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# Compact Filtenna for WLAN Applications

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***Abstract*— This manuscript proposes a Filtenna operating in the frequency range of 5.15-5.35 GHz for possible application in wireless local area network (WLAN). Initially, a monopole antenna consisting of a square loop radiating patch is designed at 5.2 GHz and is integrated into a bandpass filter (BPF) with centre frequency of 5.2 GHz. Within the proposed frequency band of operation, the filtenna exhibits omni-directional radiation pattern, good selectivity and low reflection loss. Also, the VSWR observed is less than 2 and peak antenna gain is approximately 2.5 dBi within the frequency range. A consistency is obtained between the simulation and the experiment.**

***Index Terms*—** Antenna, band pass filter (BPF), filtenna, monopole.

## I. INTRODUCTION

Wireless Communications has witnessed exemplary growth in the recent years owing to the invention of several wireless services. Some of them being, wireless local area network (WLAN), worldwide interoperability for microwave access (WiMAX), Global Positioning System (GPS), mobile phone, Bluetooth, etc. This growth has led to exponential spurge in the design and development of passive components like Antennas [1]-[9] and bandpass filter (BPF) [10]-[12] for wireless communication systems. Light weight, conformability to planar circuits and robustness are some of the desired features of any component of the communication system. However, individual antennas and BPFs are usually the largest components compared to the others. Thus, it is in the best interest of designers and users if both antenna and BPF are designed as a single compact module to provide both filtering and radiation properties. The integrated module is referred to as filter-antenna or generally filtenna.

Several papers on design of antenna have been reported for WLAN and WiMAX applications [1]-[8] where the response of radiation is not smooth and out-of-band. To reduce the radiation from notched undesired frequencies, the return loss should be minimum at out-of-band frequencies. Several other papers on design of filters have been reported for WLAN and WiMAX applications [10]-[12].

In [10], the filter is designed for Bluetooth and WLAN using DGS but it is subjected to high EM radiation. In [11]-[12], a dual BPF is designed using SIRs to create second passband for reducing spurious frequencies. It is difficult to control the passband individually using SIR, since the dual passbands response is synthesized by the two resonator responses synchronously.

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By integrating the filter and the antenna into a single module, the problems have been well addressed by the use of filter antenna [13]-[18].

In [13], the design is used to make the system more compact improving the noise performance. The higher gain is achieved by filter antenna using mutual synthesis approach [14]. High selectivity is achieved by developing the filtering antennas on low temperature co-fired ceramic substrate [15]. In [16], the design of the filter and UWB antenna reduces the overall component size. The filter antenna design [17] shows better bandwidth and larger gain. The filter antenna design [18] for WLAN and WiMAX application exhibits fair bandwidth and selectivity but radiation response needs improvement. Several fractal shaped antennas have been proposed for WiMAX and WLAN applications [19-20]. Compact dual-band pentagonal ring fractal patch antenna [21] shows stable omnidirectional radiation pattern. With the help of EBG structures in microstrip based one-dimensional Koch fractal patterns [22], improved low pass filtering is reported. A new type [23] of compact frequency selective surfaces is proposed, based on fractal filter-antenna array.

The proposed Filtenna operates in the range of 5.15-5.35 GHz frequency for possible application in WLAN. The structure under consideration is of monopole configuration, consisting of a square loop radiating patch with dimensions designed for operation at 5.2 GHz. This antenna is then integrated with a bandpass filter (BPF) having a center frequency of 5.2 GHz. The optimized filtenna depicts omni-directional radiation pattern, good selectivity and low reflection loss within the operating band. Also, the VSWR observed is less than 2 and peak antenna gain is 2.5 dBi. The simulation software used is, IE3D, Zeland Software, version 14.11. The structure is fabricated on FR4 substrate whose dielectric constant ($\varepsilon_r$) = 4.4, thickness (h) of 1.6 mm and the loss tangent is 0.016. Later, the measured data is compared to the simulated results.

