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Interference Cancellation Performance of Adaptive Array of ESPAR antennas

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1. Introduction

In this report, we consider interference cancellation performance of an adaptive array using ESPAR (Electronically Steerable Passive Array Radiator) antennas [1], [2] as elements. This array of ESPAR antennas has ability of both N-port weight control of the array and M-reactance control of each ESPAR element. By using the ESPAR antenna as elements, we can change each element pattern with simple varactor-control circuits.

Interference cancellation performance of this antenna and normal adaptive array are shown in this report. The results show that this antenna has a better interference cancellation performance than the conventional adaptive array, especially when there are many interference signals.

2. The Proposed ESPAR Array Antenna

Configuration of the proposed antenna is illustrated in Fig.1. In this figure, we show 2-element ESPAR array (N=2). Each ESPAR antenna has 6 parasitic elements (M = 6 in fig. 1).

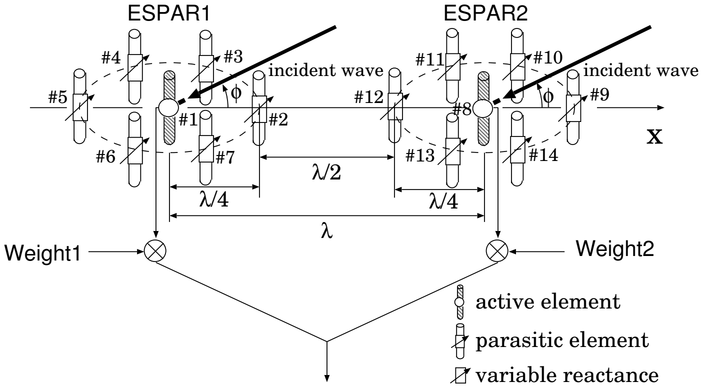

Figure 1: Proposed antenna

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In the proposed antenna, reactances loaded with the parasitic elements in each ESPAR antenna are controlled, in addition to output weight of each ESPAR antenna. All elements in a usual adaptive array have unchanged element patterns as shown in Fig. 2. On the other hand, the proposed antenna has elements whose pattern can be changed. This concept is shown in Fig. 3.

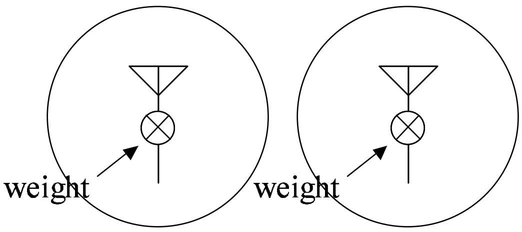

Figure 2: Element patterns of the usual adaptive array

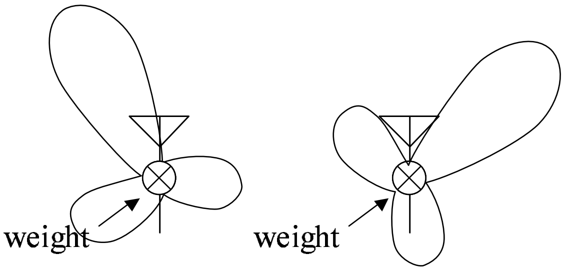

Figure 3: Element patterns of the proposed array

This antenna, in other words, is a kind of layered (adaptive) array antenna that has M weights of varactors in the first layer and N weights in the second layer.

Received signal of the proposed array can be given by

$$r(t) \quad = \quad \boldsymbol{w}_0^T(\boldsymbol{W}^T\boldsymbol{A}\boldsymbol{s}(t) + \boldsymbol{n}(t)), \tag{1}$$

where $\boldsymbol{w}_0$ is the weight vector of the ESPAR output, $\boldsymbol{A}$ is a mode matrix whose column corresponds to the mode vector of the incoming wave, $\boldsymbol{s}(t)$ is a signal vector, and $\boldsymbol{n}(t)$ is an additive Gaussian noise vector.

