A NOVEL COAXIAL FED PATCH ANTENNAS AT TVWS BAND CHANNELS 24 AND 28 FOR RURAL WIRELESS COMMUNICATION

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ABSTRACT

Microstrip patch antennas are useful for wireless communication as the technology is continuously evolving. Contacting types of microstrip patch antennas, coaxial-probe feeding, will be discussed and designed for the applications of television white space (TVWS). As the digital switchover in many countries is completed or nearly completed, TVWS is desired to be utilized for good purposes. One of them is to provide Internet access. Coaxial-probe fed single-layer single-patch microstrip patch antennas which are directional antennas, are proposed to provide wireless communication in rural areas by broadcasting hotspots. CST Microwave Studio is used to design and simulate the proposed antennas. To widen the bandwidth of the first proposed antenna, improvements are made and can be observed in the rectangular patch antenna with modified U-slots and E-shaped rectangular patch antenna. Both coaxial fed microstrip patch antennas are in good measurements and feasible to cater to the applications of TVWS at the respective channels which are Channel 24 and Channel 28.

1.0 INTRODUCTION

The element of microstrip patch antenna consists of a metal patch placed above a larger ground plane where the patch is printed on a microwave substrate material with different permittivity. Different methods to couple power into or out of microstrip antenna can be categorized into contacting and non-contacting; the former are coaxial and microstrip line feed where the connection to transmission line is direct whereas the latter transfers power between feedline and radiating patch by using electromagnetic field coupling [1]. In this paper, microstrip patch antenna with coaxial-probe feeding will be discussed. Usually, the coaxial probe has a characteristic impedance of 50 Ohms. The inner conductor of the coaxial connector extends from the ground to the patch passing through the substrate whereas the outer conductor extends from the ground up to the substrate. Fabrication is easier using coaxial feed method and it produces low spurious radiation. In addition, the feed can be placed at any suitable position in the patch to match the input impedance. Nonetheless, modelling is difficult as drilling a hole in the substrate is inevitable and the connector juts outside the ground plane [2].

The presence of wireless communication is inevitable in today's world. One of the Sustainable Development Goals proposed by the United Nations is to build resilient infrastructure where information and communication technology is essential. However, digital divide between rural and urban regions remains an issue throughout the world. A statistic in 2018 showed that globally, 3.9 billion people, or 51.2 per cent of individuals are online but 80 per cent of individuals in the least-developed countries have no access to the Internet [3]. This may be due to the high cost of infrastructure deployment as well as low population density in rural areas.

To fill the gap, television white space (TVWS) can be utilized. TVWS is the inactive or unused space exploited between actively used spectrums in very high frequency (VHF) or ultra-high frequency (UHF) spectrum where its frequency spans from 470 MHz to 790 MHz [4]. It is assigned for terrestrial television (TV) broadcasting and is usually underutilized [5]. Plenty of white spaces are available to be discovered, notably in rural areas as a result of lesser TV stations and lower population density [6]. Moreover, most of the developed and developing countries have either completed or are in the process of switching TV stations from analogue to digital transmission. In Malaysia, the digital switchover (DSO) is completed [7]. As the spectrum efficiency of digital TV is higher, the digital switchover will free up most of the TV bands and regulators can reassign these spectra for other wireless purposes with the certain requirements met. The main objective of this paper is to design and simulate the coaxial-probe fed microstrip patch antennas with reflection coefficient of less than -10 dB which resonated in the frequency range of 470 MHz to 790 MHz for TVWS applications which is to provide wireless communication in rural areas by broadcasting hotspot.

2.0 LITERATURE REVIEW

2.1 Microstrip Patch Antenna

With the advancement of wireless communication systems, microstrip patch antenna is commonly used and has becoming one of the vital elements in the system. It is known for its compact structure, low profile, ease of fabrication, simple geometry and compatibility with monolithic microwave integrated circuits (MMIC) designs [8, 9].

However, there are some disadvantages such as surface wave excitation and narrow bandwidth. Besides, the physical size of microstrip patch antennas is rather large at VHF and UHF spectrum where the TV white space frequencies are located. To increase the bandwidth while minimizing the size of the antenna, slots can be cut on the patch, shorting pins can be used, parasitic patches can be added, and thicker substrates can be used [10].

Microstrip patch antennas have been widely designed and implemented for the higher frequencies such as L-band, S-band and C band which is approximately 1 GHz to 8 GHz. However, design of microstrip patch antenna that operates at UHF band for the usage of TVWS applications is scarce. One of the studies proposed a U-shaped monopole antenna with meandering technique for TVWS application where the gain measured was 2.2 dBi and 3.7 dBi at 500 MHz and 798 MHz respectively with impedance bandwidth of 57% [11].

