THE RF REFERENCE LINE FOR TRISTAN

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Abstract

A description is given of the phase stabilization of the 508.58 MHz RF phase reference line for TRISTAN, an e^--e^+ colliding beam ring, with eight RF stations around its 3018 m circumference. Each reference line between the stations is phase stabilized by its own independent feedback system. The reference signal is transmitted through the coaxial cable to the receiving unit in the next station, where a part of the received signal is converted to its second subharmonic. The subharmonic is returned through the same cable to the transmitting unit and converted back to 508.58 MHz to be compared with the reference signal. The experimental results of the system are presented.

Introduction

In TRISTAN main ring, 30 klystrons, 52 APS-cavity units, and 16 superconducting cavity units will be installed.[1] At the present stage, 16 klystrons and 32 APS-cavity units are installed and operating at an average klystron power of 780 KW at 25 GeV beam energy. These klystrons and its control devices are placed at eight RF stations located on both sides of four collision points as shown in Fig. 1. An RF signal from a master oscillator in the central control room is distributed via cascaded reference line segments. The reference line segment consists of a transmitting unit, a receiving unit and a coaxial cable. The signal is sent to D7 RF station, where it is divided in two, one passing through D7-D5-D4-D2-D1 path and the other through D7-D8-D10-D11-D1 path. Each path consists of four line segments and its total cable length is about 1900m. At the D1 RF station, an RF phase of these two paths is always monitored to check the feedback performance.

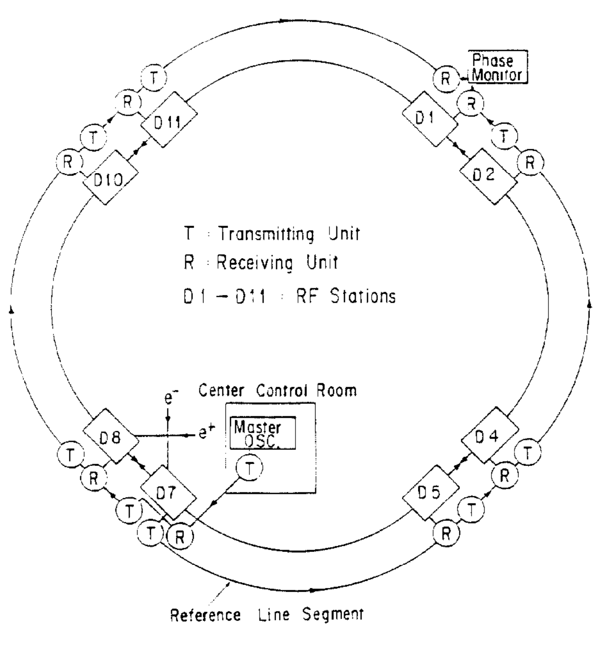

Fig. 1 TRISTAN RF reference line.

The RF Reference Line

The TRISTAN main ring(MR) and the accumulation ring(AR) have their own master oscillators. The nominal AR operation frequency is 508.577MHz, and the MR frequency is 508.5808MHz. The master oscillator is a synthesizer with a frequency stability of 5×10^{-10} per day and noise level of -120 dB at 1 kHz deviation. The AR master oscillator is supplied a 10MHz reference clock from the MR master oscillator. At the beam transfer from the AR to the MR, two oscillators are phase locked after the AR frequency is adjusted to the MR one.[2]

The block diagram of the reference line segment is shown in Fig. 2. The phaselock method is as follows. The input RF signal (508.58MHz) is divided in two way; one is used as a reference of phase detection, and the other is passed through a phase shifter and transmitted to a receiving unit in the next RF station through the transmission coaxial cable. The sample of the received RF signal is converted to its second subharmonic and returned back to the transmitting unit through the same transmission coaxial cable. The returned second subharmonic signal is converted back to 508.58MHz and passed through another phase shifter and fed into the down frequency converter to 1 MHz. A phase comparison with the reference signal is done at 1 MHz. An error signal is filtered and amplified in the feedback controller and fed back to the two phase shifters. The advantage of using the second subharmonic frequency is that one can isolate the backward returned signal from the forward transmission signal. The phase detection is therefore not affected by signal reflections and by cross-talks in a directional coupler and a 90° hybrid. The phase detector measures just twice the phase variation observed at the receiver output. To compensate the phase variation of the received signal, the detected phase is fed back to the two phase shifters. Each phase shifter has a different non-linear response between the phase shift and control voltage, and its maximum deviation from 20 degrees/Volt line is amount to about 10 degrees. The simple way to get a pair of phase shifters with the same characteristics is to linearize the overall phase response by feeding the control voltage through the voltage converter. Using this voltage converter, a deviation of the phase shift between the two phase shifters can be less than ±1 degree.

