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A Folded Metal-Plate Monopole Antenna with Shorted Pin for DTV Application

Zengrui Li[1, *], Longdan Tan[1], Guowei Yan[2], Junhong Wang[3], and Yaoqing Yang[4]

Abstract—In this paper, a novel folded metal-plate monopole antenna is presented for indoor digital television (DTV) signal coverage in the 454–1300 MHz band. The proposed antenna consists of a folded metal-plate with two asymmetrical bevels and a shorted pin connecting the metal-plate with a ground plane. The folded structure extends the lower frequency band and reduces the height of the antenna for better application to DTV. Experiment results show that the antenna achieves a bandwidth for $|S_{11}| < -10\,\text{dB}$ ranging from 454 MHz to 1300 MHz and shows stable radiation patterns in three coordinate planes.

1. INTRODUCTION

In recent years, digital television broadcasting has been widely operated in many countries. DTV broadcasting can provide high definition television (HDTV) programs, interactivity services and data services. Several types of DTV reception antennas which can be embedded in handheld devices have been proposed [1–4]. However, due to the development of the modern cities and an increase in mobile communication, the urban electromagnetic environment has become complex, sometime even obstructed. In some tall buildings or low basements, received signals may be very weak or nonexistent. Indoor DTV antennas are desired to effectively increase the signal levels in such environments.

In [5–7], antennas used for indoor wireless communications were proposed and studied. In [5], a wideband antenna with a conical monopole, a top loaded circular patch and a T-shape feed probe was designed for a DTV-H (470–706 MHz) system. Similarly, a compact monopole wire-patch antenna fed by an L-shape probe was presented in [6]. Another indoor antenna which can radiate with horizontal polarization was also a candidate for indoor wireless communication and was presented in [7]. The antennas mentioned above have some drawbacks such as their structures are very complex and give rise to difficulty in fabrication.

In this paper, the implementation and measurement of a novel folded metal-plate monopole antenna with a shorted pin for DTV applications are presented. To enhance bandwidth, two asymmetrical bevel edges were cut on both sides of the metal plate [8]. The folded plate can extend the current path to lower the operating frequency [9], but it also causes a coupling capacitance between the folded metal plane and ground plane. For better impedance matching, a shorted pin, which can be regarded as coupling inductance, is placed between the folded metal plate and the ground plane to compensate for the capacitance effect caused by the folded metal plate. Furthermore, using this structure can make the antenna smaller, which is desirable for indoor DTV application. Details of the antenna design and experimental results are presented and discussed in the following sections.

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* Corresponding author: Zengrui Li (zrli@cuc.edu.cn).

[1] School of Information Engineering, Communication University of China, China. [2] The State Administration of Press, Publication, Radio, Film and Television of the People's Republic of China, China. [3] Institute of Lightwave Technology, Beijing Jiaotong University, China. [4] The University of Nebraska-Lincoln, Nebraska, USA.

2. ANTENNA DESIGN

2.1. Antenna Structure

The configuration of the proposed antenna is shown in Fig. 1. The antenna is mainly constructed by folding a metal plate using a single 0.8 mm-thick copper sheet. A shorted pin, which is a copper cylinder with a diameter of 1 mm, is used to connect the folded metal plate to the ground plane. The ground plane consists of a circular 0.8 mm-thick copper sheet. A 50 Ω SMA connector is used to feed the antenna from the back of the ground plane and the feeding gap is $d = 2$ mm. The proposed antenna was optimized and finally fabricated with the optimal parameters listed in Table 1.

