

Ultra-Wideband (UWB) Bandpass Filter using Optimum Short Circuited Stub

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Abstract— In this paper, the description of Ultra Wide Band Bandpass filter design techniques and to show the different aspects of the design technique used. This paper presents a ultrawideband (UWB) bandpass filter using stepped impedance stub loaded resonator and the Multiple-mode resonator. The resonators is so formed to allow its five resonant frequencies in the UWB passband, which extends from 3.1 GHz to 10.6 GHz. SISLR is found to have the advantage of providing more degrees of freedom to adjust the resonant frequencies. The MMR In the design, the first three resonant frequencies of the MMR are correctly in step to be located equally within the band. Then, the parallel-coupled lines at the two sides are parallelly stretched so as to raise the frequency combination degree with the coupling crest near the center of the UWB. The simulated results showing good wideband filtering performance with sharp rejection outside the passband.

Keywords— Ultra-Wideband(UWB), Bandpass Filter, Stepped Impedance Stub Loaded Resonator(SISLR), Multiple Mode Resonator(MMR).

I. INTRODUCTION

ULTRA-WIDEBAND (UWB) technology is a very promising solution for high-resolution radar, high data-rate communication, and power-efficient RF tracking and situating systems. It offers a number of captivating features such as low intricacy and low cost, carrier-free transmission, and vigorous resistance to astringent multipath and jamming, as well as passive interferences. Since the Federal Communications Commission (FCC) first sanctioned the utilization of the unlicensed operation band from 3.1 to 10.6 GHz for commercial applications [1], UWB systems have several advantages: They have a bandwidth of 7.5 GHz, which can fortify a high transmission data rate (up to 500 Mb/s); they have low energy density over a wideband spectrum engendered by short pulse excitation, which not only makes the UWB system arduous to intercept but additionally minimizes interference by other radio systems; and they have astronomically low transmission energy (less than 1.0 mW), which is auspicious for hand-held radio systems. Scholarly researchers and industry engineers have been passionate in the intend of UWB filters. The technical requisites for UWB filters are low insertion loss, flat in-band group delay, and high out-of-band selectivity. There are different design techniques for designing the Ultra Wideband (UWB) Band pass filter. These techniques can be classified as multiple-mode-resonator (MMR) techniques, hybrid

microstrip/coplanar-waveguide (CPW) techniques, optimum short-circuited stubs techniques ,electronic-band-gap (EBG) structure loaded techniques ,cascaded high-/low-pass filters techniques and multilayer broadside-coupled techniques in association with packaging materials such as liquid crystal polymers (LCP) and low-temperature cofired ceramics (LTCC)[2]. The MMR technique aims to arrange multiple resonant modes in a fused resonating arrangement to design a UWB filter. The pristine design utilizes a homogeneous physical topology as the stepped-impedance resonator (SIR) structure.[2] Compact UWB bandpass filters can be designed by utilizing hybrid microstrip and CPW techniques, where the microstrip-to-CPW transitions and CPW shorted stubs were adopted as quasilumped-circuit elements for realizing a high-pass filter. By introducing a cross-coupled capacitance between I/O ports of this high-pass filter, and by congruously designing the coupled open circuited stubs, a compact UWB bandpass filter can be designed with two transmission zeros located proximate to the passband edges[2]. EBG-loaded structures can be used to propose UWB bandpass filters with improved upper stopband performance. The EBG structure is implemented using capacitive-loaded transmission lines[2]. In the Cascaded high-/low-pass filters techniques UWB filter developed by cascading a broadband bandpass filter and a broadband bandstop filter[2]. The FCC-defined UWB indoor limit covers some frequency bands utilized by subsisting radio communication systems, such as the 5 GHz wireless local access network band and 8 GHz satellite communications systems. As a result, some notching bands are desired in the design of UWB bandpass filters to reduce interference from those radio communication systems[2]. Recently, several methods for designing UWB BPFs have been proposed. In [2], the UWB BPF comprised a cascade of low and high pass structures. The concept of multimode resonators (MMR) used for UWB BPF was initially proposed in [3], where the first three resonant modes of the MMR were utilized to design the filter. In [4], pseudo-interdigital stepped impedance resonators (PI-SIRs) were proposed to develop a UWB BPF. In [7], MMR with three pairs of the circular impedance-stepped stubs was developed to suppress harmonic response and obtain the wide upper-stopband. All the above-mentioned SIR-type UWB BPFs showed good passband performance except the

