Design of the Pattern Adjustable Base Station Antenna for WCDMA Applications

Sang Ho Lee[1] · Jung Nam Lee[1] · Don Shin Lee[2] · Jong Kweon Park[1] · Hak Sun Kim[1]

Abstract

In this paper, we have proposed the pattern adjustable base station antenna for WCDMA applications. The proposed antenna consists of an omni-antenna(sleeve monopole) and two movable reflectors. The two reflectors can be controlled by mechanically and used to adjust the horizontal pattern of the base station antenna. The antenna was designed, fabricated, and measured. The antenna covers the entire WCDMA band for VSWR<1.4. The measured antenna gain is more than 15 dBi over the operating frequency range. By changing the angle (a) and the distance (d) of the antenna, the pattern adjustment of the proposed base station antenna is found to be possible.

Key words : WCDMA, Base Station Antenna, Pattern Adjustable Antenna, Reflector, Sector Antenna.

Ⅰ. Introduction

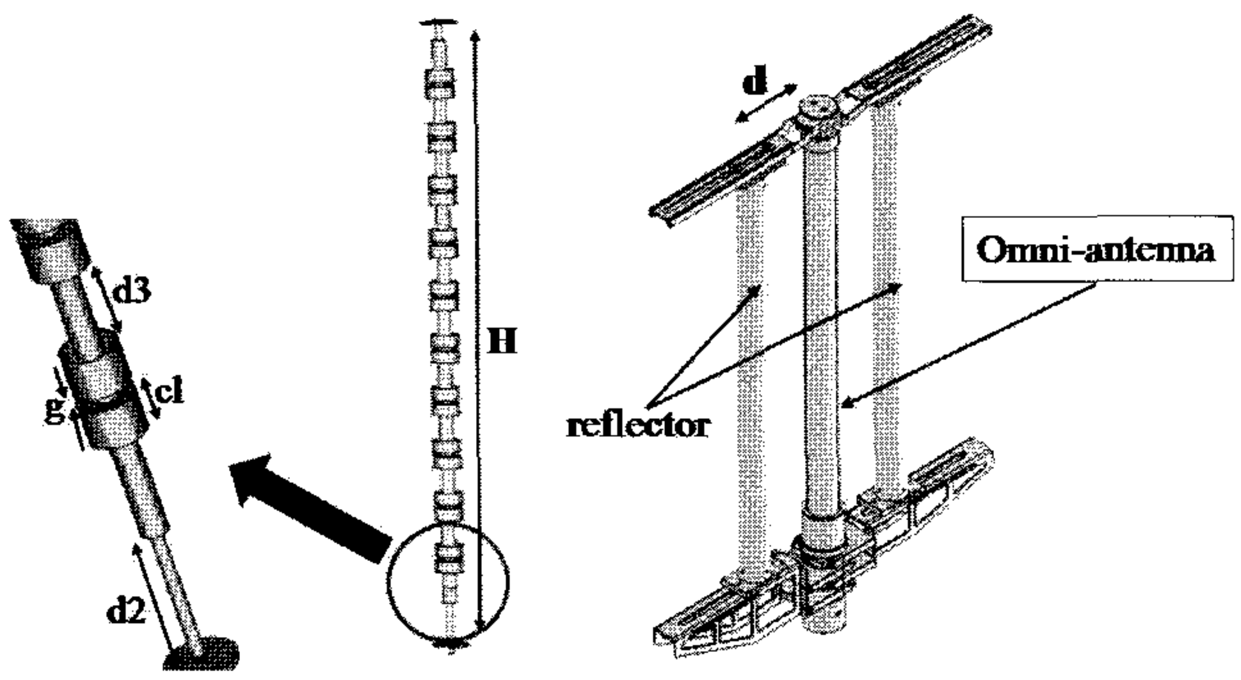
In mobile communications, the service area for base station antennas is sectored in order to increase the subscriber capacity. In the case of a three-sector wireless zone configuration, an antenna with a 120° beam is used for one sector. In the six-sector configuration, the antenna beam width is 60°[1]. Typical base station antennas have the characteristic of vertically narrow but horizontally broad beam widths. Due to the gradual variations in the horizontal plane of the radiation, the inter-sector coverage overlapping area is generally very wide and the antenna's side-lobe levels are very high. Further, it is known that a beam width narrower than the sector angle used as a service area is effective for increasing the subscriber capacity[2]. In [2], an antenna configuration for reducing the beam width by placing metal conductors near the antenna is proposed. Miniaturization technique of the base station antenna for a six-sector wireless zone configuration is proposed and discussed[3]. At present, the omni-antenna and the sector antenna are widely used. In the case of the omni-antenna, the electromagnetic wave is propagated into not only the service area but also the non-service area(mountains and fields). The electromagnetic wave is wasted if the omni-antenna is used in this terrain. In sector antenna, the antenna pattern should be adjusted according to the service area. However, the process of adjusting beam pattern is very complicated and the coverage area becomes narrow because of the sharp beam pattern. So all beam directions in several base stations should be controlled[4]~[6].

In this paper, to use effectively the electromagnetic wave propagating into the non-service area we have proposed the pattern adjustable base station antenna. We can control the beam direction and the gain of the antenna according to the service area characteristics by adjusting the antenna configuration manually. The proposed antenna is composed of the two reflectors and an omni-antenna(sleeve dipole array)[7]~[11]. The two reflectors can be adjusted mechanically and can be used to obtain the desired pattern in the service area by controlling the angle (a) and the distance (d) of the reflectors (see Fig. 1). Thus, we have improved the antenna gain of the service area and reduced the antenna gain of the non-service area. Also, the proposed antenna has the advantage of low cost, for example, the setup cost of the antenna is cheaper than that of the omni and sector antennas. The proposed antenna covers the entire WCDMA band(1,885~2,170 MHz) for VSWR<1.4. The measured antenna gain is more than 15 dBi over the operating frequency range, which is about 5 dB greater than the traditional omni-antenna.

