ABSORBER LOADING STUDY IN FOI 36.7 m^3 MODE STIRRED REVERBERATION CHAMBER FOR PULSED MEASUREMENTS

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I. Background

What is a Reverberation Chamber ?

The reverberation chamber (RC), is a highly conductive, electrically large, shielded cavity normally equipped with one or several stirrers (tuners) to provide a statistically uniform and statistically isotropic field.

Reference: IEC 61000-4-21

Reverberation Chambers are used by the EMC Community for Susceptibility Testing, Coupling and Emission Analysis.

II. INTRODUCTION

A experimental study was conducted to gain better understanding of the influence of different loadings of a 36.7 m^3 reverberation chamber.
The chamber was loaded with two different types and up to eight pieces of microwave absorbers.
For different chamber loading the Q-values, the lowest usable frequency for 200 uncorrelated stirrer positions, the agreement with the expected exponential power distribution, the chamber time constant and field build up process, has been studied.

III. Q-value

$$Q = \frac{16\pi^2 V}{\lambda^3}\frac{P_r}{P_t}$$

$$\frac{P_r}{P_t} = \frac{a_e}{\frac{4\sqrt{\pi\mu_r}}{\sqrt{Z_0\sigma\lambda}}S + 2a_e}$$

$$a_e = \frac{\lambda^2}{8\pi}$$

Pr/Pt = Chamber insertion loss

S = Surface area

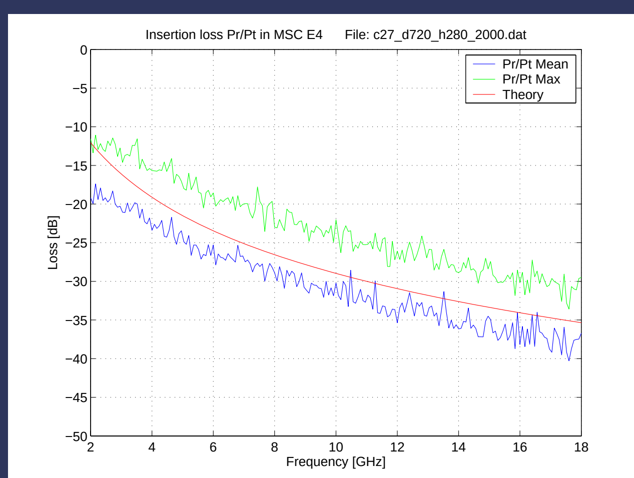
V = Chamber volume

σ = Conductivity

λ = wavelength

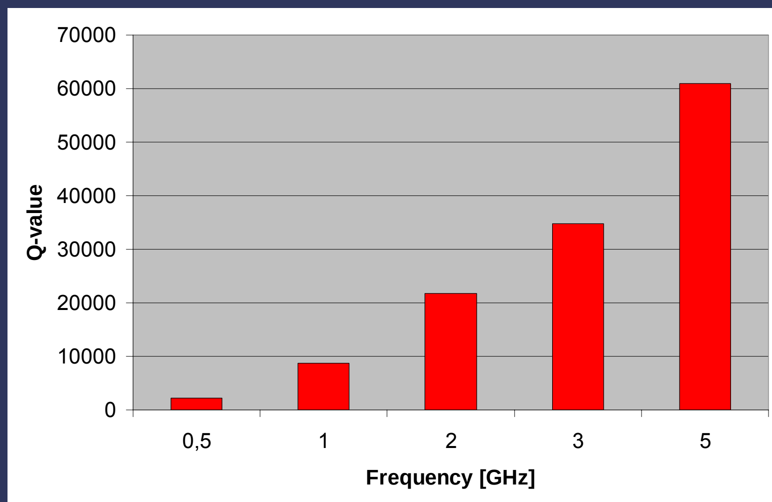
Pr/Pt Chamber insertion loss vs .frequency

Measurements using full 2 port calibrated Network Analyzer



< Pr/Pt > Mean over 200 Stirrer positions

Q-values vs. frequency for empty Chamber



Why Pulsed Measurements ?

