# Indoor Communications scenario In The Electrical Engineering Departement Building -University of Skikda- Based on RSS, Frequency and Path Losses

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*Abstract*— **This research work outlines a study of indoor propagation environment. The electrical engineering department building at SKIKDA university was taken as a model; it was designed and executed using the properties provided by the indoor simulation software "Wireless Insite". The study was performed at 2.4GHz, 5.2GHz and 30 GHz. Indoor propagation models must take into account obstructions inside the targeted building, the locations of access points, in addition to reflection, diffraction and scattering. However, study of the characteristics of multipath propagation based on parameters of delay propagation, path losses and received power RSS was carried out. Effects of building materials were taken into account by calculating the actual values of permeability and conductivity of each material. The results obtained for different parameters and cases show that the positioning of sensors, thickness and type of material of the walls, play a major role in the selection of the coverage range for indoor communication, another fundamental consideration was related to the specification of the transmitter antenna such as frequency, polarization, selection of an appropriate E and H plane and orientation of the antenna.**

*Keywords*—***Wireless insite software; RSS; Path losses, spread delay, frequency.***

## I. INTRODUCTION

Wireless communication is reaching new heights due to its enormous business benefits. Wireless technology can provide network speed, flexibility and efficiency. It has become a powerful tool for the tech-savvy generation (new term for modern technology) because it can promote information sharing and increase productivity.

The explosive growth of wireless systems coupled with the proliferation of laptops and palmtops suggests a bright future for these networks, both as stand-alone systems and as part of the larger network infrastructure. However, many technical challenges remain robust, providing the performance needed in the design of wireless networks to support emerging applications [1].

One of the advantages of wireless technology is its ability to pass through obstacles (doors, walls, etc.) and cover the entire building with a stable signal. Indoor communications concerns all information or display media set up inside a building, which happens inside airports, stations, shopping centers or others.

The mobile propagation channel is particularly characterized by a strong influence of the surrounding clutter and objects around the transmitters and receivers in a wireless system. These obstructions primarily determine how the signal propagates along a specific path and therefore should not be underestimated. Thus, it is very important to identify the characteristics of these obstructions and their distribution, in order to account for these changes and variations in field strength. Indeed, the interior wireless design is very specific to the building; that is, each building has its unique characteristics which make the radio propagation different, and therefore the expected performance of the system will vary. However, an accuracy evaluation of the technology available to design an indoor wireless system should not be overlooked. For example, cellular operators may aim to be at the forefront of the latest technology, but this does not necessarily guarantee that system performance has been fully optimized. The use of

advanced technology does not guarantee that the indoor cellular system is well designed, but nevertheless represents a valuable infrastructure from which the performance of the system can be improved and optimized [2].
Wireless InSite is a commercial software used to predict channel parameters within indoor and outdoor environments. The software has been validated at 900 MHz and 1800 MHz [3] and at 2.4 GHz and 5 GHz [4,5]. Wireless InSite considers the effects of material electrical properties. It also allows the user to configure waveform, antenna types and the properties of the transmitter and receivers. In this study, a sinusoidal waveform is used for simulation at 2.4, 5.2 and 30 GHz of different access points (AP) indoor the electrical departement of university of Skikda, to seek the optimal AP sites. This paper aims to investigate the accuracy of results when applying real properties of concrete and wood component of the building using Wireless InSite.

## II. THEORETICAL ASPECT AND DESIGN OF BUILDING

A 3D simulation model of the target building (the electrical engineering department of the University of Skikda), was designed and executed using the properties provided by the Wireless Insite software. The building has a ground floor and three floors with a height of 3 m for each floor and two auditoriums outside. We are going to take the building's ground floor as a target. This level includes four (4) offices, seven (7) classrooms, an archive room and a toilet as shown in figure.1. Construction materials include brick walls, ceiling, partitions between floors which are concrete, glass windows and wooden doors, with thicknesses (0.28, 0.30, 0.003, 0.045m) respectively. We will install transmitting antennas and receiving antennas in specific points of the level, which we will discuss later. We considered the sensitivity and effect of different building construction materials on wave propagation and telecommunications traffic indoors [6].

