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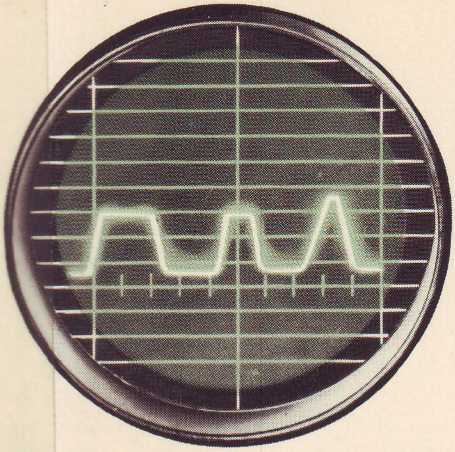
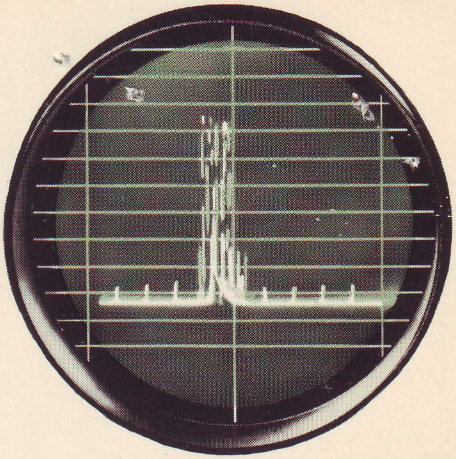
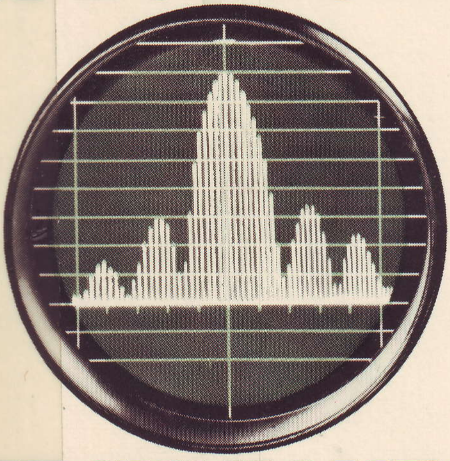
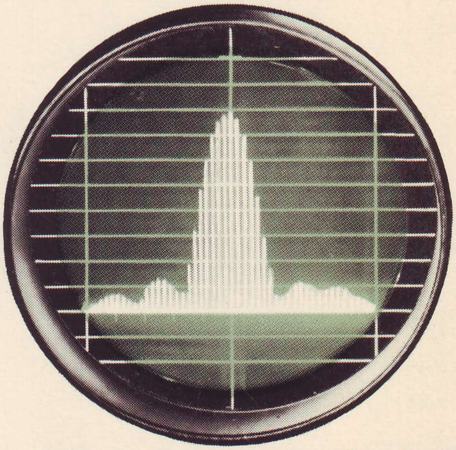




SPECTRUM ANALYZER





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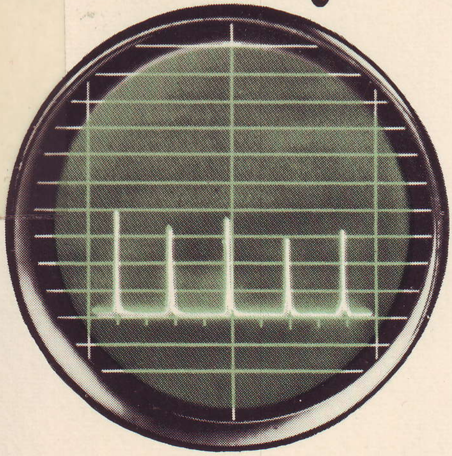

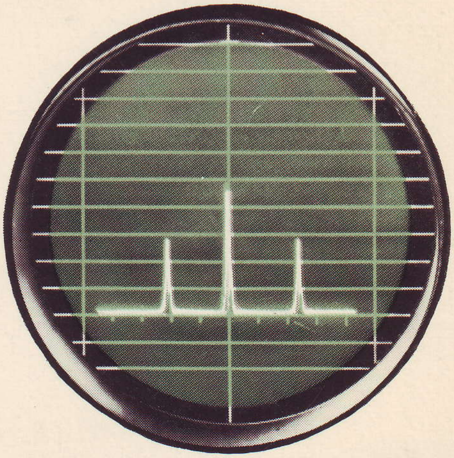

POLARAD ELECTRONICS CORPORATION
43-20 34th STREET, LONG ISLAND CITY 1, N. Y.

POLARAD

SPECTRUM ANALYZER TECHNIQUES HANDBOOK

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FOREWORD

Recent years have seen the radio frequency spectrum analyzer evolve from a special purpose device into a highly refined and versatile measuring instrument, having wide applications in all fields of radio and electronic engineering.

As the world's foremost designers and producers of spectrum analyzers, we at Polarad have had a unique opportunity to explore the underlying principles governing the operation of the spectrum analyzer and also to put the instrument to work in many diverse applications, both in the laboratory and on the production line.

We have long felt the need for gathering together some of the available knowledge on the theory of operation, design considerations and applications of spectrum analyzers, to form a reference handbook which could be used by engineers and other technical personnel interested in such information. This booklet represents our attempt to meet that need.

We sincerely hope that you will find this booklet instructive and informative. If it merits a place in your reference library, then it has more than served its purpose.

D. L. Jaffe

D. L. JAFFE
President

POLARAD ELECTRONICS CORPORATION

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INTRODUCTION

A radio-frequency spectrum analyzer is a device which provides a panoramic display of the signal distribution in a selected portion of the radio-frequency band. The display takes the form of a plot of amplitude versus frequency, usually on the screen of a cathode ray oscilloscope.

Much useful information can be obtained from such a display. The presence or absence of signals of interest, their frequencies, frequency differences, relative amplitudes, and the nature of their modulation, if any, may be determined from the spectrum analyzer display.

It is our purpose to discuss the general theory of spectrum analyzer operation and to describe some of the many applications in which the spectrum analyzer has been found to be useful.

HISTORY

Little work was done in the field of panoramic presentation of radio frequency spectra during the years preceding World War II. However the huge amount of organized research and development work in the field of microwave radar performed as part of the war effort had as one of its results a tremendous expansion in the scope of measurement techniques and measuring apparatus available to the practicing engineer. At the Massachusetts Institute of Technology Radiation Laboratory spectrum analyzers of various types were developed for use as test equipment in the design of pulsed oscillators for radar transmitters. Wide range panoramic receivers for countermeasures applications were designed at the Radio Research Laboratory of Harvard University to facilitate the detection and analysis of radio and radar signals.

Despite the rather specialized nature of its original applications, the spectrum analyzer has proved to be a highly versatile device in the field of radio-frequency instrumentation. It can be employed in the design and adjustment of transmitters; in the checking and calibration of oscillators, attenuators, wavemeters, etc.; as a sensitive detector in bench test work; as a means of studying modulated signals of all types; and in many other applications where it is desirable or convenient to have available a panoramic display of signal amplitude and/or sideband structure.

GENERAL THEORY OF OPERATION

A spectrum analyzer is essentially a narrow-band superheterodyne receiver which is repeatedly swept in frequency over a selected portion of the radio-frequency band. At the same time, the horizontal deflection of the spot on a cathode ray tube moves in synchronism with the sweep. The vertical deflection of the spot is proportional to the output voltage of the receiver. The resultant display is a plot of amplitude versus frequency over the radio-frequency band of interest.

Figure 1 illustrates the block diagram of a simple spectrum analyzer. It must be pointed out that the diagram shows only the basic elements that are necessary to explain the operation of the analyzer. A practical instrument contains many more features, depending on its design and application.

The waveform of output voltage from the sweep generator is usually a sawtooth, so that the loal oscillator is swept between two frequency limits in a linear manner. The same sawtooth waveform is applied to the horizontal deflection plates of the cathode ray tube, so that the movement of the spot across the screen is proportional to frequency. The local oscillator output is fed into the mixer, where it combines with the incoming radio-frequency signal. If the frequency difference between the two inputs to the mixer is equal to the intermediate frequency of the analyzer, the resulting difference signal is amplified by the intermediate-frequency amplifier. In order to make the difference signal voltage proportional to the incoming radio-frequency signal

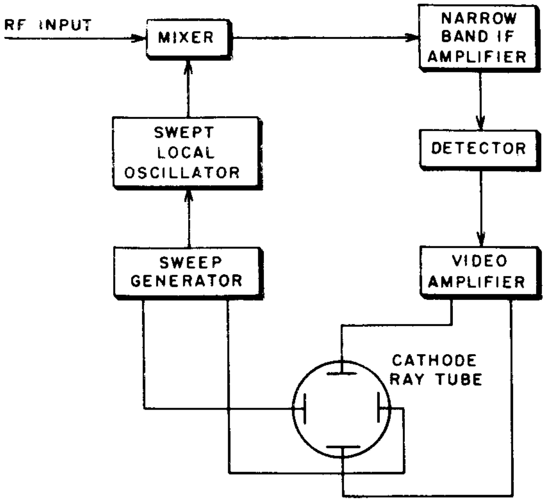

Figure 1. Block Diagram of a Simple Spectrum Analyzer.

voltage, the local oscillator power supplied to the mixer must be much greater than the incoming signal power.

After passing through the intermediate-frequency amplifier, the signal is detected and then amplified by the video amplifier to a level suitable for application to the vertical deflection plates of the cathode ray tube.

DESIGN CONSIDERATIONS

The foregoing discussion of the basic components of a radio-frequency spectrum analyzer was not concerned with the design of the various elements for proper operation of the instrument. Such factors as the rate of frequency sweep, the dispersion (range of frequency sweep), bandwidth and center frequency of the intermediate-frequency system, the bandwidth of the video amplifier, and the overall sensitivity of the system must be carefully considered in the design of a practical spectrum analyzer. The manner in which these factors affect the presentation of various types of signals will now be discussed.

A. C-w Signals.

The trace on the screen of a spectrum analyzer while receiving a continuous-wave signal is shown in figure 2. If the sweep speed is very low, the trace is a plot of the band-pass characteristic of the intermediate-frequency amplifier, and therefore the resolving power R of the analyzer is equal to the 3-db band-

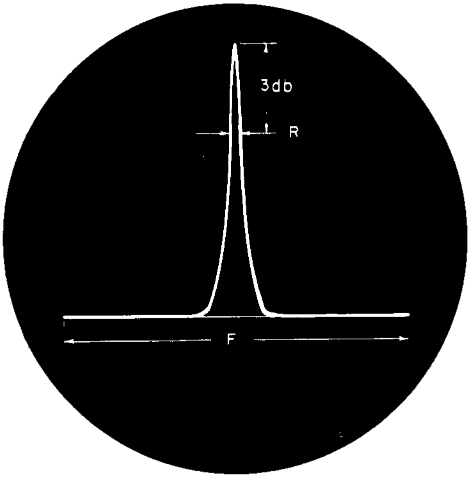

Figure 2. Typical C-w Signal.

width of the intermediate-frequency amplifier.[1] As the sweep rate is increased, the pip becomes reduced in amplitude and widened out. Both the resolving power and the sensitivity of the analyzer are thus degraded due to the limited response time of the tuned circuits.

It can be shown[2] that the loss in sensitivity due to the sweep rate is given by

$$a_s = \left[1 + 0.195 \left(\frac{F}{TB^2} \right)^2 \right]^{-1/4} \qquad (1)$$

where a_s is the response relative to that obtained with a zero sweep rate,

B is the 3-db bandwidth of the intermediate-frequency amplifier in cycles per second,

F is the sweep width (dispersion) in cycles per second, and

T is the sweep time interval in seconds. Thus F/T is the sweep rate in cycles per second per second.

The loss in resolving power due to the sweep rate is given by

$$\frac{R}{B} = \left[1 + 0.195 \left(\frac{F}{TB^2} \right)^2 \right]^{1/2} = \frac{1}{a_s^2} \qquad (2)$$

R/B may be interpreted as the apparent bandwidth of the spectrum analyzer when sweeping, relative to the steady-state bandwidth.

Equations (1) and (2) are plotted in figures 3 and 4 respectively.

Thus a spectrum analyzer having an i-f bandwidth of 5 kc and displaying 25 mc at a sweep frequency of 20 cps would have a loss in sensitivity, due to scanning, of 9.5 db, while the resolution R would be 44 kc. In order to obtain a resolution substantially equal to the i-f bandwidth, the dispersion would have to be reduced to below approximately 300 kc in this example. The sensitivity would then be, for all practical purposes, equal to the zero-sweep-rate value.

---

[1] The definition of resolving power is somewhat arbitrary. R is taken to be the displayed width of the c-w pip at the 3-db points. Thus if the pip is 25 kc wide at the 3-db points, the resolution R is said to be 25 kc. Two pips of equal amplitude and separated in frequency by R as so defined would barely be distinguishable from each other on the screen.

[2] See Appendix A.

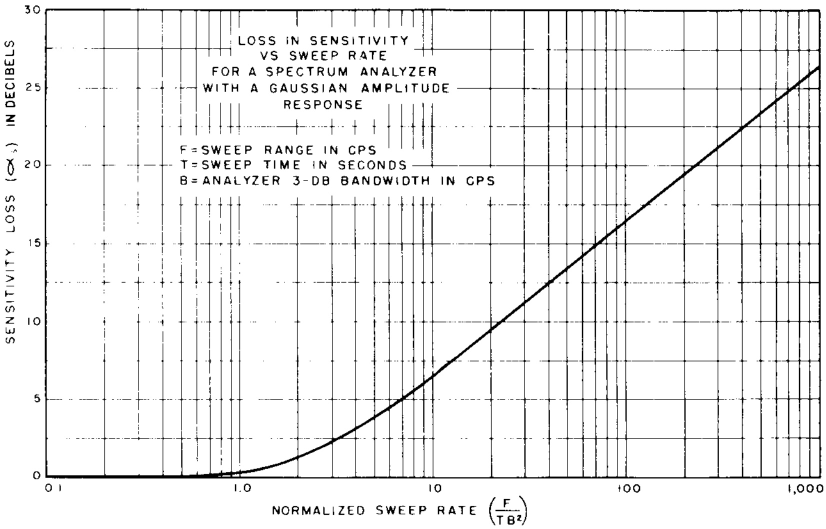

Figure 3. Sensitivity Loss vs Sweep Rate.

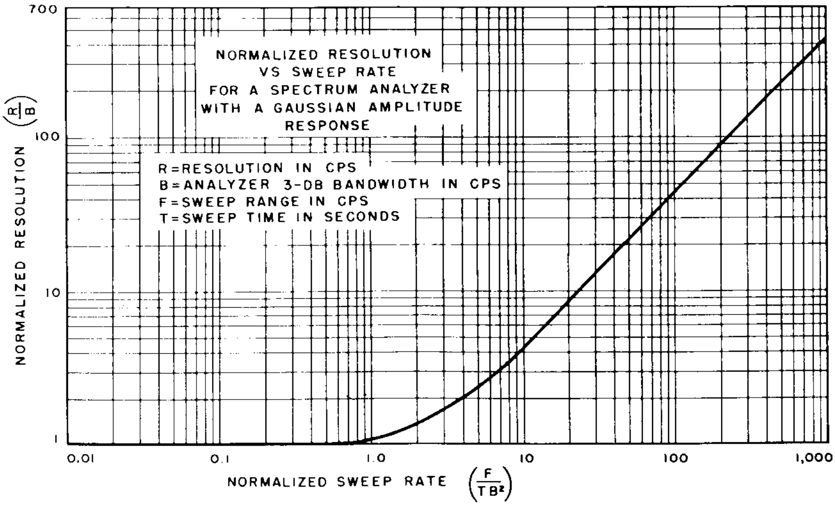

Figure 4. Normalized Resolution vs Sweep Rate.

B. Amplitude-modulated Signals.

The spectrum of a single-tone amplitude-modulated signal can be shown[3] to consist of the original carrier frequency plus a pair of side frequencies; one above and one below the carrier. Such a spectrum is shown in figure 5. The amplitude of either sideband voltage with respect to the carrier voltage is *m/2*, where *m* is the percentage modulation; and the frequency difference between the carrier and either sideband is equal to the modulating frequency.

