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DESIGN AND ANALYSIS OF DIPOLE CHARACTERISTICS AND ITS ARRAYS

***D.SRAVANI, **Dr.M.SURENDER KUMAR**

**M.Tech Scholar, Department of ECE, KLR College of Engineering& Technology, Palvancha, khammam, Telangana - State, INDIA*

***Principal, KLR College of Engineering & Technology, Palvancha, Khammam, Telangana - State, INDIA*

ABSTRACT

Antenna is an electronic device which is the source of electromagnetic (energy) wave[1]. Antenna is a radiantly element which radiates electromagnetic energy in free space in all directions. Dipole is radiantly element which radiates directionally. The dipole is characterized by its length[11]. When the length of the dipole antenna is increased the radiation pattern becomes change and introduced side lobes.

In the pattern work Design of dipole and its array antenna systems are presented. In modern communication systems such as Satellite links, GPS, wireless local networks often require antennas with low cost high gain with narrow beams. The dipole array antennas are an useful in such cases. In this work design of dipole arrays are presented and compare with ideal array system slots are obtained with good agreement.

1. INTRODUCTION

An **antenna** (or **aerial)** is an electrical device which converts electric power into radio waves, and vice versa[2-5]. It is usually used with a radio transmitter or radio receiver. In transmission, a radio transmitter supplies an electric current oscillating at radio frequency (i.e. a high frequency alternating current (AC) to the antenna's terminals and the antenna radiates the energy from the current as electromagnetic waves (radio waves). In reception, an antenna intercepts some of the power of an electromagnetic wave in order to produce a tiny voltage at its terminals that is applied to a receiver to be amplified.

At frequencies below 3 GHz, many different types of antennas are used. The simplest is a length of wire, connected at one end to a transmitter or receiver. More often, the radiating/receiving element is placed at a distance from the transmitter or receiver and AC is delivered to or from the antenna by means of an RF transmission line also called a feed line or feeder.

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In computer and Internet wireless applications, the most common type of antenna is the dish antenna used for satellite communications. Dish antennas are generally practical only at microwave frequencies (above approximately 3 GHz). The dish consists of a paraboloidal or spherical reflector with an active element at its focus. When used for receiving, the dish collects RF from a distant source and focuses it at the active element. When used for transmitting, the active element radiates RF that is collimated by the reflector for delivery in a specific direction.

Typically an antenna consists of an arrangement of metallic conductors (elements) electrically connected (often through a transmission line) to the receiver or transmitter. An oscillating current of electrons forced through the antenna by a transmitter will create an oscillating magnetic field around the antenna elements, while the charge of the electrons also creates an oscillating electric field along the elements. These time-varying fields radiate away from the antenna into space as a moving transverse electromagnetic field wave. Conversely during reception the oscillating electric and magnetic fields of an incoming radio wave exert force on the electrons in the antenna elements causing them to move back and forth, creating oscillating currents in the antenna.

KEY WORDS: Dipole, Array Antennas, radiation pattern multiplication, Radar communication.

2. DIPOLE ANTENNA DESIGN FORMULATION

The dipole antenna or dipole aerial is one of the important and commonly used types of RF antenna. The dipole aerial or antenna is widely used on its own, but it is also incorporated into many other RF antenna designs where it forms the radiating or driven element for the overall antenna. The dipole is a simple antenna to construct and use, and many of the calculations are quite straightforward.

As seen the antenna consists of a radiating element that is split, normally in the center to allow a feeder to apply power to it from a transmitter, or to take power from it to a receiver. The length of the radiating element determines many of the properties of the dipole antenna from its impedance, center operating frequency, etc. As such this is an important feature of the antenna. Often the term dipole antenna tends to indicate a half wave dipole[1].