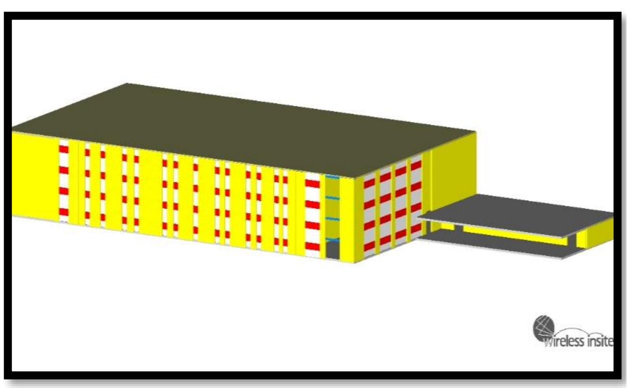


Figure 1: 3D view of the proposed target

An analytical calculation of the parameters η (permittivity) and σ (conductivity) of each constituent material must be carried out, or via the graphical interface GUI offered by Matlab (figure.2).

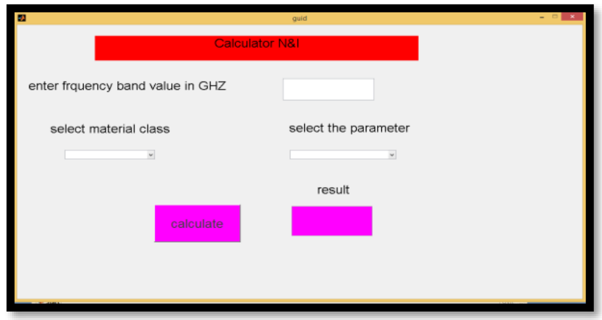


Figure 2: GUI window

In order to improve the accuracy of indoor propagation, valuable efforts have been made to study the effect of different building materials on different frequency bands, as reported in [7]. Additionally, wall measurements have been used to obtain an accurate characterization of a particular wall material in a target environment [6]. Two general representations followed by the WI software are necessary for this mission and known as the relative permittivity ε and conductivity σ. Relative permittivity represents the reflection of material influences on the electric field, which strongly depends on the selected frequency [8]. In most ray tracing simulators, the values given for different materials are approximate values which do not represent the actual measurement in a real environment and result in an inaccurate prediction of simulation results [9-10]. Each characteristic of matter can be represented by equation [7]:

$$\varepsilon = \eta' - \eta'' \quad (1)$$

where $\eta'$ and $\eta''$ represent the real part and the imaginary part of the relative permittivity, respectively. For conductivity, it describes the imaginary part of relative permittivity. The conversion between them can be clarified in equation (2).

$$\sigma = \eta''\omega \quad (2)$$

**ω** is the angular frequency of the transmission carrier frequency in radians / sec. Accordingly, $\varepsilon$ can be rewritten on the basis of a subsequent equation and as shown by equation (3) [11]:

$$\varepsilon = \eta' - j\frac{\sigma}{\omega} \quad (3)$$

and

$$\eta'' = 17.98\ \frac{\sigma}{f} \quad (4)$$

The values of σ and $\eta'$ as a function of the frequency can be estimated, using the recommendations of the International Telecommunications Union (ITU) [12]:

$$\sigma = cf^{d} \tag{5}$$
$$\eta' = af^{b} \tag{6}$$

where $a$, $b$, $c$ $et$ $d$ are constants of subsequent equations supplied by ITU for use when dealing with frequency-dependent materials problems.

Tables 1 summarize calculations results of the target materials constituent parameters.