## II. FILTER-ANTENNA DESIGN

### *A. Antenna Design*

A square shaped monopole antenna is designed for operation at $f_o$ = 5.2 GHz. The dimensions of the antenna are obtained from the following equations [24]:

$$W = \frac{c}{2 f_0 \sqrt{(\varepsilon_r + 1)/2}} \tag{1}$$

$$L_{eff} = \frac{c}{2 f_0 \sqrt{\varepsilon_{r\,eff}}} \tag{2}$$

$$\Delta L = \frac{0.412 h (\varepsilon_{r\,eff} + 0.3)(w/h + 0.264)}{(\varepsilon_{r\,eff} - 0.258)(w/h + 0.8)} \tag{3}$$

The actual length (L) is obtained by subtracting $\Delta L$ from $L_{eff}$ as shown below

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$$L = L_{eff} - 2\Delta L \tag{4}$$

hence L = 13.2 mm by using $L_{eff}$ = 14.65 mm & $\Delta L$ = 0.7263 mm

The transmission line model is ideally applicable for infinite ground plane although in real situations, the ground plane is finite. The results obtained for Transmission Line model with finite ground plane, can be approximated to that with infinite ground plane, if ($L_g \times W_g$) > 6h, where, ($L_g \times W_g$) is the ground plane dimension and h indicates the thickness of substrate.

Therefore, the ground plane dimensions for the structure under consideration, can be given as

Lg = 6 h + L= 6 (1.6 mm) + 13.19 mm = 22.79 mm=23 mm

Wg= 6 h + W =6 (1.6 mm) + 17.55 mm = 27.15 mm

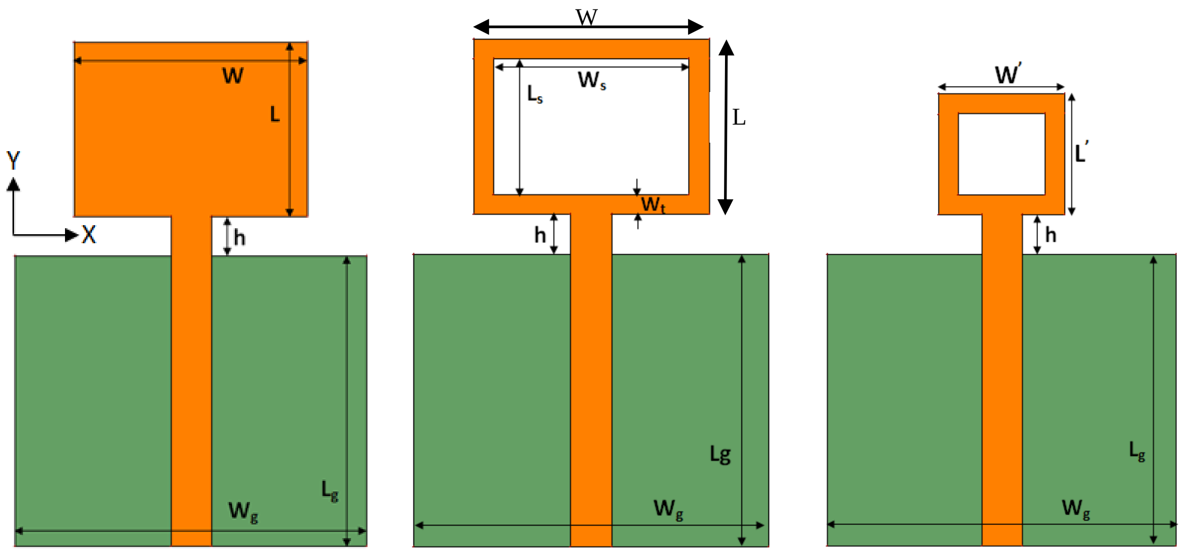
Hence the resultant dimensions of the antenna is shown in Table 1.

TABLE I. DIMENSIONS OF THE ANTENNA

| Resonant frequency (GHz) | W (mm) | L (mm) | Lg (mm) | Wg (mm) | h (mm) |
|---|---|---|---|---|---|
| 5.2 | 17.55 | 13.2 | 23 | 27.15 | 3 |

Using these dimensions, a microstrip patch antenna is designed as shown in Fig. 1 (a). A rectangular slot with length (Ls) 10.2 mm and width (Ws) 14.55 mm, is cut from the microstrip patch of length 13.2 mm and width 17.55 mm, as shown in Fig. 1 (b). Hence a ring is formed having a width of $W_t$ = 1.5 mm.

