Adaptive MICROSTRIP Array Antennae Design and Characterization for Wi-MAX Transceiver

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ABSTRACT
Array antennae are preferred over other type of antennae for the use in Wi-MAX mobile communication systems due to increasing demand for higher capacity, better coverage and higher transmission quality. Further more if the antennae array is adaptive in nature, it can maximize the efficiency of transceiver. This research work concentrates on three different microstrip antennae array configurations, namely uniform circular, uniform concentric and modified uniform concentric circular for 3.3 GHz frequency band for Wi-MAX application [1], [2]. The configurations of antennae arrays considered three parameters - half power beamwidth, number of side lobes and main lobe to side lobe ratio. The simulations have been performed for three antennae arrays using MATLAB version 7.5 platforms for standard IBM PCs. A series of LMS adaptive algorithms are used to update weight vectors of the received noisy signals to match with desired signals. The simulation results show that modified concentric circular array outperforms other array configurations in terms of half power beamwidth, number of side lobes and main lobe to side lobe ratio.

General Terms
Communication Systems, Smart Antennae, Wireless Technology, Adaptive Algorithms.

Keywords
Wireless and mobile communication, computing, high speed communication networks, LMS algorithm, modeling and simulation, WiMAX Transceiver.

1. INTRODUCTION
The demand for wireless mobile communication services is growing at a high rate. It can be anticipated that communication to a mobile device will be available at all times, at all places on the earth in the near future. An array of antennae may be used in different ways to improve the performance of communication systems. A very popular type of antennae array called circular array, has several advantages over other schemes [3]. The advantages include all-azimuth scan capability and invariant beam pattern [4]. Concentric circular array (CCA) contains many concentric circular rings of different radii and number of elements. This array pattern has several advantages including the flexibility in array pattern synthesis. It is also easy to design, for both, narrowband and broadband beamforming applications [5], [6]. The Worldwide Interoperability for Microwave Access (Wi-MAX) is a telecommunication technology that provides wireless transmission of data using a variety of transmission modes from point to multi point links [7]. The technology is based on IEEE 802.16 standard which specifies the air interface at the physical layer and medium access control layer [8], [9].

The Wi-MAX standard specifies 2 to 11 GHz as usable operating frequency range for modulation and channel access etc., Wi-MAX base station antenna requires a minimum current gain of 18 dB with a beamwidth of 10 degrees [3]. This paper focuses on the concentric and modified concentric microstrip patch array antennae [10], [11] for Wi-MAX applications. Microstrip patch antennas are popular, because they have a very low profile, mechanically rugged and can be conformable. They are often mounted on the exterior of aircraft and spacecraft, or are incorporated into mobile radio communications devices. Microstrip Antennas are also relatively inexpensive to manufacture and design because of the simple 2D physical geometry [4-5]. In this work, the microstrip array is simulated at 3.3 GHz using MATLAB 7.5 version for uniform circular, uniform concentric and modified uniform concentric circular array configurations.

The development of adaptive antenna includes the design of array antenna, optimizing the array antenna parameters and the development of adaptive array algorithms. The requirements of the antenna array, utilized in both base stations and mobile stations, for Wi-MAX applications includes the sufficient bandwidth, narrow beamwidth, low side lobes and small physical size [11].

To get desired signal from any received signal which arrives at the receiver antenna with Multiple Access Interference (MAI) and Additive White Gaussian Noise (AWGN), it is essential to reduce the noise to a minimum allowable level. To achieve this weight vectors are updated by using Least Mean Square (LMS) algorithm and multiplied with the strength of the received signal. The output of the system is estimated based on the continuously updated variable element weights. The output is the weighted sum of the received signals at the array elements and the respective noise. The weights are iteratively computed and updated based on the present weights, reference signal and past weights. The reference signal is approximated to the desired signal using a rigorous training session at the receiver. The reference signal usually has a high degree of correlation with the desired signal. The higher the degree of correlation, the higher is accuracy and the early convergence the algorithm of takes place.