Table 1 : Calculated values of conductivity σ and of relative permittivity $\eta'$ of different target materials at 2.4 GHz. And 5.2 GHz.

| Material | Material Thickness (m) | $f$= 2.4 $GHz$ | | $f$= 5.2 $GHz$ | |
|---|---|---|---|---|---|
| | | $\eta'$ | σ | $\eta'$ | σ |
| Concrete | 0.30 | 5.31 | 0.00127 | 5.31 | 0.00238 |
| Brick | 0.28 | 3.75 | 0.038 | 3.75 | 0.038 |
| Wood | 0.045 | 1.99 | 0.053 | 1.99 | 0.12 |
| glass | 0.003 | 6.27 | 0.65 | 6.27 | 1.65 |

## III. SIMULATION RESULTS AND DISCUSSIONS

In order to get accurate results, we created an omnidirectional antennas profile of Tx (transmitters) and Rx (receivers). Gain was fixed for both Tx and Rx at 2 dBi with vertical polarization, and an effective bandwidth of 20 MHz. A waveform profile must be formed, its properties which are the values of: carrier frequency, bandwidth and phase, are set in our case were respectively at 2.4 GHz, 20 MHz and zero. The creation and distribution of AP (access points) within the target must be chosen carefully. In our case, a total of seventeen (17) points were distributed in the middle of each room on the ground floor of the department. In addition, two points were distributed as waypoints along the corridors with a separation distance of 8 m and two points in the middle of the two amphitheatres with a height of 2 m above the ground, the transmission properties are specified and shown in figure.3.

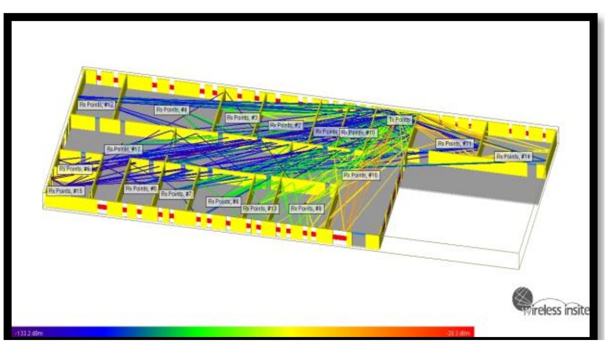

Figure 3: Signal propagation of 1 Tx and 17 Rx at 2.4GHz

The most important properties to consider are: power and transmission input height, which are 30 dBm and 2.8 m, respectively.

RSS, is the strength of a signal measured at the receiving antenna, it may give a better location approximation than proximity [13]:

$$RSS = \sum_{K=1}^{L} \overline{\left|\beta_k^d(t)\right|^2} \tag{7}$$

where β (t) is the arrival trajectories amplitude at a certain time, d is the distance and L is the number of trajectories between the transmitter and the receiver.

Tables 2 summarize results given by WI of RSS, number of propagations and delay spread of the received signal in the case of 1Tx and 17Rx.

Table 2**:** Propagation simulation results at 2.4 GHz with 1Tx and 17 Rx.

| Tx | Nomber of propagation | RSS (dBm) | Average arrival time (s) | delay spread (s) |
|---|---|---|---|---|
| Rx1 | 10 | -34.02 | $3.515000e^{-008}$ | $3.204200e^{-008}$ |
| Rx2 | 10 | -50.57 | $6.941500e^{-008}$ | $4.896000e^{-008}$ |
| Rx3 | 10 | -61.37 | $1.143800e^{-007}$ | $4.354600e^{-008}$ |
| Rx4 | 10 | -69.98 | $1.256800e^{-007}$ | $2.130200e^{-008}$ |
| Rx5 | 10 | -76.83 | $2.211400e^{-007}$ | $2.786200e^{-008}$ |
| Rx6 | 10 | -87.08 | $2.178600e^{-007}$ | $1.653700e^{-008}$ |
| Rx7 | 9 | -99.97 | $2.685600e^{-007}$ | $5.063700e^{-008}$ |
| Rx8 | 3 | -101.61 | $2.720500e^{-007}$ | $2.211200e^{-009}$ |
| Rx9 | 8 | -104.85 | $2.404100e^{-007}$ | $1.064300e^{-008}$ |
| Rx10 | 9 | -98.64 | $2.213900e^{-007}$ | $2.443000e^{-008}$ |
| Rx11 | 10 | -70.32 | $1.680200e^{-007}$ | $1.710900e^{-008}$ |
| Rx12 | 10 | -71.25 | $1.553100e^{-007}$ | $1.615600e^{-008}$ |
| Rx13 | 10 | -47.13 | $1.307200e^{-007}$ | $8.297300e^{-009}$ |
| Rx14 | 10 | -34.96 | $4.310400e^{-008}$ | $1.294700e^{-008}$ |
| Rx15 | 10 | -51.44 | $1.029100e^{-007}$ | $1.658400e^{-008}$ |
| Rx16 | 10 | -33.77 | $6.514700e^{-008}$ | $1.680600e^{-008}$ |
| Rx17 | 10 | -79.52 | $2.293600e^{-007}$ | $5.473800e^{-008}$ |

