



Synthesis & Analysis of Adaptive Beamforming Smart Antenna for Advanced Communication Systems

Amritpal Singh Bhinder, Arvind Kumar
Amity Institute of Telecom Technology & Management
Amity University, Noida, U.P, INDIA

Abstract: Recent developments in the field of wireless communication systems are due to the development in field of Smart Antennas. These Antennas are capable of fulfilling high demand of data rate, capacity and also offers good quality of services to wireless communication systems. These characteristics can be obtained by increasing the gain of antenna in the desired direction; which is achieved by directing main lobes of the antenna beam pattern towards the desired users and null patterns in the direction of interferers. The most important feature of a smart antenna is its beam forming capability. During beam forming the smart antenna creates a directional beam toward the desired user and nulls the signal in the directions of undesired users by appropriately adjusting the magnitude and phase of the signal transmitted by each of its elements. In comparison to Omni-directional transmissions, beam forming reduces interference, allowing more concurrent transmissions in the network. Moreover, by concentrating the transmission energy in a specific direction, beam forming creates a signal that is in order of the magnitude stronger than that of the signals in other directions. This technique can be used to increase the coverage of a particular area or data rate or the spectral efficiency of the system. The increased signal-to-noise ratio results in a larger gain in the direction of the desired user, and also provides better control of the distribution of spatial interference in the cell. Beam forming can be applied to the both downlink and uplink.

This paper focuses on synthesis and analysis of adaptive beam forming smart antennas. RLS and LMS Algorithm methodology has been applied to observe the behavior of antenna. The obtained results are compared via simulations and the effectiveness of the proposed system is verified for different wireless communication networks.

Keywords: Smart antenna, Planar array, Adaptive beam forming, Switched beam forming

I. Introduction

Wireless operations are currently searching for new technologies to be implemented into the existing wireless communications infrastructures for capacity enhancement and quality improvement. Smart Antennas are suitable candidate for this purpose. These are the antenna array consisting of multiple Omni-directional antenna elements, combined with smart signal processing algorithms [3]. These systems have been long predicted to provide much better performance than existing antennas in terms of power consumption, user capacity and noise suppression [1, 2]. These advantages are due to the antenna array and the performance of digital signal processing techniques used in the system. It can increase the capacity of wireless communication networks significantly by increasing the spectrum efficiency while at the same time reducing the transmitted power. Smart antennas are capable of reducing the Signal-to-Noise (SNR) over a digital link and hence reduce the bit error rate (BER) of the communication link. This allows modern receivers to operate at higher data rates.

Switched Beam Systems and Adaptive Systems are two types of Smart Antennas. In the first case there are a finite number of predefined beam patterns, while in the second beam patterns can be, in real-time, orientated in any direction in response to its signal environment. In an adaptive antenna system, beam forming algorithms the weight of antenna arrays can be adjusted to form certain amount of adaptive beam to track corresponding users automatically and at the same time to minimize interference arising from other users by introducing nulls in their directions [5].

The most important feature of a smart antenna is its beam forming capability. When beam forming to a user, the smart antenna creates a directional beam toward the desired user and null the signal in the directions of undesired users by appropriately adjusting the magnitude and phase of the signal transmitted by each of its elements. In comparison to omni-directional transmissions, beam forming reduces interference allowing more concurrent transmissions in the network. Moreover, by concentrating the transmission energy in a specific direction, beam forming creates a signal that is orders of magnitude stronger than that of the signals in other directions. This technique can be used to increase the coverage of a particular data rate or the spectral efficiency

of the system. The increased signal-to-noise ratio results in a larger gain in the direction of the user, and also provides better control of the distribution of spatial interference in the cell. Beam forming can be applied to the downlink and uplink.

II. Theory

The well suited array configuration for communication system is usually a planar array. The inability of linear array to scan 3D space (required in most of the portable devices) is the basic reason because of which; the planar array came into existence. In the system, we have $M \times N$ identical elements; the array factor with its maximum along θ_0, ϕ_0 , for an even number of elements in each direction can be given as

$$[AF(\theta, \phi)]_{M \times N} = 4 \sum_{m=1}^{M/2} \sum_{n=1}^{N/2} w_{mn} \cos[(2m-1)u] \cos[(2n-1)v] \quad (1)$$

where, $u = \frac{\pi dx}{\lambda} (\sin\theta \cos\phi - \sin\theta_0 \cos\phi_0)$ and $v = \frac{\pi dy}{\lambda} (\sin\theta \sin\phi - \sin\theta_0 \sin\phi_0)$

in equation (1), w_{mn} is the individual element's amplitude excitation and is separable distributions as $w_{mn} = w_m w_n$, for non separable distribution, $w_{mn} \neq w_m w_n$.

