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A COMPACT UWB MICRO STRIP PATCH ANTENNA USING COPLANAR WAVE GUIDE FEEDING FOR BIO MEDICAL APPLICATIONS

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ABSTRACT

A compact antenna for ultra wide range applications is proposed using coplanar wave guide feeding. The dimensions of the proposed model are 25 x 25 x 1.6 mm^3. The enhanced frequency range of 2.8-13.59 GHz is obtained as per return loss criterion by introducing the staircase model. The voltage wave standing ratio is less than 2 over the entire bandwidth. The resonant frequencies obtained are 3.2 GHz, 5.8 GHz, 9.7 GHz, and 12.6 GHz. In addition to the ultra wide band range of 3.1-10.6 GHz as per FCC regulations, the antenna is also operatable in X-band range and the partial range of Ku band from 12-13.59 GHz. The proffered antenna is suitable for applications of UWB like medical imaging, RADAR imaging, tracking, measurements and communications.

Keywords: ultra wide band, coplanar wide guide, X-band, Ku-band.

1. INTRODUCTION

1. Ultra wide band antenna

Ultra wide band technology is an advancing wireless communication technology that transmits very short pulses of the sub nanosecond interval. In ultra wide band technology, the RF energy is spread over a very wide spectrum of GHz, hence it is the wide spread spectrum. This is a very different approach in wireless technologies when compared to conventional narrowband technologies. The ultra wide band range of frequencies has fractional bandwidth greater than 0.2. According to FCC regulations, the ultra wide band is licensed for the band of 3.1 GHz to 10.6 GHz as per FCC regulations. This upgrading technology has appreciable

Characteristics such as low transmission energy, multipath immunity, high data rate, secure and robust communications as the signals are imperceptible random noise to other conventional systems. Because of these significant characteristics, this promising technology has a very wide range of applications in communications and measurements, medical imaging, radars and surveillance etc.

This emerging technology has provoked the interest in the upgrowth of UWB antennas as antenna is the vital part of UWB system design. The antenna that is capable of receiving at the same time on all frequencies of the band can be called as UWB antenna. As the acceleration of charge is the key mechanism for radiation, structures designed for UWB antenna must expedite the acceleration of charge over the large range of frequencies. The antenna required for operating in the ultra wide band can be designed to resonate at multiple frequencies.

B. Need for CPW

For UWB antenna, ideally the impedance matching and the radiation pattern should be stable all over the band of frequencies. Practically, the performance and the behavior of the antenna should be consistent. But, for general micro strip patch antennas, the frequency dispersion would be very high. Frequency dispersion is the property of micro strip transmission lines that have different group velocities at different frequencies. The coplanar waveguide feeding may be one of the solutions for this problem.

In coplanar waveguide feeding micro strip patch antenna, all the conductors supporting the wave propagation are located on the same plane. Compared to the general micro strip patch antenna, the number of electric and magnetic lines in the air is more than that of in the coplanar wave guide fed patch antenna.

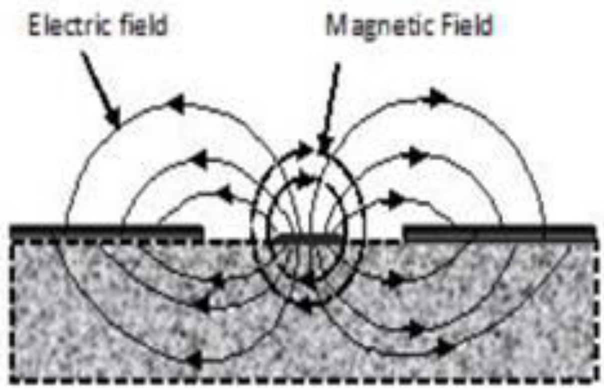

Figure-1. Illustration of Electric and Magnetic Fields in CPW Fed Microstrip Patch Antenna.

