

Path loss Measurement at Indoor Commercial Areas using 28GHz Channel Sounding System

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Abstract— In this paper, we present path loss characteristics based on channel measurements in indoor commercial area at 28 GHz. The measurement campaign has been conducted in Seoul railway station and Incheon international airport terminal, which were selected to represent indoor hotspot regions in Korea. In order to compensate for the path loss increase due to higher frequencies, high-gain directional horn antennas are used to reliably establish channel links between a transmitter and a receiver. Based on the measurement results, we investigate directional path loss exponents and shadow fading factors using close-in free space path loss model.

Keywords—Millimetre-wave, indoor channel measurement, path loss, shadow fading, channel modelling

I. INTRODUCTION

Recently researches on the Fifth generation (5G) wireless communications have been paid a lot of attention. According to the definition by the METIS project, the candidate frequency bands for 5G applications range from 0.45 to 85 GHz, and the bandwidth is from 0.5 up to 2 GHz [1]. Therefore, characterization of millimetric channel with a wide bandwidth i.e. beyond 500 MHz for various types of applications and environments began to attract much research attentions recently. In order to investigate feasibility of millimetre-wave bands, channel measurement campaigns were conducted in various indoor and outdoor environments [2]. These millimetric propagation measurements have faithfully accounted for new statistical temporal and spatial channel models [3]-[5]. So far, especially for LMDS technology (28 GHz) and various deployments at the 60 GHz band, outdoor channel characteristics in these bands have been experimentally investigated in a number of papers and reports [2]-[5]. However, hitherto, indoor propagation results except for a few in the 60 GHz [6] and 70 GHz [7] band have not been reported sufficiently.

This paper investigates the directional path loss characteristics obtained from field measurement campaign at indoor commercial areas in Korea. Section II introduces a 28GHz wideband MIMO channel sounder and summarizes a measurement campaign we conducted. In Section III, the analysis results in terms of path loss and shadow fading are described. Finally, to wrap up the work, conclusions are given in Section IV.

II. SUMMARY OF MEASUREMENT CAMPAIGN

A. 28GHz Wideband Channel Sounder

The path loss measurement campaign was performed using the millimetre-wave Band Exploration and Channel Sounder (mBECS) system, which was developed by Electronics and Telecommunications Research Institute (ETRI), Korea. The mBECS system is a wideband channel sounder for measuring the spatial and temporal characteristics of a 500 MHz bandwidth channel in the 28 GHz frequency band. Table 1 lists a detailed specification of the channel sounder. This channel sounder can be operated reciprocally, i.e., a user can configure one end as a transmitter (TX) and the other end as a receiver (RX).

TABLE 1. SPECIFICATION OF 28GHz CHANNEL SOUNDER

Description	Specifications
Carrier Frequency	28 GHz
Channel Bandwidth	500 MHz
PN Code length	4095 chips
Sliding factor	12,500
Receiver chip rate	499.96 MHz
Maximum TX Power	29dBm
Automatic Gain Control range	< 60 dB

As shown in Figure 1, the mBECS system consists of a baseband module (BBM), a transceiver module (TRXM), a timing module (TIM), a RF module (RFM) and a steerable horn antenna. The BBU generates the periodic PN sequences as a pulse shaped probing signal with a chip rate of 500 Mcps. The TX signal is up-converted to the 28 GHz band by the TRXM and RFM and transmitted through the TX horn antenna. We implement a channel sounder using a swept time delayed cross-correlation (STDCC) technique [8]. At the receiver, the sliding correlation of a received signal with a PN sequence of a chip rate of 499.95 MHz is carried out at the RX TRXM. The RX BBM stores channel impulse responses to hard-disk for analysis of channel characteristics. The high precision rubidium oscillator of TIM provides a very accurate reference clock within 1ns for synchronization between a transmitter and a receiver [9]. The positioner shown in Figure 1 can mount a directional horn antenna and can rotate the orientation of the horn antenna both horizontally and

vertically with 1° accuracy to control the bore-sight of transmitting/receiving beams during measurement.

