Wireless Indoor Antenna Design For Smart TV Application

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***Abstract*—This paper present a new indoor digital microstrip TV antenna in wireless connection. A Rectangular Microstrip Patch Antenna for lower UHF (ultra high frequency) incorporated with a single Slotted Complementary Split Ring Resonator (SCSRR) on the partial ground plane has been designed. The microstrip antenna is designed using CST2015 Simulation Software. The antenna designed is specific to 566 MHz with bandwidth of 357 MHz. A single SCSRR is used as a miniaturization technique to reduce the size of the microstrip antenna that can be applied in lower UHF especially in DTV broadcasting frequencies in Malaysia. The antenna design was limited to a size of 20.1 cm x 21.2 cm using FR-4 substrate with thickness 1.6mm and dielectric constant of 4.3. The performance of the designed antenna in terms of return loss, VSWR, radiation pattern, HPBW and line impedance at four frequencies; 478 MHz, 566 MHz, 606MHz, and 742 MHz was analyzed. The proposed antenna can be considered to achieve the objective based on the simulation results.**

***Index Terms*—Rectangular Microstrip Patch Antenna, Slotted Complementary Split Ring Resonator (SCSRR), partial ground plane, UHF, DTV, return loss, VSWR, radiation pattern, HPBW, line impedance.**

I. INTRODUCTION

With today fast pace technology development, the wireless communication system covers a very wide area of applications. In wireless communication system, antenna is used to transmit and receive signals. The well-known antenna design in wireless communication system is a microstrip patch antenna which has several advantages such as light weight, low fabrication cost, conformability and can be easily installed with other devices [4-6, 9]. In this study, a new indoor microstrip patch antenna for TV broadcasting application is proposed. The antenna will be designed to support the advance technologies in Smart TV application which able to receive and broadcast signals (receiver) without being wired to the old TV tuner system.

Based on the Standard Definitions of Radio Spectrum Segments, TV broadcast signals require a VHF (very high frequency) or lower UHF (ultra high frequency) band, typically from 30 MHz to 3 GHz. In Malaysia, the Malaysian Communication and Multimedia Commission (MCMC) has introduced the free-to-air digital television broadcast (DTV) since 2005. The frequency band of the DTV broadcast in Malaysia has been optimized between 470 MHz to 798 MHz as shown in Figure 1. Therefore, this application needs an antenna which can operate within these frequency ranges. However, the conventional microstrip patch antenna suffers from narrow bandwidth which leads to the limitation of frequency range. This is due to the compact size of the antenna itself.

But recently, several studies have been proposed to enhance the bandwidth of the microstrip patch antenna for TV broadcast application [7, 8, 10, and 11]. The studies include the antenna shape selection, the feeding technique and the substrate design. Furthermore, several advance techniques have been developed and attached to the antenna which improved the radiating performance of the antenna [4, 5, 10, and 11]. Hence, an effort to implement a VHF or lower UHF microstrip patch antenna is proposed in this project which will focus on the performance of the proposed antenna design.

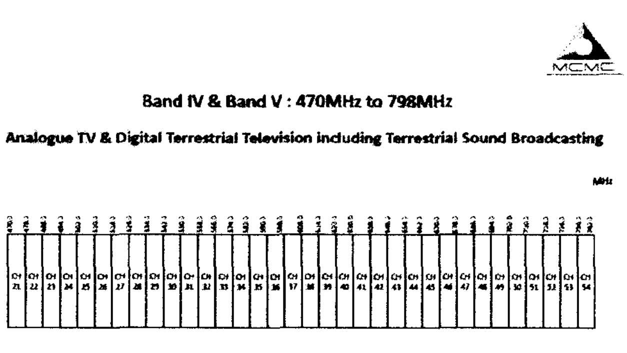


Figure 1: Broadcasting frequency bands in Malaysia

In this paper, a simple rectangular microstrip patch antenna with microstrip line feeding [10] is designed using CST2015 Simulation Software. The microstrip antenna is specific to 566 Mhz with bandwidth of 357 MHz shown that the antenna is able to operate at lower frequency ranges. The objective is to characterize the patch microstrip antenna which can radiate in lower UHF for TV broadcasting transmission and reception signals. The size of the microstrip antenna becomes large when designed for low frequencies application. However, it is desirable to design a smaller or compact microstrip patch antenna in modern communication systems. Therefore, a single Slotted Complementary Ring Resonator

