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Investigation of the effect of Metamaterial on the Dual band Antenna performance for resonating between GSM 900 & Wi-Fi

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Abstract

In the proposed work, a dual band antenna has been designed and fabricated on a Rogers (RT/Duroid 5880tm) substrate of permittivity 2.2 and thickness 1.6mm for resonating between GSM 900 & Wi-Fi. The novelty of the proposed work lies in loading Split Ring Resonator in the Ground plane of the Antenna for improving the Return loss in the higher band and the radiation pattern. Various antenna performance parameters such as Gain, Bandwidth, Return loss and radiation pattern were investigated with and without meta material loading.

Keywords: GSM, Wi-Fi, SRR, Metamaterial

INTRODUCTION

Present day Wireless Communication systems use dedicated Antennas for supporting fixed wireless communication standards such as GSM, Wi-Fi, DSRC, PCS, DCS and so on. With the tremendous growth of the different types of Wireless Technologies supporting different standards such as 4G,5G and so on, it becomes difficult to use single Antenna tuned to a particular frequency band. The need of the hour is to use the Antennas that are multi-functional and with omni directional radiation pattern. The only solution to this kind of a problem is to use Reconfigurable multi band Antennas which show significant performance in addressing new system requirements. A reconfigurable Antenna is one that can dynamically change its frequency band, polarization, radiation pattern or a combination of these to achieve the desired Frequency band. These Antennas can be realized using different types of Techniques such as Electrical, Optical, Physical or a material change. Electrically reconfigurable Antennas use switches such as PIN diodes to either connect or disconnect a particular portion of the Antenna to achieve Frequency configurability. However they suffer from various disadvantages such as presence of biasing lines to activate the switch which affects the radiation pattern considerably. These switches exhibit nonlinear characteristics and suffer from insertion loss. Optical switches use GaAs photodiode that result in conduction of electrons from valence band to conduction band when the Laser light is made to fall on the device. But again the problem here is that the activation mechanism requires Laser for its operation and optical switches too exhibit lossy characteristics. Physically reconfigurable Antennas do not need any kind of switches or activation mechanism but again it depends on the limitation of the Antenna structure to be reconfigured. The use of smart materials such as ferrites and liquid crystals in the space filling the dielectric show a change in the resonant frequency of the Antenna but they suffer from low tenability range and low efficiency. They require electrodes and a voltage source for applying the bias voltage which further complicates the design. To overcome the above mentioned problems multi band frequency reconfigurable Antennas are a solution to this problem where in independent tuning can be obtained for a particular frequency bands of interest by using metamaterial loading either on the Antenna surface or in the Ground plane, cutting of slots of different shape on the Antenna structure or by using a partial Ground plane to give a Monopole like characteristic [1]. In [2], a novel 9-shaped multiband frequency reconfigurable monopole antenna was designed using PIN diodes for wireless applications on a 1.6 mm thick FR4 substrate loaded with a truncated metallic ground surface. The designed antenna operated for both single and dual frequency band based on switching states. When the switch was turned OFF, the antenna operated in a single band mode namely Wi-Max, resonating at 3.5 GHz. Consequently when the switch was turned ON, the Antenna resonated at 2.45 GHz and 5.2 GHz .The proposed structure resulted in a gain of 1.48dBi, 2.47dBi and 3.26dBi for 2.45 GHz,3.5 GHz and 5.2 GHz respectively. The proposed antenna showed a reasonable value of VSWR below 1.5 for all the three frequencies indicating a good impedance match. In [3], a tri-band monopole antenna for WLAN/Wi-Max applications was proposed which consists of a horizontal H-shaped patch, an L-shaped open ended stub loaded with deformed inverted T-shaped strip. The bandwidths of the proposed antenna were 340MHz (2.4-2.74 GHz), 340MHz (3.41-3.75 GHz) and 640MHz (5.24-5.88 GHz) for WLAN, lower Wi-Max and upper Wi-Max bands respectively. The Antenna Gain reported were 2.08dBi, 1.93dBi and 2.48dBi for 2.5GHz, 3.5GHz and 5.8GHz respectively. The proposed antenna resulted in a compact size along with nearly omnidirectional radiation characteristics. In [4], a novel compact dual-band monopole antenna using Defected Ground Structure (DGS) was presented for resonating at 2.5GHz and 3.5GHz respectively. The proposed antenna resulted in a Bandwidth of 400MHz and 530MHz for 2.5GHz and 3.5GHz respectively. The radiation pattern was nearly Omni directional with constant Gain in both the Frequency bands of interest. In [5], a dual band antenna based on fractal geometry using CPW feed is proposed on a FR4 substrate for GSM900 and Wi-Fi frequency bands respectively. The antenna resulted in a gain of 2.41dBi, 6.24dBi, a bandwidth of 111MHz and 107MHz for the lower and upper bands respectively. The return loss of the proposed Antenna were - 21.0dB,-28.75dB for both the bands respectively. The proposed Antenna was compact with a dimensions 70mm×70mm . In [6], novel design of a dual-band Microstrip antenna loaded with Complementary Split Ring Resonators (CSRRs) resonating at 3.71GHz and 5.28GHz were presented. The resultant Antenna showed a Gain of 5.2dBi and 6.4dBi for 3.7GHz and 5.2GHz respectively. The dual band was realized by etching three CSRRs in the ground plane of a conventional patch antenna. The proposed antenna shows good performances at both resonant frequencies. The CSRRs embedded in the ground plane primarily affected the first operating band but showed minor effect on the second operating band. The radiation pattern was nearly Omni directional in the 3.7GHz band and hemispherical for the 5.7GHz band. In [7], a novel fractal antenna for GSM applications is proposed. This antenna uses second iteration of Sierpinski carpet for fractal geometry. This antenna radiates at 900MHz and 1.8GHz and gives an Omni directional radiation pattern. The antenna gives a return loss of -23dB and -17.0dB, Gain of 2.79dBi and 2.67dBi for 900MHz and 1.8GHz frequency band respectively. It covers a frequency band of 100 MHz at resonant of 900 MHz and 80 MHz at 1800 MHz. The reported Antenna dimensions were 13.65cm×10.7cm×0.24cm. In[8],a dual band Microstrip fractal antenna using a Sierpinski triangle shape along with a modified ground plane is proposed. The antenna resonates at three frequencies 1.58GHz (GPS band), 3.5GHz and 5.6GHz (WiMAX band). The proposed antenna gives a gain of 4.1dBi, 3.75dBi and return loss of -24dB, -15dB and -20dB for 1.58GHz, 3.5GHz and 5.6GHz respectively. The Bandwidths reported were 50MHz and 250 MHz for the lower and upper bands respectively. The Antenna is designed on a FR4 substrate and is compact with dimensions of 50mm×50mm. In [9], dual band David fractal Microstrip patch antenna for GSM and WiMAX applications has been proposed. The antenna resonates at 1.8GHz and 3.4GHz and gives good radiation pattern and moderate gains of 6.93dBi and 5.3dBi for 1.8GHz and 3.4GHz respectively. The antenna gives a return loss of -18.7dB, -14.3dB for 1.8GHz and 3.4GHz respectively. The radiating structure resulted in a -10dB impedance bandwidth of 55MHz and 31MHz, Gain of 6.93dBi and 5.3dBi for the lower and upper bands respectively. The radiation patterns reported were hemispherical for 1.8GHz and horizontal figure of 8 for 3.5GHz respectively. In [10], a Dual band fractal monopole antenna suitable for a Long Term Evolution (LTE) standard has been proposed on an Arlon.

