Interaction Notes

Note 613

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Damping Electromagnetic Resonances in Equipment Cavities

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Abstract

For moderately shielded cavities containing various conducting equipment, one can reduce the resonant fields that may enter the cavity through various penetrations. This involves judicious placement of wires loaded with resistors to dampen such resonances, removing electromagnetic energy.

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1. Introduction

In [1] techniques for damping resonances in shielded enclosures were discussed. These included, firstly, inserting resistive loading on conductors to use them load the cavity resonances. This is done in ways which do not interfere with desired signals and electrical power. Secondly, grids of resistors were placed in available empty volumes to effectively couple to cavity modes. Experimental results showed a reduction of cavity fields by one to two orders of magnitude (20 to 40 db).

The present paper extends those concepts to some practical applications, such as found in screened enclosures with equipment racks (or other large structures) and personnel.

2. Insertion of Single Loaded Wires in Empty Cavities

First consider a canonical problem to exhibit the principles involved. As in Fig. 2.1 consider a rectangular-parallel piped cavity with conducting walls (metal, metal mesh, metal coated plastic, etc.).

2.1 The resistors

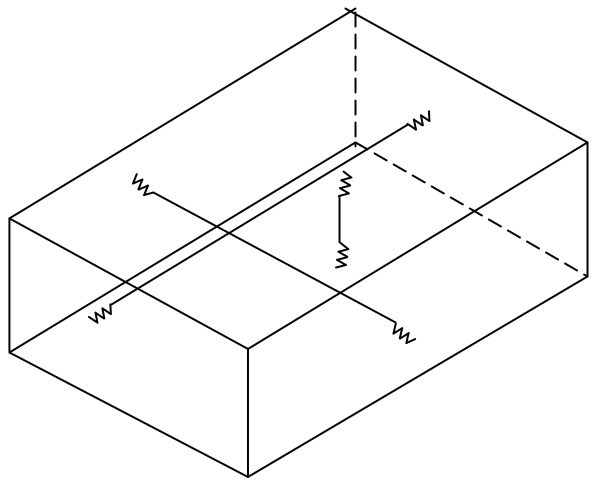
Consider firstly a wire connected (shorted) to two opposite walls of the cavity. For waves propagating along the wire the connection points to the walls are current maxima. Therefore place resistors of value R there.

Think of this wire as an approximate transmission line of characteristic impedance

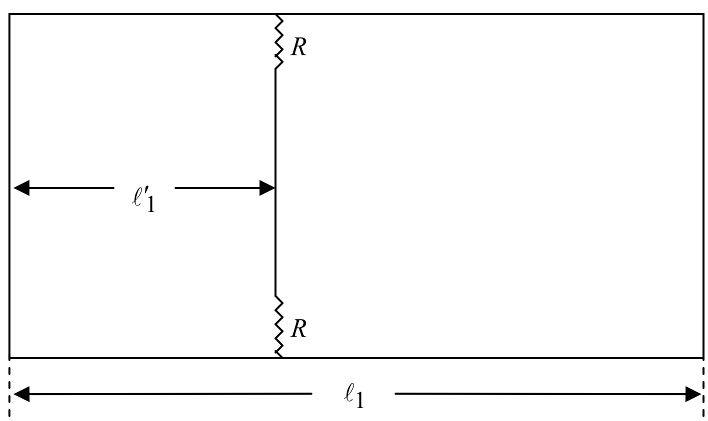
$$\begin{aligned} Z_c &= \frac{Z_0}{2\pi} \ell n\left(\frac{\Psi_{\text{outer}}}{\Psi_{\text{w}}}\right) \simeq 60\ \ell n\left(\frac{\Psi_{\text{outer}}}{\Psi_{\text{w}}}\right) \\ Z_0 &= \left[\frac{\mu_0}{\varepsilon_0}\right]^{1/2} \equiv \text{wave impedance of free space (ohms)} \\ &\simeq 377\ \Omega \\ \Psi_{\text{w}} &\equiv \text{wire radius} \\ \Psi_{\text{outer}} &= \text{distance to parallel walls (roughly)} \end{aligned} \tag{2.1}$$

