New Compact Microstrip Patch Filtenna Structures with Partitioned Ground for 3G/4G Applications

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***Abstract*— In this paper, new compact narrowband, broadband and ultra-wideband microstrip patch filtenna structures (dual/triple/forth) have been proposed and presented. The proposed filtennas have been analyzed, investigated and optimized using the microwave CST_Studio simulator for three different ground geometries. The presented filtenna structures are mounted on FR4-substrate, and resonate within the band from 3.0 GHz up to 18 GHz. Simulation results show that using the concept of partitioned ground (Digital ground Structure), the resonance frequencies as well as the operating bands of the patch filtenna can be controlled. The presented paper added a new concept for filtenna design.**

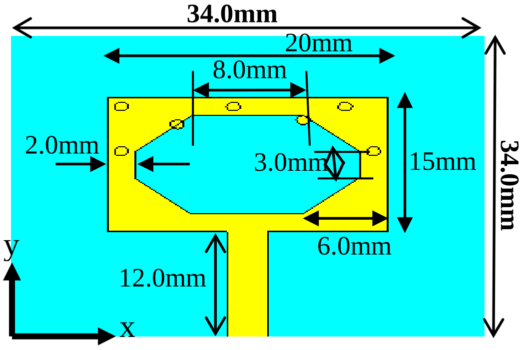
***Index Term*-- Compact; Broadband; Dual-band; Patch antennas**

I. INTRODUCTION

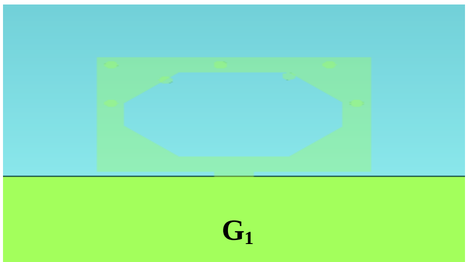
Microstrip antenna configurations have numerous benefits in wireless communication and radar systems applications. This is due to its small size, low cost, less weight, easy fabrication, and excellent compatibility with the typical manufacturing process of MMIC planar circuits. A compact microstrip patch antenna structure with built-in filter is very important element in wireless communication system. Such antenna is referred to as filtenna. Therefore, any antenna structure that can perform radiation and filtration is an important subsystem for indoor/out-door communication systems. To achieve the 3G/4G wireless communication system constrains, the antenna should be a wideband as well as compact in size. In addition, the antenna characteristic must be optimized over the operating frequency range. In this paper, two new compact filtenna structures have been analyzed, investigated, and presented. Our proposed filtennas are based on concept of partitioned ground which acts as shunt resonator circuit controlling the global patch resonance. Section II presents a detailed description of our proposed microstrip patch filtennas. These filtennas have three ground structures and two different short circuits geometries (vies). Simulation results of these filtenna configurations are analyzed and presented in section III. A detailed parametric analysis of proposed patch filtenna configurations and their simulation results are also presented in section III. Finally, section IV concludes the presented paper.

I. PATCH FILTENNA COFIGURATION AND DESCRIPTION

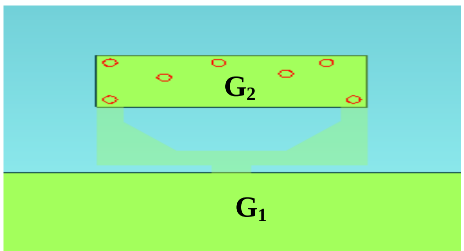
Two filtenna structures have been proposed and presented as show in Fig.1 and Fig.2. The first patch filtenna presented in Fig.1.(a) has three ground geometries. This includes single, two and three ground strips as shown in Fig.1.(b) through Fig.1.(d). In addition, seven vies are used as short circuit to control patch resonance. The basic patch dimensions are 15mm length and 20mm width. The patch is mounted on a single FR-4 substrate (ε_r=4.7, 1.6 mm height, and tangential loss of 0.02) and the conductor thickness is assumed to be 0.035mm. This patch is fed with 50 Ohm transmission line of length 12.0mm. The second patch filtenna configuration is the same as the first one except it has different number and locations of short circuit vies. These proposed filtennas are assumed to operate in the 3G/4G frequency band. The dimensions and location of the two vies configurations are given in table (1) and table (2) respectively.