ANTENNA DESIGN

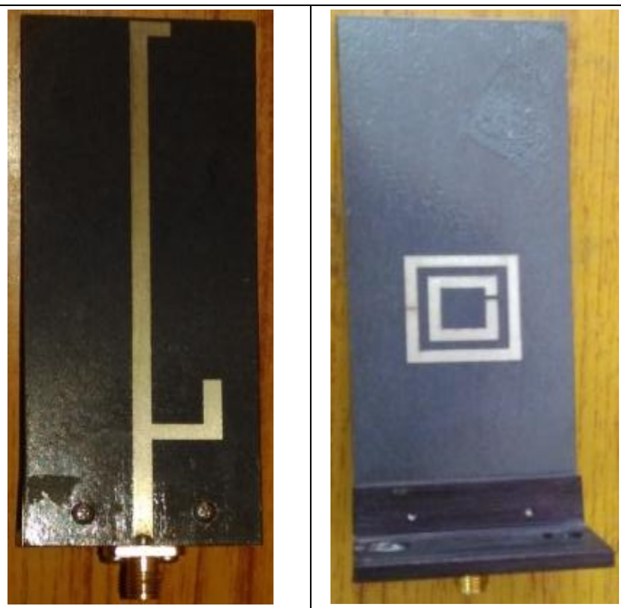

Figure 1: (a) Snapshot of the Dual band Antenna on Rogers **(b)** Split Ring resonator in the Ground plane.

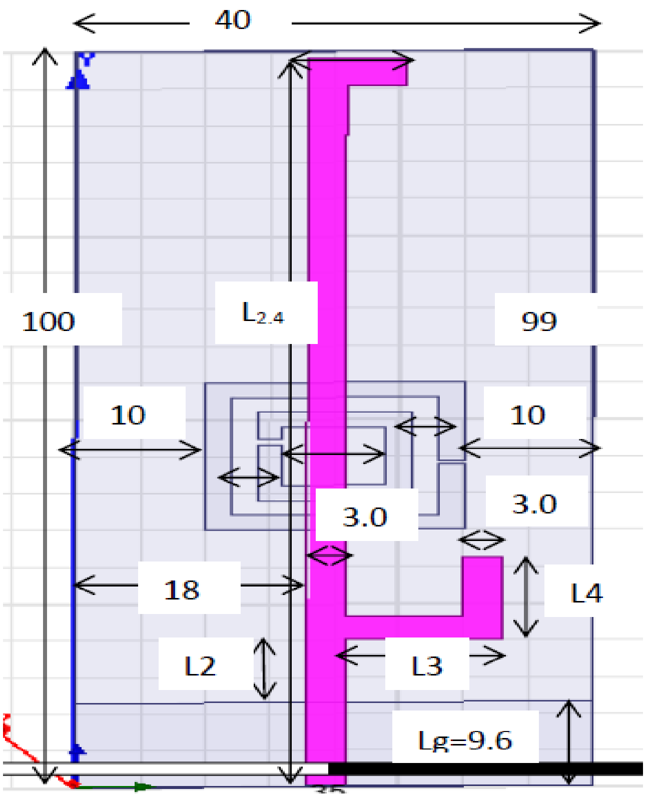

Figure 2: Snapshot of the Simulated dual band antenna on Rogers substrate with a permittivity of 2.2 and 1.6mm thickness.

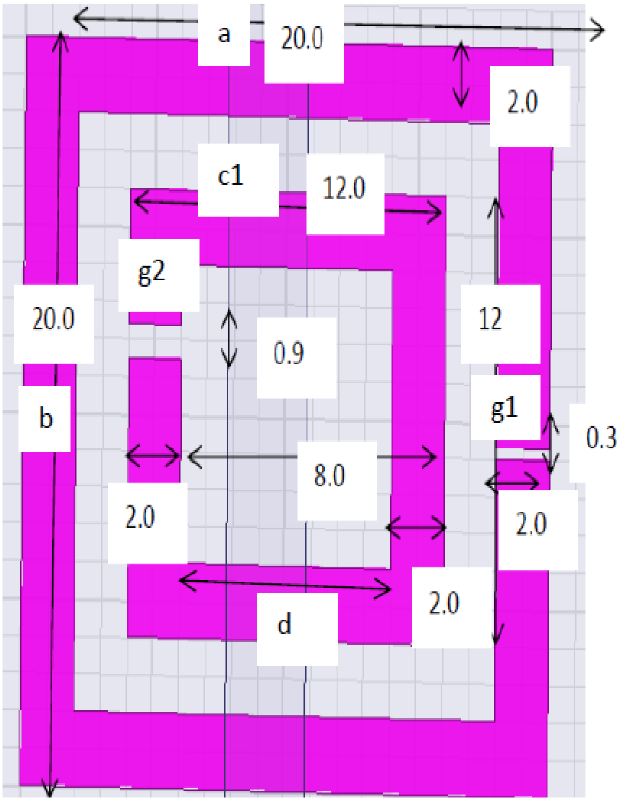

Figure 3: Snapshot of the Split Ring Resonator in the Ground plane in HFSS

METHODOLOGY

In the proposed work a dual band Antenna has been designed, simulated and Fabricated on a Rogers substrate of permittivity 2.2 and thickness 1.6mm to tune between GSM 900 and Wi-Fi (2.4GHz) Frequency band. The longer conductor is designed to resonate at GSM 900 Frequency band while the shorter strip is used to resonate for getting the 2.4GHz Frequency band. To improve the return loss a Split ring Resonator has been printed on the Ground plane. The outer split Ring is designed for GSM 900 Frequency band and the shorter one is designed for getting the 2.4GHz band. Here the effect of the split Ring is to absorb any spurious radiations entering into the antenna strucuture and make the pattern Omni directional. Here monopole class of Antenna structures are investigated that give reduction in the size of the structure which are characterized by a partial Ground plane.

DESIGN EQUATIONS

$$L1 = L_{0.9GHz} = \frac{\lambda g}{4} \quad (1)$$

Where L1=Length of the Main Monopole resonating at 0.9GHz.

λg=Guide wavelength.

$$\lambda g = \frac{\lambda_0}{\sqrt{\varepsilon_{reff}}} \quad (2)$$

Where ε_{reff}= Effective electrical permittivity of the dielectric substrate.

