Gap-coupled Circular Microstrip Patch Antenna for 60 GHz Millimeter Wave Applications

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***Abstract*- In this paper, the design of the gap-coupled circular microstrip antenna with multi-layer substrate for 60 GHz technology is presented. The two circular patches are placed closed to each other. The feed patch is the excited by microstrip line feeding technique and the parasitic patch is excited by gap-coupling. The designed antenna is simulated and optimized using CST Microwave Studio simulator based upon finite difference time domain method. The designed antenna produces a band width of 57.2 GHz to 64 GHz. The radiation pattern of the designed antenna at 60 GHz is presented. The radiation efficiency and the directivity of the designed antenna is 90.82% and 12.27 dBi respectively.**

Keywords: 60 GHz technology, gap-coupling, microstrip antenna.

I. INTRODUCTION

The major challenges in wireless communication are to increase the bandwidth, data rate and to decrease the interference. Using 60 GHz technology, these parameters of the wireless communication can be increased. The 7 GHz frequency band around 60 GHz ranging from 57 GHz to 64 GHz worldwide. The parameters discussed above can be improved using 60 GHz technology due to very high frequency as compared to the existing wireless system frequency [1-3]. Various advantages of 60 GHz technology have been discussed in [2].

There are various advantages of the microstrip antennas as compared to the conventional microstrip antennas such as low profile, small size, easy to fabricate, low fabrication cost etc[4-5]. Due to these advantages, these antennas are commonly used for light weight applications such as missile, air craft, aerospace, wireless communication. However these antennas have the limitation of low gain and narrow bandwidth. By changing the substrate parameters, the bandwidth of the microstrip antennas can be increased, but this method causes the generation of spurious radiation and poor radiation. Gap-coupling is one of the suitable methods to enhance the bandwidth of these antennas [6-9].

In this paper, a gap-coupled circular microstrip patch antenna is designed for 60 GHz applications. The design of the antenna is optimized using the CST microwave software based upon finite difference time domain method. The radiation and the total efficiency of the designed antenna are 90.82% and 88.56 %, respectively. The organization of the rest of the extended abstract is as follows: The geometrical configuration of the designed antenna is discussed in section II. Section III discusses the simulated results with discussion. Finally, section IV concludes the work.

II. ANTENNA GEOMETRY

The geometrical configuration of the proposed multi-layer gap-coupled microstrip patch antenna for 60 GHz technology is depicted in Fig. 1. Two microstrip circular patches are placed closed to each other as shown in Fig. 1. The left microstrip circular patch is the feed patch and excited by microstrip line feeding technique. The right circular metallic microstrip patch is excited by gap-coupling. The radius of feed patch is 'r_1' and of parasitic patch is 'r_2'. The thickness, the dielectric constant of the upper, middle, and lower substrate layers are 'h_1', ε_{r1}, and 'h_2', 'ε_{r2}' & 'h_3', 'ε_{r3}' respectively. The length and the width of the microstrip feed line is 'L' and 'W' respectively.

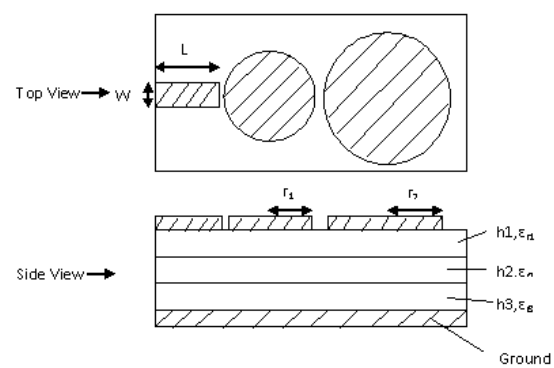


Fig. 1 Geometrical configuration of the multi-layer gap-coupled circular microstrip antenna.

III. RESULTS AND DISCUSSION

The designed gap-coupled circular microstrip antenna is simulated using FDTD based CST microwave studio software. The dimensions of the optimized simulated model is given in Table-I. The return loss of the designed gap-coupled microstrip antenna is shown in Fig. 2. From this figure, it can be observed that the designed antenna produces a frequency band from 57.2 GHz to 64 GHz, which can be used for 60 GHz technology. The radiation pattern of the designed microstrip antenna is shown in Fig. 3. The radiation

characteristics of the antenna have been described in table-II. The effect of the gap distance between adjacent edges of the feed patch and parasitic patch on the resonant frequency of the designed gap-coupled microstrip antenna is shown in Fig. 4. From this figure it is clear that the resonant frequency of the antenna decreases on increasing the gap between adjacent edges of patches. The variation of the resonant frequency with the thickness of the air-gap is also shown. From Fig. 5, it can be observed, that the resonant frequency can be easily controlled by varying the air-gap thickness. The resonant frequency increases on increasing the thickness of the air gap as shown in this figure.

