Enabling the Internet of Things
IoT Testing Basics
White Paper

Abstract:

In the Understanding the IoT Technologies paper in the “Enabling IoT Series” we discussed the variety of technologies that are supporting IoT applications. For each of these technologies to succeed, the designs must be optimized and debugged during the R&D phases, and then verified prior to manufacturing release. This second white paper of our IoT series focusses on the role that test plays for the successful deployment of these emerging IoT applications.

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ROHDE&SCHWARZ

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1 Introduction

With the dawn of Machine-to-machine communications (M2M) and the Internet of Things (IoT), we as part of the connected “things” will interact with the world around us seamlessly. This may offer an opportunity to experience life with greater joy and efficiency; where activities, tasks, information, responses, will be handled barely without any human interaction. To meet these future promises, a lot of work and focus must go into the development and testing of these products and services.

At first, one may think that these devices are very low cost; so why bother testing an IoT device? The main value-add of the Internet of Things comes essentially from application software that relies on real-time sensor data. These wirelessly connected devices are the enabler - but only if they offer security, reliability, and 24/7 connectivity. Customer experience, business success and sometimes even our life may depend on the reliability and availability of a single sensor.

As we discussed in the first part of the this IoT Series, there are many technologies being developed and deployed to support the wide variety of IoT applications. Whatever the technology, the typical IoT system will still have the same core building blocks Fig.1. The specific technology will be incorporated into a module that houses the sensors, actuators, and any additional devices are needed to support the application. The module will communicate wirelessly with a gateway connection that will then link it to a Wide Area Network (WAN). This may either be connected to the general internet or a virtual private network. The information may be stored and accessible on a cloud server, where the user may be able to access the information on a variety of devices – PC, tablet, phone, watch, etc.

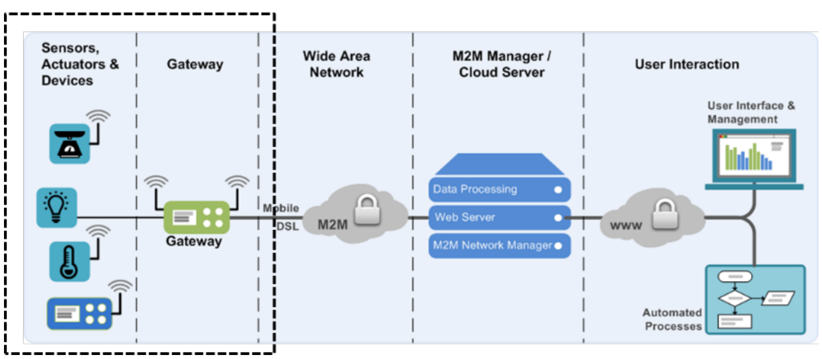


Figure 1: A typical IoT system.

2 IoT Test Challenges

While IoT offers a seemingly unlimited number of opportunities and services, there are many challenges in this very dynamic and demanding market environment Fig. 2. First, you need to pick the best technologies based on performance, deployment model, interoperability, costs and availability. What range will you require? What about data rates and battery life? Picking the most appropriate technology is a critical first step.

How complex will your design be? A faster time to market may be achieved by integrating off-the-shelf modules & components. The harder way is to begin with a design concept, build your own prototypes and then transition to a cost optimized mass product. Either way your design needs to ensure a highly reliable operation under all relevant conditions. Plus, you will need to understand the different needs for regulatory certification. These factors need to be budgeted into your design process.

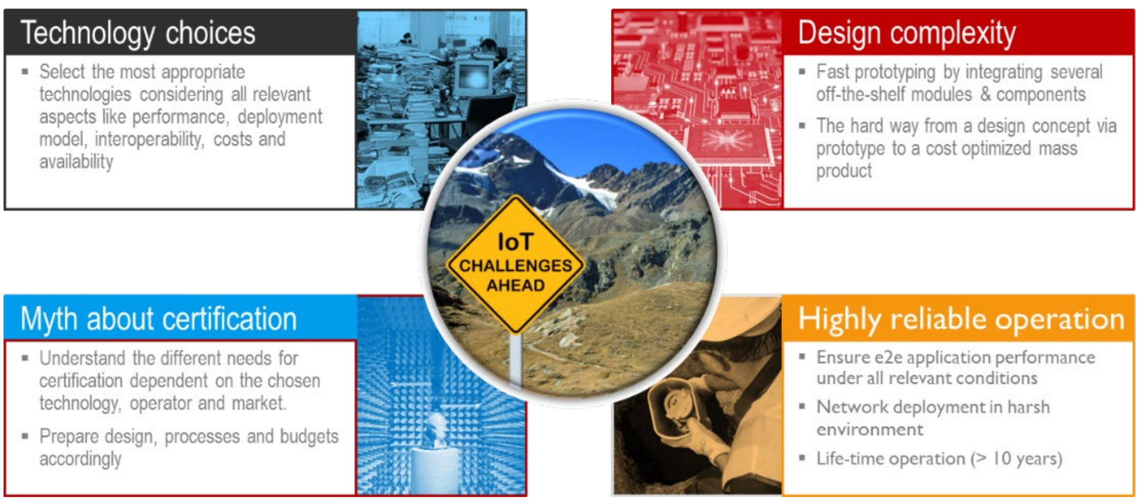


Figure 2: Design and test challenges in the IoT marketplace.

Whether you design your own components or integrate off-the-shelf components may depend on your in-house technical expertise. Is wireless design a core competency? The required skills for understanding circuit theory, antenna design, or wireless protocols might not be available. Some may be more focused on the software application, which is critical of course, but reliability and performance will ultimately be required for the products success. It is important to have access to a person or resources that understand the technology and the requirements.

The research and development stage will require more testing. This can range from validating your design's performance as well as pre-certification testing. Having the right resources will help to determine your test needs so that you can develop a test plan. Setting up your own certification lab is expensive, as is outsourcing the process to a certified test house. Once the product reaches manufacturing, you will need to determine what critical features must be measured and what metrics will be required to pass. Optimizing your test plan will help ensure a successful product hits the market in a timely manner.

