ELECTRONIC DETECTION CIRCUIT FOR A STRIPLINE BEAM POSITION MONITOR

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Abstract

A low–cost, easy adjustable electronic detection circuit, consisting of easy–available electronic components, has been designed to measure the amplitude of a signal that is picked up by a stripline. Thirty stripline beam position monitors will be used in the 10–75 MeV Racetrack Microtron Eindhoven to measure the position of electron beam. The difference divided by the sum of the signal amplitudes of two opposite striplines is a measure of the beam position, which is to be measured throughout the microtron within 0.3 mm to fulfil the microtron's closed orbit conditions. The power of one single stripline signal is detected by two microwave diode detectors, which are matched to the characteristic impedance of the stripline. After passing a pre–amplifier with balanced outputs the two resulting signals are transported over a 10 m shielded twisted–pair transmission line. An instrumentation amplifier is used to condition the signal to be measured by an AD–converter. The use of a balanced system ensures high rejection of noise pick–up on the twisted–pair transmission line. The lower detection limit is estimated to be in the order of 1 mA.

1 RACETRACK MICROTRON

The 10–75 MeV RaceTrack Microtron Eindhoven (RTME), which is shown in figure 1, will serve as injector for the 400 MeV electron storage ring EUTERPE [1]. RTME itself has a 3 GHz travelling wave linac as injector, which supplies an initial beam of about 10 mA. In the microtron a 5 MeV standing wave cavity accelerates the electrons 13 times.

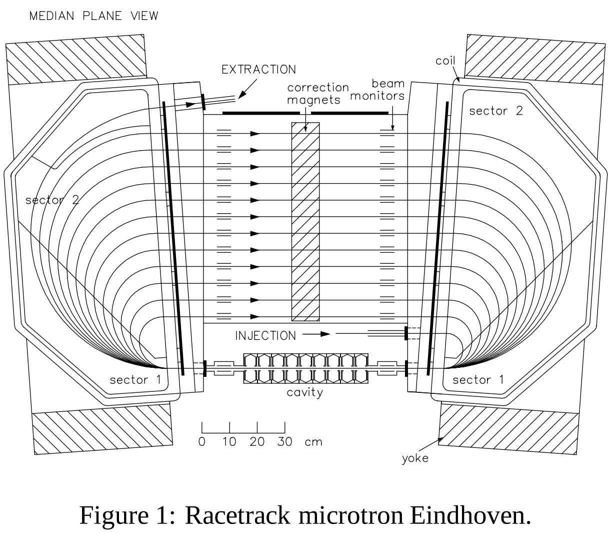

Figure 1: Racetrack microtron Eindhoven.

Two 2–sector magnets separated by a drift space are the main components of RTME's electron optical system [2]. These magnets are tilted in their median planes to obtain $180°$ bending angles, which are necessary to obtain closed orbits in RTME. As the magnets are not ideal and because of alignment errors it is not possible to obtain $180°$ bending in the horizontal plane for all different orbits simultaneously.

An array of small dipole magnets is located halfway the two bending magnets to ensure closed orbits. These dipole magnets are adjusted by beam position measurements in the return paths of the electron beam in the microtron [3].

Stripline beam position monitors (BPM's) [4] are used to measure the beam positions, which are to be measured within 0.3 mm to be able to close the orbits. The mechanical design is briefly reviewed in section 2. The electronic circuit to detect the amplitude of the stripline signals is described in section 3. Test bench measurements of this electronic circuit are discussed in section 4.

2 MECHANICAL DESIGN

About 90 mm long rectangular beam pipes with two striplines facing each other are placed at many locations along the beam in the microtron. A cross–section of the mechanical design is shown in figure 2. The advantage of the rectangular shape is that the beam position measurements in the horizontal and vertical direction are not coupled [3].

The stripline signals consist of harmonic signals with a discrete spectrum: $n \times 3$ GHz ($n = 0, 1, 2, ...$). As the bunch–length is very small in comparison with the accelerating wavelength the 3 GHz component has a large magnitude and will be used for the measurements. The difference divided by the sum of the amplitudes of the left and the right

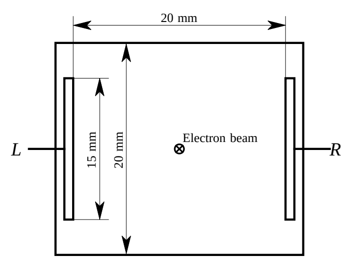

Figure 2: Cross–section of a stripline BPM.

stripline is a direct measure of the beam position [3].

