GETTING STARTED WITH WIRELESS COEXISTENCE TESTING

On the critical path to ensuring device performance

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ROHDE&SCHWARZ

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CONTENTS

WHY WE NEED TO PERFORM COEXISTENCE TESTING

With over 20 billion wireless devices deployed, avoiding interference between devices through frequency management is a difficult but important issue. Many sensors need to transmit and receive data and the time interval between transmissions varies depending on the application. Most wireless sensors function independently without any synchronization between them. Depending on their location, sensors can be exposed to many different RF environments that change constantly as a function of the mobility and other RF devices at the current location. In case of a failure during data transfer, the resultant data loss may pose a threat to user safety with some applications. Thus, it is critical to implement stringent wireless performance testing for products that support multiple combined radio modules.

Wireless coexistence testing helps understand the behavior of devices in different RF environments and ensure that the receiver performance of connected devices fulfills the intended use case.

WHERE ARE CONNECTED SENSORS LOCATED?

Smart home

- Domestic appliances
- Smart lighting
- Smart doorlocks
- Smart meters

Aerospace

- Drones
- ATC equipment
- Aircraft onboard Wi-Fi connectivity
- Satellite FSS
- Navigation systems

Smart city

- Smart parking
- Street lighting
- Trashcans
- Public hotspots
- Payment devices

Smart transportation

- Fleet management
- Car-to-everything communications
- In-vehicle connectivity
- Payment devices

Medical

- Remote surgery
- Wireless medical implants
- External control devices
- Patient health tracker

Others

- Manufacturing and industrial IoT
- Smart fitness
- Sport tracker

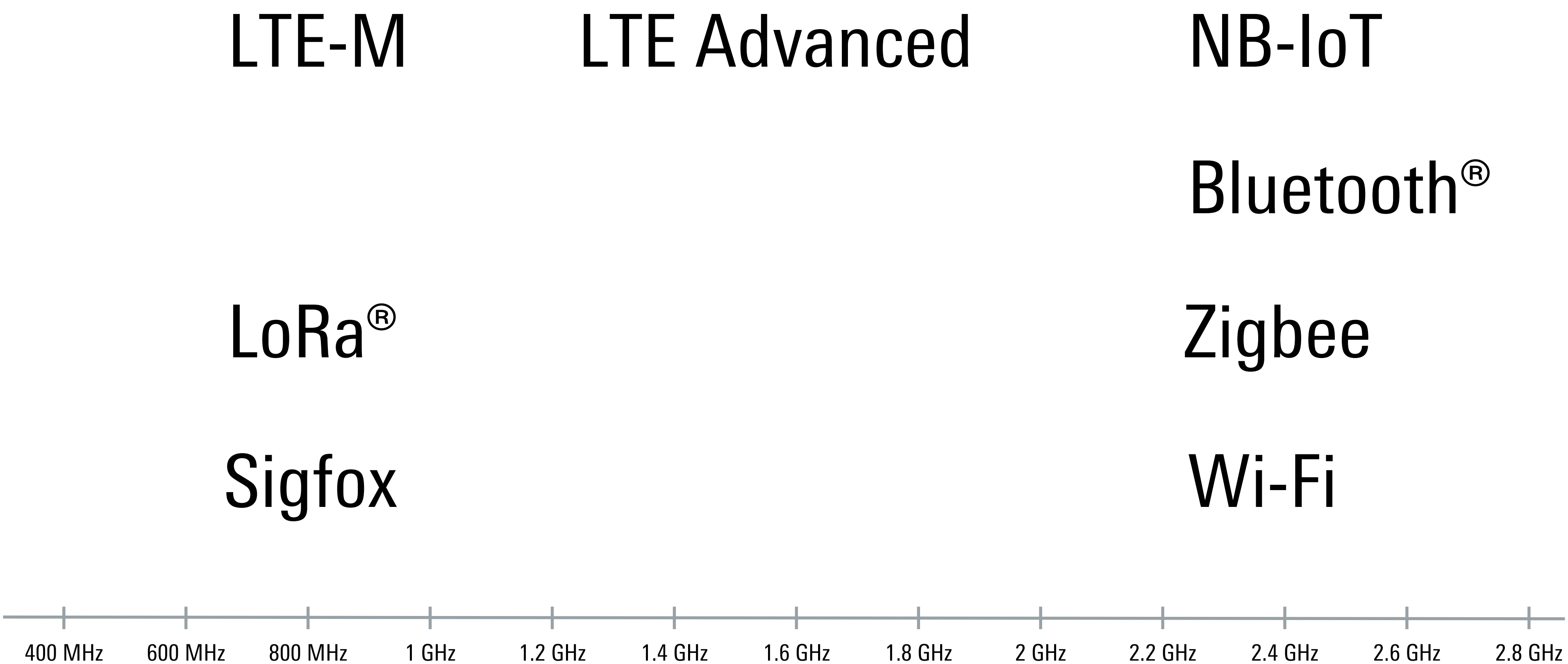
WIRELESS STANDARDS, FREQUENCIES AND REGIONS