Next, you need to determine how your company will implement the test plan. What test tools are needed; will you purchase, or rent test equipment? When buying equipment, it is important to consider your current needs, as well as future-proofing your investment for what needs you may have moving forward.

Often the capital equipment budget can be justified by clearly demonstrating your “cost of test” under different scenarios. In the beginning it is common to focus on the actual equipment expenses. However, it is important to factor in your time to market needs, the role of performance among a competitive field, and the actual test times of each unit in manufacturing. Whether you buy, rent or outsource is an important consideration when thinking about your testing needs.

3 Determining Your Test Needs

To help determine your testing needs, we created the following checklist to help guide you through the many considerations for your application.

- Wireless technology choice - Which licensed or unlicensed technology best matches your need? This is based on many parameters, including performance needs such as data rate, range and battery life.
- Wireless device strategy – Which design route will you go – either the chip-on-board or module approach? This will have an impact on both your R&D and manufacturing test and budget needs.
- Device form factor - Is it a wearable device? Is it small or is it something larger? The form factor will determine not only the RF test needs, but also any environmental tests that may be required.
- Device deployment - Where will this device be used? Will it be in oil tanks? Will it be in a fleet management system or inside a temperature controlled van? In addition to form factor, the environment the device is used in will also help determine the type of testing required.
- Country of device usage – What country will your product be used in? Perhaps it will be used in many countries. It is not uncommon for the standards to have slightly different frequencies or requirements from one country to the next.
- Network Operator - Does the local operator have their own set of requirements? What things must be done and what cannot be done?
- Regulatory / Certification test - Many countries have their own terms of compliance and regulatory agencies. Your product must be approved by the local regulatory agency prior to being sold in their area.

4 R&D Testing

Typically, most IOT devices will go through six phases of development (Fig.3). In this white paper we will focus on the R&D and manufacturing phases, while the third paper will focus on the Pre-Compliance and Compliance phase. The deployment and services phases are important, however as we are still in the early days of rolling out IoT applications we will leave that as a potential future paper for this series.

Figure 3. Testing during the IoT device and network life cycle.

The R&D and design validation testing phases are important to ensure that your product is ready, not only for the Compliance phase, but for volume manufacturing as well (Fig.4). Poor performing products can be expensive to recover from in later phases and may also lead to business failure.

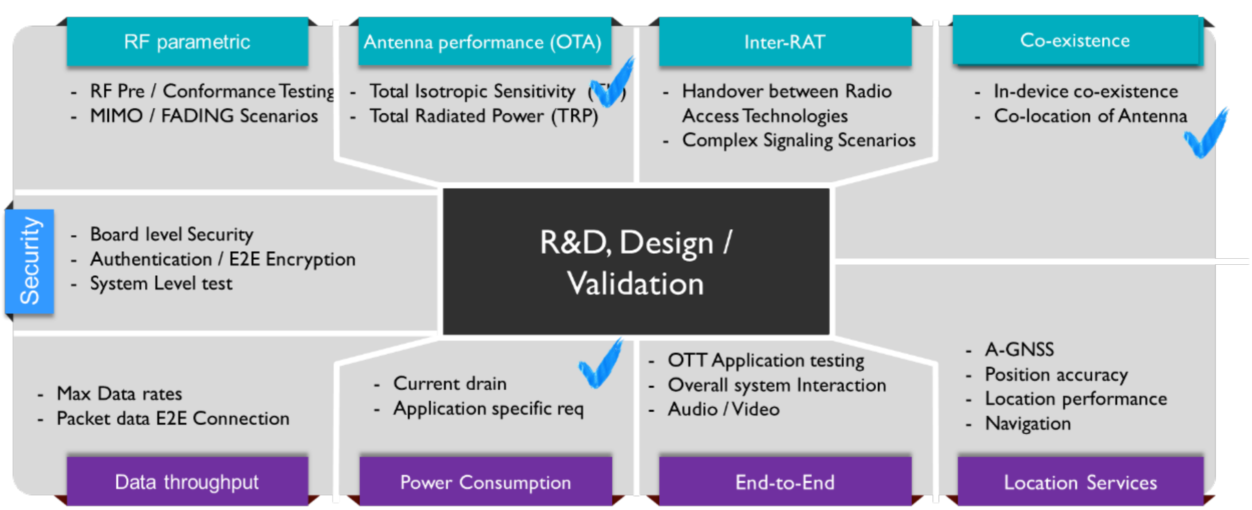


Figure 4. Typical test applications in R&D and Design Validation

RF parametric testing includes testing the RF characteristics of your device as it would perform in the network. For example, is it meeting the Bluetooth or WiFi standards? If your product is going to be operating in a licensed band, like NB-IoT, does it comply with the regulations? Testing needs to include different environmental scenarios, such as vibration and temperature extremes. If your device will be mobile, that may involve unwanted reflections or different power levels.

Verifying antenna performance is probably one of the most critical testing piece. Total Isotropic Sensitivity (TIS) defines the total available receive performance and is typically measured in a special antenna test range. The Total Radiated Power (TRP) determines both your transmission range and receiver sensitivity. We'll discuss antenna testing further in the next section.

For those that have mobility with their devices, you have what are called "Inter-RAT". RAT is Radio Access Technology and Inter-RAT occurs when there is a handover from one network to another. Testing involves creating complex signaling scenarios and evaluating how the device manages the transitions.

Coexistence testing is especially important today as many devices have more than one transmitter, such as Wi-Fi, Bluetooth, LTE, etc. Internal co-existence involves testing compatibility when the transmitting signals are part of the same device. External co-existence is similar, except you are evaluating your device when it is around other devices that have transmitting signals. We'll be discussing this further as well.