Then choose

$$R \equiv Z_c \tag{2.2}$$



A. Cavity with three loaded wires



B. View of one wire in cavity

Fig. 2.1 Damped Rectangular-Parallel piped Cavity

This terminates the waves on the wire for maximum power absorption. Typical values might be

$$\Psi_w \simeq 1\,\text{mm} \;, \quad \Psi_{outer} \simeq 1\,\text{m} \tag{2.3}$$

giving

$$R_s \simeq 60\,\ell n\left(10^3\right) \simeq 0.4\,k\Omega \tag{2.4}$$

2.2 Positioning the wire

For positioning the wire consider Fig. 2.1B. As is well known the modes of such a cavity are those of a rectangular waveguide with the addition of conducting planes perpendicular to the direction of propagation. One set of modes has an integer number N_1 of half wavelengths $\lambda / 2$ (guide wavelengths) in the distance ℓ as

$$\ell_1 = N_1 \frac{\lambda}{2} \tag{2.5}$$

Consider H (TE) modes with E parallel to the wire. Then we need

$$\frac{\ell_1'}{\ell_1} \neq \text{ratio of small integers} \tag{2.6}$$

(e.g., not in a harmonic ratio as in musical harmony). If desired, this can be chosen as a transcendental number (which cannot be expressed as the ratio of integers). Note that modes also have an ℓ_2 between two more conducting walls parallel to the same wire. The above conditions apply to ℓ_2' as well.

This still leaves the question of where the position is optimal. For high-order modes ℓ_1 could be as small as $\lambda / 4$. However, for low-order modes where the electric field is maximum at about $\ell / 2$, one might prefer the wire to be near (but not at) $\ell / 2$. However, the next mode has a null at $\ell / 2$.

Three wires, of course cover three polarizations of the electric field. One need not limit oneself to only three wires. More can be added as needed.

3. Incorporation of Damping With Existing Conductors inside Cavity

In applying the technique of the previous section to realistic situations one encounters various conducting objects in the cavity. One would like to incorporate these objects into the damping scheme, effectively making them part of the "wires" previously discussed.

Consider the general situation in Fig. 3.1. Here we have some equipment racks which may contain various electronic equipment (computers, amplifiers, clocks, μwave sources/receivers, power supplies, etc.). If the rack itself is conducting it can take the role of a wire. One might connect this to the conducting ceiling via wire and resistors, and to the metal floor similarly. (Note there may be a dielectric floor above the metal floor for cable runs. If part of the floor is metal, one can also connect to this.)

There may also be overhead metal cable trays. These can also be used for part of the damping system, as indicated.

The only real constraint is where *not* to connect with wires and resistors. This includes walkways and chairs for personnel. If there are multiple floors involved then one needs clear stairs/ladders. However, even some of the metal here may be incorporated in the damping system.

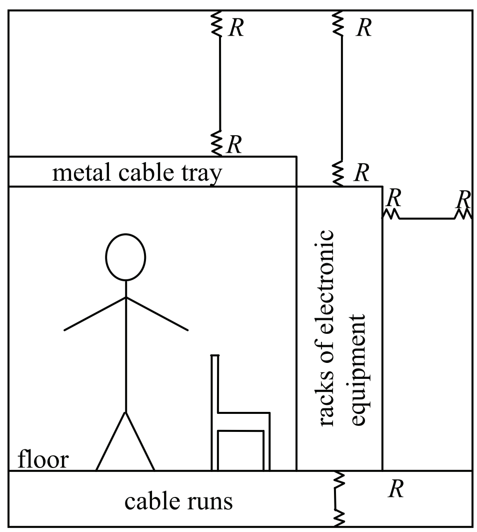


Fig. 3.1 Screen Room with Racks of Equipment Cross-Section View

4. Concluding Remarks

As we can see there are many things one can utilize to channel cavity resonances into resistive loads, thereby reducing interfering cavity fields that may have entered via unwanted, and perhaps unknown, apertures.

References

1. C. E. Baum, “Damping Transmission-Line and Cavity Resonances”, Interaction Note 503, May 1994; C. E. Baum and D. P. McLemore, 12th Zurich EMC Sym., 1997, pp. 239-244.