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DESIGN CONSIDERATIONS OF BROADBAND RECTANGULAR PATCH ANTENNA WITH EMBEDDED REACTIVE LOADING

Hua-Ming CHEN* **and Yi-Fang LIN****
***Department of Physics**
National Kaohsiung Institute of Technology, Kaohsiung 807, Taiwan
E-mail hmchen@cc.nkit.edu.tw
****Department of Electronic Engineering**
Cheng-Shiu Institute of Technology, Kaohsiung 833, Taiwan

1. Introduction

Some broadband design of the rectangular or circular microstrip antennas have been reported [1, 2] in which the broadband operation is obtained by embedding a U-slot in the rectangular or circular patch. In these reported designs all require the use of an air or foam substrate, which result in a required large antenna volume and does not fabricate easily for broadband operation. In this paper, a new broadband design of rectangular microstrip antenna in which a cascade of two microstrip-line sections is embedded within a rectangular slot cut in the patch (see Fig. 1). The embedded microstrip-line sections also provide as an integrated reactive loading [3] and the patch is printed on a thin substrate. It appears that by selecting proper dimensions of the slot and microstrip-line sections, the excitation of the first broadside-radiation modes of TM_{10} and TM_{20} can be perturbed and these two modes of similar radiation characteristics can be excited at frequencies close to each other, to achieve a wide operating bandwidth. Details of the antenna design and experimental results are presented and discussed.

2. Antenna design scheme and experimental results

Fig. 1 shows the proposed reactive loading rectangular microstrip antenna for broadband operation. The rectangular patch has dimensions 40 mm × 30 mm and is printed on a substrate of thickness h and relative permittivity ε_r To provide the reactive loading, a cascade of transmission line consisting of two different straight microstrip-line segments is embedded inside a rectangular slot cut in the rectangular patch. Both the microstrip structure and slot cut are symmetric to the y-axis, and their related dimensions are given in Fig. 1. For the present design with $h = 1.6$ mm, $\varepsilon_r = 4.4$ and a ground-plane size of 75 mm× 50 mm, a single probe feed located at a position x_p away from the patch center can excited two resonant modes. Fig. 2 shows the two lowest-order resonant frequencies as a function of microstrip-line segment L. First note that, for the unloaded reactive loading, the first two broadside-radiation modes TM_{10} and TM_{20} of the rectangular patch can be excited. However, when the reactive loading are presented, a new resonant mode, denoted as $TM_{\delta 0}$ $(1 < \delta < 2)$ here, is excited. And,

TM_{10} mode is seen to remain relatively constant but TM_{80} mode tends to decrease as L increases. Once the desired resonant frequencies are obtained, impedance matching must be considered for both frequencies. Changing the feed position may have good impedance matching for one frequency but may have not for the other. Unfortunately, for higher frequency ratio, the impedance at the two frequencies moves considerably in opposite directions while the resonant frequencies stay relatively unchanged. Thus proper choice of microstrip-line dimensions and location of the probe feed provides the impedance matching at the desired dual frequencies.

Fig. 3 illustrates the effect of changing the microstrip-line width W for the proposed antenna with $L = 11$ mm. It is noted that, microstrip-line width $W< 4$ mm, the two frequencies approach each other when W increases. The upper resonant is seen to remain relatively stable but the lower one decreases when $W> 4$ mm. So, in the vicinity of the microstrip-line width, $W = 4$ mm, the two resonant frequencies are nearly degenerate. While changing the location of feed for the impedance match, the resonant frequencies may change slightly. To adjust the frequencies to the desired levels, the reactive loading needs to be altered a little. In practice it may be necessary to repeat the above procedure to obtain the good impedance matching at the two desired frequencies.

From above procedure a set of parameters are obtained. And, due to the embedded reactive loading in the rectangular patch, the first two broadside-radiation modes TM_{10} and TM_{80} of the patch can be excited at frequencies close to each other to make the antennas' operating bandwidth broaden. Fig. 4 shows the measured return loss for the proposed design. It is first found that the two resonant modes (TM_{10} and TM_{80}) are excited with good impedance condition, and the measure return loss at the two frequencies is > 25 dB. The obtained bandwidth is about 4.6% which is ~ 2.5 times that (1.85%) of a corresponding rectangular microstrip antenna without reactive loading. The radiation patterns of the proposed antenna at the two operating frequencies are also measured in Fig. 5. It is seen that both operating modes have the same broadside radiation patterns and polarization planes, and cross-polarization radiation is well below -20 dB in the broadside direction. The measured maximum received power against frequency is shown in Fig. 6. The two operating frequencies 1738 MHz and 1781 MHz are seen to have a relatively stable antenna gain, and the gain is less with center frequency at 1760 MHz.

3. Conclusions

A single-feed broadband microstrip antenna with embedded reactive loading has been implemented. The design process is physically intuitive and relatively simple, which makes the antenna bandwidth up to 4.6% without thick substrate and the input impedance can be easily matched for both frequencies. The radiation patterns and antenna gain have been measured to confirm the usefulness of the proposed antenna. More extensive studies of the proposed antenna are underway.

4. References

[1] T. Huynh, and K. F. Lee, "Single-layer single-patch wideband microstrip antenna", *Electron. Lett.*, vol. 31, no. 16, 1995, pp. 1310-1312.

[2] K. M. Luk, and K. F. Lee, and W. L. Tam, "Circular U-slot patch with dielectric superstrate", *Electron. Lett.*, vol. 31, no. 12, 1997, pp. 1001-1002.

