SPECTRUM ANALYZER APPLICATIONS IN CABLE TELEVISION

I. Switzer, P. Eng.
Chief Engineer
Maclean-Hunter Cable TV Limited
27 Fasken Drive
Rexdale, Ontario, Canada

Spectrum analyzers are bound to find many applications in cable television systems because of their close family relationship to the familiar signal level meter. Signal level meters are heterodyne receivers tunable manually and are usually single conversion receivers, tuned manually, fixed IF bandwidth with a moving coil meter indication of input signal level. Spectrum analyzers are also heterodyne type receivers but have electrically swept local oscillator(s) and usually display the input signals on an oscilloscope type display signal amplitude versus frequency. The more sophisticated versions have logarithmic display over a range of 70 db or more, selectable bandwidths, and very stable sweep and tuning characteristics.

Our company has been using spectrum analyzers for more than four years, principally for observation of signal levels in various parts of the system and for finding and eliminating many sources of spurious signals in cable television systems. Our early spectrum analyzers had 5 KHz bandwidth, tuning range of 1 to 300 MHz in a single display and a 50 db dynamic signal display range. About six months ago we acquired a more sophisticated spectrum analyzer system consisting of a Hewlett-Packard 141T display frame with 8553B RF section, 8552B IF section, 8443A tracking generator/counter, and an 8554L RF section. The 8553B tunes 1 KHz to 110 MHz (in a single sweep if desired) and has a range of IF bandwidths from 300 KHz down to 10 Hz. The associated IF section provides 70 db display (10 db/division) or 16 db of display in a 2 db/division mode. Linear display is also available. The 8554L RF section tunes 1 to 200 MHz but is limited to 300 Hz bandwidth by the less stable oscillators in this RF section. The 8443A which operates with the 8553B RF section adds a tracking oscillator which acts as a sweep generator which frequency tracks with the associated receiver. A built in frequency counter operates with a "marker" on the display to permit 8 digit reading of any desired point on the display. The counter provides 10 Hz resolving power and has an internal clock specified to 3 parts in 10^8 accuracy. Detailed specifications are available from the manufacturer.

TRACKING GENERATOR APPLICATIONS

The tracking generator works only with the 8553B RF head and is consequently limited to a 110 MHz range. We use heterodyne conversion techniques to extend the range to higher frequencies but this can be done only over a narrow frequency range, e.g. one or two TV channels, because of flatness problems in the accessory mixers. Figure 1 is a simplified block diagram of the spectrum analyzer and tracking generator/counter. This combination makes an extremely useful sweep generator instrument. Spurious frequency components in the sweep signal output are ignored by the selectivity of the receiver section. The 70 db dynamic range in the display makes it possible to observe response over a wide amplitude range. This is particularly useful in working with channel band pass filters and with head end processing equipment. The associated counter permits easy direct digital reading of frequency at any point on the display. Dispersion calibration is reliable and this also assists in the examination of cable TV equipment.

continued...

Frequency range of the tracking generator/spectrum analyzer combination can be extended by use of a double heterodyne technique similar to that used in cable TV head end signal processing equipment. A local oscillator of the desired frequency drives two mixers, one acting as an up converter for the tracking generator signal and the other as a down converter to bring the signal back to the tuning range of the spectrum analyzer. The selectivity of the spectrum analyzer looks after image problems. A pad in the input to the splitter assists the hybrid splitter in providing isolation between the two mixers. A combination of good mixer isolation characteristics and good isolation in the splitter hybrid provides adequate overall isolation. Local oscillator drive must be adequate to make up for pad and splitter loss. The local oscillator stability and frequency accuracy affect any frequency measurements made with counter in this system. A laboratory signal generator is adequate for most purposes. Its frequency can be measured separately. For many purposes, we use a special local oscillator which we developed to extend the range of the 8553B RF section to 220 MHz.

We have developed a special purpose heterodyne "block converter" for converting the 110-220 MHz band down to 0 - 110 MHz so that it can be tuned on the 8553B RF section, see Figure 3. The 1 MHz clock signal from the 8443A counter is multiplied up to 110 MHz and used as the local oscillator in a block converter. This 110 MHz local oscillator is also available for use in the double heterodyne range extension system discussed above. At the present stage of development of this converter, the local oscillator is not as clean as we would like for use with the narrowest dispersion and bandwidths available on the 8553B and we may introduce a phase lock loop system to generate a cleaner local oscillator locked to the 110th harmonic of the 1 MHz clock signal.

The double heterodyne system was modified slightly to permit use of cable system carriers as frequency markers in examining the characteristics of a "high performance" channel band pass filter for channel 11. The filter had been ordered to provide maximum rejection of a strong local channel 10 signal. See Figure 4. Cable system carriers were mixed into the input of the channel 11 filter being tested using a hybrid directional coupler. Rejection of channel 10 visual carrier is seen to be only 26 db and channel 10 sound carrier is only about 6 db down! The wide dynamic range visible in a single display makes this a very useful technique for the examination of filters and processing equipment.

An old single channel amplifier strip (channel 11) was selected for demonstrating the use of the tracking generator in checking head end processing equipment. This strip was retrieved from a pile of obsolete equipment. Figure 5 shows the frequency response as observed with the tracking generator and with a conventional sweep generator and broad band detector. The strip is obviously very badly aligned. This is obvious even from the conventional sweep display in 5C. Figure 6 shows results after a preliminary re-alignment.

It is possible to check the alignment of processing equipment by injecting the tracking oscillator signal at reduced level through a directional coupler at the input of the processing unit and recovering it for the spectrum analyzer at the output of the processor. This technique is demonstrated in Figure 7. Generator level has been reduced to about 40 db below visual carrier so as not to interfere with the programme. Beat interference seems barely perceptible at this level. In Figure 7B

continued...

the analyzer gain has been raised and bandwidth reduced slightly to present a greater range of the processor response curve. Response is same as that observed without signals present. Any significant anomalies in processor frequency response can be detected in this way since dispersion range and centre frequency can be changed at will.

The tracking generator range is 10 KHz to 110 MHz and it makes a very good video sweep generator for checking the response of video equipment. It can be used to check the frequency response characteristics of modulators, particularly if a sample of the unmodulated RF carrier is available for use in a product detector system. See block diagram, Figure 8. We have also obtained usable results with the use of an independent local oscillator instead of the modulator carrier, particularly with higher modulating frequencies.

Figures 8B and 8C show the modulating frequency response of an IF modulator used in many of our cable systems. The unmodulated carrier was not available in this case and a signal generator operating close to the carrier frequency was used as the local oscillator. Response is fairly flat to just past 5 MHz.

The tracking generator and spectrum analyzer have been used as the sweep generator and tracking receiver for swept displays of group delay in RF equipment. The basic block diagram is shown in Figure 9. The group delay test set operated on the 20 KHz modulating frequency and group delay was displayed on another oscilloscope. The spectrum analyzer display showed the amplitude response of the system and provided frequency marker information.

