ECHAHID HAMMA LAKHDAR UNIVERSITY - EL-OUED
Under the Supervision of the DGRSDT and in collaboration with the CRTI
International Pluridisciplinary PhD Meeting (IPPM'20)
23-26, 2020 1st Edition, February

Impact of Antenna Polarization on a Statistical Channel Modeling in 5G Cellular Communications

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Abstract
The millimetre wave (mmWave) is alleged as an important element invention to respond to the rapid increase in wireless demand for mobile traffic using its huge bandwidth. But, 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 and cross-polarization (X-pol) are two main 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 direction represents X-pol. This paper presents an analysis of polarization impact on a statistical channel modeling for 28 GHz & 73 GHz mmWave channel using NYUSIM Model.

Keywords: 5G, channel modeling, co –polarization cross-polarization, power delay profile (PDP).

1. Introduction

The current mobile communication technology is confronted to spectrum poverty and high capacity defiance the coeval explosive of mobile traffic. The next wireless mobile generation (5G) has begun research in the millimeter wave (mmWave) band. mmWave band width is from the frequency 10 GHz to 300 GHz which certainly fast enable multi-gigabit communication services such as internet of things (IoT), and vehicle to everything (V2X) [1], [2] The latest outdoor application scenarios come out from urban networks (e.g., buildings, shopping malls, urban centers, etc) and backhaul networks also conduct to the use of mmWave frequencies , particularly on 28 GHz band and 73 GHz band [3]–[4].

Although the mmWave spectrum solves the bandwidth poverty problem, the tight line-of-sight (LOS) and high weather dependency has an effect on the system performances. In addition, the massive-input-massive-output (MIMO) antenna polarizations of electromagnetic fields (EM) also affect the system performances at mmWave frequency ranges. The placement of different transmitting and receiving objects in 5G networks introduces narrow beam radiation patterns such as like Co-pol and X-pol [5]. The Co-pol depicts the wanted radiation direction of transmitted signals and X-pol represents the orthogonal propagation of the desired wave.

In this work, we simulate an urban microcell scenario using two different mmWave bands (28 GHz and 73 GHz) so as to investigate the impact of Co-pol and X-pol on NYUSIM channel modeling. Further, we analyze different statistical mmWave channel characteristics to know the polarization model for the mmWave bands. This study contributes to our knowledge by addressing the details of antenna polarization impacts on the performance of a 5G statistical mmWave channel system in a particular scenario.

2. Statistical 3-D SSCM channel modeling

In this research, we use a significant 3D SCCM based test system (NYUSIM) developed by New York University [6]. NYUSIM offres a close in (CI) distance parameter which is a novel segment of this test system that outcomes in greater reliability crosswise over different path loss informational indexes [7].

2.1 Path Loss Model

When an EM wave propagates from the transmitter to the receiver, because of the proximity of scatterers and reflectors in the path, the power degrades. We use the attendant path loss model and characterized as:

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

Where d_0 and λ represent the separation distance between TX & RX and wavelength of the signals, respectively.

NYUSIM refers free space CI path loss model f_c; d (dB) within 1 m distance, while assumes atmospheric factors and illustrated as [6]:

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

where: $d \geq 1m$, f denotes the carrier frequency in GHz, d is the 3D T-R separation distance, n represents the path loss exponent (PLE), AT attenuation term caused by the atmosphere, x_σ^{CI} is a zero-mean Gaussian random variable with a standard deviation σ in dB, and $FSPL(f,1m)$ denotes the free space path loss in dB at a T-R separation distance of 1m at the carrier frequency f, the CI path loss formula is an individual process which is applicate in NYUSIM channel model expressed as:

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

2.2 Received Signal Power

The power of the received signal is related to the path loss during propagation of a distance d between the transmitter and receiver, the antenna gain and the transmitted power. The received power can be expressed as:

$$\Pr[dBm] = Pt[dBm] + Gt[dB] + Gr[dB] \times PL(d)[dB] \quad (4)$$

Where: $\Pr$, Pt, Gt and Gr denotes received signal power, transmitted power, transmitting and receiving antennas gain, respectively. $PL(d)$ represents average path loss at distance d .

The path loss between the co-polarized TX and RX antennas PL_{V-V} can be presented as [8]:

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

where d, P_{t-V} , P_{r-V} (d), G_t and G_r represent TX-RX separation distance (m), transmitted power into the vertically polarized TX antenna (dBm), received power at the output of the vertically polarized RX antenna (dBm), gain of the TX and RX antennas (dBi), respectively.

