Single Feed Compact Wideband Antenna for Wireless Communication Applications

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Abstract—Wideband terminal and base station is required to serve not only existing 1st and 2nd generation mobile communication systems but also 3rd generation systems. In this paper, we presents a feasibility study on single feed compact wideband antenna for wireless communication applications including GSM (890-960 MHz), GPS (1575 MHz), DCS (1710-1880 MHz), PCS (1880-1990 MHz), UMTS (1900-2200 MHz), ISM (2400-2480 MHz), IMT2000 and satellite DMB bands. The original antenna was designed for partial discharge detection sensor in high voltage diagnostic system. However, we modified the original prototype to achieve shifted down resonant frequency for wideband wireless communication applications. The experimental result shows good return loss characteristics and radiation patterns except for the total gain at each resonant frequency. The maximum measured gain was 2.45 dBi ~ 3.18 dBi at 1710 MHz ~ 1880 MHz.

Index Terms—Wideband, antenna, GSM, GPS, DCS, PCS, UMTS, ISM, IMT2000, satellite DMB.

I. INTRODUCTION

In the recent years, there has been an increasing demand on providing enhanced functionality for wireless communications services with wideband terminal or base station. Wideband resonance point of view, pulse and broadband applications require that the antenna with good impedance matching and high radiation efficiency on entire band. [1-2]

Furthermore, many techniques have been proposed to increase resonance bandwidth and compact size from experimental results. [3-4] According to the present demand on wideband antenna based on UWB technology, we focus on the three major areas of feasibility study related to size reduction, wideband or multiple band, and radiation pattern.

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In this paper, we have modified the partial discharge (PD) detection sensor originally developed for high voltage diagnosis as to applying feasibility for multiple band resonance. [5]

Attenuation of electromagnetic PD pulse is a function of frequency along the propagation path. The higher the frequency components will be attenuated rapidly when they travel along the high voltage equipments. Therefore, the detectable electromagnetic (EM) wave emitted from PD includes broadband signal of VHF/UHF (30MHz to 300MHz / 300MHz to 3000MHz). [5]

We tried to modify UWB sensor based on new design compact low frequency techniques which can operate at GSM900, GPS1575, DCS1800, PCS1900, UMTS2000, ISM2450, IMT2000 and satellite DMB bands. CST MS version 5.1, microwave simulation software was used to design and implement wideband antenna.

II. DESIGN AND FABRICATION

Generally, microstrip patch antennas consist of a metallic patch that is on the top of a grounded dielectric substrate of thickness h, with relative permittivity, and permeability.

Patch antennas are widely used in microwave frequency range but they are often used in millimeter-wave frequency range as well by modifying various shapes of patch design [6]. The metallic patch essentially creates a resonant cavity, where the patch is the top of the cavity, the ground plane is the bottom of the cavity and the edges of the patch from the sides of the cavity.

The edges of the patch act approximately as an open-circuit boundary condition.

Hence, the patch cavity modes are described by a double index (m,n). For (m,n) cavity mode of the rectangular patch, the electric field has the form.

$$E_x(x,y) = A_{mn}\cos\left(\frac{m\pi x}{L}\right)\cos\left(\frac{n\pi x}{W}\right) \tag{1}$$

where L is the patch of length and W is the patch width. The patch is usually operated in the (1,0) mode, so that L is the resonant dimension, the field is essentially constant in the y direction. The resonant frequency of the (1,0) mode is given by

$$f_0 = \frac{c}{2L_e\sqrt{\varepsilon_r}} \tag{2}$$

where c is the speed of light in vacuum. To account for the fringing of the cavity fields at the edge of the patch, the length, the effective length Le is chosen as

$$L_e = L + 2\Delta L \qquad (3)$$

The Hammerstad formula for the fringing extension is [7] as follow.

$$\Delta L / h = 0.412 \frac{(\varepsilon_{eff} + 0.3)(\frac{W}{h} + 0.264)}{(\varepsilon_{eff} - 0.258)(\frac{W}{h} + 0.8)} \qquad (4)$$

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}(1 + 10\frac{h}{W})^{-1/2} \qquad (5)$$

For this mode the patch may be regarded as a wide microstrip line of width W, having resonant length L, that is approximately one half-wavelength in the dielectric. The current is maximum at the centre of the patch, while the electric field is maximum at the "radiating" edges, x=0, and x=L. The width W is usually chosen to be larger than the length (W=1.5L is typical) to maximize the bandwidth, since the bandwidth is proportional to the width of the antenna bandwidth.

The basic of this design is a rectangular element improved for wider bandwidth in low frequency and can detect signal from near field. The width of the patch element is chosen 1.5 times of resonant length and modified with two notched patch which can be operate both low and high frequencies as ultra-wide band operating. Our UWB sensor design was realized on FR4 substrate (er=4.4, thickness =2.4mm) in order to have low cost. At Low frequencies the antenna size is the principal constraint, e.g. at 500MHz, the dimension of λ/2 antenna is 30 cm. It is very difficult to integrate as a sensor. Therefore to reduce the antenna size at low frequency by using notched patch antenna.

