IN-SERVICE NOISE MEASUREMENTS ON A CATV SYSTEM

By

Charles W. Rhodes
Manager
Television Products Development

TEKTRONIX, INC.
Beaverton, Oregon

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Measurement of the signal-to-noise ratio in communications systems is of fundamental importance - both in evaluating performance and in planning preventative maintenance.

In television systems, the signal-to-noise ratio is measured in terms of the peak amplitude of the picture signal and the RMS noise amplitude. The picture signal amplitude with which we are concerned modulates the picture tube. That is, it is the blanking level-to-peak white level not the sync tip-to-peak white, i. e. $\sim$700 mV. Signal level is easily measured with a television waveform monitor.

Noise cannot be measured in terms of peak amplitude. This is because of the statistical nature of noise. That is, noise (being random) has peak amplitudes which vary with time in a random fashion. Theoretically, if one waits long enough, an infinitely large noise pulse will come along. Noise pulses could be several volts in amplitude, but these occur so seldom that they can be neglected.

Experience has shown that the subjective appearance of noise is related to the noise power level. It has long been the practice to measure noise levels in terms of average noise power, thus avoiding the occasional high noise peaks. Noise power may be expressed in RMS volts. Thus, the measurement of noise is simply the problem of measuring power or RMS voltages.

However, this isn't as easy as it may at first appear. In television, we are concerned with noise power extending to 4 MHz. As the noise voltage is a complex waveform, not a sinewave, we cannot measure peak or average voltage and know the RMS value. In communications engineering, the usual approach to measuring RMS voltage, or noise power, is to measure the heating effect produced by the unknown power dissipated in a known load. This can be carried out in the laboratory to very great precision. However, the circuit must be taken out of service for the test.

When one considers the power levels to be measured (a 40 dB S/N ratio = 6.6 mV in 75 Ω = 0.44 microwatts), it is at once apparent that the equipment must of necessity be delicate and perhaps not well-suited for rugged field use. The skill levels required are not generally available outside of laboratories. In short, measurement of RMS noise levels in the field is not practical. Furthermore, even if practical, it requires that the system is taken out-of-service for the test. In the case of CATV systems, this is not at all convenient.

The ideal test scheme permits accurate in-service testing and uses equipment suitable for field usage. In-service testing requires that the noise may be measured in the presence of the video signal, whose power level varies unpredictably. One scheme is to observe the video signal and noise on an oscilloscope. By observing the noise only on a line or two of the vertical blanking level, video information is eliminated quite easily.

On the other hand, the oscilloscope is fundamentally a peak reading instrument - it does not indicate RMS at all. For true "white noise" there is, however, a conversion factor which some observers have developed to relate apparent noise on an oscilloscope to its true RMS value. This factor has been reported as 14 to 18 dB, the higher value being favored.[1-2]

However, aside from the question of the correction factor, a much more serious source of error lies with the variations in observed noise between different observers, changes in the trace intensity on the waveform monitor, and the apparent noise level changes which occur with the changes in the brightness of the room in which the measurement is made. Variations of 6 dB have been reported due to this latter cause alone.[2]

Clearly, where preventative maintenance is to be determined by signal-to-noise level measurements, much greater repeatability in test methods is needed. As CATV system performance may be a matter of litigation, such large margins in the test results is undesirable.

Tektronix, Inc., has developed a new method which eliminates both sources of error. This method is suitable for field usage and in-service testing. It is based upon the comparison of the noise to be measured with a second, known noise source. Here, the observer needs only to make a comparison, not a

[1]L. E. Weaver, "The Measurement of Random Noise in the Presence of a Television Signal," BBC Engineering Monographs (No. 24), March, 1959.

[2]L. E. Weaver, "Television Video Transmission Measurements."

judgment. His comparison will, in our experience, be repeatable within ±2 dB in every case; and will be within 1 dB in most cases. Different observers will obtain the same results, which are independent of the waveform monitor's intensity or ambient illumination. The waveforms obtained are shown in Figures 1a and 1b, page 3. These figures illustrate the basic concept. Figures 2a and 2b show the results of small variations in noise levels.

In any comparison technique, it must be first determined that like is being compared with like. That is, two noise sources should both have similar distribution of energy over the same frequency spectrum.

