5.4: FINE GRAIN SPECTRUM ANALYSIS OF PULSED MICROWAVE AMPLIFIERS

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In the design, construction, and evaluation of high power microwave amplifiers and their associated transmitter systems, a high degree of emphasis is currently being placed on the development of microwave amplifier systems which can amplify complex microwave pulse spectra without introducing noise or spurious modulation into the spectrum. In the usual microwave pulse spectrum, the energy as a function of frequency takes the familiar Sin x/x distribution as shown in Figure 1.

For a periodic pulse train, the energy within this distribution is concentrated in discrete "lines" centered about an f_0 carrier "line." The "line" spacing is constant and equal to the pulse repetition frequency. Figure 1a shows this "line" structure.

In following this pulse spectrum through a typical microwave amplifier, each of these "lines" can be treated as a c.w. carrier. It is possible for the microwave amplifier to modulate each of these carriers with any time variant input signal impressed on the amplifier. These

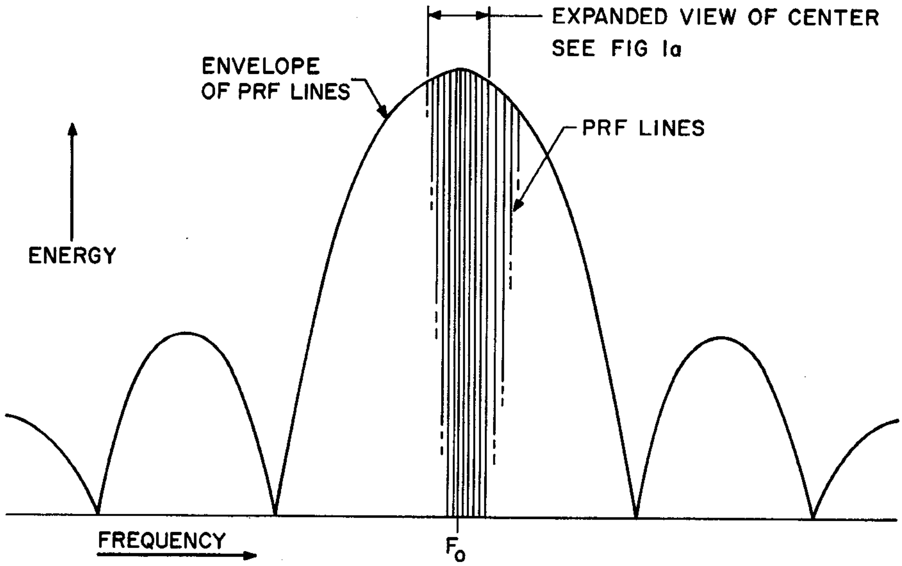

Fig. 1. Energy distribution of microwave pulse spectrum.

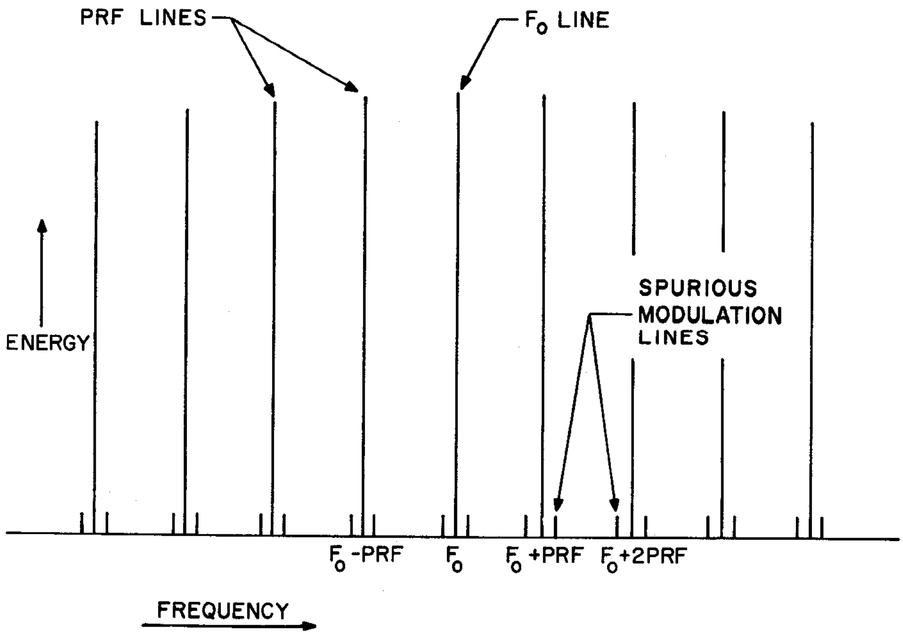

Fig. 1.a Expanded view of center lobe.