Conflict with high Q-values

Time to achieve field stability is about 10 – 20 µs

High power sources have limited pulse duration

Testing Wireless Communication systems

Pulsed Measurements
Chamber Time Constants

According to the avionic standard DO-160F [4] one shall load the chamber with absorbing material to get a time constant that is 40 % of the pulse duration i.e. for a typical radar source with pulse duration of 1 μs we need to make the chamber time constant about 0.4 μs. The time constant is defined as 63% of the pulse final value.

IV. Chamber Loading

36.7 m^3 Chamber with eight Rantec VHP-12 absorbers in the Floor Configuration

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Reverb Chamber with six Eccosorb AN-77 absorbers on Styrofoam blocks in Working Volume Configuration

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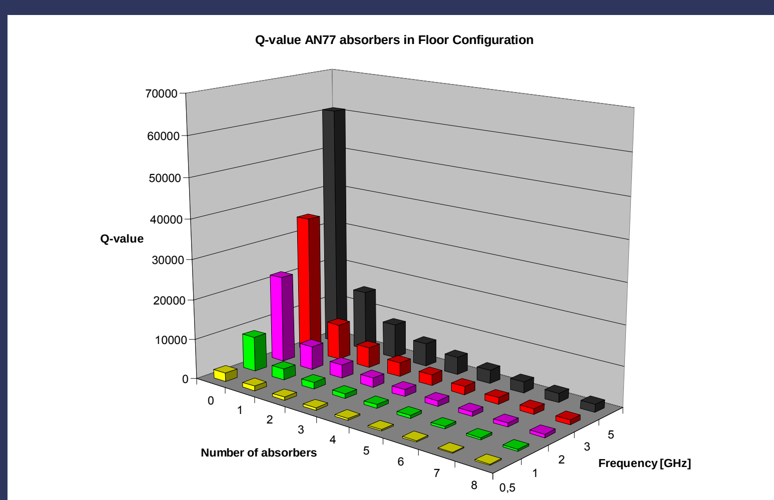
Q-value vs. Frequency and number of AN77 absorbers



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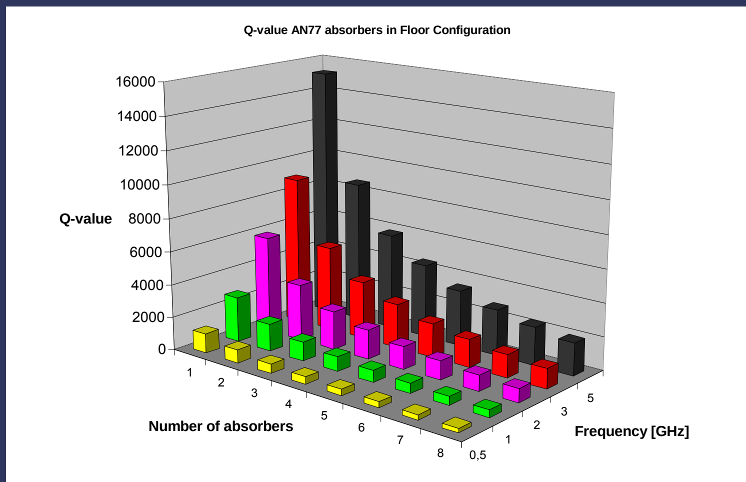
Q-value vs. Frequency and number of AN77 absorbers



Q-value relation due to loading

	Floor Configuration	Working Volume
Eccosorb AN77	$\frac{Q}{Q_{AN77_{FC}}} \approx 4 \cdot n$	$\frac{Q}{Q_{AN77_{WV}}} \approx 6 \cdot n$
Rantech VHP12	$\frac{Q}{Q_{VHP12_{FC}}} \approx 8 \cdot n$	$\frac{Q}{Q_{VHP12_{WV}}} \approx 10 \cdot n$

