STABILITY MEASUREMENTS AT THE VICKSI-RF-SYSTEMS

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Summary

Methods and results of stability measurements at the VICKSI-RF-systems are given. Both amplitude- and phase-stability have been measured in the frequency range from 10 to 20 MHz. The short term stability of the amplitude is found to be better than 10^{-3} and the long term stability is measured to be less than $2 \cdot 10^{-4}$. The phase stability has been determined to be better than 0.04 degrees over a period of 20 hours.

Phase Regulation System

The DEE-voltages of the two cyclotron-RF-systems are phase regulated separately, using as reference the signal generator common to both systems as shown in the block diagram "PHASE REGULATION SYSTEM" (fig. 1). The reference is compared with the RF-output signal from a capacitive pick-up in each resonator. To measure the phase between these two signals we use an RF-phasemeter. This meter detects, filters and sums the phases between the corresponding negative and positive zero-crossings. The level of the resulting regulation signal extends from plus to minus five volts DC corresponding to plus to minus 100 degrees RF-phase. A second phase range can be chosen, which is shifted by 180 degrees with respect to the zero point of the first range.

The phasemeter output signal drives two phase shifters connected in series in the modulator. Each shifter consists of a bridge network including a PIN-diode. The RF-resistance of the diode can be varied by the regulation signal, which causes a phase modulation of the applied RF. Connecting two phase shifters of this type in series reduces the effect of non-linearity of each with respect to the total phase shift range. This range extends continuously from minus 100 to plus 100 degrees. For phases exceeding this range a fast additional shift of 180 degrees is possible.

The phase modulation response time of the modulator is 100 μs and the response time of the phasemeter 20 μs (3 dB point).

Amplitude Regulation System

As shown in the block diagram "AMPLITUDE REGULATION SYSTEM" (fig. 2), each of the two cyclotron RF-systems is regulated at low power levels with an RF-modulator (maximum output power 2 W). The regulation signal modulates the RF-drive by means of both a video amplifier and a mixer in order to improve the linearity and the dynamic range of the amplitude modulation.

The modulator receives the regulation signal via the RF-drive control from the RF-detector. Here two RF-input signals are rectified and summed, then subtracted from the amplitude reference signal. The final regulation signal results from the error signal amplified ten times.

The RF-input signals of the detector come from two capacitive pick-ups placed in the resonator in opposite positions with respect to the DEE in order to decrease the influence of possible mechanical DEE-oscillations.

