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DESIGN AND ANALYSIS OF A COMPACT FILTENNA FOR BLUETOOTH, WI-MAX, WLAN & 5G-MID BAND APPLICATIONS

B. Ramesh[1], K. Koteswara Rao[2], K.P. Vinay[3], K. Hema Divya[4], G. Deepika[5], M.K. Prudhvi[6], D.S. Vaishnavi[7]

[1]Ph. D Scholar, School of Electronics, KIIT University, Bhubaneswar, Odessa

[1,2]Assistant Professor, Dept. of ECE Raghu Engineering College, Dakamarri, Andhra Pradesh

[3]Professor, Dept. of ECE, Raghu Engineering College, Dakamarri, Andhra Pradesh

[4, 5, 6&7]Student, Dept. of ECE, Raghu Engineering College, Dakamarri, Andhra Pradesh

Abstract: In order to provide an efficient, low cost, and small size radiating structure that passes a certain frequency band with negligible amount of interference, the combination of filters and antennas is proposed to form a single element called filtenna. To enhance the overall system performance by reducing the impedance mismatch, circuit size, losses, etc., the antenna and the filter could be integrated. The integrated device will serve as a multi-function module that performs**,** simultaneously**,** filtering and radiating functions is called filtenna. This combination filter and antenna achieves many important advantages of wide bandwidth, small electrical size and an improved performance for frequency selectivity. This paper presents a filtenna element with compact size that can radiate in the frequency range (1.9-5.5 GHz). The proposed filtenna radiates in the 5G mid band frequency range (3.6 GHz) and perfectly rejects all the frequencies outside this range. The filtenna is composed of a printed circuit antenna that is terminated with a crescent shaped stub that is coupled electromagnetically with a miniaturized sharp band-pass filter. Moreover, the structure has an omnidirectional pattern with reasonable gain value within the band of interest, and this makes the antenna very suitable for portable 5G devices.

KEYWORDS: band-pass, dual-band, filtenna, monopole antenna.

I.INTRODUCTION

In the field of communication systems, whenever the need for wireless communication arises, there occurs the necessity of an antenna. Antenna has the capability of sending or receiving the electromagnetic waves for the sake of communication, where you cannot expect to lay down a wiring system. Antenna is the key element of this wireless technology.[1] Antennas have undergone many changes, in accordance with their size and shape. There are many types of antennas depending upon their wide variety of applications.[2] hexagon slotted circular monopole antenna [3], 9-shaped monopole antenna [4], star shaped antenna [5], dumbbell shaped slot antenna [6]. Each shape can be used for different applications like Single- band [7], [8], dual band [9], and single-dual band [10]. However, given the nature of most bands and extent interferers, antennas need a tight controller to suppress the interference and to eliminate the unwanted signals where other system exists.

The filtenna is a special device whose distinguishing feature provides a complete or partial suppression of some aspects of the signal, that is, the removal of some undesired frequencies or frequency bands. It is modified to cover the intended rang by using many techniques of stub-loaded multiple mode resonator [11], This combination (Filter + antenna) achieves many important advantages of wide bandwidth, small electrical size, and an improved performance for frequency selectivity. There are several technics to give filtering antenna, of two edge-coupled filters and two hairpin filters [12], a C-shaped narrow band resonator and an E-shaped wideband resonator [13], and custom- designed coupling probe structures [14], a pair of parasitic elements and pair of slits [15-16]. This new filtering antenna combination is called Filtenna.

In this paper, a compact and sharp printed circuit filter is combined with a printed circuit antenna that is terminated with a crescent shaped stub to form a filtenna with large selectivity. The resulted filtenna perfectly covers the 5G mid-band that occupies the frequency range 3.6-3.7 GHz and perfectly rejects all the frequencies outside the intended range of frequencies. Structure of a filtenna is designed by using coupled electromagnetically to the proposed antenna to attain the compactness in the structure. The simulation results verify the perfect frequency coverage for the 5G mid-band applications in term of the reflection coefficient and transmission coefficient. In addition, the results also show an omnidirectional radiation pattern with reasonable gain value. It is clear that the current is mainly concentrated over all antenna arms and the top part of CLL element at 3.6GHz. The omnidirectional radiation pattern of the proposed design and its compact size make the filtenna to be a superior selection for portable 5G mid-band gadgets.

