PRACTICE 06

TRANSMISSION MEASUREMENTS ON RF CAVITIES

INSTRUMENT: Keysight P9374A (300kHz – 20GHz, 1600 points)

Premises

VNA calibration is not necessary for the measures of f0 and QL.

$$S_{21}(f) = \frac{S_{21}(f_0)}{1 + jQ_L\delta} \quad \text{con} \quad \delta = \frac{f}{f_0} - \frac{f_0}{f} \qquad (1)$$

being S21 (f0) real number. In case of **symmetrical coupling** β

$$Q_L = \frac{Q_0}{1 + 2\beta}$$

QL can be found both from |S21| and $\angle$S21. In order to obtain QL from |S21|, use instrument Bandwidth Search measurement (**Search->Bandwidth & Notch->Bandwidth Search**). Measurements are always updated with **Tracking ON**.

To visualize the variations of the traces, you can save the trace in memory and you can visualize it with the data being acquired. **Right-Click on the trace -> Memory-> (Data->Mem)**, then select **Data and Memory Trace** (to see them together).

In case you have multiple traces, select in the trace number to be saved using the Multipe Traces command in DataAcquisition9.m.

	Frequency	Q factor
TM010	1.91333×10^9	16515.4
TM110	3.04859×10^9	20847.
TE111	3.80535×10^9	18896.3

Modes chart of the pillbox in S band

1. MULTICELL CAVITY (S BAND): f0, QL

Connect the device **without calibration**, visualizing S21 from 1 to 3 GHz.

1.1 Report the formula of |S21(f)/S21(f0)|, of the phase ∠S21(f) and its linear approximation around f0. **(REPORT)**

1.2 For the first 3 modes, <u>acquire and report the magnitude and the phase of S21</u> in a frequency range clearly showing the Lorentzian shape of the amplitude and the typical trend of the phase around the resonance frequency. <u>Measure f0 and QL from |S21|</u>. **(REPORT)**

1.3 **For each mode measured in 1.2**, <u>plot |S21(f)/S21(f0)|</u> from measured f0 and QL, using Eq. 1 and compare it (in the same plot) with the measurement. On the x-axis of the plots use the normalized deviation from the resonance frequency δ (as shown in the lectures). **(REPORT)**

1.4 **For each mode measured in 1.2**, approximate the ∠S21(f) with a linear fit around the resonance frequency. From the slope, obtain a <u>measurement of QL</u> (with uncertainty). Produce a <u>plot</u> overlapping the <u>measurements of ∠S12(f))- ∠S12(f0)</u>, the <u>linear fit</u> around f0 and the <u>theoretical formula</u> of ∠S21(f) (i.e. Eq. 1 using f0 and QL measured in 1.2). On the x-axis of the plots use the normalized deviation from the resonance frequency δ (as shown in the lectures). **(REPORT)**

1.5 Report in a final table the measured f0, the QL factor measured from the |S21| (automatic 3dB bandwidth) and the QL factor measured from the ∠S21 (linear fit) with uncertainty. **(REPORT)**
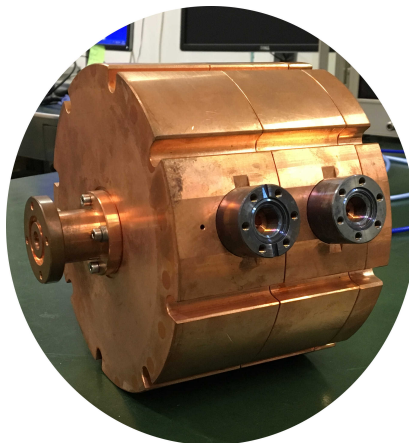
2 TUNER EFFECT IN A RESONANT CAVITY

Consider just the TM010 mode (first mode) of the pillbox cavity.

2.1 With the caliber, measure the initial position of the tuner. With the tuners in the initial position, <u>measure the resonance frequency</u> and save the measurement of |S21| in the instrument memory. Choose an appropriate measurement frequency span, looking for the sensitivity to the tuner variations (each tuner has to move of about 1cm).

2.2 Insert the first tuner, keeping the other one fixed in the original position; then before moving the second one, **take back the first tuner in the original position** (check with measurements, for example using the memory function). For each tuner, vary the tuner position to see the effect on the resonance frequency, by inserting each tuner of about 10mm in total. <u>Plot the measurements (**f0, QL**</u>) as a function of the position of the tuner (5 points for each tuner); the plots have on the x-axis the position of the tuner and on the y-axis **f0** or **QL** <u>Report the data</u> in a table as well.

