CONTROLLED BIAS PREHEATING FOR VARIABLE DUTY FACTOR IMPATT TRANSMITTER

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ABSTRACT

A biasing technique has been devised which compensates for thermal changes in solid state transmitter operation. Use of this technique allows operation over a range of duty factors and extended environmental temperature conditions. The concept is discussed and test results presented.

INTRODUCTION

When an active solid state device is used, it invariably is heated to some degree because of the application of a DC bias. This is particularly significant with high power devices such as IMPATT diodes because the thermal limitation on the device is the criteria which establishes the maximum power available. The average temperature and the extreme values are very much dependent upon the waveform duty factor selected.

This paper presents a biasing technique which makes use of this bias heating effect, thereby compensating for thermal changes due to variations in pulsed waveforms. Utilization of this technique also provides for operation over an extended environmental temperature range.

DISCUSSION

Using the bias to heat a device during the normally "off" time in a pulsed waveform is in itself not new.[1] Allowing a low level bias current to flow to "keep the diode warm" or to "prime" it for a cleaner start is often referred to as prebiasing. The new idea presented here is that of precisely controlling the amount of prebias to establish the temperature at a particular time in the waveform while the waveform duty factor and the ambient temperature are allowed to vary.

Diode impedance characteristics are temperature dependent, resulting in transmitter performance variation as the junction temperature of the device is changed. For a given waveform (duty, pulsewidth) there is a maximum output power which can be achieved without exceeding the junction temperature limits. The RF circuits are designed based upon the diode characteristics at a given level. If the waveform or the ambient temperature is changed without retuning the circuits, the performance will change accordingly.

The waveforms discussed cover a wide range of duty factors (3 to 15%), resulting in a factor of five in the changing amount of dissipated power in the diodes. At high peak power levels, the temperature rise due to this dissipation is a significant part of the resulting temperature. Designing to a compromise tuning condition (at a mid-range temperature) would result in poor operation at the high and low duty factors, and tuning to the high end (15%) would result in totally unacceptable operation at the 3% case.

Figure 1 shows the general influence of temperature on oscillation frequency. The frequency scale is relative, to show changes, and could fall anywhere in the operating range of the diode. The second curve indicates the rate of change of frequency with temperature. Three important characteristics are demonstrated by these curves: 1) The operating frequency band will shift with average temperature change. 2) The diode will have a tendency to chirp down in frequency during a pulse due to heating. This effect reduces the injection locking range and bandwidth. 3) The temperature effects on frequency are reduced at higher temperatures. This effect is beneficial. For maximum power and efficiency it is preferable to operate in the high temperature range (consistent with reliability considerations).

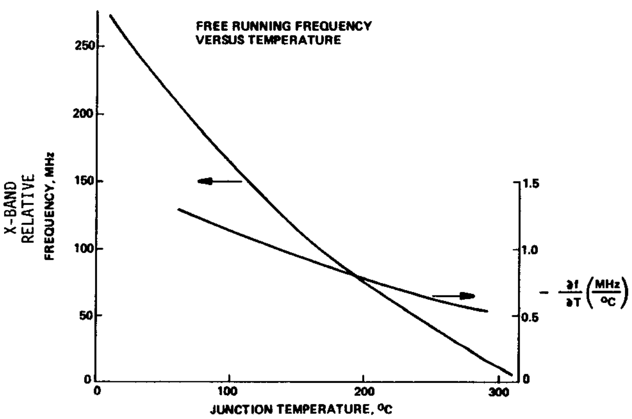

Figure 1. Temperature Influence on Frequency for a Single Diode

The temperature also influences the output power. Large temperature changes can result in significant power reduction during portions of the pulse depending on tuning. Power and frequency variations can be overcome by introducing an additional control parameter to compensate for the diode junction temperature variations due to ambient and duty factor changes.

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Temperature conditioning is accomplished by "preheating" the diode with bias current to a predetermined value prior to the desired time of RF pulsing. Figure 2 displays this technique. The time, t_o, is the beginning of the RF bias pulse, and the dashed lines to the left designate two possible ways of preheating. In amplitude control (I_A) the preheating bias current is on during the whole interpulse interval and the temperature at t_o is established by controlling I_A. The time control technique utilizes a much higher bias current (I_T) and controls the bias on-time (t_H). Both techniques have been demonstrated at Hughes. The advantages and disadvantages of each depend on the waveforms to be compensated.

