KEY FREQUENCY
PARAMETER MEASUREMENTS AND INSTRUMENTS

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Measuring CATV system performance has been spotlighted by new FCC rules requiring periodic system performance tests. But, then, system performance measurements have always been important, and in recent years have been receiving increasing attention. Also receiving increasing attention are spectrum analyzers to meet measurement needs.

Figure 1 shows a synopsis of the FCC's specifications as well as a list of specifications that might be used as engineering standards in a high quality system. Of course, the engineering standards are considerably tighter since the aim of establishing these standards is to achieve nearly flawless performance. All of the standards relating to signal amplitude, spurious signals, cross modulation, signal-to-noise ratio, hum and radiation can be measured easily with a spectrum analyzer. However, some of these standards such as carrier frequency and system flatness cannot be measured by spectrum analyzers alone. In the past few years, great strides have been made in spectrum analyzer performance. Spectrum analyzers such as the TEKTRONIX 7L12 are available with absolute calibration that reads the input level directly without external calibration. They also have accurate logarithmic displays that read directly in dB, as well as highly linear, calibrated frequency sweeps for making frequency difference measurements, plus many more features that make RF measurements easy.

Other, more economical, spectrum analyzers such as the TEKTRONIX 1401A-1 with fewer features are also available. This analyzer also has a logarithmic display, linear in dB, but it cannot make level measurements without first referring to its internal calibrator. This is a slight inconvenience when compared to the 7L12, but it is a relatively easy instrument to use. The striking advantage of the 1401A-1 is that it is a small, light, highly portable battery-operated instrument suitable for field work. But it is restricted somewhat in performance and cannot make some of the more difficult measurements. However, it can make all of the amplitude measurements with ease.

All Standards Relate to Values at Subscribers' Terminals

	FCC	DESIRED ENGINEERING STANDARDS
AMPLITUDE STANDARDS		
a) Minimum visual sync-tip level	0dBmV	+3dBmV
b) Maximum visual sync-tip level	Below overload	+10dBmV
c) Maximum amplitude difference between visual carriers 6MHz apart	3dB	1dB
d) Maximum amplitude difference between any visual carriers	12dB	7dB
e) Minimum visual/aural ratio	13dB	13dB
f) Maximum visual/aural ratio	17dB	17dB
g) Maximum FM station amplitude		-7dBmV
h) Minimum FM station amplitude		-20dBmV
i) Maximum variation between FM stations on adjacent channels		3dB
j) Long-term variations in amplitude	12dB	
FREQUENCY STANDARDS		
a) Visual frequency accuracy	±25kHz	±25kHz of standard channel frequency
b) Intercarrier frequency	4.5MHz ± 1kHz	4.5MHz ± 1kHz
c) FM frequency accuracy		±2kHz of standard channel frequency
CATV SYSTEM FLATNESS SPECIFICATIONS		
a) Amplitude response within any TV channel	±2dB	±.5dB (-.75MHz + 3.6MHz from visual carrier)
b) Amplitude response for entire spectrum		±2dB
SYSTEM FAULT STANDARDS		
a) Hum or low frequency variations	5% peak to peak	1%
b) Visual carrier to noise ratio (4MHz BW)	36dB min.	40dB
c) Visual carrier to coherent spurious signal ratio (i.e., intermodulation)	46dB min.	-45 to -60dB (depending on position with respect to visual carrier)
d) Cross modulation ratio		-51dB (-57dB trunk)
e) Reflections within system (shadows)		-40dB
ISOLATION		
a) Subscriber to subscriber isolation	18dB	30dB
RADIATION		
a) Up to 54MHz	15μV/M @ 100'	
b) 54 to 216MHz	20μV/M @ 10'	
c) Above 216MHz	15μV/M @ 100'	
VIDEO CHARACTERISTICS (BASE BAND SYSTEMS)		
a) Differential gain		.5dB
b) Differential phase		±1 degree
c) Envelope delay variations		Per FCC Standards

Fig. 1. CATV system specifications.

AMPLITUDE MEASUREMENTS

Figure 2 shows a spectrum analyzer display of a typical TV signal. The visual carrier is the large signal to the left, and the aural carrier is the large signal to the right. The smaller signal between the visual and aural carrier is the chroma subcarrier, carrying the color information in the picture. Measurement of the visual carrier frequency is made with a TEKTRONIX Type 7D14 Digital Counter. The character readout of this frequency is at the top left on the CRT. The rest of the readout presents most of the pertinent scale factor information needed to interpret the photo. The upper center format indicates the vertical scale factor of the display as 10 dB per division in this case. The upper right indicates the input signal level to produce full scale deflection, or -10 dBm. The 6 dB minimum-loss pad is used to convert the input impedance to 75 Ω. To convert the reading to dBmV, add 55 dB to the reading in dBm. In this case, the output level is +45 dBmV. The format at the lower left indicates the bandwidth that the analyzer IF uses to separate the various components (resolution bandwidth) is 30 kHz. At the lower right, the readout indicates the horizontal scale is 1 MHz per division.

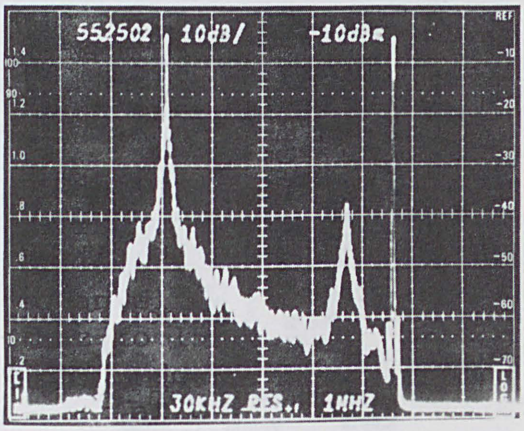

Fig. 2. Typical TV signal. A 7D14 was used to measure the visual carrier frequency.

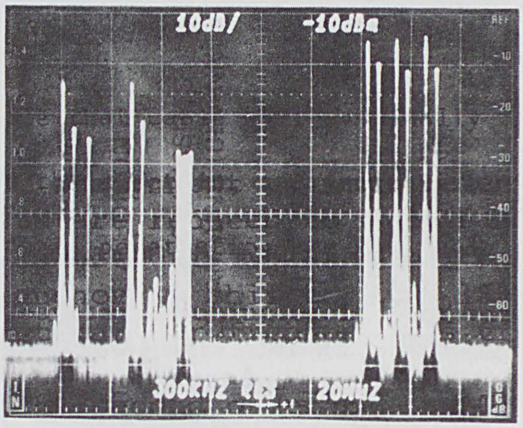

Fig. 3. CATV head end output.

Figure 3 shows the head end output of a CATV system. The system is located in Portland, Oregon, where, before the new FCC rules, it could not import any foreign signals. Therefore, the system is lightly loaded, carrying only the six local TV signals (2, 3, 6, 8, 10, 12), as well as nine FM stations. At the time this photo was taken, Channel 3 was not on the air.

The photo shows the general condition of the head end: the readout shows that the vertical scale factor is 10 dB per division and the reference level is -10 dBm (+45 dBmV). Channel 2 is the first signal on the left, with the visual and aural carriers in the same relative positions as in Figure 2. The visual level of Channel 2 is +31 dBmV and the aural level is +22 dBmV for a visual/aural ratio of 9 dB.

The large carrier just to the right of Channel 2 is the aural output of the Channel 3 strip amplifier when Channel 3 is off the air. The Channel 3 visual output under these conditions is just to the right of the Channel 2 aural carrier at a level of -70 dBm (-15 dBmV). Channel 6, the next TV station, is correctly operating at the same output level as Channel 2, but with a 3 dB less visual/aural ratio. The low-level signals above Channel 6 are the unprocessed FM carriers as broadcast, leaking through onto the cable. The block of carriers just above the FM carriers are the processed FM signals at an amplitude of -38 dBm (+17 dBmV). The high-band signals (Channel 8, 10, 12) are all within 2 dB of each other, and 9 dB greater in amplitude than the low-band signals; this system employs block tilt. After the various low-level signals between the carriers are identified, a photo such as this can serve as a system record that even includes a tabulation of some of the spurious signals.

Moving the frequency span to 10 MHz per division and slightly retuning the center frequency, we arrive at Figure 4. Here a more detailed view of the low band and the FM band is obtained. Note the two spurious signals below Channel 2. The close-in one, being 46 dB down from the Channel 2 carrier, will cause no problem. A detailed look at the high band is presented in Figure 5.

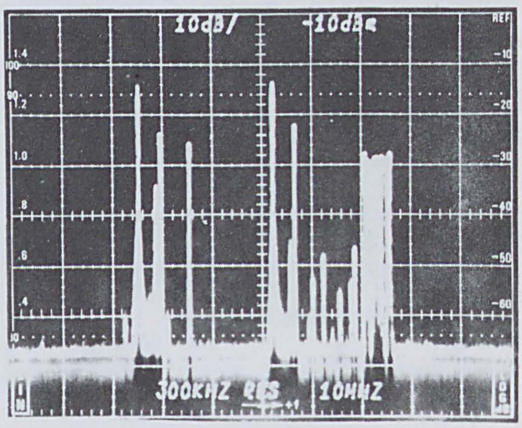

Fig. 4. Low band and FM band output. Channel 2's level is +31 dBmV.

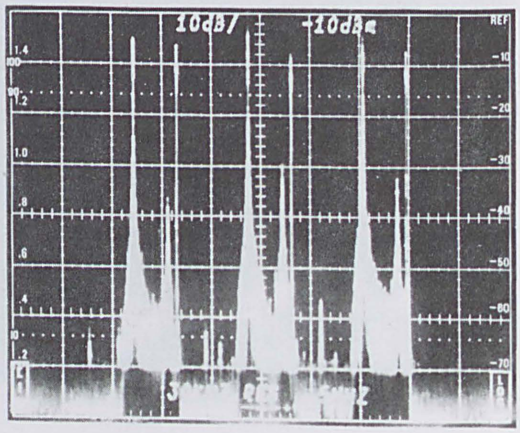

Fig. 5. High band output. Channel 2's output level is +40 dBmV.

