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Planar broadband antenna for 2G/3G systems

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ABSTRACT

A planar antenna with broadband gestalt is presented for mobile networks. The structure of the antenna is made up of a folded dipole pair with an L-figure microstrip coupling line. The microstrip coupling along with the dipoles are attached on a similar substrate. The radiation parts are plotted at 1.7 GHz, 2.2 GHz, and 2.7 GHz. A flexible coaxial cable made of perfect electric conductor (PEC) material is attached to the L-figure microstrip whereas the outside conductor made up of RO4350B material is attached to the coplanar strip of line. The gain of the antenna is almost 9 dBi. The benefit of the planar structure is that it offers a simple feeding structure and compact size that is necessary for second generation (2G)/third-generation (3G)/long-term evolution (LTE) systems. Finally, the antenna proposed is designed by using computer simulation technology (CST) microwave studio.

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1. INTRODUCTION

The brisk advancement in the mobile communication field requires broadband and cheaper antennas. Of the different generations, the second generation (2G), like the GSM1800, can be operated in ranges from 1700 MHz to 1880 MHz and 1850 MHz to 2000 MHz. Wideband code division multiple access (WCDMA) and code division multiple access-2000 (CDMA-2000) are third-generation (3G) communication systems that operate in the frequency range of 1920 MHz to 2180 MHz. Long-term evolution (LTE), like the LTE2500 and LTE2300, have frequency ranges of 2500 Mhz to 2690 MHz and 2300 MHz to 2400 MHz respectively. Hence the essential bandwidth is 45% i.e., 1.65 GHz to 2.75 GHz for antennas working in the base station 2G/3G/LTE mode [1], [2]. Hence modern antennas applicable for mobile communication purposes must be capable of covering all the required frequency bands.

In the recent past, different types of planar antennas and their properties have been researched and evolved for broadband stations. Most frequently used are dipole and patch antennas because of their directional properties and sizes, also patch antennas have a narrower bandwidth [3]. An L-shaped probe has been used as it enhances the bandwidth. L-shaped antennas provide bandwidths of approximately 28% at return loss greater than 10 dB. Similarly, bowtie-shaped metal patch antenna attains bandwidth of approximately 44% (return loss (RL) > 10 dB) but parallelly surfaces with higher impedance are also required [4]. Printed dipoles on the lower side along with the balun and proper impedance matching are proposed to achieve higher bandwidth. Adjusted balun and the printed dipole in [5] reached a bandwidth of 40% (RL > 10 dB). The double-layered structure as given in [6] integrated along with dipoles attains a bandwidth of 50% (RL > 10 dB), but the antenna gain substantially drops. All the dipole configurations discussed have a nonplanar structure. Different slot cuts, their positions, and configurations determine the bandwidth and directivity of antennas, and a suitable shape is arrived at after analyzing the requirements and comparing it with the results obtained.

The antenna designed in [7] has four radiators that are looped and fed using a Y-shaped line and attains a higher bandwidth at higher frequencies nearing 2.7 GHz but the antenna fails to extend to lower frequency ranges for 2G applications. The design mentioned in [8], [9] consists of printed dipoles that are double-sided and series fed and attain a bandwidth of approximately 20% at 1.6 GHz but at the same time antenna operation is constrained in the upper segment with a constant bandwidth of 25% at 1.5 GHz. A novel design has been developed and applied in [10]-[12] and has a pair of folded dipoles that operate efficiently in a frequency range of 1.65 GHz to 2.7 GHz. However, the antenna is limited only to array applications which makes it difficult to be redesigned or reconfigured for various applications primarily because of its rigid geometry and necessary pairing of printed dipoles and its counterparts [13].

