Experimental Study on Protection Distance between Analog TV and Digital TV in Adjacent UHF Frequency Bands at Terrestrial Television

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ABSTRACT — ***Office of the National Broadcasting and Telecommunication Commission (NBTC), the Thai governmental organization decided to launch digital broadcasting. The implementation has to carry by the broadcasting license; the digital transmission testing has to carry on broadcasting on channel 30 while the analog television has to broadcast on channel 29. The adjacent channel interference must occur between analog television signal and digital television signal because of 20 MHz spacing between both signals.***

This paper proposes the experimental study of testing in order to measure and determining the degradation caused by the analog PAL television signal interferences on the digital television signal. The previous researches have been presented since the beginning of DVB-T broadcasting at several sites by M.N. Sanchez et al. [1] and M. M. Valez et al. [2]. They carried out the laboratory tests to measure the degradation of the bit error rate (BER) caused by analog PAL TV. The variations of adjacent channel interference with regarding the distance from the base station to determine the quality of the digital signal both in town and out of town.

Keywords — Digital TV, PAL TV, Field Strength, Adjacent Channel Interference, Power Ratio, Bit Error Rate, Carrier to Noise ratio.

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1. INTRODUCTION

To broadcast the analog television and digital television while the channels are closed frequency spectrum, there is overlapped frequency spectrum. The degradations are effects from the problem of adjacent channel interference; the next problem is the digital signal quality.

2. THEORY

Ban Nonsaard Station (located at Ban Nonsaard city) is a broadcasting base station in the Sakaeo province, located in the eastern part of Thailand, around 210 km in the east of Bangkok with geographic coordinates; Lat 13° 41 ′ 00 ″ N, Long 102° 33′ 30″ E. Whole terrain is irregular and with numerous mountains, hills and gorges.

The adjacent channel interference results from signals which is frequency adjacent to the required signal as illustrated in Figure 1. It results from imperfect receiver filters which do not have brick wall cutoffs and as a result allow nearby frequencies to leak into the pass band.

The effect of adjacent channel interference in radiation cover service area for channel 29 (analog TV) and channel 30 (digital TV) is illustrated in Figure 1 whereby there is an overlapping of the two closed frequency spectrums which rises to degradations in the received signal strength for both analog and digital television [3].

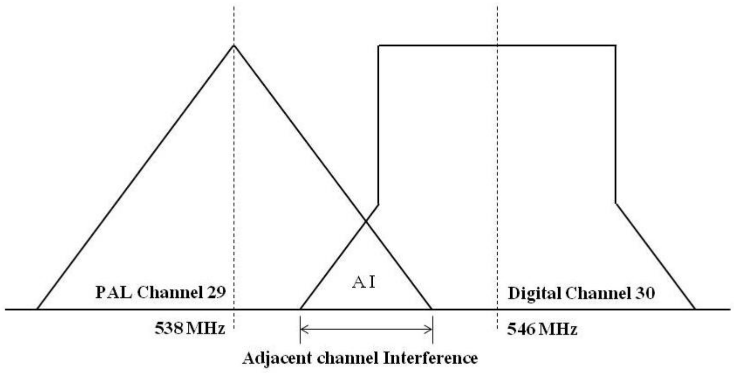

Figure 1: Illustration of adjacent channel interference

The problem of adjacent channel interference (AI) arises from used practical filters for the spectrum of the different channels. Practical filters do not have sharp cutoffs as there is a transition width between the pass-band and the stop-band regions. There is overlapping of the spectrum of the adjacent frequencies, which rises to an additional peak between the center frequencies of the two adjacent frequencies. Figure 2 shows the ideal filter characteristic, |H *(f)*| is the magnitude of adjacent channel frequency.

General, a guard band is available between the spectrums of the two adjacent frequencies in order to minimize the adjacent channel interference [5]. The overlapping occurs in the guard band, is small and does not contribute much in degrading the received signal strength.

