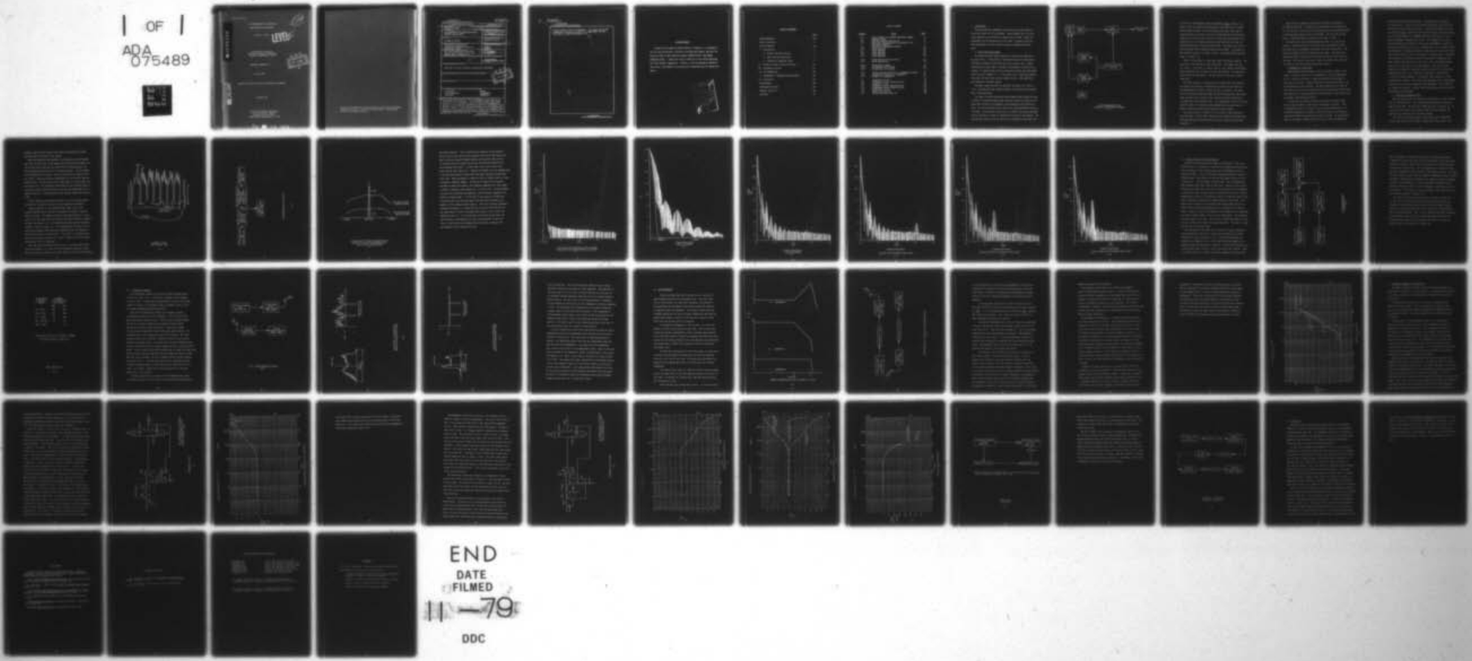
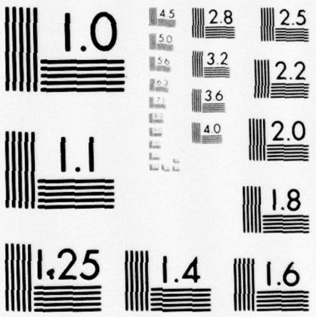
AD-A075 489 NORTHEASTERN UNIV BOSTON MASS ELECTRONICS RESEARCH LAB F/G 17/2
FM TRANSMISSION OF TELEVISION FROM ROCKETS AND BALLOONS.(U)
JUL 79 W F THORN F19628-76-C-0111
UNCLASSIFIED SCIENTIFIC-3 AFGL-TR-79-0160 NL

1 OF 1
ADA
075489



END
DATE
FILMED
11-79
DDC



MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF

AFGL-TR-79-0160

(12)

# FM TRANSMISSION OF TELEVISION FROM ROCKETS AND BALLOONS

Willard F. Thorn

Northeastern University
Electronics Research Laboratory
Boston, Massachusetts 02115

SCIENTIFIC REPORT NO. 3

11 July 1979

Approved for public release; distribution unlimited

Prepared for

Air Force Geophysics Laboratory
Air Force Systems Command
United States Air Force
Hanscom AFB, Massachusetts 01731

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

MIL-STD-847A
31 January 1973

19 REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

18

1. REPORT NUMBER
AFGL-TR-79-0160

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER
14 Scientific-3

4. TITLE (and Subtitle)
6
FM TRANSMISSION OF TELEVISION FROM ROCKETS AND BALLOONS

5. TYPE OF REPORT & PERIOD COVERED
Scientific Report No. 3
9 Interim rept.

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)
10 Willard F. Thorn

8. CONTRACT OR GRANT NUMBER(s)
15 F19628-76-C-0111,
F19628-76-C-0152

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Northeastern University
Electronics Research Laboratory
Boston, MA 02115

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
62101F
16 76590102
17 01

11. CONTROLLING OFFICE NAME AND ADDRESS
Air Force Geophysics Laboratory
Hanscom AFB, Massachusetts 01731
Monitor/Eben M. Hiscock/LCR

12. REPORT DATE
11 11 July 1979

13. NUMBER OF PAGES
56

14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)
12 57

15. SECURITY CLASS. (of this report)
Unclassified

15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

DDC
RECEIVED
OCT 22 1979
E

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Television
FM Transmission
Bandwidth
Noise
Preemphasis
Deemphasis

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report deals with the use of preemphasis filtering in FM transmission of television. The television cameras and transmitter are to be located on rocket or balloon instrumentation payloads. The large RF bandwidth necessary for television transmission requires a large transmitted power for the distances of interest. The use of preemphasis will reduce the required transmitted power considerably below that required for a picture of

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

127 500

similar quality without preemphasis. This thesis shows how preemphasis filtering can provide an improvement and what the limits of these improvements are.

# ACKNOWLEDGMENTS

I would like to thank my thesis advisor, Professor J. S. Rochefort, for his time and helpful criticism in writing this thesis, the work for which was done on AFGL Contracts Number 19628-76-C-0111 and Number 19628-76-C-0152. I would also like to thank all of my fellow employees for their helpful suggestions. Finally, I wish to express my appreciation to Ms. Julie Roberts for doing such an excellent job of typing this thesis.

# TABLE OF CONTENTS

| | Page |
|---|---|
| Acknowledgements | iii |
| Table of Contents | v |
| List of Figures | vi |
| I. Introduction | 1 |
| A. Typical Television System | 1 |
| B. Band width *vs*. Resolution | 4 |
| C. Spectrum of Composite Video | 5 |
| II. Effects of Noise on Picture Quality | 17 |
| III. Transmission System | 21 |
| IV. Why Preemphasis | 26 |
| V. Preemphasis - Deemphasis Possibilities | 33 |
| VI. Conclusions | 46 |
| Bibliography | 48 |
| Referenced Footnotes | 49 |
| Related Contracts | 50 |
| Personnel | 51 |

# LIST OF FIGURES

| Figures | Title | Page |
|---|---|---|
| I-1 | Block Diagram of a Typical Television Camera | 2 |
| I-2 | Composite Video | 7 |
| I-3 | Spectrum Analysis Test Set-up | 8 |
| I-4 | Modulation Characteristics of HP Model 612 A UHF Signal Generator | 9 |
| I-5 | Spectrum of Unmodulated Carrier | 11 |
| I-6 | Video Spectrum | 12 |
| I-7 | Video Spectrum | 13 |
| I-8 | Video Spectrum | 14 |
| I-9 | Video Spectrum | 15 |
| I-10 | Video Spectrum | 16 |
| II-1 | Noise Sensitivity Test Set-up | 18 |
| II-2 | Noise Sensitivity | 20 |
| III-1 | Transmission System | 22 |
| III-2 | RF Spectrum of FM System | 23 |
| III-3 | RF Spectrum of FM System | 24 |
| IV-1 | General Characteristics for a Preemphasis System | 27 |
| IV-2 | Transmission System with Preemphasis | 28 |
| IV-3 | Examples of Preemphasis | 32 |
| V-1 | Preemphasis Filter | 35 |
| V-2 | Preemphasis Filter Characteristics | 36 |
| V-3 | Deemphasis Filter | 39 |
| V-4 | Deemphasis Filter Characteristics | 40 |
| V-5 | Preemphasis System Characteristics | 41 |
| V-6 | Phase Shift Curves | 43 |
| V-7 | Phase Shift Test Set | 44 |
| V-8 | Pre-De Evaluation Test Set | 45 |

## I. Introduction

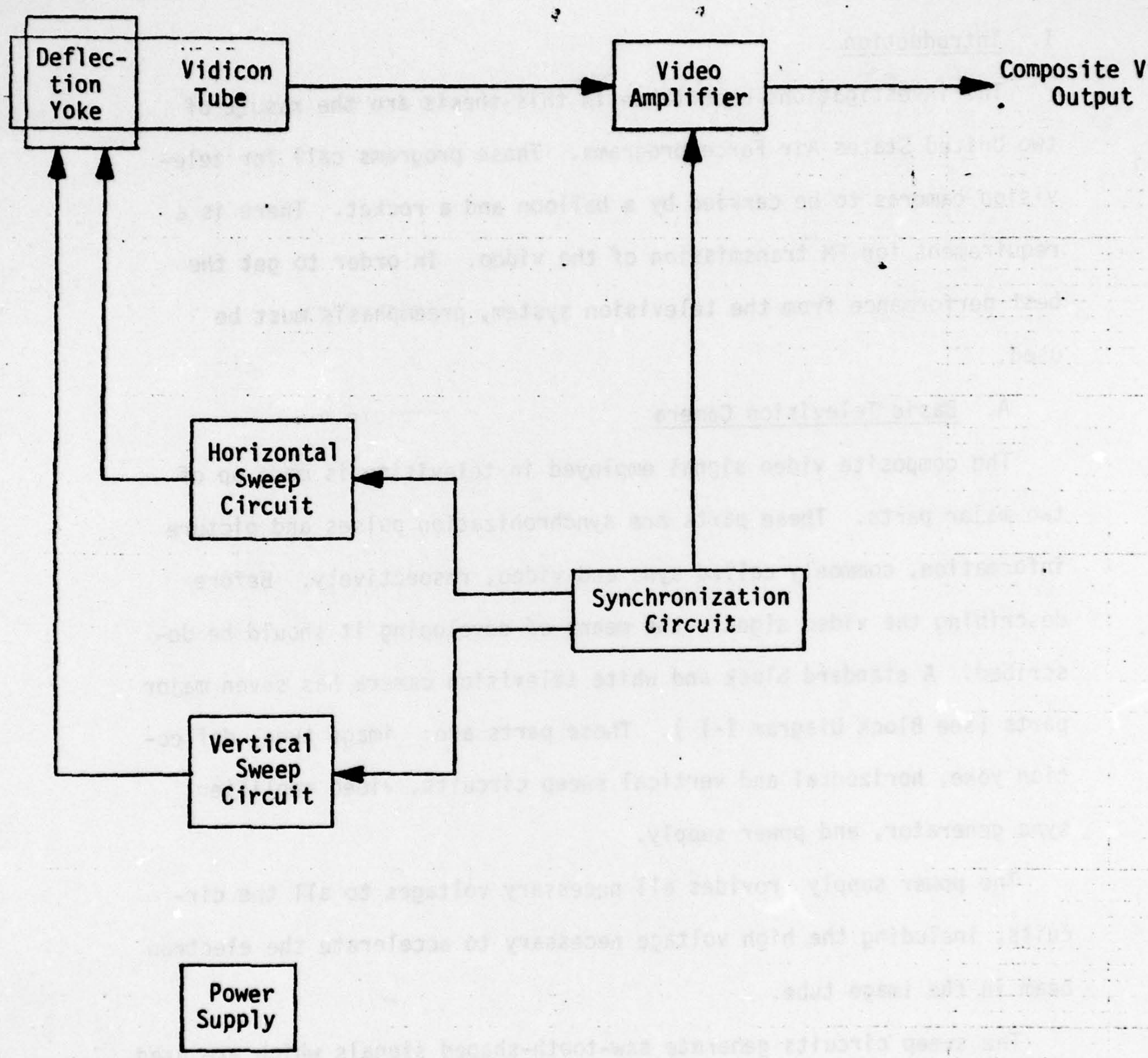
The investigations undertaken in this thesis are the result of two United States Air Force programs. These programs call for television cameras to be carried by a balloon and a rocket. There is a requirement for FM transmission of the video. In order to get the best performance from the television system, preemphasis must be used.

### A. Basic Television Camera

The composite video signal employed in television is made up of two major parts. These parts are synchronization pulses and picture information, commonly called sync and video, respectively. Before describing the video signal, the means of developing it should be described. A standard black and white television camera has seven major parts (see Block Diagram I-1 ). These parts are: image tube, deflection yoke, horizontal and vertical sweep circuits, video amplifier, sync generator, and power supply.

The power supply provides all necessary voltages to all the circuits, including the high voltage necessary to accelerate the electron beam in the image tube.

The sweep circuits generate saw-tooth-shaped signals which are used to deflect the electron beam across the photo-sensitive surface of the image tube by means of the magnetic field produced by the deflection yoke. The vertical sweep rate is 60 Hz, and causes deflection from top to bottom. The horizontal sweep rate is 15,750 Hz, and causes the beam to move from left to right (as viewed from the back of the camera). The scan pattern starts in the top left and is deflected to the right side.



BLOCK DIAGRAM OF A
TYPICAL TELEVISION CAMERA
I-1

This left to right movement takes approximately $\frac{1}{15,750}$ second. The beam is then very rapidly deflected back to the left; this is called the horizontal retrace. While the beam has been moved from left to right and back to the left, it has also moved down due to the vertical deflection so that the next line will be lower than the previous line. Standard TV uses an interlace system so that only half the lines are scanned (every other line) during each frame. This means that a 60 Hz scan rate gives thirty complete pictures every second. The purpose of the interlace system is to reduce flicker. A complete picture has 525 lines, or 15,750 ÷ 30.

There are many types of image tubes used in television cameras. The type used is not important to this discussion. The common types are all similar. They differ in aspects such as size, voltage requirements, type of photosensitive surface, and light sensitivity. All types function in much the same manner. The type used for tests was a vidicon image tube.

A vidicon tube has an electron gun in the back end. This produces an electron beam aimed at a photosensitive surface in the front end. The photosensitive surface is about one inch in diameter. The sweep circuits previously described sweep the electron beam across the screen. Light focused on this surface causes the beam to become modulated as it sweeps past light and dark areas. This modulation is fed to the video amplifier where it is amplified and combined with the sync pulses to produce composite video--the end product of the TV camera.

The picture tube in a monitor is very similar to the image tube just described. The two major differences are screen size and the electron beam modulates the photosensitive surface instead of being modulated by it.

Sync pulses are needed to synchronize the monitor's scanning to the camera's scanning. If they are not synchronized, the picture will roll (if the scan rates are close to being equal) or be indistinguishable (if the two sweep rates are not well matched). This rolling can take place in either horizontal or vertical directions, or both.

