Sensor and Simulation Notes

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# Design of Electromagnetic Test Sites

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Abstract

This paper considers some of the first-order design principles for electromagnetic test sites. These involve the location and polarization of the electromagnetic source, as well as reduction of scattering from the test site (earth and other structures) onto the test object.

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## 1. Introduction

A common problem in designing electromagnetic test sites concerns the proximity of the object under test to nearby scatterers such as earth, water, metal and dielectrics. These modify the response of the test object such that one is concerned about the applicability of the test results to the situation encountered in the operational environment of the system.

A first problem concerns the influence of such scatterers (nearby earth, etc.) on the field incident on the system. For example, the incident field may not be a desired uniform plane wave. Of course, one can use an anechoic chamber, but for large systems (e.g., aircraft) this may be difficult, since the chamber should be many times the size of the system under test.

Not only may the test geometry greatly distort the incident field, it can also greatly alter the response of the system under test (change its Green function). This can modify the complex resonance frequencies by the presence of the local satterers [1, 3, 7].

In this paper we discuss various techniques for improving the fidelity of the test when the system under test must be close to local scatterers such as earth.

## 2. Some considerations for Anechoic Chambers

To begin this discussion, consider the classical anechoic chamber. As in Fig. 2.1, we have a metal enclosure with absorbers on the walls. Classically, these absorbers are resistively loaded cones, many wavelengths in length. This is the classical high-frequency solution.

As one goes down in frequency the problem becomes more difficult. As discussed in [2] one can construct a special resistor grid which can extend the absorber function to lower frequencies. Both longitudinal and transverse resistors are included in a sparse wire grid to dampen both E and H oscillatory cavity modes. Perhaps an optimal solution would involve using both techniques with the resistor cones interspersed within the resistor grid.

The above considerations are extended in [6} where more extensive use is made of resistively loaded conductors traversing the cavity. This points out the desirability of increasing the fraction of the cavity volume occupied by the damping structures. For a given volume reserved for the test object and electromagnetic radiator, this will generally increase the cost as one would expect.

