Experimental Evaluation of Multiple Antenna System for In-Vehicle Digital Television Reception

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Abstract Multiple antenna techniques provide more reliability and increase capacity of communication systems without any additional bandwidth or transmit power. In this paper, a multiple antenna system for in-vehicle digital television (DTV) reception has been implemented and evaluated by the field experiment. Four patch antennas and a set-top box were installed in a shuttle bus which provides a transport service for Eastern Seaboard factories. The DTV reception in the shuttle bus has been tested and assessed over the routes around Rayong City in the North, East, West, and South directions, where the weak signal coverage has been encountered in several areas along the routes. Good reception quality and reliability have been achieved all the way along the test routes without any interruption.

Keywords Digital terrestrial television, In-vehicle TV reception, Multiple antenna system.

1. INTRODUCTION

The terrestrial digital television (DTV) has been deployed in Thailand since 2014. Presently the DTV network consists of 39 broadcast stations providing the coverage of about 85% of the whole country, and it has been continuously expanding. The home reception is currently available in almost all residential areas. Besides watching TV at home, some people may want to watch TV in vehicles while travelling on the road, especially for a long trip or under traffic congestion. However, some suburban or rural areas passed by the main and local routes possess weak or even none of DTV signal coverage. As a result, the DTV reception in vehicles while passing through such areas can be intermittently unavailable and thus watching TV is interrupted.

ATP30 is a public company which provides a transport service for Eastern Seaboard factories. The company has about 200 shuttle buses commuting between Rayong City and Map Ta Phut to convey workers to and from factories in Eastern Seaboard. Every shuttle bus offers the in-vehicle TV service to their passengers during travel. The TV service was previously provided by the satellite TV system. However, it suffered signal fading when the bus passed through the areas having high buildings, tall trees, or high-voltage transmission towers, as well as under heavy rain condition. On the other hand, the terrestrial DTV service in the shuttle bus is unfeasible due to the weak signal coverage in several areas along the route so that the poor reception was encountered periodically.

This work has proposed the implementation of multiple antenna techniques for the terrestrial DTV reception in the shuttle bus to solve the company's problem. Multiple antenna techniques have shown to provide more reliability and increase capacity of communication systems without any additional bandwidth or transmit power [1]. The utilization of multiple antenna techniques for digital video broadcasting (DVB) systems has been introduced and studied previously in [2]. A DTV reception system consisting of four patch antennas and a set-top box were installed in a shuttle bus of ATP30 company. The field experiment has been carried out to evaluate the DTV reception performance in the shuttle bus travelling along the test routes around Rayong City in the North, East, West, and South directions, each within the distance about 30 km from the nearest broadcast station at Khao Yaida. Field test results are reported in this paper. It is shown that good DTV reception in the shuttle bus was achieved all the way continuously along the test routes without any interruption.

2. BASIC PRINCIPLE

The implementation of multiple antennas on receive side is known as single-input multiple-output (SIMO), which is described by a block diagram in Fig. 1. The use of multiple antennas with sufficiently large spacing provide different propagation paths (or channels). In the SIMO system with N antennas on the receive side, N copies of the same data are transmitted via N different channels having independent fading characteristics. Even if one of the link fails to deliver the data, there is still high chances of proper delivery of the data via the other links. Additional fading channels reduce the probability that all channels are in a deep fade, thus increasing the reliability of the overall transmission. The improvement in reliability results in the performance improvement, known as diversity gain.

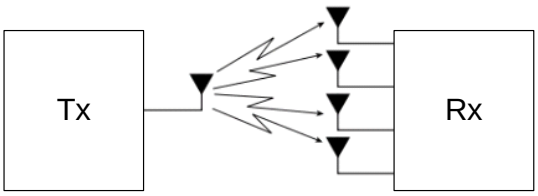


Fig.1. Block diagram of single-input multiple-output (SIMO) system.

The total number of diversity paths for the SIMO system with N receive antennas is $1\times N = N$. The channel model for the system is given by

$$\mathbf{y}[m] = \mathbf{h}[m]\cdot x[m] + \mathbf{w}[m] \quad (1)$$

$$y_i[m] = h_i[m]\cdot x[m] + w_i[m], \quad i = 1,\ldots,N \quad (2)$$

where $w_i[m]$ is additive noise of channel i which is independent across channels (or receive antennas), and $h_i[m]$ are fading coefficients of channel i.

The optimal diversity combining is obtained by

$$r[m] = \mathbf{h}[m]^* \cdot \mathbf{y}[m] = \|\mathbf{h}[m]\|^2 \cdot x[m] + \mathbf{h}[m]^* \cdot \mathbf{w}[m] \quad (3)$$

with the signal-to-noise ratio (SNR) given by

$$\gamma = \|\mathbf{h}\|^2 \mathrm{SNR} = (N\cdot \mathrm{SNR})(\frac{1}{N}\|\mathbf{h}\|^2) \quad (4)$$

where N is the power (or array) gain and the diversity gain is $\|\mathbf{h}\|^2 / N$.

3. Experiments and Results

The Configuration of four antennas and a set-top box for a DTV reception is illustrated by Fig. 2.

Fig.2. Configuration of four antennas and a set-top box for a DTV reception system.

