Push-Pull Tunnel Diodes*

Presented in this note is a discussion of the advantages of using a pair of tunnel diodes arranged parallel to the signal and in series to the dc power supply. Large improvements are shown to exist in both dynamic range and large signal stability.

Tunnel-diode microwave amplifiers have at present the reputation of being small-signal devices. The noise figure of the devices, while not being as low as may be obtained with a well-designed reactance amplifier, is still quite competitive in the low-noise field. When a tunnel-diode preamplifier is used before a system, signals within very few db of noise may be amplified to a level well above the noise of the succeeding stages, so that the noise figure of the system will be essentially that of the preamplifier. However, in most microwave systems proper handling of small signals is not enough. Large signals must also be faithfully reproduced. The tunnel-diode amplifier will show marked change in gain at input signal levels of the order of -35 dbm.

It is the object here to point out an arrangement for using two tunnel diodes which, it is estimated, should improve the dynamic range of the amplifier by a factor of approximately 20 db so that, with germanium units, the point at which saturation begins will be approximately -15 dbm (for an assumed gain of 15 db).

Consider the pair of tunnel diodes connected in a circuit as shown in Fig. 1. The diodes are connected in shunt with the transmission line for the ac signal. The line as shown would represent a coaxial or parallel-plate transmission line system.

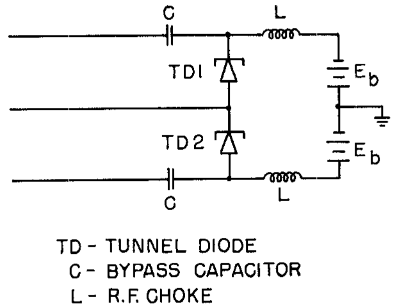

Fig. 1—Diode arrangement for push-pull operation.

The current-voltage (I-V) and conductance-voltage (G-V) curves for a representative germanium unit are shown in Fig. 2.

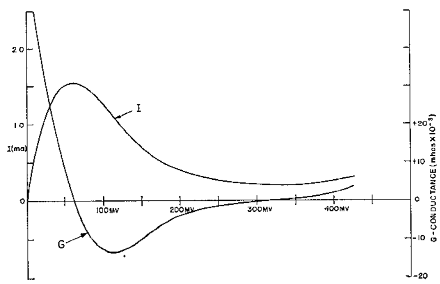

Fig. 2—Current-voltage characteristic of a typical germanium unit.

The composite current-voltage (I-V) characteristics are illustrated in Fig. 3. Shown are the individual I-V curves of each diode, the composite current and the equivalent current (for noise purposes) as seen by the signal circuit. E_b is the value of bias set by the voltage sources as shown in Fig. 1. The most interesting feature is now shown by the composite conductance vs voltage characteristic presented to an input signal, and illustrated in Fig. 4. Three curves of conductance are shown, each for a different value of bias voltage E_b. For a value of $E_b=0.165$ v, an extremely flat conductance characteristic is obtained for signal voltage deviations of over 100 mv. For a 115-mv interval on curve No. 2, a conductance change of less than 6 per cent has taken place. For the same bias point a single diode alone requires a voltage deviation of approximately 5 mv for a 6 per cent conductance change.

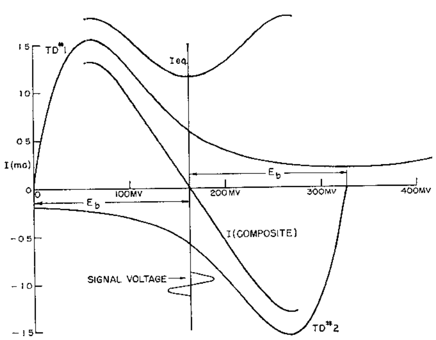

Fig. 3.—Composite current-voltage characteristic for push-pull arrangement.

The constant conductance characteristic may be used with little or no degrading effect on noise figure. Curve No. 1 has been constructed for the characteristic obtained with $E_b=0.150$ v, at which point the diode used has its minimum I/G ratio, and hence minimum noise figure. Curve No. 2 was displaced slightly to obtain better dynamic characteristics. The amount of displacement ($\Delta E_b=12.5$ mv) resulted in negligible change in the I/G ratio, and hence in the expected noise figure.

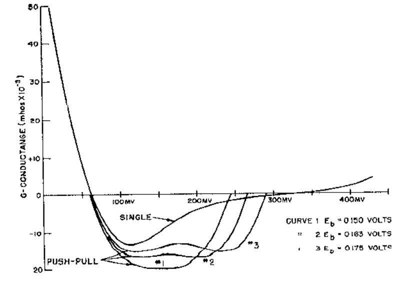

Fig. 4.—Conductance-voltage characteristic of a single unit and of the push-pull arrangement.

The capacitance variations likewise are minimized with the diode combination. As the capacitance of a diode is a slowly increasing function of the junction voltage, for a given change in E_b the increase in capacitance of one diode is almost completely compensated by the decrease in the other. Thus, for signal voltages of the order of 100 mv, an almost constant capacitance characteristic is obtained. This will minimize the tendency toward loss in gain at high signal levels due to detuning of the resonant circuits.

Likewise, stability under large signal conditions will also be improved. For stability, the source conductance (G_s) (as seen by the diodes) must remain greater than the magnitude of the negative conductance ($|G_d|$). If the peaks of a large signal can drive the diode to the point where the negative conductance is greater than the source conductance, then instability may occur. The device may be "shocked" into oscillation if, due to rectification within the diode, the bias point can shift in the direction necessary to maintain the oscillations. If the "shocked" oscillations cannot persist, there is still the possibility of the building up of higher-frequency parasitic oscillations within that part of the signal cycle during which the condition $G_s-|G_d|<0$ exists. With the double-diode scheme, when $G_s-|G_d|$ has been adjusted for proper gain, a much more stable arrangement is obtained, since now, under large signal peaks, the negative conductance will only decrease and not increase, as is obvious from the composite curves of Fig. 4.

A second and very important use would be for harmonic mixing. Because of the symmetry of the conductance curve about the bias point, the odd harmonic coefficients of the Fourier series expansion of the conductance evaluated about the bias point will all be zero. The even terms remain, allowing second- and higher-order (even) harmonic mixing. For the assumption that the image currents are short-circuited it has been estimated[1] that, if the diodes are biased as in curve No. 1, a local oscillator swing of 140 mv peak-to-peak would allow approximately 22 db of conversion gain with a noise figure of approximately 5 db. This noise figure represents a degradation of about one db from that expected if the same diodes were to be used as an amplifier. If tunnel diodes are to be used most efficiently in the high microwave or millimeter wave ranges, then the most efficient local oscillator scheme must be utilized. This double diode converter arrangement appears to be one such possibility.

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[1] L. E. Dickens and C. R. Gneiting, "A tunnel diode amplifying converter," IRE TRANS. ON MICROWAVE THEORY AND TECHNIQUES, vol. MTT-9, pp. 99–101; January, 1961.