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A CPW fed Modified Ring Patch Antenna with DGS for Multi Frequency & Wideband Wireless Communications

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ABSTRACT

This paper describes a modified ring patch antenna to obtain wide band and multifrequency responses for applications in wireless communication. Radial slots and tuning arms at the inner periphery of the ring are added for better impedance matching and enhancement of bandwidth. The antenna is fed by coplanar waveguide (CPW) and defective ground structure (DGS) is introduced by cutting two parallel slots in the ground plane. The patch is etched on FR4_epoxy dielectric substrate with dielectric constant 4.4 and thickness 1.6mm over the ground plane. Ansoft HFSS software tool is used for the simulation and modelling of the antenna and design optimization. When a simple microstrip line inset fed ring shows an impedance bandwidth (S_{11} <-10dB) of 3% at 3.5GHz with return loss of -9dB, the modified configuration of the antenna produces multi frequency response with return loss peaks (≤ -15dB) at 1.12GHz, 2.35GHz, 2.49GHz, 2.9GHz, 3.3GHz & 3.5GHz. In this configuration the highest impedance bandwidth of 29% is obtained in the frequency range from 2.35GHz to 3.2GHz. The return losses and radiation patterns are measured using a Vector Network Analyzer. Simulation results agreed well with those of experimental ones. The antenna can be used in various applications in wireless communication.

Keywords:— *CPW fed patch antenna, defective ground structure, multifrequency antenna, ultra wide bandwidth antenna.*

I. INTRODUCTION

Enhancement of bandwidth is one of the most challenging works in designing a patch antenna for wireless communication applications. Several techniques are used by many authors and published in the literature. R. Chair, et. al[1] described a CPW-fed ultra wideband slot antenna with u-shaped tuning stub that shows a large impedance bandwidth in the frequency range from 5.5GHz to 22GHz. E. S. Angelopoulos, et.al [2] presented a coplanar waveguide fed circular and elliptical slotted patch with high bandwidth in the frequency range from 1.3GHz to 20GHz. A good work on CPW fed slot antenna is also reported by

V.A. Shameenab et al [3]. Tejbir Singh, et al[4] has reported a CPW-fed patch antenna operating in UWB range (3.1GHz to 10.6GHz) with uniform gain. A CPW-fed antenna was also reported by Xuan Xiong, et.al [5] where the antenna covers the UWB spectrum from 3.1GHz to 10.6GHz. Djelloul Aissaoui, et.al[6] described a CPW fed fractal antenna which covers UWB from 5.8GHz to over 14.4GHz. Many other authors [20-23] described ultra wideband performance of different microstrip configurations. Li, et.al described a switchable UWB slot antenna using DGS configuration [24].

The objective of this paper is to design a wideband antenna (-10dB bandwidth >25%) suitable for applications in wireless communication. The basic annular ring patch antenna on FR4_epoxy dielectric substrate (ε_r=4.4) of thickness 1.6mm above a ground plane resonates at 3.5GHz for inner radius a=8 mm and outer radius b=32.5mm for operation in TM_{120} radiation mode. The outer dimension is almost 50% reduced to 17mm with the modified configuration as shown in Figure 1. This model is fed with coplanar waveguide (CPW) and defective ground structure (DGS) is introduced. The configuration is fed from an inset microstrip line of 50ohm. The inset depth is optimised by iterative process using Ansoft HFSS software tools for best impedance match at R/3, where R is the average radius of the ring. The radial slots on the patch and tuning stubs on the inner periphery are introduced to enhance the bandwidth and also to obtain wideband multi-frequency performances. The modified ring yields multi frequency response with return loss peaks ≤ -15dB) at 1.12GHz, 2.35GHz, 2.49GHz, 2.9GHz, 3.3GHz & 3.5GHz and the impedance bandwidth of 29% in the frequency range from 2.35GHz to 3.2GHz. Ansoft HFSS software tool is used for the simulation and modelling of the antennas for optimum performance. The radiation patterns and return losses are measured using vector network analyzer. The measurement results show good agreement with those of the simulation.

