Dielectric Fortification for Wide-Beamwidth Patch Arrays

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Abstract

This paper describes a general methodology for the design of wide beamwidth dual-polarized radiating patches. The half power beamwidth (HPBW) of a patch can be broadened by use of metallic boundaries surrounding the near-field of the patch. However, the use of metallic boundaries also reduces the overall frequency bandwidth of the radiator. This paper proposes dielectric fortification as an alternative approach for the beamwidth broadening of a dual-polarized patch antenna. It is demonstrated that significant broadening of pattern beamwidth is possible by incorporating a relatively thin layer of dielectric walls surrounding the radiator. A desirable broad beamwidth can be handily achieved by use of appropriate thicknesses of the dielectric walls. The effect can be further enhanced by incorporating metallic backing at the outside surfaces of the walls. This technique allows beam broadening without significant degradation in either the cross-polarized radiation pattern, or frequency bandwidth.

Background

Adaptive sectorization in wireless network demands a new breed of 3-way controlled beam antennas which are capable of on-tower or remotely controlled adjustment of azimuth pattern. One of the important elements for such developments is the availability of dual-polarized radiators with relatively broad beamwidth over a large operating frequency. For optimum array performance, it is also desirable that the azimuth pattern of the radiator can be adjusted to allow optimization of azimuth beam pattern, port isolations, and the overall directivity of the array. A typical patch radiator has a HPBW between 60 deg and 75 deg. Design of variable beamwidth array using radiating elements with such narrow beamwidth will require smaller element spacing to minimize ripples in the azimuth beam pattern. This, in turn, results in unnecessarily high cross coupling between ports. To minimize such compromises, it is necessary to increase the element spacing by using radiating elements with broader HPBW.

Use of metallic boundaries in the near-field enables broadening of HPBW of a patch antenna up to approximately 90 deg at the expense of the overall frequency bandwidth. The proposed method of dielectric fortification between the radiator and the metallic boundaries provides a systematic means for significant broadening of HPBW over a large frequency bandwidth. Subsequently, this method allows optimization of array performance by selecting appropriate thickness or height of the dielectric material. The dielectric loading in this manner does not seem to degrade performance in the cross polarization pattern as long as the dielectric loading is symmetrical in all four directions.

Dielectric Fortified Stacked Patch

Fig. 1 shows the isometric and cross-sectional views of a dielectric fortified stacked patch. In this case, a dual linearly polarized aperture-coupled stacked patch is used. Two radiating patches are fed by a pair of orthogonal cross slots on the bottom ground. The radiating patches are centered in a square area with a perimeter formed by four dielectric walls with the outside dimension of approximately half-wave length. The outside surfaces of the dielectric walls can be backed by electrically conductive walls. This arrangement allows a compact construction of the patches. The top radiating patch can be conveniently flash-mounted on top of the dielectric walls, while the lower radiating patch are secured at a predetermined height from the ground via small recessed grooves cut onto the inside surfaces of the dielectric walls.

The electrically conductive layer may be of the equal height as the dielectric walls, or preferably recessed from the top of the dielectric walls for better frequency bandwidth. For a given dielectric material with a fixed height, the HPBW is directly proportional to the thickness of the dielectric walls.