modulating signals usually arise from mechanical vibrations, electrical transients, and power line based disturbances. As such, they are usually confined to frequencies between 1 c/s and 5 kc/s. The modulation may be either amplitude or phase modulation depending on the modulating mechanism. In the case of phase modulation, the modulation index is so low that only the first modulation line of the series is significant. These modulating signals show up in the microwave pulse spectrum as discrete modulation "lines" surrounding each of the f_o and $f_o \pm n$ PRF "lines." (Ref: Figure 1a.)

Various microwave amplifiers have different modulation sensitivities. Some of these sensitivities are listed as follows:

Traveling Wave Tubes

Helix, collector, and filament sensitivity to power supply ripple and electrical transients.

Helix sensitivity to mechanical vibration.

Klystrons

Collector and modulator anode sensitivity to power supply ripple.

Focus coil sensitivity to power supply ripple.

Electron beam disturbance due to AC filament excitation.

Mechanical vibration due to air and water coolant flow.

Triodes and Tetrodes

Filament, bias, and plate sensitivity to power supply ripple.

Microwave cavity sensitivity to mechanical vibration.

To study and analyze the modulation components within the fine grain microwave pulse spectrum, a spectrum analyzer with a very fine resolution, 1 c/s or less, and a wide dynamic range, 50 db or better, is required. Commercially available microwave spectrum analyzers do not approach this resolution. Commercial analyzers do exist in the audio range which have the required resolution and dynamic range. This type of analyzer can be used to display the interline modulation and noise in selected segments of the microwave pulse spectrum if an appropriate frequency converter is used.

Converting a microwave signal with a bandwidth of several megacycles to audio involves two problems. The microwave signal must be reduced in bandwidth as it is converted to lower frequencies to avoid zero frequency foldover of portions of the microwave spectrum. This involves crystal filtering at the lower frequencies. The transfer oscillators used in the frequency conversion process must have frequency stabilities an order of magnitude greater than the audio analyzer resolution (less than 1 c/s). For the higher frequency transfer oscillators, this represents impractical stability requirements. It has been assumed in this development that the carrier frequency of the microwave signal spectrum also possesses stability greater than the audio analyzer resolution. In most cases, this assumption is false.

To get around this stability problem, the coherent converter shown in Figure 2 was developed. With this system, it becomes the function of the spectrum analyzer to generate the microwave signal used to excite the amplifier under test.

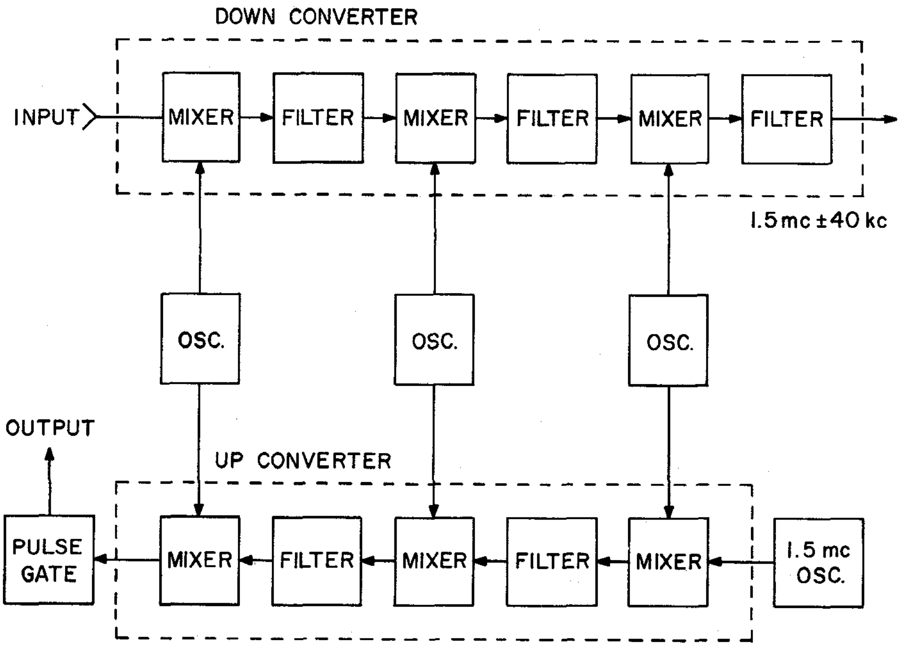

Fig. 2. Coherent converter.