(SCSRR) [13, 14] is implemented on the partial ground plane in order to miniaturize the size of the microstrip antenna while retaining the resonance at low frequencies.

II. DIGITAL TERRESTRIAL TELEVISION

Digital Terrestrial Television (DTTV) is a Digital Television (DTV) broadcasting technology that has transformed the viewing experience which includes the generation, manipulation, recording and transmission of the television images and sounds [10, 15]. In digital transmission, the images and sounds are initially converted into digital computer data and transmitted afterwards. The digital data is then quickly reassembled into the original picture and sound when the receiver such as the digital decoder box received the signal. Lastly, it is displayed in the television. The digital tuner (decoder) attached to the receiver used to remove any interface from the signals before converting them back to the original images and sounds. Although it requires an addition step in signal transmission, it provides a better quality of sound and picture compare to the older analog method.

DTTV signals are broadcast over essentially the same VHF/UHF bands as the older analog terrestrial TV signals. But, a different antenna for the reception of DTV will need to be used. Digital TV antennas may be divided into outdoor and indoor type. A well-known outdoor antenna used for household reception of TV signal is Yagi-Uda antenna [2]. The antenna which consists of a number of arms that running perpendicular to it covers only a portion of the respective VHF/UHF band [10]. The antenna works by receiving the frequency signal from the sub-station antenna and transmit the signal to the TV through the tuner through a wired connection so that the broadcast channel is displayed. This paper proposed an antenna design for indoor TV application which transmit and receive the DTV signals wirelessly.

III. COMPLEMENTARY SPLIT RING RESONATOR (CSRR)

Recently, using metamaterials to perform antennas miniaturization have been widely studied and used [13, 14, 16]. The materials are synthesized with desirable features including double-negative materials and artificial magnetic materials in the form of Split-Ring Resonators (SRRs) [14, 17]. SRR is formed by two concentric metallic rings with a split on opposite sides. It acts as an LC resonator with distributed inductance and capacitance excited by a time-varying external magnetic field component of normal direction of resonator [14, 19]. SRR provides a high quality factor of an electrically small LC resonator. In [14, 16, 17], the CSRR is defined as the negative images of SRR where the basic mechanism is the same to both resonators except for excited the axial electric field. With adjustment of the size and geometric parameters of the CSRR, the resonant frequency can be easily tuned to the desired value.

The potential to miniaturize the patch antennas by etching out the CSRR on the antenna design was explored recently [13, 14]. The results indicate that the size reduction of the microstrip patch was achieved which shown an improvement in the focusing parameter such as gain, return loss and radiation pattern. In [13], four shapes of a single CSRR structure had been studied through the effect on the microstrip patch design. It shown that the square SRR obtain a highest impact in terms of gain value compared to the other three shape of SRR; circular, rhombic and triangular. Therefore, this concept is applied to the microstrip patch antenna design in this study except it is designed on the ground plane.

IV. METHODOLOGY

The implementations of this project including two main part which are software design and hardware. The software used for this simulation is CST2015 Microwave Studio which is used in designing the microstrip patch antenna. The antenna was then fabricated on the FR4 substrate with dielectric constant, $\varepsilon_r = 4.3$ and thickness, $h = 1.6$ mm. The fabrication of the proposed antenna is verified using Vector Network Analyzer (VNA). Report and documentation was written after the fabrication antenna results meet the requirement. Figure 2 shows the step during implementations of this project.