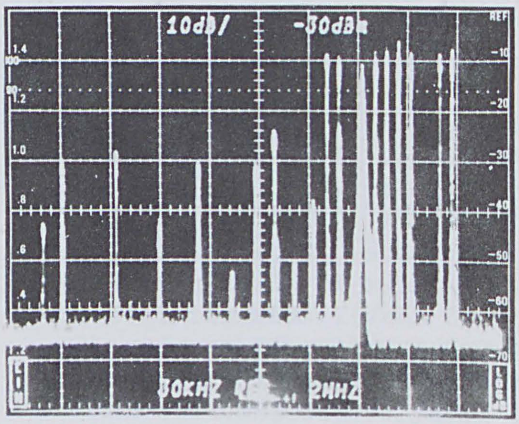

Fig. 6. FM band output. The processed FM output level is about +16 dBmV.

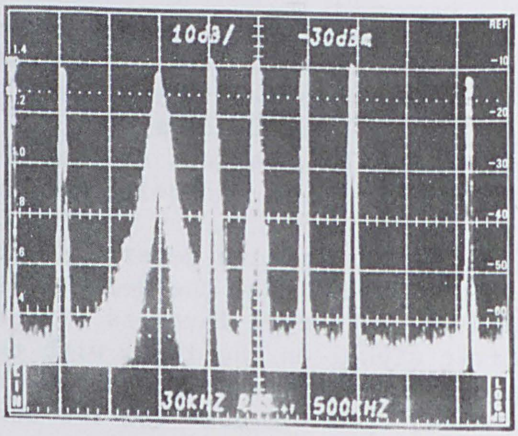

Fig. 7. Output of FM processors. One unit is misadjusted.

Figure 6 shows the FM band. The processed signals are at the high end of the band and are about 20 dB higher than the unprocessed signals at the low end. As shown in Figure 7, the processed signals are at 0.5 MHz spacing with the exception of two gaps left open since these are unassigned FM broadcast allocation frequencies. Note the signal that is much wider than the rest. An oscillator was misadjusted and the converter was nonoperational. This was found as these pictures were being taken, and a quick adjustment by the technician put the converter back in business.

To make highly accurate amplitude measurements, the 7L12 has been provided with a 2 dB per division mode. Figure 8 is a picture of the high-band carriers' amplitudes. With this 2 dB per division vertical scale factor, we can observe that Channel 8 is operating at -13.4 dBm (+41.6 dBmV) and Channels 10 and 12 are within 1 dB of the same level. The more sensitive 2 dB per division scale factor affords easy and accurate power measurements. Periodic checks of the spectrum analyzer's accuracy are easily done with an internal calibrator.

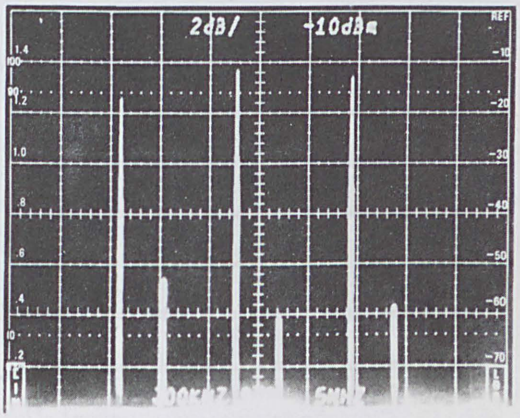

Fig. 8. High band output at 2 dB per division. Channel 8's level is +41.6 dBmV.

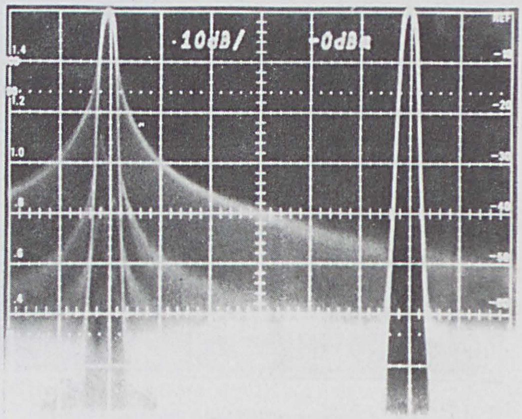

Fig. 9. Cross modulation measurement. Lower frequency carrier modulated with a 15.75 kHz squarewave. Higher frequency carrier is CW.

SYSTEM FAULT MEASUREMENTS

Cross modulation. As in most things, the economy models of spectrum analyzers cannot do some of the things that more elaborate ones can do. This is the case in cross-modulation measurements. The 7L12 can make this measurement with ease, but the 1401A-1 lacks high resolution circuitry.

Cross modulation is generally measured[1] by applying thirteen visual carriers of the VHF spectrum at the correct operating level to the input of the amplifier to be tested. Twelve of the thirteen carriers are simultaneously modulated with a 15.75 kHz squarewave, while the thirteenth carrier is left unmodulated.

[1]NCTA Spec 002-0267, *CATV Amplifier distortion characteristics*.

This thirteenth carrier is then carefully tested at the amplifier's output to see if it has become modulated by passing through the amplifier simultaneously with the twelve modulated carriers.

Figure 9 shows one of the modulated carriers next to the unmodulated carrier. The analyzer is set for a 300-kHz resolution bandwidth, which gives a full peak reading of the carrier amplitude. From the photo, we ascertain that the two carriers are of equal amplitude. The second step is tune to the modulated carrier and measure the amplitude of the 15.75-kHz sideband. This amplitude is the calibration level for the actual measurement. Figure 10 shows this measurement. The carrier has fallen 6 dB in amplitude because we are now measuring the average amplitude of the carrier instead of seeing its peak amplitude. The first sideband is down 12 dB. The third step is to tune to the unmodulated carrier and again measure the amplitude of the first sideband. Figure 11 shows this measurement. The 15.75-kHz sideband is down 65 dB. The cross-modulation ratio is -65 dB + 12 dB = -53 dB.

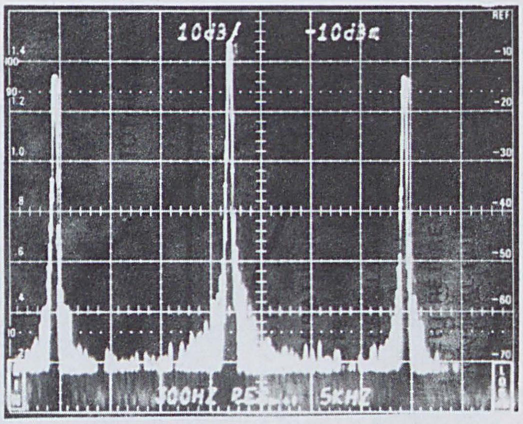

Fig. 10. Cross modulation measurement. This is the modulated carrier with its first 15.75 kHz sidebands.

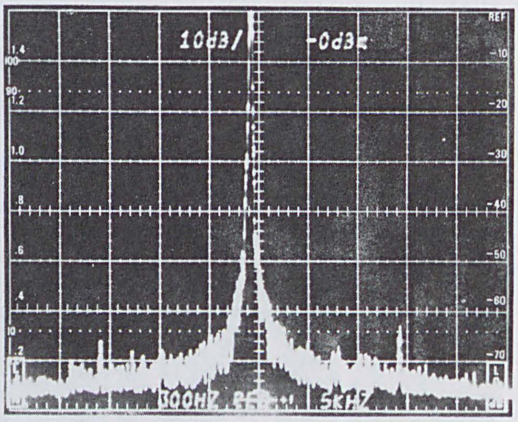

Fig. 11. Cross modulation measurement. This is the CW carrier with its low level 15.75 kHz sidebands. The cross modulation level is -53 dB. (Sideband level Fig. 10 - Sideband level Fig. 11)

Note that with a 15.75 kHz squarewave of reasonable symmetry, the calibration of step two will be within a dB or so of 12 dB. In Figure 11, the first sideband is about 5 dB above the noise floor of the spectrum analyzer. Therefore, the 7L12 is capable of measuring cross modulation down to about -58 dB.

Intermodulation. Intermodulation occurs when two signals applied to an amplifier produce more than two signals at the amplifier output because of nonlinearity. The 1401A-1 can measure intermodulation 60 dB down. The 7L12 can measure intermodulation to a level of 70 dB down. Figure 12 shows a typical measurement. Channel 8 is on the right and Channel 10 on the left. Between them are two low level signals that are the result of the third order curvature of the amplifier. The visual and aural carriers of Channel 8, which are 4.5 MHz apart, combine to form an intermodulation spurious·product 4.5 MHz above and below aural and visual carriers, respectively[2]. The small signal just below Channel 10's visual carrier is one of the intermodulation products produced by Channel 8. Similarly, the small signal just above Channel 8's aural carrier is one of the intermodulation products produced by Channel 10. In this case they are about 57 dB below the visual carriers.

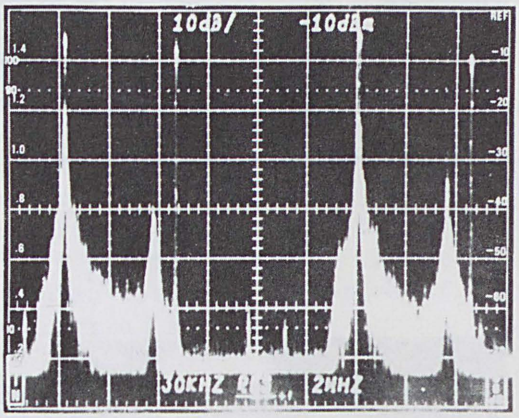

Fig. 12. Intermodulation measurement. Intermodulation is 57 dB down.

