A HIGH-POWER SOLID-STATE C-BAND TRANSMITTER FOR MLS APPLICATIONS

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ABSTRACT

A solid-state C-band transmitter was developed for the Microwave Landing System. The key component of the transmitter is a solid-state power amplifier using GaAs Read-profile IMPATT diodes to obtain operating output levels approaching 20 Watts. The transmitter also contains a phase-locked oscillator, a phase modulator integrated into the power amplifier, and a pulse shaping network to achieve minimum spectrum spreading. The entire transmitter, including power supplies, logic circuits and heat sinks, is contained in a 12" x 12" x 6-1/2" package.

INTRODUCTION

High efficiency Read-profile IMPATT diodes with CW power output of 11 Watts in C-band have been reported recently[1]. Using these diodes, a solid-state power amplifier with output approaching 20 Watts at 5 GHz was designed as a part of a ground-based transmitter for the Microwave Landing System (MLS). The transmitter contains a commercially available crystal-controlled oscillator-multiplier, DPSK modulator, high power amplifier, and all the necessary power supplies and logic circuitry. The DPSK modulator is TTL compatible and capable of meeting the phase and amplitude characteristics of the MLS system. The entire transmitter is contained in a 12" x 12" x 6-1/2" package which includes power supplies and heat sinks.

DESIGN APPROACH

The basic configuration of the transmitter is shown in Figure 1, along with nominal power levels and the amplifier gain distribution. Two output ports are provided so that the unit may be used, either as a self-contained transmitter with internal modulation capabilities or as a signal source for systems having external modulators.

The crystal-controlled oscillator-multiplier is a commercially available unit. It consists of a temperature-controlled crystal oscillator at 105.43750 MHz (at mid band) followed by a X48 multiplier in a phase-locked loop configuration for an output of +20 dBm at 5061 MHz (at mid band). The operative frequency is set within the 5031 to 5091 MHz band by installing the proper crystal in the oven.

The remaining RF circuits are integrated into one microstrip module shown in Figure 2. The output of the oscillator-multiplier is amplified to +29 dBm using an IMPATT-diode injection-locked oscillator (ILO). The ILO is built on a ferrite substrate microstrip. The use of ferrite substrates throughout the unit allows an economical means of fabricating circulators and interstage isolators. The DPSK modulator is also constructed in ferrite substrate microstrip by using a PIN diode to terminate one port of a circulator. The PIN diode will be switched between the open and short circuit modes to provide 0^{o} and 180^{o} phase shift. Transmission loss through this modulator is less than 2 dB.

Diodes in the power amplifier stages are GaAs Read-profile diodes in quadri-mesa configuration. With the exception of the power-combined last stage, all circuits are fabricated on ferrite substrate. Each amplifier substrate contains a circulator, an impedance transformation, and stabilizing networks, an isolator, and a low-pass filter network for D.C. bias through the isolator. The power-combined circuit is built on an alumina substrate because it was physically advantageous to separate the amplifier substrate from the circulator. The output isolator signal path direction can be changed to either output #1 or #2 by reversing the magnet which is accessible under the unit. A loosely coupled detector diode is also included on this output substrate. This provides a D.C. monitor signal of the RF output level.

An amplitude attenuator is included at output #2 to reduce off-channel emissions at the bi-phase modulation frequency caused by the phase modulator. The attenuator utilizes PIN diodes between two 3 dB hybrids so that the amplifier remains well matched. The attenuator and 3 dB hybrids were fabricated using Duroid stripline construction and integrated into the amplifier housing.

Amplitude modulation provides an equivalent cosine square amplitude envelope during the phase transition of the DPSK modulator and turn-on and off of transmitted pulse to minimize off-channel spurious emissions. The output stages of the power amplifier are pulsed off to achieve greater on-off power ratio required by the MLS system. Thus, three separate TTL trigger inputs are required for the independent control of phase modulation, amplitude modulation, and power amplifier gain.

