E 106:
Hohlraumresonatoren (Cavities)

Revision: June 2008

Remark: Single counting experiment

1 Aim of experiment

In this experiment you should get familiar with the different fundamental measurement methods of high frequency technology. In particular, you are introduced to the scalar and vectorial reflection measurement by determining, as an example, the characteristics of resonant cavities. The resonant eigenmodes and the corresponding quality factors, coupling coefficients and shunt impedances are obtained experimentally.

2 Required knowledge

- Propagation of electromagnetic waves in cables and wave guides: field distribution, cut-off frequency, attenuation, reflection coefficients, standing wave ratio
- Components of high frequency technology and their applications: directional coupler, circulator
- Cavities: Classification of possible oscillatory modes, determining functions of the corresponding field distributions
- Excitation of forced oscillations, equivalent circuit of the resonator with excitation, coupling coefficient
- Resonance curve of the scalar reflection coefficient, determination of the FWHM for different coupling coefficients, determination of the quality factor (loaded, unloaded)
- Resonance curve of the complex reflection coefficient, determination of the resonant frequency, FWHM, quality factor, coupling coefficient
- bead pull measurement (perturbation method), determination of the shunt impedance, transit time factor

3 Literature

To be borrowed from the assistant in charge of this experiment 1–2 weeks before the experiment.

- Supplemental script: details on the assignments, the experimental method and analysis

For some additional reading, the following materials can be downloaded on the web page[1] of the experiment (partly password protected, ask the assistant):

- W. Hillert: Vorlesungsskript ”Particle Accelerator Physics I”, S. 66–83
- C. Peschke: “Messungen und Berechnungen zu longitudinalen und transversalen Shuntimpedanzen einer Elektronen-Positronen-Linearbeschleuniger-Struktur”, S. 41–52
- W.F.O. Müller: “Untersuchungen zu Moden höherer Ordnung in konstanten und variierten Beschleunigerstrukturen für zukünftige lineare Collider”, S. 41–52

4 Assignments

Exercises before the experiment:

1. Use the mode chart and the dimensions of the cavity from the supplemental script to calculate the ten lowest eigenmodes of the cavities. Make the simplifying assumption of a closed, ideal hollow cylinder and use the zeros of the Bessel functions and their derivatives to calculate the corresponding frequencies.
2. Familiarize yourself with the units “dB” and “dBm”.

Preparations together with the assistant:

3. Familiarize yourself with the different modes of operation of the vektor network analyzer. Activate the auxiliary functions (line, marker) and think about how they may facilitate your measurements. Calibrate the analyzer for an arbitrary frequency range.

In the following you will find a short version of the assignments as an overview and for control. For details of procedure and analysis as well as further questions and information refer to the more detailed supplemental script being available from the assistant.

[1] `http://www-elsa.physik.uni-bonn.de/`, to be found under the topic `Lehrveranstaltungen`

Attenuation and reflection in coaxial cables:

4. Measure the attenuation and the reflection coefficient of the coaxial cables “RG142” (brown) and “ST-18” (blue) in the frequency range of 0.01–8 GHz. Document your results.

Scalar measurements, to be performed on both resonators:

5. Use the network analyzer to display the modulus of the reflection coefficient in a region around the calculated resonant frequencies. Measure all resonances you can find until 8 GHz according to the following steps. What is the effect of the position of the coupling on the excitation of the eigenmodes?
6. Determine the resonant frequencies of the eigenmodes with their corresponding errors. Compare the results of the measurement with the calculated results and explain the discrepancies.
7. Measure the respective reflection coefficient in resonance and calculate from this a value for the coupling coefficient (Which restriction has to be considered?).
8. Calculate the value for the reflection coefficient at the FWHM. Measure the corresponding width of each curve and use it to determine the loaded quality factor (including error) for the different oscillatory modes.

Vectorial measurement:

9. Measure the frequency response of the complex reflection coefficient in the region of the first eigenmode for the resonator with the loop coupling on the lateral surface of the cylinder.
10. Determine the resonant frequency, the quality factor and the coupling coefficient including their respective errors. Compare these values with the results of the scalar measurements.
11. Calculate the unloaded quality factor, the external quality factor and the power loss taking the coupling coefficient into account.
12. Repeat the described measurement and the determination of the denoted variables for three further oscillatory modes in the frequency range until 8 GHz.

Perturbation measurements:

13. Measure the resonant frequency of the first eigenmode in dependence on the position of the perturbing object in sufficiently small steps.

14. Measure the change in the reflection against the position of the object at the frequency of the first eigenmode.
15. Determine the field strength at the position of the object for both methods and calculate the shunt impedance by integrating (summation!) over the E-field. Take the transit time factor for ultrarelativistic particles into account! Give a value for the error of the shunt impedance.
16. Plot E against the position of the object. Determine the corresponding errors and include the error bars in the plot.
17. Give an estimate as to which extent the cavities are suitable for particle acceleration.

5 Procedure and analysis

For details of procedure and analysis please refer to the more detailed supplemental script being available from the assistant.