SETUP FOR MEASURING RF CHARACTERISTICS OF ACCELERATING CAVITIES

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Abstract

The BINP accelerating cavities are incorporated with fundamental mode tuners and Higher Order Modes (HOM) tuners. A special computerized setup is used for measuring RF characteristics of the fundamental mode and HOMs. Amplitude-frequency and phase-frequency characteristics of the evacuated cavities are measured at different tuners positions. The setup allows to take measurements at the fundamental mode frequency (180.4 MHz) and in the frequency range of 225-1800 MHz. The frequency range may be extended up to 3600 MHz, if necessary. The measurement circuit contains a sweep-generator and a superheterodyne receiver. The receiver is tuned simultaneously with the sweep-generator. The setup provides the dynamic range of 70 dB and the sensitivity of 3 μV. The range of the measured quality factor values extends from 800 to 100000. Also the characteristic impedances are measured using the small perturbation technique. About 100 modes are considered for each cavity. Up to now already over 15 cavities have been measured at this setup.

Introduction.

After fabrication of RF cavity its electrical properties are measured at the low signal level. A special measuring setup was created at BINP, Novosibirsk for that purpose. It is possible to measure the following cavity parameters:

1. Q-value, shunt impedance, coupling coefficients of cavity coupler and of sampling loop at the fundamental mode frequency.
2. Q-value and resonance frequency of HOMs versus cavity tuners position in a frequency range of 225 – 3600 MHz.
3. Distribution of electric field at the cavity axis for fundamental mode and HOMs for calculation of a transit time factor and shunt impedance at HOMs.

The measuring setup has several parts:

a. control modules of the fundamental mode tuners,
b. control modules of HOM tuners,
c. automatic fundamental mode frequency control units,
d. Q-value measuring modules,
e. HOM analyzer,
f. Setup for measurement of distribution of electric field at the cavity axis.

Measurement of HOMs.

Before measurement of HOMs, RF cavity is pumped to a rough vacuum. Two vacuum tight RF probes are inserted in opposite beam ports of the cavity along its axis. RF cavity is excited through one probe from oscillator of the HOM analyzer and electromagnetic field in the cavity is measured by the analyzer receiver from the other probe. It allows to investigate cavity HOMs, which have a longitudinal electric field at the cavity axis. These modes have a strong influence at the longitudinal beam instabilities.

Tuners position determines a frequency of HOM and its Q-value. These parameters are calculated from a shape of a resonant curve, that is measured by the HOM analyzer. The final result of measurement is a map showing dependence of HOM frequencies versus position of the tuning elements. It is possible to find a favorable position of tuners, so that HOMs are not excited by a beam, which may cause beam instabilities. The example of a measurement result is shown in Fig. 1. Frequency of HOM is plotted as a function of the position of 4 tuning elements.

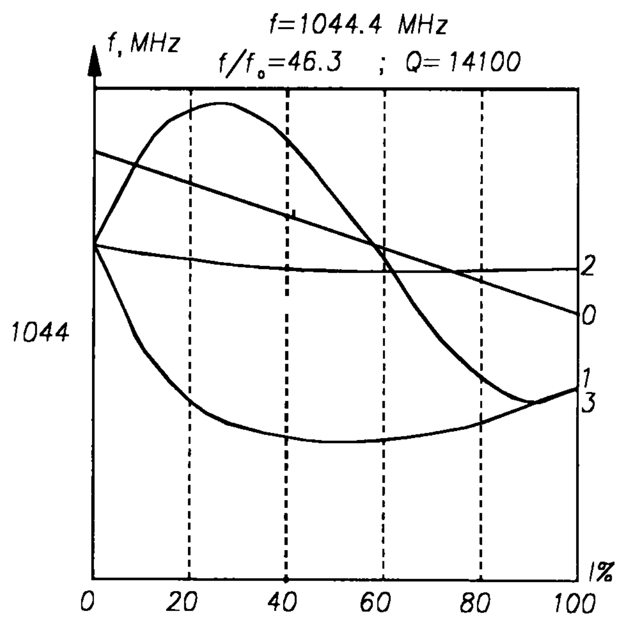

Fig. 1: Result of HOM measurement. Frequency of HOM is plotted as a function of the position of 4 tuning elements.

