DESIGNING MEDTECH DEVICES FOR REAL-WORLD WIRELESS PERFORMANCE

An RC Testing Framework

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Introduction

It is becoming increasingly common for medical devices to be equipped with wireless technology. A connected device can be monitored remotely by a doctor to save costs, while also adding convenience and safety for the user. Continuous glucose monitors, ECG sensors, infusion pumps, and vital-sign trackers use technologies such as Wi-Fi and Bluetooth to communicate. A common scenario is that devices must be able to run for months or even years on tiny coin-cell batteries, which has made Bluetooth Low Energy a popular technology [1].

The advent of wireless technologies in MedTech devices not only puts constraints on the efficient use of limited energy resources, but also requires that devices remain fully functional in environments with many other wireless signals. Coexistence, which is the ability to perform a task in a shared environment with other systems that are also performing tasks, is therefore a key factor. Coexistence challenges can be posed by other wireless devices such as routers, mobile phones, and other MedTech devices, or by unintended signal sources like microwave ovens [2]. How can these challenges be addressed?

Bluetest

January 2026
Document No. BTW-26-001.

Reverberation Chambers: A Versatile Wireless Tool

To measure, optimize and ensure the wireless performance of a device, it has become more common to use a reverberation chamber (RC). It is capable of measuring parameters like Total Radiated Power (TRP), Total Isotropic Sensitivity (TIS), data throughput and antenna efficiency. The test volume is more flexible compared to traditional Over-the-Air (OTA) measurement chambers and it is possible to measure repeatable performance of virtually any wireless standard [3].

The electromagnetic conditions inside an RC create a multipath environment, meaning the signal undergoes multiple reflections before reaching the device under test (DUT). It is also statistically uniform, ensuring that all orientations of the DUT will be covered during a measurement sequence.

These properties resemble an indoor environment quite well. This was explored in a project at Bluetest where the data throughput of four different Wi-Fi devices was measured both inside a house and inside an RC. As seen in Figure 2, the performance of the devices was very similar in both cases.

The main advantage of a test chamber is that it offers a repeatable test environment, while a real-life scenario cannot. Changes in a real environment are due both to items moving physically as well as to other wireless devices behaving in an unpredictable manner.

Total Radiated Power

TRP is the total amount of radiated power, meaning that it is integrated over all directions. In traditional chambers, this requires the DUT to be rotated to point in different angles in both azimuth and elevation. The RC method (see Figure 1) is statistical and rests on the fundamental property that the radiated power of an antenna is proportional to the power that reaches the receive antenna in the chamber. This makes it possible to measure an accurate TRP value in typically one minute per channel.

The DUT is controlled wirelessly during the measurement by a communication tester, which both controls the DUT and acts as a measurement instrument. The TRP is affected by the performance of the radio and the efficiency of the antenna. Optimization of these parameters will help the DUT conserve energy and prolong the lifetime of the battery [4].

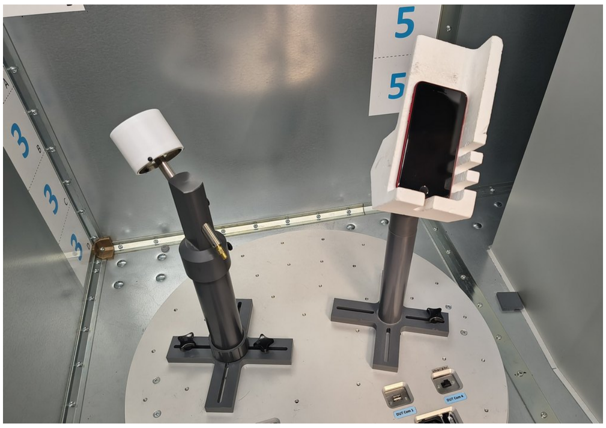

Figure 1. Example TRP setup.

Total Isotropic Sensitivity

TIS is a figure of merit that quantifies the sensitivity of a receiver in an Over-the-Air (OTA) setup by integrating the sensitivity over all directions. The measurement setup for TIS is the same as for TRP. The differences lie in how the equipment is used, the measurement sequences, and the calculations. TIS is, just like TRP, affected by parameters such as the efficiency of the antenna, mismatch between the receiver and the antenna, objects in the vicinity of the antenna, and the performance of the receiver itself [4]. A receiver that performs well is able to pick up and decode weak signals, which prevents retransmissions and saves battery power.

Phantoms and Live Person Measurements

The number of body-worn and other close-to-body devices is steadily increasing. The body generally makes it more difficult for a signal to propagate, and it is therefore important to test for such cases to avoid unexpected signal deterioration. A repeatable way of doing this is to use, for example, a head or hand phantom that simulates the effect of a real person inside the RC.

It is also possible to take this concept one step further by measuring how a real person affects the wireless properties of the device. This requires a reverberation chamber that is large enough for a person to fit inside and be able to move around. The key benefits are that it becomes easy to study how people with different types of physiology affect the device [5].

