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An Integrated Antenna-Filter Co-Design Cascade Approach for UWB Range

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***Abstract*— In this paper, an antenna-filter is designed and simulated using IE3D software for UWB range. A UWB circular monopole microstrip antenna and an UWB filter are cascaded on the same layer to cover ultra wide bandwidth (UWB). Instead of using the traditional 50Ω interfaces, the impedance between the filter and antenna is optimized to improve the performance. The proposed antenna-filter will operate at the center frequency of 6.5GHz.**

Keywords*— *UWB microstrip antenna, UWB microstrip filter, Antenna-filter co-design.

I. Introduction

Since U.S. Federal Communications Commission (FCC) authorized the unlicensed use of UWB (range of 3.1–10.6 GHz) for commercial purposes, the research into ultra-wideband (UWB) technology has risen dramatically [1]. With rapid development of broad operating frequency, one serious challenge is the miniaturization of antenna with broad impedance bandwidth and higher radiation frequency. Miniaturization and low cost are the two most fundamental demands for receiver front-end. One way to miniaturize a front-end receiver is to embed its passive circuitries and interconnects into a package, which is called system-in-package(SIP)[2]. Another way is to integrate required multiple functional circuitries into one device without 50Ω (or 75Ω) constraints, refered to as co-design[3]-[7]. The co-design method can change the structure of the circuit, improve the performance of the circuits, and simplify the connections between different components. A three-dimensional (3D) cavity filter/duplexer and antenna are integrated in [3]. The three-dimensional (3-D) integration approach using multilayer low-temperature co-fired ceramic (LTCC) technologies has emerged as an attractive solution [4] for these systems due to its high level of compactness and mature multilayer fabrication capability. In [5] a Dielectric Resonator Antenna (DRA) is simultaneously used as filtering device named as the DRA filter. A multi-layer, multi-technology antenna/filter device has been proposed as a convenient answer to future system performances requirements [5]. But all these designs were not suitable for the planar applications. The concept of the integration of a pass band filter inside a rectangular patch antenna was demonstrated in [6]. Nevertheless, this kind of structure should be improved in term of radiation efficiency, miniaturization and control of the bandwidth. In [7], a two-pole filter was realized by integrating a filter and an antenna. Jianhong Zuo, Xinwei Chen, Guorui Han, Li Li, and Wenmei Zhang, presented a codesign antenna filter in [8].

Depending upon the concept introduced in[8] a co-design antenna–filter is presented here. A UWB circular monopole antenna is integrated with a UWB filter on the same layer. This co-design approach is used to reduce the structure size. The proposed antenna-filter co-design covers the UWB, i.e. the return loss (S_{11}) <=-10dB for the range 4.06-10.6GHz. the simulated results indicate that the proposed co-design approach can be used to reduce the size and improve the bandwidth.

II. Co-design of Antenna and Filter

The configuration of the antenna-filter co-design is shown in Fig.1. As shown in configuration a UWB circular monopole antenna is cascaded with a UWB filter using 50Ω interface. The UWB filter is obtained by integrating a stepped impedance LPF and quarter-wave short-circuited stubs acting as HPF. Both are embedded on the same substrate, and share the same ground plane. With this configuration, the size of the whole device can significantly reduced.

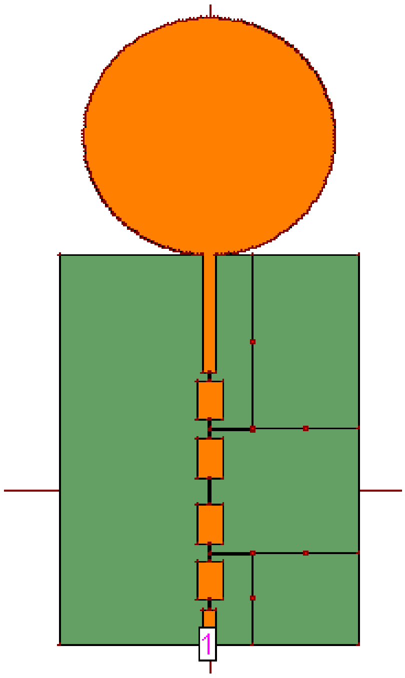

Fig. 1 Configuration of Antenna-Filter Co-design

A. Filter Design[9]

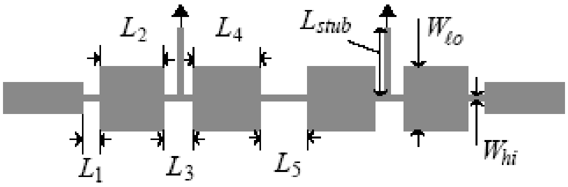

Fig. 2 Configuration of UWB Filter

TABLE I MEASUREMENTS OF UWB FILTER

L_1	L_2	L_3	L_4	L_5	L_{stub}	W_{hi}	W_{lo}
0.85	3.22	1.54	3.39	2.27	3.45	0.23	3.15

