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PAPR Impact over the PER of Vehicle-to-Vehicle Communications with Fading Channels

Italo Alexander Carreño, Frank Andrés Eras 0000-0002-7844-5670, Thomas Borja, Diego Javier Reinoso* 0000-0003-0854-1250, Luis Felipe Urquiza 0000-0002-6405-2067, Martha Cecilia Paredes 0000-0001-5789-4568

Departamento de Electrónica, Telecomunicaciones y Redes de Información, Escuela Politécnica Nacional

* Correspondence: diego.reinoso@epn.edu.ec

1 **Abstract:** Peak-to-Average Power Ratio (PAPR) is one of the main problems in wireless
2 communications using Orthogonal Frequency Division Multiplexing (OFDM). Its behavior is random
3 and can produce problems for the hardware implementation, directly influencing the Packet Error
4 Rate (PER). In this article, the PER is obtained for channels with Rayleigh and Rician fading. In the
5 simulation, a High Power Amplifier (HPA) is added to the transmitter and for PAPR reduction Simple
6 Amplitude Predistortion-Orthogonal Pilot Sequences (OPS-SAP) technique is used.

7 **Keywords:** PAPR; HPA; OPS-SAP; PER; fading models

8 1. Introduction

9 Orthogonal Frequency Division Multiplexing (OFDM) is a digital communication scheme
10 that transmits using multiple orthogonal carriers [1]. It is an attractive technology for wireless
11 communications because it offers considerable high spectral efficiency, multipath delay spread
12 tolerance, immunity to the frequency selective fading channels and power efficiency [2].

13 One of the main drawbacks of the OFDM system is the high Peak-to-Average Power Ratio (PAPR)
14 of transmitted OFDM signals. The PAPR in OFDM transmission can be defined as the ratio of peak
15 power with respect to average power. A high PAPR requires that the power amplifiers work in a very
16 large linear region, otherwise, the saturation of the devices occurs, causing out-of-band radiation that
17 affects adjacent bands and within the band that attenuates and displaces the signal, increasing the Bit
18 Error Rate (BER) [3].

19 The simplest way of modeling a wireless communication channel is using the Additive White Gaussian
20 Noise (AWGN). However, for a more accurate model it is necessary to take into account the fading,
21 which is the variation of the signal in time and frequency, caused mainly by the multipath, lost by
22 trajectory and by shadows due to obstacles. The main two models for the fading are Rayleigh and
23 Rician that are used for NLOS (Non-Line-of-Sight) and LOS (Line-of-Sight), respectively.

24 2. Theoretical Review

25 2.1. IEEE 802.11p Communication System

26 The OFDM physical layer model will follow the training and reception process described in the
27 IEEE 802.11 standard [4] using an AWGN, Rayleigh, and Rician channel. With a bandwidth of 10
28 MHz, the eight possible combinations of coding rate and modulation scheme available in the IEEE
29 802.11 standard [4] that allow to obtain different speeds for data transmission are implemented, these
30 combinations are shown in Table 1.

Modulation Scheme	Bits Per Modulated Symbol (m)	Coding Rate (r)	Data rate v_i [Mbps]
BPSK	1	1/2	3
BPSK	1	3/4	4.5
QPSK	2	1/2	6
QPSK	2	3/4	9
16QAM	4	1/2	12
16QAM	4	3/4	18
64QAM	6	2/3	24
64QAM	6	3/4	27

Table 1. Configurations allowed for IEEE 802.11p. [4]

31 2.2. PAPR Problem

32 The major obstacle in the transmitter side of any OFDM system, occurs when the signal has a
 33 very high peak instantaneous power with respect to its average power, due to the possibility that
 34 the subcarriers can be aggregated with identical phase in a certain time, thus the time-domain signal
 35 achieves a very important contribution of power [5]. The signal peaks lead to certain hardware
 36 components such as Digital-Analog Converters and Analog Amplifiers to have a behavior below their
 37 maximum performance.

38 2.3. Channel Models

39 2.3.1. AWGN Model

40 It is the simplest channel model in a wireless communications environment. The mathematical
 41 expression in received signals that passed through the AWGN channel is: $r(t) = s(t) + n(t)$ where $s(t)$
 42 is the transmitted signal and $n(t)$ is noise. It is the basic communication channel model and it is used
 43 as a standard channel model since the transmitted signal gets disturbed by a simple additive white
 44 Gaussian noise process [6].

