

R&D OF THE ATF TIMING SYSTEM

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Abstract

R&D is being pursued for the timing system of the Accelerator Test Facility (ATF). A highly sophisticated timing system is essential to the successful operation of the accelerator complex, composed of damping ring, DR injector linac, positron target, beam instrumentation and control. In the proposed system a reference signal is distributed to the whole accelerator complex using a special temperature-compensated optical fiber. Techniques for several components like high precision prescaler/delay modules are under evaluation. Further, the proposed energy compensation scheme of the ATF Linac depends on the availability of stable reference clock signals at S-band frequency of 2856 ± 4.33 MHz. The overall plan and status of the development are presented.

Overview

The outline of the timing system has been presented in [1]. In this paper, a brief overview and the status and the status of the development of the necessary components is presented.

In the ATF, most of the components and technologies for a linear collider will be tested. The fundamental frequency is generated using a 1428 MHz master oscillator and the other necessary frequencies are generated from this reference signal using frequency multipliers and dividers (figure 2).

The generated reference signals are distributed using a special temperature-compensated optical fiber. The properties of this fiber have been reported in [2]. The signal is first converted to light using eo converter and then distributed using the optical fiber. The reverse conversion from light to electrical signals is done near each of the components requiring reference signals (gun, bunchers, klystron modulators etc.).

Electron Gun Timing

The timing to trigger the electron gun is generated by synchronizing the damping ring revolution clock 2.16 MHz with signal from AC line zero crossing timing generator using a CAMAC delay module. The AC line synchronization generator provides 50 Hz triggers

at a fixed phase of the power line frequency. The delay module generates a pre-trigger pulse for the S-band linac, the damping ring and the main linac. The synchronized signal is then distributed using the Beam Timing Distributor. This signal is also used as a source for the gun trigger pulse.

Bunch number selector synchronizes the beam clock (357 MHz) and the pretrigger pulse. To pulse the electron gun, a gate is opened using the pretrigger pulse. A preset counter counts the beam clock cycles and closes the gate when the preset count is reached. The gate signal is delivered through the optical fiber and an RF amplifier to the gun grid.

Energy compensation and reference timing

A novel method for compensation of multibunch energy spread has been proposed and is going to be tested in the ATF. The principle of energy compensation is shown in the following figure.

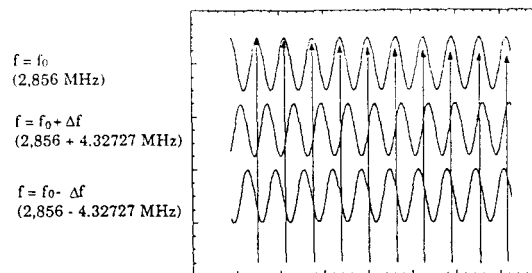


Figure 1. Principle of the energy compensation system.

When a bunch train enters the accelerating cavity, the energy gain of the bunches later in the train is smaller than that of the earlier ones. The energy spread caused by beam loading can be compensated by having a small number of RF cavities whose frequency is slightly different from the main 2856 MHz accelerating frequency. In the ATF linac, 2 out of total of 18 3-meter accelerating structures are used as compensating sections. When the bunch train enters these sections, the energy gain of the successive bunches is different due to the fact that they are injected in different phases relative to the accelerating wave. To compensate for the resulting single-bunch energy spread, two frequencies, $f + \Delta f$ and $f - \Delta f$ are necessary.