The sync pulses are inserted between scan lines, i.e. during the retrace. Positive polarity of the video signal corresponds to white or bright areas, and negative corresponds to black or dark areas. The pulses are negative polarity relative to the video. This means that the picture tube is blacked out during the retraces so these lines are not seen. The vertical sync pulse is made to be twenty-one lines wide to allow for its lower frequency and slower retrace.

### B. Bandwidth vs. Resolution

Video bandwidth and horizontal resolution go hand in hand in television. Vertical resolution is not dependent on the video bandwidth at all. Vertical resolution is determined totally by the number of scan lines per picture. Standard television has about 500 usable lines of resolution from top to bottom. The other twenty-five are taken by the vertical sync pulse and overscan at the top and bottom of the picture tube (overscan is scanning beyond the top and bottom of the picture tube to produce a more pleasing picture).

In order to have equal horizontal and vertical resolution there must be the equivalent of 666 lines of horizontal resolution. (This is determined by the 3 x 4 aspect ratio of standard television.) To facilitate bandwidth calculation, assume the picture to be displayed has 666 alternating black and white vertical stripes. As the electron beam in the camera is swept across the screen, it will be modulated by the black and white stripe pattern. This modulation will appear as a square wave. There will be 333 cycles during each scan, one black and one white stripe making each cycle. This 333-cycle pattern will occur in about $\frac{1}{15,750}$ second--the time required to scan across the screen. If the 333-cycle pattern in .0000634 second was continuous, it would have a fundamental frequency of 5.24 MHz. If a lowpass filter with a cut-off frequency of 5.24 MHz is used to set the bandwidth, a 666-line horizontal resolution will result. Although this is not a normal picture, this bandwidth is required to produce a sharp image of any vertical line, such as the corner of a wall or the edges of a vertical pole. In commercial television, the effective vertical resolution is about 400 lines. This reduction from 500 lines to 400 lines is not a noticeable change unless a very fine pattern is being displayed. Since the vertical resolution is reduced in commercial television due to less than perfect cameras and monitors, etc., horizontal resolution is intentionally reduced to conserve bandwidth. The maximum video frequency is 4 MHz for commercial stations. Tests here have shown that for our requirements 2 MHz will be the minimum acceptable video bandwidth. This conclusion was obtained by putting a low-pass filter between the camera and monitor and reducing the bandwidth.

### C. Spectrum of Composite Video

There are several ways to display the video signal in order to determine its characteristics. Each method provides different information about the waveform. The three most common ways are: amplitude vs. an x-y grid with a monitor, amplitude vs. time on an oscilloscope, and amplitude vs. frequency with a spectrum analyzer.

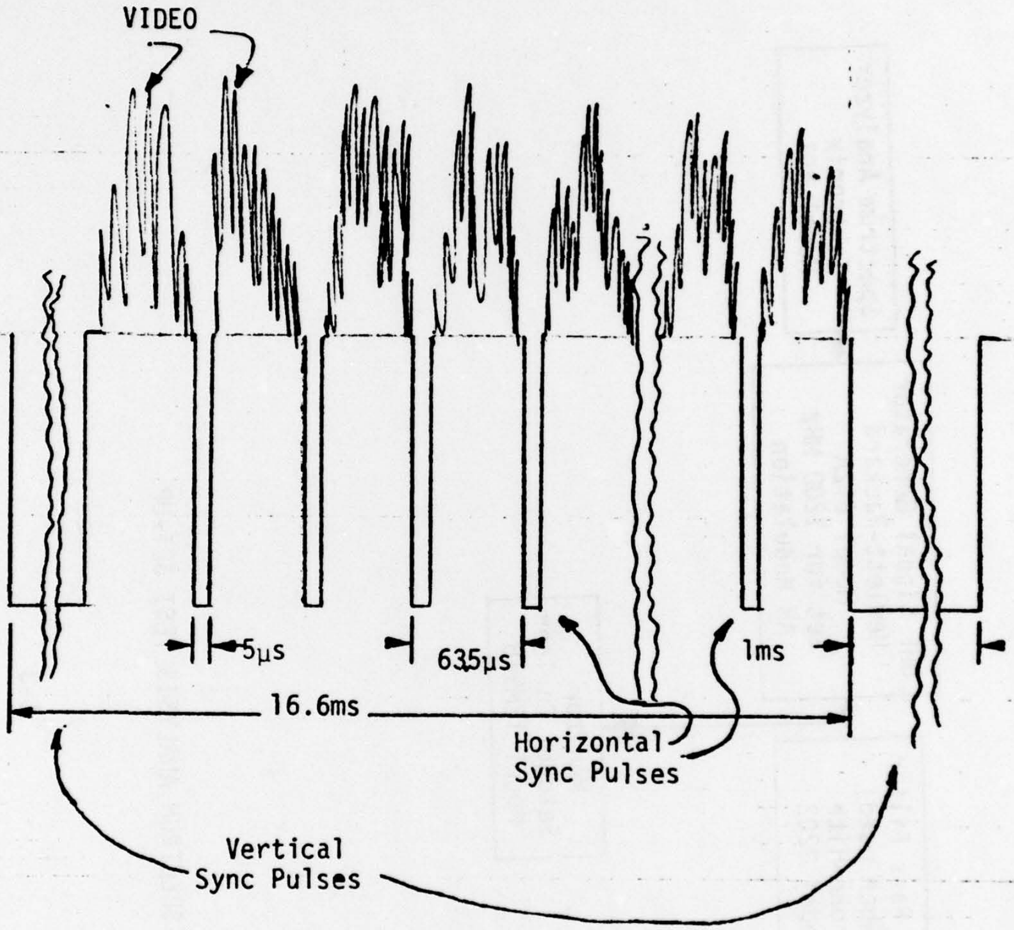
In a monitor, an electron beam in the picture tube is modulated by the video signal while the beam is swept across the screen. This produces light and dark areas on the screen corresponding to bright and dim areas on the face of the vidicon.

When the composite video waveform is displayed on an oscilloscope, the first thing one sees is the repetitive sync pulses (see Figure I-2). The vertical sync pulses will be spaced 16.6 milliseconds apart, and the horizontal pulses will be 63.5 microseconds apart. The DC average for the waveform will be zero. The sync pulses will go negative from this value. The video (picture information) will go positive from the average value. The more positive the video signal is, the brighter the picture will be. The magnitude of the video for the brightest parts of the picture will be about the same as the sync pulse magnitude, but of opposite polarity. These features are the same as commercial television video.

Picture features can sometimes be seen in an oscilloscope display and motion of an object in the picture can generally be detected.

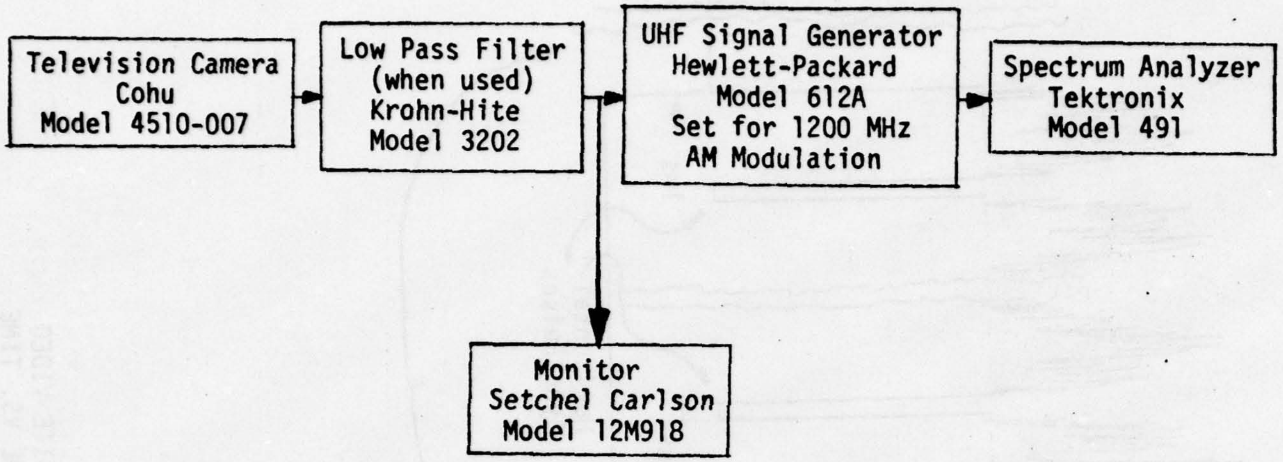
Spectrum analysis of the composite video signal required an indirect approach due to the lack of equipment to display a spectrum from DC to 5 MHz. The method used was to amplitude modulate a 1.2 GHz carrier with the video signal and display this AM spectrum on a spectrum analyzer (see Figure I-3). The modulation/spectrum analyzer frequency response is shown in Figure I-4. This method worked very well for displaying the wideband video spectrum although the very low frequencies were distorted by the 1.2 GHz carrier. The video is a wideband signal by itself, but when translated to 1.2 GHz, it looks like a narrow band spectrum and is easily displayed.

When the video spectrum of a blank scene (a surface with uniform color and contrast, i.e. a wall with no discernable features) or with the lens covered is examined, one finds frequencies of 60 Hz and 15,750 Hz

