100-MILLIWATT OUTPUT UP-CONVERTER USING FOUR SCHOTTKY DIODES

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ABSTRACT

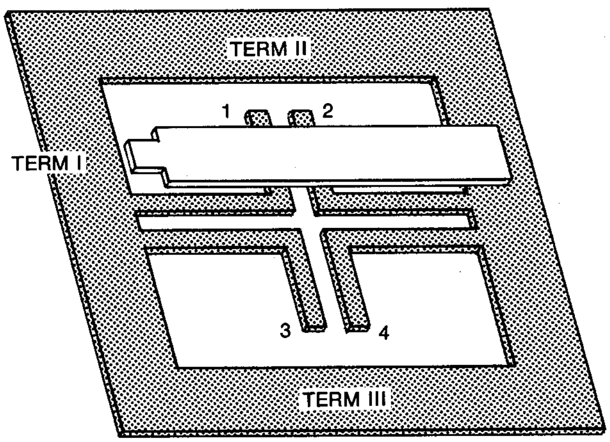
Description is given for a compact double-balanced strip hybrid up-converter that translates a modulated 70-MHz signal to the 2-GHz frequency range. Four high-voltage Schottky barrier diodes are pumped at a +28 dBm to provide a single sideband power output of +20 dBm. Pump level is more than 20 dB below the sideband power level over an octave bandwidth.

Introduction

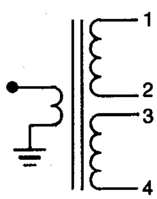
The medium-power four-diode up-converter described in this paper was designed for a microwave radio relay system to translate a 70-MHz modulated signal to the 2-GHz frequency range. Achieving higher output power from the up-converter would allow fewer stages to be used in a power amplifier that followed. A commercial up-converter could not be found that could achieve the +18-dBm single sideband power output for a +29-dBm rf pump power input. Because the if. voltage could be easily generated, it was not a consideration in the up-converter design. Design requirement included low cost, small size, fixed tuning, low AM-to-PM conversion, and low-level harmonics in the output frequency range.

Circuit Description of Single Quad Up-Converter

Microstrip and balanced strip transmission lines were chosen for the balun and hybrid circuits shown in figures 1 and 2. The plastic substrate was 15-mil-thick Duroid 5880 made by the Rogers Corp. Corresponding points on the strip transmission lines and on the equivalent circuits are identified. Theory for the baluns and hybrid may be obtained from Oltman[1] and Mouw[2].



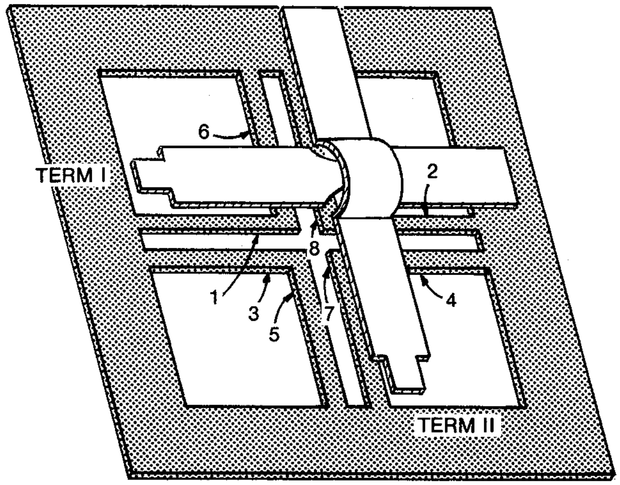
a. Rf Circuit.



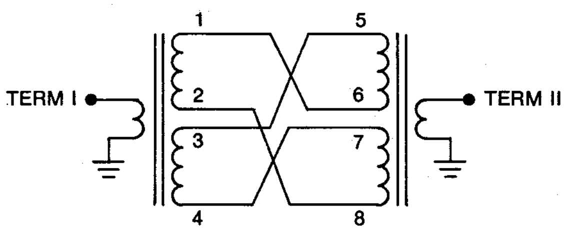
b. Equivalent Circuit.

Figure 1. Strip Conductor Dual Balun.

A single primary conductor is used in the figure 1 balun to equally couple to two colinear balanced line pairs producing a potential between lines 1 and 2 at terminal II that is equal and in phase with the potential between lines 3 and 4 at terminal III. No potential exists between lines 1 and 3 or between lines 2 and 4.



a. Rf Circuit.



b. Equivalent Circuit.

