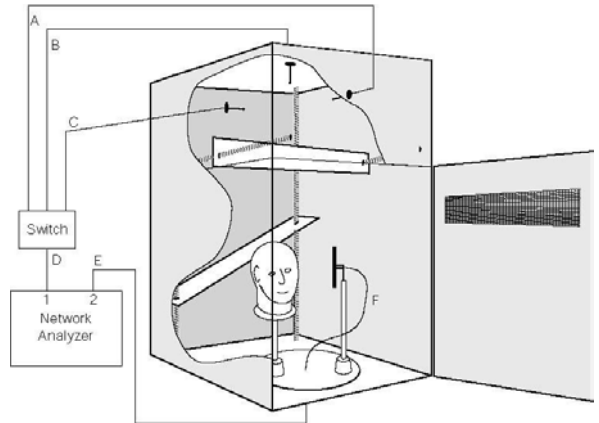


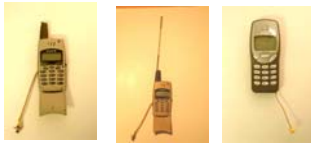
Measuring Antennas in Reverberation Chamber

Per-Simon Kildal, Fellow IEEE, Charlie Carlsson, Kent Rosengren, Jan Carlsson, Andreas Wolfgang, Jian Yang
Bluetest AB and Chalmers University of Technology, Sweden

- The radiation efficiency is the most important performance parameter of an antenna on a mobile terminal in a multipath propagation environment.
- The **radiation efficiency** can be measured in a reverberation chamber.
- The radiation efficiency is reduced by three contributions:
 - **Reflections** due to mismatch at input port of antenna.
 - Absorption in antenna itself due to **lossy materials**.
 - Absorption in **lossy objects (phantom)** near antenna.
- The **input impedance** can also be measured, as it would be seen if the antenna and the phantom were located in an anechoic chamber. This is obtained by complex averaging of S_{11} over the stirrer positions. Thereby the statistic contribution from the chamber is removed.
- The results below are for a **validation case** consisting of a dipole at distance from a PVC cylinder filled with tissue equivalent liquid.

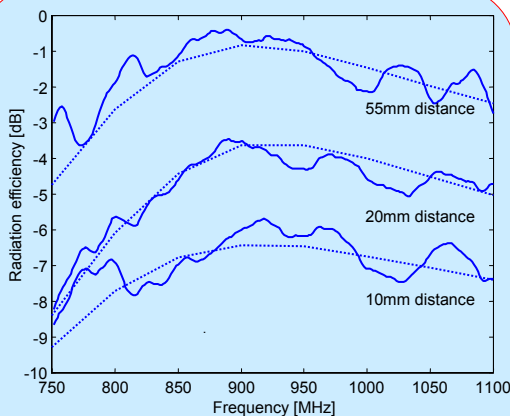


Bluetest RC800 reverberation chamber and setup for antenna measurements. The field is stirred by 2 mechanical stirrers, a platform stirrer, polarization stirring and 25 MHz frequency stirring.

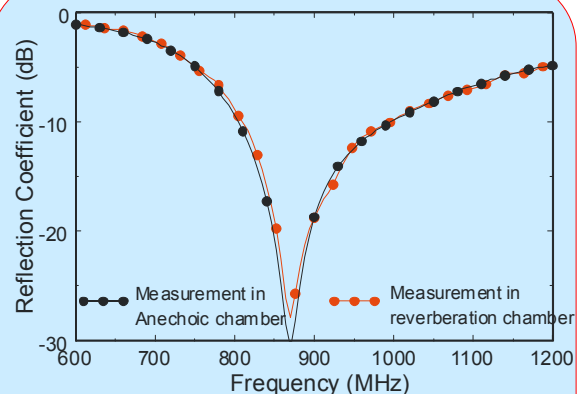


Example of real antennas on phones provided with cable for measuring RL and radiation efficiency.

Photo shows validation case when it is located in anechoic chamber.