The scope of works in this project is described as flow chart shown below:

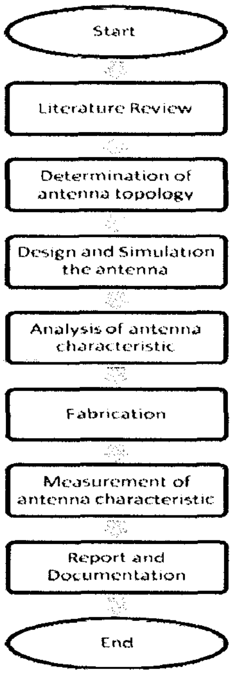


Figure 2: Flowchart for antenna design process.

V. ANTENNA DESIGN

A. Antenna Geometry

The geometrical design of the rectangular slotted microstrip patch antenna is shown in Figure 3. The antenna is designed on a FR4 substrate with the dimension of 201.58 mm width,Ws x 212.18 mm length, Ls with thickness of 1.6 mm and the dielectric constant of 4.3. It consists of a rectangular patch with a length, Lp=95.3 mm and width, Wp=161.5 mm. The center of the patch antenna is connected to the microstrip transmission line which is used to feed the power into the radiator to get the optimum result [3]. The partial ground plane with dimension of 141.5 mm width, Wg x 101.8 mm length, Lg is printed on the back side of the substrate. Table 1 describes the parametric dimensions of the proposed antenna.

A single Slotted Complementary Split Ring Resonator (CSRR) in rectangular shape as shown in Figure 4 is designed at the center of the ground plane. The split ring resonator is designed with the dimension of 40mm width, Wc x 40mm length, Lc. The gap between the split ring is fixed to 1.0mm [13]. The CSRR is symmetrically incorporated into the design to achieve the size reduction for lower frequency antenna [12-14, 16].

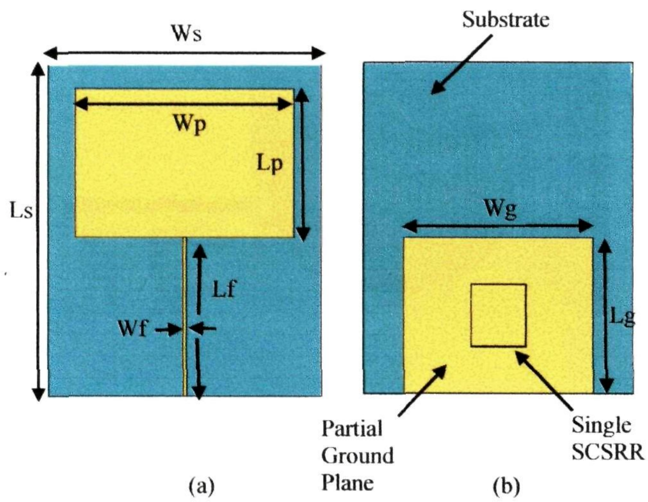


Figure 3: Geometry and dimensions of antenna (a) front view (b) back view

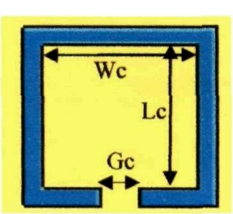


Figure 4: Geometry and dimensions of a single Slotted Complementary Split Ring Resonator (SCSRR)

Table 1: Dimension of the microstrip patch antenna

Parameter	Symbol	Dimension (mm)
Substrate width	Ws	201.58
Substrate length	Ls	212.18
Patch width	Wp	161.5
Patch length	Lp	95.3
Feed width	Wf	2.8
Feed length	Lf	101.8
Ground width	Wg	141.5
Ground length	Lg	101.8
SCSRR width	Wc	40
SCSRR length	Lc	40
Gap between split ring	Gc	1

B. Antenna Characteristics

In this design, when the size of the microstrip antenna reduces, it will effect to the antenna performance. Therefore some parameters need to be specified to improve the performance of the antenna. This is done by by using a partial ground instead of full ground and by incorporating the single SCSRR on the partial ground plane of the microstrip antenna. Both methods are used to get the desired operating band of the microstrip antenna which is approximately around 470 MHz to 800 MHz. The parameter that should be considered is the size of the ground plane and the split ring.

