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SIGNAL PROCESSING FOR THE CLIC BEAM POSITION MONITOR

J.P.H. Sladen

Abstract

It is foreseen that the accelerating sections of the CLIC main linac will contain an integral transverse beam position monitor. Capable of micron resolution, the monitor will consist of a millimetre wave resonant cavity. This paper presents a signal processing scheme suitable for such a pick-up. The main difficulties result from the need for high frequency selectivity as well as for the requirement to measure the sign of the beam's displacement.

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It is foreseen that the accelerating sections of the CLIC main linac will contain an integral transverse beam position monitor. Capable of micron resolution, the monitor will consist of a millimetre wave resonant cavity. This paper presents a signal processing scheme suitable for such a pick-up. The main difficulties result from the need for high frequency selectivity as well as for the requirement to measure the sign of the beam's displacement.

Introduction

To measure transverse beam position along the CLIC main linac, millimetre wave resonant cavities have been proposed [1,2,3]. A simple E_{110} cylindrical cavity is envisaged, to be fabricated as an integral part of the accelerating structure [4]. The pick-up cavity signals are to be used in a feedback system, together with precision movers, so as to maintain the transverse alignment along the linac to the order of 10 µm.

Resolution of the monitor will be limited by interference from modes excited with large amplitudes at the cavity's electrical centre. For a short cavity, the principal interference comes from the E_{010} mode and results from the finite energy in this mode at the frequency of the E_{110} resonance. With a high Q cavity, resolution of under 1 µm will be possible at 30 GHz, albeit with a modest contribution from symmetry rejection via two diametrically opposite cavity outputs. However, to achieve this resolution, the signal measurement must be carried out in a bandwidth narrower than that of the E_{110} resonance and this suggests the use of a heterodyne receiver as a means of detection. Consequently, this approach has been taken for the signal processing scheme to be described in this paper.

There is also the possibility of a degradation in the resolution of the monitor due to interference from the RF power pulse. To reduce this risk, the pick-up cavity's E_{110} mode frequency has been chosen above that of the RF pulse, at 33 GHz.

The sign of the beam's displacement and hence the phase of the pick-up signal must be measured. For this, some phase reference is required. To avoid the addition of a reference cavity with a fundamental tuned to 33 GHz, use of the RF pulse as reference is proposed, despite the frequency offset.

