DUAL BAND MSA DESIGNS FOR GPS AND GSM APPLICATIONS

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ABSTRACT

New designs of obtaining a dual frequency bands antenna operate on the dual frequency bands of Global Positioning System (GPS) and Global System for Mobile Communications (GSM) with a single-feed square micro-strip antenna are proposed and experimentally studied. The proposed designs are based on the different patch dimensions loaded with four rectangular 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 that can be used in GPS and GSM applications. Details of the design considerations of the proposed antennas are described, and experimental results of the obtained dual-band performances are presented and discussed.

Keywords: micro-strip antenna, design, GPS application, GSM, dual band performance.

1. INTRODUCTION

Micro-strip antennas have been one of the most innovative topics in antenna theory and design in recent years, and are increasingly finding application in a wide range of modern microwave systems [1]. Inherently they have numerous advantages like easy to fabricate using standard integrated circuit techniques, have a low profile, are conformal, and can be easily integrated in arrays and with electronic components. Nevertheless, micro-strip antennas typically suffer from narrowband radiation (a few percent of center frequency), low gain, poor polarization purity, tolerance problem and limited power capacity. However, applications such as frequency tuning take advantage of the inherent narrow bandwidth of the micro-strip antenna.

Systems such global position system (GPS) and Global System for Mobile Communications (GSM) are required to operate at two different frequencies apart too far from each other. Micro-strip antennas can avoid the use of two different single band antennas. Variety of methods has been proposed to obtain dual frequency operation. Among them, loading slits [2], using slots in the patch [3], [4], loading the patch with shorting pins [5]-[7], using stacked patches [8]-[11], or using two feeding ports [12] are the mostly exploited ones. In addition, there are planar antennas of special geometries to achieve dual-band operation [13].

This paper has introduced and investigated the design of a multiband micro-strip antennas by studying the effect of loading four rectangular slots with different dimensions into a square MSA on the antenna multiband characteristics, antenna designs operate on the dual frequency bands of the Global Positioning System (GPS) and the Global System for Mobile Communications (GSM) were presented.

2. PROPOSED ANTENNA DESIGNS

The geometry of the proposed micro-strip antenna was modeled using the classical equations [14]:

$$W = \frac{c}{2\, f_r\sqrt{(\varepsilon_r + 1)/2}} \quad (1)$$

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

$$L_{eff} = L + \Delta l \quad (3)$$

$$\Delta l = 0.412h\,\frac{(\varepsilon_e + 0.3)(\frac{W}{h} + 0.264)}{(\varepsilon_e - 0.258)(\frac{W}{h} + 0.813)} \quad (4)$$

$$L_{eff} = \frac{\lambda_o}{2\sqrt{\varepsilon_e}} = \frac{c}{fr\,\sqrt{\varepsilon_o}} \quad (5)$$

Where W is the width of the patch, L is the length of the patch, Δl is the additional length on each end due to the fringing field along the widths, ε_r is the dielectric constant of the substrate, ε_e is the effective dielectric constant, c is the speed of light in a vacuum, f_r is target frequency and h is the thickness of the substrate.

The resonance frequency for any $TM\ mn$ mode is given by James and Hall [15] as:

$$f_r = \frac{c}{2\sqrt{\varepsilon_r}}\left[\left(\frac{m}{L}\right)^2 + \left(\frac{n}{W}\right)^2\right] \quad (6)$$

Two micro-strip antennas with different patch size are designed by loading four rectangular slots into a square micro-strip patch antenna as shown in Figure-1.

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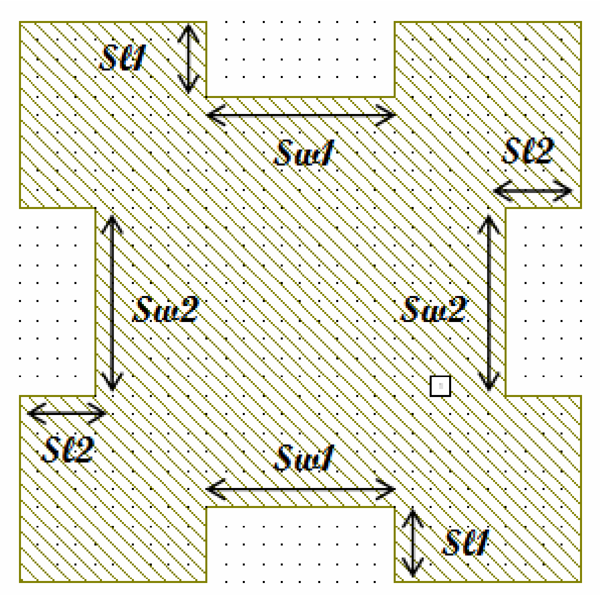

Figure-1. Antenna configurations with four rectangular slots.

Where Sl is the slot length, and Sw is the slot width.

Length and width of the slots have been changed in order to achieve the desired MSA performances.