VI. RESULT AND DISCUSSIONS

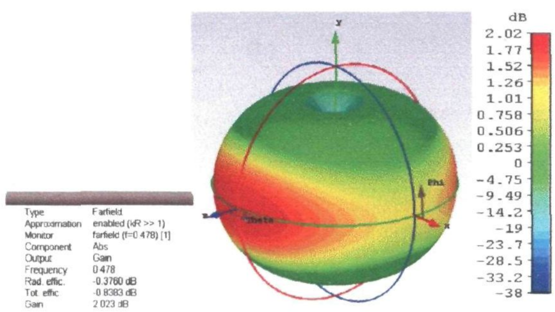
The main parameters that considered in this study are the radiation pattern; in terms of antenna gain and half-power beamwidth (HPBW), return loss, voltage standing wave ratio (VSWR) and line impedance matching of the antenna.. From the simulation, the proposed microstrip patch antenna may operate in lower UHF with bandwidth of 357 MHz between 478 MHz to 835 MHz. The simulation results for four frequencies band including the resonance frequency are analyzed and compared in this paper. These frequencies are determined from DTV broadcasting frequencies in Malaysia as shown in Figure 1 previously, which indicates the minimum frequency, f_{min} of 478 MHz, the resonance frequency, f_r of 566 MHz, the center frequency, f_c of 606 MHz and lastly the maximum frequency, f_{max} of 742 MHz. All the simulation results for these four frequencies band are concluded in Table 2.

A. Radiation Patern

I. Antenna Gain, G

Antenna gain is usually described as the ratio of the power produced by the antenna from a far-field source which is transmitted in the direction of peak radiation to the power produced by a hypothetical lossless isotropic antenna, which is equally sensitive to signals from all directions [1].

From Figure 5, the radiation pattern shows the gain of 2.02 dB at 478 MHz, 2.37 dB at 566 MHz, 2.51 dB at 606 MHz and 3.01 dB at frequency 742 MHz respectively. The simulation results explained that the proposed microstrip antenna is available to radiate in lower frequency bands up to 700 MHz even though the size of the antenna reduces. It indicates that the highest gain obtained when the antenna radiated at the maximum frequency of 742 MHz. The gain decreases for radiation at lower frequency as shown. However, it seems the antenna still can radiate at lowest frequency of 478 MHz.



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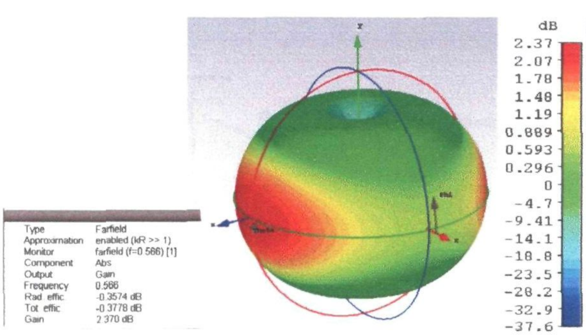

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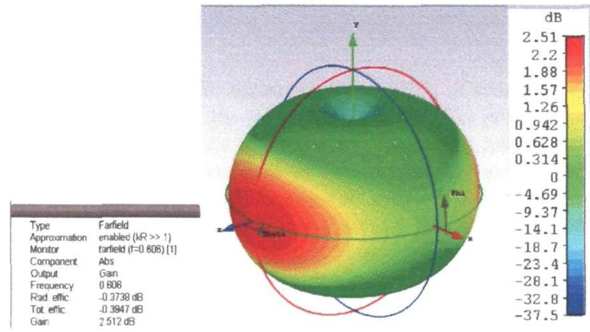

