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DESIGN OF A MICROSTRIP FILTERING ANTENNA WITH SIR FILTER FOR 5G GLOBAL APPLICATIONS

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Abstract

A novel microstrip antenna with filtering characteristics is proposed for 5G Global wireless communication applications. The proposed filtenna consists of three parts: the monopole radiating patch antenna; the Stepped Impedance Resonator (SIR) filter; and the feeding microstrip line. The structure design is achieved on one-sided glass epoxy FR-4 substrate with dielectric constant $\varepsilon_r = 4.4$ and thickness h = 1.6 mm. The proposed microstrip filtering antenna is a compact single-layer filtering microstrip antenna with characteristics of low profile and a wide-band impedance bandwidth of about 3.5 GHz which makes the design suitable for broad casting data for long distance communications. The simulation results are generated by using the Computer Simulation Technology (CST) software package. The S_{11} parameters obtained when single SIR filter is used are not in the desired operating frequency but the S_{11} parameters obtained when two SIR filters are used.

Keywords: Microstrip filtering antenna, Stepped impudence resonator (SIR), Wide-bandwidth, 5G Global Applications..

INTRODUCTION:

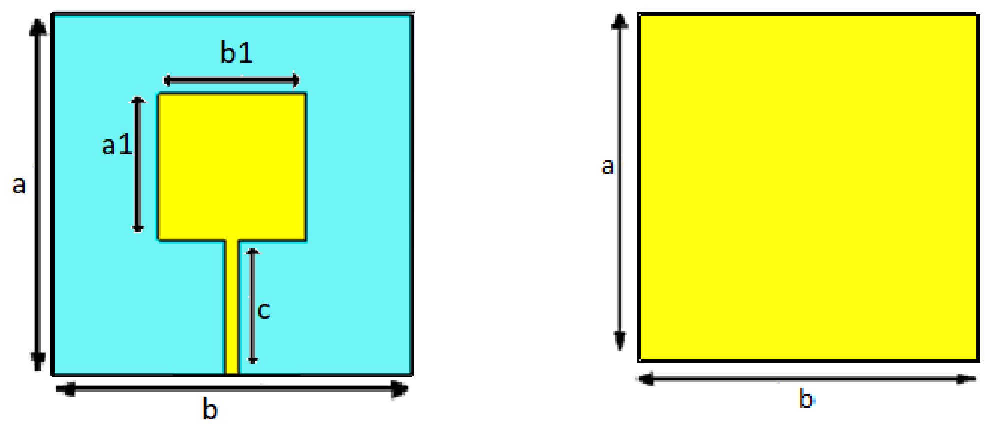
The most commonly used planar antenna is a microstrip antenna which is suitable for many wireless applications and also easily integrable with many VLSI circuit boards [1-3]. Microstrip Patch Antenna (MPA) has been designed and widely characterized as many years ago for various reasons, the most important was that it had a low profile, light weight and had a low fabrication cost [4-6]. The radio frequency current is applied between the antenna and ground plane. Different techniques have been developed in order to achieve rapid solutions to enhance radiation specifications such as bandwidth and gain [7-8]. The radiating patch can assume in any shape like rectangle, circle, square, dipole and triangle [9-10]. While designing an antenna the researcher should also consider the electrical characteristics of these antennas such as center frequency (f_0), voltage standing wave ratio (VSWR), return loss, gain and radiation pattern of the antenna [11-12]. One way to minimize the overall circuit size and increase the bandwidth is to integrate the Stepped Impedance Resonator (SIR) filter with the monopole patch antenna in one single module [13]. This integration changes the structure of the circuit, improves the performance of the circuit and simplifies the connection among various components [14]. A compact single-layer filtering microstrip antenna with diverse characteristics of low profile, high gain, wide band, and high selectivity will be implemented [15-16].

In this paper, a novel compact filter-antenna design with a wide-band performance for 3.5 GHz and 5G Global wireless communications is presented. Unlike other microstrip filter-antenna designs proposed in the literature, the design proposed in this paper has some advantages such as compact size, simple structure, high gain, and wide bandwidth with good S_{11} characteristics. Also, this is a compact filtering antenna utilizing SIR filter along with microstrip line feed.

