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A RESEARCH VISION

5G coverage study with ICS Telecom: analysis of losses due to climatological factors in 5G technology for the metropolitan areas of the city of Bogotá D.C.

Estudio de cobertura en 5G con ICS Telecom: análisis de perdidas por factores climatológicos en tecnología 5G para las zonas metropolitanas de la ciudad de Bogotá D.C.

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Abstract

In this project is has been made a study and later coverage analysis for a cellular telecommunication network in 5G technology a metropolitan scenario of Bogota city, Colombia. It starts, with an explanation of what is 5G and what is expected of this technology. With this preamble, it's established the parameters of simulation for 5G technology, defining the frequency 3 GHz until 100 GHz, what it entails the use of millimeter waves. For the base stations in the simulations, it was made given two operators of the five existing in the country (operators X and Y).

The scenario was chosen with the purpose of study the case most presented in the moment of develop and design of cellular telecommunication system as are the systems without line of sight (NLOS) which is observed on the Universidad Nacional de Colombia facilities, where are wide green zones and buildings between 4 and 10 floors.

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In agreement to the results it's evidence that the free space losses of signal high signal loss due to the to the multiple obstacles with they encounter. In the simulations were taken into account the climatological effects as rain and fog that increase the signal loss.

Keywords: 5G, 5G Path loss, Cellular networks, Coverage study, Millimeter waves, Telecommunications.

Resumen

En este proyecto se realizó un estudio y su posterior análisis de cobertura para una red en tecnología 5G en un escenario metropolitano de la ciudad de Bogotá, Colombia. Se inicia, con una explicación de qué es 5G y qué se espera de esta tecnología. Con este preámbulo se establecieron los parámetros de simulación para la tecnología 5G, definiendo las frecuencias de 3 GHz hasta los 100 GHz, lo que conlleva al uso de ondas milimétricas. Para la ubicación de las estaciones base para las simulaciones, se realizaron teniendo en cuenta dos operadores de los cinco existentes en el país (operadores X y Y).

El escenario fue elegido con el propósito de estudiar el caso más presentado en el momento de desarrollo y diseño del sistema de telecomunicaciones celulares como son los sistemas sin línea de visión (NLOS) que se observa en las instalaciones de la Universidad Nacional de Colombia, donde se encuentran zonas verdes amplias y edificios entre 4 y 10 pisos.

De acuerdo a los resultados obtenidos se evidencia que la perdida de señal en el espacio libre es elevada debido a los múltiples obstáculos con los que se encuentra. En las simulaciones se tuvieron en cuenta los efectos climatológicos como la lluvia y la niebla que incrementan las pérdidas de la señal.

Palabras clave: 5G, Pérdida de señal 5G, Redes celulares, Estudio de cobertura, Ondas milimétricas, Telecomunicaciones.

1. Introduction

At present the existing cellular networks such as 2G, 3G and 4G are practically reaching their limits; this is due in large part to the massification of what is called the Internet of Things (IoT): industrial automation, home automation, implementation of smart cities, industry 4.0, etc.
By 2020, this will generate that the connected devices will quintuple those that were for the year 2010 from 12.5 billion to 50 billion users worldwide, therefore, the generation of data will also increase in relation from 1 to 10 lo which means if in 2010 approximately 2.4 exabytes (EB) of data were generated, by 2020 approximately 24.3 EB will be generated [1].
In Colombia, the situation is similar, the quarterly ICT bulletins generated by the Ministry of Information Technologies and Communications show the growth of cellular telecommunications services nationwide for all operators of approximately 5 million users, going from 60.7 million users in the third quarter of 2017 to 68.5 million users for the second quarter of 2019, which indicates that approximately one Colombian citizen has between 1 and 3 cellular telecommunications services, therefore, the growth that occurs has and is estimated to have may leave the telecommunications infrastructure deficient in relation to the growing demand, which will represent imminent problems of congestion [2].
On the other hand, access to the internet through cellular telecommunications services has grown in the same period of time and has increased by approximately 20%; Cellular telecommunications services in 4G technology being the most in demand, increasing internet accesses by up to 95%, due to the speed of information transfer compared to other existing technologies. On the other hand, internet access through cellular telecommunications services has grown in the same period of time has increased by approximately 20%; Cellular telecommunications services in 4G technology being the most demanded, increasing internet accesses by up to 95%, due to the speed of information transfer compared to other existing

technologies [2]; this denotes the current congestion of cellular telecommunications services in this technology where the Communications Regulation Commission (CRC) shows the coverage problems of the 4G technology service, which only has a coverage of 62%[3].

