Simulation Of Single Dual-Band Perturbed Printed Antenna

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Abstract- A single dual band rectangular microstrip antenna operating at L-band has been successfully designed and simulated. The design procedure starts from the formulation for the width dimension of the microstrip antenna. Upon achieving the most appropriate antenna width, the design proceeds to determining the most appropriate antenna length. The designed antenna is then simulated using a full wave electromagnetic simulation software. Analysis of one port characteristics is carried out on the designed antennas. The performance focuses on the return loss, input impedance, voltage standing wave ratio, current distribution and charge distribution. The designed antenna is then simulated with perturbed structures introduced. It is found that the antenna is well matched at its corresponding frequency of operations.

Keywords
Perturbed structures, dual-band operation, microstrip antenna.

I. INTRODUCTION

Research on single antennas operating at dual band frequencies has received great interests lately [1]-[6]. In addition, dual frequency antennas having compact structures are also attractive for low profile devices and space-limited applications. This paper focusses on the basic rectangular microstrip structure with perturbations introduced into the antenna radiating structure. The presence of the perturbation can in fact control the ratio of the dual frequencies as desired. The chosen frequencies are 1.575 GHz (Global Positioning System, GPS, application) and 1.8 GHz (Global System for Mobile, GSM, application).

II. MOTIVATION

A coaxially fed rectangular antenna having cross slot perturbation on the radiating structure exhibits dual frequency operation, in addition to having size reduction, compared to its corresponding non perturbed structure [1]. The ratio of the two frequencies is controlled by the shape and size of the perturbation structure.

Four L-shaped slot perturbations introduced into a coaxial feed rectangular antenna resulted in reducing the size of the antenna by almost 50 % [2]. The location of the feed does not depend on the length of the perturbed structure. Similar observations have been reported [3]-[6].

In this paper, the perturbation segment in the form of a simple L-shaped slots are introduced into the antenna radiating structure.

III. DESIGN CONSIDERATIONS

The geometry of the antenna is depicted in Fig. 1. The rectangular patch has a dimension of L x W and it is printed on a microwave laminate having substrate of thickness h and relative permittivity ε_r. The dimensions L and W can be obtained from the formulations available in the literature [7]. The size of the antenna, L x W, is determined mathematically as 33.2 mm x 30 mm. The chosen microwave laminate has the following parameters: $\varepsilon_r = 6.15$ and $h = 1.9$ mm.

The embedded L-shaped perturbation segment is placed close to the radiating edge of the patch. The perturbation segment has two sections of different widths (w_1, w_2) and lengths (l_1, l_2). By varying these parameters, the frequency ratio for the antenna can be tuned in the desired range. The slots are placed at a distance away from the radiating and non-radiating edges of d_W and d_L, respectively ($d_W = d_L = 1$ mm). The length l_1 is set to 1 mm and the width w_1 is set to $[(W/2) - d_w]$ mm for each side of the antenna. Good impedance matching of two operating frequencies can be obtained by using a probe feed and EMC feed placed along the centerline (x-axis) of the patch, a distance d_f away from the patch centre.

The basic antenna resonates at different modes. The perturbation segment introduced is able to control the ratio of the first two resonant frequencies.

Numerical simulations are then performed on the antenna structure using Ensemble SV [8]. The perturbation segment is varied in terms of its length and width and their effects are analysed. In this paper, the behaviour of the first two resonant frequencies are studied and analysed.

IV. SIMULATION RESULTS AND DISCUSSION

Firstly, l_2 is increased from 2 mm to 8 mm with an increment of 2 mm and the antenna is simulated. The behaviour of the resonant frequencies against varying l_2 are plotted in Fig. 2.

Secondly, w_2 is increased from 6 mm to 12 mm with an increment of 2 mm and the antenna is simulated. The behaviour of the resonant frequencies against varying w_2 are plotted in Fig. 3.

The corresponding frequency ratios against varying l_2 and w_2 are then computed and plotted in Fig. 4.

The behaviour of both resonant frequencies against varying l_2 and w_2 are plotted in a single graph for direct comparison as illustrated in Fig. 5.

The computed frequency ratios and the corresponding perturbation segment dimensions are given in Table 1.

From Fig. 2, it is found that by increasing l_2, both resonant frequencies decrease. From Fig. 3, it is clearly seen that, by increasing w_2, the first resonant frequency increases while the second resonant frequency decreases. As l_2 is increased, the frequency ratio decreases. This decrease is lower than that of increasing w_2.

The desired frequency ratio is 1.14 which is the ratio between GPS and GSM operating frequencies. From Table 1, it is observed that the nearest desired frequency ratio is achieved when $l_2 = 6$ mm and $w_2 = 14$ mm.

