comparison of (2) and (3) shows that results for vertically polarized waves are obtained from (5)–(7) on multiplying the right-hand sides by $(2C^2-1)$.

R. BURMAN
Dept. of Physics
Victoria University of Wellington
Wellington, New Zealand

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Y-Junction Circulator at 258 GHz

We have developed a three-port circulator at 258 GHz as part of an amplifier operating on the principle of resonance saturation of a dipolar gas.[1]

The circulator consists of a symmetric *Y*-junction with an accurately centered ferrite post. The groove dimension corresponds to RG137 rectangular waveguide (0.043 inch by 0.0215 inch). This geometry was found to have at the given frequency the least loss. The design is similar to circulators obtained by Thaxter and Heller[2] at 140 GHz.

Constructional features are a split-machined structure, optical polished and gold plated surfaces, and integrated flanges. Figure 1 shows the waveguide grooves milled in a tellurium copper block which mates with a flat counterpiece. The flat section has a center hole for a copper sleeve containing the ferrite post.

First with all three arms matched[3] the power division in the junction without tuning sleeve and ferrite was measured and found to be −4.8 dB (port 1–2) and −4.6 dB (port 1–3) for a center hole diameter of 0.024 inch. Theoretically a reflection coefficient of 0.45 was estimated from data taken at lower frequencies.[4]

Inserting the tight fitting copper sleeve with the ferrite into the junction, we experimentally determined the condition under which good circulator operation occurred. The variables are: a) the diameter of the ferrite rod and copper sleeve, b) the length the copper sleeve protrudes in the junction L_1, c) the length the ferrite rod protrudes from the copper sleeve L_2, and d) the total length of the ferrite. The results are given in Table I.

Manuscript received August 1, 1966; revised August 24, 1966. This work was performed under AF Contract 30(602)-3847, Rome Air Development Center, Air Force Systems Command, Griffiss AFB, Rome, N. Y.

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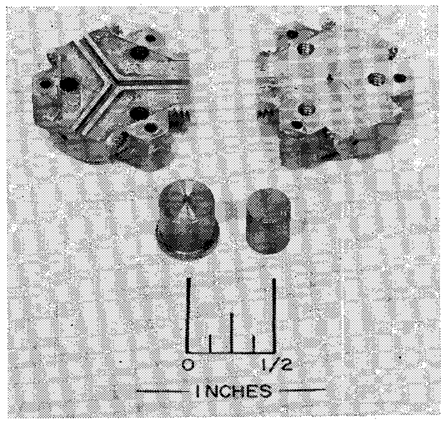

Fig. 1. Photograph of machined circulator. Copper cylinder with tuning sleeve holding ferrite magnet and the alnico magnet are shown in front.

TABLE I

Circulator number	Copper sleeve		Ferrite (Trans Tech TT2-111)			Bias field
	Outer diameter (inch)	Protruding length L_1 (inch)	Diameter (inch)	Protruding length L_2 (inch)	Ferrite rod length (inch)	
1	0.024	0.004	0.019	0.0068	0.085	300–500 G
2	0.024	0.002	0.010	0.0138	0.065	
3	0.020	0.006	0.010	0.0140	0.065	

