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Design of Dual Band Filtering Microstrip Antenna for Global Mobile Broadband Services and Wi-Max Applications

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Abstract: In this article, the design of dual band filtering microstrip antenna with sharp frequency response with low insertion loss is presented for Global Mobile and Wi-Max Applications. The proposed filtering antenna is designed on FR4 substrate with dielectric constant 4.3 and loss tangent 0.025 having the dimension of $23\times31\times1.6mm^3$. The Defected Ground structure is implanted for ground plane with dimension of $23\times7.5\times0.035mm^3$. The rectangular patch is used as radiating element with dimension of $7\times6\times0.035mm^3$. A rectangular slot is connected at the bottom side of the patch to improve the operating characteristics. Further, to achieve the frequency selective characteristics a microwave filter with square ring shaped with inner square slot is connected to the rectangular patch. The proposed filtering antenna is operating at dual band frequencies i.e., at 2.64GHz and 3.09GHz with sharp pass and stop band characteristics. The achieved operating frequencies are very much useful for global mobile broadband services and Wi-Max applications. The proposed antenna is simulated using CSTMWS Tool.

Keywords: Microstrip filtering antenna, Defected Ground structure, Global mobile broadband services, Wi-Max Applications

I. INTRODUCTION

The International Telecommunications Union (ITU) says that the 2.6 GHz band (2.5 GHz to 2.69 GHz) is the best place for 4G and 5G networks to offer global internet mobile services. This part of the frequency range will be important for mobile broadband uses in the future [1]. A number of frequency bands below and above this one are already in use by other cell services. So, to keep interference from neighboring frequency bands from happening, we need to make an antenna system that can filter out messages that aren't in the right band. A planar microstrip antenna is the best choice for mobile devices because it is made up of a ground plane and a metal radiating patch that is etched onto a dielectric PCB base. It is very easy to handle multiple frequencies, change the polarization, and reconfigure a microstrip antenna [2].

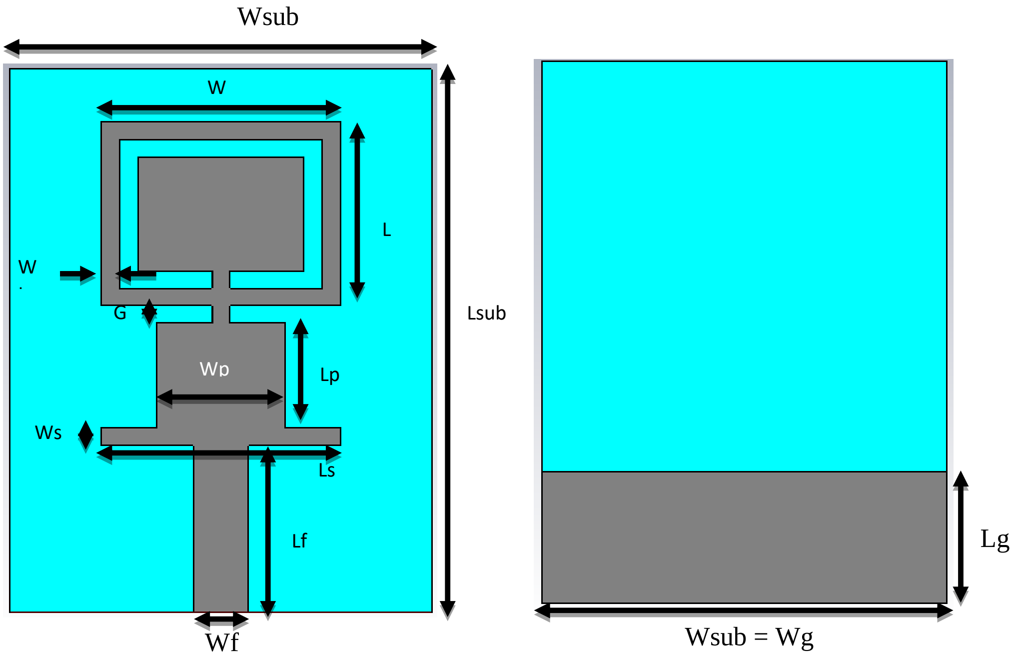
There is something called a "filtenna" that sends and gets passband signals and blocks out-of-band signals that are close by [3]. In-band filtering for the RF front-end can be done in a number of different ways, and each has its own pros and cons. In [4], a ceramic-based short-ended coupled line is studied for the purpose of creating a filter that can be used at the base station to handle a lot of power. In [5], an idea for a dual microstrip line low pass (LPF) filter is put forward. This filter has a large stop band and a sharp roll-off rate. A non-uniform filtering method is used in [6] to stop the higher order harmonics when making an active antenna for a wireless local area network (WLAN). When reading [7], a programmable filter with adjustable fold properties is used to make the RF front-end better at blocking jamming over a wide frequency range. In real life, the form of a filtering antenna depends on what it is used for. A study in [8] looks at the lower gain response in the passband of a filtenna of a fan-shaped radiator with a defective ground structure (DGS) and a Butterworth bandpass filter. A high gain filtering antenna is described in [9]. It has a driven patch, a stacked patch with shorting pins, and a U-slot built into the patch.