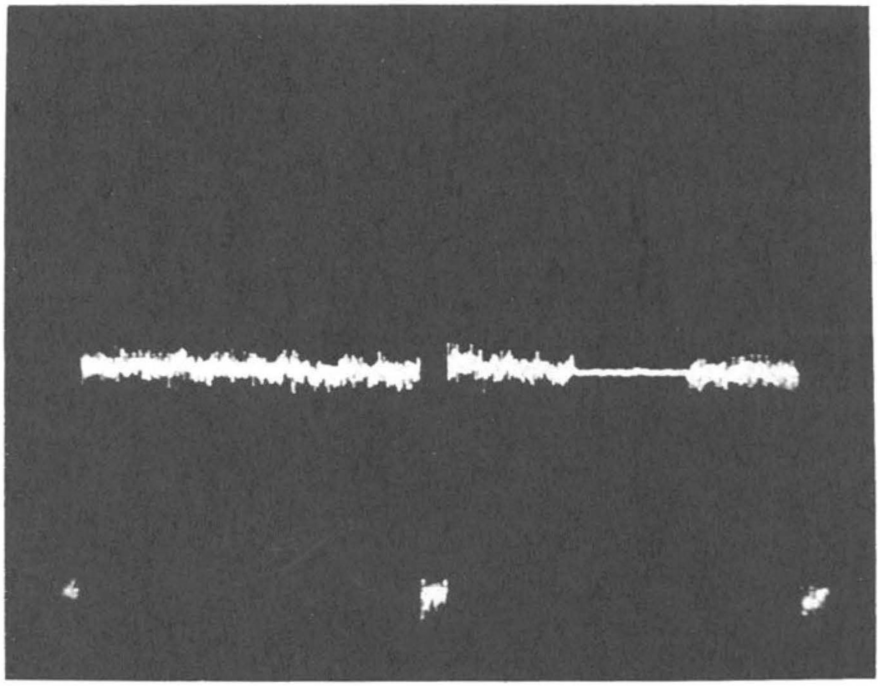
Fortunately, the random noise encountered in CATV systems (which accounts for snow in the picture) has approximately equal energy at all frequencies within the video band. This is called "white noise," and is readily generated by electronic means. Such a noise generator may be calibrated in the laboratory using a true RMS power measuring instrument. The long-term variations in RMS noise power will be small, hence frequent recalibration is not considered necessary. True RMS calibration in the factory avoids the question of the appropriate conversion factor mentioned above, with its spread of 4 dB. The only precaution in this measurement technique is that the noise being measured and the noise it is being compared with have the same frequency spectrum, or nearly so.

In many television systems, the bandpass extends considerably above 4 MHz. This is true of cameras and microwave radio relay links and may also be true of some demodulators. As noise above 4 MHz does not in general degrade the picture, it is desirable to exclude it from any measurements. White noise generators are inherently wideband. Their output includes significant energy above 4 MHz. Modern waveform monitors have only gradual roll-off in frequency above 4 MHz.

A low-pass filter, flat to 4 MHz, then exhibiting very rapid attenuation above 4 MHz, is required. Such filters are readily manufactured for 75 Ω circuits. Their design is given in the CCIR Volume 5 recommendation 451-1. These 75 Ω low-pass filters are essential to noise measurements. The filter must be placed in the measurement setup so that both noise signals are affected by it. A typical measurement setup is shown in Figure 3. The signal source shown is a CATV demodulator. The action of the Tektronix Type 147 is shown functionally in Figure 4.

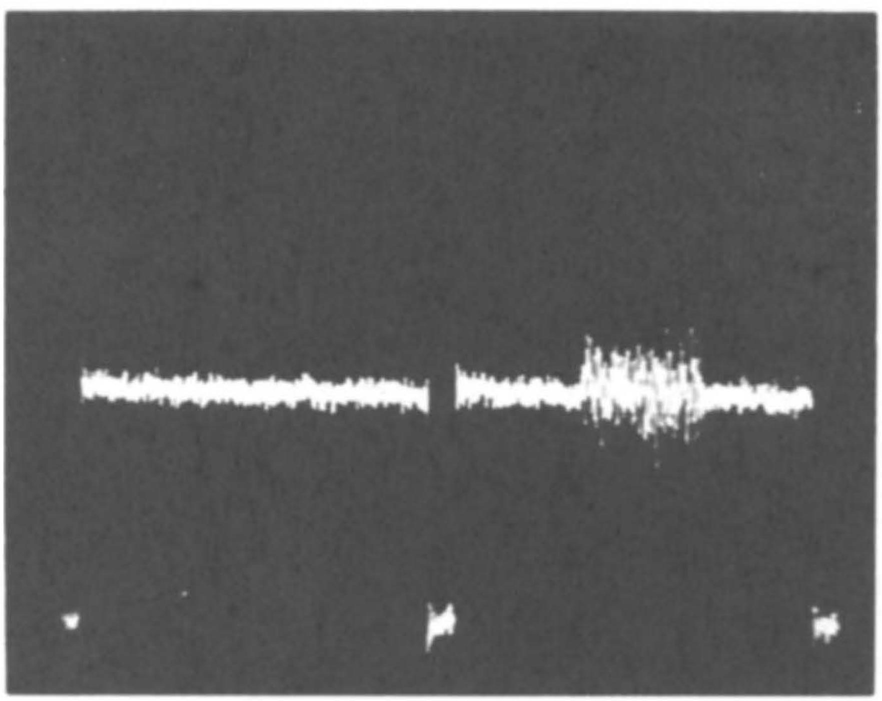
NOISE INSERTION MODE

Noise is deleted from center of chosen test line in vertical blanking interval. Noise from the noise generator in the Tektronix Type 147 is inserted in center of the chosen test line.



