Technical E-Paper

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Using the ANECHOIC CHAMBER in the design of antennas

PART ONE: how an anechoic chamber looks like.

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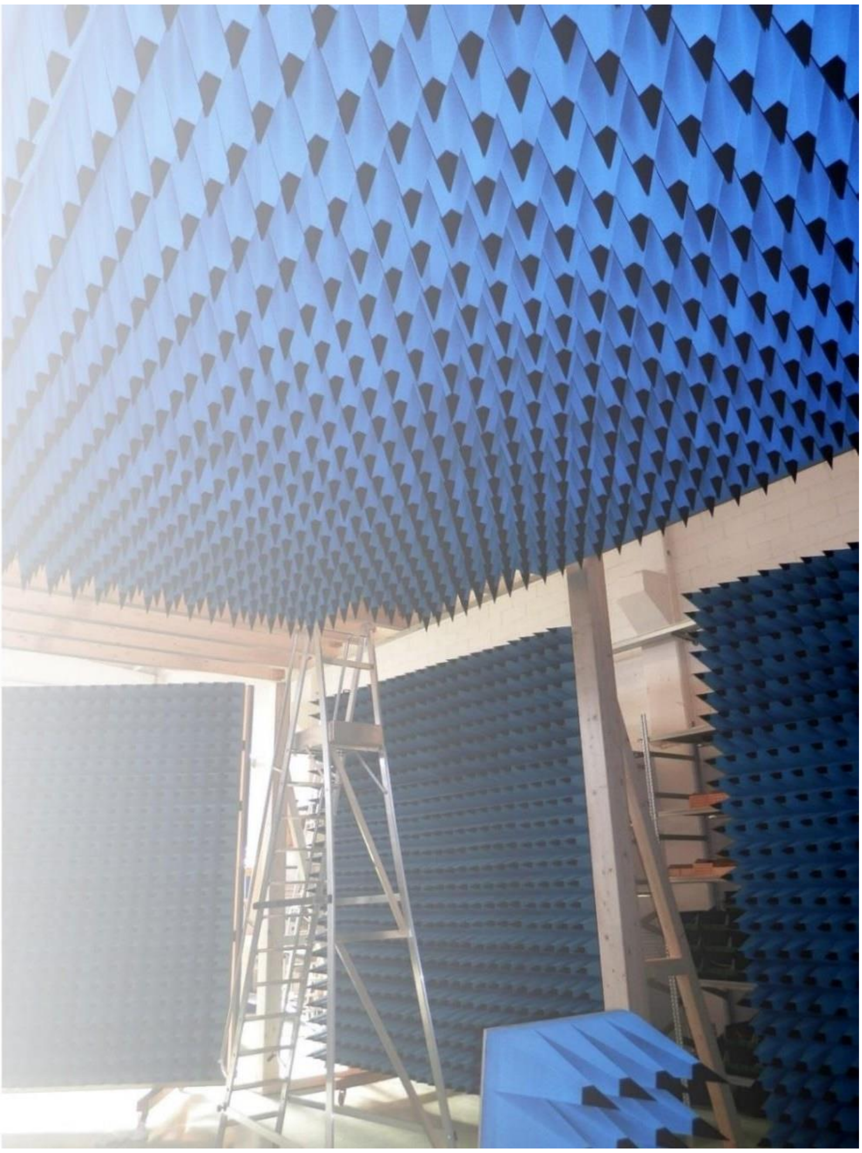
Here we take a brief look, in three parts, at one of the most important pieces of equipment used in antenna research and development: the ***anechoic chamber***.

PART ONE:
What is an anechoic chamber and how does it measure the electrical parameters of antennas?

PART TWO:
What steps can be taken to obtain reliable measurements when designing a new antenna?

PART THREE:
What other laboratory equipment is required to measure the radiation parameters of antennas?



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1. Introduction.

The design of any antenna for professional use must necessarily contemplate both intermediate and final testing and characterization of the prototype or prototypes.

Therefore, for a specialized company it is important to have a fully-equipped laboratory, which enables easy performance of accurate, reliable and repeatable electrical tests.