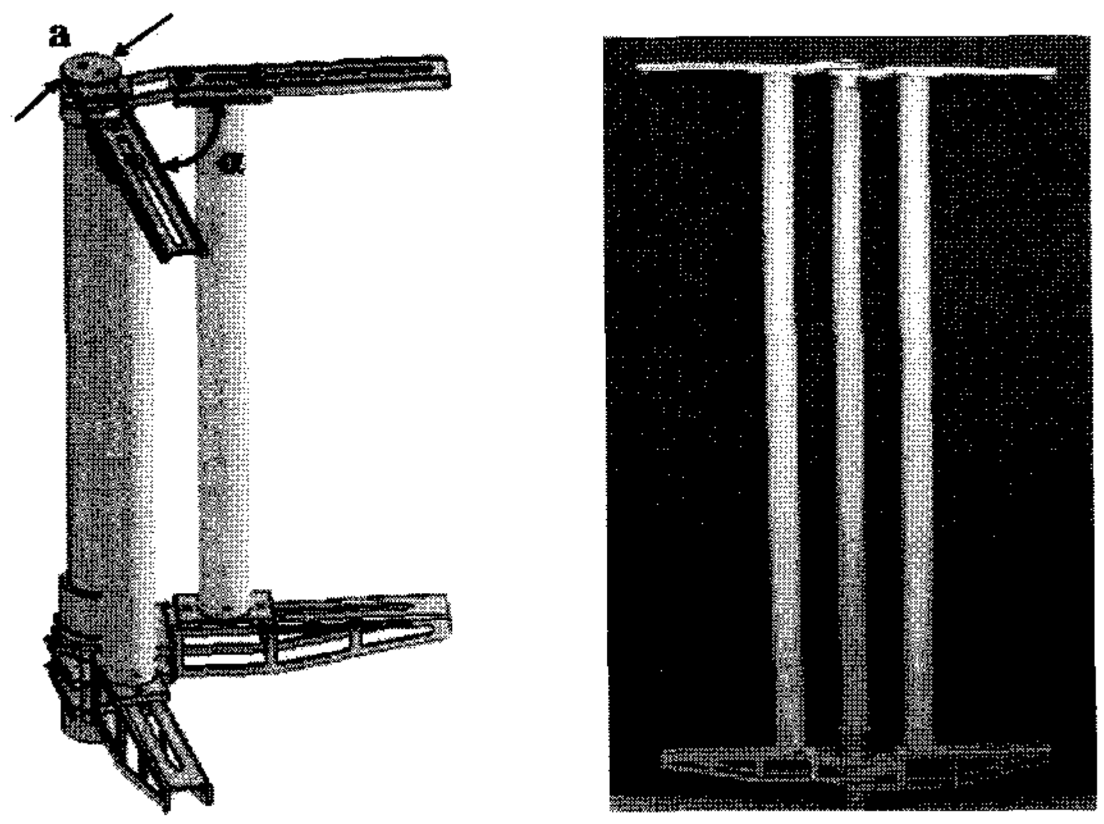
Ⅱ. Antenna Design and Measured Results

Fig. 1 shows the geometry of the pattern adjustable base station antenna for WCDMA system. The proposed antenna consists of an omni-antenna(sleeve dipole array) and two reflectors. The two reflectors can be controlled by mechanically and used to adjust the horizontal pattern of the base station antenna. The antenna is excited by using 50 Ω coaxial feed lines. The designed para-

Manuscript received April 17, 2008 ; June 12, 2008. (ID No. 20080417-019J)
[1]Department of Radio Wave Engineering, Hanbat National University, Daejeon, Korea.
[2]High Gain Antenna Co., Ltd., Gyunggi-Do, Korea.



(a) Details of the omni-antenna (b) The proposed antenna



(c) The proposed antenna (d) Photograph

Fig. 1. The beam pattern adjustable base station antenna.

meters of the proposed antenna are H=1,800 mm, a=50 mm, g=10 mm, $d2$=130 mm, $d3$=65 mm, and cl=30 mm. In Fig. 1(a) and (c), d is the distance between the omni-antenna and the reflector and α is the angle composed of the omni-antenna and two reflectors. Fig. 1(b) shows the details of the omni-antenna(sleeve dipole array). Fig. 1(d) is the photograph of the fabricated antenna. The proposed antenna was fabricated and measured using an Agilent Vector Network Analyzer(85107B) in an anechoic chamber. The characteristics of the proposed antenna were measured in various d: 70, 80, 90, 100, 110, 140, 150 mm and α: 180°, 150°, 120°, 90°, 60°, 45°. In this paper, the representative samples were selected at d: 80 mm, 130 mm and α: 130°, 120°, 90°, 45°, respectively. VSWR was measured for all cases and it was shown that WCDMA band is satisfied with VSWR<1.4. The measured and simulated results of VSWR for the case of α=180° and d=80 mm are given in Fig. 2 showing that WCDMA band(1,885~2,170 MHz) is satisfied with VSWR<2 on simulated result and VSWR < 1.4 on measured result. Fig. 3 shows the measured VSWR as a function of d versus frequency. In this figure, VSWR is less than 1.4 for all distances. The simulation results have been obtained from the two different commercial software(HFSS of Ansoft and MWS of CST) to make sure that the obtained results are trus-