Four antenna system and a set-top box were installed in a shuttle bus of ATP30 company which provides a transport service for Eastern Seaboard factories. The shuttle bus commutes between Rayong City and Map Ta Phut. The DTV signal coverage in Rayong areas is broadcasted from the station at Khao Yaida, Rayong, as shown in the map of Fig. 3.

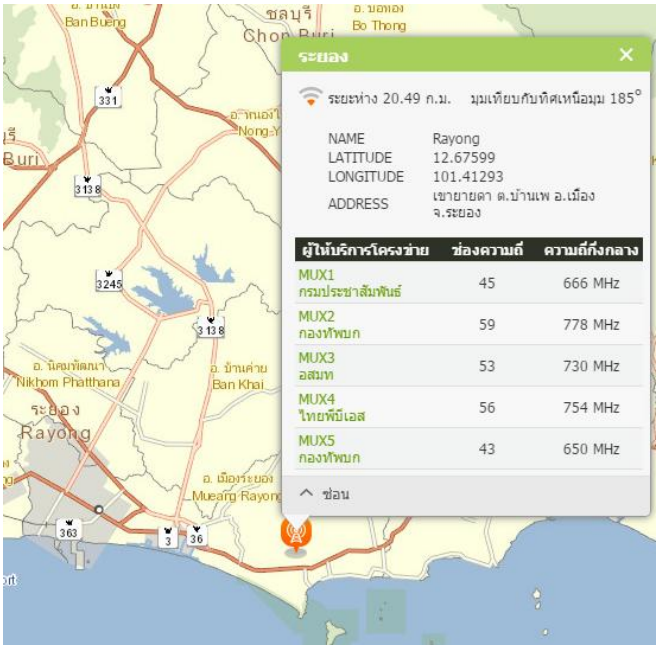


Fig. 3. The location and MUX details of the DTV broadcast station at Khao Yaida, Rayong.

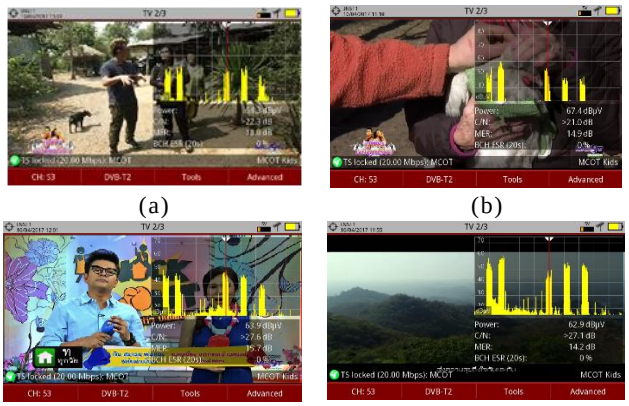
Four antennas employed are the patch antennas developed by these authors as presented in [3]. The antenna has the Omni-directional pattern with the following characteristics: return loss (at center frequency) is 30.7 dB, VSWR (at center frequency) is 1.05, input impedance is about 52-60 Ω, and forward gain is 6 dB. Two antennas are installed on the top-right and top-left corners of the windshield, respectively, while the other two antennas are mounted on the right and left windows at about 3 m from the front of the bus, as shown in Fig. 4.

Fig. 4. The positions of four antennas installed in a shuttle bus.

The shuttle bus was driven for the field test over the selected routes around Rayong City in the North, East, West, and South directions, each within the distance about 30 km from the broadcast station at Khao Yaida. The DTV reception in the shuttle bus

was measured and assessed by using a field strength meter. It was found that the received signal strength is 80-100% of the full scale all the way along the test routes even the bus was travelling at the fast speed, as shown by the indicator on the TV screen in Fig. 5. The received signal spectra in the selected test areas are shown in Fig. 6.

Fig. 5. Signal indicator on the screen showing strong received signal level while the bus was moving at the speed of 80 km/hr.



(a) (b)

(c) (d)

Fig. 6. Received signal spectra in the selected test areas in Rayong; (a) North: Janudom Junction, (b) East: Noen Sam Lee Junction, (c) West: Nong Fab Junction, (d) South: Map Ya Intersection.

The corresponding received signal parameters are shown in Table 1. It was found that the received signal power is more than 60 dBμV and the C/N is greater than 20 dB in all test areas. As a result, good reception quality and reliability has been achieved without any interruption.

Table 1: Received signal parameters in the test areas.

Areas	Power (dBμV)	C/N (dB)
North: Janudom Junction	64.3	22.3
East: Noen Sam Lee Junction	67.4	21.0
West: Nong Fab Junction	63.9	27.6
South: Map Ya Intersection	62.9	27.1

4. Conclusions

A multiple antenna system for the DTV reception in a shuttle bus has been implemented and its performance was evaluated by the field experiment. The DTV reception system consisting of four patch antennas and a set-top box were installed in a shuttle bus of ATP30 company. The DTV reception in the shuttle bus was tested and assessed over the routes around Rayong City in the North, East, West, and South directions, each within the distance about 30 km from the broadcast station at Khao Yaida. The results show good reception quality and reliability achieved by the four antenna system all the way along the test routes without any interruption.

References

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