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Performance Analysis of Digital Video Broadcasting - Second Generation Terrestrial (DVB-T2) Propagation for Fixed Reception in The Central Region of Malaysia

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Abstract: Due to the increasing demand of services and content, Quality of Service (QoS) has become an important aspect in digital broadcasting industry especially with the implementation of Digital Terrestrial Television (DTT) in Malaysia. Thus, the performance of DVB-T2 in Malaysia should be investigated because there are areas which are not in the coverage due to variety of terrain, where some areas received weak DVB-T2 signals. Apart from geological and topographic factors in Malaysia, the selection of DVB-T2 parameters is also an important factor in determining signal strength and coverage This research has proposed to study the performance analysis of DVB-T2 propagation for fixed reception in Malaysia's central region. The Field Strength Measurement (FSM) was set up to evaluate the QoS of DVB-T2 signal such as Field Strength (E), Modulation Error Ratio (MER), and Carrier to Noise Ratio (C/N) at specific test points across Malaysia's central region. The FSM was simulated at the designated test points using CHIRplus_BC software to evaluate the performance of Single Frequency Network (SFN) at three locations of transmitter. The DVB-T2 Modulation and Forward Error Correction (FEC) code rate parameters were simulated in order to evaluate the improvement in terms of coverage area. It can be concluded that the coverage of DTT is reduced with the increase in the distance of the measurement area to the transmitter. The finding also shows that the field strength value obtained from FSM and simulation was comparable.   Furthermore, from the simulation results. it can be perceived that the coverage area across the central region of Malaysia could be improved by optimizing the modulation and FEC code rate. However, there is a trade-off between the signal coverage and channel capacity. The greater the signal coverage the less the channel capacity.

Keywords: DTT, DVB-T2, Field Strength, Fixed Reception, Performance Analysis

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1. INTRODUCTION

Digital terrestrial television (DTT) is a terrestrial television technology in which land-based (terrestrial) television station's broadcast the television content in digital format via radio waves to television in consumers' residences. Compared to the previous analogue television, DTT is a significant technical development and has essentially replaced the analogue that had been in common use since the middle of the 20th century. The perks of shifting to DTT include effective usage of limited radio spectrum capacity, the availability of more than analogue television channels, better quality videos, and potentially lower operating costs for broadcasters. Different countries have adopted various standards for digital broadcasting. Digital Video Broadcasting – Second Generation Terrestrial (DVB-T2) standard has been chosen as the standard to substitute the analogue TV system in Malaysia. The deployment of DTT in Malaysia, together with the growing demand for services and contents by Content Service Provider (CSP) has forced the operators to meet the QoS criteria while providing high bit rate information security and error protection. Figure 1 illustrates the digital and analogue television receiving the broadcast DTT signals from a tower using fixed antenna.

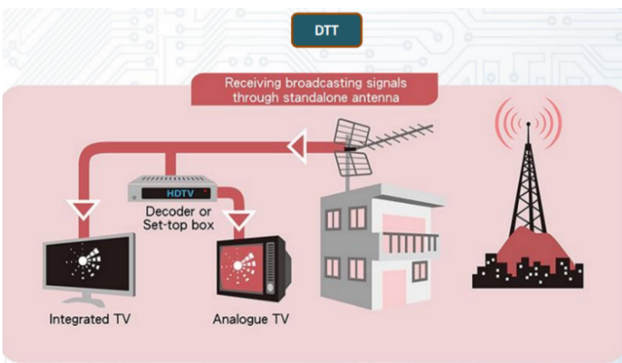


Figure 1. Receiving DTT Signals.

Currently, signal coverage for DTT in Malaysia reaches 95.3% of the populated area, and the rest is supported by Direct to Home (DTH) broadcasting (DVB-S)[1]. However, the drawback of DTH broadcast is that the signal is susceptible to rain attenuation because it propagates using high-frequency carrier. Furthermore, only designated areas will have access to DTH coverage in Malaysia. As DTT service providers, they need to ensure the QoS of DTT, including signal strength and quality transmitted throughout the region is provision. In Selangor, 23 locations were identified receiving weak DTT signals or not in the coverage. MYTV designates these areas as non-coverage areas and allow the residents in this area to receive DTH instead of DTT. In Selangor, these areas are specific areas in Banting, Beranang, Hulu Langat, Kajang, Rawang, Semenyih, Serendah, and Tanjung Sepat [2]. The DTH coverage information can be accessed through website www.mytvbroadcasting.my. Although the populated coverage is 95.3%, some areas received weak signals due to Malaysia's terrain. In addition to the effects of geological and landscape forms in Malaysia, the selection of DVB-T2 transmission parameters are very important for good reception of the received signal. The QoS parameters that can be related to the operational of DVB-T2 transmission through measurement are Modulation Error Rate (MER), Bit Error Rate (BER), Carrier to Noise Ratio (C/N), Field Strength, and coverage range [3].