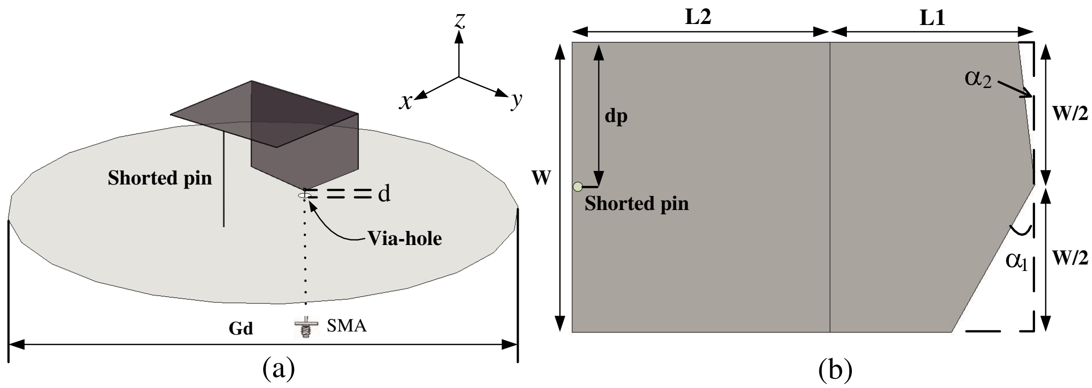


Figure 1. Geometry of the proposed antenna: (a) 3D structure of the antenna, (b) the antenna unbent into a plane structure.

Table 1. Dimensions of the proposed antenna.

parameters	W	L_1	L_2	d_p	d	G_d	α_1	α_2
value	110 mm	78 mm	98 mm	55 mm	2 mm	500 mm	30°	7°

2.2. Parametric Study

In theory, all the parameters of the antenna have an effect on the performance of the antenna, which include the two bevel angels on both sides of the metal plate, the size of the folded metal plate, and the size of the ground plane. In this section, the effects of some key parameters on the proposed antenna are studied. The proposed antenna was simulated and optimized with the assistance of ANSYS high frequency structure simulator (HFSS) Ver. 12 [10].

The effect of the bevel angle α_1 on $|S_{11}|$ is presented in Fig. 2. With an increase of α_1, the lower-edge frequency remained nearly constant, but the upper-edge frequency increased apparently. However, when α_1 is larger than 35°, the value of $|S_{11}|$ around 640 MHz will be larger than -10 dB. The effect of α_2 on $|S_{11}|$ is similar to that of α_1, as shown in Fig. 3. When α_2 is larger than 9°, the value of $|S_{11}|$ will not meet the demand of DTV bandwidth defined by $|S_{11}| < -10$ dB.

Figure 4 shows the $|S_{11}|$ versus frequency for several different widths W of the metal plate. Increasing W causes a decrease of the upper-edge frequency and a lower $|S_{11}|$ in the middle of the band. The effect of the length L_1 of the metal plate with the bevelled edge is shown in Fig. 5. When L_1 is increased, both of the lower-edge frequency and upper-edge frequency decrease, which means the operating bandwidth of the antenna shifts towards the lower resonant frequency. But for the indoor DTV applications, the height of the antenna should be taken into consideration. Therefore, the appropriate L_1 value should make the antenna cover the DTV bandwidth and satisfy the size requirement of indoor applications.

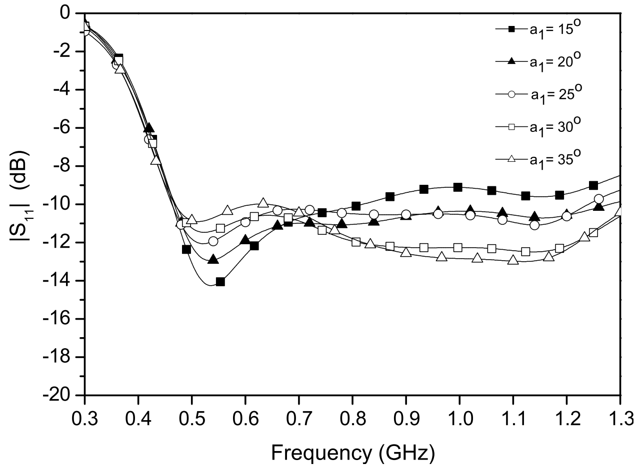


Figure 2. Simulated $|S_{11}|$ of various bevel angle α_1 with other parameters given in Table 1.