Since 2-ESPAR array is considered in this report, then $\boldsymbol{w}_0$ can be given by

$$\boldsymbol{w}_0 = [w_{01}^* w_{02}^*]^T, \tag{2}$$

where w_{0i} is the weight of the i-th ESPAR antenna ($i = 1, 2$), ^{T} denotes the transpose operation, and * represents the complex conjugate operation. $\boldsymbol{W}$ is an *Equivalent Weight Matrix* of the ESPAR antennas expressed by

$$\boldsymbol{W} \quad = \quad Re[z_s](\boldsymbol{Z} + \boldsymbol{X})^{-1}\boldsymbol{U}_0, \tag{3}$$

where z_s is an internal impedance at the output port of each ESPAR antenna. In this model we assume that the each ESPAR has the same impedance. $\boldsymbol{Z}$ is the impedance matrix of the array. We have 14 elements (7×2) totally, hence the matrix becomes 14×14. $\boldsymbol{X}$ is the matrix defined by

$$\boldsymbol{X} \quad = \quad diag(z_s, jx_2, jx_3, \ldots, jx_7, z_s, jx_9, jx_{10}, \ldots, jx_{14}), \tag{4}$$

where x_i is the reactance loaded with the i-th parasitic element, and $diag(\bullet)$ denotes a diagonal matrix. $\boldsymbol{U}_0$ is a 14×2 matrix defined by

$$\boldsymbol{U}_0 \quad = \quad \begin{bmatrix} 1 & 0 & \cdots & 0 & 0 & 0 & \cdots & 0 \\ 0 & 0 & \cdots & 0 & 1 & 0 & \cdots & 0 \end{bmatrix}^T. \tag{5}$$

The proposed antenna controls $\boldsymbol{w}_0$ and $\boldsymbol{X}$ to optimize the received signal.

3. Simulation Results

To confirm interference cancellation performance of the proposed antenna, we carried out computer simulations of output SINR and directional pattern of the array. In this simulation, direction of arrivals (DOA) of designed and interference waves are assumed to be known. Also to derive optimum weights and reactances, the Direct Search [3], [4] is employed in this study. In these simulations, mutual couplings between the two ESPAR antennas are neglected for simplicity. Simulation parameters are listed in Table.1.

Table 1: Simulation parameters

element lengths	5.6 [cm]
element radius	0.5 [mm]
resistance loaded with active elements	100[Ω]
frequency	2.47 [GHz]
SNR	20 [dB]
SIR	0 [dB]
starting reactance	0 [Ω]
starting weight	$1 + j0$
iteration count	100

Figure 4 shows output SINR results of the proposed and conventional 2-element adaptive array for 2-wave incidence (one designed wave from 20 degrees and one interference wave from 70 degree). Figure 5 shows directional pattern of each antenna at iteration 100. As shown in Fig.5, since this is not an overloaded environment for the arrays, both antennas can make deep null at the DOA of interference in this case and show almost the same SINR performance.