3 ELECTRONIC DESIGN

A block–scheme of the electronic circuit that measures the amplitude of one stripline signal is shown in figure 3. A microwave diode detector has been chosen as a low–cost alternative to the heterodyne receiver, because the tangential sensitivity, *i.e.* the lowest signal power level for which the signal–to–noise ratio at the output is 8 dB, of modern Schottky–Barrier–type diodes is about -55 dBm [5] [6]. On the other hand the lowest expected signal power is in the order of -35 dBm.

Two forward biased microwave diode detectors of the Schottky–Barrier–type (Philips BAV46), located in a copper–gilt housing (see figure 4), detect the 3 GHz microwave signal. These detectors produce two output signals of opposite sign. The impedance of the detector circuit matches with the 50 Ω stripline pick–up probe with a bias current of 650 μA. The two output signals are amplified and transmitted along a 10 m shielded twisted–pair transmission line.

In the receiver the signals are subtracted by means of an instrumentation amplifier, which acts as a balanced line receiver. Consequently, the influence of a noisy environment is highly rejected; the Common–Mode–Rejection is better than 60 dB. The line receiver is followed by a lowpass–filter. A baseline restorer is used to stabilize the baseline, which results in a better signal–to–noise ratio citearbel. A peak detector converts the signal, which is pulsed due to the pulsed beam, in a DC–signal, which is fed to an AD–converter.

The difference divided by the sum of the amplitudes of two opposite stripline signals is determined with the detection software. This has two advantages. First, a calibration function can easily be applied in case the detection circuits for the left and right stripline are a bit different. Hence, the need for hardware adjustments is eliminated. Second, also the sum of both signals can be retrieved, which is a rough measure of the beam current (accuracy in the order of 10%).

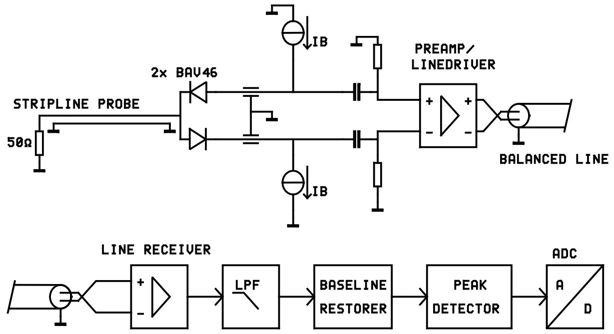

Figure 3: Block–scheme of the beam position monitor processing system.

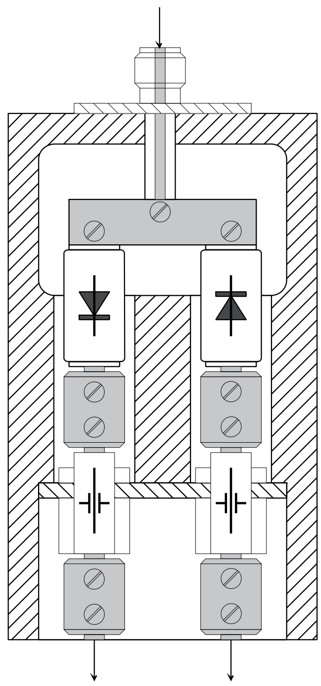

Figure 4: Copper–gilt housing of the microwave diode detectors. The signal conductors are marked gray.

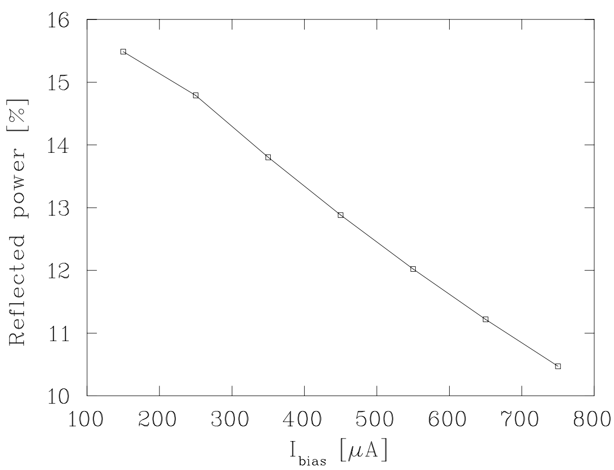

Figure 5: Reflected power as a function of the bias current.