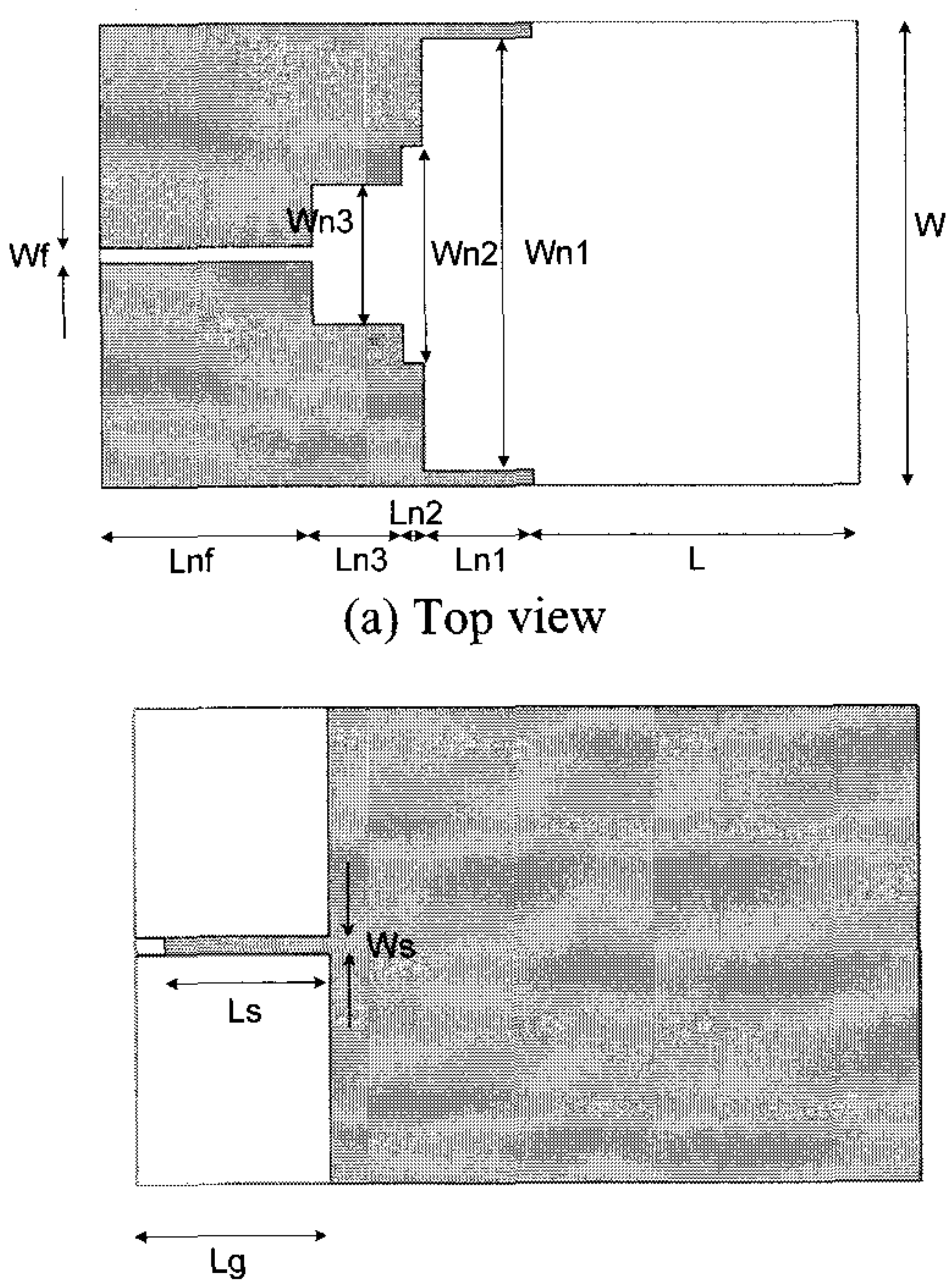
Simulation has been carried out with CST MWS version 5.1, to determine resonant bandwidth, return loss and input impedance. The rectangular patch element is feed by microstrip line access, which is a common microwave transmission line that offers fairly good performances in the term of bandwidth at low cost.

To increase the antenna bandwidth, two cutting notches are used in the rectangular patch by controlling impedance stability. These notches alter the electro magnetic coupling between the rectangular patch and ground plane. The width of the notches is particularly effective either at low or high frequencies. Matching can be obtained by inserting a slot in the ground plane. The characteristics of the antenna highly depend on the ground plane shape: The best result can be obtained changing ground length Lg with the ground slot of Ws.

These notches alter the electromagnetic coupling between the rectangular patch and ground plane [7]. In sensor design structure, the main rectangular patch element is modified with three notched patched elements and microstrip line feeding method is used. Some parts of ground region is removed and modified with ground slot to get wider bandwidth.

The width of the notches is particularly effective either at low or high frequencies. Matching improvement can be obtained by inserting a slot in the ground plane [6]. The optimization parameters are Wn1, Wn2, Wf and Ws while we fixed feed line length Lf.

The overall size of this structure is 106×64 mm^2. The width and the length of the feed line Wf and Lf are fixed 2mm and 29.6mm to obtain the input impedance of 50Ω. The complete UWB antenna sensor design diagram is as shown in Fig 1.



(a) Top view

(b) Bottom view

Fig. 1 Geometry of the proposed antenna.

Several parameters optimizations are made by simulation to get the desired bandwidth and target frequency. Optimization procedure is shown in Fig. 2 ~ Fig. 5, respectively.

In the Fig. 2, we simulated parameter sweep on slot length where ground length and notch width are fixed. Simulated result of parameter sweep on dielectric substrate thickness shows optimized value should be 2.4 mm as shown in Fig. 3. Furthermore we find the best ground length by parameter sweep between 21 mm and 27 mm where notch width and slot length are fixed. We summarized the procedure in Fig. 4 ~ 5, respectively. We found optimal ground length should be 24 mm.

To decide the resonant frequency band of the antenna, the return loss parameter S11 is carried out by simulation. The final simulation result of return loss with the optimized parameters is shown in Fig 6 where S11 in dB at GSM, GPS, ISM IEEE802.11a band was -13.11 dB, -13.24 dB and -20.55 dB, respectively. Furthermore, resonance bandwidth calculated through about 2.3 GHz.

