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GaAs Monolithic RF Modules for SARSAT Distress Beacons

Michael A. Cauley
Lewis Research Center
Cleveland, Ohio

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GaAs MONOLITHIC RF MODULES FOR SARSAT DISTRESS BEACONS

Michael A. Cauley
National Aeronautics and Space Administration
Lewis Research Center
Cleveland, Ohio 44135

SUMMARY

Monolithic GaAs UHF components for use in SARSAT Emergency Distress beacons are under development by Microwave Monolithics, Inc., Simi Valley, CA under SBIR contracts NAS3-25712 and NAS3-25403 for the NASA Lewis Research Center in Cleveland, OH. The components include a bi-phase modulator, driver amplifier, and 5 W power amplifier.

INTRODUCTION

The Search and Rescue Satellite-Aided Tracking (SARSAT) program has been credited with the successful rescue of more than 1700 persons worldwide since the first launch of a satellite in 1982. The SARSAT system is currently comprised of a series of four Soviet and U.S. satellites that continuously monitor several international distress frequencies. All four satellites are polar orbiting and make an accurate position location prediction using the doppler shift of the beacon's transmitted center frequency as the satellite passes over the beacon's area (fig. 1). Using polar orbiting satellites assures true global coverage, but typically requires a 2 hr wait to obtain a valid satellite pass. Near real time notification of beacon activation can be obtained using geostationary satellites, but there is no practical way to obtain a precise position location determination from a geostationary orbit (ref. 1).

The 406 MHz beacon is a self-contained battery operated UHF transmitter containing a digital controller, high stability oscillator, bi-phase modulator, driver amplifier and 5 W power amplifier. The block diagram of a 406 MHz beacon is shown in figure 2. Specifications for 406 beacons are defined in "Specification for COSPAS-SARSAT 406 MHz Distress Beacons" (ref. 2).

Previous 121.5 MHz beacons have serious drawbacks. Most notably the high false alarm rate, lack of beacon identification in the transmission and the continuous transmission of the beacon when activated.

The new 406 MHz system overcomes most of these drawbacks by transmitting a short (approximately 1/2 sec) digitally encoded message once every 50 sec. The message contains information such as type of emergency, unique user identification, and country code. The low transmission duty cycle lowers battery consumption and renders less frequency congestion permitting other activated beacons the opportunity to be received. 406 MHz beacons are still subject to false alarms, but since individual beacons uniquely identify the owner and nature of the emergency in the transmission, false alarms are easier to identify and resolve.

COMPONENTS OF A 406 MHz BEACON

The purpose of this development is to develop low cost RF "modules" for use in 406 MHz SARSAT Emergency Distress beacon transmitters. "Modules" indicate a packaged component subsystem ready for beacon manufacturers to include in their beacon design.

The primary application for the modules are personal locator beacons (PLB) for identifying the location of pleasure boaters, hikers, explorers or other individuals who would benefit from such a device. The modules may also prove valuable to a similar satellite system, called Argos, operating at 401 MHz, which is used for animal tracking.

Cost is a major concern for 406 MHz beacons before widespread market penetration can be achieved. Individuals who desire the improved performance of the 406 system are likely to purchase 406 MHz beacons if the cost were lowered to between \$200 to \$500 each.

While the cost of a GaAs power amplifier is likely to be higher than a comparable silicon based version, the increased efficiency may still lower overall beacon cost through reduced battery capacity requirements, resulting in a smaller battery and hence cost. In order to achieve the long battery shelf life and high energy density, current versions of 406 MHz beacons typically utilize expensive lithium thionyl chloride primary cells. Since the battery must periodically be replaced to assure full capacity, use of a highly efficient power amplifier would lower beacon maintenance costs.

The 406 MHz beacons require a highly stable oscillator that allow a satellite based doppler position location measurement to be made to within 5 km of the actual position. The oscillator must be stable to within 1 part per billion over a 1 min time interval, and operate under battery power for a minimum of 24 hr between -40 and +55 °C. This specification challenges current state of the art in low power oscillators.

The software for a prototype digital controller was designed by NASA using a low cost 80C51 single chip microcontroller (ref. 3). In production quantities, this microcontroller design costs less than five dollars per beacon. Microcontroller technology is mature and would not benefit from GaAs implementation.

