Design and Implementation of Broadband Antenna and Diplexer for Dual-Band Handsets

Myoung-Sub Joung*, Jun-Seok Park†, Hyeong-Seok Kim, Jae-Bong Lim* and Hong-Goo Cho***

Abstract - In this paper, a ceramic antenna and diplexer are designed for dual-band handset ap plications. Basically, the antenna is designed by using the meander line configuration. The diplexer presented in this paper is composed of both low- and high-pass filters. We have designed the low- and high-pass filters with attenuation poles to improve the attenuation performances of the diplexer. The attenuation poles are located at each rejection frequency region so as to improve the shrinkage characteristic of the diplexer. In order to accomplish the volume effectiveness, the antenna and the diplexer have been designed and fabricated in a multi-layer structure. The diplexer designed with a multi-layer structure has inductors and capacitors, which are implemented by LTC C (Low Temperature Co-fired Ceramics) process technique. Design of the multi-layer antenna and diplexer has been achieved by employing the full 3-D EM simulation. The designed antenna and dipl exer offer excellent return loss and broadband performances with highly isolated rejection performance.

Keywords: antenna, diplexer, LTCC

1. Introduction

The recent technology trend in mobile communication parts is extension in the direction of high-integration, high-speed, low-power and low-cost. From here on in, systems will be expected to implement all of these factors into one module. Especially, the development of MCM multi-layer technology applied LTCC has become comprehensive. Furthermore, the passive components such as inductors, capacitors and resisters are composed of 3-dimension, which need to be integrated, and so lively research is on-going for the purpose of miniaturization and confidence elevation of systems [1, 2]. A conventional ceramic dielectric antenna has been fabricated with metal pattern of suitable dimension on its surface or inside of its body. In the case of a ceramic antenna of metal pattern on its surface, tuning procedure should be necessary in order to implement the paper resonant condition and matching performance [3-6]. In terms of the radiated gain, the external antenna is more efficient than the internal antenna with multi-layer configuration [7].

In this paper, we have designed and implemented a ceramic antenna and a multi-layer diplexer for the dual-band handset application. The ceramic antenna was designed with the meander line configuration to achieve superior broadband performance and size reduction. Meander line structures employed one of the design technology studies of DRA (Dielectric Resonator Antenna) [3-5]. The antenna was implemented for contented GPS (Global Positioning System) [1575.42MHz] band IMT-2000 band to employ a meander line structure that can implement relative wide band characteristic and higher gain. Furthermore, the ceramic antenna presented in this paper demonstrated the characteristics of broadband and high-gain performance with the inductor and capacitor, and achieved the matching network for the designed meander antenna. The diplexer splits in the transmitted signal (Tx) and the received signal (Rx) at the front-end unit of wireless communication systems with comparative wide band performance. In this paper, we designed 7-section low-pass and high-pass filters for implementation of the diplexer. In order to effectively achieve the size reduction of the diplexer, the proposed structure is properly arranged by the multi-layer structure inductor and capacitor passive components in the chip by using the LTCC technique. We have designed the multi-layer antenna and diplexer by employing the full 3-D EM simulation with iterative design procedures. The designed and fabricated antenna and diplexer presented in this paper offer excellent return loss and broadband performances with highly isolated rejection performance

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2. Design of the Meander Line Antenna with Embedded Matching Circuit

In this paper, we have designed an open-ended meander line antenna with simple printing configuration on the ceramic body. The antenna was designed to provide the broadband width performance from 1500MHz up to 2200MHz for the purpose of being available to GPS and IMT-2000 service simultaneously. By employing a meander line structure as shown in Fig. 1, we can implement a relative wide band characteristic of the chip antenna. The dimension of the designed antenna is 20x4x2mm and relative permittivity for the used ceramic for the design of the chip antenna is εr 7.8. The line widths w and l are 0.8mm and 0.43mm, respectively and the metallization width x and line spacing s are 3.5mm and 0.48mm, respectively.