II.FILTENNA DESIGN

The design of the proposed filtenna is described in this section. The main design goals are: inserting a filtering element that determines the operation frequency range of the antenna with high selectivity, providing a flat gain, and providing good radiation pattern characteristics. The design structure consists of two-square Capacitively Loaded Loop (CLL) Based band pass filter similar to that presented in [21]. The composite design is depicted in Fig. It is printed on a Rogers RT5880 substrate with dielectric constant (εr) of 2.2, a loss tangent (δ) of 0.009 and thickness (h) of 0.8 mm, and half ground, and overall size 27 mm*24.2 mm as demonstrated in Fig. The design starts with a circular monopole antenna, then it is modified to moon shaped radiating antenna at 3.6 GHz with radius of (R). By replacing the second half of the CLL based filter with antenna as a parasitic element, the proposed filtenna is presented. It is fed by a 50 Ω microstrip feed line whose characteristic impedance is given by the following formula [1]:

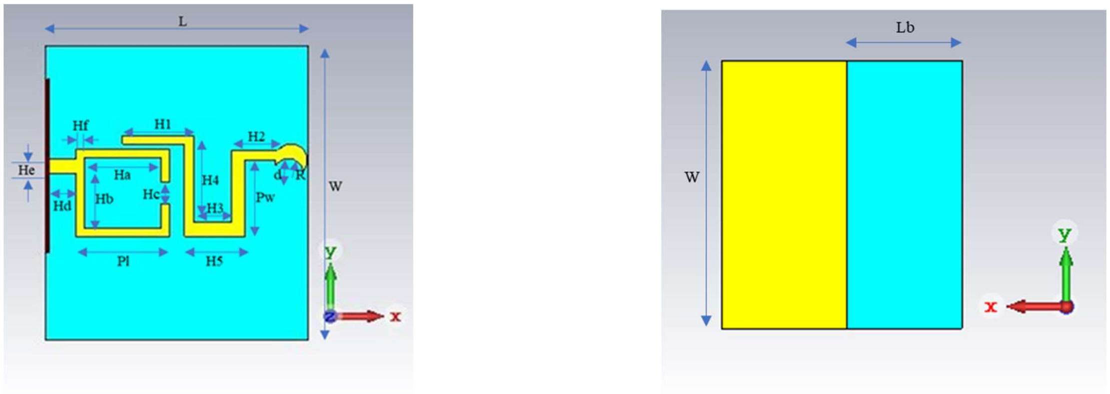
$$z_c = \frac{120\pi}{\sqrt{\varepsilon_{reff}}\left[\frac{w_f}{h}+1\cdot 393+0.667\ln\left(\frac{w_f}{h}+1\cdot 444\right)\right]} \tag{1}$$

Where, Wp denotes the width of the feed line, and h is the height of the substrate. The electrical length of the monopole antenna with respect to the centre frequency [22]:

$$l = \frac{\lambda_g}{2} = \frac{c}{2*f_C\sqrt{\varepsilon_{reff}}} \tag{2}$$

$$\varepsilon_{\gamma eff} = \frac{\varepsilon_\gamma+1}{2} + \frac{\varepsilon_\gamma-1}{2}\left[1+12\frac{h}{w_P}\right]^{-1/2} \tag{3}$$

εrd is the effective dielectric constant of monopole antenna. The optimized parameters of the proposed filtenna are given in Table 1:



(a) Top View (b) Bottom View

Fig.1. Geometry of Proposed Filtenna

Table 1 The Optimized Design Parameters of the Presented Filtenna.

Parameter	Dimensions(mm)	Parameter	Dimensions (mm)
L	24.2	He	2.01
W	27	Pl	8.65
H	0.8	Pw	8.65
R	3	H1	6.04
D	3.8	H2	5.09
Ha	6.5	H3	3.8
Hb	6.5	H4	8.65
Hc	2.5	H5	5.65
Hd	2.7	Lb	13

III. RESULTS & DISCUSSION

The simulated reflection coefficients of the antenna with filter are shown in Fig.2. The proposed antenna has a bandwidth of 3.6 GHz (from 3.36 GHz to 4.2GHz). The filtenna (antenna with filter) shows dual resonant frequencies at 3.63GHz and 3.75 GHz, respectively. Two resonance frequencies are close to each other so that they show a broad bandwidth characteristic from 3.56GHz to 3.7GHz. It effectively suppresses the unwanted signals out of the 5G mid-band. In Fig. 3, the current distribution of the filtenna is shown in order to understand the radiation mechanism at each resonant frequency .It is clear that the current is mainly concentrated over all antenna arms and the top part of CLL element at 3.6GHz as shown in Fig. 3(a). On the other hand, Fig. 3(b) exhibits that the current is concentrated around the filter arms at 3.6 GHz and a negligible amount at the antenna because the frequency 3.7GHz is outside the bandwidth of the proposed filtenna. In other words, outside the frequency coverage of the filtenna, the energy is stored within the filter rather than radiating via the antenna.

