Compact Ultra-Wideband Microstrip Bandpass Filter Using SIR Approach

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This article describes a planar filter topology that achieves two transmission zeros in a compact structure, implemented on an alumina substrate for low loss performance

Planar band pass filters (BPF) with low insertion loss, compact size, high selectivity, wider bandwidth and good stop band rejection are required for the next generation mobile and satellite communication systems. In the case of the planar filter solution, electrical performance with regard to both out-of-band rejection and in-band transmission losses, as well as cost, reliability and dimensions have to be considered. By comparison, waveguide filters are bulkier, costlier and have narrow bandwidth.

UWB filters covering the range of 3.1 to 10.6 GHz require high order designs that lead to high insertion loss and large circuit size for communication applications. Also, flat group delay over the entire pass band response needs to be ensured for distortion-free transmission. Traditional filter design approaches fail to meet these requirements due to tight coupling and uncontrolled non-linear frequency dispersion over the wide bandwidth of interest.

The UWB BPF realized using lossy material results in high insertion loss of 6.7 dB [1]. Filter configurations using cascaded ring resonator sections with open stubs have bandwidth limitations compared to the desired requirements [2]. Coupled lines using backside aperture on ground plane for enhancing coupling and inter-digital coupled lines with multimode resonators were also used for realizing the ultra-wideband performance [3, 4]. Typically, these structures require tight fabrication tolerances and are sensitive to the proximity affect of the metal enclosures when packaged with the RF integrated circuits. Electromagnetic band gap structures and defected ground plane structures [5] are also reported but can be difficult to integrate into a planar system.

Analysis and Design

Development of a UWB filter is an involved task and poses many challenges. The requirement of 110% functional bandwidth makes the widely used techniques of BPF design inapplicable. The required flat group delay over the large bandwidth and the FCC limit at the low frequency end also pose the design challenges. A simple topology is proposed here that uses an open circuited quarter-wavelength resonator and a section of quarter wavelength coupled lines instead of anti-parallel coupled lines as proposed by Hsieh and Wang [4]. The shunt open circuited resonator plays the role of series L-C resonator. So the total assembly can be viewed as the two shorted stubs coupled together with the transmission line. This structure generates a single transmission zero (TZ). To increase the selectivity of the filter, tapped quarter wavelength stepped-impedance resonators (SIR) are incorporated that generate multiple transmission zeros. The approach is cost effective and gives the desired performance over the bandwidth of interest.

Resonance Condition of an Open-Ended $\lambda g/4$ Stepped Impedance Resonator

The short circuit stub produces a pair of zeros at $f = 0$ and $f = 2f_0$, where f_0 is the mid-band frequency of the filter. In order to get transmission zeros at other desired frequen-

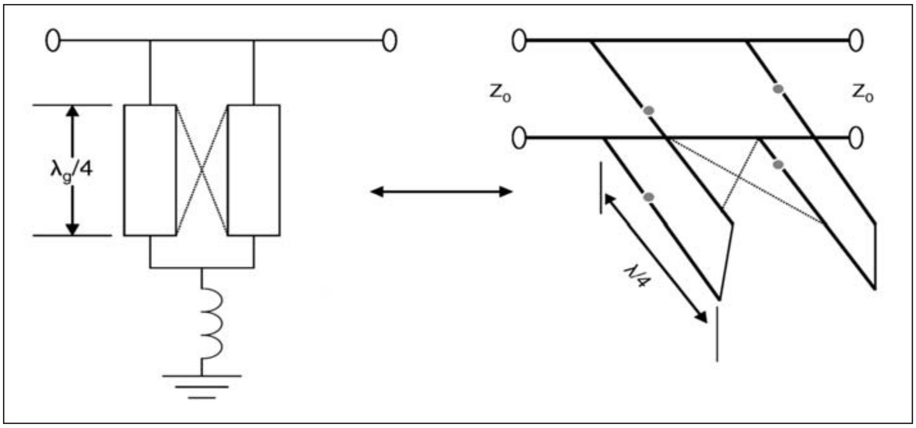

Figure 1 · Parallel coupled lines with short circuited stubs analogy.

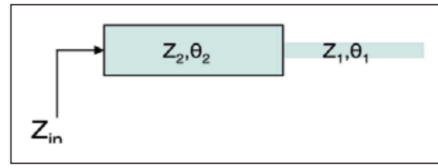

Figure 2 · Basic structure of the open-ended SIR.

