AUTOMATED SPECTRAL ANALYSIS OF MICROWAVE OSCILLATOR NOISE

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Abstract

An operational engineering model of an automated near carrier spectrum analyzer has been implemented. BASIC language programs used to control system operation have been demonstrated during actual measurement of near carrier phase noise in a C-band reflex klystron oscillator.

Introduction

The most time consuming part of making microwave oscillator noise measurements is taking, processing and plotting the spectrum data. We have developed software to use the recently introduced HP 3045A automatic spectrum analysis equipment to significantly reduce measurement time and human error as well as to improve documentation. The control programs are written in the BASIC language and operated from the function keys of the HP 9830A calculator. The flow chart and a sample operation run are given.

Test Configuration with Experimental Results

The measurement of microwave oscillator noise is based on the use of a cavity discriminator[(1)] to develop a baseband signal which is processed in a wave or spectrum analyzer. Figure 1 gives the total measurement scheme. Previously, the wave analyzer was tuned manually, the data recorded with pencil and paper, and all processing and plotting done manually. Partial automation of the spectral analysis is possible with sweeping spectrum analyzers which drive analog X-Y plotters. Manual recording and plotting is tedious and prone to operator error while the sweeping spectrum analyzers have the disadvantages of not implementing threshold check and operating at a fixed bandwidth through any one sweep. Even with this partial automation, we have found that the most time consuming portion of the measurement was operating the wave analyzer and documenting the plots. The functions involved in acquiring threshold and signal data are not optimized when using only a single fixed bandwidth filter. It can be shown[(2)] that a selection of filter bandwidths improves not only the quality of the acquired data but can significantly reduce the time required to acquire the basic information. Time improvement is realized as a result of time-bandwidth factor. The narrow bandwidth filters required in the less than one kilohertz region from the signal carrier can be exchanged for progressively wider bandwidth filters as the distance from the carrier to the analysis point increases. The wide bandwidth filters allows a significant increase to be made in sampling speed, thereby reducing the total time required for a given measurement. Also, as filter bandwidths are changed, the appropriate correction factors must be used to correct the acquired data to a common measurement base. Further improvement of the measurement meant that this human intervention in the data taking and processing had to be significantly reduced.

The development of an advanced 10 Hz to 13 MHz spectrum analyzer, the HP 3045A system, by the Hewlett Packard Loveland Instrument Division made possible the next improvements in near carrier noise measurements. The system shown in Figure 2 comprises a HP 3571A tracking spectrum analyzer which uses the HP 3330B frequency synthesizer as a local oscillator. Both of these instruments are controlled via the HP Interface Bus by the HP 9830A calculator. The latter is a full typewriter keyboard calculator which is programmed in the widely known computing language BASIC.

The reorganization of the measurement for automation is shown in Figure 3 where the calculator has taken over the control of the baseband spectrum measurement, data processing, and data plotting. Manual operation of the microwave signal source and microwave discriminator is still required although the calculator does issue instructions governing the time sequence of operations.

Development of the measurement control software was organized to utilize the function keys of the HP 9830A calculator. The following subprograms were written and stored on the function keys:

NAME	FUNCTION
CAL	Calibrates all equipment.
THRESH	Stores threshold data.
NOISE	Takes and stores noise data.
PLOT	Processes and plots noise data.
LINEAR GRID	Draws a linear grid for plotted data.
LOG GRID	Draws a logarithmic grid for plotted data.

Each of these subprograms can be operated independently as far as the calculator is concerned and this makes possible several noise data runs for one calibrate and threshold run.

Usually, the first step is operation of CAL. The calculator issues control statements and takes data to calibrate the slope (Hertz deviation per volt of output) of the microwave discriminator. This is done by applying a small frequency modulation to the source under test and adjusting for this for a known deviation. (The "carrier null" method of determining calibration is described by Ashley, et. al.[(1)]. The result of this calibration is stored in the calculator memory and used in later data processing. The flow chart for subprogram CAL is shown in Figure 4 and the BASIC program used by the HP 9830A calculator is given in Figure 5.

The second step in the measurement sequence is operation of THRESH to determine the noise floor or threshold of the discriminator. The theory is given by Ashley et. al.[(1)], but the practice is very time consuming because data for the threshold must be taken at each frequency where noise is to be measured. Now the calculator is given the frequency limits for which measurements are desired and the number of data points; then, it takes the threshold data and stores the results in an array variable which will be used later to correct actual noise data. Thus, all of the measurements are corrected for threshold before plotting.

