

# Ultra-Broad-Band Six-Sector Patch Array

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**Abstract** – Six-sector cellular arrays with proper azimuth beam patterns are able to offer network capacity increase by a factor nearly two. This article presents concept and design method of an optimum ultra broadband dual-beam array for use in such high-capacity cellular networks. Critical antenna parameters of the dual-beam arrays are discussed. A new ultra-broad-band stacked patch radiator with triple-resonance is also introduced. This new type of broadband patch radiator has a frequency bandwidth of over 45% with VSWR less than 1.5:1.

**Index Terms** — Antennas, cellular, base-station, dual-beam, six-sector, ultra-broad-band, patch.

## I. INTRODUCTION

Today's wireless cellular system demands base-station antennas to operate over an extremely wide frequency range. Antennas presently conceived for future usage are likely required to operate in spectrum covering both the UMTS and LTE bands. An ultra-broad-band array covers both bands, 1710MHz to 2690MHz, will require a frequency bandwidth of over 45%. This can be achieved either by using an ultra-broad-band radiator or two types of radiators operating in two separate bands arranged in an interleaved fashion. Interleaving low-band elements and high-band elements to form a dual-band array allows optimization of patterns in both bands. However, an ultra-broad-band array consisting of simply ultra-broad-band radiating elements provide simpler configuration with lower cost and better inter-element coupling.

Most radiators used in today's base-station antennas have limited bandwidth of approximately 26%. A new ultra broadband aperture coupled stacked patch (ACSP) has been developed for this broadband array works. This new ACSP radiator has an extended pattern and impedance bandwidth of over 45%.

## II. ULTRA-BROADBAND PATCH ARRAY

### A. Dual-Beam Array Configurations and Excitations

The dual 33° azimuth beams can be produced using various antenna array configurations. The simplest approach is to use two multi-column arrays placed in a slightly different azimuth tilt angles. However, this type of arrays uses twice the aperture size resulting in lower effective aperture efficiency. A more efficient approach is to use a common planar or curved aperture consisting of 3-column, 4-column, or a combination of 3- and 4-column of radiating elements. This method tends to produce two orthogonal

asymmetrical beams with fast pattern roll-off at the cross-over between the two beams, which is desirable for optimum performance of a six-sector antenna. Arrays with more than 4 columns tend to result in lower aperture efficiency and are undesirable due to the physical size and weight. Trade-off between 3- and 4-column dual-beam arrays typically involves consideration on its network performance, physical parameters and system complexity. Through simulations and experiments, it was found that dual-beam array provide optimum capacity and coverage in six-sector networks, if array excitations meet the following criteria [1]:

$$1. \quad \sum L_i * R_i = \delta, \quad \delta \rightarrow 0, \quad i=1 \dots N \quad (1)$$

$$2. \quad BCF = \text{Min} \left( k \int E_R(\theta, \Phi) \cdot E_L(\theta, \Phi) d\Omega \right) \quad (2)$$

$$\text{Where, } k = \left[ \int |E_R(\theta, \Phi)| \cdot |E_L(\theta, \Phi)| d\Omega \right]^{-1}$$

Equation (1) ensures port orthogonality between the two beams, where  $L_i$  and  $R_i$  represent the two complex beam excitations. The summation is zero when the two ports are perfectly orthogonal. Typically, it is desirable to keep this effect to below -20dB. Equation (2) further constraints the complex excitations such that coupling through radiation patterns,  $E_R$  and  $E_L$ , to minimum. Critical parameters affect the parameter BCF include the azimuth side-lobes, FBR, pattern roll-off rate at cross-over, cross-over point, etc. In particular, it was found that the azimuth side-lobes is one of the most critical parameters and preferably kept below -20dB, especially those side-lobes within the main lobe of the other beam. This can be difficult to achieve over a broad frequency range using a regular 3- or 4-column array. It was found that one of the most effective methods to produce patterns with low azimuth side-lobes using only 3 or 4 elements is to use configuration with alternate azimuth offset as shown in Fig. 1. Azimuth offset distance of approximately half of the element-spacing tends to produce optimum results.

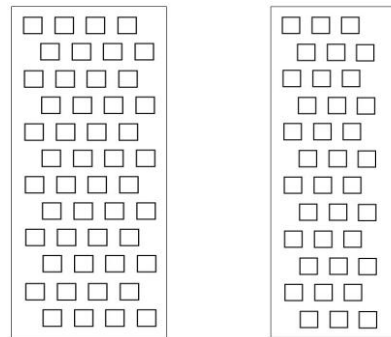


Fig.1 3-Col and 4-Col Dual-Beam Azimuth Offset Arrays.

**B. Azimuth Beam Forming Network**

An integral part of the dual-beam array is the azimuth beam forming network (ABFN), which allows multiple orthogonal beams to operate simultaneously with minimum coupling. Equation (1) and (2) set the optimum criteria for the beam former. However, the actual excitations and pattern performance are further constrained by the implementation of the azimuth beam forming network (ABFN) itself. Fig. 2 and 3 show typical configurations and excitation functions of practical 3-column and 4-column dual-beam ABFN.

