A Compact Millimetre-Wave Filtering Antenna for Intelligent Transportation Systems

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Abstract - *This article proposes a novel compact E-shaped wide-band planar filter-antenna design. Additionally, the impact of the type of dielectric material on the design's properties is examined and discussed. A monopole microstrip antenna cascaded with an E-shaped planar band-pass filter (BPF) forms the filter-antenna construction. This paper proposes a microstrip patch filtering antenna with a band-notched characteristic. The microstrip patch antenna has a bandwidth of 500 MHz The Centre frequency is 25.6GHz. The filter-antenna design is simulated and optimized using HFSSv24 software. It is measured using a Rogers TMM 10i (tm) The substrate used has a height of 1.28 mm, a dielectric constant of 9.8, and a loss tangent of 0.0020. The structure is printed on a compact size of 29.28mmx16.5mmx1.28mm. A good agreement is obtained between the simulation and measurement performance.*

Key Words: **Filtering antenna, High gain, 25.6 GHz, band-pass, Return loss,**

1. INTRODUCTION

The world is shifting toward automation these days. Any nation's transportation network is its foundation. Transportation networks contribute to national prosperity. Thus, many antenna types that can regularly receive, send, or reply to signals are needed for an intelligent transportation system. Therefore, a multiband antenna that simultaneously receives various resonant frequencies is needed. Therefore, a new filter is needed to get the necessary resonance frequency. An essential part of creating and executing Intelligent Transportation Systems (ITS) is Wireless Local Area Networks (WLANs). The use of intelligent transportation systems (ITS) in transportation has several advantages, such as the development of new traffic models, the alleviation of congestion, and increased safety. ITS depends on a multitude of data sources, including voluntary data sharing by users and a variety of traffic and infrastructure sensors, to function well. Certain well-known ITS apps, like as Waze and Google Traffic, are developed by businesses that don't make it obvious how they get this data from users [1]. ITS seeks to integrate cutting-edge communication technology into transportation networks to increase their sustainability, safety, and efficiency.V2V, or vehicle-to-vehicle Vehicles may communicate directly with one another and share information about their position, speed, and direction thanks to WLAN. This aids in managing traffic and preventing collisions. Vehicle-to-infrastructure (V2I) Automobiles and roadside units with WLAN capabilities may converse. Drivers may receive real-time traffic updates, light timings, and other important information via this interaction. Real-time traffic data gathering and distribution are supported by WLAN networks. Traffic signal optimization, congestion control, and dynamic route assistance for vehicles may all be accomplished with the use of this data. Car Radar Systems: Preventing Collisions Road safety can be improved by vehicle radar systems that operate at 25.6 GHz, which can identify possible collisions and promptly alert drivers to them. Control of Traffic Signals for Infrastructure Communication To ease congestion and boost traffic efficiency, 25.6 GHz sensors may dynamically modify signal timings while keeping an eye on traffic flow. This work presents an effective microstrip filter operating in the 25.6 GHz frequency range. Reduce insertion loss to maintain the integrity of the signal. To enhance the properties of signal reflection, optimize return loss. Antennas and filters are essential parts of ultra-wideband wireless communication equipment. Modern microstrip antennas have to be small to fit tiny, portable devices. Microstrip antennas are especially well-suited for UWB applications because of their lightweight design, low profile, affordability, and ease of manufacturing. Planar antennas come in a variety of forms and varieties, and a wealth of documentation demonstrates their basic importance to UWB technology. The filter antenna is designed to function at a center frequency of 25.6 GHz. To suppress undesired signals, a bandpass filter with notch band characteristics is needed to overcome this issue. However, to minimize insertion losses and system space, combining the band-pass filter and antenna into a single module is growing in popularity. Thus, certain filtering antennas It has been stated that filters have frequency responses such as to produce band-notch features, the Microstrip antenna is liberally combined with diffractive resonators, open stubs, parasitic strips, shorting wires, and multi-stub feeds [2].

