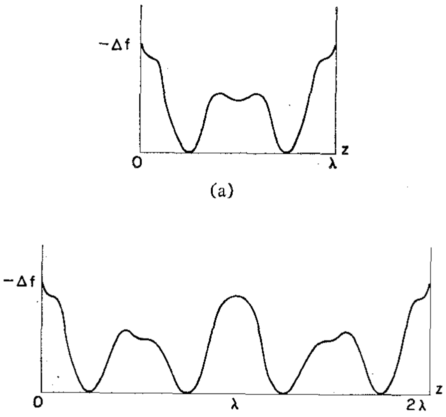


Fig. 2—Experimental data. (a) 3-disk cavity. (b) 6-disk cavity.

≈1/20. The cavity bandwidth was 343 kc at 2856 Mc; the $Q$ was about 8300. The experimental data in Fig. 2 were taken with a large bead which detuned the cavity resonance 1.62 Mc, about nine times the half-bandwidth. Thus $b=9$, $b^2=81$, and the last term in the denominator of (1) is found to add as much as 25 per cent to the signal on one side of a maximum and subtract the same amount on the other side. The correction does indeed account for the observed results.

In conclusion, it has been shown that a perturbing bead does not affect the coupling to the cavity so long as the maximum perturbation of the resonant frequency is of the order of the bandwidth of the cavity. With a perturbation amounting to several cavity bandwidths, the effective coupling to the cavity can be drastically changed, and makes the slope-detection scheme a poor method of taking the required data. A method which measures the resonant frequency directly is not affected by this phenomenon.

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## A New Microwave Mixer Suitable for Use with Very High Intermediate Frequencies*

In the conventional microwave mixer it is generally necessary to provide a low-pass filter or some similar network in the intermediate-frequency output circuit. This filter usually takes the form of a capacitance or choke, which is arranged to present, as nearly as possible, a short circuit to the signal and local oscillator frequencies. For a microwave mixer with an IF of less than 100 Mc chokes have been found to be satisfactory provided that a correct choice of the short-circuit position has been made. It is difficult, however, to design a choke system with a capacitance of less than 5 pf and, even at intermediate frequencies as high as 100 Mc, a capacitance of this value could seriously limit the fractional IF bandwidth or the noise performance attainable. At intermediate frequencies greater than 1000 Mc it was expected that the problems of design of a low-pass filter would be even greater because of the difficulty of meeting the conflicting requirements of efficient RF rejection and IF coupling.

The mixer described[1] uses a pair of crystal diodes arranged in a biphase circuit, which enables the IF output connection to be made in such a way that it is not coupled to the signal and local oscillator power. The decoupling arises from the symmetrical disposition of the two crystals and the fact that the IF output connection is normal to the electric fields of the signal and local oscillator waves, both of which are propagated in the dominant waveguide mode. This configuration eliminates the necessity for chokes in the output circuit. With this arrangement it is possible for power at even harmonics of the signal and local oscillator frequencies to couple to a coaxial output circuit. This could partly account for the somewhat low conversion efficiency measured, but no other indication of the effects of such coupling was observed.

### A Biphase Mixer for the Band 11.5–18 Gc

An experimental mixer for use over this band was constructed in WG 18 (RG91U) waveguide; coaxial crystal diodes (type VX3282) were mounted on the opposite broad faces of the waveguide. The center pins of the two crystals were connected by a post extending across the waveguide. The IF output was taken from the center of this post to a BNC connector mounted in the center of the narrow waveguide wall, the lead thus being normal to the dominant mode electric field within the waveguide. The post and crystals were offset from the center line of the waveguide in order to improve the input VSWR (Fig. 1). An adjustable back piston was placed behind the plane of the crystals and post.

The VSWR of the holder was measured, using a reflectometer, and found to vary between 0.3 and 0.7 over the frequency band. The RF leakage from the hole in the side wall of the mixer, before the BNC connector was placed in position, was found to be negligible. In the first model, no attempt was made to match the IF output circuit, and the VSWR, looking into this port, was found to be about 0.2 when the crystals were operated at 0.15-v bias and 2-ma total current.

Measurements were made of the noise figure of a receiver incorporating this mixer, and using a superheterodyne receiver as the IF amplifier, whose double-sideband noise figure varied from 8.9 db to 14.2 db over the tuning range 1.7 to 2.5 Gc.

The over-all noise figure of the complete receiver, measured over a wide range of RF and IF frequencies, was found to be between 21 and 26 db.

