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A Novel Compact Ultra-wideband Monopole Microstrip Filtenna

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Abstract: In this study, a novel compact ultra-wideband monopole microstrip filtenna having two built in band-rejection filters has been proposed and presented. The first filter is inverted U-shape slot etched within the patch while second one is two concentric rectangular slots etched within the partial ground under feeder. These filters reject WiMax/LTE band (3.3-4.0 GHz) and WLAN band (5.0-5.9 GHz). The proposed filtenna has been designed, investigated and optimized using the microwave CST_Studio simulator. The presented filtenna structure is mounted on FR4-substrate and it resonates within the band from 3.0 GHz up to 10.2 GHz. Simulation results shows that using Defective Partial Ground (DEPG) along with the Patch Slots (PS), the resonance frequencies as well as the operating bands of the patch filtenna can be controlled. The proposed filtenna has been fabricated and its parameters are measured. Good agreement has been obtained between simulated and measured parameters.

Key words: Compact UWB planar filtennas, UWB microstrip filtennas, monopole filtennas

INTRODUCTION

Printed monopole microstrip antennas with filtration characteristic have been received great attentions in Ultra-wideband applications due to their numerous benefits (Choi *et al*., 2005; Eshtiaghi *et al*., 2010; Nouri and Dadashzadeh, 2011). This is due to the well known advantages of microstrip antenna circuits (small size, low cost, less weight and easy fabrication) (Lu *et al*., 2012; Gheethan and Anagnostou, 2011). In addition, microstrip monopole antenna configuration has an Omni-directional pattern, moderate gain, low VSWR and good efficiency (Jung *et al*., 2005; Deng *et al*., 2009). Such antenna characteristic achieves the practical needs for UWB WLAN applications (Ammann and Chen, 2003). Moreover, a compact UWB monopole microstrip antenna structure with built-in band rejection filter is very important element in wireless communication systems. Therefore, any planar antenna structure (microstrip/coplanar CPW/stripline) that can simultaneously perform radiation and filtration functions is an important subsystem for indoor/outdoor wireless communication systems (Nouri and Dadashzadeh, 2011). Such planar antenna structure is referred to as planar filtenna.

One of the main advantages of planar filtenna is the filtration characteristic which reduced the cost and overall size of the transceiver circuit. There are two approaches to construct a built-in band rejection filter within the antenna structure. The first approach is to use the defective partial ground "DEPG". This can be performed by shorten the ground plane with embedded arbitrary slots under the vicinity of feeder. The second one is to use arbitrary slots shape within the patch near the edges "PS". The DEPG and/or PS alternate/change the equivalent current source of patch antenna. Thus, the antenna filtration characteristic can be controlled.

To design a planar filtenna structure, there are three main constrains must be practically considered. These are the overall filtenna size, the filtenna effective operating bandwidth and the filtration characteristic. These constrains represent the real challenge facing the current wireless communication systems (including 3G/4G systems). In fact, an efficient filtenna structure should have a compact size, a wide bandwidth and an adjustable isolated rejection bands. Furthermore, the overall filtenna characteristic must be optimized over the operating frequency range. In this study, a novel compact UWB monopole microstrip filtenna structure has been designed, analyzed and presented. The proposed filtenna is based on concept of DEPG and PS. They act as resonator circuits to control the global patch resonance. Detailed descriptions of the proposed microstrip patch filtenna are discussed and presented. This filtenna has two built in Band-Rejection filters. These are ground plane filter and

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patch filter. Simulation results of the proposed filtenna are presented and compared to the measured one. Finally, the presented study is concluded in last section.

FILTENA CONFIGURATION AND DESCRIPTION

The proposed UWB monopole microstrip filtena structure is shown in Fig. 1. The microstrip patch is mounted on a single lossy FR-4 substrate (ε_r = 4.4, 1.5 mm height and tangential loss of 0.025) and the conductor thickness is assumed to be 0.035 mm. The patch is fed with 50 Ohm transmission line of length 8.0 mm. Two rectangular slots at lower edge of the patch are used to adjust the patch impedance (inset slots).

