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Fabrication and Characterization of a Quarter Wavelength Gap Coupled Microstrip Patch Antenna

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Abstract: ***The Universal Mobile Telecommunications Systems (UMTS2100) transmission band covers frequencies from 1920 MHz to 1980 MHz. A quarter wavelength gap coupled rectangular microstrip patch antenna (QWGCRMPA) design is proposed to cover the UMTS transmission band. The proposed antenna design provides a bandwidth of 98 MHz and 50% patch area reduction. The design, fabrication and characterization of the quarter wavelength gap coupled rectangular microstrip patch antenna, to cover UMTS transmission band, are presented.***

Keywords: UMTS, Quarter Wavelength Microstrip Patch Antenna, Bandwidth, Transmission Band, Gap Coupling, Parasitic Resonator

1. Introduction

Conventional rectangular microstrip patch antennas (RMPAs) are half wavelength long compact printed resonant structures of narrow bandwidth [1]. Quarter wavelength long rectangular microstrip patch antenna, which provides 50% patch size reduction and similar functionality, is obtained by halving the conventional rectangular microstrip patch antenna along its length. One of the radiating edges of the quarter wavelength rectangular microstrip patch antenna needs to be shorted to ground [2]. Further miniaturization can be achieved by halving the quarter wavelength rectangular microstrip patch antenna along its width. Two such miniaturized patches may be gap coupled to double the bandwidth. Gap coupling is a technique to improve the bandwidth of microstrip patch antennas, in addition to using thicker substrates of lower dielectric constants [3]. The gap coupling technique involves one driven patch gap coupled to one or more parasitic patches [4] [5]. The parasitic patches may be gap coupled to the radiating edges or the non radiating edges or to all four edges of the driven patch [6].

The microstrip patch antenna incorporating coplanar gap coupled parasitic patches, has disadvantage of larger total patch area than the conventional one. The total patch area of half wavelength rectangular microstrip patch antenna that employs gap coupled parasitic patches becomes larger as the parasitic patches and the driven patch have nearly the same area. In [7] and [8], the conventional half wavelength rectangular patch was divided into several parts which were gap coupled to the central driven patch, to obtain enhanced bandwidth, without increasing the total patch area.

The design proposed and fabricated provides enhanced bandwidth and 50% patch area reduction. A conventional half wavelength rectangular microstrip patch is first divided along the width into two equal parts. The two parts are then halved along the length. The two quarter wavelength patches so obtained are gap coupled along their non radiating edges. The proposed design has been simulated to determine the dimensions of the driven patch, parasitic patch and ground plane, and feed location, to provide 98 MHz bandwidth and 50% size reduction. The simulation results show excitation of two TM_{10} modes of frequencies, driven f_d = 1950 MHz and f_p = 1980 MHz, respectively [9]. In the present paper, the results obtained for this design are described and compared with the simulation.

2. Antenna Fabrication

This section describes the microstrip antenna fabrication process and the excitation technique used in the present work. Fabrication accuracy is very critical as the microstrip patch antennas are narrow band resonant structures that usually operate in the microwave bands. Fabrication errors in the patch dimensions will shift its resonant frequency [10]. Microstrip patch antennas are generally fabricated by photo-lithographic method. Photo-lithographic method produces highly accurate etched pattern for the microstrip patch.

2.1 Fabrication Process

Photo-lithographic method requires ultra violet (UV) light of suitable wavelength and photo-resist sensitive to this wavelength. The photo-resist materials are of two types, positive and negative. The exposed portion of positive photo-resist dissolves in the photo-resist developer and that of negative photo-resist hardens. Photo-resist material in the form of dry negative photo-resist film, to be applied as lamination to the copper clad substrate and UV A type light, are used in the present work.

The step by step process for the microstrip patch antenna fabrication is now described. The first step is computer aided design of the antenna geometry. A negative of this geometry printed on transparency serves as the mask. A double sided copper clad substrate of suitable dimension is thoroughly cleaned using acetone and dried. In the second step, a negative photo-resist film is laminated to the cleaned and dried copper clad substrate. The negative mask prepared in the first step is firmly placed on the photo-resist laminated copper clad substrate. The masked and photo-resist laminated copper clad substrate is exposed to ultra violet (UV) light. The third step is to develop the UV exposed photo-resist laminated copper clad substrate. Finally, the developed copper clad substrate is chemically etched by Ferric Chloride ($FeCl_3$) solution.

2.2 Excitation Technique

Microstrip patch antenna can be fed either by a 50 ohm microstrip transmission line or by a 50 ohm coaxial connector. In the present work, coaxial feeding is employed. Coaxial feeding is done using an SMA F type connector of probe diameter 1.3 mm, with its outer conductor (flange) connected to the ground plane and the inner conductor soldered to the antenna patch.