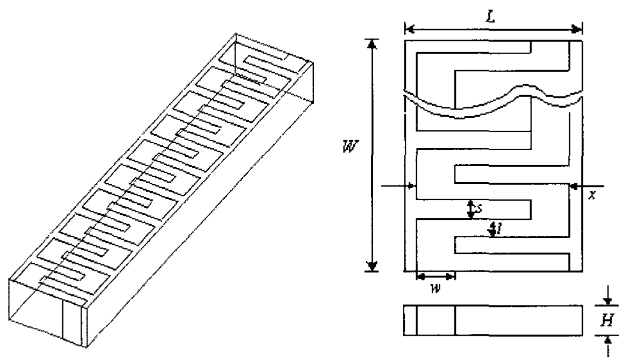


Fig. 1 Configuration of the designed meander line antenna

Next, each resonance characteristic concerning design parameters is to be observed in the antenna. The variation for thickness of substrate and relative permittivity generated a resonance at low frequency thickness and high relative permittivity. In this paper, the meander line antenna has been designed in such a way so that it has the most suitable matching condition for matching performance result as shown in Fig. 2. However, the designed meander line antenna could not provide the overall bandwidth performance of the GPS and IMT2000 services. In order to achieve the broadband characteristics for the GPS and IMT2000 services, it is essential to choose the appropriate method, which will then enhance the matching performance. Thus, in this paper, we chose the embedded matching circuit to achieve the broadband performance of the designed meander line antenna.

The embedded matching circuit has been designed by using the S1P file of the designed meander line antenna, which is simulated by full 3-D EM simulation. By using the optimization procedure on the entire circuit, we have designed the matching circuit for the designed meander line antenna with LC ladder circuit configuration as presented in Fig. 3. The simulation result of the complete meander line antenna circuit with embedded matching circuit is demonstrated in Fig. 4. By employing the embedded LC matching circuit, the broadband matching performance, which could cover the GPS and IMT-2000 services, can be achieved as indicated in Fig. 4. At the frequency band of 1.6GHz ~ 2.2GHz, the return loss shows a level below -15dB. The dimension of the designed antenna with embedded LC matching circuit is 16x13x2 mm with relative permittivity εr of 7.8.

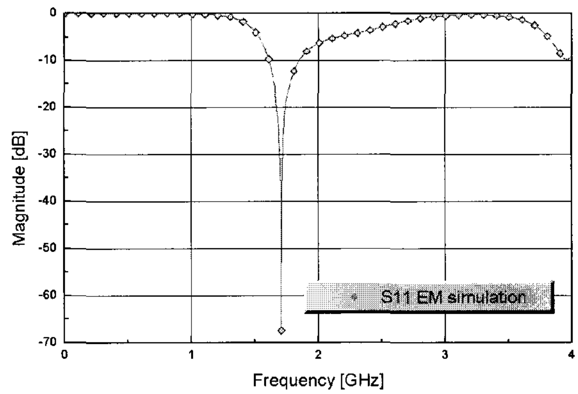


Fig. 2 Simulation result for the designed meander line antenna.

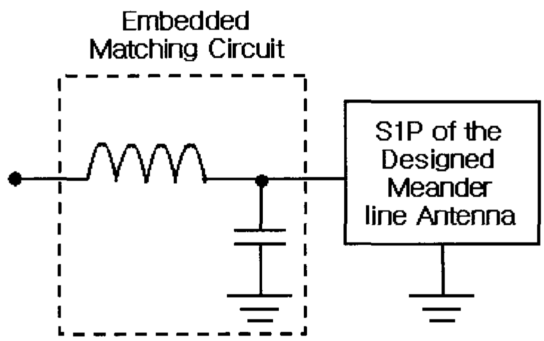


Fig. 3 Simulation result of the designed meander line antenna with embedded matching circuit.

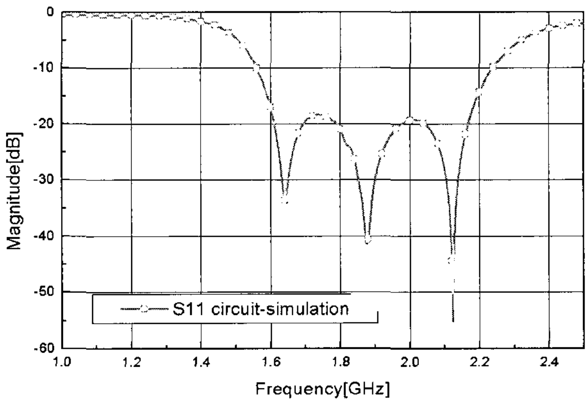


Fig. 4 Simulation result of the designed meander line antenna with embedded matching circuit.

