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Design and Fabrication of a Compact Annular Ring Slot Patch Antenna of Enhanced Bandwidth

Y. E. Mohammed Ali [1], M. K. Hussain[2]

[1,2]Dept. of Electrical Engineering, University of Mosul, College of Engineering, Mosul, Iraq

Abstract: The purpose of this paper is to design and fabrication of an annular ring slot patch antenna with short stub (ARSPA) for mobile applications Digital Cellular System (DCS) (1.71- 1.88) GHz, Personal Cellular System (PCS) (1.85 -1.99) GHz, and Universal Mobile Telecommunications System (UMTS) (1.71-2.17) GHz. Return loss and bandwidth are studied with respect to short stub location. By using short stub the bandwidth is enhanced comparing with that of without short stub. The designed antenna simulated by the software Computer Simulation Technology microwave studio (CST), through which the radiation patterns, VSWR, return loss, and gain were generated. The proposed antenna has compact size (60*60*1.6) mm. We have been good results between simulated and fabricated antenna.

Keywords: Annular Ring Slot Patch Antenna (ARSPA), Bandwidth enhancement, compact antenna, Short stub.

Introduction

The rapid development of wireless communication systems has increased the demand for compact microstrip antennas with high gain and wideband operating frequencies. Microstrip patch antenna has advantages such as low profile, conformal, light weight, simple realization process and low manufacturing cost [1]. In addition, applications in present-day mobile communication systems usually require smaller antenna size in order to meet the miniaturization requirements of mobile units. Thus, size reduction and bandwidth enhancement are becoming major design considerations for practical applications of microstrip antennas [2]. Printed slot antennas are attractive because of their wide impedance bandwidths, low cost, planar structures and easy integration with active devices or MMICs. In recent years, some microstrip-line-fed printed slot antennas have been reported because of their favorable impedance characteristics [3]. A microstrip line is the most popular of the transmission structures, mainly due to the fact that the mode of propagation in a microstrip is almost transverse electromagnetic (TEM). This allows an easy approximate analysis and yields wide band circuits. Also simple transitions to coaxial circuits are feasible [4]. This paper investigates a technique which can enhance the bandwidth of the microstrip antenna without increasing the size and the complexity of the microstrip antenna. The behavior of annular ring slot patch antenna with and without short stub in ring slot has been presented, this addition led to enhance bandwidth and obtain suitable gain.

Antenna Structure and Design

A. Theory

For the proposed annular-slot antenna, the first mode is mainly determined by the circumference of the inner slot-ring and the second mode is mainly determined by the outer circumference. The annular-slot widths and the microstrip feed line parameters also have a significant effect on performance [5]. When the circumference of the ring is equal to an integral multiple of the guided wavelength, the resonance is established and expressed as [6]:

$L = 2\pi R = n\lambda_{gs}$, for n= 1, 2, 3 .... (1)

Where L is the circumference of the ring, λ_{gs} is the guided wavelength. The guided wavelength is related to the effective dielectric constant as:

$$\lambda_{gs} = \frac{\lambda_0}{\sqrt{\varepsilon_{reff}}} \quad .... (2)$$

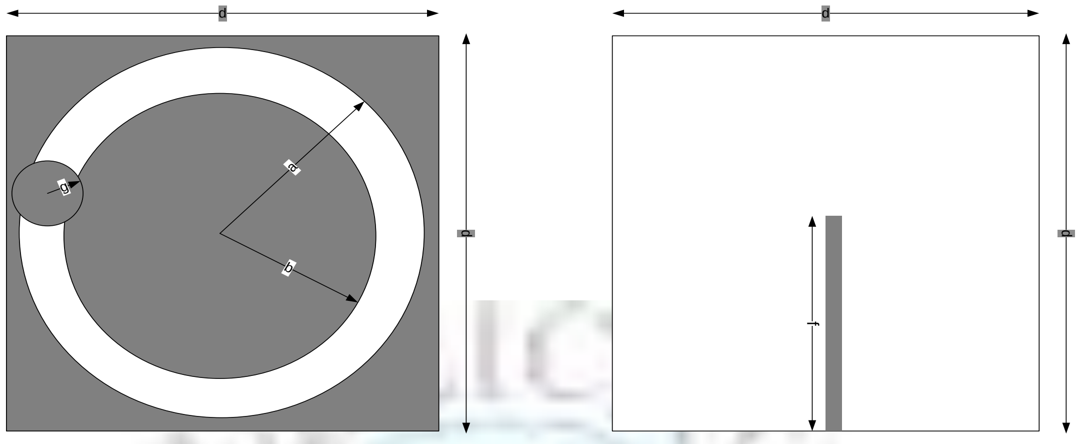
Where λ_o is the wavelength in free space, ε_{reff} is the effective dielectric constant. Thus, the resonant frequency can be represented as:

$$f_n = \frac{n\, v_o}{L\sqrt{\varepsilon_{reff}}} \quad .... (3)$$

for mode n=1, 2, 3 … where v_o is the speed of light.

