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MILLIMETER WAVELENGTH SOLID STATE OSCILLATOR AM AND FM NOISE

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ABSTRACT

A comparison of difficulty for AM and FM noise measurements at millimeter and centimeter wavelengths explains why few FM noise measurements and even fewer AM noise measurements have been reported. The AM noise measurement should be made to prove that AM noise can be neglected and to learn about the oscillator diode noise measure, M. Since millimeter wavelength solid state oscillators are relatively noisy, we show that a simple transmission line discriminator is adequate for measuring both AM and FM noise. Data will be presented for several oscillators in the most used portions of the millimeter wave bands.

INTRODUCTION

Most measurements are more difficult at millimeter wavelengths than at centimeter wavelengths and oscillator AM and FM noise measurements are no exception. Two oscillator comparisons in a phase detector are difficult because of the expense of providing a comparison oscillator. Also, this measurement of phase noise does not give the AM noise data which we also believe to be important. Our previous experience with low noise centimeter wavelength klystrons led us to develop (1) the discriminator based on a TE_{01n} cavity. If some kind of stabilization is not used, the millimeter wavelength oscillators are noisy enough that a carrier nulling transmission line discriminator (2) is adequate. We have found by experience that most oscillators do not require the carrier nulling so that the simple discriminator of the next section is often adequate. This same equipment also determines the AM noise. By careful check of the noise floor in the equipment, one can determine if a more sensitive discriminator is needed.

Implementation of this noise floor check is one of the major reasons for automating the noise measurements. Some of the factors often ignored in doing these measurements will be discussed.

A Simple Transmission Line Discriminator which can be assembled from catalog item mmWave components and test equipment is shown in Fig. 1. We have found this equipment adequate for the low Q oscillators required for FM-CW transmitters and large bandwidth injection locked oscillators used as communications transmitters.

A new and more rigorous derivation shows that the relationship between AC voltage amplitude out of the discriminator for a sinusoidal frequency modulation with the deviation $\Delta\upsilon$ at modulation frequency Fm is:

$$V = \sqrt{PmZm/2}\,(\pi\tau_g)\left(\frac{\sin\pi\tau_g Fm}{\pi\tau_g Fm}\right)\Delta\upsilon$$

Pm is the power measured at the input of the balanced mixer

Zm is the input impedance of the mixer

τ_g is the group delay for the two way trip through the long delay line.

The term $\sqrt{PmZm/2}$ shows the power dependence of the sensitivity while the term $\pi\tau_g$ shows the dependence on group delay in the transmission line. The term $\frac{\sin(\pi\tau_g Fm)}{\pi\tau_g Fm}$ shows the frequency dependence of the measurement on group delay. For waveguide delay line, a 1 meter long line will allow measurements for baseband frequencies up to 50 MHz. For higher bandwidth, the line must be shortened.

The measurement of AM noise is accomplished in the same equipment by simply moving the dumbbell short 45 degrees. The shift of 90 degrees at the balanced mixer makes the phase detector insensitive to FM and sensitive to AM.

AUTOMATION WITH THE HP 3585 SPECTRUM ANALYZER

The tedious part of AM or FM noise measurements is taking the threshold data, writing it down, taking the AM or FM data, writing it down, and then calculating the actual noise. Plotting the answers is also an unwelcome chore once one has learned to use a calculator controlled spectrum analyzer such as the HP 3585. This analyzer covers the baseband region from 20 Hz to 40 MHz and can be completely controlled via the IEEE 488 Interface Buss. We are in the prccess of converting software from a different spectrum analyzer (2) to this more modern equipment. We have noted several factors that are not fully appreciated in using this type analyzer.

1. The 2.45 dB error from logrithmic amplifiers and average responding detectors.
2. The approximately 1.2 factor between noise bandwidth and 3 dB bandwidth listed on the control knobs.
3. A 5 dB error cause by the peak storage in the digital storage if insufficient video filtering is not used.
4. The "noise" function with manual control is ignored instead of being used to avoid most of the above errors.

A TYPICAL MEASUREMENT

The measurement for a 95 GHz GaAs Transferred Electron Device (Gunn Diode) oscillator is shown in Fig. 2. Here, the data have been processed to give the spectral components caused by the AM and FM. Notice that we do show the measurement threshold. These data were manually recorded and the computations made on a hand held calculator. The software for this computation is equipment dependent and is not worthwhile to present in this convention digest.

REFERENCES:

(1) J.R. Ashley, C.B. Searles, and F.M. Palka, "The Measurement of Oscillator Noise at Microwave Frequencies", IEEE Trans. M.T.T., Sept. 1968

(2) J.R. Ashley, T.A. Barley, and G.J. Rast, Jr., "The Measurement of Noise in Microwave Transmitters", IEEE Trans. M.T.T., April 1977

