A Wide-band Monopole Antenna in Combination with a UWB Microwave Band-pass Filter for Application in UWB Communication System

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***Abstract*— A filter-antenna configuration for the application for UWB communication system is presented. Firstly, a microstrip transmission line fed monopole antenna for the wide-band (2.65 GHz-8.52 GHz) communication system is designed and Its performance is verified. Secondly, in the place of microstrip transmission line feeding, a planar UWB microwave filter is used and the performance (3.65 GHz-10.16 GHz) of the new filter-antenna configuration is noted. The new filter-antenna configuration considerably improves the antenna performance and wide-band antenna becomes the UWB antenna after the insertion of the UWB microwave filter in place of microstrip-line feeding technique. Hence, the UWB antenna can be used as the wide-band impedance matching circuit to enhance the performance of the antenna in the passband. Apart from this there is improvement in the out-of-band performance. The proposed UWB filter-WB antenna configuration is simple and compact in size providing broadband impedance matching, and consistent radiation pattern within the UWB frequency range.**

***Keywords*— Filter-antenna configuration, monopole antenna, microstrip-transmission line, microwave filter, milti-mode resonator (MMR), Ultra-wideband (UWB).**

I. Introduction

Application of ultra-wideband (UWB) technology on wireless communication system has increased considerably in last seven years. Because the UWB technology has great potential in the development of various modern wireless communication systems, the U.S Federal Communication Commission (FCC) authorized the unlicensed use of the ultra-wideband (3.1-10.6 GHz) frequency spectrum for indoor and hand-held wireless communication since early February 2002 [1]. To meet the variety of applications in UWB communication systems, many researchers around the world have been aroused on the design, research and development of UWB filter and antenna [2]-[6], which are mainly the combination of monopole and wide slot antennas because of their quasi-omnidirectional radiation pattern and wide bandwidth. In these designs, a UWB antenna can not achieve a good performance in the pass-band and restrain the upper pass-band higher than 10.6 GHz very well the same time by itself.

And now-a-days, many interests have been generated in the association of the filter with antenna. Based on the study and research on the combination of the filter and antenna, people have designed and proposed an associated model of UWB antenna and a narrow band band-stop filter for a notched band [7]. In [8], an UWB filter has been introduced on the feed-line of the UWB antenna to achieve a good VSWR from 1 GHz to 13 GHz in simulation.

In this paper an UWB filter-WB monopole antenna configuration is presented. The upper pass-band of the wide-band antenna is considerably improved by the introduction of an UWB filter in the feed position of the WB filter in place of the micros trip line. The upper pass-band improvement is due to the multi-mode resonator (MMR) technique employed in the UWB antenna. By suitable overlapping of the activated modes an ultra-wideband performance has been achieved in the UWB filter-WB monopole antenna configuration.

II. Filter-Antenna Configuration Design and Results

A. *Wide-band (WB) Antenna Design and Results*

Fig.1 shows the geometry and configuration of a wide-band (WB) antenna. The antenna was fabricated on an h=1.0 mm FR4 epoxy substrate with the dielectric constant ε_r=4.4 and loss tangent tanδ=0.0018. As shown in the figure, the radiating element is a rectangular patch printed on the substrate. The rectangular radiator is fed by a 50-Ω microstrip transmission line, which is terminated with a sub miniature A (SMA) connector for the measurement purpose. The electromagnetic software IE3D [13] is employed to perform the design and optimization process. The design parameters are L_s=44.2 mm, W_s=31.2 mm, L_g=18.2 mm, L= 17 mm, W=11 mm, w_f=1.9 mm and p=2 mm.

Fig.2 shows the return loss vs. frequency of the wide-band monopole antenna. The frequency band for this antenna extends from 2.65 GHz-8.52 GHz, which is not enough for the application in ultra-wideband (UWB) communication system.Fig.3 depicts the VSWR characteristics of the WB monopole antenna. The VSWR graph cuts the VSWR=2 line at 2.65 GHz and remains below the line till 8.52 GHz.