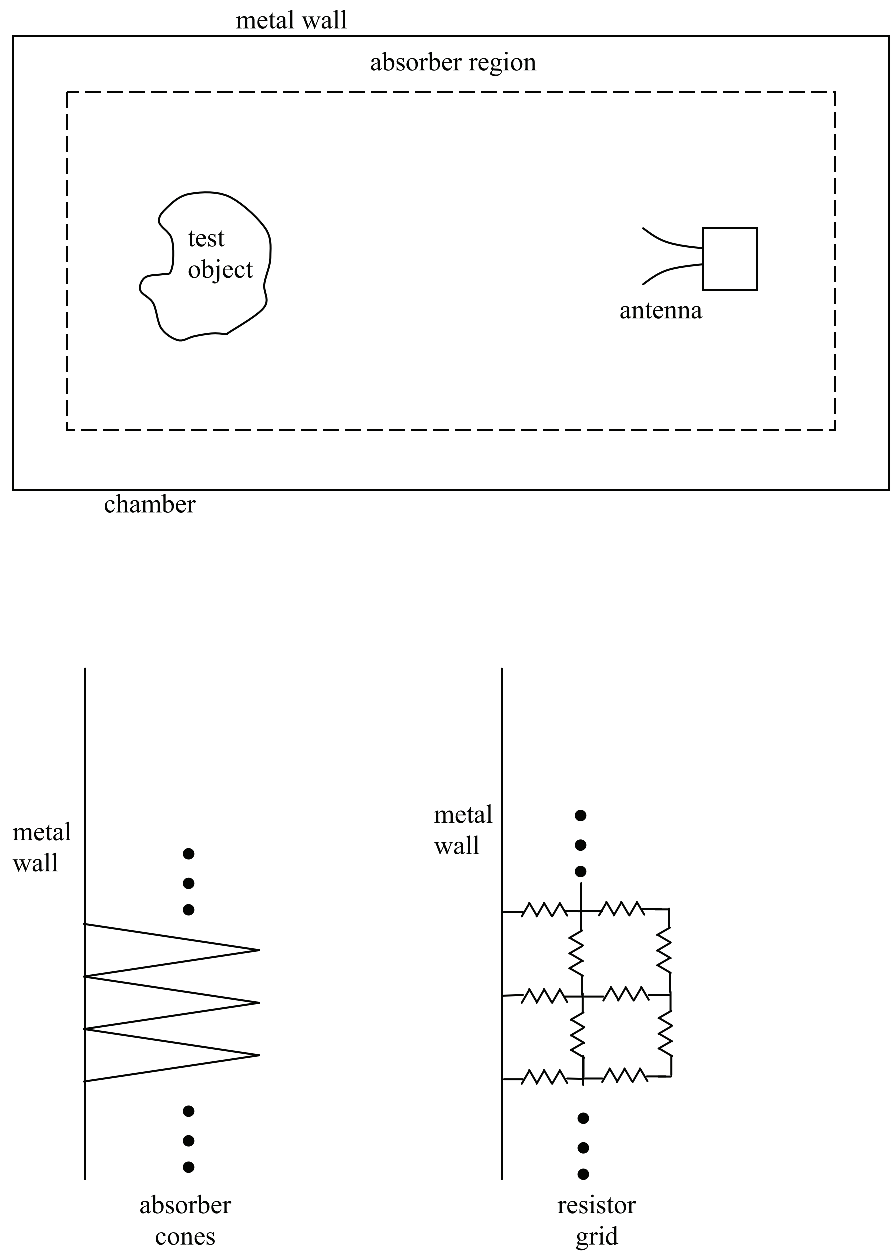



Fig. 2.1 Anechoic Chamber

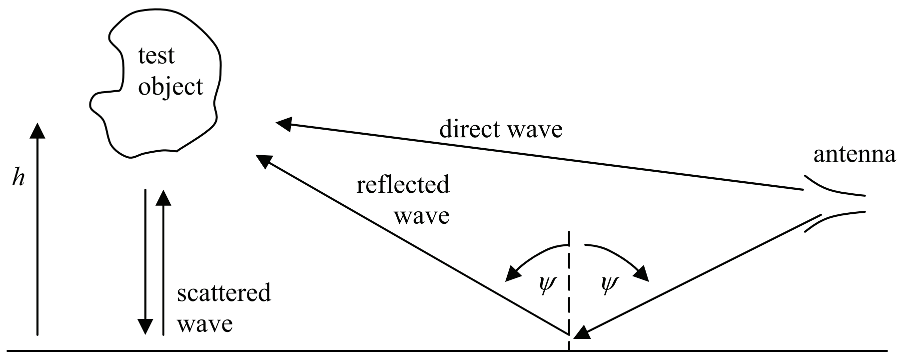
## 3. Inclusion of Ground Plane in Test-Geometry Design

As indicated in Fig. 3.1A one may have a test site where both the system under test and the incident-wave radiator (antenna) are above a nearby earth or ground plane. In this case, there is a strong reflected wave from the earth or ground plane. This can greatly complicate the response of the system under test. If, for example, the system were an aircraft or missile, and one were concerned with the in-flight response, this could greatly compromise the test validity. There is also the scattered wave from the test object which also reflects from the earth or ground plane and reinteracts with the test object, but this is normally a smaller effect (for sufficient height $h$) than that from the reflection of the direct wave.

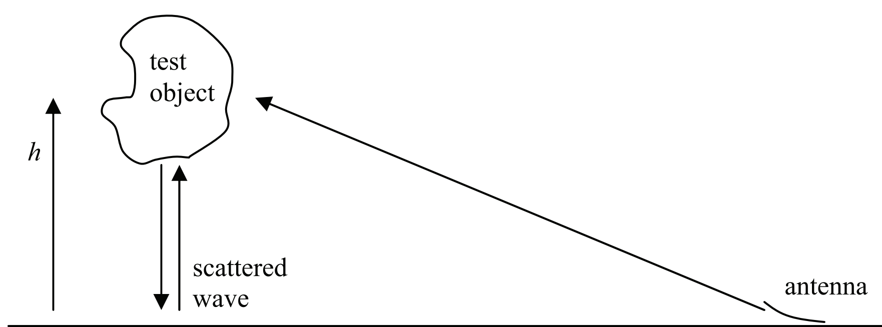
One can improve the situation in Fig. 3.1A for the case of a low conductivity soil by choice of the angle $\psi$ as the Brewster angle for the case of vertical polarization. Horizontal polarization still has a strong reflection, and so can be avoided. Polarization variation can be obtained by rotating the test object.

