Spatial Variation of Digital Television Signal in an Indoor Environment

A/P Ong Jin Teong, Ms. Yan Hong, Mr. Shanmugam Ganeshkumar
GPS Centre, College of Engineering (BLK S2-B4c-17)
Nanyang Technological University, Singapore 639798
Tel : +65 6790-5372 Fax : +65 6790-6059 Email :jtong@ntu.edu.sg

Abstract: This paper describes the equipment used and the procedures adopted for the measurement of received signals and other quality of service (QOS) parameters from a single transmitter in two identical unoccupied apartments situated at the third and fifth levels above the ground. The spatial variations of the received signal in the apartments have been analyzed and the main results presented. The behaviour of other parameters will be briefly discussed and would be presented in more details in later papers. The objective of this study is to refine the measurement procedures, which will be used later to characterize the received signal (and other QOS parameters) in different indoor environments in the dense urban Housing Development Board (HDB) environments in Singapore. The results will be used for the planning of the future fixed digital TV service in Singapore.

Key words: spatial variations, quality of service (QOS), digital TV

1. INTRODUCTION

For the planning of the future fixed wireless digital TV service in Singapore, the reception of signals and other QOS parameters in both the indoor and the outdoor environments must be characterized to be able to determine the number and characteristics for transmitters required to provide a minimum acceptable service to be provided. Since approximately 90% of the Singapore population lives in the high-density urban HDB environment, the characterization of QOS parameters in such environment is extremely important. The reception in such environments has not been investigated before.

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This paper will concentrate on initial measurements in the indoor environment [1]. For this preliminary study two unoccupied three bedroom housing units - one at level three and another at level five were used for the first campaign of measurements. These two units are part of 18-unit on a 12 story block situated in the campus of the Nanyang Technological University. There are several other blocks of housing blocks in the vicinity. This particular block was chosen because there is line-of-sight from level five to the TV transmitter. At level three the transmitter is blocked by housing block about 220 meters away.

In section 2 the equipment used for the measurements and the procedures will be briefly described. Measurements were made along a line in the apartment and, at selected locations, detailed measurement were made within a one square meter. Some spatial variations of the received signals are shown in section 3. Over small-scale spatial distances there are significant variations of the received signals, however if the signals over a short but larger-scale distance are averaged, the average signal varies across the room. The small-scale spatial variations of signals are similar to the temporal variations (fading) encountered in a mobile environment. In section 4, the cumulative distribution function (CDF) of the received signals is analyzed. Other interesting observations are also briefly reported in section 5.

2. Measurement Set-up and Procedures

During this experiment, transmission from the transmitter located at Bukit Batok was used. The elevation of this site is 80meters m.s.l. The antenna is located 214 meters above ground level. The transmission channel selected is Channel 37, with 602MHz as central frequency and 8 MHz bandwidth. The transmitter EIRP is around 47.78 dBW.

To obtain a reference receiving signal outside the apartment, the equipment used consisted of HP 8595E Spectrum Analyzer, Log-Periodic Antenna, laptop computer. The Labview V5.1 software preinstalled in the laptop controlled the HP 8595E Spectrum Analyzer via a GPIB-PCMCIA interface and recorded the measurement results (*Figure 1*). With this equipment set-up, the antenna was held outside the room window, pointing towards the transmitter for 3 minutes. A total of 256 measurements were made and the median value was taken as the outside reference receiving signal value.

Figure 1. Equipment set-up for obtaining the signal strength outside the window

The indoor measurement system shown in Figure 2 consists of the following:

- TV & Satellite Analyzer (PROMAX, Prolink-7)
- Indoor TV Omni-directional antenna (SOUND TECH, HL-669A)
- Tripod stand
- Laser pointer
- Attenuators (10dB, 6dB, 3dB)
- Personal Computer

Figure 2. Indoor Measurement equipment setup

Firstly, the measurement **along a line** (1-D) was conducted in the living area (on both the 5th floor and 3rd floor). A long piece of masking tape with 5cm markings was pasted on the floor from one end of the living room to the family room (1135cm in length). The layout of the apartment is shown in Figure 3.3. The antenna was mounted on a tripod stands at a height of 127cm and moved point by point along the line. For all measurement the

antenna was orientated in the direction of the transmitter. A total of 227 values were collected and used to represent the statistics of the signal strength variation along the line.