In [10], a wideband, small, and adaptable filtering patch antenna is created. It has three J-shaped probes, a Wilkinson power divider, and phase shifters in the feed network. In [11], a low-profile polarization diversity filtering antenna design is shown. The antenna is powered by a coupling probe that was specially made for it. A duplex filter antenna with two vias and a substrate integrated waveguide (SIW) is described in [12] to improve the pass band's sensitivity. It has a 4.2% impedance bandwidth at 9 GHz. The plan for a dual circularly polarized cavity-backed filtenna using SIW technology is shown in [13]. At 10 GHz, the operating bandwidth is 12 %. In [14], a full-duplex filtering antenna that is vertically integrated and has a SIW cavity is developed. This antenna has a measured gain of 4.36 dBi and an impedance bandwidth of 3.2% at 4 GHz. For the filtenna design in [15], they use a circular radiator with a coplanar feed, shorting stubs, and a defective ground structure (DGS) to get a 20.34% fractional impedance bandwidth and a 1.88 dBi peak realization gain. A slot-loaded rectangular patch with shorting pins, linked lines, and DGS are used to get good impedance matching and high gain when making a small dual band filtenna [16].

A review of the literature shows that the main problem with the current filtering antennas is that they are very hard to design. A lot of those methods aren't flat and compact. At frequencies that aren't in the band, the return loss often goes above the accepted minimum value, and these antennas can't reduce the unwanted radiation that notching frequencies cause. The ways that screening antennas are made are also application-specific and the described solutions are of the general purpose variety. In this paper, the design of dual band microstrip filtering antenna is proposed with sharp frequency response and low insertion loss values. The frequency selective characteristics are achieved by implementing two switches. The operating frequencies are very much useful for Global mobile services and Wi-Max applications.

II. FILTERING ANTENNA DESIGN

The geometry of the proposed filtering antenna is shown in Fig.1. The proposed filtering antenna designed on the commercially available material FR4 substrate with dielectric constant ε_r= 4.4 and with loss tangent value is tanδ=0.025. The overall size of the proposed filtering antenna is 31×23×1.6mm^3. The ground plane length is optimized to 7.5mm by incorporating the Defected Ground Structure. Initially, the rectangular shaped radiating element is used having the dimension of 7×6mm^2. The proposed antenna is fed with simple microstrip lone feed. The width of the feed line is optimized to achieve the better operating characteristics. To improve the operating frequency characteristics a rectangular slot with dimension of 13.1×1mm^2 is added at the bottom end of the rectangular patch. All dimensions of the proposed design is tabulated in Table-1.