Two band rejection filters have been built in the proposed filtenna structure. These filters are referred to as patch band rejection filter "PBRF" and ground band-rejection filter "GBRF". The PBRF is an inverted U-shape slot near the patch edges. The GBRF consists of two concentric rectangular slots located symmetrically under the feeder. The impact of the two filters dimensions and locations on the filtenna performance has been investigated and optimized. The final optimized filtenna dimensions are listed in Table 1.

Table 1: Optimized dimensions of the proposed filtenna

Dimension	Value (mm)	Description
L_1	4.50	As shown in figure
L_2	2.00	As shown in figure
L_f	8.00	Feeder length
L_{gnd}	6.00	Ground length
L_{sub}	20.00	Substrate length
R_1	3.50	As shown in figure
R_2	3.00	As shown in figure
W_1	3.50	As shown in figure
W_f	2.78	Feeder width
W_n	1.20	As shown in figure
W_{sub}	15.00	Substrate width
h	1.50	Substrate thickness
$L_{1\,slot}$	7.00	As shown in figure
$L_{2\,slot}$	1.40	As shown in figure
W_{slot}	2.60	As shown in figure

SIMULATION RESULTS AND DISCUSSION

The proposed filtenna design has been simulated and investigated using the CST_simulator assumed high dense mesh and thick PML layers. The basic antenna parameters have been computed and optimized and the results of simulation are presented the in following figures (Fig. 2-4). First, Fig. 2 illustrates scattering parameter "$|S_{11}|$", standing wave "SWR" and maximum gain "G_o". As it is clear from this figure, adding a patch slot and/or a ground slots creates different isolated band rejections. The center frequency and the bandwidth of such filter can be adjusted using the slots dimensions and locations. The two rejection bands are: 3.3- 4.0 GHz (PBRF) and 5.0-5.9 GHz (GBRF). The same results have been obtained for both standing wave (SWR = 2 over the passband) and maximum gain (Go = 4 dB). It should be noted that the number of band rejection filters is based on the number of slots within the patch and their locations. This depends on the patch geometry and dimensions. On the other hand, defective partial ground can provide only one band rejection filter. Second, Fig. 3 presents the radiation efficiency, the total radiation efficiency and the power radiated. It should be noted that radiation efficiency is about 90% over the passband and less than 10% in the rejection bands. Also, the power radiated is less than 10% within the rejection bands. Finally, Fig. 4 illustrates the

