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A 20-WATT C-BAND BPSK MODULATED FET TRANSMITTER FOR MICROWAVE LANDING SYSTEM

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ABSTRACT

A modularized 20 watt C-band BPSK modulated FET transmitter is developed for Microwave Landing System. The transmitter contains a x6 active multiplier using bipolar and FET, a BPSK modulator with proper amplitude shaping to achieve more than 30 dB suppression in off-channel emission and a FET power amplifier chain with a four-way power output stage.

INTRODUCTION

The Microwave Landing System (MLS), which is presently being developed in several countries including the US, is considered to be the future system to gradually replace the present Instrument Landing Systems (ILS).[1,3] The MLS provides better tracking of the aircraft and offers more precise landing guidance. Typically 10 to 20 watts of rf power in C-band is required for the MLS transmitter. In the past, this power level could only be achieved with a Traveling Wave Tube Amplifier (TWTA) or an IMPATT amplifier.[4] The recent advancement in GaAs devices and circuit power combining technology[5,6,7] made it possible to construct a 20 watt, compact FET power amplifier for MLS transmitter. The transmitter, to be described in this report, is of modular construction. It consists of an x6 active multiplier using bipolar and field effect transistors, a BPSK modulator with proper amplitude shaping to achieve more than 30 dB suppression in off-channel emission, and an FET power amplifier chain to amplify the transmitting signal to 20 watts. The modular construction offers more flexibility in system selection and easier system maintenance. The design approaches and the circuit performance for the various function modules will be described in the following paragraphs.

THE BLOCK DIAGRAM

The block diagram of the MLS transmitter is shown in Figure 1. The overall transmitter assembly consists of three major rf functional subassemblies, namely; a) x6 multiplier, b) BPSK modulator, and c) power amplifier. A printed circuit board containing switch modulator driver and FET bias regulator circuits are also included in the transmitter assemblies.

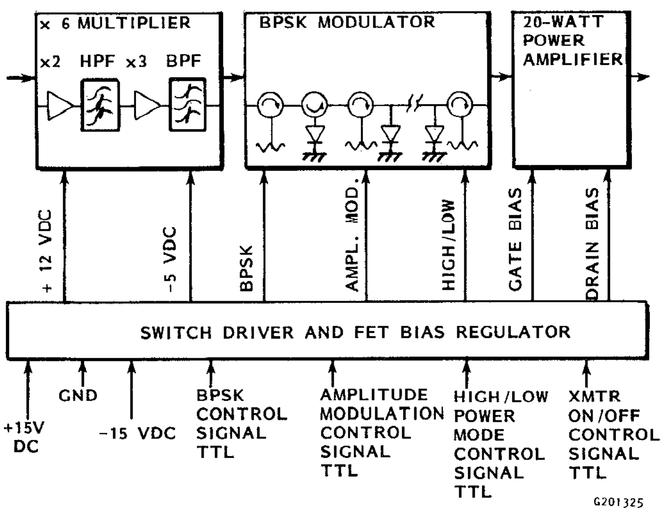

Fig. 1. Block Diagram of the 20-Watt Solid-State MLS Transmitter.

The x6 multiplier accepts an input signal of 10 ± 2 dBm from an exciter in the frequency range of 838.5 to 848.5 MHz, and then multiplies it up to the range of 5031 to 5091 MHz, the MLS carrier frequency, with gain of 9 dB. The multiplier is followed by a BPSK modulator with provision of amplitude shaping for off-channel spectral emission suppression. The modulated signal is then amplified by the FET power amplifier chain to the 20 watt level, with power gain of 30 dB.

CIRCUIT DESIGNS AND MODULE PERFORMANCE

x6 Multiplier Module

Active frequency multipliers using bipolar or field effect transistors[8,9,10] offer the advantage of possible conversion gain or lower conversion loss than the conventional diode multipliers. The diode multipliers have nominal conversion loss of 6 dB for doubler and 10 dB for tripler circuits. The active multiplier circuit used in our transmitter consists of a doubler using bipolar transistor, a tripler using FET, and a single-stage FET amplifier to attain +18 dBm output power. The multiplier module is shown in Figure 2. The input circuits for both the doubler and the tripler are designed to obtain the best impedance matching at their corresponding input frequencies, i.e. 838.5 to 848.5 MHz for doubler and 1677 to 1697 MHz for tripler.

