ELEVEN OCTAVE MMIC BASED STIMULUS MODULE FOR LIGHTWEIGHT SYSTEMS

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ABSTRACT

A compact RF and microwave stimulus module for broadband applications has been developed. The module covers a frequency bandwidth of 1800:1, slightly less than 11 octaves. The unit exhibits excellent rejection of unwanted signals, while providing leveled power output, automatic gain control, amplitude and square-wave modulation, and self-test features. This lightweight integrated multi-function package is efficient, reliable, and reproducible.

INTRODUCTION

This paper describes a stimulus module for electronic countermeasures (ECM) and portable test equipment applications. A stimulus module processes signals from a swept source such as a YIG tuned oscillator (YTO). In this case the YTO provides coverage from 4 to 18 GHz with substantial harmonic content. Using band-switching and frequency conversion, the output frequency range is extended from 10 MHz to 18 GHz and harmonics are suppressed. This type of module thus becomes the "heart" of systems where very broad swept frequency range is required.

All of the circuitry is contained in a 30 cubic inch laser sealed module. The unit operates over a temperature range of -40 to +85 degrees centigrade. A photograph of the stimulus module is shown in Figure 1. Compact packaging has been achieved by extensive use of monolithic microwave integrated circuit (MMIC) chips in conjunction with microwave integrated circuit (MIC) compatible components. It is presently used in a portable test system which demonstrates considerable weight and size reduction when compared with older technology.

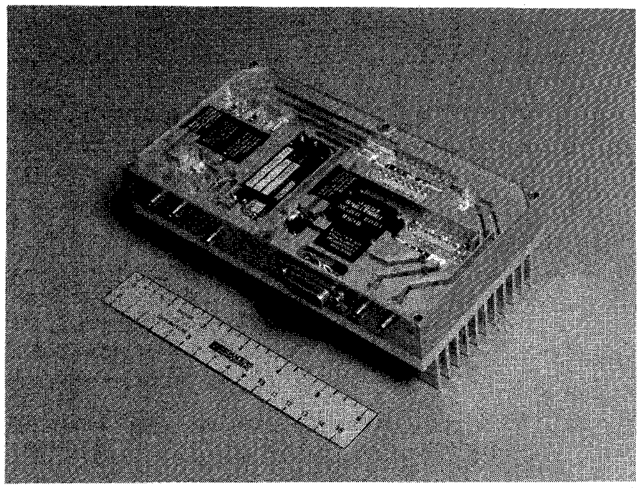

FIGURE 1. STIMULUS MODULE

CIRCUIT TOPOLOGY AND PERFORMANCE

The circuit topology is shown in Figure 2.

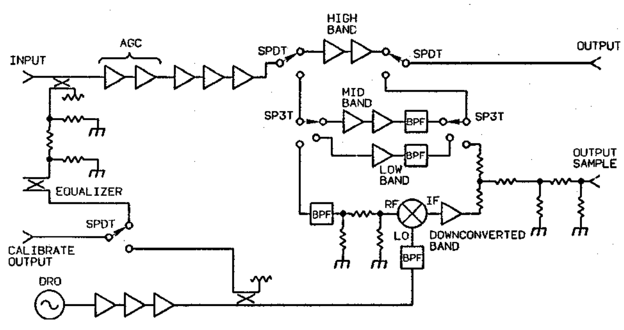

FIGURE 2. STIMULUS BLOCK DIAGRAM

The input common amplifier path provides amplification, AGC and variable attenuation. The signal is then directed to a choice of four channels that are selected by GaAs MMIC switches. Figure 3 shows a layout of these amplifier stages followed by cascaded SPDT and SP3T switches.