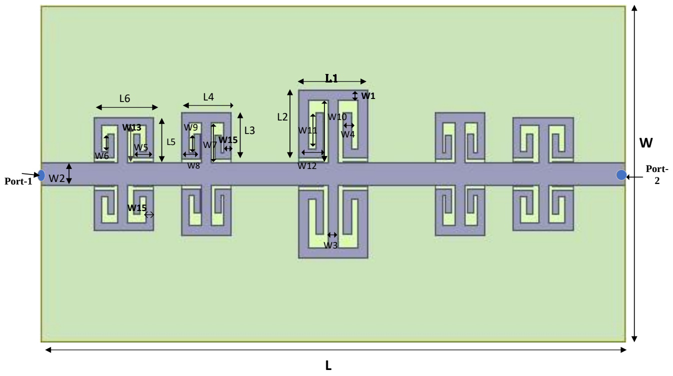
2. LITRATURE SURVEY

It is demonstrated that a dipole microstrip filter antenna may yield a nearly circular gain pattern by using parasitic resonators. The parasitic components, which were used to produce two radiation nulls and two transmission zeros outside of the band in the bandwidth, The design is based on using stepped-impedance resonators. An F4B-2 substrate, kind of material was used in the design, having a thickness of 1.1 mm and a dielectric constant of 2.4. A 9 mm-high layer of air between the design includes ground layers and heated layers. The proposed filter antenna has a fractional BW of 4.2% and operates at 1.85 GHz. It generates strong signals in the targeted frequency band in addition to There are three shorting vias (connections to the ground), two strip lines, four lines, and a rectangular microstrip. It is constructed on an 80 x 80 mm substrate with a 4 mm thickness. The substrate material has a 2.6 is the dielectric constant and 0.003 is the loss tangent (δ). The antenna's broad bandwidth, which spans from 2.19 GHz to 2.68 GHz, allows it to cover a large frequency range. and it performs best at 2.4 GHz. It keeps its efficiency above 90% while offering a powerful 9.5 dBi gain [3]. For upcoming wireless devices, a new filter antenna design with several layers is being introduced. The design includes three T-shaped microstrip antenna with transmission lines with open loop rings. Using efficiently reduces unwanted frequency range noise signals. [4]. Additionally, this balun filter-antenna configuration with a significant roll-off skirt factor is apparent. A fourth-order quasi-Yagi antenna is coupled to a multilayer balun microstrip filter in this configuration. Five-step impedance resonators are used by the balun filter to increase the passband rejection ratio. The filter antenna has a bandwidth of 22.9% and works at 2.5 GHz. At the passband's boundaries, it generates two transmission zeros. A 5.4 dBi gain and robust rejection of undesired signals are achieved by the design. Benefits of the design include high signal suppression and a broad bandwidth however multilayer substrate technology is required. [5]. Recently, a novel small and strong microstrip filter antenna was created. This antenna performs well despite its modest size. It consists of Multilayer technology contributes to the design's compactness. The substrate used in the construction is a Rogers RT5880, this filter antenna is very thin (0.5 mm thick) and has a material that helps it work well with a frequency of 2.6 GHz. It has a gain of 2.1 dB and a bandwidth of 2.8%, meaning it can pick up signals over a small range around that frequency. The main benefit of this design is that it's small and compact, but it has a complex structure because it uses several layers. [6]. In this work, a unique kind of antenna for usage in wireless communication systems is introduced. A Circular Polarize Ultra-Wide Band (UWB) filtenna is what it's known as. In addition to covering a large frequency range, this antenna has the ability to filter off a particular band when required. The antenna has a feature that is included in its design and construction bandpass filter with an inverted T shape that aids in filtering particular frequencies. It also features a stepped patch in the shape of a square, which is a feature of UWB antenna. The frequency range of the UWB patch antenna is 3 GHz to 14 GHz. Rogers 4350 material of a very low loss tangent of 0.0037 and a relative dielectric constant of 3.38, is used in the antenna's design. The antenna's base material has a thickness of 1.525.6 mm. The antenna is small and straightforward, and it is known as an Inverted F Antenna (IFA). This "filtenna" is capable of covering the whole Ultra-Wideband (UWB) frequency range, with the exception of one purposefully excluded band (the "notched band). The antenna produces a circular pattern by emitting signals in two distinct ways known as the E & H-plane polarizations. With a high peak gain of 6.8 dBi, it can efficiently send and receive signals in certain directions. The gain of the proposed IFA is considerably reduced in the notch band and outside of the UWB band [2]. Last year, a new microstrip filtering antenna was introduced, which is made for 4G and 5G wireless networks. The filtering antenna, a crucial component of wireless devices' RF front ends, performs radiation and filtering duties. The filtering antenna features a hairpin bandpass filter and an elliptical microstrip antenna. The right size of the hairpin filter helps achieve good impedance matching. The design is simple, compact, and coplanar, and it includes the bandpass filter. The antenna is built using FR4, a common material. Thickness of this material is 0.8 mm. The dielectric constant, which is 4.4 in this instance, is one of its characteristics. The loss tangent, which is 0.0025, is another significant characteristic. These characteristics impact the antenna's functionality. At 2.6 GHz, the filter-antenna configuration is in operation. The proposed filtering antenna's coplanar filter significantly reduces its design complexity and compacts it [7].

