DESIGNED FOR HP-IB SYSTEMS

Programming Note

HP 8566B/8568B/Models 216/226/236-92 August 1985

Supersedes: None

AMPLITUDE MODULATION MEASUREMENTS USING THE FAST FOURIER TRANSFORM on the HP 8566B and 8568B Spectrum Analyzers

OVERVIEW

AM depth measurements using spectrum analyzers are generally made in the time domain or swept frequency domain. The advantages of making AM measurements in the Fast Fourier Transform (FFT) frequency domain are orders-of-magnitude improvement in speed, resolution, accuracy, and rejection of incidental FM. Many measurements which cannot be made in the swept frequency domain or time domain can easily be made in the FFT frequency domain. AM measurements in the FFT frequency domain are possible using an external controller. However, the advanced signal processing functions and downloadable program (DLP) capability of the HP 8566B and HP 8568B allow the user to make AM measurements in the FFT frequency domain quickly and directly from the front panel without using an external controller.

This Programming Note describes a DLP which makes AM measurements on carriers with levels ≥ -20 dBm, frequencies ≥ 10 MHz, modulation rates from 0.5 Hz to 15 kHz, modulation depths of 0.1% to 99%, and incidental FM having up to 10 kHz peak deviation. Basic percent AM accuracy is ± 0.2 dB (2.5% of reading). In some cases, measurement range can be extended by program modification.

Prerequisites

To more easily understand this programming note, some experience with HP 8566B/8568B remote and manual operation is required. An understanding of Programming Notes **HP 8566B/8568B/Models 216/226/236-90 Storage, Display and I/O of Variables and Traces** (publication number 5952-9398) and **HP 8566B/8568B/Models 216/226/236-99 A Structured Approach to Downloadable Programming** (publication number 5952-9392) is recommended. An understanding of HP Application Note 150-1 **Spectrum Analysis... Amplitude and Frequency Modulation** (publication number 5952-1051) is required.

Reference Materials

Analyzer reference materials include the **HP 8566B/8568B Quick Reference Guide** (publication number 5955-8970), the **HP 8566B/8568B/9816/9826/9836-1 Introductory Operating Guide** (publication number 5952-9389), and the "Command Syntax Reference" found in the **HP 8566B/8568B Operating and Programming Manual** (part numbers 8566-90040 and 8568-90041).

Equipment Used

HP 8566B or 8658B Spectrum Analyzer.
HP 9000, Series 200 Model 216, 226, or 236 Desktop Computers.

RUNNING THE PROGRAM

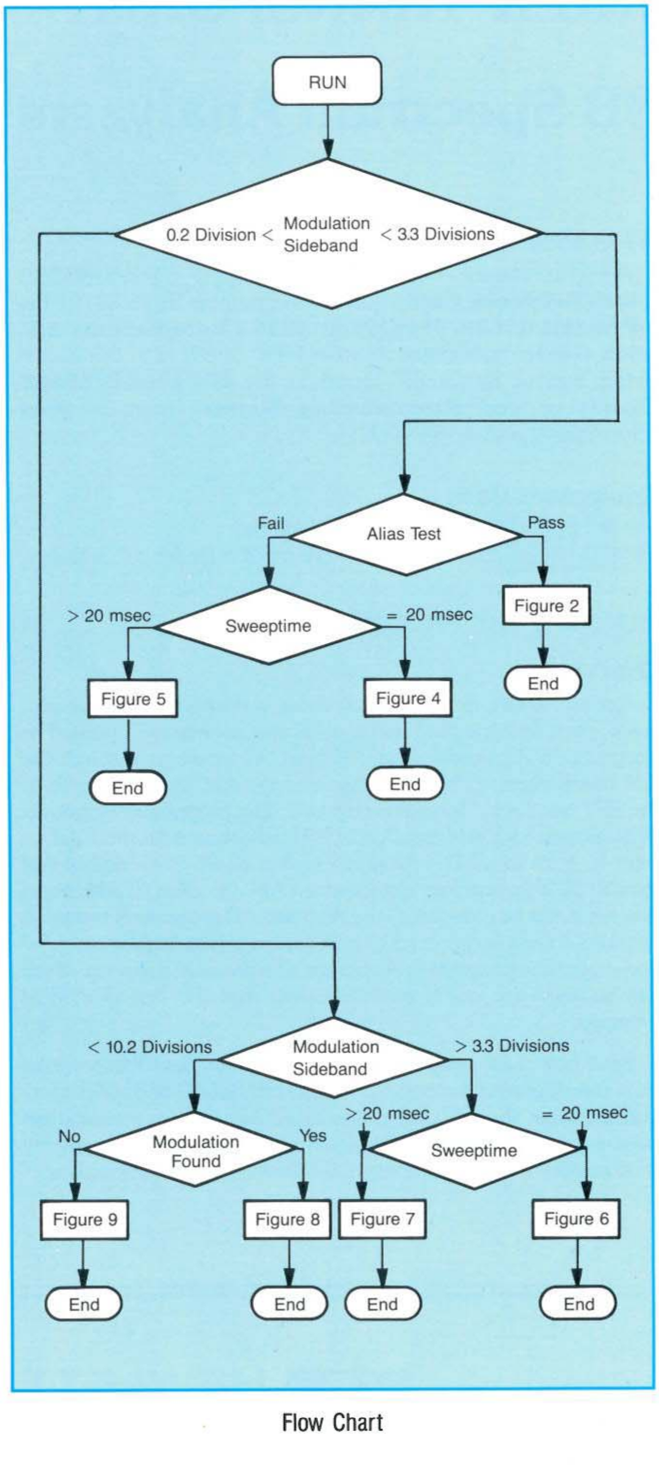
Overview

Appendixes A, B, and C show three versions of the same program, each designed to meet a particular user-requirement. The programs in Appendix A and B lead the operator through the AM measurement. No expertise making AM measurements in the FFT frequency domain is required. The program in Appendix A measures both AM depth and AM distortion with modulation rates to 8.25 kHz. The program in Appendix B measures AM rates to 15 kHz, but does not measure AM distortion. If AM distortion need not be measured, the Appendix B program is preferred because it runs more quickly and can measure higher modulation rates. The program in Appendix C is the core program which can be used for quick measurements that the operator must interpret.

Enter one of the programs into the computer. Save this program on a disk. Connect the computer to an HP 8566B or 8568B spectrum analyzer. Press [RUN] to download the program into analyzer memory. Load only one program at a time into analyzer memory (this purges analyzer memory). Follow the directions below.

AM Depth and AM Distortion Measurements in FFT Frequency Domain (Appendix A Program)

The signal used for the AM measurement examples is shown in Figure 1. Because it has relatively large FM, AM cannot be measured in the swept frequency domain, and the measurement is made in the FFT frequency domain. To do this, first place a marker on the signal of interest, then activate signal track. Zoom in on the signal by reducing the span to 1 MHz. **Run the program by pressing [Shift] [1] [Hz].** The program is fully automatic; no operator intervention is required at this point. Depending on the signal characteristics, one of several possible situations will occur. Refer to the program flowchart.



Flow Chart

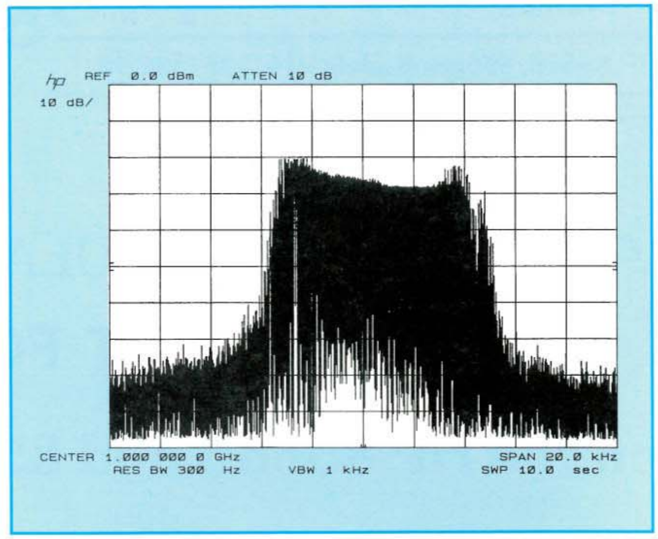


Figure 1. AM with relatively large FM cannot be measured in the swept frequency domain. This is the signal used for all the example measurements (except the one in Figure 3).

0.2 Divisions < Modulation Sideband < 3.3 Divisions

If the AM depth is $\geq 0.1\%$ and the modulation sideband lies between 0.2 and 3.3 horizontal FFT frequency-axis divisions, an alias test is performed. Failure of the alias test means that either the sweeptime is too slow or the modulation frequency is beyond the measurement range. If the signal passes the alias test, 16 averages are performed to improve repeatability, and the measurement results are displayed. An example is shown in Figure 2. Note the modulation has been translated back to baseband by the FFT. The carrier is shown at 0 Hz; the AM and distortion sidebands are to the right. At the end of the program, relative amplitude and frequency measurements can be made using delta marker. To show the extent of errors introduced by even small amounts of angle modulation, **the FFT and swept frequency domains may be compared by pressing [FREQUENCY SPAN] [2] [5] [kHz], [CLEAR-WRITE] Trace B, [CONT] Sweep, [AUTO] RES BW, [AUTO] Video BW, and [AUTO] SWEEP TIME.** Adjust center

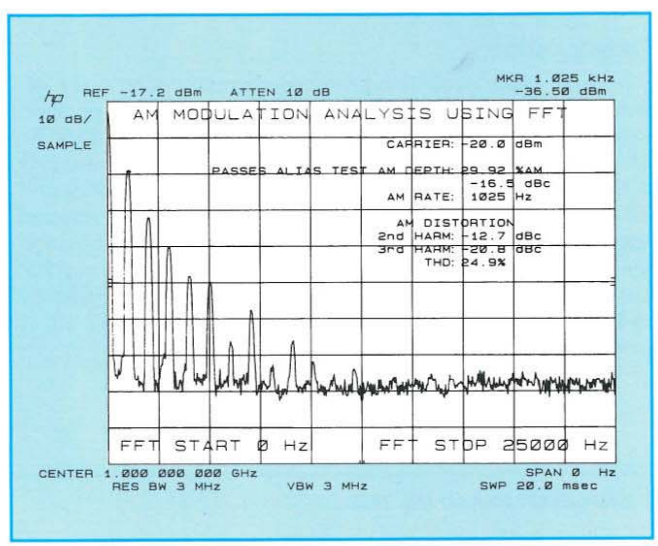


Figure 2. The signal shown in Figure 1 is easily measured in the FFT frequency domain.

frequency if necessary (see Figure 3). The program may be re-run by pressing [SHIFT] [1] [Hz]. If any control settings are changed, first press [RECALL] [1] to return to the previous analyzer control settings before re-running the program.

