# Design of Dual Band Antenna by EMC Feeding Structure

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## Abstract

In this paper, the wideband microstrip antennas for the PCS & IMT-2000 dual band are studied. Experimental and simulation results on the dual band antenna are presented. Simulation results are in good agreement with measurements. The experimental and simulation results confirm the wideband characteristics of the antenna. The studied antenna satisfies the wideband characteristics that are required characteristics for above 420 MHz impedance bandwidth for the PCS & IMT-2000 dual band antenna. In this paper, through the designing of a dual band antenna, we have presented the availability for PCS & IMT-2000 base station antenna.


## I. INTRODUCTION

The limit of a cellular mobile phone service in the past was that the mobile communication was difficult to be fixed as a general service to individuals. But with the beginning of PCS service, mobile communication has changed the general mobile communication service to citizens. The world telecommunication market has changed focus to the data transfer service from the voice service due to the increasing demand for internet and multimedia fields and rapid development of technology. The changing of telecommunication brought the birth of IMT-2000. Owing to using common frequency and the global roaming service world wide, IMT-2000 is the next generation of mobile communication services to allow communication with anyone, anywhere, and anytime by mobile phone. IMT-2000 is a wire-wireless integration service that offer both high quality voice service, image service, high-speed data service and intelligence services based on a fixed network. Recently, frequencies of the mobile communication service have become higher and higher its service has changed to a wideband telecommunication as focus has changed to internet and multimedia services from narrow-band communications such as voice[1]. IMT-2000 service will soon replace PCS and DCS service.

In this paper, the dual band antenna for PCS & IMT-2000 service was studied, in order to make a foundation of the wideband mobile telecommunication service. The PCS & IMT-2000 dual band antenna that was studied in this paper will solve environmental problems such as over abundance base station as well as preventing double investment. Most directional antennas for mobile telecommunication base station have a dipole array structure. The PCS & IMT-2000 dual band antenna is required to be above 420 MHz wideband characteristics. The dipole antenna was designed easily, but it was not proper because it had narrow bandwidth[2].

In this paper, the wideband microstrip antennas for the PCS & IMT-2000 dual band are described. Various researched results for a method of physical structure, a stacked microstrip antenna, and a U-slot antenna and so on were recently reported as the design techniques of the wideband microstrip antenna.

The method of physical structure is more compact because of the occurrence of surface wave and high-order mode using thick and low permittivity substrate. The stacked microstrip antenna can obtain 30 % higher wideband characteristics by double resonant effect using more than two patches stacked vertically, but it had problems such as the size of the antenna and the fabrication. The U-slot antenna that was proposed by K. F. Lee was reported as having wideband characteristics above 30 % within 3～4 GHz frequency range[3]～[5]. The U-slot antenna had a probe feed structure. The U-slot antenna could not obtain wideband characteristics above 420 MHz in the frequency range of the PCS & IMT-2000 because it was assumed that this structure had inductance at probe. Considering the wideband antenna, it was expected that the necessary point was suppression of the inductance at feed structure.

The antenna in this paper, antenna had wideband characteristics through the improved design of the feed structure of the microstrip antenna. The studied antenna is small and it can be used over all frequency ranges of domestic three PCS service provider and IMT-2000.

## II. MICROSTRIP ANTENNA WITH EMC FEEDING STRUCTURE

Generally, the feeding method of the microstrip antenna can be classified as a microstrip feeding, a probe feeding, and an