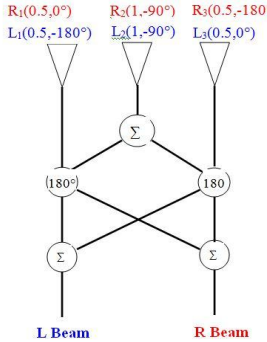


Fig. 2 3-Column ABFN

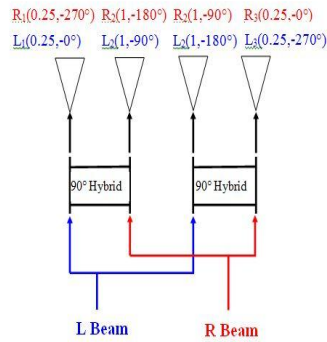


Fig. 3 4-Column ABFN

These beam formers can be implemented using low-cost printed microstrip hybrids.

**C. Ultra-broadband Stacked Patch**

The proposed ultra-broadband radiator is a dual linearly polarized aperture-coupled stacked patch. This radiator is a natural extension of a conventional ACSP. However, instead of dual resonances in a typical ACSP, the proposed ultra-broadband patch has three resonances. The third resonance is induced by the raised finite ground plane. One added advantage of this radiating structure is the elimination of the back-cavity used in a conventional ACSP. This reduces the overall complexity and cost of the radiator. The ultra-broadband ACSP can operate over 45% with input VSWR better than 1.5:1dB, over the frequency range of 1710MHz to 2690MHz. Fig. 4 and 5 show geometries of the ultra-broadband patch. Fig. 6 and 7 show typical radiation patterns and VSWR over the bandwidth. The radiation patterns are uniform across the frequency bandwidth from 1.7GHz to 2.7GHz. This radiator is also able to achieve the 30dB port isolation required in a typical base-station antenna.

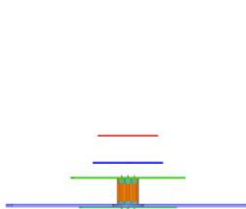


Fig. 4

Side view broadband patch

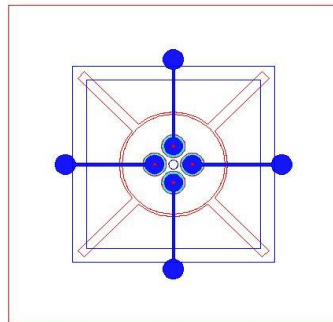


Fig. 5 Top view broadband patch

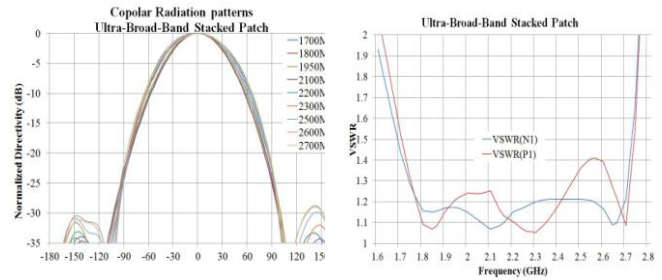


Fig. 6 Patterns of broad-band patch

Fig. 7 VSWR of broad-band patch

**III. EM SIMULATIONS**

Radiation patterns of a 3-column and a 4-column dual-beam full array are simulated using the well-known commercial finite element code ANSYS HFSS. Azimuth element spacing of the arrays is set to 75mm. Fig. 8 compares azimuth patterns of the 3-column and the 4-column arrays. Critical parameters of these patterns for six-sector network operation include the antenna gain, half-power-beamwidth (HPBW), pattern roll-off rate at beam intersect, the cross-over point, azimuth side-lobes, front-to-back ratio (FBR) and pattern roll-off at  $\pm 60$ deg. A 4-col array tends to have slightly narrower HPBW and, therefore, slightly higher gain, typically 0.5dB to 1dB. Both arrays are able to produce compatible asymmetric beam patterns with fast roll-off ( $>1.5$ dB/deg) at beam crossing with level of cross-over point between -7dB to -13dB. The azimuth side-lobes of both arrays are typically below -20dB. Both arrays also have compatible front-to-back ratio (FBR) and azimuth side-lobes.

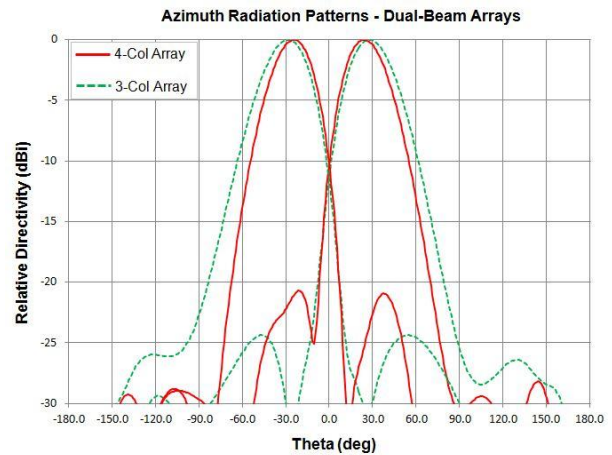


Fig. 8 Az radiation patterns of 3-col and 4-col dual-beam array

**IV. CONCLUSION**

This paper presented a design methodology for the implementation of multi-column dual-beam arrays for use in optimum six-sector cellular networks. Concept of a new ultra-broadband aperture coupled stacked patch is also introduced for the broadband arrays. The ultra broadband patch has triple resonances and is able to operate over 45% bandwidth from 1710MHz to 2700MHz.

**REFERENCES**

[1] S. Foo, "On Higher-Order-Sectorization Cellular Arrays," *Int'l Sym. on Antennas and USNC-URSI Radio Science Meeting*, July 6-11, 2014.