University of Texas at Arlington

Challenges of RF Systems Report

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Ever since Nikola Tesla developed his first remote-control boat, it has been clear that wireless technology will be used extensively in the future. Today this same technology is used in everything from playing music on your car radio to communicating with satellites. Each of these cases needs to be tested and designed before they are ever built. MathWorks provides its RF toolbox to help simulate and model these situations so that developers and designers can properly build their systems. A useful webinar presented by Steve Ajemian and Mike McLernon went over the main concerns and challenges of terrain and urban RF communication. Steve Ajemian, the lead presenter, is the Industry Manager for Aerospace and Defense for MathWorks.

The presentation started by explaining the multiple systems that go into the process of simulating a scenario. The levels of these systems in decreasing scope are the mission, system of systems, the system, and the engineering components (Ajemin 2022). Every mission has some goal and will usually be connected to other systems to carry out its function. An RF setup needs to be able to account for challenges within its system, other systems, and the environment around it. Challenges for the RF system would include accounting for how much power is being used to transmit, what type of antenna is used, and the performance of the setup. This RF system will need to connect to other systems such as visibility tools, and performance analytics (Ajemin 2022). RF systems also must deal with multiple types of environmental challenges. The main challenges are those of rural and urban areas (Ajemin 2022). In rural areas, the curvature of the earth and atmospheric interference can cause signals to not be received. In urban areas, the size, shape, reflectivity, and locations of buildings cause signals to be reflected and scattered.

The first of these environmental challenges presented was how the terrain in rural areas affects the needs of an RF system. The first issue discussed was about how communicating antennas usually need a line-of-sight connection to receive each other. If the antenna doesn’t have a line-of-sight connection, then they need to be raised up to see each other (Ajemin 2022). While the antenna is now able to communicate with each other, there is an increased construction cost due to the materials and labor needed to raise the antenna to a sufficient height. The second issue discussed was about atmospheric and terrain interference. Because the signal emitted from an RF system must go through the atmosphere, the atmosphere absorbs some of the energy from the EM wave and weakens the received signal. Additionally, trees, water, and other surface materials can cause signal reflections that interfere with the original signal. There are two solutions to these issues. The first is to have multiple antenna stations or more power to each station. These solutions are simple but not optimal and can cost more if there is an excessive amount of stations or too much power being used. The second solution is to use a beaming antenna (Ajemin 2022). A beaming antenna can focus its emission in certain directions so the signal can travel further. This solution is more complex but because the signal can travel further, less power and fewer stations are needed. The MathWorks RF Toolbox allows developers to simulate these scenarios and allows them to come to the best solution for their needs.

The second environmental challenge discussed in the presentation are those that arise in an urban environment. An urban environment usually has multiple buildings in the way of line-of-sight connections, so reflections need to be considered (Ajemin 2022). These types of problems are especially important for 5G providers inside cities because 5G signals have difficulty going through walls to get to their destination. Some ways to improve the connection within the desired area are to increase the power of the antenna, place more antennas around the city, and strategically place the antenna to the signal reflects of buildings and structures to best propagate around the city. As discussed before, increasing the power, or placing more antennas solves the problem but at an increased cost. This solution is not optimal because there is usually a setup that can decrease the number of antennas used and decrease the power used by those antennas. Steve Ajemian discussed the inefficiency of these solutions and showed us how the RF Toolbox allows developers to simulate the placement, and reflectivity of buildings along with the resulting signal strength of an antenna. With the information from the simulation, users can tweak the setup of the planned RF system set up so they can make the most optimal solution to their needs.

A few days later I downloaded a trial version of the RF Toolbox and followed the MathWorks example of 5G wireless simulations over terrain. The software allows you to import the terrain data based on the latitude and longitude of a location (MathWorks 2022). With this data, users can view the surrounding area in a 3D site viewer. Users can also place emitting and receiving antennas based on their location and view them in the site viewer (MathWorks 2022). This allows users to see the line-of-sight connection between each antenna and determine whether part of the terrain is in the way. Lastly, the RF Toolbox lets the user specify how much beamforming is used by the antenna. This can be viewed in the site viewer so it can be easily visualized by the user (MathWorks 2022). This ability to simulate beamforming allows users to render the improved signal strength in the direction of the receiving antenna (MathWorks 2022).

Additionally, I read parts of a research thesis on millimeter-wave systems in cities. Millimeter waves are EM waves in the “frequency band between 30GHz and 300GHz” (Seraj 2019, 23). 5G uses the frequency band between 3 and 30GHz also known as centimeter waves (Seraj 2019, 23). By increasing the frequency of the signals used, more information can be transferred over a set amount of time. The drawback to this though is that higher frequency bands are more prone to interference and are less likely to propagate through walls. Additionally, water vapor absorbs frequencies between 164 and 200 GHz (Seraj 2019, 25). Overall, while 5G technology uses centimeter waves to communicate, increasing the frequency band to millimeter waves has multiple difficulties relating to how the signals will propagate through the air, walls, and other materials.

In conclusion, before attending this webinar and doing some extra research, I did not know how many simulations, research scenarios, and overall effort went into making sure that an RF system was optimal. I’ve understood that antennas are usually placed on top of hills and buildings to get the best coverage but now I know that the alternative is to either build a longer antenna or to make multiple stations. Both alternatives are not optimal and waste materials and money. As a future computer science major, I will be working on technology that is required to be connected to other devices. While this connection can be through a wire, wireless connections are becoming more common. I now know what tools are available to simulate the RF propagation so that I and others can determine how strong of a connection there can be between devices.

References

Ajemian, Steve, and Mike Mclernon. “Scenario Modeling and RF Propagation for Aerospace and Defense Applications.” Challenges for RF systems. Challenges for RF systems, 15 Sept. 2022.

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Seraj, Ahmad Shahpoor. *Study on Propagation Characteristics of 5G Millimeter-Wave Wireless Communication Systems for Dense Urban Environments*. Waseda University, 2019.

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