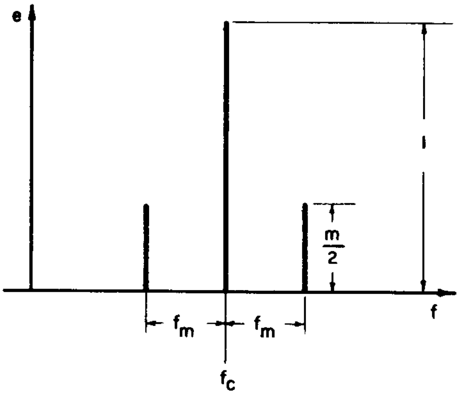

Figure 5. Spectrum of a Single-tone AM Wave.

If the modulating wave is complex, each frequency component in the modulating wave contributes a pair of side frequencies to the spectrum. These side frequencies are located equidistantly on each side of the carrier, and are spaced away from the carrier by the frequency of the modulating wave being considered.

Note that the spectrum of a complex amplitude-modulated wave, shown in figure 6, is symmetrical about the carrier frequency. This is a necessary condition for pure amplitude modulation. Note also that all components of the spectrum are separated by the fundamental frequency of the modulating wave. This is because the Fourier components of a complex wave are harmonically related. The relative amplitudes of any pair of sideband frequencies is proportional to the amplitude of the corresponding Fourier component of the modulating wave.

A typical spectrum analyzer display of a single-tone amplitude-modulated signal is shown in figure 7. It is apparent that the resolving power of the spectrum analyzer affects the ability of the instrument to display the sideband structure of the amplitude-modulated signal. In order to separate adjacent signals of equal amplitude, the frequency difference between these signals

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[3] See Appendix B, Part 1 for the derivation of single-tone and complex-wave amplitude-modulated spectra.

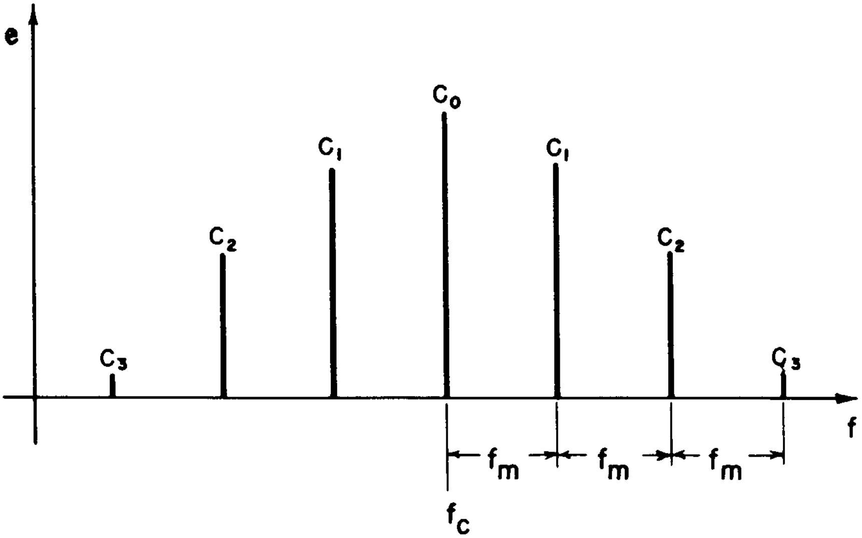

Figure 6. Spectrum of a Complex AM Wave.

must be at least equal to the analyzer resolution; while for unequal signals the frequency difference must be greater, due to the tendency of the large pips to mask the adjacent smaller ones. Thus the lowest modulating frequency which can be discerned by observation of the pair of sidebands adjacent to the

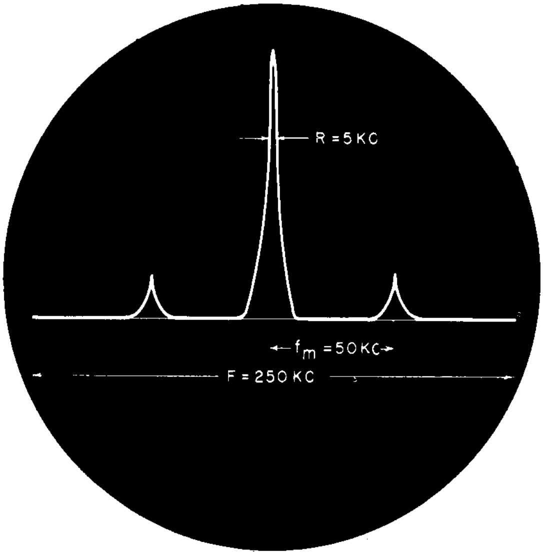

Figure 7. Spectrum Analyzer Display of Single-tone AM Signal.

carrier is somewhat higher than *R*. Hence a spectrum analyzer with an i-f bandwidth of, say 25 kc, would not be suitable for the detailed analysis of a voice-modulated signal. However, such a signal might still be identified as being amplitude-modulated by the serrated appearance of the carrier pip on the analyzer screen, as illustrated in figure 8. If the resolution is extremely coarse compared to the width of the sidebands, the signal will appear as a pip fixed in position and bobbing up and down in amplitude.

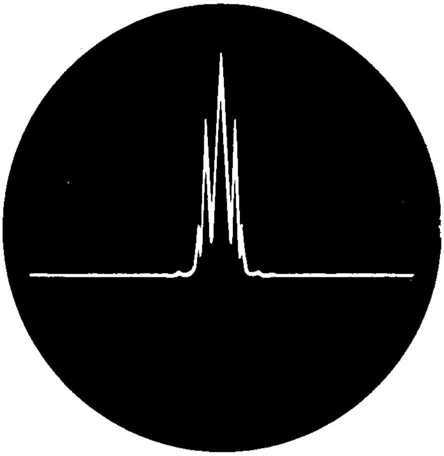

Figure 8. Spectrum Analyzer Display of Single-tone AM Signal with Coarse Resolution.

For wide-band amplitude modulation, as encountered in television broadcasting and in certain other applications, the spectrum analyzer may be used to determine the distribution of sideband energy and to measure the modulation bandwidth.

C. Frequency-modulated Signals.

Unlike the situation in amplitude modulation, where superposition holds, the spectrum of a frequency-modulated wave cannot be deduced from the frequency distribution of the modulating signal.[4] Instead, it is necessary to perform a Fourier analysis of the modulated wave itself.[5] In the case of a single-tone frequency modulation, the spectrum of the modulated wave is

---

[4] The special case of very small modulation index is an exception; superposition holds to a first approximation in this case.

[5] An example of such an analysis as used to derive equation (3) is given in Appendix B, Part 2.

given by

$$e(t) = \sum_{n=-\infty}^{\infty} J_n(\beta) \cos 2\pi (f_o + nf_m)\, t \tag{3}$$

where $J_n(\beta)$ is the nth Bessel coefficient of β,

β is the modulation index $= \dfrac{\Delta f}{f_m}$

$$= \frac{\text{Maximum frequency deviation of the carrier}}{\text{Modulating frequency}}$$

and

f_o is the unmodulated carrier frequency.

Equation (3) is seen to be composed of the carrier and an infinite series of pairs of side frequencies. The amplitude of the nth upper or lower side frequency is given by $J_n(\beta)$, the Bessel coefficient; while the spacing between adjacent side frequencies is equal to f_m, the modulating frequency.

Figures 9 and 10 illustrate the spectra of two frequency-modulated signals having the same maximum frequency deviations but different modulation indices. Notice that as β, the modulation index, becomes larger, the number of significant sideband components increases, and their amplitudes tend to become equal. In the limit, as β approaches infinity, the spectral energy is evenly distributed over a band exactly $2\Delta f$ wide.

It is apparent that, for proper display of the sideband structure of a frequency-modulated signal, the spectrum analyzer should have a resolution good enough to separate adjacent sidebands. Since these sidebands are generally of unequal amplitudes, the analyzer resolution should be smaller than the lowest modulating frequency.

If the spectrum analyzer resolution is so coarse as to include all of the significant side frequencies of the modulated signal, the display appears as a single pip, constant in amplitude and shifting back and forth in frequency.

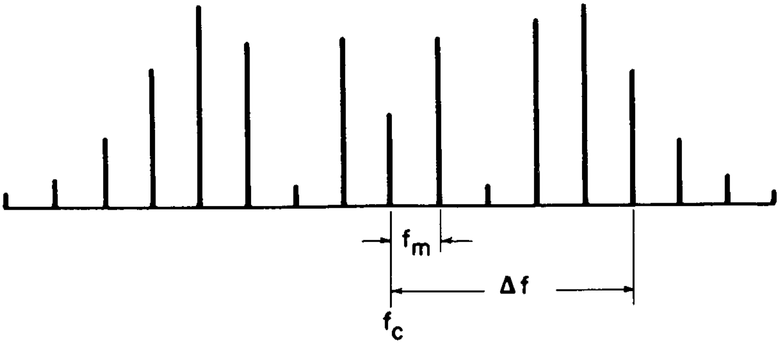

Figure 9. Single-tone FM Signal with $\beta = 5$.

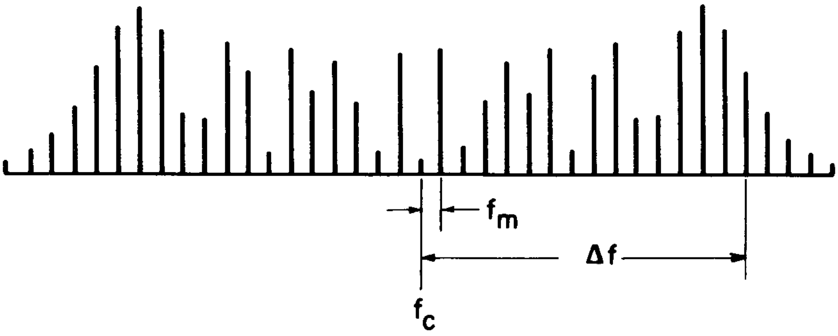

Figure 10. Single-tone FM Signal with $\beta = 15$.

D. Pulse-modulated Signals.

Pulse modulation is a special case of amplitude modulation in which the carrier is on during certain chosen intervals (pulses), and is off between these intervals. This is usually done in order to increase the ratio of peak to average power in the modulated wave. The modulating signal may be used to vary the amplitude (PAM), width (PWM), position (PPM) or other characteristics of the pulses being transmitted.

If the modulated carrier is composed of rectangular pulses of width τ at a pulse repetition frequency f_r, the frequency spectrum is given by[6]

$$e(t) = \tau f_r \sum_{n=-\infty}^{\infty} \frac{\sin n\pi f_r \tau}{n\pi f_r \tau} \cos 2\pi (f_c + n f_r) t \qquad (4)$$

where f_c is the carrier frequency.

Thus the spectrum envelope has a characteristic $\frac{\sin x}{x}$ frequency distribution as shown in figure 11. A linear spectrum analyzer however, displays only the absolute magnitude of the spectrum, since phase information is disregarded by the detector. The presentation is therefore as shown in figure 12. It is noted that the minima of the spectrum envelope occur at frequencies $\frac{1}{\tau}, \frac{2}{\tau}, \ldots\ldots$ away from the carrier frequency. Thus a 1 microsecond pulse has a spectrum whose central lobe is 2 mc wide.

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[6] See Appendix B, Part 3.

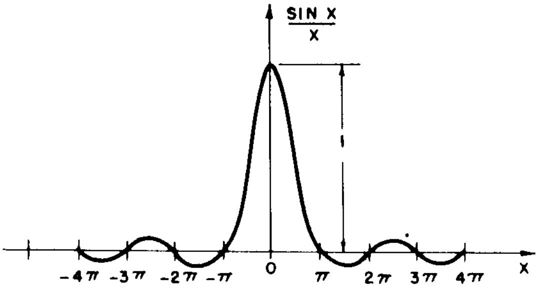


Figure 11. Plot of the Function $\frac{\sin x}{x}$.

The vertical lines of the spectrum are the sideband frequency components, and are spaced apart by the pulse repetition frequency, f_r. They are referred to as the PRF or spectral lines.

In order to display the PRF line structure of the spectrum, the resolving power of the spectrum analyzer must be smaller than the pulse repetition frequency. However, the spectrum envelope may still be adequately resolved even though the analyzer resolving power is far too coarse to separate the spectral lines. This is illustrated in figures 12 and 13. Figure 12 shows a spectrum in which the PRF lines are resolved; while figure 13 shows a spectrum which appears to be continuous, since the resolution is not fine enough to display the spectral lines. Note, however, that the spectrum envelope is well resolved in both cases.

Experience has shown that, for adequate resolution of the envelope of a pulse spectrum, the resolving power should be smaller than one-tenth the reciprocal of the pulse length; i.e. for adequate resolution,

$$R\tau \leq 0.1 \tag{5}$$

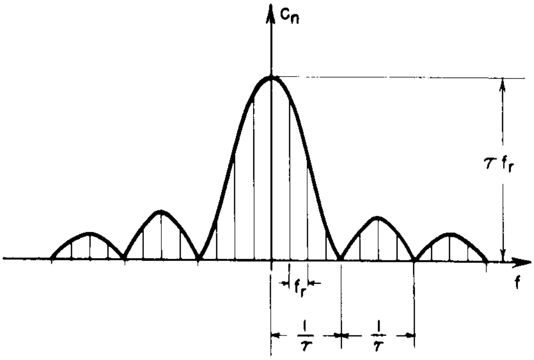


Figure 12. Amplitude Spectrum of a Pulse-modulated Wave.

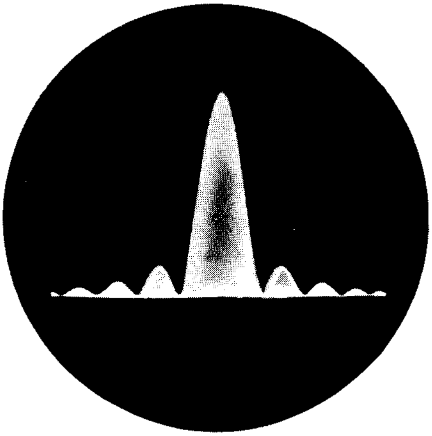


Figure 13. Spectrum of a Pulse-modulated Wave with Adequate Resolution of Envelope but not of PRF Lines.

If R is greater than 0.1τ, the minima of the spectrum envelope do not go entirely to zero. Thus a spectrum analyzer having a resolution of 25 kc will resolve the spectra of pulses up to 4 microseconds in length.

The amount of detail in the spectrum depends upon the relationship between the pulse repetition frequency and the analyzer sweep frequency. This is illustrated by figure 14. The conditions here are identical to those of figure 13 except that the pulse repetition frequency has been decreased from 10 kc to 500 cycles. The vertical spikes are not to be confused with the spectral PRF lines, which the analyzer is totally unable to resolve in this case. Each spike represents a pulse received at the input to the analyzer. Thus N, the total number of spikes on the analyzer screen, will be equal to the number of pulses

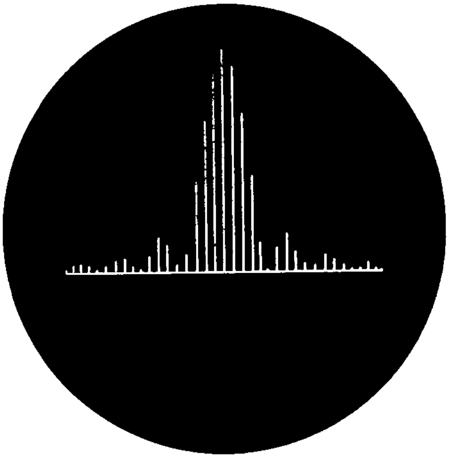


Figure 14. Spectrum of a Pulse-modulated Wave with Adequate Resolution of Envelope but Poor Definition due to Excessively High Sweep Frequency.

received during the sweep time interval. Hence,

$$N = T f_r \tag{6}$$

The definition of the spectrum will be adequate if 50 or more spikes are present on the screen. Hence, from equation (6), the analyzer sweep frequency should be no greater than one-fiftieth of the pulse repetition frequency. If this requires such a slow sweep that flicker results, it may be necessary either to use photographic techniques or to employ a long-persistence screen.

Bandwidth of I-F Amplifier.

