AN ULTRAMINIATURE 2 TO 18 GHz MMIC RF CONVERTER FOR EW APPLICATIONS

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ABSTRACT

Advances in gallium-arsenide (GaAs) monolithic microwave integrated circuits (MMIC's), miniature microwave filter technology, and planar microwave interconnection technology have made possible dramatic reductions in the size and weight of complex radio frequency (RF) modules. These technologies have been utilized in the design and implementation of a 2 to 18 GHz miniature, MMIC-based, RF converter line replaceable module (LRM) for EW applications. The converter, packaged in a standard electronic module (SEM-E) housing measuring only 5.88 in. x 6.68 in. x 0.685 in., represents an approximate 5:1 reduction in size compared to an equivalent MIC version. A detailed discussion of the RF converter design is presented, along with measured performance data. The results are believed to be the first reported for a MMIC-based converter of this type, packaged in SEM-E format.

INTRODUCTION

Modern receivers for Electronic Warfare (EW) interferometer applications generally utilize multiple-broadband, high-sensitivity, high-dynamic range, RF converters. The RF converters of such systems are among the most critical subassemblies, since both dynamic range and sensitivity are greatly influenced by their performance. Additionally, phase and amplitude tracking between RF converters is necessary to accurately determine angle or direction of arrival (AOA, DOA) data, as channel-to-channel imbalances degrade the system's direction finding (DF) accuracy. Although minor imbalances can be corrected through calibration, DF accuracy is enhanced if the channels closely track. Significant advances in device and MMIC technology have enabled the realization of these systems, which occupy as little as one-tenth the volume of conventional implementations.

The converters were designed for use in a two–channel interferometer system. The use of MMIC's and quasi-MMIC's was maximized so that the performance, uniformity, and cost advantages offered by this technology could be fully exploited (1). A 5:1 size reduction compared to a conventional MIC implementation was achieved.

The converters have a minimum single signal dynamic range of 45 dB over an instantaneous bandwidth of 500 MHz. The nominal gain of the LRM is 13 dB and is variable over a 12 dB range in 0.25 dB increments which permits channel balancing during system calibration. The uncalibrated converters achieved ±1.9 dB rms amplitude balance and ±13 degrees rms phase tracking. The converter noise figure is 8.5 dB at 6 GHz and increases linearly to 12.8 dB at 18 GHz.

FUNCTIONAL DESCRIPTION

The RF converter serves as a low-noise, high-dynamic range interface between the system's antennas and intermediate frequency (IF) processor, over a wide instantaneous bandwidth. The converter also plays a key role in establishing the sensitivity and signal handling capability of the receiver. A block diagram of the RF converter module is presented in Figure 1. Note that the high- and low-band preselectors are packaged in a separate SEM-E housing.

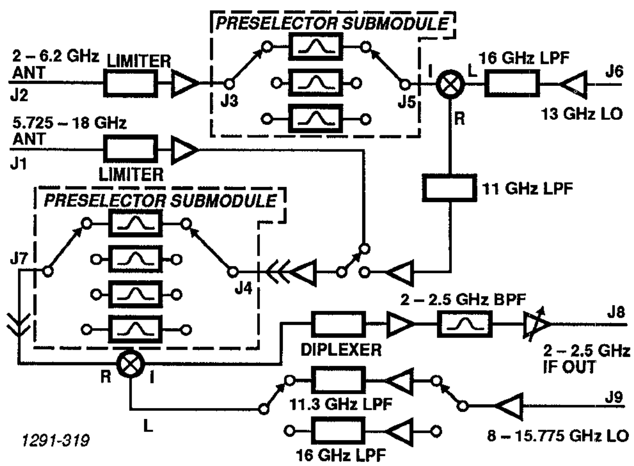

Figure 1. RF Converter Functional Block Diagram

The 2 to 18 GHz input range is divided into two bands: a low band that covers the 2 to 6.2 GHz range and a high band which covers the 6.2 to 18 GHz range. The 2 to 6.2 GHz input is preamplified and passed to the low band preselector where it is divided into three overlapping bands. The output of the preselector is then routed back to the converter where it is upconverted into the high band via a fixed LO centered at 13 GHz. The 6.2 to 18 GHz input is preamplified and routed to the high band preselector where it is divided into four overlapping bands. The preselector output is then directed back into the converter where it is downconverted to the 2.0 to 2.5 GHz IF frequency range in 500 MHz wide overlapping segments. A variable gain

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stage is included in the IF portion of the converter so that the gain of each channel in the system can be equalized at the IF band center during system calibration thereby improving the accuracy of DF measurements.