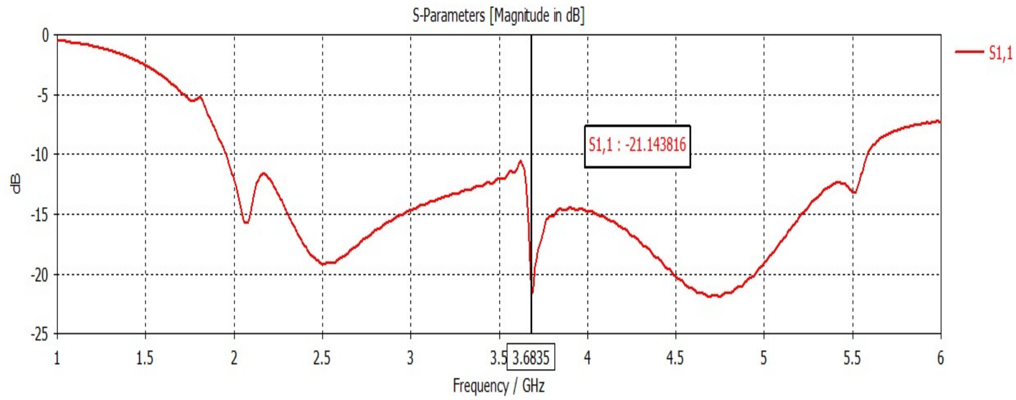


Fig. 2. Reflection coefficient plot of the proposed filtenna

In practice, the most commonly quoted parameter in regards to antennas is S_{11}. S_{11} represents how much power is reflected from the antenna, and hence is known as the reflection coefficient (sometimes written as gamma: or return loss. If S_{11}=0 dB, then all the power is reflected from the antenna and nothing is radiated. When connected to a network analyser, S_{11} measures the amount of energy returning to the analyser - not what's delivered to the antenna and the S_{11} value is -21.14dB as shown in fig. 2.