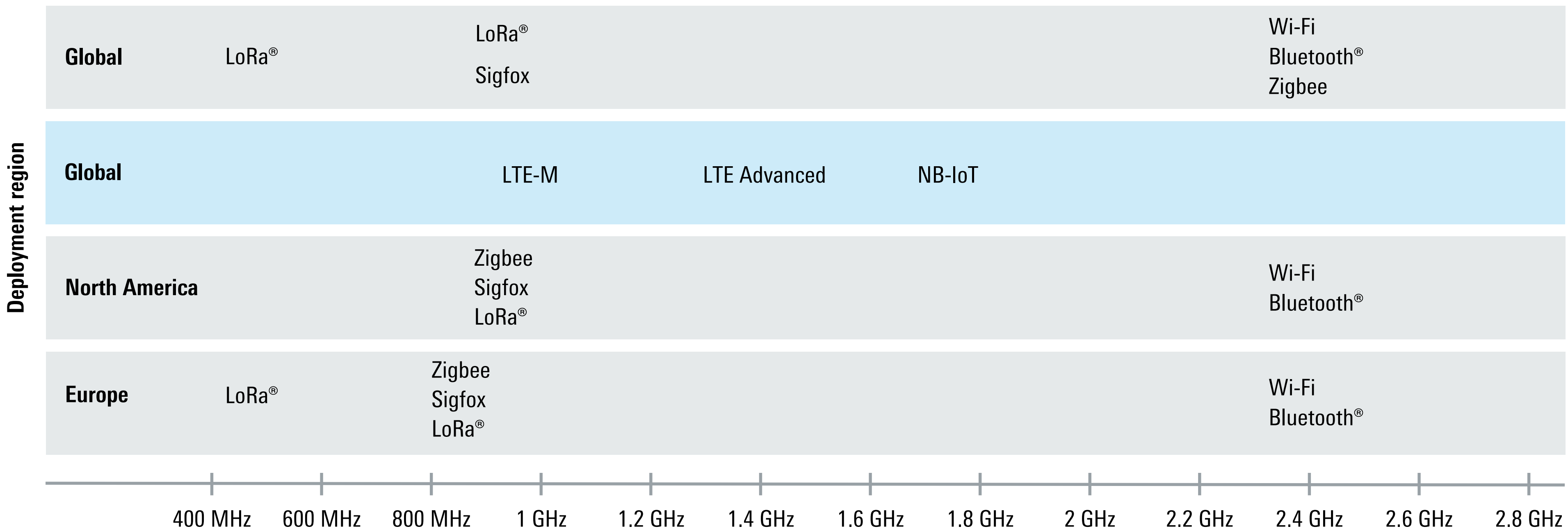
The most popular technologies for connected devices are unlicensed wireless communications standards such as Zigbee, Wi-Fi and Bluetooth®. Devices that require longer battery life (up to years) but very low data rates use LPWAN technologies such as LoRa®, Sigfox and Google Thread. IoT applications where mobility is an important aspect most commonly use some version of LTE.

Since practically all of these technologies use different frequency bands depending on the region, the question of where a product will be sold (e.g. APAC, Europe, North America) is very important when planning and performing wireless coexistence testing.

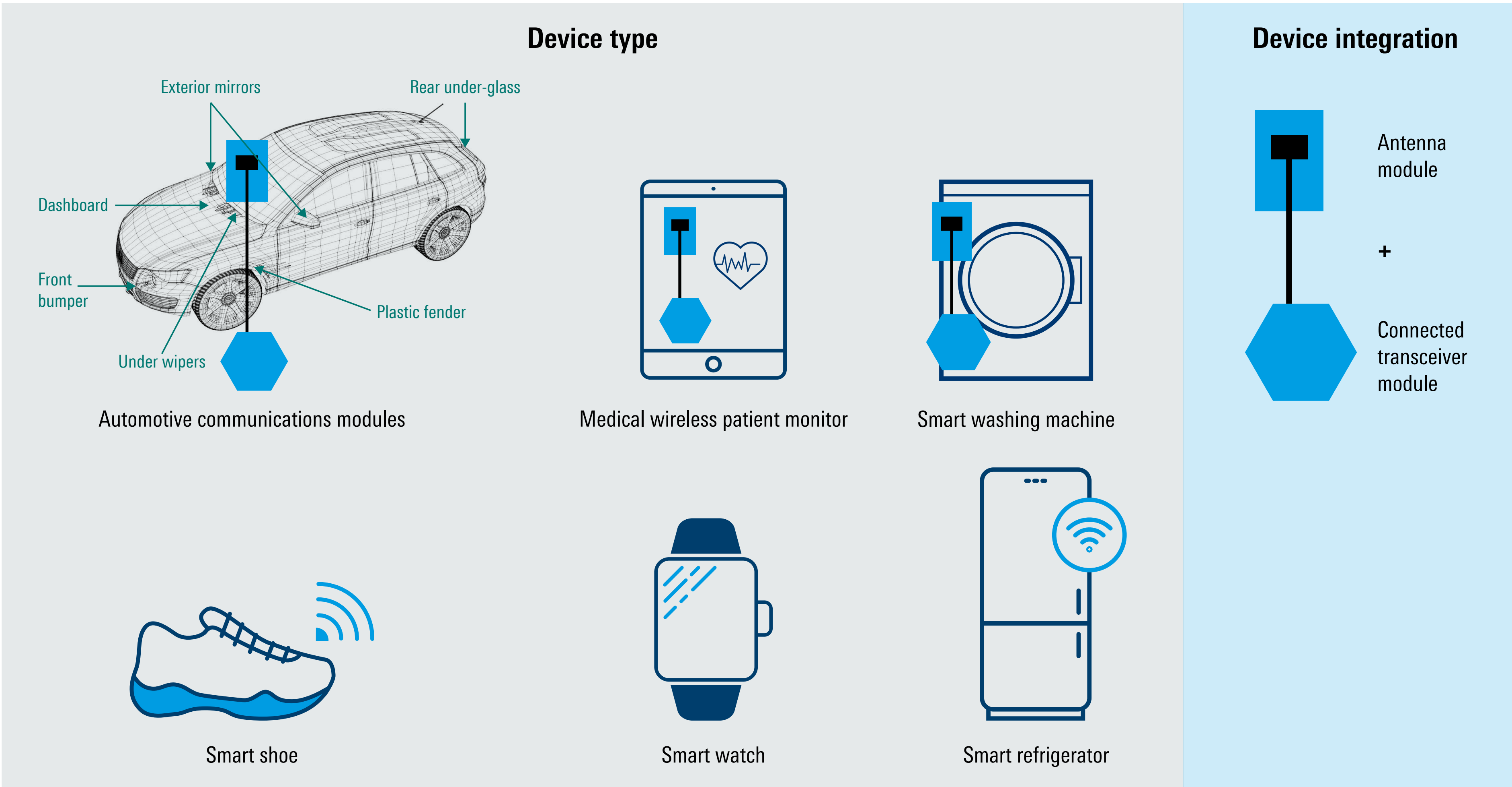
Users can also potentially carry smaller products to other regions than the one the product is intended for. The product should therefore take into account the applicable regulations in those regions, too.