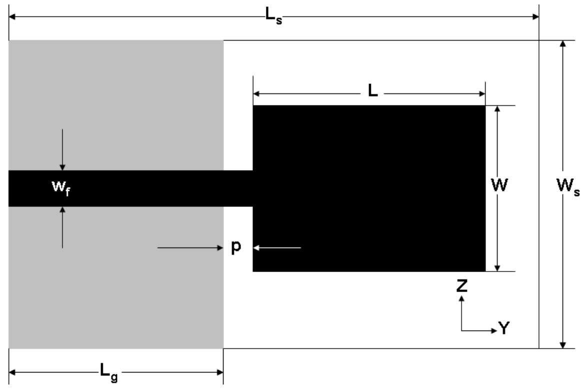


Fig. 1. Geometry and configuration of WB monopole antenna.

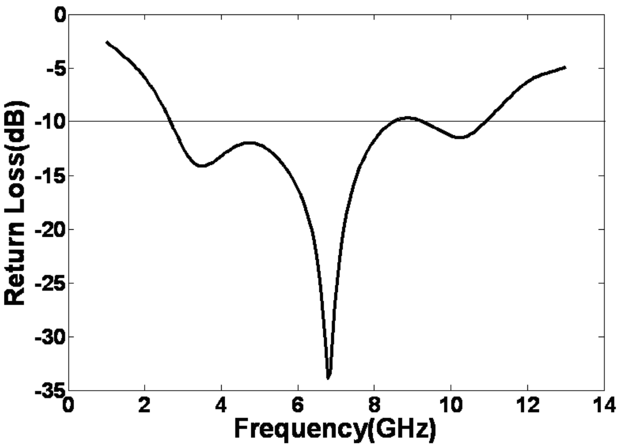


Fig. 2. Return Loss vs. frequency of WB monopole antenna.

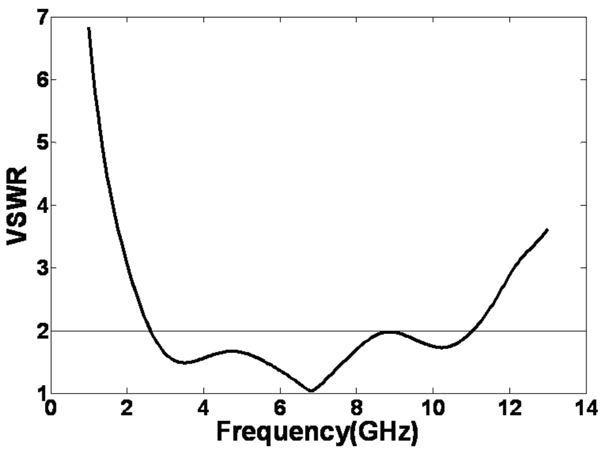


Fig. 3. VSWR vs. frequency of WB monopole antenna.

B. UWB Bandpass Filter Characterization

An ultra-wideband filter can be realized by employing multi-mode resonator technique (MMR). The MMRs are formed by incorporating three pairs of circular impedance stepped stubs in shunt with a high impedance microstrip line as shown in the Fig.4. The design methodology with the circular MMR is much easier compared to the rectangular MMR [9]. By properly optimizing the UWB filter structure fine in-band and upper stop-band performance can be explored. The simulation results exhibit the several advantages for the UWB filter. First, small insertion loss in the pass band (<1.0 dB in the 2.27 GHz to 10.33 GHz range. Second, the large and deep stop-band with the insertion loss (>30 dB in simulation) in the 11.84 GHz to more than 30 GHz range. The filter is designed on the FR4_epoxy substrate of the relative dielectric constant of 4.4 and thickness of 1.0 mm.

Multi-mode resonators (MMR) are primarily used to design the UWB filter [10]. In [10] the stub-loaded MMR is at the center position for the design of the UWB filter with two similar coupled lines are located at the left and right section After that, some new kind of modified MMRs are designed In [11], at the center of a stepped impedance resonator (SIR), three open-ended stubs are introduced to allocate the resonator modes more tightly with each other. A MMR embedded with an EBG structure is proposed for the UWB BPF to improve the upper stop-band performance [12]. But regardless of the sophisticated design of MMR based UWB band-pass filter, these filters are still suffered by the existence of periodic narrow pass-bands in the upper stop-band. To alleviate, this problem, a design of MMR is employed to replace the traditional MMR. It is composed of three pairs of circular impedance-stepped stubs in shunt with a high impedance microstrip transmission line as shown in the Fig.4.