II. Simulation & Design

The basic annular ring and subsequent modified geometrical configurations described above is simulated using Ansoft HFSS software tool. The dimensions of an simple inset microstrip line fed annular ring antenna are obtained from Eigen value equation for TM_{120} [14, 15] mode at fundamental frequency 3.5GHz

$$\frac{J_1'(ak)}{Y_1'(ak)} = \frac{J_1'(bk)}{Y_1'(bk)} \qquad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

where, $k = \frac{2\pi f_r}{c}\sqrt{\varepsilon_r}$, c = speed of light in free space = 3 X 10^8 m /sec. Equation (1) yields a=8 mm and b=32.5mm as shown in Figure 1. Here FR4_epoxy (ε_r=4.4) is used as a dielectric substrate with dimension 55mm x 55mm. The width of the feed line for 50ohm is 3mm. The ground plane is of dimension 55mm x 55mm. The antenna gives a impedance match at 3.5GHz with return loss -9dB. The -10dB simulated bandwidths are 3%.

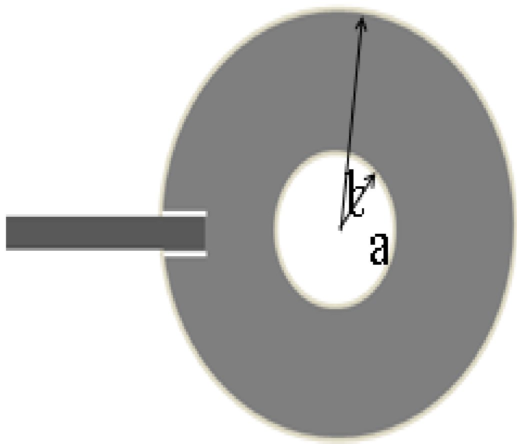


Figure 1(a) : Annular ring patch with inset microstrip line feed

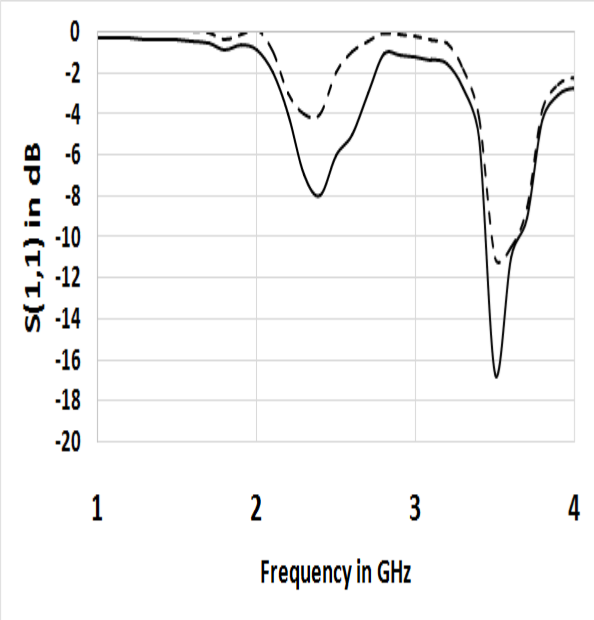


Figure 1(b): S11 vs. Frequency response

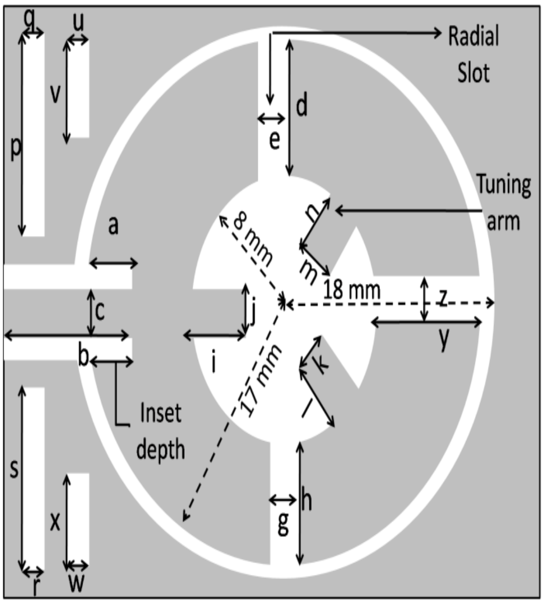


Figure 2. Geometry of modified patch with CPW fed and a DGS

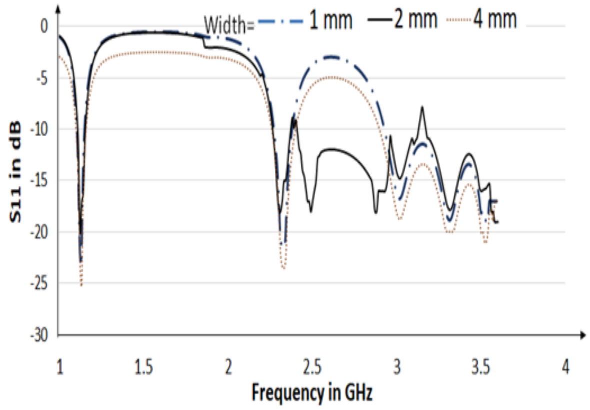
Modified Annular Ring Antenna and Parametric Study

Figure 2 shows the configuration of the modified annular ring with 3 slots and 3 tuning stubs in the inner periphery. The antenna is fed with Coplanar Waveguide (CPW) and a defective ground structure (DGS) is introduced where four rectangular narrow