Fundamentals of Accelerator Physics and Technology With Simulations and Measurements Lab

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Measurements and Analysis of Simple Microwave Cavities

This session gives you the opportunity to make hands-on measurements both on a device which mimics a radiofrequency cavity as well as actual cavities – singly and coupled. Practical experience with a Network analyzer is also offered.

1 Hands-on measurements

In this experiment you will perform measurements on a radiofrequency (RF) cavity. The first one is a pill-box cavity (some might call it a cookie box). Properties of a pill-box cavity can be calculated easily using formulae provided in the class notes and text.

1. Measure the mechanical dimensions of the small pill-box cavity for computer simulations if you did not do this already. A large pill-box cavity is provided for comparison but measurements in this assignment should be done using the small cavity. Estimate the lowest order resonant frequency, TM010 mode, from the dimensions and the formula:

$$(f_{\mathrm{nat}} = 2.405c \,/\, 2\pi r).$$

2. Open the pill box and observe the installed antennas. One is a loop and the other a straight antenna. What fields do you excite with each of the antennas?

3. Connect the pill box cavity to the network analyzer and find the exact TM010 mode frequency.

4. Display the resonant curve and measure the full width half maximum, FWHM and determine the quality factor Q.

5. Detune the cavity
   a. Lightly squeeze the cylindrical part of the cavity and observe the movement of the TM010 mode frequency. Does the frequency get lower or higher? Why?

   b. Squeeze the end plates and observe movement of the TM010 mode resonant frequency. Which 'squeeze' is more effective and why?

6. Now put two Ferrite pieces (μ_r »1) flat on the bottom around the axis of the cavity. Measure the shift in resonant frequency for the TM_{010} mode. Do the same with four Ferrite pieces arranged in a circle closer to the edge of the pill box. Think about/explain the magnitude of the frequency shift in either case in terms of the change in electric or magnetic field energy (Hint: think about the relative strength of electric and magnetic fields at different radial positions in the cavity).

7. A dielectric also changes the resonant frequency. Put a small vial of water, piece of plastic or pencil eraser in the center of the cavity and observe the shift in frequency of the TM_{010} mode. Make sure the dielectric does not distort the mode shape as measured on the network analyzer (if it does distort the mode shape the dielectric is no longer a perturbation to the fields). Measure the frequency shift as a function of radial position of the vial and plot frequency shift versus radial position of the dielectric. This is a crude electric field measurement. The frequency shift is proportional to the square of the electric field at the location of the dielectric.

2 ORNL Cavities Measurements

8. Measure the mechanical dimensions of one of the cavities provided by Oak Ridge National Laboratory. Estimate the lowest order resonant frequency, TM010 mode, from the dimensions and the formula ($f_{\text{nat}} = 2.405c\ /\ 2\pi r$) given. Sketch the electrical and magnetic field configuration of this mode.

9. Connect the cavity to the network analyzer and find the exact TM010 mode frequency. Measure the frequency spectrum (harmonic frequencies).

10. Map the range of f and Q by adjusting the tuning knob on top beginning at one limit and moving to the other. Record and plot the results - take at least 10 points. Plot both f and Q as a function of tuner position. What kind of relation(s) do you find?

11. In a real accelerator cavities/cells are coupled to each other as part of an entire system. Tune both cavities to an identical fundamental frequency then connect them together. Connect the input to one cavity and measure the response from the other. What does the frequency spectrum look like now?

12. Calculate the cell-to-cell coupling using the relation

$$K_{cc} = 2|f_\pi - f_0|/(f_\pi + f_0).$$

13. What happens as you adjust the cavity tuners?

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