Low Profile Printed Antenna with a Pair of Step-Loading for Dual-Frequency Operation

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Abstract – Several techniques have been reported to reduce the size of a microstrip antenna having dual operating frequencies. A single low profile printed antenna which provides dual-band operation by having two-step slots loading embedded close to the radiating edge is presented. The ratio of the two frequencies can be well controlled by the aspect ratio of the step-loading dimension. Simulations performed on the designed antennas showed good dual band operation of f_1 =1.575 GHz (GPS) and f_2 = 1.8 GHz (GSM) with better than -10dB achieved return losses. Satisfactory performance of dual matching are achieved when coaxial and EMC feeds are employed. The accuracy of the design is validated by using two different electromagnetic simulation softwares.

1. INTRODUCTION

Owing to the recent development in the miniaturisation of mobile communication equipments, the design of compact microstrip antennas has become important and the demand has greatly increased. In addition to the requirement for compactness, the design for dual-frequency operations have been proposed [1] – [5].

2. BACKGROUND

A single patch antenna is analysed for dual-frequency operation by cut the two narrow slots in the patch close to the patch radiating edges [1]. The ratio between the two frequencies can be varied within a range from 1.6 to 2. Two T-shaped strips are loaded at the two radiating edges of the rectangular antennas to obtain various frequency ratios by varying the design parameters of this antenna [2]. This dual-frequency microstrip antenna is very promising for many practical applications. Similar observations have been reported [3]-[5].

In this paper, perturbation segments in the form of a pair of step loading embedded in the radiating edges are introduced for dual operation compact antenna. The antenna achievable size reduction for dual operation is compared with corresponding conventional rectangular antennas.

3. DUAL BAND OPERATION DESIGN

The geometry of the L X W compact dual-frequency low profile printed antenna is illustrated in Fig.1. A step-loading is embedded in the radiating patch to decrease the resonant frequency and to achieve the desired resonant frequency ratio. The desired resonant frequency ratio needed is f_2/f_1 =1.14.

For the chosen substrate of relative dielectric constant ε_r = 3.2 and thickness h = 1.52 mm, the dimensions L and W can be obtained from the formulations available in the literature [6] or from the Micropatch software [7]. The size of the antenna, L X W, operating at 1.8 GHz is determined first. From both methods, L X W equals 46.17 mm x 35 mm.

The embedded step-loading segments have two sections of variable 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 and w_2 is set to be fixed with [(W/2) – 2] mm for each side of the step-loading.

The antenna is investigated with two feeding methods, namely coaxial probe feed and EMC feed. The feed location with good impedance matching is determined by placing the feed point along the centerline (x-axis) of the patch, a distance Δ d_f away from the patch center.

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The conventional rectangular antenna resonates at different modes. From the cavity model, the first two modes that can be excited are usually denoted by TM_{10} and TM_{01}. The TM_{10} mode is the most frequently used mode in practical applications since TM_{01} has a broadside null radiation pattern.

The above design concept has been performed on the antenna structure using Ensemble SV [8] and SonnetLite Plus v.8 [9] softwares. Ensemble SV is used to analyze the coaxial probe feed design. On the other hand, Sonnet Lite v.8 is used to analyse the EMC feed design. The performance focusses on the return loss, input impedance, voltage standing wave ratio and current distribution.

4. NUMERICAL SIMULATIONS, RESULTS AND DISCUSSION

Typical proposed antennas are simulated and investigated. Parameter l_2 is varied from 4 mm to 14 mm with 2 mm increment. The behaviour of the resonant frequencies against variation of l_2 are plotted in Fig. 2. It is clearly seen that, by increasing l_2, both resonant frequencies decrease.

The corresponding frequency ratios against varying l_2 are then computed and plotted in Fig. 3. From the figure, the inversely proportional relationship is observed when the f_2 / f_1 decreases as l_2 increases.

Variations of the dual frequencies and the frequency ratio with step-loading segment are presented in Table 1.

The desired frequency ratio between GPS and GSM operating frequencies is 1.14. From Table 1, it is observed that the nearest desired frequency ratio is achieved when l_2 = 14 mm and w_2 = 16.5 mm.