The objectives of this study are:

- To measure the Quality of Services (QoS) of DVB-T2 Single Frequency Network (SFN) signals in the designated test points for fixed reception by performing the Field Strength Measurement (FSM).
- To simulate the FSM at the designated test points using CHIRplus_BC software in order to obtain the coverage range.
- To optimize the DVB-T2 Modulation parameters and FEC code rate using CHIRplus_BC.

The first edition of the DVB-T2 standard (ETSI EN 302 755 V1.1.1) is based on a DVB blue-book released by ETSI in September 2009 [4]. Compared to the already successful DVB-T standard, the DVB-T2 specification incorporates the latest modulation and Forward Error Correction (FEC) development to increase the bit-rate capacity and improve signal robustness [4]. FEC code rate parameter defines the ratio between the number of data bits and the total number of bits transmitted. The higher the code rate the better error correction, increases the robustness of the signal but decreases the capacity. When compared to the DVB-T standard, which uses Reed-Solomon and convolutional coding, DVB-T2 introduces two additional code rates; Low-Density-Parity-Check (LDPC) and Bose-Chaudhuri-Hocquenghem (BCH) [4]. In DVB-T2, the additional modulation scheme 256-QAM is available. The choice of modulation determines the bit rate (capacity), but it also has a significant impact upon the system's robustness; higher order modulation schemes that offer more capacity are more fragile [4]. DVB-T2 also employs a Single Frequency Network (SFN), which uses the same channel frequency for all transmitters in the network. In an SFN Network the required coverage is provided through the use of multiple transmitters operating on the same frequency and carrying the same programs [5]. The issue that needs to be considered for broadcasting in SFN transmission are to make sure that all the transmitters are transmitting the same data using the same frequency and are transmitting at the same transmission time [6].

Paper in [3] has discussed on the Performance Evaluation of DVB-T2 Propagation for Fixed Reception in Bangkok. The field measurements were taken at 20 sites in Bangkok, Thailand. One of the conclusions from the analysis is that the C/N and MER are reduced when the distance increases. There are some cases where the distance is close, but C/N is lower than the distance further. This is because the point of measurement location at the closer distance has more obscure and interfere by environment than the measurement points at a further distance.

In Malaysia, a QoS measurement study of DTT signal reception was conducted in [7]. The study focuses on the transmission process of DVB-T2, which involves the transmission from the Menara Kuala Lumpur transmitter to the receiver at 100 different locations. By measuring the field strength, MER (Modulation Error Ratio) and BERaLDPC (Bit Error Rate after Low-Density Parity Check Decoder), the performance of DVB-T2 was determined by comparing the DVB-T and DVB-T2 systems. From the study, it can be concluded that the most important parameters for determining the signal reception quality in Klang Valley area are Field Strength (92% of performance), MER (100%) and BER (100%). The DVB-T and DVB-T2 systems show slight differences in terms of field strength, MER and BER [7].

In this research, similar approach is employed as in [7]. However, the focus is to conduct measurement in the central region of Malaysia. As Malaysia has only switched from analogue broadcasting to digital DTT at the end of 2019, the research on performance analysis in Malaysia was not performed comprehensively yet, that is by optimizing the Modulation and Forward Error Correction (FEC) code rate parameters of DVB-T2. Furthermore, this research also aims to study the QoS for digital DVB-T2 broadcasting, taking into account the geological terrain in the central region of Malaysia using simulation tools.

