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Investigation of Different Types of Microstrip Array Structures for Smart Cellular Base Station Antennas

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ABSTRACT

As the increasing demand for cellular mobile communications constantly increases, the need for better coverage, improved capacity, and higher quality of services rises. Smart antennas used in Global System for Mobile Communications (GSM) systems can effectively maximum capacity and improve reliability and coverage by directing beam patterns towards the desired signals and null-patterns towards the interferers. Although numerous studies for smart antennas have already been conducted including isotropic arrays, dipole arrays and microstrip arrays with various configurations like uniform linear arrays (ULA), uniform and non-uniform rectangular arrays (URA), uniform circular arrays (UCA) but not as much importance was given to concentric circular arrays (CCA). In this paper, the performance of microstrip based smart antennas with uniform linear arrays (ULA), uniform and non-uniform rectangular arrays (URA), uniform circular arrays (UCA) and concentric circular arrays (CCA) is examined by using IE3D (Integrated Electromagnetic 3-Dimensional optimization and simulation) software and compared. With the use of five different types of array antennas, the performance of smart antennas in terms of Gain, Directivity and Half Power Beamwidth are analyzed. We also simulated the Microstrip ULA with LMS algorithm for reduced mutual coupling between array elements.

INTRODUCTION

The demand for Wireless Mobile Communication services are growing at an explosive rate, with the anticipation that communication to a mobile device anywhere on the globe at all times will be available in the near future. An array of antennas may be used in a variety of ways to improve the performance of communication systems. Perhaps most important is its capability to cancel the co-channel interferences. An array works on the premise that the desired signal and unwanted co-channel interferences arrive from different directions. Current Mobile Communication Systems have employed sectorization to reduce the jammer and increase the capacity (Kretly, L.C., 2002). Increasing the amount of sectorization reduces the jammer seen by the desired signal. A drawback of this technique is that its efficiency decreases with the number of sectors, due to the antenna pattern overlap. Moreover, when the number of sector is increased, the handoffs are also increased. The beamforming and adaptive antenna arrays are very efficient capacity enhancement techniques. They have been proposed to reduce multipath fading of the desired signal and to suppress the co-channel interference. These antenna arrays have the function of optimizing the radiation pattern according to the environment. To cope with interference, smart antennas or adaptive array processing may be utilized to shape the antenna radiation pattern in such a way to enhance the desired signals and null the effect of the interfering

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signals (Randy Bancroft, 2002). The development of adaptive antenna includes the design of array antenna and optimizing the array antenna parameters such as directivity and half power beamwidth, and also the development of adaptive array algorithms. The capacity of a wireless network depends on the size of the antenna array, the beam pattern used and the speed with which the beam-former and Direction of Arrival estimator (John, D., 2006).

Microstrip Antennas are also relatively inexpensive to manufacture and design because of the simple 2D physical geometry. They are usually employed at UHF and higher frequencies because the size of the antenna is directly tied to the wavelength at the resonance frequency. It is relatively easy to print an array of patches on a single (large) substrate using lithographic techniques. Patch arrays can provide much higher gains than a single patch at little additional cost; matching and phase adjustment can be performed with printed microstrip feed structures, again in the same operations that form the radiating patches.

The remainder of this paper is organized as follows. Section 2 states mathematical models of antenna arrays for ULA, URA, NURA, UCA and CCA. Following the brief description of mutual coupling and LMS algorithm is presented in Section 3. Following the simulation results are presented in Section 4. Finally, the conclusions are given in Section 5.

2. Mathematical modeling of microstrip arrays URA, NURA, UCA and CCA:

2.1 Array factor of ULA:

Consider an n-element microstrip ULA, the array factor equation is given by [00]

$$AF = \sum_{n=1}^{N} e^{+j(n-1)\psi}$$

Where $\Psi = k\ d\cos\theta + \beta$, the maximum radiation occurs at $\psi = 0$ hence $\beta = -\ k\ d\cos\theta$, d is the distance between array elements, k is the phase factor and β is the progressive phase difference between elements.