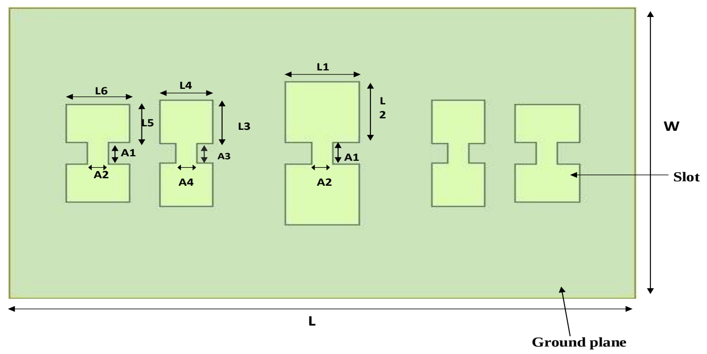
3. DESIGN SPECIFICATION

a) Microstrip filter Configuration: -

In this manuscript, the design of a 25.6 GHz microstrip filter and filtering antenna has been proposed. The proposed design works in millimeter frequency range. The proposed filter is designed on substrate material Rogers TMM 10i (tm) having a dielectric constant of 9.8 with a thickness of 1.28 mm. Figure 1 (a) shows the top layer of the filter and Figure 1 (b) shows the bottom layer of the filter. Figure 1(a) shows a 32.8 mm x 16.5 mm substrate material with a 1.1 mm thick microstrip line at its center, with two feed points, Port-1 and Port-2. The microstrip line is connected with different E-shaped stubs on both side of line having parameters of L1, L2, L3, L4, L5, L6, and w3 in mm.



(a)



(b)

Fig-1: Shows (a) top layer & (b) bottom layer of the filter.

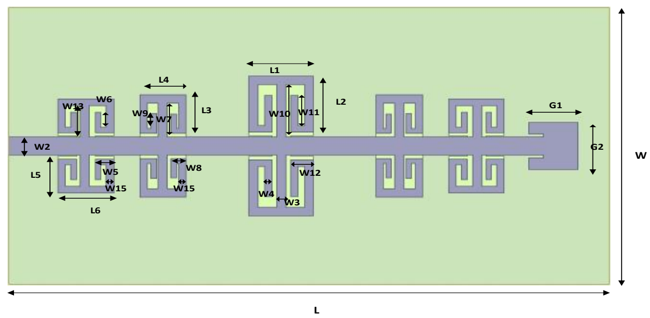
Figure 1(b) shows a ground plane of length (L) in mm and width (W) in mm. The ground plane has slotted in consecutive manner. This structure makes defected ground structure. The slot is present just below the stubs. The parameters of the slots are L1, L2, L3, L4, L5, L6 and A2 and A4.

Table-1: Parameter's values of microstrip filter.