2. RESEARCH METHOD

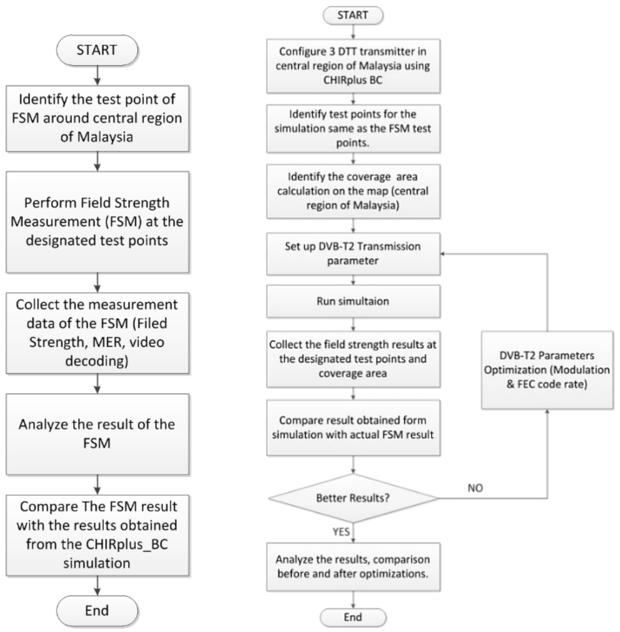
2.1 Field Strength Measurement (FSM)

To conduct the Field Strength Measurement (FSM) of DVB-T2 propagation in central region of Malaysia requires several steps as shown in Figure 2 (a). The first step is to identify the test point of FSM in the central region. The second step is to perform Field Strength Measurement (FSM) at the designated test points. The data collected from the FSM were Field Strength (E), MER and C/N. The results obtained from FSM was compared with the results obtained from the CHIRplus_BC simulation.

The measurement tools used to perform the FSM are Field Strength Meter Promax Ranger Neo+, and Antenna Maspro Denkoh which is used as the antenna receiver. The antenna was raised 10 meters above the ground level to ensure signal reception is the best for fixed reception method.

2.2 CHIRplus_BC Simulation Process

Figure 2 (b) shows the simulation process of this work. The first step is to configure three DTT transmitters in Malaysia's central region using CHIRplus BC in terms of location, ERP, height, and antenna pattern. The second step is to identify the test point location in the simulation so that it is similar to the FSM test point location. The DVB-T2 transmission parameters were set up in the simulator based on the standard for DTT broadcasts in Malaysia for 650 MHz frequency channel. The minimum field strength (E_{min}), channel capacity and coverage map results were captured after running the simulation. Finally, the simulation was also done to optimize the parameters of modulation constellation and FEC code in order to achieve better coverage area.



(a) (b)

Figure 2. Flow Chart of the (a) actual FSM and (b) CHIRplus_BC Simulation Process

2.3 Field Strength Measurement Parameters

Field Strength (E) measured the power over the entire bandwidth of the channel. It is formed by the vector addition of the directly received signal component and reflections due to obstructions in the field [8]. Coverage area means a certain area is regarded as being covered by DVB-T/T2, when the median field strength for the particular receiving situation in a specified height above ground (often 10 m)[9]. The minimum median equivalent field strength (E_{med}) DVB-T2 8 MHz system at 650 MHz is 56 dBμV/m[10]. The antenna factor is used to calculate the field strength from the antenna output level. The calculation formula of field strength at the antenna is as follows:

$$E = U + K \quad (dB\mu V/m), \tag{1}$$

$$U = P_s + 120 + 10\,log\,(Z_i) \quad (dB\mu V), \tag{2}$$

$$P_s = C/N + P_n \quad (dBW), \tag{3}$$

$$P_n = F + 10\log(k\,T_o\,B) \quad (dBW), \tag{4}$$

where, U is the measured antenna output voltage, K is the antenna factor, P_s is the receiver signal input power, Z_i is the receiver input impedance (75 Ω), C/N is the carrier to noise ratio required by the system, P_n is the receiver noise input power, F is the receiver noise figure, B is the receiver noise bandwidth, k is Boltzmann's Constant = 1.38*10–23 Ws/K, and T_o is absolute temperature = 290 K

The antenna factor depends on frequency and gain according to the following formula:

$$K = 20\,Log(f) - Gi - 29.774 \tag{5}$$

where f is the channel frequency and Gi is the antenna gain relative to an isotropic radiator.