WIRELESS STANDARDS, FREQUENCIES AND REGIONS




Deployment region
Global
LoRa®
LoRa®
Sigfox
Wi-Fi
Bluetooth®
Zigbee
Global
LTE-M
LTE Advanced
NB-IoT
North America
Zigbee
Sigfox
LoRa®
Wi-Fi
Bluetooth®
Europe
LoRa®
Zigbee
Sigfox
LoRa®
Wi-Fi
Bluetooth®
400 MHz
600 MHz
800 MHz
1 GHz
1.2 GHz
1.4 GHz
1.6 GHz
1.8 GHz
2 GHz
2.2 GHz
2.4 GHz
2.6 GHz
2.8 GHz

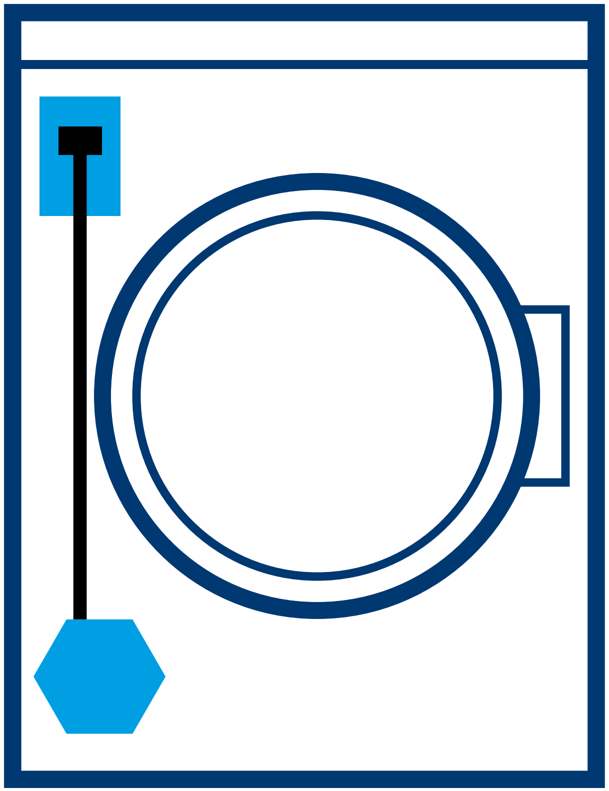
WHAT DO ALL CONNECTED PRODUCTS HAVE IN COMMON?



Every connected product has an antenna module that is connected to a transceiver module to provide the basic functions for bidirectional wireless communications. A potential problem in any device with a conductive casing or frame is related to coupling between the antenna and the conductive material. This can trigger a change in the RF properties, thereby impacting the effectiveness of the antenna. Especially in products from companies that are less familiar with wireless communications, this issue might not have been adequately addressed.

PROXIMITY WIRELESS COEXISTENCE

Device integration



Connected sensor and antenna module

Connected products are almost inevitably a combination of components sourced from different suppliers. Depending on the product design and materials used, they may pick up RF interference signals from other devices in the vicinity transmitting on the same frequency or adjacent channels. For example, in a domestic environment, possible sources of interference include:

- ▶ Smartphones
- ▶ Smartwatches
- ▶ Bluetooth® headphones
- ▶ Robot vacuum cleaners
- ▶ Smart lights
- ▶ Any RF device

The device manufacturer is responsible for compliance certification and testing.

PROXIMITY RF COEXISTENCE TESTING

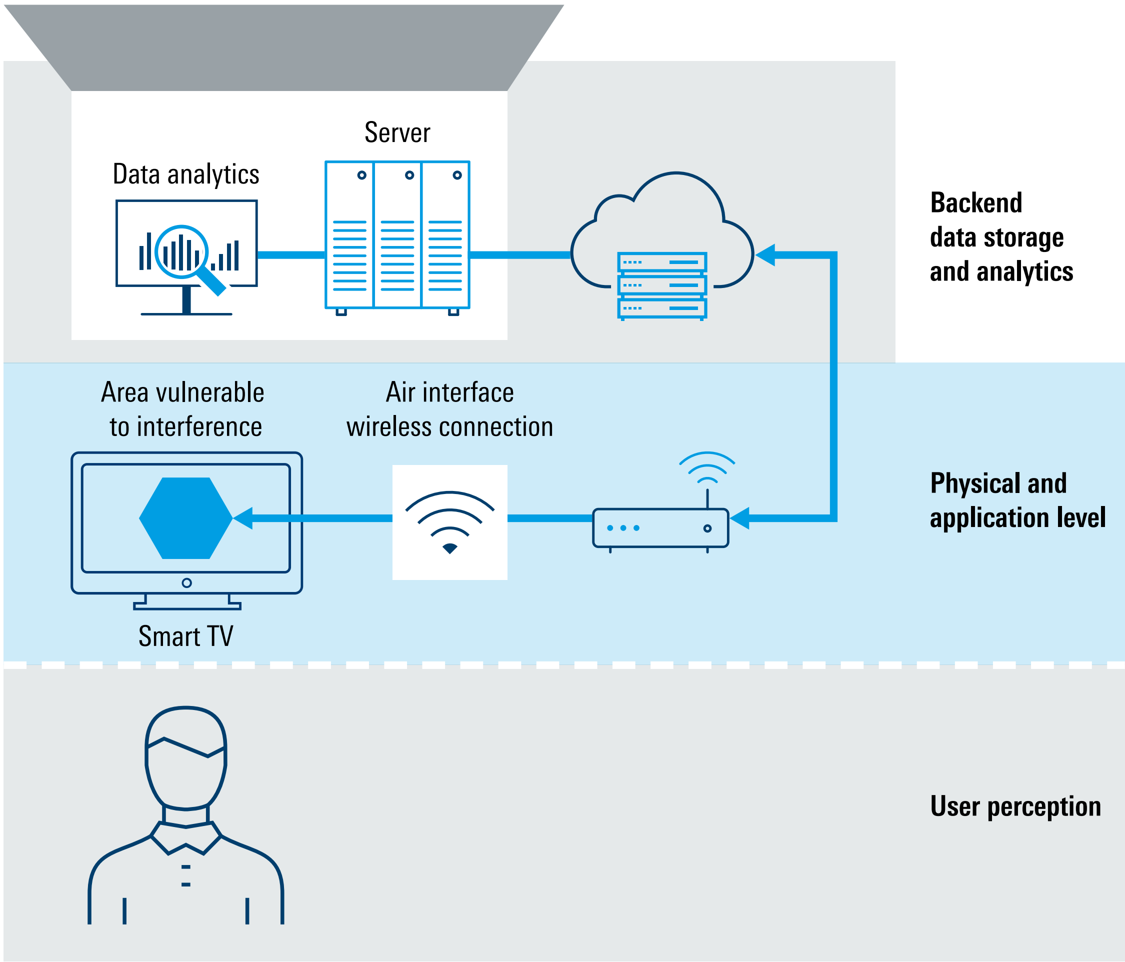
Integration of transceiver and antenna modules can also be a source of coexistence problems. Connected product manufacturers typically integrate transceiver and antenna modules from a variety of third-party suppliers. The two completely separate modules are independently certified by their suppliers. While transceiver modules are typically tested using a conducted in-device coexistence test methodology, this is not necessarily the case for antenna modules.

