Design of Wideband Patch Antennas for PCS and IMT-2000 Service

Wideband patch antennas, applicable to PCS and IMT-2000 systems, are described. In order to overcome the narrow bandwidth, typical of a microstrip patch antenna, an electromagnetically coupled (EMC) feeding structure was employed. It was implemented for both a rectangular and a triangular patch. The antenna's characteristics are described for both patch shapes. The antennas, fabricated with a rectangular patch, achieved an impedance bandwidth (SWR ≤ 2) of 595 MHz (30.36 percent), while those with a triangular patch showed a bandwidth of 643.4 MHz (32.83 percent), providing evidence that the proposed designs can be used in the PCS and IMT-2000 service frequency band.

Since the introduction of second-generation digital mobile communications service, the number of subscribers has increased dramatically, while mobile communications technology has also progressed at a rapid pace. Furthermore, many countries around the world have been finalizing the selection of service providers for IMT-2000, the third-generation of mobile communications. IMT-2000 will move beyond the voice-based services and implement wireless multimedia services.

As mobile communications providers evolve to a third-generation wireless mobile communications network, an important issue that has arisen is the reusability of the existing base station sites. In view of the limited availability of physical space for base stations in urban areas, the environmental impact of the proliferation of base stations, along with the high cost of their installation, the development of antennas that can serve both second- and third-generation mobile communications is of considerable interest.

If the narrow bandwidth of the microstrip antenna can be widened, then it can serve as a dual antenna for second- and third-generations of mobile communications systems. Recently, most of the research on microstrip antennas focused on methods to increase their bandwidth. The U-slot antenna, which achieves a relatively broad bandwidth without a parasitic patch, has been reported.[1] A broader bandwidth, obtained using an improved feeding method, has also been reported.[2]

The probe feeding, the most widely used feeding method in microstrip antennas, is not capable of producing a wideband because of the parasitic reactance generated by its feeding structure. In this article, the L-strip feeding structure, which has been shown to achieve a broad bandwidth by reducing the parasitic reactance generated from its feeding structure, is applied to rectangular and triangular patches. The patch antenna discussed is of interest because it achieves a wideband characteristic, enabling it to operate in the PCS and IMT-2000 frequency bands. Furthermore, because of the ease of fabrication, it is amenable to mass production with uniform characteristics. It can also be used in high

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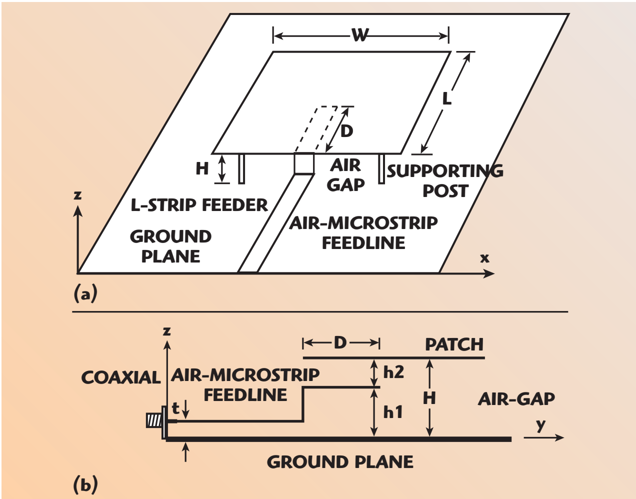


▲ *Fig. 1 Electromagnetically coupled rectangular patch antenna; (a) diagram and (b) cross section.*

TABLE I

RECTANGULAR PATCH ANTENNA DIMENSIONS (mm)

W	*L*	*D*	*H*	*h1*	*h2*
65.8	51.8	27.3	20.24	12.0	8.24

power mobile communications base stations. Finally, it is desirable commercially because it can be constructed without a dielectric substrate.

