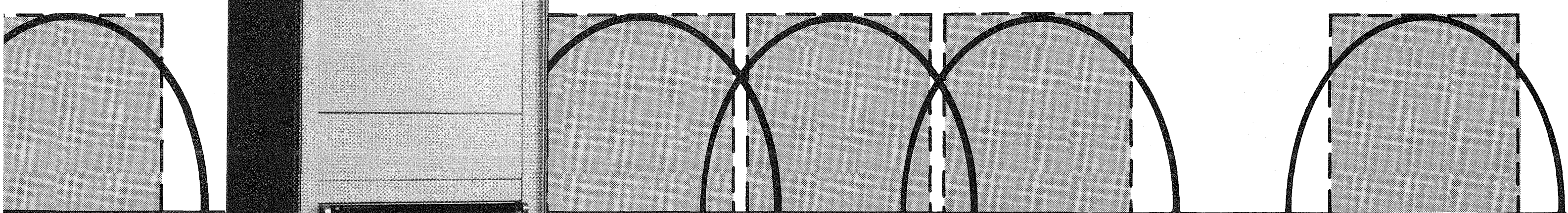
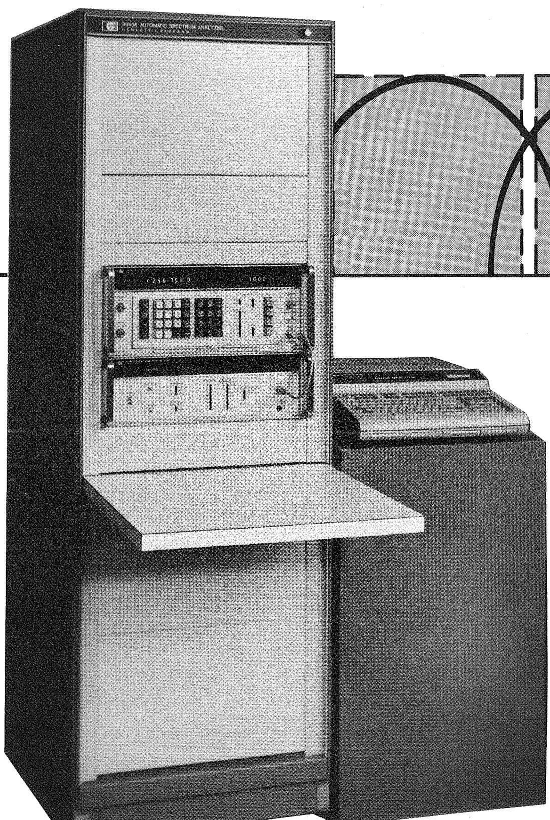
Application Note 206-1

**Spectrum Analysis
with HP-IB Systems**





Measuring Wide-Band Noise with the HP 3045A Automatic Spectrum Analyzer

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Measuring Wide-Band Noise with the HP 3045A

The purpose of this application note is to outline the basic concerns of measuring noise with the 3045A Spectrum Analyzer. The possible sources of error are discussed and a program for the HP 9825A Controller is presented for making noise measurements in bandwidths wider than the 10 kHz available in the HP 3571A.

Description of Method

The technique and theory for measuring narrow-band noise with a spectrum analyzer are described in HP Application Note 150-4. As shown in that note, spectrum analyzers read 2.5 dB low on random noise measurements because of their logarithmic amplifier and envelope detector. Also, the noise power bandwidth of the filters is defined and shown to be about 12% wider than the 3 dB bandwidth. Because the 3 dB bandwidth can vary as much as 20%, a subroutine is provided in the following program for measuring the noise power bandwidth for each bandwidth setting.

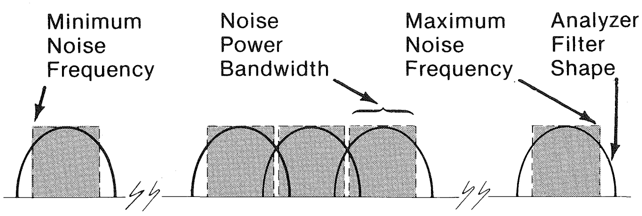


Figure 1
Wide-Band Noise Measurement Technique

To measure noise in a wider bandwidth than the 10 kHz available with the 3045A, it is necessary to take a series of properly spaced readings across the desired frequency band, convert them to power, sum them, convert the results back to dB and add the 2.5 dB mentioned above. This is easily done in a calculator-controlled spectrum analyzer like the 3045A. It is important at low frequencies to use a narrow enough bandwidth so that the local oscillator feed-through does not raise the noise floor. At higher frequencies, it is desirable for the sake of speed to use a wider bandwidth both because of its faster settling time and because fewer measurements are required to cover the desired frequency band. To assure that all the noise in the desired frequency band is measured, the readings are taken at frequencies spaced by the noise power bandwidth. Finally, 10 readings are taken at each frequency and averaged. This entire process is shown in Figure 1.

