Urban Radio Propagation Measurement for Digital TV Broadcast in Jakarta, Indonesia

By Gamantyo Hendrantoro, Member, IEEE, Hary Budiarto, A. A. N. Andana Kusuma, Arief Rufiyanto, Satriyo Dharmanto, Bambang Heru Tjahjono, Endroyono, Suwadi

Abstract—Radio propagation measurement is carried out in Jakarta, Indonesia, in anticipation of digital TV implementation in the country. Measurements are made using a fixed, portable receiver outdoors and indoors. Spatial variations of the received power, both large-scale and small-scale, are measured in these locations. Results show that the large-scale path loss variation characteristics, as described by a power-law dependence on distance with shadowing-induced variation, are typical of those found in urban areas. Small-scale spatial variations are also examined by comparing the measurements with exponential and lognormal distribution for all outdoor and indoor locations.

Keywords—digital television, measurement, radio propagation.

I. Introduction

Recent years have witnessed rapid growth in terrestrial digital TV implementation. This phenomenon does not only belong to the developed countries, but the developing ones as well [1]. In planning the digital TV broadcasting system, knowledge of radio propagation characteristics is imperative. Inexistence of such information would lead to non-optimal network planning that might result in costly operation of transmitters by the broadcast operator and low service quality on the consumer side ([2], [3]). A large number of radio propagation measurement efforts for digital TV broadcast network planning have been reported in the literature. For instance, radio channel and/or network performance measurements have been made in Germany [4], Spain [5]–[6], Ireland [7], and other countries involving the implementation of DVB-T system. Results from various countries, although obtained through possibly the same procedure, might vary to a significantly large extent. This might have something to do with the local characteristics of radio propagation environment and the specific situations in which the test transmitter and the receiver operate. For example, the type and density of buildings in large cities in different countries can considerably differ, which in turn implies different random characteristics of radio propagation pertinent with such mechanisms as reflection, transmission, scattering, and diffraction.

This article reports a measurement campaign that was carried out in downtown Jakarta, Indonesia during the 2007–2008 period. The city is the largest in population in the country, but the tall buildings are not as spatially dense as those in large cities in Europe or North America. A DVB-T test transmitter is used to transmit multiple programs, digitized versions of local TV programs originally broadcast using analog TV systems. The transmit power is approximately 400 W radiated through an omni-directional antenna at an elevation of about 120 meters. Measurements were made outdoors and indoors, targeting at reception using fixed, portable antennas. For outdoor measurement, results for LOS (line-of-sight) and NLOS (non-line-of-sight) conditions are distinguished. The analysis of measurement results reported herein focuses on distance-dependent variation of local mean of the received power, shadow fading variation, and spatial variation of received power in small areas. The article starts with the description of the measurement system, followed by the results of the measurement and analyses of the channel characteristics. The analyses are divided into two sections, namely, those on large-scale variation and small-scale variation.

II. Measurement System and Locations

A DVB-T test transmitter is used to transmit simultaneously five programs, MPEG-2 encoded versions of local TV programs originally broadcast in analog PAL system. The modulation settings used are 8K mode, 16-QAM, 3/4 code rate, and 1/16 guard interval. The test transmitter is installed on a 120 m tall tower property of the state-owned TV operator, TVRI, and is transmitting at 575.25 MHz (channel 34). The output power of the transmitter is about 400 W, but the ERP is 44.47 dBW. The DVB-T signal is radiated through a directional horizontally-polarized antenna having a half-power beamwidth of approximately 230°.

The measuring equipment consists of two sets of instruments. The first is a Promax Prodig-5 used in measurement of received power and carrier-to-noise power ratio (C/N). The second set consists of Pixelmetrix instruments that include DVStation Remote, DVStation POD-TSP, DVStation POD-DVB-T and DVStation POD-COFDM, designed to measure the performance of a digital TV network. A rectangular patch antenna commonly used for vehicular reception of TV signal is employed and invariably positioned at a height of 1.5 m above the ground. Prior to measurement in each site, the patch antenna azimuth orientation is always adjusted to obtain the best reception.

Received power measurements for outdoor large-scale path loss characterization are made in 18 sites covering a range of transmit-receive distance of up to 5 km. The map of measurement area showing the transmitter location and the measurement sites is given in Fig. 1. Fig. 2 shows photographs of the neighbourhoods of two representative sites of the outdoor measurement. Fig. 2(a) shows a site having a large building obstructing the direct path from the transmit antenna, whereas the site depicted in Fig. 2(b) is surrounded by open areas with tall buildings far in the background. Indoor measurements were made in the multi-storey BPPT building, particularly on the ground and the 21st floors. The transmit antenna is visible from the window of one side of the 21st floor, but not from the ground floor. The building is located around 4 km from the transmitter.
III. Large-Scale Spatial Variation of Received Power

Out of the 18 measurement sites, three located less than 500 m away from the transmitter are disqualified since the measurements in these locations are found to be influenced by null-approaching slope of the transmit antenna vertical pattern. In addition, after data processing it is discovered that, due to insufficiency of available data from five other sites required for spatial averaging, only ten remaining sites can be included in the large-scale variation analysis.