By using the higher frequency transfer oscillators for up conversion as well as down conversion, the instabilities of these oscillators are eliminated from the spectral display. Since the up converter supplies the amplifier under test with a coherent signal source, no external stable signal source is required. The output of the down frequency converter is at a center frequency of 1.5 Mc/s. At this frequency the bandwidth of the signal has been reduced to 80 kc/s. This signal is translated down to audio in a noncoherent crystal filtered converter as shown in Figure 3. A stepped crystal transfer oscillator allows inspection of any portion of the frequency band ± 40 kc/s about the f_o carrier frequency of the microwave signal spectrum. The low frequency analyzer chosen to be used with this converter has a dispersion bandwidth of 5 kc/s centered at 2.5 kc/s. It has a 3 db filter bandwidth of 1.5 c/s and a dynamic range of 50 db.

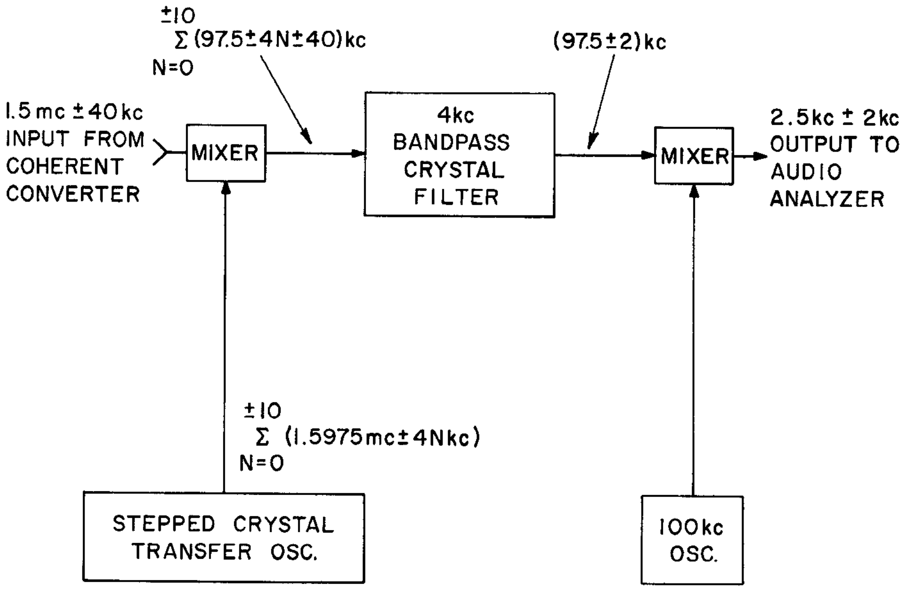

Fig. 3. Non-coherent converter.

Figure 4 shows a block diagram of the complete analyzer. With the converter system just described, the fine resolution of the audio analyzer has been transferred up to the microwave frequency of interest. This analyzer is then capable of inspecting the interline regions of a pulsed microwave signal spectrum. Figure 5 shows a picture of this analyzer.

The analyzer described above was used in the design and testing of microwave components in the UHF and L-band regions. After individual components were checked out, the analyzer was used to evaluate the overall transmitter systems. As an example of information obtained from the analyzer, a reproduction of an actual spectrum chart record is shown in Figure 6. The unit being analyzed was a UHF exciter employing a tetrode cavity mixer and two tetrode cavity amplifier stages. The region ± 150 c/s about the f_o carrier in the microwave pulse spectrum was displayed. As can be seen in the Figure, some 58 c/s, 60 c/s, and 120 c/s modulation was found in the spectrum. By careful analysis of each stage, the 58 and 60 c/s modulation was found to be caused by cavity mechanical phase sensitivity in one of the tetrode cavity amplifiers. The 58 c/s vibration was caused by an induction blower, and the 60 c/s vibration was caused by a loose core in a filament transformer. When the cavity had been desensitized, these modulations were eliminated. The 120 c/s modulation was traced to power supply ripple in all three stages.

