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Array Patterns for the Radar Antenna Systems at Different Frequency Bands

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Abstract: A radar signal was analyzed and processed using MATLAB program to introduce numerous programs and functions to study and evaluate the radar antennas. The frequencies of the bands were taken as; S-band (2 and 4) GHz, C-band (5 and 8) GHz, X-band (9 and 12.4) GHz, Ku-band (16 and 18) GHz, K-band (19 and 27) GHz. The frequencies were taken at the initial and terminal of the specified bands evaluations. In this paper, analysis and synthesis techniques for the planar arrays usage in passive frequency bands target ranging were discussed. One type of elements geometries is assumed and analyzed for the array, then rectangular element geometry has been discussed. Antennas performance was discussed; and the discussion was focused on antenna fundamentals, whereas it was dealt with radar antenna parameters such as: radiated power and maximum directivity. They were also evaluated. The rectangular array antenna was also used to study the three - dimensional array radiation patterns for the given wavelengths .The radiation patterns for the rectangular planner array for the radar system were evaluated and discussed at the given dimensions of the rectangular aperture at (5x5) m^2 and element spacing at (4λ) for the given band central frequencies. It can be noticed that the variation of element spacing has main effect on performance of radiation pattern.

Key words: Radar Antennas, Radiation Patterns, Rectangular Array; Radars.

1. Introduction

A radar is an acronym for radio detection and ranging which tends to suggest that it is a piece of equipment that can be used to detect and locate a target. Radar's function is intimately related to properties and characteristics of electromagnetic waves as they interface with the targets, then it reflect waves back by an obstacle in its path [1]. The standard approach to multiple target detection is to use phase array antennas with tapering and phase shifting hardware.

2. Theory

The field radiated by any small linear antenna is an – uniformly distributed in the plane perpendicular to the axis of the antenna. Array of antennas in an arrangement, of several individual antennas so spaced and phased that their individual contributions coming in one preferred direction and cancel in all other directions, to get greater gain or directivity. Thus, an antenna array is a system of similar antennas oriented similarly to get greater directivity in a desired direction.

2.1: Array Pattern for Rectangular Planar Array

Consider a linear array of N elements with equal spacing d, and equal – phase excitations with wavelength λ [2]. A polar plot of normalized array pattern is shown in Fig. (1) which shows a sketch of an N×N planar array formed by a rectangular grid. Now, if N of these linear arrays are placed next to one another along the y-axis, a rectangular array would be formed [3]. In this case, the strength of electric field at a far field observation point is computed as the rectangular array one-way intensity pattern is then equal to the product of the individual patterns. More precisely, [4]:

$$E(\beta,\phi) = \left|\frac{\sin((Nkd_x \sin\beta\cos\phi)/2)}{\sin((kd_x \sin\beta\cos\phi)/2)}\right| \left|\frac{\sin((Nkd_y \sin\beta\cos\phi)/2)}{\sin((kd_y \sin\beta\sin\phi)/2)}\right| \quad \ldots\ldots (1)$$

Where d_x is

the element spacing along the x-axis and d_y is the element spacing along the y-axis,.