The 5G networks come to meet the demand that will arise in the future, providing an improvement in latency and expanding the bandwidth that would vary from 0.7 gigahertz (GHz) to approximately 7 GHz [1], depending on the working frequency from 3 GHz to 100 GHz [4]. All this will become possible with the proper use of the radioelectric spectrum and the location of the base stations, among other variables that must be taken into account to maximize the propagation of the signal in free space. [5].

The signal in high frequencies, they are named as millimeter waves, are quite susceptible to the environment in which it is propagated, for which the scenarios of this project propose a changing climate characteristic of the city of Bogotá, which represents a challenge for 5G. It should be remembered that 5G has proposed several solutions for the propagation of the signal in adverse environments in order to guarantee both coverage and bandwidth to users that in previous technologies could not be implemented.

The characteristics of the selected scenario present different aspects, it has green areas with large, tall and leafy trees, with some tall buildings within the complex separated from each other. Where various adverse factors will be observed for the propagation and analysis of signals; the reflection, dispersion, refraction and diffraction produced by the signal at the moment of encountering an obstacle tend to produce effects of loss of power of the signal that vary from one material to another; Therefore, the losses in this scenario are not the same as in another.

The results obtained from this work serve as a reference to the different operators of cellular telecommunications services, entities in the telecommunications sector, regulatory entities, among others, both in Colombia and in the world, for the design and adaptation of new networks in 5G technology, evidencing the importance of considering a specific environment where you want to provide service, the definition of the best frequency for a specific environment.

The work is divided into four sections, the first section shows the introduction and fundamentals of the project; In section 2 the simulation methodology is indicated, in section 3 the results of the simulations are presented and analyzed and in the last part the conclusions are presented.

2. Simulation methodology

2.1. Similar previous studies (background)

To define the simulation parameters, similar projects carried out for macro urban (UMa), micro urban (UMi) and interior areas (InH) scenarios were analyzed, based on experimental measurements in educational entities and entities of the telecommunications sector, for frequencies from 5 to 100 GHz the results are shown in table 1 [6].

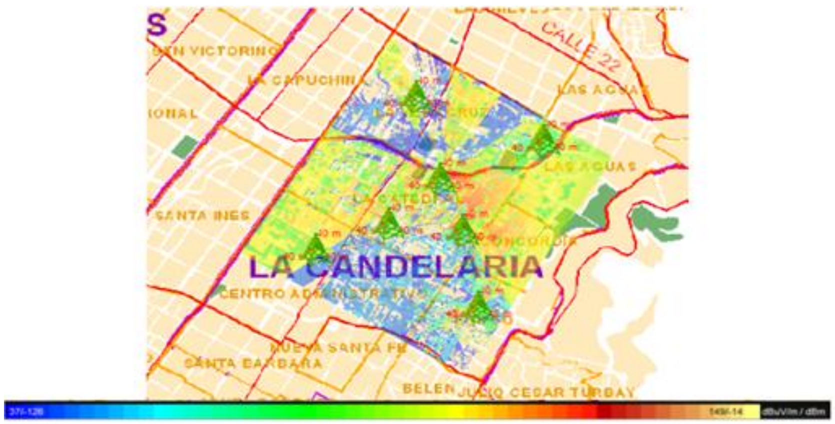
Table 1. Results of 5G experiments worldwide. Data obtained from [6].

Frequency (GHz)	Stage	Entity	Measurement type		Country and year of study
			Propagation	Multipath	
10	UMa	Universidad de Aalborg	X		Dinamarca (2015)
	UMi	Berlín HHI	X		Alemania (2016)
14	UMi	BUPT	X	X	China (2015)
15	InH	Ericsson	X		Suecia (2015)
18	UMa	Universidad de Aalborg	X		Dinamarca (2015)
19,85	InH	NTT DOCOMO	X	X	Japón (2015)
20	InH	BUPT	X	X	China (2015)
23	InH	BUPT	X	X	China (2015)
26	InH	BUPT	X	X	China (2015)
26,4	UMa	NTT DOCOMO	X		Japón (2015)
	UMi	NTT DOCOMO	X		Japón (2015)
28	UMa	NYU	X	X	Estados Unidos (2012)
		Universidad de Aalborg	X		Dinamarca (2015)
		Ericsson	X		Suecia (2015)
		ETRI Corea		X	Corea del Sur (2015)
		Samsung & KAIST	X		Corea del Sur (2015)
	UMi	NYU	X	X	Estados Unidos (2012)
		Universidad Aalto	X	X	Finlandia (2016)
		Berlín HHI	X		Alemania (2016)
		Nokia	X		Finlandia (2015)