In a prior study (ref. 5), three components were identified as ideal candidates for GaAs MMIC implementation; the bi-phase modulator, driver amplifier, and output power amplifier. Performance goals for the three modules are presented in table I. Predictions were made using the MMIC-Spice and MMIC-Spectra software packages.

POWER AMPLIFIER

Current beacons typically use thick film hybrid amplifiers with power added efficiencies of 40 to 45 percent. By utilizing GaAs MMIC's using relaxed geometries, power added efficiencies of nearly 70 percent can be achieved. This increase in efficiency improves overall beacon performance in several ways.

Higher efficiency results in a lower dc current draw for a given output power. This lower current draw significantly decreases the required battery capacity, which in turn significantly decreases the size of the beacon and lowers the battery cost.

Due to higher efficiency and lower current draw for equal output powers, the heat dissipation will be considerably lower. As a secondary effect, the beacon's frequency stability should improve as a result of the lower heat dissipation. Since the beacon transmits in bursts, heat is generated mostly during the transmission times. The resultant heat cycling may overburden the already tight requirements of the high

precision oscillator that determines the transmitted frequency affecting position location accuracy.

The power amplifier design uses two FET devices, the outputs of which are combined using a modified Wilkinson power combiner. The amplifier operates in a switching mode, increasing efficiency and requiring an output filter. When cascaded with the driver module, the predicted overall RF gain increases to 34.1 dB.

During transmitter off times, the FET's are biased to pinch off. Total leakage current for the amplifier is held to below 5 mA at worst case, conserving battery capacity. The low leakage current eliminates the need to turn off the amplifier supply voltage of an activated beacon during transmitter off time.

DRIVER AMPLIFIER

The driver amplifier buffers the low level signal from the output of the modulator and amplifies it to the level needed by the power amplifier. The driver amplifier architecture consists of a two stage FET amplifier providing a predicted gain of approximately 23.0 dB and a predicted output power of 28.5 dBm (710 mW). The FET's operate class "C" as saturated RF switches.

The driver is placed next to the output power amplifier on the wafer permitting evaluation of a single chip driver and power amplifier combination. There is sufficient distance on the wafer between the individual die's to allow for separation into separate chips if desired.

MODULATOR

Development of a standard phase modulator, will improve modulator accuracy, simplify beacon production, and reduce and or eliminate the need to periodically calibrate a beacon's modulator phase deviation. Beacon to beacon phase deviation differences can be more tightly controlled through the use of MMIC technology.

The output of the oscillator is fed directly into the modulator. Digital TTL level inputs from the microcontroller select the appropriate phase angle to be transmitted. The output of the modulator is applied directly to the driver stage.

The phase modulator is required to produce three different phase states. The 0° phase is transmitted as a continuous-wave (CW) signal for the first 160 msec of a transmission, and is used for carrier acquisition in the spacecraft receiver. After the initial CW signal, the coded message is transmitted.

All phase modulator components are located on-chip eliminating the need for periodic phase deviation adjustments. The modulator consists of a resistive power divider feeding two separate phase shifter "T" networks with phase shifts of +1.1 and -1.1 rad respectively. Following the individual phase shifters are slow transition FET RF switches. Phase state transition times are determined by large RC networks and must be greater than 50 μ sec. The transition in phase must be gradual to allow the spacecraft receiver's carrier tracking loop to remain in lock during the transition.

The 0° phase state used at the beginning of the transmission is obtained by applying equal amplitudes of the +1.1 and -1.1 rad signals to the output power combiner. Output amplitude variations are eliminated by the saturated driver amplifier following the modulator.

CONCLUSION

The use of GaAs MMIC's for SARSAT beacon subsystem components can improve the performance, efficiency, and reliability of 406 MHz SARSAT beacons. The bi-phase modulator, driver amplifier and 5 W power amplifier have been identified as ideal candidates for GaAs MMIC implementation.

The development of a highly efficient 5 W power amplifier can significantly lower the battery capacity requirement and lower heat dissipation. The development of a MMIC based bi-phase modulator can improve the accuracy and manufacturability of a SARSAT phase modulator and lower maintenance costs by eliminating the need for periodic phase deviation adjustments. The driver amplifier will provide the gain block necessary to increase the output power level of the modulator to the required level at the input of the power amplifier.

Computer simulations of the three MMIC modules indicate that the performance goals are obtainable.

