MINIATURIZED, X-BAND SOLID-STATE TRANSMITTER

*Muhammad Mizan, *Dana Sturzebecher, *Thomas Higgins and +Edward Maluszczak

*Army Research Laboratory, EPSD, Fort Monmouth, N.J. 07703
+Communications Electronics Command, Fort Monmouth, N.J. 07703

ABSTRACT

A compact X-band solid-state transmitter capable of 26 watts peak output power, with state-of-the-art frequency stability is reported in this paper. A dielectric resonator oscillator (DRO), employed as a frequency source, has a frequency stability of 80 parts per million (ppm) over the temperature range of -50°C to +50°C. A six stage GaAs MESFET RF amplifier, with an associated gain of 37 dB, also functions as a pulse modulator by changing the gate bias voltages. The last amplifier stage consists of four amplifiers operating in a power combining configuration. The transmitter including the pulse modulator is packaged into a size 7.6 cm x 5.1 cm x 2.5 cm, and has a total weight of 0.22 Kgm. The transmitter operates from a ±12 volt battery, and has an overall D.C. to RF conversion efficiency of 15%.

INTRODUCTION

The Communications Electronics Command (CECOM) manager for Special Operations Forces (SOF) is currently undergoing the development of a manportable transponder to support the Army SOF's mission. E&PSD, while providing technical support for the program, has initiated an alternative design approach, for the purpose of risk reduction, during the development phase of several critical components. One of these components, the X-band transponder, is comprised of 5 major elements, such as the antenna, receiver, signal processor, transmitter and DC battery. Some of the basic transmitter specifications are: the transmit frequency must not change by more than ±215 ppm over the military temperature range, the pulsed RF output power into the antenna must be a minimum of 22 watts under the worst operating condition, and size and weight should be kept to a minimum. The transmitter must respond within 100 ns after being enabled by the signal processor. The pulse repetition rate (PRF), is 6 kHz and the pulse width is 350 ns. The efficiency of the transmitter should be high enough to avoid the need for a large and heavy battery.

Among the different configurations considered, were GUNN and IMPATT diode oscillators, a high power pulsed MESFET DRO followed by a RF amplifier, and a low power CW DRO followed by an amplifier. The high power DRO approach offered a compact design and eliminated several amplifier stages, however, it had disadvantages of oscillator turn on delay and low efficiency. The GUNN and IMPATT diodes are capable of generating high power for short pulses, but they have very poor frequency stability.

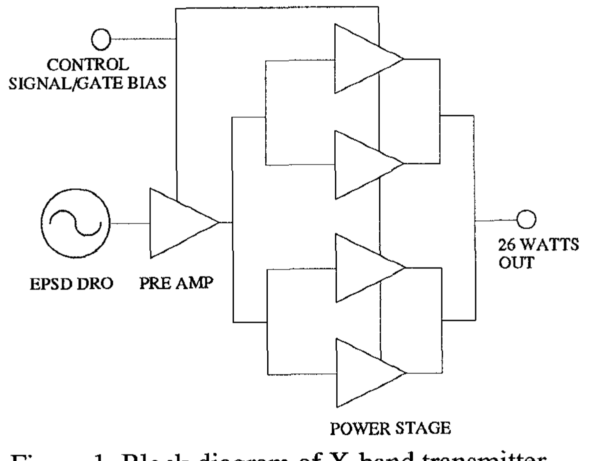

Figure 1. Block diagram of X-band transmitter

The chosen approach for the X-band transmitter is shown in Figure 1. The frequency source is a low power DRO which remains on continually, while the multistage RF amplifier functions as a pulse modulator by pulsing the gate bias voltages of all amplifier stages. The advantages of this approach over the others are high efficiency, excellent frequency stability, minimum turn on delay (less than 50 ns), and the same CW DRO can be utilized as a local oscillator in the receiver circuit.

TRANSMITTER DESIGN

The transmitter consisted of the DRO, a 5-stage 10 watt pre-amplifier, and a 26 watt power amplification stage. The oscillator was designed using a two-stage HEMT amplifier in the parallel feedback configuration, with a high Q dielectric resonator as the feedback element.

