Solving Interference Issues in a Smart Home with EMIT

The Internet of Things (IoT) is composed of many networked devices, like the modern appliances in a smart home linked to one another. Today's smart homes, cars and offices are seeing a large and growing number of these IoT devices. The popularity of IoT is driving home owners to install smart products for comfort, energy efficiency and security. The future of residential automation systems is bright, with experts forecasting solid growth in the number of smart home products over the next several years. Simulation-driven design tools are essential for engineers to create the IoT and make the smart devices reliable, inexpensive and energy efficient. This paper describes how EMIT is used to address electromagnetic and interference problems in a smart home equipped with many modern connected appliances. The paper focuses on EMIT's link analysis capability for determining a smart device's performance in the presence of other wireless sensors within a smart home environment.

Figure 1. Smart home

Motivation for Simulating EM Issues in a Smart Home

In a smart home, appliances, lighting, heating, AC, TV, computers, security and camera systems all communicate with one another wirelessly. These devices can be controlled from any room in the house and from remote locations through the internet. When you add more sensors to the smart home, the performance of other smart home products can be affected owing to insufficient signal strength between the router and a smart device and/or interference from nearby wireless devices.

The placement of a home's wireless system needs to be planned carefully when building a smart home design from scratch, and even when retrofitting a house with smart devices. For example, when developing a smart home design from scratch, the smart devices can be integrated into the design itself. This integration can be accomplished by concealing the wireless devices within walls and ceilings. Therefore, it becomes important to simulate the performance of the smart home's wireless connections prior to installation. This will save time, money and the hassle of troubleshooting difficult-to-access equipment after installation.

Early simulation leads to compressed design cycles and a substantial amount of savings on costly and time-consuming post-integration measurement and testing. Simulation tools help identify problems early in the design cycle. This enables engineers to perform system planning, including mitigation measures, and use "what if" experiments to improve device performance. An example of one such simulation tool is EMIT, which combines advanced wireless propagation models and a new link analysis capability with its co-site interference capabilities to predict the effects of interference in complex environments. EMIT uses the International Telecommunication Union's (ITU) site-generic indoor propagation model to estimate the median path loss between two wireless devices.

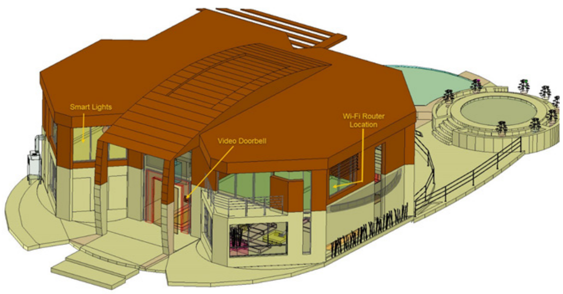

Figure 2. Smart home CAD model

Smart Home Environment

Smart homes are equipped with many smart devices, as shown in Figure 1. An example of a smart device is a video doorbell. Smart doorbell cameras work synchronously with a smartphone so you can see who is at your doorstep, record suspicious activity around your front door and get alerts and notification when visitors arrive or packages are delivered. In this paper, we look at the impact of adding a video doorbell to a smart home and model the effects of the doorbell's high-resolution video streaming on the Wi-Fi system within the home. In particular, we simulate the effects of a smartphone within the house on the Wi-Fi capabilities. We begin by analyzing the current performance of the smartphone's Wi-Fi as it is moved around inside the house (see Figure 2). The two-story smart home in our example is about 30 meters long. The Wi-Fi router is located in an office on the second floor.

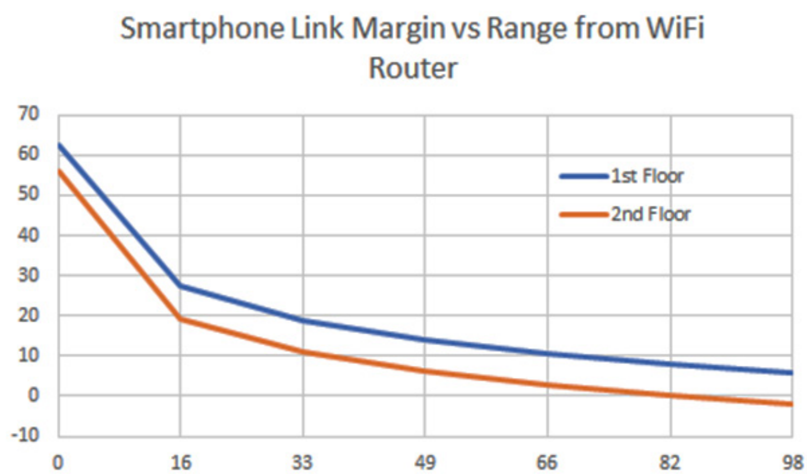

Figure 3. Smartphone link margin vs. Wi-Fi router in corner office, showing link margin (dB) on the y-axis versus distance to router (meters) on the x axis.