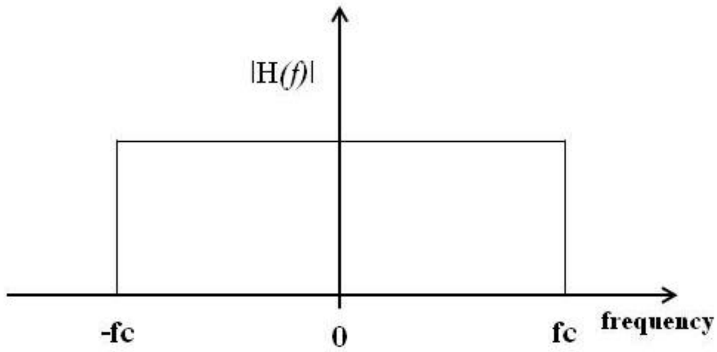

Figure 2: Ideal filter response

However, let the available limited bandwidth for TV broadcasting, the use of guard bands reduces the efficiency of the signal. This portion of spectrum has to be divided into several channels and so much allowance and cannot be guard intervals.

Some area of Sakaeo downtown has the interference signal due to the poor signal transmission. The research has done since the beginning of DVB-T broadcasting at several towns by refs. [1, 2], they carried out some laboratory tests to measure the degradation of BER caused by an analog PAL TV. This paper aims to study the variation of adjacent channel interference as regarding with the distance from the base station, then to determine whether the poor received digital signal in some area of the town depending on this channel interference. The measurement plan is specified and done in the afternoon of the summer, with temperature is about 35 ^{o}C or more. The distances are 5, 10 and 15 kilometers (km) from the base station; each point of the measuring test used a half-wave dipole antenna at the height 4 and 6 meters (m) above ground floor.

3. MEASUREMENT SETUP

DVB-T is approved by European Telecommunications Standards Institute (ETSI) [7, 8], is the most sophisticated and flexible digital terrestrial transmission system available today. It allows digital television service providers to match existing television coverage with a small fraction of the analog transmission power on the digital transmitter. It also extends the scope of Digital Terrestrial Television (DTT) for portable and mobile reception. This standard uses the Coded Orthogonal Frequency Division Multiplexing (COFDM) technique [4], Sakaeo base station has adapted for this standard.

Measurements for both, PAL for Channel 29 and Digital for Channel 30 were taken from Sakaeo base station (Ban Nonsaard location) over three concentric circles of radii 5, 10 and 15 km from the base station, respectively. A 20 W power is used to transmit the digital signal; a receiving antenna is half-wave dipole model AMC/1 UHF band from Promax is used to capture the signal. As shown in Figure 3, the measurements were arranged by using an hp spectrum analyzer model 8592L and a TV Explorer HD+ field strength meter, from Promax signal analyzer is used to measure the BER, the carrier to noise ratio (C/N), the field strength (E) and the carrier to signal interference (CSI). The signal powers for both analog and digital are measured without switching on and off the broadcasting. All used equipments were installed on the measuring vehicle [6].

