OCTAVE INPUT, S-TO Q-BAND LARGE-SIGNAL UPPER-SIDEBAND VARACTOR UPCONVERTER

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ABSTRACT

The S-to Q-band varactor upconverter described herein provides significantly greater power output/bandwidth capability than obtainable from a conventional single-sideband resistive upconverter, leading to significant potential simplification in high-modulation-rate millimeter wave transmitters. This upconverter uses high quality varactors and a unique design to provide octave (2-4 GHz) instantaneous input bandwidth, and a flat (16-22 mW), 2 GHz-wide Q-band output power-frequency response with minimum Q-band pump power expenditure.

INTRODUCTION

This paper describes the development* of an octave input bandwidth S-to-Q-band varactor large signal upper sideband upconverter for use as a single-sideband frequency translator for a millimeter wave transmitter application. It provides an efficient low noise mechanism for translating a wideband digitally modulated S-band (2-4 GHz) signal to an equal bandwidth in the Q-band (40-50 GHz) range, and it exhibits considerable lower conversion loss and higher power output capability than a resistive mixer upconverter or multiplier chain.

The S-to-Q-band upper sideband upconverter (USUC) described herein is an extension of a previous S-to-Ka-band design[1] which demonstrates a considerable improvement in conversion efficiency and power output capability as compared to the latter by virtue of the high breakdown voltage, high quality in-house varactors employed therein. In fact, the enhanced Q-band power output capability of the USUC enabled it to be used to directly drive the output TWTA in a Q-band transmitter HPA subsystem without requiring the use of intervening Q-band preamplifiers.

BASIC DESIGN CONSIDERATIONS

The S/Q-band varactor upper-sideband upconverter (USUC) described herein is operated in a highly nonlinear, large-signal mode of operation in which signal input power level is of the same order of magnitude as the pump power level and in which upconversion gain is reduced in favor of increased bandwidth and minimum Q-band pump power expenditure at useful sideband output power levels.

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The evolution of the optimum wideband design approach was based upon a previously developed[1] millimeter wave varactor USUC and is depicted schematically in Figure 1. The S/Q-band USUC model consists of the following key circuit components:

- A balanced pair of in-house high-quality, low parasitic content varactors embedded in a Q-band iris-coupled waveguide cavity, with suitable coupling provided at the input signal (f_s), pump (f_p) and upper sideband output ("sum") ($f_u=f_p+f_s$) frequencies and a suitable reactive termination provided at the lower sideband (idler) frequency ($f_i = f_p - f_s$) to prevent the flow of idler current through the varactors. The balanced varactor pair provides inherent mutual frequency separation between the signal circuit, connected thereto at the varactor midpoint and the sum and idler circuits formed within the waveguide-cavity itself.

- An S-band (2-4 GHz) coaxial signal input circuit, consisting of a series tuning inductor, multi quarter wave impedance transformer, RF-isolated varactor bias feed network and DC blocking resonator. The tuning inductor, which resonates the pumped varactor capacitance, is connected to the balanced varactor pair at the midpoint thereof.

- A Q-band waveguide pump/sum matching network which is iris-coupled to the balanced varactor mounting cavity and, provides the desired impedance at the varactor terminals at the pump and sum frequencies and presents an open circuit to the pumped varactor junction capacitance at the difference frequency.

- A Q-band waveguide four port circulator diplexer including a multi-resonator sum frequency output band pass filter to separate the pump input and sum frequency upper sideband output and provide further rejection at the latter to any residual lower sideband (idler) leakage.

This USUC schematic representation formed the basis for the design and realization of the final model S-to-Q-band USUC described herein.

Based upon a previously developed wideband USUC design approach[1], a family of calculated[2,3] S-to-Q-band USUC power output-frequency response curves are presented in Figure 2 for representative varactor and circuit parameters. Examination of these curves verified a high degree of nominal passband flatness in power output (1 dB rolloff at band edges) provided in this design. Moreover, assuming the use of high-quality (pumped cutoff frequency 400 GHz) in-house varactors the predicted upper sideband output power over the specified 2 GHz wide instantaneous Q-band range is 18 - 21 mW.

PHYSICAL EMBODIMENT OF S/Q-BAND USUC MODEL

The above schematic large-signal USUC design formed the basis for the physical implementation of a fully packaged S/Q-band upconverter model. The "heart" of the physical embodiment of this overall large-signal USUC configuration was the USUC mounting structure, a milled-out "split-block" housing, consisting of the direct interconnection of the S-band coaxial signal input circuit and Q-band waveguide varactor mounting cavity and pump/sum bandpass matching network.

