ISSN 2712-0562
Original Research

Sustainable Engineering and Innovation
Vol. 4, No. 1, June 2022, pp.97-103
https://doi.org/10.37868/sei.v4i1.id168

Towards 5G: A study of the impact of antenna polarization on statistical channel modeling

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Received Mar. 18, 2022
Revised Jun. 7, 2022
Accepted Jun. 28, 2022

Abstract

Millimeter waves (mmWave) covering frequencies from 30 to 300 GHz. Their use in telecommunications typically extends from 24 to 100 GHz. The millimeter wave is alleged as an important element invention to respond to the rapid increase in wireless demand for mobile traffic using its huge bandwidth. However, channel modeling remains difficult due to its high dependence on weather conditions and the positioning of the antenna for communication in direct visibility line-of-sight (LOS) Co-polarization (Co-Pol) and cross-polarization (X-pol) considered as the key events in the direction of the radiation element for wave transmission; where the wanted direction of wave transmission denotes the co-pol and the orthogonal propagation of the intended way denotes X-pol. This work indicates how the millimetre waves channel performances may well concerned by antennas polarization by investigating the effect of the polarization on a statistical channel modeling at 28, 38 and 73 GHz mmWave channels using a well-known model named NYUSIM model developed by New York University (NYU) employs single-frequency close-in (CI) model. Simulation results show that the effect of the change of polarization from co-pol to x-pol is similar (25 dB) for 28, 38 and 73 [GHz] channels, but different in the case of the change from co-pol to x-pol.

Keywords: Co-polarization; Cross-polarization, Direct visibility line-of-sight; NYUSIM Model

1. Introduction

Wireless communications use the radio spectrum to carry information. Such communication can be between people, people and machines or systems. In this context, the radio spectrum is also essential for mobile networks. The current mobile communication technology is confronted to spectrum poverty and high-capacity defiance the coeval explosive of mobile traffic. The 5G wireless communication deployment has already begun. However, some technical problems and expectations that need to be updated in the 5G have already been discovered, and further technological improvements are needed.

Millimeter waves (mmWave) are a new range of frequencies used for 5G located in a spectrum between 30 and 300 GHz and between 24 GHz and 30 GHz, in the case of 5G. They allow a much better throughput at the expense of range and the ability to pass through walls that are used by various services. In recent years, the study of mmWave communication for 5G has become increasingly important, which increases the importance of channel modeling indoors/outdoors in different scenarios and conditions (cell type, LoS/NLOS, antennas….) for 5G. The latest studies on mmWaves mainly at 28, 38, and 73 [GHz] bands are conducted using outdoor scenarios from urban networks [3–4]. Although the mmWave spectrum resolve the requirement for more bandwidth, however the line-of-sight (LOS) and the corresponding weather conditions, in which the path loss take into account various atmospheric weather conditions has an effect on the system performances.

Otherwise, the massive multi input-multi output (MIMO) antennas polarizations of electromagnetic fields would affect the mmWaves channel characteristics and the system performances. The narrow beam radiation patterns like Co-pol and X-pol happens due to the placement of different transmitting and receiving objects in 5G/6G system networks. We can describe the Co-pol and X-pol as the chosen radiation direction of the transmitted signal and the orthogonal propagation of the required wave respectively [5]. Since, the main challenges in achieving an optimal design of 5G / 6G wireless communication technologies is conducting a study of mmWaves channels' properties. Additional studies are required such the effect of geometric parameters on channel properties such as Co-Pol / X-Pol that are not investigated in the different recent studies [7-16]. It is hugely necessary to get an appropriate polarization model for 5G system implementation. In this sense, this papers purposes to carrying out a deep statistical analysis of the propagation of mmWaves candidates to be used by 5G and beyond systems at 28, 38 and 73 [GHz] with various Co-Pol/X-Pol scenarios for an urban Microcell.

In the literature, many path loss models are developed, but it is necessary to have knowledge about which ones are suitable for a given frequency range. We can found numerous deterministic and statistical channel models as in [17-21]. A well-known model named NYUSIM model developed by New York University (NYU) employs single-frequency close-in (CI) model [6] proved its capacity mainly compared to the 3GPP regarding to modeling methodologies and channels assessment performances [22]. Unlike the 3GPP model, which based on various legacy results below 6 GHz, NYUSIM points out a further physical basis and relies on huge real data performed using millimeter waves frequency bands [22]. Further, to investigate the polarization model for the selected mmWave bands, we analyze different statistical channel characteristics. This paper addresses more details about the effect of antenna polarization (Co-Pol / X-Pol) on statistical channel modeling system in a specific scenario.

