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Research paper

Wireless Indoor Antenna Design For Smart TV Application

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Abstract

This paper present a new indoor digital microstrip TV antenna suitable for wireless application. 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 is designed having a frequency at 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 (Digital TV) 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 1.6 mm with dielectric constant of 4.3. The performance of the designed antenna is measured in terms of return loss, VSWR, radiation pattern, HPBW and line impedance at four frequencies; 478 MHz, 566 MHz, 606MHz, and 742 MHz. The proposed antenna is fabricated and measured in verifying the design.

Keywords: *Rectangular Microstrip Patch Antenna, Slotted Complementary Split Ring Resonator (SCSRR), , UHF, DTV, VSWR, , HPBW.*

1. Introduction

With today fast pace technology development, the wireless communication system covers a very wide area of applications. 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 [1-2]. 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 [3]. 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. Recently, several studies have been proposed to enhance the bandwidth of the microstrip patch antenna for TV broadcast application [4-7]. 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 [7].

In this paper, a simple rectangular microstrip patch antenna with microstrip line feeding is designed. 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. Therefore, a single Slotted Complementary Ring Resonator (SCSRR) [8-9] is implemented on the partial ground plane in order to miniaturize the size of the microstrip antenna while retaining the resonance at low frequencies.

2. Complimentary Split Ring Resonator (Cssr)

Recently, using metamaterials for antennas miniaturization have been widely studied and used [8-10]. The materials are synthesized with desirable features including double-negative materials and artificial magnetic materials in the form of Split-Ring Resonators (SRRs) [9-11]. 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 [12]. SRR provides a high quality factor of an electrically small LC resonator. 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]. 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.

Antenna Design

The geometrical design of the rectangular slotted microstrip patch antenna is shown in Figure 1. The antenna is designed on a FR4 substrate with the dimension of 201.58 mm width ,Ws, 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. The partial ground plane with dimension of 141.5 mm width, Wg, 101.8 mm length, Lg is printed on the back side of the substrate.

Table 1 describes the parametric dimensions of the proposed antenna.

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

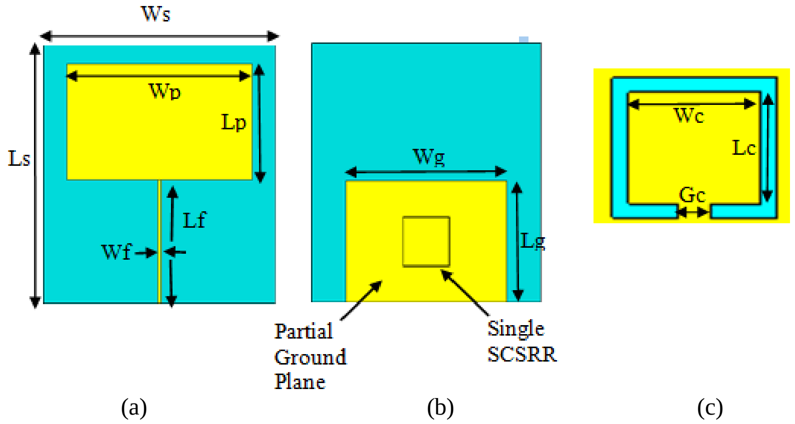


Figure 1: Geometry and dimensions of antenna (a) front view (b) back view (c) Geometry and dimensions of a single Slotted Complementary Split Ring Resonator (SCSRR)

A single Slotted Complementary Split Ring Resonator (SCSRR) in rectangular shape as shown in Figure 1(c) is designed at the center of the ground plane. The split ring resonator is designed with the dimension of 40mm width, Wc, 40mm length, Lc. The gap between the split ring is fixed to 1.0mm [8].
In this design, some parameters need to be specified to improve the performance of the antenna. This is done 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 were used to get the desired operating band of the microstrip antenna at 470 MHz to 800 MHz.

3. Analysis and Discussion

A. Measurement Result

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 [3], which indicates the minimum frequency, fmin, the resonance frequency, fr, the center frequency, fc and lastly the maximum frequency, fmax. All the simulation results for these four frequencies band are concluded in Table 2. From the simulation, the proposed microstrip patch antenna may operate in lower UHF with bandwidth of 357 MHz between 478 MHz to 835 MHz.

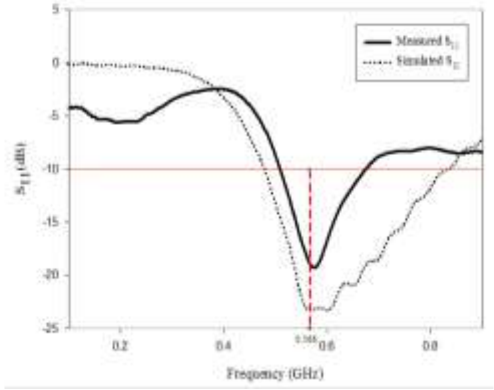
Table 2: Simulation results for the proposed indoor microstrip TV antenna

Frequency (MHz)	f_{min}	f_r	f_c	f_{max}
	478	566	606	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

