

# About Random LOS in Rician Fading Channels for MIMO OTA Tests

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## Abstract

It is often claimed that Rician fading must also be included for Over-The-Air (OTA) testing of mobile devices with Multiple-input Multiple-output (MIMO) capabilities. However, the Line-Of-Sight (LOS) component varies with orientation and location of the mobile device. Therefore, we study Rician channels with random LOS to determine its significance.

**Keywords:** Over-The-Air, MIMO, Propagation

## 1. Introduction

Today MIMO antenna systems have found several applications. With the advent of Long Term Evolution (LTE) wireless technology, MIMO antenna systems have a very promising future especially in mobile wireless devices. MIMO systems make use of antenna diversity in order to mitigate the effects of multipath fading. There are many articles already published on the characterization of MIMO terminals but the effect of user statistics i.e. user position and orientation has often been neglected. These user statistics will cause a random Line-Of-Sight (LOS) effect. Therefore, we will study the effect of random LOS in Rician fading channels to determine the significance of including the Rician environments in Over-The-Air (OTA) testing procedures for LTE devices. OTA tests are needed in order to include the performance of multipoint antennas in complete wireless system tests. This is in contrast to conductive tests where channel emulators are directly connected to the RF ports of the wireless devices instead of the antennas.

In previous studies [1]-[3] the rich isotropic environment was proposed as a reference for OTA testing of wireless devices. The rich isotropic environment assumes no LOS and a large number of independent incoming waves. The independency means that the amplitude, phase, polarization and Angle-of-Arrival (AoA) of the incoming waves are randomly generated. The reverberation chamber is a multi-mode metal cavity that emulates rich isotropic multipath environment when stirred e.g. by moving metal plates inside it. It has been used for measuring performance of active and passive antenna systems for more than 10 years, and in particular to characterize MIMO performance [4],[5]. The amplitude of the voltage samples measured on each antenna port in such a well-stirred chamber shows Rayleigh distribution (i.e. both the real and imaginary parts of the complex voltages at each antenna port are Gaussian distributed with zero mean), which can be considered as a proof of pure NLOS environment [6]. There are published papers also on emulating Rician distributed channels in reverberation chamber [7], but unfortunately such Rician distribution causes measurement uncertainty [8]. Therefore, it is of particular interest to determine the significance of the Rician distribution for testing mobile devices, and in particular when the user statistics are taken into account. The latter is studied in the present paper simply by assuming random LOS voltages, at the antenna port, with complex Gaussian probability distribution. The validity of this assumption can be found in [9].

The reverberation chamber is known to give ergodic capacity for MIMO systems that is in agreement with other prediction methods e.g. based on measurements of efficiency and far-field function in anechoic chambers [10].

## 2. Random LOS Channel

A Rician fading environment is specified by Rician K-factor of the channel, defined by the ratio between the power of LOS contribution and the average power of the multipath contribution to the channel. The LOS contribution to the channel voltage corresponds to the mean of the complex port voltage, and the multipath contribution corresponds to the statistical variations around the mean. To handle a statistically varying LOS contribution, we introduce an average Rician K-factor  $K_{av}$ , being the ratio of the average power of the LOS contribution and the average power of the multipath contribution to the port voltage. We also introduce an integer parameter T which allows the LOS contribution to fade slower than the multipath contribution. We assume that the LOS contribution remains constant for T samples (i.e. no change in the user position and orientation during T samples), and thereafter it changes randomly to another value which remains constant for another T samples, and so on. Thus, T is a relative fading period. This channel model having a random LOS contribution together with a random multipath contribution is named as ‘isotropically random Rician fading’ model in a different study presented in [11].

## 3. Rayleigh Lab

This study has been carried out using MATLAB based simulation tool called ‘Rayleigh Lab’ [2]. It is also called a multipath response simulator since it provides a theoretical response of a multipath environment on each port of a multipoint antenna system. Rayleigh Lab outputs the performance of MIMO antennas in Rayleigh fading, Rician fading, and Rician fading with random LOS. At first, Rayleigh Lab generates channels by using arrays of random numbers in MATLAB representing complex voltage samples received at the antenna ports. The user provides values for efficiencies of the antennas and correlation among them, and from these values Rayleigh Lab calculates the diversity gain and the ergodic capacity of the antenna system, by using the generated channels. The key terms such as samples, realizations, etc. used to present Rayleigh Lab results are explained in our previous studies [2], [12].

## 4. Simulation Results

Following are the results from Rayleigh lab showing Cumulative Distribution Function (CDF) for an ideal 4x4 MIMO system, i.e. with no correlation and 0 dB embedded element efficiency on all ports, using 10,000 channel samples at each port of the multipoint antenna system. For the generation of the CDFs each voltage sample in each realization is normalized by the square root of the average received power on the port. The figures show CDFs of four different realizations of the 4x4 MIMO system, each realization with a different colour. So, there are 16 CDF curves of each colour in the graphs, in addition to 16 curves showing selection combined CDF, 4 curves for each realization.

The CDF curves of Rayleigh fading and Rician fading with a fixed K-factor shown in Figure 1 are as expected. The 16 curves show some spread around the theoretical curve because we use a limited number of samples. The CDFs for Rician fading with random LOS that has the same fading period  $T = 1$  as the random multipath contribution are shown in Figure 2 for two values of  $K_{av}$ . We can observe that the CDFs are Gaussian with the same spread as in Figure 1. Thus, the sum of two Gaussian contributions is a Gaussian as well, which is not surprising at all. The same CDFs are plotted in Figure 3 when the fading period is  $T = 100$  times slower for the random LOS. We can see that the spread of these CDF curves are larger than in Figures 2, meaning that they have not converged so well as in Figures 2. The reason is that the number of independent samples in the LOS contribution is not sufficiently large. The number of uncorrelated samples is only 100 when the total number of samples is 10,000 and  $T = 100$  samples, whereas we need at least 1000 uncorrelated samples to see convergence at 1% CDF level.