A. MSA operate on the GPS and GSM (lower bands)

The square patch antenna design operate on the lower bands of both GPS and GSM applications (900 MHz and 1.227 GHz), the MSA is configured with four rectangular slots in the form of cut from the sides of the square patch antenna, the patch size is (80 x 80 mm) which is calculated from the equations of the transmission line model and from selected design parameters:

- Frequency of Operation (f_r): the resonant frequency of the antenna must be selected to operate in this frequency range of (900 MHz and 1.227 GHz). The frequency selected for this design is 1.05 GHz.
- Dielectric Constant of the Substrate (ε_r): the dielectric material applied for this design has a dielectric constant of (2.62) with height (*h*) of 5.95 mm.

The antenna is fed with probe feed, the probe feed position (X_f = 23, Y_f = -13mm) 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 center of the patch.

B. MSA operate on the GPS and GSM (upper bands)

The square patch antenna design operate on the upper bands of both GPS and GSM applications (1.575 GHz and 1.8 GHz), the MSA is configured with four rectangular slots in the form of cut from the sides of the square patch antenna, the patch size is (50 x 50 mm) which is calculated from the equations of the transmission line model and from selected design parameters:

- Frequency of Operation (f_r): the resonant frequency of the antenna must be selected to operate in this frequency range of (1.575 GHz and 1.8 GHz). The frequency selected for this design is 1.65 GHz.
- Dielectric Constant of the Substrate (ε_r): the dielectric material applied for this design has a dielectric constant of (2.62) with height (*h*) of 5.95 mm.

The antenna is fed with probe feed, the probe feed position (X_f = 13.5, Y_f = -8.5 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 center of the patch.

3. SIMULATION RESULTS

This paper propose the design of two square patch antennas each loaded with four rectangular slots configuration to provide a dual band performance. The proposed micro-strip patch antenna has been designed and simulated using Microwave Office simulation package.

Table-1 shows simulation results of the square MSA (80 x 80 mm) with different slots dimensions, in Set 3 dual band antenna behavior with a total bandwidth of (180 MHz) is achieved, the first resonance frequency is located in the frequency range of (920 MHz - 1.04 GHz) with BW of (120 MHz) make it suitable for GSM applications, while the second resonance frequency is located in the frequency range of (1.17 GHz - 1.23 GHz) with BW of (60 MHz) make it suitable for GPS applications.

Table-2 shows simulation results of the square MSA (50 x 50 mm) with different slots dimensions, in Set 3 dual band antenna behavior with a total BW of (190 MHz) is achieved, the first resonance frequency is centered at the (1.55 GHz) with BW of (120 MHz) make it suitable for GPS applications, while the second resonance frequency is centered at the (1.89 GHz) with BW of (70 MHz) make it suitable for GSM applications.

Figures 2 and 3 show the frequency response with respect to the return loss for the proposed antennas configurations.

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Table-1. Simulation results for different slot dimensions of square MSA configuration of (80 x 80 mm) operate on the dual frequency bands of GPS and GSM applications (lower bands).

	Sl1 (mm)	**Sl2** (mm)	**Sw1** (mm)	**Sw2** (mm)	$\mathbf{f_1}$ (GHz)	$\mathbf{f_2}$ (GHz)	**Bandwidth region** (GHz)	**Bandwidth** (MHz)
Set 1	12	12	20	20	1.03	1.27	(0.99 -1.07) , (1.25 -1.29)	80 , 40
Set 2	14	12	20	20	1.01	1.24	(0.96 -1.05) , (1.21 -1.26)	90 , 50
Set 3	16	12	20	20	0.99	1.20	(0.92 -1.04) , (1.17 -1.23)	120 , 60
Set 4	16	14	20	20	0.97	1.17	(0.93 -1.02) , (1.14 -1.20)	110 , 60
Set 5	16	16	20	20	0.97	1.14	(0.94 -1.00) , (1.10 -1.17)	60 , 70
Set 6	16	12	16	20	0.99	1.12	(0.94 -1.04) , (1.19 -1.24)	100 , 50
Set 7	16	12	24	20	0.98	1.19	(0.91 -1.05) , (1.17 -1.22)	140 , 50
Set 8	16	12	20	16	0.98	1.21	(0.91 -1.05) , (1.19 -1.24)	140 , 50
Set 9	16	12	20	24	0.98	1.19	(0.93 -1.04) , (1.17 -1.22)	110 , 50

Table-2. Simulation results for different slot dimensions of square MSA configuration of (50 X 50 mm) operate on the dual frequency bands of GPS and GSM applications (upper bands).

