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Analysis of Microstrip Ring Resonator for 5G Communication at Different Operating Frequencies

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Abstract: This Modern wireless communication systems are designed to operate at very high frequency and will require compact design. Microstrip Ring Resonators (MRR) have broad applications due to compact design and flexible frequency operation. In this paper, we design and analyze a microstrip ring resonator for fifth generation wireless communication networks. The proposed microstrip ring resonator is simulated using Advanced Design System (ADS) simulation tool at different frequencies. The analysis of varying the frequency ranges is presented and the effect on S- parameters is also evaluated. Due to the excellent S-parameter results of proposed MRR, the design is found to be suitable for 5G wireless communication.

Keywords: MRR; Wireless Communication; ADS; S- parameters.

I. Introduction

With rapid transition in the wireless communication from lower to higher data networks, the global scenario has completely changed and is supposed to further enhance in technical regards. Fifth generation (5G) mobile networks are supposed to become the backbone of the global wireless communication infrastructure. Therefore, it has become a hot spot for the researchers to explore more and more about this particular technology which is going to change the shape of information and communication technologies. This further has widened the scope due to larger bandwidths and high efficiency. In the current times the 5G mobile networks are identified to be operated in two frequency bands 3.3-3.6 GHz and 5GHz [1],[2]. Increasing demand of data has made efficient use of spectrum inevitable. Due to the compact design of the wireless communication systems, the antennas needs to be also designed in a way so that they can match the parameter and produce excellent outputs. A single antenna cannot provide the enough directivity until its physical dimensions are increased which is again an impractical phenomenon [3]. Therefore, design of antenna with multiple arrays can play a significant role in enhancing performance of modern wireless communication [4]. A microwave strip based ring resonator have been widely used for measuring microwave characteristics such as phase velocity, dispersion and dielectric constant [5]. Different shaped antennas are discussed in [6]. The two most common configurations of microwave resonators are linear and ring resonators [7]. The basic configuration of microstrip ring resonator is shown in Figure 1. Due to enormous applications, researchers have used microstrip ring resonators as sensors as well [8]. Apart from the main configuration of ring resonators, they can be designed in any shape depending upon the application. In [9], split ring resonator is used in horn shape as rotatory sensor. It has been shown that split ring resonators are ideal for designs for high sensitivity and high quality factor [10]. Moreover, microstrip ring resonators (MRRs) are becoming famous because of the quality that distinguish them is their ability to satisfy the increasing need smaller space in modern microwave circuits. Low cost, high quality (Q) and low radiation loss for wireless communication are added advantages [11]. The MRRs provide narrow bandwidths with high directivity. As a result of their advantageous features, many other resonator designs are introduced on the basis of MRR structure [12], [13]. The authors in [14] have presented a novel approach of ring resonator as sensor in 4G and 5G communication networks. The frequency of operation taken by the authors is 28Ghz. The proposed sensor is based on a topology named as complementary split ring resonator (CSPR). The authors received a very good dielectric sensitivity of 17.12%. Whereas the quality factor (Q-factor) value was achieved as 90 which they compare with another research. The authors suggested that this design is well suited for 4G-LTE band. Various shapes of microstrip ring resonators are being designed by the researchers [15], including the ring resonators the researchers also explored the rectangular shape of patch of split ring resonator. This paper mainly deals with the study of microstrip ring resonator specifically designed for 5G applications. This is arguably the first microstrip ring resonator with simplest shape to be analyzed for the high frequency ranges. We discuss different aspects of the design of a MRR and present the affect by varying the parameters. The results of different parameters of ring resonator at 19.10GHz, 20.10GHz and 30.20GHz is are presented. We also discuss the Q-factor the designed shape and show that it has acceptable Q-factor real time applications.

The rest of the paper is divided into following parts. Section II describe the detailed methodology used in this work, whereas section III discusses the Results and Discussion. Finally, the conclusion, future work and applications are discussed in section IV.