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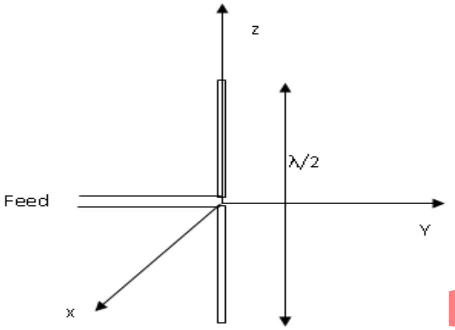

Figure.1. Radiation from Dipole Antenna

The vector potential at a point P due to the current element I dz is given by,

$$dA = dA_z a_z = \frac{\mu_0 I e^{-j\beta d} dz}{4\Pi d} a_z \qquad (1)$$

Here d is the distance from the current element to the point P. the total vector potential at P due to all current elements is given by

$$A_Z = \frac{\mu_0}{4\Pi} \int_{-H}^{H} \frac{I e^{-j\beta d}}{d} dz \qquad (2)$$

It is of interest here to consider radiation fields, d in the denominator can be approximated to r. but in the numerator, d is the phase term and it is given by

$$d = r - z\cos\theta$$

$$A_Z = \frac{\mu_0}{4\Pi} \int_{-H}^{0} \frac{I_m \, \mathrm{Sin}\beta(h + Z)}{r} e^{-j\beta(r - z\cos\theta)} dz + \frac{\mu_0}{4\Pi} \int_{0}^{H} \frac{I_m \, \mathrm{Sin}\beta(h - Z)}{r} e^{-j\beta(r - z\cos\theta)} dz$$

For a half wave dipole, $h = \frac{\lambda}{4}$

$$A_Z = \frac{\mu_0 I_m}{2\Pi\beta r} e^{-j\beta r} \left[\frac{\cos\left(\frac{\Pi}{2}\cos\theta\right)}{\sin^3\theta} \right] \qquad (3)$$

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Electric field as a function θ in free space for a dipole of length of 2H is given by the amplitude of E_θ is

$$|E_\theta| = \frac{60 I_m}{r}\left[\frac{\cos(\beta H\cos\theta)-\cos\beta H}{\sin\theta}\right] \qquad (4)$$

2.1 LINEAR ARRAYS

The graphical representations of the linear array as shown in the figure3.The elements are identical and are arranged with uniform spacing d.

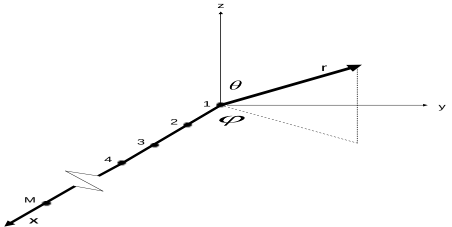

Figure: 3. Linear array

$$T = \sum_{i=1}^{N} V_i \exp[jk_0 d_i \cos\theta]$$

Where V_i is the voltage across the i_{th} slot k_0 is the free space propagation constant and d_i is the distance between first and i_{th} slot.The magnitude of the array factor may beexpressed as For the normalized array factor is given by

$$|AF|_n = \frac{\sin\left(\frac{n\psi}{2}\right)}{N\sin\left(\frac{\psi}{2}\right)}$$

Here N = number of element; ψ = βdcosθ +α; d=spacing between the elements; β= wave number.

2.2 PLANAR ARRAYS

The graphical representation of planar arrays of N X M elements are shown in figure. The principal maximum is referred to as major lobe and the remaining as grating lobes. To form or avoid grating lobes in a rectangular array the same principles must be satisfied as for a linear array.

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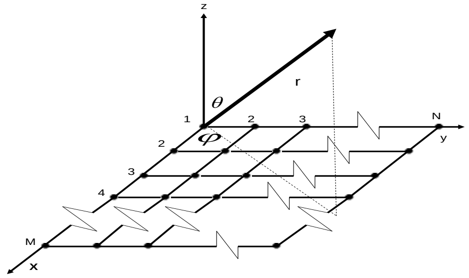

Figure: 4planararray

For the normalized planar array factor is given by

$$AF_n(\theta,\phi)=\left[\frac{1}{M}\frac{\sin(M\frac{\psi_x}{2})}{\sin(\frac{\psi_x}{2})}\right]\left[\frac{1}{N}\frac{\sin(N\frac{\psi_y}{2})}{\sin(\frac{\psi_y}{2})}\right] \qquad (8)$$

Where
$$\psi_x = kdx\sin\theta\cos\phi+\beta_x,$$
$$\psi_y = kdy\sin\theta\sin\phi+\beta_y$$

2.4 PATTERN MULTIPLICATION

` Pattern multiplication [1] is defined that resultant pattern is equal to the array factor multiplied with the element pattern i.e.The resultant pattern of an array of non-isotropic identical radiators is given by

$$E(\theta)_{\text{resultant}} = \text{Element Pattern} \times \text{Array Factor}$$

$$E=f(\theta,\phi)F(\theta,\phi)\times((f_p(\theta,\phi)+F_p(\theta,\phi))$$

Where $f(\theta,\phi)$ = Element field pattern; $f_p(\theta,\phi)$ = Element phase pattern; $F(\theta,\phi)$ = Array factor of isotropic elements; $F_p(\theta,\phi)$ = Phase pattern of array of isotropic elements.