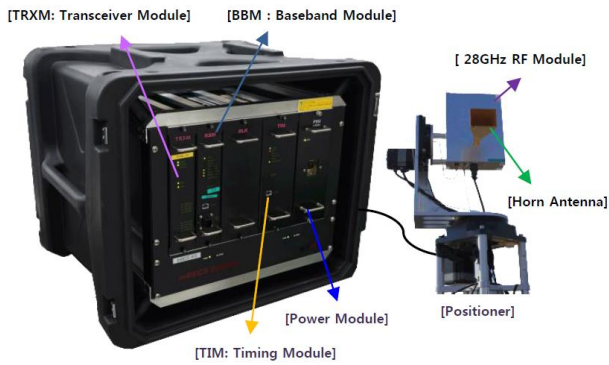


Figure 1. 28GHz wideband channel sounder system

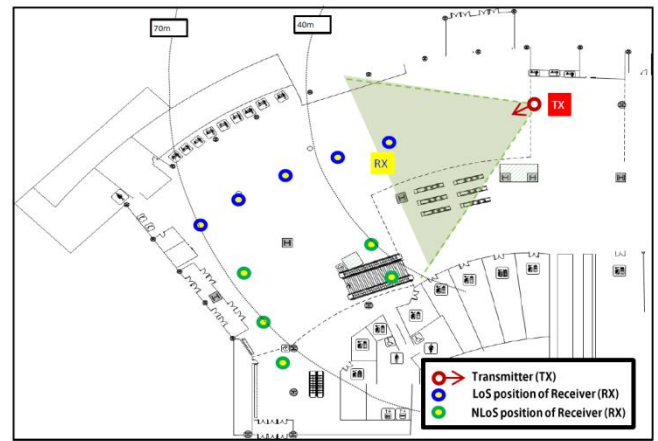
B. Indoor Measurement Campaign

The measurement campaign has been carried out in Seoul railway station and Incheon international airport terminal. The layout of two sites is different. The features of each site are given below.

- Site 1 (Seoul rail-way station, Korea): The measurement was carried out in a large hall with a dimension of 170m x 45m x 21m (height) located on the 1st floor of terminal building. The ceiling and walls of the hall are built with steel frames and thick tempered glasses. The floors are constructed with steel-reinforced concrete. There are offices, ticketing boxes and shops in the hall. A large electric notice board informing train departure-and-arrival time is on the wall.
- Site 2 (Incheon Airport terminal, Korea): The measurement has been carried out in a big hall with a dimension of 650m x 82m x 20m (height) which is on the third floor of airport passenger terminal building. Building materials look similar with the Seoul railway station except parallelly arranged check-in booths.

Figures 2 and 3 depict a detailed layout of each measurement scenarios. We installed the TX antenna at a height of 8 m and the RX antenna at 1.5 m as shown in Figure 2(b) and Figure 3(b). During the measurement, the location of TX was fixed, and the RXs were positioned at line-of-sight (LoS) and non-line-of-sight (NLoS) cases. The measurement data were collected during daytime. Considering millimetre-wave attenuation levels, we used a 60° half-power-beamwidth (HPBW) horn antenna (10 dBi gain) at TX and a 10° HPBW horn antenna (24.4 dBi gain) at RX. With these directional antennas, we investigated directional path loss characteristics.

To measure the directional path loss, we programmed to rotate the bore-sight of the RX antenna with a small step to find the best signals, while fixing the bore-sight of TX with a larger HPBW antenna to cover the entire range of interest.

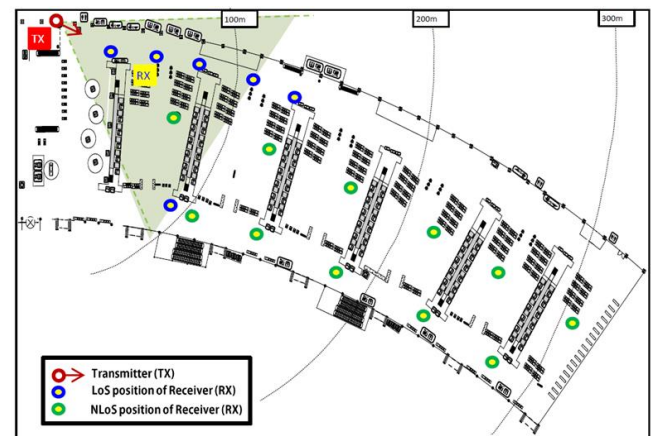


(a) Layout of measurement scenario



(b) Installation of measurement equipments

Figure 2. Path loss measurement campaign in Seoul Railway station (Site 1)



(a) Layout of measurement scenario



(b) Installation of measurement equipments

Figure 3. Path loss measurement campaign in Incheon Airport terminal (Site 2)

The rotation step size was 10° in the azimuthal direction ranging from 0° to 360° and in the co-elevation direction ranging from -10° to 10° . That is, at every measurement location, 108 ($= 36 \times 3$) samples were obtained and the best among them was selected to calculate directional path loss measurements. Note that the effects of antenna gain/patterns, cable loss and system impairments are also considered in the path loss calculation.