45 2.3.2. Rayleigh Fading Model

46 Rayleigh fading is mainly caused by multipath reception. It is a statistical model for the effect of a
 47 propagation environment on a radio signal. It is a reasonable model for the propagation of troposphere
 48 and ionosphere signals, as well as the effect of highly urbanized urban environments on radio signals.
 49 Rayleigh fading is most applicable when there is no line of sight (NLOS) between the transmitter and
 50 the receiver [6].

51 2.3.3. Rician Fading Model

52 Rician fading can be defined as a Rayleigh fading model, but the difference lies in the dominant
 53 component. In the Rician fading channel model, there is a strong dominant component present that is
 54 a non-fade signal commonly known as the line of sight component. This fading occurs when one of
 55 the paths has a stronger line of sight than others [7].

56 2.4. High Power Amplifier

57 The aim of The High Power Amplifier (HPA) is to increase the amplitude of the signal by a factor
 58 K . The main characteristic of the HPA is that they do not have a linear behavior. The most efficient
 59 operating point for an HPA is at the saturation level. However, high peaks encountered in OFDM
 60 signals can drive the nonlinear HPA into saturation [5]. In practical systems, the HPA is a device
 61 limited in power and very sensitive to the variation of the amplitude of the signal. The type of HPA
 62 most commonly used is Solid State Power Amplifier (SSPA) implemented with the Rapp Model.

63 2.5. PAPR reduction techniques

64 Currently, several techniques have been proposed to reduce PAPR in OFDM systems. They can
65 be classified into techniques that introduce signal distortion, and those that do not introduce signal
66 distortion. Each of the techniques has its advantages as disadvantages and the analysis of each of the
67 different techniques is not covered in this work.

68 One of the main techniques to reduce PAPR is the Simple Amplitude Predistortion together with
69 Orthogonal Pilot Sequences (OPS-SAP), with which it is possible to move certain constellation points
70 of the OFDM symbol to counteract the PAPR[8].

71 2.5.1. OPS-SAP technique

72 This technique for reducing PAPR is based on a two-step algorithm, where the OPS is implemented
73 in the first step and then SAP is added as the second step. In the first stage the sequence of pilots
74 that offers the lowest PAPR, of the whole set of available pilots, is inserted. In the second step, the
75 extension of certain symbols in the frequency domain is performed, the symbols to be extended are
76 chosen by means of a metric, which measures the contribution of the frequency symbols that have
77 large power peaks in the time domain [5].

78 3. Matlab implementation

79 3.1. Rayleigh and Rician block diagrams

80 The packing, scrambler, convolutional coder, interleaver, modulator, OFDM symbol, Cyclic
81 prefix aggregation, cyclic prefix extraction, OFDM symbol mapping, demodulator, deinterleaver,
82 convolutional decoder, and unpacking generator blocks were obtained from the scripts related to the
83 thesis document [9]. They create, compose and decompose OFDM symbols and packets.

84 The Up frequency block receives OFDM packets as input. A carrier frequency vector with the same
85 size as the OFDM packet is generated and it is applied to the packet to achieve the up frequency. The
86 opposite process is performed at reception (Down frequency block), the carrier frequency vector is
87 applied to the packet to change it to baseband.

88 The PAPR reduction technique block receives OFDM symbols as input, and its PAPR is obtained. If
89 this value is over 6 dB, OPS is applied. The amplifier block is carried out by using the Rapp model.
90 The block uses IBO and s parameters set at the start of simulation.

91 The application of the fading channel block is done by applying MATLAB's own functions:
92 comm.Rayleigh and comm.Rician. It receives OFDM packets as input. These functions also generate
93 the channel frequency response used later by the equalization block. The AWGN channel block is also
94 applied by a MATLAB's own function. It uses the values given by the SNR vector and the OFDM
95 packet as inputs.

96 The equalization block receives OFDM symbols at reception. The frequency response from the symbol
97 is obtained and then divided by the conjugate of the frequency response of the fading channel.

98

99 4. Simulation Results

100 Figures 1, 2 and 3 present PER vs SNR curves for amplified passband OFDM frames when they
101 cross an AWGN, Rayleigh and Rician channel, respectively. An equalization process was carried
102 out for Rayleigh and Rician channel cases. Dashed line curves represent OFDM frames without the
103 application of the PAPR reduction technique while solid line curves represent OFDM frames with the
104 application of the PAPR reduction technique.