3. RESULTS

Half wave dipole antenna is designed and obtained the radiation patterns by using the equation6. The results are presented in the tabular form 1 by changing dipole length with multiple of λ. It is observed that the 3-db beam width is decreased by measured the dipole length and obtained the number of side lobes.The radiation pattern are presented from figure 5 to 28 by using the equation (4) in both polar and rectangular form. Since the gain providing by the single element is not sufficient in most of the communication applications, a dipole array antenna system is designed by using the pattern multiplication principle in bothlinear and planar systems.

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The results are compared with the isotropic radiations and are obtained with good agreement. The patterns are drawn for N=5, 10, 20, 60,100, and are shown from figure 29 to 40. There are used in wireless communication system. The following table shows the change in 3-dB beam width, null to null beam width, main beam width and the number of side lobes for a dipole antenna by changing the length of dipole.

S.No	**Dipole Length**	**3-Db beam Width(deg)**	**Null to Null beam Width(deg)**	**Main beam width**	**Number of Side lobes**
1	0.5λ	85	180	1	-
2	λ	46	158	0.5	-
3	1.5λ	28	84	0.45	2
4	2λ	20	65	0.4	-
5	3λ	18	60	0.35	2
6	4λ	15	47	0.32	4
7	5λ	14	44	0.3	6
8	6λ	13	39	0.25	8
9	7λ	12.5	36	0.2	10
10	8λ	10.5	35	0.15	12
11	9λ	10.3	34	0.5	14
12	10λ	10	33	0.5	16

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Table 1 : Dipole characteristics by changing length of the dipole with multiple of λ.

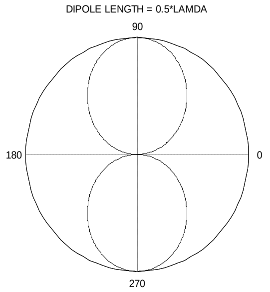

Fig.5. Polar plots of dipole antenna for L=0.5 λ

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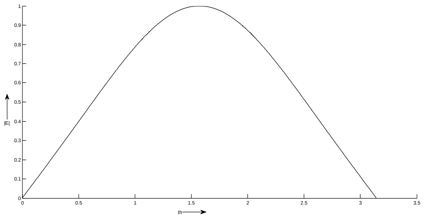

