A PHASE MEASUREMENT SYSTEM FOR RF PULSES

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Abstract

A phase measurement system was developed for HERA, LINAC 3, consisting of several completely independent stations.
Each device is controlled by the main computer system. The phase relation of rf pulse trains of a few microseconds in length can be compared. Low repetition rates are possible. An accuracy better than 0.5° was achieved over a range of 360°.
The linearity problem of phase detectors was solved on the digital side of the device. The phase characteristic was measured once as a function of phase and amplitude of the signal channel using a rather sophisticated set up. The signal of the reference channel was kept constant. This data was used for calculating the necessary correction information which was burned into several EPROMs.

Introduction

There are three linear accelerators for HERA. Like many LINACs, they have a low rf repetition rate, a reference line for phase measurements, and operate with almost all structures at the same frequency.
However, LINAC 3, which operates at 202 MHz is the exception to the other LINACs at DESY which operate at 3 GHz.
The decision was made to develope a device that could be used for all our LINACs.
This limited us to rf detection devices like microwave mixers or correlators which can be bought for all frequency ranges; however, the linearity of these devices is limited especially if they must operate at different rf levels.
Even expensive, sophisticated calibrated detectors with paired diodes would not fulfill our specifications. For this reason, a new way had to be found.

Instead of using expensive components, quadrature discriminators were built with small, inexpensive mixers. The nonlinearity problem was solved on the digital side of the device by programming the necessary corrections into lowcost EPROMs.

Drift problems were overcome by stabilizing the temperature of a few sensitive components. The necessary measurements, calculations and programming tasks were done using a computer work station.

The rf pulse phase meter is as big as a regular vector voltmeter for cw. This allows us to locate the stations where they are needed thus reducing cable costs and making measurements easier.

Computing and Measurement Set-Up

All measurements were completely done by computer. The principal set-up is shown in Fig. 1.

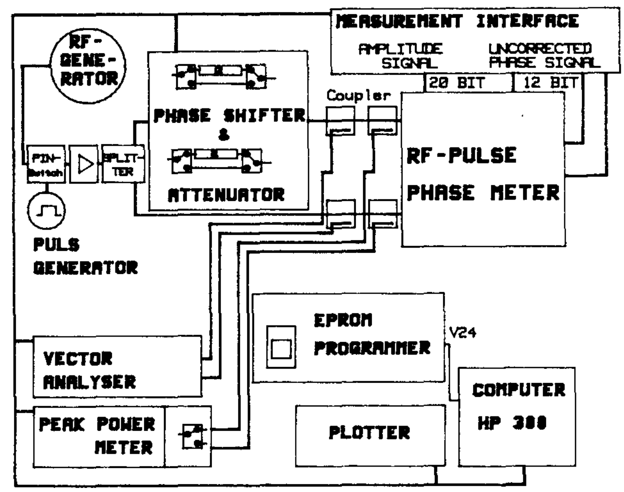

Fig. 1 Measurement set-up for testing and programming the rf pulse phase meter

The two pulsed rf signals are generated from a cw source with a PIN switch and a power splitter. One signal goes directly to the reference channel of the rf pulse phase meter. The other passes through a computer controlled high precision phase shifter and attenuator. The power of both channels can be checked by a peak power meter. A vector analyser can be used when the rf source is switched to cw.

With a measurement interface, a 20-bit amplitude signal and a 12-bit uncorrected phase signal is sent to the computer from the rf pulse meter via temporary connecting plugs. The computer connection is done by a IEEE 488 bus.

By using the information of the phase shifter and attenuator settings as well as the measured signals of amplitude and phase in the pulse phase meter, the correction for the EPROMs can be calculated. This information is then passed to an EPROM programmer via a V24 connection.

Phase Shifter and Attenuator

The heart of the calibration set-up is the phase shifter and attenuator unit which is constructed out of pairs of high precision SPDT switches. The smallest phase step is 0.1°, measured at 202 MHz.
The calibration of the steps was done with cw signals by using vector voltmeters and phase bridges.