Filtenna Design:

Step-1:

The Geometry of the proposed microstrip antenna is described in Figure 1. The designed structure is printed on one side of a glass epoxy FR-4 substrate with dielectric constant $\varepsilon_r = 4.4$, thickness is of 1.6 mm, height and width of 32 mm each. The patch is made of copper material with a height and width of 13 mm each. The feed is also made up of copper with a height of 14 mm and width of 2.5 mm, which is attached to the patch of the antenna. And on the other side of the glass epoxy FR-4 substrate a copper material with 32 mm height and width is placed. The dimensions of the designed antenna step-1 are tabulated in Table-1.



(a) Front View (b) Rear View

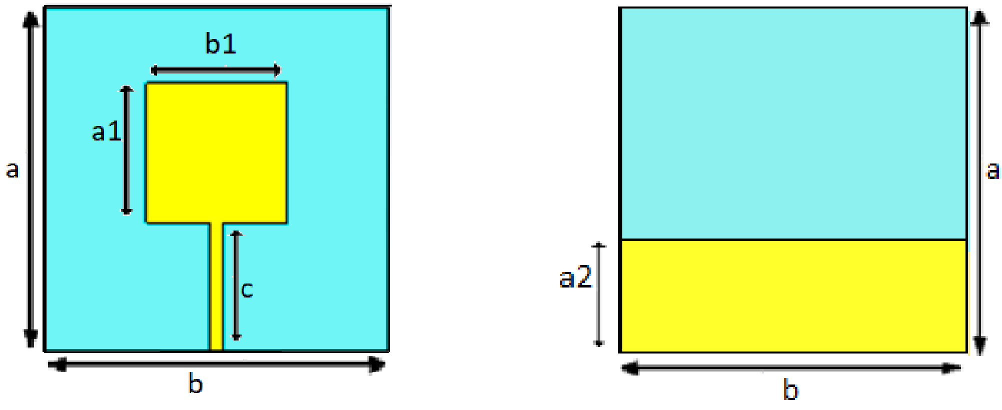
Figure 1: The proposed antenna without filter and DGS (Step1)

Table 1: The dimensions of the designed antenna step-1

Parameters	a	b	c	a1	B2
Values (mm)	32	32	14	13	13

Step-2:

In this step to achieve bandwidth the Defected Ground Structure (DGS) is implemented on the ground plane. The rectangular shaped ground is etched with dimensions of 24mmX32mm. Further, the size is optimized to achieve the better performance characteristics. The proposed antenna with DGS is depicted in figure 2. The dimensions are tabulated in Table 2.



(a) Front View (b) Rear View

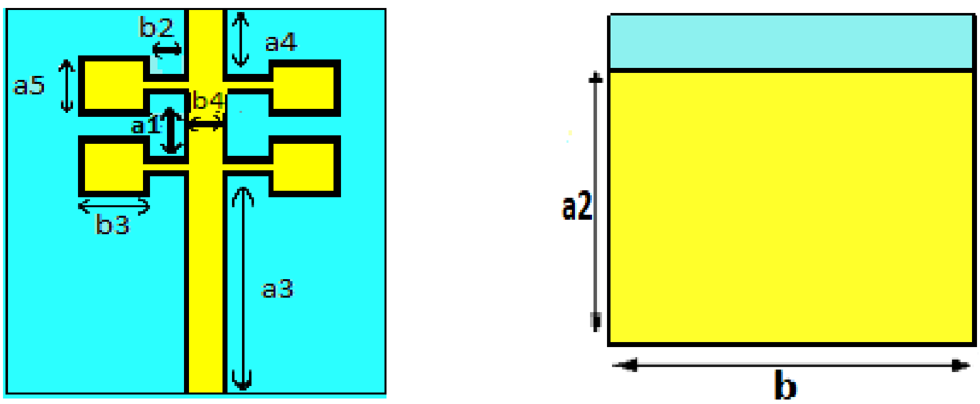
Figure 2: The proposed microstrip antenna with DGS (Step2)

Table 2: The dimensions of the proposed antenna with DGS (step 2)

Parameter	a	b	c	a1	b2	a2
Value (mm)	32	32	14	13	13	8

Step-3:

The filtering characteristics are achieved by adding stepped impedance resonator structure at the center of the microstrip feed line. This SIR filter is used to suppress the unwanted harmonic frequencies and improves the selectivity. The SIR also introduces a high impedance path at the resonant frequency, which enhances the antenna's gain. The geometry of the SIR filter is depicted in figure 3 and the dimensions are tabulated in table 3.