Fig.6. Rectangular plots of dipole antenna for L=0.5 λ

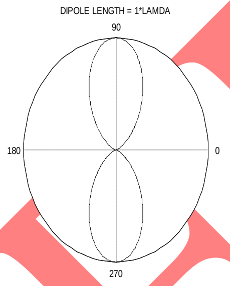

Fig.7. Polar plots of dipole antenna for L= λ

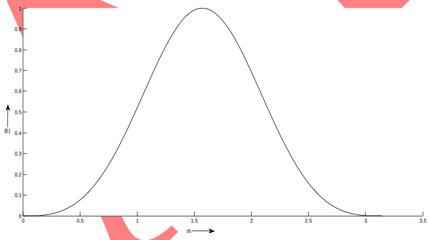

Fig.8. Rectangular plots of dipole antenna for L= λ

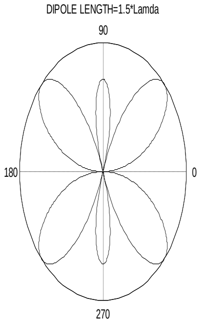

Fig.9. Polar plots of dipole antenna for L=1.5 λ

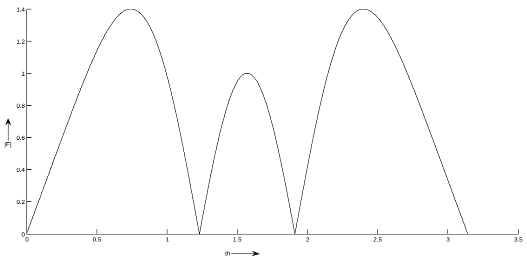

Fig.10. Rectangular plots of dipole antenna for L=1.5 λ

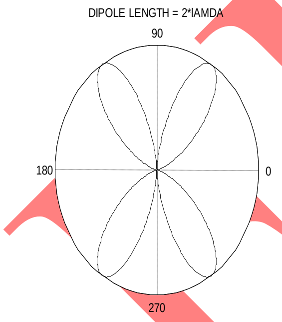

Fig.11. Polar plots of dipole antenna for L=2 λ

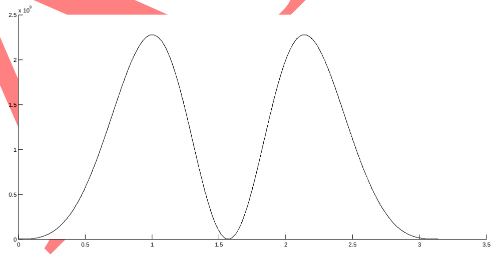

Fig.12 Rectangular plots of dipole antenna for L=2 λ

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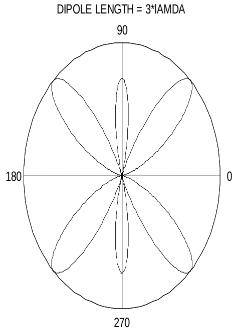

Fig.13. Polar plots of dipole antenna for L=3 λ

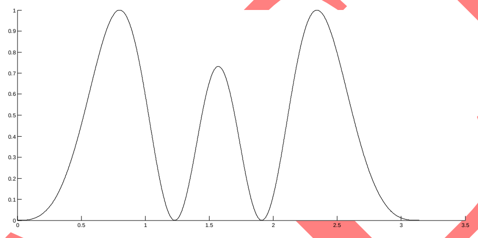

Fig.14. Rectangular plots of dipole antenna for L=3 λ

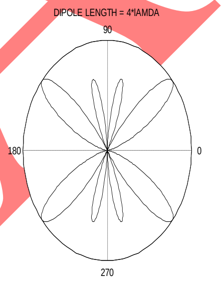

Fig.15. Polar plots of dipole antenna for L=4 λ

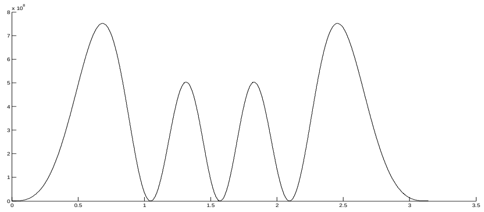

Fig.16. Rectangular plots of dipole antenna for L=4 λ

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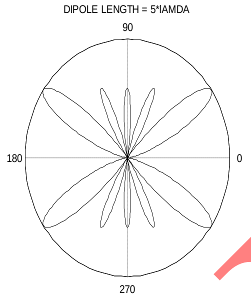

Fig.17 Polar plots of dipole antenna for L=5 λ

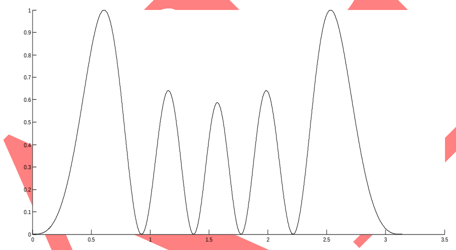

Fig.18. Rectangular plots of dipole antenna for L=5 λ

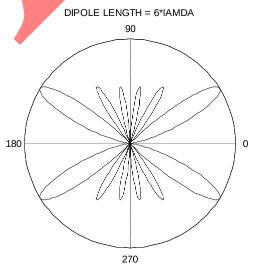

Fig.19. Polar plots of dipole antenna for L=6 λ

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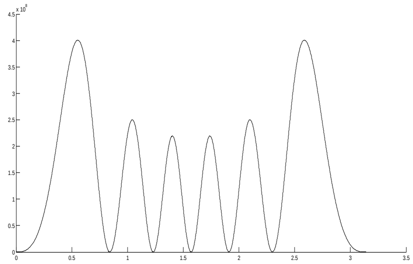