B. Propsed Antenna Geometry

The geometry of the ring slot patch antenna presented in this paper is shown in Figure (1), FR-4 substrate (ϵ_r=4.4, tangent loss = 0.02) substrate thickness (1.6 mm). Feeding by microstrip line. The dimensions of the antenna are (d=60, a=29.9, b=24.8, g=3 and f=30). All dimensions are in mm. The substrate have dimensions (60*60mm^2), the top patch has annular ring slot with short stub, the bottom contains microstrip feed line as shown in Figure.1 (b). All the dimensions are optimum values obtained after make optimization by CST software.



(a) (b)

Figure 1: Proposed antenna geometry, (a) front side, (b) back side

C. Results and Discussion

By making the optimization of the short stub location, the best location of the short stub in $\theta = 170^{\circ}$. Figure (2) shows the location of the short stub and return loss results obtained by CST for different short stub location.

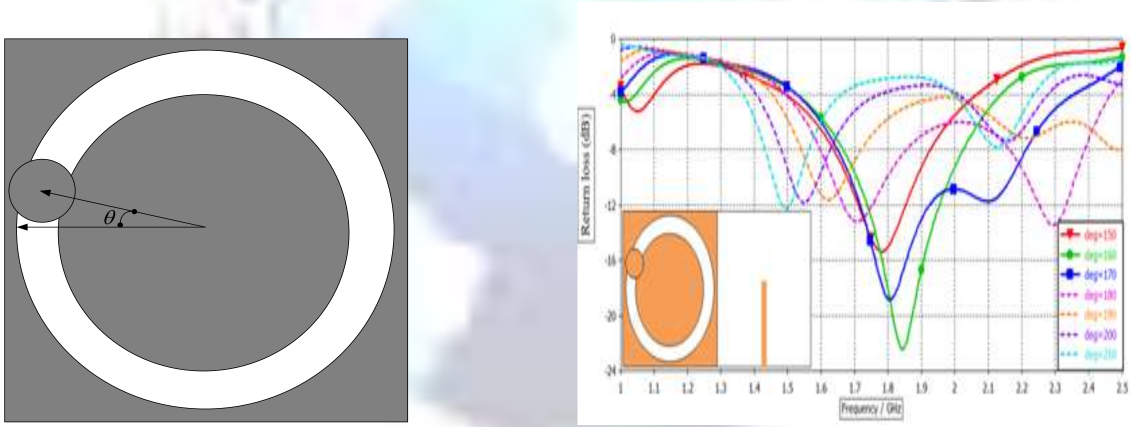
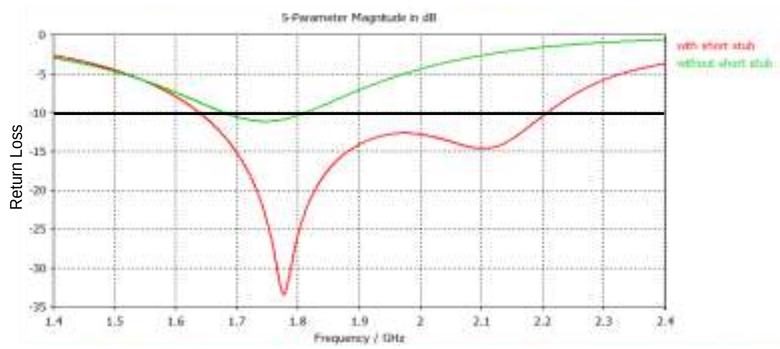
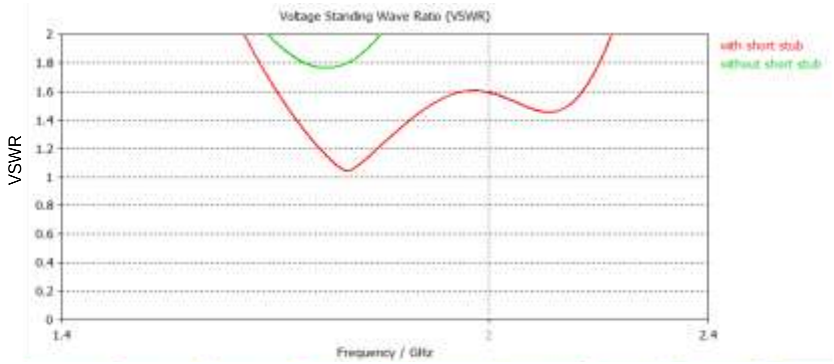