One of the important considerations in the design of a spectrum analyzer is the center frequency of the intermediate-frequency amplifier. Referring to figure 1, it is seen that the simplest form of spectrum analyzer is basically a superheterodyne receiver without any selectivity before the mixer. This means that the undesired image response must be kept off the screen by using a sufficiently high intermediate frequency. This is illustrated in figure 15. Here the pulse length τ is chosen so that the fourth side lobe of one image spectrum overlaps the third side lobe of the other. It can be safely assumed that no appreciable distortion of the desired spectrum occurs if the separation is this great. Since the center frequencies of the two images are spaced apart by twice the intermediate frequency, it follows that the intermediate frequency should be

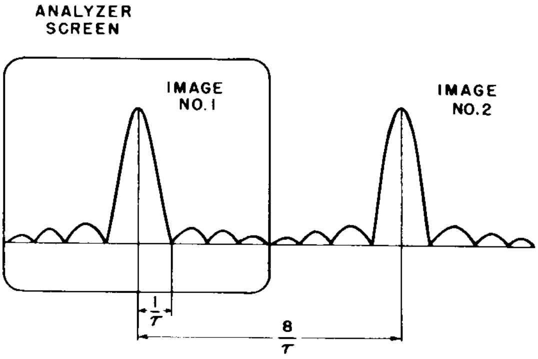


Figure 15. Appearance of Image Spectra when $f_i = \frac{4}{\tau}$.

$$f_i \geq \frac{4}{\tau_{min}} \tag{7}$$

where τ_{min} is the shortest pulse the analyzer will handle.

It is clear from the foregoing that the analyzer bandwidth determines the longest pulse that can be resolved, while the intermediate frequency limits the shortest pulse that can be accommodated. If the required range of pulse lengths to be handled is too wide, incompatible requirements are imposed upon the intermediate-frequency amplifier. As an example, consider a range of pulse lengths from 0.1 to 10 microseconds. This requires that

$$(7)\quad f_i = \frac{4}{\tau_{min}} = \frac{4}{0.1 \times 10^{-6}} = 40 \text{ mc}$$

and

$$(5)\quad R = \frac{0.1}{\tau_{max}} = \frac{0.1}{10 \times 10^{-6}} = 10 \text{ kc}$$

Since it is impractical to design a 40-mc amplifier with a 10-kc bandwidth, it is necessary to find an alternate means of accomplishing the desired results. The problem can be solved by using a double-conversion system; that is, first amplifying at 40 mc, thus obtaining the required image separation, and then converting to a lower frequency, say 1 mc, where the necessary 10-kc bandwidth can be readily obtained.

Bandwidth of Video Amplifier.

After passing through the i-f system, the signal is detected and fed to the video amplifier. The function of the video amplifier is to amplify the spike to a level suitable for application to the vertical deflecting plates of the cathode ray tube. The bandwidth of the video amplifier should therefore be great enough so that the rise time of the spike will not be seriously degraded. Referring to figure 2, the time duration of the spike between 3-db points may be taken as

$$W = \frac{RT}{F} \tag{8}$$

To simplify matters, let us assume that the rise time of the spike is equal to $\frac{W}{2}$. Making use of the fact that the rise time of a Gaussian amplifier is given by

$$\tau_r \approx \frac{0.5}{\Delta f} = \frac{RT}{2f} \tag{9}$$

where Δf is the 3-db bandwidth, we obtain, for the minimum allowable bandwidth of the video amplifier,

$$\Delta f = \frac{0.5}{\tau_r} = \frac{F}{RT} \tag{10}$$

Thus a spectrum analyzer having a 25-kc resolution, with a maximum dispersion of 25 mc and a maximum sweep frequency of 20 sweeps per second, the video amplifier bandwidth should be at least 20 kc.

APPLICATIONS

The preceding section has been concerned with the general theory of spectrum analyzer operation, with special emphasis being given to the effects of various design parameters upon the presentation of certain types of signals. It is the purpose of the present section to explore some of the practical applications of the spectrum analyzer in order to illustrate its great versatility as a useful tool in electronic engineering.

A. Trouble-shooting a Pulse-modulated Transmitter.

One of the chief uses of the spectrum analyzer is to check the operation of pulse-modulated transmitters. In particular, the spectrum analyzer may be used as a sensitive indicator of excessive frequency modulation during the pulse. Frequency modulation has the effect of broadening the spectrum; that is, removing power from the central lobe and placing excessive power into the side lobes. The greater the frequency modulation, the greater is this effect, as illustrated in figures 16e, f, and g.

Note that these spectra are symmetrical. This is a characteristic of pure linear frequency modulation. However, if linear amplitude modulation of the pulse is also present, the spectrum becomes unsymmetrical, as illustrated in figures 16i and j. In both cases, the pulse amplitude is highest when the frequency is lowest. Hence the spectrum amplitude is higher on the low-frequency side.

If there is no frequency modulation present during the pulse, the presence of incidental amplitude modulation has only a slight effect upon the spectrum. The spectrum remains symmetrical, and the shape of the main lobe is practically unaffected. The only significant difference between the spectrum of a pulse with incidental AM and that of a rectangular pulse lies in the relative amplitudes of the side lobes. Figures 16a, b, c, d and h illustrate this point. Note that triangular and trapezoidal amplitude modulation results in a reduction in the width of the spectrum. Note also that the spectrum of an error-function transient (figure 16d) has the same form as the transient itself. This fact is useful in the analysis of the characteristics of a series of single-tuned circuits, since the resultant selectivity curve approximates the error-function.

A commonly observed form of spectrum is shown in figure 16k. The pulse is trapezoidally amplitude and frequency modulated. The central portion of the pulse is unmodulated; hence the spectrum has a central lobe resembling that of a rectangular pulse. The frequency separation between the first minima is about 3 mc, indicating an effective pulse width of approximately 0.7 microsecond. Since the frequency modulation causes a downward shift in frequency at the beginning and the end of the pulse, the low-frequency side of the spectrum contains practically all of the sideband energy.

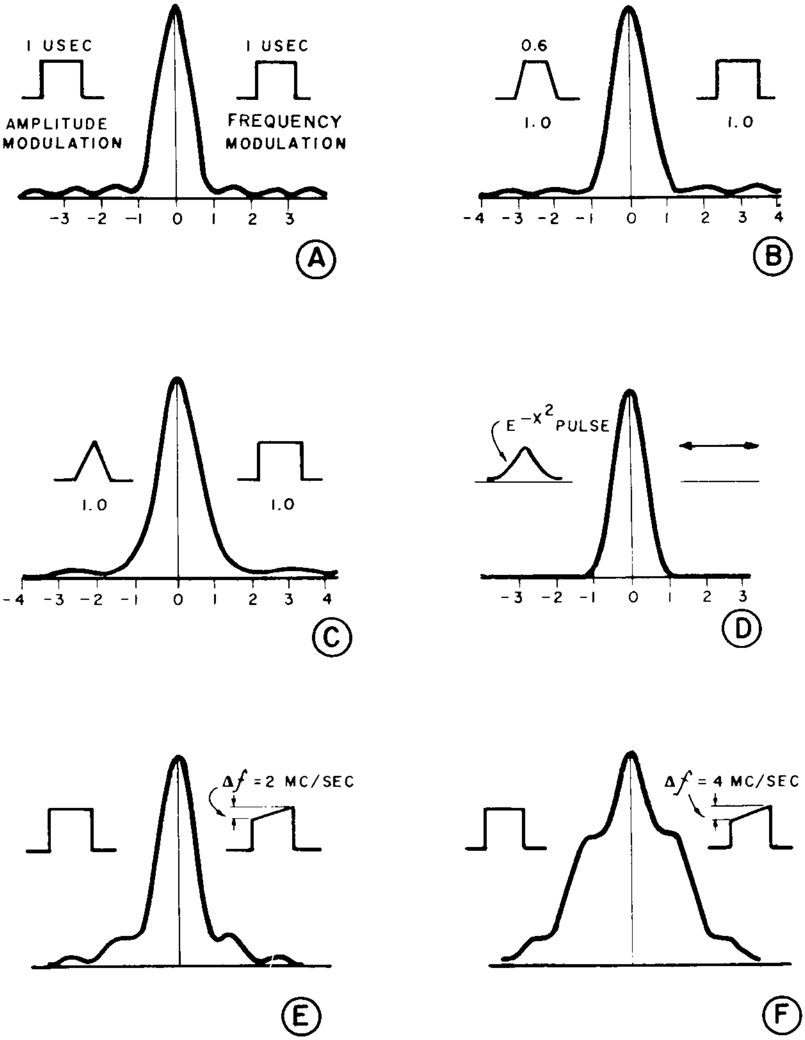
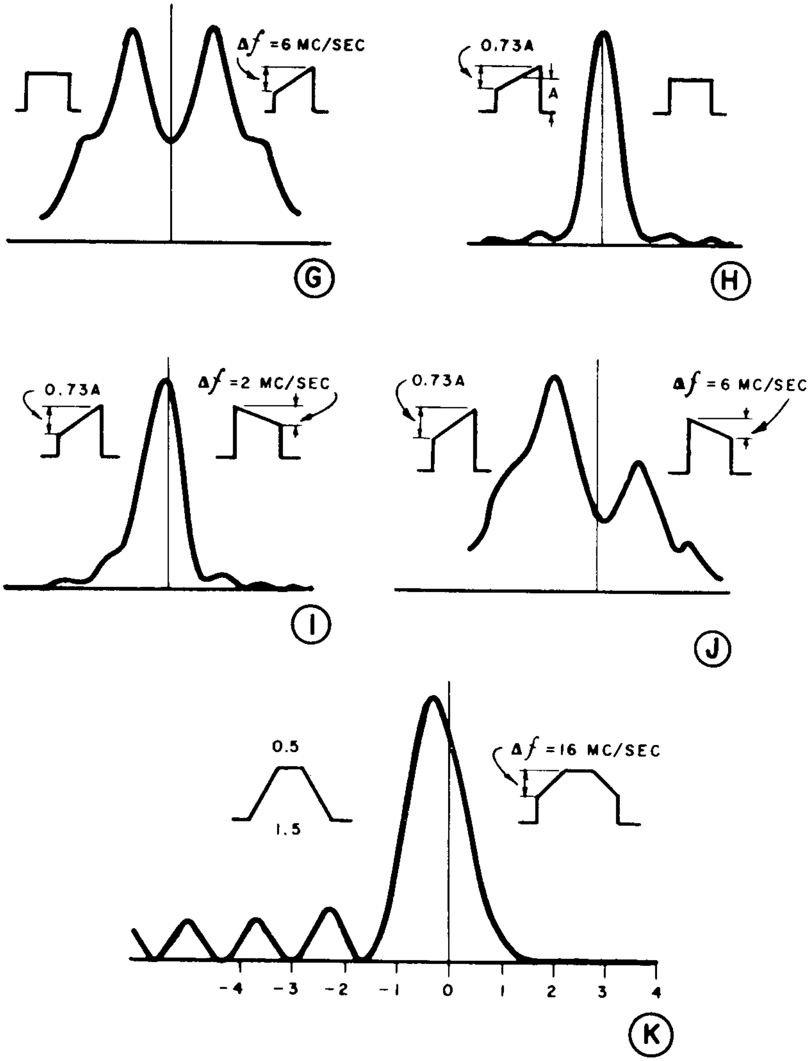


Figure 16. Representative Pulse Spectra



Representative Pulse Spectra (continued).

B. Use of the Spectrum Analyzer as a Sensitive Receiver.

Another important use of the spectrum analyzer is as a sensitive detector in bench test work. The spectrum analyzer is far more sensitive than a crystal or bolometer detector, and can therefore be used to measure a far wider range of power when used in conjunction with a calibrated r-f attenuator. This makes the analyzer particularly well adapted to standing-wave measurements, especially where high standing-wave ratios are involved. A block diagram of a typical test setup is illustrated in figure 17. By adjusting the calibrated r-f attenuator to give a constant reference output indication on the analyzer screen, the standing-wave ratio may be determined by the difference between two settings of the attenuator. If a signal generator is used as the signal source, the standing-wave ratio may be determined by noting the difference between two output readings; the calibrated r-f attenuator is therefore not required.

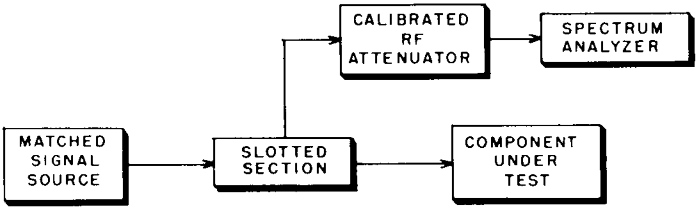


Figure 17. Typical Test Setup for Standing-wave Measurements with a Spectrum Analyzer as a Detector.

The high sensitivity of the spectrum analyzer can be used to advantage in calibrating attenuators by comparison with a standard attenuator, as shown in figure 18.

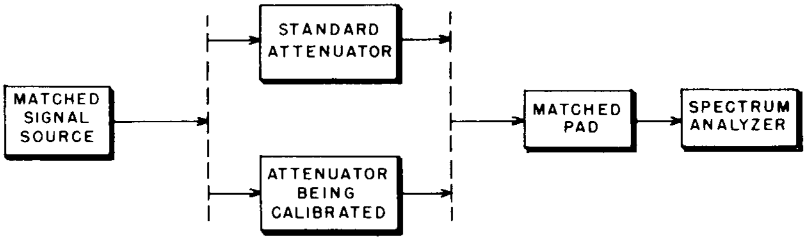


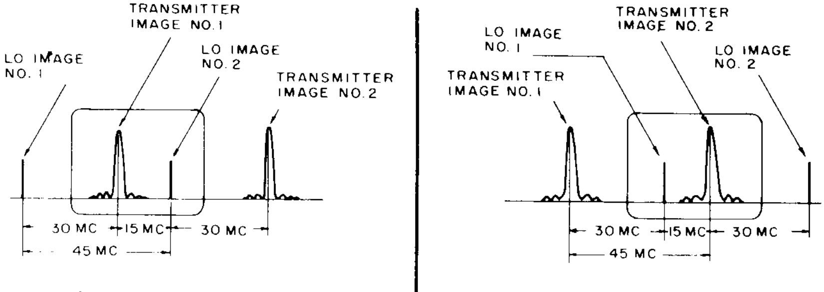
Figure 18. Typical Test Setup for Use of Spectrum Analyzer as an Attenuator Calibrator.

In measurements of these types, the spectrum analyzer has the additional advantages in that accurate tuning to the frequency of the signal source is unnecessary (because of the panoramic display) and also of providing a continuous check on the spectral purity of the source.

C. Checking AFC Action.

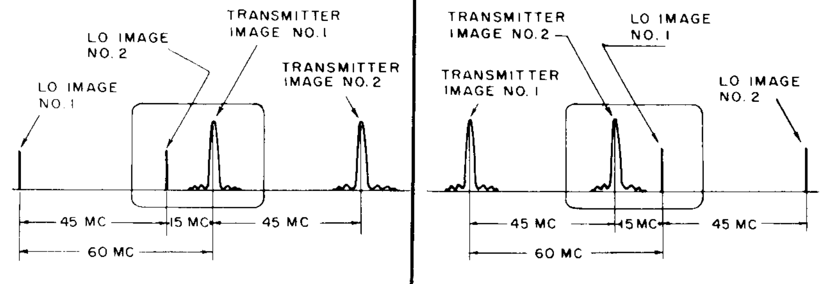
The automatic frequency control action in a radar set may be readily checked by observing the manner in which the radar local oscillator pip tracks the transmitter spectrum on the analyzer screen. However, the problem of getting the two signals to appear on the screen simultaneously requires special design techniques, inasmuch as the normal 30- or 60-mc radar intermediate frequency is greater than the maximum sweep range of the usual type of spectrum analyzer.

One solution is to select a suitable center frequency for the analyzer i-f amplifier, such that the resulting image separation insures that a radar local oscillator pip will always be close enough to a transmitter spectrum image to allow simultaneous display of the two signals on the analyzer screen. By using a frequency of 22.5 mc for the analyzer intermediate frequency, a radar local oscillator pip will be 15 mc away from a transmitter spectrum, regardless whether the radar system uses a 30- or a 60-mc intermediate frequency, or whether its local oscillator operates above or below the transmitter frequency. This is illustrated in figure 19 for each of the four possible arrangements.