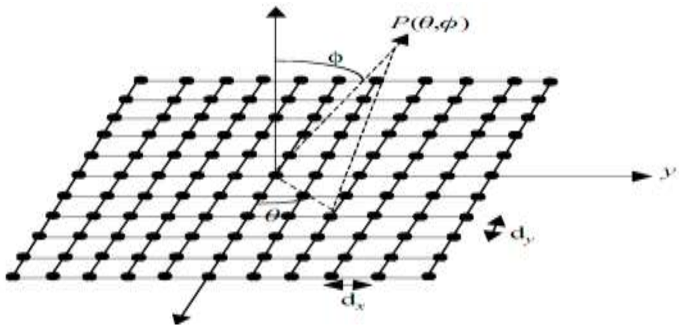


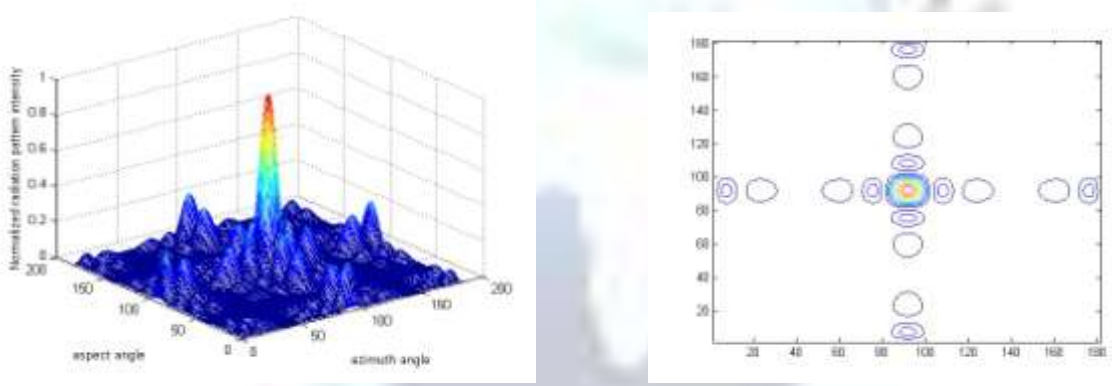
Fig. (1): Planar array geometry [5]

3. Results and Discussion

3.3: Rectangular Planar Array

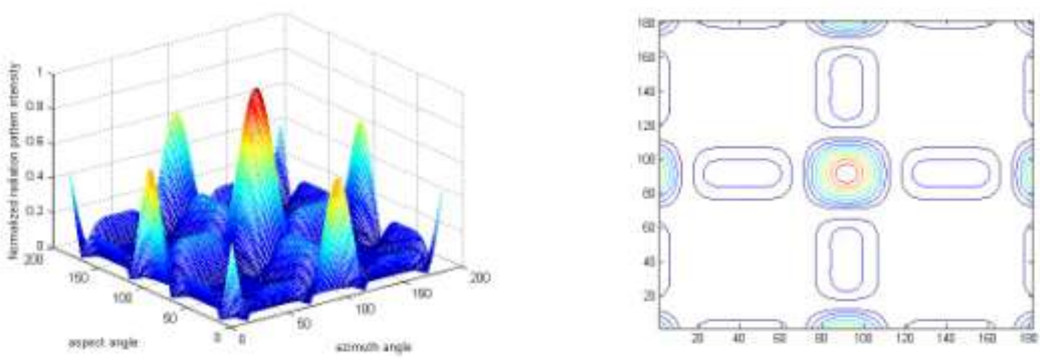
Radiation pattern of an antenna is nothing but a graph which shows the variation in actual field strength of electromagnetic field at all points which are at equal distance from the antenna. Obviously, the graph of rectangular array radiation pattern will be three – dimensional plot.

The linear array radiation pattern for rectangular linear array as well as polar coordinates was analyzed using the MATLAB program**.** The three-dimensional radiation pattern for rectangular array versus aspect and azimuth angles are shown in figures (2) up to (11) for rectangular array size [N_{ex}*N_{ey}=5*5] with isotropic elements. N_{ex} and N_{ey} which are the number of the elements in x and y directions, respectively. Also, here central frequencies are used for the following bands: S-band (f=2GHz, 4GHz), C-band (f=5GHz, 8GHz), X-band (f=9GHz, 12.4GHz), Ku-band (f=16GHz, 18GHz), and K-band (f=19GHz, 27GHz). Moreover, element spacing is uniform in x and y-direction with (dx=dy= 4λ) m.



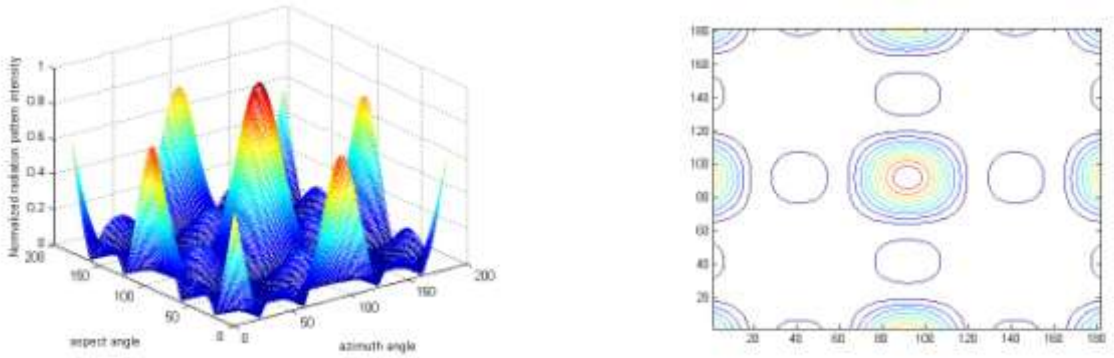
(a) (b)

Figure (2): (a): Three dimensional patterns for a rectangular array of size 5*5 dx= dy=4λ, and f = 2GHz. (b): contour plot corresponding to Fig. (a).