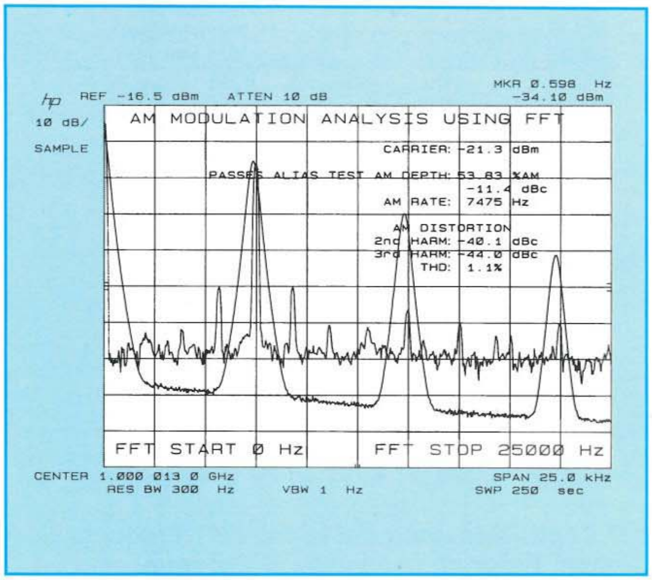


Figure 3. Comparison of FFT and swept frequency domain measurements of AM with small incidental angle modulation. Even small amounts of incidental angle modulation introduce large errors in the swept frequency domain.

If the signal fails the alias test, either the modulation rate is > 41.75 kHz or the sweeptime selected is too slow. Modulation rates greater than 8.25 kHz are beyond the measurement range of this program (see Figure 4), and no further action can be taken. Sweeptime determines the highest modulation frequency which can be measured. If the sweeptime is too slow, the modulation rate is out of range (see Figure 5). The FFT frequency domain trace may be seen by pressing [VIEW] Trace A. To continue the measurement, decrease sweeptime and re-run the program. In the example of Figure 5, press [SWEEP TIME] [2] [0] [msec] followed by [SHIFT] [1] [Hz] to re-run the program.

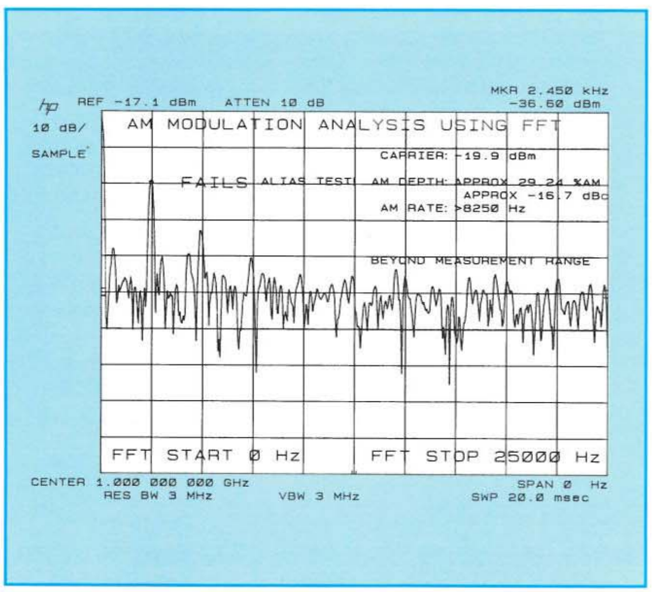


Figure 4. The 47.55 kHz rate AM "wraps around" the display, fails the alias test, and is beyond the measurement range. The measurement is not continuable.

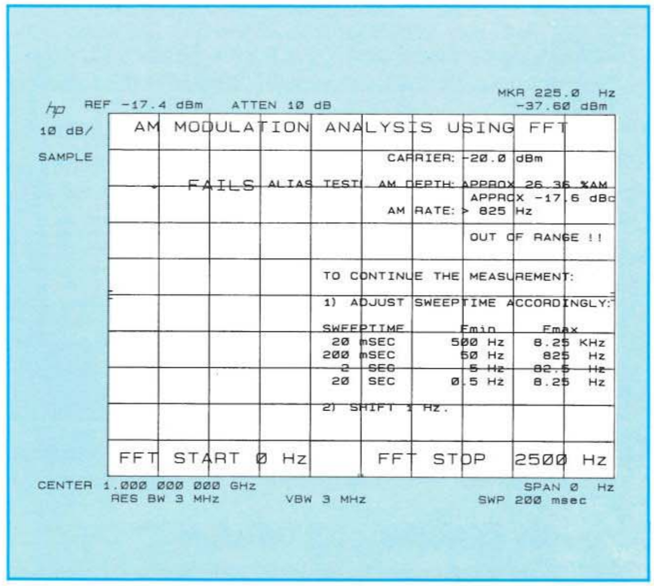


Figure 5. The 4.775 kHz rate AM wraps around the display and fails the alias test because the sweeptime is too slow. Increase sweeptime to continue the measurement.

Modulation Sideband > 3.3 Divisions

A modulation sideband greater than 3.3 divisions results in one of two possible displays, depending on whether the sweeptime is 20 msec or greater than 20 msec. If the sweeptime is 20 msec, then a modulation sideband > 3.3 divisions means that the modulation rate is > 8.25 kHz. This is beyond the measurement range of this program (see Figure 6). No further action can be taken. However, if the sweeptime is slower than 20 msec, decrease sweeptime by a factor of ten and re-run the measurement (see Figure 7). In the example of Figure 7, press [SWEEP TIME] [2] [0] [msec] [SHIFT] [1] [Hz].

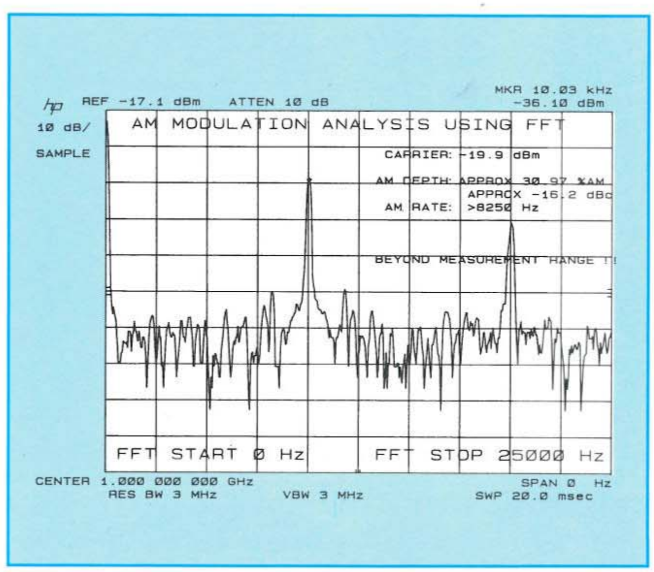


Figure 6. The 10 kHz rate AM is beyond the measurement range. The measurement is not continuable.

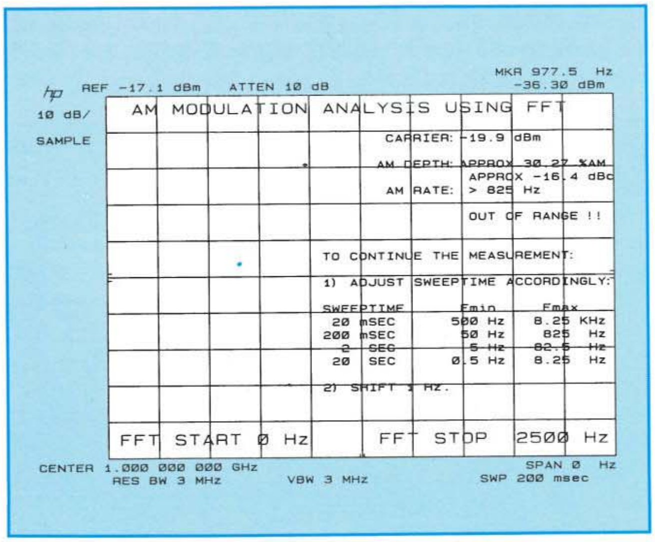


Figure 7. The 977.5 Hz rate AM is out of range because sweeptime is too slow. Decrease sweeptime to continue the measurement.

Modulation Sideband < 0.2 Divisions

A modulation sideband less than 0.2 divisions indicates that the sweeptime is too fast. Under these conditions the AM sideband is too close to the carrier and may not be resolved at low modulation levels. See Figure 8. In this case, the AM sideband is resolved and the marker readout indicates 400 Hz. The FFT frequency domain trace may be seen by pressing [VIEW] Trace A. Figure 9 shows an AM rate so low that the AM sideband is not resolvable, and there is no marker readout. To continue the measurement, increase sweeptime by a factor of 10. In the example of Figure 8, press [SWEEPTIME] [2] [0] [0] [msec] followed by [SHIFT] [1] [Hz] to re-run the measurement.

