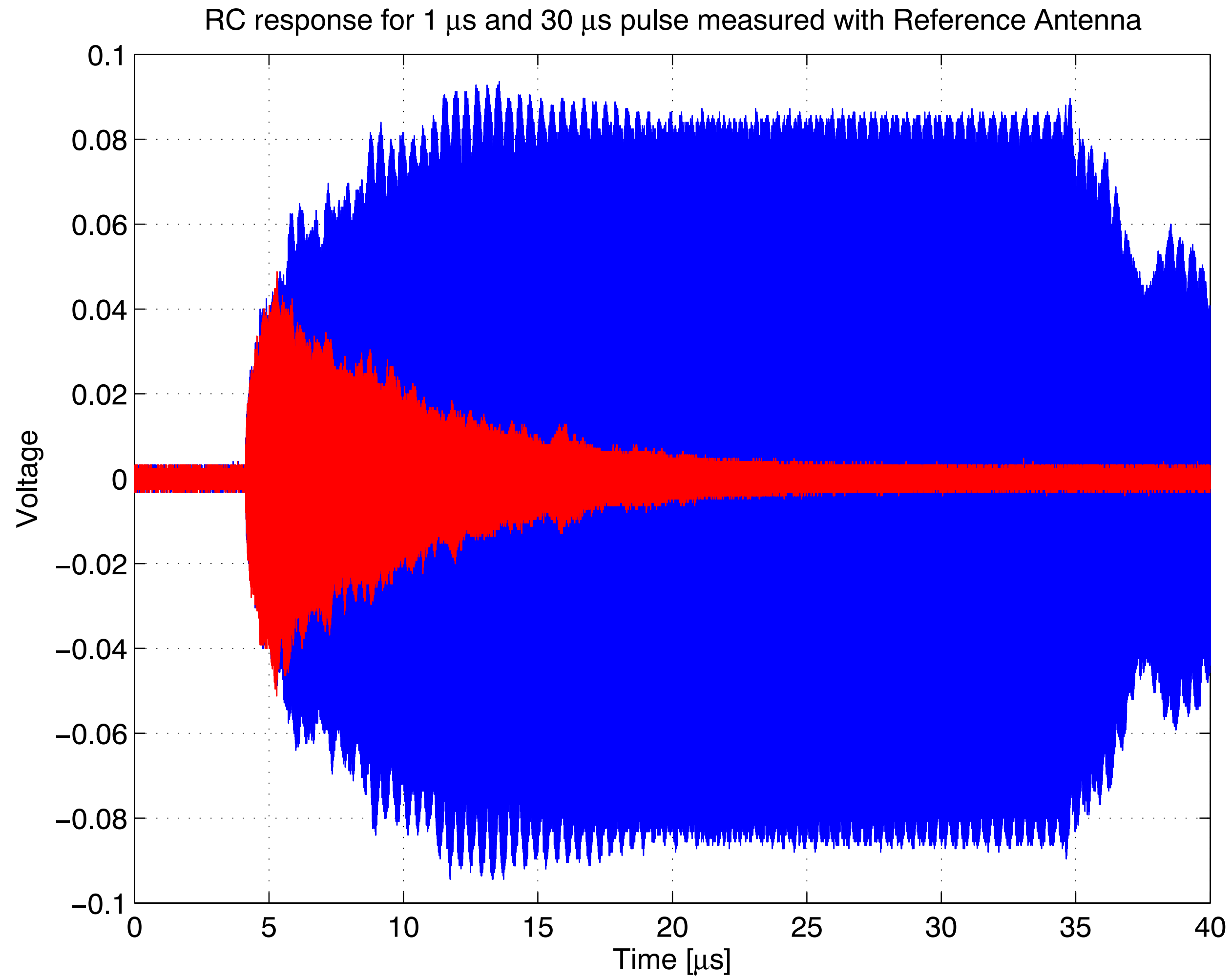
Pulsed Power 3 GHz Feasibility Study in FOI 36.7 m^3 Mode Stirred Reverberation Chamber

OLOF LUNDÉN, MATS BÄCKSTRÖM



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Abstract

A feasibility study was conducted to investigate the field build up process in a 36.7 m^3 reverberation chamber. The time to get a steady field state in the unloaded chamber will normally be about 10 - 20 μs. However, it is of great interest to investigate which field-levels that can be expected for an ordinary radar source. The particular 700 kW S-band radar we have to our disposal has typical pulse duration of 1 μs.

Maximum field strength of $E_{R,\max} \approx 35$ kV/m was achieved for 309 kW input power. The voltage ratio between the ensemble maxima, VR, due to that the chamber time constant is about 10 μs and the magnetron pulse is only 1 μs, was found to be 0.54.

The pulse characteristics have also been investigated when loading the chamber according to the aviation test standard RTCA DO-160.

This report provides a basis on how to conduct and interpret equipment HPM testing in reverberation chambers.

Keywords

Reverberation Chambers, High power, HPM

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Högnivåexcitation i modväxlande kammare (MVK). En realiserbarhetsstudie.

Sammanfattning

En realiserbarhetsstudie har utförts för att undersöka fältuppbyggnadsprocessen i en 36.7 m^3 modväxlande kammare (MVK). Tiden för att få ett stationärt fält i den olastade kammaren är normalt omkring 10 - 20 µs. Det är emellertid av stort intresse att undersöka vilken fältstyrka som man kan förvänta om kammaren exciteras från en vanlig radarkälla. För detta ändamål användes en 700 kW S-bands radar som finns tillgänglig som har en typisk pulsvaraktighet på 1 µs.
En maximal fältstyrka på $E_{R,\max} \approx 35$ kV/m uppnåddes för en ineffekt på 309 kW. Späningsförhållandet mellan ensemble maxima, VR, beroende på kammarens tidskonstant, uppmättes till 0.54.
Pulsegenskaperna har också undersökts när kammaren nedlastas med mikrovågsabsorberande material enligt standarden för provning av avionik RTCA DO-160D.
Rapporten ger ett underlag för hur tålighetsprovning av utrustning med HPM-pulser i MVK skall utföras och utvärderas.

Nyckelord
Modväxlande kammare, Högeffekt, HPM

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Index.

1. Introduction

A feasibility study was conducted to investigate the field build up process in a 36.7 m^3 reverberation chamber. The time to get a steady field state in the unloaded chamber will normally be about 10 - 20 µs. However, it is of great interest to investigate which field-levels that can be expected for an ordinary radar source. The particular 700 kW S-band radar we have to our disposal has typical pulse duration of 1 µs.
The pulse characteristics have also been investigated when loading the chamber according to the standard procedure in DO-160 [8].

2. Chamber diagnostics.

Figure 1 shows a block diagram over the low level measurement set-up to make the chamber diagnostics. All units are under computer control. The VHF-switch is provided to enable either a continuous wave (CW) or a pulsed modulated signal to the chamber. The microwave switch makes it possible to measure using an Oscilloscope with 6 GHz band width and with up to 20 Giga Samples per second or using a Microwave Spectrum Analyzer.

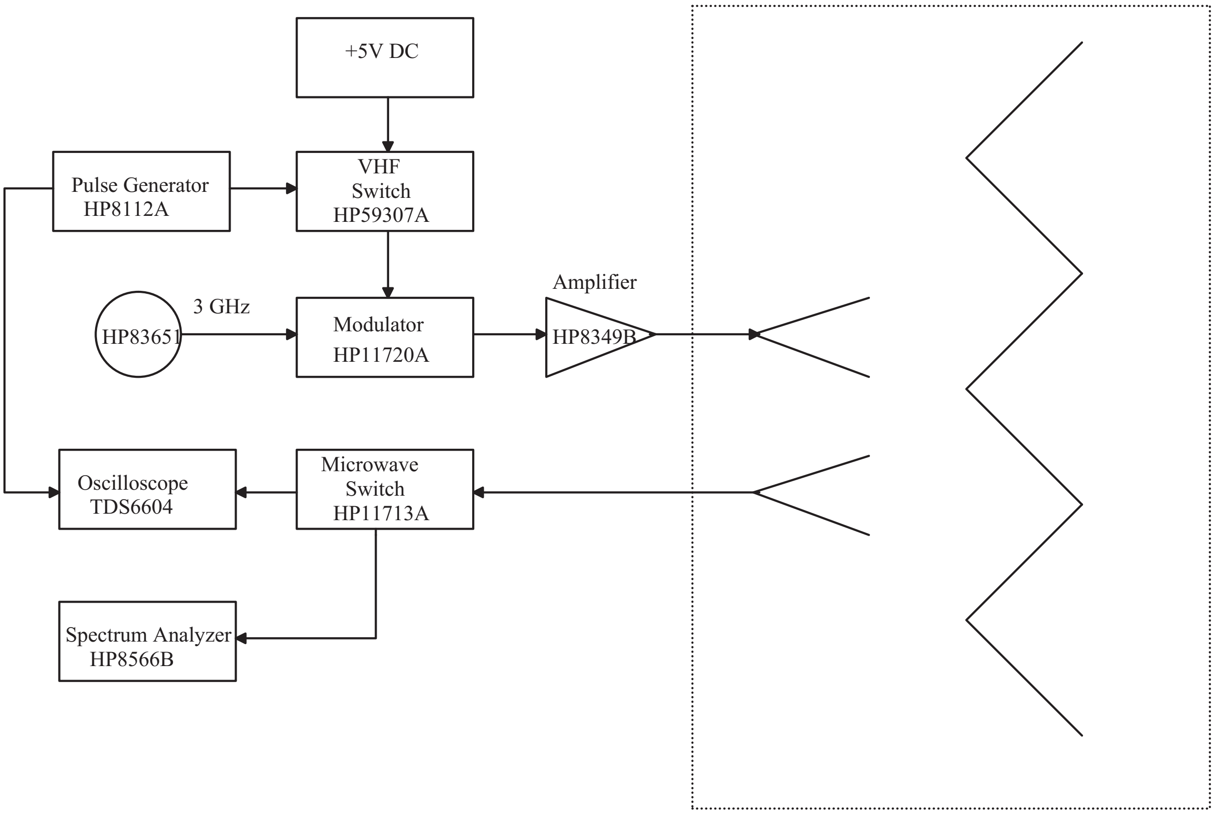


Figure 1. Schematic Measurement system Block diagram. Chamber with stirrer and antennas in right part.