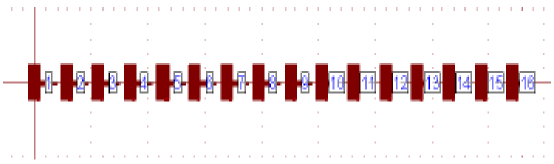

Fig. 1.1: 16-Element microstrip ULA.

An array of identical elements all of identical magnitude and each with a progressive phase are referred to as a uniform array [00]. Figure 1.1 shows the 16-element microstrip uniform linear array drawn using IE3D software with element spacing of $\lambda/2$.

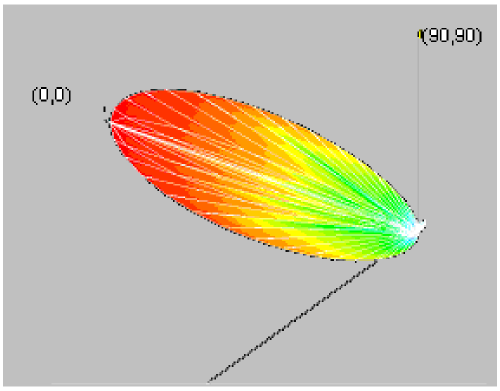

Fig. 1.2: 3D Radiation pattern of 16-element Microstrip Uniform linear Array.

2.2 Planar Array :

In addition to placing elements along a line, individual radiators can be positioned along a rectangular grid to form a rectangular or planar array. Planar arrays provide additional variables which can be used to control and shape the pattern of the array.

Planar arrays are more versatile and can provide more symmetrical patterns with lower side lobes. In addition, they can be used to scan the main beam of the antenna towards any point in space.

The array factor of planar array is given by

$$AF(\theta,\phi)=\left\{\frac{1}{M}\frac{\sin\left(\frac{M}{2}\psi_x\right)}{\sin\left(\frac{\psi_x}{2}\right)}\right\}\left\{\frac{1}{N}\frac{\sin\left(\frac{N}{2}\psi_y\right)}{\sin\left(\frac{\psi_y}{2}\right)}\right\}$$

To avoid grating lobes in the x-z and y-z planes, the spacing between elements in the x- and y- directions, respectively, must be less than λ ($dx < \lambda$ and $dy < \lambda$).

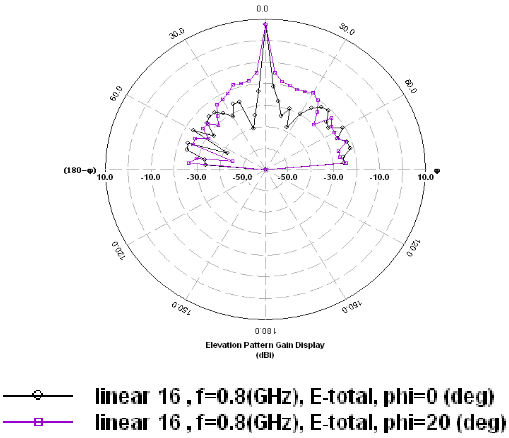

Fig. 1.3: Radiation pattern of 16-element microstrip ULA with DOA 60°.

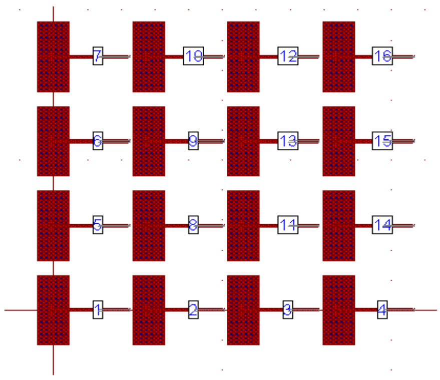

Fig. 1.4: 16-elements Microstrip Planar Array.

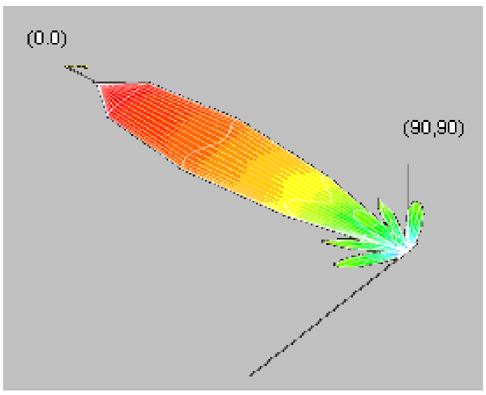

Fig. 1.5: 3D Radiation pattern of 4*4 uniform planar microstrip array with $dx=4\lambda/5.5$,$dy=4\lambda/8$.