stopbands suffer the slow increase in attenuation and there are no longer enough degrees of freedom for effective control of resonant frequencies. Compared with traditional SIR and stub-loaded resonator (SLR) in [3], [5], [6], [7], this resonator has more degrees of adjusting freedom to control its resonant frequencies, which results in conveniently relocating the required resonant modes within the UWB band. By feeding the proposed SISLR with two aperture-backed parallel-coupled feed lines at the two sides, a predicted UWB BPF is then constituted to exhibit very good in-band performance and high skirt selectivity. In [14] and [15], a microstrip ring filter with the dual stopbands below 3.1GHz and above 10.6GHz was constructed to make up the most initial UWB filter. However, this filter in fact has many problematic issues, such as unexpected passbands below 3.1GHz, narrow lower/upper stopbands, large size, complexity in configuration, and so on. Later on, an alternative UWB filter was presented in [16], which was constructed by mounting the microstrip line in the lossy composite substrate so as to attenuate the signals at high frequencies. The reported performances in [16] showed that this filter had an insertion loss higher than 6.0dB in the UWB passband and the return loss as high as 4.5dB in the upper stopband above 10.6GHz. In this letter, we present a novel compact UWB bandpass filter using a microstrip-line multiple-mode resonator (MMR) [17]–[18][19]. The MMR here is to be properly modified in configuration so as to reallocate its first three resonant modes close to the lower-end, center, and upper-end of the targeted UWB passband. Also, the coupling degree of the input/output parallel-coupled line sections is largely raised, good UWB passband performances are realized and demonstrated in theory. Later on, all the predicted parameters, i.e., insertion/return loss and group delay, are experimentally verified in a wide frequency including the UWB passband. Filter based on tri-mode electromagnetic bandgap (EBG) embedded MMR is reported to widen the upper stopband [20]. The stub-loaded MMR with four modes within UWB band was presented to improve the upper stop-band [21], [22]. Recently, UWB filters using quintuple-mode stub-loaded MMRs were presented. By introducing two side stubs to the tri-mode stepped-impedance MMR, two additional modes could be located within UWB band, and by using the open stub and short stub at the center, the even modes could be tuned while the odd mode is fixed, and the selectivity is also improved [23]. In [23], the stepped-impedance stub loaded resonator was used, and the designed five-mode UWB filter showed good filtering performance and sharp selectivity, but suffered from large size.

II. STEP IMPEDANCE SLR

The Stepped Impedance Resonator (SIR) is the TEM or Quasi-TEM mode resonator composed of more than two transmission line with different characteristics impedance. It consists of a traditional SIR with the

characteristic admittance Y_3 , Y_4 and electrical lengths $2\theta_3$ & θ_4 , which is tapped-connected to a stepped-impedance stub (SIS) in the center. The SIS is also made of transmission-line sections of characteristic admittance $2Y_1$, $2Y_2$ and electrical lengths θ_1 & θ_2 . Since the SISLR is symmetrical in structure, odd- and even-mode analysis can be adopted to characterize it. For the odd mode the equivalent circuit can be shown as in figure 3 and for even mode the circuit can be shown in figure 4. The substrate with dielectric constant 2.55 (Rogger RO4700JXRTM) with a thickness of 0.8 mm.

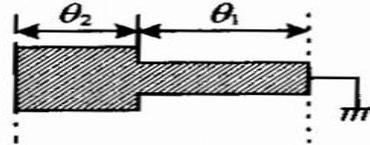


Fig 1: Basic Structure of SIR (Quarter Wavelength type)

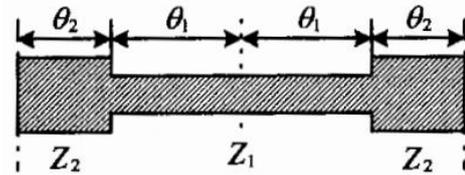


Fig 2: Basic Structure of SIR (Half Wavelength type)

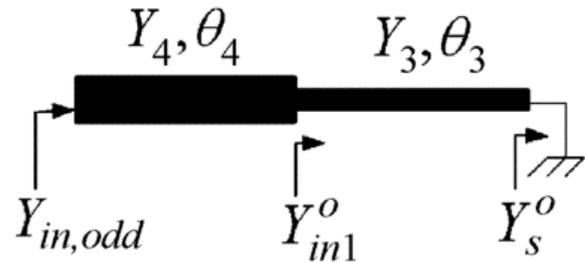


Fig 3: Basic structure SISLR, odd-mode equivalent circuit.

