CONSTANT MODULUS ALGORITHM IN SPACE REGION FOR ARRAY ANTENNA PATTERN SYNTHESIS

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1. Introduction

Beam shaping of array antenna can be carried out by controlling excitation amplitude and phase of element antenna. If the number of the observation points is less than that of the element antenna and both of the excitation amplitudes and phases are controllable, the solution of excitation can be obtained directly by the plane wave synthesis method[1]. In actual strict radio environment, the observation points become increasing, then there are many cases in which the analytical method cannot be applied. And in ordinal phased array antennas, the excitation phases are only controllable. In also this case, the solution cannot be obtained analytically.

On the other hand, CMA (Constant Modulus Algorithm) method has been known as blind adaptive beam forming in condition that the signal envelope is constant[2]. The evaluation equation of CMA operates so as to maintain the power envelope in the time region. We propose the method of which the evaluation of CMA is changed from time region to space region. By applying this method, the pattern synthesis of array antenna can be realized in wide space area and the solution of the optimum weights in the case, (i)Excitation amplitudes and phases are controllable, (ii)Only excitation phases are controllable and (iii)Only excitation amplitudes are controllable, can be obtained easily.

2. Theory

The configuration of the CMA adaptive beamforming is the same with that of MMSE except that it requires no reference signal. The development of the updating equation of the CMA is similar to the case of the Least Mean Square (LMS) algorithm. The evaluation function of CMA is as follows.

$$J = \frac{1}{4} E\left[\left(|y|^2 - \sigma^2\right)^2\right] \qquad (1)$$

where E is the time-average, y is the array combining signal and σ is the desired power envelope. In the proposed method, time –average is changed to space -average. The evaluation function is

$$F = \sum_{m=1}^{M} \left[|y_m|^2 - P_{0m}\right]^2 \qquad (2)$$

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$$y_m = \mathbf{W}^T \mathbf{X}_m \qquad (3)$$

where $\mathbf{X}_\mathrm{m}$ is the element electric field vector at m-th observation point and **W** is the weight vector. The optimum weight is obtained as follows,

(i)Excitation amplitudes and phases are controllable:

$$\mathbf{W}(k+1) = \mathbf{W}(k) - \mu \sum_{m=1}^{M} \mathbf{X}_m(k)^* y_m(k) \left\{ \left| y_m(k) \right|^2 - P_{0m} \right\} \qquad (4)$$

(ii)Only excitation phases are controllable:

$$\mathbf{P}(k+1) = \mathbf{P}(k) - \mu \sum_{m=1}^{M} \mathrm{Re}\left(j\mathbf{X}_m(k)^* y_m(k) \right) \left\{ \left| y_m(k) \right|^2 - P_{0m} \right\} \qquad (5)$$

(iii)Only excitation amplitudes are controllable:

$$\mathbf{A}(k+1) = \mathbf{A}(k) - \mu \sum_{m=1}^{M} \mathrm{Re}\left(\left(\exp(j\phi_{n0}) E_{n0} \exp(j\varphi_{n0}) \right)^* \cdot y_m(k) \right) \left\{ \left| y_m(k) \right|^2 - P_{0m} \right\} \qquad (6)$$

where **P** is the excitation phase vector and **A** is the excitation amplitude vector.

3. Numerical simulations

Numerical simulation results are shown to verify the usefulness of the proposed method. The 8-elements linear array of which the space of element is half-wave-length is supposed to be used.

(i) Null-beam synthesis by controlling excitation:

Fig.2 (a),(b),(c) show the results of the beam-forming in which main beam formed at 0 degrees and null is formed at 40 degrees. Fig.2 (a) shows the results by controlling excitation amplitude and phase, Fig.2 (b) shows that by controlling only excitation phase and Fig.2 (c) shows the results by controlling only excitation amplitude. In each case, the main beam is directed and null is formed at the desired directions.

(ii) Dual-beam synthesis

Fig.3 shows the result of the dual beam synthesis by controlling excitation phases only. The desired beam directions are –20 degrees and 40 degrees. The main beams are formed at the desired directions.

(iii) Pattern synthesis in the case the number of observation points is much than that of elements:

Fig.4 shows the results of pattern synthesis in which the number of observation points is 23(one is the main beam and other eleven points are nulls). Even in the case of the number of observation points is much than that of elements, the desired beam forming can be carried out by the proposed method.

4. Conclusion

We proposed the array antenna synthesis method of which CMA is extended to space area. The pattern synthesis is reliable in conditions that (i) Excitation amplitudes and phases are controllable, (ii) Only excitation phases are controllable and (iii) Only excitation amplitudes are controllable, by this method. If the number of the observation points is much than that of elements, the pattern synthesis can be carried out by this method.

