International Journal of Engineering & Technology, 7 (3.7) (2018) 349-353

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Analysis of Single Frequency Network (SFN) Under Delay Time

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Abstract

Single Frequency Network (SFN) is the key advantage option of Digital television terrestrial broadcast. Wherewith, it makes use of the frequency is worthwhile for planning the network. Using SFN makes it possible to cover the broadcast area with just one frequency. In this research, we present the effect of SFN, regardless of the SFN gain, Modulation Error Ratio (MER), Noise margin, by the effect of the signal delay within the guard interval (GI). The finding of this research is that show the SFN gain is higher during the echo delay that is 0 microseconds away. However, on the other hand, MER has declined. The results from this research are useful for designing and improving the SFN network of the digital television transmission.

Keywords: *DVB-T2, single frequency network (SFN); guard interval, the delay time of transmitting signals; MER, SFN Gain*

1. Introduction

The DVB-T2 [1] system is the new generation of standards developed by the DVB organization. This new generation includes the improvement of the different television broadcasting services. In the DVB-T2 system, the signal can be transmitted by the Single Frequency Network (SFN) by using the same information. SFN transmissions can be used with low power transmitters, such as repeaters, to increase signal strength. Even with the use of a gap filler, which increases the efficiency of the frequency spectrum utilization. Consequently, it can increase the coverage area, which is more advantageous than the Multiple Frequency Network (MFN)

Previous studies have investigated the efficiency of broadcast coverage of DVB-T2 with SFN transmission, which research by field test measurement for SISO and MISO modes [2-4]. However, there are a few studies about the effectiveness of SFN DVB-T2 broadcasting, especially analysing the effects of echo delay during the guard interval (GI). Therefore, the purpose of this study is to analyse SFN effects such as the power of SFN gain, Modulation Error Ratio (MER) [5-6], Noise Margin analysis, which effects due to the echo delay between the SFN transmitter in the GI range and the effect of different frequency transmission.

The rest of this paper is arranged as follows. In section 2nd, explained the parameters of this research, the equipment in the laboratory experiment, the measurement data and Analysis Procedures. In section 3rd, the results and discussion. And finally, the conclusion in the section 4th.

2. Experimental Method

This experiment research study was using two exciters for SFN transmission. Figure 1 shows a diagram of this research. We used T2-MI signal which comes from an IRD satellite receiver that receives satellite signals from the MCOT Network. MCOT is one of four digital terrestrial television service providers (MUX) in Thailand. The SFN system requires a T2-MI signal, which is generated from a T2-Gateway device. The MCOT generates a T2-MI signal from T2-Gateway at the central network to use for synchronizing to the SFN network by uplink T2-MI signal via satellite for signal distribute to the DTV MCOT network to the SFN network by uplink T2-MI signal via satellite for signal distribute to the DTV MCOT network.

Figure 1: SFN transmitter and measurement, experimental

The T2-MI signal from the ASI output of IRD is sent to the two exciters so that they both have the same signal. The exciter is connected to the GPS to use the 1PPS signal for synchronizing the SFN transmitter. In this study, two transmitters were used, the power of both transmitters is 100 mW. The transmitter can adjust the frequency and local delay of the transmitter within the GI range. Table 2 shows the modulation parameter for this experiment which GI value is 266 µS.

Table 1: The DVB-T2 channel for SFN experimental

MUX	Channel	Frequency (MHz)
NBT	47	682
ARMY 1	39	618
MCOT	35	586
TBPS	28	530
ARMY 2	51	714

Table 2: The DVB-T2 modulation parameters for Thailand

Parameter	Value
Bandwidth	8 MHz
FFT Mode	16k Extended
Pilot Pattern	PP2
Guard Interval	19/128
Constellation	64 QAM
Constellation Rotation	Off
Code Rate	3/5

The DVB-T2 analyser is ROVER HD PRO TAB is used for measuring and collecting data for analysis. This equipment has measured the RF power strength, MER, Signal to Noise ratio (SNR), Noise margin, BER before LDPC (BBER), BER after LDPC (LBER), Spectrum of Channel analysis and Carrier to Noise ratio (C/N) [7]. The first of analysis procedure is set the RF power strength of the transmitter for measure approximately 20 dB by measure from the DVB-T2 analyser. If the signal strength is too low, it will easily interference and lack reliability in the analysis. Then change the local delay of the transmitter from 0 µS to 270 µS, every 10 µS is measured and recorded the significant values for analysis. Change the frequency of the transmitter and repeat these steps again for experiment with all of five frequency of transmission.

