MORE ON SPECTRUM ANALYSIS

APPLICATION NOTE SIXTY-THREE(A)

HEWLETT hp PACKARD

APPLICATION NOTE 63A

MORE ON SPECTRUM ANALYSIS

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FOREWORD

The immediate acceptance of the Hewlett-Packard 851A/8551A shortly after its introduction to the industry can be explained only because its characteristics differ so greatly from the traditional spectrum analyzer. The Hewlett-Packard design philosophy was to provide as many analyzer controls as possible in a calibrated form so that the spectrum analyzer became literally a frequency domain oscilloscope. This, of course, implies that in many ways the new spectrum analyzer is as easy to use as a standard type of time base oscilloscope and that the applications are far more extensive than the traditional spectrum analyzer. Since an engineer spends much design time with frequency plots, so the frequency equivalent of the conventional time scope assumes new importance.

Since the publication of Application Note 63 on "Spectrum Analysis" a wide variety of additional applications of this remarkable analyzer now make it even more versatile for the user. This supplemental note will describe a number of these in detail. For further application assistance and information, contact the field office listed on the back cover.

ERRATA FOR APPLICATION NOTE 63 PRINTED JULY 1964

Equations should read as follows:

Page 15, para. B.	$\tau(\text{usec}) = \frac{2}{f_{(\text{mc})}}$.
Page 26, peak power.	$P_{pk} = P_i - 20 \log K\tau\Delta f$.
Page 38, table of transforms.	Pair 5S Frequency function $F_\omega = \pi\left[\delta(\omega + \omega_0) + \delta(\omega - \omega_0)\right]$. Pair 6S Frequency function $F_\omega = \frac{2\pi}{T} \sum_{-\infty}^{\infty} \delta\left(\omega - n\frac{2\pi}{T}\right)$.

MORE ON SPECTRUM ANALYSIS

1. HOW SPECTRUM ANALYSIS ASSISTS WORK IN MICROWAVE SEMICONDUCTORS.

The emergence of microwave semiconductors in their various forms has made the use of a spectrum analyzer in the design and production areas a virtual necessity. Microwave semiconductors are now being used in many forms: microwave transistors, parametric amplifiers, varactor harmonic generators, tunnel diodes, abrupt recovery diodes and a variety of special effect devices such as Gunn effect, Reed effect and other diodes. One characteristic underlies most of these semiconductor applications, however, and that is that the circuit outputs are generally dirty signals. Parametric and noise oscillations, signal distortions, and intermodulations are facts of life as most semiconductor designers know. The use of a spectrum analyzer therefore is extremely important in determining what the circuit is doing at any particular time.

As an example, Figure 1(A) shows a simple one-step harmonic generator using an abrupt recovery diode and being operated from a 1900 mc drive signal. A balanced diode arrangement is mounted across the coaxial drive line following an input double-stub tuner. The output signal then is tuned by the use of the waveguide cavity that is formed between the semiconductors and the waveguide slidescrew tuner stub.

The input and output impedance considerations for such diodes are critical to the operating stability of the circuit. That this is true is illustrated in Figure 1(B) (C) and (D) where the output signal is observed on the spectrum analyzer set for a 2, 000 mc sweep and the circuit mistuned to show the parametric and noise oscillations present from the harmonic generator. The last picture then shows how only a simple adjustment is required to clean up the signal so that the harmonic generator is operating in stable condition.

Several key characteristics of the -hp- 8551 analyzer set it apart from any other analyzer for microwave semiconductor work. The broad sweep capability of up to 2, 000 mc permits analysis of spurious signals well separated from the specific outputs of the microwave semiconductor circuits being tested. Another is its capability of very wide vertical display range of 60 db and its ability to withstand overload so as not to generate its own distortion products in the input mixer. This is important to be able to compare signals and distortion products. The addition of 83 db more IF range with accurately calibrated IF attenuator makes it that much more useful. Finally, by sweeping 2-4 gc with the local oscillator into a 2 gc IF, all signals between 10 mc through 10 gc may be mixed in one coax input mixer and presented on screen. In most cases this "wide-open" front end should have preselection applied with filter techniques to be discussed in later section. However, in tuning the harmonic generator above the appearance of all signals somewhere on screen is a decided advantage. Specific CRT responses can easily be identified by use of the internal signal identifier which computes the particular mixing band involved.

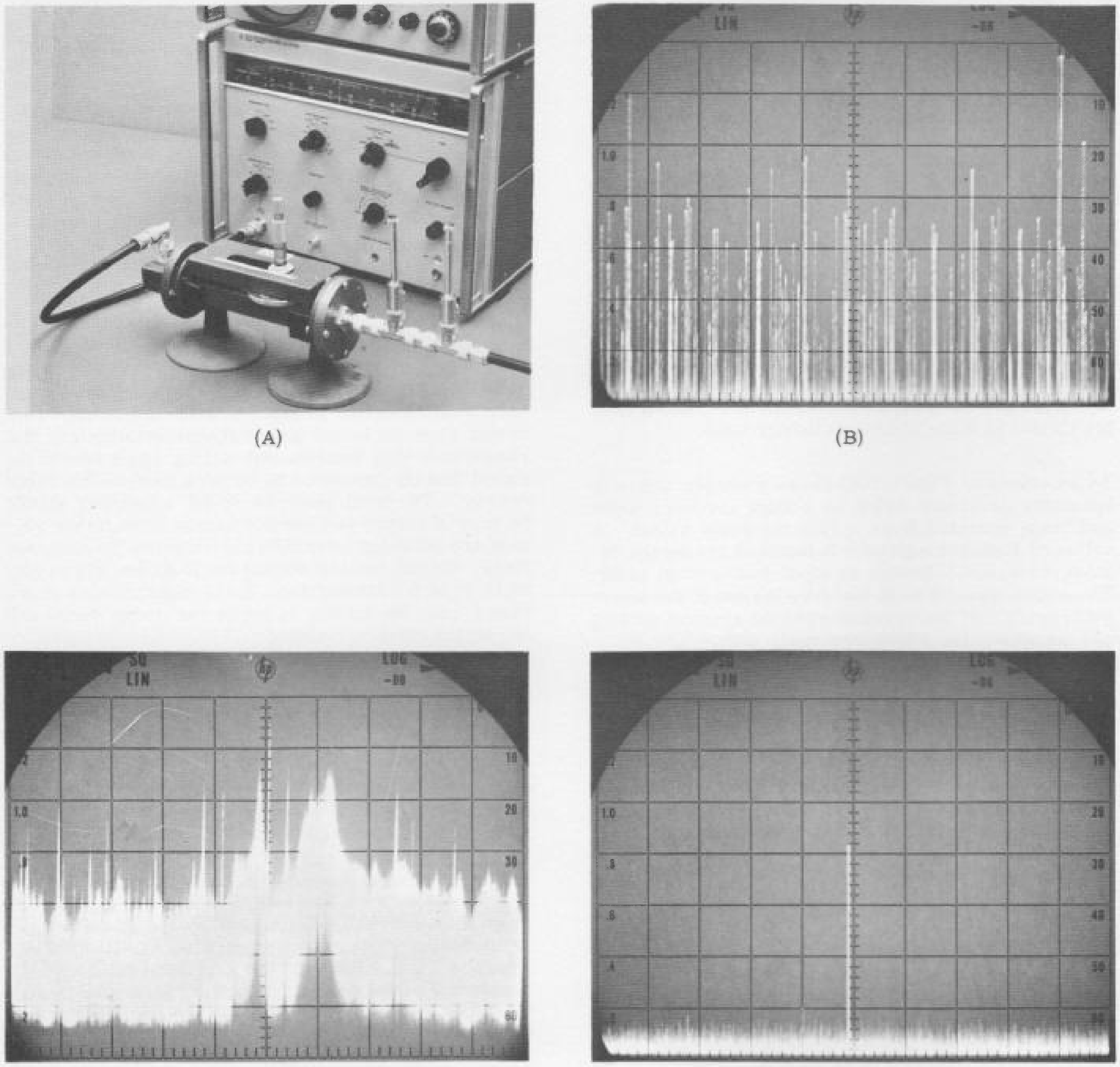
2. HOW TO DO SIGNAL AND DISTORTION ANALYSIS WITH THE ANALYZER.

Distortion and signal analysis functions are easily performed on the 8551A Spectrum Analyzer. Figure 2 shows the analysis of a signal generator output running at 800 mc and on the same trace showing the second harmonic distortion product at 1600 mc 32 db down. In this case the broad sweep characteristics and flat response in this fundamental mixing mode allows the signal and its harmonic to be presented on the same screen. The front panel 60 db RF attenuator should be used to assure that the 2nd harmonic and other signals are not being internally generated by the analyzer itself. Set the vertical display for 10 db/cm and switch in 10 db of RF attenuation. If the signal moves more than 1 cm, the mixing is not in the linear range and the signal must be reduced.

Figure 3 shows a VHF transistor amplifier operating with a 150 mc output signal under two input conditions. One shows the specified input and the second harmonic of the output properly 35 db down. (Spec 26 db) The second picture shows overdriving characteristics where many harmonic products are present. Also note noise appearing in the pass band is higher since analyzer gain was turned up.

In the case that the second or other harmonic distortion products occur in another mixing band, it is obvious that they will still appear on the same screen presentation since all harmonics appear (if 2000 mc sweep is used). However the actual calibration of the sensitivity of the second (or higher) harmonic mixing must be performed to give the proper comparison between the fundamental and the distortion products. For instance, Figure 4 shows a signal generator input at 1800 mc with its second harmonic signal appearing on the same screen and identified at 3600 mc.

To calibrate the actual power relation between the fundamental and the second harmonic product, it would be necessary to use a fundamental operating signal generator running at the second harmonic frequency to calibrate the sensitivity of the second harmonic mixing band. Also see Section 9 for general purpose sensitivity calibration technique.



(A)

(B)

(C)

(D)

Figure 1. (A) Shows an abrupt recovery diode harmonic generator setup. Parametric Oscillations and noise outputs shown in (B) and (C). Picture (D) shows proper 3800 mc output. Vertical 10 db/cm allows good readability of undesired signals.

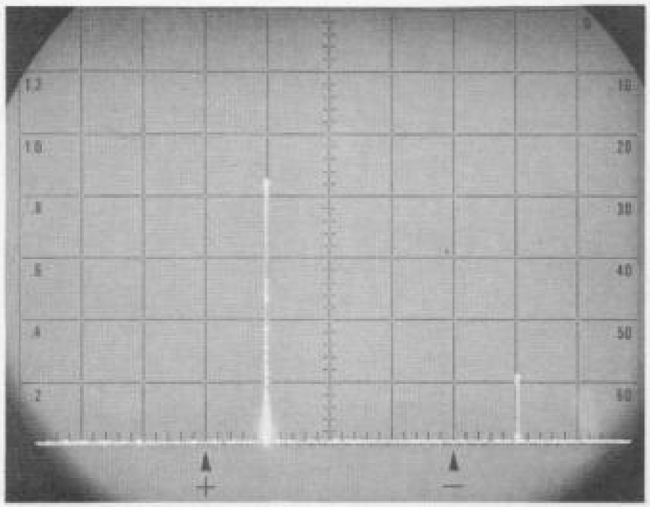
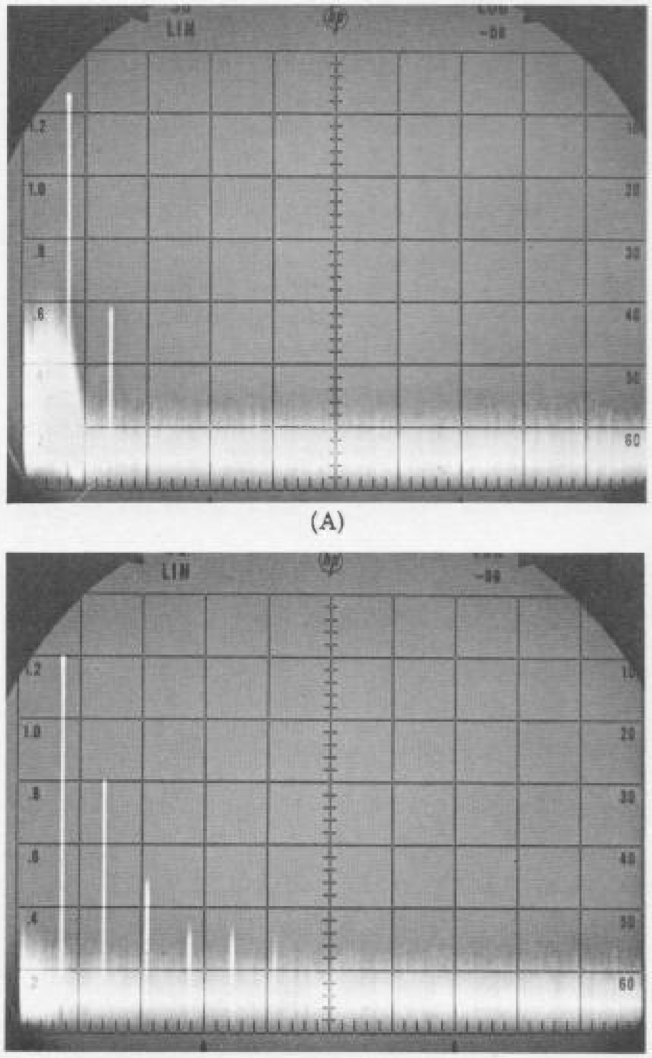


Figure 2. 800 mc signal and 1600 mc 2nd harmonic shown on one sweep. Horizontal 200 mc/cm, vertical 10 db/cm.



(A)

(B)

Figure 3. Picture (A) shows normal 150 mc transistor amplifier output. (B) shows amplifier overloaded with distortion products. Horizontal 200 mc/cm, vertical 10 db/cm.

3. USE FOR FREQUENCY COMB GENERATION

The fact that the -hp- analyzer provides one complete band from 10 to 2000 mc in one fundamental mixing mode sweep is important because a lot of semiconductor harmonic generation and frequency comb generation goes on in the range up to 2 gc. For example, in Figure 5 an abrupt recovery diode is being operated at a 50 mc rate and a 50 mc frequency comb being generated out into the 2000 mc range. In this case the comb is desired to be flat and free of its own spurious intermodulations. This adjustment in optimization of such a comb generator is a very difficult (if not impossible) thing to do without the availability of a broad sweep analyzer which provides flat response and a high frequency IF with notch filter. Analyzers with broadband second converters (100 mc) are not adequate because they transmit multiple comb response in the IF.

One precaution must be observed in measuring these characteristics of parametric and semiconductor devices. In the -hp- analyzer the local oscillator is operated from 2 to 4 gc and operated into an unbalanced mixer as the first conversion stage. This provides some L. O. output power at a level of about 1 milliwatt at the input terminal which can possibly disturb and excite external semiconductor devices under test. The best solution for eliminating this local oscillator feed-out effect on microwave devices, if it is a problem, is to use a simple low-pass filter which cuts off at approximately 1900 mc (or any other cutoff that permits working below it). Generally a filter which has a rejection band of 40 to 50 db is adequate to eliminate

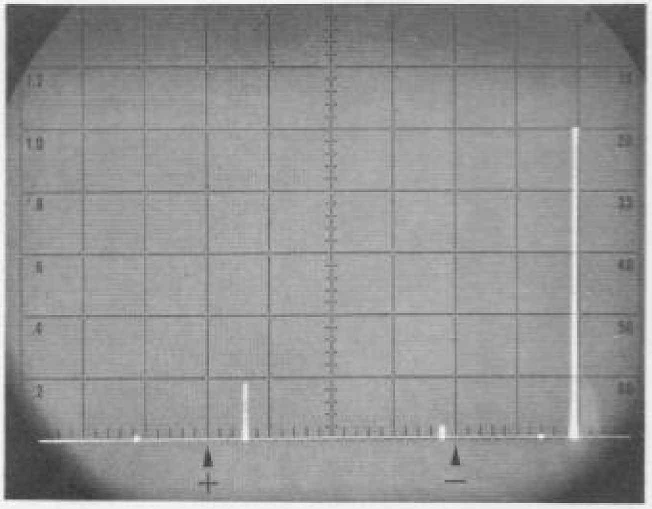


Figure 4. The 1800 mc generator output is on the right in the n = 1⁻ band. 3600 mc harmonic left of center is in the n = 2⁻ band. Horizontal 200 mc/cm, vertical 10 db/cm.

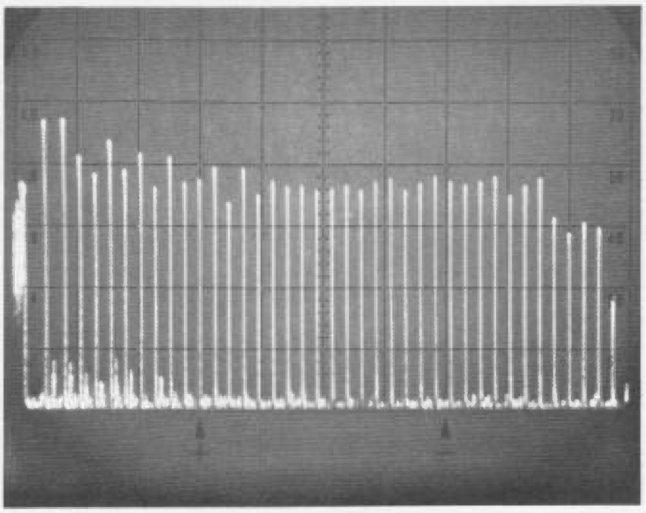


Figure 5. Full sweep from 10 mc to 2000 mc and vertical scale of 10 db/cm, allow frequency comb generator to be optimized from 50 mc base oscillator.

problems caused by the local oscillator feedout. Figure 6 shows a 1200 mc low-pass filter characteristic rejection to a broadband impulse noise generator.

If work is going on in the 2000 to 4000 mc range, which is the specific operating area of the local oscillator BWO, the use of a 2-4 gc ferrite isolator is necessary. This provides unilateral transmission of the signal under test and yet rejects the local oscillator signal from coming back out the input jack. Figure 7 shows a plot of a coaxial isolator (Melabs Model 3035), and it is noted that the out-of-band characteristics of the isolator are adequate to allow signal transmission into the analyzer all the way down to 150 mc and up as high as 5000 mc. An E&M Model S21N has good forward characteristics from 1 to 4.5 gc.

The local oscillator feedout can also be minimized in bands higher than 4 gc by simply utilizing Hewlett-Packard Model 8430A Series Bandpass Filters. More attention is given to filter technique in the following section.

Application Note 63 on page 18 provides information on the capability of tuning parametric amplifiers with the analyzer. The important characteristic which gives this capability is broad mixing range of the coaxial mixer which allows the pump, idler and signal frequencies to appear on the screen at various computed locations.

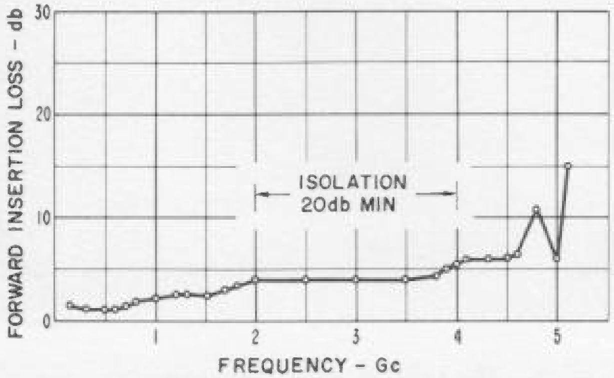


Figure 7. Typical forward insertion loss of a commercial ferrite coaxial isolator. Melabs Model 3035.

