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Design of a Dual Band GPS Micro-strip Patch Antenna

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Abstract: **New designs of obtaining a dual frequency bands antenna for the Global Positioning System (GPS) (Lower band = 1.227 GHz, Upper band = 1.575 GHz) with a single-feed square micro-strip antenna are proposed and experimentally studied. The proposed designs are based on the same patch dimensions loaded with different shape of slots in the form of cut from the sides of the square patch. The result of this work shows that the slots loaded into the square patch antennas offers further size reduction with multiband properties and GPS characteristics. Details of the design considerations of the proposed antennas are described, and experimental results of the obtained dual-band GPS performances are presented and discussed.**

Keyword:**Micro-strip Antenna, Dual band, GPS applications.**

I. INTRODUCTION

Modern wireless communication systems and increasing of other wireless applications requires low cost and high performance multiband antennas. The demand for high performance multi-standard communication systems has led the antenna research and studies in various directions; one of them is the design of multiband micro-strip patch antennas [1, 2]. Size miniaturization of the normal micro-strip patch antenna has been accomplished by various forms which include the use of high dielectric constant substrates, modification of the basic patch shapes, use of short circuits, shorting-pins or shorting-posts; or a combination of the above techniques.

Employing high dielectric constant substrate is the simplest solution, but it exhibits narrow bandwidth, high loss and poor efficiency due to surface wave excitation [3]. Modification of the basic patch shapes allows substantial size reduction; however, some of these shapes will cause the inefficient use of the available areas. Shorting-posts were used in different arrangements to reduce the overall dimensions of the micro-strip patch antenna. These shorting-posts were modelled and analysed as short pieces of transmission lines with series inductance and shunt capacitance [4].

In this paper, probe-fed square micro-strip patch antennas were used to show the effects of the slots have been loaded on the four sides of the square patch of the antenna. These square MSA designs are candidates for use in dual band GPS applications.

II. DESIGN CONSIDERATIONS OF THE PROPOSED ANTENNAS

The transmission line model can be considered for the calculations of the square micro-strip patch antenna length. The length L should be slightly less than λ/2 where λ is the wavelength in the dielectric medium and it is equal to$\lambda_o/\sqrt{\varepsilon_e}$where λ_o is the wavelength in free space and $\varepsilon_e$is the effective dielectric constant [3].$\varepsilon_e$is slightly less than $\varepsilon_r$and that's because the fringing fields around the periphery of the patch are not confined in the dielectric substrate but are also spread in the air, and it can be approximately calculated as [3,5],

$$\varepsilon_e = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left(\frac{1}{\sqrt{1+10h/W}}\right) \qquad (1)$$

Where: *h* is the patch substrate height.

The radiation edge (W) is usually chosen such that it lies within the range L < W < 2L [6].The effective length for rectangular micro-strip antenna which caused by fringing effect is measured to be,

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$$L_{eff} = L + \Delta l \quad (2)$$

Where Δl is the extension along the length and it is calculated as [6],

$$\Delta l = 0.412h\frac{(\varepsilon_e + 0.3)(\frac{W}{h} + 0.264)}{(\varepsilon_e - 0.258)(\frac{W}{h} + 0.813)} \quad (3)$$

And then, the effective length for the TM_{10} mode could be calculated from [3],

$$L_{eff} = \frac{\lambda_o}{2\sqrt{\varepsilon_e}} = \frac{c}{f_r\sqrt{\varepsilon_o}} \quad (4)$$