(a) Front View (b) Rear View

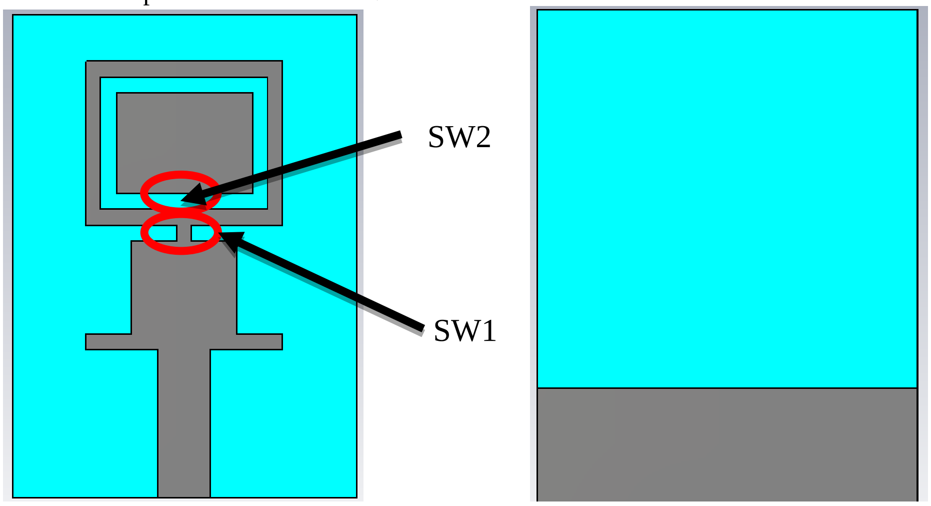
Fig.1 The geometry of the proposed filtering antenna

Table-1 The dimensions of the proposed filtering antenna

S. No	Parameter	Value (mm)
1.	Lsub	31
2.	Wsub	23
3.	Lg	7.5
4.	Wg	23
5.	Lf	9.5
6.	Wf	3.5
7.	Ls	13.1
8.	Ws	1
9.	Lp	7
10.	Wp	6
11.	G	1
12.	Wt	1

13.	L	13.1
14.	W	8.5

Further, to achieve the frequency selective characteristics a ring shaped filter is connected to the top edge of the radiating element. The Chebyshev filter prototype with maximally flat response filter is used to calculate the transfer function of the filter. The gap between the filter and radiating element is optimized to achieve the better frequency selective characteristics. Later, a square slot is etched on the inside edge of the filter to achieve the sharp passband and stop band characteristics.



(a) Front view (b) Rear view

Fig.2 The geometry of the proposed filtering antenna with ON-OFF condition

Due to this square slot inside the filter is acts as split ring resonator. Later, two switches are considered at the two junctions one is at the patch and filter junction another is at the filter and square slot. The switches are operated as ON & OFF. The switch is ON means the metallization is present and OFF metallization is not present. By ON & OFF conditions of the frequency selective nature is achieved. Fig.2 depicts the ON-OFF condition of the proposed filtering antenna.

III. RESULTS & DISCUSSION

III.I If both the switches are ON (11)

The return loss plot of the proposed filtering antenna for both the switches are ON is shown in Fig.3. This combination gives dual bands of operating frequencies at 2.64GHz and 3.09GHz with the return loss of -25.70dB and -28.61dB respectively. These operating frequencies are very much useful for global mobile services and Wi-Max applications. The operating bandwidths achieved are 277MHz and 397MHz respectively.

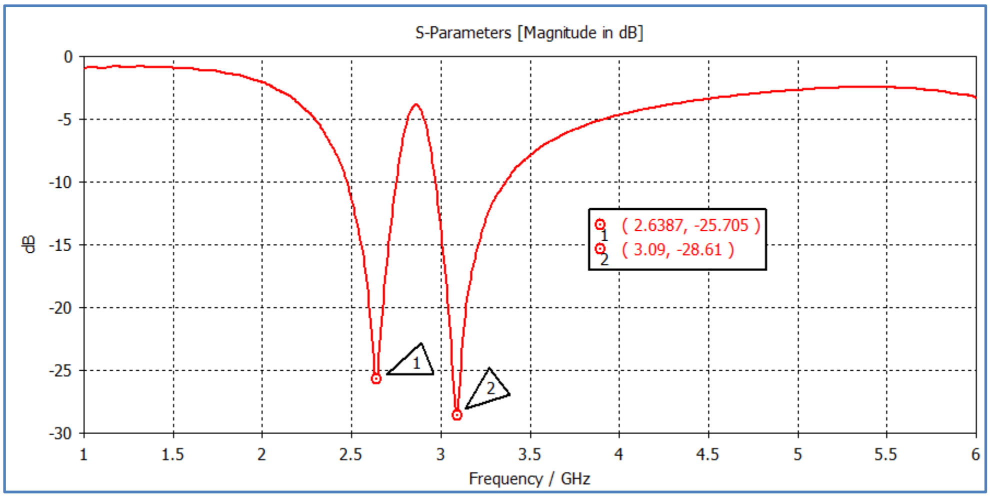


Fig.3 The return loss plot of the proposed filtering antenna when both switches ON

