HALF-CIRCULAR DIPOL ON A U-SHAPED CROSS SECTIONAL GROUND PLANE ANTENNA FOR A BROADBAND APPLICATION

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ABSTRACT

This paper presents the half-circular dipole on a u-shaped cross-sectional ground plane antenna. The dipole elements contribute from copper on the surface of the FR4 material. They are the half-circular shape. This antenna provides an average gain of 8.0 dBi from the half power beam-width of 85 degree in *xz*-plane and 60 degree in *yz*-plane. The front-to-back ratio is greater than 20 dB on the u-shaped ground plane width and length of 140 x 130 mm^2 and folded edge height of 35 mm across the frequency range of 1.6 – 2.9 GHz (VSWR<1.5:1). The antenna is fed at the center between poles by a 50 ohms coaxial cable. It is suitable to fabricate as a low-cost base station antenna with a linear polarization that cover the operating frequency of DCS, PCS, UMTS, and ISM band.

Index terms— Half-circular dipole, u-shaped cross sectional ground plane, wideband antenna, broadband antenna, unidirectional

1. INRODUCTION

The wireless communications system is continuously developed. It is not only for transmitting and receiving voices, but including of images and data. As the wireless internet at present, it is growing very fast that we can see from the extending of the internet service providers (ISPs) into everywhere with the name of WiFi or WiMAX. The advantages are convenient to install without wiring a cable-line [1], solved the problem of drilling on the floor or on the wall, and users can move around in coverage area. There are many wireless communications systems operate in different frequency ranges such as Digital Cellular System band (DCS, 1.71-1.88 GHz), Personal Communications System band (PCS, 1.85-1.99 GHz), Universal Mobile Communications System band (UMTS, 1.92-2.17 GHz), and Industrial Scientific Medical band (ISM, 2.44-2.48 GHz). DCS and PCS bands are used for the conventional mobile phone system while UMTS band is for the third generation mobile phone (3G) system which is the connecting of mobile and internet together. ISM band is used for Wireless Local Area Network (WLAN) under the standards of IEEE802.11 b and IEEE802.11 g. There are three ranges for WLAN compose of 925 MHz, 2.45 GHz, and 5.8 GHz. The 2.45 GHz range is the most popular. For all wireless communications systems, they must use the necessary equipment to operate, the antenna. Antenna is used for transmitting and receiving signal. For the present communication technology, it can combine more than one operating frequency band in one tower (base station). If only one antenna can be covered for all bands simultaneously, it is very useful and attractive. Thus, a broadband antenna is required.

For the wideband antenna, the planar monopole [2], (Wideband antenna is called the Broadband antenna if it is used for more than one communication system), it provides a very wide bandwidth but its pattern is only suitable for the omni-directional radiation and difficult to array for increasing the antenna gain. The wide slot antenna [3] which is radiated in two-directions or bi-directional radiation, although it has a wide bandwidth but an incline beam occurs at the high frequency of the operating frequency band. It is an unwanted radiation. In general, if the high gain is required, a uni-directional antenna will be chosen.

Many antennas can give a uni-directional radiation pattern, but their impedance bandwidths are not wide enough for a multi-band operation. In general, conventional dipole or half-wave dipole on flat ground plane is selected. If bandwidth is not wide enough, Baluns are together composed with those dipoles for tuning the impedance. Advantages of dipole antenna are pure linear polarization and low profile. For the wideband antenna, in addition, it is more flexible than the narrowband antenna, for example when we fabricate, we have not serious to tune the operating frequency for a critical band, makes it convenient to produce in mass production. For this, the material is also easily to find in the local market and not necessary to use an expensive substrate so the antenna is low cost as well.

This paper describes the broadband antenna that can be operated in the frequency range of 1.71 – 2.48 GHz or cover both cellular and wireless internet systems of DCS, PCS, UMTS, and ISM bands. The antenna develops from the half-circular dipole on a u-shaped cross-sectional ground plane. It is the uni-directional antenna that has not any squeeze or incline radiation pattern. The analysis was conducted by using the commercial software.