Where λ_0=Free space wavelength corresponding to frequency of operation.

$$\varepsilon_{\text{reff}} = \left[\left(\frac{\varepsilon_r + 1}{2}\right) + \left(\frac{\varepsilon_r - 1}{2}\right)\left(1 + \frac{12h}{W}\right)^{\frac{-1}{2}}\right] \quad (3)$$

Where ε_r =Relative permittivity of the substrate.

W=Width of the Monopole Antenna

h= substrate thickness.

$$Z=\frac{60}{\sqrt{\varepsilon_{reff}}} ln\left[\frac{8h}{W} + \frac{W}{4h}\right] \quad (4)$$

$$L2+L3+L4=L_{2.4\,GHz} = \frac{\lambda g}{4} \quad (5)$$

Where L2, L3 and L4 represent the side Lengths of the Monopole section.

$$Ls=6h+ L \quad (6)$$

$$Lw=6h+W \quad (7)$$

Where Ls=Substrate Length and Lw=Substrate Width

$$fr1 = \frac{c}{4(a + b - 2g1)\sqrt{\varepsilon_{reff}}} \quad (8)$$

Where c=Velocity of light=300000000m/sec

a= length of outer SRR

b= Width of the outer SRR

g1=gap width of the outer SRR

fr1=Resonant frequency corresponding to 0.9GHz

$$fr2 = \frac{c}{4(c1 + d - 2g2)\sqrt{\varepsilon_{reff}}} \quad (9)$$

c1= length of inner SRR

d= Width of the inner SRR

g2=gap width of the inner SRR

fr2=Resonant frequency corresponding to 2.4GHz.

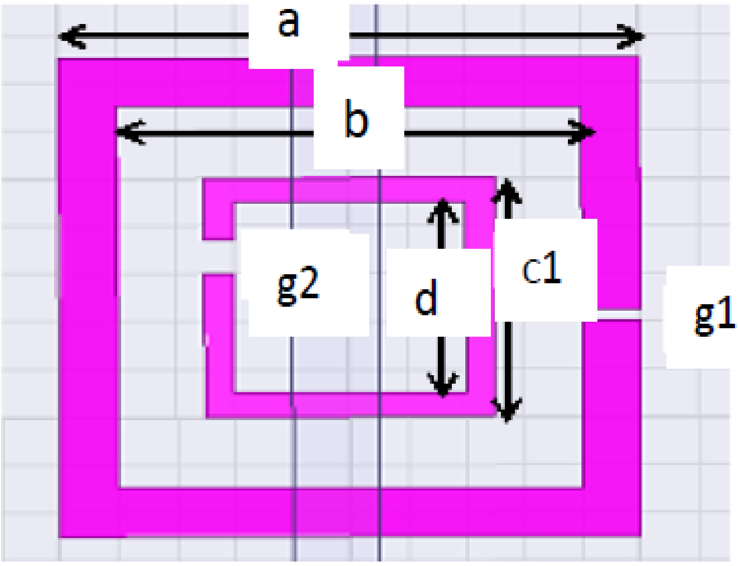

Figure 4: Nomenclature of the Split Ring Resonator

SIMULATIONS & MEASURED RESULTS

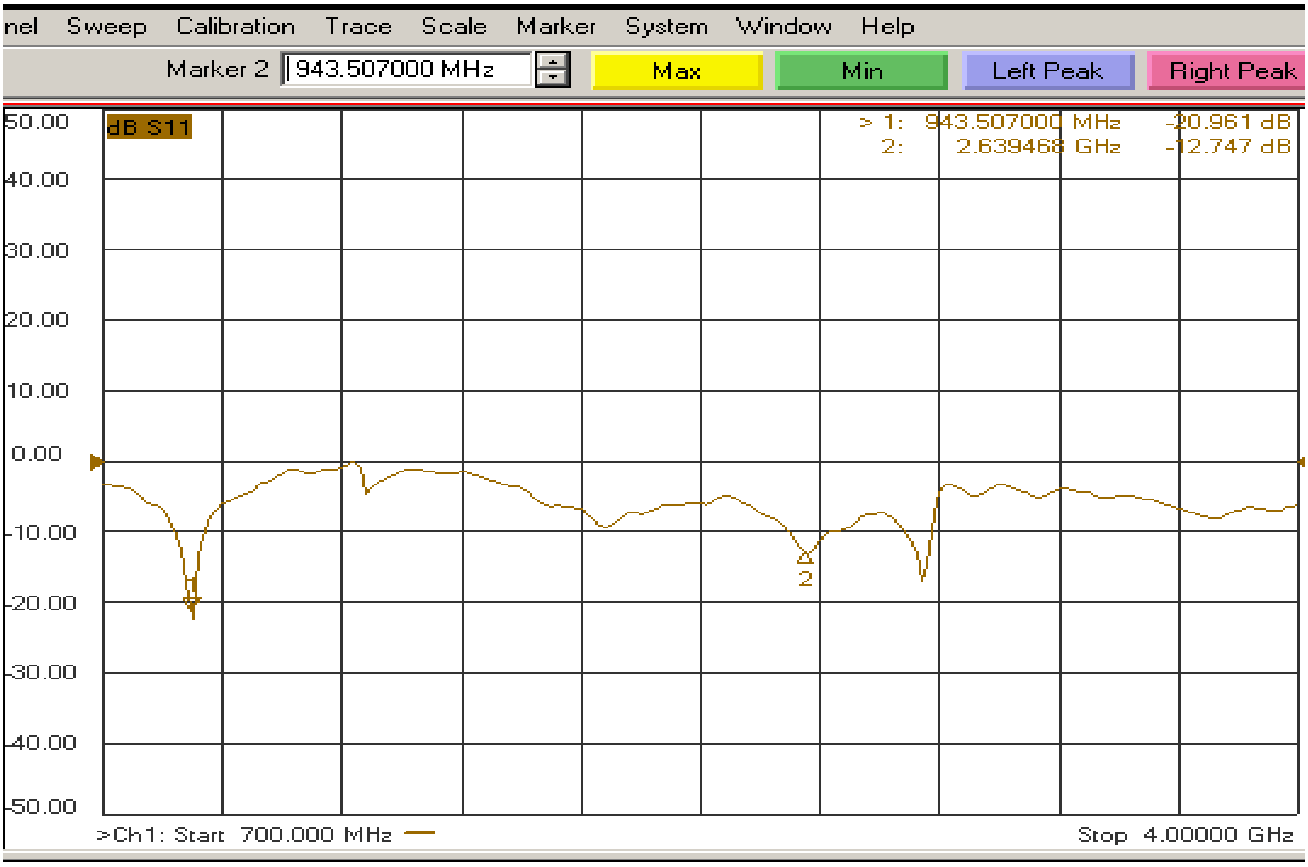

Figure 5: Snapshot of the measured Retun loss value of the Dual band Antenna as taken from the Vector Network Analyzer .As can be seen the measured return loss value is -20.96dB & -12.747dB 0.9GHz and 2.6GHz respectively.

