# Path Loss at the Exact Location of TV inside Residences using Digital Terrestrial Television Signal at 677 MHz

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Abstract— This paper presents the results of indoor propagation measurements conducted at 16 residential sites at 677 MHz using live digital television transmission of National Broadcasting Network (NBN). This study is part of the extensive measurement campaign done last 2011, in partnership with NBN, a government TV network. The main purpose of this study is to measure indoor losses caused by penetration and path loss inside residences at the exact location of analog TV sets. Average Penetration Loss (APL) for each house/building category using the difference between the measured outdoor signal level and the indoor signal level values were computed and compared with similar studies found in the literature. Path loss exponents for four residential categories represent the power law relationship between distance and received power. Path loss contributes to indoor signal reduction thus resulting to poorer television reception quality. The value of path loss exponent n which was found to be decreasing from Classes A, B ,C and D proves that indoor fixtures, interiors and household appliances inside residences contribute to indoor multipath reception.

Index Terms— Average Penetration Loss, Path loss Exponent, Digital Terrestrial Television, indoor, ISDB-T, MMSE, residences

## 1 INTRODUCTION

Throughout the world, there is a process undergoing in the broadcast industry, that is, the transition from analog terrestrial broadcast to digital terrestrial broadcast. Philippines, being a developing nation and is situated in the tropical region needs to undertake a verification and improvement of existing methodologies and techniques in the prediction of the coverage area. Knowledge on penetration losses enables Radio Frequency (RF) designers to determine the required transmit power for a reliable coverage in a specific area. Results of the study can help in system planning by making it possible to adjust the appropriate transmitter parameters. One of the aims of the study is to determine the APL inside residences using locally available materials found in classes A, B, C and D house categories in the Philippines. Detailed procedures and results of this work can be found in [1]. Another important path loss parameter is the path loss exponent n which indicates the rate at which path loss increases with distance [2]. The study will measure the path loss exponents inside the ground floor of the four identified residential categories. Distance from the main openings of the house to the location of TV set will serve as the total path distance. Several papers found in the literature have also evaluated and computed indoor penetration loss and path loss. Studies done are for buildings [3-8] and houses [9-12]. Measurements were conducted at different operating frequencies from VHF-UHF up to microwave region and for different applications like DTV, High Altitude Platforms (HAP), Universal Mobile Telecommunication Systems (UMTS), ISM and Satellite to Indoor Communication Networks. Several wall materials have also been investigated at [13, 14] and the average penetration loss of concrete wall, bricks and wood were reported including standard deviations. Path loss exponents for indoor in different buildings and environment were done at [2] yet no study inside residences at the exact location of TV sets were reported. Path loss exponents computed for the four residential categories will be useful in developing indoor prediction models.


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## 2 MEASUREMENT PROCEDURE

NBN is one of the pioneers in Digital Television. It is located at Visayas Avenue, Quezon City, transmitting at 1kW power and operating at UHF Channel 48 (677 MHz). It has a system gain of 10.77 dB using a horizontally polarized panel antenna at a height of 120 m. Table I below lists the ISDB-T Transmitter parameters used in the conduct of this study.

**TABLE I**

TRANSMITTER PARAMETERS

| Parameter | Value |
|---|---|
| Mode 3 | 8K |
| Modulation | 64 QAM SD, QPSK, 1 seg |
| Guard Interval | 1/8 |
| Convolutional Encoding | ¾ SD, 2/3 1 seg |
| UHF Channel / BW | 48 / 6 MHz |
| Frequency | 674-680 MHz (677.142 MHz) |
| Bit rate | 5 Mbps - SD, 256Kbps 1 seg |

The instrumentation diagram shown in Fig. 1 was used to carry out the measurements needed. It consists of a commercially available indoor rabbit antenna amplified by AU40S MASPRO, connected to the ANRITSU spectrum analyzer where details of MER, power received, field strength and delay profiles were captured and recorded in the data storage. Visual monitoring is achieved using analog TV with ISDB-T set top box to classify received signal as perfect, intermittent or failure.