	Sl1 (mm)	**Sl2** (mm)	**Sw1** (mm)	**Sw2** (mm)	$\mathbf{f_1}$ (GHz)	$\mathbf{f_2}$ (GHz)	**Bandwidth region** (GHz)	**Bandwidth** (MHz)
Set 1	8	10	12	12	1.61	1.97	(1.54 -1.67) , (1.93 -2.01)	130 , 80
Set 2	9	10	12	12	1.58	1.93	(1.52 -1.64) , (1.89 -1.97)	120 , 80
Set 3	10	10	12	12	1.55	1.89	(1.49 -1.61) , (1.86 -1.93)	120 , 70
Set 4	9	8	12	12	1.60	2.01	(1.54 -1.67) , (1.97 -2.04)	70 , 70
Set 5	9	9	12	12	1.59	1.97	(1.53 -1.65) , (1.93 -2.01)	120 , 80
Set 6	9	10	12	12	1.58	1.93	(1.52 -1.64) , (1.89 -1.97)	120 , 80
Set 7	9	9	14	12	1.59	1.96	(1.53 -1.65) , (1.92 -2.00)	120 , 80
Set 8	9	9	16	12	1.59	1.95	(1.52 -1.65) , (1.91 -1.99)	130 , 80
Set 9	9	9	14	14	1.59	1.94	(1.53 -1.65) , (1.90 -1.98)	120 , 80
Set 10	9	9	14	16	1.59	1.93	(1.54 -1.65) , (1.89 -1.97)	110 , 80

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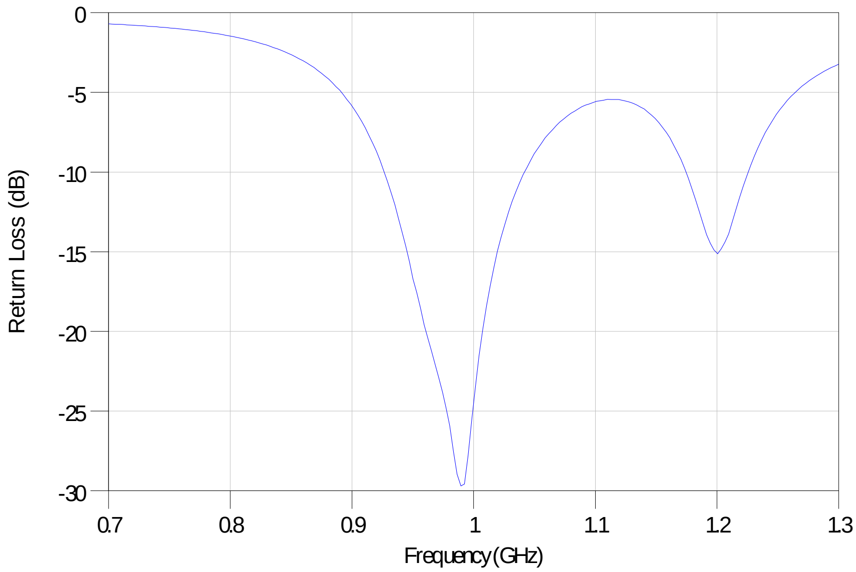

Figure-2. Frequency response for proposed MSA configuration of (80 x 80 mm) operate on the dual frequency bands of GPS and GSM applications (lower bands).

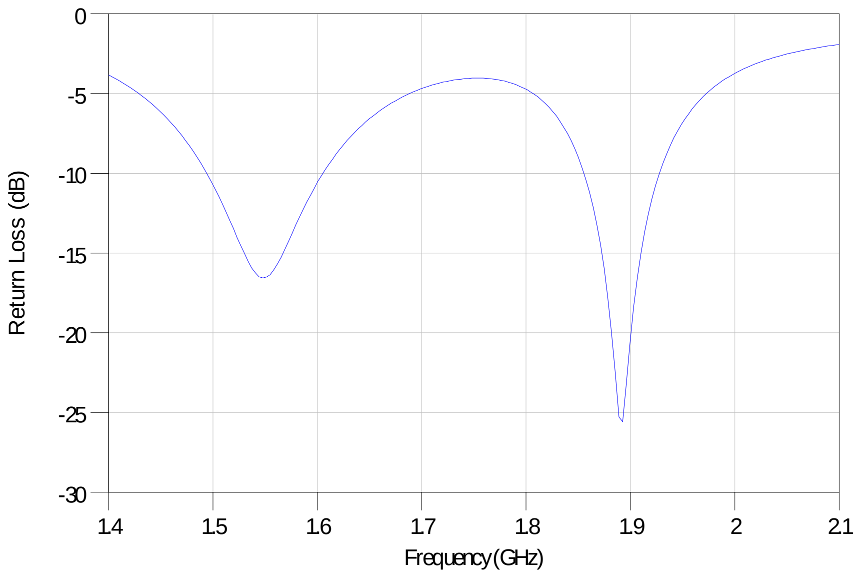

Figure-3. Frequency response for proposed MSA configuration of (50 x 50 mm) operate on the dual frequency bands of GPS and GSM applications (upper bands).

4. CONCLUSIONS

This paper introduces and investigates the design of multiband micro-strip antennas by studying the effect of loading four rectangular slots with different dimensions into a square MSA on the antenna multiband characteristics. Multiband MSA that not only can operate on dual frequency bands but on frequencies of two different applications are presented, these patches will combine the use of two applications and reduce the numbers of required antennas to be used in a single device. Such a single patch antenna designs that can operate on frequencies of GPS and GSM applications is very efficient and practical in modern communications systems.

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