Application Note

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INTRODUCTION TO REVERBERATION CHAMBERS

BLUETEST AB

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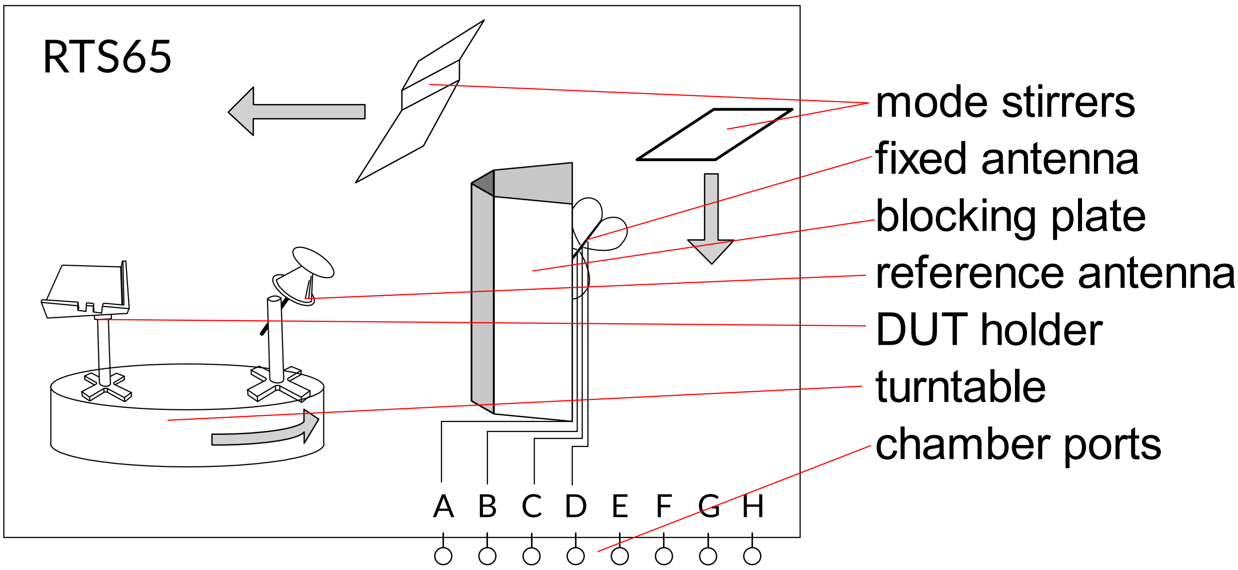
1 INTRODUCTION AND BACKGROUND

Reverberation chambers (RCs) have been used for a long time to measure radiated power and sensitivity in different applications. Early use was focused on EMC applications. Around year 2000, pioneering work was performed at Chalmers University to use RCs to measure antenna-related properties of small terminals. That work was commercialized in the company Bluetest which today is world leading in using RC technology for testing radiated performance of wireless terminals.

2 DESCRIPTION OF OPERATION OF A REVERBERATION CHAMBER

RCs are quite different from the anechoic chambers many people have come in contact with for antenna measurements. The idea is to use a metal cavity instead of a chamber with absorbing electromagnetic boundary conditions. This metal cavity can have any complex geometry and radiated quantities can be measured for a device under test (DUT) in the chamber. There is also a number of fixed receive/transmit antennas in the chamber to excite or receive signals. The sketch below highlights the main items found in a modern RC.



Present in the chamber are *mode stirrers* which have the purpose to change the electromagnetic boundary conditions seen by the DUT. Mode stirrers can be made in several different ways. In Bluetest RTS series of RCs, linearly displaced metal plates are used together with a turntable and differently polarized source antennas.

Since an RC is a metal cavity, radiation is not absorbed in the walls, but reflected and sooner or later end up at the antennas. There are many propagation paths in the chamber and these all superimpose

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on the antennas in a random fashion. This causes *fading* of the signal in the chamber. By changing the boundary conditions, different fading states are generated. Since the chamber is large, in wavelengths, many electromagnetic modes can exist in the chamber (corresponding to the propagation paths).

