ON THE POWER AND FREQUENCY STABILITY OF IMPATT OSCILLATORS

K. Wilson, J.R.G. Twisleton and J.L.B. Walker
The General Electric Company Limited
Hirst Research Centre
Wembley England

ABSTRACT

This paper presents some static and dynamic stability results achieved with Ka band Impatt oscillators. The design features needed to achieve these results and the critical measurement problems are also considered.

Introduction

The most common pump source for paramps in the U.K. is an Impatt oscillator operating in the frequency range 33-41 GHz. Generally, these oscillators must have at least a 500 MHz mechanical tuning range and provide up to 150 mW of output power. Since AM noise from the pump far from the pump frequency can degrade the paramp noise temperature[1], each pump source is fitted with a 2 or 3 section 500 MHz bandwidth filter. A photograph of a typical pump source is shown in figure 1.

It is well known that paramps are very sensitive to changes in pump power and frequency, hence one requires a very stable pump source in order to produce a stable paramp. This paper describes the stability that can be achieved with a free-running oscillator and the design features necessary to achieve these results, together with an examination of the measurement problems involved.

Oscillator Construction

A sketch of the oscillator is shown in figure 2. The cap[2] circuit is used in preference to the Kurokawa[3] or reduced height waveguide[4] circuits because of its mechanical ruggedness and compatibility with the r.f. characteristics required.

The diodes are silicon single-drift devices produced within these laboratories.

Measurement Apparatus

The paramp specifications demand that the oscillator power and frequency remain within ±0.03 dB and ±5 MHz, respectively, over 8000 hours operation. For good measurement accuracy one would like a measurement uncertainty one order of magnitude lower than these values, i.e. ±0.003 dB and ±0.5 MHz; this demands an exceptionally high precision test bench. This is shown in figure 3.

The room ambient temperature is maintained within ±1°C and the a.c. supply voltage is held within ±1 V. The contributions to the measurement uncertainty are given in Table 1 from which it can be seen that the target of ±0.5 MHz frequency uncertainty over 8000 hours is achieved with the phase-lock technique[5] shown in figure 3. However, the power measurement uncertainty is ∿ ±0.016 dB which is considered inadequate but it is, nevertheless, the best that can be achieved. Thermistor inaccuracy, claimed by the manufacturer to be within ±(0.2% of reading +½ μW) i.e. ±0.009 dB, is the major source of this power uncertainty. The required 13 dB attenuation between the oscillator and thermistor is provided by a coupler rather than by an attenuator because of the possibility of ageing with the latter. It is necessary to apply corrections to the frequency measurements for variations in the ambient atmospheric pressure and water vapour pressure. The coefficients of the oscillator frequency are -0.32 ppm/mm of Hg and -4.8 ppm/mm of Hg respectively.

TABLE 1 Contributions to Measurement Uncertainty over 8000 Hours

Source of Error	Power Uncertainty, dB
Waveguide switch resettability	±0.002
Reconnection to test bench	±0.002
Thermistor inaccuracy ±(0.2% of reading +½ μW)	±0.009
Oscillator temperature variation	±0.002
Oscillator bias current variation	±0.001
TOTAL	±0.016

Source of Error	Frequency Uncertainty, MHz
Synchroniser's crystal frequency instability	±0.02
Counter instability	±0.01
Oscillator temperature variation	±0.1
Oscillator bias current variation	±0.01
TOTAL	±0.14

Static Stability

One should distinguish between two types of stability, namely static and dynamic. Static stability refers to operation of the oscillator under nominally constant environmental conditions, e.g. oscillator attached to a test bench at room temperature. Dynamic stability refers to changes in oscillator power and frequency as a result of subjecting the oscillator to various environmental tests, e.g. storage at -50°C, vibration etc., and this will be considered in the next section.

Static stability is a function of the measurement period. Short term stability (<<1 minute) is described by AM and FM noise. The AM and FM noise of one of these 150 mW oscillators is shown in figures 4 and 5.

These results are believed to be some of the lowest reported values for this type of oscillator and are a consequence of the diode design.

Medium term stability (<1 hour) is primarily determined by the bias current stability and temperature stability of the oscillator body. Typical results are:

$$\frac{\partial F}{\partial I} = 0.6 \text{ MHz/mA} \quad , \quad \frac{\partial P}{\partial I} = 4 \text{ mW/mA}$$

$$\frac{\partial F}{\partial T} = -1.5 \text{ MHz/}^{\circ}\text{C} \quad , \quad \frac{\partial P}{\partial T} = -0.03 \text{ dB/}^{\circ}\text{C}$$

Long term stability (>1000 hour) is primarily determined by ageing effects. Results will be presented of the 8000 hour stability test mentioned in the previous section.

Dynamic Stability

Figure 6 shows the maximum permitted changes in power and frequency of an oscillator after subjecting it to the environmental tests listed in the figure, together with the actual results achieved with a typical sample. These environmental tests are relevant to airborne use. It should be remembered that the power measurement uncertainty is ∿ ±0.016 dB. Also, no correction has been made for atmospheric changes.