Comparison between radiation efficiencies of validation case measured in reverberation chamber and computed with FDTD, at different distances from lossy cylinder.

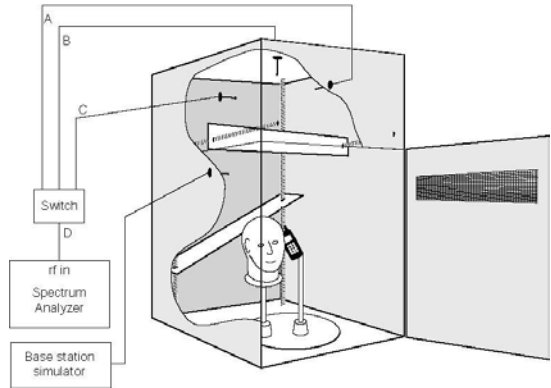


Comparison between reflection coefficients at dipole port, for 10 mm distance to lossy cylinder..

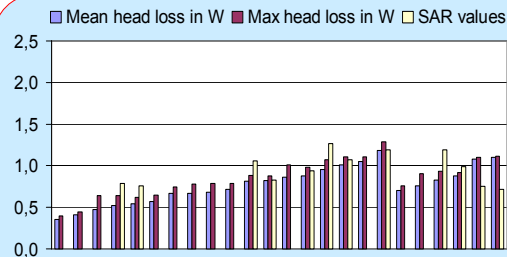
Measuring Radiated Power in Reverberation Chamber

Per-Simon Kildal, Fellow IEEE, Charlie Carlsson, Yngve Hamnerius, Nikolay Serafimov
Bluetest AB and Chalmers University of Technology, Sweden

- The total radiated power of the phone must satisfy GSM standards, otherwise the performance of the phone is not satisfactory.
- The total radiated is strongly reduced in talk position. The difference is the head loss (due to absorption and mismatch). There is a correlation between head loss in W and SAR values in W/kg.
- TCO'01 is the first quality marking of mobile phones that has requirements to the total radiated power. This is referred to by the positive term **TCP = Telephone Communication Power**.
- The TCP can be measured in the Bluetest RC800 reverberation chamber with an expanded uncertainty of less than 1 dB (2σ value).



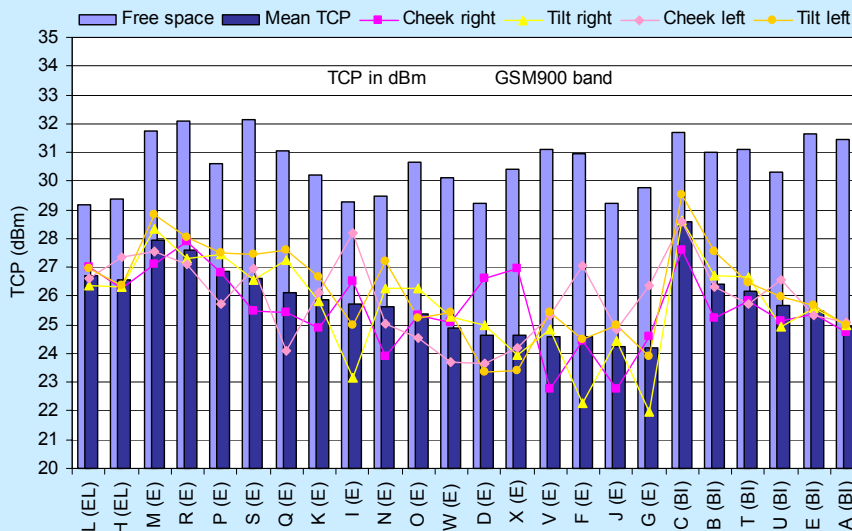
Bluetest RC800 reverberation chamber and setup for radiated power measurements. The field is stirred by 2 mechanical stirrers, a platform stirrer, polarization stirring and 25 MHz frequency stirring.



Comparison between measured TCP in W and SAR values in W/kg of same 20 phones as below.