2.4 DVB-T2 parameter set up in CHIRplus_BC

In the initial stage, the parameters as shown in Table 1 was configured in the CHIRplus_BC software. The optimization of the DVB-T2 parameters such as modulation and FEC code rate were investigated to observe the QoS improvement. The results obtained from the measurement and simulation were analyzed and compared.

Table 1. Current DVB-T2 Standard Parameters in Malaysia [11]

DVB-T2 Parameters for UHF CH 43 (650MHz)	
Channels	UHF CH 43 (650 MHz)
Bandwidth	8 MHz
Modulation	COFDM
Carrier Modulation	256-QAM
FEC Code Rate	2/3
Guard Interval	19/256
FFT Size	32k Extended
Pilot Pattern	PP2

Broadcasting network planning involves setting of the transmitter's parameters in order to provide good QoS in the intended coverage area. The parameters for the three transmitters were configured into the CHIRplus_BC working database as shown in Table 2.

Table 2. Transmitter Parametes for Simulation

Transmitter Parameters			
Transmitter	ERP (dBW)	Height (m)	Freq (MHz)
Menara KL	41	543	650
Ulu Kali	41	1786	650
Sungai Besi	41	291	650

3. RESULTS AND ANALYSIS

The results of 111 test points of Field Strength Measurement (FSM) and simulation from CHIRplus_BC are introduced in this section. The results obtained were analyzed and compared.

3.1 FSM Results

Figure 3 shows the FSM result at 111 designated test points. It is observed that when the distance increases, the signal strength is reduced.

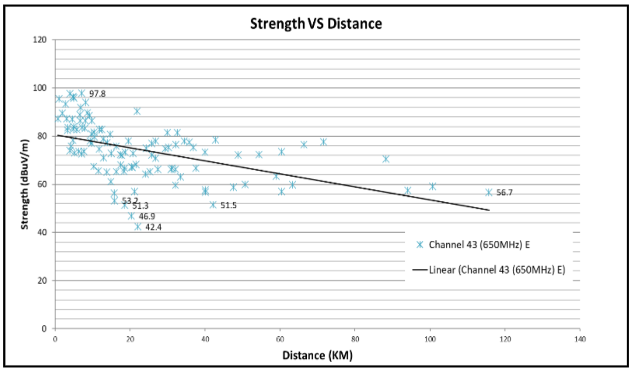


Figure 3: Field Strength Vs Distance at 111 FSM test points

The highest field strength is 97.8 dBµV/m at a distance of 7.1 km from the nearest transmitter, Bukit Sungai Besi. Five test point locations were indentified to receive signal strength of less than 56 dBµV/m. which is the minimum threshold. The locations are Kg. Paya Lebar, Sg. Lui, SK Kuala Pomson, Masjid Al-Makmur, Felda Gedangsa, Masjid Nurul Husna, Felda Sg. Tengi Selatan and Tadika KEMAS Sg. Tekala. The lowest signal strength is 42.4 dBµV/m, at a distance of 22.1 km from the nearest transmitter, which is Bukit Sungai Besi. It can also be concluded that although the distance between the transmitter and the area is near, the field strength can be low. This is due to the obstructions and signal reflections caused by the hilly terrain, plantation trees, or tall buildings around this measurement area.

3.2 CHIRplus_BC Simulation Results

In this section, the field strength simulation results obtained from the three transmitters, Menara KL, Gunung Ulu Kali and Bukit Sungai Besi were analyzed using scatter graph to observe the correlation between the received signal strength and the distance of the transmitter. Then, the received signal strength readings obtained from the FSM was compared to the simulation results and analyzed.