Thus capacitance is the parallel combination of both air and substrate.

$$c_{cpw} = c_1 + c_{air} \quad (1)$$

where,

$$c_1 = 2\varepsilon_0(\varepsilon_r - 1)\left(\frac{K(k_2)}{K'(k_2)}\right) \text{and } c_{air} = 4\varepsilon_0 \frac{K'(k_1)}{K(k_1)}$$

Therefore,

ARPN Journal of Engineering and Applied Sciences

$$c_{cpw}=2\varepsilon_0(\varepsilon_r-1)\frac{K(k_2)}{K'(k_2)}+4\varepsilon_0.\frac{K'(k_1)}{K(k_1)} \quad (2)$$

where $K(k)$ and $K'(k)$ represent the complete elliptic integral of the first kind and its compliment respectively and`

$$K_1=\frac{W}{W+2s} \text{and } K_2=\frac{\sinh(\frac{\pi W}{4h})}{\sinh(\frac{\pi(W+2s)}{4h})}$$

Thus, the effective dielectric constant becomes:

$$\varepsilon_{reff}=\frac{C_{cpw}}{C_{air}}=1+\frac{\varepsilon_r-1}{2}.\frac{K(k_2)}{K'(k_2)}.\frac{K'(k_1)}{K(k_1)} \quad (3)$$

And the impedance becomes

$$Z_0=\frac{1}{cC_{air}\sqrt{\varepsilon_{reff}}}=\frac{30\pi}{\sqrt{\varepsilon_{reff}}}.\frac{K'(k_1)}{K(k_1)} \quad (4)$$

Hence, the effective dielectric constant becomes the average of dielectric constants of air and substrate. Thus, the reduced dielectric constant of the antenna lowers the frequency dispersion of the antenna, thus giving promising consistency over the wide range of frequencies.

2. ANTENNA DESIGN

Unlike the narrow band antennas, this antenna is designed to resonate at two or more frequencies and the overlapping of these resonant frequencies cause ultra wide band range operation. Moreover, to ameliorate the antenna performance over larger bandwidth, the two ground planes are inscribed on the same plane of the radiating patch. The antenna dimensions are 25mm x 25mm x 1.6mm. The basis of the radiating patch is the rectangular patch of dimensions Lp_1 x Wp_1. The ground plane is extruded on both sides of the patch on the plane so that CPW feed can be provided. The dimensions of the ground plane are as per configurations defined below. The antenna is designed on FR-4 substrate of dielectric constant 4.4 with thickness as 1.6 mm.

A. Antenna Model-1

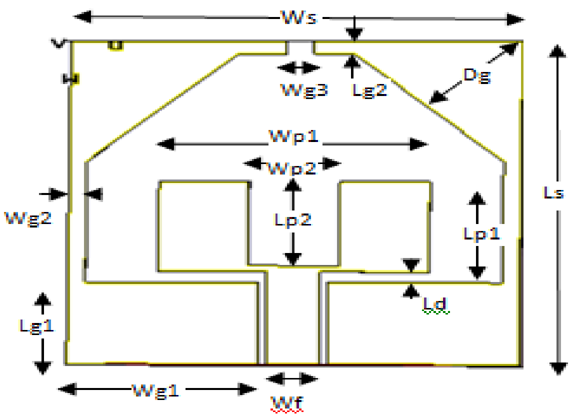

Figure-2. Schematic Diagram of Antenna model- 1.

The basic model of the antenna under comparisons has a slot of dimensions Lp_2 x Wp_2 etched into the rectangular patch as shown. Thus, the antenna design consists of two obtruded vertical strips of dimensions Lp_2 x (Wp_1-Wp_2) from the upper corners of the small rectangular patch.

B. Antenna Model-2

The antenna is designed to have two inverted L shape structures obtruded over the small rectangular patch. In this design, the vertical patch on either side is snipped with dimensions of Lt1 x Wt1 so that L-shaped structures are obtained. This design improves the impedance matching conditions.