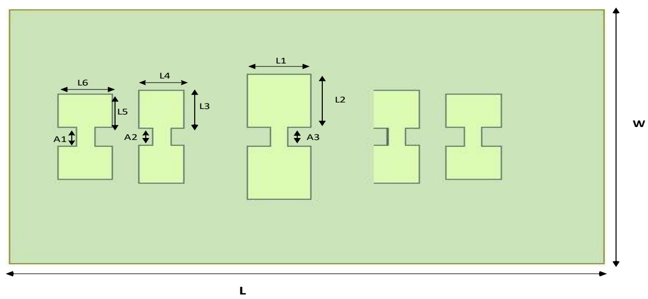
Parameters	Value(mm)	Parameters	Value(mm)
L	32.28	H	1.28
W	16.5	W3	0.5
L1	3.5	W4	0.4
L2	3.5	W1	0.5
L3	2.5	W6	1.2
L4	2.5	W10	3.1
L5	2.2	W8	0.8
L6	3	W9	1.2
W11	2	A1	1.2
W12	1.25	A2	1
W15	0.3	A3	1.1
W13	1.8	A4	1
W2	1.1		

b) Microstrip Filter-Antenna Configuration: -

After the designing of band pass filter having centre frequency of 25.6, the designed is further modified to 25.6 GHz filtering antenna. For designing the filtering antenna, a patch is connected across any one of the port. The size of the patch is modified by and set the value for resonating at centre frequency of 25.6 GHz. The design and structure of filtering antenna are shown in figure 2.



(a)



(b)

Fig-2: Shows (a) top layer & (b) bottom layer of the microstrip filter antenna.

Table-2: Parameter values of filtering Antenna.

Parameters	Value (mm)	Parameters	Value (mm)
L	32.28	H	1.28
W	16.5	W3	0.5
L1	3.5	W4	0.4
L2	3.5	W1	0.5
L3	2.5	W6	1.2
L4	2.5	W10	3.1
L5	2.2	W8	0.8
L6	3	W9	1.2
W11	2	A1	1.2
W12	1.25	A2	1
W15	0.3	A3	1.1
W13	1.8	A4	1
G1	2.8	G2	2.65
W2	1.1		

4. RESULT & DISCUSSION

The proposed designed structure of filter and filtering antenna as show figure 1 & 2 are simulated in HFSSv25.6. the proposed designed has simulated for the frequency range of 21 to 27 GHz at centre of 25.6GHz. their parameters Show in table 1 & 2.

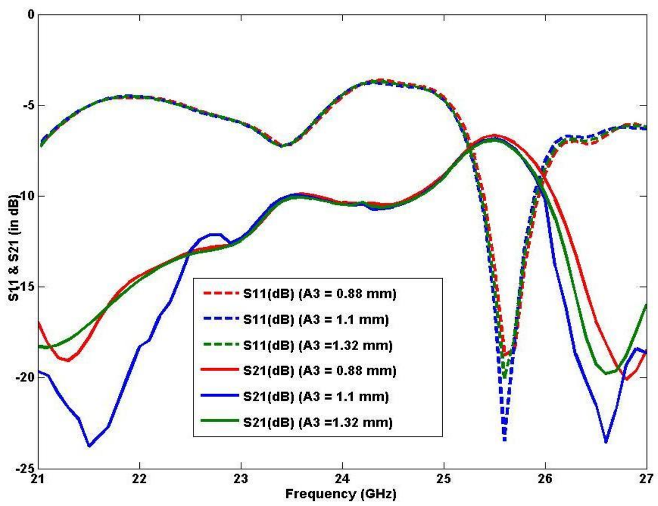


Fig.3. Parametric simulated S11(in dB) & S21(in dB) for parameter A3.