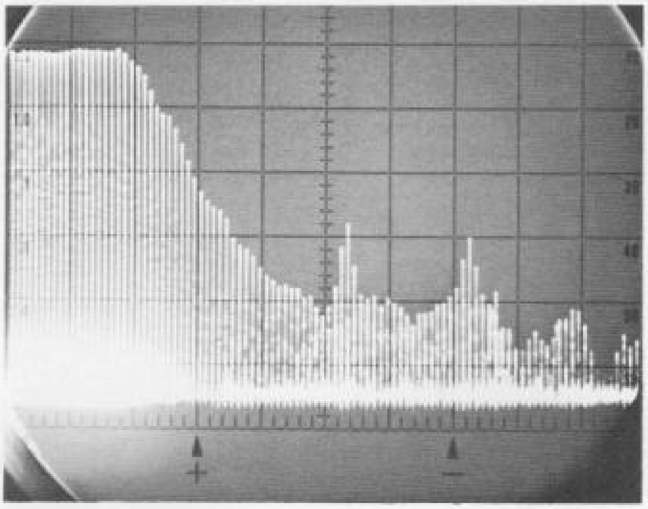


Figure 6. Filter rejection plot on a 1200 mc low-pass filter using an impulse generator. Horizontal, 1 to 2 Gc; vertical, 10 db/cm.

One problem comes up when pump or idler frequencies exist which exceed the 12.4 gc limit of the internal coax mixer. For instance a typical C-band paramp might have a K-band pump, thus it would be desirable to operate both the external waveguide mixer concurrent with the internal coax mixer.

To do this, it is only necessary to split apart the input frequencies as shown in Figure 8 to run to the appropriate mixer. The mixer outputs are the combined by going inside the analyzer and coupling together the coax leads at the coax relay A4. Coaxial wires W1 and W21 are coupled together with a BNC-Tee at terminal J15. To get access to this area it is only necessary to remove the top cover of the 8551A and swing up the converter casting. Instead of a BNC-Tee, a 3 db combining coupler at 2 gc may also be used. A coupler might provide somewhat improved performance because it stays matched and also prevents the external waveguide mixer bias from being grounded by the parallel coax mixer in this application.

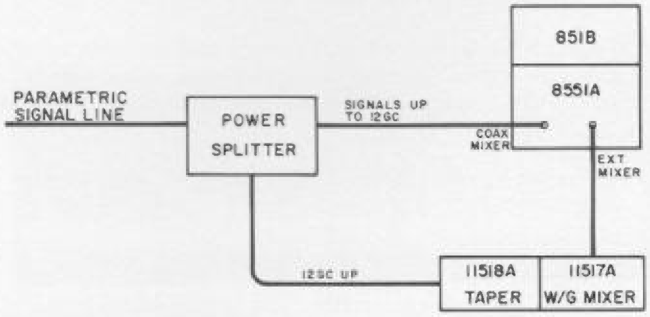


Figure 8. This diagram and a simple internal connection permits both internal coax and external waveguide mixers to operate and display concurrently.

4. HOW TO GET BEST PERFORMANCE BY USE OF FILTERS.

The proper use of a multi-band spectrum analyzer requires the understanding and application of preselection filter techniques to restrict the input signals at the front panel to a usable minimum. As shown in the following chart, the Hewlett-Packard bandpass filters now are provided in nominal 2 gc segments from 1 gc to 10 gc. Low-pass filters are also listed.

Table I. Hewlett-Packard Filters.

BANDPASS		LOW PASS		BAND REJECT	
Model	Passband	Model	L. P. Cutoff	Model	Stop Band
8430A	1-2 gc	360A	700 mc	8439A	≥ 2 mc at 2 gc (60 db down)
8431A	2-4 gc	360B	1200 mc		
8432A	4-6 gc	360C	2200 mc		
8433A	6-8 gc	360D	4100 mc		
8434A	8-10 gc	X362A*	16 gc		
8435A	4-8 gc	P362A*	23 gc		
8436A	8-12.4 gc	K362A*	31 gc		
		R362A*	47 gc		

*Model 362A waveguide low-pass filters act like bandpass type because the waveguide cuts off transmission below the lower band limit.

The bandpass filters or others should be chosen with reference to Figure 20 on page 22 of Application Note 63. Depending on the particular operating band required, the user should choose a preselection filter that restricts input signals to a specific band of operation and gives the least possible interfering mixed products.

Since the publishing of AN 63 Hewlett-Packard has added an additional Model 8439A 2 Gc notch filter which provides a 2 mc reject band centered at precisely 2000 mc. The use of this filter is recommended in any application where there are signals at the input jack that involve noise or signal level at precisely 2000 mc. The reason for this is that the first IF amplifier operating at 2 gc may be driven directly from the front panel jack. Thus if broadband noise or other signals at 2 gc are present, the baseline of the entire sweep will shift upward irrespective of what the local oscillator sweep indicates.

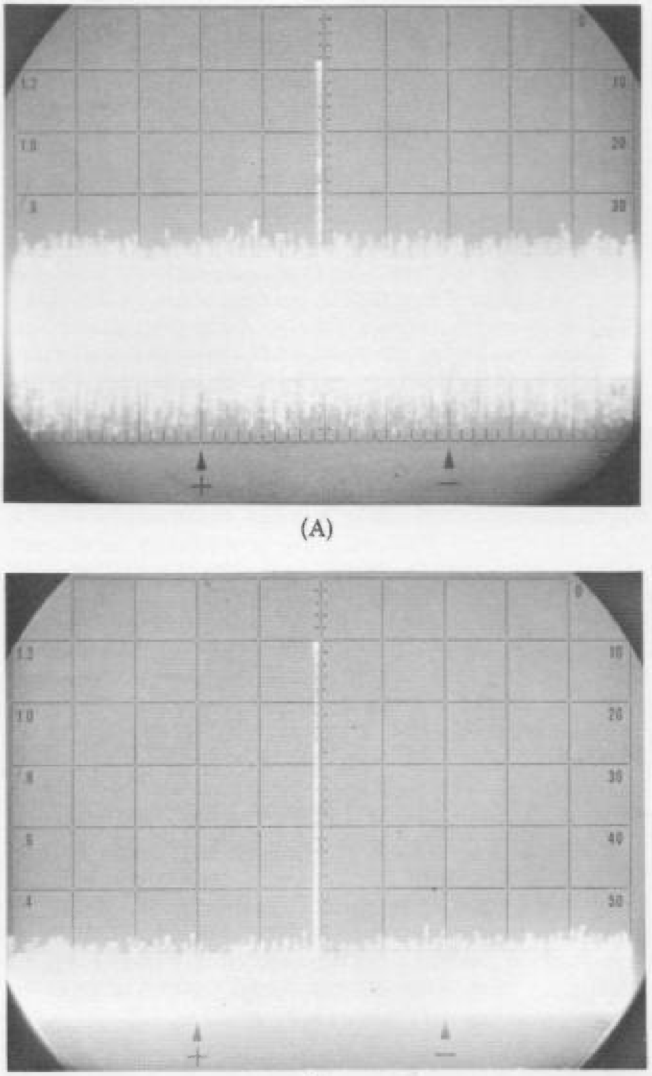
Figure 9(A) shows the baseline being raised by the presence of broad band noise at the input of the analyzer and the 9(B) shows its elimination by use of the notch filter.

The 8439A notch filter is particularly useful on harmonic generation where one of the frequency comb signals occurs directly at 2000 mc.

It's important to remember that most filters must be used between well-matched source and load. Thus a bandpass or low-pass filter should not directly follow an unmatched semiconductor for example or passband characteristics will not be preserved.

Filtering in waveguide when using the -hp- accessory waveguide mixers, 11517A and 11521A, is also easy since the -hp- Model 362A Low-Pass Filters may be utilized to eliminate spurious signals outside of the normal waveguide band. The 362A filters, although designed as low-pass filters, naturally exhibit high-pass characteristics also because the waveguide itself cuts off at the nominal band cut off frequency. This makes them useful for bandpass service from X-band and above.

Low-pass filtering is especially important when doing work below 2000 mc as mentioned before, especially in the applications that exhibit sensitivity to local oscillator outfeed, HP Model 360A and B cut off at 700 and 1200 mc, respectively, and may be used if operation is intended for input signals below those frequencies.



(A)

(B)

Figure 9. (A) 800 mc signal with broadband noise into the input mixer can feed directly into 2000 mc IF and raise baseline. (B) 8439A Notch Filter installed, vertical 10 db/cm.

Finally, another new IF filter is available for the following requirement. The present 1 kc crystal filter utilized in the narrowest IF bandwidth position has skirt characteristics that make it difficult to separate closely spaced signals. Hewlett-Packard now has available an accessory filter, Model 8442A, exhibiting the following characteristics when installed. The combination filter has a 1 kc 3 db bandwidth. The skirt selection of the filter, however, is such that it exhibits 60 db rejection at 10 kc or less bandwidth. This makes the filter extremely useful for separating closely spaced spectra. Figure 10 shows separation of two 150 mc spectra 10 kc apart with the normal 1 kc filter and with the new 8442A installed. The filter is simply placed in the 20 mc IF line between the 851B and 8551A.

It is necessary, of course, that the sweep be somewhat slower for this filter since the sweeping characteristics requires additional time for the filter to respond.

In general, then, it is highly recommended that some sort of preselection filter be employed in virtually all measurements utilizing the analyzer. The obvious exception to this is where signals of a broadband nature and all bands are to be analyzed on one presentation.

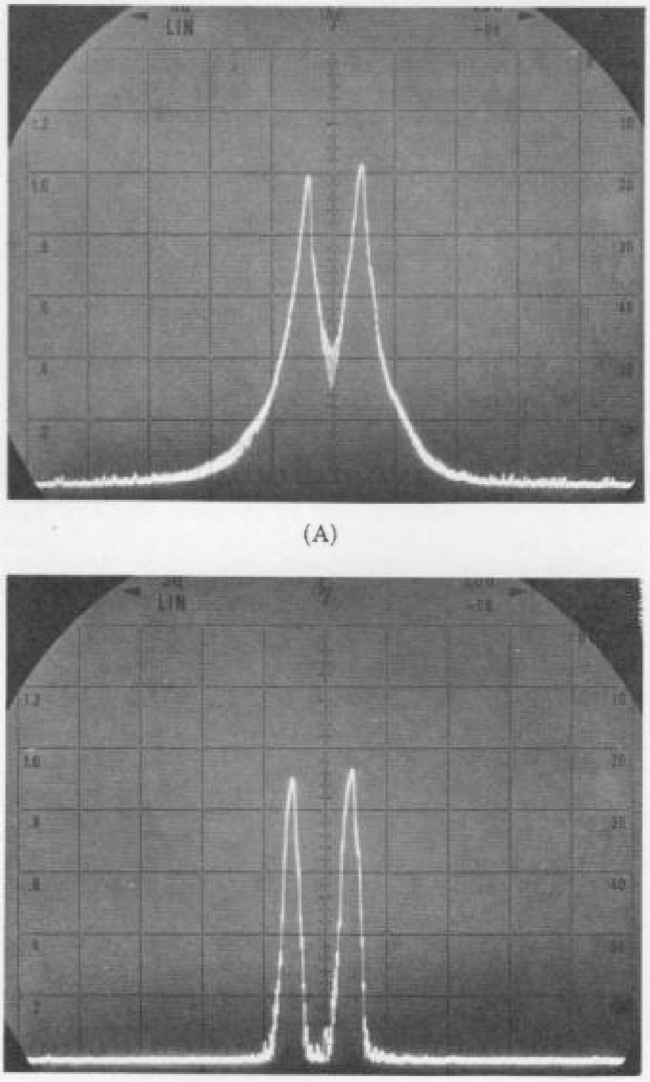
Another application requiring the use of filter techniques and tied in with the distortion limitations of analyzer's mixer is the measurement concerned with signal distortion analysis. The problem comes up when the unknown signal distortion to be measured is substantially below the carrier level. If the true distortion products are below the point where internal distortion is generated in the first mixer then a filter must be used to prevent the high level of the carrier from generating internal distortion.

The technique which can be used is to "notch filter" out the carrier with either a notch rejection filter or a low-pass filter. Following the procedures mentioned earlier, an operator would first attempt to measure signal distortion using the analyzer by itself and make the 10 db RF attenuation check to see whether internal spurious are being generated from the first mixer. If these spurious are being generated, then a high-pass filter would be used to reject the fundamental signal so that the second and third harmonic products can be analyzed.

If the distortion products are close in to the carrier then notch filter techniques must be used to reject the carrier alone while the close-in distortion products are being passed through. A tunable notch filter for this purpose is manufactured by Electro-Mechanics Company of Austin, Texas which is tunable up to 1000 mc. This filter is very sharply tuned and can be utilized to notch out the carrier signals up to that range.

Notch rejection filters similar to the -hp- Model 8439A 2 gc notch filter which exhibits a 2 mc rejection down to 60 db could be used to notch out undesired high-level signals. These multiple-tuned reject cavities can be obtained for other frequencies of interest although the tuning ranges are relatively narrow and the basic design should be consistent with the spectral requirement.

Another method of rejecting high-level signals while examining low-level signals on the same line is to utilize a preselecting transmission cavity which can be tuned to a particular signal that is to be analyzed. In this case the preselecting transmission cavity would reject undesirable signals by perhaps 40 db and pass the tuned signal of interest. The main disadvantage here is that only one desired signal can be passed at a time. However for known distortions at a known frequency, the cavity can still be used to reject other carriers and high level signals. Frequency Engineering Laboratories at Asbury Park, New Jersey offers a series of tunable bandpass filters which can be mechanically tuned to frequencies of interest and reject other unwanted signals. Typical operating procedures would be to display a band of interest, insert the filter, and then to manually tune the filter across this range and observe the signals coming through at the tuned frequencies.



(A)

(B)

Figure 10. These photos show the increased resolution possible with the -hp- 8442A 1 kc filter. (A) Normal 1 kc BW. (B) 8442A installed. Horizontal scale 10 kc/cm, at 150 mc, vertical 10 db/cm.

5. A FEW SIMPLE OPERATING HINTS IN INTERPRETING SPECTRUM PRESENTATIONS.

In the day to day operation of the analyzer, the interpretation of spectra occupies most of the operator's time and some simplified concepts on common spectra may be useful.

Figure 11(A) shows a simple CW signal as displayed on the analyzer, the horizontal axis indicating frequency and the vertical axis indicating the magnitude of the signal as it appears at the input of the analyzer. If this CW signal is modulated with a single sine wave tone two side band will appear on either side of the signal as shown in Figure 11(B). These sidebands will be separated from the carrier by the modulating frequency (fm). Figure 11(C) shows how these sidebands would look if the carrier were modulated 100% (voltage or linear display). You'll notice that the sidebands have an amplitude which is exactly half that of the carrier. In other words, as viewed in the spectrum analyzer, a 100% modulated carrier will have sideband which are 6 db down from the carrier. Thus the spectrum analyzer becomes an excellent tool for measuring per cent modulation of an AM modulated carrier.

For an arbitrary AM spectrum as shown in Figure 11(D) now on a logarithmic presentation, measure the number of db the sidebands are down from the carrier, for example, 26 db, subtract 6 db from this to obtain the number of db down the sidebands are from 100% modulation, in this case 20 db. Since 20 db attenuation is equivalent to a voltage ratio of .1 the index of modulation m in this case is equal to 1. The log display permits very small indicies to be resolved.

Very small values of frequency modulation appear in the spectrum analyzer display in exactly the same manner as amplitude modulation. This is because the spectrum analyzer does not retain phase information. If phase information was retained, the analyzer display would appear as shown in Figure 11(E) with one sideband going up and the other sideband as shown dotted extending below the base line. Here again the sidebands are separated from the carrier by the modulation frequency and the index of modulation can be determined in exactly the same manner as for AM. Measure the number of db the sidebands are down from a carrier, subtract 6 db from this figure and convert the db into a fraction. This fraction is the index of modulation. Since phase modulation is much the same as frequency modulation for low indexes of modulation its spectrum would appear identical to FM.

Figure 11(F) shows the spectrum of an AM and FM modulated carrier. You will note that the sidebands are not symmetrical in amplitude. The only way that you can have one sideband larger than the other is for both AM and FM or phase modulation to exist simul-

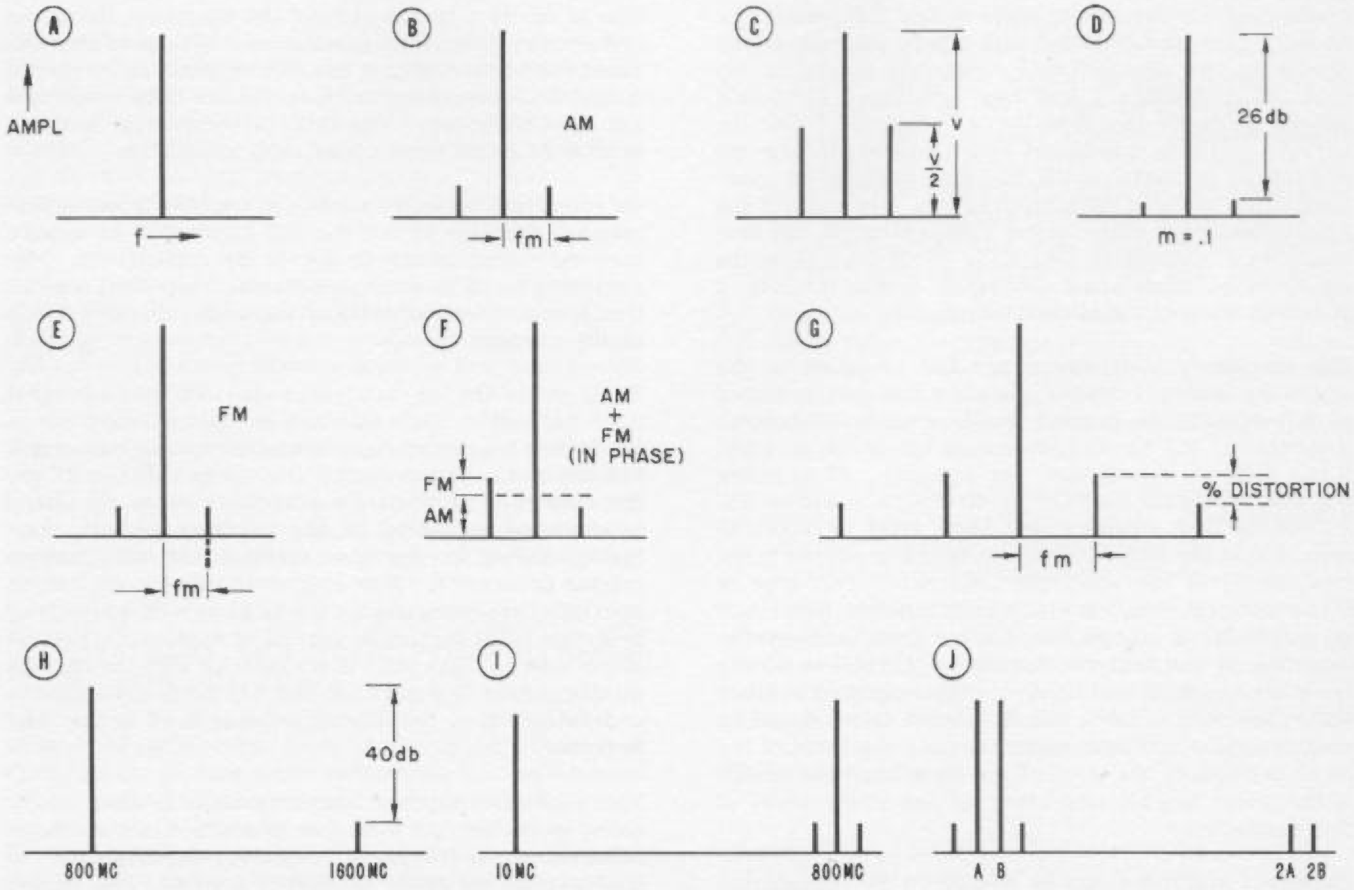


Figure 11. Typical modulation and distortion spectra. See Text.

taneously and at the same modulation frequency. Either one alone, regardless of the wave shape, will always produce a symmetrical spectrum in amplitude and frequency about the carrier. This asymmetry in amplitude can be easily explained by noting in Figure 11(E) one FM sideband extends above the line and one below the line when phase information is retained.

