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Intensive Study of Resonance Frequency of Circular Patch Antenna With Additional Lobes

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Abstract:- **In this paper, in the first part , a study of enhancement of bandwidth and return loss of circular microstrip antenna with the addition of two rectangular lobes is presented.. Here a circular patch with resonance frequency 10 GHz is designed and analyzed for its bandwidth and return loss. Two rectangular lobes of width 1.5 mm and length4.5 mm are are added with a separation of 1.5 mm. Again the analysis is done. There is a considerable enhancement of bandwidth with such a simple structure.**
In the second part analysis of the similar structure is done for different resonant frequencies and an empirical formula is proposed to calculate the resonance frequency of the entire patch. The experimentally obtained resonance frequencies are compared with the results obtained by IE3D Simulation

Keywords:- Microstrip patch antenna, bandwidth enhancement, additional lobes ,empirical formula

I INTRODUCTION

Due to several advantages of microstrip antennas,[1] these are preferred for various applications. These antennas have light weight, low volume, thin profile configuration, low fabrication cost, isotropic radiation characteristics, and negligible human body effect. These antennas have some limitations as compared to conventional antennas. Narrow impedance bandwidth, low gain, large ohmic loss in the feed structure of arrays are the major limitations of these antennas, .The size of microstrip antennas becomes larger at lower frequenciesNarrow bandwidth is a major disadvantage of microstrip antennas in practical applications. Many bandwidth-enhancement or broadband techniques for microstrip antennas have been reported[2]. One technique for bandwidth enhancement uses coplanar directly coupled and gap-coupled parasitic patches [3]. The bandwidth of microstrip antennas is inversely proportional to their quality factor. The quality factor of a resonator is defined as the ratio of energy stored to the power radiated. By changing the substrate parameters such as dielectric constant and thickness, the quality factor can be varied. By decreasing the dielectric constant, the bandwidth of the microstrip antennas can be increased [4], due to the decrease in the dielectric constant, the stored energy decreases and the radiated power increases, so the quality factor decreases, and hence the bandwidth increases. Similarly, on increasing the thickness of the substrate the stored energy decreases, hence the quality factor decreases and the bandwidth of the antenna increases [4]. But there are many disadvantages of increasing the thickness of the substrate and of using lower dielectric constants, such as increasing surface wave power resulting poor radiation efficiency

In this paper, historic development of circular microstrip antennas is presented and performance of the antenna is analyzed.. Design calculations and graphical analysis are also presented. The research overview of the microstrip antennas is also given. And various applications and challenges of gap-coupled microstrip antennas are also presented

II THEORY OF MICROSTRIP ANTENNA

The figure 1 shows a patch antenna in its basic form: a flat plate on a ground plane. The center conductor of a coax serves as the feed probe to couple electromagnetic energy in and/or out of the patch. The electric field distribution of a rectangular patch in its fundamental mode is also shown

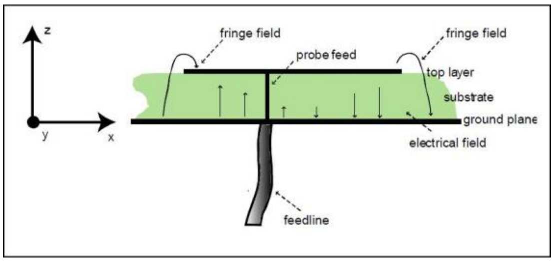


Fig 1

The electric field is zero at the center of the patch, maximum (positive) at one side, and minimum (negative) on the opposite side. It should be mentioned that the minimum and maximum continuously change side according to the instantaneous phase of the applied signal. The electric field does not stop abruptly at the patch's periphery as in a cavity rather, the fields extend the outer periphery to some degree. These field extensions are known as fringing fields and cause the patch to radiate. Some popular analytic modeling techniques for patch antennas are based on this leaky cavity concept. Therefore, the fundamental mode of a rectangular patch is often denoted using cavity theory as the TM_{10} mode.

