

## OUTPUT COUPLED LINE WAVELENGTH HYBRID RING RESONATOR CENTERED AT 3 GHZ FOR BANDPASS FILTER APPLICATIONS

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### ABSTRACT

An output coupled line wavelength ring resonator centered at 3 GHz operating frequency for bandpass filter application is presented in this paper. The proposed ring resonator demonstrates a single mode resonant frequency at 3 GHz with a pair of transmission zeroes. This ring resonator consists of even and odd mode line impedance, and coupled to the output feed lines along a quarter-wavelength of its side to generate a single-mode bandpass response with two transmission zeroes at 2 GHz and 3.5 GHz. The design of the resonator filter is simulated in Microwave Office (AWR Design Environment) based on the design specification and fabricated on Flame Retardant Type-4 (FR4) microstrip substrate with dielectric constant,  $\epsilon_r=4$  and height of thickness,  $H = 4$  mm. All the simulation and measurement results are presented and discussed in this paper to show its feasibility.

**Keywords:** line wavelength; ring resonator; two transmission zeroes; microwave filter; bandpass filter

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## 1. INTRODUCTION

In our today's modern world, microwave technology plays some many roles in order to satisfy human needs in the society and community. The applications consist are transmission signal which include sending and receiving signals in a broadcasting system such as radio, television and other device like mobile phones.

The development microwave filters and its application have rising greatly in most of telecommunication fields such as Radio Frequency (RF), microwave circuits and electronic systems due to its percussion on modern society. There are several applications of these resonator filters, including broadcasting application via satellite communication technology to civil and radar systems for military purposes.

Microstrip ring resonator mostly can be found in microwave filters, mixers, couplers, oscillator and antennas [1] [2] due to its popularity compared than patch resonator [3]. The difference between these two types of resonator is, ring resonator have the advantage in term of their ring structure that deliver low passband insertion loss and higher quality factor (Q-factor) [4]. Others attractive features of ring resonator such as low radiation loss, high Q-factor, compact size, dual-mode capabilities and sharp rejection skirts [5] [6] [7] [8] make their popularity increased for bandpass filter applications. The usage of microwave and RF filters are widely used in all the communication technologies and electronic system in order to differentiate between any wanted and unwanted signal frequencies band for filtering process [9] [10]. Most of the resonator filters have been developed since the usage of the microwave electronic devices with size miniaturization [11] [12] and it is still being implemented until today [13].

The topologies's structure of these resonators started in general with the optimum choice of circuit diagram, design specifications through optimization and then, it is implemented by using the best reasonable technologies that the manufacturing acquire. In fact, in order to respond to the demanding specifications and to improve the performance of the electronic devices, the requirement of new methodologies and circuit design, and system is as to fulfill the demand from the engineering industries.

Recent reports shows several designs and topologies of the microwave resonator filters that exhibit dual-frequencies resonance as reported in [14] and [15]. In order to produce the dual

resonance frequencies, most of the ring resonator designs needs to tune their coupling parameters and impedance's element [16] [17]. Two-transmission zeroes that presence in the bandpass responses [18] [19] could lead to the compactness of the filter's size itself as mentioned in [20] and [21]. The previous researchers have reported that, a combination of such rings with two coupled-lines at their input and output points may lead to the creation of global synthesis equations of the structure, according to the control impedance parameters:  $Z_r$ ,  $Z_{oe}$  and  $Z_{oo}$ , which are the impedance of the ring, and the even- and odd-mode impedance of the coupled lines, respectively [22] [23].

In this paper, topology of ring resonator that is another possible design by feeding the ring via a single coupled line from one of the resonator's quarter-wavelength is proposed. The output coupled line is located at the outside of the ring resonator and this will produce a single mode resonance with two transmission zeros. In this topology of hybrid ring resonator, the number of control parameters is lesser and make the design easier to construct. The transmission zeros will be maintained despite it is a single mode response.