2.2 Coaxial-Probe Feeding

2.2.1 U-Shaped Slot Patch Antenna

In terms of slot resonator, U-slot patch antenna is commonly designed and implemented to enhance bandwidth. Originally, a U-shaped slot on a rectangular patch of single-layer single-patch microstrip antenna with air substrate was designed to achieve impedance bandwidth of 10% to 40% [12]. Compared to the usage of parasitic patches, either stacked geometry or coplanar geometry, U-shaped slot will neither increase the thickness of the antenna nor the lateral size of the antenna. Unlike the addition of dissipative loads such as resistors, U-shaped slot will not reduce the bandwidth efficiency and gain of the single-layer single-patch antenna [13]. Numerous other U-shaped slot patch antennas can be observed in the literature as well [14; 17].

2.2.2 E-Shaped Patch Antenna

Like cutting a U-slot on the radiating patch of a microstrip antenna, E-shaped patch antenna is also commonly designed and implemented to enhance bandwidth. E-shaped patch can be illustrated as two parallel slots which are incorporated into the patch of a microstrip antenna. An E-shaped patch antenna has been fabricated which increased the bandwidth of the design by more than 30% [18]. The microstrip antenna is coaxially fed and operates at frequencies of 1.9 GHz and 2.4 GHz. The E-shaped patch antenna has a simpler structure compared to the U-slot microstrip patch antenna as the length, width and position of the slots are easier to regulate in order to achieve satisfactory performances.

2.3 Television White Space

TVWS has started to be vitalized in terms of its implementation in both rural and urban regions globally. Companies such as Microsoft and Google have been actively advancing TVWS technology and testing its related applications [19]. Microsoft acts as a consultant by running different projects in Singapore, UK, and parts of Africa whereas Google focuses on vertical market applications in urban and rural areas such as Tanzania and Kenya respectively.

In terms of Internet access, several studies have mentioned the high cost of deploying and maintaining infrastructure of wireless systems in the higher bands, thus TVWS can play an important role by providing cost-effective solutions [19; 21]. Especially in sparsely populated regions, providing broadband access can be challenging due to the low average revenue per user, high energy cost and geographic accessibility problems. Number of base stations deployed over an explicit service area is reduced and the mobility is increased as TVWS has lower path loss, longer transmission range and higher penetration capabilities compared to the higher frequencies. Low-cost Internet access in 5G environment for rural regions can be accomplished with the usage of TWVS spectrum [22]. By using TVWS in metropolitan areas, more powerful public Internet access with larger coverage and boosted download speeds can be accomplished [23].

3.0 METHODOLOGY

3.1 Antenna Configuration

The rectangular single-layer single-patch microstrip patch antennas are designed and simulated on a glass-reinforced epoxy laminate material named Flame Retardant-4 (FR-4). It is a cost-effective composite material which is commonly used in the fabrication of printed circuit boards [24]. In this work, a 1.6 mm thick FR-4 substrate with a dielectric constant of 4.7 and a loss tangent of 0.0025 is adapted. To feed the proposed antenna, a 50 SMA connector, where the insulator is made of Teflon and has an outer diameter of 3.2 mm and inner diameter of 0.4 mm, is connected to the proposed antenna.

3.2 Antenna Design

3.2.1 Rectangular Patch Antenna with Modified U-Slots

With resonant frequency of 498 MHz, the parameters are obtained and tabulated in Table 1.

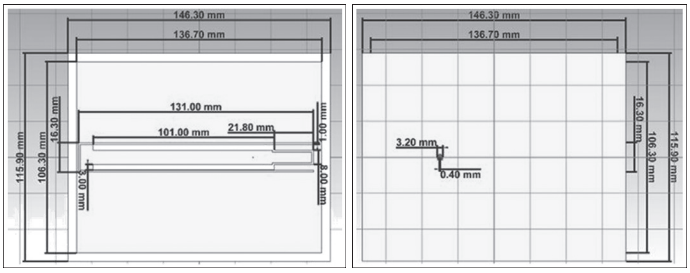
Table 1: Parameters of rectangular patch antenna with modified U-slots

Parameters	Values
Width of patch (mm)	136.7
Effective dielectric constant of substrate	4.582
Effective length of patch (mm)	107.8
Length extension, Δ (mm)	0.74
Actual length of patch (mm)	106.3
Position of probe feeding (mm)	30
Width of ground plane (mm)	146.3
Length of ground plane (mm)	115.9

With the parameters, design of the antenna is simulated in CST Microwave Studio as shown in Fig. 1.