Since this notation frequently causes confusion, we will briefly explain it. TM stands for transversal magnetic field distribution. This means that only three field components are considered instead of six. The field components of interest are: the electric field in the z direction, and the magnetic field components in x and y direction using a Cartesian coordinate system, where the x and y axes are parallel with the ground plane and the z axis is perpendicular.

In general, the modes are designated as TMnmz. The z value is mostly omitted since the electric field variation is considered negligible in the z axis.

Hence TMnm remains with n and m the field variations in x and y direction. The field variation in the y direction (impedance width direction) is negligible; thus m is 0. And the field has one minimum to maximum variation in the x direction (resonance length direction); thus n is 1 in the case of the fundamental. Hence the notation TM_{10}.

III EXPERIMENT –PART 1

A circular patch(fig 2) for frequency 10 Ghz is designed as per the formula

$$R = 1.8412\times C/\ 2\times\Pi\times fo\times\sqrt{\xi} \quad = 4.3 \text{ mm},$$

Where C is velocity of light and ξ is the dielectric constant Using IE3D Software simulation is carriedout and a return loss -32 dB is obtained(Fig 3) at a resonance frequency of 11 GHz with a band width of 1.8 GHz,at the feed point of (2.5,-0.25)

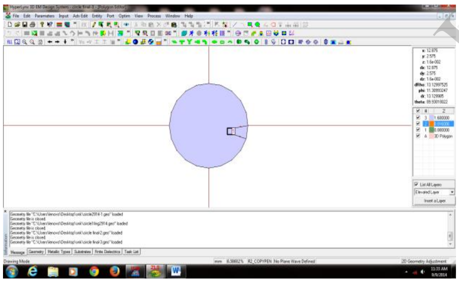


Fig 2

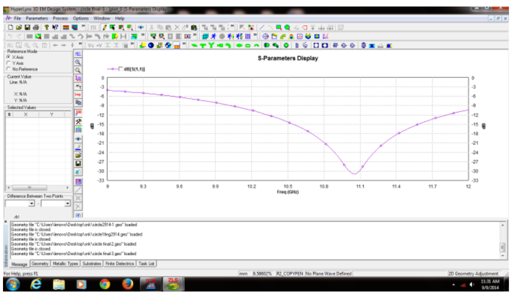


Fig 3

IV BANDWIDTH ENHANCEMENT WITH ADDITIONAL LOBES

When two rectangular lobes of length 1.5 mm and width 4.5 mm are attached with a separation of 1.5 mm(fig 4),the patch gave a return loss of -45 dB (fig 5)for a resonance frequency of 11.2 GHz at the same feed point with band width of 2.1 GHz. Thus 16% increase in BW is observed. Theoretical interpretations is yet to be carried out

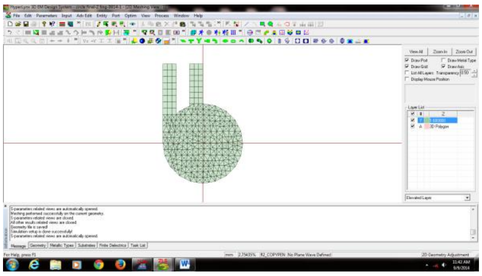


Fig 4

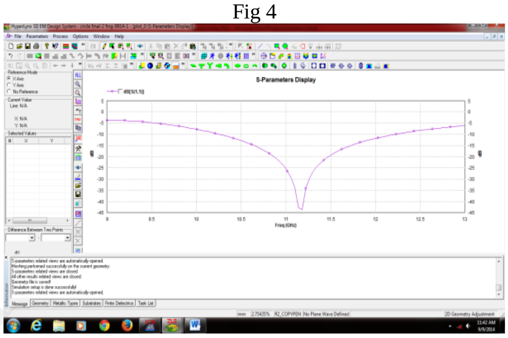


Fig 5

V PROPOSED FORMULA

this MSA can be represented by a circular patch with the addition of two direct coupled rectangular patches width (W) and length L_{eff} The width of the patch can be calculated from the following equation[5].