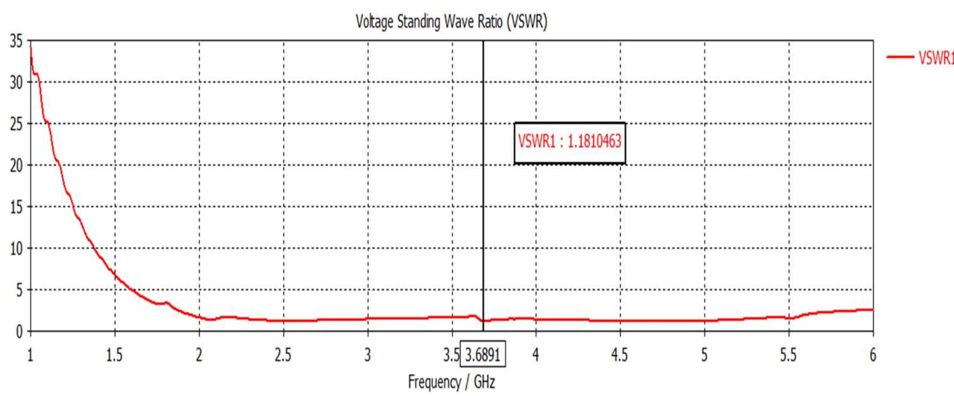
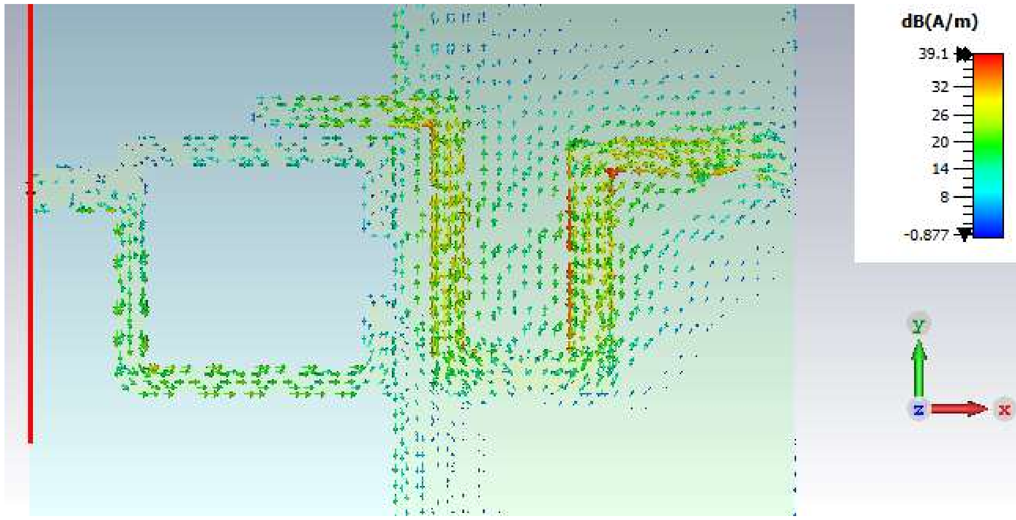
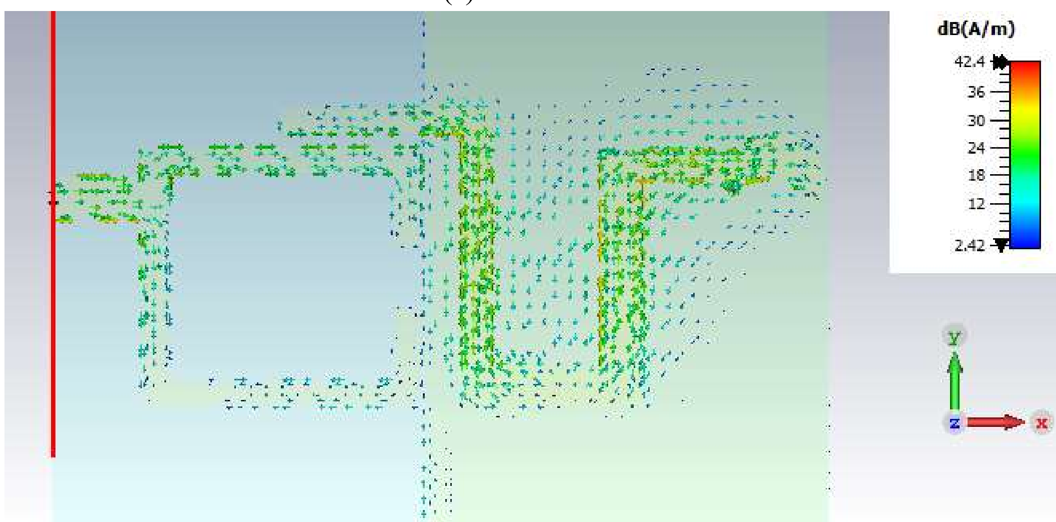


Fig. 3 VSWR plot of the proposed filtenna

Voltage standing wave ratio (VSWR) is defined as the ratio between transmitted and reflected voltage standing waves in a radio frequency (RF) electrical transmission system. It is a measure of how efficiently RF power is transmitted from the power source, through a transmission line, and into the load. The Voltage Standing Wave Ratio (VSWR) is an indication of the amount of mismatch between an antenna and the feed line connecting to it. This is also known as the Standing Wave Ratio (SWR). The range of values for VSWR is from 1 to ∞. A VSWR value under 2 is considered suitable for most antenna applications. The VSWR plot is shown in fig.3.



