The Effect of Cross Polarization And Co Polarization on Channel Modeling in 5G Communications

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Abstract- *This paper describes the effect of antenna spacing elements on channel Impulse response (CIR) in Urban Micro cell (UMi) using Uniform Linear Array (ULA) ,this helps to properly design fifth generation $(5G)$ mobile and cellular communications using $NYUSIM.NYUSIM$ is based on statistical spatial channel model for broad band millimeter wave (mm Wave) wireless communication systems. $NYUSIM$ is suitable for wide range of carrier frequencies from $0.5\ GHz\ to\ 100\ GHz, RF$ band width from $0\ to\ 800\ MHz$, antenna beam width is in the range of $7^0\ to\ 360^0$ for azimuth and $7^0\ to\ 45^0$ for elevation*

Keywords- $NYUSIM$, Channel model, $mm\ Wave$,$5G, UMA, UMi, RMa$.

I. INTRODUCTION

The design and implementation of channel models are very crucial for wireless communication system design. Channel simulators play a key role for performance analysis of communication system. Many channel simulators have already been well studied in the past[1]-[7].

Name of the simulator designer	purpose
Smith[1]	Developed a simulation tool for indoor and outdoor propagation channel, using two ray Rayleigh fading cannel model, modeled by Clarke [9].
Fraun hofer Heinrich hertz institute [2]	Developed 3D multi channel model, that predicts the performance of an UMa
[3]	Developed for indoor scenarios, which is suitable for machine to machine applications
Rappaport and Scidel [4]	Developed statistical indoor channel model, that is, SIRCIM (simulation of indoor Radio Channel Impulse response Model).Operating range 10 MHz to 60 GHz
[5],[6]	Developed simulation of mobile radio channel impulse response model (SMRCIM),that is used for simulating outdoor channels
Fung et al [7]	Developed BERSIM to simulate mobile radio communications and to estimate average Bit Error Rate .Using BERSIM link quality can be evaluated in real time without using any RF hardware.

In this paper, NYUSIM [10] is introduced which is a open source channel simulator ,used at multi meter wave (mm Wave) frequencies (28 to 73 GHz) in different outdoor environments like UMi,UMa and RMa environments [11]-[19].This simulator provides accurate channel impulse responses in both time and space. NYUSIM supports carrier frequencies in the range 0.5 GHZ-100GHz and Radio frequency band widths in the range 0 to 800 MHz. The source code is developed in MATLAB[20].NYUSIM works on Windows or Macintosh operating system even without installing MATLAB.

II. CHANNEL MODEL SUPPORTED BY NYUSIM

Omni directional channel models are well adopted across the globe in designing wireless system. But directional channel models are very important to design and implement antenna arrays to spatial uniformity and beam forming gain Multi path Input Multipath Output (MIMO) system[21][22].NYUSIM generates Channel Impulse Responses (CIR) for both Omni directional and directional channel models [10]-[19].The main advantage of NYUSIM is that it generates functions of spatial and temporal CIRs. This section describes the path loss (PL) model used in NYUSIM.

Path loss model and clustering definition in NYUSIM
Path loss model

The Close In free space reference distance (CI) path loss model with a $1m$ reference distance[12],[15],[17],[19] and an extra attenuation due to various atmospheric conditions [23],is employed in NYUSIM, which is expressed as [12],[15],[24].

$$PL^{CI}(f,d)[dB] = FSPL(f,1m)[dB] + 10n\ \log10^{d} + AT[dB] + X_{\sigma}^{CI} \ldots\ldots\ldots (1)$$

where

$d \geq 1m$

$f =$ carrier frequency in GHz

$d =$ 3D T-R separation distance.

$n =$Path Loss Exponent (PLE)

AT= Attenuation term induced by the atmosphere

X_{σ}^{CI} = Zero mean random Gaussian variable with a standard deviation σ in dB

$FSPL(f, 1m)$ = Free space path loss in dB at a T-R separation distance of $1m$ at a carrier frequency f

$$FSPL(f, 1m)[dB] = 20 \log 10^{\left(\frac{4\pi f \times 10^9}{c}\right)} = 32.4\ dB + 20\log 10^{f} \ldots\ldots\ldots (2)$$

where c = speed of light

f = carrier frequency in GHz and

$$AT[dB] = \alpha[dB/m] \times d(m) \ldots\ldots\ldots\ldots (3)$$

where α =attenuation factor in dB/m [1GHz to 100 GHz] which includes, collective attenuation effects of dry air (including oxygen),water vapor rain and haze[23].

$d = 3D\ T - R$ separation distance [1].

Figure 1 provides better insight into on propagation attenuation values due to dry air, vapor, haze and rain at mm Wave frequencies (1GHZ to 100 GHz),with a barometric pressure of 1013.25 m bar, a relative humidity of 50%, a temperature of 20^{0}C and a rain rate of 5 mm/hr [23].

