LA-UR-16-23557
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Title: TA53:19 Reverb Chamber Quick-Look

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Intended for: Report

Issued: 2016-05-19

TA53:19 Reverb Chamber Quick-Look

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April 2016

Summary

Within Building 19 of TA-53, a screen room has been evaluated for use as a reverb chamber (with deep gratitude to Dale Dalmas and Greg Dale for their assistance). The following data suggests the chamber possesses a Q of about 1500 as is. With minor modifications, it is expected to provide:

- ~70 V/m, given a 10-W, 1-GHz source.
- ~150 V/m, given a 35-W, 4-GHz source.

With minimal additional sealing of the chamber, we expect the Q to increase even more, and thus field levels for the same RF source power. Future studies need to determine leakage field levels, which will define maximum achievable field levels.

Introduction & Test Setup

Shown in Figure 1, the chamber itself is 6' by 12', and 12' tall. It is in a Q/L-classified facility, though enforcing Q-only classification is straightforward. Adopting a 'four-wavelength minimum' (n=2048), the chamber could support frequencies above 85 MHz. A higher-quality six-wavelength minimum (n=6914) would support 128 MHz and above.

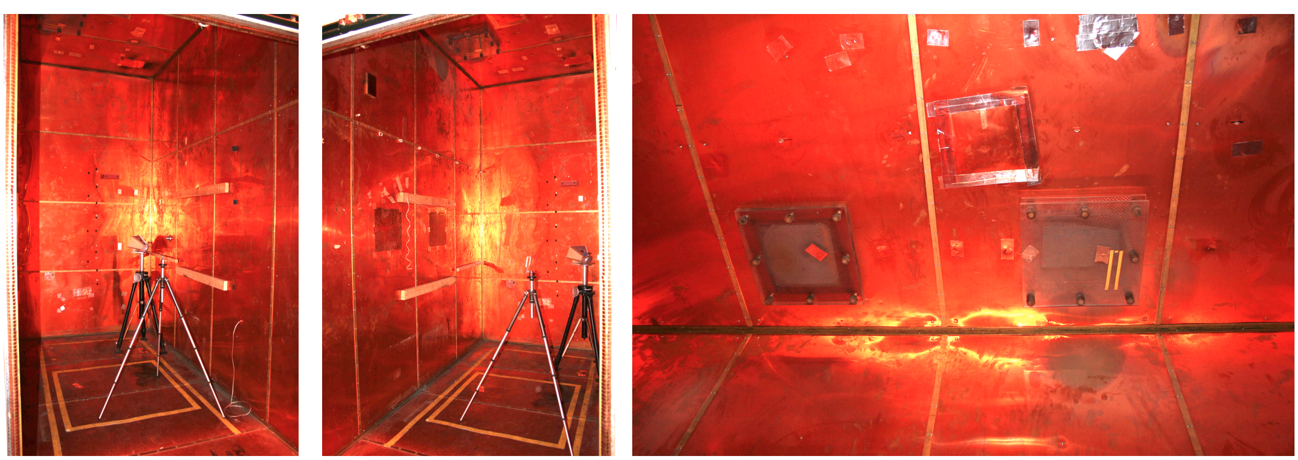

Figure 1: View of chamber inside, including tripods and overhead vents.

The third picture is pointed almost straight up at the ceiling, where two small vents (with copper mesh) are installed. These, and a third in the door itself, are likely the main culprits for the chamber's Q. Replacing these with solid copper is not difficult, and will likely increase Q significantly.

Figure 2 illustrates the front door to the room. A second door allows the full 6-foot width to be filled if desired. The screened window is the third port that needs to be repaired to improve resonant characteristics of the chamber for higher field levels.

Figure 2: Photographs of the door operation and window.

Other aspects of the chamber are shown in Figure 3. The first shows the finger-stock around the door frame, which improves the sealing characteristics significantly. The radiating horn was connected to outside sources through the port shown in the second picture. Finally, a 120V drop is located inside the chamber, and might be reducing the resonance significantly.