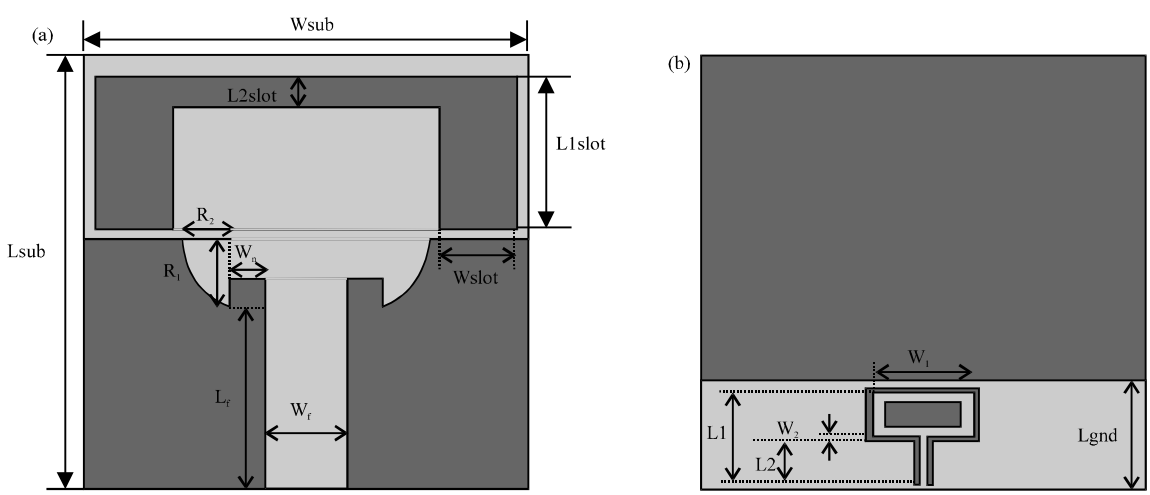

Fig. 1: Proposed microstrip filtenna, (a) Top view and (b) Bottom view

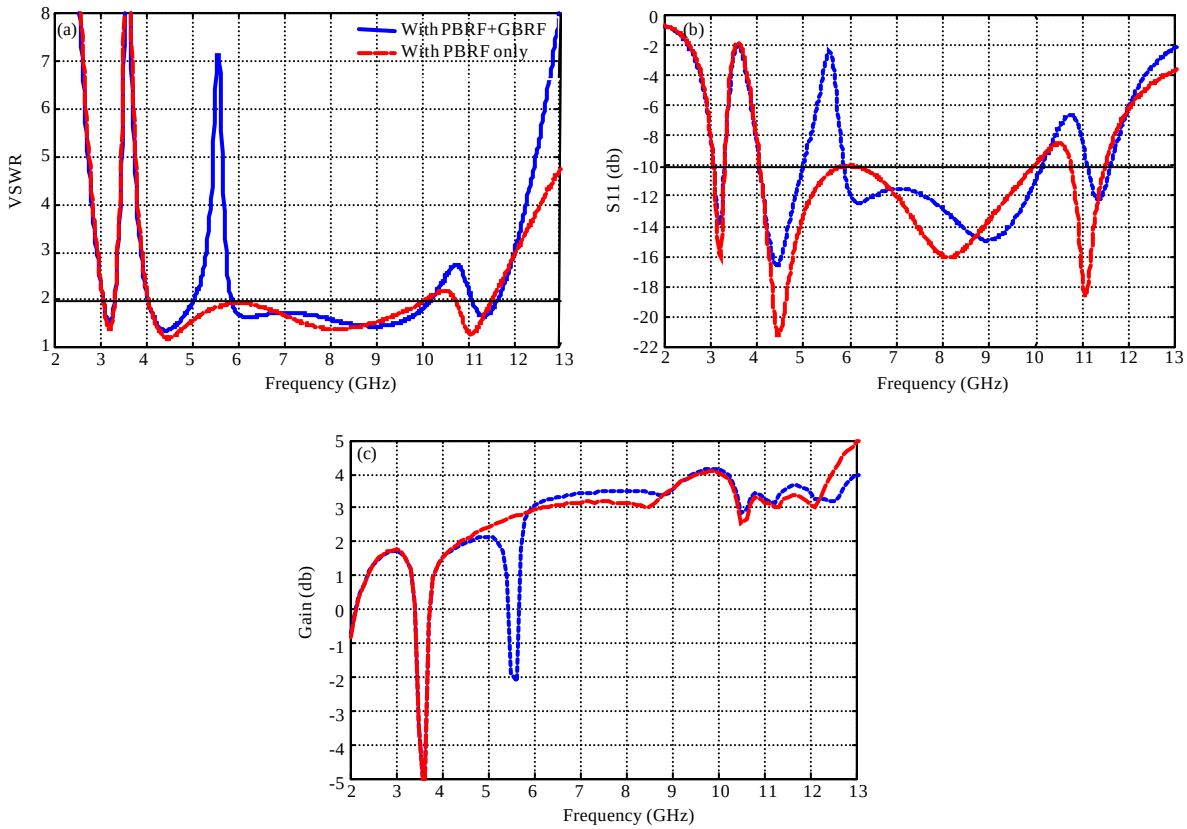

Fig. 2(a-c): Proposed monopole filtenna parameters, (a) |S11|: Patch filter-patch and ground filters, (b) SWR: Patch filter-patch and ground filters and (c) Gain: Patch filter-patch and ground filters

