Modeling and simulation of wireless signal coverage for automated mobile equipment communications in complex and metallic surroundings

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Abstract

This study investigates WiFi receiver power coverage in a simple office place (with three different wall materials of concrete, glass and drywall) and factory condition provided by 802.11ac routers operating at 5 GHz using an 80 MHz bandwidth. The whole simulation was carried out using the software Wireless InSite.

Rationale

In the twentieth century, the information age, unprecedentedly large amount of digital data are being transmitted at every moment. As more and more data are transmitted wirelessly, it is critical to ensure the efficiency of wireless signal transmission. Moreover, wireless communication is nowadays widely employed in the industrial sectors which demands high reliability. Hence, the reliability of wireless signal transmission has also become equally critical. In order to achieve efficiency and reliability, the interaction between wireless signals and its surrounding materials must be first investigated，so that subsequent actions can be taken to optimise wireless signal coverage. In this research, the interaction of one of the many wireless communication channels, IEEE 802.11(Wi-Fi) with a number of different materials will be investigated.

Research question

How are wireless signals such as IEEE 802.11 affected by the environment that it is operating in?

Hypothesis

Standard indoor environments with mostly concrete structures are more penetrable for wireless signals which ensures better signal coverage. Whereas, factory environments with more metal structures and EMI interference will cause difficulties for good wireless signal coverage.

Expected outcomes

Through computer simulation, the interaction of wireless signals with a few commonly used architecture materials will be recorded. Users can then use these data to make a more informed decision about what materials to use and where to place the antennas in order to ensure good signal coverage.

Background and purpose of research

Wi-Fi: IEEE 802.11 is part of the IEEE 802 set of LAN protocols, and specifies the set of media access control (MAC) and physical layer (PHY) protocols for implementing wireless local area network (WLAN) Wi-Fi computer communication in various frequencies, including but not limited to 2.4, 5, and 60 GHz frequency bands. (IEEE 802.11, Wikipedia)

Simulation section

Software used for the simulation: Wireless InSite

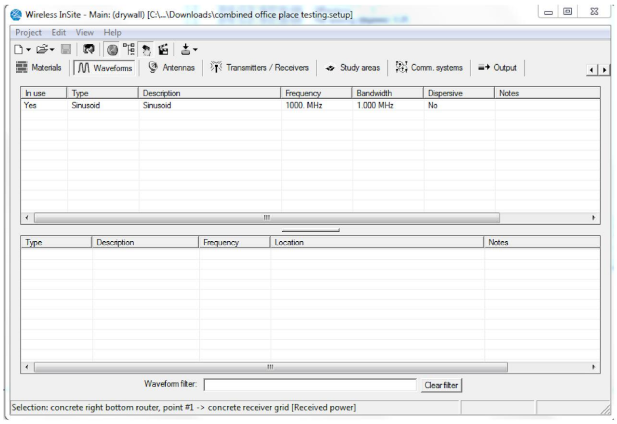
Wireless InSite® is a suite of ray-tracing models and high-fidelity EM solvers for the analysis of site-specific radio wave propagation and wireless communication systems. The RF propagation software provides efficient and accurate predictions of EM propagation and communication channel characteristics in complex urban, indoor, rural and mixed path environments. (remcom.com)

1）Wi-Fi coverage in indoor office place constructed of different materials

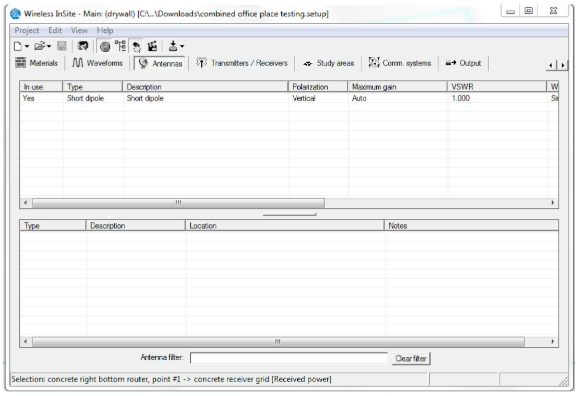
The following example investigates WiFi coverage in a one storey office place (with three different wall materials of concrete, drywall and glass) provided by 802.11ac routers operating at 5 GHz using an 80 MHz bandwidth by measuring receiver power. The WiFi routers are modelled as transmitters using short dipole antennas with input powers of 7 dBm. The routers are located on the four donors and the center of the indoor office place. Receiver grids covering the entire indoor office place were added to capture the behaviour of the signal throughout the scene. The receivers use vertically polarised short dipole antennas.