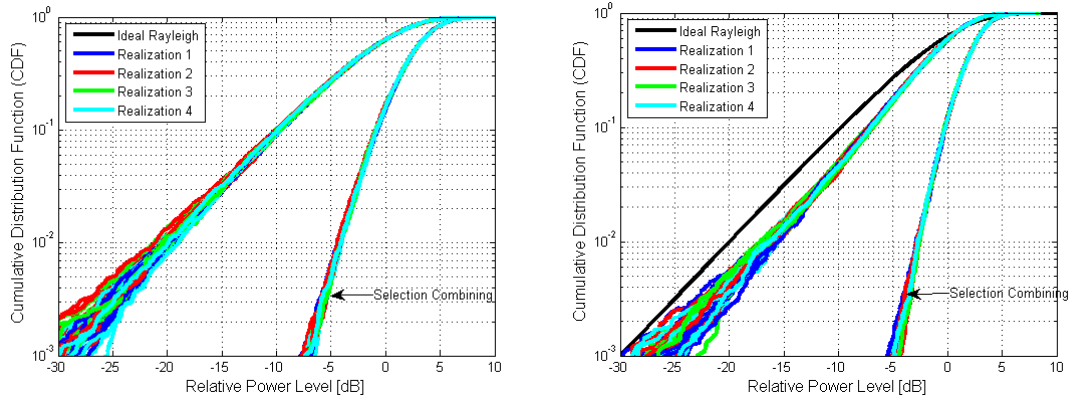


Figure 1: CDFs of pure Rayleigh fading (left) and Rician fading (right) with  $K = 3$  dB.

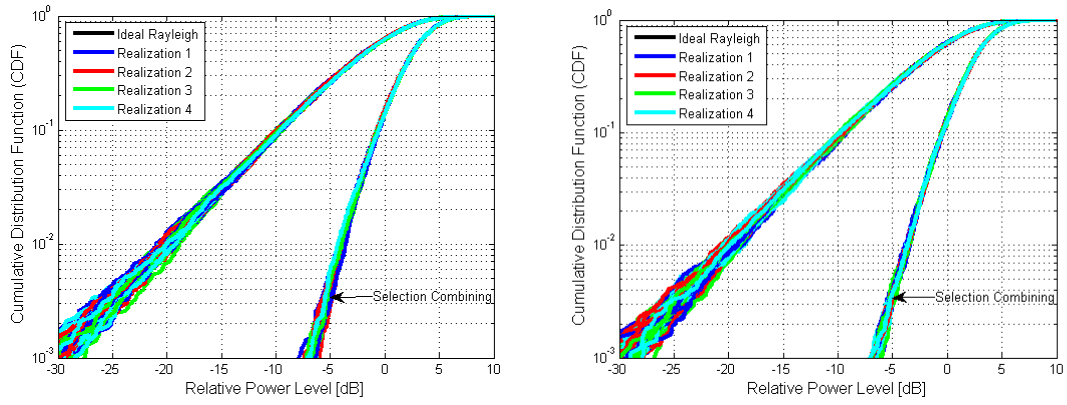


Figure 2: CDFs of Rician fading with random LOS,  $T = 1$  sample,  $K_{av} = 3$  dB (left) and 10 dB (right).

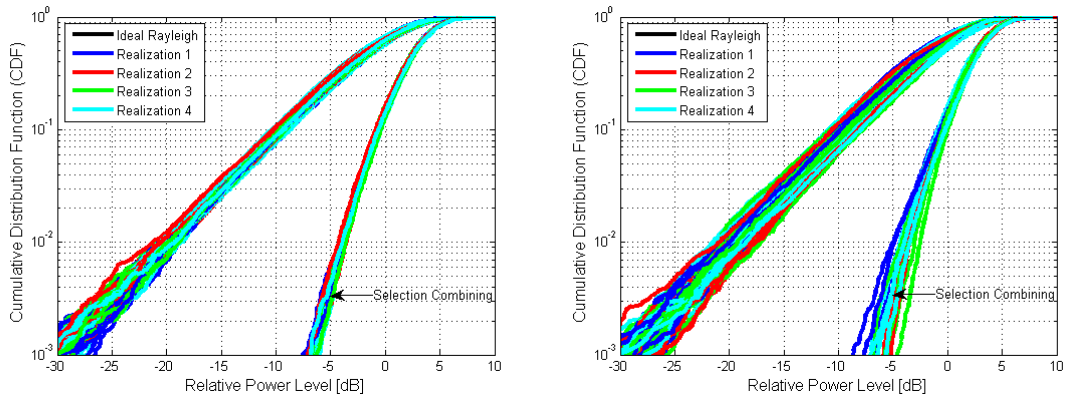


Figure 3: CDFs of Rician fading with random LOS,  $T = 100$  samples,  $K_{av} = 3$  dB (left) and 10 dB (right).

## 5. Conclusion

Arbitrary user positions and orientations will create an effect of ‘random LOS’, i.e. Rician fading environment with random Rician  $K$ -factor. We have shown that if this random LOS has a complex Gaussian distribution, the CDF of Rician fading with random LOS converges to the same

CDF as ideal Rayleigh fading with no LOS. Therefore, under these conditions there remains no need to emulate Rician fading environments for OTA testing of wireless mobile devices; they can equally well be tested under Rayleigh fading only.

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