		Huawei	X		China (2015)
	InH	NYU	X	X	Estados Unidos (2014)
		Universidad Aalto	X	X	Finlandia (2016)
		ETRI Corea	X	X	Corea del Sur (2015)
		Samsung & KAIST	X	X	Corea del Sur (2015)
		Huawei	X		China (2015)
		BUPT	X	X	China (2015)
29	UMi	Qualcomm	X		Estados Unidos (2016)
	InH	Qualcomm	X		Estados Unidos (2016)
30	UMi	Universidad de Durham	X	X	Reino Unido (2016)
	InH	Universidad de Durham	X	X	Reino Unido (2016)
37,1	UMa	NTT DOCOMO	X		Japón (2015)
38	UMa	Universidad de Austin	X		Estados Unidos (2011)
		ETRI Corea		X	Corea del Sur (2015)
	InH	ETRI Corea	X	X	Corea del Sur (2015)
41,5	UMi	Berlín HHI	X		Alemania (2016)
58,6	InH	Ericsson	X		Suecia (2015)
60	UMa	Universidad de Austin	X	X	Estados Unidos (2011)
	UMi	Universidad de Durham	X	X	Reino Unido (2016)
	InH	Universidad de Bristol	X	X	Reino Unido (2016)
		Universidad de Durham	X	X	Reino Unido (2016)
		Universidad L’Aquila	X		Italia (2012)
61	UMi	Qualcomm	X		Estados Unidos (2016)
	InH	Qualcomm	X		Estados Unidos (2016)
63	UMi	Universidad Aalto	X	X	Finlandia (2015)
	InH	Universidad Aalto	X	X	Finlandia (2015)
73	UMa	NYU	X	X	Estados Unidos (2013)
	UMi	NYU	X	X	Estados Unidos (2013)
		Huawei	X		China (2015)
	InH	NYU	X	X	Estados Unidos (2014)
		Huawei	X		China (2015)
82	InH	CEA		X	Francia (2016)
82,5	UMi	Berlín HHI	X		Alemania (2016)
83,5	UMi	Universidad Aalto	X		Finlandia (2010)

At the level of Colombia, in 2018, studies with 5G technology were found in the area of La Candelaria in the city of Bogotá, Figure 1, simulations were carried out based on ICS Telecom (office automation tool for the development and analysis of telecommunications networks) with a frequency of 28, 38, 60 and 73 GHz, with MIMO and Massive MIMO antenna arrays in order to analyze the propagation and coverage of the signal; where powers between -80 dBm and -126 dBm are observed for the mentioned frequencies. Also, for the studies carried out in the simulations in 28 Ghz, throughput tests (average success rate for data delivery) were performed for data between 32 and 135 Kbps and a success rate between 93.23% and 74.26% was observed for 64x64 and 128x128 antenna arrays respectively [7], [8].

Figure 1. Coverage study of a 5G network in the area of La Candelaria [7], [8].