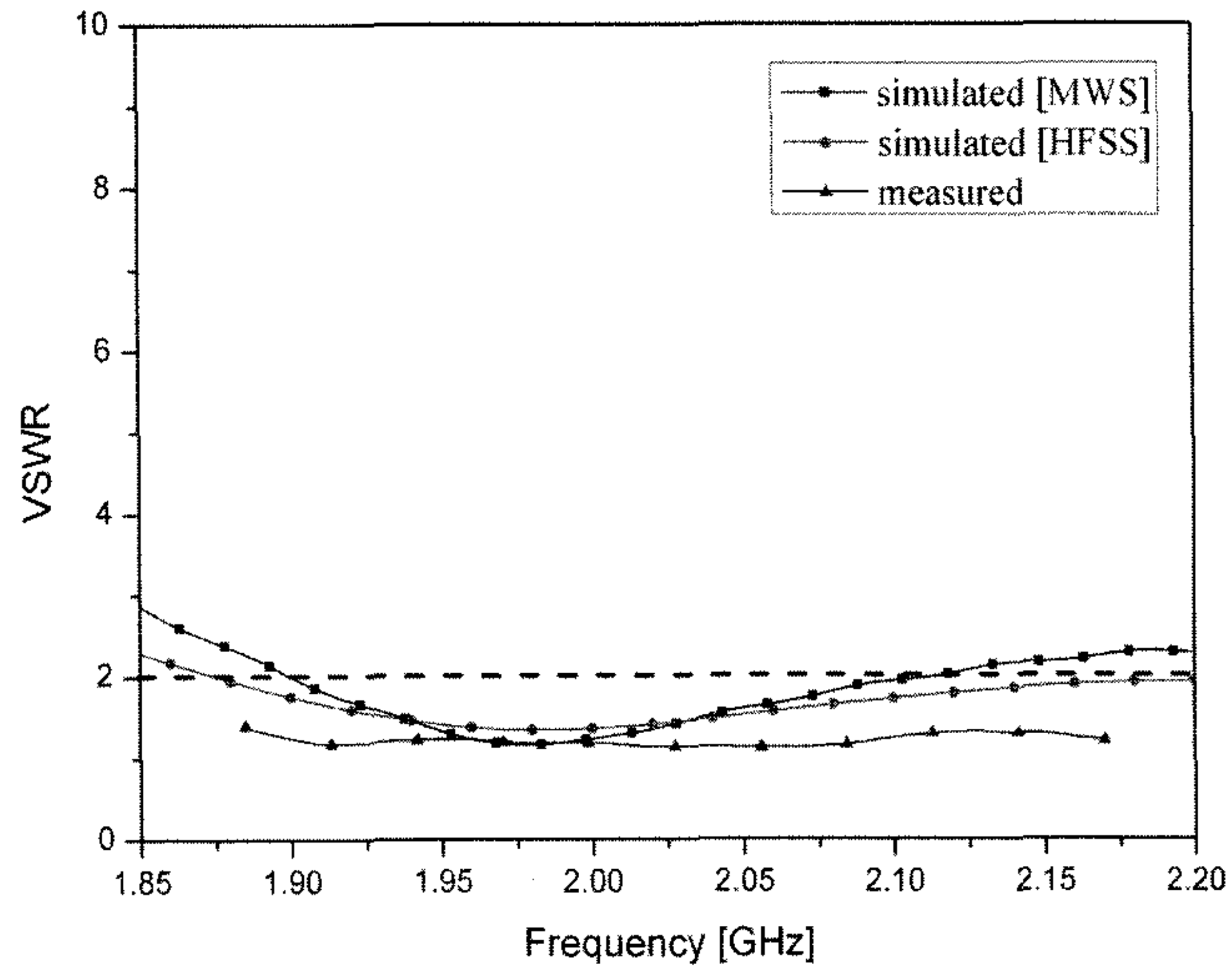


Fig. 2. Measured and simulated VSWRs for the proposed antenna(α=180° and d=80 mm).

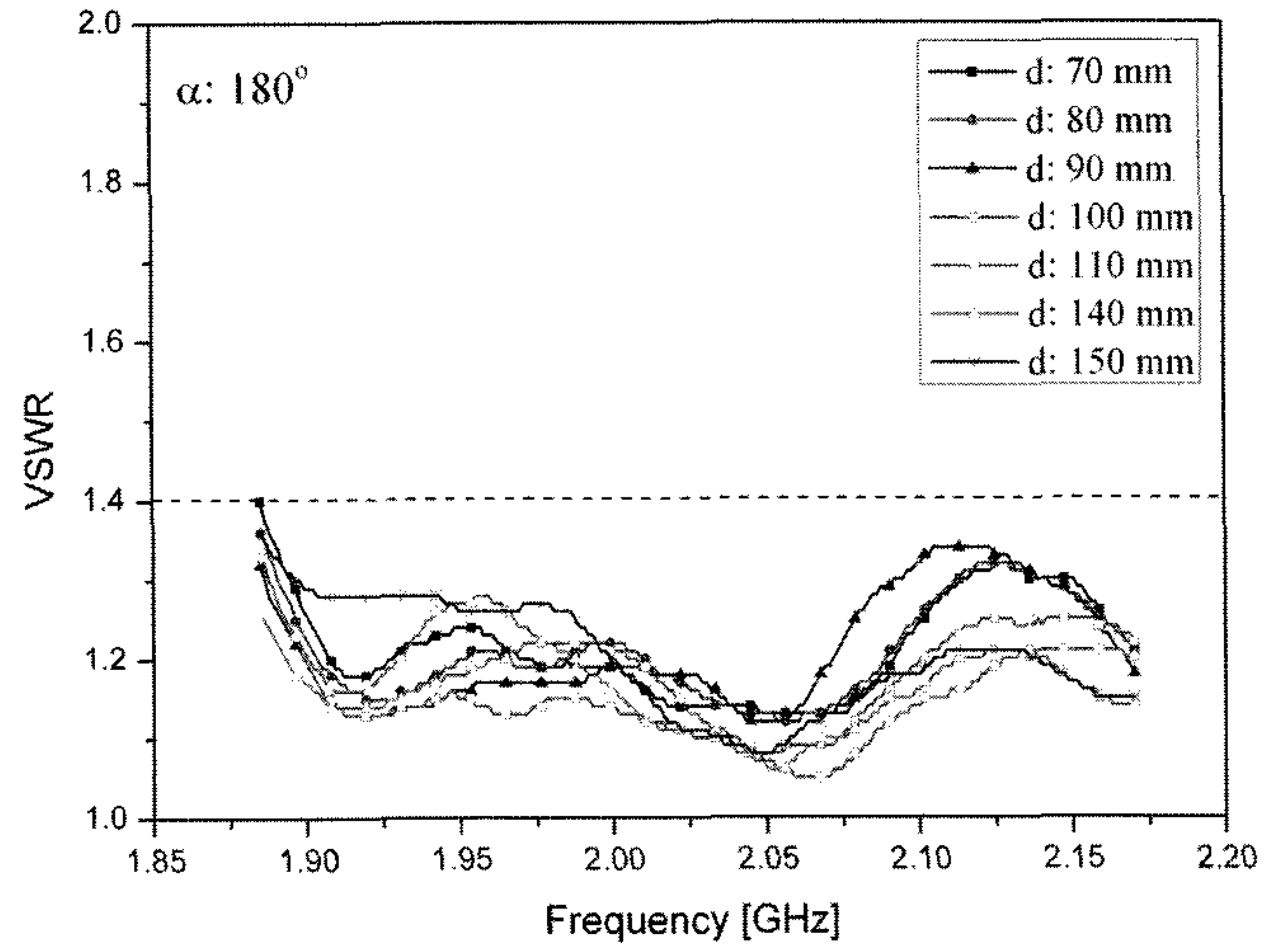


Fig. 3. Measured return loss as a function of distance d.