$$W = \frac{c}{2f\sqrt{(\varepsilon_r + 1)/2}}$$

The effective dielectric constant (εeff) is less than (εr) because the fringing field around the periphery of the patch is not confined to the dielectric speared in the air also.

$$\varepsilon_{reff} = \frac{(\varepsilon_r + 1)}{2} + \frac{(\varepsilon_r - 1)}{2}\left[1 + 10\frac{h}{W}\right]^{-\frac{1}{2}}$$

For TM10 Mode the length of the patch must be less than (λ /2) .This difference in the length (ΔL) which is given empirically by

$$L_{eff} = \frac{c}{2f_o\sqrt{\varepsilon_{reff}}}$$

For the circular patch resonance frequency is 10 GHz (**f_1**), the radius is given by

$$R = 1.8412\times C/\ 2\times\Pi\times fo\times\sqrt{\xi} \quad = 4.5 \text{ mm}$$

Length of the additional lobes is randomely selected as 1.5 mm and separation is 1.5 mm. Width is selected as 4.5 mm.

using the above mentioned formula resonance frequency corresponding to length 1.5 mm is

48 GHz($\mathbf{f_3}$)

Resonance frequency corresponding to width 4.5 mm is

14 GHz.($\mathbf{f_2}$)

The **empirical** formula for resultant resonance frequency is

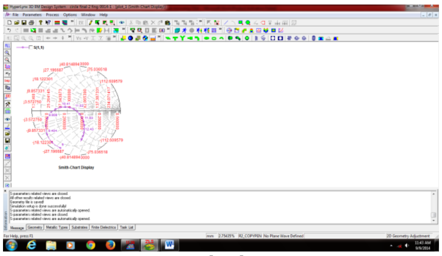
$$\mathbf{f_0=f_1+\{(f_3/f_2)-2\}^{1/2}}$$

$$=10X10^9+\{(48X10^9/14X10^9)-2\}^{1/2}$$

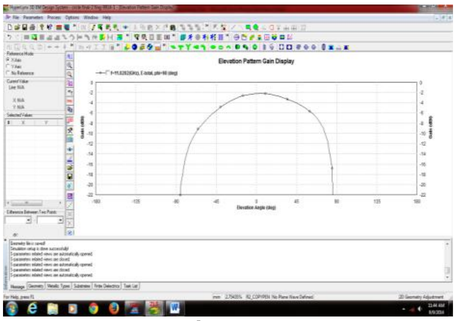
$$=11.195X10^9$$

$$=11.195GHz$$

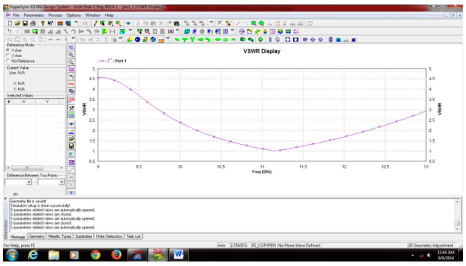
This agrees very well with the observed frequency 11.2 GHz



Smith Chart



2DRadiation pattern



VSWR Curve

VI EXPERIMENT –PART 11

To verify the above proposed empirical formula different patches of different frequencies are designed and in each case observed resonance frequency and frequency obtained by empirical formula are compared. In each case length of the lobe and separation is one third of the radius and width is equal to the radius of the circular patch.

Case 1

This Microstrip antenna consists of one circular disk and two lobes connected as shown in the figure 6.