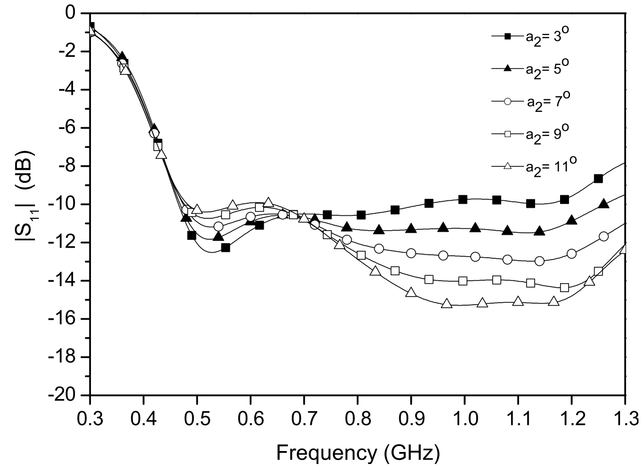


Figure 3. Simulated $|S_{11}|$ of various bevel angle α_2 with other parameters given in Table 1.

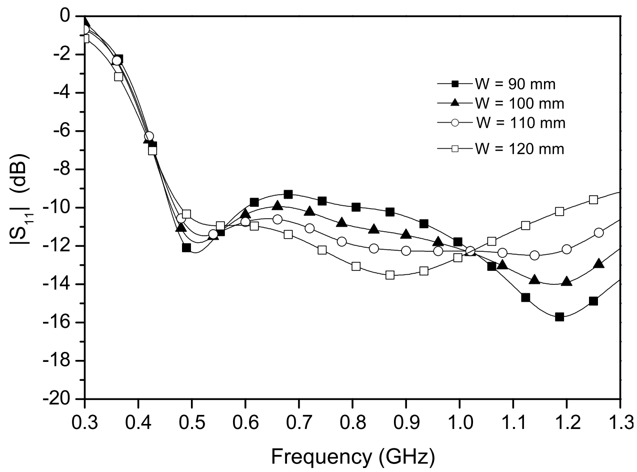


Figure 4. Simulated $|S_{11}|$ of various W with other parameters given in Table 1.

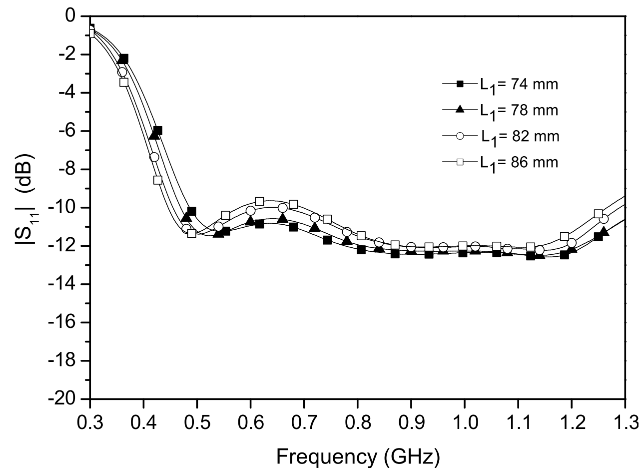


Figure 5. Simulated $|S_{11}|$ of various L_1 with other parameters given in Table 1.

As depicted in Fig. 6, when the length L_2 of the folded metal plate increases from 78 mm to 108 mm, the lower-edge frequency of $|S_{11}|$ decreases while the upper-edge frequency increases. In order to verify the effect of the shorted pin between the folded metal plate and ground plane, the simulated $|S_{11}|$ of the proposed antenna with the shorted pin and without the shorted pin is shown in Fig. 7. Fig. 7 shows that the shorted pin can reduce the lower-edge frequency and improve the operating bandwidth of the antenna.