(a) (b)

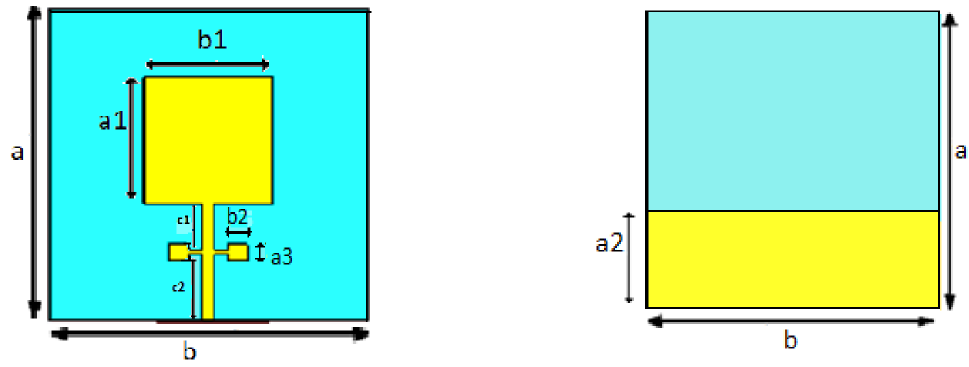
Figure 3: The proposed filter and DGS (Step3)

Table 3: The dimensions of the proposed SIR filter (step 3)

Parameters	a1	a2	a3	a4	a5	b2	b3	b4	b
Values (mm)	3	8	6	4	1.5	2	2	1.25	32

Step-4:

In this step the size and shape of the patch is optimized to achieve the desired frequency operation. This includes the width and length of the feed line as well as the location of the feed point on the patch. The total length of the feed line is 14 mm and SIR filter 1 is added at 4 mm. The front and rear views of the designed filtenna are shown in figure 4. The dimensions are tabulated in Table 4.



(a) Front View (b) Rear View

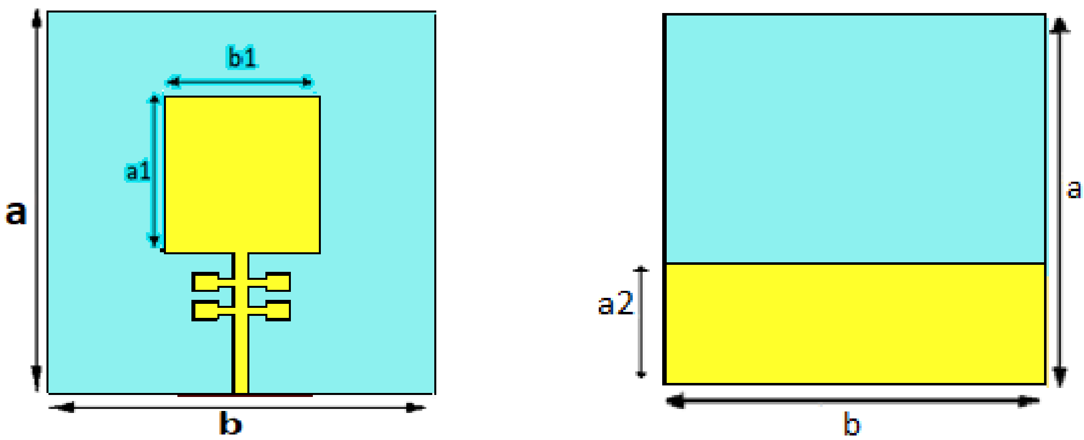
Figure 4: The proposed Filtenna with SIR filter (Step 4)

Table 4: The dimensions of the proposed filtering antenna in step 4

Parameters	a	b	c1	c2	a1	b2	a3	b2	a2
Values (mm)	32	32	6	6	13	13	1.5	2	8

Step-5:

In step-4 a SIR filter is connected to the center of the feed line. To achieve better performance characteristics another SIR filter is connected to the feed line. The geometry of the proposed filtenna with two SIR filters is shown in figure 5 and the dimensions are tabulated in Table 5.



