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Study Comparative of Parabolic and Phased Array Antenna

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Abstract: This report focuses on two typical radar antennas, parabolic reflectors and arrays. Computations of the far-field radiation patterns and comparison are implemented. We concentrate on how to scan a focused beam and steering the antennas using some modern techniques such as linear phased array, array tapering and discrete Fourier transform DFT are also introduced.

Keywords: Far-field radiation pattern; parabolic reflector; phased array antenna; Fourier transform.

1. Introduction

The antenna is one of the most critical parts of a radar system. The Institute of Electrical and Electronic Engineers (IEEE)'s defines an antenna as "a mean for radiating or receiving radio power". It transfers the transmitter energy to signals in space with a required pattern. This process is applied in an identical way on reception. A graphic representation of the relative distribution of the radiated power in space is called a radiation pattern. Investment in the antenna therefore brings direct results in terms of system performance [3]. This paper focuses on two arrangements of antennas, the parabolic dish and the array antenna.

2. Materials and methods

Antenna far-field [2]

Based on the distance away from the face of antenna, two regions are identified. Near field, ray emitted have spherical wavefronts.

Fraunhofer regions, the wavefronts can be locally represented by plane waves (Fig. 1). Most radar systems operate in the far region.

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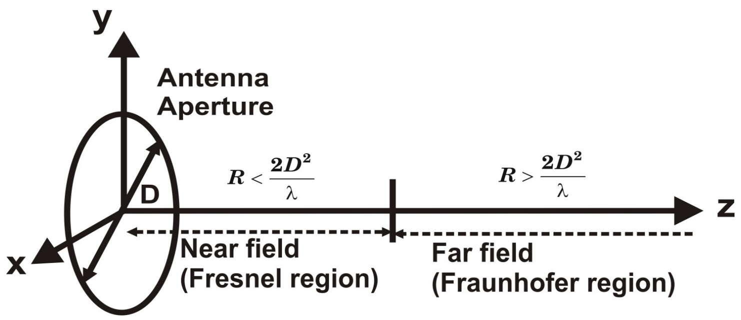

Fig. 1. Near and Far Fields of Antenna.

Parabolic antenna

Antennas based on parabolic reflectors are the most common type of the directive antennas while a high gain is required. The main advantage is that they can be made to have gain and directivity as large as required. The main disadvantage is that big dishes are difficult to mount and are likely to have a large windage.

A dish antenna consists of one circular parabolic reflector and a point source situated in the focal point of reflector. Antenna converts a spherical wave irradiating from the point source into a plane wave. Conversely, all the energy received by the dish from a distant source is reflected to a focal point. Point P is defined by range R and angular position (β,ϕ) (Fig. 2). The aperture factor at P is given by [1]:

$$E(\beta,\phi) = E(\beta) = \pi r^2 \frac{2J_1(kr\sin\beta)}{kr\sin\beta} \tag{1}$$

Where r is the aperture radius, J1 is the Bessel function. Because of the circular symmetry over the aperture, the electric field is independent of ϕ.

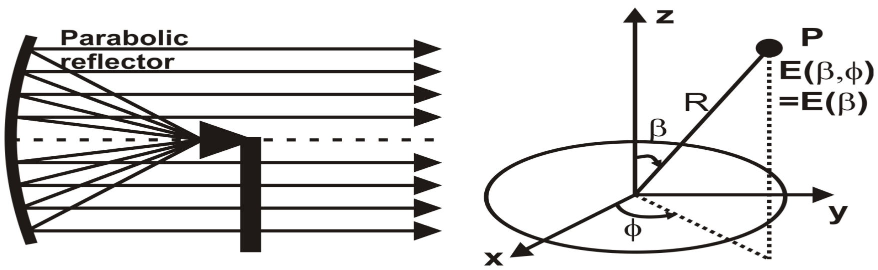

Fig. 2. Parabolic dish antenna model.

Phased array antenna [3]

An array is a composite antenna formed from two or more basic radiator elements.