For mobile applications, location services are often a key part of the solution. Whether you are using your product for navigation or locating something, this capability needs to be verified. If you are transmitting audio or video, then end-to-end testing verifies the quality of these signals as it passes through your device.

For many IoT devices, battery consumption will be a critical feature. Batteries may need to last 10 years; how do you test that? If there are different applications and activities going on in the device, how are they affecting the current draw?

Data rates will vary widely for different IoT applications. Whatever your data rate, the design will need to be optimized to support the tradeoffs between key features. Finally, security will become even more important as IoT rolls out into many aspects of our lives. It may involve protecting not only our financial assets, but in some cases our personal safety as well.

5 Over-the-Air (OTA) Testing

Over-the-Air or OTA testing involves evaluating the radiated performance of your device wirelessly - in the same manner that it will be used. This is partly due to the highly integrated nature of wireless solutions today. In the past, discrete components or subsystems could be tested with RF cables connected directly to the device. While in some cases this may still be possible, many products now have their antenna integrated directly into their design, it may even be etched onto the RF chipset. In these cases, it is no longer possible to connect an RF cable.

OTA testing standards are being developed to characterize the wireless performance of devices by defining test methodologies and performance metrics. It is meant to be the complement of the conducted measurement requirement. The CTIA organization is defining OTA test requirements for many of the standards (GSM, CDMA, W-CDMA, LTE, A-GPS, ZigBee?). Most IoT designs will use off-the-shelf modules along with some type of enclosure and an antenna. You will need to characterize the wireless performance of your devices as a final product, as testing just the module will not be enough.

OTA testing will require you to characterize your DUT for a range of Angles of Arrival (AoA). These radiated characteristics are captured in a full 3D fashion which will include variations of elevation, azimuth, as well as polarization (Fig. 5).

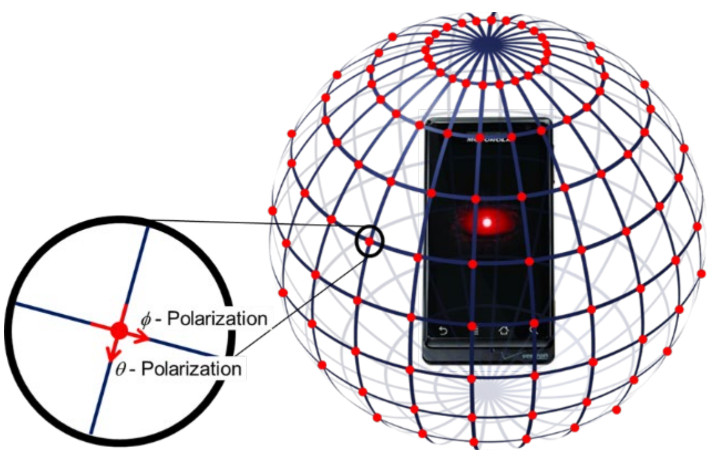
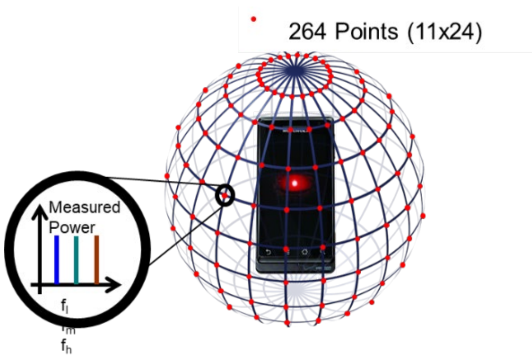
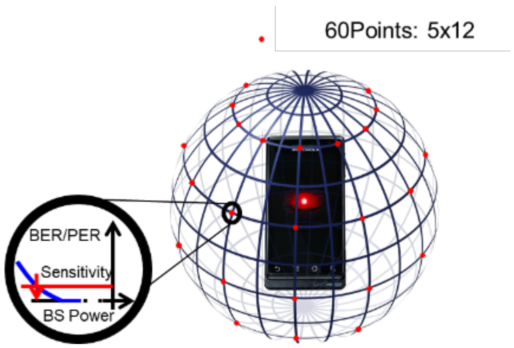


Figure 5. OTA testing requires three-dimensional evaluation.

The Total Radiated Power, or TRP, is defined for every point on this sphere (AZ, EL, Pol) and is measured at intervals of Δφ = Δθ = 15o. For TRP tests, the radiated power (EIRP) as a function of frequency/channel is measured (Fig.6a). The Total Isotropic Sensitivity, or TIS, is defined for every point on this sphere (AZ, EL, Pol) with intervals of Δφ = Δθ = 30o. For these tests, a base station (BS) signal is generated and the received signal quality, e.g., BER, BLER, FER, PER, is measured by the DUT as a function of BS down link power or EIS (Fig.6b).



TRP: Total Radiated Power



TIS: Total Isotropic Sensitivity

Figure 6. TRP and TIS test details

Receiver sensitivity measurements are critical, especially for low power networks (Fig.7). These tests require high-quality signal generation performance to ensure accurate measurements. The use of external attenuators is recommended for levels < -120 dBm, as an attenuator will lower both the signal level and the noise floor level.