Fig.20. Rectangular plots of dipole antenna for L=6 λ

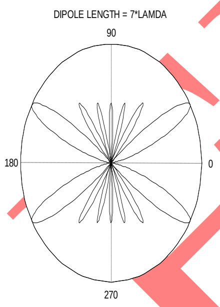

Fig.21 Polar plots of dipole antenna for L=7 λ

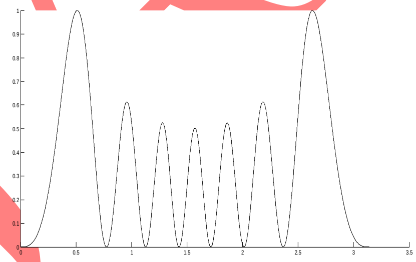

Fig.22.. Rectangular plots of dipole antenna for L=7 λ

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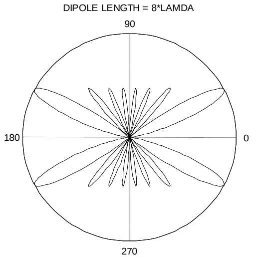

Fig.23. Polar plots of dipole antenna for L=8 λ

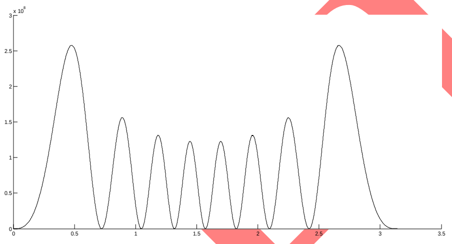

Fig.24 Rectangular plots of dipole antenna for L=8 λ

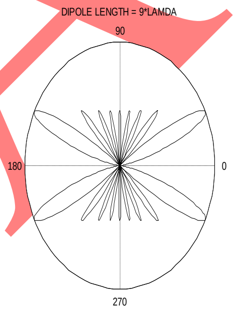

Fig.25. Polar plots of dipole antenna for L=9 λ

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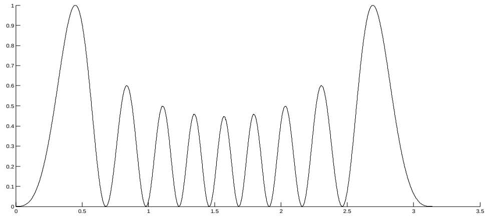

Fig.26. Rectangular plots of dipole antenna for L=9 λ

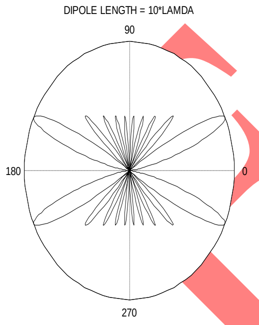

Fig.27. Polar plots of dipole antenna for L=10 λ

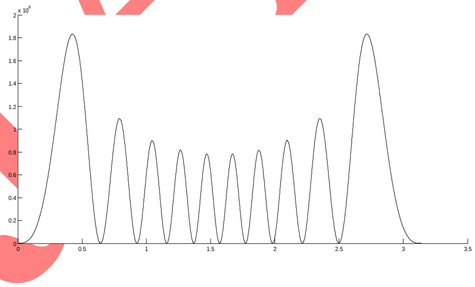

Fig.28 Rectangular plots of dipole antenna for L=10 λ

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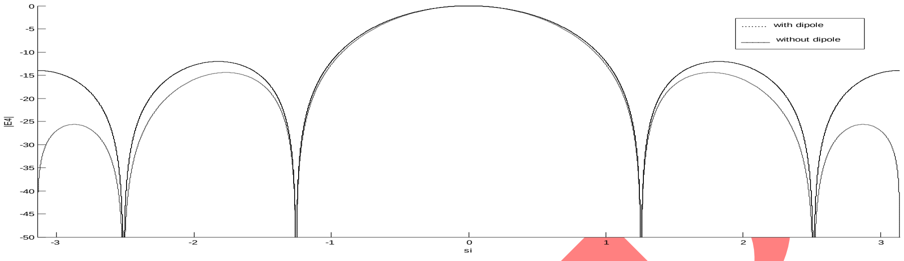

Figure:29 Radiation pattern of dipole antenna for N=5 elements of Linear array in rectangle