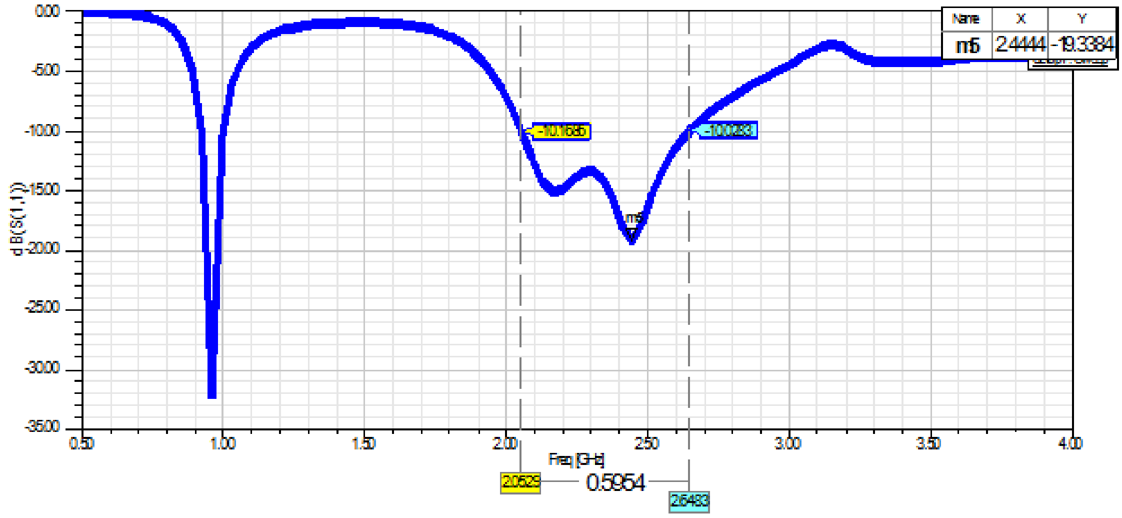

Figure 6: Snapshot of the Simulated Retun loss and bandwidth of the Antenna resonating at 2.4GHz.The reported values are -19.33dB and 595.4MHz respectively with meta material loading.

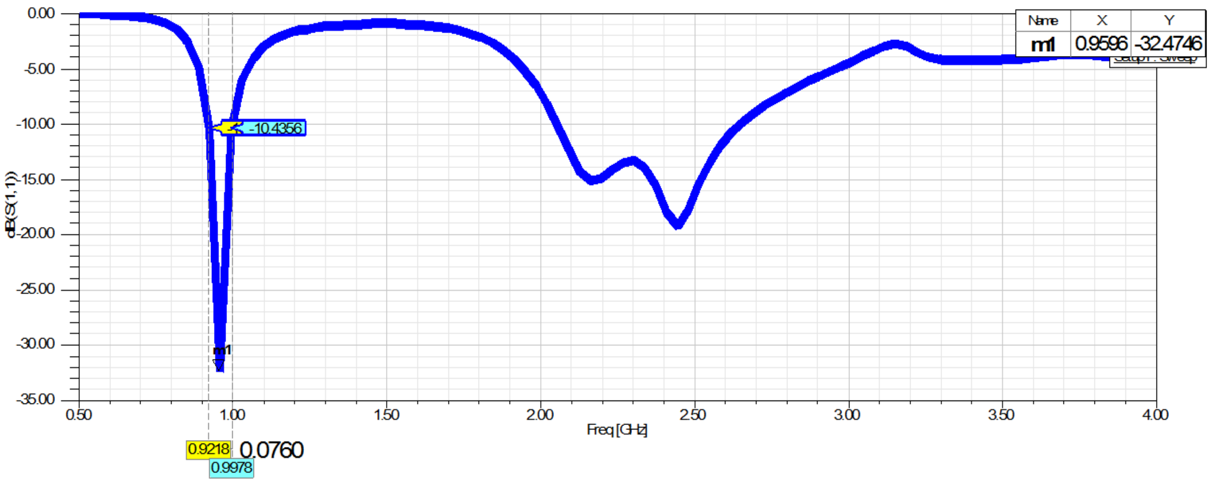

Figure 7: Snapshot of the Simulated Retun loss and bandwidth of the Antenna resonating at 0.9 GHz.The reported values are -32.476dB and 76.0MHz respectively at the GSM 900 frequency band with meta material loading.

Figure 8: The Simulated return loss values of the Antennas are -27.63dB and -10.79dB for 0.9GHz and 2.4GHz frequency bands respectively without meta material in the ground plane.The reported value of the Bandwidth are 0.075GHz for GSM band.

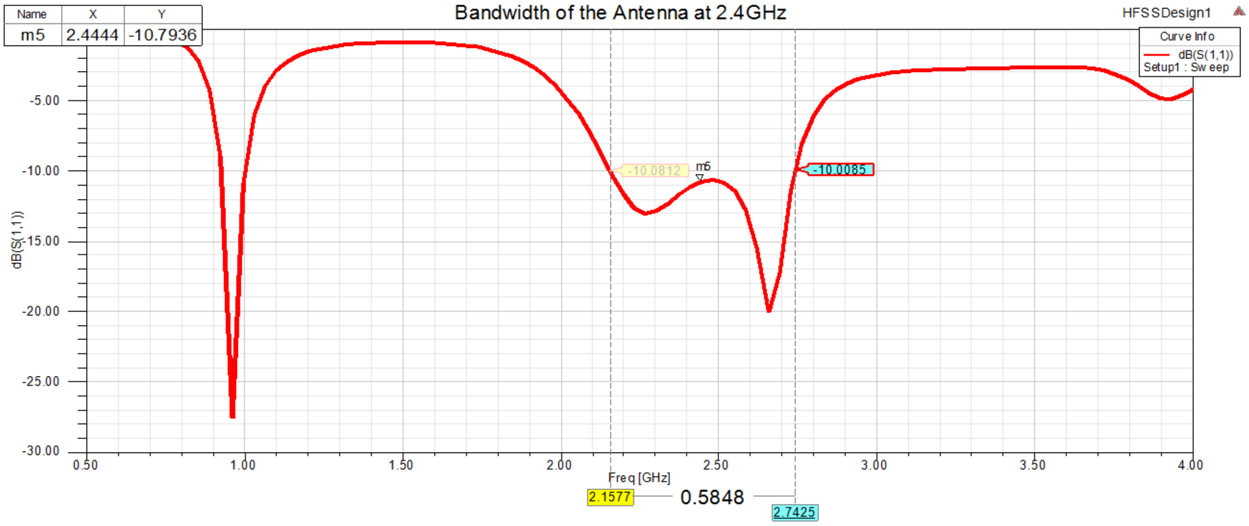

Figure 9: The simulated Bandwidth of the Antenna resonating at Wi-Fi (2.4GHz) band.The value reported is 0.5848GHz at the 2.4GHz band.

