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UNIVERSITY OF CALIFORNIA

## Engineering Division

To be presented at the Particle Accelerator Conference 1995,  
Dallas, TX, May 1-5, 1995, and to be published in the Proceedings

### **The Amplitude and Phase Control of the ALS Storage Ring RF System**

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March 1995



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This work was supported by the Director, Office of Energy Research, Office of Basic Energy Sciences,  
Materials Sciences Division, of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

# The Amplitude and Phase Control of the ALS Storage Ring RF System

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## Abstract

A 500MHz, 300KW Klystron power amplifier provides RF power to the ALS Storage Ring. In order to accommodate the amplitude and phase changes during beam stacking and decay, which demand continuously varying power levels from the Klystron, four loops are used to keep the system operating properly, with two of those loops dedicated to keeping the two cavity tuners on tune. Description of the control loops and their performance data will be given. Using the modulation anode of the Klystron in the amplitude loop will be discussed.

## Introduction

Figure 1 shows a simplified block diagram of the ALS SR (Storage Ring) RF system. The RF power is provided by one single 300KW Klystron. The output power is split into two equal parts to drive two similar cavities with a Hybrid or a Magic Tee. In the 1.5 GeV operation the dissipation of each cavity is 35KW with a coupling factor of 1.5. The cavity power dissipation should remain constant through the entire range of operating beam current of 0mA to 400mA. As the beam is demanding more power from the RF through the cavities the amplitude loop will adjust the drive of the RF system providing more power for the beam and keeping the cavities' voltage constant.

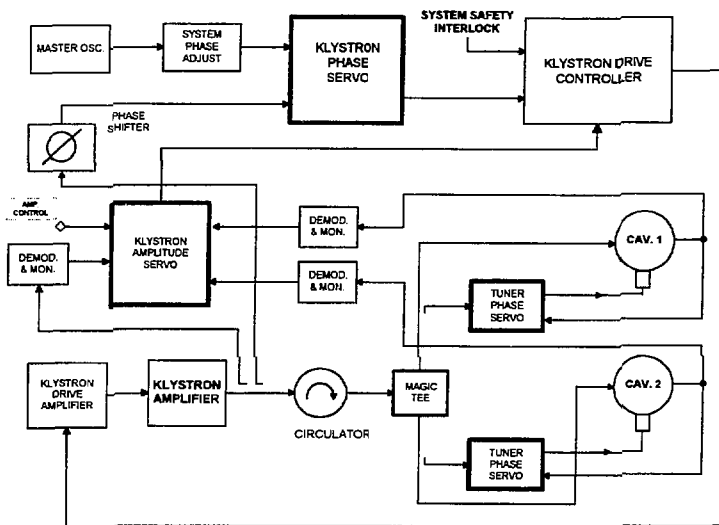


FIG.1 SIMPLIFIED BLOCK DIAGRAM OF THE AMPLITUDE AND PHASE LOOPS OF THE ALS SR RF SYSTEM

Since the RF signal must go through a phase shifter, a couple of amplifiers, an electronic attenuator and finally the Klystron, the phase of the RF signal will vary with the output power level. The phase variation may have some effect during beam stacking; therefore a phase loop has been implemented to keep the phase constant through the range of operating power. In order to keep the two cavities on tune during operation, each cavity tuner phase servo utilizes a stepping motor moving a metallic plunger in and out of the cavity to keep it on tune. The Tuner Phase Servo system has been described in detail in Ref. 1.

The master oscillator signal goes through the Klystron Phase Servo and then the Drive Controller. The Drive Controller contains an electronic attenuator and a fast RF switch. The electronic attenuator serves as the amplitude control element, the fast RF switch will shut off the RF power upon receiving an interrupt signal from the personnel and equipment safety interlock systems. The output of this Drive Controller provides input to the Klystron driver amplifier which in turn drives the Klystron amplifier. A circulator is used to protect the Klystron from power reflected from the rest of the system. The Magic Tee splits the power into two equal parts to drive the two cavities. Signals from the cavities' pick up probes are used by the Tuner Phase Servos and the Amplitude Servo to keep the cavities on tune as well as keeping the cavity voltage constant respectively.