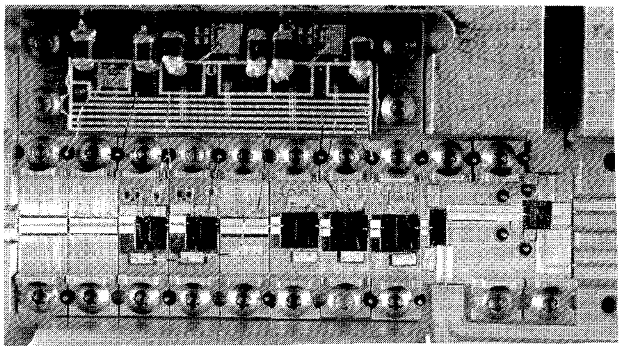

FIGURE 3. INPUT MMIC STAGES

There are three direct channels, each less than an octave in bandwidth. All channels provide amplification of the selected range of frequencies followed by filtering to reject harmonics from the source. These three frequency bands are 10 GHz to 18 GHz (high band), 6 GHz to 10 GHz (mid band), and 4 GHz to 6 GHz (low band). The fourth channel's output is developed by means of a downconverter to extend the range of frequencies from 10 MHz to 4 GHz.

The downconverter path consists of a dielectric resonator oscillator (DRO) followed by a MMIC amplifier chain to develop the power required for a mixer. The DRO delivers + 5 dBm prior to MMIC amplification. Figure 4 shows a plot of the DRO SSB phase noise spectral density versus offset frequency.

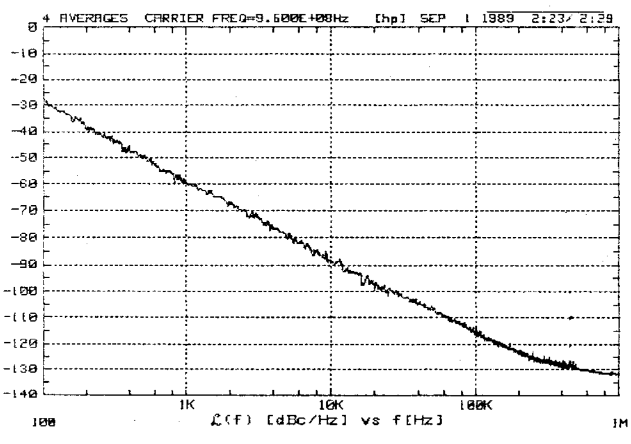

FIGURE 4. DRO PHASE NOISE

Measured frequency stability of the DRO is better than 1.5 parts per million (ppm) per degree centigrade. Frequency conversion is accomplished via a high level double-balanced mixer to provide frequency coverage from 10 MHz to 4 GHz. In order to minimize spurious products over the wide IF band from the mixer, the selected local oscillator frequency is above 11 GHz. A spurious analysis shows that the worse case m x n spurious response is -2RF + 3LO. This spur, however, is in excess of -50 dBc.

Any of the four paths can be selected using GaAs FET MMIC switches. At the common output port power is leveled within ±1 dB from 10 MHz to 18 GHz. The maximum leveled output power available is +16 dBm. The adjustable range is greater than 27 dB. The output power level is controlled by the AGC amplifiers in the common gain path. The output signal has greater than 35 dB harmonic rejection. Spurious signals are lower than -50 dBc.

Figure 5 shows the output section of the module including MMIC amplifiers, bandpass filters, MMIC switches, and a 10 to 4000 MHz power splitter. Two secondary outputs are provided which are used for frequency calibration of the YIG oscillator and leveling of the 10 MHz to 4 GHz signal. The path selection and modulation functions are controlled by a TTL compatible hybrid silicon switch driver assembly. The switching speed is typically less than 120 nanoseconds. Voltage regulation, polarity protection, and power supply sequencing for the GaAs FET amplifiers is provided by three identical hybrid voltage regulator assemblies. These are depicted in Figure 3.

CONSTITUENTS

The stimulus module incorporates a total of 18 GaAs MMIC chips. There are five distributed amplifiers using 200 μm FETs in a six-stage construction. In addition, four 6-section x 300 μm distributed amplifiers, and three 4-section x 200 μm variable gain distributed amplifiers are employed. All chips were manufactured at Lockheed Sanders.

Band switching is performed by two SPDT reflective switches, one SP3T reflective switch, and one SPDT non-reflective switch. Successful integration of the MMIC subassemblies is enhanced because all amplifier gain stages are fully RF tested on-wafer prior to dicing.