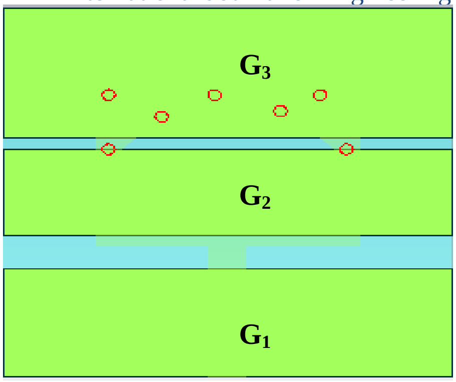
(a) Top view of proposed patch filtenna #1



(b) Bottom view #1(partial ground: 1PG)

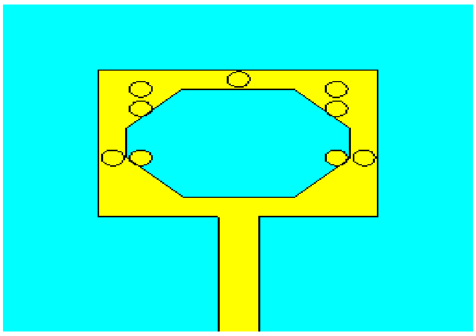


(c)Bottom View #2 (two ground strips: 2PG)

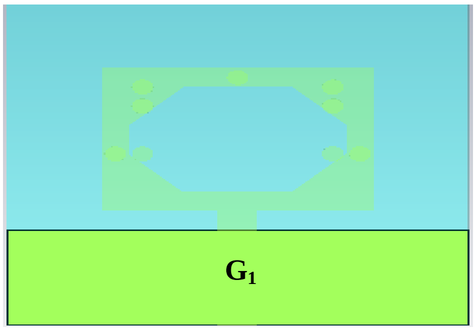


(d) Bottom View #3 (three ground strips: 3PG)

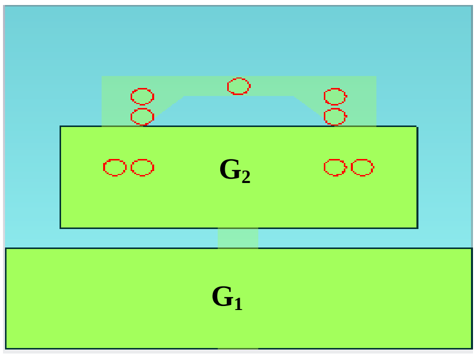
Fig. 1. Proposed filtenna #1with different ground structures



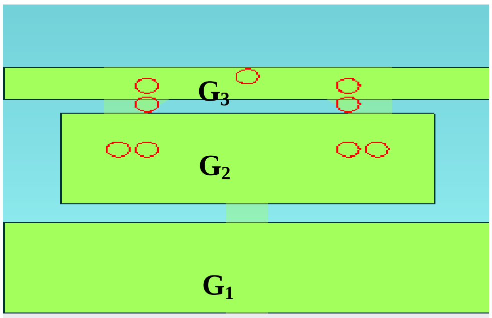
(a) Top view of proposed patch filtenna #2



(b) Bottom View #1(partial ground: 1PG)



(c) Bottom View #2 (two ground strips: 2PG)



(d) Bottom View #3 (three ground strips: 3PG)

Fig. 2. Proposed filtenna #2 with different ground structures

TABLE I
Vies dimensions and positions of filtenna #1

No.	Position (x, y)	Radius	Height
1	(8, 21)	0.5	1.67
2	(8, 26)	0.5	1.67
3	(12, 24)	0.5	1.67
4	(16, 26)	0.5	1.67
5	(21, 24.5)	0.5	1.67
6	(24, 26)	0.5	1.67
7	(26, 21)	0.5	1.67

TABLE II
Vies dimensions and positions of filtenna #2

No.	Position (x, y)	Radius	Height
1	(8, 18)	0.8	1.67
2	(10, 18)	0.8	1.67
3	(10, 23)	0.8	1.67
4	(10, 25)	0.8	1.67
5	(17, 26)	0.8	1.67
6	(24, 25)	0.8	1.67
7	(24, 23)	0.8	1.67
8	(24, 18)	0.8	1.67
9	(26, 18)	0.8	1.67