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3. Ch'en, D.R.; and Petersen, W.C.; High Efficiency Low Cost Monolithic Module for Distress Beacons. NAS3-25403, August 1988.
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TABLE I. - PREDICTED PERFORMANCE GOALS

Power amplifier	
Center operating frequency	406.025 MHz
Output power	5 W±2 dB (into 50 Ω with VSWR <1.25:1)
Input/output impedance	50 Ω
Standby current	<5 mA dc
Operating voltage	9 to 15 V dc
Power gain	11 dB amplifier only 34 dB with driver
Power added efficiency	70 percent (with drain resonators and bias off-chip)
Chip size	4.0 x 2.9 mm
Driver amplifier	
Gain	23.0 dB
Output power	28.5 dBm (710 mW)
Power added efficiency	70 percent (with drain resonators and bias off-chip)
Input/output impedance	50 Ω
Chip size	3.3 x 2.6 mm
Phase modulator	
Center operating frequency	406.025 MHz
Control voltage	TTL compatible
Input/output impedance	50 Ω
Operating voltage	0 V
Operating current	<100 μm
Phase states	0.0 rad
	+1.1 rad (±0.1 rad)
RF Insertion Loss	-1.1 rad (±0.1 rad)
Chip Size	14 dB maximum (varies with phase)
	4.0 x 1.7 mm

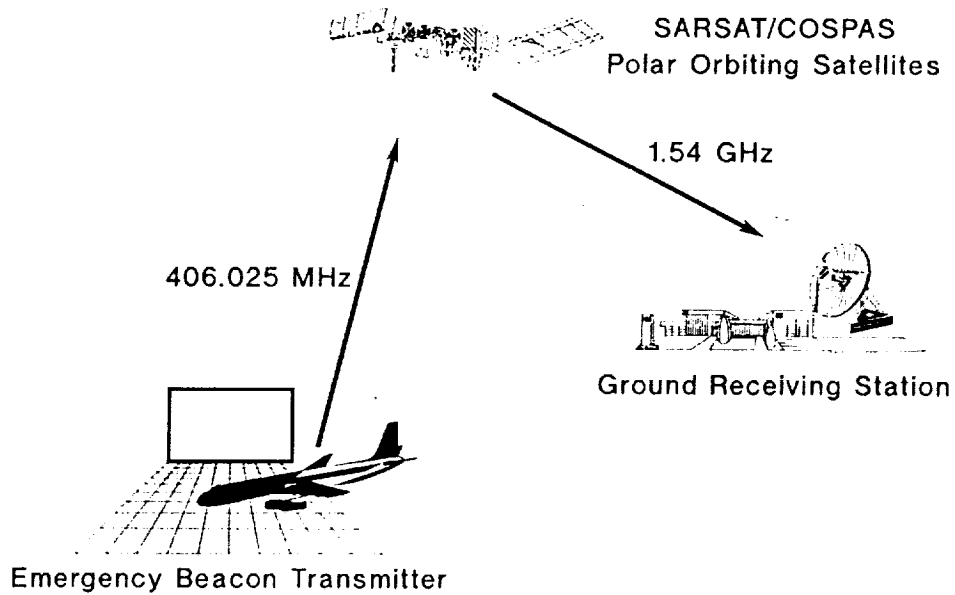


Figure 1.—COSPAS-SARSAT overview.

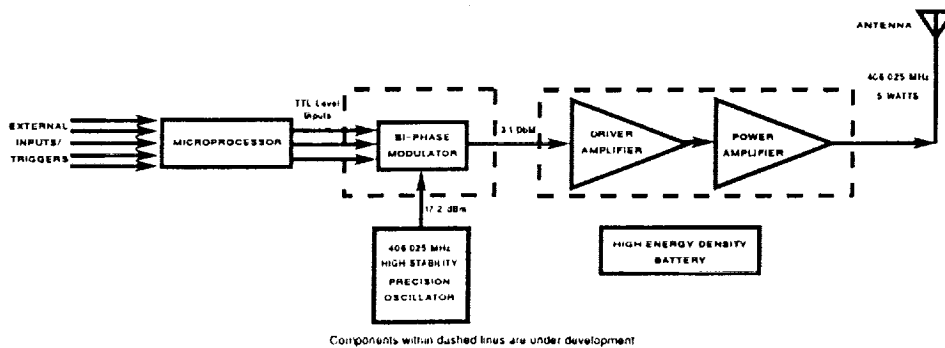


Figure 2.—Block diagram 406 MHz SARSAT beacon transmitter.

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