A change in the resonant frequency is observed for Type II as compared to Type I. To maintain the resonant frequency in Type II structure, the area is reduced by 12.85% of Type II, which is shown as the proposed antenna. The dimension of the proposed antenna is $W_g \times (L_g + h + L')$ which is 927.5 $mm^2$. The area of Type 1, Type 2 & proposed antenna are 1064.28 $mm^2$, 1064.28 $mm^2$ and 927.5 $mm^2$ respectively. Fig. 2 shows the simulated return loss ($S_{11}$) for Type 1, Type 2 and the proposed structure.




(a) Type I (b) Type II (c) Proposed antenna

Fig. 1. Structure of antenna

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From Fig. 2, it is clear that similar characteristics of return loss are achieved in the proposed antenna with size reduction of 12.85 % in comparison to the Type 1 antenna.

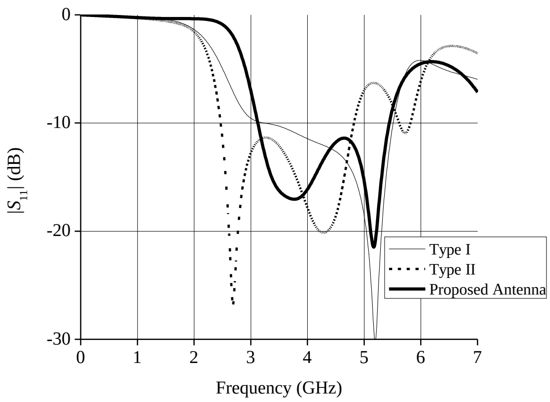


Fig. 2. Simulated result of return loss

### *B. Single Band Pass Filter Design*

A microstrip line of width = 3.06 mm with a gap ($S_1$) of 0.5 mm, in the middle of the strip, is considered for the design of the band-pass filter. The microstrip line is coupled to a resonator whose width and length is $W_2$ and $L_2$ respectively with a spacing of $S_2$. A stub with a width of $W_3$ and length $L_3$ is shorted to the resonator, aligned at the centre of the gap of $S_1$ as shown in Fig. 3. The various parameters of the filter dimensions are displayed in Table II. The electrical length and impedance depends upon the coupling between the quarter wavelength and half-wavelength resonators.

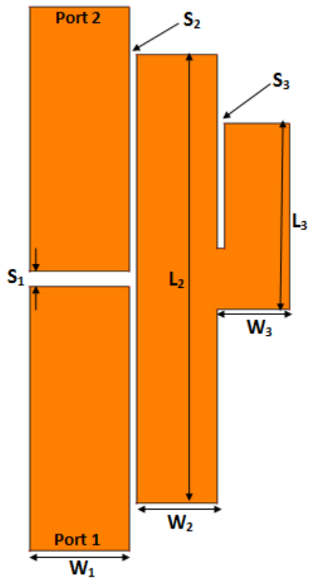


Fig. 3. Proposed filter

TABLE II. DIMENSIONS OF THE FILTER

| Parameter | $W_1$ | $W_2$ | $W_3$ | $S_1$ | $L_2$ | $L_3$ | $S_2$ | $S_3$ |
|---|---|---|---|---|---|---|---|---|
| Value (mm) | 3.06 | 2.5 | 2 | 0.5 | 15.8 | 7.9 | 0.2 | 0.2 |

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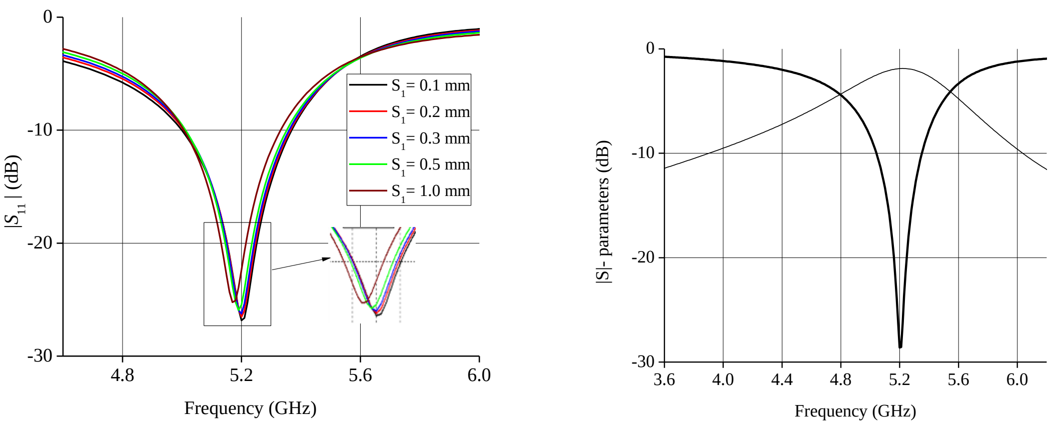
The return loss varies in accordance to the change in gap $S_1$. The simulated results for $S_{11}$ for the variation of gap $S_1$ of proposed band pass filter is shown in Fig. 4.




