Indoor Transparent Antenna for Television Reception

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Abstract— The characteristics of indoor transparent antenna are investigated. The purpose of the antenna is applied for television signal reception which is operating at Ultra High Frequency band. The antenna was made from silver coated polyester film (AgHT-4), the transparent conductive material and it is attached on a layer of glass substrate. The antenna size has width and length of 120 mm × 150 mm. It was fed by a co-planar waveguide due to the opportunity of low radiation loss and to reduce reflection of the antenna. The frequency range of 500 MHz to 800 MHz is chosen as it is the UHF television reception band and allocated by Federal Communications Commission. Due to the television station provided in Malaysia, each station have different channel with its own specification frequencies. The channels also are based on the transmitter base station location. Since the proposed project launches at Universiti Teknologi Malaysia, Skudai, Johor, Malaysia so all the channel is following the frequency from GunungPulai, Johor transmitter base station. The channel utilizations are Channel 55 (742–750 MHz): TV1, Channel 26 (510–518 MHz): TV3, Channel 42 (638–646 MHz): NTV7, Channel 44 (654–662 MHz): TV9 and Channel 46 (670–678 MHz): 8TV. Then, the proposed antenna was designed by using Computer Simulation Software (CST) Microwave Studio to obtain the simulation result. The simulated bandwidth of the antenna obtained is 448 MHz (502 MHz to 950 MHz) with bandwidth of 61.71%. It has a potential to be realized for TV reception because of the omni-directional radiation pattern and gain is more than 2.0 dBi.

1. INTRODUCTION

In recent years, the invention of antenna for television reception is increasing rapidly in order to fulfill demand and improve their performance suitable to the latest application technology. For this application, the frequency band allocated by Federal Communication Commission (FCC) is Ultra High Frequency (470–806 MHz) [1]. There are several commercial applications for UHF band, such as Digital Television (DTV, 470–806 MHz) [2–7], Digital Video Broadcasting-Terrestrial (DVB-T, 870–862 MHz) [8] and Digital Video Broadcasting-Handheld (DVB-H, 470–862 MHz) [9] and also some research works on UHF/VHF antennas as reported in [10, 11]. Looking to Malaysia situation, the television station provides the variety of station with their specification channel. Thus, the channels are based on the frequency of transmitter base station location. Since the proposed antenna was investigated at Universiti Teknologi Malaysia (UTM), Skudai, that is therefore all the channels need to use the frequency of GunungPulai transmitter base station [12, 13]. Table 1 briefs the channel utilization in GunungPulai transmitter base station, Malaysia.

Table 1: Channel utilization in Malaysia (GunungPulai transmitter base station).

Station	TV1	TV3	NTV7	TV9	8TV
Channel	55	26	42	44	46
Frequency (MHz)	742–750	510–518	638–646	654–662	670–678

From the previous research, a lot of television reception antennas have been designed and improved. One of the techniques investigated is the conductor material and substrate used. Most researchers used FR-4 substrate [2–4], but at some case or study, they used flexible Copper Clad Laminate (FCCL) film [5], Nora conductive textile and felt substrate [6, 7] and aluminum material [14]. However, this paper proposed indoor transparent antenna for television reception replacing the conventional antenna.

The transparent conductive film currently has been researched on by a decade ago. Some of the proposed applications has been done used transparent antenna are photovoltaic solar-panel integration and RF energy harvesting [15], radio frequency identification (RFID) [16], inter-vehicle communication [17], wireless local area network (WLAN) [18, 19], worldwide interoperability for microwave access (WiMAX) [20], wide-band code-division multiple-access (WCDMA) [19] and CubeSat [21]. In addition, the transparent conductive film is the best candidate to be mounted on the glass or window [20], attracts great interest, light weight, thin volume [18], limpidity and flexibility [19] and for security [22]. The transparent conductive films so called transparent conducting oxides (TCO) [15, 23] can be as indium thin oxide (ITO) [16], fluorine-doped thin oxide (FTO) [24] and silver coated polyester film (AgHT) [15, 17, 25]. It is challenges but AgHT-4 is chosen because of lower surface resistance. Lower surface resistance is more conductive. The AgHT-4 is commercially used as a sun-shielding film to cut down heat and conserve energy in homes and buildings [15].