The most expensive, and most important, piece of equipment in a research and development laboratory is the *anechoic chamber*, consisting of a controlled environment in which a condition of propagation in free space can be reproduced (or at least approximated).

A simple search on *Google* returns numerous images of test facilities, in both research laboratories and private companies, that show the inside of huge anechoic chambers capable of containing entire airplanes or vehicles to test their electromagnetic compatibility or susceptibility.

Although these fascinating photographs refer to installations costing several million euros, even the construction of smaller anechoic chambers can entail a considerable economic effort, since the absorbent material used to line the room is quite expensive, as are most of the high-tech technical materials needed for exclusive and specific uses.

As in the previous technical articles, I will try to give the reader an idea of how an anechoic chamber used to measure the radiation parameters of antennas works, mentioning how this resource is used in practice for the research and development of new antenna designs.

Without presuming to cover all aspects of such a vast topic, I will talk about the anechoic chamber in our internal research and development laboratory, based on my personal know-how experience, in the hope of making the article more interesting.

In this regard, the photo on the front page shows one stage of the construction of the anechoic chamber, designed and built in the company by the author.

2. Types of anechoic chambers.

The term *anechoic chamber* means a closed box, with load-bearing structure in dielectric or conductive material, lined internally with absorbent material whose purpose is to create a volume space, inside the chamber, as free as possible from reflections (*quiet zone*) and where the environment is completely assessed by an electromagnetic point of view.

Of course, in the case of an anechoic chamber for electromagnetic and non-acoustic applications, the absorbent material is made in such a way as to attenuate the reflected component of an electromagnetic wave that incides on it.

- ***Anechoic chambers for EMC.***

For EMC applications (electromagnetic emission and/or immunity testing), *shielded* and *semi-anechoic* type chambers are generally used: indeed, in this case, inside the chamber, it is imperative both to measure very low levels of radiated emissions and to generate very high electromagnetic field levels for immunity tests.

In the so-called *shielded rooms,* the load-bearing structure is made of metal panels bolted to each other by means of special profiles, also made of metal, to guarantee uniform electrical contact between the various elements of the outer shell. To limit their weight, these panels usually consist of a laminated wood sub-layer onto which steel or copper sheets are glued on both sides to create a double shielding. The access doors also incorporate contact elements (*fingerstock*) along the entire perimeter, made with shaped sheets of phosphor bronze or other harmonic conductor, creating a perfect Faraday cage. The chamber's metal screen is then lined internally with the absorbent material.

In *semi-anechoic* chambers, the floor simulates a perfectly conductive surface and therefore remains free of absorbent material.

- ***Anechoic chambers for testing antennas.***

Conversely, in anechoic chambers for testing antennas, the priority is to have a space with the almost total absence of reflections, called a *quiet zone*. Therefore, a shielding metal structure - which may prove to be a double-edged sword if the chamber is used in conditions where the absorbent material loses its effectiveness – is not necessary in most cases.

It is important to note that these considerations must be taken into account also bearing in mind the budget allocated to the construction of the anechoic chamber: it is clear that, if the resources made available are unlimited, it will be possible to provide an ideal, albeit not cost-effective, testing setup for the requested application.

There are essentially three types of commonly used anechoic chambers to test antennas:

a) Anechoic chambers for *Far Field Measurements;*
b) *Compact Range* anechoic chambers*;*
c) *Near Field* Measurements*.*

In an *anechoic chamber for* ***Far Field Measurements,*** a radio-connection in free space is reproduced between the ***AUT*** (*Antenna Under Test*) and an ***AR*** reference antenna, positioned at a distance ***R*** that satisfies the far field conditions. We will return to this point later, when this type of anechoic chamber will be described in more detail.

In an anechoic chamber for ***Compact Range tests*** (***Figure 1***), an expedient is used to limit the physical dimension of the chamber itself, in the case where the *AUT* has large dimensions compared to the wavelength λ. In this measurement system, the *AUT* and the reference antenna do not directly see each other as they are pointed towards the same side of the chamber, i.e. in the direction of a parabolic reflector that generates a plane wave towards the *AUT*, like in a far field condition, starting from a field radiated from a nearby source, consisting of the reference antenna.