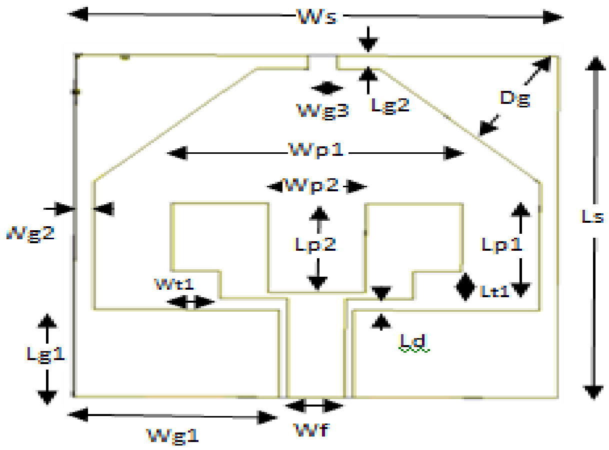

Figure-3. Schematic model of Antenna model-2.

C. Antenna Model-3

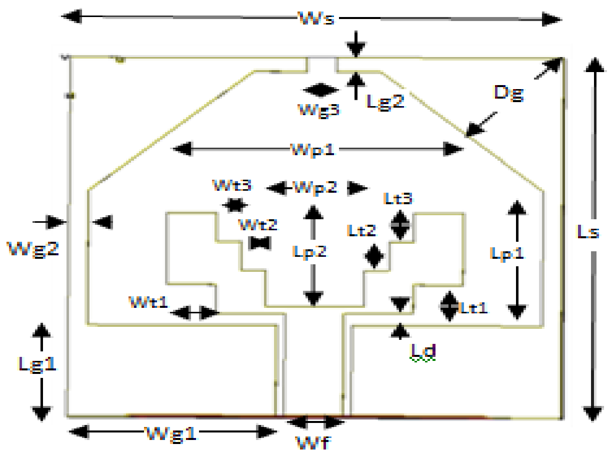

Figure-4. Schematic model of Antenna model-3.

The staircase model improves the impedance matching, thus increases the bandwidth of the antenna. In this design, the stairs of dimensions Lt_1 x Wt_1 and Lt_2 x Wt_2 are introduced at the upper sides of both L- shaped structures.

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Table-1. Design parameters of proposed antenna models.

Parameters	**Ls**	**Ws**	**Lp_1**	**Wp_1**	**Lp_2**	**Wp_2**	Dg
Value in mm	25	25	7	15	6.5	5	10
Parameters	Lg_1	Wg_1	Lg_2	Wg_2	Wg_3	Wf	Ld
Value in mm	8	10.6	1	1	1.5	3	0.8
Parameters	Lt_1	Wt_1	Lt_2	Wt_2	Lt_3	Wt_3	h
Value in mm	2	2.5	2	1.25	2	1.25	1.6

3. RESULTS AND DISCUSSIONS

The proposed antenna models are simulated in 3D EM Simulator. The plots of return loss, VSWR, radiation patterns are obtained and operating bandwidth of the antennas are realized.

A. Antenna Model-1

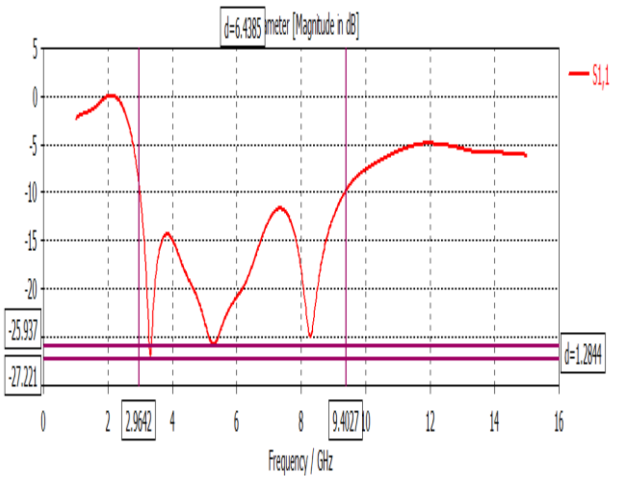

Figure-5. Simulated |S11| for Antenna Model-1.

