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Design of Microstrip Patch for Bandwidth Enhancement

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Abstract: With the modern improvement in telecommunications, the requirement for upgraded bandwidth and miniature antennas has significantly enhanced. The electronic apparatus has promptly compressed in physical size due to the advancement of integrated circuits; hence, the interest for the miniature antennas turns out to be very essential. The microstrip antenna (MSA) is one of the most desirable antennas since it has numerous advantages such as light weight, small volume and that can be made conformal to the host surface. In addition, MSAs are fabricated by using printed-circuit technology, with the goal that large scale manufacturing can be accomplished effortlessly at low cost. MSAs, which can be utilized for defense and commercial applications, are replacing many conventional antennas. Be that as it may, the kinds of uses of MSAs are confined by the antennas intrinsically restricted bandwidth (BW). Several strategies exist to get enriched bandwidth of the antenna. In the present undertaking, in this manner, the author has made an effort to design and analyze the diverse shape geometries of MSA for bandwidth upgrade. The suggested is antenna parameters such as return loss, gain and directivity.

Keywords – Microstrip Antenna, Partial ground plane, Ultra-wide band

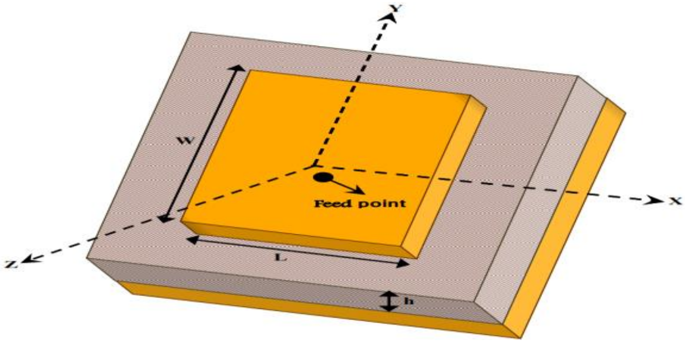
I. Introduction

The advancement of contemporary wireless communications has increased significantly owing to utilization of the wireless systems at enormous scale. The wireless system comprises of enormous assortment of equipments such as radar, navigation, landing system, direct broadcast T.V, space communications, small mobile units like laptops, cellular phones and so on. Today, we appreciate substantially more profit by the wireless system, therefore significant contributions of antennas should not be underestimated. These wireless systems are fundamentally based on electromagnetic (EM) waves which are transmitted and received through an antenna. Accordingly, an antenna is the prime element of wireless system, therefore it's impossible to design a wireless system without antenna. The system requirements can be reduced along with improved system performance through better design of antenna. The recent trend in commercial and communication devices has been to develop such kinds of antennas that are smaller, reliable and capable of sustaining great performances over an enormous spectrum of frequencies [1].

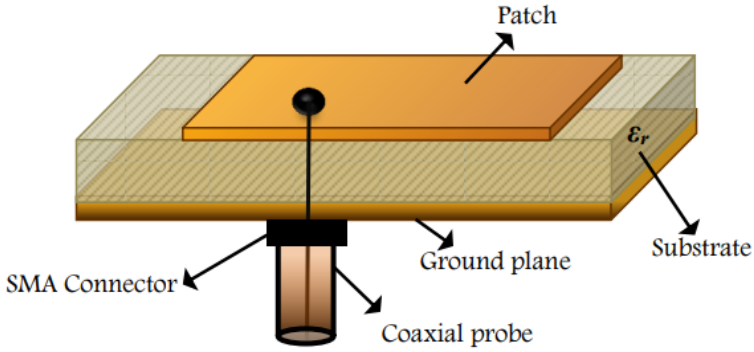
However, it was not before 1970 when the research publications started to flow with the appearance of design equations. In 1886, Henrich Hertz designed a radio system, in the transmitting side, it generates electric current and spark by an induction coil executing at 8-meter wavelength and a square loop antenna at the receiving side. The first antenna which was used in radio broadcasting transmitters of high power and Trans-Atlantic communication system is rendered by Marconi in 1885. Marconi comes to be an astrologer of wireless, his great contribution towards the development to the community prevailed as memorandum ebullience scholar in the laboratory. Practical antennas improvement hustled exceptionally quicker with the accessibility of good substrate having low loss tangent, great thermal and mechanical properties, upgraded and progressed photolithographic procedure [2, 3].

