Reverberation-anechoic chambers for EMC/EMI engineering

The proposed hybrid reverberation-anechoic chamber concept would allow both chamber manufacturers and their customers to solve some critical cost and time-to-market problems in emc and emi engineering.

By Slav Ligai, Lancetta Inc

From their inception in the 1950s by Navy Research, anechoic chambers for radiation testing and reverberation chambers for immunity testing have become a concurrent part of the EMC- and EMI-product-development process. Now, this capital investment is one of the largest financial and physical expenses of compliance engineering. Nevertheless, a constantly accelerating the time-to-market pace and decreasing product lifetimes require closing the disproportional gap between product-development cost and compliance-engineering capital investments.

REVERB-ANECHOIC CHAMBER

During last 50 years, the concept behind anechoic and reverberation chambers has never changed. It’s all about either absorption or reflection of RF energy in a rectangular conductive chamber with or without absorption materials–and almost nothing in between. Even some modifications of the concept, such as semi-anechoic or stirring reverb, don’t stray far from the initial idea of either absorbing or reflecting. The mainstream approach is to design high-performance predictable chambers based on computational electromagnetic simulation, better absorbing materials, impedance optimization, and other factors.

This situation relates partially to the fact that some standards, such as ANSI C63.5, call for a “free-space” antenna factor that is hard to imagine in a real-world environment. Accordingly, a pure anechoic chamber is a natural extension of that “free-space” concept. On the other hand, an entirely reverb environment is hard to imagine, too. Also, it’s still quite an expensive challenge to build and maintain an anechoic chamber with specified performance for a specific application.

Therefore, it could be useful to develop other types of chambers that would be less complex, less expensive, less bulky, and closer to the real-world environment. We came up with such a chamber, which we will call an R-A (reverb-anechoic) chamber. In essence, the reverb-anechoic chamber is nothing more than a mirror. The only difference is that this mirror has a special topology or shape that would allow for a mirrored image close to the original source or drain of RF energy. This simple feature would yield some interesting and useful chamber characteristics.

Instead of a regular rectangular [i] or tapped [ii] RF chamber, consider a chamber with an internal ellipsoid shape, a two-dimensional cross-section of which is an ellipse [1]. Also, assume that the ellipsoid’s surface is a good conductor. As it is well known, the above ellipsoid has two foci.

Now, if you place a source of RF radiation in one focus, you get the same mirrored source of radiation in the second focus [2] (**Figure 1**).

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[1] An ellipse (from the Greek for absence) is the locus of points on a plane where the sum of the distances from any point on the curve to two fixed points is constant. The two fixed points are called foci (plural of focus).
[2] This effect is well known, whereby two people standing in or around the foci of an elliptical “whisper chamber” can hear each other perfectly.

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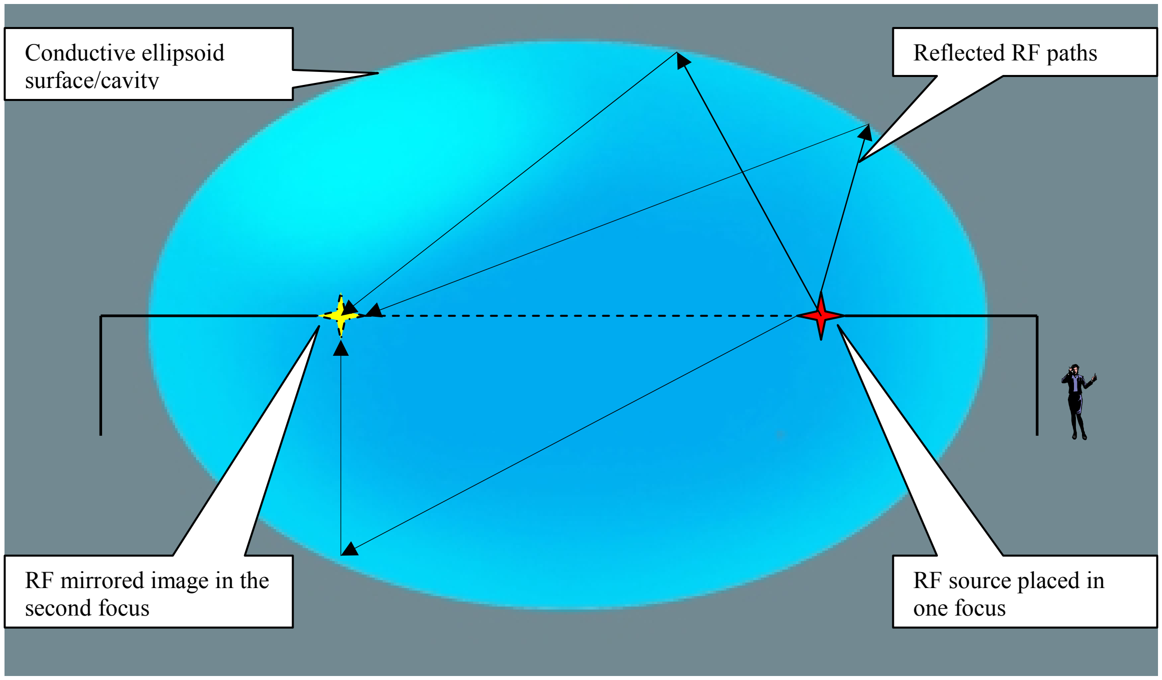