This paper presents a versatile and compact antenna that has been proposed for the broadband applications of 2G/3G mobile communication. The designed antenna comprises paired dipoles, folded, which are linked parallel to a coplanar strip. The L-shaped microstrip lines on top of the antenna are used to feed the folded dipoles, which are present on the lower side of the substrate. A $50\,\Omega$ coaxial cable is used for feeding purposes whose inner conductor is linked to the L-shaped microstrip and the outer cover is linked to a coplanar stripline. The motivation behind the work is:

– The advantage of the 3G network is that it can cover immense territory with relatively few cells. This is because the network does not require as much bandwidth and therefore requires fewer cells.
– With the advancement of fifth generation (5G) technology, overcrowding of signals due to increased bandwidth is causing the problem. Therefore, it is necessary to work on 2G/3G technology to decrease overcrowding.
– New technology like 5G requires new configuration, therefore, forcing users to buy new hardware to support the new technology. It has become important to work on existing technology to decrease costs for users.

2. RESEARCH METHOD

To satisfy features like low-cost, simple manufacturing, and integration of systems it is preferable that antennas for base stations should have lightweight and planar structure. To obtain high bandwidth along with better isolation, the feeding structures proposed were complex which resulted in a nonplanar configuration. Characteristics that determine impedance matching in planar antennas are slot width of the coplanar strip, length of the coupling microstrip line, and also the distance of the antenna from the reflector known as height [14], [15]. The design of the broadband planar antenna in computer simulation technology (CST) Microwave Studio is divided into the designs of the following subparts of the antenna.

2.1. Substrate

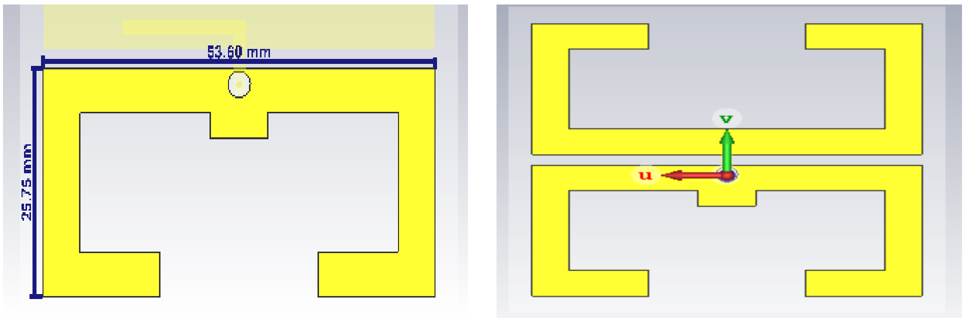
The substrate of the antenna was presented as being connected through a coat of copper of dielectric substance Rogers RO4350B with the help of CST software. The relative dielectric value is 3.48. The loss tangent of the dielectric is 0.0037 and the width is 0.76 mm [16].

2.2. Pair of folded dipoles

The structure of the planar antenna comprises a pair of folded dipoles attached parallelly to a coplanar stripline. The dipoles shown in Figure 1 are attached to the lower face of the substrate. Figure 1(a) depicts the dimensions of folded dipoles, and Figure 1(b) shows the pair of folded dipoles on the lower part of the antenna. They are made up of material copper (annealed). The length and breadth are 53.68 mm and 25.75 mm respectively. The slot width (Wd) of the gap between the two folded dipoles is a crucial thing for matching impedance. The most suitable value for (Wd) is found to be around 2.10 mm for the optimum matching of impedance [11], [17].

2.3. L-shaped microstrip

At the top face of the substrate, the L-shaped microstrip line is present whose dimensions are shown in Figure 2. Patch antennas along with L-shaped probes were suggested for enhancement of bandwidth [18]. With the use of coupling microstrip lines, an improvement in impedance matching can be obtained. The dipoles on the lower face are connected by this L-shaped microstrip [19]-[21].