Due to the many modes in the chamber that superimpose on the antennas, the received signal will follow the statistical Rayleigh distribution (see https://en.wikipedia.org/wiki/Rayleigh_distribution for details). Knowing the distribution of signals in the RC can be used to measure several different properties of the antenna system. To obtain a complete measurement, the mode stirrers are moved to several different positions and the measurements are repeated. The result is a measurement of the average performance of the device under Rayleigh fading conditions. To tune the properties of the Rayleigh faded environment, microwave absorbers can be used. These are placed and the RC and affect the power delay profile. This can be important when testing active devices.

The primary benefit of the RC compared to an anechoic chamber is that the measurements are greatly simplified, the test system has a small footprint and low price. When starting a measurement, the DUT is simply placed inside the chamber without any requirements on alignments. Measurements are then very fast. The drawback is that traditional radiation patterns (with information about far-field radiation in different directions) cannot be obtained from the measurements. If radiation patterns are essential to an application, RCs cannot be used. In many wireless applications however, the radiation pattern is not an important quantity, but radiation efficiency and related properties are of much greater importance.

2.1 PERFORMING PASSIVE MEASUREMENTS

Passive measurements are defined by that the DUT does not have a receiver or transmitter. That is, it cannot communicate on any wireless standard by itself. The DUT can still be an active antenna in the sense that it contains amplifies or other RF devices such as phase shifters. Passive measurements are usually performed using a vector network analyzer (VNA). Under normal conditions (e.g. normal output power and antenna architectures) microwave absorbers should not be used when performing passive measurements.

2.1.1 Measuring antenna efficiency

Antenna efficiency can be measured in the RC by using a VNA. The measurement requires three main steps:

1. Calibrate the VNA
2. Perform a reference (chamber/path loss) measurement
3. Measure the antenna efficiency

Of these steps, 1 and 2 only needs to be performed once. The measurement set-up for steps 1 and 2 looks like:

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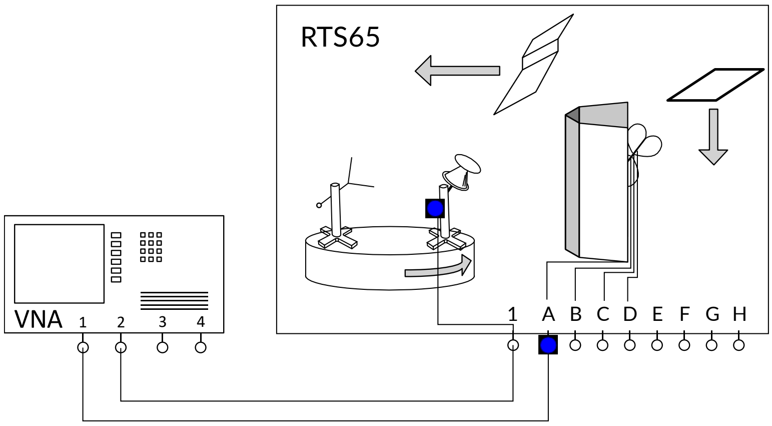
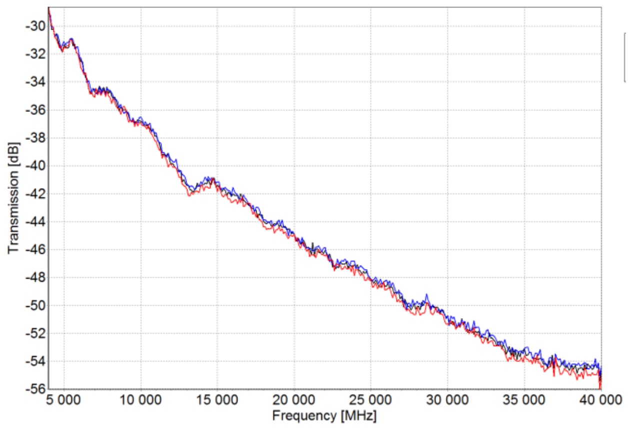
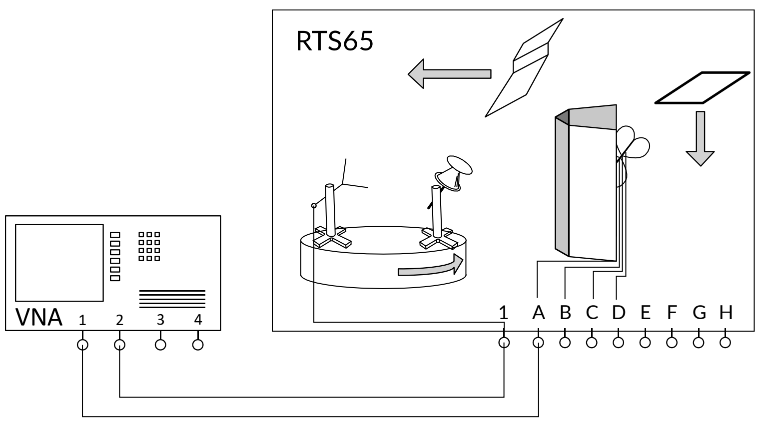