3.2.2 E-Shaped Rectangular Patch Antenna

With resonant frequency of 530 MHz, the parameters are obtained and tabulated in Table 2. With the parameters, design of the antenna is simulated in CST Microwave Studio as illustrated in Fig. 2.

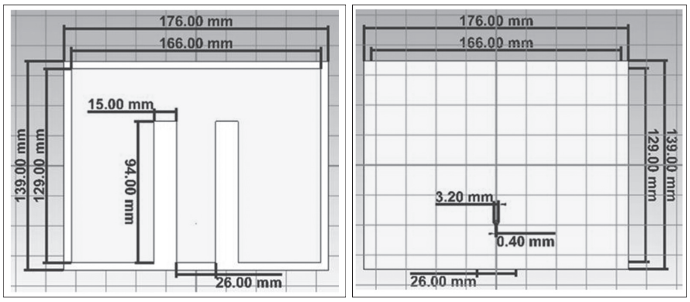


(a) (b)

Figure 1: Configuration of rectangular patch antenna with modified U-slots: (a) top view (b) bottom view

Table 2: Parameters of E-shaped rectangular patch antenna

Parameters	Values
Width of patch (mm)	166
Effective dielectric constant of substrate	4.602
Effective length of patch (mm)	130.95
Length extension, Δ (mm)	0.74
Actual length of patch (mm)	129
Position of probe feeding (mm)	26
Width of ground plane (mm)	176
Length of ground plane (mm)	139



(a) (b)

Figure 2: Configuration of E-shaped rectangular patch antenna: (a) top view (b) bottom view

4.0 RESULTS AND DISCUSSIONS

Simulation results for both rectangular patch antennas in terms of reflection coefficient, bandwidth, voltage standing wave ratio (VSWR), gain and far-field pattern are analyzed.

4.1 Rectangular Patch Antenna with Modified U-Slots

Reflection coefficient of -13.36 dB is obtained at resonant frequency of 496.8 MHz as illustrated in Fig. 3. The bandwidth of the antenna is 9.97 MHz measured from 491.72 MHz to 501.68 MHz. The bandwidth obtained is in good measurement as the frequency range of TVWS channel in Malaysia is only 8 MHz and the assigned frequency of Channel 24 is ranging from 494 MHz to 502 MHz. Besides, VSWR obtained at resonant frequency is less than 2 which is 1.55 as shown in Fig. 4.

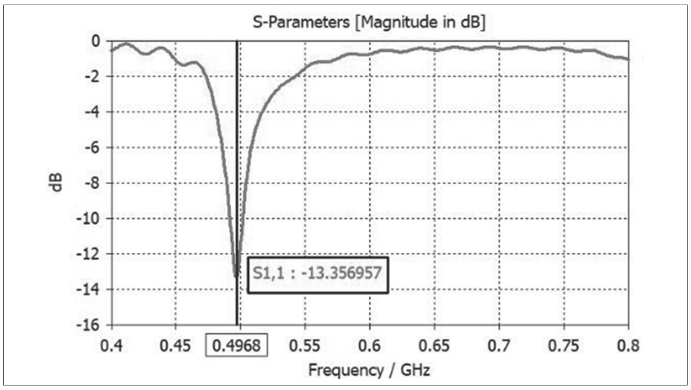


Figure 3: Simulated reflection coefficient of rectangular patch antenna with modified U-slots

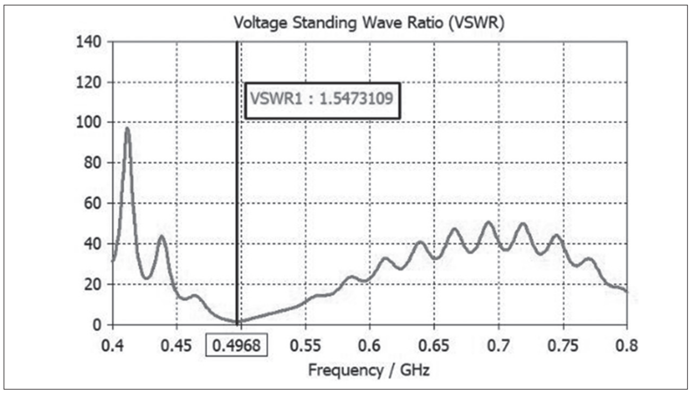
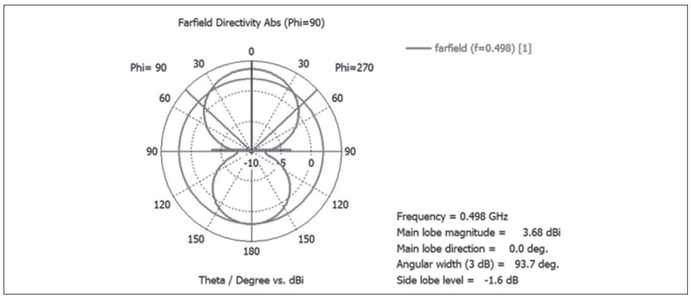


