A Triple-Band Microstrip Passive Based on Quasi Hybrid-Ring Coupler Feeding

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***Abstract*—We present a triple-band microstrip passive device using a quasi-hybrid-ring coupler feeding. The proposed hybrid-ring feeder is based on the rat-race coupling mechanism using a balanced mode arrangement. The input excitation energy is split into two superimposed excitation electromagnetic waves travelling in opposite direction though with equal amplitude but with 180^0 phase difference. The proposed feeder caused excitation resonance at modes TM_{11}, TM_{02}, and TM_{20} leading to triple bands. The findings have been validated using available numerical method and by measurement.**

I. Introduction

The demand for wide range of wireless services to the end users is provoking the ingenuity of engineers to come up with alterative multiple integrated services (MIS) technologies in wireless communications to accommodate wide variety of wireless applications [1]. It is expected that a robust broadband capability in high-mobility environment will be a pre-condition to satisfying the MIS. The broadband capability requirements must be substantial in terms of channel capacity to support coexistence of these MIS in particular in a dynamic environment. Ironically, the channel capacity is dependent on the microstrip passive, most especially the passive intrinsic ability to provide considerable frequency pattern. It has been documented that the size reduction and bandwidth enhancement are somehow mutually exclusive. In particular, the antenna that is a crucial component of the communication system must satisfy multiple integrated services design requirements in terms of performance, geometrical size, as well as meeting certain manufacturing constraints such as packaging capability, reliability, and cost considerations as listed in [2].

There has been emergence of different alternative techniques via extensive research to provide robust broadband capabilities to support MIS. In [3]-[4], the authors presented MIMO procedure to providing broadband capability, Rappaport *et al* [5] employed millimeter wave approach, whereas, E/F-shapes diversity microstrip passive are employed in [6]-[7]. However, the expanse aperture size of these alternatives eventually circumvent the achieved broadband. In this study, we proposed a simple feed similar to a rat-race hybrid semi-coupler feeding. We employ a rectangular patch as a resonator, such that the coupler feeder could excite the patch at three different locations such as the vertical sides of the rectangular patch, the lower vertical side, and the upper axis.

II. The Proposed Structure

Fig. 1 demonstrates the proposed design based on the hybrid-ring coupler feeder. The feed is a quarter wavelength long from point 2 to point 3 as shown in Fig 1. Two different radii labelled R_1 and R_2 depict the output and input radii respectively of the coupler feeder. The arm (n) on both side of the microstrip patch forms a balanced circuit arrangement as demonstrated in Fig. 2 of [8]. The two parallel microstrip transmission lines carry current in each of the arms, but in opposite directions, which therefore are 180^0 out of phase. Hence, the current-carrying conductors generate magnetic fields in a direction orthogonal to the conductors themselves.

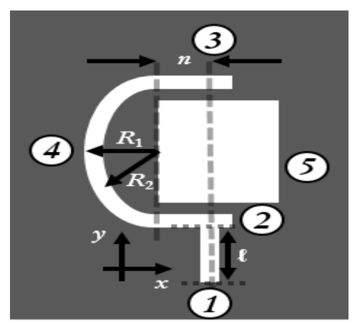

Fig. 1: The proposed feeder

Similar magnetic fields were generated from the resonator positioned in between the conductors. It is evident, therefore, that coupling will occur when the resonator (microstrip patch) is located in between but close to these current-carrying conductors. While it is adequate for only one current-carrying conductor to deliver sufficient coupling, the dual-plate current carrying conductors, otherwise known as balanced arrangement, will deliver stronger coupling once the conductors are anti-phase driven. In a similar way, Fig. 2(b) of [8] shows a practical realization of the balanced arrangement, analogous to the geometry shown in Fig. 1 above but now without the resonator. The feed is a typical half-rat-race coupler, otherwise known as a hybrid ring. The 180^0 phase shift was obtained by a combination of a power divider and a path difference of λ/2 between the two signal paths. This arrangement constitutes a simple balun. Implementing this type of feed mechanism introduces additional degree of freedom as the coupling can easily be adjusted by moving the resonator sideways.

$$f_1 = f_{11}^{TM} = k_{11}\frac{c}{2\pi\left(\varepsilon_r\right)^{0.5}} \quad (1)$$

$$f_2 = f_{20}^{TM} = k_{20}\frac{c}{2\pi\left(\varepsilon_r\right)^{0.5}} \quad (2)$$

$$f_3 = f_{02}^{TM} = k_{02}\frac{c}{2\pi\left(\varepsilon_r\right)^{0.5}} \quad (3)$$