After determining the element values for the embedded matching circuit, we constructed the physical meander line antenna with embedded LC matching circuit for 3-D EM simulation. Fig. 5 indicates the 3-D EM simulation on the physical meander line antenna with embedded LC matching circuit. The resulting bandwidth performance is about 1050MHz with VSWR 2:1. At GPS and IMT-2000 frequency bands, the return losses show less than -12dB and -15dB, respectively. Furthermore, we calculated the radiation pattern with antenna gain performance at the

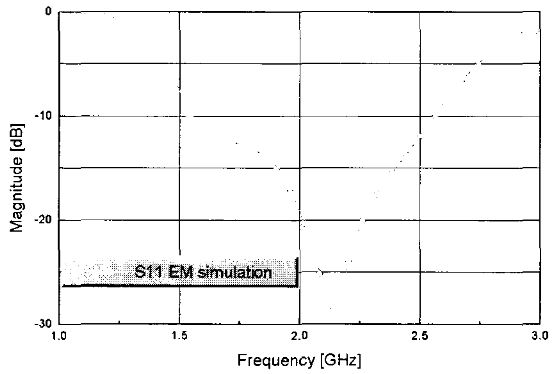
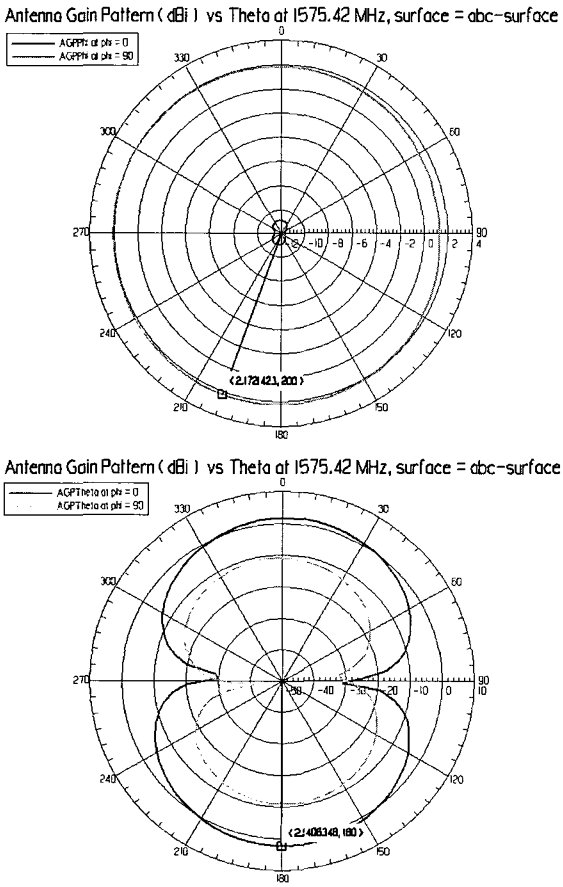
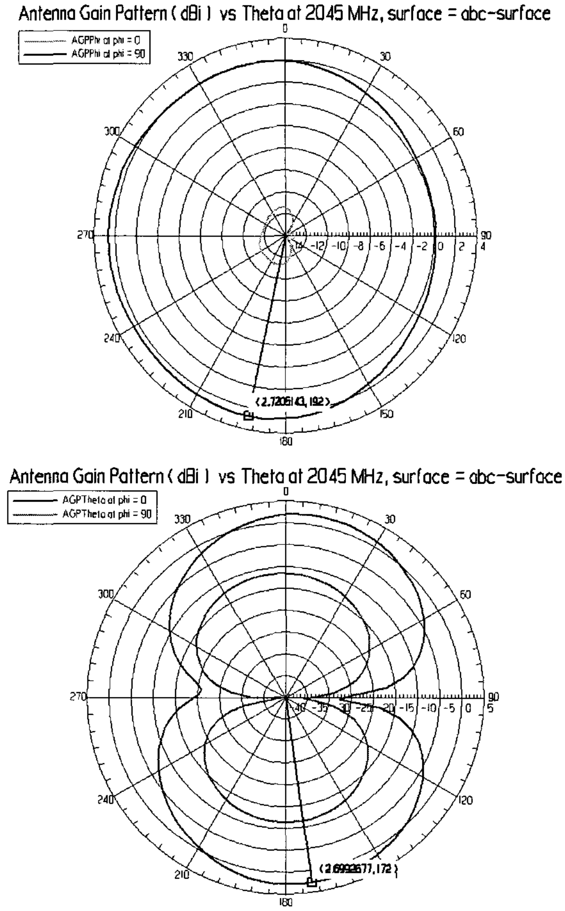


Fig. 5 EM-simulation result for the designed meander line antenna circuit with embedded LC matching circuit



(a) E- and H-plane radiation patterns at GPS band.