3.2.1 Field Strength from Menara KL Transmitter

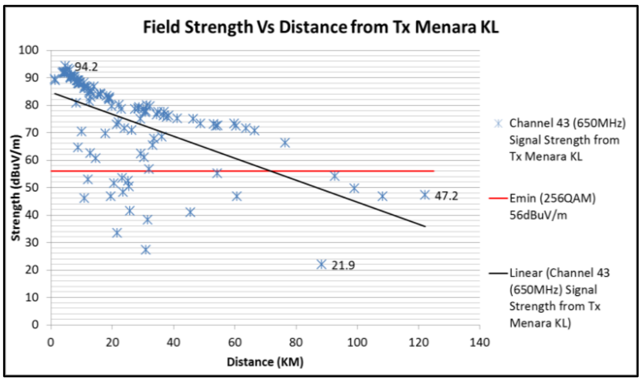


Figure 4. Simulation of Field Strength Vs Distance from Menara KL Transmitter

Figure 4 shows the field strength simulation results. Scatter graph was plotted to see the relationship between the received signal strength and the distance of 111 test points to Menara KL transmitter. It is demonstrated that when the distance increases, the signal strength reduces. The highest strength is 94.2 dBµV/m at a measurement distance of 4.62 km. Out of 111 test points, 95 had signal strength greater than 56 dBµV/m of the minimum thresholds, resulting in 89.2 % coverage. The lowest strength is 21.9 dBµV/m at 88.4 km distance from Menara KL. Lower signal coverage will be supported by higher signal transmitted from the other two transmitters. This is one of the advantages of SFN in DVB-T2 transmission. There were some test point locations where the strength is very low even though the distance to the transmitter is near. This is due to the obstruction and interference caused by the hilly terrain and tall buildings at this measurement area.

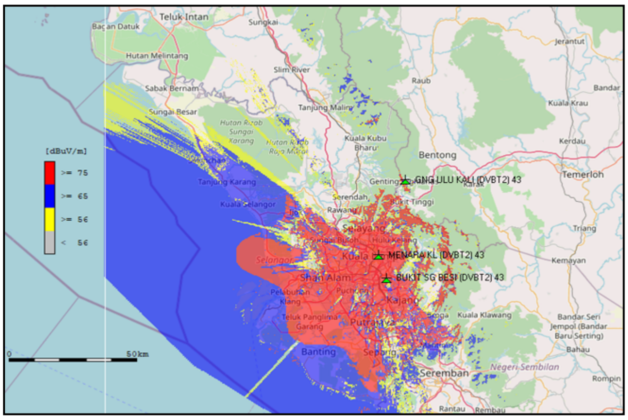


Figure 5. Simulation of coverage area from Menara KL Transmitter

Figure 5 shows the simulation of the coverage area from the Menara KL transmitter. The transmission of the DTT signal from the Menara KL transmitter focuses on the urban areas with high population density in the Klang Valley. The signal from the Menara KL could not cover the state of Pahang and the north of Selangor. This is due to the distance of the transmitter and also obstruction from hilly area of the Banjaran Titiwangsa, which is the longest range in Peninsular Malaysia. The Menara KL transmitter works as SFN network. Thus, it contributes to the increase in signal gain and further improves coverage around the central region of Malaysia especially in urban area.

3.2.2 Field Strength from Gunung Ulu kali Transmitter

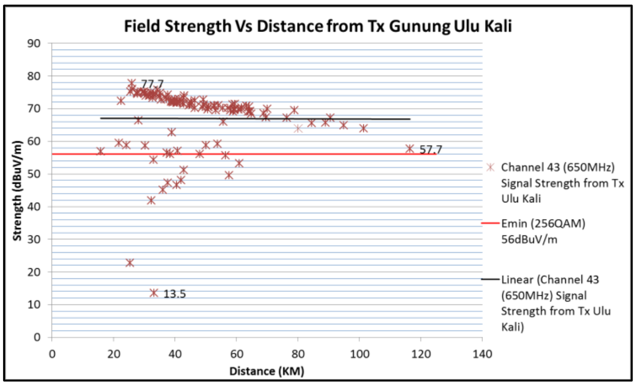


Figure 6. Simulation of Field Strength Vs Distance from Gunung Ulu Kali Transmitter

Figure 6 shows the simulation result of the received signal strength of the 111 test point from the Gunung Ulu Kali transmitter. It is shown that when the distance increases, the signal strength is slightly reduced. The highest strength is 77.7 dBuV/m at a measurement distance of 25.9 km. Out of 111 test points, 99 had signal strength greater than 56 dBµV/m of the minimum thresholds, resulting in 89.2 % coverage. The lowest is 13.5 dBμV/m which is located 33.17 km from the Gunung Ulu Kali transmitter. It is observed that six test points which were located more than 80 kilometers from the transmitter but still received excellent signal strength, which is greater than 65 dBμV/m. This shows that the Gunung Ulu Kali transmitter could transmit DTT signals over a relatively long distance due to the location of the transmitter which is installed in the mountainous area, thus reducing the probability of obstruction.