The control portion of the converter utilizes the 11 most significant bits (MSB's) contained in a 32–bit serial command stream. The control word is received by a programmable logical cell array (LCA) where it is decoded into the desired parallel words required by the converter.

CONVERTER DESCRIPTION/IMPLEMENTATION

A photograph of the RF portion of the converter LRM is presented in Figure 2. The converter is packaged in a SEM-E compatible housing that measures 5.58 in. x 6.68 in. x 0.685 in. and weighs 1.7 lb. The RF portion of the converter is partitioned into 11 multifunction RF modules. The modules are interconnected via channelized microstrip transmission line that is fabricated on RT-Duriod 6006 material. The channelized structure provides a high-isolation, low-loss interconnection medium for the converter. High-frequency slide-on connectors are utilized to terminate the RF interconnections thus enabling the converter to blindmate to the receiver's RF backplane.

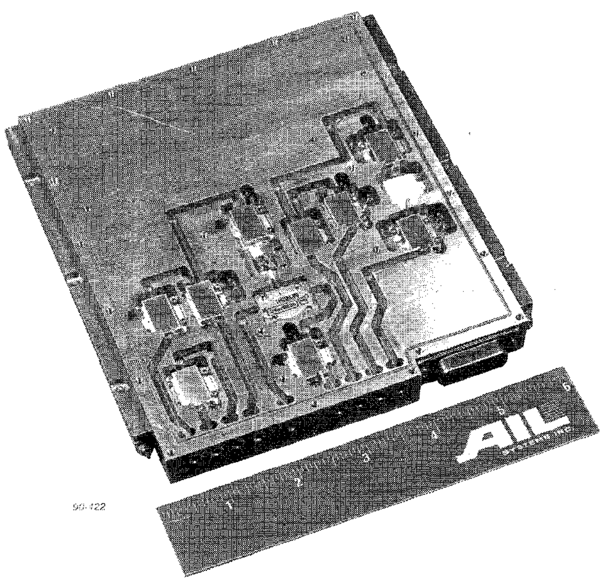

Figure 2. RF Converter Isometric View (Near Side)

The 11 RF modules contain numerous MMIC's and QMMIC's housed in drop-in packages. A photograph of an 8 to 16 GHz switched power amplifier module is presented in Figure 3 and is representative of the design approach utilized in all other modules. All QMMIC components utilize semi-insulating GaAs substrate material and conventional MMIC processing techniques to realize passive components (i.e., MIM capacitors, spiral inductors, and thin-film resistors). Discrete active devices are attached to the substrate and wire bonded to the circuits. This technique offers the advantage that devices which outperform those offered by standard MMIC processes can be integrated into the circuit to achieve superior performance.

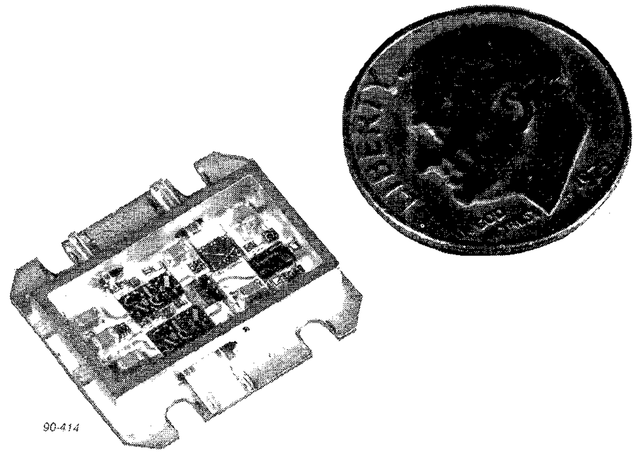

Figure 3. 8 to 16 GHz Switched LO Power Amplifier Module

For example, a QMMIC 6 to 18 GHz doubly balanced mixer which downconverts the 6 to 18 GHz RF input band to the 2.0 to 2.5 GHz IF was designed and fabricated using this technique. The mixer achieves a maximum of 10 dB conversion loss over the entire band, and is approximately three times smaller than its MIC equivalent. As another example, the low noise preamplifier in the 2 to 6 GHz band (2), provides 7 dB gain with a maximum noise figure of 3.3 dB at 25° C. This noise figure is approximately 2 dB lower than that currently available with commercial MMIC chips.

The converter also contains several miniature thin-film filters fabricated on fused silica. These filters provide rejection of harmonics from the local oscillator (LO) power amplifiers connected to both the upconverting and downconverting mixers. The filters were designed using a semilumped element approach to minimize size and are approximately five times smaller than their distributed equivalents.

