A Novel Tri-Band Branch-Line Coupler using Stepped-Impedance Resonator

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ABSTRACT
In this study, a novel structure of tri-band branch-line coupler is proposed using stepped-impedance (SIR) resonator to control the frequency ratio between the second and first resonance frequencies of such resonator. The fundamental characteristic of such resonators, the frequency ratio between the second and first resonance frequencies, is targeted as a key factor in arbitrary tuning the resonance frequencies. Based on the first and second spurious resonance harmonic of the SIR, a triple branch-line coupler is designed and simulated. The proposed BLC is shown to demonstrate a tri-band BLC with central frequencies located at 0.9, 2.6 and 4.2 GHz, respectively.

Keywords
Tri-band, Branch-line coupler(BLC),Stepped impedance resonator(SIR), Microstrip

1. INTRODUCTION
Branch-line coupler is one of the most important microwave device widely utilized in other components such as power combiners/ dividers, balanced mixers, balanced amplifiers and Butler matrix systems. Advancement in modern communication systems is imposing the new requirement in the design of these components such as compact size, wideband and multiple band operations. Recently, several techniques have been proposed to design a dual-band kind of these components including left/right-handed technique [1] or using stepped-impedance resonators or open quarter wavelength stubs [2-4]. Besides, another BLC has been proposed for wide-band application but with a single band [5] and the other one with coupled line section with dual-narrowband [6].
In [2], a two-section SIR has been recently developed to increase the design flexibilities and two novel dual-wide/narrow bands BLCs have been proposed. While this proposed model offers an effective technique to design such component, there are some limitations in the design procedure.
It is well known that the fundamental characteristic of a SIR is actually the frequency ratio between the second and first resonance frequencies [7], widely discussed in the reported papers, which has been considered either in extending the rejection band [8] or tuning of the two bands of a dual-band component [2]. Inspecting the reported papers, this factor is generally increased to a limited extent using a section of these resonators, for example about 1.7 and 2.2 for filters [7] and 2.7 for BLCs [2], respectively. Additionally, another dual-band BLC has been reported in [9] by which the size can be dramatically reduced, however at the expense of high loss for scattering parameters. Additionally, another dual-band BLC has been reported in [10] designed using t-shaped SIR. Moreover, two kinds of tri-band BLCs have been proposed in [11-12].

In this paper, a novel structure of tri-band branch-line coupler is proposed using stepped-impedance (SIR) resonator to control the frequency ratio between the second and first resonance frequencies of such resonator. The fundamental characteristic of such resonators, the frequency ratio between the second and first resonance frequencies, is targeted as a key factor in arbitrary tuning the resonance frequencies.

Based on the first and second spurious resonance harmonic of the SIR, a triple branch-line coupler is designed and simulated.

2. THE STRUCTURE OF SIR
Figure 1 shows the structure of SIR developed from the recently conventional dual-section SIR presented in [7]. It is well known that the only degree of freedom to control the frequency ratio is impedance (length) ratio and this is limited to microstrip fabrication process.

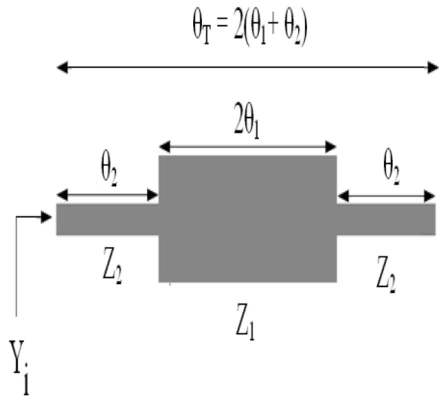

Fig 1: The structure of SIR

Inspecting the structure of the SIR, given in Fig.1, and as presented in [7], the first spurious resonance frequencies of this resonator can be derived as follows:

$$\frac{f_{S1}}{f_0} = \frac{\theta_{S1}}{\theta_0} = \frac{\pi}{2\tan^{-1}\sqrt{K}} \quad (1)$$