Fig. 4 shows the return loss responses for the proposed antenna with a pair of step-loading of various step ratios without matching factor. This behaviour provides the present dual-frequency design with a tunable frequency ratio.

Then, simulations are further performed to find the best feed location [10]. Fig. 5 shows the resonance performance of the varying location of feed point for a good impedance match agreement at 50 Ω. It is found that the best impedance match can be obtained when the feed is located 14 mm from the patch centre.

By considering the impact of matching factor, the simulated return losses for the proposed antenna are depicted in Fig. 6. The antenna is reasonably well matched at the corresponding frequency of operation for both types of feeding techniques. By achieving a return loss of better than -10 dB, both designs have good VSWRs which are less than 2.

There is a very slight inagreement between both simulation results and the desired frequencies. However, both results showed well-matched performance at the two corresponding resonances.

The antenna offers an area reduction of ~ 28 % compared to a conventional rectangular patch antenna designed for the same frequency [10]. By comparing with the conventional patch antenna, the proposed antenna is more suitable for applications where lower frequency ratio is required.

5. CONCLUSION AND FURTHER WORK

The proposed antenna has been investigated numerically using two electromagnetic simulation softwares. By varying the step-loading size, we can achieve a new type of antenna that has tunable ratio of resonant frequencies at whatever desired frequencies. The present antenna design operates well at the desired frequency ratio tuned to 1.14.

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

6. ACKNOWLEDGEMENTS

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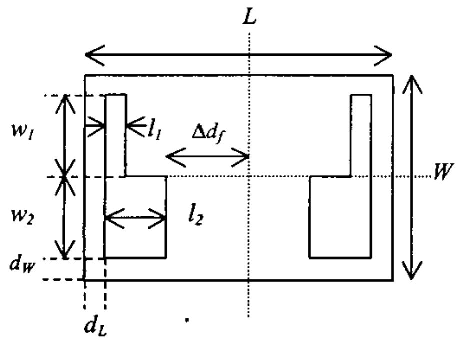


Figure 1: Dual-frequency microstrip antenna geometry with a pair of embedded step-loading at the radiating edges.

W: width of antenna

L : length of antenna

l_1, w_1, l_2, w_2 : dimensions of the step-loading

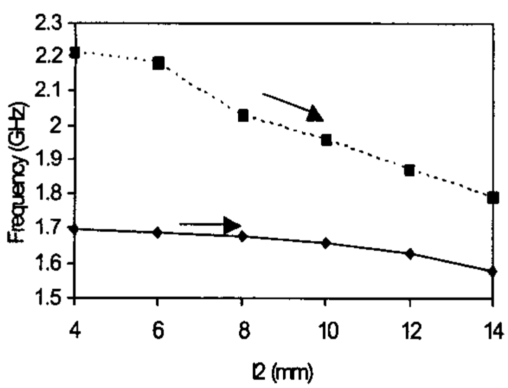


Figure 2: Relationship of the first two resonant frequencies, f_1 and f_2 , against l_2

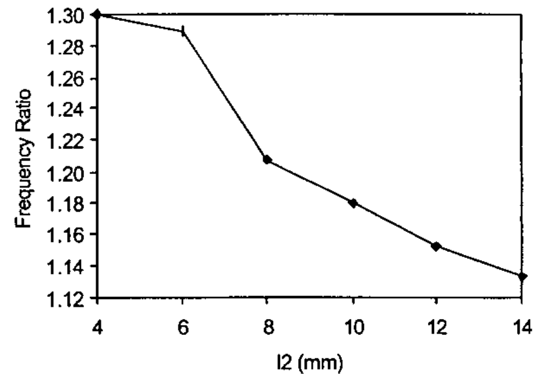


Figure 3: Relationship of resonant frequency ratio f_2 / f_1 against l_2

TABLE 1: Dual-frequency operation of the embedded step-loading at the radiating edge.
ε_r = 3.2, h = 1.52 mm, L = 46.17 mm, W = 35 mm, l_1 = 1 mm, and $d_L = d_W$ = 1 mm.

