A Ku-Band Oscillator Subsystem Using a Broadband GaAs MMIC Push-Pull Amplifier/Doubler

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Abstract—**The design and performance results of a Ku-band voltage controlled oscillator subsystem using a broadband GaAs MMIC push-pull amplifier as a frequency doubler is described. The subsystem utilizes both GaAs MMIC and Si Bipolar technologies to achieve the desired performance objectives. The oscillator sub-system is tunable over the 14–18 GHz frequency range with minimum output power of 18 dBm and phase noise of −88 dBc/Hz at 100 KHz offset from the carrier over 0 to +65°C temperature range.**

I. Introduction

LOW-PHASE noise Ku-band frequency sources have typically been constructed using push-push bipolar oscillators or by use of an X-Band fundamentally tuned oscillator combined with a frequency doubler. The push-push Bipolar VCO approach is implemented by standard hybrid MIC techniques where the high-frequency performance is limited by interconnect parasitics and bipolar device parameters. Recently, the heterojunction bipolar transistors (HBT's) have demonstrated high frequency push-push operations [1]–[3]. The X-Band Bipolar VCO with a frequency doubler approach traditionally uses diode frequency doubler [4] in conjunction with required baluns. In this letter, we describe the design and performance of a Ku-band oscillator subsystem that incorporates a GaAs MMIC push-pull amplifier/doubler in conjunction with an X-Band Si bipolar oscillator to achieve low-phase noise and medium power output at Ku-band. In order to achieve the best subsystem performance, GaAs MMIC chip designs combined with silicon bipolar MIC designs can yield performance features not found with the exclusive use of one or the other technology.

II. Oscillator Sub-System

A block diagram of a Ku-band voltage controlled oscillator subsystem is shown in Fig. 1. The oscillator subsystem consists of a Si bipolar VCO, GaAs MMIC amplifiers, MIC Balun, GaAs MMIC doubler, MIC hybrid power amplifier, bandpass filter and voltage regulator. An MIC X-Band fundamentally tuned silicon bipolar oscillator, configured in the common collector negative R configuration was designed with a tuning range of 6–10 GHz. A silicon hyper-abrupt varactor diode was utilized as a high Q tuning element.

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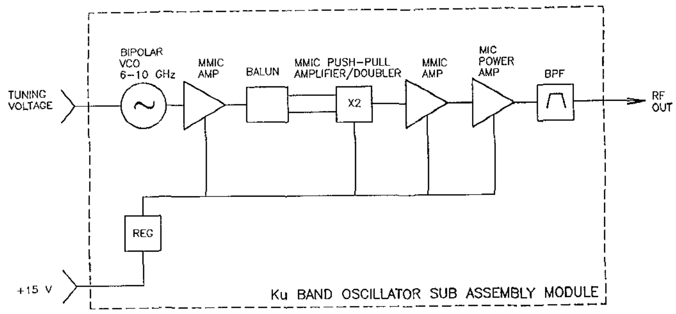

Fig. 1.

Following the oscillator is a 6–18 GHz MMIC amplifier (48 × 48 mils) which acts not only as a buffer amplifier but also provides power output leveling for the following stage, the frequency doubler.

The frequency doubling operation is performed through the use of a push-pull 8–18 GHz GaAs MMIC amplifier (Fig. 2, Chip size: 48 × 48 mils) in a push-push (outputs tied together instead of being combined through a balun) mode. This way, a frequency doubler is realized which suppresses the fundamental frequency. Fig. 3 depicts the functional block diagram of the push-push amplifier/doubler.

Let us assume that the input and output voltages on one side of the push-pull amplifiers are related by:

$$V1 = A\cos(wt + \theta)$$

$$V0 = K1V1 + K2V1^2 + K3V1^3 \ (\textit{up to third-order terms})$$

Then the two outputs from the push-pull amplifiers are given by the

$$V01 = \frac{K_2 A^2}{2} + \left(K_1 A + \frac{3}{4} K_3 A^3\right)[\cos(\mathrm{wt})] + \frac{1}{2} K_2 A^2 [\cos 2(\mathrm{wt})] + \frac{1}{4} K_3 A^3 [\cos 3(\mathrm{wt})]$$

$$V02 = \frac{K_2 A^2}{2} + \left(K_1 A + \frac{3}{4} K_3 A^3\right)[\cos(\mathrm{wt} + 180°)] + \frac{1}{2} K_2 A^2 [\cos 2(\mathrm{wt} + 180°)] + \frac{1}{4} K_3 A^3 [\cos 3(\mathrm{wt} + 180°)].$$

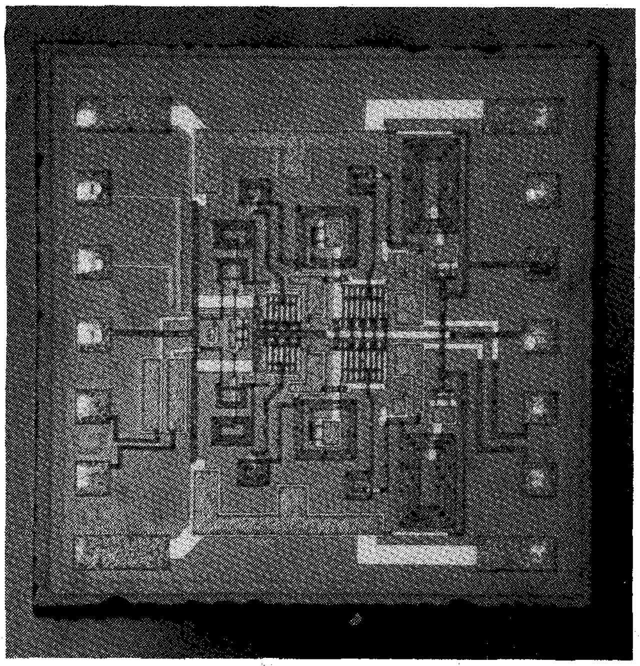

Fig. 2.