Figure 2: Optimization of the short stub location

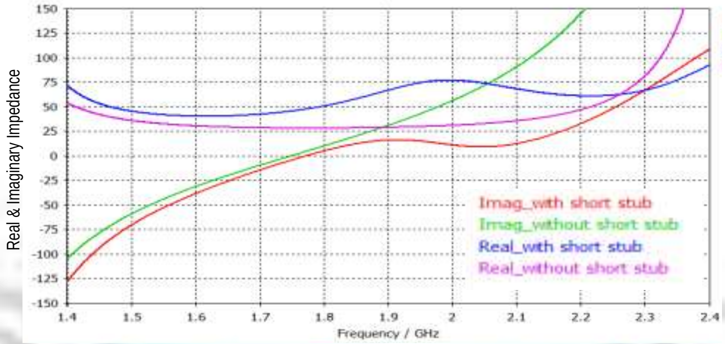
Figure(3) shows the return loss, VSWR and real/imaginary impedance respectively with and without short stub in ring slot. Observed the bandwidth enhancement after put the short stub at the ring slot, and all parameters related to antenna characteristics are improved.



(a)



(b)



(c)

Figure 3: (a) Return loss (b) VSWR (c) Real and Imaginary Impedance Comparison

Table (1) we shows the antenna parameters comparison between the annular ring slot antenna with and without short stub.

Table 1: Comparison parameter between ARSPA with & without short stub

Antenna	Bandwidth (GHz)	f_r (GHz)	VSWR	RL
CARSPA without short stub	(1.679-1.811) 0.132	1.7GHz 1.8GHz 1.9GHz 2GHz 2.1GHz	1.84 1.87 2.58 4.03 6.60	-10.57 -10.35 -7.09 -4.39 -2.64
CARSPA with short stub	(1.638 – 2.211) 0.573	1.7GHz 1.8GHz 1.9GHz 2GHz 2.1GHz	1.42 1.10 1.49 1.59 1.45	-15.12 -25.87 -14.10 -12.82 -14.64

Figure (4) shows the improvement of the realized gain between annular ring slot patch with and without short stub.

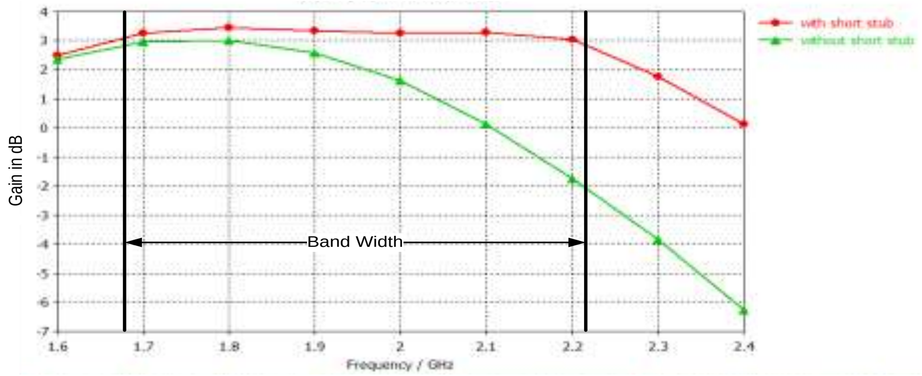


Figure 4: Gain of the proposed antenna

D. **Practical Result**

Figure (5) shows the proposed antenna after fabricated, this antenna has been subjected to two tests, the first test for return loss. Figure 6 (a) shows the proposed antenna connected to (Anritsue S332D) to test the return loss, Figure 6 (b) shows the result for this test and figure 6 (c) shows the comparison between simulated and practical results.

(a) (b)

Figure (5) Fabricated patch antenna (a) front side (b) back side

Figure 6 (a): Antenna connected to (Anritsue S332D)

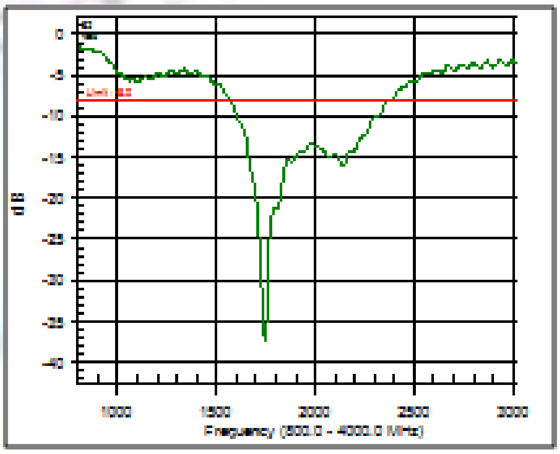


Figure 6 (b): Return loss result from (Anritsue S332D)

