V-5. Design of Stable Broadband Tunnel-Diode Amplifiers

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The design method described here establishes the desired gain at band edges and relies on the symmetry of the circuit reactance characteristic to maintain the gain over the entire band. A design for the 4 Gc to 5 Gc band resulted in a theoretical peak gain of 13 db when the gain at band edges was set at 11 db. Another design for the 5 Gc to 6 Gc range had a peak gain of 15 db.

The stability problem of tunnel-diode amplifiers results from the presence of negative conductance in the diode at all frequencies below the resistive cutoff frequency. If the diode could be isolated from the rest of the circuit by a properly matched circulator at all these frequencies, the negative conductance would only lead to a finite gain. In practice, circulators have large reflections outside the design band which can cause oscillations. The circuit in Fig. 1 shows a stabilizing admittance, $G_{st} + jB_{st}$, shunting the diode. By cancelling the negative conductance of the diode outside the passband this circuit prevents oscillations due to circulator out-of-band mismatch. The stabilizer may be seen in Figure 2. It consists of a quarter-wave line loaded with a disc resistor, followed by an eighth-wave line loaded with an adjustable capacitor. Its conductance is zero at band center and remains small over the passband of the amplifier.

The shunt inductance B_p in Fig. 1 is a shorted length of line. The shorting screw shown in Fig. 2 adjusts the length of this line. Figure 3 is an immittance diagram of a 4 to 5 Gc amplifier showing how this length is calculated. In this diagram, susceptance is positive in the lower half, while reactance is positive in the upper half. Circled points are calculated at 4 Gc, and the triangles are calculated at 5 Gc. The admittance of the diode is located at 1. The stabilizing circuit moves the admittance to 2. The shunt inductance moves the admittance to 3, which transforms to impedance at 4. The real part of this impedance at 4 Gc is set equal to the real part at 5 Gc.

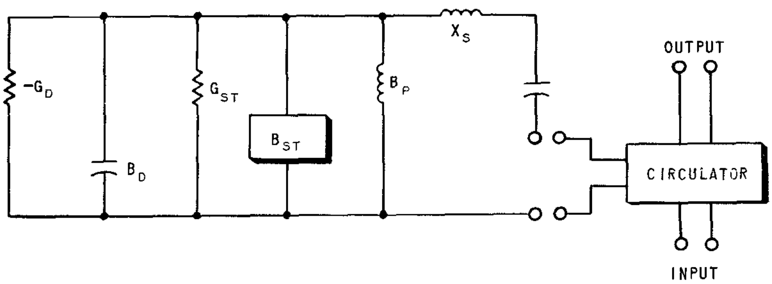

Fig. 1 Double-tuned amplifier circuit.

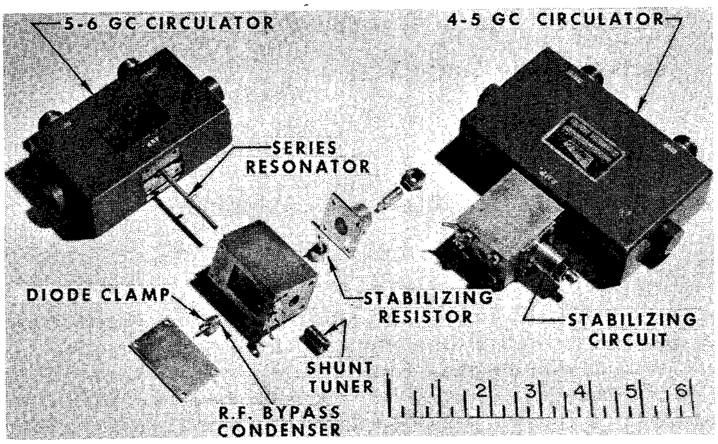

Fig. 2 C-band tunnel-diode amplifiers.

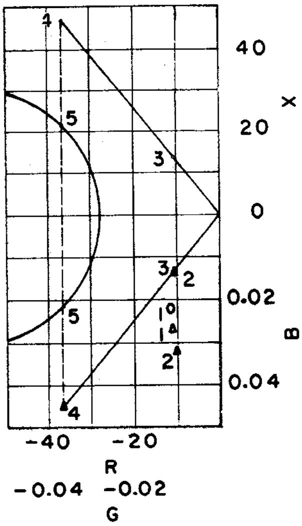

Fig. 3 Immitance chart of amplifier design.

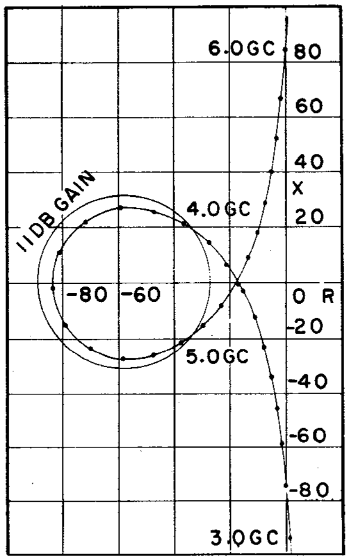

Fig. 4 Impedance of C-band amplifier.

The resulting equation involves the characteristic impedance and length of the shorted line representing the shunt inductance. A convenient value may be chosen for the characteristic impedance and the length may then be calculated.

The arc of a circle in Fig. 3 is the locus of impedances which result in 11 db gain when connected to a 50-ohm circulator. The amplifier design is completed by a series circuit which brings point 4 to point 5 on the constant gain circle. The series circuit is a shorted length of transmission line inside the center conductor which is resonant near the center of the passband.

The value of its reactance at 4 Gc and at 5 Gc may be determined from the circuit equations or by measurement on the graph. The resulting two equations determine the characteristic impedance and length of the series resonator. Figure 4 shows the impedance plot of this amplifier. The resistance becomes positive at 3 Gc and 6 Gc, so there is no possibility of oscillation beyond those frequencies. Stability between these frequencies is controlled by the circulator design. The impedance is inside the 11 db gain circle in the passband so the gain is above 11 db. Figure 5 shows the theoretical gain response of this amplifier, and Fig. 6 is an oscilloscope photograph of the output signal showing the realized gain as a function of frequency. The reference line corresponds to 10-db gain.

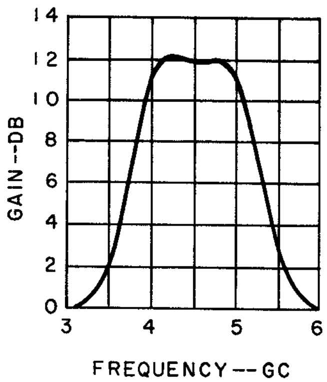

Fig. 5 Theoretical gain response of C-band tunnel-diode amplifier.

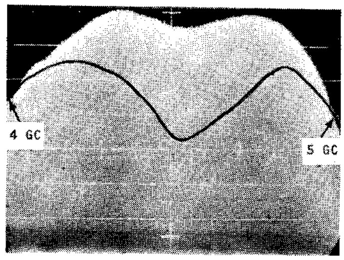

Fig. 6 Experimental gain response of 4 to 5 Gc amplifier.

Diode manufacturers find it difficult to maintain close tolerances on diode capacitance. The theoretical effect of capacitance variations was determined by assuming a fixed series circuit and tuning the shunt inductance to resonate the circuit at band center. The gain was then computed at band edges. For lower capacitance, the gain increased slightly, not more than one db. For higher capacitance, the gain dropped abruptly. This was corroborated experimentally by successfully tuning the amplifier for a variety of diodes having capacitance less than the design value.

This design technique is applicable to other frequency bands, although there may be difficulty in realizing the calculated elements at higher frequency bands.

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