HOM analyzer.

The HOM analyzer is a computer controlled device to measure the transfer quadripole parameters in the main frequency range of 225 – 1800 MHz and in the extended range of 1800 – 3600 MHz. It has a tunable oscillator and a superheterodyne receiver. The method provides for high sensitivity of the receiver. The minimum operational level of the input signal is 90 dBm. The frequency of oscillator is measured by a frequency counter in a KAMAK module. All tunable elements of the analyzer are controlled by computer. The simplified block-diagram of the oscillator part of HOM analyzer is shown in Fig. 2.

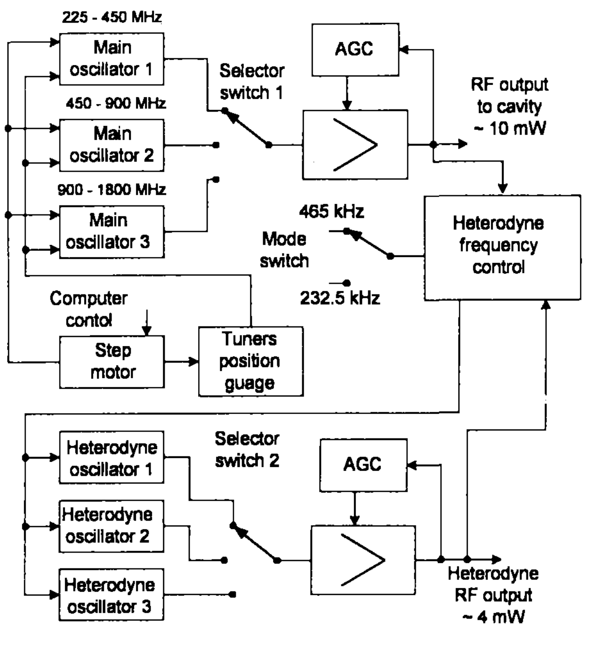

Figure 2: Block – diagram of oscillator part of the HOM analyzer.

In order to span a large frequency range, 3 tunable main oscillators are used. The tuning range of each oscillator is one octave. High Q-value copper RF cavities are used in the oscillator's resonance circuits for low parasitic frequency modulation of output signal. The value of the modulation is lower than 100 Hz, which offers 1% of accuracy for measuring Q-value up to 10^5.The tuning of the main oscillators is realized by steps in the whole frequency range using a step motor and by a varactor diode within one step of the motor. Reactive elements of a oscillator feedback circuit are tunable too. These elements are controlled by signal from the tuner position gauge. A broad-band amplifier has an automatic gain control circuit (AGC) to keep the output RF power of the unit constant.

There are 3 heterodyne oscillators, but they are tuned by varactor diodes only. This is possible because the requirements for the heterodyne parasitic frequency modulation are not very strict.

Frequency of a heterodyne oscillators is phase locked by the frequency of the main oscillator through the Heterodyne frequency control unit. It works so, that the difference of these frequencies is equal to 465 kHz at the main frequency range of HOM analyzer. For the extended range this difference is twice less – 232.5 kHz because of the specific mode of work at this range. For the extended range a frequency doubler is switched between RF output of the analyzer and the input probe. The receiver mixer works at the second harmonic of heterodyne signal at the extended range.

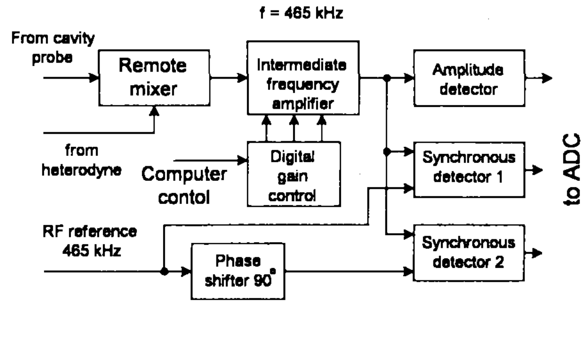

Figure 3. Block – diagram of a receiver part of the HOM analyzer.