A. RADAR IF = 30 MC
LO BELOW TRANSMITTER

B. RADAR IF = 30 MC
LO ABOVE TRANSMITTER

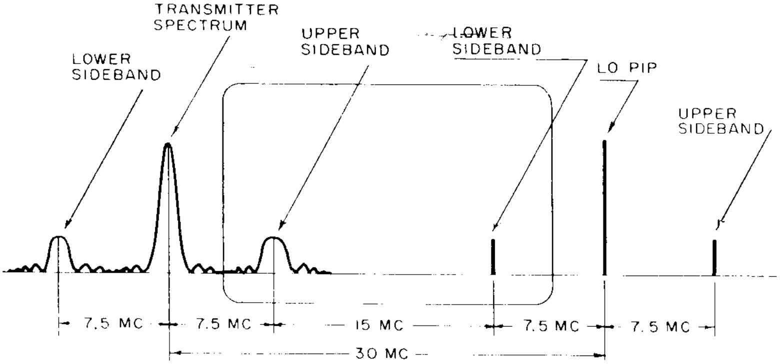


C. RADAR IF = 60 MC
LO BELOW TRANSMITTER

D. RADAR IF = 60 MC
LO ABOVE TRANSMITTER

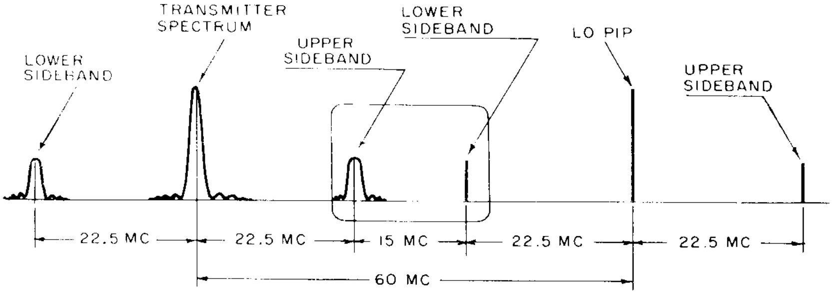
Figure 19. Transmitter and Local Oscillator Displays for 30- and 60-mc Radar IF. Spectrum Analyzer IF is 22.5 mc.

Another method for achieving simultaneous presentation of two signals which are farther apart than the maximum sweep range of the spectrum analyzer is to amplitude-modulate the analyzer local oscillator at an appropriate frequency. Sideband components of local oscillator output are thereby produced, which beat with the incoming r-f signals to produce responses on the analyzer screen. As an example, consider figure 20a where the radar intermediate frequency is assumed to be 30 mc, and the analyzer local oscillator is amplitude-modulated at a frequency of 7.5 mc. Figure 20b illustrates the case of a 60-mc radar intermediate frequency. For this case, the analyzer is amplitude-modulated at a frequency of 22.5 mc. In both illustrations, the various sideband spectra are shown reduced in amplitude.



A. RADAR IF = 30 MC

ANALYZER LOCAL OSCILLATOR
AMPLITUDE-MODULATED AT 7.5 MC



B. RADAR IF = 60 MC

ANALYZER LOCAL OSCILLATOR
AMPLITUDE-MODULATED AT 22.5 MC

Figure 20. Transmitter and Local Oscillator Displays for 30- and 60-mc Radar IF. The Spectrum Analyzer Local Oscillator is Amplitude Modulated.

D. Wavemeter Calibration.

The spectrum analyzer may be used as a sensitive detector in the calibration of cavity wavemeters. The test setup is as shown in figure 21. The cavity is tuned for maximum[7] deflection of the marker pip on the analyzer screen. The accuracy with which the cavity resonant frequency and the transmitted marker signal may thus be matched is of the order of 0.1 Q_L, where Q_L is the loaded Q of the cavity.

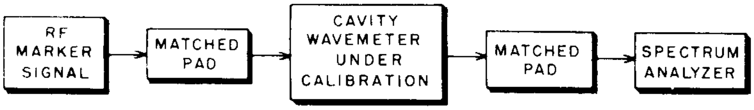


Figure 21. Test Setup for Wavemeter Calibration.

E. Detection of Spurious Transmitter Frequencies.

The panoramic presentation feature of the spectrum analyzer, plus its high sensitivity and wide tuning range, make it a valuable tool in the search for and measurement of harmonic and other extraneous outputs from a transmitter. However, since the spectrum analyzer is a superheterodyne receiver without preselection, it is susceptible to spurious responses. It is therefore necessary in this type of application to make sure that the signals being detected are true signals, and not spurious responses of the analyzer itself.

Spurious responses in the analyzer are of three general types: image responses, high-order modulation in the mixer, and i-f breakthrough. These may be identified as follows.

1. An image response may be distinguished from a true signal by the fact that its frequency appears on the opposite side of the local oscillator frequency from the true signal. Thus an image may be expected at a point on the spectrum analyzer dial spaced from the frequency of the true signal by an amount equal to twice the analyzer intermediate frequency. Whether or not the image response is above or below the indicated frequency of the true signal depends on whether the analyzer local oscillator is tracked lower or higher than the signal frequency. Hence this question must be settled in advance. For example, suppose the analyzer intermediate frequency is 160 mc, and it is known that the local oscillator is tracked higher than the signal frequency. If the analyzer indicates responses at 5,000 and 5,320 mc on the frequency dial, it is apparent that the 5,320-mc indication is the true frequency of the signal, and that the 5,000-mc response is a spurious image.

---

[7] A transmission cavity is assumed here. For a reaction cavity, the adjustment would be for minimum height of the marker pip on the analyzer screen.

2. High-order modulation in the mixer results from the fact that the mixer is a nonlinear element and therefore contains in its output frequencies comprising sums and differences of multiples of the signal and local oscillator frequencies. When any of these output frequencies falls within the passband of the analyzer intermediate-frequency amplifier, a spurious response occurs. To identify these so-called harmonic responses, it is necessary to make use of the following formulas:

Where the analyzer local oscillator is tracked higher than the signal frequency,

$$f_{dial} = \frac{n}{m}\left[f - \frac{f_i}{n}\,(m \pm 1) \right] \tag{11}$$

and where the analyzer local oscillator is tracked lower than the signal frequency,

$$f_{dial} = \frac{n}{m}\left[f + \frac{f_i}{n}\,(m \pm 1) \right] \tag{12}$$

where f_{dial} is the analyzer dial setting at which point a harmonic response is found,

f is the true signal frequency,

n is an integer indicating the order of the multiple of the signal frequency,

m is an integer indicating the order of the multiple of the local oscillator frequency, and

f_i is the analyzer intermediate frequency.

Thus, if a spectrum analyzer having a high-side local oscillator is being used with a transmitter operating at 3,000 mc, and indicates outputs at 1,787 and 1,893 mc, it is apparent from equation (11) that these are spurious responses (corresponding to $n=2$ and $m=3$) and not extraneous transmitter outputs.

3. I-f breakthrough is caused by a strong signal at the intermediate frequency reaching the i-f amplifier in spite of the shielding and selectivity of the radio-frequency circuitry. The response on the analyzer screen due to this type of signal remains stationary as the frequency, to which the analyzer is tuned, is changed.

F. Use of the Spectrum Analyzer to Determine Squegging of Oscillators and Regeneration in Power Amplifiers.

Squegging of an oscillator is characterized by periodic interruption of the oscillations at an audio or radio-frequency rate. Hence the spectrum of a squegging oscillator resembles the characteristic spectrum of a pulse-modulated wave, and therefore contains sideband components in addition to the desired oscillation frequency. The spectrum analyzer provides a handy means of checking the spectral purity of the output of a continuous-wave oscillator in order to determine whether it is squegging.

The spectrum analyzer may also be used to determine whether parasitic oscillations are present in a power amplifier. The method is similar to that for checking a transmitter for spurious outputs, as discussed in paragraph E.

G. Adjustment of Balanced Modulators.

The spectrum analyzer may be used as an aid in making adjustments on balanced modulators for minimum transmission of the carrier. It is merely necessary to tune the analyzer to the carrier frequency, and then adjust the balance of the modulator for minimum height of the carrier pip on the analyzer screen.

H. Checking the Modulation Characteristics of a Video-modulated Transmitter.

The over-all modulation characteristic of a video-modulated transmitter may be checked using a spectrum analyzer in the test setup of figure 22. For rough checking, the video-frequency signal source is set for constant amplitude at a convenient level, and the frequency of the signal source is varied over the band. Observation of the change in height of the sideband pips as they move across the analyzer screen yields information as to the over-all modulation characteristic of the transmitting system. Accurate measurements may be made by inserting an adjustable calibrated r-f attenuator ahead of the input terminals of the spectrum analyzer and bringing the output pip to some convenient height on the analyzer screen. By keeping this height constant at each frequency and reading the change in attenuation required to accomplish this, the modulation characteristic of the transmitter is thus quantitatively measured. The advantage of the spectrum analyzer as an indicator for this type of measurement lies in the fact that, due to the panoramic presentation, it is unnecessary to retune the receiver at each frequency.

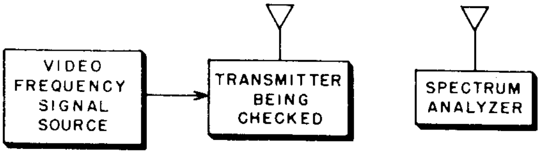


Figure 22. Test Setup for Checking Modulation Characteristics of a Video-modulated Transmitter.

I. The Use of the Spectrum Analyzer as an Aid in Tuning Oscillators.

The spectrum analyzer is particularly well adapted for use as a comparator where it is desired to accurately tune an oscillator to a given frequency. The desired frequency is displayed as a reference marker on the analyzer screen and the oscillator is tuned until its signal pip is coincident with that of the desired signal. Care must be taken that neither pip is a spurious response of the analyzer (see paragraph E).

The precision with which coincidence of two c-w signals is indicated by the spectrum analyzer is very high. If the two signals are stable and if the pips are adjusted for equal heights on the analyzer screen, the error in the frequency comparison is less than the resolution of the analyzer. Thus, if the analyzer has a resolution of 25 kc, two 10-kmc signals can be compared with an error of less than 0.00025 percent.

APPENDIX A

Determination of the Degradation of Analyzer Sensitivity and Resolution as a Function of Sweep Rate

Let us make the assumption that the analyzer selectivity curve is given by a Gaussian error function. This is true to a good approximation for an i-f amplifier composed of several synchronously-tuned stages.

The steady-state voltage amplitude response (normalized) is then

$$H(\omega) = \exp\left(\frac{-\ln 2}{2\pi^2}\right)\left(\frac{\omega - \omega_0}{B}\right)^2 \qquad (1)$$

where B is the 3-db bandwidth in cps and ω_0 is the angular center frequency (see figure A1).

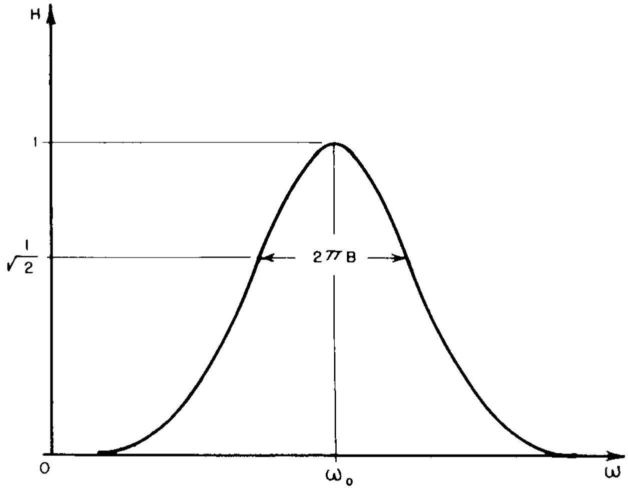


Figure A1. Normalized Gaussian Amplitude Response Curve Representing Selectivity of Analyzer I-F Amplifier.

The swept signal voltage may be represented by

$$e(t) = \epsilon^{j\theta} \qquad (2)$$

where θ is the instantaneous phase angle; hence the instantaneous angular frequency is given by

$$\omega_i = \frac{d\theta}{dt} \qquad (3)$$

Now, assuming a linearly swept signal as shown in figure A2, where $\frac{F}{T}$

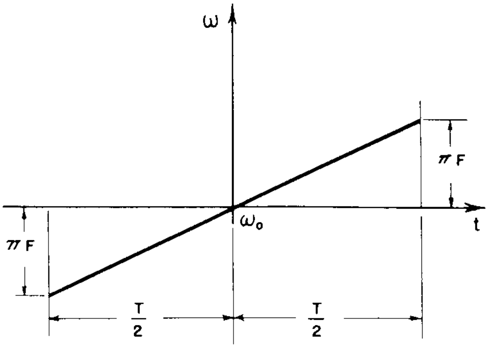


Figure A2. Time Variation of Swept Signal Frequency.

is the sweep rate in cycles per second per second, and $\omega = \omega_o$ at $t = 0$, we have for ω_i;

$$\omega_i = \omega_o + \frac{2\pi F}{T} t \tag{4}$$

Therefore, from equation (3),

$$\theta = \int \omega_i \, dt = \omega_o \, t + \frac{\pi F}{T} t^2 \tag{5}$$

Substituting into equation (2);

$$e(t) = \exp j \left(\omega_o t + \frac{\pi F}{T} t^2 \right) \tag{6}$$

The frequency spectrum of $e(t)$ is given by the Fourier transform

$$E(\omega) = \int_{-\infty}^{\infty} e(t) \, \epsilon^{-j\omega t} \, dt \tag{7}$$

$$= \int_{-\infty}^{\infty} \epsilon^{j\left[(\omega_o - \omega)\, t + \frac{\pi F}{T} t^2\right]} \, dt \tag{8}$$

Equation (8) may be evaluated as follows: Consider the integral

$$\int_{\infty}^{\infty} \epsilon^{j(at^2 + bt)} \, dt \tag{9}$$

Completing the square in the exponential,

$$at^2 + bt = a\left(t + \frac{b}{2a}\right)^2 - \frac{b^2}{4a} \tag{10}$$

Let

$$x = t + \frac{b}{2a} \tag{11}$$

whence

$$dx = dt \tag{12}$$

Substituting in equation (9) we obtain

$$\int_{-\infty}^{\infty} \epsilon^{j(at^2 + bt)}\, dt = \epsilon^{-j\frac{b^2}{4a}} \int_{-\infty}^{\infty} \epsilon^{jax^2}\, dx = 2\epsilon^{-j\frac{b^2}{4a}} \int_{0}^{\infty} \epsilon^{jax^2}\, dx \tag{13}$$

Now, equation (13) is a definite integral which may be readily evaluated by applying No. 492 of Pierce's Short Table of Integrals, viz.

$$\int_{0}^{\infty} \epsilon^{-a^2x^2}\, dx = \frac{1}{2a}\sqrt{\pi} \tag{14}$$

Thus, equation (13) becomes

$$\int_{-\infty}^{\infty} \epsilon^{j(at^2 + bt)}\, dt = \sqrt{\frac{j\pi}{a}}\, \epsilon^{j\frac{b^2}{4a}} \tag{15}$$

Making the appropriate substitutions in equation (8), we obtain

$$E(\omega) = \sqrt{\frac{jT}{F}} \exp - j\frac{T}{4\pi F}(\omega_0 - \omega)^2 \tag{16}$$

The output voltage transient of the Gaussian amplifier is given by the inverse Fourier transform

$$V(t) = \frac{1}{2\pi}\int_{-\infty}^{\infty} E(\omega)\, H(\omega)\, \epsilon^{j\omega t}\, d\omega \tag{17}$$

$$= \frac{1}{2\pi}\sqrt{\frac{jT}{F}} \int_{-\infty}^{\infty} \epsilon^{-j\frac{T}{4\pi F}(\omega_0 - \omega)^2}\, \epsilon^{-\left(\frac{\ln 2}{2\pi^2 B^2}\right)\left(\omega - \omega_0\right)^2}\, \epsilon^{j\omega t}\, d\omega \tag{18}$$

