Compact Wideband Dual-Polarized Microstrip Patch Antenna

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I. INTRODUCTION

Bandwidth enhancement by multiple resonances is a widely used technique for microstrip patch antennas. There are numerous methods to couple multiple resonances. Examples include coupled patches [1], patches with slots (e.g. U- and E-shaped) [2], [3], stacked patches [4], and patches with aperture-coupled feeds [5]. In some personal wireless communications systems, such as used for triple band option, more than 30 percent of the operating bandwidth is required. Bandwidth in excess of 70 percent can be achieved with aperture-coupled stacked patches [6]. However, such configurations occupy considerable space and are not always acceptable for integration with other circuitry. For handheld wireless systems, a compact single patch on moderately thick substrate is preferred. For such antenna, achieving more than 25 percent bandwidth and moderate gain presents a challenge.

Therefore, in this paper, we present a single-layer microstrip patch antenna on a relatively thin substrate. The design employs multiple resonances without significantly enlarging the size. It achieves 54 percent VSWR and 40 percent gain bandwith for VSWR<2 and G>2 dBi, respectively.

II. PRINCIPLE OF OPERATION AND DESIGN

Three square patches are overlapped along their diagonals as shown in Fig 1. The dimensions of the patches are (W_1 x W_1), (W_2 x W_2) and (W_3 x W_3), respectively. S_1 and S_3 indicate the overlapping dimensions of the patches. The structure has five different resonant lengths as follows:

$$
\begin{aligned}
l_1 &= W_2 + (W_3 - S_3) + 2\Delta l_1 \\
l_2 &= W_2 + (W_1 - S_1) + 2\Delta l_2 \\
l_3 &= W_2 + 2\Delta l_3 \\
l_4 &= 2W_1 - (W_1 - S_1) + 2\Delta l_4 \\
l_5 &= 2W_3 - (W_3 - S_3) + 2\Delta l_5
\end{aligned}
\tag{1}
$$

The increments to the lengths, Δl_1, Δl_2, Δl_3, Δl_4, and Δl_5, are due to the fringing fields and can be computed from formulae given in [7]. As an example, an antenna with the following dimensions was designed: three square patches of dimensions (13.5 x 13.5) mm, (7.5 x 7.5) mm and (7.1 x 7.1) mm with overlapping dimensions S_1=6.4 mm and S_3=4.6 mm; a dielectric substrate of relative permittivity ε_r=2.35 and thickness h=3.175 mm was used.

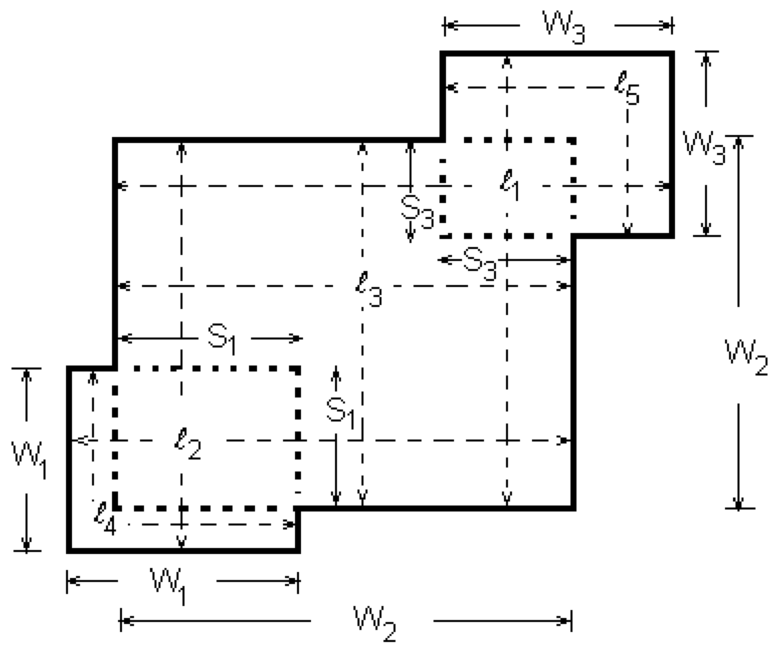

Fig.1 Geometry of the multi-resonance broadband patch.

III. NUMERICAL MODELING

The commercial software package IE3D was used to model the antenna. Resonant frequencies computed with IE3D and with equation (1) are compared in Table I. Good agreement is apparent. The differences are attributed to the inductance of the feed probe which was included in the numerical modeling.