Other miniature MIC components that compliment the MMICs include 4 microstrip compatible mechanical interdigital filters, a microstrip compatible double balanced mixer, the extremely stable DRO discussed previously, a resistive power splitter, a directional coupler, a Lange coupler utilizing air-bridge technology, an equalizer circuit and a drop-in 10 MHz to 4 GHz hybrid amplifier. The vendor supplied microwave integrated circuit components allow for individual testing with "field replaceable" SMA connectors. Specifications for these parts emphasize compatibility with their ultimate interface with microstrip circuitry. Many of the subassemblies include .005 inch thick alumina (Al_2O_3) substrates with microstrip linewidths compatible with GaAs MMIC chip geometries. The interconnecting circuits are printed on high dielectric, soft substrates with relative dielectric constant of 10.5 to maintain suitable aspect ratios to minimize mismatch errors. An example of this construction is shown in Figure 5 which shows the final stage circuit features.

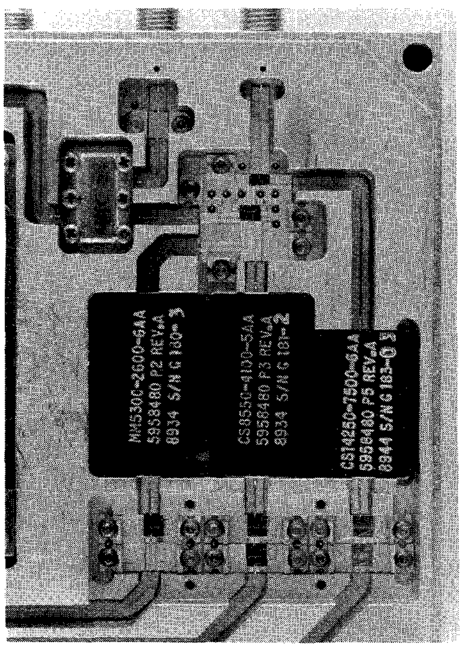

FIGURE 5. FINAL STAGE FEATURES

PACKAGING

A primary challenge was to envelop all of these diverse technologies in a 30 ounce package and insure that all the mechanical, thermal, and electrical requirements of stringent military environments are met. The packaging techniques take into account unwanted waveguide modes and housing cover effects. Special consideration was given to the means of mounting of MMIC chips to insure ease of assembly and repair. Copper-Tungsten (CuW) chip carrier materials were selected to provide low thermal resistance and compatible expansion coefficients for this module.

DC voltage distribution and MMIC switch driver chips are installed in a backside cavity on the reverse side of the module. A printed wiring board routes power and control signals to appropriate vertical feedthrough pins.

The 30 cubic inch (7.5 x 4 x 1 inch) aluminum housing is laser sealed. Fine leak rate is less than 1×10^{-5} cc/second. The module is evacuated and back filled with a 10/90 percent Helium - Nitrogen atmosphere to allow direct leak check without a bomb cycle. This technique eliminates false readings due to bubble entrapment and accelerates the leak check process for large microwave assemblies. The predicted mean-time-between-failure (MTBF) is 87,400 hours. The unit dissipates over 40 watts of power in the form of heat. It is mounted on a heat sink which does not exceed +85 degrees centigrade.

PRODUCIBILITY

The entire stimulus module is very reproducible in manufacturing. Computer Aided Engineering (CAE) provides capability for extensive simulation to predict performance of MMICs and associated integrated assemblies. Additional contributing factors include computer aided design drawings, numerically controlled machining, extremely repeatable MMIC amplifier and switch performance, and careful specification of parameters on all parts. From this documentation, very detailed process sheets for assembly are easily created. Another factor affecting repeatability is worse case tolerance analysis on both electrical performance and mechanical dimensions. Modern software programs significantly enhance the turn-around time and accuracy of analysis, specification creation, part drawings, processes, assembly drawings, test procedures and computer driven test equipment. Computer Aided Testing (CAT) verifies functionality and enhances design models used in CAE to more accurately insure proper actual performance versus predicted performance.

CONCLUSIONS

The development of this compact assembly demonstrates that silicon MMIC, GaAs MMIC and MIC technology can be successfully integrated in a very lightweight and small size package that provides an easily deployable wideband swept frequency capability. Provision for individual test of constituent components prior to integration facilitates the isolation of non-functional components.

ACKNOWLEDGEMENTS

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