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Dual-band Slotted Patch Antenna with Diagonally Offset Deed for GPS and WLAN

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Abstract - Spurred by the constant pressure to achieve miniaturization, researchers have designed many different types of compact antennas. One such type is the slotted patch antenna used for dual band operation. In this paper, we propose a novel method of selecting the feeding point of the antenna, which results in superior antenna performance in terms of return loss. Computer simulations verify the validity of the proposed method.

Keywords: Dual-band Antenna, Global Positioning System, Slotted Patch Antenna, Wireless LAN

1. Introduction

Microstrip Patch Antennas (MPAs) have been extensively used in commercial and military communication systems because of their attractive properties. Ideal dual-band patch antennas should have similar performance at both operating frequencies in terms of radiation properties and simultaneous impedance matching. The multi-frequency patch antennas including the dual frequency antenna found in the literature can be divided into two categories such as multi-resonator antennas and reactive loading antennas. A multi-resonator printed antenna can be fabricated on a single dielectric layer by using aperture coupled parallel rectangular dipoles. The reactive loading patch antenna consists of a single radiating element in which the double resonant behavior is obtained by connecting coaxial or microstrip stubs at the radiating edge of a rectangular patch. Another type of reactive loading can be introduced by etching slots on a patch. The slot loading allows significant modifications to the resonant modes of the unslotted rectangular patch, particularly when the slots cut the current lines in the unslotted patch.

In general, many possible feed methods are available for MPAs. For example, connecting a microstrip line directly to the edge of a patch is a good option for coplanar applications. By properly inserting a pair of cuts in the patch, impedance matching between the patch and line can readily be achieved without further additional matching elements. Alternatively, the impedance matching condition can be controlled by changing the position of the feed point Typically, the patch can be fed by a buried line below the patch or a microstrip line through a small non-resonant aperture on a ground plane. By correctly controlling the electromagnetic coupling between the feed line or aperture and the patch, the feed and patch can be properly matched in a broad frequency range. Furthermore, the radiation characteristics of the MPAs within their operating bandwidths are important design considerations. Usually, the ratio of cross-polarization to co-polarization radiation levels in specific planes within certain beam widths should be lower than the specified levels for the applications requiring high polarization purity. Both geometric and electrical parameters of the MPA mainly affect the cross-polarized radiation. For example, for a rectangular MPA, the ratio of cross-polarization to co-polarization radiation levels primarily depends on its aspect ratio and the thickness and/or dielectric constant of the substrate supporting the patch. Therefore, the proper selection of feeding configurations and geometric structures may be conducive to enhancing the radiation performances of MPAs.

Maci et. al. [1] suggested a dual-band slot-loaded patch antenna having a structure consisting of a rectangular patch with two narrow slots etched close and parallel to the radiating edge. They tried to find the optimal feed position located on the line connecting the centers of the two slots. However, the numerical equations shown in [1] to design the slot-loaded patch antenna were not suitable for working with the substrate of the high dielectric constant.

In this paper, we study the same structure of the slot-loaded patch antenna in [1]. However, we suggest a new feeding position being located on the diagonal line as in Fig. 1, which is suitable for the Global Positioning System

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(GPS) L1 frequency of 1.575GHz and WLAN of 2.45GHz using the substrate of the dielectric constant of 9.1. The effects on the resonant frequency of the structural parameters are also studied.

2. Antenna Structure

The geometry of the slot-loaded patch antenna (SPA) with patch dimensions L and W is shown in Fig. 1. Two narrow slots with dimensions Ls and d are etched into the rectangular patch such that they are parallel to the edges. The location of the slot corners relative to the patch corners is determined by the dimensions sw and sl, where sw<<W and sl<<L. As mentioned, the SPA can be fed by a probe or a coupling aperture. In this study, a probe feed is investigated.

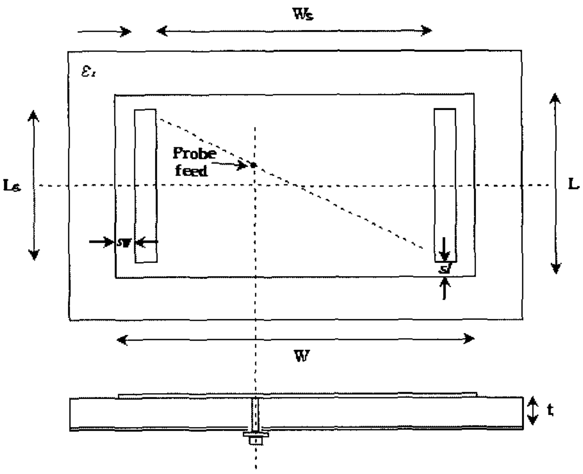


Fig. 1 Geometry of probe feed SPA

The resonant behavior of the SPA may be explained by starting with the cavity model description of an unslotted rectangular patch. The first three modes that can be excited in the cavity are usually denoted by TM_{100}, TM_{200} and TM_{300}. These modes correspond to longitudinal current distributions on the patch. Obviously, boundary conditions require that nulls in the current distribution exist at the radiating edges where the current distribution is perpendicular to the patch edge. The TM_{100} is the most widely used in practical applications since the TM_{200} mode has a broadside-null radiation pattern and the TM_{300} mode produces grating lobes.