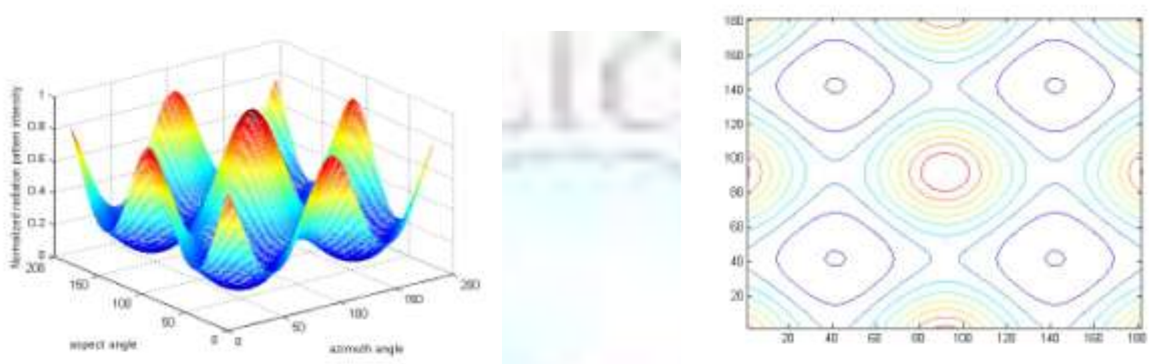
(a) (b)

Figure (3): (a): Three dimensional patterns for a rectangular array of size 5*5 dx=dy=4λ, and f = 4GHz. (b): contour plot corresponding to Fig. (a).



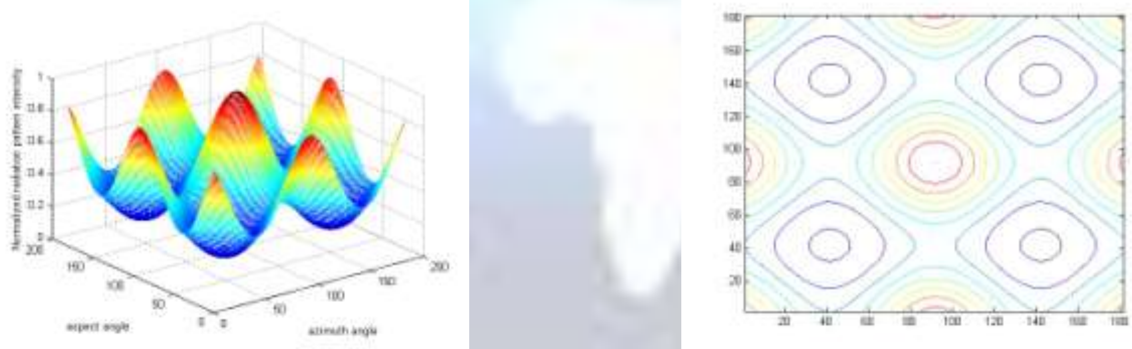
(a) (b)

Figure (4): (a): Three dimensional patterns for a rectangular array of size 5*5 dx=dy=4λ, and f = 5GHz. (b): contour plot corresponding to Fig. (a).