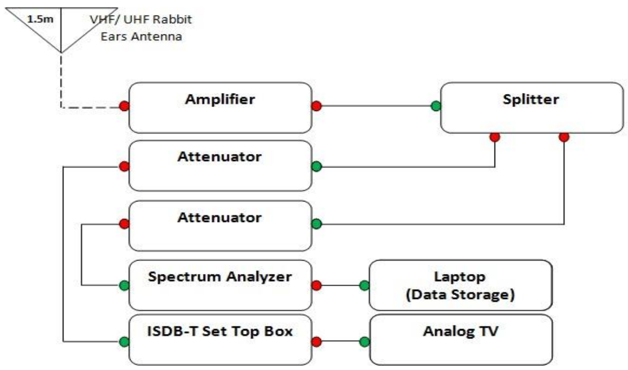


Fig 1. Measurement Instrumentation

### 2.1 Penetration Loss Measurements

Measurements were made at the façade and inside of sixteen (16) residences in Quezon City. Four (4) residences per dwelling classification were selected based on the type of construction materials used. Please refer to Figure 2 for sample residences per classification and Table II for tabulated descriptions. Typical residential houses in the Philippines are constructed with non-uniform walls composed of doors and windows. Outdoor-to-indoor studies considered structural opening along the path under the assumption that outdoor to indoor paths are possible only through wall openings such as doors and windows [15] . The largest openings of the house that were used as measurement test points are doors and windows. Diverse sizes and materials were considered in different residential classes.

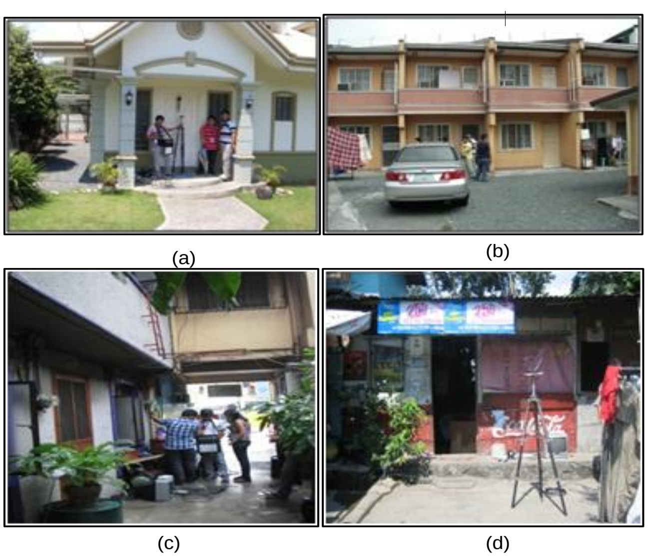


Fig 2 Sample residences for (a) Class A (b) Class B (c) Class C(d) Class D

**TABLE II.**

CLASSIFICATION OF IDENTIFIED HOUSES ACCORDING TO CONSTRUCTION MATERIALS

| Class | Type | House / Building Materials | Typical Door and Window Size |
|---|---|---|---|
| A | Building, Single Detached, Duplex Townhouse | heavily reinforced concrete, glass doors and windows, metals | $D_{wood}$= 2.11m x 1.07m $D_{glass, sliding}$ = 2.44m x 1.98m W = 2.29m x 1.29m |
| B | Town house | reinforced concrete, wood, glass | D = 2.11m x 0.86m W = 1.47m x 1.19m |
| C | Apartment | slightly reinforced concrete, wood, glass | D = 1.96m x 0.9m W = 1.38m x 1.28m |
| D | Shanty | light non-reinforced materials | D = 1.83m x 0.75m W = 0.61m x 0.85m |

Detailed measurement procedure in determining penetration loss can be found in [1].

### 2.2 Path Loss Measurements

Path Loss from the transmitter to the exact location of TV set of the identified house was computed using the equation below.

$$PL = Pt\ (dBm) - Pr\ (dBm) \qquad (1)$$

Power received, field strength, MER and delay profile were measured using cluster measurements of about 1 square meter from the analog TV. The antenna is positioned manually at 9 points in the front and back of the TV set. Figure 3 shows the actual measurement points done in every analog TV found at the ground floor of each residence considered. Note that major openings considered are doors and windows closest to the TV set. Reference signal at 1m from the openings (outside and inside) were also captured. Figure 4 are sample pictures captured during the conduct of the study performed at the living room of the residences at which doors and windows were left open. Figure 5 is an actual layout of the residences considered showing all the distances of the TV set from the wall openings. Indoor fixtures are no longer shown but were noted in details.