To achieve a 5 MHz frequency stability for a 40 GHz oscillator means that the distance between the cavity end plate and cap-post in figure 2 must not move by more than 1 part in 10^4, i.e. 1 μm in this case! This has been achieved by the use of an offset spring and an anodised aluminium choke as shown in figure 2. Other insulants such as enamel, tape and PTFE between the choke and body have been tried but none have produced such good results as an anodic coating because of the latter's surface hardness.

To achieve an adequate stability during the 90°C dry heat test it has been found necessary to thermally cycle the isolator approximately 10 times between +60 and +90°C prior to assembly of the oscillator in order for the device to pass the stability test. This reduces the hysteresis in the isolator's S parameters (in particular that of the input vswr) vs. temperature which otherwise can cause a permanent frequency change of some MHz following this test.

Acknowledgements

This work has been carried out with the support of Procurement Executive, Ministry of Defence, sponsored by DCVD.

The authors would like to thank the Royal Signal and Radar Establishments at Malvern and Baldock for providing the AM and FM noise measurements, and also to thank P. Brook and C.A. Tearle for their help and advice during the course of this work. The authors would also like to thank S. Kitrick for providing the measurements for figure 6.

References

1. C.A. Tearle and K.R. Heath, "IMPATT Pump Sideband Noise and its Effect on Parametric Amplifier Noise Temperature", IEEE Trans. Microwave Theory Tech., Vol. MTT-23, pp. 1036-1042, December 1975.

2. T. Misawa and N.D. Kenyon, "An Oscillator Circuit with Cap Structures for Millimeter-wave IMPATT Diodes", IEEE Trans. Microwave Theory Tech., Vol. MTT-18, pp. 969-970, 1970.

3. F.M. Magalhaes and K. Kurokawa, "A Single-tuned Oscillator for IMPATT Characterisations", Proc. IEEE, Vol. 58, pp. 831-832, May 1970.

4. T.T. Fong, K.P. Weller and D.L. English, "Circuit Characterisation of V-band IMPATT Oscillators and Amplifiers", IEEE Trans. Microwave Theory Tech., Vol. MTT-24, pp. 752-758, November 1976.