Fig.5 shows the equivalent transmission line network of the UWB BPF. The interdigital coupled-line can be equaled as two single transmission lines at the two sides and a J-inverter susceptance in the middle. The final design parameters of the UWB BPF are given as L_1=2 mm, L_2=6.15 mm, L_3=1.85 mm, L_4=6 mm, L_5=0.63 mm, W_1=1.9 mm, W_2=0.1 mm, R_1=0.75 mm, R_2=0.6 mm, W_3 (strip width) =0.2 mm and S_1 (gap width) =0.1 mm.

The UWB passband extends from 2.27 GHz to 10.33 GHz, which is shown in the Fig.6 (a). The upper stopband is largely extends up to and beyond 25 GHz with an insertion loss larger then 20 dB. Meanwhile the group delay (<0.3 ns) in Fig 6(b) is small and flat in the passband.

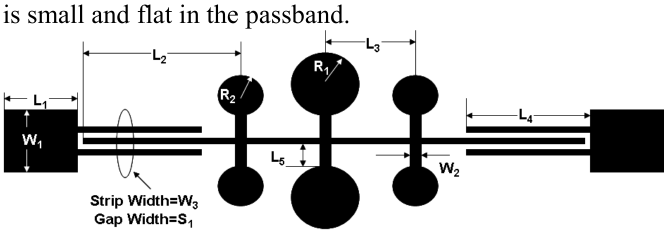


Fig. 4. Configuration of UWB bandpass filter.

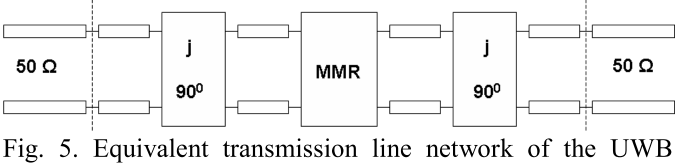
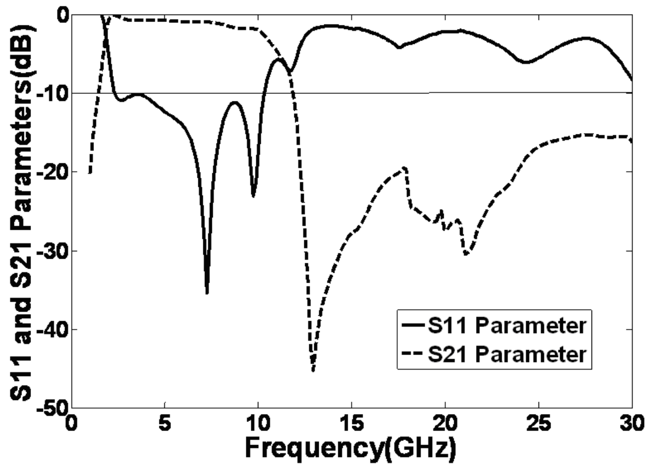
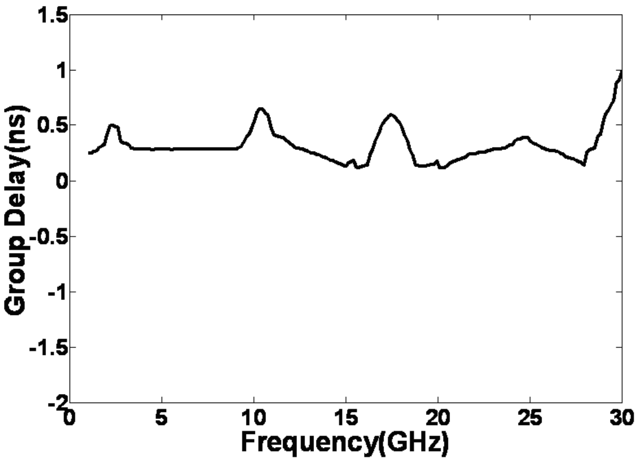


Fig. 5. Equivalent transmission line network of the UWB BPF.



