A New Automatic Frequency Regulation System*

Introduction

A considerable number of frequency regulation systems for voltage tunable sources such as klystrons are presently available. The most prominent of these is the Pound Regulator[1] which provides an excellent stable source. Perhaps the only disadvantages of the Pound system are the initial cost and the rather critical adjustments necessary when starting up.

The system described here was designed for stabilization of a VA-96 (K-band) klystron, but is readily applicable to any other voltage-tunable microwave source. In essence, the error signal is derived from a phase comparison of two signals. One is a driving signal of 100 kilocycles per second which is also used to modulate a reference cavity (in size), and the second signal is the rectified microwave signal reflected from the reference cavity. A block diagram of the system is shown in Fig. 1.

The advantages of this system are that it is economical in equipment, and it is easy to align and adjust. Furthermore, the output is monochromatic and isolated from the stabilization loop. Additional isolation may be secured, if desired, by use of a ferrite isolator.

Cavity Modulation

Several means of modulating the cavity dimensions were considered. Magnetostriction driving, mechanical oscillations, and piezoelectric crystals are all feasible. The choice may be made on the basis of obtaining an error signal from the phase detector in a time much shorter than the reciprocal of the highest harmonic of the noise. For example, in the case of klystrons operating from rectified ac, the highest noticeable harmonic of the ripple would likely be less than 1000 cycles per second; hence the system response should be faster than one millisecond.

A mechanical modulation system using a cam and motor or solenoid driven end plate for the cavity is not easily driven at frequencies in excess of a few hundred cycles per second. For high frequencies it is much more feasible to utilize either magnetostrictive or piezoelectric devices. Using such mechanisms, frequencies of 100 kilocycles or more are obtainable which permit sufficiently fast response times even after the integration of a phase detector.

Experimental Results

Experimentally, it was discovered that piezoelectric modulation was more easily adaptable to a K-band cavity than magnetostriction modulation. Using a 100-kc 50-volt peak-to-peak signal applied to a Rochelle salt crystal, the resonant frequency of the cavity could be varied from about 22.2 kmc to 24.2 kmc. The cavity was

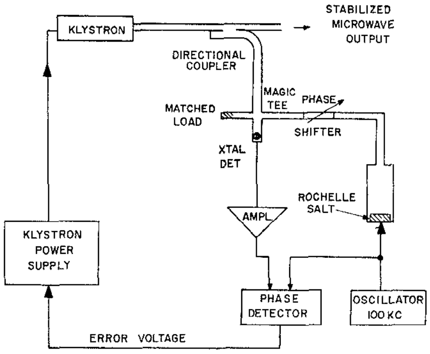

Fig. 1—Block diagram of the modulated cavity frequency stabilization scheme.

constructed with a foil-plated Rochelle salt crystal as one end plate. The crystal was obtained from a headphone and aluminum foil was cemented to the crystal face. It is likely that a quartz crystal would permit operation at higher frequencies if desired.

Frequency stability measurements have thus far been confined to comparing the frequency drift with and without the feedback loop. It appears that the system is stable to better than one megacycle, and probably is stable to within 50 kc. However, we have not experimentally measured the deviation precisely since we have no available stable source for comparison. Future experiments will utilize this source for paramagnetic resonance experiments and will permit a more exact determination of frequency drift. The theoretical calculation of stability involves the gain of the feedback loop. For the present setup, the stability should theoretically be within 50 kc.

Acknowledgment

I am indebted to G. D. Ewing for carrying out the experimental measurements, and to Prof. A. M. Portis for an interesting discussion of other stabilization methods.

J. R. Singer
Electrical Engrg. Dept.
University of California
Berkeley, Calif.

* Received by the PGMTT, May 18, 1959; revised October 9, 1959. This research was supported in part by the Faculty Research Committee, University of California, Berkeley.

[1] R. V. Pound, "Frequency stabilization of microwave oscillators," Proc. IRE, vol. 35, pp. 1405–1415; December, 1947.

On Some Problems in Designing Microwave Faraday-Rotation Devices*

During recent years a substantial effort has been made to obtain special ferrites for microwave applications. The authors' opinion is that in many cases this effort was not supported by real necessity and that many existing commercial materials may reveal surprising microwave properties after a persistent and careful preparation of working conditions.

An investigation of the microwave behavior of a Ferroxcube B5-type ferrite was carried out in this laboratory and the material was not found to be less attractive than many ferrites designed especially for the X band.

Faraday rotation in cylindrical structures with longitudinal magnetization has been studied in detail. Substantial experience was gained in measuring techniques and soon it became apparent that many data on Ferroxcube B5 quoted in the literature are erroneous. Causes of these errors are ascribed to higher mode effects which seriously affect the measurements if only ferrite rod diameter is greater than some critical value. Critical diameters experimentally determined were found to be in good agreement with theoretical calculations by Waldron.[1]

The optimum sample geometry was determined, and for this geometry Ferroxcube B5 figure of merit values were obtained up to 250°/db, with losses not greater than 0.1 db/inch. Broad-band isolators and circulators were next built and their total forward loss was found to be less than 0.35 db, reverse loss being greater than 40 db over the 8600–10,000-mc band, and greater than 60 db at the middle 300 mc.

Two basic systems were used throughout this work. The first one was used to measure the figure of merit as a function of ferrite rod diameter. A special instrument ("Faraday Rotating Meter") working on principles given by Hogan was designed for this purpose. The angle of Faraday rotation was measured with an accuracy of $\pm 0.05°$ and the corresponding losses with an accuracy of ± 0.05 db. Several facilities were provided to enable quick measurements of a large number of samples.

All other measurements were carried out with a fixed angle of Faraday rotation equal to 45°, as this angle is the most important for practical applications. A schematic diagram of an experimental arrangement designed for this purpose is given in Fig. 1.

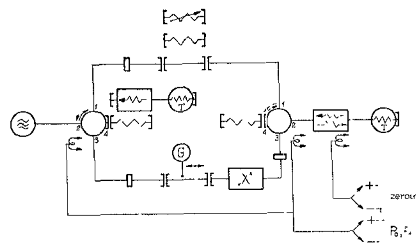

Fig. 1—Universal set-up.

In this arrangement, the two circulators, magnetized from a common dc power supply and controlled by a common switch, are directing the power flow from the generator to the power meter through one of the two transmission paths available. In one position of the switch, the power enters the power meter through the reference path; in the other position, it travels through the device under test before entering the thermistor mount. A comparison of two deflections of the power indicator, corresponding to the two positions of the switch, gives the attenu-

* Received by the PGMTT, October 6, 1959.

[1] R. A. Waldron, "Electromagnetic wave propagation in cylindrical waveguides containing gyromagnetic media," J. Brit. IRE, vol. 18, pp. 733–746; December, 1958.