IEEE Transactions on Microwave Theory and Techniques, vol. MTT-26, no. 2, February 1978

HIGHLY STABLE, LOW NOISE MILLIMETER-WAVE IMPATT OSCILLATOR.

Hiroshi Okamoto , Mutsuo Ikeda
Musashino Electrical Communication Laboratory, N.T.T., Musashino-shi, Tokyo 180, Japan.
Shinji Kodaira
Kisarazu Technical College, Gion, Kisarazushi, Chiba 292, Japan.
Keisuke Miyazawa
Tokyo Astronomical Observatory, University of Tokyo, Mitaka-shi, Tokyo 181, Japan.

A highly stable and low noise IMPATT oscillator at 75 GHz is realized by using the parametric injection locking technique along with an AFC circuit in which a crystal oscillator is used as a reference.
Noise level of this oscillator is lower by 25 dB as compared with that of the free-running IMPATT oscillator and the frequency stability is as good as $10^{-8}/°C$.

Parametric injection locking (PIL) is an attractive method to reduce sideband noise of a millimeter-wave solid-state oscillator such as an IMPATT oscillator.[1] The features of this technique are that an arbitrary low-frequency signal source can be used for injection locking and that the locking bandwidth is wide enough for practical use. This letter reports that a low noise and highly stable 75 GHz IMPATT diode oscillator is realized by using the PIL and an automatic frequency control (AFC) circuit.

The block diagram of the circuit developed here is shown in Fig.1. Parts shown by thick lines are waveguide circuit (WRJ-740). A Si double-drift region (DDR) IMPATT diode is used in the oscillator, whose free-running frequency f_0 is 75.5 GHz and the output power P_0 is 16 dBm. An idler cavity is located at about $8\lambda_g$ away from the diode, and its Q_{ext} is 2000. A signal from a varactor tuned transistor oscillator (1.5-1.7 GHz), which is designated as VFO, is injected through the bias circuit of the IMPATT oscillator. The IMPATT oscillator is then locked parametrically, and its sideband noise is reduced by more than 25 dB compared with that in the free-running state, as shown in Fig.2. The locking bandwidth is 700 MHz when the injection signal power is 23 dBm.

A part of the oscillation output is picked up and supplied to a frequency discriminating circuit, which produces a DC signal proportional to a drift $\delta f_0'$ in the oscillation frequency f_0' of the locked IMPATT oscillator. This DC signal is fed back to the varactor in the VFO, thereby changing the injection signal frequency f_{inj} so as to cancel the drift $\delta f_0'$ in the frequency f_0'. The loop gain of the AFC circuit is 30 or more.

The frequency discriminating circuit is constructed as follows. An output from a crystal oscillator (112.50 MHz) is multiplied by 16 times, and it lockes a transistor oscillator (L.Osc.) at 1.80 GHz. The output of the latter is supplied to a step recovery diode (SRD), which produces many harmonic components. The 6th harmonic signal (10.80 GHz) is selected by a band pass filter, and supplied to a GaAs Schottky diode harmonic mixer. One of the mixing products between this reference signal (10.80 GHz) and the signal (75.53 GHz) from the locked IMPATT oscillator lies at or near 70 MHz, and it is amplified and supplied to a frequency discriminator, whose center frequency is set at 70 MHz and the bandwidth is 0.2 MHz.

When the ambient temperature T around the IMPATT oscillator and the idler cavity is changed by δT, the oscillation frequency f_0' changed by δf, which can be measured by observing the signal (~70 MHz) from the harmonic mixer by using a spectrum analyzer. Fig.3 shows the measured data on δf v.s. δT. Although this curve is not a straight line, δf is only 10 KHz when δT is 11°C. This means that the temperature coefficient of the frequency f_0' of the locked IMPATT oscillator is less than $1.2\times10^{-8}/°C$, or the same order as that of the crystal oscillator used here.

Baprawski et al.[2] recently discussed on various methods of stabilizing millimeter-wave solid-state oscillators, and proposed the phase locking technique. Although their circuit construction was economical and compact, as is also the case in the present method, the sideband noise in the phase locked oscillator did not reduced but rather increased at around 1 MHz off-carrier frequency, as compared to that in the free-running state. In the present stabilizing circuit, on the other hand, no such increase in the noise is observed as shown in Fig.2.

Authors wish to thank Mr.M.Ino for the preparation of the DDR IMPATT diode.

(1)H.Okamoto et al., 1977 Intern'l Microwave Symp.C3.3.
(2)J.Baprawski et al., Microwave J., vol.19, p.41, 1976.

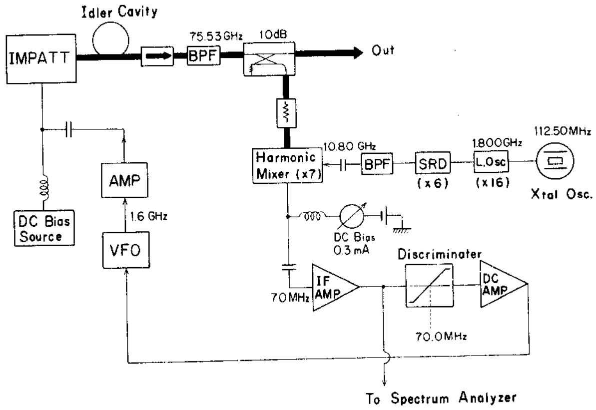

Fig.1 Block diagram of the circuit used here.

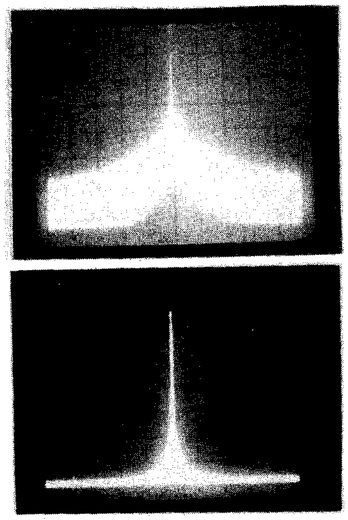

Fig.2

Spectra of the oscillation output.
Upper; free-running state.
Lower; locked state.
Horizontal 1 MHz/div.
Vertical 10 dB/div.

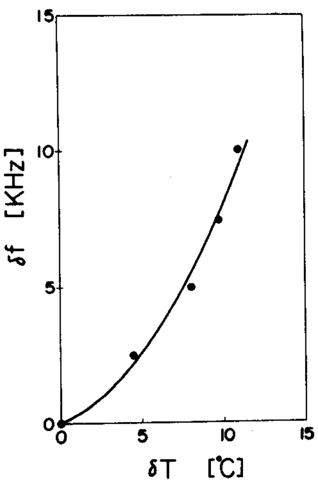

Fig.3

Frequency shift v.s. tenperature change.

Manuscript received September 8, 1977.
0018-9480/78/0200-136$00.75