Beamforming using Particle Swarm Optimization

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***Abstract*:- Beamforming is a signal processing technique by which an array of receivers sensitive to signals from all directions can be processed to form one larger signal. Beamforming technique is a key factor to high throughput objective - achieved by reduction in errors occurring in data transmission and reception. In this paper digital beamforming is to be designed with a specified response like a sidelobe level reduction, forming a null response points in interference direction or jamming frequency improving the gain of the antenna towards intended user. So we use optimal beamforming using optimization technique, to achieve a desired response. For that Particle Swarm Optimization (PSO) is a desired candidate. PSO is known as a heuristic robust stochastic optimization technique based on swarm intelligence that is inspired by the behaviour of bird flocking, which applies the concept of social interaction to problem solving in various fields such as physics, chemistry, economics and engineering where the goal is to maximize efficiency or other kinds of variables. The PSO technique optimizes the particles' objectives by updating the velocity and position of each particle based on best fitness function and moving particle swarm in the area with higher objective function value. Eventually, all particles gathers around the point with the highest objective value.**

1. INTRODUCTION

Array processing techniques like a beamforming help in improving the system performance, such as coverage increase, multipath fading mitigation, gain improvement, SNR, SINR and side lobe level reduction. Thus, application of antenna arrays in wireless communications may be considered as one of the most promising ways to accommodate the rapidly growing service demands for multimedia transportation. The received signals on an array of sensors are multiplied by a complex weights before summing to produce the array output and directional constraints on array weights are imposed to have a desired response of the array in a given look direction. The constraints protect the desired signal arriving from the look direction when the array weights are obtained by solving some optimization problem. As the signal bandwidth increases the performance of the array system using this narrowband structure, where induced signals are multiplied by complex weights, starts to deteriorate. For processing broadband signals, a tapped delay line (TDL) filter in front of each element is used and filter coefficients are determined by solving some constrained beamforming problem. Many of these constraints are designed to obtain a desired frequency response of the processor in the look direction while simultaneously cancel the unwanted directional sources impinging on the array from other directions.

2. BEAM FORMING

Beamforming is a technique that focuses a wireless signal towards a specific receiving device, rather than having the signal spread in all directions from a broadcast antenna, as it normally would. This results in more direct connection is faster and more reliable than it would be without beamforming.

2.1 HOW BEAMFORMING WORKS

A single antenna broad casting a wireless signal radiates the signal in all directions (if it is blocked by some physical object). That's how electromagnetic waves work. But if you wanted to focus that signal in a specific direction, to form a targeted beam of electromagnetic energy the technique for doing this involves having multiple antennas in close proximity, all broad casting the same signal at slightly different times. The overlapping waves will produce interference that in some areas is *constructive* (it makes the signal stronger) and in other areas is *destructive* (it makes the signal weaker, or undetectable). If executed correctly, this beamforming process can focus your signal where you want it to go.

3. ARRAY PROCESSING

Array processing metrics are often assessed noisy environments. The model for noise may be either one of spatially incoherent noise, or one with interfering signals following the same propagation physics. Estimation theory is an important and basic part of signal processing field, which is used to deal with estimation problem in which the values of several parameters of the system should be estimated based on measured/empirical data that has a random component. As the number of applications increases, estimating temporal and spatial parameters become more important. Array processing emerged in the last few decades as an active area and centered on the ability of using and combining data from different sensors (antennas) in order to deal with specific estimation task (spatial and temporal processing). In addition to the information that could be extracted from the collected data the framework uses the advantage prior knowledge about the geometry of the sensor array to perform the estimation task. Array processing is used in radar, sonar, anti jamming and wireless communications. The problems associated with array processing include the number of sources used, their direction of arrivals and signal waveforms.

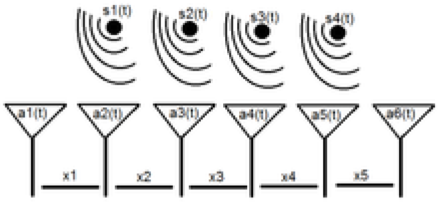


Fig 1: Array processing

4. ANTENNA PATTERN

An antenna pattern is either a function or a plot describing the directional properties of an antenna. The pattern can be based on the function describing the electric or magnetic fields. In that case, the pattern is called a field pattern. The pattern can also be based on the radiation intensity function defined in the previous section. In that case, the pattern is called a power pattern. The antenna pattern may not come from a functional description but also may be the result of antenna measurement. In this case the measured pattern can be expressed as a field pattern or as a power pattern.