The rest of paper is arranged as follows. Section 2 explains the array geometry of uniform circular array (UCA), LMS algorithm and analysis of radiation characteristics [12]. Section 2.1 includes detains on the uniform concentric circular array (UCCA), while other sub sections explain the proposed model. It also includes explanations on modified concentric circular array (MCCA), the variations of half-power beamwidth (HPBW), number of side-lobes and main-lobe to side-lobe ratio [13]. Section 3 deals with the results and discussions of proposed circular array configurations. The section 3 also includes analysis and characterization based on the LMS algorithm reiteration and a comparative performance. Section 4 concludes the paper with anticipated future work.

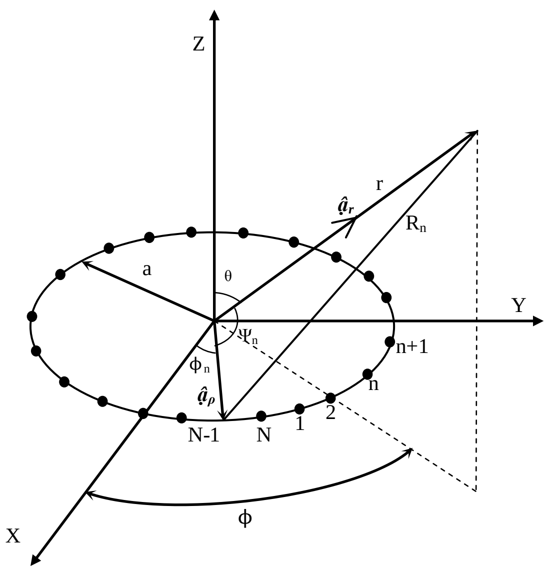

Fig 1: Uniform Circular Array

2. GEOMETRICAL STRUCTURES OF ARRAYS

2.1 Uniform Circular Array

The circular array, in which the elements are placed in a circular ring, is an array configuration of very practical interest and a wide variety of applications in various technologies including wireless and onboard satellite use [6]. In uniform circular array, N elements are placed in a circular ring of radius 'a'. The spacing between the elements is 0.5 lambdas as shown in Figure 1. Using circular array, the beam scanning of 360^0 can be obtained without change in antenna design parameters [7]. This gives flexibility for use.

The array factor for the circular arrays deployed for the purpose of communication transceivers and relays is decided by amplitude excitation of n^{th} element and the Phase excitation of n^{th} element. The radiation pattern of 8 and 16 elements UCA is obtained by the array factor approach and LMS algorithm as an adaptive character in the system. From Figure 2 and Figure 3, it is evident that by increasing the number of elements reduces the HPBW but results in increased number of the side lobes.