Based upon the design procedure and circuit implementation described in the preceding sections, the final S/Q-band large signal USUC model was configured in accordance with the schematic previously depicted in Figure 1, and was packaged into a lightweight pressurizable enclosure which included a bias and monitor network and a pump level attenuator in accordance with Figure 3.

A BITE output was provided to check if the upconverter is operational when the pump power is 50 mW and no signal power is applied. ± 15 Vdc prime power is required only to operate the BITE circuitry.

The final USUC package shown in the photograph of Figure 4 has dimensions of 7 x 6 x 2 inches and weighs less than 4 lbs.

The measured output power-frequency performance of the final USUC package presented in Figures 5 and 6, exhibited 15 to 24mW upper-sideband output power over the 2-4 GHz/ 2 GHz wide Q-band instantaneous input/output frequency range (nominally +12.8 dBm, with about ±1.0 dB passband ripple) for signal and pump input levels of 100 mW each. Also shown in Figure 6 is the USUC performance under reduced pump and signal drive levels, such that a minimum upper sideband output power level of 10 mW is maintained.

Other aspects of final measured performance included:

- Lower-sideband and pump rejection at the output port: greater than 40 dB.
- Output power variation with pump level essentially linear (1 dB/dB) over the 75-150 mW pump power range and at 100 mW signal input power, as evidenced by the family of output power transfer curves, depicted in Figure 6A.
- Output power essentially saturated with respect to signal input power at 100 mW pump level with less than 0.5 dB variation at any given passband input/output frequency for input signal levels of 50-100 mW, as shown in Figure 6B. This quality is quite useful in FM or PM transmitting systems which require minimization of residual AM.
- Pump input port mismatch 1.6:1 VSWR under 100 mW input signal drive.
- Upper sideband output port mismatch 1.3:1 VSWR under 100 mW input signal drive.

Clearly, the measured performance of the final USUC model compared quite closely with the corresponding theoretical predictions.

The final S/Q-band USUC package herein was delivered for incorporation in a Q-band HPA subsystem.

REFERENCES

1. H.C. Okean and L.J. Steffek, "Octave Input, S to Ka-Band Large Signal Upper Sideband Varactor Upconverter", 1974 IEEE-GMTT Symposium Digest, pp 218-220.