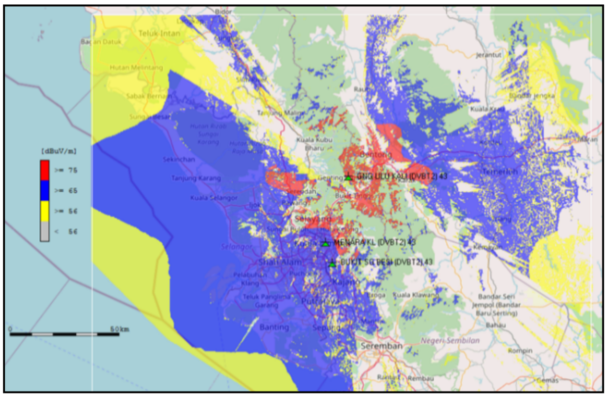


Figure 7. Simulation of coverage area from Gunung Ulu Kali Transmitter

Figure 7 shows the coverage area of the Gunung Ulu Kali transmitter. The transmission of the DTT signal from the Gunung Ulu Kali transmitter provides a very long transmission range covering most areas in the central region of Malaysia, including some area in the state of Pahang excluding the hilly range. Transmission from Gunung Ulu Kali transmitter could also reach the north and south of Selangor, which is not covered by Menara KL and Bukit Sungai Besi transmitters. This shows that Gunung Ulu Kali transmitter could transmit DTT signals over relatively long distance due to the position of the transmitter which is installed in the mountainous are. The Gunung Ulu Kali transmitter also works as SFN. It contributes to the increase in signal gain and further improves coverage around the central region of Malaysia.

3.2.3 Field Strength from Bukit Sg. Besi Transmitter

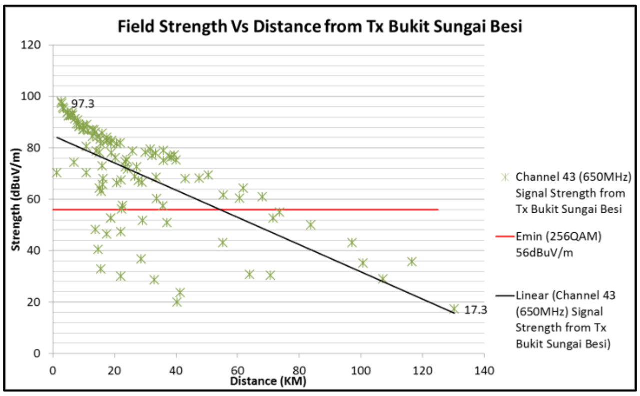


Figure 8. Simulation of Field Strength Vs Distance from Bukit Sungai Besi Transmitter

Figure 8 shows the simulation result of received signal strength from the 111 test point to the Bukit Sungai Besi transmitter. The trend line shows that as the distance to the transmitter increases, the signal strength decreases. At a distance of 2.88 km, the strongest signal is 97.3 dBμV/m. Out of 111 test points, there were only 87 had signal strength greater than 56 dBμV/m of the minimum thresholds, resulting in 78.4% coverage. The received signal strength drops to 17.3 dBμV/m at a distance of 130.35 km from the transmitter. Even though the distance of test location to the transmitter is near, there were some test point locations where the signal strength is very low. This is due to the mountainous terrain and the density of tall buildings obstructing and interfering the signal at this location. The height of this transmitter is only 291 meter which is the lowest among other transmitters resulting in small coverage.

