X-BAND PULSED SOLID STATE TRANSMITTERS

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ABSTRACT

This paper describes a pulsed X-band solid state transmitter capable of power levels greater than 135 watts peak and 45 watts average. Three separate transmitters were built, two used silicon double drift IMPATTs and the third used Gallium Arsenide single drift IMPATTs as the active RF elements. Hybridized constant current pulse modulators were used to bias the diodes. A comparison of the RF performance of the three transmitters is given. The transmitter is form factored for use in missile or airborne applications.

Introduction

Recent developments in high peak power pulsed IMPATT diodes and the state of the art diode combining techniques have made medium power solid state transmitters a viable option for active RF missile seekers[1]. The TM_{010} cylindrical cavity developed by [2]Harp and Stover are capable of combining 16 IMPATT diodes at X-band formed the basic combiner approach for the transmitters. This combiner provides high diode packing density, stable out-of-band operation, and moderate bandwidths.

Design Approach

The transmitter chain consisted of three injection locked oscillators in the configuration shown in Figure 1. Gain levels G_1, G_2, and G_3 were chosen to meet output power, bandwidth and relative P.M. noise requirements given in Table I.

TABLE I

DC	INPUT POWER	650 WATTS
RF	INPUT POWER	100 MW PEAK/60 MW (PEAK)
RF	OUTPUT POWER ·	31 WATTS (AV)
	DUTY FACTOR	33%
POWER VARIATION ·		0 5 dB
RELATIVE P.M. NOISE		-80 dBc/KHZ
MECHANICAL VIBRATION·		6.0 g's (RMS)
TEMPERATURE RANGE .		8° TO 55°C

The first driver stage was a single diode coaxial design with a screw in the sidewall for fine tuning. The second stage is a three-diode cylindrical TM_{010} resonant cavity combiner. The final power stage of the transmitter is a 16-diode cylindrical combiner. A cross-section of the final stage is shown in Figure 2. The entire chain is operated injection locked.

Constant current source pulse modulators are used to bias the IMPATT oscillators. The pulser circuits have individual channel shut down capability to provide graceful degradation in the event of diode failure. Pulser and T.O. blanking timing was set to overlap stage to stage by 10 to 20 nanoseconds to insure optimum noise performance. Five hybrid pulse modulators are used in each transmitter; each hybrid providing four (4) identical pulsed current channel outputs. A picture of a four-channel hybrid pulser is shown in Figure 3.

Performance

Three transmitters were built. The first used HP 5082-0710[3] silicon double drift IMPATT diodes. This diode consists of a ring structure mounted on a gold flashed copper heatsink. A second transmitter used the D1010 diode developed by the Hughes Electron Dynamics Division. This diode is a pill structure mounted to a type IIA diamond heatsink. The third transmitter used a hi-lo single drift, gallium arsenide IMPATT developed by Varian. The typical performance of each diode type is given in Table II at the current levels used in the transmitter. The diodes were operated at reduced power for increased reliability. The diodes were measured under large signal operation at a fixed duty factor, pulse repetition frequency, and current level in a fixed tuned coaxial mount and grouped according to RF power and frequency. A typical power versus current curve of the gallium arsenide single drift IMPATT is given in Figure 4.

TABLE II

MANUFACTURER	DEVICE TYPE	DESIGNATION	PEAK OPERATING CURRENT (ma)	AVERAGE POWER (WATTS)	DC/RF EFFICIENCY (PERCENT)	THERMAL RESISTANCE θ_T = °C/WATT
HEWLETT PACKARD	SILICON *D D.	5082-0710	620	2.8	9 5	6.5
HUGHES ELECTRON DYNAMICS	SILICON *D.D. ON IIA DIAMOND	D1010	520	2 5	11.0	4.4
VARIAN	GaAs SINGLE DRIFT	VSX-9251	890	3 0	20 0	8 0

*D D. -DOUBLE DRIFT

A summary of the important performance parameters of the three solid state transmitters is given in Table III. Three different bandwidths are given in the table. In addition to the conventional injection locked bandwidth, a 1 dB bandwidth and a noise bandwidth under fixed tuned conditions are listed for each transmitter. The 1 dB bandwidth is the injection locked bandwidth over which the output power varies less than 1 dB. The noise bandwidth is the locking bandwidth over which the relative Phase Modulated (P.M.) noise in 1 kHz bandwidth at 5 kHz from the carrier is less than -80 dB below the carrier frequency. The power versus frequency characteristics of the three transmitters at room temperature are given in Figure 5. The gallium arsenide transmitter had 10 dB lower noise levels at 100 kHz from the carrier, higher output power, higher gain, higher overall system efficiency, and higher reliability than the silicon units. This unit was selected for environmental testing.