Inserted noise is much less than noise on signal

Figure 1a

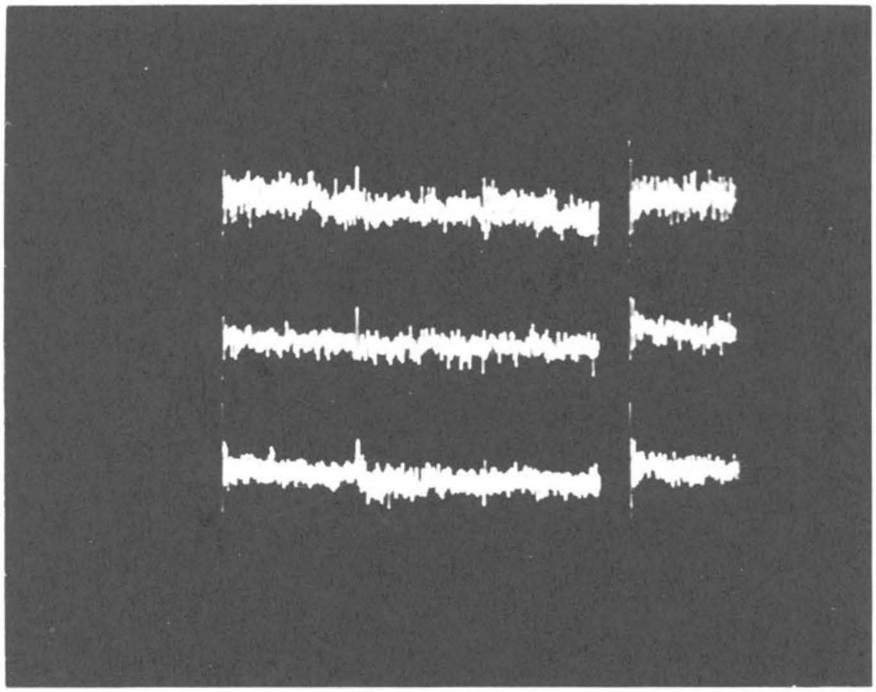


Inserted noise is much greater than noise on signal

Figure 1b

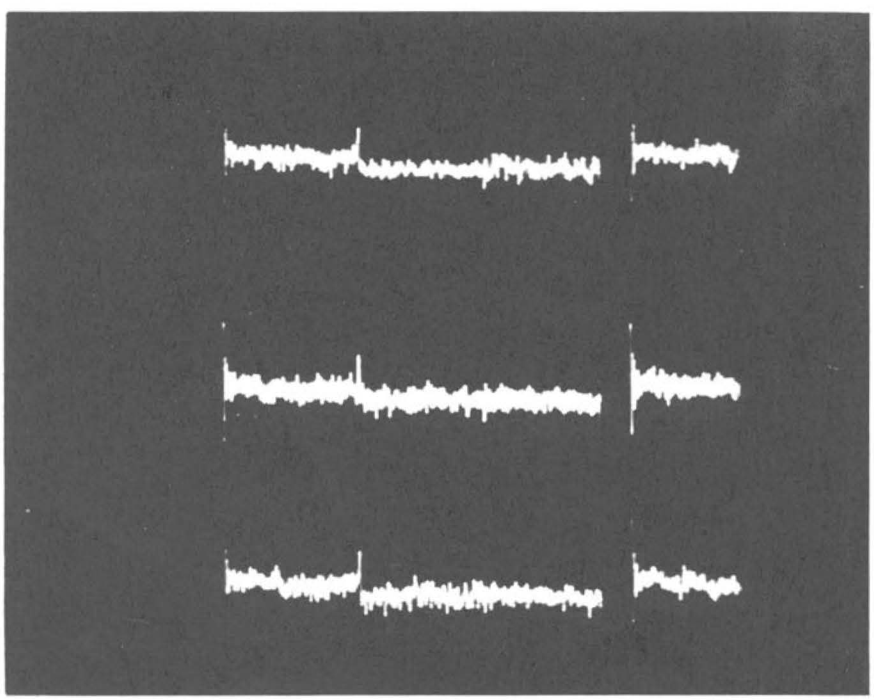
NOISE LEVEL DISCRIMINATION

