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Microwave Memos

Memo 3

The Microwave - Oven Theorem :

All Power to the Chicken

I. Introduction

Question:

What is the difference between a microwave oven and a mode stirred chamber?

Answer:

The former cooks chickens and the latter cooks electronics.

II. All Power to the Chicken

As illustrated in Figure 1 we have a closed volume referred to as a microwave oven. In the usual convention for time-harmonic waves ($e^{j\omega t}$ dependence) we have the real power (averaged over a cycle)

$$P_{in} = P_c + P_w + P_s$$

$$P_{in} \equiv \frac{1}{2} Re \left[\int_{S_{in}} \left[\tilde{\vec{E}}(j\omega) \times \tilde{\vec{H}}(-j\omega) \right] \cdot \vec{1}_{in} \, dS \right]$$

$$= \text{power into chamber}$$

$$P_c \equiv -\frac{1}{2} Re \left[\int_{S_c} \left[\tilde{\vec{E}}(j\omega) \times \tilde{\vec{H}}(-j\omega) \right] \cdot \vec{1}_c \, dS \right]$$

$$= \text{power into chicken}$$

$$P_w \equiv -\frac{1}{2} Re \left[\int_{S_w} \left[\tilde{\vec{E}}(j\omega) \times \tilde{\vec{H}}(-j\omega) \right] \cdot \vec{1}_w \, dS \right]$$

$$= \text{power into walls}$$

$$P_s \equiv -\frac{1}{2} Re \left[\int_{S_s} \left[\tilde{\vec{E}}(j\omega) \times \tilde{\vec{H}}(-j\omega) \right] \cdot \vec{1}_s \, dS \right]$$