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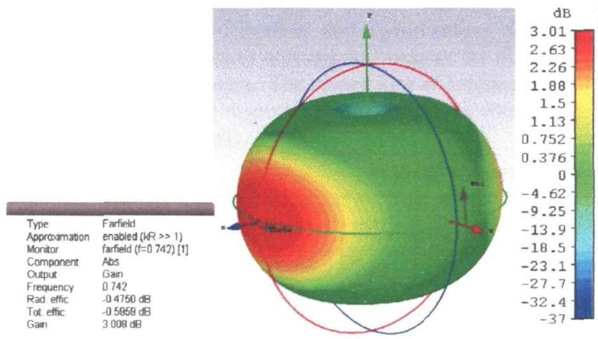
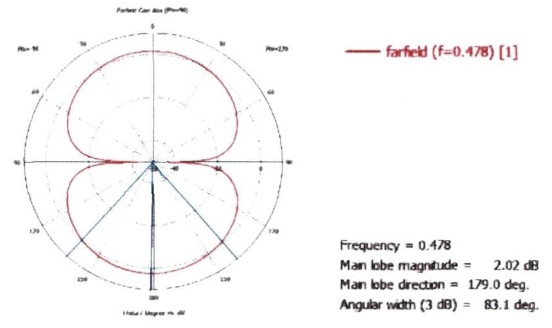


(d)

Figure 5 : Radiation Pattern – Antenna Gain at frequency (a) 478 MHz (b) 566 MHz (c) 606MHz (d) 742 MHz

II. Half-Power BeamWidth, HPBW

The Half-Power Beamwidth (HPBW) is the angle between the half-power of an antenna pattern or beam over which the relative power is at or above 50% of the peak power. It can be concluded that the smaller value of HPBW, the better it will avoid from others signal interference. Figure 6 shows the radiation pattern which indicates HPBW at 478 MHz is 83.1 degree. As for the resonance frequency at 566 MHz, the HPBW is 80.1 degree. At 606 MHz, the HPBW is 78.7 degree while at 742 MHz, HPBW is 73.9 degree. This shows that at the maximum frequency, the interference with undesired signal is minimum.



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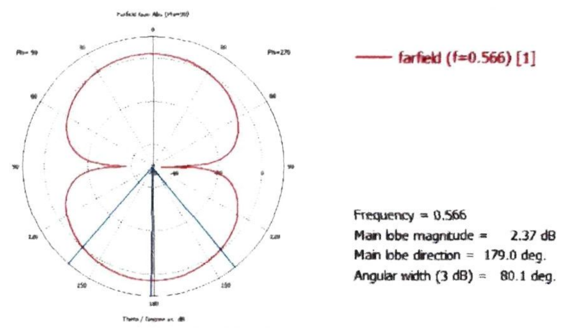

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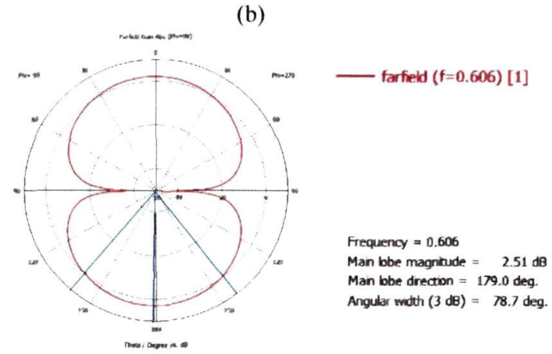