Waveform Monitor Response - "Flat"
Noise Bandlimited - 4 MHz



±2 dB

Figure 2a



±3 dB

Figure 2b

IN-SERVICE NOISE MEASUREMENT

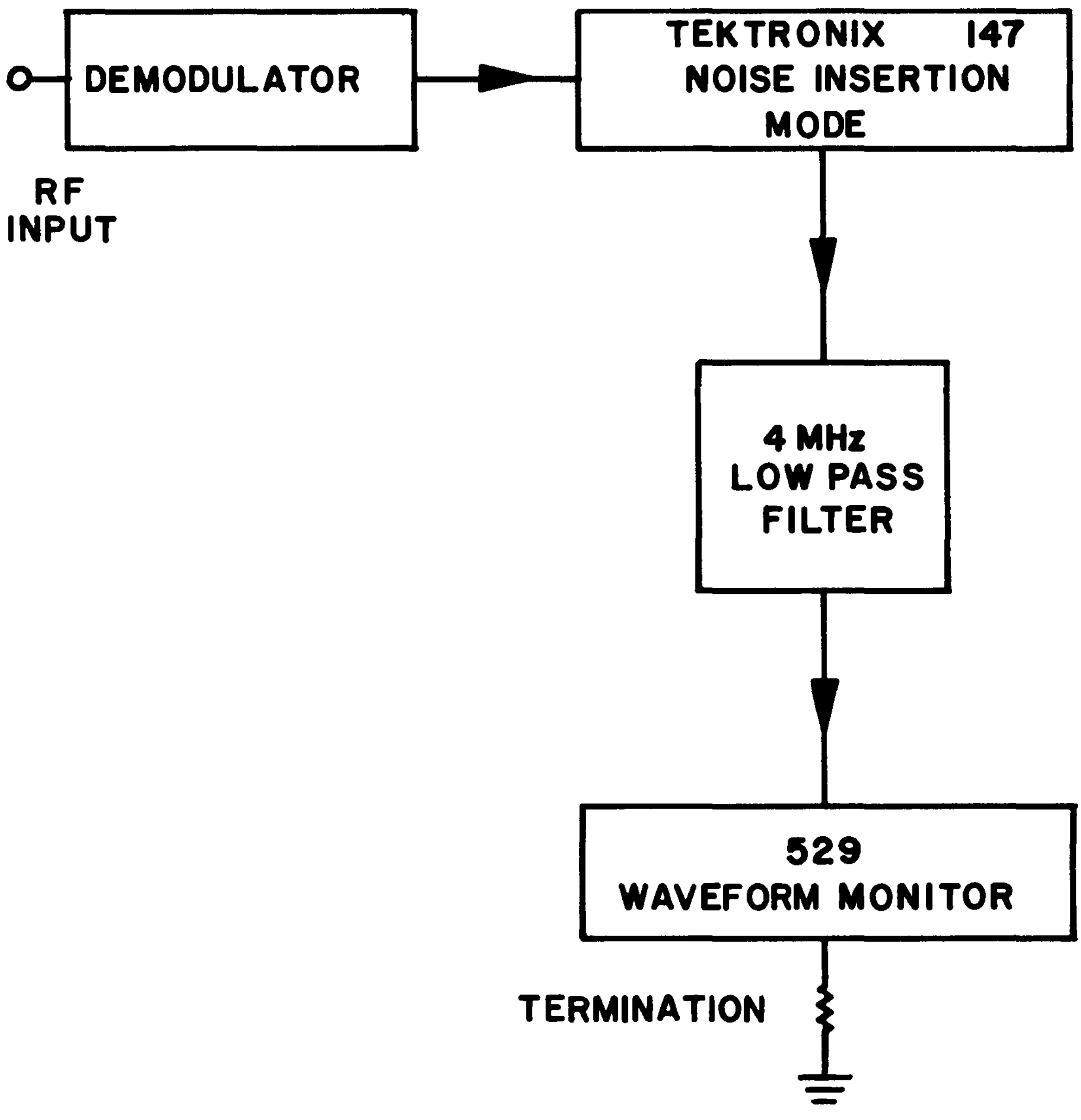
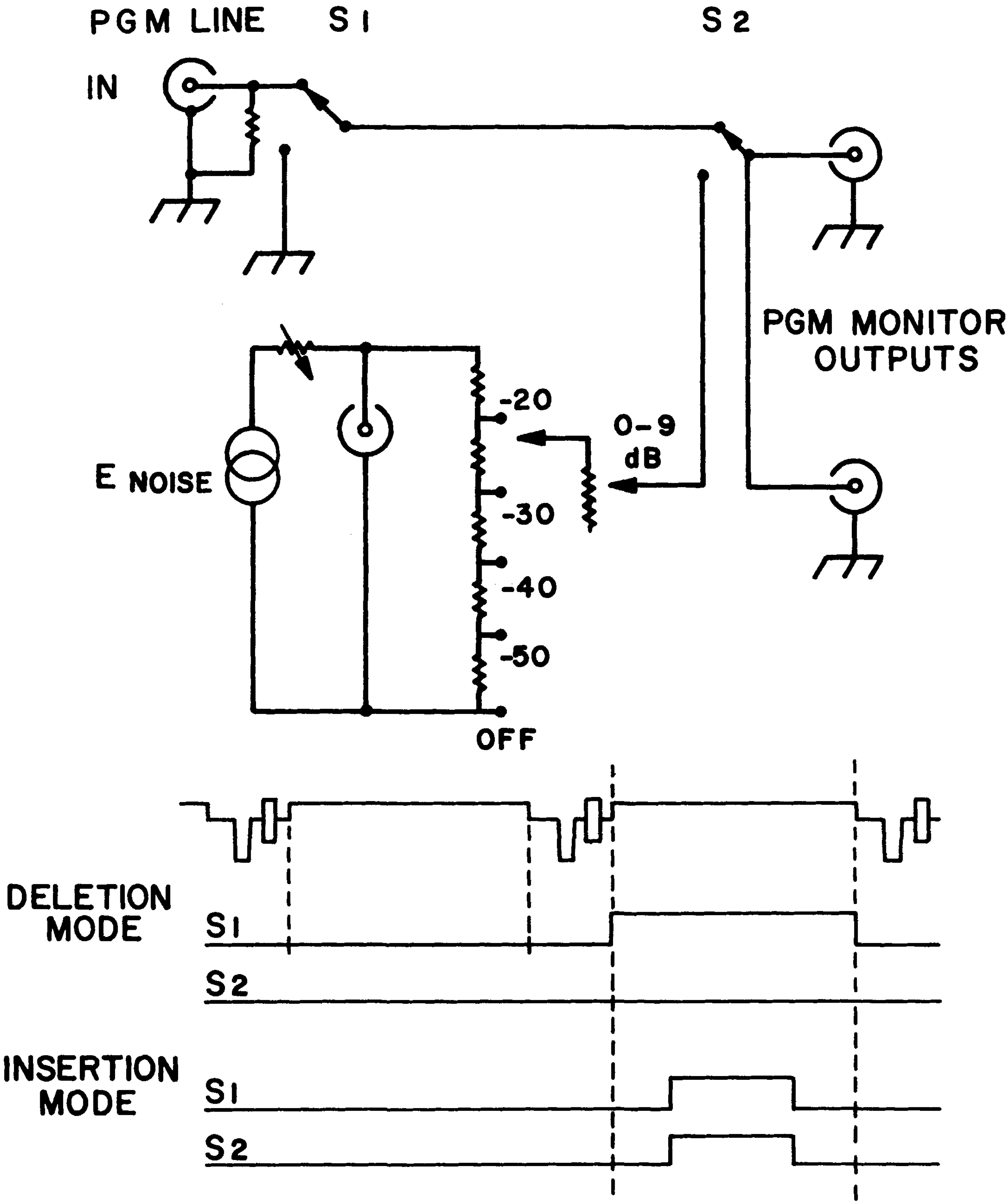


