0.1 Planar or Cylindrical Geometry?

In a four-faced PPPAR to scan the required space, each fixed faced should cover 90 °of the surrounding azimuths. This means that the radiation pattern of each planar array antenna should be steered from -45° to +45° in Azimuth direction. For NWS weather applications, the maximum required scan angle in the elevation direction is 20°. The main disadvantage of using planar phased array antennas compared to conventional mechanically steered reflector antennas is the change in beam characteristics and polarization coupling depending on the beam direction. In a planar array antenna, it is possible to achieve a low cross-polarization level while the beam steering is performed on principle planes, however, if the beam steering is required on off-principle planes, having low cross-polarization which would be acceptable for MPAR applications is almost impossible. In **lei2015comparison** Lei et al. show that at the maximum steering angle of a planar array antenna for weather application, the cross-polarization level increases to -12.4 dB which is not acceptable for weather radar measurements. Based on weather radar requirements and deficiencies of the planar array antenna, a cylindrical polarimetric phased array antenna is designed and proposed for MPAR application. The CPPAR demonstrator, a 2m diameter cylindrical array antenna designed and fabricated by the Advanced Radar Research Center (ARRC) of the University of Oklahoma **saeidi2017low**. As shown in Fig. 1 M×N element cylindrical array antenna consists of N rows of M-element circular array antenna. For the cylindrical array antenna, the beam is formed from a 90° sector of a cylinder, and for the beam steering in azimuth, an active column from one side of the activated 90° sector (Column A in the Fig. 1 (b)) is turned off and another inactive column from another side of the 90° sector (Column B in the Fig. 1 (b)) is turned on.

Chapters/Ch2_Figs/cppar.pdf

Figure 1: Cylindrical array antenna azimuth scanning **saeidi2017high**

So, the beam is always formed from a 90° sector of a cylinder and the scanning on a diagonal plane is not required. Also, due to the symmetry of cylinder around its axis, the radiation pattern will be always symmetric and won't change for beam steering in azimuth. For beam steering in elevation, steering is only required on principle planes which results in low cross-polarization level as the cylindrical array antenna scans the required space **saeidi2017cross**. Thus, for MPAR weather surveillance, the cylindrical geometry is preferred. However, it is difficult to characterize the radiation pattern of an element in a cylindrical geometry. But, because the radiation pattern of an element in a large cylindrical array antenna is similar to the radiation pattern of the same element in a large planar array **josefsson2006conformal**, the embedded element and subarray radiation patterns have been characterized using a 12×12-element planar array antenna.

0.2 Frequency Scanning Aperture Coupled Microstrip Patch Antenna Array with Matched Dual-Polarization Radiation Patterns

A CPPAR demonstrator (as shown in Fig. 2) was designed and developed. It is a 2-meter diameter cylinder populated by 96 columns of frequency scanning array antennas. Although the antenna shows high port-to-port isolation and low cross-polarization, it suffers from a mismatch between both peaks and the overall shapes of the co-polarized patterns. This contrasts with the weather observation requirement of having a correlation coefficient higher than 0.99, which requires a patterns mismatch of less than 0.5°.

In this paper, a precise phase correction method to achieve a pair of matched horizontal and vertical patterns is proposed, implemented, and tested. A step-by-step phase matching between outputs of a row of feed lines cells is carried out. It is followed by phase adjustment between the major outputs of two feed lines. In doing so, a pair of similar horizontal and vertical co-polarization patterns with their peaks mismatch less than ±0.2° within the whole frequency bandwidth is achieved. The simulation results are verified by radiation patterns measurements where a good agreement within the whole frequency bandwidth is observed.

