TN-68-5
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R. McConnell
February 1968

RF CONTROL SYSTEM FOR SLAC STORAGE RING

The block diagram of an accelerating station for the proposed SLAC 3 GeV electron-positron storage ring is shown in Fig. 1 which is reproduced from the proposal of September 1966. In the period since this proposal was written additional work has been done on the design and construction of a prototype rf accelerating station and has led to the replacement of many of the boxes of Fig. 1 by actual hardware. The purpose of this note is to present these further details of the various control systems. The general requirements of the rf system of the storage ring together with a detailed description of a prototype rf cavity is given in an earlier report.*

Automatic Gap Voltage Control System

A system to maintain constant gap voltage in the cavity during filling and operation has been devised. The system block diagram is given in Fig. 2.

Using a Fairchild 709 IC operational amplifier and the modulator in the HP606A Signal Generator, this system has reduced 20 dB variations to 2 dB, and 3 dB variations to 0.5 dB. Optimization of the system must await more detailed design specifications on the rf drive system.

* "RF Cavity for SLAC Storage Ring," M. A. Allen, L. G. Karvonen, R. A. McConnell, SLAC-78, October 1967

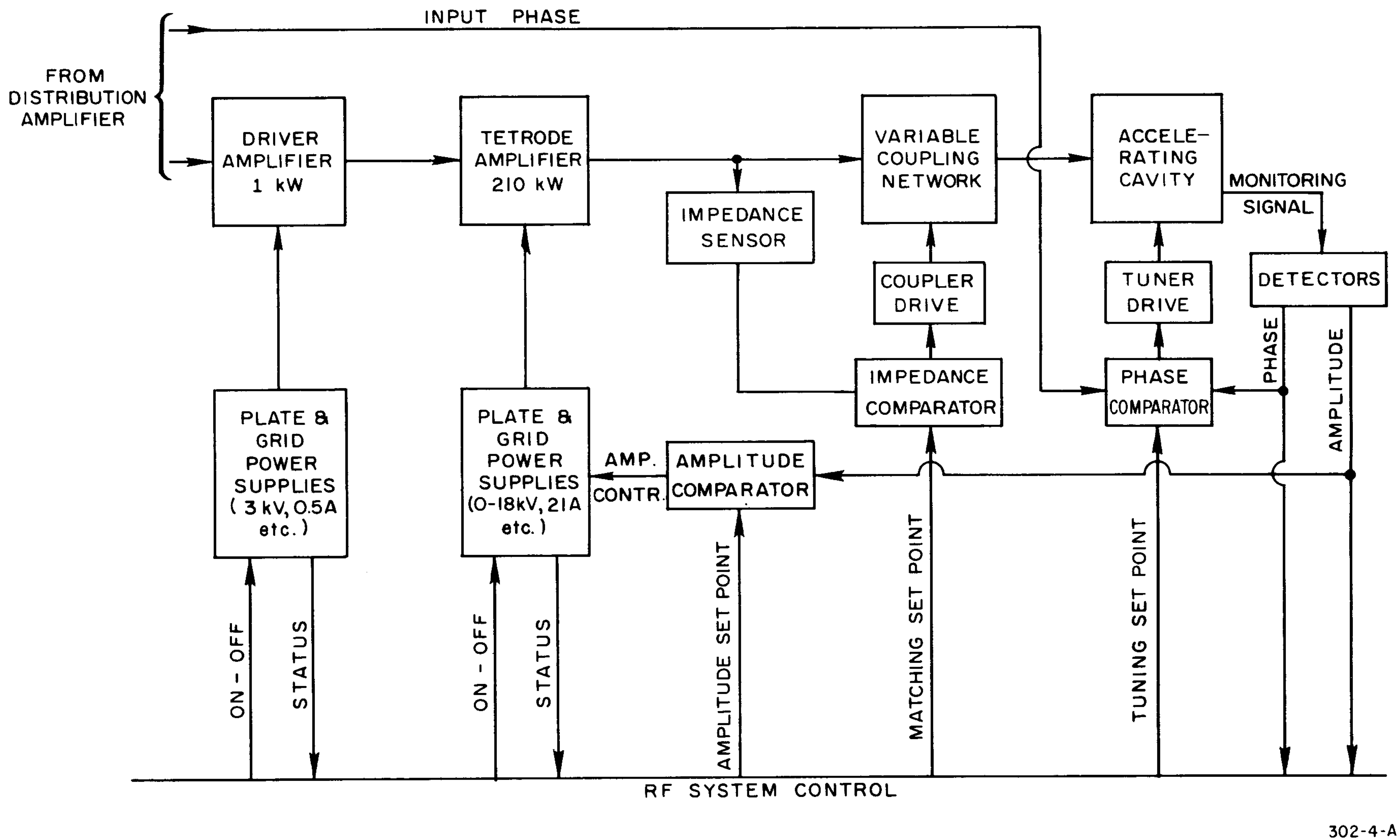


FIG. 1 - BLOCK DIAGRAM OF AN ACCELERATING STATION.

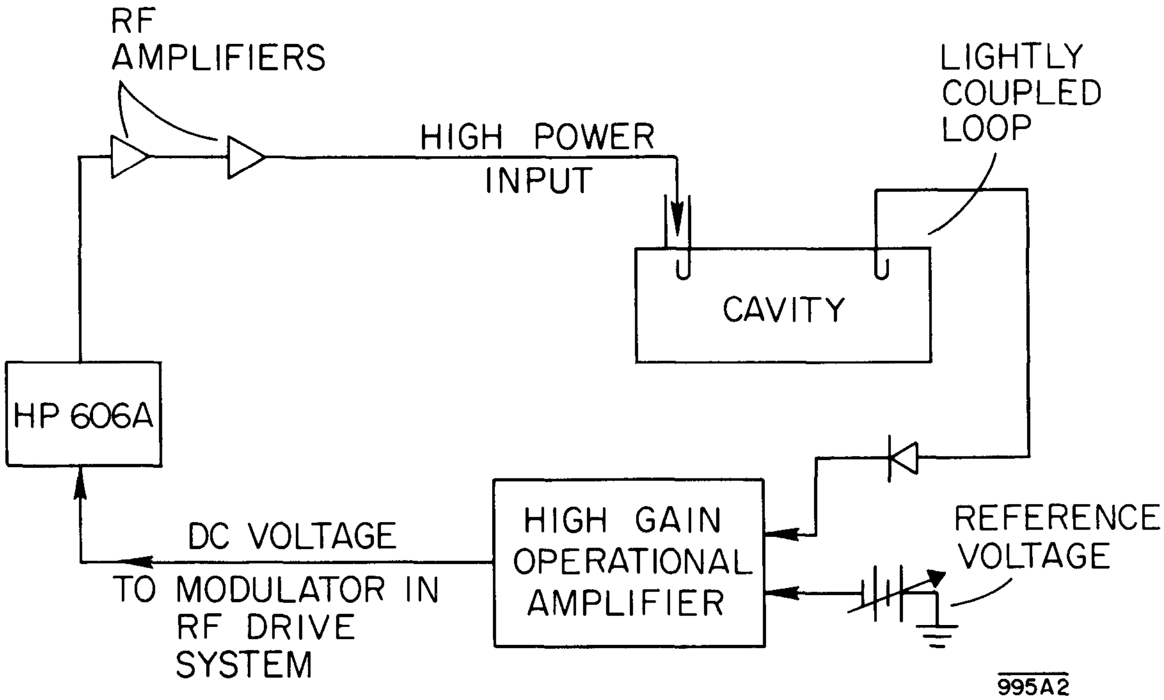


Fig. 2 - Automatic Gap Voltage Control System

Automatic Coupling System

The coupler for the storage ring cavity must meet the following requirements:

(1) The coupler must be continuously variable during the filling of the ring.

(2) The coupler must be capable of matching resistive loads over a range of 60 to 1.

(3) The coupler must be capable of transferring 200 kilowatts cw power with as little load as possible.

(4) The coupler should not introduce reactance in the transmission line to the cavity.

A coupler which meets several of these requirements and shows promise of meeting all of them has been designed. A circuit diagram of the coupler is given in Fig. 3.