MICROSTRIP PATCH ANTENNAS WITH EMC FEEDING STRUCTURE

Generally, the feeding methods of a microstrip antenna can be classified as microstrip feeding, probe feeding and EMC feeding. The microstrip feeding is easily fabricated by connecting the microstrip to the edge of the patch directly, but the impedance matching is not convenient compared to probe feeding and unwanted radiation can occur from the feed line. Feeding by a coaxial probe has the advantages of ease in impedance matching and low spurious radiation, and the disadvantage of having to be physically connected to the center of the patch. The coaxial-fed microstrip antenna has a narrow impedance bandwidth. The third method, known as EMC feeding, was first proposed by K.F. Lee.[2]

EMC feeding is different from the other feeding methods. Spurious radiation does not occur and it has the advantage of offering a wideband characteristic without any matching circuit. ***Figure 1*** shows the electromagnetically coupled rectangular patch antenna. The structure of the L-strip feeder acts as a series L-C_c resonant circuit connected in series with the parallel R-L-C resonant elements of the patch. The horizontal part of the L-strip feeder within the patch provides a capacitance to compensate for the inductance introduced by the vertical part of the L-strip feeder. For the probe-fed patch antenna, the probe only provides an inductance, which degrades the bandwidth performance of the patch antenna. Here, the coupling mechanism is predominately capacitive. The patch itself is represented by a parallel R-L-C resonaut circuit. C_c is the coupling between the L-strip feeder and the patch. The coupling is controlled primarily by three factors — the inset length (D) of the L-strip feeder, the patch width (W) and the height (h_1) of the L-strip feeder. Simulations made while varying the parameters that are sensitive to the characteristics of the electromagnetically coupled patch antenna led to an antenna with optimum characteristics. The simulations were conducted using IE3D,[3] a commercial simulator, based on the method of moment (MoM). The EMC feeding structure was implemented with both a rectangular and triangular patch, and the performance characteristics of each antenna were verified.

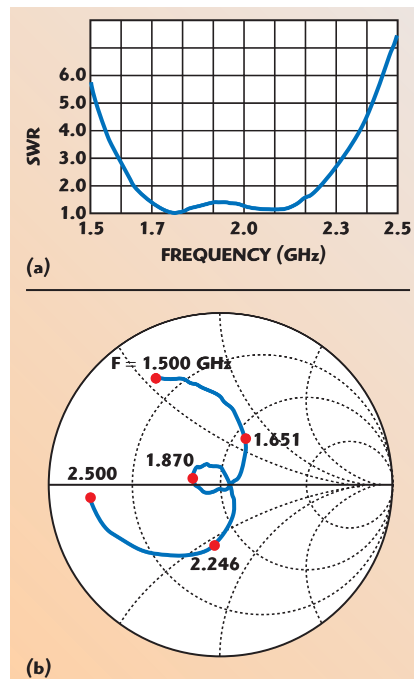
Rectangular Patch Application

A rectangular patch is the most widely used configuration because its shape readily allows theoretical analysis. The maximum coupling occurs when D is approximately equal to half the length of the patch.[4] As D gets larger, the impedance locus moves down the Smith chart. Also, as the L-strip feeder height (h_1) increases, the impedance locus moves down the Smith chart. The design parameters for the optimized rectangular patch antenna are listed in ***Table 1***.

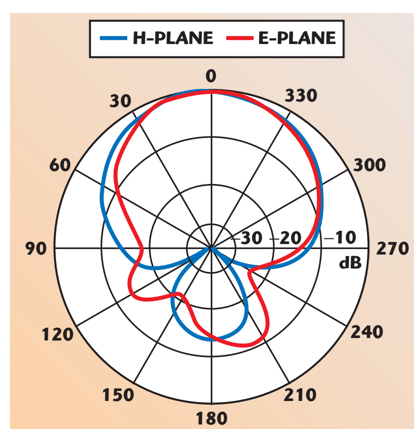
A photograph of the fabricated rectangular patch antenna is shown in ***Figure 2***. The patch and the ground plate were constructed using 0.3 and 1 mm thick metal plates, respectively.