105 These figures show a minimal difference in the PER when the OPS-SAP technique is used for low
106 data rates (until 18 Mbps). For 24 Mbps and 27 Mbps data rates a considerable difference is observed.
107 In this case the PAPR reduction technique is able to improve the PER significantly.

108 PER performance is similar in the cases of AWGN and Rician. However, the Rayleigh case
 109 presents a decrease in performance of 5 dB on average compared with the AWGN case. This is caused
 110 due to Rayleigh fading since there is no line of sight in this type of fading.

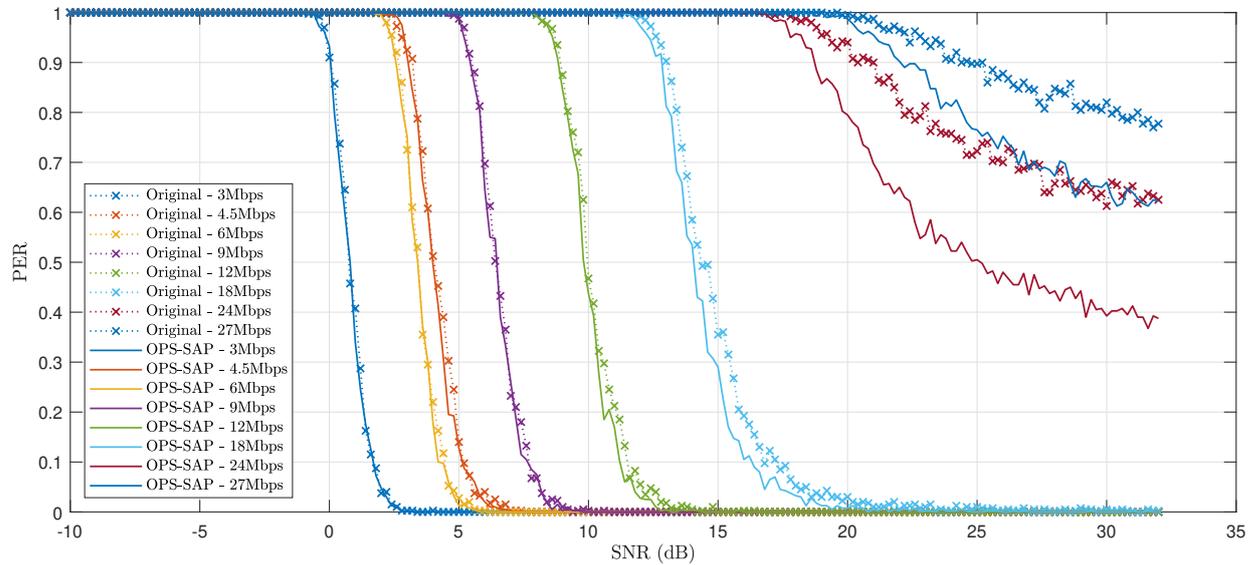


Figure 1. PER vs SNR of amplified passband signal (5.9 GHz) with AWGN channel, SSPA, IBO=6 dB).