The results of the link analysis in EMIT demonstrate that the smartphone maintains its link, as indicated by a positive link margin in Figure 3 within the entire house provided the router is located in the corner office. There is no performance degradation except when you take the phone to the opposite end of the house on the second floor where the link margin drops to approximately -2.0 dB, causing the download speeds to be slightly slower but still providing adequate performance.

The corner office on the second floor appears to be an acceptable location for the router. However, will the Wi-Fi router still maintain sufficient wireless link and signal strength when you add more smart devices, such as smart bulbs and a high-resolution video doorbell in the smart home? Since most smart bulbs and video doorbells use standard radios in the unlicensed spectrum, we can take advantage of EMIT's built-in radio models (shown in Figure 4) to quickly model these systems. The smart lights typically use Z-wave communication while the video doorbell connects directly to your Wi-Fi system.

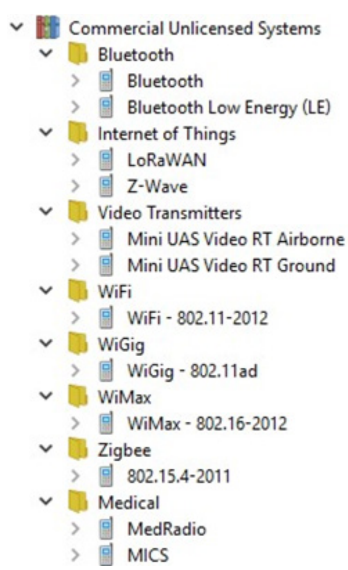

Figure 4. EMIT's built-in radio models include commercial unlicensed systems

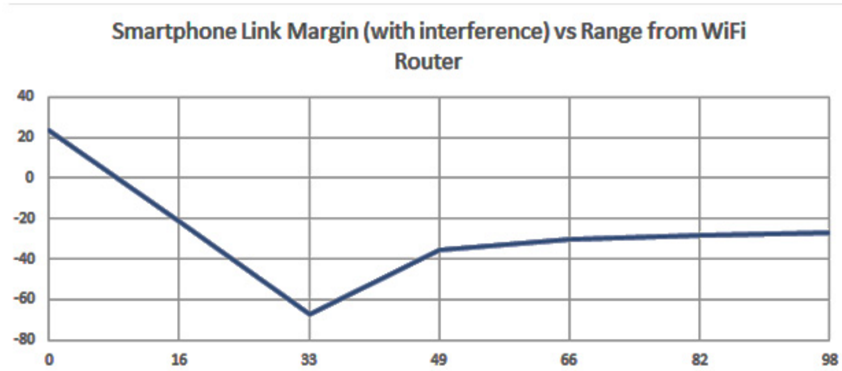

Figure 5. Smart phone link margin (db) on y axis versus distance to router (meters) on the x axis

What happens to our smartphone's performance when these systems are installed in the smart home and operating at the same time? See the plot in Figure 5. The smartphone's range is significantly reduced due to interference. It will experience performance degradation if the phone is placed more than 20 feet from the router. The phone works best when it's very close to the router and reaches its peak performance within the office.

The wireless link quality is especially poor due to pronounced interference about 10 meters (33 feet) from the Wi-Fi router owing to the video doorbell installed at this location. Results from EMIT reveal that the strong interference occurs because the video doorbell also uses Wi-Fi. The two signals overlap and are competing for the same spectrum.

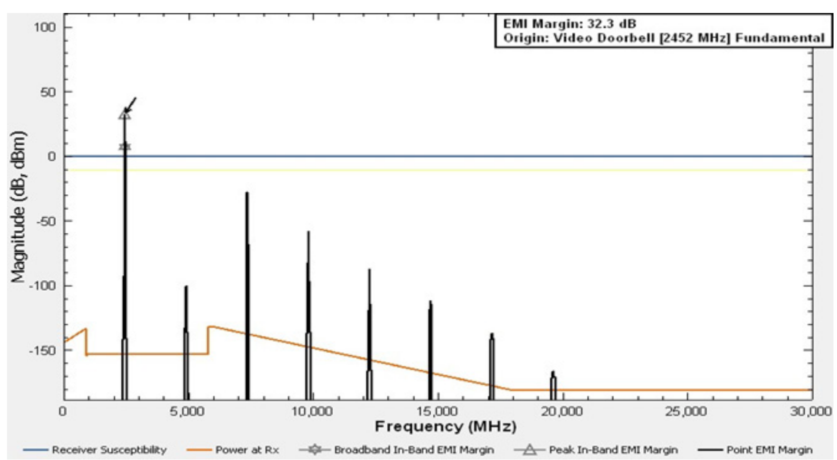

Figure 6. Interference diagram

Fortunately, EMIT allows you to explore mitigation measures to handle this interference. In this example, the easiest solution is to utilize the dual band capabilities of most Wi-Fi routers today. Since the doorbell is located relatively close, approximately 10 meters, to the Wi-Fi router, we can switch the doorbell to the higher 5.8 GHz band, which experiences more path loss due to the higher operating frequency.