Once the two components are connected and integrated into the final product, the separate certification that was performed for each component is no longer valid for the new product. For example, the antenna module can exhibit coupling with the body of the product, thereby boosting the reception of interference from nearby devices transmitting on adjacent frequencies.

In order to ensure proper performance under real-world conditions, proximity RF coexistence testing must be performed on the product in its final state using over-the-air (radiated) signals.

INTENDED USE AND CONSEQUENCE: SMART TV

Netflix



In this case, the smart television is connected to the internet via WLAN.

When the user wants to watch a program by streaming data from Netflix, for example, the TV fetches data from the Netflix server.

If there is an interference source close to the TV, this can disrupt the IP packet data reception from the server, causing a degradation in performance quality.

Consequence: Delayed or incomplete data transfer, resulting in degraded user experience.

WIDELY VARYING DEVICE RF ENVIRONMENT

EXAMPLE: SECURITY CAMERAS

IP based smart security cameras are commonly used in a variety of commercial and private establishments with different interference densities. Major variable factors include the connected devices that people carry with them as well as the presence of certain fixed interference sources. A given smart security camera will experience very different RF environments depending on where it is deployed.

CREATING A TEST PLAN

The creation of test plans represents a vital part of wireless coexistence testing. A good plan structures the whole test process and helps identify the relevant test points and frequencies that need to be addressed quickly and effectively. It also helps establish a baseline for acceptable wireless performance.

A test plan is divided into multiple modules and sub-modules. The key modules are risk assessment, understanding the intended use of the product, determination of product performance, definition of physical and application layer key performance indicators (KPI), RF test environment reproduction, testing and documentation.

CREATING A TEST PLAN FOR PERFORMING COEXISTENCE TESTING

TEST PLAN

- Risk assessment
  - Type of device (classification based on potential harm to user health in case of failure)
  - Supported technologies and freuquencies
  - Wanted and interference signals
- Intended use and sources for communications disruption
  - Interference signal
  - Antenna radiation pattern
- Determination of functional performance and worst-case scenario definition
  - Physical layer KPIs (throughput, PER, BLER) or application layer KPIs (audio and video quality)
- RF environment reproduction
- Testing under worst-case conditions
- Report and documentation

TEST PLANS

MODULE 1: RISK ASSESSMENT

IoT DEVICES

Negligible risk	Minor risk	Moderate risk	Major risk
Tier 4	Tier 3	Tier 2	Tier 1
▶ Washing machine ▶ Refrigerator ▶ Smart meter	▶ Navigation device ▶ Smart light ▶ Robot vacuum ▶ Automotive infotainment	▶ Cooking stove ▶ Coffee maker ▶ Microwave	▶ Medical implant ▶ Remote surgery ▶ Automotive eCall ▶ Pet tracker ▶ Baby monitor

Example of four-level risk classification of wireless devices based on ISO 14971 (which has five levels). Device classification by author.

