U-7

A COMPACT BROADBAND MULTIFUNCTION MIC MODULE

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Abstract

A development effort is described that yielded a compact broadband module using soft and hard substrate material employing microstrip, slot line, and coplanar line. Integrated functions include coupling, limiting, upconversion, downconversion, broadband amplification, amplitude modulation, switching, gating, and stable frequency generation. A new high-level frequency converter with a +28 dBm intercept point resulted in high dynamic range, spurious-free operation (−45 dBc). Extremely flat amplification with low current drain is achieved with novel distributed and cascode FET amplifiers at S-C and X-bands.

Introduction

Reducing the size, weight, and power consumption of modern electronic systems requires compact, efficient, plug-in, multifunction modules. Key parameters are broad bandwidth, flat frequency response, low power consumption, high speed, high dynamic range, and low spurious signal generation. This paper describes details of the microwave substrate materials and layout to miniaturize the module. This module includes 9 basic functions and 19 individual circuits. The design and experimental performance of the various circuit functions are presented with emphasis on the new high-level, high dynamic range, frequency converter; ultrastable, high-power dielectric resonator FET oscillator; and two novel FET amplifiers: the distributed and the cascode amplifiers.

Description

Module Function

The module function is to convert an X-band RF signal to an IF signal (2.6 to 5.2 GHz) with its own internal K_u-band dielectric resonator FET oscillator (DRO). At IF, the signal is amplified, split, and switched between various IF channel paths that are gated, amplified, and attenuated with a linear voltage variable attenuator (VVA). The IF signal is outputed three places and inputed two places. Finally the signal is upconverted to X-band and, using the same DRO signal, amplified and outputed.

Module Layout

Figure 1 illustrates the compact 7.1 inch × 4.2 inch × 0.8 inch MIC 20 ounce module. This module is plugged into external circuitry through the use of low VSWR spring-loaded RF connectors developed by Selectro Corporation. This module contains one X-band limiter, three 60 dB multipole IF switches, two frequency converters, five couplers, four IF amplifiers with a total gain of 80 dB, two 25 dB VVA's, one 36 dB RF limiting amplifier, and one DRO.

To prevent RF coupling between the circuit functions, to minimize ground plane discontinuities, and to provide lower-level testability, the components were distributed among nine individual assemblies placed within a one-piece channelized case. Eight of the nine substrates are visible in figure 1; the DRO and a one-piece printed circuit board containing the control and bias circuitry are on the opposite side. The soft substrate assemblies are made of either 0.015 inch thick Rogers 5880 Duroid (ϵ_r = 2.2) or 0.025 inch thick 3-M Epsilam 10 (ϵ_r = 10.2) dielectric laminated to a 0.10 inch thick aluminum plate. Drop-in alumina substrates (0.025 inch thick) containing 3 dB RF and IF Lange couplers or switch circuitry are bonded into pockets in the soft substrate assemblies. The FET's and PIN diodes are soldered to small gold-plated copper pedestals attached to the ground plane. Covers on both sides are soldered to the plated aluminum chassis, sealing the entire unit hermetically.