2.1 SFN Gain

SFN is the receiving any signals of multi transmitters by the same data and frequency, but different in delay time between those transmitters in the SFN network [8]. Because of the reception from many transmitter has a gain that is called SFN gain. From equation (1) shows the SFN gain calculation. The received signal from one transmitter has a signal strength equal to Pv, the received signal looks similar to the MFN reception. Consequently, when signals are received from two transmitters or more transmitters, the power strength will increase to 2Pv [9-12]. This gain depends on the location of the receiver.

$$SFNG\ (dB) = SFNpower - MFNpower \qquad (1)$$

The location reception for the SFN [13-16] network has an effect on the received signal. Because of the strength of the signal received from many transmitters in the SFN network are different of received signal power, including different delay times. There are overlays of signals in many forms. The equation for the received signal can be written as

$$r_k = \sum_{n=1}^{N_t} h_k^{(n)} \otimes x_k^{(n)} + w_k\ , \qquad (2)$$

where r_k is received signal of SFN, k is the number of multipath signal, w_k is AWGN , $\otimes$ is convolution, $x_k^{(n)}$ is original multipath transmit signals and $h_k^{(n)}$ is the SFN channel response from the n transmitter, write the equation as follows.

$$h_k^{(n)} = \left[h_k^{(n)}(\tau_1), \ldots, h_k^{(n)}(\tau_{\max}) \right], \qquad (3)$$

where τ_1 is the delay signal in SFN network, l_{th} is path of transmit signal and τ_{max} is the last path delay value of the $h_k^{(n)}$. Each receiver's receiving the signal is not the same time. Since the distance of the transmitter from the receiver is not equal. The equations that describe the delay of each transmitter are as follows.

$$r'_k = \sum_{n=1}^{N_t} h_k^{(n)} \otimes x_{k+T_D(n)}^{(n)} + w_k\ , \qquad (4)$$

where r'_k is the equation adjustment of the delay of the transmitted signal, and $T_D(n)$ is the compensation delay of the transmission value from n of the transmitter.

2.2 Modulation Error Ratio

Quality of service (QoS) is very important for broadcasting. Modulation Error Ratio (MER) can demonstrate the modulation efficiency as well as field efficiency [17-18]. Digital television transmissions, especially DVB-T2 used QAM modulation. Consequently, each dot of the constellation symbolizes the information that is sent in the part of the symbol data. The MER shows the distortion of the amplitude and phase of modulation which shows the result of the received signal due to the receiving channel.

The incoming IQ signal creates a dot on the constellation. If the point that creates not is exactly the point of reference, the MER value is high. The error value of each dot in the constellation point is $\delta I + \delta Q$. The unit of measurement for MER is dB, write the equation as follows.

$$MER = 10 \times \log_{10} \left\{ \frac{\sum_{j=1}^{N} \left(I_j^2 + Q_j^2 \right)}{\sum_{j=1}^{N} \left(\delta I_j^2 + \delta Q_j^2 \right)} \right\} dB \qquad (5)$$

2.3 Minimum Received Signal

Due to the QAM modulation, the received signal is very relevant to the amplitude. On the other hand, can be compared to continuous wave (CW) signal with a uniform average amplitude of the average received signal. From the previous topic, IQ signals were transmitted through the propagation channel are distorted by phase and amplitude all the time, which makes the creation of dots on the constellation incorrect location point. As a result, the original symbol data was sent have to error at the receiver. Therefore, signal strength measurement with C/N is important to inspect the signal quality. To confirm QoS results from the modulation as described in the equations of minimum C/N required are (6) (7) and (8)

$$P_n(dBW) = F + 10log(kT_0B) \qquad (6)$$

$$P_s min(dBW) = P_n + C/N \qquad (7)$$

$$U_s min(dBuV) = P_s min + 120 + 10log(Z_i) \qquad (8)$$

where B is noise bandwidth [Hz], C/N is RF carrier to noise [dB], F is noise figure [dB], P_n is input noise power [dBW], P_s min is minimum signal received power [dBW], U_s min is minimum signal received voltage with Z_i [dBµV], Z_i is input impedance of a receiver (75Ω) and k is Boltzmann constant (1.38*10-23 Ws/K).

2.4 Signal Detection

In this research, using the DVB-T2 analyser receives the signal from the antenna. The received signals are recorded and analysed [19]. The MER of about 20 dB will ensure that the signal is stable, which will give a bit error rate before editing with LDPC, or bBER at about 2 x 10^{-2}. For the minimum receive signal value that can still be awarded, the bBER value must not be lower than this. The channel BER will be sent to the LDPC block to correct the bit error. After the correction, the bit error rate after LDPC was called LBER. The LBER value without signal error is approximately $1x10^{-7}$. After passing the LDPC, it will correct the BER again at BCH. The value obtained from with the last block of Forward Error Correction (FEC) is $2x10^{-11}$. The measurement test point is shown in Figure 2.

