Wave Chaotic Properties of Cascaded Complex Enclosures

Shukai Ma[1], Bo Xiao[1,2], Thomas M. Antonsen[1,2], Edward Ott[1,2] and Steven M. Anlage[1,2]

Department of Physics[1],
Department of Electrical and Computer Engineering[2],
University of Maryland,
College Park, MD, 20742-4111
skma@terpmail.umd.edu

Abstract— Predicting the power transmission properties of interconnected enclosures, like a chain of cabins in a ship, is of keen interest to various communities. Here we utilize the Random Coupling Model (RCM) to understand the measured wave properties of the cavity cascade systems. By building models that describe the random coupling between apertures and cavities, we are able to produce theoretical predictions for the statistics of impedance (Z) elements for cascade cavities that are in semi-quantitative agreement with data.

Keywords: Random Coupling Model (RCM), electromagnetic interference, interconnected enclosures, radiating aperture

The Random Coupling Model (RCM) [1] predicts the statistical properties of waves inside a chaotic, by using both the Random Matrix Theory and also system specific features which can be determined by structure dimensions and material. Previous studies on 2-port single cavity experiment are conduct [2]. The statistic properties, like probability density function, of the experimental normalized impedance matrix elements are of good agreement with the RCM predictions. According to the RCM theory, the loss of a ray-chaotic enclosure can be solely characterized by the loss parameter α.

Since arranging full sized cavities (~1m^3 per cavity) is difficult in regular-sized rooms, we use the scaling relationship from Maxwell's equations to obtain a scaled-down-in-size cavity system while preserve the loss parameter of the full scale cavity. Experiments show that the statistics of the single cavity two-port impedance matrix elements for full scale and scaled enclosures that have the same loss parameter α matches with each other.

We next study the transmission property for a multi-cavity cascade system. The cavities are connected by circular or rectangular shaped apertures. We study trans-impedance

$$Z_t = \frac{V_{RX}}{I_{TX}} \quad (1)$$

and the input impedance

$$Z_{in} = \frac{V_{TX}}{I_{TX}} \quad (2)$$

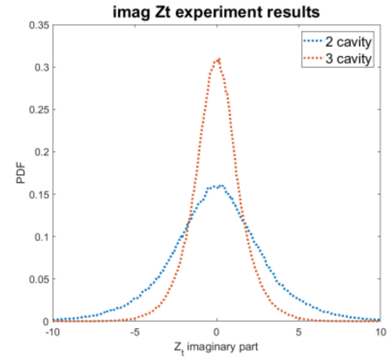

Figure 1. Example of the imaginary part of transmission impedance Z_t for cavity cascade experiments.

of the cavity system, where the subscripts TX and RX refers to the transmission and receiving end. To obtain these quantities, we use RCM to characterize the single cavities within the cavity-cascade chain.

$$Z_{cav} = i \cdot Im(Z_{rad}) + Re(Z_{rad})^{0.5} \cdot \xi \cdot Re(Z_{rad})^{0.5} \quad (3)$$

As shown in the Fig.1, the blue and red curves are the statistics of the imaginary part of the measured trans-impedance ($Im[Z_t]$) from 2 and 3 cavity cascades with circular shaped apertures. We can find that the probability density function for 3-cavity experiment is more concentrated near 0, which corresponds to the extra cavity introduces more loss and less fluctuation.

To establish the theory for connecting cavities, we adopt the theory proposed by Gradoni, *et al*. [3]. According to the physical dimension of the apertures, we calculate the radiation admittance of the aperture modes. Dictated by the dimension of the apertures and the operating frequency range in the experiment, the number of propagating modes will change accordingly. Afterwards we will integrate radiation property of apertures with the cavity information characterized using RCM theory [4]. In this formalism, we are able to obtain the total transmission impedance and input impedance of the entire cavity cascade system. We will then compare the predicted values generated using this formalism, with the experimental data that we obtained.

REFERENCES

[1] Zheng, Xing, Thomas M. Antonsen, and Edward Ott. Electromagnetics 26.1 (2006): 3-35.
[2] Xiao, Bo, et al. arXiv preprint arXiv:1802.10167 (2018).
[3] Gradoni, Gabriele, *et al*. IEEE Transactions on Electromagnetic Compatibility 57.5 (2015): 1049-1061.
[4] Gradoni, Gabriele, *et al*. Wave Motion 51.4 (2014): 606-621.

ACKNOWLEDGEMENT

This work is supported by ONR under Grant No. N000141512134, AFOSR COE Grant FA9550-15-1-0171, and DURIP grant N000141410772, and the Maryland Center for Nanophysics and Advanced Materials.