Figure 3



TEKTRONIX 147 NOISE MEASURING PLAN

Figure 4

Switches S_1 and S_2 are, of course, electronic switches. They operate during the chosen noise test line within the vertical blanking interval. S_1 is the deleter switch. When measuring noise, the instrument is said to be in the INSERTION MODE. Then, S_1 disconnects the incoming video signal from the input to S_2 during the middle half of the test line. At that time, switch S_2 substitutes the output of the built-in white noise source for the incoming video signal at the monitor outputs. One of these monitor outputs feeds the 4 MHz low-pass filter which removes all noise above 4 MHz from both incoming signal and locally generated noise. It is essential to terminate the filter at the waveform monitor. The effect of the 4 MHz filter is shown in Figure 5.

In the lower portion of Figure 5, the filter was connected incorrectly between the demodulator output and the Type 147 input. Here, the inserted noise observed on the waveform monitor is wideband, and the system noise (preceding and following the inserted noise) is bandlimited. The difference is much more apparent in viewing the monitor than is shown in the photograph.

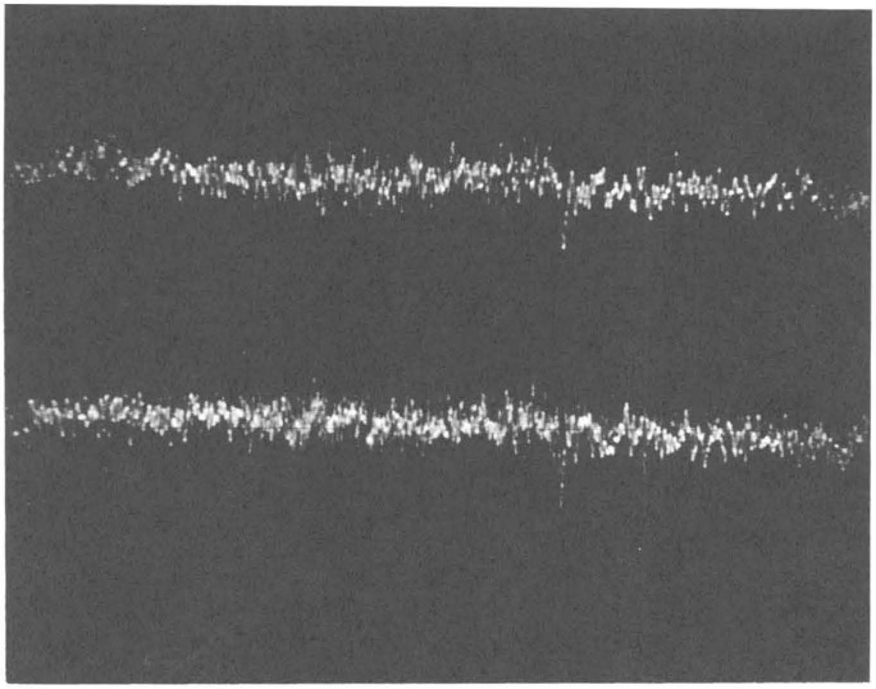
In the DELETION MODE, S_1 operates, disconnecting the incoming video during the entire active portion of the chosen test line. The action of S_1 and S_2 is so timed that no sync pulse or color burst is deleted. S_2 does not operate in the DELETION MODE. Video signals coming from the Type 147 in the DELETION MODE do not have any noise present during the active portion of the test line. This is shown in Figure 6.