3. Circular Array:

The circular array, in which the elements are placed in a circular ring, is an array configuration of very practical interest as shown in Figure 1.7 . If N isotropic elements are equally spaced on the XY plane along a circular ring of the radius a.

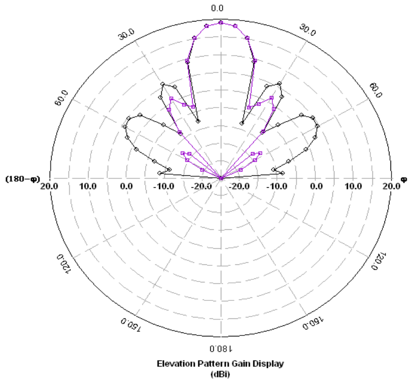

Fig. 1.6: 2D Radiation pattern of 4*4 planar microstrip array with dx=dy=λ/2.

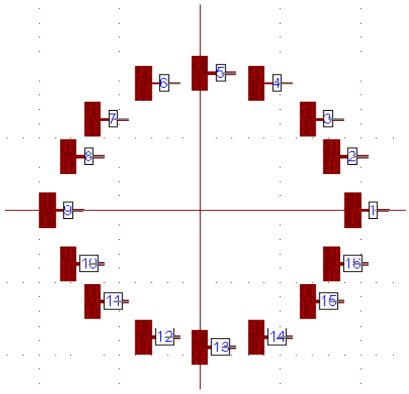

Fig. 1.7: Circular Array.

The normalised field of the array can be written as

$$E_n(r,\theta,\phi) = \frac{e^{-jkr}}{r}[AF(\theta,\phi)]$$

where

$$AF(\theta,\phi) = \sum_{n=1}^{N} I_n \, e^{j[ka\sin\theta\cos(\phi-\phi_n)+\alpha_n]}$$

The above equation represents the array factor of a circular array of N equally spaced elements.

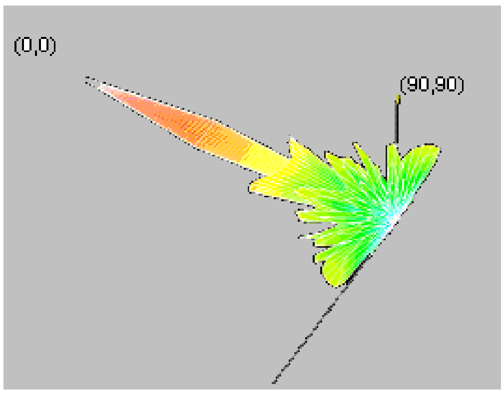

Fig. 1.8: 3D Radiation pattern of 16element circular microstrip array.

4. *Concentric Circles:*

The concentric circular array, in which the elements are placed in a concentric circular fashion as shown in Figure 2.2. Here the number of elements in each concentric circle decides the beam width and number of side lobes in the radiation pattern (Constantine, A., Balanis, 1997).

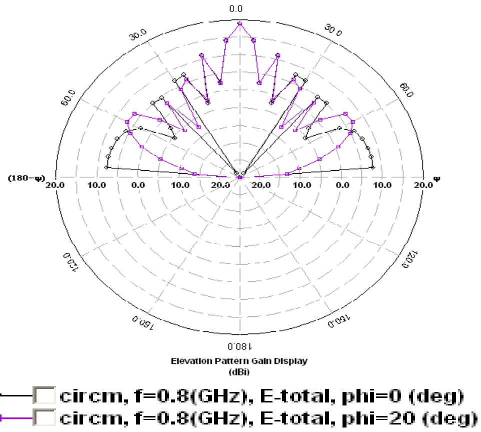

Fig. 2.0: 2D Radiation pattern of 16 element circular microwave array.