TECHNOLOGIES SUPPORTED

- Bluetooth®
- Wi-Fi
- LTE
- LoRa®
- Sigfox

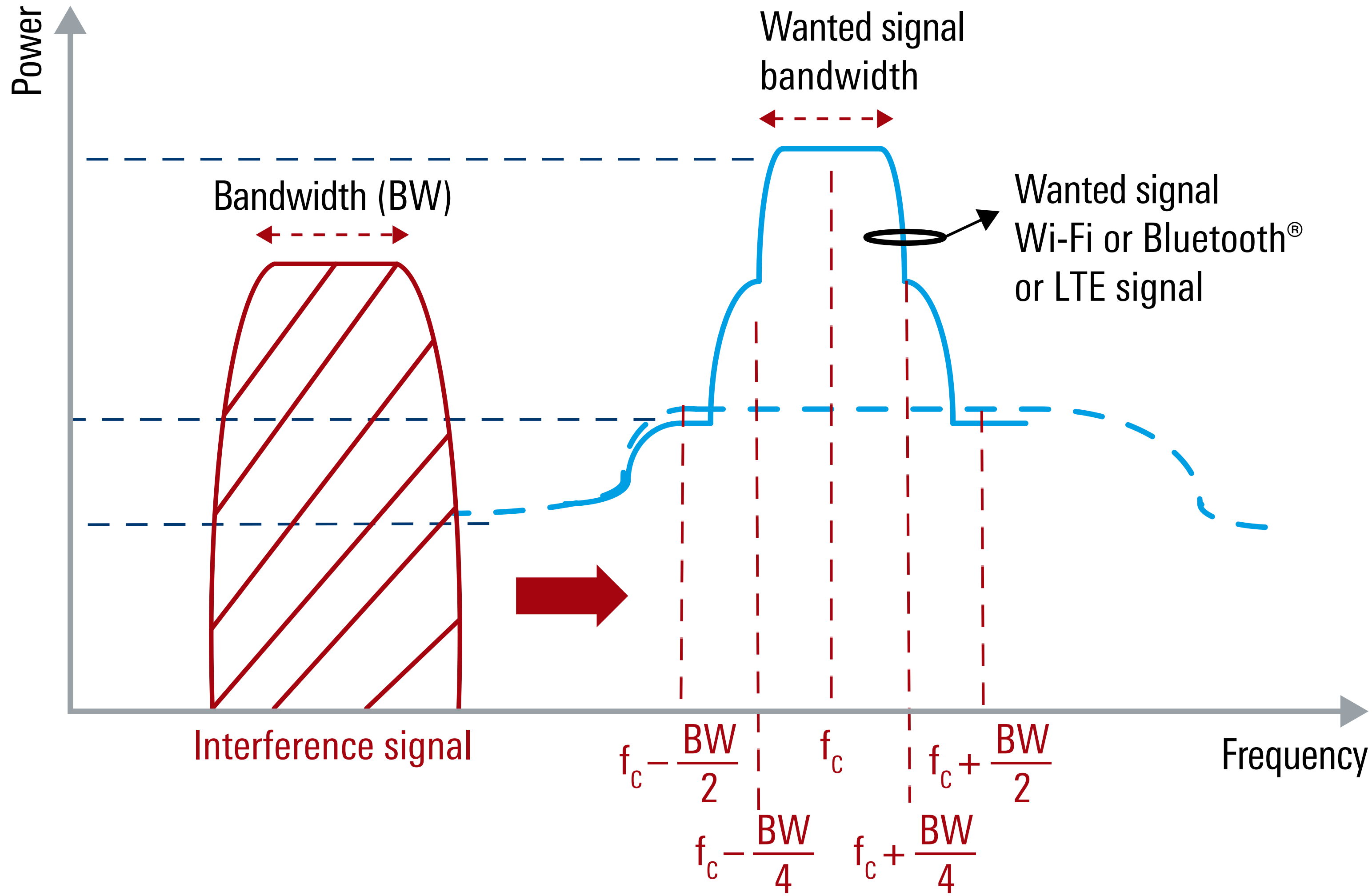
The example is based on a product supporting the following technologies and bands in order to help understand the methodology.

FREQUENCIES

	LTE800	LTE2600	WLAN	Bluetooth®
LTE800	Red	Green	Green	Green
LTE2600	Green	Red	Orange	Orange
WLAN	Green	Orange	Red	Red
Bluetooth®	Green	Orange	Red	Red

- Green: Not critical; can be ignored
- Orange: Adjacent channels; needs to be tested
- Red: Overlapping frequency; needs to be tested

WANTED SIGNAL AND INTERFERENCE SIGNAL



RISK ASSESSMENT

TYPE OF DEVICE

Devices are classified and then listed according to their risk tier categorization. The tiers are color-coded and organized by increasing risk if a failure to operate caused by a wireless coexistence issue would result in injury to the user of the product. Tier 4 is for products where the potential impact of an injury is almost negligible, while Tier 1 is for products with the potential for injuries that could be fatal to the user.

Tier 3 and tier 4 products are tested less stringently than tier 1 and tier 2 products. The main difference in the test setups for these tiers lies in the number of interference sources used during the tests.

INTERFERENCE SIGNAL

Once the products have been classified and the test setup has been selected, the communications technologies and frequencies that are supported are determined and the interference signals and their spectral positions are defined for the test. There are multiple approaches for selecting the interference signals. The first involves a risk assessment matrix. The second requires choosing in-band and out-of-band positions for the interference signals and varying the properties of the interference signals (e.g. bandwidth, power level, spectral position). Interference signals may also be recorded from the real world and played back in the lab while performing the measurements.

MODULE 2: INTENDED CASE OF DEVICE UNDER TEST

- Define use case for product (examples)
  - Medical implant (pacemaker, drug delivery system): in hospital, at care home or on the road
  - Home appliance (washing machine, coffee maker): locations around the house or in offices
  - Car infotainment: on the road, at charging stations, at the factory, in a garage or mechanic's workshop
- Interference signal
  - Types as wideband modulated, bandwidth and in-band or out-of-band
  - Quantity: 1, 2, 3 or more
- Antenna radiation pattern
  - Antenna pattern after integration changes
  - Angle of higher coupling

INTENDED USE CASE DETERMINATION

DIFFERENT PRODUCTS ARE EXPOSED TO DIFFERENT RF ENVIRONMENT TYPES ON A DAILY BASIS BY THEIR USERS.

Mobile wireless medical devices are worn or carried by their users at hospitals and medical practices, at their homes, in supermarkets, at care homes and in other everyday environments. Home appliances are normally limited to the kitchen or other areas inside the home with more restricted RF environments. Cars, in contrast, are subject to highly variable RF environments as they drive through urban and rural areas or visit filling stations or electric vehicle charging stations. Understanding the intended area of use will help reproduce a comparable EM environment in the lab for each of the products being tested.