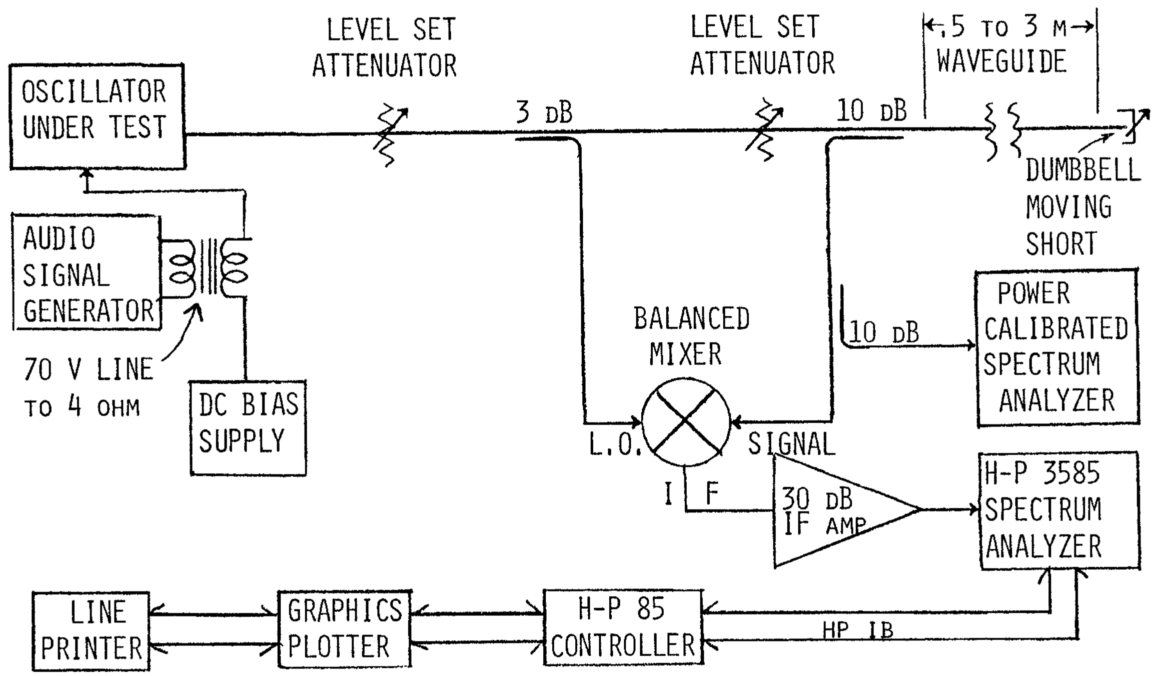

Fig. 1. A waveguide component frequency discriminator for noise measurements.

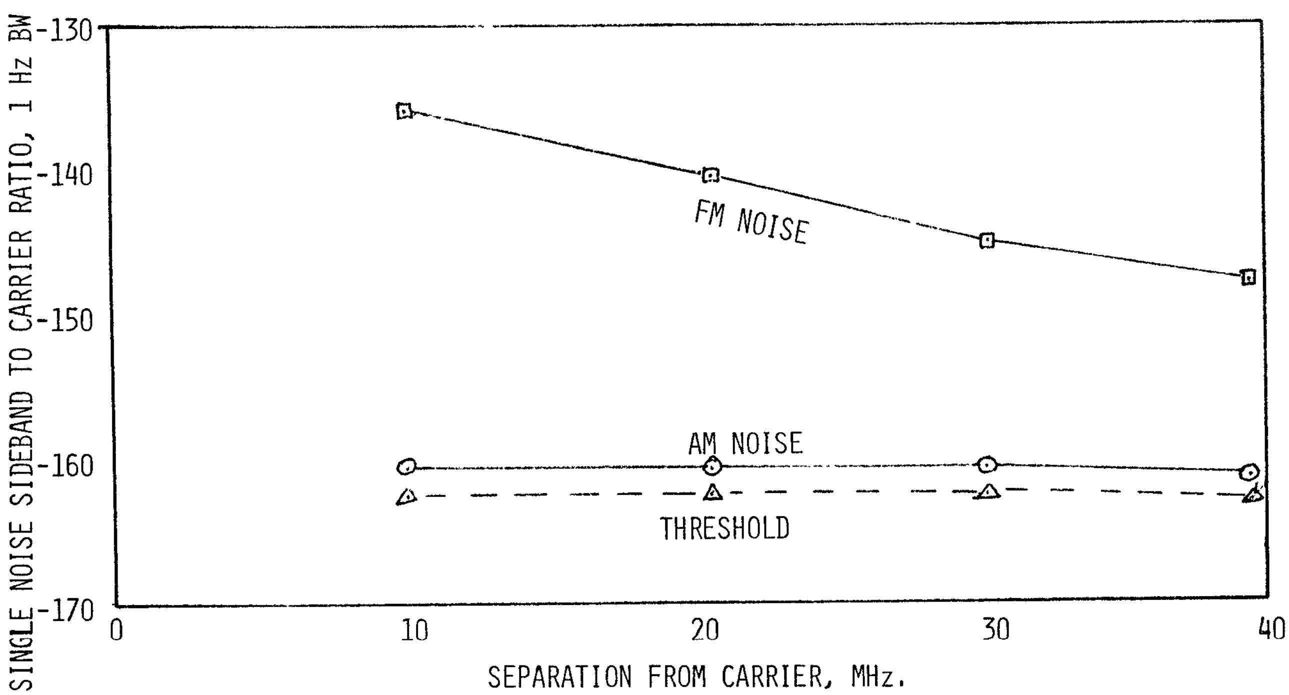

Fig. 2. Measured AM and FM noise from a 2 Gunn diode, 40 mW, 94 GHz oscillator.