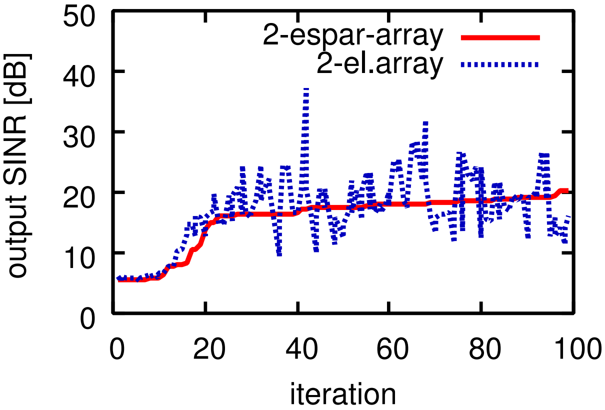

Figure 4: Comparison of convergence of SINR

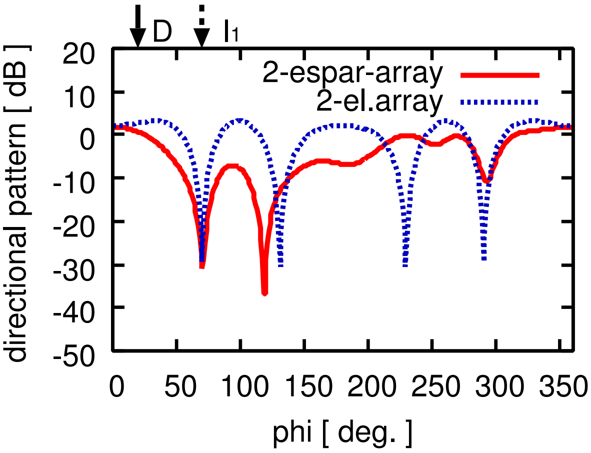

Figure 5: Power directional pattern

Figure 6 shows results of output SINR results for the arrays in 7-wave incidence environment (one designed wave from 20 degrees and 6 interference waves from 70, 110, 170, 240, 300, and 340 degrees). The directional patterns at iteration 100 are shown in Fig.7. Obviously this is an overloaded environment for the conventional 2-element array.

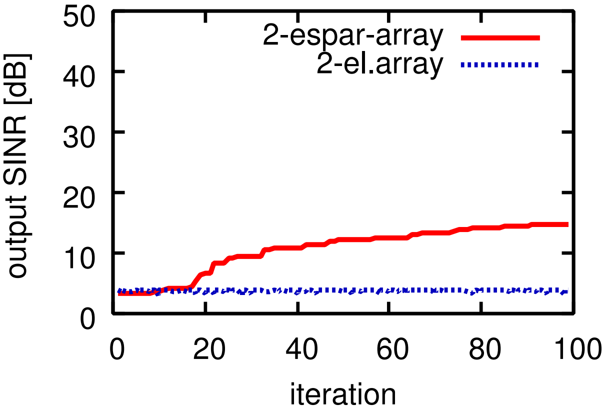

Figure 6: Comparison of convergence of SINR

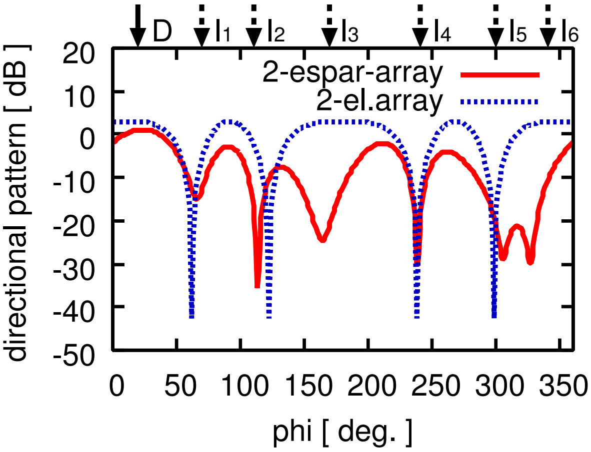

Figure 7: Power directional pattern

As shown in Fig.7, the conventional adaptive array cannot make nulls to reject the interference waves. It is because that the conventional 2-element adaptive array has only 1 degree of freedom for interference rejection. Proposed antennas, on the other hand, can remove interference waves effectively. These results show that reactance control at parasitic elements in ESPAR antenna can improve interference cancellation performance effectively.

4. Conclusions

In this report, we consider interference cancellation performance of an adaptive array whose elements are the ESPAR antennas. Since the element pattern of the array can be controlled, the array of ESPAR antennas has a good ability of interference rejection in comparison with that of the conventional array without parasitic elements.

This is the fundamental study of the array, hence we used the Direct Search algorithm to derive the optimum reactances and the weights with *known* DOAs. Further study for adaptive weight control algorithm still remains to be considered. It will be done in near future.

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