3. Measurements

Measurements were made at 3 GHz with the pulse durations of 1, 20 and 30 µs. The Pulse Repetition Frequency (PRF) was 1 kHz. Chamber input power +20 dBm. CW measurements were also made for the same stirrer position, see the data acquisition flow chart in Figure 2.

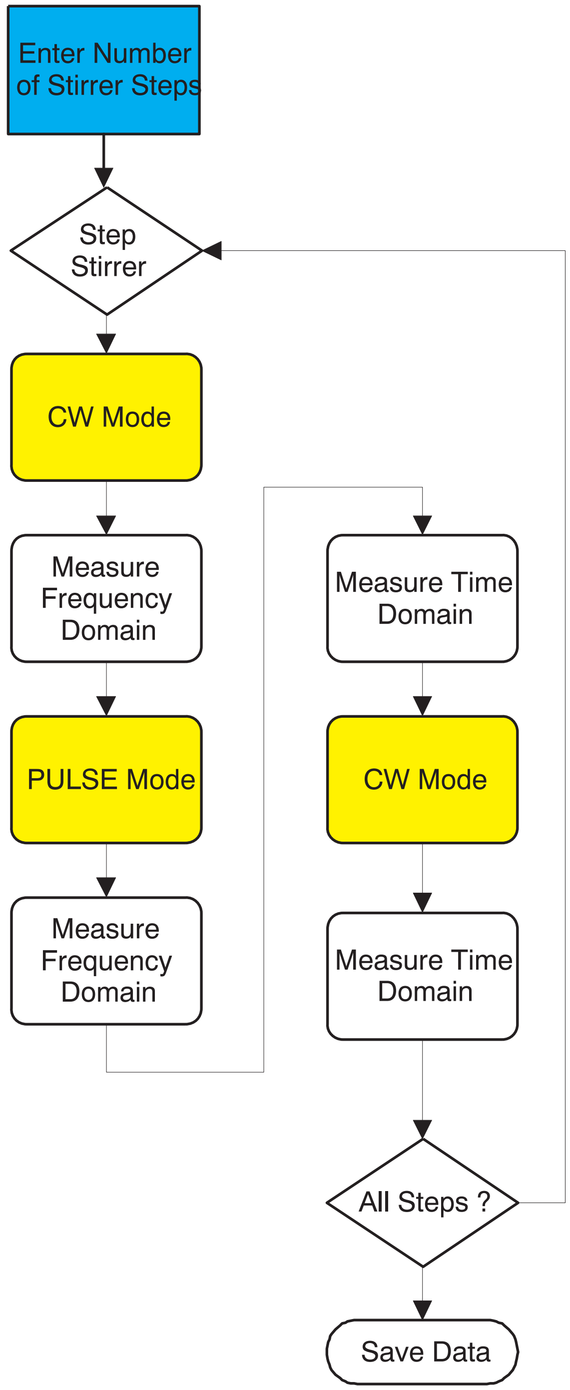


Figure 2. Measurement flow chart for chamber diagnostics.

100 000 samples was acquired with the oscilloscope for each of the CW and the pulsed modes for each of the 200 stirrer positions. The sampling interval was 200 ps.

4. Ensemble max concept

Normally some type stirrer/tuner is used in a reverberation chamber to achieve a statistically isotropic and homogeneous field distribution. Of interest are the ensemble values over one complete revolution. The performed measurements were done at 200 discreet stirrer steps and the ensemble maximum values in the chamber were collected. As an example the concept is illustrated for three stirrer positions and 1μs pulses in Figure 3 and Figure 4. In appendix A.1 twelve time responses, for the 1μs pulse, of the 200 stirrer steps have plotted to further illustrate the complex signal behavior.

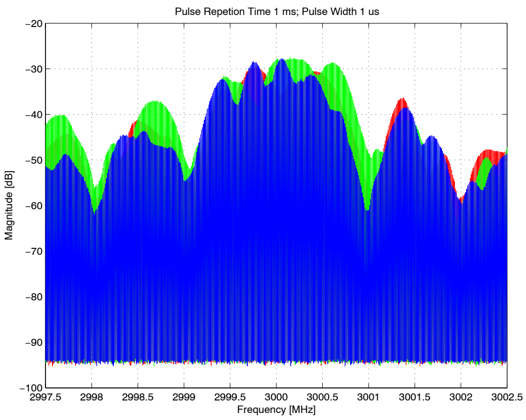


Figure 3. Ensemble spectrum over three stirrer positions

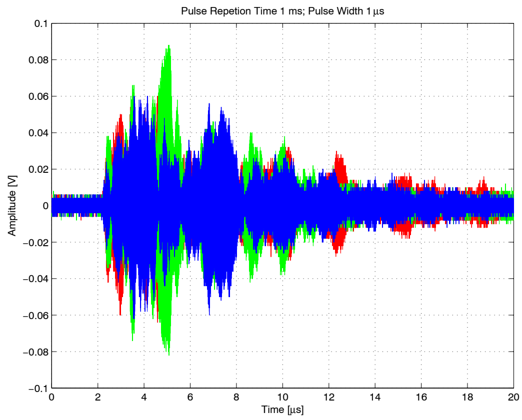


Figure 4. Ensemble time response over three stirrer positions

5. Results. Short pulse excitation

A frequency domain analysis of measurements of the chamber input signals are shown in Figure 5 and Figure 6. The corresponding ensemble maximum, over 200 stirrer steps measured in the chamber with the reference antenna, are shown Figure 7 and Figure 8 (note that the power levels in Figures 7 and 8 are shall not be related to those in Figures 5 and 6). The relation between maximum in CW and pulsed spectra can be expressed as the Pulse desensitization αP [1].

$$\alpha P = 20*\log 10\ (\tau_{eff}*K*B) \qquad (1)$$

where τ_{eff} = the pulse duration, K = impulse bandwidth, in this case 1.5, and B = analyzer bandwidth, in this case 100 kHz.

$\alpha P = 20*\log 10\ (1e\text{-}6*1.5*100e3) = -16.5$ dB

From the reference measurements Figure 5 and Figure 6 it can be seen that:
$\alpha P = -9.8 - (-26.5) = -16.7$ dB.
From the ensemble measurements Figure 7 and Figure 8 it can be seen that:
$\alpha P = -2.1 - (-17.5) = -15.4$ dB.

To conclude, the ensemble measurements in the frequency domain seems to give a reasonable representation the pulse spectra.

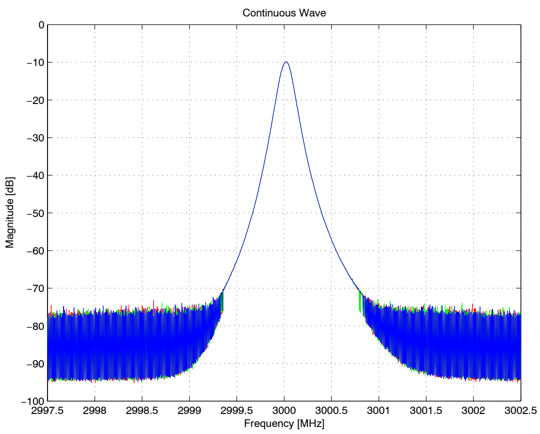


Figure 5. Chamber input signal. Frequency domain. CW. Max -9.8 dBm

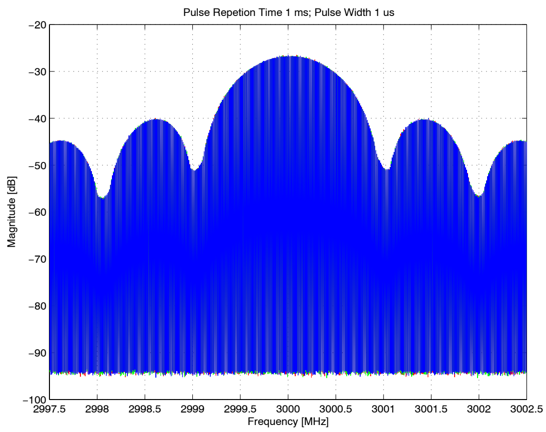


Figure 6. Chamber input signal. Frequency domain. Pulse width 1 µs. Max -26.5 dBm

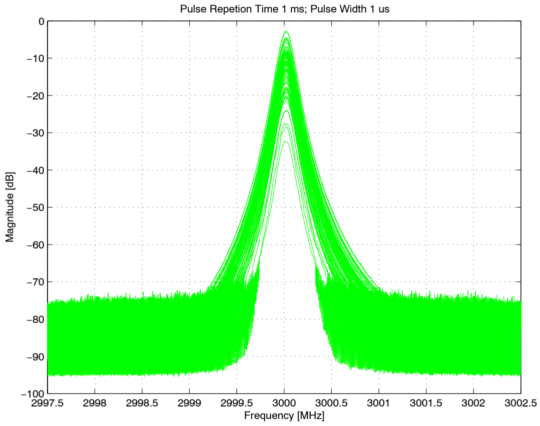


Figure 7. Signal measured with reference antenna in the chamber. Frequency domain. CW Max -2.1 dBm. 200 stirrer steps.

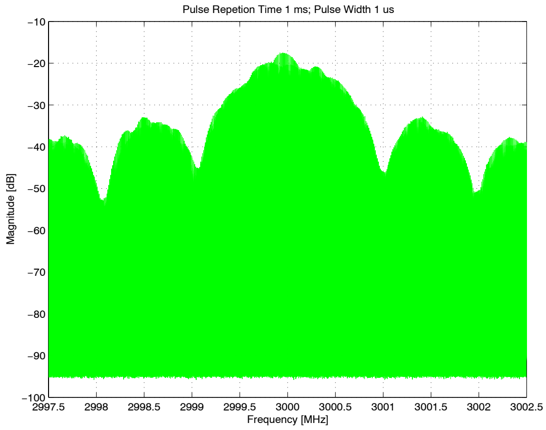


Figure 8. Signal measured with reference antenna in the chamber. Frequency domain. Pulse width 1 μs. Max -17.5 dBm. 200 stirrer steps.