2.2. Simulation software

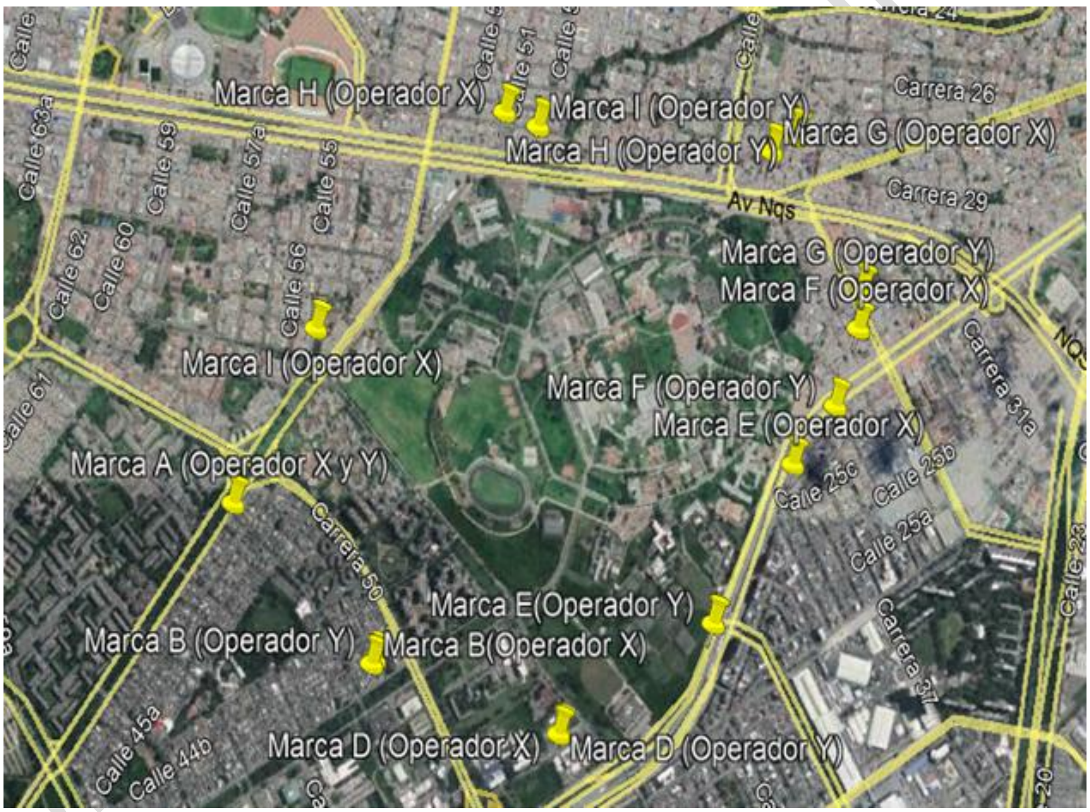
For the development of the simulations, ICS Telecom will be used, which is a paid network design software. It has a wide range of propagation models depending on the frequency and the environment in which it works and what is to be obtained from the simulations. These models range from empirical to deterministic models; even climate environment models. Also models indoor coverage systems; which means that it can show the signal levels and penetration of the same in indoor environments such as rooms of houses, office buildings, among others [1].

On the other hand, it is necessary to choose between digital cartography of 50, 15 or 5 meters depending on the resolution that you want to give to the simulations, so for metropolitan areas, and especially for projects in 5G technology, you should use the highest resolution possible high (5 meters) in order for the analysis to be as close to reality; the other resolutions of 50 and 15 meters are used for rural projects where too much resolution is not necessary due to the terrain conditions and much smaller urban environments such as municipalities [9].

2.3. Study scenario

Universidad Nacional de Colombia (Bogotá). This scenario has different characteristics for the propagation of signals, from the point of view of telecommunications engineering, within which we have leafy wooded areas with trees of great height and size, these areas are located at various points within of the University. Also, we have both green and concrete open areas, Figure 2. It is the perfect setting to analyze electromagnetic signals for NLOS systems (without line of sight); where no base station has the ability to have a direct line of sight.

Figure 2. Location of base stations [10].



2.4. Simulation parameters

The ICS Telecom simulation tool has the characterization to simulate 5G transmission within its configuration options. Table 2 presents the main simulation parameters.

Table 2. Base station simulation parameters.

Parameter	Value
Transmission potency	10 W
Antenna gain	23 dBi
Antenna arrangement	4x4
Frequency	3-100 GHz
Modulation	64 QAM

Source: own.

Also, you can choose the simulation model for the calculations by choosing the deterministic model ITU – R 525/526 [11] fitted with the diffraction geometry model and the subpath attenuation model Delta Bullington. Also, we have the propagation calculations referred to the effects of gases with the standard ITU – R 676, the effects of fog with the norm ITU – R 840, and the effects of rain with the norm ITU – R 838/530. For Bogotá among the necessary parameters we have the temperature, which is recorded with a maximum measurement of 19.9, a minimum measurement of 17.8 and an average of 14.9 degrees Celsius, the atmospheric pressure, we have a maximum of 752.1 hPa, a minimum of 751.1 hPa and an average of 751.6 hPa, we have rainfall, a maximum of 129 mm, a minimum of 39 mm and an average of 89 mm [12], air humidity is made up of the value of vapor (absolute humidity) which is normally 12 g/m^3 and water (relative humidity) which is normally located at 0.025[13].