2. P. Penfield and R. Rafuse, "Varactor Application", MIT Press, Cambridge, Mass., 1964.

3. P.S. Henry "An Efficient Microstrip Upconverter for Ka-Band, 1975 IEEE-GMTT Symposium Digest, pp

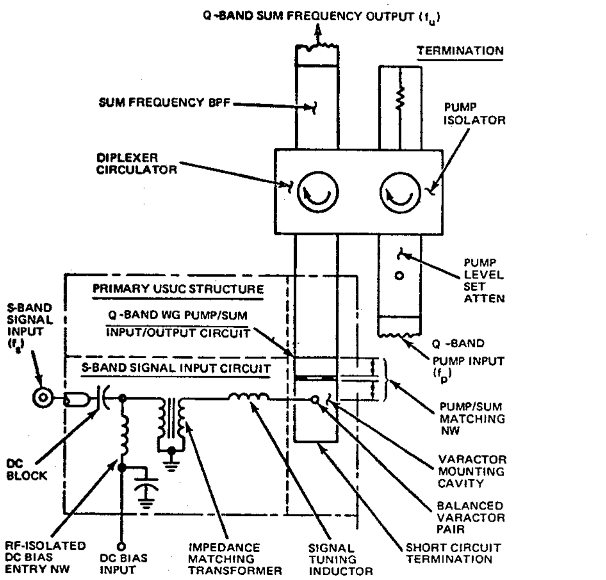

FIGURE 1 SCHEMATIC LAYOUT OF S/Q-BAND USUC

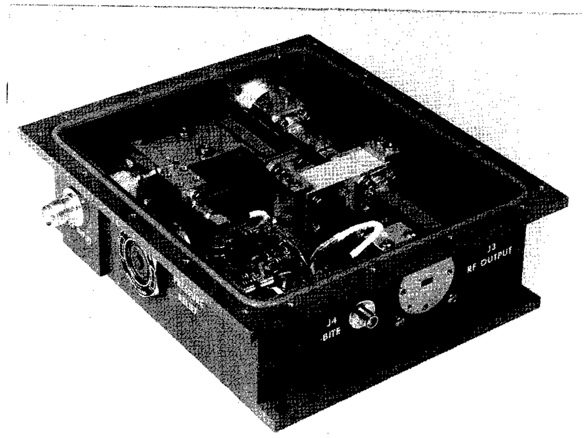

FIGURE 4 FULLY PACKAGED S-TO-Q-BAND POWER UPCONVERTER ASSEMBLY

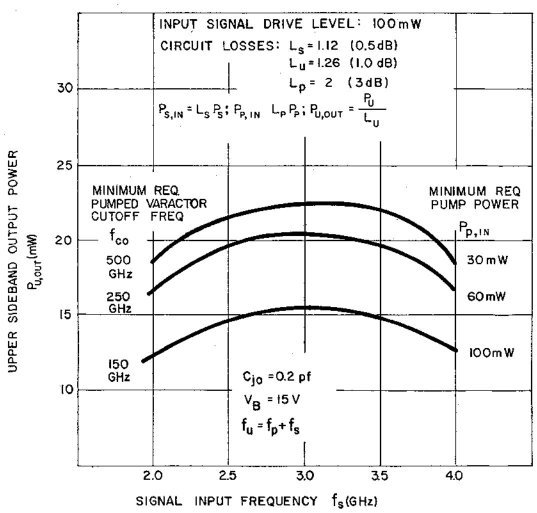

FIGURE 2 THEORETICAL S-TO-Q-BAND LARGE SIGNAL USUC OUTPUT POWER-FREQUENCY RESPONSE CURVES

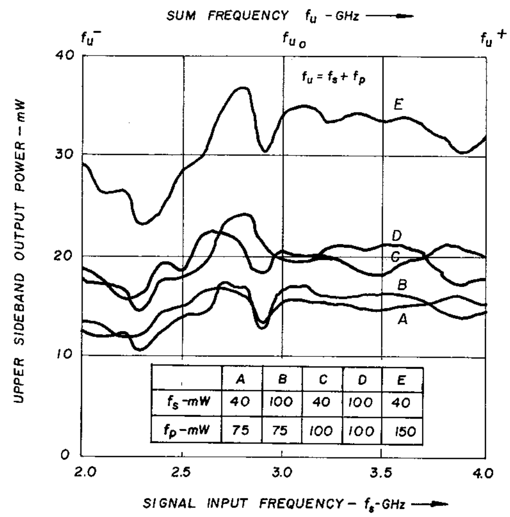

FIGURE 5 MEASURED POWER OUTPUT-FREQUENCY RESPONSE, OF FINAL S/Q-BAND USUC MODEL

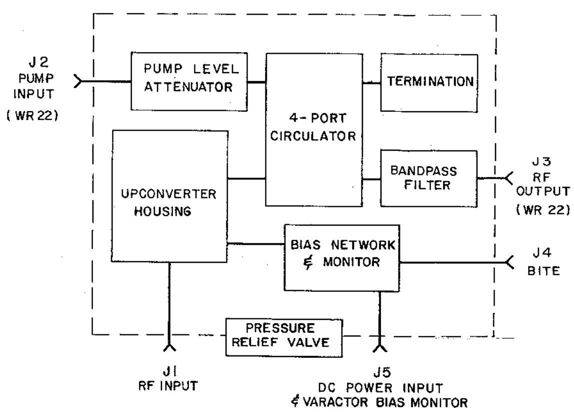

FIGURE 3 BLOCK DIAGRAM OF FINAL FULLY PACKAGED S/Q-BAND USUC ASSEMBLY

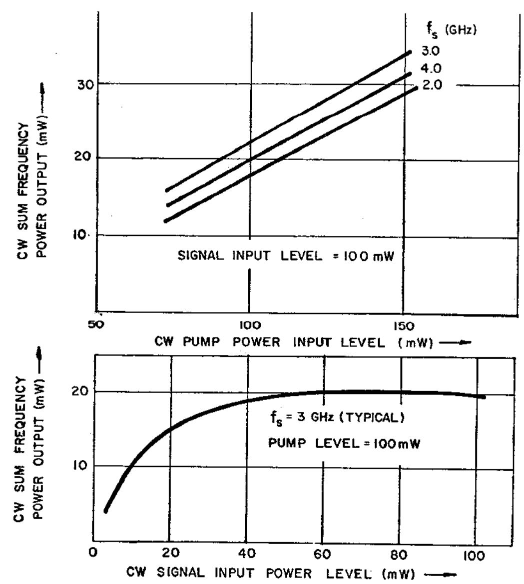

FIGURE 6 MEASURED SIGNAL AND PUMP LEVEL SENSITIVITY OF FINAL USUC MODEL