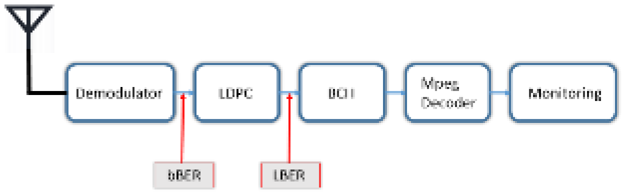

Figure 2: The measurement of bBER and LBER

3. Results and Discussion

Figure 3 Displays The SFN Gain Compared With Different Of Frequency For All Of 5 Muxs. From This Figure Is Compared Between The Delay Time Of The Transmitted Signal (0 µs To 270 µs) And SFN Gain. The Result Shown, If The Increase Delay Time Of Transmitting Signal, The SFN Gain Has A Tendency To Increase. Especially For The High Frequency.

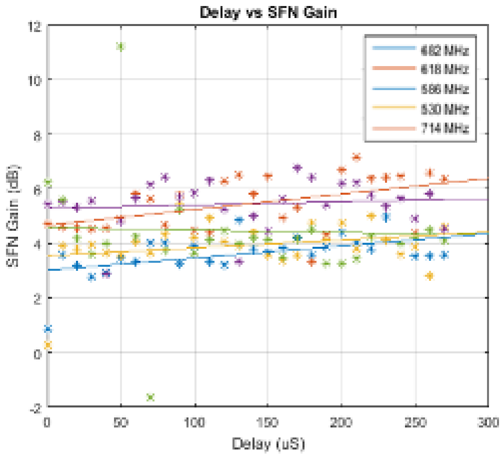

Figure 3: Delay vs SFN gain

All of 5 MUXs the result are the same. For example the higher frequency 714 MHz have more high SFN gain more than the lower frequency. The SFN gain approximately 5 dB. The modulation error ratio or MER when compared with the delay time of transmitting signal change is shown in figure 4. The maximum echoes delay achieved by SFN reception is 270 µS. The MER tends to decrease over the 0 µS interval. The average MER is approximately 18 dB throughout the guard interval. Using the low frequency broadcasts, MER values will be less fluctuation than high frequency broadcasts when the echo delay changed within GI.

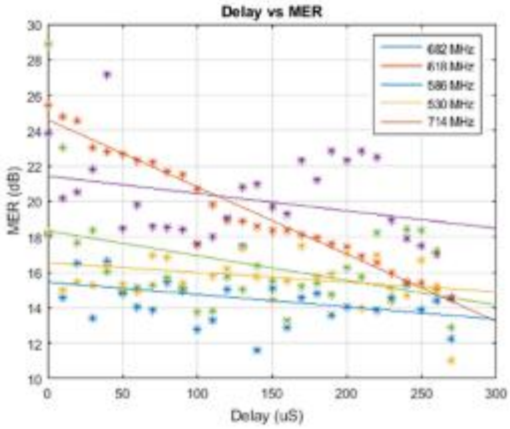

Figure 4 : Delay vs MER

For high frequency, MER at the long delay time of transmitting signal decrease more than lower frequencies. From this experiment, MER is approximately 18 dB. As a result, the SFN in higher frequency, the transmitting signal is difficult to detect the signal. The MER of Figure 4 and the Noise Margin of Figure 5, as compared to the effect of the echo delay, can be seen to be in the same direction. The echo delay time approaches 0 µS, the MER is high and when the echo delay increases from 0 µS to 270 µS, the MER decreases. This is corresponding with the Noise Margin, and is identical in all frequencies used in the experiment.

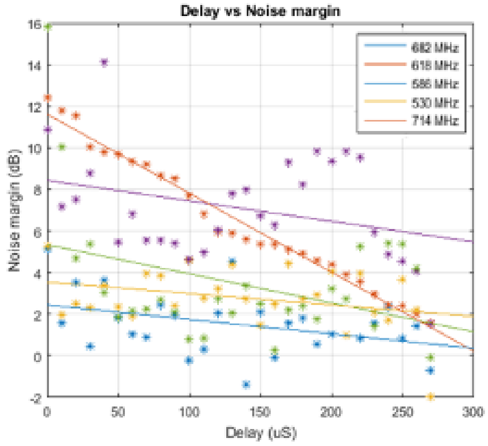

Figure 5: Delay vs Noise Margin

From Figure 5, when the echo delay approaches 0 µS, a strong attenuation of the signal is called 0 dB echo will do severely degrading of the received signal. At this point, the success of the signal reception will require a higher MER than the other echo delay within the GI, Noise margin is lower, signals are more difficult to receive and may be missing, if the strength of the signal received from the two SFN transmitters or more transmitters has equal the signal strength.

