Evaluation of Interference Due to Rain in Millimeter Waves

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***Abstract*— Wireless telecommunications systems operating in the millimeters waveband are heavily affected by rain. This work presents a prediction method for the evaluation of bistatic interference due to rain in urban environments for millimeters waves. The Signal-to-Interference power ratios (S/I) for mmWave frequency and several scattering angles have been calculated for regular and irregular urban areas.**

***Keywords*— Propagation, millimeters wave frequencies, rain, scattering, interference.**

I. Introduction

The use of millimeter wave frequencies for the future cellular systems has gained a great interested in the recent years since it has been proposed for the fifth generation of communication mobile (5G)[1]. The millimeter wave bands ranging from 30 to 300 GHz enable the use of simpler air interfaces in order to obtain high data rate. Since there is large available bandwidth (e.g. 2Ghz)[2]. Specific studies of the effects of radio propagation of communications systems operating in the millimeter wave range are necessary to analyze the effects on this frequency range. During propagation in terrestrial or satellite radio links in the millimeter wave range, signal attenuation and scattering occur due to atmospheric particles and hydrometeors [3], [4].

The scattering produced by hydrometeors in the millimeter wave range can cause co-channel interference between fixed systems, between neighboring mobile cells and between satellite systems [5]. Interference due to rainfall occurs when the electromagnetic energy transmitted by an antenna is intercepted by a rain cell, causing lateral scattering and is received by antennas from other fixed systems, satellite communications systems or another cell of the mobile system (depicted in Fig.1). The scattering produced by a rain cell can be calculated basically by the bistatic radar equation [6], [7]. This work reviews the interference caused by rain in millimeter wave ranges in urban areas using the bistatic radar equation.

II. Bistatic Rain Scattering

In this study we consider the first-order multiple scattering approach to be valid. The relationship between the physical processes responsible for this scattering and the coupling it produces can therefore be described by the bistatic radar equation [6], [7] and it is defined by:

$$P_r = P_t \frac{\lambda^2}{(4\pi)^3} \iiint \frac{G_t\, G_r\, \eta A}{r_t^2\, r_r^2} dV \qquad (1)$$

where P_t is the transmitted power, λ is the wavelength, r_t, r_r are the distances between antenna transmited and antenna received to common volume, A are the path attenuations to the scattering volume, G_t, G_r are the antenna gain function and η is the scattering cross section (SCS).

Considering scattering by raindrops, η is described in terms of the bistatic radar reflectivity Z [4]:

$$\eta = \frac{\pi^5}{\lambda^4} \left|\frac{m^2-1}{m^2+2}\right|^2 Z \qquad (2)$$

where m is the complex permittivity of water, λ is the wavelength and Z is the radar reflectivity.

The radar reflectivity at the ground due to rain is determinate from the rain fall rate R in mm/h, the relation of DeWolf that has the best fit in millimeters waves [7]:

$$Z = 340 \, x \, 10^{-18} R^{1.46} \qquad (3)$$

III. mmWave Scenarios

There are 2 types of scenarios: Regular and irregular scenarios. Fig. 2a presents the map of Salamanca, Madrid (Spain) from METIS-TC2 [8] as a regular scenario and Fig.3a presents the map of Ipanema, Rio de Janeiro (Brazil) as a irregular scenario. The density of access points (the red dots in Fig 2a and Fig.4a) are uniformity distributed along streets and corners.

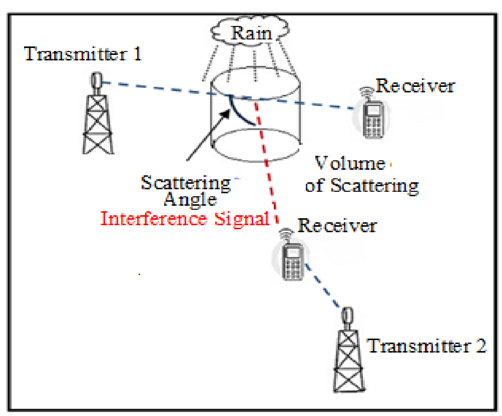

Fig.1 Interference geometry of rain scattering.