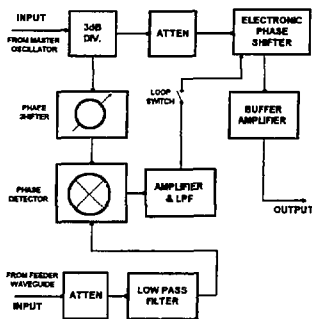


FIG. 2 SIMPLIFIED BLOCK DIAGRAM OF THE PHASE SERVO

## The Phase Loop

Figure 2 is a block diagram of the Phase Servo. The master oscillator signal is split into two parts. One part goes to the electronic phase shifter and the output amplifier, the other part goes through a mechanical phase shifter to a double balance mixer as the Local reference signal. A directional coupler in the feeder waveguide picks up portion of the RF signal and feeds it back to the RF port of the mixer. The IF output of the mixer is filtered and amplified and fed back to the Electronic Phase Shifter to compensate for the phase change in the signal path. During testing without beam, the amount of phase variation of the system without feedback is more than 30 degrees between an operating power level of 30KW and 80KW. By closing the loop the phase variation is reduced to less than 0.25 degree. At the present time 80KW is the operating power for the two cavities without beam. With a beam current of 400mA at 1.5GeV the total RF power required is about 115KW. With the phase loop open between 80KW and 115KW the phase variation is less than 10 degrees. With the loop closed the phase variation is reduced to less than 0.25 degree. For normal operation the power is brought up to 80KW and the phase error is adjusted to zero, the phase loop is closed at this point. Any phase variation from this point on will be compensated by the electronics phase shifter according to the phase error voltage from the phase detector. The electronics phase shifter has a range of 300 degrees.

## The Amplitude Loop

Figure 3 shows a simplified block diagram of the Amplitude Servo. During operation the DC amplitude control signal normally comes from the control system. A preset value is used to provide 80KW of power to the two cavities for 1.5GeV - 1.9GeV operation. An adjustable input amplitude limiter is used to limit the input amplitude control to ensure that the set point would not exceed 80KW. This amplitude control signal is used as the reference voltage for both the feeder feedback loop and the cavity feedback loop. At the power level of 80KW, equal weights of cavity one and cavity two signals are summed together and adjusted

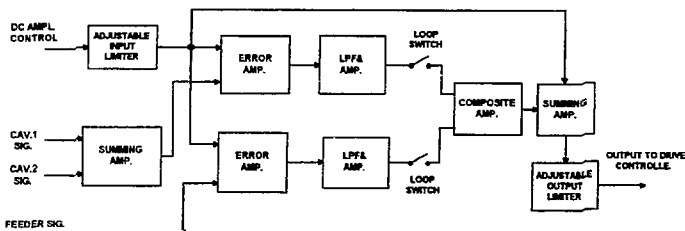


FIG.3 SIMPLIFIED BLOCK DIAGRAM OF THE AMPLITUDE SERVO

to the same level as the reference signal. The same procedure is carried out for the feeder channel. The error amplifiers on both channels produce correction signals which are filtered and amplified. The two loops can be opened or closed by the two loop switches. The two correction signals are then summed and monitored by the output amplitude limiter before it is used to control the Klystron drive. The output amplitude limiter is used mainly to limit the maximum power output of the Klystron in case of any mishap occurring in the signal path that may demand an exceedingly high power output from the system. The feeder loop is mainly used to reduce ripple in the power supply; more than 35dB of reduction of ripple has been achieved. The cavity loops are essential for counteracting beam loading effects. During beam accumulation more and more power is supplied to the beam to compensate for the losses due to bending magnets and insertion devices, the amplitude loop detects any drop in cavity voltage and increase the drive power to the Klystron to make up for the losses. The cavity loop has successfully kept the cavity voltage constant through the entire range of beam current of 0 mA to 400 mA at 1.5 GeV operation. We expect the same in the 1.9GeV operation.

### Conclusion

The Tuner Phase loops, the amplitude loops have been operating successfully since ALS began operation. The amplitude feedback loop is using an electronic attenuator in the Klystron Drive Controller to control the power output of

the Klystron. The modulation anode in the Klystron was originally planned to be used as the amplitude control element, however due to problems in the factory supplied control system, design changes have to be made before the modulation anode can be used for that purpose. The present system works well as long as the Klystron beam current demand does not exceed the maximum allowed collector dissipation of 300KW. The Klystron Phase loop has been operating only for a short time, its performance will be reported in due time.

### Acknowledgment

The work was supported by the Director, Office of Energy Research, Office of Basic Energy Sciences, Materials Sciences Division, of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098 with Lawrence Berkeley Laboratory.

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