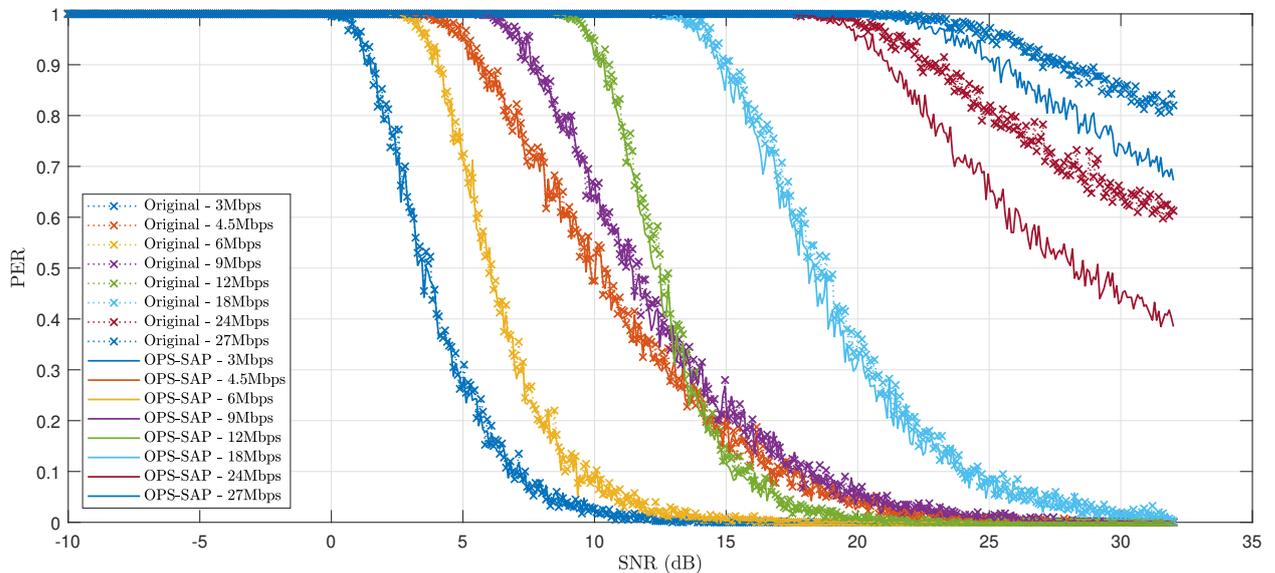


Figure 2. PER vs SNR of amplified passband signal (5.9 GHz) with Rayleigh fading channel, SSPA, IBO=6 dB.

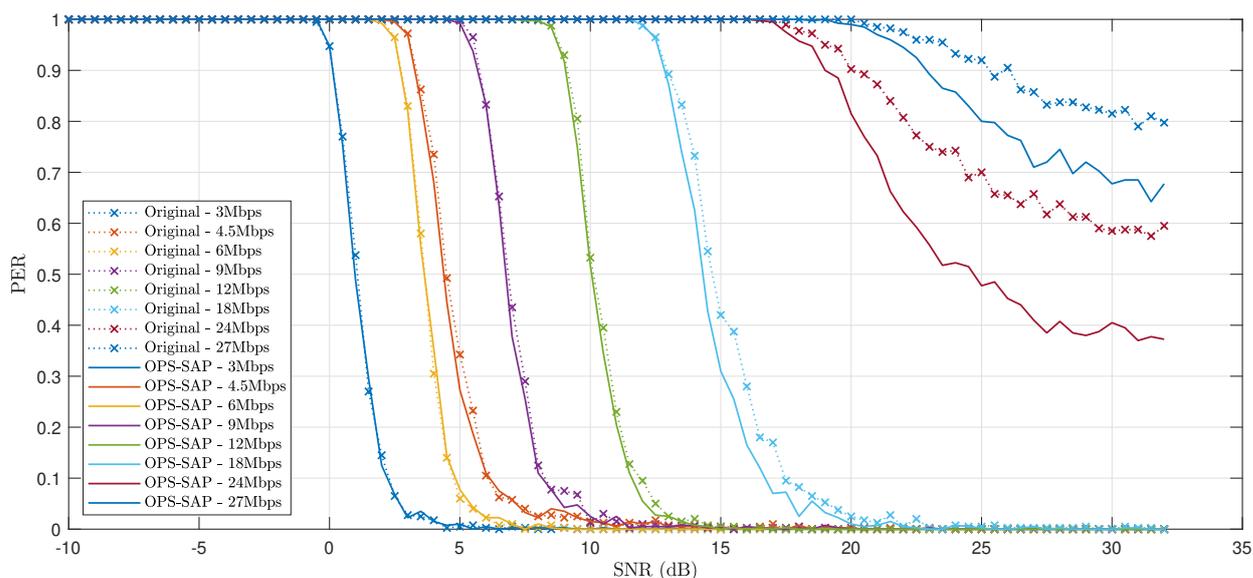


Figure 3. PER vs SNR of amplified passband signal (5.9 GHz) with Rician fading channel, SSPA, IBO=6 dB.

111 Figures 4, 5, and 6 present PER vs SNR curves for amplified baseband OFDM frames when they
 112 cross an AWGN, Rayleigh and Rician channel respectively. Similarly to the previous figures, dashed
 113 line curves represent OFDM frames without the application of the PAPR reduction technique whilst
 114 solid line curves represent OFDM frames with the application of the PAPR reduction technique. These
 115 figure do not show a considerable difference when comparing frames with and without technique
 116 which leads to the conclusion that PAPR reduction technique does not affect the PER performance
 117 significantly. Same as passband frames, PER performance is similar in the cases of AWGN and Rician.
 118 However, the Rayleigh case presents a decrease in performance of 8 dB on average compared with the
 119 AWGN case. This is caused due to Rayleigh fading since there is no line of sight in this type of fading.