2. ANTENNA DESCRIPTIONS

For the antenna structure, it is the dipole antenna that suspend on a u-shaped cross-sectional ground plane in *yz*-plane as shown in Figure 1. The half-circular dipole contributes from copper on the surface of FR4 material with has the relative permittivity ε_r of 4.9 and size of 80 x 90 mm^2. Both poles are the half-circular shape patch which mirror itself at the center. Thus, for the dimensions of this antenna, it has the dipole radius *r* of 40 mm while the length *l* of 54 mm, and the gap between poles *g* of 2 mm. The thickness of copper on FR4 surface is about 0.05 mm when for the FR4 is 1.6 mm. The half-circular dipole separates from the aluminum ground plane *h* of 35 mm. The ground plane has the size *Gx* and *Gy* of 140 mm and 130 mm, respectively, and the height *Gz* of 35 mm while its thickness is 1 mm. The antenna is fed by a 50Ω coaxial cable between the half-circular dipoles. To compare and confirm the accuracy of the simulation, the prototype of the proposed antenna is fabricated with the dimensions and the materials as indicated. The FR4 substrate of the half-circular dipole is supported by 4 plastic legs. All dimensions are indicated as show in Table I.

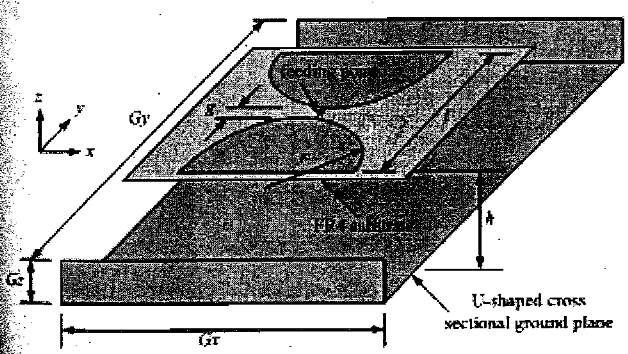


Figure 1 Structure of the proposed antenna

3. SIMULATED AND MEASURED RESULTS

The dimensions of the antenna were optimized by the simulation. From the study, we found that the width of the ground plane in the *x*-direction (*Gx*) is less sensitive to the input impedance thus it is fixed at 140 mm or about $1.0\lambda_0$ in size for the good front-to-back ratio less than -20 dB and gain of ~8.5 dBi when λ_0 is the central frequency between 1.7 - 2.5 GHz or at 2.1 GHz. G_z is assigned to equal with the appropriate height of *h*. However, it can be slightly different from *h* (lower or higher). Amount of *g*, *r*, and *l* are used to tune the impedance matching. To simplify the analysis, *g* and *l* are fixed at 2 mm and 54 mm, respectively.

Table I
Dimensions of the proposed antenna

Parameters	Dimensions (mm)
g	2
r	40
l	54
h	35
Gx	140
Gy	130
Gz	35
thickness of FR4 substrate	1.6
thickness of ground plane	1

After analysis, the appropriate parameters are chosen as indicated in Table I. The simulated result of the return loss (S_{11}) is agrees with the measured as shown in Figure 2. The return loss of the fabricated antenna was measured in anechoic chamber. Both simulated and measured return losses of this antenna provide the bandwidths of 47.62% (VSWR<1.5:1) between the frequency range of 1.6 - 2.6 GHz. However, the range of measured bandwidth is slightly narrower than the simulated one.

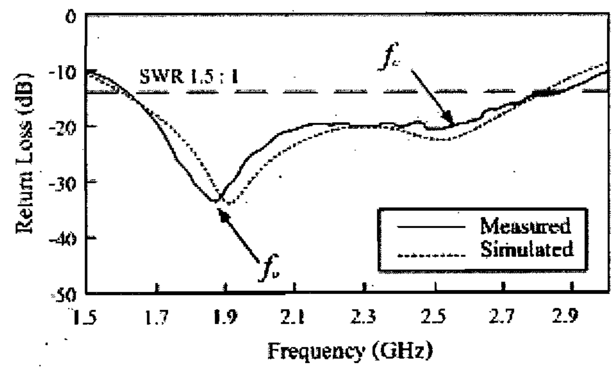


Figure 2 Measured and simulated return losses of the proposed antenna

From Figure 2, it found that u-shaped cross-sectional ground plane creates a new resonance at a higher frequency of band. Thus, f_D and f_G are assigned for the low and high resonant frequencies when f_D is the resonant frequency due to the dipole and f_G is from the u-shaped cross-sectional ground plane. Though the corresponding resonant modes are generated in the parallel planes, however, there is little electromagnetic coupling between the two modes. Therefore a double-resonance characteristic of the antenna is achieved as a superposition of these two independent resonant modes. The wide bandwidth is obtained by providing a suitable difference between the two resonant frequencies.