0.2.1 Antenna Design

To demonstrate the idea of CPPAR for weather measurement, a 19-element series-fed array of dual-polarized aperture coupled patches was designed and tested **karimkashi2013dual**. In the current version, the array is designed to operate in the frequency range from 2.75 to 2.95 GHz. Taconic TLX-8 with a dielectric constant of 2.55 is used in all layers. As shown in Fig. 3 (a), the first ground plane is etched on the reverse side of the first substrate with a height of 0.787 mm. The feed lines are placed on the front side of the first substrate. H-shaped slots and second ground plane are laid on the front side of the second substrate with a height of 0.787 mm. The two ground planes are connected to each other with three walls of metalized holes along the feed lines. The third layer is a 3.175 mm thick substrate and contains the square radiating patches, and 5 mm thick substrate with slightly bigger square patches are laid on the third layer to increase the bandwidth of array antenna.

The geometry of the designed 19-element array is shown in Fig. 3 (b). The width and length of each column are 64.52 mm and 1.524 m respectively. The spacing between elements is 70 mm and the length of feed lines are optimized to have a 0° phase shift between patches at 2.73 GHz. Since wavelengths are smaller at higher frequencies, there will be a phase shift between array elements which results in beam steering at higher frequencies.

For weather measurements, it is crucial that the antenna has matched horizontal and vertical polarization radiation patterns. However, the measured radiation patterns of the previous design showed that there is a 1.3° beam pointing angle mismatch between measured horizontal and vertical radiation pattern at 2.8 GHz. The primary reason for this mismatch is a 25 dB Taylor amplitude distribution which has been applied to improve the side lobe level. In the series feed design, because the amplitude of excitation of elements cannot be controlled discretely at excitation ports, the slots size and shape are changed to adjust the excitation amplitude of each patch. In the previous design, the feed lines had a periodic form and they were repeated for each element with no change, which caused variant phase shifts between

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Figure 2: OU/NSSL CPPAR demonstrator.

elements through horizontal and vertical feed lines and subsequently resulted in the beam pointing angle mismatch. To avoid this deficiency, the feed line length should be optimized for each element separately. For feed line length adjustments, as shown in Fig. 3 (a), each element is separately excited from port 1 and ports 3. The feed line between port 1 and 3 has not been changed and only the length l_1 is adjusted so the phase of S_{42} becomes equal to the phase of S_{31} at 2.8 GHz. The feed line length adjustment process is repeated

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Figure 3: Geometry of 19-element array antenna; (a) single element layers, (b) 19-element array, (c) 3 columns of fabricated 19-element array.

for all 19 elements.

The new optimized feed line for the vertical port is used in the new design. The geometry of 3 columns of the fabricated new version is shown in 3 (c).

The simulated and measured S-Parameter results of the array antenna are shown in Fig. 4. The simulated and measured return loss for both polarization are below -11 dB from 2.75 to 2.8 GHz and below -15 dB from 2.8 to 3 GHz. The simulated and measured isolation between horizontal and vertical ports

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Figure 4: Simulated and measured S-Parameter of designed array antenna.

are below -40 dB in the entire frequency band.

The horizontal and vertical co-polarization radiation patterns of the isolated column are measured in the far field anechoic chamber of Advanced Radar Research Center (ARRC) of The University of Oklahoma.

To examine the mutual coupling effects of adjacent elements, the radiation pattern of the 3-column array when the middle column is excited and two side columns are terminated is also measured.

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Figure 5: Measured H-Pol and V-Pol co- and cross-polarization radiation pattern of isolated column.

The measured radiation patterns of isolated (or single) column and embedded column (or 3-column) at 2.8 GHz, are shown in Fig. 5 and Fig. 6, respectively. For the isolated column, the beam mismatch at 2.8 GHz is 0.04° and for 3-column measurement, the beam mismatch at 2.8 GHz and 2.81 GHz are 0.19° and 0.01° respectively. The beam pointing angle mismatch for the old version and the current version from 2.7 to 2.9 GHz are compared in Fig. 7. It is evident that in the new version the mismatch is within the acceptable region

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Figure 6: Measured H-Pol and V-Pol co- and cross-polarization radiation pattern of middle column in 3-column measurement.

from 2.75 to 2.87 GHz **Saeidi2017CPPARconf**, **Saeidi2017CPPARjour**.

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Figure 7: Beam pointing angle mismatch versus frequency.