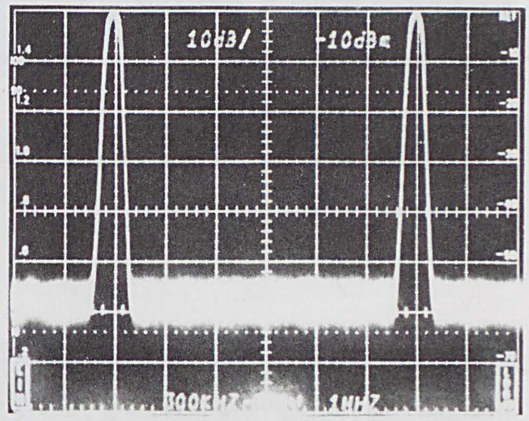

Fig. 13. Noise measurement. The signal-to-noise ratio is 45 dB.

Noise. A spectrum analyzer can easily measure a signal-to-noise ratio. In the case of a CATV system, the measurement can be made directly without any special techniques if the S/N ratio is 50 dB or less. Figure 13 shows this measurement. The system is operating in its normal mode, except substitution carriers have replaced all of the signals. The noise is at a uniform level between the two carriers at -53 dB down from full screen. The 7L12 spectrum analyzer's bandwidth is 300 kHz so this number must be modified to allow at the 4 MHz S/N ratio used in CATV measurements. The amplitude difference between 4 MHz and 300 kHz noise bandwidths is 11 dB[3]. However, logarithmetic displays read about 2 dB low in noise measurements. Therefore, the 4 MHz S/N measurement of this system is 58 - 11 - 2 = 45 dB.

Co-Channel Interference. Only the more elaborate analyzers such as the 7L12 can make this measurement. Figure 14 shows the carrier and the first two 15.75-kHz sidebands of a TV signal. 10 kHz above the carrier is another signal that is another TV carrier assigned to the same channel but offset by 10 kHz in frequency. Note that the 7L12 is capable of making this measurement down to about the -60 dB level.

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[2]Kenneth L. Simons. "The Decibel Relationships Between Amplifier Distortion Products," *Proc IEEE*, Vol 58 #7 July 1970.

[3]NCTA Spec 002-0267, *CATV Amplifier distortion characteristics*.

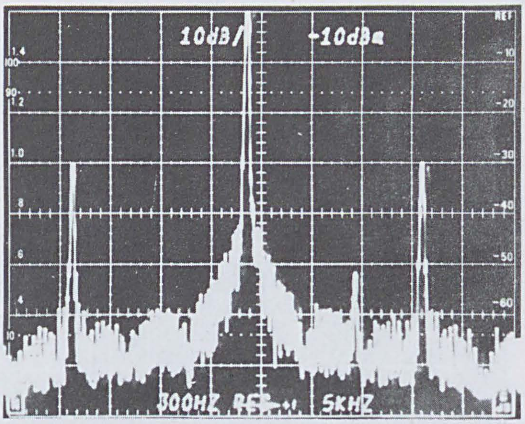

Fig. 14. Co-channel interference. The co-channel signal is 51 dB down.

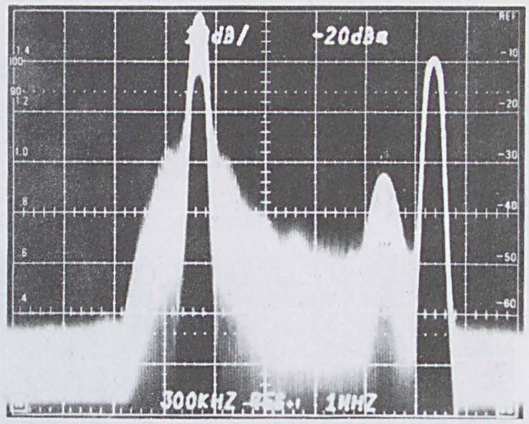

Fig. 15. Typical TV signal.

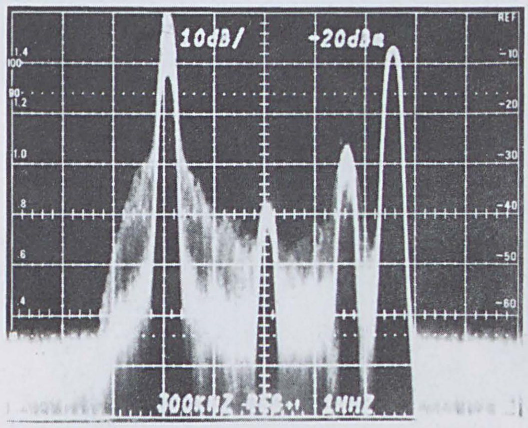

Fig. 16. TV signal with 40 dB down interfering signal.

Fig. 17. TV picture with 40 dB down interfering signal.

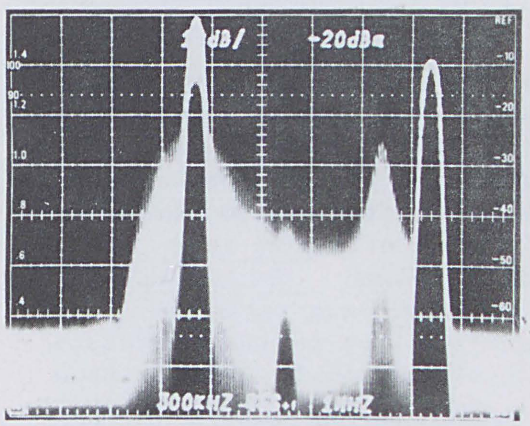

Fig. 18. TV signal with 50 dB down interfering signal.

Fig. 19. TV picture with 50 dB down interfering signal.

Interfering Signals. We've already discussed stray and interfering signals away from the TV signals. But what about interfering signals within a TV channel? To explore this point, some tests were run in the lab deliberately adding a CW signal to a TV signal and observing the result. Figure 15 is a normal TV signal. Figure 16 shows the same signal with a 40 dB down interfering signal 2 MHz above the visual carrier. Figure 17 shows the resultant herringbone on the TV picture. Figure 18 shows the same interfering signal, but it is now 50 dB down. The resulting herringbone shown in Figure 19 is just perceptible, lowering the interfering signal's amplitude by another 10 dB to -60 dB below sync tip results in a still visible signal in the spectrum analyzer display in Figure 20, but results in no visible picture degradation. When there is doubt about whether or not some feature within the spectrum analyzer display at a TV signal is an interfering signal, the problem can be resolved by looking at the display over a period of time as the picture content changes. Any fixed low-level feature, with the exception of the chroma signal, is probably an interfering signal.

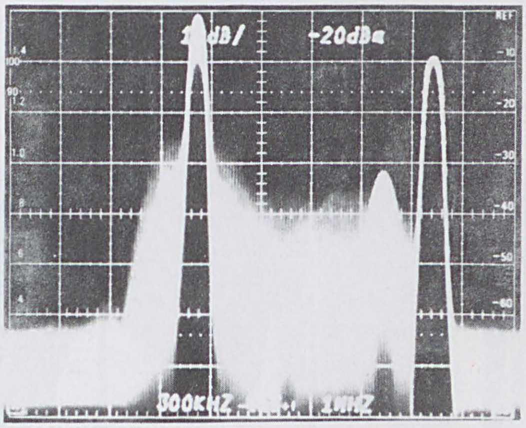

Fig. 20. TV signal with 60 dB down interfering signal.

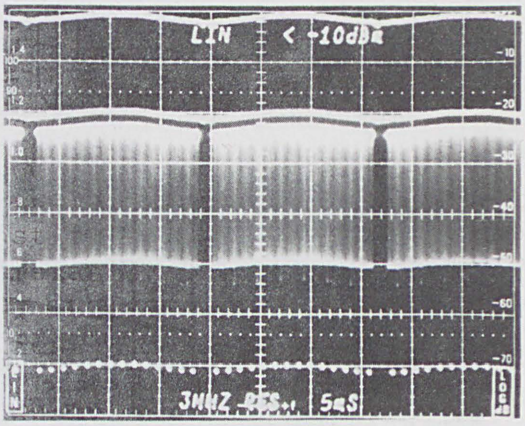

Fig. 21. Hum measurement. Hum is 2.5% P-P of sync tip amplitude.

Hum. Hum can be measured by using the spectrum analyzer as a wideband receiver and viewing the resulting video with respect to time. Figure 21 shows the 7L12 being used as a 3-MHz bandwidth receiver to look at a TV transmitter. When the frequency span control of the 7L12 is set to zero, the CRT readout display reads the time per division of the sweep instead of frequency per division. The linear scale is used for maximum sensitivity. The line across the top of the screen is the sync tip level. The sync tip level is varying .2 divisions with a full scale deflection. Therefore, the hum is $.2 \div 8 = 2.5\%$.

Radiation. Radiation is measured by using a calibrated antenna and measuring the amplitude of the signals by it. Reference must be made to a correction chart provided by the antenna manufacturer before the actual field strength may be determined.

Testing for signals leaking from CATV systems may be a frustrating experience. It will be difficult to separate the signal picked up directly from the signal that is leaking from the cable. Only when signals on the cable are at a different frequency will it be possible to get an unambiguous reading. Adding CW signals at some unused frequencies to the CATV system's normal load and at the same level as the visual signals may aid in measuring radiation levels with less confusion.

Conclusion. The author has attempted to show how, with the aid of a spectrum analyzer, a great many of the difficult, time consuming CATV measurements can be made conveniently. A spectrum analyzer is not the only measuring instrument a CATV operator needs. But, it is a basic instrument that makes many measurements by itself, and enhances the measurement capability of many other pieces of test equipment.

SUMMARY OF

FCC TECHNICAL STANDARDS FOR CATV*

Following is an illustrated summary of the principal technical standards established by the FCC. All verification measurements shown in the illustrations were taken *in the field* with a TEKTRONIX 1401A-1 Spectrum Analyzer.