The transmitter includes two thermostatically controlled switches, one for cooling, and one for overtemperature protection.

TRANSMITTER PERFORMANCE

The output power versus frequency characteristic under CW conditions of the power-combined output stage is shown in Figure 3. Power output over the frequency band 5.0 to 5.1 GHz was 20 Watts with 10 Watt RF input. The pulsed response of the amplifier is shown in Figure 4. The pulse width is 5 msec. at a 25% duty cycle. The output power is the same as observed under CW conditions.

The transmitter is phase modulated at a 15 KHz data rate. A spectrum analyzer display of the phase modulated signal is shown in Figure 5. The carrier null is greater than 30 dB. The MLS requires that in a 160 KHz bandwidth 240 KHz away from the carrier the sideband frequency components be -40 dBc. This is accomplished by using an output attenuator that attenuates the transmitted signal 20 dB minimum during the phase transition period. The effect of the amplitude modulator located at port 2 in the transmitter is shown in Figure 6. The total integrated 240 KHz away from the carrier is attenuated greater than 40 dB. The attenuation function used in the amplitude attenuator approximated a cosine square function.

CONCLUSIONS

It has now been demonstrated that high efficiency Read-profile GaAs IMPATT diodes can be used to achieve output levels of 20 Watts at C-band in a practical application. This solid state transmitter with its small size, weight, and power consumption is capable of meeting the essential power output, phase, and amplitude requirements of the MLS system.

ACKNOWLEDGMENT

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REFERENCE

1. M. G. Adlerstein, R. N. Wallace and S. R. Steele, "High Power C-Band Read IMPATT Diode", Electronics Letters, 11, 18, 430 (1975).