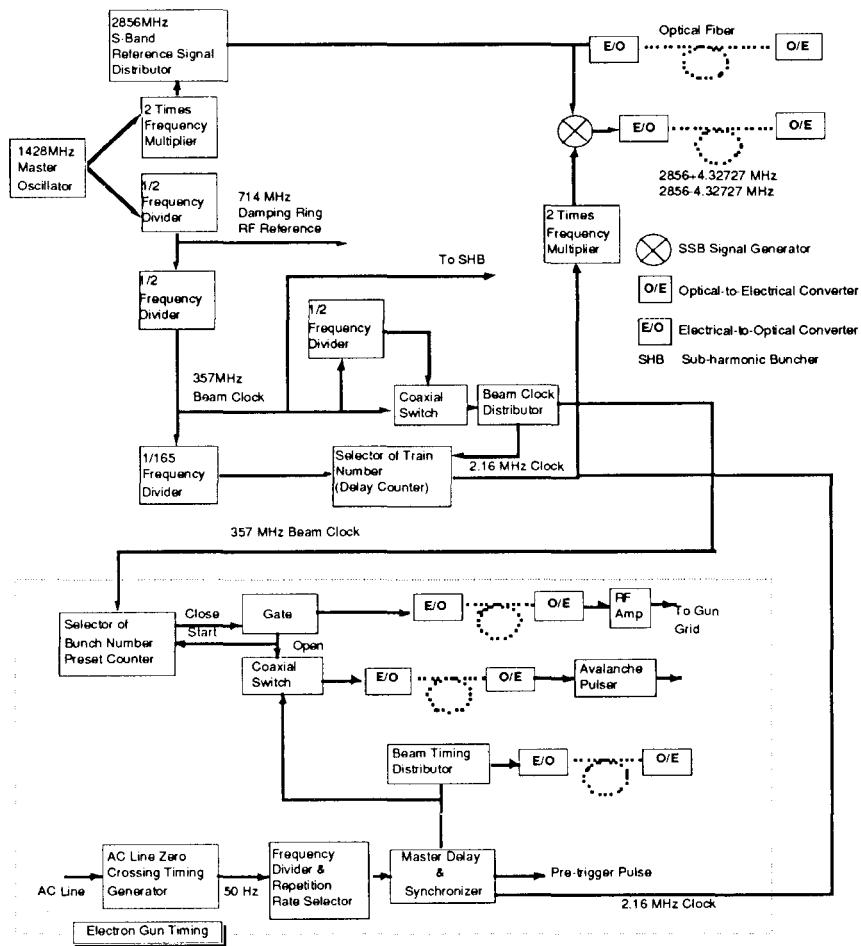


Figure 2. The ATF timing system

The allowed jitter of the reference signals for the compensating sections is extremely small (order of 1 ps), as bunches are injected into a phase where the accelerating RF field changes most rapidly. Even a small jitter results in large uncertainty in the energy gain of the bunches. These two signals are generated by mixing the reference signal and 4.327 MHz signal (twice the DR revolution frequency, 1/660 of the linac RF) and then taking the desired sidebands.

The most common method to generate single sideband (SSB) signals is to use a balanced mixer to generate a dual-sideband signal and then cancel the unwanted frequency by using sharp bandpass filters. In our case, the passband of the filter has to be very narrow to achieve the desired suppression larger than 30 dB for the sidebands. Using a cavity filter would be the only conceivable method to achieve this sharp cut.

Another feasible method is the phasing SSB modulation method. In this method, quadrature pair of both the RF and IF signals is generated and then fed into into a pair of double balanced mixers. (see figure 4).

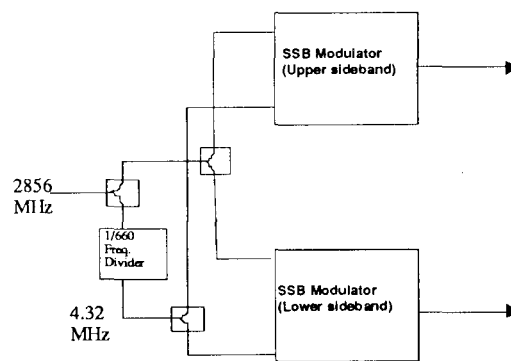


Figure 3. Generation of the reference signals.