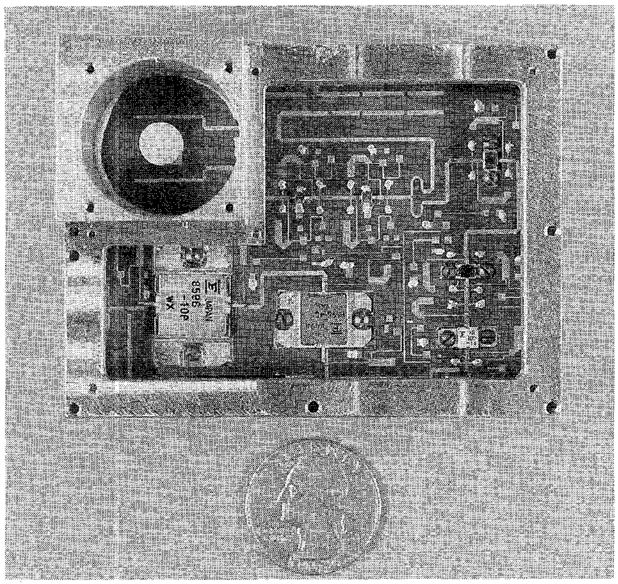

Figure 2. Photo of DRO and pre-amp stages

The unloaded Q of the Murata Erie resonator used in the oscillator circuit was 20,000 at X-band and had a dielectric constant of 24.2 and a 0.0 ppm/°C temperature coefficient. The resonant circuit was optimized for a high loaded Q, which implies low phase noise and high frequency stability. HEMTs were used to minimize power consumption, and to obtain the high gain needed to overcome the DR insertion loss. The DC power consumed by the DRO was less than 50 mW. A test circuit was built into the transmitter circuit for the purpose of testing the DRO and the resonant cavity characteristics before connection to the rest of the transmitter circuit.

The pre-amplifier, consisting of MESFET devices, had a minimum gain of 32 dB, and was capable of delivering 10 watts. Figure 2 shows a photograph of the DRO/ preamp. The output stage of the transmitter, shown in figure 3, utilized four Fujitsu FLM8596-10P power MESFETs, in a Wilkinson divider/combiner configuration, to produce 5 dB of gain or 26 watts of output power at room temperature. At the drain of each FET amplifier, a capacitor in the bias circuit provided the current required for the on portion of the pulse. The gate bias voltages were pulsed to provide the proper modulation and gain.

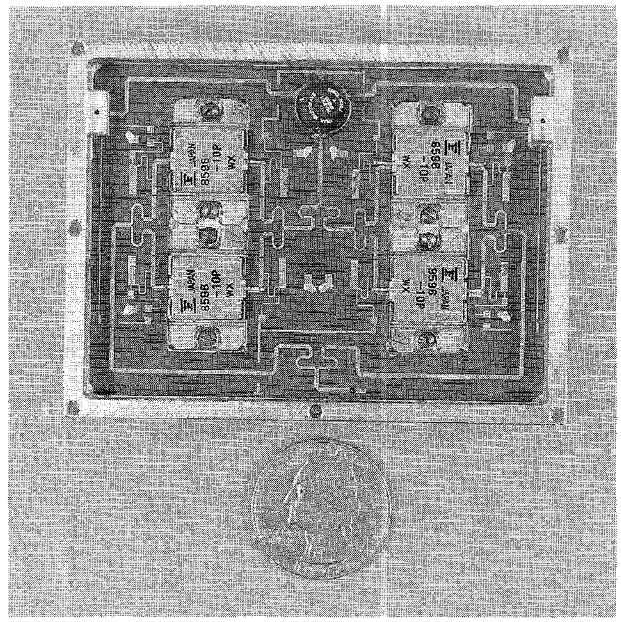

Figure 3. Photo of high power stage of X-band transmitter

PACKAGE DESIGN

The package design played an important roll in size and weight reduction. Since the problem of heat removal was eliminated due to the short pulse width and low duty cycle, the devices were all mounted on a small lightweight aluminum chassis. The transmitter circuit was separated into two layers; the DRO and pre-amp were mounted on one side of the aluminum plate, and the high power stage on the opposite side. Transition between layers was done with a special feedthrough technique, with an insertion loss of less than 0.5 dB at X-band. Another interesting aspect of this design, was test ports at several different places in the circuit for trouble shooting purposes,which would be highly advantageous in a production environment.