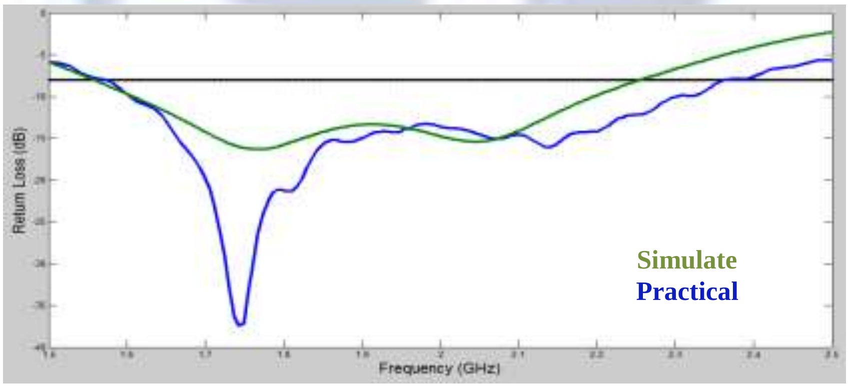


Figure 6 (c): Comparison between simulated & practical results

The second test for radiation pattern. The far field patterns of the proposed antenna was measured in anechoic chamber in the department of Electrical Engineering / University of Mosul. Figure 7 (a) & (b) shows outside and inside the anechoic chamber and the transmitter and receiver locations inside it. The used spectrum analyzer (GSP-830, GWINSTEK 9KHz - 3GHz) was placed outside the chamber and connected to the receiver through SMA cable. The antenna in the receiver side was placed on a turn table with remote control to scan the antenna by 360^{o} from outside the chamber.

Wires, turn table and other parts were protected by absorbing material to reduce reflections. The signal generators used to supply the transmitter antennas was (Anritsu/ MG3670B/ 2.25 GHz).

Figure 8 shows the comparison between simulated and practical radiation pattern, from the result of radiation pattern the antenna have Omni directional behavior and the results of the practical and theoretical test substantially identical.

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Figure 7: (a) Outside anechoic chamber

(b) The transmitter and receiver location inside anechoic chamber.

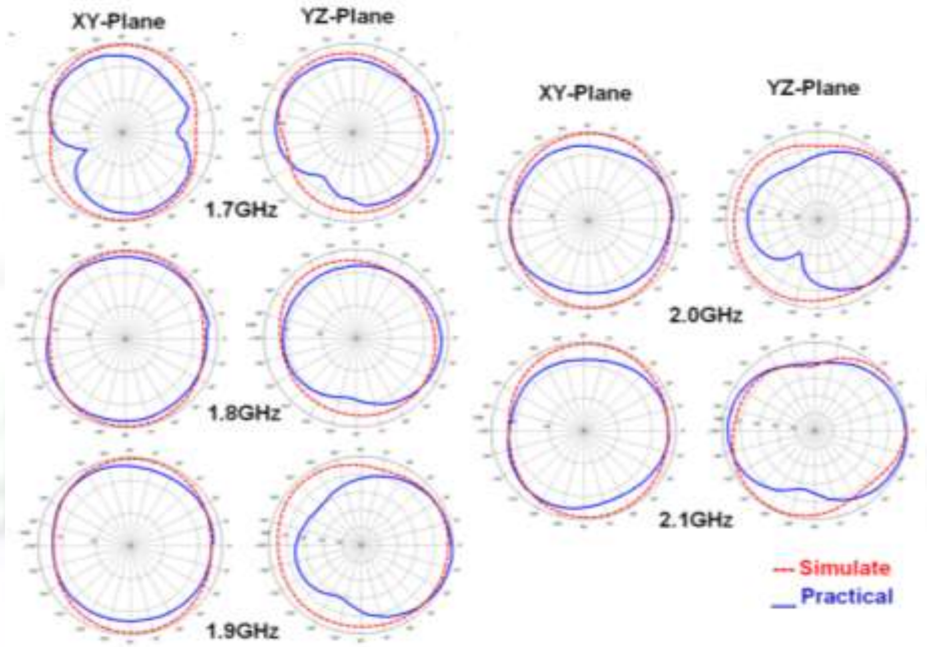

Figure 8: Compare between simulated & practical radiation pattern

Conclusion

The annular ring slot patch antenna with wideband characteristics has been studied. By using the design parameters of the proposed patch structure, the antenna exhibited wideband along with moderate gain characteristics. The measured bandwidth is 800 MHz (for return loss less than -8 dB). However, the proposed antenna obtained not only wide bandwidth, but also has gain of 3.45 dB with omni-directional radiation characteristics. As this antenna is wide band, low profile and light weight, it finds applications in mobile application DCS, PCS and UMTS.

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