THE HF-PHASE MEASURING EQUIPMENT OF THE EINDHOVEN AVF-CYCLOTRON

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Abstract

For the HF-phase measurements a sampling system is used since several years. The sampling system transforms the HF-beam signals to low frequencies. Then relatively simple correlation techniques are applied. In this way noise background is suppressed and HF-phases of beams with currents as low as 60 nA are measured accurately.
A comparison is given with a technique that directly applies the correlation at high frequencies using double balanced mixers. In this case HF-phases are measured with currents down to 30 nA.

1. Introduction

A HF-phase measuring system was built as a part of the automatic control project of the Eindhoven AVF-Cyclotron[1,2,3].
This system, using sampling techniques, has proved to be very reliable and accurate. A second system, using HF double balanced mixers, was tested this year. This system has the advantage of a principally better signal to noise ratio than the sampling system and has a rather simple construction resulting in much lower costs.
Both systems are described briefly in section 2.1 and 2.2. The results of the two systems are compared in section 3.
In both cases, the HF-phase is determined from the correlation of a phase probe signal with two reference signals - derived from the acceleration voltage - with a phase difference of 90°.

2. Measuring methods

2.1 The sampling system

A simplified block schema of the system is given in fig. 2.1.1. The signals of the phase probes above and beneath the median plane of the cyclotron are added and fed to the sampling system in the control room (≈60 m). The reference signal is taken from the Dee via a capacitive divider and is used to trigger the sampling system.
The odd-sampling technique[4] is used to suppress all odd harmonics in the phase probe signals. In fact, this technique forces the sampling system to trigger both on the positive and the negative zero crossing of the Dee voltage, i.e. the reference signal.
The frequency of the reference signal is doubled in order to correlate with the second harmonic of the phase probe signals.
Both probe signals and reference signal are transformed down by the sampling system from ≈40 MHz (second harmonic) to 1 kHz. The sampling system, delivered by Tektronix, consists of 3 dual sampling units type 3S1 and one trigger unit type 3T2, all mounted in a power rack type 129.
To correct for phase shifts in the cables and filters a six channel variable LF-delay line is developed (Philips bridge bucket delay line M30).

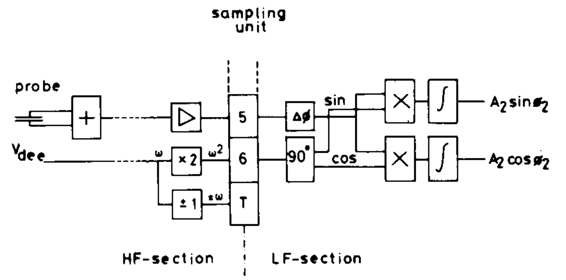

Fig. 2.1.1 A simplified block schema of the HF-phase measuring equipment. The sampling units are used to transform the phase probe signals (channel 1...5) and the reference signal (channel 6) from ∿40 MHz (second harmonic) down to 1 kHz.

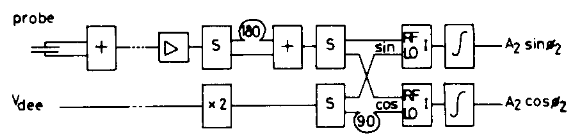

Fig. 2.2.1 A block schema of the phase measuring system using double balanced mixers. Signal splitters S are also used as adders +. In this experimental setup cables are used to perform phase shifts of 180° and 90°.

The correlations are carried out with standard analogue multipliers and low pass filters (τ≃1 sec). The output signal levels are 100 mV to 2 V. These signals are fed to a CAMAC multiplexer (Borer type 1701) and then digitized by a dual slope integrating ADC (Borer type 1241). Moreover, the signals are fed to a vector generator which draws the HF-phase and amplitude on a TV monitor.

2.2 The balanced mixer system

In this case the correlations are carried out directly at the HF level. Applying two signals with the same frequency to the RF-input and to the LO-input (Local Oscilator) of a balanced mixer (in our case Mini-Circuits Laboratories MCL type ZAD1), the IF-output (Intermediate Frequency) has a DC component which is proportional to the cosine of the phase difference between the two input signals.
The block schema of the system is given in fig. 2.2.1.
The odd harmonics are suppressed by splitting the probe signal into two cables (using MCL type ZSC2 splitters) with a difference in length corresponding with a difference of n·180°, if n is the harmonic

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number. Then they are added again. The phase difference of 90° needed for the correlation is also effectuated by a cable delay.
The signal levels of both the probe signals (after amplification) and the reference signal are about -10 dbm (≈70 mV at 50 Ω). The output DC components are a few milli volts (unterminated output).
The correlation products are again fed to the CAMAC multiplexer and ADC.

