PHASING SYSTEM FOR THE INJECTOR OF BEIJING ELECTRON POSITRON COLLIDER (BEPC)

ZHOU Xiao-guang, ZHONG Shi-cai

Institute of High Energy Physics,
Beijing, P.R.C.

Summary

The Injector of Beijing Electron Positron Collider is an 1.4 Gev. Electron Linear Accelerator. The sixteen klystrons and their energy doublers are used to provide microwave accelerating power for electron (or positron) beam. In order to make the energy of the accelerated electron beam maximum and the energy spectrum width minimum, every klystron must be phased to make the crests of the RF traveling wave in the accelerator coincide with the electron bunch centers. If phasing is imperfect, the fractional energy spread for small α and θ can be shown to become

$$\frac{\Delta V_{Tot}}{V_{Tot}} \doteq -\frac{1}{2}\left(\frac{\alpha}{2}+\frac{\Sigma\theta n}{N}\right)^2$$

where N is the number of sections, $\Sigma\theta n$ is the algebraic sum of the individual phasing errors and α is the angular spread. For this purpose, a phasing system has been designed and built in the BEPC Injector. The system is based on the beam induction technique. The heterodyne technique is used to process signals and to do phase discrimination. The step motor-driven phase shifters (FOX phase shifter) are used to shift the phases of klystrons.
A single board microcomputer is used to provide programme control for the system. The system can phase every klystron automatically or manually and can manually shift the phase of any klystron as operator likes. The system can be operated by operator at Central Control Room, Injector Control Room or Local Panel. The system has been installed well in the klystron gallery of BEPC Injector.

Inord to leave over the possibility improving the system in the future, 17 equal length phase stable cables are used to be reference signal cable and phase sample cables.

System Explanation

A simplified block diagram of the Phasing System is shown in Fig.1.

When the klystron Kn is phased, Kn, accelerating section An, directional coupler Dn, Cable Cn, phase shifter Sn are connected with phase detector PD, amplifier A and loop filter F to become a servo loop. At first, klystron Kn is set to the "standby" pulse position, that is, Kn is 10 ms delayed, then both beam-induced signal and klystron signal are gotten from directional coupler Dn and transmitted to phase detector PD with the same cable Cn. Then the phase of beam-induced signal is compared with the reference signal in the phase detector and the different signal gotten from PD is used to control phase shifter S until the phase difference between beam-induced signal and reference signal becomes +90°. Then klystron signal is compared with the reference signal too in PD, the signal gotten from PD is used to control Sn until the phase difference between klystron signal and reference signal becomes -90°. So the phase difference between beam-induced wave and klystron wave becomes 180°. The klystron Kn is returned to accelerate. In this case, crests of the RF traveling wave in the accelerating section An coincide with the electron burch centers, that means, phasing klystron Kn has been finished.

In the same way, other klystrons can be phased. Here, phase detection is very important step that affects phasing precision directly. But the phase detection error that is due to amplitude deviation error is very difficult to avoid because the amplitude difference between beam-induced signal and klystron signal is very large (30-50db), top of beam-induced signal is not flat and shape of klystron signal rather looks like a wedge. So an amplifier & limiter is wanted to make the amplitude of both beam-induced signal and klystron signal equal and constant and their tops flat, meantime no additional phase error is produced. But it is very difficult to build a amplifier & limiter like this in microwave range, however, in the lower frequency range it is possible.

That is why the heterodyne technique is used to process signals and to do phase discrimination in the system.

The beam-induced signal, klystron signal and reference signal are mixed with local frequency signal respectively in two mixers, then frequency of them become intermidiate

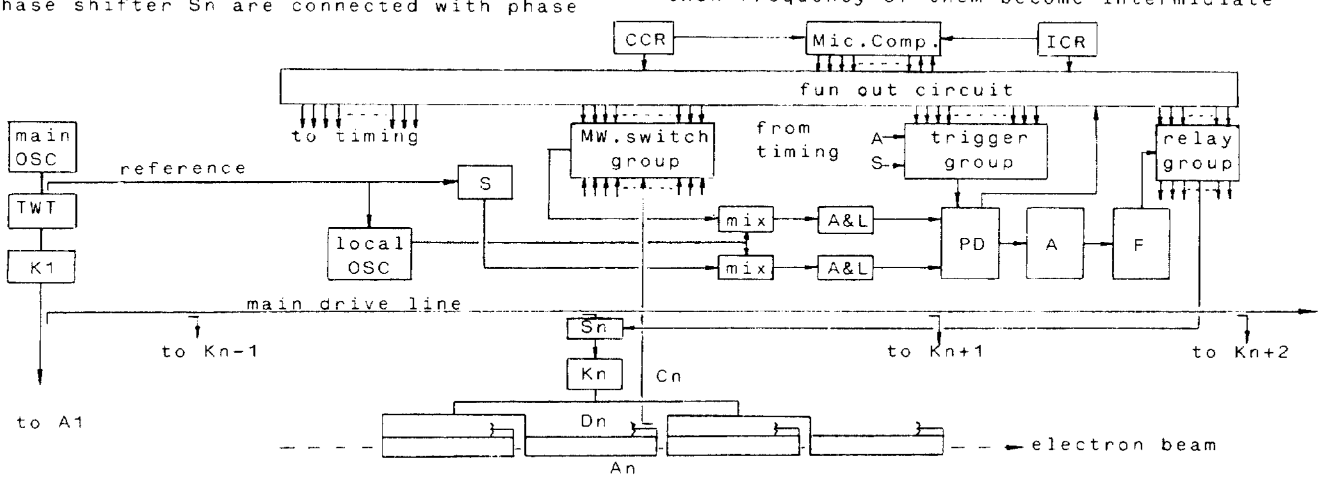

Fig.1. Block Diagram of Phasing System.

frequency that is much lower than microwave. So the satisfactory amplifier & limiter and phase detector that work in intermediate frequency were designed and built. But the pulse envelope of beam-induced signal is very narrow (0.83μs), its frequency spectrum is very wide so band width of amplifier & limiter must be wide enough to avoid distortion, that means, the intermediate frequency can't be too low. So 20 MHz is chosen as the intermediate frequency.

