# HIGH-POWER MICROWAVE AMPLIFIER USING ANTI-PARALLEL AVALANCHE-DIODE PAIR*

Hirohisa Kawamoto

RCA Laboratories
Princeton, N. J. 08540

## Abstract

A new microstrip-circuit amplifier is composed of two high-efficiency avalanche diodes placed in anti-parallel fashion, one-half wavelength apart in a transmission line. The amplifier provides a 200 W output power with a 10 dB gain.

## Mechanism of Amplification

Two high-efficiency avalanche diodes, each placed at the end of an approximately one-half wavelength transmission-line in opposite polarity with each other, (shown in Figure 1), have worked together as a high-power reflection-type amplifier. This circuit configuration will be called an anti-parallel pair of high-efficiency diodes. Oscillators using the anti-parallel pairs are to be published elsewhere.[1,2] The two diodes forming the anti-parallel pair are both reverse-biased to the breakdown voltage. An input-output transmission line is connected to the midpoint 0 of the two diodes as shown in Figure 1. A low-pass filter is placed in the input-output line, one-quarter wavelength from the midpoint. A circulator is placed in the input-output line next to the low-pass filter.

Schematic RF-waveforms, within the anti-parallel amplifier circuit shown in Figure 2, will illustrate the mechanism of amplification. The arrows in Figure 2 indicate the wave-travelling directions that are important in understanding the mechanism. A positive half-sine wave Ai of the input signal travels through the midpoing to the diode $D_1$. As a result of electron-hole plasma formation inside the diode[3,4], a positive voltage $A_1$, over the breakdown voltage, induces a negative pulse $B_1$ on the diode. A sampling-oscilloscope measurement has demonstrated such response of the high-efficiency avalanche diode in the anti-parallel amplifier. The pulse $B_1$ travels to the output terminal through the midpoint, and forms a negative half-sine wave Bo of the output signal. The distance between the diode and the midpoint is so adjusted that a round trip time from the midpoint to the diode equals one-half cycle of the input signal, i.e., the distance between the two diodes is slightly less than one-half wavelength. A negative half-sine wave Bi of the input signal, therefore, arrives at the midpoint just when the negative pulse $B_1$ arrives at the midpoint from the diode $D_1$. The signal Bi combined with a portion of $B_1$ forms a negative pulse $B_2$, and travels to the diode $D_2$. $D_2$ is placed in opposite polarity with respect to $D_1$. The negative pulse $B_2$ induces a positive pulse $A_2$ on the diode $D_2$, in the same manner that a positive pulse has induced a negative pulse on the diode $D_1$. $A_2$ travels to the output terminal through the midpoint, and forms a positive half-sine wave Ao of the output signal. The next Ai of the input signal arrives at the midpoint just when $A_2$ arrives at the midpoint. Ai combined with a portion of $A_2$ forms the negative pulse $A_1$ and travels to the diode $D_1$. $A_1$ induces the negative pulse $B_1$ of the next cycle, which travels to the output terminal and forms a negative half-sine wave Bo of the output signal.

The anti-parallel pair acts as an amplifier when the amplitude of Bo and Ao is higher than that of Ai and Bi. The mechanism of the anti-parallel-pair amplifier is similar to that of a conventional push-pull amplifier. One of the two active devices in the circuit amplifies one half-cycle of the input signal, and the other amplifies another half-cycle of the input signal. The anti-parallel circuit has small even harmonic contents at the midpoint between the two diodes, similar to a push-pull circuit. It is believed that tuning of the circuit with a small second harmonic content is easier than that of a single-diode amplifier which has a larger second harmonic content.[5,6]

## T-Shaped Microstrip Amplifier Circuit

The anti-parallel amplifier experiment has been performed using a T-shaped, 50-ohm microstrip-line circuit (Figure 3). The diode used is a p-n-$n^+$ tapered-cylinder structure with a diameter of approximately 0.020 inch and an n-region resistivity of approximately 6 ohm-cm[1]. A 1.0 to 2.0 GHz bandpass filter is used as a DC block as well as to ensure a single frequency in power measurements. The tuning plates E and F serve as the low-pass filter.[7] The tuning plates G, H, and I are fine tuning elements.