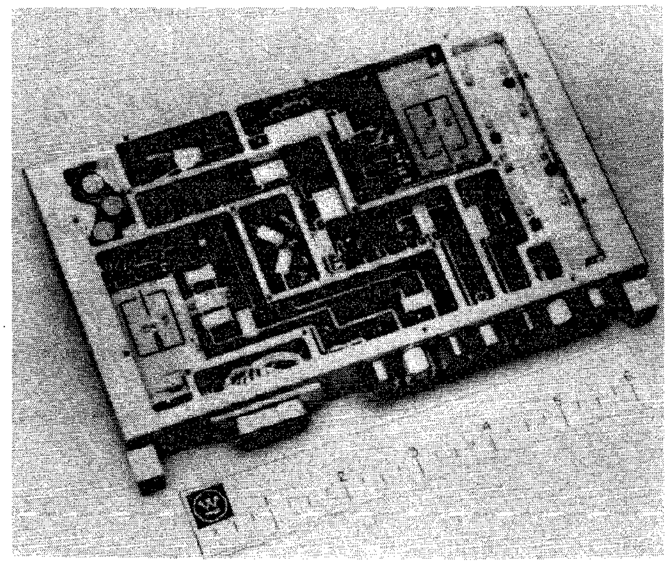


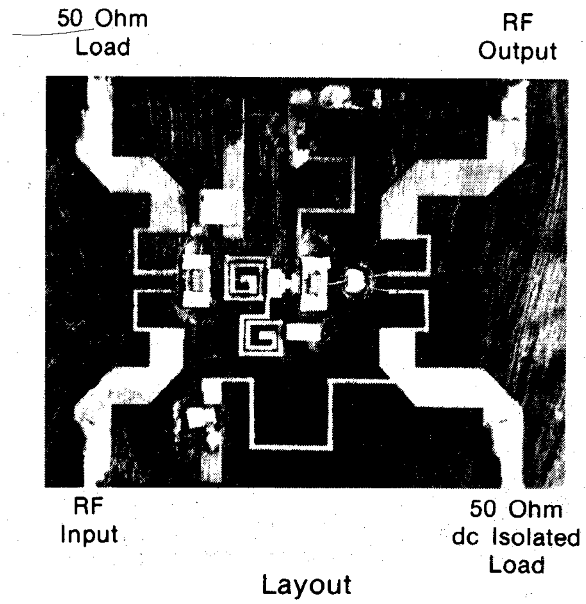
Figure 1. MIC Module

Distributed Amplifier

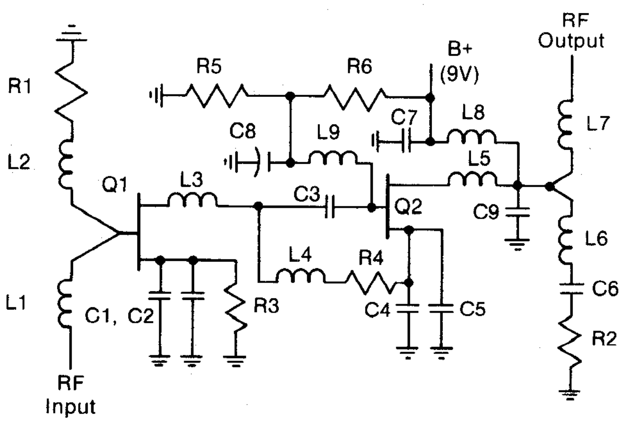
Figure 2 shows the 0.47 inch by 0.63 inch distributed IF amplifier stage layout and schematic. The amplifier is termed distributed because the FET input or output capacitance to ground is used in conjunction with series printed inductors with a 50 ohm termination to form a distributed transmission line that has low VSWR providing $\sqrt{2L/C}$ = 50 ohms.

The input transmission line consists of the series inductor L1, the FET Q_1 input capacitance, and the series L2-R1 termination. The output distributed transmission line consists of series inductors L6 and L7, and shunt capacitor C9 in parallel with the output capacitance of FET Q2 and its bonding wire inductance L5.

The remaining part of the RF circuit consists of an equalizing feedback circuit (L4, R4) required for flat gain versus frequency and inductor L3 between stages which matches Q1 to Q2. The amplifier is constructed on Rogers 5880 Duroid. All other capacitors (C1 through C8) provide either low impedance dc blocking or RF bypass. Inductor L8 provides a bias inject to both transistors which are connected in series with respect to dc, conserving current (power). Voltage drops across R3 and R4, in conjunction with the dc voltage supplied through inductor L9, provides gate bias for both FET's.



Layout



L1, L2, L6, L7	1 nH	C1 Through C8	10 pF
L3	5.5 nH	C9	0.4 pF
L4	5.8 nH	R1 Through R4	50 Ohms
L5	0.5 nH	R5, R6	10 kΩ
L8, L9	High L Bias	Q1, Q2	Dexcel 2501

Schematic

Figure 2. Distributed Amplifier

Computer optimization yielded a flat gain of 10 ±0.25 dB and a maximum VSWR of 1.4:1 over the range 2.6 to 5.2 GHz. The measured gain of the amplifier (figure 3) was 13.25 ±0.25 dB, somewhat higher than the computer-generated values, with a maximum VSWR of 1.6:1 and an output 1 dB gain compression power of 10 dBm.