3. Results

In fig. 3.1 measured HF-phases of protons (final energy 20 MeV) at radii 30, 40 and 50 cm are given as a function of the magnetic induction of the outermost concentric correction coil B10. The explanation of the shape of the curves is given in ref. 1 and 2.
At an internal beam current of 1 μA both methods give the same results. At an internal beam current of ≈30 nA the balanced mixers still give reliable data as can be seen in fig. 3.2. The lower limit of the sampling system is (in our case) ≈60 nA.
Table I summarises the stabilities of the two systems over a period of 2 minutes. The instability due to the bridge bucket delay line can be reduced using delay lines with more than 30 steps (buckets). The double balanced mixers show a better behaviour. Because there are no active elements in the mixers the reliability may be expected to be very good.

We would like to thank prof. dr. H.L. Hagedoorn for the many fruitful discussions.

TABLE I. The standard deviations σ (deg) of the second harmonic phase measured with the two systems at different internal beam currents

		30 nA	1 μA	10 μA
sample system	+)	9.0	3.0	0.7
	-)	---	1.0	0.1
mixers		3.0	0.4	0.05

+) = with the bridge bucket delay lines
-) = without the bridge bucket delay lines

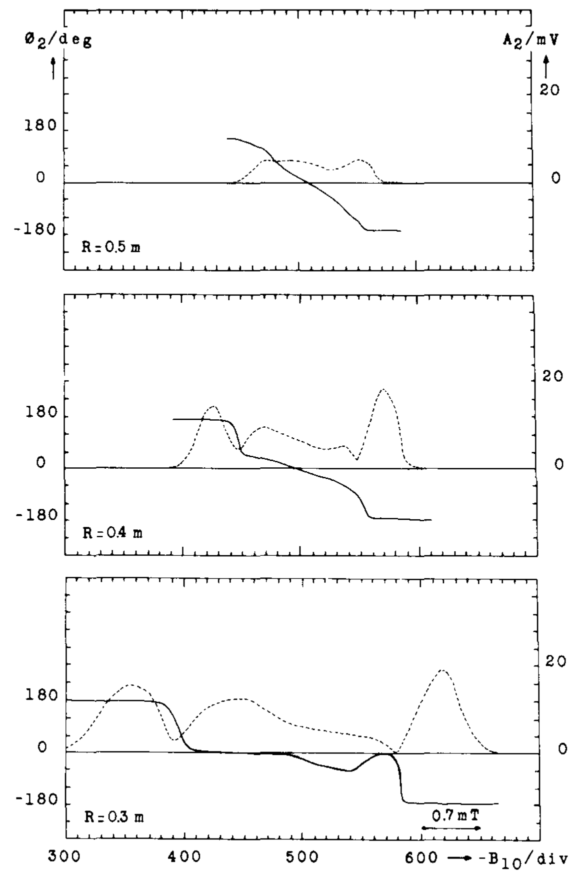

Fig. 3.1 The HF-phase (solid line) and the amplitude (dashed line) of the second harmonic of the probe signals at 30, 40 and 50 cm radius vs the magnetic induction of the outermost concentric correction coil B10. These curves are measured with the balanced mixers method at an internal beam current of 1 μA.

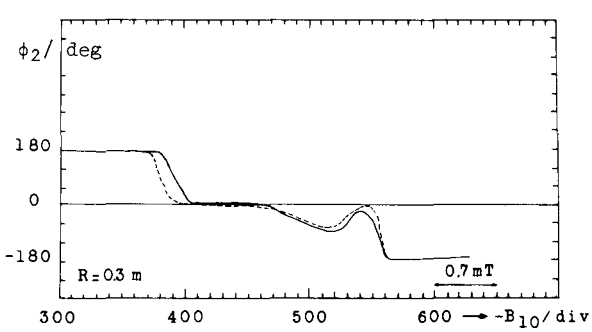

Fig. 3.2 The HF-phase of the second harmonic of the probe signal at 30 cm at an internal beam current of 1 μA (dashed line) and 30 nA (solid line) measured with the balanced mixer system vs the magnetic induction of the correction coil B10.

References

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