<u>Simulation factors setting and floor plan</u>

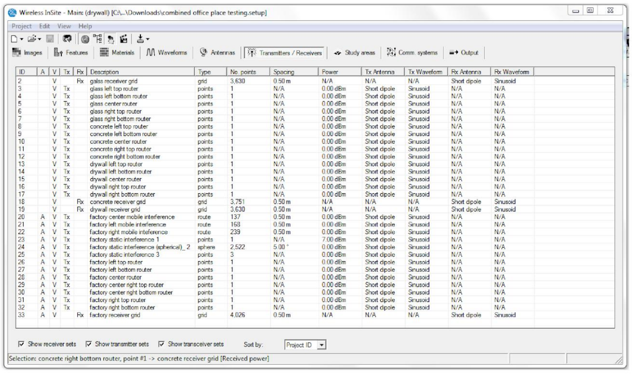
The detailed settings of the antennas, transmitters, receivers, communication systems and waveforms are shown below in figures 1.



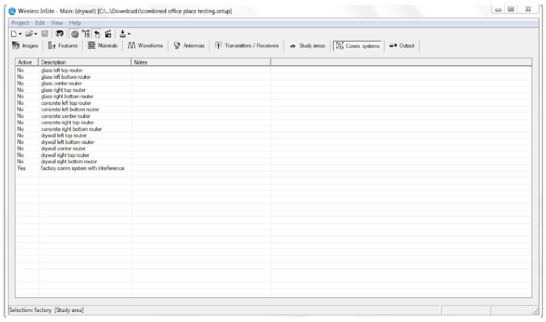
waveform setting



antennas setting

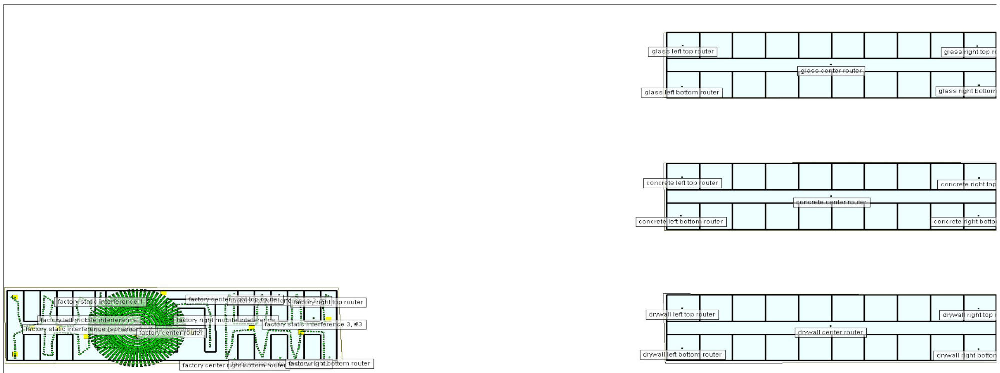


transmitters and receivers setting

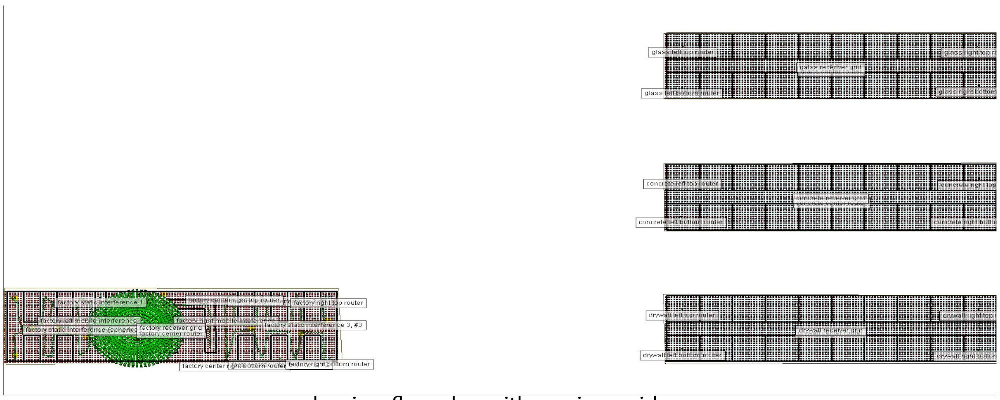


communication sysetms setting

FIGURE 1



sky view floorplan without receiver grid



sky view floorplan with receiver grid

FIGURE 2

results and interpretation

With respect to the colour spectrum in Figure 4, we can conclude from figure 3 that the ability to obstruct WiFi signals of concrete materials is stronger than the other two materials. While that of drywall and glass materials are similar. It can be seen in the "concrete results" that purple colour starts to appear in the fifth room from left whereas in the "drywall results" and "glass results" purple colour only starts to appear in the sixth room.

