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Study the effect of attenuation and analysis of wireless LAN signal in an indoor environment with some physical obstacles

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Abstract
Wireless communication technology using local area network (LAN)technology is considered the most widely used communication technology today, especially in indoor places such as companies, hospitals and homes . But there are downsides that affect the work of this technology, especially the interference that occurs with these waves and the impact of some physical obstacles, and these two characteristics are considered one of the most prominent challenges facing the spread of this technology.. These waves are affected by numerous physical obstacles along their propagation path, such as building walls and iron or wood sections, which sometimes obstruct the waves.
This study highlights a practical study of the effect of the thickness, proximity, and distance of these obstacles on the signal source. A 2.4 GHz router was used. It was observed that the thickness of some obstacles has a significant impact on the quality of the transmitted signal, as does the distance of the signal source from the user. Based on the results extracted from this practical study, a set of points emerge that must be taken into account to improve the quality of transmission and reception of such waves.
Keywords - Wi-Fi , wireless Communication , LAN , Routers , 2.4 GHz

Literature reviews

The researchers Sayidmarie and al-Mashhadani (2014) analyzed physical obstacles and walls on the wireless local area network (WLAN) signal inside some university buildings at a frequency of 2.45 GHz. This study was based on direct field measurements of signal strength using an RSSI scale. Then the results were compared with the traditional logarithmic distance model, which determines the loss when penetrating walls of different thickness and materials. The results of this study showed that the number of walls and the type of material between the transmitter and the receiver have a pronounced effect on signal attenuation, and the results indicate that the loss when penetrating walls is much higher than when penetrating other walls[1].
Rath et al. (2017) also conducted a study in which a realistic path loss model occurred and developed inside some buildings to evaluate the performance of a Wi-Fi network in various indoor environments, such as offices, halls, corridors. Using frequencies of 2.4 and 5 GHz, the researchers compared well-known theoretical models, such as Log-Distance and cost-231, with some actual measurements taken from different environments. The results of the research team indicated that the proposed experimental model provides higher accuracy in predicting the values of signal attenuation inside buildings[2].

Another study determines the effect of some materials used in construction on the spread of the Wi-Fi signal by comparing the strength of the signal captured without any hindrance with the strength of this signal captured after placing a barrier in the form of a building.
According to the results of this research, plastic is the most effective material for reducing the strength of the Wi-Fi signal when it is used as a barrier. On the other hand, it was found that a wall or a hollow plank of wood has less effect in reducing the strength of the Wi-Fi signal when used as a barrier[3].
A field study conducted by Sarkar et al. (2021) focused on studying the impact of dynamic obstacles and the movement of people within some indoor and indoor environments on the performance of Wi-Fi networks. These experiments were conducted in some closed halls, with the movement of a number of people inside the rooms. RSSI and productivity values were also compared in different scenarios. These results showed that the movement of people in these rooms causes a noticeable change in signal strength, perhaps up to 12 dB, and also leads to a noticeable decrease in data transfer rate as the intensity of people's movement increases[4].
A study by Ubaidat et al. (2024) dealt with reducing the variability of the received signal and its intensity value (RSS) with distance changes within environments and indoor areas by focusing and relying on averages at different frequencies and altitudes. The results showed that relying on taking averages improves the accuracy of statistical modeling by attenuating the signal intensity inside buildings and reducing the random fluctuations that occur in them[5].

Introduction :

In the last decade, the use of Wi-Fi technology has witnessed a major boom in multiple environments, including healthcare facilities, workplaces, universities, and homes. The popularity of Wi-Fi technology is due to its ease of application and use in everyday life[6].
In order to ensure an optimal use of a smooth and reliable Wi-Fi experience, it is essential that the transmitted signal maintains its strength during its journey from the transmitter to the receiver. In a typical scenario, radio waves are easily transmitted from the transmitting antenna to the receiver without any loss in any part of their power. However, the reality is quite different. Once the Wi-Fi signal is sent from the transmitter, it passes through several obstacles and various factors that may cause its weakness[7].
A lot of wireless network problems may be caused by physical obstacles, such as walls, windows, doors, and others .
Radio waves can pass through a lot of different materials, but some of these materials reflect or absorb these signals, which is a major reason for their attenuation.
The international communication Union of Radio (ITU-R) has confirmed that the electrical properties of materials and their structure have a significant impact on the propagation of radio waves[8]. This association stressed the importance of understanding the losses in wireless signal quality caused by building materials and structures, in order to provide guidance to engineers on preventing or reducing interference in the propagation of radio waves inside buildings and facilities using this technology . For these reasons, it is necessary to distinguish between materials such as glass, wood and concrete when exposed to radio signals.
There are several different ways to enhance the signal strength in Wi-Fi devices, one of which is the use of a directional aluminum plate reflector, as hypothesized by this study[9] . Another study was conducted, it is possible that a reflector installed a small hole in the wall structure where there is a Wi-Fi signal inside[10]. Also referred to in, a method for assessing Wi-Fi signal strength has been universally agreed upon, producing scope for further exploration and developments[6]. Over the past