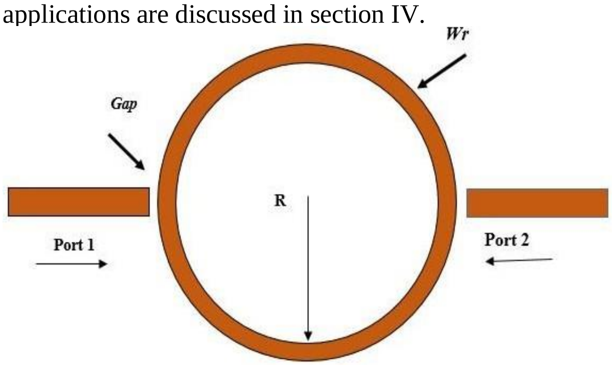

Figure 1: Basic shape of (MRR)

II. METHODOLOGY

In this section we discuss the simulation method used to design microstrip ring resonator. The proposed MRR is simulated using ADS simulation tool which is an open source software specially built for designing microwave devices. The proposed MRR is shown in the Figure 2. We selected FR4 substrate material because it is easily available for fabrication purpose. The proposed MRR is a two port with width (W=6mm) and length (L=10mm) of the box. The thickness of FR4 substrate is kept as 0.035mm with the operating frequency of 30.20GHz. In addition, the height of substrate is 1.6mm and dielectric constant is 4.25. At first we calculate from the equations (1) and (2). We use one of these equation according to w/h ratio. If the ratio is less than 1 we use equation (1) and if ratio is greater than 1 than we use the equation (2). After getting the value of substitute that value into equation (3) to get the desired resonant frequency fn where c is the speed of light and r is the radius. Here n is the mode number where n represents the natural numbers (n=1,2,3,4,5), after getting the radius of ring resonator, we find the coupling gap using equation (4).

$$\varepsilon eff = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{2}\left[\left(1+\frac{12h}{w}\right)^{-\frac{1}{2}} + 0.04\left(1-\frac{w}{h}\right)^2\right] for\ \frac{w}{h}<1 \quad (1)$$

$$\varepsilon eff = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{2}\left[\left(1+\frac{12h}{w}\right)^{-\frac{1}{2}}\right] for \geq \frac{w}{h} 1 \quad (2)$$

$$fn = \frac{nc}{2\pi r\sqrt{\varepsilon eff}} \quad (3)$$

$$\Delta L = 0.421d\left(\frac{\varepsilon eff+0.3}{\varepsilon eff+0.258}\right)\left(\frac{\frac{w}{d}+0.262}{\frac{w}{d}+0.818}\right) \quad (4)$$

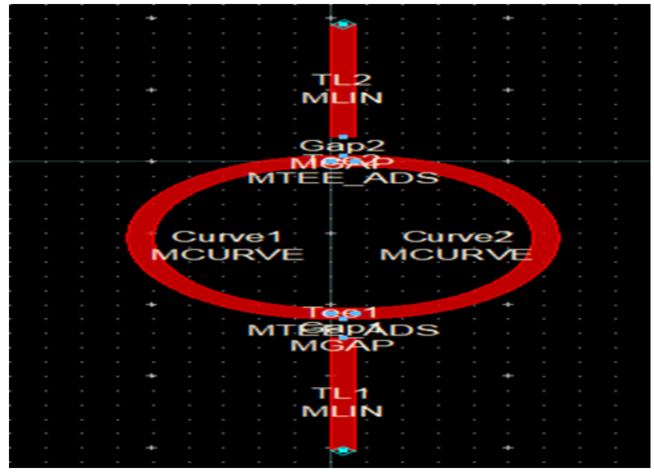

Figure 2: MRR layout in ADS

A. *Schematic Diagram of Designed MRR*

The schematic diagram shown in Figure 3 is designed in ADS. One can note (MSUB) which actually represents the microstrip substrate FR4 along the values of height, dielectric constant and thickness. In S-parameter block the frequency range starts from 28GHz and stops at 32GHz with the stepping of 100MHz. The input and output impedance (Z) is kept as 50 ohms. MLIN in the schematic diagram denotes the microstrip transmission line in which length and width values. Whereas, MGAP shows microstrip spacing between the microstrip transmission line and microstrip ring with the value of spacing gap as shown in Table I. Moreover, two microstrip curves (MCURVE) are used for making the complete ring in 360 degrees. The given schematic diagram is at 30GHz; other parameters vary according to the change in the frequency. We also show the 3D diagram of the designed MRR in Figure 4. The impact of varying the frequency is discussed in section IV.