2. Statistical spatial channel model

In this research, we use a significant statistical spatial channel model (SSCM) system named NYUSIM [6]. which have been advanced and adopted by researchers to assess the communication systems performance and simulate channel characteristics [23].

2.1. Path loss model

The associated path loss model which describes the characteristics as the electromagnetic wave propagates from the transmitter (TX) to receiver (RX), due to the proximity of scatterers, reflectors in the path and degradation of the power is expressed by [6]:

$$PL(d_0) = 20\log_{10}(\frac{4\pi d_0}{\lambda}) \tag{1}$$

d_0 and λ represent TX and RX, the separation distance and signals wavelength, respectively.

NYUSIM also characterized by free space CI path loss model where, f_c; d (m) contained by a distance of 1 m, whereas adopts atmospheric features which expressed by [6]:

$$PLCI(f,d)[dB] = FSPL(f,1m)[dB] + 10n\log 1\,0(d) + AT[dB] + x_\sigma^{CI} \tag{2}$$

$d \geq 1m$, f (GHz) indicates the carrier frequency, $d[m]$ characterizes the transmitter (TX) and the receiver (RX) distance, n signifies the Path Loss Exponent (PLE), AT describes the attenuation as a result of atmosphere, x_σ^{CI} denotes a zero-mean Gaussian random variable where σ denotes the deviation [dB], and $FSPL(f,1m)$ signifies the free space path loss with the carrier frequency f and TX-RX separation distance of $1m$, the formula of the path loss that is used by NYUSIM channel model is a distinct process getted by:

$$FSPL(f,1m)[dB] = 10\log_{10}\left(\frac{4\pi f \times 10^9}{c}\right) = 32.4[dB] + 20\log_{10}(f) \tag{3}$$

2.2. Path loss model

The power of the received signal depends on: the path loss due to the propagation TX-RX of the wave with a distance d, gains and transmitted power. The RX signal power is described by:

$$\Pr[dBm] = Pt[dBm] + Gt[dB] + Gr[dB] - PL(d)[dB] \tag{4}$$

$\Pr$ and Pt are the powers of received and transmitted signals respectively,
Gt and Gr are TX and RX antennas gain separately,
$PL(d)$ is the path loss average according to distance d .

The co-polarized TX and RX path loss PL_{V-V} to be expressed by [24]:

$$PL_{V-V}(d) = P_{t-V} - P_{r-V} + G_t + G_r \tag{5}$$

where:

d is the distance [m] between TX-RX,
P_{t-V} is the power of the transmitted signal into the vertically polarized TX antennas (dBm),
P_{r-V} is the power of the received signal induced in the RX antenna that is polarized vertically (dBm),
G_t, G_r are TX - RX gains respectively [dBi].

Otherwise, the path loss of X-pol PL_{V-H} to be expressed with the identical distance through the cross-polarized antenna (V-H) by [8]:

$$PL_{V-H}(d) = P_{t-V} - P_{r-H} + G_t + G_r \tag{06}$$

where:

d is distance [m] between TX and RX,
P_{t-V} is the power to be transmitted into the vertically polarized TX antenna (dBm),
P_{r-H} is the power of the received signal induced in the RX antenna output that is polarized horizontally (dBm),
G_t is TX antennas gain (dBi),
G_r is RX antennas gain (dBi).

3. Results and discussion

We study the most used mmWave channels (28, 38 and 73 [GHz]) in terms geometric parameters on channel properties that are Co-pol and X-pol using the NYUSIM model. Simulation parameters and assumptions regarding channel and antenna properties are shown in Tables 1. The outcoming results for each channel suggested in this paper to be done by figures and tables for all polarization scenarios (co-pol/x-pol). Figure 1 shows the Directional Power Delay Profile for 28, 38 and 73 GHz with polarization scenarios, we have summarized the finding in Table 2. For 28, 38 and 73 [GHz] channels, the effect of the change of polarization from co-pol to x-pol on channel characteristics are 26,9 dB, 24 dB, 27,6 dB respectively regarding path loss and received power. Figure 2 shows the Omnidirectional Power Delay Profile for 28, 38 and 73 GHz under polarization scenarios. The results are summarized in Table 3. For 28, 38 and 73 [GHz] channels, the effect of the change of polarization from co-pol to x-pol on channel characteristics is similar (25 dB) regarding received power and path loss. The results describing received power with the PLE for directional and omnidirectional PDP to be presented by Tables 2 and Table 3 where, it is shown that the polarization demonstrated remarkable impacts on directional PDP compared to omnidirectional PDP in both path loss exponent (PLE) and received power.