The simulation results shows 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. However, it seems the antenna still can radiate at lowest frequency of 478 MHz. Meanwhile, the HPBW is decreased when antenna radiate from lower frequency to higher frequency which shows that at the maximum frequency, the interference with undesired signal is minimum. The approximation results of return loss, S11 graph parameter of the microstrip antenna for four frequencies band are compared and analyzed. The best return loss of -23.289 dB is obtained at the resonance frequency, f_r of 566 MHz. However, at 478 MHz, the return loss is -9.96dB which is higher than -10dB. The signal transmitted may encounter a loss of power which is reflected back. Therefore, a modification and optimization is conducted to the microstrip antenna to improve its ability to radiate at lower frequencies. From the result obtained, it can be concluded that for the antenna, a small amount of reflection exist back to the microstrip. The voltage standing wave ratio (VSWR) of the simulated results indicate specific frequency signals between the operating bandwidth that produce the lowest VSWR values. It shows that the antenna could produce the lowest VSWR value when operating at the resonance frequency, f_r 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. The line impedance optimized from the proposed antenna in this paper is 49.86 Ω. 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.

B. Measurement Result

The fabricated microstrip antenna was measured to observe the real performance of the antenna. The microstrip antenna is measured at the resonance frequency,fr at 566 MHz.



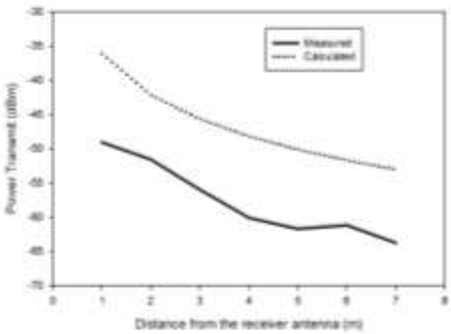
(a)

(b)

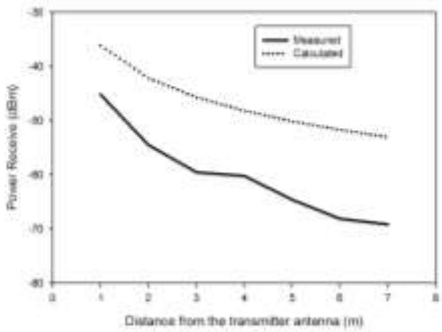
Figure 3: (a) Comparison between measured and simulated of the return loss, S_{11} of the microstrip; (b) Comparison of 2-dimensional radiation pattern between the measured and simulated results antenna.

Table 3: Calculation and measurement result of Indoor Propagation of the proposed microstrip TV Antenna in Free Space.

Distance (m)	Power Transmit (dBm)		Power Receive (dBm)	
	Theory / Calculation	Measured	Theory / Calculation	Measured
1	-36.1263	-49.06	-36.1263	-45.14
2	-42.1469	-51.56	-42.1469	-54.47
3	-45.6687	-56.02	-45.6687	-59.56
4	-48.1675	-60.07	-48.1675	-60.2
5	-50.1057	-61.69	-50.1057	-64.55
6	-51.6893	-61.14	-51.6893	-68.06
7	-53.0282	-63.74	-53.0282	-69.1



(a)



(b)

Figure 4: (a) Plotted Graph of Transmitting Power Results for Indoor Propagation Measurements of the microstrip TV antenna in Free Space; (b) Plotted Graph of Receiving Power Results for Indoor Propagation Measurements of the microstrip TV antenna in Free Space

Figure 3a shows the comparison between the measured S11 which is approximately match to the simulated S11 of the microstrip antenna at resonance frequency, fr. However, the measured return loss parameter seems to be significantly shifted towards a smaller bandwidth compared to the simulation result. The bandwidth is shifted about 51.8% from 357 MHZ in simulation to 172 MHz in measurement. This is due to variation of the antenna dimension during fabrication process. In addition, the different loss between measurement and simulation may be caused by the high loss tangent of the substrate, radiation loss of the microstrip and VNA cable loss.

Figure 3b shows the comparison of 2-dimensional radiation pattern between the measured and simulated results. From the observation at 566 MHz, the simulated and measured results shown that the microstrip antenna yields the standard doughnut shaped radiation pattern which fulfills the omnidirectional pattern throughout the operating frequency of the antenna. Table 3 represents the calculated and measured results for indoor propagation experiment of the proposed microstrip TV antenna in free space. Figure 4a and 4b represent the plotted results from Table 3. The graph shows a decreasing in transmit and receive power of the microstrip TV antenna throughout the antenna distance from the transmitter and receiver. From observation, there was a significant difference between theoretical and measured results influenced by construction materials of the building and the building type. The floor loss which is 13 dB [13] have been considered theoretically in calculated results.

4. Conclusion

A simple rectangular shaped antenna with a transmission line incorporating with a single Slotted Complementary Split Ring Resonator, SCSRR on a partial ground plane was optimized at 566 MHz and characterized to operate in lower UHF for TV broadcasting transmission and reception signals. Through some theoretical and experimental values, the microstrip TV antenna has shown that it may provide a strong radiation capability through the lower frequencies that may avoid the signal interference within the operating bands

Acknowledgements

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