A 6.8-10.7 GHz EW MODULE USING 72 MMICs

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ABSTRACT

A dual 6.8-10.7 GHz receive/transmit module with synthesized local oscillators (LOs) has been developed. The use of 72 MMICs allows this complex module to be implemented in a small, light weight package suitable for use in airborne systems. This module is combined with receive and transmit block converter modules to build a 2-18 GHz electronic warfare system.

INTRODUCTION

Many electronic warfare (EW) systems require a high performance front/back end covering all or part of the 2-18 GHz band. Electronic countermeasures systems, radar warning receivers, unmanned vehicles, decoys, expendables, and a variety of other EW systems and platforms are placing increasingly stringent requirements on the size, weight, power consumption, and reliability of the front end. An effective method of meeting these requirements is to make extensive use of MMICs to allow packaging of major sections of the front/back end in each of a small number of MIC modules. This can provide a significant savings in space otherwise required for connectorization and mounting hardware, in addition to the space saved by using the inherently smaller MMIC chips themselves. Several state-of-the-art MIC modules, with up to 100 MMICs per module, were designed and fabricated using this approach. These modules can be combined to meet various EW system front/back end requirements. The MIC/MMIC module discussed in this paper was designed to form a high performance core component for these systems.

SYSTEM OVERVIEW

Figure 1 presents the block diagram of one potential EW system front/back end. Any input signal in the 2-18 GHz band can be converted to a 700 MHz intermediate frequency (IF) where a variety of signal processing techniques may be efficiently applied. The signal can then be reconverted up in frequency for transmission. In the implementation shown, blocks of frequencies in the 2-18 GHz input band are first converted to a common 6.8-10.7 GHz band in a block converter module. The Agile Receive/Transmit Module (ARTM) then provides conversion between the 6.8-10.7 GHz band and the 700 MHz IF. The only variable frequency LO required in this scheme is the 1st LO in the ARTM module. Fast tuning is provided by the use of a high speed synthesizer for this LO. The MMIC based ARTM module, pictured in Figure 2, is the subject of this paper.

AGILE RECEIVE/TRANSMIT MODULE ARCHITECTURE

The ARTM includes dual converted receive and transmit chains, LO distribution chains, and the microwave portion of the frequency synthesizer which is used as the tunable first LO. The 19.1-23 GHz output from this synthesizer tunes the desired frequency from the 6.8-10.7 GHz RF input band into the 12.3 GHz 1st IF. The 12.3 GHz 1st IF is converted down to the 700 MHz 2nd IF with the use of a fixed 13 GHz 2nd LO. This conversion sequence is reversed in the transmit chain. High speed phase locking circuits allow the synthesizer to tune for the desired signal in under 5 microseconds.

As shown in Figure 1, the 19.1-23 GHz synthesizer output is generated from the doubled output of a voltage controlled oscillator (VCO) which can be phase locked to a 48-78 MHz direct digital synthesizer (DDS) or other suitable reference. To translate the doubled VCO output down in frequency for phase locking, the 19.1-23 GHz band is first converted to a 6.1-10 GHz band by mixing with the same 13 GHz input used for the 2nd LO in the receive and transmit chains. The 6.1-10 GHz band is then divided down to a 762-1250 MHz band using a divide-by-8 MMIC frequency divider. This 762-1250 MHz synthesizer IF is then divided down to the reference frequency using an external divider. Differing external components and reference sources can be used as required to provide the desired phase noise and close-in spurious characteristics.

The architecture of the ARTM was selected to allow module size to be kept to a minimum while providing excellent performance in all key areas. The selected frequency translation scheme uses relatively high LO and IF frequencies to keep the filters small, while avoiding requirements for a tunable preselector or switched filter bank at the input. High isolations between the receive and transmit chains are achieved using simple filters in the LO paths due to the separation of the RF and IF frequencies from the LO frequencies. Selection of the conversion scheme in the receive and transmit chains was heavily based on keeping the higher level mixer single tone spurious products out of the IF bands and on minimizing LO leakages. Amplifiers and other components were selected and positioned in the RF chains to maximize dynamic range while minimizing power consumption.