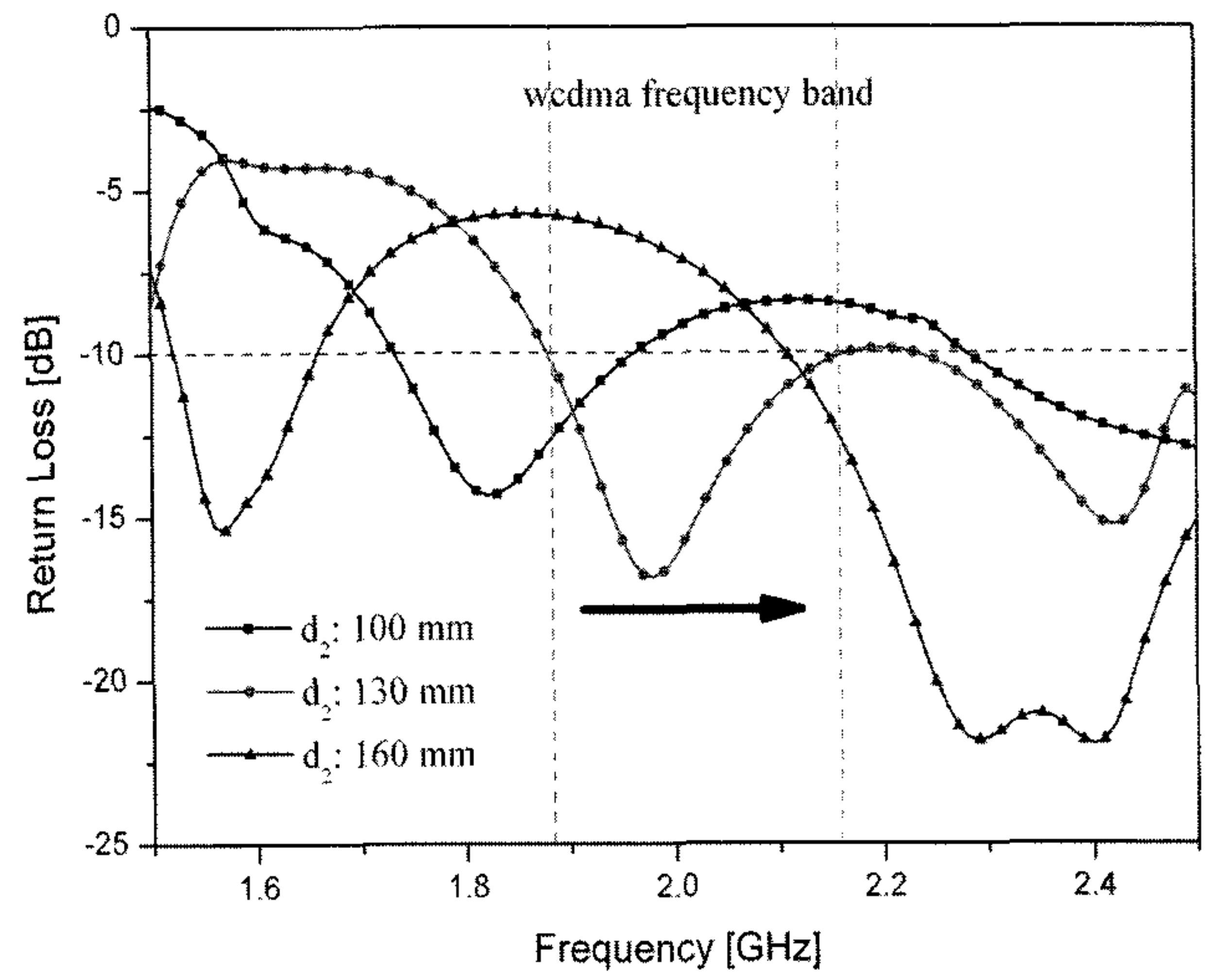
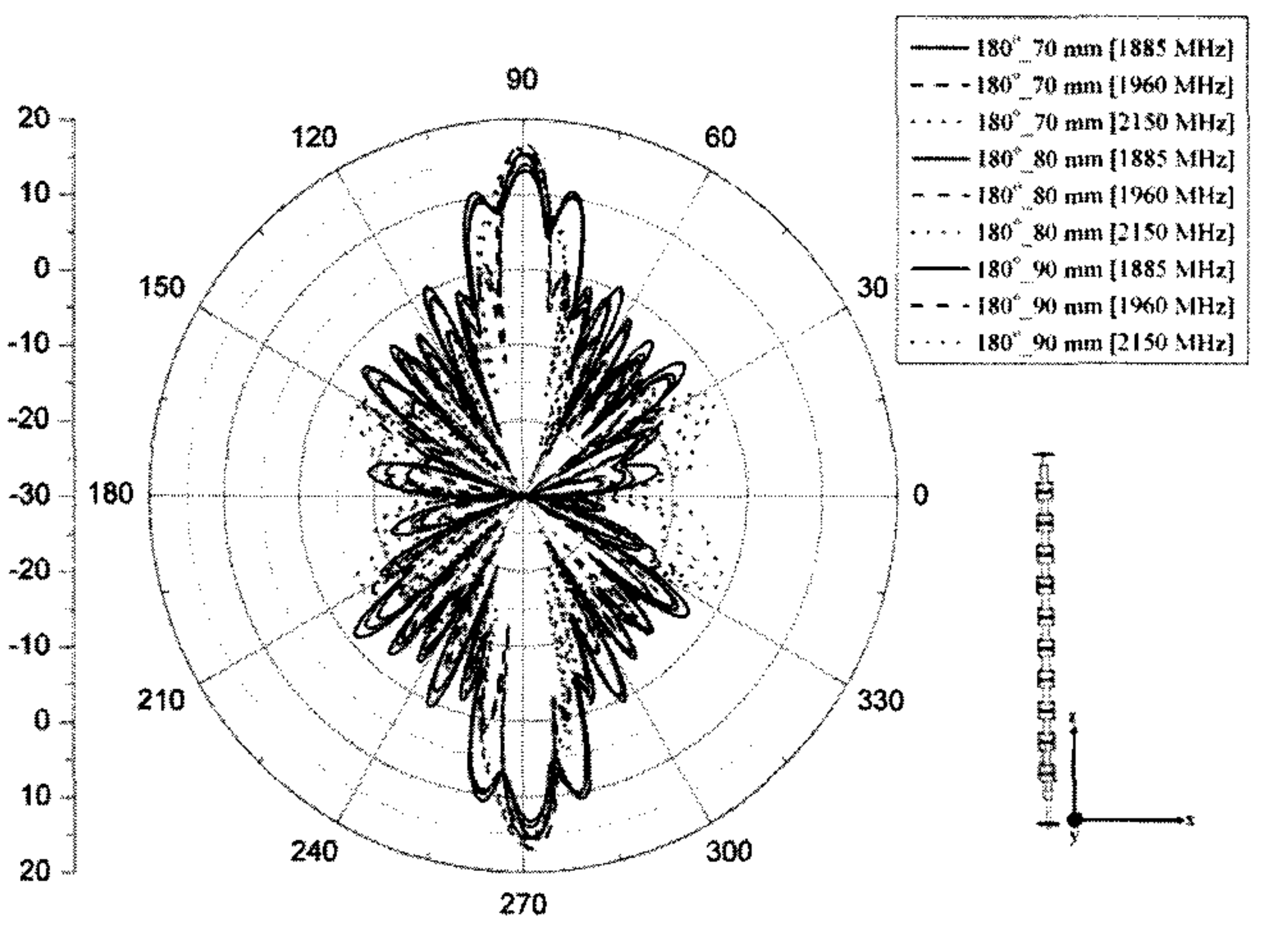