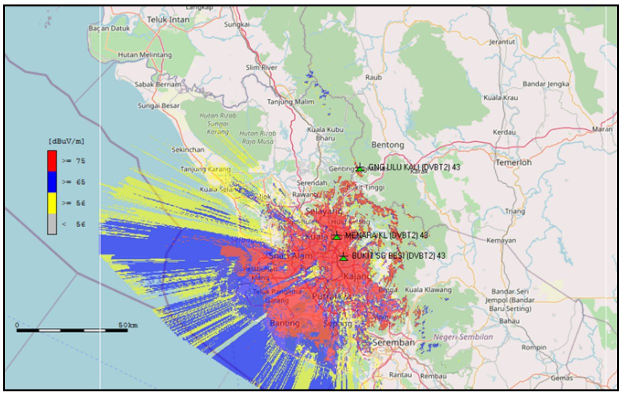


Figure 9. Simulation of coverage area from Bukit Sungai Besi Transmitter

Figure 9 is the coverage area of the Bukit Sungai Besi transmitter's. The transmission of the DTT signal from the Bukit Sungai Besi transmitter is also targeted for the high-density urban area in Klang Valley. Apart from improving coverage around urban area, Bukit Sungai Besi transmitter provides DTT signal to the affected areas if the Menara KL transmitter is faulty. The signal from the Menara KL could not cover Pahang and north of Selangor. This is due to the distance of the Bukit Sungai Besi transmitter and the hills that run across the Banjaran Titiwangsa, which is Peninsular Malaysia's largest range.

3.3 Comparison of Actual FSM and Simulation

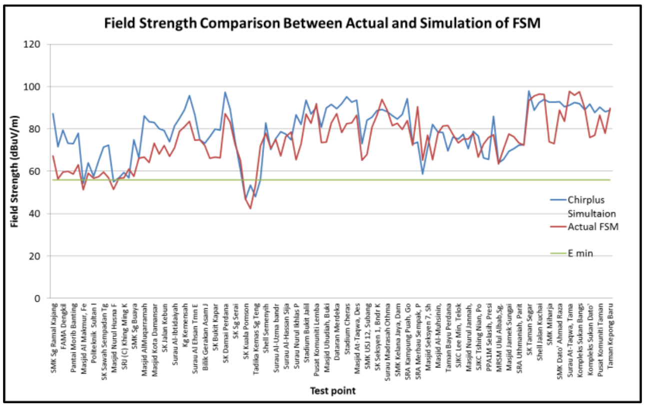


Figure 10. Comparison of field strength value betwen FSM and CHIRplus_BC simulation

The comparison of the field strength value obtained from the FSM and simulation is shown in Figure 10. From this graph, it is found that the measured field strength and the simulation value is within the same range, although there were slight deviations. It shows the measurement accuracy of the FSM. The difference in the field strength readings between the FSM and simulation may be due to the transmitter's parameters set up in the CHIRplus_BC database, such as ERP or the antenna pattern, which is not similar to the actual transmitter. In addition, obstructions and interference from tall building and hilly terrain in the measurement area causing the field strength value of FSM to be lower than the simulation. However, five test point locations which show the lowest Field Strength readings, less than the threshold of 56dBµV/m remained the same for both FSM and simulated results. The location of the test point were Kg. Paya Lebar, Sg. Lui, SK Kuala Pomson, Masjid Al-Makmur, Felda Gedangsa, Masjid Nurul Husna, Felda Sg. Tengi Selatan and Tadika KEMAS Sg. Tekala. The results of this simulation also show that the overall coverage at the test points reached 95.5%. This indicates that with the SFN function, all three transmitters have successfully increased the coverage in the central region of Malaysia.

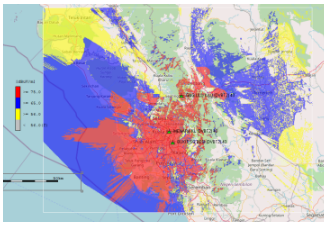
3.4 Simulation of Modulation and Code Rate Parameters

The following section discussed the simulation of two DVB-T2 parameters, which are the Modulation and FEC code rate using CHIRplus_BC in order to observe the improvement of the coverage range and field strength. Parameters for DVBT2 such as bandwidth, FFT size, constellation, Guard Interval and FEC code rate were configured in the database while the modulation constellation and FEC code rate parameters were varied because based on study in [4], these parameters affect the robustness and the coverage of the DVB-T2 signal.