Figure 2. Strip Conductor Hybrid.

The hybrid in figure 2 is formed by orthogonally joining two baluns such that the line pairs from one balun that have opposing potential are joined to two equal potential lines of the other balun to obtain isolation. For instance, lines 1 and 2 that are opposite potential for an input at Terminal 1 are joined to lines 6 and 8, respectively, which are at the same potential for an input at Terminal II.

The four diodes are sequentially alternated in polarity and have one of their leads connected to each of the four junctions formed at the intersection of the quadrature colinear lines on the hybrid. Their other leads are joined together to form the if. terminal, which is unbalanced to ground. Conduction through the diodes may be followed from the equivalent circuit in figure 3. For instance, an input at Terminal I will cause conduction through diodes D2 and D1 for one polarity and through diodes D3 and D4 for opposite polarity. An input at Terminal II will cause conduction through diodes D3 and D1 for one polarity and through diodes D2 and D4 for opposite polarity.

To reduce power saturation in the earlier up-converter models, it was necessary to isolate the diode bias circuits as shown in figure 3 because the polarity of one diode pair forward biased the other polarity pair. Adjustment of either bias resistor R1 or R2 will minimize the pump carrier in the output line. The capacitor C1 has a low impedance to both the if. and rf frequencies. By separating the bias of the original up-converter diodes (improved diodes discussed later), it was possible to increase power output from approximately +12 to +15 dBm using a +29-dBm pump power.

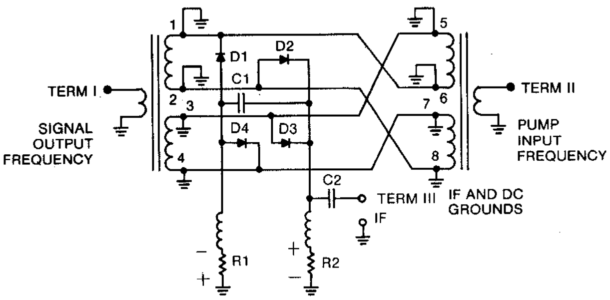
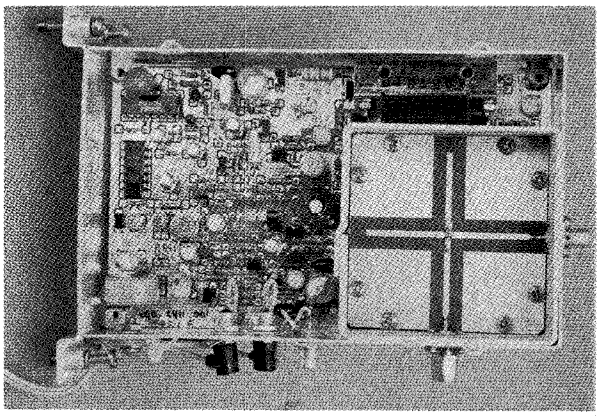
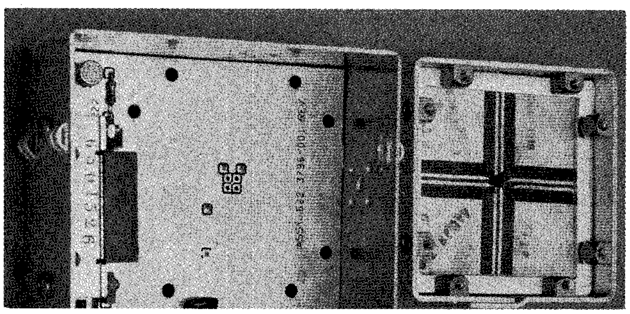


Figure 3. Single Quad Double-Balanced Up-Converter With Bias Isolation.

A photograph of the final model is shown in figure 4. The if. circuit board, which is not considered as part of this paper, contains amplifiers and associated circuitry that provide an adjustable if. voltage to the up-converter diodes.



a. View From Top of Rf Board.