slots are cut on the ground plane of the antenna. The modified antenna is simulated using Ansoft HFSS tools for the design optimization. The slots are cut symmetrically from both sides of the patch. It is seen that this configuration reduced the outer radius size (b=17mm) by almost 50% for the desired performance. The feed line is inset in the antenna by 4 mm for better matching. The dimensions of the longer slots are 18mm x 2mm and the dimensions of the shorter slots are 10mm x 2mm. The dimensions of the geometrical configurations are as shown in Table I. Bandwidth and the tuning of the antenna is primarily controlled by addition of reactive elements like the radial slot width, stub on the inner circle and linear slots on ground plane.

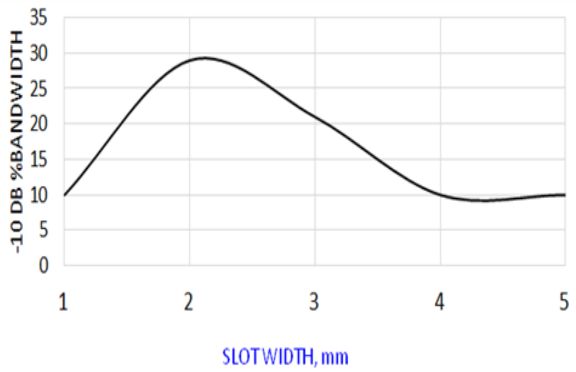
Table 1: Design parameter with values in mm

a=4	b=15	c=3	d=15	e=2	g=2
h=15	i=6	j=3	k=2	l=3	m=2
n=3	o=15	p=18	q=2	r=2	s=18
u=2	v=10	w=2	x=10	y=15	z=2

To verify the effects of the different design parameters on return loss and impedance bandwidth a parametric study is made. The return loss characteristics vs. frequency for different slot width cut within the ring are shown in Figure 3a. The radial slot width e=z=g is made optimum to 2 mm for obtaining the highest bandwidth. This configuration yields multifrequency operation with –ve peak return losses at 1.12GHz, 2.35GHz, 2.49GHz, 2.9GHz, 3.3GHz & 3.5GHz and the impedance bandwidth of 29% in the frequency range from 2.35GHz to 3.2GHz. Figure 3(b) shows the variation of bandwidth with the slot width.