The circuit operates as either an amplifier or an oscillator, depending on the number, sizes and positions of the tuning elements. The amplifier tends to be a saturation-type amplifier rather than a linear amplifier although it does have a short linear portion in the input-output characteristics. The saturated output power is 200 W with a 10 dB gain. The detected RF-envelope is clean at the saturated level. However, it is noisy at low levels as previously reported.[8] The bandwidth of the amplifier is 17.5 MHz. The center frequency of amplification is 1.01 GHz which corresponds to a one-half microstrip wavelength of 10.4 cm. The distance between the diodes is 8.3 cm. The difference between the one-half wavelength and the physical distance has been attributed to a response time-delay of the diode.[1] The time delay falls in the order of 0.1 ns for almost all UHF and L-band diodes[1,5,9] including the diodes used here.

In conclusion, it has been demonstrated that an approximately one-half wavelength spaced, anti-parallel diode pair works as a high-power amplifier. The anti-parallel microstrip circuit is suitable for amplifier application because of the low second harmonic content.

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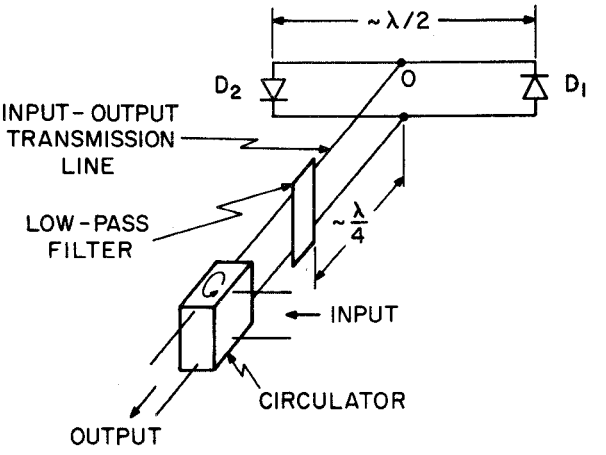


Figure 1 - RF-equivalent circuit of the reflection-type amplifier using the anti-parallel avalanche-diode pair.

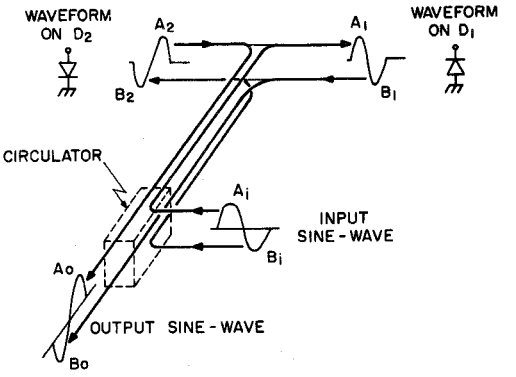


Figure 2 - RF waveforms inside the anti-parallel amplifier illustrating the mechanism of amplification.

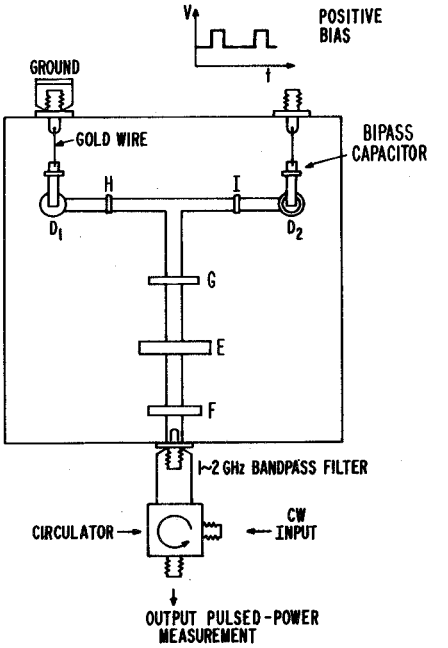


Figure 3 - An anti-parallel amplifier using a T-shaped microstrip-line circuit.