SPECTRUM ANALYZER APPLICATIONS

The spectrum analyzer is convenient for investigation of system operating levels and has been used for that purpose by a number of systems for some time. The 8554L head is convenient for this purpose since it will display up to 1200 MHz in a single display. Low and high band may be displayed simultaneously. The 1200 MHz tuning range makes it convenient for use with UHF signals. The 300 Hz IF bandwidth and stability are adequate for most "general purpose" system applications. Co-channel interference can be easily recognized and measured with 8554L RF section. Most intermodulation products can be distinguished with this RF head, except those occurring at "near zero beat". Utility of the spectrum analyzer for distortion product measurement can be increased by use of a set of channel band pass filters as external preselectors or preferably a tunable band pass filter. These external RF preselectors reduce the risk of generating unwanted distortion products in the spectrum analyzer first-mixer.

The special bandwidth and stability characteristics of the 8553B RF section and associated 8552B add some additional applications to the cable TV engineer's bag of tricks. The 10 Hz IF bandwidth, 20 Hz/division dispersion and associated frequency counter make it possible to use the instrument for precise determination of carrier frequencies (to about 10 Hz precision). Low level spurious signals can be observed and "counted". Frequency determination helps considerably in determining the source of a spurious carrier. Many of the characteristics of the 8553B section can be used in the 110 - 220 MHz band by the use of the precision heterodyne converter previously described.

continued...

Figure 10 shows a series of steps in the analysis of a co-channel interference problem on channel 2. Figure 10A shows the entire channel with visual and aural carriers and chroma information. Channel 3 carrier is also visible. In 10B the co-channel components are visible. The channel 2 carrier here operates with zero offset. Co-channels are visible with +and - offsets. The - offset is the stronger and is only 36 db below carrier. In 10C we examine the - offset co-channel more closely. It appears as a single carrier about 10 KHz below the carrier. The component about 6 KHz below the carrier is believed to be an intermodulation product. These observations were made after about 25 amplifiers in Cascade, but are valid with respect to the co-channel component. In 10D dispersion has been narrowed and bandwidth reduced to 30 Hz. Gain has been increased by 20 db. Three separate co-channel carriers are now apparent. In 10E we go to maximum resolving power and show the three co-channel interfering carriers. Their relative level has changed since the previous observation (interval about 5 minutes). Their relative frequency has also changed due to slight drift in the individual transmitters. The centre frequency in 10E has been marked as 55.24003 MHz. The individual carrier frequencies can be interpolated from the 50 Hz/division calibrated dispersion. The drift of the individual interfering carriers can be easily observed on the spectrum analyzer because of the exceptional stability of the analyzer. The analyzer drift can be noted by reference to the associated frequency counter. When used in our laboratory, we reference the counter to a Loran C derived frequency reference which is accurate to at least 1 part in 10^9. In field work, we rely on the crystal-in-oven in the counter which is specified to be about 3 in 10^8 after three hours warm up.

The 10 Hz bandwidth and exceptionally good shape factor permit using the spectrum analyzer to check hum modulation by observing and measuring the 60 Hz and 120 Hz modulation sidebands of the affected RF carrier. This is demonstrated in Figure 11. For demonstration, we used a small 53.25 MHz crystal oscillator energized by a battery. Figure 11A shows the spectrum of the bettery energized crystal oscillator. Figure 11B shows the spectrum after passing through a small MATV type amplifier. The 120 Hz sidebands (full wave power supply) are barely visible at about -70db. Figure 11C shows hum modulation in another small amplifier. Sidebands are about 60 db down. Hum modulation observations of this kind cannot be made on carriers with ordinary TV modulation. The hum modulation sidebands are completely obscured by the sidebands caused by the vertical sync pulse information.

The spectrum analyzer was used to analyze the characteristics of the 110 MHz local oscillator developed for the 110-220 MHz block converter. Figure 12 shows a succession of bservations on this oscillator. Figure 12A some spurious 10 MHz and 1 MHz components. The 10 MHz sidebands are about 70 db down. The 1 MHz components are about 65 db down. Figure 12B shows the 1 MHz sidebands more clearly. A significant noise component in the main carrier is now apparent. It appears to have the shape of the 110 MHz bandpass filter used to separate the desired 110 MHz harmonic component. Figures 12C and 12D show the noise more clearly. This noise level and other spurious products will have to be reduced below 60 db before the local oscillator is satisfactory for this purpose.

A spectrum analyzer is a convenient instrument for calibration of FM deviation using a carrier null technique. Frequency modulation by a sinusoidal modulating frequency can be analyzed in terms of Bessel functions which indicate periodic nulls of the carrier as deviation is increased. The second Bessel carrier null occurs for a modulation index of 5.52007 and a simple calculation indicates that a modulating frequency of 4.53 KHz and deviation of 25 KHz will produce the second carrier null in the case of standard TV aural carrier modulation. To set the FM

continued...

modulation level on a cable TV modulator, a modulating frequency of 4.53 KHz is used and the modulation level increased until the second null is observed on the spectrum analyzer. The nulls are easily seen as the modulation level is increased. A VU or voltmeter can then be used to indicate proper audio level for 100% FM modulation. Figure 13A shows an unmodulated aural carrier. This is not a very good modulator as the unmodulated carrier should show less frequency deviation than is apparent here. In Figure 13B, FM at 4.53 KHz has been applied and modulation level adjusted to the second carrier null. Depth of mull is approximately 25 db. Figure 13C shows the same display at 10 KHz/division dispersion. Figure 13D shows the spectrum of the modulating signal (4.53 KHz). Number and amplitude of distortion products are immediately apparent. Principal distortion product is the third harmonic and it is about 20 db below carrier. The spectrum analyzer can be used for analyzing audio signals above 1 KHz. Note that the occupied bandwidth (to the -40 db points) is about 80 KHz. This is somewhat more than observed on broadcast station carriers. We suspect that most broadcast stations undermodulate somewhat.

The spectrum analyzer can be used to investigate the characteristics of a television modulator by direct observation of the RF spectrum when modulated by sinusoidal modulating signals of controlable frequency. The series of photographs in Figure 14 shows RF spectrum of an IF modulator, of a type often used in cable systems, when modulated by a good quality sinusoidal oscillator. Modulation was set to 80% at 1 MHz video by observing the RF modulation envelope. Modulating Signal was then reduced by 20 db to reduce the harmonic distortion in the modulator. The video oscillator was swept manually over the desired range while the spectrum analyzer swept at quite a fast rate. The display was built up using the storage feature of the oscilloscope and was photographed using a time exposure while the video oscillator was manually swept. Figure 14A shows the spectrum as the video oscillator is tuned from 1 MHz to 10 MHz. This is an IF modulator and the vestigial sideband is the upper sideband. The up-converter will invert the sidebands and remove most of the "out-of-band" components. In Figure 14B, the gain has been increased to bring the sidebands to the top reference line. The vestigial sideband characteristic is not correct. It is not cutting off soon enough. Figure 14C and 14D show this vestigial sideband more clearly. Two photographs have been taken with different exposures to optimize different parts of the display.

A multiburst signal at normal level was used as the modulating signal and the resulting RF spectrum observed. The multiburst used has bursts at 0.5 MHz, 1.5 MHz, 2.0 MHz, 3.0 MHz, 3.6 MHz and 4.2 MHz. The spectrum at video frequency is shown in Figure 14A. The photograph should have shown the 0.5 MHz component at same level as the others. The resulting RF spectrum is shown in Figure 15B. Vestigial sideband is not adequate, as previously demonstrated. A full field multiburst like this should be a good signal for checking the frequency response from a broadcast transmitter right through a cable system.