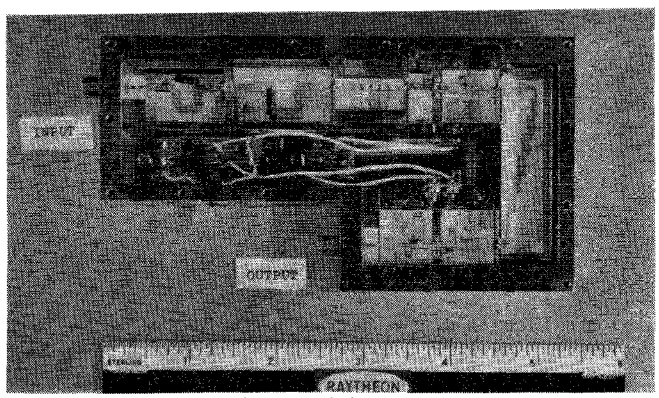

Fig. 2. X6 Multiplier Module.

The output circuits are designed to obtain the best impedance matching for the desired output frequencies while providing reactive terminations at unwanted frequencies. The doubler circuit provides a conversion gain of 3 dB while the tripler circuit has a conversion loss of 2 dB. The output amplifier using a Raytheon RPX2322 medium power FET provides 12 dB gain at +18 dBm output. A lumped element high pass filter is placed between the doubler and the tripler circuits, and a parallel-line-coupled bandpass filter is placed at the output of the tripler circuit to achieve a spurious output of 65 dB below the carrier at the output of this mulitplier module.

As will be discussed later, this spurious level will be further reduced by the power amplifier module pass-band characteristics.

BPSK Modulator Module

The BPSK modulator includes a circulator coupled PIN diode phase modulator, a shunt-mounted PIN diode for amplitude shaping to prevent spectral spreading and a single-diode, shunt-mounted attenuator for high /low power output operation. The BPSK modulator is designed to operate at a modulation rate of 15 KHz. The amplitude shaping circuit is controlled so that the phase switching occurs during the minimum rf amplitude ($\leq$ -20 dB). The transition between the full rf amplitude to minimum rf amplitude is 10 μsec with a phase transition of 200 nsec. The off-channel emissions contained in a 160 KHz bandwidth at 240 KHz or greater away from the carrier for this type of BPSK modulator is greater than 30 dB.[4] This off-channel emission suppression is at least 10 dB better than the straight constant amplitude BPSK modulator.

Input and output isolators are also included in the BPSK modulator module for better input and output matching, and to minimize phase pushing by the external circuit loadings. Phase accuracy of 180° $\pm$ 3° has been achieved. The BPSK module is shown in Figure 3. The isolators and the circulator are fabricated on ferrite microstrip substrate, using thin film photolithographic method.

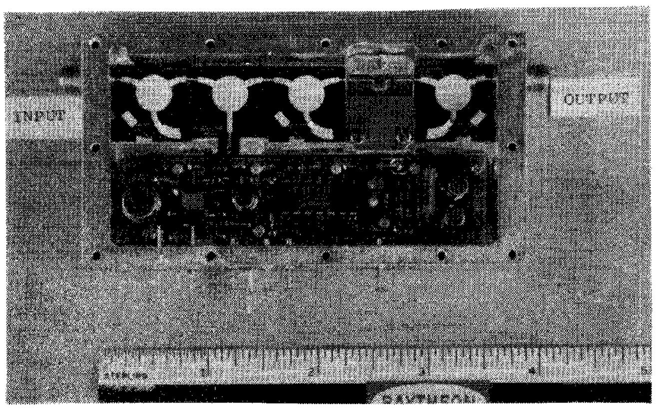

Fig. 3. BPSK Modulator Module.

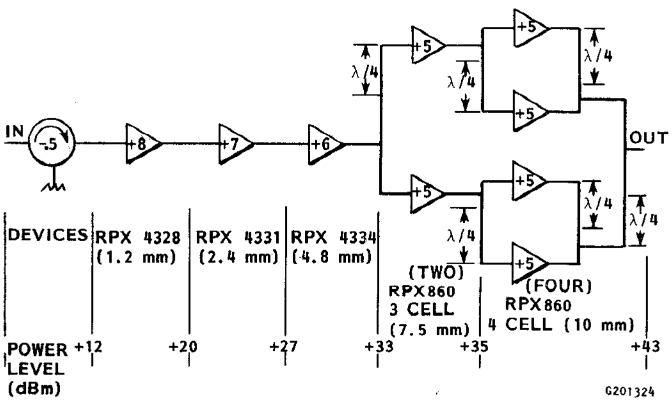

Fig. 4. Schematic Block Diagram of 20-Watt FET Amplifier.

