Indoor Channel Characterization for Future 5G Applications

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***Abstract*— The shortage of frequency band below 6 GHz available for communications and data transfer has recently fostered the interest toward the millimeter wave (mmW) spectrum. In fact, mmW carrier frequencies allow for larger bandwidth allocations thus higher data transfer rates. It is therefore useful to evaluate the channel propagation properties of mmW within an indoor environment. In particular, the statistical parameters such as path loss exponent and shadowing have been examined by using a reliable numerical solver based on a ray-tracing (RT) technique. The results for both line-of-sight (LOS) and non-line-of-sight (NLOS) conditions at 28 GHz and 72 GHz are reported for the case of an office environment.**

Keywords—millimeter wave; path loss; 5G; indoor.

I. Introduction

The growth of the data traffic and the number of users in mobile communications has recently led to consider the millimetre wave (mmW) frequency spectrum (30 GHz-300 GHz) as a candidate to increase the bandwidth and the capacity in order to ensure several gigabit per second data rete [1], [2]. Historically, mmW bands were not taken into account because of the concerns regarding the propagations issues, such as atmospheric absorption, rain or foliage attenuation, as well as higher mmW path loss (*PL*) relative to frequency bands below 6 GHz. In fact, according to the Friis's law, the *PL* increases as a function of the frequency. However, if we consider that today's cell size i around 200 m, it can observed that the atmospheric loss can be neglected for the mmW as well, since it does not determine a significant additional *PL* for mmW [3] being these additional attenuations lower than 1-2 dB for these short distances. Another important advantage of using mmW is the possibility of compensating the greater *PL* by using high-gain antennas. In particular, a high-gain steerable antenna array can select the most suitable beam direction able to reduce the *PL* at the handset mobile side [1], [4], [5].

The future extensive planning of a 5G network inside an indoor environment, such as a factory or office, requires the detailed knowledge of the indoor channel in order to choose the topology of the network, the best transmitter position and the most suitable antenna. To this aim, the estimate of the large-scale *PL* for the characterization of the mmW indoor channel is addressed in this work. More in detail, the *PL* and the shadowing are evaluated at two different frequencies, 28 GHz and 72 GHz by resorting to an in-house code based on RT techniques [6] in the case of both line-of-sight (LOS) and non-line-of-sight (NLOS) receivers.

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II. Millimiter Wave Indoor Characterization

The indoor environment used to assess the performance of the large-scale *PL* at 28 GHz and 72 GHz, is reported in Fig. 1. All the objects in the room (windows, doors and furniture) have been defined with the appropriate electric proprieties. More in detail, the transmitter (*Tx*) is placed at 2 m above a metallic cabinet, whereas several receivers (*Rx*) are distributed inside the room over two lines at an height of 1 m from the floor. The red line represents the receivers in LOS condition (*Rx#: LOS*), whereas the green line depicts the receivers in NLOS condition (Rx#: NLOS). The overall dimension of the room is 15 x 10 m.

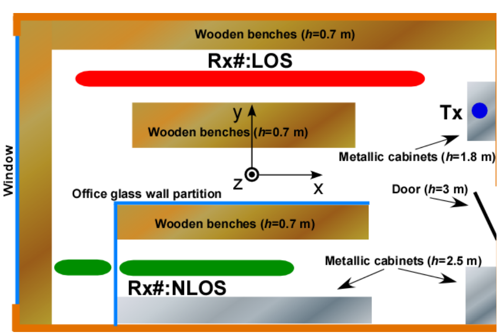

Fig. 1. Top view of the simulated indoor scenario used to evaluate the large-scale path loss by using ray-tracing.

In a preliminary analysis, all antennas were considered as isotropic radiators in order to evaluate the large-scale *PL*. The *PL* is defined as the ratio between the transmitted power (P_T) and the received power (P_R). Generally, the large-scale *PL* is described by using a distance-dependent model [7], where the *PL* is expressed in dB as a function of the distance (d):

$$PL(d) = \alpha + 10 \cdot n \log\left(\frac{d}{d_0}\right) + \chi \qquad (1)$$

where α represents the free space *PL* at a reference distance $d_0 = 1$ m [8], *n* is the *PL* exponent, and χ is a zero mean lognormal distribution random variable characterized by the standard deviation (σ_χ) that represents the shadowing factor. These parameters were estimated by using the minimum mean square error (MMSE) [9] approach that fits the simulated data with smallest σ_χ. The estimated *PL*, at 28 GHz and 72 GHz, for both LOS and NLOS scenario, has been reported in Fig. 2 and Fig. 3, respectively.

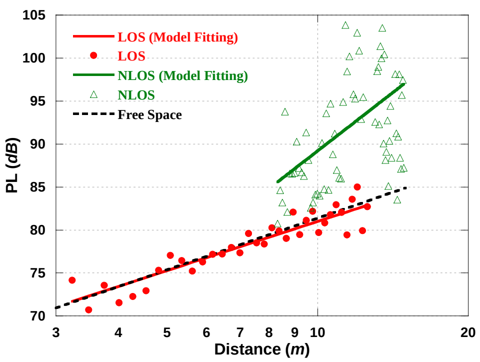

Fig. 2. *PL* as a function of distance (*m*) for both LOS and NLOS scenario at 28 GHz.

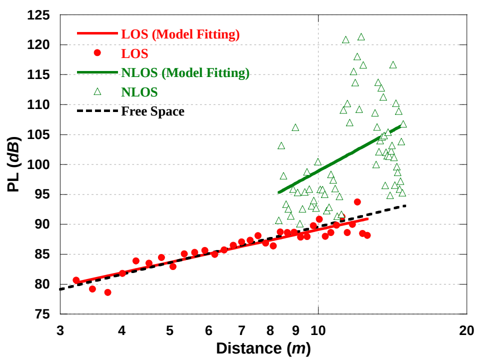

Fig. 3. *PL* as a function of distance (*m*) for both LOS and NLOS scenario at 72 GHz.

As a summary, the data are also presented in Table I, where the free space reference *PL* (*FS PL*(d_0)) is also added as a reference. It can be observed that in LOS condition the *PL* exponent (*n*) is slightly smaller than free space (*FS*) propagation (*n* = 2), for both considered frequencies. This is not surprising since the multipath effect in an indoor environment tends to improve the link *PL (possiamo citare la fonte??)*. In particular, *n* is slightly lower at 72 GHz with respect to 28 GHz, whereas the shadowing effect is almost the same σ_χ (around 1.3 dB) for both frequencies. On the contrary, when a receiver suffers the NLOS condition, the simulated *PL* is higher than the *FS* one, for both frequencies. Also in this case the *PL* exponent is slightly better for the higher frequency (72 GHz).

The effect of the antenna radiation pattern scan is ongoing and the results will be presented at the conference in order to provide a comprehensive characterization of the indoor channel for 5G communications.

TABLE I. PARAMETERS OF THE PATH LOSS AT 28GHZ ANS 72GHZ

Frequency	LOS			NLOS			*FS PL*(d_0)
	n	σ_χ	α	*n*	σ_χ	α	
28 GHz	1.9	1.33	62	4.52	6.08	44	61.38
72 GHz	1.81	1.29	71	4.49	7.82	54	69.58

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Commentato [FC1]: Ma le rete si dovrebbero incontrare a d0=1m secondo l’equazione (1). Mi sbaglio? Anche nel paper di Rappaport è così.