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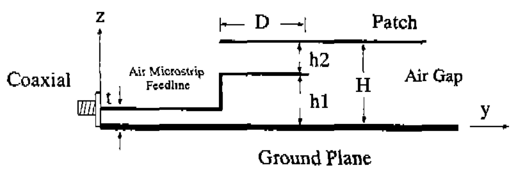
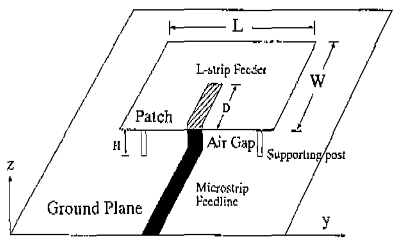
EMC(electromagnetically coupled) feeding. The microstrip feeding is fabricated easily by connecting the microstrip to edge of the patch directly, but impedance matching is not convenient in comparison with probe feeding and unwanted radiation can occur from the feed line. Feeding by a coaxial probe has the advantages of ease in impedance matching and low spurious radiation and the disadvantage of having to be physically connected to the center conductor to the patch. The coaxial fed microstrip antenna has a narrow impedance bandwidth. The method, known as EMC feeding, was first proposed by K. F. Lee[6],[7].

The EMC feeding is different from the other feeding method. Spurious radiation does not occur and it has the advantage of obtaining the wideband characteristics without any matching circuit. Fig. 1 shows the electromagnetically coupled patch antenna. The structure of the L-strip feeder acts as a series L-$C_c$ resonant element, which is connected in series with the parallel R-L-C resonant element of the patch. The horizontal part of the L-strip feeder provides a capacitance to suppress the inductance introduced by 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[8]. The coupling mechanism is predominately capacitive. The parallel R-L-C circuit represents the patch itself. Component Cc is the coupling from the L-strip feeder to the patch. The coupling is controlled primarily by three factors, the inset length of the L-strip feeder, the patch width and the height(h2) of the L-strip feeder.

Therefore, after simulation by the variation of parameters that are sensitive to the characteristics of the electromagnetically coupled patch antenna, an antenna with optimum characteristics is fabricated. Table 1 shows the parameters of design antenna simulated through 7 models.




(a)




(b)

Fig. 1. Geometry of electromagnetically coupled patch antenna. (a) side view, (b) perspective view.

Table 1. Dimension of antennas(in mm.)

| | L | W | H | H1 | H2 | D |
|---|---|---|---|---|---|---|
| Ant. A | 51.8 | 65.8 | 20.24 | 12 | 8.24 | 24.3 |
| Ant. B | 51.8 | 65.8 | 20.24 | 12 | 8.24 | 22.8 |
| Ant. C | 51.8 | 65.8 | 20.24 | 12 | 8.24 | 25.8 |
| Ant. D | 51.8 | 65.8 | 20.24 | 10.5 | 9.74 | 24.3 |
| Ant. E | 51.8 | 65.8 | 20.24 | 13.5 | 6.74 | 24.3 |
| Ant. F | 52.8 | 67.8 | 20.24 | 12 | 8.24 | 24.3 |
| Ant. G | 50.8 | 63.8 | 20.24 | 12 | 8.24 | 24.3 |

The electromagnetically coupled patch antenna has two loops. A small resonant loop must be moved to near VSWR=1 for designing the antenna that has broadband characteristics. Fig. 2 shows the variation of impedance loci by changing of the L-strip feeder length of the antenna. If the L-strip feeder length becomes shorter, then impedance locus is moved clockwise. The L-strip feeder length is approximately half of patch length. Coupling is increased the most then bandwidth of the antenna is reaches the maximum.

Fig. 3 shows impedance loci for variation of L-strip feeder height (h2). If the L-strip feeder height(h2) becomes shorter, the impedance locus is moved clockwise. In this paper, 8.24mm(0.0538 $\lambda o$) of the L-strip feeder height has the best characteristics.

Fig. 4 shows the variation of impedance loci by changing of patch width and length. If the patch width and length become shorter, impedance locus is moved clockwise and impedance locus is sensitive, especially to the change of patch width.

