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OTA Methods for 5G BTS Testing – Survey of Potential Approaches

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Abstract

Through the recent decades, the technical area of antenna testing has undergone disruptive changes, since modern telecommunication systems demand ever increasing test cases. OTA (Over the Air) testing initially mostly concerned making sure that cellular phones complied with radiation pattern and efficiency requirements [1]. For future BTS (Base Transceiver Station) systems, OTA testing will cover a much larger proportion of the testing needed for a transceiver product. Testing of multi-antenna devices will further require more advanced test methods, in many times involving spatial channel models [2]. This paper presents different existing OTA test methods of wireless transceivers, and what adaptations of these which may be needed for testing future 5G BTS systems. Aspects of both conformance testing and performance testing are discussed.

1. Introduction

BTS systems face the same challenge as the cellular phones always did, in the aspect that the interface between the radio and the antennas is non accessible due to the tight integration. Moreover, with massive multiple-input multiple-output (MIMO) technology, the number of antennas on a BTS will become very large, which makes is practically impossible to measure the BTS performance via RF connector. Traditional BTS testing, involving the combination of radio performance measured in the RF connector, combined with the knowledge of the full sphere radiation pattern of the BTS antenna, was sufficient and enough to characterize that the BTS system was conformant with certification requirements. Currently, 3GPP specifies both conductive and OTA tests for BTS [3].

2. OTA BTS Test Scenarios

BTS testing can roughly be categorized in three groups: 1) conformance test (approval tests, pass/fail type of tests), 2) performance tests (e.g. throughput), and 3) production tests (also pass/fail).

The objective with BTS RF conformance testing, is to assure that the BTS complies with standard specifications. For instance, 3GPP specifications have RF requirements on transmitter (TX) and receiver (RX), such as total radiated power (TRP), equivalent isotropically radiated power (EIRP), adjacent channel leakage power ratio (ACLR), spurious emissions, and receiver sensitivity. BTS conformance testing further involves such testing which is done for product certification. BTS conformance testing can be subdivided in two categories – *certification testing* and *product testing*. Certification testing is done on a few samples of the final product, while product testing is done on every manufactured piece of the final product in the production facility.

The objective with BTS performance testing, is to mimic a virtual test drive system. The BTS is setup in a way similar to the scenario as had it been located in a realistic field trial scenario. This implies that the test system needs to involve not only the BTS, but also the fading channel, and the UE's that the BTS interacts with. With BTS performance testing, it is possible to test and evaluate different kinds of beamforming and algorithm features.

3. BTS conformance testing

The following chapter discusses potential methods for BTS conformance testing. Conformance testing can be subdivided into two sub-categories - certification testing and product testing. Certification testing is comprehensive and involves many test cases which demand very high accuracy on the test equipment. Product testing is typically done with some relaxation on test coverage and test accuracy, in order to keep the measurement time and equipment cost reasonable.

3.1 BTS certification testing at sub-6GHz

At Sub-6GHz, the following OTA measurement approaches are already defined in 3GPP.

- Far field anechoic chamber (AC) based methods
    - Near field
    - Far field
- Reverberation chamber (RC) based methods
- Two-stage method (2S)
- Ultra Compact Test Chamber with planar wavefront generator (PWG).

For certification tests, intended to make sure that the product complies with 3GPP RF specifications, very high accurateness measurement requirements are needed. For measurement cases that involve qualifications in different spatial directions, directional methods such as far field anechoic chamber is needed, while the reverberation chamber can be used to measure parameters that are not related with spatial characteristics, such as TRP and ACLR ratios.

3.2 BTS certification testing at mmWave

Likewise to the sub-6G case, mmWave will put a high demand to verify the characteristics of the spatial RF performance, and far field method will be the most suitable method for certification testing. For tests that do not require spatial characteristics, reverberation chamber may be a potential method, but at the writing time of this paper, it is not yet well proven that reverberation chambers will be accurate enough to be qualified for certification tests at mmWave.