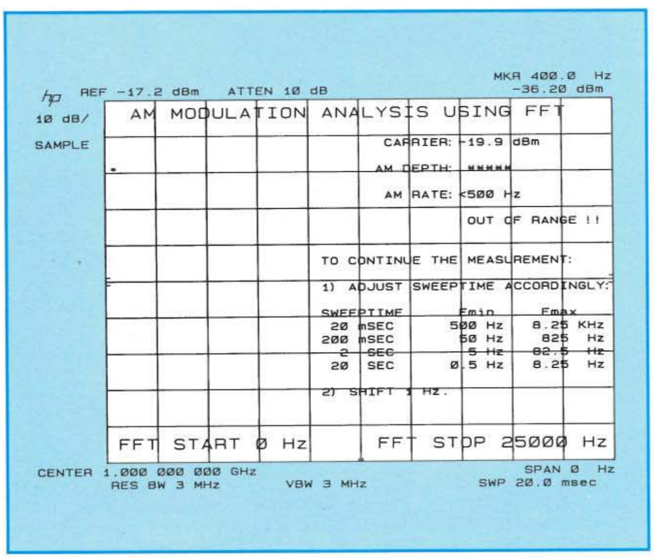


Figure 8. The 400 Hz rate AM is out of range because the sweeptime is too fast. Decrease sweeptime to continue the measurement.

Modulation < 0.1%

In this case, the AM cannot be measured in the FFT frequency domain using this program. Whatever sweeptime is chosen results in a display that looks like Figure 9. Again, the FFT frequency domain may be seen by pressing [VIEW] Trace A.

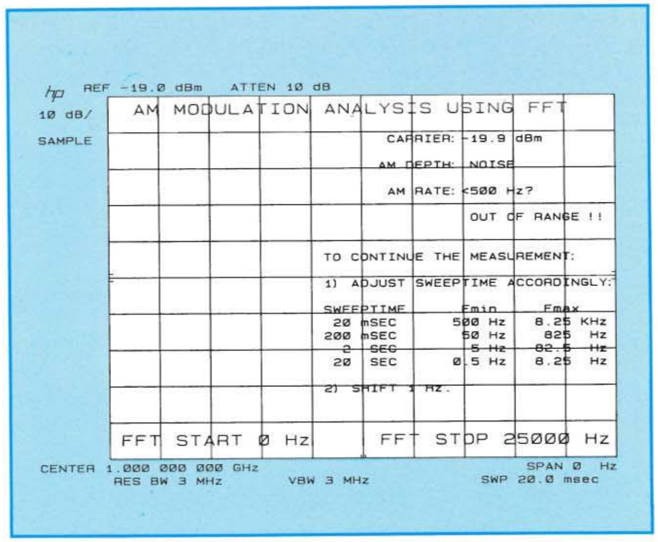


Figure 9. No modulation sideband has been found. Either there is no modulation, or the sweeptime is too fast. Increase sweeptime to continue the measurement.

AM Depth Measurement in the FFT Frequency Domain Program (Appendix B Program)

This program measures AM rates to 15 kHz, but does not measure AM distortion. If AM distortion does not need to be measured, this program is preferable because it runs more quickly and can measure higher modulation rates. The step-by-step procedure and the program operation are identical to the previous program with the following exceptions:

1) to start, press [SHIFT] [2] [Hz];
2) AM distortion is not measured;
3) averaging is performed only if the AM depth is less than approximately 1% AM;
4) AM rates to 15 kHz are measured; and
5) this program is faster.

Figure 10 shows a measurement made with this program.

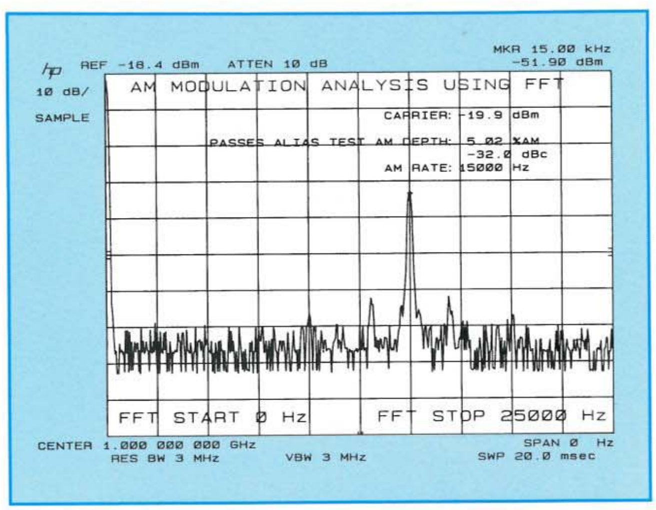


Figure 10. The 15 kHz rate AM is measured with the Appendix B program.

Core Program (Appendix C Program)

The core program is the shortest practical program possible, but the operator must interpret the results.

To make a measurement, first place a marker on the signal of interest, activate signal track, and zoom in on the signal by reducing the span to 1 MHz. Set the VBW (video bandwidth) to 3 MHz. Set the RBW (resolution bandwidth) to 3 MHz or narrower, as desired. Adjust the reference level to place the envelope peaks at or below the reference level. Press [SHIFT] [3] [Hz]. A single FFT is performed. The delta marker shows the AM depth in dBc. See Figure 11. The upper trace is the demodulated AM time domain waveform. The lower trace is the FFT frequency domain representation.

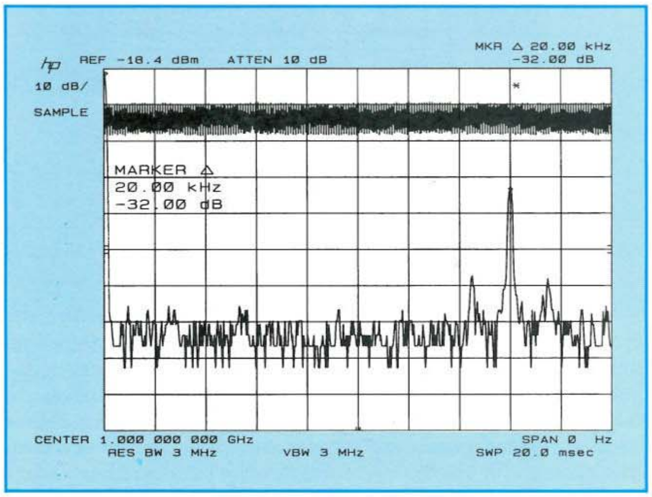


Figure 11. Higher rate AM can be measured with the core program of Appendix C. The operator must interpret the results.

FUNDAMENTALS OF AM MEASUREMENTS IN THE FFT FREQUENCY DOMAIN

Introduction

As discussed in HP Application Note 150-1, AM measurements using spectrum analyzers are generally made in either the swept frequency domain or the time domain. However, these measurement techniques have their limitations.

In the swept frequency domain, incidental angle modulation can significantly affect AM sideband levels (refer to HP Application Note 150-1). For example, microwave signal generators with pin diode modulators have high incidental phase modulation at high carrier frequencies and/or at high AM depth. It is common for these microwave signal generators to have an actual AM depth much less than the measurement in the swept frequency domain indicates. And there may be no tell-tale sideband asymmetry; no clue that the measurement is incorrect.

An alternative is to make the measurement in the time domain. For peak deviations much less than the resolution bandwidth (RBW), there is no FM-to-AM conversion. Hence, a time domain measurement using a sufficiently wide RBW strips off the incidental angle modulation. In this case, the incidental angle modulation does not affect measurement accuracy. However, a limitation of the time domain is that AM distortion and AM noise can significantly affect the measurement of AM depth. Also, AM distortion cannot be measured directly.

One solution to these limitations is to use downconversion, where one spectrum analyzer acts as a downconverter and a second low frequency spectrum analyzer or waveform recorder analyzes the demodulated waveform. For spectrum analyzers with digitized traces, a low-cost alternative is to use a controller to perform an FFT on the digitized time domain waveform. The most cost-effective solution, however, is to use a spectrum analyzer with sophisticated signal processing functions (such as FFT) and downloadable program capability. No costly second spectrum analyzer or external controller is required. The measurement is made quickly and internally in the FFT frequency domain. The advantages of making AM measurements in the FFT frequency domain are orders-of-magnitude improvement in speed, resolution, accuracy, and rejection of incidental FM. Many measurements which cannot be made in the swept frequency or time domains can easily be made in the FFT frequency domain.

Maximum Frequency Range and Resolution

The FFT is one algorithm for transforming demodulated AM data from the time domain to the frequency domain. The maximum frequency range (Nyquist frequency) of the FFT is

$$F\ max = \frac{N}{2} \cdot \frac{1}{\text{Period of Time Record}}$$

where N is the number of samples (generally 1001) and the Period of Time Record is the sweeptime. F max is the maximum modulation frequency which can be measured by the FFT. F max becomes higher as the sweeptime is reduced.

When sweeptime increases by a factor of 10, F max is reduced by a factor of 10, and frequency readout resolution is improved by a factor of 10. The formula is

$$\text{frequency readout resolution} = \frac{2}{N} \cdot F\ max.$$

Hence, a sweeptime of 20 msec yields an F max of 25 kHz and resolution of 50 Hz.

Aliasing

Due to a phenomenon called aliasing, modulation frequencies higher than F max are mixed down to the frequency range of the FFT. These alias products cause erroneous results. For example, if F max is 25 kHz, then 26 kHz, 74 kHz, or 76 kHz signals all appear at the same position on the display as does a 24 kHz signal. See Figure 12.

Figure 12. Aliasing in the FFT frequency domain. Signals higher in frequency than F max "wrap around" the display.