The evaluation of equation (18) may be simplified by making the following substitutions: Let

$$c = \frac{T}{4\pi F} \tag{19}$$

and

$$d = \frac{\ln 2}{2\pi^2 B^2} \tag{20}$$

also let

$$K = \frac{1}{2\pi}\sqrt{\frac{jT}{F}} \tag{21}$$

then equation (18) becomes

$$V(t) = K\int_{-\infty}^{\infty} \epsilon^{-d(\omega - \omega_o)^2}\, \epsilon^{-jc(\omega_o - \omega)^2}\, \epsilon^{j\omega t}\, d\omega \tag{22}$$

$$= K\epsilon^{-\omega_o^2(d + jc)} \int_{-\infty}^{\infty} \epsilon^{\left\{-(d + jc)\,\omega^2 + [2d\,\omega_o + j\,(2c\,\omega_o + t)]\,\omega\right\}}\, d\omega \tag{23}$$

Let

$$Z_1 = d + jc \tag{24}$$

and

$$Z_2 = 2d\omega_o + j\ (2c\,\omega_o + t) \tag{25}$$

Substituting in equation (23), we obtain

$$V(t) = K\epsilon^{-\omega_o^2 Z_1} \int_{-\infty}^{\infty} \epsilon^{-Z_1\omega^2 + Z_2\omega}\, d\omega \tag{26}$$

Now

$$-Z_1\,\omega^2 + Z_2\,\omega = -Z_1\left(\omega - \frac{Z_2}{2Z_1}\right)^2 + \frac{Z_2^2}{4Z_1} \tag{27}$$

hence

$$V(t) = K\epsilon^{-\omega_o^2 Z_1}\, \epsilon^{\frac{Z_2^2}{4Z_1}} \int_{-\infty}^{\infty} \epsilon^{-Z_1\left(\omega - \frac{Z_2}{2Z_1}\right)^2} d\omega \tag{28}$$

Now let

$$W = \omega - \frac{Z_2}{2Z_1} \tag{29}$$

whence

$$dW = d\omega \tag{30}$$

$$\therefore V(t) = K\epsilon^{-\omega_o^2 Z_1}\, \epsilon^{\frac{Z_2^2}{4Z_1}} \int_{-\infty}^{\infty} \epsilon^{-Z_1 W^2}\, dW \tag{31}$$

Again applying equation (14), we obtain for the integral factor of equation (31)

$$\int_{-\infty}^{\infty} \epsilon^{-Z_1 W^2} dW = 2\int_{0}^{\infty} \epsilon^{-Z_1 W^2} dW = \sqrt{\frac{\pi}{Z_1}} \qquad (32)$$

Thus, we have for equation (31),

$$V(t) = K\sqrt{\frac{\pi}{Z_1}}\, \epsilon^{-\omega_o^2 Z_1}\, \epsilon^{\frac{Z_2^2}{4 Z_1}} \qquad (33)$$

$$= \frac{1}{2\pi}\sqrt{\frac{j\pi T}{F(d+jc)}} \exp\left\{\frac{[2d\,\omega_o + j\,(2c\,\omega_o + t)]^2}{4\,(d+jc)} - \omega_o^2\,(d+jc)\right\}$$

$$(34)$$

Now, it must be remembered that we are actually interested in determining the envelope, $A(t)$, of the real part of $V(t)$. Since $V(t)$ is complex in our case, it may be represented by

$$V(t) = |V(t)|\,\epsilon^{j\phi(t)} \qquad (35)$$

$$\therefore Re\,\{\,V(t)\,\} = |\,V(t)\,|\cos\phi\,(t) \qquad (36)$$

which has the envelope

$$A(t) = |V(t)| \qquad (37)$$

Now equation (34) has the form

$$V(t) = Z\exp\,[\phi_1\,(t) + j\,\phi_2\,(t)] \qquad (38)$$

where Z is complex, and $\phi_1(t)$ and $\phi_2(t)$ are real. Hence, from equation (37),

$$A(t) = |\,Z\,|\exp\phi_1\,(t) \qquad (39)$$

Now

$$Z = \frac{1}{2\pi}\sqrt{\frac{\pi T}{F}}\cdot\sqrt{\frac{j}{d+jc}} \qquad (40)$$

$$\therefore \left|Z\right| = \frac{1}{2\pi}\sqrt{\frac{\pi T}{F}}\,(c^2+d^2)^{-1/4} \qquad (41)$$

also

$$\phi_1\,(t) + j\,\phi_2\,(t) = \frac{[2d\,\omega_o + j\,(2c\,\omega_o + t)]^2}{4\,(d+jc)} - \omega_o^2\,(d+jc)$$

$$(42)$$

whence

$$\phi_1(t) = \frac{-dt^2}{4(c^2+d^2)} \tag{43}$$

Substituting equations (41) and (43) into equation (39), we obtain

$$A(t) = \frac{1}{2\pi}\sqrt{\frac{\pi T}{F}}\,(c^2+d^2)^{-1/4}\ \exp\frac{-d}{4(c^2+d^2)}\,t^2 \tag{44}$$

It will be noted that $A(t)$ has the form of the Gaussian error function. Now let a be the maximum amplitude of $A(t)$. Thus

$$a = \frac{1}{2\pi}\sqrt{\frac{\pi T}{F}}\,(c^2+d^2)^{-1/4} \tag{45}$$

Substituting equations (19) and (20) into equation (45), we obtain, for a

$$a = \left[1 + \left(\frac{2\ln 2}{\pi}\right)^2\left(\frac{F}{TB^2}\right)^2\right]^{-1/4} \tag{46}$$

$$= \left[1 + 0.195\left(\frac{F}{TB^2}\right)^2\right]^{-1/4} \tag{47}$$

The resolution of the spectrum analyzer is the apparent bandwidth of the output transient as viewed on the screen. This is given by

$$R = \frac{F}{T}\cdot\Delta t \tag{48}$$

where Δt is the time required to sweep between the 3-db points of the transient envelope. Referring to equation (44), it follows that

$$\frac{1}{\sqrt{2}} = \exp\frac{-d}{4(c^2+d^2)}\left(\frac{\Delta t}{2}\right)^2 \tag{49}$$

whence

$$\Delta t = \left[(8\ln 2)\left(\frac{c^2+d^2}{d}\right)\right]^{1/2} \tag{50}$$

Substituting equations (19) and (20) into equation (50) yields

$$\Delta t = 4\pi B\left[\left(\frac{T}{4\pi F}\right)^2 + \left(\frac{\ln 2}{2\pi^2 B^2}\right)^2\right]^{1/2} \tag{51}$$

Therefore, from equation (48),

$$\frac{R}{B} = \left[1 + \left(\frac{2\ln 2}{\pi}\right)^2\left(\frac{F}{TB^2}\right)\right]^{1/2} \tag{52}$$

$$= \left[1 + 0.195\left(\frac{F}{TB^2}\right)^2\right]^{1/2} \tag{53}$$

APPENDIX B

Determination of Various Modulation Spectra

Part 1. Amplitude Modulation. See figure B1.

Let the carrier be represented by

$$e_c = \epsilon^{j\omega_c t} \tag{1}$$

and the modulating function by

$$e_m = A_m\ (t) \tag{2}$$

then the modulated wave is given by

$$e(t) = A_m\ (t)\ \epsilon^{j\omega_c t} \tag{3}$$

In the general case, Am(t) is complex, and therefore may be represented in the interval $-\pi/\omega_m < t < \pi/\omega_m$ by the complex Fourier series

$$e_m = A_m\ (t) = \sum_{n=-\infty}^{\infty} C_n\ \epsilon^{jn\omega_m t} \tag{4}$$

where

$$C_n = \frac{\omega_m}{2\pi} \int_{-\pi/\omega_m}^{\pi/\omega_m} A_m\ (t)\ \epsilon^{-jn\omega_m t}\ dt \tag{5}$$

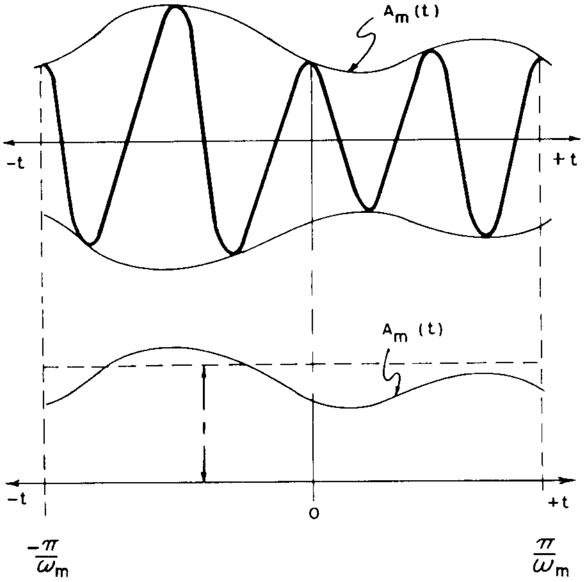


Figure B1. Amplitude Modulation.

Hence equation (3) becomes, assuming $\omega_c >> \omega_m$,

$$e(t) = \sum_{n=-\infty}^{\infty} C_n \epsilon^{j(\omega_c + n\omega_m)t} \tag{6}$$

For the special care of single-tone amplitude modulation

$$A_m(t) = 1 + m \cos \omega_m t \tag{7}$$

Therefore equation (3) becomes:

$$e(t) = \epsilon^{j\omega_c t} + \frac{m}{2} \epsilon^{j(\omega_o + \omega_m)t} + \frac{m}{2} \epsilon^{-j(\omega_o - \omega_m)t} \tag{8}$$

Part 2. Frequency Modulation.

Note: Since the analysis of complex-wave frequency modulation is extremely involved, yielding highly complicated spectrum equations, only the single-tone case will be considered.

In single-tone frequency modulation, the frequency of the carrier is caused to vary in a sinusoidal manner at a rate given by f_m, the frequency of the modulating function. The maximum frequency deviation Δf_c, of the carrier, varies with the amplitude of the modulating wave; and is limited by law or the system design to a certain maximum value, e.g. 75 kc in commercial f-m broadcasting. The instantaneous frequency of the carrier may thus be expressed by

$$f_c = f_o + \Delta f \cos \omega_m t \tag{9}$$

where f_o is the frequency of the unmodulated carrier, and $\omega_m = 2\pi f_m$, the angular frequency of the modulating wave.

The carrier may be represented by

$$e = \epsilon^{j\theta} \tag{10}$$

where

$$\theta = \int \omega \, dt = 2\pi \int f \, dt \tag{11}$$

$$= 2\pi \int_0^t (f_o + \Delta f \cos \omega_m t) \, dt \tag{12}$$

$$= 2\pi f_o t + \frac{\Delta f}{f_o} \sin \omega_m t \tag{13}$$

$$\therefore e = \exp\left[j \left(2\pi f_o t + \frac{\Delta f}{f_o} \sin \omega_m t\right) \right] \tag{14}$$

Let us define the modulation index as follows: Modulation Index

$$= \beta = \frac{\Delta f}{f_o} \tag{15}$$

Thus

$$e = \epsilon^{j\beta \sin \omega_m t} \epsilon^{j\omega_o t} \tag{16}$$

Equation (16) may be expressed as a Fourier series as follows:

$$e = \sum_{n=-\infty}^{\infty} C_n \epsilon^{jn\omega_m t} \epsilon^{j\omega_o t}, \tag{17}$$

where

$$C_n = \frac{\omega_m}{2\pi} \int_{-\pi/\omega_m}^{\pi/\omega_m} \epsilon^{j\beta \sin \omega_m t} \epsilon^{-n\omega_m t} \, dt \tag{18}$$

Let

$$\omega_m t = x \tag{19}$$

Then

$$C_n = \frac{1}{2\pi} \int_{-\pi}^{\pi} \epsilon^{(j\beta \sin x - nx)} \, dx \tag{20}$$

$$= J_n (\beta) \tag{21}$$

$$\therefore e = \sum_{n=-\infty}^{\infty} J_n (\beta) \, \epsilon^{j(\omega_o + n\omega_m)t} \tag{22}$$

$$\therefore Re \left\{ e \right\} = \sum_{n=-\infty}^{\infty} J_n (\beta) \cos 2\pi \left(f_o + n f_m\right) t \tag{23}$$

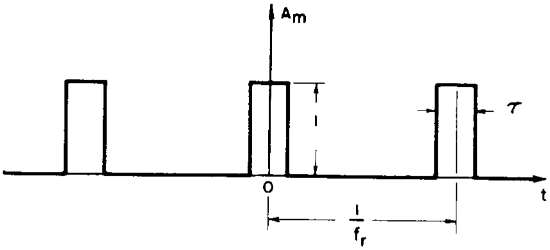


Figure B2. Envelope of Pulse-modulated Carrier.

Part 3. Pulse Modulation.

Referring to equations (3) through (6) and figure B1, let $A_m(t)$ be as shown in figure B2. Thus,

$$A_m(t) = 1 \text{ for } -\frac{\tau}{2} < t < \frac{\tau}{2}, \qquad (24)$$

$$A_m(t) = 0 \text{ elsewhere in the interval } -\tfrac{1}{2} f_r \text{ to } \tfrac{1}{2} f_r$$

Substituting in equation (5) we have

$$C_n = f_r \int_{-\frac{1}{2} f_r}^{\frac{1}{2} f_r} A_m(t)\, \epsilon^{-j2\pi n f_r t}\, dt \qquad (25)$$

$$= f_r \int_{-\tau/2}^{\tau/2} \epsilon^{-j2\pi n f_r t}\, dt = -\frac{1}{j\,2\pi n}\left(\epsilon^{-jn\pi f_r \tau} - \epsilon^{jn\pi f_r \tau}\right) \qquad (26)$$

$$= \frac{\sin n\pi f_r \tau}{n\pi} = \tau f_r \frac{\sin n\pi f_r \tau}{n\pi f_r \tau} \qquad (27)$$

Equation (6) becomes

$$e(t) = \tau f_r \sum_{-\infty}^{\infty} \frac{\sin n\pi f_r \tau}{n\pi f_r \tau}\, \epsilon^{j2\pi(f_c + nf_r)t} \qquad (28)$$

$$\therefore Re\left\{e(t)\right\} = \tau f_r \sum_{-\infty}^{\infty} \frac{\sin n\,\pi f_r \tau}{n\,\pi f_r \tau} \cos 2\pi\,(f_c + n f_r)\, t \qquad (29)$$

SPECTRUM ANALYZERS
BY
POLARAD

Polarad Electronics Corporation produces a complete line of spectrum analyzers. A program of constant research and development makes Polarad an outstanding leader in the field of spectral displays. Many years of specialization and rigid quality standards have resulted in accurate and reliable spectrum analyzers designed to satisfy the most challenging requirements. Polarad's spectrum analyzers have gained wide acceptance in military laboratories as well as in leading commercial laboratories and manufacturing plants.

Polarad spectrum analyzers currently available are briefly described in the following pages.

SPECTRUM ANALYZER

Model TSA 10 mc to 44,000 mc

— high sensitivity —
— accurate frequency calibration —
— internal frequency marker —

1 kc to 80 kc variable resolution

Model TSA

APPLICATIONS

- Displays the power spectrum of modulated signals (amplitude, frequency, or pulse modulation).
- Detects and measures the frequency of low-level r-f signals.
- Checks magnetron output spectrum and determines width of main lobe, double moding and misfiring.
- Compares two r-f signals having a small frequency separation.
- Measures attenuation, insertion loss and gain of r-f components.
- Sensitive indicator for VSWR measurements.
- Measures bandwidth of noise generators.

FEATURES

- Single knob UNIDIAL® tuning control.
- Direct-reading linear frequency dial.
- Adjustable frequency dispersion.
- Self-contained frequency marker for measuring small frequency differences.
- Tuning of microwave klystron oscillators accomplished by non-contacting shorts, assuring long equipment life.
- Wide range of sweep speeds.
- Five-inch cathode-ray tube display.
- Electronically regulated power supplies.
- Internal variable-frequency marker.
- Logarithmic display for relative amplitude measurement over a large dynamic range.
- Video filter provided for observation of closely spaced signals.