Slot length, l_2 (mm)	Slot width, $w_1 = w_2$ (mm)	f_1 , (GHz)	f_2 , (GHz)	Freq. ratio f_2/f_1
4	16.5	1.70	2.21	1.30
6	16.5	1.69	2.18	1.289
8	16.5	1.68	2.03	1.208
10	16.5	1.66	1.96	1.180
12	16.5	1.63	1.87	1.153
14	16.5	1.58	1.79	1.133

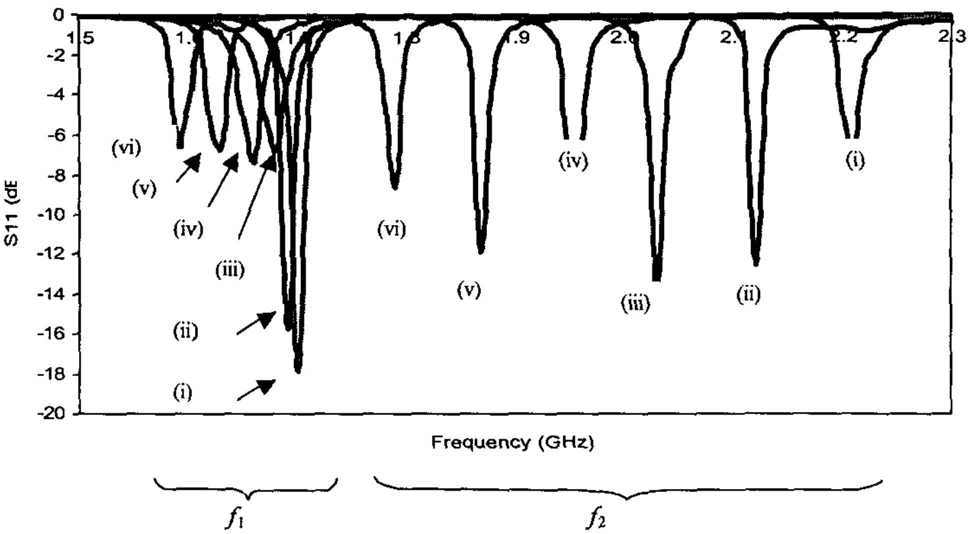
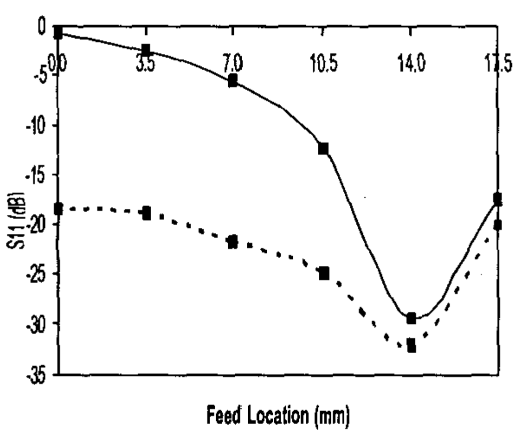


Figure 4: Simulated return losses responses for the proposed antenna with w_2 = 16.5 mm and different values of l_2. (i) l_2 = 4 mm, (ii) l_2 = 6 mm, (iii) l_2 = 8 mm, (iv) l_2 = 10 mm, (v) l_2 = 12 mm and (vi) l_2 = 14 mm.



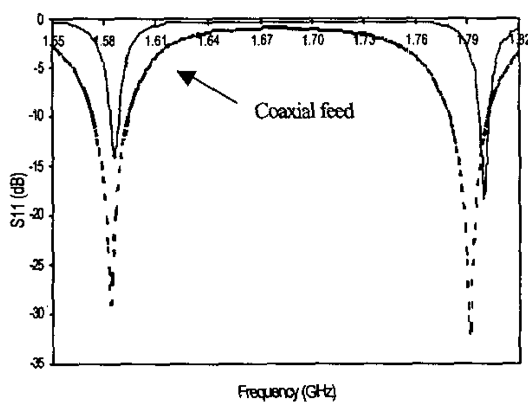


Figure 5: Simulated return losses at different feed locations for dual operations.

Figure 6: Simulated return losses for the proposed antenna with the best feed position for two feeding methods.