few years, multiple research teams have made remarkable progress in the field of wireless communications, as evidenced by numerous publications.

2. Materials and methodology

Bands of 2.4,GHz were used in this work for the Wi-Fi signal. This is due to the widespread use of these ranges, especially in indoor environments.
1-A router TP-Link TL-WR940N type was used to transmit data at this frequency.
A wireless router that supports IEEE 802.11n/g/b standards with speeds up to 450 Mbps. Equipped with 3 external antennas for improved wireless coverage.Contains 4 LAN ports and 1 WAN port.Supports multiple operating modes, including access point and range extender.Features advanced security settings such as WPS encryption and bandwidth management.
2 - CHNADKS Electromagnetic radiation measuring device
A device was also used to detect the electric and magnetic field signals of the waves transmitted from the router. This device reads both the electric and magnetic field values separately, as well as the radiated energy. It is equipped with an audible and visual alarm system when safe radiation values are exceeded.
• It is equipped with an LCD screen to display readings and graphs.
It operates on a rechargeable battery that lasts up to 16 hours.
It relies on a Geiger-Muller tube to analyze radiation and accurately determine its levels.

3. Method used

The working methodology involves placing the router in a fixed position and gradually moving away from it, starting from a distance of 40 cm to 480 cm by increasing 40cm in every stepp, with a barrier near the router. Electromagnetic radiation was measured using a CHNADKS device.

Working Setup

The router was placed in an open room to ensure optimal signal measurement conditions.The device was set to 2.4 GHz to test its sensitivity to various obstacles.
A CHNADKS device was used to measure electromagnetic radiation at several points, as previously mentioned.

2 - Data Recording

The maximum value (Max Mode) of the measuring device was used to obtain the highest radiation levels at each point.
The recorded values for the electromagnetic field and radiated power at each point were recorded. Table 1 represents the change in distance with each of the electric field, energy density, and magnetic field intensity in space .

Distance (cm)	Electric Field Density(V/m)	Power Density(mW/m$_2$)	Magnetic Field Density(mGS)
40	9	24.03	0.297
80	7.9	21.09	0.26
120	7.7	20.55	0.254

160	7.1	18.95	0.234
200	6.8	18.15	0.224
240	6.7	17.88	0.221
280	6.5	17.35	0.214
320	6.4	17.08	0.211
360	6.1	16.28	0.201
400	5.9	15.75	0.194
440	5.7	15.21	0.188
480	5.4	14.41	0.178

In Figure 1, the values of each change in distance and the corresponding change in the value of the electric field were taken. We notice a decrease in the electric field intensity values with increasing distance between the neighbor and the radiation source.

