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:

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

$$P_d = \mp \frac{f_d}{f_R} P_R \tag{2}$$

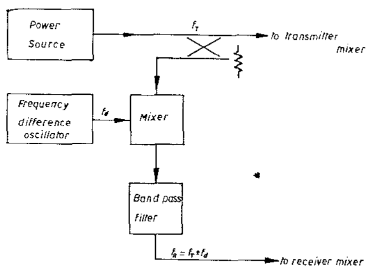

Fig. 1. Block diagram of the commonly used beat frequency generators utilizing frequency shift.

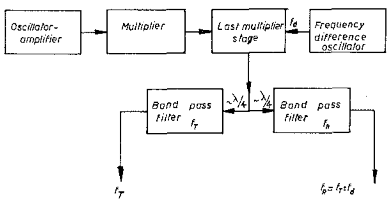

Fig. 2. Block diagram of the proposed beat frequency generator.

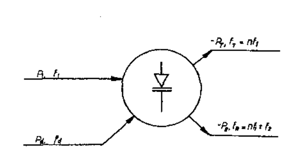

Fig. 3. Frequency-power flow diagram of the multiplier-frequency shifter.

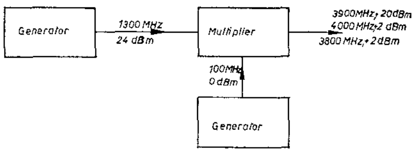

Fig. 4. Block diagram of experimental setup together with the frequency values and power levels measured.

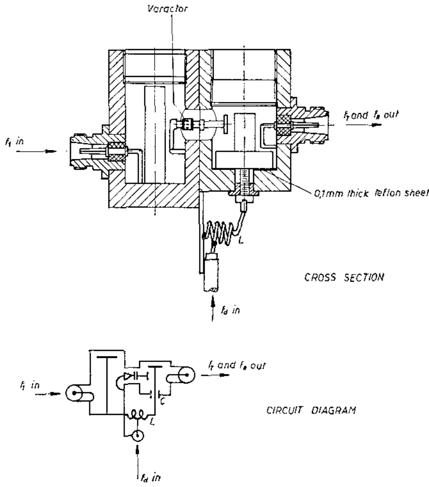

Fig. 5. Cross section and circuit diagram of experimental unit.

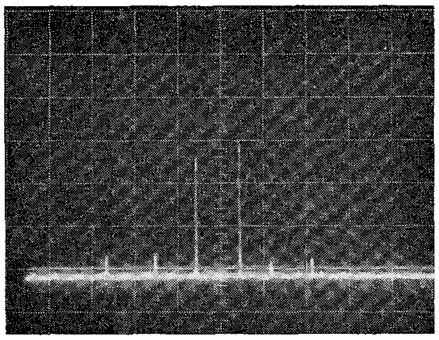

Fig. 6. Output spectrum as seen with a bread board spectrum analyzer. Dispersion is about 70 Mc/s per division. A higher value of f_d (about 180 Mc/s) was used for the sake of clearness.

being:

$$f_R = nf_1 \pm f_d. \tag{3}$$

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.

GIORGIO LUZZATTO
Societa' Italiana Telecomunicazioni
Siemens
Milano, Italy

Manuscript received January 4, 1965.

[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.

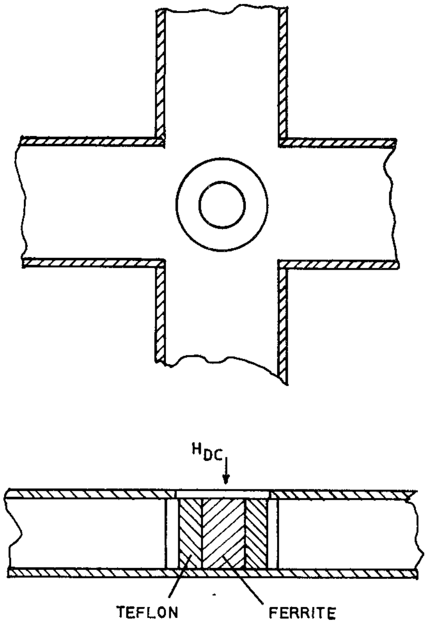

Fig. 1. Four-port X-band waveguide junction circulator.

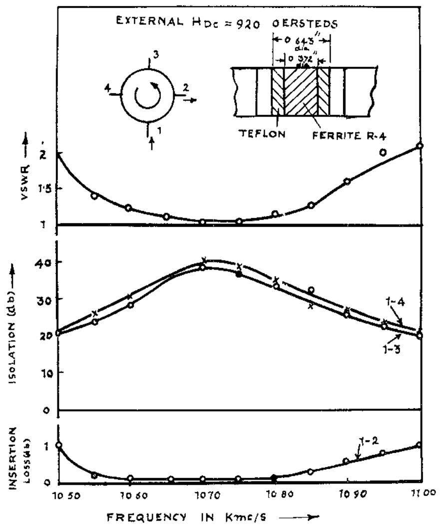

Fig. 2. Performance characteristics of the circulator.

loading on performance. Figure 3 shows the effect of adding the dielectric material to the junction. For a given diameter of the ferrite post, the circulation frequency decreases as the diameter of teflon cylinder is increased (Curve I). Teflon increases the effective diameter of the ferrite cylinder, thereby reducing the circulation frequency. Curve II shows the effect of dielectric loading on bandwidth. Bandwidth increases with increase in the diameter of teflon cylinder.