The simulated return loss for the proposed antenna is depicted in Fig. 6. This behaviour provides the proposed dual-frequency design with a varying tunable frequency-ratio. The antenna is reasonably well matched at the corresponding frequency of operation.

The simulated VSWR at the desired frequency of operations achieved with $l_2 = 6$ mm and $w_2 = 14$ mm is shown in Fig. 7. The antenna is found to be resonating at f_1 =1.577 GHz and f_2 = 1.818 GHz with corresponding reasonably good VSWR of 1.5 and 1.25, respectively.

There is a very slight disagreement between both simulation results and the desired frequencies. This is due to the limitation of the software. However, the disagreement is not significant.

V. CONCLUSION AND FURTHER WORK

This paper proposes a low profile dual-frequency rectangular antenna design having an embedded pair of L-shaped perturbation segments introduced at the radiating edges of the antenna. The first two operating frequencies can easily be controlled by changing the dimensions of the two sections of L-shaped perturbations embedded in the patch. By varying the size of the L-shaped perturbation segments, the frequency ratio of the first two resonant frequency can be tuned to the desired value of 1.14.

An antenna size reduction of about 15 % has been achieved. The results obtained indicate that the proposed design exhibit a compact structure compared to the conventional rectangular antenna operating at a particular frequency.

Work is currently under way in implementing the hardware for experimental verification.

VI. ACKNOWLEDGEMENT

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VII. REFERENCES

[1] Kin Lu Wong dan Kai-Ping Yang, "Small dual-frequency microstrip antena with cross slot", Electronics Letters, Vol. 33, No. 23, pp. 1916-1917, 1997.

[2] Wen-Shyang Chen, Chun-Kun Wu dan Kin-Lu Wong, "Compact circularly polarised microstrip antenna with bent slots", Electronics Letters, Vol. 34, No. 13, pp. 1278-1279.

[3] Jui Han Lu, "Dual-frequency operation of rectangular microstrip antenna with bent-slot loading", Asia-Pacific Microwave Conference, pp. 1343-1340, 2000.

[4] Shun Shi Zhong dan Jun Hai Cui, "Compact dual frequency microstrip antenna", Antennas and Propagation Society International Symposium, IEEE, Vol. 4, pp. 2196-2199, 2000.

[5] Jui Han Lu, "Single-feed dual-frequency rectangular microstrip antenna", Antennas and Propagation Society International Symposium, IEEE, Vol. 4, pp. 2192-2195, 2000.

[6] Kai Ping Yang and Kin Lu Wong, "Compact dual frequency operation of rectangular microstrip antennas", IEEE AP-S, pp. 1652-1655, 1999.

[7] Warren L Stutzman and Gary A Thiele, "Antenna Theory and Design", Wiley: New York, 1998.

[8] http://www.ansoft.com

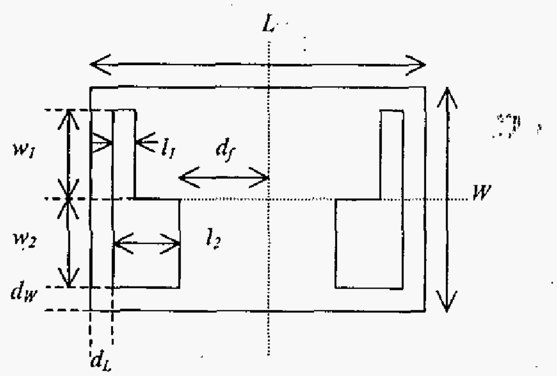

Fig. 1. Geometry for dual-frequency microstrip antenna with a pair of L-shaped perturbation segment.

W : width of antenna

L : length of antenna

l_1, w_1, l_2, w_2 : dimensions of the perturbation segment

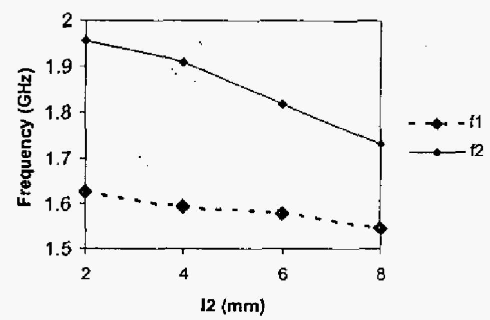

Fig. 2. The first two resonant frequencies, f_1 and f_2, against l_2.

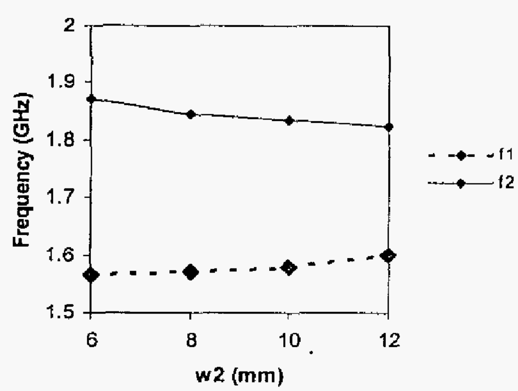

Fig. 3. The first two resonant frequencies, f_1 and f_2, against w_2.