In another case we have placed three Tx in specific places. Keeping the 17 Rx in their locations, we operate each Tx separately to distinguish the best positions which give relatively optimal powers as shown in figure.4.

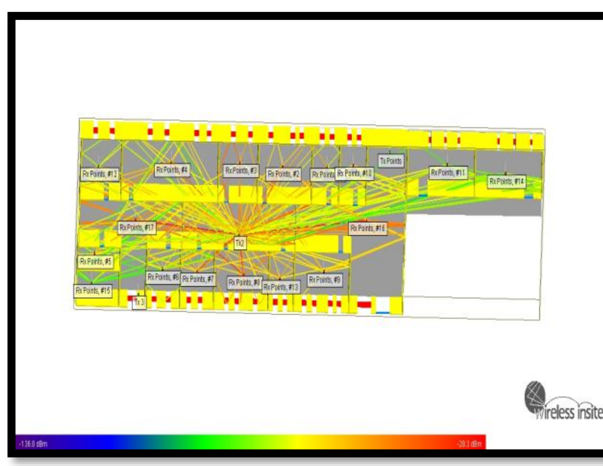

Figure 4: Signal propagation of 3 Tx and 17 Rx at 2.4GHz

Figure 5 and 6 show RSS total power and Tx2 trajectory losses plots versus distance with 3Tx at 2.4 GHz respectively. It can be observed that Tx2 position offers less losses for most of Rx compared to Tx1 and Tx3, this is due to the architectural nature of the targeted building, because the ground floor has a wide corridor open to all the teaching rooms, there are fewer obstacles for Tx2 than Tx1 and Tx3.