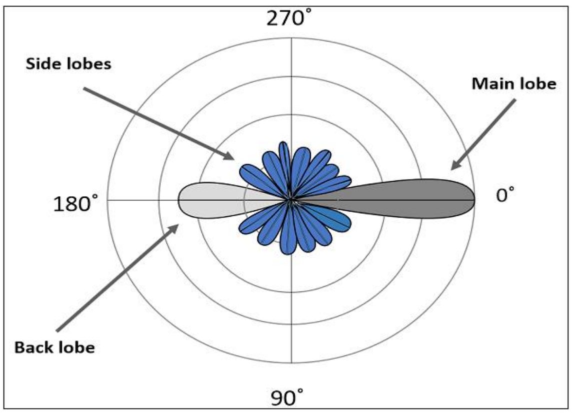


Fig 2: Radiation pattern

5. LINEAR ARRAYS

The simplest array geometry is the linear array. Thus, all elements area aligned along a straight line and generally have a uniform inter element spacing.
Linear arrays are the simplest to analyse and many valuable insights can be gained by understanding their behaviour. The minimum length linear array is the two-element array.

6. ANTENNA RECEIVER MODEL

We have uniform linear array antenna with

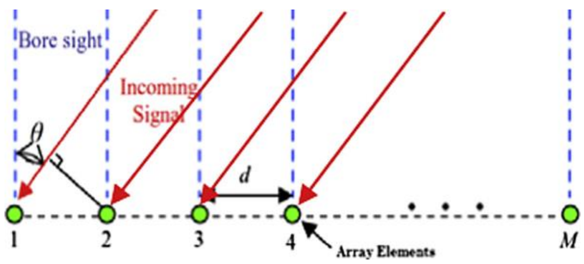


Fig 3: Uniform linear array antenna.

- number of elements =M,
- inter-element spacing= d,
- number of incident signals= D,
- number of data samples = k.

$$r = e^{-i\omega t}$$

$$r = e^{-i2\pi f t}$$

$$r = e^{-i2\pi\frac{ct}{\lambda}}$$

$$r = e^{-i2\pi\frac{x}{\lambda}}$$

$$r_{total} = \sum_{n=1}^{4} e^{-i2\pi\frac{x_n}{\lambda}}$$

$$r_{total} = e^{-i\varphi}\sum_{n=1}^{4} e^{-i2\pi\frac{(n-1)d\cos\theta}{\lambda}}$$

The incident signals from ‘‘D’’ users are represented in amplitude and phase at some arbitrary reference point (origin of the coordinate system) by the complex quantities S1,S2, . . . ,SD also white Gaussian noise added to the Signal as vector (n). Directions of the incident signals represented by the steering vector a(hi) for ith user so we have matrix ‘‘A’’ its size M * D the first column a(h1) is the steering vector for the 1st user and so on.

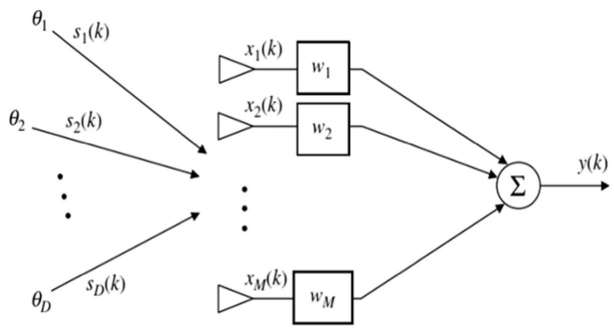
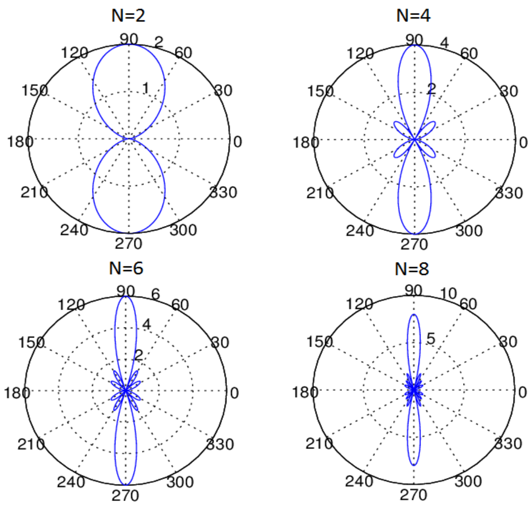


Fig 4: Uniform linear array antenna RX model.



Uniform Linear Array with varying array length

7. PARTICLE SWARM OPTIMIZATION

Optimization means finding a better solution to a problem. It is the process of adjusting inputs to obtain a desirable output. optimization deals with seeking for the minima or maxima of a function within a search space. Particle swarm optimization is one of the famous global optimization techniques which is inspired by social behaviour of swarms in the nature. The swarms like bird flock, bees swarm and fish school are very successful in finding food in nature. They are in continuous interaction with each other while searching for food in a large area. Each bird or fish tells the location and quantity of the food that it found to the others. Thus, by taking into the location and quantity data from each member of the swarm, whole swarm tends towards the optimum location where maximum amount of food is present. Particle swarm optimization can be used in solution of multidimensional nonlinear global optimization problems effectively. It has a very simple concept and can be implemented by using primitive mathematical operators which make the technique computationally inexpensive in terms of both memory and speed requirements.