Where *Q* is the empty chamber Q-value and *n* the number of absorbers

V. Time Constants

Relation Q vs. Time Constant

$$\tau = \frac{Q}{2 \cdot \pi \cdot f}$$

f = frequency

Time constant is defined as 63 % of the pulse final value

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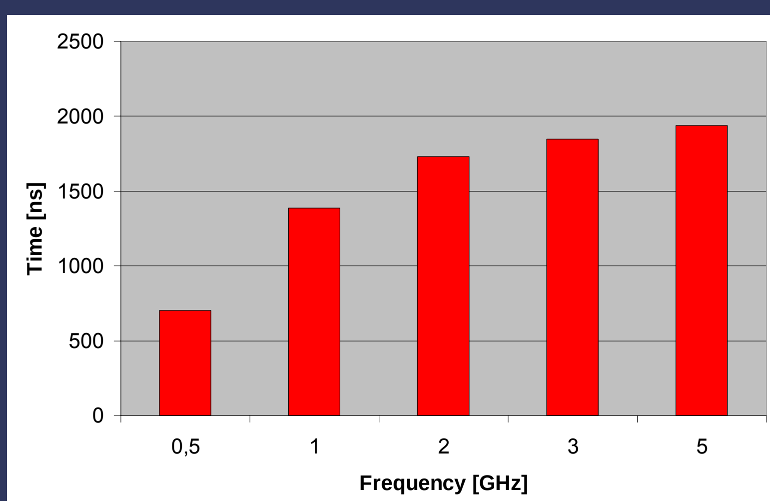
Time Constants for Unloaded Chamber



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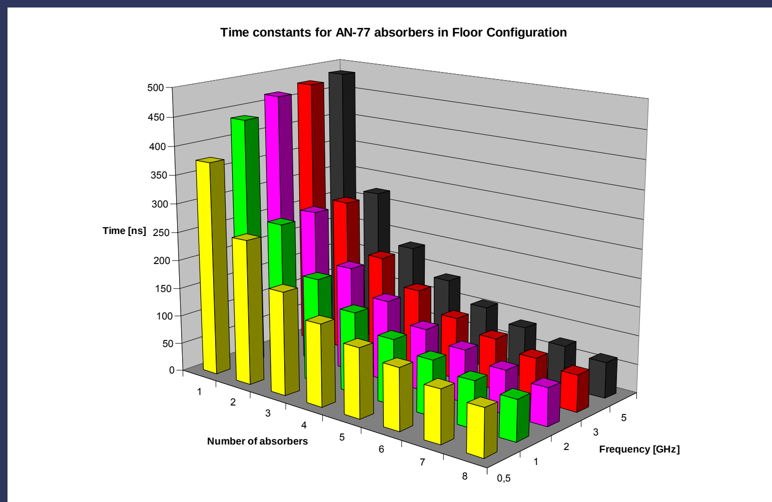
Time Const. vs. Freq. and number of AN77 absorbers