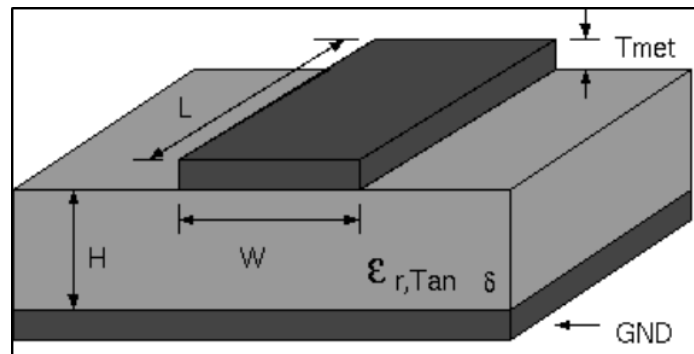
This resonator is capable to be operated for bandpass filter applications. All the proposed idea is tested through simulation and measurement on FR4 microstrip substrate of characteristics:  $\epsilon_r = 4$ ,  $h = 1.6$  mm and  $\tan \delta = 0.02$ . This report is divided into four sections as follows: Section 1 discuss the introduction and past research of microwave ring resonator filters and its application. Section 2 illustrates the methodology of hybrid ring resonator circuit diagram, section 3 presents and discusses the simulation and measurement results and section 4 will summarize the conclusion of this paper.

## 2. THE METHODOLOGY OF HYRID RING RESONATOR

The methodology process of hybrid ring resonator consists of two parts, which is simulation and measurement. The simulation results are divided into three phases: ideal simulation, circuit simulation and Electromagnetic (EM) simulation. The design of hybrid ring resonator is built based on the desired specification as listed in Table 1 below. Fig. 1 shows the cross-section of the FR4 board microstrip for hybrid ring resonator.

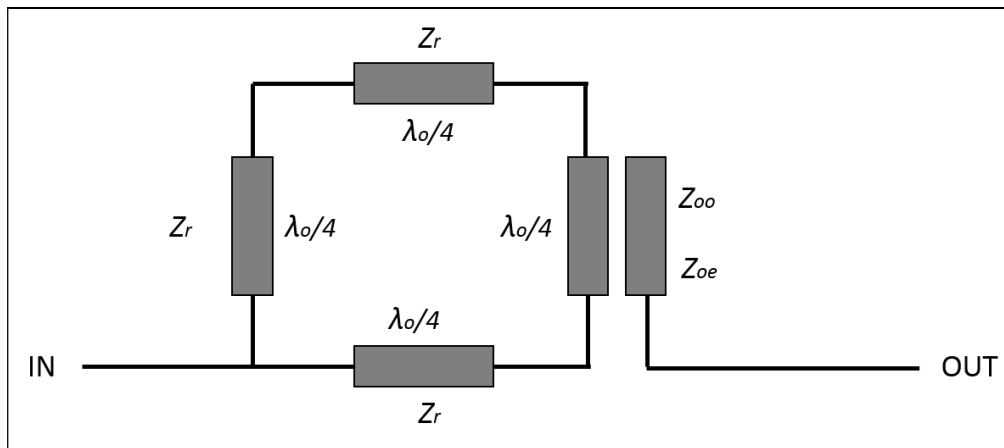
**Table 1.** Design specifications

Specifications	Values
Center frequency	3 GHz
Type of substrate	Flame Retardant Type 4, FR4
Dielectric constant, $\epsilon_r$	4
Substrate thickness, H	1.6 mm
Loss tangent, $\tan \delta$	0.01
Metal thickness, $T_{\text{met}}$	35 $\mu\text{m}$

**Fig.1.** FR4 microstrip substrate cross-section

### 2.1. Ideal Diagram in Transmission Line Circuit

The ideal diagram of hybrid ring resonator in transmission line circuit is described in Fig. 2. The ring is constructed from three quarter-wavelength ( $\lambda_0/4$ ) ring impedances,  $Z_r$  and a single symmetrical quarter-wavelength coupled-line,  $Z_{oo}$  and  $Z_{oe}$  that connected to the output port. The ideal transmission line diagram consists of three types of impedances which are:  $Z_r$  (ring characteristic impedance),  $Z_{oo}$  (odd mode characteristic impedance) and  $Z_{oe}$  (even mode characteristic impedance).