The X-pol path loss PL_{V-H} is then calculated at the same distance [8] with the cross-polarized antennas (i.e., V-H) as follows:

$$PL_{V-H}(d) = P_{t-V} - P_{r-H} + G_t + G_r \quad (6)$$

where d, P_{t-V}, P_{r-H}, G_t and G_r represent TX-RX separation distance (m), transmitted power into the vertically polarized TX antenna (dBm), received power at the output of the horizontally polarized RX antenna (dBm), gain of the TX and RX antennas (dBi), respectively. X-pol adverts to transmitting in one polarization state and receiving in the orthogonal polarization state.

3. Simulation Environment and Result Interpretation

In this section, we simulate the most used millimeter wave channels (28 GHz, 38GHz and 73 GHz) with both Co-pol and X-pol gathering edge using the NYUSIM model.

The simulation parameters and the hypotheses concerning the properties of the channels and antennas are represented in Tables I.

The simulation results for the polarization scenarios (co-pol/x-pol) for each channels proposed in this study were produced in the form of figures and organized by type of result.

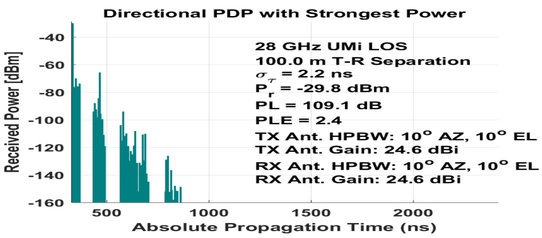
Fig. 2 shows the Omnidirectional Power Delay Profile at 28, 38 and 73 GHz for the polarization scenarios. From fig 2, we can summarize results in Table 3.

For 28 GHz, 38 GHz and 73 GHz channels, the effect of the change of polarization from co-pol to x-pol on channel characteristics (path loss and power received) is same (25 dB) .

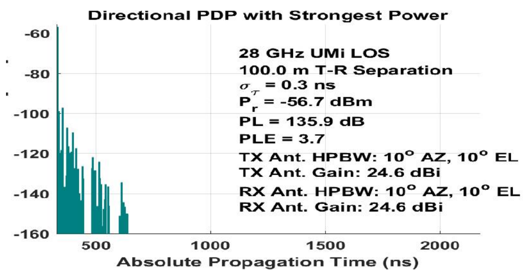
The simulated PLE and the received power esteemed for directional and omnidirectional PDP are shown in Table 2 and Table 3. From tables, we say that the polarization mismatch very effects in directional PDP rather than omnidirectional PDP in case of received power and path loss exponent (PLE).

Table 1. Channel and antenna simulation parameters.

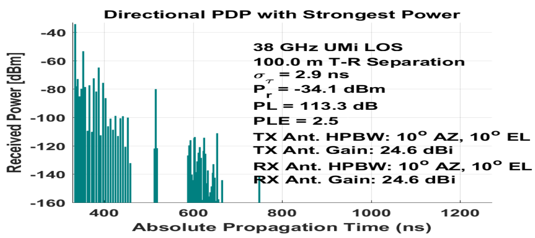
CHANNEL PARAMETERS	Value	Antenna parameters	Value
RF Frequency	28/38/73 GHz	**TX Array Type**	ULA
RF Band Width	800 MHz	**RX Array Type**	ULA
SCENARIO	UMi	**TX/ RX Ant. Elements**	1/1
ENVIRONNENT	LOS	**TX Ant. Element Spacing**	0.5λ
T-R Separation (m)	100	**RX Ant. Element Spacing**	0.5λ
TX Power (dBm)	30	**TX Ant. Azimuth HPBW**	10°
Num RX	1	**TX Ant. Elevation HPBW**	10°
Press (mbar)	1013	**RX Ant. Azimuth HPBW**	10°
Hum %	50	**RX Ant. Elevation HPBW**	10°
Temp. C°	20		
Pol	c-pol/x-pol		