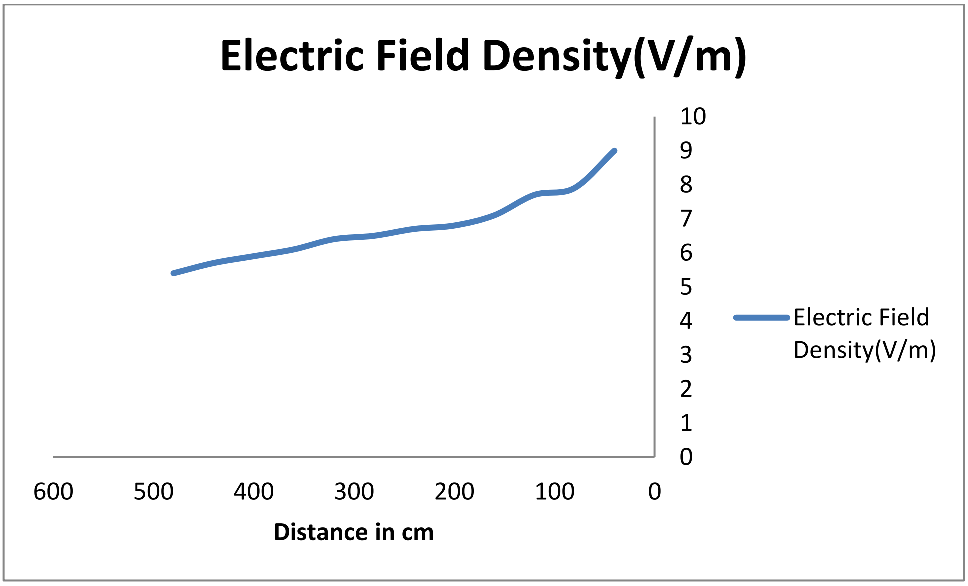

Figure 1 represents the change of the electric field density vs the change in distance in space.

Figure 2 is a diagram comparing the effect of increasing the distance with changing electromagnetic radiation energy values In a indoor or without any barrier or building wall .

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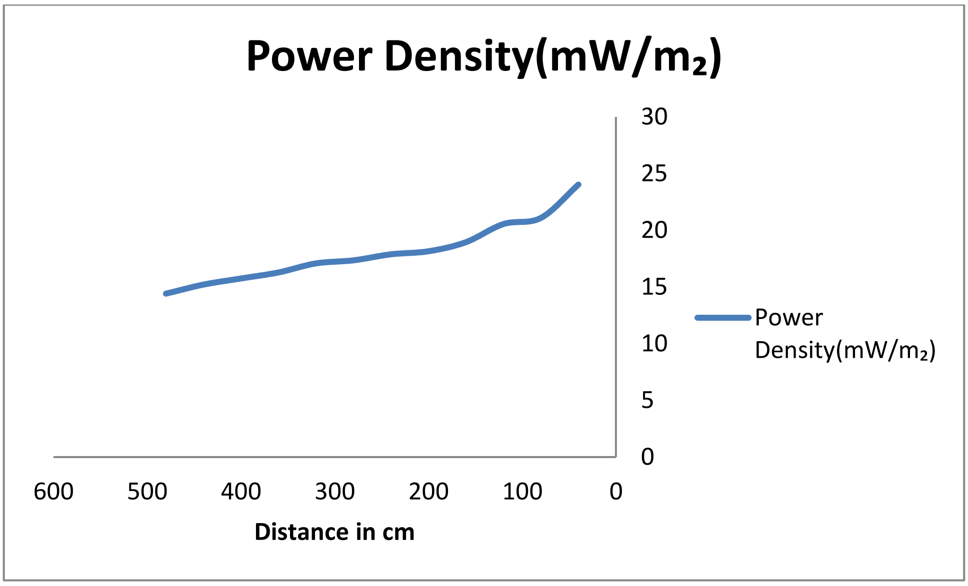

Figure 2 represents the change in power density vs the change in distance in space.

Figure 3 represents the change in distance values with magnetic ray values in the presence of the wall. We notice in this figure how the values of the graph slope downward.

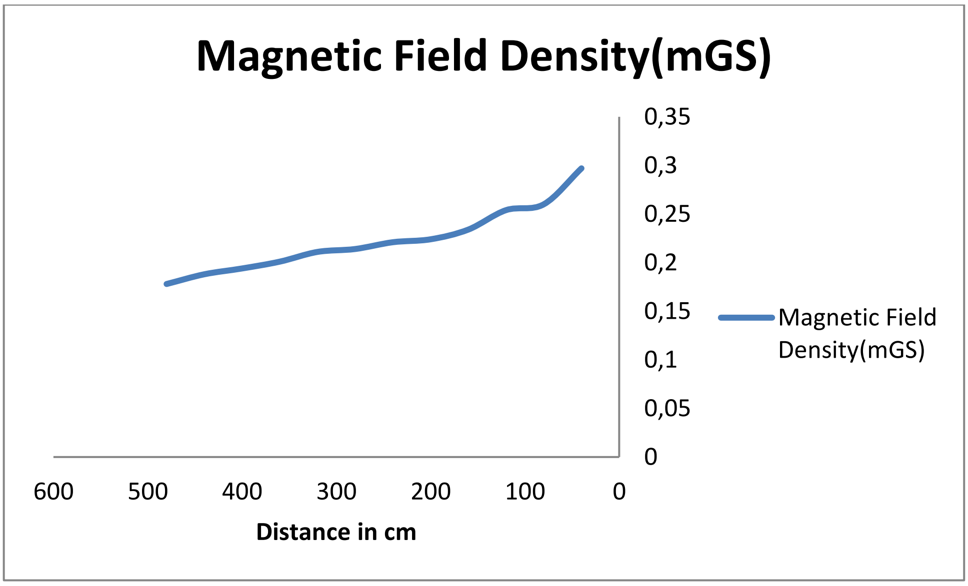

Figure 3 represents the change in magnetic field vs the change of distance in space.