In Figure 15C the low frequency modulation characteristics are being checked. Figure 15C is a multiple observation with successive modulating frequencies of 50, 100, 200, 300 and 400 Hz. The photograph was taken from the multiple observation on the storage tube. Low frequency sidebands are not symetrical which probably indicate some FM'ing of the carrier at these frequencies.

continued...

Figure 15D was taken to show the resolving power of a good spectrum analyzer. The photograph shows interlace of chrominance and luminance sidebands at about 1 MHz. The signal was a video "saturated colour bar". This observation was made on video components about 2.6 MHz below colour subcarrier. This kind of observation is within the power of the 8554L head since only 5 KHz/division dispersion and 300 Hz bandwidth were used. The high resolution head permits study of the "fine structure" by using the 10 Hz bandwidth.

SUMMARY

A few special applications of the spectrum analyzer and tracking generator/counter have been illustrated. Additional applications abound and the usefulness of these instruments is limited only by the ingenuity of the engineer using them.

How It Works

Both spectrum analyzer and TG/C mate to form a signal-analysis and swept-frequency measurement system that embodies versatility and precision. Basically, the TG/C generates a signal that coincides in frequency with the spectrum analyzer's tuning—and then accurately measures this signal's frequency on an 8-digit counter.

The spectrum analyzer is a triple-conversion receiver with three local oscillators (LO). For wide scan widths, the first LO sweeps while the third LO tunes to a fixed frequency. The second LO, a crystal oscillator is always tuned to 150 MHz. For narrow-scan widths (20 kHz/cm and lower), the first LO phase-locks to a crystal-controlled reference (at 100-kHz intervals) and the third LO sweeps. With a 2-MHz bandwidth, the 200 and 50 MHz IF's are

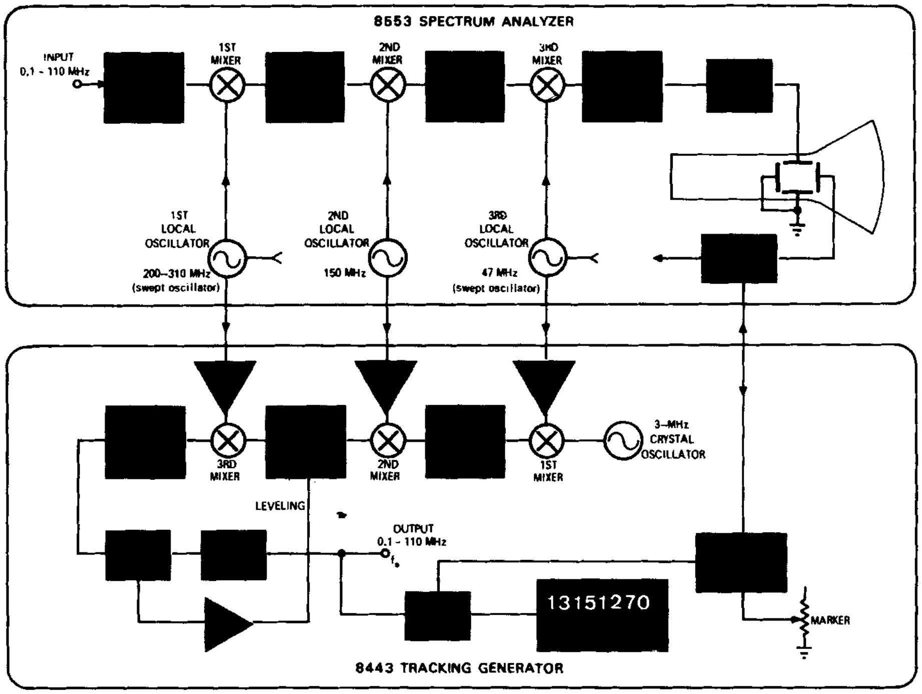


Figure 1 (courtesy Hewlett-Packard)