As long as the highest frequency component of the modulation is less than F max, no aliasing can occur. Therefore, a filter can be used to remove the alias products. An ideal anti-aliasing filter is infinitely steep. However, since real filters have gradual roll-off and finite rejection, large signals which are not well-attenuated in the transition band can still alias into the FFT frequency range. There is no way to avoid this; hence the usable FFT frequency range is lower than F max.

Although the RBWs and video bandwidths (VBWs) cannot be used as anti-aliasing filters since neither has sufficiently steep roll-off, both can be used for alias testing. It is best, though, to use the widest RBW for maximum FM rejection and use only the VBWs for the alias test.

Usable Frequency Range

When the VBWs are used for the alias test, the usable FFT frequency range for AM depth and AM distortion measurements is restricted to the shaded area shown in Figure 13. Regardless of sweeptime and F max, this corresponds to 0.2 to 3.3 divisions.

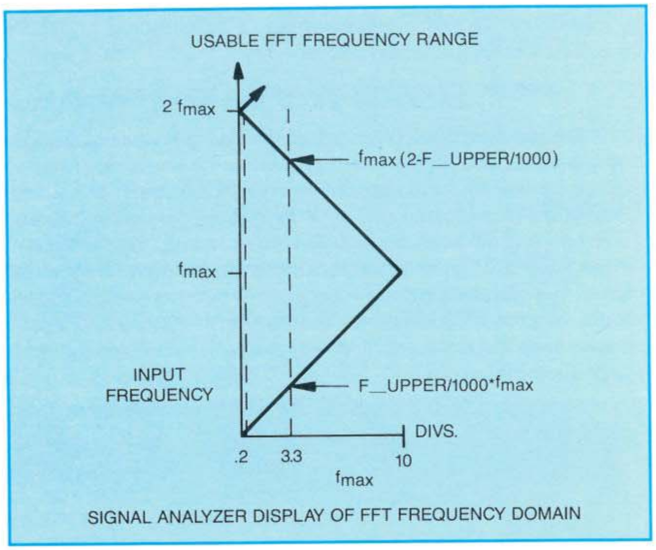


Figure 13. Usable FFT frequency range when measuring AM depth and AM distortion to the third harmonic (Appendix A program).

Low-depth modulation with a modulation frequency < 0.2 divisions results in a low-level sideband so close to the nearby large carrier (the d.c. term in the FFT frequency domain) that the sideband cannot be resolved. In this case, the sweeptime must be increased. Because modulation rates greater than 3.3 divisions cause the third and higher harmonics to "wrap around" the display, the third harmonic cannot be measured for modulation rates greater than 3.3 divisions. If harmonic distortion does not need to be measured, the frequency range can be extended to six divisions as discussed in the "Extending Measurement Range" section below.

Table I shows the usable frequency range of the FFT as a function of sweeptime. As long as the AM modulation rate lies within one of these four frequency ranges, the measurement of AM depth and AM distortion to the third harmonic can be made. No other values of sweeptime are necessary.

For signals within the usable frequency range, make the aliasing test as follows. First make an FFT frequency domain measurement using the widest VBW. Make a second measurement using the VBW shown in Table I. If the fundamental (the AM sideband depth in dBc) changes less than eight dB, then it is not an alias product.

Table I. Usable frequency range, sweeptime, and aliasing test for AM measurements in the FFT frequency domain when using the Appendix A program.

MOD Frequency .2 Divs	3.3 Divs			Aliasing Test	
Min Hz	Max Hz	Fmax	Sweeptime	VBW #1	VBW #2
500	8250	25 kHz	20 msec	3 MHz	10 kHz
50	825	2.5 kHz	200 msec	3 MHz	1 kHz
5	82.5	250 Hz	2 secs	3 MHz	100 Hz
0.5	8.25	25 Hz	20 secs	3 MHz	10 Hz

Window Functions

There is another property of the FFT which affects its use in frequency domain analysis. If the sweep does not contain an integral number of cycles of the demodulated AM waveform, the FFT algorithm is computed on the basis of a discontinuous, highly distorted waveform. The solution to this problem is windowing.

The FFT function has three windows to choose from: uniform, Hanning, and flattop. The uniform window is used for transients only. The Hanning window has better frequency accuracy but poorer amplitude accuracy than the flattop window. However, the better frequency accuracy of the Hanning window is not realizable because frequency accuracy also depends on sweeptime accuracy. The flattop window is used for best amplitude accuracy when analyzing periodic waveforms such as demodulated AM. Table II shows its characteristics. The aspect ratio shows how many 3 dB bandwidths will fit into the frequency range, and is a figure of merit for resolution.

Shape factor is a figure of merit for selectivity; it shows how well low-level AM sidebands can be resolved from the nearby carrier. Both shape factor and aspect ratio are excellent. More information can be found in HP Application Notes 150 and 243.

Table II. Flattop window characteristics.

3 dB BW	0.72% of Fmax
Shape Factor: (60 dB BW/3 dB BW)	2.6
Aspect Ratio: (Fmax/3 dB BW)	140

MEASUREMENT CONSIDERATIONS

The advantages of AM measurements made in the FFT frequency domain are speed, resolution, accuracy, and rejection of incidental FM.

Accuracy

The basic accuracy of AM depth and AM distortion measurements is ±0.2 dB (±2.5% of reading). FFT noise degrades basic measurement accuracy by reducing linearity and generating phantom spectral components. These effects can be lumped together into the category of "noise."

Variance in the measurement due to noise is reduced by averaging a number of measurements. Refer to Figure 14. Above 1% AM (AM sideband < −46 dBc), averaging has no significant effect; the standard deviation of the measurement is approximately 0.1 dB or better. At 0.1% AM (AM sideband −66 dBc), 16 averages reduce the standard deviation by a factor of 2 (from 0.8 dB to 0.4 dB). Since each average requires roughly 0.5 sec, more than sixteen averages may not be worth the extra time. For example, 128 averages further reduces the standard deviation by less than a factor of 2 (from 0.4 dB to 0.25 dB), but takes 8 times longer (over 60 seconds).

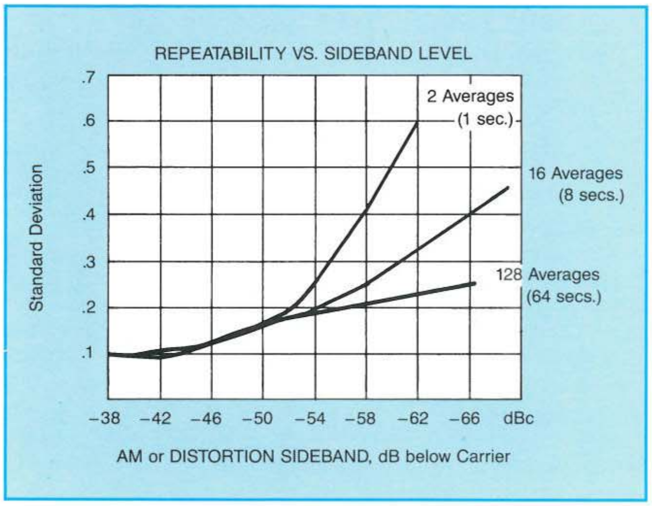


Figure 14. Repeatability in the FFT frequency domain depends on AM and AM distortion sideband levels.

The graph is only approximately correct for standard deviation in distortion measurements. At simultaneous high AM depths and high modulation rates, the standard deviation will increase somewhat due to the raised noise floor.

Modulation rate accuracy is a direct function of sweeptime accuracy (10% of reading).

FM Rejection

Using the 3 MHz RBW results in a very high degree of immunity to angle modulation. FM rejection is < 0.1% AM for FM deviations < 10 kHz. This means that AM measurements can be made in the presence of relatively large FM or that incidental AM measurements can be made on FM.

Speed and Resolution

The FFT frequency domain provides improvement in resolution by at least a factor of 100 over measurements made in the swept frequency domain. For example, modulation rates below 10 Hz can be measured in the FFT frequency domain but not in the swept frequency domain. Even for equivalent resolutions, the FFT provides an advantage in speed of at least a factor of four.

Internal Distortion, Spurious and Dynamic Range

All distortion measurements are affected by internally generated distortion. The rule of thumb is, for less than 1 dB error due to internal distortion, the internal distortion must be more than 20 dB below the distortion being measured. Distortion measurements are also affected by noise. The rule of thumb here is, for less than 0.5 dB error due to noise, keep the Signal/Noise ratio greater than 10 dB.

Typical internally generated distortion is 50 dB below the AM sideband at 50% AM. The noise floor is 82.7 dB below the reference level at low depth AM. However, the noise floor rises at simultaneous, high AM depths and high modulation rates. Noise and distortion are plotted in Figure 15. The maximum dynamic range is > 50 dB for > 15% AM. From the rules given above, usable dynamic range is 40 dB at 15% AM. In other words, at 15% AM, 1% AM distortion can be measured to approximately 1 dB accuracy. Higher levels of distortion can be measured more accurately. For example, the measurement in Figure 16 is essentially unaffected by internal distortion.

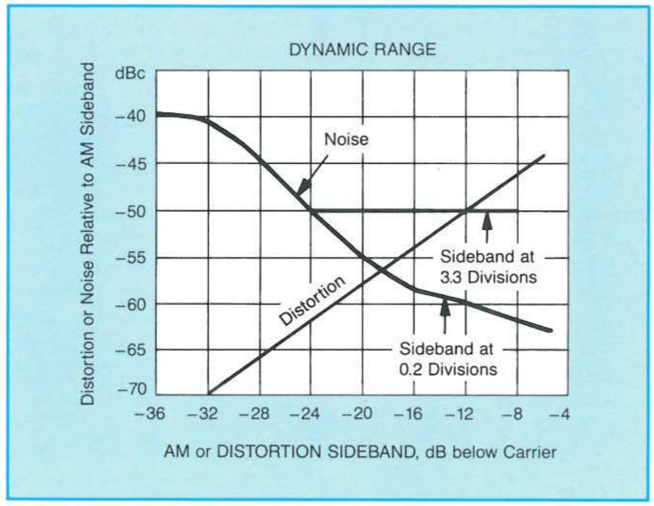


Figure 15. Dynamic Range of AM measurements in the FFT frequency domain.