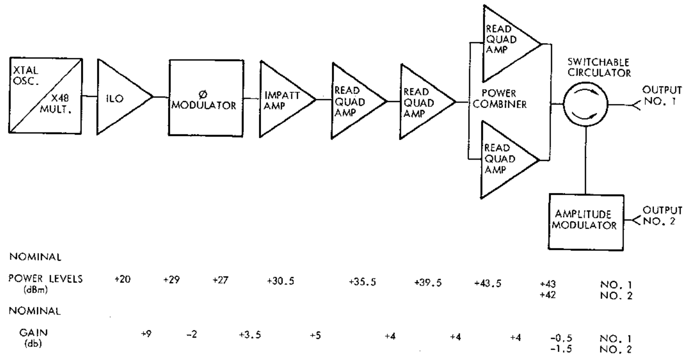

Figure 1 Transmitter Block Diagram

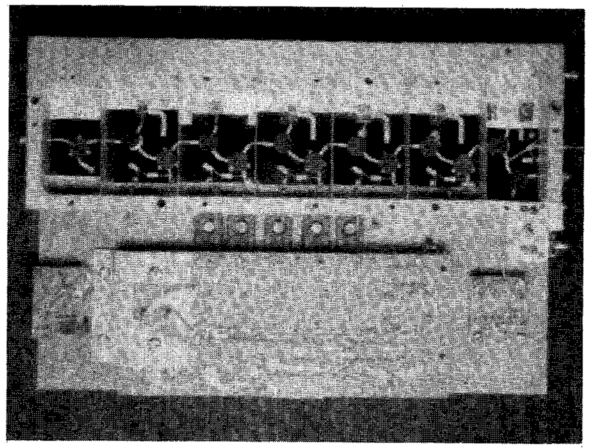

Figure 2 Photograph of the Amplifier Module

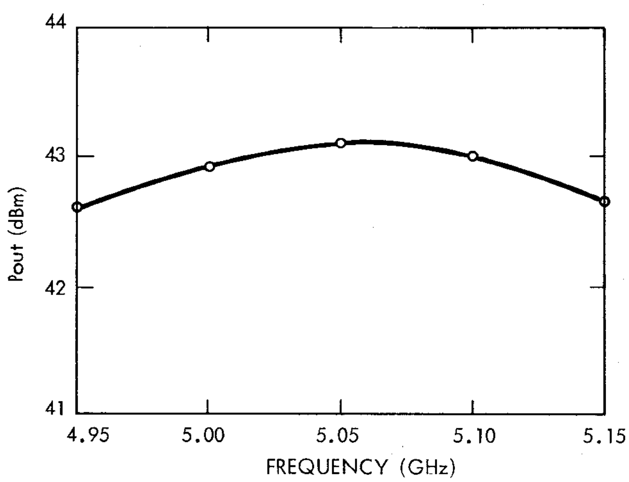

Figure 3 Power Output of Main Output Stage Vs. Frequency

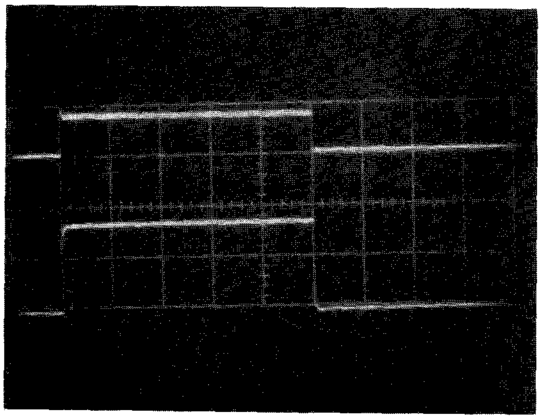

Figure 4 Detected RF Output of the Power Amplifier Operated in Pulsed Mode with 5 msec. Pulsewidth and 25% Duty Cycle.
Upper Trace: TTL Trigger
Lower Trace: Detected RF Output
Horizontal Scale: 1 msec./div.

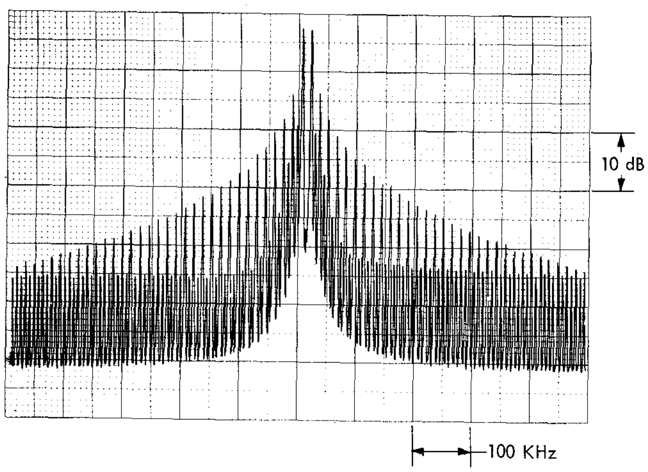

Figure 5 Spectrum of CW Signal with Phase Modulation

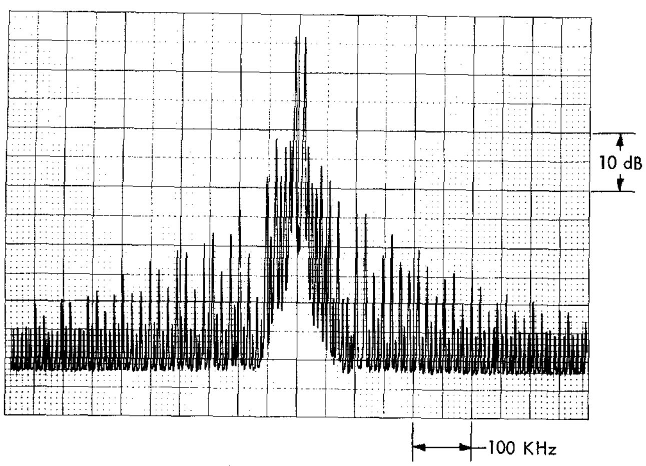

Figure 6 Spectrum of Simultaneous Phase and Amplitude Modulation