TABLE. I SIMULATION PARAMETERS

Parameters	**Value (mm) at frequency 30.2GHz**	**Value (mm) at frequency 20.10 GHz**	**Value (mm) at frequency 19.10 GHz**
R	1.45 mm	1.35 mm	1.45 mm
L	2.5 mm	2.0 mm	2.0 mm
W	0.17mm	0.19mm	0.19mm
S	0.54 mm	0.34 mm	0.34 mm

III. RESULTS AND DISCUSSION

In this section, we present the analysis on results achieved through simulations. We investigate the performance of proposed ring resonator based on microwave parameters a three operating frequencies i.e 19.10GHz, 20.10GHz and 30.2GHz respectively. Reflection coefficient (S11) and the transmission coefficient (S21) are plotted with respect to frequency as given in Figure 5. We obtained the return loss value as minimum of -30.7dB at the operating frequency of 19.10GHz and transmission coefficient is - 0.004dB, which is better for the high frequency with minimum insertion loss The magnitude of S11 and S21 are presented in Figure 6 with value of S11 equal to 0.029 and S21 equal to 1 at same operating frequency. Figure 7 illustrates the phase of ring resonator coefficient of S11 and S21. The value of S11 obtained at 18.10GHz is 179.008 peaks and the S21 obtained at 19.00GHz is 178.183 peaks. The metamaterial behavior of microstrip ring resonator is confirmed from the phase reversal of S11 and S21. Besides the resonant frequency another factor that can be considered as very much important is the load quality factor or the Q-factor [16]. Q-factor basically denoted the measure of accuracy of ring resonator.

TABLE. II SIMULATION RESULTS

	Parameters	F=19.10	F=20 GHz	F=30.2 GHz
	S11	-30.709	-29.446	-38.568
	S21	-0.004	-0.005	-0.001
Magnitude	S11	0.029	0.004	0.012
	S21	1.000	0.999	1.000
Phase	S11	179.00	179.08	85.396
	S21	178.18	178.18	175.39

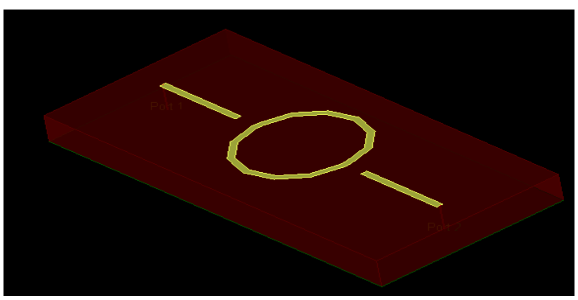
Figure 4: 3D Shape of proposed (MRR)