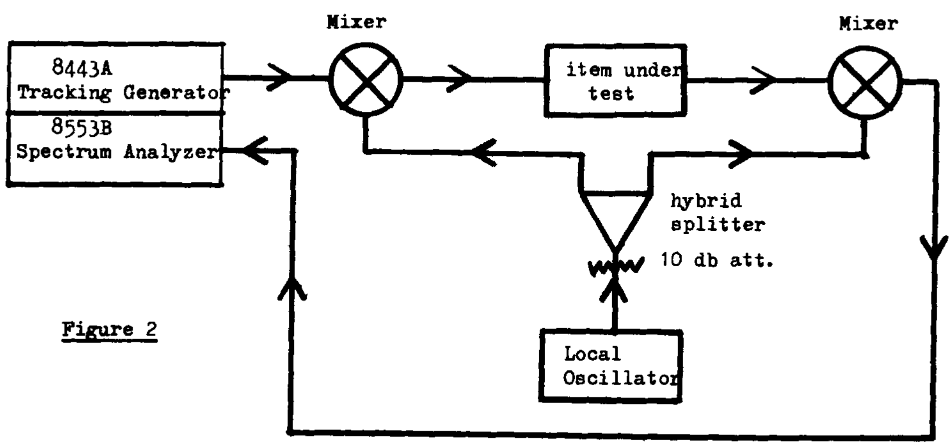


Figure 2

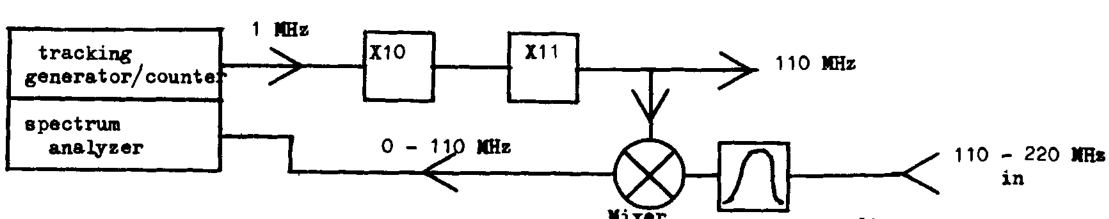
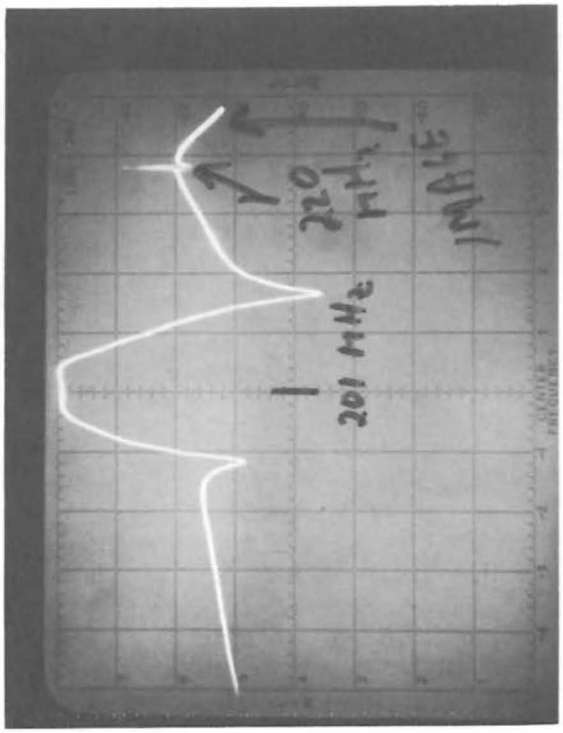
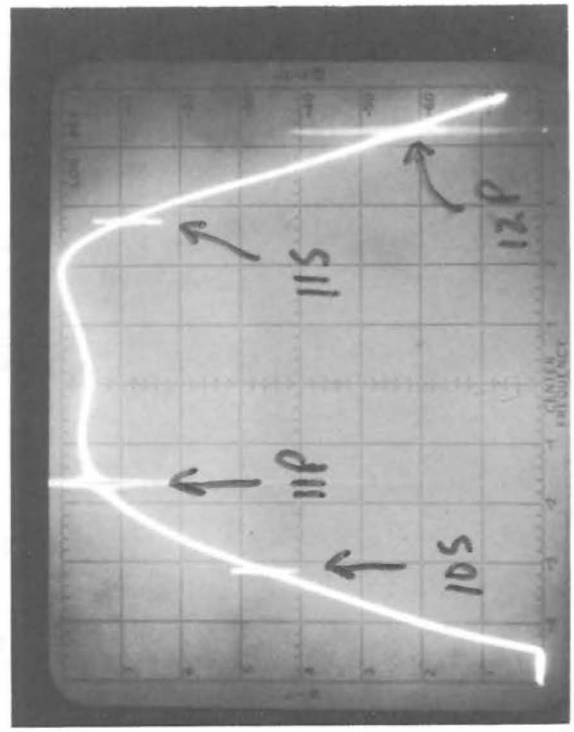
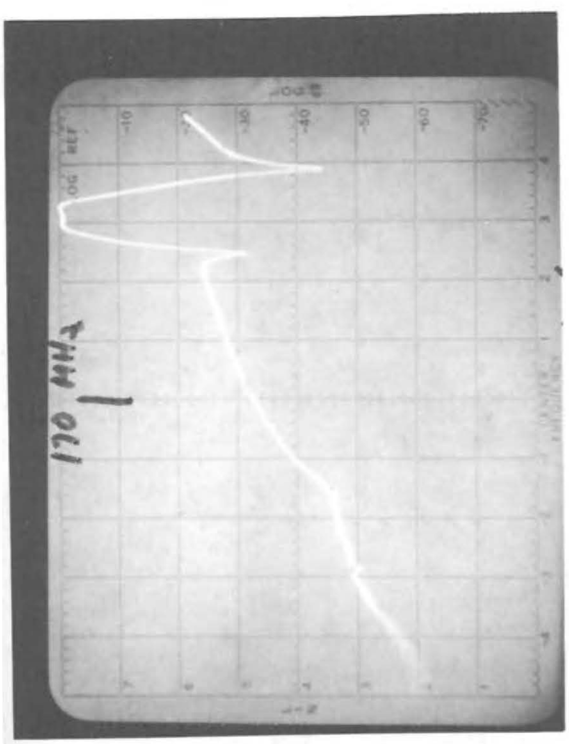
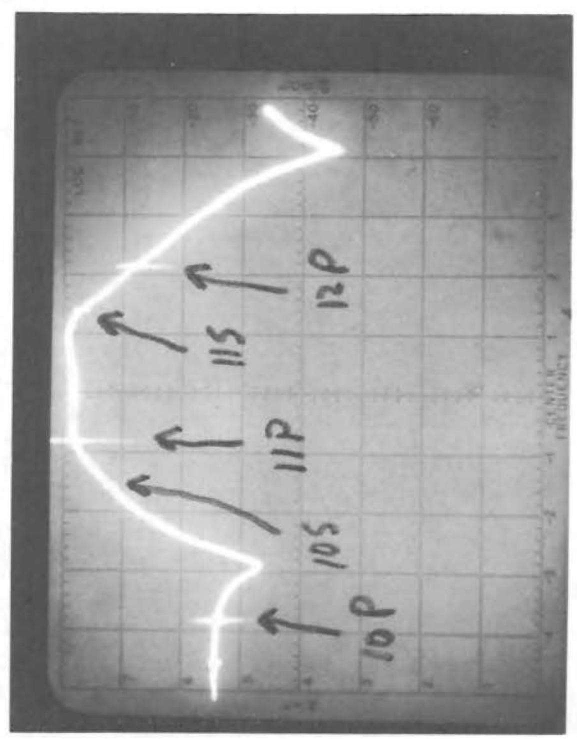