Figure 3 shows the SWR and impedance curves of the fabricated rectangular patch antenna. The SWR is ≤ 2 in the frequency range 1651 to 2246 MHz, corresponding to an impedance bandwidth of 30.36 percent centered at 1960 MHz. ***Figure 4***

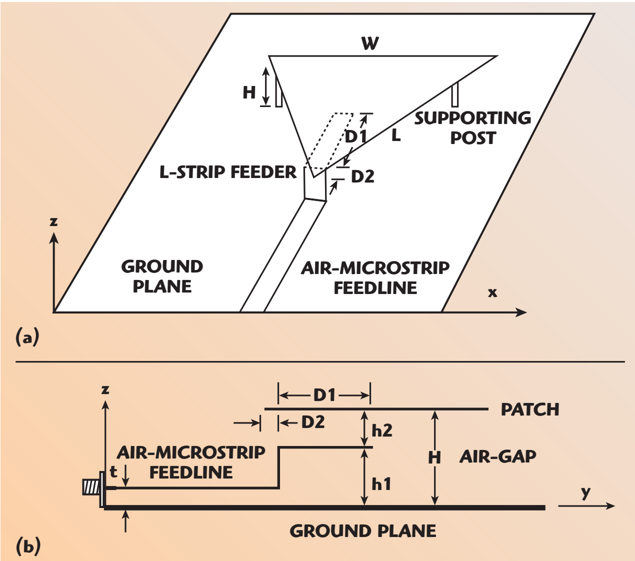
▲ *Fig. 2 The rectangular patch antenna.*



▲ *Fig. 3 The rectangular patch antenna's (a) measured SWR and (b) impedance.*



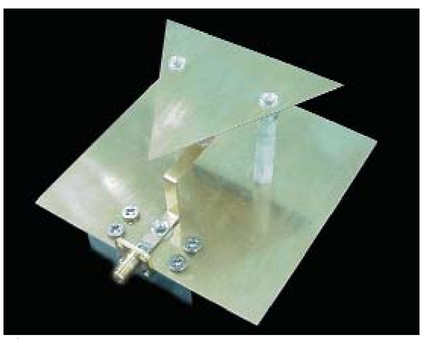
▲ *Fig. 4 Rectangular patch antenna radiation patterns measured at 1750 MHz.*



▲ *Fig. 5 Electromagnetically coupled triangular patch antenna; (a) diagram and (b) cross section.*

TABLE II
TRIANGULAR PATCH ANTENNA DIMENSIONS (mm)

W	L	D1	h1	h2	H	D2
65.8	65.8	23.5	17.0	18.5	35.5	1.0



▲ *Fig. 6 The triangular patch antenna.*

shows the H- and E-plane radiation patterns at 1750 MHz. The 3 dB beamwidths are 44.5° and 44° in the H- and E-plane, respectively. The measured maximum gain is 7.55 dBi. The radiation patterns are relatively stable across the passband.

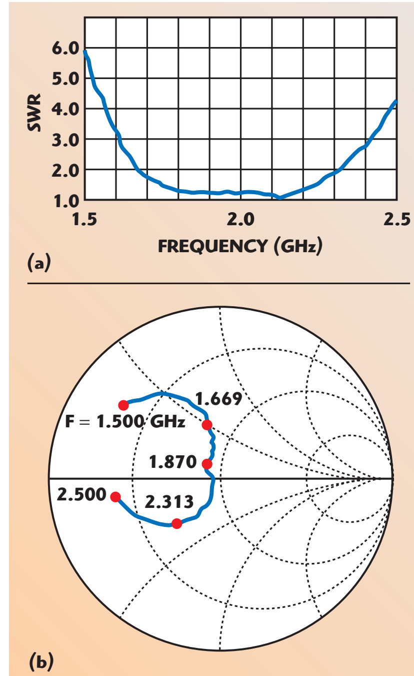
Triangular Patch Application

Generally speaking, the triangular patch is similar to the rectangular patch in size while exhibiting similar radiation characteristics.[5] Therefore, it has the advantage of reduced coupling between adjacent radiating elements in an array antenna. ***Figure 5*** shows a diagram of an electromagnetically coupled triangular patch antenna.