Component Description

We use two types of transmission coaxial cable; one is type WF-H50-7, 29mm outer diameter, and 30dB/km attenuation at 508.58 MHz. It is used for a short distance line about 160 - 200 m long, so the total cable loss is amount to 5 - 6 dB. The other is type WF-H50-13, 50.7mm outer diameter, and 18dB/km attenuation, and used for a long distance line about 760m long, so the total cable loss is amount to 14 dB. The maximum phase-temperature coefficient of these transmission cables are 10 ppm/°C.

The phase shifter consists of hybrids and diodes, and has a range of -200 to 200 degrees for -10V to 10V control voltage. In this feedback system, two phase shifters are used in the forward line and the backward line and controlled by the same control voltage to make a same phase shift. As described previously, the control voltage converter is used to linearize the overall response of the phase shifter. The converter is a kind of function generator which can vary a slope

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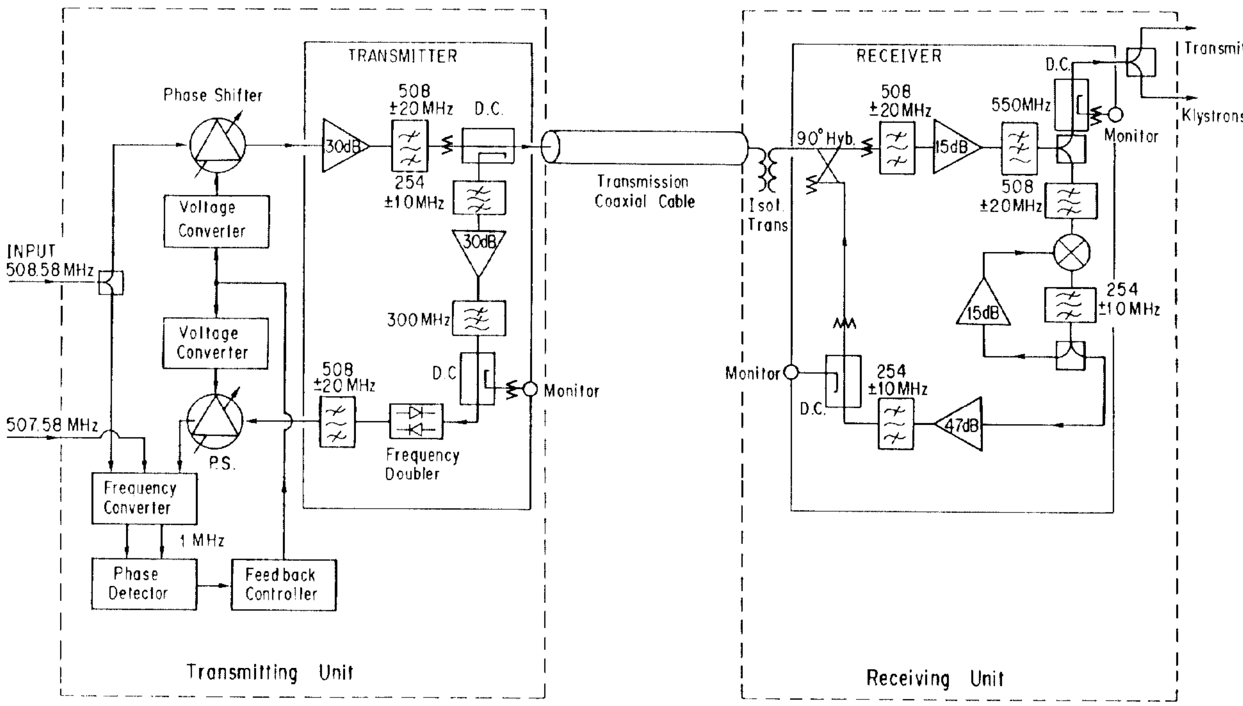

Fig. 2 Block diagram of the reference line segment.

within 20% in each ten sections. By using this converter, deviation from 20 degrees/V line is reduced to below ± 0.5 degree. The phase difference between a pair of phase shifters is less than ± 1 degree over the range of -180 to 180 degrees.

To detect a phase of 508.58 MHz signals, the frequency is converted down to 1 MHz by a mixer using a 507.58 MHz local signal. A phase detection of 1 MHz signal is made by detecting a zero-cross time difference using comparators.

The feedback controller is a module which consists of a summing amplifier, a CR-filter, a loop amplifier, and a loop on/off switch. The time constant of the CR-filter and the loop gain are controllable. The output control voltage can be limited for protection against a feedback failure. This module is used for all other feedback loops in the TRISTAN RF system, such as phaselock loops for klystrons and voltage control loops for cavities. In this reference line feedback system, the time constant of CR-filter is set to 52 ms and the loop gain is set to 40dB.

Performance Test Results

The performance of the feedback system was tested by using a simulated transmission line instead of the actual cable in the MR. The simulated line consists of a 40m long RG-213/u cable, a line stretcher and an attenuator. The line attenuation is adjusted to the value of the actual line. The line stretcher is used to shift the phase of the line. The 40 m RG-213/u cable has 7.0 degrees/°C phase-temperature coefficient, and it is larger than 5.5 degrees/°C for the 760m long MR cable.

