The Impact of Truncated Ground Structure on the Parameters of Fabricated Microstrip Patch Antenna

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***Abstract*—**In this work a prototype of conventional rectangular microstrip patch antennas (RMPA)with rectangular patch has been practically fabricated on PTFE (Teflon) substrate (dielectric constant=2.1, loss tangent=0.0004) of 1.5mm thickness. The whole size of antenna is 30×30×1.5mm3 with patch dimensions of 20×12×0.035mm3. The antenna was energizedbymicrostrip inset line feed. Significant parameters of antenna like Return Loss, VSWR, Bandwidth and Input Impedance was experimentally measured using Vector Network Analyzer (VNA).Furthermore the length of ground structure of the antenna was reduced to 16mm. The measurements were taken and compared with conventional RMPA. Conventional RMPA resonated at 7.5GHz at a Return Loss of -11.16dB, Voltage Standing Wave Ratio (VSWR)of 1.77 and a -10dB Bandwidth of 174MHz (7.581GHz-7.407GHz). The same antenna with truncated ground structure (TGS) resonated at 1.93GHz giving a Return Loss of -29.44dB, VSWRof 1.10 and -10dB Bandwidth of 312MHz (2.116GHz-1.804GHz). The conventional RMPA may be used for C-Band applications while RMPA with TGS may be used for GSM applications. For a frequency of 1.93GHz the RMPA with TGS presented a miniaturized antenna.

Index Terms—**RMPA, VSWR, VNA,TGS, PTFE (Teflon), Defected Ground Structure**

I. Introduction

Currently, several printed monopole antennas have been suggested through implementingseveral favorable excitationarrangements like the microstripline [1-2] and the co-planar waveguides [3-4]. In these proposed monopole antennae, anoutsized solid ground structuretaking the profile of a square, rectangular, circular or elliptical shape is commonlyapplied. Different from these antennas, a novel ground constructioncalled defected ground structure (DGS) has newly been explored. Producing different shaped defects in the ground structure are found to be aneasy and effective technique to decrease the antenna dimensions as well as to excite extra resonance modes [5-6].In its simplest form Patch Antenna comprises normally of four portions: radiating patch, ground conductor, dielectric substrate, and the feeding mechanism [7]. The bodily size of theantenna is approximately a one-half wavelength long segment of rectangular microstrip line. Using air as substrate, the length of the rectangular patch antenna is just abouthalf of a wavelength of free-space. Whereas a dielectric is utilized as a substrate material, the length of the antenna drops with the rise in the dielectric constant of the substrate. Due to stretched electric "fringing fields" the electrical length of the antenna is larger than the actual resonant length. An initialprototype of the microstrip antenna is a piece of microstrip transmission line bearing same loads on both edges to depict the radiation losses [8-9].

In [10] a microstripantenna having rectangular patch has been designed implementing defected ground and slits. A dumble shape was employed in the ground plane. It gives a size reduction of almost 90% and brings change in the resonant frequency lowering it from 3.22 GHz to 1.07GHz at -23dB return loss and giving 50MHz bandwidth.

The author of [11] established that the designing antenna implementing DGS improve the performance parameters of the antenna and offer a smaller size of patches as well.This results in overall decrease in size of antenna.

In [12] the narrow bandwidth as a disadvantage of conventional microstrip antenna has been overcome by applying DGS method. The bandwidth of the antenna with truncated ground construction has dramaticallywidened from 195 MHz to 523MHz. Also, there wasdecrease in the sizes of the radiating patch as well.

In [13] it was observed and concluded that the performance parameters of the antenna with the implementation of defected ground were enhanced as compared to conventional.

Author of the [14] hasresolved that the microstrip antennas having defectsin the ground plane offers wide bands as compared to the conventional antennas.

The antennas under consideration have been designed for C-band and GSM applications and the bandwidth of the C-band is from 4GHz-8GHz.

II. Design of the Fabricated Antenna

A. RADIATING PATCH AND GROUND LAYER

Theupper conducting layer, radiating patch and the ground layer is fabricated of copper foil. Copper surface is commonlylayered with corrosion resistant materials such as gold, tin or nickel. These metals are usually utilizeddue to their small specific resistance, resilient to oxidation, solder ability and strong adhesion. The thickness of conducting layers used in the fabrication of these antennas is heldconstantat 0.035 mm.