**Fig.2.** The transmission line of hybrid ring resonator

Based on the figure above, the total perimeter of the ring is equal to one wavelength at the operating frequency,  $f_0$ . The input port located at the left side of the ring is inserted directly, with the length of quarter-wavelength away from the parallel coupled line ( $Z_{00}$  and  $Z_{oe}$ ). The output port is connected to the coupled line, accurately at the closer end to the input point.

## 2.2. Circuit Diagram of Hybrid Ring Resonator

The circuit diagram's topology of single-mode ring resonator is realized in microstrip form. The microstrip substrate which is FR4 substrate is added in this circuit and the microstrip discontinuities such as bend and T-junction is also added to connect all the transmission line impedances in the circuit diagram. A discontinuity in a microstrip is caused by an abrupt change in the geometry of the strip conductor, and electric and magnetic field distributions are modified near the discontinuity. The altered electric field distribution gives rise to a change in capacitance, magnetic field distribution and inductance. Discontinuities commonly encountered in the layout of practical microstrip circuits such as Steps, Open-Ends, Bends, Gaps, and Junctions. The  $50 \Omega$  (Ohm) lines are added at the input and output port. These lines are called as transparent line. Fig. 3 below demonstrates the circuit diagram of resonator.

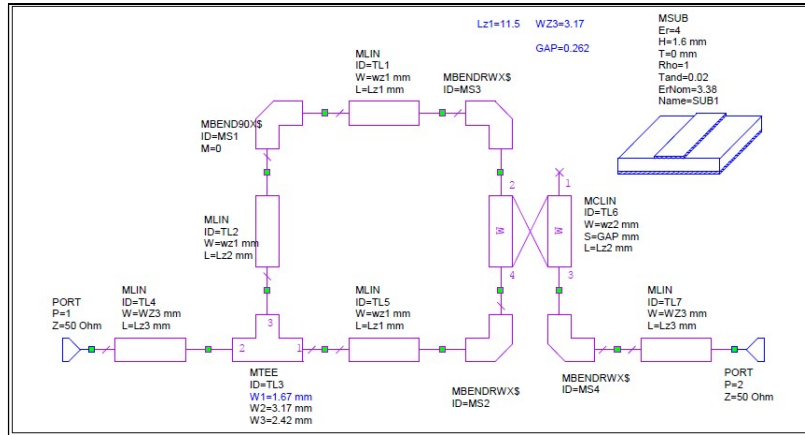


Fig.3. Circuit diagram of hybrid ring resonator

### 2.3. Electromagnetic (EM) Diagram of Hybrid Ring Resonator

Figure 4 shows the extraction method to obtain EM layout with the implementation of AXIEM method in the AWR software. The size and dimension of EM layout, which consist of width,  $w$  and length,  $l$ , are converted directly from the circuit diagram. EM Extraction can be used to conveniently verify the performance of collections of elements using an EM simulator.

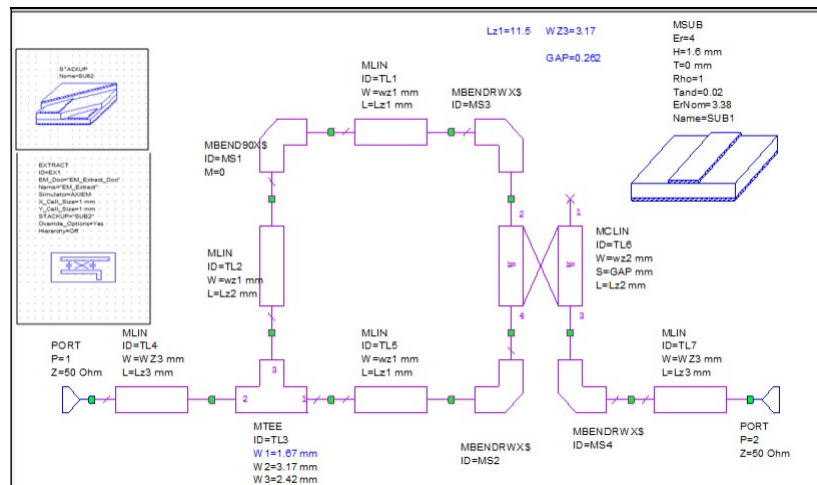
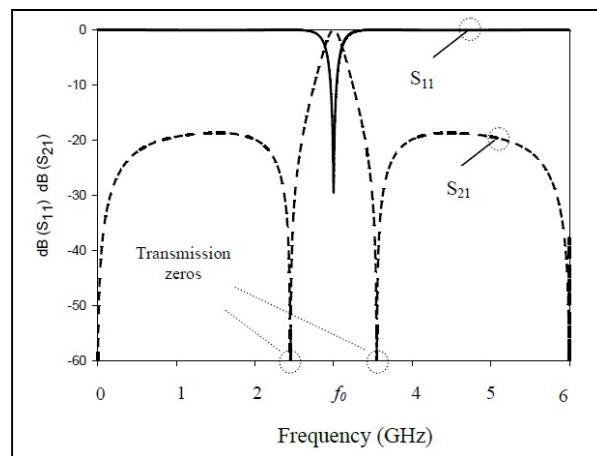