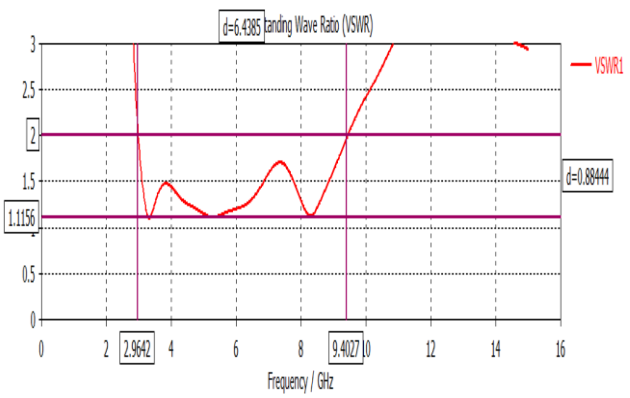

Figure-6. Simulated VSWR for Antenna Model-1.

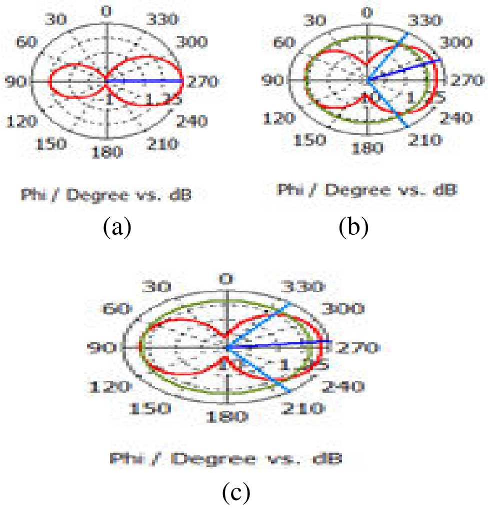

Figure-7. Absolute gain at theta=90deg for Model-1 at resonant frequencies (a) 3.33GHz, (b) 5.29GHz, (c)8.3GHz.

For the antenna proposed of model-1, the return loss is -26.4dB at 3.33GHz, -25.6dB at 5.29GHz, -25dB at 8.3GHz. The bandwidth of the antenna obtained is 2.99GHz to 9.34GHz with resonant frequencies as 3.33GHz, 5.29GHz, and 8.3GHz. The main lobe magnitudes of absolute gain for $\theta=90^0$ are 1.99dB at 3.33GHz, 3.78dB at 5.29GHz and3.42dB at 8.3GHz. The minimum VSWR obtained is 1.11

B. Antenna Model-2

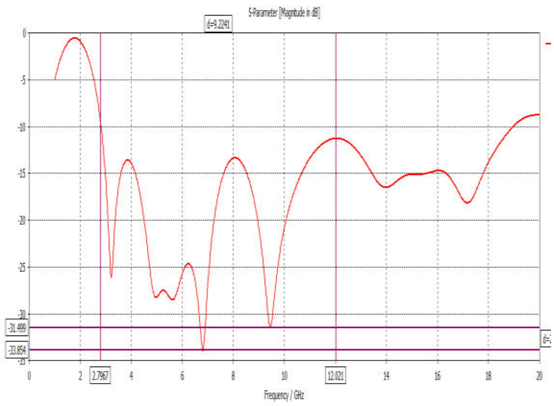

Figure-8. Simulated |S11| for Antenna Model-2.

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For the antenna proposed of model-2, the return loss is -25.96dB at 3.19GHz, -33.9dB at 6.79GHz, -31.38dB at 9.43GHz. The bandwidth of the antenna obtained is 2.82GHz to 13.71GHz with resonant frequencies as 3.19GHz, 6.79GHz, and 9.43GHz The main lobe magnitudes of absolute gain for $\theta=90^0$ are 2.17dB at 3.19GHz, 4.29dB at 6.79GHz and 5.44dB at 9.43GHz. The minimum VSWR obtained is 1.03.