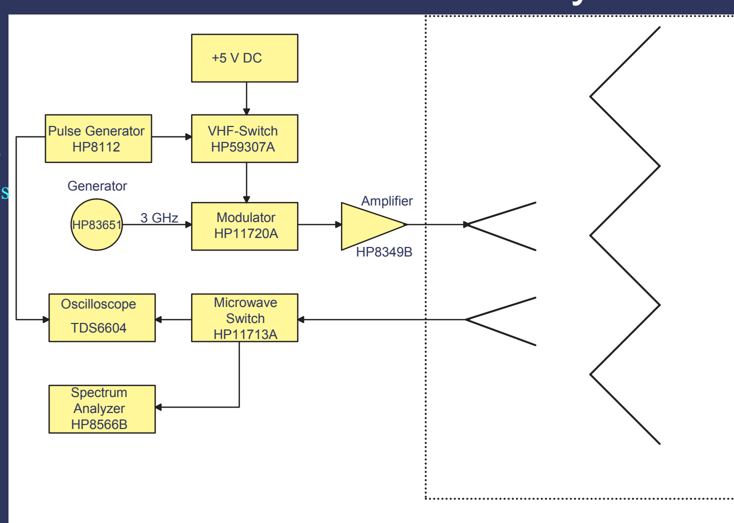
VI. 3 GHz Pulsed Power Study

P_t = 1 & 30 μs

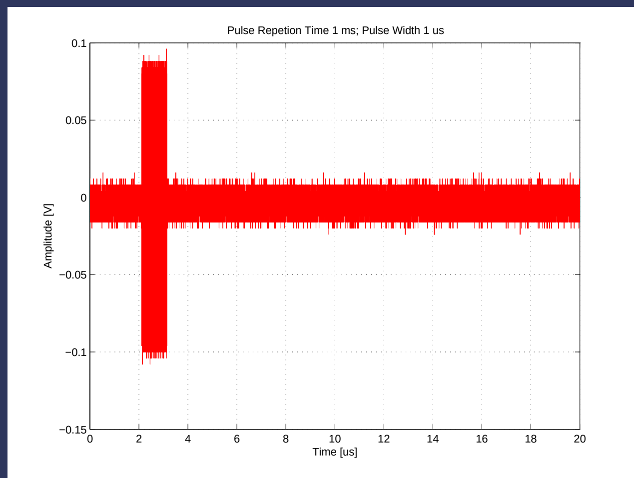
PRF = 1 kHz

Tx = + 20 dBm

200 Stirrer steps

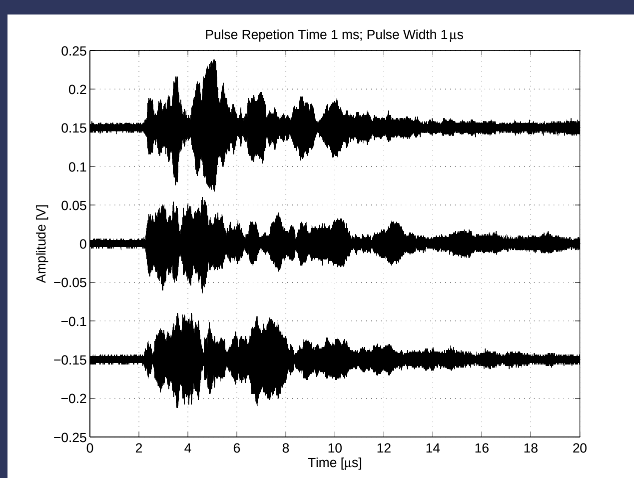


3 GHz Chamber input 1 µs pulse

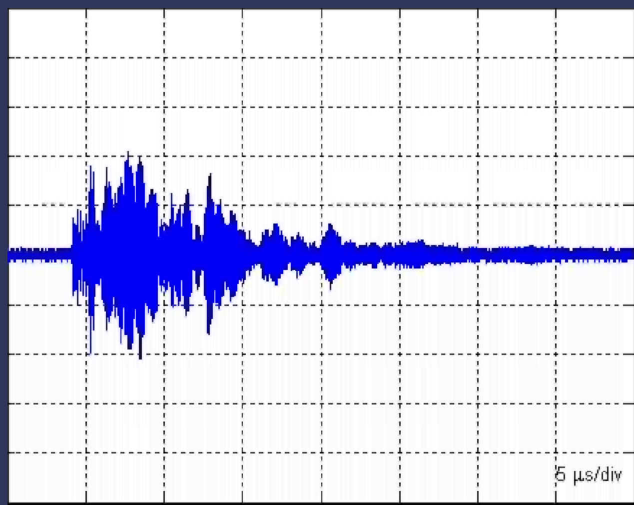


3 GHz Chamber output 1 µs pulse

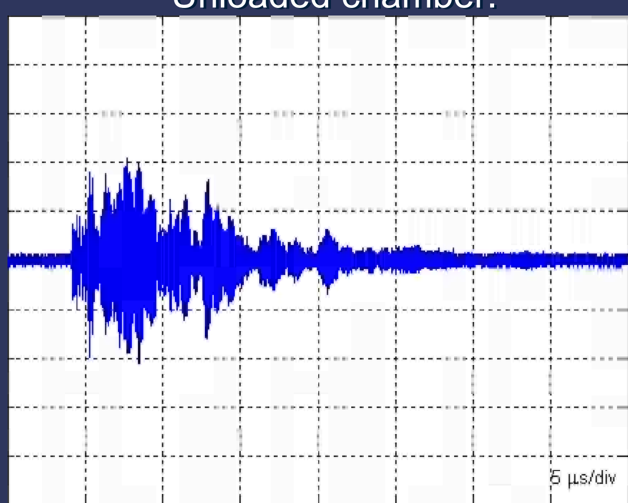
3 stirrer pos



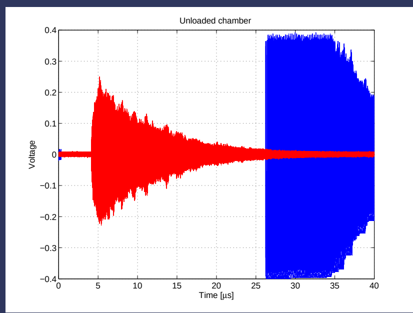
1 µs pulse. 200 stirrer steps. Unloaded chamber

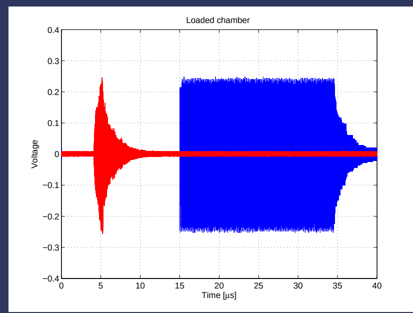


1 µs pulse. Ensemble over 200 stirrer steps. Unloaded chamber.



Ensemble max for the Unloaded and Loaded Chamber response using 1 µs and 30 µs pulse durations





VII. Lowest Usable Frequency

Correlation coefficients