II. SIMULATION RESULTS

The two filtenna configurations discussed in the previous section are simulated using microwave CST_Studio, and the results are presented in this section. Table (3), summaries all considered cases of our simulations. First, effects of adding slot and/or short circuit vies on the patch resonance are evaluated and investigated as compared to the conventional patch "CP " (rectangular patch with the same dimensions and has no slot nor vies and it has full ground). The results are presented in Fig.3 and Fig.4. It is clear from these figures that the conventional patch has multi resonance frequencies due to the mismatch between the patch and the feed line (Inset has not been used). In addition, adding either slot or vies has the effect of shifting the resonance frequency bands.

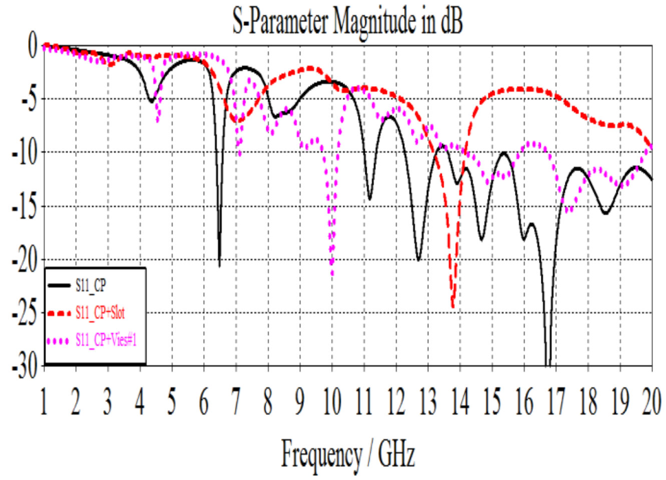


Fig. 3. $|s_{11}|$ of CP versus adding slot or short circuit vies#1

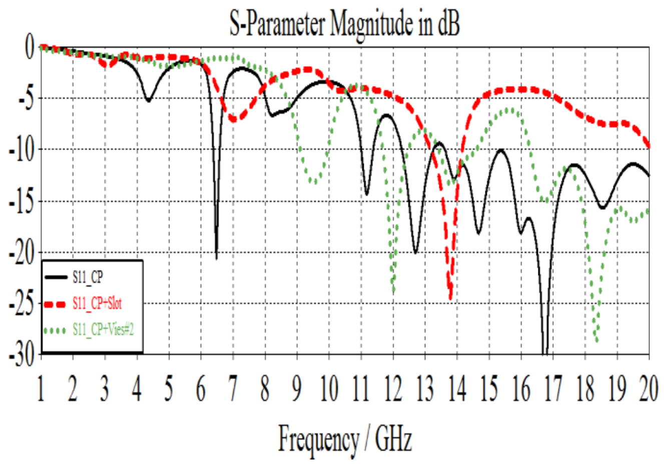


Fig. 4. $|s_{11}|$ of CP versus adding slot or short circuit vies#2

Moreover, the effects of combining both slot and short circuit vies are presented in Fig.5. It is clear from the figure that, the resonance frequencies as well as the frequency bands is dependent on the slot size and the vies geometry. The first vies distribution (Vies#1: given in table (1)) has the narrow resonances at 4.0 and 8.5 GHz and wideband resonance at 13.7 GHz. On the other hand, a single wideband resonance has been occurred in case of second vies distribution (vies#2: given in table (2)). Second, the effects of partial ground (single ground strip) in presence of slot and vies has been investigated and the results are illustrated in Fig.6 and Fig.7. The effect of adding slot and vies along with the partial ground act as a bandpass filter built-in with conventional patch antenna. This leads to compact dual broadband antenna (1st band from 3.0 GHz to 5.0 GHz, and 2nd band from 12.0 GHz to 15.5 GHz).