The geometry of UWB filter is as shown in Fig. 2. This configuration is obtained by integrating stepped impedance LPF and quarter-wave short-circuited stubs HPF. To cover the entire UWB range cutoff of LPF is selected as 10GHz and the HPF at 3GHz. Then these two designs are embedded to form a composite BPF. This structure of composite BPF is implemented on RT-duroid with the dielectric constant ϵ_r=2.2 and substrate thickness=0.508mm. The structure consist of the high impedance Z_h=130Ω and low impedance Z_l=30Ω microstrip lines. In the composite BPF the locations of quarter wave stubs are optimized to compact the design. The filter is designed to cover the UWB range (3.1GHz-10GHz). Here a Butterworth LPF filter with N=9 is chosen and impedance ratio is selected 130Ω/30Ω. All design measurements for stepped impedance LPF are given in Table 1.

The electrical length of each element is calculated by using following formulas

$$\beta l_i = \frac{CZ_l}{R_0} \quad (1)$$

$$\beta l_i = \frac{LR_0}{Z_h} \quad (2)$$

Where R_0 is the filter load impedance and L and C are normalized element values of the low pass prototype. Then from these electrical lengths physical lengths of each element can be easily calculate.
As the name indicates HPF consists of short-circuited stubs of λ/4 lengths.

B. Antenna Design[11]

The microstrip antenna used here is a circular monopole antenna. Broadband planar monopole antennas have all the advantages of the monopole in terms of their cost, and ease of fabrication besides, yielding very large bandwidths. Fig. 3 shows the geometry of circular monopole antenna. The width of the micro strip feed line is calculated and optimized to achieve 50 Ω impedance. On the other side of the substrate, the conducting ground plane with a length Lg and width Wg. Radius of the patch is calculated using following equation.

$$LF = \frac{7.2}{2.25R+g} \quad (3)$$

Where LF is lower frequencyin GHz, R is radius of the circular patch in cm, and g is substrate thickness in cm.

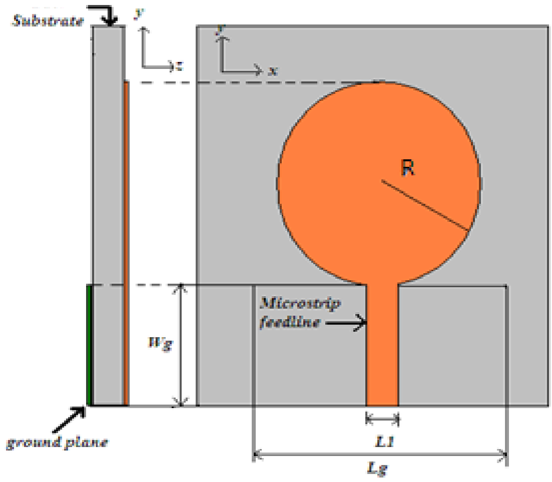

Fig. 3 Geometry of Circular Monopole Antenna

III. SIMULATED RESULTS FOR CO-DESIGN ANTENNA-FILTER

Fig. 4 shows the layout of UWB filter implemented on RT-duroid. Fig. 5 shows the results of UWB filter, which shows clearly that the UWB filter implemented on RT-duroid cover the total UWB range (3.2-10.6GHz).

Fig. 6 shows the return loss S_{11} of the cascaded UWB filter and circular monopole antenna. This result signifies that when