This shows that $M+N$ excitation values need to be computed from a separable distribution, while $M \times N$ values are needed from non separable distribution. [6] In Antenna Beamforming, knowledge of arriving signal is gained and applied via algorithms and processed by digital signal processor (DSP) in the smart antenna system.

Objectives of incorporating Digital Signal Processors (DSP) are:

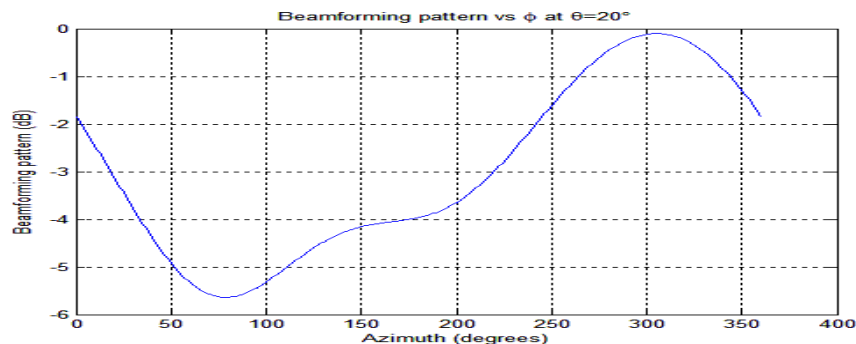
- i. To estimate the direction of arrival (DOA) of all the impinging signals.
- ii. To estimate the appropriate weights to ideally steer the the maximum radiation of the antenna pattern towards the SOI and nulls towards the SNOI.

In adaptive beam forming technique, main focus is to adapt the beam by adjusting the magnitude and phases of each antenna element such that the desirable patterns of radiation are formed [7].

Information given by DOA algorithm is processed by means of an adaptive algorithm which will further steer the maximum radiation pattern towards the SOI and nulls towards the SNOI. Generally for reference purpose or for training purposes, we use Least Mean Square (LMS) Algorithm. [8-9] With use of the adaptive beamforming algorithm, need of DOA information is not required but instead of this it uses the reference signal to adjust the magnitudes and phases of each weight to match the time delays created by the impinging signals into the array. This requires solving a linear system of normal equations as compare to normal equations directly because the signal environment is constantly changing.

III. Simulation

Planar array are designed, composing of only rectangular patches. Planar arrays of 2×2 , 4×4 , 6×6 and 8×8 elements of rectangular microstrip patches having spacing between the elements $\lambda/2$. Designs are analysed using MATLAB 7.0, to observe the behavior of the array. SOI has magnitude of $0.5 + 5j$ and SNOI is complex conjugate of SOI. Theta and Phi for SOI is 20 degree whereas for SNOI is 45 degree. Beamforming Patterns are observed at azimuth angle of 20 degree. Responses of antenna array are shown in Fig. 1 and 2.



(a)