The heart of the control circuitry is a programmable LCA. The LCA converts the serial word received from the system into the required parallel words. The LCA also interfaces to a digital-to-analog (D/A) converter which is used to adjust the gain of the converter in 0.25 dB increments over a 12 dB range. The control circuits are interconnected by a multiwire interface board. Power management and voltage sequencing are provided by a TTL-controlled sequenceable HEXFET regulator circuit.

Electromagnetic interference (EMI) and electromagnetic compatibility (EMC) issues were addressed by providing EMI filtering of control and power lines, as well as EMI gasketing of the housing assembly. Additionally, RF and digital portions of the converter are isolated from each other to prevent false triggering of control circuits.

PERFORMANCE

A summary of the key performance parameters is presented in Table 1. The converters have a nominal gain of 13 dB which is controllable over ±6 dB in 0.25 dB increments via the IF variable gain stage. The gain was maintained to within ±3 dB flatness over the 4.5 to 18 GHz range. The lower band edge had to be restricted to 4.5 GHz to eliminate certain spurious interference. Subsequent converter units will include an additional filter network (unavailable at the time of testing) which will allow full coverage down to 2 GHz. The voltage standing wave ratio (VSWR) on all ports was less than 2.3:1 and was typically less than 2.0:1. The VSWR of the converter was slightly degraded by the unoptimized coax-to-microstrip transition provided by the blindmate RF connectors. This transition limited the VSWR to approximately 1.9:1 in specific segments of the operating band. When integrated with the preselector assembly, the converters achieved a minimum 45 dB single signal dynamic range. The minimum spurious free dynamic range was approximately 40 dB and is typically 45 dB over most of the band. The 40 dB limitation is mainly due to second harmonic distortion which is present over a small portion of the spectrum.

Table 1. RF Converter Key Performance

Parameter	Performance
RF Input Frequency	4.5 – 18.0 GHz
IF Output Frequency	2.0 – 2.50 GHz
Instantaneous Bandwidth	500 MHz
VSWR (all ports)	2.3:1, max
Nominal Gain	13 dB
Gain Control	±6 dB in 0.25 dB increments
Gain Flatness	±3 dB, max.
Noise Figure	13 dB, max
Single Signal Dynamic Range	45 dB, min
Spur–free Dynamic Range	40 dB, min
DC Power Consumption	20 W, max

The amplitude and phase tracking data for the 6 to 14 GHz band is presented in Figure 4. The two converters achieved ±1.9 dB rms amplitude tracking and ±13 degrees rms tracking. Similar performance was achieved for the 10 to 18 GHz range.

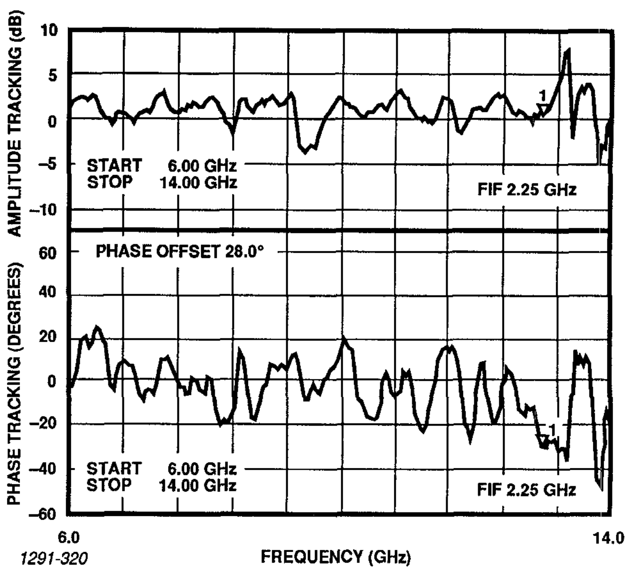

Figure 4. RF Converter Measured Amplitude and Phase Tracking

The noise figure is approximately 8.5 dB at 6 GHz and rises linearly to approximately 12.8 dB at 18 GHz. A 10 dB pad was placed in the path to simulate the loss of the preselector unit which was unavailable at the time this test was performed.

CONCLUSIONS AND SUMMARY

A MMIC-based RF converter was developed which with the addition of a filter network operates over the 2 to 18 GHz frequency band. The converter is packaged in a SEM-E housing that blindmates to the receiver's backplane. The RF portion of the converter is partitioned into 11 multifunction hybrid modules that contain the various MMIC and QMMIC circuits. The modules are packaged in hermetic, drop-in packages. Unique QMMIC-based circuitry is utilized to achieve superior performance compared to commercially available MMIC devices.

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