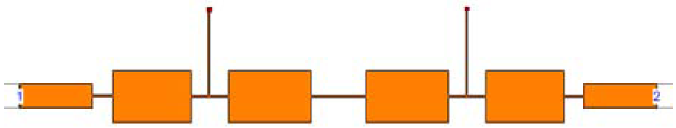

Fig. 4 Layout of UWB Filter

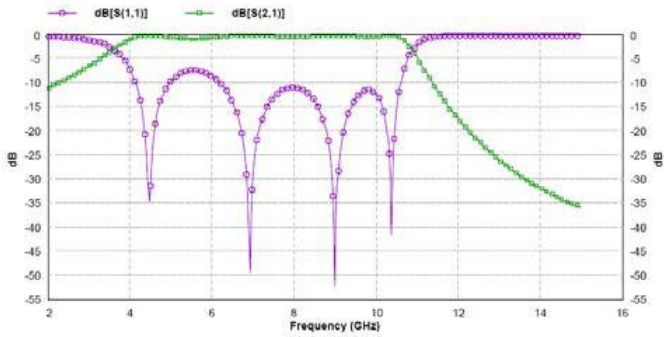

Fig. 5 Return Loss S_{11} And S_{21} Of UWB Filter

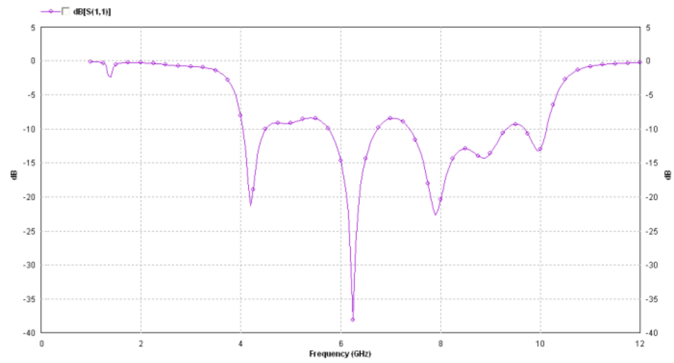

Fig Fig. 6 Return loss S_{11} of Antenna-Filter Co-design

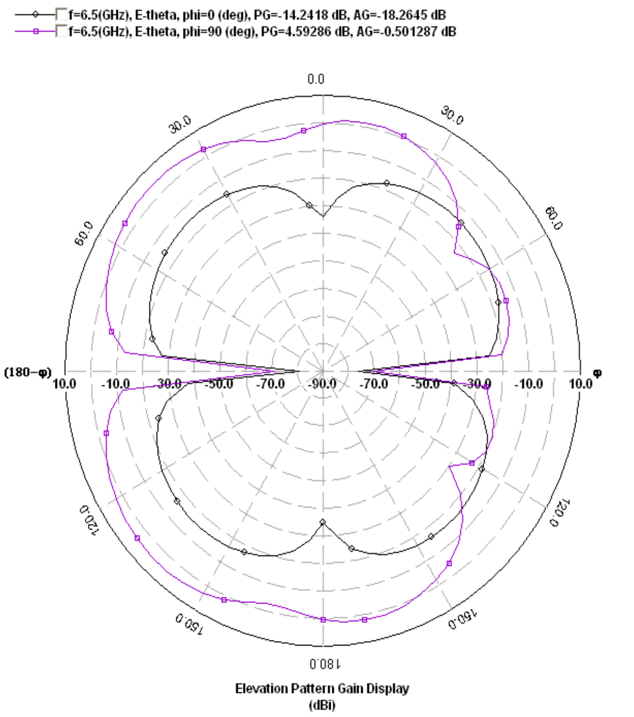

Fig. 7 Radiation pattern for Co-design antenna-filter at centre frequency 6.5GHz.

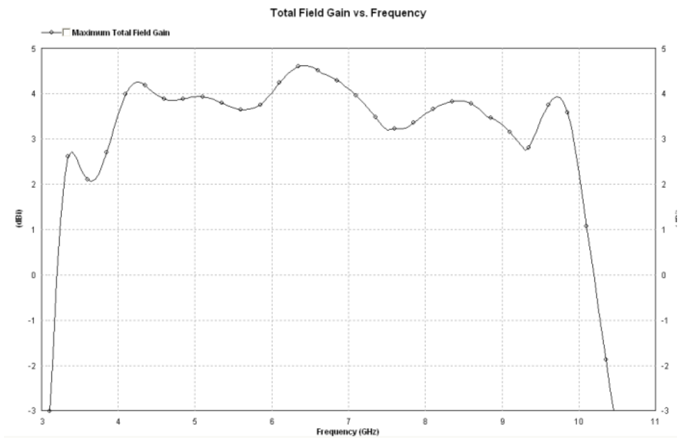

Fig. 8 Gain for co-design antenna-filter

the circular monopole antenna and UWB filter are cascaded the return loss S_{11} is < -10dB and covers the whole UWB range.

Radiation pattern of proposed antenna-filter at the centre frequency 6.5GHz is shown in Fig. 7, whereas Fig. 8 shows the gain Vs frequency plot from 3GHz to 11GHz. It can be seen that the gain of co-design antenna-filter is larger than 2.8dBi in the bandwidth of $|S_{11}| \leq -10$dB, and the peak gain is 4.6dBi.

IV. Conclusion

A co-designed antenna-filter is presented. The simulated results demonstrate the co-design can be used for Ultra Wide Bandwidth (UWB) at a compact size.

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