2. ANTENNA DESIGN

The indoor transparent antenna for television reception is designed using AgHT-4. It is fed by 50 Ω co-planar waveguide (CPW) and mount on a piece of glass, with thickness of 2 mm and dielectric constant of 7. The AgHT-4 is 0.175 mm thick and has a surface resistance of 4 Ω-Sq. The conductivity is 2×10^5 S/m. The AgHT-4 consists of ITO which is coated at the polyethylene terephthalate (PET) substrate with relative permittivity, ε_r of 3.24. Figure 1(a) shows the geometry of the antenna and Figure 1(b) shows the thickness of the antenna. All the antenna parameters are summarized in Table 2.

The proposed antenna is overall length, l and width, w at 150 mm and 120 mm, respectively. It is fed by 50 Ω co-planar waveguide (CPW) antenna. A portion of transparent film has been cut at the left side. So the left sidelength, l_1 is 35 mm. The feed line width, w_s is 3 mm and feed gap, g is 0.3 mm. Therefore the length of CPW ground, l_{CPW} is 9.9 mm. The CPW is fed to the antenna because of it has much benefit such as no soldering point, easy fabrication [3] and a simplified configuration with a single conductive layer. Therefore in terms of art, the CPW design will offer satisfactory impedance matching over a wide frequency range and the ability to maintain nearly omnidirectional radiation pattern.

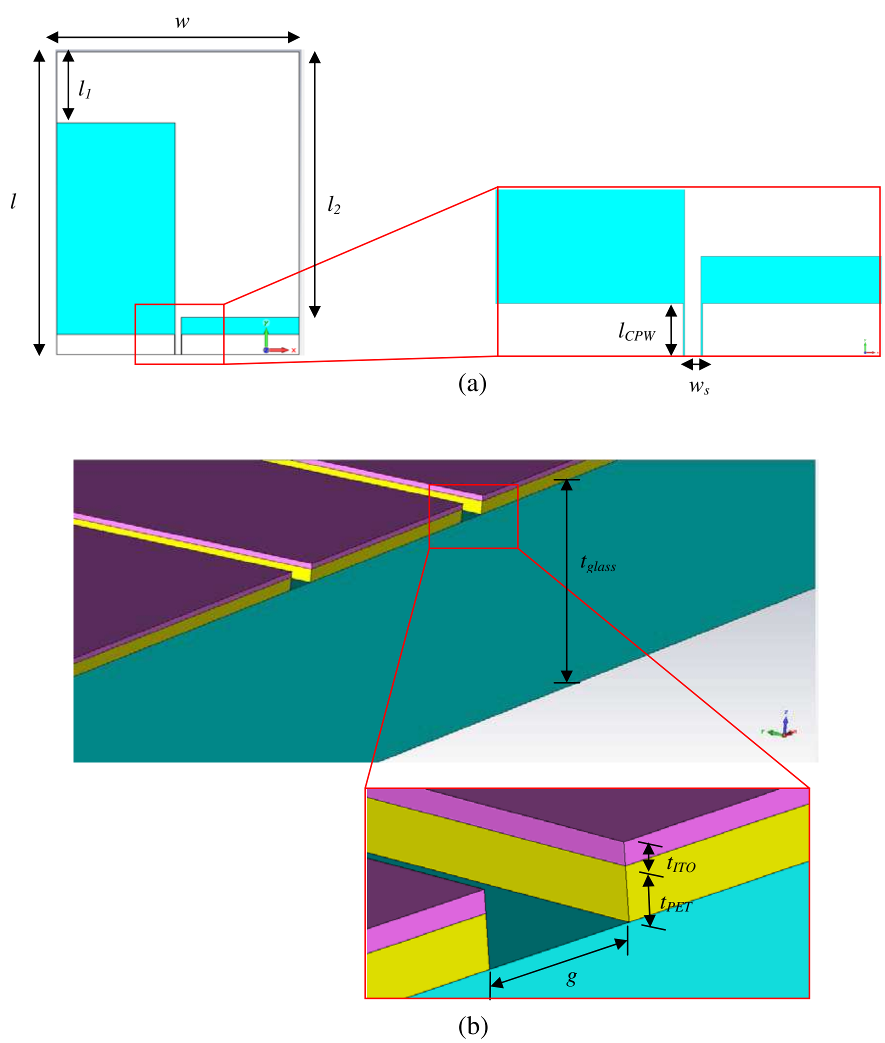

Figure 1: (a) Geometry of the proposed antenna. (b) Thickness of the antenna.

Table 2: Summary of the antenna parameters.