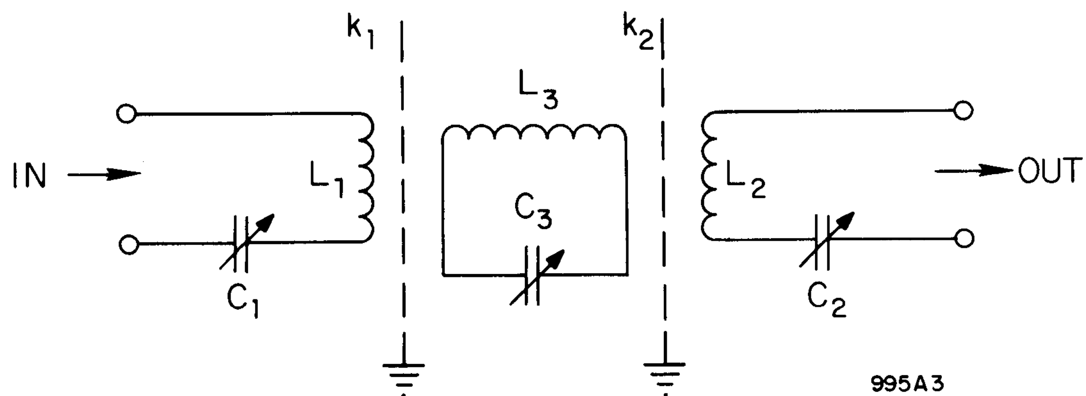


Fig. 3 - High Power Coupler

Each of the three circuits is adjusted to resonance in the absence of the other two circuits. Then, by adjusting the position of the central circuit, C_3L_3, the coupling coefficients k_1 and k_2 are made to vary. If the input is terminated with a source resistance, R_S, and the output with a load resistance R_L, the following approximate relationship exists:

$$\frac{k_1}{k_2} = \left[\frac{R_S}{R_L}\right]^{\frac{1}{2}} \qquad (1)$$

A particular advantage is derived from the fact that the central circuit is mechanically "floating." No sliding metallic contacts are required. All the power is transmitted through coupling of the magnetic fields, with no direct electrical connections. At power levels of 200 kW, and at an impedance of 50 ohms, the transmission line must handle 4500 volts and 63 amperes. The absence of sliding metallic contacts facilitates the transmission of these high voltages and currents.

A low power version of the coupler has matched impedances over a range of 10 to 1. A high power version has been tested successfully at 35 kW, and shows 0.08 dB insertion loss (2%). The high power version provides matching over a range of only 3 to 1. However, by constructing the inductances in flat spiral form rather than in solenoidal form, it should be possible to increase the space available for the central circuit to travel in. Also, with the spiral inductor, it should be possible to make the central circuit self-resonant, and eliminate the variable capacitance.

The purpose of the Faraday shields is to eliminate capacitive coupling between the inductors. This feature has not yet been tested, and in its absence, reactive effects, presumably due to capacitive coupling, have been noticed.

The coupler is driven by a two-phase motor and motor driver unit identical to that used in the automatic tuning system. The motor driver unit receives differential input from diode detectors which sample the standing wave on the input transmission line at points $\frac{\pi}{4}$ and $\frac{\pi}{2}$ from the plane of the cavity.