The 20 measured phones (left) and example of hand phantom used in other measurements. (right).



Measured TCP values of 20 different phones in different CENELEC positions relative to head phantom. The phones are grouped according to their antenna type. EL = Extractable Long antenna, E = External antenna, BI = Built-In antenna

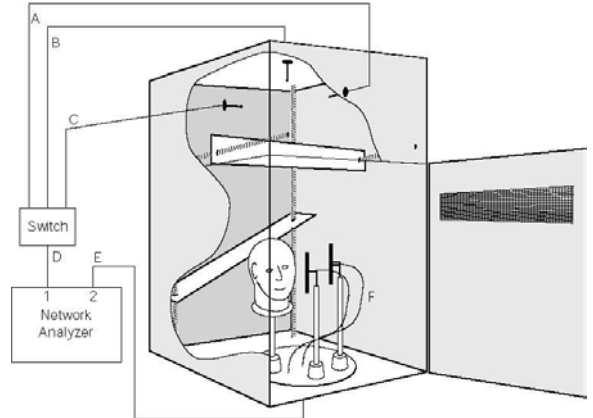
Measuring Diversity Gain in Reverberation Chamber

Per-Simon Kildal, Fellow IEEE, Kent Rosengren, Charlie Carlsson
Bluetest AB and Chalmers University of Technology, Sweden

- A reverberation chamber simulates a uniform multipath environment when the modes are stirred. Diversity antennas will be used to improve performance of future mobile communication systems.
- The reverberation chamber is the **only laboratory equipment that can measure diversity gain**. The alternative is to drive the measurement equipment around in a real multipath environment, such as in a city.
- The measurement setup in the Bluetest RC800 chamber is shown in the drawing. The simulated multipath environment is repeatable, so we can measure the two antenna branches one after the other.
- We can measure diversity gain relative to different single-antenna references. The **apparent diversity gain** is measured relative to one of the branches. A more practical **effective diversity gain** is measured relative to an ideal reference antenna, which is lossless and matched to 50 Ohms. The **actual diversity gain** is measured relative to an existing single-antenna solution, with a certain **radiation efficiency**.
- Definition formulas of the different diversity gains (SNR=signal-to-noise ratio):

$$G_{\text{effdiv}} = \frac{(SNR)_{\text{div}}}{(SNR)_{\text{idealref}}} = \frac{(SNR)_{\text{div}}}{(SNR)_{\text{branch}}} \cdot (e_{\text{rad}})_{\text{branch}}$$

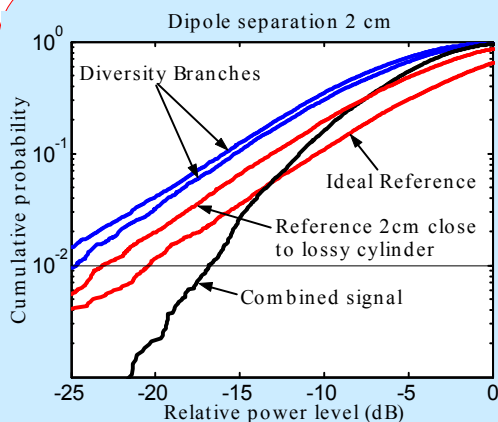
$$G_{\text{apparentdiv}} = \frac{(SNR)_{\text{div}}}{(SNR)_{\text{branch}}}, \quad G_{\text{actualdiv}} = \frac{(SNR)_{\text{div}}}{(SNR)_{\text{refcase}}}$$



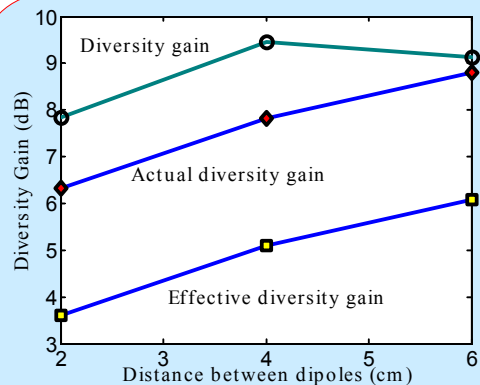
Bluetest RC800 reverberation chamber and setup for diversity measurements. The field is stirred by 2 mechanical stirrers, a platform stirrer, polarization stirring and frequency stirring.