In the study, the power-law relation between the median received power and transmit-receive distance is adopted, on top of which the occurrence of spatially varying lognormally distributed shadow fading is also assumed. The expression for received power $S$ in Watts is thus:

$$S = kr^{-\alpha}10^{L/10}$$  \hspace{1cm} (1)

where $k$ represents the modified transmit power in Watts that incorporates the effects of effective radiated power, antennas used (which can be estimated using Lee’s expression, as suggested by Rebhan and Zander [8]) and distance normalizing factor $1000^{-\alpha}$, $r$ denotes the distance in km between the transmitter and the receiver, $\alpha$ denotes the distance exponent and $10^{L/10}$ represents lognormally distributed shadowing (i.e., given in decibels, $L \sim N(0, \sigma)$).

Two parameters are especially of interest, namely, the distance exponent $\alpha$ characterizing the power-law decrease of the median received power (or equivalently, the power-law increase of median path loss) with distance from the transmitter and the standard deviation $\sigma$ of the variation in dB around the median, i.e., the shadowing variation. Scatter plot of the measurements together with the power-law fit is given in Fig. 3. The fitting process results in a distance exponent $\alpha$ of 3.28 with a shadowing standard deviation $\sigma$ of 8.12 dB. These results are typical of urban UHF radio propagation channels commonly seen in both broadcasting systems and cellular phone networks [3], [9].

![Fig. 1 – Area of path loss measurement](image)

![Fig. 2 – Photographs of two areas of measurement site: (a) with a tall building blocking the direct path from transmit antenna and (b) with an open area surrounded by buildings in the far background](image)

![Fig. 3 – Power-law fit to the relative received power](image)
IV. Small-scale Spatial Variation

For the outdoor measurement, categorization into LOS and NLOS is simply based on the visibility of the transmit antenna tower from the receiver position, which is confirmed visually all the times by means of a binocular. The analysis involves measurements from several LOS and NLOS sites, with different distances from the transmitter. Following [4], in each measurement location a 100 m × 100 m area is determined, within which twenty measurements are made at different, randomly selected points. The distribution of received power for different sites are given in Figs. 4–6, while Table I recapitulates the measurement data from all sites. The mean power is computed in linear scale but given in dBm in Table I.

Representative results for outdoor LOS measurement are presented in Fig. 4. The cumulative distribution of received power for each site approaches both exponential and lognormal, the former suggesting Rayleigh distribution of received signal envelope. However, the farther the distance of the site from the transmitter, the two theoretical distributions become more distinct. In the parking lot of BPPT building complex, the distinction is quite clear. Received power levels in the probability range below 0.5 appears to be lognormal, whereas those above 0.8 probability are closer to exponential. Those with probabilities in the 0.5–0.8 range are lower than both exponential and lognormal. For NLOS sites, as depicted in Fig. 5, the received power distribution from the site at 3 km distance is well approximated by both exponential and lognormal. However, for the site at the park of the National Monument, about 4.5 km from the transmitter, the distribution is closer to lognormal, although more measurements should probably be made for this location.

For indoor locations inside BPPT building, it can be observed from Fig. 6 that the higher the floor on which the
receiver is, the greater the mean received power, as expected. The ground floor measurement reveals better fit to lognormal.

However, measurements on the higher floors show that the distribution in the lower probability range is closer to lognormal, but in the higher probability range it approaches exponential better. As such, the theoretical distribution model that best describes the received power on higher floors is inconclusive at this point. The same thing also happens for LOS measurements in the parking lot of the same building, as explained earlier. By comparing the mean received powers obtained on different floors with the outdoor results from the parking lot, it can be seen that the outdoor-to-indoor floor-average penetration loss might range from 5–22 dB, dependent on the floor height.

From the small-scale measurements, the coverage level in percentage at each site can be estimated of all twenty locations in which the detected C/N is greater than a specified threshold. In this case we set the threshold to 16.7 dB, the minimum required C/N for QEF reception. The outdoor locations are categorized into three classes with respect to their respective distance from the transmitter, namely, near (500 m–1 km), medium (1–4 km), and far (>4 km). The indoor measurement is made in the BPPT building as previously explained. The results are tabulated in Table II. In general, LOS sites produce satisfactory coverage regardless of the distance in the range of 500 m–5 km for our current transmission setting. All of sites show probability of “outage” (defined herein as probability of finding a point within the local area of interest that experiences less than QEF quality) of less than 10%. However, when NLOS conditions are concerned, only the near site indicates probability of outage of less than 10%, whereas the sites in the medium and long distance categories experience outage of more than 90%. The latter suggests coverage quality of less than 10%, far below the acceptable level of 70% [10]. Despite these findings, the SFN transmitter power and spacing that should be used in practice is still inconclusive since all the measurements are done with transmit power fixed at 400 W.