1. Frequency of the visual carrier: 1.25 MHz ± 25 kHz above channel boundary.

   a. At output of converter: 1.25 MHz ± 250 kHz

2. Frequency of aural subcarrier: 4.5 MHz ± 1 kHz above visual carrier.

   Verification of these standards involves high accuracy frequency measurements. These can be made with a TEKTRONIX 7D14 Counter in any TEKTRONIX 7000 Series oscilloscope mainframe with readout.

3. Minimum visual signal level: 1 mV across 75 Ω (see Figure 1).

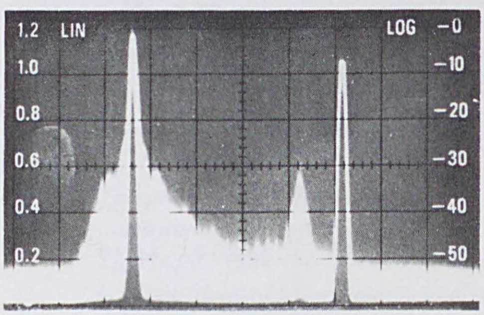

Fig. 1. Visual signal level shown is +10dBmV across 75 Ω; 1401A-1 Spectrum Analyzer has absolute amplitude calibration and 10 dB/div log display.

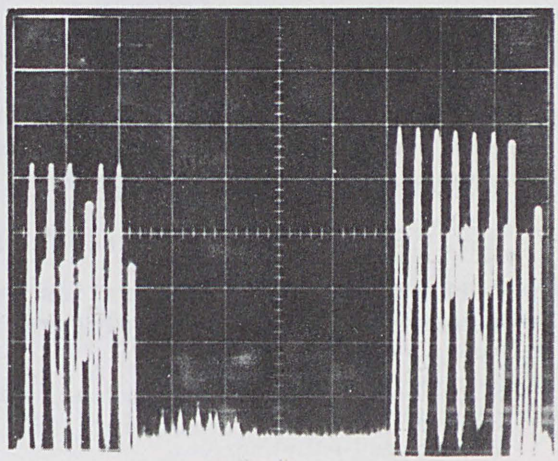

Fig. 2. Photo shows a fully loaded CATV system with high and low band pilot carriers. Vertical log mode is 10 dB/div. (2 dB/div is available in the 7L12 and 2.5 dB/div in the 1401A-1.) The frequency span per division is in an uncalibrated position in this photo to allow closer signal spacing for ease in viewing channel-to-channel variations.

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*Extracted from *THAW, New Rules to End the Cable TV Freeze*; National Cable Television Association, Inc.; Washington, D.C.

4. Permissible signal level variation: 12 dB total (see Figure 2).

   a. Maximum adjacent channel variation: 3 dB

   b. Maximum of all channels: 12 dB

5. Maximum signal level: Below threshold of degradation.

   Maximum signal levels are required to be held to values which will not overload a subscriber's receiver.

6. Maximum hum and low-frequency disturbance levels: 5%.

   The peak-to-peak variation in visual signal level, caused by hum, can be measured with a spectrum analyzer in the non-sweeping (zero frequency span) mode. In this mode the analyzer functions as a superheterodyne receiver, followed by a demodulator. Hum modulation can be seen in Figure 21 of previous article.

7. Within channel frequency response: ±2 dB.

   Channel frequency response can be measured with a signal generator, covering the desired range, and the spectrum analyzer. A plot of the signal generator amplitude versus frequency is first made with the spectrum analyzer; then the system response is plotted and the appropriate correction added to the spectrum analyzer displayed amplitude. A sweep generator may be used in lieu of a manually tuned generator.

8. Aural signal level: 13 to 17 dB below visual signal level.

   Aural to visual signal ratios for all channels can be measured easily in one picture (see Figure 2).

9. Signal-to-noise level for all signals picked up or delivered within its Grade B contour: 36 dB (see Figure 3).

10. Signal-to-intermodulation and non-offset carrier interference: 46 dB (see Figure 4).

11. Subscriber terminal isolation: This measurement can be made with a calibrated spectrum analyzer such as the 7L12 or 1401A-1 and a signal generator covering the frequency range of interest. The signal generator output is first measured at the desired reference level (example: 0 dBmV) with the spectrum analyzer. The signal generator is then fed into the line at subscriber (A) and monitored with the spectrum analyzer at subscriber (B). The dB difference between the reference signal and the observed signal can be measured directly. Furthermore, interference to any channel can be observed at a glance.

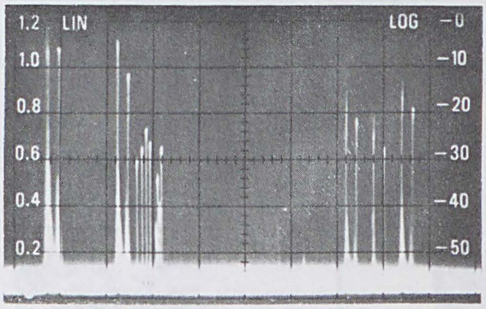


Fig. 3. The photo shows signal-to-noise measurement of low band, FM and high band. Here the vertical log mode is 10 dB/div and the spectrum analyzer resolution bandwidth has been chosen to give a 55 dB dynamic display range. The spectrum analyzer noise floor is measured with the input terminated in 75 Ω. System noise is referred to this level. The 60 dB and 70 dB dynamic ranges are featured on the 1401A-1 and 7L12, respectively.

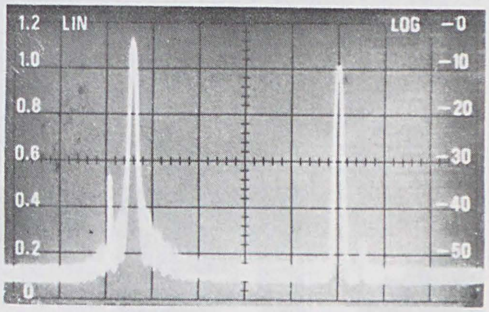


Fig. 4. Photo of 1401A-1 CRT shows spurious response on low side of visual carrier 30 dB below visual carrier amplitude. Spurious response on the high side of the aural carrier is down 46 dB below the visual carrier amplitude. Intermodulation measurements to 60 dB can be made with the 1401A-1 and to 70 dB with the 7L12.

The FCC has not imposed any restriction on frequency usage. Unauthorized radiation at any frequency from a cable system is, however, the responsibility of the cable operator. The new radiation limits are:

Frequencies (MHz)	Radiation Limit Microvolts/meter	Distance from Cable (feet)
Up to 54	15	100
54 to 216	20	10
Over 216	15	100

Radiation in μV/meter can be made easily with the 1401A-1. Figures 5 and 6 show the unit in use with a calibrated antenna. The antenna in the photo is Singer's MD-105-T1, covering 20 MHz to 200 MHz. Figure 7 is a convenient nomograph to obtain μV/meter from the spectrum analyzer reading in dBmV into 75 Ω (1401A-1) or dBm into 50 Ω (7L12).

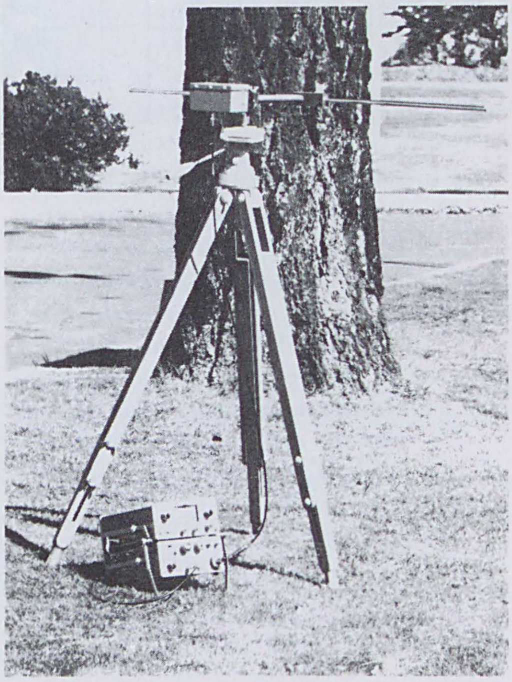


Fig. 5.

Fig. 6.