SPECIFICATIONS

Plug-in R-F Tuning Units

Model No.	Frequency Range in mc	Sensitivity in —dbm	R-F Attenuator Range	Accessories Supplied:		Input Connection
				Description	Part No.	
STU-1B	10 to 400 350 to 1,000	90 to 105 88 to 95	0 to 100 db 0 to 100 db	patch cable r-f cable	A24845 BP12551	Type N
STU-2B	910 to 2,200 1,980 to 4,560	85 to 95 75 to 90	0 to 100 db 0 to 100 db	patch cable	BP12551 A24845	Type N
STU-3B	4,370 to 11,000 8,900 to 22,000	77 to 90 65 to 85	0 to 100 db use external attenuator above 12.4 kmc	patch cable Type N adapter wrench kit r-f cable	A24845 SIJ1700 A25109 BP12551	Type N
				mixer-to-waveguide adapter for 12.4 kmc to 18 kmc	C20947	UG-541/U choke flange for RG-91/U waveguide
				mixer-to-waveguide adapter for 18 kmc to 22 kmc	B24550	UG-425/U cover flange for RG-53/U waveguide
STU-4B	21,000 to 33,000	57 to 75	external attenuator			UG-425/U cover flange for WR-34 waveguide
				waveguide adapter for 21 kmc to 26.5 kmc	B22330	UG-425/U to UG-381/U cover flange for WR-34 to WR-96 waveguide
				waveguide adapter for 26.5 kmc to 33 kmc	B22331	UG-425/U to UG-425/U cover flange for WR-34 to RG-53/U waveguide
STU-5B	33,000 to 44,000	50 to 65	external attenuator			UG-383/U cover flange for RG-97/U waveguide
				adapter assembly	B146207	UG-383/U to UG-599/U cover flange for RG-97/U to RG-96/U waveguide
				adapter assembly	B146208	UG-383/U to UG-600/U choke flange for RG-97/U to RG-96/U waveguide

(1) Sensitivity = Signal + Noise = 2 x Noise at minimum resolution and dispersion

(2) Specifications subject to change without notice.

Display and Power Supply Unit Model DU-1A

Spectrum Display	Signal amplitude on vertical axis (log or linear) versus frequency on horizontal axis.
Logarithmic Display	3 db per graticule, to 24 db.
Variable Bandwidth	1 kc to 80 kc.
Sweep Frequency Rate	1 to 30 cps, adjustable.
Frequency Dispersion:	
Below 55 mc tuning range	100 kc to 5 mc, adjustable.
Above 55 mc tuning range	150 kc to 25 mc, adjustable.
RF Attenuation Range	0 to 100 db, 10 mc to 12.4 kmc.
IF Attenuation Range	0 to 50 db continuously variable.
Maximum Power Input	250 milliwatts.
Synchronization	External, line frequency, or free running.
Variable Marker Oscillator Range	± 14 mc.
Facilities for Camera Mounting	Provided on CRT bezel.
CRT Graticule Illumination	Edge lighting provided.

Display Tube	5 inch flat face CRT.
Power Requirements:	
Model TSA	115/230 vac, ± 10%, 50/60 cps, 500 watts.
Model TSA-F	115/230 vac, ±10%, 50-1000 cps, 500 watts.
Dimensions	18¾" wide x 20½" high x 25¾" deep. Flush panel mounting available.
Weight	135 lbs, including one tuning unit.

Accessories supplied:

1. One wrench kit No. A25109.
2. One amber filter No. B27336-1.
3. One power cable No. B111144.
4. Dust covers for tuners when more than one r-f tuning unit is ordered.
6. Handbook on "Spectrum Analyzer Techniques".
7. Instruction manual.

Accessories available:

1. Model DA-4 open channel instrument dolly for convenient handling of equipment.
2. Model SB-1, rack-mounting brackets for mounting the Model TSA with the cabinet partially projecting from front edge of rack.
3. Model SB-2, rack-mounting brackets for mounting the Model TSA with its control panel flush with front edge of rack.
4. Switching Unit allows operation of two or more r-f tuning units without plugging the units in separately.

COMBINATION SYNCHROSCOPE - SPECTRUM ANALYZER

Model TSA-S 10 mc to 44,000 mc

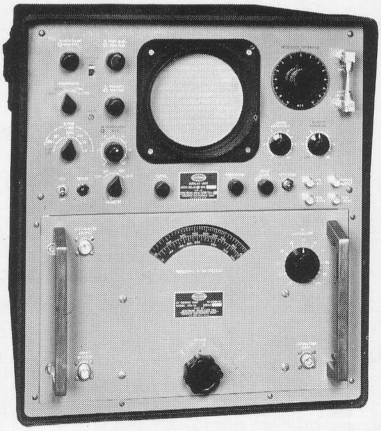
Displays spectrum amplitude as function of frequency. Wide choice of bandwidths. Calibrated triggered sweeps.

APPLICATIONS

- Complete signal analysis (AM, FM or pulse) as a function of time (synchroscope operation) as well as of frequency (spectrum analysis operation).
- Measurements of pulse repetition rates, pulse widths and pulse rise times.
- Measurement of spectral characteristics of pulse-modulated signals.
- Sensitive pulse and cw receiver applications, such as propagation studies and antenna pattern plots.
- Waveform monitoring.
- FM identification and measurement.
- Checking of microwave oscillators, including magnetrons and klystrons, for pulling, double-moding and other types of malfunctioning.
- Detection and identification of spurious AM and FM signals.
- Simultaneous observation of several signals, such as tracking of signals within a radar system.
- Measurements of microwave component characteristics, such as attenuation, insertion loss, gain and VSWR.
- Countermeasures analysis.

FEATURES

- Linear frequency calibration, with UNIDIAL® tuning of microwave oscillators.
- Non-contacting shorts in tuning cavities, assuring long equipment life and noise-free tuning.
- Low i-f amplifier noise figure, contributing to high sensitivity.
- Wide range of bandwidths for optimized sensitivity and bandwidth characteristics.
- Triggered, calibrated sweep and video delay.
- Internal, external, and power line trigger and sync operation.
- Self-contained frequency marker, for measuring small frequency differences.
- Video, sweep, and trigger outputs available at front panel jacks for x-y recording and triggering.



Model TSA-S

SPECIFICATIONS

Plug-in R-F Tuning Units

Model No.	Frequency Range in mc	Sensitivity* in —dbm	R-F Attenuator Range	Accessories Supplied: Description	Accessories Supplied: Part No.	Input Connection
STU-1B	10 to 400 350 to 1,000	90 to 105 88 to 95	0 to 100 db 0 to 100 db	patch cable r-f cable	A24845 BP12551	Type N
STU-2B	910 to 2,200 1,980 to 4,560	85 to 95 75 to 90	0 to 100 db 0 to 100 db	r-f cable patch cable	BP12551 A24845	Type N
STU-3B	4,370 to 11,000 8,900 to 22,000	77 to 90 65 to 85	0 to 100 db use external attenuator above 12 kmc	patch cable Type N adapter wrench kit r-f cable	A24845 SIJ1700 A25109 BP12551	Type N
				mixer-to-waveguide adapter for 12 kmc to 18 kmc	C20947	UG-541/U choke flange for RG-91/U waveguide
				mixer-to-waveguide adapter for 18 kmc to 22 kmc	B24550	UG-425/U cover flange for RG-53/U waveguide
STU-4B	21,000 to 33,000	57 to 75	external attenuator			UG-425/U cover flange for WR-34 waveguide
				waveguide adapter for 21 kmc to 26.5 kmc	B22330	UG-425/U to UG-381/U cover flange for WR-34 to WR-96 waveguide
				waveguide adapter for 26.5 kmc to 33 kmc	BP22331	UG-425/U to UG-425/U cover flange for WR-34 to RG-53/U waveguide
STU-5B	33,000 to 44,000	50 to 65	external attenuator			UG-383/U cover flange for RG-97/U waveguide
				adapter assembly	B146207	UG-383/U to UG-599/U cover flange for RG-97/U to RG-96/U waveguide
				adapter assembly	B146208	UG-383/U to UG-600/U choke flange for RG-97/U to RG-96/U waveguide

* Sensitivity (Signal + Noise = 2 x Noise at minimum resolution and dispersion)

Sensitivity	Figures given in the above table are for a minimum discernable signal.
Frequency Dial Accuracy	± 1% of dial reading; except for Model STU-1 which is ±1% of the local oscillator frequency.
Shielding Attenuation	Greater than 100 db.

Display and Power Supply Unit, Model DU-3

Display	Signal amplitude on the vertical axis versus frequency on the horizontal axis.
Resolution, Variable	5 kc, 50 kc, 500 kc, or 5 mc, depending upon bandwidth selected.
Sweep Rate of Spectrum Analyzer	1 to 30 cps adjustable.
Sweep Periods per Screen Diameter	2 to 100,000 microseconds in six steps.
Sweep Expansion	Three screen diameters.
Frequency Dispersion:	
Below 55 mc	400 kc to 5 mc.
Above 55 mc	400 kc to 25 mc.
I-F Attenuation	0 to 50 db continuously variable.
Trigger and Syncronization	External, internal, or line frequency.
External Trigger and Sync Voltages Required	+5 volt minimum.
Vertical Output Available	+ 1 volt into 1,000 ohms impedance at maximum gain.
Horizontal Output Available	10 volts p-p into 5,000 ohms impedance.
Trigger Pulse Amplitude	+ 5. volts into 1,000 ohms impedance.
Display Tube	5 inch flat face, with graticule illumination, and bezel provided with facilities for camera mounting.
Power Requirements:	
Model TSA-S	115/230 vac ± 10% 50/60 cps 500 watts;
Model TSA-SF	115/230 vac, ±10%, 50-1000 cps, 500 watts.
Dimensions	18¾" wide x 20½" high x 25¾" deep. Flush panel rack mounting available.
Weight	135 lbs including one tuning unit.

Accessories Supplied with Basic Model DU-3A:

One wrench kit No. A25109

One amber filter No. B27336-1

One power cable No. B111144

Dust covers for tuners when more than one tuning unit is ordered

Instruction Manual for Model TSA-S

Handbook "Spectrum Analyzer Techniques"

Accessories Available:

Instrument Dolly Model DA-4	Open channel dolly for convenient handling of the equipment.
Rack Mounting Brackets Model SB-1	For mounting with the cabinet partially projecting from front edge of rack.
Rack Mounting Brackets Model SB-2	For mounting with the control panel flush with front of edge of rack.
Switching Unit	Allows operation of two or more r-f tuning units, without plugging the unit in separately.

WIDE DISPERSION SPECTRUM ANALYZER

Model TSA-W 10 mc to 44,000 mc

25 kc to 80 mc dispersion*

Logarithmic display accommodates signals within a large dynamic range.

I kc to 80 kc variable resolution

Model TSA-W

APPLICATIONS

- Spectrum analysis requiring narrow or wide dispersion range, high sensitivity and resolution.
- Measuring spectral characteristics of pulse-modulated signals.
- Simultaneous observation of several signals, such as tracking of signals within a radar system.
- Frequency-modulation identification and measurement.
- Checking microwave oscillators, including magnetrons and klystrons for pulling, doublemoding, and other types of malfunction.
- Detecting and identifying spurious signals.
- Measurements of microwave components characteristics, such as attenuation, insertion loss, gain and VSWR.
- Comparing two r-f signals having a small frequency separation.

FEATURES

- Wide frequency dispersion for displaying spectra of narrow pulses.
- High resolution, enabling analysis of wide pulses.
- Logarithmic display for relative amplitude measurements over a large dynamic range.
- Wide range marker oscillator, calibrated in frequency difference and pulse width.
- UNIDIAL® tuning of microwave oscillators.
- Improved sensitivity.
- Low i-f amplifier noise figure.
- Vernier marker oscillator dial, yielding high scale resolution.
- Effective pulse intensification circuit, for bright display.
- DC operation of sweeper and klystron filaments for minimum incidental FM.
- Sweep and video outputs provided for x-y recording.
- Video filter provided for observation of closely spaced signals.

*100 mc useable dispersion available on special order.

SPECIFICATIONS

Plug-in R-F Tuning Units

Model No.	Frequency Range in mc	Sensitivity in —dbm	R-F Attenuator Range	Accessories Supplied: Description	Accessories Supplied: Part No.	Input Connection
STU-1B	10 to 400 350 to 1,000	90 to 105 88 to 95	0 to 100 db 0 to 100 db	patch cable r-f cable	A24845 BP12551	Type N
STU-2BW	910 to 2,200 1,980 to 4,560	85 to 95 75 to 90	0 to 100 db 0 to 100 db	r-f cable patch cable	BP12551 A24845	Type N
STU-3BW	4,370 to 11,000 8,900 to 22,000	77 to 90 65 to 85	0 to 100 db use external attenuator above 12.4 kmc	patch cable Type N adapter wrench kit r-f cable	A24845 SIJ1700 A25109 BP12551	Type N
				mixer-to-waveguide adapter for 12.4 kmc to 18 kmc	C20947	UG-541/U choke flange for RG-91/U waveguide
				mixer-to-waveguide adapter for 18 kmc to 22 kmc	B24550	UG-425/U cover flange for RG-53/U waveguide
STU-4BW	21,000 to 33,000	57 to 75	external attenuator			UG-425/U cover flange for WR-34 waveguide
				waveguide adapter for 21 kmc to 26.5 kmc	B22330	UG-425/U to UG-381/U cover flange for WR-34 to WR-96 waveguide
				waveguide adapter for 26.5 kmc to 33 kmc	B22331	UG-425/U to UG-425/U to cover flange for WR-34 to RG-53/U waveguide
STU-5BW	33,000 to 44,000	50 to 65	external attenuator			UG-383/U cover flange for RG-97/U waveguide
				adapter assembly	B146207	UG-383/U to UG-599/U cover flange for RG-97/U to RG-96/U waveguide
				adapter assembly	B146208	UG-383/U to UG-600/U choke flange for RG-97/U to RG-96/U waveguide

Specifications subject to change without notice.

Display and Power Supply Unit, Model DU-2A:

Sensitivity	Figures given in the above chart are for Signal + Noise = 2 x Noise at minimum resolution and dispersion
Frequency Dial Accuracy	± 1% of dial reading; except for Model STU-1WA which is ± 1% of local oscillator frequency.
Shielding Attenuation	Greater than 100 db.
Spectral Display	Signal amplitude on the vertical axis (log or linear), versus frequency on the horizontal axis.
Logarithmic Display	3 db per graticule division, to 24 db.
Variable Bandwidth	1 kc to 80 kc, continuously variable.
Sweep Frequency Rate	1 to 30 cps adjustable.
Frequency Dispersion:	
Below 55 mc	25 kc to 5 mc;
Above 55 mc to 1,000 mc	25 kc to 25 mc;
1,000 mc to 44,000 mc	25 kc to 80 mc in 2 bands: 25 kc to 10 mc, and 1 mc to 80 mc.
I-F Attenuation Range	0 to 40 db, continuously variable.
Internal Markers	Variable marker calibrated in frequency-difference from 160 mc, in both increasing and decreasing increments, with adjustable amplitude.

Synchronization	External, free running, or line frequency.
Maximum Power Input	250 milliwatts.
CRT Display Tube	5 inch flat face, with edge lighting on graticule, and camera mounting facilities on the CRT bezel.
Power Requirements:	
Model TSA-W	115/230 vac ± 10% 50/60 cps 500 watts;
Model TSA-WF	115/230 vac ± 10% 50-1000 cps 500 watts.
Dimensions	18¾″ wide x 20½″ high x 25¾″ deep. Flush panel rack mounting available.
Weight	135 lbs with one tuning unit.

Accessories Supplied with Basic Model DU-2A:

One wrench kit No. A25109.
One amber filter No. B27336-1.
One power cable No. B111144.
Dust covers for tuners when more than one tuning unit is ordered.
Instruction Manual for Model TSA-W.
Handbook on "Spectrum Analyzer Techniques".

Accessories Available:

Instrument Dolly Model DA-4 for convenient handling of the equipment.
Rack Mounting Brackets Model SB-1 for mounting with the cabinet partially projecting from front edge of rack.
Rack Mounting Brackets Model SB-2 for mounting with the control panel flush with front edge of rack.
Switching Unit to allow operation of two or more tuning units without plugging the units in separately.

MULTI-BAND, SINGLE UNIT SPECTRUM ANALYZER

Model SA-84

Complete frequency coverage, 10 to 40,880 mc, all in one unit.

