A Multiplier-Frequency Shifter Suited to Beat Frequency Generators in Microwave Repeaters

In microwave repeaters, as is well known, a single power source is used for heterodyning the coming signal down to the IF and again up to the transmission frequency, the block diagram being that of Fig. 1. The power source has the correct frequency for the transmitter mixer, and the receiver local oscillator frequency is obtained by its mixing with that of another "frequency difference" crystal controlled oscillator.

To avoid the expensive and space consuming mixer, we thought to commit its duty to the last stage of the power source since in our case the latter was a varactor multiplier chain. The price to pay in doing this is a branching device required to separate the frequencies coming out from the unique output port (see block diagram in Fig. 2). A proposed branching device is shown in Fig. 2.

The feasibility of such an arrangement first involved writing down the Manley-Rowe power relations for the general case shown in Fig. 3. Using the simple method by Salzberg[1] such formulas were found to be:

$$P_1 = -P_T - \frac{nP_R}{n \pm f_d/f_1} \qquad (1)$$

$$P_d = \mp \frac{f_d}{f_R} P_R \qquad (2)$$

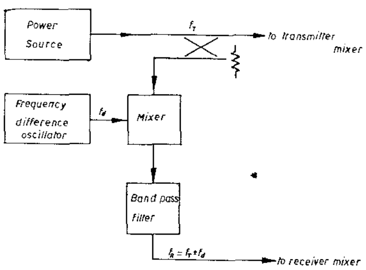

Fig. 1. Block diagram of the commonly used beat frequency generators utilizing frequency shift.

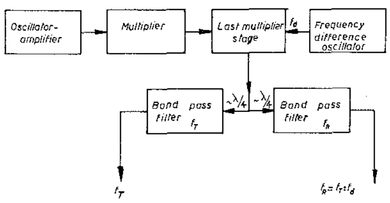

Fig. 2. Block diagram of the proposed beat frequency generator.

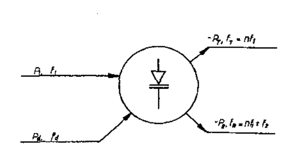

Fig. 3. Frequency-power flow diagram of the multiplier-frequency shifter.

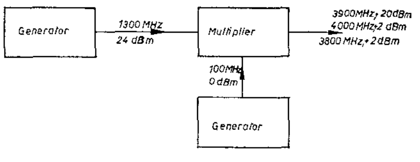

Fig. 4. Block diagram of experimental setup together with the frequency values and power levels measured.

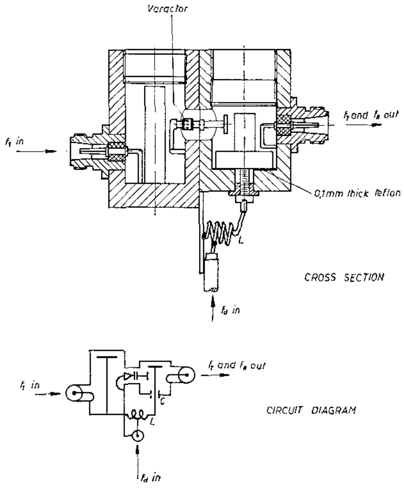

Fig. 5. Cross section and circuit diagram of experimental unit.

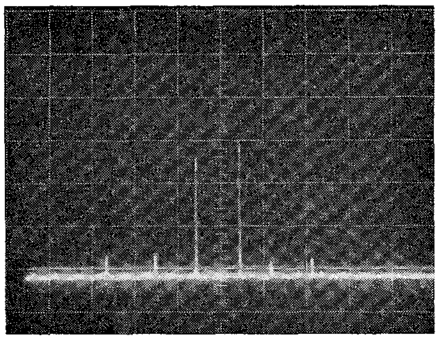

Fig. 6. Output spectrum as seen with a bread board spectrum analyzer. Dispersion is about 70 Mc/s per division. A higher value of f_d (about 180 Mc/s) was used for the sake of clearness.

being:

$$f_R = nf_1 \pm f_d. \qquad (3)$$

It can be recognized that the two processes of frequency multiplication and up-conversion are somewhat independent. The conversion from f_d to f_R appears as the well-known three frequencies parametric up-conversion [upper or lower sideband depending upon the sign, + or −, chosen in (2)]. The frequency multiplication from f_1 to f_T appears only slightly disturbed by the concurrent up-conversion.

A lowering in power output can be observed at f_T, the up-conversion being at the expense of input power P_1.

Figure 4 shows the experimental setup and the results obtained. Experience shows that this method (patent pending) is convenient also from the efficiency point of view, since measured values of power allow one to consider a practically one-to-one ratio of power output at f_R to lowering of power at f_T, when signal at f_d is supplied. With the previously used method such a ratio could be made at best one to ten, employing a varactor up-converter.

Figure 5 shows the cross section and the circuit diagram of the mixer-multiplier output stage. Coil L is made to tune out at f_d the RF by-passing capacity C.

Figure 6 shows the output spectrum as seen with a bread-board spectrum analyzer which is capable of sufficiently high dispersion, due to the use of a BWO swept oscillator. Each frequency is seen as a couple of close lines due to the 30 MHz IF of the system (General Radio 1216 A) which puts signal and image 60 MHz apart.

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[1] Salzberg, B., Masers and reactance amplifiers basic power relations, *Proc. IRE* (*Correspondence*), vol 45, Nov 1957, pp 1544–1545.

A Four-Port Waveguide Junction Circulator and Effects of Dielectric Loading on its Performance

This communication describes a four-port X-band waveguide junction circulator. The effects of dielectric loading on its performance are also included. The circulator employs a right angled H-type junction of two X-band waveguides. The junction is loaded with a cylindrical post of R-4 ferrite filling the height of the waveguide. A full height teflon cylinder surrounds the ferrite post (Fig. 1). Hitherto, no four-port waveguide circulator using this ferrite-dielectric configuration has been reported in the literature. The earliest four-port waveguide junction circulator is due to Yoshida.[1] He used a ferrite rod along with a suitable impedance element at the right place in the usual H-type four-port waveguide junction. Davis, Coleman, and Cotter have reported their investigations on four-port waveguide junction circulator in a recent publication.[2] Their circulator also employed a central polarized ferrite post, which was half the waveguide height, on top of which was a cylindrical brass post. In another configuration they used a full height brass post surrounded by a closely fitting ferrite tube, which in turn was surrounded by a dielectric tube.

Figure 2 shows the performance obtained with a ferrite post diameter of 0.372 inch along with teflon cylinder diameter of 0.643 inch. Isolation is greater than 20 dB from 10.5 to 11.00 Gc for both the isolated ports. Insertion loss is less than 0.5 dB over most of the band. A magnetic field of 920 gauss was needed for this performance.

Different diameters of teflon cylinder were tried to study the effects of dielectric

Manuscript received January 13, 1965.

[1] Yoshida, S., X circulator, *Proc. IRE* (*Correspondence*), vol 47, Jun 1959, p 1150.

[2] Davis, L. E., M. D. Coleman, and J. J. Cotter, Four-port crossed waveguide junction circulators, *IEEE Trans. on Microwave Theory and Techniques*, vol MTT-12, Jan 1964, pp 43–47.