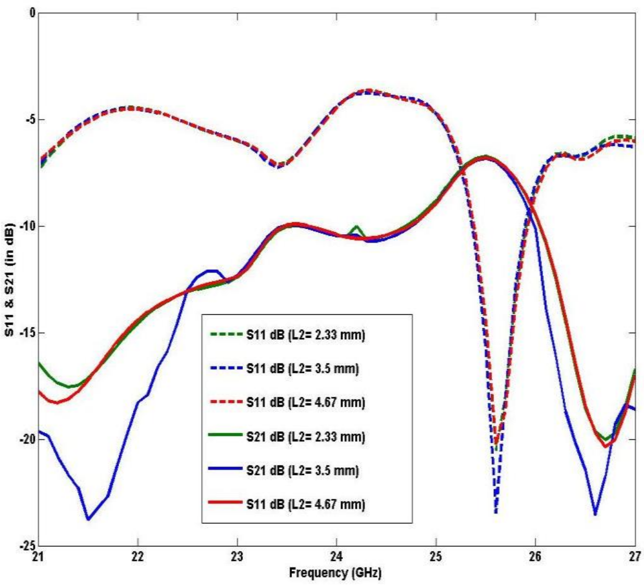


Fig-4: Parametric simulated S11(in dB) & S21(in dB) for parameter L2.

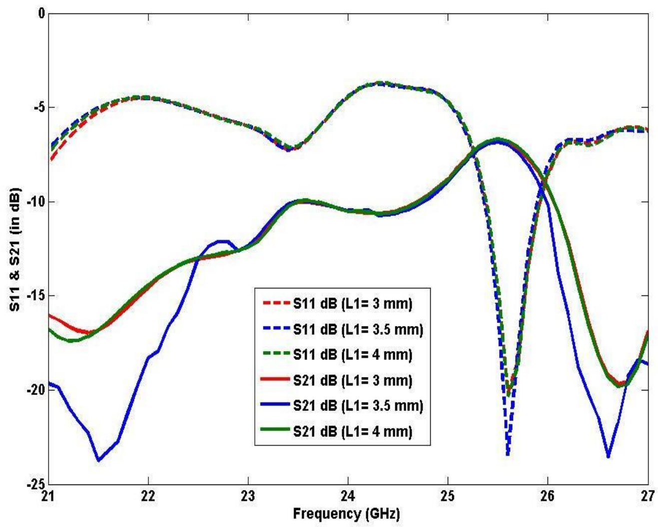


Fig-5: Parametric simulated S11(in dB) & S21(in dB) for parameter L1.

The outcome of the parametric analysis in figure 3,4,5 . This is the return loss result (in dB) for the ground plane slot specification. This result demonstrates that for A3=1.1mm, L1=3.5mm, L2=3.5mm. we obtain the appropriates resonance frequency at 25.6 GHz.

Table-3: Parametric Result

Parametrs	Value (in mm)	S11 (in dB)	Minimum S21 (in dB)	Resonant Frequency (in GHz)
A3	0.88	-18.7	-20.08	25.6
	1.1	-23.45	-23.57	25.6
	1.32	-20.04	-19.77	25.6
L1	3	-20.5	-20.03	25.6
	3.5	-23.45	-23.57	25.6
	4	-20.23	-20.3	25.6
L2	2.33	-20.11	-19.65	25.6
	3.5	-23.45	-23.57	25.6
	4.67	-20.3	-19.75	25.6

Table 3 shows that parametric analysis result of different parameters i.e. A3, L1, L2. From this table it is clearly visible that for A3=1.1 mm, L1=3.5mm, L2=3.5mm is best fitted values for above design as shown as figure 1.

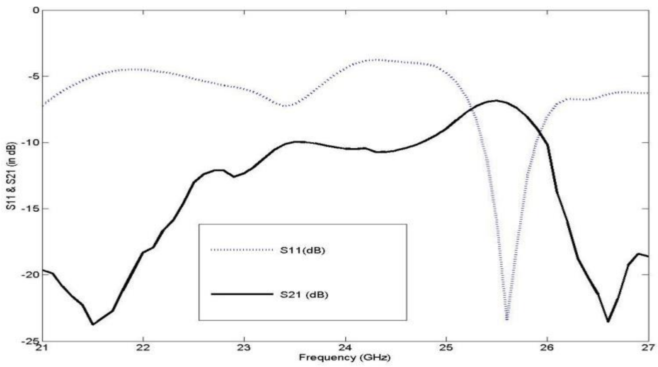


Fig-6: Shows simulated S11 (in dB) & S21 (in dB).

Figure 6 shows the simulated S11(dB) & S21(in dB) for the final filter designed. This result shows S11 has centre frequency of 25.6 GHz &-23.45dB. while the minimum S21 has the minimum S21 has values of -23.57dB. From the figure it is clearly shown that the S21 has completely pass the S11 band So this shows that the proposed designed is be haves like a band pass filters having centre frequency of 25.6GHz.