An important feature of the ARTM architecture results from the use of the 13 GHz input as both the 2nd LO and as a source in the synthesizer down converter. Injection of the 13 GHz signal into the synthesizer converter causes the frequency stability characteristics of this signal to be superimposed on the 19.1-23 GHz 1st LO under phase locked conditions. These characteristics are therefore injected into both mixers of the dual conversion receive (or transmit) chain, but with phasing that results largely in cancellation. This scheme allows the frequency stability of the received and transmitted signals to be much

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better than that of the 13 GHz source itself. Figure 3 shows a comparison of the frequency stability of the received signal versus the frequency stability of the source used as the 13 GHz input. For this test a high stability 7.1 GHz signal was input at the receive side RF port of the ARTM and the converted output was viewed at the 700 MHz 2nd IF.

MODULE CONSTRUCTION - DUAL ARTM

The MIC/MMIC circuits comprising one ARTM are all located on the visible face of the housing shown in Figure 2. The back face of the housing is identical to the front face so that two ARTMs are available in the 4.6"x3.9"x0.9" package. The housing is machined from aluminum and incorporates soldered hermetic feedthru pins and laser welded covers to provide hermeticity. Field replaceable SSMA connectors were used on the RF ports to reduce connectorization area.

There are a total of 72 MMICs and 28 filters in the two sided module. MMICs and other active components are mounted on screwed down carrier plates for repairability while filters and interconnects are attached directly to the housing with flexible epoxy. Voltage regulators are included in the module to protect the MMICs from supply transients and to keep VCO pushing low. Filters were fabricated on alumina except for the narrowband 12.3 GHz IF filter. This filter was fabricated on a temperature stable ceramic and exhibited under 3 MHz drift in center frequency between +25°C and +95°C versus the 53 MHz drift measured for the same filter on 99.6% pure alumina.

A typical MMIC carrier assembly used in the module is shown in Figure 4. This 7 MMIC assembly is the 19.1-23 GHz source used in the synthesizer. The 19.1-23 GHz output is obtained by doubling the output from a 9.5-11.5 GHz MMIC VCO. Doubling is accomplished by mixing the VCO output with itself.

A number of MMICs were designed for use in the ARTM including the VCO, mixer, 19-23 GHz amplifier, and power splitter chips used on the assembly shown in Figure 4. The VCO MMIC provides negative resistance over a 9-16 GHz band. An external varactor/inductor tank circuit is used to tune the 9.5-11.5 GHz band required for this application. The 19-23 GHz amplifier provides 9 dB of gain and over 16 dBm of saturated output power. The mixer is a double balanced passive design with an 8-23 GHz RF band and a 0-11 GHz I.F. band. Mixer conversion loss averages about 9 dB. This mixer is also used for conversion between the 6.8-10.7 GHz RF band and the 12.3 GHz IF in the receive and transmit chains. The 2-way passive power splitter MMIC exhibits 1.5-2 dB insertion loss, 14 dB output port isolation, 0.3 dB amplitude tracking, and 7.5° phase tracking from 6 to 20 GHz.

In addition to reducing size, simplifying assembly, enhancing reliability, and reducing power consumption, the use of MMICs also results in improved RF performance. In mixers, the excellent balance and reduced parasitics of the MMIC implementation reduce the level of single tone spurious products and the level of LO leakages[1]. In the development of high frequency VCOs, wider tuning bands can be achieved using MMIC technology due to the elimination of critical bond wire parasitics. This was exhibited in the parallel development of MMIC and discrete fundamental 19-23 GHz VCOs to replace the VCO/doubler assembly in the ARTM. The MMIC VCO was able to tune 18.6-25.5 GHz, about twice the band of the discrete VCO, when both used the same varactor/inductor tank circuit.

MEASURED PERFORMANCE

The receive side response of the ARTM is shown in Figure 5, with the 1st LO tuned to several discrete frequencies. The bandpass response exhibited in this figure is determined by the 12.3 GHz IF filter which has a 3 dB bandwidth of 320 MHz. If desired, a narrowband filter may be added at the 700 MHz 2nd IF port to provide greater selectivity or reduce total noise power.

