Compact Digital Television (DTV) Antenna for Indoor Usage

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ABSTRACT

A compact indoor digital antenna for digital terrestrial television is proposed. The design of the antenna begins with the material selection to construct the antenna by using CST software with a standard monopole antenna design. The antenna is then simulated and optimized. A bandwidth of 290 MHz (46.14%) between 500 MHz and 790 MHz is achieved with the antenna gain more than 3 dBi. Simulated results is used to demonstrate the performance of the antenna. The simulated return losses, together with the radiation patterns and gain are presented and discussed.

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1. INTRODUCTION

Malaysia is one of the country in Association of Southeast Asian Nations (ASEAN) which is currently undergo the process of transition from analog to digital television broadcasting. Digital Video Broadcasting – Terestrial 2 (DVB-T2) has been chosen by the Malaysian Communications and Multimedia Commission (MCMC) for the broadcast transmission standard for the country’s digital terrestrial television. Due to the increasing interest in digital television (DTV) broadcasting, a compact DTV antenna for indoor terrestrial signal reception antenna is needed. Moreover, when it comes to size, a DTV antenna should be compact, small and easy to place anywhere. The designed DTV antennas that are currently available are quite large and bulky. There are several numbers of compact DTV antennas have been reported in the past research, but these antennas do not match the standard performance for indoor use.

In [1], a printed spiral antenna with a self-complementary configuration was developed. This antenna has a spiral shaped metal strips and slots provided on ground planes as their counterparts. There are two types of antenna configuration, single and twin spiral that were fabricated. According to [1], for single spiral with unbalanced feed, their widths of metal strip and slot were at 0.5 mm. The spiral has 14 turns with a total dimension of 30 mm × 30 mm. Based on the measured results the return loss is not better than -5 dB within the UHF bandwidth which is between 400 MHz and 700 MHz for the single spiral. However, for the twin spiral with balanced feed, excellent return loss is obtained, which is less than -10 dB. Although the twin self-complementary spiral antenna has a good return loss that is less than -10 dB, the antenna becomes 60 mm × 60 mm, which is double compared with the single spiral self-complementary antenna. According to the past research, another digital indoor antenna that has been proposed in [2] was J-shaped monopole antenna array. The antenna consists of J-shaped $\lambda/4$ monopole antenna array with a coplanar waveguide feed.

It has a simple matching circuit consists of an open-ended slotted line and high impedance step section that were installed between the antenna and the ground plane of the coplanar waveguide to reduce the reflection from the antenna. Based on the research paper, this type of antenna has a dimension of 91 mm × 62 mm. The return loss of this antenna is better than -10 dB which is good for indoor reception antenna. However, it has a small bandwidth at UHF which is around 350 MHz to 450 MHz for VHF and 580 MHz to 620 MHz for UHF. That means it cannot cover all of digital frequency standard.Next, a wideband printed dipole antenna operating from 470 MHz to 806 MHz for digital television signal reception has been proposed in [3]. The dimension of the antenna is 20 mm × 227 mm. Although the dimension of the proposed antenna is compact, the gain of the antenna is slightly low which varies between 1.5 and 2.8 dBi. In [4], a compact dipole antenna for DTV applications by utilizing L-shaped stub and coupling strip has been proposed. The proposed antenna has a compact size which is 20 mm × 200 mm with an operating frequency from 470 MHz to 862 MHz. However, the measured reflection coefficient is referred at -6 dB which will affect the total efficiency of the antenna. Low antenna total efficiency will produces low antenna gain. Similar antennas with low antenna gain have also been presented in [5-7].

In this paper, a compact antenna design that is suitable for indoor use and has comparable performance is presented. The design is optimized by the shape of the antenna, the type of material use and the shape of the film strip on the antenna. The design is optimized using CST Studio software through simulation process. A bandwidth of 290 MHz is achieved, operating from 500 MHz to 790 MHz. The optimized antenna performance is comparable to any other DTV indoor antenna that is available nowadays.