3. Experimental Procedure and Results

The proposed antenna design is illustrated in Fig 1. It consists of two quarter wavelength patches printed on grounded RT5880^{TM} substrate [11]. The left hand side patch is probe fed using SMA F type coaxial connector. The dimensions of two patches, ground plane and feed location are detailed in the Table 1. The total patch area is 1444.8275 mm^2 and ground plane is 6378.1039 mm^2. The design is fabricated using photo-lithography as described earlier.

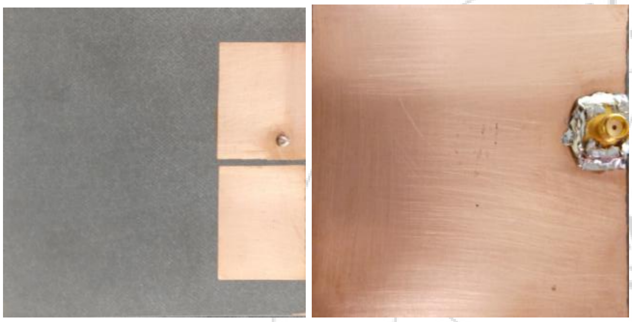

Figure 1: Quarter Wavelength Gap Coupled Rectangular Microstrip Patch Antenna

Table 1: QWGCRMPA Design Parameters

Parameter	Value in mm	Parameter	Value in mm
L_d,	23.758518	x_f	32.790992
L_p	23.482393	y_f	5.5
W_d,	30.406516	g	1.5
W_p	30.406516	d	1.30
L_g	79.863032		
W_g	79.863032		

3.1 Return Loss and Bandwidth

The HP 851OC network analyzer is used for the measurement. Network Analyzer is calibrated for Port I. The test antenna is connected to the Port I of the S-parameter test set. The measured S_{11} data in the network analyzer is acquired and stored in ASCII format in the computer. The frequency for which the return loss value is minimum is taken as resonant frequency f_o of the antenna. The range of frequencies for which the return loss value is with in the -10 dB points is usually treated as the bandwidth of the antenna.

3.2 Radiation Pattern

The co-polar and cross-polar E-Plane and H-plane radiation patterns of the test antenna are measured by keeping the antenna inside an anechoic chamber in the receiving mode. The far field patterns are measured at a distance

$$d \geq 2D^2/\lambda_{min}$$

where
D is the largest dimension of the antenna and
λ_{min} is the smallest operating wavelength.

HP 8510C Network Analyzer, interfaced to an IBM PC, is used for the pattern measurement. The PC is also attached to the position controller. The test antenna is mounted on the antenna positioner and kept inside the anechoic chamber. The test antenna is connected to port 2 and the standard transmitting antenna is connected to Port 1 of the network analyzer. In order to measure the radiation pattern, the network analyzer is kept in S_{21}/S_{12} mode with the frequency in the range within the -10 dB return loss bandwidth.

3.3 Results

The experimental results compared with simulation, are presented here. The input characteristics are presented in figures 2 to 5. The radiation characteristics are presented in figures 6 to 9.