Figure 3 shows the current on the ground plane surfaces. The current on dipole strongly flows and directs to the +*y*. It drives the current on the u-shaped cross-sectional ground plane to simultaneously flow in the same direction.

The current is caused by the resonant mode of the u-shaped cross-sectional ground plane. Thus, its resonant mode is represented as the resonance of the finite ground plane. The approximate equation representing the resonance of the u-shaped cross-sectional ground plane is given by

$$Gy+2Gz = (2n-1)\lambda_G/2 \quad (1)$$

where n is a natural number. From the equation, the left hand-side part represents the path length of the current. In this case, n is equal to 2. For the case of n = 1, it does not play a critical role in determining the frequency of the operating bandwidth.

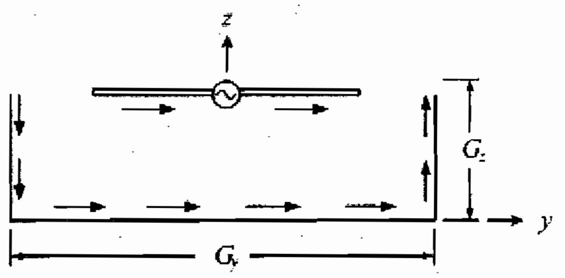


Figure 3 Current directions of the proposed antenna

To show the antenna characteristics, some parameters of the proposed antenna are varied. The first parameter to vary is Gy which is used for indicating the antenna size in +/-y directions. When Gy is varied, all parameters are fixed as Table I. Figure 4 shows the simulation results of the return loss of difference Gy. It is found that, Gy is mainly sensitive to the frequency at the position of low and high of the bandwidth (VSWR<1.5 : 1) while Gy is decreased from 140 mm to 130 mm and to 120 mm, respectively. The operating bandwidth is extended when the impedance matching is become decreased. The resonant frequencies are clear to observe where the low resonant frequency is from the half-circular dipole elements and the high resonant frequency is from the u-shaped cross-sectional ground plane.

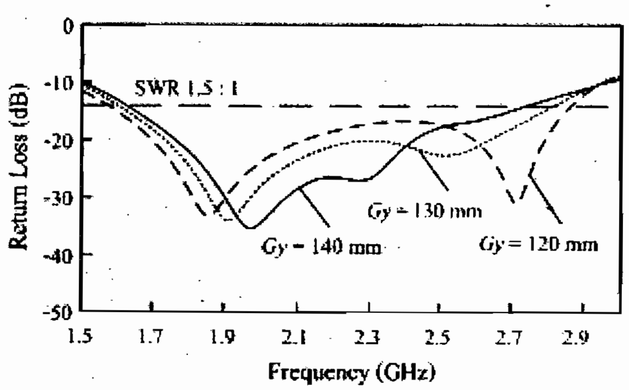
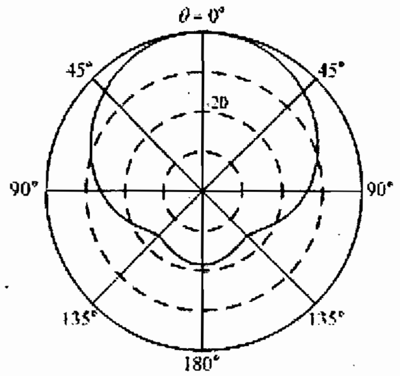
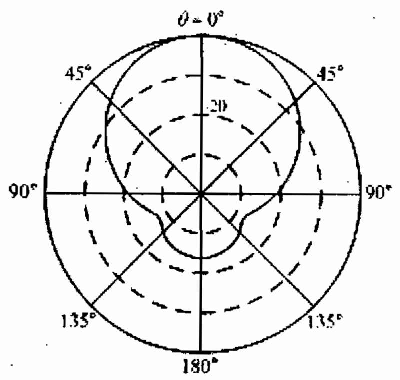


Figure 4 Simulated return losses of difference G_y

Figure 5 shows the simulated yz-plane co-polarized patterns. The cross-polarized patterns are not show because they are low when compared with the co-polarized patterns. The radiation patterns are simulated at the operating frequencies of 1.7, 2.1, and 2.5 GHz for the low, mid, and high of the band, respectively. It was found that the front-to-back ratio is greater than 22 dB for all operating frequencies. The half power beam-widths (HPBW) are 70°, 60°, and 45° for the operating frequencies of 1.7, 2.1, and 2.5 GHz, respectively. The beam-widths depend on l and Gy, if they are extended the beam-width become narrower.