$$\equiv \text{power into mode "stirring" device} \tag{2.1}$$

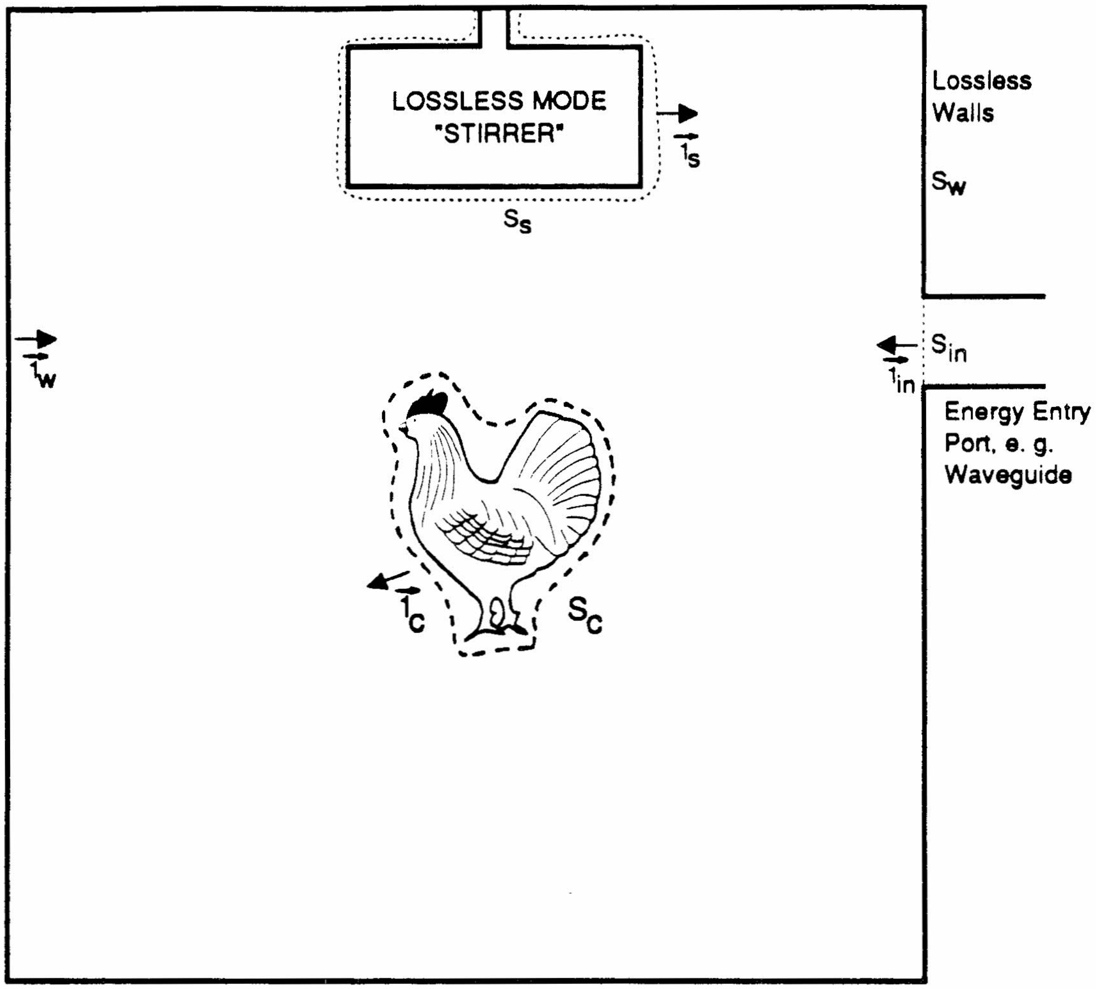

Figure 1. Microwave Oven or Mode-Stirred Chamber

Note that there are two closed surfaces

$$S_o = S_{in} \cup S_w \cup S_s \equiv \textit{oven surface}$$

$$S_c \equiv \textit{chicken surface}$$

$$\tag{2.2}$$

Now (2.1) is a statement of the Poynting vector theorem in the form of power in equals power out. An ideal microwave oven has

$$\mathbf{P_w} = \mathbf{0} \ \ \textbf{(lossless walls)}$$

$$\mathbf{P_s} = \mathbf{0} \ \ \textbf{(lossless mode "stirrer")} \tag{2.3}$$

giving

$$\mathbf{P_c} = \mathbf{P_{in}} \ \ \textbf{(all power to the chicken)} \tag{2.4}$$

Note that this result is independent of the position and orientation of the mode stirrer. The angular velocity of the mode stirrer is also assumed sufficiently small that no significant power is imparted to or extracted from the cavity fields.

Note that (2.4) is independent of frequency. It is also independent of where the chicken is located in the cavity. This does not say whether a gizzard or a drumstick gets more power since (2.4) only gives the total. Ostensibly the mode stirrer helps to more uniformly distribute the power deposition (time averaged over stirrer rotation) in the chicken. Also note that the appropriate input impedance of the cavity depends on stirrer and chicken, i.e., no chicken implies no power in and thus a reactive input impedance.

III. The Electronic Chicken

Now consider some electronic system (a radio, an aircraft, etc.) placed in a mode-stirred or reverberating chamber (alternate name for microwave oven, of whatever power level) [1]. Such a system is then an electronic chicken as far as the equations in the previous section are concerned. So for the electronic chicken (2.4) is directly applicable. All power P_{in} appears as P_c in the electronic chicken. Of course, the power deposited in individual transistors, etc., can vary, but the total is constrained by (2.4).

Note that usually a high Q (low loss) is often required of such a chamber to increase the field level inside for a given power into the chamber [1]. It is precisely low chamber loss ($P_w \simeq 0$, $P_s \simeq 0$) which enforces (2.4). It would appear that what is being done here is for the convenience of the tester, rather than the scientific validity of the results.

Presumably the purpose of testing a piece of electronic equipment is to determine its performance in a particular environment of concern. This might be, for example, a plane electromagnetic wave such as an aircraft might undergo. This is almost never characterized by (2.4). The transfer function to some pin (or failure port [2]) in the sense of volts per V/m (or effective height) is in general a highly variable function of frequency. This is also sometimes thought of as an absorption cross section giving the ratio of power absorbed to that incident per unit area. However, (2.4) says that all power is absorbed at all frequencies. Considering the simple case of only one energy absorbing load in the system (say a resistor on an antenna port), what does such a frequency-independent result tell us about the plane-wave response. It would seem nothing of significance.

Suppose we consider some subsystem such as a black box inside an aircraft. Placing this black box in a mode-stirred chamber still gives (2.4). So what have we learned? The black box does not in general react that way when connected into the actual impedances of the aircraft.

Instead of the power into the chamber one might measure the fields in the chamber for normalizing the results. Note, however, that the electronic chicken is a significant load in the chamber ("ideally" the only loss in the chamber). So the fields before introducing the system are radically different from those after introducing the system, even in an incident-field sense. Even in the presence of the system the fields are so complicated that one is faced with the problem of what fields (what components of $\vec{E}$ and $\vec{H}$) at what locations to use. Remember that the fields are in general quite reactive.

IV. Concluding Remarks

How can anyone seriously consider such a test procedure?

References

1. M. T. Ma, M. Kanda, M. L. Crawford, and E. B. Larsen, A Review of Electromagnetic Compatibility/Interference Measurement Methodologies, Proc. IEEE, 1985, pp. 388-411.

2. C. E. Baum, Black Box Bounds, Interaction Note 400, May 1983, and Proc. EMC Symposium, Zurich, March 1985, pp. 381-386.