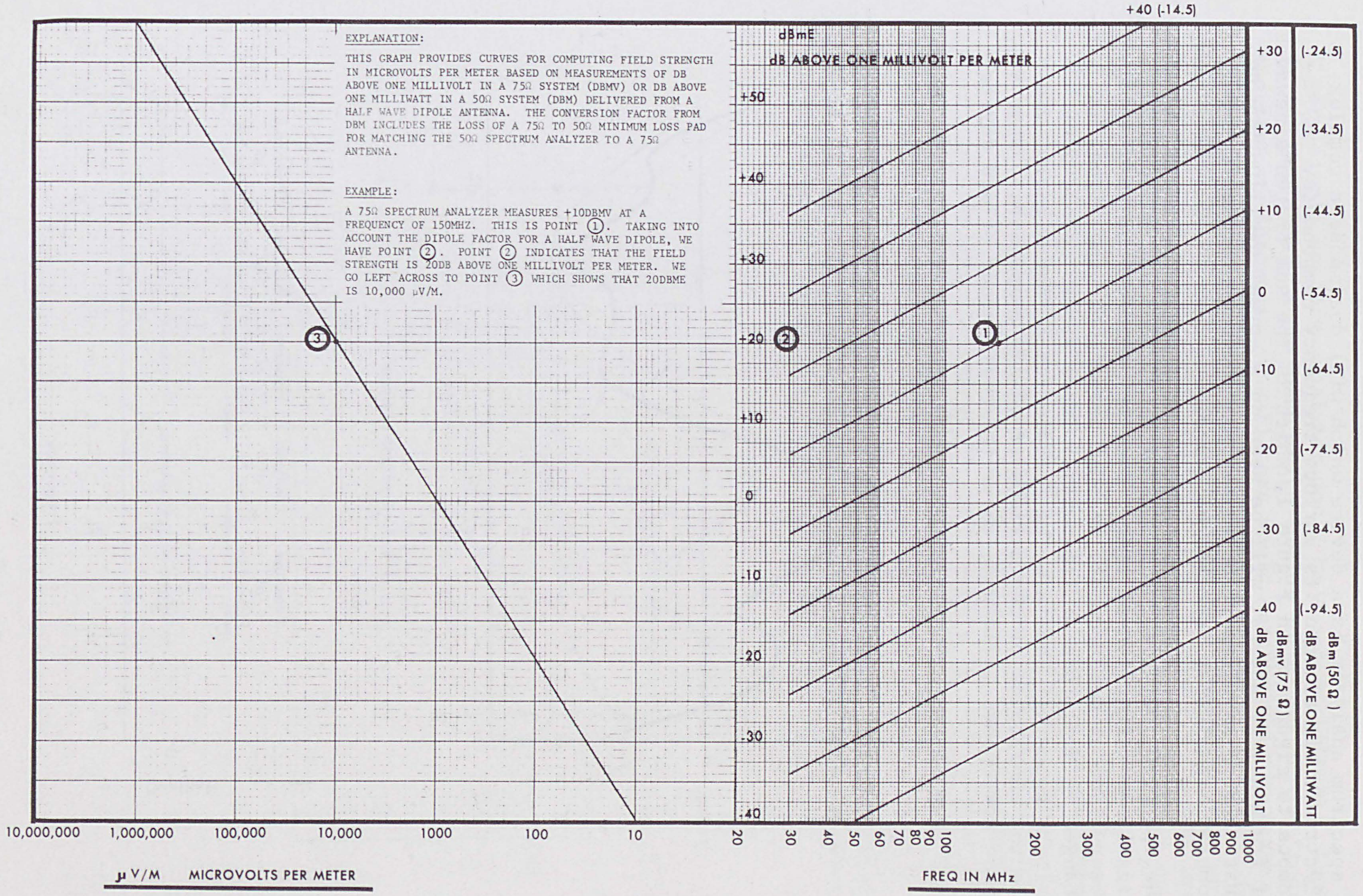

EXPLANATION:
THIS GRAPH PROVIDES CURVES FOR COMPUTING FIELD STRENGTH IN MICROVOLTS PER METER BASED ON MEASUREMENTS OF DB ABOVE ONE MILLIVOLT IN A 75Ω SYSTEM (DBMV) OR DB ABOVE ONE MILLIWATT IN A 50Ω SYSTEM (DBM) DELIVERED FROM A HALF WAVE DIPOLE ANTENNA. THE CONVERSION FACTOR FROM DBM INCLUDES THE LOSS OF A 75Ω TO 50Ω MINIMUM LOSS PAD FOR MATCHING THE 50Ω SPECTRUM ANALYZER TO A 75Ω ANTENNA.
EXAMPLE:
A 75Ω SPECTRUM ANALYZER MEASURES +10DBMV AT A FREQUENCY OF 150MHZ. THIS IS POINT ①. TAKING INTO ACCOUNT THE DIPOLE FACTOR FOR A HALF WAVE DIPOLE, WE HAVE POINT ②. POINT ② INDICATES THAT THE FIELD STRENGTH IS 20DB ABOVE ONE MILLIVOLT PER METER. WE GO LEFT ACROSS TO POINT ③ WHICH SHOWS THAT 20DBME IS 10,000 μV/M.
dBmE
dB ABOVE ONE MILLIVOLT PER METER
+50
+40
+30
+20
+10
0
-10
-20
-30
-40
+40 (-14.5)
+30 (-24.5)
+20 (-34.5)
+10 (-44.5)
0 (-54.5)
-10 (-64.5)
-20 (-74.5)
-30 (-84.5)
-40 (-94.5)
dBmv (75 Ω) dB ABOVE ONE MILLIVOLT
dBm (50 Ω) dB ABOVE ONE MILLIWATT
10,000,000
1,000,000
100,000
10,000
1000
100
10
μV/M MICROVOLTS PER METER
20
30
40
50
60
70
80
90
100
200
300
400
500
600
700
800
900
1000
FREQ IN MHz

Fig. 7.

WHAT IS A SPECTRUM ANALYZER?

A spectrum analyzer is a device which will decompose a complex electronic signal into its various frequency components. A composite signal as in Figure 1, which is the sum of two sinewaves of frequency F_1 and F_2, will be seen on a normal oscilloscope as just that -- a voltage-time waveform. The scope presents the complex signal as a function of time.

The spectrum analyzer, on the other hand, does not represent signals as a function of time. Over the interval of the observation or measurement, we must assume that the signal has not changed in amplitude or frequency. These variables are our primary concern: What are the frequencies of our signal? What are the amplitudes of the various frequency components? What are these components telling us about the performance of our device?

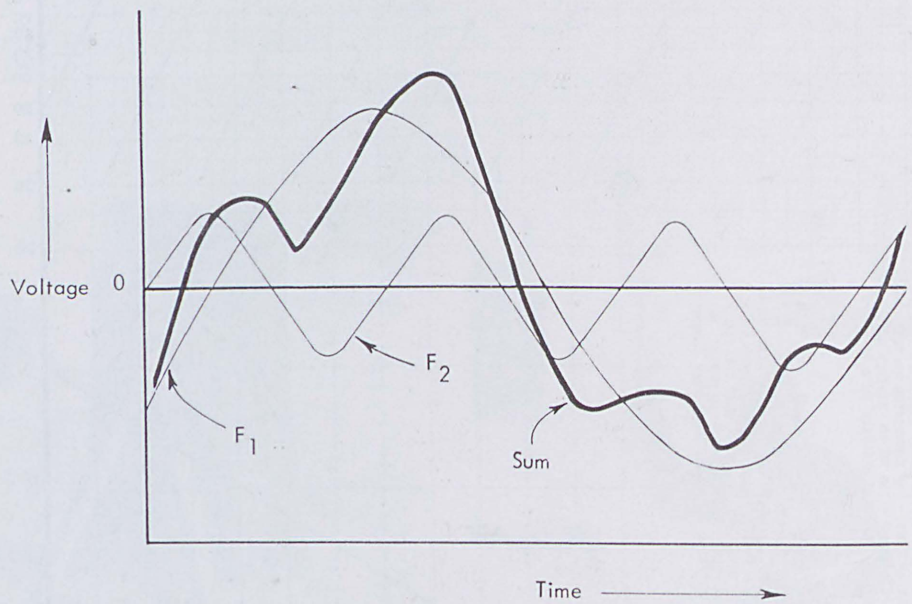


Fig. 1. Composite signal.

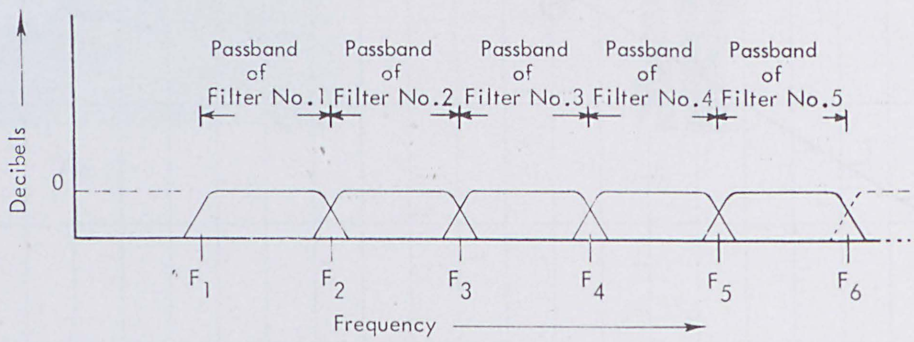


Fig. 2. Filter passband characteristics.

A very simple spectrum analyzer would be a set of filters. Each filter would have a passband which covers a portion of the frequency spectrum of interest. The filters would successively increase in frequency while their passbands are made to overlap slightly, in order that no portion of the broad range of frequencies over which we intend to study is left gapping. (See Figure 2.) Inputs are connected together so that the complex signal will be common to all filters as shown in Figure 3.

The outputs are connected to a commutator device, a system which will look at the output of each filter sequentially. This commutator device could be as simple as a multiple pole switch or a diode matrix or a Time Division Multiplexer. The commutator, then, is sampling the output of each filter, in turn, and in that time only will the output show a signal which is passing through that particular filter.

This system is known as Filter Spectrum Analyzer. The difficulty with this system is that it takes a great many filters to cover a large frequency range.

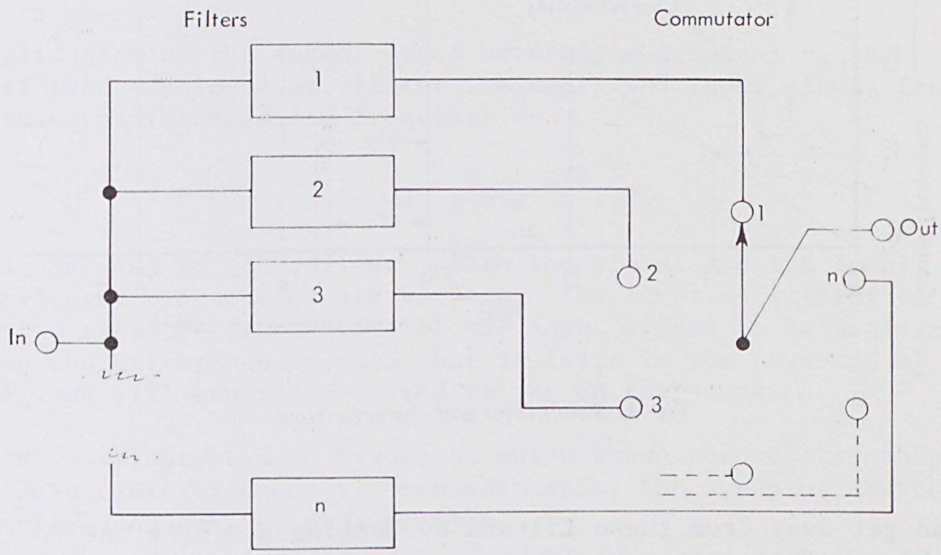
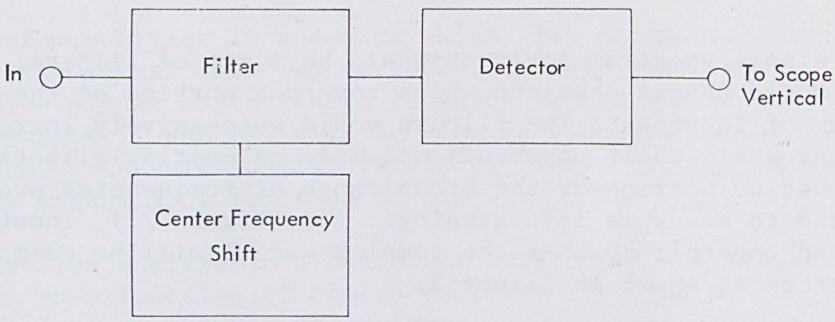


Fig. 3. Simple spectrum analyzer.



