TUESDAY, MAY 16, 1961
SESSION 5: LOW-NOISE MICROWAVE AMPLIFIERS

2:00 PM - 4:45 PM
CHAIRMAN: G. WADE
RAYTHEON COMPANY
BURLINGTON, MASS.

5.1 LOW-NOISE TRAVELING-WAVE TUBES

Dean A. Watkins
Stanford University

Recent developments have made available a number of different devices for low-noise microwave amplification. These include the maser, the solid-state and electron-beam parametric amplifier, and the traveling-wave tube. In some applications, the ultimate in noise figure offered by the solid-state maser is important and useful, so that it is the only choice. In many other applications, such as the background temperature being near room temperature or countermeasures or sources of interference determining the minimum detectable signal, all of the available devices are suitable from a noise standpoint and the choice of which device to use is made on the basis of other factors. Some of these factors are: gain, bandwidth, weight, size, reliability, stability, large-signal performance, phase characteristics, and power requirements.

Recent improvements in the noise figure of wide-band traveling-wave tubes have made them even more attractive than previously. Tubes covering 2 to 1 bandwidths with maximum noise figures of 4.5 db and minimum values below 3 db are available in several frequency bands. Permanent magnet focusing may be employed.

A schematic traveling-wave tube is shown in Fig. 1. The sources of noise in the tube are (1) interception noise, caused by catching electrons on gun electrodes or on the early part of the helix and (2) shot noise introduced at the cathode by current and velocity fluctuations. Source (1) has now been entirely eliminated in well designed and constructed tubes. Improved understanding of the nature of (2) has led to the recently obtained low noise figures. Figure 2 shows the velocity-jump or three-region gun which transforms the noise space-charge waves so as to minimize the noise excitation on the helix. This type of gun gave noise figures of about 6 db—the value thought at one time to be the minimum obtainable value. Improved understanding of the behavior of noise in a low velocity region as obtained from calculations carried out at Stanford led to confidence in the possibility of lower values. Figure 3 shows typical theoretical results. This plus calculations on a low-velocity drifting beam led to the gun configuration of Fig. 4 which features a number of closely spaced electrodes near the cathode in addition to the electrodes of the gun of Fig. 2. Typical broadband noise performance is shown in Fig. 5.

The techniques are readily extended to as low a frequency as 250 mc/s and as high as 15 kmc/s. At mm wavelengths, noise figures in the 10 to 15 db range are obtainable and development programs to achieve this are under way.

Gain of TWT's is high—30 db being typical—and stability is good. Power input requirements are under 1 watt. Weight may be as high as 10 pounds. Life in excess of 20,000 hours has been demonstrated.

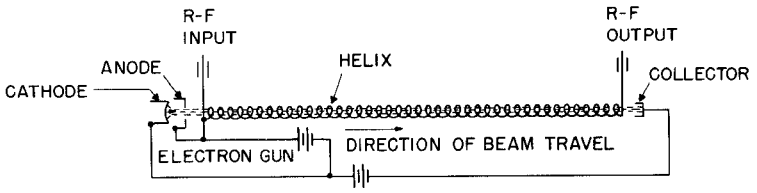

Figure 1 - Schematic Traveling-Wave Tube.

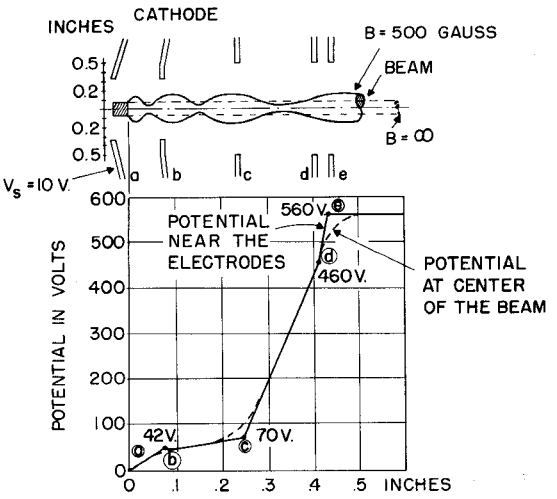

Figure 2 - Velocity-Jump or Three-Region Gun.

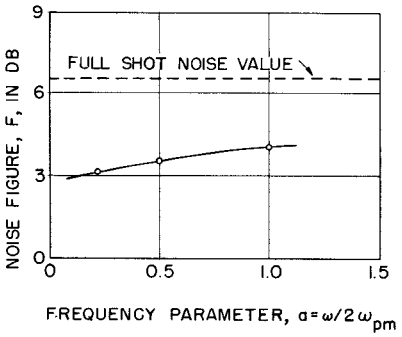

Figure 3 - Minimum Noise Figure vs Frequency for a Space-Charge Limited Cathode at 1000°K.

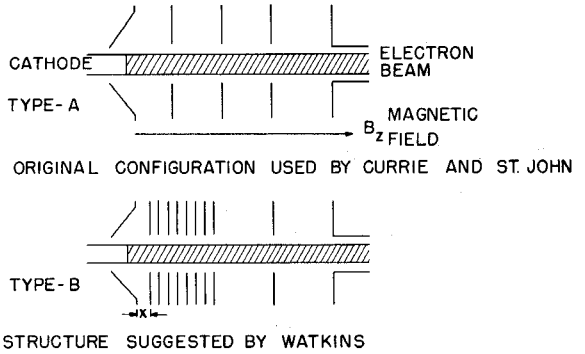

Figure 4 - Low-Noise TWT Guns.

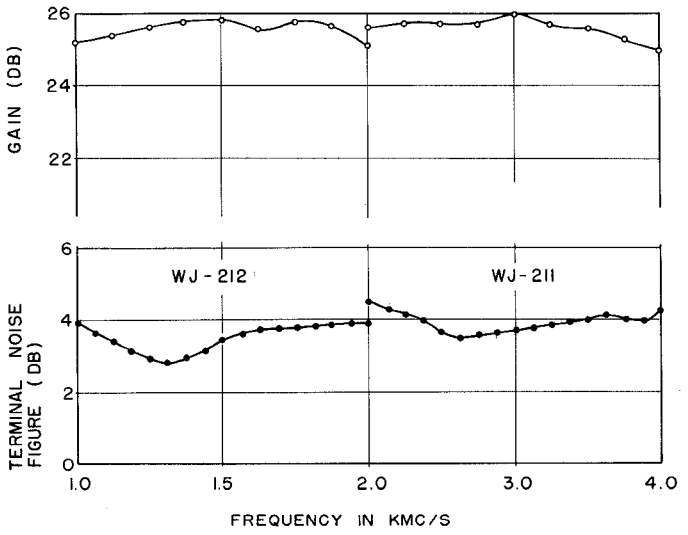

Figure 5 - Noise Figure and Gain vs Frequency for Low-Noise TWT's.