Comments on Waveguide Mounted Tunnel Diodes

Studying the application of tunnel diodes to microwave generation, I was most interested by the discussion between Ishii [1] and McPhun [2].

I think I have realized a better mounting than Ishii's. The improvement resides in a reduction of high frequency leakages, allowing outputs of very high amplitudes, which give strong lines on a Polarad spectrum analyzer.

A very rich spectrum was thus evidenced, with diodes of many types, such as RCA 1N3129 and 1N3849, Sylvania D4168A, GE 1N3219A, all having a presumed self-resonant frequency far below the waveguide cutoff.

The lines of this spectrum appeared to be the harmonics of a fundamental frequency, which was assumed to be the self-resonant frequency of the diode and its parasitic elements.

The loading by the waveguide was negligible below its cutoff frequency.

Evidently the detectable frequencies belonged to harmonics the frequencies of which were higher than the waveguide cutoff frequency.

In particular I used the GE 1N3219A tunnel diode studied by Ishii and his collaborators [3].

I never saw two isolated frequencies (the diodes being centered in the tapered part of the waveguide), but I observed the third, fourth, and fifth harmonics.

The weak fifth harmonic may have been missed by Ishii and his co-workers in their investigations, leading them to an erroneous conclusion on the existence of two autonomous resonant frequencies.

To illustrate my statements I give the listed harmonics of an RCA 1N3849 tunnel diode, measured in my mounting for a fixed bias, with their rank and their relative amplitudes.

From those measurements the fundamental appears to be near 1113 MHz.

It may be noticed that the first detected oscillation is slightly above 6600 MHz, the RG 52 U waveguide cutoff frequency.

Measured frequencies (MHz)	6670	7790	8895	9990	11110	12210	13340	14400	15580	16650	17800	nothing	20000	21000
Rank	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Amplitudes	5	60	60	60	2	22	20	7	13	8	13		1	4

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Author's Comment[1]

1) The writer would like to congratulate Rivier's successful experiment on the microwave harmonic operation of waveguide mounted tunnel diodes. Under certain conditions the writer and his colleagues have also observed the harmonic spectrum similar to the one reported in Rivier's correspondence. Similar harmonic phenomena was reported to the writer by Jackson, Ver Planck, and Swain[1].

2) Rivier's correspondence makes, however, the writer remember a story of many blind men touching a big elephant. A waveguide mounted tunnel diode, though it is as tiny as a tear drop of a humming bird, behaves like the huge elephant touched by the blind men. It behaves differently under different conditions.

3) So far as the writer knows, a waveguide mounted tunnel diode potentially works under the following different modes under various conditions [2].

a) Single frequency mode [3]
b) Harmonic mode [4]
c) Multifrequency mode [5]
d) Multifrequency and harmonic mode [6].

Here, the multifrequencies mean frequencies which are not harmonically related to each other. As Rivier states, his waveguide mount is evidently different from the one the writer used. Therefore, it is not necessary that it will reproduce the same results as the writer's waveguide mount. It is not surprising that Rivier did not find the two frequencies oscillating simultaneously.

4) There is an apparent error in Rivier's correspondence. He stated that he "used the GE IN 3219A studied by Ishii and his collaborators," referring to his [3]. The fact is that the diode used in his [3] is not the GE IN 3219A but the TI XA650 in the TO-18 case.

5) The two-frequency operation is only a special case of multifrequency operation. It seems that Rivier is not aware of the fact that detailed theoretical and experimental verification of multifrequency operation of waveguide mounted tunnel diodes is now available in the literature [3]–[6]. Theory of operating a tunnel diode above its "resistive cutoff frequency" has also been published in literature [3], [7]–[9]. Therefore, it will not be repeated here.