Fig.4. Extraction method to obtain EM layout

### 3. RESULTS AND DISCUSSION

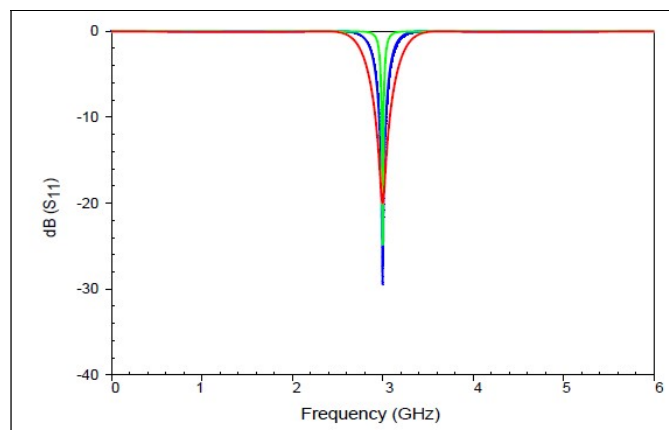
#### 3.1. Ideal Simulation Results

Fig. 5 shows the ideal simulation results of the resonator retrieve from the AWR software, where a single resonance and two transmission zeros can be seen immediately in the rejection bands, and the optimum values for the line impedances are:  $Z_r=53.8 \Omega$ ,  $Z_{oe}= 94.2 \Omega$  and  $Z_{oo}= 54.6 \Omega$ . It is shown that the resonant frequency is obtained at center frequency,  $f_0$  while two transmission zeros are found on the both sides of bandpass filter. The transmission zeros are occurring due to the cross coupling between non-adjacent resonator that is used to improve the skirt rejection of the microstrip filters.



**Fig. 5.** Ideal Simulation result of the hybrid ring resonator

#### 3.2. Variation of ideal response in terms of $Z_R$ , $Z_{oo}$ and $Z_{oe}$



**Fig.6.** Variation of return loss ( $S_{11}$ ) response in terms of  $Z_R$ ,  $Z_{OO}$  and  $Z_{oc}$

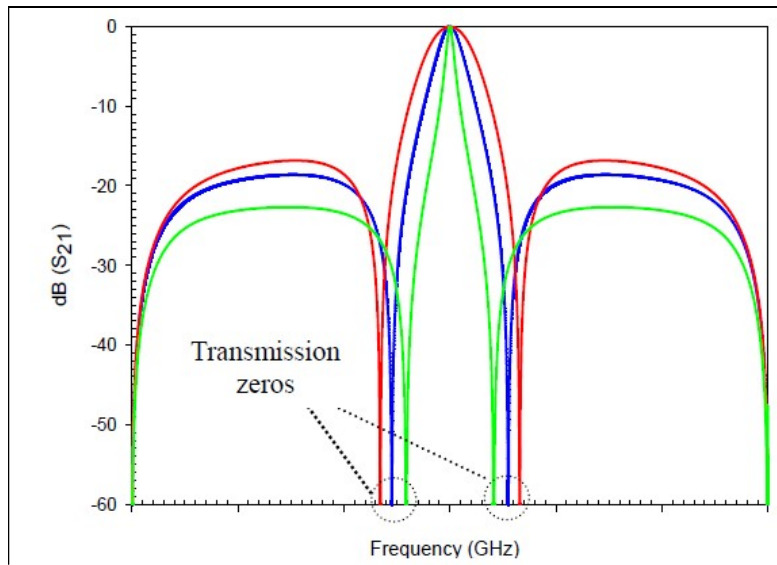


Fig.7. Variation of insertion loss response in terms of  $Z_R$ ,  $Z_{OO}$  and  $Z_{oe}$