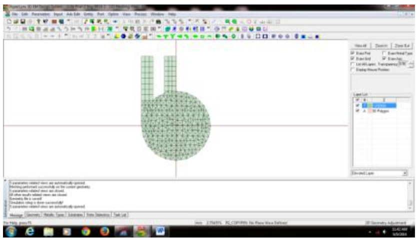


Fig 6

This Microstrip Patch antenna has a circular disk antenna of radius 3.9mm with two side lobes of equal dimensions of length 1.3mm and width of 3.9mm separated by a distance of 1.3mm which is equal to length of the lobe. Frequency of circular disk is 11 GHz. Frequency observed in the IE3D for this pattern is 11.25GHz and frequency calculated from empirical formula is 11.6GHz. Error is 3 %.

Case 2

This Microstrip Patch antenna has a circular disk antenna of radius 4.3mm with two side lobes of equal dimensions of length 1.43mm and width of 4.3mm separated by a distance of 1.43 mm which is equal to length of the lobe. Frequency of circular disk is 9.98 GHz. Frequency observed in the IE3D for this pattern is 11.4GHz and frequency calculated from empirical formula is 10.57GHz. Error is 7 %.

Case 3

This Microstrip Patch antenna has a circular disk antenna of radius 4.5mm with two side lobes of equal dimensions of length 1.5mm and width of 4.5mm separated by a distance of 1.5 mm which is equal to length of the lobe. Frequency of circular disk is 9.53GHz. Frequency observed in the IE3D for this pattern is 10.13GHz and frequency calculated from empirical formula is 10.9GHz. Error is 7 %.

Case 4

This Microstrip antenna consists of one circular disk and two lobes connected as shown in the figure 6.Microstrip Patch antenna has a circular disk antenna of radius 5.1mm with two side lobes of equal dimensions of length 1.7mm and width of 5.1mm separated by a distance of 1.7 mm which is equl to length of the lobe. Frequency of circular disk is 8.41 GHz. Frequency observed in the IE3D for this pattern is 10GHz and frequency calculated from empirical formula is 9.02GHz. Error is 9 %

Case 5

This Microstrip antenna consists of one circular disk and two lobes connected as shown in the figure 6.Microstrip Patch antenna has a circular disk antenna of radius 6mm with two side lobes of equal dimensions of length 2mm and width of 6mm separated by a distance of 2 mm which is equal to length of the lobe. Frequency of circular disk is 7.15 GHz. Frequency observed in the IE3D for this pattern is 7.7GHz and frequency calculated from empirical formula is 7.75GHz. Error is 0.6 %.

Following(fig 7) is the graph comparing the observed and theoretical resonance frequencies.

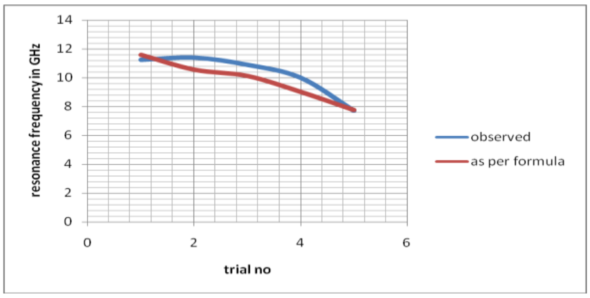


Fig 7

VII FURTHER STUDY

Similar experiment can be performed for different patches of different frequencies, resonance frequencies obtained by IE3D simulation can be compared with the value obtained by empirical formula and a relevant theory can be proposed.

VIII RESULT AND CONCLUSION

Analysis revealed that addition of patches enhanced the bandwidth by nearly 16 percent.. Addition of patches is the potential method to enhance the bandwidth of the conventional microstrip antennas. For multi-band applications also, this is suitable method. Various structures using different types and sizes of the patches, number of patches, such microstrip antennas can be designed for various applications. Gap-coupling along with some other bandwidth enhancement techniques can be used together to produce ultra large bandwidth, and the antennas can be designed for various wideband applications.

The empirical formula almost holds good for all trials within the experimental errors. In coming days suitable theory can be developed which may agree very well with the experimental results.

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