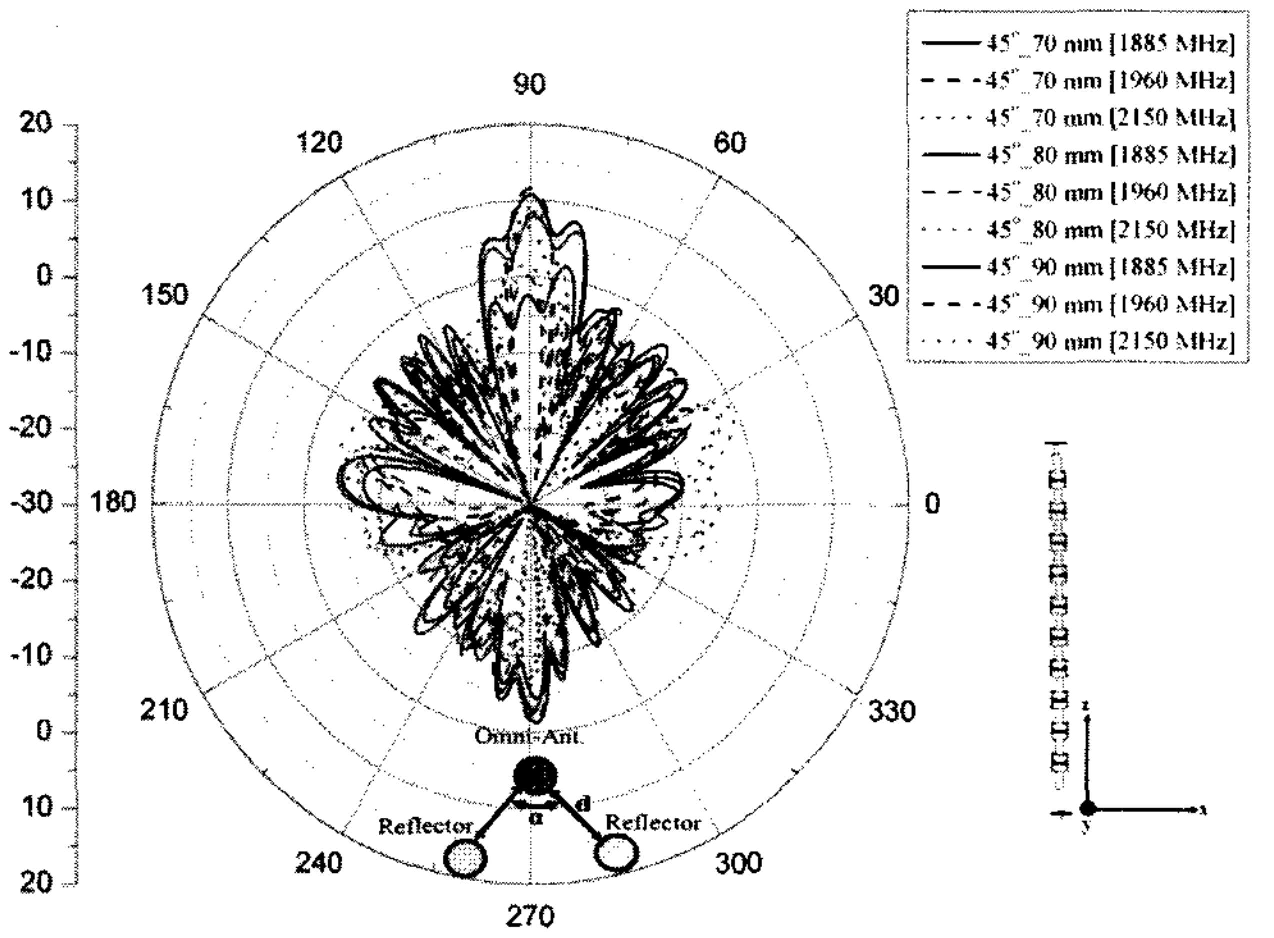