The transmit side response of the ARTM is shown in Figure 6. A 700 MHz input signal is tuned across the 6.8-10.7 GHz band at the transmit side output by sweeping the 1st LO across its band.

Table 1 shows additional measured ARTM performance.

Parameter	Measured
Receive Side Gain	5–8 dB
Transmit Side Gain	2–5 dB
IF Bandwidth	320 MHz
Noise Figure–Receive	18.5–20.5 dB
Single Tone Spurious–Receive (–5 dBm in)	–60 dBc
OIP_3 (Two Tone)–Receive	15 dBm
LO Leakage to RF Output	–74 dBm Max
RF In to RF Out Isolation	70 dB
Size	4.6"x3.9"x0.9"
Weight	1.1 Lbs
Power Consumption	22 Watts

Table 1. ARTM Measured Performance

CONCLUSION

The design and measured performance of a dual Agile Receive/Transmit Module suitable for use in an EW front/back end has been presented. The use of 72 MMICs allows this complex module to be implemented with the small size and weight needed for airborne systems, while providing high dynamic range and fast tuning. Use of a synthesized 1st LO along with a LO cancellation scheme provides excellent frequency stability and low phase noise.

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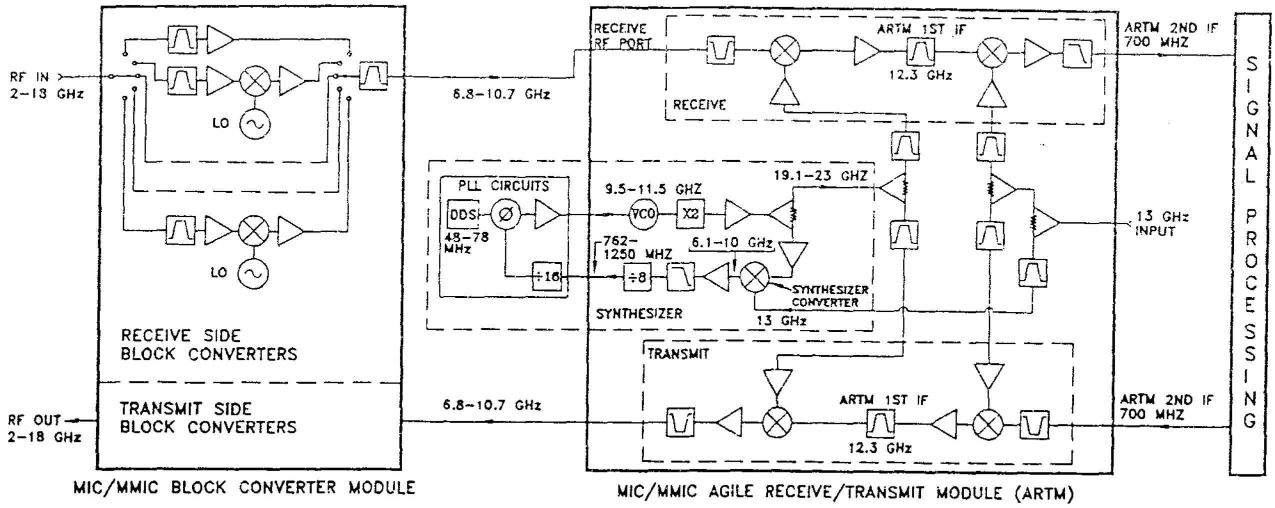