$$\rho(r) = \frac{1}{N-1} \cdot \frac{\sum_{i=1}^{N} \left(x_i - \langle x \rangle\right) \cdot \left(x_{i+r} - \langle x \rangle\right)}{\sigma_x^2}$$

Where

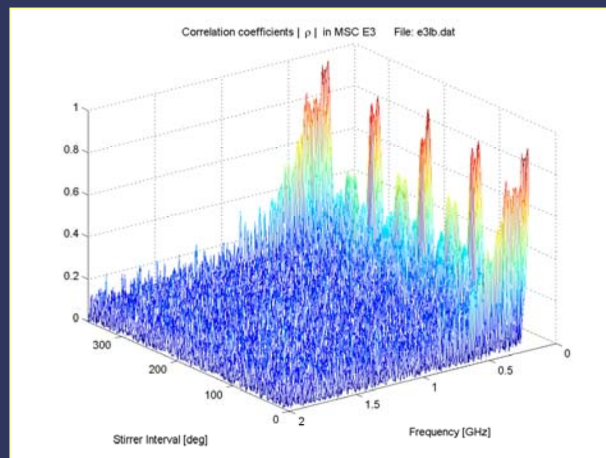
r is the interval between two stirrer positions

x1, x2, x3 … is the normalised received power

N is the number of stirrer positions

Auto-correlation performed on all stirrer intervals for each frequency.

Measured:
0.2 - 2 GHz in
201 points
200 Stirrer Steps



Note the symmetry effects of the cross-shaped stirrer at low frequencies.

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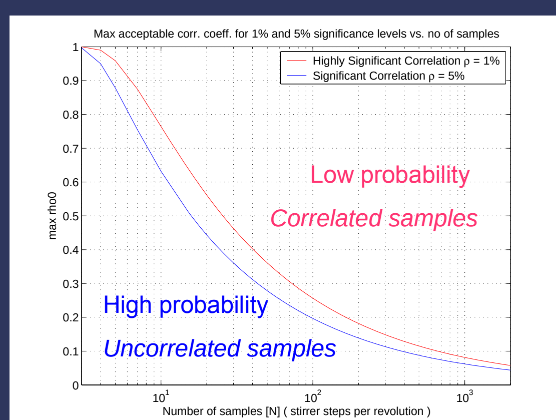
Max acceptable measured correlation coefficient for 1% and 5% significance vs. No. of samples