The data were compared in the presence of physical obstacles such as walls, allowing to monitor the effect of these elements on signal propagation.

Table 2 shows the changes in electric and magnetic field values and energy intensity with varying distance when a 30 cm thick brick wall is placed.

Distance (cm)	Electric field Density(V/m)	Power Density(mW/m₂)	Magnetic field Density(mGS)
40	3.6	9.612	0.118
80	3.2	8.544	0.105
120	3.1	8.276	0.102
160	2.9	7.743	0.095
200	2.7	7.209	0.089
240	2.5	6.675	0.082
280	2.2	5.874	0.072
320	2	5.34	0.066
360	1.9	5.073	0.062
400	1.8	4.806	0.059
440	1.7	4.539	0.056
480	1.6	4.272	0.052

In Figure 4, the values for each change in distance and the corresponding change in electric field value were taken in the presence of the concrete wall or barrier. We observe a decrease in electric field intensity values as the distance between the neighbor and the radiation source increases.

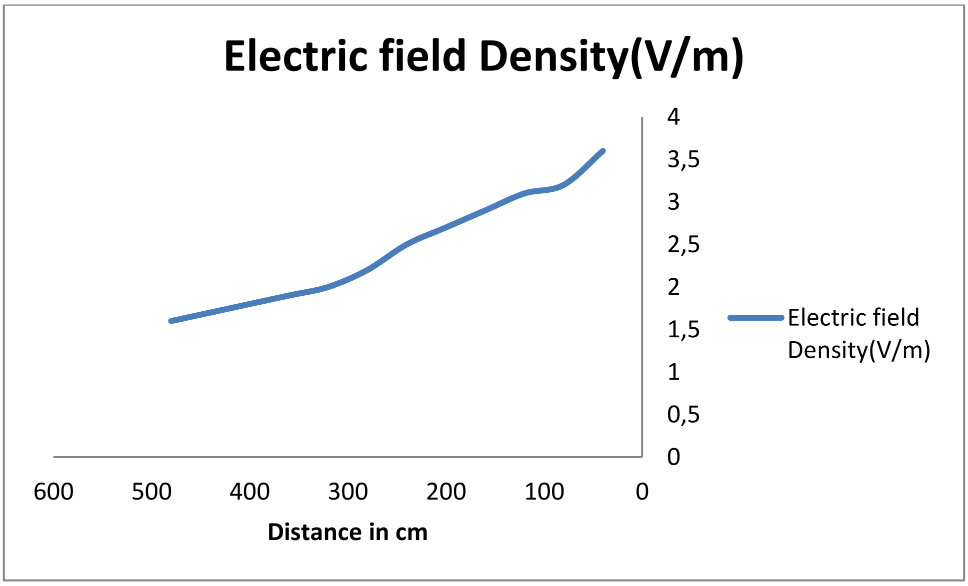

Figure 4 shows the variation of the electric field with distance in the presence of a building wall with a thickness of 30 cm.