Description	Parameter	Length (mm)	Description	Parameter	Length (mm)
Length of glass	l	150	Length of CPW ground	l_{CPW}	9.9
Width of glass	w	120	Thickness of glass	t_{glass}	2
Left side length of transparent film	l_1	35	Thickness of PET	t_{PET}	0.1225
Right side length of transparent film	l_2	131.5	Thickness of ITO	t_{ITO}	0.0525
Feed gap	g	0.3	Feed line width	w_s	3

3. SIMULATED RESULT AND DISCUSSIONS

The performance of this transparent antenna is very sensitive to many parameters. The parameters can be as the size of the radiation element, the size of the ground plane, and the gap between the plane and the ground [17]. Since the frequency range should be at least 500 MHz to 800 MHz to receive all the stations. So a parametric study has been done to achieve the frequency range. Figure 2 shows the variation of reflection coefficient magnitude (dB) by changing the left side length, l_1. The simulated reflection coefficient magnitude covers from 500 to 800 MHz is at length of 25 mm to 60.5 mm. At 96 mm, the bandwidth becomes smaller and there is no radiation at 131.5 mm length. Table 3 has shown the bandwidth of the left side length changes. It can be concluded that the longer the left side length, the lower the bandwidth.

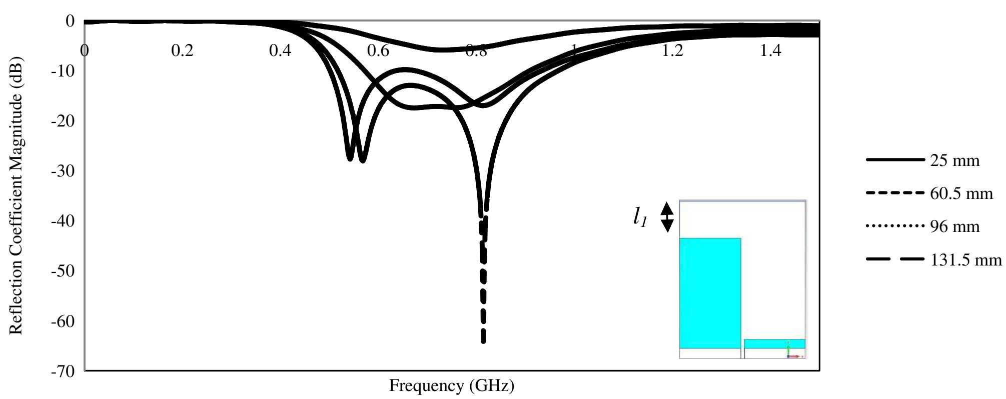

Figure 2: The variation of reflection coefficient magnitude at different left side length.

Figure 3 shows the simulated result that completely covered frequency range of 500 MHz to 800 MHz at the left side length, l_1 of 35 mm. The frequency range is 502 MHz to 950 MHz. It completely covers the frequency at GunungPulai transmitter base station. The bandwidth obtained is 448 MHz or 61.71% of the fractional BW. The minimum value of reflection coefficient magnitude obtained is -32.68 dB.

Figure 4 shows the simulated radiation pattern at 514 MHz, 629 MHz, 642 MHz, 658 MHz, 674 MHz and 743.25 MHz, respectively. All the radiation patterns are omnidirectional. The omnidirectional radiation is acceptable for indoor TV reception. Due to such pattern form, low gain are

Table 3: The bandwidth of left side length.

Left side length, l_1 (mm)	Frequency range (MHz)	Bandwidth (MHz)
25	502–934	432
60.5	516–968	452
96	572–910	338
131.5	No, higher than -10 dB	-

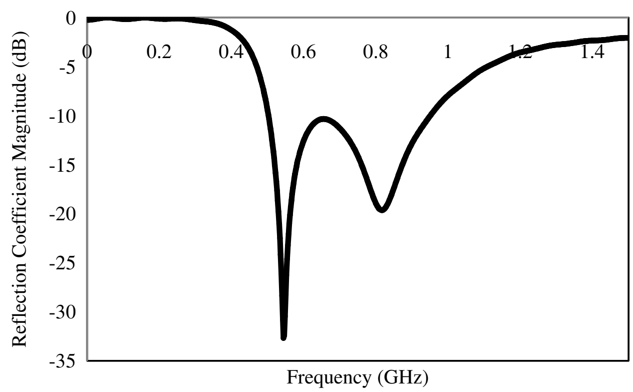

Figure 3: The simulated return loss at 35 mm left side length, l_1.

