Comparison of Large Scale Parameters of mmWave Wireless Channel in 3 Frequency Bands

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***Abstract* - This paper investigates the large scale parameters (LSPs) of wireless channels with measurements at frequencies of 7.5 GHz, 28 GHz and 73 GHz for indoor light-of-sight (LOS) and non-light-of-sight (NLOS) scenarios. Comparison of the measured LSPs (RMS-DS, ASA, ESA) of these channels at different frequencies shows some differences between high and low frequency measurements. These studies indicate that more measurements will be needed for a full understanding of high-frequency millimeter-wave (mmWave) channels. This understanding is critically important for the successful application of high-frequency technologies in future 5G communication systems.**

***Index Terms* — Channel, large scale parameters, 5G communication, millimeter-wave.**

1. Introduction

The requirements for higher throughput and higher system capacity are among the main driving forces for the development of future wireless communication systems. Although the 4G communication systems can provide data transmission rates much improved from previous systems, with the emergence of new applications such as virtual reality [1] and the internet of things [2], much higher capacity and transmission rates will be needed for supporting the successful new applications. This has stimulated research for 5G technologies, which has received considerable attention in both academic and industrial research [3]–[5].

A practical method for achieving a higher transmission rate is to use mmWave bands, for example the E-band (71-76 GHz and 81-86 GHz), where wide-bandwidth channels are available. However, the radio transmission properties of these channels are not yet fully understood or characterized.

In this paper, we report some measurements of wireless channels for three mmWave band frequencies of 7.5 GHz, 28 GHz and 73 GHz. These measurements indicate that some LSPs may vary across different frequency bands. This demonstrates that the characteristics of high-frequency channel are different in some aspects from the low-frequency channel.

2. Measurement Method and Scenarios

An ultra-wideband channel sounder based on a vector network analyzer was designed to measure the wireless channels. We measured the channels at the frequencies of 7.5 GHz, 28 GHz and 73GHz. The channel bandwidth was 1 GHz.

The program of measurement was as follows: For each measurement location with fixed azimuth and elevation angles of the receiver (RX), a sequence of single tones was generated by the sounder system with a frequency spacing of 1 MHz. These tones were transmitted in sequence to the RX. For each tone, the RX was tuned to the corresponding frequency. When each measurement sequence was finished, the azimuth and elevation angles or the location of the RX was changed and the process was repeated. For each RX location, five elevation angles were considered: -10°, -5°, 0°, 5° and 10°. For each elevation angle, measurements were made with the azimuth angles changing from 0° to 360° with a step of 5°. Both the transmitter (TX) and the RX antennas were directional antennas with horizontal polarization. The measurement campaign was conducted in an indoor office environment illustrated in Fig. 1 including both LOS and NLOS scenarios. The TX antenna height was 2.5 meter and the RX was 1.5 meter. The TX and RX timing was synchronized through a common rubidium clock.

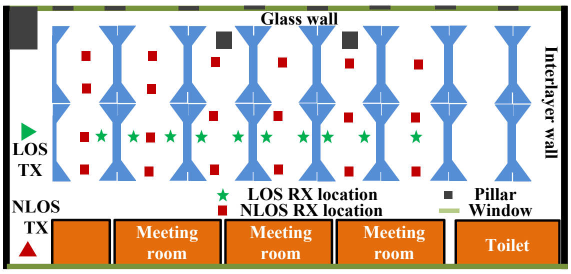

Fig. 1. Plan view of the indoor office environment

3. Comparison of LSPs for Different Frequencies

Three important LSPs were measured: root mean square delay spread (RMS-DS), azimuth spread at arrival (ASA) and elevation spread at arrival (ESA) [6]. These LSPs have a close relationship with the coherence bandwidth and coherence distance. The larger the RMS-DS, the smaller the coherence bandwidth while the larger the ASA or ESA, the smaller the coherence distance in horizontal or vertical planes. The detailed calculation method for RMS-DS, ASA and ESA can be found in [6].

For these LOS and NLOS scenarios, the calculated values of LSPs are listed in Table I. While we calculated and studied the LSPs for every RX location in Fig. 1, Table I, shows only the median of the LSPs for all locations.