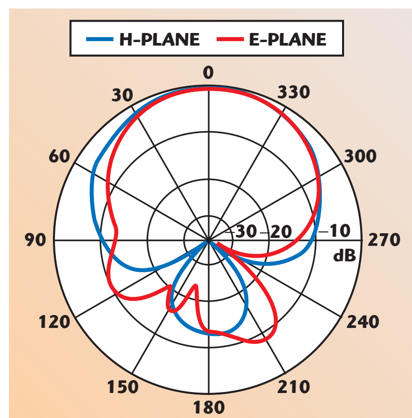
In the case of the triangular patch, the coupling value is sensitive to changes in the L-strip feeder's length (D_1), height (h_1) and patch width (W), producing variations in impedance bandwidth.

For a rectangular patch, the maximum coupling occurs when the feeder length is positioned in the middle of the patch ((L/2). However, this condition does not hold for a triangular patch, which is structurally different from a rectangular patch. Thus, in order to optimize the L-strip feeder's length (D_1), repeated simulations are necessary. As D_1 gets larger, the impedance locus moves to the right of the Smith chart. Furthermore, since the impedance locus moves down the Smith chart as the height (h_1) increases, the impedance matching is carried out readily. The design parameters for an optimized triangular patch antenna are listed in ***Table 2***.

Figure 6 shows a photograph of the fabricated triangular patch antenna. In ***Figure 7***, the SWR as well as the impedance curves of the triangular patch antenna are shown. The SWR is ≤ 2 in the frequency range 1669.6 to 2313 MHz, corresponding to an impedance bandwidth of 32.83 percent centered at 1960 MHz. ***Figure 8*** shows the H- and E-plane radiation patterns at 1750 MHz. The 3 dB beamwidths are 42.9° and 43° in the H- and E-plane, respectively. The measured maximum gain is 7.1 dBi. These radiation patterns are similar to those of the rectangular patch and display considerable stability within the passband. Compared to a rectangular patch antenna, a triangular patch antenna shows a broader impedance bandwidth and a slightly lower gain. However, its performance characteristics are adequate for PCS and IMT-2000 service antennas. K.L. Wong reports that a triangular U-slot patch antenna, using a probe-fed structure,[6] has an impedance bandwidth of 18.3 percent at 1677 MHz and 17.8 percent at 1709 MHz. Therefore, it follows that the feed structure of a microstrip antenna is an important parameter that deter-



▲ *Fig. 7 The triangular patch antenna's (a) measured SWR and (b) impedance.*



▲ *Fig. 8 Triangular patch antenna radiation patterns measured at 1750 MHz.*

TABLE III
COMPARISON BETWEEN RECTANGULAR AND TRIANGULAR PATCH ANTENNAS

	Impedance Bandwidth (MHz)	Max Gain (dBi)	H-plane HPBW (°)	E-plane HPBW (°)
Rectangular patch	595.0	7.55	44.5	44
Triangular patch	643.4	7.10	42.9	43

mines its bandwidth characteristics. It is suggested that in order to improve the bandwidth characteristics of a microstrip antenna, feeding structures such as EMC must be examined. ***Table 3*** shows the measurement results for both the rectangular and triangular patch antennas.

CONCLUSION

This article presents the design of a microstrip antenna using an EMC feeding structure. A wider bandwidth is achieved compared to the narrow bandwidth of a conventional microstrip antenna. The patch antenna described in this article has the advantage of ease of fabrication since it does not require either a chemical etching process or a dielectric subtrate unlike the conventional microstrip antenna. This type of structure can be used in high power mobile communication base station antennas. ■

References

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