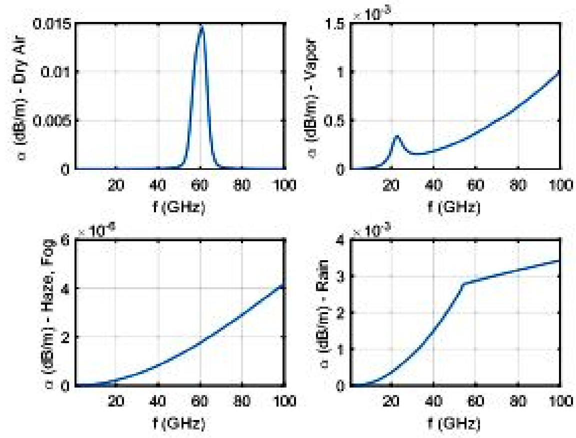

Fig. 1: Propagation attenuation due to dry air, vapor, haze, and rain at mmWave frequencies, with a barometric pressure of 1013.25 mbar, a relative humidity of 80%, a temperature of 20◦C, and a rain rate of 5 mm/hr [23].

Clustering definition in NYUSIM:

NYUSIM uses time cluster (TC) and spatial lobe (SL) concepts to describe multipath behavior in Omni directional channel impulse responses (CIRs). TCs are composed of multipath components traveling close in time, and arriving from potentially different directions in a short propagation time window. SLs denote primary directions of departure (or arrival) where energy arrives over several hundred nanoseconds [6]. Per the definitions given above, a TC contains multipath components traveling close in time, but may arrive from different SL angular directions, such that the temporal and spatial statistics are decoupled and can be recovered separately. Similarly, an SL may contain many multipath components arriving (or departing) in a space (angular cluster) but with different time delays. This distinguishing feature is obtained from realworld propagation measurements [1], [5] which have shown that multipath components belonging to the same TC can arrive at distinct spatial pointing angles and that energy arriving or departing in a particular pointing direction can span hundreds or thousands of nanoseconds in propagation delay, detectable due to high-gain rotatable directional antennas. The TCSL clustering scheme is physically based, for instance, it utilizes a fixed intercluster void interval to represent the minimum propagation time between possible obstructions causing reflection, scattering, or diffraction, and is derived from field observations based on about 1 Tb of measured data over many years, and can be used to extract TC and SL statistics for any measurement or ray-tracing data sets [6].

III. GUI AND SIMULATOR BASICS

The screen shot in figure 2 illustrates the GUI of NYUSIM.NYUSIM performs Monte Carlo simulations, generates certain number of samples of CIRs at a specific T-R separation distance. The number of samples and T-R separation distances are to be given by the user.

A .Input Parameters

There are 28 input parameters on GUI of NYUSIM. They are divided into two categories: Channel parameters and Antenna parameters. Channel parameters consists of 16 basic input parameters related to propagation channel and antenna properties consists of 12 input parameters about the Tx and Rx antenna arrays.

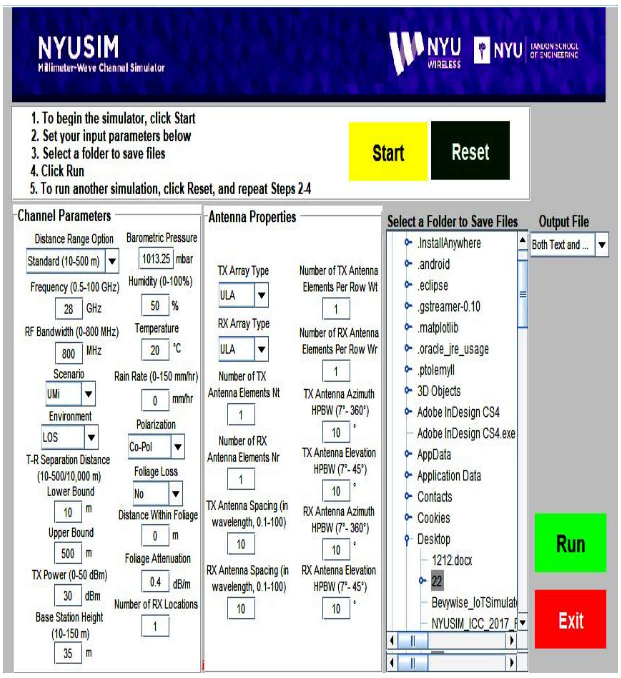

Fig. 2: Graphical User Interface (GUI) of the NYUSIM channel model simulator

B. Output Files

In each simulation run 6 figures are generated. The six output figures are

- 3D AOD power spectrum
- 3D AOA power spectrum
- A sample of Omni directional power delay profile (PDP)
- A sample of directional PDP with strongest power
- A series of PDPs over different receive antenna elements
- Path Loss scattering plot