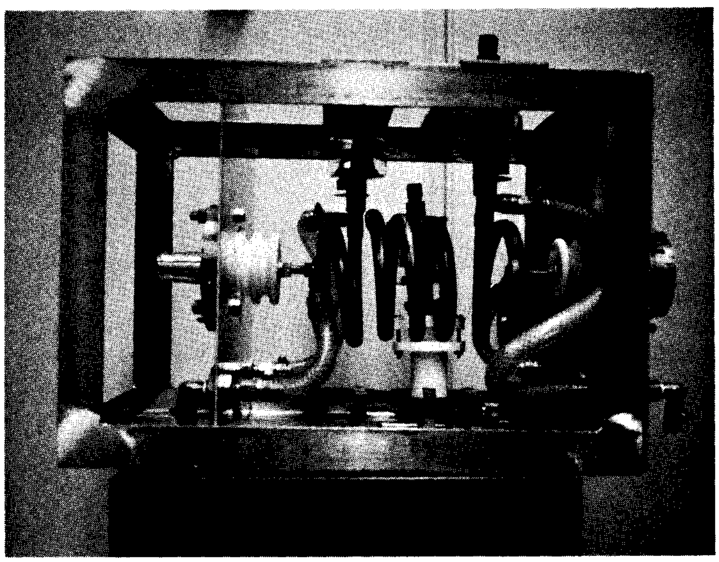


Fig. 4

A block diagram of the complete automatic coupling system is given in Fig. 5. This coupler is described in detail in TN-68-4.

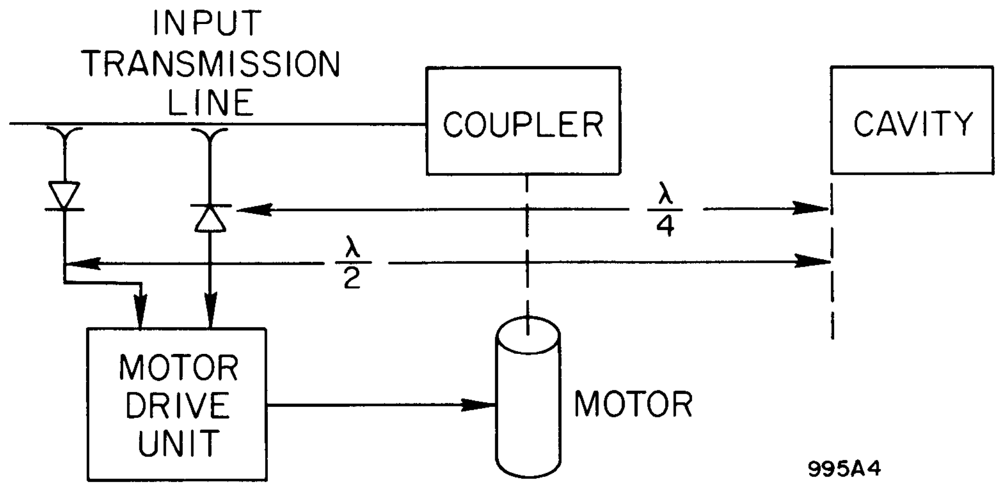


Fig. 5 - Automatic Coupling System

Automatic Tuning System

A block diagram of the automatic tuning system is given in Fig. 6.