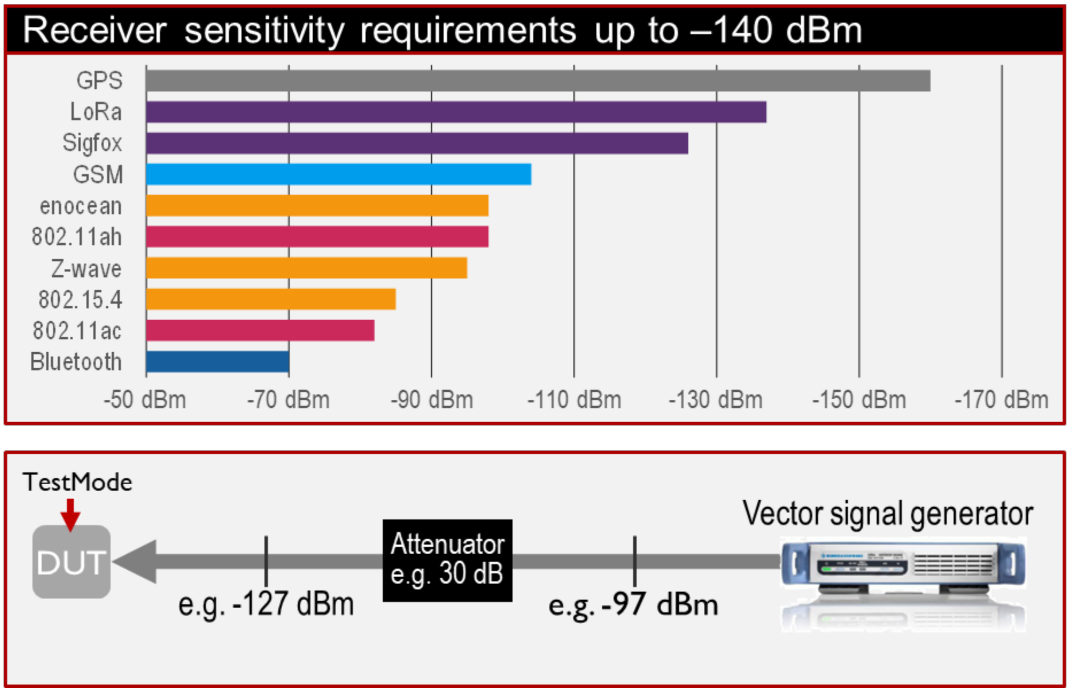


Figure 7. Receiver sensitivity measurements are critical

For the OTA test setup, a metal shielded anechoic chamber or box is used to house the DUT during the test (Fig.8). This shields the DUT from ambient RF signals and creates a low noise environment for measuring receiver sensitivity. The DUT is mounted on a multi-axis gimbal that enables the TRP and TIS measurements.

A base station emulator is used to create test signal environments, such as Bluetooth, WiFi, SigFox, etc. The beauty of the emulator is that you can simulate network scenarios with different power levels, different channels – all in a controlled environment. It is repeatable and can be used to verify performance in challenging situations.

Finally, there's an automation tool that controls the process of the measurements while stepping through the channels or frequencies.

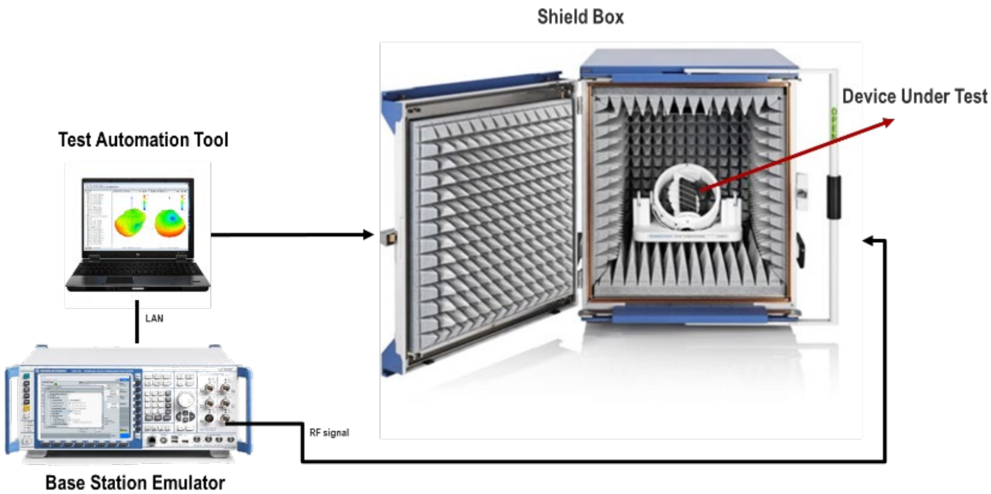
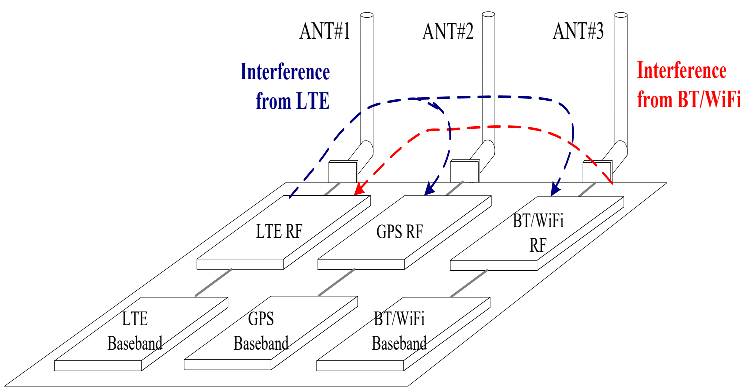


Figure 8. Typical OTA test setup.

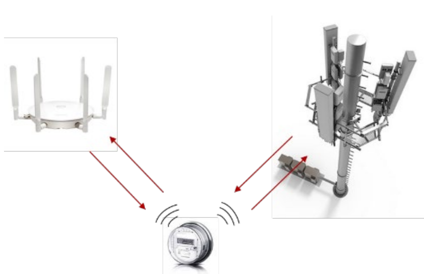
6 Coexistence Testing

Unfortunately, it may not be as simple as adding IoT technology into your product. You must ensure that when your device is operational it will not be impacted by other radiators, as well as not impact the performance of external devices within your transmission range. In the third paper of this series we discuss the certification process that will be required before you may sell your product in the marketplace. Verifying your design during the R&D phase will reduce time to market and lower your overall product development costs.