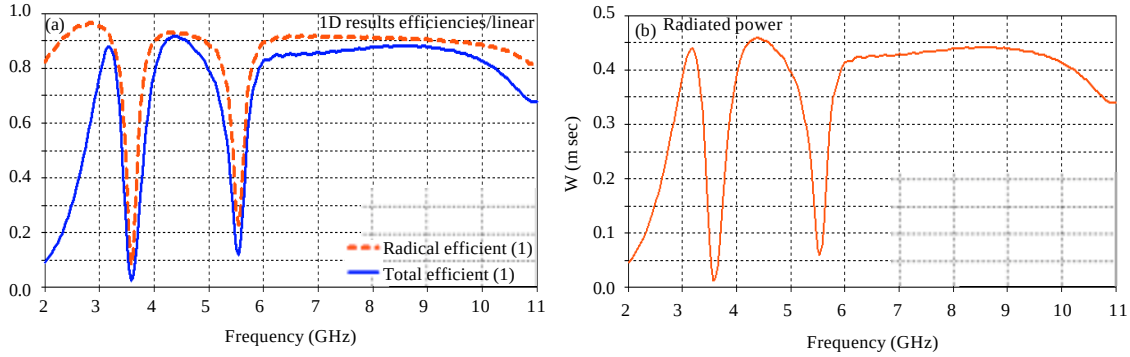

Fig. 3(a-b): Efficiency and radiated power of proposed filtenna with the two band rejection filters, (a) Filtenna efficiency and (b) Filtenna radiated power

filtenna radiation pattern for different frequencies within the baseband. It is clear from the figure, approximately omni-directive pattern over the passband has been achieved (at 4, 6 and 8 GHz).

FABRICATION AND MEASUREMENTS

The proposed filtenna structure has been fabricated on FR-4 substrate using the thin film technique and

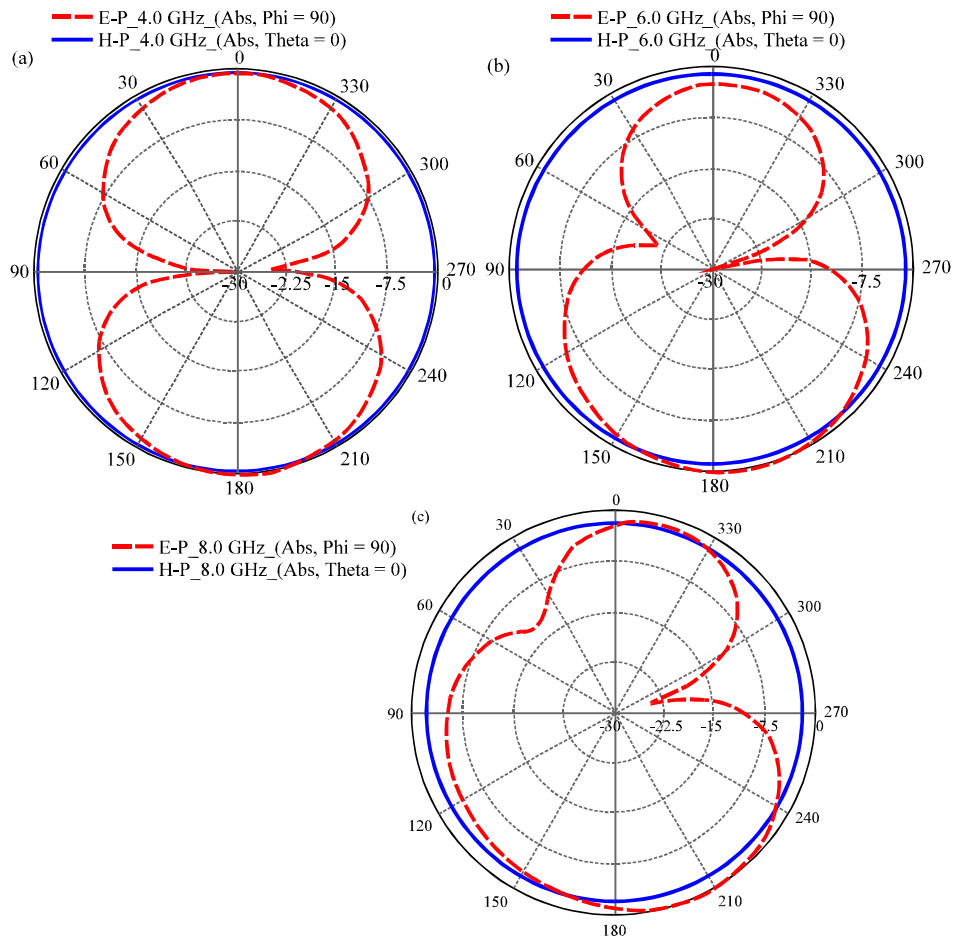

Fig. 4(a-c): Radiation pattern of proposed filtenna with the two band rejection filters, (a) Radiation pattern at 4.0 GHz, (b) Radiation pattern at 6.0 GHz and (c) Radiation pattern at 8.0 GHz