The proposed feed is able to initiate triple-band resonance. Investigating the resonance capability using this coupling feeder based on the commercially available finite integration technique solver indicates that the first resonance occurs around the two vertical edges of the microstrip patch upon excitation due to TM_{11} mode. Two other resonances are as a result of excitation of modes TM_{02} occurring at the upper horizontal axis of the patch whereas, TM_{20} mode occur at the lower horizontal axis. These three resonances are defined by Eqs. (1) to (3), where c is the speed of light, ε_r is the relative permittivity, and k is the wave number.

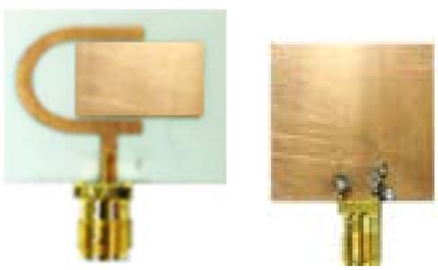

Fig. 2: The prototype

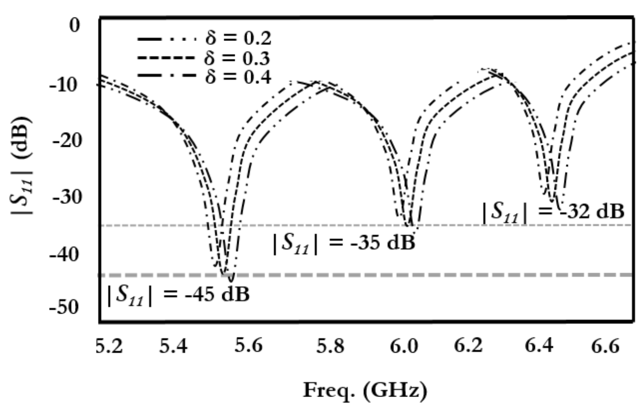

Fig. 3: The $|S_{11}|$ vs. coupling space (δ)

III. Results and Discussion

To validate the concept, a proof-of-concept was designed using CST studio. The resulting design was fabricated on Roger duroid laminate as depicted in Fig. 2. The simulated and measured $|S_{11}|$ parameter is as shown in Fig. 3 with respect to the coupling space between the upper (TM_{02}) and lower (TM_{20}) arms of the microstrip patch, as well as the effect of the radii differential (R_1-R_2) coupling strength that influences the TM_{11} mode. The effect of these coupling spacing, in particular, the coupling space between the upper and lower arm, affects resonance frequency, such that an increase shifts the resonance to higher frequency. Therefore, the space is set at δ = 0.3 mm. The $|S_{11}|$ parameter for f_1 (TM_{11}) is -45 dB, f_2 (TM_{20}) is -35 dB, whereas for f_3 (TM_{02}) is -32 dB. The frequency pattern for f_1 is 5.77 - 5.20 GHz, f_2 is 6.26 - 5.80 GHz, and f_3 is 6.60 – 6.31 GHz. Fig. 4 shows the $|S_{11}|$ parameter of the proposed using a coupling space δ = 0.3 mm.

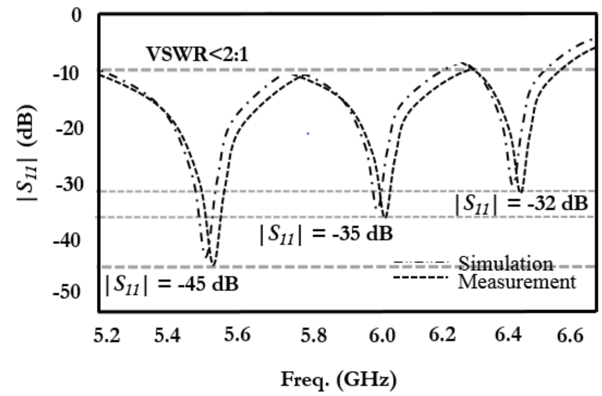

Fig. 4: The $|S_{11}|$ of the proposed design

IV. Conclusion

A simple coupler feed is introduced. The feed is able to excite triple resonances, and enhance a broadband capability to support MIS applications. The broadband capabilities of the proposed structure is validated by the relevant equations to support the resonance are stated.

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