Analysis on Linear Planar Antenna in X-Band Range

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Abstract –Wireless communication technology has expanding its wings in recent past times. One cannot separate the advancement of wireless systems without antenna engineering. In this work, an antenna has been designed in X-band which extends between 8GHz to 12GHz. The outcome of this work has found its applications in the wireless communication systems, space wave communication, Radar and Sonar systems. The designed antenna is a linear and planar in nature with metallic conductors placed serially. Out of the four available feeding techniques, microstrip edge feed has been chosen and all the dimensions are calculated as per transmission line cavity model equations. Primary parameters of an antenna like gain, directivity, impedance matching axial ratio and standing wave ratio were observed and based on it; the performance of planar antenna has been stated. HFSS software is the platform to implement this work.

Index Terms – Electromagnetic Spectrum, HFSS, Linear planar antenna, Microstrip edge feed, Transmission line cavity model, X-band.

1. INTRODUCTION

Electromagnetic spectrum has been widely spread both in terms of frequency and wavelength. Depending upon the range of frequencies, the entire spectrum has been sub divided into several bands namely C, S, X, K, Ku, Ka etc [1]. Each band has its own range of frequencies and enormous number of applications in the field of science and technology, research and development, communication systems and so on. Radar and Sonar are immensely being operated in the X-band i.e., 8GHz to 12GHz [2]. These systems which are used in this range are highly dependent on the feeding methodology. Hence high precision sources and detectors were deployed. Among all the bands in the electromagnetic spectrum, X-band found number of applications in almost all the advanced scientific technologies because of the reason that it has high penetration, radiation intensity along with the spectroscopy [3].

The designing of an antenna in the X-band needs the high attention in the aspect such as interference of noise components into the radiated signal to the receiver. Here, in this work a group of conducting elements are arranged serially with each other and operated in the X-band to give the adverse characteristics.

An Antenna is nothing but a matching device that provides the impedance matching between the source element and the load [4]. A simple conducting element can act as an antenna provided that there must be morphological changes in its structure. The source element is always responsible for radiating energy towards the receiver. As in case of communication system both the source and load are separated by long distance, a flaring is done to the antenna such that it can radiate the energy upto long distances with minimal degradation in the signal energy.

In order to determine, how good the performance of the communication system, the antenna should display appreciable gain, directivity, impedance matching and bandwidth along with the radiation patterns. High gain, low physical size, broad bandwidth, versatility are the primary factors which are to be considered an antenna for any system and these factors can greatly compensate the involvement of antenna in many contemporary fields of engineering.

The other important parameters of an antenna are bandwidth and beamwidth. Bandwidth is an important factor through which the appropriate utilization of the spectrum can be determined. The antenna bandwidth can be defined for impedance, radiation and polarization [5].

Impedance bandwidth is the basic consideration for any antenna design, which permits the maximum energy to be transferred from source to load. Maximum or minimum energy radiation along a specified direction can be ensured by radiation bandwidth. The loss in the radiation due to polarization mismatch can be reduced by a well defined polarization bandwidth.

2. ANTENNA GLOSSARY

An antenna can always be a radiator, hence in this context a planar radiator significantly equivalent to the planar antenna. The only discriminating factor between the coplanar and non coplanar antenna is the geometrical position of the ground i.e. whether the ground is placed above the substrate or below the substrate [6]. The feeding techniques and the method of analysis are always same for both the planar and non co planar radiators.

The reason because planar antenna has grabbed the attention of researchers is, low manufacturing cost than the waveguide based technology and are considerably low weight and compact. The secondary reason is the planar nature of antenna makes the radiator ideal for array structure. The ease of integration with the microwave and millimeter circuit components is the important factor that makes the planar integrated antenna so desirable [7]. The ability of the transmission lines to integrate with 3 terminal devices makes possible to use for feeding both the planar and non co planar waveguides.

In air wave communication, telecommunications and space wave communication there is an obvious use of antenna but in order to make the system compact and flexible the antenna which is being installed in those systems should also posses the low profile features and miniaturized structure [8]. As the planar patch antennas are well known for their low weight, small size and compactness, these antennas are extensively being implemented in various research activities.