The spectrum analyzer adds together the AM and FM spectra and displays the absolute magnitude of the result. One sideband is added to and the other sideband is reduced. The difference in the amplitude between these two sidebands is twice the amplitude of the FM vector. Realizing this, both the AM index of modulation and the frequency index of modulation can be measured. This measurement depends on the peak FM deviation being in phase with the peak AM. That is the general case since incidental FM is usually caused by the peak excursion of amplitude modulating elements such as a power amplifier reacting on an oscillator. If the FM were not present the AM sidebands would be exactly the average of the two sidebands shown. This level can then be used to calculate the percentage of AM modulation. The ratio of the FM vector to the AM vector multiplied by the AM index of modulation will be the frequency index of modulation. It is important to note that these measurements must be made on a linear scale.

One of the important new terms which confronts the user of a wide dynamic range spectrum analyzer is the concept of distortion. The spectrum analyzer is a very useful tool in measuring distortions. Figure 11(G) shows a carrier modulated with a pure sine wave tone producing two symmetrical sidebands spaced at the modulating frequency and two additional sidebands spaced at twice the modulating frequency from the carrier. These additional small sidebands are the distortion products which resulted because of nonlinearities in the modulating process. The ratio of the smaller sideband to the larger sideband is the per cent distortion. Distortion sidebands 20 db down from the fundamental modulating sidebands would indicate a 10% distortion of the modulation signal.

The extremely wide sweep and flat response of the spectrum analyzer makes possible the measurement of distortion in the carrier itself. Figure 11(H) shows a carrier at 800 Mc and its second harmonic at 1600. If the 1600 Mc signal was, for example, 40 db below the 800 Mc signal the carrier distortion would be 1%. In making this measurement care must be taken to assure that the distortion shown is not produced in the input mixer of the spectrum analyzer. This type of distortion in the analyzer is called harmonic distortion. No specification for this distortion is given in the specifications of the analyzer because it varies so widely from band to band and from one frequency to another within the band. Since this distortion is produced by nonlinearities in the mixing process, the level of the local oscillator, the level of the signal and the design of the mixer are all important factors in the level of this distortion.

Harmonic distortion can be measured by introducing a clean carrier into the spectrum analyzer at a low level and increasing the input level until distortion products are first observed. This typically will vary from -30 dbm to -20 dbm on Band 1. The difference in carrier level and distortion product level is a measure of the harmonic distortion. To keep this ratio as large as possible the input signal level should be kept as low as possible and maximum sensitivity in the analyzer utilized.

The second important type of distortion which can occur in the spectrum analyzer is second order intermodulation. This is shown in Figure 11(I). This occurs when a high frequency signal such as a carrier at 800 Mc mixes with an equal amplitude low frequency signal such as a carrier at 10 Mc to produce sidebands around the higher frequency signal. These sidebands will be spaced, in this case, 10 Mc from the carrier. This type of distortion is measured as before by introducing a clean 10 Mc and 800 Mc signal of the same amplitude into the analyzer and increasing their amplitude together until the sidebands around the 800 Mc signal are observed. The ratio of the 800 Mc carrier to its sideband is a measure of the second order intermodulation.

The third type of distortion important in the analyzer is called third order intermodulation. This type of distortion occurs when two signals closely spaced together are of large enough amplitude to produce harmonics at twice their frequency. These harmonics then intermodulate with the fundamental signals to produce sidebands around the fundamental signals as shown in Figure 11(J). This third order intermodulation is really a combination of the harmonic distortion and second order intermodulation. It is measured the same way by introducing two clean signals at frequency A and B, increasing their amplitude until sidebands are first observed. The ratio of the carrier to these sidebands is the third order intermodulation.

On important measurements, of course, it is recommended practice to use the RF attenuator to assure that the input mixer is not being overdriven. By switching in 10 db on the attenuator, any real distortion product from an external signal should move 10 db on the screen.

Early use of the -hp- analyzers also indicates a general need for better understanding of spectral displays in the higher frequency regions where multiple responses are present. In the region from 4 gc to 10 or 12 gc, the existence of multiple responses from the many products of harmonic mixing can be especially confusing unless an operator understands the various mixing processes. It is suggested that the section on spurious responses on pages 9 to 11 as well as the preselection filter section on page 23 of Application Note 63 be reviewed. This text, in conjunction with the various mixing curves of Figure 9C (AN 63) gives a reasonable understanding of the mixing process used in the -hp- analyzer.

The multiple response characteristic is also easily noted in the section 9 of this note which shows many different sweep frequency records of the display of the analyzer in the upper frequency bands. The region above 8 gc, as an example, can be a relatively troublesome area at first glance since it can be seen from

Figure 9A (AN 63) that at 8.5 gc there are no less than five major responses occurring on the display as the local oscillator sweeps from 2 to 4 gc. These responses also show up in Figure 12E where a BWO was placed on the input and swept from 8 to 10 gc. It is noted that five different responses appear across the trace.

It should be noted that there are many areas from 4 gc upward where three or more multiple responses can occur and proper technique should be used to eliminate their confusion. As an example, let us suppose that an operating band from 5.4 to 5.9 gc is desired. On first glance the n = 1+ harmonic might appear to be best because of increased sensitivity in the fundamental mixing mode. On the other hand looking at Figure 9C (AN 63), we can see that the sweep from 5.4 to 5.9 in the n = 1+ mode will also get interfering signals on the trace with the n = 2- mode as the local oscillator sweeps from 3.40 to 3.84 gc. Proper technique in this case would indicate the use of the n = 3- band in spite of the fact that some sensitivity would be lost in using the third harmonic mixing.

As a general operating rule, the mixing band should never be used in regions where several mixing products are converging, such as the end points of the 6 gc input frequency or at 8 gc or 10 gc where several more of the mixing products converge. At 4 gc input, for instance, it would not be good practice to use either the n = 1+ or the n = 3- but instead work at the n = 2- mode.

Note that -hp- 8430A series of preselection bandpass filters in no way alleviate the multiple response problem since they do nothing but limit the input frequencies to a usable minimum. In the above example, for instance, restricting the input frequencies to 5.4 to 5.9 gc does nothing to eliminate n = 1+ and n = 2- interference near 6 gc.

Nor, obviously, can the bandpass filters be used to select certain harmonics of the L. O. BWO before driving into the mixer. This is because a high L. O. drive level is needed to get the one mixing crystal in and out of the conductance region at the fundamental frequency.

Considering all of the above information and the curves and sweeping displays, it is obvious that the best solution is to choose the appropriate mixing harmonic and restrict the general sweep of the local oscillator to areas where interfering modes are not present.

6. HOW TO MEASURE THE FM LINEARITY OF KLYSTRONS AND OTHER VOLTAGE-TUNED MICROWAVE TUBES.

Page 20 of Application Note 63 discussed a technique known as the Crosby Zero Method for measuring frequency deviation. An extension of this technique may be used to conveniently measure the FM modulation linearity of klystron repellers and similar microwave tubes. The -hp- analyzer is an excellent tool for this measurement since the technique depends on discerning the point where the carrier has gone to zero in a spectrum display. The -hp- analyzer's 60 db display range provides extreme accuracy in this measurement. Changes in linearity as small as 0.1% can be measured by measuring small changes in the index of modulation.

The technique depends on the fact that at an index of modulation (carrier peak deviation/modulation frequency) of 2.405 the center frequency component of the spectrum goes to zero. By setting up the precise 2.405 index of modulation at various points on a tube tuning curve, the modulation sensitivity can be measured and a comparison of these modulation sensitivities gives the tuning linearity across the range.

The technique used is to modulate the microwave source with a low frequency test signal with small deviation and then position the modulating voltage along the tuning curve by DC voltage changes on the tube.

The measurement procedure is as follows:

1. Set up the tube to be tested on CW and position its frequency in the center of its band. Tune in the signal on the spectrum analyzer.
2. Connect a modulating oscillator whose frequency is monitored with an electronic counter to the FM input jack of the tube under test. The modulating oscillator must maintain a constant amplitude within the accuracy of the linearity desired. Thus a 1% change in amplitude of the oscillator results in a 1% inaccuracy in the linearity measurement.
3. Pick a convenient modulating frequency, such as 10 kc, which provides FM sidebands that are easily discerned with the -hp- analyzer at every 10 kc spacing.
4. Increase the audio modulating signal voltage until the amplitude of the carrier on the analyzer log display first goes down to zero. As the carrier amplitude is decreasing the other sidebands are appearing on both sides of the carrier at the 10 kc spacing. At the first carrier equal zero point the modulating index is 2.405. Read and log the exact electronic counter readout of the audio frequency.
5. Now tune the repeller to another point on the tuning curve using the appropriate DC repeller voltage adjustment. The presentation will move off the analyzer display. After returning it back on the center of the analyzer, the carrier spectral line has moved up from zero.
6. Without readjusting the oscillator amplitude, reset the modulation frequency until the carrier zero is again realized and again read the modulation frequency with the electronic counter.
7. Since at both conditions of measurement the modulation index has been set to $m = 2.405$ it can be shown that the modulation linearity is equal to the percentage change in modulation frequency. If the modulation signal amplitude was constant, the fractional change in slope (sensitivity) is calculated as follows:

$$\text{Linearity} = \frac{fm_1 - fm_2}{fm_1}$$

where fm_1 and fm_2 are the first and second modulating frequencies.

Thus, if the first modulation frequency was 10.00 kc and the second modulation frequency was 10.100 kc the tuning linearity is 1%.

The carrier zero method of measuring FM deviation is also a very powerful technique for use in calibrating FM signal generators and other FM deviation meters. For the -hp- analyzer, modulation frequencies in the 10 kc range are most useful since this is generally within the passband of most FM modulation circuits and, at the same time, provides a display that can have the spectral lines spaced by at least 1 cm for good resolution on the spectrum analyzer. Table II is a useful chart that provides the modulation frequency to be set on the counter for commonly used values of deviation for the various orders of carrier zeros.

The procedure for setting up a known deviation is as follows:

1. Select the column with the appropriate deviation required, such as, for example, 250 kc.
2. Select an order of carrier zero number which gives a frequency in the table that is commensurate with the normal modulation bandwidth of the generator to be tested. For example, if an audio modulation circuit is provided in the 250 kc example above, it will be necessary to go to the 5th carrier zero to get a modulating frequency within the audio passband of the generator. (16.74 kc)
3. Set the modulating frequency to 16.74 kc. Monitor the generator output spectrum on the analyzer and adjust the amplitude of the audio modulating signal until the carrier amplitude has gone through four zeros and stop when the carrier is at its fifth minimum. With the modulating frequency of 16.7 kc and the spectrum at its fifth zero, then a unique 250 kc deviation is being provided by the setup. The modulation meter may then be calibrated. You can make a quick check by moving to the adjacent carrier zero and resetting the modulating frequency and amplitude. (i.e., 13.84 at the sixth carrier zero in the above example).

Other intermediate deviations and modulation indexes are settable using various orders of side band zeros but these are influenced by incidental amplitude modulation. Since it is known that amplitude modulation does not cause the carrier to change but instead puts all the modulation power into the sidebands incidental AM will not affect the Crosby zero method above.

7. HOW TO PROVIDE ACCURATE FREQUENCY MEASUREMENTS WITH THE SPECTRUM ANALYZER.

Several methods are available for improving the 1% frequency accuracy of the basic dial drive in the 8551A. First and easiest is the use of the local oscillator output connector on the rear of the instrument which provides a sample of the local oscillator frequency in use at any particular time. Thus an electronic counter, such as an -hp- 5245L and a 5254A plug-in reads directly to 3 gc or a transfer oscillator and counter, can be used to read out the LO frequency from 2 to 4 gc. The signal appearing on the CRT display, of course, is displaced from the LO frequency by the IF frequency. The 2 gc IF frequency offset is normally accurate within about 1 mc. This provides a relatively fast and easily computed signal frequency, especially if working down in the area where an electronic counter and a converter plug-in can be used directly.

For better accuracy of the 2 gc offset, it's best to measure it for a particular analyzer. Simply set the frequency dial for 2 gc and narrow sweep width until the 2 gc BWO signal comes straight through the 2 gc IF and count the BWO frequency. Be sure to narrow the sweep width down to 10 kc/cm or so to get best resolution. Once the 2 gc offset is measured, the 20 mc IF filters and 180 and 1800 mc LO frequencies will remain quite stable for some time.

For frequency monitoring accuracies in the 0.1% range, it is also possible to use a coaxial wavemeter, such as the -hp- Model 536A, operated from the local oscillator output on the rear into a crystal detector with the frequency dip presented on a separate oscilloscope. Thus as the local oscillator is sweeping to present the analyzer display, the frequency meter can be tuned to the center of the scope display. Naturally, the same wavemeter could have been used in the main RF line running into the spectrum analyzer also and the dip noted in the 851B CRT display, although with signals such as pulsed RF waveforms it is usually difficult to get enough power absorbed from a broad spectrum to see the wavemeter dip clearly.

Marker generator techniques are also available to measure frequency more accurately -- either on an absolute basis or as is more often desired, on a rela-

Table II. List of Modulation Frequencies to be used to set up Certain Convenient FM Deviations.

Order of Carrier Zero	Modulation Index	Commonly Used Values of FM Peak Deviation										
		7.5 kc	10 kc	15 kc	25 kc	30 kc	50 kc	75 kc	100 kc	150 kc	250 kc	300 kc
1	2.40	3.12	4.16	6.25	10.42	12.50	20.83	31.25	41.67	62.50	104.17	125.00
2	5.52	1.36	1.81	2.72	4.53	5.43	9.06	13.59	18.12	27.17	45.29	54.35
3	8.65	.87	1.16	1.73	2.89	3.47	5.78	8.67	11.56	17.34	28.90	34.68
4	11.79	.66	.85	1.27	2.12	2.54	4.24	6.36	8.48	12.72	21.20	25.45
5	14.93	.50	.67	1.00	1.67	2.01	3.35	5.02	6.70	10.05	16.74	20.09
6	18.07	.42	.55	.83	1.88	1.66	2.77	4.15	5.53	8.30	13.84	16.60

tive frequency basis. The -hp- Model 8406A frequency comb generator provides 1, 10, and 100 mc frequency marker spacing from an internal crystal oscillator and is relatively flat in amplitude up to 6 gc. Thus, the CRT display may be easily calibrated by successively using the 100 mc spacing, then the 10 mc, then the 1 mc marks to narrow in on an unknown signal.

Two other functions are available in the 8406A. It may be driven externally from a stable tunable generator such as the -hp- 606A or Boonton 3200A. Also, it may be operated in an amplitude modulated mode where a raster of sub-markers are generated around the 100 mc marks for instance from an external source.

Other convenient marker combinations are the Model 606A generator driving a Model 10511A spectrum generator which puts out useful harmonics up to 1000 mc. Also the Boonton 3200A driving its harmonic doubling probe Model 13515A has harmonics up to 2000 mc. These frequencies may be injected into the front end of the analyzer by use of a resistive tee or directional coupler that permits them to enter the input mixer along with the signal under test. These marker frequencies mixed with the local oscillator can present deflections on the CRT whenever the mixed frequency is 2000 mc. Furthermore the comb is presented across the entire spectrum width of display spaced at the modulating frequency.

It should be noted that the harmonic comb spectra are not needed above 2000 mc since once a beat is obtained on the n = 1 - band ($f_S = n f_{LO} \pm 2$ Gc) against the BWO then that particular point on the CRT is marked for various harmonics of the local oscillator. For instance, an unknown signal at 5500 mc would be presented on the spectrum analyzer screen as the LO frequency passed through 3500 mc. If a marker harmonic frequency of 1500 mc was injected into the analyzer at the same time, this marker would also appear on the screen in the same location. Thus if the 606 frequency was tuned to 50 mc and counted on an electronic counter, a very accurate determination of the unknown frequency could be made from the 30th harmonic. (1500 Mc or 5500 Mc)

8. HOW TO EXTEND THE USEFULNESS OF THE SIGNAL IDENTIFIER ON NOISY OR UNSTABLE SIGNALS.

The theory of design in the unique signal identifier of the -hp- analyzer depends on shifting the second LO frequency a calibrated amount and thereby computing the harmonic mixing number n. The specific procedure calls for using a 100 kc/cm sweep width and adjusting the signal identifier for a ±2 cm trace shift which then reads out the desired n number.

On noisy, drifting, or otherwise unstable unknown signals, harmonic identification may be a problem when using the required but relatively narrow 100 kc/cm spectrum width. The following procedure is useful in these situations.

1. Set the sweep width calibration to 10 mc/cm.

2. Using a simple type N tee on the front panel input apply a Model 606A or 608C/D Signal Generator to the input mixer in parallel with the unknown signal. In the higher microwave frequencies, it may be better to use a resistive power divider such as Weinschel Model 1506.

3. Set the signal generator for 10 mc. The input mixer will mix the 10 mc signal with the unknown and provide AM sidebands on the screen. Turn up the power until the sidebands are made to appear on the unknown spectrum.

4. Turn the harmonic band selection to the n = 1 band. If the first order sideband appears at 1 cm then obviously the harmonic mixing number is n = 1 (10 mc/cm). If the first order sideband from the signal generator comes on the screen at 1/2 cm or less, then turn the band switch up to n = 2 or 3 beyond until a 1 cm deflection is noted. When the first order sideband is at 1 cm then the proper band and harmonic number is being used.

5. Now to determine whether the unknown signal is on the plus or minus mixing product -- take the signal modulation off of the noisy or drifting signal and reduce the sweep width to the point where the signal can be maintained in the center of the screen.

6. Now move the front panel signal identifier knob up as far as necessary to get the signal to move plus or minus and use the normal signal identifier direction sense to determine whether the unknown is a plus or minus mixing harmonic.

7. Better resolution can be obtained by using the same technique except that a mixing frequency of perhaps 50 mc fed in parallel to the unknown signal can be used so that 5 cm deflection is noted on the CRT. This would be useful if harmonic numbers of five or more were being used.

8. For microwave input frequencies, the 608 modulating generator may be easily coupled into the mixer by feeding it directly through the <u>main</u> line of a 10 db directional coupler. The unknown microwave signal then would be coupled in through the side arm. With this hookup, the coupling valve at 10 mc would effectively isolate the 608 from the microwave source but would still pass the unknown microwave through.

9. When using the 11517A and 11521A waveguide mixers, (where relatively higher harmonic numbers are common) the modulating generator may be coupled in parallel at the BNC connector of the mixer.