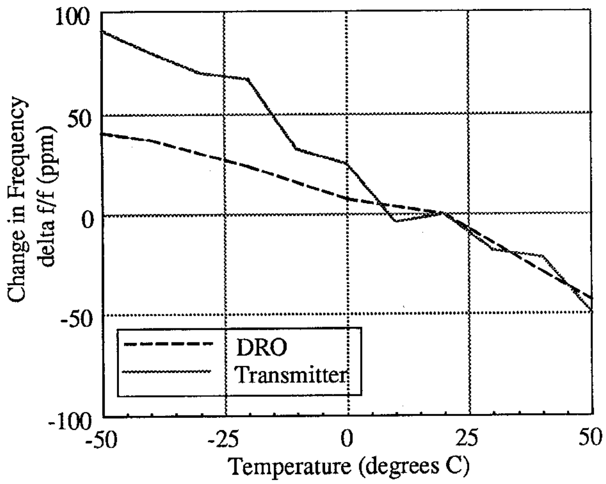

Figure 4. Frequency stability of CS DRO and and pulsed transmitter

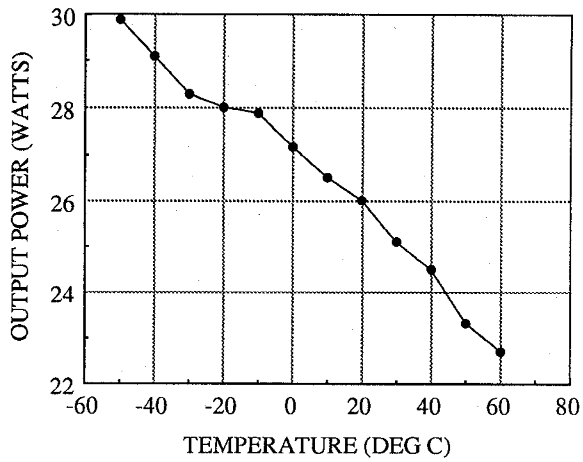

Figure 5. Power variation with teperature

PERFORMANCE

The DRO was capable of generating 7 dBm under the worst [temperature] operating conditions. The frequency vs temperature characteristic of the transmitter is shown in Figure 4. The total change in frequency of the DRO alone (i.e. with out the amplifier) was ±40 ppm over the required temperature range (-50 °C to +50 °C). This is better than the specification by a factor of five. There were no temperature compensation techniques employed to achieve this result. The transmitter frequency stability measured during pulsed operation is also in Figure 4. The difference in temperature stability for the two different cases is due to a frequency pulling effect which could be eliminated by the placement of an isolator between the oscillator and the amplifier. The output peak power variation verses temperature, shown in Figure 5, was measured with a Wavetek 8502A peak

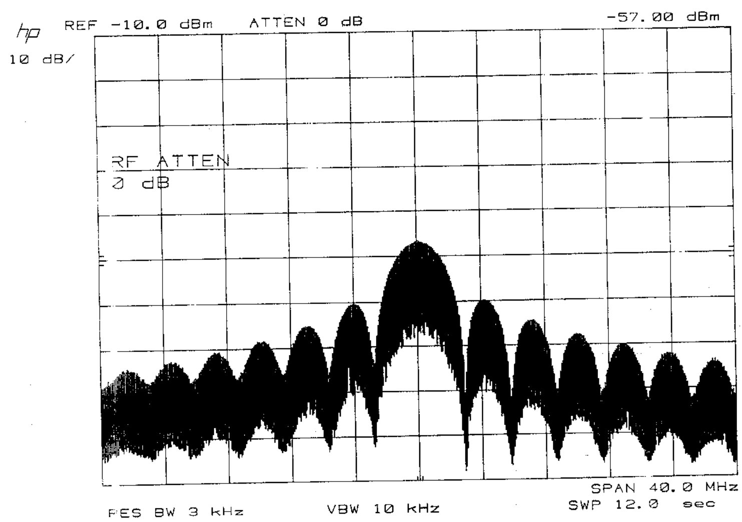

Figure 6. Output power spectrum of 26 Watt pulsed X-band transmitter.