TABLE III

DEVICE TYPE	AVERAGE POWER AT f_o (WATTS)	PEAK POWER AT f_o (WATTS)	PEAK OPERATING CURRENT IOP (mA)	INJECTION BAND WIDTH (MHz)	SYSTEM GAIN (dB)	1dB BAND WIDTH (MHz)	NOISE B W (MHz)	SYSTEM EFFICIENCY n_T (%)
HP/5082 0710	40	120	660	228	27 5	161	147	5 6
EDD/ D1010	35	105	510	165	27 5	165	145	6 4
VARIAN	45	134	890	130	33 5	130	130	9 2

Environmental Performance

The GaAs transmitter was placed in a thermal chamber and its performance evaluated over the temperature range 8°C to 55°C. To operate over the full temperature range the unit had to be tuned at 55°C instead of at ambient.

A bandwidth reduction of 35 MHz was observed from room temperature operation for a system gain of 33 dB. Relative P.M. noise levels showed no significant difference from ambient temperature levels. A.M. noise levels less than -90 dBc were measured at high, low and center frequencies of the locking band. Also operation for 60 seconds with no active cooling was demonstrated at soak temperatures of 0°C and 30°C.

The transmitter was subjected to vibration levels of 6.0 g's RMS along all three principal axes of the transmitter. This demonstrated the mechanical integrity of the unit. Relative P.M. noise levels were measured during vibration and a worst case noise increase from -80 dB to -70 dB was encountered 1.0 kHz from the carrier. For all vibration conditions, relative P.M. noise was less than -90 dBc at 5.0 kHz from carrier. A picture of the form factored gallium arsenide transmitter is shown in Figure 6.

Summary

Three Solid State Transmitter designs have been presented which meet severe electrical and environmental system specifications. The GaAs approach was selected to maximize the transmitter efficiency. The system efficiency, for both GaAs and Si configurations, was approximately one half the diode efficiency.

The development of this transmitter clearly represents a major milestone in the history of X-band Solid State transmitters. The application of this design will establish transmitters of this type in a position previously occupied by tube technology.

References

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3. Pfund, G.; Snapp, C. P.; and Podell, A., "Pulsed Double Drift Silicon IMPATT Diodes and Their Application," IEEE Transactions on Microwave Theory and Techniques, volume MTT-22, pp. 1134-1140, December 1974.