(a)



(b)

Fig. 6. (a) Simulated frequency response of the UWB BPF and (b) Group delay.

C. UWB Filter-WB Antenna Configuration

Fig.7 shows the geometry of the UWB filter-WB antenna configuration. The microstrip line feeding of the WB antenna is replaced by an UWB filter and the performance of this combination is observed and compared with the performance of the WB antenna fed by the microstrip transmission line.

Fig.8 represents the return loss vs. frequency of the UWB filter-WB antenna configuration and is compared with the original wide-band (WB) antenna fed by microstrip transmission line. In case of WB antenna, the pass-band extends from 2.65 GHz to 8.52 GHz, which is not sufficient for the operation in the UWB systems. The pass-band has two resonances, which are at 3.41 GHz and 6.78 GHz respectively.

But when this WB monopole antenna is attached with the UWB filter in place of microstrip line at the feed position, there is remarkable improvement in the upper stop-band regions with four prominent resonances. The upper stop-band of the UWB filter-WB antenna configuration is shifted towards the left and extends up to 10.16 GHz. Because of this UWB filter, the upper stop-band is shifted from 8.52 GHz (WB Antenna) to 10.16 GHz (UWB filter-WB antenna configuration) and now the WB monopole antenna can be appropriately usable in the UWB communication system domain. The lower stop-band of the UWB filter-WB antenna configuration is also shifted towards right from 2.65 GHz (WB Antenna) to 3.65 GHz (UWB filter-WB antenna configuration).

The main reason behind the improvement in the upper stop-band of the UWB filter-WB antenna configuration is due to the multi-mode resonator (MMR) characteristics of the UWB filter. In the pass-band region of the UWB filter-WB antenna configuration four prominent resonant modes are activated. Because of the adequate and appropriate overlapping of these four resonant modes a UWB characteristic is generated and converts the WB antenna into an UWB antenna.

Fig.9 depicts the VSWR characteristics of the UWB filter-WB antenna configuration. The VSWR graph cuts the VSWR=2 line at 3.65 GHz and remains below the line till 10.16 GHz.

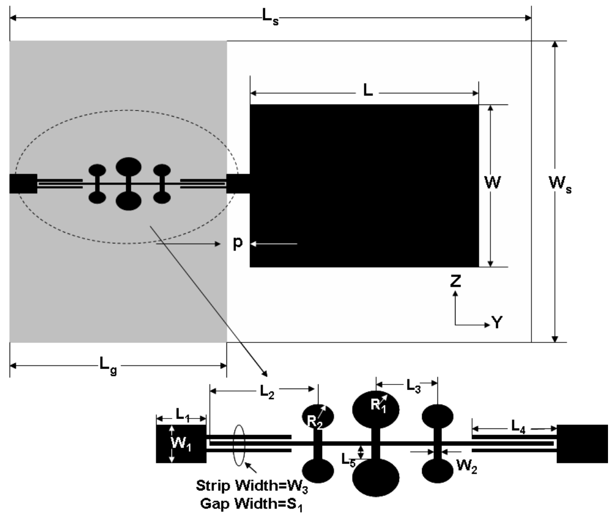


Fig. 7. Geometry of the UWB filter-WB antenna configuration.

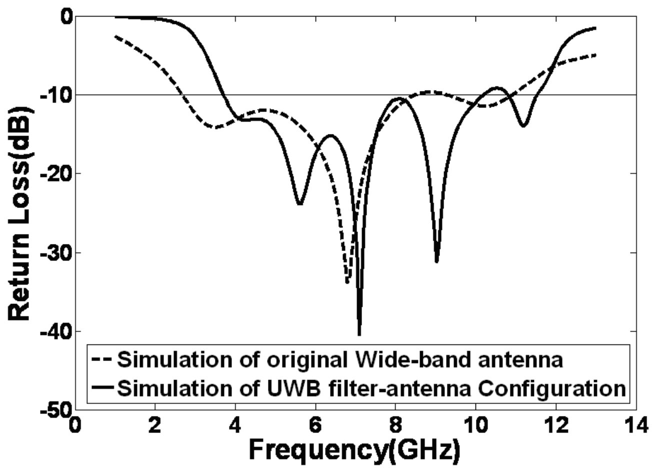


Fig. 8. Return loss of the UWB filter-antenna configuration compared with the original WB antenna.