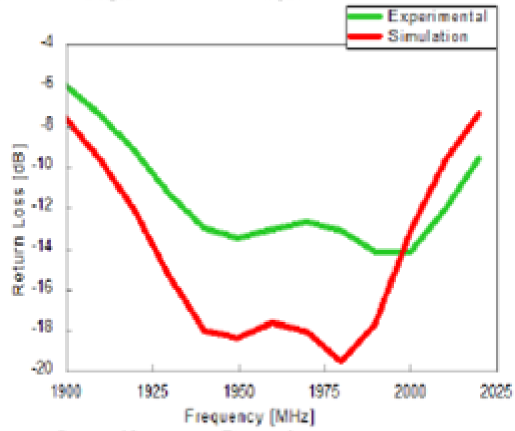

Figure 2: Return Loss

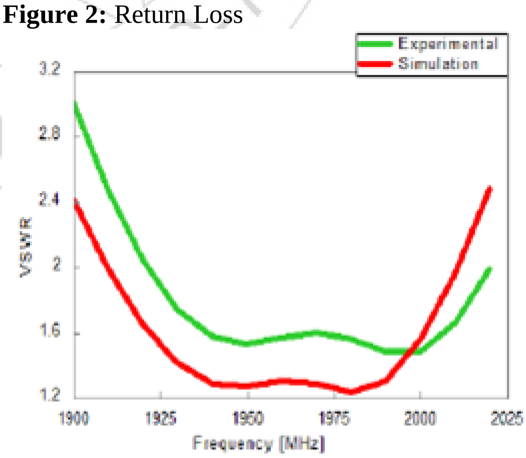

Figure 3: VSWR

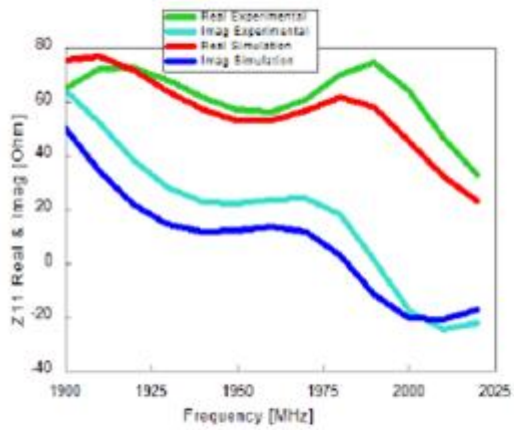

Figure 4: Impedance

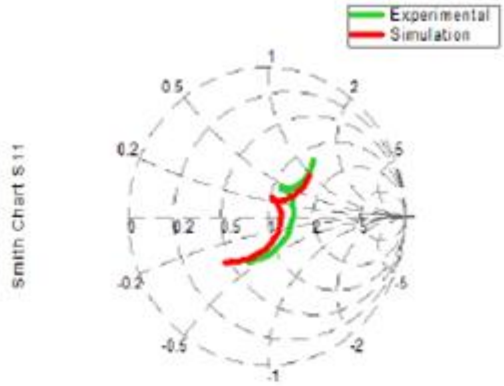

Figure 5: Smith Chart

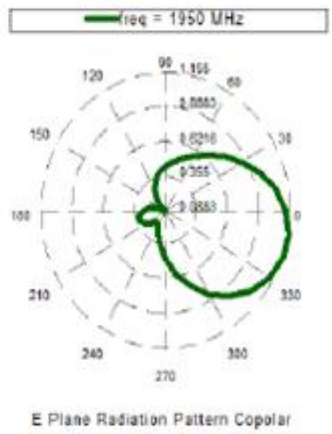

Figure 6: Copolar E Plane Radiation Pattern

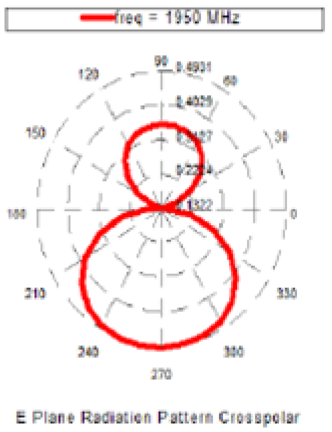

Figure 7: Crosspolar E Plane Radiation Pattern

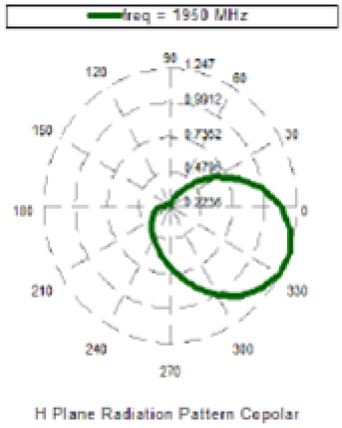

Figure 8: Copolar H Plane Radiation Pattern

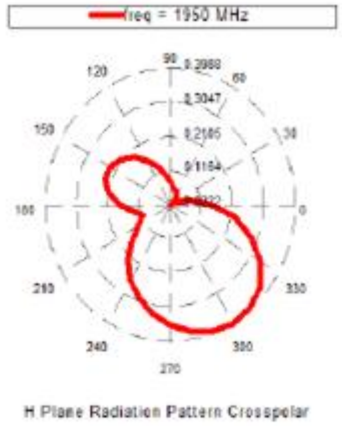

Figure 9: Crosspolar H Plane Radiation Pattern

4. Conclusions and Discussions

The experimental results for the input characteristics are presented in Figs 2 to 5. Fig 2 shows return loss bandwidth of 95 MHz. The lower and upper cutoff frequencies are, f_L = 1923 MHz and f_U = 2018 MHz, respectively. Experimentally, two resonant frequencies, corresponding to the driven and parasitic quarter wavelength rectangular patchess, are found to be f_d = 1950 MHz and f_p = 1990 MHz, respectively.

The return loss at f_d = 1950 MHz is -13.52 dB and at f_p = 1990 MHz is -14.14 dB. From Fig 4, the antenna input impedance, Z_{11} at f_d = 1950 MHz and f_p = 1990 MHz, are found to be, Z_{11} = 56.70 + j21.97 ohm and Z_{11} = 74.40 + j0.83 ohm, respectively. The Smith chart in Fig 5 shows a knot, conforming the excitation of two TM_{10} modes, corresponding to the driven and parasitic patcches.

The experimental results for the radiation characteristics are presented in the Figs 6 to 9. The radiation patterns in the two principle planes are shown. The E plane pattern is broadside but squinted, having beam maximum of 1.15501 at 340^o and beam width of 140^o. The E plane pattern shows presence of back radiation. The front to back ratio is ≈ 4.12. The E plane pattern also shows presence of cross polar component. The maximum value of cross polar component is 0.493 at 270^o. The H plane pattern is also broadside but squinted by 30^o and shows presence of cross polar component. The maximum value of cross polar component is 0.34 at 300^o.

The squinted radiation pattern can be corrected by adding a quarter wavelength parasitic patch to the left of the driven patch. The additional parasitic patch will further enhance the bandwidth. The cross polar components need to be reduced.

5. Acknowledgements

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