oscillator as shown in Figure 2. Remove the antenna rods and connect the vertical input terminals of the oscilloscope to the antenna inductor terminals with a short piece of television lead-in wire. Set the oscilloscope input switch to direct vertical input. The linear sweep frequency switch is turned to the highest range and the synchronizing switch is turned to internal. Horizontal gain control is set for a long, horizontal trace line with the oscillator turned off. With the oscillator turned on and with no modulation, the radio frequency carrier wave can be observed on the oscilloscope screen. To show the modulation pattern, strike a tuning fork and hold it in front of the microphone.

Transistor receiver and field strength meter. Radio transmission and reception can now be demonstrated. The transmitting antenna should be inserted in the oscillator. With the oscillator and modulator turned on, signals should be received in an adjoining room. A phonograph player may be substituted for the microphone if desired. Relative field strength intensity of the signal may be read from the meter mounted on the receiver. The receiving antenna may be moved or rotated to illustrate the effects of polarization. A maximum response will be found when the transmitting and receiving antennae are parallel to each other, and minimum when they are at right angles.

Frequency measurement with Lecher-wires. Lecher-wires constitute a very convincing demonstration of the wave nature of radio. Remove the antenna rods from the oscillator and connect the two wires from one end of the Lecher-wire system across the antenna inductor. The wires should then be stretched across the room so that the wires are taut and parallel. String can be tied to any convenient support to hold the wires in this position.

When the VHF oscillator is operating, standing waves of potential and current are set up on the Lecher-wires somewhat similar to sound waves in an organ pipe.

If an alternating voltage is applied to one end of the Lecher-wire system, a small interval of time is required for the voltage pulse to move down the lines. When the pulse reaches the ends of the wires, a reflection occurs setting up the standing waves. A reversal of phase takes place at the open ends of the wires, and the ends become points of maximum potential variation. Hold the small neon lamp so that the short stiff wires soldered to the base contacts connect the lamp across the Lecher-wires. As the lamp is moved along the line, it lights up brilliantly as it passes a voltage antinode, and it grows dim or goes out as it passes a voltage node. The distance between two consecutive nodes or antinodes is a half wave-length of the electromagnetic waves produced by the oscillator.

The frequency can be determined by dividing the velocity of electromagnetic waves in free-space by the wave-length. Velocity and wave-length must be expressed in the same units of length. The velocity of the electromagnetic wave is slightly less in wire than in free-space. However, the velocity of light in free-space, 186,000 miles per second or 300,000,000 meters per second, may be used to compute frequency.

Polarization of radio waves. Sutton[1] suggests this striking demonstration of the wave nature of radio. The receiving antenna is placed parallel to that of the transmitter and about two wave-lengths away. The polarizing frame is then placed midway between the two and rotated in a plane

[1]Sutton, Richard M., Demonstration Experiments in Physics. New York: McGraw-Hill Book Company, Inc., 1938, p. 456-457.

normal to the line joining their centers. The maximum energy absorption takes place when the wires on the frame are parallel to the antennae. When the frame is in this position, the signal strength as indicated by the receiver is weakest. When the wires are perpendicular to the antennae, they have very little influence on signal strength. This is an exact analogy of an optical polarizing medium such as tourmaline.

CHAPTER IV

CONCLUSION

The demonstration experiments in this report should form a nucleus for a unit on radio. They are not meant to take the place of individual experiments, but to supplement those normally done. For those students interested in amateur radio, they should prove valuable. Most of the theory required for the amateur radio license[1] can be illustrated with the apparatus.

Other experiments could be worked out, both individual and demonstration. The power supply can be used for a source of direct current for experiments in electricity and the audio amplifier should prove useful in experiments with sound.

By the use of demonstrations, it is hoped that the principles of radio and electronics can be made real to the student, thereby making the teaching of this branch of physics more effective.

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[1]The American Radio Relay League, West Hartford, Connecticut, offers a number of low cost publications on this subject.

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