A 0.75- TO 6-GHz VARACTOR UP-CONVERTER BROADBANDED AT ALL THREE PORTS

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Abstract

Bandwidths of 500 MHz have been achieved at the signal, pump, and upper sideband ports for output levels of 80 mW by using a heavily overdriven varactor in a low-inductance mount and matching into a contiguous band diplexer.

Introduction

High-level up-converters with broadband signal, pump, and upper sideband (USB) ports simplify the design of earth terminals for satellite communications. The broad instantaneous bandwidths provide a system flexibility which allows wideband baseband information to be up-converted to a number of channels in the transmit band through suitable selection of the local oscillator (pump) frequency. The high-level capability reduces the gain required of the transmitter power amplifier.

Current broadband up-converters employ varistor devices such as point-contact or Schottky-Barrier diodes as the nonlinear element, usually in a 4-diode bridge circuit. Output power levels are typically limited to a milliwatt. Where higher power levels are required, varactor up-converters have been employed, but at a sacrifice in bandwidth. Output bandwidths have typically been limited to 1 percent.

Varactor up-converter design technology has been directed primarily toward the realization of stable operation and high power. Some theoretical and practical work has been done to broadband two of the three ports, either the signal-USB or the signal-pump ports.[1] This paper deals with simultaneous broadbanding at all three ports and introduces a new technique to broadband varactor circuits: broadband matching of a pumped, mounted varactor to a diplexer filter network. This technique is applied to the design and realization of an up-converter having the following characteristics:

Signal center frequency:	855 MHz
Signal bandwidth:	100 MHz minimum at -1 dB
Pump:	5.070–5.570 GHz
Upper sideband:	5.925–6.425 GHz minimum at ±1 dB
Power output:	30 mW minimum 80 mW maximum

Design Considerations

Stability considerations are of primary importance in the design of varactor circuits. Parametric instabilities have been analyzed[2] and a set of circuit constraints have been proposed to avoid their excitation.[3] The broadband matching techniques to be employed here have been carefully engineered to satisfy the stability constraints.

Figure 1 is a simplified block diagram of the up-converter. The circuit consists of a pump-USB diplexer and a signal arm comprising a lowpass filter, quarter-wave transformer, and signal tuning circuit.

According to Conning,[4] varactor capacitance and drive are chosen at C_{min} = 1.0 pF and M = 2.5 to yield a low loaded Q value for the diode. This results in a real-part pumped impedance, R_o, of 5.1 ohms at the pump-USB mean frequency (f_o = 5.7 GHz) and an average capacitance, C_{ave} = 5.0 pF for a punch-through (γ = 0) device. When the chip is mounted in a micropill package inside a 3.5-mm coaxial line, the equivalent circuit of the pumped diode can be closely approximated across the pump-USB band by a series L-C network resonant at 4.7 GHz in series with a frequency-dependent resistor described by equation (1):

$$R(f) = R_o\left[\frac{f_o}{f}\right] \quad (1)$$

The low-inductance package and mounting arrangement yields a low resonator reactance slope. The diode resonant frequency is raised to the pump-USB mean frequency by adding external series capacitance without affecting the reactance slope. Control of the reactance slope and resonant frequency are necessary to match the diode to the contiguous band diplexer.

The diplexer design theory has been described previously.[5] It is a contiguous band design derived from singly terminated prototype filters. The design employed here uses parallel connected bandpass filters coupled to the diode through an impedance inverter.[6] The computed normalized driving point impedance at the inverter terminals of the lumped equivalent circuit diplexer is shown in Fig. 2. The real part of the impedance has a Chebycheff response and the imaginary part has a negative sloping response versus frequency passing through zero at the crossover frequency. Filter and inverter impedances are chosen to match the average real part of the diode impedance. The resulting negative reactance slope of the diplexer is cancelled through proper design of the positive

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reactance slope of the mounted diode, which provides effective diode tuning across the diplexer bandwidth.

Design Realization

A realization of the up-converter is shown in Fig. 3. It is constructed in 7-mm coaxial line using the split-block technique. The circuit is complete as shown and was designed with the aid of an interactive microwave circuit analysis computer program (GCP) to match the diode from and into 50 ohms.