3.3 BTS product testing at sub-6G

Product testing will put restrictions on the cost and the size of the OTA chamber. The size of the chamber is probably restricted to be just about some few meters is size. The product testing will involve a small subset of the group of test cases done in the certification OTA testing. Such tests may involve EIRP, error vector magnitude (EVM), ACLR. It is directly understood that the far field chamber is too big and too costly for this measurement scenario. Some of the tests, which do not relate with spatial performance, could be done in the reverberation chamber (for instance TRP, total isotropic sensitivity (TIS). The ultra compact PWG chamber seems to be an attractive solution for production testing, but it remains to be proven that the chamber can become cost efficient enough, easy enough to handle, and accurate enough.

3.4 BTS product testing at mmWave

Product testing at mmWave puts even more questions on how the preferred test system would look like. As we move up in frequency the electrical size of the antenna will increase, and, the far field distance increase even further, which would make it unfeasible even for the far field chamber to perfectly represent the radiated characteristics. The challenge becomes even tougher when the target is to measure the OTA performance of a modulated signal, since not only a near-field to far-field conversion is needed, but also the modulated carrier needs to be recorded in every measurement position, and later be converted to the equivalent signal in the farfield. On the other hand, the antenna physical size may be smaller in mmWave due to the shorter wavelength. The PWG chamber might be designed also for mmWave measurements, but the number of probes in the PWG generator will become very large, and whether or not the excitations of the PWG will be accurate enough to guarantee a planar wavefront in the test zone, is a question that is still prevailing.

4. BTS performance testing

Performance tests are needed to measure the BTS performance in realistic test conditions. The Figure of Merit (FoM) could be, e.g., end-to-end throughput.

For Sub-6Ghz, performance testing, there are results [4] showing that a virtual drive test can be done in an MPAC (Multi Probe Anechoic Chamber), with a reasonable number of OTA probes and a reasonable number of fading generators. A possible competing method would be to do performance testing in reverberation chamber and in the anechoic chamber, the former one generating a Rayleigh-like channel, with rays impinging from any possible directions, the latter one Rice-like, with a single ray incoming from some direction. The RIMP and the Random-LOS methods has proven to show how well a product performs in these two extreme situations [5]. For small cell micro-BTS, normally residing in situations that have more angular spread than macro-BTS, the results are probably more relevant than for the case of a macro-BTS, when the angular spread is generally much smaller.

For performance testing at mmWave, probably the MPAC chamber is a viable method. Since multipath components are more scarce and the power delay profile is shorter at mmWave, this leads to some considerations how to map the fading generator to the probe antennas.

5. Description of the potential BTS OTA test methods

In this chapter, the different test methods previously discussed, are presented in more detail.

5.1 Anechoic chamber, far field measurement

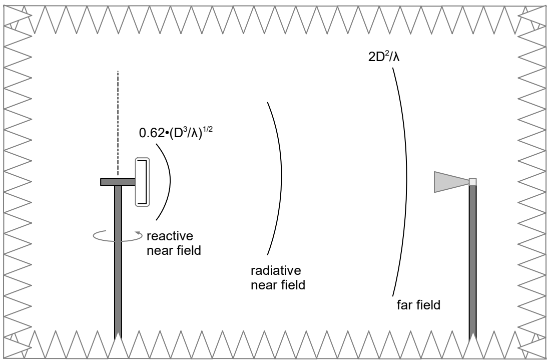

Figure 1. Far field measurement chamber.

Far field measurement chambers can be subdivided in a set of subgroups, such as compact ranges, multi-probe ranges e.g. SATIMO, far field ranges. They all have the objective of measuring the radiated far field of the AUT. The AUT is normally revolved on some kind of turntable, while keeping the measurement antenna fixed. Far field test ranges have been optimized for many decades and vast selections of materials instrumentation and equipment are available to measure antenna performance with very good accuracy. Certification of radiation performance of wireless products is hence commonly done via far field measurement methods.