Table 1. Simulation parameters of the considered channels with antennas

CHANNEL PARAMETERS	**Values**	**Antennas parameters**	**Values**
RF Frequencies	28/38/73 GHz	Type of TX Arrays	ULA
RF Band Width	800 MHz	Type of RX Arrays	ULA
SCENARIO	UMi	Antennas Elements of TX/ RX.	1/1
ENVIRONNENT	LOS	Space between TX Antennas element	0.5λ
Distance [m] between TX-RX	100	Space between TX Antennas element	0.5λ

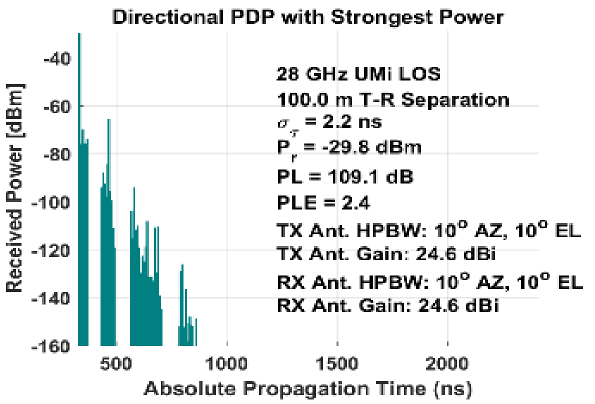
CHANNEL PARAMETERS	Values	Antennas parameters	Values
TX Power (dBm)	30	TX Antennas. Azimuth HPBW	10°
RX Number	1	TX Antennas. Elevation HPBW	10°
Press (mbar)	1013	RX Antennas. Azimuth HPBW	10°
Hum %	50	RX Antennas. Elevation HPBW	10°
Temp. C°	20		
Pol	c-pol/x-pol		

Table 2. Directional PDP results

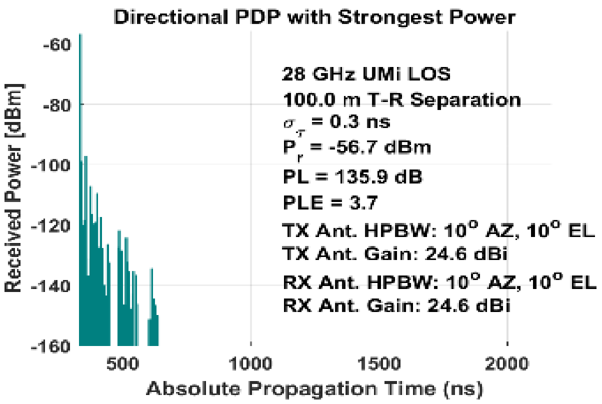
Frequency Band	Polarization	σ_τ	Pr	PL	PLE
28	Co-Pol	2,2	-29,8	109,1	2,4
	X-Pol	0,3	-56,7	135,9	3,7
38	Co-Pol	2,9	-34,1	113,3	2,5
	X-Pol	0,2	-58,2	137,4	3,7
73	Co-Pol	0,9	-35,4	114,6	2,2
	X-Pol	3,0	-63,0	142,2	3,6

Table 3. Omnidirectional PDP results

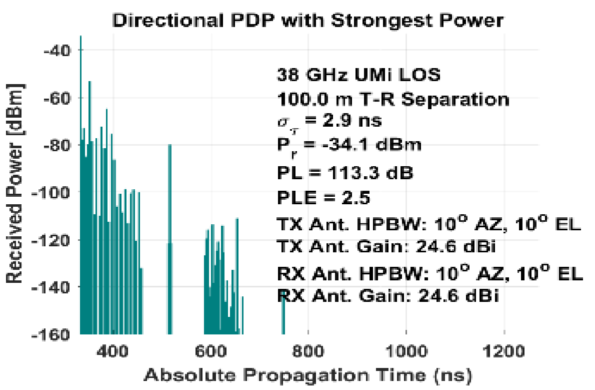
Frequency Band	Polarization	σ_τ	Pr	PL	PLE
28	Co-Pol	19,2	-75,4	105,4	2,2
	X-Pol	16,5	-100,4	130,4	3,5
38	Co-Pol	22,9	-78,1	108,1	2,2
	X-Pol	17,4	-103,1	133,1	3,5
73	Co-Pol	13,8	-83,8	113,8	2,2
	X-Pol	24,1	-108;8	138,8	3,5