(a)



(b)

Figure 3:Return loss and bandwidth characteristics of CPW fed modified ring with DGS

(a) S_{11} vs. Frequency for different radial slot width in the ring

(b) Variation of -10dB Bandwidth vs. Radial slot width

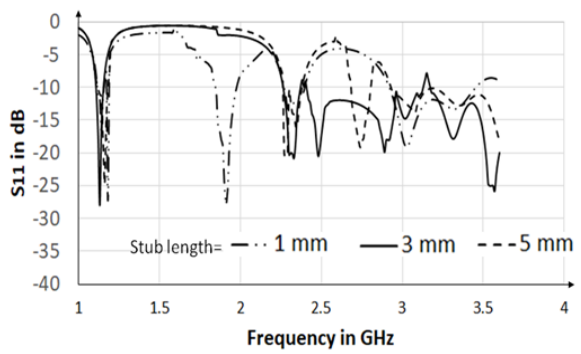
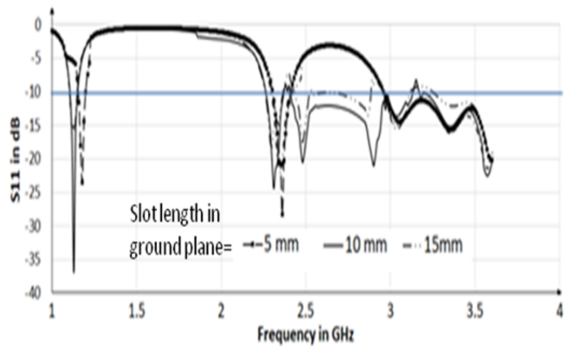


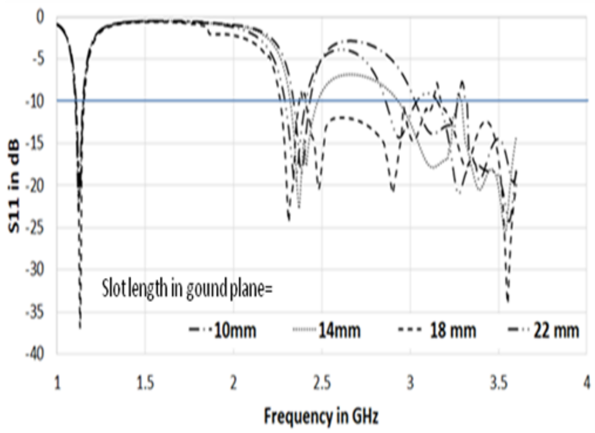
Figure 4: Return loss characteristics of CPW fed modified ring with DGS for different radial tuning stub length

The radial stub lengths at the inner periphery of the ring affect the matching characteristics over the band and influence the tuning of the antenna. After optimising the slot width, radial stub lengths are optimised for further better impedance matching. The radial stub lengths are chosen as very small in compare with the wavelength (~λ/10). It is seen that as the length is increased the resonant frequencies tends to shift as shown in figure 4. The optimised length of the tuning stubs for the best matching with the design frequency is obtained as i=6 mm, l=n=3 mm. By comparing the return loss characteristics it is seen that after adding the tuning stubs both the bandwidth and impedance matching at resonance frequencies are improved.

As the perturbation on the ground plane effects the current distribution, this also influences the antenna characteristics. Two pair of linear narrow slots having dimensions 18 mm x 2 mm (outer pair of slots) and 10 mm x 2mm (inner pair of slots) is introduced on the ground plane. It is seen that the lengths of the slot influences both the effective bandwidth and resonant frequency of the antenna. It is found that there is an optimum dimension of the longer pair of slots for the best performance of the antenna which is 18 mm x 2 mm as shown in figure 5a. In the same manner the dimension of the shorter pair of slots are varied and it can be observed that (Figure 5b) for a dimension of 10 mm x 2 mm the antenna is found to be in best matching with the operating frequency and wider bandwidth.