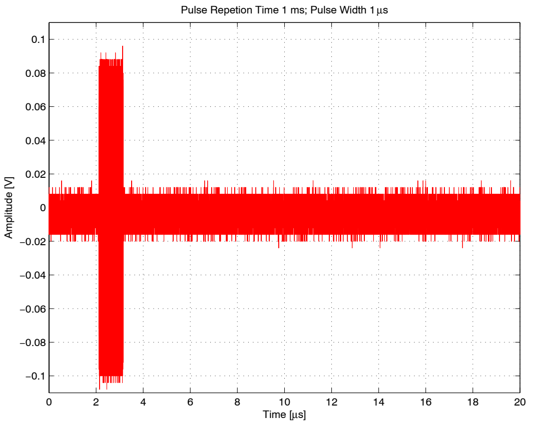


Figure 9. Pulse width 1 μs Chamber input signal. Time domain.

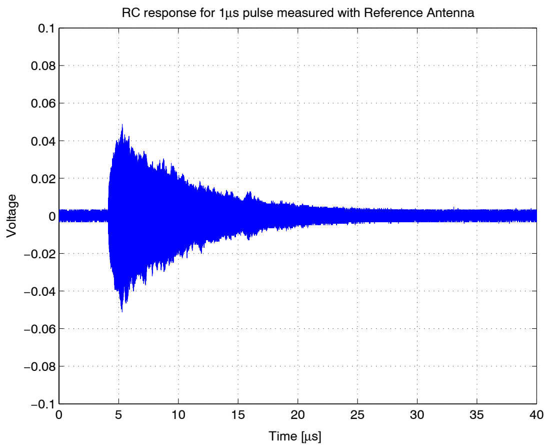


Figure 10. Ensemble Pulse for pulse width 1 μs. 200 stirrer positions. Chamber output signal max 48.8 mV. Time domain.

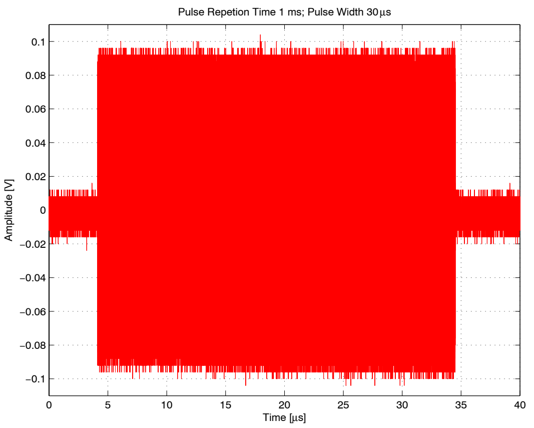


Figure 11. Pulse width 30 μs Chamber input signal. Time domain.

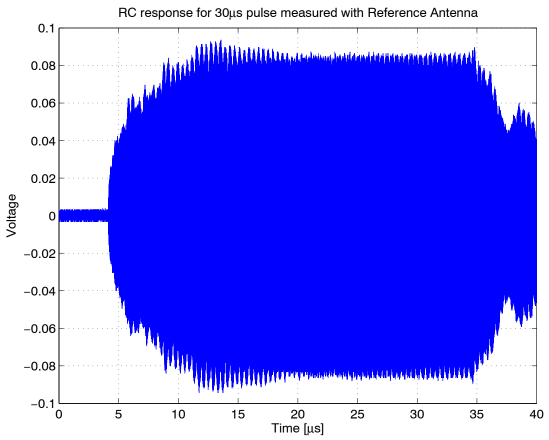


Figure 12. Ensemble Pulse for pulse width 30 μs. 200 stirrer positions. Chamber output signal max 90 mV. Time domain.

The pulse modulated 3 GHz chamber input signals can be seen in Figure 9 and Figure 11.

The Voltage Ratio between the ensemble maximum values for 1 μs, Figure 10, and 30 μs, Figure 12, pulses is VR = 48.8e-3/90e-3 ≈ 0.54.

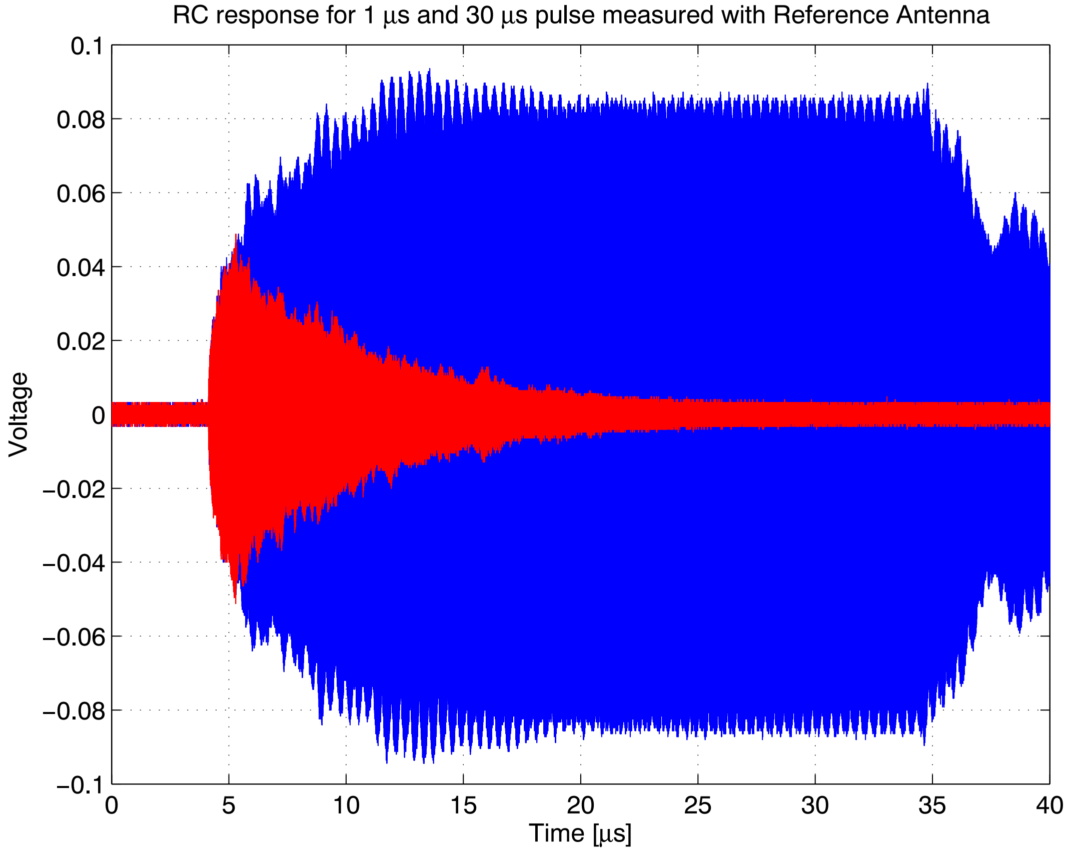


Figure 13. 1 µs (red) and 30 µs (blue) ensemble pulses superimposed. From Figure 10 and Figure 12

Figure 13 shows as expected that the ensemble pulse shapes are very similar during the first microsecond.

6. Estimate of field strength in a reverberation chamber

In an ideal reverberation chamber the ensemble average, in practice the average over all stirrer positions, of the square of the magnitude of the total electric field, $\langle E_T{}^2 \rangle$ fulfils:

$$\langle E_T{}^2 \rangle = \frac{\langle P_r \rangle \cdot 8\pi \cdot Z_0}{\lambda^2} \qquad (2)$$

where P_r is the power received in a (ideal) reference antenna and $Z_0 \approx 120\pi$ is the wave impedance of free space. Using the relation [Eq. (43) in [7]:

$$\langle P_r \rangle = \frac{\lambda^3 \cdot Q}{16 \cdot \pi^2 \cdot V} \cdot P_t \qquad (3)$$

the average field strength of the total electric field, $\langle E_T \rangle$, in the chamber can be estimated by:

$$\langle E_T \rangle \approx \sqrt{\frac{P_t * Q}{\varepsilon_0 * \omega * V}} \qquad (4)$$

For a rectangular component of the electric field, E_R, since $\langle {E_T}^2 \rangle = 3 \cdot \langle {E_R}^2 \rangle$, we can approximate:

$$\langle E_R \rangle \approx \frac{1}{\sqrt{3}} \sqrt{\frac{P_t * Q}{\varepsilon_0 * \omega * V}} \qquad (5)$$

where P_t is the input power, Q is the Q-value for the chamber and V is the chamber volume.

Assuming Equation (3) to be exact the error in (4) is, for all choices of the number of stirrer positions, N, always less than 0.36 dB, cf. the comment in connection to Eq. (6) below. The error in (5), assuming (3) to be exact, is limited to about 1 dB for values of N smaller than 1000, see the discussion in connection to Equation (6) below.

For the S-band magnetron with 700 kW nominal pulsed power, Q = 34800 and V = 36.7 m^3, this would, neglecting transmission losses, give an average of the total electric field of about 63 kV/m under CW conditions. To get an estimate of the average of the peak electric field strength for the 1 μs pulse we use the multiplication factor VR (see above) which yields the average total electric field strength for a complete stirrer revolution of about 34 kV/m. The scalar power density at the peak of the 1 μs pulse can be calculated from $S = E_T^2/(120*\pi)$ [W/m^2]. This turns out to be about 3.1 MW/m^2. Thus, the corresponding average (over all stirrer positions) peak power received from the reference antenna in the reverberation chamber can be calculated to 1.2 kW from $\langle P_r \rangle = S \cdot \lambda^2 / 8\pi$, where λ = the wavelength.

7. High Power Measurements

7.1. Introduction

The 700 kW S-band source, normally used for high level testing, is located in an adjacent shielded room to the mode stirred chamber. This magnetron has been in operation since 1959 and works at present more reliable at somewhat lower powers. For simplicity a 15 m waveguide was connected between the source and the reverberation chamber, see Figure 14 and Figure 15. The waveguide losses were measured to 0.7 dB at 3 GHz. The block diagram can be seen in Figure 16.