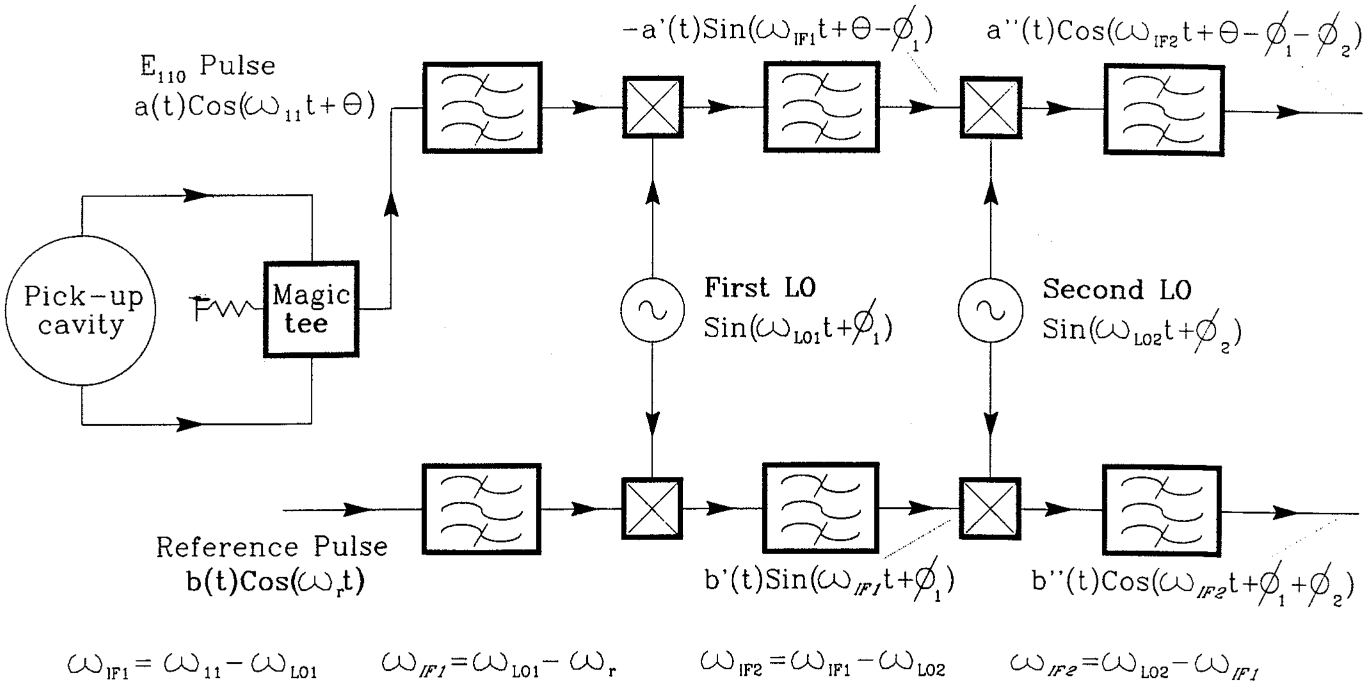

Fig. 1 Pick-up cavity signal processing with two common local oscillators

Signal Processing

To obtain the sign of the bunch displacement from the resonant cavity, the phase of the output signal needs only to be measured approximately. However, for unequal reference and E_{110} frequencies, even this is not straightforward. The proposed solution is to mix down the cavity and reference signals with common local oscillators (LOs). A simplified block diagram for the case of two local oscillators is given in Fig. 1, where only the vertical displacement and reference paths are shown. The twin cavity outputs are combined in a magic tee to obtain the symmetry rejection. The magic tee's difference output pulse is taken to be of the form $a(t)\cos(\omega_{11}t + \theta)$, where ω_{11} is the E_{110} resonant frequency and θ is the required phase shift. The reference signal pulse is given by $b(t)\cos(\omega_r t)$, where ω_r is the frequency of the RF pulse. Due to the local oscillator phase inversion between the two paths, θ cannot be found by simply phase-comparing the two final intermediate frequency (IF) outputs. ϕ_1 and ϕ_2 must first be estimated from the reference channel, using the arrival of the RF pulse as a trigger. It should be noted that this scheme requires phaselock neither to the main linac beam nor to the RF pulse.

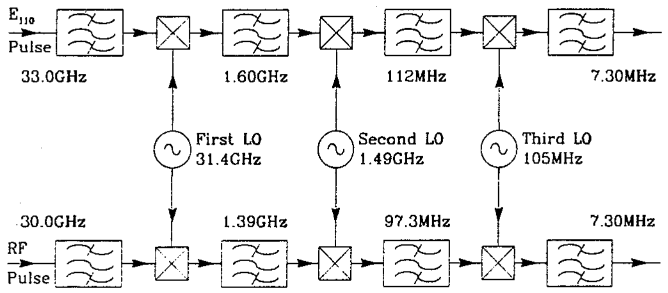

Fig. 2 Receiver configuration for 33 GHz position pick-up cavity

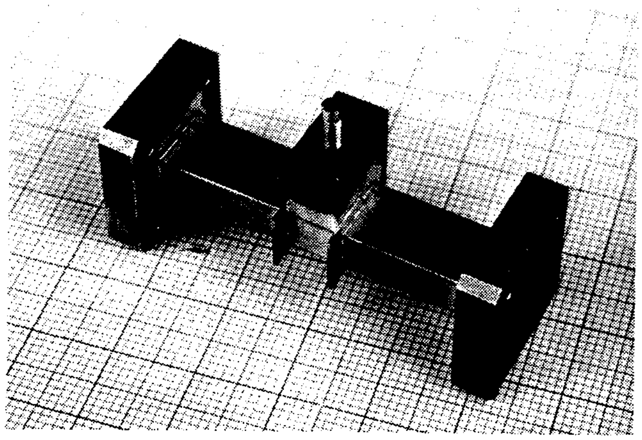

Fig. 3 30 GHz waveguide filter

For a large frequency offset between the cavity and reference, the first IFs are necessarily high. The number of further pairs of IF stages depends essentially on the amount of filtering available. The configuration to be used for the 33 GHz cavity is shown in Fig. 2. There are three pairs of IF stages.

