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INVESTIGATION ON COMPACT, HIGH GAIN MICROSTRIP ANTENNA PROVIDING MULTIFREQUENCY OPERATION

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Abstract: Simulated and experimental investigations on a compact, single layer and single probe fed circular Microstrip patch antenna with multi-frequency operation are presented in this paper. This novel design is achieved by cutting four rectangular slots at ground plane of Microstrip patch antenna. Generally Microstrip antenna exhibits narrow bandwidth and single or dual frequency operations. After modifications researchers have been able to design the antenna to have broad band, compactness or multi frequency operation or any one of them. However in this paper two characteristics have been achieved simultaneously. One is compactness and other is multi frequency operation. Compared to the conventional circular patch antenna the proposed antenna can achieve 94% size reduction. Septa frequency operation has also been achieved effectively by adjusting the number of circular ring, their size and feed position. Simulated investigations are done by Ansoft Designer software based on method of moment. Measurement is done using standard microwave test bench.

Keywords: Microstrip antenna; return loss; multi-frequency; Ansoft Designer; radiation pattern

1. INTRODUCTION

Micro strip patch antennas are widely employed in many practical applications due to low profile, light weight, low cost, conformability, ease of fabrication, integration with RF devices etc. [1–4]. Septa-frequency microstrip antennas with a single feed are required in various radar and communication systems, such as in wireless communication viz. 890 MHz to 960 MHz for GSM, 1920 MHz to 2170 MHz for UMTS, 3.4 GHz to 3.6 GHz for WiMAX, 4.9 GHz to 5.9 GHz for WLAN, WiMAX etc. [5]. Researchers have already worked on multifrequency operation of microstrip antenna [6-7]. A good number of research works have also been done on size reduction or compactness [8-12].

In this paper a simple slotted circular, single layered, defective grounded and coaxial probe fed Microstrip patch antenna has been presented. This compact patch antenna can radiate with resonance at seven resonating frequencies of 0.8GHz, 1.04GHz, 2.58GHz, 3.34GHz, 3.44GHz, 4.58GHz and 4.7GHz. This antenna can be used in WiMAX and WLAN application and almost 96% size reduction has been achieved by cutting the unequal slots in ground plane.

2. ANTENNA DESIGN

Fig. 1 shows the geometry of the designed compact linearly polarized antenna. The layout of the antenna has been drawn in Ansoft software designer. A circular patch of size 15mm is circulated by four concentric circular ring patches of unequal width. The outer radius of outer ring is 38mm. The circular ring patch is fed through a coaxial feed. The feeding point is so positioned to obtain best impedance matching.