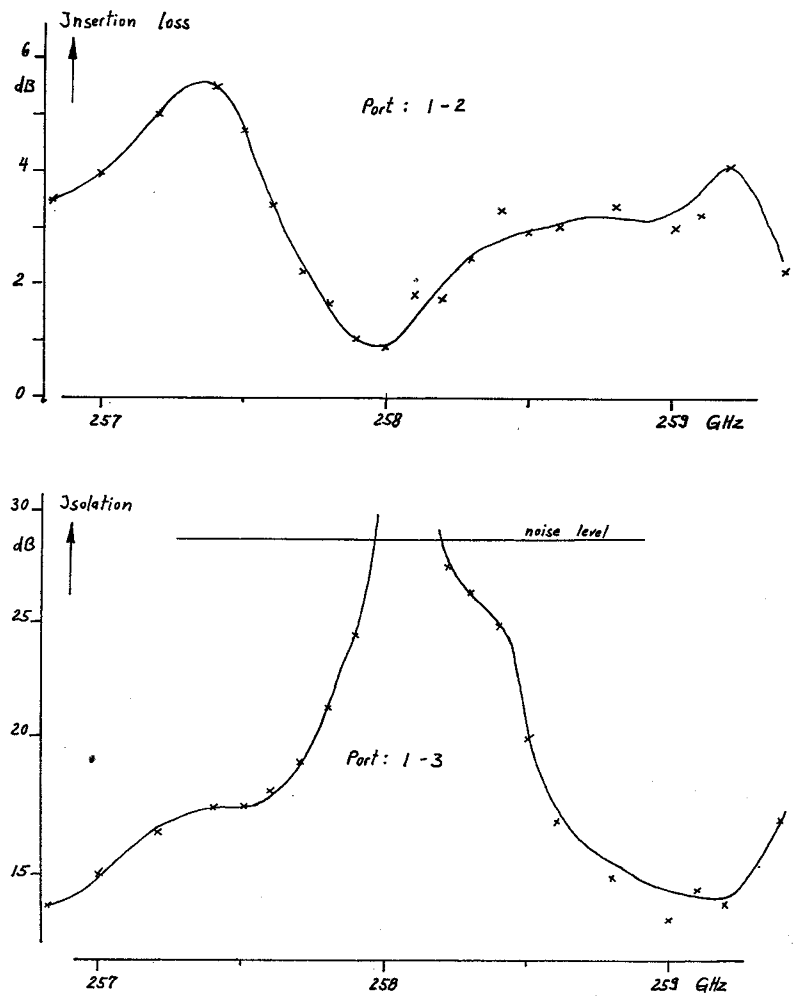

Fig. 2. Frequency characteristic of 258-GHz circulator.

Our final measurements showed typical insertion loss and isolation characteristics as given in Fig. 2. At 258.2 GHz[1] we measured for circulator no. 1:

Port	Bias Field 500 G	500 G (opposite circulation)	0 G
1—2	1.8 dB	21 dB	8.2 dB
1—3	27 dB	2.0 dB	8.0 dB
2—3	2.1 dB	27 dB	8.0 dB
2—1	21 dB	2.3 dB	7.4 dB
3—1	1.5 dB	17 dB	6.6 dB
3—2	24 dB	2.5 dB	8.0 dB

The lack of good loads[3] and VSWR measuring equipment prevented high accuracy (±0.2 dB) of the measurements. The mm wave power was generated by a second harmonic generator (point-contact silicon diode) driven by a VARIAN VC714 klystron.

ACKNOWLEDGMENT

The authors would like to acknowledge many helpful discussions with O. Giddings, and the technical assistance of T. Mehrhof and G. Parsons.

H. J. LIEBE[5]
B. SENITZKY[6]
TRG
a Division of Control Data Corp.
Melville, N. Y.

[5] Presently with NBS/ESSA-4402.09, Boulder, Colo.
[6] Presently with Electrophysics Department, Brooklyn Polytechnic Inst., Farmingdale, L. I., N. Y.

Beam Waveguide Excitation by the Aperture Field of a Tubular Waveguide

Abstract—**The excitation of a lens-type beam waveguide by the aperture field of a conventional waveguide of circular cross section is treated, assuming that a superposition of an H_{11}-mode and a E_{11}-mode is propagating in the metallic waveguide. The launching efficiency for the dominant beam mode depends on the amplitude ratio of the H_{11}- and E_{11}-modes and on the ratio of the beam mode parameter to the radius of the tubular waveguide. If both quantities are chosen appropriately a theoretical launching efficiency of 98.3 percent can be achieved.**

DISCUSSION

The excitation of a lens-type beam waveguide by a conventional metallic waveguide was first studied by Baskakow.[1] He considers the structure shown in Fig. 1. A metallic waveguide of circular cross section terminates in the plane $z=0$; outside the waveguide aperture this plane is assumed to be covered by a perfectly conducting screen. The plane $z=0$, simultaneously, is the input plane of a beam waveguide with circular lenses. The distance z_0 of the first lens from the plane $z=0$ is half the spacing of the lenses.

Baskakow assumes that, in the metallic waveguide, a field of the H_{11}-type is propagating in the positive z-direction, and calculates the launching efficiency for the dominant beam mode of the beam waveguide. If the lens diameter is sufficiently large, the field of this mode in the plane $z=0$ is linearly polarized, has a Gaussian amplitude distribution, and a plane phase front. The launching efficiency which is defined by the power ratio of the dominant beam mode and the H_{11}-mode depends on the quantity R_0/ρ_0 where R_0 is the radius of the metallic waveguide, and ρ_0 is the mode parameter of the beam waveguide, i.e., the radius at which the energy density in the dominant beam modes has decreased by a factor e. For $R_0/\rho_0=1.84$ the launching efficiency reaches an optimum value of 86.7 percent.[2]

If in the tubular waveguide an E_{11}-mode of appropriate phase and amplitude is superimposed to the H_{11}-mode, the cross-sectional field distribution in the aperture of the waveguide will closely approximate the Gaussian field distribution of the dominant beam mode in the plane $z=0$. This has been demonstrated by Chaffin and Beyer[3] who used a dual mode $(H_{11}+E_{11})$ horn with a phase correcting lens at the aperture.

