Transmission Cavity and Injection Stabilization of an X-Band Transferred Electron Oscillator

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Abstract

The theory and operation of a novel new oscillator is presented. The F.M. Noise at X-band is less than .3 Hz rms in a 100 Hz bandwidth while the carrier stability is that of a high quality Quartz oscillator. The oscillator consists of a Transferred Electron Oscillator (Gunn Diode) in a moderate Q cavity transmission stabilized with a TE_{011} resonator at X-band. A low level signal is injected between the oscillator cavity and the stabilizing cavity to synchronize the X-band oscillation with a harmonic of a 100 MHz Quartz oscillator. The locking power is sufficient to hold synchronization for tens of minutes without significantly degrading the F.M. noise of the system. The oscillator system has made possible several breakthroughs in frequency and time measurements.

Summary

It is well known [1] that a combination scheme is needed to obtain low FM noise at modulation frequencies above 20 kHz along with low FM below this frequency and carrier long term stability. A recent need for a microwave signal is to enable accurate frequency determination of infrared laser frequency [2]. Here, a microwave source is effectively multiplied by several hundred to beat with the laser radiation in a Josephson junction. To maintain spectral quality, the FM noise must be low. To facilitate detection of a stable beat, the carrier stability must be excellent.

A survey of readily available signal sources in X-band is given in Fig. 1 to guide the choice of oscillators to combine. The noise of all the simple oscillators (non-stabilized) except for the two resonator klystron is too high for this application. In terms of availability over most of the X-band range, either the Gunn Diode or reflex klystron oscillator is most desirable. With a TE_{011} transmission stabilizing cavity, either of these oscillators has adequately low FM noise above 20 kHz with a 1/f component coming in below this range and an inadequate carrier stability.

A quartz crystal controlled oscillator driving a frequency multiplier chain has adequate carrier frequency stability and low FM noise below 20 kHz. The rise in FM noise above 20 kHz is not acceptable for this particular application. But, combining the low baseband performance of the crystal controlled oscillator with the high baseband performance of a cavity stabilized Gunn Diode or reflex klystron oscillator will yield a composite system with the best features of both.

There are two well understood methods of using a crystal controlled oscillator to improve a direct microwave oscillator. The electronic servo or phase lock loop uses some method of voltage control of frequency (the repellor electrode of a klystron, a varactor tuner for diode oscillators) to adjust instantaneous frequency of the direct oscillator to maintain phase coherence with the crystal controlled signal. A second way is to use injection phase locking [3]. We determined that injection locking would have low enough threshold [4] and decided to use this approach.

Injection of a synchronizing signal at the transmission cavity output port of a cavity stabilized oscillator would result in most of the synchronizing signal being reflected from this port. The quintessence of our idea is to inject the synchronizing signal between the oscillator and the transmission cavity as shown in Fig. 2. The reasons are twofold: 1) this is an efficient point for signal injection, and 2) this lets the transmission cavity serve as a filter for AM noise and spurious signals in the synchronizing signal output.

The idea was first demonstrated and used with a reflex klystron as the direct microwave oscillator. Power supply drift proved objectionable so a Gunn diode oscillator was substituted. A commercially available electronic oscillator synchronizer was used to electronically phase lock an auxilliary reflex klystron to selectable harmonics of a 100 mHz crystal controlled oscillator. It is worth noting that this oscillator has higher FM noise throughout the baseband region than an oscillator-multiplier chain controlled by the same 100 mHz crystal.

The resulting oscillator system proved simple to set up (using a microwave spectrum analyzer to indicate the approach and capture of the synchronizing signal) and reliable to operate. The reflex klystron version would remain locked for 5 to 10 minutes without adjustment. The Gunn diode oscillator would remain locked for as long as one desired.

The effective external Q of the combined Gunn diode oscillator and TE_{011} cavity was measured [5] and found to be 5770. The measured FM noise spectrums of the direct oscillator and the crystal controlled synchronizing signal along with the Q_X value allow prediction of system FM noise for various locking signal power levels. The measured results are presented in Fig. 3. These data show that it is possible to select a locking power which gives adequate control of the carrier frequency without appreciably degrading the FM noise above 20 kHz. The particular synchronizing signal used had an unexplained rise in the FM below 5 kHz that obscures the value of this method for reducing the 1/f FM noise from the Gunn Diode. A separate experiment with a cavity stabilized reflex klystron proved that the FM noise at low modulation frequencies does follow the low noise of a crystal-oscillator, multiplier-chain source.