2. ANTENNA DESIGN

The antenna design begins with the selection of material for the antenna. The FR4 material which is made from woven glass and epoxy is chosen to design this antenna. For the ground plane, transmission line and antenna patch, annealed cooper will be used. The thickness of the FR4 material used The FR4 material has a thickness of 1.6 mm with permittivity of 4.3 and tangential loss of 0.0019. The transmission line, antenna radiator and ground plane have a thickness of 0.035 mm. Their thickness must be less than 1/40 of the operating wavelength otherwise the performance of the antenna will be degraded [8]. The design process is conducted using Computer Simulation Technology (CST) software. In this case, the antenna should obtain an antenna gain more than 3 dBi with a bandwidth from 480 MHz to 750 MHz.

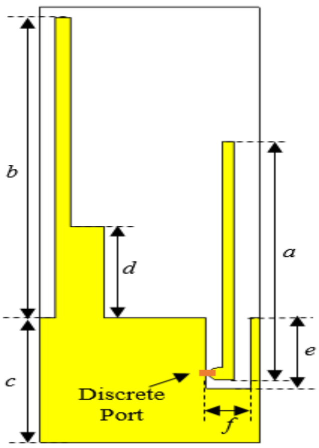


Figure 1. Dimension of the proposed antenna

Figure 1 shows the dimension of the proposed antenna. The size of the antenna is given by L = 210 mm × W = 73 mm. The length of the radiator is given by a = 115 mm and the reflector length is b = 120 mm. The length of ground plane is given by c = 60 mm. The length of d = 44 mm, e = 34 mm and f = 15 mm.The design begins with a standard monopole antenna with the length of antenna radiator of 115 mm starting from discrete port to the top as illustrated in

Figure 2 from the simulation, the result shows that the designed antenna is resonating at 750 MHz. The radiation pattern is omnidorectional with a gain of 2.13 dBi. In this case, the antenna gain does not meet the minimum requirement of 3 dBi. Furthermore, the bandwidth is not wide enough to cover all the digital standard worldwide. Some modification has to be made to increase the gain and bandwidth of the antenna.

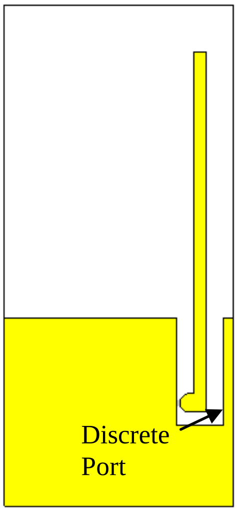


Figure 2. Standard design of monopole antenna

Since the requirement of the antenna gain must be more than 3 dBi and a wide bandwidth to cover all the digital standard, a reflector is placed on the left side of the antenna radiator as shown in Figure 1. From the simulation result on Figure 1, when the reflector is placed, the antenna gain is increases to 4.4 dBi and the -10 dB bandwidth is between 500 MHz and 790 MHz. It is proved that with the additional of a reflector, it provides extra coverage at the lower frequency and the antenna performance is also improved.

3. RESULTS AND ANALYSIS

Figure 3 shows the result of return loss simulation of the proposed antenna. The proposed antenna has the best return loss of -25 dB at 510 MHz and the operating frequency is between 500 MHz and 790 MHz at -10 dB level. This proved that the design of the proposed antenna meets the requirement needed. Figure 4 shows the current distribution of the proposed antenna which clarify the mechanism responsible for the impedance-badnwidth improvement. In figure 4(a), the 500 MHz resonant mode is mainly induced with the current path of approximately $0.5\lambda_o$ while Figure 4(b) shows the current path of 650 MHz with a length of approximately $0.25\lambda_o$. Meanwhile, the resonance mode at 750 MHz can be determine by the current path at approximately $0.2\lambda_o$ as shown in Figure 4(c).