(a) Front View (b) Rear View

Figure 5: The proposed antenna with filter and DGS (Step 5)

Table 5: The dimensions of the proposed filtering antenna in step 5

Parameter	a	B	a1	b1	a2
Value (mm)	32	32	13	13	8

Results and Discussion:

Return loss Characteristics:

The proposed antenna is simulated using 3D simulation Tool CST Microwave Studio. The S_{11} plot of the proposed antenna for step 1 is shown in figure 6. The simulated return loss plot clearly shows that the antenna has a band of operation from 5.2 GHz to 5.4 GHz with a return loss of less than -10 dB. The minimum return loss is achieved at 5.325GHz of -12.33dB.

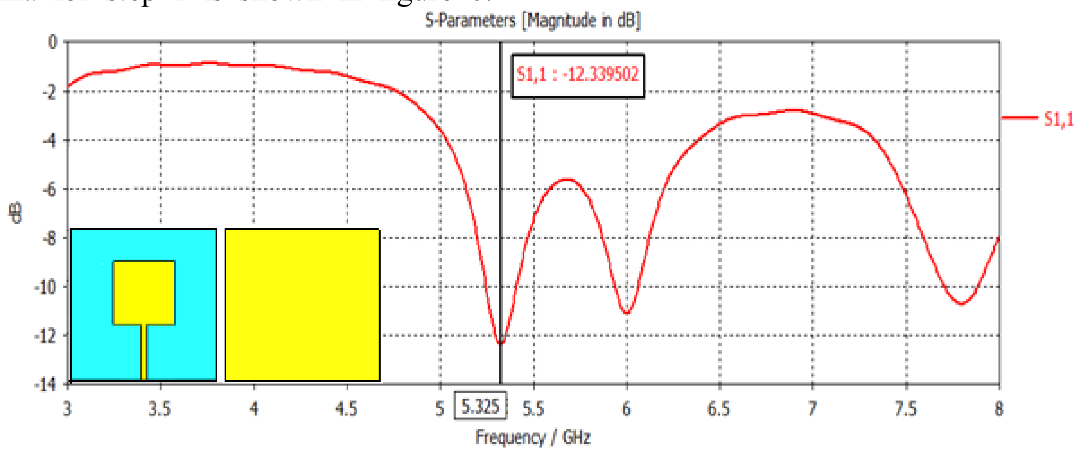


Figure 6. S_{11} of the proposed antenna for step 1

The S_{11} plot of the proposed antenna with DGS is shown in figure 7. The simulation results show that the antenna has a wide bandwidth from 1.83 GHz to 4.37 GHz with a return loss of less than -10 dB. The bandwidth offered at step 2 is given by 2.54GHz. The size and shape of the patch is optimized to achieve the better operating frequency. This includes the width and length of the feed line as well as the location of the feed point on the patch.

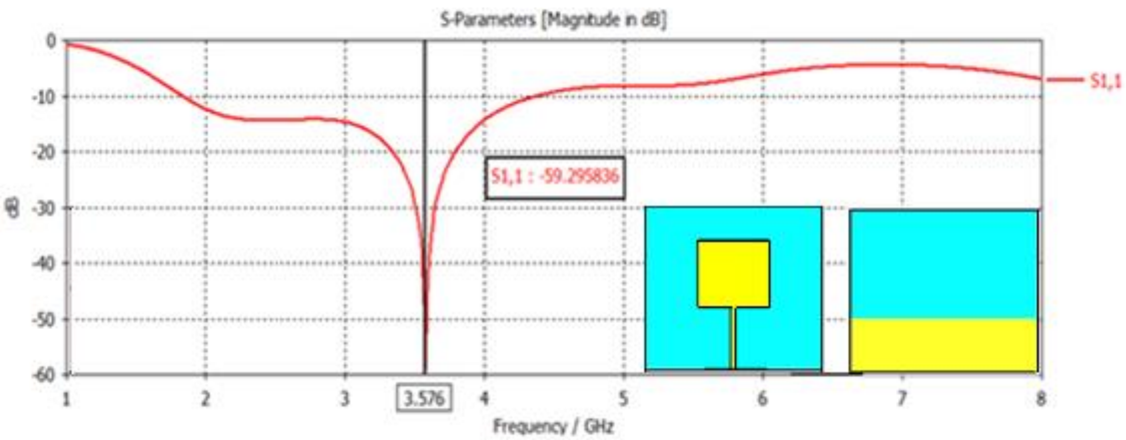


Figure 7. S_{11} plot of the proposed antenna with Defected Ground Structure (DGS) for step 2

