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Adaptive Array for Interfering Signals Cancellation Based on Power Minimization Algorithm

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Abstract

Adaptive arrays have a widespread use in modern communications systems due to their beamforming, beam steering and interference mitigation abilities. Most commonly employed method of interference mitigation is to determine the direction of arrival (DOA) of the unwanted signal and place a null in its direction in the antenna's radiation pattern. However, determining the DOA with a high precision, especially in the case of multiple interferers, can be a cumbersome task, requiring expensive, state-of-the-art hardware and sophisticated algorithms. In this work, we present a real-time, low-cost alternative to DOA-based interference mitigation, which uses a stochastic power minimization approach to cancel out interfering signals.

1 Introduction

Intentional or unintentional Electromagnetic interference in critical RF communication links has become a serious issue in today's world of automation. Typically, antenna arrays are designed to identify direction of arrival (DOA) of these unwanted signals before nulling them through adaptively reconfiguration of the radiation pattern of the receiving array (see Figure 1). RF signals from various elements are first down converted to IF signals then digitized using ADCs to estimate the angle of arrival of the unwanted signals. In addition to the high cost of these ADCs and mixers, the process of determining the DOA is time consuming and, in most cases, does not allow for real-time operation.

2 Approach

As a low-cost alternative, and potentially a relatively faster option, power minimization design can be used to mitigate unwanted interference. This approach does not require any prior knowledge of the direction of the interfering signals and is suitable for scenarios where the power level of the wanted signal is known. The power minimization scheme [1] simply requires the ability to detect the total power incident on the receiver at any given time [2]; the minimization is triggered once the received power exceeds a specified threshold. In other words, summed RF signals are rectified, then the DC level is fed to microcontroller to stochastically optimize and the complex weights of the adaptive array to yield the desired radiation pattern characteristics.

3 Optimization Algorithm

There are various types of stochastic optimization algorithms that can be used to accomplish this task, including genetic algorithm (GA), particle swarm optimization (PSO) [3-6], ant colony (ACO), artificial immune system optimization (AIO), etc. Here, we utilize PSO for its simplicity and familiarity.

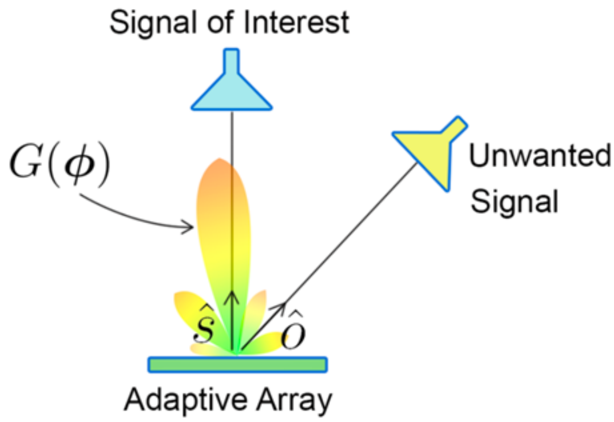


Figure 1. Schematic of the wanted and unwanted received signals.

In the optimization, two constraints were specified. The first one is the total received power and the second is the drop in the main beam level. In order to allow real time operation, the algorithm was implemented on an Artix 7 FPGA, which yielded sub-millisecond convergence times. The results indicate the need for a relatively large number of iterations for certain angles of incidence, especially for those close to the broadside direction of the array. A big advantage of this approach is that the algorithm does not care about how many interfering signals there are. It will search the optimization space until a solution that satisfies the two constraints is found (provided that one exists). Preliminary results are shown in Figure 4.