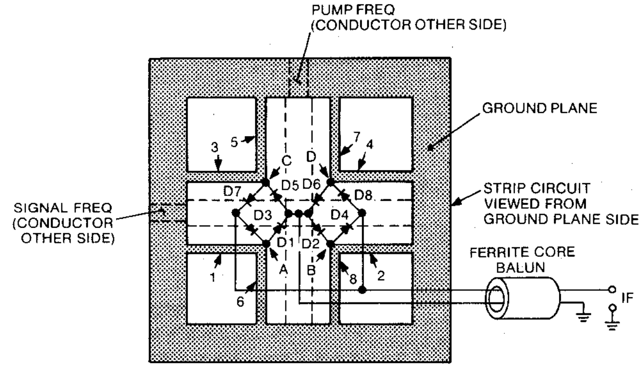


b. View Under Rf Board Showing Four Diodes.

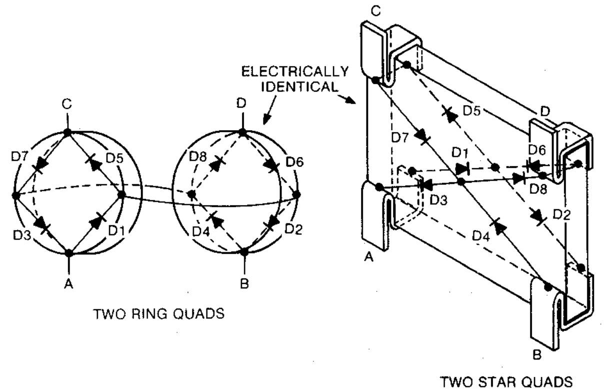
Figure 4. Final Up-Converter.

Full-Wave Double Quad Double-Balanced Up-Converter

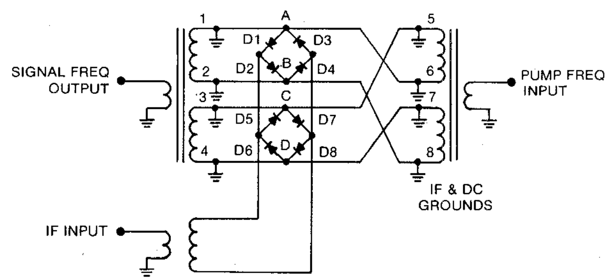
Another circuit type that was investigated provided full wave rectification of the rf signals. This circuit is shown in figure 5a. Note that rectification on both halves of the rf cycle are now possible by using two diode quads. As a matter of interest, it is shown in figure 5b that the two diode quads may be configured either as two ring quads or as two star quads and yet the two are identical. The equivalent circuit for this arrangement is shown in figure 5c. The if. signal leads are balanced and are converted to an unbalanced output through a balun. Circuit and diode labels are used on the equivalent circuit appearing in figure 5c to correspond with the same label on the microstrip circuit in figure 5a. An up-converter that was constructed using the two diode quads had power output and isolation similar to the single quad; therefore, the double quad was not used for the final model because of cost and biasing considerations.



a. Rf Circuit.



b. Identical Diode Connections Configured as Two Quads or Two Stars.



c. Equivalent Circuit.

Figure 5. Full-Wave Double-Balanced Up-Converter.

Diode Characteristics

Initial up-converter tests used pin diodes with a 25-nanosecond lifetime, which allowed the diode impedance to follow the 70-MHz voltage swing but prevented the rf voltage from changing the diode impedance. These diodes were later replaced by high-voltage Schottky barrier diodes because the latter provided higher power output. The final version of this Schottky diode was unusual in its characteristics and will now be described.

After evaluating many diodes, it was determined that one type performed better than all others. An inspection of the diode I-V characteristics in figure 6 will show that the diodes that are labeled "A" do not become saturated at higher voltages. The single sideband power output of the up-converter increased from +15 dBm using the "B" diodes to +20 dBm for the "A" diodes using a +29-dBm pump power input. These diodes are from the Microwave Associates MA 47160 group, which have a breakdown voltage of 70 volts minimum. By specifying the voltage drop for a given forward current, it was possible to define diodes usable for higher power output.