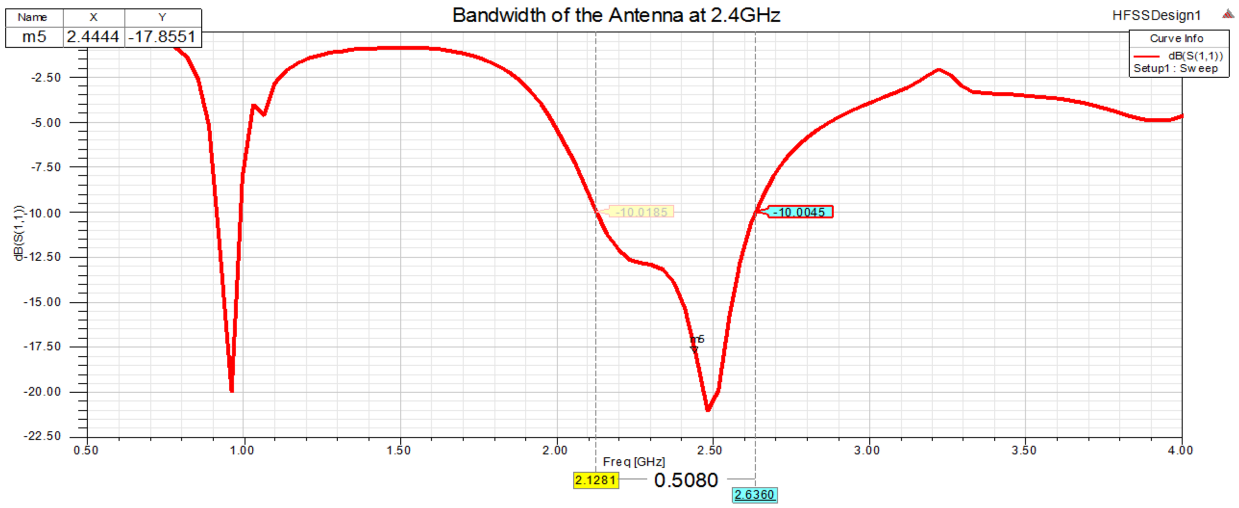

Figure 10: Snapshot of the Bandwidth of the Antenna resonating at 2.4GHz.The reported values are 0.508GHz at the 2.4GHz Frequency band with retaining only the outer ring

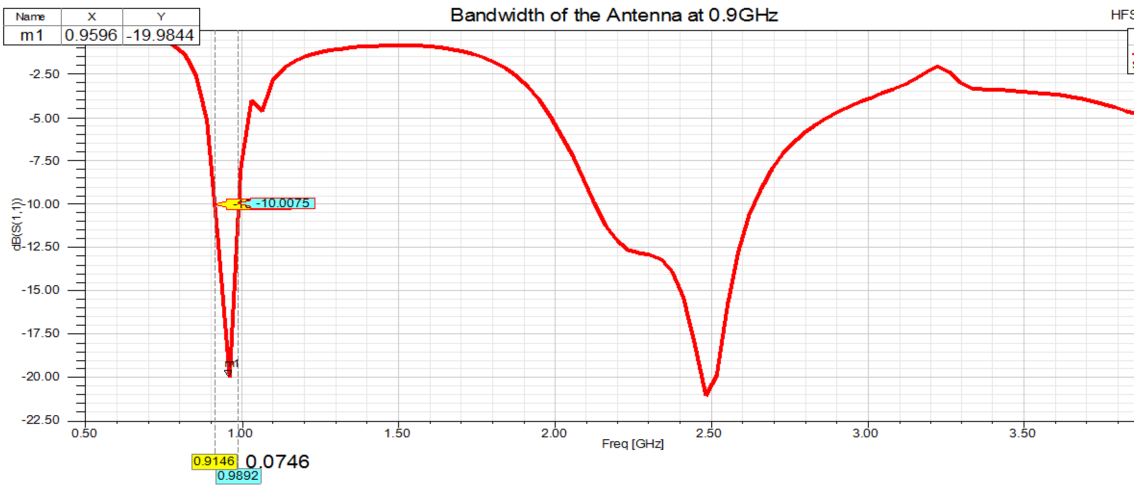

Figure 11: Snapshot of Bandwidth of the Antenna resonating at 0.9 GHz. The reported values are 0.0746GHz with retaining only the outer ring.

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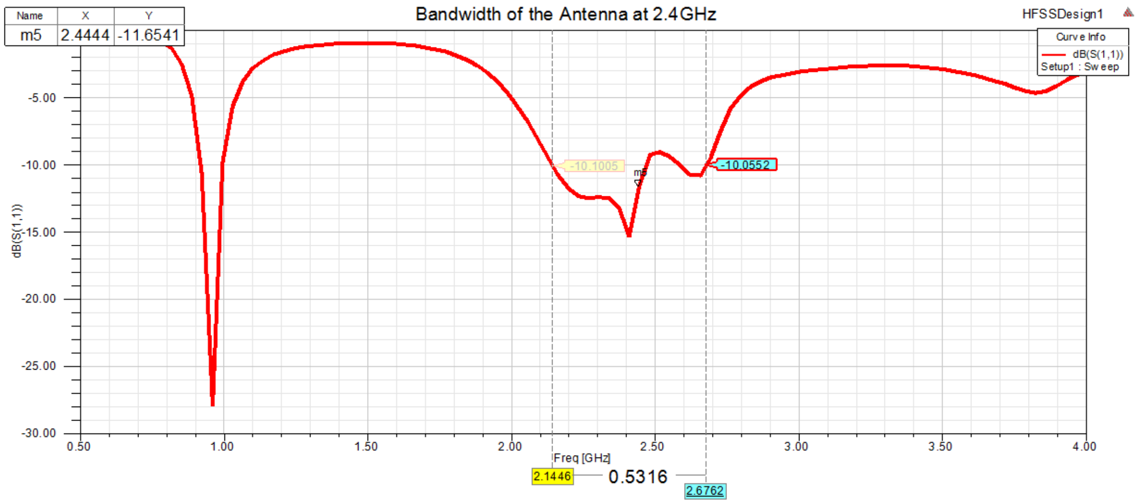


Figure 12: Snapshot of the Bandwidth of the Antenna resonating at 2.4GHz.The reported values are 0.531GHz at the GSM 900 Frequency band with retaining only the inner ring.