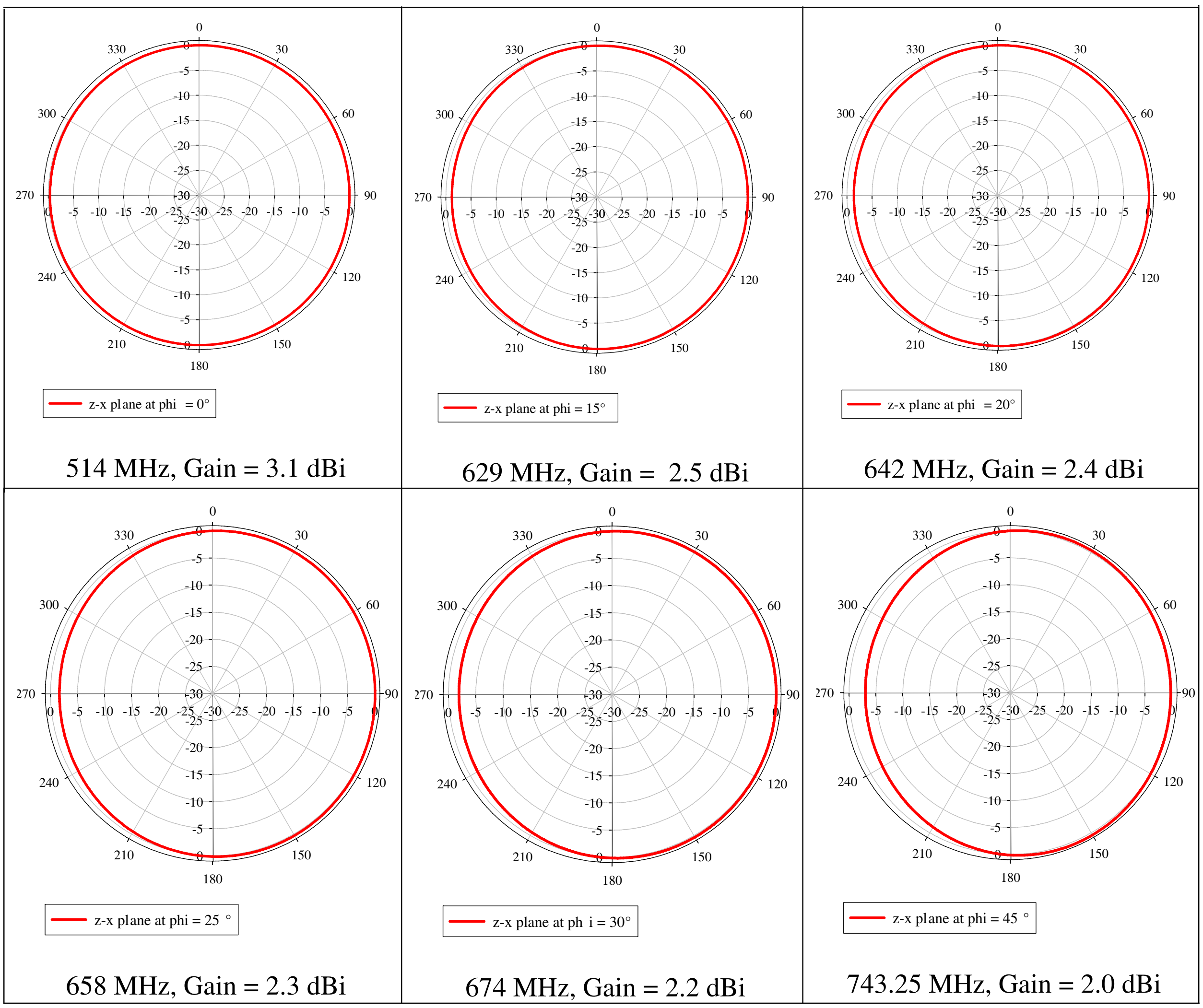

Figure 4: The simulated radiation pattern at frequency of 514 MHz, 629 MHz, 542 MHz, 658 MHz, 674 MHz and 743.25 MHz.

achieved as it varies from 2.0 dBi to 3.1 dBi at the specific channel frequency shown in Figure 4.

4. CONCLUSION

The proposed indoor transparent antenna has been presented. The transparent conductive film implemented by the antenna shows that the coverage frequency fulfilled the requirement of television signal reception. The simulated frequency range successfully covers the frequency from 502 MHz to

950 MHz which including the necessary frequency band for TV broadcasting; 510 MHz to 750 MHz. Therefore, the bandwidth achieved was 448 MHz (or 61.71 %) with gain is at least 2.0 dBi. By having an omnidirectional pattern in all frequency channels, such antenna could become a good candidate for indoor TV reception.

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