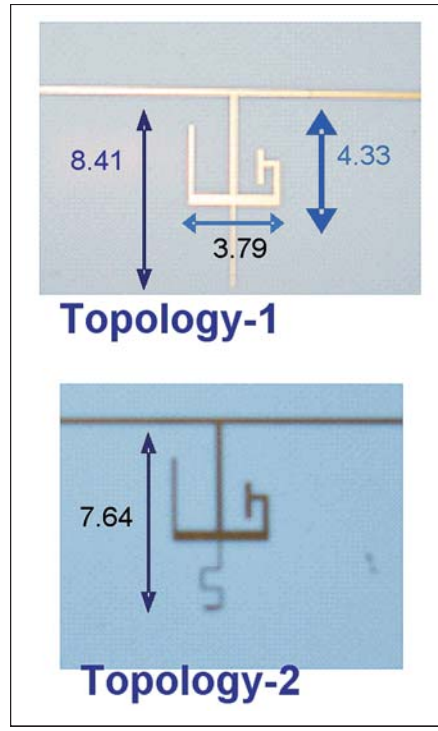

Figure 3 · UWB filter topologies. Topology 2 has a meandered output stub to reduce length. (Dimensions in mm.)

cies, the short-circuited stub is replaced with two section open-ended stubs. The two section open circuit can produce a pair of transmission zeros, one in the low stop band and other in the upper stop band. However, the size of the circuit increases significantly in this approach. This is circumvented by coupling the anti-parallel lines together as shown in Figure 1.

The impedance of the SIR resonator shown in Figure 2 can be derived using the transmission line theory, as follows:

$$Z_{in} = jZ_2 \frac{Z_2 \tan\theta - Z_1 \cot\theta_1}{Z_2 + Z_1 \tan\theta_2 \cot\theta_1} \quad (1)$$

where Z_1 and Z_2 are the characteristics impedances of the two cascaded sections and θ_1 and θ_2 are the corresponding electrical lengths ($\theta_1 + \theta_2 = \Pi$). Let $Z_{in} = 0$, so determining the resonance frequency of the SIR is given as

$$\tan\theta_1 = A\cot\theta_2 \quad (2)$$

where A is the impedance ratio of the SIR defined as

$$A = Z_1 / Z_2 \quad (3)$$

The resonance condition of the SIR can be adjusted by changing the width and length of Z_1 and Z_2. As the frequency deviation, f / f_0 directly depends on A, frequency tuning is facilitated by adjusting A. In the present case, the Z_1 is taken as 54/70 ohms and Z_2 is taken as 39 ohms to achieve UWB frequency range.

Fabrication and Measured Performance

The realized UWB filter uses the microstrip configuration on an alumina substrate (ε_r = 9.9, thickness = 0.25 mm). The frequency response of the filter is simulated by using the EM simulation of ADS and Linmic 6.3. The size of the filter assembly is reduced from 8.41 × 3.8 mm to 7.64 × 3.8 mm by meandering the output stub as shown in Figure 3.

The measurements carried out using PNA (E8361A series, 10 MHz-67 GHz) from Agilent technologies showed good agreement with the simulated responses for both the filter assemblies as shown in Figure 4.

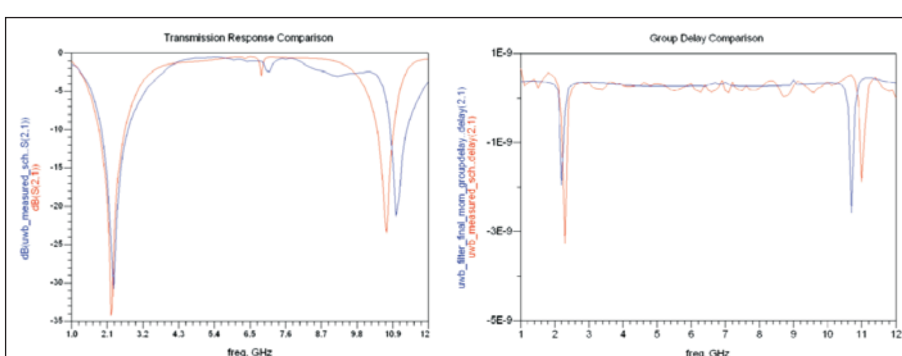

Figure 4 · Comparison of the simulated and measured characteristics.

These filters show insertion loss <1 dB including connector losses and flat group delay of <1 ns in the specified band. The slight deviation between the measured and simulated performance at the higher frequencies is mainly due to the imprecise calibration and fabrication tolerances of the filter.

Additional filter sections using this or other transmission zero techniques can be used to improve stopband performance.

Conclusion

Compact UWB filters using the shorted parallel coupled lines have been demonstrated in this paper. The performance measurements carried out showed good agreement with the simulations. The SIR approach adapted resulted in considerable size reduction and good selectivity compared to other reported topologies. The simple geometry, compact size and good RF performance, ease of integration and compatibility with MMICs makes it an attractive choice for use in wireless and communication systems.

Author Information

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