Underline which quantities are influenced by the tuner and explain why the two tuners have different effects. **(REPORT)**
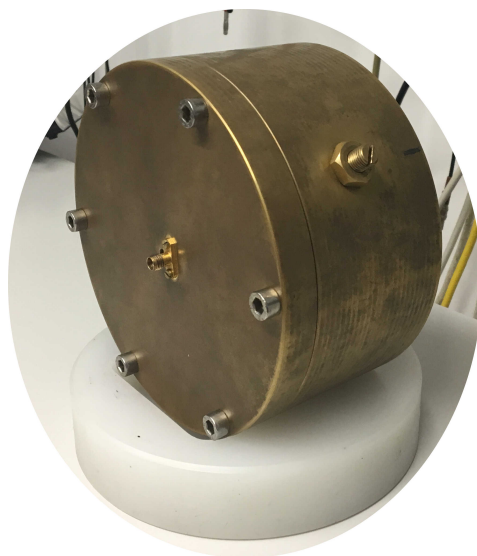
3 Perturbative field measurements in a resonant cavity

On the desk is installed a cavity with two cells (it is the prototype of the RF deflector of an electron accelerator). A nylon thread passes on axis with an attached small perturbing object (metallic sphere).

3.1 For the two modes with frequency lower than 2GHz, measure the unperturbed resonance frequency f0 and the unloaded Q0 factor, leaving the sphere outside the cavity. Use transmission measurements by choosing the coupling (i.e. the position of the antennas) to measure **Q0** (and not **QL**). Once the (low) coupling is fixed, you can reduce the **IF-BW** to increase the signal to noise ratio of the measurement. Use the automatic measure of Q (i.e. automatic 3dB bandwidth). **(REPORT)**

3.2 Consider the second mode (f0~1.964GHz) and measure the resonance frequency. **Introduce the sphere in cavity in different positions**: for each position, measure the distance from the input in the cavity and measure the perturbed resonance frequency **f**. Do it for 20 points (properly chosen) in order to cover all the length of the device; include, obviously, the case of the sphere outside the cavity both at the beginning of the measurement and at the end. To speed it up, report directly the data in an Excel table. Plot |f−f0|/f0 as a function of the location of the sphere. Comment the results, underlining why |f −f0|/f0 represents a field measurement on the cavity axis. **(REPORT)**

Suggestion In |f − f0|/f0 measurements, do some **preliminary measurements** to choose appropriately the best measurement span (that guarantee a good resolution) and use the memory function. A good span can be around 600kHz. You can measure the resonance frequency continuously, putting the marker on the maximum in **tracking** mode. Remember that the cavity mode has (on the axis) only the electric field and so the resonance frequency is perturbed always in the same direction… choose the frequency range accordingly.
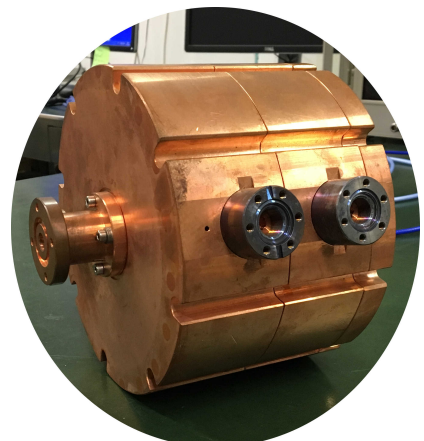
4 COAXIAL CAVITY WITH SYMMETRICAL COUPLING

The coaxial cavity can be excited with two movable antennas that allow you to vary the coupling β for each antenna.

1) Identify the first resonant mode (around 290MHz) with transmission measurements.

2) Configure the device in order to visualize **3 traces**: S11, S22 and S21, centered within 2MHz span. Measure the Q0 factor by under coupling the antennas as much as possible (monitor the coupling with the measurements of S11 and S22). Report the measurement of QL (=Q0) and plot |S11|, |S22| (put the two traces in one single plot) and |S21|. **(REPORT)**

3) Tracking S11 and S22, increase the coupling **in a symmetrical way** until you reach a minimum of |S11| (|S22|) **of about 3.5 dB** lower than the value outside resonance. In such symmetrical coupling condition, report the measure of QL (≠Q0) and plot the measurements of |S11|, |S22| (this two in one plot) and |S21|. **(REPORT)**

4) From the measure of QL (symmetrical coupling) and Q0, estimate β and compare it with the value obtained from the **ReflectionFitResonance.m** routine applied to the measurement of |S11| (or |S22|). **(REPORT)**