The simulated return loss plot of the designed filtenna with single SIR filter is shown in figure 8. The simulation results show that the antenna has operating bandwidth of 300MHz from 1.56 GHz to 1.87 GHz. The size and shape of the SIR filter are optimized to get the desired operating characteristics.

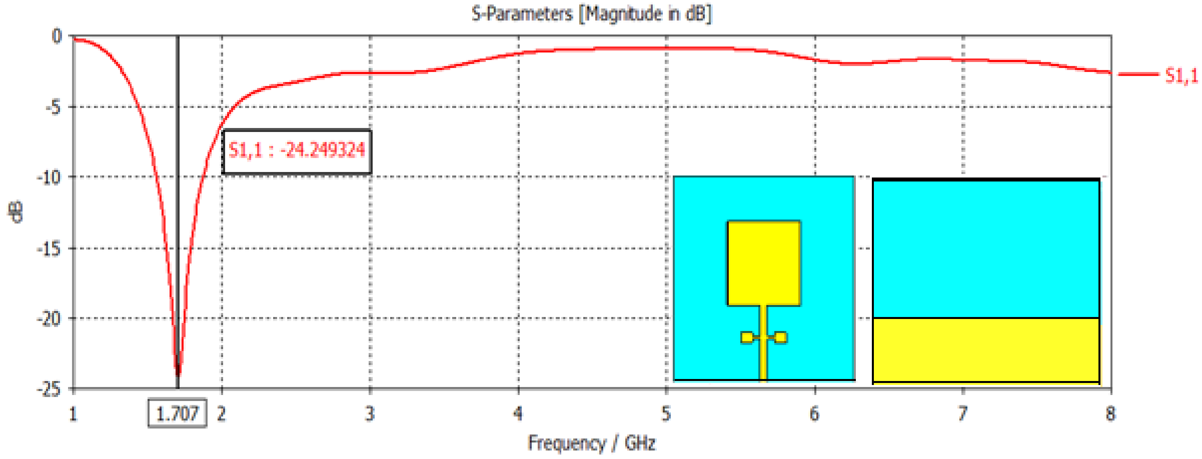


Figure 8. S_{11}-parameter of the proposed antenna with a single SIR filter

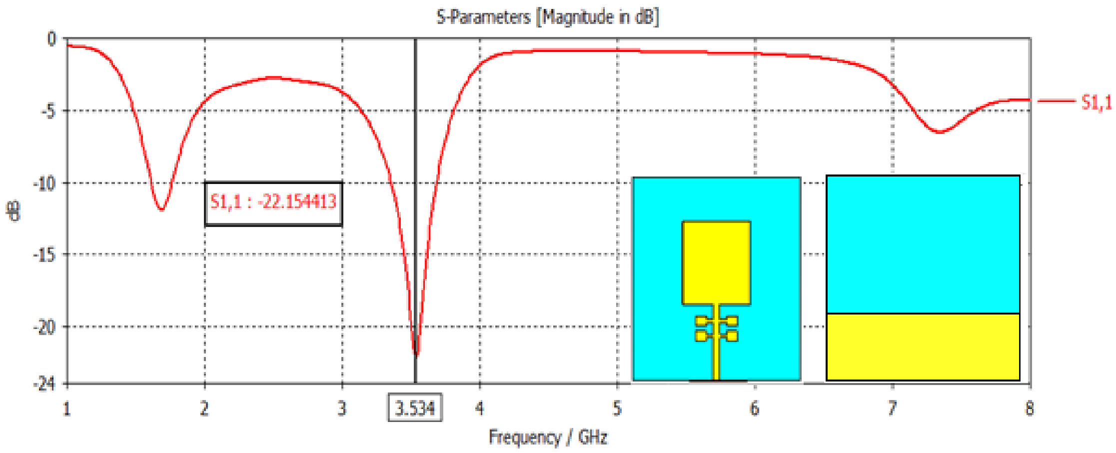


Figure 9: S_{11}-parameter of the proposed antenna with a double filter

The Return loss plot of the filtenna with double SIR filters is shown in figure 9. The simulation results show that the antenna has a wide bandwidth of 3.35 GHz to 3.68 GHz with a return loss of less than -10 dB. The SIR filter introduces a transmission zero at 0.5 GHz with a depth of -22 dB, which enhances the antenna's selectivity. The size and shape of the patch can