6) It would be extremely desirable if the mounting contruction of Rivier's waveguide mount is published, for he claims that it is better than the writer's design. It is true that a better design than the writer's design is possible. In fact the writer thinks that a waveguide mount designed by Schomaker [10] is superior to the writer's design. Using his waveguide mount, he generated X-band signals with as many as twenty separate 1N3219A diodes and confirmed the writer's work. The writer wishes that both Rivier and Schomaker publish their design so that many people can become aware of their excellent designs.

7) Rivier states, regarding his [3], that "the weak fifth harmonic may have been missed by Ishii and his co-workers in their investigations, ..." If Rivier were right, then the writer and his co-workers must have missed not only the fifth harmonic but also the second, third, sixth, seventh, eighth, ninth, tenth, and all the way up except the eleventh harmonic. The experimental evidence stated in Rivier's reference [3] contradicts Rivier's contention.

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[1] Manuscript received January 11, 1965.

The Backfire Antenna: New Results

In a first communication [1] it was shown that the "backfire" principle greatly increases the gain of an endfire antenna without adding to its length. The backfire antenna patterns reported in [1] had a gain of 5 to 6 dB above that of an equal-length ordinary endfire antenna, a sidelobe level of

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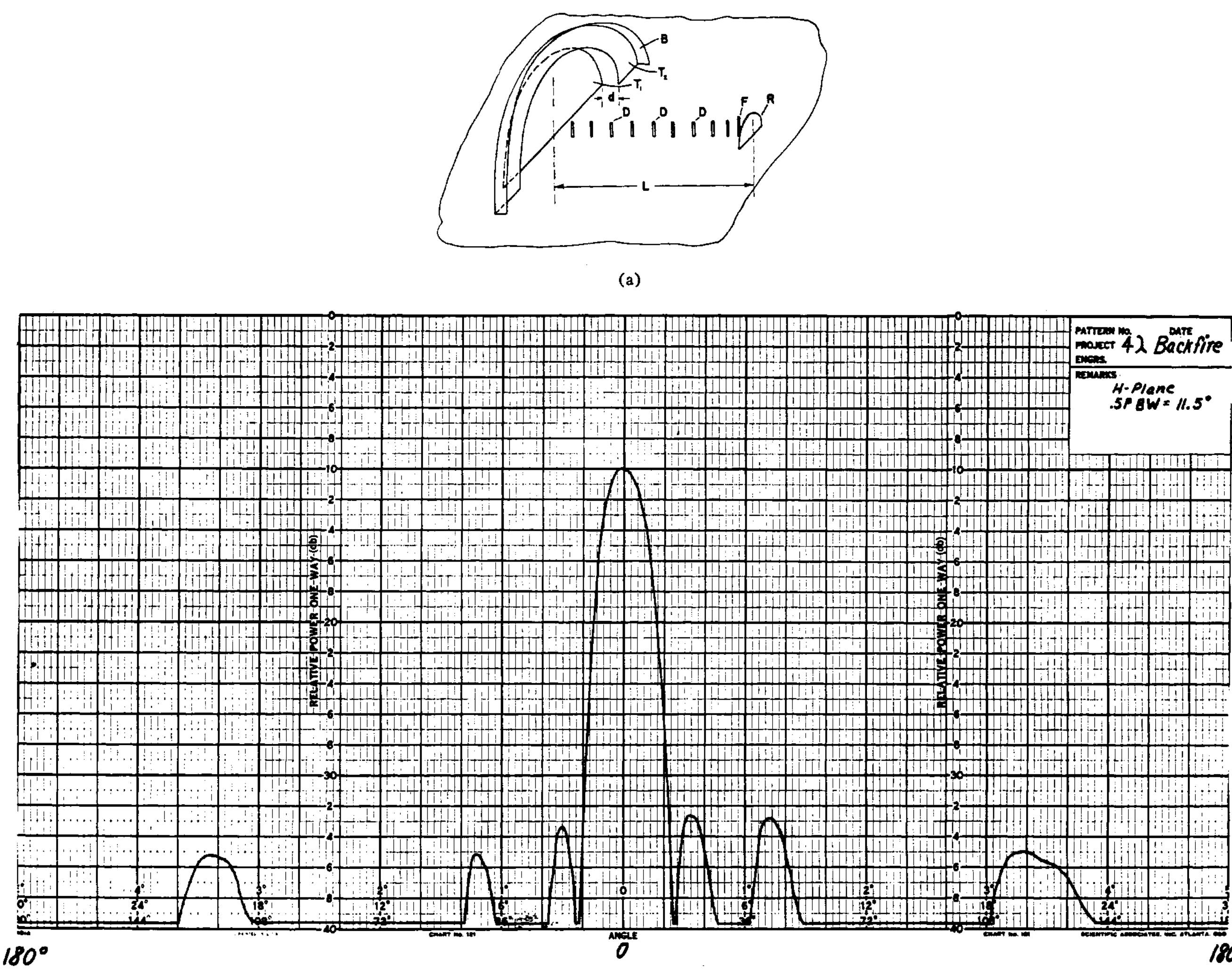


