MINIATURE P-Code GPS TRANSLATOR

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ABSTRACT

A GaAs MMIC chip set and its integration into a P-code GPS translator for use in tracking high speed objects is presented. The translator provides over 125dB of transmission gain with 3.5dB noise figure, occupies 18 cm^3, survives 16,000G mechanical shock and operates from -40 °C to 85 °C.

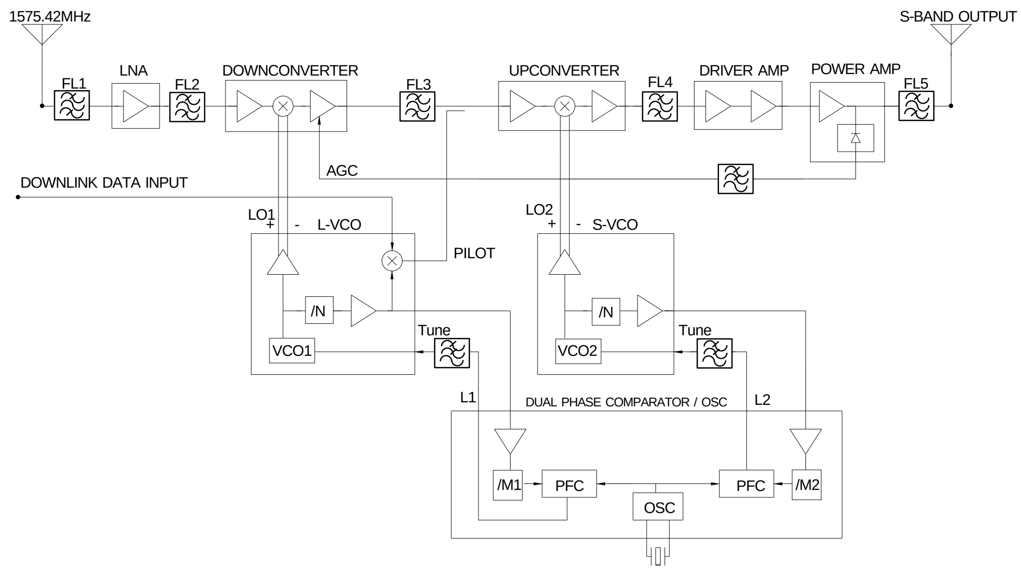
INTRODUCTION

Global Positioning System (GPS) translators for tracking high speed objects at ranges up to 40km are described. In this application, the GPS positioning signals received by a projectile being tracked are relayed to a remote data collection site for processing. The only on-board equipment needed is a frequency translator to generate a new carrier frequency for the GPS data. Equipment built using conventional hybrid circuits technology [1,2] cannot be incorporated in projectiles because of excessive size and cost. However, by developing custom Monolithic Microwave Integrated Circuit (MMIC) chip sets, it is possible to miniaturize translators to fit within projectiles and withstand high acceleration. This paper discusses the smallest and most rugged P-code translator reported to date [3]. It occupies half the volume of our previously reported C/A-code translator [4]. The larger P-code bandwidth required the development of a higher power MMIC chip set. These MMICs are integrated together with ceramic and Surface Acoustic Wave (SAW) filters to realize an 18cm^3 translator which provides over 125dB of transmission gain with 3.5dB noise figure, survives mechanical shock of 16,000G and operates from -40°C to 85°C.

SYSTEM ARCHITECTURE

The translator converts the incoming P-code L1 GPS signals to a higher frequency within the 2200-2290 MHz telemetry band and provides the extremely high amplification required to overcome path loss. The dual conversion translator architecture, shown in Figure 1, was selected due to the high gain of the module and low isolation between transmit and receive antennae. Active circuit functions are performed within the eight MMICs shown while custom ceramic and SAW filters maintain stability and noise figure.