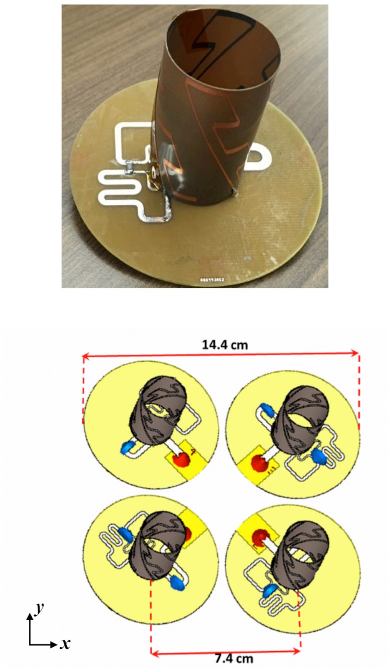


Figure 2. A 2x2 adaptive array, each element is followed by a phase shifter and a programmable anttenna to adjust its complex weight

4 Results

Figure 3a shows the measured radiation pattern of the quadrifiller helical antenna array (Figure 2) in reference mode. After introducing an unwanted signal incident from $\theta = -75°$, the power minimization algorithm was triggered until the total received power was brought down to the acceptable threshold. As shown in Figure 3b, the measured radiation pattern shows a clear -25dB null in the direction of the interferer, while the boresight gain was only reduced by 0.75dB.

5 Conclusion

Power minimization algorithm implemented on fast FPGA based on stochastic optimization can lead to nulling of interfering signals with minimal latency. The low-cost approach can be easily extended to more than one interfering signal and its speed can be further accelerated using an SoC with a higher clock speed.

6 References

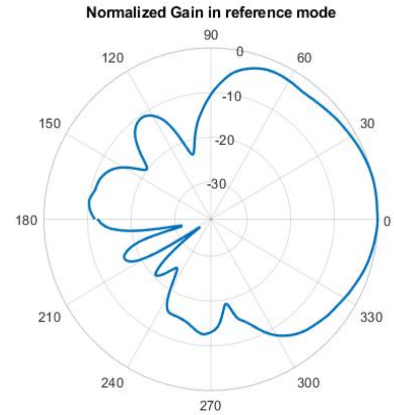
1. S. C. Johnson and A. D. Snider, ”Antenna array output power minimization using steepest descent adaptive algorithm,” The 2005 IEEE Annual Conference Wireless and Microwave Technology, 2005., 2005, pp. 92-95.

2. R. Kazemi, J. Palmer, F. Quaium, A. E. Fathy, ”Steerable Miniaturized Printed Quadrifilar Helical Array Antenna Using Digital Phase Shifters for BGAN/GPS Application,” IET Microwaves, Antennas & Propagation, 2018.

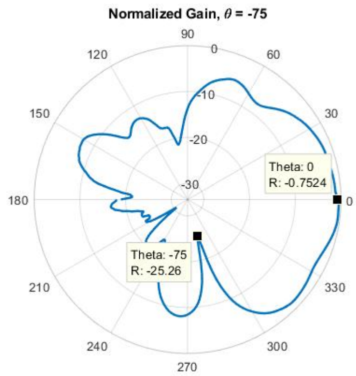
3. J. Kennedy and R. Eberhart, “Particle swarm optimization”, Proc. IEEE Int. Conf. Neural Networks, vol. 4, pp. 1942-1948, 1995.
4. J. Robinson and Y. Rahmat-Samii, “Particle Swarm Optimization in Electromagnetics,” IEEE Trans. Antennas Propag., vol. 52, no. 2, pp.397–407, Feb. 2004.

5. D. Gies, and Y. Rahmat-Samii, “Particle Swarm Optimization for Reconfigurable Phase-Differentiated Array Design,” Microwave and Opt. Tech. Lett., Vol. 38, No. 3, August 2003.

6. N. Jin and Y. Rahmat-Samii, “Advances in particle swarm optimization for antenna designs: Real-number, binary, single- objective and multi-objective implementations,” IEEE Trans. Antennas Propagat., Vol. 55, 556–567, 2007.



a)



b)

Figure 4. a) Radiation pattern before nulling, b) radiation pattern after introducing a null at -75° degrees, broadside gain dropped only by 0.75 dB, while the null depth is -25 dB.