Figure 1—This cross-section of ellipsoid cavity shows two foci and some schematic RF paths.

This shape's function is simple: Instead of covering all internal walls with absorbers and tuning up their input impedances, just place a small piece of absorber with a tunable impedance network in the second focus point. The effect is the same or close to what you'd normally obtain in a regular anechoic chamber. Namely, you won't get any reflected radiation going back to the RF source that is located in the first focus.

Therefore, you reach the anechoic chamber effect within a purely "reverberating" chamber by placing a small piece of absorber in the second focus point. On the other hand, if you place a good reflective material—say, a conductive ball in the second focus—you would reach the effect of a reverberating chamber. Namely, most of the transmitting power would reflect back to the RF source in the first focus. Thus, we call this type of chamber a reverb-anechoic chamber.

R-A CHAMBER APPLICATIONS

One of the most obvious applications for an R-A chamber would be RF radiation measurements, including radiation patterns. By placing a receiving antenna in or near the second focus of the R-A chamber, you can measure the radiation power level of the transmitting DUT (device under test) that you place in the first focus, as you would normally do in a regular anechoic chamber.

As previously mentioned, the second focus contains the radiation image of the DUT that you place in the first focus. It allows the measurement of radiation patterns or 3-D images of the DUT instantly in one step—with no mechanical angle scanning. Electrical field probes would be the ideal candidates for those kinds of pattern measurements.

For immunity testing, the R-A chamber could present a whole array of opportunities, too. By changing shape, reflective characteristics, and positions of the "second focus ball," you can reach a variety of reverberation modes with different degrees of real-world environment simulation.

Shielding could be another special application for this type of chamber. Due to its focusing ability, the R-A chamber could concentrate the outside RF ambient radiation on its two internal foci with absorbing material and create a silent zone between those two absorbing points. This type of shielding could be useful for quick or temporary RF protection of bulky constructions or mobile units.

You could develop some acoustic or optical applications with this type of chamber, as well. For instance, you could measure or research optical or acoustic images you create in the second focus without interaction with real object you place in the first focus. In some cases, that artificial image of a real radiating object could substitute computational simulation of complex objects.

R-A CHAMBER PERFORMANCE

Performance of the R-A chamber depends of the accuracy of such parameters as ellipsoid geometry, transmitter and receiver positions in foci, and impedance network—377Ω for the free space—of the absorbing ball. With an accuracy of 0.5% in testing-equipment position and the impedance network, the projected attenuation in the anechoic mode could be better than –45dB at a frequency range of 30 MHz to 40 GHz, at a very reasonable cost.

By tuning just the impedance network, you can gradually tune up the R-A chamber's attenuation level and bring it from the "free-space" environment up to the point of making it a purely reverberation chamber. This situation would occur when someone is interested in measurements in a "real-world" environment, which lies somewhere between anechoic and reverberation modes.

R-A CHAMBER AND INDUSTRY STANDARDS

It is apparent that you can use a standard calibrated antenna with a "free-space" antenna factor when working with an R-A chamber in the anechoic mode. The "free-space" antenna factor is usually received on OATS (open-area test site), which some of the standards mentioned above implement.

The R-A chamber in its anechoic mode does implement the same "free-space" concept that the OATS standards target. The R-A chamber could be a much more flexible, less costly, and reliable tool compared with OATS and, if implemented in the EMC industry, it could be the tool of choice that a new industry standard could support. It also lacks some of the drawbacks of conventional OATS.