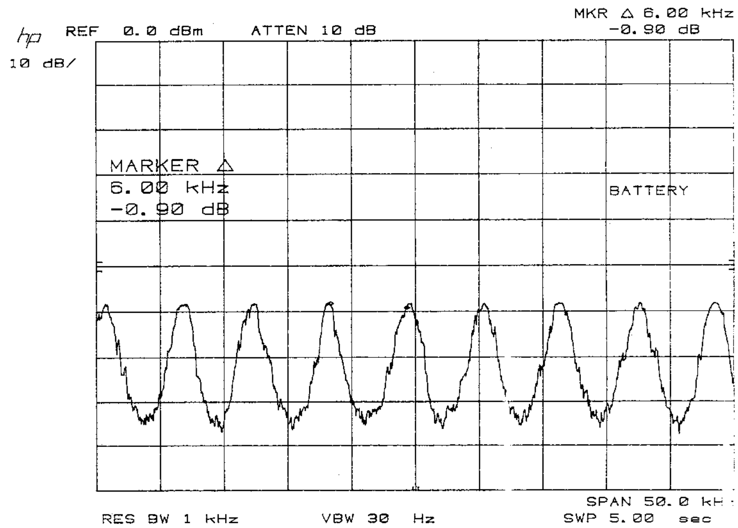

Figure7. Individual frequency components of 26 Watt pulsed X-band transmitter.

power meter. This is a typical power variation expected from MESFET amplifiers, and is acceptable for the system requirements. The transmitter's pulsed RF spectrum is shown in Figure 6. In Figure 7, the individual frequency components can be seen, showing the 6 kHz pulse repetition rate (PRF) and the spectral purity of the output signal.

CONCLUSIONS

A miniaturized X-band solid-state transmitter has been designed, fabricated, and tested to fulfill mission requirements for a US Army transponder system as an alternate design approach. The unit weighs 0.22 Kgm and has an overall dimension of 7.6 cm x 5.1 cm x 2.5 cm. It is capable of delivering 26 Watts of pulsed RF power, and operates from a 12 volt battery. The transmitter has built-in test ports for the purpose of testing and isolating faulty RF components. The package is small enough to be considered for other applications such as IFF or distress beacons.

The transmitter could be configured for CW operation by mounting it on a proper heat sink. Although the

small enough to be considered for other applications such as IFF or distress beacons.

The transmitter could be configured for CW operation by mounting it on a proper heat sink. Although the
system requirement is for a single frequency, it has close to a 1 GHz bandwidth. In the future, the power output stage could be modified to provide higher output power by replacing existing power devices with more advanced power devices as they become available.

REFERENCES

1. C. Peignet, Y.Mancuso, et al., "A 16 Watt Pulsed X-Band Solid State Transmitter", 1988 IEEE MTT-Symposium Digest of Papers, pp. 417-420, May 1988.

2. M. Mizan, T. Higgins, and D. Sturzebecher, "Ultra-Stable, Low Phase Noise Dielectric Resonator Stabilized Oscillators for Military and Commercial Systems", NASA's Technology 2002 Conference, Digest of Papers, Baltimore, MD, December 1-3, 1992.

3. M. Mizan, D. Sturzebecher, and T. Higgins and Arthur Paolella, "An X-Band, High Power Dielectric Resonator Oscillator for Future Millitary Systems", to be published in IEEE Transactions on Ultrasonics Ferroelectrics and Frequency Control.