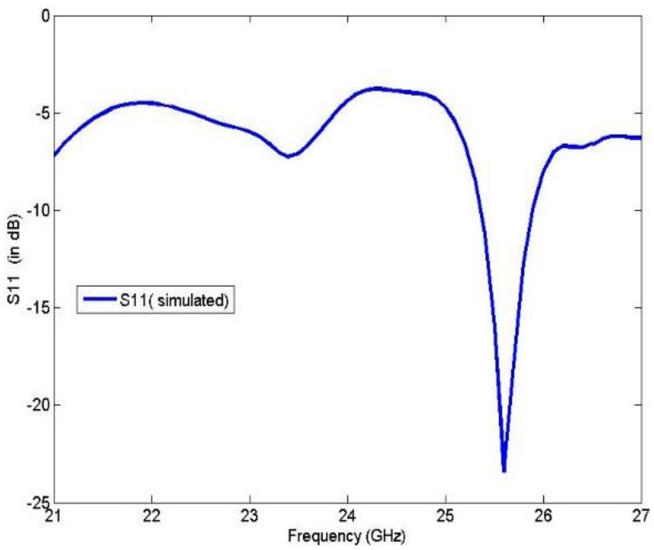


Fig-7: Simulated S11(dB) of Filtering Antenna.

After getting the propose filtering results the structure has been modified to filtering antenna as shown figure 2. The figure 7 shows the S11 result of filtering antenna having resonant frequency of 25.6 GHz. The filtering antenna works in band range of 25.6 GHz to 25.9 GHz with approximate 500MHz bandwidth.

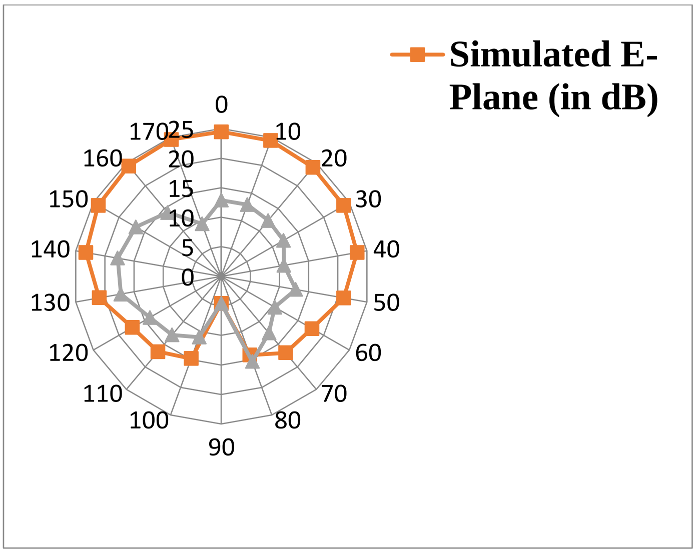


Fig-8: Shows simulated E-plane & H-plane of Filtering Antenna.

figure 8 shows that is simulated E-plane and H-plane result at centre frequency of 25.6GHz. from the results it is clearly show that the filtering antenna is circularly polarized.

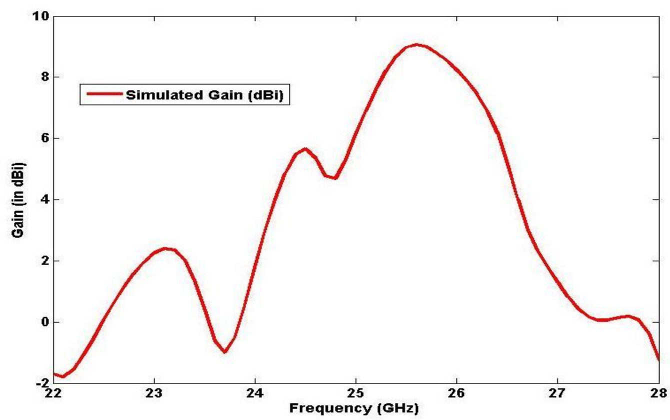


Fig-9: Simulated Gain (dBi) of Filtering Antenna.