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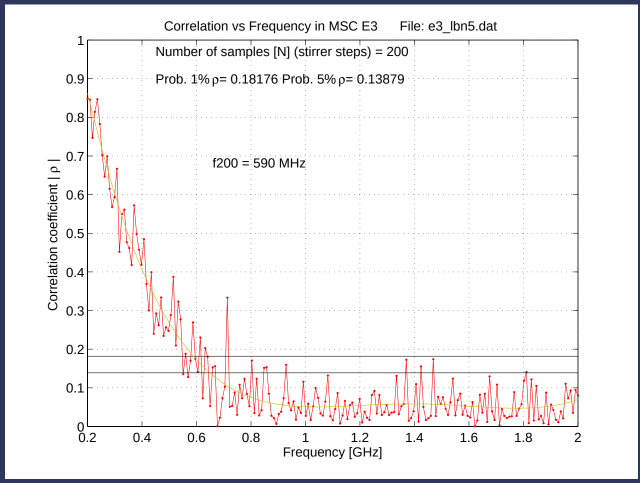
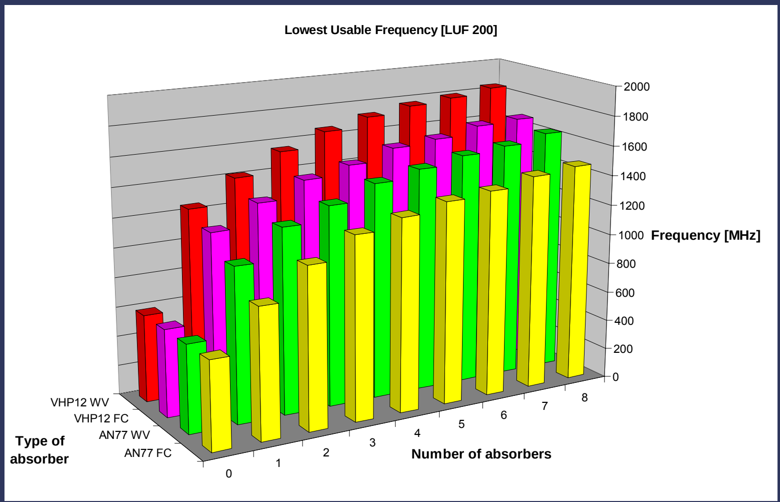
Lowest Usable Frequency f_{200}



Lowest Usable Frequency LUF_{200}



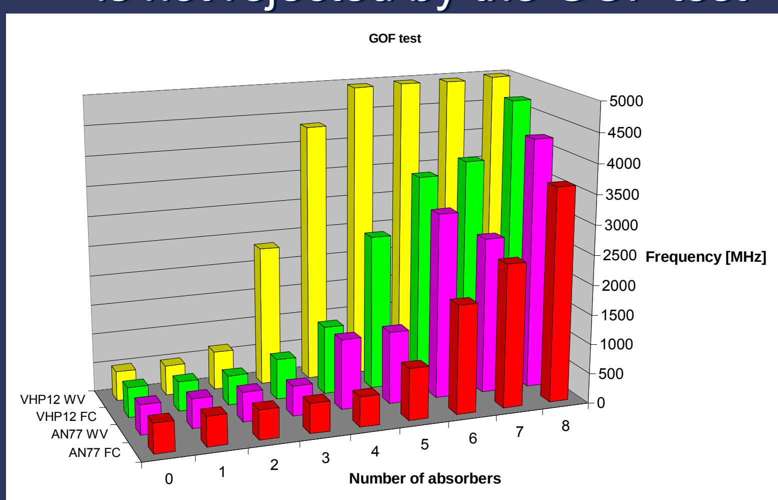
VIII. Goodness of fit tests

We expect that the received power follows a chi-square distribution with 2 DOF.

To decide whether our observed distribution is consistent with the expected theoretical

we calculate the Cumulative Distribution Function (CDF), and perform a $\chi 2$-test.