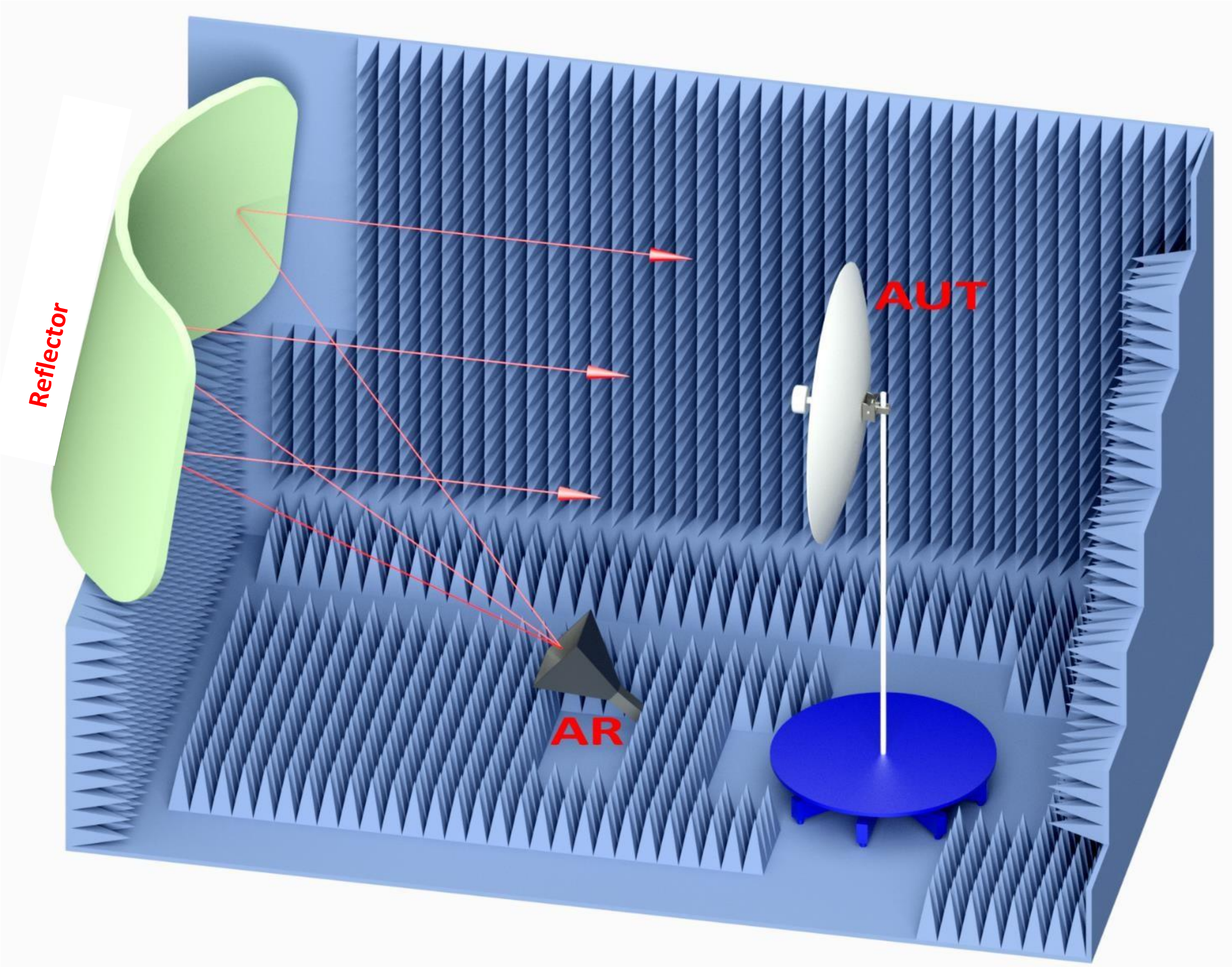

Figure 1
Compact Range Test Setup.