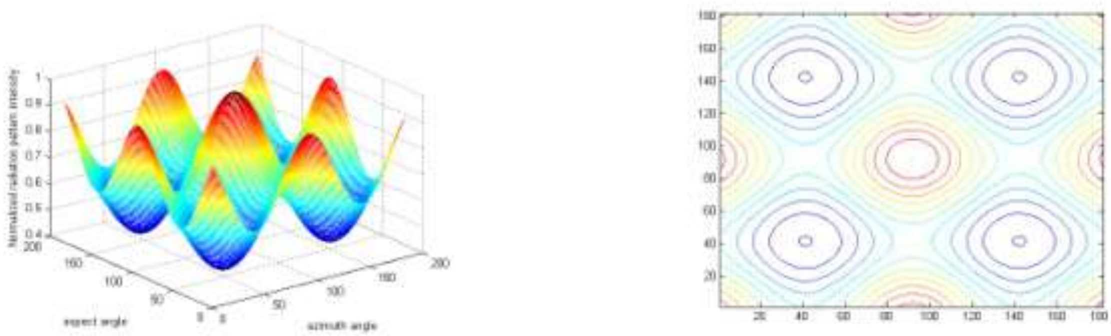
(a) (b)

Figure (5): (a): Three dimensional patterns for a rectangular array of size 5*5 dx=dy=4λ, and f = 8GHz. (b): contour plot corresponding to Fig. (a).



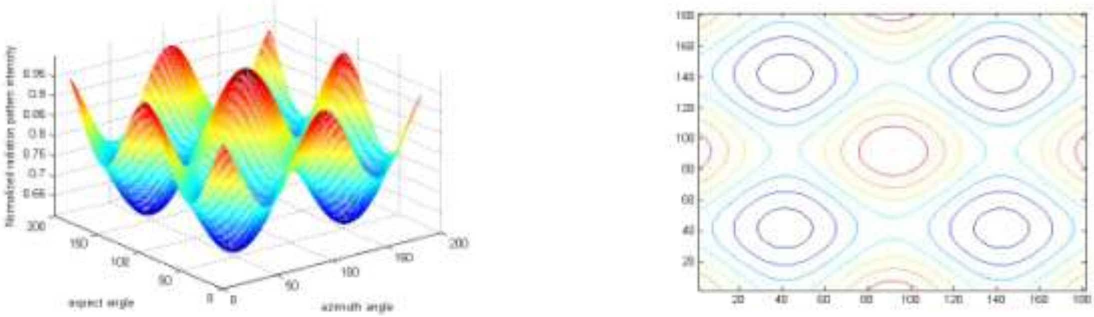
(a) (b)

Figure (6): (a): Three dimensional patterns for a rectangular array of size 5*5 dx=dy=4λ, and f = 9GHz. (b): contour plot corresponding to Fig. (a).



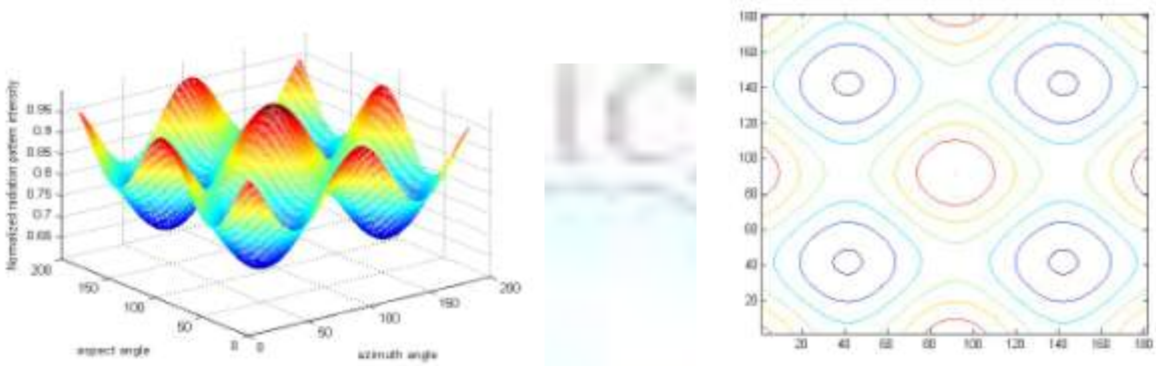
(a) (b)

Figure (7): (a): Three dimensional patterns for a rectangular array of size 5*5 dx=dy=4λ, and f = 12.4GHz. (b): contour plot corresponding to Fig. (a).



