Axial-Rotation Beamwidth Adjustable Arrays For Wireless Communications

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Abstract

This paper presents a simple concept of beamwidth adjustable array suitable for wireless communications. The azimuth beamwidth of the proposed antenna array is continuously variable through on-axis rotation of a single-column or a dual-column staggered array. Radiating elements of the array are arranged in off-center positions between alternate elements in the azimuth direction and are mounted on separate reflectors, alternately. With a proper choice of offset distance, HPBW variation from 36 deg to over 100 deg is feasible with a rotation angle of less than ±35 deg, for a typical UMTS frequency between 1.7GHz and 2.2 GHz.

Background

There seems to be increasing interest in the community of wireless communications for 3-way antenna arrays for future implementation of adaptive sectorization. Three-way antennas allow advanced functionalities of elevation beam tilt, azimuth scan and HPBW variation in the azimuth through remote control. A typical wireless base station antenna today is already equipped with remote electrical tilt function. The azimuth scan can be implemented by use of a simple pedestal. This article describes an antenna concept that will enable the third function of beamwidth control in the azimuth through axial rotation.

Several concepts of variable beamwidth array have been explored at Powerwave, including 3-column arrays, staggered planar array and axial rotation arrays. Each method has its own merit and disadvantages in terms of antenna gain, aperture size, range of HPBW variation, cross-polarization performance and cost. Axial rotation arrays seem to offer good compromise among these parameters. The single-column array offers a low-cost approach with a very good range of HPBW variations. The 2-column method provides a higher gain with a slightly more limited range in HPBW variation.

Axial Rotation Variable Beamwidth Arrays

Results of the present works suggest that the azimuth beamwidth can be varied by axial rotation of a single-column or dual-column staggered array. The resultant azimuth patterns will be acceptable provided that the rotation does not incur significant variation in element spacing in the aperture plane. Fig. 1(a) shows the single-column case, in which the radiating elements are arranged in off-center positions between alternate elements in the azimuth direction. Radiating elements are mounted on different reflector, alternately. The nominal distance of center offset between the alternate elements in the azimuth direction determines the overall azimuth pattern. A larger offset distance allows more beamwidth variation in the azimuth direction. However, the side lobe level in the azimuth also increases as the offset distance increases.

Fig. 1(b) shows the two-column array concept. In this case, the radiating elements are physically arranged in a rectangular two-column fashion in the azimuth direction. These radiating elements are, however, mounted on separate reflector alternately, as in the single-column case. Again, the displacement of the phase center (Δd) must be relatively small in comparison to the element spacing (d) in the azimuth. Furthermore, amplitude taper is desirable as shown in Fig. 1(c) to avoid high ripple in the main beam. In either case, the two reflectors are rotated in opposite directions in order to increase the azimuth beamwidth. The maximum rotation angle is typically limited to below ±35 deg before significant beam split.