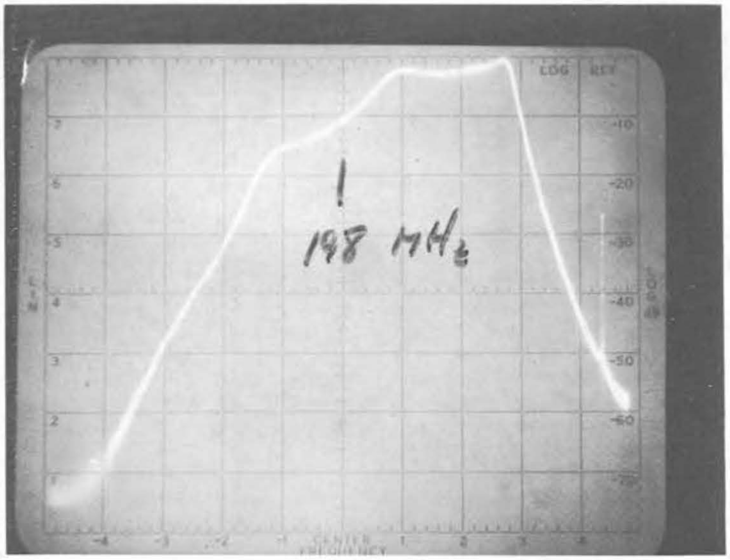
FIGURE 3

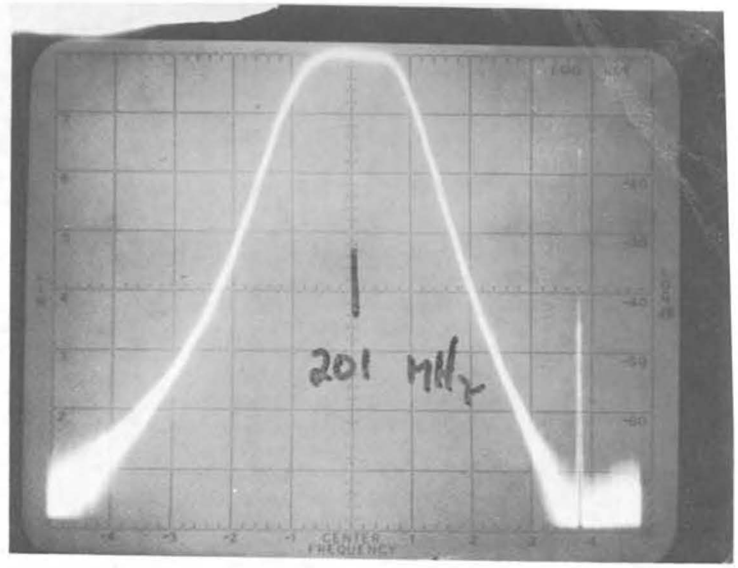

201 MHz
220 MHz
IMAGE

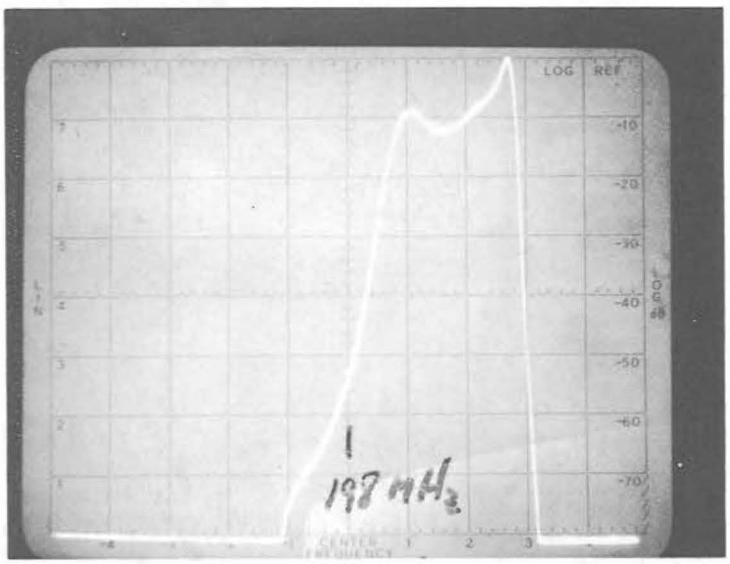

10S
11P
11S
12P

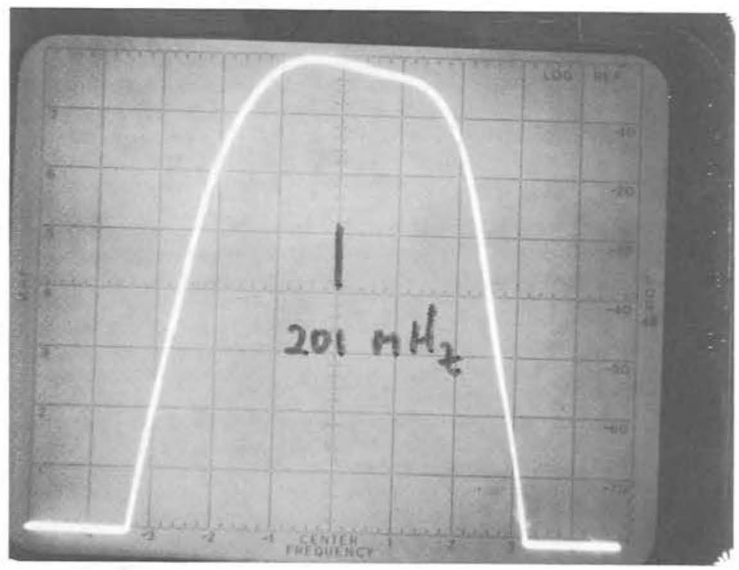

170 MHz

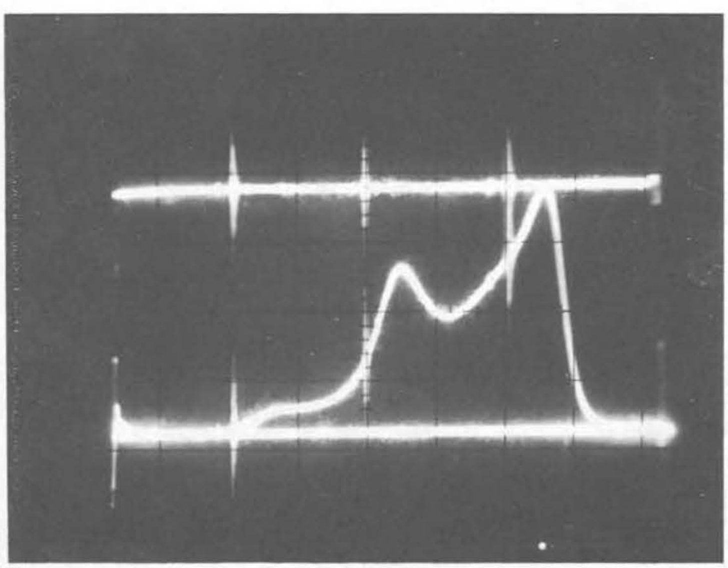

10P
10S
11P
11S
12P

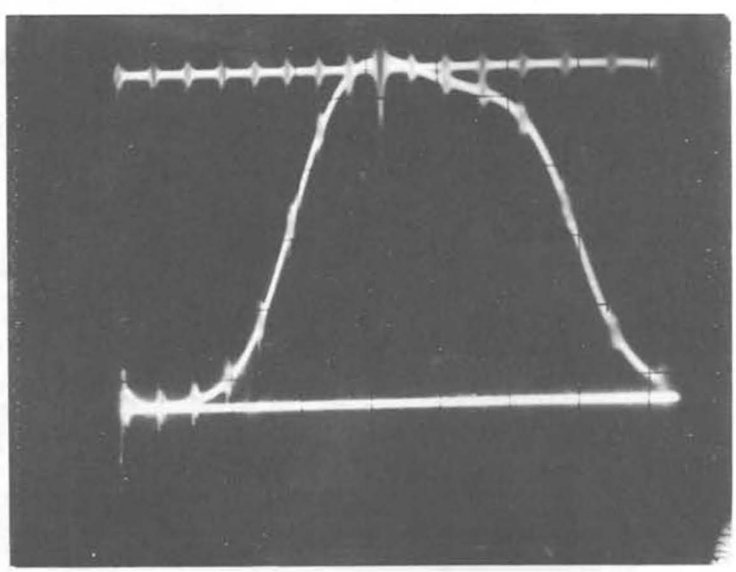

LOG
REF
198 MHz
CENTER FREQUENCY

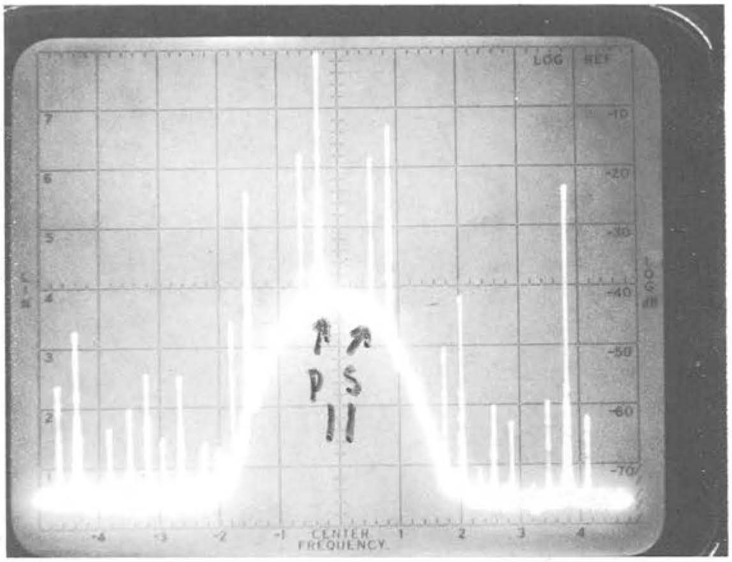

201 MHz
CENTER FREQUENCY

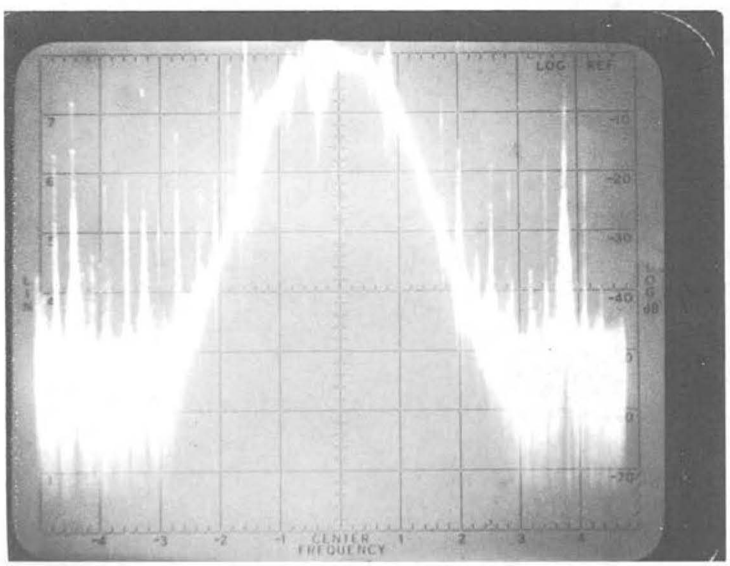

LOG