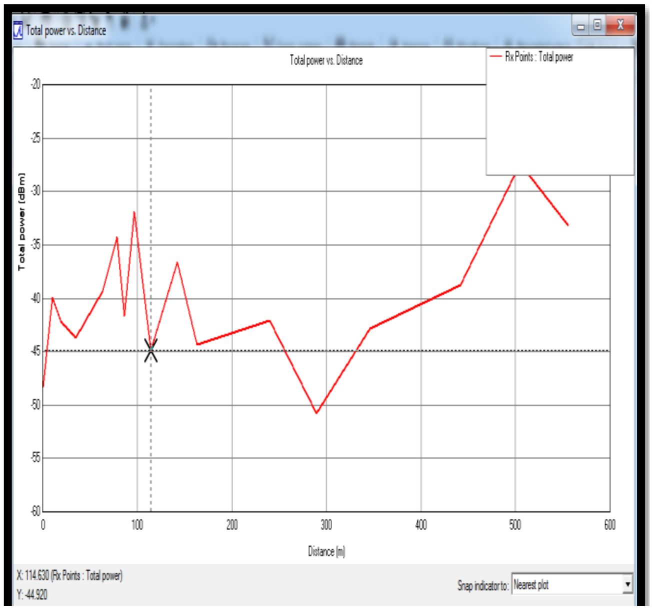


Figure 5: RSS total power plot versus distance for 3Tx at 2.4 GHz

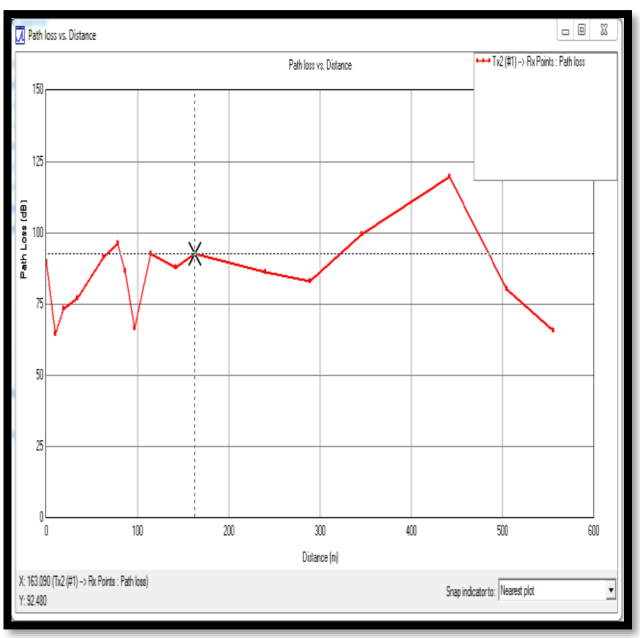


Figure 6: Tx2 trajectory losses for Tx2 at 2.4GHz

Some results obtained for different cases are summarized in Table 3. It can be confirmed that Tx1 position offers relatively high, but Tx2 position offers less path losses. Therefore, Tx3 position does not provide better coverage of all Rx. However, the same remarks were observed if we change transmission frequencies to 5.2 GHz and increasing to 30 GHz, keeping the same circumstances.

Table 3**:** Comparison of results for different cases at 2.4 GHz.

| Tx | | Rx | RSS (dBm) | Path losses (dB) |
|---|---|---|---|---|
| 1Tx | | Rx1 | -34.02 | 87.82 |
| | | Rx2 | -50.57 | 103.83 |
| 3Tx | Tx1 | Rx1 | - 48.1 | 79.37 |
| | | Rx2 | | 97.12 |
| | Tx2 | Rx1 | | 91.52 |
| | | Rx2 | -40.01 | 64.50 |
| | Tx3 | Rx1 | | 127.61 |
| | | Rx2 | | 111.84 |

Table 4 summarize simulation results for received power RSS, for different transmission frequencies ranging from 2.4 GHz, 5.2 GHz and up to 30 GHz. It has been observed that the value of the path loss increases with increasing both frequencies and separation distance. For example, at 30 GHz, path loss was 134 dB. On the other hand, RSS decreases with the increase in frequency in our case.

Table 4**:** RSS and path losses comparison between 2.4 GHz frequencies; 5.2 GHz; 30 GHz.

| **Rx** | **RSS (dBm)** | | | **Path losses (dB)** | | |
|---|---|---|---|---|---|---|
| | 2.4GHz | 5.2GHz | 30GHz | 2.4GHz | 5.2GHz | 30GHz |
| Rx1 | -34.02 | -59.15 | -72.93 | 87.82 | 88.75 | 102.21 |
| Rx2 | -50.57 | -80.21 | -90.16 | 103.83 | 107.41 | 127.95 |
| Rx3 | -61.37 | -83.64 | -103.93 | 117.29 | 116.35 | 134.31 |

## IV. CONCLUSION

Through this research work, we investigated the field of indoor communications by doing a parametric study of the communications traffic inside the department of electrical engineering at university of Skikda, using performance of Wireless Insite simulator. It is important to mention that the thickness and type of wall material play a major role in the selection of the coverage range for indoor communication, and the degree of wave penetration as well as the location of the sensors. Another substantive consideration related to the specification of the transmitter antenna such as polarization, selection of the appropriate E and H plane and antenna orientation should be taken into account. The propagation characteristics of different radio frequencies such as 2.4 GHz, 5.2 GHz and 30 GHz were studied and compared in terms of path losses and the power received for indoor environment of the ground floor of the building targeted department. It was concluded that in the same millimeter band there is a smaller delay deviation if increasing frequency, but relatively low powers and high path losses, which will result in a preferable ability to improve the quality of internal communication by reducing the frequency. On the other hand, these results can add significant knowledge in the design of real buildings, including the selection of material types to achieve high performance of 5G.

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