Extremely low noise InGaP/GaAs HBT oscillator at C-band

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A state-of-the-art very low phase noise integrated hybrid dielectric resonator oscillator (DRO) working at 6.7GHz has been designed and fabricated using a self-aligned InGaP/GaAs HBT as the active device. Very low PM noise has been experimentally obtained: –124dBc/Hz at 10kHz off-carrier. This result is compared with other silicon oscillator circuits fabricated with a similar topology. At least a 12dB improvement for the HBT technology is observed.

Introduction: The development of wireless communication products has led to rapid improvements in microwave devices and the use of better circuit design approaches. As a result, high performance signal synthesisers have been fabricated in which phase noise and stability play important roles. We present in this Letter a method for designing and realising heterojunction bipolar transistor dielectric resonator oscillators (HBT DROs).

Active device: In recent years, it has been demonstrated that heterojunction bipolar transistors exhibit a low level of $1/f$ noise [1]. To fabricate our circuit we have used a four finger InGaP/GaAs HBT with a total emitter area of $240 mm^2$ ($4 \times 2\mu m \times 30\mu m$). The circuit is fabricated using the MOCVD technique with the self-aligned base metallisation process. The epitaxial structure is described in [2]. This transistor has been especially designed for X-band high power applications but as it exhibits low phase noise characteristics it is a very good candidate for low phase noise applications.

The main characteristics of this transistor are f_t and f_{max} of 20 and 40GHz, respectively, at V_{ce} = 6V and I_c = 80mA. The DC current gain is 15 and the HBT exhibits a collector-emitter breakdown voltage ~18V.

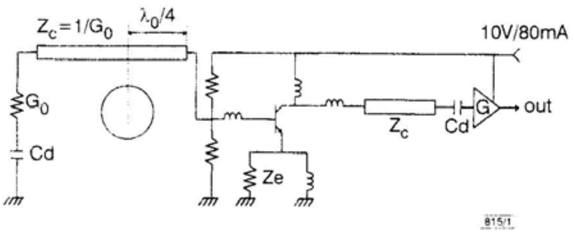


Fig. 1 *Series feedback common emitter HBT DRO*

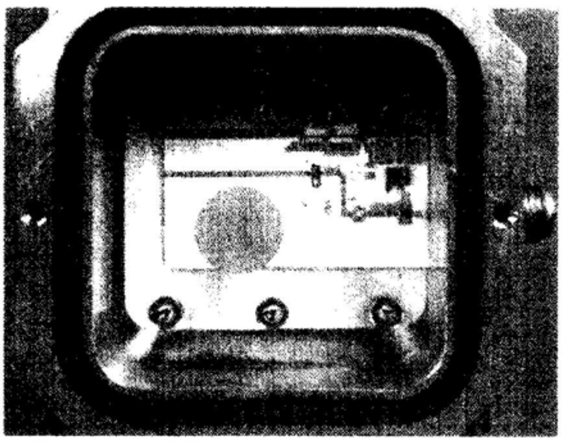


Fig. 2 *Photograph of DRO*

Oscillator architecture design: A series feedback-type oscillator circuit topology is used, with the dielectric resonator ($Q_0 f_0 = 10^{14}$ Hz) coupled to the transmission line connected to the base of the transistor (Figs. 1 and 2). As is well known, this topology gives very low phase noise and eliminates spurious frequencies and instabilities [3].

The input and output matching networks are designed using the open-loop method [4], where the collector current source and the base-emitter capacitance are controlled by an independent external voltage generator, E_g (Fig. 3). The simulations are performed in

(i) Linear simulations are carried out to optimise the group delay, the transistor small-signal gain and the small signal open-loop gain ($H(\omega_0)$). The latter is given by

$$H(\omega_0) = 20 \log\left(\frac{V_{be}(\omega_0)}{E_g(\omega_0)}\right) \quad (1)$$

$H(\omega_0)$ indicates the transistor gain compression in oscillation. When the transistor oscillates, the large small-signal gain of the circuit is equal to 1, so the transistor gain is compressed by $C_{dB} = H(\omega_0)_{dB}$.

(ii) Nonlinear simulations are carried out to fine-tune the oscillation frequency, analyse the nonlinear stability and track spurious oscillations around the oscillation frequency.