$$\left(Y_{in,odd} = \frac{Y_4 (Y_{in1}^o + jY_4 \tan \theta_4)}{(Y_4 + jY_{in1}^o \tan \theta_4)} \right) \quad (1)$$

$$Y_{in1}^o = -jY_3 \cot \theta_3 \quad (2)$$

Resonance condition is $Y_{in,odd} = 0$

The equation (1) can be deduced as

$$k_4 \tan \theta_4 \tan \theta_3 = 1 \quad (4)$$

$$k_4 = \frac{Y_4}{Y_3} \quad (5)$$

$$\alpha_1 = \frac{\theta_3}{\theta_3 + \theta_4} \quad (6)$$

$$\theta_4 = \frac{\theta_3(1 - \alpha_1)}{\alpha_1} \quad (7)$$

Put equation (6) in equation (4)

$$k_4 \tan \theta_3 - \cot \left(\frac{\theta_3(1 - \alpha_1)}{\alpha_1} \right) = 0 \quad (8)$$

Equation (8) corresponds to the odd mode resonance are dependent on α_1 and k_4 . The ratios of first two odd mode resonance frequency can be determine by length ratio and admittance ratio.

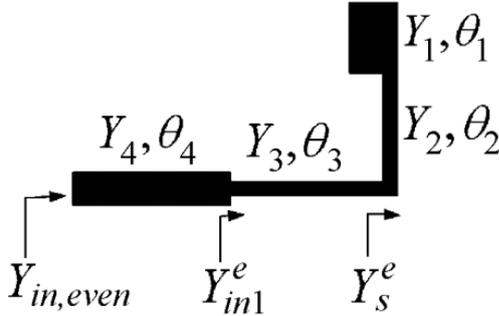


Fig 4: Basic structure of SISLR ,even-mode equivalent circuit.

For even mode, the input admittance is given as,

$$\left(Y_{in,even} = \frac{Y_4 (Y_{in1}^e + jY_4 \tan \theta_4)}{(Y_4 + jY_{in1}^e \tan \theta_4)} \right) \quad (9)$$

Where

$$Y_{in1}^e = \frac{Y_3 (Y_s^e + jY_3 \tan \theta_3)}{(Y_3 + jY_s^e \tan \theta_3)} \quad (10)$$

$$Y_s^e = \frac{Y_2 (jY_1 \tan \theta_1 + jY_2 \tan \theta_2)}{(Y_2 + j(Y_1 \tan \theta_1) \tan \theta_2)} \quad (11)$$

where

$$k_1 = \frac{Y_1}{Y_2}$$

And $Y_1 = Y_2$ at resonance condition $Y_{in,even} = 0$

$$k_1 \tan \theta_1 = \frac{\tan(\theta_3 + \theta_1) + k_4 \tan \theta_4}{k_4 \tan \theta_4 \tan(\theta_3 + \theta_1) - 1} \quad (12)$$

$$\alpha_2 = \frac{\theta_1}{\theta_1 + \theta_2 + \theta_3 + \theta_4} \quad (13)$$

$$\alpha_1 = \frac{\theta_1}{\theta_T} \quad (14)$$

$Y_3 = Y_4$ equation (2) reduced as

$$k_1 \tan (\alpha_2 \theta_T) + [\tan (1 - \alpha_2) \theta_T] = 0 \quad (15)$$

The dielectric constant for the substrate used is 2.55 and the thickness of 0.8 mm.UWB passband is satisfactorily realized with two transmission zeros on both the side of passband. The band of 3.1GHz to 10.6 GHz is obtained. The return loss lower than -10dB is getting.

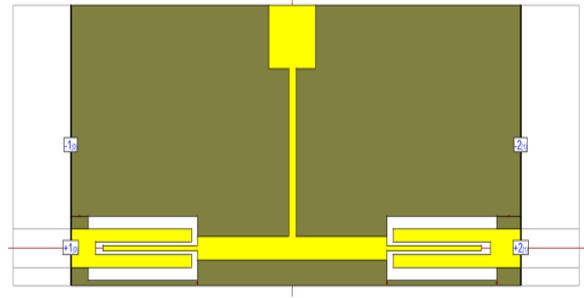


Fig 5: Stepped Impedance Stub Loaded Resonator.

III. MULTIPLE MODE RESONATOR

The MMR consists of one half-wavelength low-impedance line section in the center and two identical (Quarter wavelength) high-impedance line sections at the two sides. With respect to its configuration, this proposed MMR may be categorized as a so-called stepped-impedance resonator (SIR). As a nonuniform transmission line resonator, the SIR was proposed in [24] to enlarge the frequency spacing between the first and second-order resonant modes so as to effectively widen the upper stopband above the leading passband of a bandpass filter. In this aspect, only the first-order resonant mode is really utilize in the filter design, whereas the second-order and the other resonant modes lead to the appearance of multiple-band spurious harmonics in the designed filter. However, in our MMR, all the first three resonant modes are taken into account together.