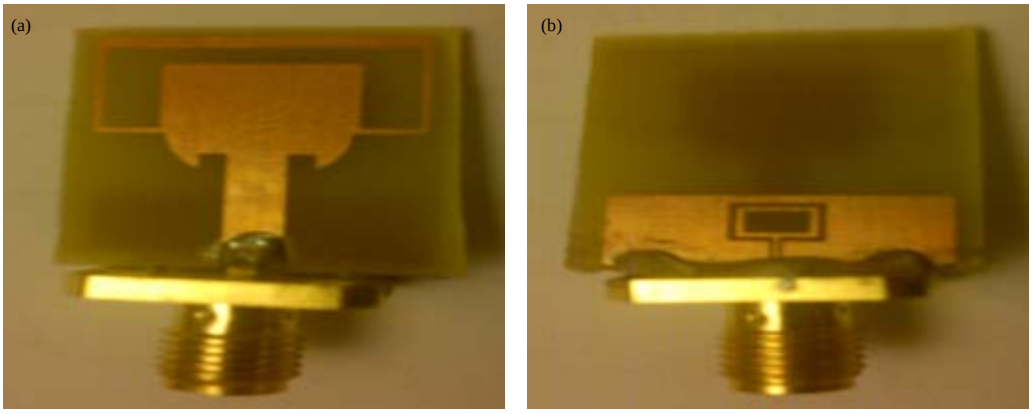

Fig. 5: Fabricated UWB monopole filtenna, (a) Top view and (b) Bottom view

presented as shown in Fig. 5. Return loss $|S_{11}|$ and SWR have been measured using an HP-analyzer network and illustrated in Fig. 6. Good agreement has been obtained between measured and simulated parameters as presented in Fig. 7. The main reasons for discrepancy in measured parameters are the compact size of filtenna and SMA