be adjusted to the desired frequency. This includes the width and length of the feed line as well as the location of the feed point on the patch. The comparative analysis of all the steps is shown in Figure 10. From the plot it is clearly observed that the step 4 namely the filtenna with double SIR filters give the good results with respect to frequency of operation and bandwidth.

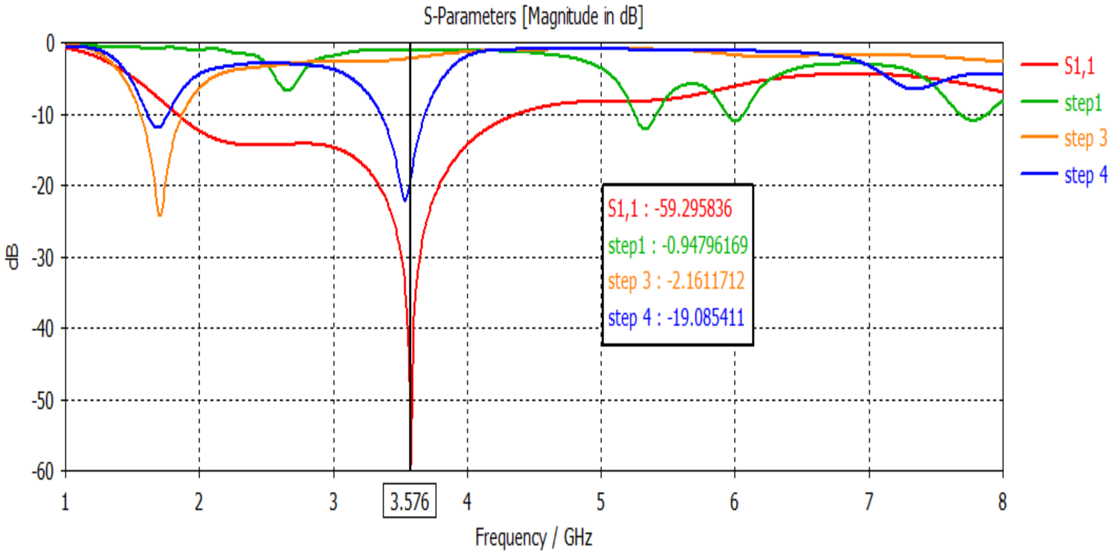
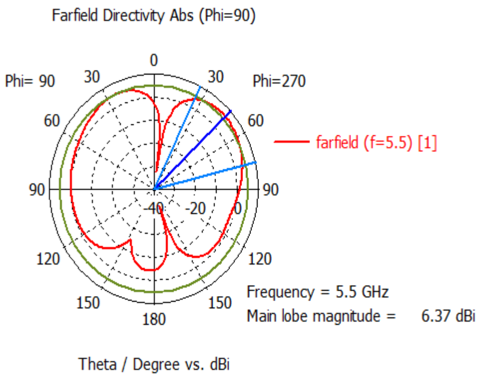


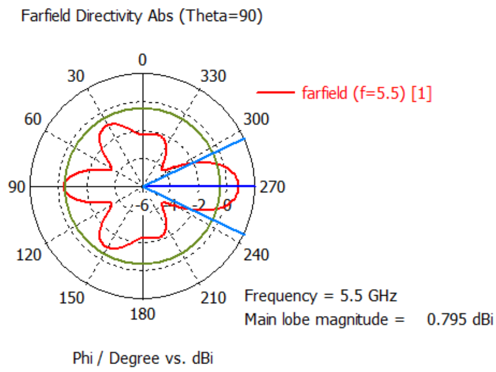
Figure 10: S parameter of the all the designed antennas

Pattern Characteristics:

The far filed radiation pattern characteristics of antenna design for step 1 are shown in the Figure 11. This antenna offers the maximum gain of 6.37dBi at 5.5GHz for E-plane where as it offers less gain for H-plane. It is clear that the proposed antenna offers good Omni directional radiation pattern for E-plane.