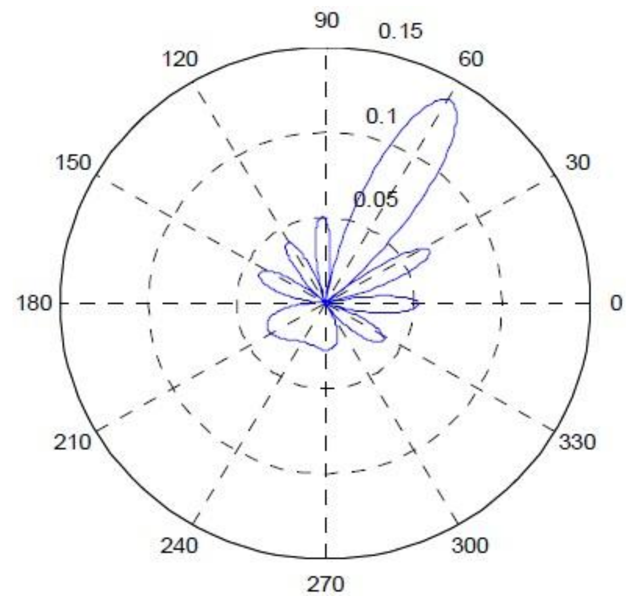

Fig 2: Radiation Pattern of UCA for N=8, DOA=60^0

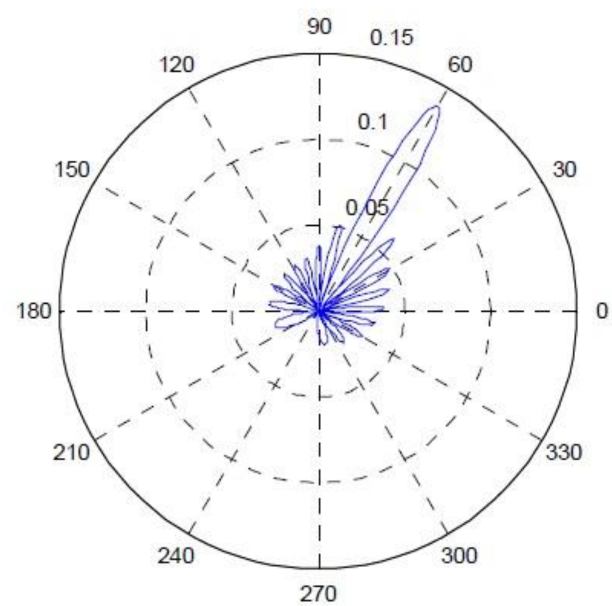

Fig 3: Radiation Pattern of UCA for N=16, DOA=60^0

2.2 Uniform Concentric Circular Array

The concentric circular array consists of concentric circular rings in successive fashion as shown in Figure 4. Here the number of elements in each concentric circle decides the beam width and number of side lobes in the radiation pattern. Figure 4 shows the configuration of concentric circular arrays in which there are M concentric circular rings. The m^{th} ring has a radius r_m and number of elements N_m where $m = 1, 2. . . M$. It assumed that the elements are uniformly spaced within the ring. The array factor of concentric circular array is obtained by pattern multiplication concept.

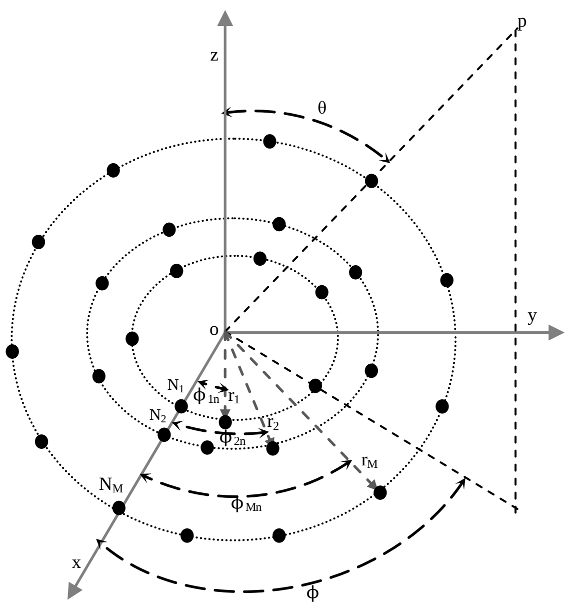

Fig 4: Uniform concentric circular array

It has been found that the existence of the central element can control the side-lobe level with minimal beamwidth increase with the main lobe to side lobe ratio of *20 dB* [8]. This was achieved by increasing the number of rings in the array ($M = 7$, 8 and 15), which results in increased number of side lobes. For uniform concentric circular array ($M = 2$), the half power beamwidth widens but the number of side lobes decrease as shown in Figure 5.