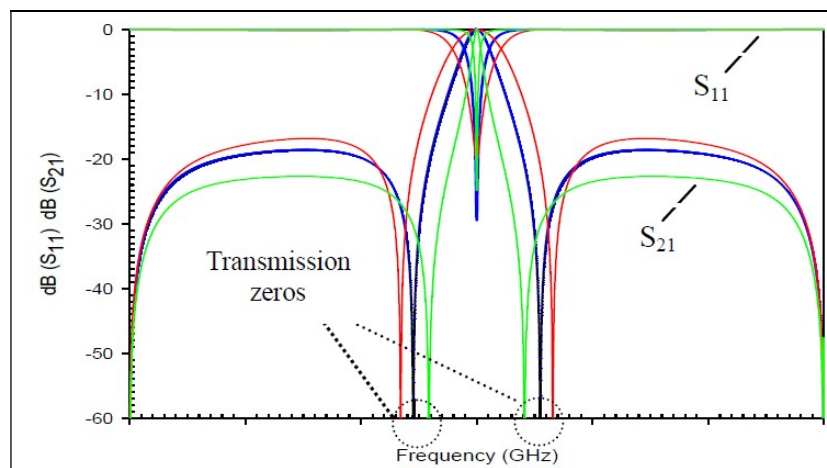


Fig.8. Variation of response in terms of  $Z_R$ ,  $Z_{OO}$  and  $Z_{oe}$

Fig. 6 until 8 illustrate the resonator ideal response in terms of variation of impedance values of the ring and the coupled line i.e  $Z_r$ ,  $Z_{oo}$  and  $Z_{oe}$  respectively. By varying these parameters, it can be observed that the bandwidth and the position of the transmission zeros are also varied [24]. It can be seen that, when the impedance values are increased, the bandwidth will become wider and vice versa.



### 3.3. Circuit Simulation Results

Fig. 9 presents the circuit simulation result where the center frequency is obtained at 3 GHz according to the specifications as mentioned earlier. The solid line shows the response of return loss ( $S_{11}$ ) in dB and the dashed line shows the response of insertion loss ( $S_{21}$ ) in dB. When the ring resonator's filter power drop to half (3 dB), the value of relative bandwidth (BW) that have been calculated based on the equation (1) below is equal to 32.13%. It shows that this hybrid ring resonator is achieved to be conducted for bandpass filter application within frequency range of 1 GHz until 6 GHz.