The lowpass filter is a stepped impedance design having a cutoff frequency of 1.2 GHz and a characteristic impedance of 32 ohms. Signal tuning is accomplished by selecting the appropriate impedance of the short-circuited line, which is one-quarter wavelength long at 5.7 GHz. The 10K shunt resistors halfway along the line are chosen to be transparent in the band of interest and have sufficiently low RF impedance at 10–12 GHz to provide a uniform high impedance looking into the signal tuning circuit across the second harmonic band of the pump frequency.

The pump-USB diplexer consists of parallel connected bandpass filters having a characteristic impedance of 35 ohms. The filters use capacitively coupled resonators, each approximately one-half wavelength long at the filter center frequency. The frequency response of the resonators is made aperiodic by inserting a high-impedance section at mid-length. Thus, the second passband of each filter is raised to a frequency above that of the pump-USB second harmonic band. The diplexer is connected to the diode through a 14.5-ohm quarter-wave (at 5.7 GHz) transmission line which serves as an impedance inverter.

Measured Performance

The swept pump frequency response at various signal levels is shown in Fig. 4 for a signal frequency of 855 MHz. The minimum and maximum gain are 4.8 and 5.35 dB, respectively, across a pump band from 5.07–5.57 GHz at a signal level of 10 mW and a pump level of 300 mW.

The swept signal frequency response is shown in Fig. 5. The bandwidth is about 500 MHz at -1 dB and the maximum gain slope is 0.032 dB/MHz at an output level of 30 mW.

A typical amplitude transfer characteristic is shown in Fig. 6. The up-converter is capable of operating at pump levels in excess of 1 watt. Circuit linearity improves for large pump/signal power ratios.

References

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4. S. W. Conning, "An Analysis of the High-Power Varactor Up-Converter," Proceedings of the IREE Australia, July 1966, pp. 163–173.

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6. Ibid, Section 4.12.

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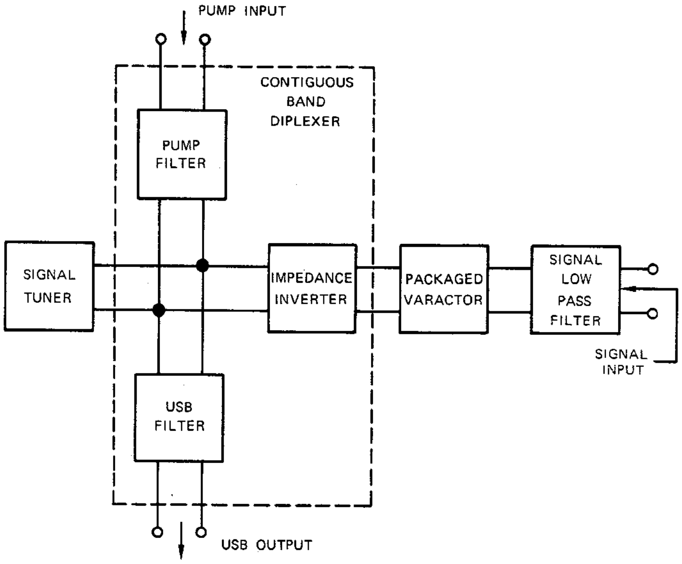