All switch combinations were measured and then sorted by computer.
For the calibration of the phase shifter, we relied on conventional cw phase measurement devices. This limited our absolute accuracy. The reproduceability of the phase shifter was checked and turned out to be very good. The measurement accuracy was calculated relative to this calibration unit.

RF Pulse Phase Meter

The block diagram for the rf pulse phase meter is shown in Fig. 2. The phase detector is basically a quadrature discriminator which delivers signals proportional to sine(phi) and cosine(phi), where phi is the phase information to be measured.

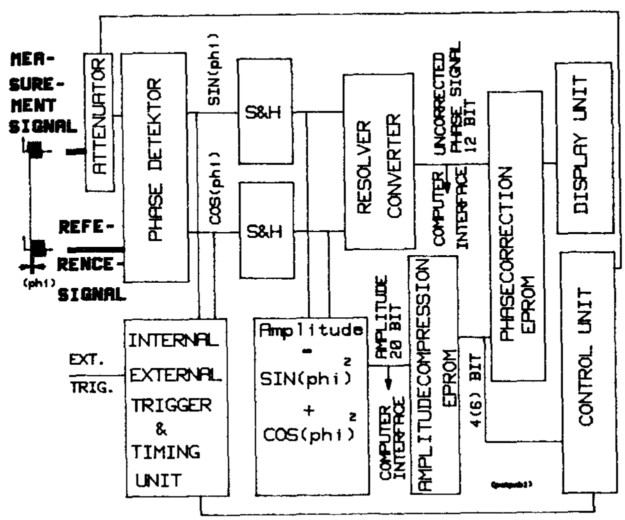

Fig. 2 Block diagram of the rf pulse phase meter

These signals, along with the length of the rf pulse are sampled and converted into a 12-bit digital field.
The timing of the sampling pulses can be shifted over the full pulse length.
The trigger can be generated internally, but external triggering is also possible.

The signals are then converted in an onechip circuit to a phi signal. This is the uncorrected phase signal previously mentioned.

The necessary rf level information is generated by adding the squares of the sin(phi) and cos(phi) signals in an onechip multiplier and adder circuit.
These 20 bits of information are also delivered to the computer.
The linearity of the sin(phi) and cos(phi) signals can be judged best in a polar diagram. A plot of a detector measurement is shown in Fig. 3.

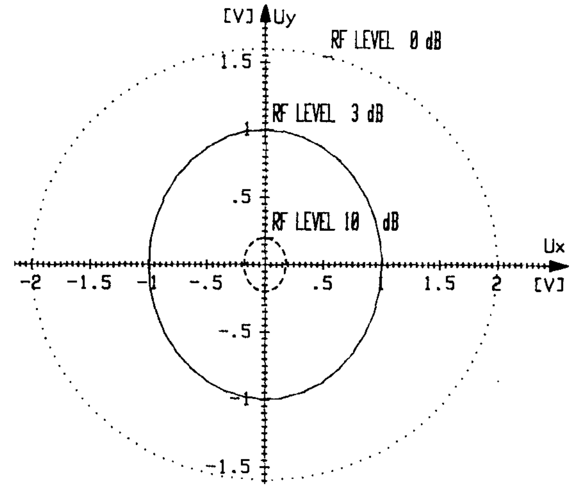

Fig. 3 Polar diagram of the phase detector signals sin(phi) and cos(phi)

The rf level is proportional to the radius, and the phi value is the angle of the radius.

In a x - y plot, one obtains the signals as shown in Fig. 4.

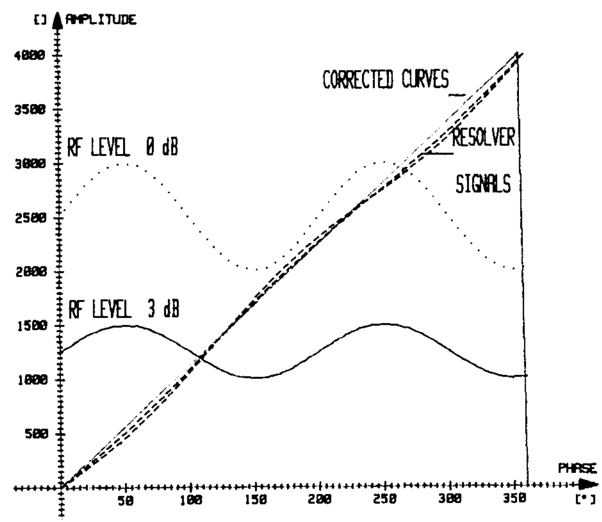

Fig. 4 Uncorrected and corrected phase signals for two amplitudes and the rf level signals

In an ideal case, one would get straight lines. Due to imbalances in the detector, one gets the resolver signals as shown in Fig. 4. The characteristics of these signals remain constant and can therefore be corrected.

