Experimental Rician K-factor characterization in a laboratory environment at the 25 to 40 GHz frequency band

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***Abstract*—In this work, an analysis of the Rician K-factor in a laboratory environment from 25 to 40 GHz has been carried out. The variation of the estimated K-factor has been assessed in frequency from a channel measurements campaign in both line-of-sight (LOS) and non-LOS (NLOS) conditions. Mean values of the K-factor ranging from 0.48 to 3.43 dB for LOS conditions, and from -5.54 to -0.56 dB for NLOS conditions, have been derived. The results reported here enable us to get insight into the propagation channel characteristics and can be of interest to evaluate the performance of fifth-generation (5G) networks in laboratory environments.**

I. Introduction

In wireless propagation channels, the Rician factor, also known as K-factor, is a parameter used to relate the power of the deterministic multipath component (MPC) and the power of all stochastic MPCs. The K-factor can be derived from time, space, or frequency measurements in a small-local area, and can be used as a measured of the temporal, spatial of frequency selectivity of the propagation channel [1]. Low values of the K-factor are associated to a severe selectivity, and in the limit, a value equal to 0 ($-\infty$ dB) corresponds to Rayleigh fading. Thus, the knowledge of the K-factor is of paramount importance because it can improve the design and evaluation of different transmission techniques, e.g., orthogonal frequency division multiple access (OFDMA) and adaptive modulation schemes, that affect the final system performance.

Based on a millimeter wave (mmWave) channel measurements, covering the 25-40 GHz frequency band, the K-factor is analyzed in this conference contribution. The channel measurements have been collected in a typical laboratory environment characterized by the presence of highly reflective objects. In this sense, novel and useful results to evaluate the performance of the future fifth-generation (5G) networks in the frequency bands adopted by the last World Radio Communications (WRC) of the International Telecommunications Union (ITU) in 2019, e.g., 26 and 38-GHz bands [2], are presented in this contribution.

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II. Channel Measuremets

The propagation channel measurements were carried out in a laboratory with numerous reflective objects. These objects and their spatial distribution in the laboratory form a rich-multipath environment due to different reflection, diffraction and scattering propagation processes. The propagation environment consists of a 13.5m-by-7m room with a height of 2.63 m.

The complex channel transfer function (CTF) was measured in the frequency domain using a channel sounder based on the Keysight N5227A vector network analyzer (VNA). The QOM-SL-0.8-40-K-SG-L ultra-wideband antennas, with vertical polarization, were used at the transmitter (Tx) and receiver (Rx) sides. The Tx subsystem was connected to the VNA through a radio over fiber (RoF) link to avoid the high losses introduced by cables at mmWave frequencies, improving the dynamic rage in the measurement. The Rx antenna was located in a XY positioning system, implementing a 7×7 uniform rectangular array (URA). The separation of the URA elements was 3.04 mm (less than $\lambda/2 = 3.7$ mm at 40 GHz). The CTF was measured from 25 to 40 GHz, with $5\,000$ frequency points. Thus, the frequency resolution is 3 MHz, which corresponds to a maximum observable distance of 100 m, much larger than the laboratory dimensions. In the measurements, the Tx antenna was located in different locations, whereas the Rx subsystem was remaind fixed in the same location, next to one of the laboratory walls imitating the position of a base station or access point. A total of 6 Tx locations, 4 in line-of-sight (LOS) and 2 in non-LOS (NLOS) propagation conditions were considered. Before the measurements, a proper response calibration process was performed. Thus, the measured CTF takes into account the join response of the propagation channel and the Tx and Rx antennas, also known as the radio channel. More details about the channel sounder used and the measurement procedure, omitted here due to space restrictions to 2 pages, can be found in [3].

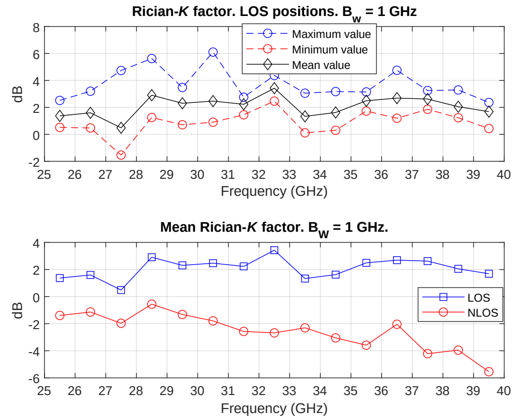

Fig. 1. Maximum, minimum and mean Rician K-factor in LOS positions as a function of the frequency for a bandwidth of each sub-band of $B_W = 1$ GHz. Mean Rician K-factor in both LOS and NLOS positions as a function of the frequency for a bandwidth of each sub-band of $B_W = 1$ GHz.