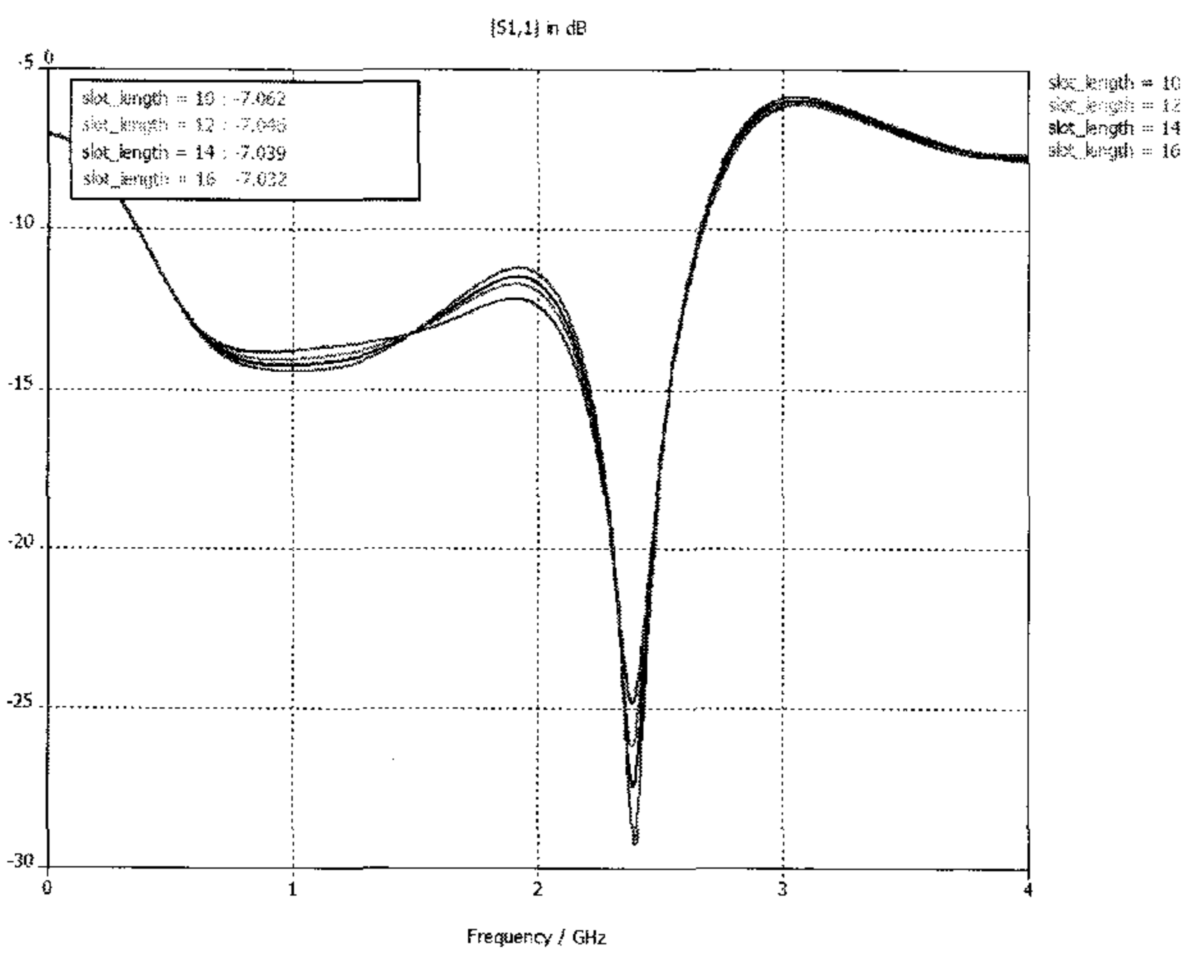


Fig. 2 Simulated result of parameter sweep on slot length where ground length and notch width are fixed.

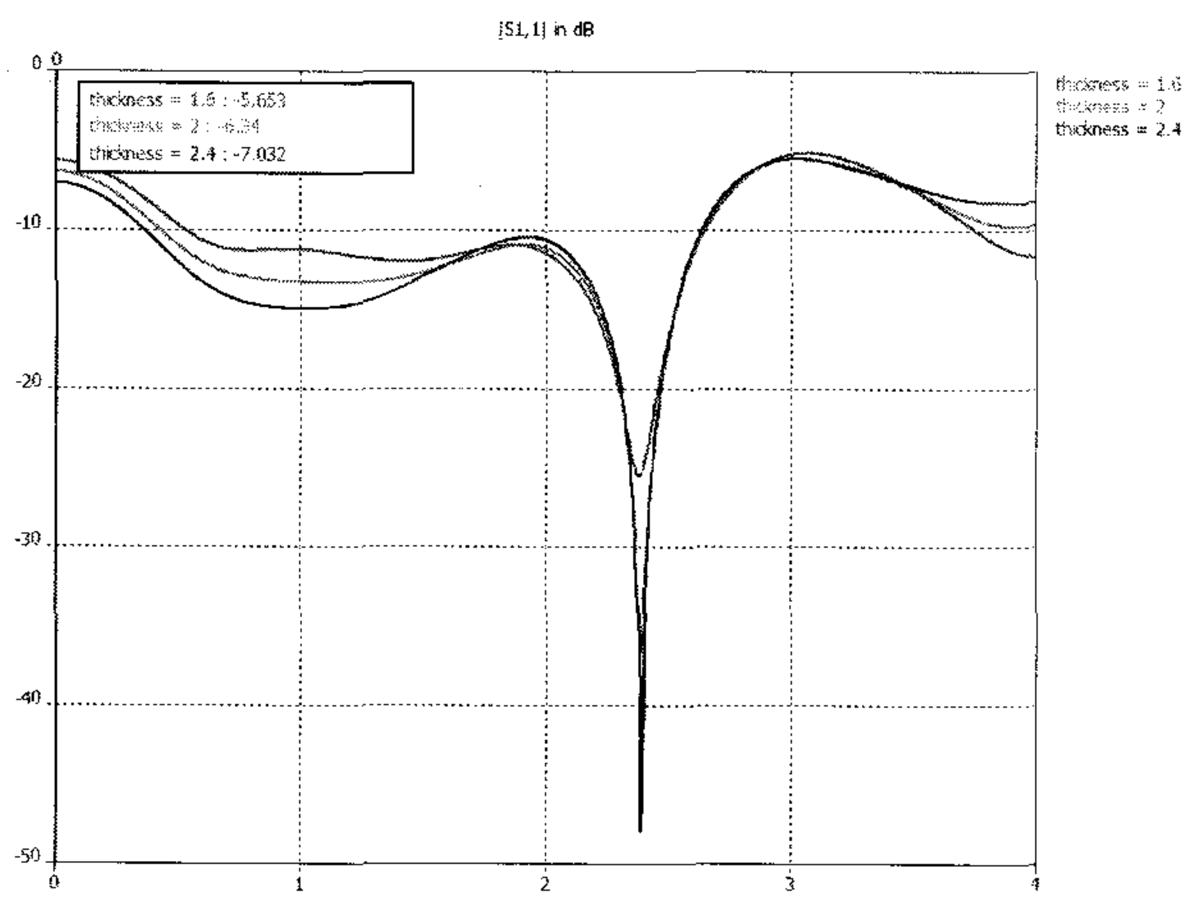


Fig. 3 Simulated result of parameter sweep on dielectric substrate thickness.