REF
198 MHz
CENTER FREQUENCY

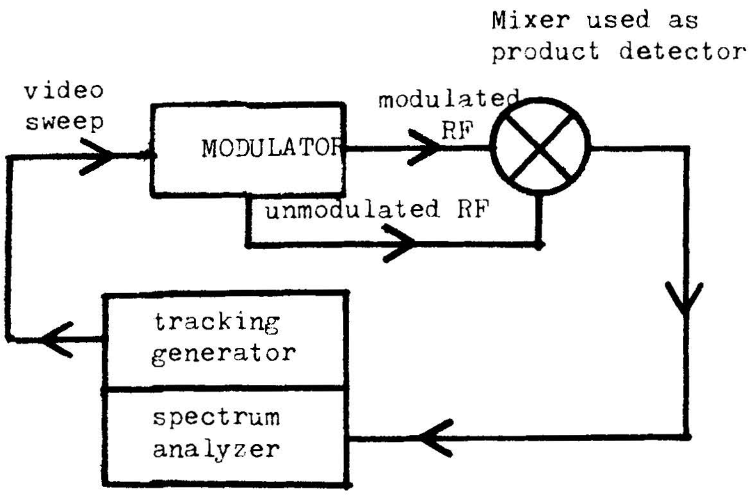

LOG
REF
201 MHz
CENTER FREQUENCY

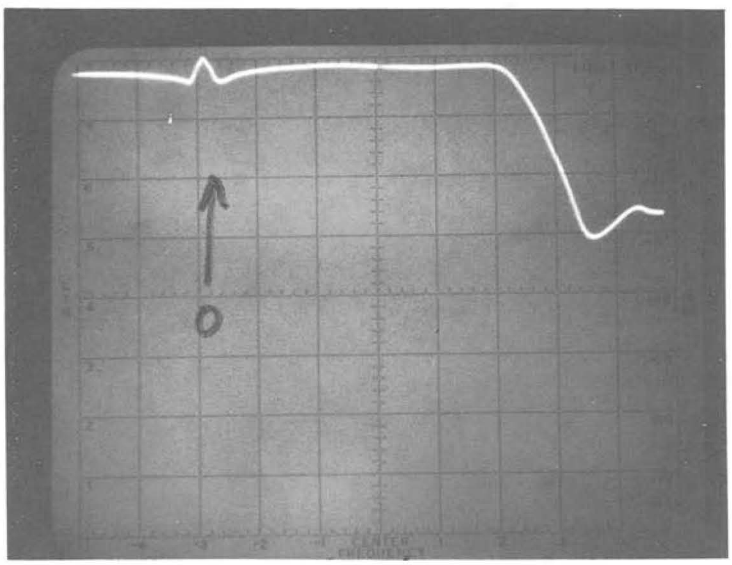


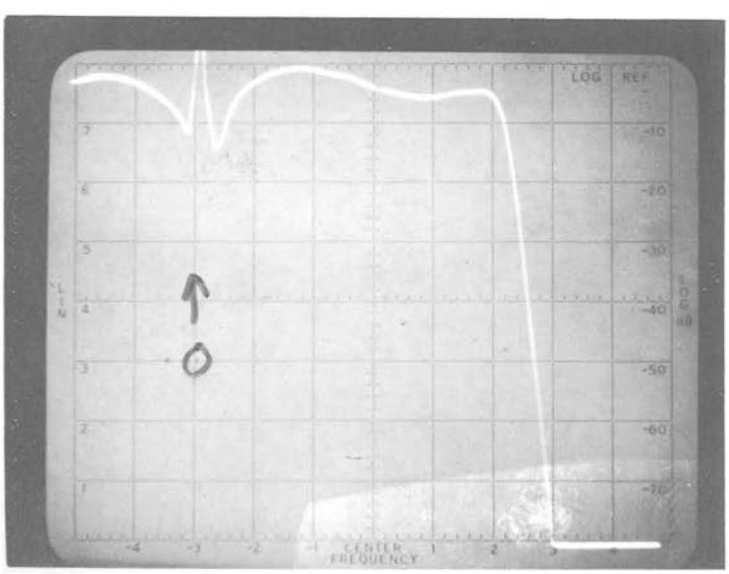


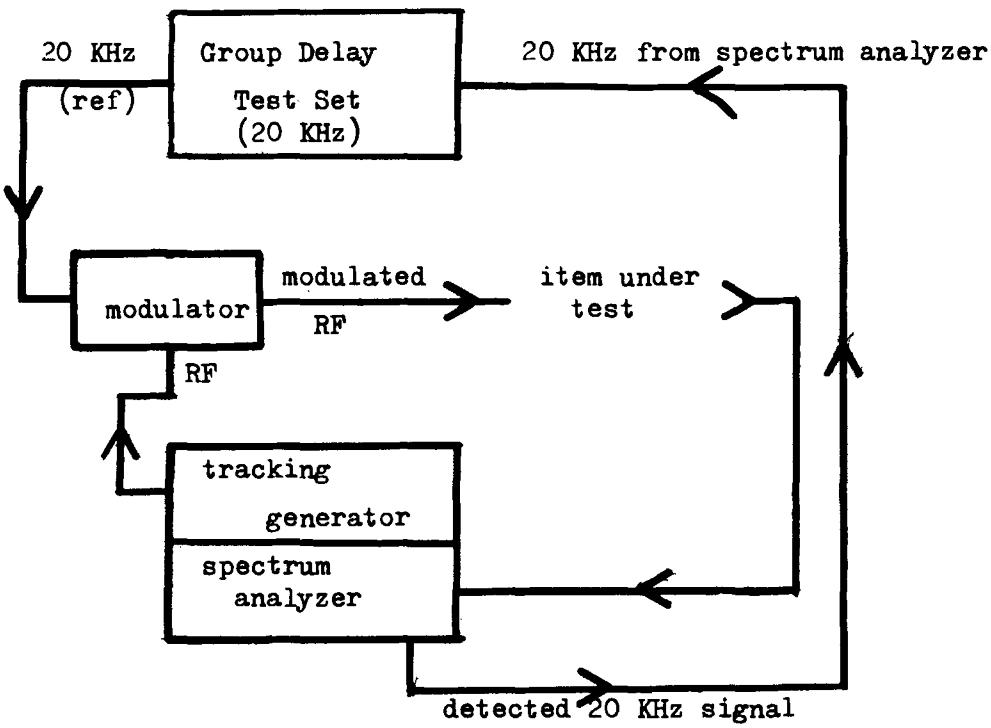

LOG
REF
-10
-20
-30
-40
-50
-60
-70
LOG dB
LIN
7
6
5
4
3
2
P
S
-4
-3
-2
-1
CENTER FREQUENCY
1
2
3
4


LOG
REF
-10
-20
-30
-40
-70
LOG dB
LIN
7
6
4
1
-4
-3
-2
-1
CENTER FREQUENCY
1
2
3
4


Mixer used as
product detector
video
sweep
MODULATOR
modulated