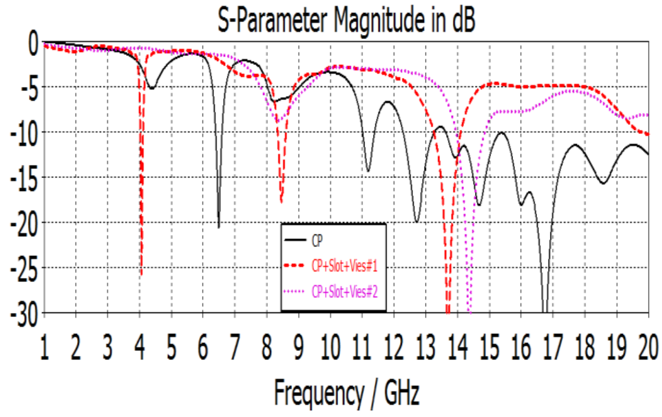


Fig. 5. $|s_{11}|$ of CP versus adding slot and short circuit vies

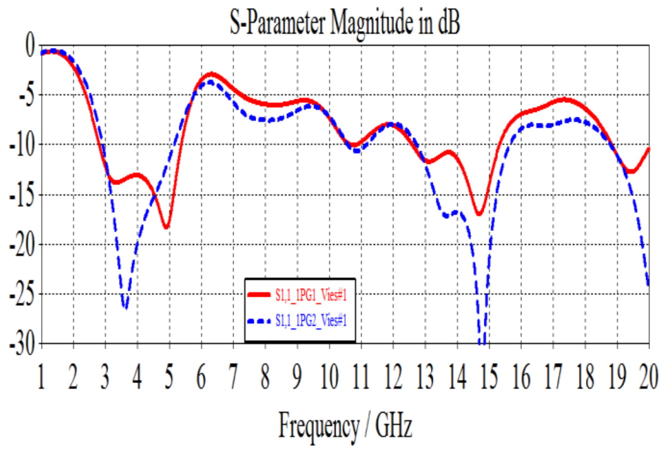


Fig. 6. $|s_{11}|$ of Proposed filtennas (adding slot and vies) with partial ground of length 10.0 mm

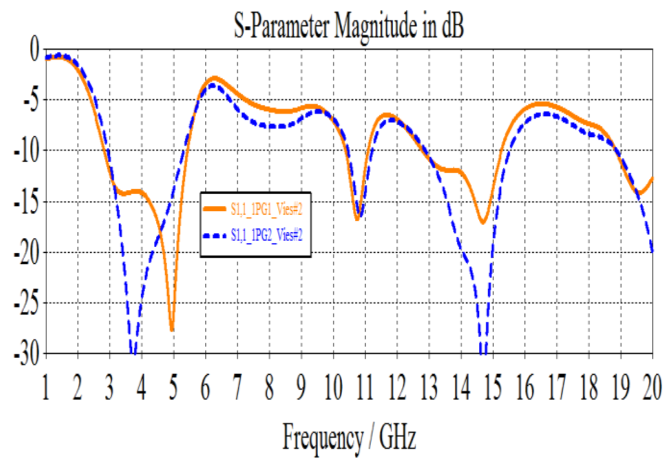


Fig. 7. $|s_{11}|$ of Proposed filtennas (adding slot and vies) with partial ground of length 11.0 mm

The third study is to investigate the effect of two ground strips in presence of slot and different via distributions on patch resonances. A parametric study has been performed for the dimensions of the two ground strips and vies listed in table (1) through table (3). The results of simulation are presented in Fig.8 and Fig.9. It is clear from these figures that the conventional patch with two ground strips and short circuit vies can operate at different isolated frequency bands. Thus, the antenna resonances and bandwidths can be easily controlled. In fact, the obtained results indicate very important issue for filtenna design. An arbitrary conducting patch (may have a slot) mounted on substrate of partitioned ground strips with arbitrary geometries in presence of short circuit vies act as bandpass filter. The characteristic of such filter depends on three main parameters. This includes the number of vies and their geometries, ground geometry, and slot size. In addition, the proposed filtennas are very compact in size, and it can operate in a wideband from 3.0 GHz to 4.5 GHz as shown form these figures. Finally, the fourth study is to investigate the effect of three ground strips in presence of slot and different via distributions on the patch resonances. The results of simulation are illustrated in Fig.10 and Fig.11. As it is clear for these figures, the proposed filtenna can operate at different isolated broadband and ultra-wideband frequencies. For example, the proposed filtenna#2 can resonate in an ultra-wideband from 12.0 GHz to 15.5 GHz while it can also resonate in a wideband from 2.5 GHz to 3.5 GHz (see Fig.11, black curve-solid).