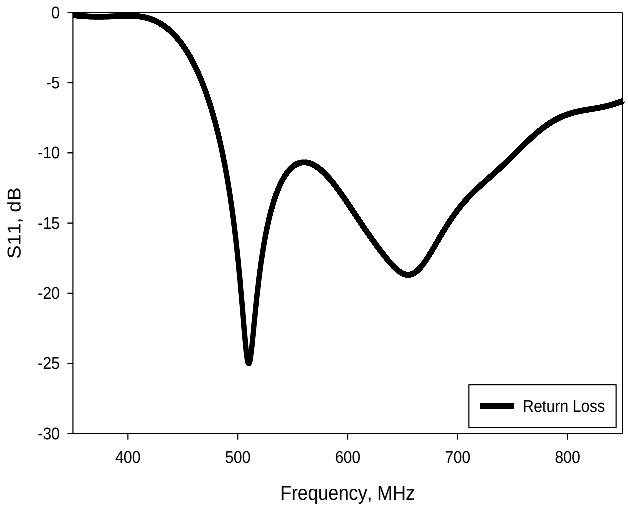
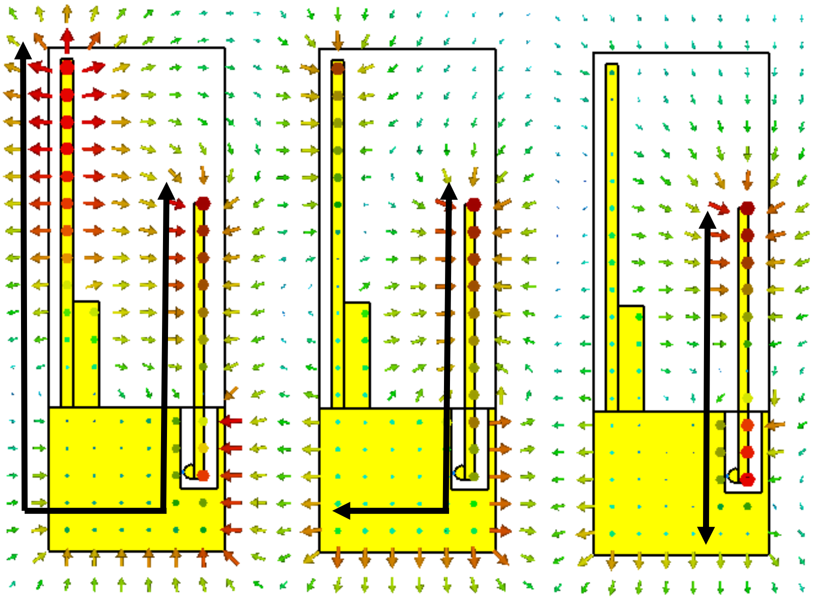


Figure 3. Simulation result of the monopole antenna with a radiator and a reflector



(a) (b) (c)

Figure 4. Current distribution of the proposed antenna at (a) 500 MHz, (b) 650 MHz, and (c) 750 MHz

Figure 5, 6 and 7 shows the radiation pattern in 3D for E-plane and H-plane respectively. The antenna has been simulated at different frequency bands such as 500 MHz, 560 MHz, 650 MHz and 750 MHz to ensure it can cover all the digital standards. Morever, Figure 8 and 9 show the radiation pattern that has been measured in anechoic chamber at 500 MHz and 700 MHz for E-plane and H-plane. From the simulation and measurement results, the radiation pattern producesan omnidirectional pattern. The proposed antenna produces linear polarization in E-plane and H-plane. The antenna gain is more than 3 dBi at the operating frequency between 500 MHz and 790 MHz as illustrated in Figure 10 which meet the minimum requirement of 3 dBi. Once again, the proposed antenna has a better performance with the standard monopole antenna. This also can be proved by observing the total efficiency of the proposed antenna as illustrated in Figure 11. The total efficiency is maximise at frequency of 550 MHz and the rest are not less than 80 percent which means the performance will not be degraded at any frequency band starting from 500 MHz to 790 MHz.