(b) E- and H-plane radiation patterns at IMT-2000 band.

Fig. 6 Radiation patterns of the designed meander line antenna with embedded matching circuit at the frequencies of 1575.42MHz and 2045MHz.

center frequencies of the GPS and IMT-2000 services for the designed meander line antenna. Fig. 6 illustrates the simulated radiation patterns of the designed meander line antenna with embedded matching circuit at the frequencies of 1575.42MHz and 2045MHz. The peak gain performances of each frequency are 2.32dBi and 2.72dBi at 1575.42MHz and 2045MHz, respectively. The resulting band width and radiation performances are excellent, so the designed meander-line antenna with embedded matching circuit can be adapted to a practical dual band system.

3. Design of the multi-layer diplexer

In order to separate the GPS and IMT-2000 frequency bands from the meander line antenna, we have designed the diplexer circuit, which is composed of both low-pass and high-pass filters. We have designed the low-pass filter at the cutoff frequency of 1600MHz with 0.01dB ripple-level. Also, we have designed the high-pass filter at the cutoff frequency of 1850MHz, which is the full frequency band for IMT-2000 service. Then we have constructed the diplexer circuit as indicated in Fig. 7. In the construction of the diplexer circuit, each element of low-pass and high-pass at the antenna port should be eliminated because either low pass-band or high pass-band resonance occurs in these elements. Resonance at the in-band of each filter might cause a deviation from its original performance. All filters have been designed with 50Ω port impedance. In the case of the diplexer, the port impedances including the antenna port are also 50Ω. Furthermore, we have constructed the diplexer circuit with multi-layer configuration for the purpose of applying it to the LTCC technique. Fig. 8 portrays the comparison between circuit- and EM-simulations. To avoid error in connection work, the inductor and capacitor of each must be connected with precise understanding of the series/parallel state and design rule during the design of EM simulation. The dielectric constant used in the design of the diplexer is identical with the meander line antenna, ε_r 7.8. Overall dimension of the designed multi-layer diplexer is 4.4×2.2×1mm. The return loss performance at each frequency band, GPS and IMT-2000 service band, is less than -15dB and the insertion loss is 0.3dB and 1.2dB for the GPS and IMT-2000 band, respectively. These loss performances are quite good for the application of the dual band handset. However, the rejection performance of each frequency band is less than 20dB. This performance causes a noise floor at each band performance leading to a decrease in the sensitivities of each service. Thus, it is necessary for the diplexer to improve the rejection performance without any degradation of loss performance and change in dimensions. The only way to achieve this purpose is to have one element of each low-pass and high-pass filter change to resonant circuit to produce the attenuation poles of low-pass and high-pass filters at corresponding frequency bands as shown in Fig. 9. We have constructed and modified the physical diplexer circuit with these resonant circuits into multi-layer configuration.

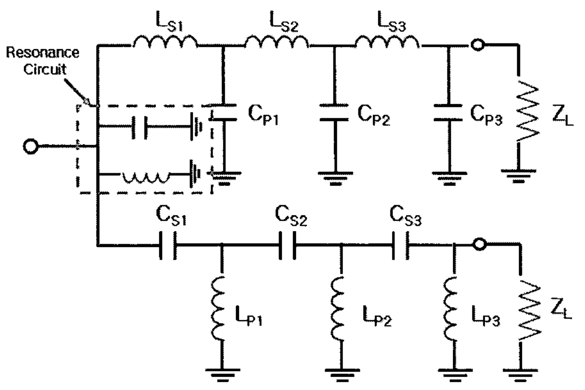


Fig. 7 Comparison between the EM-simulations and circuit simulations.

