Ultra Wideband Microstrip Bandpass Filter with Mitred Tee Junction

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Abstract—*A compact wideband bandpass filter is proposed in this paper by means of short-circuited-stub loaded ring resonator and tapped feed lines. Filter with center frequency at 3.23 GHz and fractional bandwidth of 86.1% is designed. Some suggestions for improvement have been made in this paper particularly pertaining to the bend dimensions which will lead to a more compact and finer tuning of the already available filter characteristics.*

Keywords— *(SCSL-RR),UWB, short-circuited stubs, UI-RR,Mitred.*

I. INTRODUCTION

Ultra-wideband communications is fundamentally different from all other communication techniques due to employing extremely short-time pulses to communicate between transmitters and receivers. The short duration of UWB pulses generates very wide bandwidth (GHz) in frequency domain.

UWB is not a new technology. It was first used by Guglielmo Marconi in 1901 for transmitting the Morse code sequences across the Atlantic ocean using spark gap radio transmitters. However, the benefit of a large bandwidth and the capability of implementing multi-user systems provided by electromagnetic pulses were never considered at that time.

UWB communications different from narrowband communications because a continuous waveform has well-defined signal energy in a narrow frequency band that makes it vulnerable to intercept and detect. UWB systems use carrier-less, short duration pulses with very low duty cycle (<0.5%) for transmission and reception of the information. The energy of such signals is spread over a very wide range of frequencies (GHz) thus UWB signals very difficult to detect and intercept.

As defined by the Federal Communications Commission's (FCC) First Report and Order, UWB signals must have bandwidths of greater than 500 MHz or a fractional bandwidth larger than 20% at all times of transmission. Fractional bandwidth is the ratio of a signal's actual bandwidth to its center frequency.

Since UWB signals energy is spread over a very wide range of frequencies, it has very low power spectral density, meaning that each frequency has a very low power. The PSD of a UWB signal is below the noise floor of a typical narrowband receiver, therefore UWB signals look like noise to radio services.

It is difficult to detect UWB signals because of the low duty cycle, UWB signals have very low transmission average power, therefore an eavesdropper has to be very close to the transmitter (about 1 meter) to be able to detect the transmitted information. In addition, UWB pulses are time modulated with codes unique to the transmitter/receiver pairs. This time modulation adds more security to UWB transmission, since detecting picosecond pulses without the prior knowledge of their time of arrival information is next to impossible.

UWB signals penetrate through walls Unlike narrowband technology, UWB systems can penetrate effectively through different materials. The reason is that the low frequencies covered in the broad range of UWB frequency spectrum have long wavelengths and allow UWB signals to penetrate through different materials including walls.

Time synchronization a challenge in UWB communications since sampling and synchronization of nanosecond pulses pose a major limitation in the design of UWB systems. In order to sample these narrow pulses, very fast analog to digital converters (ADCs) are needed and the strict power limitations and short pulse duration make the performance of UWB systems highly sensitive to timing errors such as jitter and drift. This can become a major issue in the success of pulse position modulation (PPM) receivers that rely on detecting the exact position of the received signal.

Ultra wideband systems are mostly used for military applications such as radar and through applications. Thus ultra-wideband systems such as through wall applications operate in the lower region of the frequency spectrum. Since these frequencies have larger wavelengths these signals can penetrate through walls.

II. PRINCIPLE OF SCSL-RR BANDPASS FILTERS

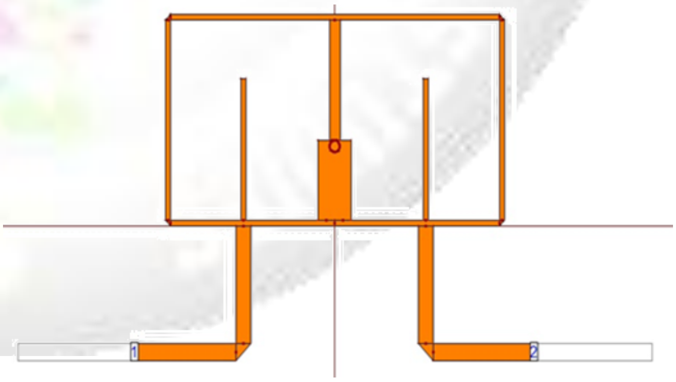

Fig. 1: SCSL-RR

Figure 1 depicts the schematic of the proposed microstrip short-circuited-stub loaded ring resonator (SCSL-RR). In my design, the filter is constructed on the substrate with a relative permittivity er" = 10.8 and a thickness h = 0.635 mm. Initially, the sizes of the two short-circuited stubs are kept to be fixed. When the short-circuited stubs are properly installed on the Y -symmetrical plane of the ring resonator, an additional resonant mode can be produced at frequency lower than the 1st resonant mode of the uniform impedance ring resonator (UI-RR).