The DELETION MODE is used where it is desired to measure the noise which is occurring within a CATV system. For example, at the head end site, where a microwave radio relay is fed baseband video from a demodulator, the Type 147 may delete all noise present at the output of the demodulator. In Figure 7, a 147, operating in the DELETION MODE, is shown connected to the microwave transmitter's video input.

At the output of the microwave link, a second 147 (see Figure 8), is operating in the INSERTION MODE. Noise is measured on the waveform monitor. Of course, the principle can be extended down the cable system to measure noise at the furthest subscribers' drop. This setup was shown in Figure 3.

Line 16 is well-suited for noise measurements. Under present FCC Rules, Line

EFFECT OF 4 MHz BANDLIMITING



Top

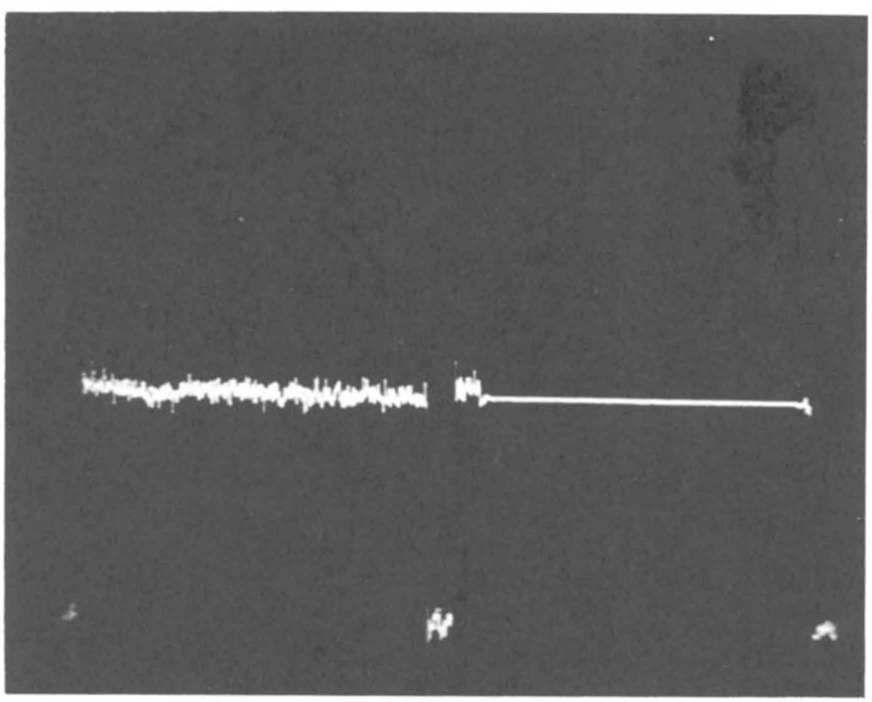
System and inserted noise both bandlimited to 4 MHz and matched at 40 dB.

Bottom

System noise bandlimited to 4 MHz, but inserted noise not bandlimited.