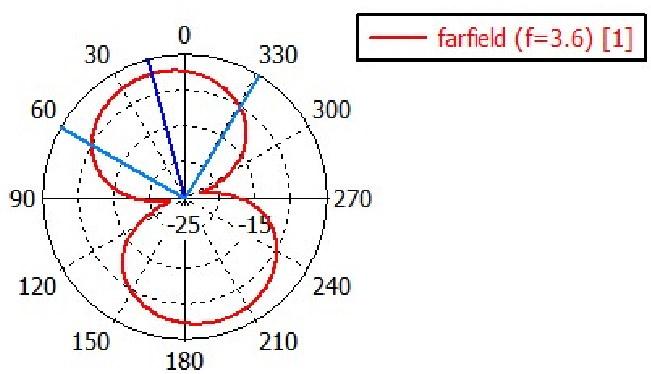
(a) at 3.6GHz



(b) at 3.7 GHz

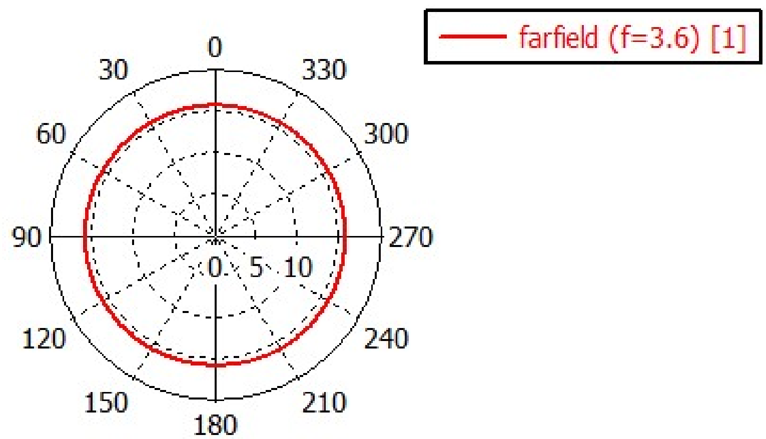
Fig. 4. Surface current distribution (a) at 3.6GHz and (b) at 3.7 GHz.

The simulated 2D-polar power patterns of the filtenna at 3.7GHz are illustrated in Fig. 4. (a) and (b), respectively. It is clear that the filtenna provides good radiation characteristics with a bidirectional power pattern shape in the E-plane, a stable omnidirectional radiation patterns in H-plane, and gain value of 2.89 dBi.



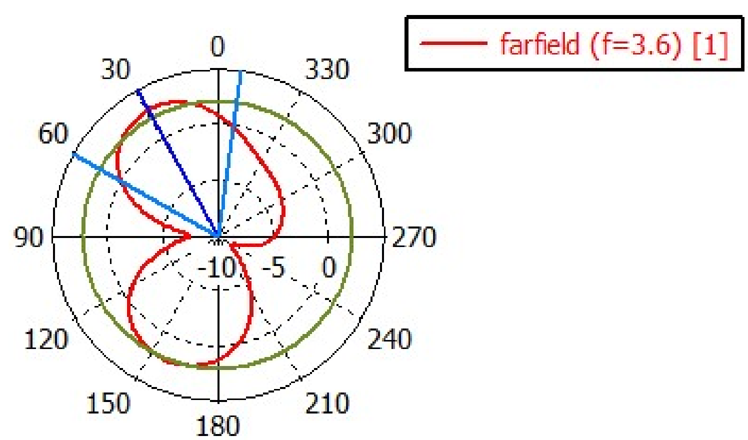
(a)E-plane

E-Plane is always the plane that contains the electric component of the EM radiation and the direction of maximum radiation. The E plane will dictate whether the linear polarization is horizontal or vertical. In this arrangement when the elements are excited then maximal radiation emission occurs from the broadside (i.e., the direction normal to the array axis) while the little amount of radiation is emitted from the other directions. Thereby providing a bidirectional radiation pattern. The reason for its bidirectional radiation pattern is that it radiates in both directions along the broadside.



(b)H-plane

This plane relates to the magnetic portion of the EM energy generated by a linearly polarized antenna. It will always be perpendicular to the E plane. In radio communication, an omnidirectional antenna is a class of antenna which radiates equal radio power in all directions perpendicular to an axis (azimuthal directions), with power varying with angle to the axis (elevation angle), declining to zero on the axis. Especially in receiving or sending radio waves equally well in all directions. Omni-Directional antennas also work well when you are receiving from a signal that you are unsure where it originates because its signal is received from all angles Another great use is to broadcast a hotspot from a central area of a location such as a park, fairgrounds, backyard, etc...



(c)Both E&H-plane

Fig. 5. The E & H-plane far field radiation patterns

The E& H- Plane far field radiation patterns are shown in fig. 5(a), 5(b) & 5(c). The E-plane and H-plane are reference planes for linearly polarized waveguides, antennas and other microwave devices.

IV.CONCLUSION

A compact filtenna with sharp rejection capability of the non-desired radiation outside the 5G mid-band has successfully been designed. A printed circuit antenna is combined electromagnetically with a half CLL filter to form the proposed design. In spite of its small size ($24.2 \times 27 \times 0.8\ mm^3$), the filtenna matching and radiation characteristics are so suitable for radiating the 5G mid-band EM energy and suppressing the others that cause interference with them. The filtenna reflection coefficient has reduced values at the pass band (3.6-3.7 GHz) that reaches to less than -15dB. The omnidirectional radiation pattern of the proposed design and its compact size make the filtenna to be a superior selection for portable 5G mid-band gadgets.

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