3. PORPOSED MODELLING

The procedure for designing an antenna involves number of stages and the design can be accomplished using several platforms. The mathematical representation of antenna parameters can be done using Matlab software. Electromagnetic simulators can be used to simulate the antenna structure which gives the better perception to the designer. Here in this endeavor structure simulation software has been used. The structural representation of antenna includes substrate, patch, ground, feedline and a radiation box. One cannot confine to a particular order in defining and designing these objects.

Choosing a material for the design and fabrication is the major task which includes lot of ground work. The change in material properties leads to the undesirable characteristics. A substrate material must always be a dielectric one with some dielectric constant (ε_r). Rogers RT/Duroid 5880 is the substrate material for the designed antenna with a dielectric constant of 2.2. The patch is a conducting element which is responsible for the radiation of an antenna. Copper is the conducting element with the relative permittivity of unity.

Transmission line model is the best method to analyze the planar antenna and the microstrip antenna. In this method of analysis, the width 'W' and height 'h' of the patch and the substrate will be mentioned precisely [9]. For an antenna to be designed, the dimensions must be calculated using the model equations. The line model provides the equations to calculate the dimensions for length and width of patch, feedline, feed point and transmission line. The feedline can be either a inset feed or the edge feed with their own equations to calculate the dimensions.

The desired range of operating frequency for this antenna is X-band which extends from 8 to 12GHz. The central frequency can be anything in between that range and the dimensions of the antenna were dependent on the operating frequency.

The following are the design equations using transmission line model [9].

Width of the patch is given by following relation.

$$W = \frac{1}{2 f_r \sqrt{\mu_0 \varepsilon_0}} \sqrt{\frac{2}{\varepsilon_r + 1}} = \frac{\lambda_0}{2} \sqrt{\frac{2}{\varepsilon_r + 1}} \quad (1)$$

In the above equation, λ_0 is the operating wavelength.

An effective dielectric constant can be determined as follows.

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \left(1 + 12 \frac{h}{W}\right)^{-1/2} \quad (2)$$

Where 'h' is the height of the substrate material.

Extension in length due to fringing effect is given by following relation.

$$\frac{\Delta L}{h} = 0.412 \frac{\left(\varepsilon_{reff} + 0.300\right)\left(\frac{W}{h} + 0.264\right)}{\left(\varepsilon_{reff} - 0.258\right)\left(\frac{W}{h} + 0.800\right)} \quad (3)$$

Actual patch length after including the extended length is

$$L = \frac{1}{2 f_r \sqrt{\varepsilon_{reff} \mu_0 \varepsilon_0}} - 2\Delta L = \frac{\lambda_0}{2\sqrt{\varepsilon_{reff}}} - 2\Delta L \quad (4)$$

By using the above formulae which were derived using transmission line model, the dimensions of the designed antenna has been tabulated as follows.

Table 1: Dimensions of the linear planar antenna

S.No	Object Name	Dimensions
1	substrate (length, width, height)	70mm. 200mm. 1.6mm
2	patch (length, width, height)	50mm. 170mm. 0.017mm
3	feedline (length , width, height)	3.29mm. 7.9mm. 0.017mm
4	ground (length, width, height)	70mm. 200mm. - 0.017mm

5	radiation box (length , width, height)	90mm. 200mm. 20mm
6	feed point (In XZ plane)	16.45mm. 6.72.
7	cylindrical Slots	Radius = 2mm Height = 1.6mm

The gain and directivity of an antenna can be concentrated in single direction and multiple directions based on which the antenna can be comes under the category of either Omni directional or isotropic. Gain of an antenna can be varied from far field to near field. Hence in order to provide discrimination between the near fields and far field the radiation box is always included in the antenna design [11]. The radiation box is always composed with air as a medium with dielectric constant of unity. Due to the change in the values of the relative permittivity between the device and the free space fringing effect will occurs which leads to change in the antenna dimension. While calculating the dimensions, the length of the patch should be taken as per fringing effect.