B. DIELECTRIC MATERIAL

Selection of an appropriate dielectric material is the principal step in designing a microstrippatch antenna. There are numerous substrates existing in marketplace. The features which are of more significancein the substrate selection are permittivity and tangent loss. The substrate must also be robust and capable to withstand high temperatures during soldering development and has high resistant towards chemicals used in fabrication procedure. Following substrate materials of 1.5mm thickness is used in this indigenous work as it is economical and readily available in the local market.This dielectric material is flexible and it has low losses as compared to other substrate materials. PTFE (Teflon) used in this construction is having dielectric constant of 2.1 and tangent loss of 0.0004. These material offer outstanding electric properties but have a low melting point and offer poor adhesion.

C. DESIGN SPECIFICATIONS

The majorphase in the design of a microstrip antenna with patch of rectangular shape is to select the basic design parameters which are Operating Frequency (f_o), Permittivity (dielectric constant) of the substrate (ε_r) and thickness of the substrate(h). The width, length and ground dimensions may be derived as follows.
The patch width is calculatedby means of equation 1.

$$W = \frac{C}{2fo\sqrt{(\frac{(\varepsilon r+1)}{2}}} \quad (1)$$

The effective dielectric constant is consideredvia equation 2.

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left\{\frac{1}{\sqrt{1+12h/w}}\right\} \quad (2)$$

The dimension of effective length is derived via equation 3.

$$Leff = \frac{c}{2fo\sqrt{\varepsilon reff}} \quad (3)$$

The extension in length is planned by formula 4.

$$\Delta L = 0.412h\frac{(\varepsilon_{reff}+0.300)}{(\varepsilon_{reff}-0.258)}\frac{\left(\frac{W}{h}+0.264\right)}{\left(\frac{W}{h}+0.813\right)} \quad (4)$$

The actual length of patch is found by means offormula 5.

$$L = Leff - 2\Delta L \quad (5)$$

Analysis of patch antenna through transmission line model is valid to antennas having boundless ground surface. Neverthelessit'sindispensableto design a finite ground in practical. According to [14] the ground length Lg and ground width Wgare derived with the help of equation 6 and 7.

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

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

D. DETERMINATION OF INSET FEED DEPTH:

Inset-feed attains a good impedance matching therefore is used in this project. The feed must be sited at that location on the radiating patch, where the input impedance equals to 50 ohms for the desired resonant frequency.

III. CONVENTIONAL RMPA

This proposed rectangular antenna of has been constructed on 1.5 mm thick Teflon.Geometrical magnitudes of the antenna are specified in Table 1. The detailed sketch is displayed in Fig. 1.

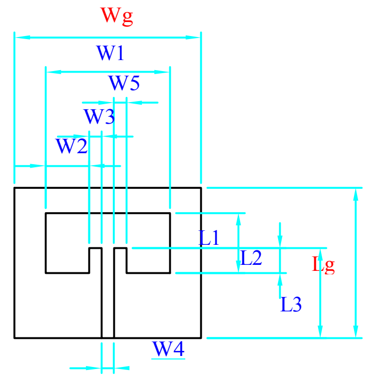

Fig. 1: Sketch of Conventional RMPA

Table 1: Geometrical parameters of RMPA

Facet	Magnitude (mm)	Facet	Magnitude (mm)
Wg	30	W5	2
Lg	30	L1	12
W1	20	L2	5
W2	7	L3	18
W3	2		
W4	2		

Table 2: RMPA outputs

Resonance frequency, f_r	Bandwidth (BW)	Bandwidth (%)	Return Loss @ f_r	VSWR @ f_r	Impedance @ f_r
7.51GHz	174MHz	2.31 %	-11.16 dB	1.77	55.6+j29.7

The fabricated antenna was experimentally investigated for Return Loss, VSWR and Input Impedance using vector network analyzer.The measuring capacity of the mentioned vector network analyzeris from 1KHz to 8GHz.Table 2 summarizes the results. The antenna resonates at 7.51GHz within C-band as shown in Fig. 2. The bandwidth offered by the antenna is 174MHz(2.31%). The voltage standing wave ratio is well under the tolerable value of 2 and is shown in Fig. 3. From the smith chart shown in Fig. 4 it is evident thatthe input impedance of antenna is 55 + j29 Ω at resonance which shows a normal impedance match of the antenna with the50 Ω line. In Fig. 5 the front and back view of the RMPA has been shown.