Far field measurement chambers can directly be excluded from production testing due to their large size. Concerning frequency band, they are feasible both at lower and higher frequencies, provided that the distance between the AUT and the measurement antenna is larger than the far field distance. This restriction can be circumvented by using a reflector in the radiation chamber, creating a planar wave front with a smaller chamber size.

5.2 MPAC (Multi Probe Anechoic Chamber)

Figure 2 visualizes the concept of an MPAC (Multi Probe Anechoic Chamber). The target of an MPAC is to emulate a realistic environment, with specified properties of angular spread and delay spread. Mapping of channel model onto the probe antennas is described in [6]. Between the BTS and the UE's, one or several fading generators with bidirectional ports are located, so that both the UL and DL air interface channels become equivalent to some standardized channel model. The challenge with MPAC OTA testing is to realize a test zone that is large enough to enclose a large BTS antenna, while at the same time keeping the number of OTA probes and the number of fading generators low. The MPAC is mainly intended for BTS performance testing, i.e. virtual drive testing.

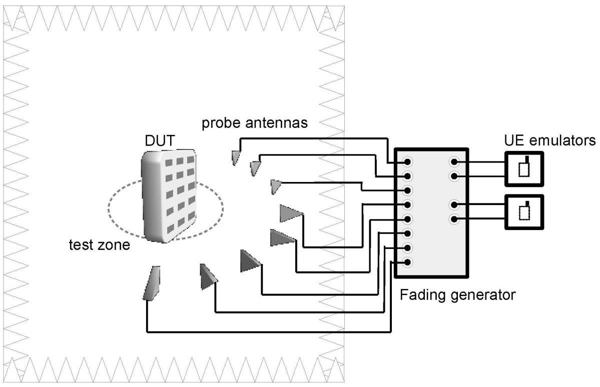

Figure 2. MPAC (Multi Probe Anechoic Chamber).

5.3 Ultra Compact PWG Chamber

The Ultra Compact PWG chamber is an OTA solution that is intended to make the test setup as small and compact as possible. From technical point of view, the immediate choice for product testing would be a far field chamber, but it can quickly be disregarded, since it is too big, too costly, and too time consuming to be used in production test. An interesting method is instead to create a virtual far field by means of a so called PWG (Planar Wavefront Generator).

The basic idea of a PWG, is to let a set of waves emanate from a number of probe antennas in the PWG. The optimum positions of the probes of a PWG have been presented in [7], and results in a sparse array grid. The excitations of the PWG probe antennas are calculated as the inverse of the transfer matrix between the PWG probes and some calibration probes that scan the test area prior to the positioning the AUT in this test zone.

Performance parameters of the AUT, such as radiation pattern, EIRP, spurious emissions and EVM can be characterized in a similar way as had the AUT been located in a far field chamber, although the size of the PWG Ultra Compact Chamber is much smaller. There are reports showing that the total chamber size could be in the size as about double the AUT size.

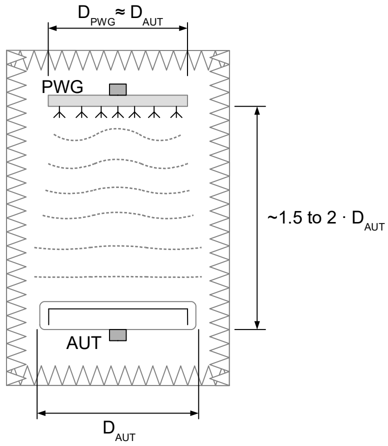

Figure 3. PWG Ultra Compact Chamber.