Lowest Frequency where $\chi 2$-distribution is not rejected by the GOF test

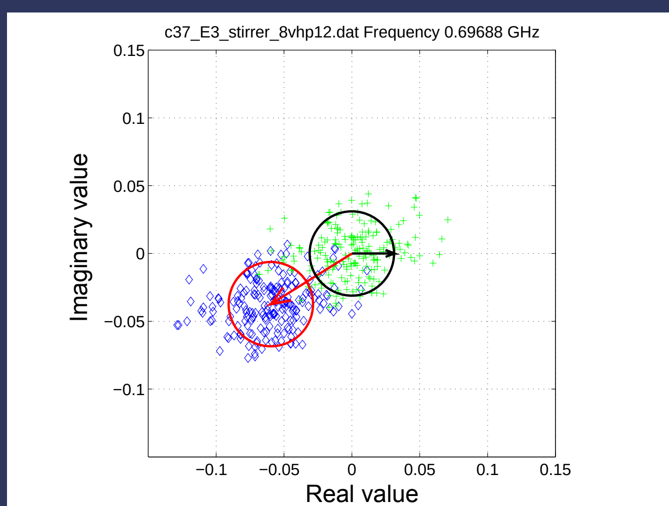


IX. Direct Path Components

The complex values, the real and the imaginary parts, of the measured insertion loss vs. all stirrer positions are expected to follow a normal distribution centered around zero.
Failing to do so mean that the stirrer is not able to stir the field efficiently.

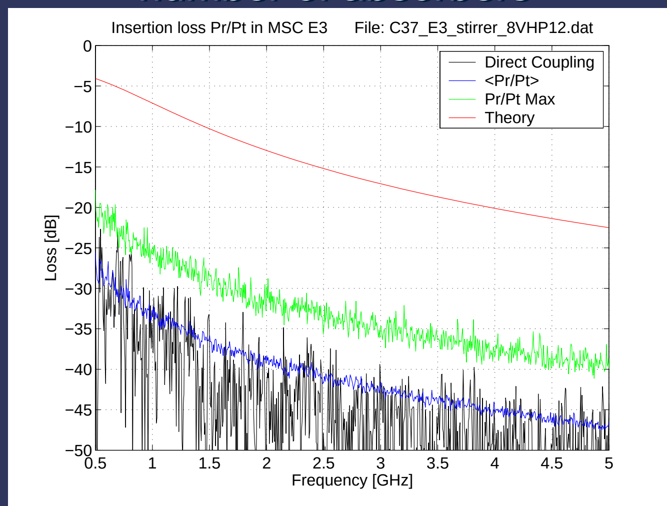
Plot of complex data at 696.88 MHz

Red arrow = Direct coupling between Tx and Rx antennas



Influence of direct component vs. the number of absorbers

0 to 8 VHP-12 absorbers In Working Volume



X. Conclusions

- Chamber loading according to the procedure in DO-160F gives approximately the same maximum field strength for the 1μs pulse, as for the unloaded chamber but a shorter pulse duration i.e. lower energy available for the EUT.
- One should be careful in using such complex pulses for RS-testing as the dwell time for the maximum field strength is very short and it might not be easy to tell what you are testing.
- Lowest usable frequency for uncorrelated samples will increase when the chamber is loaded. In other words, at a given frequency the number of uncorrelated stirrer positions will decrease when the Q-value is decreased.

Conclusions continued

- The $\chi 2$-distribution is affected due to chamber loading. This indicates that one must be careful when loading to not destroy the field isotropy.
- The fact that the lowest usable frequency LUF_{200} from correlation calculations and the GOF test don't coincide better is reflecting that one can have uncorrelated data even if it is not a chi-square distribution.

Conclusions continued

- Unstirred high frequency components are very likely to occur when the chamber is loaded
- This implies that data have some unwanted bias and that the statistically isotropic environment is violated.
- In RS- and RE-testing unstirred components cannot be corrected for which might lead to erroneous testing and that the chamber definitions are invalid.