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Beam Steerable Dipole Antenna Array

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Abstract
In this research a dipole antenna array with beam steering capabilities with operative frequency of 1 GHz is designed and analyzed. The designed dipole antenna array includes five dipole antennas. The phase of individual elements in the array is changed in order to achieve beam steering capabilities. Return loss and radiation pattern characteristics of antenna array is analyzed using High Frequency structure simulator to analyze the performance and beam steering capabilities of designed dipole antenna array.

Index Terms—Dipole antenna, Return loss, Beam steering.

1. Introduction

Dipole antennas due to their extraordinary features like low profile design, low cost and ease to install are extensively used for the purpose of transmitting and receiving the electromagnetic signals. In its most basic form, a dipole antenna consists of two metallic dipoles fed at the center as shown in Fig (1). The length of antenna decides the operative frequency of antenna. Fringing fields also affect the equivalent length of antenna and hence must be taken care of while deciding the resonant frequency of dipole antenna.
Length (L) of antenna required to operate on a particular frequency(*f*) is related by

$$L = \frac{\lambda}{2} \quad \text{Where} \quad \lambda = \frac{3*10^8}{f}$$

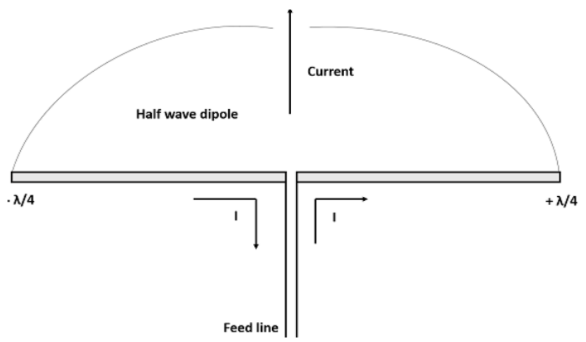

Figure1. Dipole Antenna

One limitation of dipole antenna is its low gain. This limitation can be overcome by using arrays of antennas. Array of dipole elements are used to achieve high gain and desired radiation pattern. The radiation pattern of antenna array can be calculated by multiplying the radiation pattern of single element and antenna array factor. For N element antenna array in one dimension array factor is given by

$$AF(\theta) = \sum_{n=1}^{N} I_N e^{i\alpha} e^{(ikdcos\,\theta)} \;------------\; (\mathbf{1})$$

Here antenna elements are separated by distance d. I_N is the magnitude of feeding current to various elements. α Is the progressive phase shift between antenna elements. The point of observation makes angel θ with array axis and k is phase shift constant.
Enhanced beam steering and side lobe reduction can be achieved by arranging antenna elements in two dimensional arrays. When antenna elements are arranged in two-dimensional structure then array factor is given by

$$AF(\theta,\varphi) = \sum_{m=0}^{M-1}\sum_{n=0}^{N-1} I_{mn} e^{i\alpha_{mn}} e^{(ik\,\hat{r}.\vec{r}_{mn})} \;--------\; (\mathbf{2})$$

I_{mn} is the magnitude of feeding current of mn^{th} element.
$\vec{r}_{mn}$ Is the location of mn^{th} element.

$$\vec{r}_{mn} = x_{mn}\hat{x} + y_{mn}\hat{y} + z_{mn}\hat{z}$$

And

$\hat{r}$ is the location of observation point

$$\hat{r} = Sin\,\theta\,cos\,\emptyset\,\hat{x} + Sin\,\theta\,Sin\,\varphi\,\hat{y} + Cos\,\theta\,\hat{z}$$

α_{mn} is the excitation phase difference between elements.

By using antenna arrays signals interfere and resultant radiation pattern is enhanced. At constructive interference gain is increased while at destructive interference gain is reduced.

In order to achieve beam steering capabilities array elements are to be fed with variable phases[1-5].

In this research first a dipole antenna is designed for 1 GHz. Dipole antenna array is achieved by using five elements of dipole antenna. Phase of individual elements are varied in order to achieve beam steering capabilities.

2. Results and Discussion

The structure of dipole Antenna designed using High Frequency Structure Simulator for 1 GHz is shown in Fig (2).

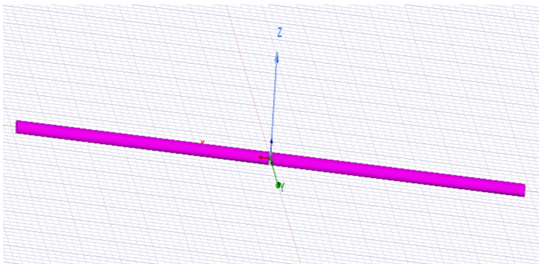

Figure 2. Structure of dipole Antenna

The scattering parameter at Port 1 is measured to be -17 db. and is shown in Fig (3). This indicates a good matching between source and antenna.