An alternate configuration in Fig. 3.1B completely avoids the ground reflection of the incident wave. In this case a ground plane is made an image plane. The source antenna (or "half antenna" if one prefers) is mounted on the ground plane, giving vertical polarization. The full antenna pattern includes an image below the ground plane. This greatly simplifies the field incident on the test object. This still leaves the interaction of the scattered fields (from the test object) with the ground plane back to the test object. This can be minimized by appropriate choice of the height $h$, of the test object from the ground plane ($h >>$ test object size). Again variability of direction of incidence and polarization can be achieved by rotation of the test object.

The above considerations can be combined with those in Section 2 to give a semianechoic chamber as in Fig. 3.2. In this case we have both ground-plane and wall reflections with which to be concerned. We need to shape the chamber so that there is no focus of wall reflections (including via the ground plane) on the test object. Most importantly, use of the ground plane as an image plane for the source antenna has removed an undesired reflected wave.




A. Antenna above earth or ground plane




B. Antenna (or "half antenna") using metal ground plane as a symmetry plane

Fig. 3.1 Test Site With Earth or Ground Plane

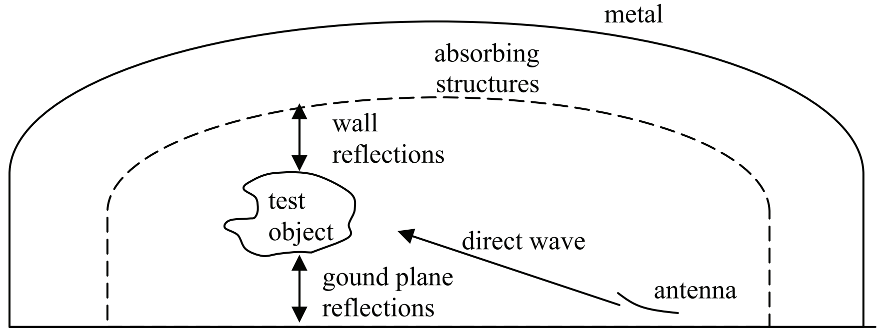
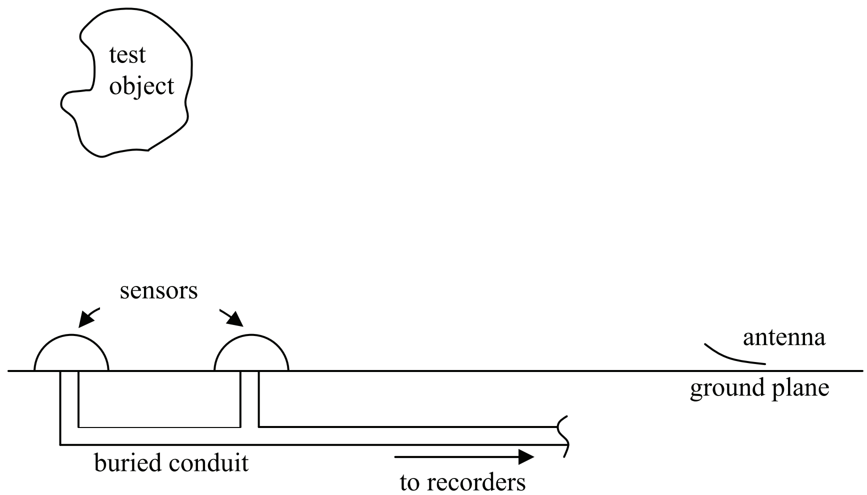