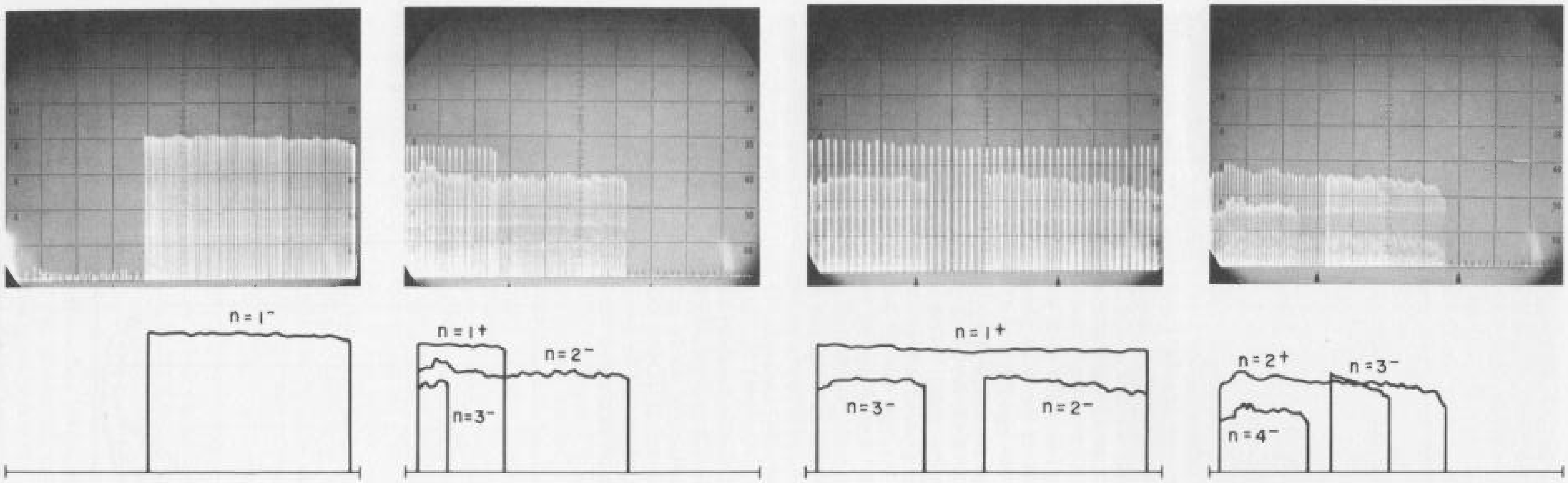
9. HOW TO MAKE THE ANALYZER INTO A CALIBRATED RECEIVER.

Some real usefulness to the spectrum analyzer can be envisioned when it is realized that in the linear display mode the CRT presents a sensitive sweeping, microwave voltmeter presentation. In the log display the analyzer represents a sweeping power meter. All that is necessary is to provide calibration for the various sweeping bands of the analyzer which can be transferred to a calibration grid as will be described. The calibration is especially useful when relative measurements are being made on two different harmonic mixing bands which naturally have different sensitivities. The example of Figure 4 with an 1800 mc signal and 3600 mc harmonic is typical, and easily done.

With the voltage and power calibration grids available, the operator can then utilize the analyzer to directly monitor with good accuracy all sorts of microwave phenomena that requires calibrated information rather than the relative information that is presented by normal spectrum analyzer techniques. Thus applications of RFI measurements, spectrum surveillance, and the like are easily done and the power measured by referring to the calibration chart. The procedure for preparing a calibration chart follows.

1. Set the analyzer for a 100 kc bandwidth, 2 gc IF, the spectrum width for 200 mc/cm and the band for n = 1 position. All input signals will be run in this mode since all signals up through 12.4 gc will show up on screen. Set the display for LOG, and connect an -hp- 8614A UHF signal generator to the input. Set the signal generator output for -20 dbm power at 800 mc. Set the input RF attenuator to 10 db.
2. Now adjust the IF attenuator so that the signal at 800 mc comes right up to the -30 db grid line on the vertical scale. Use a sweep speed that is slow enough to prevent sweep reduction of signal. 30 ms/cm is satisfactory for 100 kc bandwidth.
3. Put on the scope camera and set the analyzer sweeping; expose the graticule with UV and as the analyzer sweeps repeatedly, manually tune the signal generator from 800 mc to 2000 mc. This will then give a presentation such as that of Figure 12(A). It represents the frequency response of the analyzer to a -30 dbm signal at the input mixer (-20 dbm at the input and 10 db RF attenuation). It's obviously necessary to record the setting of the RF attenuator, the IF attenuator, the BW and sweep speed so that these conditions may be repeated. In this case the readings were, for example, 10 db, 58 db, 100 kc, and 30 ms/cm, respectively.
4. Using an -hp- Model 8616A Leveled Signal Generator, a similar sweep is run as the signal generator is manually tuned from 2000 to 4600 mc at -20 dbm. That pattern is shown in Figure 12(B). Do not change the RF, IF attenuators, BW or sweep speed.
5. A 693A/B sweep oscillator then operating from 4-8 gc is utilized as shown in Figure 13 to provide a calibrated mixer input at -30 dbm in the 4-8 gc range. In this case the RF attenuator remains at 10 db. Separate runs are made from 4-6 gc and from 6-8 gc so that mode displays may be distinguished more easily. See Figure 12(C) and (D).
6. The various mixing modes, of course, overlap. Figure 12 mode plots show most of them. They may also be determined by use of the frequency dial to see where a particular CW frequency appears. Or, Figure 9c of Application Note 63 is helpful.
7. A similar sweeping setup may be utilized in X-band where an -hp- Model 694A/B sweep oscillator is utilized with a 789C Directional Detector to provide -30 dbm input signal to the analyzer mixer. Again sweep X-band in two segments, 8-10 gc and 10-12.4 gc.
8. Make another sweep using the 200 mc IF and sweeping the input from 1.8 to 4.2 gc with an 8616A generator at -20 dbm output.
9. When all of the appropriate Polaroid camera pictures are obtained, it is a simple matter to abstract the information from them and plot a curve which is the calibration chart for the particular spectrum analyzer when used with the controls set as recorded in Paragraph 4. If operating in one particular band, of course, the calibration response can actually be grease pencilled across the CRT face plate. If operating in various bands such as would be required by RFI testing or harmonic analysis, then the chart can be referred to for a particular band of interest. In any event, the chart is a direct power calibration of the CRT graticule for the control positions indicated. Figure 14 is a calibration chart constructed from the Polaroid pictures of Figure 12.
10. It is also useful to calibrate the relative response of the various IF bandwidths since the peak gain is not preserved from one bandwidth to the next. Measurements at one frequency is all that is needed for example 800 mc. For this measurement, set the dial to 800 mc and sweep width to 1 mc/cm. After setting a reference at -30 db for the 100 kc bandwidth at 800 mc, change the bandwidth switch to 1 mc and record the vertical deflection as the calibration graph of Figure 14. Then switch to the 10 kc, 3 kc, and 1 kc and record those vertical deflections. It will likely be necessary to use the stabilized mode at 10 kc and less. Since the IF bandwidth response is not related to the particular harmonic mixing band, these ratios between IF bandwidth response hold for any of the measurements if sweep speed does not limit response. Thus, the chart shown in Figure 14 can be corrected if the operator wants to move to a different IF bandwidth for more resolution.

By getting the spectrum analyzer set up for the power calibration as described, it is available for a variety of measuring purposes all the way from direct power measurements on other low level phenomena to RFI measurements and the like. The same sort of calibration procedures may be followed to calibrate the analyzer in the linear mode for a μvolt or millivolt readout. In fact, the reading resolution in the linear mode is far better than log for certain applications.

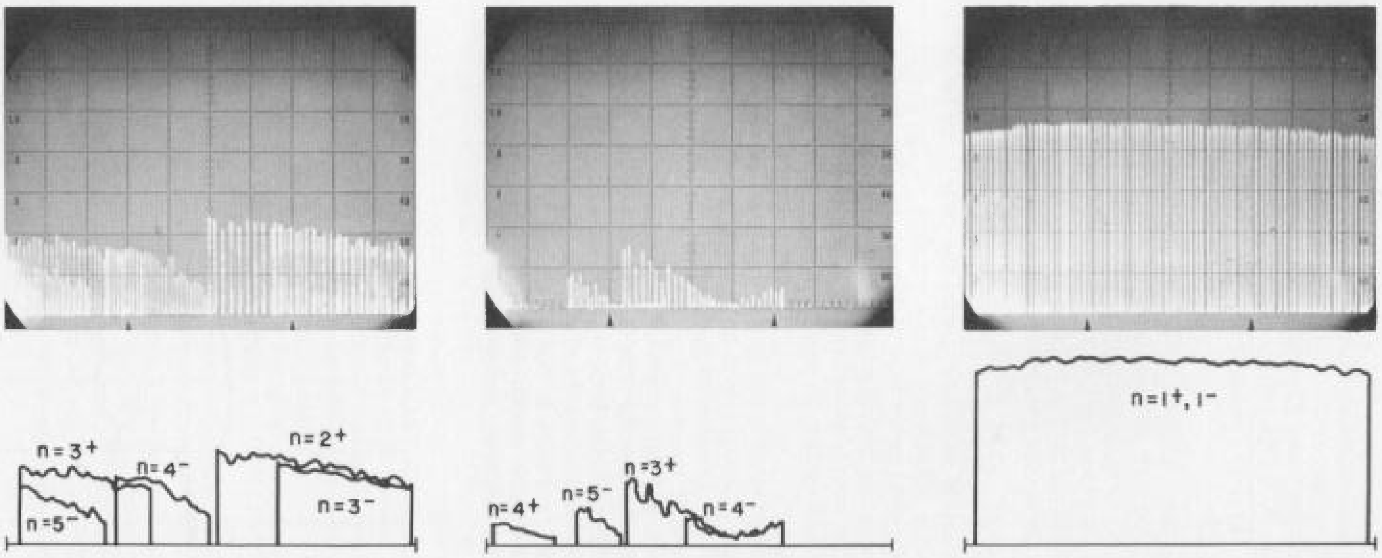


(A) 800-2000 mc sweep

(B) 2-4.6 gc

(C) 4-6 gc sweep

(D) 6-8 gc sweep



(E) 8-10 gc sweep

(F) 10-12.4 gc sweep

(G) 1.8-4.2 gc sweep 200 mc IF

Figure 12. Signal generator sweeps provide calibration of the analyzer sensitivity in various mixing modes.

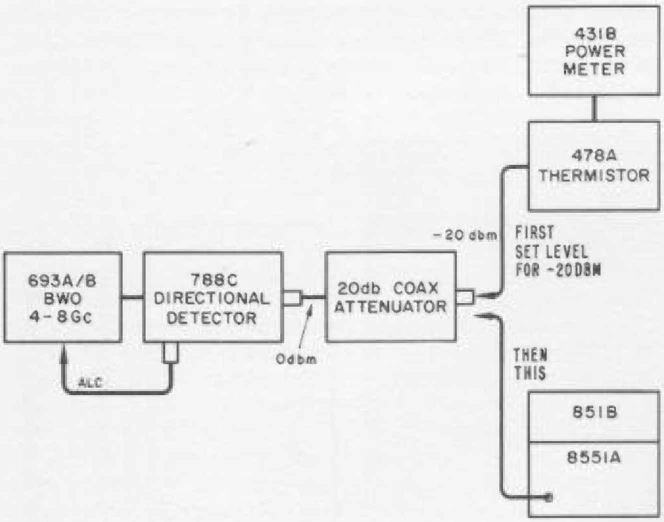


Figure 13. Setup for generating flat output from 4-8 gc at -20 dbm.

It is immediately seen how useful the chart can be in the previously mentioned measurement of harmonic content of a signal generator of Figure 4. The fundamental is in one mixing band and harmonics in another. Referring the two frequencies to Figure 14 chart gives one correction factor to apply to the CRT readout.

Since the calibration described is dependent on various analyzer gain considerations as well as mixer conversion loss, it is recommended that such calibrations be re-performed if there is any question regarding the basic accuracy such as when an overload may have been applied which could have damaged the input mixer crystal. This is easily done by spot-checking any particular point with a convenient signal generator. If the operator uses care in the handling of the analyzer, calibrations every month would be considered satisfactory. The basic accuracy of the overall system is dependent on the signal generator accuracy itself as well as the resolution and care with which the photographs and calibration charts were prepared. It is likely that overall calibration accuracies of approximately ±3 to 5 db are achieved in power calibrations. A need for increased accuracies would require that the analyzer be actually calibrated down at the area of interest or over the specific band of interest.

10. HOW THE HP ANALYZER PROVIDES FOR SELF-CHECKING OPERATION.

Because of the specific design of the -hp- analyzer which provides for the local oscillator sweeping from 2 to 4 gc and the IF running at 2 gc, an extremely convenient self-check capability is built-in and provides a day-to-day confidence factor in the use of the machine. Self-check procedure is as follows:

By tuning the BWO to 2 gc, as indicated on the frequency dial of the front panel, the BWO signal will pass directly through the 2 gc IF amplifier. Furthermore because of the unique internal phase locking capability of the -hp- analyzer, it is possible to phase lock while sweeping the BWO. This, of course, is the normal stabilized mode of sweep. Thus the "test signal" being injected through the IF under these conditions is an extremely linear sweep being referred back to the 10 mc sweeping-stabilizing VHF oscillator which is the reference to the phase lock circuit. After passing through the rest of the amplifier and conversion stages in the analyzer, the signal is shown on the CRT display.

Place the vertical display switch in LOG, the IF BANDWIDTH to 100 kc, tune to 2 gc, and you will find that at some setting of the IF gain control a full scale L. O. signal can be displayed on the CRT (see Figure 15). This setting should be determined upon receipt of the spectrum analyzer and the IF gain settings logged for

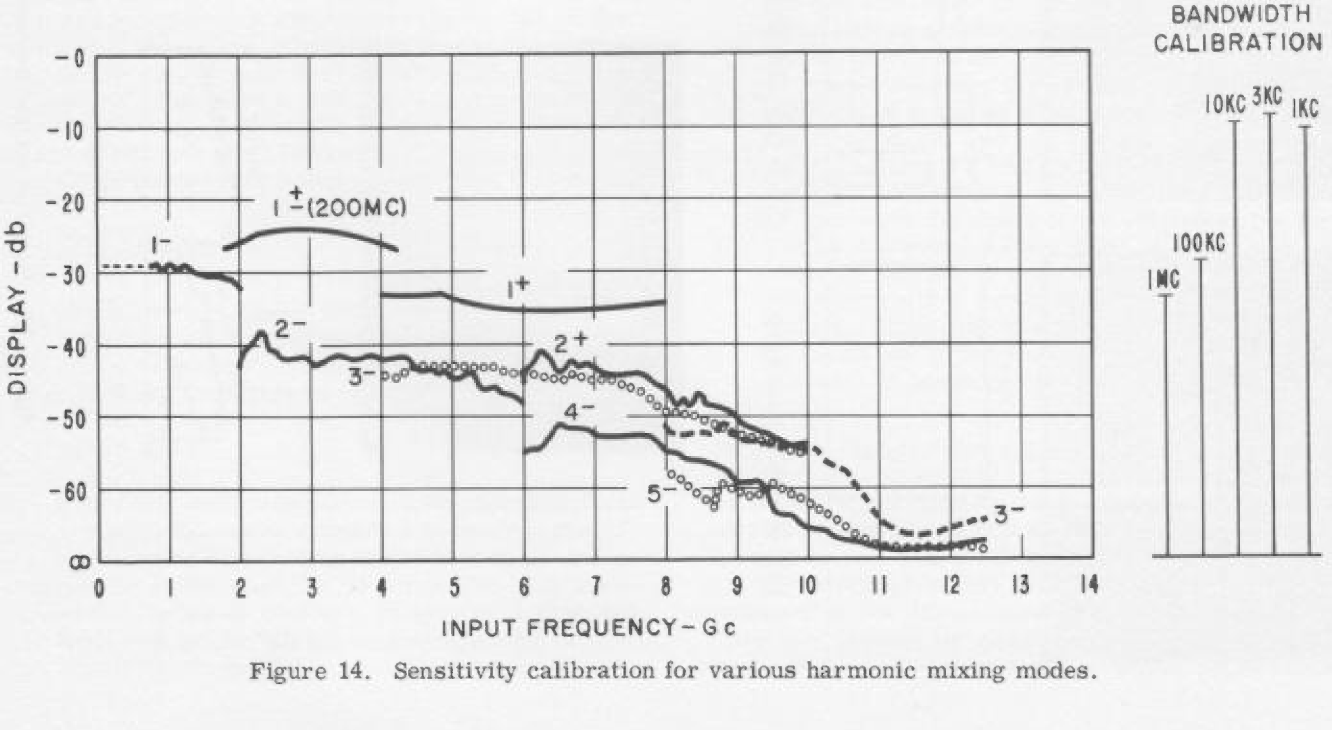


Figure 14. Sensitivity calibration for various harmonic mixing modes.

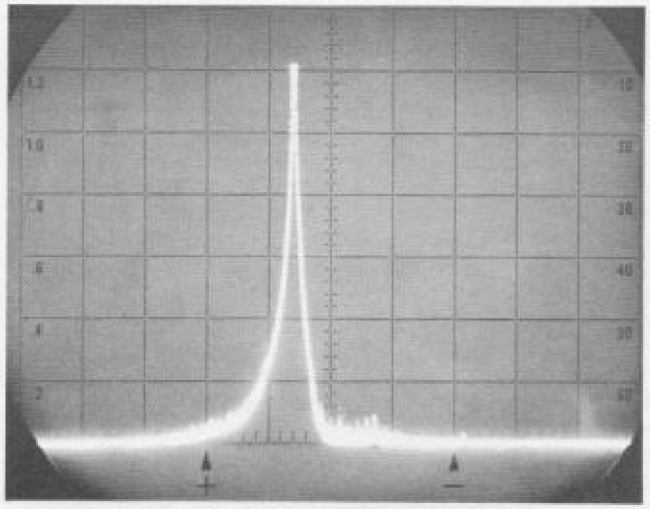


Figure 15. The BWO local oscillator serves as a convenient and very linear test signal for analyzer self-check.

future reference. These IF gain settings represent a figure of merit for the particular analyzer. If at any later time the BWO power or any of the amplifier or filters fail, additional gain would be required to get the same full scale reading on the CRT.

At the same time the IF gain figure of merit is measured as above, the 908A L. O. load on the rear panel of the analyzer should also be removed and the BWO power output measured with a microwave power meter. This power output should also be recorded and later, when any change occurs, it can be immediately determined whether the changes are due to the BWO local oscillator power or the amplifier string failing.

The availability of the extremely linear phase lock BWO sweep internal to the unit obviates the need for any additional sweeping sources in checking the calibration accuracy and IF bandwidths of the 2 gc and 200 mc IF amplifiers. Frequency markers may be generated and injected into the front of the unit to aid in this bandwidth calibration, as was explained in Section 7 on Marker Techniques.

Normally there is so much BWO feedthrough that in the linear vertical display even the internal IF attenuators do not permit on-scale presentation on the CRT. To use the BWO for calibrations of the linear mode, the IF signal should be attenuated by placing an -hp- 355D VHF attenuator in place of the rear panel 2 gc IF input-output jumper cable. Although the 355D is only rated to 1 gc it works adequately at 2 gc and provides good padding for these BW adjustments.

Here is the method to calibrate the IF bandwidth. Tune the dial to 2 gc and center the BWO signal on the CRT display. Set the SPECTRUM WIDTH to 1 mc/cm, IF BANDWIDTH to 1 mc and STABILIZE the BWO. Use the 355D and the IF GAIN CONTROL so that with the vertical display in LINEAR the signal on the CRT is exactly 6 cm high. Now increase the IF GAIN by 3 db; the original reference at 6 cm is now the half power point on the display. Since the spectrum width is 1 mc/cm and IF bandwidth 1 mc at the half power point the signal displayed on the CRT should be approximately 1 cm wide. The other IF bandwidths can be checked in the same manner by comparing against the appropriate spectrum width settings.

Note that when in the stabilized mode two advantages are realized. First, the linearity of the sweep is much better, as mentioned before. Second, the signal source (the LO BWO) now has a minimum amount of residual FM. This is so because we are using only the L. O. BWO as the signal source rather than an external sweeping generator. If we used an external generator we would have the combined residual FM of the external generator plus the BWO L. O. to contend with.