(a) (b)

Figure 1. Folded dipoles: (a) dimensions of folded dipoles and (b) pair of folded dipoles on the lower part of the antenna

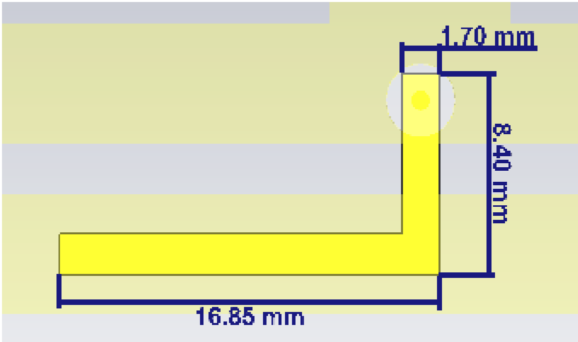
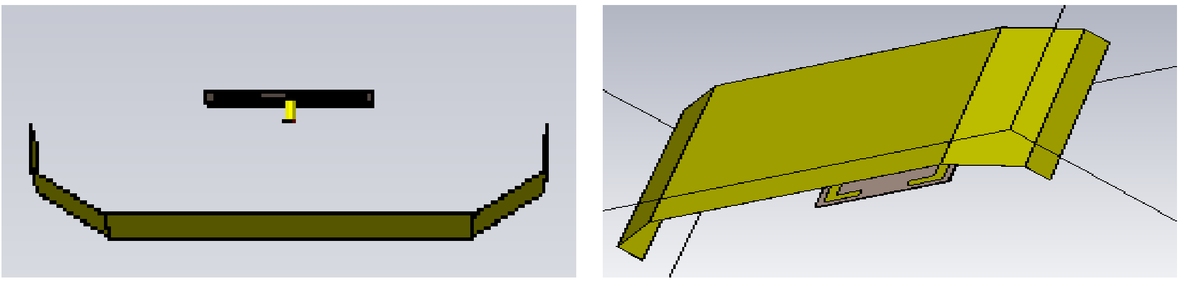


Figure 2. Dimensions of L-strip microstripline

2.4. Reflector

An antenna reflector is a gadget that bounces back electromagnetic waves. Antenna reflectors act as a device for transmitting radio frequency (RF) energy or can be made as part of an antenna structure. Here the reflector as shown in Figure 3 is integrated into the antenna, as it serves to change the radiating pattern of the antenna, modifying gain in a specific direction. Figure 3(a) shows the reflector at a distance H from the antenna, and Figure 3(b) shows the bottom view of reflector. Without the reflector, the matching of impedance is not good (i.e., $H = \infty$). When the reflector is used, the matching of impedance is enhanced. But care is needed, not to get the antenna too close to the reflector as the impedance matching starts deteriorating after a certain distance, hence the best results were found at $H = 42$ mm [22]-[24].

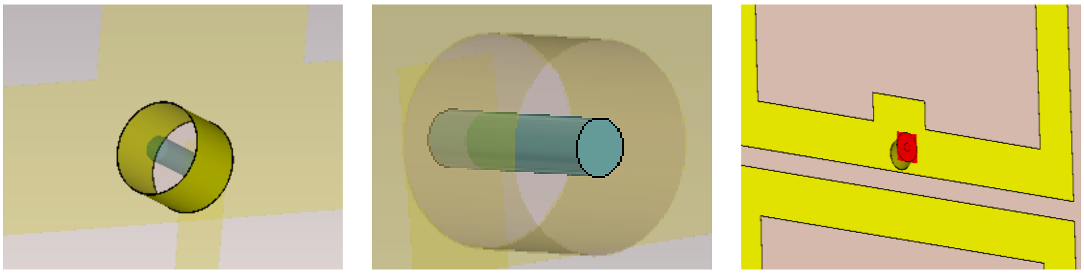


(a) (b)

Figure 3. Design of reflector: (a) at a distance H from the antenna and (b) bottom view of reflector

2.5. Microstrip patch antenna (MPA) feed line and impedance matching

A feedline has the purpose to excite to transfer by direct or indirect contact. There are varieties of different ways of feeding and we have applied microstrip feed. Here, we have used the coaxial probe as shown in Figure 4 for feeding purposes, the outer conducting part of the probe is made of Rogers RO4350B material and the inner conducting part is made of perfect electric conductor (PEC) material [25], [26]. Figure 4(a) shows the outer cover of coaxial probe, Figure 4(b) shows the inner conductor of coaxial probe, and Figure 4(c) shows the feed part of the coaxial cable. The inside conductor of the 50 Ω coaxial probe is connected to the L-shaped microstrip and the outer covering of the wire is connected to the coplanar strip along with the antenna. The radius of the inner conducting part is 0.416 mm and the radius of the outer conductor is 1.8 mm [27], [28]. Advantages of coaxial feed are can be fabricated with ease, impedance matching can be done, and low spurious radiation.