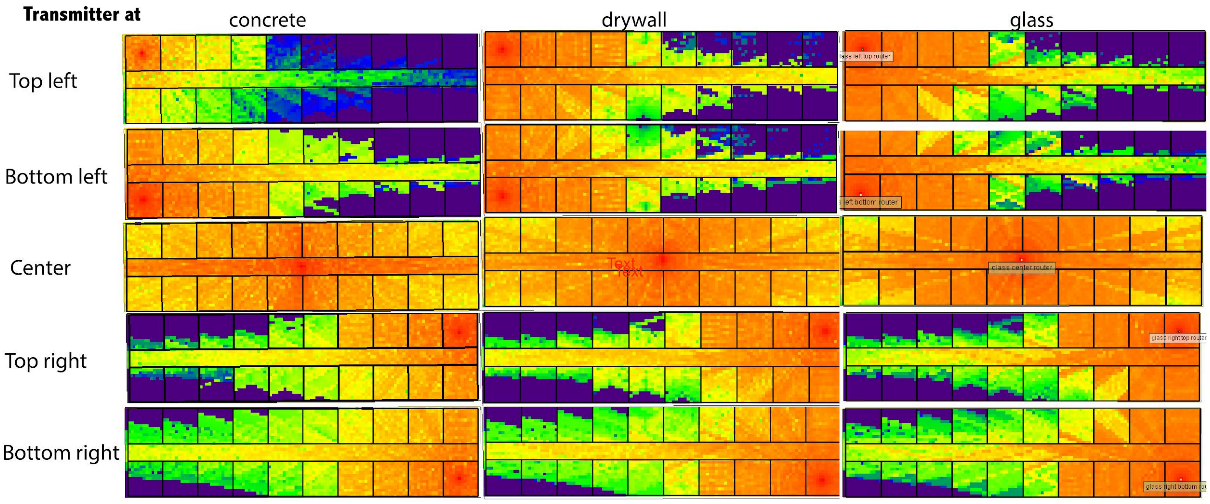


FIGURE 3

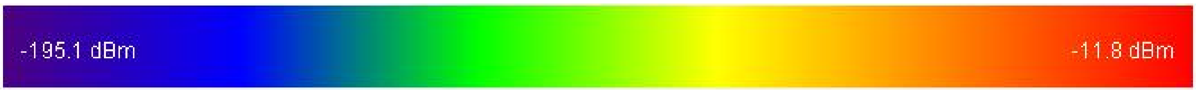


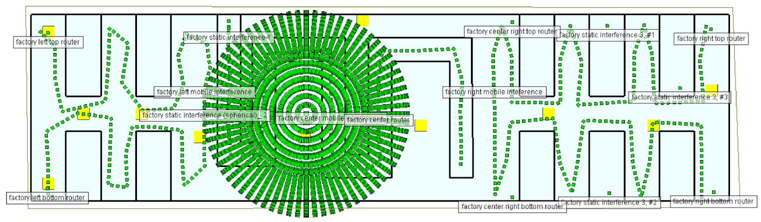
FIGURE 4, RECEIVER POWER SPECTRUM

2) Wi-Fi coverage in indoor factory condition with metallic structures and EMI

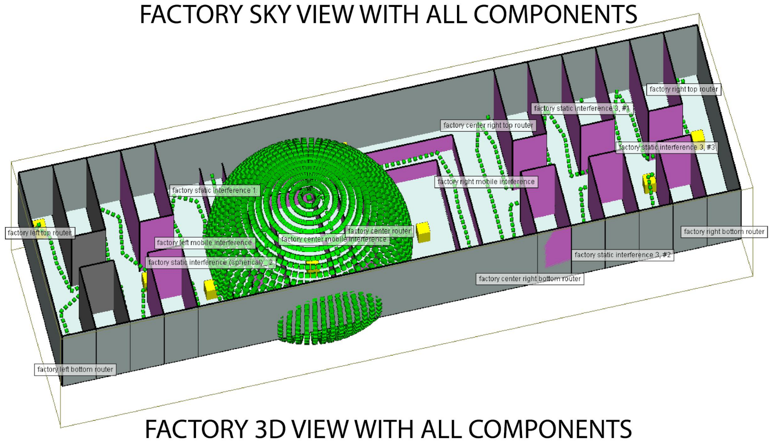
The following example investigates WiFi coverage in a one storey factory provided by 802.11ac routers operating at 5 GHz using an 80 MHz bandwidth by measuring receiver power. The WiFi routers are modelled as transmitters using short dipole antennas with input powers of 7 dBm. The routers are located on the four donors and the centre of the indoor office place. Receiver grids covering the entire indoor office place were added to capture the behaviour of the signal throughout the scene. The receivers use vertically polarised short dipole antennas.

Apart from the difference in architectural structure, there are three other major modifications in the floor plan in the factory condition simulation. Firstly, the walls in the factory floor plan consist of a mixture of concrete and metal materials to a simulate the metallic mechanise in factories.(Figure 5) Secondly, there are various transmitters, mobile and static, that serve as EMI interference in the factory. (Figure 7) Lastly, there are human bodies in the factory to provide another additional interference. (Figure 6)