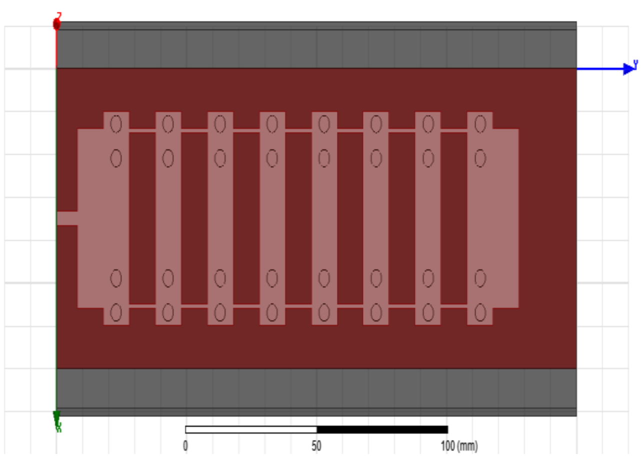

Figure 1. Structure of Linear Planar Antenna

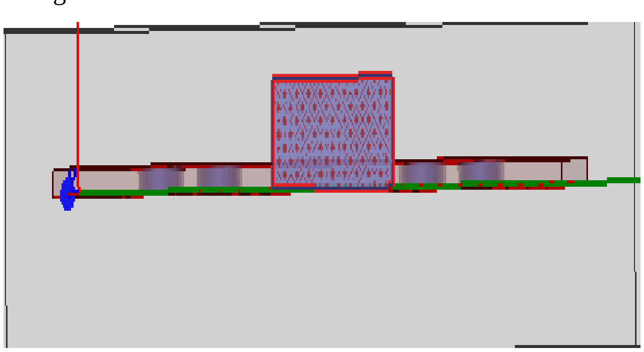

Figure 2. Wave port excitation to the antenna

Feeding an antenna is the next essential step. There are 4 types of feeding techniques depending upon their nature either contacting or non-contacting feed. Among the available feeding techniques microstrip edge feed is used because of its ease to implement and fabricate. A feed point is the port through which the excitation will be given. Here in this design a wave port is created to excite the antenna.

4. RESULTS AND DISCUSSIONS

High frequency structure simulator software is the major tool to implement this work. Using the HFSS tool designer can analyze the antenna and it also helps in studying the parameters like Gain, Directivity, Axial Ratio, Impedance matching and Standing wave ratio.

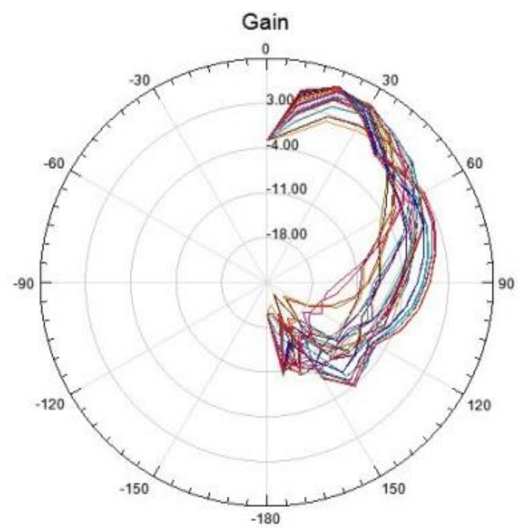

Figure 3. Gain of the antenna in dB.