$$BW (\%) = \frac{f_H - f_L}{f_c} \times 100\% \tag{1}$$

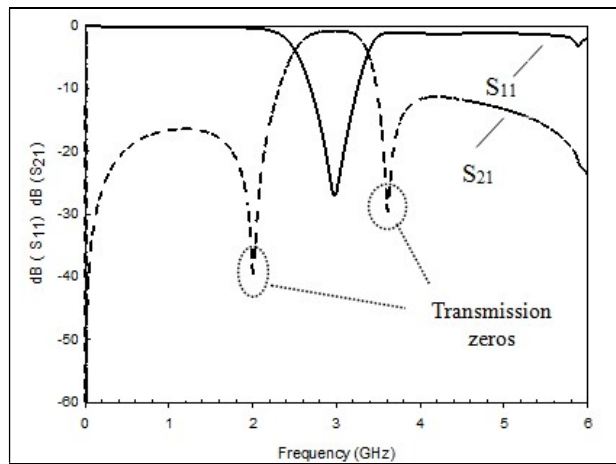


Fig.9. Circuit simulation result of hybrid ring resonator

### 3.4. Electromagnetic (EM) simulation results

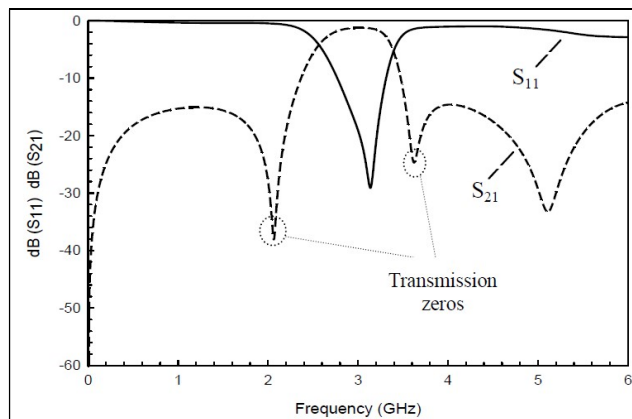
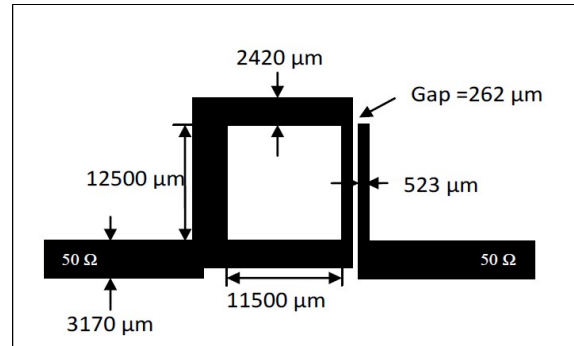


Fig.10. EM simulation result with two transmission zeroes

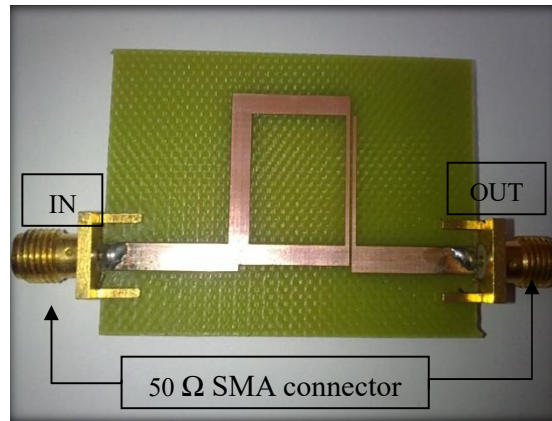
Fig. 10 indicates the electromagnetic (EM) of two responses which are  $S_{11}$  (return loss) and  $S_{21}$  (insertion loss). The two transmission zeros at the passband is located at 2.05 GHz and 3.6 GHz with relative bandwidth of 31.24%. The value return loss is found to be 28.75 dB while the insertion loss is 1.08 dB. The center frequency in the EM simulation is slightly shifted to the right to 3.08 GHz from the original center frequency at 3GHz due to the existence of the microstrip discontinuities such as bend and T-junction and the effect of parasitic elements.

#### 4. IMPLEMENTATION OF HYBRID RING RESONATOR

The proposed ring resonator topology has been implemented on the design of a microstrip resonator at 3GHz using FR4 Epoxy glass substrate choose characteristics are given as follow:  $\epsilon_r = 4$ ,  $h = 1.6$  mm,  $\tan \delta = 0.02$  and  $T = 0.035$  mm. The overall layout and dimensions with its fabricated photo of the circuit are depicted in Fig. 11 and Fig. 12. The 50  $\Omega$  SMA connector is connected at the input and output port as the impedance source and impedance matching.