5.4 Reverberation chamber

OTA testing in reverberation chamber is today a well proven method to characterize antenna performance. The method has mainly been used for testing handheld devices, but has recently also been found useful for testing small cell BTS antennas [5], and also macro BTS antennas [8]. The principle of the method is to locate the AUT in a reflective chamber equipped with mode stirrers. When revolving the mode stirrers, the electromagnetic modes inside the chamber create a large set of random simultaneous incoming waves that impinge into the test zone where the AUT is located. This creates a fading process which is very similar to theoretic Rayleigh fading. The method is useful to characterize antenna radiation parameters that are independent of angular spread.

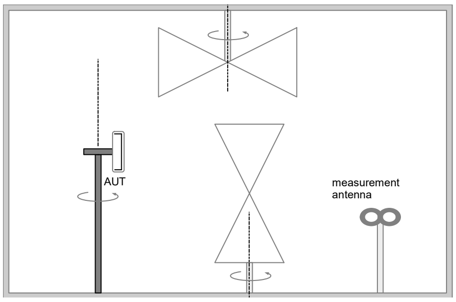

Figure 4. Reverberation Chamber.

5.5 Near field measurement chambers

Near field testing is based on the theory of near field to far field conversion. By measuring the radiation pattern in the radiate near field, it is possible to translate the field to the corresponding far field radiation pattern by means of a Fourier transform. To do this conversion, the radiated near field needs to be known in many points enclosing the AUT. The method hence becomes time consuming, especially if the test involves a modulated waveform in the AUT. The measurement will then not only involve measuring the field components, in every measurement point the modulated signal needs to be recorded for a certain time period. After recording the modulated signal in all measurement points enclosing the AUT, the far field equivalent modulated signal is calculated by post processing the recorded data. It is easily understood that this method becomes complex and time consuming. It is however, foreseen as a potential method for mmWave conformance testing, since the PWG ultra compact method probably will face at least equivalently technical challenges to be realized in practice.

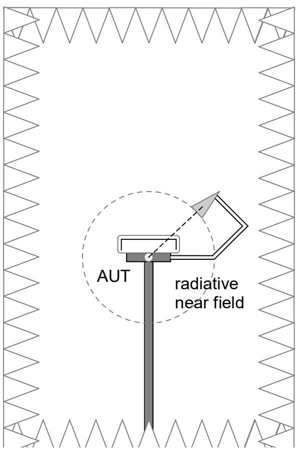

Figure 4. Near Field Test Chamber.

5.6 EMC measurement chambers

Some of the requirements concerning current 3GPP conformance RF tests, involve measurements to be done at frequencies as low as 9kHz, and up to 12.75GHz. The probable test is an EMC test chamber which visually looks similar to the far field measurement chamber in Figure 1, except attenuation materials, test antennas and instruments are designed for testing at lower frequencies.

6. Summary

The discussions on different OTA test methods for future BTS systems with many antenna ports, are summarized in Table 1. The items marked with an asterisk (*) are related with further study, as to the best of our knowledge, the feasibility of the related method is not yet fully proven.

Table 2. Overview of potential OTA test methods for future BTS systems with many antenna ports.

	Sub6G	**mmWave**
Conformance testing (angular dependent)		
Production test	Ultra Compact PWG	Near field testing* / Ultra Compact PWG*
Certification test	Far field anechoic chamber	Far field anechoic chamber
Design test	Ultra Compact PWG	Near field testing* / Ultra Compact PWG*
Conformance testing (angular independent)	Reverberation chamber / Far field anechoic chamber	Reverberation chamber* / Far field anechoic chamber
Conformance testing (angular independent) Very low frequency Very high frequency	EMC chamber Reverberation chamber*	EMC chamber Reverberation chamber*
Virtual drive testing / Performance testing – small angular spread	MPAC	MPAC*
Virtual drive testing Performance testing – isotropic angular spread	Reverberation chamber	Reverberation chamber*

7. References

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[2] 3GPP TR 37.976, "Measurement of radiated performance for MIMO and multi-antenna reception for HSPA and LTE terminals", v1.4.0, April 2011.

[3] 3GPP TS 36.141, "Base Station (BS) Conformance Testing", V8.4.0, September 2009

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