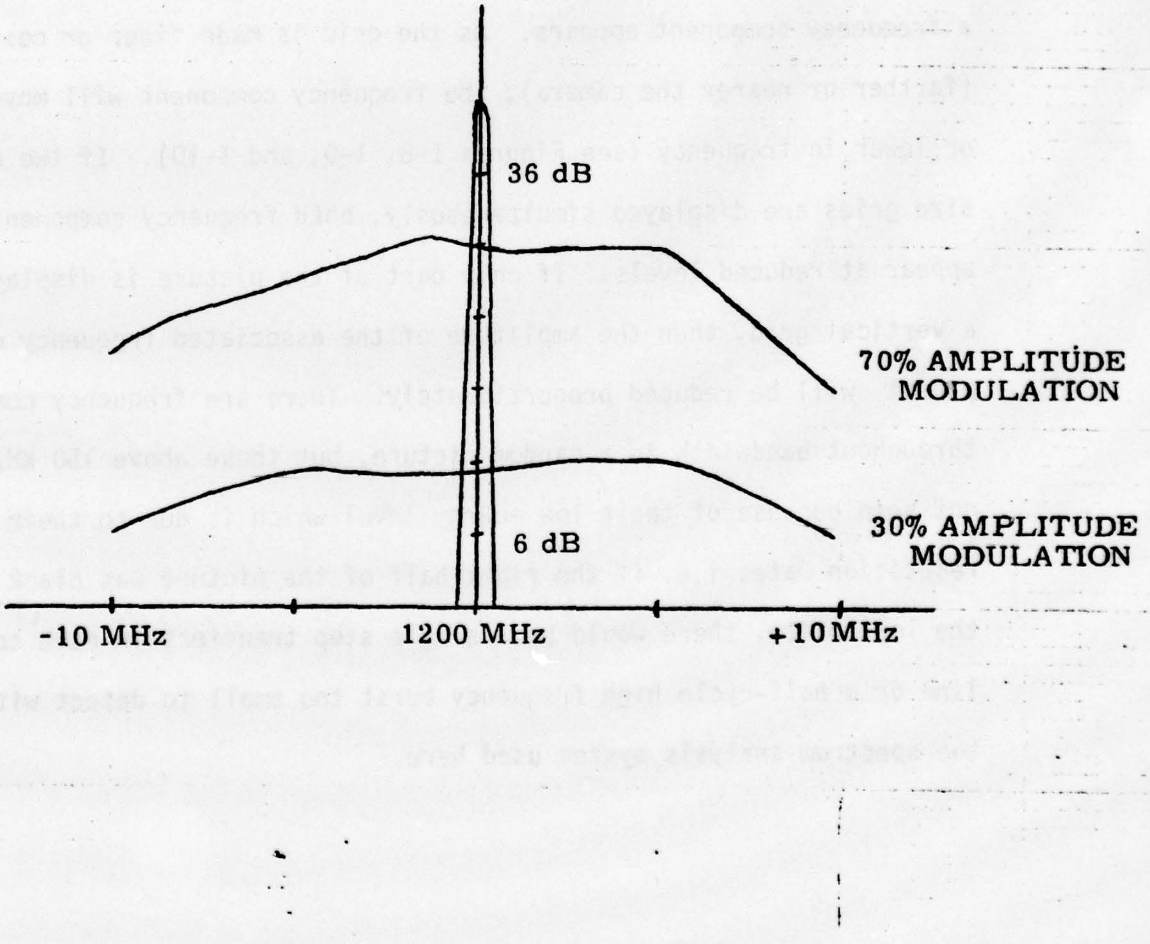


COMPOSITE VIDEO
AMPLITUDE VS. TIME

I-2

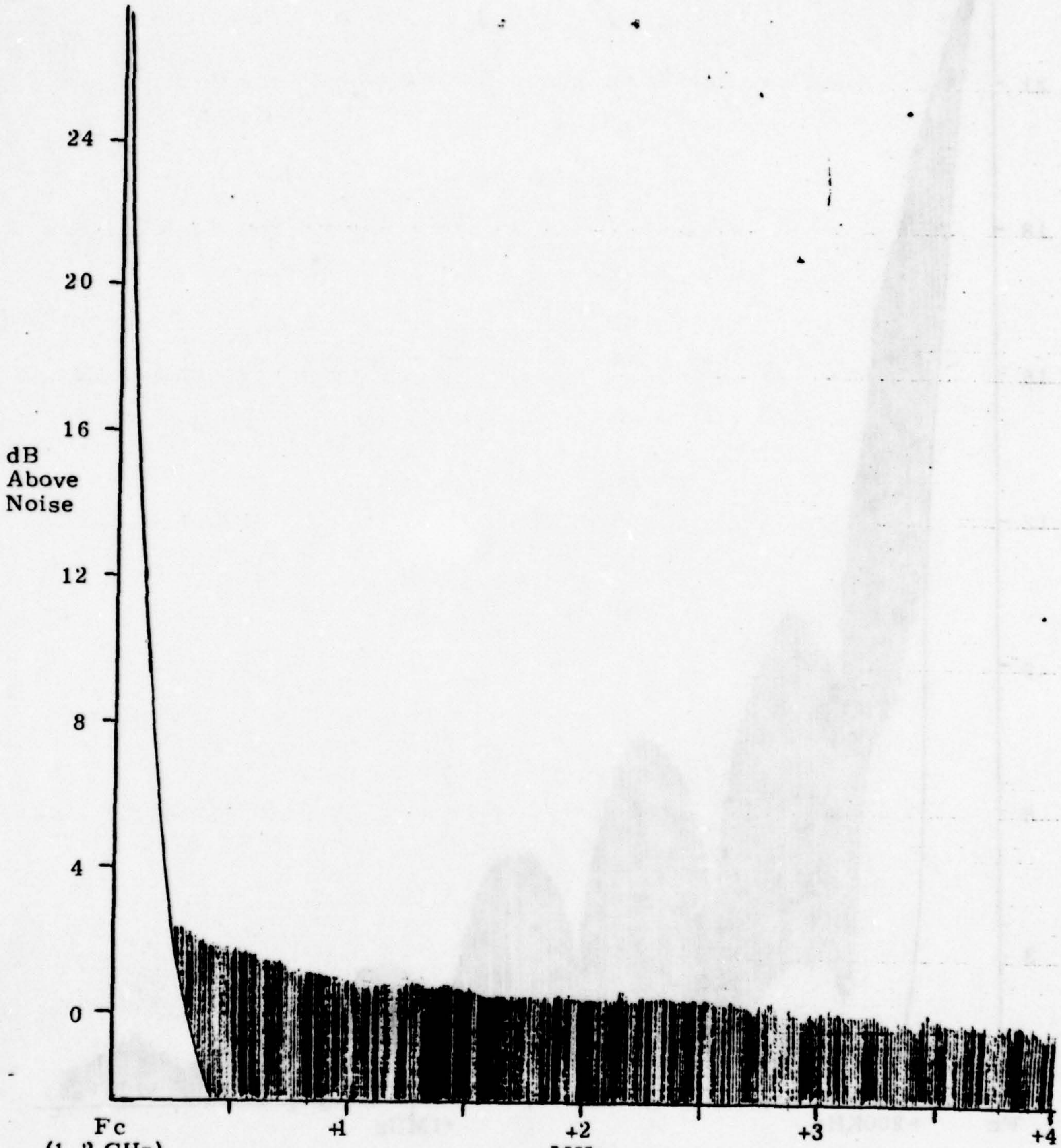


SPECTRUM ANALYSIS TEST SET-UP

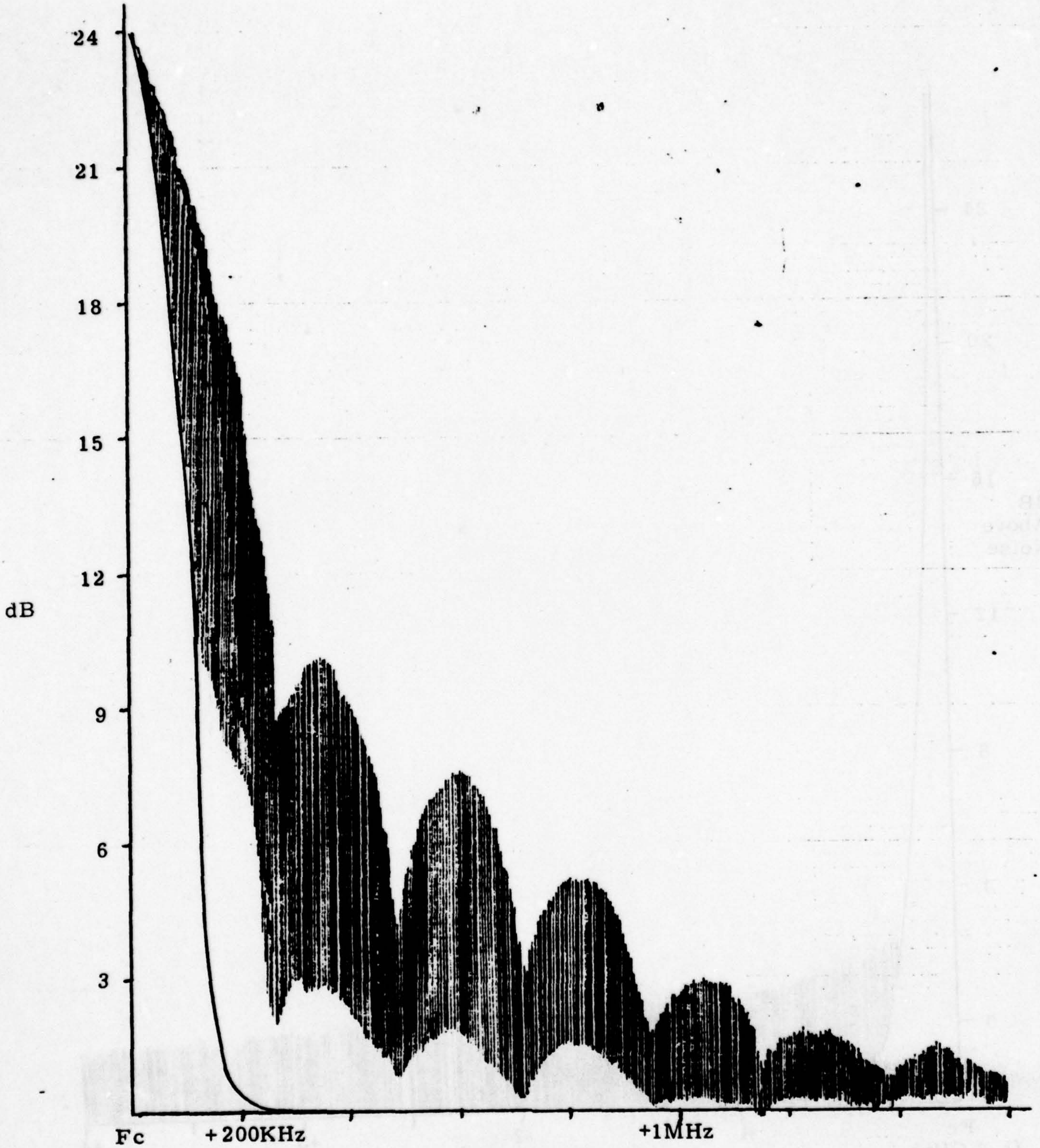


MODULATION CHARACTERISTICS OF
HEWLETT PACKARD MODEL 612A
UHF SIGNAL GENERATOR
I-4

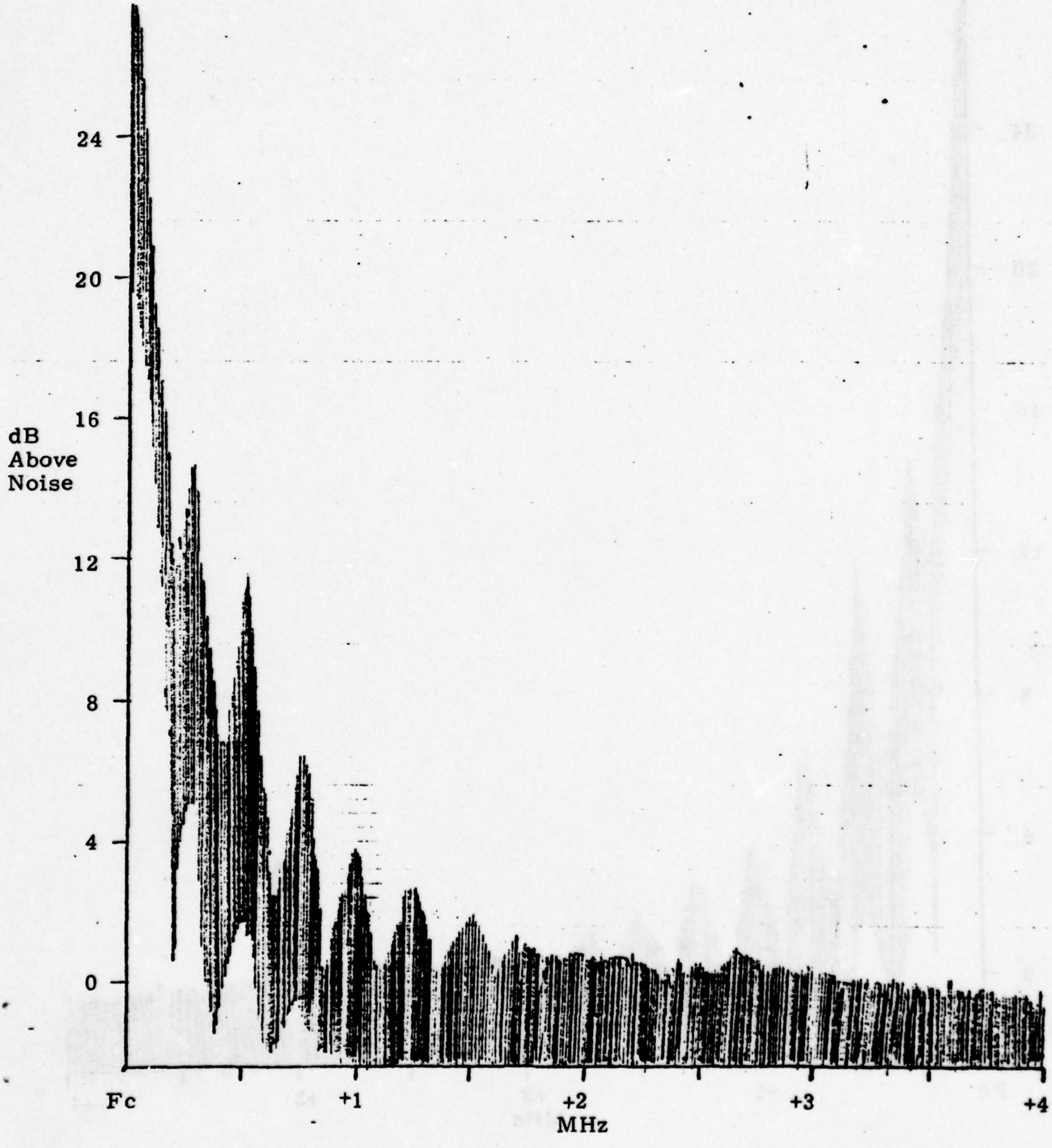
and their harmonics. This is basically the spectrum of two additive pulse trains at the vertical and horizontal scan rates (see Figure I-6). When the picture contains random objects, the spectrum looks similar to the spectrum with a blank picture that has had noise added to the areas between sync pulses. In both cases, very little can be seen above 150 KHz (see Figure I-6). Figures I-6 through I-10 are reproductions of the spectrum analyzer display that have been retouched to make them more clear. When the camera is aimed at a grid of uniform vertical lines, a frequency component appears. As the grid is made finer or coarser (farther or nearer the camera), the frequency component will move higher or lower in frequency (see Figures I-8, I-9, and I-10). If two different size grids are displayed simultaneously, both frequency components will appear at reduced levels. If only part of the picture is displaying a vertical grid, then the amplitude of the associated frequency component will be reduced proportionately. There are frequency components throughout bandwidth in a random picture, but those above 150 KHz are not seen because of their low energy level which is due to their low repetition rate; i.e. if the right half of the picture was black and the left white, there would be a single step transient in each scan line or a half-cycle high frequency burst too small to detect with the spectrum analysis system used here.