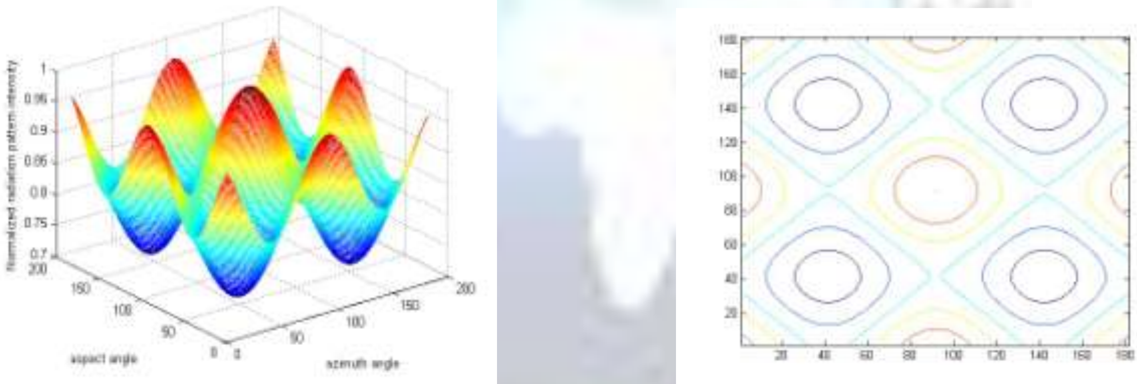
(a) **(b)**

Figure (8): (a): Three dimensional patterns for a rectangular array of size 5*5 dx=dy=4λ, and f = 16GHz. (b): contour plot corresponding to Fig. (a).



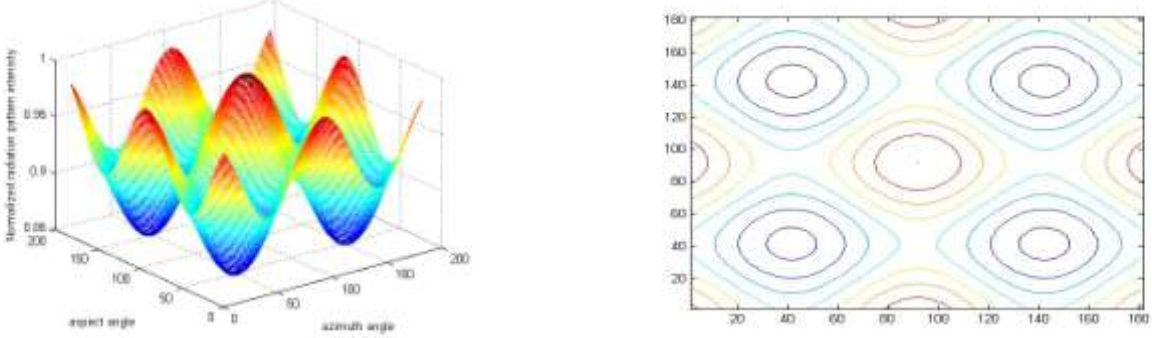
(a) **(b)**

Figure (9): (a): Three dimensional patterns for a rectangular array of size 5*5 dx=dy=4λ, and f = 18GHz. (b): contour plot corresponding to Fig.(a).



(a) **(b)**

Figure (10): (a): Three dimensional patterns for a rectangular array of size 5*5 dx=dy=4λ, and f = 19GHz. (b): contour plot corresponding to Fig. (a).



(a) **(b)**

Figure (11): (a): Three dimensional patterns for a rectangular array of size 5*5 dx=dy=4λ, and f = 27GHz. (b): contour plot corresponding to Fig. (a).

Conclusion

According to the present analysis procedures and the computed results of radar - systems, rectangular array shapes of radar's antenna, the following important conclusions can be noticed:

1- In array design, the positions of sparse array elements is an important concern for optimal performance. A new and very fast low-side lobe pattern synthesis method for planar array antennas with periodic element spacing is described.

2- Polar plot of radiation patterns as produced by a rectangular array are shown in Figures (2) up to (11). It can be noticed that the radiation pattern depends upon element spacing and frequency of bands. The number of side lobes of the radiation was increased via decreasing frequency and increasing element spacing. The maximum peak of radiation occurred at steering angle β= 30 degree.

3- The radiation patterns of rectangular planner arrays are shown in Figures (2) to (11). The number of side lobes was decreased as a result of either increasing frequency or decreasing element spacing. However, the maximum value of the radiation power occurs at θ equals either 0 degree or 180 degree.

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