The noise measurement subroutine in the program takes all these considerations into account and its results consistently agree with a true RMS measurement of band-limited, white noise *to within* $\pm$ *0.2 dB*.

Potential Source of Measurement Error

The main problem with this measurement technique is that it doesn't actually measure the true RMS value of the signals in the desired frequency band. Thus, if a coherent signal is present in the measurement range, it can be emphasized by as much as the 2.5 dB correction factor mentioned above. Also, if the noise is not white (i.e., not frequency flat) but steeply slopes through the noise power bandwidth, the reading will be in error. This is because the reading is an average, not true RMS. This error can be minimized if, as is typically the case, the frequency regions of non-white noise are known (e.g. low frequencies typically have l/f noise). If narrow bandwidths are used in these regions, the measurement error will be reduced because within the noise power bandwidth, the noise is closer to white. The program presented later can be modified by the user to minimize this error in his problem frequency range.

Disagreement with other Kinds of Analyzers

Just as spectrum analyzers need a 2.5 dB correction factor, other kinds of analyzers which are not true RMS require their own correction factors. For instance, the HP 331A Distortion Analyzer can be used as a wide band voltmeter, but its meter is average responding. This causes the 331 to read 1.05 dB lower than a true RMS measurement when measuring white noise.

Analyzers can disagree because they are measuring in different bandwidths. For instance, it may be desired to measure the noise in an audio amplifier. In this case, we are interested in the noise only from 20 Hz to 20 kHz as this is the maximum range the ear can hear. This is easily done with the 3045A program, but without external filters the 331A will measure the noise out to several megahertz. As there could be significant noise beyond 20 kHz, the 331A might read considerably higher than the desired result. One must not depend on the roll-off of the audio amplifier to limit the noise as it often will not.

A third possible source of disagreement occurs when the noise measured by the 3045A and another non-RMS analyzer is not frequency flat or contains coherent signals (tones). As stated before, the 3045A will not read the same as a true-RMS measurement. In addition, the other analyzer will also be in error, *but not by the same amount*. Therefore, both analyzers can give a wrong answer, but not necessarily the same wrong answer.

Finally, the possible lack of accuracy of the comparison analyzer can cause disagreement with the 3045A. This can be minimized by calibrating the analyzer at the normally expected noise level.

Actual Measurements

Despite all the warnings, it should be pointed out that a 331A calibrated at the noise level read consistently *within .18 dB* of the 3045A on band-limited white noise.

Program Description

A flowchart for the program is given in figure 2 and the program itself is in figure 3. The program is actually a series of subroutines which can be called by the programmer to execute the desired measurement. The user's program which calls these routines starts on line 33 and is labeled "START". A typical two-line user program is included in the listing. This format makes it easy for the programmer to incorporate these routines in his own program.

After the system has warmed up, the program can be run as follows. Lines 1-4 dimension the variables and set up the formats. The user must connect the 3330B synthesizer output to the input of the 3571A analyzer when prompted by the display "CONNECT LO TO ANALYZER INPUT". This allows the software to calibrate the system to 0 dB with a 1 volt input from the 3330B (50 Ω). This is done in lines 5-7. These lines also program the instruments to the desired test conditions. The program then jumps to line 33, the user's program. Here the user can call the "CAL" or "NOISE" subroutine or a routine he has added to the program.

The "CAL" subroutine (lines 25-32) measures the noise power bandwidth of every bandwidth setting of the 3571. It does this by tuning the analyzer about a 1 MHz signal. The user must connect this signal from the rear panel when prompted by the message "CONNECT 1 MHz TO ANALYZER INPUT" (line 25). The subroutine measures the noise power bandwidth by a 30 point trapazoidal approximation to a true integral of power between the -60 dB points of the filter and divides this integral by the peak power. The results are stored normalized to the 3 dB bandwidth in B[0] to B[7] (3 Hz to 10 kHz respectively). Since the noise power bandwidth is stable and this routine takes just over one minute to execute, it is recommended that it be done infrequently. (It is perhaps sufficiently accurate for most applications to use the nominal values of B[ ] set up in the Loader routine, line 4. This can be determined by experiment.) No variables need to be passed to the "CAL" routine.