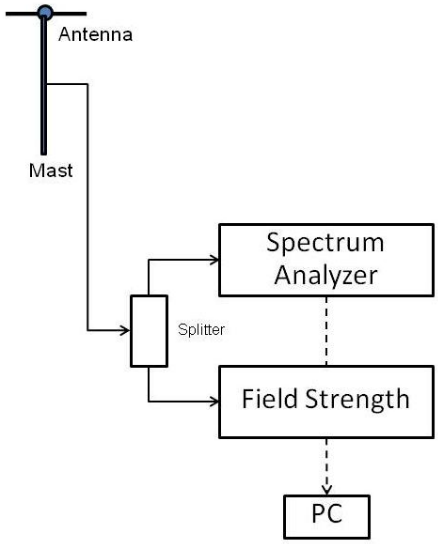

Figure 3: Measurement system block diagram

4. METHODOLOGY AND EXPERIMENTAL DETAILS

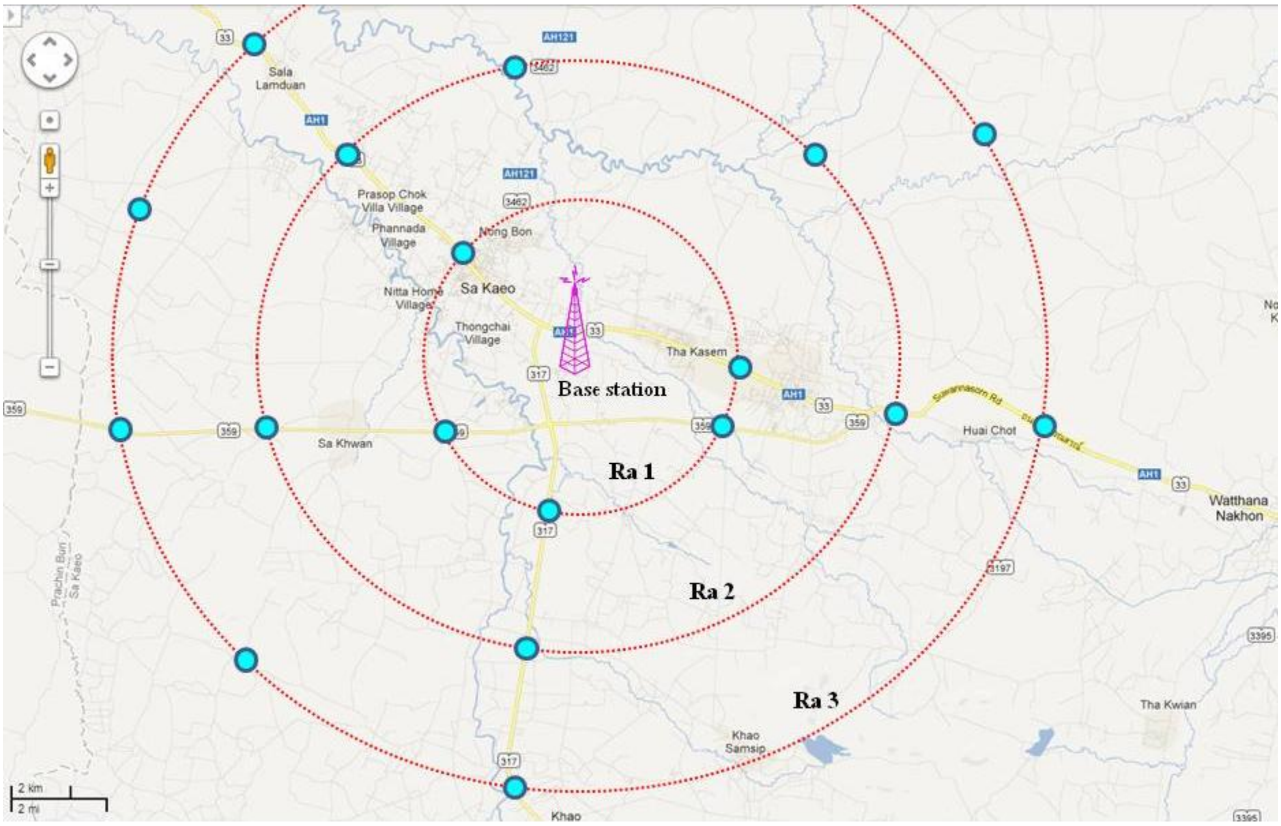

Figure 4: Map of the radiation area of Sakaeo base station (Ban Nonsaard location).

Figure 4 shows the map for the radiation area of Sakaeo base station (Ban Nonsaard location). Measurement locations were divided into three groups, three radiation areas (Ra) concentric circles Ra1, Ra2 and Ra3. The radius represents the horizontal distance between the measured point (receiving antenna) and the transmitter. The radii of Ra1, Ra2 and Ra3 are 5, 10 and 15 km, respectively. Points were selected on the circles as shown in Figure 4 and determined the measuring sites.

The vehicle was stopped at each point and the half-wave dipole antenna from Promax was raised up to the height and was properly oriented towards the transmitter to achieve the maximum signal strength as shown in Figure 5. The measurements were carried out around the relay station, the received signal had been captured by the field strength, and then the BER value, the minimum C/N, CSI were recorded.

Figure 5: Measurement system at the vehicle mobile unit

5. RESULTS AND DISCUSSIONS

5.1 Power ratio variation with radiation area for Ra1, Ra2 and Ra3

Power ratio (PR) in dB, is the degradation of received power between digital TV signal (P_{rD}) and analog TV signal (P_{rA}) and is given as the following formula [9]:

$$PR\ (dB) = P_{rD}\ (dB) – P_{rA}\ (dB) \tag{1}$$

and

$$P_{rD}\ (dB) = E_{rD}\ (dBV/m) + A_e\ (dB) – 10\log_{10}(120\ \pi) \tag{2}$$

$$P_{rA}\ (dB) = E_{rA}\ (dBV/m) + A_e\ (dB) – 10\log_{10}(120\pi) \tag{3}$$

Where

E_{rD} is the field strength of the digital signal for channel 30 (546 MHz) at the receiving antenna.