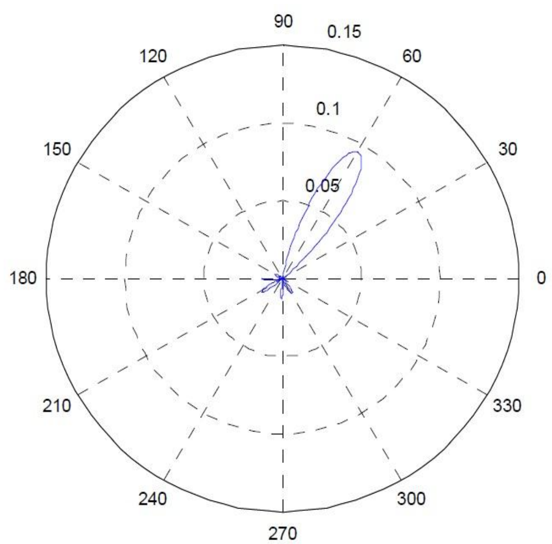

Fig 5: Radiation Pattern of UCCA for M=2, DOA = 60^0, N1 =4 and N_2 =8

2.3 Modified Concentric Circular Array

In the proposed method of MCCA, the number of side lobes has been drastically reduced by using minimal number of rings ($M = 4$). In this array configuration, the main lobe to side lobe ratio is

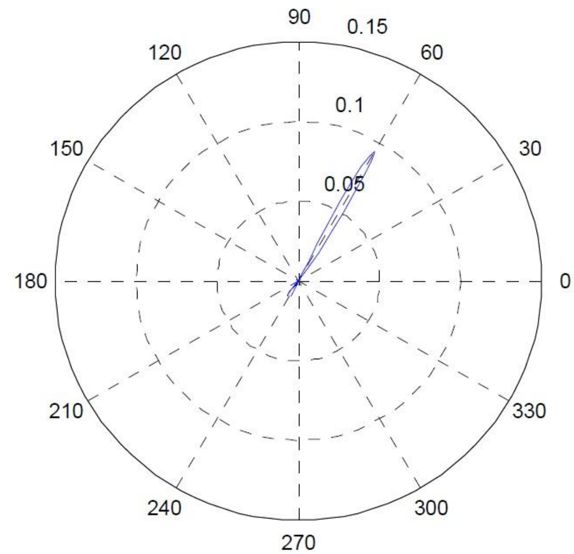

Fig 6: Radiation Pattern (Polar plot) of MCCA for M=4, DOA = 60^0, N_1 =4, N_2 =8, N_3 =16 and N_4 =32

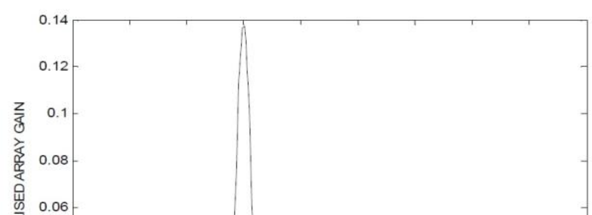

Fig 7: Radiation Pattern (Cartesian plot) of MCCA for M=4, DOA = 60^0, N_1 =4, N_2 =8, N_3=16, and N_4 =32

kept invariant. This is obtained by varying only number of elements in each ring rather than as a function of the number of element of the innermost circular array.

The simulation is performed in two stages. In stage 1, , rings N_1 through N_4 have *4*, *8*, *16*, and *32* elements. The simulated results are presented in Figure 6 and Figure 7. Figure 6 represents a Polar plot for normalized array gain at direction of arrival at 60^o at the location user. Figure 7 represents a Cartesian plot for normalized array gain at the direction of arrival at 60^o at the location of user.

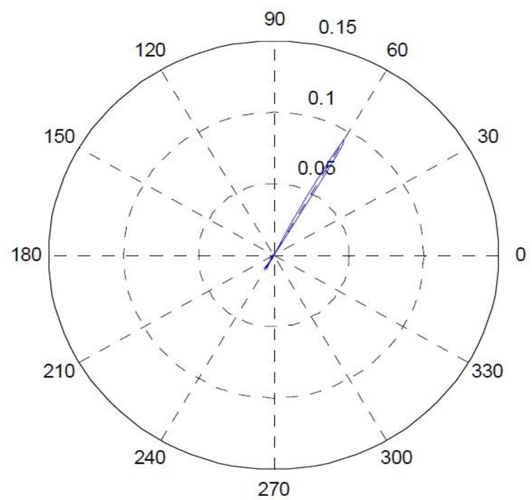

Figure 8. Radiation Pattern (Polar plot) of MCCA for M=4, DOA = 60^0, N_1 =8, N_2 =16, N_3 =32, and N_4=64.