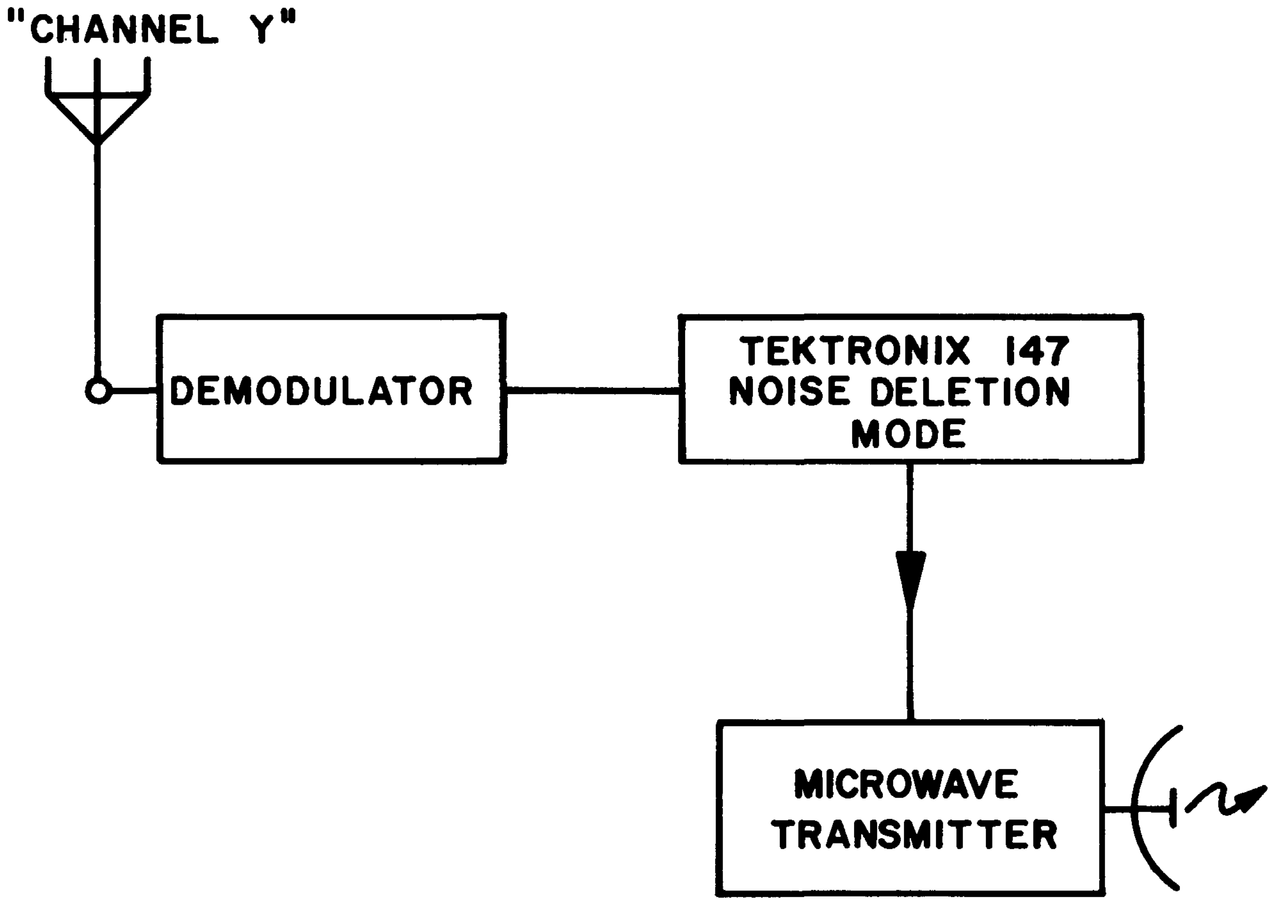
Figure 5

NOISE DELETION MODE



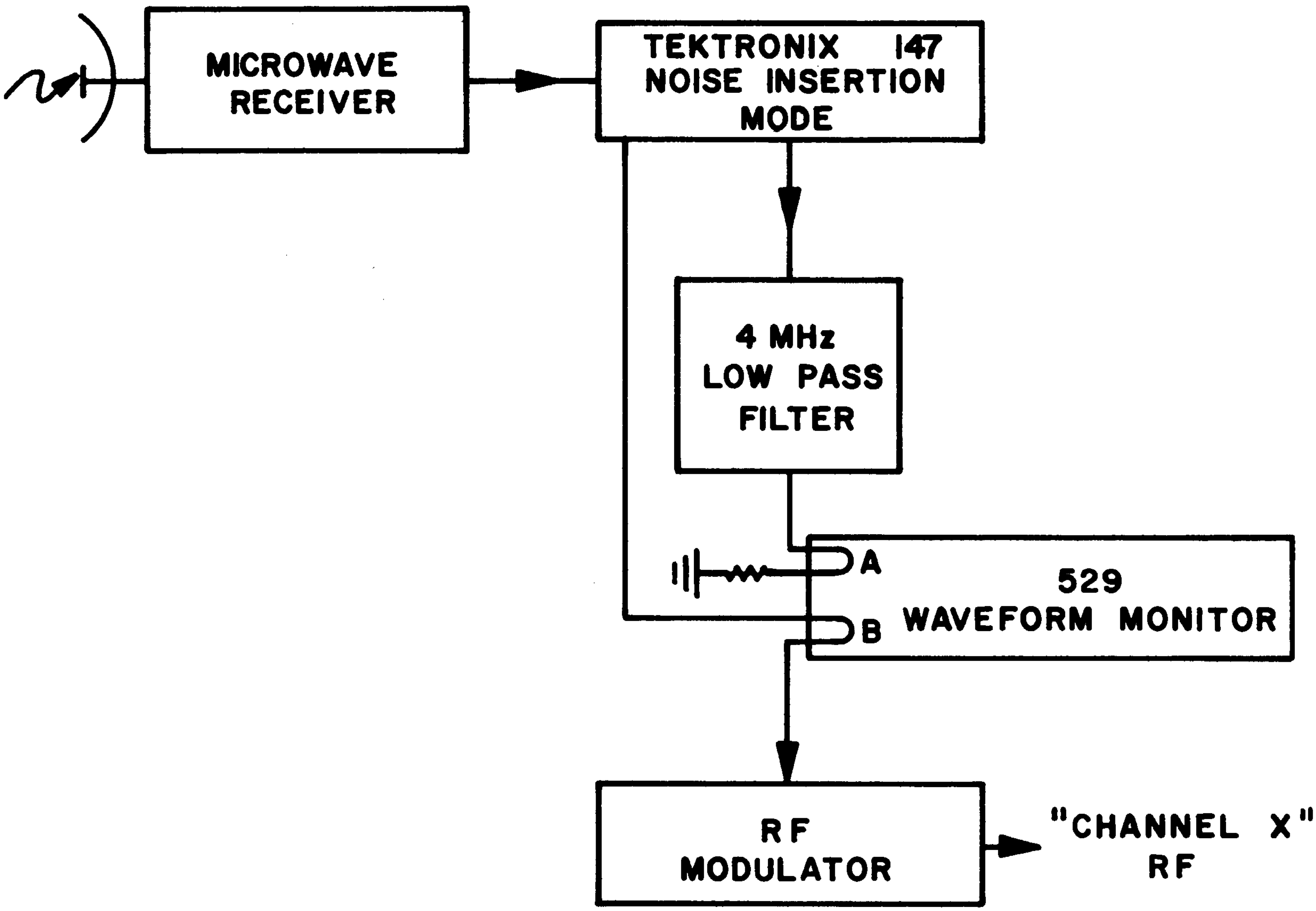
Display shows two successive lines in vertical blanking interval as shown on waveform monitor using the line selector.

Figure 6



IN-SERVICE MICROWAVE RELAY
NOISE MEASUREMENT
VIT SIGNALS MAY ALSO BE INSERTED

Figure 7



IN-SERVICE MICROWAVE RELAY
NOISE MEASUREMENT

MICROWAVE VIT SIGNALS
MAY BE MONITORED

Figure 8

16 cannot be modulated. Lines 17 - 20 may be used for test and other purposes in the near future. Line 21 may carry video at times. Noise levels on Line 21 may be higher than on Line 16 because Line 21 may carry noise from a video tape recorder. Hence, Line 16 is the optimum noise test line for CATV.

The fact that noise measured on Lines 16 and 21 may be different in measuring off-the-air signals is due to the broadcasters' practice of employing video processing amplifiers at the input of the transmitter. These processing amplifiers act as sync and blanking deleters, thereby removing noise distortion which the program sync and blanking have suffered. New sync, blanking and, sometimes, burst are reinserted by the broadcasters' processing amplifier. Noise on Line 16 will usually be deleted, leaving it a quiet line; while noise on Line 21 may not be deleted.

Noise is frequently measured through a noise weighting filter which is designed to attenuate high frequency noise components as the higher frequency noise components are less objectionable in the picture. If all sources of noise had the same power/frequency distribution, noise weighting would not be necessary. Noise in CATV systems is "white noise" and no weighting is necessary. Noise arising in microwave (FM) relay links is not white noise. Its noise spectrum is called triangular (noise rising 6 dB/octave from about 200 kHz).

If all the noise to be measured were "triangular," a filter could be included in the Type 147 noise generator to give triangular noise. However, in practice, the noise level in television signals is not all contributed by the FM portion of the system so a triangular noise spectrum is not suitable. One way to avoid the problem of "triangular" vs "white" noise is to measure the noise using both the FLAT and CHROMA bandpass characteristics of the waveform monitor. The 4 MHz low-pass filter is used in both cases. The two numbers give information about the frequency distribution of the noise being measured. This concept has yet to be developed and field tested. It is offered in the hope that CATV engineers may wish to pursue the matter.

Noise measurements may prove useful in planning preventative maintenance of the system. Routine noise level monitoring at well-chosen points within the system is not enough. Where careful records are kept of performance, the system's long term performance can be determined. Obviously, where noise levels are increasing with time, a condition is located which is going to require correction.

In summary, the noise level of standard 1.0 volt video signals may be accurately measured by deleting the noise on part of a vertical blanking line and inserting "white noise." By comparison, on a waveform monitor the level of inserted noise is adjusted to equal the noise being measured. The noise level is determined from the settings of the calibrated noise attenuator. Bandlimiting is required between the Tektronix Type 147 monitor output and the waveform monitor. The method is especially well-suited to the CATV industry.