The current advancements in wireless communication technology and remarkable growth in the wireless communication market, which made wireless devices affordable and more reliable. Researchers have devoted their investigations to construct novel design or modification to the standard antenna to produce either broad bandwidth or diverse frequency activity in a solitary component. In spite of, such of these modifications bear drawbacks corresponding to the size, height of the substrate or overall dimension of the individual element, and the enhancement in bandwidth typically suffers from deterioration of the other characteristics [4].

On account of these, the requirement of compact, portable, low cost and light weight antenna has increased regularly [5, 6]. MSA has drawn maximum attention to improve the performance and supports high mobility for wireless devices. MPAs have diversified applications such as aerospace vehicle, missile, space telemetry including commercial areas i.e. mobile-satellite-communications, direct broadcast satellite (DBS) systems, global positioning system (GPS), remote sensing and hyperthermia, etc. In its most simple form, MPA comprises of a radiating patch and ground plane that are detached by the dielectric substrate and fed at an appropriate location of the patch as shown in Fig. 1.



(a)



(b)

Fig. 1: Basic Configuration of microstrip antenna (a) Top view (b) Side view

II. PARAMETRIC OPTIMIZATION

The design parameters that govern the input impedance are substrate height, feed-point location and gap width.

2.1 Effect of Feed Point Location

For three different feed-point locations from the center of the patch, there is variation in the VSWR with frequency, shown in Fig. 2. With increase in frequency, the input impedance moves in a clockwise direction in the smith chart [7, 8]. As x moves from 1mm (feed-point is shifted to the edge), the input impedance loci shifts in the right direction on the smith chart implying that the impedance is increasing. A perfect match of 50 ohm feed-line is obtained for 4.75 mm along –x direction, which gives a bandwidth of 3.21 GHz for VSWR 2.

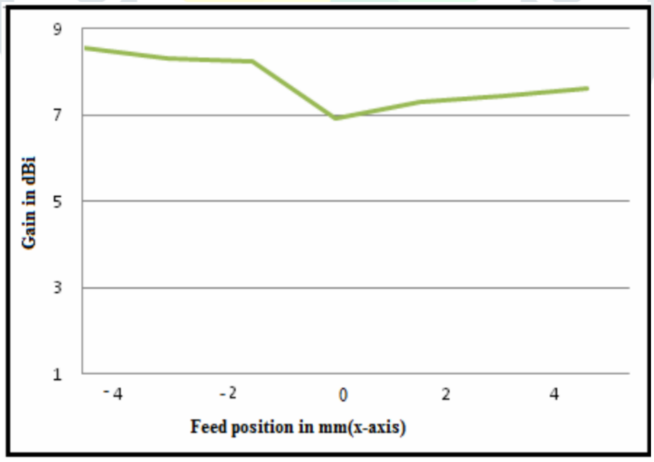


Fig. 2: Gain variations of microstrip antenna

2.2 Effect of Gap Width

Gap width governs the interaction between the coupled patch and the main patch. Increase in the gap width decreases the size of the impedance loci, because the interaction between the resonators decreases. Also the impedance loci shift toward the left side of the smith chart is shown in Fig. 3(a) and (b). Further increase in the gap width decreases the size of the impedance loci and the loop disappears for larger gap width. In this case, the gap width is varied from 0.0073 to 0.033. The optimized value of 0.0073 gives good bandwidth thereby increasing the interaction between the co-patch and the main patch [9].