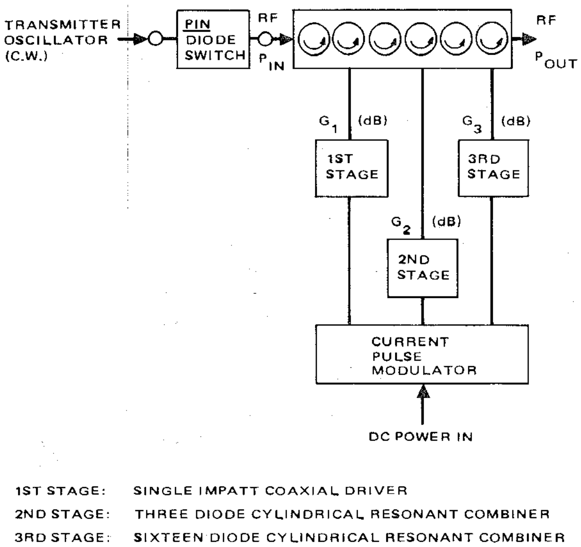

Figure 1

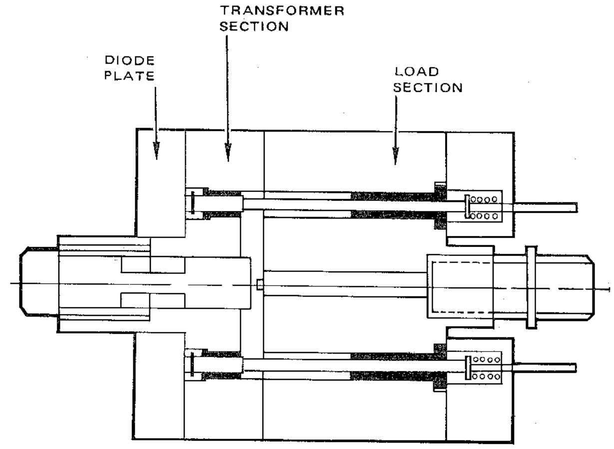

Figure 2: Combiner Cross Section

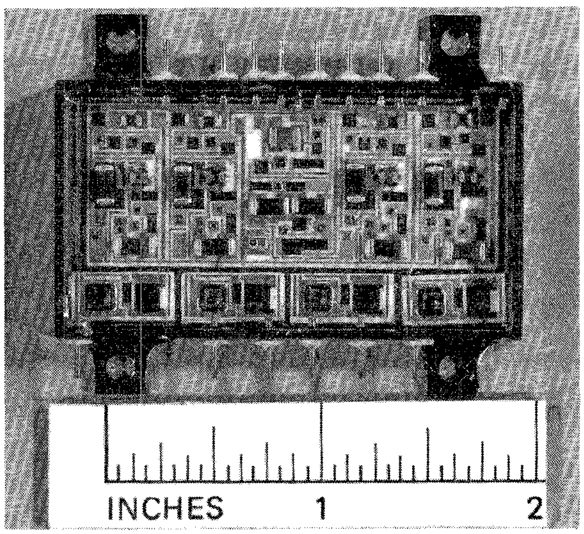

Figure 3. Close up picture of the Hybrid.

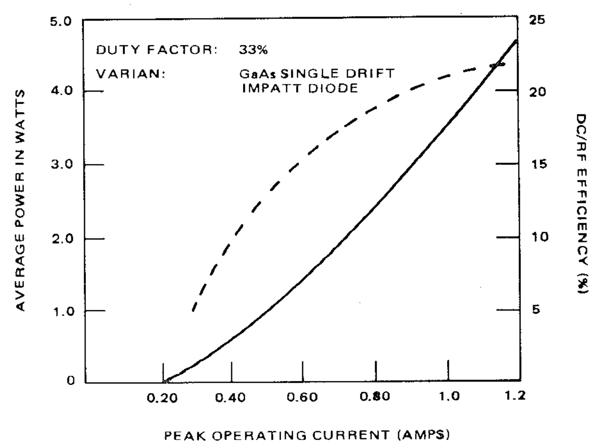

FIGURE 4

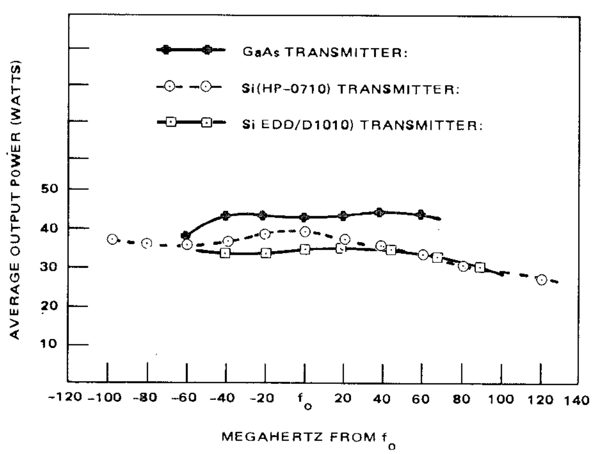

FIGURE 5

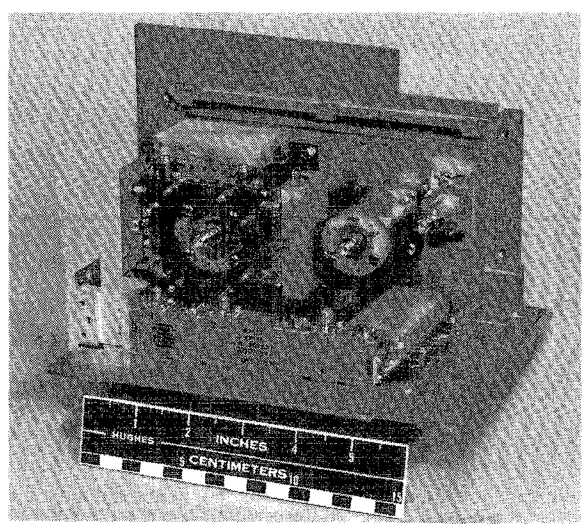

Figure 6. Form Factored X-Band Solid State Transmitter