(a) (b) (c)

Figure 4. Coaxial probe: (a) outer cover, (b) inner conductor, and (c) feed part of the coaxial cable

2.6. Determination of feed point

After determining the feed type with specified parameters, the matching impedance was aimed to be as close to 50 Ω. The connector has to be attached at some distance to balance the impedance. To get the least quantity of the return loss hit and trial method was used [29]-[32].

3. RESULTS AND ANALYSIS

Using the CST Microwave Studio, we have simulated the antenna. Various parameters of the antenna are analyzed such as S-parameter which shows how much energy is transferred back and tried to keep it minimum; Impedance matching so that the desired signal can be emitted without any back transfer. We have analyzed the reflection coefficient and tried to keep it below 8 dB as per our requirement. The transmission coefficient at 1.5 GHz, 2.5 GHz, is -8 dB, -14 dB respectively. Furthermore, different parameters like voltage standing wave ratio (VSWR), Fairfield, S-parameter, directivity have been properly demonstrated.

3.1. S-parameter

The input and output combinations between terminals in an antenna are represented by an S-parameter. It is called a reflection coefficient as it shows how much energy per unit time is reflected and is denoted by S1,1 and also called return loss. For impedance equalization, the slot width of the stripped line is a principal parameter. Figure 5 depicts the results for varying return loss of the antenna with varying slot width (Wd). We get the best impedance matching by keeping Wd to 2.1 mm.

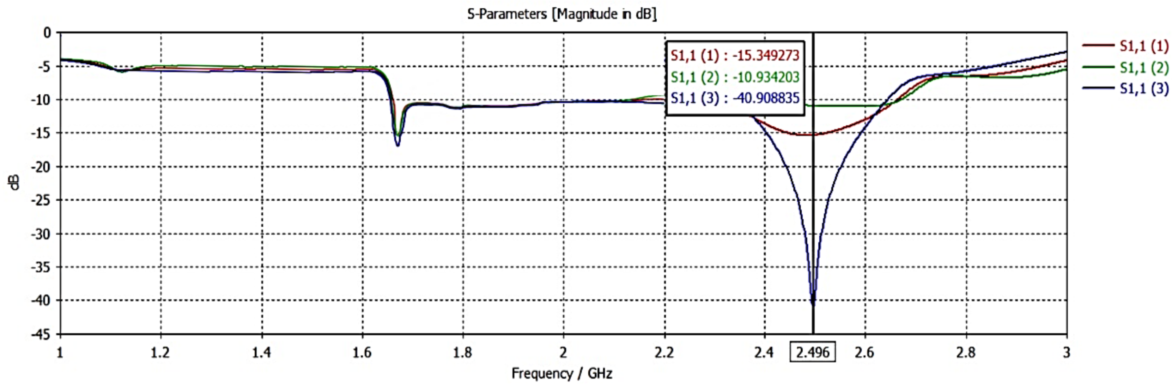


Figure 5. Return loss vs frequency plot where S1,1(1)-Wd = 1.5 mm, S1,1(2)-Wd = 2.7 mm, S1,1(3)-Wd = 2.1 mm

Impedance matching is also changed by the distance of the antenna from the reflector, known as H. Figure 6 depicts the dependence of height on return loss of the antenna. The impedance matching quality lowers when the antenna moves towards the reflector and also degrades when placed too far away from the antenna. The best results are at a height of 42 mm.