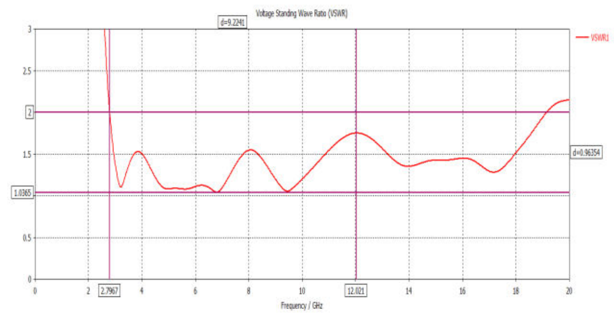
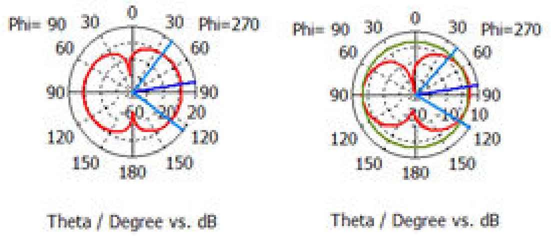
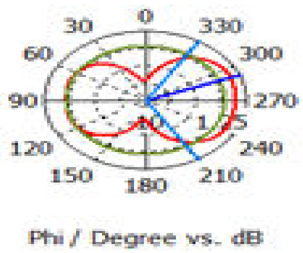


Figure-9. Simulated VSWR for Antenna Model-2.



(a) (b)



(c)

Figure-10. Absolute gain at Theta=90deg for Model-2 at resonant frequencies at (a) 3.19 GHz, (b) 6.79 GHz, (c) 9.43GHz.

C. Antenna Model-3

For the antenna proposed of model-3, the return loss is -41.74dB at 3.19GHz, -43.55dB at 5.69GHz, -58.73dB at 9.61GHz, -36.65dB at 12.6GHz. The bandwidth of the antenna obtained is 2.8GHz to 13.59GHz with resonant frequencies as 3.19GHz, 5.69GHz, 9.61GHz and 12.6GHz. The main lobe magnitudes of absolute gain for $\theta=90^0$ are 1.95dB at 3.19GHz, 3.25dB at 5.69GHz, 3.44dB at 9.61GHz and 3.54dB at 12.6GHz. The minimum VSWR obtained is 1.01.

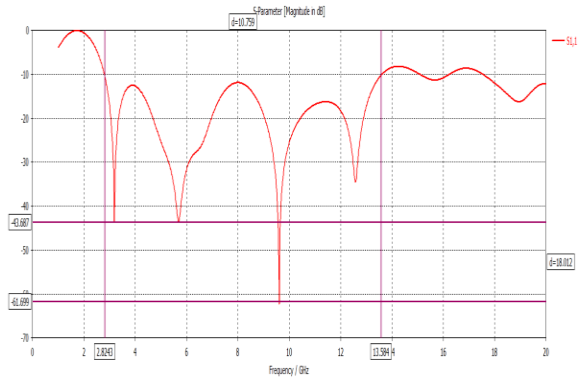


Figure-11. Simulated |S11| for Antenna Model-3.

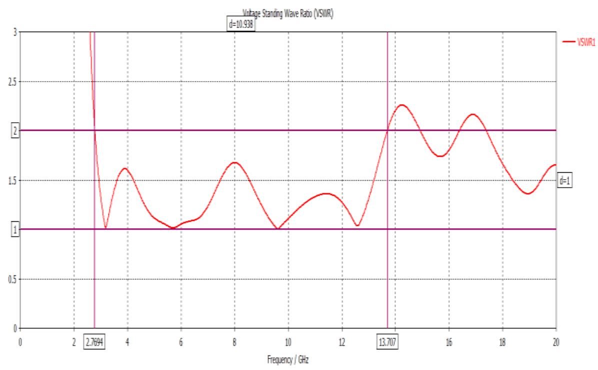
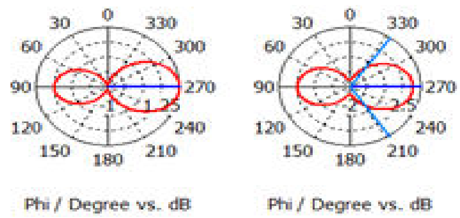
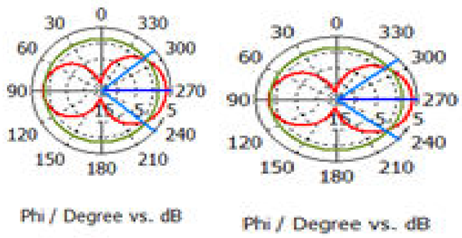