For the location of the base stations, the coverage maps of the existing 4G mobile network of two mobile telecommunications operators (Operator X and Operator Y) were used. [14].

For the rest of the configuration of the base stations (height, sectorization, etc.) the recommendation ITU-R M.2412-0 [15].

2.5. Simulation procedure

After locating the base station points in the digital cartography of Bogotá, we proceed to configure the base station parameters first with a frequency of 3, 10, 22, 32, 47, 60, 72, 82 and

100 GHz, Figure 3 and 4. Coverage simulations of the received power level are performed, from which the results are obtained for analysis in the study area with the settings established for a sunny day and a day with moderate rain.

Figure 3. Simulation samples at 3 GHz (Left sunny day, Right rainy day)).

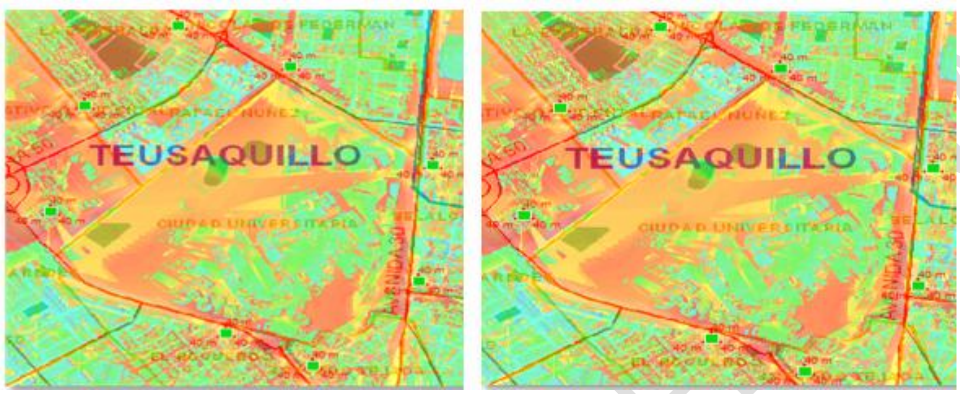


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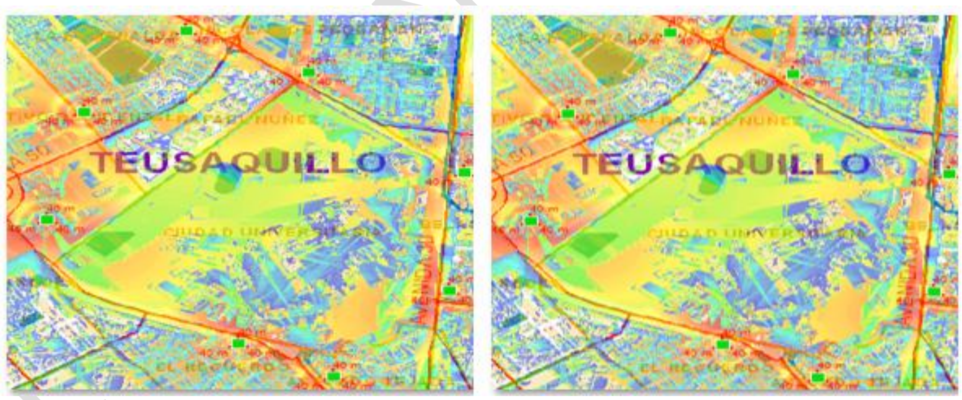
Figure 4. Simulation samples at 100 GHz (Left sunny day, Right rainy day).