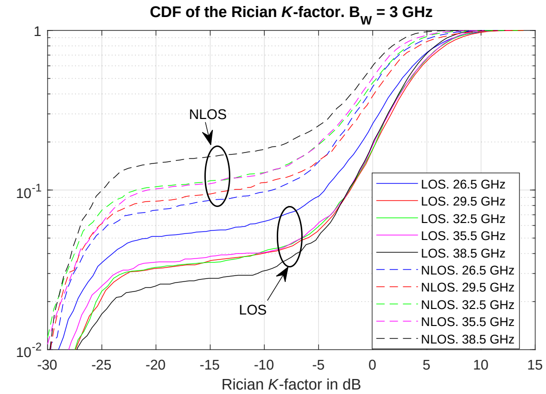

Fig. 2. Cumulative distribution function of the Rician K-factor for LOS and NLOS positions with a bandwidth of each sub-band of $B_W = 3$ GHz.

III. Measurement Results

In order to assess the behavior of the K-factor in frequency, the whole band from 25 to 40 GHz has been divided into sub-bands of 1, 2 and 3 GHz. The K-factor parameter has been estimated in space over all URA positions and then averaged along the frequency points inside each sub-band. The function `mle` of Matlab®, which implements the maximum likelihood estimator (MLE), has been used to estimate the K-factor.

In Fig. 1, the K-factor has been plotted for a sub-band bandwidth of $B_W = 1$ GHz. The K-factor for the LOS positions shown in the upper sub-plot exhibits moderated values ranging from -1.53 dB at 27.5 GHz to 6.1 dB at 30.5 GHz. The mean value of the K-factor ranges from 0.48 to 3.43 dB in LOS conditions and from -5.54 to -0.56 dB with NLOS conditions as it is illustrated in the lower sub-plot. These values are slightly smaller than those reported in [4], where K-factor from 9.5 to 10.1 dB and -4.6 to -1 dB were derived in a laboratory environment in the 28-32 GHz frequency range, with LOS and NLOS conditions, respectively. In [5], the mean value of the estimated K-factor was 9.04 dB in an open office with LOS conditions at the 26-GHz frequency band using a horn Rx antenna. However, in [6] similar values to those obtained in this work, with a mean value of 6.15 dB, were measured in an open office with LOS conditions at 26 GHz. It should be noted that our environment is highly dispersive, where angular spread values in azimuth ranging from $44.87°$ to $148.11°$ have been derived using the space alternating generalized expectation-maximization (SAGE) algorithm with 100 estimated MPCs.

On the other hand, as it can be seen in the lower sub-plot of Fig. 1, the mean value of the K-factor decreases in frequency for NLOS conditions from -1.39 to -5.54 dB at 25.5 and 39.5 GHz, respectively, with $B_W = 1$ GHz. Nevertheless, in LOS conditions no trend is observed in the mean values of the K-factor. Besides, the standard deviation of the K-factor along each sub-band with $B_W = 1$ GHz oscillates from 0.37 to 4.92 dB in NLOS and from 0.59 to 2.87 dB in LOS conditions.

Fig. 2 shows the cumulative distribution function (CDF) of the K-factor for both LOS and NLOS conditions, and with $B_W = 3$ GHz. The central frequencies of each analyzed sub-band are 26.5, 29.5, 32.5, 35.5 and 38.5 GHz. Interestingly, in LOS condition the higher the central frequency the smaller dispersion of the Rician K-factor. On the contrary, in NLOS condition the trend is the opposite: as the central frequency increases the dispersion of the K-factor grows.

IV. Conclusions

In this conference contribution, the Rician K-factor in a laboratory environment has been analyzed from channel measurements at the 25 to 40 GHz band. Mean values ranging from 0.48 to 3.43 dB for LOS conditions, and from -5.54 to -0.56 dB for NLOS conditions, have been derived. These values of the K-factor, together with its frequency behaviour, can be used to evaluate the performance of 5G networks in these environments. Due to the space restriction here, a full study with more results will be presented at the conference.

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