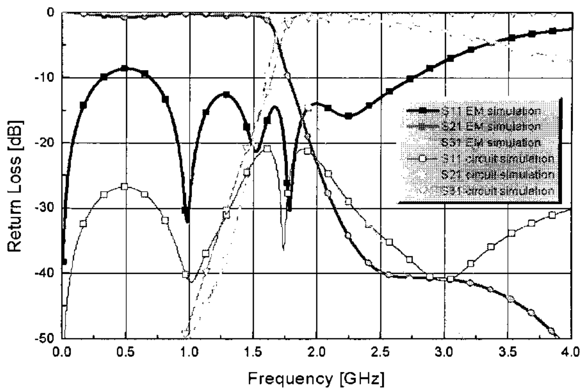


Fig. 8 Comparison between the EM-simulations and circuit simulations.

Fig. 10 presents a comparison between the EM- and circuit-simulations for the designed diplexer circuit with two resonant circuits. The return loss performance at each frequency band, GPS and IMT-2000 service band, is less than -17dB and the insertion loss is 0.3dB and 1.6dB for the GPS and IMT-2000 band, respectively. Moreover, the rejection performance of each band is -21dB and -31dB for GPS and IMT-2000 service, respectively.

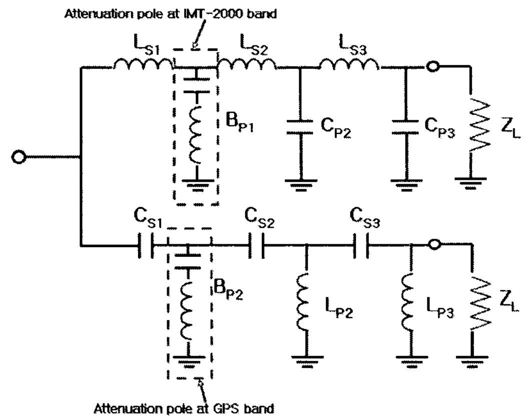


Fig. 9 Schematic of diplexer with resonant circuits to produce the attenuation poles.

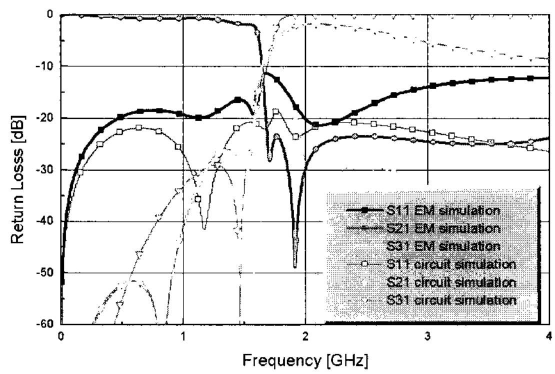


Fig. 10 Comparison between the EM-simulations and circuit simulations of notch took diplexer.

4. Fabrication and Measurement

We have fabricated a meander line antenna with embedded LC matching circuit and a diplexer with resonant circuit. The process used for fabrication is LTCC technology. Fig. 11 indicates the photography of the fabricated meander line antenna with multi-layer configuration. Fig. 12 presents the measurement performance of the fabricated meander line antenna with embedded LC matching circuit. The dimension of the fabricated antenna 16x13x2mm and relative permittivity for the used ceramic for the design of chip antenna is εr 7.8. The measured bandwidth performance is about 800MHz with VSWR 2:1, which is a little narrower than the EM-simulation. However, it is sufficient for the antenna to apply GPS and IMT-2000 services to the dual band handset.

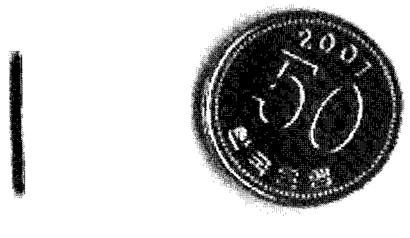


Fig. 11 Photo of the fabricated meander line antenna.