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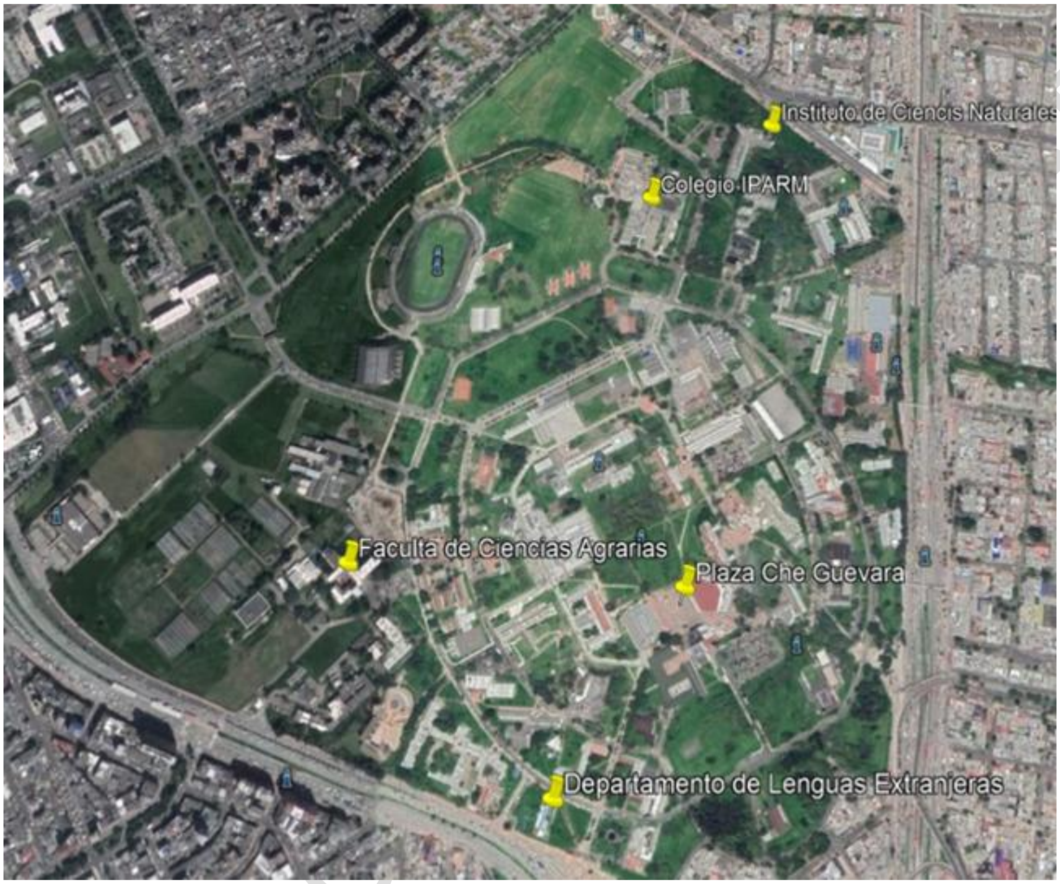
3. Result of the simulations

To perform the analysis of the results, signal measurement points were established; the coverage is given by different stations located at different points and the radiation system from the base stations to the users is an NLOS system, as mentioned above; You will need several measurement points (Figure 5) distributed in the cardinal points and a central one, with which it is intended to analyze most of the area.

Figure 5. Location of measurement points [10].