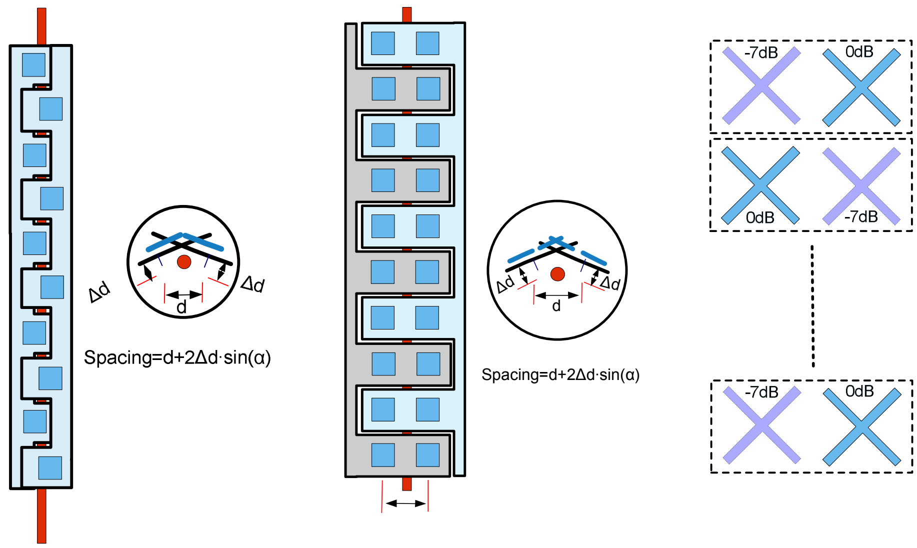

Fig. 1(a)
1-col Axial Rotation VBA

Fig. 1(b)
2-col Axial Rotation VBA

Fig. 1(c)
Amplitude taper pattern

The two-column array provides a higher directivity at the expense of a smaller beamwidth variation. However, beam split may possibly occur at higher rotation angle. This deficiency can be remedied by imposing amplitude taper between the two elements in the azimuth direction (Fig 1(c)). Amount of amplitude taper is a compromise between the desire array directivity and the maximum achievable azimuth beamwidth before the occurrence of beam split.

One-Column Axial-Rotation Variable Beamwidth Array

One-column variable beamwidth array (VBA) has only one array parameter for azimuth pattern control: the offset distance between the two alternate radiators. Azimuth patterns of the array have been simulated using HFSS at different offset distances: d=0mm, 75mm, 90mm and 100mm. Table 1 summarizes the HPBW and directivity of the array. Evidently, a larger offset distance (d) gives a wider range of HPBW variation and higher directivities. However, if the offset distance is too large, the SLL in the azimuth direction may become unacceptable. The optimum offset distance (d) seems to be in the neighborhood of 90mm at the UMTS frequencies. A larger offset is likely to have unacceptable azimuth sidelobe level.

Table 1: HPBW and Dmax of 1-column VBA

Offset (mm)	HPBW (deg)	Dmax (dBi)
D = 0	66 – 100	15 - 17
D = 75	42 – 136	14 – 19
D = 90	38 - 120	14 – 19
D = 100	36 - 108	15 - 19

Fig 2 shows the simulated azimuth patterns at 2200MHz of one-column VBA at various rotation angles with offset distance set at d=90mm. The HPBW starts at 38 deg when the rotation angle is 0 deg. The beam pattern slowly opens up to over 120 deg when the rotation is about 40 deg. Sidelobe levels are well below -20dB. Cross-polar field components are below -18dB within HPBW. No beam split is observed.

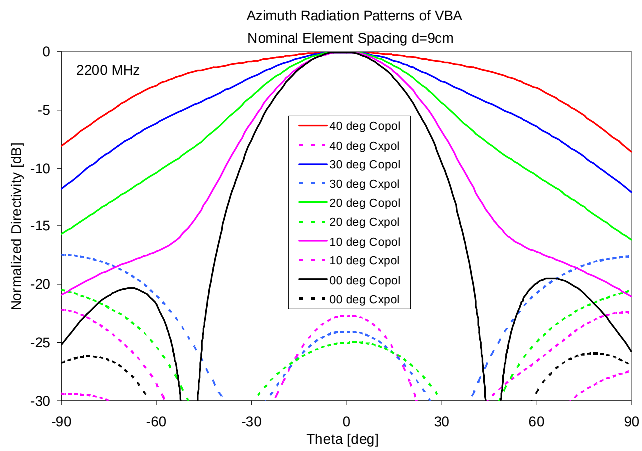

Fig. 2: Azimuth patterns of 1-column VBA (d=90mm)

Two-Column Axial Rotation VBA

The one-column VBA offers good azimuth patterns but is inherently low gain. This leads to the concept of two-column VBA. Simulations show that axial rotation of a two-column staggered array tends to produce significant split beam at high rotation angles, above 30 deg. Proper amplitude taper is, therefore, necessary to provide compromise between directivity and beam pattern. Fig. 3 show the simulated azimuth patterns of a two column VBA with d=95mm. Fig. 3(a) gives the azimuth patterns without any amplitude taper in the azimuth direction. In this case, the beam pattern starts to split at rotation angle above 30deg and a significant null occurs in the middle of the main beam at rotation angle near 40deg. This undesirable effect is mitigated by applying a suitable amount of amplitude taper between the two azimuth elements. Notice that the taper function reverses alternately in the elevation direction. Fig. 3(b) shows the simulated azimuth patterns with 10dB amplitude taper. In this case, the HPBW is varying between 38 deg and 96 deg for rotation angle up to 30deg. The directivity is between 16 dBi to 21dBi for a 10-element array with an element spacing of 125mm in elevation direction. The ripple in the main lobe is within 1dB. The cross-polar field components seems to be lower with amplitude taper and are below 18 dB within HPBW with 10 dB amplitude taper.

