Therefore, a new set of points was chosen[1] from the data published by Olson [2] and by Denson and Halford [5], with the current/radius ratio held constant at 641 mA/cm. These data are given in Fig. 3. The dashed line represents a linear least squares fit of the data: $n = 1.9$ in (1). The solid line is the von Engel and Steenbeck formula with $c = 0.106$. Not only do the data form a consistent set, but also the slope is much closer to the expected value than it was in Fig. 2.

Conclusion

It has been shown that plasma noise sources obey the new similarity rules which require scaling the currents at constant current/radius ratios, thus finally resolving the apparent inconsistencies in the measurements taken over the last 25 years. Also, the data can be plotted as a straight line which permits easy generation of a curve from the data and easy identification of deviations in the data.

[1] In spite of the huge volume of published data on plasma noise temperatures, the vast majority of it cannot be used for various reasons: 1) The radius is not specified. 2) The current dependence is not given. 3) The filling pressure is not given. 4) The currents used are outside of the I/r range available from other tubes. Probably the reasons for the above state of affairs are as follows. 1) The traditional similarity rules were adhered to too closely; thus data were usually given for only one current, and only the pr product was given, not p or r. 2) Overzealous editors demanded omission of some of the data for sake of brevity; it seems that all unpublished portions of data "vaporize" shortly after the published portions actually appear in print. Therefore, only at an I/r ratio of 641 mA/cm was enough microwave data available to present enough points to establish a curve.

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Letters

Interdependence of Gain and Idler Conversion Loss in Parametric Amplifiers

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***Abstract*—Interdependence of gain and idler conversion has been experimentally investigated in parametric amplifiers having single diode circuit configuration. The results indicate that for high gain amplifiers, the inherent idler rejection is inadequate, and larger lengths of pump waveguide, designed to be below cutoff at idler frequency, are to be used for reducing the effect of pump sideband noise on the noise temperature of the parametric amplifiers.**

I. Introduction

The subject of pump noise transfer in parametric amplifiers has recently received considerable attention [1]–[3]. The noise sidebands associated with the pump source can significantly degrade the noise figure of the parametric amplifiers. Tearle and Heath [3], have shown that the degradation in noise temperature due to AM noise associated with the pump source can be predicted to a fair degree of accuracy with the expression

$$10 \log \Delta Te = \frac{N}{C} + Po - A - 10 \log k - G \qquad (1)$$

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where ΔTe is the degradation in noise temperature, N/C is the AM noise of the pump source, Po is the pump power, A is the conversion loss, and G is the gain of the amplifier. The conversion loss A is the ratio of the injected power at the idler frequency to the output power at the signal frequency. Expression (1) shows that the degradation in noise temperature can be made very small by increasing the conversion loss A of the amplifier.

The idler conversion loss A, as conceived by Tearle and Heath [3], is made up of two parts:

1) that which determines the amount of power at idler frequency coupled into the idler circuit;
2) that which determines the amount of idler power down-converted to power at signal frequency.

The contribution due to part 1) depends on the circuit configuration and is different for single-diode and double-diode parametric amplifiers. In the case of the double-diode circuits, part 1) can be adjusted independently of paramp gain to a very high value either by making small adjustments to varactor dc bias voltages or by preselection of well-matched diode pairs [3]. As a consequence of this, very little power at idler frequency (e.g., sideband noise on the pump) is coupled into the idler circuit, and the degradation in noise temperature due to AM noise of the pump source isc onsiderably reduced. In the case of single-diode parametric amplifiers, the pump waveguide line is designed to be below cutoff at idler frequency. Hence any idler frequency noise sidebands of the pump are attenuated in this waveguide. The idler conversion loss can therefore be increased by increasing the length of the pump waveguide.

The contribution due to part 2) is very much dependent on the gain of the parametric amplifier, and is not independently adjustable to a very high value in either single-diode or double-diode parametric amplifiers. This is a consequence of the parametric amplifier action, which requires that the energy produced in the circuit at the idler frequency be converted to the energy at the signal frequency by nonlinear mixing with the pump frequency. Thus in single-diode parametric amplifiers as well as in double-diode parametric amplifiers, the increase in conversion loss A should be accompanied by the decrease in gain G of the amplifier. The combined effect of idler conversion loss A and amplifier gain G is to be considered while estimating the degradation in noise temperature ΔTe as given by (1). This has been experimentally verified.