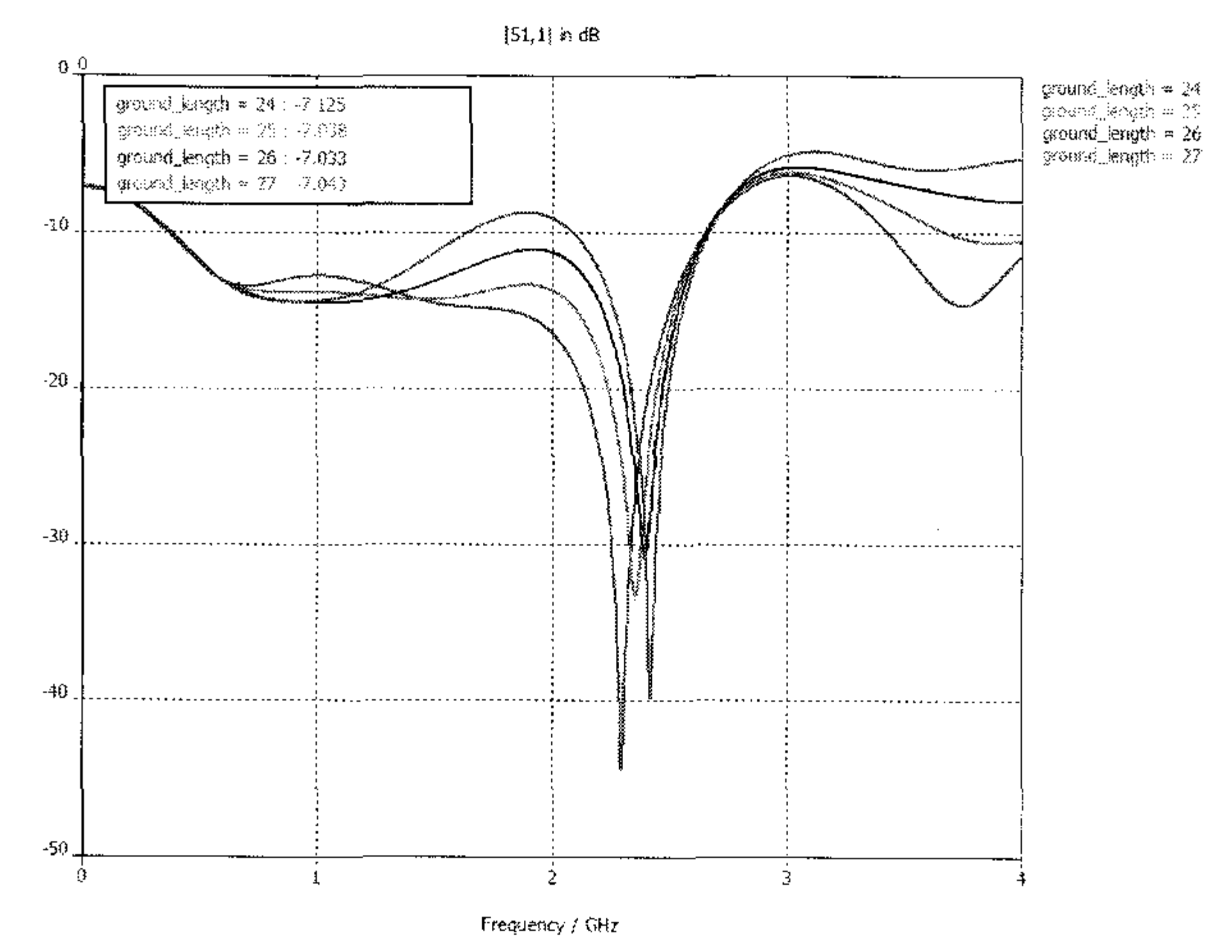


Fig. 4 Simulated result of parameter sweep on ground length between 24 mm and 27 mm where notch width and slot length are fixed.

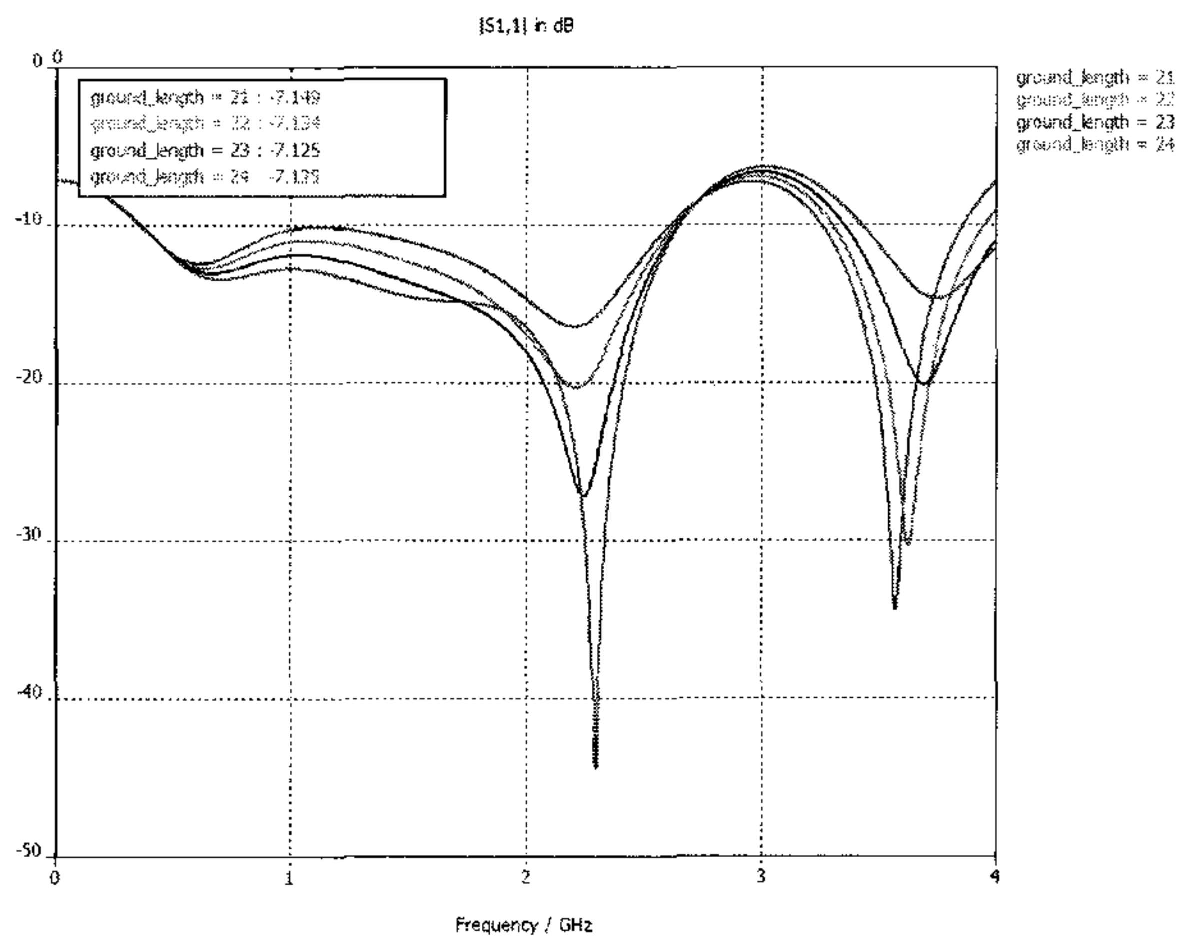


Fig. 5 Simulated result of parameter sweep on ground length between 21 mm and 24 mm where notch width and slot length are fixed.