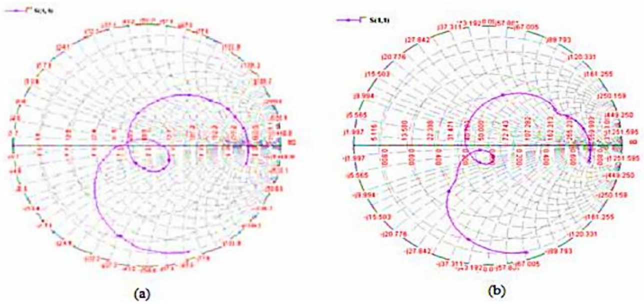


Fig. 3: (a) Smith chart for optimized gap width (b) Smith chart for increased gap width

2.3 Effect of Slot

Cutting slots in the radiating patch reduces the resonant frequency. Slot is considered as capacitive reactance on the patch. For a given slot length, resonance frequency decreases with increase in slot width. The increase in slot width increases the impedance linearly. For maximum slot length (15mm), the resonant frequency variations are minimum and maximum for minimum slot length (5mm). Slot loaded microstrip antenna is analyzed using equivalent circuit concept, in which the capacitive reactance of the slot on the patch counteract the inductive reactance of the probe. Fig. 4 shows the variation of bandwidth for various slot lengths [10, 11].

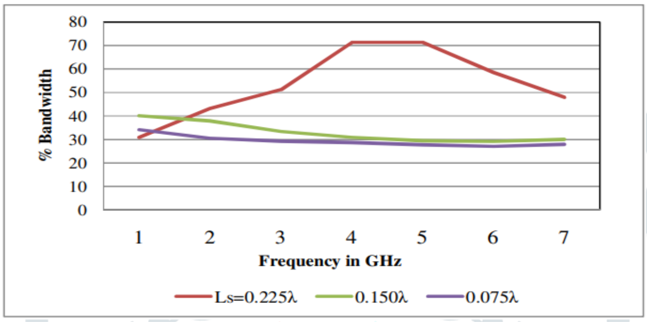


Fig. 4 Bandwidth variations for various slot lengths

2.4 Effect of Height, h

With increase in height h, from 0.08Ʒ to 0.09Ʒ the fringe fields from the edges increase, which increases the extension length and hence the effective length, thereby decreasing the resonance frequency. The bandwidth of the antenna increases from 1.575 GHz to 3.21 GHz, for the optimized height 0.09Ʒ. The increase in the probe inductance of the feed moves the input impedance in clockwise, thereby introducing inductive shift [12].

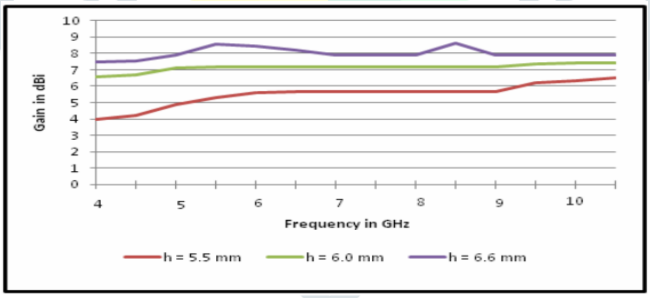


Fig. 5: Gain variations of microstrip antenna

2.5 Effect of Width, W

Patch width affects the bandwidth to a larger extent [13]. A larger patch width increases the bandwidth, radiated power and the radiation efficiency. Patch width is chosen greater than the patch length, with good excitation. It is observed that the patch width various from 0.45Ʒ<W

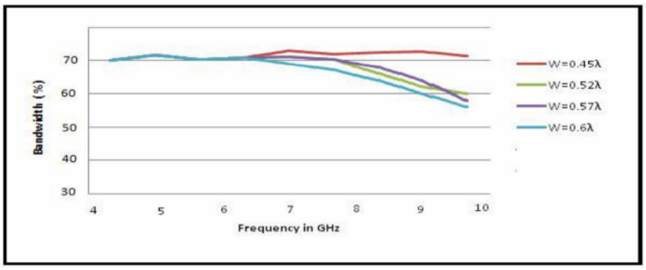


Fig. 6: Bandwidth variations of microstrip antenna

III. ANTENNA DESIGN

In an aperture coupling feed (ACF) microstrip patch antenna, separate dielectric substrate is used for the feed network and the patch antenna. Since all layers adhere to conformal printed circuit technology, fabrication is thus made simple. However, alignment between layers and correct selection of aperture size and position will be critical in controlling the antenna impedance. The natural existence of small gaps between the layers of dielectric substrate can significantly change the input impedance values.