<u>Simulation factors setting and floor plan</u>

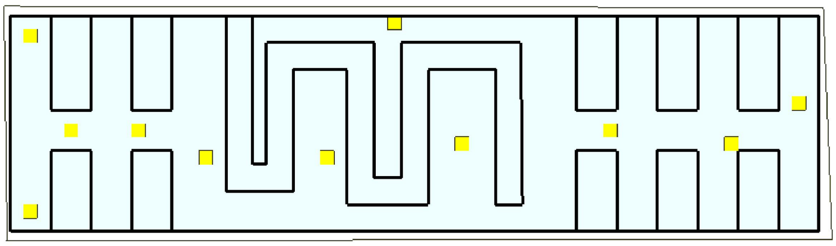


FACTORY SKY VIEW WITH ALL COMPONENTS

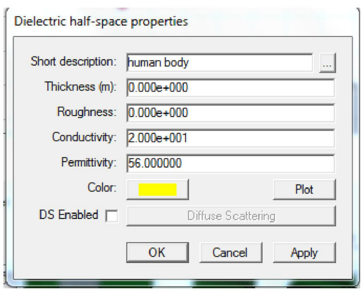


FACTORY 3D VIEW WITH ALL COMPONENTS

FIGURE5, FACTORY COMPONENTS

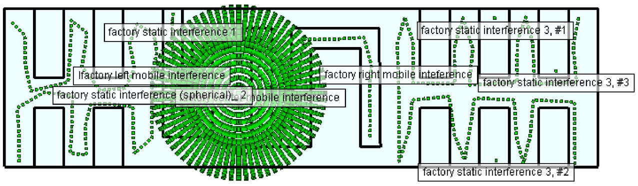


FACTORY HUMAN BODY DISTRIBUTION

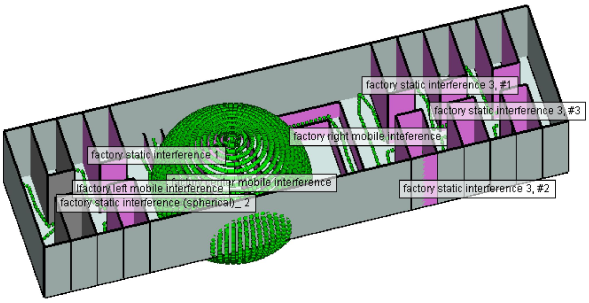


FACTORY HUMAN BODY PROPERTY

FIGURE 6, FACTORY HUMAN BODY



FACTORY INTERFERENCE SKY VIEW



FACTORY INTERFERENCE 3D VIEW

FIGURE 7, FACTORY INTERFERENCE

<u>results and interpretation</u>

Due to the limited capacity of the workstation the aforementioned simulation was ran on, results were not obtained. In the future, the same simulation can be run on a server with sufficient capacity.

3) Additional simulation

In the aforementioned simulations, only three transmissions are allowed. (Figure 8) To further investigate how materials that allow higher number of transmissions will affect receiver power, one additional simulation of the drywall office place was run with six transmissions allowed.

<u>results and interpretation</u>

