An Automatic Gain Control System for Microwaves*

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Summary—This paper describes a system which can keep the power level in a microwave set-up constant with good accuracy in spite of variations of the input power level.

The system uses a variable attenuator based on the Faraday rotation in magnetized ferrite and thereby achieves a frequency response up to about 500 cps with the present equipment and much better potential response.

Variations in input power are reduced by a factor varying from 10 to 400 depending on available power and on the detector used to detect the output power.

IN ORDER to keep the power level in a microwave set-up constant with good accuracy, it is necessary to have a system consisting of three parts.

1) A sensing element.
2) A control element.
3) A comparator and amplifier element which detects changes in the output from the sensing element and feeds an error signal back to the control element.

In the X-band system to be described here, the sensing element is a standard crystal detector, the control element is a ferrite modulator—the Gyraline R-920 NA—and the comparator-amplifier is a special unit made for this application.

Fig. 1 shows a block diagram of the set-up. The output voltage from the crystal is compared to a reference voltage, the difference is amplified and the output current controls the attenuation introduced by the Gyraline. The stabilization factor or loop gain is then determined by the components used and also by the level of the microwave power. Loop gain $=P_1/P_2+P_2\times S\times A\times M$ where

P_1 = input power in μW,
P_2 = output power (regulated) in μW,
$a=P_1/P_2=a(ig)$ = attentuation of Gyraline,
ig = Gyraline current in mA,
S = detector sensitivity in $mV/\mu W$,
A = amplifier gain in mA/mV,
$M=da/di_g=M(ig)$ = slope of attenuation characteristic.

The system in its present form uses the Gyraline R-920 NA as a control element in spite of the rather poor modulation frequency response of this unit, because this Gyraline combines a very good sensitivity M with a microwave characteristic that covers the whole X-band.

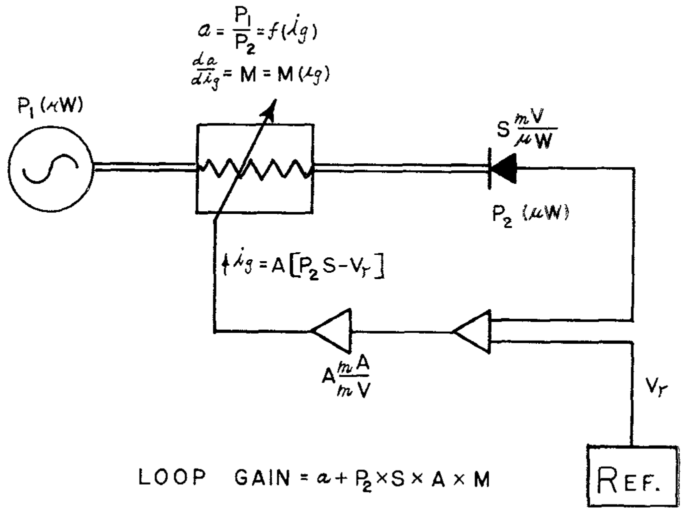

Fig. 1.

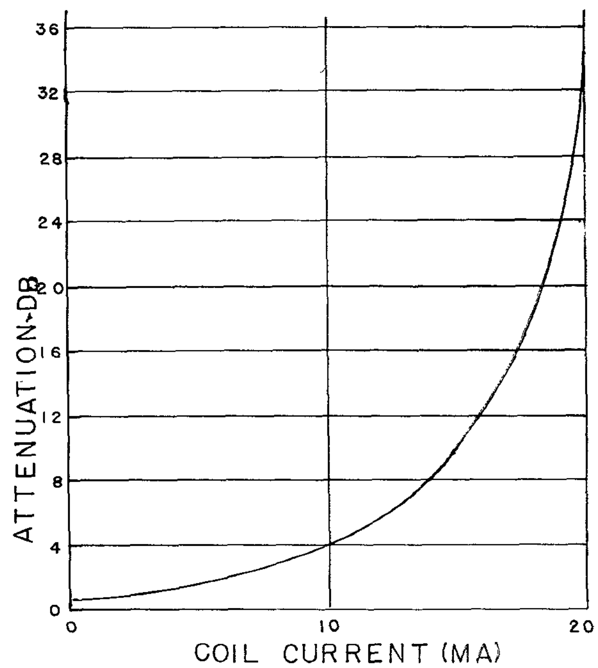

Fig. 2.

The Gyraline is a microwave variable attenuator using the Faraday rotation in magnetized ferrite. This type of unit has been described in several places so that only an outline of the principle is required here. The rectangular waveguide is coupled to a circular guide excited in the TE_{11} mode; a rod of ferrite in the center of the waveguide will rotate the plane of polarization so

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that only a part of the power can be accepted by the rectangular output waveguide while the rest is dissipated in an absorber, the angle of rotation and therefore the attenuation depending on the magnetic field applied to the ferrite. In the Gyraline this magnetic field is supplied by a coil wound around the waveguide so that the attenuation is determined by the coil current. Fig. 2 shows a typical characteristic for Gyraline R-920 NA. In this Gyraline the coil has a very high number of turns which gives a good sensitivity but also a high inductance with corresponding poor response at high frequencies. Fig. 3 shows the frequency response of the R-920 NA and it is seen that the 3 db point is around 110 cps.