The elements could be dipoles, dish reflectors... synthesize narrow directive beams that may be steered. Phased arrays use electronic steering by controlling the phase or amplitude scaling of current feeding the array elements (Fig. 3)

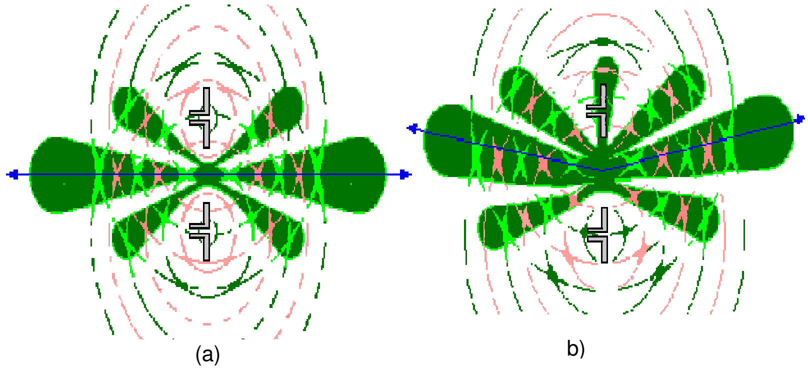

Fig. 3. Two antenna elements. (a) fed with same phase, (b) different phase.

Linear array antennas

The array factor is a function of number of elements, distance, phases and magnitudes. With direction sine sinβ:

$$E(\sin\beta) = \sum_{i=1}^{N} e^{j(i-1)(kd\sin\beta)}$$

$$\text{With } k = 2\pi/\lambda \qquad (2)$$

The power radiation pattern is calculated using Eq.(2):

$$G(\sin\beta) = |E_n(\sin\beta)|^2 = \frac{1}{N^2}\left(\frac{\sin((Nkd\sin\beta)/2)}{\sin((kd\sin\beta)/2)}\right)^2 \qquad (3)$$

As shown in Fig. 4, steering the main beam into the direction $\sin\beta_0$ is accomplished by making the phase difference between two adjacent elements equal to $kd\sin\beta_0$:

$$G(\sin\beta) = \frac{1}{N^2}\left(\frac{\sin[(Nkd/2)(\sin\beta - \sin\beta_0)]}{\sin[(kd/2)(\sin\beta - \sin\beta_0)]}\right)^2 \qquad (4)$$

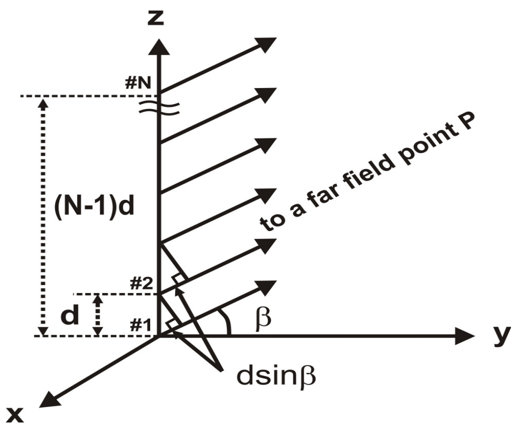

Fig. 4. Uniform linear arrays.

3. Results and discussion

The radiation pattern describes the relative strength of the radiated field in various directions from the antenna. Our results focus to describe this parameter.

Parabolic dish pattern

Fig. 5 shows a plot of the Eq.(1) computes the pattern for dish diameter d, wavelength λ. Fig. 5 illustrates the main lobe, including the undesirable sidelobes. Sidelobes can be a source of problems for a radar system. In the transmit mode the represent wasted radiated power illuminating directions other than the desired main beam direction, and in receive mode they permit energy from undesired directions to enter the system. A idealize radar antenna produces a pencil main beam. Because of irregularities in the production, the aperture distribution is Fourier Transform then the pattern has a conical form. To achieve low sidelobes, the distribution should be Gaussian, or if the antenna is so small, the radiation pattern has no sidelobes. In the Fig. 5, the first case the diameter d of the dish is three times of wavelength λ (0.3m) has more sidelobes than the latter case with d is two times of λ (0.2m).