When the two narrow slots are etched close to the radiating edges (small values of sl and sw), minor perturbations of TM_{100} are anticipated because the slots are located close to the current minima. The radiative mechanism associated with the first mode is essentially the same as that of a patch without slots. As a consequence, the resonant frequency is only slightly different from that of a standard patch.

On the other hand, the slots are located closer to a current peak of the unperturbed TM_{300}, significantly modifying this current distribution. The currents circulate around the slot and shift the resonant frequency closer to that of the TM_{100} mode. The perturbed TM_{300} mode has two useful properties; the resonant frequency is considerably lower and, as shown subsequently, the radiation pattern loses the typical three-lobe shape of the unperturbed TM_{300} mode, which is similar to that of the TM_{100} mode.

3. Design parameters and dual frequencies

To ensure good radiation efficiency, the aspect ratio between the patch length and width is similar to the ratio of the two resonant frequencies associated with the TM_{100} and TM_{300} modes, f_1 and f_2, respectively.

$$W/L \doteqdot f_2/f_1$$

The length L is the main geometric parameter that determines f_1, though it also has a strong effect on f_2. Increasing L decreases both f_1 and f_2, with the second mode more significantly affected. The slot geometry determines f_2, therefore the slot parameters, d, sl, and sw, can be adjusted to shift f_2 to a lower frequency. Also, the width of the patch, W, is inversely proportional to f_1 and can be varied to optimize the antenna.

4. Simulation Results

The SPA is designed to receive the GPS L1 band (1.576GHz) and the WLAN/Bluetooth band (2.45GHz=f_2),

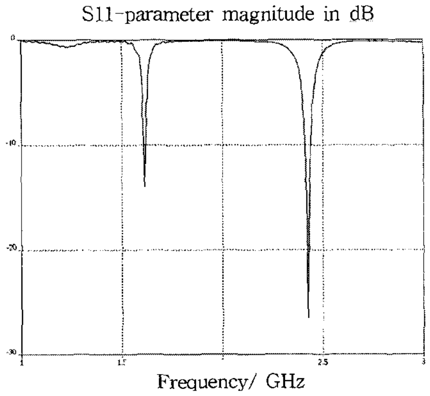
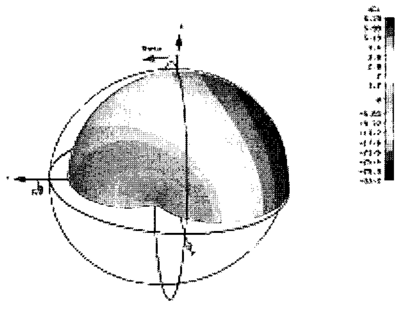
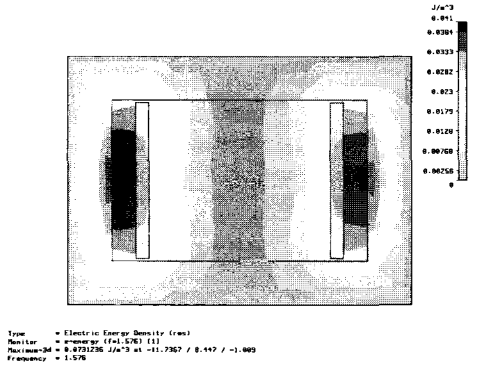


Fig. 2 Simulated amplitude of input reflection coefficient for SPA without tuning resonators fed by coaxial probe. L=18.25 mm, W=29.953 mm, d=1.45mm, sw=2.74 mm, ε_r=9.1, t=1mm

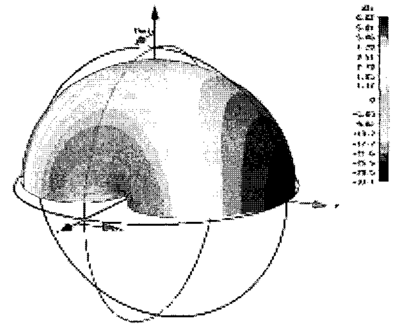
simultaneously. The SPA dimensions are L=18.25 mm, W=29.953 mm, d=1.45mm, sw=2.74 mm, ε_r=9.1, t=1mm. The structure is simulated with the CST Microwave Studio 5.0. The S parameters at the two frequencies are shown in Fig. 2; $|S11|$=10.65 dB at f_1, $|S11|$= 27.3dB at f_2; f_1= 1.576GHz, f_2=2.45GHz. The narrow bandwidth at the two resonances is due to the small substrate thickness. It is worth noting that the bandwidth of the upper resonance is wider than that of the lower resonance.