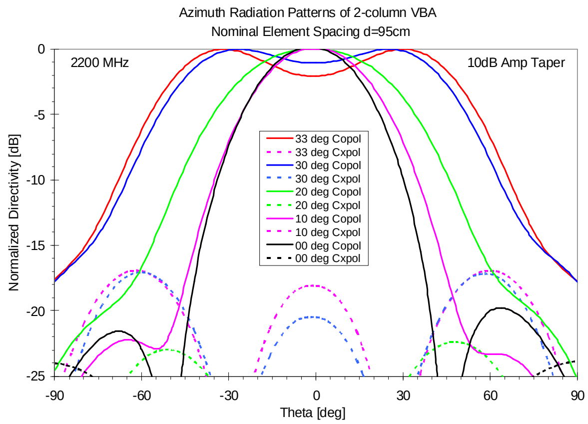

Fig. 3(a): Az patterns (10 dB taper)

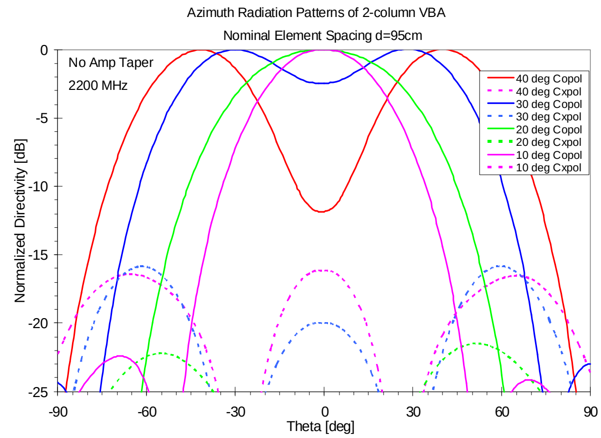

Fig. 3(b): Az patterns (No taper)

Fig. 4 and 5 show the worst-case cross-polar and co-polar mutual couplings in the array. These simulations assumed that the maximum rotation angle is 30 deg and the amplitude taper is approximately 7 dB. The predicted couplings in the cross-polar components are below 30 dB and coupling in the co-polar components are expected to be less than -23dB.

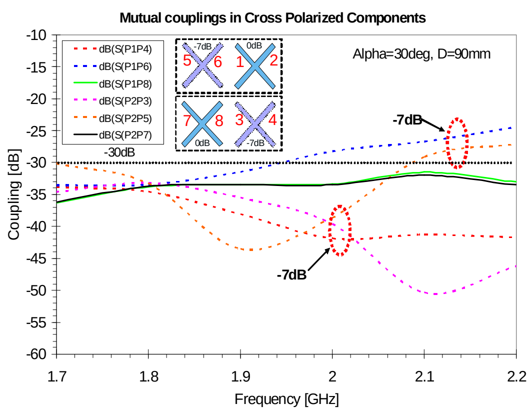

Fig. 4 Cross-polarized couplings

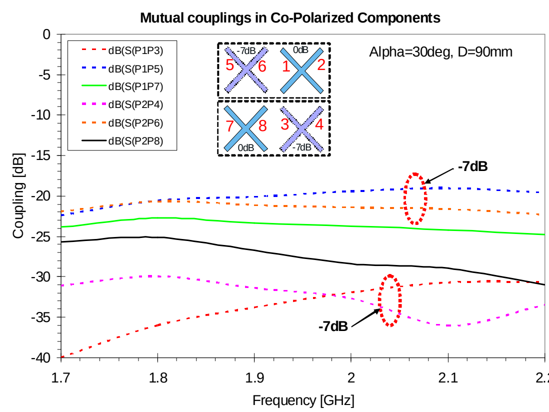

Fig. 5 Co-polarized couplings

Conclusion

This paper demonstrated that the azimuth beamwidth control by axial rotation of a staggered array is well suited for 3-way antenna applications. Axial rotation arrays offer good azimuth beam patterns with wide range of HPBW with relatively low cross-polar field components. The single-column array offers a low-cost approach with a very wide range of HPBW variations. The 2-column array provides a higher gain at a slightly more limited range in HPBW variation.