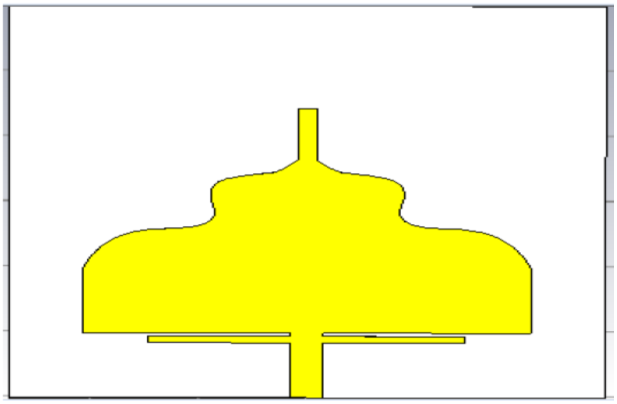


Fig. 7: Parasol Design of Microstrip Antenna

Absence of abrupt current discontinuities in ACF makes it relatively easy to design the antenna accurately.

The design of the central strip and substrate takes a major part in deciding antenna parameters. Strip line feeding antennas, despite their small size, can give outstanding bandwidth efficiency. The substrate in microstrip antenna is mainly required for the mechanical support of the antenna metallization. For this purpose, the substrate needs to make of a dielectric material, which may affect the electrical performance of the antenna, circuits and transmission line. The choice of substrate, in most cases, depends on some characteristic parameters like: (i) homogeneity and isotropicity, (ii) dielectric constant and loss tangent. In this thesis dielectric constant are used and FR-4 material.

Smaller size of the antenna is an essential prerequisite for modern networking strategies such as application of millimeter wave frequency bands in 5G communications.