(a) (b)

Fig. 4. (a) Simulated return loss for different gap spacing (b) Filter response at $S_1$= 0.2 mm.

Fig. 4. shows that as the value of gap-spacing ($S_1$) increases the return loss shifts towards left, in other words, the resonant frequency and $S_{11}$ decreases. The spacing $S_1$ is selected to be 0.2 mm, considering the limitation of accuracy and precision in fabrication and the corresponding simulated return loss of the filter drops to 26 dB, as shown in Fig. 4 (b).

Fig.5 shows the simulated return loss curve $S_{11}$ for the proposed antenna and filter. It is observed from the graph that the BW of proposed antenna ranges from 3.17 GHz to 5.47 GHz while as the BW of proposed filter is ranges from 5 GHz to 5.36 GHz at and below -10 dB level. The purpose of the proposed filter is to pass certain band of frequencies lying within the BW of the proposed antenna. For this the proposed filter and antenna both should resonate at the same frequency, i.e., 5.2 GHz in this case.

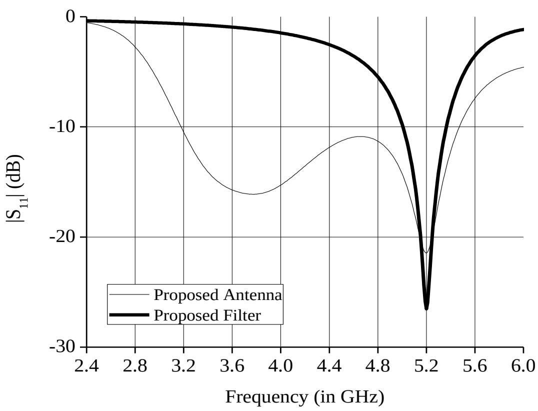



Fig. 5. Return loss curves for proposed antenna and filter.

### *C. Integration of Antenna and Filter*

The antenna and filter are integrated into a single module and the resultant filtenna is shown in Table III. Fig. 6 (b) shows the simulated $S_{11}$ result for the filtenna under consideration.

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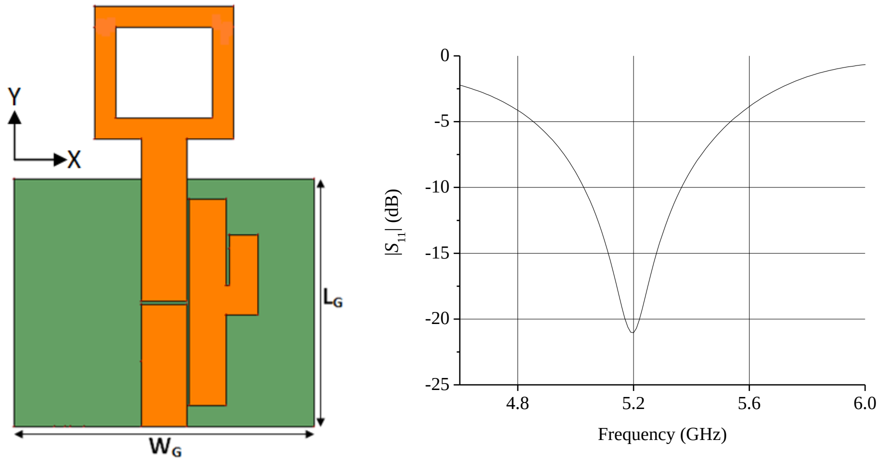


Fig. 6. (a) Structure of Proposed Filtenna; (b) Simulated return loss response.