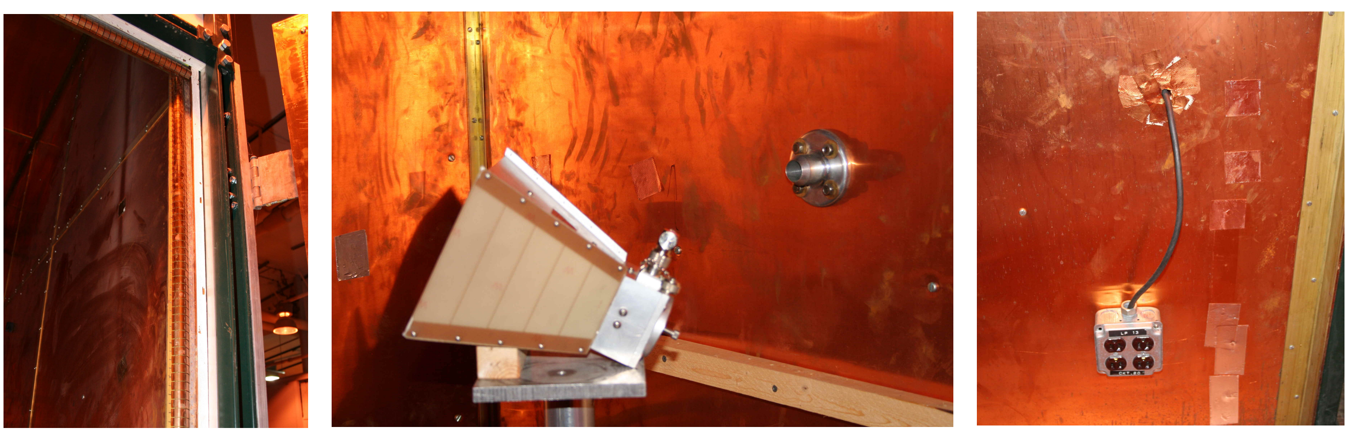

Figure 3: View of chamber doors, radiating horn, and 120V drop.

The probe (from Narda) is specified to 3 GHz, but during tests, fields were reported up to 6 GHz. An amplifier rated for 35 W at 2-6-GHz was used. However, a lack of high-power protection limited the test to less than 3 W for these tests. The probe is battery powered, and has fiber-optic capability. However, a broken fiber required use of a USB cable that extended to the floor and through a penetration.

Measurements of Resonant Q

The following plots report data taken at a single location in the chamber, for a frequency range from 2 GHz to 6 GHz. Small frequency steps (0.1 GHz, with a couple repeated points) were taken between 2 GHz and 3 GHz, while larger steps (0.5 GHz) extended to 6 GHz. There is no mode-mixing 'fan,' and these measurements were at a single point. Hence, large fluctuations are expected as the probe might be at a node for one frequency and at a peak for the next frequency.

The raw electric field is plotted in Figure 4, though the amplifier's gain was very non-uniform through the range. The black trace follows the measured data. Blue shows the square root of forward power, with an arbitrary constant (14) to overlay the two curves.

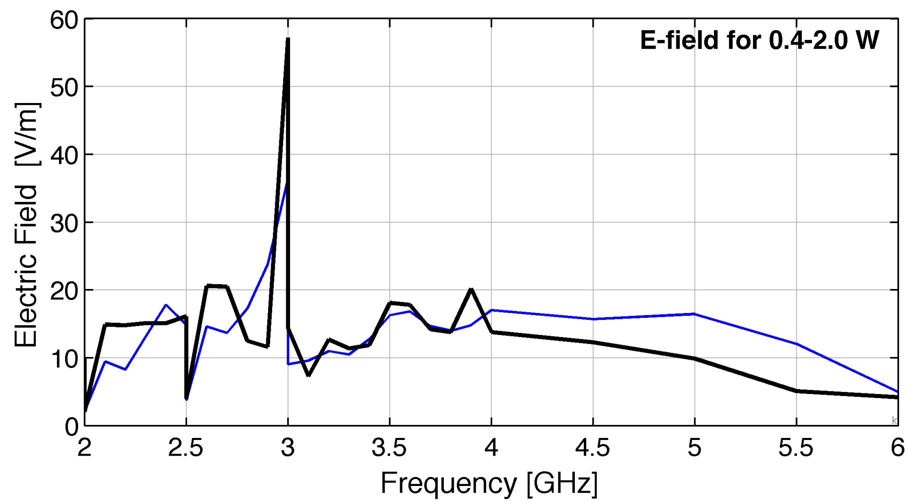

Figure 4: Plot of raw field strengths (black), with scaled power overlaid (blue).

Comparing these curves, one can answer the question, "How much field can we expect for an amplifier of X power?" Calling this the chamber efficiency, Figure 5 shows this factor in units of V/m per sqrt(W). The factor of 14 is about the average during the tests; the field levels increase significantly after several holes were taped over, as discussed in the next section.