In order to improve the performance an attempt was made to match the IF output

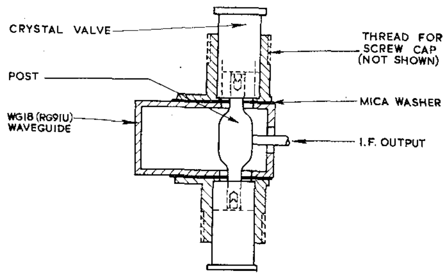


Fig. 1—Arrangement of diodes.

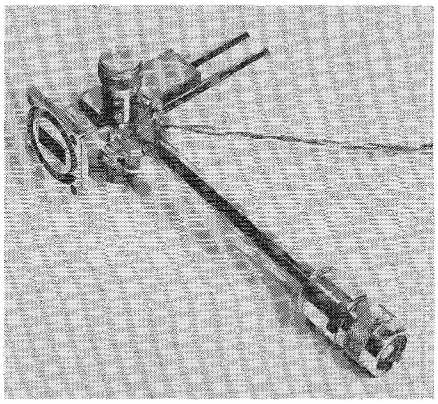

Fig. 2—Experimental mixer.

TABLE I

| Local Oscillator Frequency (Gc) | Mean Over-all Noise Figure (db) | Mean Image-Matched Conversion Loss (db) |
|---|---|---|
| 11.5 | 17.4 | 8.5 |
| 13.0 | 17.6 | 8.5 |
| 16.0 | 15.8 | 6.5 |
| 17.0 | 15.7 | 7.0 |
| 18.0 | 17.8 | 8.5 |

IF = 2.42 Gc.
Noise figure of IF amplifier = 9.2 db.

circuit, using a shunt stub and a transforming section (Fig. 2); by this means, a match varying between 0.35 and 0.88 over the band was obtained.

Measurements of receiver noise figure, conversion loss, and effective noise-temperature ratio were made using noise tubes as signal sources at RF and IF frequencies. The results of these measurements are given in Table I.

An estimate of the contribution to the conversion loss arising from the presence of the parasitic barrier capacitance and spreading resistance indicates that the conversion loss at 2 Gc in the crystals alone should be insignificantly different from that at, say, 45 Mc. The discrepancy observed in the present mixer is thought to be due to the effects of mismatch and dissipative loss in the IF circuit. This is confirmed by the fact that the VSWR in the IF circuit was better than expected. Measurements of the effective noise-temperature ratio at the output plug of the biphase mixer gave a mean value of 1.4. This somewhat low value is probably also produced by the loss in the output circuit. For comparison, the measured noise-temperature ratio and image-matched con-

* Received by the PGMTT, November 11, 1961.

[1] British Patent Application No. 25881/60.

version loss is a conventional single-ended mixer at an IF of 45 Mc were found to be 2.2 and 5.0 db, respectively.

### Conclusions

It has been shown that it is possible to achieve decoupling between the RF signal and the IF circuit of a microwave mixer by using two crystals in a symmetrical "bar-and-post" circuit, avoiding the necessity for filters. A mixer has been constructed using this principle, and conversion losses in the range 6.5–8.5 db have been observed at an RF of 15 Gc and an IF of 2 Gc.

A parametric amplifier[2] has also been constructed which uses this principle to isolate the pump and idler from the signal circuit.

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[2] British Patent Application No. 9651/61.

## A High-Power S-Band Filter*

This note describes the measured performance of a high-power S-band "waffle-iron" filter. Techniques for designing varying-impedance corrugated waveguide filters in rectangular waveguide have been available for some time [1]. If propagation is restricted to the dominant $TE_{10}$ mode, these filters have wide well-matched pass bands and wide high-attenuation stop bands. Unfortunately, the filters may have spurious transmissions in the stop band when power is incident upon them in other modes, such as $TE_{20}$ or $TE_{30}$, if the guide wavelength of these modes at the stop-band frequencies is equal to the guide wavelength of the $TE_{10}$ mode at the pass-band frequencies of the filter.

A technique for suppressing these higher-order $TE_{m0}$ modes in the stop band was devised by Cohn [2], [3], which consists of cutting longitudinal slots through the corrugated filter. If the center-to-center spacings of the bosses formed by milling the longitudinal slots is less than one-half of the free-space wavelength at the highest operating frequency, the characteristics of the modified filter depend almost exclusively on frequency rather than on the reciprocal guide wavelength. Hence, higher-order $TE_{m0}$ modes are almost completely suppressed in the stop band.

The wide stop band of these filters makes them particularly attractive for use in suppressing the spurious harmonic emissions from high-power transmitters. However, early versions of these filters (which have sharp edges) are susceptible to breakdown. Weber [4] has shown that in the vicinity of the sharp edges, the electric-field intensity approaches infinity. Therefore, components with sharp corners, such as the earlier filters, are inherently low-power devices. The present filter was designed to determine the power-handling capacity of these filters when the sharp edges are rounded to minimize electric gradients within the filter.