(1)

$$\frac{f_{S2}}{f_0} = \frac{\theta_{S2}}{\theta_0} = 2\left(\frac{f_{S1}}{f_0}\right) - 1 \quad (2)$$

(2)

$$\frac{f_{S3}}{f_0} = \frac{\theta_{S3}}{\theta_0} = 2\left(\frac{f_{S1}}{f_0}\right) \qquad (3)$$

As presented in [7], the relationship between these spurious resonance frequencies can be calculated in terms of the impedance ratio of the two sections of the SIR defined as K= Z_1/Z_2 and given in (1), these frequencies depend on the impedance ratio of K. Fig.2 shows the relationship between the first three spurious resonance frequencies in terms of K [7].

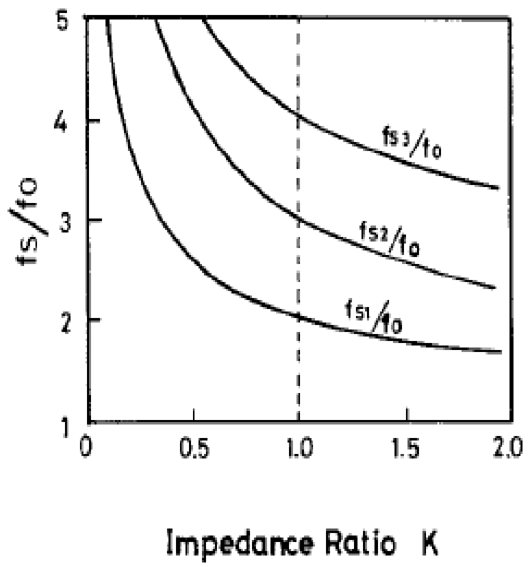

Fig 2: The relationship between spurious resonance frequencies and impedance ratio

As demonstrated in the curves given in Fig.2, a SIR can be used as the main resonator and by the higher spurious resonance frequencies, a novel multi-band BLC can be designed and simulated.

3. TRI-BAND BRANCH-LINE COUPLER (BLC)

As demonstrated in the previous section, a SIR can be chosen and the higher resonance frequencies supported to design a novel multi-band BLC. In this section, by supporting the first two spurious resonance frequencies of a SIR, a novel tri-band BLC is designed and analyzed. Fig.3 shows the proposed layout for the novel tri-band BLC in which the conventional transmission lines are replaced by four SIR given in Fig.1.

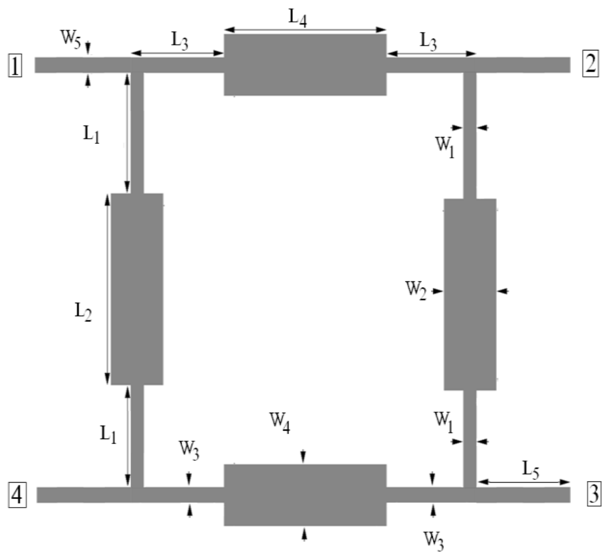

Fig 3 :The layout of the proposed tri-band BLC using SIR

After implementing the tri-section SIR instead of the conventional transmission lines as given in Fig.3, the parameters of the BLC are optimized using an EM simulator tools (ADS) on a 0.762-thick- substrate with dielectric constant of 3.5. Table 1 gives the optimized parameters for the proposed BLC.