Small non-linearities in the spectrum analyzer's sweep ramp cause spurious signals in the FFT frequency domain which are symmetrically spaced about the AM and AM distortion sidebands. These spurious signals are an FM phenomenon: as the modulation rate is increased by a factor of two, the spurious level increases 6 dB. The spurious sidebands do not affect measurement accuracy as long as the spurious sideband pair is at least 20 dB below its corresponding AM or AM distortion sideband.

Figure 16 shows spurious sidebands of a sample instrument at 1825 Hz and 3650 Hz about the large AM sideband. These are −32 dBc and −41 dBc respectively. Because they are more than 20 dB below the AM sideband, they do not affect the percent AM measurement accuracy. However, they may affect the second harmonic distortion measurement accuracy if the AM rate is near either of these two frequencies (1825 Hz or 3650 Hz). Also, the frequency and level of the spurious signals vary considerably from instrument to instrument.

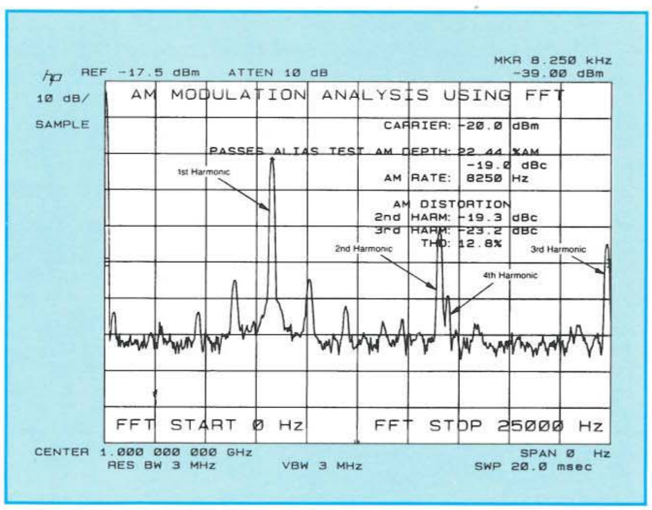


Figure 16. The modulation consists of an AM sideband and second, third, and fourth harmonics. The fourth harmonic has "wrapped around" the display due to aliasing. All other signals are spurious sidebands of the sample instrument. These vary considerably from unit to unit.

EXTENDING MEASUREMENT RANGE

Modulation Rates

Modulation rates below 0.5 Hz can be measured by increasing the sweeptime appropriately. Modulation rates above 8.25 kHz can be measured, but the capability to measure harmonic distortion is sacrificed. If the second harmonic only is to be measured, the usable FFT frequency range can be extended to 4.95 divisions, regardless of sweeptime (in a 20 msec sweeptime this corresponds to an F max of 12.375 kHz). When harmonic distortion measurements are not needed, usable FFT frequency range can be pushed to 6 divisions and above. This change is made in line 430; a measurement range of 6 divisions corresponds to an F_upper of 600 cells. Above 3.3 divisions, however, the alias test value in line 440 should be determined experimentally, as it may be instrument dependent. Choose an alias test value such that modulation rates less than F_upper/1000*F max — the highest modulation rate in the usable FFT frequency range of Figure 13 — pass the alias test, but modulation rates greater than F max*(2−F_upper/1000) — the lowest frequency which "wraps around" into the usable FFT frequency range of Figure 13 — fail the alias test.

AM Depth

It is not possible to measure AM depths in excess of 100% due to severe waveform distortion. Measurements below 1% AM require averaging. Measurements below 0.1% AM are not reliable because of system noise.

Carrier Level < −20 dBm

The minimum carrier level required to make the measurement is shown in Table III. For AM depths greater than 1%, the carrier level can be reduced by approximately 20 dB. For lower carrier levels, an RBW < 3 MHz may be used to improve Signal/Noise ratio. However, each time the RBW is reduced by a factor of 10, the FM rejection is also reduced by a factor of 10. An RBW ≥ 13.3 *(modulation rate) ensures that there will be no additional error in measured percent AM, and an RBW ≥ 40 * (modulation rate) ensures that there will be no additional error in measured AM distortion. These minimum RBWs prevent roll-off of the filter bandwidth from affecting the measurement.

Carrier Frequency < 10 MHz

Carriers below 10 MHz can be measured. However, an RBW < 3 MHz must be used to eliminate LO feedthrough. The comments above also apply here.

Table III. Minimum carrier level for AM measurements in the FFT frequency domain.

Frequency Band	Minimum Carrier Level (3 MHz RBW, 10 dB RF Attenuator)
10 MHz - 2.5 GHz	−20 dBm
2 - 5.8 GHz	−20 dBm
5.8 - 12.5 GHz	−13 dBm
12.5 - 18.6 GHz	−10 dBm
18.6 - 22 GHz	−7 dBm

AM Depth and AM Distortion Measurement in the FFT Frequency Domain

PROGRAM DESCRIPTION

The code of the AM and AM Distortion Measurement in the FFT Frequency Domain Program is divided into the following functional sections:

Initialize

All variables and traces are defined in this section. Variables are assigned a pre-set value.

S_etup

This functional definition ensures the analyzer is set up in the proper state: single sweep, zero span, sample detection, free run trigger, 3 MHz RBW, and 3 MHz VBW are all required modes of operation. Only one of four sweeptimes is allowed. An RBW ≤ 3 MHz may be used as discussed in "Extending Measurement Range."

A_utorange

This function places the AM modulation envelope peak at the reference level and selects linear detection.

A_lias

This function locates the highest amplitude AM sideband in the FFT frequency domain. If this sideband lies between 0.02 and 3.3 horizontal divisions, an aliasing test using the proper VBW is performed.

A_verage

For an AM sideband which lies between 0.02 and 3.3 horizontal divisions and which also passes the alias test, this function sequentially sweeps and averages 16 FFTs. Less averaging may be used to speed the measurement; however, the repeatability of low-distortion measurements and low-depth AM (< 1% AM) measurements is degraded.

M_easure

This function computes F max (Nyquist frequency), which is displayed as "FFT Stop Freq." If a modulation sideband was found in the **A_lias** function, **M_easure** determines the modulation rate.

C_ompute

This function computes the carrier level in dBm, and AM depth in dBc and percent. The P_eaks array is searched for second and third harmonics. All other signals are ignored (except in the unlikely case that a higher harmonic "wraps around" the display and happens to lie in the same position as the second or third harmonic, or in the unlikely case that an AM distortion sideband coincides with a spurious signal). Second and third harmonic distortion is calculated in dBc. Total harmonic distortion is calculated in percent.

Disp_One

This function displays the annotation and measurement results for FFT Start and Stop frequency, AM depth, and AM rate. If the modulation sideband is greater than 3.3 horizontal divisions and the sweeptime is 20 msec, or if the modulation fails the aliasing test, "Beyond Measurement Range" is displayed.

Disp_Two

If the AM sideband is out of range but the measurement is continuable, this function displays the sweeptime selection table.

Disp_Three

For modulation rates in the usable frequency range of the FFT, this function displays second, third, and total harmonic distortion. It also displays the alias test results (pass or fail).

Main Program

This section assigns a name and a softkey to the main program. The main program sequentially executes the functions described above.