20-Watt Power Amplifier Modules

A schematic diagram of a 20 watt FET power amplifier module is shown in Figure 4. Gain and power distribution for each individual stage are also shown on this diagram. The overall amplifier consists of a three-stage driver amplifier sub-module and a two-stage 6 FET power amplifier sub-module, as shown in Figure 5. The three driver amplifier stages utilize Raytheon RPX4300 series FETs with 1.2 mm, 2.4 mm and 4.8 mm gate periphery in first, second and third stages, respectively. The two-stage power amplifier sub-module contains a two-way power splitter to the input stage and followed by a four-way power combining circuits utilize Wilkinson power dividers with additional 90° phase off-set in alternative arms to minimize the input and output VSWRs.[11] Raytheon RPX860 series FETs are used in power amplifier module with 7.5 mm and 10 mm gate pheripheries in each of the input and output stage FETs, respectively. Both RPX4300 series and RPX 860 series FETs are fabricated with "via-holes" technology[5].

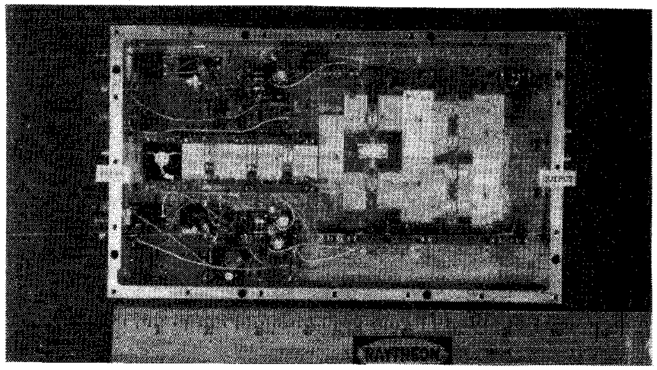

Fig. 5. 20 Watt FET Power Amplifier Module.

The driver amplifier provides 2.5 watts output power to the input of the 20 watt output power amplifier sub-module. The overall amplifier chain has a gain of greater than 30 dB with 9.5 amp. of bias current at +10 V, which is regulated from +15 V power supply. Fourteen percent of power added efficiency is calculated, including the bias regulator loss.

PERFORMANCE OF THE MLS TRANSMITTER

Power output of the transmitter is 20 watts measured across the whole MLS band at room temperature, and less than 0.5 dB degradation even at the baseplate temperature of +80°C. The power output response at several elevated temperatures is plotted in Figure 6. The output power level of the second and third harmonics of the output frequencies are more than 50 dB down from the carrier. The spurious level measured from 0.8 GHz up to the 16 GHz range is at least 85 dB down from the carrier. This low spurious level is achieved by proper filtering in the multiplier and the limited pass-band characteristics ($\leq$ 10%) of the amplifier. The output spectrum of the BPSK modulated transmitter has a carrier suppression of greater than 25 dB, which corresponds to a phase imbalance of 180° $\pm$ 3°. With phase switching time of 200 ns and amplitude transition time of 10 μs, the power level of any off-channel emission, as measured in a 160 KHz bandwidth, 240 KHz or more away from the carrier frequency, is more than 30 dB below the on-channel effective carrier power level.

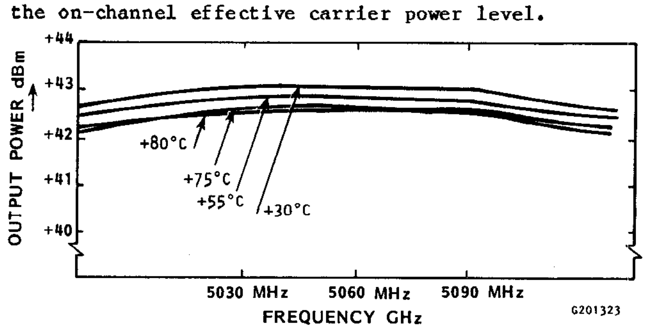

Fig. 6. Output Power Characteristics of the 20 Watt Transmitter.

The bias regulator of the transmitter also included a TTL compatible on/off switch to cut off the positive drain supply to the bipolar and all FET stages. More than 80 dB of on/off ratio is measured with this on/ off switch. The transmitter draws 9.7 amps and 50 milliamps from +15 V and -15 V power supplies, respectively. This corresponds to an overall power dissipation of 145 watts and an efficiency of about 14%.

CONCLUSION

A small size, lightweight 20 watt C-band BPSK modulated FET transmitter is developed. The transmitter is capable of meeting the MLS requirements.

ACKNOWLEDGEMENTS

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