Figure 14. Part of Waveguide system.

Figure 15. Magnetron, adjustable power splitter, coupler and waveguide switch.

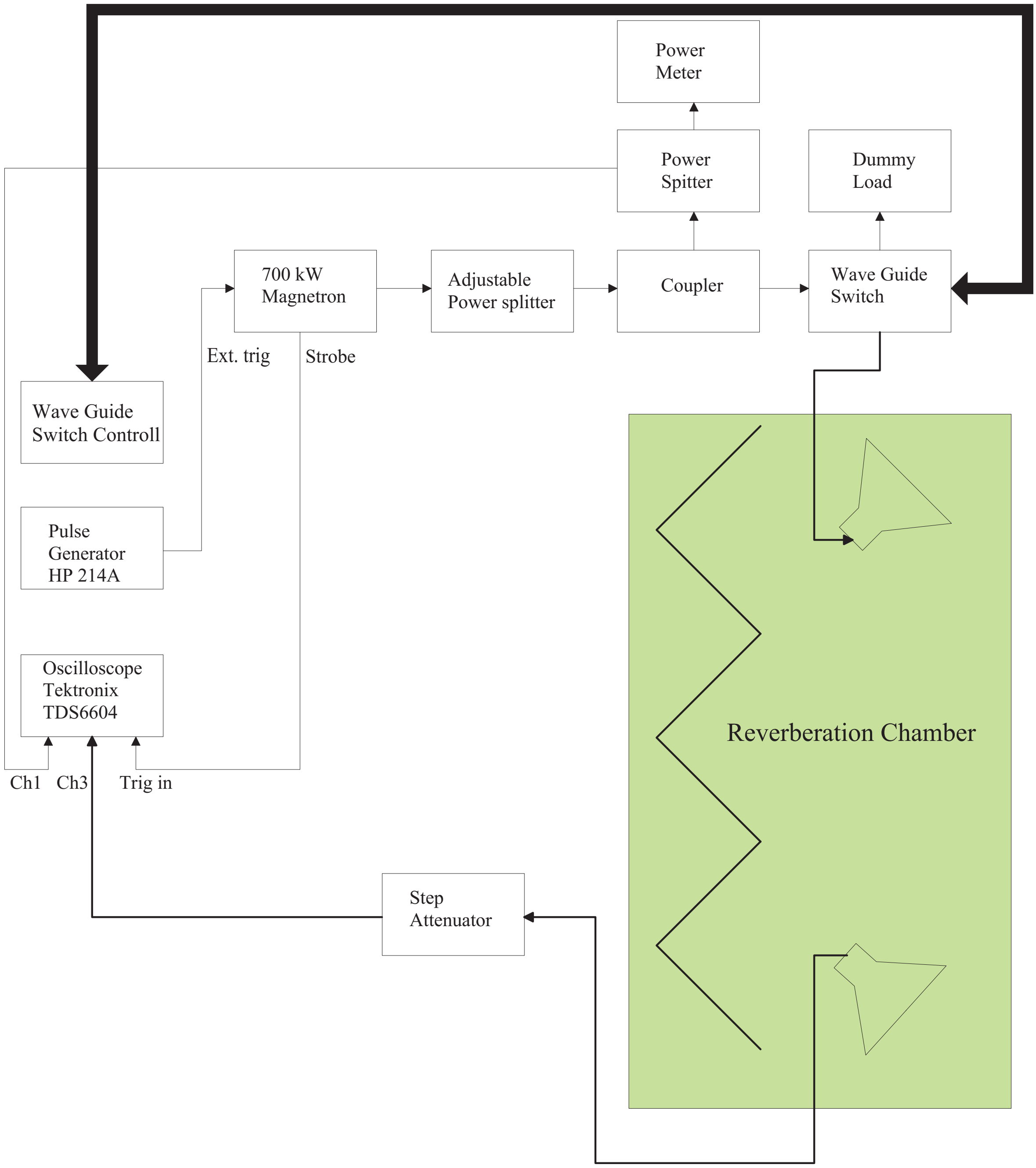


Figure 16. Block diagram for High power measurements using 700 kW S-band source.

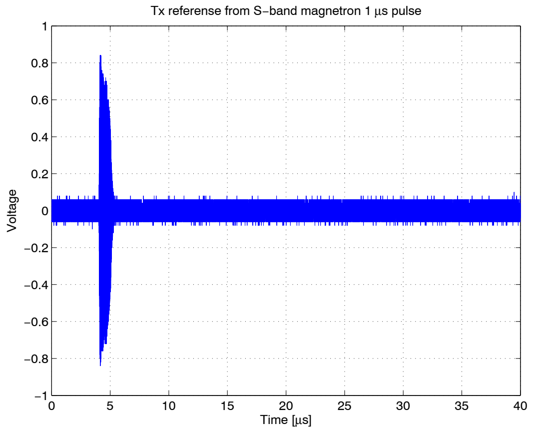


Figure 17. Transmitted signal from the magnetron, 1 µs pulse. Max 840 mV. $P_{t,\,magnetron}$ = 366 kW

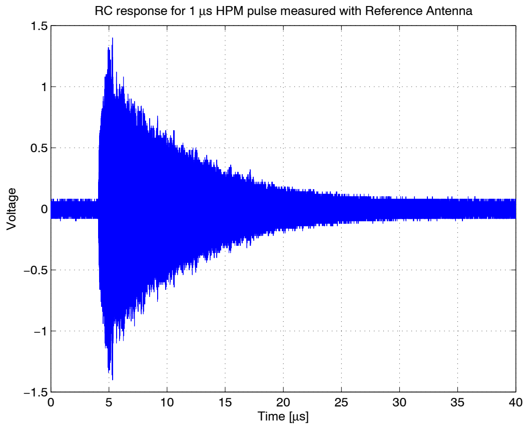


Figure 18. Reverberation chamber response signal for 1 µs pulse measured with reference antenna. Max 1400 mV. $E_{R,max}$= 35 kV/m

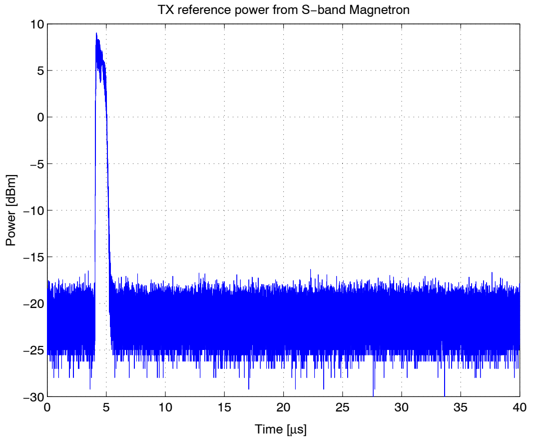


Figure 19. Transmitted power from the magnetron, 1 µs pulse. Max power 9 dBm

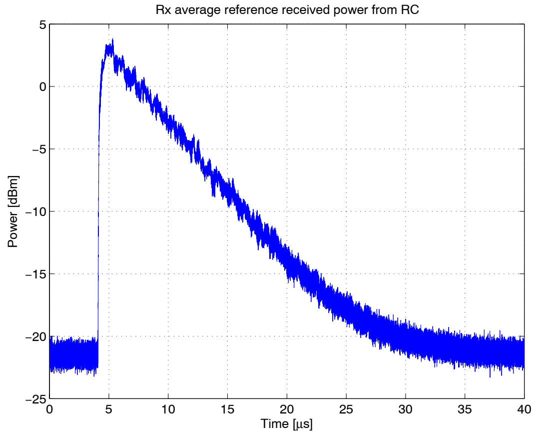


Figure 20. Reverberation chamber power response for 1 µs pulse measured with reference antenna. Max power 3 dBm

Figure 21. Reference antenna.

Figure 22. Transmitting antenna.

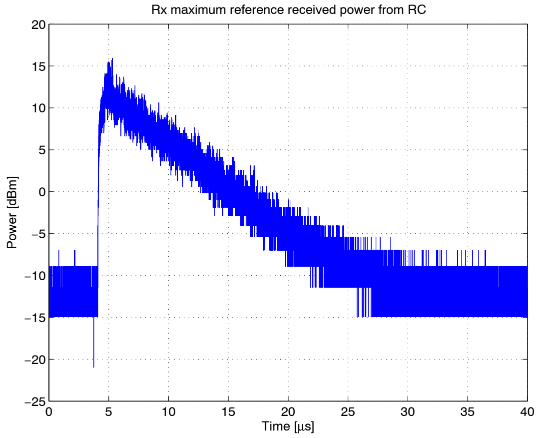


Figure 23. Rx reference maximum received power from RC

7.2. Chamber input power.

The transmitted power is monitored at CH1 on the oscilloscope. The total attenuation is 76.6 dB. The RMS value in 50 ohms, from Figure 17, is 594 mV which corresponds to 9 dBm, Figure 19. Taking the cable losses and the coupling into account, 17.3 + 59.3 = 76.6 dB, this gives the transmitted power to 366 kW (85.6 dBm). Adding the waveguide losses 0.7 dB gives the chamber input power 309 kW. This gives using (2) the average total electric field strength $\langle E_T \rangle \approx 42$ kV/m. Reduced with the factor VR from above this gives the expected average peak field strength $\langle E_T \rangle \approx 23$ kV/m for a 1 µs pulse length.

7.3. Chamber average received reference power.

The reference antenna can be seen in Figure 21. The total attenuation between the antenna and the oscilloscope is 53.6 dB. The average received peak power over the 200 stirrer steps in 50 ohms, Figure 20, gives 3 dBm. This gives the received average peak power in the antenna, 3 + 53.6 = 56.6 dBm or 457 W.