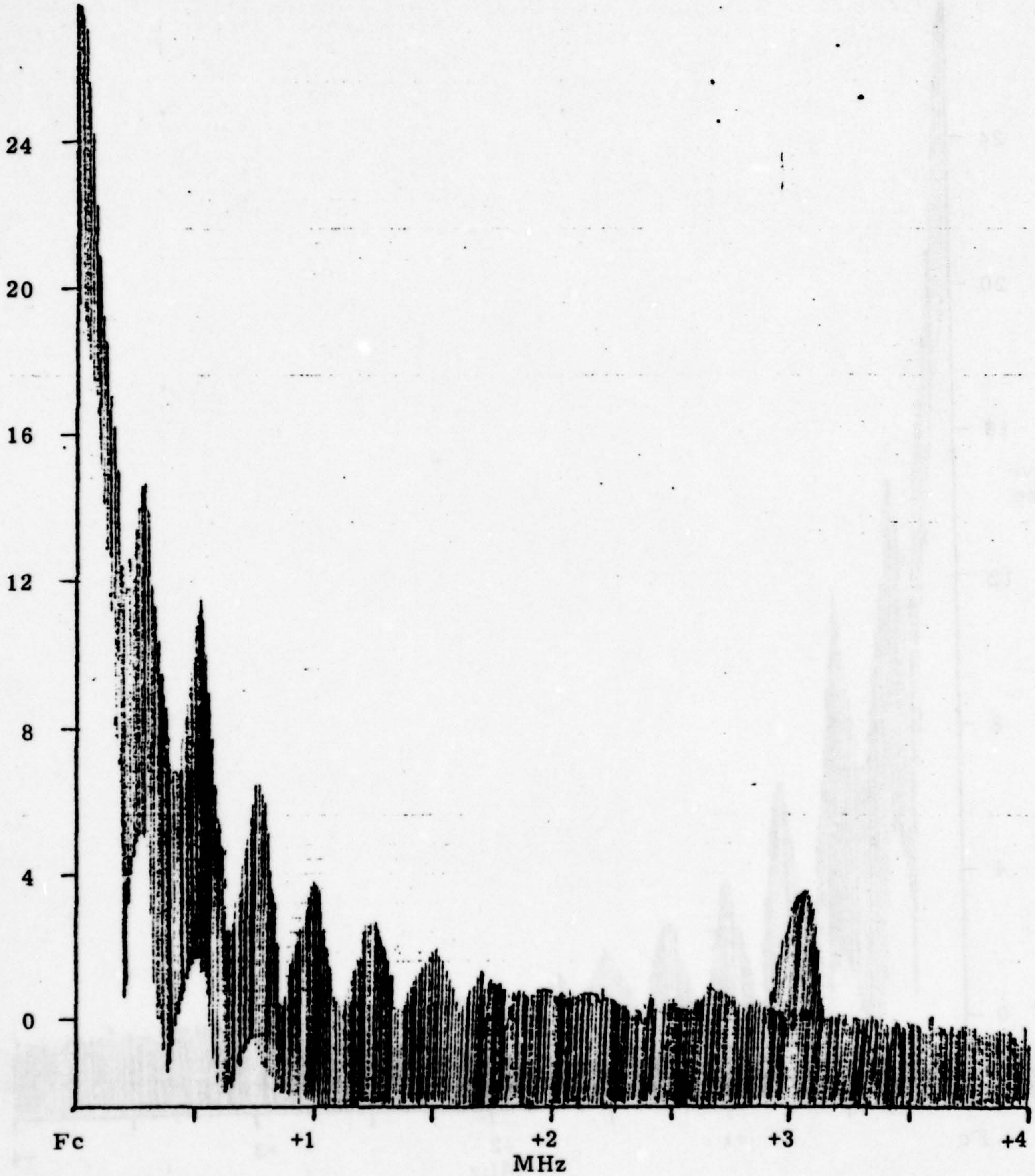
SPECTRUM OF UNMODULATED CARRIER
USED FOR VIDEO SPECTRUM ANALYSIS
I-5



VIDEO SPECTRUM
LENS COVERED
I-6



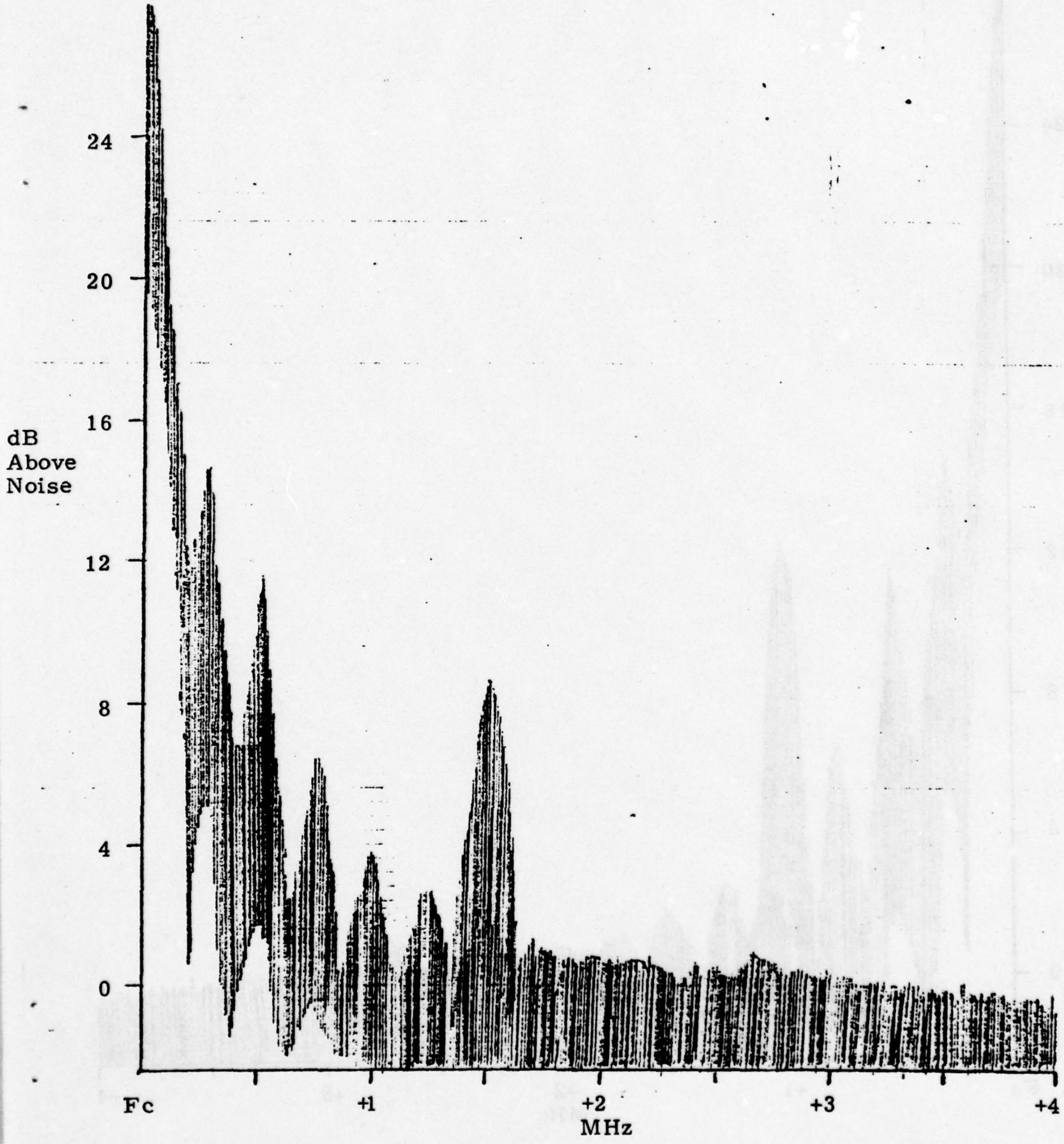
VIDEO SPECTRUM
LENS COVERED
I-7



VIDEO SPECTRUM

$\frac{1}{8}$ GRID AT 54 INCHES FROM LENS

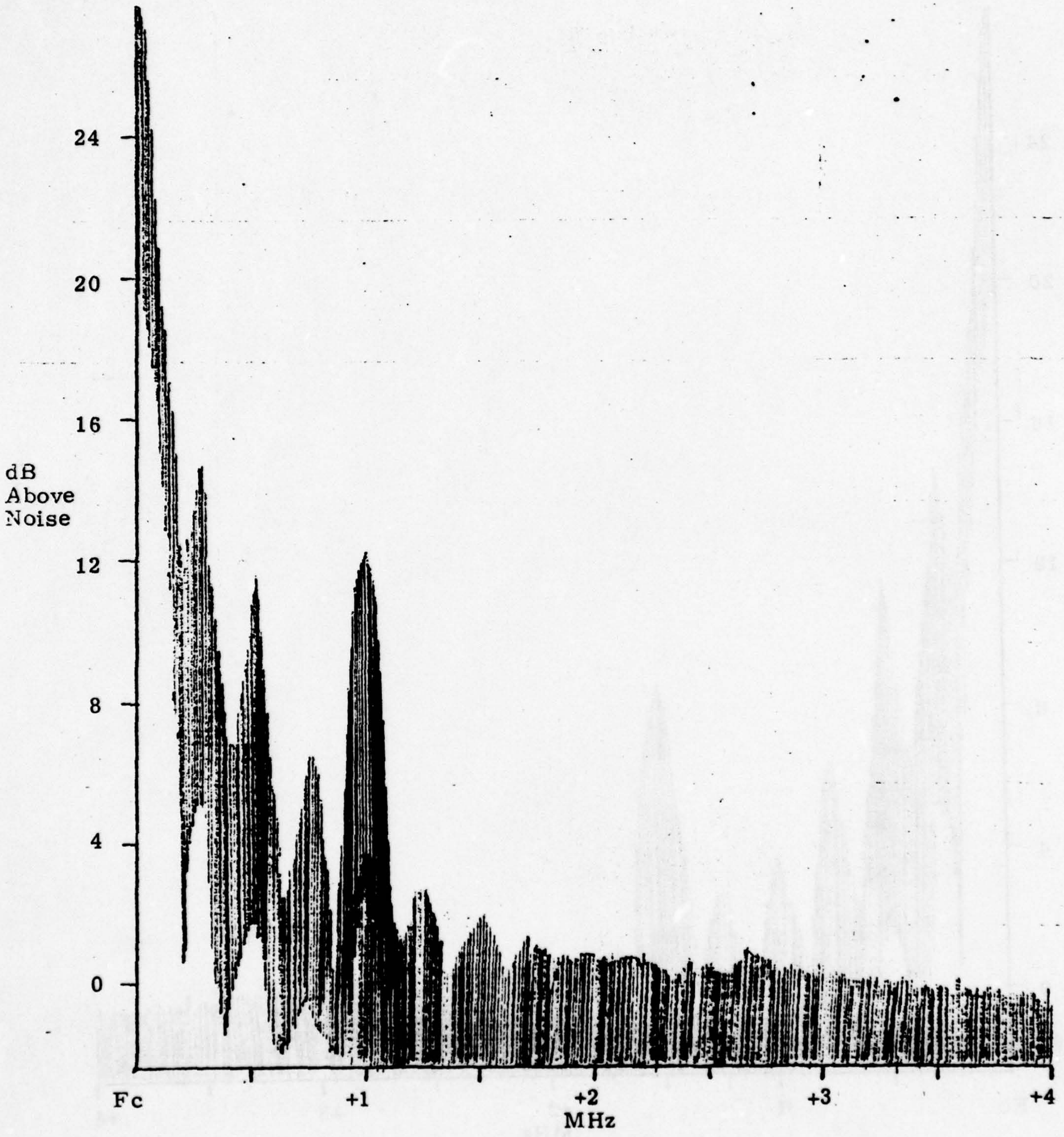
I-8



VIDEO SPECTRUM

$\frac{1}{8}$ INCH GRID AT 27 INCHES FROM LENS

I-9

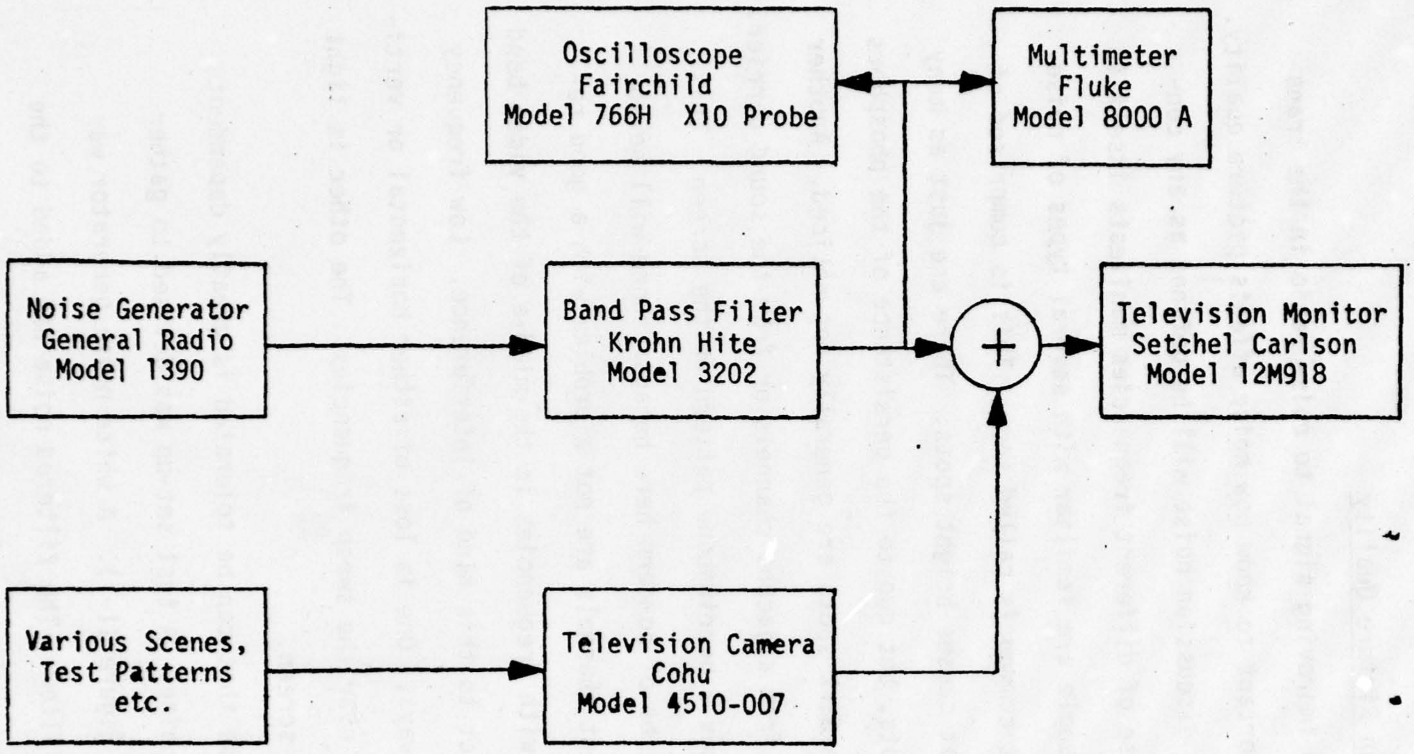


VIDEO SPECTRUM
$\frac{1}{8}$ INCH GRID AT 16 INCHES FROM LENS
I-10

## II. Effects of Noise on Picture Quality

Before dealing with improving signal to noise ratio in the transmission link, it is important to know how noise affects picture quality. For the purpose of this discussion noise will be defined as any contaminating signal. Noise of different frequencies manifests itself in different ways. Most people are familiar with several types of noise in television. The most common is called snow. This is comprised of high frequency noise that causes bright spots. There are just as many dark spots as bright spots, but due to the persistance of the phosphors in the picture tube, the dark spots are generally not noticed. Another common type of noise is from adjacent channels or from the sound carrier. This interference produces a herringbone pattern on the screen. This type of noise should not be of concern here because there will be no sound carrier and adjacent channels are not a problem with a good receiver. However, noise with frequencies in the middle of the video band can cause a similar effect to this kind of interference. Low frequency noise can appear in two ways. One is loss of either horizontal or vertical sync if the noise is near the sweep frequencies. The other is light and dark bars across the screen.

The amplitude of noise that can be tolerated is greatly dependent on the frequency of the noise. A test set-up was devised to gather information on this (see Figure II-1). A white noise generator was connected to a bandpass filter. The filtered noise was added to the composite video and displayed on a monitor. The noise amplitude was set at the maximum level at which a useful picture was still present. What is a useful picture is a matter of personal judgement and varies with



NOISE SENSITIVITY
TEST SET-UP
II-1

what is displayed. A poorer picture can be tolerated when watching a parking lot for thieves than can be tolerated when giving prerecorded lessons in teaching. The criterion used here was to be able to recognize objects in the picture. The low frequency end of the noise level was mostly dependent on when the monitor lost synchronization. This means that low frequency noise levels are somewhat independent of what is being displayed. Middle and high frequency noise levels are greatly dependent on what is being displayed. If only large objects (relative to what portion of the screen they fill) are displayed, a large noise level can be tolerated. If the scene is rapidly changing, a much lower level can be tolerated regardless of object size.

The results of the noise injection test are shown in Figure II-2. For this test, the video level was held constant and the noise was increased to the maximum possible level that still allowed a useful picture. A great deal more noise can be tolerated at low frequencies than at high frequencies. This is due to objects being badly distorted by low frequency noise and still being recognizable while the high frequency noise tends to hide the objects more than it distorts the contrast levels of the objects or upsets sync.

| 3 dB POINTS OF BAND PASS FILTER | MAXIMUM NOISE AMPLITUDE millivolts | |
|---|---|---|
| | RMS | PP |
| 20 - 200 Hz | 322 | 700 |
| 200 - 2 KHz | 184 | 500 |
| 2K - 20 KHz | 46 | 200 |
| 20K - 200 KHz | 23 | 70 |
| 200K - 2 MHz | | 70 |