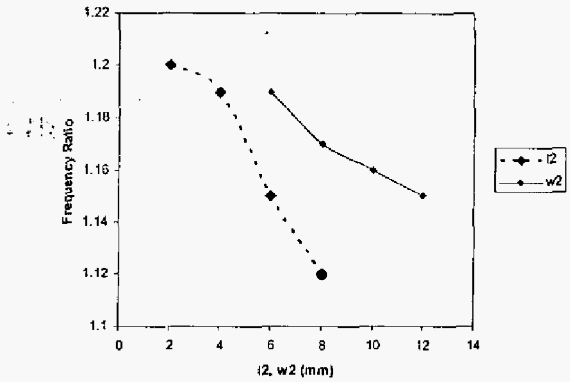

Fig. 4. The frequency ratio f_2/f_1 against l_2 and w_2.

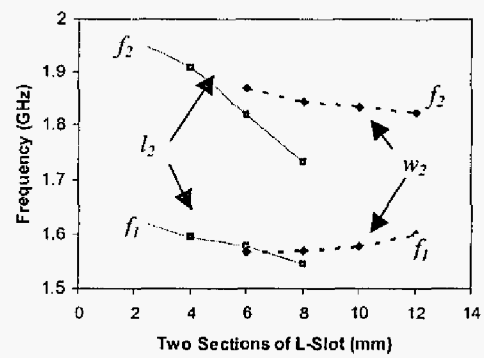

Fig. 5. The first two resonant frequencies, f_1 and f_2, against the two sections of the L-segment perturbation.

Table 1. Dual-Frequency operation of the perturbed printed rectangular antenna.
$\varepsilon_r = 6.15$, $h = 1.9$ mm, $L = 33.2$ mm, $W = 30$ mm, $l_1 = 1$ mm, $w_1 = 14$ mm and $d_L = d_W = 1$ mm.

Slot length, l_2(mm)	Slot width, w_1(mm)	f_1, (GHz)	f_2, (GHz)	Freq. ratio f_2/f_1
2	14	1.627	1.956	1.20
4	14	1.594	1.908	1.19
6	14	1.577	1.818	1.15
8	14	1.546	1.732	1.12

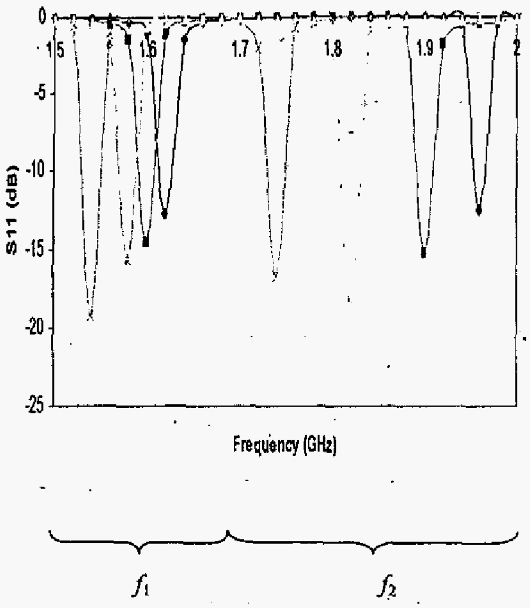

Fig 6. Simulated return losses for the proposed antenna with $w_2 = 14$ mm and

(i) $l_2 = 2$ mm
(ii) $l_2 = 4$ mm
(iii) $l_2 = 6$ mm
(iv) $l_2 = 8$ mm

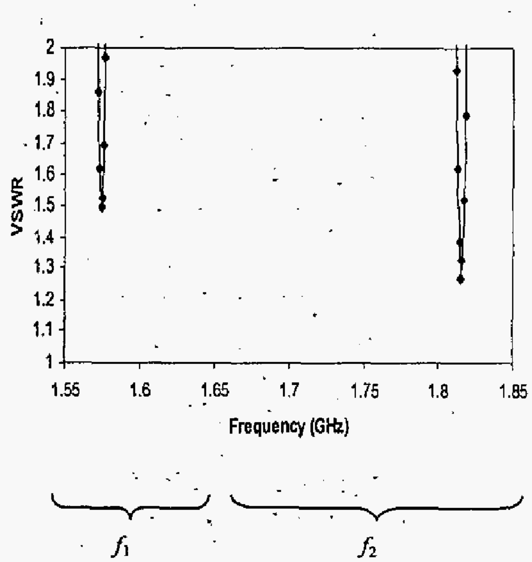

Fig 7. Simulated VSWR for $l_2 = 6$ mm and $w_2 = 14$ mm.