It can be concluded from the result that for materials that number of transmissions is a significant factor in simulating the receiver power of WiFi signals as in the result below there are barely any weak signal spot. (Figure 9)

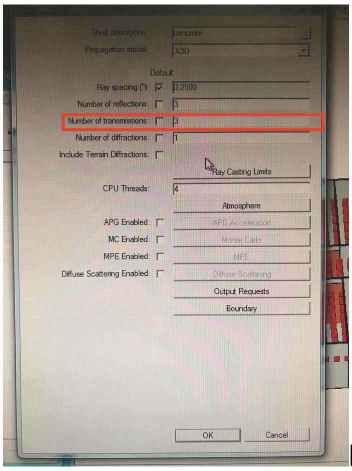


FIGURE 8

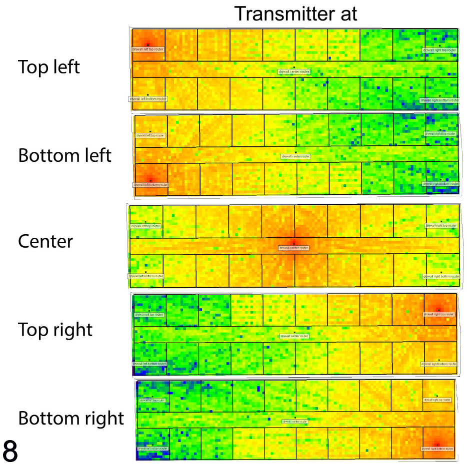


FIGURE 9

Future research

As we proceed further into the digital age, larger bandwidth and faster transmission are demanded. Although WiFI has made possible fast wireless transmission with large bandwidth but only within short distances. For long distance transmission, the world is now working on the fifth generation of the cellular mobile communications. Among the many changes planned for 5G is the expansion into higher frequencies in the millimeter wave spectrum. In the future, simulations of the propagation of millimetre waves can be run with different diffusion pattern patterns to investigate how millimetre waves interact with deferent materials.

Abbreviation

EMI: Electromagnetic interference

bibliography

(remcom.com): https://www.remcom.com/wireless-insite-em-propagation-software, accessed 6 Jan 2019

(IEEE 802.11, Wikipedia): https://en.wikipedia.org/wiki/IEEE_80q2.11, accessed 6 Jan 2019