IN THIS MODULE, THE NUMBER OF INTERFERENCE SIGNALS USED FOR THE MEASUREMENT IS SELECTED.

Integration of an external antenna into the device changes the electrical properties of the integrated product. A new 3D radiation pattern measurement needs to be performed at this stage. The result of this measurement will help to understand the areas of higher antenna coupling for the device itself.

MODULE 3: FUNCTIONAL PERFORMANCE AND WORST CASE DETERMINATION

- Data based wireless technology KPI on physical layer
  - Data throughput, PER, BLER
  - WLAN: PER 10%, LTE: 2% PER data throughput: 21 Mbit/s or 84 Mbit/s
  - Received modulation signal quality: error vector magnitude (EVM)
- Application level KPI (data rate reduced; audiovisual experience is not acceptable)
  - Video quality (frame freeze, dead pixels)
  - Audio quality (upper frequency or lower frequency elements missing)
- Worst-case scenario
  - Cell edge condition
  - Multiple interference sources

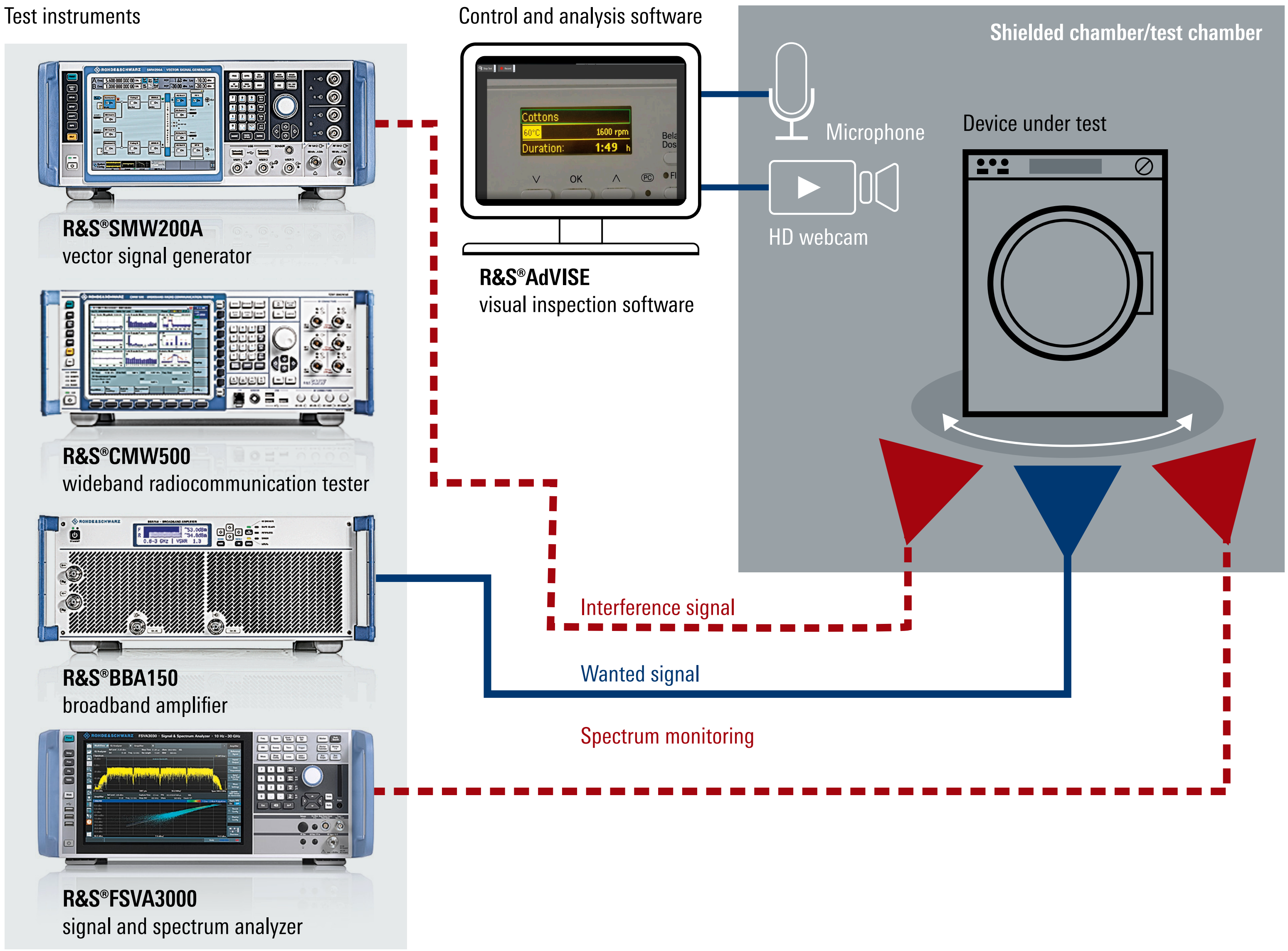
FUNCTIONAL PERFORMANCE AND WORST-CASE SCENARIO DETERMINATION

First, the physical layer and application layer KPIs are documented for the ideal case without the presence of any interference. For most communications links, the physical layer KPIs include the packet error rate (PER), bit error rate (BER) and data throughput. Since nowadays it is very common to have integrated display and speaker systems in certain products, the application layer KPIs include video quality information such as the frame rate, motion freeze and frame freeze as well as audio quality parameters such as the audio frequency response.