Model SA-84

APPLICATIONS

- Determining:
  - Presence and level of r-f signals.
  - R-F signal characteristics.
  - Attenuation, insertion loss and gain characteristics of r-f components.
- Checking, observing and measuring:
  - Spectrum associated with pulse-modulated signals.
  - Output spectrum of magnetrons for width of main lobe, and malfunctioning due to double-moding or misfiring.
  - The tracking of r-f components within a radar system.
- Comparing two r-f signals having a small frequency separation.
- Sensitive indicator for VSWR measurements.

FEATURES

- 10 to 40,880 mc frequency range in a single tuning unit.
- Unique band selector shows only the band in use, eliminating operator reading error.
- Expanded direct-reading slide-rule dial.
- Internal r-f attenuation, 10 to 12,400 mc.
- Stable local oscillators covering more than one octave reduce required number of frequency bands.
- Expanded frequency marker with graduations every 200 kc permits measurement of very small frequency differences.
- Provisions for multipulse spectrum decoder.
- Direct waveguide inputs in addition to Type N.
- Non-contacting shorts to tune klystron oscillator, assuring long equipment life and noiseless tuning.
- Flat 5-inch cathode-ray tube display.
- Rugged construction meets government equipment specifications including shock, environment, vibration and interference.

SPECIFICATIONS

Frequency Range	10 to 40,880 mc, covered in eight bands

Band 1	10 to 410 mc	Low frequency local oscillator
Band 2	250 to 980 mc	
Band 3	700 to 2,120 mc	
Band 4	2,000 to 4,400 mc	High frequency klystron local oscillator
Band 5	4,200 to 8,900 mc	
Band 6	6,300 to 13,500 mc	
Band 7	12,800 to 27,200 mc	
Band 8	19,250 to 40,880 mc	

Spectrum Display	Signal strength on the vertical axis versus frequency on the horizontal axis
Resolution Bandwidth (at the 3 db points)	20 kc at all frequencies
Frequency Dispersion	
10 to 55 mc	500 kc to 5 mc, adjustable
55 to 40,880 mc	500 kc to 25 mc, adjustable
Sweep Repetition Rate	1 to 30 cps adjustable
Synchronization	Internal line frequency
Spectrum Calibrator Frequency	160 mc center frqeuency with a tuning range of ±12.5 mc
Spectrum Calibrator Accuracy	±5% of the available display or ±1 mc for the maximum display
Frequency Dial Accuracy	10 to 2,000 mc, ±1% of the fundamental local oscillator frequency; above 2,000 mc, ±1%, of dial frequency.
I-F Attenuation	From 0 to 60 db, step-variable in nominal 6 db increments
Cathode-Ray Tube	5 inch, phosphor coating, flat face
Facilities for Camera Mounting	Provided on CRT bezel
CRT Graticule Illumination	Edge lighting provided
Operating Temperature Range	0 degrees C (32 degrees F) to 55 degrees C (131 degrees F)
Power Requirements	103.5 to 126.5 volts rms a-c, 50 to 1,000 cps., 380 watts power consumption
Dimensions	19⅝ high by 17⁷⁄₁₆ wide by 26⅛ inches deep
Weight	145 lbs.

Sensitivity (Signal + Noise = 2 x noise at minimum dispersion)

Frequency Range	Sensitivity in—dbm	R-F Attenuation	Flange Termination
10 to 400 mc	65 to 90	0 to 100 db	Type N
400 to 980 mc	57 to 80	0 to 100 db	Type N
1,000 to 2,000 mc	50 to 75	0 to 100 db	Type N
2,000 to 12,000 mc	65 to 90	0 to 100 db	Type N
12,000 to 40,000 mc	40 nominal	external attenuators available	Type N waveguide: UG — 419/U UG — 595/U UG — 599/U

Accessories supplied with model:

- One set of colored filters
- One wrench kit
- One alignment tool

Cable assembly	6 feet	Type N	A 109817
Cable assembly	18 inches	Type N	A 109816
Power cable			A 109818

Accessories Available:

Ku Band Attenuator	C 105314
K Band Attenuator	C 105341
Ka Band Attenuator	C 105342
Rack Mounting Brackets	
DA-3 Instrument Dolly	
Bandpass Filters	
TC-84 Transit Case	

WIDE DISPERSION SINGLE-UNIT SPECTRUM ANALYZER

Model SA-84W 10 to 40,880 mc

Complete frequency coverage, 10 to 40,800 mc, in a single unit. Choice of dispersion bandwidths for narrow and wide pulse analysis. 1 to 80 kc variable resolution. 25 kc to 80 mc dispersion range.

APPLICATIONS

- Checking, observing and precise measurement of:
  - — Spectral characteristics of wide or narrow pulses.
  - — FM characteristics.
  - — R-F signals with relatively wide frequency separation.
  - — Harmonic and spurious content of signals.
  - — Interference and leakage.
  - — Tracking of r-f components within a radar system.
- Secondary frequency standard
  - — Frequency measurement of high and low level signals – pulse, FM cw, etc.
  - — Frequency difference between two closely spaced signals.
- Sensitive, accurate indicator:
  - — Precise attenuation, insertion loss.
  - — VSWR meter with large dynamic range.

Model SA-84 W

FEATURES

- 10 to 40,880 mc frequency range in a single tuning unit.
- Calibrated dispersion over 80 mc.*
- Minimum dispersion 25 kc.
- 1 to 80 kc variable resolution.
- .01% crystal frequency calibrator markers over complete R-F range.
- Accurate i-f attenuator.
- Expanded direct-reading slide-rule dial.
- Unique band selector shows only the band in use, eliminating operator reading error.
- Internal r-f attenuation, to 12,400 mc.
- Stable local oscillators covering more than one octave reduce required number of frequency bands.
- Expanded variable frequency marker covering a range of ± 40 mc.
- Provisions for multipulse spectrum decoder.
- Direct waveguide inputs in addition to Type N.
- Non-contacting shorts to tune klystron oscillator, assuring long equipment life and noiseless tuning.
- Video filter provided for observation of closely spaced signals.

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*100 mc useable dispersion available on special order

SPECIFICATIONS

Frequency Range	10 to 40,880 mc, covered in nine bands
Band 1	10 to 240 mc
Band 2	240 to 640 mc
Band 3	640 to 1,440 mc
Band 4	1,040 to 2,240 mc
Band 5	2,000 to 4,400 mc
Band 6	4,200 to 8,900 mc
Band 7	6,300 to 13,500 mc
Band 8	12,800 to 27,200 mc
Band 9	19,250 to 40,880 mc
Spectrum Display	Signal strength, log or lin, on the vertical axis versus frequency on the horizontal axis
Logarithmic Display	Approx. 3 db per graticule division, to 24 db. Maximum log display 36 db (40 db available on special order)
Resolution Bandwidth (at the 3db points)	1 to 80 kc variable
Frequency Dispersion	
10 to 240 mc	25 kc to 10 mc, adjustable
240 to 40,880 mc	25 kc to 80 mc, adjustable (2 ranges)
Sweep Rate	1 to 30 cps adjustable
Synchronization	Internal line frequency, external, or free running
Crystal Calibrator	
10 mc up to 240 mc	1, 10 mc
240 to 2,240 mc	50 mc
2,000 to 40,880	100 mc
Accuracy	0.01%
Variable Marker Range	±40 mc
Marker Accuracy	±5% maximum display
Frequency Dial Accuracy	10 to 2,000 mc, ±1% of the fundamental local oscillator above 2,000 mc, ±1% of dial frequency
I-F Attenuation	
Variable	0 to 40 db
Step	0 to 20 in 1 db steps (Accuracy 0.1 db per db)
Cathode-Ray Tube	5 inch, P7 phosphor coating, flat face with edge lighting provided (Other phosphors available on special order)
Facilities for Camera Mounting	Provided on CRT bezel

Specifications subject to change without notice.

Operating Temperature Range	0 degree C (32 degrees F) to +50 degrees C (122 degrees F)
Power Requirements—SA-84W	115/230 volts rms AC, 50 to 60 cps., 500 watts power consumption
SA-84WF	115/230 volts rms AC, 50 to 1000 cps., 500 watts power consumption
Dimensions (overall)	20½ high by 18¾ wide by 25¾ inches deep (Flush panel rack mounting available)
Weight	140 lbs.

Sensitivity (Signal + Noise = 2 x noise at minimum resolution and dispersion)

Frequency Range (mc)	Sensitivity in—dbm	R-F Attenuation	Flange Termination			Polarad Part No.
10 to 640	70 to 95	0 to 100 db	Type N			
640 to 1,440	65 to 85	0 to 100 db	Type N			
1,040 to 2,240	55 to 80	0 to 100 db	Type N			
2,000 to 12,400	65 to 90	0 to 100 db	Type N			
12,400 to 40,880	40 (nominal)	external attenuators available	**Frequency**	**Wave Guide**	**Flange**	
			12.4 to 18 kmc	RG-91/U	UG-419/U	B124386
			18 to 26 kmc	RG-53/U	UG-595/U	B124067
			26 to 40 kmc	RG-96/U	UG-599/U	B124063

Accessories supplied with model:

One set of colored filters B27336-1
One wrench kit A25109
R-F Cable A109816
R-F Cable A109817
Line Cord B111144
Instruction Manual

Accessories Available:

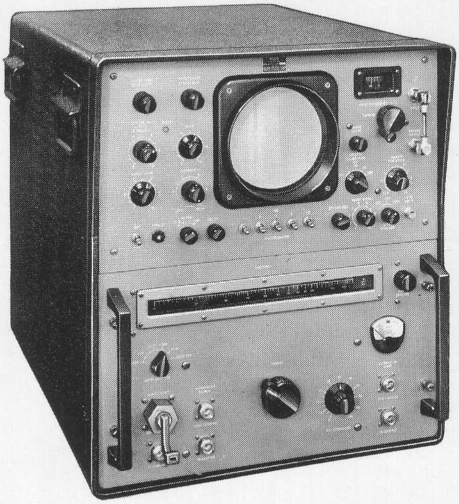
Ku Band Attenuator	AT-Ku
K Band Attenuator	AT-K
Ka Band Attenuator	AT-Ka

Rack Mounting Brackets, flush or non-flush
DA-4 Instrument Dolly
R-F Bandpass Filters (F-Series)
- F-750 (750-1,260 mc)
- F-1180 (1,180-2,120 mc)
- F-2050 (2,050-3,650 mc)
- F-3550 (3,550-6,900 mc)
- F-6300 (6,300-11,800 mc)

WIDE DISPERSION SINGLE-UNIT SPECTRUM ANALYZER

Model SA-84WA 10 to 63,680 mc

Complete frequency coverage, 10 to 63,680 mc, in a single unit. Choice of dispersion bandwidths for narrow and wide pulse analysis. 1 to 80 kc variable resolution. 25 kc—80 mc dispersion.



APPLICATIONS

- Checking, observing and precise measurement of:
  - — Spectral characteristics of wide or narrow pulses.
  - — FM characteristics.
  - — R-F signals with relatively wide frequency separation.
  - — Harmonic and spurious content of signals.
  - — Interference and leakage.
  - — Tracking of r-f components within a radar system.
- Secondary frequency standard.
  - — Frequency measurement of high and low level signals – pulse, FM, cw, etc.
  - — Frequency difference between two closely spaced signals.
- Sensitive, accurate indicator:
  - — Precise attenuation, insertion loss.
  - — VSWR meter with large dynamic range.

FEATURES

- 10 to 63,680 mc frequency range in a single tuning unit.
- Calibrated dispersion over 80 mc.*
- Minimum dispersion 25 kc.
- 1 to 80 kc variable resolution.
- .01% crystal frequency calibrator markers over complete R-F range.
- Accurate i-f attenuator.
- Expanded direct-reading slide-rule dial.
- Unique band selector shows only the band in use, eliminating operator reading error.
- Internal r-f attenuation, to 12,400 mc.
- Stable local oscillators covering more than one octave reduce required number of frequency bands.
- Expanded variable frequency marker covering a range of ± 40 mc.
- Provisions for multipulse spectrum decoder.
- Direct waveguide inputs in addition to Type N.
- Non-contacting shorts to tune klystron oscillator, assuring long equipment life and noiseless tuning.
- Video filter provided for observation of closely spaced signals.

*100 mc useable dispersion available on special order

SPECIFICATIONS

Frequency Range	10 to 63,680 mc, covered in ten bands
Band 1	10 to 240 mc
Band 2	240 to 640 mc
Band 3	640 to 1,440 mc
Band 4	1,040 to 2,240 mc
Band 5	2,000 to 4,400 mc
Band 6	4,200 to 8,900 mc
Band 7	6,300 to 13,500 mc
Band 8	12,800 to 27,200 mc
Band 9	19,250 to 40,880 mc
Band 10	40,000 to 63,680 mc
Spectrum Display Note 5″ usable display	Signal strength, Log or Lin, on the vertical axis versus frequency on the horizontal axis
Logarithmic Display	Approximately 3 db per graticule division, over 24 db—maximum log display 36 db
Resolution Bandwidth (at the 3 db points)	1 to 80 kc variable
Frequency Dispersion	
10 to 240 mc	25 kc with expanded H gain to 10 mc, adjustable
240 mc to 63 kmc	25 kc with expanded H gain to 80 mc, st'd., 100 mc on special order, adjustable (2 ranges)
Sweep Rate	1 to 30 cps, adjustable
Synchronization	Internal line frequency, external, or free running
Crystal Calibrator	
10 mc up to 240 mc	1 or 10 mc
240 to 2,240 mc	50 mc
2,000 to 40,880 mc	100 mc
Accuracy	0.01%
Variable Marker Range	±40 mc
Marker Accuracy	±5% maximum display
Frequency Dial Accuracy	10 to 2,000 mc, ±1% of the fundamental local oscillator frequency or 2 mc, whichever is greater. Above 2,000 mc, ±1% of Dial
I-F Attenuation	
Variable	0 to 40 db
Step	0 to 20 in 1 db steps (Accuracy 0.1 db per db)

Cathode-Ray Tube	5 inch, phosphor coating, flat face with edge lighting provided
Facilities for Camera Mounting	Provided on CRT Bezel
Operating Temperature Range	0 degree C (32 degrees F) to +50 degrees C (122 degrees F)
Power Requirements	115/230 volts rms AC, 50 to 60 cps, 500 watts power consumption
Dimensions (Overall)	20½ high by 18¾ wide by 25¾ deep
Weight	135 pounds

***Sensitivity** (Signal + Noise = 2 x noise)

Frequency Range (mc)	Sensitivity in dbm	R-F Attenuation	Flange Termination		
10 to 640	100 to 115	100 db	Type N		
640 to 1,440	95 to 110	100 db	Type N		
1,040 to 2,240	90 to 110	100 db	Type N		
2,000 to 4,400	105 to 115	100 db	Type N		
4,200 to 8,900	100 to 115	100 db	Type N		
6,300 to 13,500	90 to 105	100 db	Type N		
12,800 to 27,200	75 to 100	external attenuators available	**Frequency**	**Wave Guide**	**Flange**
19,250 to 40,880	60 to 95				
40,000 to 63,680	45 to 85				
			12.4 to 18 kmc	RG-91/U	UG-419/U
			18 to 26 kmc	RG-53/U	UG-595/U
			26 to 40 kmc	RG-96/U	UG-599/U
			40 to 63 kmc	RG-97/U	UG-383/U

Accessories supplied with model:
One set of colored filters B27336-1
One wrench kit A25109
R-F cable A109816
Line Cord B111144
Instruction Manual
R-F cable A109817

Accessories Available
Ku Band Attenuator
K Band Attenuator
Ka Band Attenuator
Filter, R-F
Rack Mounting Bracket, flush or non-flush
DA-4 Instrument Dolly

Specifications subject to change without notice.

*Minimum dispersion and resolution settings.

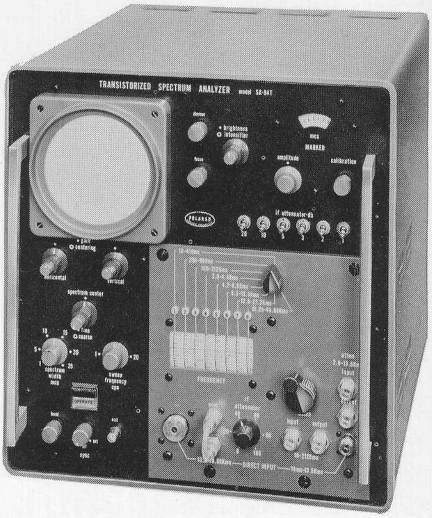
TRANSISTORIZED MICROWAVE SPECTRUM ANALYZER

Model SA-84T 10 mc to 40,880 mc

- High Sensitivity
- One Tuning Unit
- Mobile Battery Operation

APPLICATIONS

- Mobile spectral measurements.
- Measuring spectral characteristics of pulse-modulated and FM signals.
- Detecting and identifying spurious signals.
- Checking microwave oscillators, including magnetrons and klystrons for pulling, doublemoding, and other types of malfunctions.
- Checking the tracking of radar system components.
- Measuring the frequency difference of two r-f signals.
- Countermeasures analysis.