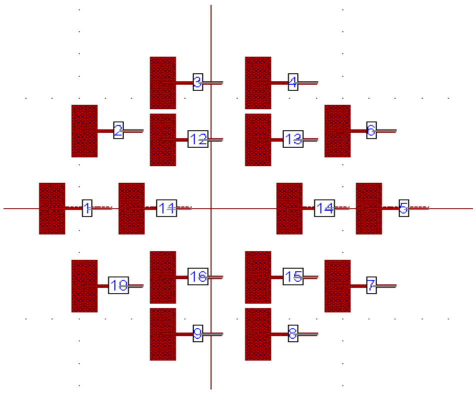

Fig. 2.2: Concentric Microstrip Circular Array-16 elements.

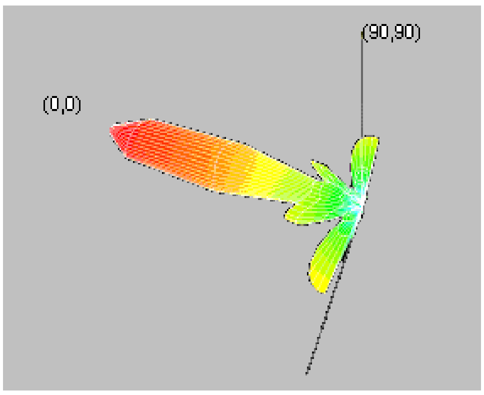

Fig. 1.9: Radiation pattern of 16 element microstrip concentric circular array with 45°.

RESULTS AND DISCUSSIONS

The number of elements considered for simulation environment is 16 and the frequency is 800 MHz. Various parameters of these configurations such as gain, directivity, 3-dB Beamwidth were tabulated and compared. From the table 1, it was proved that the circular configuration provides a very narrow beamwidth which proportionately increases the capacity of the cellular mobile network. Consequently the concentric circular array induces less number of side lobes than the circular array but the 3 dB beamwidth increases twice than that of the circular array. Hence there results a trade off between number of side lobes and the 3 dB beamwidth. Moreover the gain remains stable for all planes i.e.Azimuthal and elevation plane. When the number elements are increased the directivity and beamwidth can be improved and found suitable for smart antennas in mobile communication. The 3-dB beamwidth is less for the configurations having 2N number of circles than the configurations having 2N+1 number circles where N is an integer. Hence it is proposed that circular configurations promise to the substantial improvement in the capacity of the cellular mobile network.

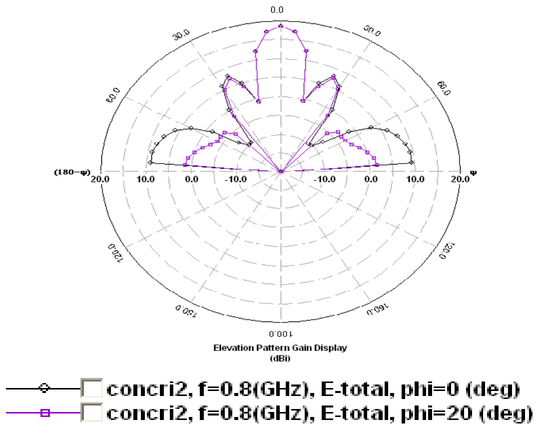

Fig. 2:1Radiation pattern of 16 element microstrip concentric circular array with 60°.

Table 1: Comparative simulation results for various array configurations.

Configurations	Gain (dBi)	Directivity (dBi)	3 dB Beamwidth (deg)
Linear	7.126	19.2513	(5.01632, 63.984)
Planar-uniform	18.98	20.5163	(16.8046, 17.8262)
Planar-non uniform	4.672	20.0142	(17.7027, 18.9827)
circular	18.71	19.8755	(7.55546, 7.68755)
Concentric- circular	18.48	20.1934	(14.7313, 15.1501)

Conclusion:

In the design and optimization of smart antenna systems for optimum capacity in cellular mobile communication networks, antenna parameters, such as array size mutual coupling, gain, half power beamwidth, and directivity are important considerations in arriving at the capacity requirements for a network. Also antennas that exhibit adaptive patterns with maxima toward the signal of interest and nulls toward the signal not of interest usually lead to higher throughput, compared to non-adaptive patterns.

From our analysis we conclude that the Microstrip Smart Antennas with Circular configurations with adaptive algorithms are most suitable for wireless cellular communication networks.

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