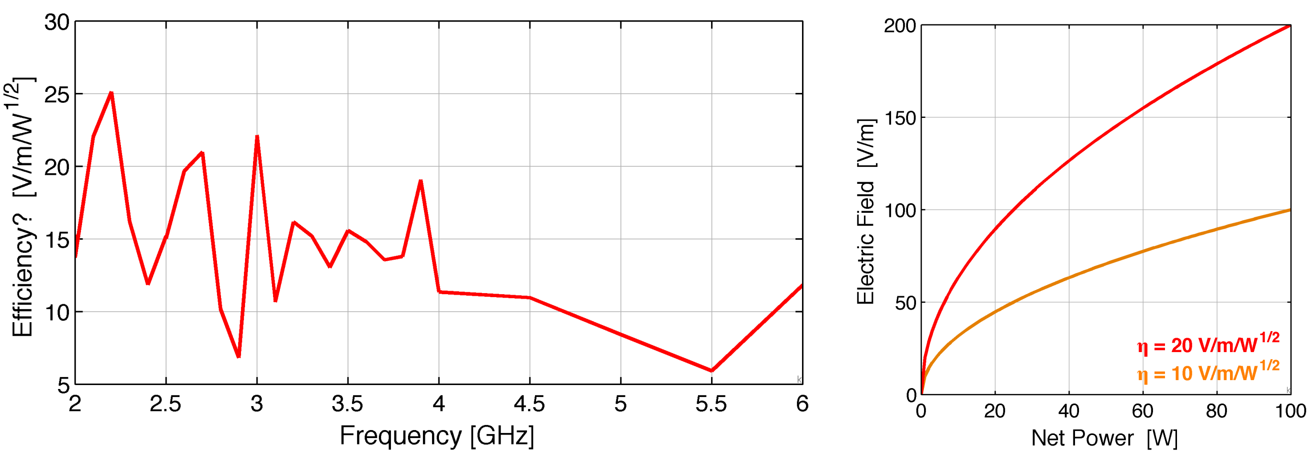

Figure 5: Chamber 'efficiency' to relate power to field, and a scaling guide.

The right plot of Figure 5 shows the attainable field levels for an amplifier of a given power. A scaling using 10 and 20 are shown. Sealing the mesh and other holes will increase that factor, and the '20' curve is probably a conservative estimate of the possible chamber efficiency.

This efficiency factor is related to the Q of the chamber. Q is plotted in Figure 6 (magenta); again, the single-point, single-mode issues with the arrangement gives large variation, but an average of 400-600 can be ascertained. Significant increases in Q are expected with chamber sealing, removal of lossy materials, and door repairs.

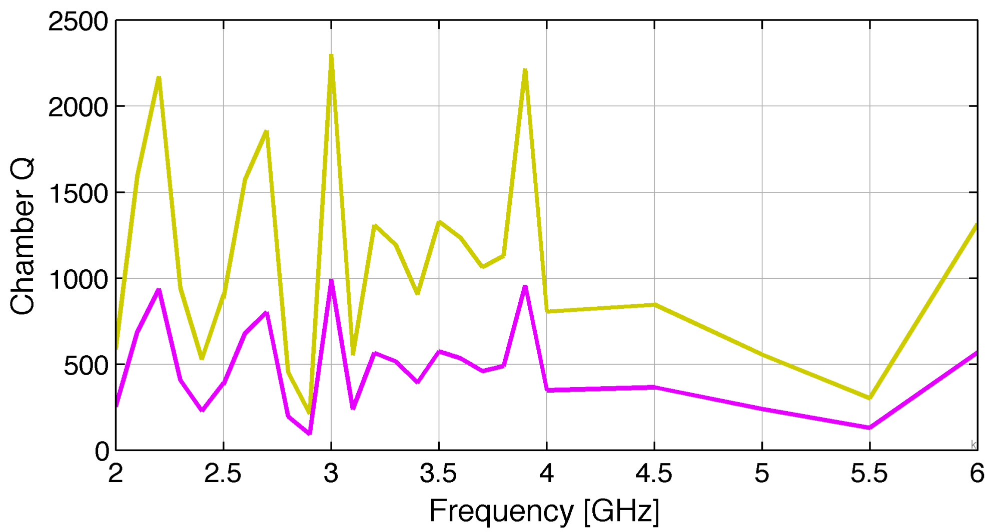

Figure 6: Calculated Q (purple) from data before taping of holes; subsequent data suggests scaled Q (yellow).