FIG. 1. BLOCK DIAGRAM OF VARACTOR UP-CONVERTER

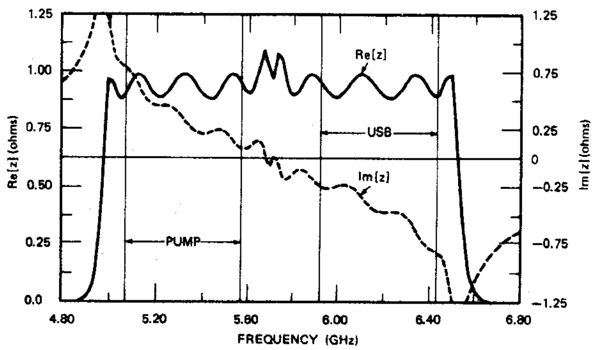

FIG. 2. COMPUTED NORMALIZED DRIVING POINT IMPEDANCE FOR THE LUMPED EQUIVALENT DIPLEXER

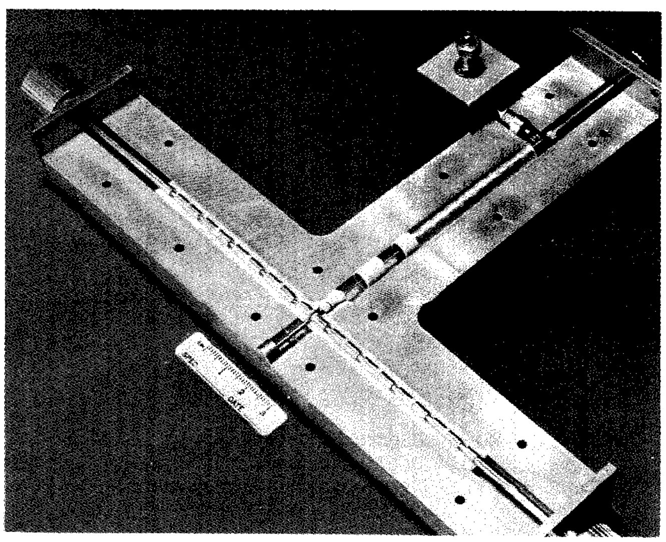

FIG. 3. UP-CONVERTER CIRCUIT

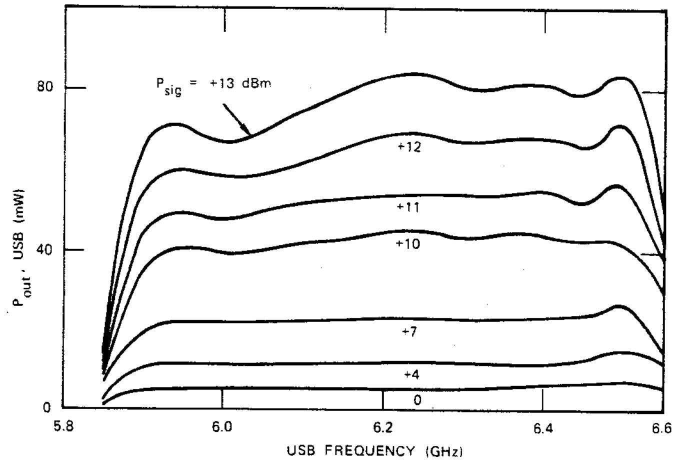

FIG. 4. PUMP-UPPER SIDEBAND FREQUENCY RESPONSE

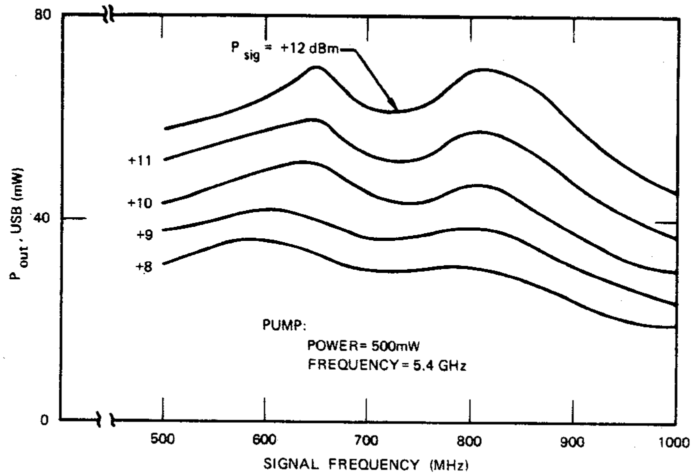

FIG. 5. SIGNAL-UPPER SIDEBAND FREQUENCY RESPONSE

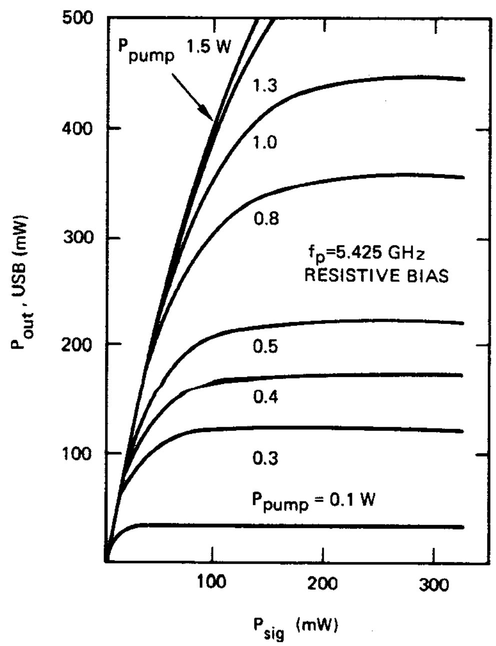

FIG. 6. TRANSFER CHARACTERISTICS