OATS is a finite metal plane with periodic structure—isolated metal sheets with connective metal strips between them. The metal sheets, which connect electrically by "sandwiching" their edges between metal strips, tend to increase the site surface impedance due to moisture, rusting, temperature, breathing, dust, and other factors.

Due to a periodic structure (square cells), the surface impedance is not uniform across the site. So, instead of surface electromagnetic waves transmitting along the end edges of OATS, those waves could transmit in the air across every metal sheet edge over which a contact scatters rust. As a result, this unwanted radiation would interfere with transmitted one. It can cause ripples at high frequencies and a mutual coupling effect between the transmitter and the receiver.

The R-A chamber is free from such problems. Moreover, because the R-A chamber is tunable by its nature, you can get all types of antennas factors between "free-space" and reverberation mode. This characteristic could be handy in some practical cases, where EMC engineers seek a "real-world" environment.

CONCLUSION

An R-A chamber—which could consist of low-cost material such as Mylar film with double sided metallization (the same material used for balloons), inflating equipment, mounting equipment, and other equipment—is unlikely to exceed $10,000 to $100,000. This price range will make the R-A chamber affordable for most small and medium electronics OEMs. Therefore, the reverb-anechoic chamber would fall into the spending category of regular test equipment, not the major capital investment of several million dollars for big, regular chambers. This strategic marketing change would substantially decrease the purchasing risk for managers.

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Because of the very light weight, it is possible to even orient the inflated ellipsoid vertically when the testing facility allows. Thus, you could save some real estate on the production floor (**Figure 2**).

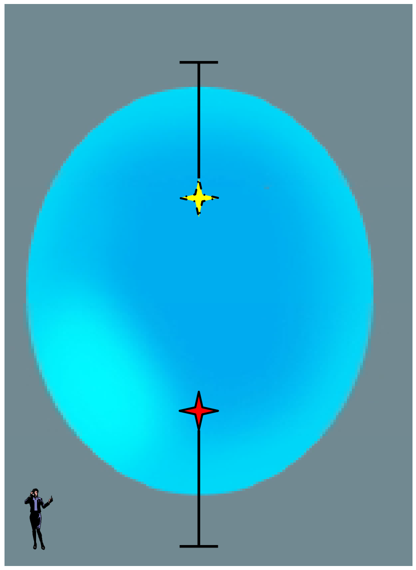

Figure 2—It is possible to vertically orient this inflatable R-A Chamber.

Even with a horizontally oriented R-A chamber, you can always save some space by completely or partially deflating the R-A chamber upon test completion and inflating it for the next series of EMC tests. Of course, in some cases you could place the R-A chamber outside the buildings.

The hybrid reverb-anechoic chamber concept could yield some EMC/EMI testing abilities that you can't otherwise achieve on regular chambers. For instance, due to their very light weight, you could build R-A chambers for very low frequency testing. In most cases, it's cost prohibitive to build a regular chamber of 100 to 200m just to run some tests below 3 MHz. On the contrary, it's quite affordable to build and run an outdoor test with inflatable R-A chamber of that size.

The cost difference between regular chambers and R-A chambers could be on the order of one or two, which opens a whole array of new opportunities for an OEM to accelerate its product-development process. This new, less restrictive, less expensive, and tunable class of chambers could be affordable for EMC/EMI engineers, which could bring flexibility and speed to the entire design and testing process.

Vendors could develop the R-A chambers pretty quickly. Meanwhile, the OEMs could try this new concept of the hybrid reverb-anechoic chamber[iii] on their own to achieve some immediate benefits, such as low cost EMC evaluation. All they would need to have is a Mylar or similar film with a double metallization layer.

Author's biography

Slav Ligai is the CEO and Director of R&D for Lancetta, Inc. He has more than 25 years of diversified, innovative *experience in various industries and companies, including Solectron Corporation, ESCO Technologies, Applied Nanotech, and the Academy of Science of Russia. He has had numerous innovative articles published in leading industrial magazines. He received his master's degree in physics from Novosibirsk University and his PhD (abd) from the Institute of Thermo Physics of Russia. You can reach him at sligai@lancetta-inc.com or sligai@gmail.com.*

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[i] Modeling of Anechoic Chamber Using a Beam-Tracing Technique, B.Chung et al, Progress in Electromagnetic Research, 49, 2004
[ii] Using Tapered Chambers To Test Antennas, V. Rodriguez, Evaluation Engineering Magazine, May 2004
[iii] Patent pending