Annotated Program Listing

```
10    ! File name: "FFT_ONE"        Date:  4/85
20    !                             DLP BYTES: 7530
30    ! Description of  Program:    This program performs an AM MODULATION
40    !                             ANALYSIS USING FFT on demodulated, time-domain
50    !                             waveforms. It measures CARRIER LEVEL,AM DEPTH,
60    !                             AM RATE, AM DISTORTION, and TOTAL HARMONIC
70    !                             DISTORTION.
80    !                             Restrictions: Carrier level >= -20 dBm,
90    !                                           AM depth 0.1-99%
100   !                                           AM rate 0.5 Hz to 8.25 kHz.
110   !                                           8566B/68B VER 14.1.85 (REV C)
120   !                                                         OR LATER
130   !
140   ASSIGN @Sa TO 718
150   OUTPUT @Sa;"DISPOSE ALL;"
160   OUTPUT @Sa;"MEM?"
170   ENTER @Sa;M
180   !
190   ! INITIALIZE:
200   !
210   OUTPUT @Sa;"TRDEF P_EAKS,100;"    ! Peaks location, cells
220   OUTPUT @Sa;"VARDEF C_ARRIER,0;"   ! Carrier Level, dBm
230   OUTPUT @Sa;"VARDEF F_IRST,0;"     ! AM Depth, dBc
240   OUTPUT @Sa;"VARDEF F_IRSTPOS,0;"  ! AM sideband position, cells
250   OUTPUT @Sa;"VARDEF S_ECOND,0;"    ! AM 2nd harmonic distortion, dBc
260   OUTPUT @Sa;"VARDEF S_UPPER,0;"    ! upper,lower extreme positions
270   OUTPUT @Sa;"VARDEF S_LOWER,0;"    !  of 2nd harmonic, cells.
280   OUTPUT @Sa;"VARDEF S_ECONDPOS,0;"! exact position of 2nd harmonic, cells
290   OUTPUT @Sa;"VARDEF T_HIRD,0;"     ! AM 3rd harmonic distortion, dBc
300   OUTPUT @Sa;"VARDEF T_UPPER,0;"    ! upper,lower extreme positions
310   OUTPUT @Sa;"VARDEF T_LOWER,0;"    !  of 3rd harmonic, cells
320   OUTPUT @Sa;"VARDEF T_HIRDPOS,0;"  ! exact position of 3rd harmonic, cells
330   OUTPUT @Sa;"VARDEF P_ERCENT,0;"   ! AM depth, %
340   OUTPUT @Sa;"VARDEF R_ATE,0;"      ! AM Rate, Hz
350   OUTPUT @Sa;"VARDEF F_STOP,0;"     ! FFT Stop Frequency, Hz
360   OUTPUT @Sa;"VARDEF I_NDEX,1;"     ! count variable
370   OUTPUT @Sa;"VARDEF A_TWO,.0000001;" ! relative level 2nd, linear units
380   OUTPUT @Sa;"VARDEF A_THREE,.0000001;" ! relative level 3rd, linear units
390   OUTPUT @Sa;"VARDEF T_HD,0;"       ! Total Harmonic Distortion, %
400   OUTPUT @Sa;"VARDEF S_T,0;"        ! Sweeptime, secs
410   OUTPUT @Sa;"VARDEF T_EST,0;"      ! Alias Test results, dB
420   OUTPUT @Sa;"VARDEF V_BW,0;"       ! Video BW, Hz
430   OUTPUT @Sa;"VARDEF F_UPPER,331;"  ! Upper limit to measurement range, cells
440   OUTPUT @Sa;"VARDEF D_B,-8;"       ! Alias test value, dB
450   !
460   ! SUBROUTINES:
470   !
480   ! S_ETUP
490   !
500   OUTPUT @Sa;"FUNCDEF S_ETUP,@"
510   OUTPUT @Sa;"TRDEF WINDOW,1001;"  ! N=1001 samples
520   OUTPUT @Sa;"TWNDOW WINDOW,FLATTOP;"
530   OUTPUT @Sa;"KS);SAVES 1;IP;RCLS 1;"
540   OUTPUT @Sa;"SNGLS;SP0HZ;DET SMP;TM FREE;"
550   OUTPUT @Sa;"BLANK TRA;CLRW TRB;"
560   OUTPUT @Sa;"RB3MZ;VB3MZ;HD;"
570   OUTPUT @Sa;"MOV S_T,ST;"                         ! Selects one of four
580   OUTPUT @Sa;"IF S_T,LT,.05;MOV S_T,.02;"          ! sweeptimes:
```

```
590   OUTPUT @Sa;"ENDIF;"                           !      20 mSEC
600   OUTPUT @Sa;"IF S_T,GT,5;MOV S_T,20;"          !     200 mSEC
610   OUTPUT @Sa;"ENDIF;"                           !       2  SEC
620   OUTPUT @Sa;"IF S_T,GT,.5;IF S_T,LT,5;"        !      20  SEC
630   OUTPUT @Sa;"MOV S_T,2;ENDIF;ENDIF;"
640   OUTPUT @Sa;"IF S_T,GT,.05;IF S_T,LT,.5;"
650   OUTPUT @Sa;"MOV S_T,.2;ENDIF;ENDIF;@"
660   !
670   ! A_UTORANGE
680   !
690   OUTPUT @Sa;"FUNCDEF A_UTORANGE,@"
700   OUTPUT @Sa;"DA3072;D3;PU;PA 96,592;"
710   OUTPUT @Sa;"TEXT /AUTORANGING LEVEL.../;"
720   OUTPUT @Sa;"DW1044;"
730   OUTPUT @Sa;"ST2SC;RL30DM;LG 10DB;HD;TS;"      !  Auto ranges AM modulation
740   OUTPUT @Sa;"MKPK HI;MKRL;MKOFF ALL;RL UP;LN;" !  envelop peak to Reference
750   OUTPUT @Sa;"HD;TS;MKPK HI;MKRL;RL UP;"        !  Level.  Saves State.
760   OUTPUT @Sa;"MKOFF ALL;MOV ST,S_T;SAVES 1;KS(;@"
770   !
780   ! A_LIAS
790   !
800   OUTPUT @Sa;"FUNCDEF A_LIAS,@"
810   OUTPUT @Sa;"DA3072;PU;PA 96,592;"
820   OUTPUT @Sa;"TEXT /ALIAS TEST.../;"
830   OUTPUT @Sa;"DW1044;HD;"
840   OUTPUT @Sa;"TS;FFT TRA,TRB,WINDOW;VIEW TRA;"
850   OUTPUT @Sa;"MKPX 13DB;PEAKS P_EAKS,TRA,AMP;"
860   OUTPUT @Sa;"MOV F_IRSTPOS,P_EAKS[1];"
870   OUTPUT @Sa;"IF F_IRSTPOS,GE,20;"                     ! Performs Aliasing Test
880   OUTPUT @Sa;"   IF F_IRSTPOS,LE,F_UPPER;"             ! for signals between
890   OUTPUT @Sa;"      MOV T_EST,TRA[F_IRSTPOS];"         ! .02 and 3.3 horizontal
900   OUTPUT @Sa;"      DIV V_BW,200,S_T;"                 ! Divisions.
910   OUTPUT @Sa;"      MOV VB,V_BW;"                      ! VBW selected:
920   OUTPUT @Sa;"      TS;FFT TRB,TRB,WINDOW;"            !       20 mSEC    10 kHz
930   OUTPUT @Sa;"      SUB T_EST,TRB[F_IRSTPOS],T_EST;"!     200  SEC     1 kHz
940   OUTPUT @Sa;"      DIV T_EST,T_EST,10;"               !        2  SEC   100  Hz
950   OUTPUT @Sa;"ENDIF;ENDIF;"                            !       20  SEC    10  Hz
960   OUTPUT @Sa;"@"
970   !
980   ! A_VERAGE
990   !
1000  OUTPUT @Sa;"FUNCDEF A_VERAGE,@"
1010  OUTPUT @Sa;"DA3072;PU;PA 96,592;"
1020  OUTPUT @Sa;"TEXT /AVERAGING.../;"
1030  OUTPUT @Sa;"DW1044;"
1040  OUTPUT @Sa;"VB3MZ;HD;"
1050  OUTPUT @Sa;"IF F_IRSTPOS,GE,20;"              ! For signals between .02
1060  OUTPUT @Sa;"   IF F_IRSTPOS,LE,F_UPPER;"      ! and 3.3 horizontal DIVs
1070  OUTPUT @Sa;"      MOV I_NDEX,1;"              ! which pass the alias
1080  OUTPUT @Sa;"      IF T_EST,LT,D_B;"           ! test, sequentially
1090  OUTPUT @Sa;"         MOV I_NDEX,16;"          ! sweep and average 16
1100  OUTPUT @Sa;"      ENDIF;"                     ! FFT's.
1110  OUTPUT @Sa;"      REPEAT;"
1120  OUTPUT @Sa;"        TS;FFT TRB,TRB,WINDOW;"
1130  OUTPUT @Sa;"        AVG TRA,TRB,16;"
1140  OUTPUT @Sa;"        ADD I_NDEX,I_NDEX,1;"
1150  OUTPUT @Sa;"      UNTIL I_NDEX,GE,16;"
1160  OUTPUT @Sa;"ENDIF;ENDIF;@"
1170  !
1180  ! M_EASURE
```

```
1190  !
1200  OUTPUT @Sa;"FUNCDEF M_EASURE,@;"
1210  OUTPUT @Sa;"BLANK TRB;LG 10DB;"
1220  OUTPUT @Sa;"DIV F_STOP,500,S_T;"                    ! Measure FFT Stop Freq
1230  OUTPUT @Sa;"IF F_IRSTPOS,NE,0;"                     ! If modulation exists
1240  OUTPUT @Sa;"   MKPX 12DB;PEAKS P_EAKS,TRA,AMP;"     ! measure rate of
1250  OUTPUT @Sa;"   M2;MKP P_EAKS[1];MKREAD FFT;"        ! largest signal.
1260  OUTPUT @Sa;"   HD;MOV R_ATE,MF;"
1270  OUTPUT @Sa;"   MKPX 12DB;PEAKS P_EAKS,TRA,FRQ;"     ! Sort harmonics by freq
1280  OUTPUT @Sa;"ENDIF;@"
1290  !
1300  ! C_OMPUTE
1310  !
1320  OUTPUT @Sa;"FUNCDEF C_OMPUTE,@;"
1330  OUTPUT @Sa;"DA3072;PU;PA 96,592;"
1340  OUTPUT @Sa;"TEXT /COMPUTING...          /;"
1350  OUTPUT @Sa;"DW1044;HD;"
1360  OUTPUT @Sa;"SUB C_ARRIER,TRA[1],1000;"         ! Compute CARRIER LEVEL
1370  OUTPUT @Sa;"DIV C_ARRIER,C_ARRIER,10;"
1380  OUTPUT @Sa;"ADD C_ARRIER,C_ARRIER,RL;"
1390  !
1400  OUTPUT @Sa;"IF F_IRSTPOS,NE,0;"                     ! If modulation exists,
1410  OUTPUT @Sa;"   SUB F_IRST,TRA[F_IRSTPOS],TRA[1];"! Compute AM DEPTH,
1420  OUTPUT @Sa;"   DIV F_IRST,F_IRST,10;"               !             dBc
1430  OUTPUT @Sa;"   EXP P_ERCENT,F_IRST,20;"             !              %
1440  OUTPUT @Sa;"   MPY P_ERCENT,P_ERCENT,200;"
1450  OUTPUT @Sa;"ENDIF;"
1460  OUTPUT @Sa;"IF F_IRSTPOS,GE,20;"               ! If signal is between
1470  OUTPUT @Sa;"   IF F_IRSTPOS,LE,F_UPPER;"          ! .02 and 3.3 DIVs, then
1480  OUTPUT @Sa;"   MPY S_UPPER,F_IRSTPOS,2;"       ! Compute 2nd harmonic
1490  OUTPUT @Sa;"   ADD S_UPPER,S_UPPER,10;"        ! position to +/-10 cells.
1500  OUTPUT @Sa;"   SUB S_LOWER,S_UPPER,20;"
1510  OUTPUT @Sa;"   MPY T_UPPER,F_IRSTPOS,3;"       ! Compute 3rd harmonic
1520  OUTPUT @Sa;"   ADD T_UPPER,T_UPPER,10;"        ! position to +/-10 cells.
1530  OUTPUT @Sa;"   SUB T_LOWER,T_UPPER,20;"
1540  OUTPUT @Sa;"   MOV I_NDEX,1;"
1550  OUTPUT @Sa;"   REPEAT;"                                ! Locate positions