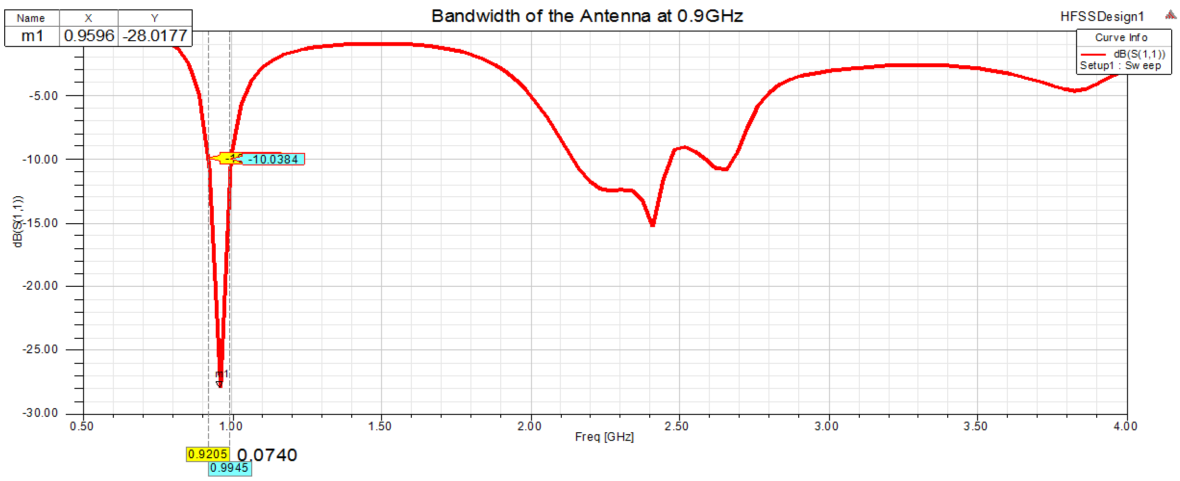


Figure 13: Snapshot of the Bandwidth of the Antenna resonating at 0.9GHz.The reported values are 0.0740GHz AT THE GSM 900 FREQUENCY BAND WITH RETAINING ONLY THE INNER RING.

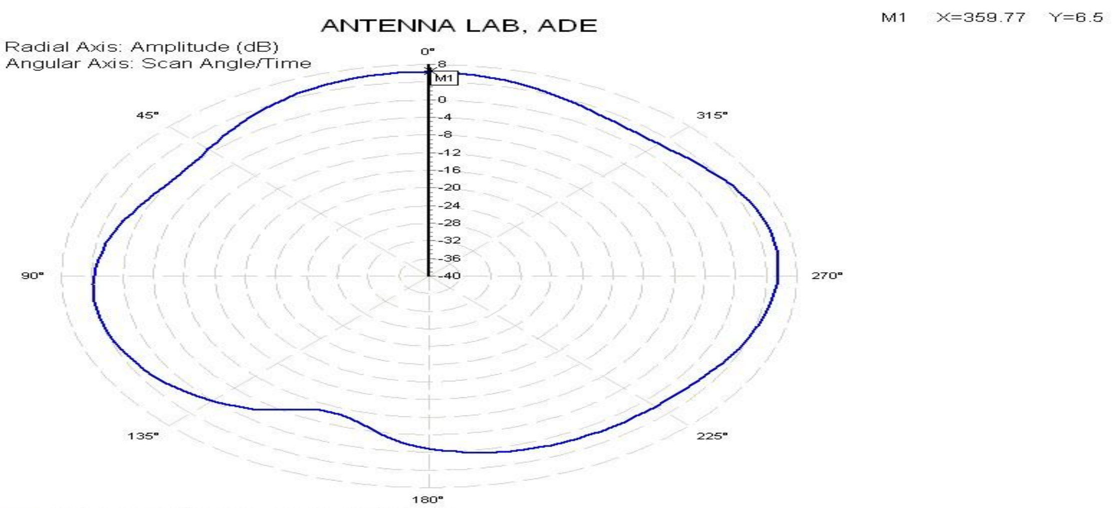


Figure 14: Snapshot of the measured Antenna radiation pattern under H plane at 0.9GHz. The pattern is nearly omni directional with a peak boresight Gain of 6.5dB.

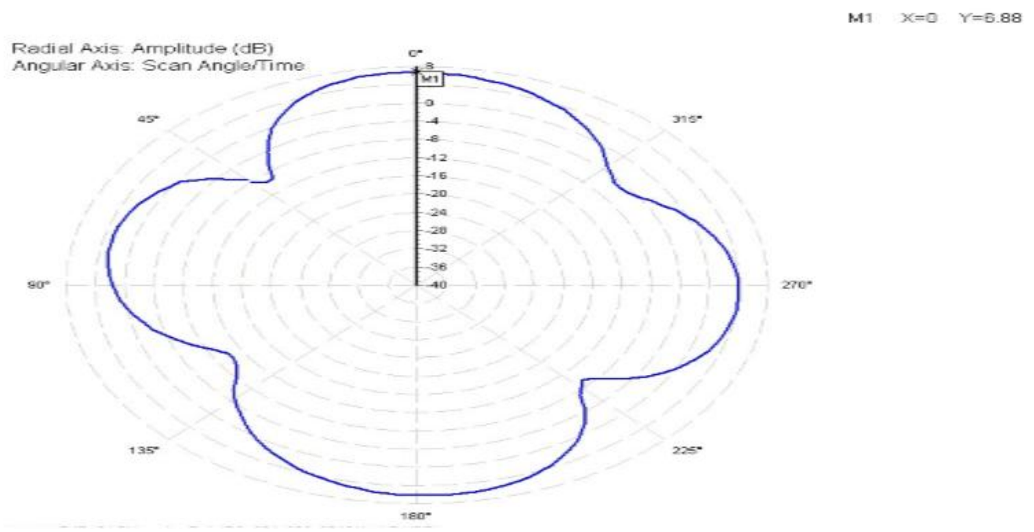


Figure 15: Snapshot of the measured Antenna radiation pattern under H plane at 2.4GHz. The pattern is nearly omni directional with a peak boresight Gain of 6.88dB.

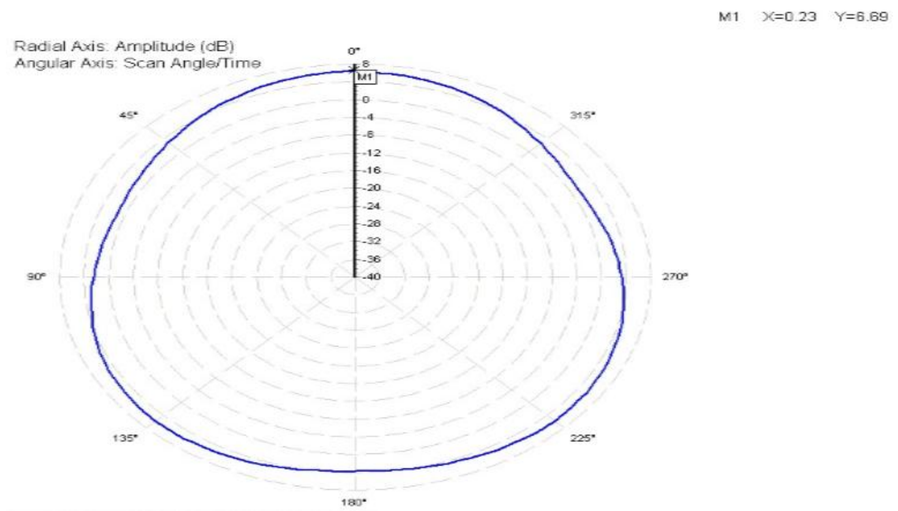


Figure 16: Snapshot of the measured Antenna radiation pattern under E plane at 0.9GHz. The pattern is nearly Omni directional with a peak boresight Gain of 6.69dB.

