Design and Implementation of an Integrated Rf Antenna-Filter Co-Design For Uwb Applications

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Abstract*: In the co-design approach, the patch antenna and hairpin filter is sandwiched with ground plane. The impedance at the interfaces is optimized to improve the performance of the antenna-filter, without restricting it to 50Ω. Impedance optimization is done using via hole. The simulation of S_{11} parameter for patch antenna has operating center frequency of 6.5GHz. The low pass hairpin filter is designed at 6.5GHz and simulated to show S_{11} parameter. Then design of co-design approach is done and simulation of S_{11} parameter for the antenna-filter co-designed approach provides operating frequency range of 6.5 – 6.9GHz which has increased bandwidth capacity, reduction in size and high gain.*

Keywords *- Antenna, co-design, filter, patch, hairpin.*

I. Introduction

Miniaturization and low cost are the two most fundamental demands for RF receiver front-ends. One way to miniaturize an RF front-end is to embed its passive circuitries and interconnects into a package, which is called system-in package (SIP) [2], [3]. Another way is to integrate required multiple functional circuitries into one device without the 50Ω (or 75Ω) constraints, referred to as co-design [4]–[11]. The co-design method can change the structure of the circuit, improve the performance of the circuits, and simplify the connections between different components. For example, the noise figure of a RF antenna-filter-LNA system has been significantly improved with the co-design strategy [4]. In [5] and [6], antennas were co-designed with an amplifier and transceiver to attain higher integration degree. Similarly, an RF device was implemented by integrating three-dimensional (3-D) cavity filters/ duplexers and antennas [7]. In [8], the resonator of an antenna also acted as an element of filter. In [9] and [10], a coplanar antenna-filter was co-designed. In [11], a two-pole filter was realized by integrating a filter and an antenna. In this letter, a co-designed antenna-filter is presented. A microstrip patch antenna is layered on the top of a hairpin filter, and they share the same ground plane. A via hole is implemented to connect the antenna and the filter.

The impedance at the interfaces is optimized to improve the performance of the antenna-filter, without restricting it to 50Ω. The proposed antenna-filter operates in the frequency band 6.5–6.9 GHz, and the bandwidth for |S11|<=-10dB is increased when compared with traditional cascade connection of antenna-filter. The simulated results indicate that the proposed co-design approach can be used to reduce the size, improve the bandwidth, and increase the gain.

II. CO-DESIGN OF ANTENNA AND FILTER

The configurations of the traditional and the co-designed antenna-filters are shown in Fig. 1. Unlike the traditional antenna-filter in which the components are cascaded with 50Ω interfaces [Fig. 1(b)], co-designed antenna-filter is assembled vertically and connected using a metalized via hole, as shown in Fig. 1(a). Also, the ground plane is sandwiched in the middle and shared by both the antenna and the filter. With this configuration, the size of the whole device can be significantly reduced. In order to avoid the electromagnetic (EM) interference between the antenna and the filter, they are arranged to have the parallel current. Furthermore, the impedance at the interfaces is optimized by adjusting the location and dimension of the via hole to attain better performance.

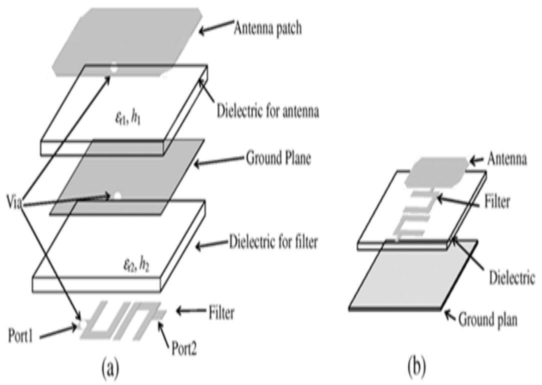

Fig. 1 Antenna-filter with (a) co-design version, (b) traditional version.