References

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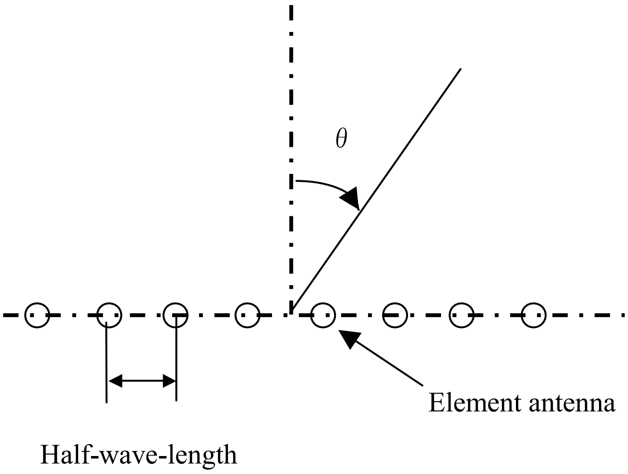

Fig.1 8-elements linear array antenna

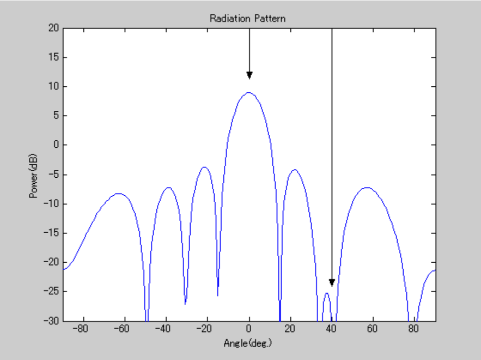

Fig.2(a) Null pattern synthesis
(Excitation amplitudes and phases are controllable.)

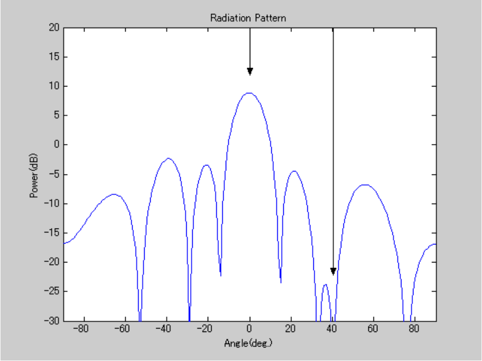

Fig.2 (b) Null pattern synthesis
(Excitation phases are only controllable.)

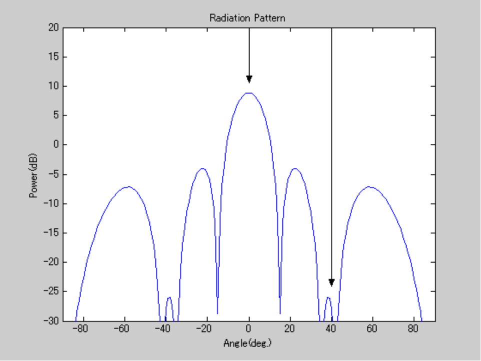

Fig.2 (c) Null pattern synthesis
(Excitation amplitudes are only controllable.)

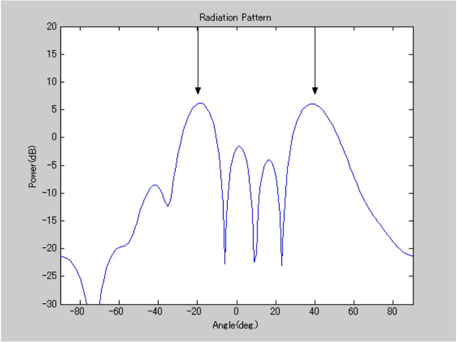

Fig.3 Dual-beam synthesis
(Excitation phases are only controllable.)

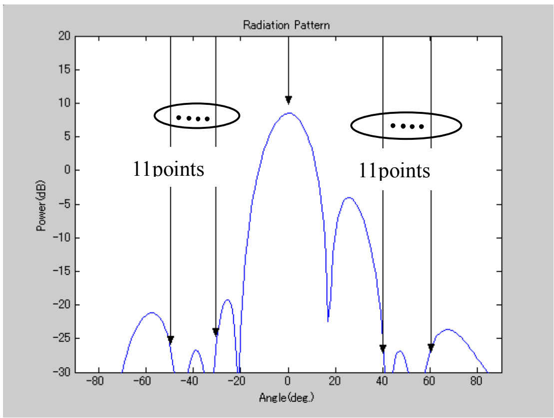

Fig.4 Pattern synthesis
(Number of observation points
> Number of elements)