Video Level During Test 112 MVRMS, 600MVPP

Test Set-up Shown in Figure II-1

NOISE SENSITIVITY

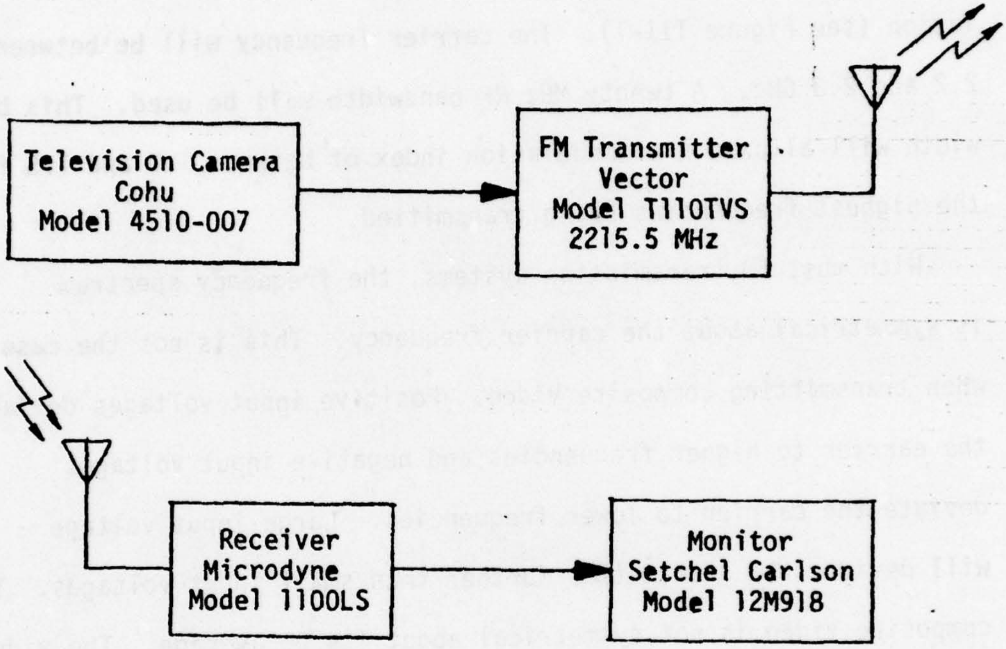
II-2

## III. Transmission System

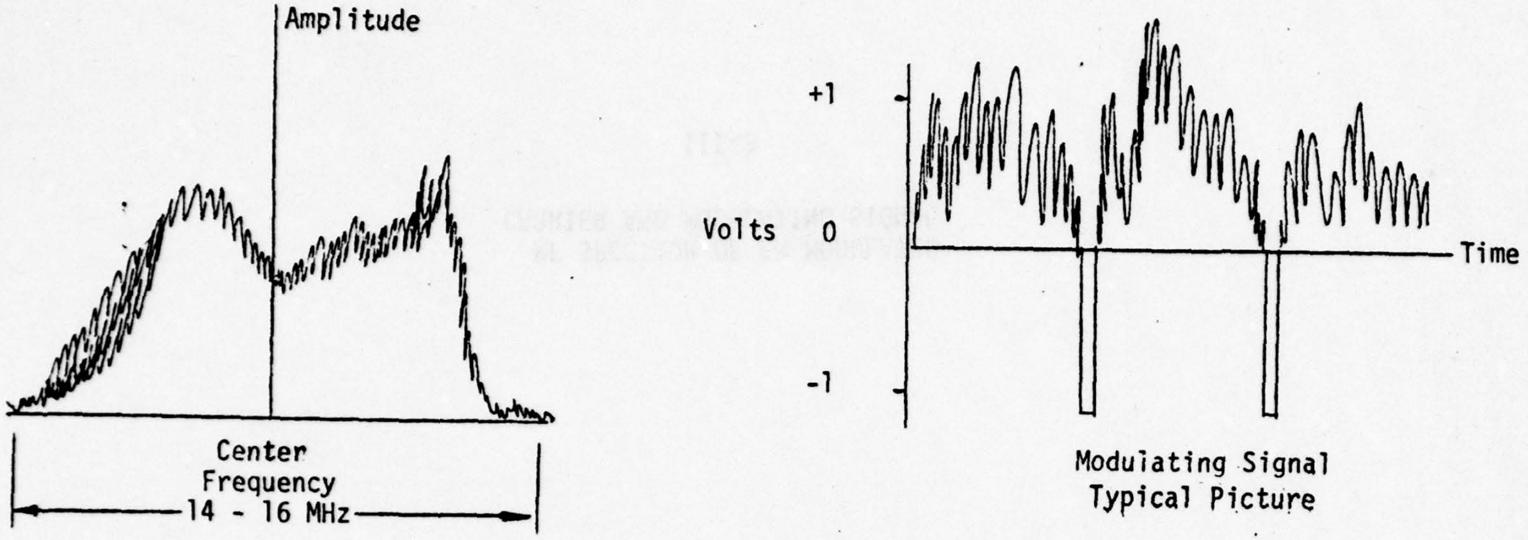
The transmission system to be used will employ frequency modulation (see Figure III-1). The carrier frequency will be between 2.2 and 2.3 GHz. A twenty MHz RF bandwidth will be used. This bandwidth will allow a β or modulation index of between 1.0 and 1.5 for the highest frequencies being transmitted.

With most FM transmission systems, the frequency spectrum is symmetrical about the carrier frequency. This is not the case when transmitting composite video. Positive input voltages deviate the carrier to higher frequencies and negative input voltages deviate the carrier to lower frequencies. Large input voltage will deviate the transmitter further than small input voltages. The composite video is not symmetrical about its DC average. The video portion deviates the transmitter frequency up while the sync pulses deviate the frequency down. This means that the lower sideband carries the sync information while the upper sideband carries the picture information. With a normal picture being transmitted, the upper and lower sidebands are about the same width but different shapes (see Figure III-2). When the lens is covered, the upper sideband shrinks to almost nothing (see Figure III-3). The unbalanced spectrum will sometimes make the automatic frequency control in the receiver think the receiver is mistuned. This effect is small due to the low duty cycle of the sync pulses and is not a problem.

It might be possible to use more of the RF bandwidth for picture information and less for sync pulses and improve picture quality under



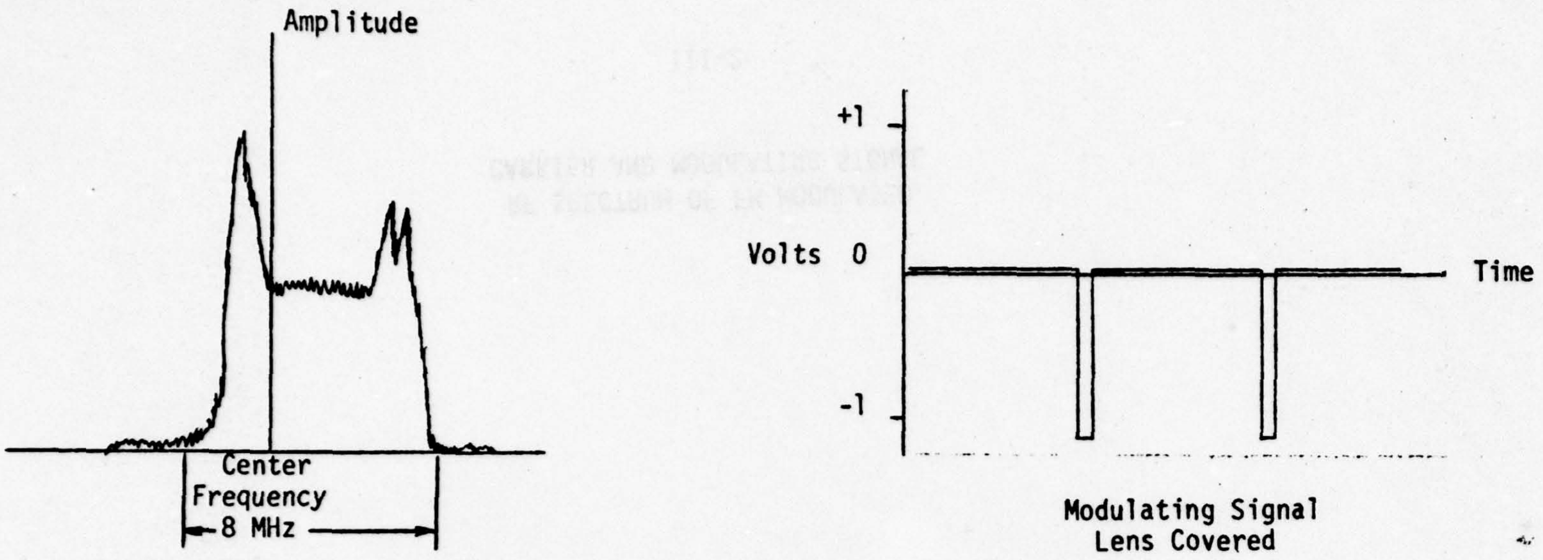
F M TRANSMISSOIN SYSTEM
III-1



Modulating Signal
Typical Picture

RF SPECTRUM OF FM MODULATED
CARRIER AND MODULATING SIGNAL

III-2



Modulating Signal
Lens Covered

RF SPECTRUM OF FM MODULATED
CARRIER AND MODULATING SIGNAL

III-3

low s/n conditions. This could be done by reducing the sync pulses' amplitude relative to the composite video amplitude. The amplitude of the sync pulses is not critical so long as they are not too small to be separated from the composite video and will still produce blanking during retrace. The noise level in the received signal is dependent on the bandwidth of the receiver but is independent of how this bandwidth is used. By using more of the bandwidth for the picture information a higher signal to noise ratio may be obtained. This improvement is at the expense of the signal to noise ratio of the sync portion of the composite video signal. Due to the repetitive nature of the sync pulses, a much poorer signal to noise condition may exist here than in the video portion and still produce a useful picture.

In the FM transmission system to be used the noise picked up during transmission and the noise generated by the receiver in its RF and IF sections is white noise. This white noise is bandlimited by the IF section. The bandlimited noise signal and the transmitted signal are both fed into the FM demodulator. The output from the demodulator will contain noise as well as the demodulated signal, video in this case. The noise power at the demodulator output is proportional to the square of frequency; i.e. there is four times as much noise at 2 MHz as there is at 1 MHz. This means that higher frequencies of the baseband signal, in this case composite video, will have poorer signal to noise ratios than the lower frequencies. This combined with the higher sensitivity of the television system to high frequency noise means that the amount of snow will in general be what will determine the minimum acceptable signal to noise ratio for a transmission system.

## IV. WHY PREEMPHASIS

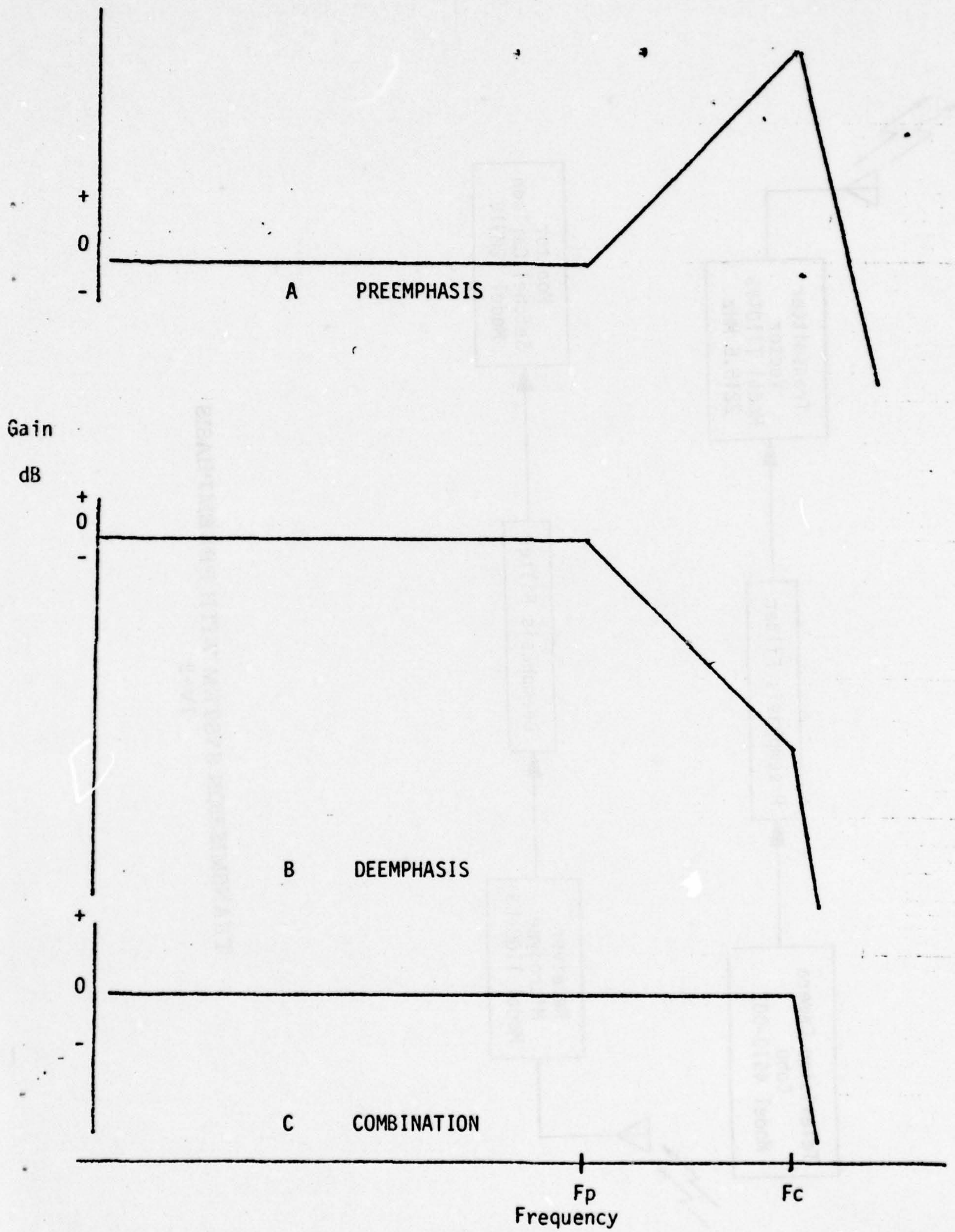
Tests have shown that the TV system is more sensitive to high frequency noise than low frequency noise. The noise level out of an FM receiver at a particular frequency can be shown to be proportional to the square of the frequency when the receiver is operating above its threshold. Since there is more noise and a greater sensitivity to noise at higher frequencies, the high frequency noise (snow) is what will limit how low a signal to noise ratio into the receiver will be acceptable.

The purpose of preemphasis in this system is to reduce the effects of noise at the high end of the video. This can be accomplished by placing a premodulation filter with amplitude characteristics like those shown in Figure IV-1a between the camera and transmitter and also placing another filter with amplitude characteristics like those shown in Figure IV-1b between the receiver and monitor (see Figure IV-2).

A filter with characteristics like those shown in Figure IV-1a will boost the amplitude of the upper part of the video spectrum relative to the rest of the video. This means that the higher frequencies will be emphasized prior to transmission--thus the name preemphasis.

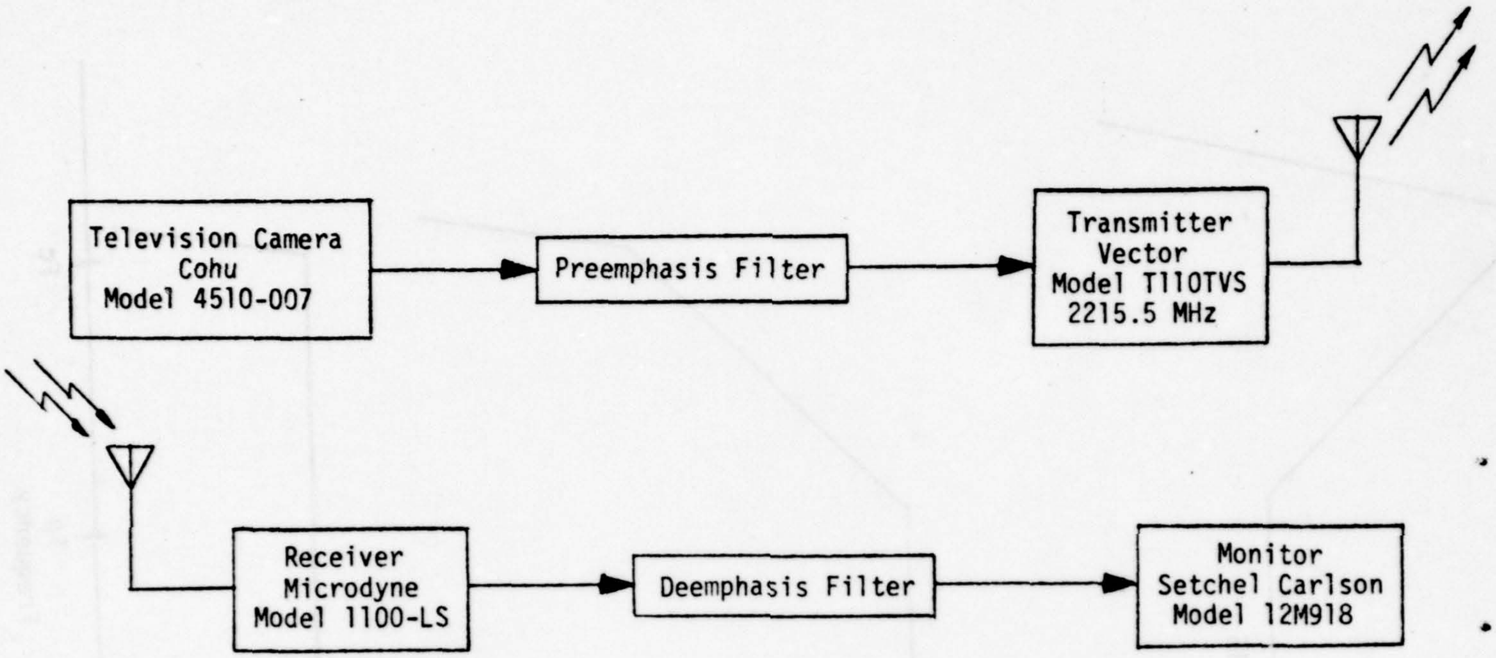
The second filter, shown in Figure IV-1b will reduce the amplitude of the upper part of the video spectrum relative to the rest of the video. In addition to filtering the video the noise must also pass through this filter.