The third step is to use NOISE to take data at the same frequencies where the threshold is known from the previous step. This is completely under the control of the calculator which again stores the results in its memory (as an array variable.) During this step, the human operator can observe the operation of the source under test and the microwave discriminator tuning. Those of us who have spent many hours of tuning a wave analyzer and recording data with pencil and paper especially appreciate the ease of this step.

Probably the most enjoyable step is pushing the calculator key labeled PLOT. This subprogram takes the arrays for threshold and noise, calibration factors, and other corrections to compute threshold corrected noise deviation while the calculator driven plotter plots complete results. Documentation is made painless by answering "yes" to a displayed question, "Do you want to label the axes?" The result is a plot such as the one in Figure 6 where everything but the caption was put there by the plotter. The linear grid portion was plotted by activating the proper function key. After years of doing noise measurements the hard way, it is pure pleasure to watch the plotter deliver the results of automated noise measurements.

Conclusion

An engineering model of the automated near carrier spectrum analyzer has been successfully tested. These tests have established the capability and feasibility of using highly sophisticated measurement hardware to improve the basic accuracy of acquiring and documenting data. The computer was programed to perform the threshold data correction function prior to plotting the data.

Although these tests used a single fixed bandwidth filter for the data acquisition function, this type measurement can be improved further by using a group of selectable bandwidth filters to reduce data acquisition significantly. The computer can easily be programed to pick the proper filter bandwidth for each frequency range, calculate the required correction factor for bandwidth normalization, accomplish the threshold correction computation and plot the normalized corrected data to the desired format.

A major achievement resulting from this exercise could well be the basic simplicity of the process described. It has been implied that the data acquisition function became extremely simple. The previous methods used for data collection of near carrier spectral information required highly skilled personnel for all portions of the test. This automated techniquewould require highly trained personnel for setup only, then personnel with relatively low skill levels can collect data with the same accuracy as anyone. This feature is sufficient in itself to permit production line measurement of parameters heretofore provided at considerable additional cost for the spectral data.

Acknowledgements

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References

(1) J. R. Ashley, C. B. Searles, and F. M. Palka, "The measurement of Oscillator Noise at Microwave Frequencies," IEEE Transactions Microwave Theory Techniques, Vol. MTT-16, No. 9, pp 753-760, September 1968.

(2) J. R. Ashley, T. A. Barley, and G. J. Rast, Jr., "Wave Analyzer Dynamic Range and Bandwidth Requirements for Signal Noise Analysis," US Army Missile Command report, TR-RE-76-26.

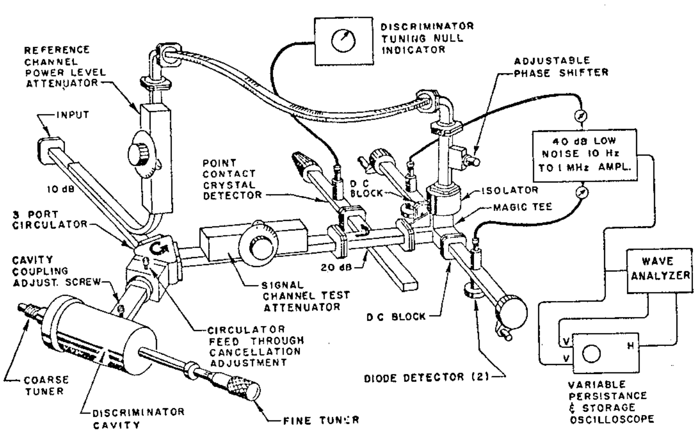

Figure 1. A cavity discriminator for near carrier noise measurement.