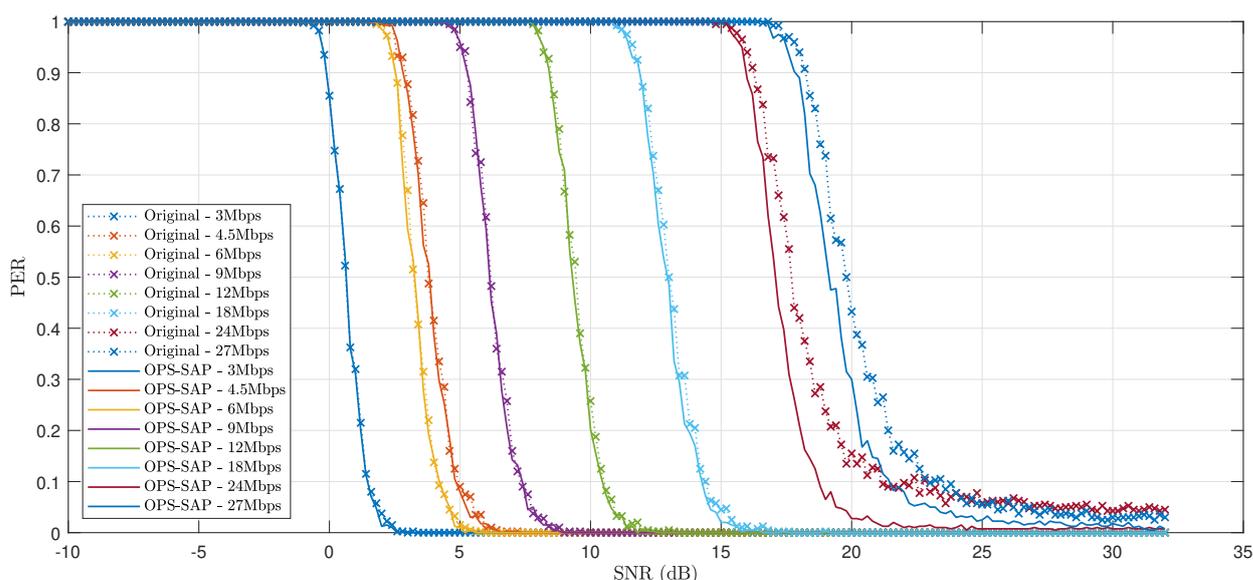


Figure 4. PER vs SNR of amplified baseband signal with AWGN channel, SSPA, IBO=6 dB