The "NOISE" routine (lines 8-24), on the other hand, needs several variables. These are:

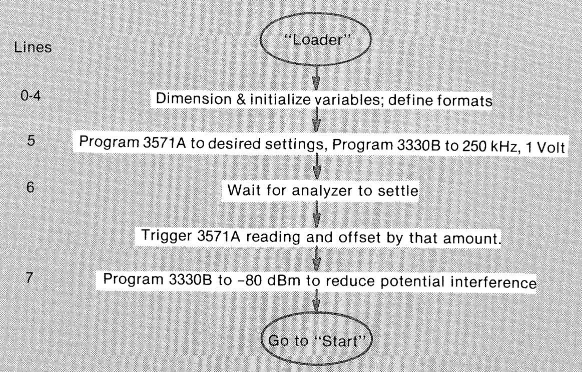
p1	minimum freq. of desired measurement
p2	maximum freq. of desired measurement
flag 1	set for autoranging input
flag 2	set to print total noise
flag 3	set to plot noise vs. frequency

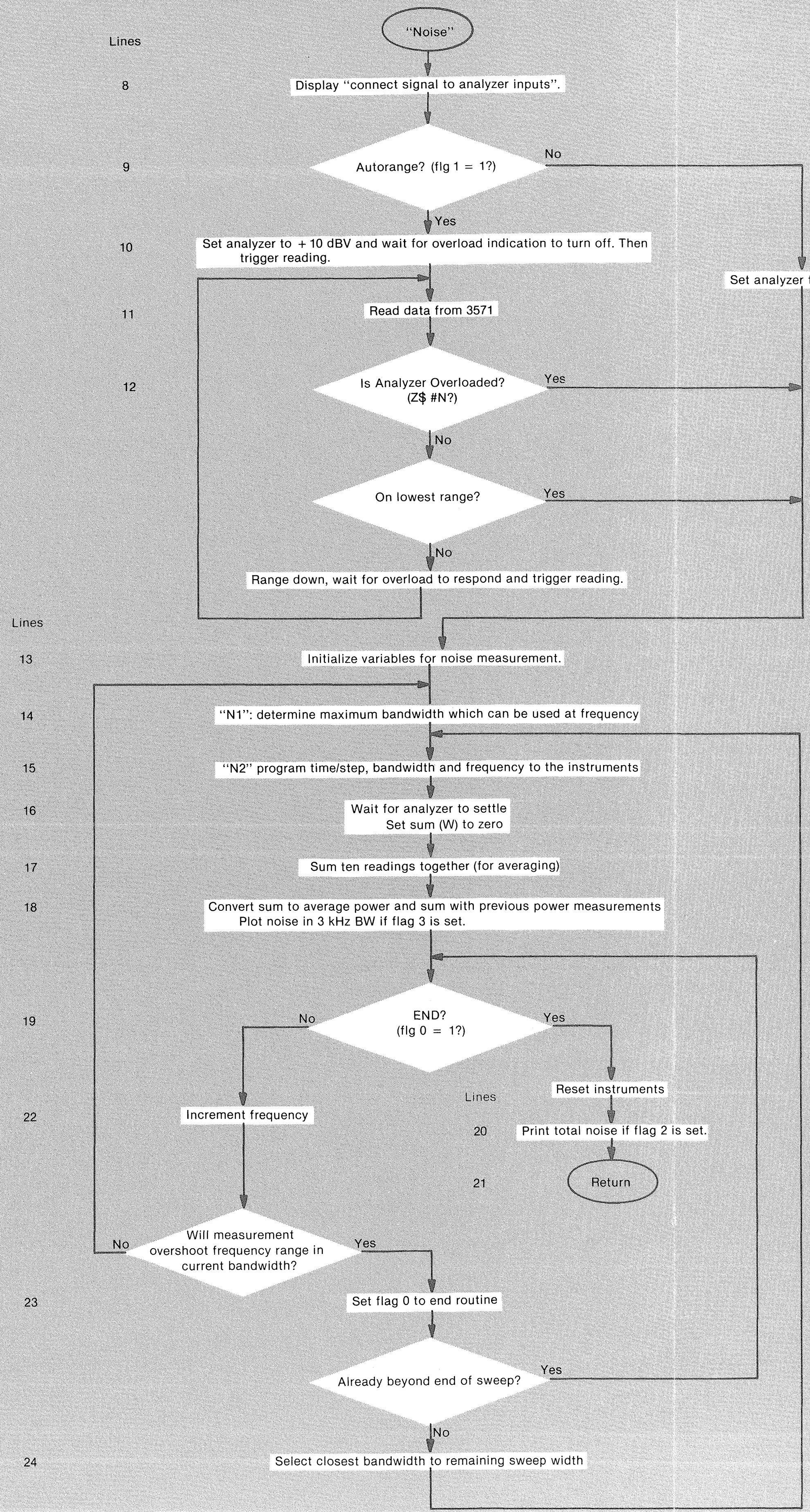
The example user's program in line 33 measures the noise from 10 kHz to 700 kHz. Flag 1 is set to autorange the input (lines 10-13) until it is one range overloaded. This is the best range for noise measurements where harmonic distortion is generally not a problem. If flag 1 were not set, the analyzer would be set to its -60 dBV range by line 9, which would speed the test by avoiding the autorange routine. Flag 2 is set to print the total noise on the calculator printer (line 20), otherwise there would be no output at all.