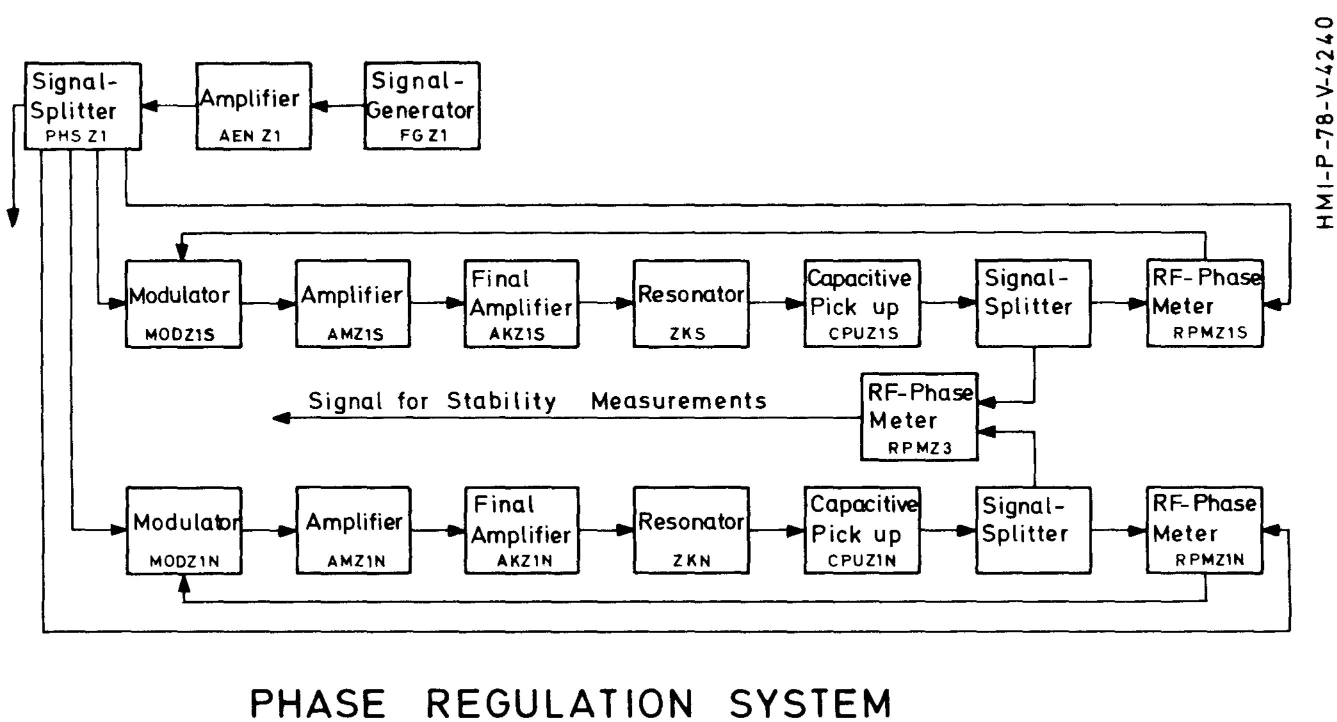

Fig. 1

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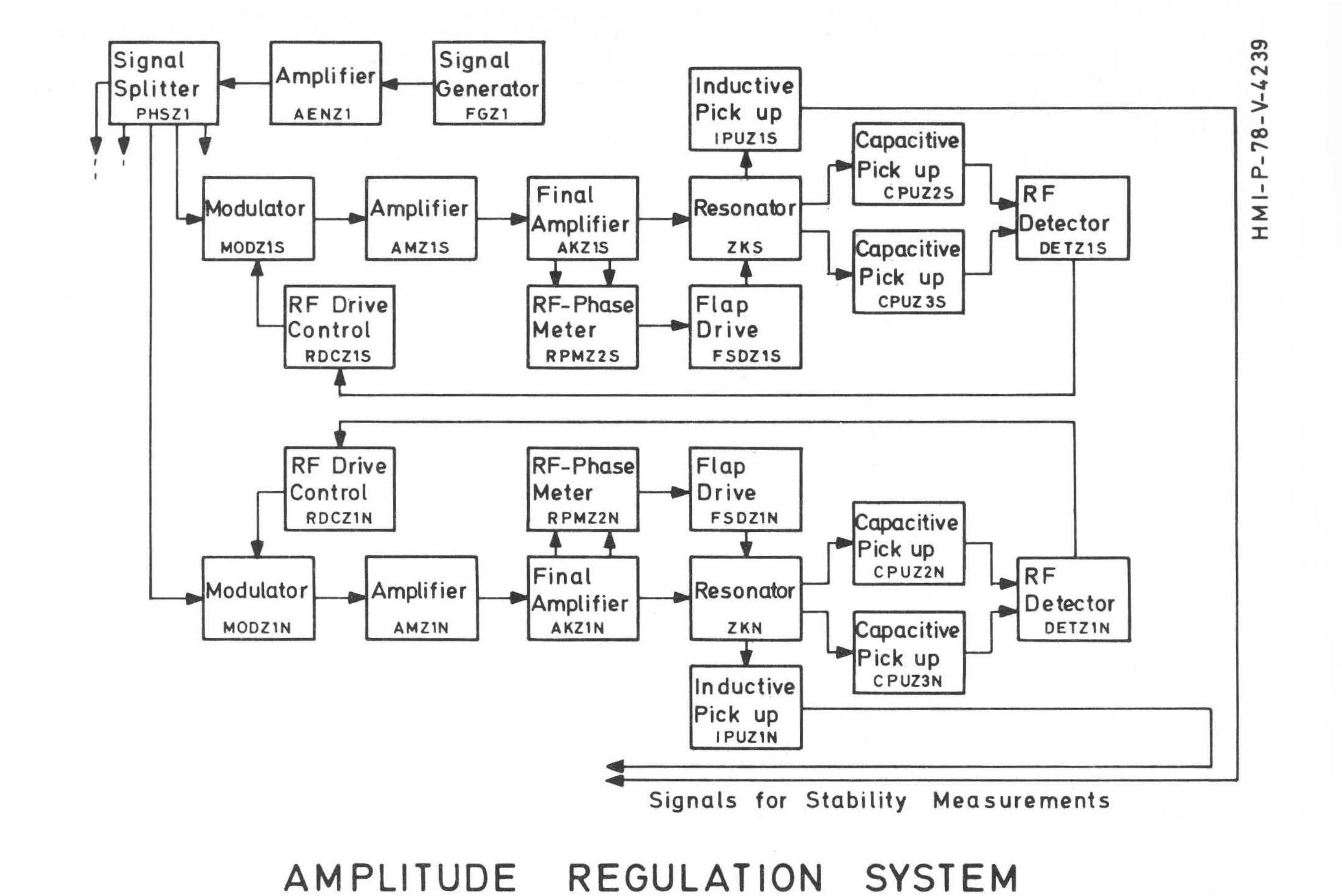