As for indoor reception in a multi-story building, the result shows that although the building itself is located in the ‘far’ category, the reception might still be acceptable on a

![Fig. 6 – Cumulative distribution of received power on different floors in the BPPT building, namely, (a) the ground floor and (b) 21st floor](image)

### Table I: Summary of small-scale measurement results

<table>
<thead>
<tr>
<th>Site</th>
<th>Approx. Distance from Tx (km)</th>
<th>Condition</th>
<th>Mean Power (dBm)</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Senayan</td>
<td>0.5</td>
<td>Outdoor, LOS</td>
<td>–46.39</td>
<td>LN, Exp</td>
</tr>
<tr>
<td>Kuburan Karet</td>
<td>2.5</td>
<td>Outdoor, LOS</td>
<td>–51.74</td>
<td>LN, Exp</td>
</tr>
<tr>
<td>BPPT parking lot</td>
<td>4</td>
<td>Outdoor, LOS</td>
<td>–53.32</td>
<td>–</td>
</tr>
<tr>
<td>Taman Lawang</td>
<td>3</td>
<td>Outdoor, NLOS</td>
<td>–74.21</td>
<td>LN, Exp</td>
</tr>
<tr>
<td>Monas</td>
<td>4.5</td>
<td>Outdoor, NLOS</td>
<td>–75.09</td>
<td>LN</td>
</tr>
<tr>
<td>BPPT 21st floor</td>
<td>4</td>
<td>Indoor, LOS through one side of the building</td>
<td>–58.38</td>
<td>–</td>
</tr>
<tr>
<td>BPPT 3rd floor</td>
<td>4</td>
<td>Indoor, NLOS</td>
<td>–70.28</td>
<td>–</td>
</tr>
<tr>
<td>BPPT ground floor</td>
<td>4</td>
<td>Indoor, NLOS</td>
<td>–75.24</td>
<td>LN</td>
</tr>
</tbody>
</table>
Table II Percentage of locations not achieving QEF quality

<table>
<thead>
<tr>
<th>Condition</th>
<th>Location</th>
<th>Percentage of Locations with C/N &lt; 16.7 dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outdoor, LOS</td>
<td>Near</td>
<td>9.4%</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>6.4%</td>
</tr>
<tr>
<td></td>
<td>Far</td>
<td>9.5%</td>
</tr>
<tr>
<td>Outdoor, NLOS</td>
<td>Near</td>
<td>9.7%</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>90.1%</td>
</tr>
<tr>
<td></td>
<td>Far</td>
<td>94.9%</td>
</tr>
<tr>
<td>Indoor</td>
<td>Ground floor</td>
<td>79.2%</td>
</tr>
<tr>
<td></td>
<td>21st floor</td>
<td>34.3%</td>
</tr>
</tbody>
</table>

sufficiently high floor, such as the 21st floor (QEF-quality coverage of approximately 66%). This achievement might result from the presence of LOS path between the transmitter and that floor of the building. On the other hand, reception on the ground floor indicates unacceptable coverage with only about 20% of the local area undergoing C/N of QEF quality or better.

V. Conclusions

The results of UHF propagation measurement in downtown Jakarta have been reported. In particular, it is found that the large-scale variation of path loss, which includes the impact of distance and environment-dependent lognormal shadowing, is typical of those found in urban areas in other parts of the world for broadcasting and cellular network applications. Study on the small-scale spatial variation of received power in locations relatively close to the transmitter, i.e., 3.5 km or less, the variation approaches both exponential and lognormal. The variation in NLOS sites located 4 km or more away from the transmitter, either outdoors or indoors, tends to follow lognormal distribution. However, LOS sites in the same range of distance follow neither exponential nor lognormal. It is also found that the average building penetration loss ranges from 5–22 dB depending on the existence of LOS path from the transmitter to the floor.

Results of small-scale spatial variation also shows that the presence of LOS path from the transmitter determines the acceptability of reception, especially for medium and far distance reception sites. In addition, use of repeaters appears to be necessary for reception in buildings far from the transmitter site, especially on the lower floors that tend to experience NLOS condition.

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References


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G. Hendrantoro, Endroyono and Suwadi are with Department of Electrical Engineering, Institut Teknologi Sepuluh Nopember, Campus ITS Sukolilo, Surabaya 60111, Indonesia, Email: {gamantyo, endroyono, suwadi}@ee.its.ac.id.

H. Budiarto, A. A. N. A. Kusuma, A. Rufiyanto and B. H. Tjahjono are with Division of Information Technology and Electronics, Agency for the Assessment and Application of Technology (BPPT), Jl. M. H. Thamrin 8, Jakarta 10540, Indonesia, Email: {hary, kusuma, arief, bambang}@inn.bppt.go.id.

S. Dharmanto is with Alphatron Asia Pte Ltd, 10 Ubi Crescent #07-99, Ubi Techpark, Singapore 408564, Email: satriyo@alphatron.com.sg.

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