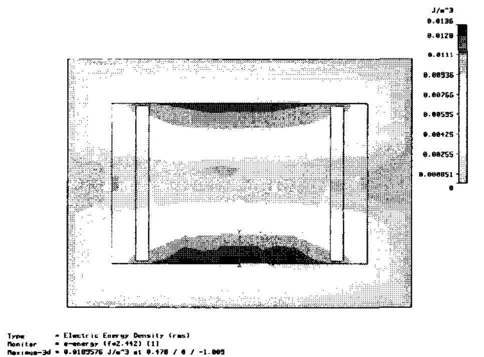
(a) Far field pattern at 1.576 GHz



(b) Electric energy density at 1.576 GHz



(c) Far field pattern at 2.45GHz



(d) Electric energy density at 2.45GHz

Fig. 3 Simulated radiation patterns and electric energy density for SPA; f_1=1.576GHz, f_2=2.45GHz

Fig. 3 indicates the 3D radiation pattern and electric energy density at both modes. At f_1, the directivity=6.793 dBi and the gain=6.571 dB. At f_2, the directivity=6.621dBi and the gain=6.571dB.

A diagonally offset feed location has also been investigated. Generally, it is easy to find the feeding point through the electromagnetic simulation tool result rather than by the mathematical analysis.

From the simulation result, it is found that when the feed point is located about 2mm apart from the center of the patch it gives a satisfactory S-parameter value at the desired frequency. As the dimension of the patch changes, the feed point can be selected with the tolerance of 1mm. In case the feed point is selected diagonally, it has smaller changes in the feed point. In other words, the feed point is the crossing point between the diagonal line and vertical line that is located 2mm left from the center of the patch. The most significant feed positions among the several candidate feed points are (1,1) and (2,2) as illustrated in Fig. 4. Optimizing the S_{11} parameter is achieved at feed point (1,1) for the upper frequency f_2, and at (2,2) for the lower frequency f_1 as shown

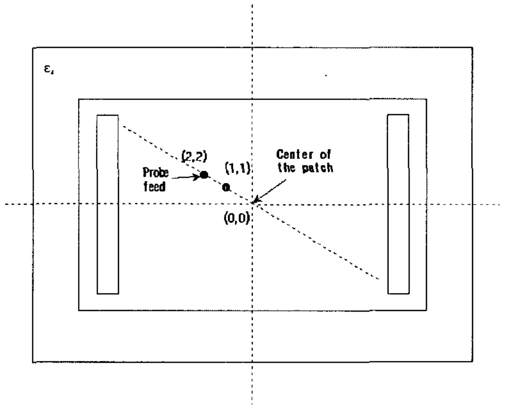
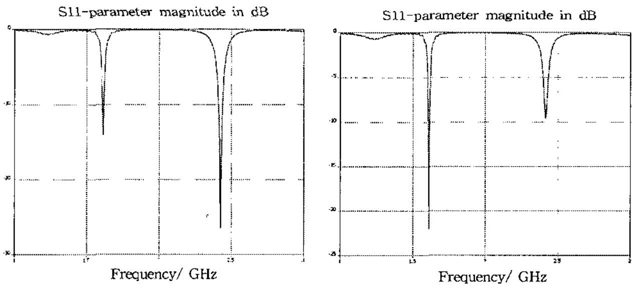


Fig. 4 The feeding point from (1,1) to (2,2)



(a) the point (1,1) (b) the point (2,2)

Fig. 5 The S parameter amplitude with the feeding point changed diagonally. W=28.95mm, L=16.25mm, sl=0.3mm; sw=0.5mm, d=0.5mm; ε_r=9.1, t=5mm in Fig. 5. Moreover, the S-parameters at the two frequencies complement each other, which mean that it is possible to obtain the desired input reflection coefficient amplitude at the specific frequencies. When one frequency band requires a broader bandwidth than the other, the feed location can be adjusted to meet the specifications.

5. Conclusions

We investigated the slot-loaded patch antenna with diagonally offset feed for GPS and WLAN. The feeding position of a new dual-frequency antenna was also studied. With the diagonally offset feed, feed position and S-parameter values could be easily obtained. Using higher dielectric materials, it is possible to reduce antenna dimensions when the antenna for GPS and WLAN is designed. By changing the feed point, the reflection coefficient value can be adjusted at two frequencies. Finally, the dual capability of the antenna with a diagonal single feed point has been demonstrated by simulations. Further investigations for the slot design and feed positions are in progress.

Acknowledgements

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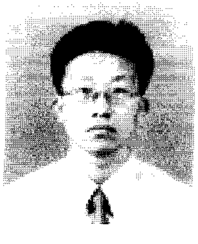

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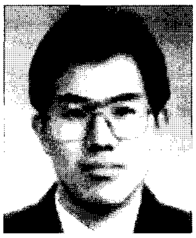

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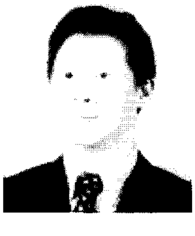

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