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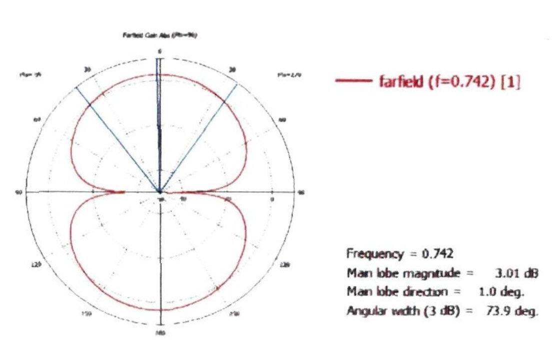

(d)

Figure 6 : Radiation Pattern – HPBW at frequency (a) 478MHz (b) 566 MHz (c) 606 MHz (d) 742 MHz

B. Return Loss

Figure 7 shows the approximation results of return loss, S_{11} graph parameter of the microstrip antenna. The return loss for four frequency bands is compared. The return loss is the ratio of the Fourier transform of the incident pulse and the reflected signal [3]. It represents the loss of power in the signal which is reflected back to the microstrip. Small value of return loss leads the antenna closely to operate at its maximum power. From the result obtained, it can be concluded that for the antenna have a small amount of reflection back to the microstrip. The best return loss, -23.289dB is obtained at the resonance frequency, f_r of 566 MHz. However, at 478 MHz, the return loss is -9.96 which is higher than -10 dB. The signal transmitted may encounter a loss of power which is reflected back. Therefore, a modification and optimization shall be conducted to the microstrip antenna to improve its ability to radiate at lower frequencies. The return loss at frequency 606 MHz and 742 MHz are respectively at -23.19 dB and -15.61 dB which are below -10dB.

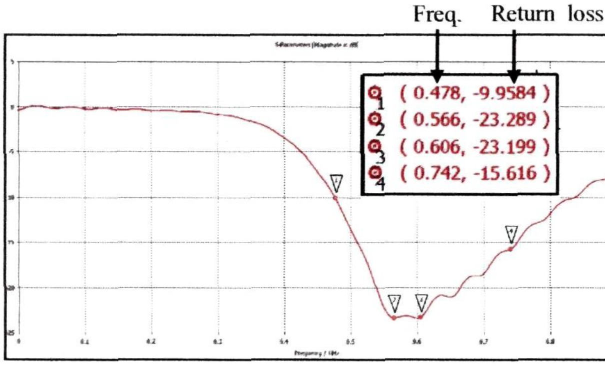

Figure 7: Return loss graph of the simulated microstrip antenna (1) 478 MHZ, (2) 566 MHz, (3) 606 MHz (4) 742 MHz

C. Voltage Standing Wave Ratio, VSWR

The voltage standing wave ratio (VSWR) of the simulated results is shown in Figure 8. VSWR represent the mismatching between an antenna and the transmission line where a perfect matching antenna would have a VSWR value close to unity [3]. From the result, there are specific frequency signals between the operating bandwidth that produce the lowest VSWR values. As shown, the VSWR at 478 MHz is 1.9315. At 566 MHz the VSWR is 1.147 while at 606 MHz the VSWR is 1.1487. Lastly the VSWR at 742 MHz is 1.3971. For comparison, it shows that the antenna could produce the lowest VSWR value when operating at the resonance frequency, fr of 566 MHz which indicate the perfect matching between the antenna and the transmission line.

The overall results show that the microstrip antenna is almost matched to the transmission line for the determined operating bands. In other words, there are less power reflected from the microstrip antenna during transmitting and receiving the signals within the DTV frequency bands as stated.

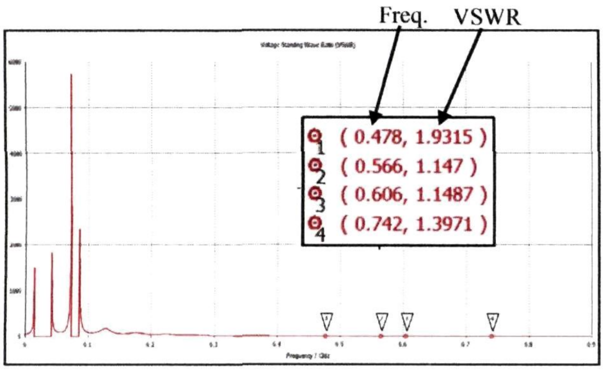

Figure 8 : VSWR of the simulation result (1) 478 MHz (2) 566 MHz (3) 606 MHz (4) 742 MHz