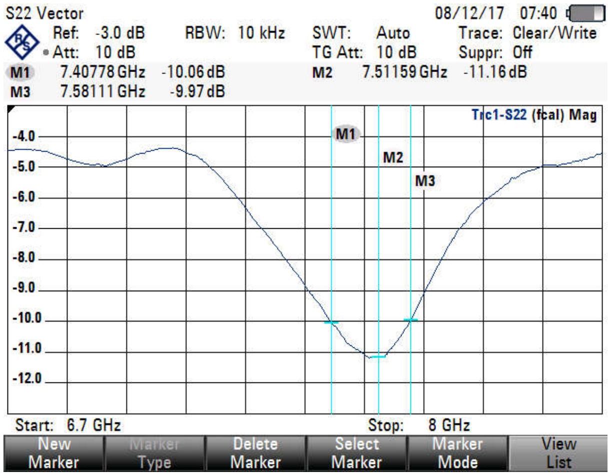

Fig. 2: Return loss of RMPA

Fig. 3: VSWR

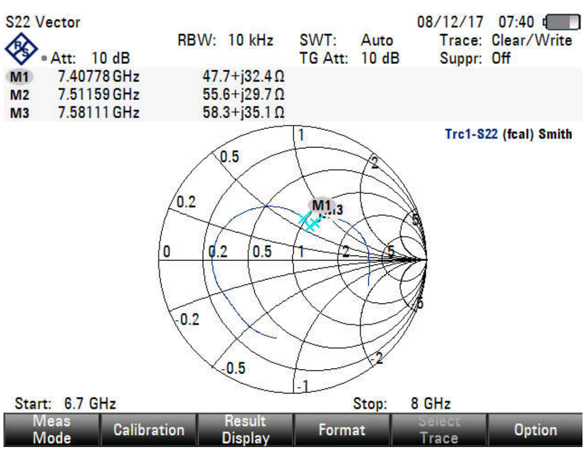

Fig. 4: Smith chart displayinginput impedance

Fig. 5: Front and back view of RMPA

IV. RMPA WITH TGS

The length Lg of ground plane of the conventional RMPA was reduced to 16 mm. The antenna was tested and results of truncated ground version of RMPA are given in Table 3.

Table 3: Results of RMPA with TGS

Resonance frequency, f_r	1.93GHz
Bandwidth, BW	312MHz
Bandwidth (%)	16.1%
Return Loss @ f_r	-29.4 dB
VSWR@f_r	1.1
Impedance @f_r	53.4-j0.36 Ω