Furthermore, the current distributions of the proposed antenna at 530 MHz, 666 MHz and 754 MHz were studied and presented in Fig. 8. At lower frequency, the current distributes along the shorted pin and the edges of metal-plates. For the higher band, the current flows mainly around the beveled edges of the metal-plate. Therefore, the shorted pin adds an extra mode to the proposed antenna and determines the lowest frequency, which can also been proved by Fig. 7. And the beveled edges have a crucially effect on the upper edge of the operating bandwidth.

3. RESULTS AND DISCUSSION

According to the results discussed in previous sections, the prototype of the proposed antenna has been fabricated and measured at the Communication University of China (CUC). Fig. 9 shows the photo of

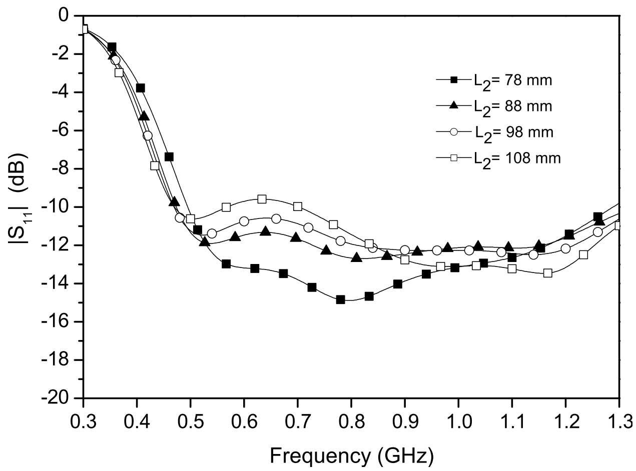


Figure 6. Simulated $|S_{11}|$ of various L_2 with other parameters given in Table 1.

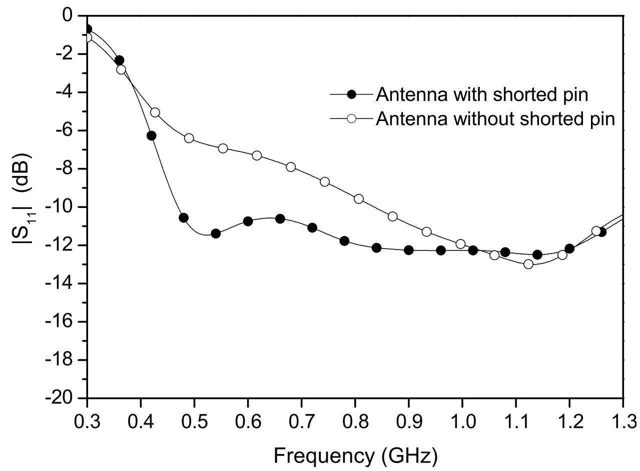
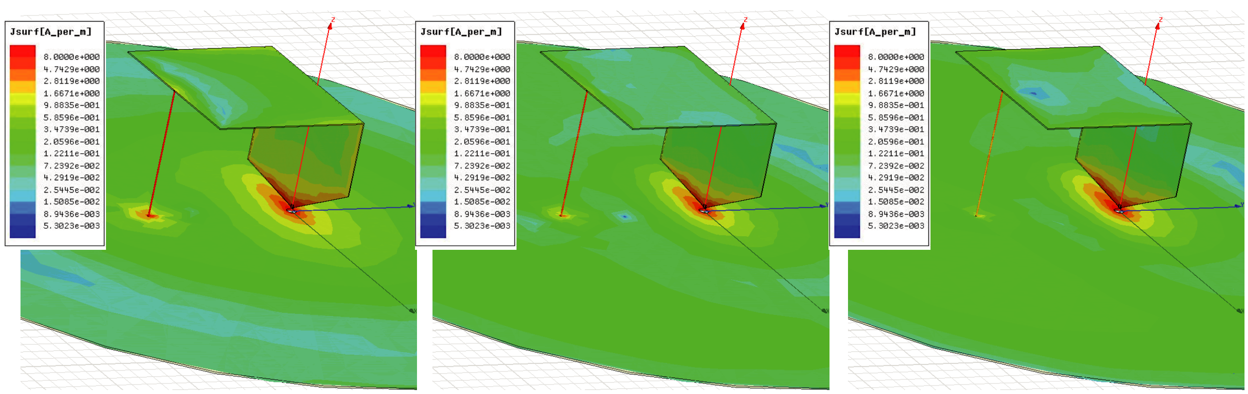


Figure 7. Simulated $|S_{11}|$ of effect of shorted pin with other parameters given in Table 1.