The video must pass through both filters. If the two filters



GENERAL CHARACTERISTICS FOR A PREEMPHASIS SYSTEM

IV-1



TRANSMISSION SYSTEM WITH PREEMPHASIS
IV-2

are well matched, the video leaving the deemphasis filter will be returned to its original form with the exception that it will be band limited. The noise introduced during transmission and detection will only pass through the deemphasis filter and will be attenuated.

If the transfer function of the filter in Figure IV-1a is H(f) then the filter in Figure IV-1b should have a transfer function of $\frac{1}{H(f)}$. It is not always possible to realize the $\frac{1}{H(f)}$ function for a given H(f) function. This limits the choices for H(f) to those functions with realizable inverses.

The general characteristics of the two filters are determined in part by the need for them to be inverses of each other up to Fc (see Figure IV-1). They both drop off above Fc. This is the highest frequency that need be transmitted or displayed. The preemphasis filter cuts off the video at Fc to keep unnecessary signals from deviating the transmitter and thereby increasing the required bandwidth. The deemphasis filter cuts off the video signal at Fc to prevent noise above Fc from reaching the monitor.

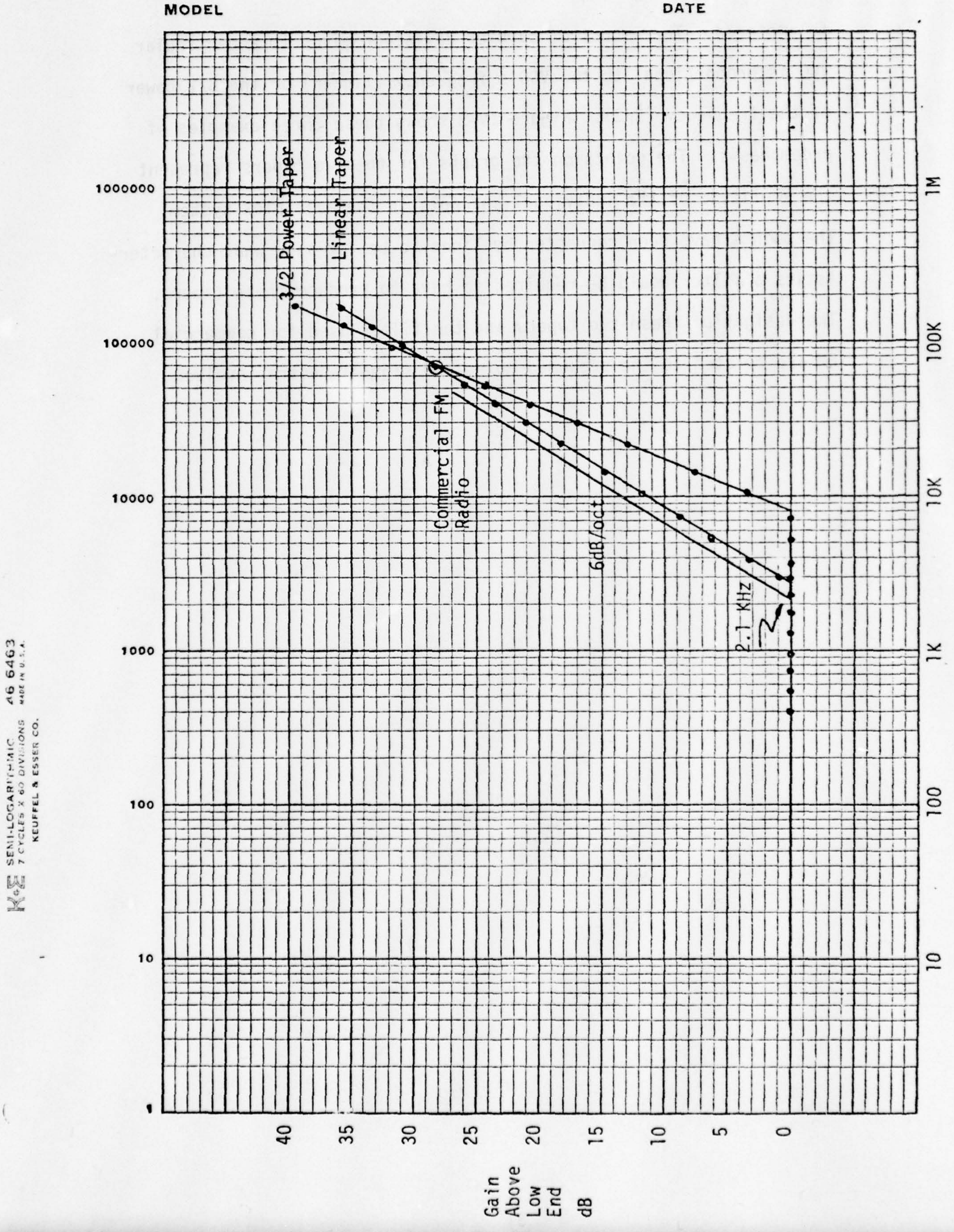
The slopes of the two filters must be equal but opposite if the received signal is to match the original video. In an FM transmission system the noise power present increases with the square of the frequency. Also the television system's sensitivity to noise doubles with each decade increase in frequency. Since there is a greater sensitivity to noise at higher frequencies and an increase in the level of noise present at higher frequencies, the deemphasis filter must be made to decrease gain with increased frequency and the preemphasis filter must increase gain with increased frequency. The degree of preemphasis is determined by the slopes of the filters;

steeper slope means more preemphasis.

The frequency Fp (see Figure IV-1) where the preemphasis starts is determined by several factors. It must be low enough to provide sufficient preemphasis but high enough that significant increases in transmission bandwidth or reductions in transmitter deviation by frequencies below Fp are not necessary. The increase in bandwidth or reduction in deviation could reduce the signal to noise ratio of the lower frequencies to a point where they would be worse than the higher frequencies.

As the degree of preemphasis is increased, the matching of the two filters becomes very critical. Small amplitude variations due to mismatched filters are no problem, but phase shifts can be. Phase shifts can cause a ghosting effect which tends to blur the picture. This matching problem makes a low order preemphasis desirable. If the degree of preemphasis is increased beyond that which is necessary (how much is necessary will be shown later), the degree of filter matching becomes unnecessarily complicated, and transmitter deviation by low frequencies may have to be reduced to a point where a loss in picture quality may occur. A best degree of preemphasis cannot be specified without specifying what the picture to be televised will be. This is due to the video spectrum being dependent on the scene being televised.

Commercial FM radio stations use a single pole RC filter for preemphasis of the audio spectrum.[1] There are two variations of preemphasis used with FM-FM telemetry systems: linear and 3/2 tapers.[2] These tapers are both IRIG standard and have been developed for use in frequency modulating a carrier with VCO's (voltage controlled oscillators) that have been frequency modulated by the data to be telemetered. The amount of carrier deviation given to a particular VCO is proportional to the VCO's frequency (linear) or the 3/2 power of the frequency (3/2). Figure IV-3 shows these three examples of preemphasis. The points on the graphs for the two tapers represent the amplitude of the individual channels in the multiplex system. The points have been connected by lines to better show what characteristics a filter would be required to have to produce these tapers. The designs of these two tapers and the filter used for commercial FM are related to the presumed noise and signal spectra involved.



EXAMPLES OF PREEMPHASIS
IV-3

## V. Preemphasis-Deemphasis Possibilities

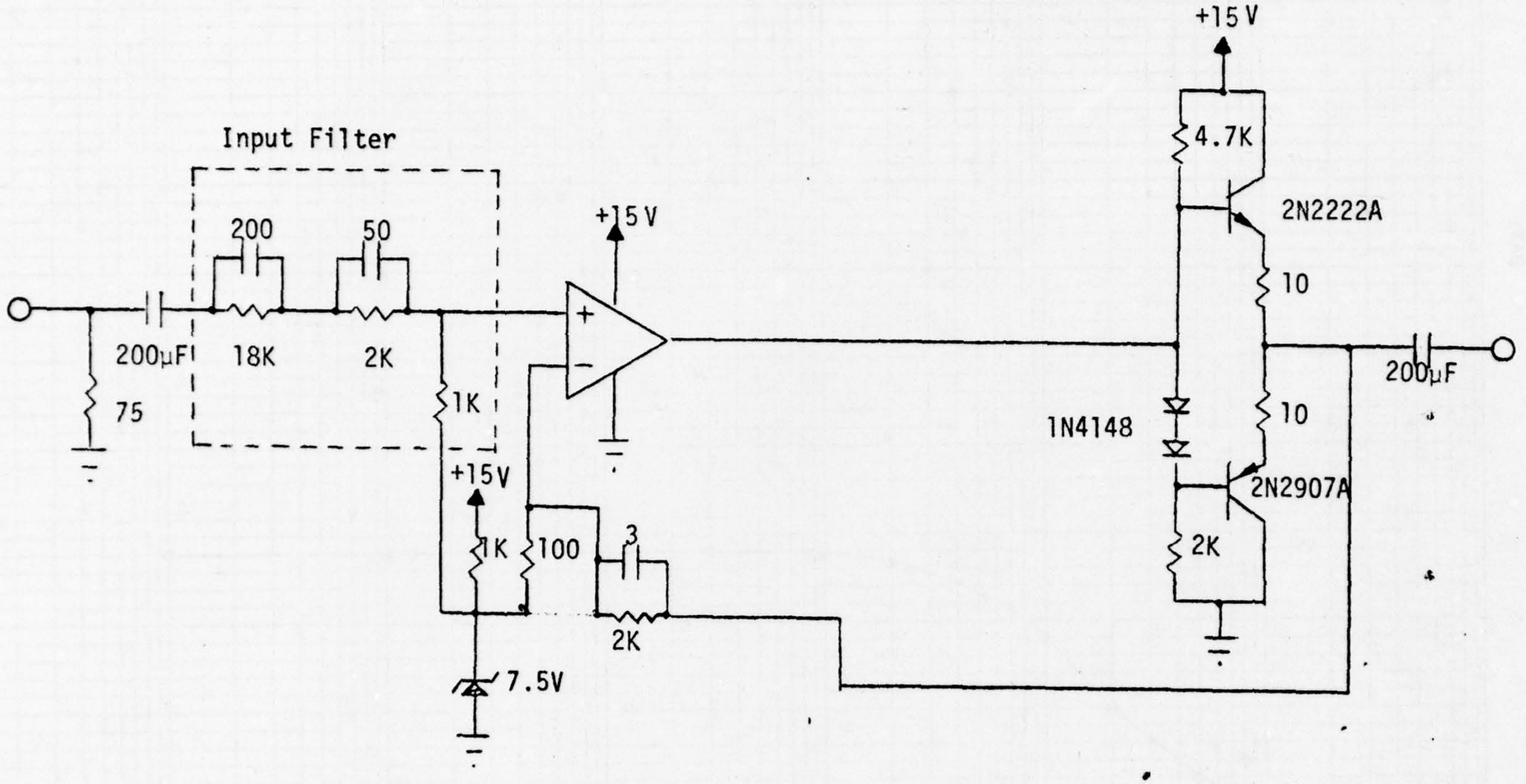
The number of possible circuits to provide transfer functions like those shown in Figure IV-1 is almost endless. The purpose of this thesis is to find the best one for FM transmission of television from rockets and balloons.

A single pole RC filter with its 3 dB point at 40 KHz (Fp) was chosen for several reasons. One is its simplicity. With this type of circuit an accurate match between preemphasis and deemphasis filters can be made so there is no picture degradation due to slight mismatch of filters.

A second reason is the 20 dB/decade slope, as is provided by a single pole filter, comes very close to the 23 dB/decade increase in degradation of the picture by noise. This 23 dB/decade increase is the result of a 20 dB/decade increase in noise power from the FM demodulator and a 3 dB/decade increase in noise sensitivity of the television system (see Figure II-2). A 23 dB/decade filter could be made using active filter techniques but would be much more complex and two inverse filters might not be realizable. It is the opinion of the writer that the increase in complexity and resulting reduction in reliability outweighs the 3 dB/decade change in filter slope.

Spectrum analysis tests showed that about half of the power of the composite video signal is below 30 KHz. The amplitude level of the frequencies drop gradually above 30 KHz. The 40 KHz 3 dB point of the filter allows the 20 dB/decade increase in gain without the need to significantly reduce transmitter deviation or increase the bandwidth. If a 3 dB point below 40 KHz is used much larger signals are encountered at the filter output. This is the result of lower frequencies with appreciable amplitude being amplified and from the increased filter gain at high frequencies. These larger signals require reducing deviation by lower frequencies or increasing bandwidth. 40 KHz is also below the frequency at which noise would become a problem without preemphasis; i.e. the picture will be completely hidden by snow before noise below 40 KHz would become a problem. This was shown by the tests described in Chapter II.