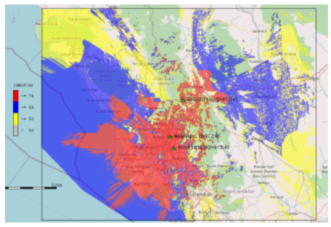
Table 3. Simulation Result of DVB-T2 Modulation and FEC Code Rate Parameter

Modulation	FEC Code Rate	E_{min} (dBµV/m)	Test point coverage (%)	Capacity (Mbps)
256QAM	2/3	56	95.5	34
256QAM	1/2	50	97.3	27.4
64QAM	2/3	50	97.3	27.4
64QAM	1/2	48	98.2	20.5
16QAM	2/3	46	100	18.3
16QAM	1/2	44	100	13.7
QPSK	2/3	40	100	9.1
QPSK	1/2	38	100	6.8

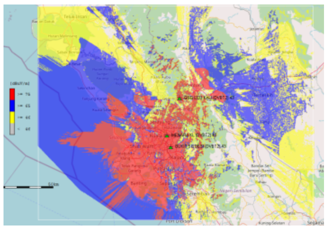
Table 3 shows the simulation results. It is found that the minimum field strength (E_{min}) measurement reading decreases according to the modulation scheme that is from the 256 QAM to the QPSK. In addition, E_{min} measurement was also reduced with the change of the standard FEC code rate 2/3 to the highest FEC code rate 1/2. The highest E_{min} reading of 56 dBµV/m is captured when the modulation was set to 256 QAM and FEC code rate was set to 2/3. The coverage area for the set up was 95.5% of the 111 test points. To achieve 100% coverage, the required parameters are 16 QAM, FEC code rate of 2/3 with E_{min} reading of 46 dBµV/m. Channel capacity decreases with increasing coverage area. At 95.5% coverage, channel capacity is the highest which is 34 Mbps, while at 100% coverage area, channel capacity is reduced to 18.3 Mbps, which reduces the capacity to 46%. This indicates that although there is an increase in coverage area and decrease in E_{min}, there is drawback to the channel capacity.



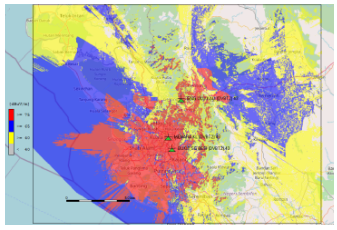
Coverage with 256 QAM



Coverage with 64 QAM



Coverage with 16 QAM



Coverage with QPSK

Figure 11. Comparison of SFN coverage map of various modulation parameters

Figure 11 shows the comparison of SFN coverage map of various modulation parameters as in Table 3. It is found that the coverage area increases especially at the hillside in Hulu Langat dan Hulu Selangor. Although the area is hilly, the region is populated and categorized as rural area. With the changes in modulation from high-order 256 QAM to 16 QAM and FEC code rate of 2/3, five test point areas, Kg. Paya Lebar, Sg. Lui, SK Kuala Pomson, Masjid Al-Makmur, Felda Gedangsa, Masjid Nurul Husna, Felda Sg. Tengi Selatan and Tadika KEMAS Sg. Tekala as mentioned in Section 3.3 have managed to get the DTT coverage.

4. CONCLUSION

It can be concluded that the objectives of this study has been achieved. The FSM performed on 111 test points in the central region of Malaysia shows that there were areas which is not covered by DTT particularly the areas that are close to hills and ranges due to geographical terrain factors. In addition, the coverage of DTT is reduced with the increase in the distance of the measurement area to the transmitter. Furthermore, obstruction from tall buildings and hills in the measurement area also caused the DTT coverage to deteriorate. Simulation of coverage area conducted for three transmitters; Menara KL, Gunung Ulu Kali and Bukit Sungai Besi, showed the DTT transmission performance of these three transmitters. The advantage of the Single Frequency Network (SFN) approach for DVB-T2 transmission is shown in this simulation, where these three transmitters provide good coverage across the central region of Malaysia. SFN can exhibit network gain, where signals from this three transmitters contribute to a higher received signal level and improved coverage in central region of Malaysia. Moreover, the field strength results obtained from the FSM and the simulation is almost in the same range, although there are slight deviations. It shows the measurement accuracy of the FSM. Finally, simulation of modulation parameters and FEC code rate have shown that the coverage area across the central region of Malaysia can be improved by optimizing these parameters.

However, there is drawback in terms of channel capacity reduction that need to be taken into account in the selection of the parameters. This study can give a high impact with further discussions with the DTT operator as an effort to improve the QoS of the DTT in Malaysia. In the end, this impact will benefit the most Malaysians

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