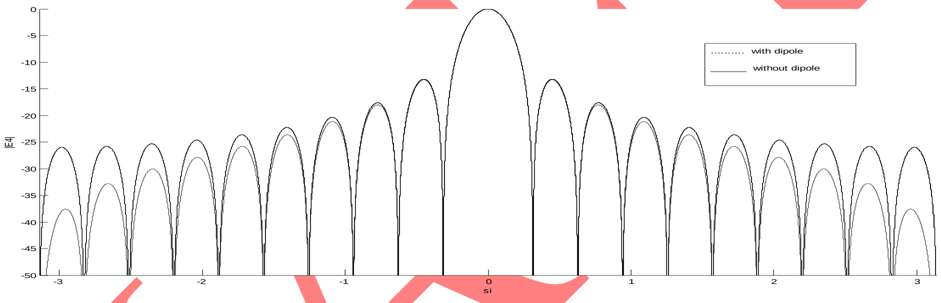

Figure:30 Radiation pattern of dipole antenna for N=20 elements of Linear array in rectangle

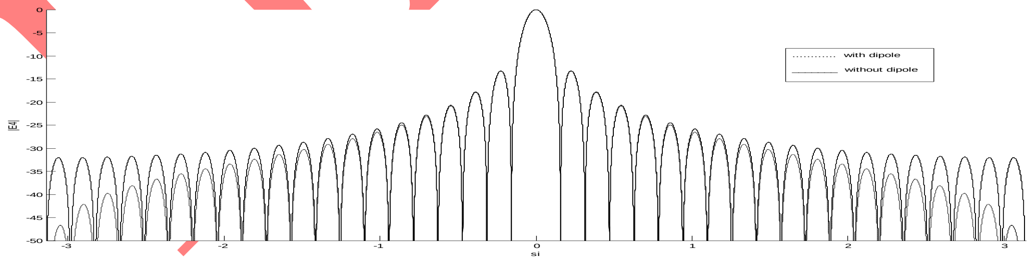

Figure:31. Radiation pattern of dipole antenna for N=40 elements of Linear array in rectangle

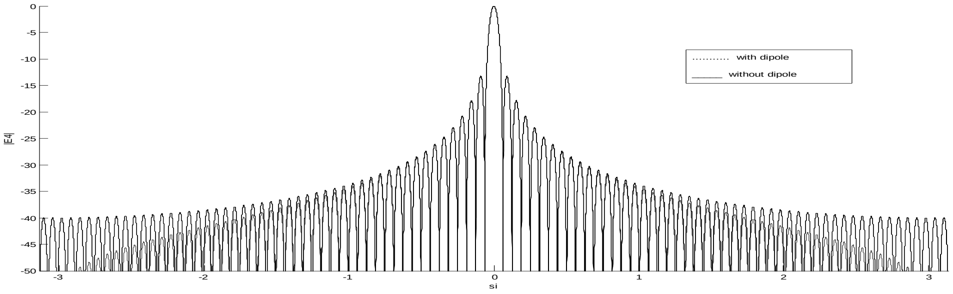

Figure:32. Radiation pattern of dipole antenna for N=100 elements of Linear array in rectangle

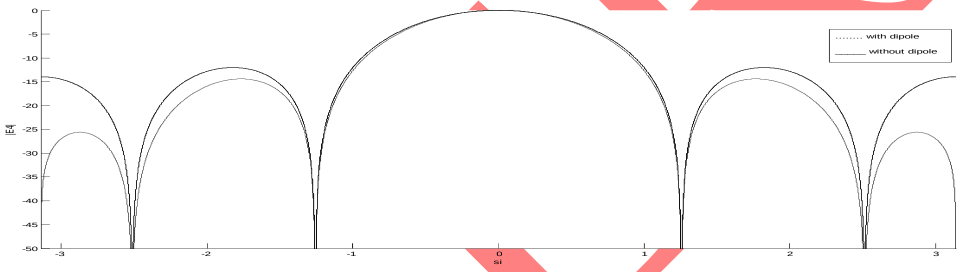

Figure:33. Radiation pattern of dipole antenna for N=5 elements of Planar array in rectangle