(a) (b) (c)

Figure 8. Current distributions of the proposed antenna at (a) 530 MHz, (b) 666 MHz, (c) 754 MHz.

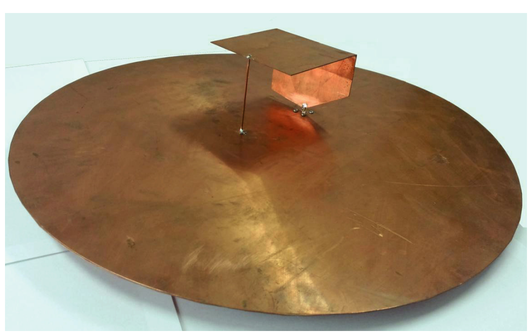


Figure 9. The photo of the construct antenna.

the proposed antenna. The measurements of the $|S_{11}|$ and far field radiation patterns of the antenna were obtained by using an Agilent E5071C Vector Network Analyzer in an anechoic chamber.

The measured and simulated $|S_{11}|$ of the proposed antenna are shown in Fig. 10. Close agreement between the measured result and the simulated result can be observed. The measured operating bandwidth defined by $|S_{11}| < -10$ dB ranges from 454 to 1300 MHz, which covers the DTV frequency band (470–860 MHz).

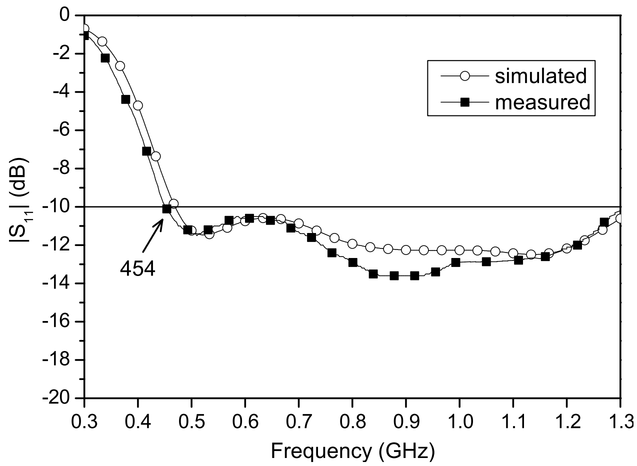


Figure 10. Measured and simulated $|S_{11}|$ of the proposed antenna.