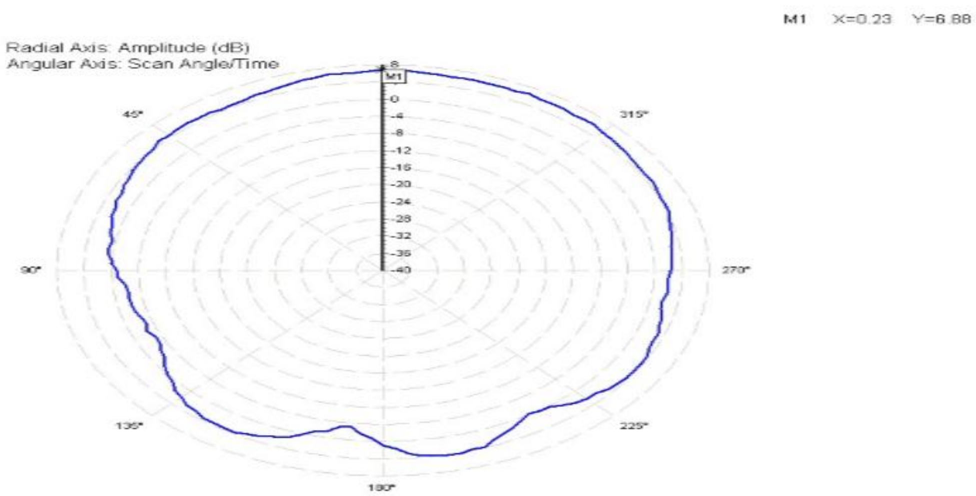


Figure 17: Snapshot of the measured Antenna radiation pattern under E plane at 2.4GHz. The pattern is nearly Omni directional with a peak boresight Gain of 6.88dB.

RESULTS AND DISCUSSIONS

In the proposed work on dual band Antenna loaded with a metamaterial,the measured return loss values reported were -20.96dB and -12.74dB while the simulated return loss values were close to -32.47dB (GSM) & -19.33dB (Wi-Fi) indicating that the antenna radiates efficiently in both the lower and the upper band respectively. The simulated VSWR values were 1.26 (GSM 900) and 1.24(Wi-Fi) indicating a good impedance matching at both the Frequency bands of interest. The measured peak Gain stood at 6.69dB (GSM 900) and 6.88 dB (Wi-Fi) under E plane. In the case of H plane, the peak Gains reported were 6.5dB(GSM900) and 6.88dB(Wi-Fi) ,where in the Gain variation was in the range from 6.5dB(2.4GHz H plane) to 6.88dB under(2.4GHz H,E plane).The simulated and measured Bandwidths agree well. The measured Bandwidths reported were 79MHz (GSM) and 97MHz (Wi-Fi). The measured pattern was Omni directional under H plane with a peak Gain of 6.69dB (GSM 900) and 6.88dB (Wi-Fi).Under E plane the pattern reported was nearly Omni directional with a peak boresight gain of 6.69dB(GSM 900) and 6.88dB(Wi-Fi).

Table 1. Showing the comparison of the simulated and measured results of the Dual band antenna resonating at GSM 900 & Wi-Fi bands with metamaterial loading

Sl No	Antenna parameters	Simulated		Measured	
1	Resonant Frequency (GHz)	0.9	2.4	0.94	2.6
2	Return loss(dB)	-32.47	-19.3	-20.96	-12.74
3	VSWR	1.26	1.24	1.2	1.65
4	Gain(dB)	6.7	7.07	6.69(E) 6.5(H)	6.88(E) 6.88(H)
5	Bandwidth (GHz)	0.076 (0.92 to 0.997)	0.595 (2.05 to 2.64)	0.079 (0.896 to 0.975)	0.097 (2.59 to 2.687)

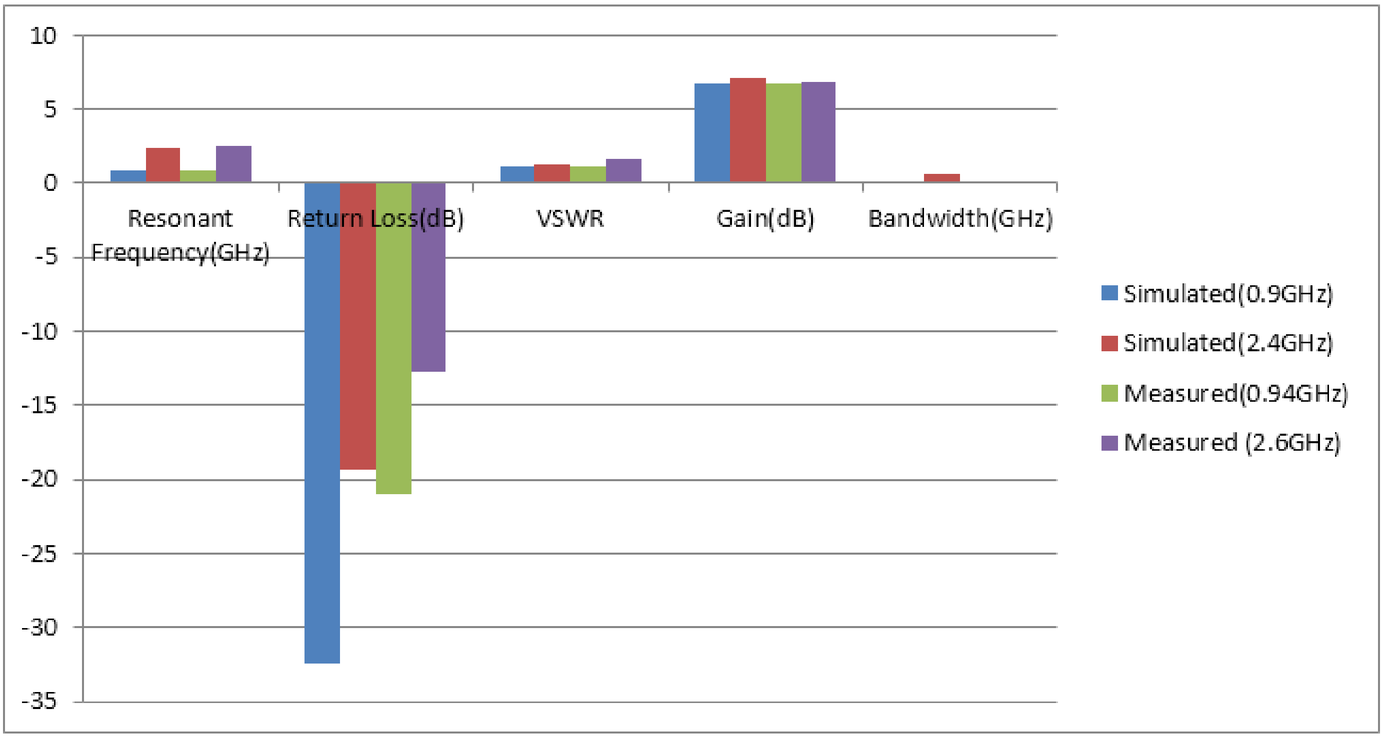
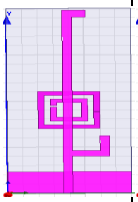
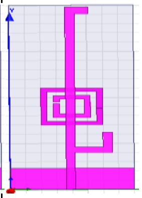
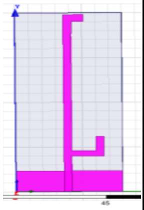
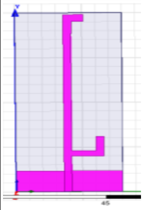
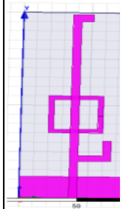
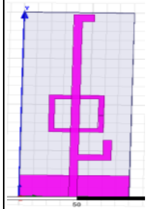
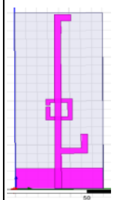
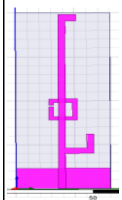


