A SOLID STATE, 5 WATT, 6 GHz, MICROWAVE SOURCE FOR HIGH CAPACITY FM RADIO RELAY

by

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Abstract

The design and performance of a 5 Watt 6 GHz solid state source intended for use in a high capacity FM microwave repeater is described. It utilizes a 2 GHz power amplifier and step recovery diode multiplier and generates 5 Watts with an overall efficiency of 8%. FM noise is less than 3.5 Hz RMS in a 1 KHz slot from 60 KHz to 10 MHz off carrier.

Introduction

Travelling Wave Tube amplifiers have been widely used to provide transmitter power for FM microwave radio relay applications. Significant improvements in cost and reliability can be realized by replacement of the TWT and its associated high voltage power supply with a solid state transmitter. One approach suitable for high capacity FM transmission is shown in Figure 1. In this scheme, the output of a high power microwave source is modulated by the IF signal in a high level varactor up-converter.

This paper describes the design and performance of a 5 Watt 6 GHz Microwave Source for such a transmitter.

Design Details

The generator block diagram is shown in Figure 2. A starting frequency of 2 GHz was chosen as the highest frequency common to the common carrier communications bands at 2, 4, and 6 GHz.

The 2 GHz oscillator is a high "Q" coaxial design which is phase locked to a VHF crystal oscillator.

The power amplifier consists of 3 cascaded stages as shown in Figure 2. A modular approach was chosen; the individual transistor stages being built and optimized on separate carrier plates. This approach greatly eases manufacturing difficulty and maintains flexibility in accommodating different frequency bands and transistor types.

3 GHz transistors were chosen rather than 2 GHz devices because of their much higher efficiency, gain and bandwidth capability. The low efficiency of presently available 2 GHz power transistors would result in junction temperatures approaching 200^{o}C at 55^{o}C ambient. Junction temperatures are further lowered by use of solder-down packages and copper carrier plates which result in a measured overall thermal resistance of only 6^{o} C/W.

A broadband input match to the transistor is realized with multipole bandpass impedance matching networks as described by Matthaei.[1] In the circuit shown schematically in Figure 3 the input impedance of the transistor is brough to parallel resonance with a lumped capacitor, transformed to 50Ω, and coupled to the second resonator. This arrangement gives an input VSWR of 1.5 : 1 over a 150 MHz bandwidth. The output matching network is a straightforward $\lambda/4$ transformer.

The performance capability of the individual modules is 5.6 Watts with 45% efficiency and 7 dB gain.

The power splitters/combiners are microstrip interdigitated 3 dB couplers as reported by Lange.[2] An approximate analysis method based on a superposition of single and coupled microstrip data was developed to optimize the dimensions and determine tolerance requirements. The measured coupling is within 2.5% of that predicted. A microstrip circulator is used at the output for isolation.

The overall power amplifier is capable of 18 Watts. The output is set by a variable voltage supply, typically to 14 Watts, to achieve the required source output.

The X3 multiplier uses a multi-chip step recovery diode. The single diode approach permits simple multiplier construction and alignment. The device is mounted in WR-137 reduced height waveguide with a coaxial input circuit. The generator output requirement of +37.0 0 dBm is achieved with 40% conversion efficiency over a 2% pretuned band. At this output level the diode is exceeding its reverse breakdown limitation. This, however, has some beneficial effects. Both a decrease in drive power or an increase in temperature tend to increase multiplier efficiency. This characteristic makes closed loop compensation of the generator unnecessary. Figure 4 shows the effect on multiplier efficiency when a diode is exceeding its reverse breakdown limitation. The abcissa is normalized to P_{BVR}, the input power level where avalanching first occurs. Driving the diode into avalanche breakdown introduced no significant additional noise. The diode junction temperature was typically 80°C above air ambient, well within its thermal limitations.

Performance

- output frequency	5.9 → 6.4 GHz
- output power	5 Watts
- operating range	0 → 55°C ambient
- F.M. noise	<3.5 Hz RMS deviation in a 1 KHz slot. (60 KHz → 10 MHz from carrier) (equivalent to <-87.0 dBm0 3.1 KHz slot, 140 KHz deviation no pre-emphasis).
- Frequency stability	$<15 \times 10^{-6}$
- Level variation with temperature.	.4 dB

A demodulated FM noise, spectrum covering 10 KHz to 10 MHz is shown in Figure 5. A photograph of a packaged generator is shown in Figure 6.

References

(1) Matthaei G.L., "Synthesis of Tchebycheff Impedance Matching Networks, Filters and Interstages", IRE Trans. 1956, CT3, p. 163.