III. FILTER DESIGN

Fig. 2 shows the configuration of hairpin filter. The filter is designed to have a fractional bandwidth (FBW) of 6% at 6.5 GHz. We choose a two-pole butterworth low-pass filter prototype. The low-pass prototype parameters include g_0=1, g_1=1.4142, g_2=1.4142, and g_3=1[11]. Based on the low-pass parameters, the design parameters of the band-pass can be calculated by

$$Q_{e1} = \frac{g_0 g_1}{FBW};\ Q_{en} = \frac{g_n g_{n+1}}{FBW}$$

$$M_{i,i+1} = \frac{FBW}{\sqrt{g_i g_{i+1}}}\ for\ i = 0\ to\ n-1$$

where Q_{e1} and Q_{e2} are the external quality factors of the resonators at the input and output port, and $M_{i,i+1}$ are the coupling coefficients between the ith and (i+1)th resonators. For this design, we have Q_{e1}=23.57, Q_{e2}=23.57, and $M_{1,2}$=0.042.

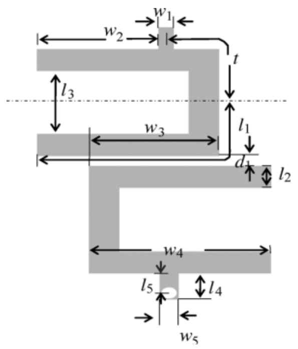

Fig. 2. The configuration of the hairpin filter.

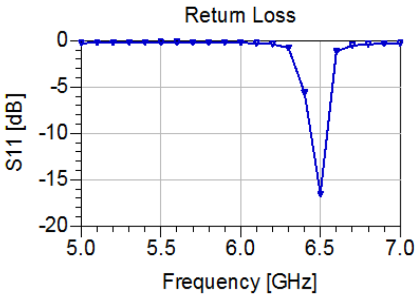

Fig. 3. S11 parameters for the filter.

IV. Antenna Design

The structure of the microstrip rectangular patch antenna with four sharp cuts is shown in Fig. 4. The antenna is designed to operate at the center frequency of 6.5 GHz, and the sharp cuts are used to improve the bandwidth. The optimized design parameters for the antenna with 50Ω interface impedance are used accordingly to provide better bandwidth. The simulated results are shown in Fig. 5.

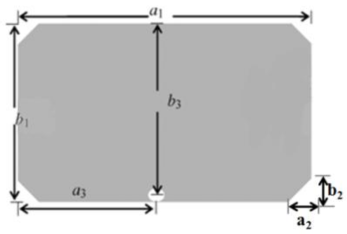

Fig. 4. The configuration of the microstrip patch antenna with four sharp cuts.

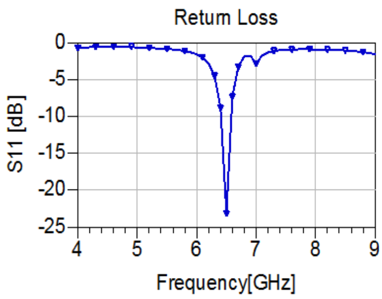

Fig. 5. S11 parameters for the antenna.

V. Simulated Results For Co-Design Antenna-Filter

With the designs of antenna and filter, the co-designed antenna-filter [shown in Fig. 1(a)] is implemented. We also optimize the location and dimension of the via hole, the coupling between via and ground plane, and the impedance at the interface of the antenna and the filter. Design of co-design approach is done and simulation of S_{11} parameter for the antenna-filter co-designed approach provides operating frequency range of 6.5 – 6.9GHz. Fig. 6 shows the simulated parameters for the co-designed antenna-filters. Obviously, due to the better coupling between the antenna and the filter, as well as via hole and ground plane, two resonant frequencies appear that show the co-designed version has a broader bandwidth, which increases bandwidth capacity.

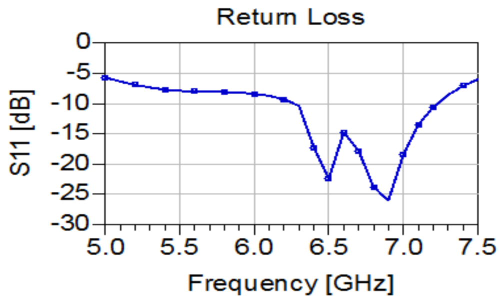

Fig.6 Simulated S11 parameter for the co-design approach.

VI. Conclusion

A co-designed antenna-filter is presented. The simulated results demonstrate the co-design can be used to improve the bandwidth, the gain of the antenna and also it can reduce the size of device. Since co-designed antenna-filter design provides broader bandwidth, more number of users can use channel for wireless communications.

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