1560  OUTPUT @Sa;"      ADD I_NDEX,I_NDEX,1;"                ! of any 2nd or 3rd
1570  OUTPUT @Sa;"      IF P_EAKS[I_NDEX],LE,S_UPPER;THEN" ! harmonic peaks.
1580  OUTPUT @Sa;"         IF P_EAKS[I_NDEX],GE,S_LOWER;THEN"
1590  OUTPUT @Sa;"            MOV S_ECONDPOS,P_EAKS[I_NDEX];"
1600  OUTPUT @Sa;"      ENDIF;ENDIF;"
1610  OUTPUT @Sa;"      IF P_EAKS[I_NDEX],LE,T_UPPER;"
1620  OUTPUT @Sa;"         IF P_EAKS[I_NDEX],GE,T_LOWER;"
1630  OUTPUT @Sa;"            MOV T_HIRDPOS,P_EAKS[I_NDEX];"
1640  OUTPUT @Sa;"      ENDIF;ENDIF;"
1650  OUTPUT @Sa;"      IF P_EAKS[I_NDEX],GE,T_UPPER;MOV I_NDEX,100;"
1660  OUTPUT @Sa;"      ENDIF;"
1670  OUTPUT @Sa;"      IF P_EAKS[I_NDEX],EQ,P_EAKS[100];MOV I_NDEX,100;"
1680  OUTPUT @Sa;"      ENDIF;"
1690  OUTPUT @Sa;"   UNTIL I_NDEX,EQ,100;"
1700  OUTPUT @Sa;"   IF S_ECONDPOS,NE,0;"                                 ! Compute
1710  OUTPUT @Sa;"     SUB S_ECOND,TRA[S_ECONDPOS],TRA[F_IRSTPOS];"! 2nd
1720  OUTPUT @Sa;"     DIV S_ECOND,S_ECOND,10;"                           ! HARMONIC.
1730  OUTPUT @Sa;"   ENDIF;"
1740  OUTPUT @Sa;"   IF T_HIRDPOS,NE,0;"                                  ! Compute
1750  OUTPUT @Sa;"     SUB T_HIRD,TRA[T_HIRDPOS],TRA[F_IRSTPOS];"       ! 3rd
1760  OUTPUT @Sa;"     DIV T_HIRD,T_HIRD,10;"                             ! HARMONIC.
1770  OUTPUT @Sa;"   ENDIF;"
1780  OUTPUT @Sa;"ENDIF;ENDIF;"
```

```
1790  OUTPUT @Sa;"IF F_IRSTPOS,NE,0;"
1800  OUTPUT @Sa;"   IF S_ECONDPOS,NE,0;"
1810  OUTPUT @Sa;"      EXP A_TWO,S_ECOND,10;"
1820  OUTPUT @Sa;"   ENDIF;"
1830  OUTPUT @Sa;"   IF T_HIRDPOS,NE,0;"
1840  OUTPUT @Sa;"      EXP A_THREE,T_HIRD,10;"
1850  OUTPUT @Sa;"   ENDIF;"
1860  OUTPUT @Sa;"   ADD T_HD,A_TWO,A_THREE;"                ! Compute TOTAL
1870  OUTPUT @Sa;"   SQR T_HD,T_HD;MPY T_HD,T_HD,100;"      ! HARMONIC
1880  OUTPUT @Sa;"ENDIF;"                                  ! DISTORTION.
1890  OUTPUT @Sa;"@"
1900  !
1910  ! DISP_ONE
1920  !
1930  OUTPUT @Sa;"FUNCDEF DISP_ONE,@;"
1940  OUTPUT @Sa;"DA2864;DW145;DA2578;DW147;DA3072;D2;"
1950  OUTPUT @Sa;"D3;PU;PA 112,608;"
1960  OUTPUT @Sa;"TEXT /AM MODULATION ANALYSIS USING FFT /;"
1970  OUTPUT @Sa;"D3;PU;PA 104,64;"
1980  OUTPUT @Sa;"TEXT /FFT START 0 Hz      FFT STOP  /;"
1990  OUTPUT @Sa;"DSPLY F_STOP,5.0;TEXT /  Hz/;"
2000  OUTPUT @Sa;"D2;PU;PA 600,848;"
2010  OUTPUT @Sa;"TEXT / CARRIER: /;"
2020  OUTPUT @Sa;"DSPLY C_ARRIER,3.1;TEXT /  dBm/;"
2030  OUTPUT @Sa;"PU;PA 600,784"
2040  OUTPUT @Sa;"TEXT /AM DEPTH: /;"
2050  OUTPUT @Sa;"IF F_IRSTPOS,LT,20;"
2060  OUTPUT @Sa;"   IF F_IRSTPOS,EQ,0;"
2070  OUTPUT @Sa;"     THEN;TEXT / NOISE/;"
2080  OUTPUT @Sa;"     ELSE;TEXT / *****/;"
2090  OUTPUT @Sa;"ENDIF;ENDIF;"
2100  OUTPUT @Sa;"IF F_IRSTPOS,GT,F_UPPER;THEN;"
2110  OUTPUT @Sa;"   TEXT /APPROX  /;"
2120  OUTPUT @Sa;"   DSPLY P_ERCENT,5.2;TEXT /  %AM/;"
2130  OUTPUT @Sa;"ENDIF;"
2140  OUTPUT @Sa;"IF F_IRSTPOS,GE,20;THEN;"
2150  OUTPUT @Sa;"   IF F_IRSTPOS,LE,F_UPPER;THEN;"
2160  OUTPUT @Sa;"     IF T_EST,GT,D_B;;"
2170  OUTPUT @Sa;"       THEN DSPLY P_ERCENT,5.2;TEXT /  %AM/;"
2180  OUTPUT @Sa;"       ELSE TEXT /APPROX  /;DSPLY P_ERCENT,5.2;TEXT /  %AM/;"
2190  OUTPUT @Sa;"ENDIF;ENDIF;ENDIF;"
2200  OUTPUT @Sa;"PU;PA 760,752;"
2210  OUTPUT @Sa;"IF F_IRSTPOS,GT,F_UPPER,THEN;"
2220  OUTPUT @Sa;"   TEXT /APPROX  /;"
2230  OUTPUT @Sa;"   DSPLY F_IRST,4.1;TEXT /  dBc/;"
2240  OUTPUT @Sa;"ENDIF;"
2250  OUTPUT @Sa;"IF F_IRSTPOS,GE,20;"
2260  OUTPUT @Sa;"   IF F_IRSTPOS,LE,F_UPPER;"
2270  OUTPUT @Sa;"      IF T_EST,GT,D_B;"
2280  OUTPUT @Sa;"      THEN DSPLY F_IRST,4.1;TEXT /  dBc/;"
2290  OUTPUT @Sa;"      ELSE;TEXT /APPROX  /;DSPLY F_IRST,4.1;TEXT /  dBc/;"
2300  OUTPUT @Sa;"ENDIF;ENDIF;ENDIF;"
2310  OUTPUT @Sa;"PU;PA 600,720;"
2320  OUTPUT @Sa;"TEXT / AM RATE: /;"
2330  OUTPUT @Sa;"IF F_IRSTPOS,LT,20;THEN;"
2340  OUTPUT @Sa;"   MOV I_NDEX,0;"
2350  OUTPUT @Sa;"   TEXT /< /;"
2360  OUTPUT @Sa;"   MPY R_ATE,F_STOP,.02;"
2370  OUTPUT @Sa;"   DSPLY R_ATE,3.0;"
2380  OUTPUT @Sa;"   IF F_IRSTPOS,EQ,0;"
```

```
2390  OUTPUT @Sa;"      THEN;TEXT /  Hz?/;"
2400  OUTPUT @Sa;"      ELSE;TEXT /  Hz/;"
2410  OUTPUT @Sa;"ENDIF;ENDIF;"
2420  OUTPUT @Sa;"IF F_IRSTPOS,GT,F_UPPER;THEN;"
2430  OUTPUT @Sa;"   TEXT / > /;"
2440  OUTPUT @Sa;"   MPY R_ATE,F_STOP,.33004;"
2450  OUTPUT @Sa;"   DSPLY R_ATE,4.0;"
2460  OUTPUT @Sa;"   TEXT /  Hz/;"
2470  OUTPUT @Sa;"   IF S_T,GT,.05;"
2480  OUTPUT @Sa;"      THEN;MOV I_NDEX,0;"
2490  OUTPUT @Sa;"      ELSE;PU;PA 600,592;"
2500  OUTPUT @Sa;"      TEXT /BEYOND MEASUREMENT RANGE !!/;"
2510  OUTPUT @Sa;"ENDIF;ENDIF;"
2520  OUTPUT @Sa;"IF F_IRSTPOS,GE,20;"
2530  OUTPUT @Sa;"   IF F_IRSTPOS,LE,F_UPPER;"
2540  OUTPUT @Sa;"      IF T_EST,GT,D_B;"
2550  OUTPUT @Sa;"        THEN DSPLY R_ATE,5.0;TEXT /  Hz/;"
2560  OUTPUT @Sa;"        ELSE TEXT/> /;"
2570  OUTPUT @Sa;"        MPY R_ATE,F_STOP,.33004;"
2580  OUTPUT @Sa;"        DSPLY R_ATE,4.0;TEXT /  Hz/;"
2590  OUTPUT @Sa;"        IF S_T,LT,.05;THEN;"
2600  OUTPUT @Sa;"           PU,PA 600,592;"
2610  OUTPUT @Sa;"           TEXT /BEYOND MEASUREMENT RANGE/;"
2620  OUTPUT @Sa;"           ELSE;MOV I_NDEX,0;"
2630  OUTPUT @Sa;"ENDIF;ENDIF;ENDIF;ENDIF;@"
2640  !
2650  ! DISP_TWO
2660  OUTPUT @Sa;"FUNCDEF DISP_TWO,@;"
2670  OUTPUT @Sa;"IF I_NDEX,EQ,0;THEN;"
2680  OUTPUT @Sa;"   PU;PA 760,656;"
2690  OUTPUT @Sa;"   TEXT /OUT OF RANGE !!/;"
2700  OUTPUT @Sa;"   BLANK TRA;"
2710  OUTPUT @Sa;"   PU;PA 504,560;"
2720  OUTPUT @Sa;"   TEXT /TO CONTINUE THE MEASUREMENT:/;"
2730  OUTPUT @Sa;"   PU;PA 504,496;"
2740  OUTPUT @Sa;"   TEXT /1) ADJUST SWEEPTIME ACCORDINGLY:/"
2750  OUTPUT @Sa;"   PU;PA 504,432;"
2760  OUTPUT @Sa;"   TEXT /SWEEPTIME      Fmin      Fmax/;"
2770  OUTPUT @Sa;"   PU;PA 504,400;"
2780  OUTPUT @Sa;"   TEXT / 20 mSEC      500 Hz   8.25 KHz/;"
2790  OUTPUT @Sa;"   PU;PA 504,368;"
2800  OUTPUT @Sa;"   TEXT /200 mSEC       50 Hz    825  Hz/;"
2810  OUTPUT @Sa;"   PU;PA 504,336;"
2820  OUTPUT @Sa;"   TEXT /  2  SEC        5 Hz   82.5  Hz/;"
2830  OUTPUT @Sa;"   PU;PA 504,304;"
2840  OUTPUT @Sa;"   TEXT / 20  SEC      0.5 Hz   8.25  Hz/;"
2850  OUTPUT @Sa;"   PU;PA 504,240;"
2860  OUTPUT @Sa;"   TEXT /2) SHIFT 1 Hz./;"
2870  OUTPUT @Sa;"ENDIF;@"
2880  !
2890  ! DISP_THREE
2900 !GOTO 2620
2910  !
2920  OUTPUT @Sa;"FUNCDEF DISP_THREE,@;"
2930  OUTPUT @Sa;"IF F_IRSTPOS,GE,20;THEN;"
2940  OUTPUT @Sa;"  IF F_IRSTPOS,LE,F_UPPER;THEN;"
2950  OUTPUT @Sa;"     IF T_EST,GE,D_B;THEN;"
2960  OUTPUT @Sa;"       PU;PA 632,656;"
2970  OUTPUT @Sa;"       TEXT /AM DISTORTION/;"
2980  OUTPUT @Sa;"       PU;PA 600,624;"
```

```
2990  OUTPUT @Sa;"      TEXT /2nd HARM: /;"
3000  OUTPUT @Sa;"        IF S_ECONDPOS,EQ,0;"
3010  OUTPUT @Sa;"          THEN TEXT / NOISE/;"
3020  OUTPUT @Sa;"          ELSE DSPLY S_ECOND,4.1;TEXT /   dBc/;"
3030  OUTPUT @Sa;"        ENDIF;"
3040  OUTPUT @Sa;"      PU;PA 600,592;"
3050  OUTPUT @Sa;"      TEXT /3rd HARM: /;"
3060  OUTPUT @Sa;"      IF T_HIRDPOS,EQ,0;"
3070  OUTPUT @Sa;"        THEN TEXT / NOISE/;"
3080  OUTPUT @Sa;"        ELSE DSPLY T_HIRD,4.1;TEXT /   dBc/;"
3090  OUTPUT @Sa;"      ENDIF;"
3100  OUTPUT @Sa;"      PU;PA 600,560;"
3110  OUTPUT @Sa;"      TEXT /      THD: /;"
3120  OUTPUT @Sa;"      DSPLY T_HD,4.1;TEXT / % /;"
3130  OUTPUT @Sa;"ENDIF;ENDIF;ENDIF;"
3140  OUTPUT @Sa;"PU;PA 304,784;"
3150  OUTPUT @Sa;"IF T_EST,LT,D_B;"
3160  OUTPUT @Sa;"   THEN;D3;PU;PA 176,512;"
3170  OUTPUT @Sa;"   TEXT /FAILS/;"
3180  OUTPUT @Sa;"   D2;PU;PA 400,784;"
3190  OUTPUT @Sa;"   TEXT /ALIAS TEST!/;"
3200  OUTPUT @Sa;"ENDIF;"
3210  OUTPUT @Sa;"IF T_EST,GT,D_B;"
3220  OUTPUT @Sa;"   IF T_EST,NE,0;THEN;TEXT /PASSES ALIAS TEST/;"
3230  OUTPUT @Sa;"ENDIF;ENDIF;"
3240  OUTPUT @Sa;"DW1044;HD;@"
3250  !
3260  ! MAIN PROGRAM
3270  !
3280  OUTPUT @Sa;"FUNCDEF FFT_ONE,@"
3290  OUTPUT @Sa;"S_ETUP;"
3300  OUTPUT @Sa;"A_UTORANGE;"
3310  OUTPUT @Sa;"A_LIAS;"
3320  OUTPUT @Sa;"A_VERAGE;"
3330  OUTPUT @Sa;"M_EASURE;"
3340  OUTPUT @Sa;"C_OMPUTE;"
3350  OUTPUT @Sa;"DISP_ONE;"
3360  OUTPUT @Sa;"DISP_TWO;"
3370  OUTPUT @Sa;"DISP_THREE;"
3380  OUTPUT @Sa;"@"
3390  OUTPUT @Sa;"KEYDEF 1, FFT_ONE;"
3400  !
3410  !
3420  OUTPUT @Sa;"MEM?"
3430  ENTER @Sa;Mem
3440  DISP M-Mem
3450  END
```