III. MEASUREMENT RESULTS

From the measurement data, we obtained the directional path loss values of LoS and NLoS case, respectively. As shown in Figures 4 and 5, we fitted to the path loss formula as below:

$$L(d)[\text{dB}] = PL(d_o) + 10n \log_{10} \left(\frac{d}{d_o} \right) + X_\sigma \quad (1)$$

, where d is the TX-RX separation distance, n is path loss coefficients and X_σ is the typical log-normal random variable with 0 dB mean and standard deviation σ .

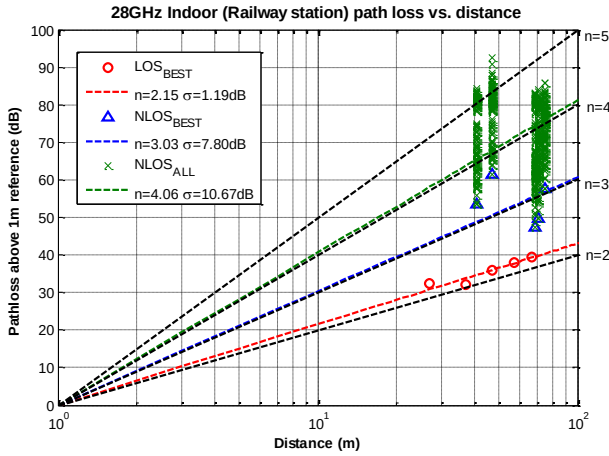


Figure 4. Measurement results of directional path loss (Site 1)

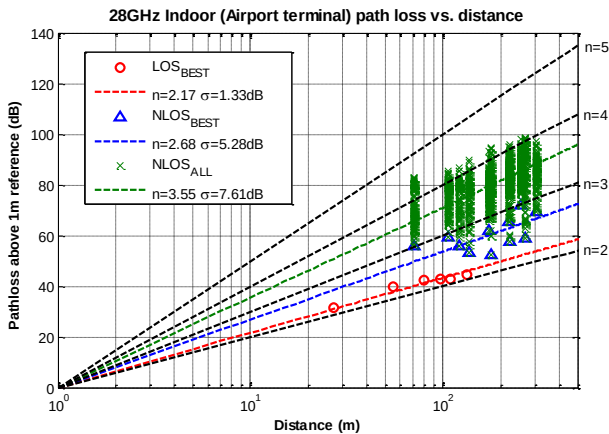


Figure 5. Measurement results of directional path loss (Site 2)

In our case, we used this model as the *close-in freespace reference model*. That is, we fixed $PL(d_o)$ with the free space

path loss at d_o as an anchor point, then we determine n by fitting measurement data to the model. In our case, d_o is 1m and $PL(d_o) = 61.38$ dB at 28GHz. Note that the subscript 'ALL' in Figure 4 means all samples obtained from steering antenna angles, while 'BEST' denotes the highest received power among measured results obtained from steering directional antennas both in azimuthal and elevation directions. That is, 'BEST' can be understood whether the beam alignment between TX and RX is done.

Table 2 summarizes the path loss coefficients such as path loss exponents (PLEs) and shadow fading factors (SF) obtained from our channel measurement campaigns in two different indoor environments (site 1 and site 2) of Korea.

TABLE 2. DIRECTIONAL PATH LOSS EXPONENTS AND SHADOW FADING IN INDOOR COMMERCIAL AREAS AT 28GHz

Area	LoS _{best}		NLoS _{best}		NLoS _{all}		$d_{\max}$ [m]
	n	σ [dB]	n	σ [dB]	n	σ [dB]	
Site 1	2.15	1.19	3.03	7.8	4.06	10.67	75
Site 2	2.17	1.33	2.68	5.28	3.55	7.61	300
mean	2.16	1.26	2.86	6.54	3.81	9.14	

IV. CONCLUSIONS

In this paper, we provide the experimental path loss characteristics based on channel measurement at railway station and airport terminal which is representative indoor hotspot regions in Korea. From our measurement results, we can observe that PLEs in LoS cases are very close to that of free space curve ($n = 2$). In contrast, the PLEs of NLoS cases were obtained with a range of 2.68 to 3.03 in the situation of best beam-alignment between TX and RX. If we consider all directions of the rotated horn antenna, relatively high path loss values ($n = 3.5 \sim 4$) can be seen in our measurement. Considering reliable establishment of communication links in millimetre-wave bands, a high-gain directional beam is necessarily used in order to compensate for larger path loss due to the higher frequency bands. Therefore, these directional channel characteristics obtained from measurements using a unique pointing angle antenna will be useful to system design perspective. To build trust in the propagation physics of the millimetric channel, we believe that the results through more extensive measurement should be shared.

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interests in multiple-antenna/multiple-user/multi-cell resource allocations, device-to-device communications, and wireless propagation channel measurements and modeling.



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