In Fig. 3, a phase shift of the received signal (circle plots) is shown as a function of a phase shift of the transmission line. To check the feedback system, a phase of the returned signal(dot plots) is also shown. Because the loop gain is a hundred, the phase shift is approximately a hundredth of the phase shift of the transmission line(solid line of Fig. 3). The received signal phase should be half of the returned signal one as shown in dashed line. The deviation of the circle plots from the dashed line is due to the difference of the phase shift-voltage characteristics between the two phase shifters. The maximum deviation from the expected value is about 0.6 degree, small enough for the reference line.

The response for the frequency change is shown in Fig. 4. The solid line is the expected phase shift calculated from the cable length and the loop gain. The origin of a large deviation from the calculation is a difference of the number of the band-pass filters used in the forward and the return path. The band-pass filter has a large frequency dependent phase shift. In the TRISTAN MR, the frequency change is less than ± 10 kHz, so the phase error due to band-pass filters is less than about ± 0.2 degrees per segment. However,

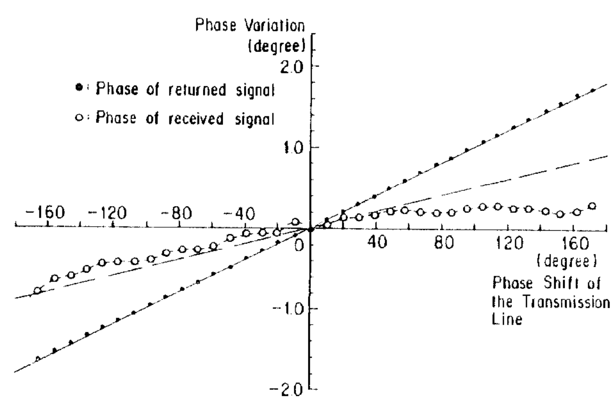

Fig. 3 Phase response of the feedback system versus a phase shift of the transmission cable by a line stretcher.

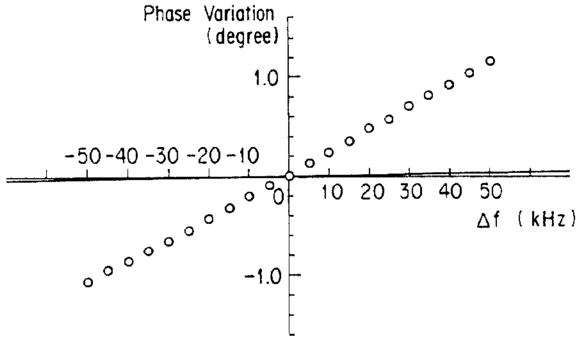

Fig. 4 Phase response for RF frequency change.

since this error is accumulated in the cascaded segments, the feedback system must be improved to have less frequency dependent error.

A heat cycle of 25±20 °C is applied to the 40 m RG-213/u cable in the temperature controlled cabinet, and its phase responses are shown in Fig. 5. Though the RG-213/u cable has a large phase-temperature coefficient as mentioned above, the phase shift at the receiving point is controlled within 0.8 degree by this feedback system. The cables used in the MR have a smaller phase-temperature coefficient and are mostly laid in the air-conditioned tunnel, so this heat cycle test will be harder than a practical case.

Conclusion

The feedback system of the reference line is tested using a model transmission cable. The error of the system is 0.8 degree for 25±20°C temperature change, and 0.2 degree for 10 kHz frequency change. The TRISTAN main ring's system has worked stably for four months, and provides a sufficient phase stabilization.

References

[1] K. Akai et al., "RF System with room-temperature cavity of the TRISTAN e^+e^- storage ring" Proc. of the 13th conference on high energy accelerators, Novosibirsk, 1986.

[2] J. Urakawa et al., "Bucket matching system between TRISTAN AR and MR" contributed paper to this conference.

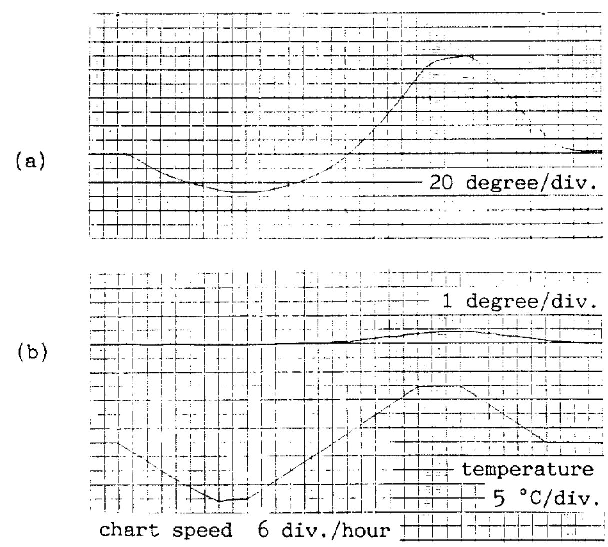

Fig. 5 Phase response for temperature change of the test cable.
(a) with no feedback
(b) with feedback