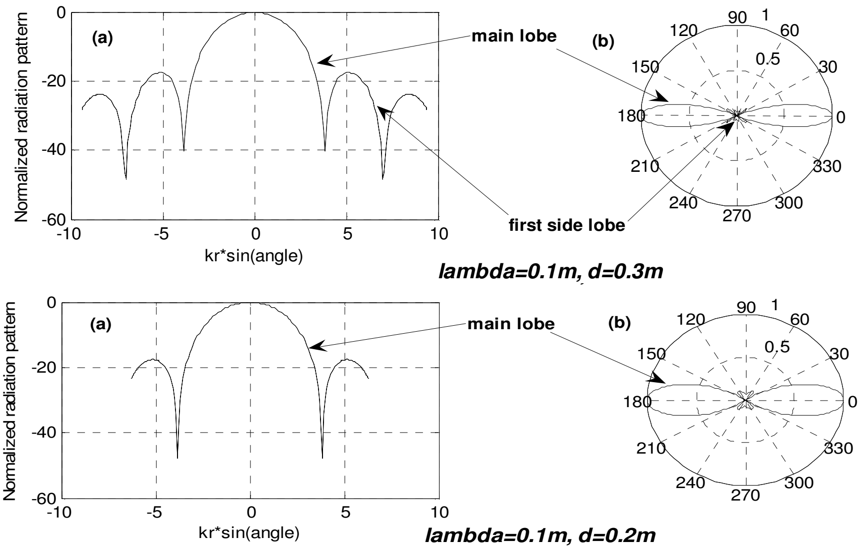

Fig. 5. (a) Circular aperture pattern, (b) Polar plot.

Linear Array pattern

Fig. 6 shows plot of the Eq.(3) versus $\sin\beta$ for N = 8.

The first maximum occurs at $\beta = 0$, and is denoted as the main lobe. Other maxima are called grating lobes that are undesirable and must be suppressed. By the calculations and showing in the Fig.(6a, b, c), d < λ. The Fig.(6d, e, f) notes how grating lobes get closer to the main beam as the element distance is increased, thus, limiting the steering capability of the array.

The steering simulation results of Eq.(4) are presented in Figure 7.

The cases of Fig. 7a, b are good for scanning operation. The element distance d should not be larger than wave length λ, (Fig. 7c,d), that means more grating lobes and will limit the steering capability of the array like the case of Fig. 6d, e, f