Meanwhile, another resonant mode resonating at frequency higher than the 1st resonant mode of the UI-RR can be produced .Thus it is expected that the first three resonant modes can be used to make up a wide passband.

From IE3D simulation results we see the resonant frequencies of the 1st and the 3rd resonant modes can be tuned by the sizes of the short-circuited stubs. As the lengths of the stubs increase from 2.4 to 3.4mm under the fixed stubs' widths of 0.4 mm, the 1st and the 3rd resonant frequencies move down to lower frequency band simultaneously while the 2nd resonant frequencies remain almost unaffected. Similarly, the 1st and the 3rd resonant frequencies move up to higher frequency band simultaneously as the widths of the stubs increase from 0.4 to 0.8mm when the length of the stubs is fixed as 3.4 mm. Hence, it provides us with a degree of freedom to tune the 1st and the 3rd resonant frequencies. However, it is difficult to realize a wideband BPF with controllable bandwidth since the 1st and the 3rd resonant frequencies move down or up simultaneously as the sizes of the two short-circuited stubs are set to be the same.

In order to control the bandwidth effectively, the sizes of the two short-circuited stubs are no longer kept to be the same. The sizes of one stub remain unchanged (Lt1 = 3.4 mm, Wt1 = 0.4 mm), while the length (Lt2) and width (Wt2) of another stub are changed from 3.4 to 2.4mm and 0.4 to 1.4 mm, respectively. As shown in results, the 3rd resonant frequency can be tremendously shifted up, while the first one slightly moves up. At the same time, the second resonant frequency is still kept unchanged almost. It hints that the bandwidths of the comprised passband can be determined or controlled by properly setting the sizes of the two short-circuited stubs to be unequal. In order to design a wideband BPF with flat in-band response, tight coupling need to be realized at both feeder-line ports. In our design, the tapped feeding structure is implemented due to its advantages such as enhanced coupling strength and easy fabrication. Following the above description, we can understand that the feeding position should be fixed in order to excite the 3rd resonant mode at a specified frequency. In this way, the desired coupling strength between the resonator and feed lines can be not easily realized in a wide band covering the first three resonant frequencies. To facilitate this problem the two identical open-circuited stubs are introduced in connection to the ring resonator at the same locations of the two feeding lines as shown in the simulation results. The coupling degree of concern can be now controlled by tuning the length of these two open-circuited stubs. As illustrated in simulation results, the magnitude of /S21/ decreases with the length of the open-circuited stub from 0 to 2.0mm under the condition that other parameters are fixed, i.e., Lt1 = 3.4 mm,Wt1 = 0.4 mm, Lt2 = 3.4 mm, Wt2 = 1.4 mm, indicating that the coupling becomes weak gradually[1].

III. PROPOSED MODIFICATION AND CHANGES

The modification is proposed to the schemes above to finely tune filter characteristics.

A. *Optimum mitre by Douville and James*

In order to build a complete circuit in microstrip, it is often necessary for the path of a strip to turn through a large angle.

An abrupt 90° bend in a microstrip will cause a significant portion of the signal on the strip to be reflected back towards its source, with only part of the signal transmitted on around the bend. One means of effecting a low-reflection bend, is to curve the path of the strip in an arc of radius at least 3 times the strip-width. However, a far more common technique, and one which consumes a smaller area of substrate, is to use a mitred bend.

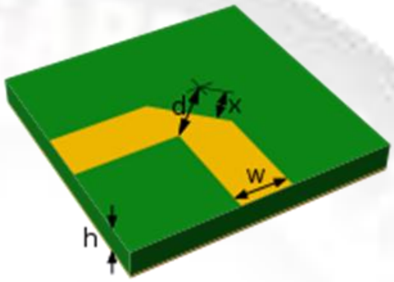

Fig. 2:MItred band

Microstrip 90° mitred bend. The percentage mitre is 100x/d.To a first approximation, an abrupt un-mitred bend behaves as a shunt capacitance placed between the ground plane and the bend in the strip. Mitring the bend reduces the area of metallization, and so removes the excess capacitance. The percentage mitre is the cut-away fraction of the diagonal between the inner and outer corners of the un-mitredbend.The optimum mitre for a wide range of microstrip geometries has been determined experimentally by Douville and James.They find that a good fit for the optimum percentage mitre is given by

M=100*(x/d) %

M=(52+65 e-(27/20)(w/h)) %

Subject to w/h >0.25 and the with the substrate dielectric constant er< 25 This formula is entirely independent of er. The actual range of parameters for which Douville and James present evidence is 0.2 5< (w/h) < 2.75 and 2.5 <er< 25. They report a VSWR of better than 1.1 (i.e., a return better than −26 dB) for any percentage mitre within 4% (of the original d) of that given by the formula. At the minimum (w/h) of 0.25, the percentage mitre is 98.4%, so that the strip is very nearly cut through.