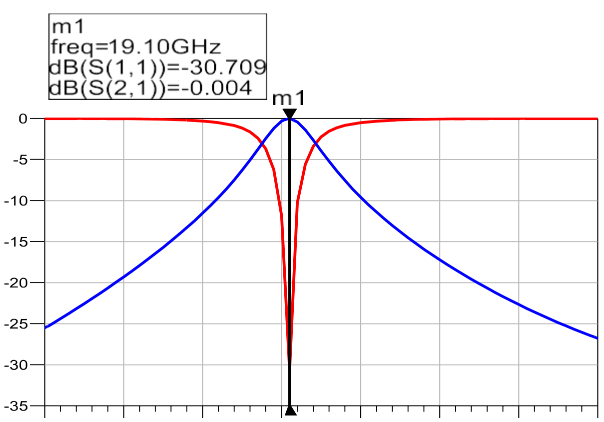

Figure 5: S11 and S21 of (MRR) at 19.10 GHz

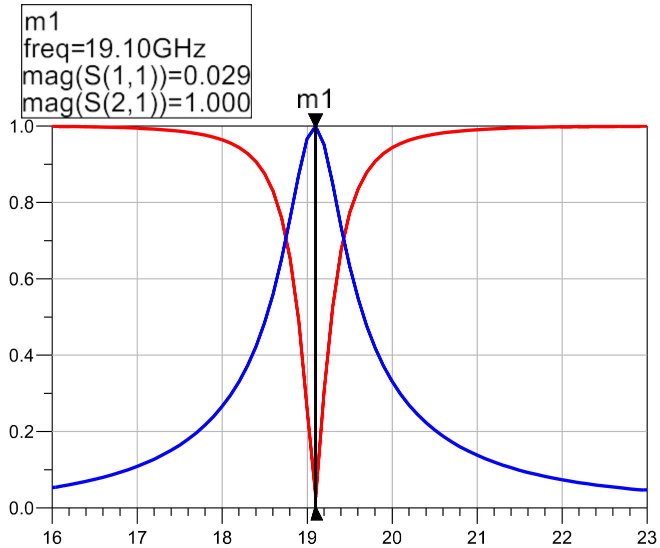

Figure 6: Magnitude S11 and S21 of ring resonator

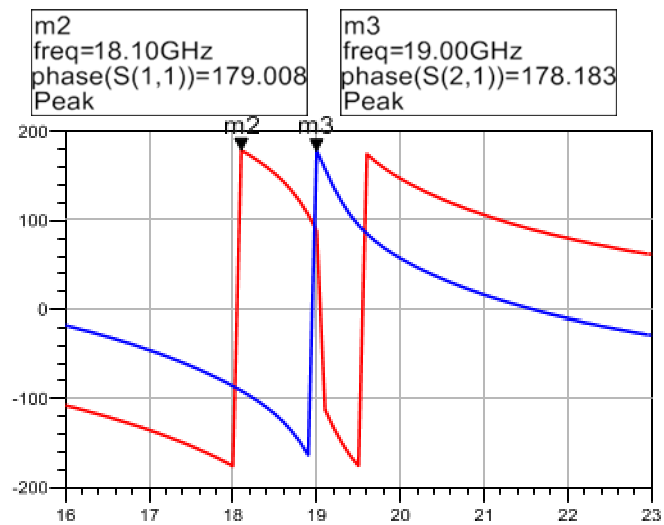

Figure 7: Phase S11 and S21 of ring resonator

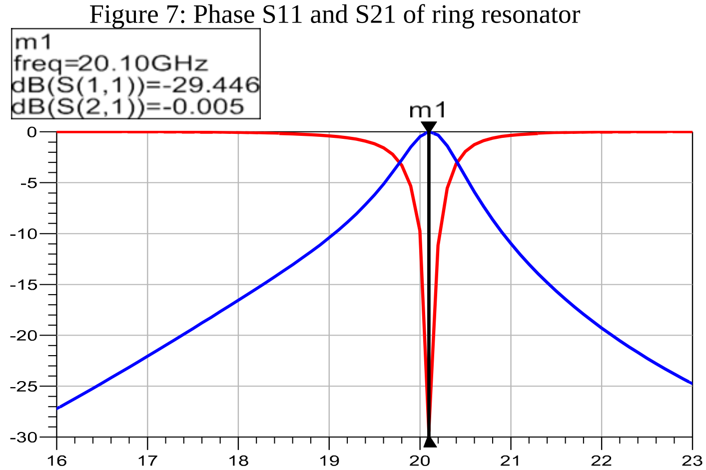

Figure 8: Reflection coefficient (S11) and Transmission coefficient (S21) of ring resonator at 20GHz

We obtained the return loss value as minimum of -29.44dB at the operating frequency of 20.10GHz as shown in Figure 8 which is better for the high frequency with minimum insertion loss and the transmission coefficient is -0.005dB. The magnitude of S11 and S21 are illustrated in the given Figure 9 with value of S11 is 0.034 and S21 is 0.99 at the same operating frequency. Figure 10 demonstrated the phase of ring resonator coefficient of S11 and S21. The S11 is obtained at 18.30GHz is 179.083 peaks and the S21 is obtained at19.80GHz is 178.181 peaks.