Fig. 2

The amplitude response time of both detector and modulator is 10 μs (3 dB point).

The phase- and amplitude regulation system described here has been designed and built by SCANDITRONIX, Uppsala, Sweden.

Amplitude Stability Measurements

One additional inductive pick-up in each resonator delivers the RF-signal for the amplitude stabilty measurements.

The long term instabilities are measured by rectifying the RF-pick-up signal with an RF-millivoltmeter and subtracting it from a reference in a differential voltmeter. "Long term instabilities" means variations of a measured quantity with time constants of more than one second.

Testing of the measuring set up without any RF-signal applied to the input determines the noise to be about 80 μV. On this noise a very low frequency ripple with amplitudes of about 150 μV and time constants of about one to two hours is superposed.

Using an RF-signal with an amplitude modulation of known frequency one can measure the response time, which is less than one second (3 dB point).

The recording of the error signal gives the result shown in fig. 3. The signal consists of about 200 μV noise superposed on a ripple with time constants of about 20 minutes, which is supposedly caused by thermal time constants of the resonator. These values correspond to an amplitude stability factor of $2 \cdot 10^{-4}$ for a period of one hour. For longer periods only an upper limit of

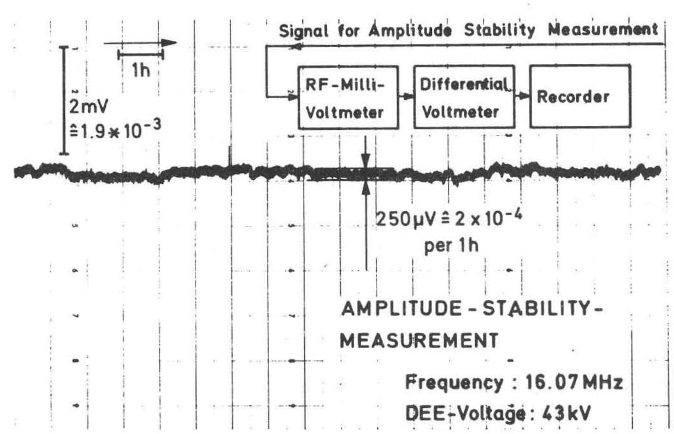
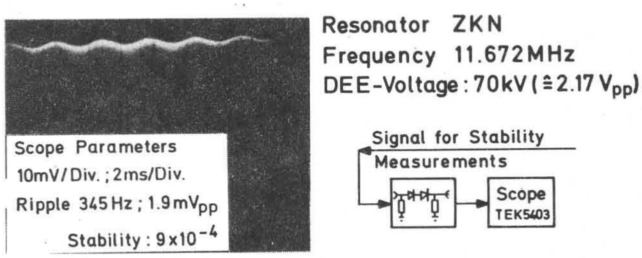