7.4. Chamber average field strength.

As was shown above it holds (approximately):

$$\langle E_T \rangle \approx \sqrt{\frac{\langle P_r \rangle \cdot 8\pi \cdot Z_0}{\lambda^2}} \qquad (6)$$

In the same manner as going from Equation (4) to (5) we can also write:

$$\langle E_R \rangle \approx \sqrt{\frac{\langle P_r \rangle \cdot 8\pi \cdot Z_0}{3 \cdot \lambda^2}} \qquad (7)$$

The error in (6) is, for all choices of the number of stirrer positions, N, always less than 0.36 dB [2]. The error in (7) is larger than the error in (6). From column 4 and 5 in Table 1 we see that the error increases from 0 dB for N = 1, 0.93 dB for N = 20, 1.00 dB for N = 200 to 1.02 dB for N = 1000. Thus, for N values of practical interest the error is about 1 dB.

From (6) we get the average peak field strength $\langle E_T \rangle \approx 20.8 \approx 21$ kV/m.

The difference in from the expected average field strength 23 kV/m to the measured 21 kV/m is -0.9 dB.

7.5. Chamber maximum received power.

The RMS value of the ensemble maximum in 50 ohms, from Figure 18, is 920 mV which corresponds to 17 mW or 12.3 dBm, Figure 23. This gives the maximum received peak power, 12.3+ 53.6 = 65.9 dBm or 3.89 kW.

7.6. Chamber maximum field strength.

Due to the fact that the power, P_r, received in a reference antenna follows the same statistical distribution as the square of an rectangular component of the electric field, $E_R^{\,2}$, means that the maximum of a rectangular component of the electric field, $E_{R,\max}$, can be approximated using equation (7) above, with the same uncertainty i.e. around 1 dB for typical values of N:

$$E_{R,\max} \approx \sqrt{\frac{P_{r,\max} \cdot 8\pi \cdot Z_0}{3 \cdot \lambda^2}} \approx \frac{8\pi}{\lambda} \cdot \sqrt{5 \cdot P_{r,\max}} \qquad (8)$$

This expression is used to estimate the maximum electric field in the IEC standard [3].

Note that a corresponding approximation erroneously assuming $E_{T,\max} = \sqrt{3} \cdot E_{R,\max}$ yields a much larger error than Equation (8). The value of $E_{T,\max}$ will be overestimated and the error will increase by the number of stirrer positions used. As an example, from Table 1 in [2] we get an expected error of 2.5 dB for N=200, cf. also next paragraph and Figure 2 in [2].

From $\langle P_{r,\max} \rangle = 3.89$ kW we get from (8) that $E_{R,\max} \approx 35$ kV/m (since it holds that $\langle E_T^{\,2} \rangle = 3 \cdot \langle E_R^{\,2} \rangle$ we can estimate $E_{T,\max}$ using the second and fourth column in Table 1 in [2], yielding for N = 200: $E_{T,\max} \approx \sqrt{3} \cdot \sqrt{3.321/5.878} \cdot 35 = 46$ kV/m).

The difference between the average measured peak field strength $\langle E_R \rangle \approx 12.0$ kV/m and the maximum 35 kV/m is 9.3 dB. On would expect this difference to be 2.721 i.e. 8.7 dB for N=200 (5th column for N=200 in Table 1, in [2]).

Note: Since the equations (4) to (8) above are exact if the average of the square of the electric field is used instead of the magnitude of the electric field (and, evidently, the right hand sides of the equations are squared) it is more appropriate to compare the measured max to mean ratio of 9.3 dB with the value for P_r and $E_R^{\,2}$ in the fourth column in Table 1 in [2]. This gives an expected ratio equal to 7.7 dB. From Figure 47 in [4] we get the value for the median value 7.5 dB and the 95% confidence interval to be between 6.0 and 9.5 dB. Thus, the measured value is within the 95% confidence interval. Still, the differences to the expected mean and median is rather clear. The difference could be due to the fact that the 1 μs pulses do not reach the steady state level due to the long time constant of the chamber. This makes the determination of $E_{R,\max}$ uncertain, cf. the measured pulses in Appendix A.

8. Comment on definition of test level

8.1. An ongoing debate

The discussion o how to define the test level for a radiated susceptibility test in a reverberation chamber has been going on for a long time. By test level it is meant the estimated maximum level stressing the EUT for a given number of statistically independent (in practice uncorrelated) stirrer positions. Or, if the stirrer is rotated continuously, the maximum attained over a complete turn of the stirrer. The main alternatives have been to define the test level in terms of the magnitude of the total electric field or in terms of the magnitude of a rectangular component of the electric field. In this report we have chosen the latter, which is also the approach in the IEC standard [3]. The reason for our choice is that the power absorbed by an antenna in a reverberation chamber follows the same statistical function as the magnitude of the square of a rectangular component of the electric field, together with the experience that the power delivered to an electronic component inside a EUT follows the very same distribution. The latter is of course not surprising since the wires and cables picking up the energy are expected to behave as antennas. The total electric field, on the other hand, may be of interest e.g. in direct heating of the bulk of a component, cf. the discussion in [2]. In the standard DO-160D [8] the magnitude of the total electric field strength is chosen. The test level, $E_{T,\max}$, is derived from:

$$E_{T,\max}{}^{2} \approx P_{r,\max} \cdot 8\pi \cdot Z_0 / \lambda^2 \qquad (9)$$

However, as already mentioned, Equation (9) involves quite a large error. To our knowledge this will be corrected for in the forthcoming version of DO-160E. The expected error for different number of stirrer positions N can be derived from Table1 in [2]. Since the exact relation between E_T and P_r is given by Equation (2) above we shall compare the maximum to mean ratios for $|E_T|^2$ and P_r. It follows that Equation (9) yields an overestimate of the true value of $E_{T,\max}$ by

$\sqrt{2.929/2.046} = 1.20$, i.e. 1.6 dB for N =10

$\sqrt{4.499/2.746 = 1.28}$, i.e. 2.1 dB for N = 50

$\sqrt{5.878/3.321} = 1.33$, i.e. 2.5 dB for N = 200

8.2. A new definition using the electric field. A better alternative?

In a statistical sense the most appropriate choice of the test level would presumably be $E_{Test} = \sqrt{3} \cdot E_{R,\max}$. The motivation is that the power dissipated in a load (e.g. a critical component in a EUT) in a test in a reverberation chamber equals $P_{r,\max} = (\lambda^2/8\pi) \cdot \eta \cdot q \cdot (3 \cdot E_{R.\max}{}^2 / Z_0)$. In this expression the parameter η represents the losses and q the impedance mismatch factor between the load and the wire (wire in a broad sense) connected to the load, cf. Equation (1) in [5]. In a plane wave test using one angle of incidence and one polarization, both randomly chosen, one gets a similar expression for the expectation value of $P_{r,\max}$. In this case $3 \cdot E_{R,\max}{}^2$ is replaced by $E_{inc}{}^2$, where E_{inc} is the magnitude of the plane wave electric field of the field irradiating the EUT. The reason for the equality between the two expressions is that the random choice of the angle of incidence yields an expected value of the directivity of the EUT equal to one, while the expected value of the polarization becomes ½.

8.3. Using power instead of electric field. The ultimate solution?

As shown above it is not completely straightforward to choose between $E_{T,\max}$ and $E_{R,\max}$ (or $\sqrt{3}\cdot E_{R,\max}$!) as the most appropriate definition of the test level in a reverberation chamber. One way to circumvent the problem would be to define the test level in terms of the power absorbed by an ideal antenna, thus leaving the somewhat confusing notation of electric field in a reverberation chamber behind. This seems to be a univocal entity, cf. [6] (reference [6] will be followed by a report more explicitly dealing with this approach).

9. Chamber loading.

According to the standard DO-160D [8] one shall load the chamber with absorbing material to get a time constant that is 40 % of the pulse duration i.e. we need to make the chamber time constant about 0.4 µs. The time constant is defined as 63% of the pulse final value. This can be calculated from the chamber Q-value as $\tau = \dfrac{Q}{2\pi f}$ where f is the frequency.

The Q-values have been measured for different number and type of absorbers in floor and working volume configuration and cab be seen in Table 1. The corresponding time constants can be seen in Table 2.

Q-value for E3 at 3 GHz

Q E3	VHP12WV	AN-77WV	VHP12FC	AN-77FC
0	34800	34800	34800	34800
1	3710	6300	4890	8970
2	1940	3400	2680	5130
3	1190	2240	1840	3490
4	840	1310	1460	2260
5	605	1070	1090	2050
6	502	903	915	1690
7	413	775	755	1400
8	323	667	613	1210

Table 1. Q-values for chamber E3 at 3 GHz for 0 to 8 Eccosorb AN-77 and Rantec VHP-12 absorbers in floor configuration (FC) and in the working volume (WV).

Time constant in ns for E3 at 3 GHz

	VHP12WV	AN-77WV	VHP12FC	AN-77FC
0	1846	1846	1846	1846
1	197	334	259	476
2	103	180	142	272
3	63	119	98	185
4	45	69	77	120
5	32	57	58	109
6	27	48	49	90
7	22	41	40	74
8	17	35	33	64

Table 2. Time constants in ns for chamber E3 at 3 GHz for 0 to 8 Eccosorb AN-77 and Rantec VHP-12 absorbers in floor configuration (FC) and in the working volume (WV).

From Table 2 we select one piece AN-77 in floor configuration to our investigation to get the time constant 0.476 µs. Results from the unloaded chamber can be seen in Figure 24 for 1 µs and 30 µs and in Figure 25 for the loaded chamber. These are low level measurements c.f. Figure 1.