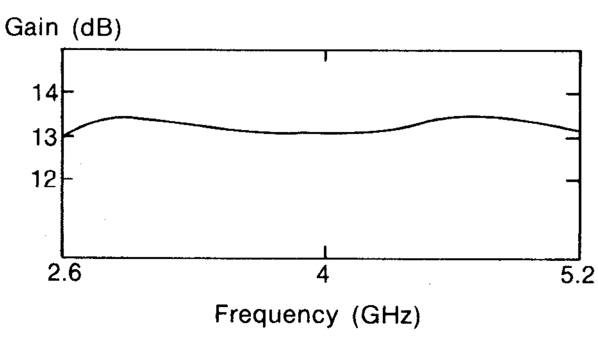
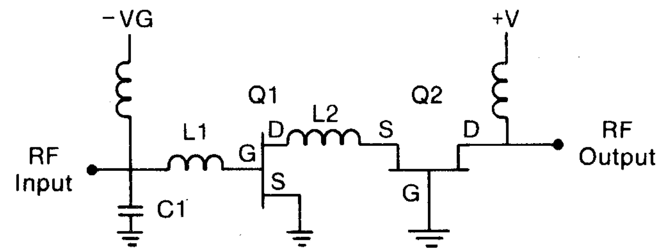


Figure 3. Distributed Amplifier Gain Response

Cascode Amplifier

Matching of medium and high power amplifiers over wide bandwidths generally requires[1] multisection input and output matching networks or a combination of these networks with lossy feedback.[2] A novel cascode circuit has been developed for this module, both at the IF and RF bands, which achieves high gain and improved bandwidth capabilities with a simple interconnection network between the FET's as depicted in figure 4. The drain of the input common-source FET is connected through inductor L2 to the source of the output common-gate FET.



Frequency	IF Band (2.6 - 5.2 GHz)	RF Band X-Band
Q1, Q2	Dexcel 3615	HP 5001
L1 (nH)	1.5	0.4
L2 (nH)	2.3	0.81
C1 (pF)	0.05	0.4
Calc Gain (dB)	10.9 ± 0.4	8.9 ± 0.4
Meas Gain (dB)	11 ± 0.5	12 ± 0.6
Measured P_O (dBm) for 1 dB Gain Compression	23	13

Figure 4. Cascode Amplifier

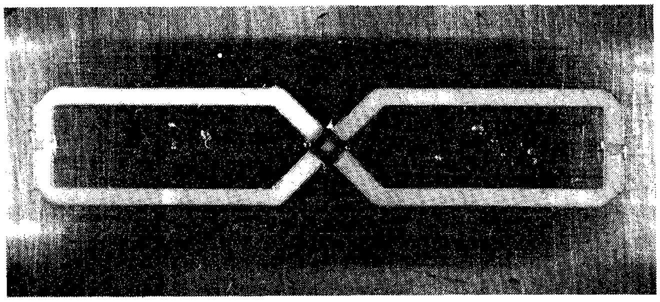
The inductor provides natural broadband flat internal matching. The input shunt-C, series-L network provides additional gain. The net effect is a flat gain versus frequency with a 1 dB output power compression point that is fairly constant over the operating frequency range. The unit is very compact, since inductance values required for matching are low and readily obtained with bond wires. The amplifiers exhibit high input and output VSWR's and are used in a balanced arrangement using 3 dB Lange couplers. The tuned gain is somewhat higher than the computer-optimized values for the X-band unit.