Figure 1. EW System Front/Back End Block Diagram

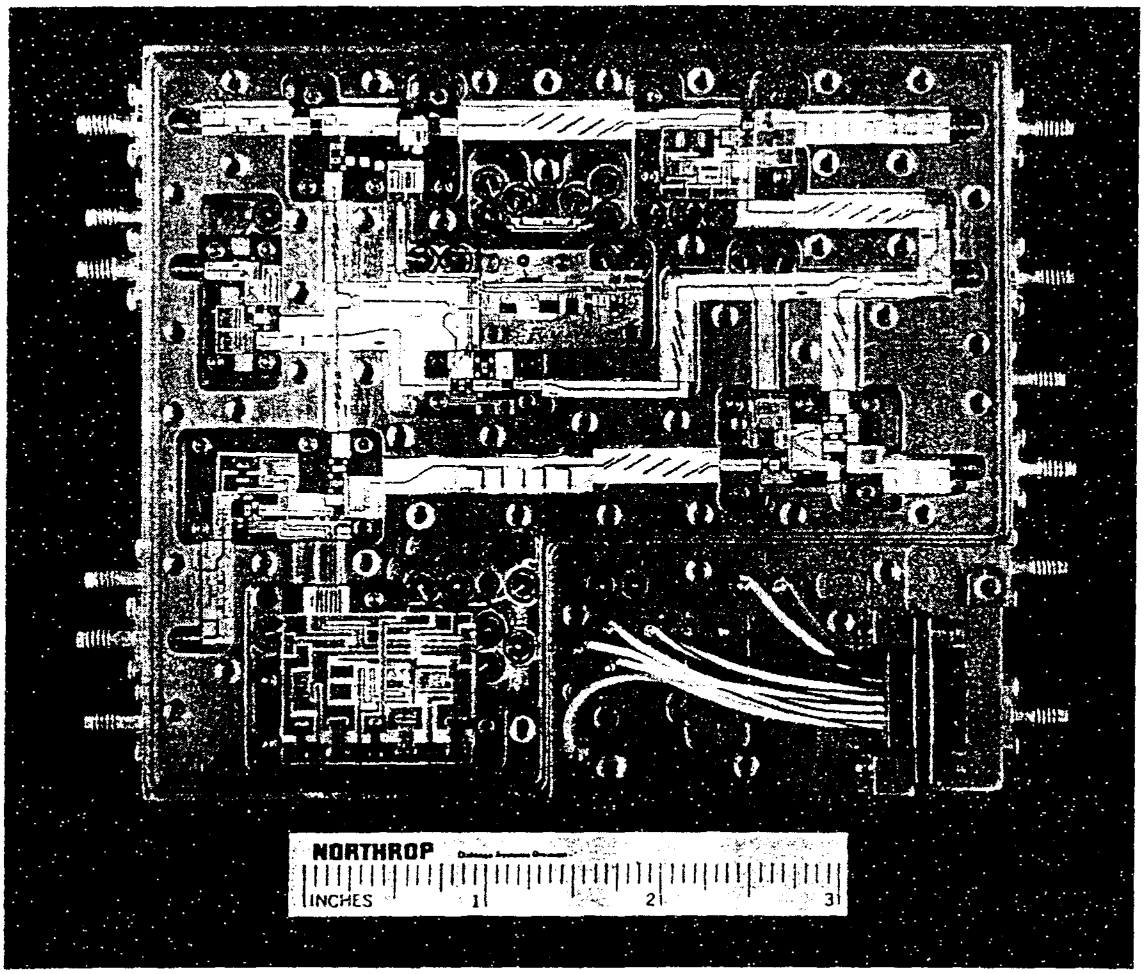

Figure 2. Agile Receive/Transmit Module (ARTM)

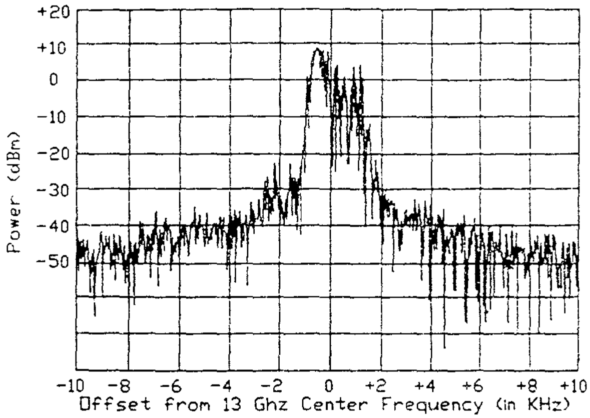

Figure 3A. Noisy Signal Used as the 13 GHz Input to the 2nd LO & to the Synthesizer Converter.