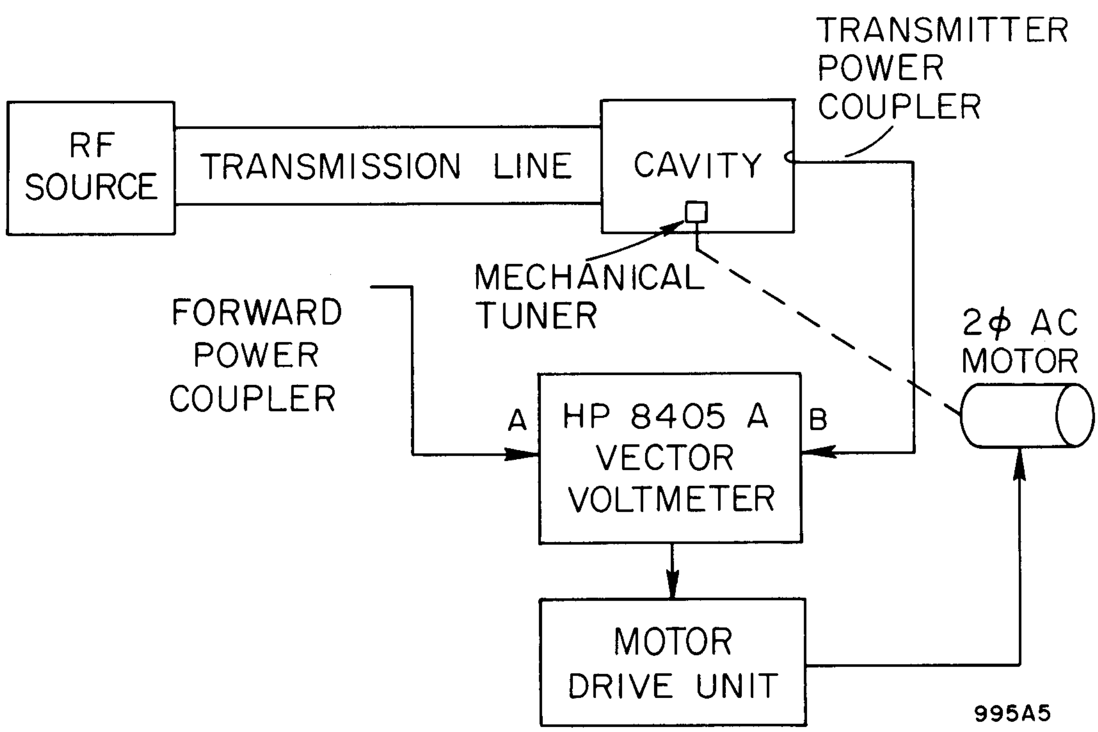


Fig. 6 - Automatic Tuning System

The HP Vector Voltmeter performs a phase measurement between the incident signal and the transmitted signal, and produces a voltage proportional to the phase difference of these two signals. The transmitted signal is represented (except for a scale factor) by the vector sum of the incident signal and the reflected signal. Inspection of Fig. 7 shows that the vector representing this sum goes to $\pm 90^{\circ}$ far from resonance, and passes through 0° (with respect to the incident signal) at resonance.

The d.c. voltage from the vector voltmeter is sent to the motor driver unit, where it is chopped, amplified and used to excite one winding of a 2 phase a.c. motor. The other winding is supplied with a constant amplitude excitation voltage from the motor driver unit. The a.c. motor in turn drives the mechanical tuner.

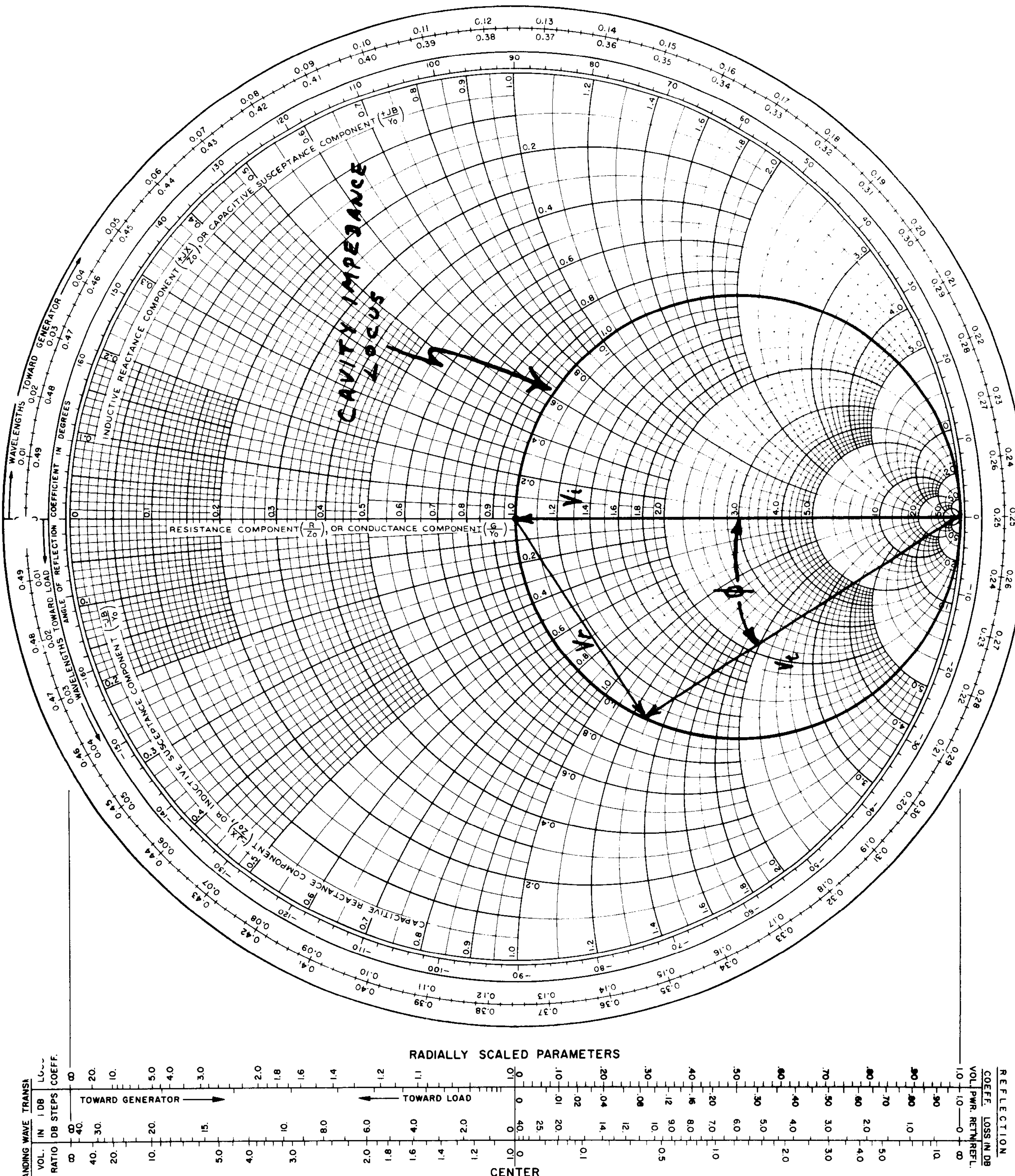
The mechanical tuner provides a tuning range of 2.4 MHZ. The tuner is a slow device and requires several minutes to tune through its entire range. This tuner has been described in detail in SLAC Report No. 78.