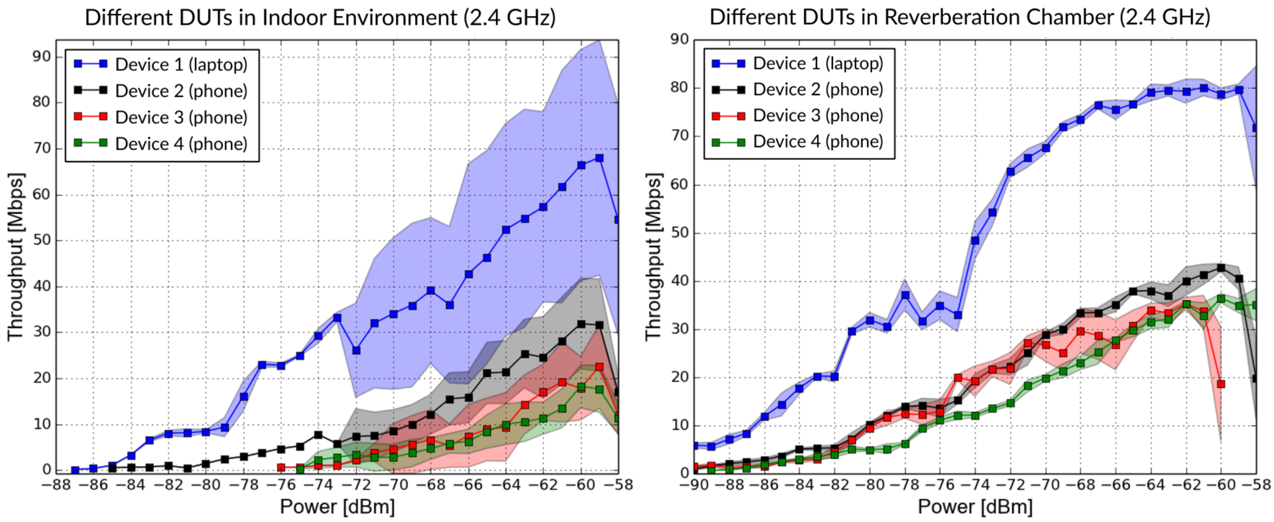

Figure 2. Comparison of how indoor environment measurements correlate with a reverberation chamber. Each measurement was repeated three times in the three different locations. The shaded area represents one standard deviation. The lower standard deviation indicates that the repeatability in the RC is much better compared to the real world case.

ACLR and Spurious Emissions

It can be challenging to create a well-behaving and efficient wireless device. It is not enough to generate a radio frequency (RF) signal that carries the desired payload; it is also necessary to avoid littering the air with unwanted RF signals. These unintentional RF emissions are usually divided into three categories, all of which can be measured in a reverberation chamber [6]:

Adjacent Channel Leakage Ratio

Most wireless communication technologies produce signals that are assigned to specific channels, each corresponding to a particular part of the frequency spectrum. The channel power is determined by integrating the power over this portion of the spectrum. Ideally, no power should be transmitted outside the allocated frequency range, as this can interfere with other channels of the same service or with other spectrum users. The Adjacent Channel Leakage Ratio (ACLR) specifies how much power unintentionally leaks into a neighboring channel.

Spectrum Emission Mask

Spectrum Emission Mask (SEM) is a frequency-dependent limit line that specifies the maximum permitted power density at various offsets from the carrier, usually starting inside the channel and extending several MHz beyond the band edge.

Spurious emissions

Spurious emissions are unwanted emissions originating from harmonics, intermodulation products, parasitics, and frequency-conversion products. They occur outside the desired bandwidth. Limits for spurious emissions may apply across a very wide frequency range.

Coexistence

Interference from other radio sources is common in most populated environments today, whether at home or in a hospital. Ensuring robustness under such conditions can be the difference between the success and total failure of a wireless device. This is especially true in the Industrial, Scientific, and Medical (ISM) bands such as 2.4 GHz, where traffic can be dense since these bands are open to technologies like Bluetooth and Wi-Fi.

In a study performed by Svedjenäs et al [7], the degradation of the TIS value was investigated in the presence of an interference signal in an RC. One of the measurement setups that was used is seen in Figure 3. It was found that the TIS value was degraded by up to 10 dB, depending on the distance between the interferer and the DUT. It was also concluded that the measurement setup could by simplified by using a white Gaussian noise (AWGN) interferer instead of a modulated signal.

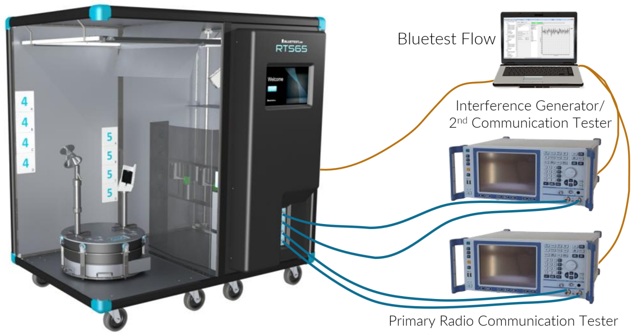

Figure 3. Measurement setup for coexistence testing. The interferer can be a signal from a wireless standard or random noise.

Conclusion

As more medical devices are being equipped with wireless features, it is important to verify the performance of these features. A reverberation chamber has been shown to be a useful tool for verifying the wireless performance of these devices, with the ability to quickly, accurately, and repeatably measure metrics such as TRP, TIS, and spurious emissions. It also provides a controlled environment for designers to evaluate the performance of devices in the presence of other radio signals, which allows them to identify and fix issues due to coexistence before a device is in production.

References

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