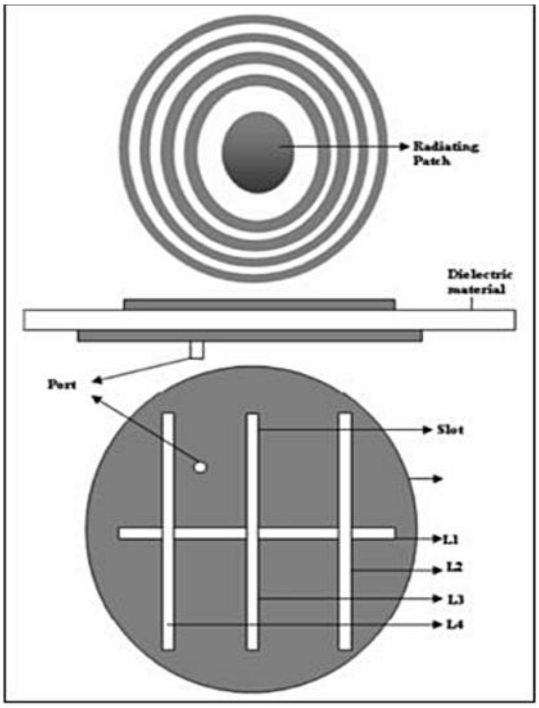

Fig.1 Design of the Antenna with slot

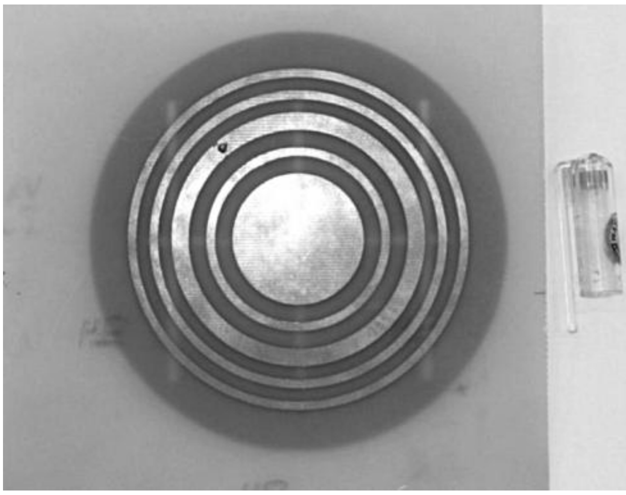

Fig.2 Top view of the fabricated Antenna

For best matching of input impedance, the radiating patch is positioned at the centre with respect to ground plane of the antenna. Four rectangular slots are embedded in the ground plane at the centre position. The crossed slot has unequal lateral lengths, L_1=70mm, L_2=64mm, L_3=64mm and L_4=64mm, with a slot width W=2mm.These patches are printed on FR4 substrate, of permittivity €=4.4 and thickness 1.6 mm. The radius of the ground plane of the circular ring Microstrip patch antenna operating at the frequency of (fr) 3.19GHz is 48mm. The Top view and Bottom view of the fabricated antenna is shown in Fig.2 and Fig.3 respectively.

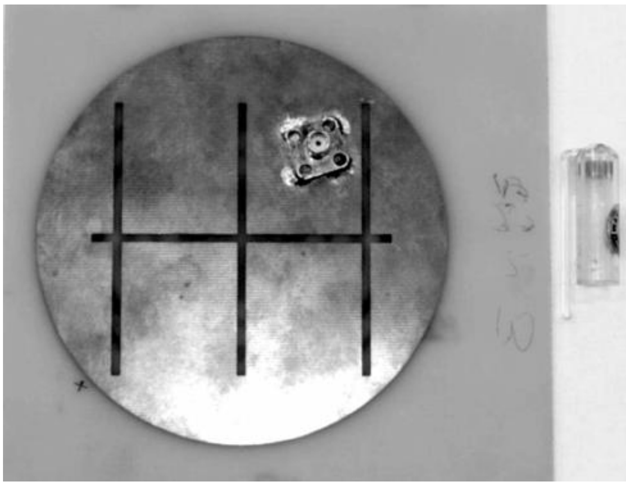

Fig.3 Bottom view of the fabricated Antenna

3. FABRICATION AND MEASUREMENT

For experimental investigation, the proposed microstrip antenna is fabricated on a FR-4 substrate. The gain measurement of the fabricated antenna is performed at the S & L band using a standard microwave test bench. The designed antenna is placed in receiving position.

The transmitting horn antenna is connected to an Agilent microwave source. The designed receiving antenna is connected to an Agilent Power meter. The measurement set up is shown in Fig.4. For the measurement of return loss Agilent made Network Analyser has been used. The return loss of this antenna is measured using Network Analyser.

Fig.4 Picture of the measurement set up

4. RESULTS AND DISCUSSIONS

The radius (a) of the Antenna is calculated from conventional equations

$$a = \frac{F}{\sqrt{\left\{1+\frac{2h}{\pi \epsilon_R F}\left[\ln\left(\frac{\pi F}{2h}\right)+1.7726\right]\right\}}} \quad \text{....... (1)}$$

$$\text{where, } F = \frac{8.971\times10^{9}}{f_r\sqrt{\epsilon_r}} \quad \text{.............................. (2)}$$

$\epsilon_r =$ Relative dielectric constant.

The resonant frequency of the antenna without slot is 3.19GHz and that of slotted antenna is 0.8GHz.

From the equations 1 & 2 one may calculate the radius of the antenna which resonates at a particular frequency. The outmost radii of the antenna with resonant frequency of 3.19 GHz and 0.8 GHz are 1.267cm and 5.2cm. That means if one wants to design an antenna without slotted ground plane to resonate at 0.8GHz, its outer most radius will be 5.2cm. Hence,

compactnes = $[\{\pi\,(5.2)^2 - \pi\,(1.267)^2\}/\,\pi\,(5.2)^2]$ x 100% = 94%. So, one gets 94% size reduction of the designed antenna.

Fig.5 shows the Return loss vs. Frequency plot for antenna without slot. Resonant frequency of the antenna without slot is 3.19GHz and the value of the return loss is -21.22dB.