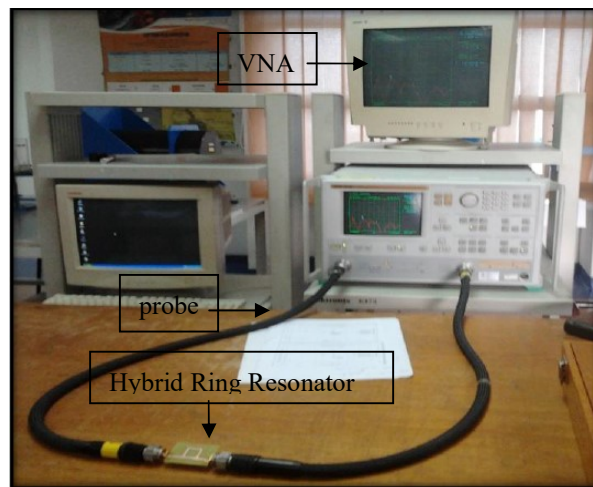


**Fig.11.** Final layout of the microstrip ring resonator



**Fig.12.** Fabricated photo

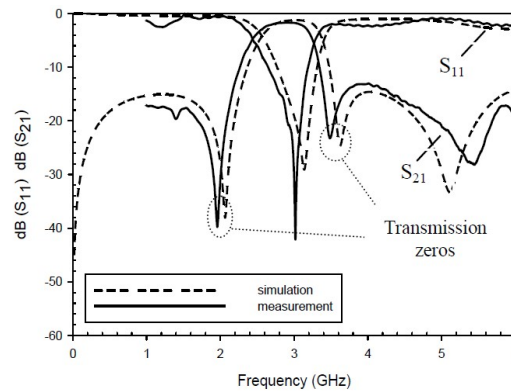
The prototype of ring resonator is measured and tested by using the Vector Network Analyzer (VNA) as shown in Figure 13 below and its results are observed in term of  $S_{11}$  and  $S_{21}$ . The Device Under Test (DUT) of the ring resonator was connected via the cable probe to the port of VNA to measure the responses.



**Fig.13.** The measurement process of hybrid ring resonator

The results of simulation and measurement are shown in Figure 14. It can be observed that the measured resonator resonates at a slightly shifted frequency of 3.025 GHz while two transmission zeros are obtained at 2 GHz and 3.5 GHz respectively. The shifted frequency might be happened due to the error in defining the value of dielectric constant [25]. The measured result is acceptable as it still within the frequency range for bandpass filter

application. Both simulated and measured responses had shown good passband response, high selectivity with two transmission zeros, and good impedance bandwidth throughout the tuning parameters.



**Fig.14.** Simulation and measurement results of hybrid ring resonator

#### 4. CONCLUSION

A complete design of one-wavelength ring resonator was proposed to exhibit a single-mode resonance with a dual of transmission zeros at 2 GHz and 3.5 GHz. The hybrid ring resonator is fed through a single quarter-wavelength coupled-line and had reduced the number of control parameters of the ring i.e. the line impedance and the even-and odd-mode impedance of the coupled-line. The proposed idea was verified successfully through simulations and measurements of microstrip resonator using lossless FR4 epoxy glass substrate with center frequency at 3 GHz. The frequency responses for this resonator had achieved good passband response, compact in size and good impedance matching.

#### 5. ACKNOWLEDGEMENTS

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#### 6. REFERENCES

- [1] Singh D K, Kumar P, and Rizvi N Z. Microstrip transmission line sensor for rice quality detection: An overview. *Int. J. of Engineering Research and General Science*, 2014, 2(4):589–598