The resonance frequency for any *TM mn* mode is given by James and Hall [7] as,

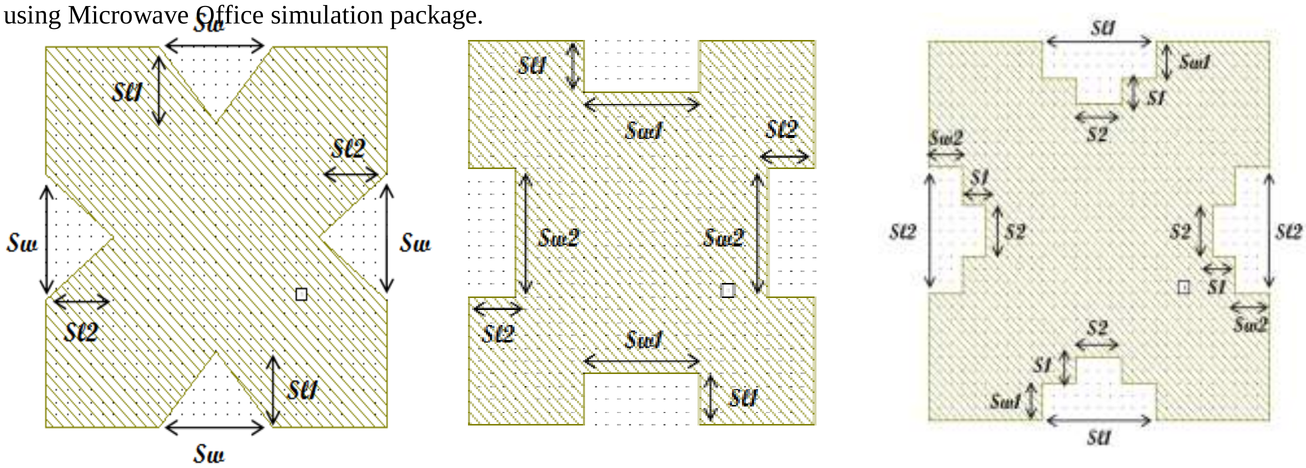
$$f_r = \frac{c}{2\sqrt{\varepsilon_r}}\left[\left(\frac{m}{L}\right)^2 + \left(\frac{n}{W}\right)^2\right] \quad (5)$$

Where: ε_r is the relative permittivity.

The first step is to design a single band square patch antenna with a resonance frequency of 1.46 GHz which lies in the range of the dual GPS bands (1.277 GHz & 1.575 GHz). For this value and according to the above analysis, the patch dimensions of 60 mm x 60 mm (L = W) can be printed on a ground substrate of thickness (h) 5.95 mm (~2.8 % of the working wavelength).Cross linked polystyrene glass with dielectric constant 2.62 has been used in the design of the antenna. The antenna is fed with probe feed, the probe feed position (X_f= 15, Y_f = -9 mm) was chosen in order to provide a good impedance matching between the antenna and the feed for the multiband antenna performance, with (0, 0) is the centre of the patch.

III. SIMULATION RESULTS

This paper propose the design of three square patch antennas each loaded with different slots configuration to provide a GPS dual band performance as shown in Fig. 1. The proposed micro-strip patch antenna has been designed and simulated using Microwave Office simulation package.



(a) (b) (c)

Fig. 1 optimum antenna configurations with:(a) four triangular slots (b) four rectangular slots (c) four steps shape slots

Table 1 shows a comparison between three antenna designs with respect to their slots dimensions, resonance frequencies and bandwidths. Fig. 1(a, b) shows that the micro-strip patch was used is of the same dimensions with different shape of slots are loaded in the patch antenna for each design when designing a dual band GPS antenna, in Design 1 the square patch antenna is loaded with four triangular slots while in Design 2 the antenna is loaded with four rectangular slots and in Design 3 the antenna is loaded with four steps shape slots.

TABLE I: SIMULATION RESULTS FOR DIFFERENT SLOT DIMENSIONS OF MSA CONFIGURATION

Design	Sl1 (mm)	Sl2 (mm)	Sw1 (mm)	Sw2 (mm)	f1 (GHz)	f2 (GHz)	Bandwidth Region (GHz)	Bandwidth (MHz)
1	20	14	20	20	1.275	1.57	(1.18 – 1.37) , (1.54 – 1.61)	190 , 70
2	14	10	12	16	1.27	1.56	(1.22 – 1.33) , (1.54 – 1.59)	110 , 50
3	12	8	12	16	1.24	1.53	(1.21 – 1.33) , (1.49 – 1.57)	120 , 80
	2nd step slots of dimensions (S1 = 4 mm , S2 = 8 mm)							

The simulation results obtained in Table 1 from loading the antenna with different slots shapes configurations show that the proposed antenna configurations gives the optimum dual band antenna performance with GPS characteristics, Design 1 provide a GPS dual band performance with a total bandwidth of (260 MHz), while Design 2 provide the dual band GPS operation with a total bandwidth of (160 MHz) , Design 3 uses different type of slots with a steps shape to design the dual band GPS antenna with a bandwidth of (200 MHz).Fig. 2 shows the frequency response with respect to the return loss for the antenna configurations shown in Fig. 1.