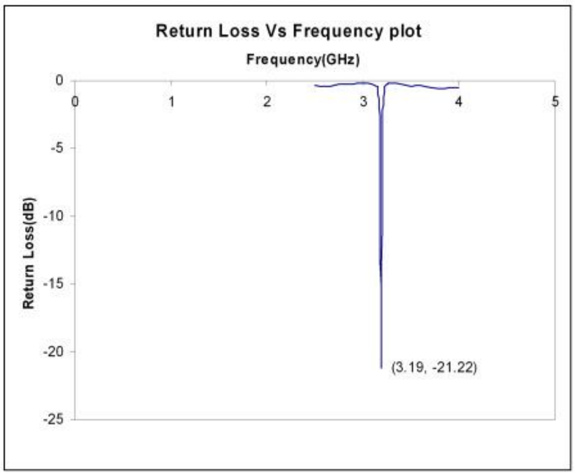

Fig. 5 Return loss vs. frequency plot for the antenna without slot

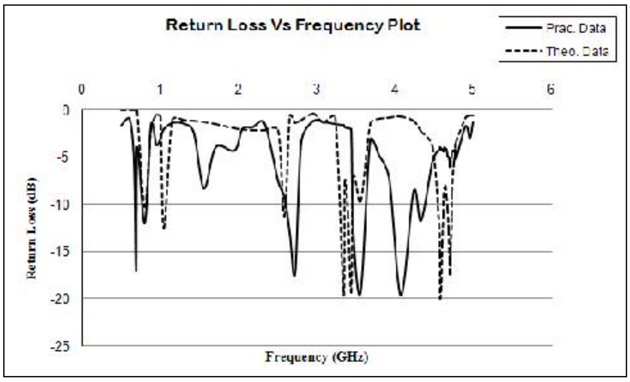

Fig. 6 Return loss vs. frequency plot with theoretical and practical value for the antenna with slot

The theoretical and measured return loss Vs frequency plot of the antenna with slot is shown in Fig. 6. From this figure it is shown that the designed antenna resonates at seven resonant frequencies, and it is also shown that after measurement, the resonant frequencies are shifted at the left side due to fabrication tolerances. Otherwise the theoretical and measured values of return loss and frequencies are almost the same. The theoretical and practical gain vs. frequency plot is shown in Fig.7. The number of resonant frequencies are changed with number of rings, which is shown in Fig.8.

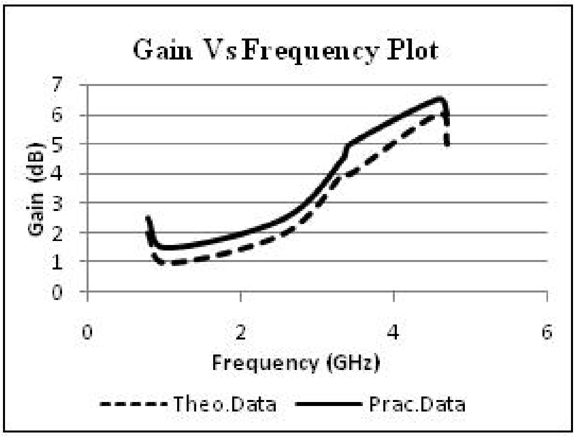

Fig. 7 Simulated and measured gain vs frequency plot

Table 1 Theoretical value of resonant frequencies with their corresponding return losses of antenna with slot

Frequency (GHz)	Return loss (dB)
0.8	-10.29
1.04	-12.48
2.58	-11.25
3.34	-19.58
3.44	-19.26
4.58	-19.9
4.7	-17.4

Table 2 Measured values of resonant frequencies with their corresponding return losses of antenna with slot

Frequency (GHz)	Return loss (dB)
0.68	-17
0.8	-12
2.716	-17.3
3.47	-13
3.56	-19.2
4.07	-19.6
4.336	-11.7

Table 3 Theoretical and measured value of gain of the antenna

Frequency in GHz	Theoretical value of Gain in dBi	Measured value of Gain in dBi
0.8	2	2.5
1.04	1	1.5
2.58	2	2.5
3.34	4	4.5
3.44	4	5
4.58	6	6.5
4.7	5	6

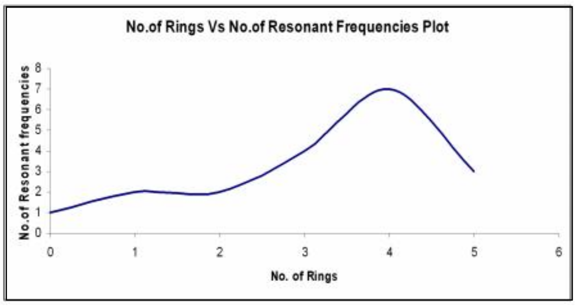

Fig.8 Number of rings vs. number of resonant frequencies plot

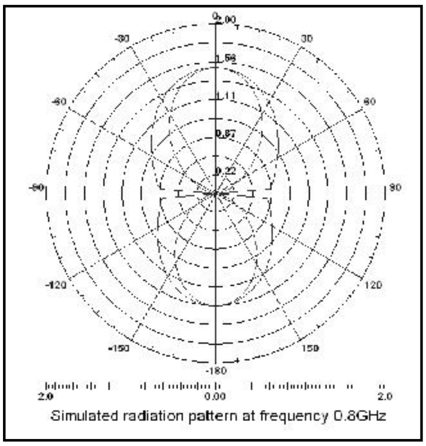

Fig. 9 Theoretical radiation pattern at fr= 0.8 GHz

Table 1 and Table 2 show the theoretical and measured values of resonant frequencies and return losses. From Table 3 it may be observed that measured gains of the antenna at different frequencies are in agreement with the theoretical results.

