REDUCTION OF FM NOISE IN MICROWAVE DIODE OSCILLATORS BY CAVITY AND INJECTION STABILIZATION

J. R. Ashley
University of Colorado
Colorado Springs, Colorado 80907

F. M. Palka
Sperry Electronic Tube Division
Gainesville, Florida 32601

ABSTRACT

The Avalanche or Gunn diode oscillators in simple single resonator circuits usually have considerably more FM noise then Klystron or crystal-oscillator, multiplier-chain type signal sources. Transmission cavity stabilization by TE_{01n} mode cavities is applied to both Avalanche and Gunn diode X-Band oscillators to yield simple, useful signal sources with FM noise lower than most other signal sources. Some additional studies show that a cavity stabilized silicon avalanche diode oscillator used as a synchronizing signal to injection phase lock a Gunn oscillator has the best combination of low FM and AM noise.

SUMMARY

The present state of the art for FM and AM noise of various X-Band signal sources is illustrated by Figures 1 and 2. The AM noise shown in Figure 2 is not excessive and the AM noise of either the reflex klystron or Gunn oscillator is adequately low for simple transmitters which do not have a power amplifier stage. Presently, the most pressing problem is the reduction of FM noise in the microwave diode oscillators.

Transmission cavity stabilization is a very simple method of noise reduction. Improved methods for measuring oscillator Q_x and cavity parameters [1] have simplified the application of transmission cavity stabilization to both Avalanche and Gunn diode oscillators.

A Sperry X-Band Avalanche diode oscillator operating at 9.27 GHz, 120 mW output power, and a Q_x of 65 was used to perform passive cavity stabilization experiments. The silicon Avalanche diode used had a breakdown voltage of 90 volts, a Cj (0 volts) = 1.2 pf, and was operating at 35 mA and 3.5 watts of input power. This oscillator was stabilized with a TE_{011} cavity, 8.5 dB transmission loss, and measured Q_o = 21,000. For this oscillator, the calculated stabilization factor is 280 and the measured (by observing the change in current modulation sensitivity) stabilization is 240. In Figure 3, the FM noise is seen to be reduced by the same factor.

This same oscillator when operated with a larger, TE_{014} mode cavity with Q_o = 47,000 and 3 dB transmission loss has a measured S = 325 as compared to the predicted S = 362. Note that only 3 dB transmission loss was used for this experiment. By increasing the transmission loss to 8.5 dB, the FM noise of this cavity stabilized ATTO would be that shown by the dotted curve in Figure 3. This is the same FM noise as can be obtained from an unstabilized low noise two-cavity klystron.

The same theoretical considerations applied to a Varian Gunn diode oscillator operating at 9.72 GHz, 65 mW output power, and a Q_x = 1720, stabilized with a TE_{011} cavity with 6.7 dB Transmission loss and Q_o = 23,000 show that a smaller stabilizing factor is expected because of the higher Q of the oscillator resonator. In this example, S = 10.5 was predicted and S = 8.5 was measured. The FM noise is again reduced by this same factor. Notice that the 1/f low frequency rise is reduced but not eliminated by cavity stabilization. For this reason, the silicon Avalanche diode with a stabilizing cavity has lower FM noise below 10 kHz.

FM noise can also be lowered by injection phase locking [2] although this leaves the problem of obtaining an adequate injection signal. Since an injection phase locking experiment on an avalanche oscillator [3] showed measured FM noise which is not in complete agreement with existing theory, we set up a similar experiment for the Varian Gunn diode oscillator. A low noise two-cavity klystron stabilized by a TE_{015} cavity was again used as the injection signal source for the measurement. As in the case of the Avalanche diode experiment, the FM noise below 10 kHz was not reduced as much as present theory predicts. We feel that the presence of the same behavior in both Avalanche and Gunn diode oscillators indicates that an improved noise theory is needed.

Kurokawa's theory shows that AM noise is essentially unchanged by injection stabilization. Measurements verify that in the range of normal operation where the oscillator (free running) frequency is very close to the synchronizing frequency, the AM noise is unchanged by injection stabilization. Thus, the superior AM noise from a Gunn oscillator can be combined with the freedom from 1/f FM noise in the silicon Avalanche diode oscillator by using a transmission cavity stabilized silicon Avalanche diode oscillator to injection lock a Gunn diode oscillator. This combination has what we believe to be the lowest combined FM and AM noise of any solid state signal source.

We acknowledge the support of F. B. Fank of Varian who supplied the Gunn oscillators. Also, a portion of the work was supported by Contract F33615-69-C-1519 for the Air Force Avionics Laboratory, Wright-Patterson Air Force Base, Ohio.