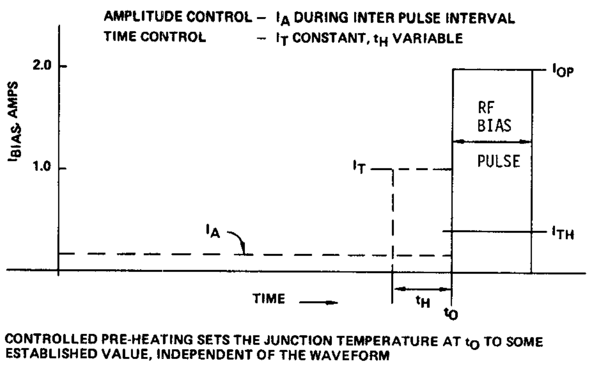

Figure 2. Bias Current Waveform as a Function of Time, Showing Preheating Pulse to Set Junction Temperature

Figure 3 shows the temperature profiles for four duty factors without preheating and with a 0°C heatsink. Preheating essentially shifts the lower curves up to the 15% duty line, resulting in similar performance at all duties, as shown in Figure 4 where an amplitude type reheating was used. Consider first the 3% duty line of Figure 4a. The power is low and the bandwidth is about 170 MHz. As the duty

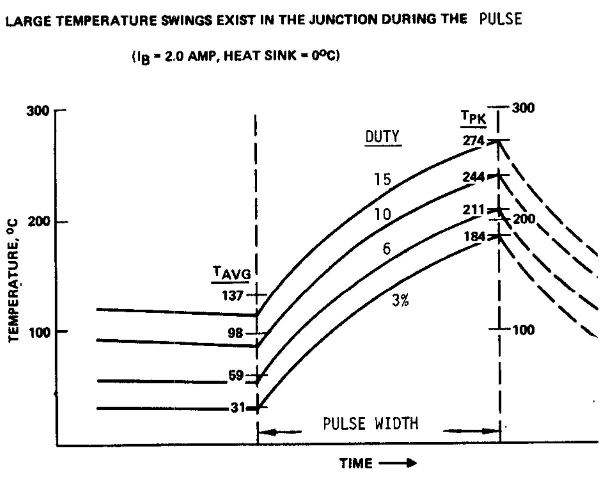

Figure 3. Temperature Profiles for Four Duty Factors Without Preheating

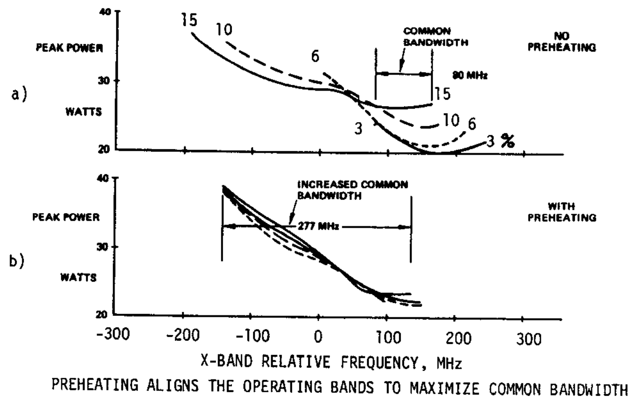

Figure 4. Peak Output Power of Single Silicon IMPATT Diode Oscillator

factor is increased, both the power and the bandwidth increase, accompanied by a general downward shift in frequency. At 15% duty, the bandwidth is up over 300 MHz but, unfortunately, shares only 80 MHz of common band with the 3% duty. Controlled preheating on the lower duties raises the average temperature so that the performance in Figure 4b is obtained. The hotter operation produces a wider bandwidth for the lower duties and also aligns the bands to get more than 250 MHz of common band, a significant performance improvement.

Preheating can also be used to compensate for cold environmental conditions. By using some additional control circuitry and a heatsink temperature sensor, it is possible to tailor the preheating pulse to adjust for the bulk temperature as well as the waveform.

Preheating through the bias has two particular advantages which are not available through other heating means. First, the heating time constant is minimum since we are directly heating the device and it is very small. This allows essentially instantaneous or pulse to pulse adjustment if necessary. The second advantage is power conservation or system efficiency. The total energy necessary to heat and power the semiconductor at the lower duties is always less than that required to power the device for the highest duty. In addition, energy is not being used (such as an oven) to heat the enclosing structure.

CONCLUSIONS

A useful means of thermally compensating an IMPATT diode for changes in waveform duty factor and ambient temperature has been demonstrated. Tests show that the concept works equally as well with power combiners as with single diodes. Additional examples and theoretical effects will be discussed in the presentation for both silicon and GaAs IMPATTs.

REFERENCE

(1) Patent #4,306,237 Carl Tresselt, Bendix Corp.