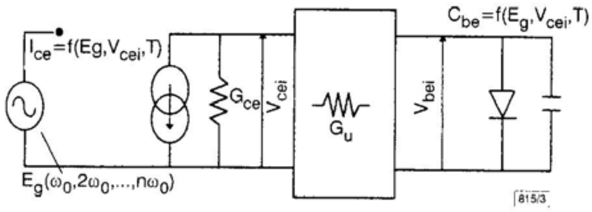


Fig. 3 *Nonlinear diagram of open loop oscillator*

Oscillator measurements: The source includes an FET buffer amplifier circuit with 6dB gain, processed in the UMS (United Monolithic Semiconductors) foundry. We have chosen a hybrid technology in order to facilitate the optimum tuning of passive elements to obtain a lower phase noise.

The HBT DRO is integrated on a 0.6mm alumina substrate in an ($48\times48\times24 mm^3$) aluminium alloy package. To obtain the final results, the circuit was biased with a collector voltage of 10V and a total supply current of 80mA.

The signal purity of the HBT DRO has been characterised using both direct spectrum analyser measurement and phase noise measurements. Careful simulations and experiments on the circuit enabled us to optimise the phase noise characteristics. In this manner, we obtained our best result: very low phase noise power density of –124dBc/Hz at 10kHz off-carrier at 6.7GHz (f_0). Other characteristics are also very good: Oscillator output power is

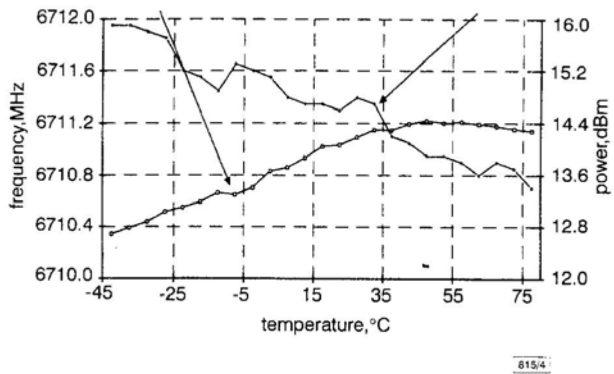
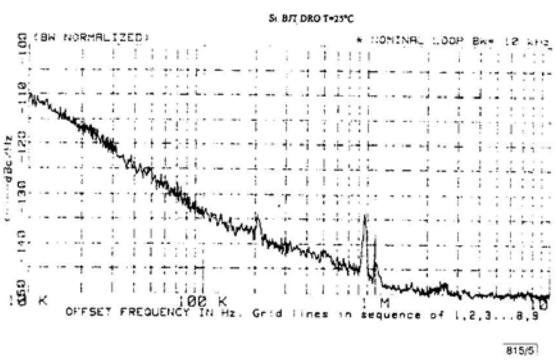


Fig. 4 *Frequency and output power against temperature*

14.3dBm at f_0 with harmonics lower than –29dBm. Frequency stability and output power deviation are less than 1ppm/°C and 2.3dBm, respectively, for temperatures ranging from –45 to 85°C. Experimental results of frequency and power variation against oscillator temperature are shown in Fig. 4.



An SiBJT DRO source was designed with the same oscillator topology as the HBT DRO for the same oscillation frequency (6.7GHz). We observed an improvement of at least 12dBm for the HBT DRO (Figs. 5 and 6).

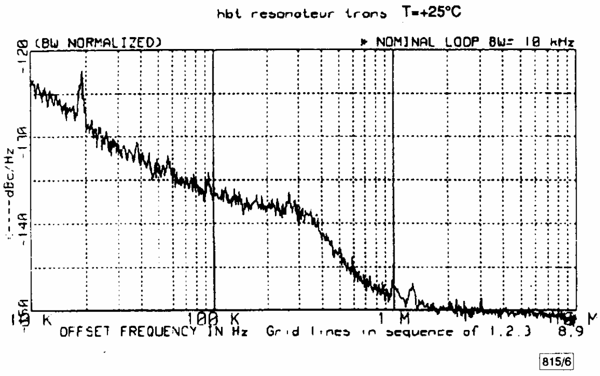


Fig. 6 *HBT DRO*

Conclusions: A hybrid dielectric resonator oscillator has been simulated and fabricated with an InGaP/GaAs bipolar transistor for an oscillation frequency of 6.7GHz. State-of-the-art results for this kind of circuit have been obtained: –124dBc/Hz at 10kHz from carrier. These excellent results demonstrate the very good properties of InGaP/GaAs HBTs for the design of high frequency and low noise oscillators.

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