Fig. 1. Backfire antenna on ground plane. (a) Backfire structure. (b) H-plane pattern.

at best 13 dB, and a backlobe of 18 dB. The purpose of the present note is to show that more recent work has resulted in far better pattern control: the gain is now 8 or more dB above that of an equal-length ordinary endfire, the sidelobe level is below 22 dB, and the backlobe is close to 30 dB.

A sketch of a typical high-performance backfire structure is shown in Fig. 1(a). The nine monopoles D on a conducting ground plane serve as surface-wave structure, T_1 is a semicircular plane reflector of 2.0 λ radius, T_2 a plane-reflector ring of 1 λ width with an outside radius of 3.0 λ (the function of T_1 and T_2 will be explained later); B marks a rim of about 0.25 λ width surrounding the edge of T_2, and R is a semicircular plane reflector of 0.50 λ radius, spaced 0.20 λ from the feed F. The spacing between the feed and the first director is 0.20 λ; all other directors are spaced 0.40 λ from each other. The total length L of the backfire, measured between T_1 and R, is 4.0 λ. The distance d between T_1 and T_2 was experimentally adjusted for maximum gain and found to be about 0.25 λ.

The H-plane radiation pattern of this backfire model, measured at X band ($\lambda = 3.3$ cm) is presented in Fig. 1(b). It shows a half-power beamwidth of 11.5°; the sidelobes are down at least 22.5 dB, and the backlobe is more than 30 dB below the maximum. Since the beamwidth in all other planes was found to differ only slightly from that in azimuth, a gain of about 23.5 dB above isotropic is implied. An even slightly higher gain was obtained from a freespace S-band model of this 4 λ long backfire shown in Fig. 2.

A comparison of these results with those of an optimized Yagi of 4 λ indicates an increase in gain of more than 8 dB. To achieve a gain of this magnitude with an ordinary array, one of the recently built NASA antennas [2] uses 36 cavity-backed slots as shown in Fig. 3(b) (gain = 21.2 dB) and another uses 16 Yagis, each 2 λ long as shown in Fig. 3(a) (gain = 22.4 dB). Figure 3(c) shows an artist's conception of the backfire of Fig. 2 scaled for the frequency range of the antennas of Figs. 3(a) and (b). The area of the physical aperture of three antennas is approximately the same.

More general information about the backfire is presented in [3]–[5]; backfire antennas for various frequency ranges are discussed in [6]. For special applications, for example, for use as monopulse antennas, backfire antennas can be arrayed in front of a common plane reflector.