(a)



(b)

Figure 5: Return loss characteristics of CPW fed modified ring with DGS for different slot lengths in the ground plane

a. Shorter slot length on the ground plane (5 mm, 10mm, 15mm: longer slot length =18mm)

b. Longer slot length on the ground plane (10 mm,14mm,18mm, 22 mm; shorter slot length =10mm)

The return loss vs. frequency, bandwidth, and radiation characteristics at resonant frequencies are determined using the Ansoft HFSS simulator. The experimental results are obtained using a vector network analyzer as shown in Figure 6.

Figure 6. The hardware design and experimental setup for S11 response

III. Results and Discussion of Modified Annular Ring Antenna

A modified annular ring patch antenna with CPW inset feed and defective ground structure (DGS), as shown in Figure 2, is analyzed using Ansoft HFSS software tool and the results for return losses and radiation characteristics are experimentally verified. Figure 7 shows the simulated and measured results of return loss of the modified configuration. The antenna exhibits its capability to operate at multifrequencies: 1.12, 2.35, 2.49, 2.9 and 3.5GHz with very good return losses better than -20dB. It is also observed that the antenna achieved 29% impedance bandwidth at 2.8GHz with return loss better than -10dB. It is seen that HFSS simulated return loss characteristics agree well with that of experimental one.

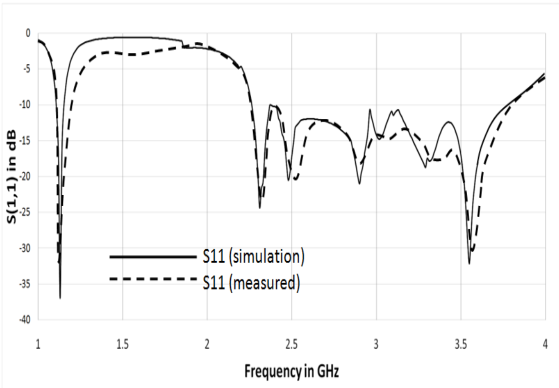
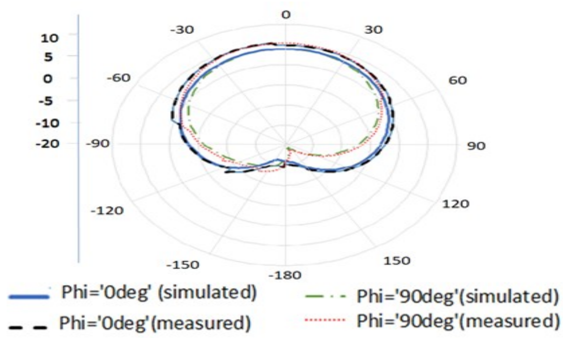
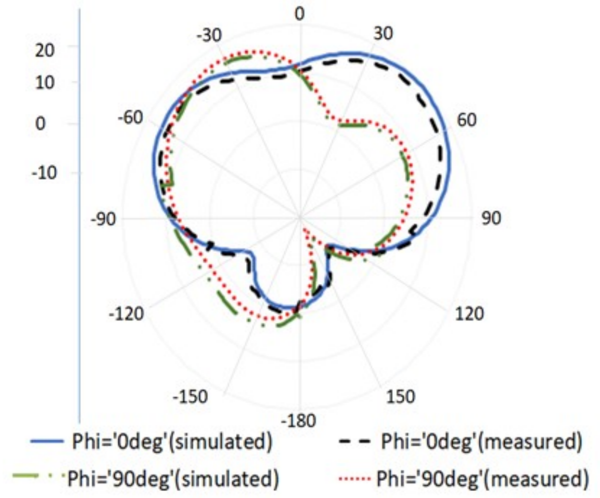


Figure.7 Return loss vs frequency of the modified ring patch

The simulated and measured radiation patterns for frequencies 2.49GHz and 3.5GHz are shown in Figure 8(a-b).



