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

Shweta Sanjay Pawar
M.E.Student: E&TC Department
SEOE Kharghar
Navi Mumbai, India

Sonal Gahankari
Assistant Professor: dept. of E&TC
SCOE Kharghar
Navi Mumbai, India

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, referred 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, Guoru Han, Li Li, and Wennwei Zhang, presented a codesign antenna filter in [8].

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]

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 $\varepsilon_r=2.2$ and substrate thickness=0.508mm. The structure consist of the high impedance $Z_h=130\Omega$ and low impedance $Z_l=30\Omega$ 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 $130\Omega/30\Omega$. All design measurements for stepped impedance LPF are given in Table 1.

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

$$\beta_l = \frac{CZ_l}{R_0}$$ (1)

$$\beta_l = \frac{LR_0}{Z_h}$$ (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 $\lambda/4$ 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 microstrip feed line is calculated and optimized to achieve 50 $\Omega$ impedance. On the other side of the substrate, the conducting ground plane with a length $L_g$ and width $W_g$. Radius of the patch is calculated using following equation.

$$LF = \frac{7.2}{2.25R_gg}$$ (3)

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

<table>
<thead>
<tr>
<th>L1</th>
<th>L2</th>
<th>L3</th>
<th>L4</th>
<th>L stub</th>
<th>W hi</th>
<th>W lo</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.85</td>
<td>3.22</td>
<td>1.54</td>
<td>3.39</td>
<td>2.27</td>
<td>3.45</td>
<td>0.23</td>
</tr>
</tbody>
</table>

TABLE I

MEASUREMENTS OF UWB FILTER

The 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
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.

REFERENCES