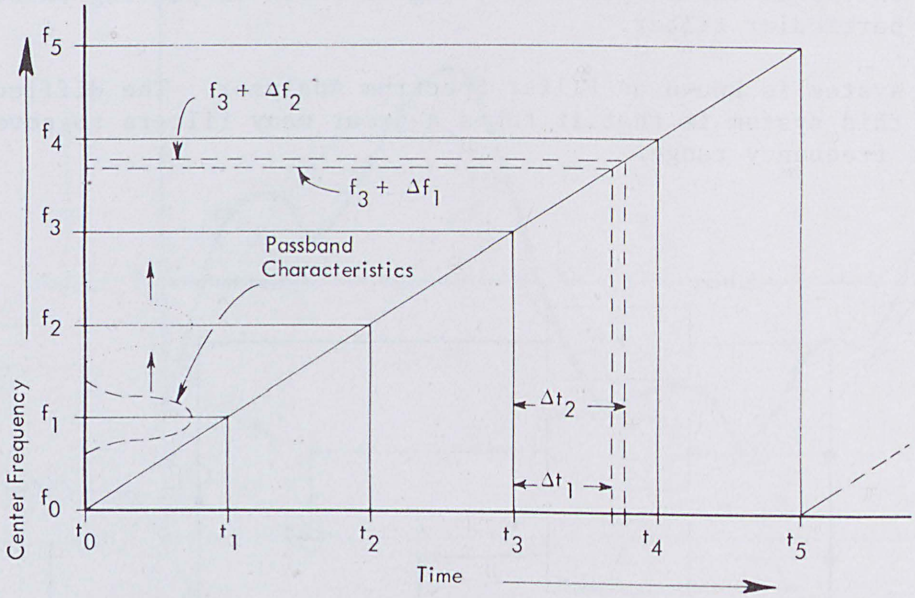


Fig. 4. Swept filter and characteristics.

We can get away from these filters by letting a single one do the switching. This system would have a single filter whose center frequency is adjustable over the frequencies of interest as in Figure 4. Here at t_1, the filter center frequency is located at F_1 and has a passband characteristic shown by the dashed lines. At t_2, the passband has moved to center itself at F_2 (dotted lines). This shifting continues at a constant rate until time t_5, where the center frequency is reset to its low end and shifting begins again.

The next variation in the evolution of spectrum analyzers has no center frequency swept filter. Its filter is a stationary one, and instead of bringing this filter to the frequency of the signal, the signal is brought to the frequency of the filter -- HETERODYNE! Figure 5 shows the block diagram. The input is now fed into a mixer, where it beats with some frequency from a local oscillator.

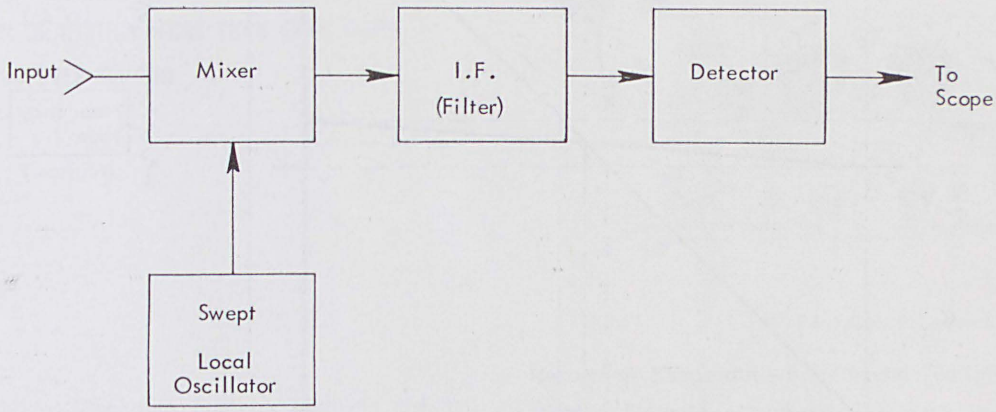


Fig. 5. Front end swept local oscillator version.

Application of the normal super heterodyne equation -- the difference in local oscillator frequency and input signal frequency equals the intermediate frequency --

$$f_{L.O.} - f_{sig} = f_{I.F.}$$

will be used to its fullest. Both the signal and the local oscillator frequencies are varying. The local oscillator is swept over a range of frequencies of the input signal to be analyzed. When the difference is such that it falls in the passband of the I.F., we will see the detected output on the scope.

This is illustrated in Figure 6, which shows the relationship between center frequency, frequency span, the sweeping sawtooth waveform and the CRT presentation.

Modern spectrum analyzers can cover frequency ranges from fractions of a hertz to thousands of megahertz and can measure signals from fractional microvolts to many volts in amplitude level. Their applications are literally limitless. For a more detailed discussion of what these versatile instruments can do, we refer you to TEKTRONIX publication number 062-1334-00, "Spectrum Analyzer Measurements, Theory and Practice."

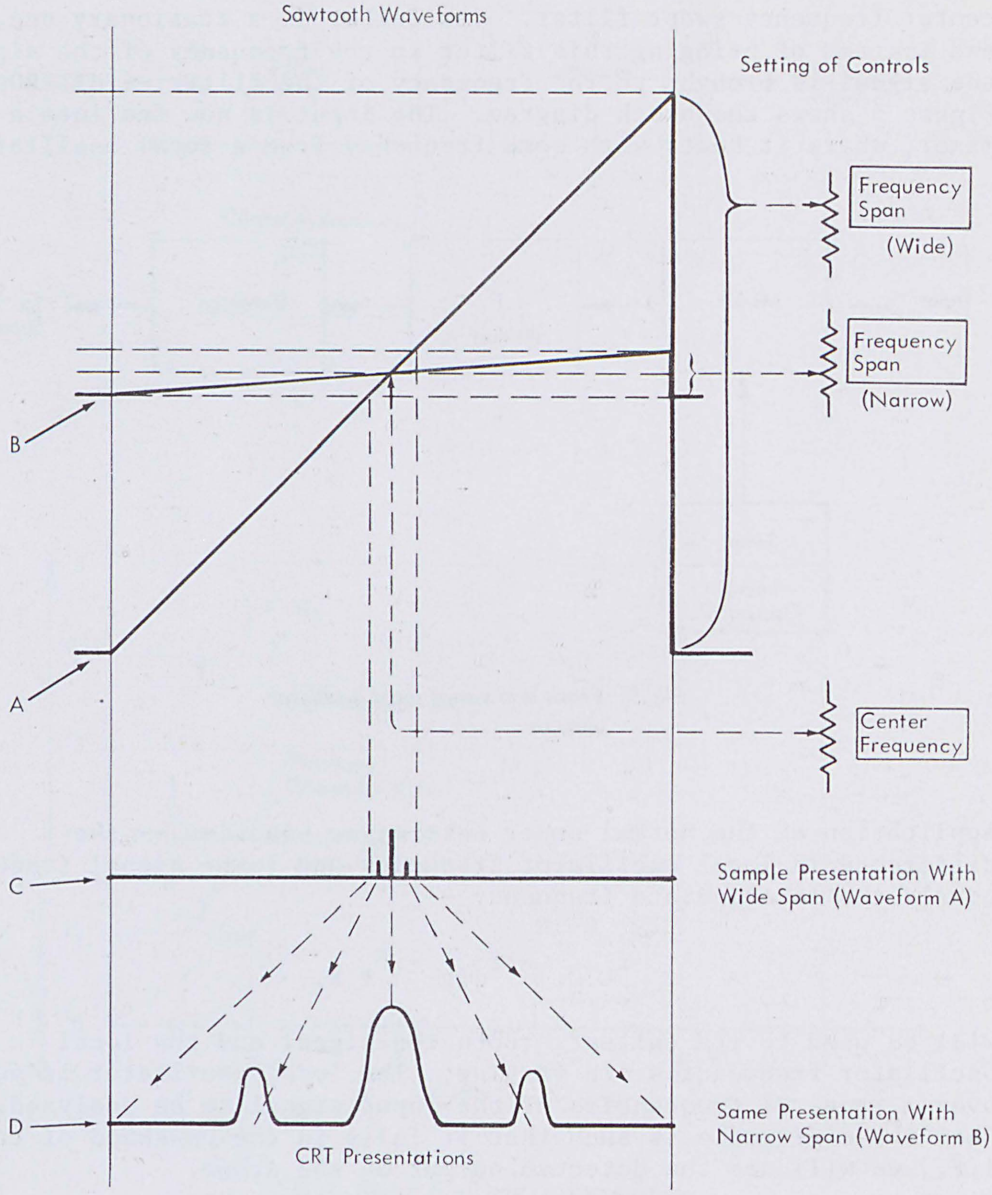
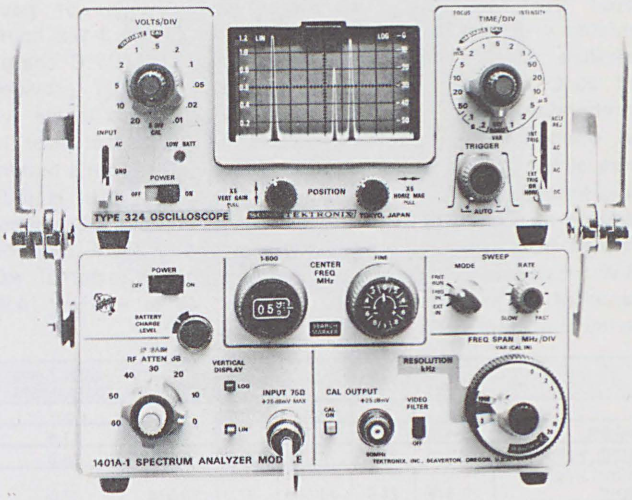


Fig. 6. Frequency span and center frequency controls.