Example of simple two-dipole diversity antenna located 2 cm from a cylinder filled with tissue-equivalent liquid. Results are given below.



Example of statistics of measured signal levels at 900 MHz.

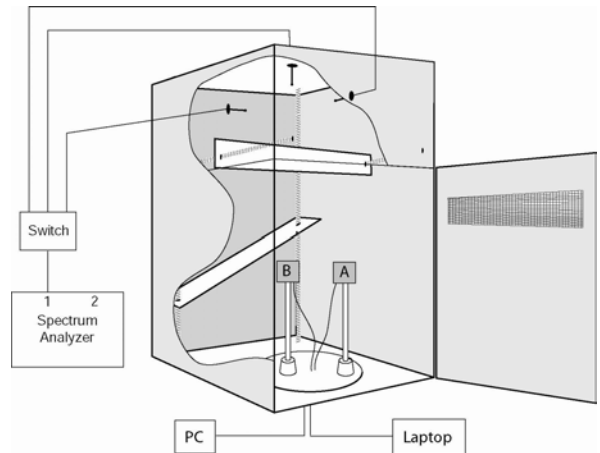


Diversity gains by selection combining at 1% cumulative probability level. The actual diversity gain is measured relative to a single dipole located the same 2 cm distance from the cylinder. 900 MHz.

Bluetooth Measurements in a Reverberation Chamber

Charlie Orlenius, Andreas Wolfgang, Per-Simon Kildal, Fellow IEEE,
Bluetest AB and Chalmers University of Technology, Sweden

- The **radiated power** of *Bluetooth* units can be measured in a reverberation chamber.
- The reverberation chamber supports a uniform field environment, i.e. all incident angles is represented in the chamber.
- Possible to easily include objects, such as a head phantom or a metallic table, in the setup to simulate the influence on the performance of the unit.
- The present setup can be used without the need for a radio communication tester.
- An example of a test case is shown below, where a commercial *Bluetooth* dongle is tested in free space and a position corresponding to normal use.



Bluetest RC800 reverberation chamber and setup for Bluetooth measurements. The field is stirred by 2 mechanical stirrers, a platform stirrer, polarization stirring and 25 MHz frequency stirring.



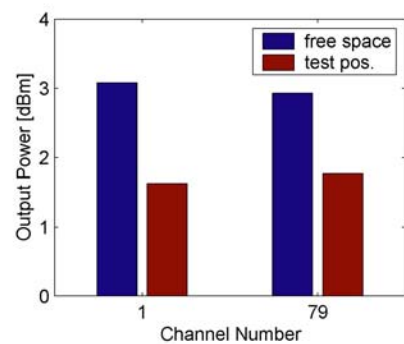
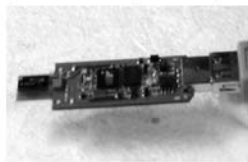
Radios that comply with the *Bluetooth* wireless specification operate in the unlicensed, 2.4 GHz radio spectrum ensuring communication compatibility worldwide. These radios use a spread spectrum, frequency hopping, full duplex signal at up to 1600 hops/sec. The signal hops among 79 frequencies at 1 MHz intervals to give a high degree of interference immunity. Up to seven simultaneous connections can be established and maintained.



The Bluetooth word mark and logos are owned by the Bluetooth SIG, Inc. and any use of such marks by Bluetest AB is under license. Other trademarks and trade names are those of their respective owners.

Module in test position (in the case and connected to a laptop, standing on a simulated wooden table)

Test module in free space (taken out of the case and placed on styrofoam)



Output power of a commercial Bluetooth module in free space location and inside a case mounted to a laptop computer, both measured in a reverberation chamber.