Research Paper Presentation

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Title and Authors

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Effect of Path Loss Models on Performance of 5G Compatible MIMO WINDOW-OFDM Systems

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Abstract

1. In wireless communication systems, MIMO antenna architectures have the capability to enhance channel capacity and reliability.
2. OFDM is another technique, popular for high speed data transmission, robustness to frequency selective channels, low OOB(Out Of Band) emission and low PAPR(Peak to Average Power Ratio).
3. Employment of mm-waves frequency bands with the above two technologies is a major advancement. But the problems of propagating mm-waves frequency signals are time delay, fading, propagation and scattering losses.
4. So to attain better performance, optimizations of propagation parameters are crucial.

So, we will discuss about the effect of various Path Loss (PL) Models(ABG and CI) to design and analysis of a 4×4 MIMO W-OFDM system using several modulation techniques(16-DPSK, 16-PSK, 16-QAM) for 5G wireless communication. For window filters, Blackman, Hamming, and Bartlett windows have been considered.

Keywords and some definitions

Multiple Input and Multiple Output (MIMO):

Technique for sending and receiving more than one data signal simultaneously over the same channel by exploiting multipath propagation.

Orthogonal Frequency Division Multiplexing (OFDM):

Method of encoding digital data on multiple carrier frequencies, instead of a single wide frequency bandwidth.

Windowed Orthogonal Frequency Multiplexing (W-OFDM):

A technique which uses a simple window to regulate OOB emission and PAPR along with the OFDM.

Bit Error Rate (BER):

It is the number bit errors (bits received that are altered due to noise) per unit time.

Proposed System Model

Block Diagram

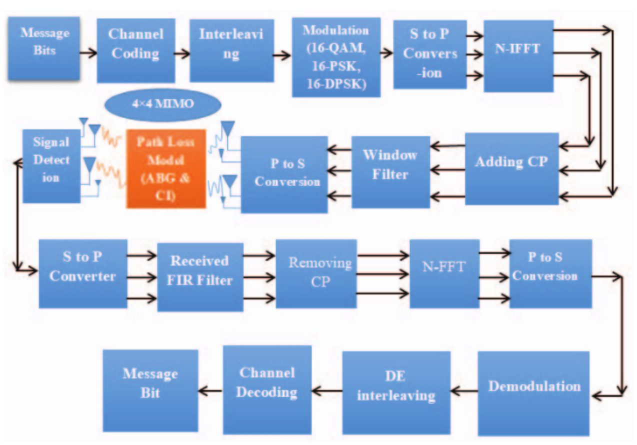

Figure: Proposed System Model of 4×4 MIMO using Path Loss Models and W-OFDM

Proposed System Model

1. Firstly, bits of stream have been used as an input that transmits only a single binary bit of information.
2. Bits of stream pass through the channel coding also known as forward error control coding that will detect and correct bit error in digital communication system.
3. Interleaving is implemented for combating bursts of error.
4. Modulation is the process of imposing digital information signal on to a very high-frequency carrier signal. Here three modulations (16-DPSK, 16-QAM, and 16-PSK) techniques have been used.

Proposed System Model

1. IFFT is Inverse Fast Fourier Transform. Each of the N-OFDM channels considered produces a symbol. These N symbols(maybe N 16-DPSK or 16-QAM or 16-PSK) are converted to N OFDM symbols by IFFT in time domain.
2. A Cyclic Prefix is a repetition of the first section of symbol that is appended to the end of the symbol for reducing inter-symbol interference from the prior symbol.
3. Window filters have been used to design the digital filter. Blackman, Hamming and Bartlett windows are used here.
4. Two PL models, ABG(Alpha-Beta-Gamma) and CI(Close-In) are considered. Generally, ABG model reduces the PL for data transmission and CI FSPL(Free Space Path Loss) minimizes the power loss of radio signal.

More about FSPL

1. FSPL is the attenuation of radio energy or loss in strength of a signal between the feed points of two antennas.
2. For all radio signals, high frequency signals experience greater FSPL as compared to lower frequency signals.
3. FSPL is calculated by equation (1)

$$\text{FSPL} = 20\log_{10}(d) + 20\log_{10}(f) + 20\log_{10}\left(\frac{4\pi}{C}\right) \tag{1}$$

where d is the distance between transmitter to receiver, f = operating frequency in GHz and C = Speed of light.