Fig. 3.2  Application to Semianechoic Chamber

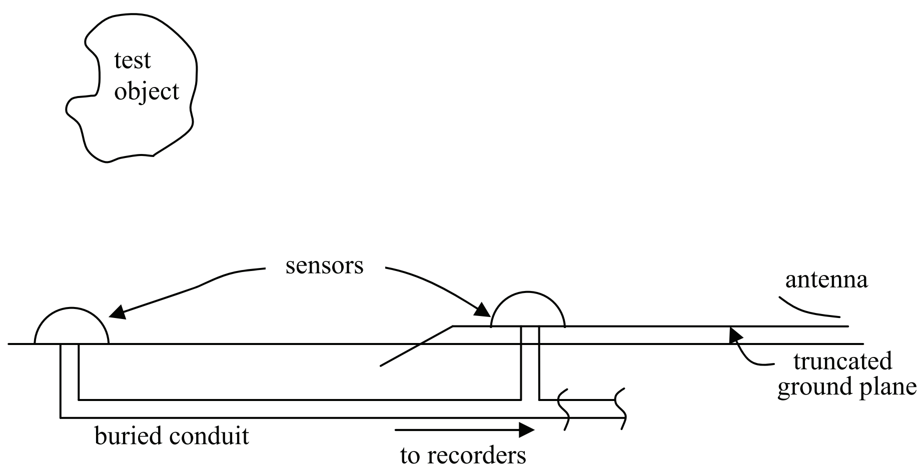
## 4. Combination of Ground Plane With Earth

Now consider combining the image plane for the electromagnetic source with earth under the test object as in Fig. 4.1.  begin with the ground-plane configuration in Fig. 4.1A in which the ground plane extends under both source and test object.  (Of course the ground plane should be connected to the earth around the perimeter in a manner to minimize reflections from the ground-plane edge.) In this case one can have sensors mounted on the ground plane to monitor the electromagnetic environment (as often done in EMP simulators). These signals are then brought under the ground plane plane (typically in a conduit) to the recorder location.

Next modify this geometry as in Fig. 4.1B by removing the portion of the ground plane under the test object.  This reduces the interaction of the test object via reflection from the earth instead of a ground plane.  Now the ground plane should be gradually transitioned into the earth to minimize diffraction from this region toward the test object.  An example of such a transition is that in the SIEGE EMP simulator from the surface to the buried transmission line [4].  One can still place sensors on the ground plane and the earth with signals routed as indicated.




A. Full ground plane




B. Part of ground plane replaced by earth

Fig. 4.1 Ground Plane and Sensors

## 5. Influence of Local Scattering Buildings on Test-Site Design

Open-air test sites can have various large equipment (cranes, etc.) and buildings (for instrumentation, offices, etc.) near the test area. One needs to consider the placing and shaping of such structures for minimum perturbation of the test environment.

Figure 5.1 shows an example of an instrumentation building (perhaps including a screen room) buried on the test site. In this case, one might have a ground plane from the source extending over the building. This leaves an option as to whether or not to extend the ground plane under the test object.

Figure 5.2 shows an example of an above-ground building positioned and shaped for minimal scattering toward the test object. A first technique is to place the building in a null of the transmitting antenna and, thereby, in the opposite direction from the test object. Of course, antennas have patterns and nulls are not perfect. One may use a $\vec{p} \times \vec{m}$ antenna [5] as an example of such a null in the back direction. In this manner one is concerned only with the scattered fields from a distant test object as in Fig. 5.2A.

A second technique is to minimize the scattering from the building by use of stealth shaping. Figure 1A (top view) shows a wedge shape to minimize the scattering in the direction of the test object from the source antenna and from the test object itself. This technique is extended by orienting the edge of the wedge as in Fig. 5.2B (side view) so that the scattering is directed away from the test object. One can also use resistive loading on the building exterior to reduce the scattered fields.

At low frequencies the $r^{-3}$ scattering implies that the building needs to be sufficiently far away compared to its height.

## 6. Concluding Remarks

There are then many things to be considered in the design of an electromagnetic test site. The fundamental problem is to expose the test object (system under test) to an electromagnetic environment which is like some real environment of concern to the extent possible and/or practical. This is a quantitative question requiring serious analysis.

There are many details not considered here. There are issues involving transporting real-time electromagnetic test data to recorders. These include cable routing, use of fiber-optic links, location of recorders (with appropriate shielding), use of special sensors, etc. Fortunately the community has much experience with such design questions, primarily in the design and use of EMP simulators.