The AM noise of the Gunn oscillator was not changed by either the cavity stabilization or the injection stabilization at the levels used here. Figure 4 gives the measured AM noise of this particular Gunn Diode oscillator. This serves to show that the r.f. spectrum near the carrier is controlled by the FM noise rather than the AM noise.

This 9.5 GHz oscillator system was used successfully to irradiate a Josephson junction along with a 3.8 THz H_2O laser radiation. A beat between the 401 st klystron harmonic and the laser fundamental was achieved to verify the excellent performance of this signal source.

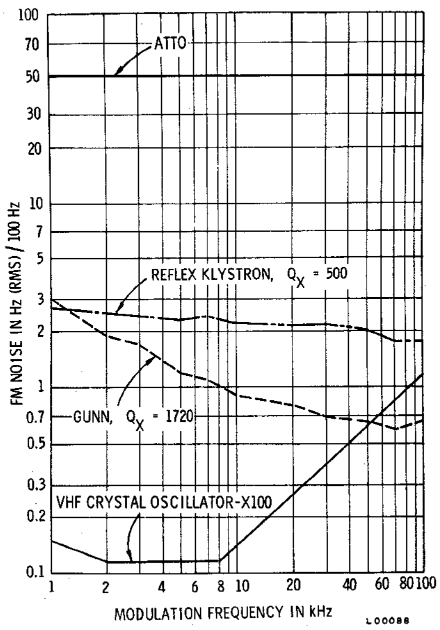

FIGURE 1

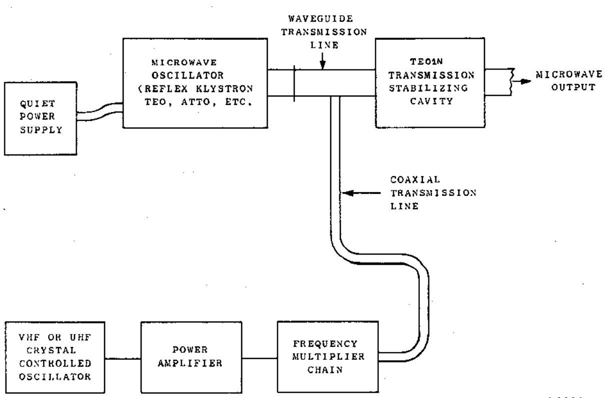

FIGURE 2

References

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[5] J. R. Ashley and F. M. Palka, "A Modulation Method for the Measurement of Microwave Oscillator Q," IEEE Trans. Microwave Theory and Techniques, Vol. MTT-18, No. 11, pp. 1002-1004, November, 1970.

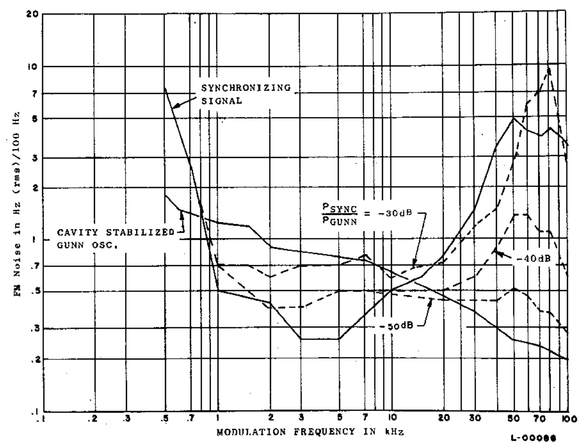

FIGURE 3

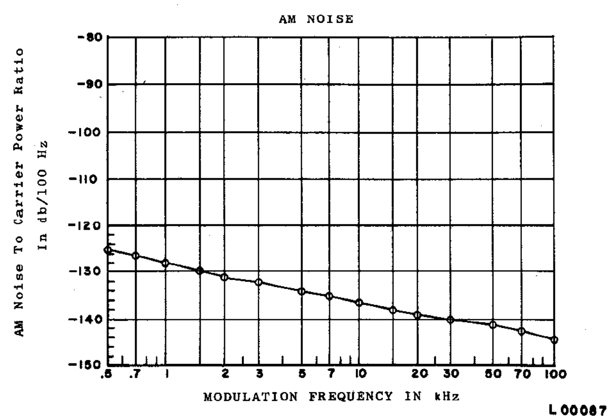

FIGURE 4