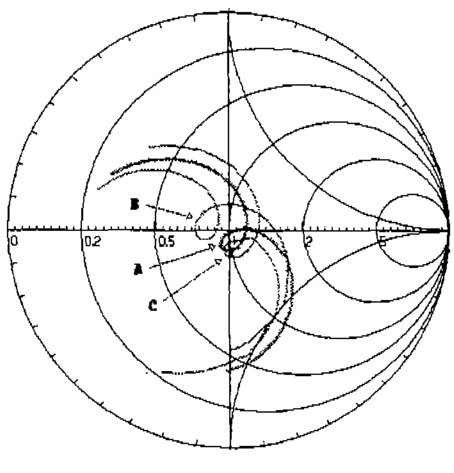
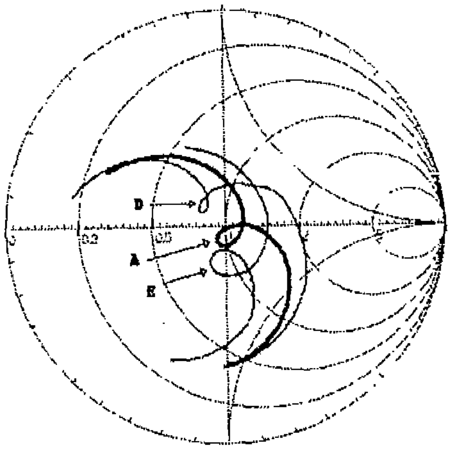



Fig. 2. Impedance loci for antennas as the L-strip feeder length ($D$) is varied from 1,500 MHz to 2,500 MHz frequency band (Ant. B, A, C).




20.6510

Fig. 3. Impedance loci for antennas as the L-strip feeder height (*h*2) is varied from 1,500 MHz to 2,500 MHz frequency band(Ant. D, A, E).

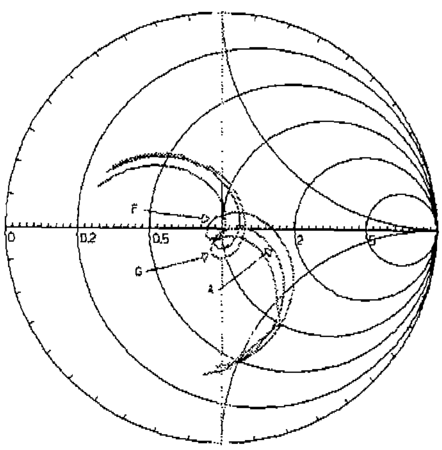
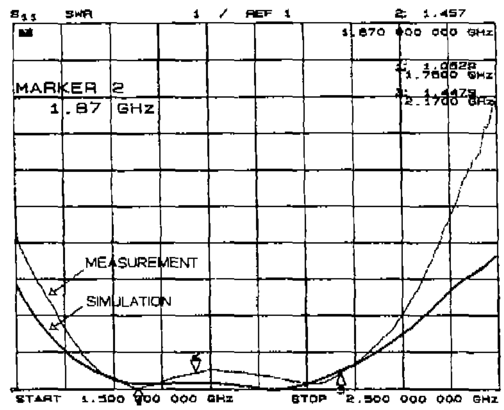



Fig. 4. Impedance loci for antennas as the width(*W*) and length (*L*) of patch is varied from 1,500 MHz to 2,500 MHz frequency band (Ant. F, G, A).

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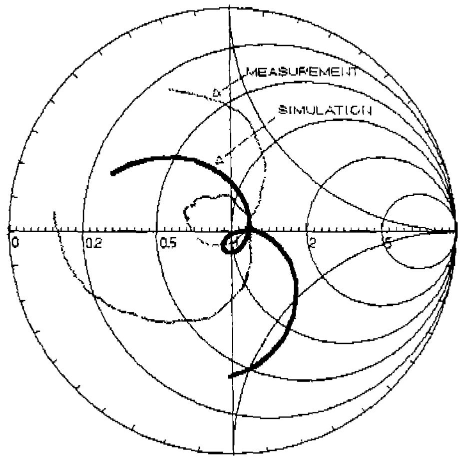



(b)