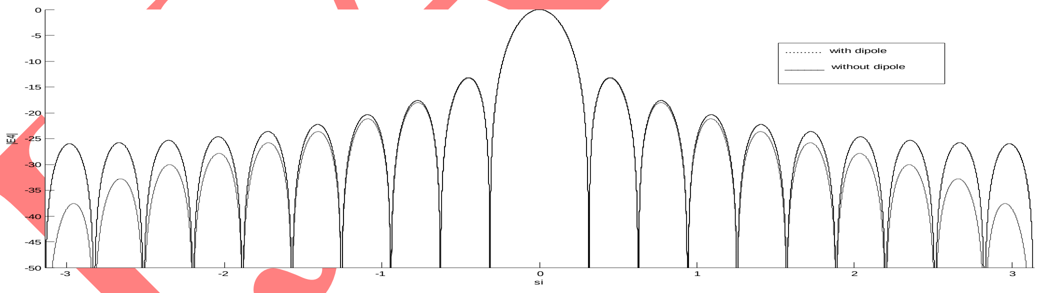

Figure:34. Radiation pattern of dipole antenna for N=20 elements of Planar array in rectangle

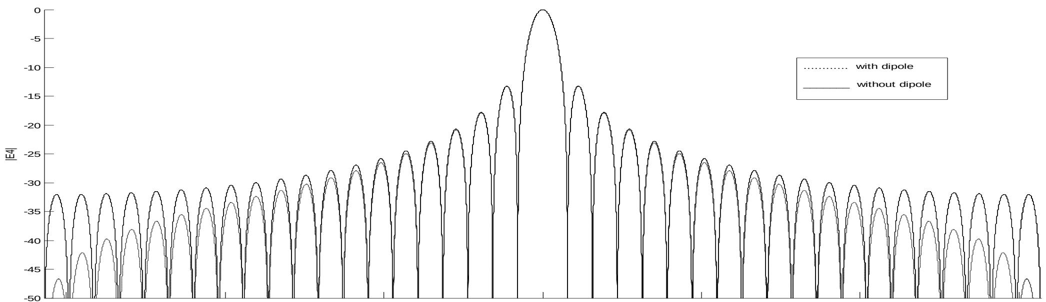

Figure:35. Radiation pattern of dipole antenna for N=40 elements of Planar array in rectangle

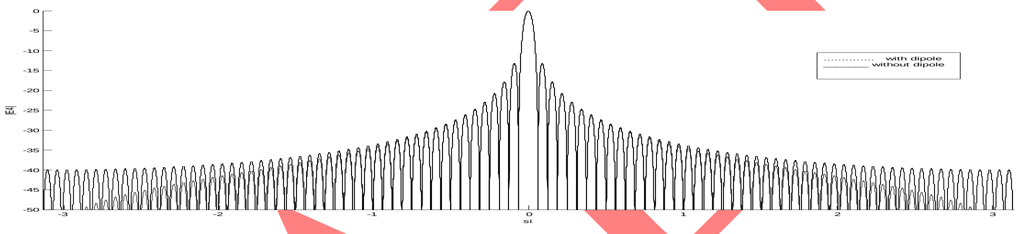

Figure:36. Radiation pattern of dipole antenna for N=100 elements of Planar array in rectangle

4. CONCLUSIONS

The design and analysis of dipole antenna have been described here. The characteristics of dipole antennaand its field patterns are plotted for different lengths i.e., from 0.5λ to 10λ. 3 dB beam width, number of side lobes and null to null beam width are identified from the results. The 3dB beam width is reduced when the dipole antenna length is increased.The array field patterns of both linear array and planar array are plotted and their results are presented. Using pattern multiplication the linear array and planar array radiation patterns are also drawn for different values of N and M. The main beam width reduced when the numbers of elements are increased. These are useful in Satellite and Rader communications.

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AUTHORS BIO- DATA

1. **Ms. D. Sravani,**: received her B. Tech From JNTU-Hyderabad with Distinction, Presently Pursuing M. Tech , from KLR College of engineering and Technology-Paloncha affiliated to Jntu-Hyderabad.

2. **Dr. M. Surendra Kumar** received his B.Tech from Nagarjuna University and M. Tech, Ph.D. from Andhra University. He has 18 years of teaching experience. He published 23 technical papers in National and International conferences and journals. His fields of interest are Antennas and wave propagation, Microwave engineering and Radar Engineering. Presently he is working as a Principal in K

L R College of Engineering & Technology- Paloncha, Khammam -Dist, Telangana

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