5. Hewlett-Packard Application Note 190.

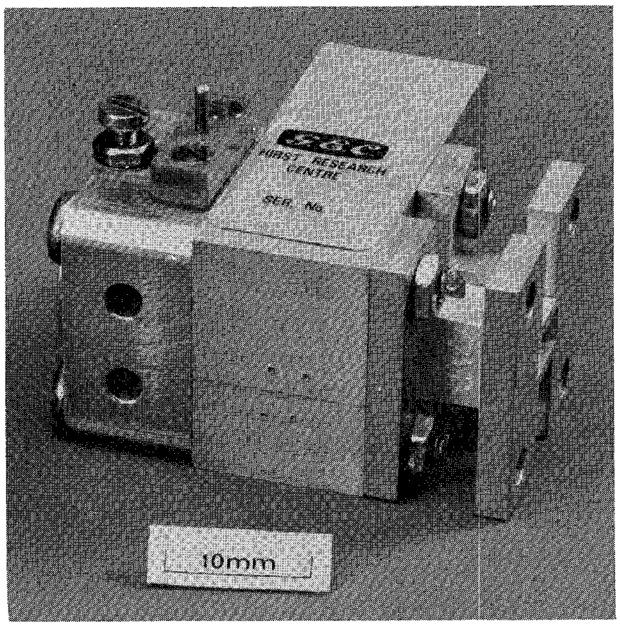

Figure 1
Photograph of a typical oscillator

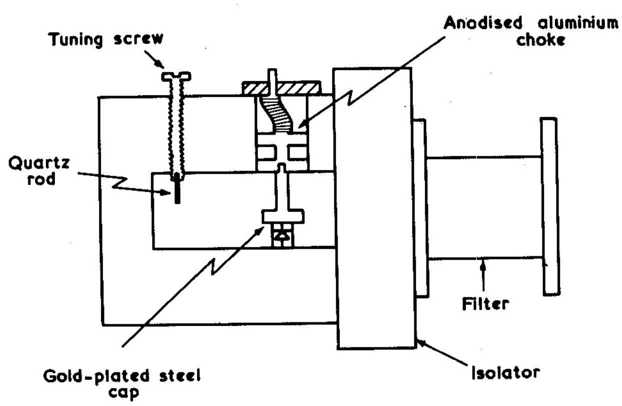

Figure 2
Schematic diagram of the oscillator

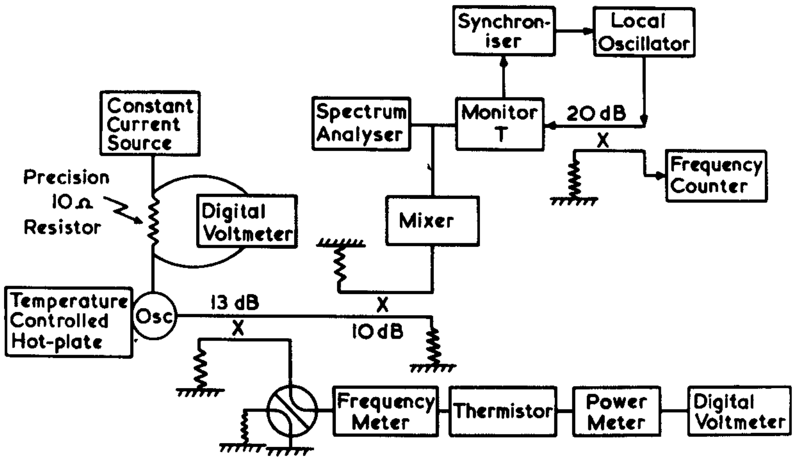

Figure 3
Measurement apparatus

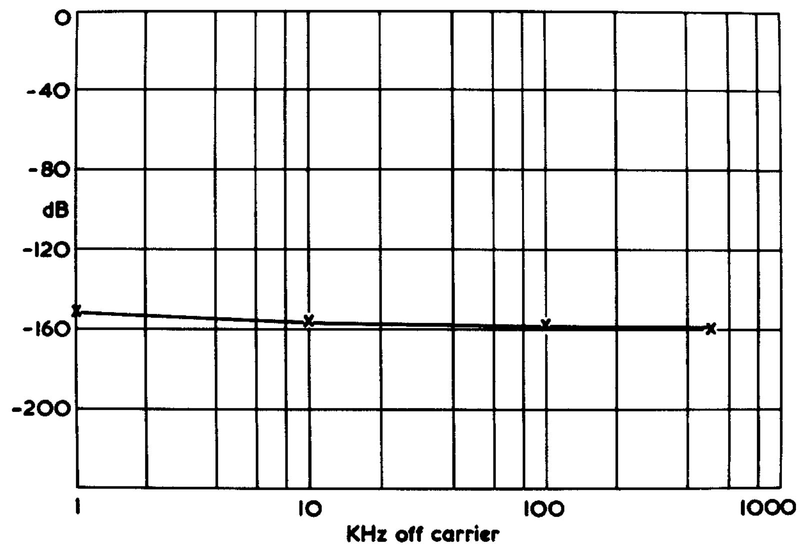

Figure 4
SSB AM Noise

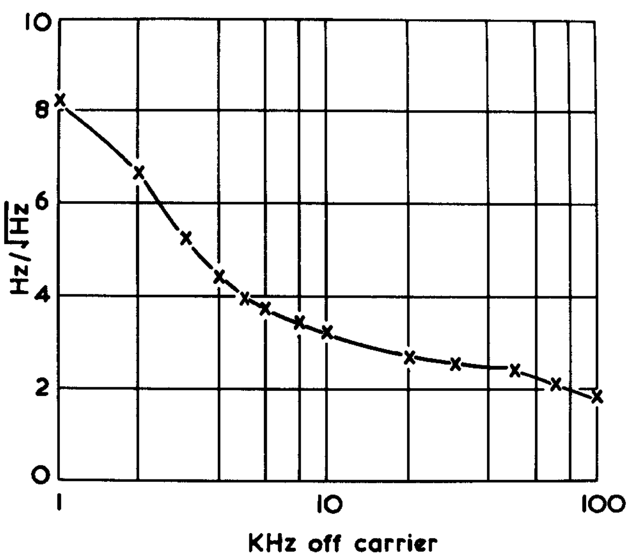

Figure 5
SSB FM Noise

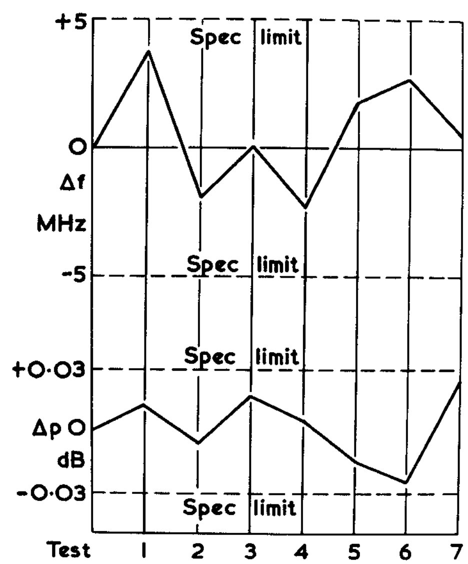

Figure 6
Environmental test results

ENVIRONMENTAL TESTS

1. Dry heat at +90°C for 2 h.
2. -50°C chamber for 2 h.
3. 15 h continuous operation.
4. Topple from each end.
5. Vibration swept frequency 10-1000 Hz.
6. Vibration endurance
   (acceleration = 10g, f = 10-25 Hz
   (acceleration = 1g, f = 25-2000 Hz
7. 1200 bumps, 2 per second, 10 g acceleration along 3 mutually perpendicular axes.