4 TEST BENCH MEASUREMENTS

The behaviour of the detector circuit has been measured with a HP–8753C Network Analyzer. The detector matches better at higher bias currents (see figure 5). However, above 650 μA the behaviour at low input power levels becomes more worse (see figure 6). Thus the choice of a bias current of about 650 μA seems to be most optimal.

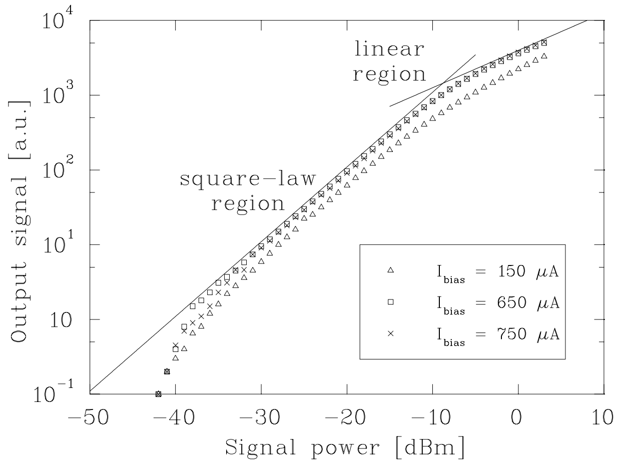

Figure 6: Measured output signal as a function of the input power for several different bias currents.

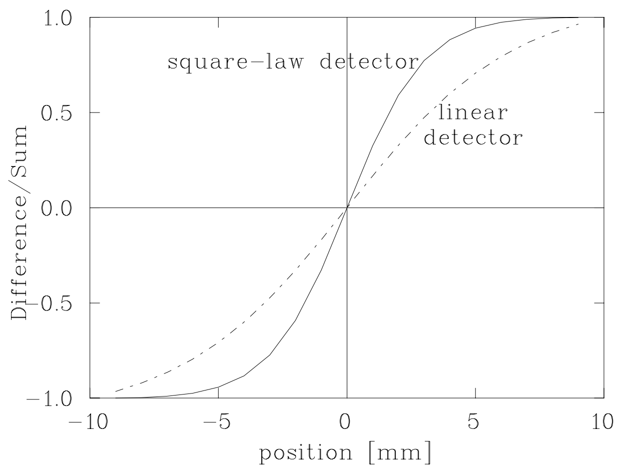

Figure 7: Calculated difference/sum as a function of position for a linear detector and for a square–law detector.

The detector behaves as a good square–law detector in the region from -35 dBm to -10 dBm, which corresponds to beam currents of 1 to 10 mA. An advantage of this is that the sensitivity in the centre of the beam position monitor is larger than for a linear detector (see figure 7). In order to meet the required 0.3 mm accuracy, the power of one single stripline signal has to measured within 10%. This is true for beam currents larger than about 2 mA. For 5 mA the position accuracy is estimated to be about 0.1 mm.

Much attention has been paid to the rejection of noise pick–up on the transmission line; the Common–Mode–Rejection is better than 60 dB. Nevertheless, it is still this noise pick–up that determines the measurement accuracy and the lower detection limit, which is somewhat lower than 1 mA, rather than the microwave diode detectors themselves.

5 CONCLUDING REMARKS

Although the resolution of a heterodyne receiver is much better than a Schottky–Barrier microwave diode detector, the latter does meet our requirements. Moreover, it is much more simple and costs much less. The measurement accuracy and the lower detection limit can still be optimized if the noise pick–up on the transmission line is rejected better.

The expected input power is in the square–law region of the detector. This provides a higher sensitivity in the centre of the beam position monitor.

It has two advantages to feed the two stripline signals to the computer independently. First, if the two detection circuits are a bit different, a calibration function can be applied, such that there is no need for hardware adjustments. Second, the sum of the two signals is also a rough measure (about 10% accuracy) of the beam current.

6 REFERENCES

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