HARMONIC BEAM RECONFIGURATIONS USING PARTICLE SWARM OPTIMIZATION IN TIME MODULATED ARRAYS

K. Vara Prasad, P Satyanarayana, Ch.Raghavendra, K. Satish Kumar

Department of ECE, V. R Siddhartha Engineering College, Vijayawada

ABSTRACT

Time-modulation (TM) arrays is implemented by using a set of radio-frequency switches in the beam forming network to modulate, by means of periodic pulse sequences to control the antenna radiation features. The on–off reconfiguration of the switches that can be easily implemented via software unavoidably generates harmonic radiations that can be suitably exploited for multiple channel communication purposes. An innovative approach to the design of time-modulated arrays able to generate multiple and simultaneous harmonic beam patterns pointing towards different directions is presented. In time modulated arrays, because of the introduction of the periodic time modulation, multiple harmonic signals are generated. The synthesis of the pulse sequence controlling the RF switches is performed by means of a Particle Swarm Optimizer (PSO) to generate multiple harmonic beams able to simultaneously receive multiple signals arriving on the antenna from different directions. Towards this aim and in order to independently receive a signal on each harmonic channel generated by the receiving time-modulated array each harmonic beam has to be optimized such to have a maximum towards the DoF of one arriving signal and deep side lobes or nulls along the directions of other signals.

Index Terms: Time-modulated arrays, harmonic beam forming, multiple-input multiple-output (MIMO), reconfigurability, secure communication.

1. INTRODUCTION

In recent years, several solutions have been proposed in the scientific literature for the design and synthesis of adaptive/smart antennas. In this framework, there has been recently a renewed interest towards the use of time as an additional Degree of Freedom (DoF) for the antenna synthesis to obtain performance, which is not achievable with conventional antennas.

Besides several positive features, modulating the element excitations by means of a sequence of time pulses generates undesired harmonic radiations (the so-called sideband radiations (SRs)), which affect the performance of time modulated antenna arrays, thus limiting their practical applicability. In the past, most researches have been focused on synthesizing a desired pattern shape at the antenna central frequency and simultaneously minimizing the power in the harmonics. As a matter of fact, these power losses unavoidably reduce the antenna directivity, since they have to be filtered out to correctly receive the desired signal. More recently, the research interest in time-modulated antenna arrays has been redirected towards making use of these harmonic radiations. The synthesis of simultaneous and multiple harmonic beams for applications like direction finding and beam steering has been investigated to improve the reliability of the communication system.

II. BEAM FORMING

Beam forming is a technique used in sensor arrays for directional signal transmission or reception. This is achieved by combining elements in phased arrays in such a way that signals at particular angles experience constructive interference while others experience destructive interference. Beam forming can be used at both the transmitting and receiving ends in order to achieve spatial selectivity. The improvement compared with omni-directional reception/transmission is known as the directivity of the element.

Beam forming techniques can be used with any antenna system. They are used to create a certain required antenna directive pattern to give the required performance under the given conditions. Smart antennas are normally used - these are antennas that can be controlled automatically according the required performance and the prevailing conditions.

Smart antennas can be divided into two groups:

- **Phased array systems:** Phased array systems are switched and have a number of pre-defined patterns - the required one being switched according to the direction required.
- **Adaptive array systems (AAS):** This type of antenna uses what is termed adaptive beam forming and it has an infinite number of patterns and can be adjusted to the requirements in real time.

MIMO beam forming using phased array systems requires the overall system to determine the direction of arrival of the incoming signal and then switch in the most appropriate beam. This is something of a compromise because the fixed beam is unlikely to exactly match the required direction.

Adaptive array systems are able to direct the beam in the exact direction needed, and also move the beam in real time - this is a particular advantage for moving systems - a factor that often happens with mobile telecommunications. However the cost is the considerable extra complexity required.

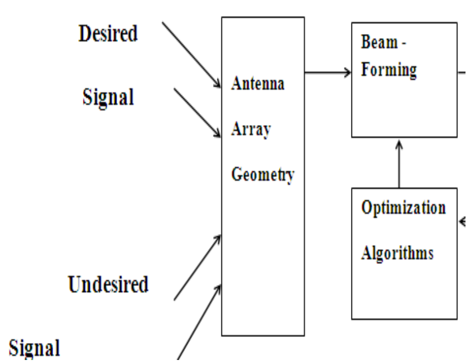

Fig.1: Block diagram of smart antenna system.