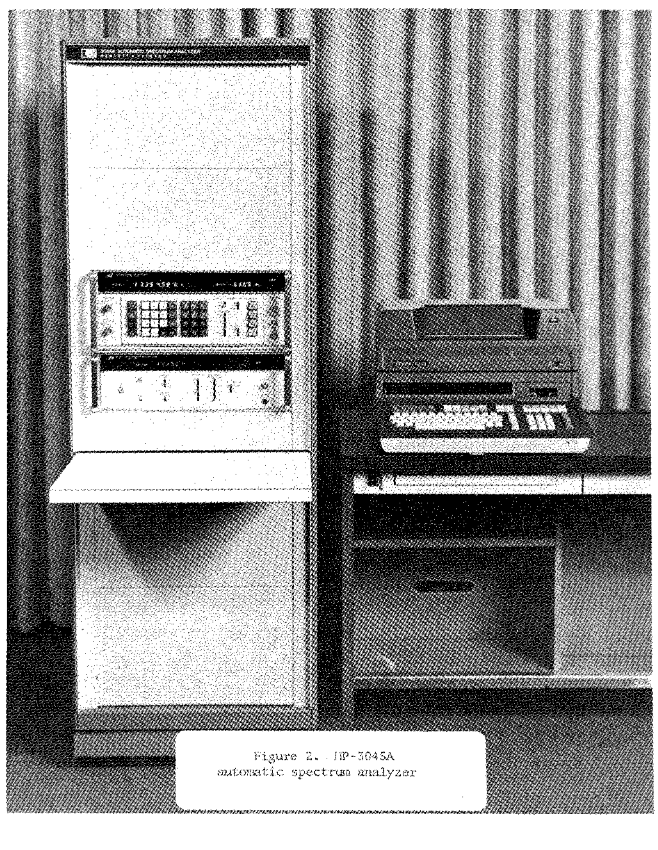

Figure 2. HP-3045A automatic spectrum analyzer

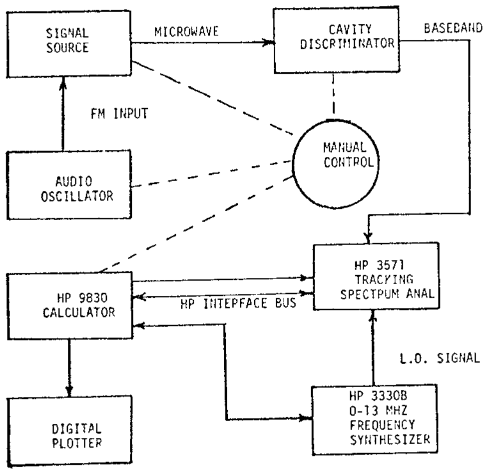

Figure 3. Automated measurement of near carrier noise.

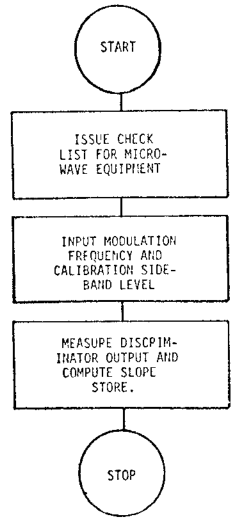

Figure 4. Flow chart - subprogram CAL.

```
4    OUTPUT (13,6)768,
6    FORMAT B
10   DIM A$[3],B$[36],C$[36],TS[101],NS[101],FS[101],BS[101]
20   DISP "HAS THE SIGNAL SOURCE WARMED UP",
30   INPUT A$
40   IF A$="NO"  THEN 20
50   DISP  "IS THE DISCRIMINATOR ALIGNED",
60   INPUT A$
70   IF A$="NO" THEN 50
80   DISP  "DO YOU HAVE A CARRIER NULL";
90   INPUT A$
100  IF A$="NO" THEN 80
110  DISP "WHAT IS CALIBRATE MOD. FREQ.";
120  INPUT A
140  DISP "HOW MANY DB BELOW CARRIER NULL",
150  INPUT D
160  DISP "HAVE YOU CHECKED INPUT OVERLOAD",
170  INPUT A$
180  IF A$="NO" THEN 160
190  B=100
200  F=A
202  GOSUB FNF(F) OF 202
210  GOSUB FNM(0) OF 210
220  S=2.405*A*(10↑(-D/20))/V
230  B$="THE DISCRIMINATOR SLOPE IS"
240  C$="PEAK HERTZ PER VOLT"
250  PRINT B$,S,C$
252  PRINT LIN(3)
260  DISP B$
270  WAIT 1000
280  DISP S,C$
290  WAIT 5000
292  K1=S/(SQR(2)*1 13)
300  DISP "CALIBRATION IS COMPLETE"
310  END
```

Figure 5. Program - CAL subprogram.

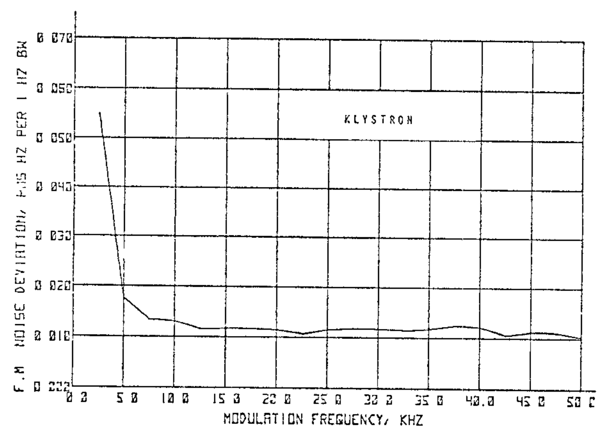

Figure 6. A typical result of the automated near carrier noise measurement.