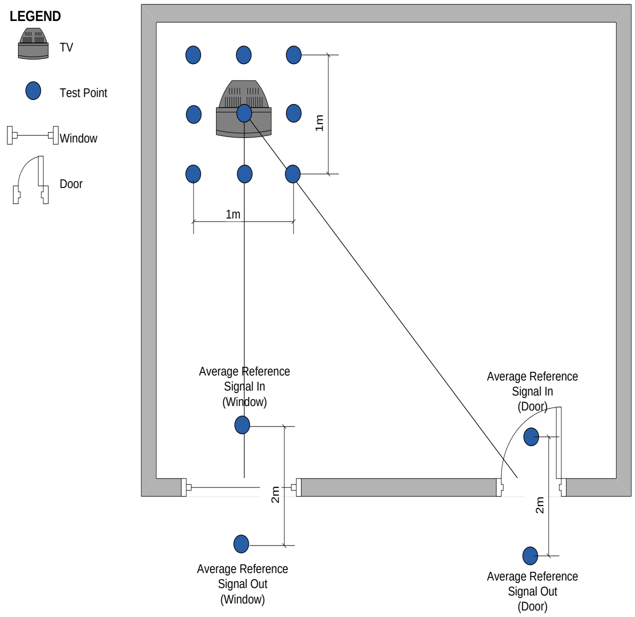


Fig 3. Measurement points at the location of TV

(a)

(b)

Fig 4(a) and 4(b). Sample measurements inside residences where antenna is located in one cluster position.

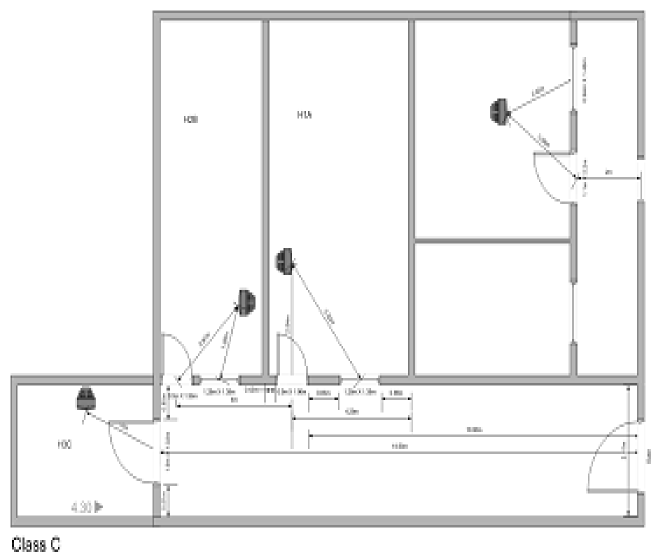


Fig 5. Layout of Class C residences

## 3 MEASUREMENT RESULTS

### 3.1 Penetration Loss

Thirty Six (36) measurements inside and outside of the identified 16 residences were made for a total of 576 collected signal power levels. The average penetration loss for each large openings of the house i.e. doors and windows, was computed using Equation 2. Detailed description of the identified residences can be found in Table III.

$$APL(dB) = Mean\ Pr\ out\ (dBm) - Mean\ Pr\ in\ (dBm) \quad (2)$$

### 3.2 Determining Path Loss Exponents

Fifty four (54) measurements including reference signal per residence were made for a total of 864 collected power signals for 16 residences. Path loss at the exact location of the analog TV was computed using Equation 1. Figure 6 shows the plot of the collected path losses for all residences.

**TABLE III**

RESIDENTIAL DESCRIPTION AND APL

| Class | Type of House and Construction Material | Typical Size | APL (dB) | σ (dB) |
|---|---|---|---|---|
| A | Overall | | 3.67 | 2.52 |
| | Building, Single Detached, Duplex Townhouse with oversized wooden door and glass sliding doors | D = 2.11m x 1.07m Thickness = 0.04m Ds= 2.44m x 1.98m (Sliding Door) | 4.35 | 1.64 |
| window | oversized glass window | W1 = 2.29m x 1.29m | 3.02 | 5.12 |
| B | Overall | | 11.27 | 6.83 |
| door | Town houses with screened wooden door | D = 2.11m x 0.86m Thickness Door = 0.04m Screen = 0.03m | 11.67 | 7.23 |
| window | glass window with aluminum screen | W = 1.47m x 1.19m | 10.33 | 4.18 |
| C | Overall | | 9.34 | 11.02 |
| door | 2-3 storey apartments with screened wooden door, oversized steel framed door with aluminum screen | D = 1.96m x 0.9m Thickness Door = 0.04m Screen = 0.03m | 13.87 | 7.11 |
| window | screened wooden-framed glass window, jalousie window | W = 1.38m x 1.28m | 6.30 | 12.49 |
| D | Overall | | 6.02 | 6.89 |
| door | Shanties with G.I. Sheet wooden framed door , thin wooden door (lawanit) | D1 = 1.83m x 0.75m | 6.79 | 7.73 |
| window | GI sheet, jalousie and wooden window | W1 = 0.61m x 0.85m | 7.40 | 6.90 |