Fig. 4. Simulated return losses versus frequency as a function of $d2$.



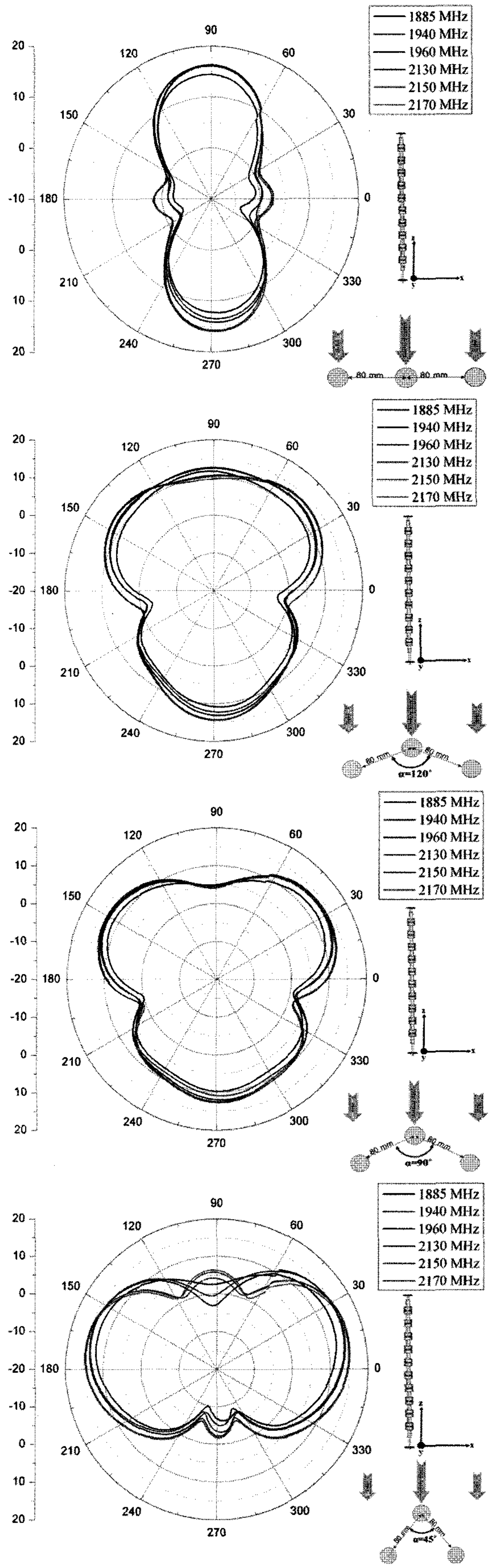
(a) Distance



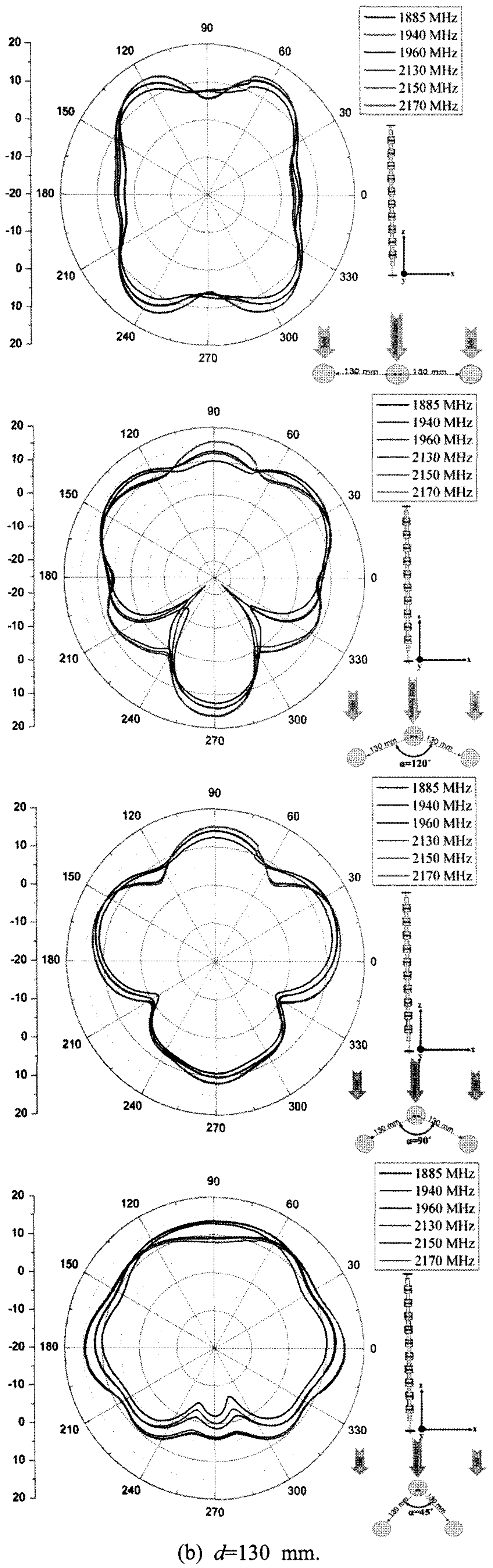
(b) Angle

Fig. 5. Measured vertical patterns as a function of distance d and angle α.

table. Fig. 4 shows the simulated return losses versus frequency as a function of $d2$. One parameter is changed at a time while the others are kept constant. From the figure, the WCDMA band can be controlled by changing $d2$. Fig. 5 shows the vertical patterns of the proposed antenna as a function of angle α and distance d. From the figure, the distance d has a negligible effect on the vertical radiation pattern but the angle α has a considerable effect on the vertical radiation pattern. As the angle α is changed from 180° to 45°, the vertical radiation patterns are changed from two directional to one directional. Also, the vertical pattern of the proposed antenna is more sharpened(about 5 dB: See Fig. 7). The measured horizontal patterns as a function of the angle and the distance are shown in Fig. 6. The pattern can be changed by controlling the angle and the distance and also it is possible to obtain the beam pattern similar to the sector antenna(α=90°). Fig. 6(a) shows that as the angle is smaller, the two reflectors have a relatively large effect on the pattern shape. Thus, the proposed pa-



(a) d=80 mm



(b) d=130 mm.