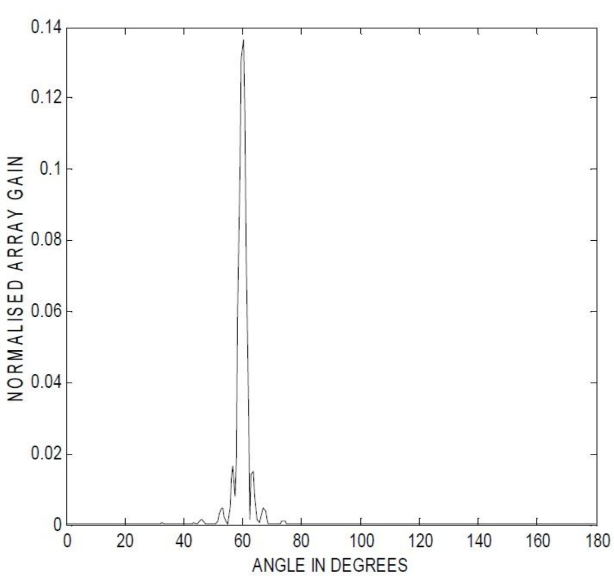

Fig 9: Radiation Pattern (Cartesian plot) of MCCA for M=4, DOA = 60^0, N_1 =8, N_2 =16, N_3=32, and N_4=64.

The stage 2, has *8, 16, 32,* and *64* elements. The normalized array gain has been illustrated in Figure 8 and Figure 9 for polar and Cartesian plots respectively.

2.4 Adaptive LMS Algorithm for Array

As shown in Figure 10, a uniform linear array with N isotropic elements forms LMS algorithm based system for microstrip antennae array. The desired signal is normally reconstructed from the received signal, the interfering signal and additional noise. As shown in the Figure 10, the outputs of the individual microstrip antenna are linearly summed up after performing weight correction such that the antenna array pattern is optimized to have maximum possible gain in the direction of the desired signal and minimizes in the direction of the interferers. The weights are computed using LMS algorithm based on Minimum Squared Error (MSE) principle. It works on the basis of estimation of signal from the array output by minimizing the error between the reference signal and the desired signal estimate. The output x(t) equal to w*y(t)). Computational solution is achieved iteratively using the LMS algorithm.

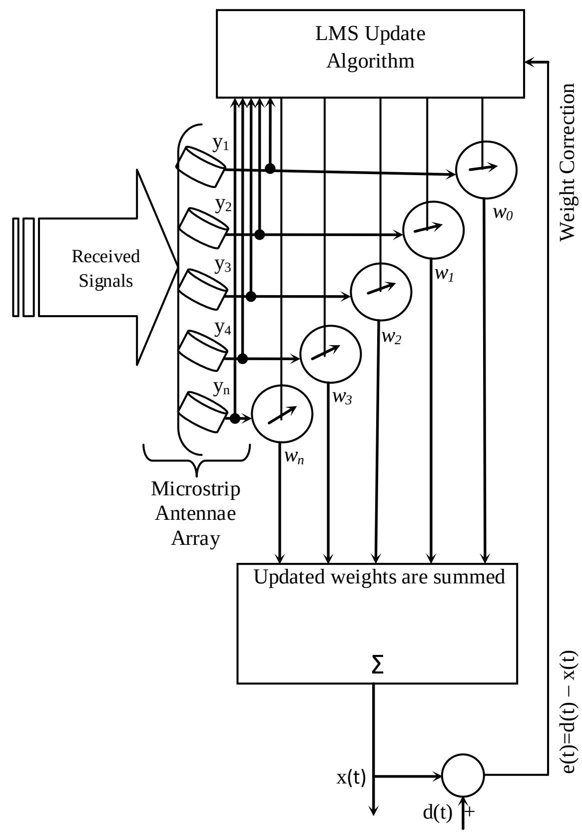

Fig 10: Adaptive algorithm for enhancing overall efficiency of microstrip array antennae