[3] N. Fayyaz, and S. Safavi-Naenin, "Bandwidth enhancement of a rectangular patch antenna by integrated reactive loading", *1998 IEEE AP-S Int'l Symp. Dig.*, pp. 1100-1103.

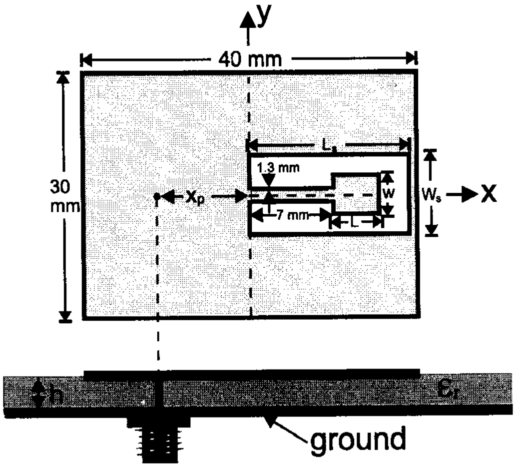

Fig. 1 Geometry of a broadband rectangular microstrip antenna with embedded reactive loading. The dimensions shown in the figure is not to scale.

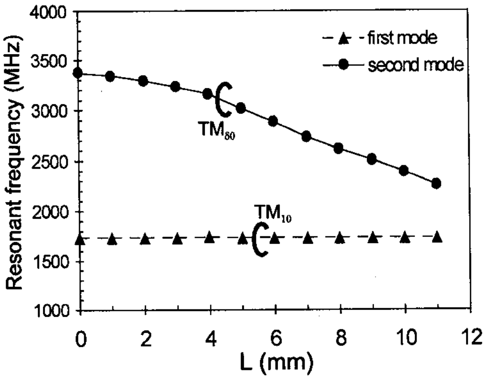

Fig. 2 Resonant frequencies as a function of the length of microstrip-line segment with W = 0.5 mm, L_S = 19 mm and W_S = 11 mm. Patch dimensions are given in Fig. 1.

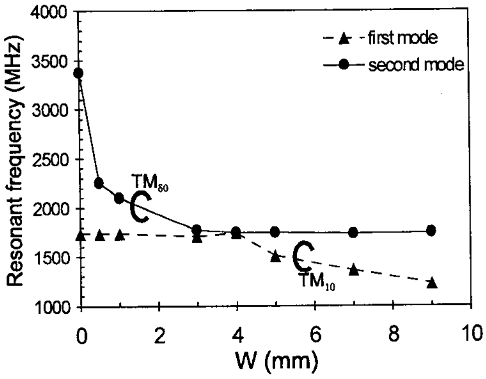

Fig. 3 Resonant frequencies as a function of the width of microstrip-line segment with L = 11 mm, L_S = 19 mm and W_S = 11 mm. Patch dimensions are given in Fig. 1.

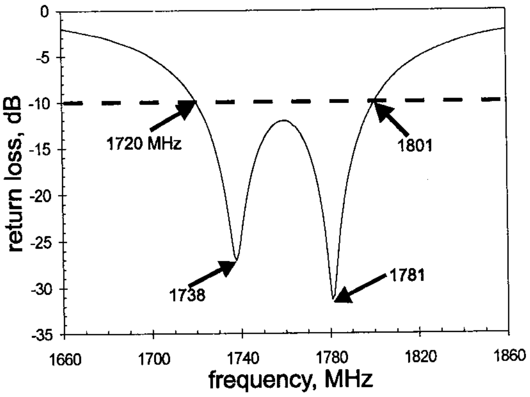

Fig. 4 Measured return loss for proposed broadband antenna; $\varepsilon_r = 4.4$, $h = 1.6$ mm, ground-plane size = 75 mm × 50 mm, L =9.2 mm, W = 4.0 mm, $L_S = 19$ mm and $W_S = 10.4$ mm . Patch dimensions are given in Fig. 1.

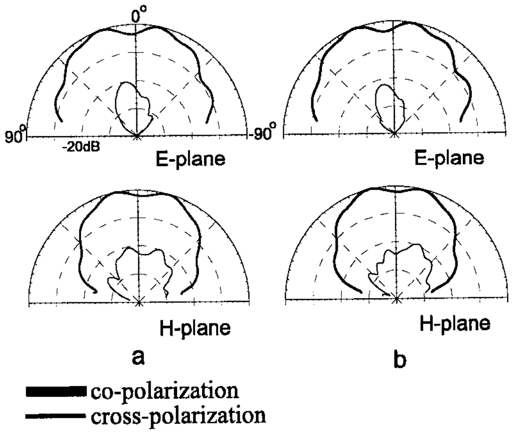

Fig. 5 Measured E-plane and H-plane radiation patterns for the proposed antenna shown in Fig. 4 with $x_p = -10$ mm. (a) f = 1738MHz. (b) f = 1781 MHz.

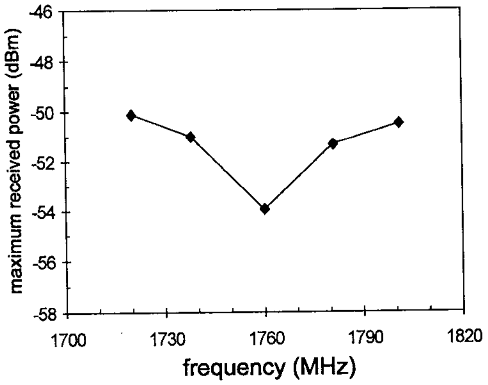

Fig. 6 Maximum received power in broadside direction against frequency for the proposed antenna shown in Fig. 4.