RF
unmodulated RF
tracking
generator
spectrum
analyzer

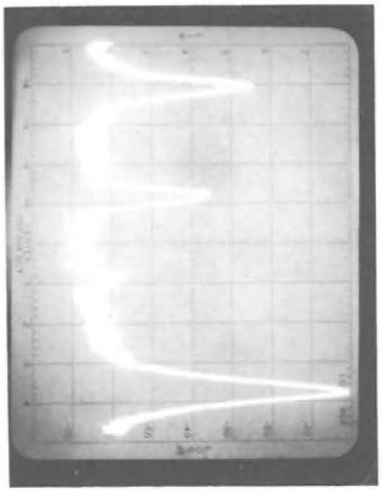

0
CENTER
FREQUENCY

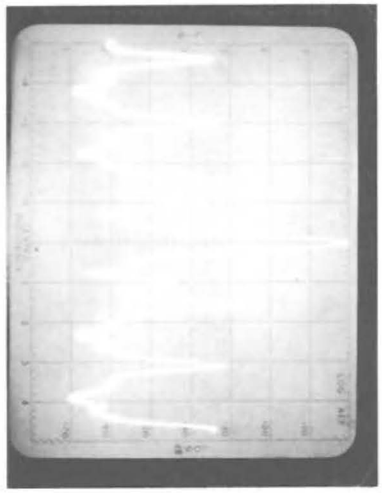

LOG
REF
-10
-20
-30
-40
-50
-60
-70
0
CENTER
FREQUENCY

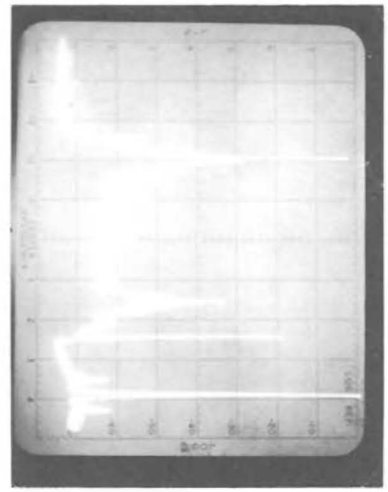


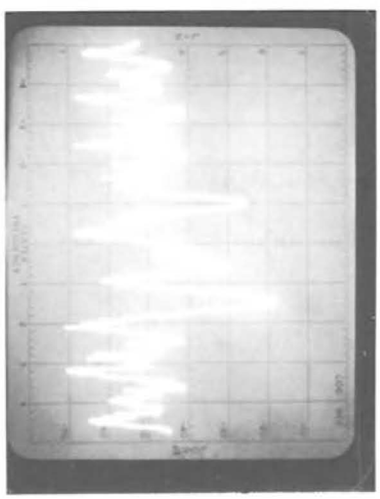
20 KHz
(ref)
Group Delay
Test Set
(20 KHz)
20 KHz from spectrum analyzer
modulator
modulated
RF
item under
test
RF
tracking
generator
spectrum
analyzer
detected 20 KHz signal