Table I: Comparison of resonant frequencies

Resonant length	Physical dimension (mm)	Fringing field length (mm)	Total length (mm)	Calculated resonance frequency (GHz)	Resonance from IE3D (GHz)
l_1	16	2.63	21.26	4.98	4.7
l_2	14.6	2.45	19.5	5.4	5.1
l_3	13.5	2.33	18.16	5.84	5.7
l_4	(7.5x2)-1.1	1.7	17.3	6.2	6.7
l_5	(7.1x2)-2.5	1.65	14.8	7.2	7.4

The current distribution on the patch is shown in Figure 2. In the extreme edges, it illustrates the curved paths along the mean dimension l_4 and l_5, and thus confirms the corresponding resonant frequencies given by equation (1). The dual-polarized behavior is explained as follows: At resonance frequencies f_1, f_2 and f_3, the antenna has two radiating strips perpendicular to each other, which radiate in vertical and horizontal polarizations (c.f. Fig. 1). At resonance frequencies f_4 and f_5, the radiating strip has a bend at the center, and its radiation is due to two perpendicular edges, which provides dual polarization.

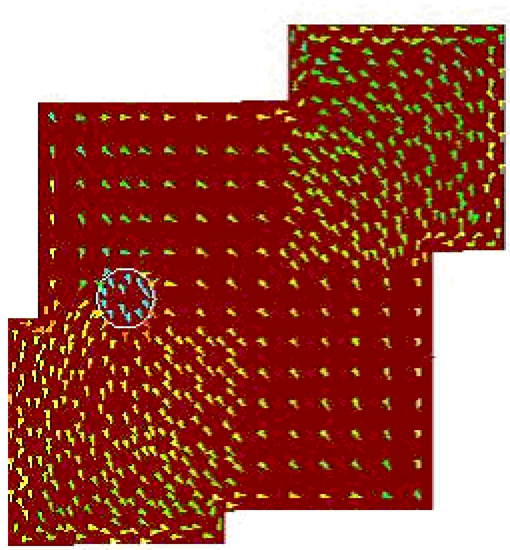

Fig 2. Current distribution on the patch surface and location of the feed.

Figures 3 and 4 illustrate the VSWR and gain of the antenna. Due to the fact that the radiating apertures of the two edge patches are relatively smaller compared to those of the main patch, the gain decreases at higher frequencies. It is expected that the gain can be increased by adding periodic elements, e.g., [8].

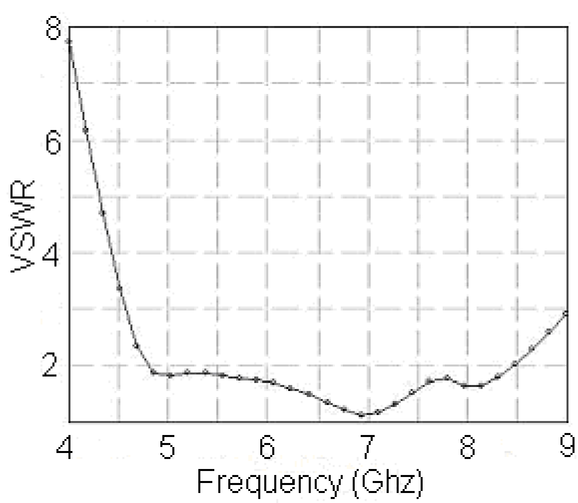

Fig. 3 VSWR of the antenna.

IV. CONCLUSIONS

A compact dual-polarized microstrip patch antenna has been designed, and formulas for its preliminary design have been provided. The arrangement of overlapping patches and their associated resonant frequencies are verified by a commercial field solver. The structure is easily fabricated on a single-layer and relatively thin substrate for applications in hand-held devices. The design guidelines are straightforward so that the antenna can easily be used in other frequency bands and with different substrate materials. Furthermore, the antenna gain can be increased by adding periodic elements.

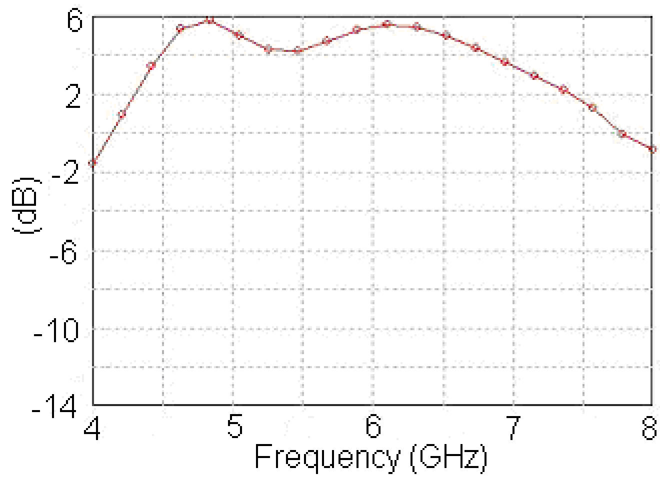

Fig. 4 Gain of the antenna.

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