(a)



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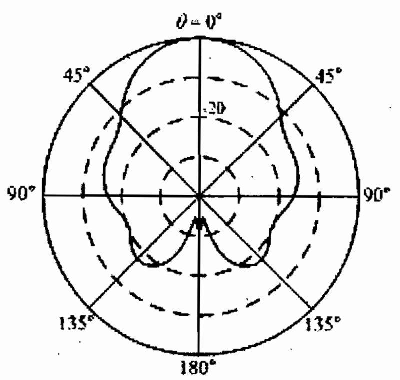
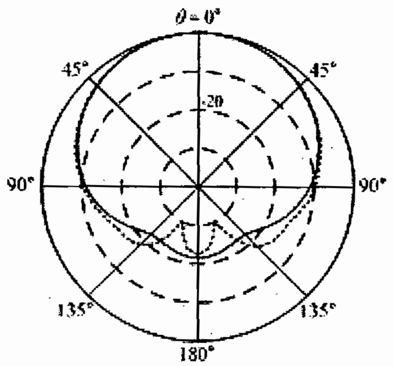


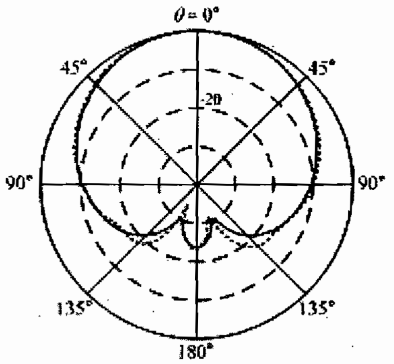
(c)

Figure 5 Simulated yz-plane radiation patterns of the proposed antenna at the frequency of (a) 1.7 GHz (b) 2.1 GHz, and (c) 2.5 GHz

Figure 6 shows the simulated horizontal plane (xz-plane) co-polarized patterns compare with the measured ones. The cross-polarized patterns are not show because they are low too. The measured radiation patterns are experimented in the anechoic chamber at the operating frequencies of 1.7, 2.1, and 2.5 GHz for the low, mid, and high of the band, respectively. It was found that the front-to-back ratio is greater than 22 dB for all operating frequencies. The half power beam-widths are 90°, 85°, and 95° for the operating frequencies of 1.7, 2.1, and 2.5 GHz, respectively. The patterns for all are symmetry.



(a)



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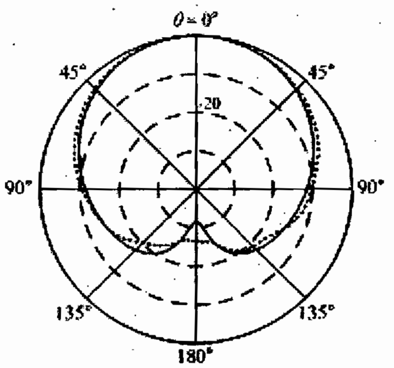

(c)

Figure 6 Simulated : solid; and measured : doted; horizontal radiation patterns in xz-plane of the proposed antenna at the frequency of (a) 1.7 GHz (b) 2.1 GHz, and (c) 2.5 GHz

For the antenna gain of the proposed antenna across the bandwidth, it is about 8.0 dBi in the average. It is slightly increase from low to high of the frequency in the band.

4. CONCLUSION

This paper presents the wideband half-circular dipole on a u-shaped cross-sectional ground plane antenna. From the analysis, we found that the antenna has the HPBW at the mid band in xz-plane of 85° and yz-plane of 60° and front-to-back ratio across the operating range of >20 dB with the ground plane size of 140 x 130 mm^2 and folded edge of 35 mm. The average gain is 8.0 dBi. The measured return loss has a bandwidth of 57.78% between 1.6 – 2.9 GHz (VSWR<1.5:1). Advantages of this antenna are easily to fabricate, low-profile, and low-cost. The antenna is suitable for a base station which has a linear polarization either of DCS, PCS, UMTS, and ISM band or more than one technology together.

5. REFERENCES

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