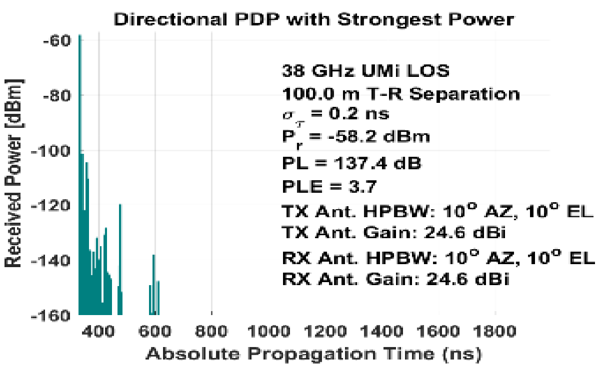
(a) The C-Pol for 28 GHz



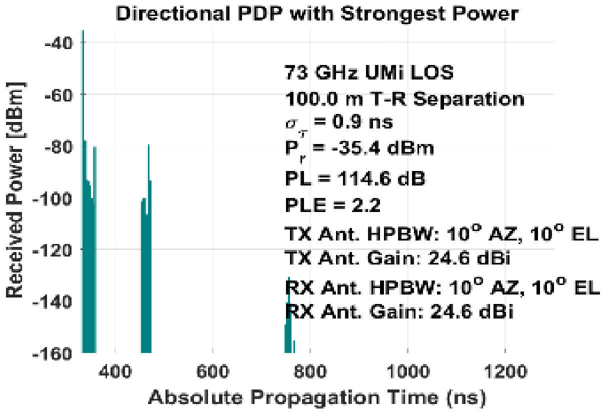
(b) The X-Pol for 28 GHz



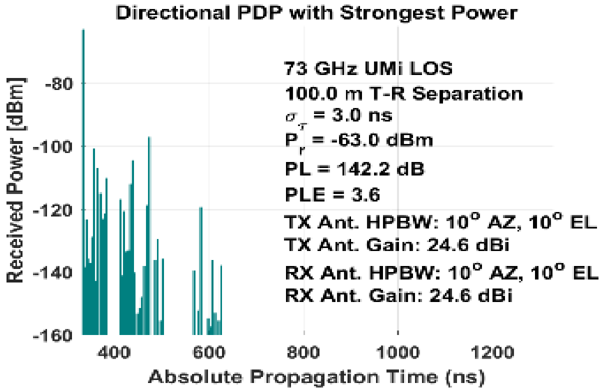
(c) The Co-Pol for 38 GHz



(d) The X-Pol for 38 GHz

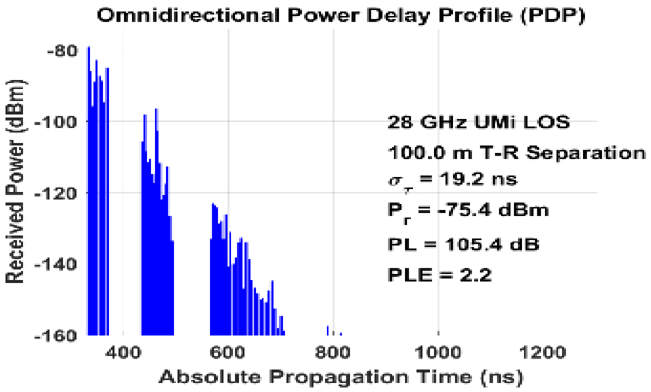


(e) The Co-Pol for 73 GHz

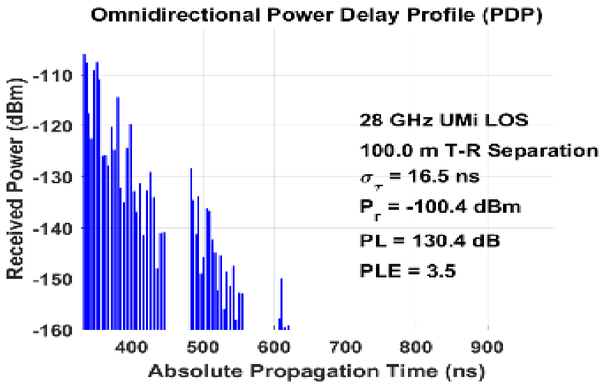


(f) The X-Pol for 73 GHz

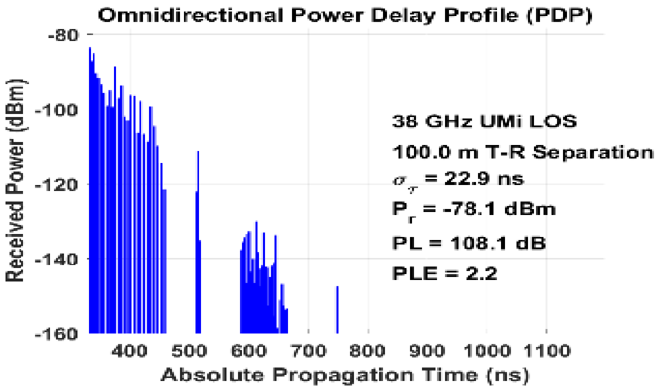
Figure 1. Directional power delay profile