Calculating PL

For CI model

The equation of CI FSPL model is given by the equation (2)

$$\mathrm{PL}^{\mathrm{CI}}(f,d)[\mathrm{dB}] = \mathrm{PL}_{\mathrm{FS}}(f,d_0)[\mathrm{dB}] + 10n\log_{10}\left(\frac{d}{d_0}\right) \tag{2}$$

$\mathrm{PL}_{FS}(f,d_0)$ is FS propagation loss at distance $d_0 = 1$m for isotropic antenna and n is the PL exponent.
$d_0 = 1$ in Eq(2):

$$\mathrm{PL}^{\mathrm{CI}}(f,d)[\mathrm{dB}] = \mathrm{PL}_{\mathrm{FS}}(f,1m)[\mathrm{dB}] + 10n\log_{10}(d) \tag{3}$$

Calculating PL

For CI model

Equation of FS propagation loss at distance $d_0 = 1$m becomes

$$\mathrm{PL}_{\mathrm{FS}}(f, 1m)[\mathrm{dB}] = 20 \log_{10}\left(\frac{4\pi f}{C}\right) \tag{4}$$

From (3) and (4), final equation for CI model is

$$\mathrm{PL}^{\mathrm{CI}}(f, d)[\mathrm{dB}] = 20 \log_{10}\left(\frac{4\pi f}{C}\right) + 10n \log_{10}(d) \tag{5}$$

Calculating PL

For ABG model

The equation of PL for ABG model is given by the equation (6)

$$\mathrm{PL}^{\mathrm{ABG}}(f,d)[\mathrm{dB}] = 10\alpha\log_{10}(d) + \beta + 10\gamma\log_{10}(f) \tag{6}$$

where α and γ represent coefficients dependence of PL on distance and frequency respectively. Similarly β represents an optimized offset value for PL in dB.

In our experiment, the parameters α, β and γ are chosen for the line of sight communication in a suburban environment and the values of these parameters are $\alpha = 1$, $\beta = 69.4$, $\gamma = 2$.

Insights from the equations of PL in two different models

- In the equation (5) CI model have an inherent frequency dependency of PL and it has only one parameter. Its frequency dependence can be expressed primarily by the frequency dependent FSPL term.
- On the other side equation (6) the ABG models has three parameters alpha, beta and gamma has not only depend on frequency but also depend on several parameters.

Experimental Results and Analysis

Summary of Simulated Model Parameters

Table: Simulated Model Parameters

Parameters	Types
Message Type	12800 binary bits
Operating frequency (f)	28 GHz
Carrier Spacing	60 kHz
Data Rate	48 Mbps
Bandwidth	20MHz
Antenna configuration	4 $\times$4
Channel Coding	$\frac{1}{2}$ Rated Convolutional Code

Summary of Simulated Model Parameters

d_0	1
Alpha (α)	1
Beta (β)	69.4
Gamma (γ)	2
Digital Modulation	16-DPSK, 16-QAM, 16-PSK
IFFT / FFT Size	256
FIR (Band pass) Filters	Bartlett, Hamming, Blackman
SNR	-10 to 8 dB
Distance Considered (d)	100 m
Signal Detection(Channel Estimation) Scheme	MMSE (Minimum Mean Square Error)

Experimental Results and Analysis

Comparison of Symbol Error Rate

By decreasing the symbol error probability, we can transfer the data accurately.

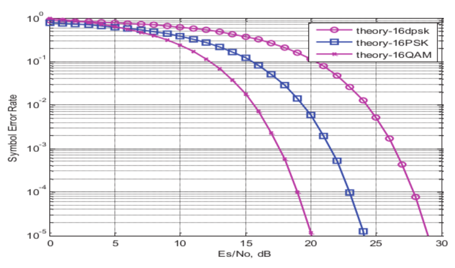

Figure: Probability of Symbol Error curve for 16-DPSK, 16-QAM and 16-PSK

From the figure, the order of probability of symbol error for digital modulations is 16-QAM < 16-PSK < 16-DPSK.

Experimental Results and Analysis

Channel Capacity for SISO and various MIMO configurations

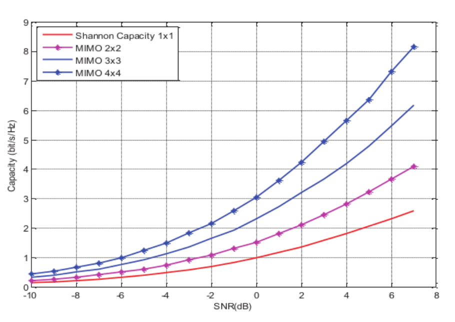

Figure: Channel Capacity for SISO and various MIMO configurations.

As the no.of antennas increase, the channel capacity also increases. So Channel capacity is maximum for MIMO 4×4 and minimum for SISO.

Experimental Results and Analysis

Comparison of FS, CI, and ABG PL Models

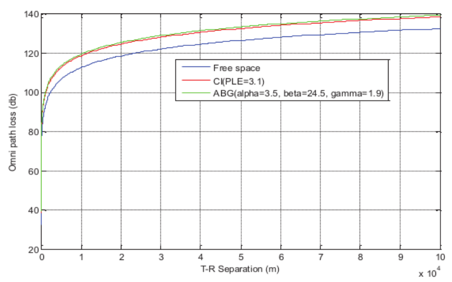

Fig. 4: Comparison of FS, CI, and ABG PL Models.

Figure: Comparison of FS, CI, and ABG PL Models.

From the figure, order of PL for these 3 models are FSPL < CI < ABG.

Comparison of BER

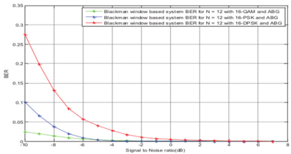

Fig. 6: Blackman window based MIMO W-OFDM system BER for N = 12 with 16-DPSK, 16-PSK, 16-QAM and ABG model.