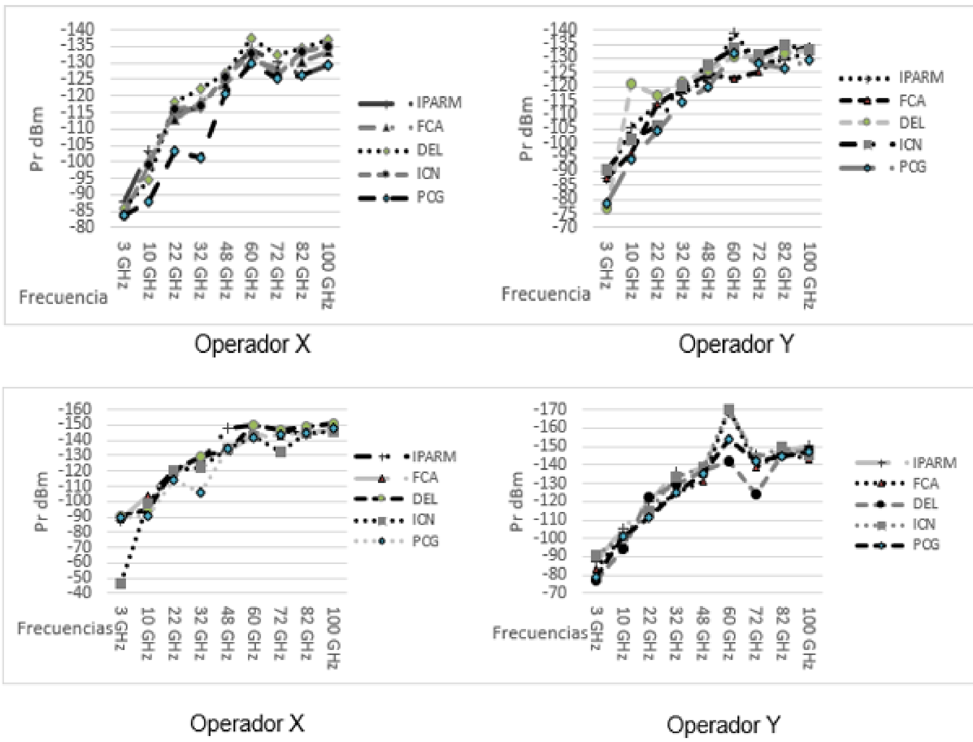


3.1. Analysis of the results

For the analysis of the results, ICS Telecom uses the Friis equation, taking the power in the air depending on the distance. Although, added to this, it also analyzes the dispersion generated by the obstacles. It is determined that signals above -150 dBm would be in a coverage range of low coverage seen by users (taking into account the power of the receiving station between 1 W) with a level between 90-100 dBm, this subject to diffraction and reflection of nearby elements [16].

It was established which is the station that provides the best coverage at the points established to perform the measurements. Starting from this analysis, we can establish how the power loss is from a frequency of 3 GHz to 100 GHz in the different measurement points for the scenario for both the X and Y operator, which is shown in Figure 6.

Figure 6. Analysis of results for operator X and Y (top sunny day, bottom rainy day).



Source: own.

One of the main disadvantages of 5G mobile networks is the great loss of power when you have no line of sight. This is the most prone scenario when designing mobile networks because there is no prior knowledge of where the user is specifically located and even worse when the obstacles that exist between the Tx and the Rx are not known. This can be understood with the results obtained, in the scenario of the National University, where the stations never have a direct line of sight due to the obstacles in the way, which weakens the signal causing a fading that is reflected in the received signal level. and / or captured in the different areas.

For the analysis, in operator X the free space losses are approximately 40 dBm from 3 GHz to 60 GHz, but after 60 GHz the signal power tends to stabilize at levels between -125 and -140 dBm; while for operator Y we have a signal loss of approximately 45 dBm for a frequency between 3 and 60 GHz, but equally, the power stabilizes after 60 GHz between -120 and -135 dBm.

Rain is one of the climatological factors with the greatest losses, which is more significant in NLOS systems. With the X operator we can see that between 3 GHz and 48 GHz it has an attenuation of 35 dBm, but compared to the previous case where signal losses are observed in free space, it can be seen that the losses for each measurement point have a variation of 10 dBm at 3 GHz and again from 48 GHz to 100 GHz.

As an example, the power at 3 GHz in the previous case is -80 dBm, in this case we have -90 dBm. Losses stabilize at 48 GHz with powers between -140 and -150 dBm, except for the cases where a gain of measurement point 4 was observed in the Institute of Natural Sciences, which due to the environment of the point, reflections of the signal are generated obtaining gains for a power of -46 dBm approximately, which can be seen in Figure 6.

In the case of the Y operator, the behavior is similar to the previous one, where there is a signal loss of 50 dBm for a frequency between 3 GHz and 48 GHz, but there are excessive losses due to the oxygen absorption channel in the frequency of 60 GHz with powers between -140 and -170 dBm where the connection with the Rx would be null, after 60 GHz the losses caused by the absorption channel are exceeded and the power stabilizes at -150 dBm approximately; which can be seen in Figure 6.

4. Conclusions

The results presented establish that there is a power of -83.76 dBm and -103.76 dBm for a frequency between 3 GHz and 22 GHz, which shows a signal power loss of 24.1% for these frequencies; but from 22 GHz to 100 GHz, the signal power is -103.22 dBm and -135.22 dBm, respectively, where the losses are higher and reach 31.06%. Consequently, 5G in the studied scenario loses between 3GHz and 100 GHz 61.43% of the signal power in free space.

Climatological factors such as rain indicate an additional loss for 3 GHz is 7.16%, while for a frequency of 100 GHz the loss is 9.61%, verifying that the higher the frequency the rain causes greater attenuation.

Based on what is related to the simulations, it is possible to observe that the NLOS scenarios, which of which will be the most common when the time of deployment arrives, becomes the great challenge to be able to provide a good level coverage to users where they are You can see that any obstacle generates losses, especially at frequencies above 30 GHz where the electromagnetic signal is little affected by interference and can have a large bandwidth, but after this the signal suffers more fading in its path, which shortens its transmission distance; In addition to this, the signals in high frequencies, or better in millimeter frequencies, would not have enough power to project through obstacles such as walls, glass and other materials that are commonly found in any metropolitan environment

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