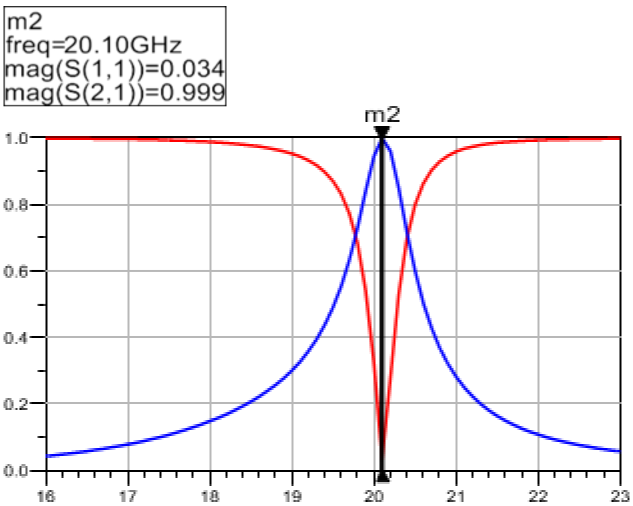

Figure 9: Magnitude S11 and S21 of ring resonator at 20GHz

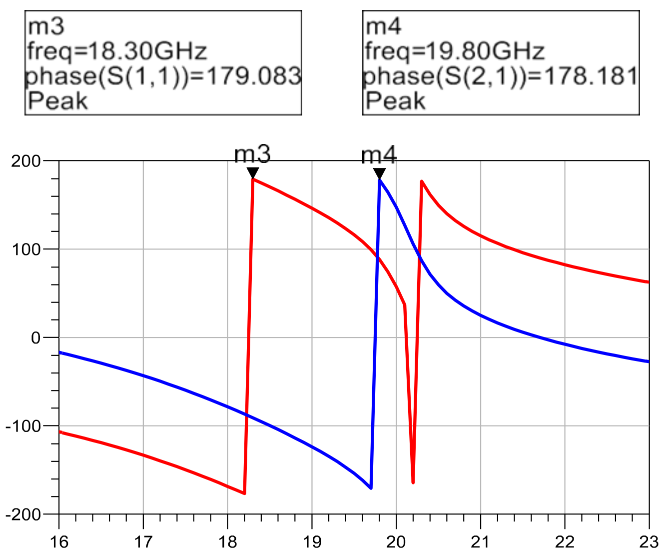

Figure 10: Phase S11 and S21 of ring resonator at 20GHz

The return loss or reflection coefficient (S11) and the Transmission coefficient (S21) are plotted vs frequency as presented in the Figure 11. We obtained the return loss value as minimum of -38.56dB and the Transmission coefficient is - 0.001dB at the operating frequency of 30.2GHz, which is better for the high frequency with minimum insertion loss. The magnitude of S11 and S21 are presented in Figure 12 with value of 0.012 and 1.0 respectively at the same operating frequency. Figure 13 shows the phase of ring resonator coefficient of S11 and S21. The S11 is obtained at 85.396 peaks and the S21 at 175.396 peaks at the operating frequency is 30.20GHz.

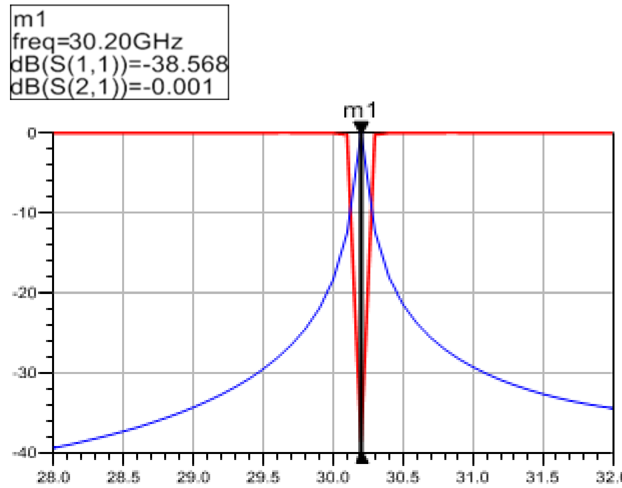

Figure 11: Reflection coefficient (S11) and Transmission coefficient (S21) of ring resonator at 30GHz.

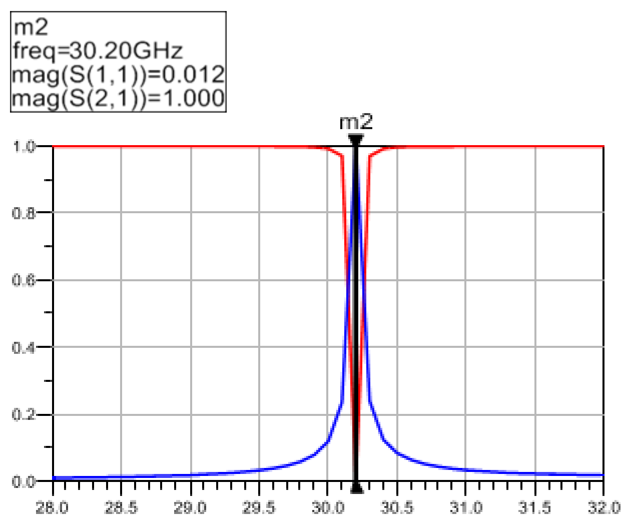

Figure 12: Magnitude S11 and S21 of ring resonator at 30GHz.