Similar analyses on klystrons and TWT's have been performed. It has been found that this fine line coherent spectrum analyzer is a very useful diagnostic tool in the design of precision microwave amplifiers and radar transmitter systems.

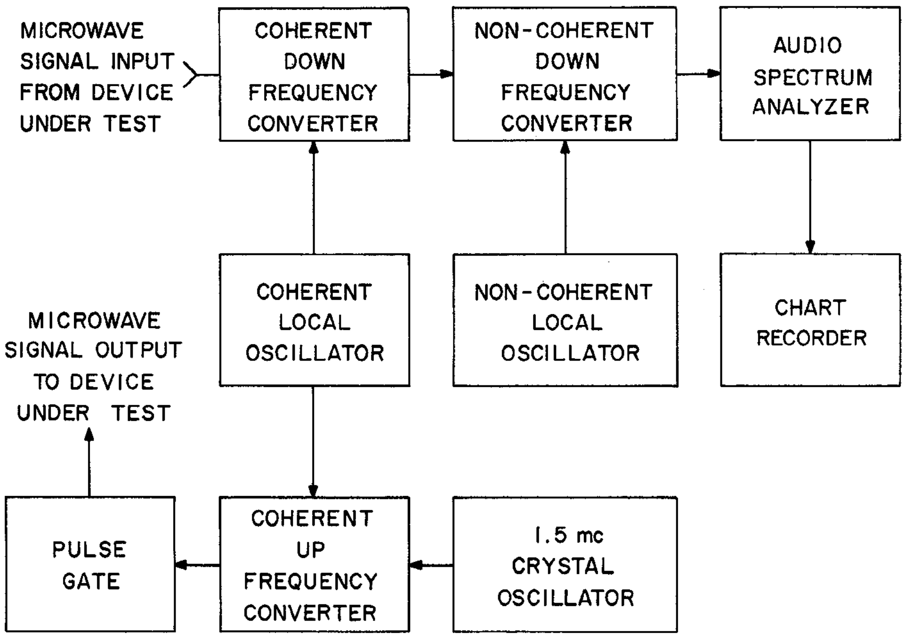

Fig. 4. Fine line coherent spectrum analyzer block diagram.

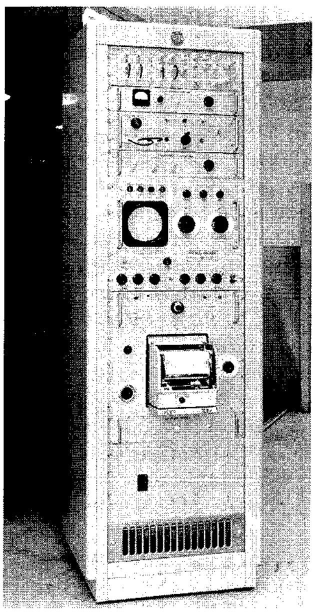

Fig. 5. Fine line coherent spectrum analyzer.

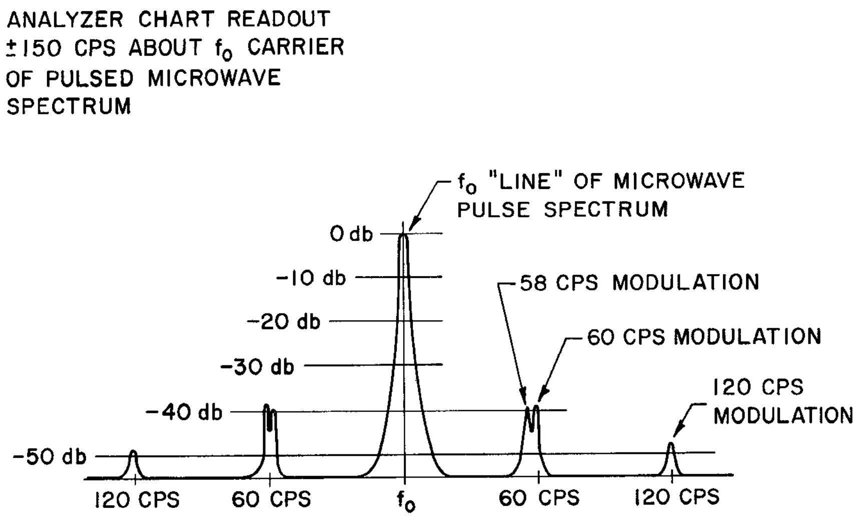

Fig. 6. Fine grain spectrum display.