The reflector, illuminated by the reference antenna, is used in near field conditions, even if the radiation diagram of this system approximates a far field condition with respect to the antenna under test (*AUT*). A Compact Range test setup thus becomes a very complex system, consisting not only of the anechoic chamber but also of an elaborate testing system that enables production of a flat wave, with known characteristics, in the region of space of the chamber in which the *AUT* is positioned.

Another antenna characterisation technique is represented by ***Near Field Measurements*** . These methods depend on the type of *AUT,* whose radiated field is measured, both in amplitude and in phase, on a given reference surface. From this measurement, which we can identify in an initial approximation with the illumination of the antenna, the far field is obtained by means of mathematical algorithms.

Similarly to the *Compact Range* method, near field measurements are also usually applied to high-gain antennas, which are highly directional and have negligible radiation in certain directions. However, the shape and size of the acquisition surface of near field measurements depend greatly on the type of *AUT*.

3. Absorbent materials.

The absorbent materials used in the construction of anechoic chambers are essentially of two types: *ferrites* and *pyramidal absorbers*.

- ***Ferrites*** are tiles made of a special ceramic material with excellent absorption characteristics, from about 30 MHz up to 500 MHz. They are 100×100 mm in size and a few millimetres thick and can be supplied individually or already mounted on 300×300 mm or 600×600 mm panels. They are usually used alongside pyramidal absorbers to extend the performance of the chamber to lower frequencies.

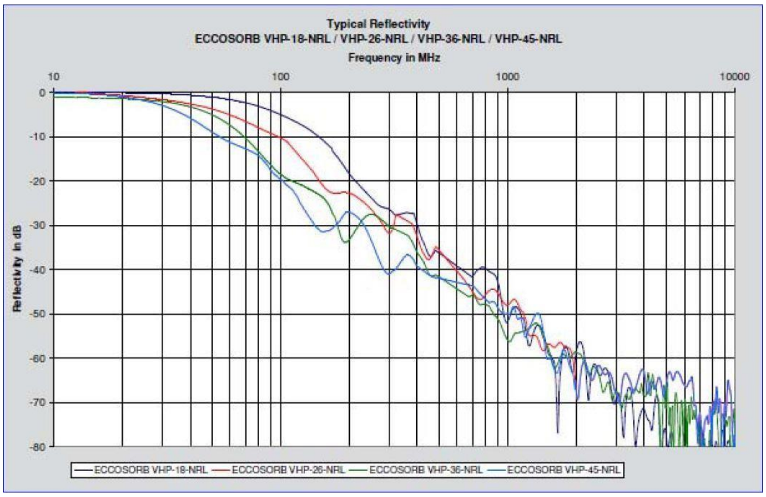

Figure 3
Reflectivity of the *ECCOSORB VHP-NRL* pyramidal absorbers
(Source: *Emerson & Cuming*).

- ***Pyramidal absorbers*** ("*cones*") are panels, made of rigid or expanded material (typically urethane foam) impregnated with carbon or colloidal graphite, or a resistive substance capable of absorbing electromagnetic waves (***Figure 2***).

Their particular shape, consisting of pyramidal elements with a square cross-section glued to a base to form a 610×610 mm *panel*, is designed to trap the incident electromagnetic beam, which is reflected many times between the walls of the cones, dissipating the associated energy in the form of heat.

Figure 2 shows one of the 610×610 mm panels, produced by the company *Emerson & Cuming* and used by the company to build the anechoic chamber. The figure highlights the main dimension ***H***, i.e., the size of the cones, on which depends the minimum operating frequency of the absorbers, that is, a kind *of cut-off frequency*.

Of course, remember that the higher the value of ***H***, the lower the "cut-off frequency".