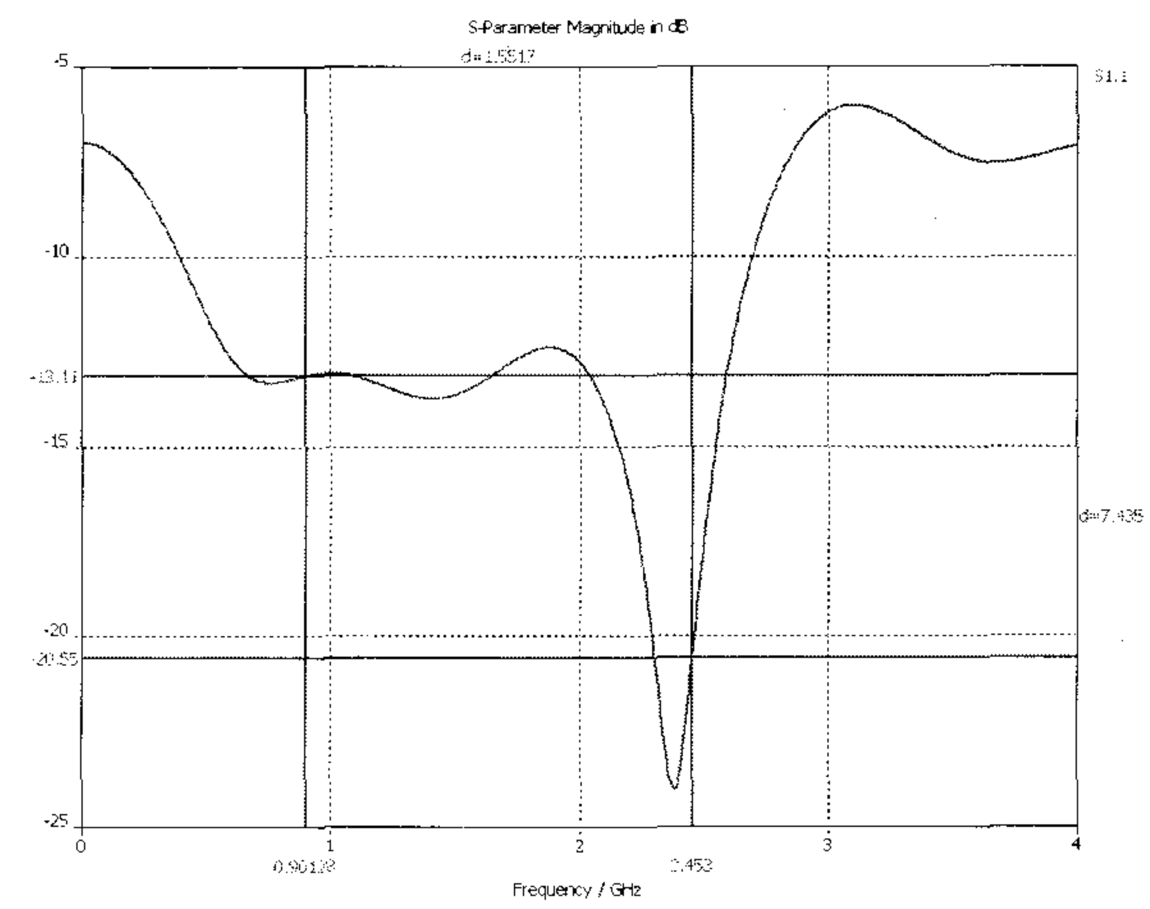


Fig. 6 The return loss simulation results with final dimensions and showing -10dB bandwidth.

The operating -10 dB bandwidth of proposed antenna was optimized at the frequency from 365MHz to 2,624 MHz as shown in Fig 6.

The radiation pattern is one of the important characteristics of the antenna. As to the simulation result, we found the maximum antenna gain could be up to 7.26 dBi, however measured value is much less than simulated result.

It is considered that alignment between feed line on the radiating element and slot line on the ground plane could have influence on total antenna gain.

After several simulations on optimization of return loss with the desire frequencies, the final dimensions of the parameters in UWB sensors are shown in Table. 1.

Table 1 Designed parameters of the proposed antenna

Parameter	Value(mm)	Parameter	Value(mm)
W	64	W_f	2
L	45.6	L_n	30.8
W_{n1}	60	L_f	29.6
W_{n2}	30	L_g	26
W_{n3}	9.65	W_s	2.4

The radiation pattern of this wideband antenna was simulated at 1.5 GHz and shown in Fig 7.

Proposed antenna was fabricated by photolithographic etching technique, making the construction relatively easy an inexpensive using with FR4 dielectric material.

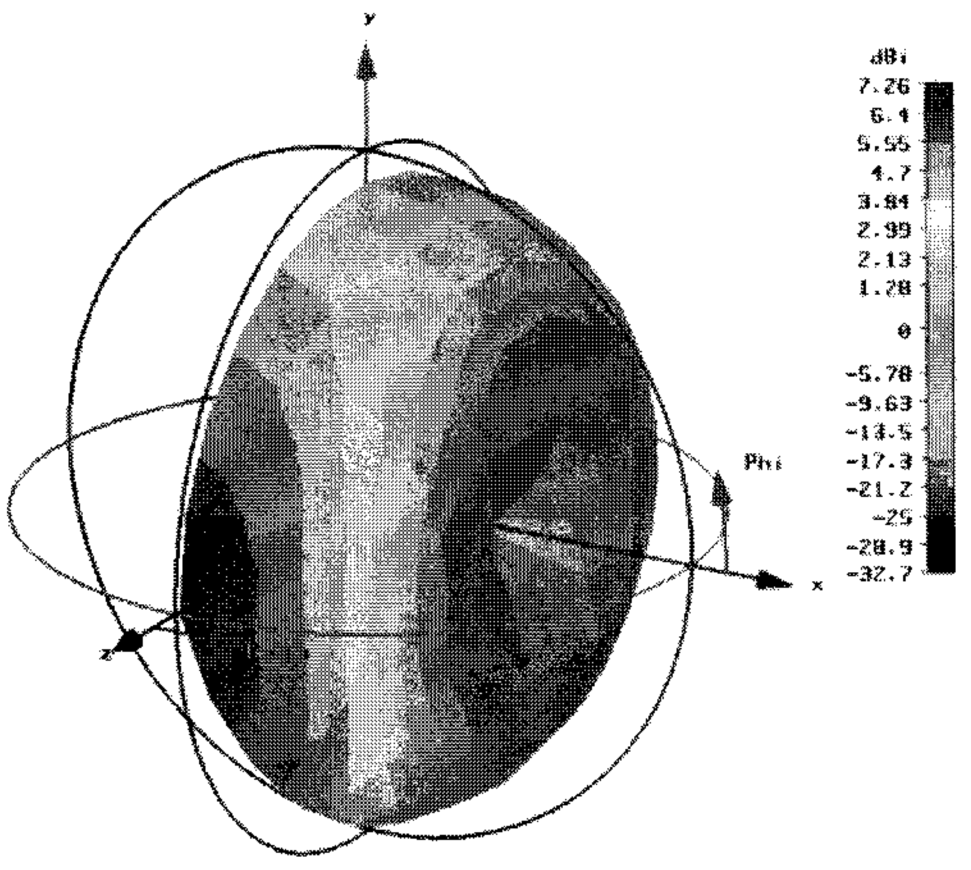


Fig. 7 Simulated far-field radiation pattern.