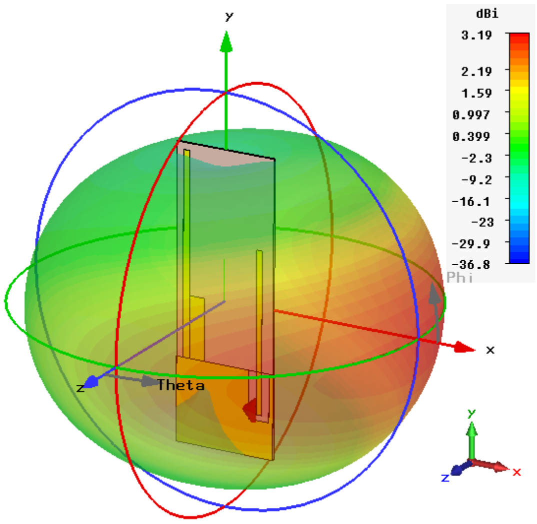


Figure 5. 3D radiation pattern of the proposed antenna at 650 MHz

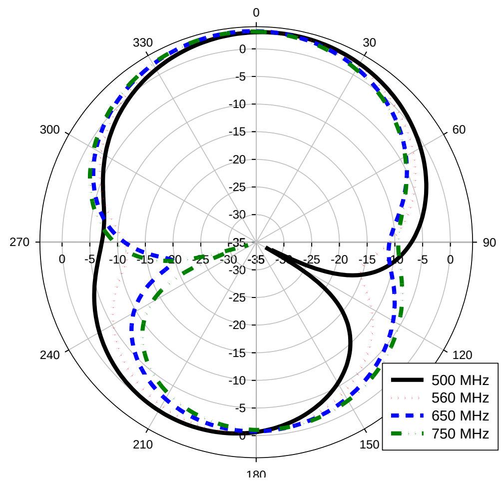


Figure 6. Radiation pattern of the proposed antenna in E-plane

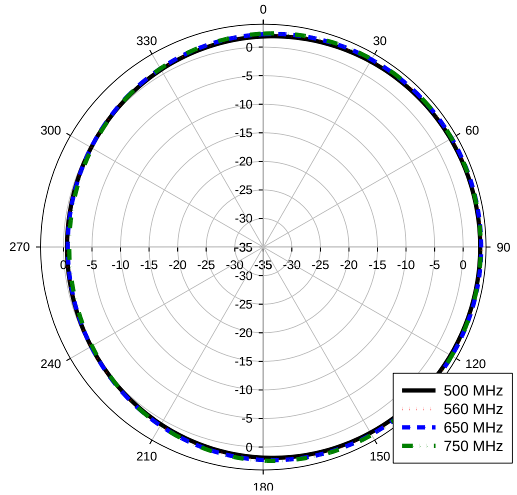
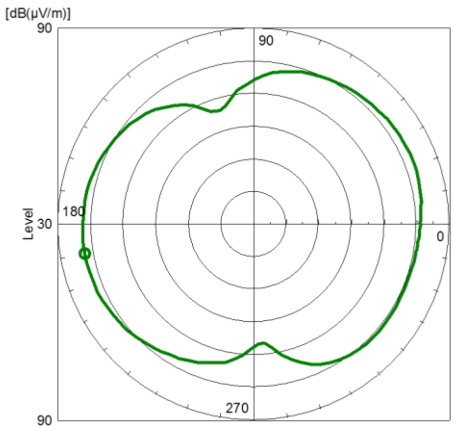
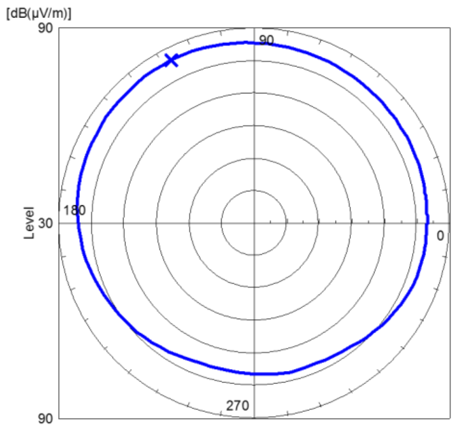