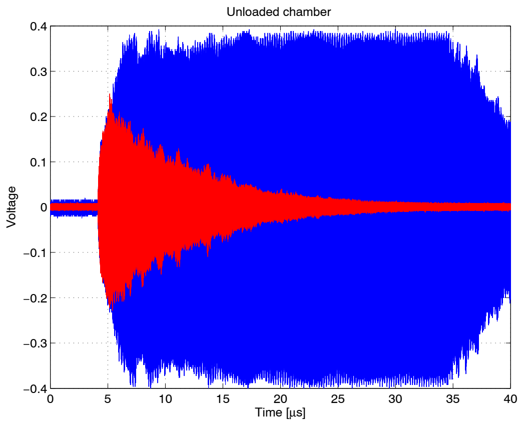


Figure 24. Unloaded chamber. 1 µs and 30 µs pulse. Max for the 1 µs pulse is 0.250 V

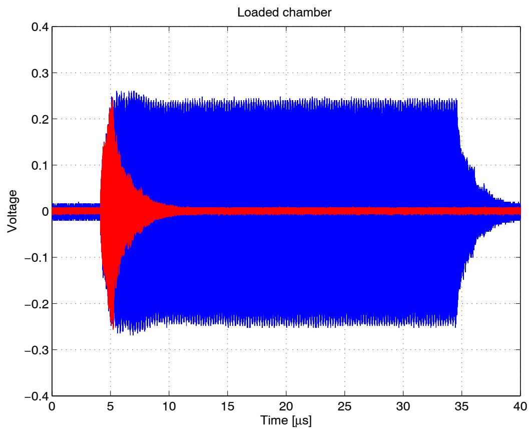


Figure 25. Chamber loaded with one AN-77 absorber. 1 µs and 30 µs pulse. Max for the 1 µs pulse is 0.246V

One can observe that the 1 µs pulse has a very similar maxima values in the loaded and unloaded configuration although that the total energy, i.e. the length of the pulse, is sufficiently higher in the unloaded case.
From high level testing, as illustrated in figure 16, we make the same conclusions. See Figure 26. No significant magnitude change can be observed at this frequency when loading the chamber. Individual pulses from unloaded chamber and loaded chamber can be seen in Appendix A.2

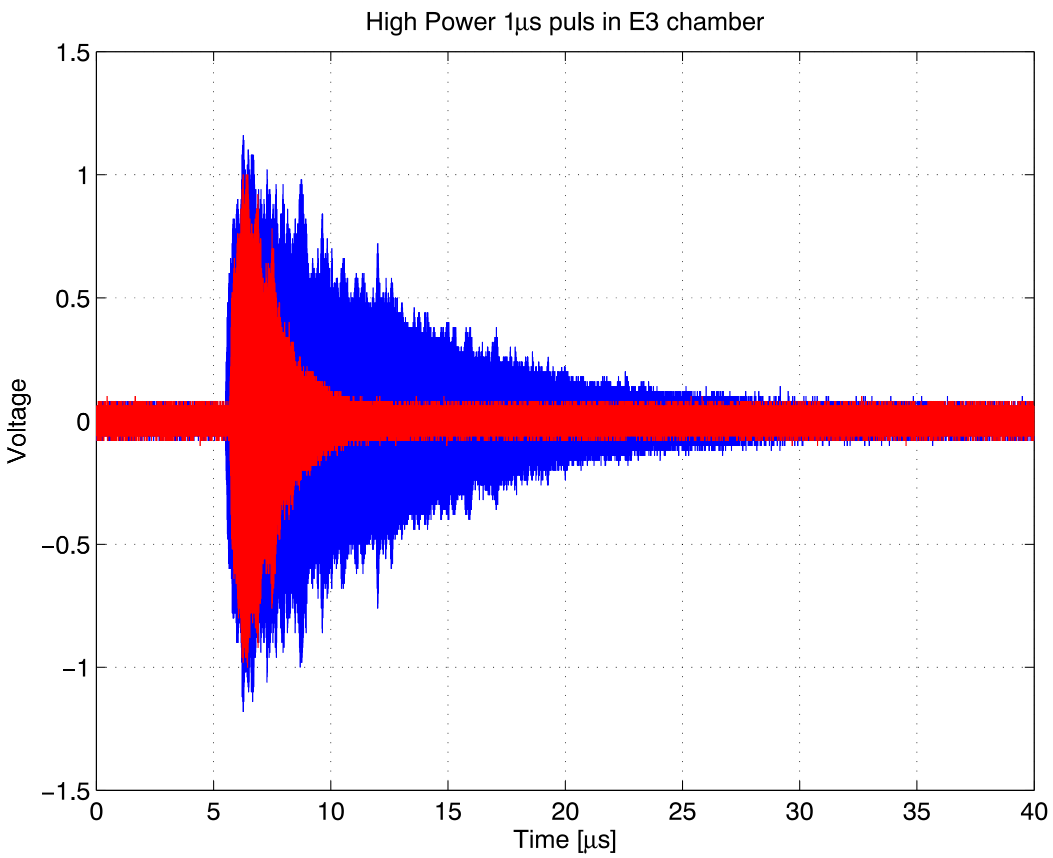


Figure 26. High level testing in the loaded (red) and the unloaded (blue) chamber.

10. Vulnerability experiments.

Some simple RS testing was performed on a couple of electronic calculators. As the electronic calculators were mounted in a shielded box, Figure 27, they survived at $E_{R,\max} \approx 35$ kV/m. However without the electromagnetic shield they were permanently destroyed after exposure.

Five USB 256 MB memories, Figure 28, were also exposed to the same radiation without any noticeable degradation even if connected to extension cords.

Figure 27. Electronic calculator.

Figure 28. Five USB256 MB memories.

11. Conclusions

A feasibility study has been conducted to investigate the use of a 3 GHz magnetron as a source for HPM testing. A maximum field strength of $E_{R,\max} \approx 35$ kV/m was achieved for 309 kW input power. The voltage ratio between the ensemble maxima, VR, due to that the chamber time constant is about 10 µs and the magnetron pulse is only 1 µs, was found to be 0.54.

Chamber loading according to the procedure in DO-160D [8] gives approximately the same field strength but lower total energy and shorter pulse duration.

12. References

[1] Application Note 150 – 2, Spectrum Analysis … Pulsed RF, November 1971, Hewlett Packard 5952-1039

[2] J. M. Ladbury and G. H. Koepke, “Reverberation Chamber Relationships: Corrections and Improvements or Three Wrongs Can (almost) Make a Right,” in Proceedings of the 1999 IEEE International Symposium on Electromagnetic Compatibility, Seattle, USA, pp. 1-6.

[3] IEC 6100-4-21, “Electromagnetic compatibility (EMC). Part 4.21: testing and measurement techniques – Reverberation chamber test methods”, International Electrotechnical Commission, IEC, 2003.

[4] Olof Lundén, Mats Bäckström and Niklas Wellander, ”Evaluation of Stirrer Efficiency in FOI Mode-Stirred Reverberation Chambers”, FOI Scientific Report, FOI-R—0250—SE, October 2001. Swedish Defence Research Agency FOI, Sensor Technology, P.O. Box 1165, SE-581 11 Linköping, Sweden.

[5] Mats Bäckström, Karl Gunnar Lövstrand, ” Susceptibility of Electronic Systems to High-Power Microwaves: Summary of Test Experiences”, IEEE Transactions on Electromagnetic Compatibility, Vol. 46, No. 3, August 2004, pp. 396 – 403.

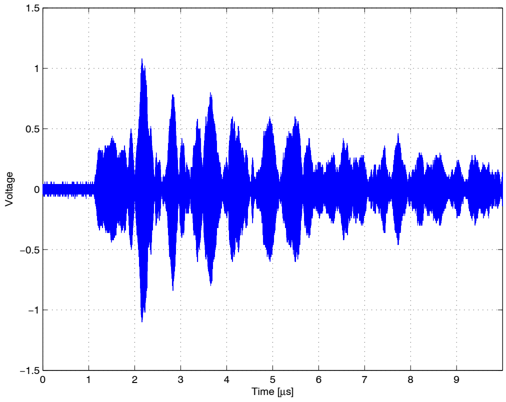
[6] Magnus Höijer, “The Maximum Power Available to Stress Onto the Critical Component in the Equipment Under Test when Performing a Radiated Susceptibility Test in the Reverberation Chamber”. Accepted for publication in IEEE Transactions on EMC, May 2006.

[7] D. A. Hill, M. T. Ma, A. R. Ondrejka, B. F. Riddle, M. L. Crawford, and R. T. Johnk [1994], “Aperture Excitation of Electrically Large, Lossy Cavities,” IEEE Transactions on Electromagnetic Compatibility, EMC-36, 3, pp. 169-178.

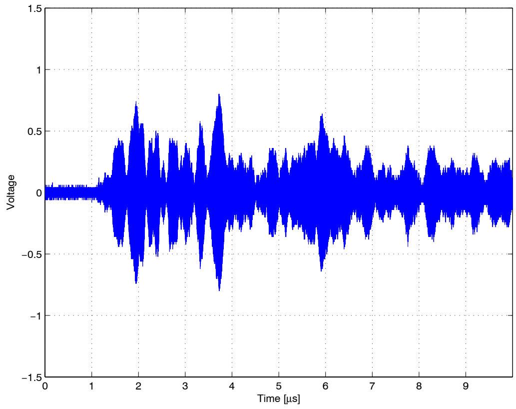
[8] “RTCA/DO-160D Environmental Conditions and Test Procedures for Airborne Equipment, Section 20 Radio Frequent Susceptibility (Radiated and Conducted)”, RCTA, Inc., Washington D.C., USA, March 1997.

Appendix A.1

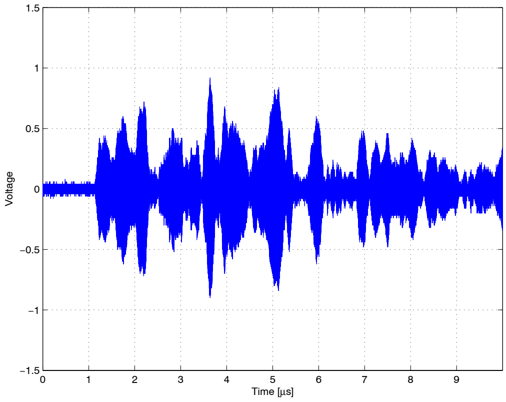
Twelve individual low level 1µs pulses from unloaded chamber.