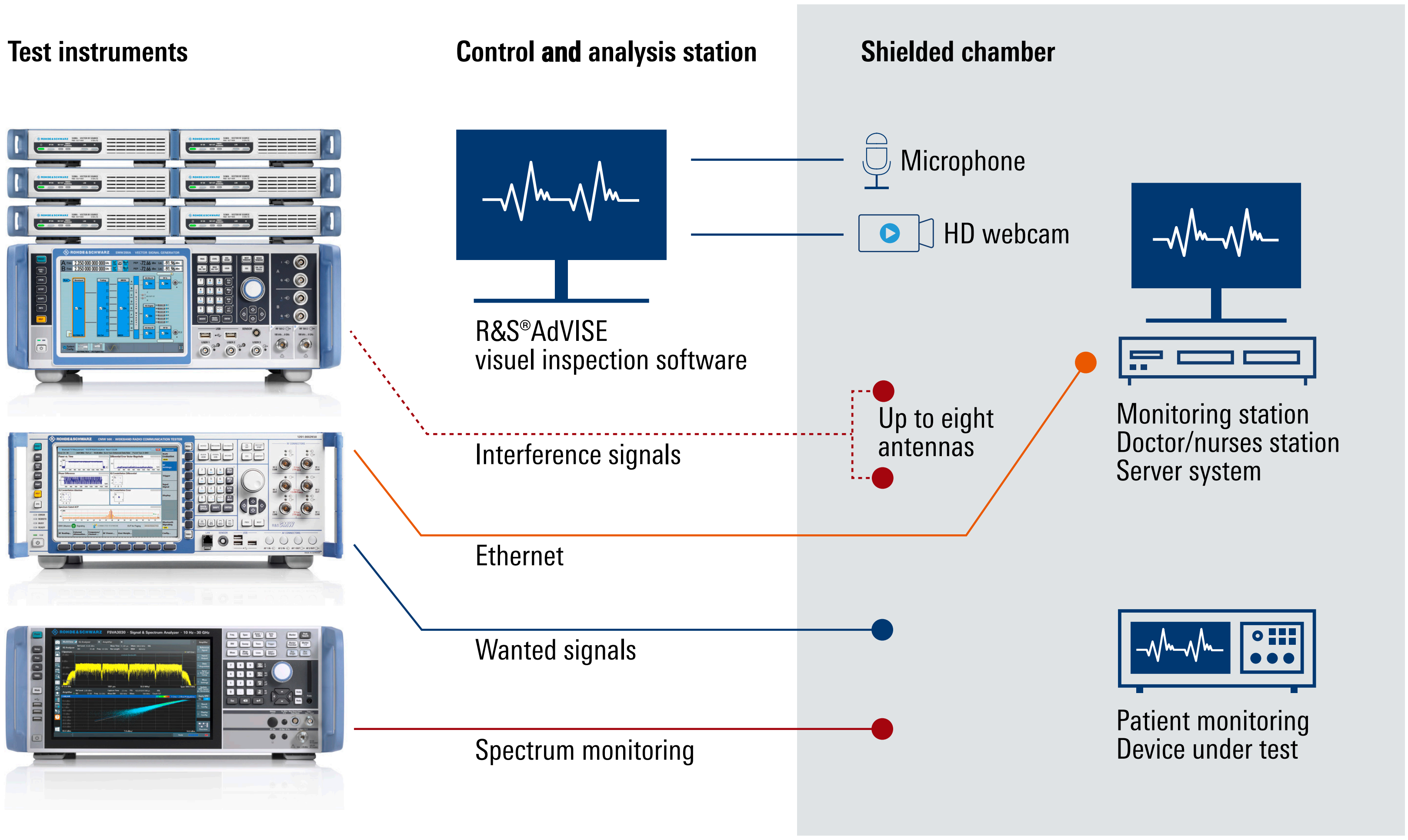
For WLAN, the cell radius is about 10 m and for LTE, it is about 2 km. At the cell edges, the receive power level is low. If a strong interference signal is transmitted on an adjacent frequency channel by another device located near the receiver, it can unintentionally jam the wanted signal reception by the receiver. Thus, receivers require higher sensitivity to cope with cell edge conditions. For coexistence testing, it is important to understand the behavior of the receiver under cell edge conditions. The worst case for cell edge conditions according to the different standards supported by the device under test is also defined in this module.

TEST SETUPS

TESTING TIER 3 AND TIER 4 PRODUCTS



TESTING TIER 1 AND TIER 2 PRODUCTS



TIER 3/4 AND TIER 1/2

The two test setups for performing over-the-air wireless coexistence testing are very similar. The only noticeable difference lies in the number of RF sources generating interference. Tier 1 and tier 2 require much more stringent testing in order to ensure they maintain their performance even in the presence of a large number of RF interference sources. The interference signals are generated using a vector signal generator such as the R&S®SMW200A or the smaller R&S®SGT with no display.