Figure 18: Showing the comparison of the simulated and measured Antenna performance parameters such as Resonant Frequency, Return Loss, VSWR, Gain and Bandwidth of a dual band Antenna resonating at 0.9GHz and 2.4GHz respectively with Metamaterial loading

Table 2. Comparison of the Simulated Antenna parameters of a Dual band Antenna resonating between GSM (900) and Wi-Fi (2.4GHz) on a Rogers substrate (RT/Duroid permittivity 2.2 and thickness 1.6mm) under different configurations

	0.9GHz with SRR 	2.4GHz with SRR 	0.9GHz without SRR 	2.4GHz without SRR 	0.9GHz with outer ring 	2.4GHz with outer_ring 	0.9GHz_ with inner ring 	2.4GHz_ with inner_ring 
Return Loss(dB)	-32.47	-19.33	-27.63	-10.79	-19.9	-17.85	-28	-11.6
VSWR	1.2	1.24	1.3	1.8	1.3	1.2	1.2	1.7
Gain(dB)	6.7	7.07	6.67	7.02	6.63	7.016	6.6	7.06
Bandwidth (GHz)	0.076	0.595	0.075	0.58	0.074	0.507	0.074	0.326

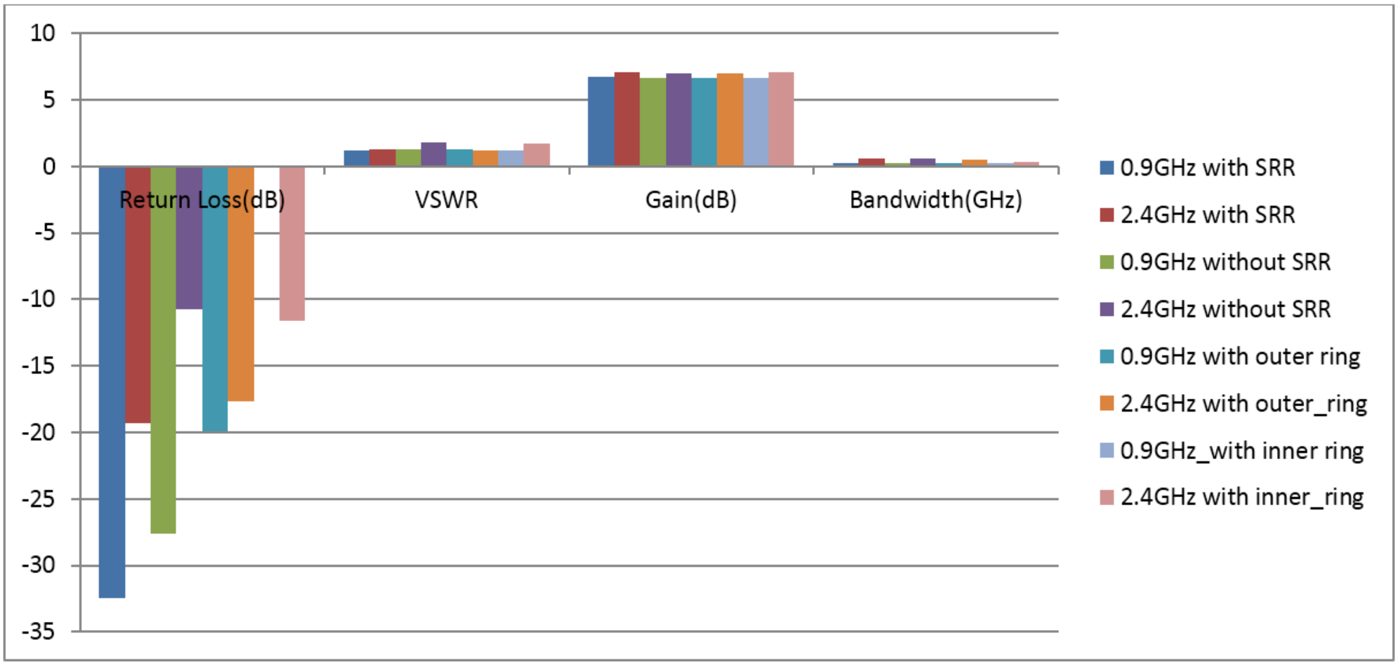


Figure 19 Showing the comparison of the Simulated Antenna structure designed using Rogers's substrate under different configurations of the Antenna structure

CONCLUSION

The metamatrial loading in the Ground plane has the effect of improving the Return Loss, Gain and Bandwidth in the GSM 900 & Wi-Fi (2.4GHz) band when compared to that without metamaterial loading. The outer Ring has the effect of lowering the return loss value in the GSM band (-27.63dB to -19.9dB) but has improved the S11 value in the Wi-Fi band(-10.79dB to -17.65dB) but has no significant effect on the Gain and Bandwidth when compared to without metamaterial loading.The inner ring has the effect of marginally improving the Return loss value in both the bands when compared to without meta material loading.

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