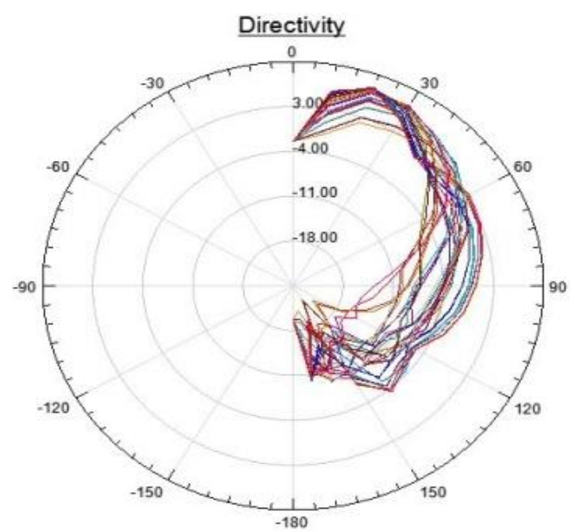

Figure 4. Directivity of the antenna.

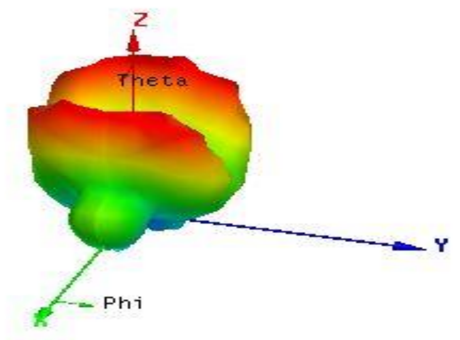

Figure 5. Three dimensional polar plot.

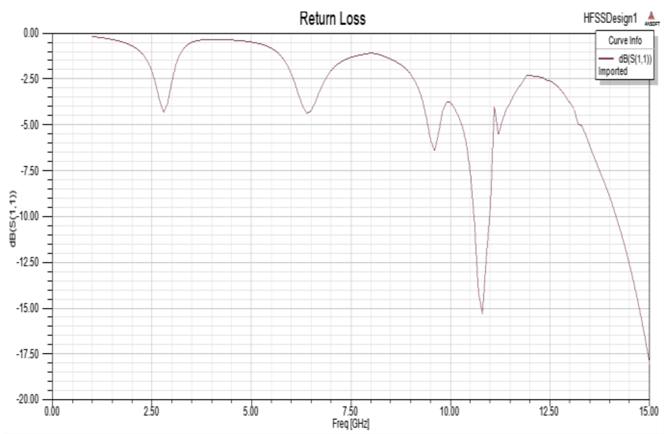

Figure 6. Return loss curve.

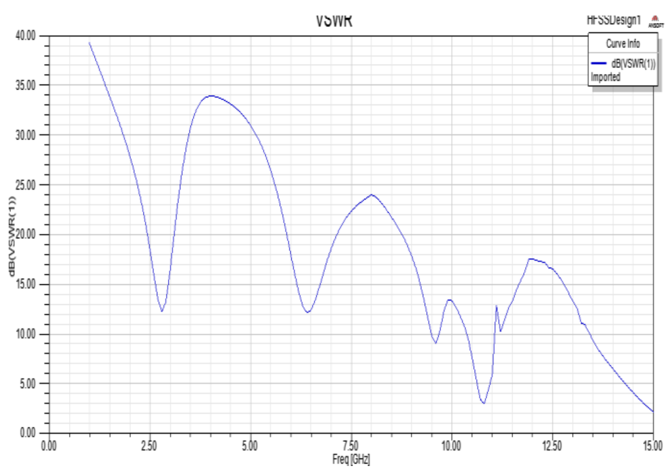

Figure 7. VSWR values of the antenna

From the plots, the values can be easily depicted. The antenna central frequency is around 10GHz which is lies in the X-band. The return loss of the antenna is -21.5dB through which it can be stated that the impedance matching between the source to load is good and the energy degradation is very minimal. The antenna can also be operated in tri-band with less impedance matching. Gain is 7.5969dB, directivity is 8.3785dB and axial ratio is 70.66.

5. CONCLUSION

Here in this pursuit the linear planar antenna operating at X-band with 10GHz as central frequency has given the desirable characteristics. Gain and directivity values of this antenna were also meeting the microstrip technology requirements. Hence it can use in the wireless communication systems. The gain of this antenna can be further enhanced by introducing the concept of double negative materials into the substrate, which can be considered as the future scope of this work.

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