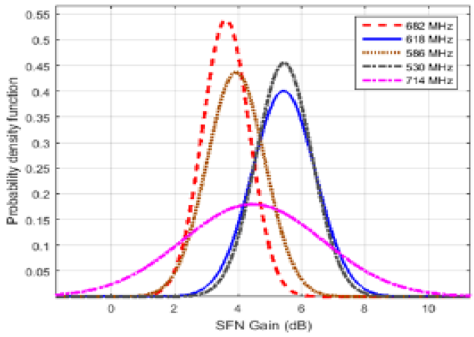

Figure 6: PDF of SFN gain

In addition, by comparing figure 6 and figure 7 shown the probability density function of SFN gain and cumulative probability of MER. It can be confirmed that the effect of high frequency, SFN gain and the MER is also influenced by the long delay time of transmitting signal of two transmitters for SFN network, the effective gain decreases because high frequency is interference more than lower frequencies.

Figure 8 and Figure 9 shows the relationships between SFN gain, MER and delay in the GI range. Figure 8 shows the frequency at 530 MHz. Figure 9 shows the frequency at 682 MHz. it can be seen that the effect of echo delay approaching 0 uS, SFN gain and MER is lower. The average MER of Figure 8 is approximately 20 dB, and Figure 9 is 18 dB. The SFN gain of the 530 MHz frequency is 5.5 dB, while the 682 MHz frequency is 3.5 dB. It shows when using the high-frequency for broadcast, the MER and SFN gain to be affected by the echo delay in the SFN broadcast more than using the lower frequency for broadcast.

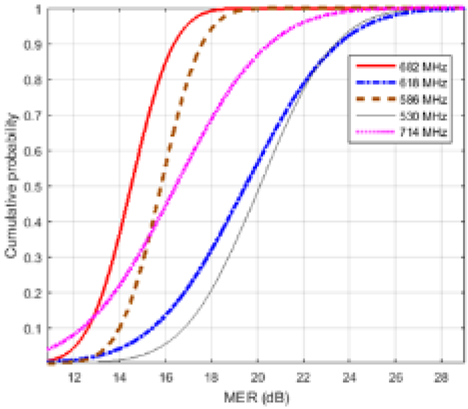

Figure 7: CDF of MER

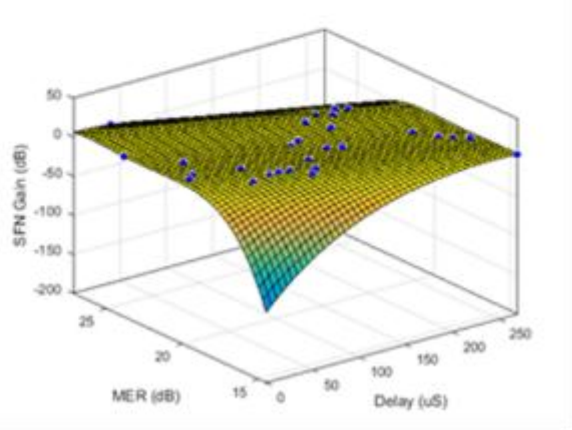

Figure 8: The SFN gain performance (530 MHz)

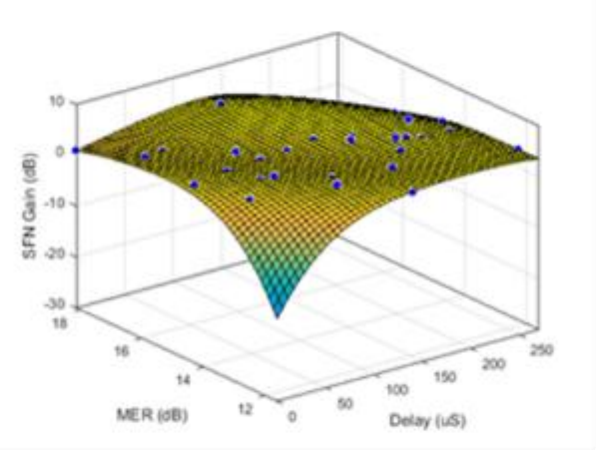

Figure 9: The SFN gain performance (682 MHz)

4. Conclusion

This paper described the result of delay diversity due to the SFN environment by the experimental analysis. The presented technique uses two transmitters and DVB-T2 analyser receivers. To check the improvement of the presented result the delay time of transmitting signal. The results show that the SFN gain affected by the echo delay time within GI. The delay time of the echo delay for SFN transmissions approaching 0 μS is greater than the other echo delay range. The MER performance of SFN is lower than that of the one-transmitter or MFN. The maximum SFN gain, MER, and noise margin diversity gains depending on about for suitable of the delay time of transmitting signal. This experimental and research result is useful for SFN network design. Therefore, this experimental data result can be used to optimize for the optimal signal reception for DTV especially SFN network. And even used as data for the planning of the network to optimize the DTV coverage area.

Acknowledgement

This research was supported by MCOT Company and undergraduate students from the Institute of Technology Ladkrabang, Bangkok. We are thankful to our colleagues and my advisor Dr. Sathaporn Promwong who provided expertise that greatly assisted the research.

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