NEW ALARM CIRCUIT USED FOR INJECTION LOCKING OSCILLATOR OF MICROWAVE COMMUNICATION EQUIPMENT

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Cavity-controlled microwave local oscillators (1) are widely used since they are tunable over a wide frequency range with excellent output characteristics and generate little noise.

However, the maximum frequency stability is limited to $\pm 5 \times 10^{-5}$.

To increase the frequency stability, a crystal-controlled oscillator is used to perform injection locking in the cavity-controlled oscillator.

This paper describes a new injection locking method, explains the theory of injection locking alarm circuit and compares the experimental results with mathematical calculations.

The injection locking method and alarm circuit based on this technique are very simple and easy to incorporate into high frequency-stability microwave local oscillator.

Theory of Operation

The oscillator circuit can be shown by an equivalent circuit having current source i_o and LCR circuit. Assume that: (1) the oscillator is connected to a line having characteristic impedance Zo; (2) and injection locking input signal (Vi) is applied; and (3) the output signal (Vo) is locked to the injection locking input signal. The following formulas are then applicable.

$$V = Vo + Vi \quad (1)$$

$$i = (Vo - Vi) / Zo \quad (2)$$

$$i = i_o - (1/R + J\omega c - J\, 1/\omega L)V \quad (3)$$

here = 2 f, f=injection locking input signal frequency

= $(2\pi f_o)^2 = 1/LC$, f_o=oscillator free-running frequency

From (1) - (3)

$$V_o = \frac{RZ_o}{R+Z_o+j\ RZ_oX}\, i_o + \frac{R-(Z_o+j\ RZ_oX)}{R+Z_o+j\ RZ_oX}\, Vi \quad (4)$$

$$\text{here } X \doteqdot 2\ \frac{\omega - \omega_o}{\omega_o} \sqrt{\frac{C}{L}}$$

Put $\omega = \omega_o$, that is, in the injection locking center, X is zero.

$$\text{Then} \quad V_o = \frac{RZ_o}{R+Z_o}\ i_o + kVi \quad (5)$$

$$\text{here } k = \frac{R-Z_o}{R+Z_o}$$

If $Z_o > R$ $(-1<k<0)$, then $V_o = 0$ at $Vi = \frac{RZ_o}{Z_o-R}\, i_o$.

That is, the oscillator output becomes zero at the injection locking center $(\omega = \omega_o)$ by properly selecting the values of k and Vi.

Further, when Vi is kept at the constant value $\frac{RZ_o}{Z_o-R}\, i_o$, the output under $\omega \doteqdot \omega_o$ is,

$$\left|V_o\right| \doteqdot 2\ \frac{\omega - \omega_o}{\omega_o}\ \frac{RZ_o}{R+Z_o} \sqrt{\frac{C}{L}}\ \left|Vi\right| \quad (6)$$

Therefore, when the oscillator free-running frequency (f_o) deviates from the injection locking input frequency (f), then V_o increases symmetrically from zero.

By applying this characteristic, detecting of injection locking operation is possible.

Circuit Composition

Conventional method directly apply the injection locking input signal to the cavity-controlled oscillator output terminal. However, the new method uses an additional injection locking terminal which is separate from the output terminal.

The oscillator and injection locking alarm circuit compositions are shown in Fig. 2.

The cavity-controlled transistor oscillator is used at 1 GHz band. The desired microwave power is obtained by a wide band frequency multiplier which multiplies this oscillator output power.

The injection locking terminal is connected to a loop in the cavity. Since the injection locking input signal is applied to this loop through a circulator, injection locking alarm output power P_o (corresponding to V_o in formula (5)) is branched which permits monitoring.

Fig. 3 shows the 7 GHz band cavity-controlled GUNN diode oscillator to which the above mentioned injection locking method is applied. The injection locking terminal is a window that provided at the side wall of the cavity.

Experimental Results

Fig. 4 shows the experimental results which were obtained from the circuit shown in Fig. 2. This experiment was made to confirm formula (5).

The injection locking input signal frequency was set to $\omega = \omega_o$ and level to P_i (which corresponds to Vi in formula (5)). k shows the matching condition between oscillator and load at the injection locking terminal.

When P_i is increased from zero, P_o decreases and becomes minimum at the point where the first term of the formulas is equal to the second term. By further increasing P_i, the second term becomes larger than the first and P_o is increased.

Fig. 5 shows the experimental results applicable to formula (6). P_i was set to a value where P_0 was minimum under the condition k=-0.84 in Fig. 4. The curve of P_0 vs ω is shown in Fig. 5. It shows that when f deviates from the center frequency, P_0 increases symmetrically as indicated by formula (6). Therefore, the experimental results coincide with the formulas.

Conclusion

The injection locking method and alarm circuit based on the circuit shown in Fig. 2 are very simple and easy to incroporate into a high stability microwave local oscillator. They have the following features.