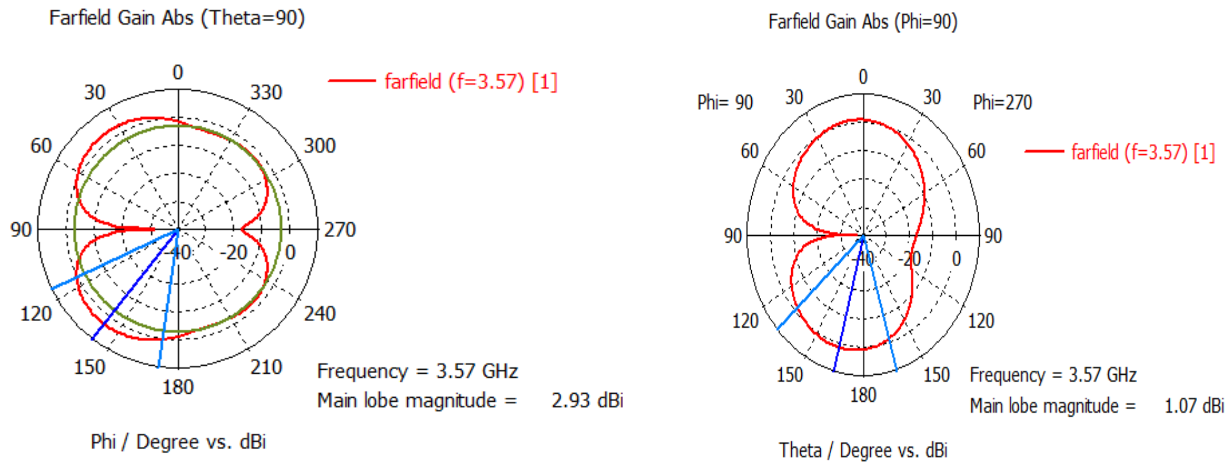
(a) E-Plane



(b) H-Plane

Figure 11. Far field Radiation patterns for the proposed design step 1

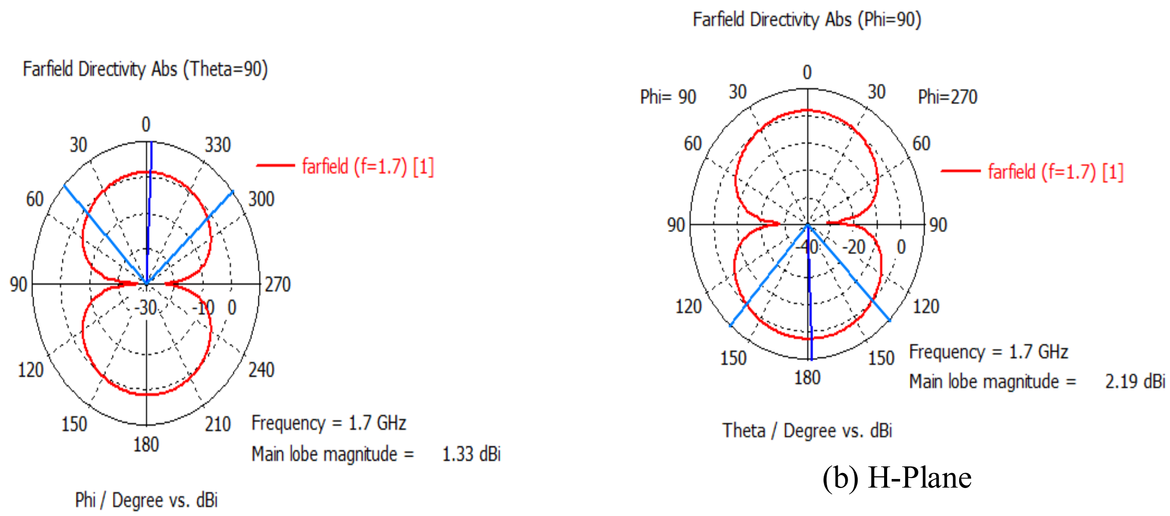
The 2D-polar radiation patterns of the proposed antenna for step 2 are shown in figure 12. The antenna offers the gain of 2.93 dB at the resonant frequency of 3.57 GHz. It is observed that the proposed design shows the bidirectional radiation patterns in both E & H –planes.