If a better response is required, it would be possible to use a less sensitive Gyraline, such as the R-920 or R-920 HF, which have 3 db points at 3 kc and 50 kc, respectively, but the stabilization factor would then be reduced by a factor of 6 and 30, respectively. However, even the present system has a response much faster than anything possible with mechanical attenuators.

Fig. 4 shows a block diagram of the comparator-amplifier unit or agc amplifier. The incoming dc voltage is compared to a reference voltage and the difference voltage is fed to a crystal chopper driven from a square wave oscillator. The resulting ac signal is amplified and rectified in a synchronous rectifier which, in turn, drives the dc output amplifier. This system reduces drift of the amplifier to a negligible value but also introduces some problems of its own, mainly the need for filtering between the rectifier and dc amplifier, which necessarily gives phase shift and therefore must be closely controlled to insure the stability of the whole system.

In order to give this filtering and also to compensate to some extent for the poor response of the Gyraline, a filtering network was built around the dc amplifier so that the chopper frequency 3 kc is attenuated more than 40 db while the over-all system has a reasonably flat response up to 500 cps which was thought to be be sufficient for most applications; *e.g.*, a bwo covering the X band with 30 sweeps per second.

The agc system described here uses a standard crystal detector as the sensing element because this is the most sensitive, but for some applications where the microwave frequency is swept over a wide range, the available crystal detectors have too wide variation in sensitivity—a variation that will not be counteracted by the agc because it will try to keep the dc output from the detector constant even if this requires the microwave power level to vary. In such cases, the input comparator must be modified to work with a barretter or thermistor, *e.g.*, in a bridge set-up where the feed-back through the Gyraline tends to make the bridge self-balancing, but this would require a redesign of the input and would probably be far less sensitive, *i.e.*, a good stabilization could only be achieved at much higher power levels.

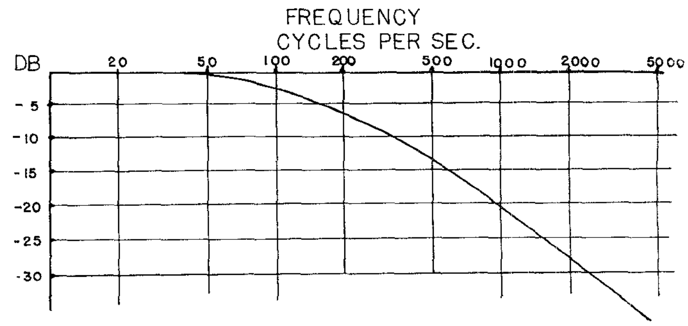

Fig. 3.

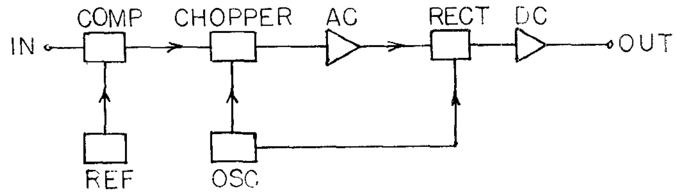

Fig. 4.

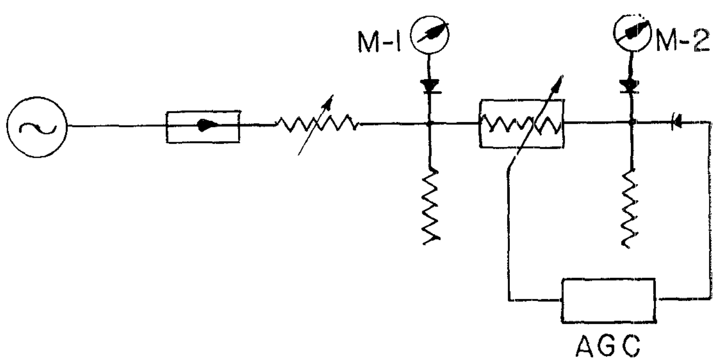

Fig. 5.

Fig. 5 shows a set-up for rapid testing of tw Tubes where the power level from the bwo is held constant during the sweep so that the output from the twt amplifier is directly proportional to its gain. In this case, it does not hurt that the crystal detectors are frequency sensitive as long as the two detectors are closely matched over the frequency range. In a typical case, the bwo has an output varying from 10 mw to 50 mw, the Gyraline works with a minimum attenuation of 5 db and the directional coupler attenuates 10 db giving a power level at the agc detector of 300 μw. This would give a stabilization factor around 100. In a broad-band set-up the directional coupler should be of the multihole type to avoid too much frequency sensitivity in the coupling.

The agc amplifier described here can be used with the proper detectors and Gyralines to obtain a constant power level in other frequency ranges from about 6 kmc to about 35 kmc. At lower frequencies, the Gyralines become more lossy because of imperfections in the ferrite material and, at the same time, they require more driving current than the present agc amplifier can deliver, but the same principle can still be applied.