1401A
1401A-1

SPECTRUM ANALYZER

- GATED MODE for PULSED R.F. and TELEVISION
- 75-OHM INPUT (1401A-1)
- 50-OHM INPUT (1401A)
- AC, DC or BATTERY POWERED
- UP to 500 MHz in ONE DISPLAY
- FREQUENCY and AMPLITUDE CALIBRATOR
- 60-dB LOG DYNAMIC RANGE
- INTERMODULATION DISTORTION MORE THAN 60-dB DOWN
- FLAT WITHIN 1.5 dB OVER 200 MHz



1401A/323 Spectrum Analyzer System

The 1401A and 1401A-1 Spectrum Analyzer Modules are an expansion of the plug-in concept of using an oscilloscope for spectrum analysis. These modules, used with the SONY/TEKTRONIX 323, 324, or other oscilloscopes, provide measurement facilities in the 1 MHz to 500 MHz frequency range. The 1401A is designed for 50 Ω systems, the 1401A-1 is for use with 75-Ω systems. Statements about the 1401A apply also to the 1401A-1 unless indicated.

The 1401A and 1401A-1 are compatible with any oscilloscope having 0.5 V/div horizontal deflection factor (adjustable ±10%) and 1.2 V full-screen vertical deflection.

One of the unique features of the 1401A is automatic center frequency positioning in the search mode. At 50 MHz/div frequency span (dispersion), the center frequency automatically becomes 250 MHz, preventing a possible erroneous display. In the search mode, the center frequency control positions a negative marker to indicate that part of the spectrum which will appear at center screen when the frequency span is reduced to less than 50 MHz/div.

Design of the 1401A/323 provides for easy carrying and convenient viewing and access. Power may be obtained from the normal AC line, 6 to 16 VDC, or internal rechargeable batteries.

ANALYZER CHARACTERISTICS

Center Frequency—Continuously selectable with 10-turn digital frequency readout control over the range of 1 to 500 MHz. Absolute accuracy within ± (5 MHz +5% of dial reading). Fine control provides a calibrated variation of up to plus or minus 1 MHz, within 10%.

CW Sensitivity	1401A	1401A-1
3 kHz Resolution	at least −100 dBm	at least −45 dBmV
100 kHz Resolution	at least −85 dBm	at least −30 dBmV
1000 kHz Resolution	at least −78 dBm	at least −23 dBmV

Frequency Span (dispersion)— 50 MHz/div to 100 kHz/div in 9 steps (1-2-5 sequence), accurate within 10% over a 10 div display, plus 0 Hz span. Frequency span can be continuously varied (uncalibrated) from any calibrated value toward zero.

Resolution Bandwidth— 3, 100, and 1000 kHz.

Display Flatness—Amplitude variations are within 1.5 dB to 200 MHz and 3 dB to 500 MHz.

Incidental FM— 20 kHz or less.

Intermodulation Distortion— 1401A at least 55 dB down with two signals at −30 dBm (+25 dBm 1401A-1), one MHz apart; 60 dB down with signals at −40 dBm (+15 dBm 1401A-1).

Frequency Stability—Within 50 kHz over any 5 minute interval after 20 minute warm-up and measurement at +20°C to +30°C ambient. Temperature coefficient = 0.5 MHz/°C or less.

Input Power	1401A	1401A-1
Maximum with RF attenuation	+30 dBm	+80 dBmV
Without attenuation	−30 dBm	+25 dBmV

RF Attenuator— 0 to 60 dB in 10 dB steps (accurate within +0.2 dB + 1% of dB reading).

If Gain Control—At least 30 dB range.

Vertical Display—Linear and log.

Dynamic Range—At least 60 dB in log mode at 10 dB/div.

SWEEP CHARACTERISTICS

Free Run—Sweep rate continuously variable from one sweep per second or less to at least 100 sweeps per second.

External Trigger—Accepts an external positive pulse of 1 to 10 V, at least 100 ns width, 1 MHz or less.

External Horizontal—Input accepts signal of 0 to +5 V. 0 V corresponds to approximately 0 frequency and +5 V corresponds to approximately 500 MHz in Search Mode. 10 V maximum input.

CALIBRATOR

Frequency— 50 MHz within 0.01%.

Amplitude of the Fundamental—1401A, −30 dBm; 1401A-1, +25 dBmV. Accuracy, within 0.3 dB at 25°C and within 0.5 dB from −15°C to +55°C.

OTHER CHARACTERISTICS

Power Sources—Battery operation: removable power pack contains 6 size "C" NiCd cells providing at least 3-1/2 hours operation. Maximum time is achieved at 20°C to 25°C charge and 20°C operating temperature. Internal charger provides for charging the internal batteries when connected to the AC line, operating or nonoperating. Recharge requires at least 16 hours at full charge. A Trickle Charge position prevents battery self-discharge when not in use. Battery charge level is indicated on an expanded scale DC voltmeter. External DC source: operates from an external DC source of 6 V to 16 V, requires 4.8 W. External AC source: operates from an external AC source of 90 to 136 V, or 180 to 272 V; 48 to 440 Hz, 14 W maximum at 115 VAC.

	1401A 1401A-1		323 324		1401A/323 1401A/324	1401A-1/323 1401A-1/324
	in	cm	in	cm	in	cm
Height	3-1/2	8.9	3-1/2	8.9	7	17.8
Width w/handle	8-1/2	21.6	8-1/2	21.6	9-3/8	23.8
Depth w/panel cover	10-5/8	27.0	10-5/8	27.0	10-5/8	27.0
Depth w/handle	13	33.0	13	33.0	14-4/8	37.2
	lb	kg	lb	kg	lb	kg
Net weight w/o accessories	7-1/2	3.4	≈ 8	≈ 3.6	≈15	≈ 6.8
Domestic shipping weight	13	5.9	≈14	≈ 6	≈23	≈10.4
Export-packed weight	21	9.5	≈22	≈10	≈31	≈14.0

SPECTRUM ANALYZER MODULE

1401A Included Accessories— 8′ power cable assembly; panel cover; blue filter; amber filter; three 5-1/2″, 50 Ω BNC to BNC cable assemblies; 6′ 50 Ω BNC to BNC cable assembly; screwdriver; strap assembly; operator's handbook (1401A); instruction manual (1401A).

Order 1401A

SPECTRUM ANALYZER MODULE

1401A-1 Included Accessories—Same as for 1401A except: Insert for instruction manual; two BNC to F adapters; change 6′, 50 Ω BNC to BNC cable assembly to 6′ 75 Ω BNC to BNC cable assembly.

Order 1401A-1

SPECTRUM ANALYZER SYSTEM

1401A/323 (P7 Phosphor) Included Accessories—Two 8′ power cable assemblies; two panel covers; blue filter; amber filter; smoke gray filter; three 5-1/2″, 50 Ω BNC to BNC cable assemblies; 6′, 50 Ω BNC to BNC cable assembly; two strap assemblies; viewing hood; probe package P6049; BNC to banana post patch cord; BNC to binding post adapter; screwdriver; accessory pack; operator's handbook (1401A); instruction manual (1401A); operator's handbook (323); instruction manual (323).

Order 1401A/323P7

Order 1401A-1/323P7

SPECTRUM ANALYZER SYSTEM

1401A/324 (P7 Phosphor) Included Accessories—Two 8′ power cable assemblies; two panel covers; blue filter; amber filter; smoke gray filter; three 5-1/2″, 50 Ω BNC to BNC cable assemblies; 6′, 50 Ω BNC to BNC cable assembly; two strap assemblies; viewing hood; probe package P6049; BNC to banana post patch cord; BNC to binding post adapter; screwdriver; accessory pack; operator's handbook (1401A); instruction manual (1401A); operator's handbook (324); instruction manual (324).

Order 1401A/324P7

Order 1401A-1/324P7

OSCILLOSCOPE SUMMARY

CHARACTERISTIC	323	324
Bandwidth	DC to 4 MHz	DC to 10 MHz
Risetime	90 ns	36 ns
Deflection Factor	10 mV/div to 20 V/div at full bandwidth	
	1 mV/div at 2.75 MHz	2 mV/div at 8 MHz
Input R and C	1 megohm paralleled by approx 47 pF	
Time Base	5 μs/div to 1 s/div	1 μs/div to 0.2 s/div
Magnifier	X10	X5
CRT Display Area	6 x 10 divisions (1/4-inch divisions)	
Phosphor	P7 supplied when ordered with 1401A or 1401A-1	
Amplitude Calibrator	Internal, 0.5 V at external jack	
Power Sources	Internal batteries	Internal batteries
	External 6 to 16 VDC	External 6.5 to 16 VDC
	90 to 136 VAC	115 VAC ±10%
	180 to 272 VAC	230 VAC ±10%
	48 to 440 Hz	48 to 440 Hz
	14 W at 115 VAC	20 W at 126 VAC

The SONY/TEKTRONIX Type 323 and 324 are manufactured and marketed in Japan by Sony/Tektronix Corporation, Tokyo, Japan. Outside of Japan, they are available from Tektronix, Inc., its marketing subsidiaries and distributors.