In addition to using the BWO as a built-in signal source, the fact that a 2 gc input signal can come directly through the first IF without mixing permits measuring the "relative" conversion efficiency of the input mixer diode. In this case a leveled signal generator such as an -hp- 8614A is used.

Set the VERTICAL DISPLAY to LOG. Tune the 8614A to exactly match the 2 gc IF frequency. Since no mixing is needed to get this signal through the 2 gc IF, it makes no difference what the L. O. frequency is. Thus the baseline on the CRT lifts and becomes a straight line across the CRT. Now tune the spectrum analyzer to around 1800 mc (band 1) on the tuning dial. Use the ΔF control on the -hp- 8614A generator to make sure you get maximum vertical deflection of the baseline. With the IF BANDWIDTH in the 100 kc position, adjust the IF GAIN control so that the baseline is at -10 db line on the LOG DISPLAY.

Without changing any other adjustments on the analyzer or the signal generator, tune the generator down to 1800 mc. You will see that the signal on the CRT is now lower in amplitude than the original baseline reference. The 8614A has a leveled output and thus the 2000 and 1800 mc signals were of equal amplitude at the input since we have changed none of the other settings on the generator or analyzer. The only difference is that now mixing is taking place. This means that the difference in signal level is a relative indication of conversion loss in the first mixer diode. Since the vertical display is in LOG, we can read the conversion loss right off the display at 10 db/cm. Or, increase the IF GAIN until signal is again at the -10 db reference line and take the increase in gain required to be the conversion loss of the diode.

Typically the relative conversion loss in this fundamental mixing mode is between 5 and 13 db. This value should be recorded so that at a later time it will be easy to determine if any damage has been done to the input mixer diode. Note that this "relative" conversion loss is not the same as normally defined since that would be measured by bypassing the mixer with internal connections.

Complete step-by-step bandwidth adjustment and other internal adjustments are available in the spectrum analyzer operating and servicing manual supplied with the instrument. Nevertheless in the day-to-day application of spectrum analyzer these simple self-check features permit the operator to make a front-panel check and quickly assure himself that his analyzer is operating properly.

11. HOW TO DO SELECTIVE PULSE GATING USING STANDARD COMMERCIALLY AVAILABLE EQUIPMENT.

There are several important applications that require the ability to selectively gate recurrent pulses into the spectrum analyzer. One of these is the traditional multi-pulse coded waveforms used in transponder identification and the like. In these cases it is generally important to be able to selectively gate a particular pulse out of the coded pulse train for analysis of its spectra to be sure that the transmitter tube is operating properly on each pulse of the RF digital code.

Another important application is in antenna range locations where a number of different high-power signals may be on the air at any one time and interference from one causes spurious signals to appear on the analyzer trace.

Figure 16 shows how a standard Hewlett-Packard Model 8403A/8730A PIN Modulator with its associated pulse circuitry may be used to selectively gate these waveforms. The modulator is used as a gate in the 2 gc connection from the 2 gc IF to the 2nd converter.

A pulse time reference is furnished to the Model 8403A and its delay controls adjusted so that its pulse output frames the desired RF pulse on a dual channel scope. At the same time the spiked pulse output switches the PIN into an unattenuated condition so that the pulse appearing at the first IF is being passed through into the display circuitry. In this way the spectral output is such that only the spectrum of the individual desired pulse is presented and not a multiple pulse presentation that is incapable of resolution.

In the case of antenna ranges where square-wave modulation is sometimes used on the low-power transmitters in the presence of other higher power interfering signals, the same technique may be used. In that case the 8403A modulator is adjusted for square-wave modulation and synchronized using land line synchronization from the transmitter at the remote area (see Figure 17). Thus the desired received signal is gated on a synchronous basis and the interfering signals pass through on a random basis.

Although the PIN line may be placed directly in the RF input line, it is recommended that it be placed in the 2 gc IF line because match is not so critical and insertion loss is less critical. The general usefulness of the PIN diode line as a gating element for microwave circuitry is therefore seen. The excellent input and output match in both the on and off condition exhibited by the -hp- 8730A/B PIN line series makes it very useful for synchronous detection purposes in selective RF detection.

12. HOW TO PROVIDE RECTILINEAR ANTENNA PATTERN MEASUREMENTS WITH AZIMUTH CORRELATION.

Pages 27 through 29 of AN 63 described a rectilinear method of plotting antenna patterns which gave another versatile mode of operation to the analyzer where excellent dynamic range is displaced. A minor limitation to the method was that it did not permit direct correlation of horizontal display with the test antenna azimuth.

The newest Model 851B display units now being shipped have an additional sweep drive capability which permits this function. By applying 0-15 volts to the 851B display unit the trace is made to move across the screen. The spectrum width should be set to zero. Thus, a voltage ramp taken from the test antenna pedestal azimuth indicator may be used to drive the horizontal display plates of the CRT. This provides for direct calibration of the horizontal scale of the rectilinear plots of patterns as the analyzer is used as a fixed tuned receiver.

13. HOW TO GET MORE SENSITIVITY FROM FUNDAMENTAL MIXING 6 GC TO 40 GC.

The addition of the external sweep input on the 851B Display Unit gives the capability of fundamental mixing up to 40 GC using an external -hp- 690 series sweep

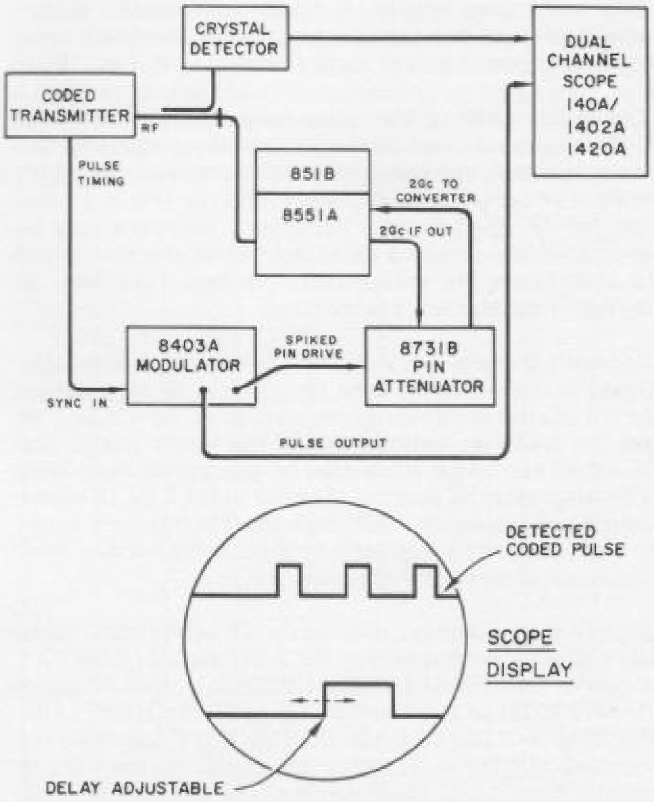


Figure 16. Commercial PIN modulator is used to selectively gate multipulse transponder spectra.

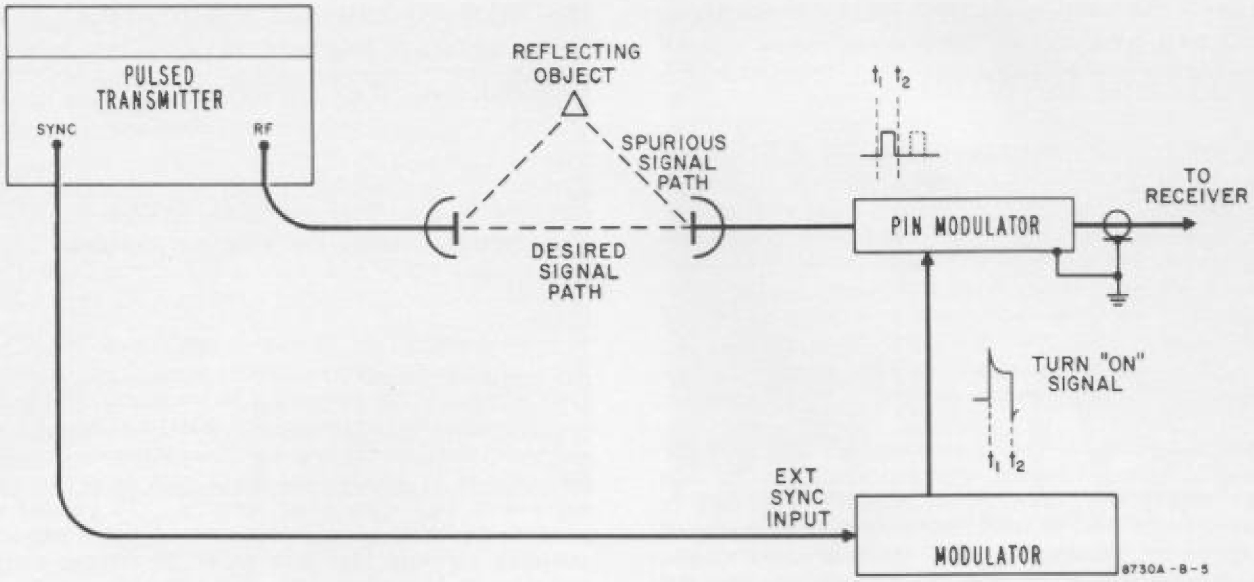


Figure 17. Multiple antenna interference may be minimized by a synchronizing gate.

oscillator as L. O. The advantage of using the -hp- 690 sweep oscillator is that the fundamental mixing provides increased sensitivity in the higher bands over that available by harmonic mixing of the 8551A. Direct mixing can be done up to 40 gc with available -hp- 690 sweepers and, by using the second harmonic, mixing displays can be made above 40 gc using accessory waveguide equipment.

The block diagram of Figure 18 shows a particular setup which is used for X-band sweep. The 694A/B X-band sweep oscillator is driven through a directional coupler into the Model 11521A X-Band Waveguide Mixer with the unknown signal coming in the other port of the waveguide coupler. The Mixer output at 2 gc is fed back into the external mixer input of the 8551A Spectrum Analyzer and after conversion presented on the CRT. (The range switch should be set to 8.2 - 18 gc range to connect 2 gc IF to front jack.) Also turn the power switch to stand by so the internal BWO is shut off. Thus a BWO sweep between 8 and 10 gc mixes an input frequency from 10 to 12 gc. Likewise a sweep on the backward-wave oscillator from 10 to 12 gc gives a mixing from 8 to 10 gc. Obviously the 2 gc offset inherent in the use of a 2 gc first IF in these applications requires that the front panel reading on the backward-wave oscillator be translated by 2000 mc. Appropriate preselector filters may be used to reject unwanted images.

It will be noted that the main limitation to this technique is the fact that at the narrow sweep width positions, the residual FM of the backward-wave oscillator becomes a factor. For that reason, sweep widths of less than 1 mc or so may become marginally useful although the broad sweeps and broad dynamic range of the analyzer is preserved in this application. Either the "Δf" or "Start-Stop" sweep functions of the 690 sweep oscillator may be used as desired. The external sweep input function of the 851B Display Unit is specifically adjusted for direct use with Hewlett-Packard 690 Sweep Oscillator sweep outputs.

The other block diagram shown in Figure 19 gives the typical equipment setup for a sweep to be made in R-band (26 to 40 gc) utilizing an -hp- Model 697A Sweeper and again feeding through the appropriate 11520A R-Band Adapter and into the 11517A Waveguide Mixer. It should also be noted that in a sweep from 26 to 40 gc from a 697A Sweep Oscillator that the image separation with a 2 gc IF will be 4 gc and thus double imaging is presented in the signals shown on a full 26 to 40 gc plot. If it is necessary to reject this image, narrower bands may be swept.

One limitation will occur in applications where high power radiated signals are present. The unwanted signals can be coupled into the relatively unshielded BWO's of the sweeper and thus give unwanted mixing

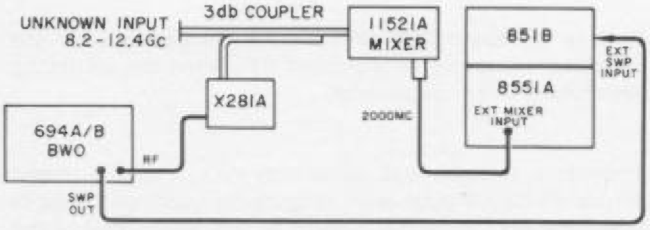


Figure 18. -hp- 694 series sweeper can be used to get fundamental mixing from 8 - 12.4 gc.

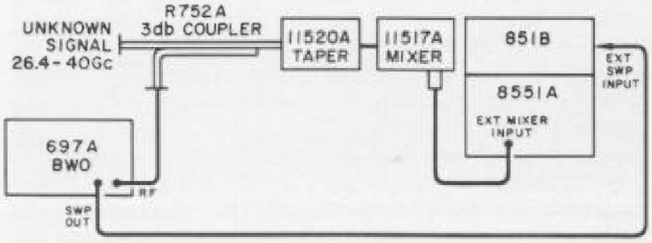


Figure 19. Setup for more sensitivity in 26 - 40 gc range.

products. Thus attention to external cabling technique is indicated. HP can also supply BWO tubes with RF shielding such as is used in the well-shielded 8551A BWO tube.

The use of the external sweep input on the 851B Display Unit gives several other interesting functional capabilities. For extremely slow sweeps and special setups it is possible to get a sweep slower than the present 3 sec/cm by the use of an external function generator, such as an -hp- Model 202A or Model 3300A Low-Frequency Function Generator. The analyzer of course tunes along with the input ramp sweep. An operator's own function ramp can also be used if other system synchronism must be tied in to RF sweep.

Finally, the external sweep input may also be used for a manual sweep function whereby a simple 15 volt power supply (HP 721A Power Supply) programs in voltages from 0 to 15 volts allowing manual sweep of the Spectrum Analyzer across its calibrated range. The analyzer will, of course, sweep over whatever RF range is set up on the 8551A front panel spectrum width control as the external sweep input voltage goes from 0 - 15 volts.

14. HOW TO OBTAIN VIDEO ENVELOPE INFORMATION FROM THE HP ANALYZER.

Sometimes there is important information to be gained in a video-time analysis of the unknown RF signal coming into a particular analyzer. This is easy to obtain in the -hp- analyzer merely by using the 20 mc IF test point at the rear of the 851B. The series of pictures of Figure 20 shows the type of additional information that can be obtained by utilizing the time domain scope to obtain information on the signal. The Hewlett-Packard 140A/1402 scope presents directly a 20 mc waveform and is accurately calibrated on a time base so that the pulse repetition frequency may be noted from (C). The RF frequency spectrum of the pulse is noted in (A) and (B), one in the log display and one in linear display. From the lobe bandwidth it is noted that the RF pulse width indicates that the RF pulse should be approximately 3.3 microseconds wide.

The time domain picture (D) confirms this and for comparison purposes the actual RF output pulse is detected by a crystal video detector and also presented on the oscilloscope (E) and shows the same thing.

Some surveillance operators depend upon determining rep rate merely by listening in on earphones; and, of course, this also can be tapped off of the vertical output of the 851B Display Unit.

If even wider band video information is desired the entire 3 mc bandwidth of the 2 gc IF amplifier can easily be used for fast rise time video information. The technique is to simply tap off of the 2 gc interconnection on the rear of the 8551A utilizing a power splitter or a directional coupler which operates at 2 gc. Part of the signal is fed back into the 8551A for the normal frequency analysis while the other portion of the signal is split off into a travelling-wave tube amplifier. This amplifier, such as an -hp- Model 491C or a low noise travelling-wave tube amplifier is then fed directly into a video detector, such as an -hp- 423A. These broadband circuits then provide fast response video information from the RF signal which is tuned in.

15. HOW TO MAKE IMPROVED X-Y RECORDINGS OF THE ANALYZER DISPLAY.

Hewlett-Packard highly recommends as a first choice the keeping of spectrum records by use of camera photography. The camera with its virtually instantaneous peak detection capability is hard to beat for seeing everything on the trace. For instance, broadband RFI caused by single shot transients is presented as extremely fast wide band spectra. To record such phenomenon with an XY recorder requires expensive coupling circuits that give pulse stretching characteristics at greater complexity. The camera techniques are fast and if many pictures are to be made, a convenient routine may be followed which provides calibration information on an envelope into which the photograph may be placed.

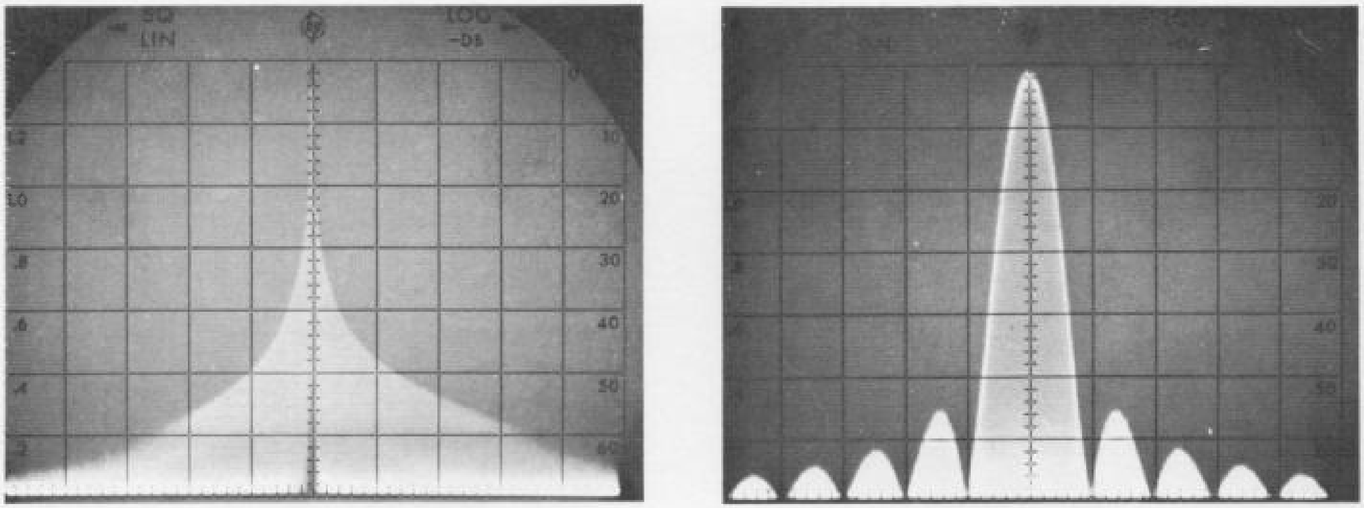
Notwithstanding the above, X-Y coordinate recorder outputs are provided on the rear of the 851B display unit. These are intended primarily for XY recording of CW type signals. Thus the actual video output from the rear terminals to the XY recorder is a signal corresponding to the CRT deflections as the analyzer sweep is made across the signal. Because of the response time of the typical XY recorder, it is necessary to utilize a very slow sweep speed especially if sharp skirts are presented on the trace.

As an added hint in this application, it might be noted that no pen lift circuit is provided, such as is available in the -hp- model 690 sweepers, so that the operator must observe the trace and manually lift the pen as the recorder reaches the end of its track.

The use of an XY Recorder for pulse-type spectra recording presents a different problem, however, in that the video signal arriving at the XY recorder actually is an envelope of the pulsed RF being applied to the input of the analyzer. As such, the XY recorder merely integrates the average value under the curve and generally does not respond.