In experiments to gain a better under-

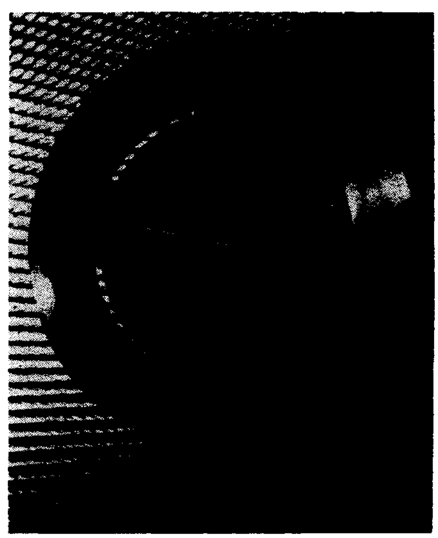
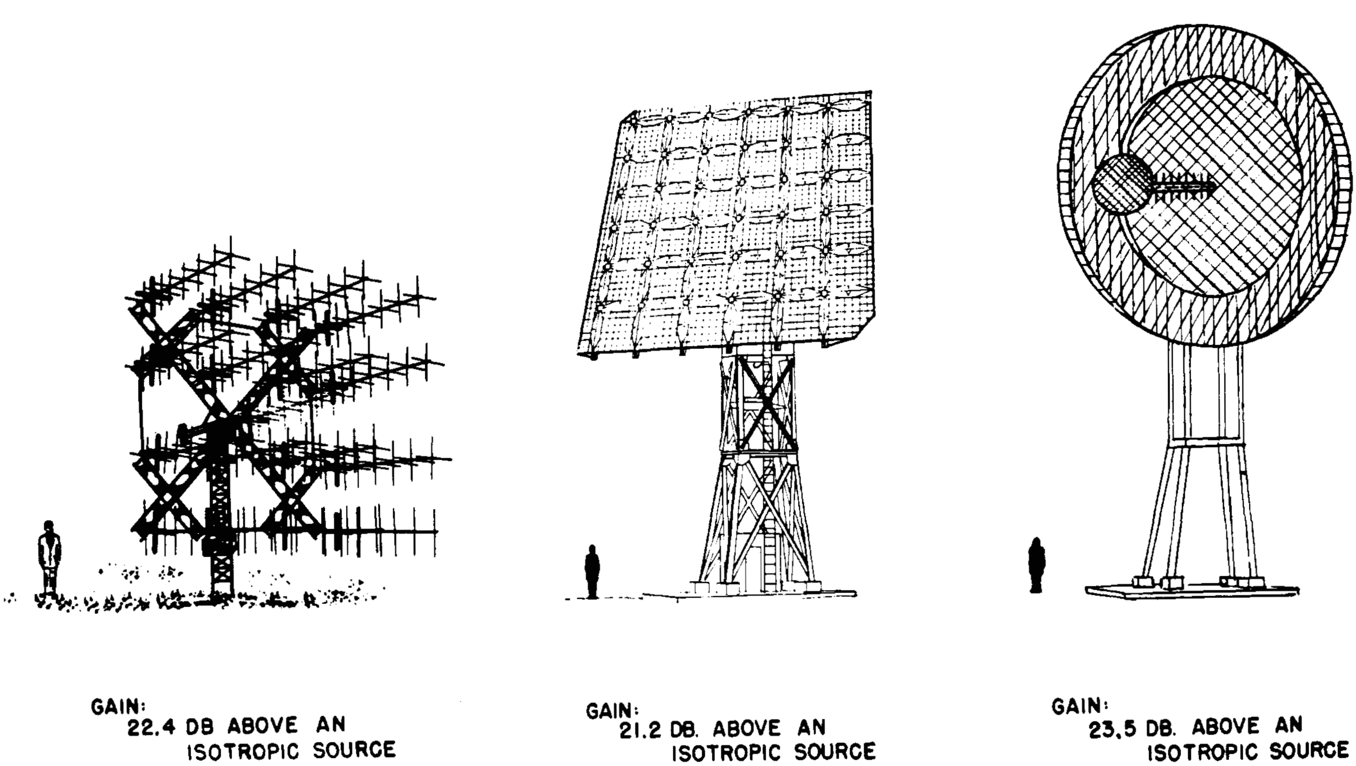


Fig. 2. S-band model of 4 λ-backfire antenna.