Model SA-84T

FEATURES

- Transistorized for mobile operation.
- Covers complete frequency range with a single tuning unit.
- Mobile battery (12 volt) operation as well as power line operation.
- Direct reading frequency dial.
- Self-contained frequency marker for measuring small frequency differences.
- Adjustable frequency dispersion.
- Single knob UNIDIAL® frequency control.
- Electronically regulated power supplies.

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SPECIFICATIONS: MODEL SA-84T

Frequency Range	10 mc to 40,880 mc, covered in eight bands, in one tuning unit. Band 1: 10 to 410 mc Band 2: 250 to 980 mc Band 3: 700 to 2,120 mc Band 4: 2,000 to 4,400 mc Band 5: 4,200 to 8,900 mc Band 6: 6,300 to 13,500 mc Band 7: 12,800 to 27,200 mc Band 8: 19,250 to 40,880 mc
Spectrum Display	Signal amplitude on the vertical axis versus frequency on the horizontal axis.
Resolution Bandwidth	20 kc at all frequencies (at 3 db points).
Frequency Dispersion:	
10 mc to 55 mc	500 kc to 5 mc, adjustable.
55 mc to 40,880 mc	500 kc to 25 mc, adjustable.
Sweep Repetition Rate	1 to 30 cps adjustable.
Synchronization	External, or line frequency.
Spectrum Calibrator Frequency	160 mc center frequency with a tuning range of ±13 mc; accuracy of ±5% of the available display or ±1 mc for the maximum display.
Frequency Dial Accuracy	±1% of the fundamental local oscillator frequency 10 mc to 2000 mc; ±1% of dial reading above 2,000 mc.
I-F Attenuation	Calibrated from 0 to 41 db, variable in 1 db increments; accuracy 0.1 db/db.
Display Tube	5 inch CRT phosphor coating; with edge lighting provided on graticule.
Facilities for Camera Mounting	Provided on CRT bezel.
Operating Temperature	—10°C to 55°C (14°F to 131°F).
Power Requirements	AC: 115/230 volts ±10%, 50/60 cps, 140 watts; DC: 12 volts nominal, 110 watts.
Dimensions	16 7/16" wide x 17¾" high x 18½" deep.
Weight	100 lbs. with tuning unit.

Frequency Range	Sensitivity	R-F Attenuation	Input Connection
10 to 400 mc	-90 to —105 dbm	0 to 100 db	Type N
400 to 980 mc	-85 to —95 dbm	0 to 100 db	Type N
1,000 to 2,000 mc	-80 to —90 dbm	0 to 100 db	Type N
2,000 to 4,000 mc	-90 to —105 dbm	0 to 100 db	Type N
4,000 to 12,000 mc	-75 to —90 dbm	0 to 100 db	Type N
12,000 to 40,880 mc	-55 dbm nominal	External attenuators available.	Waveguide adaptor: B124386, UG-419/U cover flange, for 12 to 18 kmc.
			Waveguide adaptor: B124067, UG-595/U cover flange, for 18 to 26 kmc.
			Waveguide adaptor: B124064, UG-599/U cover flange, for 26 to 40 kmc.

notes: (1) Sensitivity equal to minimum discernable signal.

(2) Specifications subject to change without notice.

Accessories Supplied:

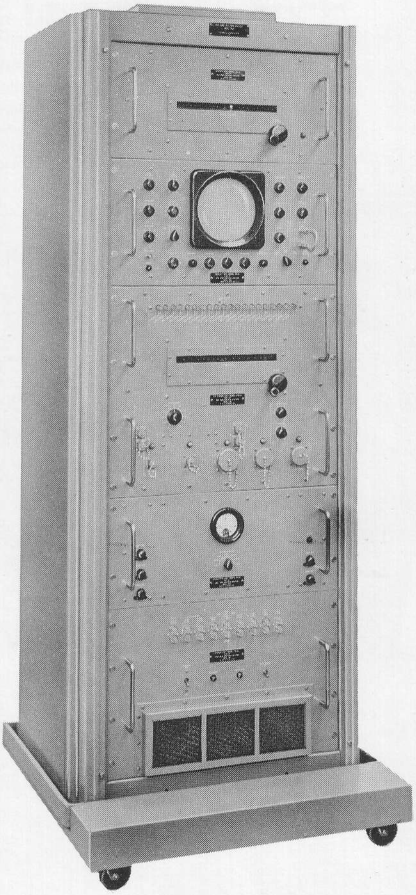
One wrench kit no. A25109
One amber filter no. B27336-1
One r-f cable no. BP12551
One Instruction Manual for Model SA-84T.
One handbook on "Spectrum Analyzer Techniques".

Accessories Available:

Instrument Dolly Model DA-4 for convenient handling of equipment.
Brackets, Rack Mounting, either flush-mount or non-flush-mount.
Bandpass Filters.
Attenuators, Ku band.
Attenuators, K band.
Attenuators, Ka band.

WIDE BAND SPECTRUM ANALYZER

Model WSA 10 MC to 40,000 MC



APPLICATIONS

- Simplifying field intensity measurements by displaying the entire range of each band (up to 4,000 mc).
- Determining pulse widths and pulse shapes by spectrum analysis techniques.
- Observing and measuring sidebands associated with modulated signals.
- Checking the tracking of a radar system's transmitter and receiver.
- Measuring noise spectra.
- Simplifying broadband jamming measurements.
- Determining r-f attenuation, insertion loss, and gain characteristics of microwave components and systems.

FEATURES

- Wide band display up to 4000 mc.
- Rapid band selection by illuminated push button switches.
- Frequency marker for measuring frequency-differences up to 4000 mc.
- End markers indicating frequency limits of each band.
- Center marker allowing operator to switch from wide band to narrow band without hunting for the r-f signal; displays true r-f center.
- Internal r-f attenuators (0 to 100 db) for signals up to 12.4 kmc; external attenuators available for use above 12.4 kmc.
- Automatic Fail-Safe circuitry to protect Backward-Wave-Oscillators.
- I-F attenuation from 0 to 60 db.
- Large 7-inch cathode ray display tube.
- Fixed resolution of 20 kc and 1.5 mc.
- UNIDIAL® control for simplicity of tuning.

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SPECIFICATIONS MODEL WSA

Frequency Range	10 mc to 40,000 mc in 20 Bands:
Band 1	10 to 410 mc
Band 2	410 to 800 mc
Band 3	800 mc to 1.32 kmc
Band 4	1.32 to 2.2 kmc
Band 5	2.2 to 3.5 kmc
Band 6	3.5 to 4.5 kmc
Band 7	4.5 to 6.1 kmc
Band 8	6.1 to 8.0 kmc
Band 9	8.0 to 9.15 kmc
Band 10	9.15 to 10.6 kmc
Band 11	10.6 to 12.4 kmc
Band 12	12.4 to 13.6 kmc
Band 13	13.6 to 15.5 kmc
Band 14	15.5 to 18.5 kmc
Band 15	18.5 to 22.0 kmc
Band 16	22.0 to 26.0 kmc
Band 17	26.0 to 28.5 kmc
Band 18	28.5 to 32.0 kmc
Band 19	32.0 to 36.0 kmc
Band 20	36.0 to 40.0 kmc

R-F Frequency Dial Drum Accuracy	±5% of dial setting
Band Selection	Automatic; with illuminated push-buttons.
Dispersion	Narrow Band: 1 mc to 25 mc. Wide Band: 50 mc to 4,000 mc.
Resolution	Narrow Band: 20 kc Wide Band: 1.5 mc
Sweep Repetition Rate	1 to 30 cps; adjustable.
Synchronization	External, off, or line frequency.
Spectrum Calibrator	Generation of direct reading frequency markers to measure frequency deviation from 1 mc to 4,000 mc, accuracy of ±5%.
Spectrum Display	Signal amplitude on vertical axis versus frequency on horizontal axis.
I-F Frequencies	8200 mc, 3600 mc, 1000 mc, 160 mc, 64 mc; depending on band selection.
I-F Attenuation	0 to 60 db.
Internal R-F Attenuator Range	0 to 100 db (Variable), for use up to 12.4 kmc.
End Band Markers	Automatically marks end limits of band in use to operator.
Center Frequency Marker	Automatically marks center of band in use to operator, permitting switching from wide band to narrow band without hunting for the r-f signal.
Fail-Safe System	Automatic fail-safe circuitry protects life of microwave oscillator tubes.

Operating Temperature Range	—20°C to 55°C (—4°F to 130°F)
Display Tube	7 inch CRT, phosphor coating, flat face, with edge lighting provided on graticule.
Camera Mounting Facilities	Provided on CRT bezel upon request.
Power Requirements	115 vac ±10%, 50/60 cps (1725 watts).
Dimensions	82" high x 33" wide x 33" long, on roller dolly.
Internal Ventilation	Cool running, hollow center, forced chimney type.
Weight	1000 lbs. crated.

Sensitivity

Frequency Range	Nominal Sensitivity	R-F Attenuation	Input Connection
10 to 410 mc	—80 dbm	0 to 100 db	Type N
410 to 12,400 mc	—70 dbm	0 to 100 db	Type N
12.4 to 18.5 kmc	—60 dbm	External attenuator	Waveguide: Choke flange for RG-91/U
18.5 to 26.0 kmc	—50 dbm	External attenuator	Waveguide: Choke flange for RG-66/U
26.0 to 40.0 kmc	—50 dbm	External attenuator	Waveguide: Choke flange for RG-96/U

Note: (1) Sensitivity figures referred to minimum discernable signal (narrow band operation).
(2) Specifications subject to change without notice.

Accessories Supplied:

1—amber filter No. B27336-1
1—wrench kit No. A25109
1—cable assembly, Type RG-9A/U
1—cable assembly, Type RG-9A/U
    with Type UG-21D/U
1—cable assembly, Type RG-71/U
    with Type UG-260A/U
1—power cable

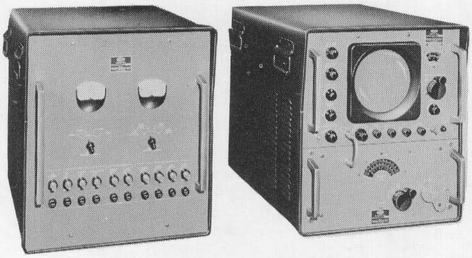
Accessories Available:

Ku band variable attenuator C105314
K band variable attenuator C105341
Ka band variable attenuator C105342
Band pass filter for each band.

EHF SPECTRUM ANALYZER

Model DA-70
50 KMC to 100 KMC

Wide dispersion—accurate frequency calibration—one single tuning unit.



FEATURES

- 50,000 mc to 100,000 mc frequency coverage using a single tuning unit.
- Dispersion continuously adjustable from 50 mc to 1,000 mc.
- Frequency dial accuracy of ± 1%.
- One UNIDIAL® frequency control for simplicity of tuning.
- Fail-safe circuitry prevents damage to microwave oscillators and amplifier tubes.
- High frequency i-f's assure good image rejection.
- Frequency markers for spectrum calibration have a ± 5% accuracy.
- One BWO covers complete frequency range.
- Flat 7-inch cathode ray tube.
- Power supply is metered for monitoring all major voltages and currents required for optimum operation.

APPLICATIONS

- Observation of pulsed signals as narrow as 0.01 microseconds.
- Measuring spectral characteristics of pulse modulated signals.
- Simplifying field intensity measurements.
- Waveform monitoring.
- Checking the performance of microwave oscillators, such as klystrons and magnetrons, for pulling or double-moding.
- Detecting and identifying spurious signals.
- Simultaneous observation of several signals within a radar system.
- Measuring the attenuation, insertion loss, gain or VSWR of microwave components.
- Countermeasures analysis.

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SPECIFICATIONS:

Frequency Range	50 kmc to 100 kmc with one tuning unit in three bands: Band 1: 50 to 62 kmc Band 2: 60 to 80 kmc Band 3: 75 to 100 kmc.
Sensitivity	—50 dbm nominal.
***Frequency Dispersion**	50 mc to 1,000 mc continuously variable.
Frequency Dial Accuracy	± 1%.
***Resolution**	1 mc.
Input Connection	RG-99/U Waveguide with a UG-387/U cover flange.
I-F Attenuation	0 to 60 db, internal, continuously variable.
Synchronization	Internal, off, or external.
Sweep Rate	1 to 30 cps adjustable.
Display Tube	7 inch flat face cathode ray tube.
Frequency Difference Marker	Negative pulse, amplitude variable 0 to 3 cm; accuracy of ± 5%.
Input Power Required	115 vac ± 10% 50/60 cps, 900 watts.
Weight	100 lbs. for Display Unit; 150 lbs. for Power Supply Unit.
Dimensions (Overall)	17⅝″ wide x 20″ high x 24¾″ deep each for Display Unit and Power Supply Unit.

*Narrower dispersion and resolution available on request.

Accessories Supplied:

1—Power cable, 3 conductor cable.

2—Waveguide adaptors: RG-97/U to RG-99/U; RG-98/U to RG-99/U.

1—Instruction Manual for Model DA-70 Spectrum Analyzer.

1—Handbook of "Spectrum Analyzer Techniques".

MULTIPULSE SPECTRUM SELECTOR

Model SD-1

Permits spectrum analysis of any selected pulse within a multiple pulse train.

APPLICATIONS

- The Model SD-1 Multipulse Spectrum Selector, when used with the Polarad Model TSA or SA-84 Spectrum Analyzer, makes possible the spectrum analysis of individual pulses in a pulse group.*
- Useful in analysis and design of telemetry equipment, IFF, beacons, and radar systems.
- Can be used with any spectrum analyzer or receiver having an intermediate frequency of 160 mc (or 140 mc on special order).

*See "Gate Selects Pulses for Spectrum Analysis" in **Electronics**, Vol. 29, No. 8, August 1956, by Alan Ross & Leonard Simon.

FEATURES

- Automatic gating of spectrum analyzer during the interval of pulse analysis.
- CRT display of pulse group.
- Sweep expansion provided for inspection of closely grouped pulses.
- Pulse intensification to facilitate pulse selection.
- Continuously variable sweep width.
- Continuously variable gate width and gate position for pulse selection.
- Triggered sweep on first pulse in any pulse train.
- Provision for external sync and gate.
- Self-contained unit.

Model SD-1

SPECIFICATIONS

Outputs:	
Video	0 to 8 volts positive, source impedance less than 1000 ohms signal-to-noise ratio 45 db.
Sync Pulse	Negative, 25 volts from 22K ohms.
Audio	Loudspeaker (0.5 watts) or external earphones.
Inputs:	
Video	1.5 volts peak (maximum), input impedance 75K ohms.
Sync Pulse	Negative triggers, 120 volts into 50K ohms.
Audio	Voice (microphone provided), input impedance of 2000 ohms.
Tape Speeds:	
Playback and record	15 inches per second.
Rewind	60 feet per second.
Fast Forward	60 feet per second.

Tape	Standard ¼ inch, 1 mil instrumentation type with 3600 feet of tape permits 48 minutes maximum continuous recording time. 10½ inch reels.
Heads, 4	Video record, video playback, audio record-playback, and audio-video case.
Motors, 3	1—synchronous motor for capstan drive. 1—supply reel motor. 1—take-up reel motor.
Input Power	115 volts, ±10% 60 cps, 240 watts.
Dimensions	Rack mounting: Standard 19 inch rack panel. Bench Case: 19½″ high by 21¾″ wide by 17″ deep.
Weight	100 pounds.
Accessories Supplied	1 dynamic microphone, 1 reel of tape, 1 take-up reel.

NOTE:

Polarad Electronics Corporation reserves the right to change the specifications without notice in order to improve the product.

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POLARAD

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