Wireless coexistence can be defined as the ability of multiple heterogeneous wireless systems to share the same or adjacent frequency spectrum without undue interaction or interference effecting transmission or reception of signals and data. In this paper we discuss both in-device and external co-existence (Fig.9). In-device co-existence ensures that there is no interference from components or hardware that is internal or within the device itself. External co-existence makes sure that the device's performance is not degraded or interfering with external signal sources.



In-Device Co-existence



External Co-existence

Figure 9. Coexistence Testing

With all the different IoT technologies being developed in the unlicensed band this will become an important issue. In addition, several of these technologies operate near licensed bands such as LTE. Fig.10 shows an example of the different technologies planned at a few frequencies.

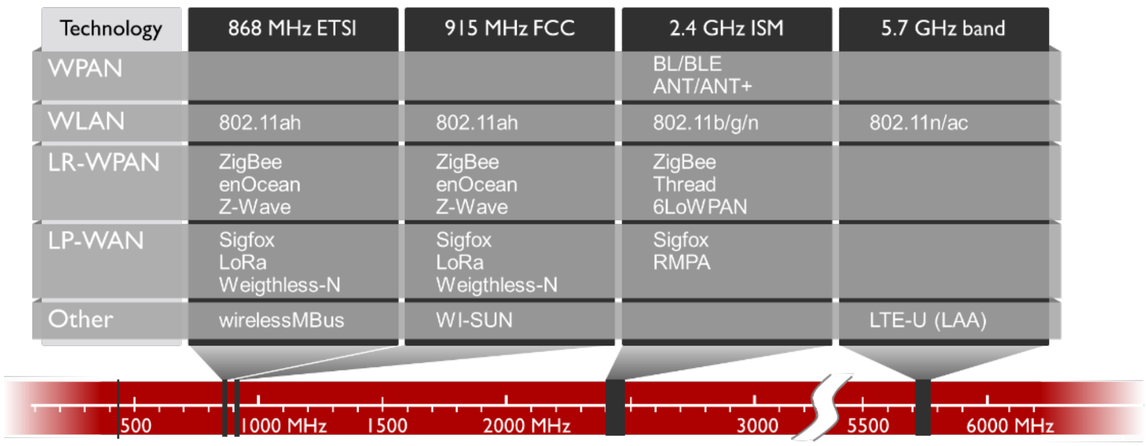


Figure 10. Several wireless technologies operate in the same spectrum bands.

For example, Fig.11 shows measurements on a WiFi device which is operating at 802.11n channel 13, at 2472 MHz. This device also has an LTE transmitter operating in band 7 at 2510 MHz with a 20 MHz signal bandwidth. The measured results indicate the sideband is bleeding over quite close to the WiFi channel 13.

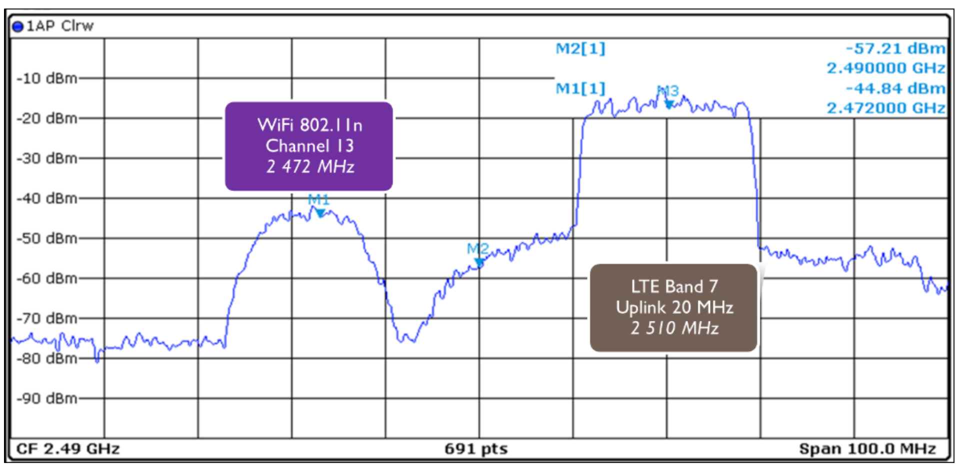
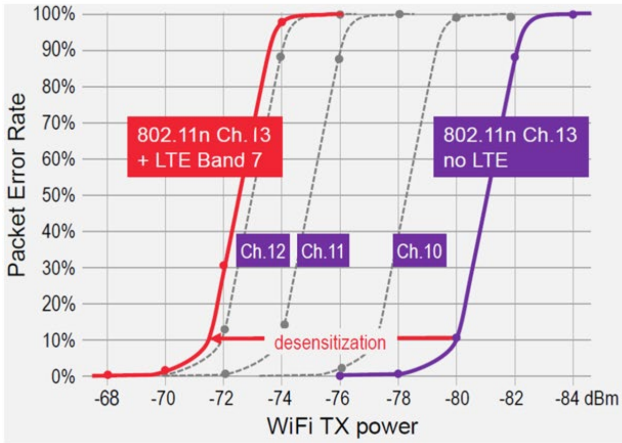


Figure 11. LTE/WiFi In-Device Coexistence: Spectrum View.

These results suggest there could be an in-device coexistence problem. Fig.12 shows the same Wi-Fi signal, without the LTE transmission, in purple. The WiFi sensitivity is around -80 dBm before there is a rise in the packet error rate. The result in red shows the WiFi Packet Error Rate once the LTE signal is turned on. The results show that this Wi-Fi device is very susceptible to desensitization by the LTE signal, which will result in a significant impact to its WiFi performance.



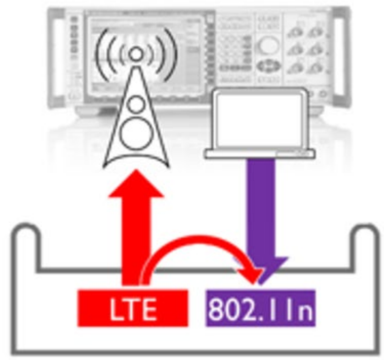


Figure 12. Testing for co-existence problems should begin during development.