Fig. 6. Measured horizontal patterns as a function of distance d and angle α.

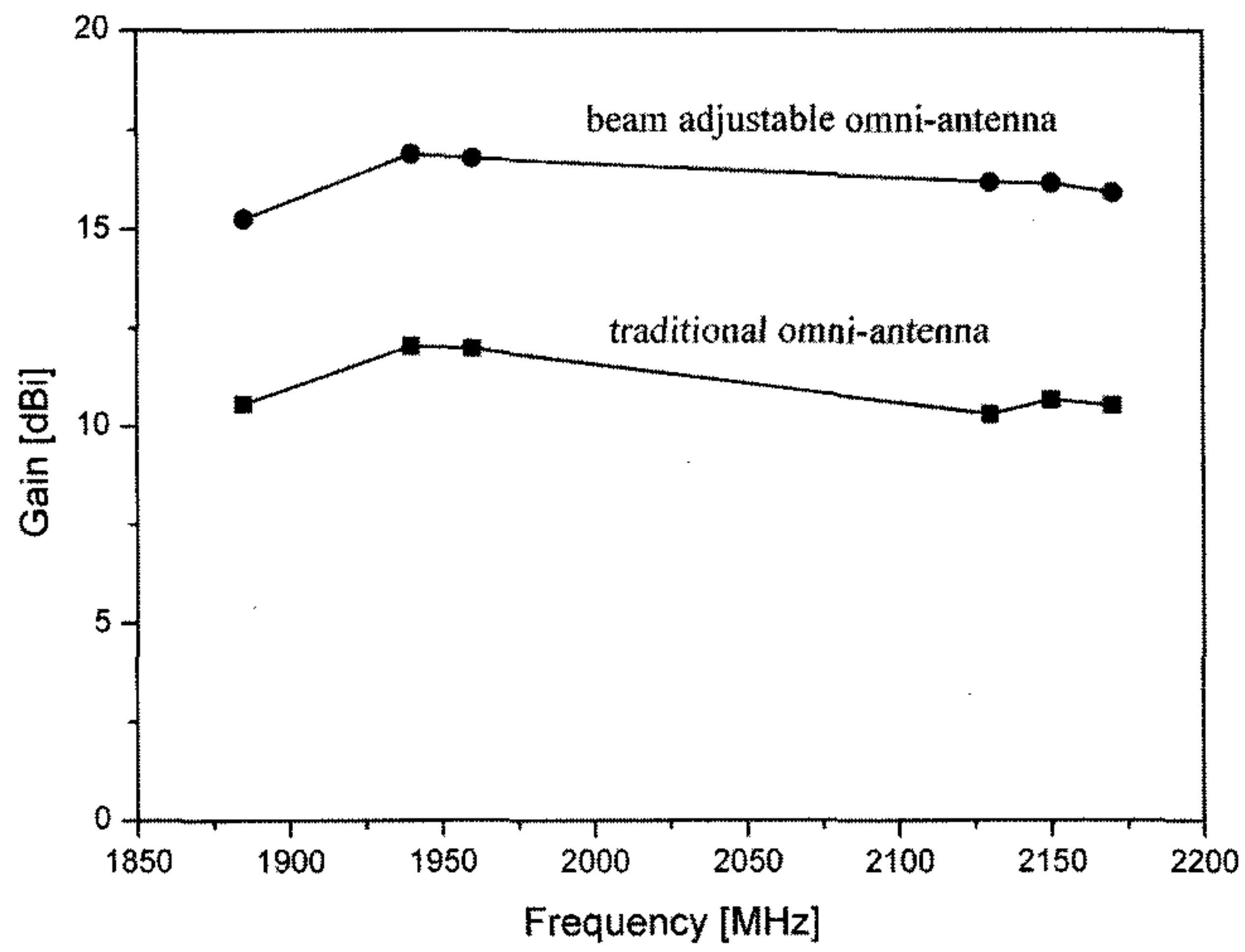


Fig. 7. Measured vertical antenna gain.

ttern adjustable base station antenna can be used to control the beam direction and the directivity of the horizontal pattern according to the characteristics of the service area. First we have made a look-up table as a function of the angle α and distance d. Second we have survey the terrain characteristics of the service area. Finally, we have set up the proposed base station antenna. The measured antenna gain across the operating frequency band is shown in Fig. 7 and compared the gain of the omni-antenna with that of the proposed antenna (α=180° and d=80 mm). As shown in the figure, the gain of the proposed antenna is about 5 dB higher than the traditional omni-antenna.

Ⅲ. Conclusion

Beam pattern adjustable base station antenna for WCDMA applications has been proposed. By changing the angle and the distance of the two reflectors we can control the beam direction and the gain of the horizontal pattern of the antenna. Good impedance matching(VSWR< 1.4) is obtained over the entire WCDMA band. From the measured results, the pattern adjustment of the antenna is found to be possible and the measured antenna gain is about 5 dB greater than the traditional omni-antenna. Therefore the proposed antenna can be used as the base station antenna for WCDMA applications.

This work was supported by the second stage of BK21.

References

[1] Y. Ebine, "Design of base station antennas for next

generation cellular mobile radio (IMT-2000)", *Tech. Rep. IEICE (2000)*, AP2000-4.

[2] Y. Kimura, Y. Ebine, "Control of horizontal radiation pattern of base station antenna for cellular mobile communications by performing approach arrangement of slender metal conductors", *Electronics and Communications in Japan*, Part 1, vol. 88, pp. 20-31, 2005.

[3] Y. Yamaguchi, Y. Ebine, "Design of a base station antenna with 60° beam width in the horizontal plane for cellular mobile radios", *Electronics and Communications in Japan*, Part 1, vol. 87, pp. 68-76, 2004.

