MINIMIZATION OF JAMMING EFFECTS FOR PLANAR ARRAY ANTENNAS BY USING ADAPTIVE SIDE LOBE REDUCTION METHOD IN SPACE DOMAIN

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Key words: Jamming Effects, Adaptive Planar Array Antennas.

ABSTRACT

In this study, ratio of gain of the planar array antenna into target direction to those of jamming direction are maximized by weighting signals which are received each antenna with different coefficients before integration. The set of these coefficients set is found by adaptive steepest descent method. In numerical results, this algorithm is applied for given scenario and good agreement is observed.

I.INTRODUCTION

In today's technology, most of advanced radar systems use electronic beam steering planar array, such as USA national missile defence system project. Reduction of sidelobes in planar array antenna is very important topic. Because of fact that minimizing of jamming effects and using the power efficiently are depend on side lobe level.

Several methods have been proposed for reduction of sidolobe of the planar array antenna. Tapering of received signals using different weighting functions is a method for this aim [1]. However this method is not adaptive for given jamming direction and causes mainlobe beamwidth enlarging so angular resolution of radar decrease [1].

An adaptive array steers its beam towards a desired signal while simultaneously steering a null towards an undesired, interfering signal and thereby maximizing the signal-to-noise ratio of the desired signal [2]. Adaptive nulling is considered to be the principal benefit of the adaptive techniques employed by adaptive array systems [3].

Firstly, an adaptive interference nulling was recognized by Howells [4], [5]. Subsequently, a control law which maximizes signal to noise ratio (SNR) was improved by Applebaum [6]. Self-traning or self-optimizing control was applied to adaptive arrays by Widrow and others [7-9]. The self optimizing control was established on the least mean square error (LMS) algorithm that was based on the steepest descent.

Modern military forces depend heavily on electromagnetic systems for surveillance, weapon control communication and navigation. Electronic countermeasures (ECM) are used by hostile forces to degrade the effectiveness of electromagnetic system. As a result of using ECM, ECCM (Electronic counter countermeasures) are used in radar systems for ECM threat [10]. ECM includes jamming which is intentionally and deliberately signals for the purpose of interfering and disturbing radar signals.

Due to signal that come from radar is inversely proportional with r^4, it is a weak signal. r is the distance of target. In order to amplify radar signal, receiver antenna has great gain. A receiver diagram of a radar antenna is depicted in Fig. 1. Jamming signal is very strong according to the signal that come from the target. The amplitude of poynting vector of expected signal from the target is P_t, antenna gain at the main lobe is G_t. Poynting vector of jamming signal is P_j and antenna gain at the direction of jamming is G_j.

$$P_t << P_j \tag{1}$$

but

$$G_t >> G_j \tag{2}$$

so

$$P_j G_j >> P_t G_t \tag{3}$$

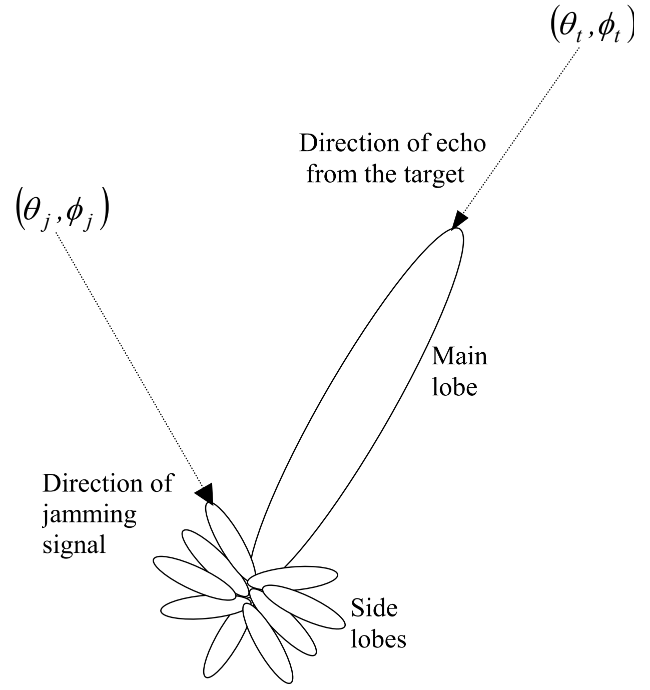

Figure 1. Receiver diagram of a radar antenna

Jamming signal effects expected and returned signal from the target. In order to cope with this problem:

i) The directions of jamming signals have to be determined.

ii) Amplitudes of radiations have to reduce to zero.

iii) When the radiation diagram is partially changed the direction of main lobe shouldn't be replaced.