A Smart antenna system consists of a number of elements which are arranged in different geometries (like Linear, Circular etc.,) and whose weights are adjusted with signal processing techniques and evolutionary algorithms to exploit the spatial parameters of wireless channel characteristics under noisy environment. Fig.1 shows the block diagram of smart antenna system.

III. BEAM FORMING USING PARTICLE SWARM OPTIMIZATION

There has been recently a renewed interest towards the use of time as an additional degree of freedom for the antenna synthesis to obtain performance, which is not achievable with conventional antennas. The use of the fourth dimension for array design has a long history dating back to the pioneering work by Shanks and Bick more in the late 1950s. They proposed to use a set of radio-frequency (RF) switches to modulate one or more antenna parameters (e.g., element excitations, aperture size, etc.) through periodic time sequences to obtain radiation characteristics which cannot be easily achieved by conventional phased arrays. Afterwards, Kummer et al. gave a more detailed treatment of the effects of time-modulation on the received/transmitted signals and proposed an experimental prototype to obtain an ultra-low side lobe antenna. In the slots of an eight-element linear array have been progressively switched-off starting from the tails of the array while maintaining only the two central elements always active to enforce an average tapering in the time domain for side lobe reduction. Ever since then, a lot of effort has been made in the research community to use time-domain parameters to design antennas with enhanced performance

In time modulated arrays, because of the introduction of the periodic time modulation, multiple harmonic signals are generated. In the past, most researches have been focused on synthesizing a desired pattern shape at the antenna central frequency and simultaneously minimizing the power in the harmonics. As a matter of fact, these power losses unavoidably reduce the antenna directivity, since they have to be filtered out to correctly receive the desired signal. More recently, the research interest in time-modulated arrays has been redirected towards making use of these harmonic radiations. The synthesis of simultaneous and multiple harmonic beams for applications like direction finding and beam steering has been already investigated to improve the reliability of the communication system. Indeed, the individual harmonic patterns, each associated with a characteristic frequency, can be utilized as independent information channels which may be separated at the receiver and each one utilized in a conventional manner. This key feature of arrays enables their use for simultaneous operations and potentially to harvest multiple replicas of a signal thus leading to their applications in multiple-input multiple-output (MIMO) systems. The same antenna structure can also be used to receive multiple independent signals which carry different information.

IV.RESULTS

Beam Forming:

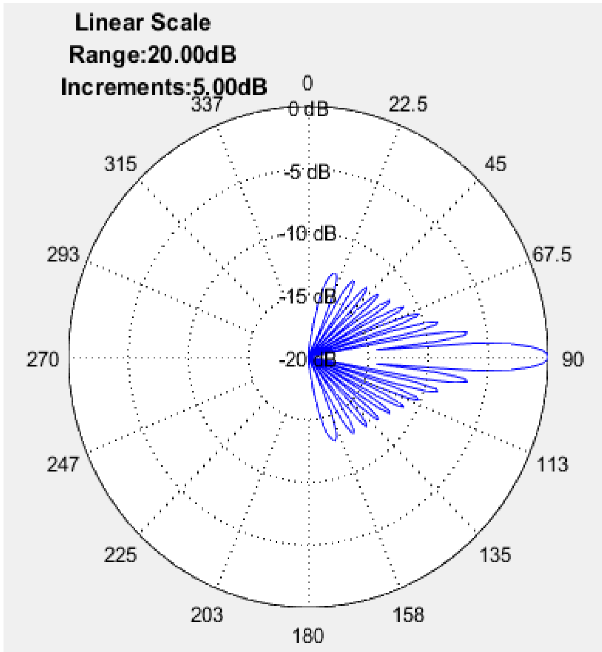

Fig2: Radiation pattern of signal in the direction of 90^0.

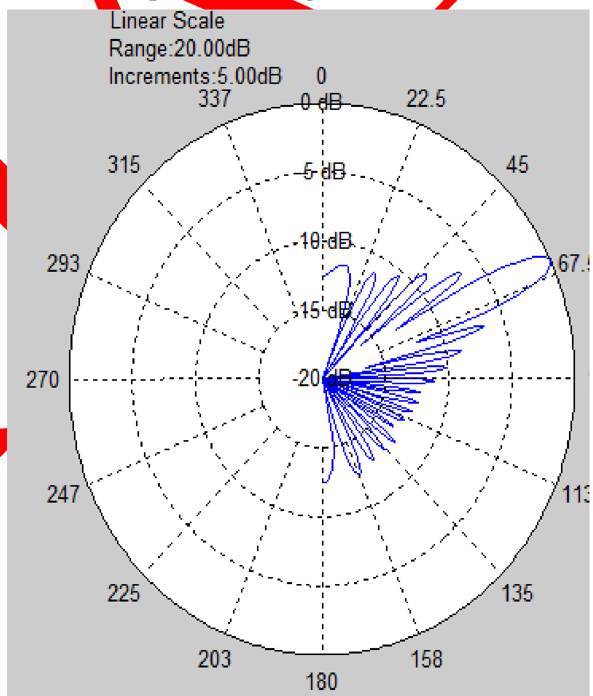

Fig 2: Radiation pattern of signal in the direction of 61^0.