The circuit shown in Figure V-1 has the gain vs. frequency shown in Figure V-2. The circuit is basically the video amplifier shown in the RCA Linear Integrated Circuit Handbook. This amplifier has an RC filter placed on the non-inverting input. This circuit is AC coupled at both input and output. The AC coupling allows the filter to be powered by a single 15 volt supply. There are two parallel RC networks in cascade on the input. The first provides the 40 KHz 20 dB/decade part of the curve. The second RC compensates for a drop in amplifier gain above 1 MHz. The slope of this filter as actually measured is approximately 10 dB/decade. The RC filter never reaches its natural 20 dB/decade slope due to other characteristics of the circuit. The poles and zeros are too close together to reach the final slope for any of them. It was found necessary to use two RC combinations in cascade just to keep the slope at 10 dB/decade up to 3 MHz. When more filtering was used to try to get the desired 20 dB/decade slope, the circuit was unstable. The amplifier gives a 27 dB gain at low frequency while the resistors on the input provide a 26 dB attenuation. The resultant 1 dB gain provides the proper signal level to give the desired deviation of the transmitter by the video. The preemphasis peaks at 3 MHz and drops rapidly above 4 MHz. The rolloff above 4 MHz is quite acceptable since earlier tests have shown that an acceptable picture can be obtained when the video spectrum is passed through a lowpass filter set for 2 or 3 MHz cut-off. The circuit is limited to a maximum gain of 23 dB (amplifier and filter combined). When the circuit gain was increased

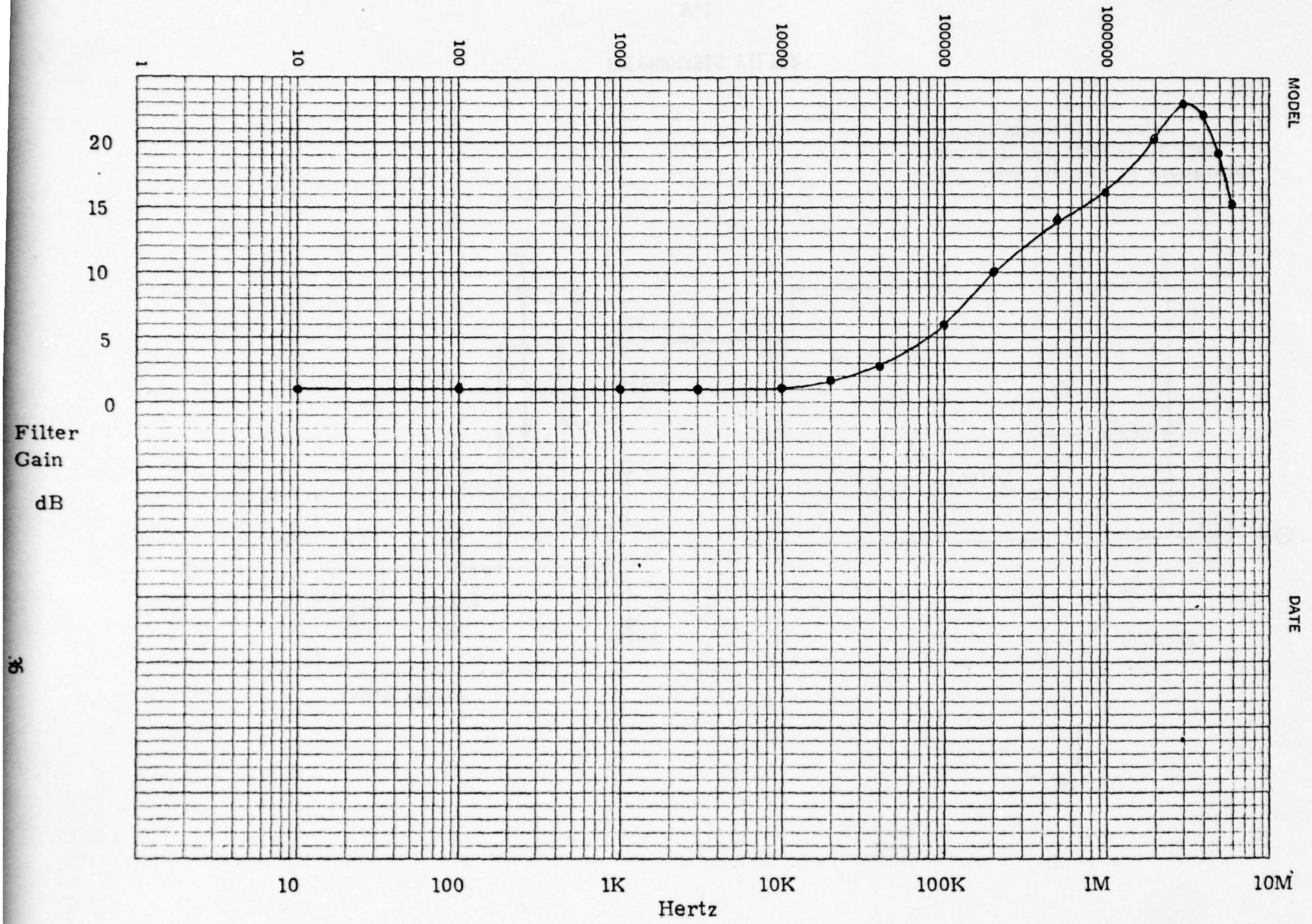


All capacitances in picofarads
and all resistances in ohms
unless otherwise shown

PREEMPHASIS FILTER

K+E SEMI-LOGARITHMIC 7 CYCLES X 60 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 6463



PREEMPHASIS FILTER CHARACTERISTICS

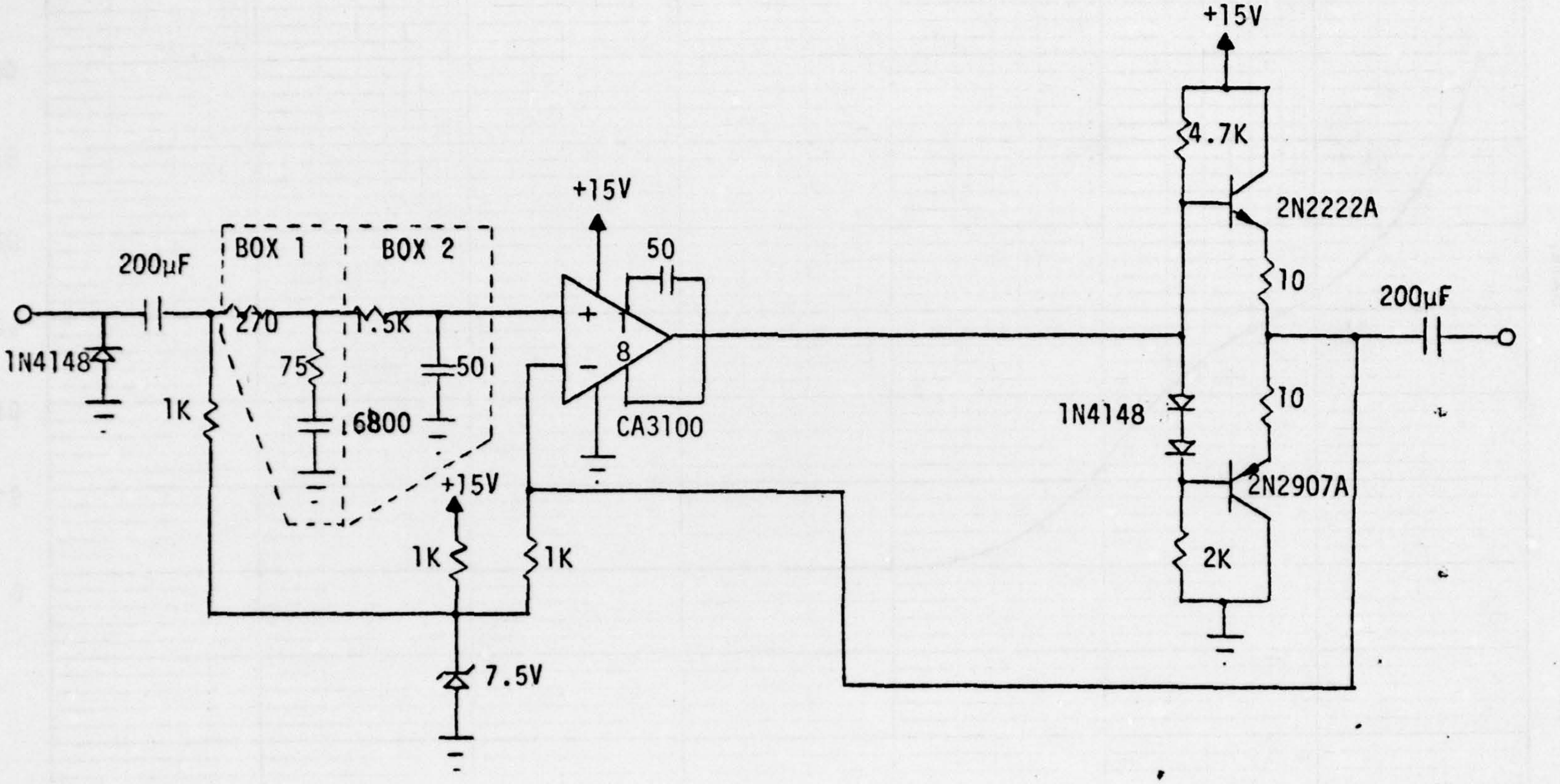
V-2

much above 23 dB it was on the borderline of oscillating. The difference between high frequency gain and low frequency gain is 22 dB (see Figure V-2). This means that frequencies around 3 MHz are preemphasized 22 dB above frequencies below 10 KHz.

The deemphasis circuit and its gain vs. the frequency curve is shown in Figures V-3 and V-4 respectively. The part of the circuit in Box 1 is the inverse of the filter on the input of the preemphasis circuit. This provides restoration of the video signal. The part of the circuit in Box 2 is a lowpass network to attenuate any frequency above 2.5 MHz. The 3 dB point for this is about 2.5 MHz. The diode across the input limits the input signal level into the filter. Shot noise or clicks start to take over the picture as the receiver nears its threshold. Clicks produce large spots, about 1/8 inch diameter on the monitor. The clicks are much larger in amplitude than the video coming out of the receiver. The diodes clip off anything that exceeds this forward conduction level at about .6 volts. The video signal should never reach this level and so will not be affected by the limiting. The clicks will exceed the conduction level and their amplitude will be limited to the conduction level. This reduces the degree to which the clicks upset the picture.

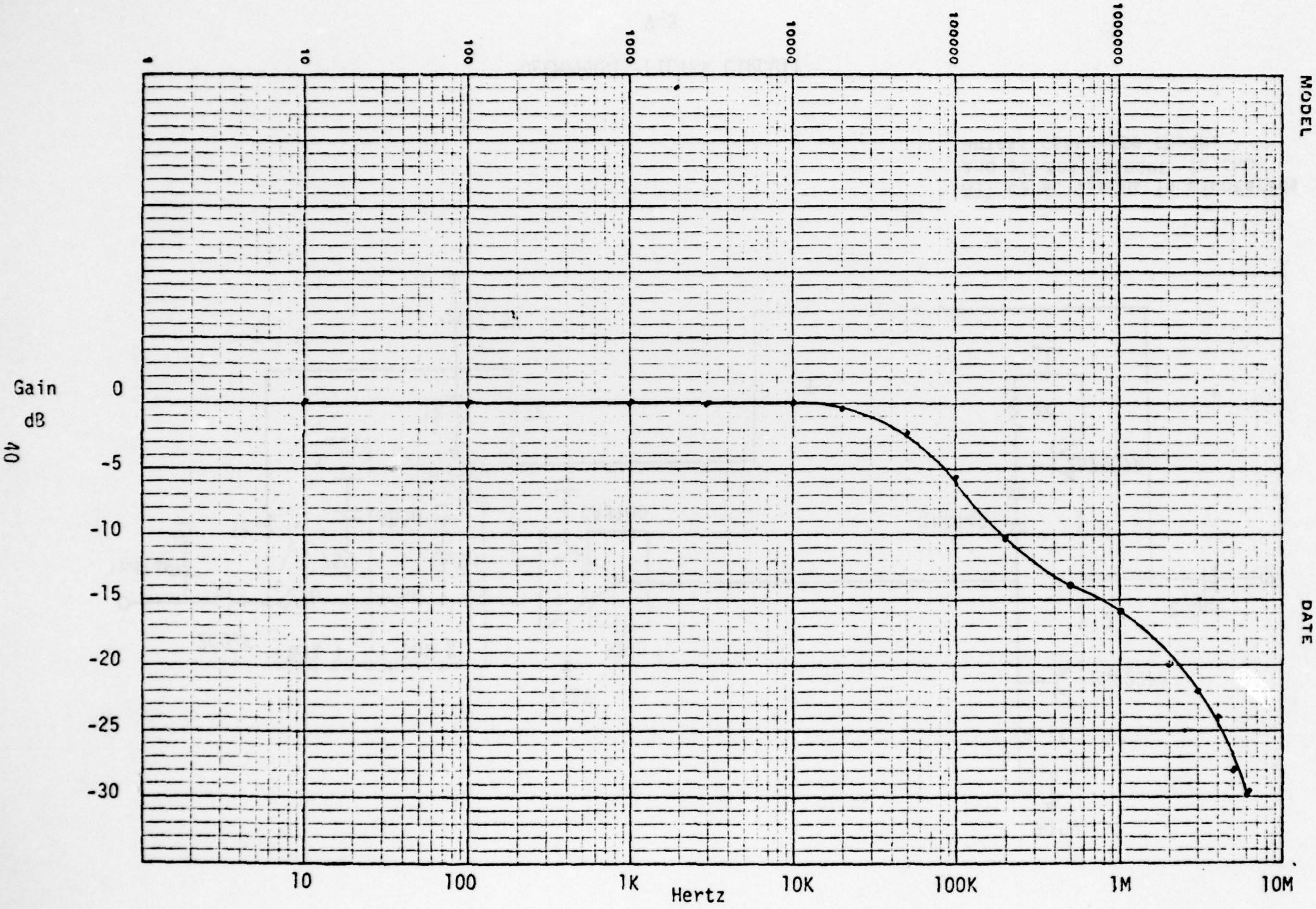
The combination of both the preemphasis and deemphasis filters produce the transfer curve shown in Figure V-5. The individual filters are also shown. The flat part of the curve is shown at 0 dB. The combined gain of the two filters and the transmitter-receiver system is near 0 dB, but may be adjusted as required to provide the proper level into the monitor.