From Fig. 6 (b), it is clear that the proposed filtenna resonates at 5.2 GHz which is best suited for WLAN application and has a return loss of 21.03 dB.

TABLE III. DIMENSIONS OF THE PROTOTYPE FILTENNA.

| Parameter | $W_1$ | $W_2$ | $W_3$ | $S_1$ | $L_2$ | $L_3$ | $S_2$ | $S_3$ | $L'$ | $W'$ | $L_G$ | $W_G$ | h |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Value (mm) | 3.06 | 2.5 | 2 | 0.2 | 15.8 | 7.9 | 0.2 | 0.2 | 9.2 | 9.55 | 17.06 | 20.5 | 3 |

(a) (b)

Fig. 7. Photograph of the prototype filtenna (a) Top view and (b) Bottom view.

## III. MEASUREMENT OF DIFFERENT PARAMETERS OF THE PROTOTYPE DEVELOPED

The return loss is measured for the prototype developed, as shown in Fig. 7, using Vector Network Analyzer (VNA). The measured result is compared to that of the simulated response. The simulated and measured results are in good agreement, as is evident from the graph shown in Fig. 8. Some

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discrepancies in the experimental results may be attributed to the manufacturing tolerances and the variation in the material characteristics of the sample supplied. The measured results show better response in terms of return loss which is 32.5dB while the simulated value is 21.06 dB.

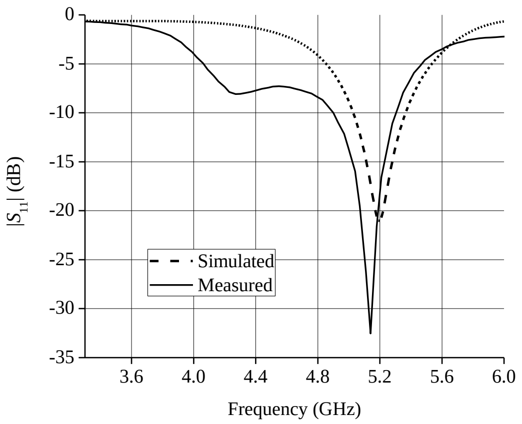



Fig. 8. Simulated and Measured return loss curve

*A. VSWR and Gain*

The voltage standing wave ratio (VSWR) and Gain of the proposed filtenna is shown in Fig. 9 (a) and Fig. 9 (b) respectively. The simulated VSWR is 1.54 dB while the measured value is 1.3 dB at 5.2 GHz which is less than 2. The passband gain of 2.5 dBi (approximately) and high rejection other than the pass band is achieved.

The graph in Fig. 9 (a) shows the comparison between the measured VSWR to that of simulated VSWR curves. The measured results exhibit a complete match to the simulated values.

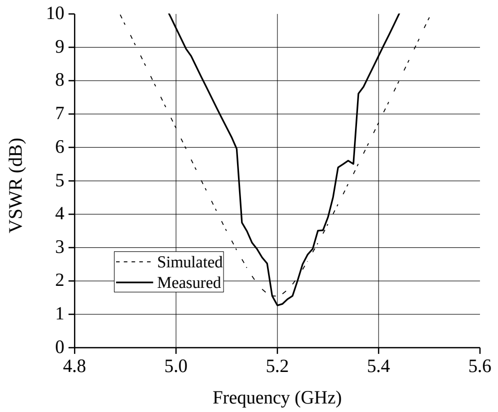



Fig. 9. (a) Simulated and Measured VSWR curve

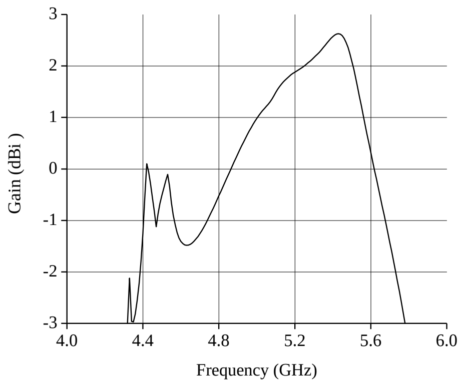



Fig. 9. (b) Simulated Gain curve

*B. Radiation Pattern*

The simulated radiation patterns at 5.2 GHz for the proposed filtenna are depicted in Fig. 8. The inference drawn from Fig. 10 (a) and Fig. 10 (b) is that the simulated E-plane pattern reflects a typical monopole radiation pattern and the H-plane pattern is omni-directional at the resonant frequency. The simulated and measured co-polarization and cross polarization for the proposed filtenna is also shown in Fig. 11 (a) & Fig. 11 (b) respectively.