E_{rA} is the field strength of the analog signal for channel 29 (538 MHz) at the receiving antenna.

A_e is the effective antenna aperture and the constant 120π is the intrinsic impedance of free space in ohms.

Substitute (2) and (3) in (1), the power ratio (PR) can be obtained as follows and the values as shown in Table 1:

$$PR\ (dB) = E_{rD}\ (dBV/m) – E_{rA}\ (dBV/\ m) \tag{4.0}$$

$$PR\ (dB) = E_{rD}\ (dB\mu V/m) - E_{rA}\ (dB\mu V\ /\ m) \quad (4.1)$$

Where

$$E\ (dBV/m) = E\ (dB\mu V/m) - 120 \quad (5)$$

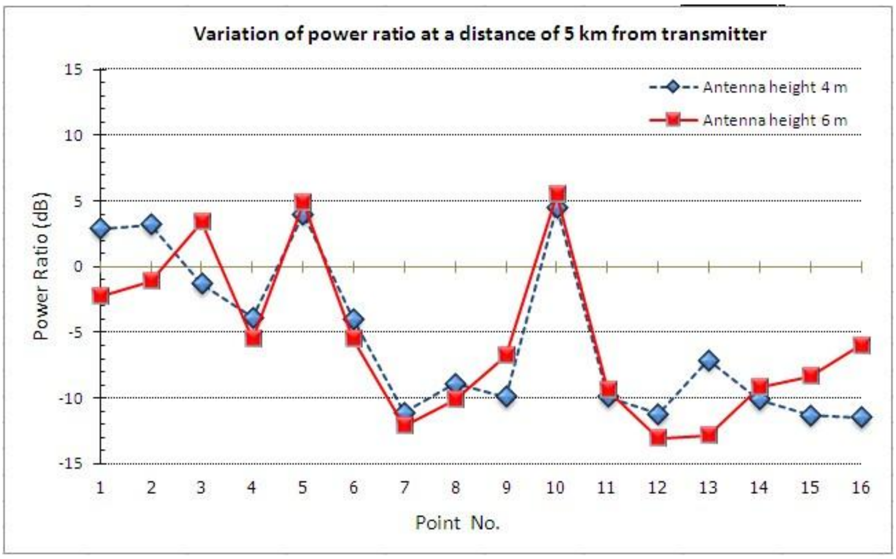

Figure 6: Variation of power ratio for dataset Ra 1

The graph for Ra1 in Figure 6 shows more negative values rather than positive values of power ratio. It shows that the received signal for analog TV is better than the received signal for digital TV by a mean value of -4.5 dB (Table 2).

The degradation in the digital signal may be explained by the fact that a PAL channel (channel 29) is adjacent with respect to the digital channel 30. According to RCC-04 [9], the recommended protection ratio can be obtained from ITU-R BT 1368-2 [10] in 2000 or from CEPT [11]. The frequency difference (Δf) is the vision carrier of the analog television signal (538 MHz) minus the center frequency of the digital TV signal (546 MHz) in MHz and is equal to 8 MHz. It corresponds to a protection ratio of -11 dB from the ITU table of protection ratios (dB) for a digital TV signal interfered by a PAL TV signal [11].

Figure 6, in practical all PR at the measuring points around the base station at distance of 5 km is different; it indicates there is channel interference. Most measuring points satisfy the lower adjacent protection ratio (LAPR) recommended by ITU-R. However, at three measuring points (P 7, P 15 and P 16) of Ra 1, the LAPR was not met; the values of PR are lower than the recommended ITU-R value of -11 dB.

The obtained results refer to the 4 m antenna height. However, the better signals can be received due to the path loss reduction depending on the reduction in multipath effects while increasing the antenna height to be 6 m. The interference level remains unchanged as shown in Figure 6 which is clearly shown by the calculated value of the mean interference level of -5.5 dB and a standard deviation of 6.5 dB, approximately as same as the obtained values for the 4 m antenna height. The presence of the lower adjacent channel interference (LACI) persists while raising the antenna height to be 6m, but PR does not depend upon the antenna height. This experiment shows there are interferences at measuring points P 7, P 12 and P 14 of Ra 1 since the PR values are less than -11 dB, specified in [10].