(1) This alarm circuit operates as the monitoring and alarm of frequency drift, the oscillator output power and the injection locking input power with only one detector.

(2) Injection locking and detecting can be added to any oscillator by providing an injection locking terminal in the cavity. This permits a common oscillator to be manufactured both for terminal microwave equipment with injection and repeater with no injection. Because terminal station equipment needs a higher frequency-stabilized local oscillator than repeater.

(3) This injection locking system has similar noise characteristics as does the conventional automatic phase control (APC) system without the need for a frequency variable element which is required for APC.

(4) For this system, frequency stability can be kept with the cavity-controlled oscillator which can afford to use for repeater station equipment when the injection locking input power turned off.

On the other hand, for the conventional APC system, frequency stability become so deteriorated that cannot be used when the reference frequency input power turned off.

Acknowledgements

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References

(1) R. Tamura, "Cavity-Controlled Oscillator and its Application", Proceedings of the Fourth Colloquium on Microwave Communication, Budapest, 21-24 April, 1970.

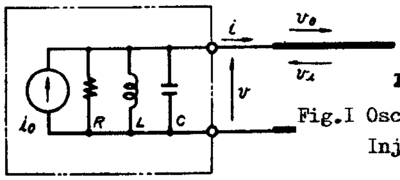

Fig.I Oscillator Model for Injection Locking Analysis

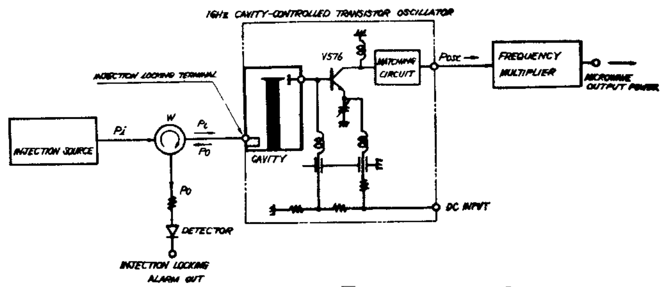

Fig.2 Circuit Composition of Microwave Local Oscillator used New Injection Locking Method

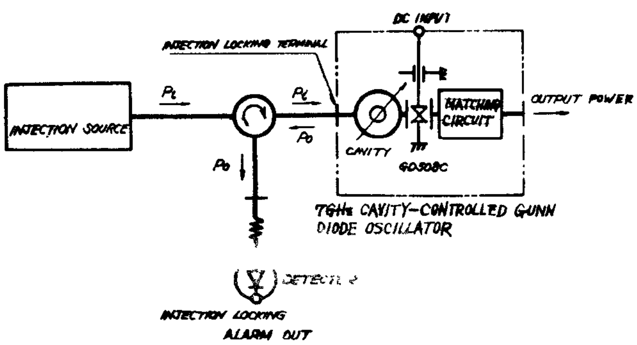

Fig.3 Circuit Composition of 7GHz Cavity Controlled GUNN Diode Oscillator used New Injection Locking Method

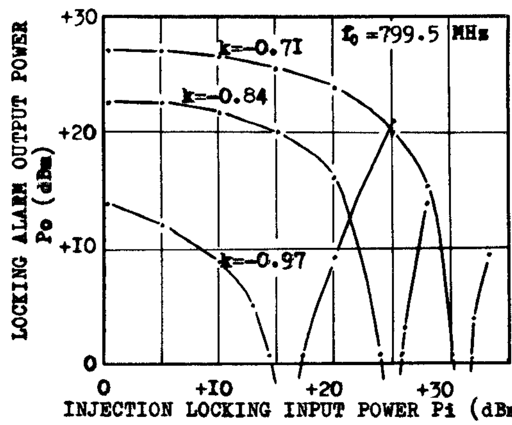

Fig.4 Locking Alarm Output Power vs. Injection Locking Input Power for Circuit of Fig.2

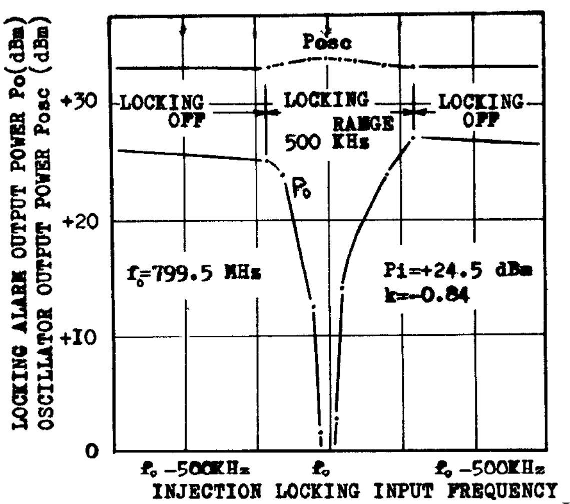

Fig.5 Locking Alarm Output Power and Oscillator Output Power vs. Injection Locking Input Frequency for Circuit of Fig.2

Notes