Figure 5 shows the path loss (directional and Omni directional)scatter plot generated after N simulation runs over the entire distance along with the fixed PLE and fading standard deviation using the minimum mean square error (MMSE) technique [15],[17].In the legend of figure 5

n: represents PLE
σ: shadow fading standard deviation
Omni : Omni directional
dir : directional
dir-best: direction with strongest received power

To produce directional path loss at each Rx location .NYUSIM searches for all possible pointing angles in increments of azimuth and elevation of HPBWs of the Tx/Rx antenna specified by the user on GUI after first generating the Omni directional PDP. The TX/Rx antenna gain pattern is calculated by NYUSIM using equations (45) and (46) in [13] based on Azimuth and elevation HPBWs of Tx and Rx antennas as mentioned by the user on GUI

Directional path loss(DPL) $=$Tx power $+$Tx and Rx antenna gain $-$directional received power [11],[12].

DPL and DPLE will always be larger (because directional channel is always lossy) than Omni directional , because, the directional antenna will spatially filter out many MPCs due to its directional pattern ,then Rx receives fewer MPCs hence less energy, so the directional path loss is higher after removing the antenna gain effect from the received power [12],[17].

Output Data files

For each simulation run, five sets of .txt files and five corresponding .mat files are generated, namely, “AODLobePowerSpectrumn Lobex.txt”, “AODLobePowerSpectrumn.mat”, “AOALobePowerSpectrumn Lobex.txt”, “AOALobePowerSpectrumn.mat”, “OmniPDPn.txt”, “OmniPDPn.mat”, “DirectionalPDPn.txt”, “DirectionalPDPn.mat”, “SmallScalePDPn.txt”, and “SmallScalePDPn.mat”, where n denotes the nth RX location (i.e., nth simulation run), and x represents the xth spatial lobe. After N continuous simulation runs, another three .txt files and three corresponding .mat files are produced, i.e., “BasicParameters.txt”, “BasicParameters.mat”, “OmniPDPInfo.txt”, “OmniPDPInfo.mat”, “DirPDPInfo.txt”, and “DirPDPInfo.mat”. The files “BasicParameters.txt” and “BasicParameters.mat” subsume all the input parameter values as shown on the GUI when running the simulation. The files “OmniPDPInfo.txt” and “OmniPDPInfo.mat” contain four columns where each column represents a key parameter for each of the N omni directional PDPs from N continuous simulation runs, including T-R separation distance, omni directional received power, omni directional path loss, and omni directional root-mean square (RMS) delay spread. The files “DirPDPInfo.txt” and “DirPDPInfo.mat” contain 10 columns where each column represents a key parameter for each of the directional PDPs from N continuous simulation runs, such as time delay, received power, phase, azimuth and elevation AODs and AOAs of each resolvable MPC (i.e., antenna pointing angle), along with directional path loss and directional RMS delay spread. Each “AOD Lobe Power Spectrumn Lobex” file is associated with a corresponding 3D AOD power spectrum output figure, and contains five parameters (columns) of each resolvable MPC in an AOD spatial lobe, namely: pathDelay (ns), path Power (mWatts), path Phase (rad), AOD (degree), and ZOD (degree). Similar parameters are contained in each .txt and .mat file "AOA Lobe Power Spectrumn Lobe x" that is associated with the output figure of 3D AOA power spectrum.

Each "OmniPDPn" file is associated with an omnidirectional PDP output figure, and contains two columns: the first column denotes the propagation time delay in nanoseconds, and the second column represents the received power in dBm. Each .txt and .mat file "Directional PDPn" is associated with the output figure of directional PDP with strongest power, and contains two columns: the first column denotes the propagation time delay in nanoseconds, and the second column represents the received power in dBm. Each .txt and .mat file "Small Scale PDPn" is associated with the output figure of the series of omnidirectional PDPs over different RX antenna elements, and contains three columns: the RX antenna separation in terms of number of wavelengths, the propagation time delay in nanoseconds, and the received power in dBm.