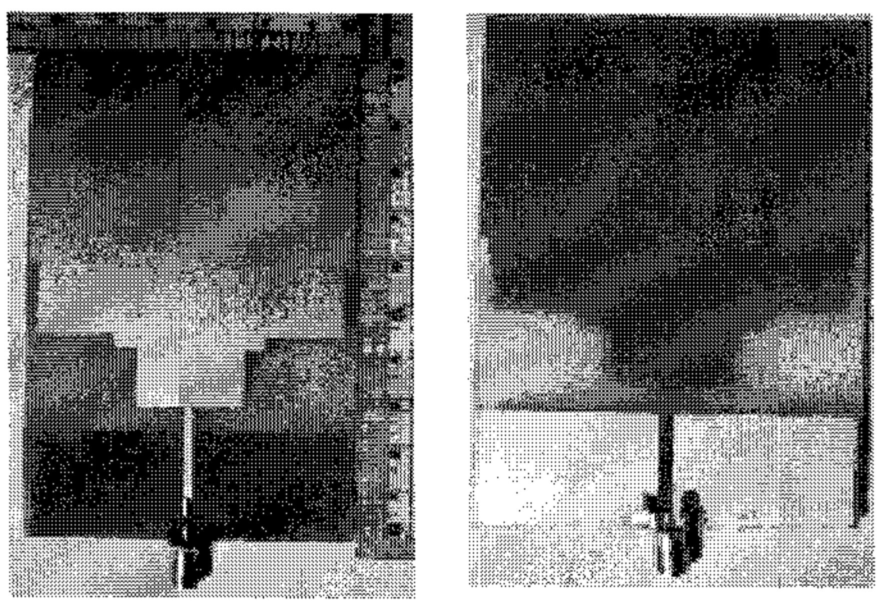


Fig. 8 Prototype of the fabricated wideband antenna.

III. EXPERIMENTS

The measured return loss for each frequencies and radiation pattern are shown Fig. 9 ~ Fig. 13, respectively. Good agreement with resonant characteristics is observed except for antenna gain. The Maximum gain was 2.45 dBi ~ 3.18 dBi at 1710 MHz ~ 1880 MHz.