3. RESULTS AND DISCUSSIONS

The results shown in Table 1 indicate that a uniform circular array configuration with *16* number of elements is found to have narrow HPBW (*10.3^o*) which in tern indicates higher directivity and low beamwidth. It can also be observed from Table 1 that as the number of elements increases, the directivity and half power beamwidth improves, however, it results in increased number of side lobes which is undesirable. When the elements are arranged in uniform concentric circular fashion (*M=2*), it is found that a single main lobe is formed (Figure 5) with increased half power beamwidth. This is undesirable. It, however, results in reduced number of side lobes (5 in this case).

Table 1. Comparison of UCA And UCCA for DOA=60^0

Array Configurations	HPBW (Degrees)	Number of Side Lobes
Circular Array (N=8)	20.6265	7
Circular Array (N=16)	10.3132	16
Concentric Circular Array (M=2)	17.1887	5

To overcome the above mentioned contrasting results of parameters (Table 1), this paper proposes a modified concentric circular array configuration with number of rings *M=4*. As shown in Table 2, it is evident that by varying the number of elements in each ring rather than increasing the number of rings have shown improvements in performance in terms of number of side lobes, reduced HPBW and desired main lobe to side lobe ratio.

Table 2. Comparison results of MCCA for DOA=60^0

Modified Concentric Circular Array	HPBW (degrees)	Number of Side Lobes	Main Lobe to Side Lobe Ratio(dB)
N1=4, N2=8, N3=16 & N4=32	4.5837	4	18.416
N1=8, N2=16, N3=32 & N4=64	2.2918	3	18.272

For the example, as shown in Table 2, there are 4 rings in each case. The number of elements, however, varies in each case. The first row of Table 2 shows number of elements *4, 8, 16* and *32* for *4* rings respectively. Similarly second row shows the elements *8, 16, 32* and *64*. It can seen that for MCCA, the number of side lobes drastically reduced (4 and 3 respectively), without affecting the main lobe to side lobe ratio. Also the HPBW is reduced to 4.5837 and 2.2918 respectively for MCCA which is highly desirable. The improvement is about 73% and 86% respectively compared to UCCA (Table 1 and Table 2). Hence the proposed MCCA has outperformed other circular array configurations. The authors are of view that it will be highly suitable for Wi-MAX base station antennae applications. The outputs of the individual microstrip antenna are estimated based on the iteratively updated weights by using LMS based adaptive algorithm. It functions on the principle of the minimization of squared errors. LMS algorithm has greatly improved for the maximum possible gain in the direction of the desired signal. It also has minimized the gain in the direction of the interferers.

4. CONCLUSIONS

This research work has analyzed the design and simulations of concentric circular microstrip patch array configurations for 3.3 GHz with different element spacing. The various array parameters namely, half power beamwidth, number of side lobes and main lobe to side lobe ratio are simulated and analyzed using MATLAB 7.5 version platform. LMS algorithm is used to train the system and continuously improve the efficiency of the smart antennae system.. The simulation results make clear that modified concentric circular array without increasing the number of rings has improved performance for Wi-MAX application requirements. The extension of this work will include stacked circular and cylindrical array configurations by optimizing the mutual coupling effects due to surface waves. The future work will also include different microstrip array configurations to be designed and simulated using high frequency simulation software. Also the prototypes of the antenna elements will be designed and the reflection co-efficient versus frequency and the radiation patterns will be measured and a comparison study will be carried out.

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