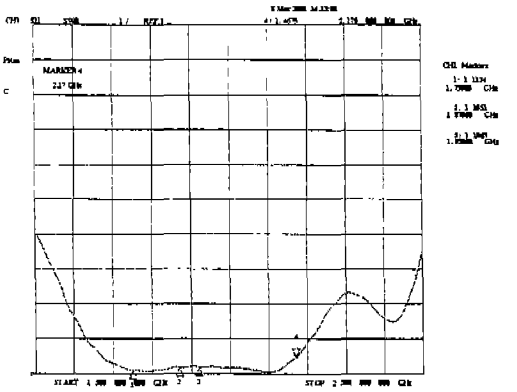
Fig. 5. Simulated and measured curves of VSWR for single element Ant. A. (a) VSWR, (b) impedance loci (from 1,500 MHz to 2,500 MHz).

## Ⅲ. MEASUREMENT RESULTS

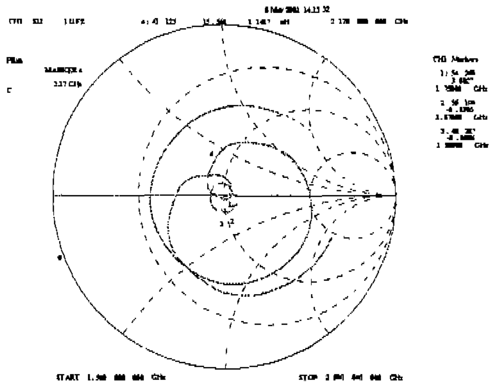
The simulated and measured curves of VSWR for electromagnetically coupled patch Ant. A are shown in Fig. 5. There is reasonable agreement with the measured results shown in Fig. 5. The impedance locus simulated from 1,500 MHz to 2,500 MHz frequency band. It was found that the antenna can be designed to have wideband characteristics. Measured impedance locus has a double-loop characteristic for the wideband operation. The impedance bandwidth(VSWR$\leq$2) of the designed single element is 590MHz(30.1 %). Using the frequency bandwidth of PCS & IMT-2000, we confirm VSWR below 1.5, which is a good characteristic. Thus the wideband characteristic of the EMC feeding structure antenna is confirmed experimentally.

Fig. 6 shows measured curve of VSWR for 2-element array. The element spacing is $0.8\lambda_0$(122 mm). A quarter-wave transformer provides a 50 $\Omega$ input impedance. A symmetrical power divider distributes equal power to the 2-elements. The impedance bandwidth(VSWR$\leq$1.3) for 2-element array was found to be above twice, which is still considerably better than the single element.

Fig. 7 shows photograph of prototype antenna. Fig. 8 shows measured antenna gain. The gain measured by the gain-comparison method. The gain of the single element is 6.5 dBi and



(a)



(b)

Fig. 6. Measured curve of VSWR for 2-element array. (a) VSWR, (b) impedance locus.

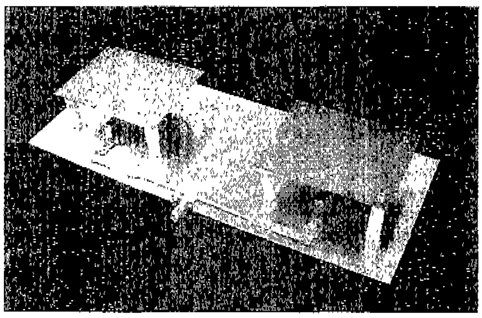


Fig. 7. Photograph of prototype antenna.