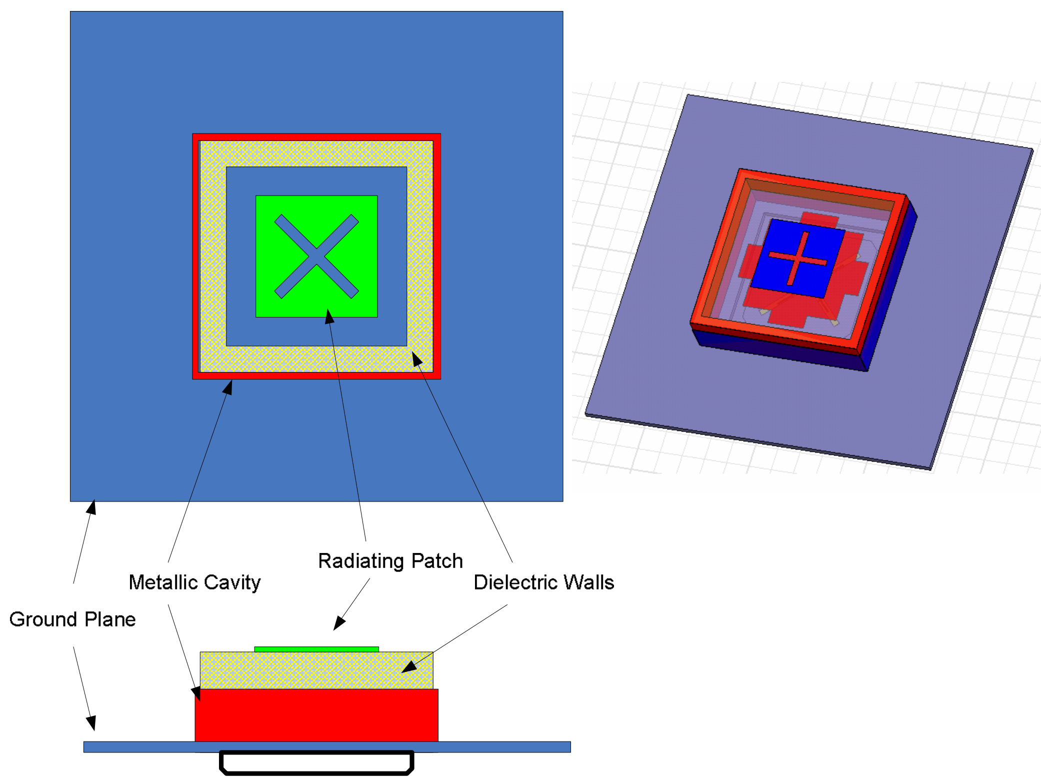

Fig. 1: Isometric and Cross-Sectional Views of Dielectric Fortified Stacked Patch

Simulations and Results

A fullwave FEM model of a dual-polarized aperture-coupled stacked patch with dielectric fortification is simulated using the Ansoft HFSS. For the purposes of these demonstrations, FR-4 (ε_r=4.6) is assumed for dielectric material. The height of dielectric walls is fixed at 20mm and the height of the metallic boundaries is kept at 14mm. Fig. 2 shows the simulated azimuth HPBW for various thicknesses of dielectric walls. As indicated in the figure, the HPBW is varying from 70 deg to 125 deg for value of the dielectric thickness between 0mm and 7,5mm.