TABLE I
DIMENSIONS OF THE PROPOSED ANTENNA

Radius of feed patch (mm)	1.5
Radius of parasitic patch (mm)	2
Thickness of upper the substrate (mm)	0.2
Dielectric constant of the upper substrate	2.2
Thickness of the middle substrate (mm)	0.5
Dielectric constant of the middle substrate	1
Thickness of the lower substrate (mm)	0.3
Dielectric constant of the lower substrate	2.2

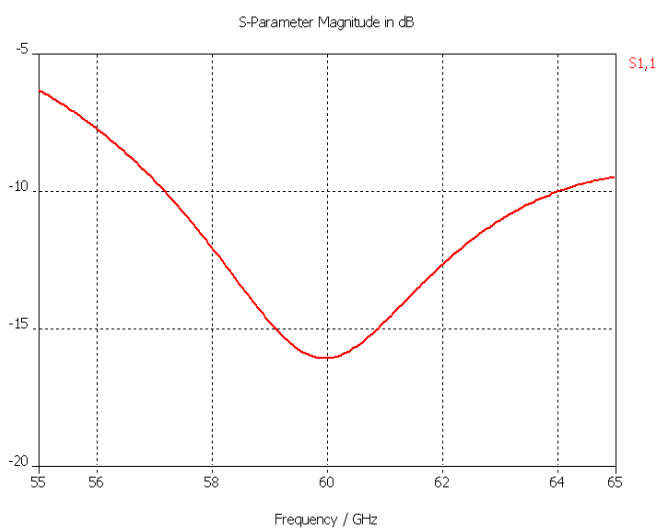
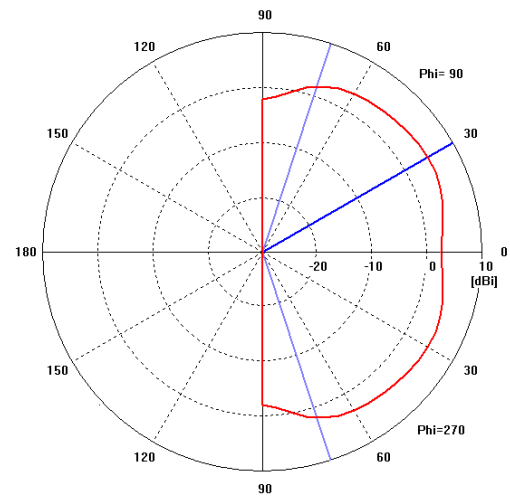


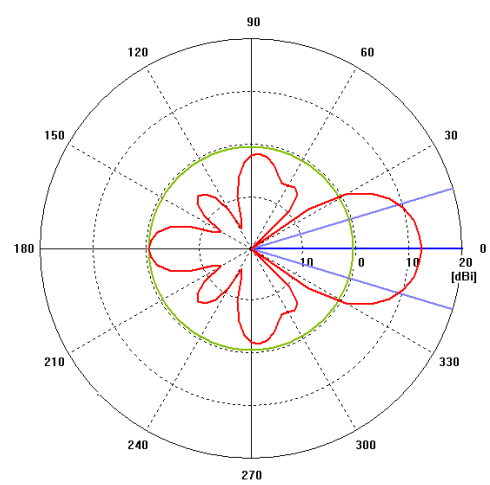
Fig. 2 Return loss of the gap-coupled circular microstrip antenna.

TABLE II
RADIATION CHARACTERSTICS AT 60 GHz OF THE PROPOSED ANTENNA

Radiation Efficiency	0.9082
Total Efficiency	0.8856
Directivity (dBi)	12.27
Main lob magnitude (dBi) (theta plane)	4.7
Main lobe direction (theta plane) (in degrees)	30
3 dB Angular width (in degrees) (theta plane)	143.6
Main lob magnitude (dBi) (phi plane)	12.3
Main lobe direction (phi plane) (in degrees)	0
3 dB Angular width (in degrees) (phi plane)	33.6
Side lobe level (dB)	-12.8



(a)



(b)

Fig. 3. Radiation papttern of the antenna at 60 GHz, (a) theta plane, (b) phi plane.

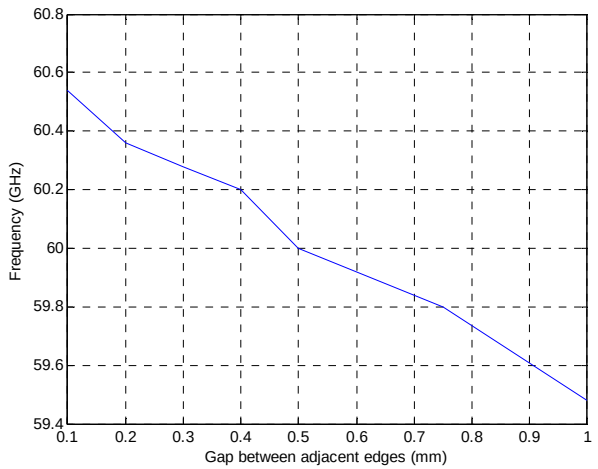


Fig. 4. Variation of resonant frequency with gap between adjacent edges of feed patch and parasitic patch.

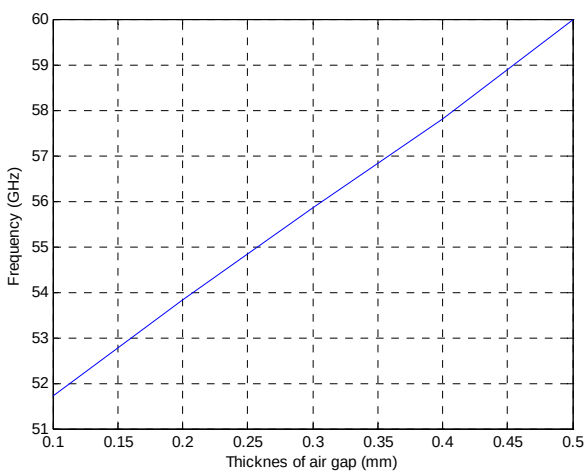


Fig. 5 Variation of resonant frequency with thickness of air gap.

IV. Conclusion

In this paper, a gap-coupled circular microstrip antenna has been designed for 60 GHz applications. The designed microstrip antenna is optimized using FDTD based CST Microwave simulator. The designed gap-coupled microstrip antenna produces a frequency band of 6.8 GHz for 60 GHz technology. The radiation efficiency up to 0.9082 and the total efficincy upto 0.8856 is achieved.

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