Table 1 shows the results of the power ratio between analog and digital TV at 5, 10 and 15 km from the base station. Figure 7 shows the plot of the variation of PR at a distance of 10 km around the transmitter. The increasing of distance from the base station reflects the increasing of path loss which is proportional to the distance from the base station. Thus, the signals of lower power are expected to be received. However, the measurements and calculations show the overlapping area not depending on the distance from base station. The adjacent channel interference for a distance of 10 km from the base station which depends on the overlapping is expected to be approximately same as distance of 5 km. It is clearly shown in Figure 7 for both 4 m and 6m antenna heights which provide the mean values and standard deviations approximately the same values in Table 2 that obtained from Figure 6. Most values of PR satisfy the recommended ITU-R LAPR of -11 dB. Three locations at Ra 2 (P 5, P 7 and P 8) suffer from LACI at the 4 m antenna height and four points at Ra 2 (P 2, P 3, P 7 and P 8) suffer the same while raising the antenna height to be 6 m. It should be noted the locations P 7 and P 8 are the most affected the building in the downtown.

Table 1: Power ratio between analog and digital TV at a distance of 5, 10, 15 km from the base station

Point No.	Antenna Height (m)	Level Difference (dB)		
		Ra 1	Ra 2	Ra 3
P 1	4	2.9	8.6	3.5
	6	-2.3	9.7	2.9
P 2	4	3.2	-7.9	1.7
	6	-1.1	-12.9	1.1
P 3	4	-1.3	-7.9	-12.9
	6	3.4	-11.8	-13.1
P 4	4	-3.9	-5.3	8.9
	6	-5.5	-8.1	10.0
P 5	4	4.0	-17.5	-8.7
	6	4.9	-20.1	-7.7
P 6	4	-4.0	-5.8	-12.4
	6	-5.5	-9.8	-11.2
P 7	4	-11.1	-29.4	-7.5
	6	-12.1	-31.0	-6.9
P 8	4	-8.9	-30.7	6.5
	6	-10.1	-29.7	7.9
P 9	4	-9.9	-3.1	15
	6	-6.8	-6.3	16.7
P 10	4	4.5	-8.9	9.5
	6	5.5	-9.7	11.9
P 11	4	-9.9	-2.6	-9.8
	6	-9.4	-1.6	-11.1
P 12	4	-11.2	-2.1	-3.8
	6	-13.1	-5.6	-4.5
P 13	4	-7.1	-6.5	0.6
	6	-12.9	-1.7	1.9
P 14	4	-10.1	-1.6	-7.8
	6	-9.2	1.7	-5.9
P 15	4	-11.3	9.8	12.8
	6	-8.4	3.9	10.7
P 16	4	-11.5	-7.3	5.2
	6	-6.0	-11.4	8.1
P 17	4	No	No	15.5
	6	No	No	13.8
P 18	4	No	No	-6.5
	6	No	No	-5.5