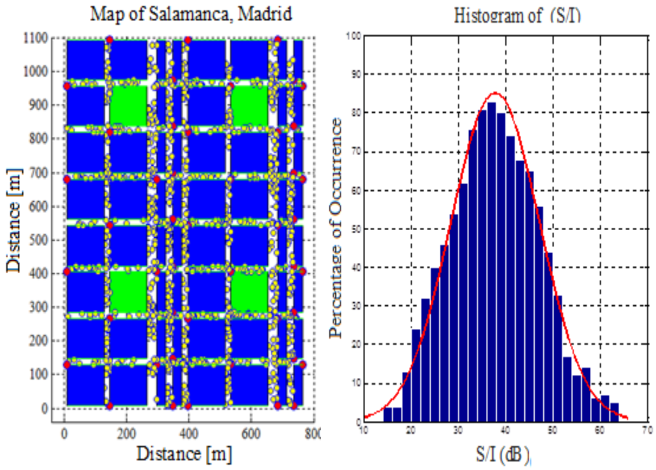

Fig. 2. a) Map of Salamanca, Madrid [8] and the position of APs and Users. b) Histogram of S/I for Salamanca, Madrid.

IV. SIMULATION RESULTS

The general system-level parameters of the APs and mobile receivers are given in table 1.

Table 1. System Simulation

Parameter	Value
Frequency	30 GHz
AP array	4 sectors polarized vertically
Mobile antennas	Omni-directional antennas
AP Tx power	24 dBm/sector
Mobile Rx power	2dBm
Beam Half Power	10

The users are connected with the near AP in line-of-sight conditions. The density of users is 1000 users/km^2 (yellow dots in Fig. 2a and Fig. 4a) and are uniformly random distributed along streets. There are 1000 users in each urban scenario.

In this section are presented the downlink simulation results for the different scenarios presented in the previous section. In order to analyze the effect of rain scattering, the ratio signal- interference (S/I) has been calculated using the bistatic radar equation.

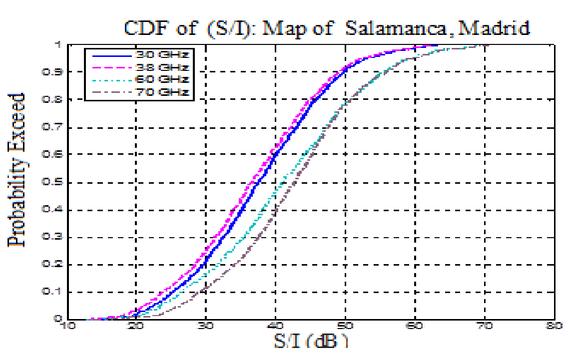

Fig. 3. Variation of frequencies in calculation of CDF for S/I.

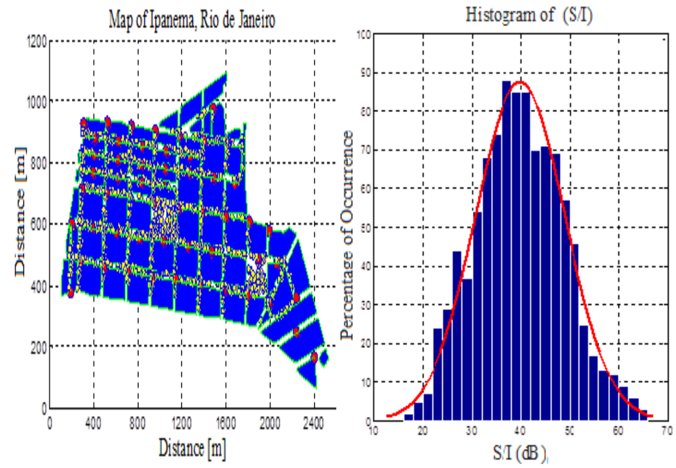

Fig.4. a) Map of Ipanema, Rio de Janeiro and the position of APs and Users. b) Histogram of S/I for Ipanema, Rio de Janeiro.

The results present values between 16 and 64 dB that are shown in Fig 2b and Fig. 4b as histogram representations. The red lines depicts that the results presents a distribution normal. The results that have values below of 30 dB depict levels very high of interference in the reception caused by interference cochanel. In Fig 3 are showed the frequency variations as CDF representation for the regular scenario.

V. CONCLUSIONS

The prediction method for the evaluation of bistatic interference due rain scatter in millimeters wave and the simulation tool developed were used to estimate the effects of the scattering angle, frequency in the calculation of interference levels (S/I).

In summary, a larger scattering cross section generates greater interference by being an effect multiplied by the volume in wireless systems in case of rain.

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