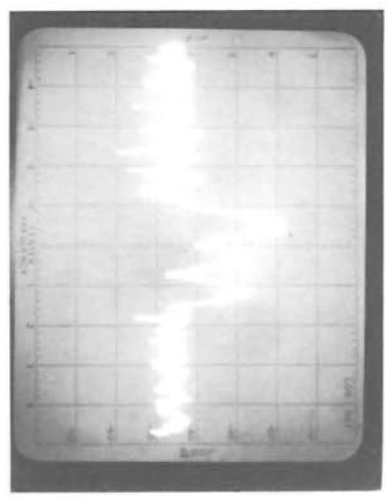
Figure 9

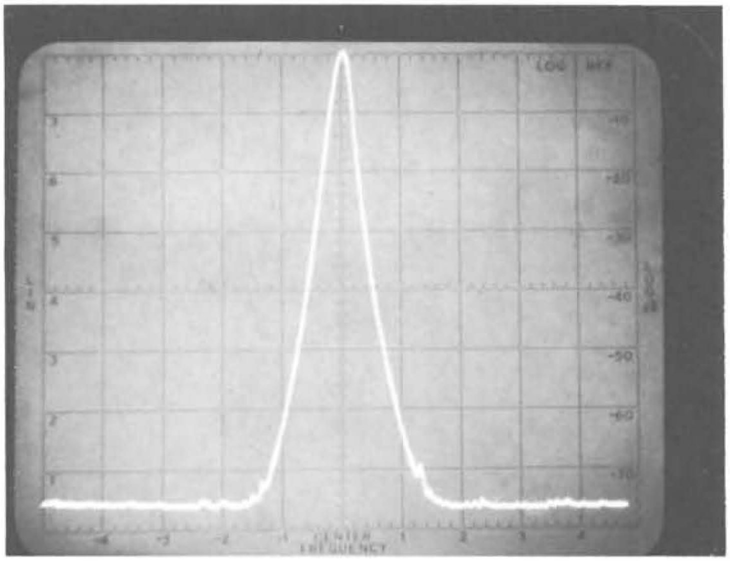


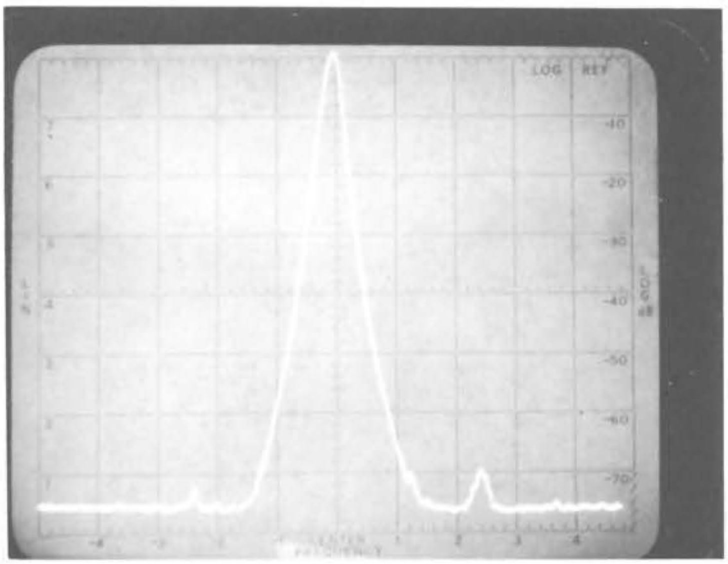


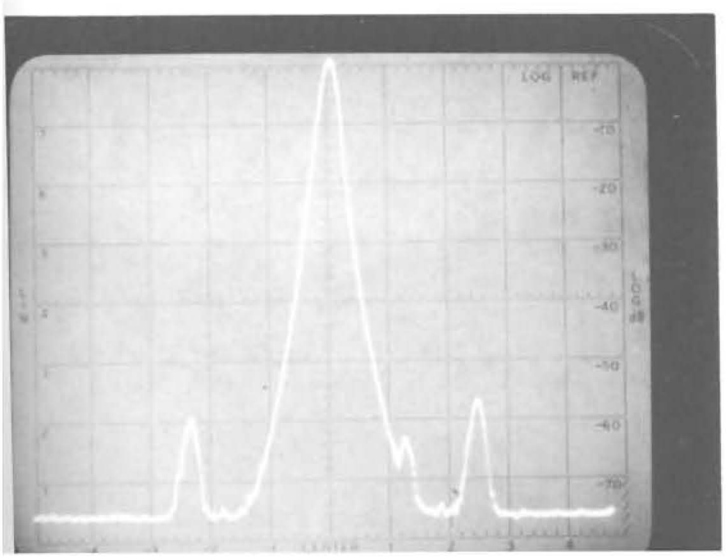


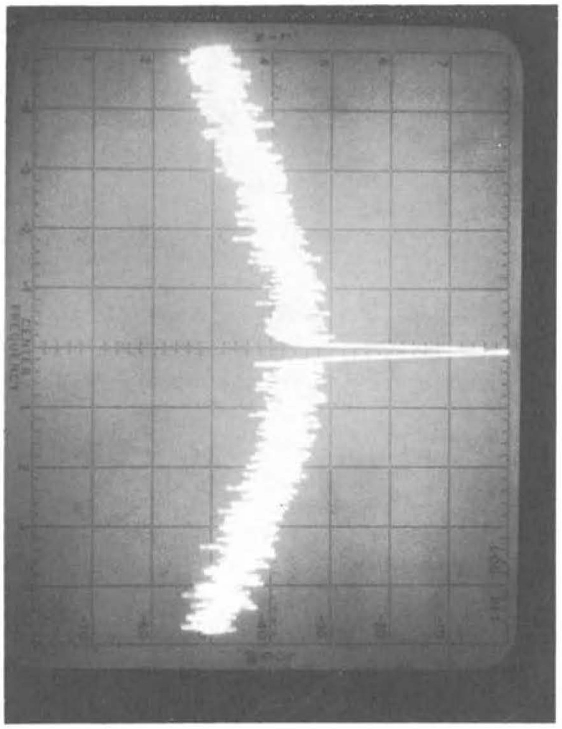


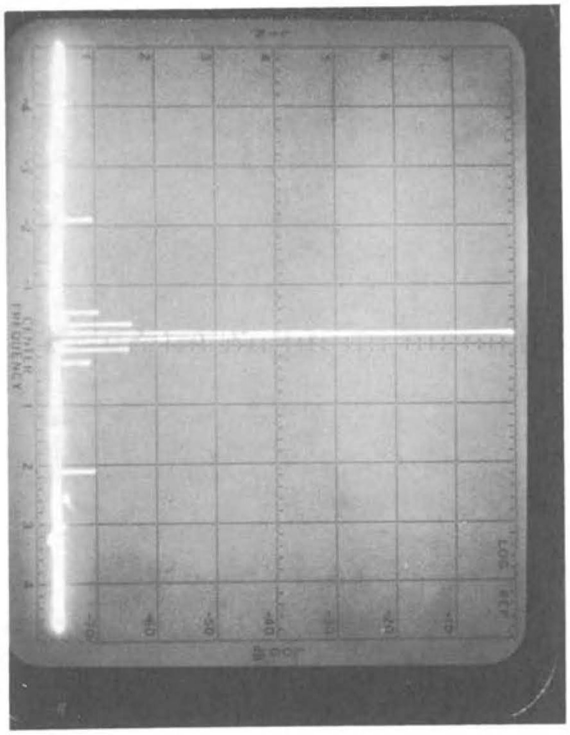


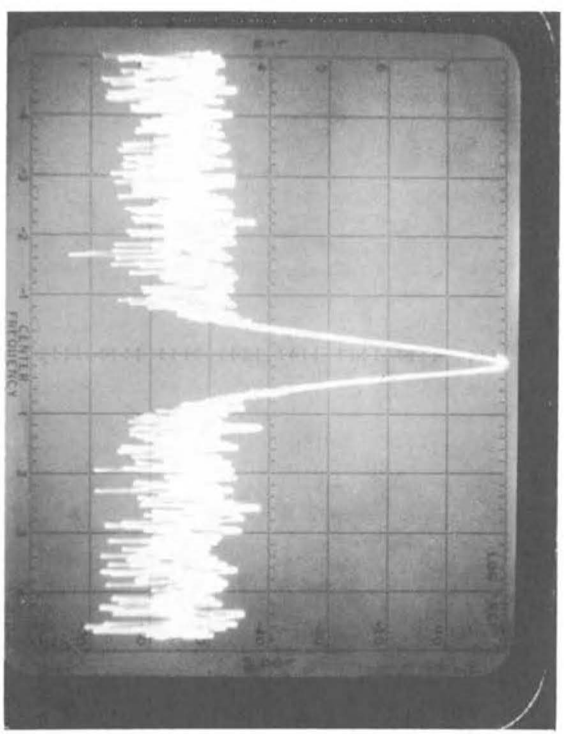


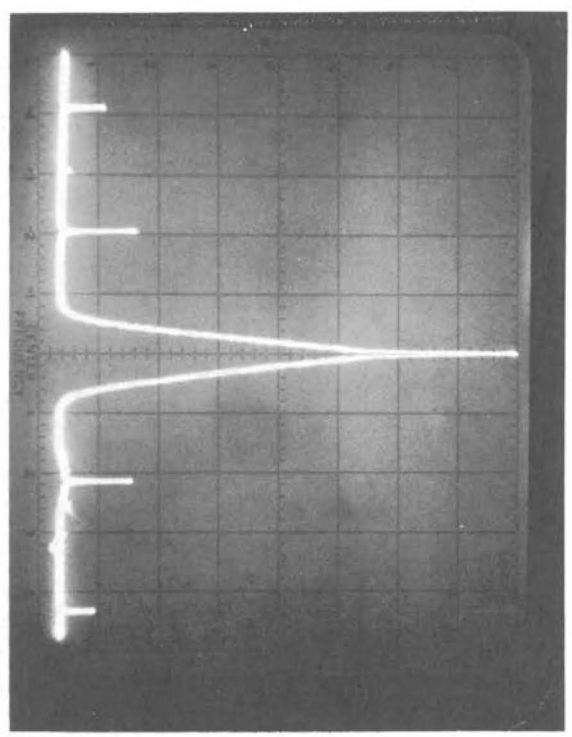





CENTER
FREQUENCY


CENTER
FREQUENCY


CENTER
FREQUENCY


CENTER
FREQUENCY