The test setup for co-existence testing is basically the same OTA test setup, but with a few additional antennas (Fig.13). The added antenna is used to expose the DUT to the signals that are needed to verify its capability to co-exist. The base station emulator can be used to generate these signals to verify performance. Testing in this environment ensures repeatable results and gives control over power levels etc. to verify functionality.

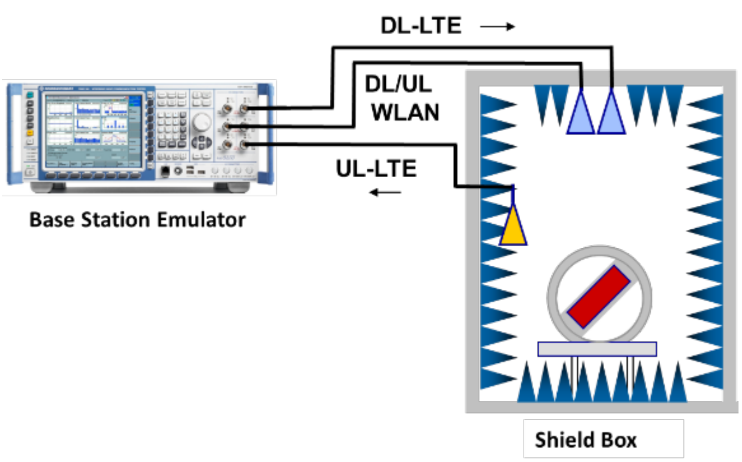


Figure 13. Typical test setup for co-existence testing.

7 Power Consumption

There are many reasons to test power consumption on your device. For many products, battery life is becoming a key marketing feature. For example, do you want a smart watch that lasts for 8 hours or 8 days? Another example may be a very low data rate, low power application that can advertise a 10-year battery life.

In addition to the positive marketing of power consumption, there is also a negative side regarding safety concerns. The news is very quick to call out products that catch fire, injure people or damage property. The impact of these failures has literally impacted the bottom line of companies by millions and even billions of dollars. Not to mention the long-term damage to their reputations.

How do you verify battery performance? First, you need to understand how much power is being consumed by the different activities in your device. For cost reasons, IoT devices often use an embedded design approach. The various functional cores are integrated on chip and module level. With the integration of wireless radios, the complexity of embedded designs increases significantly. A typical IOT device has different components, such as a wireless chip, an A/D converter, memory, power management, processor, and sensors (Fig.14). Each of components are drawing current or power from the battery, understanding how much is key.

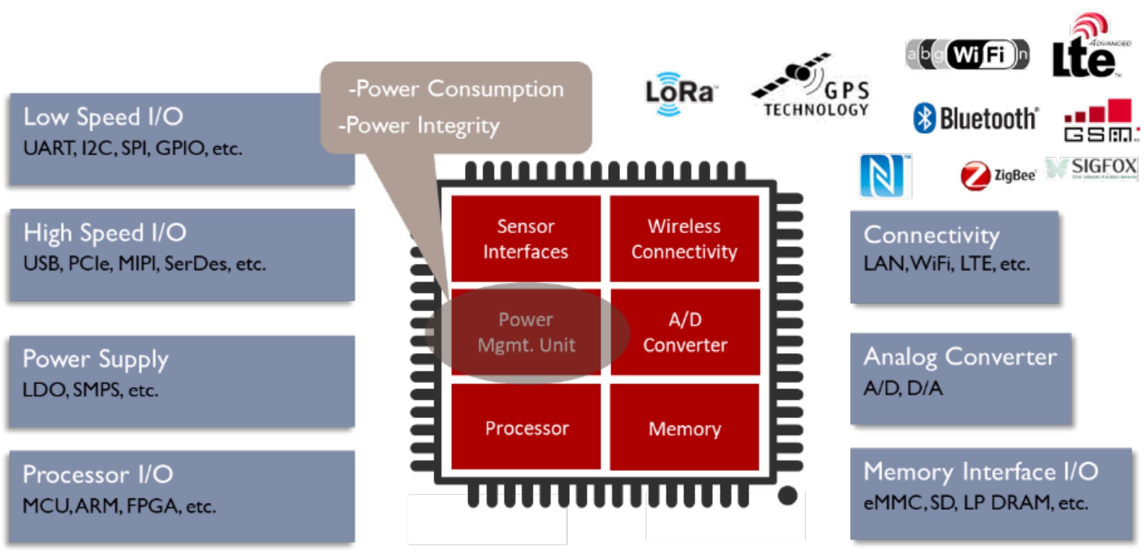


Figure 14. Key components and interfaces for embedded wireless devices.

Fig.15 shows an example test setup for power consumption testing. This solution addresses these key challenges:

- Measure very low and transient current, voltage and power simultaneously
- Evaluate power consumption of each key interface for proper management independently and simultaneously
- Simulate real life use cases with wireless network
- Synchronize signaling activities with power measurement

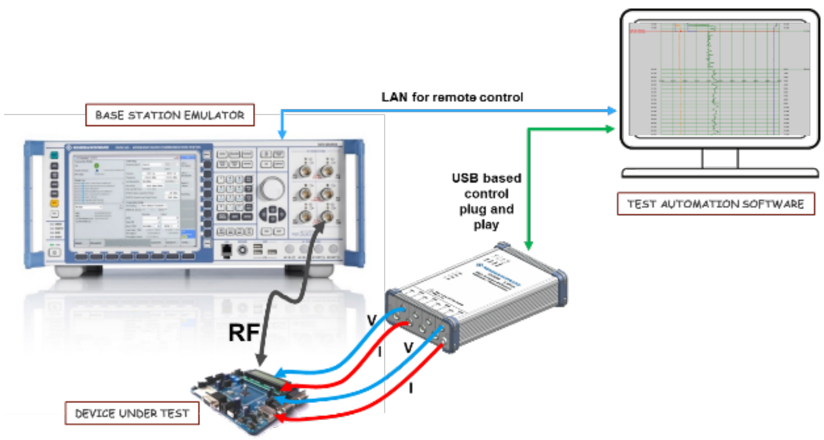


Figure 15. Example test setup for power consumption test.