(2) Lange J., "Interdigitated Stripling Quadrature Hybrid", IEEE Trans. 1969, MTT-17, p. 1150.

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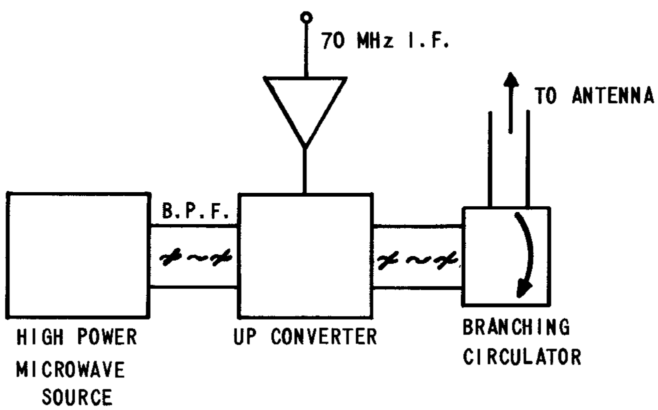

FIG. 1 SOLID STATE TRANSMITTER

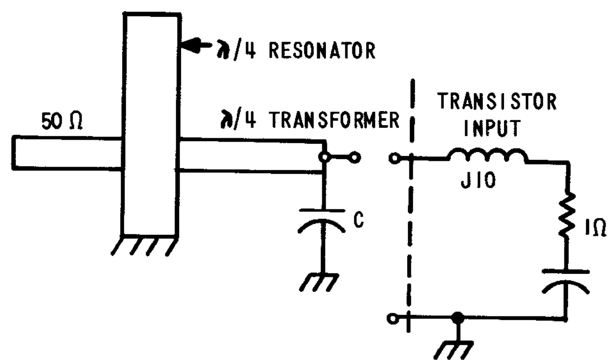

FIG. 3 TRANSISTOR INPUT MATCHING NETWORK