The signal path consists of low noise amplification to establish system noise figure, downconversion to an IF within the VHF band which allows a high selectivity SAW filter to limit noise bandwidth, upconversion to the telemetry band and amplification to the required output power level. Gain variation over temperature is compensated through an AGC leveling loop, consisting of a detector in the output stage of the power amplifier, a low-pass filter and a variable gain IF amplifier in the downconverter. The local oscillators are provided by two phase-locked loops using a common crystal reference oscillator to maintain close-in phase coherence. The master oscillator is stabilized with an AT-cut crystal optimized for ruggedness. A harmonic of the reference forms a pilot signal which allows the translated GPS signals to be acquired by the ground receiver during doppler-, temperature- and shock-induced output frequency shifts. BPSK modulation of the pilot provides a low data rate downlink.



▲ ***Figure 1***. *GPS translator block diagram.*

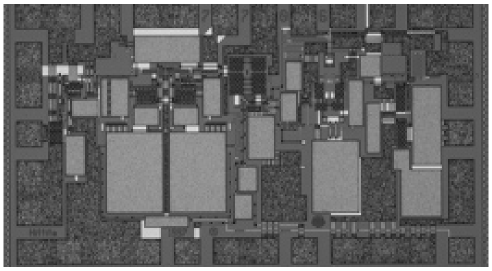
MMICS

Photographs of the custom downconverter, upconverter, driver amplifier, power amplifier, L-band VCO, S-band VCO and phase comparator MMICs are shown in Figure 2. All MMICs, excluding the power amplifier, are fabricated using a standard 1 µm gate-length, enhancement/ depletion GaAs MESFET foundry process. The power amplifier uses a 0.25 µm gate-length, AlGaAs P-HEMT foundry process. A commercial MMIC is used for the LNA. Table 1 summarizes the performance of the custom MMICs, packaged in 10-lead ceramic flat packs.

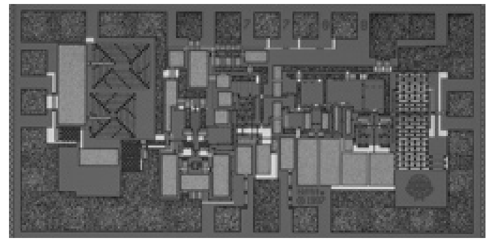
The downconverter consists of a three-stage RF amplifier, a double-balanced Gilbert cell mixer and a six-stage variable gain AGC amplifier. The upconverter includes a four-stage IF amplifier, a double-balanced mixer and a four-stage RF amplifier. The driver amplifier consists of a three-stage pre-amplifier followed by driver and output amplifier stages. The single-bias power amplifier is a common-source configuration with integrated power detector. The VCOs incorporate balanced topologies, thin film resistors and high Q inductors to reduce phase noise. On-chip static dividers provide prescaling. The dual phase-frequency comparator/master oscillator/dual divider chip uses digital phase-frequency designs with integrated charge pumps.

Downconverter	
Conversion Gain	20-70 dB
One dB Output Compression	13 dBm
Noise Figure	7 dB
Input / Output VSWR	<1.1:1
Bias Requirements	70 mA@8V
Upconverter	
Conversion Gain	34 dB
One dB Output Compression	-3 dBm
Noise Figure	10 dB
Input / Output VSWR	<1.8:1
Bias Requirements	80 mA@5V
Driver Amplifier	
Gain	39 dB
One dB Output Compression	23 dBm
Noise Figure	6.5 dB
Input / Output VSWR	<2.8:1
Bias Requirements	400 mA@8V
Power Amplifier	
Gain	12 dB
One dB Output Compression	29 dBm
Noise Figure	5.5 dB
Input / Output VSWR	<2.0:1
Bias Requirements	425 mA@8V
L - Band VCO	
Tuning Range	1.2-1.9 GHz
Output Power	0 dBm (X2)
Data Modulator 3 dB Bandwidth	20 MHz
Bias Reqirements	70mA@5V
S - Band VCO	
Tuning Range	1.8-2.6 GHz
Output Power	0 dBm (X2)
Bias Reqirements	120 mA@5V
Dual Phase-Frequency Comparator Dual Divider/Reference Oscillator	
Phase Comparator Sensitivity	0.3 V/rad
Phase Comparator Noise @1kHz Offset	-115 dBc/Hz
Bias Reqirements	125 mA@5V