The yellow trace in Figure 6 is a scaled copy of the Q data. Toward the end of the testing effort, copper tape was used to plug many small holes (discussed in the next section, including Figure 9). A quick test of the field strength showed significant increases in peak field (from 16 V/m to 24 V/m). If all of the field levels were scaled by a similar increase, the calculated Q increases significantly. The yellow curve in Figure 6 shows a Q that averages around 1400, with peaks reaching above 2000.

It is important to list sources of concerns with the chamber performance and measurement technique:

1) Large mesh windows and vents were not yet replaced with solid copper.
2) The field probe is only rated up to 3 GHz; reported fields above that are possibly reduced.
3) Two circulators were rated for 5-6 GHz; actual radiated power below 5 GHz are possibly reduced.
4) The field probe used a USB cable to communicate to the outside.
5) Other possible field absorbers existed, such as the (ungrounded) horn and the 120-V power drop.

All five items would cause Q and efficiency to drop. Thus, it is expected that Q can be increased significantly with simple fixes to these issues.

Measurements of Spatial Variation

The probe was moved across the width of the chamber. The horizontal axis of Figure 7 depicts the 6-foot wide chamber. The probe was moved in one-foot increments sideways, along three different lines. For these measurements, the field was averaged across a frequency sweep from 2 GHz to 3 GHz. The data was also normalized to a 1-W source. Note the expanded vertical scale.

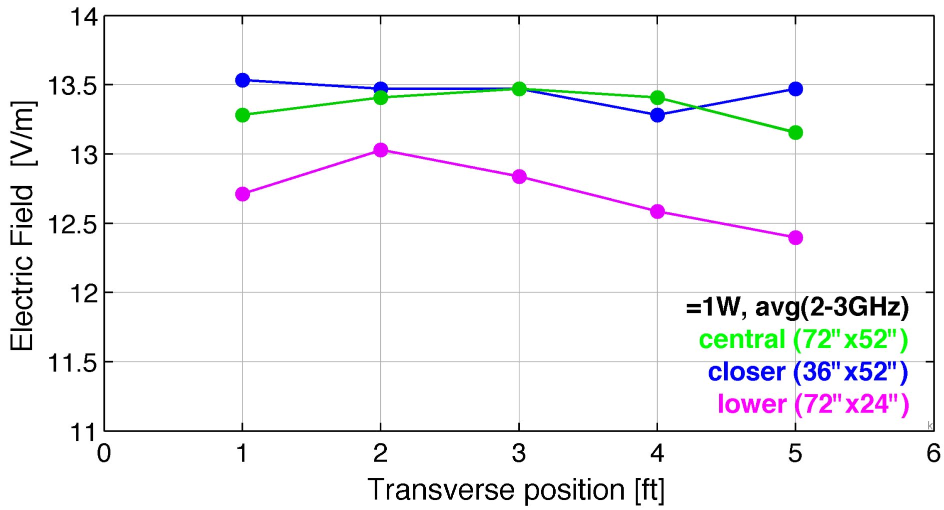

Figure 7: Field strength across chamber at 1 W and averaged over frequencies.

For a single frequency, the field variation is expected to be much higher. At 2.5 GHz, two linear scans were performed and plotted in Figure 8. It is important to note that the probe itself and its tripod were partially metallic; moving it changes the chamber's boundary conditions.