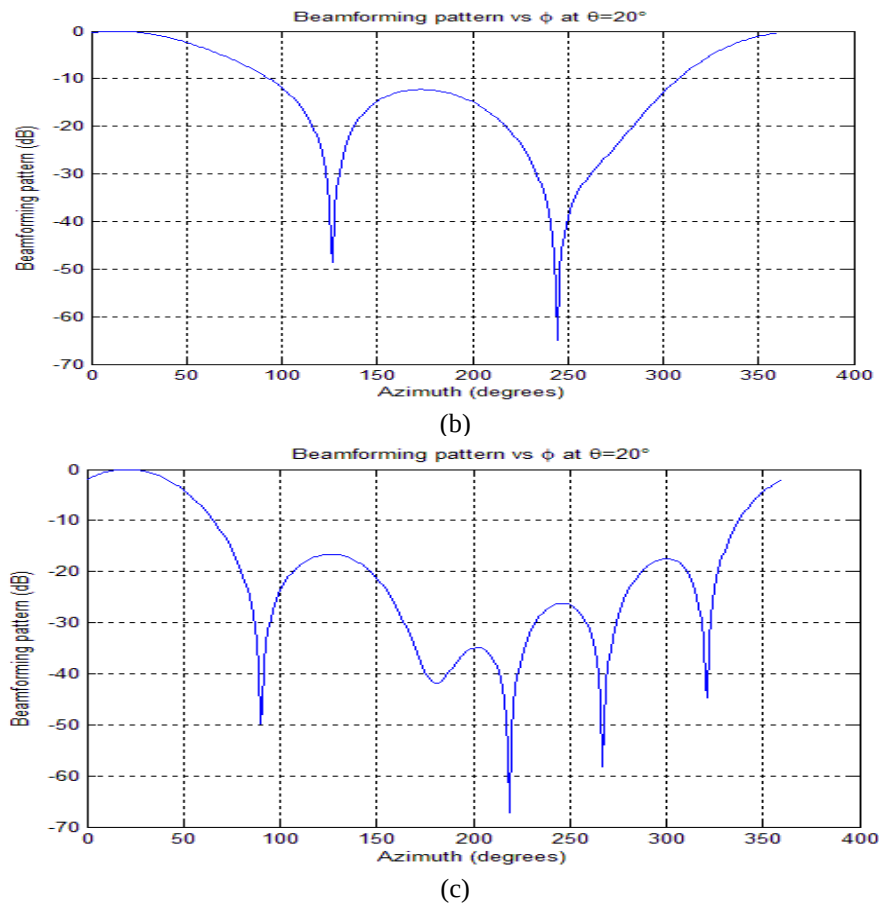
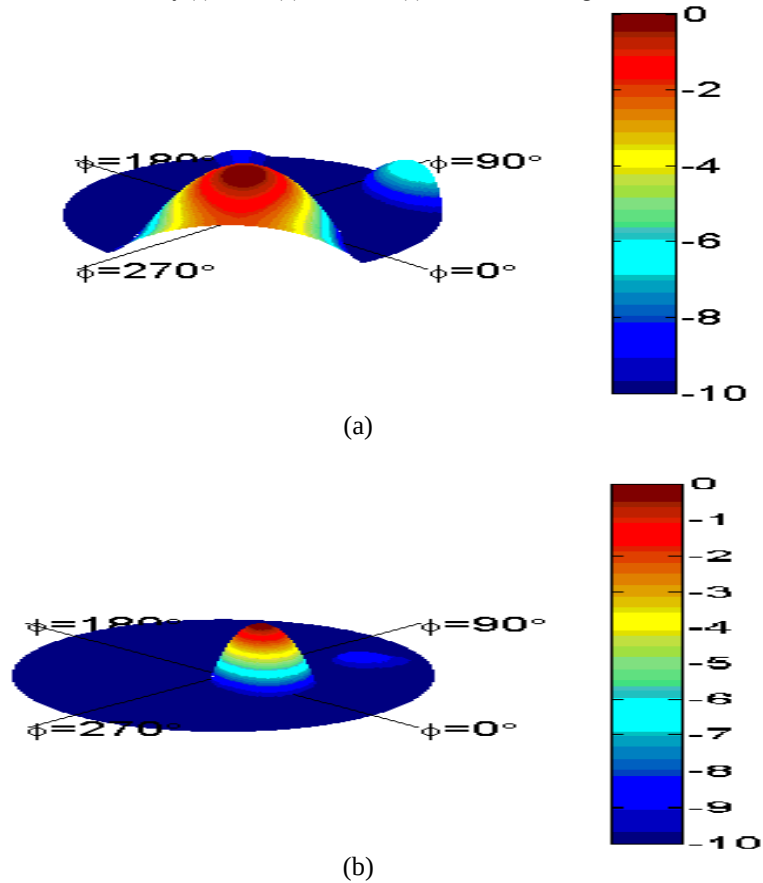


Fig. 1 Amplitude responses of Planar Array (a) 2 X 2, (b) 4 X 4, and (c) 6 X 6. Users at angle 22° and interferes at angle 45°



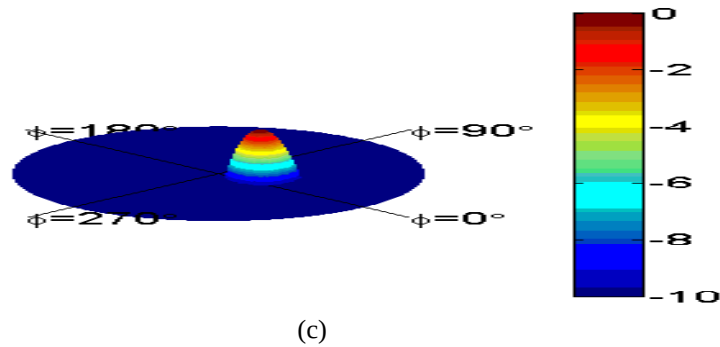


Fig 2. 3D spectrum responses of Planar Array (a) 2 X 2, (b) 4 X 4, and (c) 6 X 6. Users at angle 22° and interferes at angle 45°

VI. Conclusion

The array factors are produced from complex weights or excitations that depend on the signal environment. Each beam former is equipped with an different plannar array and receives an SOI, $\theta_0=22^\circ$, $\theta_1=22^\circ$, at broadside and and SNOI at $\phi_1=45^\circ$, $\phi_2=0^\circ$. By attenuating the strength of the interferer more, it would be expected that the throughput of the adaptive beamformer will be higher than the throughput of the non adaptive beamformer since the cochannel interference is reduced and the SIR is higher. These simulation results show that for this particular network for beamforming periods. Due to its narrower beam width; the main beam of the larger array can receive the signals-of-interest more accurately and rejects the more signals-not-of-interest. But it has a drawback that it increases the cost and the complexity of implementation and also it increases the convergence time for the adaptive algorithm, thereby reducing the bandwidth.

VII. References

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