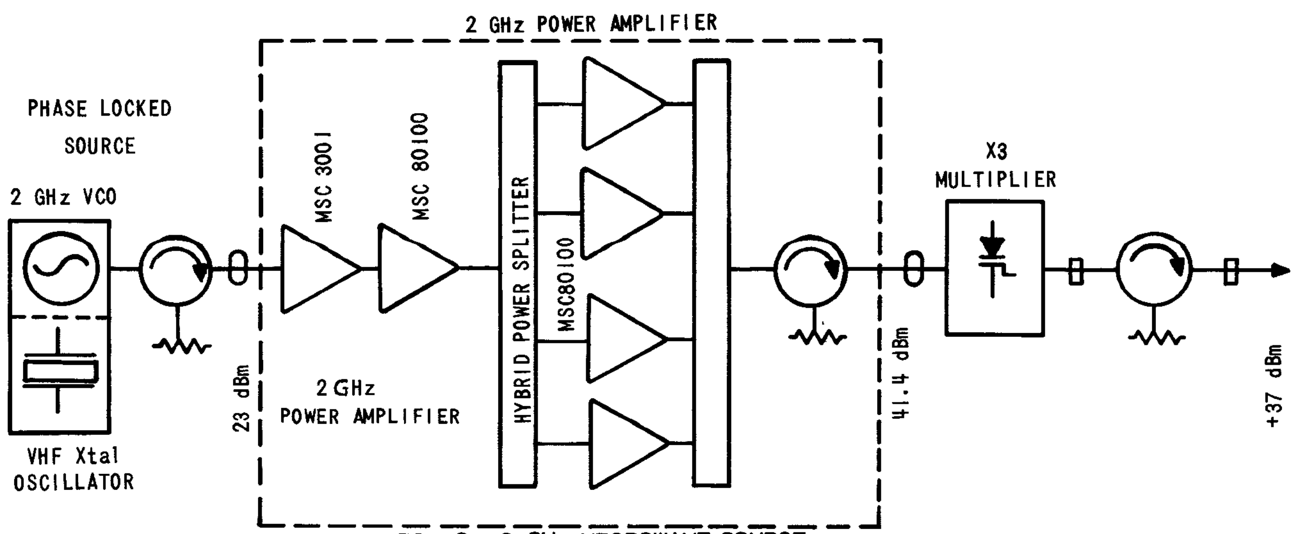

FIG. 2 6 GHz MICROWAVE SOURCE

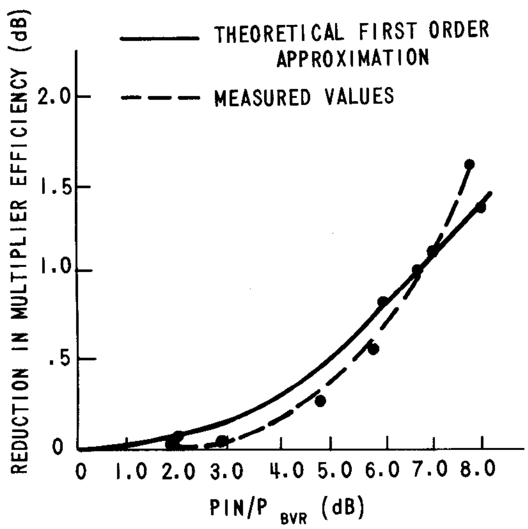

FIG. 4 REDUCTION-OF MULTIPLIER EFFICIENCY VS PIN/P BVR

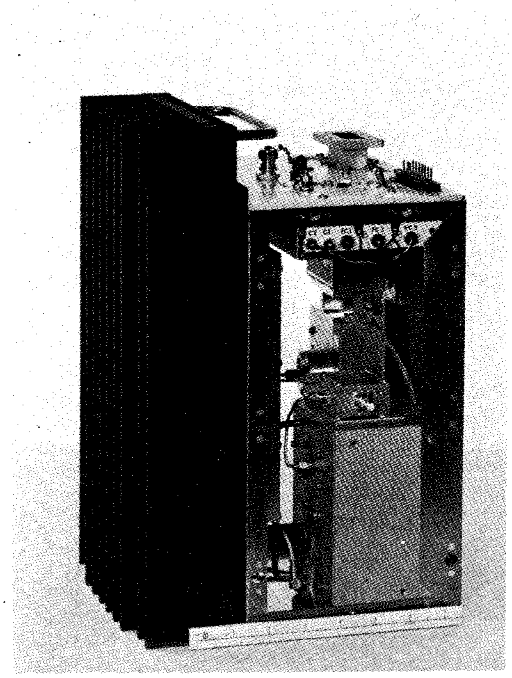

FIG. 6 6 GHz MICROWAVE SOURCE

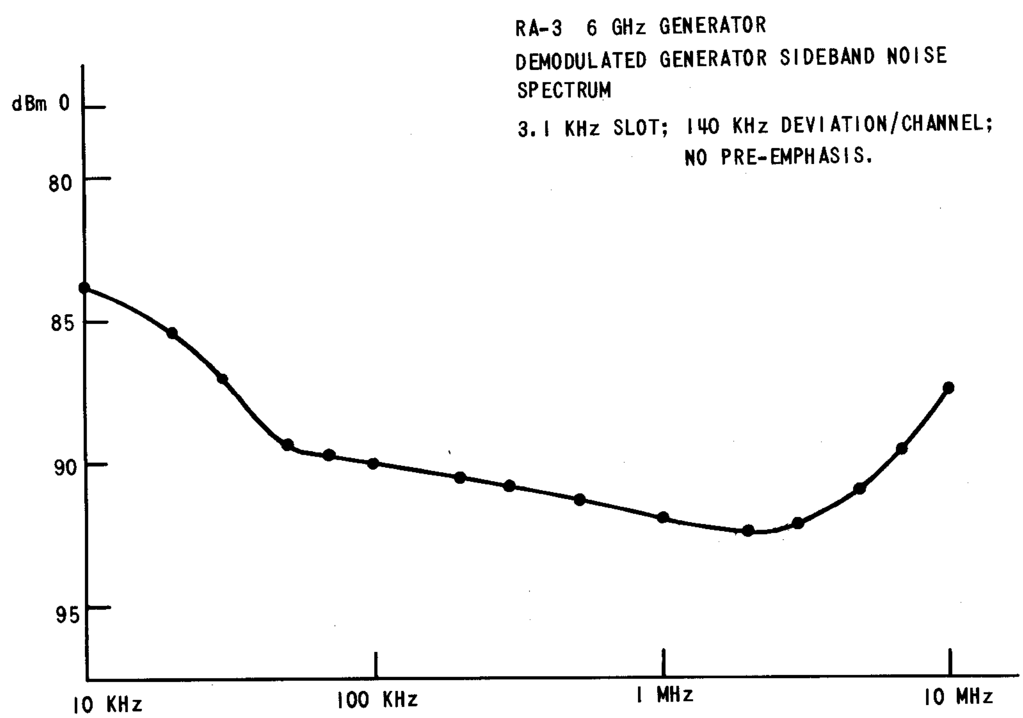

FIG. 5