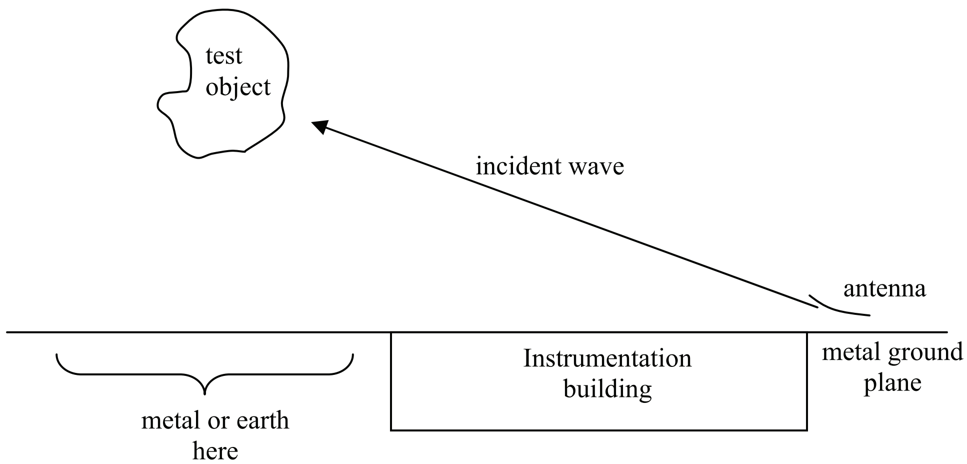



Fig 5.1 Buried Instrumentation Building

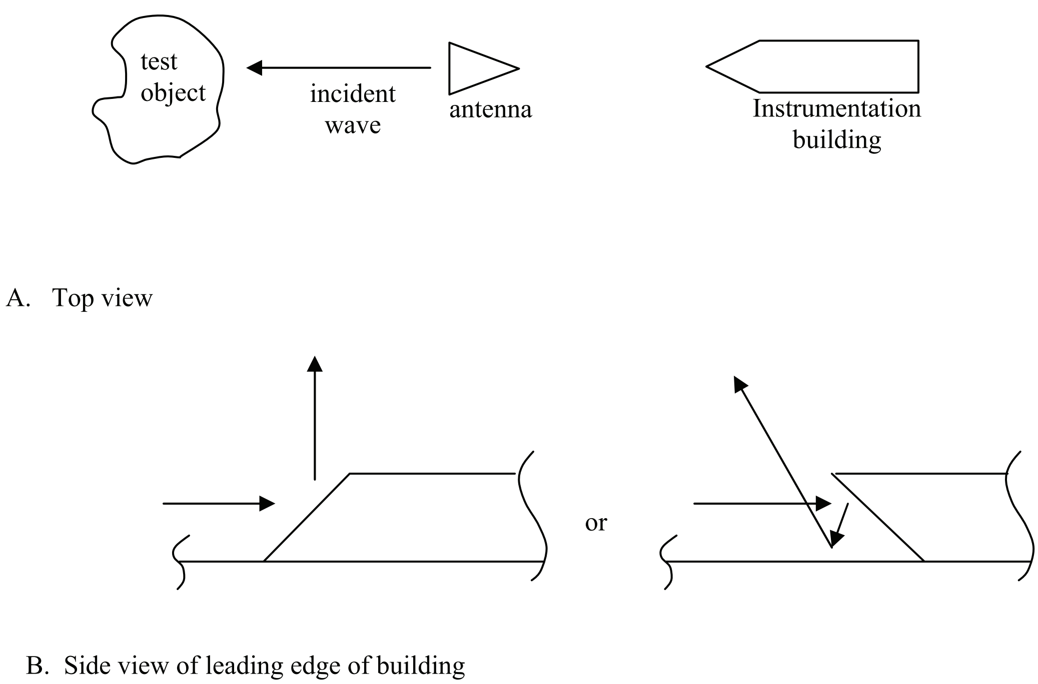



Fig. 5.2 Shaped (Stealth) Building

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