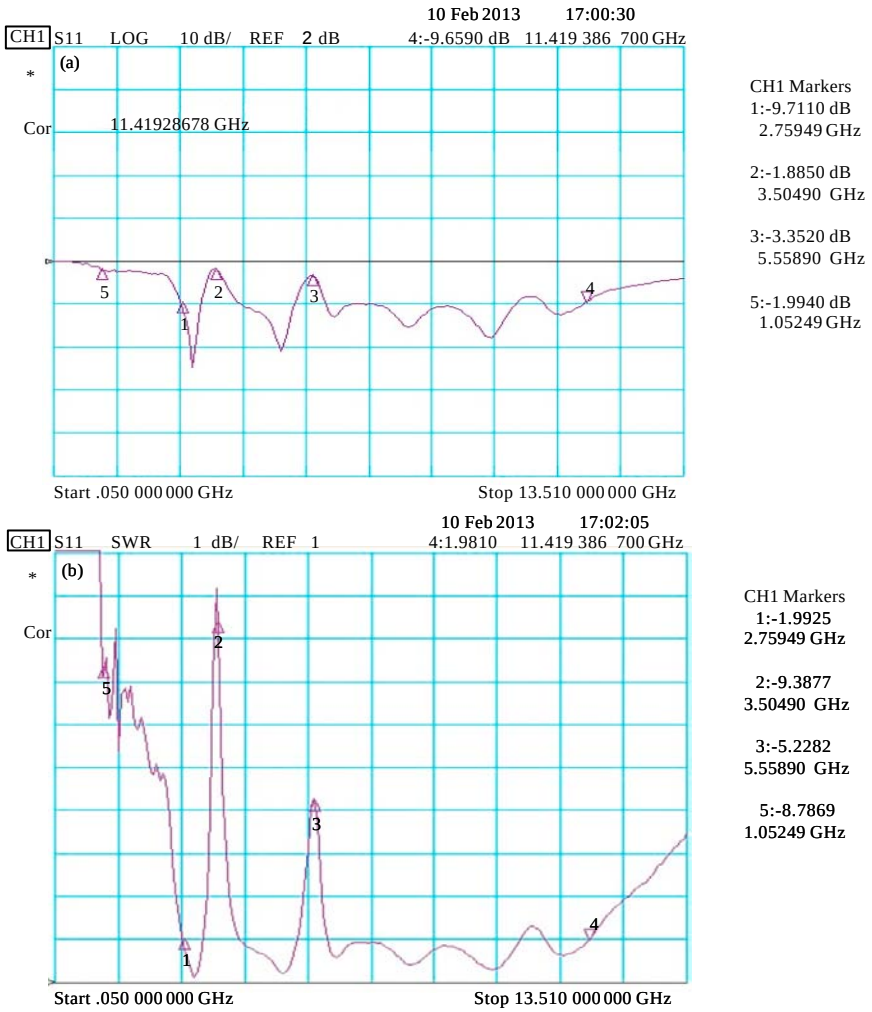

Fig. 6(a-b): Measured UWB monopole filtenna parameters, (a) $|S_{11}|$ and (b) SWR

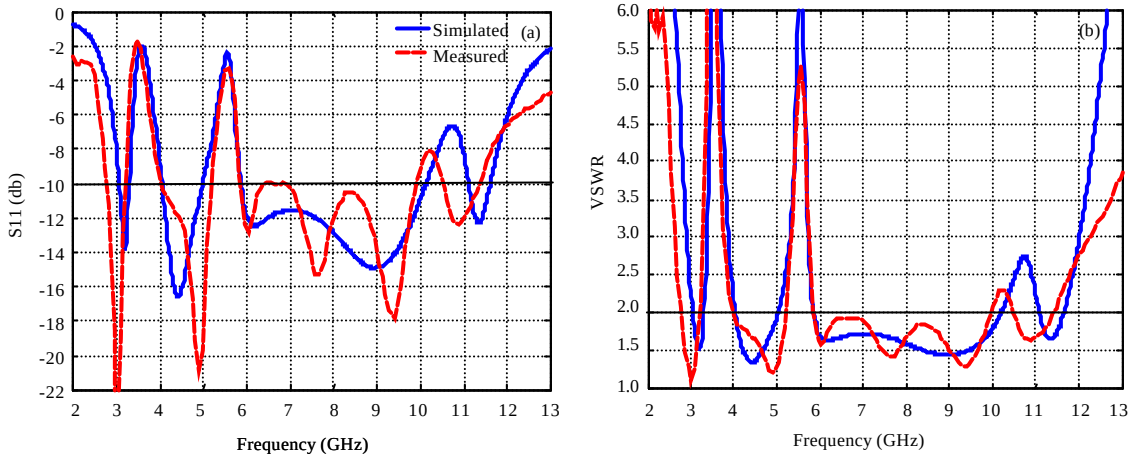

Fig. 7(a-b): Comparison between measured and simulated filtenna parameters, (a) $|S_{11}|$ and (b) SWR

connector. In fact, the size of SMA connector is comparable with filtenna size. In addition the soldering of the connector affects the resonance of the filtenna.

CONCLUSION

A novel compact UWB monopole microstrip filtenna structure with two built-in Band Rejection Filters has been proposed (PBRF and GBRF). The filtenna has been designed, analyzed and simulated. The results of simulation show that the resonance frequencies of the proposed compact patch filtenna can be controlled within isolated bands. To design such filtenna, three steps are required. First, design a monopole microstrip patch antenna with partial ground configuration to resonate within the standard UWB. Second, add slots to the patch antenna near the edges and/or to the partial ground under the antenna feeder. This creates two different band rejection filters. Finally, optimize the filter dimensions for the desired frequencies. These steps have been verified for the proposed filtenna. The presented filtenna has been fabricated on FR-4 substrate and its parameters are measured. Good agreement has been obtained between the measured and simulated parameters. Future work will include design and analysis of UWB monopole microstrip filtenna for MIMO applications.

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