Fig. 3

$4 \cdot 10^{-4}$ can be defined due to the long term instabilities of the measuring set up, especially those of the RF-millivoltmeter.

The short term instabilities are measured directly at the pick-up with a scope, just cutting out the top of the pick-up signal with diodes to decrease the signal to noise ratio. "Short term instabilities" means variations of the measured quantity with time constants of less than one second.

One of the results is given in fig. 4: A ripple of 345 Hz and 1.9 mV_{pp} corresponds to an amplitude stability factor of $9 \cdot 10^{-4}$. In addition, a 50 Hz and a 2.2 Hz ripple with amplitudes corresponding to a stability factor of about $1.4 \cdot 10^{-4}$ could be measured. Thus a total short term stability of about 10^{-3} is obtained.



AMPLITUDE STABILITY MEASUREMENT, SHORT TERM.

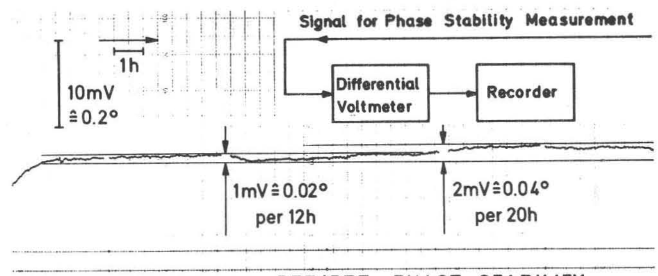
Fig. 4

This measurement has been performed at the north resonator. The total short term stability of the other one is about twice as good. The difference between these two results can be explained by mechanical vibrations of the measuring pick-up at the north resonator. A turbopump mounted directly to this cavity runs at approximately 20000 turns per minute. By switching off this pump the stability factor improves considerably. It is planned to mechanically decouple the pumps from the cavity by means of bellows.

Phase Stability Measurements

The phase stability measurements of the DEE/DEE-phase are accomplished with a phase signal from a third RF-phasemeter of the same type as used for the regulation. This third phasemeter is connected via signal splitters to the output of the capacitive pick-ups installed for phase regulation (fig. 1). A differential voltmeter compares the measured DEE/DEE-phase (50 mV DC per degree) with the internal reference. The resulting error signal is recorded. This measuring set up has a response time of less than one second.

Phase shifts of both resonators in the same direction are not sensed with this procedure. Temperature drifts of the two phase-meters used in the closed loop would cause such shifts. But since the measuring phasemeter is of the same type and is placed at the same location as the meters used for regulation, the unknown temperature drift must be about the same for all phasemeters. So the drift of the instrument used for the measurement, which must show up in the records, gives also a good hint of the stability of the phase between one Dee and the signal generator.



DEE/DEE - PHASE-STABILITY - MEASUREMENT
Frequency : 12.19 MHz
DEE-Voltage : 83 kV

Fig. 5

The result is shown in fig. 5: From this and other comparable measurements no constant frequency ripple can be determined. The DEE/DEE-phase stability is found to be better than 0.04 degrees within a period of 20 hours and better than 0.02 degrees within a period of 12 hours after initially warming up for one hour.

References

1) A. Susini and R. Aahgren, Design and Operation of the RF-System for the VICKSI Cyclotron, IEEE Trans. Nucl. Sci., NS-24, No. 3, 1710, June 77

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