6.5～7.55 dBi in frequency bandwidth of PCS and IMT 2000, respectively. The measured maximum gain of the single element was found to be 7.55 dBi at 2,170 MHz. The 2-element array is higher than 8.13 dBi from 1,750 MHz to 2,170 MHz, with a

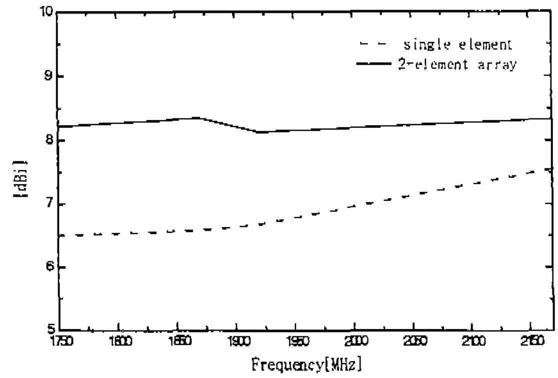



Fig. 8. Measured gain curve.

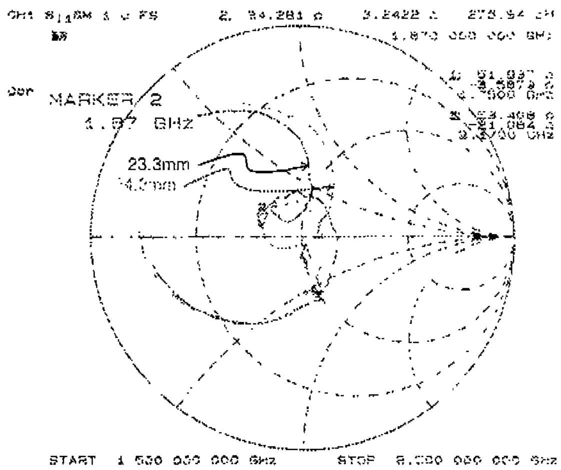



Fig. 9. Measured impedance loci for antennas as the L-strip feeder length is varied($D$=23.3, 24.3 mm).

peak of 8.35 dBi at 1,870 MHz. It has relatively flat gain characteristics.

Fig. 9 reconfirms the variation of impedance loci by changing of the L-strip feeder length. If L-strip feeder length becomes shorter, impedance locus is moved counter-clockwise, and that makes loop smaller. Therefore, the bandwidth of the antenna becomes small because patch and coupling are reduced.

Fig. 10 show the measured radiation patterns of single element antenna at 1,855 MHz. The half power beamwidths are 40.5° and 38.5° in the E-plane and H-plane, respectively.

Fig. 11 show the measured radiation patterns of 2-element array antenna at 1,855 MHz. The half power beamwidth in the H-plane is 32°. In the E-plane, it is 39.5°. A front-to-back ratio of 19.3 dB was measured. The radiation patterns were measured from 1,750 to 2,170 MHz and show practically no degradation when compared to patterns at 1,855 MHz.