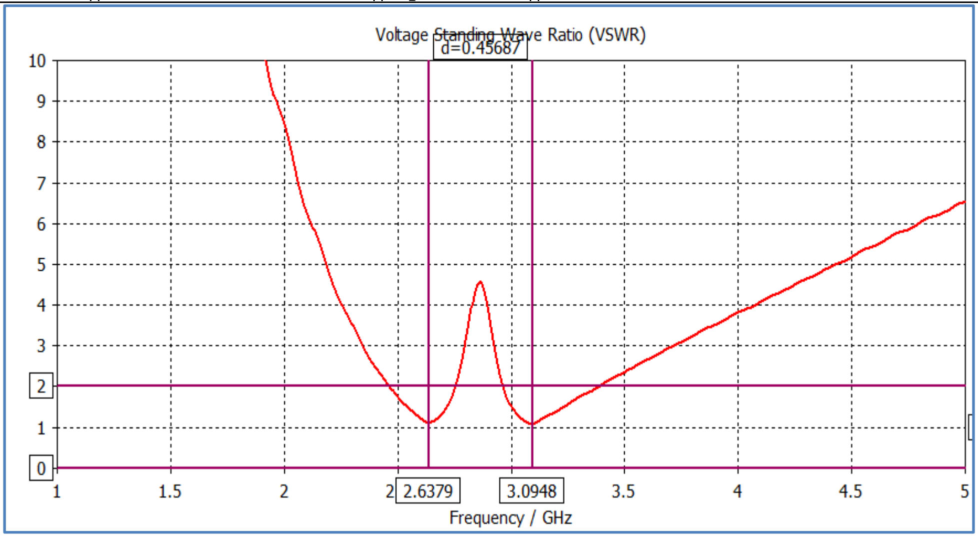
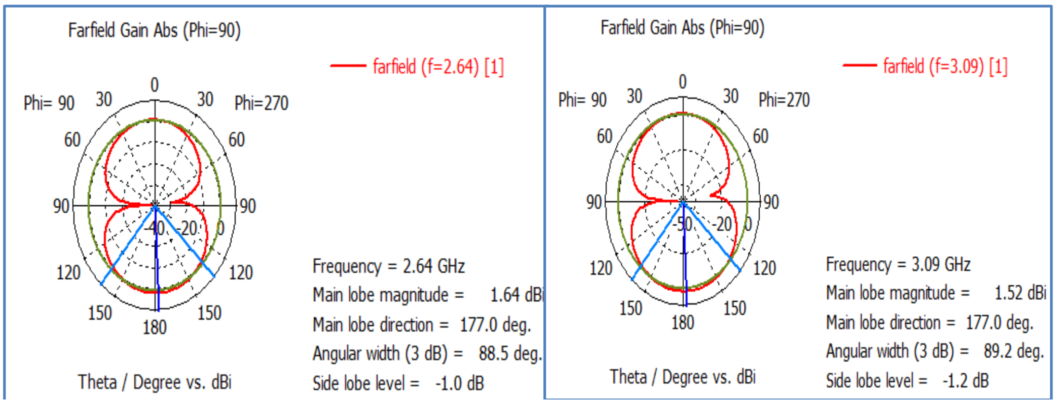