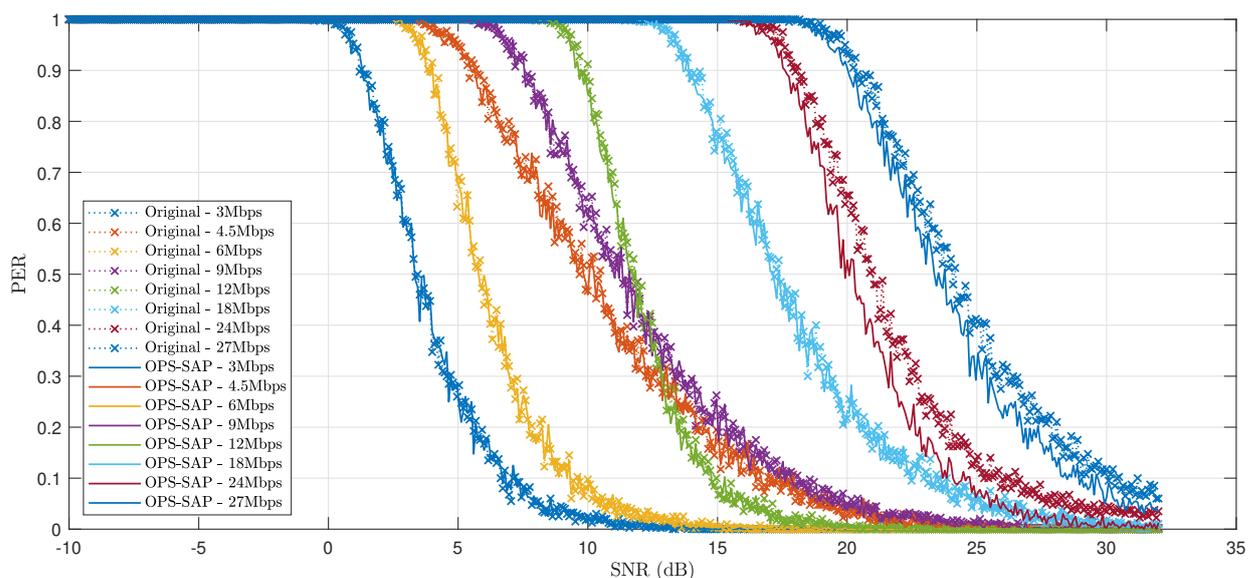


Figure 5. PER vs SNR of amplified baseband signal with Rayleigh fading channel, SSPA, IBO=6 dB

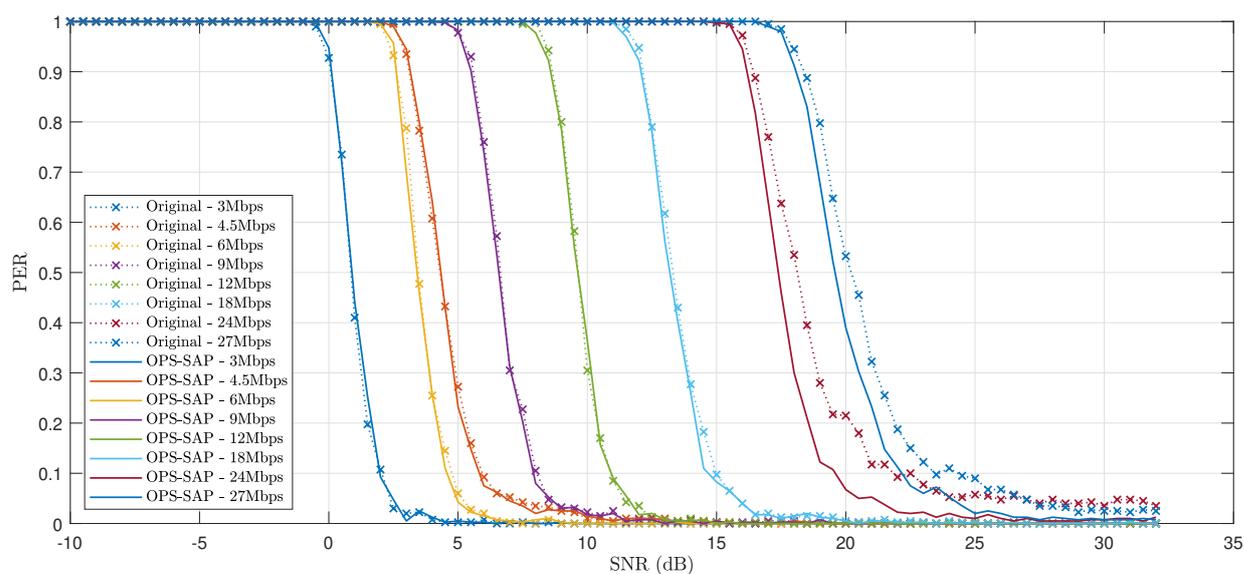


Figure 6. PER vs SNR of amplified baseband signal with Rician fading channel, SSPA, IBO=6 dB

120 5. Conclusions

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- For high data rates (24 Mbps and 27 Mbps) the use of the OPS-SAP technique for the reduction of the PAPR is of great importance due to the improvement that the curves show since they are displaced to the left.
 - The channel with the best PER is the AWGN followed by the Rician channel and finally the Rayleigh channel. There are very few differences between the AWGN channel and Rician. On the other hand, the Rayleigh channel shifts the curves to the right in several dBs, taking the AWGN channel as a reference, in addition to the aforementioned, the Rayleigh channel is the only one that presents nonlinearities in its curve, in other words it varies a lot on a small scale but maintaining the characteristic form.

- 130 • Even though the AWGN channel obtains the best PER, the Rayleigh and Rician channel models
131 are widely used because they are closer to the reality.

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