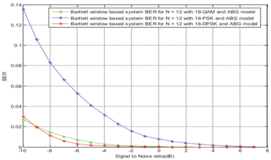

Fig. 8: Bartlett window based MIMO W-OFDM system BER for N = 12 with 16-DPSK, 16-PSK, 16-QAM and ABG model.

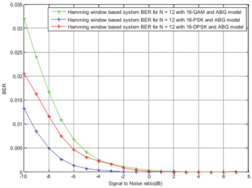

Fig. 11: Hamming window based MIMO W-OFDM system BER for N = 12 with 16-DPSK, 16-PSK, 16-QAM and ABG model.

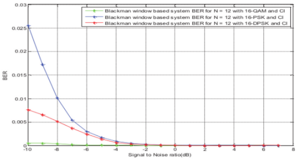

Fig. 7: Blackman window based MIMO W-OFDM system BER for N = 12 with 16-DPSK, 16-PSK, 16-QAM and CI model.

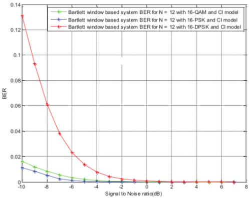

Fig. 9: Bartlett window based MIMO W-OFDM system BER for N = 12 with 16-DPSK, 16-PSK, 16-QAM and CI model.

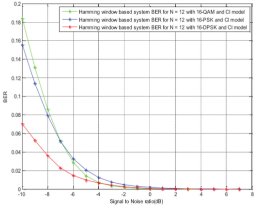

Fig. 10: Hamming window based MIMO W-OFDM system BER for N = 12 with 16-DPSK, 16-PSK, 16-QAM and CI model.

Figure: Comparison of BER for the 3 digital modulations for different window filters and PL models

Comparison of BER

From the simulations, we can select the system with minimum BER. SNR is taken as -10dB.

Window name	PL Model	Modulation Name	BER	Selection
Blackman	ABG	16-QAM	0.023	✓
		16-PSK	0.100	
		16-DPSK	0.275	
	CI	16-QAM	0.002	✓
		16-PSK	0.007	
		16-DPSK	0.026	
Bartlett	ABG	16-QAM	0.028	✓
		16-PSK	0.138	
		16-DPSK	0.030	
	CI	16-QAM	0.018	
		16-PSK	0.015	✓
		16-DPSK	0.130	
Hamming	ABG	16-QAM	0.032	
		16-PSK	0.013	✓
		16-DPSK	0.021	
	ABG	16-QAM	0.182	
		16-PSK	0.158	
		16-DPSK	0.070	✓

Table: Selections of minimum BER

Comparison of BER

Second Selections of minimum BER

Table: Second Selections of minimum BER based on PL Models, and different window and modulation systems.

Window name	PL Model	Modulation Name	BER	Selection
Blackman	ABG	16-QAM	0.023	
	CI	16-QAM	0.002	✓
Bartlett	ABG	16-QAM	0.028	
	CI	16-PSK	0.015	✓
Hamming	ABG	16-PSK	0.013	✓
	CI	16-DPSK	0.070	

Comparison of BER

Final Selections of minimum BER

Window name	PL Model	Modulation Name	BER
Blackman	**CI**	**16-QAM**	**0.002**
Bartlett	CI	16-PSK	0.015
Hamming	ABG	16-PSK	0.013

Table: Final Selections of minimum BER based on PL Models, and different window and modulation systems.

Experimental Results and Analysis

Insights from the Comparison of BER

1. From the above table; Blackman window, CI PL model and 16-QAM digital modulation based MIMO W-OFDM system shows minimum BER performance as compared to other two combinations.
2. At -10 dB SNR, Blackman window, CI PL model and 16-QAM digital modulation based MIMO W-OFDM system performs enhancement of 8.12 dB as compared to Bartlett window, CI PL model and 16-PSK digital modulation based MIMO W-OFDM system and 8.75 dB as compared to Hamming window, ABG PL model and 16-PSK digital modulation based MIMO W-OFDM system.

Experimental Results and Analysis

PAPR Comparisons

1. Minimum the PAPR values, more efficient the power amplifier in the transmitter.
2. Estimated PAPR values for W-OFDM system is 9.401 dB and that of CP-OFDM system is 9.4523. So these values show that the PAPR performance of W-OFDM is better than CP-OFDM system.

Conclusion

Conclusions and Inference

1. A comprehensive study of MIMO W-OFDM system has been made by exploiting ABG and CI PL models to analyze minimum BER, channel capacity of various MIMO configurations and PAPR by using 16-DPSK, 16-PSK, 16-QAM digital modulations and Blackman, Bartlett and Hamming window filters under the implementation of MMSE signal detection scheme.
2. From simulation study it can be said that CI PL model based MIMO W-OFDM system with Blackman window and 16-QAM digital modulation is very much robust and effective in retrieving transmitted signals.

Thank You