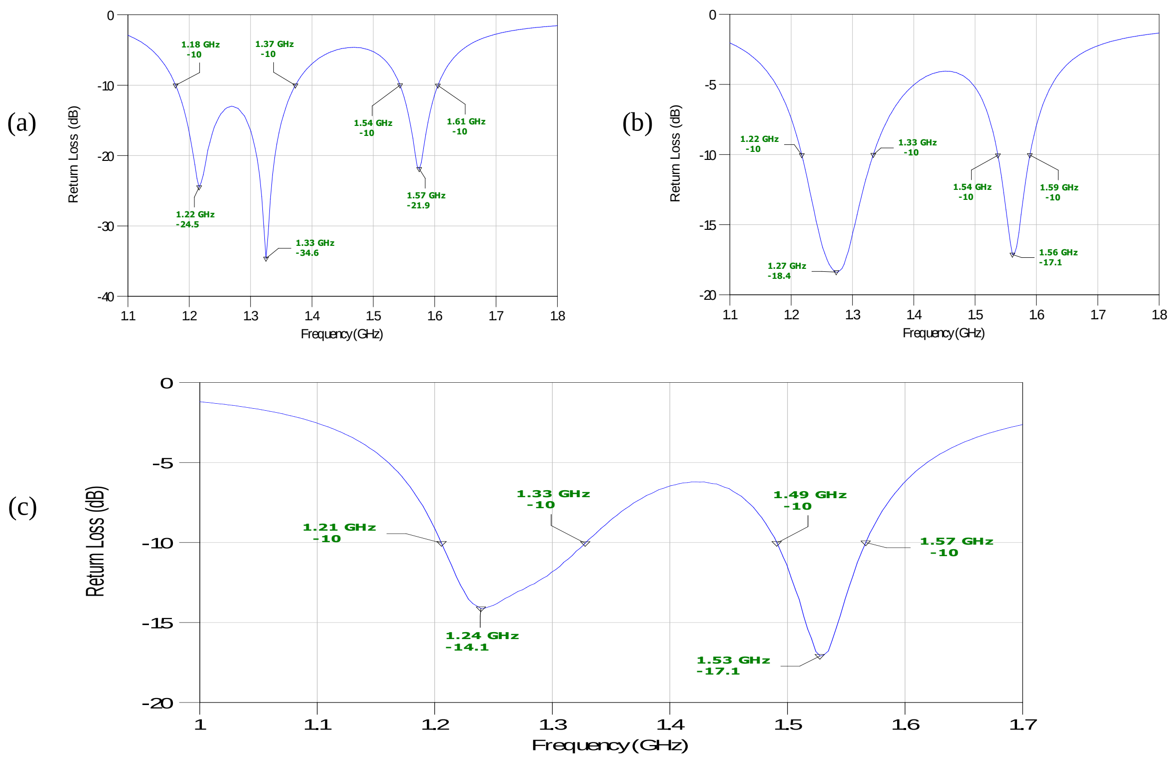


Fig. 2 frequency response with respect to the return loss for MSA loaded with: (a) four triangular slots (b) four rectangular slots (c) four steps shape slots

IV. CONCLUSION

This paper introduces and investigates the design of multiband micro-strip antennas by studying the effect of loading different shapes of slots into a square MSA on the antenna multiband characteristics. The three designs give a dual frequency bands that can be used in GPS Applications. Simulation results of these studies and the comparison of the three designed GPS antennas shows that the effect of the slots on the antenna performances. Adding slots into the patch of the antenna introduces a size reduction in the designed antenna patch (in our case a size reduction of 6.5 % and dual band behaviour were achieved in comparison when designing a MSA that can operate on a frequency band of 1.227 GHz). It also can produce more than one resonance frequency by generating a second or even a third resonant frequency yielding a multiband antenna performance. Finally, it was observed that Patch antennas loaded with rectangular slots produces resonance frequencies with lower bandwidths than that of antennas loaded with triangular slots.

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