Fig.4 The VSWR plot of the proposed filtering antenna when both switches ON

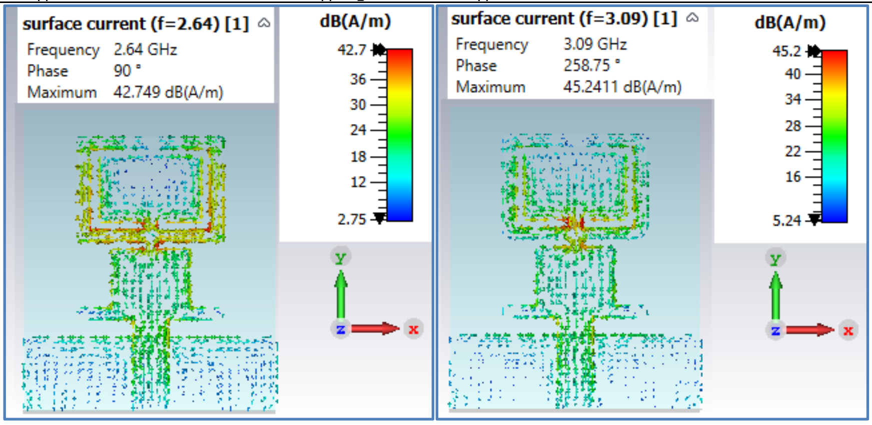
The VSWR plot of the proposed design with 11 switching condition is shown in Fig.4. From the figure it is clear that for both the operating frequencies the VSWR is less than 2. The far-field 2D-Gain plots of the proposed design with both the switches ON is shown in Fig.5. The far-field peak gain obtained is 1.64dBi at 2.64GHz and 1.52dBi gain is obtained at 3.09GHz respectively. The gain values achieved low due to the metallization on the substrate. But, at the operating frequencies the sharp pass band and stop band characteristics are observed due to the filter transfer characteristics.



(a) At 2.64GHz (b) at 3.09GHz

Fig.5 The far-field gain of the proposed filtering antenna when both switches ON

The distribution of surface current for the proposed design for 11 combination for both the operating frequencies is shown in Fig.6. The maximum surface current of 42.74dB (A/m) is distributed at an operating frequency of 2.64GHz. Whereas, surface current of 45.2dB (A/m) is distributed at 3.09GHz. From the surface current plots it is clearly observed that due to the low value of surface current at 2.64GHz the maximum peak gain of 1.64dBi is achieved. Due to the high value of surface current at 3.09GHz less value of peak gain is obtained.



(a) At 2.64GHz (b) At 3.09GHz

(b) Fig.6 The surface current distribution of the proposed filtering antenna when both switches ON

III.II If one switch is ON another switch OFF

If one of the switch is ON and another switch is OFF then proposed filtering antenna acts as a frequency selective device and will operate any one of the two operating frequencies. For (10) combination the proposed design is operating at 2.69GHz and for (01) condition the proposed design is selecting the 3.09GHz frequency band. Due to this the interference created by nearby systems can be eliminated by operating the switches ON & OFF. If both switches are OFF then the proposed antenna acts as a band rejection filter. No operating frequency is achieved foe the switching combination of (00). The parametric sweep of the feed line width for switching combination of (10) is shown in Fig.7. The feed line width is optimized from 2.5mm-3.5mm and lowest value of return loss of -34.03dB is achieved for 3.5mm width. From the parametric sweep plot it is clearly observed that even the width of the feed line is varied the operating frequency is not shifting from 2.69GHz. Therefore, the frequency selectivity is only depends on the filter parameters but not on the antenna parameters.

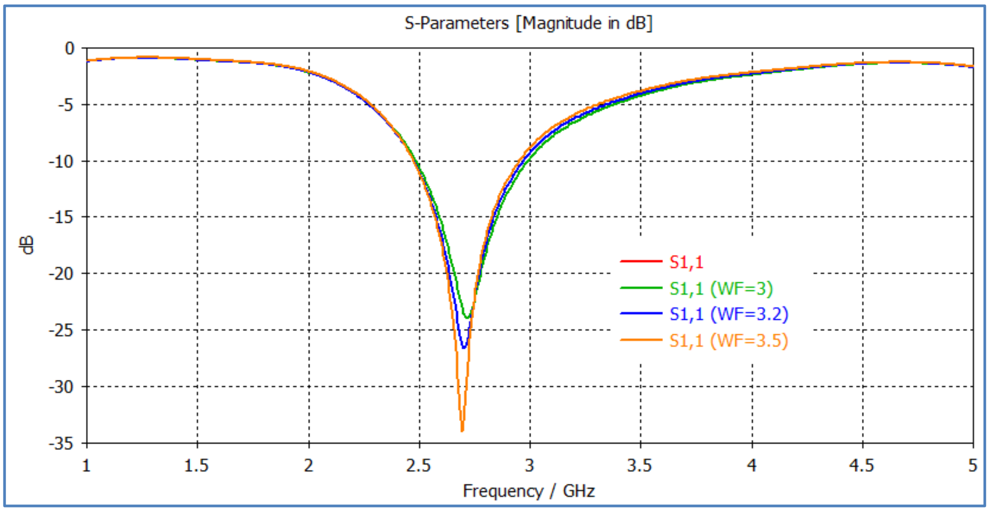


Fig.7 The parametric sweep of the feed line width for the switching combination of (10)

The return loss plot of the proposed filtering antenna for the switching combination of (10) is shown in Fig.8. This combination is resonating at a frequency of 2.69GHz with the return loss of -34.03dB. The bandwidth achieved is 375MHz.