(a) (b) (c)

Fig. 3. Comparison of 4λ-backfire antenna with an array of Yagis and a slot array. All three antennas have approximately the same area of physical aperture. (a) Array of 16 Yagis (each 2λ). (b) Array of 36 cavity-backed slots. (c) 4λ backfire antenna.

standing of the backfire radiation mechanism, it has been found that for optimum performance the element parameters have to be chosen such that an extremely high VSWR is obtained over the entire length of the backfire antenna and that in order to fulfill this condition, the distance between T_1 and R must be a multiple of half a wavelength. These observations suggest that the space between the reflector T_1 and R acts as a cavity similar to the resonating cavity of the laser. This was first recognized by F. J. Zucker and is mentioned by him in his note on the backfire antenna [7].

The maximum gain of the backfire antenna is proportional to its length, provided the phase velocity by proper choice of the height and spacing of directors D has been progressively adjusted to its optimum value. The optimum phase velocity on the backfire antenna is very nearly the same as on an ordinary endfire antenna that is twice as long. The backfire gain depends additionally on the size of reflector T_1 (Fig. 1(a)): assuming for the moment that T_2 is removed, then there exists an optimum size for T_1 beyond which the gain decreases, to increase again as the size is further increased, then to decrease once more, etc. The explanation for this behavior is straightforward. The backfire radiation pattern is the vector sum of the field E_1 radiated by the surface-wave distribution across the virtual aperture located approximately in the plane of reflector R, and of the field E_2 radiated directly from the feed F; when these are in phase, the gain is maximized. Increasing the size of reflector T_1 beyond the first maximum does intercept additional energy from the direct feed radiation E_2, but this energy is no longer in phase with E_1. By adding the plane reflector ring T_2 and optimally adjusting its size and spacing from T_1, the in-phase relation can again be satisfied and the gain is now increased another 2.3 dB beyond its maximum with T_1 alone. A quantitative estimate of the design parameters will be given in [7].

The backfire should be a useful antenna in the gain range from 15 to 30 dB above isotropic where conventional endfires would be impractically long and paraboloids are not competitive in cost. It should be especially useful as a replacement for multi-element arrays. The much simpler feed system and drastically reduced weight are especially valuable features.

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A Modulation Technique for Eliminating Interference in CW Radars

In this communication a method of obtaining transmitter-receiver isolation in a CW radar is indicated. With the proper modulation of the transmitted signal and processing of the received signal, it is possible to attenuate signals derived from short range objects, including transmitter leakage. This principle, which has been utilized in radar altimeters and allied applications [1], can be applied, by modulating and processing the signals differently, to long-range, high-velocity CW radars in which pulse Doppler may not be attractive because of volume handling or other requirements.

If the carrier is sinusoidally modulated, the received signal is homodyned and square-law detected, and the lower-frequency term is extracted, the voltage is of the form

$$v_3 = E_0 \cos\left[2\pi f_c\left(\frac{2r}{c} + \frac{2vt}{c}\right) + 2m \sin 2\pi f_m t \cos 2\pi f_m\left(t - \frac{r}{c} - \frac{vt}{c}\right)\right]$$

where r and v are target range and velocity.

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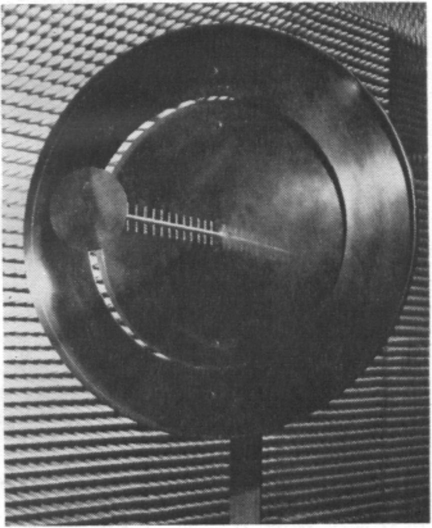

Fig. 2. *S*-band model of 4 λ-backfire antenna.