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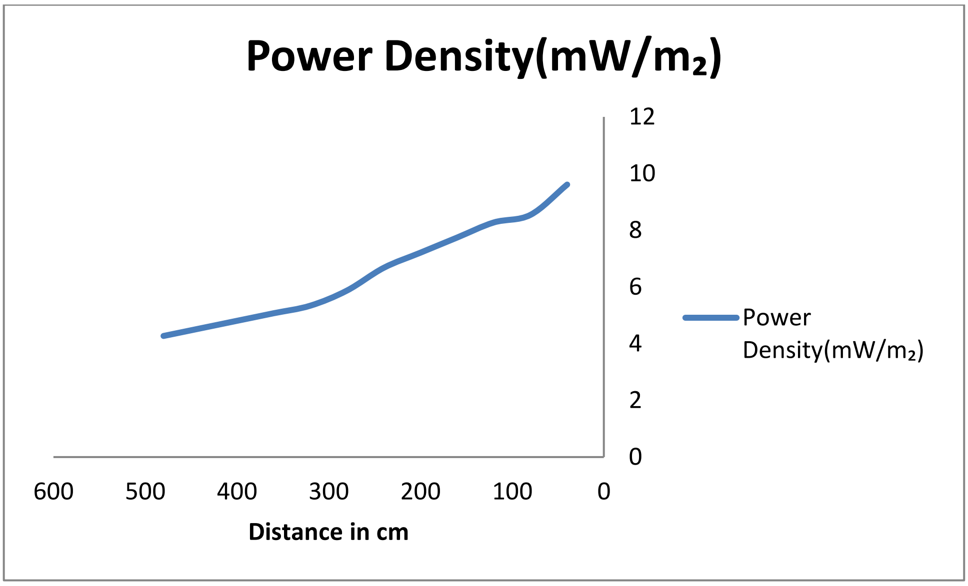

Figure 5 shows the change in energy intensity with distance when there is a building wall with a thickness of 30 cm.

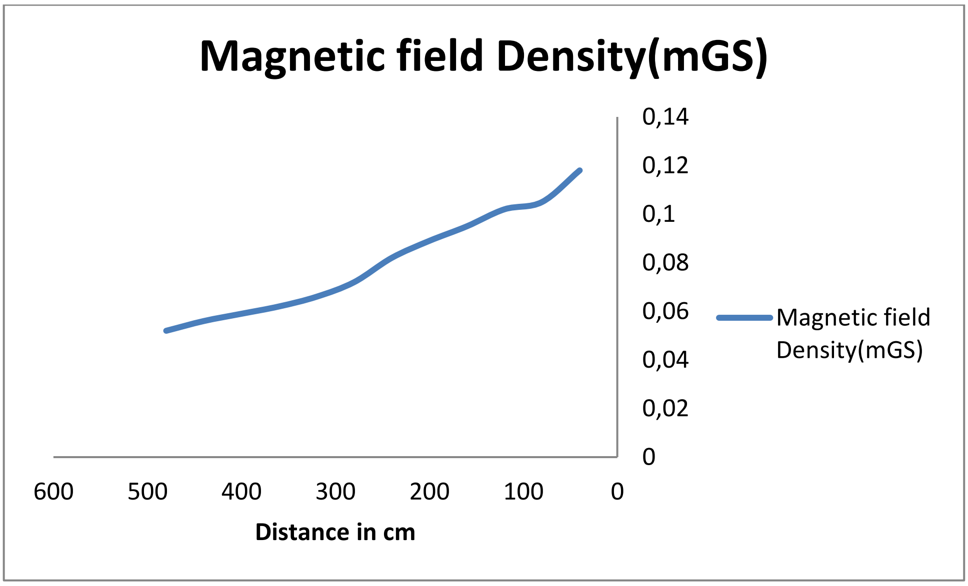

Figure 6 shows the change in the magnetic field with distance in the presence of a building wall 30 cm thick.

While Figure 7 represents the curve diagrams for each of the three intensity values, which are electric, energy and magnetic radiation in the presence of a building wall with a thickness of 30 cm.

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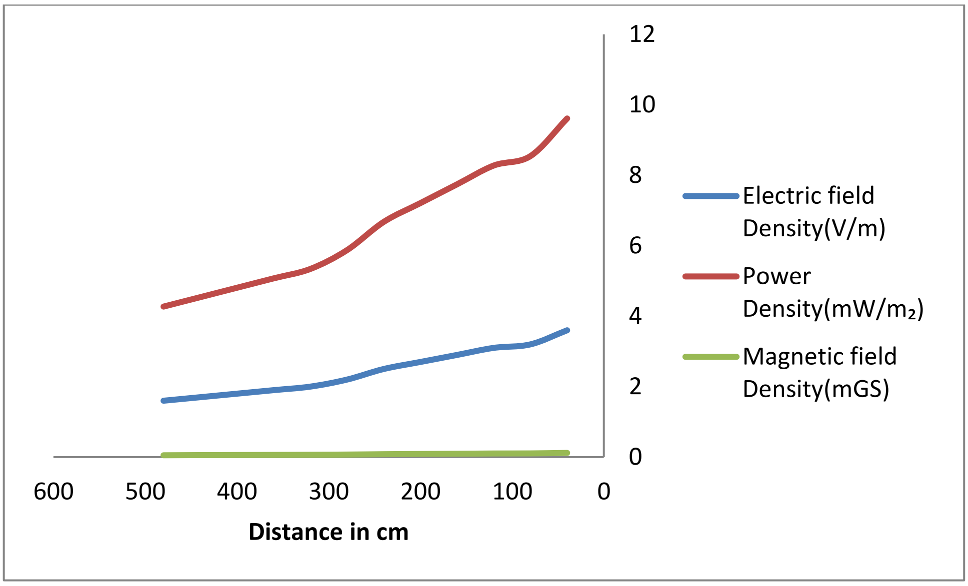