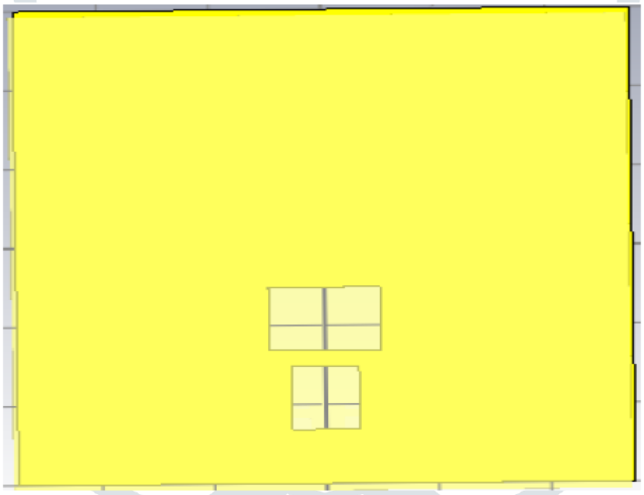


Fig. 8: Bottom View of Parasol Design

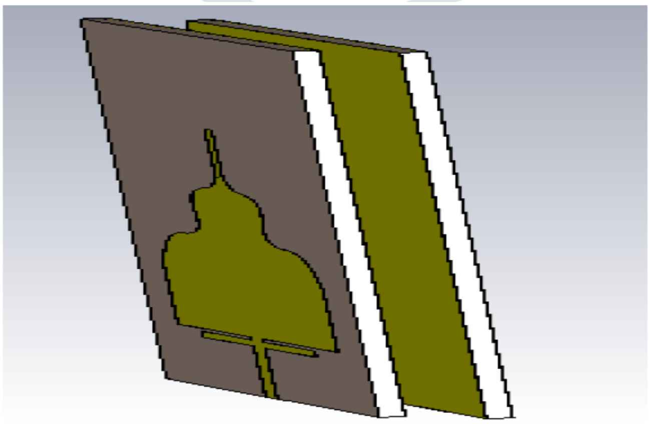


Fig. 9: Design Reflector of Parasol Design

Width of microstrip antenna is simply given as

$$W = \frac{c}{2f_0\sqrt{\frac{\varepsilon_r+1}{2}}} \tag{1}$$

Where,

W= Width of Patch

ε_r= Dielectric constant of the substrate

Actual length of microstrip antenna is given as

$$L_{actual} = L_{eff} - \Delta L \qquad (2)$$

Where,

L_{eff}= Effective length of the patch.

ΔL = Extended electrical length

Effective length of the patch is simply given by

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{reff}}} \qquad (3)$$

Where,

ε_{reff}= Effective dielectric constant

For low frequencies the effective dielectric constant is essentially constant. At intermediate frequencies its values begin to monotonically increase and eventually approach the values of dielectric constant of the substrate. Its value is given by,

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1 + 12\frac{h}{W}\right]^{-\frac{1}{2}} \qquad (4)$$

h = thickness of the substrate

In microstrip antenna, radiation occurs due to the fringing effects. Due to fringing effects electrical length of patch is greater than its physical length. This fringing depends on the width of patch and height of substrate [7].Now the extended electric length is given by

$$\Delta L = 0.412h\frac{(\varepsilon_{reff}+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_{reff}+0.3)(\frac{W}{h}+0.8)} \qquad (5)$$

The width of microstrip line in microstrip antenna is given as follows:

For

$$\frac{W_{eff}}{h} \geq 2$$

$$W_{eff} = \frac{2h}{\pi}\left\{\frac{\varepsilon_r - 1}{2\varepsilon_r}\left[\ln(B-1) + 0.39 - 0.\frac{61}{\varepsilon_r}\right] + B - 1 - \ln(2B-1)\right\}$$

And for

$$\frac{W_{eff}}{h} \leq 2$$

$$W_{eff} = \frac{8he^A}{e^{2A} - 2} \qquad (6)$$

$$W_f = W_{eff} - \frac{t}{\pi\left[1 + \ln\left(\frac{2h}{t}\right)\right]} \qquad (7)$$

Where, A and B are given as follows

$$A = \frac{Z_{ol}}{60}\left(\frac{\varepsilon_r+1}{2}\right)^{0.5} + \frac{\varepsilon_r-1}{\varepsilon_r+1}(0.23 + 0.11/\varepsilon_r)$$

$$B = \frac{377\pi}{2Z_{ol}\sqrt{\varepsilon_r}} \qquad (8)$$

IV. RESULTS AND DISCUSSION

CST Studio Suite® is a high-performance 3D EM analysis software package for designing, analyzing and optimizing electromagnetic (EM) components and systems.

Electromagnetic field solvers for applications across the EM spectrum are contained within a single user interface in CST Studio Suite.

The solvers can be coupled to perform hybrid simulations, giving engineers the flexibility to analyze whole systems made up of multiple components in an efficient and straightforward way.

Return loss:- Return loss is a measure of how well devices or lines are matched. A match is good if the return loss is high. A high return loss is desirable and results in a lower insertion loss.

Directivity:- Directivity of an antenna is defined as the ratio of the radiation intensity in a given direction from the antenna to the radiation intensity averaged over all directions.

Antenna Directivity (D)= 4 π(maximum radiation intensity)/total radiation power

Gain:- The gain of an antenna in a given direction is defined as the ratio of the intensity, in a given direction, and the radiation intensity that would be obtained if the power accepted by the antenna were radiated isotropically.