Table 1: the optimized parameters for the proposed BLC

L_5	L_4	L_3	L_2	L_1	**Optimized Parameter**
5 mm	17 mm	17 mm	17 mm	17 mm	Physical Length
8.82°	30°	30°	30°	30°	Electrical Length
W_5	W_4	W_3	W_2	W_1	**Optimized Parameter**
1.715 mm	3.492 mm	2.91 mm	2.058 mm	1.715 mm	Physical Length
50 Ω	30.68 Ω	35 Ω	44.48 Ω	50 Ω	Characteristic Impedance

After optimizing the parameters of the proposed BLC, its performance is simulated using an EM simulator tools (ADS). Fig.4 shows the scattering parameters of this novel tri-band BLC.

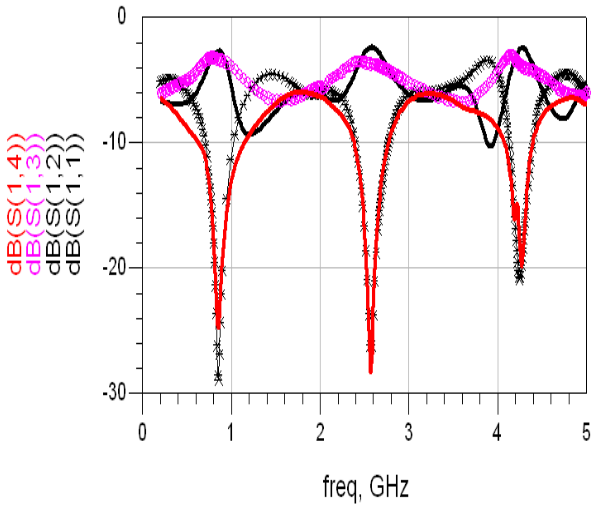

Fig 4: the scattering parameters of this novel tri-band BLC

Inspecting the simulated performance of the proposed BLC, three bands are demonstrated using this concept whose central frequencies are located at 0.9, 2.6 and 4.2 GHz, respectively. Another important parameter to be considered is the phase difference of the two outputs of the coupler which is shown in Fig.5.

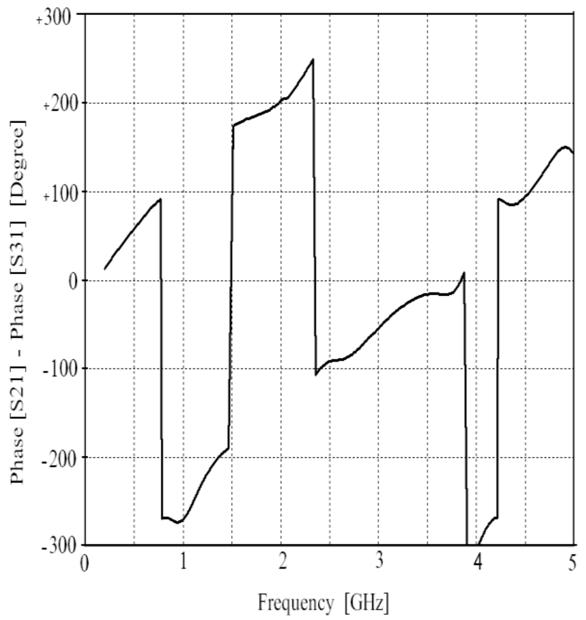

Fig 5: The phase difference of the output ports of the proposed BLC

As given in the phase difference of the outputs of the proposed BLC, this parameter is obtained to be +90°, -90° and +90° for three bands respectively.

4. CONCLUSION

In this study, a novel structure of tri-band branch-line coupler has been proposed using stepped-impedance (SIR) resonator to control the frequency ratio between the second and first resonance frequencies of such resonator. The fundamental characteristic of such resonators, the frequency ratio between the second and first resonance frequencies, has been targeted as a key factor in arbitrary tuning the resonance frequencies. Based on the first and second spurious resonance harmonic of the SIR, a triple branch-line coupler has been designed and simulated. The proposed BLC has been shown to demonstrate a tri-band BLC with central frequencies located at 0.9, 2.6 and 4.2 GHz, respectively.

5. REFERENCES

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