Figure 7. Radiation pattern of the proposed antenna in H-plane

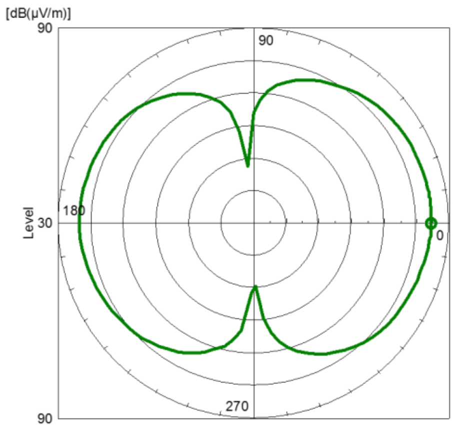


(a)

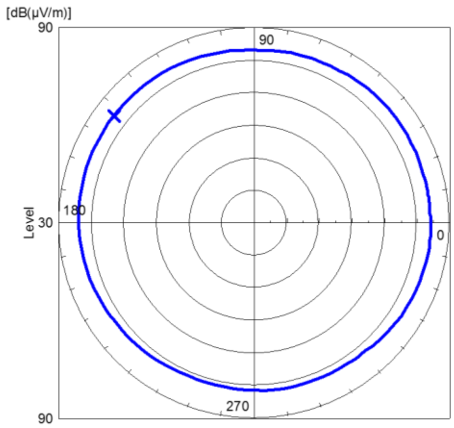


(b)

Figure 8. Radiation pattern measured at 500 MHz for (a) E-plane and (b)H-plane



(a)



(b)

Figure 9. Radiation pattern measured at 700 MHz for (a) E-plane and (b) H-plane

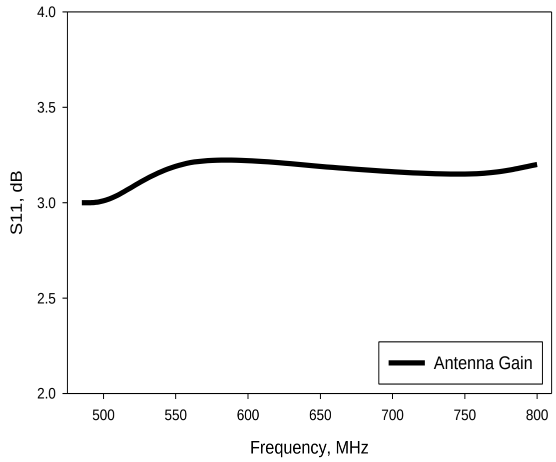


Figure 10. Gain of the proposed antenna

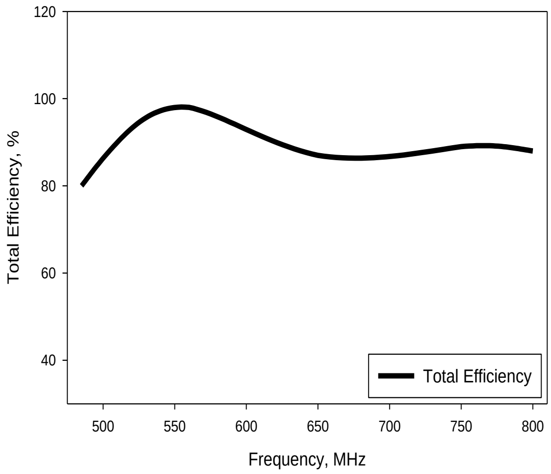


Figure 11. Total efficiency of the proposed antenna

4. CONCLUSION

A new type of compact indoor reception digital antenna has been proposed. This antenna consists of a radiator and a reflector that attached to the ground plane to receive the digital signal. The antenna gain has been observed through simulation to meet the minimum standard requirement which is more than 3 dBi at all frequency band. The proposed antenna has a bandwidth of 290 MHz which is determined between 500 MHz and 790 MHz at -10 dB level which can cover all digital standards. From evaluation of C/N of digital terrestrial broadcasting, it is confirmed that the proposed monopole antenna with a reflector has the capability to be applied into an indoor digital terrestrial broadcasting reception and related application fields.

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