Electromagnetic Wave Chaos in 3D Cavities

TREND FAIR 2011

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Purpose

To determine the applicability of the Random Coupling Model in predicting the susceptibility of a circuit in a 3D cavity not known to produce wave chaos.

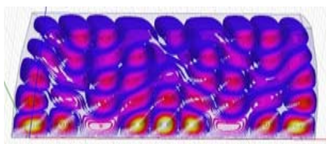
Introduction

Assumptions

1) λ >> L
   - Treat EM waves as optical rays
2) n >> 1
   - Many modes within cavity
3) Random Plane Wave Hypothesis
   - Local field is superposition of many plane waves

Implications

1) System is wave chaotic
2) Ray orbits are exponentially sensitive



- Complexity of modes at equilibrium within a cavity

Random Coupling Model

Cavity Impedance

$$Z = j\,\mathrm{Im}[Z_{rad}] + \ddot{z}\,\mathrm{Re}[Z_{rad}]$$

Cavity Impedance expressed as an expansion over the M modes in the cavity

$$Z(k) = \frac{-j}{\pi}\sum_{n=1}^{M} \Delta k_n^2 \frac{R_R(k_n) w_n^2}{k^2(1 - j/Q_{ul}) - k_n^2}$$

Radiation Impedance characterizes the system-specific coupling of any arbitrary port geometry to the cavity

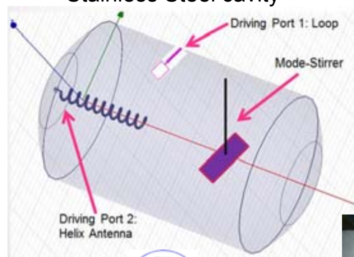
$$Z_{rad}(k) = \frac{-j}{\pi}\int_0^\infty \frac{dk_n^2}{k^2 - k_n^2} R_R(k_n)$$

Normalized Impedance characterizes the universal aspects of the cavity

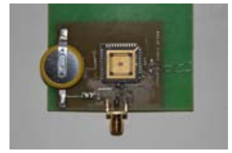
$$\ddot{z} = \frac{(Z - j\,\mathrm{Im}[Z_{rad}])}{\mathrm{Re}[Z_{rad}]}$$

Apparatus

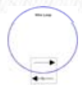
Stainless Steel cavity



CMOS Buffer



Isolator to break TRS



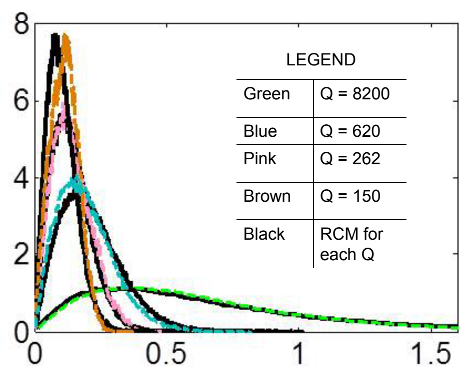
Basic Parameters

# of Absorbers:	4	2	1	0
Quality Factor (Q):	150	262	620	8200

Volume	2.16 m^3
Surface Area	9.38 m^2
Mean Mode Spacing	.291 m^{-2}

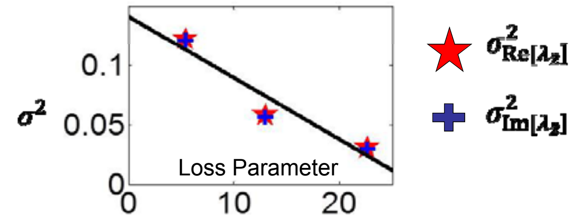
Results

a) Comparison of experimental probability density functions (PDFs) with RCM predictions of PDFs

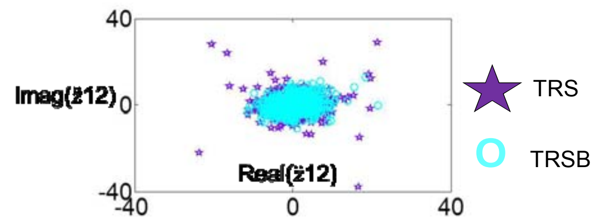


Results

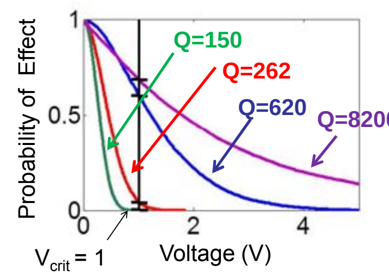
b) Variance vs. Loss Parameter for Q = 620, 262, 150



c) Real(ż12) vs. Imag(ż12) in TRS and TRSB for Q=8200



d) RCM predictions of cumulative distribution functions



Q	PoE
8200	60.2%
620	71.0%
262	79.6%
150	82.2%

Conclusions

- Verified applicability of RCM to a general cavity
  - Predicted experimental PDFs using measured Q's
  - Confirmed RCM theory that $\sigma^2_{Re[\lambda_z]} \cong \sigma^2_{Im[\lambda_z]}$
  - Measured reduced variance in TRSB
- Qualitatively assessed method of predicting PoE of a circuit using only 6 inputs to RCM

Future Work

- ❑ Investigate more extreme loss cases
- ❑ Develop an equivalent circuit model to calculate voltage statistics for arbitrary port impedances
- ❑ Refine experimental procedure to measuring Q