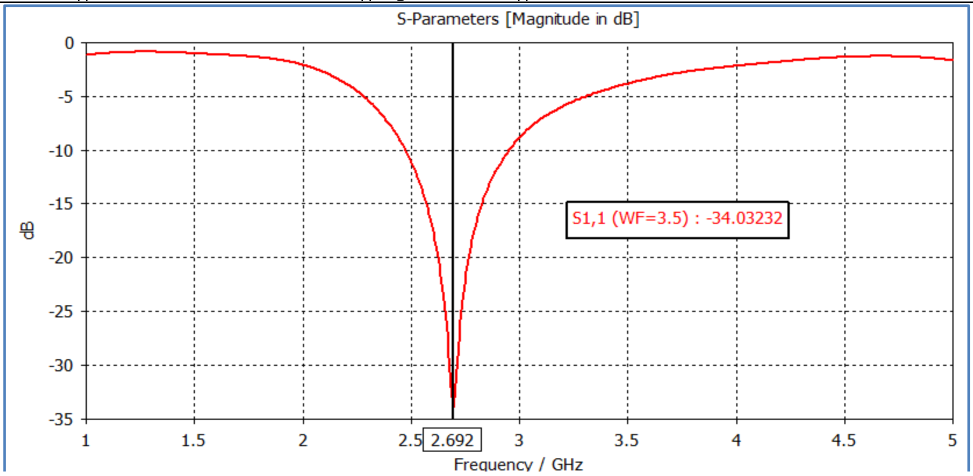


Fig.8 The return loss plot of the proposed filtering antenna for the switching combination of (10)

The VSWR plot of the proposed filtering antenna for (10) switching combination is shown in Fig.9. The VSWR value is below 2 for the operating frequency.

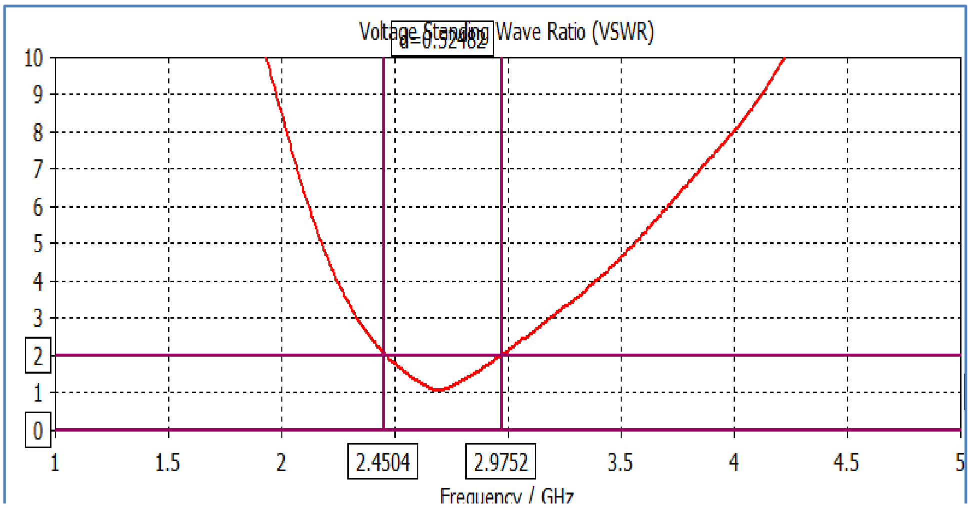


Fig.9 The VSWR plot of the proposed filtering antenna for (10) combination

The far-filed gain of the proposed antenna for (10) combination is shown in Fig.10. The gain value is 1.72dBi at the operating frequency 2.69GHz. The shape of the pattern resembles the shape of figure of eight. The bi-directional radiation pattern is observed due to the defected ground structure.