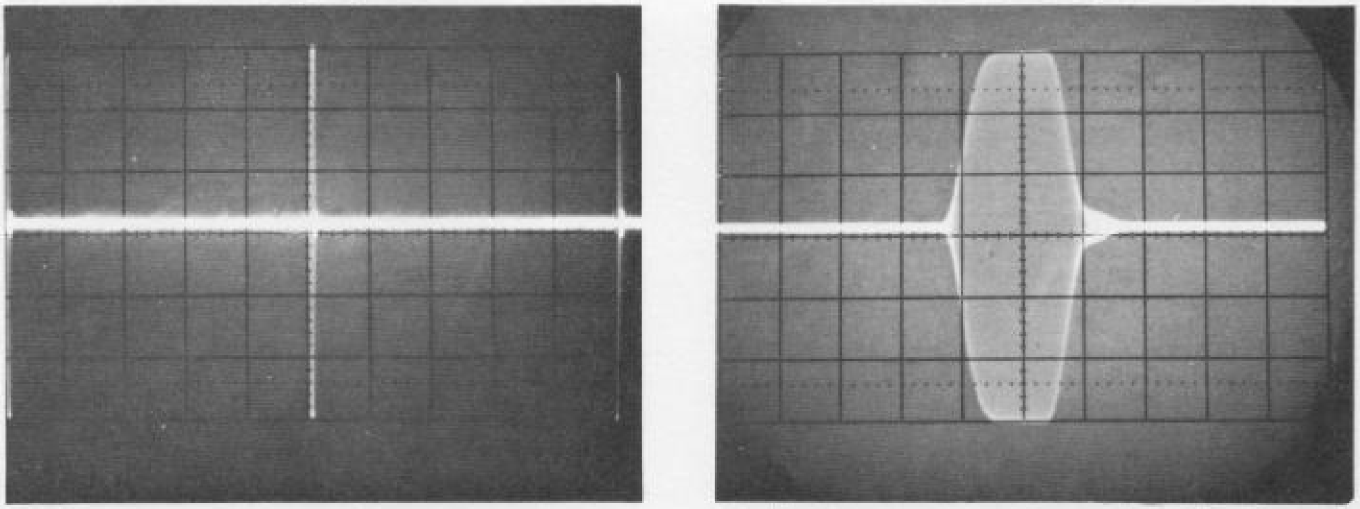
If it is necessary to provide XY recordings of the spectral response of a pulsed RF, then the following procedure is recommended.

Provide a simple peak detection circuit at the output of the 851B display unit (Figure 21) and use this to drive the high impedance input of the Y-channel of the XY recorder. This circuit works well with repetition rates down to about 50 pps. It can be used on IF bandwidths up to and including 100 kc.



(A) Spectrum Width - 10 Mc/cm
IF Bandwidth - 10 Kc
Log Display, f_c = 1620 Mcs

(B) Spectrum Width - 300 Kc/cm
IF Bandwidth - 10 Kc
Linear Display, f_c = 1620 Mcs



(C) Here the PRF period is noted as 250 μsec giving a PRF of 4 Kc. (50 μS/cm)

(D) The RF pulse has a voltage pulse width of slightly over 3 μsec agreeing with the analyzer prediction.

(E) For comparison, the output RF pulse is shown detected by a 423A Crystal Detector.

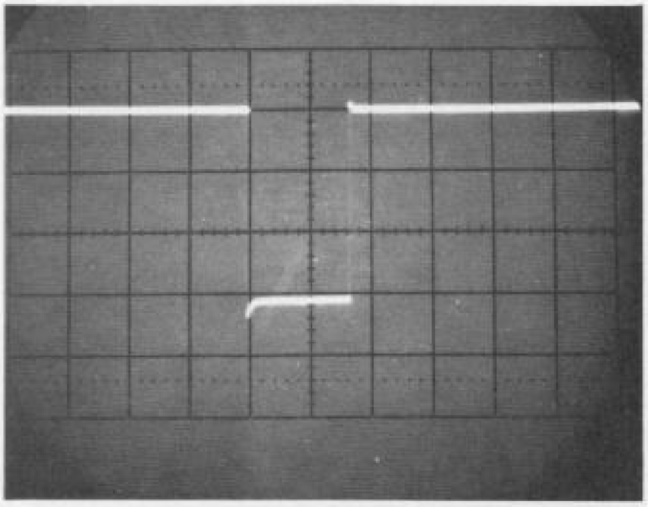


Figure 20. This is a hypothetical spectrum surveillance situation where an interfering signal at 1620 Mc is noted. By narrowing the spectrum width control, it is noted that the interfering signal is a pulsed RF type. The main lobe nulls are approximately 600 Kc apart, thus 2/Pulse Width yields an RF pulse width of approximately 3.3 μseconds. Time Domain Information (C) and (D) was made by connecting a Model 140A Scope to the 20 Mc IF test jack. The IF signal here is time correlated with the incoming RF signal.

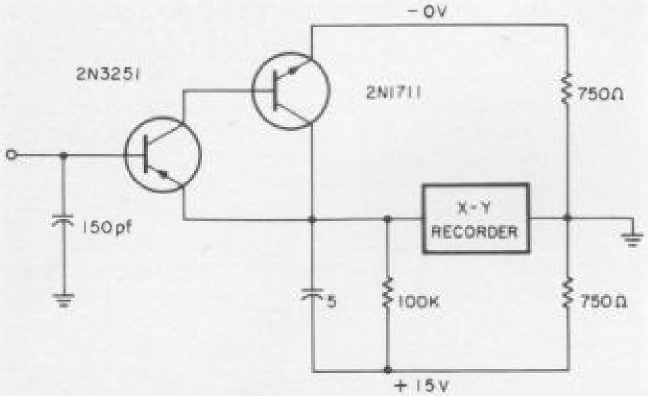


Figure 21. This simple peak detector provides more sensitivity for X-Y recordings of pulse waveforms.

16. HOW TO VERIFY VERY FAST PULSE RISE TIME MEASUREMENTS.

Present tunnel diode pulse generators are achieving subnanosecond rise times with ease these days and the sampling oscilloscope method of measuring the rise times becomes marginal. The broad sweep analyzer provides a method of showing video-type pulses directly and analyzing them for pulse shape characteristics and rise time considerations. For instance, a 1 nanosecond width video pulse should exhibit a spectrum zero at 1000 mc. Figure 22, as an example, shows a 10 nanosecond width pulse with spectral components extending all the way out to 2 gc and its first spectral zero at about 100 mc. This technique is a powerful check on fast pulse circuitry.

Not only can envelope zero crossings tell much about pulse widths, but the frequency envelope shape reveals the rise and fall time characteristics of the video pulse. Referring to Figures 7 and 8 on page 37 of AN 63 shows how a frequency spectra envelope differs between an ideal rectangular pulse (6 db/octave) and a triangular one (12 db/octave). These transforms are useful in interpreting fast video pulse spectra. The more common trapizoidal wave shape falls between these two limiting cases. Thus an unknown pulse with an envelope exhibiting 7 to 8 db/octave spectral envelope falloff has a rise time slope nearing a perfect rise. The spectral envelope can be measured in the log mode with readings made at octave frequency intervals. If the falloff is near 12 db on any octave, the pulse is near triangular. If the operator can control pulse width on the test pulse, then he can narrow it until 12 db/octave is obtained and know it is triangular.

17. HOW TO GET MORE SENSITIVITY IN SPECTRUM SURVEILLANCE APPLICATIONS.

The -hp- analyzer was specifically designed for a completely wide open front end so that it could be used in a variety of applications. Thus no RF passive or active preselection is provided and the input goes directly to the first mixer. This means that the mixer conversion loss and the noise figure of the first 2 gc IF amplifier presents a relatively poor noise figure to an input signal. For spectrum surveillance purposes and a number of other requirements, therefore, RF preselection and amplification is desirable and, in fact, required in many cases. It was determined that whenever this sort of preamplification is required it is best to do it on a specific application basis so the preamplification can be specifically chosen for bandwidth, gain, and noise considerations and put in the right place. For obvious reasons it is recommended that RF preamplifiers be placed very close to the receiving antennas, such as the conical spiral or periodic logarithmic antennas used in surveillance testing.

Although a wide variety of preamplifiers can be used, the following listing is offered as a suggestion since they have been tried and found suitable for providing low-noise gain.

10 TO 150 MC

The -hp- Model 461A is a broadband amplifier intended for video amplifier service but useful for preamplification. When used in its 40 db gain position (the 20 db attenuates at the input), it provides approximately 16 db noise figure operating in a 50 ohm input-output system, resulting in overall system improvement of as much as 15-20 db.

10 TO 500 MC

The Boonton Model 230A is a tunable narrow-band power amplifier but one which provides excellent small-signal gain too. It has low noise figure and is useful across the entire VHF band. The 230A provides a minimum of 24 db of gain with bandwidths ranging between 700 kc and 1.4 mc and thus is entirely suitable for preamplifying most of the AM and FM modulated signals on the air in this frequency range. Since it is a narrow band tunable amplifier it also provides its own preselection capability and thus rejects many of the other high level signals often on the air in the vicinity of a receiving antenna.

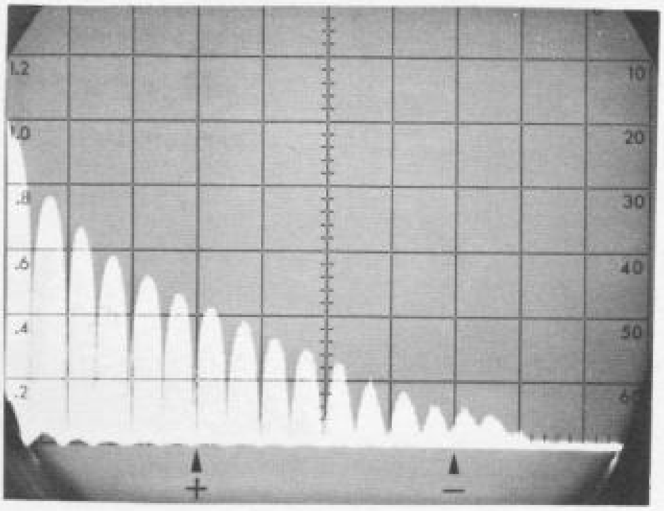


Figure 22. Pulse spectrum of a 10-nanosecond pulse exists out to almost 2 Gc. (Horizontal 200 Mc/cm.)

30 TO 1000 MC

Two models of tunable RF amplifiers are provided in this band by Electro International, Inc., Box 391, Anapolis, Maryland. One model covers the 30 to 300 mc range in two bands with approximately 23 db of gain, 4.5 db noise figure and bandwidths from 2 and 5 mc. The second model covers the 300 to 1000 mc range in a tuned mode width a bandwidth from 3.5 mc and 15 mc and a nominal gain of 26 db. The bandwidths of these amplifiers again are adequate for most of the signals encountered in this VHF and UHF band.

UP TO 1000 MC

Applied Technology, Inc. at 3410 Hillview Avenue, Palo Alto, California, provides a broadband untuned amplifier series that operates in the 100 to 1000 mc frequency range.

Band	Model	Gain	Noise Figure
100 - 200 mc	SP 110	25 db	4 db
200 - 400 mc	SP 120	25 db	4 db
250 - 500 mc	SP 150	25 db	4.5 db
300 - 600 mc	SP 130	30 db	6 db
300 - 1000 mc	SP 140	25 db	8 db

Most semiconductor and other preamplifiers cause a loss of the analyzer dynamic range. A typical preamplifier dynamic range would be about 30 db and thus care must be exercised to avoid overloading the amplifier with either the signal under test or other adjacent high level signals that might be in the area. Passive preselector filters may be used.

1000 MC TO 12,000 MC

The most convenient method for covering the microwave frequency range is a series of low-noise octave range traveling-wave tubes. These are typified by a Series from Watkins-Johnson Company, 3333 Hillview Avenue, Palo Alto, California, exhibiting the following charcteristics.

Band	Model	Gain	Noise Figure
1 - 2 gc	WJ-268	25 db	5.0 db
2 - 4 gc	WJ-269	25 db	5.5 db
4 - 8 gc	WJ-271	25 db	6.5 db
8 - 12 gc	WJ-276	25 db	8.5 db

These traveling-wave tubes are particularly well suited for preselector service since they are individually packaged in a small physical size and self-contained with their own power supply operating directly from 115 volt line. As such, they may be conveniently mounted on the remote pedestal holding the receiving antenna and provide low-noise amplification into the drive line back to the analyzer. The tubes, although fairly broadband, provide some element of preselection. However, they should actually be used in conjunction with the -hp- 8430A Bandpass filters mentioned in Section 4 so that better band selection may be realized.

As other preamplifiers are encountered and evaluated they will be reported in subsequent editions.

18. HOW TO USE THE SPECTRUM ANALYZER FOR RFI MEASUREMENTS.

The present and expanding spectrum utilization has required increased attention by industry to radio frequency interference and thus much increased activity is being generated in the areas of RFI testing and control. Hewlett-Packard's own environmental test lab has begun the use of the 851B/8551A Spectrum Analyzer in frequency ranges where sensitivity is adequate since the measurement time is greatly reduced because of the wide-range sweeps available.

Although there are a wide variety of specifications, limits and procedures, much common information underlies many of the tests and may be useful. Some of the current government specifications are:

MIL - I - 16910C (Navy)
MIL - STD - 826 (A. F.)
MIL - I - 6181D (A. F.)
MSFC - SPEC - 279 (NASA)

In general, the sensitivity of the -hp- analyzer is adequate to measure interference signals over the range from 200 mc to 10 gc. In the region from 10 mc to 200 mc, the specifications generally require more sensitivity so design work is proceeding at HP on a broadband low noise preamp to be used for RFI measurements in that range.

The types of RFI radiation usually considered are:

A. Conducted. Three types of spurious radiations conducted through power line, CW, pulsed CW and broadband. Measured by connecting RFI analyzer across a standard line impedance stabilization network. These are not performed by microwave analyzers.

B. Radiated. Self-explanatory. Measured by connecting RFI analyzer into antenna placed a specified distance from unit under test.

   1. CW. (Narrow band) Discrete or single frequency radiation.
   2. Pulse CW. (Broadband) Where spectral width is greater than a specified receiver bandwidth.
   3. Broadband. Wide band radiation such as generated by noise or impulse sources. Since noise and broadband radiation is dependent upon bandwidth, radiation intensity specifications are stated in terms of μv/mc below 1 gc. (μv/mc/meter above 1 gc.)

The units of radiation intensity measurement vary with the frequency range. Below 1 gc. Antennas are generally located within the near field of radiation pattern. Measurements generally are made in terms of voltage induced on a standard antenna at specified distance. 1 to 10 gc. Antennas are located in far field, or Fraunhofer region, at shorter wavelengths and standard antenna field intensity formulas can be used with gain calibrated antennas. Measurements are made in terms of μvolts/meter at specified antenna distance.

The following procedures will supplement the information from page 24 and 25 of Application Note 63.

CW RADIATED

In the 200 mc to 1000 mc range and in the 10 kc bandwidth position, the -hp- spectrum analyzer has a sensitivity specification of -95 dbm for a 50Ω system. Since -107 dbm is equivalent to 1 μvolt in a 50Ω system, this means that the analyzer sensitivity is equivalent to +12 db above 1 μvolt. Allowing about 8 db for the dipole to 50Ω correction plus cable loss and 6 db for the specification requirement that the receiver sensitivity be 6 db better than the spec limit, the effective sensitivity is +26 db UV. In a typical narrow band CW/RFI specification the specification limit is 30 db above a μvolt (antenna induced) (dbuv) at 200 mc to +40 dbuv at 1000 mc. (See Figure 23). This means that the basic sensitivity of the analyzer is adequate to measure narrow band CW RFI in this range.

An appropriate low-pass filter, such as the Model 360B, should be used. Generally a tuned dipole is utilized for the receiving antenna and it is tuned to the recommended frequencies of the required specifications. The analyzer is calibrated by a signal generator method across the frequencies of use. In this case the analyzer would be set up for a 200 to 1000 mc sweep and a signal generator applied to the input terminal at the various frequencies of interest. The signal generator power setting would be determined by the particular antenna gain characteristic and the conversion correction from the 72Ω dipole to 50Ω line. A typical correction is +7.7 db, since the specification is in terms of an open circuit dipole but the load on the dipole balun is 50Ω.

As seen by the typical limit line of Figure 23, various signal generator settings would be needed to calibrate the analyzer graticule. A grease pencil or transparent mask might be useful.

1000 TO 10,000 MC

The analyzer has also been found adequate for sensitivity in the 1 to 10 gc range and much the same procedure is followed as above. The Polarad CA-LPR model log periodic antenna is recommended since excellent flatness characteristics are obtained and adequate antenna gain is available to utilize the available sensitivity of the analyzer. The general narrow-band CW RFI specifications are +60 db above a microvolt per meter (+dbve) for this range. Again correction must be made for the antenna gain and the preselection interdigital filter losses in the range of interest. Preselection is recommended and sweeps of less than 2 gc are also recommended for these measurements.

However, for quick look considerations the mixer on the analyzer can be left wide open and be fed directly from the 1 to 11 gc antenna so that all signals in that range of reception can be presented on the front panel of the analyzer at all times. This would be used for quick surveillance type RFI reception so that adjustments may be made to the equipment under test. After various components have been corrected then recourse can be made to the individual preselection bandwidths for detailed study of the specification.

PULSED C-W

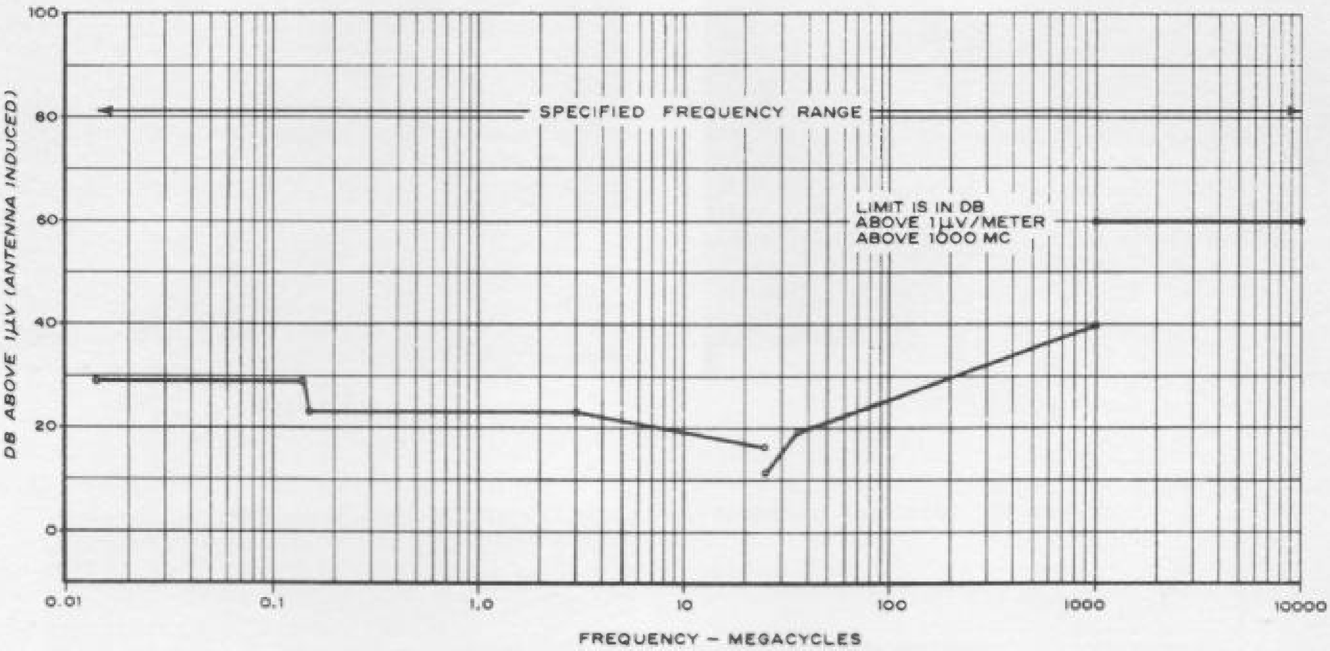
The pulsed-CW response (line spectrum display) are calibrated the same as CW signals except for the correction which must be made for the pulse desensitization caused by the finite bandwidth of the spectrum analyzer. It is generally better to work on a wider bandwidth, such as 100 kc, position for this test since it does not present as much desensitization to the signal being measured. Typical limits for this test are also presented in Figure 23. Pulsed CW signals are measured in μv/mc and plotted under the broadband limits.