Figure 4: Simulated VSWR of rectangular patch antenna with modified U-slots

The gain obtained at resonant frequency of 498 MHz is 3.68 dBi and it can be observed that the antenna is a directional antenna. The polar form and 3-dimensional form of far-field patterns are illustrated in Fig. 5.



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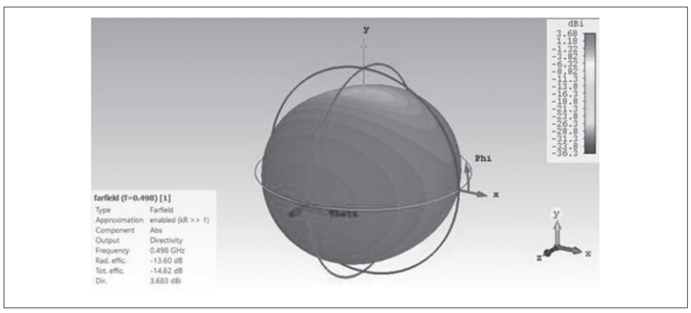


(b)

Figure 5: Simulated far-field patterns of rectangular patch antenna with modified U-slots: (a) polar form (b) 3-dimensional form

The simulation results obtained were in good measurement. The reflection coefficient and bandwidth are enhanced by cutting the modified U-slots on the rectangular patch. The proposed antenna can be used to cater to TVWS Channel 24 where the assigned frequency is 498 MHz.

4.2 E-shaped Rectangular Patch Antenna

Fig. 6 depicts that the reflection coefficient is -49.91 dB at resonant frequency of 529.6 MHz. The bandwidth of the antenna is 9.22 MHz measured from 525.02 MHz to 534.24 MHz. The bandwidth obtained is in good measurement as it fulfills the bandwidth requirement of TVWS channel in Malaysia which is 8 MHz. Furthermore, the antenna resonates within the assigned frequency of Channel 28 which is ranging from 526 MHz to 534 MHz. Moreover, VSWR obtained at resonant frequency is approximately equal to 1 which is 1.01 as shown in Fig. 7.

The antenna is a directional antenna and the gain obtained at resonant frequency of 530 MHz is 4 dBi. Fig. 5 illustrates the polar form and 3-dimensional form of far-field patterns.

The simulation results obtained for the E-shaped rectangular patch antenna are desirable amongst the other two proposed antennas. The E-shaped patch antenna is enhanced through bandwidth enhancement method which is adding two parallel slots on the patch. The E-shaped patch antenna can be used to cater to TVWS Channel 28 where the assigned frequency is 530 MHz as it fulfilled the bandwidth requirement and resonated at the assigned frequency.