(a)



(b)

Figure 8. Measured and simulated Radiation Patterns of different resonant frequencies (a) 2.3GHz (b) 3.5GHz

To consider an antenna for UWB applications the antenna needs to have omnidirectional radiation pattern. The designed antennas display required radiation pattern for the whole operating frequency band as shown in Figure 8 (a-b).

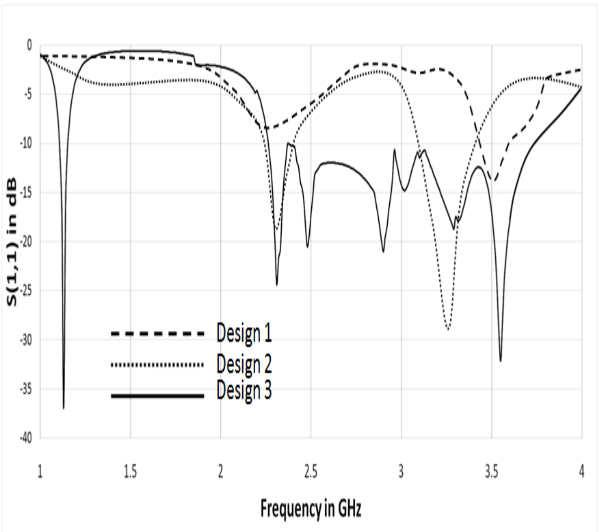


Figure 9: The comparative S11 vs. Frequency study of three designs, Design 1- With micostrip line feed, Design 2 – CPW feed, Design 3 – CPW feed with DGS

Three designs of the prototype are made to verify the feeding effect. The CPW feed is found to be most effective. The overall performance of the three antennas is given in Table 2.

Table 2: The Modified Annular Ring Antenna Performance Parameters

Design	Operating Freq in GHz	Bandwidth in %		S11 in dB		Gain in dBi	Efficiency in %	Applications
		Simulation	measured	Simulation	measured			
I	3.5	6	5.3	-17	-12	1.5	63	WiMax, IEEE 802.16e
II	2.4 3.3	8 15	15	-19 -18	-10 -20	2.8	70.5	ISM band applications, WiMAX Applications
III	1.2 2.3 3.6	3 4.5 29.4	3 35	-45 -25 -32	-33 -22 -30	3.5	78	ISM band applications, Wireless Communication applications, Public Wireless Hotspot,Bluetooth ,Wi-Fi applications,WiMAX

From the computed results it is seen that all the performance parameters are enhanced in the final design of CPW fed antenna where the DGS is added. Hence it can be stated that CPW feed technique enhance the bandwidth of the antenna and adding DGS to CPW helps to enhance the overall performance of the antenna including more enhancement in bandwidth.

V. CONCLUSION

A modified microstrip patch antenna with coplanar waveguide feed is designed and tested through HFSS tool. The operating frequency range of the antenna is 1GHz to 3.5GHz. The impedance bandwidth with VSWR ≤ 2.0 is 29% for CPW fed antenna with DGS. The antenna resonates at frequencies 1.12GHz and 2.4GHz-3.28GHz. It could be used in modern communication devices. According to the FCC and the International Telecommunication Union Radio communication Sector (ITU-R) currently define ultra wideband (UWB) antenna as an antenna transmission in the UWB frequency range for which emitted signal bandwidth exceeds the lesser of 500 MHz or 20% of the arithmetic centre frequency [17]. Hence the proposed antenna can be used in wideband applications. The measurement results show a good agreement with the designed antenna. All the structures produced broadside radiation patterns in the operating frequency range. Therefore, from the above work it can be concluded that introduction of DGS along with the CPW feed produces wider bandwidth and better impedance matching. An enhancement of percent bandwidth from 3% to 29% is seen in the experimental analysis. The designed antenna is suitable for ultra wideband applications. The proposed antenna can also be used for multiband multifrequency applications.

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