D. Line Impedance

The line impedance optimized from the proposed antenna in this paper is 49.86 Ω as shown in Figure 9. This impedance value indicates that the signal transferred from the source to the load is quite good as it approaching to meet the impedance matching value which is 50 Ω. Hence, the antenna may work properly over the DTV broadcasting frequency bands. In future, the antenna impedance matching can be improve by altering the transmission line parameters in terms of the feeding technique design including the material used, size and dimension of the feed line. Besides, the split ring resonator parameter also may be one of the factor to improve the impedance matching as it affects the back radiation level of the antenna.

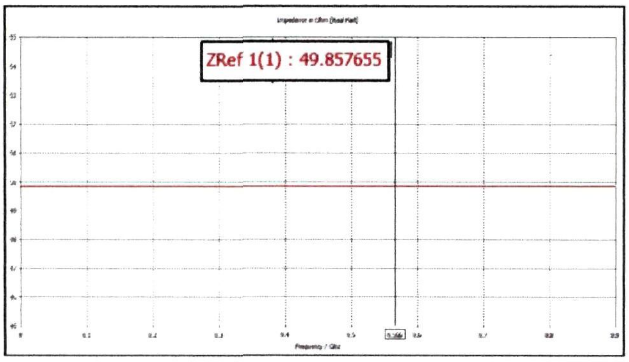

Figure 6: Line impedance of the simulated microstrip antenna

Table 2: Simulation results for the proposed indoor microstrip TV antenna

Frequency (MHz)	f_{min} 478	f_r 566	f_c 606	f_{max} 742
Gain (dB)	2.02	2.37	2.51	3.01
HPBW (degree)	83.1	80.1	78.7	73.9
Return Loss (dB)	-9.9584	-23.289	-23.199	-15.616
VSWR	1.9315	1.147	1.1487	1.3971
Line Impedance (Ohm)	49.86	49.86	49.86	49.86

VII. CONCLUSION

An indoor microstrip TV antenna for digital television, DTV broadcasting reception is presented in this paper. The proposed design is a simple rectangular shaped antenna with a transmission line incorporating with a single Slotted Complementary Split Ring Resonator, SCSRR on a partial ground plane. The incorporated design is used for the miniaturization technique to reduce the size of the microstrip antenna. The microstrip antenna is optimized at 566 MHz and characterized to operate in lower UHF for TV broadcasting transmission and reception signals. The proposed antenna was able to work at low frequency with miniaturization of the antenna size. The antenna gain shows that the proposed antenna has strong radiation capability through the lower frequencies. With the HPBW values, the microstrip antenna may avoid the signal interference within the operating bands. In addition, the proposed antenna shows quite low in return loss which means that the antenna may operate approaching to its maximum power as there is less power reflected back to the radiator. The VSWR and line impedance prove that the designed antenna could reach the impedance matching.

VIII. FUTURE RECOMMENDATION

For future development, further studies in the following parameters should be done to analyze the effect and improve the performance of the microstrip antenna. The parameters which can be considered are the size of the patch and the feed line, the gap between the split ring and the number of split rings used. Furthermore, the complex design of microstrip antenna such as a circular or an array antenna can be investigated further in seeking better signal reception [8,10]. An improvement to meet the matching impedance also shall be considered in the future by choosing an appropriate technique in designing the feed of the antenna such as using a coaxial probe due to ease in impedance matching and low spurious radiation [20]. Furthermore, the material including SMA/coaxial connector or FR4 may be considered to use. Next, the different shapes of the CSRR also would be the factor to affect the antenna performance.

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