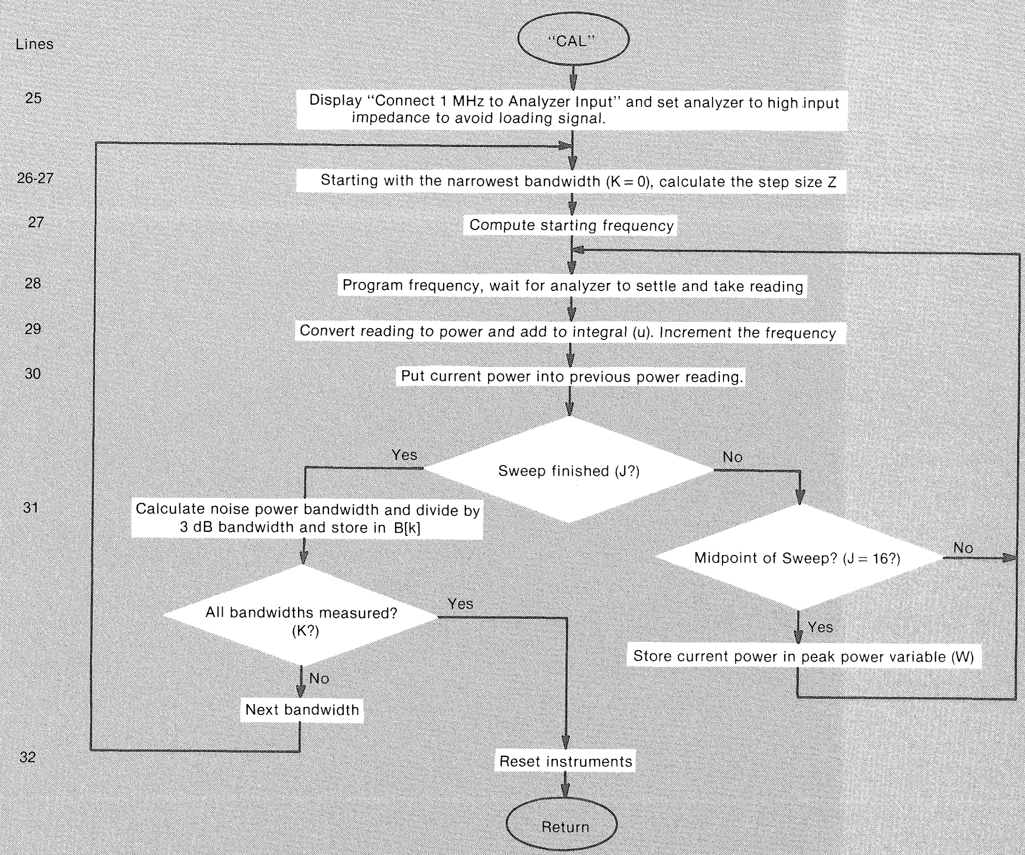
Flag 3 could be set to plot the noise in dBV normalized to a 3 kHz bandwidth on a HP 9862 Plotter (line 18). A "Scale" statement is needed in the user's program if the plotter is to be used. This and any axes drawing or labeling can be added by the programmer to suit his own particular requirement.