Figure 7 shows the change in the values of the electric and magnetic fields and the energy intensity of electromagnetic radiation with varying distance in the presence of a building wall with a thickness of 30 cm.

Figure 8 represents a comparison between the curve diagrams for each of the three intensity values: electric, power, and magnetic radiation.

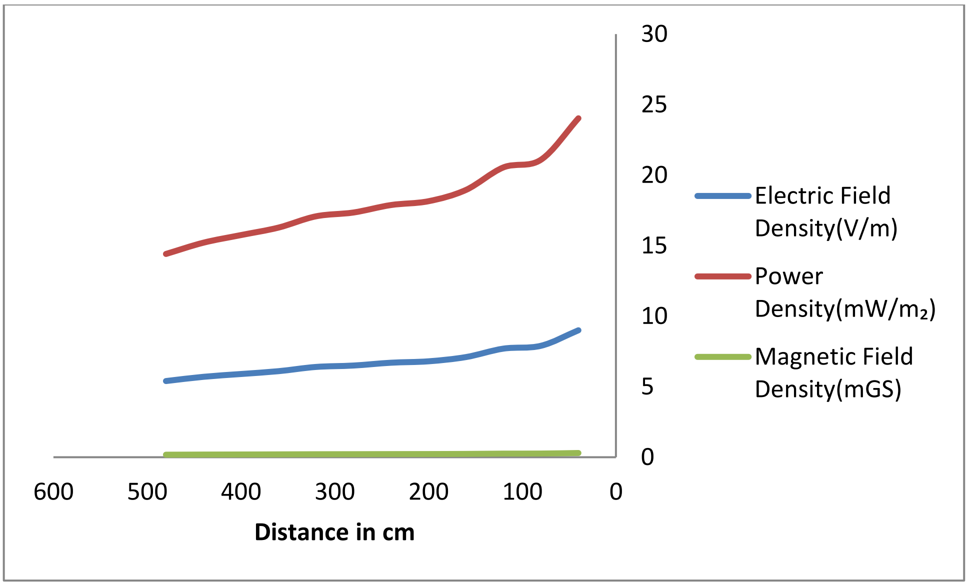

Figure 8 shows the change in the values of the electric and magnetic fields and the power density of electromagnetic radiation VS the distance in space.

By comparing the last two figures, we notice two important points:

1- The behavior of the two figures in terms of the change in the shape of the graph of the points is almost similar.

2- In the case where there is no construction barrier in the path of the wave, the distance the electromagnetic wave travels is longer than the distance it travels when a barrier is present.

Discussion

The effect of physical materials on wireless signal propagation varies according to their electrical and structural properties. For example, the results showed that the further we move away from the router in an obstacle-free environment, the signal strength gradually weakens, which is natural according to the inverse square law that describes the behavior of electromagnetic waves. Walls made of construction materials such as brick, sand, or cement show a more noticeable effect on the signal, especially when they contain metallic elements like rebar. The composition of the wall, including its porosity and the number of its layers, contributes to an increase in the absorption rate. Also, an increase in the wall thickness, for example 30 cm, prolongs the duration of the wave's stay inside the medium, which increases the amount of absorbed energy and, in turn, leads to a greater degradation of the signal.

Conclusion:

When focusing on the results of the previous tables and data, they show us that the nature of the barrier placed in front of the wave front and its thickness play an important role in the strength and quality of the radio signal. The experiment has proved that moving away from the router in an open environment causes a noticeable weakening of the signal, and this is considered normal and consistent with the physical laws of wave propagation. As for the walls with a thickness of 30 cm, they showed a noticeable decrease in the three recorded values compared to these values in free space, due to the building materials, as this leads to a significant absorption of the signal.

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