8 Manufacturing Test

The focus of manufacturing test is to build on the work done in the previous phases (R&D, Validation, Compliance). The key point is to verify parts are put together properly and end of line final tests are done before the product is shipped to the end user. The goal is to get as many devices through the production line as possible while suppressing cost of test. Testing is streamlined to the bare minimum with a strong focus on cost and speed of test. Fig.16 highlights some of the common ways of improving test time.

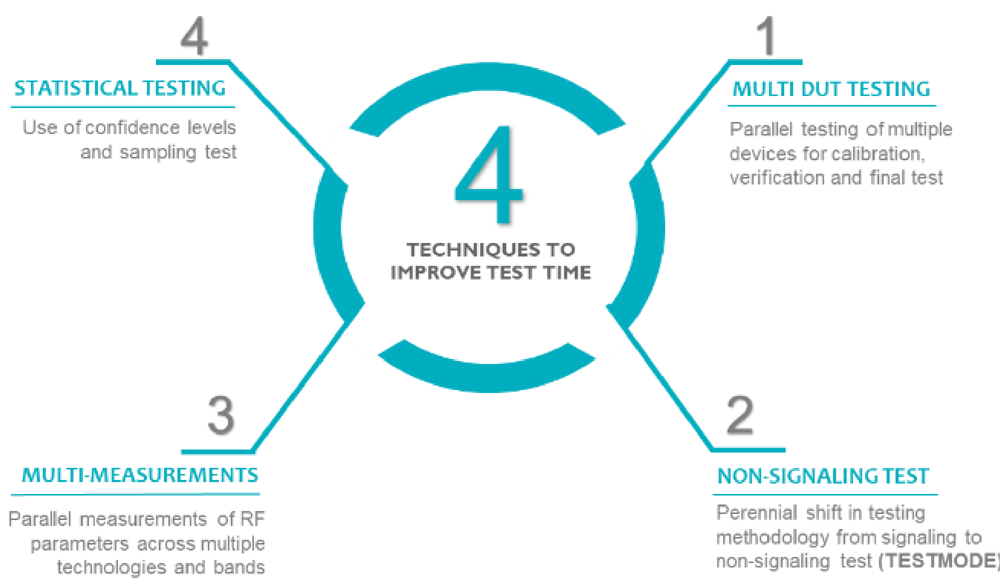


Figure 16. In manufacturing: Test Time = Money.

The manufacturing process begins with assembling the various devices and PCB boards (Fig.17). Prior to the start of a production test run, the test stations are calibrated, and the performance is verified against known standards.

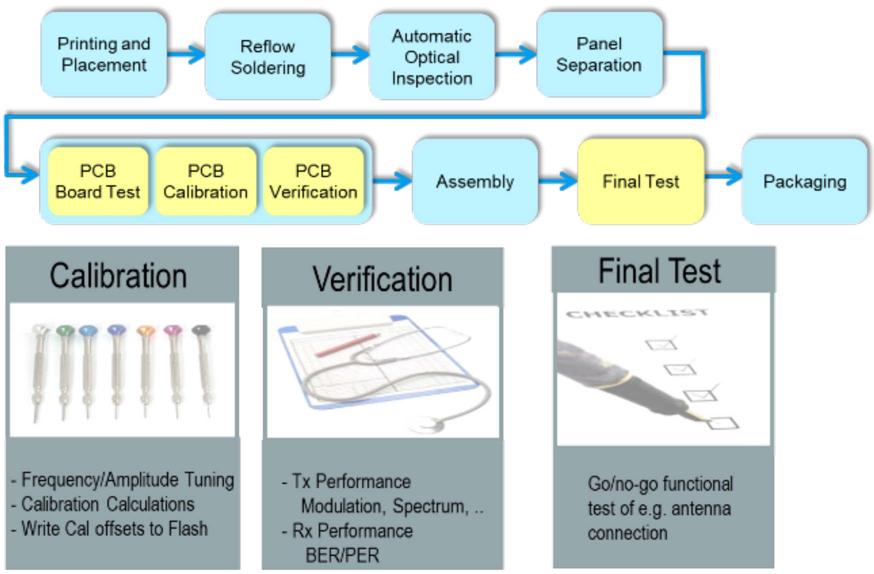


Figure 17. Typical manufacturing process.

Fig.18 shows an example manufacturing test set up. This is now a very streamlined test solution with multiple RF ports. In this example, four DUTs are tested in parallel. The entire test process is automated via a PC controller to both increase throughput and minimize test error. The results typically provide a pass/fail result.