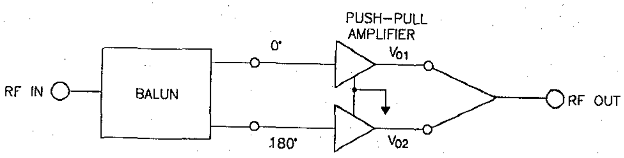

Fig. 3.

Combining these two outputs, we get:

$$V01 + V02$$
$$= K_2 A^2 + \left(K_1 A + \frac{3}{4} K_3 A^3\right)[\cos wt - \cos wt]$$
$$+ \frac{1}{2} K_2 A^2 [\cos 2\,wt + \cos 2\,wt]$$
$$+ \frac{1}{4} K_3 A^3 [\cos 3\,wt - \cos 3\,wt],$$

i.e., $V01 + V02 = K_2 A^2(\text{dc}) + K_2 A^2 \cos 2\,wt$ (2nd harmonic).

The combined outputs only produce the 2nd harmonic and the dc component of the input signal and hence, frequency doubling is accomplished. The measured fundamental suppression of this push-pull amplifier/doubler is 20dBc (Fig. 4) at 8.5GHz frequency and is limited by the fundamental frequency matching networks of the push-pull amplifier.

Following the frequency doubler is a medium power 6-18GHz MMIC amplifier (48 × 48 mils) that amplifies the doubled output frequency up to a power level of nominally 8-10 dBm. This power level is sufficient to drive a Ku-band balanced MESFET MIC amplifier that provides enough gain to achieve an output power of 18 dBm at +65°C. A hairpin bandpass filter was designed to suppress the unwanted subharmonics to less than −40 dBc.

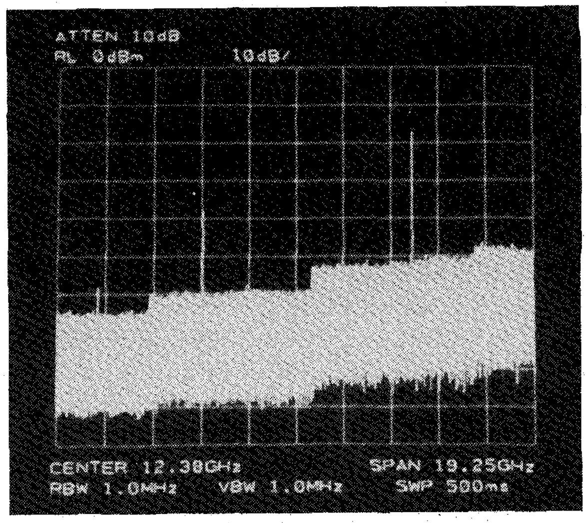

Fig. 4.

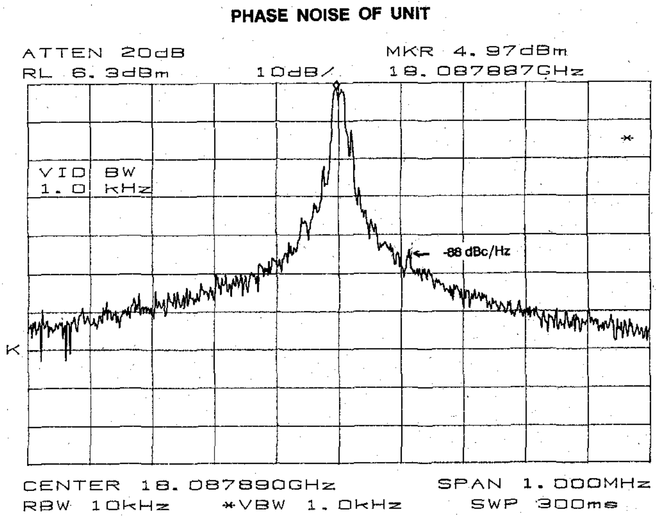

Fig. 5.

TABLE I
SUMMARY OF PERFORMANCE
(0-65°C)

Frequency Coverage	14-18 GHz
Tuning Voltage	0-10 V
Power Output	18 dBm min
Power Output Flatness	1 dB
Frequency Drift	< 1.5 MHz/oC
Phase Noise	< −88 dBc/Hz @100 KHz offset
Harmonics	≤ −30 dBc
Spurious	≤ −40 dBc
Pushing	< .02%
Pulling (2:1 VSWR)	< 12 MHz

All these functions have been integrated into an SMA connectorized module measuring only 1.8 × 1 × 0.65 inches in size. Table I details the performance of the module. The measured phase noise performance of the module is shown in Fig. 5. The measured results show an approximate degradation of 8 dB in the phase noise of the signal (−88 dBc/Hz from −96 dBc/Hz@100 KHz offset from the carrier) which is comparable to the theoretical prediction of 6 dB degradation when the signal is doubled.

III. Conclusion

We have successfully demonstrated the application of a broadband GaAs MMIC push-pull amplifier as a frequency doubler in the design and development of a Ku-band voltage controlled oscillator subsystem. Both GaAs MMIC and Si Bipolar technologies have been used to achieve the desired system performance objectives.

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