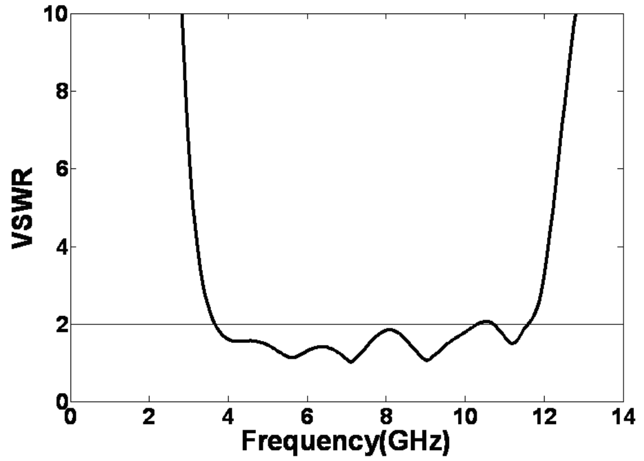


Fig. 9. VSWR vs. frequency of the UWB filter-WB antenna configuration.

Fig.10 shows the E-plane and H-plane radiation pattern of the UWB filter-WB antenna configuration at 4, 5.5,7 and 9 GHz respectively. The H-plane radiation pattern is purely omni-directional at all the simulated frequencies. The E-plane radiation pattern is highly directional along 0^0 and 180^0 respectively at all the simulated frequencies. There is absolutely no change in the shape of E-plane radiation pattern at all the simulated frequencies. Hence the UWB filter-WB antenna configuration exhibits stable and constant radiation pattern at all the frequencies.

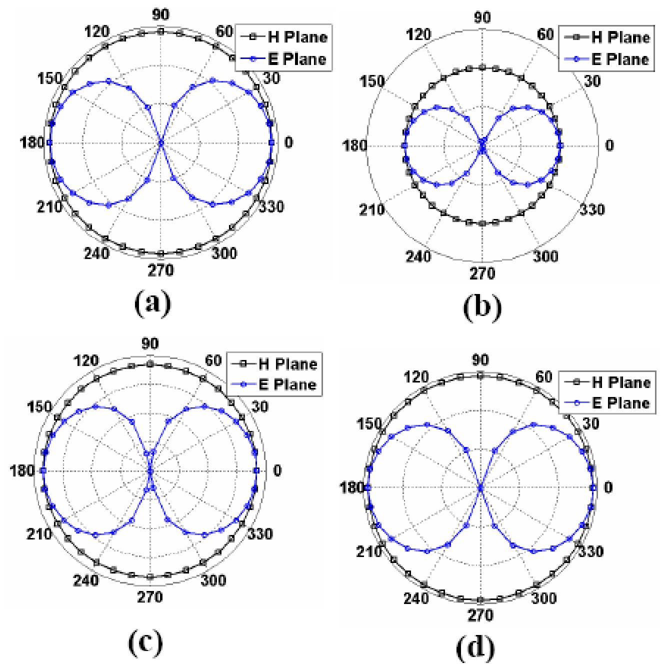


Fig. 10. Simulated E-plane and H-plane radiation patterns of UWB filter-WB antenna configuration at (a) 4 GHz, (b) 5.5 GHz, (c) 7 GHz and (d) 9 GHz.

III. Conclusions

A UWB filter-WB antenna configuration is presented in this paper. An UWB filter plays a vital role in improving the upper stop-band performance of a wide-band monopole antenna by employing the multi-mode resonator (MMR) technique in the UWB filter. By suitable and adequate overlapping of these activated modes of the UWB filter, a wide-band antenna's performance is transformed in to the characteristics of an UWB antenna. The proposed UWB filter-WB antenna configuration is simple and compact in size providing broadband impedance matching, and consistent radiation pattern within the UWB frequency range.

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