High-Level Mixer

A new planar doubly balanced high-level mixer has been developed using microstrip, coplanar line, and slot line. The mixer uses a combination of techniques reported by de Ronde[3] and Aikawa.[4] Figure 5 illustrates the unitized eight-diode high barrier silicon beam lead ring quad manufactured by Alpha Industries (DMJ 4759) mounted in the coplanar section of the mixer. The unit exhibited a third-order intercept point of +28 dBm (input), conversion loss of 7.5 ±0.5 dB, maximum spurious response of −45 dBc, 1 dB gain compression at +13 dBm input power, maximum VSWR of 1.5:1, and minimum isolation of 25 dB between any port across the 2.6 to 5.2 GHz IF band. The mixer used 23 dBm LO power at K_u-band with X-band RF frequency. Identical mixers were used for downconversion and upconversion and were constructed on Epsilam 10.

Dielectric Resonator FET Oscillator (DRO)

Figure 6 illustrates the K_u-band FET DRO on Duroid microstrip. A flange-mounted packaged MSC 88004 power FET provided 0.5 watt of output power (14 percent efficiency) when stabilized. An open-circuited stub on the gate at optimum length provides peak negative resistance when the transistor's output drain terminal is biased negative with respect to ground. A puck of Transtec D-38 is strategically located on the output circuit to lock the frequency to



Diode Quad Embedment

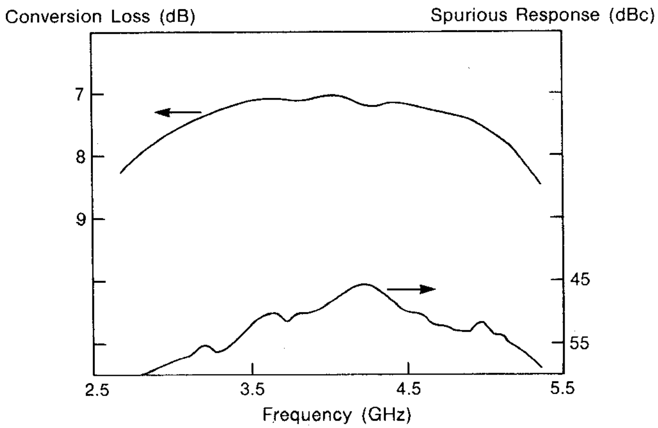


Figure 5. High-Level Frequency Converter

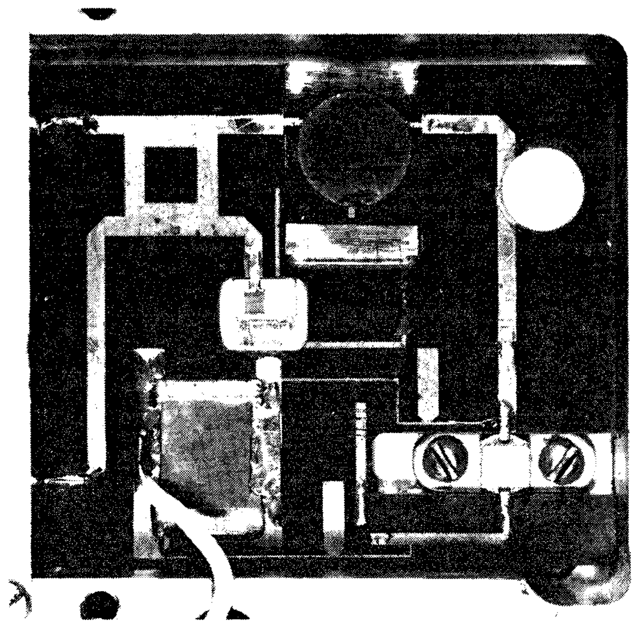


Figure 6. Dielectric Resonator FET Oscillator

within ±3 MHz from −55°C to 95°C. A microstrip ferrite isolator cascaded by a branch line hybrid coupler provides two 23 dBm outputs to drive each mixer.

Conclusions

Novel broadband circuits coupled with advanced large-scale-integration techniques have led to the development of a high-performance, compact microwave module.

Acknowledgements

The author wishes to thank Rick Hess, Jed Rosen, Joe Faulkner, John Gipprich, Steve Payer, and Gabor Lutor for their participation in this development, as well as Larry Dickens for his many valuable suggestions.

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