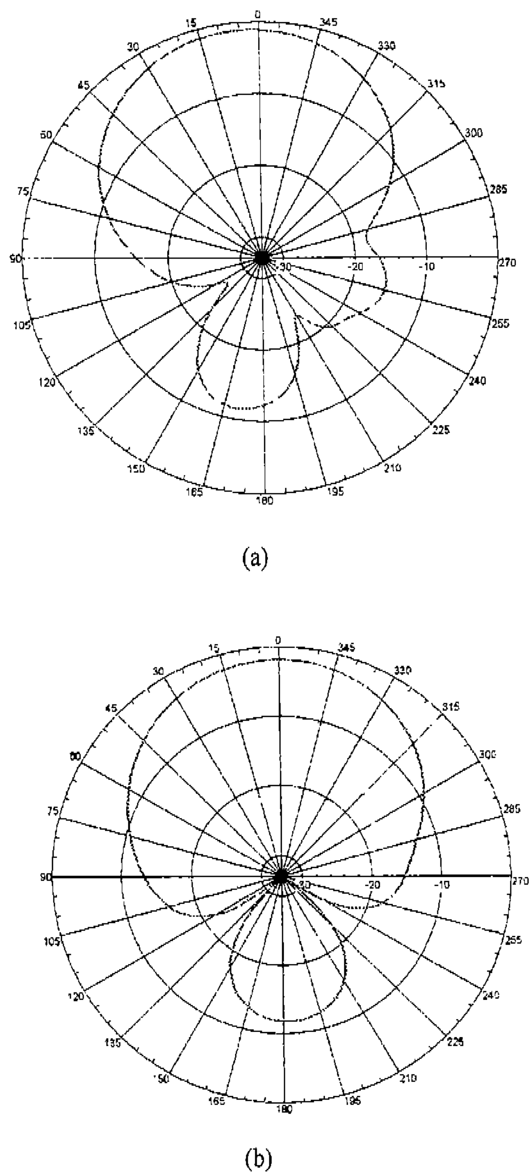


Fig. 10. Measured radiation patterns of single element at 1,855 MHz. (a) E-plane, (b) H-plane.

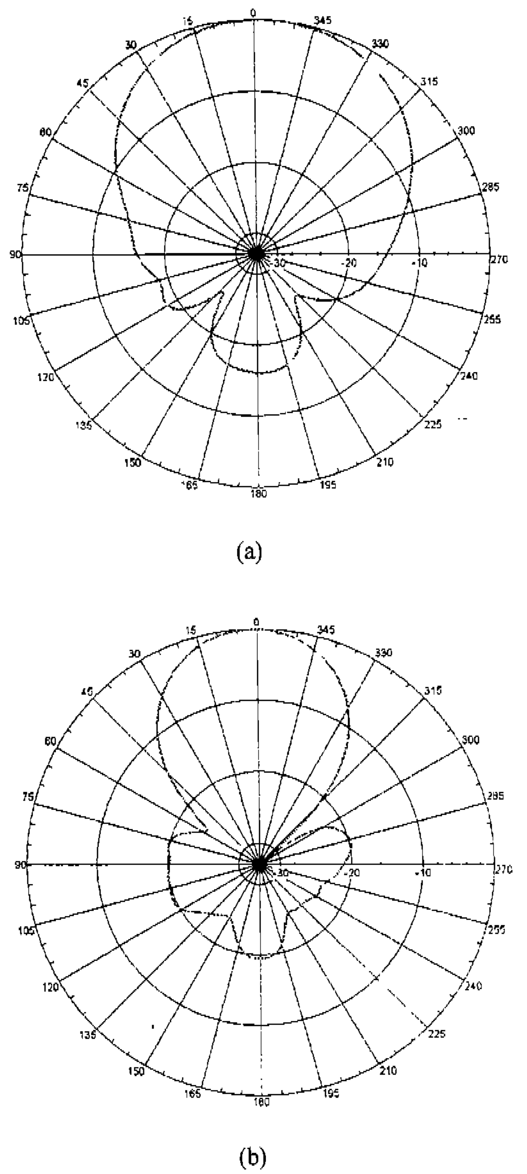


Fig. 11. Measured radiation patterns of 2-element array at 1,855 MHz. (a) E-plane, (b) H-plane.

## Ⅳ. CONCLUSION

In this paper, the PCS & IMT-2000 dual band antenna was designed using the EMC feeding structure. The studied antenna satisfies the wideband characteristics that are required characteristics for above 420 MHz bandwidth for the PCS & IMT-2000 dual band antenna, and it has advantages of fabrication for mass production because the antenna has a simple structure. The impedance bandwidth(VSWR≤2) of the designed antenna is 590 MHz(30.1 %). The radiation patterns have been measured across the passband and which are stable within the PCS & IMT-2000 dual band. The gain of the studied 2-element array is higher than 8.13 dBi from 1750 MHz to 2170 MHz.

The other advantage of the antenna is that it can be adapted with affinity for the environment because this antenna is light and small. The studied antenna can be designed easily for extension of array because it has simple structure. If this antenna is developed for use in base station antennas, it is expected that it can also prevent double investment due to use of a common base station.

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