There was no appreciable phase shift produced by the circuits below 100 KHz. The phase shift increased gradually from 100 KHz to 1.5 MHz and increased rapidly above 1.5 MHz (see FiguresV-6 and V-7). Square waves of frequency below 1 MHz can be passed through both filters in series with very little distortion, slight overshoot on the leading edge above 100 KHz and small exponential decay on frequencies

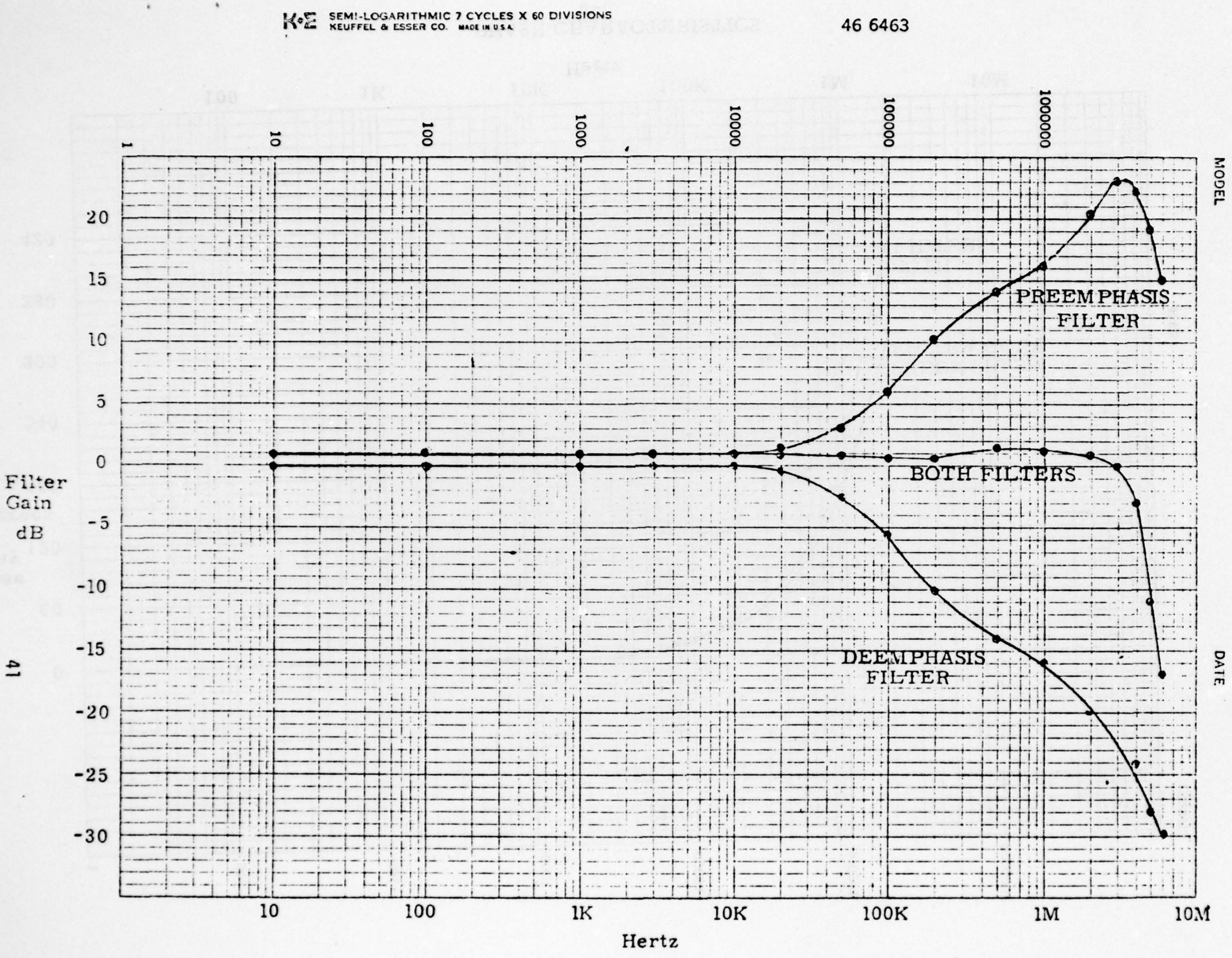


All capacitances in picofarads
and all resistances in ohms
unless otherwise shown.

DEEMPHASIS FILTER CIRCUIT

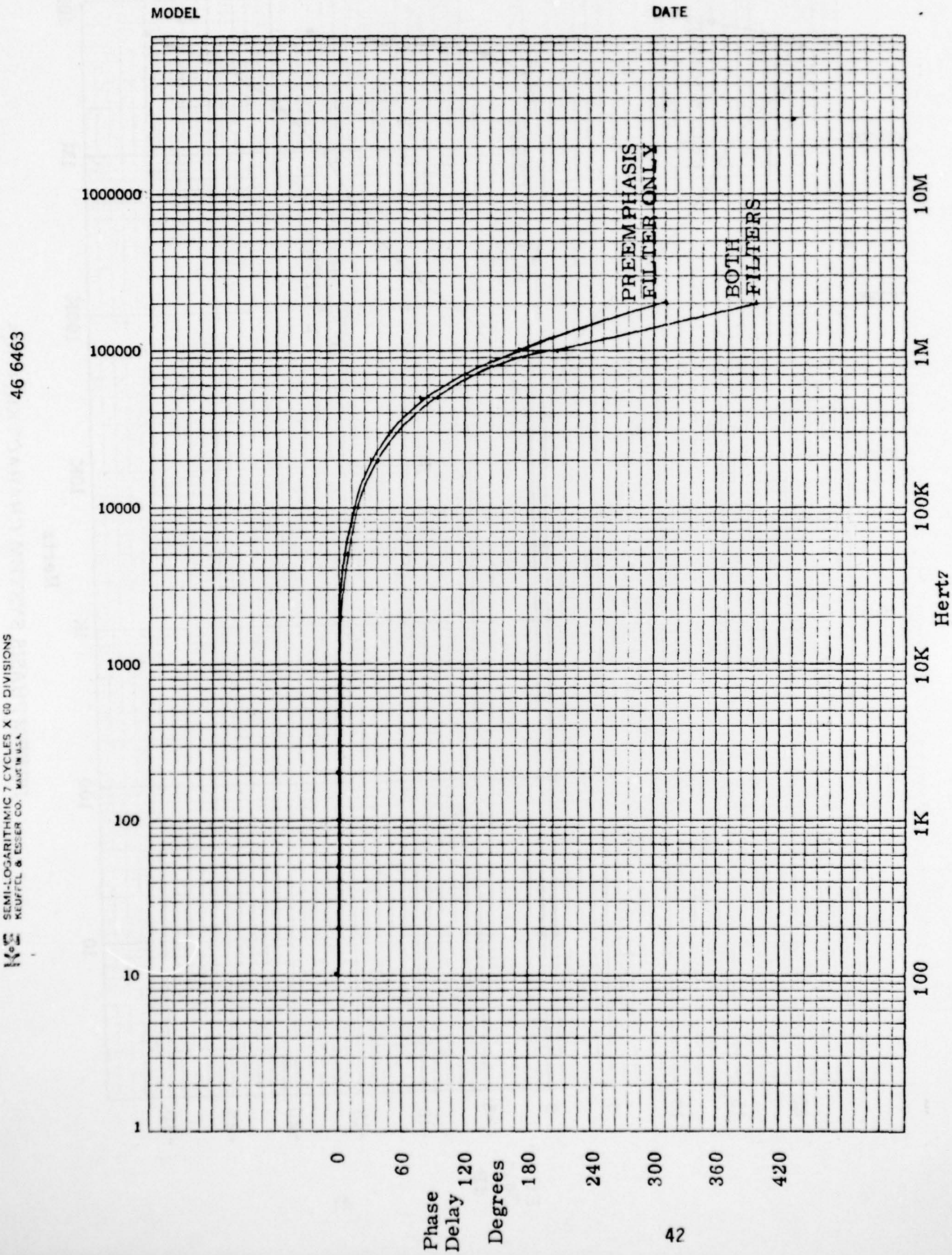


DEEMPHASIS FILTER CHARACTERISTICS
V-4

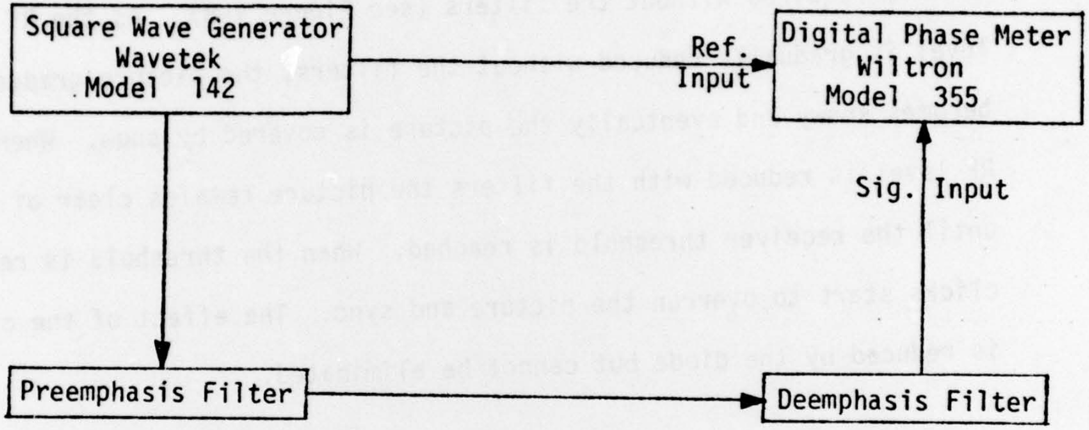


PREEMPHASIS SYSTEM CHARACTERISTICS

V-5



PHASE CHARACTERISTICS
V-6



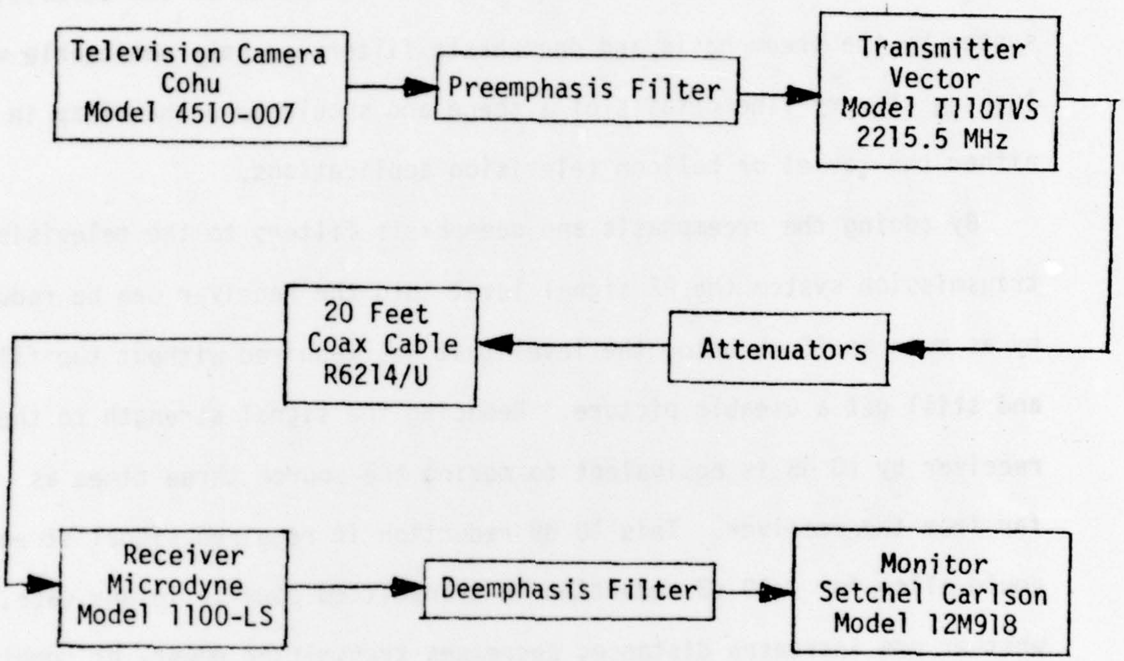
Digital phase meter compares phases of the reference input and signal input and displays the phase lag or lead.

PHASE SHIFT
TEST SET-UP

V-7

below 100 Hz due to AC coupling. A 2 MHz square wave passed through both filters comes out more like a sine wave than a square wave. This distortion of square waves above 2 MHz is expected due to the sharp rolloff above 3 MHz.

The use of these filters provides an improvement of about 10 dB. The RF level into the receiver can be reduced by about 10 dB below the minimum required without the filters (see Figure V-8). As the RF level is gradually reduced without the filters, the picture gradually becomes snowy and eventually the picture is covered by snow. When the RF level is reduced with the filters the picture remains clear of snow until the receiver threshold is reached. When the threshold is reached clicks start to overrun the picture and sync. The effect of the clicks is reduced by the diode but cannot be eliminated.



Preemphasis - Deemphasis
Evaluation Test Set-up

## VI. Conclusion

With good signal strength to the receiver there is no noticeable reduction in picture quality associated with the use of the preemphasis system previously described. The bandwidth reduction of the television system by the preemphasis and deemphasis filters is only noticeable when looking at very fine details of a scene and should be no handicap in either the rocket or balloon television applications.

By adding the preemphasis and deemphasis filters to the television transmission system the RF signal level into the receiver can be reduced by as much as 10 dB below the level that was required without the filters and still get a useable picture. Reducing the signal strength to the receiver by 10 dB is equivalent to moving the source three times as far from the receiver. This 10 dB reduction in required signal strength could allow for a 10 dB reduction in transmitted power. In any case, whether one increases distance, decreases transmitter power, or combines these specification changes to the television transmission system, the preemphasis system represents a substantial improvement over the system that uses the video as it comes from the camera to modulate the transmitter.

There is very little more that can be gained by preemphasis than the circuits described here provide when used with the receiver and transmitter used for these tests. The transmission system can operate down to the receiver's threshold with good picture quality. Reaching the threshold results in click noise. The effect of the click noise can be subdued by limiting the maximum signal amplitude with diodes. This only reduces their effect; it cannot eliminate the click. Filtering will only smear out the clicks it will not simply attenuate them. An explanation for this can be found in the book Principles of Communication Systems by H. Taub and D. L. Schilling. If any further improvement is to be made, a lower receiver threshold must be provided. There is work being done in that regard, such as phase lock loop detection instead of discriminators, lower noise amplifiers, and FM feedback. When a better receiver becomes available for this application, a review of the preemphasis should be done.

# BIBLIOGRAPHY

Telemetry Group, Inter-range Instrumentation Group, Telemetry Standards, Secretariat Range Commanders Council, White Sands Missile Range, New Mexico, Document 106-73, 1975.

Cohu, Television Camera Manual 4500 Series, Technical Manual 6X-595, Cohu Electronics, San Diego, California, August 1975.

H. Taub and D. L. Schilling, Principles of Communications Systems, McGraw-Hill, 1971.

A. B. Carlson, Communication Systems: An Introduction to Signals and Noise in Electrical Communication, McGraw-Hill, 1968.

J. S. Rochefort, Course Notes for 03.873 Communication Systems 1975-1976.

RCA Electro-Optics Handbook, Technical Series EOH-11, RCA Corporation, August 1974.

RCA, RCA Integrated Circuits, RCA Corporation, April 1976.

## REFERENCED FOOTNOTES

[1] H. Taub and D. L. Schilling, Principles of Communications Systems, McGraw-Hill, 1971.

[2] J. S. Rochefort, Course Notes for 03.873 Communication Systems, 1975 - 1976.

# RELATED CONTRACTS AND PUBLICATIONS

| | |
|---|---|
| AF19(604)-3506 | 1 April 1958 through 30 June 1963 |
| AF19(628)-2433 | 1 April 1963 through 30 September 1966 |
| AF19(628)-5140 | 1 April 1965 through 30 September 1968 |
| F19628-68-C-0197 | 1 April 1968 through 30 September 1971 |
| F19628-71-C-0030 | 1 April 1971 through 31 March 1974 |
| F19628-73-C-0148 | 9 January 1973 through 30 April 1976 |
| F19628-76-C-0111 | 12 January 1976 through present |

R. H. Marks, "Evaluation Studies of Telemetry System Components," Scientific Report No. 1, Contract No. F19628-76-C-0111, 11 January 1977.

R. H. Marks, "Evaluation Studies of Telemetry Systems Components," Scientific Report No. 2, Contract No. F19628-76-C-0111, 11 May 1978.

# PERSONNEL

A list of the engineers, technicians and student assistants who contributed to the work reported is given below:

J. Spencer Rochefort, Professor of Electrical Engineering, Department Chairman, Principal Investigator.

Lawrence J. O'Connor, Senior Research Associate, Engineer.

Norman C. Poirier, Research Associate, Engineer.

Willard F. Thorn, Research Associate, Engineer.