For better protection against interference, the mixer of the superheterodyne receiver is assembled in the output probe. Intermediate frequency signal comes from the mixer output to a band pass amplifier of 465 kHz (6 kHz bandwidth). A gain of the amplifier is controlled by calibrated steps. Computer memory stores these calibration coefficients. The amplifier input is connected to one amplitude detector and to 2 synchronous detectors. Reference signal for the last two detectors are in quadrature. That method permits to measure the complex transfer functions of quadripole in a big dynamic range with a good linearity.

Measurement of electric field distribution.

Distribution of electric field along the cavity axis is measured by the method of small perturbation. A small ceramic cylindrical body (diameter 8 mm, length 20 mm) is pulled along the cavity axis. A shift of the mode resonance frequency is measured. A choice of the body material and shape offers a low disturbance of magnetic and transverse electric fields in the cavity.

The tunable RF generator 3 (see Fig.4) provides a signal to excite the RF cavity 4. A phasemeter 14 measures the phase difference of RF signals at RF cavity input and output. Phase shifter 11, 12 are adjusted so, that the output DC voltage at the phasemeter output is zero. Frequency of RF generator 3 is locked by the signal from phasemeter 4 output through a "phase-lock 2" switch. Therefore the frequency of RF generator is kept equal to the resonance frequency of the cavity mode.

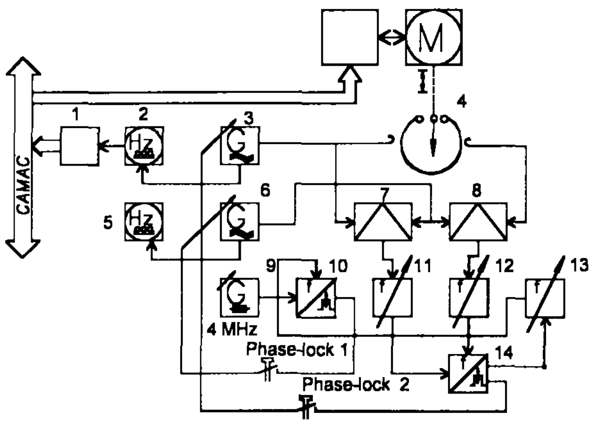

Fig. 4: Block-diagram of setup for R/Q measurement.

The operational frequency of the phasemeter 14 is 4 MHz, so there are two broad band mixers 11, 12 with the heterodyne RF generator 6. Its frequency is stabilized too by a feedback loop through the "Phase-lock 1" switch.

The ceramic body is pulled by a mechanism using step motor M and the frequency counter 2 measures the shift of the mode resonance frequency. An example of measurement is shown in Fig. 5.

Nearly 100 HOMs are considered for each cavity. Results of measurement are used for calculation of the transit time factor and of the R/Q value. Using Q-value, the impedance of a cavity for a beam is calculated for this mode.

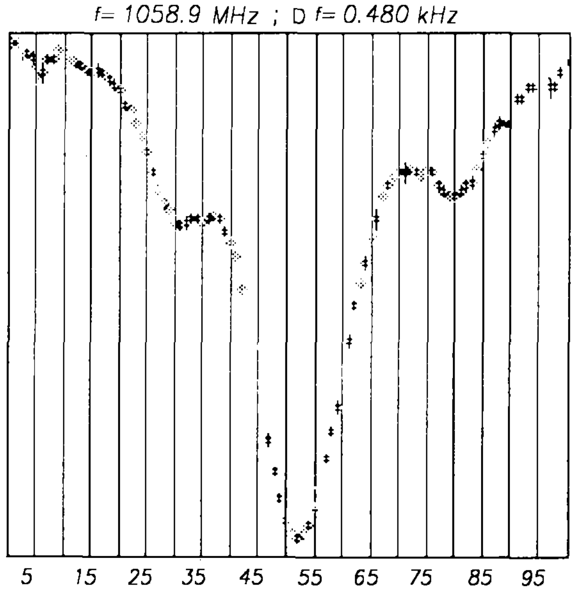

Fig. 5: Result of R/Q measurement. A shift of a cavity HOM resonance frequency is plotted as function of the perturbing body position.

Conclusion.

This setup was used at BINP to measure parameters of more than 15 cavities.