One disadvantage of the system is that the transmitted signal becomes very small at frequencies far from resonance, and if sufficiently small, may produce erroneous phase readings in the vector voltmeter.

A major virtue of the system is derived from the 80 dB dynamic range of the vector voltmeter. The large dynamic range makes it possible to lock the cavity to the exciting frequency at very low power levels, (20 mW) below the point at which multipactor occurs. Then a step increase in power of, for example, 60 dB can be made so that the rf voltages in the cavity reach values above the multipactor range before the multipactor effect builds up to significant proportions. In the meantime the automatic tuning system maintains the cavity tuned to the driving frequency. Without the automatic system, the cavity changes frequency so rapidly when high power is applied (because of dimensional changes) that the rf voltages in the cavity decrease to the point where multipactor sets in.

NAME	TITLE AUTOMATIC TUNING SYSTEM	DWG. NO. FIG. 7
SMITH CHART FORM 82BSPR (2-49)	KAY ELECTRIC COMPANY, PINE BROOK, N.J. ©1949 PRINTED IN U.S.A.	DATE 1-29-68

IMPEDANCE OR ADMITTANCE COORDINATES



Electronics - Vol. 17, No. 1, PP. 130–133, 318–325, Jan. 1944

A MEGA-CHART

Motor Drive Units

In the coupling and tuning systems described above, motor drive units are shown. The motor drive units are modifications of the units used to control phase shifters in the 2-mile accelerator automatic phasing system. The modifications consisted of the addition of a 30 Hz multivibrator (which replaced the external drive used by the original units), and conversion from pulse to d.c. input.

Automatic System Interactions

The three automatic systems can interact with one another. For example, detuning of the cavity causes gap voltage to decrease, both because of the diminished cavity response, and because of the impedance mismatch at the cavity input which reduces the power delivered to the cavity. Also, the coupling system as described above will receive false input signals from the standing wave pattern on the input line when cavity detuning takes place. Gap voltage is, of course, a function of coupling.

One possible solution to the interaction problem is to sequence each system. For example, the coupler system can be prevented from acting until after the tuning system has completed its operation. Such interactions have not been studied except in a general qualitative way. A major task for the future is both the optimization of all loops and a quantitative study of the interactions.