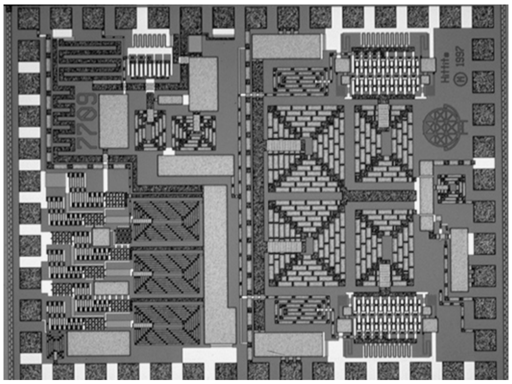
▲ ***Table 1***. *MMIC performance summary (@ 25 ^{o}C).*



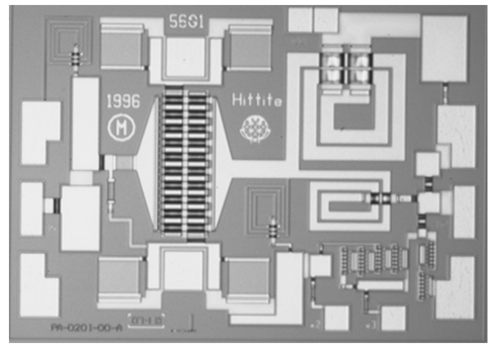
Downconverter



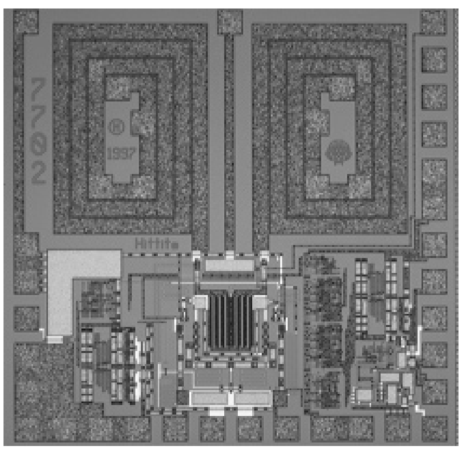
Upconverter



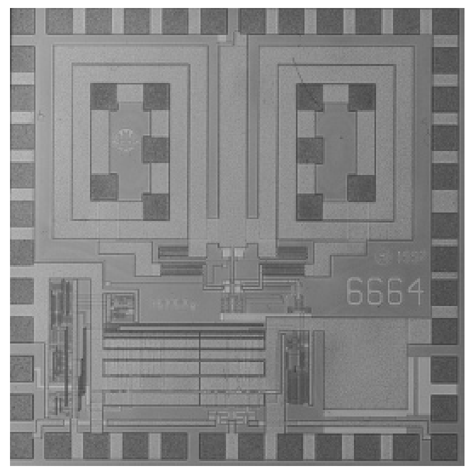
Driver amplifier



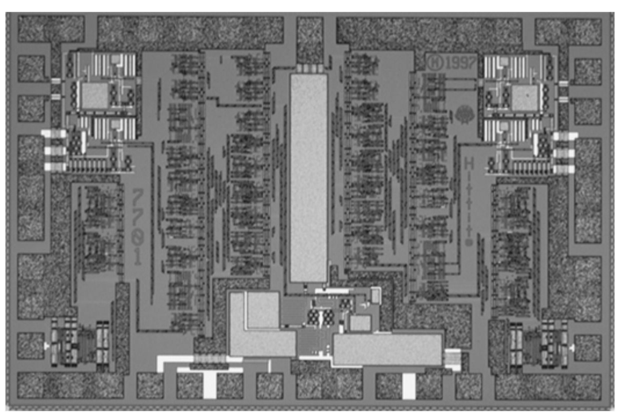
Power amplifier



L-Band VCO



S-Band VCO



Dual Phase-Frequency Comparator/Dual Divider/ Master Oscillator

▲ ***Figure 2**. Photographs of translator MMICs*

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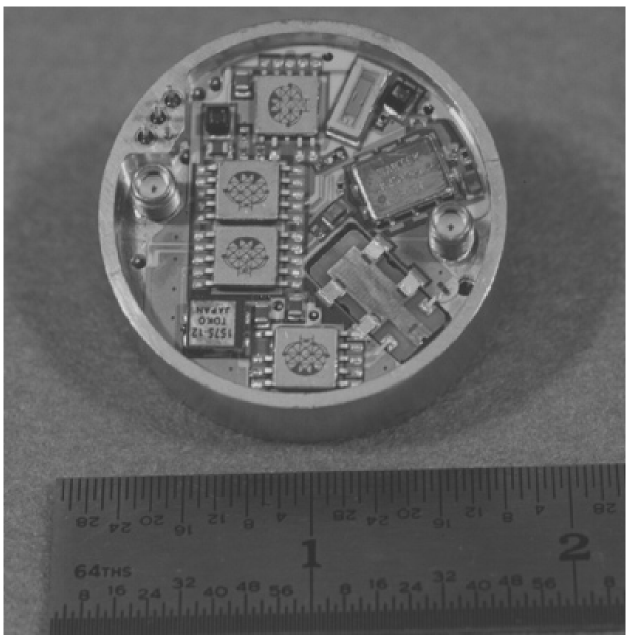
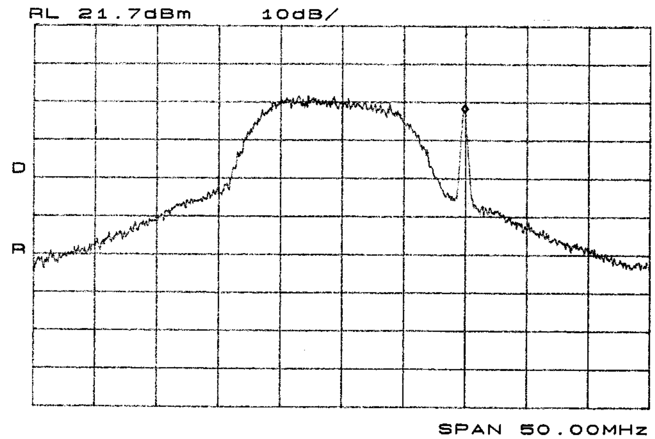
TRANSLATOR ASSEMBLY AND EVALUATION

The translator circuitry is shown in Figure 3. The packaged MMICs, quartz crystal, ceramic filters, SAW filter, capacitors, resistors and inductors are mounted on FR4 circuit boards which are attached to a puck-shaped kovar housing. Feedthroughs interconnect the two back-to-back circuit boards. SSMA jacks provide RF connection to the antennae while feedthroughs connect to the power conditioner. The 85 gram, 4.1cm diameter by 1.3cm high translator withstands a mechanical acceleration of 16,000G.



▲ ***Figure 3***. *Photograph of P-code translator.*

The initial translator prototype module was successfully evaluated over the specified temperature range of -40°C to 85°C. Figure 4 shows the S-band output spectrum at 85°C. The 20MHz wide P-code L1 signal is truncated to reduce output power requirements. Pass band ripple does not exceed ±1 dB over the extended temperature range. The pilot signal, offset from the GPS signal, is used by the remote processor to acquire the translated GPS spectrum. Power consumption at room temperature is 8.7W.



▲ ***Figure 4***. *Translator output spectrum @85 °C.*

DISCUSSION AND CONCLUSION

Seven different MMIC circuits were designed, fabricated, and evaluated. These were used in the fabrication of a miniature P-code translator, together with a MMIC LNA, custom filters, crystal, circuit boards, and other hardwareand components. This $18cm^3$ module is the first reported to fit within such a small envelope, survive 16,000G mechanical shock and successfully translate wideband GPS signals over a -40° C to 85°C operating temperature range.

ACKNOWLEDGMENTS

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