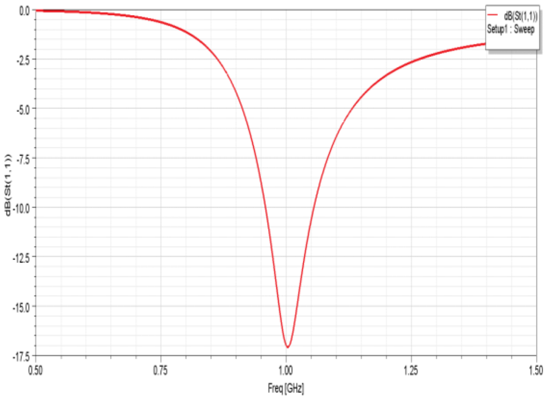

Figure 3. S_{11} graph of dipole antenna.

The Radiation Pattrn of designed dipole antenna is shown in Fig (4). A gain of 2.5 dB is achievable from designed dipole antenna.

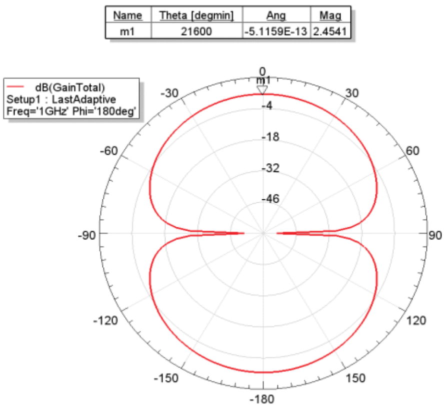

Figure 4. Radiation Pattern of planar dipole antenna.

An array of five dipole elements designed using HFSS is shown in Fig (5).

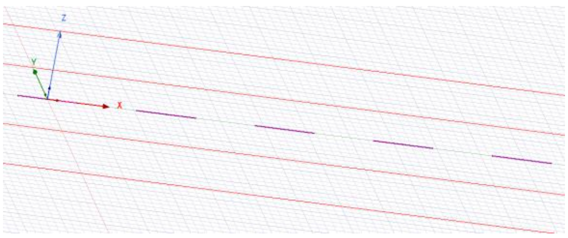

Figure 5. Dipole array

Here all antenna elements are excited with input signal of 1 Watt with input phase of zero degree. The Radiation Pattrn of designed dipole antenna array is shown in Fig (6). A gain of 9 dB is achievable from designed dipole antenna. Now by keeping the input power of 1 Watt to each element, the phase of each element is progressively changed by 45°. The resultant radiation pattern of antenna array is shown in Fig (7). From the results it is pertinent to mention that radiation pattern maximum had been tilted by 8^0 due to progressive phase shift of 45^0 between antenna elements. Further magnitude of side lobes is also reduced up to a large extend.

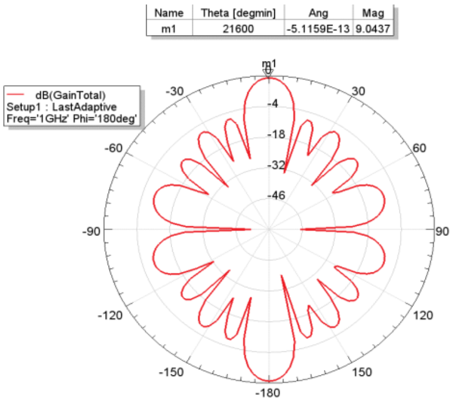

Figure 6. Radiation Pattern of planar dipole antenna array

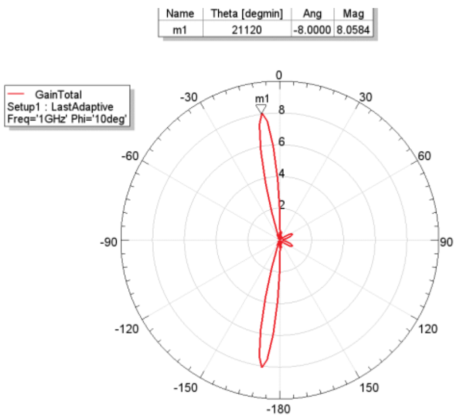

Figure 7. Radiation Pattern of planar dipole antenna array with progressive phase shift of 45°.

Conclusion

A beam steerable dipole antenna array having gain of 8 dB and beam steering by 8° is designed by progressive phase shift of 45° between antenna array elements.

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