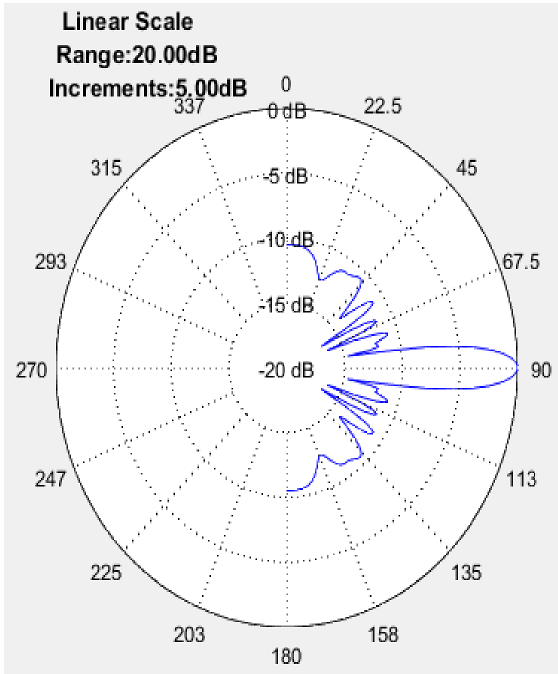

Fig3: Radiation pattern of signal after application of PSO

Main objective of the project is increase of "Signal-to-Noise Ratio" (SNR) by decreasing "Side Lobe Level" (SLL). Comparison between values of SNR before and after application of PSO algorithm is done.

Comparison between analytical and PSO methods:

h=0		
(dB)	**Analytical**	**PSO**
AF	0.0	0.0
SNR	25.5	29.8

Clearly, SNR increases after application of PSO algorithm by 4.3 dB. As the paper clearly suggests increase of SNR by decreasing SLL of the radiation pattern of given antenna array, AF remains same before and after application of PSO, as Array Factor depends on main lobe. Above values are for 0^{th} harmonic of the antenna array.

CONCLUSION

The suitability of time modulated arrays as enabling technology for the antenna front-end has been discussed. The array factor of the antenna and harmonics of the pattern radiation are observed. The effects of the optimization of the switch-on instants in time-modulated linear arrays have been analyzed and discussed. It has been shown that such an additional control positively affects the instantaneous performance of the radiation pattern. A set of results obtained through a PS-based technique has been reported to support such a conclusion. Starting from this preliminary study, further investigations will regard the analysis of time-modulated arrays when dealing with more realistic scenarios and the presence of interference signals.

REFERENCES

[1] E. T. Bekele, L. Poli, P. Rocca, M. D'Urso, and A. Massa, "Pulse shaping strategy for time modulated arrays—Analysis and design," *IEEE Trans. Antennas Propag.*, vol. 61, no. 7, pp. 3525–3537, Jul. 2013.

[2] Linear Antenna Array with Suppressed Sidelobe and Sideband Levels using Time Modulation, 3rd International Conference on Computers and Devices for Communication (CODEC-06), Institute of Radio Physics and Electronics, University of Calcutta, December 18-20, 2006.

[3] T. Hong, M. Song, and Y. Liu, "RF directional modulation technique using a switched antenna array for physical layer secure communication applications," *Progr. Electromagn. Res.*, vol. 116, pp. 363–379,2011.

[4] M. P. Daly and J. T. Bernhard, "Beam steering in pattern reconfigurable arrays using directional modulation," *IEEE Trans. Antennas Propag.*, vol. 58, no. 7, pp. 2259–2265, Jul. 2010.

[5] J. C. Brégains, J. Fondevila, G. Franceschetti, and F. Ares, "Signal radiation and power losses of time-modulated arrays," *IEEE Trans. Antennas Propag.*, vol. 56, no. 6, pp. 1799–1804, Jun. 2008.