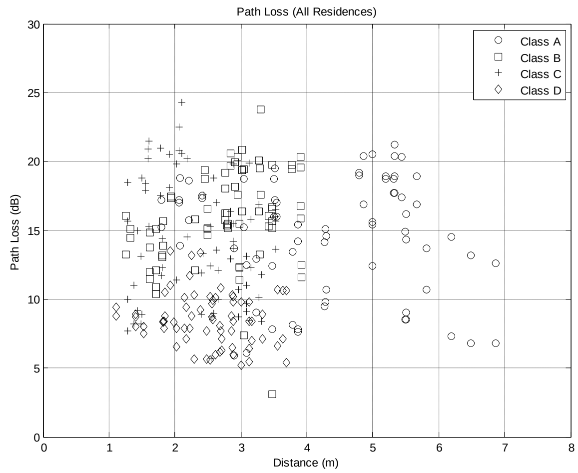


Fig 6. Computed path losses for all residences

Using Log Distance Path Loss Model, path loss exponent n for all residential types were determined.

$$PL(d)[dB] = \overline{PL}(d) + X_\sigma = \overline{PL}(d_0) + 10n\,log\left(\frac{d}{d_0}\right) + X_\sigma \quad (3)$$

Minimum mean square error (MMSE) was used to estimate path loss exponent's n for all residential types using the sum of squared errors between the measured and estimated received power.

$$J(n) = \sum_{r=1}^{k} (Pr - \widehat{Pr}\,(n))^2 \quad (4)$$

Table IV shows the resulting path loss exponent values and its corresponding standard deviations in dB.

**TABLE IV**

SUMMARY OF PATH LOSS EXPONENTS AND STANDARD DEVIATION FOR ALL RESIDENTIAL TYPES.

| Residential Class | Average Path Loss (dB) | Path Loss Exponent *n* | σ (dB) | Ave Dist of TV from Doors and Windows (m) |
|---|---|---|---|---|
| A | 14.59 | 3.37 | 11.46 | 4.31 |
| B | 15.89 | 2.43 | 5.89 | 2.74 |
| C | 14.36 | 2.33 | 6.06 | 2.34 |
| D | 8.53 | 2.16 | 6.56 | 2.48 |

### Class A

Diversity of residential types of this Class resulted to a large standard deviation of 11.46 dB due to different floor areas and indoor fixture arrangements. Location of TV sets from doors and windows has an average distance of 4.31m. This corresponds to the path distance resulting to an average path loss of 14.59 dB. Path loss exponent for this Class is 3.37. Modern Indoor fixtures and arrangement were observed in this class.

**Class B**
Townhouses of this Class located in one compound were found to have one door and one window as main openings at the facade. Identical units were considered with almost same location of TV sets of around 2.74m from the main openings. Path loss of 15.89 dB and standard deviation of 5.89 dB were obtained with indoor fixtures and appliances cramped in a small floor area. This resulted to a 2.43 path loss exponent value.

**Class C**
Apartments or row houses considered in this study are not identical in terms of floor area and orientation. Average distance of TV to main openings is 2.34m with an average path loss of 14.36 dB and 6.06 dB standard deviation. Indoor fixtures and appliances for this class were found to be less than Class B. This resulted to a path loss exponent of 2.33.

**Class D**
This class has the lowest indoor path loss values computed. Average path loss is only 8.53 dB and the small reduction in signal strength is due to minimal indoor fixtures and appliances found near the measurement points. Average distance from doors and windows to TV is 2.48 m. Path loss exponent is the lowest at 2.16 with standard deviation of 6.56 dB due to varying house structures considered in this Class.

## 4 CONCLUSION

This paper presents the results of penetration loss and indoor path loss measurements at 677 Mhz of residential houses classified as Class A, B, C and D. The APL for classes A, B, C and D are Class 3.67 dB; 11.27 dB; 9.34 dB and 6.02 dB, respectively. Path loss exponents' n for the four residential classes considered were computed and presented. Class A residences have the farthest ground floor TV location from the main openings like doors and windows. This resulted to the highest path loss exponent value of 3.37. Class D has the lowest average path loss at 8.53 dB and path loss exponent of 2.16. Path loss exponents which were found to be decreasing from Class A-D can also be accounted to the construction materials used, indoor fixtures, arrangements and appliances around or close to the TV set. The path loss exponent values obtained can be used in developing indoor models in estimating radio path loss. Authors are now in the process of modeling radio path loss inside residences. Further measurements are performed to gather more data samples in developing and validating the indoor model.

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