Table 4 return loss of different concentric annular ring

Number of rings	Without ring	With one rings	With two rings	With three rings	With four rings
Number of resonant frequencies	1	2	2	4	7
Values of resonant frequencies in GHz	2.96	3.02, 3.32	3.24, 4.69	2, 3.32, 3.48, 4.68,	0.8, 1.04, 2.58, 3.34, 3.44, 4.58, 4.7
Return Loss in dB	-14.31	-14.5 -12.1	-13 -4.7	-15.1 -10.74 -19.87 -12.95	-10.29 -12.48 -11.25 -19.58 -19.26 -19.9 -17.4

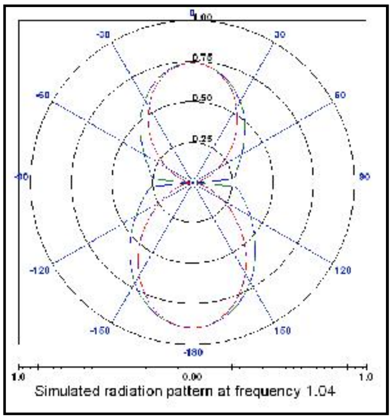

Fig.10 Theoretical radiation pattern at fr = 1.04 GHz

Table 4 shows the comparative study of the theoretical values of the return losses of different antennas loaded with different numbers of rings. The radiation pattern for the antenna with slot at some frequencies 0.8GHz, 1.04GHz, 3.52GHz are shown in the Fig. 9–Fig. 11 respectively. Fig. 12-Fig.14 show the practical radiation pattern of the designed antenna at 0.8GHz, 1.04GHz and 3.53GHz frequencies respectively.

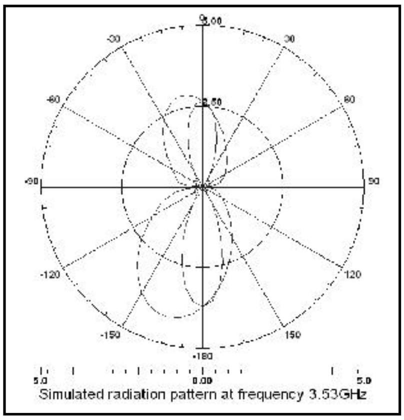

Fig. 11 Theoretical radiation pattern at 3.53 GHz frequency

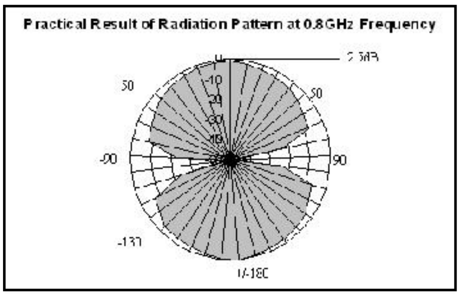

Fig.12 Practical radiation pattern at 0.8GHz frequency

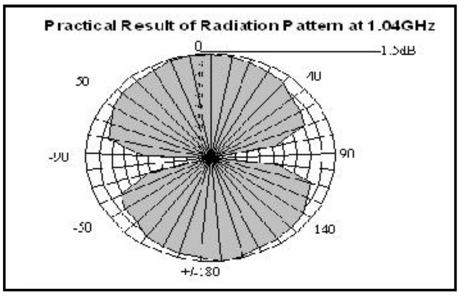

Fig. 13 Practical radiation pattern at 1.04GHz frequency

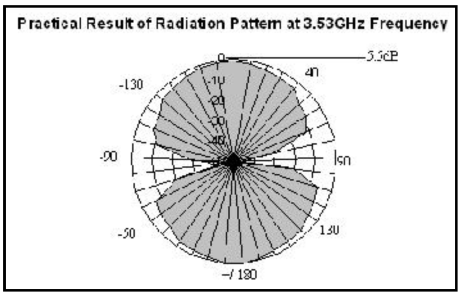

Fig.14 Practical radiation pattern at 3.52GHz frequency

5. CONCLUSIONS

Microwave engineers and researchers are exercising their best effort to achieve size reduction, multifrequency operation and gain enhancement. Different papers are published with any one of the above three achievements. In few journals some research works are reported showing achievements of two qualities among them. However, no past work included all the qualities mentioned above. The proposed antenna operates at seven resonant frequencies. It has been observed that the lowest resonant frequency translates into size reduction of 94%. Highest gain of 6dBi is also achieved. Using this design, seven different antennas can be substituted by one antenna. It is clear that radiation patterns at different resonating frequencies are good and stable. So no doubt this achievement in a single antenna will usher in new era in the field of microwave communication.

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