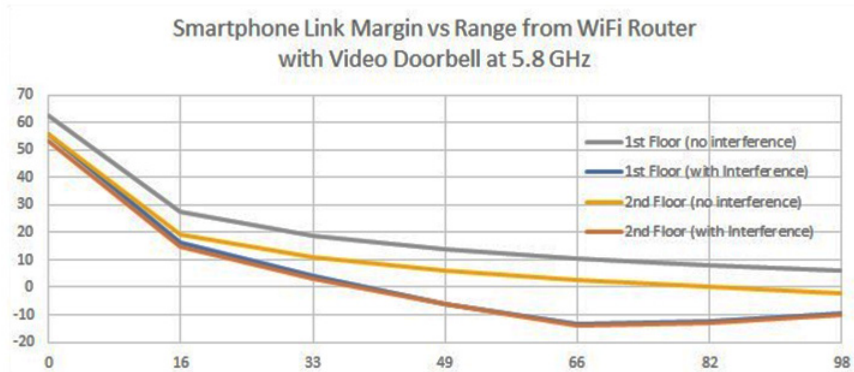

Figure 7. Phone link margin (dB) vs. range from Wi-Fi router (meters) with doorbell at 5.8 GHz

Reconfiguring the doorbell to operate using the 5.8 GHz Wi-Fi band resolves the primary source of interference as shown in Figure 7. However, the smartphone's Wi-Fi still experiences interference due to broadband emissions from the smart bulbs, which operate on Z-Wave technology. In this case, the performance is acceptable for less than half of the house and is extremely poor near the smart bulbs located approximately 20 meters from the router. This represents yet another link margin problem that needs to be solved.

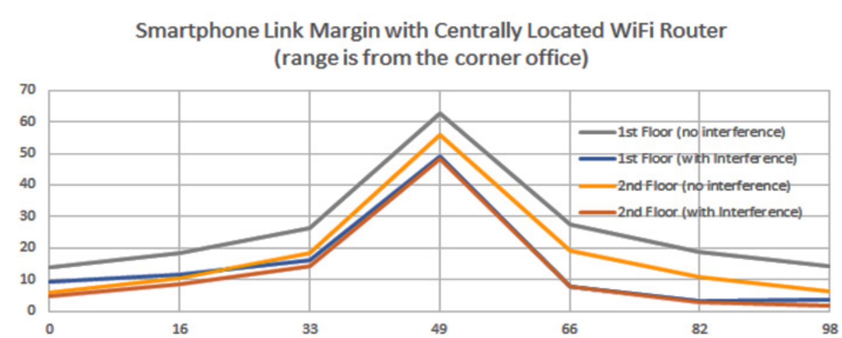

Figure 8. Router relocated to the center of the house. Link margin (dB) on the y-axis versus distance to router (meters) on the x axis.

In this case the solution may not be as simple as changing the frequency of the smart bulb, as we did for the video doorbell due to the device's capability. A relocation of the Wi-Fi router must be considered to improve the link margins, and to improve the interference-free signal strengths observed at the other end of the house. When the Wi-Fi router is relocated to the center of the house on the second floor, the resulting link margin is shown in Figure 8.

With the Wi-Fi router located in the center of the house, we can boost the signal strength and achieve complete coverage throughout our home even after the installation of several smart devices.

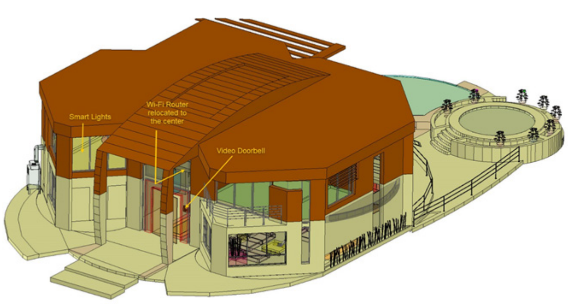

Figure 9. Smart home with router relocated to the center

Conclusion

Smart home products are becoming very popular. An increasing number of devices and appliances in your home are communicating with one another and your smartphone. Getting these sophisticated smart products to work in a complex electromagnetic environment without performance degradation can be challenging. Simulation tools such as EMIT effectively address interference and electromagnetic problems, enabling companies to develop smart devices that are energy efficient and reliable.

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