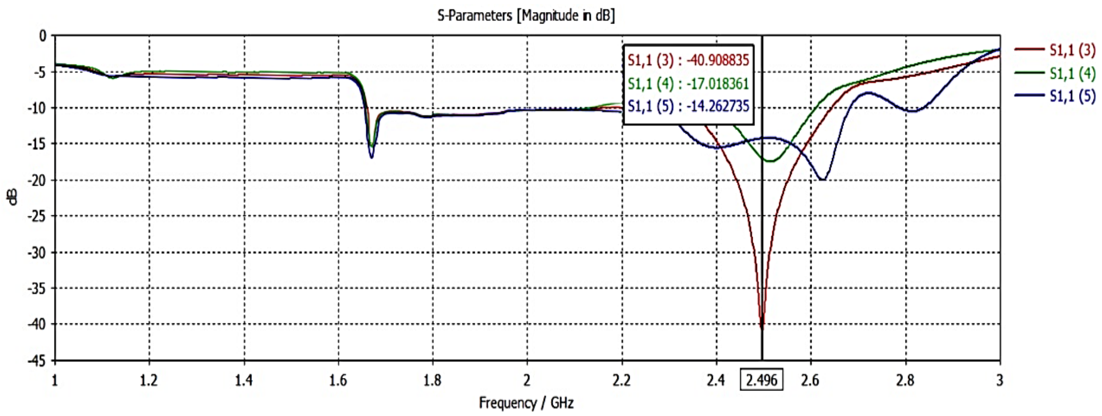


Figure 6. Return loss vs frequency plot where S1,1(3)-H = 42 mm, S1,1(4)-H = 32 mm, S1,1(5)-H = 52 mm

3.2. VSWR

VSWR shows a comparison of how well the energy per unit time is transferred along the transmission line of the point of load. A matched antenna has less reflection coefficient as well as a low value of VSWR. Figure 7 depicts the results obtained for VSWR in the required frequency range.

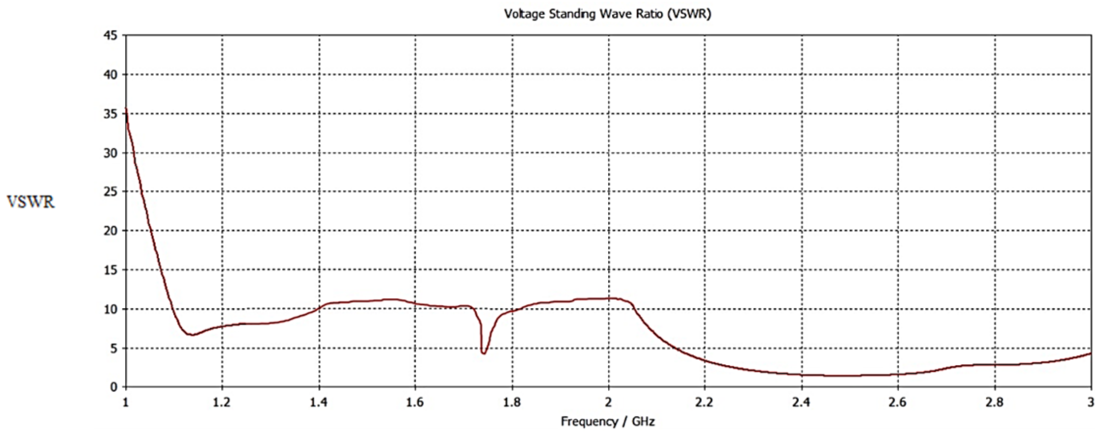


Figure 7. VSWR vs frequency plot

3.3. Directivity

It is a parameter that shows the degree to which the radiation is shown in a particular direction. Figure 8 depicts the radiation pattern obtained at 1.65, 2.25, and 2.75 GHz. The observed range of frequency is from 1.65 to 2.75 GHz to demonstrate and analyze radiation, directivity over the frequency range of operation. Figure 8(a) shows the radiation pattern at a frequency of 1.65 GHz and Phi = 0, Figure 8(b) shows the radiation pattern at a frequency of 1.65 GHz and Phi = 90, Figure 8(c) shows the radiation pattern at a frequency of 2.25 GHz and Phi = 0. Figure 8(d) shows the radiation pattern at a frequency of 2.25 GHz and Phi = 90, Figure 8(e) shows the radiation pattern at a frequency of 2.75 GHz and Phi = 0, and Figure 8(f) shows the radiation pattern at a frequency of 2.75 GHz and Phi = 90.