The two highlighted points indicate where the VNA is calibrated. Once it is calibrated, the average propagation loss in the chamber is measured by using a known *reference antenna* (RA). Bluetest uses a well characterized discone antenna. The propagation loss includes losses in the fixed antennas in the chamber as well as radiation losses due to lossy objects in the chambers. The plot below depicts a typical reference measurement in an RC.



Once the average propagation losses are known, the VNA is connected to the antenna under test (AUT) in a set-up as:



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The same measurement is repeated as in the reference measurement case and the relative difference corresponds to the efficiency of the AUT. Note that he RA and AUT are kept in the chamber during all measurement steps. The antenna not used for a measurement should be terminated for maximum accuracy.

2.2 TESTING ACTIVE DEVICES

There are several active device performance metrics that cannot be tested directly using a VNA since the transceiver is connected to the DUT antenna. Examples of such parameters are total radiated power (TRP), total isotropic sensitivity (TIS) and system throughput (TPUT). These parameters are convenient to test in an RC but it is required that it is possible to communicate with the DUT in some way. One way to do that is by connecting the DUT to a system emulator (a base station emulator in the case of mobile handsets). But it is also possible to control the DUT using wired connections or program it in advance to putting it in the RC, depending on the capabilities of the DUT and the lab equipment. The first step in measuring active devices is a reference measurement in the same manner as for passive measurements.

2.2.1 Measuring TRP

Next, the DUT is connected to a system emulator (SE) and the measurement is set-up with the appropriate measurement parameters. This is a complicated procedure which is significantly simplified by using a measurement software such as Bluetest Flow. The SE commands the DUT to radiate at maximum power and that power is measured by the SE. The resulting measured power is then scaled by the reference measurement, resulting in a measurement of the TRP.

2.2.2 Receiver testing

Receivers are tested using either TIS or TPUT. For these measurements, the Rayleigh fading environment found in an RC provides a realistic radio channel for devices with small antennas compared to reality where also multiple reflections of the signal causes the signal to be Rayleigh faded.

TIS is measured by sending a bit stream to the DUT and having the DUT report the bit error rate (BER) back to the SE. This is done in fixed mode stirrer positions and the power is gradually reduced until a predefined, standard-dependent, bit error rate is obtained. Then the measurement is repeated for several mode stirrer positions and the (harmonic) average is computed.

For TPUT, mode stirrers are normally run continuously and throughput data is measured at different transmit power levels.

3 SUPPORTED MEASUREMENTS IN BLUETEST RTS

Several types of measurement can be performed in Bluetest RTS. The following list highlight the passive types of measurements that are automated using Bluetest Flow:

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- Antenna efficiency
- Antenna diversity
- MIMO capacity

The following list highlight the active types of measurements that are automated using Bluetest Flow:

- TRP
- TIS
- TPUT (On MAC or IP layer)

In addition, RTS can also be used to measure more complex set-ups, e.g.

- ACLR
- Beamforming gain
- Spurious emission
- Adjacent channel blocking

4 REFERENCES AND FURTHER READING

- www.bluetest.se
- D. Hill, Electromagnetic fields in cavities, Wiley
- Stephen J Boyes and Huang Yi, Reverberation Chambers Theory and Applications to EMC and Antenna Measurements
- C. Orlenius and M. Andersson, Measuring Performance of 3GPP LTE Terminals and Small Base Stations in Reverberation Chambers, found at www.bluetest.se/technology/articles/measuring-performance-3gpp-lte-terminals-and-small-base-stations-reverberation

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