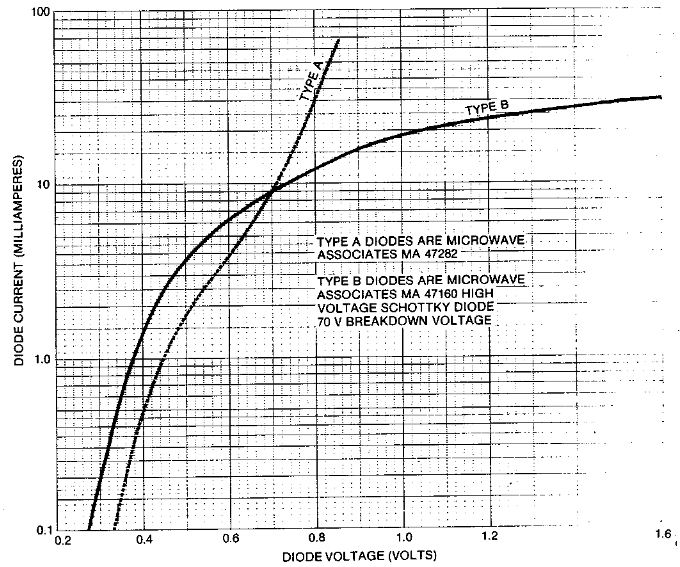


Figure 6. Typical Schottky Barrier Diode I-V Characteristics.

Performance Data

Single sideband power output of the up-converter is shown in figure 7 as a function of pump power input and if. drive voltage. Further increase of output was possible for higher pump power input, the limitation being diode dissipation. The pump level in the output was 20 dB minimum below the sideband level. This typical performance was obtained from 1500 to 3000 MHz.

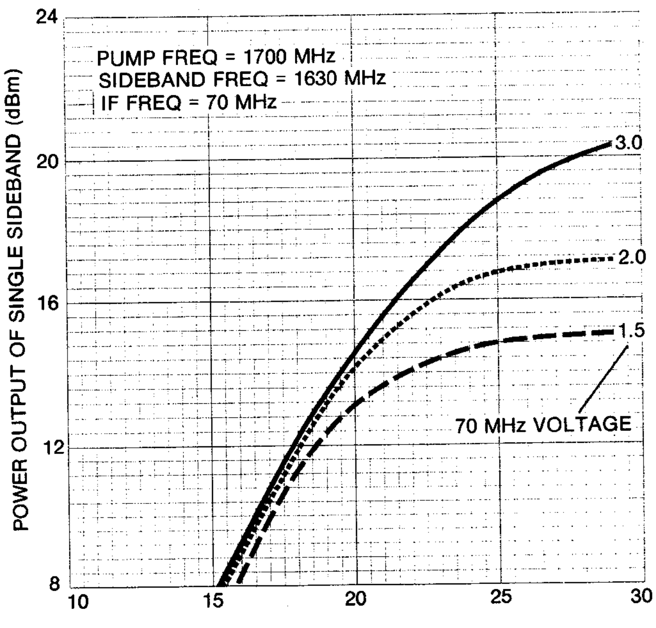


Figure 7. Up-Converter Power Output Characteristics.

It was necessary near the end of the development program to reduce the up-converter if. drive voltage to meet two requirements for systems operation. One of these requirements was the level of the 70-MHz harmonic in the 2-GHz frequency range. This harmonic needed to be 100 dB below the sideband power output. The normal level of the if. harmonic related to the sideband power output with 3 volts if. input to the diodes was 55 dB. To meet the 100-dB carrier suppression, the if. voltage was reduced to approximately 1.5 volts. This lower if. voltage also caused the other requirement, the AM-to-PM conversion, to be reduced from approximately 3° per decibel to approximately 0.5° per decibel. The Schottky diode performance exceeded that of the pin diode for both requirements, contrary to what would be expected. The high conversion efficiency of the Schottky diode met the revised sideband power output when the if. voltage was lowered to the linear region, thereby giving low 70-MHz harmonic output and also a low AM-to-PM conversion. This revised single sideband power output was +12 dBm, which ironically required an up-converter with a high (for example, +20 dBm) power output capability.

Conclusion

An economical, compact, medium-power up-converter has resulted from the use of low-cost components, a broadband microstrip and balanced strip circuit design, diode bias isolation, and a class of high-voltage Schottky diodes that do not show compression at high diode forward voltages.

[1]George Oltman, "The Compensated Balun," IEEE Transactions on Microwave Theory and Techniques, vol. MTT-14, No. 3, March 1966, p. 112-119.

[2]Robert B. Mouw, "A Broadband Hybrid Junction and Application to the Star Modulator," IEEE Transactions on Microwave Theory and Techniques, vol. MTT-16, No. 11, November 1968, p. 911-918.