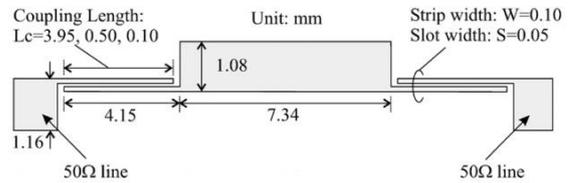


Fig 6: Basic Multiple-Mode Resonator.

$$Y_s^e = jY_2 \frac{2(k \tan \theta_1 + \tan \theta_2)(k - \tan \theta_1 \tan \theta_2)}{k(1 - \tan^2 \theta_1)(1 - \tan^2 \theta_2) - 2(1 - k^2)} \tan \theta_1 \tan \theta_2 \quad (16)$$

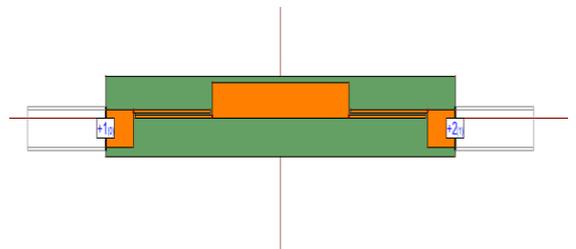


Fig 7: Multiple-Mode Resonator.

IV. RESULTS

The simulator used is IE3D electromagnetic simulator for designing the structure. IE3D is the full wave simulation and optimization package for 3D and planar microwave circuits. It solves Maxwell's equations in an integral form.

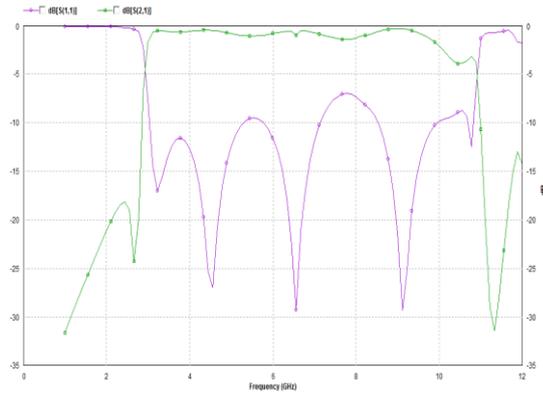


Fig 8: Simulation Results of Stepped Impedance Stub Loaded Resonator.

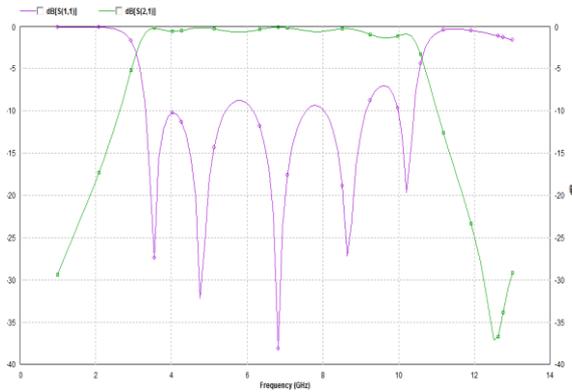


Fig 9: Simulation Results of Multiple Mode Resonator.

As seen from Fig - the insertion loss (transmission coefficient) S_{21} is minimum in the UWB passband the S_{21} is almost equal to zero. The return loss S_{11} is less than -10 db within the band. The relationship between input port and output ports (or terminals) in an electrical system can be described by S-parameters. In the simulation, the normally used parameter in regards to filter is S_{11} . The S_{11} shows that how much power is reflected from the antenna, therefore it is known as the reflection coefficient (or return loss).

V.CONCLUSIONS

In this paper, the Stepped Impedance Stub Loaded Resonator and the Multiple Mode Resonator is synthesized and analyzed by utilizing the IE3D simulator. SISLR can provide more degrees of liberation to control the resonant frequencies, making the resonator suitable for UWB BPF application. Predicated on the SISLR, a design of the UWB BPF is investigated to demonstrate high UWB bandpass performance. A MMR is introducing quarter-wavelength parallel coupled lines in the input and output ports, a UWB passband with five transmission poles is achieve as illustrate. Within the UWB passband, the precise insertion and return losses are lower than 2.0 dB and higher than 10.0 dB, respectively, while the group delay varies in between 0.20 and 0.43 ns.. Otherwise, two transmission zeros gievn by the stepped-impedance stub are at the lower and upper cutoff frequencies, resulting in a sharp

passband performance. The simulated and quantified results show low passband insertion loss, good return loss and sharp selectivity.

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