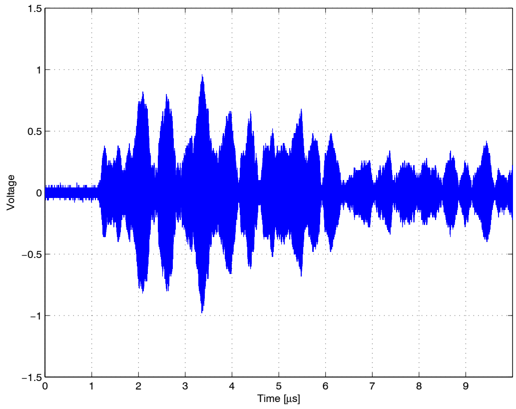
1. Max 1.08 V



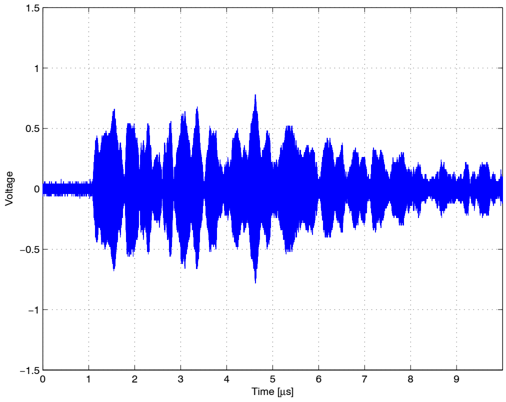
2. Max 0.8 V



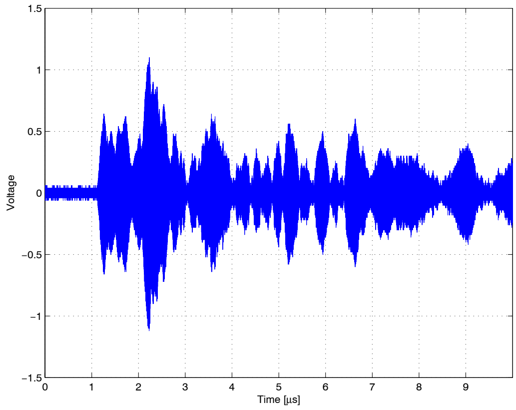
3. Max 0.92 V



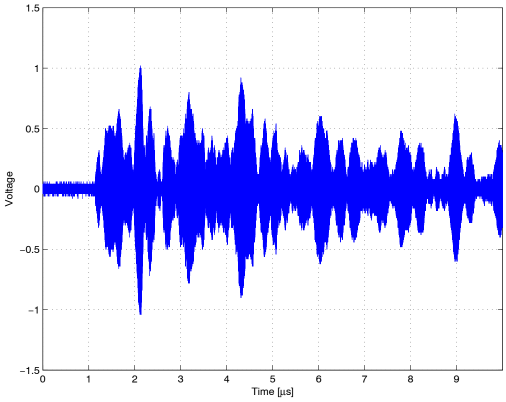
4. Max 0.96 V



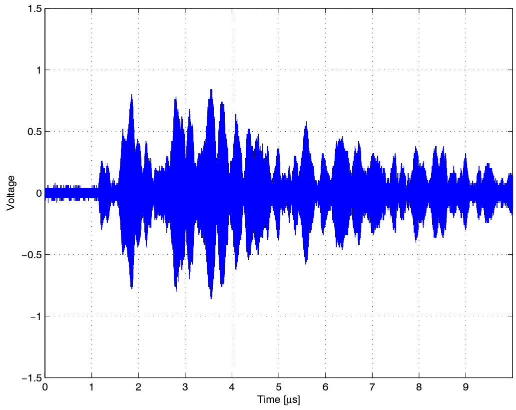
5. Max 0.78 V



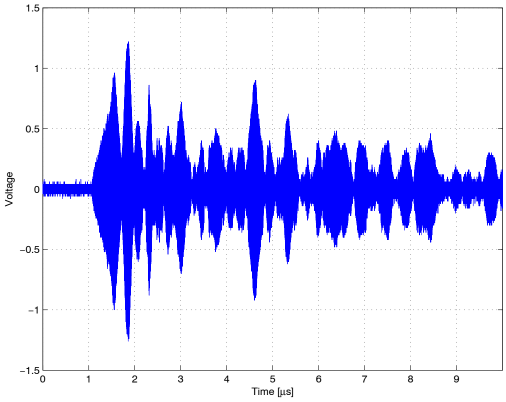
6. Max 1.1 V



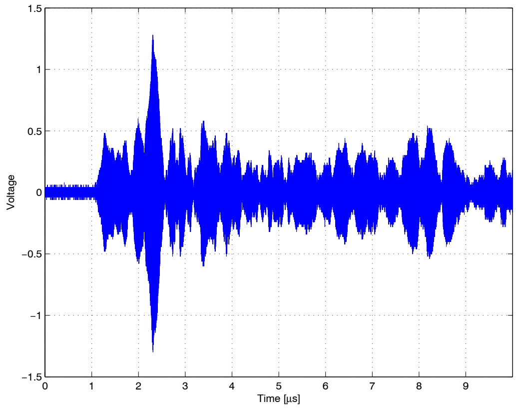
7. Max 1.02 V



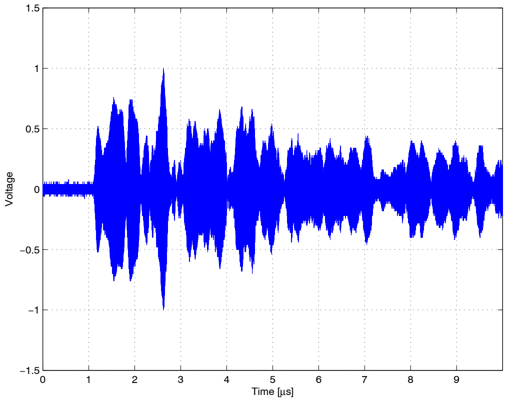
8. Max 0.84 V



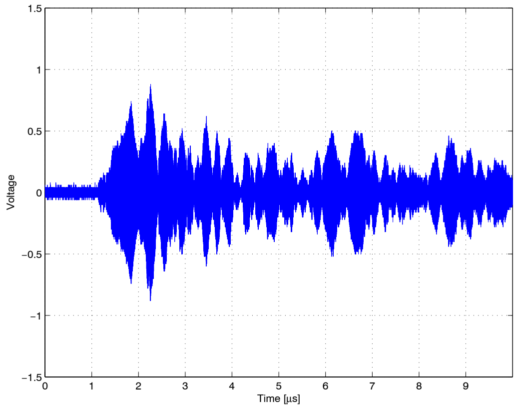
9. Max 1.22 V



10. 1.28 V



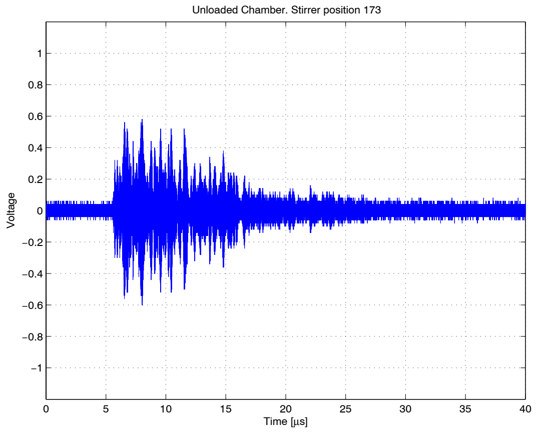
11. Max 1.0 V



12. Max 0.88 V

Appendix A.2

Individual High Power pulses from unloaded chamber (left column) and loaded chamber (right column).



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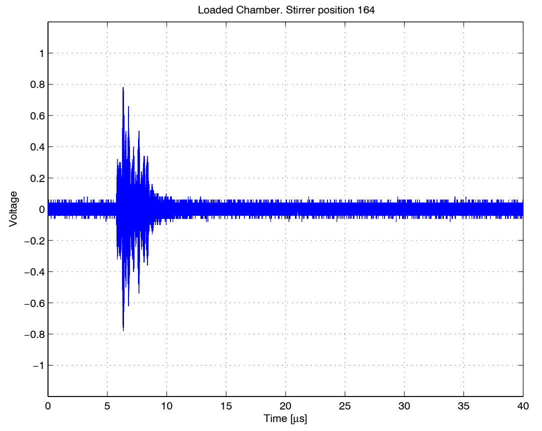
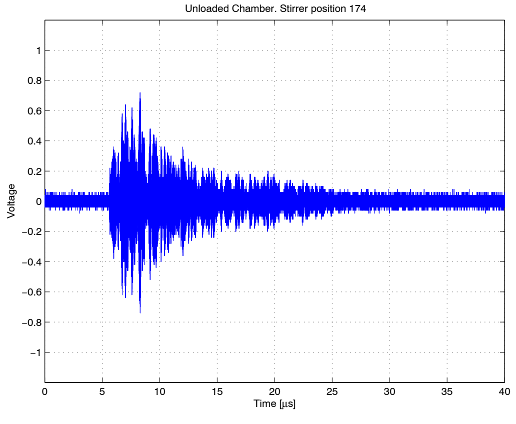


Loaded Chamber 01. 164



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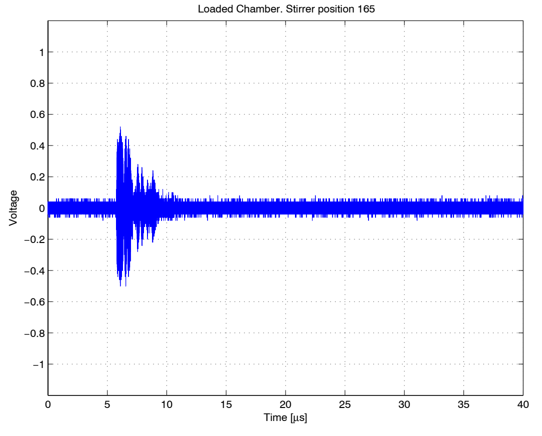

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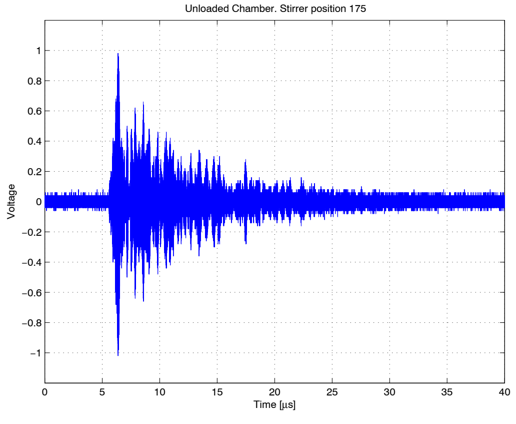