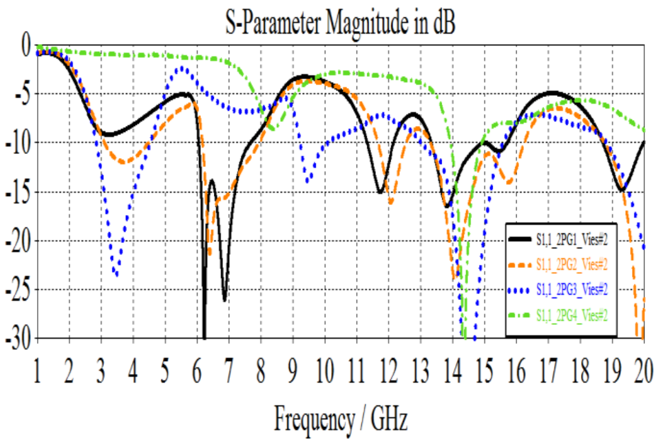


Fig. 8. $|s_{11}|$ of proposed filtena #1(2PG)

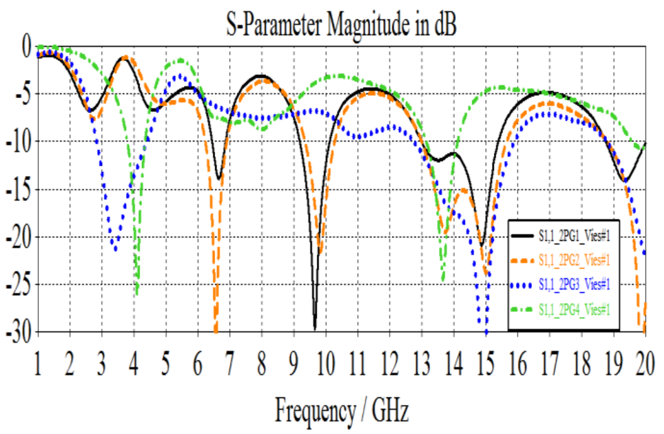


Fig. 9. $|s_{11}|$ of Proposed filtena #2(2PG)

TABLE III
Dimensions and locations of partitioned ground

	G_1	G_2	G_3	Case #
Length and Width of each ground Strip (W_i, L_i)	(0, 34)	-----	-----	S11_CP+ Vies#1
	(0,34)	-----	-----	S11_CP+ Vies#2 S11_CP
	(0, 34)	-----	-----	**S11-1PG1**
	(0,10)	-----	-----	
	(0, 34)	-----	-----	**S11-1PG2**
	(0,11)	-----	-----	
	(0, 34)	(0, 34)	-----	**S11-2PG1**
	(0,10)	(15,27)	-----	
	(0, 34)	(0, 34)	-----	**S11-2PG2**
	(0,11)	(15,27)	-----	
	(0, 34)	(7, 27)	-----	**S11-2PG3**
	(0,11)	(20, 27)	-----	
	(0, 34)	(7, 27)	-----	**S11-2PG4**
	(0,19)	(20, 27)	-----	
	(0, 34)	(0, 34)	(0, 34)	S11-3PG1
	(0,11)	(15,21.5)	(23.5, 30)	
	(0, 34)	**(0, 34)**	**(0, 34)**	**S11-3PG2**
	(0, 11)	**(15,21.5)**	**(23.5, 27)**	
	(0, 34)	(0,34)	(0, 34)	S11-3PG3
	(0,11)	(15,21.5)	(23.5, 34)	
	(0, 34)	(0, 34)	(0, 34)	S11-3PG4
	(0,11)	(18,21.5)	(23.5, 27)	
	(0, 34)	**(0, 34)**	**(0, 34)**	**S11-3PG5**
	(0,12)	**(15,21.5)**	**(23.5, 27)**	
	(0, 34)	(4, 30)	(0, 34)	S11-3PG6
	(0,12)	(15,21.5)	(23.5, 27)	
	(0, 34)	**(4, 30)**	**(7, 27)**	**S11-3PG7**
	(0,12)	**(15,21.5)**	**(23.5, 27)**	
	(0, 34)	**(0, 34)**	**(0, 34)**	**S11-3PG8**
	(0,10)	**(13, 21)**	**(22, 34)**	