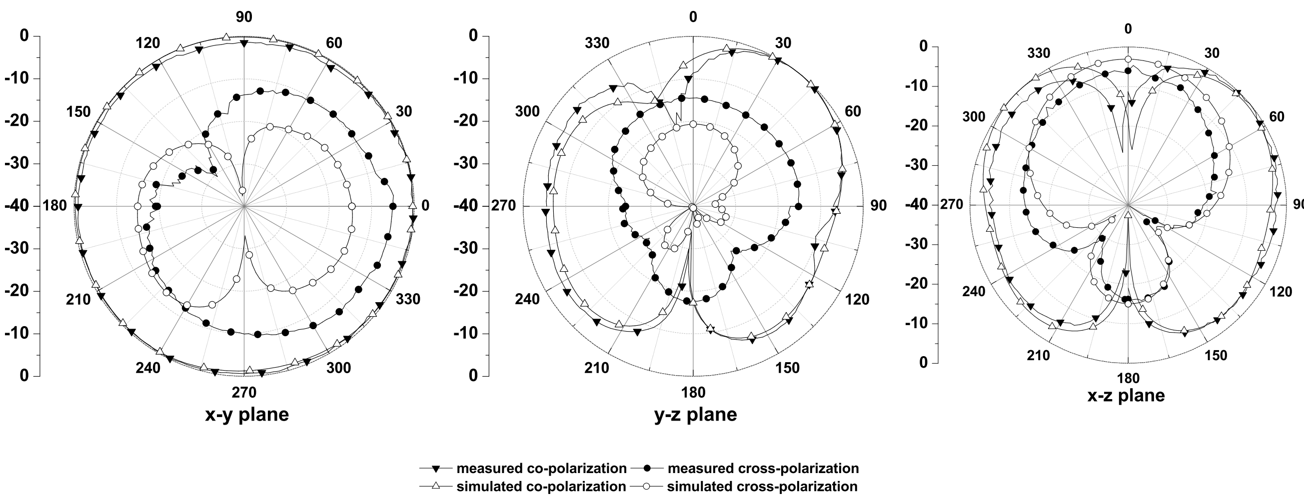


Figure 11. Measured and simulated radiation patterns at 530 MHz.

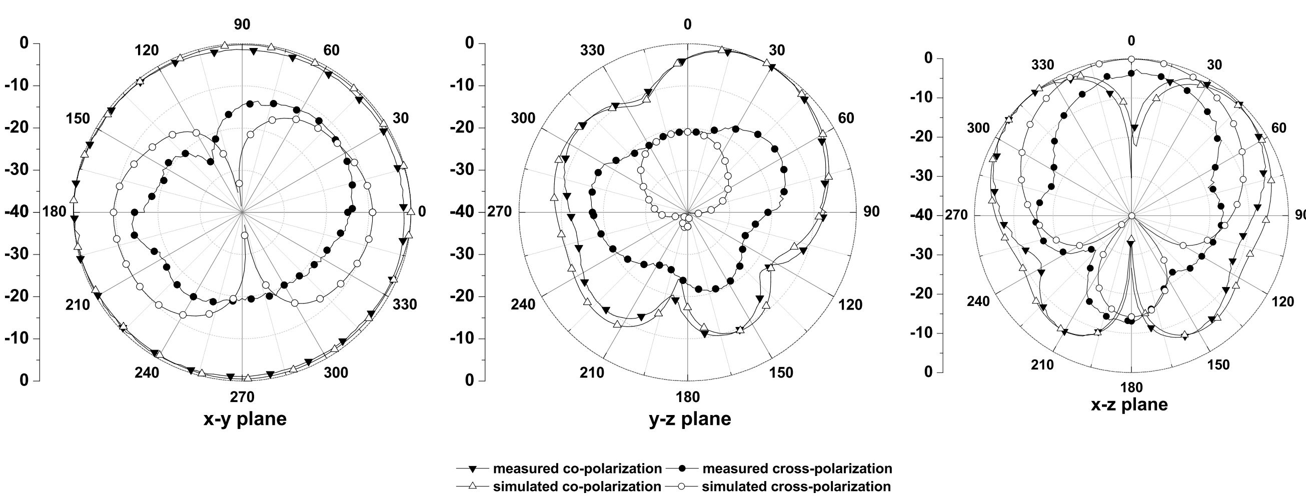


Figure 12. Measured and simulated radiation patterns at 666 MHz.