In the following it will be shown that such dual mode excitation leads to theoretical launching effieiencies for the dominant beam mode of up to 98.3 percent.

If an H_{11}-mode of amplitude A and an E_{11}-mode of amplitude B is propagating in the tubular guide whose radius is so large that the phase velocity of the modes approaches the free space velocity, the distribution of the tangential field components in the plane $z=0$ is

$$E_\rho^{(1)} \approx +\left\{A\bar{\gamma}\frac{J_1(\bar{\gamma}\rho)}{\bar{\gamma}\rho} + B\gamma J_1'(\gamma\rho)\right\} \cdot\cos\phi \approx \sqrt{\frac{\mu}{\epsilon}}H_\phi^{(1)}$$

$$0 \leq \rho \leq R \quad (1)$$

$$E_\phi^{(1)} \approx -\left\{A\bar{\gamma}J_1'(\bar{\gamma}\rho) + B\gamma\frac{J_1(\gamma\rho)}{\gamma\rho}\right\} \cdot\sin\phi \approx -\sqrt{\frac{\mu}{\epsilon}}H_\rho^{(1)}$$

where ρ and ϕ are polar coordinates, and $\gamma R_0=a_{11}$, $\bar{\gamma}R_0=\bar{a}_{11}$ are the first zeros of the Bessel function $J_{11}(x)$ and its derivative $J_1'(x)$, respectively:

$$a_{11} = 3.8317 \qquad \bar{a}_{11} = 1.8412. \quad (2)$$

On the metallic screen outside the waveguide aperture E_ρ and E_ϕ are zero.

$$E_\rho^{(1)} = E_\phi^{(1)} = 0 \quad R_0 \leq \rho < \infty,\ z = 0. \quad (3)$$

If the lenses are sufficiently large, i. e., if

$$\sqrt{\frac{k}{2z_0}}R > 2.5$$

the dominant beam mode in the plane $z=0$ has a Gaussian field distribution[4]

$$E_\rho^{(2)} = +e^{-1/2(\rho/\rho_0)^2}\cos\phi = \sqrt{\frac{\mu}{\epsilon}}H_\phi^{(2)}$$

$$E_\phi^{(2)} = -e^{-1/2(\rho/\rho_0)^2}\sin\phi = -\sqrt{\frac{\mu}{\epsilon}}H_\rho^{(2)}$$

$$0 \leq \rho < \infty \quad (4)$$

where ρ_0 is the mode parameter which is determined by the focal length f and the spacing $2z_0$ of the lenses

$$\rho_0^2 = 2\frac{z_0}{k}\sqrt{2\frac{f}{z_0} - 1}. \quad (5)$$

Since the field distribution (4) of the dominant beam mode is a real function, maximum launching efficiency is obtained, if the H_{11}-mode and the E_{11}-mode have the same phase in the plane $z=0$, in other words if the amplitude factors A and B are both real. As the beam modes of the beam waveguide are mutually orthogonal, the amplitude C of the dominant beam mode is given by

$$C = \frac{\int_0^{2\pi}\int_0^{R_0}(E_\rho^{(1)}E_\rho^{(2)} + E_\phi^{(1)}E_\phi^{(2)})\rho d\rho d\phi}{\int_0^{2\pi}\int_0^{\infty}(E_\rho^{(2)2} + E_\phi^{(2)2})\rho d\rho d\phi}. \quad (6)$$

With (1) and (4) this expression can be rewritten as follows

$$C = \frac{A}{\rho_0}\cdot F\left(\bar{a}_{11},\frac{R_0}{\rho_0}\right) + \frac{B}{\rho_0}\cdot F\left(a_{11},\frac{R_0}{\rho_0}\right) \quad (7)$$

where

$$F\left(a,\frac{R_0}{\rho_0}\right) = a\cdot\frac{R_0}{\rho_0}\int_0^1 e^{-1/2(R_0/\rho_0)^2u^2}J_0(au)udu. \quad (8)$$

The launching efficiency of the dominant beam mode, i.e., the ratio between the power transmitted in this beam mode and the power transmitted in the metallic waveguide is

$$\eta = C^2\cdot\frac{\int_0^{2\pi}\int_0^{\infty}(E_\rho^{(2)}H_\phi^{(2)} + E_\phi^{(2)}H_\rho^{(2)})\rho d\rho d\phi}{\int_0^{2\pi}\int_0^{R_0}(E_\rho^{(1)}H_\phi^{(1)} + E_\phi^{(1)}H_\rho^{(1)})\rho d\rho d\phi}. \quad (9)$$

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