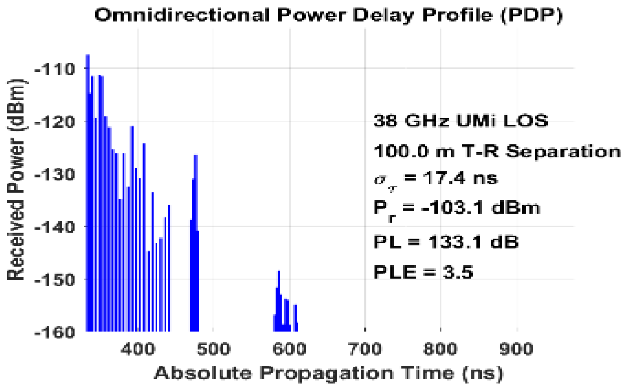
(a) The Co-Pol for 28 GHz



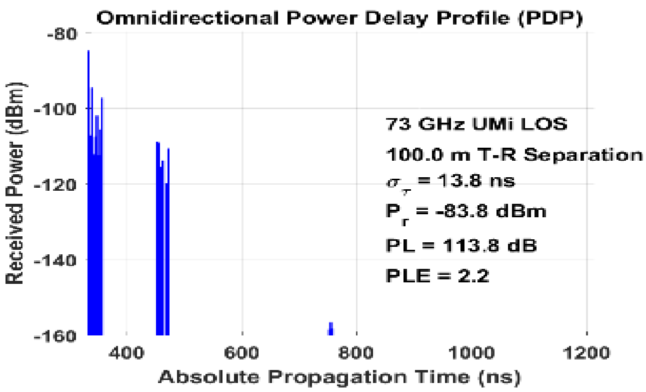
(b) The X-Pol for 28 GHz



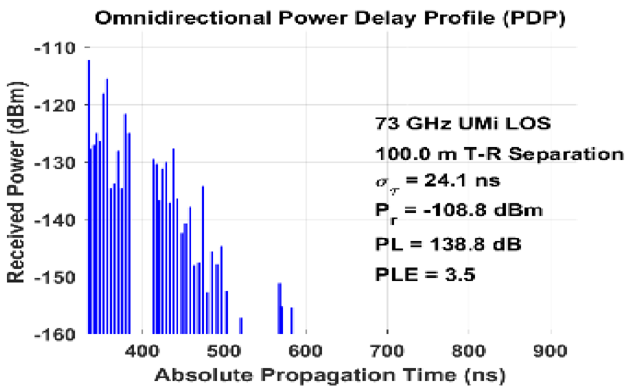
(c) The Co-Pol for 38 GHz



(d) The X-pol for 38 GHz



(e) The Co-Pol for 73 GHz



(f) The X-Pol for 73 GHz

Figure 2. Omni directional power delay profile

4. Conclusion

This paper focused on the impact of geometric parameters on channel properties that are Co-Pol / X-Pol not investigated in the different recent studies. In this sense, this papers purposes to carrying out a deep statistical analysis of the propagation of some mmWaves candidates to be used by 5G and beyond systems by considering the impact of polarization (Co-Pol / X-Pol) at 28, 38 and 73 [GHz] for urban Microcell. A perceivable simulation was performed by NYUSIM model. The study was conducted through a coeval developed 5G channel model in which the model features of polarization was integrated. This work indicates how the millimetre waves channel performances may well concerned by antennas polarization.

It is found that for 28, 38 and 73 [GHz] channels, the effect of the change of polarization from co-pol to x-pol in terms of path loss and power received are 26,9 dB, 24 dB, 27,6 dB respectively. Besides, For 28, 38 and 73 [GHz] channels, the effect of the change of polarization from co-pol to x-pol is similar (25 dB). The Power delay profile (PDP) with path loss exponent (PLE) were performed. The finding show that assembling of antenna polarization capable to advance/decrease the propagation delay and PLE of the link. The strength of the study results is valuable in understanding the impact of polarization on 5G channels establishment. It is immensely necessary to get an appropriate polarization model for 5G system implementation.

Declaration of competing interest

There are no financial or non-financial conflicting interests in any of the content discussed here.

Funding information

No support from any financial institution was obtained for this study.

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