Figure-12. Simulated VSWR for Antenna Model-3.



(a) (b)



(c) (d)

Figure-13. Absolute Gain at Theta=90deg for Model-3 for resonant frequencies at (a) 3.19 GHz, (b) 5.69GHz, (c) 9.61GHz (d) 12.6GHz

D. Comparisons between the models

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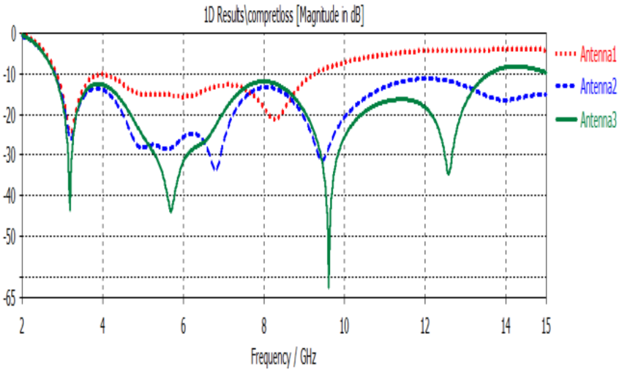

Figure-14. Comparison of return loss for three models.

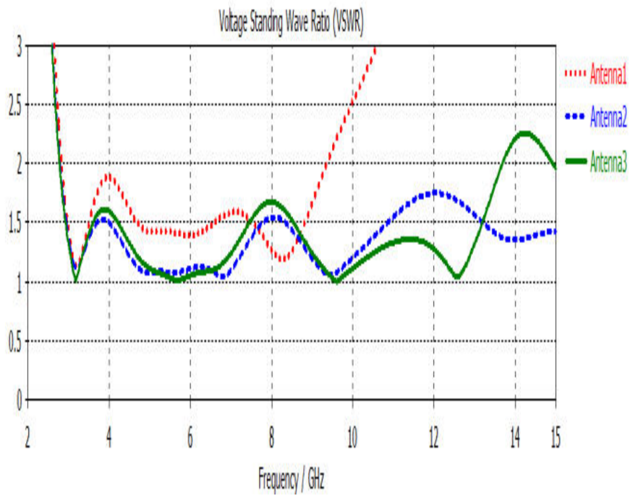

Figure-15. Comparison of VSWR for three models.

Model	Return loss at resonant frequency	VSWR	Operating frequency range	Gain (dB)
1	-26.43dB at 3.33GHz -25.66dB at 5.29GHz -24.90dB at 8.29GHz	1.11	2.99GHz to 9.34GHz	3.56
2	-25.96dB at 3.19GHz -33.90dB at 6.79GHz -31.38dB at 9.43GHz	1.03	2.82GHz to 13.71GHz	4.86
3	-41.74dB at 3.19GHz -43.55dB at 5.69GHz -58.73dB at 9.61GHz -36.65dB at 12.6GHz	1.01	2.80GHz to 13.59GHz	4.22

4. CONCLUSIONS

Three compact CPW fed micro strip antennas are designed and the results are compared. According to return loss criterion (< -10dB), the antenna with staircase patch has operatable range from 2.8-13.59 GHz and it is the largest range of two antenna ranges with gain as 4.22dB. This antenna is suitable for all UWB applications like medical imaging, RADAR and surveillance, measurements and communications. As the antenna is compact and UWB technology is advancing in the medical field, the proposed antenna can be used for biomedical applications as a wearable antenna by changing the conducting and dielectric materials.

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