Amplifier & limiter

A block diagram of the Amplifier & limiter and phase detector is shown in Fig.2. Here, four band pass filters are extremely same.

Mid-band frequency	20 MHz
Band width (3db)	10 MHz

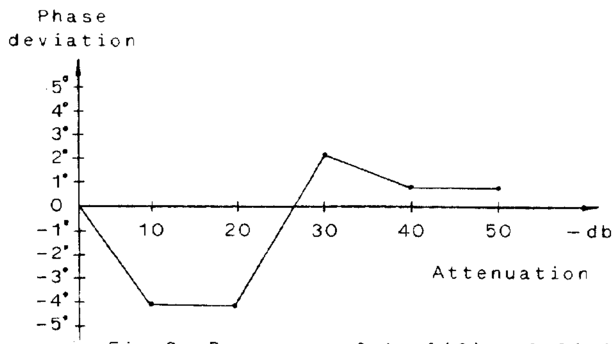

Fig.3. Responce of Amplifier & limiter.

Because the gain of the Amplifier & limiter is very high (80db), attention must be paid to avoiding self-oscillating and reducing noise.

In Fig.2, SRA-3 is a double ballance mixer which is used to be wobbler.

Local Frequency Generator

The Local Frequency Generator was built to provide a local frequency which is 20MHz higher (or lower) than RF frequency. Fig.4 is a block diagram of local frequency generator. It is a automatic frequency control oscillator.

Operational frequency	2876 MHz
Amplitude	50 mw
Frequency stability	1×10^{-6}
Locking range	4.5 MHz

Microcomputer Control System

Microcomputer control system for phasing system is composed of a Z80 single board computer, interface circuits, fun out circuit, microwave switch group, relay group, trigger group etc. A control program which is adjusted beforehand is memorized in an EPROM. Three PIO are developed to provide 17 outlets and 2 inlets for the system to connect the computer with the peripheral equipments. When the "AUTO" button is pressed, the program memorized in the EPROM is picked out to control the system working sequentially. At first, a signal from the outlet No.1 is transmited to the fun out circuit through the interface circuits. Then the fun out circuit gives several signals to the microwave switch group, relay group, trigger group and timing system to make corresponding microwave switch, relay, trigger etc, work and set klystron K1 to the "standby". So a servo loop including K1 is shaped. The rest may be deduced by analogy. When the phase difference between beam-induced signal and reference signal or between klystron signal and reference signal becomes +90° or -90° within ±1°, phase detector gives a signal to computer, asking it to go to next step or to phase next klystron. After all klystrons being phased, computer gives an answer back to the operator-a LED lit.

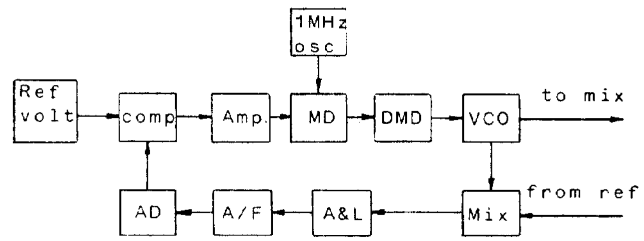

Fig.4. Block diagram of local generator.

Monitoring Phase Information

In order to monitor phase information of each klystron, the signal from power combiner or amplitude detector (Fig.2) are transmited to the central control room and Injector control room through two coaxial cables and displayed on oscilloscope. The signals from power combiner are 20MHz signals, their envelopes show phase informations. The signals from amplitude detector are video signals. So 20MHz band pass filters and low pass filters can be used to restrain interference.

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Reference

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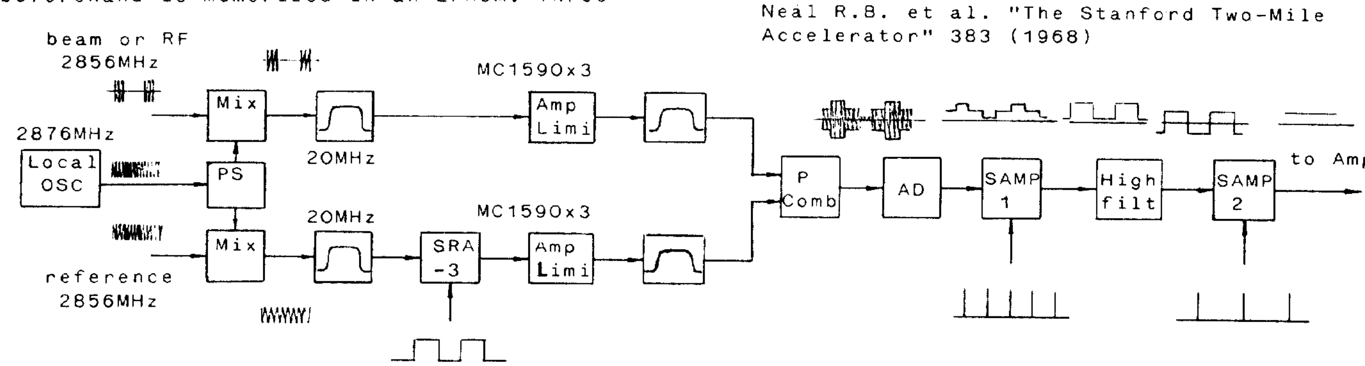

Fig.2. Block diagram of A&L and PD.