[4] B. J. Lee, F. J. Harackiewicz, K. H. Kong, J. H. Byun, and S. H. Yang, "Dual-band dual-circularly polarized sector antenna for GPS and DAB system", *Microwave and Optical Technology Letters*, vol. 46, no. 1, pp. 43-46, 2005.

[5] H-. T. Chou, J. S. Wang, and Y. T. Hsiao, "An experimental implementation of resistive plates to enhance the performance of the mobile base station antennas", *Microwave and Optical Technology Letters*, vol. 37, no. 4, pp. 276-280, 2003.

[6] T. Ohgane, "Spectral efficiency improvement by base station antenna pattern control for land mobile cellular systems", *Global Telecommunications Conference*, pp. 913-917, 1993.

[7] N. J. Bae, H. K. Choi, "Analysis of the sleeve dipole array antennas using the moment method", *Journal of Korean Institute of Electromagnetic Engineering and Science*, vol. 10, no. 7, pp. 973-984, 1999.

[8] T. J. Judaz, W. L. Ecklund, and B. B. Basley, "The coaxial collinear antenna: Current distribution from the cylindrical antenna equation", *IEEE Trans. Antennas Progagat.*, vol. AP-35, no. 3, pp. 327-331, 1987.

[9] T. J. Judaz, B. B. Basley, "Improved theoretical and experimental models for the coaxial collinear antenna", *IEEE Trans. Antennas Progagat.*, vol. AP-37, pp. 287-296, 1989.

[10] A. Sakitani, "Analysis of coaxial collinear antenna: Recurrence formula of voltages and admittances at connections", *IEEE Trans. Antennas Progagat.*, vol. AP-39, no. 1, pp. 15-20, 1991.

[11] J. Taylor, "The sleeve antenna", Doct. Dissertation, Cruft Lab., Harvard Univ., Cambridge, MA., 1950.

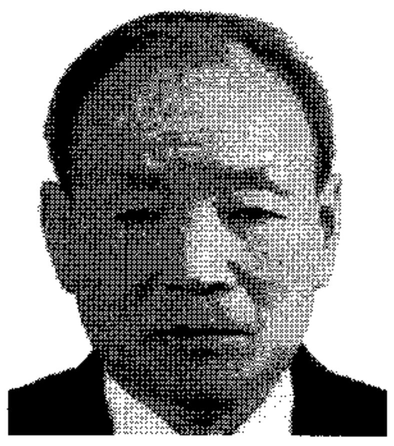
Sang Ho Lee

was born in Korea in 1957. He received the B.S. degree in the electronic engineering from Hanbat National University, Daejeon, Korea, in 1990, and M.S. degree in the department of radio wave engineering from Kwangwoon University, Seoul, Korea, in 1998. He is currently working toward the Ph.D. degree in the department of radio wave engineering at the Hanbat National University. From 1992 to 2004, he was a department manager at the SK Telecom. In 2006, he founded the AM Tech., where he is the president of the company. His research interests are base station antenna, passive device, and mobile communication applications.

Jung Nam Lee

was born in Korea in 1977. He received the B.S. and M.S. degrees in the department of information and communication engineering, Hanbat National University, Daejeon, Korea, in 2004 and 2006, respectively. From 2005 to 2006, he worked as commission research engineer at RFID/USN Group of Electronics and Telecommunications Research Institute(ETRI), Daejeon, Korea. He is currently working toward the Ph.D. degree in the department of radio wave engineering at the Hanbat National University. His research interests are small antenna, RFID antenna, ultra-wide band(UWB) antenna, and DVB-H antenna design.

Don Shin Lee

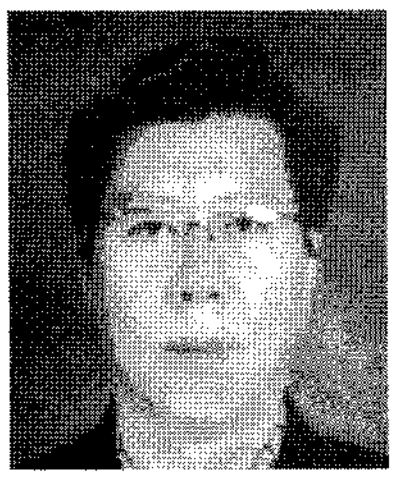


was born in Korea in 1935. He received the B.S. degrees in the electronic engineering from Hanyang University, Seoul, Korea, in 1963. From 1996 to 1999, he was an adjunct professor at Chungbuk National University and Gyeongsang National University. In 1970, 1992, and 1993, he founded the High Gain Antenna, High Gain Telecom, and Kukdong Telecommunication where he is the president of the company, respectively. His research interests are base station antenna, satellite communication antenna, and mobile communication applications.

Jong Kweon Park

was born in Korea in 1969. He received the B.S. degree in electronic engineering from Kyungpook National University, Daegu, Korea, in 1994, and the M.S. and Ph.D. degrees in electrical engineering from Korea Advanced Institute of Science and Technology(KAIST), Daejeon, Korea, in 1997 and 2001, respectively. From 2001 to 2002, he was a Research Engineer at Electronics and Telecommunications Research Institute(ETRI), Daejeon, Korea. In 2002, he joined the department of radio wave engineering, Hanbat National University where he is currently a Professor. His research interests are wave scattering analysis, fractal antenna, ultra-wide band (UWB) antenna, DVB-H antenna, and T-DMB antenna design.

Hak Sun Kim



was born in Korea in 1959. He received the B.S., M.S., and Ph.D. degrees in electrical engineering from Korea Aerospace University, Gyeonggi-Do, Korea, in 1979 and 1993, respectively. From 2004 to 2007, he was a technical adviser at Samsung Electro-Mechanics, Gyeonggi-Do, Korea. From 2001, he was a technical adviser at Samsung Advanced Institute of Technology, Gyeonggi- Do, Korea. In 1993, he joined the department of information and communication engineering, Hanbat National University where he is currently a Professor. His research interests are circuits and system, RF circuit design, mobile communication RF system, RF system for RFID.