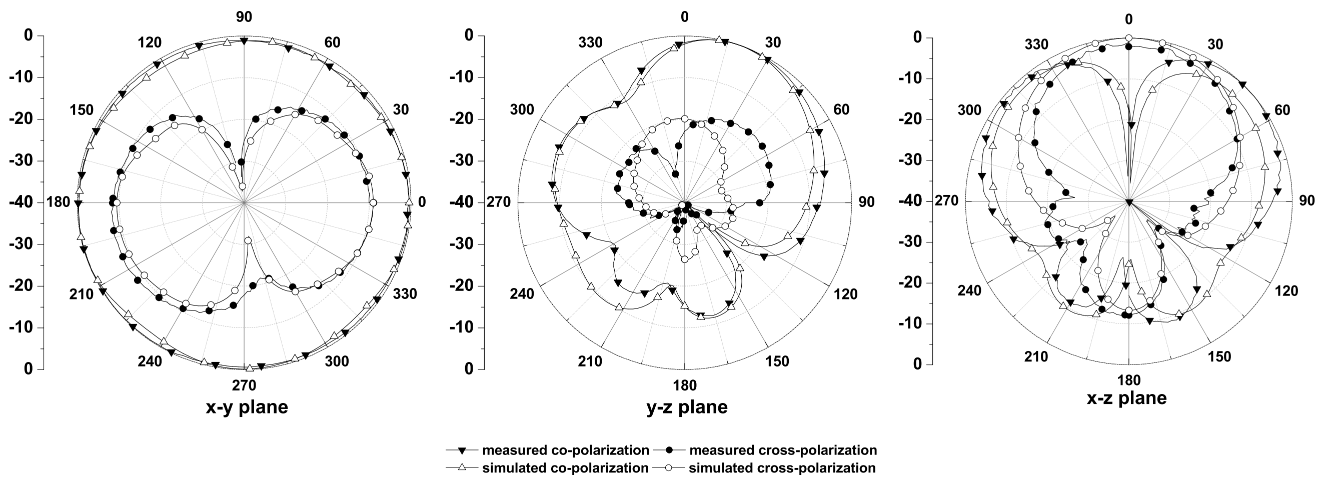


Figure 13. Measured and simulated radiation patterns at 754 MHz.

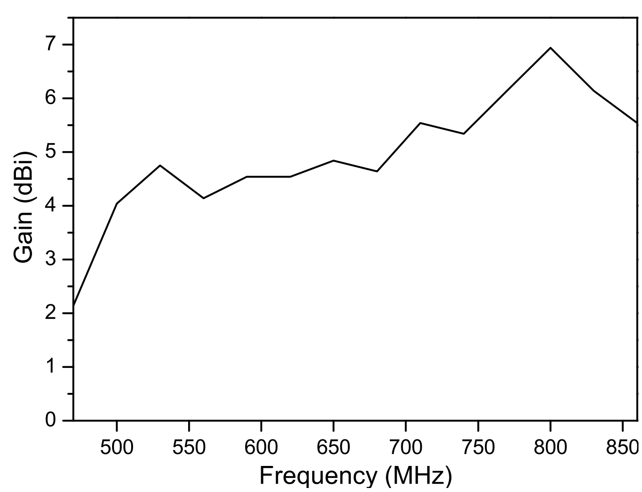


Figure 14. Measured gain of the proposed antenna.

The far field radiation patterns in the xoy, yoz and xoz plane at frequencies of 530 MHz, 666 MHz and 754 MHz were measured, as shown in Fig. 11, Fig. 12 and Fig. 13, respectively. It can be observed that the antenna has nearly omnidirectional radiation patterns at different frequencies in the x-y plane. Due to the folded metal plate structure, the radiation patterns in the y-z plane are asymmetrical and the direction of maximum radiation is $\theta = 30°$. In the x-z plane, the antenna radiates like the normal monopoles with symmetrical radiation patterns. But the cross-polarization in the x-z plane is larger than that in other two planes, because the folded metal plate contributes orthogonal radiation power in this plane. Fig. 14 shows the measured antenna gain versus frequency. Within the operating bandwidth, the measurement gain of the antenna varies between 2.1 and 6.9 dBi.

4. CONCLUSION

A novel folded metal-plate monopole antenna with shorted pin has been presented. The proposed antenna has a folded metal structure with bevel edges on both sides and a shorted pin connecting the metal plate with a circular ground plane. A prototype of the proposed antenna has been implemented and measured. Measurements show the antenna can achieve a -10 dB $|S_{11}|$ bandwidth of 454–1300 MHz and produce stable radiation patterns in three coordinate planes. Due to the compact size of the folded design, the proposed antenna lends itself well to indoor DTV signal applications.

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