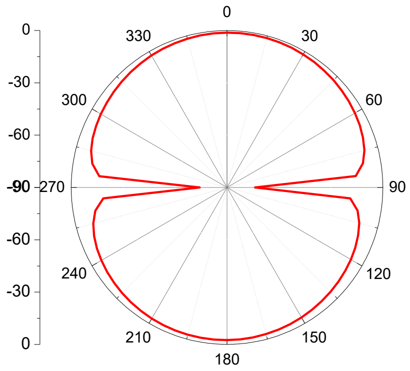



Fig. 10. (a) E-plane radiation pattern

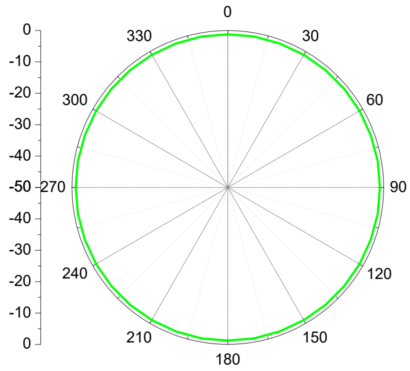
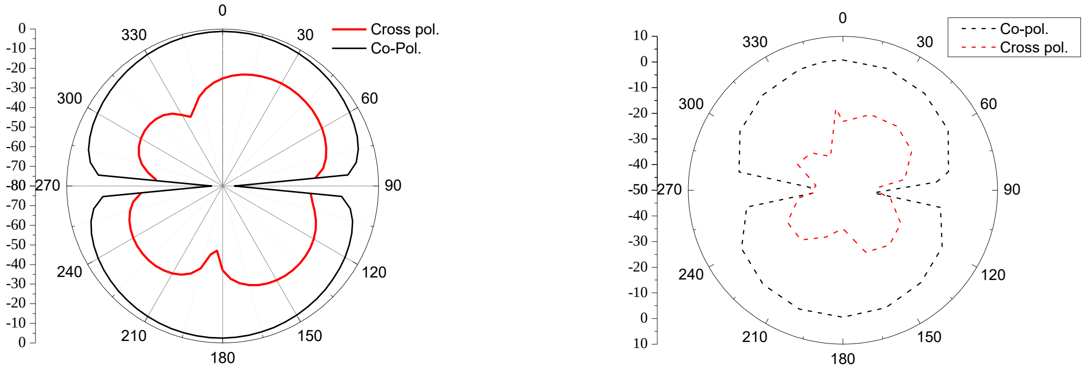



Fig. 10. (b) H-plane radiation pattern




(a) (b)

Fig. 11. Co-polarization and Cross polarization (a) Simulated and (b) Measured.

The measured values are in partial agreement to the that of simulated response. As evident from the polar plot, the measured pattern exhibits higher cross polarization levels as compared to that of the simulated results. The co-polarization levels are acceptable, as shown in the Fig. 11 (a and b).

Table IV summerises the comparison of the proposed structure to the existing/published works

TABLE IV. COMPARISON CHART

| Structure under consideartion in | Gain | Size |
|---|---|---|
| [7] | 5.35 dBi | 35×25 = 875 mm$^2$ |
| [8] | - | 45×28 = 1260mm$^2$ |
| [18] | 3.5 dBi | 62×44 = 2718 mm$^2$ |
| Proposed | 2.5 dBi | 29.26×20.5 = 599.83mm$^2$ |

## IV. CONCLUSION

The proposed filtenna has an appreciable compactness, with an area of 599.83 mm$^2$ (29.26 × 20.5). The measured and simulated results show better response in terms of return loss which is 32.5dB and 21.06 dB respectively. The simulated VSWR is 1.54 dB while the measured value is 1.3 dB at 5.2 GHz. Passband gain of 2.5 dBi and high rejection other than the pass band is achieved.

In addition to this, the filtenna has the advantages of low cost and ease of fabrication, which makes it suitable for integration with various portable devices operating in the range of 5.15-5.35 GHz for possible application in wireless local area network.

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