Secondly, an **area measurement** (2-D) was done in the master room (on 5th floor only). A 1m x 1m grid paper, with 400 points evenly distributed at 5cm spacing each, was placed near the master room. The same indoor TV antenna facing transmitter site was placed over the grid paper. To determine the point of measurement accurately, a laser pointer was attached to the tripod stands and the laser beam was shone on the grid paper, coinciding with the desired point. The total amount of 400 data was collected along the path pre-assigned for further analysis.

3. SPATIAL VARIATION OF RECEIVED SIGNALS

3.1 Measurement along a line

A total of 227 values were taken along the line on both of 5th floor and 3rd floor and displayed in Figure 3 & Figure 4 respectively.

Figure 2. Signal Variation for Straight Line on Fifth floor

Figure 4. Signal Variation for Straight Line on Third floor

From the figures presented above, it can be seen that there is a large variation of the received signal with small-scale changes in location. The signal varies as much as 35dB on Fifth Floor (27 dB on Third Floor) due to the effects of wall transmission loss and multipath propagation. It is observed that the signal strength drops when the received signal has to travel through more walls (Refer to Figure 5).

Figure 5. Apartment Layout

3.2 Measurement within a square

Figure 6. 3D Plot of Signal Strength Distribution

A 3-D distribution of signal strength for the 1m by 1m square is shown in Figure 6.

The x-y axis of the graph plotted indicates the measuring points within the square while the z-axis shows the signal strength. The origin is at the bottom right hand corner of the graph. From the graph, it can be seen that the maximum and minimum signal values of the area occurring at the point (6.5, 20) and point (20, 7.5) respectively.

The result shows that at points with line-of-sight (LOS) to the transmitter there is lower multipath “fading” and with no wall transmission loss, the signal strength is stronger. At positions of the points blocked by the wall or other obstruction there are high multipath “fading” and wall transmission losses; hence the signal strengths are weaker.

4. STATISTICAL DISTRIBUTIONS OF RECEIVED SIGNAL AND QOS

Figure 7 depicts the cumulative distribution function (cdf) for the signal strengths measured along the line on the fifth floor.

Figure 7. The Cumulative Distribution Function

By using MatLab programming, the mean of the distribution is found to be 63.83 dB μ V. This represents the average signal strength across the line. The median, which is the 50% point of the cdf, is also found to be 64.7dB μ V. Since the mean and median are not of the same value, [thus it can be concluded that the signal is not log normally distributed (Note: The received signals are in dB).

The cdf of the raw data collected for the line on the fifth floor was plotted on the probability paper. It can be seen that between 26% to 95% there is a straight-line fit. This suggests that as a rough approximation a lognormal distribution could be used to model the variation of signal strengths up to approximately 95% probability. The standard deviation for this cdf is 7dB. In the definition for area coverage for DVB-T [2], 95% coverage over a small area is defined as “good” and 70% is defined as “acceptable”. To obtain a more accurate lognormal distribution, the received signals should be averaged over a short distance (to remove the large variations of the signal strength with small-scale distance changes). The analysis is not yet completed.

5. OTHER SIGNIFICANT OBSERVATIONS

In this experiment, other parameters such as the *statistical distribution of BER*, *correlation of Rx signal with BER*, *time variation* (small scale effects due to the presence of personnel) were investigated. When one person walked across the area between the transmitter and receiving antenna the signal strength varied; there were also amplitude variations across the video

spectrum. Difference results were obtained when directional antenna instead of omni-directional antenna were employed. The data are being analysed and will be presented in details in later papers.

6. CONCLUSIONS

In this paper, we presented preliminary results of the spatial variation of the received signal strength of the DVB-T TV received signal operating at UHF band in an indoor environment.

The signal strength on the third floor has greater variation as compared with that on the fifth floor. This is could be because that the receiving antenna on the third floor does not have any line-of-sight (LOS) to the transmitter, the multipath signals gives rise to Rayleigh “fading”. On the fifth floor, there is a dominant signal, giving rise to Ricean “fading” which is not as deep as Rayleigh.

There is a rise in the wall transmission loss when there is an increase in the number of buildings and walls between the transmitter and the receiver.

The received signal could be roughly approximated by a lognormal distribution over a range of probability.

7. REFERENCES

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