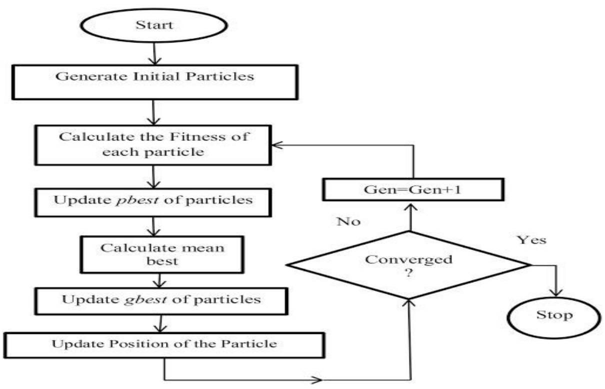
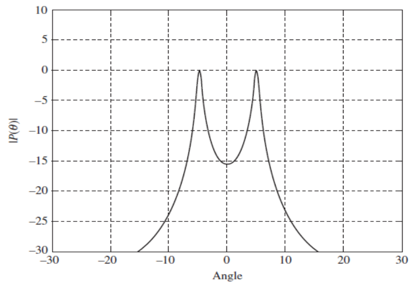
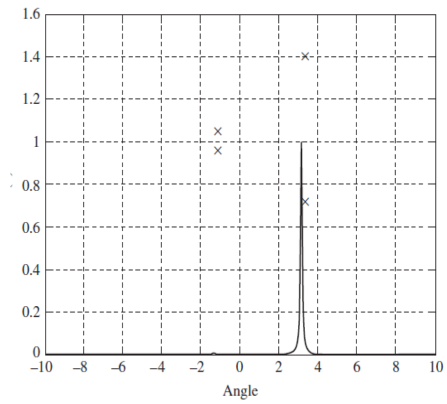


Fig 5: Flow chat of PSO

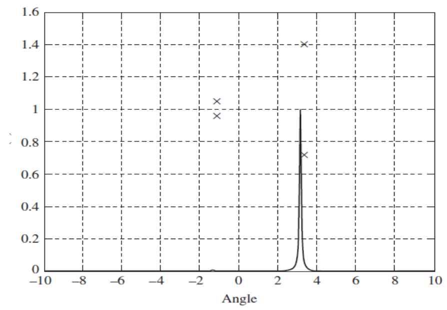


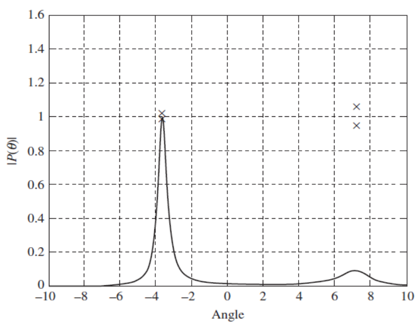


8. CONCLUSION

The PSO algorithm is successfully used to optimize the weights set for optimal beamformer to exhibit a beamformer response with either suppressed sidelobes null placement in certain directions, or both.

As an evolutionary algorithm the PSO method will most likely be an increasingly attractive alternative, in the electromagnetic and antennas community, the PSO algorithm is much easier to understand and implement and requires minimum mathematical preprocessing.





9. REFERENCES

[1] Godara, Lal C. "Applications of antenna arrays to mobile communications.I. Performance improvement, feasibility, and system considerations." Proceedings of the IEEE 85.7 (1997): 1031-1060.Ding, W. and Marchionini, G. 1997 A Study on Video Browsing Strategies. Technical Report. University of Maryland at College Park.
[2] Godara, Lal C. "Application of antenna arrays to mobile communications. II. Beam-forming and direction-of-arrival considerations." Proceedings of the IEEE 85.8 (1997): 1195-1245.
[3] Takao, Kazuaki, M. Fujita, and T. Nishi. "An adaptive antenna array under directional constraint." IEEE Transactions on Antennas and Propagation 24.5 (1976): 662-669.
[4] Vook, F. W., and R. T. Compton. "Bandwidth performance of linear adaptive arrays with tapped delay-line processing." IEEE Transactions on Aerospace and Electronic Systems 28.3 (1992): 901-908.
[5] Frost, Otis Lamont. "An algorithm for linearly constrained adaptive array processing." Proceedings of the IEEE 60.8 (1972): 926-935.
[6] Compton, R. T. "The bandwidth performance of a two- element adaptive array with tapped delay-line processing." IEEE Transactions on Antennas and Propagation 36.1 (1988): 5-14.
[7] Rodgers, W. E., and R. T. Compton. "Adaptive array bandwidth with tapped delay-line processing." IEEE Transactions on Aerospace and Electronic Systems 1 (1979): 21-28.
[8] Ahmed, K., and R. Evans. "An adaptive array processor with robustness and broad-band capabilities." IEEE transactions on antennas and propagation 32.9 (1984): 944-950.
[9] Er, Meng, and A. N. T. O. N. I. O. Cantoni. "A new approach to the design of broad-band element space antenna array processors." IEEE journal of oceanic engineering 10.3 (1985): 231-240.
[10] Mailloux, Robert J. Phased array antenna handbook. Vol. 2. Boston: Artech House, 2005.
[11] Liu, Wei, and Stephan Weiss. Wideband beamforming: concepts and techniques. Vol. 17. John Wiley & Sons, 2010.