The S-band filter designed for power testing is shown in Fig. 1. Fabricated of oxygen-free high-conductivity copper, the filter consists of two pairs of identical parts that can be relatively easily machined. A sketch of the interior of the filter is shown in Fig. 2. The stepped transformers with rounded corners which match the filter to the standard S-band waveguide are also shown in Fig. 2. These transformers are not slotted; they prevent modes with horizontal components of electric field from passing through the longitudinal slots in the filter.

This type of filter is designed by initially neglecting the presence of the longitudinal slots and by using as the frequency variable the reciprocal of free-space wavelength instead of the reciprocal guide wavelength. At the pass-band frequencies, the principal effect of the longitudinal slots is to reduce the capacitance between the filter bosses. This is compensated for by reducing the spacing between the bosses until the capacitance is approximately the same as that between the transverse ridges in the filter with no longitudinal slots. When the gap spacing is correct, the pass-band frequency characteristics of the longitudinally slotted filter are essentially the same as those of the unslotted prototype, while the stop band is free of spurious responses which might otherwise be caused by propagation of the $TE_{20}$, $TE_{30}$ ··· $TE_{m0}$ modes.

The VSWR of the high-power filter in the 2.7–4.1-Gc pass band is less than 1.6. It is judged that the VSWR of the pass band of the high-power filter can be reduced by increasing the length of the 90° transforming end sections at each end of the waffle-iron filter.

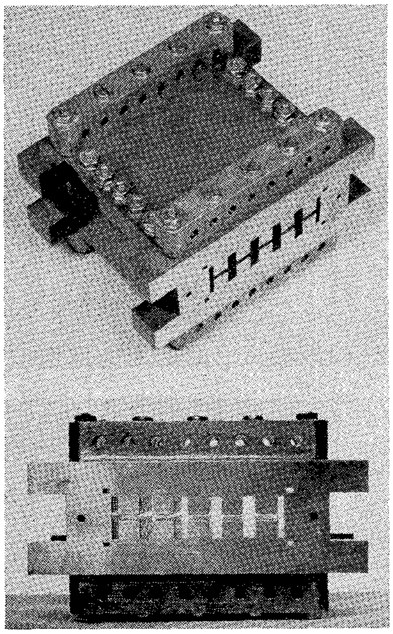

Fig. 1—High-power S-band waffle-iron filter.

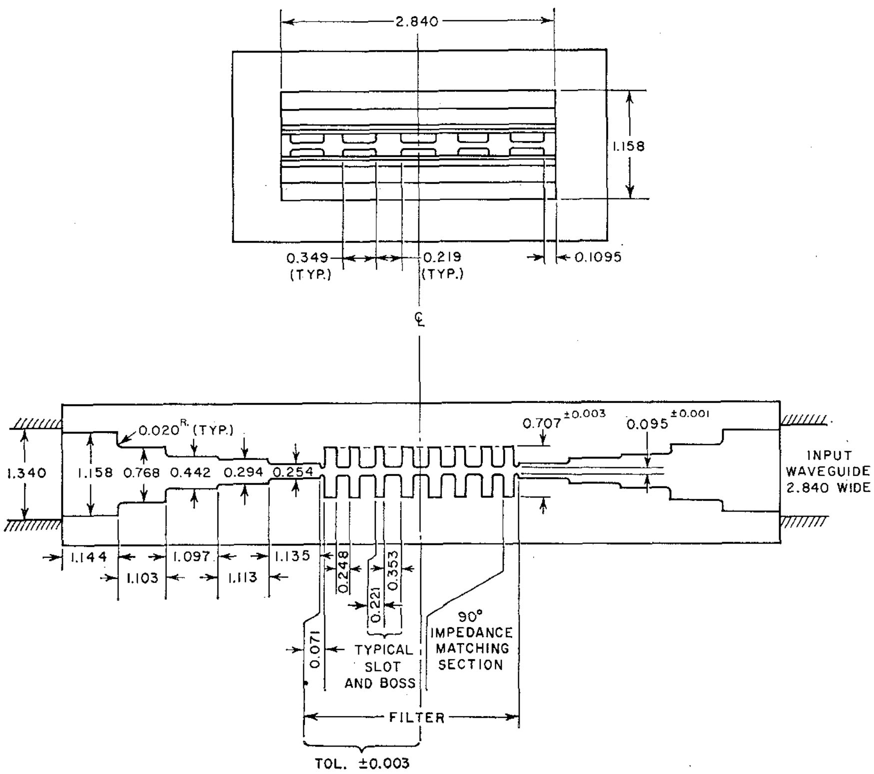


Fig. 2—Sketch of high-power waffle-iron filter giving internal dimensions.

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