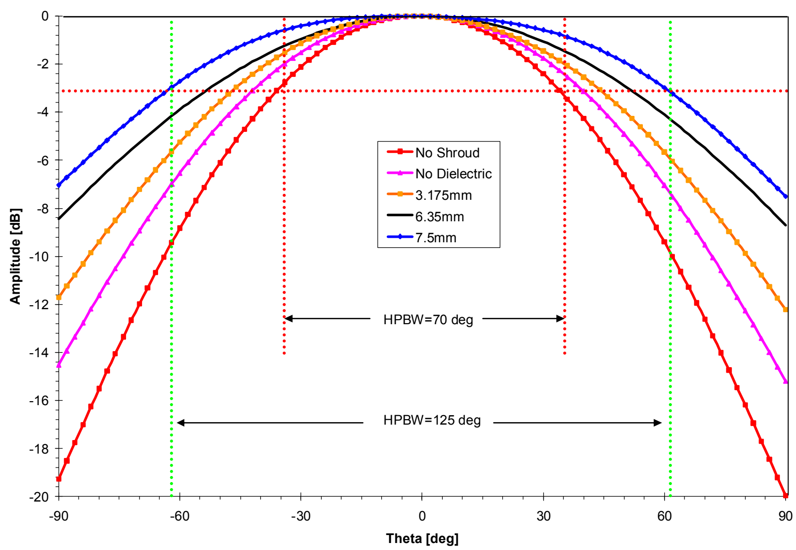

Fig. 2(a) Azimuth HPBW

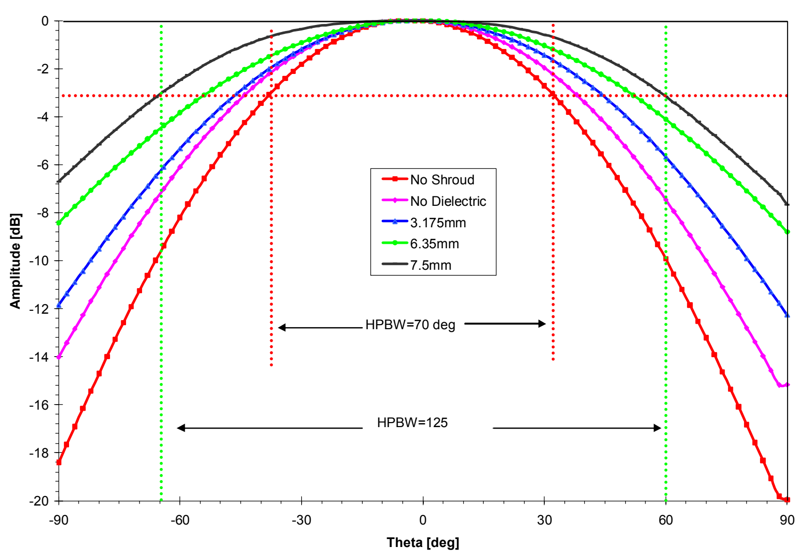

Fig. 2(b) Elevation HPBW

Fig. 3 shows a typical co-polar and cross-polar pattern of a dielectric-loaded stacked patch in the azimuth plane. Cross-polar component in the main beam is typically below -30 dB. Fig. 4 gives a simulated plot of return losses of the radiator. The frequency bandwidth for VSWR below 1.5:1 is over 19.4% without any input tuning and can be broadened to over 26% by incorporating a broadband input matching circuit.

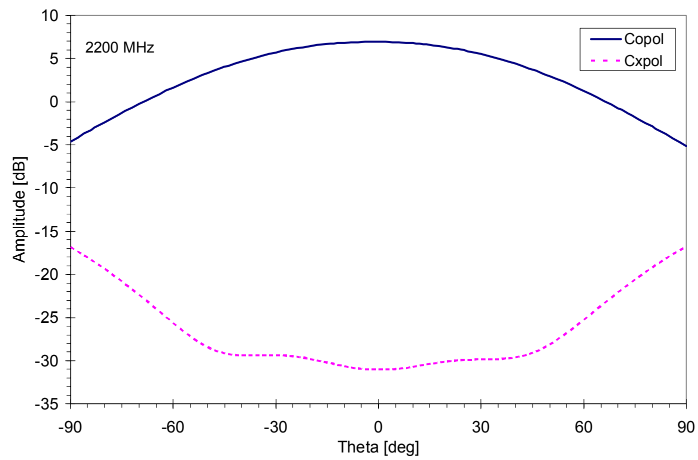

Fig. 3: Typical Co-polar and Cross-polar Patterns

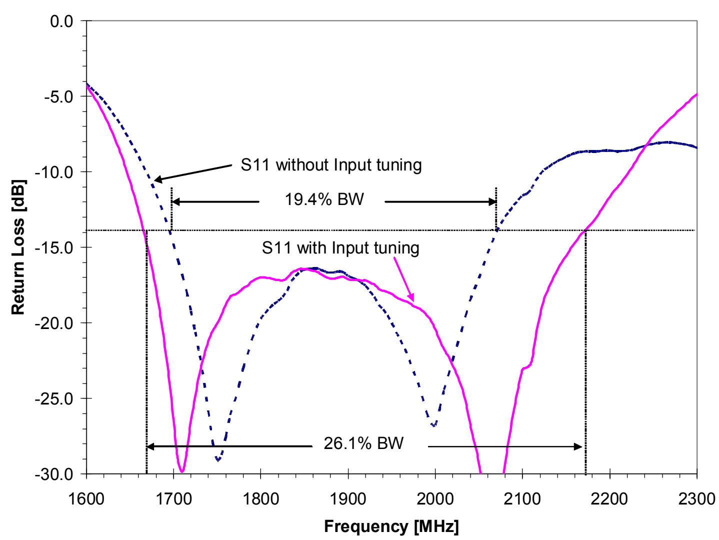

Fig. 4: Typical Return Loss

Conclusion

A general beamwidth broadening by dielectric fortification for patch radiators is introduced (patent pending). This method can be applied to dual polarized patches. It allows broadening of the HPBW over a relatively broad bandwidth and does not degrade the radiation performance in the cross polarized field.