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- [2] Abouelnaga T G, Mohra A S. Novel compact harmonic-rejected ring resonator based bandpass filter. *progr. Electromagnetics Research C*, 2017, 74, 191–201
- [3] Mezaal Y S, Eyyuboglu H T. Investigation of new microstrip bandpass filter based on patch resonator with geometrical fractal slot. *PLoS ONE*, 2016, 11(4):1–12.
- [4] Alahnomi R A, Zakaria Z, Ruslan E, Ab Rashid S R, and Mohd Bahar A. A. High-Q sensor based on symmetrical split ring resonator with spurlines for solids material detection. *IEEE Sensors Journal*, 2017, 17(9):2766–2775
- [5] Bruster A, Zakaria Z, Ruslan E, and Mutalib A A. Review of bandpass with tunable notch microwave filter in wideband application. *Int.J.of Eng and Tech. (IJET)*, 2015, 7(3):825–832
- [6] Lu H S, Wu W W, Huang J J, Zhang X F, and Yuan N C. Compact dual-mode microstrip bandpass filter based on greek-cross fractal resonator. *Radio Eng.*, 2017, 26(1):275–284
- [7] Kushwah V S, Tomar G S, and Bhadauria S S. Design of grooved microstrip patch resonator filters for mobile communication. *Int. J. of Future Generation Communication and Networking*, 2016, 9(5):131–142
- [8] Xu Z, Xia H. Miniaturized multilayer dual-mode substrate integrated waveguide filter with multiple transmission zeros. *Prog. In Electromag. Research*, 2013, 139, 627–642
- [9] Belen M A, Mahouti P, Partal H P, Demirel S, and G Yıldız. Design and simulation of a tunable bandpass filter using varactor diodes for wireless and radar applications. *J. of Eng. and Natural Sciences*, 2015, 33, 85–93
- [10] Pingle M N S. A review on micro strip band pass filters for global positioning system applications. *Int. J. on Recent and Innov. Trends in Comp. and Comm.*, 2014, 2(8):2114–2116
- [11] Huang T, Shao Z. A size-miniaturized bandpass filter with selectivity-enhanced and high harmonic suppression performance. *Int. J. of Microwave and Wireless Technologies*, 2017, 1–7
- [12] Tao H, Zhen H S, and Yong M H. Size-miniaturized and selectivity - enhanced bandpass filter using folded stepped-impedance resonators. *Micro. and Opt. Tech. Letters*, 2017, 59(1):60–62
- [13] Okeke E N, Emole C, and Anorue E C. Miniaturization of microwave devices: It ' s effect in improving electronic circuits. *Int. J. of Latest Trends in Eng. and Tech.*, 2014, 4(2):48–51
- [14] Alqaisy M, Chakrabraty C, Ali J, and Alhawary A. A miniature fractal based dual-mode

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- dual-band microstrip BPF design. *Int. J. of Micro. and Wire. Tech*, 2014, 7(2):127–133
- [15]Chen C F, Chang S F, Tseng B H, Weng J H. Compact dual-band stepped-impedance resonator filter with separate coupling paths. *Electronics Letters*, 2014, 50 (21):1551
- [16]Shehan J W, Adams R S. A waveguide horn antenna with coupled resonator notch filter designed by the lagrangian formulation for metamaterials. *Progr. In Electr. Research B*, 2016, 69:17–29
- [17]Vryonides P, Nikolaou S, Kim S, and Tentzeris M M. Reconfigurable dual-mode band-pass filter with switchable bandwidth using PIN diodes. *Int. J. of Micro. and Wireless Tech*, 2015, 7(6):655–660
- [18]Gu H, Wang J, Pan J, and Zhang G. Compact 60 GHz LTCC balun bandpass filter with two transmission zeroes. *Elec. Letters*, 2015, 51(8):637–638
- [19]Xue Q, Jin J Y. Bandpass filters designed by transmission zero. *IEEE Trans. on Micro. Theory and Techniques*, 2017, PP(99):1–8
- [20]Jun X, Hong W, Hui Z, and Hongjun T. Compact bandpass filter with multiple coupling paths in limited space for ku-band application. *IEEE Micro. and Wirel. Comp. Letters*, 2017, 27(3):251–253
- [21]Cheng F, Lin X Q, Jiang Y, Song K J, and Fan Y. Microstrip filters with adjustable transmission zeros using inductive-coupled open stub-loaded resonators. In *PIERS Proceedings 2014*, pp. 1360–1363
- [22]Wu X, Sun H, and Ge J. Tri-mode stub-loaded ring resonator and its application to miniaturized wideband bandpass filter design. In *10<sup>th</sup> Global Symposium on Millimeter-Waves*, 2017, pp. 31–33
- [23]Arain S M, Abassi A B, Nikolaou S, Vryonides P. A square ring resonator bandpass filter with asymmetrically loaded open circuited stubs. In *5<sup>th</sup> International Conference on Modern Circuits and Systems Technologies*, 2016, pp. 8–11.
- [24]Avinash K G, Rao I S. Highly selective dual-mode microstrip bandpass filters using triangular patch resonators. *Adv. Electro.*, 2017, 6(1):77-84
- [25]Huang X G, Feng Q Y, Xiang Q Y, Jia D H. Design of bandpass filter with transmission zeros using zeroth-order resonator and u-shaped resonator. *Prog. In Electro. Research Symp. Proc.*, 2012, 857–860

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