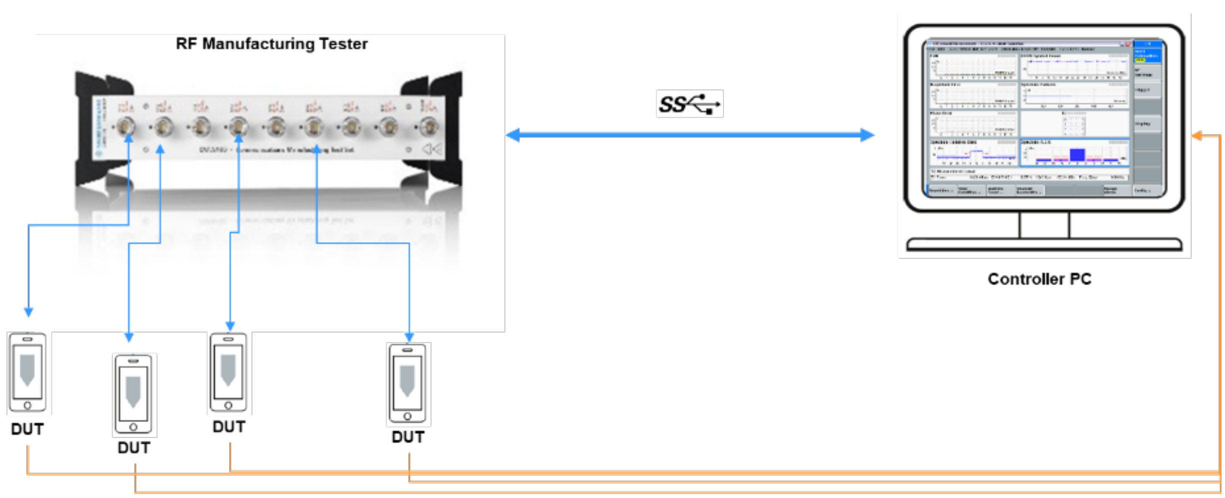


Figure 18. Example manufacturing test setup.

9 Test Solutions

Testing may seem to be very complicated, time-consuming and costly, especially for players entering the wireless communications arena for the first time Fig.19. As an expert in wireless communications, Rohde & Schwarz will help you understand the critical testing requirements for your IoT device and can provide you with the proper test solutions to validate your device from the early R&D phase all the way through to manufacturing.

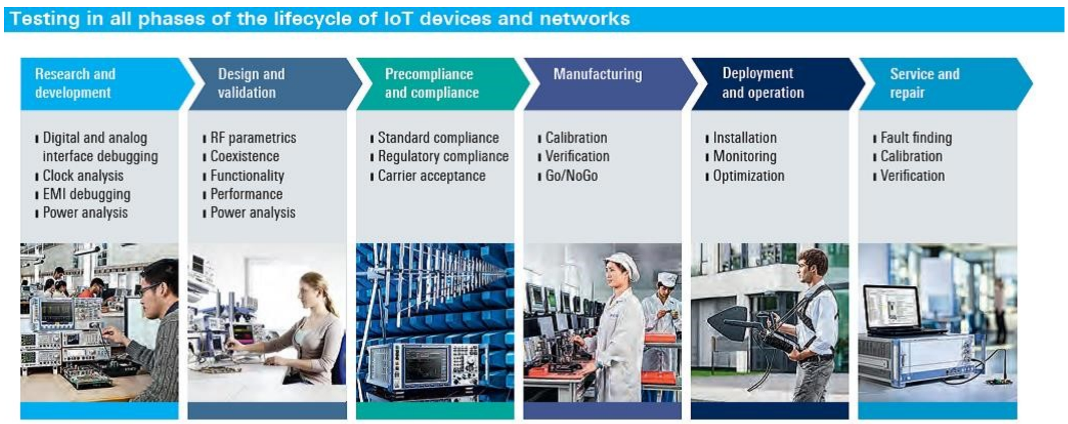


Figure 19: Rohde and Schwarz supports testing throughout the entire product lifecycle.

Test and measurement solutions from Rohde & Schwarz cover all major cellular and noncellular technologies. Our comprehensive product portfolio offers the right solution for your IoT device – from the first product idea through the full device lifecycle. The following are examples of our many solutions for IoT product development:

Smart debugging of embedded designs.

Troubleshoot your IoT device at the system level through time-correlated analysis of analog components, digital interfaces, protocol-based buses, power supplies and RF signals with a digital oscilloscope.

End-to-end application testing.

Explore the functionality and performance of your IoT device from the end-to-end perspective by analyzing data and signaling traffic, quality of service and battery consumption under realistic network conditions.

Wireless test setups for R&D and manufacturing.

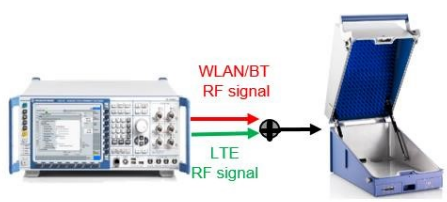
Test the radio interface of various wireless standards over the air with a compact test system consisting of a signal generator, spectrum analyzer and RF shielded box.

Conformance testing.

Test the EMC conformance of your IoT devices operating in the 2.4 GHz and 5 GHz ISM bands such as Bluetooth® and Wi-Fi.

Antenna Performance testing.

Verify proper functionality for IoT device transmitter and receiver within specification by performing TRP/TIP measurements in an Over-the-Air test environment.



Co-Existence testing.

Analyze receiver sensitivity by testing the device under conditions where multiple technologies are communicating at the same time. Eg. WLAN (or BT) and LTE.

10 Summary

The IoT space is growing at a rapid pace and covers many different types of applications. The device requirements for each application vary greatly and it can be challenging to address these requirements. While IoT devices may be very low cost, their main value-add relies on 24/7 access to real-time sensor data.

For these new technologies to succeed the designs must be optimized and debugged during the R&D phases, and then verified prior to manufacturing release. Proper testing of your design ensures highly reliable operation under all relevant conditions and needs to be budgeted into your design process.

In the next paper of our IoT series, we will discuss the certification requirements and provide an overview of the agencies that define the process.

Rohde & Schwarz

The Rohde & Schwarz electronics group offers innovative solutions in the following business fields: test and measurement, broadcast and media, secure communications, cybersecurity, radiomonitoring and radiolocation. Founded more than 80 years ago, this independent company has an extensive sales and service network and is present in more than 70 countries.

The electronics group is among the world market leaders in its established business fields. The company is headquartered in Munich, Germany. It also has regional headquarters in Singapore and Columbia, Maryland, USA, to manage its operations in these regions.

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Sustainable product design

- Environmental compatibility and eco-footprint
- Energy efficiency and low emissions
- Longevity and optimized total cost of ownership

Certified Quality Management ISO 9001

Certified Environmental Management ISO 14001

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