Adaptive array antennas are used for these processes.

II. FORMULATION OF THE PROBLEM

A planar array antennas which consist $A_{11}, A_{12}, \ldots A_{NM}$ antennas is illustrated in Figure 2.

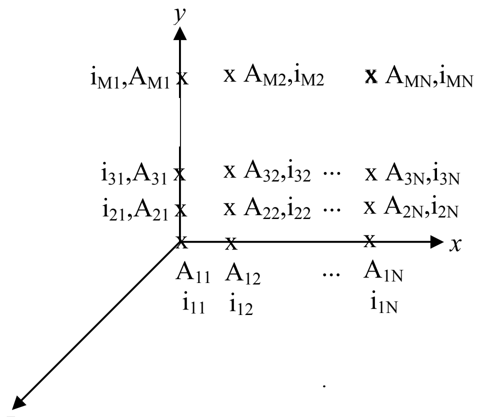

Figure 2. Planar array antennas.

For $r >> \lambda$ and $r >> A_{11}A_{1N}, A_{11}A_{MM}$, radiation field of A_{11} at $P(r,\theta,\phi)$ can be expressed as

$$\vec{E}_{11} = \vec{u}_{11} i_{11} \frac{e^{-jkr}}{r} f(\theta,\phi) \tag{4}$$

where $\vec{u}_{11}$ is unit vector in the direction of $\vec{E}_{11}$ and i_{11} is feeding current of A_{11}. The radiation fields of $A_{12}, A_{13}, \ldots, A_{1N}$ can be expressed as

$$\vec{E}_{12} \cong \vec{u}_{11} i_{12} \frac{e^{-jkr_{12}}}{r} f(\theta,\phi) \tag{5}$$

$$\vec{E}_{13} \cong \vec{u}_{11} i_{13} \frac{e^{-jkr_{13}}}{r} f(\theta,\phi) \tag{7}$$

$$\vec{E}_{1N} \cong \vec{u}_{11} i_{1N} \frac{e^{-jkr_{1N}}}{r} f(\theta,\phi) \tag{8}$$

Total electric field for linear antennas in the x-direction for $P(r,\theta,\phi)$ is given as below

$$\vec{E}_{totalx} = \vec{E}_0(\theta,\phi) I_{DX} \tag{9}$$

where

$$\vec{E}_0(\theta,\phi) = \vec{u}_{11} \frac{e^{-jkr}}{r} f(\theta,\phi) \tag{10}$$

$$I_{DX} = \left[i_{11} + i_{12} e^{jkd_2 \vec{u}_r . \vec{u}_d} + \ldots + i_{1N} e^{jkd_N \vec{u}_r . \vec{u}_d} \right] \tag{11}$$

I_{DX} is array factor in the x direction and $d_2, \ldots d_N$ are distances of antennas along x direction to origin Let's assume $\vec{u}_d = \vec{u}_x$ and $d_2 = d_x$ $d_3 = 2d_x$ $d_N = (N-1)d_x$ then (11) reduces to

$$I_{DX} = \sum_{n=1}^{N} i_{1n} e^{jk(n-1)d_x \sin\theta \cos\phi} \tag{12}$$

Similarly when linear antennas are considered in the y-direction for $P(r,\theta,\phi)$, array factor in the y direction is given as below

$$I_{DY} = \sum_{n=1}^{M} i_{m1} e^{jk(m-1)d_y \sin\theta \sin\phi} \tag{12}$$

In this condition total array factor (I_{DT}) and electric field is obtained for planar array as

$$I_{DT} = I_{DX} I_{DY} \tag{13}$$

$$I_{DT} = \sum_{n=1}^{N}\sum_{m=1}^{M} i_{nm} e^{jk\left[(n-1)d_x \sin\theta \cos\phi + (m-1)d_y \sin\theta \sin\phi\right]} \qquad (14)$$

$$\vec{E}_{totalxy} = \vec{E}_0(\theta,\phi) I_{DT} \qquad (15)$$

It is asumed that $P_t(r,\theta_t,\phi_t)$ is the target point and feeding currents have phase $\phi_{nm}(\theta_t,\phi_t)$.