TABLE I
Median RMS-DS, ASA and ESA for Three Frequencies

LSPs	Scenario	Frequency		
		7.5 GHz	28 GHz	73 GHz
RMS-DS [ns]	LOS	11.47	11.62	12.47
	NLOS	31.28	24.87	25.83
ASA [degree]	LOS	54.93	42.15	38.15
	NLOS	65.88	57.77	51.73
ESA [degree]	LOS	6.75	5.17	5.41
	NLOS	6.90	6.09	5.17

It can be seen from Table I that in the LOS scenario, the RMS-DS and ESA change only slightly across the frequencies measured. There is, however, a relatively large change of ASA across the three frequencies in the LOS scenario. This indicates similar coherence bandwidth and coherence distance in the vertical plane at different frequencies for the indoor office LOS environment, whereas coherence distance in the horizontal plane becomes larger as the frequency increases.

This phenomenon can be further understood by studying the azimuth-delay profile. Fig. 2 shows example 7.5 GHz and 28 GHz LOS azimuth-delay profiles at the same RX location. These two cases are chosen as an example illustrating a relatively large difference between the values of ASA (see Table I). Each point in these profiles represents a propagation path whose time delay and azimuth angle of arrival are given by its abscissa and ordinate respectively. The abscissa spacing is determined by the reciprocal of bandwidth, which is 1 nanosecond (ns) in these measurements. The ordinate spacing is determined by the angular spacing in the azimuth plane, which is 5° in these measurements. The color of each point indicates the relative power, which has been normalized by the maximum power received at the measurement point.

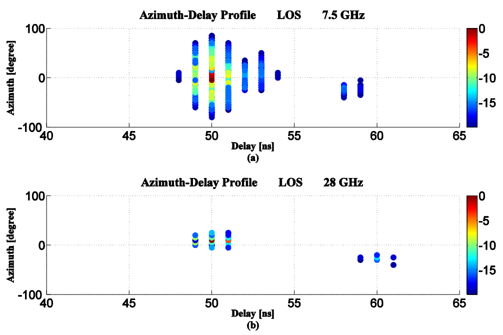

Fig. 2. Azimuth-delay profiles for LOS scenario at 7.5 GHz (upper) and 28 GHz (lower)

It can be seen that the power distribution for the 28 GHz channel (Fig. 2(lower)) is more concentrated along the azimuth axis than for the 7.5 GHz channel (Fig. 2(upper)). This implies that the ASA for the 28 GHz channel may be smaller than for the 7.5 GHz channel. This is consistent with what we have observed in Table I. Since every point denotes a path, Fig. 2 clearly indicates that some paths in the 7.5 GHz channel are not observed in the 28 GHz channel. This may be caused by a relatively large propagation loss or power loss due to specular or diffuse reflection of the higher frequency signal. The power loss due to reflection has a close relationship with the reflective materials. Further measurements need to be conducted to obtain the reflection/ scattering properties of various typical materials for high frequency signal in future research. There are two groups of "lost" paths illustrated in Fig. 2. The first group includes paths whose angle of arrival is greater than about 40°. The second group includes paths whose time delay is 48 ns, 52 ns, 53 ns or 54 ns. The disappearance of the first path group leads to a smaller ASA of this 28 GHz channel. However, the disappearance of the second group of paths has little influence on LSPs since their power is very low. This can also be demonstrated by checking the similar RMS-DS of 7.5 GHz and 28 GHz channels for the LOS scenario in Table I.

Our measurements indicate that the characteristics of higher-frequency channels may be different from channels whose frequency is below, for example, 10 GHz. Therefore, for the successful application of high-frequency technologies in 5G communication systems, industry and academia should carefully measure channel characteristics to ensure accurate modeling of the new high-frequency channels. These comments have focused on the LOS measurements. Some variation of LSPs is also observed in Table I for the NLOS scenario.

4. Conclusion

The LSPs of a wireless indoor channel for LOS and NLOS scenarios were measured at the frequencies of 7.5 GHz, 28 GHz and 73 GHz. The results show that some LSPs (for example, the ASA) have an apparent frequency dependency. This implies that the high-frequency channel is different in some aspects from the low-frequency one. This phenomenon was further illustrated using the azimuth-delay plane. In the future, more studies are still needed to better understand the high-frequency channel and to enable construction of an effective model.

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