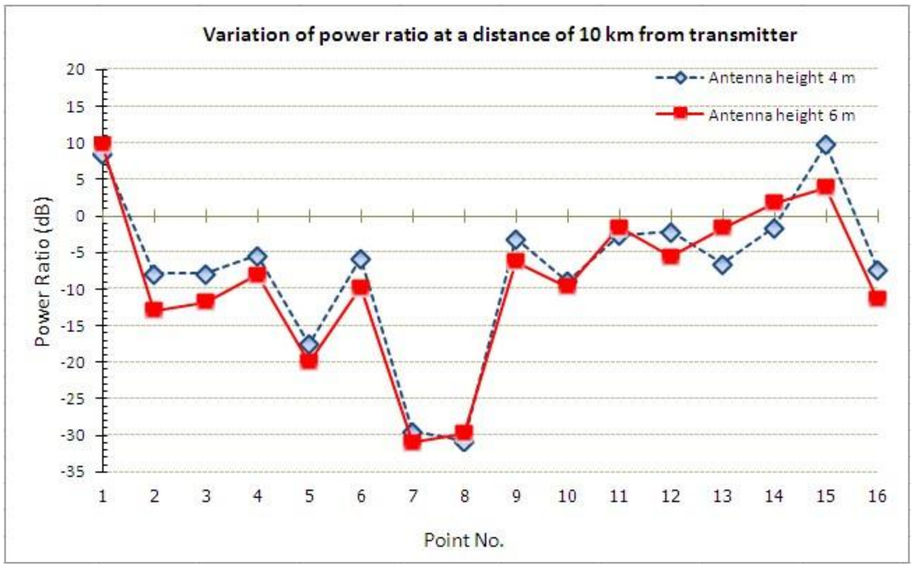

Figure 7: Variation of power ratio for dataset Ra 2

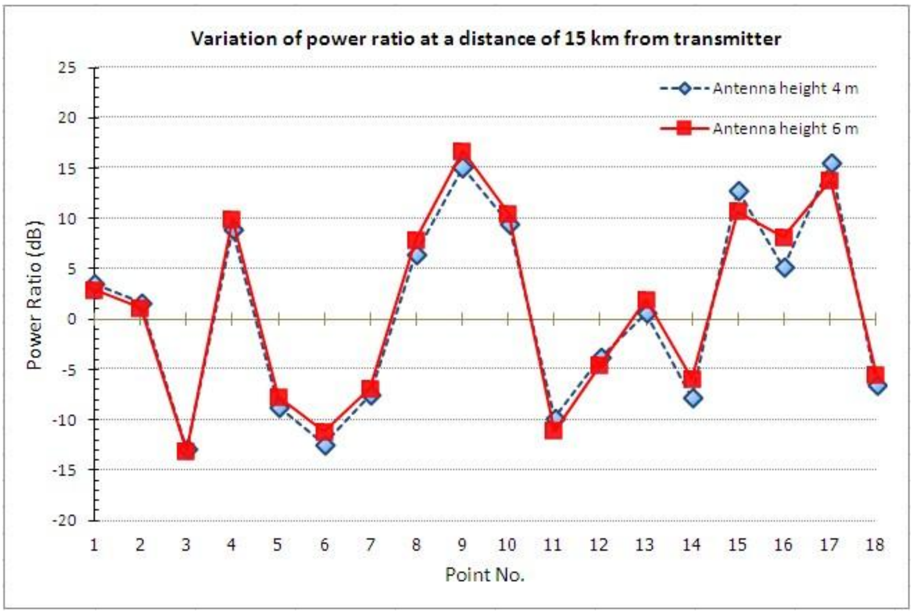

Figure 8: Variation of power ratio for dataset Ra 3

Table 2: Comparison of power ratio for the three distances (5, 10, 15 km)

	Ra 1		Ra 2		Ra 3	
	4 m	**6 m**	**4 m**	**6 m**	**4 m**	**6 m**
Std. dev.	6.14	6.49	7.51	7.79	7.73	7.14
Mean	-4.51	-5.56	-3.66	-4.14	-1.76	-1.57

Table 2 shows the comparison of power ratio at 5, 10, 15 km. The obtained results are plotted in Figure 8 for a distance of 15 km, it proves that the area of adjacent channel interference or AI due to the overlapping of the two spectrums remains constant and does not depend on the distance from the base station. Two measuring points at Ra3 (P 3 and P 6) for both 4 m and 6 m antenna heights have lower PR than recommended in [10].

6. CONCLUSION

Field strength measurements were carried out to check the degree of adjacent channel interference of the existing analog TV signal over the newly digital TV signal in the Sakaeo downtown. The calculations show that most of the measuring points have a PR that meet the recommended ITU-R protection ratio of -11 dB. Measurements were made using the different antenna heights for 2 m of each step. The tests show that there is negligible effect on the value of the channel interference at the 4 m and 6 m antenna heights. The experiment were carried on based on three distances from the base station, the results for distances of 5, 10 and 15 km and can prove that the power ratio due to the overlapping of the two spectrums remains constant and does not depend upon the distance from the base station.

Most measuring points satisfy the lower adjacent protection ratio recommended by ITU-R. Only at 36 measuring points out of 13 points around Sakaeo base station, the LAPR cannot be found, the values of PR are lower than the recommended ITU-R value of -11 dB. Sakaeo downtown is the mostly affected region; an extensive measurement plan has to be conducted to identify the problem that exists at Sakaeo downtown since the PR is very low when compared with the ITU-R value.

7. ACKNOWLEDGEMENT

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