From the above radiation patterns, it can be observed that at 1.65 GHz, 2.25 GHz, and 2.75 GHz there is hardly any notable deviation in patterns of radiation ranging across a broad frequency range of operation which is desired. Figure 9 depicts the Farfield plot which presents the directivity of the antenna concerning theta and phi plane at 2.5 GHz where return loss is the least. The gain versus frequency response is observed in the next subsection.

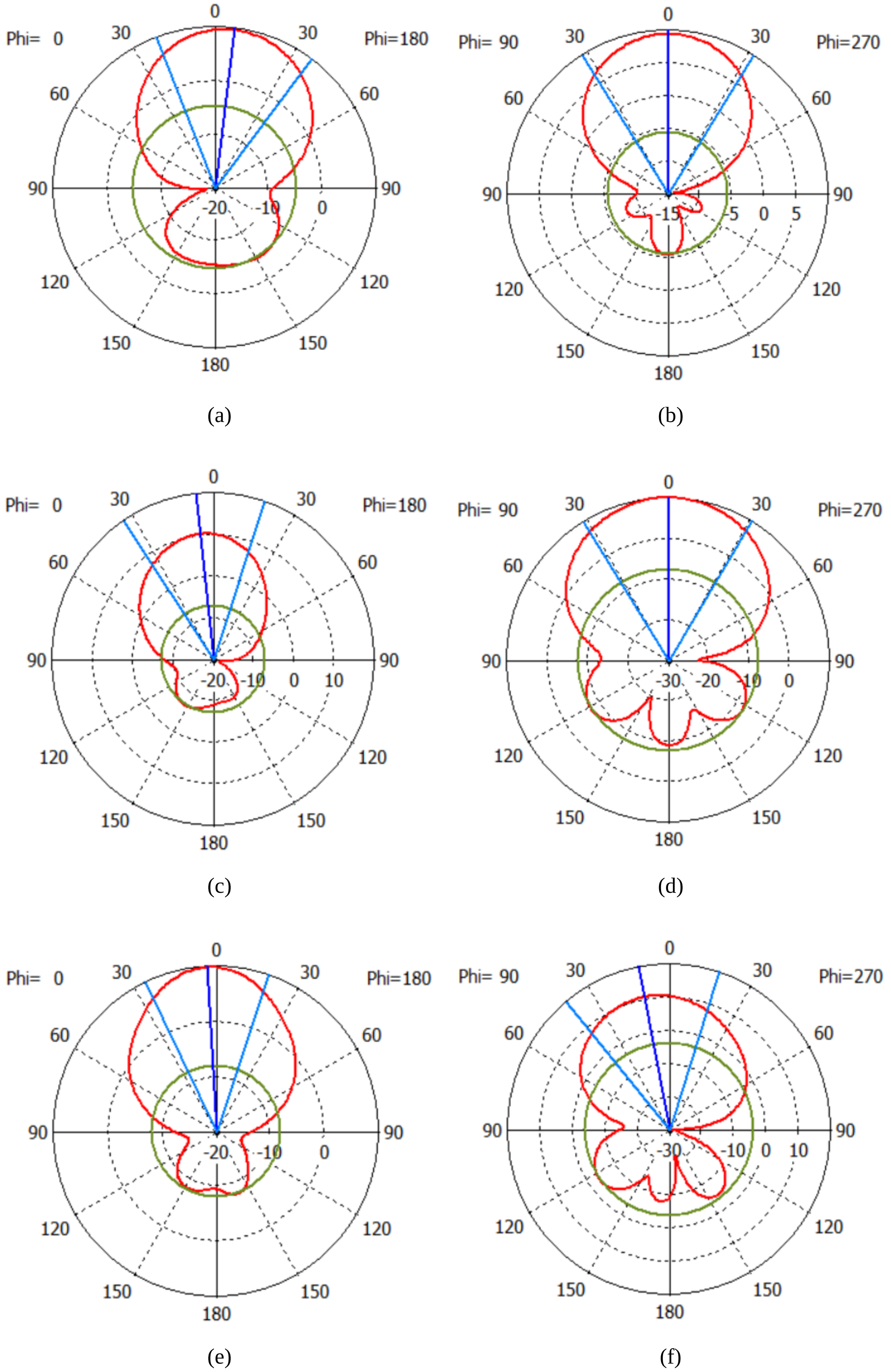


Figure 8. Radiation patterns at frequencies: (a) 1.65 GHz, Phi = 0; (b) 1.65 GHz, Phi = 90; (c) 2.25 GHz, Phi = 0; (d) 2.25 Ghz, Phi = 90; (e) 2.75 Ghz, Phi = 0; and (f) 2.75 Ghz, Phi = 90