$$\phi_{nm}(\theta_t,\phi_t) = -jk(n-1)d_x \sin\theta_t \cos\phi_t - jk(m-1)d_y \sin\theta_t \sin\phi_t \qquad (16)$$

In this case, total array factor (I_{DT})

$$I_{DT(\theta_t,\phi_t)} = \sum_{n=1}^{N}\sum_{m=1}^{M} i_{nm} \qquad (17)$$

is found. In this condition phase of every *MxN* antenna have to be adjusted for the main lobe direction which has 85. Total electric field at the target point for planar array

$$\vec{E}_{total}(\theta_t,\phi_t) = \vec{E}_0(\theta_t,\phi_t) I_{DT(\theta_t,\phi_t)} \qquad (18)$$

is found Similarly total electric field at the direction of jamming can be expressed as

$$\vec{E}_{total}(\theta_j,\phi_j) = \vec{E}_{10}(\theta_j,\phi_j) I_{DT(\theta_j,\phi_j)} \qquad (19)$$

It is desired that target-to-jamming ratio of antennas' gains have to reach maximum value. So desired ratio (DR) is defined in the below

$$DR = max\left|\frac{G(\theta_t,\phi_t)}{G(\theta_j,\phi_j)}\right| \qquad (20)$$

Gain of an antenna as defined as [10]

$$G(\theta,\phi) = \frac{\sqrt{\varepsilon/\mu}\,|E_{rad}|^2}{\dfrac{W_{total}}{4\pi r^2}} \qquad (21)$$

So the ratio of radiated fields must be maximum. The distance of target is further than jamming. Moreover, the ratio of radiated fields depend on distance of target and jumming place. It is sufficient that the ratio of array factors of target-to-jamming must be maximum. This ratio is found as

$$\left|\frac{I_{DT(\theta_t,\phi_t)}}{I_{DT(\theta_j,\phi_j)}}\right| = \left|\frac{\sum_{n=1}^{N}\sum_{m=1}^{M} i_{nm}}{\sum_{n=1}^{N}\sum_{m=1}^{M} i_{nm} e^{\phi_{nm}(\theta_j,\phi_j)+\phi_{nm}(\theta_t,\phi_t)}}\right| \qquad (22)$$

where

$$\phi_{nm}(\theta_j,\phi_j) = jk(n-1)d_x \sin\theta_j \cos\phi_j + jk(m-1)d_y \sin\theta_j \sin\phi_j \qquad (23)$$

The feeding currents are optimized in order to obtain maximum ratio value. So optimized ratio (*OR*) is defined in terms of dB as

$$OR = 20\,log_{10}\left|\frac{I_{DT(\theta_t,\phi_t)}}{I_{DT(\theta_j,\phi_j)}}\right| \qquad (24)$$

III. NUMERICAL RESULTS

All of the numerical results are obtained for $d_x = d_y = \frac{\lambda}{2}$, $N = M = 10$ $f = 100MHz$. Initial value of feeding current $I = 1\,A$ is chosen. In order to obtain maximum value of (24) Adaptive Steepest Descent Algorithm is used. For different target and jamming angles ($\theta_t,\phi_t,\theta_j,\phi_j$), optimized results are compared with general formula and is given in Table 1.

θ_t	ϕ_t	θ_j	ϕ_j	I=1 A OR	ASDA I=1 A (initial value) OR	Recovery
20°	45°	30°	120°	43.6 dB	341.8 dB	298.2 dB
35°	60°	50°	75°	18.45 dB	338 dB	319.55 dB
50°	75°	85°	100°	37.79 dB	346.5 dB	308.71 dB
60°	90°	75°	120°	17.38 dB	332 dB	314.62 dB
75°	120°	90°	180°	42.6 dB	93.19 dB	50.59 dB

Table 1. Comparison of optimization ratios.

4. CONCLUSIONS

In Table 1, optimized values of target-to-jamming ratio of array factors are tabulated for different target and jamming angles. A considerable improvement of target-to-jamming ratio of array factors is achieved.

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