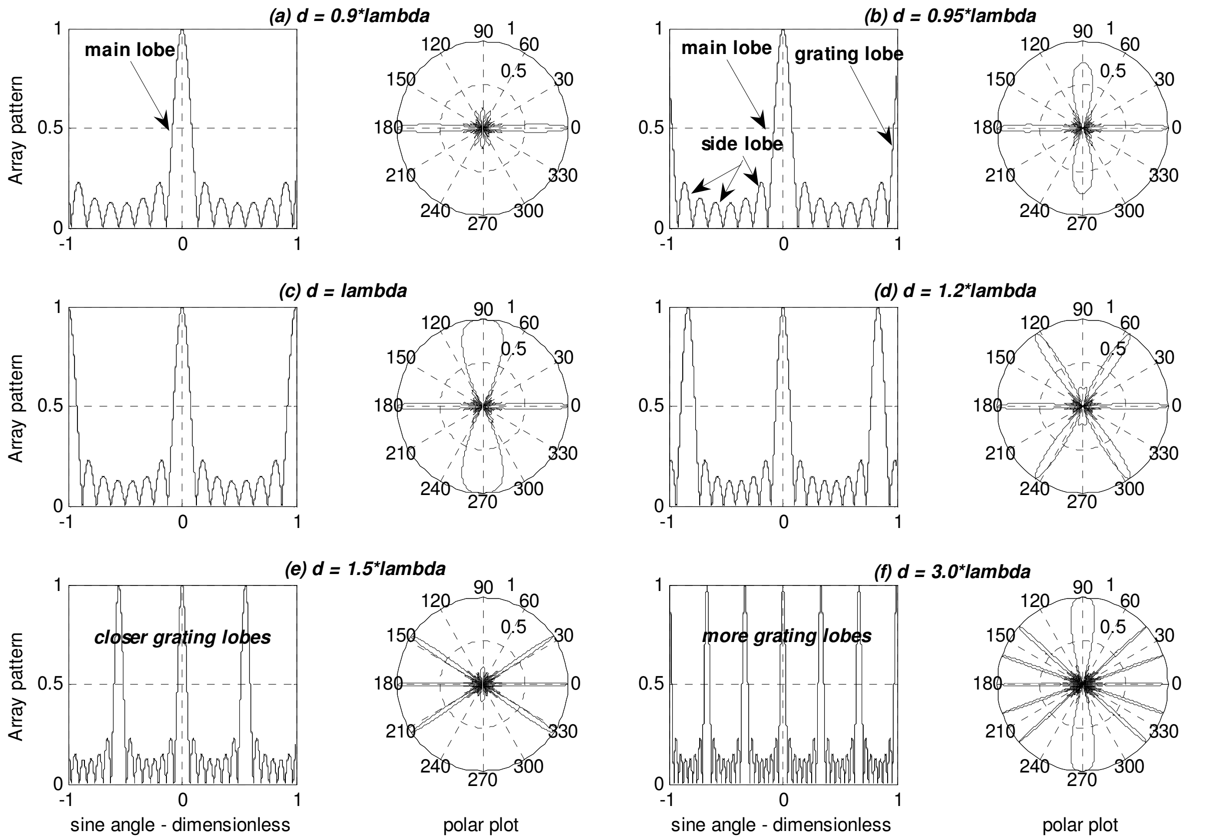

Fig. 6. Radiation pattern for a linear array with different element distance d.

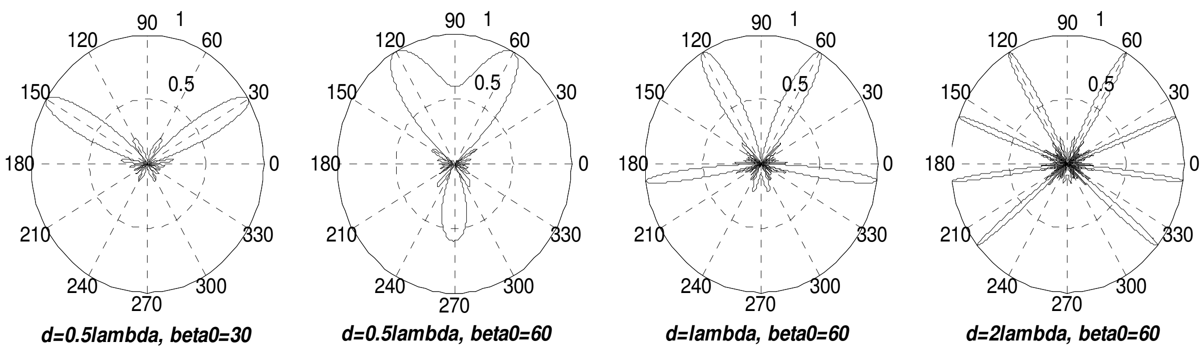

Fig. 7. Radiation pattern while steering for a linear array with different element distance d.

4. Discussion

From the simulations, experiments and refer to [3], [5], we can conclude that phased array antenna is more advantages than parabolic antenna. The most advantage is the ability of steering radiation pattern. For phased array antenna, it is flexible to steer its radiation pattern to any designed angle with only change in phased shifting or amplitude scaling. In compare with parabolic antenna, we can not steer the radiation pattern with out steering whole antenna. But parabolic antenna is usually very big and there are impacts of inertial and friction, so it's difficult to steer whole parabolic antenna or in other hand, it's difficult to steer radiation pattern of parabolic antenna. Therefore phased array antenna is known as smart antenna, or modern antenna, or active antenna. It is a new convolution in antenna technology

5. Conclusion

In radar antenna techniques, many structures of antenna, especially array antenna with varied shape of elements have been designed for special purposes. In our report, we just focus on radiation pattern of parabolic antenna and linear array antenna then compare the advantage and disadvantage of them. Next research, we are going to concentrate on reducing sidelobe level and canceling noise from certain direction.

Acknowledgments

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