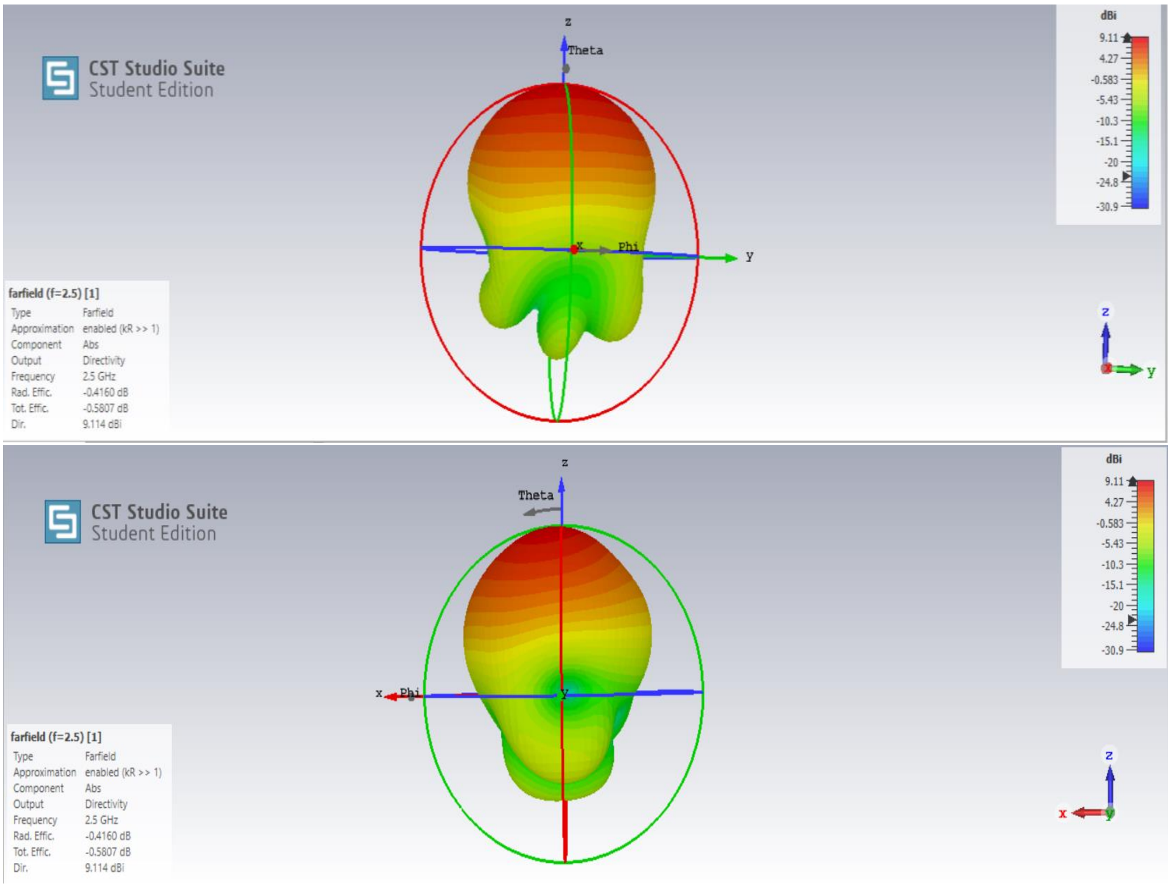


Figure 9. Farfield plot simulated for 2.5 GHz

3.4. Gain vs frequency

A Gain of an antenna relates the amount of power that is being transmitted in direction of peak radiation to the power transmitted by an isotropic source. Figure 10 depicts the dependence of gain and frequency. The maximum gain is obtained at a frequency of 2.5 GHz. Table 1 presents the change in antenna parameters concerning the width of the coplanar stripline. From this Table 1, it can be observed that with the increase in slot width of the coplanar stripline (Wd) directivity increases but bandwidth does not increase accordingly. Hence $Wd = 2.1$ mm is the optimal value and there is compensation between directivity and bandwidth of the antenna.

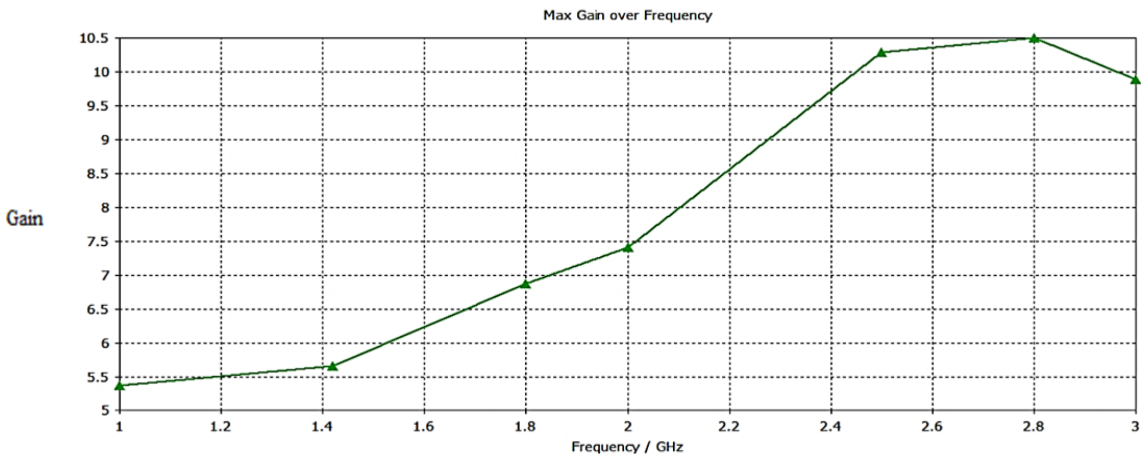


Figure 10. Gain vs frequency plot

Table 1. Change in antenna parameters concerning the width of coplanar stripline

Width (Wd)	Directivity	Bandwidth
$Wd = 1.5\ mm$	10.3 dBi	306 MHz
$Wd = 2.1\ mm$	10.4 dBi	347 MHz
$Wd = 2.7\ mm$	11 dBi	248 MHz

4. CONCLUSION

A broadband planar antenna to work in the operating frequency range of 1.65 GHz to 2.75 GHz has been simulated successfully using CST Microwave Studio. The desired results were found out at $Wd = 2.1$ mm and $H = 42$ mm. The proposed antenna can be used to enhance 2G/3G communication which needs to work in multiple frequency ranges and can meet the new standards of communication. The main advantages we get are its comparatively small size, better impedance matching, less reflection coefficient, more VSWR, and better directivity. Shortly, one can proceed with a similar type of framework consisting of an antenna array that can provide better gain and directivity at the same time providing better bandwidth with almost the same reflection coefficient. The disadvantage of the wide range of frequency operations is the noise factor can also be mitigated.

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