The 20-bit rf amplitude information is reduced to fields of 4 (6) bits. The pages are addressed with this information where the phase correction is stored for different rf levels.
In a rf level range where the correction of the phase signal changes a lot, one can increase the number of pages for the phase correction.

A typical threedimensional plot for the amplitudedependent phasecorrection signal is given in Fig. 5.

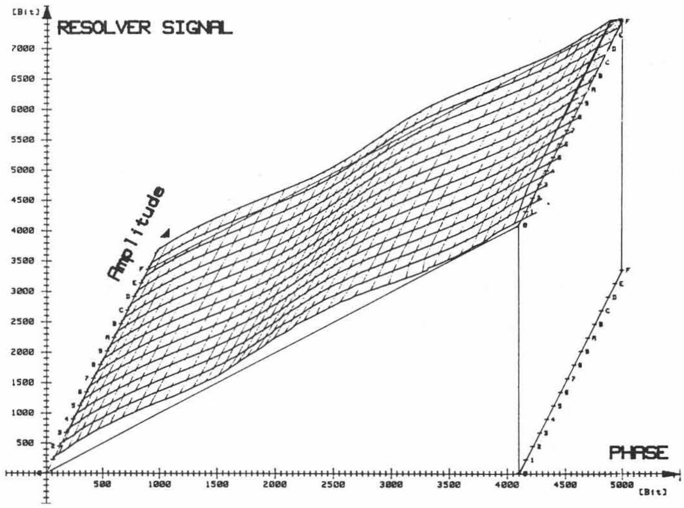

Fig. 5 Three dimensional plot of the phase correction signal

The detector can be corrected within a level range of 18 dB by the aforementioned method. An expansion to 50 dB is done by a two step attenuator which is controlled automatically by the generated amplitude information.
In order to avoid problems in the phase range around zero, the device automatically adds 180° in rf phase when this range is reached.
The phase information is displayed as both analog and digital forms.
A photo of the rf pulse phase meter can be seen in Fig. 6.

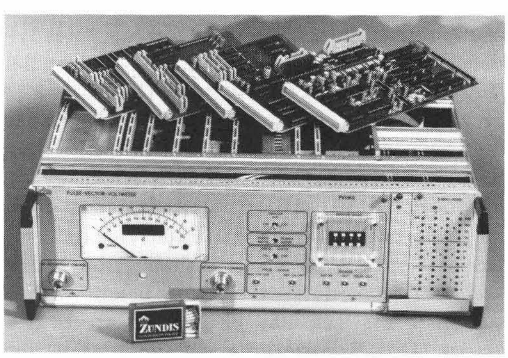

Fig. 6 Front view of the rf pulse phase meter

Set-up for the HERA LINAC 3

The H^--LINAC operates at 202.56 MHz and has five rf generators for the three Alvarez tanks, the RFQ and the debuncher. Each generator has also a rf phase meter with a remote controlled switch where the forward and reflected waves of the rf generator and the cavity loop are monitored. Since all these signals are present in the rf generator no additional cabling is necessary. The information is read out by the main computer system. Each device can also be used for local phase measurements.

Conclusion

A flexible system for measuring rf pulse phases was developed for the HERA LINAC 3.

The linearity problem of phase detectors was solved by correcting the deviations on the digital side of the apparatus.

The typical characteristics of the device were measured one time with a sophisticated set-up. The calculated corrections were stored into EPROMs of the rf pulse phase meter.

Acknowledgements

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A patent for the rf pulse phase meter is pending.

References

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