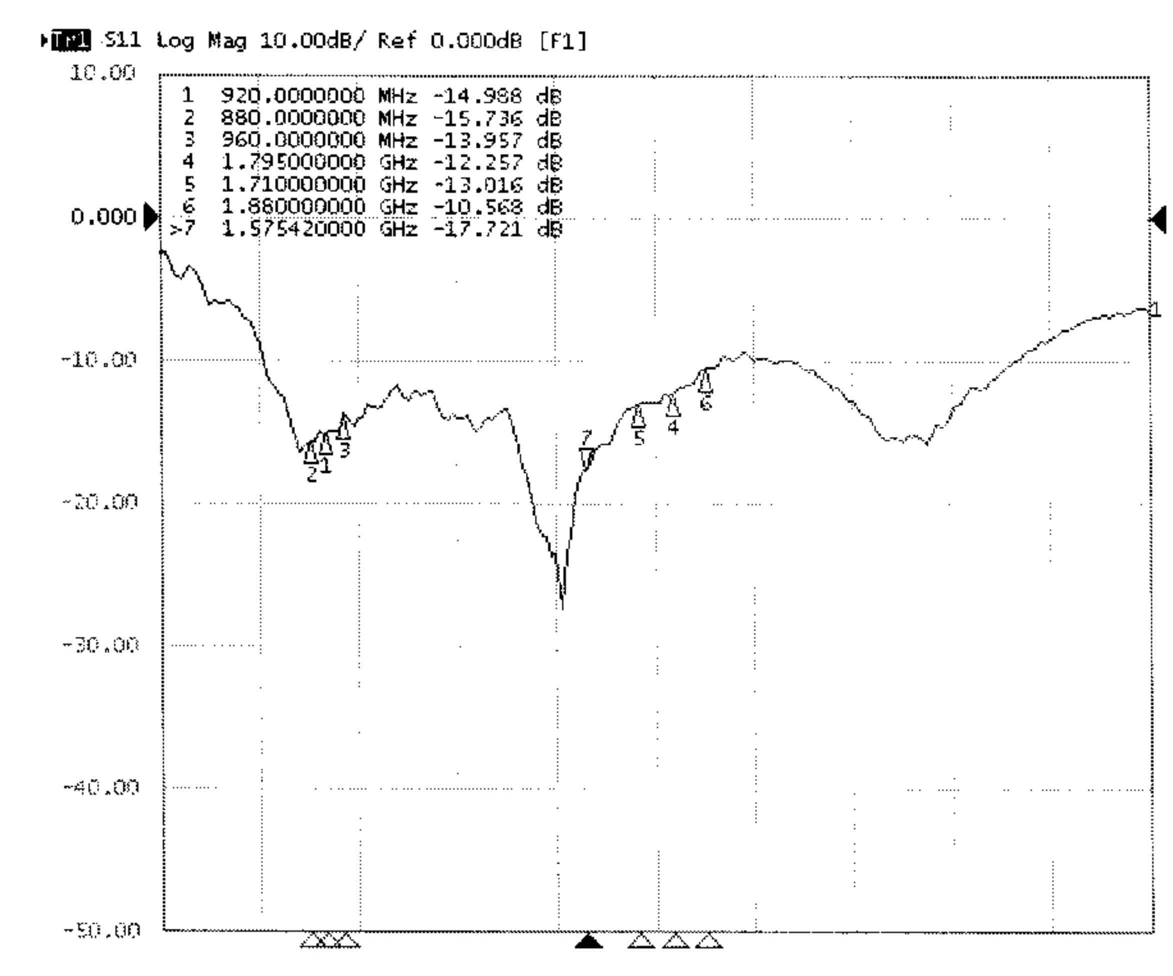


Fig. 9 Measured return loss for the proposed antenna

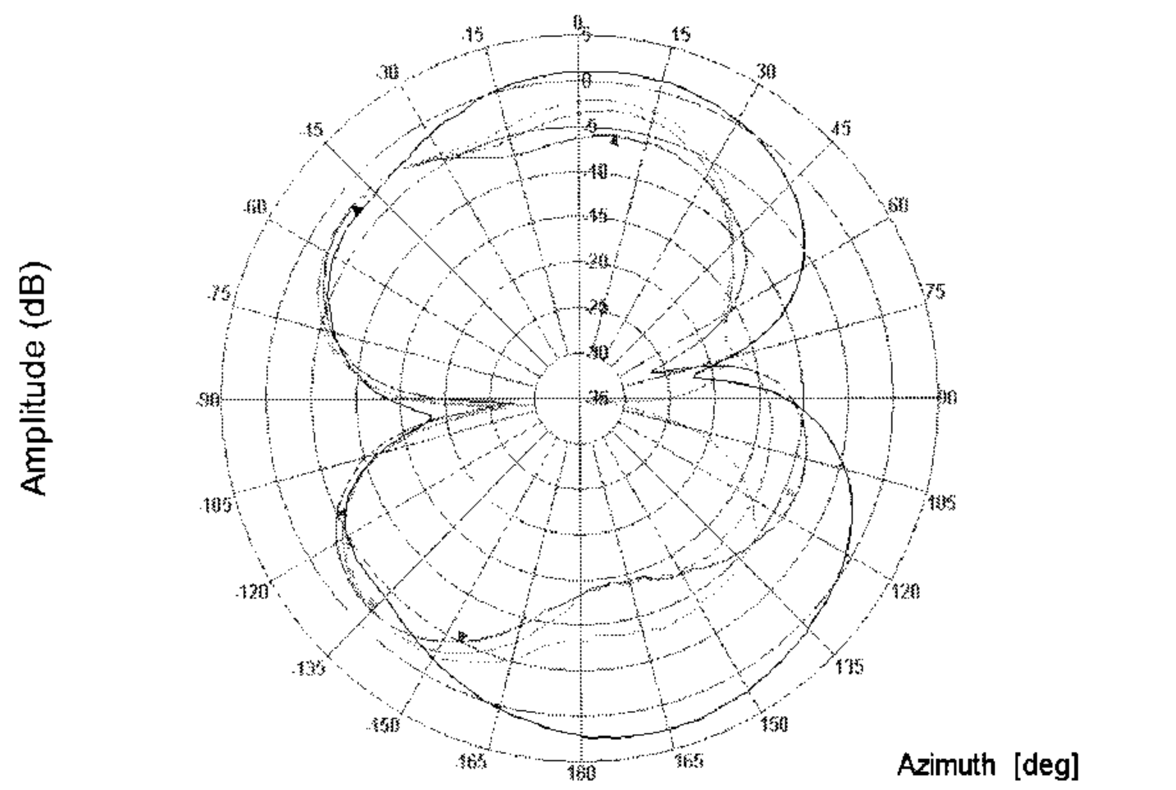


Fig. 10 Measured E-pattern at 880MHz, 920MHz, 960MHz, 1575.42MHz, respectively.

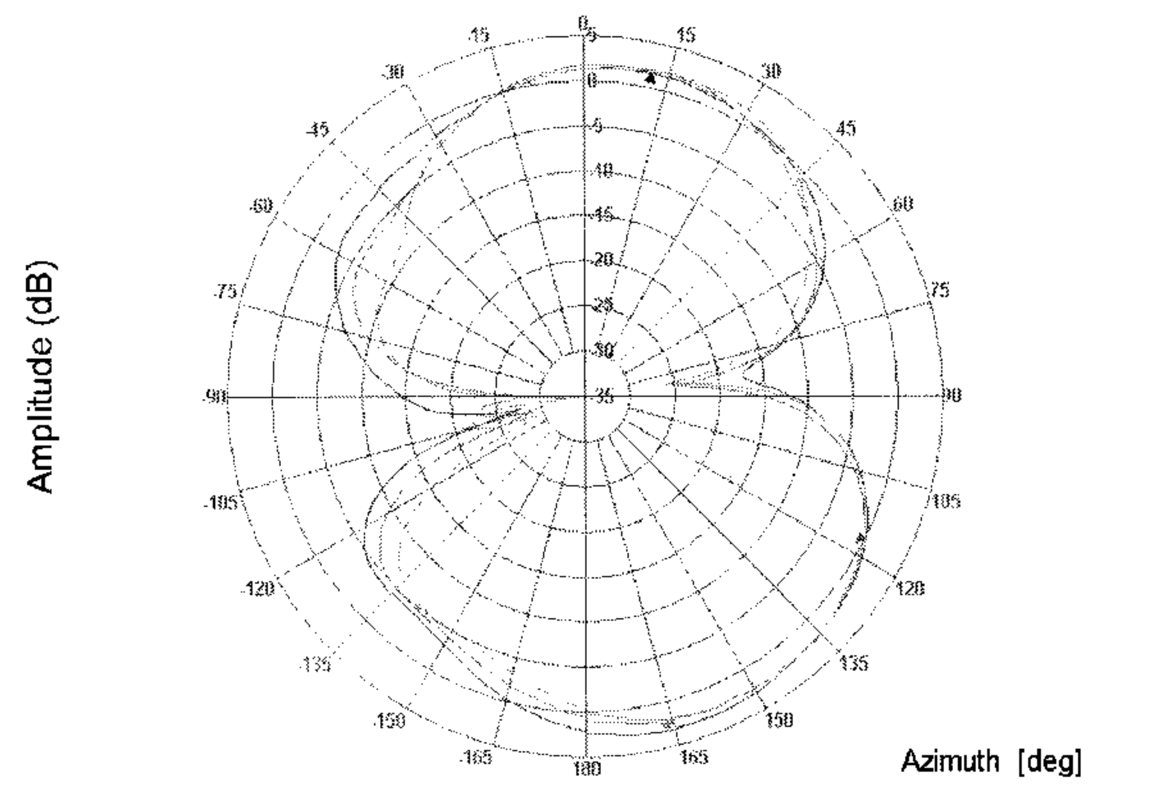


Fig. 11 Measured E-pattern at 1710MHz, 1795MHz, 1880MHz, respectively.