The pulse desensitizing factor is computed from a knowledge of the pulse width of the interference and the BW used. $\alpha = 20 \text{ LOG } K\tau\Delta f$ (See page 25 AN 63)

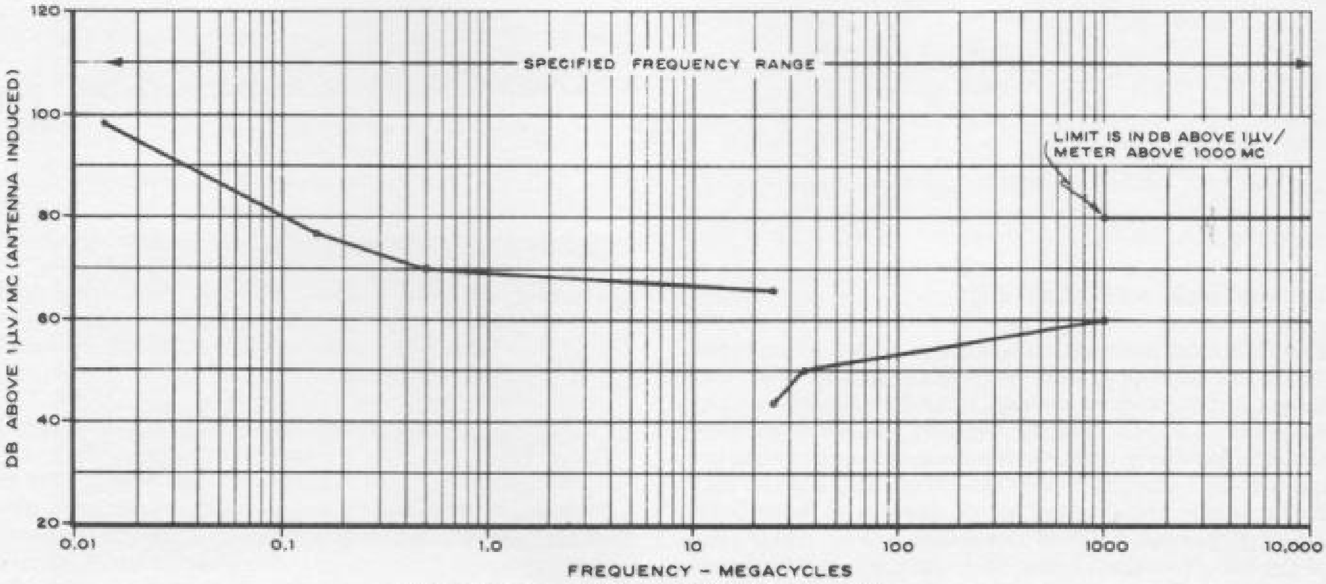
BROADBAND

1. Broadband signals such as noise can be conveniently measured in terms of power/unit bandwidth over broad ranges.
2. Connect a microwave power meter, -hp- 431B/478A to the 20 Mc IF test point on the rear of the 851B through an -hp- 461A VHF Amplifier.
   a. Set the vertical display control to linear.
   b. Set the IF bandwidth to 1 Mc.
   c. Tune in the signal from the calibrating signal generator.
   d. Reduce the spectrum width to zero by turning the vernier completely counter-clockwise. This makes a fixed tuned receiver. Adjust the tune control for maximum CRT deflection on the analyzer.
   e. Adjust the gain of the amplifier and power meter and the analyzer's RF and IF attenuators for a convenient reference setting on the 431B for a given RF signal generator input power.
   f. Reduce the signal generator power by 10 db and check to see if the power meter indication decreased 10 db.
   g. The spectrum analyzer is now calibrated in dbm/Mc. A correction should be made for the fact that the band pass shape of the 8551A 1 Mc bandwidth position is such that it corresponds to a 1.1 mc equivalent noise bandwidth. (.5 db)
   h. Connect the noise source to the analyzer and read the power/Mc on the 431B. This reading could also be converted back to dbuv/mc to plot on broadband limit curves.

Many varieties of specialized RFI tests may be performed with the spectrum analyzer, limited only by the imagination of the operator. For instance, in the sequence of pictures shown in Figure 24, the -hp- analyzer was set up with a dipole antenna and the ignition noise from a 1957 Ford monitored. The display frequency range is 1 to 2 Gc and ignition noise components are noted strongly across most of the range. The analyzer may, as before, be calibrated to read directly in -dbm/mc of power density by utilizing a signal generator. Note the partial shielding influence of the hood position.

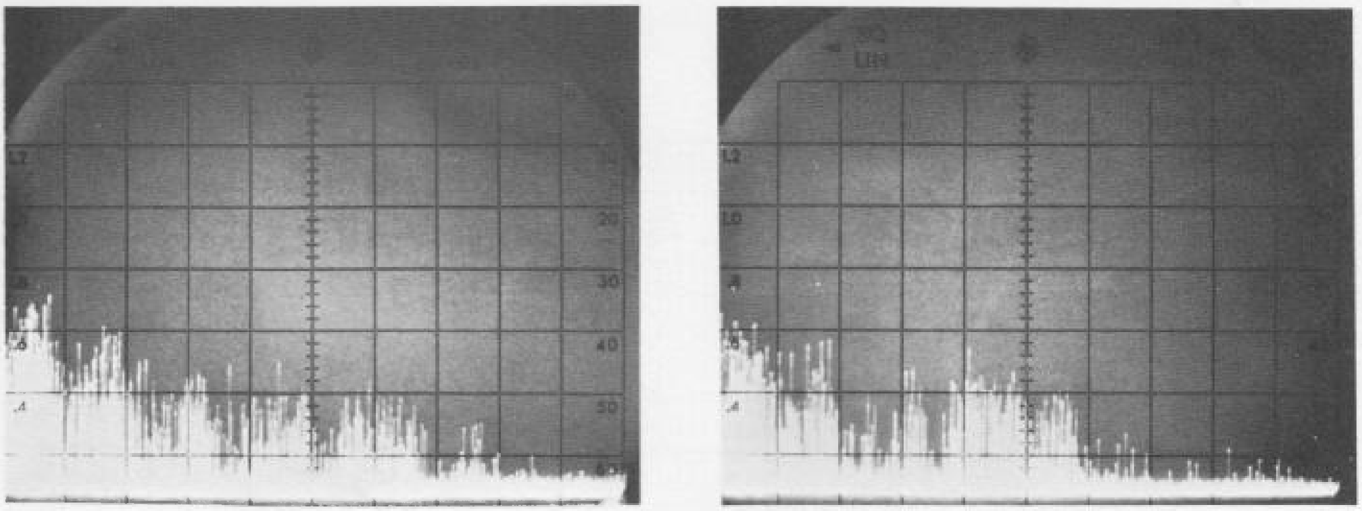


NARROWBAND (CW) RADIATED INTERFERENCE LIMITS



BROADBAND RADIATED INTERFERENCE LIMITS

Figure 23. Hewlett-Packard RFI limits for radiated interference (MIL-I-6181D from 150 kc up).



Hood up

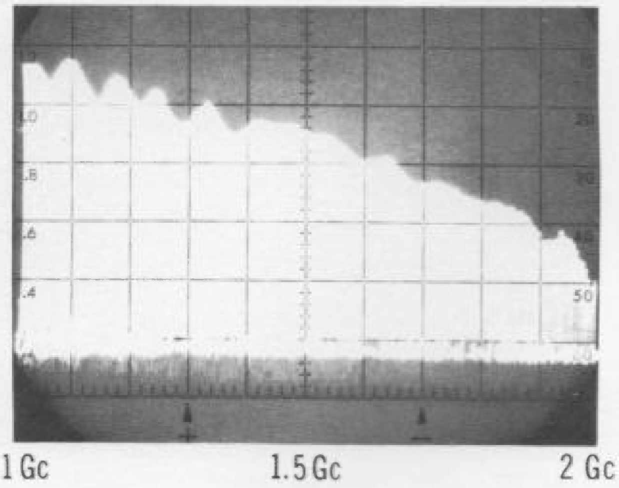
Hood down

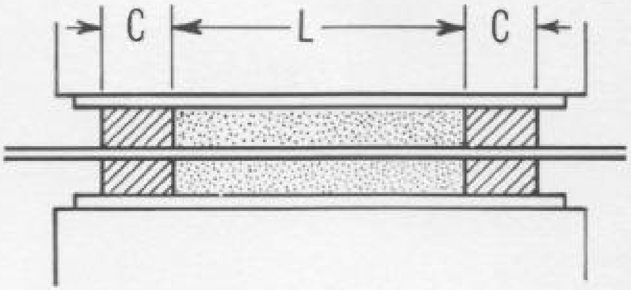
Figure 24. 1957 Ford ignition system shows influence of hood up or down.

19. OTHER APPLICATIONS

The following pages are a series of spectral pictures which encompass a wide variety of applications that show off the general usefulness and versatility of the analyzer. These various applications were encountered in the early work with customers that are utilizing the -hp- analyzer. Several represent some relatively unique applications which may be of benefit to other people encountered in similar work. Again, one of the main features of the -hp- analyzer is its general versatility which permits it to be used in a variety of applications. We hope that some of the ideas presented here will be useful to you. Be sure to call your local -hp- field engineer whenever any applications or technical problems are encountered which may be solved with spectrum analysis.

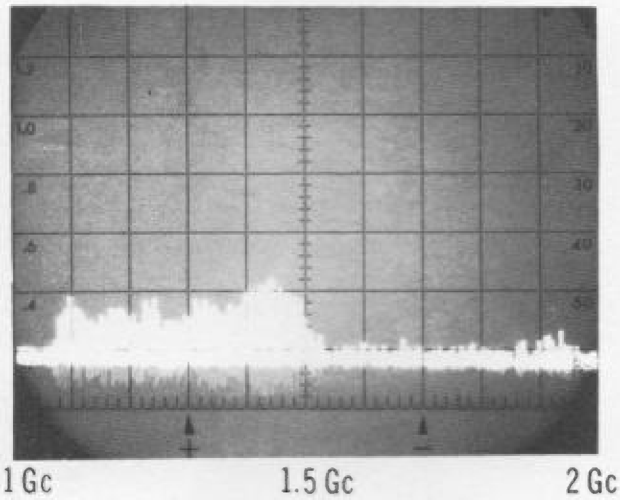
The following figures show the results of attempts to shield the leads of a backward-wave oscillator tube for RFI leakage. RFI filters were constructed for the leads as shown in the photograph and the pictures show the amount of conducted RF leakage for the frequency range between 1 and 2 gc. Note that a little polyiron material applied at the proper places does a better job than a lot of polyiron.

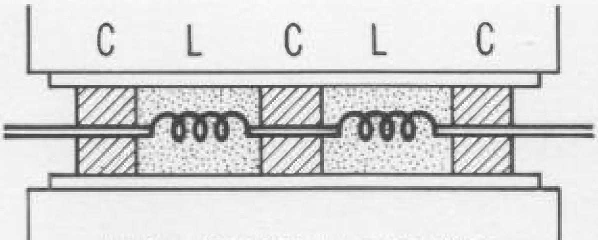




STRAIGHT WIRE SOLID POLYIRON

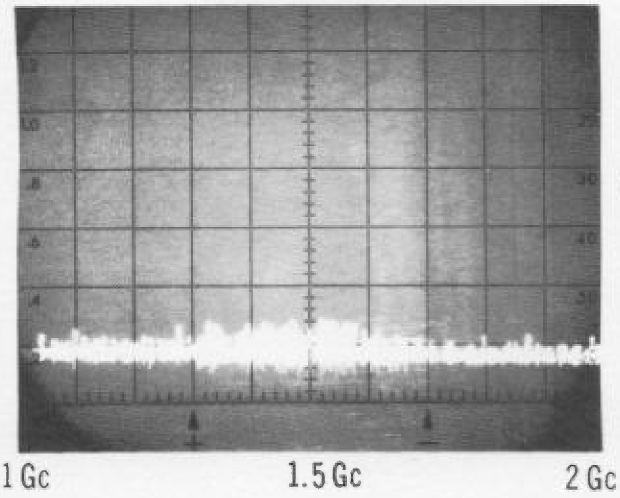
(a)

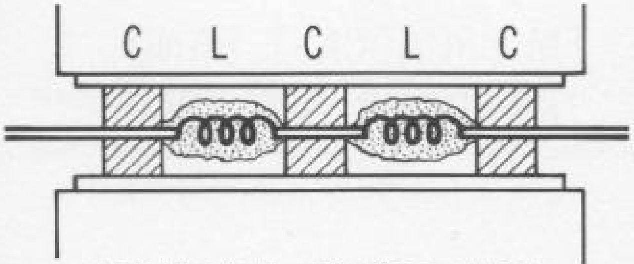




INDUCTORS IMBEDDED
IN POLYIRON

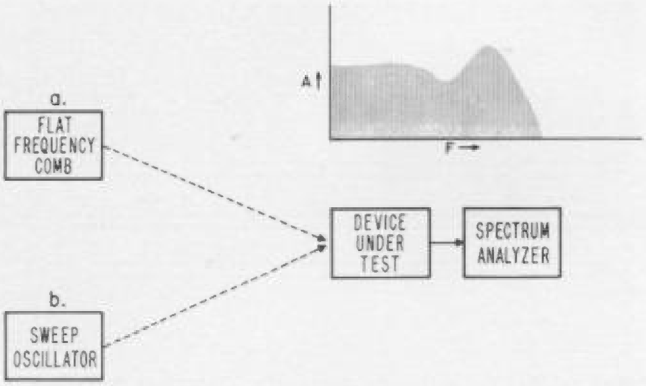
(b)





INDUCTORS COATED WITH
THIN LAYER OF POLYIRON

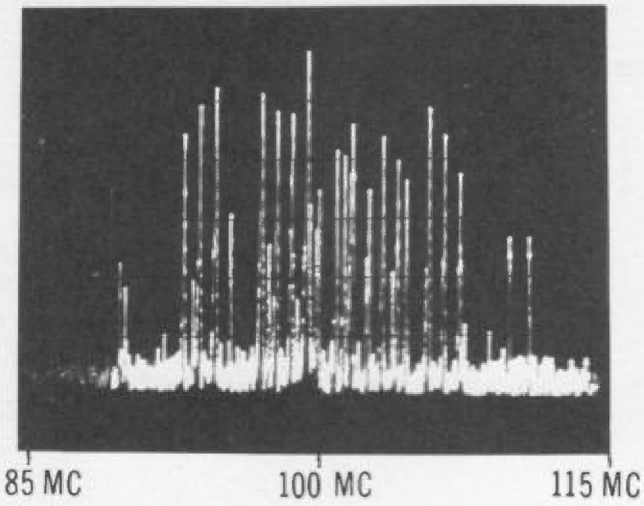
(c)



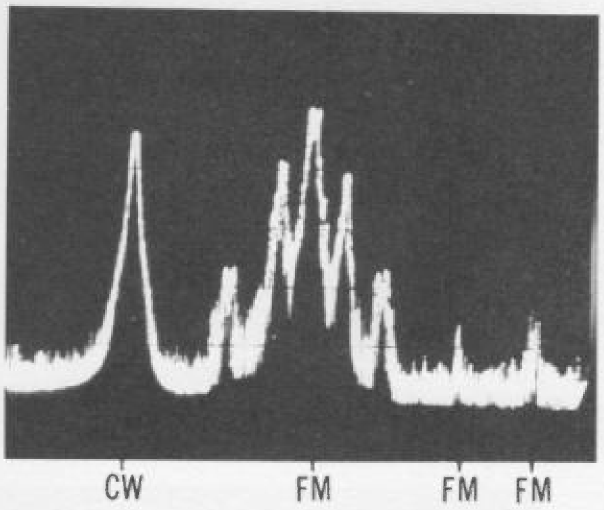
Frequency Response. The method shown above uses a flat amplitude comb generator to provide instantaneous plotting of frequency response of filters, attenuators, or amplifiers. The sensitivity and 60 db dynamic range obtained here is not available in most swept frequency techniques employing video detection. Furthermore, video detection measures total power and does not discriminate frequency. The spectrum analyzer will display mixing products, harmonics, or spurious signals generated within the tested device.

Site Survey. With preselectors such as band pass filters or YIG tunable filters, the spectrum analyzer will provide the information needed for site survey. A typical recording of the FM Broadcast band is shown below. (88-108 mc) The expanded view shows two strong stations, one with and one without modulation. Two weaker stations can also be seen on the right.

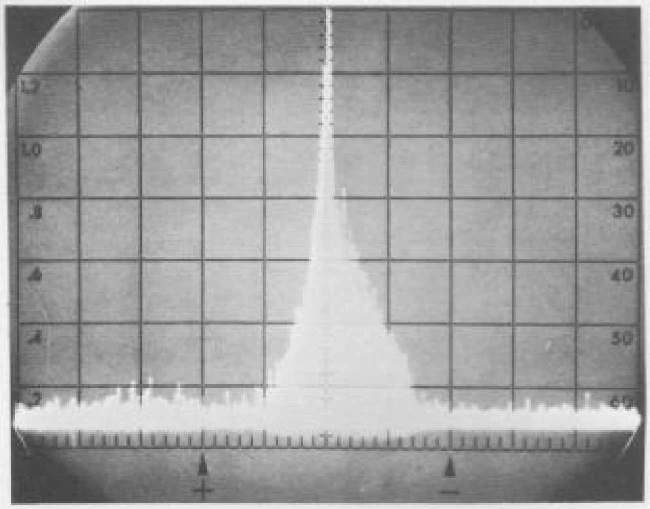
For statistical recordings more elaborate output accessories are necessary. A preset gate could deliver pulses to a digital register whenever a signal appears above the preset threshold. These pulses can be sorted into appropriate registers representing a frequency interval as controlled by the frequency sweep of the analyzer. The sampling process continues for every sweep of the analyzer. After a 24 hour period, or longer, the registers can be read for the statistical "on time" of the signals.