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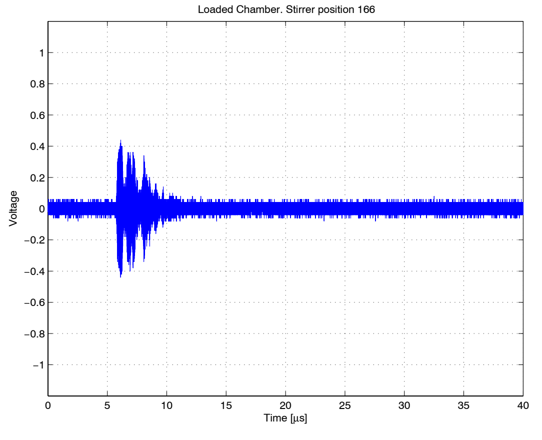

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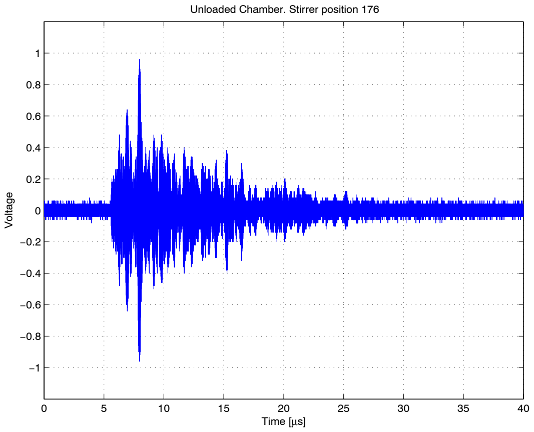

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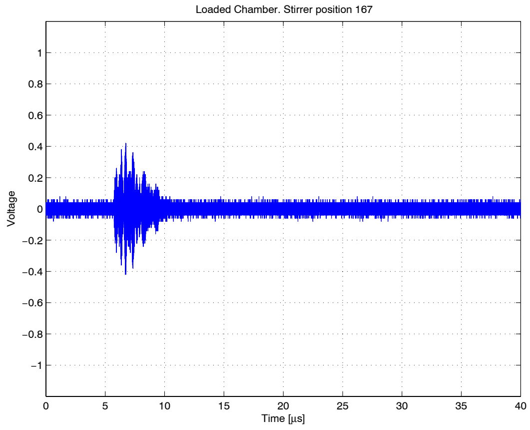

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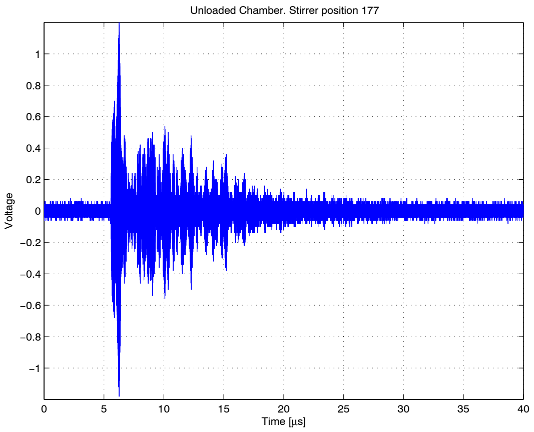

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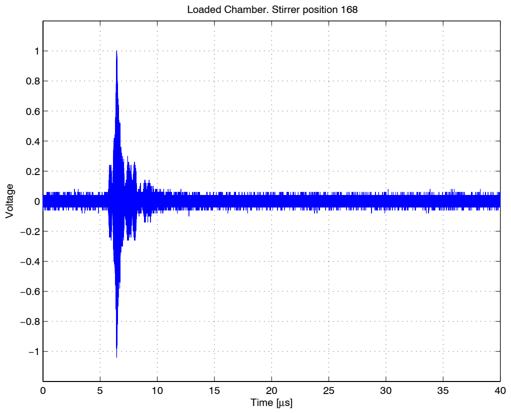

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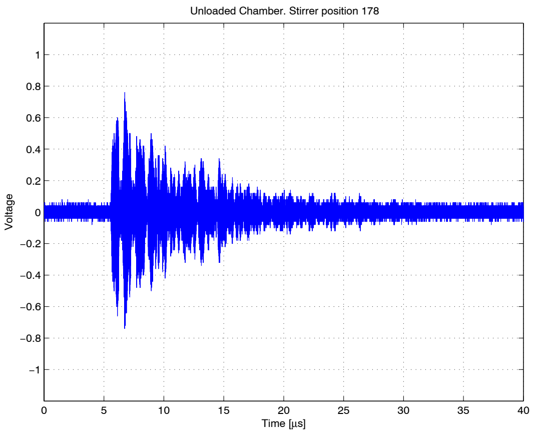

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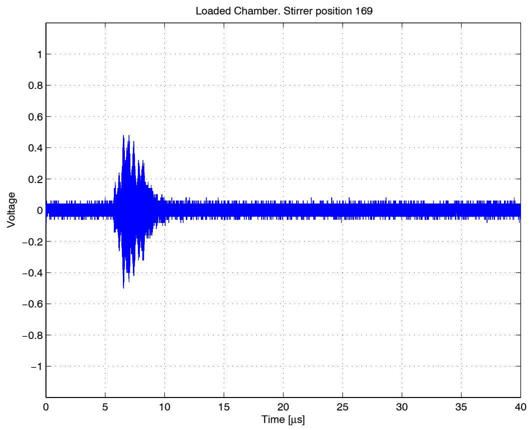

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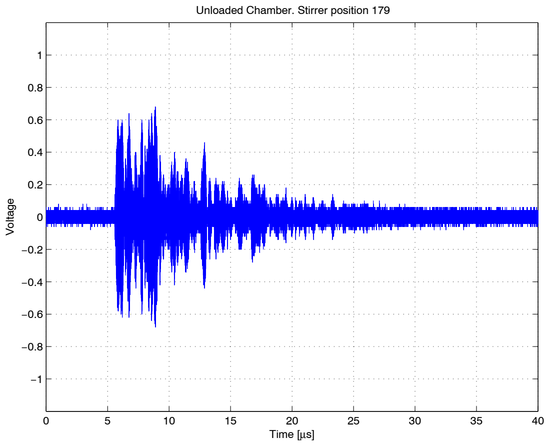

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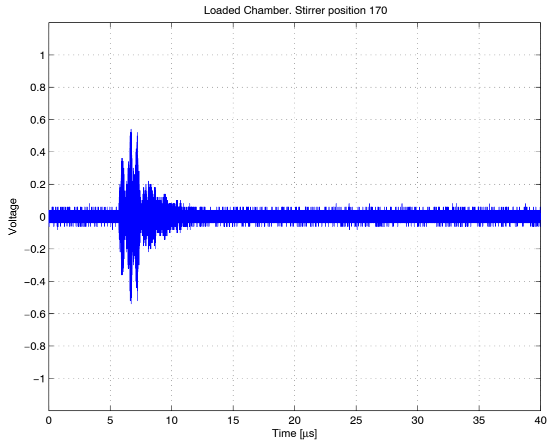

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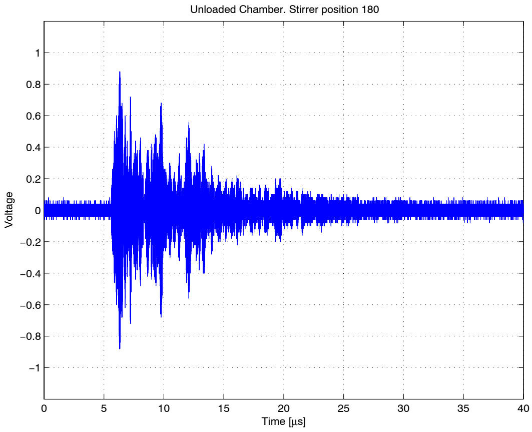

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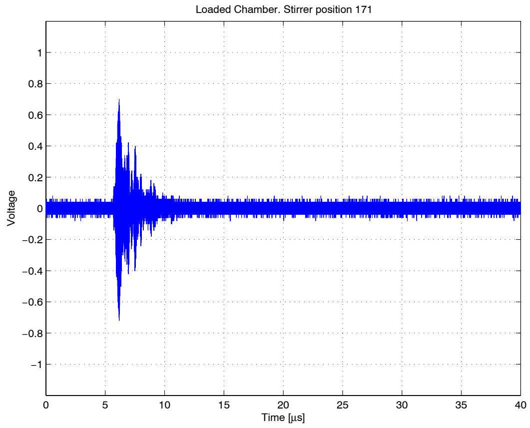

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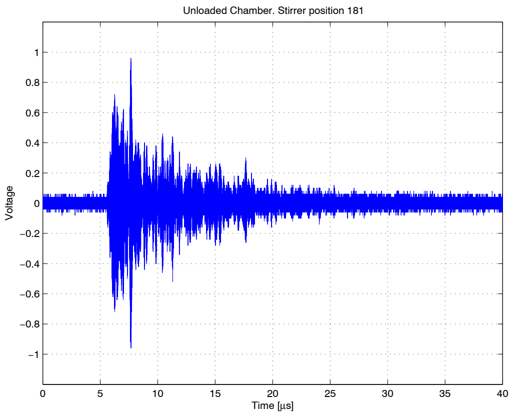

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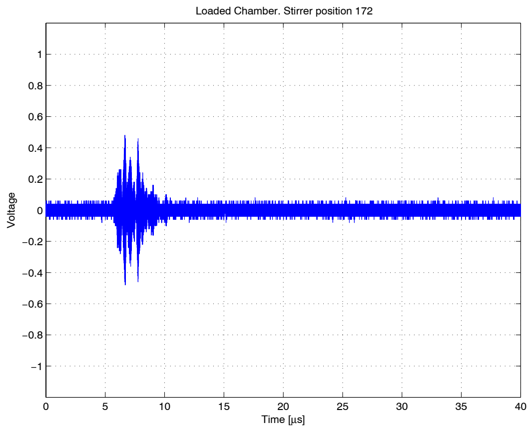

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