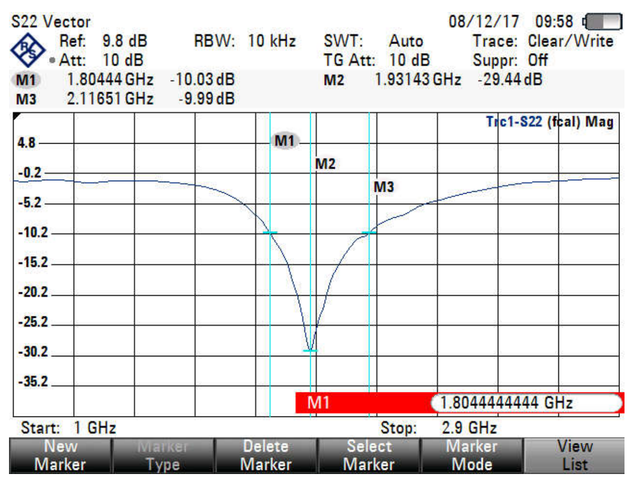

Fig. 6: Return Loss of TGS implemented RMPA

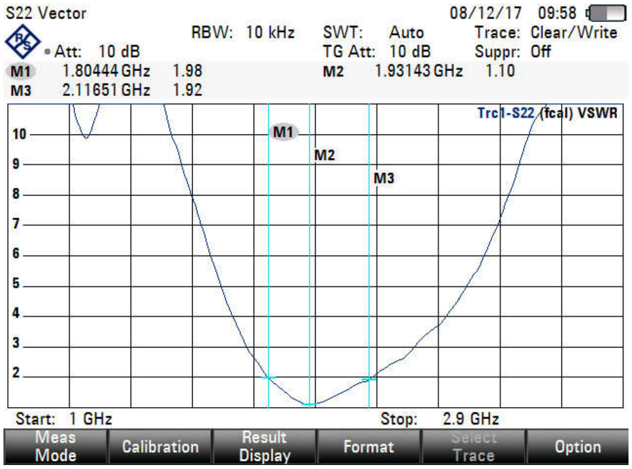

Fig. 7: VSWR of RMPA with TGS

The antenna showed sole resonance placed at 1.93GHz.The return loss presented at central frequency is -29.44dB. The offered bandwidth is 312MHz (16.16%) as exposed in Fig. 6. Voltage standing wave ratio is depicted in Figure 7. The antenna input impedance is 53.4-j0.36 (Fig. 8) which demonstrates excellent impedance match. In Fig. 9 the front and back view of the fabricated antenna has beenshown.

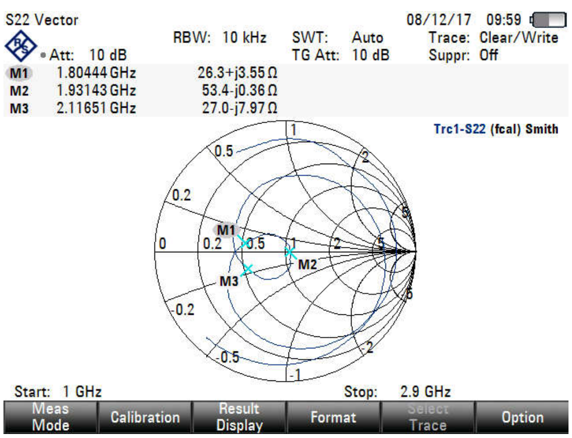

Fig. 8: Smith Chart showing Input Impedance of RMPA with TGS

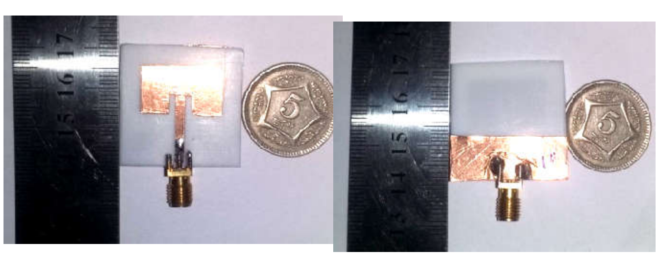

Fig. 9: Front and Back View of RMPA with TGS

V. CONCLUSION

In this work a conventional RMPA was practically fabricated on Teflon substrate. Experimental measurements of antenna were taken using network analyzer of Rohde&Schwarz. Then the ground plane length of the antenna was reduced. Table 4 summarizes comparative analysis of fabricated antennas. The resonance of conventional RMPA occurs at 7.51GHz in C-Band. It gives a -10dB bandwidth of 174MHz(7.581GHz-7.407GHz). The VSWR figure remainsless the tolerable value of 2 within the whole bandwidth. The Input Impedance of the antenna at central frequency is 55 + j29 Ω which illustrate that a normal impedance match of the antenna with the 50Ω line has been achieved. The resonance frequency of RMPA with TGS changes which supports the conclusion of [10] and [12]. The antenna gives a -10dB bandwidth of 312MHz (2.116GHz-1.804GHz). The % bandwidth increases from 2.31% to 16.16% in case of TGS as presented in Table 4. The VSWR remains below 2 for the frequency range. The input impedance of antenna at resonant frequency is 53.4-j0.36 Ω. This shows that promising impedance matching has been achieved. For the resonant frequency of 1.93GHz the antenna and patch dimensions are miniaturized by employing TGS which supports the conclusion drawn by [11] and [13]. With TGS the antenna presented better performance as compared to the conventional one.

Table 4: Comparative analysis of fabricated antennas

Parameter	RMPA	
	Conventional (without TGS)	With TGS
Resonance frequency, fr	7.51GHz	1.9GHz
Bandwidth	174MHz	312MHz
Bandwidth (%)	2.31 %	16.16 %
Return Loss @ fr	-11.16dB	-29.44dB
VSWR@ fr	1.77	1.10
Impedance @ fr	55.6+j29.7 Ω	53.4-j0.36 Ω

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