The circulator operated with a somewhat degraded performance without the teflon cylinder. Maximum isolation decreased to about 30 dB for both the isolated ports but the insertion loss remained almost the same. Bandwidth also decreased to about 240 Mc.

Teflon ($\epsilon=2.1$) was chosen for use because it was readily available. Dielectric material of higher dielectric constant ($\epsilon=6$

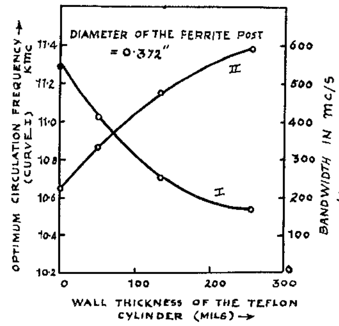

Fig. 3. Effects of dielectric loading on performance.

or 7) would have been much more effective in increasing the bandwidth.

The full height configuration has the advantage of having lower demagnetization factor that the partial height configuration because of the longer dimension along the direction of magnetization. This makes it possible to use a smaller magnet to supply the same internal magnetic field.

G. S. Sidhu
O. P. Gandhi
Central Electronics Engineering
Research Institute, PILANI
(Rajasthan) India

Error of Doppler Radar in Target Speed Determination for Traffic Control

The purpose of this correspondence is to show the theoretical error of Doppler radar in target speed determination for traffic control due to its carrier frequency deviation. Most Doppler radars for traffic police utilize the tuning fork calibration technique immediately before monitoring the target speed.[1] In this way, the audio-frequency part of the Doppler radar is accurately calibrated. The police operator does not usually calibrate the carrier frequency before monitoring speed and no such instruction is usually given to the operator. According to the author's experience and the experience of others[2] an error due to the carrier frequency deviation is often asserted in court. Effect of short-time frequency fluctuation of the carrier frequency of a Doppler radar was investigated by Brady and found to be insignificant.[3] In this correspondence, the effect of long-time frequency deviation from the originally designed value due, for example, to a faulty power supply (such as the failure of the voltage regulator) or defected transmitter tube, is investigated. A relation among the target speed ν, carrier frequency f_0, Doppler frequency f_d, and the velocity of light c is given by the following well-known equation.[4,5,6]

$$f_d = \frac{2\nu}{c} f_0. \tag{1}$$

The output display from the Doppler radar is a speed meter which is actually a Dopper frequency counter output voltmeter. The speed scale on the output meter is calibrated in such a way that the scale is proportional to the Doppler frequency. If the proportionality constant is k, then the relation between the speed meter reading ν_m and the doppler frequency f_d is

$$\nu_m = kf_d = \frac{2k\nu}{c} f_0. \tag{2}$$

If, for some reason such as faulty power supply or a defective microwave transmitter tube, f_0 is deviated $\pm\Delta f_0$, then the meter will deviate $\pm\Delta\nu_m$.

$$\nu_m \pm \Delta\nu_m = \frac{2k\nu}{c} \cdot (f_0 \pm \Delta f_0). \tag{3}$$

Therefore, the error in the speed meter reading is

$$\Delta\nu_m = \frac{2k\nu}{c} \cdot \Delta f_0. \tag{4}$$

From (2), the proportionality constant is

$$k = \frac{c}{2f_0} \cdot \frac{\nu_m}{\nu} \cdot \tag{5}$$

The scale of the speed meter was made in such a way that, if there is no fault, the reading ν_m is exactly equal to the target vehicle's speed ν. Therefore,

$$\frac{\nu_m}{\nu} = 1. \tag{6}$$

Substituting (6) to (5)

$$k = \frac{c}{2f_0} = \frac{\lambda_0}{2} \cdot \tag{7}$$

It is interesting to note that *the proportionality constant between the speed meter reading and the Doppler Frequency is equal to the half wavelength* ($\lambda_0/2$) *of the carrier wave.* Substituting (7) into (4)

$$\Delta\nu_m = \nu \frac{\Delta f}{f_0} \tag{8}$$

or

$$\frac{\Delta\nu_m}{\nu} = \frac{\Delta f_0}{f_0} \tag{9}$$

applying (6) to (9)

$$\frac{\Delta\nu_m}{\nu_m} = \frac{\Delta f_0}{f_0} \cdot \tag{10}$$

Manuscript received November 2, 1964; revised January 25, 1965.

[1] For example, *Manual, Stephenson Transistor Radar Speed Analyzers T-62A and T-63 Series*, Stephenson Corp., Red Bank, N. J.

[2] For example, an unpublished undated private copy of an article entitled, "Reprinted from Dicta, Radar Evidence in the Courts," by P. J. Carosell of the Denver Bar, Colo., and W. C. Coombs of the Denver Research Inst., University of Denver, Colo. This document was brought to the author's attention by T. H. Schaus, Attorney at Law, Milwaukee, Wis., before November 25, 1964.

[3] Brady, M. M., Frequency stability requirements on coherent radar oscillators, *Proc. IRE (Correspondence)*, vol 47, May 1959, pp 1001–1002.

[4] Ridenour, L. N., *Radar System Engineering*, vol I, Radiation Lab. Ser. New York: McGraw-Hill, 1947.

[5] Barlow, E. J., Doppler radar, *Proc. IRE*, vol 37, Apr 1949, pp 340–355.

[6] Skolnik, M. I., *Introduction to Radar Systems*. New York: McGraw-Hill, 1962, p 72.