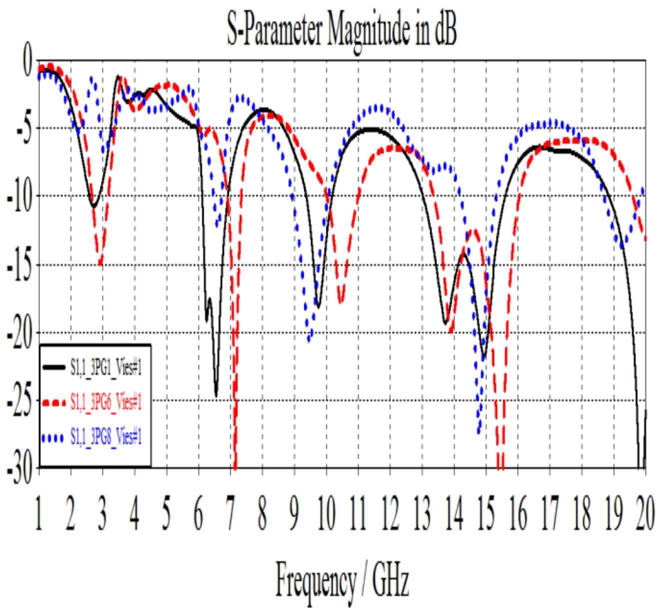


Fig. 10. $|s_{11}|$ of proposed filtena #1 (3PG)

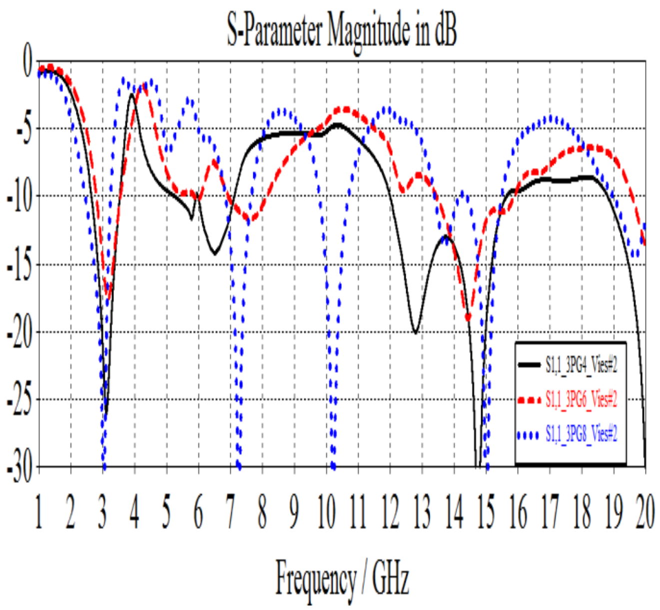


Fig. 11. $|s_{11}|$ of proposed filtena #2 (3PG)

IV. CONCULUSION

New compact patch filtenna structures have been proposed, analyzed, designed and simulated (narrowband, broadband, dual-band, and ultra-wideband). The results of simulation show that the resonance frequencies of our proposed compact patch filtenna structures can be controlled within different isolated bands. To design such filtenna, three steps are required. First, select a conventional patch antenna to resonate at a specific required frequency in the 3G/4G wireless band. Second, the add slot and array of vies to the patch antenna. Finally, the ground plane is divided into two or three partitions. These steps have been verified using two different vies geometries and three different ground shapes for the same patch. Based on our results, the partitioned ground, slot and short circuit vies act as built-in bandpass filter with conventional patch antenna. The proposed filtenna structures can be used for many of applications. This includes mobile, GPS, wireless networks, and radar systems. The present paper has a new and simple method to design a planar filtenna and/or operates at the desired frequency bands. Future work will include design and implementation of two port filtenna for MIMO applications using our proposed method.

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