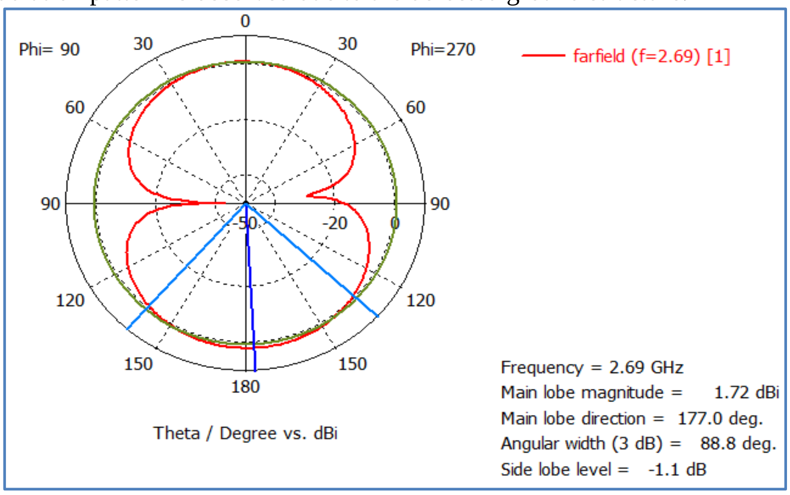


Fig.10 The far-filed gain of the proposed filtering antenna for (10) combination

The surface current distribution of the proposed filtering antenna for (10) switching combination is depicted in Fig.11. The maximum of 41.28 dB (A/m) is observed at the operating frequency. The maximum current is coupled at the junction of the patch and the filter.

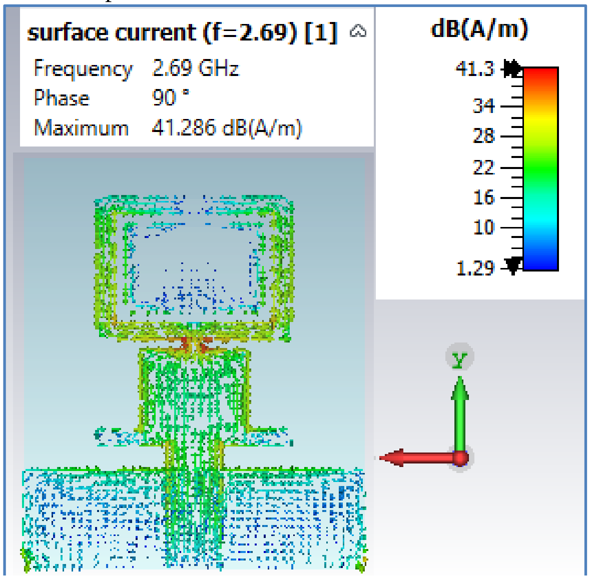


Fig. 11 The surface current distribution of the proposed filtering antenna for (10) combination

The summary of the operating frequencies along with their applications for all 4 switching combinations is summarized in Table-2.

Table-2. The summary of the operating frequencies of the proposed antenna

S. No	Switching Combination		Operating Frequencies	Bandwidth(MHz)	Applications
1.	OFF(0)	OFF(0)	Band Rejection Filter	- -- -	- -- -
2.	OFF(0)	ON(1)	3.09GHz	280	Wi-Max Applications
3.	ON(1)	OFF(0)	2.69GHz	375	Global Mobile Services
4.	ON(1)	ON(1)	2.69GHz, 3.09GHz	277, 397	Wi-Max, Mobile Services

IV. CONCLUSION

The dual band filtering antenna for Global Mobile services and Wi-Max applications is presented. The proposed design offers sharp frequency response with low insertion loss at the desired operating frequencies. The filtering action is enabled by assuming two switches at the junctions of the patch and filter. Due to this the antenna frequency selectivity is achieved and it is operating at both the frequencies for (11) combination. For (10) & (01) combinations the proposed design is choosing one of the frequency from both the operating frequencies. For (00) combination the proposed design acts as a band rejections filter. All the simulations are carried out using commercially available software CSTMWS Tool.

V. FUTURE WORK

In future, the proposed antenna will be fabricated and measured. The agreement between the simulated and measured results will be estimated.

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