Hardware

Millimetre wave filters have been developed for the E_{110} and reference paths. Because of the need for high first IFs, the front-end filtering requirements are not too stringent and can be achieved using high Q single-cavity type filters. These have been made using precision WR28 OFHC copper waveguide, commercially available with adequate dimensional tolerances and surface finish. 0.5 mm thick irises were brazed into slots milled in the waveguide walls. The irises are positioned to within 20 μm, the input window being slightly larger than that of the output so as to improve the input match. Tuning is achieved by a central sapphire rod. The 30 GHz filter is shown in Fig. 3 and its frequency response in Fig. 4. It has a bandwidth of 50 MHz, an insertion loss of 1.5 dB and an input SWR of 1.03. This construction technique could readily be employed for higher order iris-coupled filters.

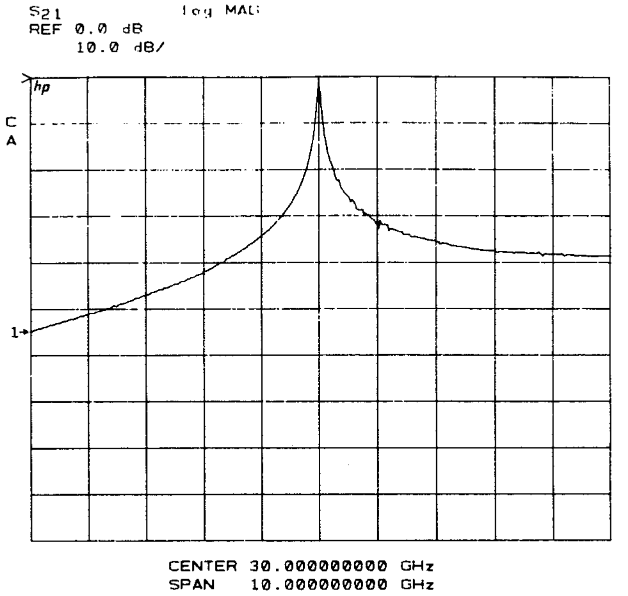

Fig. 4 30 GHz waveguide filter response

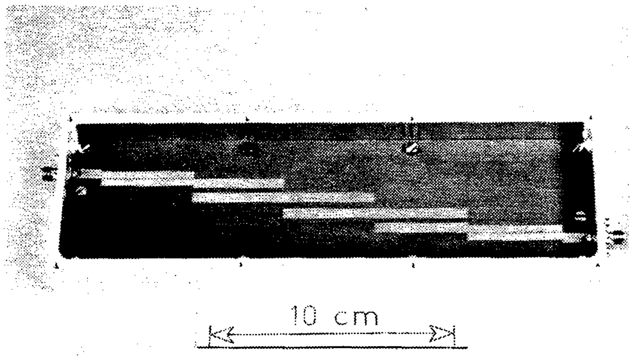

Fig. 5 1.39 GHz IF filter

The first IF filters both consist of four parallel coupled microstrip resonators on a PTFE substrate. The 1.39 GHz filter is shown in Fig. 5 and its frequency response in Fig. 6.

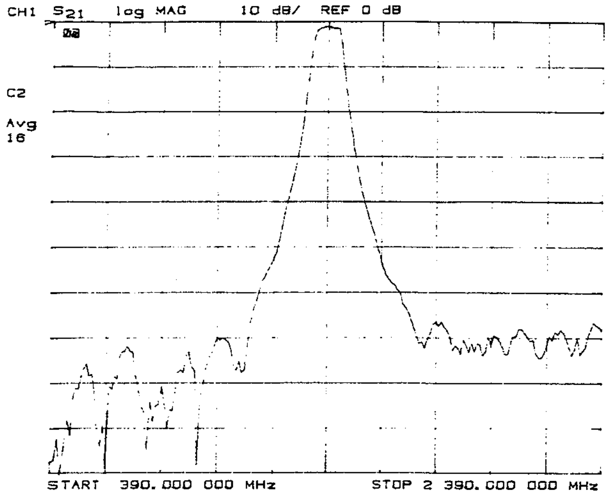

Fig. 6 1.39 GHz IF filter response

The first local oscillator is currently being developed. This will consist of a Gunn oscillator locked to a quartz crystal via a 3.92 GHz synthesizer and a × 8 harmonic mixer.

Acknowledgements

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References

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