Figure 9 shows the simulated frequency (GHz) Uses us Gain(in dB) Plot. From the figure it shows that the peak gainof 9.06 dBi.

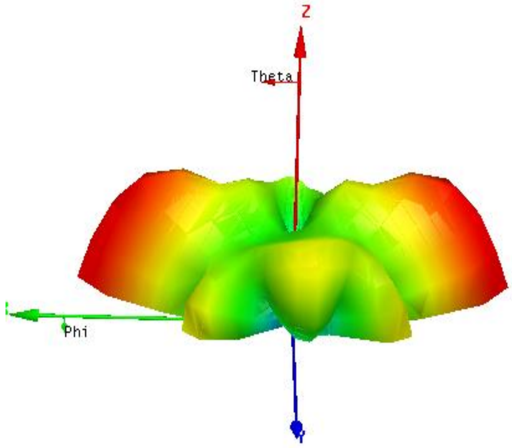


Fig-10: Simulated 3D polar plot at 25.6 GHz of filtering Antenna.

Figure 10 shows the 3-D polar plot of Gain(in dB).

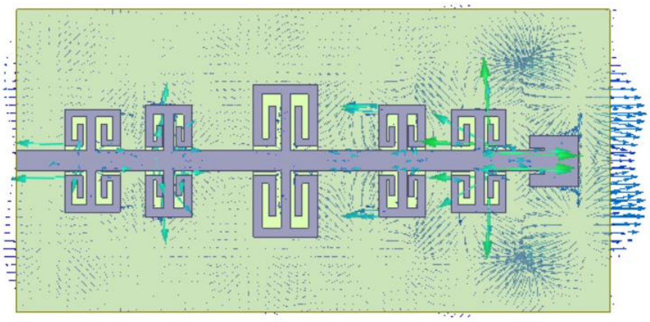


Fig-11: Simulated vector current field distribution.

Fig.10 shows the surface vector current distribution over the patch and ground plane.

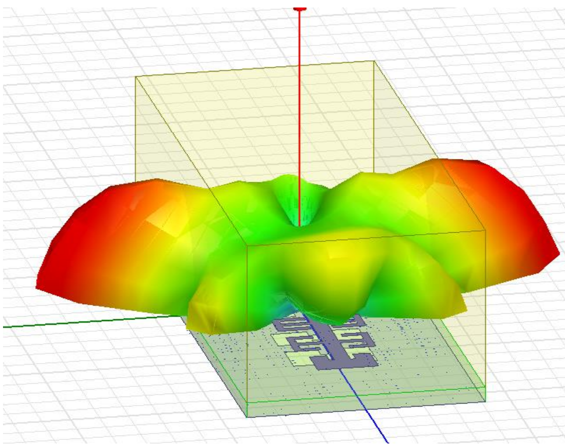


Fig.12. Radiation of Filtering Antenna.

Table-4: Comparison between the proposed design and others.

Ref	Centre frequency	Return loss (dB)	Gain (dBi)
Proposed work	25.6	23.45	9.06
[3]	2.4	15	4.03
[5]	3.1 -7.98	-	3.58- 6.8
[6]	2.61	33.95	2.2
[2]	1.85	-	7.6
[7]	6.4	18.2	2.014
[8]	2.19–2.68	14	9.5
[9]	11.65	>12	5.6

5. CONCLUSIONS

This paper is present a compact 25.6 GHz WLAN microstrip filter play a crucial role in enhancing intelligent transportation systems (ITS). The compact filter design addresses the critical need for efficient, reliable, and high-speed communication in ITS applications, ensuring minimal interference and clear signal transmission. These designs have done by HFSSv25.6. The successful integration of this filter into ITS devices can lead to significant improvements in the performance and efficiency of transportation systems. By providing robust connectivity and high-speed data transfer, this technology contributes to the safety, reliability, and overall effectiveness of modern transportation networks. This advancement aligns with the broader goals of enhancing transportation safety, efficiency, and sustainability through cutting-edge communication technologies.

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