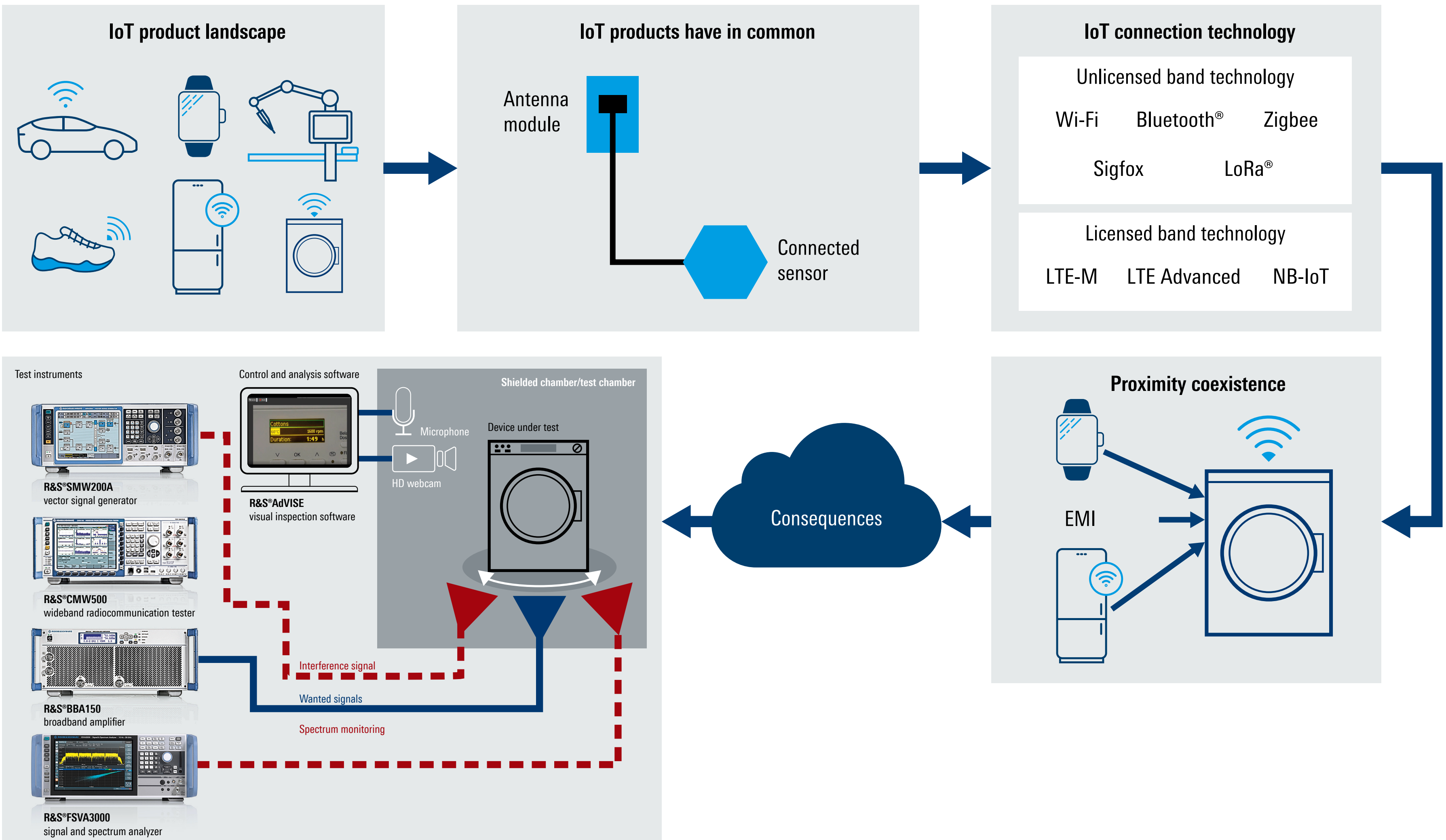
The R&S®CMW500 radio communication tester is used in the setups to emulate active networks for both cellular and non-cellular communications. Using the R&S®CMW500, it is possible to monitor the physical layer KPIs under ideal conditions as well as in interference scenarios. For 5G network emulation, the R&S®CMX500 is also required. Optionally, a power amplifier such as the R&S®BBA150 may be required to emulate very strong interference signals in the test environment. R&S®AdVISE audiovisual inspection software uses off-the-shelf HD cameras and microphones to monitor application layer KPIs during the tests.

The tests must be performed in an area that is not subject to any unintended electrical signals. The test antennas and device under test are placed inside a shielded anechoic RF chamber such as the R&S®DST200. The type of shielded chamber that is required depends on the size of the DUT as well as its operating frequency. A suitable chamber is one that has high shielding effectiveness in the frequency band of the wanted signal as well as up to at least the third harmonic of this frequency band.

WHEN IS THE RIGHT TIME TO THINK ABOUT RF COEXISTENCE TESTING?

The correct answer is in the design stage. It is extremely expensive to rectify a coexistence issue later in the product development cycle.

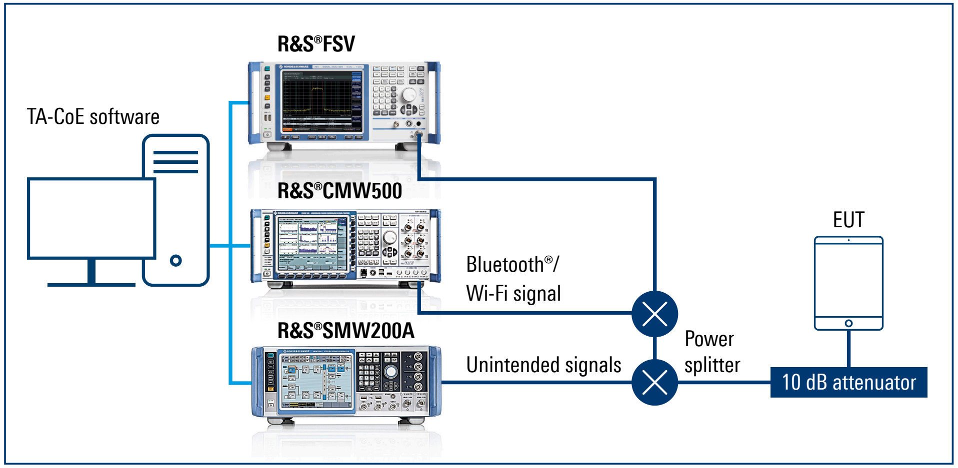
QUICK SUMMARY IN PICTURES



WIRELESS COEXISTENCE TESTING PRODUCTS AND SOLUTIONS FROM ROHDE & SCHWARZ

Rohde & Schwarz offers turnkey solutions as well as individual T&M equipment for wireless coexistence testing. Rohde & Schwarz also specializes in chamber technology.

TA-CoE software for ANSI C63.27



Coexistence testing products

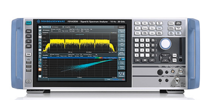
Interference

R&S®SGT

R&S®SMW

Monitoring

R&S®AdVISE



R&S®FSV3007

Over-the-air

R&S®DST200

Calibration

R&S®ZVL3

Network emulation

R&S®CMW500

R&S®CMX500

Battery performance

R&S®RTO/RTE

Amplifier

R&S®BBA150

Rohde & Schwarz

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