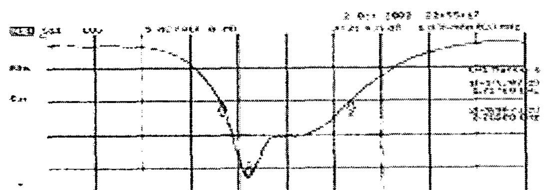


Fig. 12 Measurements on the fabricated meander line antenna

Fig. 13 shows the photograph of the fabricated diplexer with multi-layer configuration. Fig. 14 indicates the measurement performance of the fabricated diplexer with the two embedded resonant circuits. The dimension of the fabricated diplexer is 4 mm x 2 mm x 0.85 mm and relative permittivity for the used ceramic for the design of chip antenna is εr 7.8. Thickness of the green sheet used for the fabrication is 50μm before sintering. The interior electrode employed in the screen printing process for the fabrication of circuits is Ag. The return loss performance at each frequency band, GPS and IMT-2000 service band, is less than -15dB and the insertion loss is 1.2dB for both the GPS and IMT-2000 band. Moreover, the rejection performance of each band is -19.6dB and -34dB for GPS and IMT-2000 service, respectively.

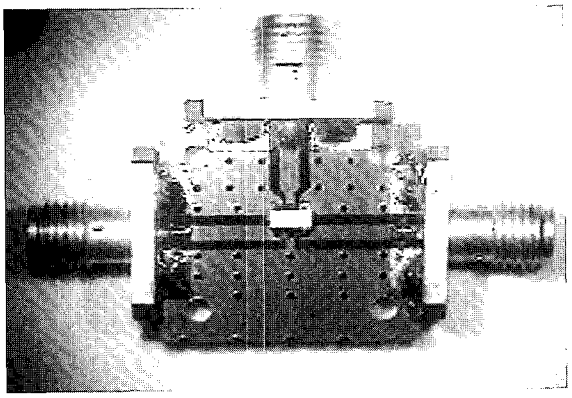


Fig. 13 Photo of the fabricated diplexer.

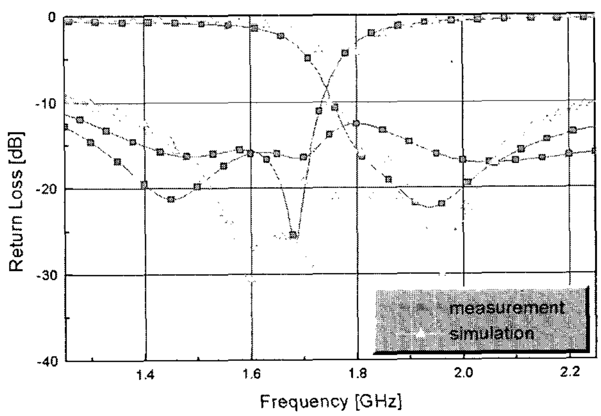


Fig. 14 Comparisons between the EM-simulations and fabricated diplexer measurements.

5. Conclusion

In this paper, we have designed and implemented a ceramic antenna and a multi-layer diplexer for dual-band handset application. In order to achieve the broadband characteristics for the GPS and IMT2000 services, we have chosen the embedded matching circuit to attain broadband performance of the designed meander line antenna. In order to improve the rejection performance of the diplexer circuit, we have constructed and modified the conventional diplexer circuit with these resonant circuits into multi-layer configuration. We have fabricated the meander line antenna with embedded LC matching circuit and the diplexer with resonant circuit based on LTCC technology. We have obtained a bandwidth performance of 800MHz with VSWR 2:1, which is sufficient for the dual band handset application of GPS and IMT-2000 services. In the case of the diplexer, we have obtained that the return loss performance at each frequency band, GPS and IMT-2000 services, is less than -15dB and the insertion loss is 1.2dB for both the GPS and IMT-2000 band with excellent rejection performance of each band. The results of this paper might be extended to the antenna integrated single module for dual band handset applications.

Acknowledgements

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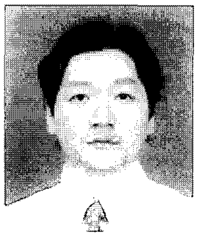

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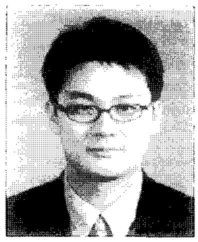

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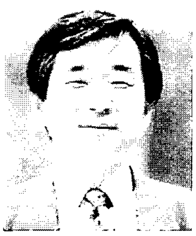

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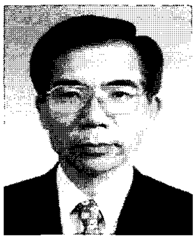

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