Results

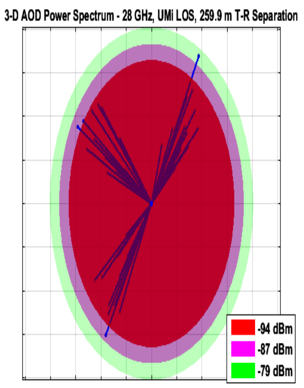

Figure 3: 3D AOD power spectrum

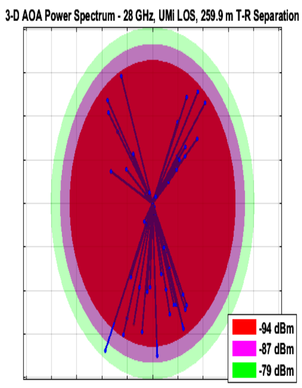

Figure 4: 3D AOA power spectrum

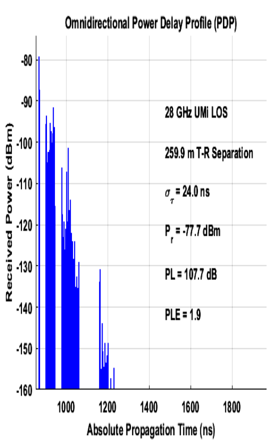

Figure 5: Omni directional PDP

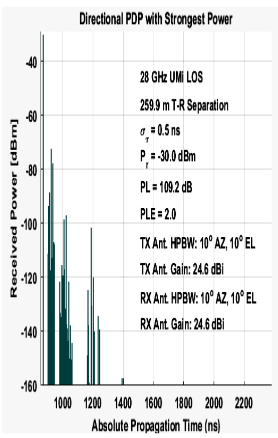

Figure 6: Directional PDP with strongest power

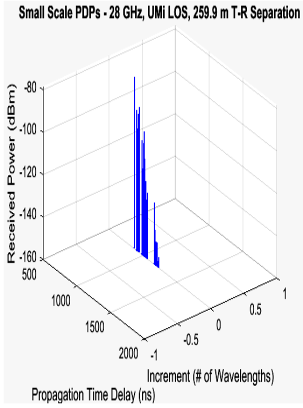

Figure 7: Small scale PDP

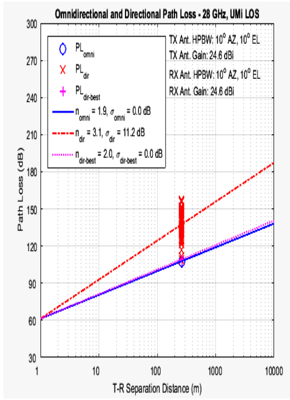

Figure 8: Omni directional and directional path loss

Table 1: CIRs at different antenna spacing's

		Spacing between elements in λ						
		1λ	**5λ**	**10λ**	**20λ**	**40λ**	**80λ**	**100λ**
Omni Directional PDP	σ_T ns	15.8	20.4	21.4	20.2	16.8	12.3	0
	P_r dBm	-69.8	-70.8	-61.9	-84.4	-81.5	-93.7	-82.6
	P_L dB	99.8	100.8	91.9	114.4	111.5	123.7	112.6
	PLE	1.9	2	1.6	2.1	1.9	2.4	1.9
Directional PDP	σ_n ns	0.9	6.1	1.1	2.6	1.4	1.4	0
	P_t dBm	-24.7	-26.4	-15.7	-41	-38.6	-49.1	-33.4
	P_L dB	103.9	105.6	94.9	120.2	117.8	128.3	112.6
	PLE	2.1	2.2	1.8	2.4	2.1	2.5	1.9
	Tx gain dBi	24.6	24.6	24.6	24.6	24.6	24.6	24.6
	Rx gain dBi	24.6	24.6	24.6	24.6	24.6	24.6	24.6
Path Loss	n_{omni}	1.9	2	1.6	2.1	1.9	2.4	1.9
	σ_{omni} dB	0	0	0	0	0	0	0
	n_{dir}	3	3	3	3	2.8	3.1	1.9
	σ_{dir} dB	8.7	9.3	8.9	8.2	9.1	8.5	0
	$n_{dir-best}$	2.1	2.2	1.8	2.4	2.1	2.5	1.9
	$\sigma_{dir-best}$ dB	0	0	0	0	0	0	0
T-R separation in meters		266	179.8	255.9	305.2	442.4	437.6	463.4

Applications of NYUSIM

The output figures and data files generated from NYUSIM can be used to simulate CIRs for mm Wave system to investigate MIMO channel performance and to perform BER simulations[7],[33].Using NYUSIM the condition number of a MIMO channel can be obtained as discussed in [41]

Condition-number measurements are an excellent engineering tool for several reasons:

- They effectively measure MIMO operation by combining the effects of noise and undesirable channel correlation.
- They are measured directly from channel frequency response, without the need for demodulation or a matrix decoder.
- They are a frequency- or subcarrier-specific measurement, useful for uncovering frequency response effects.
- They relate a somewhat abstract matrix characteristic to practical RF signal characteristics such as SNR.

IV. CONCLUSION

This paper describes an open source channel simulator (NYUSIM), used for broad band propagation measurements at mm Wave frequencies. NYUSIM generates wideband PDPs/CIRs channel statistics for differenr spacings of antenna elements in Urban Micro Cell (UMi) environment. The performance of CIR is estimated using uniform Linear array.

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