REFERENCES

[1] J. R. Ashley and F. M. Palka, "A modulation method for the measurement of microwave oscillator Q," (Correspondence IEEE Trans. MTT, Nov. 1970.

[2] K. Kurokawa, "Noise in synchronized oscillators," IEEE Trans. Microwave Theory Tech., vol. MTT-16, pp. 234-240, April 1968.

[3] J. R. Ashley and F. M. Palka, "Measured FM noise reduction by injection phase locking," Proc. IEEE (Correspondence), Vol. 58, pp. 155-157, January 1970.

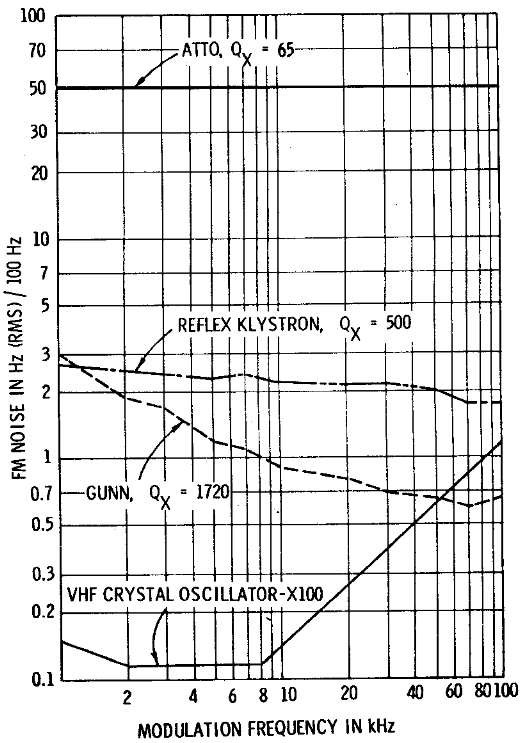

Figure 1. FM Noise of X-Band Oscillators.

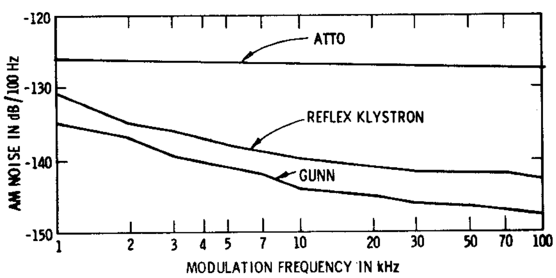

Figure 2. AM Noise of X-Band Oscillators.

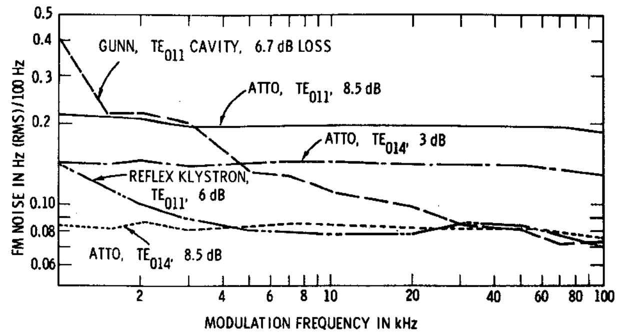

Figure 3. FM Noise of Cavity Stabilized X-Band Oscillators.

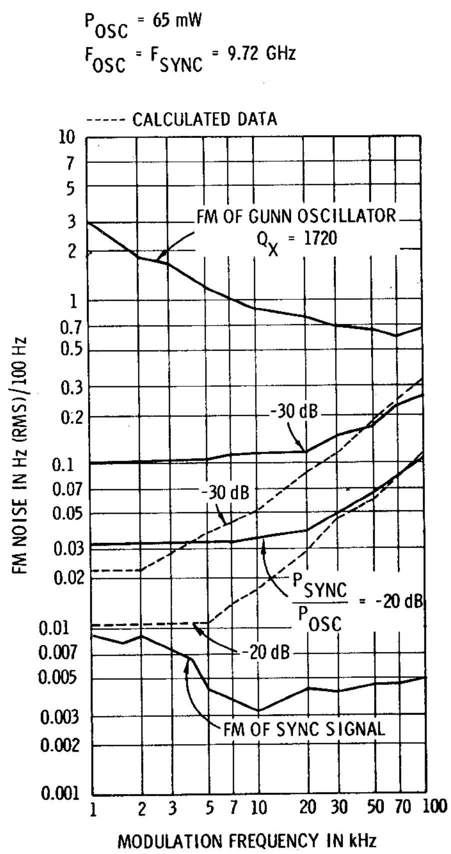

Figure 4. FM Noise of Injection Locked Gunn Oscillator.