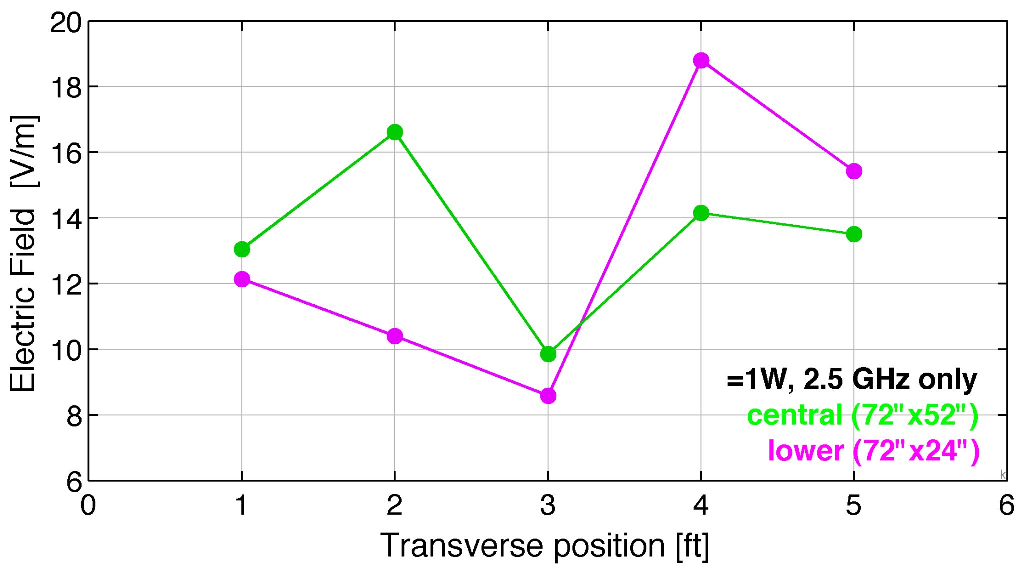

Figure 8: Field strength across chamber at 1 W at 2.5 GHz only.

After the spatial scans, shown above, a few specific-scenario measurements were performed, all at the same frequency of 2.5 GHz. For each of the following five measurements, the probes was not moved from a relatively central position. These single-measurement levels are displayed in Figure 9.

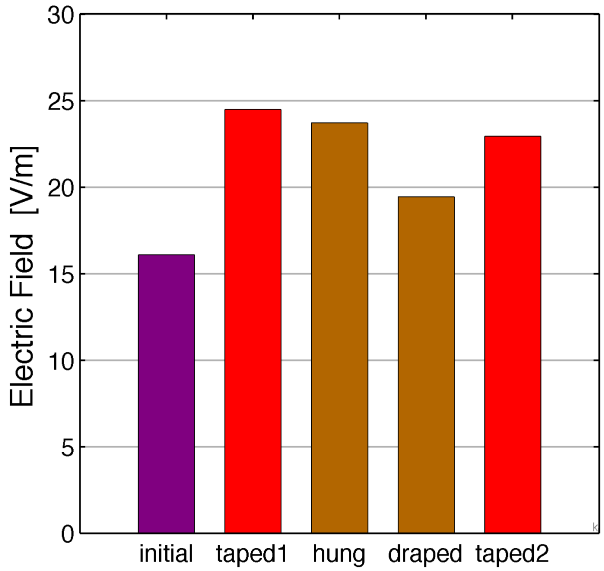

Figure 9: Test case data to understand effect of taping and routing.

The first plotted field level ('initial') was part of the earlier scan, at around 16.5 V/m. Then copper tape was applied to about eight small holes (the largest about 1.5 inches in diameter). This taping should increase Q discernably, and the second measurement ('taped1') is indeed ~35% higher in field level. While error bars for a single data point will be rather high, the increased value was used to calculated the higher Q data presented in Figure 6 (yellow).

Since all measurements used a probe with a USB cable extending to the ground before exiting through a port, measurements were taken with the cable shifted in position. The third measurement ('hung') shows a small decrease in fields after the USB cable was hung on the wall next to the port. The fourth measurement ('draped') purposefully draped the USB cable across the chamber twice, attempting to absorb field energy and reduce the chamber's Q. Then the cable was returned to its initial position, and the final ('taped2') measurement shows that the field strength returned to within 10% of the previously taped level.

Future upgrades

This report is an attempt to characterize the chamber as it was found, but there are many 'low hanging fruits' for improvement. A list of those include:

1. Installation of a slowly-rotating 'fan.' Estimate $10k for M&S, $8k labor (stepper motor).
2. Sealing of mesh holes. Estimate $2k total.
3. Improved door functionality (repair latches and brass seals). Estimate $4k total.

In addition, there are several possible upgrades in the group's field probe and source capabilities:

4. Fiber-powered, compact probe > 3GHz. Estimate $25k (upgrading our battery probe is $7k).
5. Horn, directional coupler, isolator protection. Estimate $8k (varies with bandwidth and power).
6. Wideband amplifier sources 1W-35W. Free.
7. Wideband amplifier sources at 50W-2kW. Estimates $10k to $50k.

Several of these tasks are being undertaken for the needs of the B61-LEP program. Other upgrades are being proposed in support of both the LEP programs and Stratcom missions. Two nearby anechoic chambers and a small TEM stripline are also in operation for these programs and for low-level RF emissions testing.

Another report provides predicted field levels for specific RF sources in the 1-MHz to 10-GHz range using this structure when it is operational. For survivability studies, field levels up to 500 V/m are expected with sources. Vendors have quoted higher-power sources that would exceed 1 kV/m in this chamber.

This report is part of a greater effort to improve and consolidate a focused electromagnetics capability at the Laboratory. This capability is expanding to support future mission needs.

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