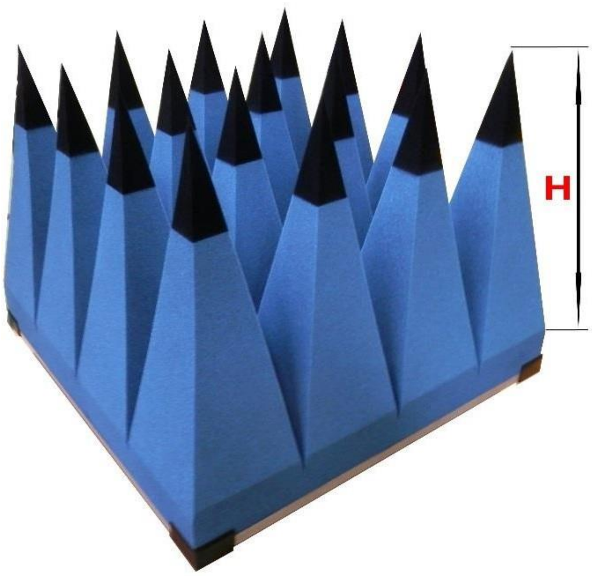

Figure 2
ECCOSORB VHP-NRL Pyramidal Absorbers
produced by *Emerson & Cuming*.

In the literature there are various mathematical expressions that estimate the reflectivity values of a given absorbent material, both as a function of its thickness and the angle of incidence. Moreover, reflectivity curves are available from the various absorber manufacturers, i.e., the attenuation of a reflected beam with respect to an incident wave in the normal direction to the panels themselves, similar to those shown in ***Figure 3***.

For our specific application, absorbers with *H=420 mm* (*ECCOSORB* VHP-18) have been chosen because, having already been used in the field years ago, they are an excellent compromise between mechanical dimensions and electrical performance.

4. Construction of the anechoic chamber.

The construction of the anechoic chamber in our company drew on the past experience of the author who, over his career, has had the opportunity to see and use various chambers, both large and small.

Therefore, the following recommendations were taken into consideration in the project, with the aim of creating a far field testing system, suitable for the characterisation of antennas from V/UHF up:

- Use of branded pyramidal absorbers, with well-defined and guaranteed electrical specifications;
- Use of a load-bearing structure in dielectric material (laminated wood), with a design that minimises the use of metal connecting elements (unshielded chamber);
- Design of mobile walls with wheels that can be completely and easily moved, both to carry out maintenance and to be able to enter the chamber with bulky objects;
- Floor covered with "visible" pyramidal absorbers, that is not of the raised type (floating) with the cones positioned below it.

It is not possible here to go into the construction details of this structure in depth, or to explain the reason for the construction choices made.

Indeed, these subjects alone would take up far more than one article.

Figure 4 shows the covering of the roof structure with panels of absorbent material: each square has been glued, using a specific adhesive supplied by *Emerson & Cuming*, to a laminated wood support with milled housings or eyebolts to allow its installation respectively on the vertical walls and on the ceiling.

At the end of the construction, around 400 panels of absorbent material were put in place, both in the form of "cones" and flat sheets, the latter used near the edges of the chamber.

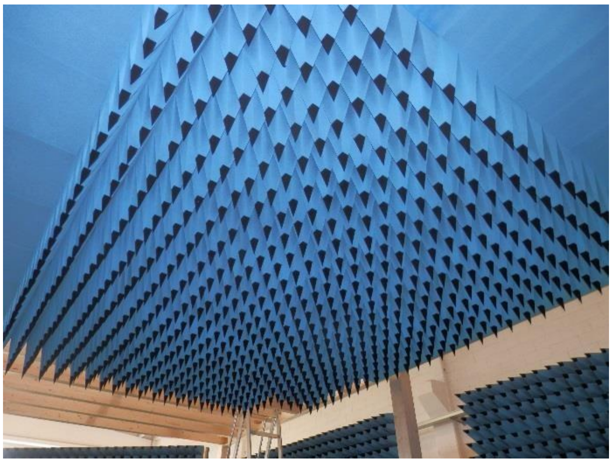

Figure 4
Detail of the anechoic chamber under construction: assembly of the absorbers on the roof structure.

For any needs and/or question feel free to contact us at

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