(a) E-Plane (b) H-Plane

Figure 12. Far filed radiation patterns for the proposed antenna for step 2.

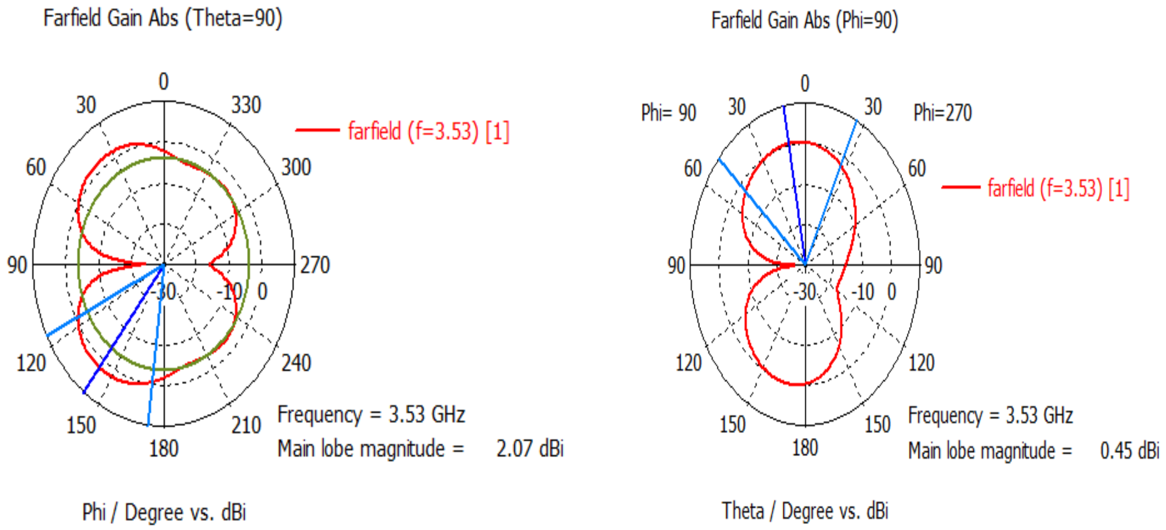
The far field radiation pattern of the proposed filtenna for step 4 is shown in figure 13. From the figure it is clearly observed that the proposed filtenna offers stable bidirectional radiation patterns for both E&H- planes. And also it shows the figure of eight shaped radiation pattern with maximum gain of 2.19dBi at 1.7GHz frequency.



(a) E-Plane (b) H-Plane

Figure 13. Far field Radiation patterns of the proposed filtenna for step 4

The far field radiation pattern of the proposed filtenna for step 5 is shown in figure 14. The filtenna offers a maximum gain of 2.07 dBi at the resonant frequency of 3.53 GHz. The E-plane radiation pattern shows almost unidirectional radiation pattern with some vestigial side band whereas the H-plane radiation pattern is bi-directional.



(a)E-Plane (b)H-Plane

Figure 14. Far field radiation patterns for the proposed filtenna for step 5

Conclusion:

In this work, a compact microstrip filtenna with double SIR filter is designed for 5G global wireless applications. The step by step design parameters are analyzed and presented for each step starting from rectangular patch without DGS, then with DGS and finally integrated with SIR filters. All performance characteristics like return loss, VSWR, Gain and E&H-Plane radiation characteristics are presented. The proposed antenna without SIR filter and with DGS offers a maximum bandwidth of 2.54GHz. But, after integrating with SIR filters the pass band frequency is drastically reduced to 330MHz. It means that if suppresses the ripple components and passes only the desired frequency ranges only. The simulation results show that the antenna meets the desired specifications and can be used in modern day 5G wireless communication systems. The design shows good performance and is suitable for Wireless & Satellite communication, Radar system, medical applications, Converged Multimedia Services, and Research and Scientific Applications.

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