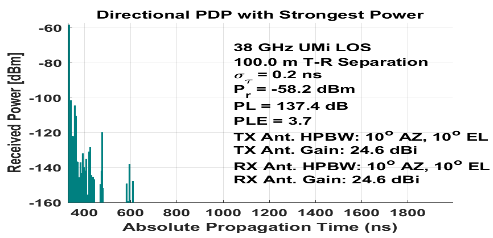
(a) Co Polarization at 28 GHz



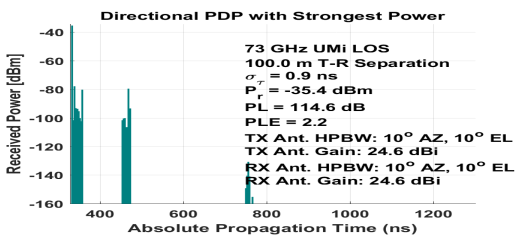
(b) Cross Polarization at 28 GHz



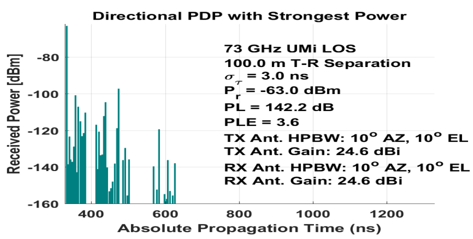
(c) Co Polarization at 38 GHz



(d) Cross Polarization at 38 GHz

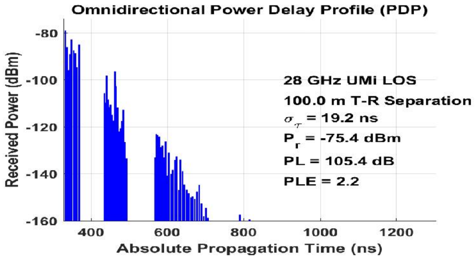


(e) Co Polarization at 73 GHz

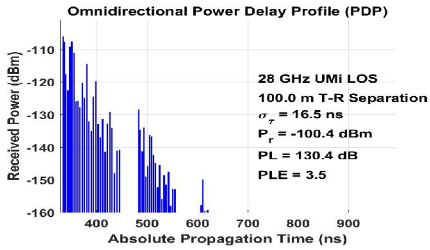


(f) Cross Polarization at 73 GHz

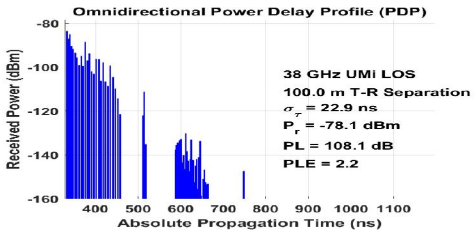
Fig. 1. Directional Power Delay Profile



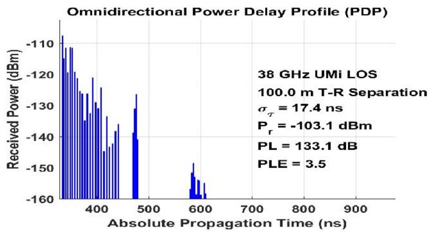
(a) Co Polarization at 28 GHz



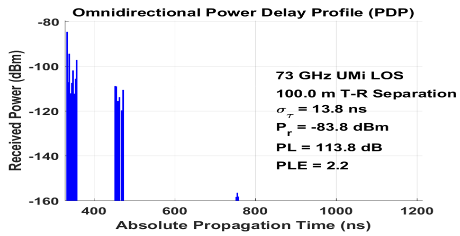
(b) Cross Polarization at 28 GHz



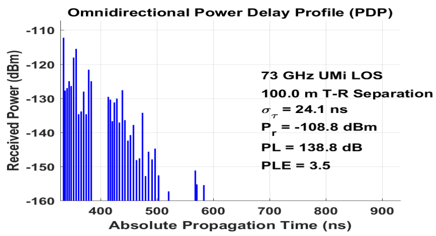
(c) Co Polarization at 38 GHz



(d) Cross Polarization at 38 GHz



(e) Co Polarization at 73 GHz



(f) Cross Polarization at 73 GHz

Fig. 2. Omni Directional Power Delay Profile

Table 1. 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 III. 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

4. Conclusion

The present study was planned to define the impact of polarization in a 5G mmWave spatial statistical channel model for two strong applicants of upcoming 5G revolution. To anatomize the insights of the channel, a perceivable simulation was executed using NYUSIM. The study was conducted through a coeval developed 5G channel model where features model of polarization was integrated. The study indicates how the performance of mmWave channel can be affected by antenna polarization .Power delay profile including way path loss exponent for two diverse mmWave recurrence groups was enrolled. Results show that assembling of antenna polarization can enhance or reduce the propagation delay, path loss exponent of the liaison. The study outcomes strength is precious to comprehend the impact of polarization on 5G channel demonstrating. It is immensely fundamental to get a legitimate polarization model for 5G cell systems.

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