The user program example (lines 33-34) is a simple program to measure band-limited noise with the 3045A and then ask the user to input the mV reading from a true RMS voltmeter. Both answers are printed in dBV for ease of comparison and then the controller starts another measurement. The number of possible user programs is large and the programmer is encouraged to experiment.

Figure 2
Flow Chart







Addresses

717 — 3571A HP-IB address
704 — 3330B HP-IB address

Variables

Loader Routine
- B[ ] — noise power bandwidth ÷ 3 dB bandwidth
- I — index

Autorange Routine
- X — voltage reading (ignored)
- Z — input range counter
- Z$ — "N" or "O" for normal or overload

Noise Subroutine
- F — current measurement frequency
- I — bandwidth index
- K — 3 kHz normalized noise reading for plotting
- U — total power measured
- V — voltage reading from 3571
- W — sum of dB readings for averaging
- X — minimum frequency of sweep
- Y — maximum frequency of sweep
- Z — noise power bandwidth

Cal Subroutine
- J — frequency index
- K — bandwidth index
- U — sum of power readings in a bandwidth
- W — peak power reading
- X — previous power reading
- Y — current power reading
- Z — frequency spacing of samples

Figure 3
Program

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0: "NOISE MEASUREMENT PROGRAM":
1: "Loader":rem 7;dsp "CONNECT LO TO ANALYZER INPUT";stp
2: dim B[0:7],Z$[1]
3: fmt 1,"V",f.0;fmt 2,"L",f.1,"=";fmt 3,"B",f.0;fmt 4,b
4: for I=0 to 7;1.13→B[I];next I
5: wrt 717,"R2S0B2V6M1Z0";wrt 704,"BID↑SM0=N13.01;L250>O0;"
6: wait 3000;wrt 717,"T";wait 200;wrt 717,"PT";wrt 717,"P"
7: wrt 704,"N80<";gto "START"
8: "NOISE":dsp "CONNECT SIGNAL TO ANALYZER INPUT";stp
9: if flg1=0;wrt 717,"V0";gto +4
10: "AUTORANGE":7→Z;wrt 717.1,Z;wait 4000;wrt 717,"T"
11: red 717,Z$,X
12: if pos(Z$,"N")#0;if (Z-1→Z)>=0;wrt 717.1,Z;wait 600;wrt 717,"T";gto -1
13: 0→U→W;p1→X→F;p2→Y;-1→I
14: "N1":gto -0;if 50*3↑(I+1→I)>F or I=7;gto +1;B[I]drnd(tn↑((I+1)/2),1)→Z
15: "N2":wrt 704.4,85-I;F+Z/2→F;wrt 704.2,F;wrt 717.3,I
16: wait 2000/Z;0→W
17: for J=1 to 10;wrt 704,")";fmt f.2;red 717,V;W+V→W;next J
18: 2.5+W/10+10log(3000/Z)→K;U+tn↑(W/100)→U;if flg3;plt F,K
19: "N3":gto +3;if flg0;cfg 0;wrt 717,"V6B2";wrt 704,"G";gto +1
20: if flg2;fxd 2;prt "NOISE (dBV)",10log(U)+2.5
21: ret
22: F+Z/2→F;if Y-F>=Z;-1→I;gto "N1"
23: sfg 0;if Y-F<=0;gto "N3"
24: drnd(2log(Y-F)-1,1)→I;drnd(tn↑((I+1)/2),1)→Z;gto "N2"
25: "CAL":dsp "CONNECT 1MHz to ANALYZER INPUT";stp ;0→K;wrt 717,"Z2"
26: "C1":wrt 717.3,K;0→U→X→Y→J;11drnd(tn↑((K+1)/2),1)/30→Z;wait 300
27: 1e6-15Z→V
28: "C2":wrt 704.2,V;wait 70+3000tn↑(-(K+1)/2);wrt 717,"T";red 717,Y
29: tn↑(Y/10)→Y;V+Z→V;if J#0;U+(Y+X)Z/2→U
30: Y→X;if (J+1→J)<=30;gto "C2";if J=16;Y→W
31: U/Wdrnd(tn↑((K+1)/2),1)→B[K];gto "C1";if (K+1→K)>7;gto +1
32: wrt 717,"B3Z0";wait 300;ret
33: "START":sfg 1,2;cll ´NOISE´(1e4,7e5)
34: ent "mV?",Z;prt 20log(Z1e-3);spc ;gto -1
*22587
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