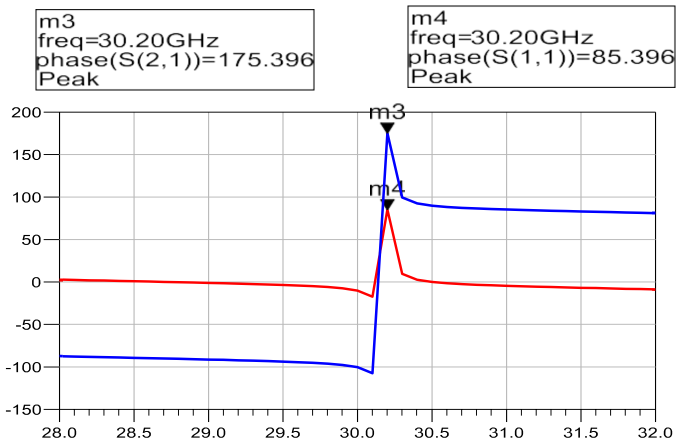

Figure 13 Phase of proposed MRR at 30.20 GHz

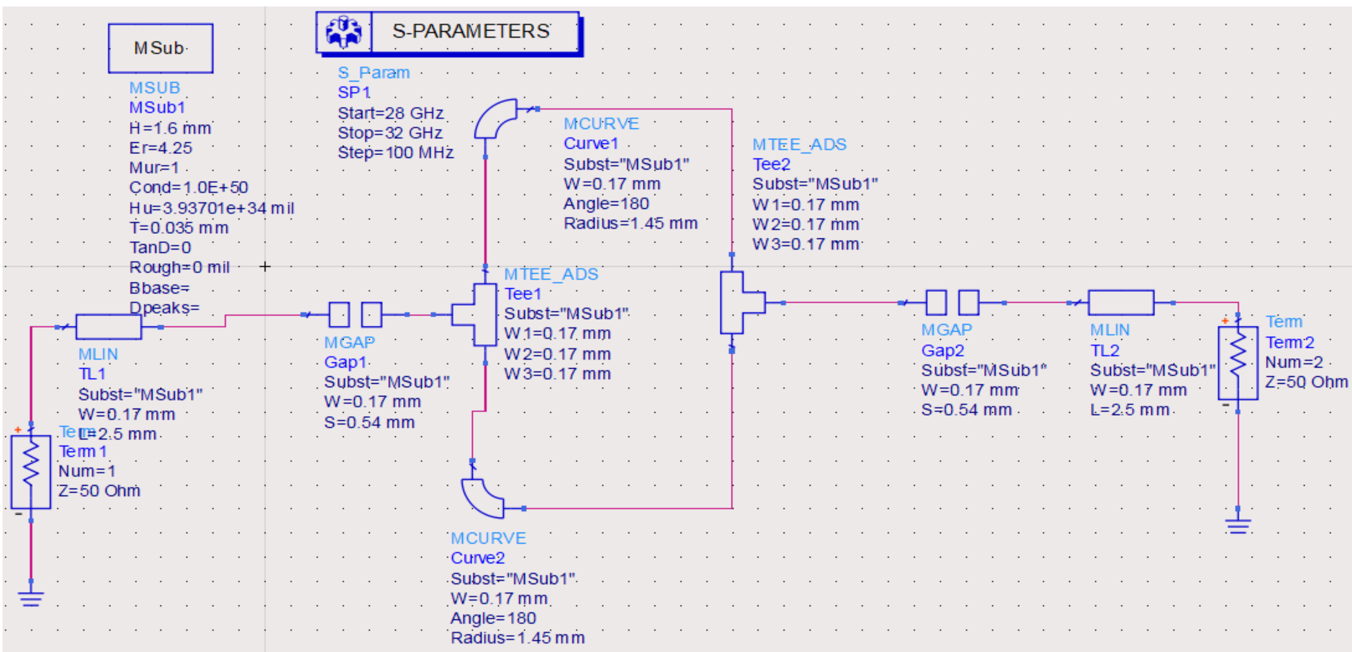

Figure 14: schematic diagram of the proposed MRR using ADS simulation tool.

IV. CONCLUSION

Microstrip ring resonator have numerous advantages due to compact design and flexible frequency ranges. In this paper we propose MRR for 5th generation networks which is the need of the current wireless communication systems. Our designed MRR is able to give excellent results on different operating frequency ranges. We achieved suitable s-parameters for the current 5G communication. The Table II shows the comparison of different values of S-parameters at different operating frequencies. This microstrip ring resonator can be fabricated for the realization of the results achieved through simulation as a future work.

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