The mixer outputs are fed into a power combiner. The undesired passband signals from the mixers are at opposite phases and cancel each other. The desired sideband signals are in same phase and are amplified when combined. Both sidebands can be generated by changing the phase relation of the signals fed into the mixers. The

phasing method does not need any sharp filters, but is highly dependent on the performance of the balanced mixers and the phase-shifting networks. However, as the frequencies are fixed the necessary signals with 90° phase difference can be generated relatively easily, using a quadrature hybrid for the high frequency and an active all-pass filter for the low frequency.

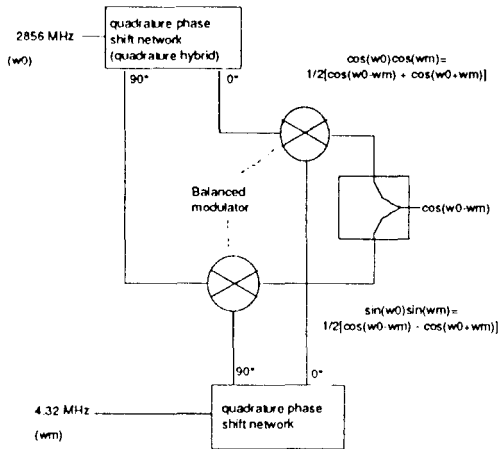


Figure 4. Phasing SSB modulator.

By this method, the unwanted sideband could easily be reduced more than 40 dB, the bigger problem being the LO-RF-isolation of the mixers. With proper tuning, the undesired frequencies (carrier, intermodulation products) could be reduced about 30 dB.

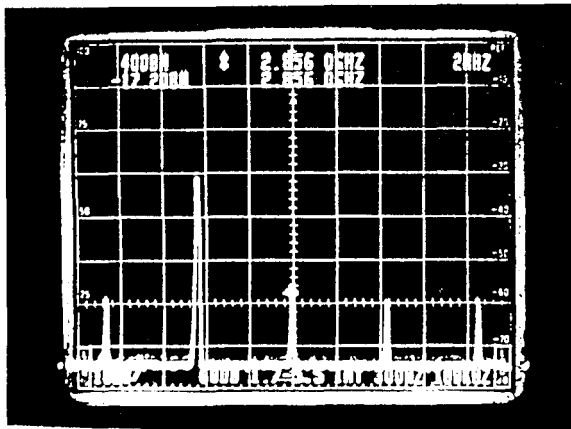


Figure 5. Measured frequency spectrum of generated 2856 - 4.327 MHz signal.

We measured the jitter of the generated signal by the following method: the reference signals were generated using the method explained above. The signal was fed into a digitizing oscilloscope (HP), triggered using the 4.33 MHz signal and the relative phase difference of these two signals was measured. As the risetime of the low-frequency signal is very low compared with the ref. signal, the jitter looks rather large using this method. The real jitter is expected to be much smaller than this value. The reference signal is a rather pure sine wave, as can be seen in figure xx, measured by using the reference signal as a trigger. A jitter of $s = 4$ ps was achieved using the phase difference method only. The actual jitter is expected to be even smaller, as the oscilloscope triggering accuracy is lowered by the relatively slow risetime of the triggering signal. However, if the jitter value achieved by this method alone is not small enough, we can use a cavity filter to further reduce the unwanted carrier and sideband frequencies; by this method a jitter less than 1 ps is expected to be achieved.

Conclusions

The R&D for the essential elements for the timing system is proceeding steadily. Performance values that are very near to the required ones has already been achieved with prototype hardware. From this experience we expect that the requirements will be fulfilled. As the 800 MeV ATF linac will be completed soon, the real performance of the system can be verified in beam tests. The operation of the entire timing system will be verified after the ATF damping ring is completed, in the early 1995.

References

1. J. Urakawa et. al.: Gun trigger system for the ATF. To be published in Nucl. Instr. and Meth. A.
2. S. Tanaka et. al., KEK Report 90-5(1990)

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