Highly Stable, Low Noise Millimeter-wave IMPATT Oscillator.

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Summary

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 compared with that of the free-running IMPATT oscillator, and the frequency stability is as good as $10^{-8}/^{\circ}C$.

Parametric injection locking (PIL) is an attractive technique 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 can be used for injection locking and that an available locking bandwidth is wide enough for practical use. In this letter, a low noise and highly stable 75 GHz IMPATT diode oscillator is demonstrated as an application example of the PIL technique.

Fig.1 shows a block diagram of the circuit developed here. Parts shown by thick lines are waveguide circuit (WRI-740). A Si double-drift-region (DDR) IMPATT 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 diode 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 this AFC circuit is 30 or more.

The frequency discriminating circuit is constructed as follows. An output from a crystal oscillator (112.5 MHz) is multiplied by 16 times, and it locks a transistor oscillator (L.Osc.) at 1.8 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 bandpass filter, and supplied to a GaAs Schottky diode harmonic mixer. One of the mixing products between the signal (10.80 GHz) from the crystal oscillator 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 around both the IMPATT diode oscillator and the idler cavity is changed by δT, the oscillation frequency f_0' changes by $\delta f_0'$, which can easily be measured by observing the signal (~70 MHz) from the harmonic mixer with a spectrum analyzer. Fig.3 shows the frequency shift as a function of the temperature change. The frequency change $\delta f_0'$ is seen to be only 10 KHz when the temperature change δT is 11°C. This means that the temperature coefficient of the frequency f_0' of the locked IMPATT oscillator is 1.2×10^{-8} or less, or the same order as that of the crystal oscillator used here.

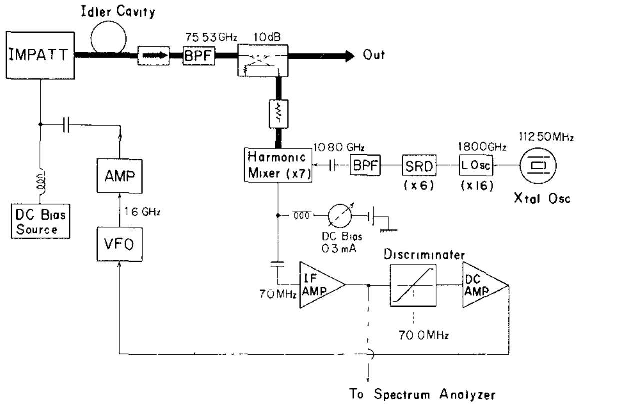

Fig.1. Circuit diagram.
Thick lines indicate waveguide circuits and others coaxial line circuits.

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

(1) H.Okamoto et al., 1977 International Microwave Symposium C.3.3.
(2) J.Baprawski et al., Microwave J., vol.19, pp.41, 1976.

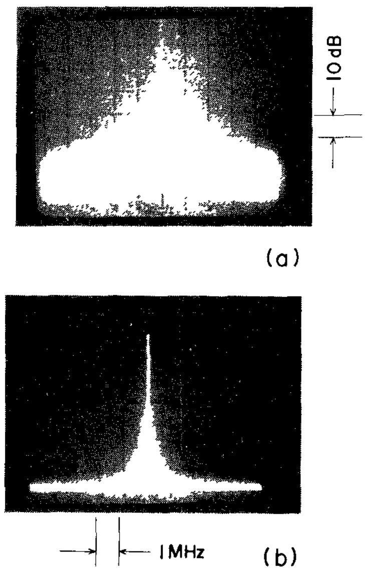

Fig.2. Oscillation Spectrum.
(a) free-running state.
(b) locked state.

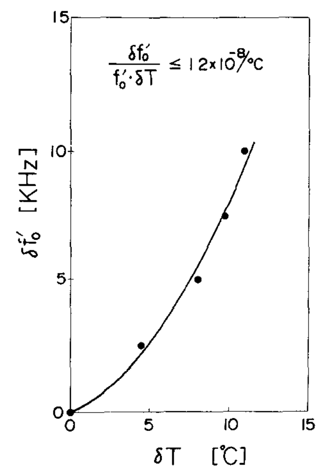

Fig.3. Frequency change $\delta f_0'$ v.s. temperature change δT.