For both the curved and mitred bends, the electrical length is somewhat shorter than the physical path-length of the strip.

B. *Microstrip Mitered Bend and Tee Junction*

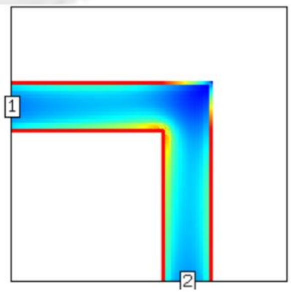

Fig. 3:Un-MItred band

The microstrip bend is a discontinuity where current flow around a corner is critical .Note in the diagram below the current null at the outer corner and the current maximum on the inner corner

Below the bend has been mitered with a simple 45 degree cut. This causes the equivalent capacitance to decrease almost by 50% and the series inductance to increase slightly.

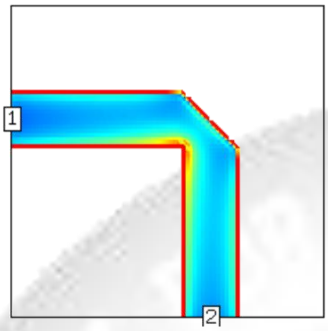

Fig. 4:45 degree MItred band

Finally, the "optimum" miter has been computed using equations by Douville and James as shown below

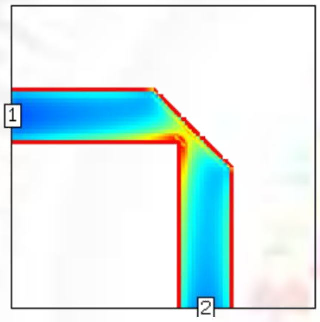

Fig. 5:MItred band

Another interesting and frustrating discontinuity is the tee-junction. The example below is driven at port one. Note how the current flows around the corners. It takes considerable time/distance for the normal microstrip current distribution to be re-established on the left and right arms. The result is a considerable area with very little current flow across from thecommon arm.

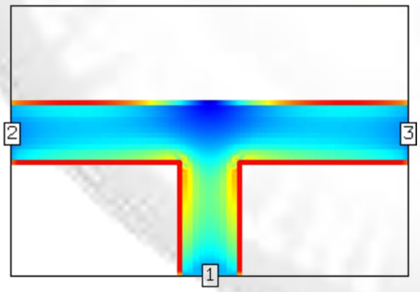

Fig. 6:Unmatched Tee Junction

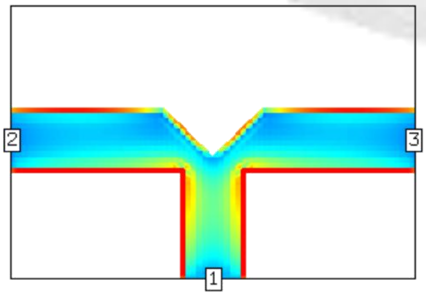

Fig.7:MItred Tee Junction band

The junction above is unmatched. One published matching technique shapes the "dead" area across from the common arm. The application of the technique [6] is shown below.

C. Study effect on bandwidth due to different combinations of short circuited stub dimensions

In this letter, a microstrip short-circuited-stub loaded ring resonator (SCSL-RR) and tapped feed lines are utilized together to develop a novel compact wideband BPF. By attaching the two dissimilar short-circuited stubs to the uniform-impedance ring resonator (UI-RR), the three resonant modes are appropriately excited to form up a wide passband. In design, the first and the third resonant frequencies can be freely controlled by making the two short-circuited stubs dissimilar in length and width. These short-circuited stubs can also bring out excellent DC-choked property. In addition, two open-circuited stubs are introduced at the connection points between the UI-RR and the tapped feed lines, aiming to adjust or enhance the coupling strength as desired. These open-circuit stubs improve the upper stopband performance by introducing transmission zeros. After the mechanism of the proposed BPF is described, a compact, low-loss wideband BPF prototype is to be designed and fabricated.

IV. CONCLUSIONS

In this letter, a novel microstrip-line UWB bandpass filter with compact size is proposed. By using Douville and James mitering formula illustrated in theory.The proposed design is expected to have lower metallization surface area as compared to design shown in [1].Thus helping to reduce unwanted capacitances and thus helping to obtain improved characteristics with finer tuning.

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