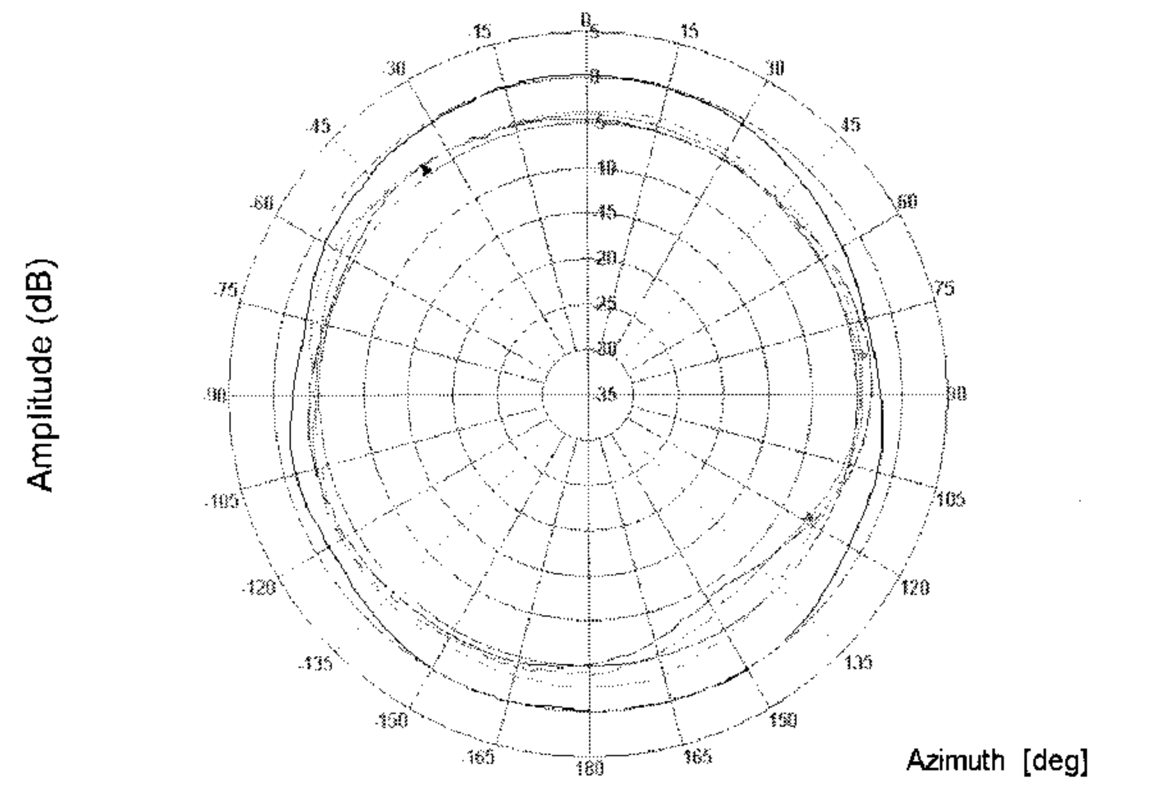


Fig. 12 Measured H-pattern at 880MHz, 920MHz, 960MHz, 1575.42MHz, respectively.

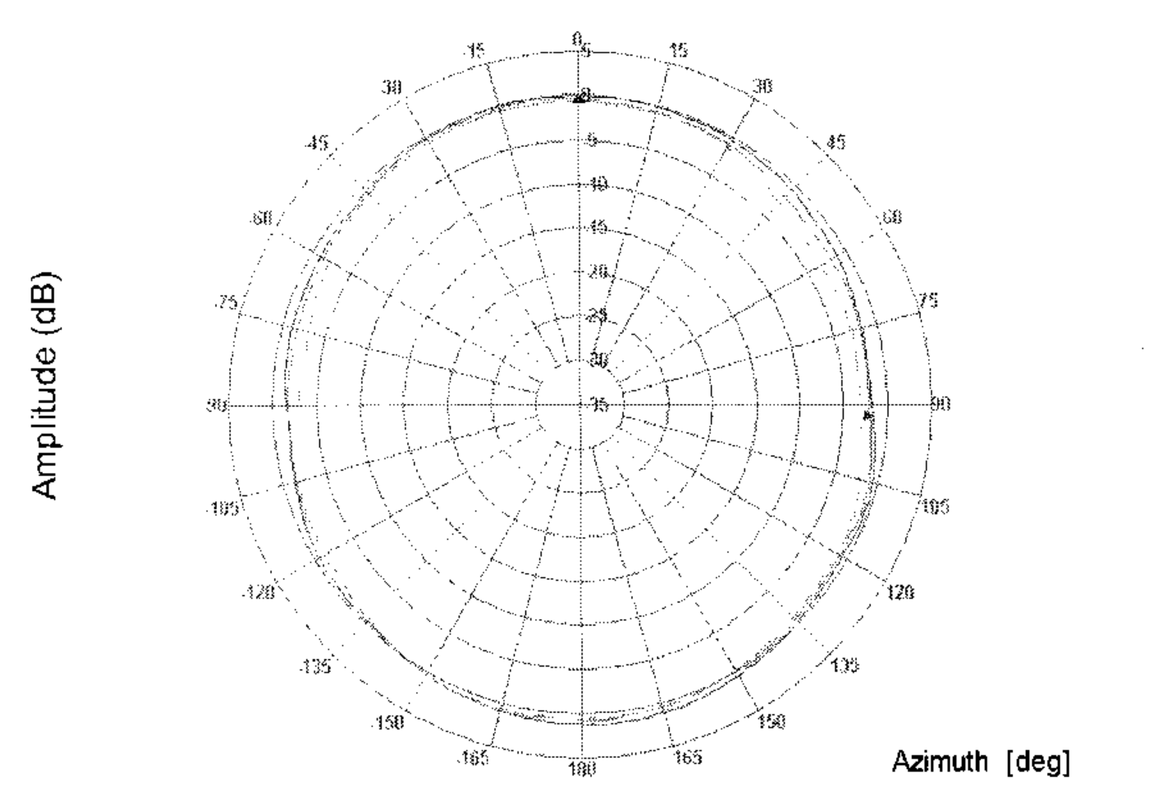


Fig. 13 Measured H-pattern at 1710MHz, 1795MHz, 1880MHz, respectively.

IV. CONCLUSIONS

In this paper, we presented feasibility study on single feed compact wideband antenna for multiple wireless communication applications. The experimental results shows good return loss characteristics and radiation patterns at each resonant frequency. The maximum measured gain was 2.45 dBi ~ 3.18 dBi at 1710 MHz ~ 1880 MHz. The proposed antenna is able to operate at the GSM, GPS, DCS, PCS, UMTS, ISM IEEE802.11a, IMT2000 and satellite DMB bands and its performance is verified by experimental results.

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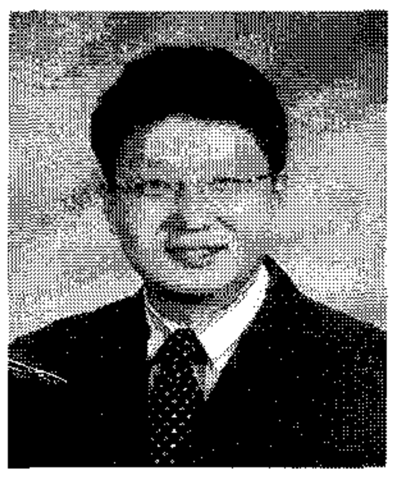

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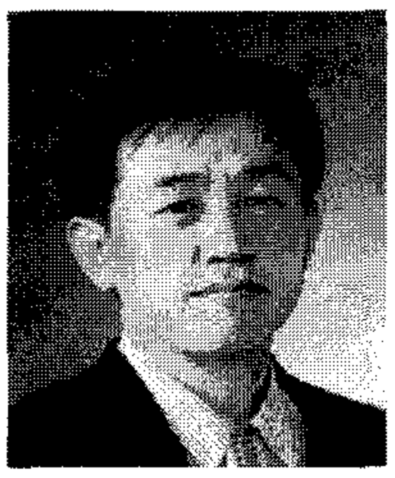

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