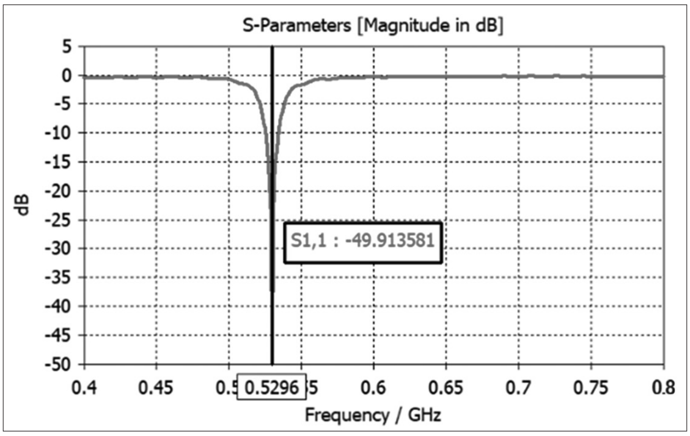


Figure 6: Simulated reflection coefficient of E-shaped rectangular patch antenna

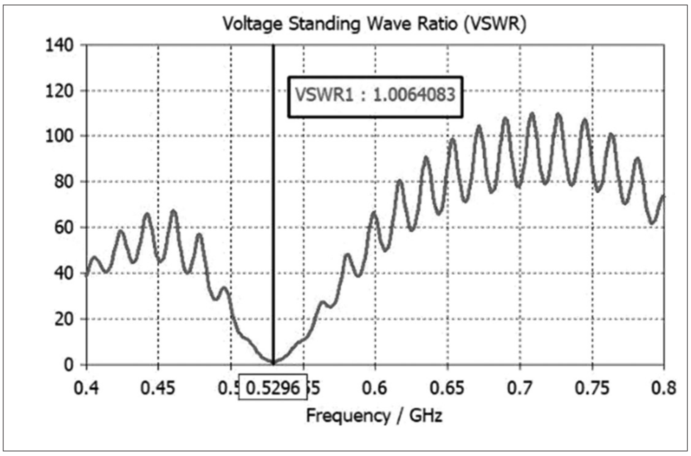
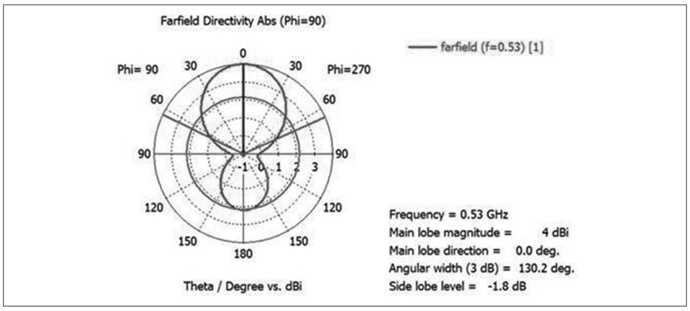
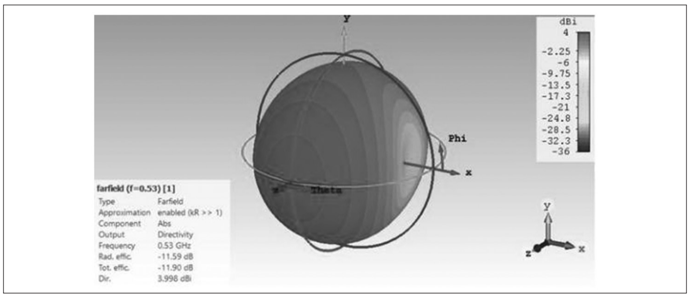


Figure 7: Simulated VSWR of E-shaped rectangular patch antenna



(a)



(b)

Figure 8: Simulated far-field patterns of E-shaped rectangular patch antenna: (a) polar form (b) 3-dimensional form

4.3 Gain Comparison of Antennas

The two antennas display a satisfactory reflection coefficient targeting the respective channels. The rectangular patch antenna with the modified U-slots successfully caters to the bandwidth for Channel 24 and the E-shaped rectangular patch antenna caters to the bandwidth for Channel 28. When using these antennas in a practical scenario after fabrication, one antenna can be used at a time, ideally at the client station, where either Channel 24 or 28 can be used for the connection depending on the antenna. Both antennas are directional, and there should ideally be no movement of the client station after a connection has been established. The E-shaped rectangular patch antenna, having a slightly higher gain of 4 dBi will have a stronger chance of connecting at longer distances in comparison to the U-slot antenna, with its lower gain of 3.68 dBi. This will not, however, be a significant difference, and both antennas should be able to connect effectively at close ranges.

5.0 CONCLUSION AND RECOMMENDATIONS

It is vital to research on coaxial fed microstrip patch antennas for the application of TVWS with the constant evolving of technology and the lack of Internet access for rural communities. Coaxial feeding is desired since it is easy to fabricate and produces low spurious radiation. Moreover, to match the input impedance, the feed can be placed at any desired position in the patch. All in all, this paper is to propose a single-layer single-patch coaxial-probe fed microstrip patch antenna to provide wireless communication in the rural area by broadcasting hotspot. The proposed antennas' design and simulations have been carried out and desirable results are obtained and the feasibility of the proposed antenna is proven. Both coaxial fed microstrip patch antennas are in good measurements and feasible to cater to the application of TVWS at the respective channels which are Channel 24 and Channel 28. ■

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PROFILES

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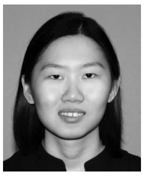

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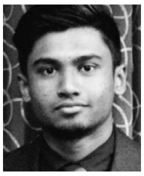

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