II. Experimental Results

The interdependence of gain and idler conversion loss in a single-diode parametric amplifier has been experimentally investigated. A parametric amplifier having single-tuned signal and idler circuits has been designed, using a circuit configuration similar to that described by Aitchison *et al.* [4]. The signal frequency is around 3.0 GHz, whereas the pump frequency has been chosen to be around 15.0 GHz. Pump power of about 80 mW is obtained from a waveguide cavity Gunn oscillator, and is applied through a waveguide designed to be below cutoff at idler frequency. The experimental setup used for measuring the idler conversion loss is identical to that described by Tearle and Heath [3]. The gain as well as the idler conversion loss are measured as a function of signal frequency. Three different circuit conditions, each corresponding to different values of maximum gain, have been obtained by using three different values of the impedance of the quarter-wave transformer at the signal frequency [4]. Pump power, as well as the pump frequency, is maintained constant during the experimental investigations.

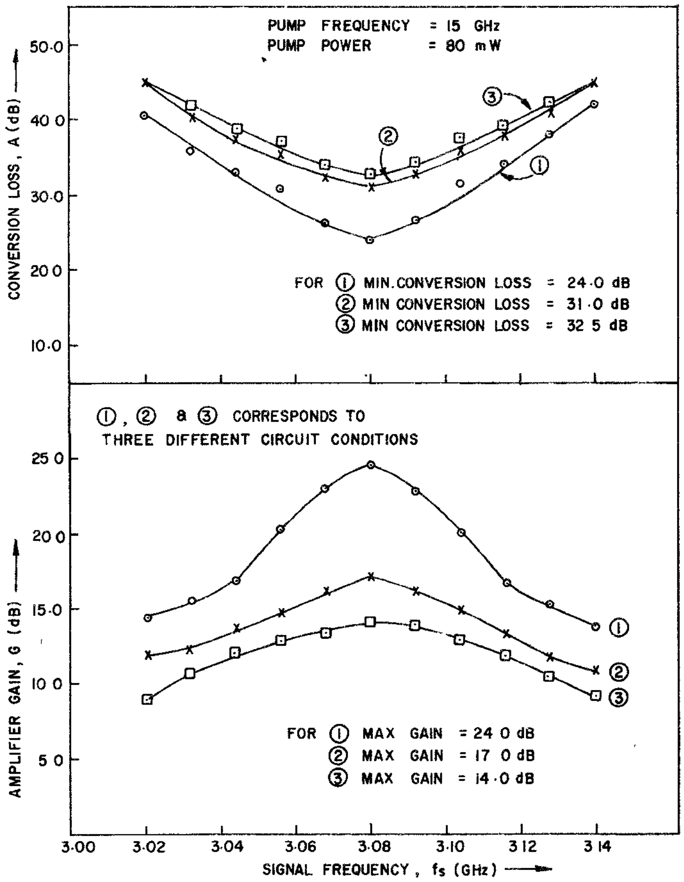

Fig. 1. Measured amplifier gain and idler conversion loss characteristics of an *S*-band nondegenerate parametric amplifier.

Fig. 1 shows the measured amplifier gain and idler conversion loss characteristics of the parametric amplifier. The conversion loss has a minimum value at a frequency where the amplifier gain is maximum. This is true for all the three different signal circuit conditions. There is a corresponding increase in the idler conversion loss for a decrease in the gain of the amplifier at frequencies away from the center frequency of the amplifier. For example, the minimum values of idler conversion loss are 24.0, 31.0, and 32.5 dB, respectively, for the gain of 24.0, 17.0, and 14.0 dB at the center frequency of the amplifier. The attenuation of the pump waveguide at the idler frequency has also been measured and has been found to be about 16.0 dB. The experimentally measured values of idler conversion loss include this contribution.

III. Conclusion

These results show that idler conversion loss A of single-diode parametric amplifiers cannot be easily increased to very large values without affecting the gain of the amplifiers. The only way to increase A without affecting gain is to use a long length of the pump waveguide, which is designed to be below cutoff at idler frequency. This is in contrast to the results obtained by Tearle and Heath [3] for double-diode parametric amplifiers, where inherent filtering of the double-diode circuit allows the adjustment of idler conversion loss to a very high value, independent of paramp gain. In many applications, single-diode paramp circuit design provides a good noise factor and also yields significant improvements in reliability by reducing the number of varactors and minimizing the pump power requirements, and is therefore preferable to the double-diode paramp circuit. However, it may be desirable to operate single-diode parametric amplifiers at high gain, resulting in lower values of inherent conversion loss. In these cases, the idler rejection may not be adequate when using an IMPATT pump which is characterized by a large amount of associated AM noise [3], and the use of a bandpass filter in the pump line may become necessary for low-noise operation of the parametric amplifiers.

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