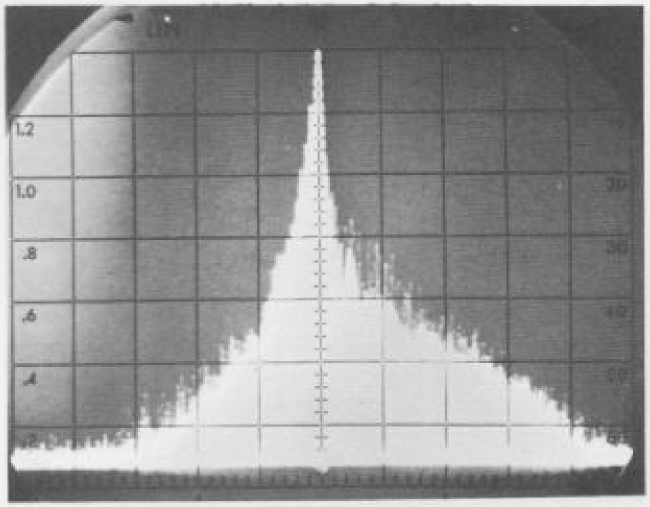
FM BROADCAST BAND
88-108MC 3MC/CM



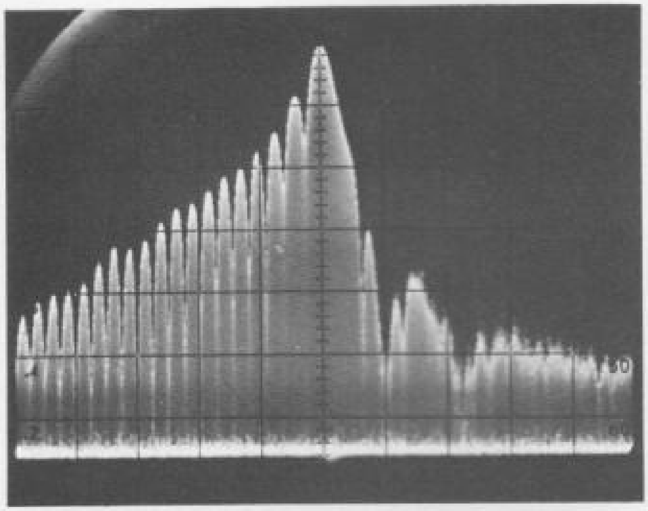
TYPICAL FM STATIONS
100KC/CM



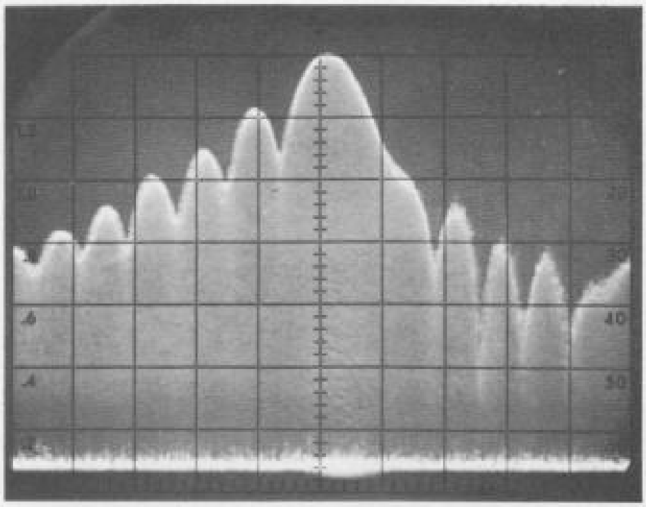
30 mc/cm



10 mc/cm

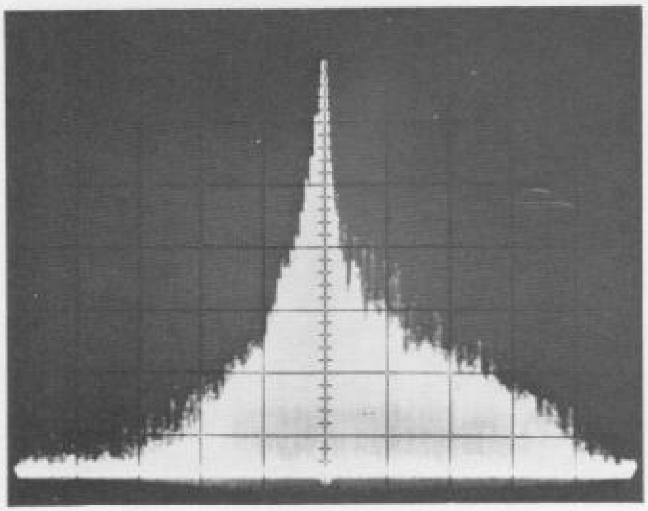


3 mc/cm

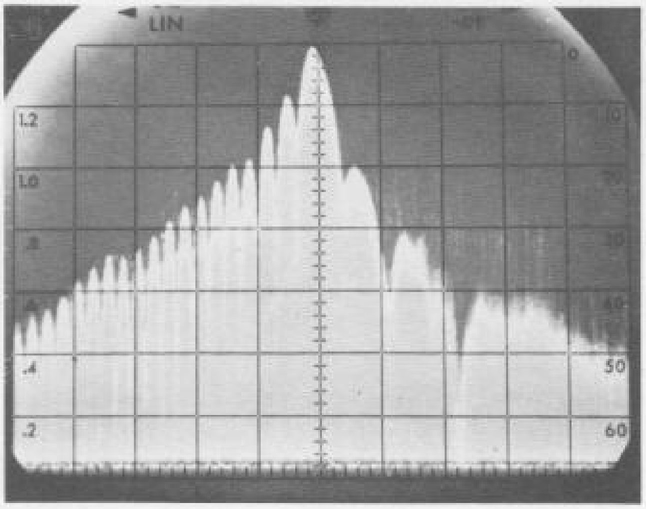


1 mc/cm

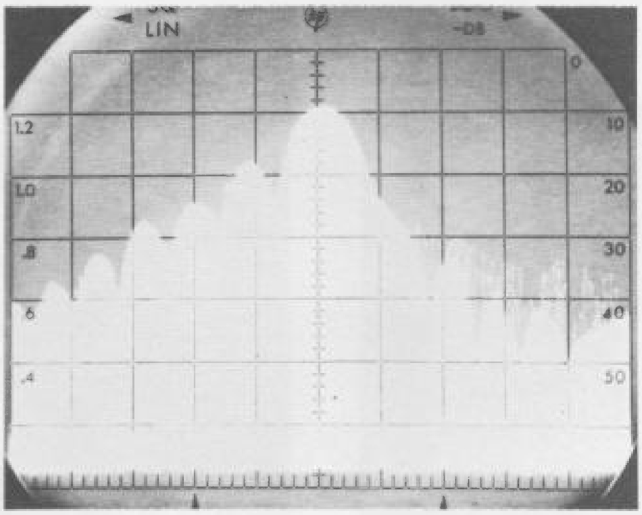
The above is a typical spectrum signature of the fundamental frequencies of an "L" band radar with an approximate 1.0 μsec pulse width. The above pictures were made with a 10 kc band width and show the 60 db log presentation. Note transients from magnetron along with extreme FM. Transients would not be seen on conventional analyzers with 40 db display range.



10 mc/cm



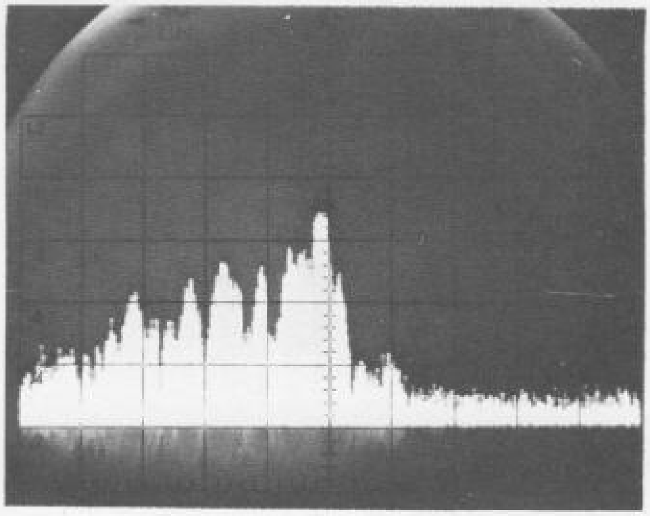
3 mc/cm

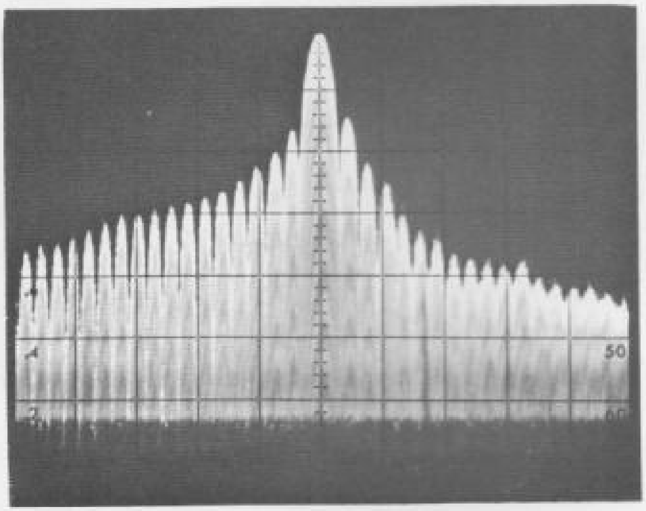


1 mc/cm

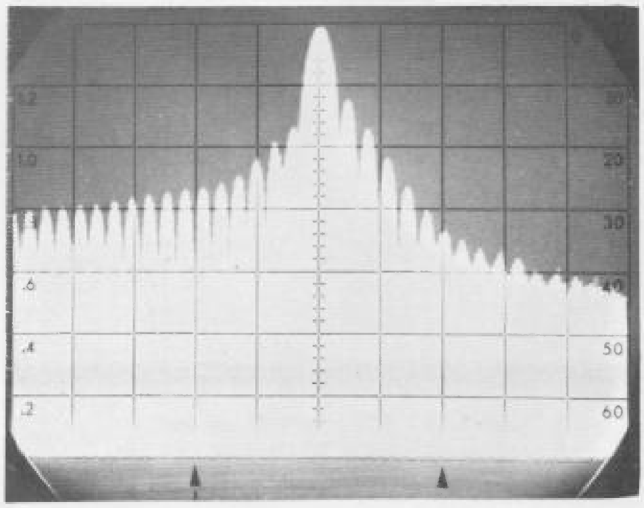
Here is a radar where the magnetron is moding rather badly. Note the transients occurring on the high side of the carrier frequency. Only a high speed photographic record would show this.

This is the third harmonic output of a radar operating at a pulse width of 4.5 μsec and f_c of 1300 mc. An interdigital filter (2-4 Gc) was used to trap out the fundamental. The sweep width is 3 mc/cm.

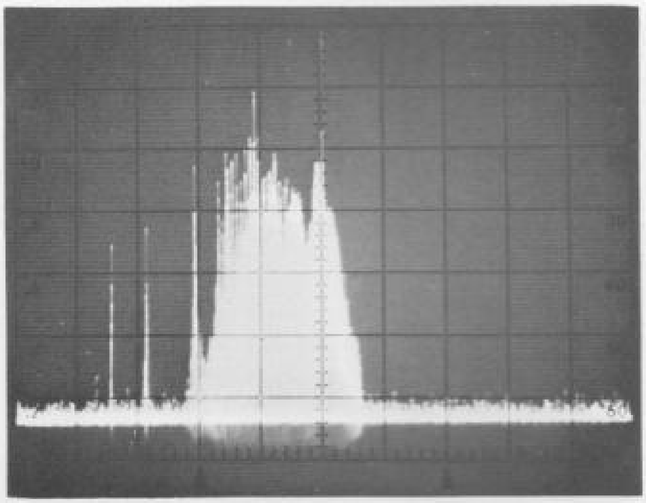




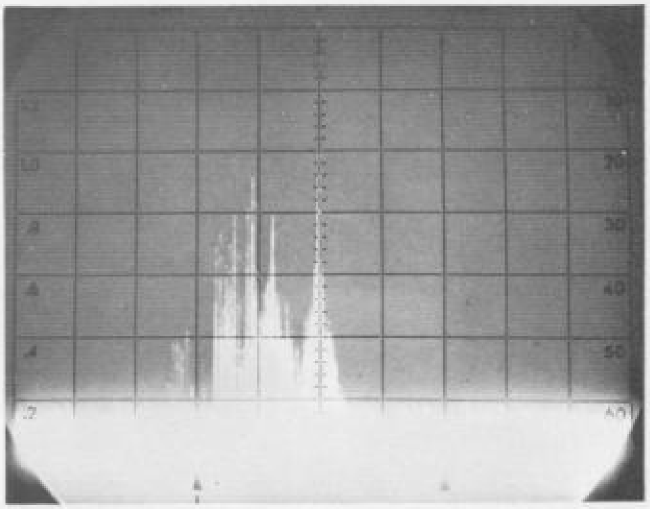
Channel A; 1 mc/cm



Channel B; 1 mc/cm

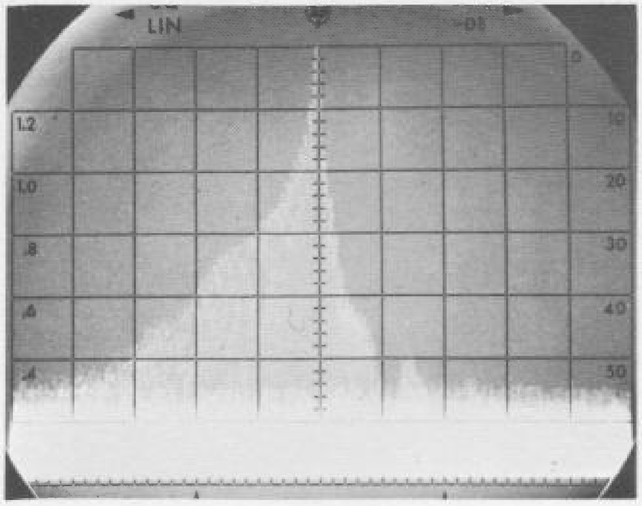


Magnetron output; 100 mc/cm

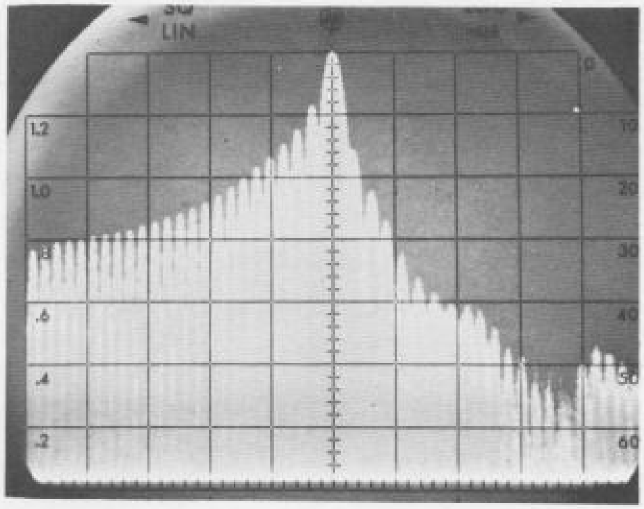


Duplexer output; 100 mc/cm

This is another radar which employed two channels. Channel "A" operated normally, but Channel "B" had marginal FM. The magnetron output had considerable noise and spikes showing up which did not show up on the duplexer output. Note the one picture when the base-line dimmer was not used. When base-line dimmer is used, true base level remains at zero.

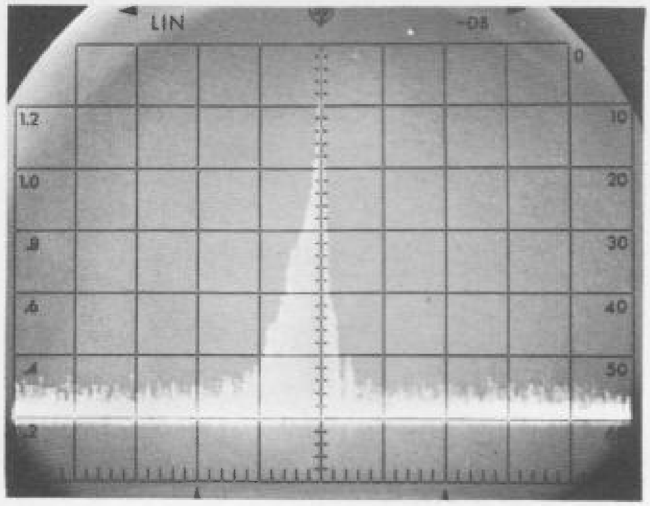


L Band Radar 300 pps/4.5 μsecond
3 mc/cm Spectrum Width Log Display

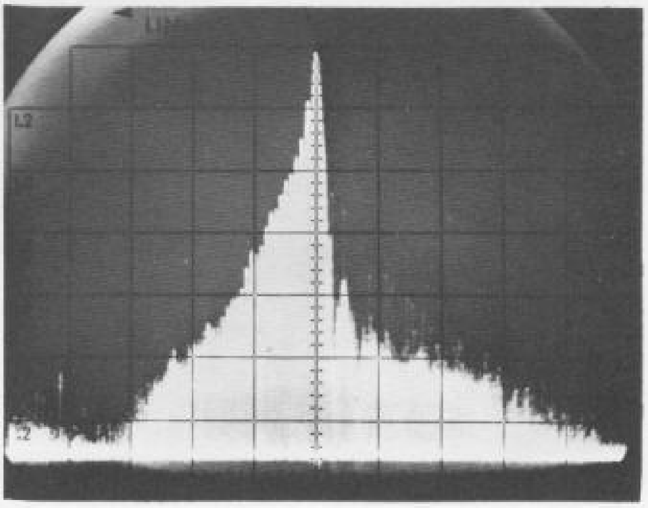


Same conditions as at left except 1 mc/cm
Spectrum Width

Here is a spectrum display of one of the cleanest radars noted. Note the absence of moding. The FM present seems to be normal for conventional magnetron.

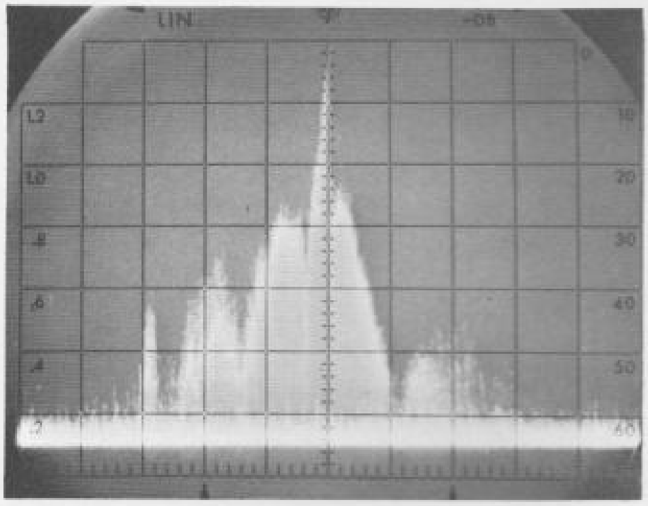


4.5 μsec



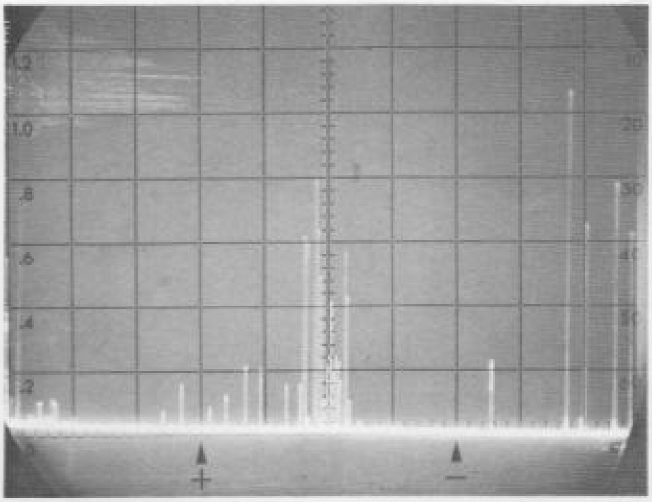
1 μsec

These are spectrums of a radar when the pulse width is changed from 4.5 μsec to 1.0 μsec. Note the change in spectrum. An IF bandwidth of 10 kc and sweep width of 10 mc/cm was used. Note the increased transient effects on narrow pulse operations.



This is a display of a 1 megawatt radar at mid-L band showing spurious radiation over 300 mc below the main carrier and interfering in TACAN channels. Horizontal 100 mc/cm, vertical 10 db/cm. Some emitted broadband output is only 20 db down from carrier (10 kw).

10 mc to 200 mc sweep shows TV Channels and FM stations.



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