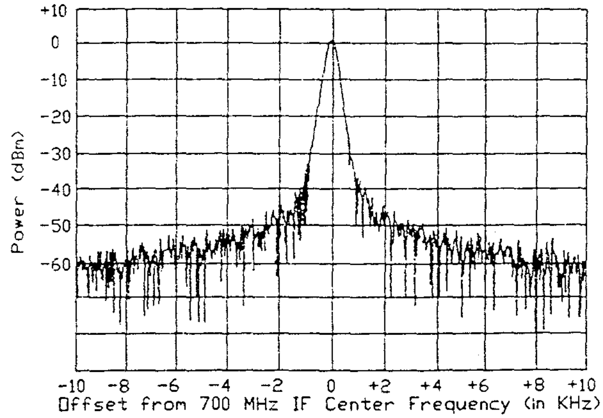

Figure 3B. Received Signal Frequency Stability when the Signal Shown in Figure 3A is used as the 13 GHz Input.

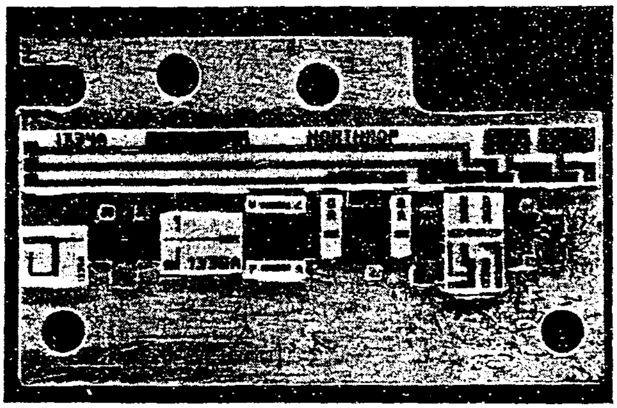

Figure 4A. VCO/Doubler Carrier Assembly

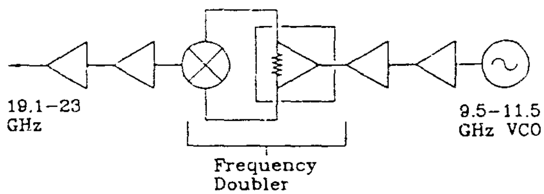

Figure 4B. VCO/Doubler Carrier Assembly Block Diagram

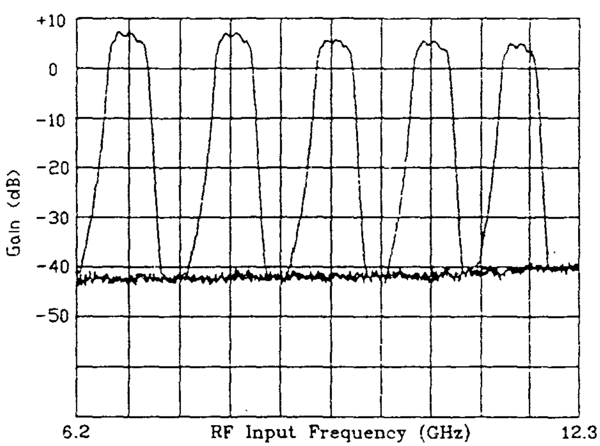

Figure 5. ARTM Receive Side Response

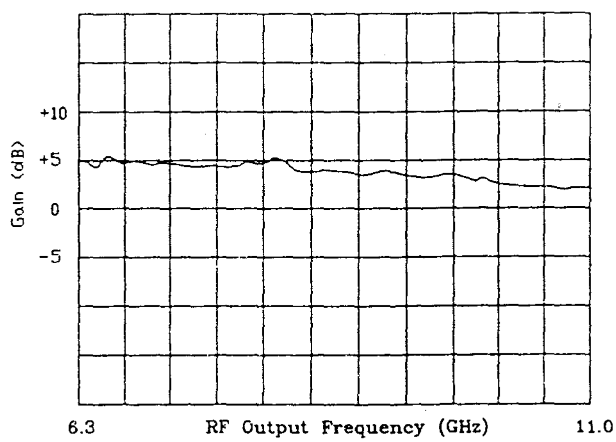

Figure 6. ARTM Transmit Side Response