APPENDIX B

AM Depth Measurement in the FFT Frequency Domain

PROGRAM DESCRIPTION

The program description and flow chart are identical to the program in Appendix A except that

1) The usable frequency range has been extended to 15 kHz,
2) Harmonic distortion is not measured, and
3) Averaging is performed only on AM depths <1%.

ANNOTATED PROGRAM LISTING

This program is derived from the program in Appendix A by making the following deletions, additions, and changes.

Deletions

Delete lines 70, 250-320, 370-390, 1460-1880, and 2930-3130.

Additions

Add these lines:

```
10    ! File name: "FFT_TWO"        Date:  2/85
20    !                             DLP BYTES: 5422
60    !                             AM RATE.
100   !                                                AM rate 0.5 Hz to 15 kHz.
430   OUTPUT @Sa;"VARDEF F_UPPER,601;" ! Upper limit to measurement range, cells
2440  OUTPUT @Sa;"    MPY R_ATE,F_STOP,.6;"
2450  OUTPUT @Sa;"    DSPLY R_ATE,5.0;"
2570  OUTPUT @Sa;"          MPY R_ATE,F_STOP,.6;"
2580  OUTPUT @Sa;"          DSPLY R_ATE,5.0;TEXT /   Hz/;"
2780  OUTPUT @Sa;"    TEXT / 20 mSEC        500 Hz      15 kHz/;"
2800  OUTPUT @Sa;"    TEXT /200 mSEC         50 Hz    1500  Hz/;"
2820  OUTPUT @Sa;"    TEXT /  2  SEC          5 Hz     150  Hz/;"
2840  OUTPUT @Sa;"    TEXT / 20  SEC        0.5 Hz      15  Hz/;"
2860  OUTPUT @Sa;"    TEXT /2) SHIFT 2 Hz./;"
3280  OUTPUT @Sa;"FUNCDEF FFT_TWO,@"
3390  OUTPUT @Sa;"KEYDEF 2, FFT_TWO;"
```

Changes

Change the existing lines as follows:

```
1070  OUTPUT @Sa;"       IF TRA[F_IRSTPOS],LT,530;"
1071  OUTPUT @Sa;"          THEN MOV I_NDEX,1;"
1072  OUTPUT @Sa;"          ELSE MOV I_NDEX,16;"
1073  OUTPUT @Sa;"       ENDIF;"
```

APPENDIX C

Core Program

Program Listing

```
10    OUTPUT 718;"FUNCDEF FFT_THREE,@"
20    OUTPUT 718;"TRDEF WINDOW,1001;"
30    OUTPUT 718;"LN;KSe;MKOFF ALL;"
40    OUTPUT 718;"VIEW TRA;CLRW TRB;SNGLS;TS;"
50    OUTPUT 718;"TWNDOW WINDOW,FLATTOP;"
60    OUTPUT 718;"FFT TRA,TRB,WINDOW;"
70    OUTPUT 718;"LG 10DB;MKREAD FFT;"
80    OUTPUT 718;"VIEW TRB;MKPK HI;M3;MKPK NH;@"
90    OUTPUT 718;"KEYDEF 3, FFT_THREE;"
100   END
```

APPENDIX D

Bibliography

"Spectrum Analysis. . .Spectrum Analyzer Basics," Hewlett-Packard Application Note 150, 1974.

"Spectrum Analysis. . .Amplitude and Frequency Modulation," Hewlett-Packard Application Note 150-1, 1971.

"The Fundamentals of Signal Analysis," Hewlett-Packard Application Note 243, 1982.

"Teaming Up a 5180A Waveform Recorder and a Spectrum Analyzer for New Time-Domain Measurement Capabilities," Hewlett-Packard Application Note 313-2.

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