OPTIONAL ACCESSORIES

Protective Cover—The protective cover for the 1401A or 1401A-1 can be used during transport or storage, and is constructed of waterproof blue vinyl.

Order 016-0112-00

Power Pack—Extra power pack, in addition to the one supplied with the 1401A or 1401A-1, allows one power pack to charge while the other is powering the analyzer. An identical power pack is used in the 323. Pack contains six size "C" NiCd cells and battery charger.

Order 016-0119-02

Adapter—BNC 75 Ω to 50 Ω minimum loss attenuator.

Order 011-0112-00

Battery Set—Set of six NiCd cells.

Order 146-0012-01

CHARACTERISTICS

Frequency Tuning Range—100 kHz to 1.8 GHz continuously variable; accuracy ± (10 MHz + 1% of dial indication).

Frequency Span—500 Hz/div to 100 MHz/div in 1-2-5 sequence. 0 Hz (analyzer, not swept) and maximum span (1.8 GHz over 10 div), modes are also selectable. A continuously variable span control is provided.

Calibrator—50 MHz ±0.01% −30 dBm ±0.3 dB. Harmonics of 50 MHz are generated for frequency span calibration.

Reference Level—Selectable −100 dBm to +30 dBm in 10 dBm steps, a 10 dB variable control is also provided.

Log Display Mode Dynamic Range—70 dB at 10 dB/div; 14 dB at 2 dB/div; log scale accuracy ±0.1 dB/dB, ±1.5 dB maximum over the full dynamic range.

RF Attenuation—0 dB to 60 dB in 10 dB steps ± (0.2 dB + 1% of setting).

Resolution Bandwidth (6 dB down)—300 Hz to 3 MHz in decade steps ±20%.

Resolution Shape Factor—4:1, 60 dB to 6 dB.

Video Filter Bandwidth—Automatically selected by the resolution control.

CW Sensitivity—−110 dBm at 300 Hz Resolution; −108 dBm at 3 kHz Resolution; −100 dBm at 30 kHz Resolution; −90 dBm at 300 kHz Resolution; −80 dBm at 3 MHz Resolution.

Internal Spurious Responses—Less than −100 dBm referred to input.

Intermodulation Distortion—Third order: 70 dB down from two −30 dBm signals. Second order: 70 dB down from two −40 dBm signals (at any frequency span).

Incidental FM—Phase locked Mode: 200 Hz (P-P) maximum; not phase locked: 20 kHz (P-P) maximum.

Display Flatness—±1.5 dB, with respect to 50 MHz.

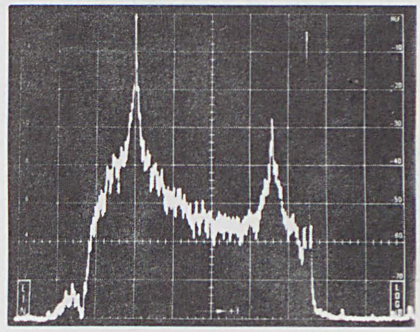
Maximum Safe Input Power—RF Attenuation 0 dB: +13 dBm. (−30 dBm linear operating limit) RF Attenuation 60 dB: +30 dBm (Power rating of attenuator).

Sweep Rate—1 μs/div to 10 ms/div in 1-2-5 sequence continuously variable between steps. Variable control has 100:1 range in 10 ms/div to decrease sweep rate to approximately 1 s/div.

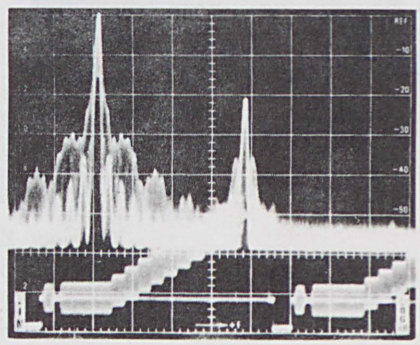
Triggering Modes—Normal, Peak-to-Peak Auto, Single.

Triggering Sources—Vertical Amplifier channels, Power frequency and free run.

DIMENSIONS	in	cm	WEIGHTS (approx)	lb	kg
HEIGHT	5.0	12.7	NET	10	4.5
WIDTH	5.5	14.0	DOMESTIC SHIPPING	13	5.9
LENGTH	14.5	36.9	EXPORT-PACKED	18	8.2



This is the RF spectrum of a television transmitter showing output filter characteristics (pedestal shape) and video, color burst and audio. Frequency span is 1 MHz/div in this display on a 7403N Oscilloscope. Resolution is 30 kHz and the log mode provides 10 dB per div.



The upper display is the RF spectrum resulting from a modulated staircase plus sync and color burst. The lower display is a time base display of the modulated staircase. The simultaneous displays were plotted with a 7A18 Amplifier and a 7B53AN Time Base plus the 7L12 in a 7504 Oscilloscope.

Included Accessories—6-ft BNC cable (012-0113-00); adapter BNC male to N female (103-0058-00); special spectrum analyzer graticules (implosion shields 337-1439-01 for 7403N or R7403N, 337-1159-02 for other 7000 Series); Amber light filter (378-0684-01.

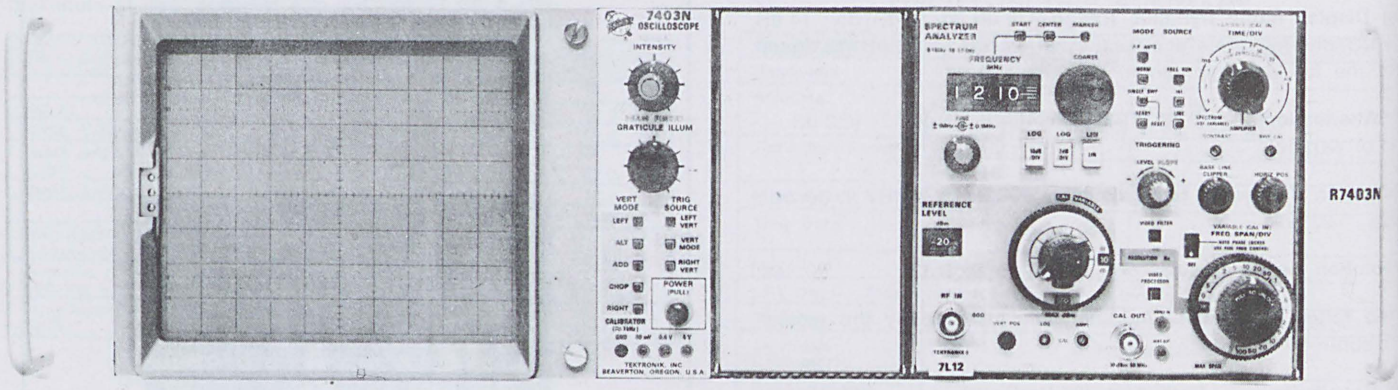
Order 7L12 SPECTRUM ANALYZER
Order R7403N OSCILLOSCOPE

For P7 phosphor and an internal spectrum analyzer graticule.
Order R7403N MOD 08 P7SA

7L12
R7403N

SPECTRUM ANALYZER

- CONVERTS ANY 7000-SERIES OSCILLOSCOPE TO AN EXCELLENT SPECTRUM ANALYZER
- 0 Hz to 1800 MHz IN ONE DISPLAY
- FULLY CALIBRATED DISPLAYS
- 300 Hz to 3 MHz RESOLUTION
- 4:1 RESOLUTION BANDWIDTH SHAPE FACTOR
- 70 dB DYNAMIC RANGE
- INTERMODULATION DISTORTION 70 dB BELOW FULL SCREEN
- SPURIOUS FREE OPERATION
- AUTOMATIC PHASE LOCK
- −110 dBm SENSITIVITY



5¼-inch rackmount R7403N with 7L12 installed.

The 7L12 Spectrum Analyzer Plug-In converts the R7403N Oscilloscope into a high-performance spectrum analyzer. This rackmount system is only 5¼ inches high and is useful in transmitter monitoring and elsewhere in TV spectra measurements.

The 7L12 is a swept front-end spectrum analyzer plug-in for all 7000-Series Oscilloscopes. These run from the rackmounts that are only 5¼ inches high, to 500 MHz real-time bandwidth units. The multiple plug-in concept of the 7000 Series allows simultaneous time and frequency domain displays. 7000-Series mainframes with CRT READOUT will display Reference Level, dB/div, Frequency Span, Resolution and Time/div on screen. All display parameters are calibrated and quantitative information is displayed on both front panel and CRT READOUT. CRT READOUT of display parameters is a unique 7L12 feature.

Excellent resolution shape factor (4 to 1) enables the 7L12 user to measure low-amplitude signals close to full screen signals. The wide, 3 MHz resolution position of the 7L12 enhances narrow pulse spectrum analysis and demodulated waveform measurements.

Much effort has gone into human engineering factors designed to make the 7L12 easier to use and to reduce the chance of human error. A case in point is the three frequency indication modes from which the operator can choose. In the maximum span mode, the frequency dial indication corresponds to the CRT position of a negative-going marker while the analyzer displays the maximum frequency span of 1800 MHz. When the frequency span is reduced, the operator has a choice of two frequency indicating modes, START or CENTER. The former, particularly useful for harmonic and distortion analysis, sweeps with the indicated frequency corresponding to the extreme left hand edge of the display. In the center mode, which is primarily of interest for symmetrical modulation spectra, the center of the display corresponds to the frequency indicated.

Another human engineering innovation is the RF input and reference level self-computing differential mechanism. This mechanism provides direct readout of the full-screen reference level, RF attenuation, and maximum input power for linear operation. Values are presented in dBm on the front panel. The 7000-Series Oscilloscope mainframes with CRT READOUT will also display the full screen reference level value in dBm on the CRT. Further operational ease is provided by color-keyed sections on the front panel.