Gain of an antenna (G) = Antenna efficiency * Antenna directivity (D)

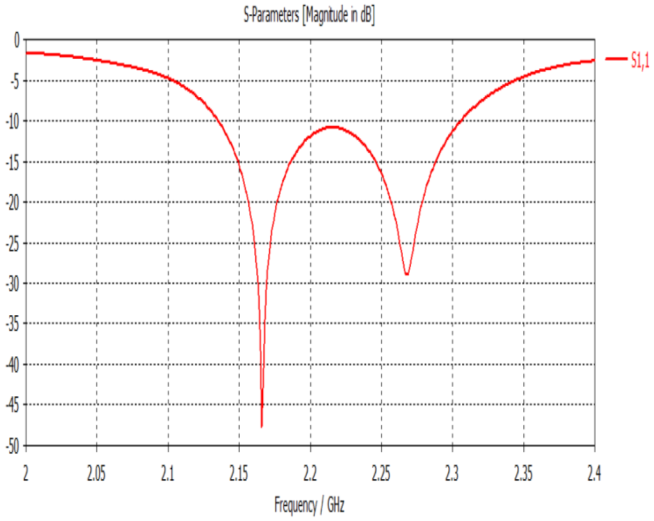


Fig. 10: Return loss vs frequency plot

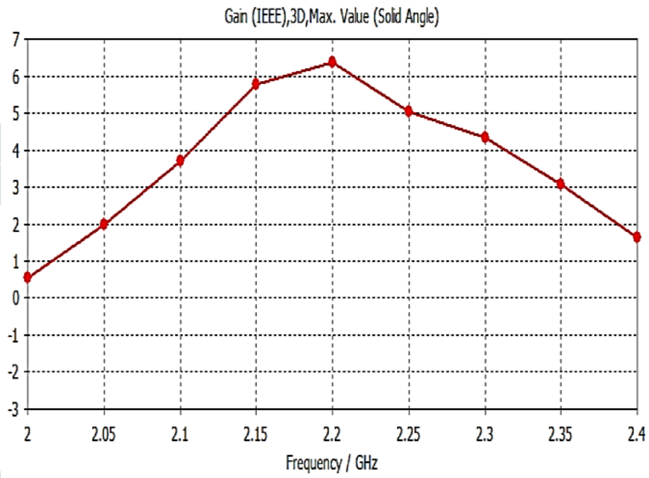


Fig. 11: Gain vs frequency plot

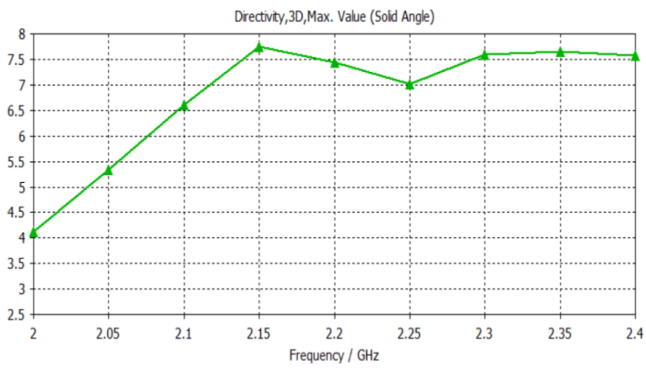


Fig. 12: Directivity vs frequency plot

Table 1: Comparison of Previous and Proposed Technique

Design	fr(GHz)	S_{11}(dB)	G(dB)	D(dBi)	η	VSWR	BW(MHz)
Base paper	2.45	-28	5.4	7.7	0.58	1.082	44.7
Presented	2.16	-50	6.3	7.75	0.85	1.05	170

V. CONCLUSION

The microstrip patch antenna is a resonant structure that comprises of a dielectric substrate in between a metallic conducting patch and a ground plane. It is the most advisable antenna since it has numerous points of interest such as light weight, low profile and simplicity of fabrication. Subsequently having numerous appealing highlights, microstrip antenna got extensive consideration for several applications like mobile communications, satellite communications, radar, and other many types of equipment. However, they have constrained bandwidth and inferior radiation attributes that restricts the application in practice. In this endeavour, an attempt has been made to upgrade the bandwidth with better radiation characteristics of the antenna by approach of modifying the ground plane as well as patch structures.

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