The Lenkurt Demodulator

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Microwave for TV TRANSMISSION

A few years ago the transmission of television signals over microwave radio was limited almost entirely to the facilities used by the national broadcast networks. Since these facilities primarily connected major population centers, they were engineered and maintained by a relatively small number of experienced personnel. Now the situation has changed radically. Many small telephone companies are being called on to carry television for the broadcasting industry, educational television systems, and others. New applications are continually appearing for industrial television, and community antenna television is growing very rapidly.

The result is that many people suddenly find themselves in some part of the television business, bombarded with strange terminology, and sometimes even forced to make decisions about things they may not fully understand. Even those with sound technical backgrounds in communications often find themselves wondering about some of the "whys" of television transmission. This article is written in an attempt to answer some of the questions concerning the transmission of television over microwave radio.

A microwave system has been likened to a pipeline or a railroad. Each provides a hauling service, transporting a commodity from one point to another. But even though the basic idea is similar, the physical arrangements of these transportation systems are vastly different. Each is tailored to the characteristics of the commodity to be transported.

Even more specifically, different microwave systems have different characteristics, depending on the types of traffic they may be called upon to handle, just as a railroad uses one car for lumber and another for passengers. So it is that microwave systems which carry television signals differ from those which carry multiple voice channels. Often the same basic system can be used for either type of service, but the arrangement is different.

Video Signal Characteristics

A logical place to start a study of a transportation system is with an analysis of the traffic. In this case, this means the characteristics of a television signal. There are two parts to the signal, video and audio; and they are often transmitted independently. The video signal is more complex and it sets the transmission standards.

The television picture is produced by a varying voltage which represents the various shades of gray, from white at one extreme to black at the other. A higher voltage produces a whiter image, and a lower voltage a darker image. This voltage is divided into "sections" 63.5 microseconds long. Each section contains the information for one scanning line on the picture. The lines are separated by synchronizing pulses which cause the electron beam to retrace and start a new line. The last line at the bottom of the picture completes a "field," which represents half the picture. The trace then starts at the top again, interlacing the new lines between the lines of the previous field. This second field completes the "frame," forming an entire picture. In the NTSC (National Television Standards Committee) system, there are 30 such frames per second. Each frame consists of 525 scanning lines.

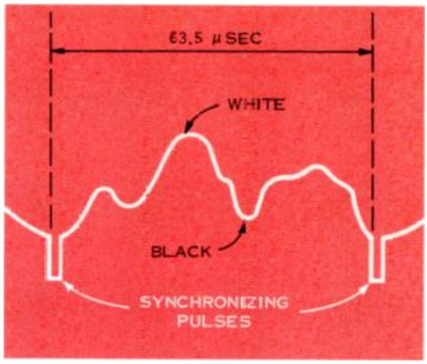

Figure 1. Voltage waveform for one scan line of a television signal. Higher voltage produces a whiter image.

A color signal contains the same basic intensity information as a black and white signal, in addition to the color information. The color information is carried by a color subcarrier — a continuous signal at 3.58 Mc. Different colors are indicated by shifting the phase of this subcarrier, while the saturation or richness of the color is indicated by varying the amplitude of the subcarrier. This is one of the most critical parts of the television signal. Distortion of the color subcarrier may result in unusual color combinations. For example, a normally attractive, blonde, rosy-cheeked actress appears grotesque with bright green hair and a fiery-red face. Viewers tend to blame the receiver manufacturer when this occurs. But often at least part of the signal distortion is in the transmission. (For a discussion of the tests which establish acceptable performance, see "Performance Testing of Television Channels," THE LENKURT DEMODULATOR, October and November 1963.)

Transmission Techniques

A basic microwave transmitter for television transmission (shown in Figure 2) is essentially the same one that would be used for message traffic. In either case, the "heart" of the transmitter is the klystron. The klystron is usually the only vacuum tube used in modern solid-state equipment. Its function is to take the amplitude-varying baseband input and translate it to a frequency-varying radio signal at a much higher frequency. The klystron is tuned to produce a nominal center frequency when no modulating signal is applied. When a modulating voltage is applied, it causes the klystron output to swing back and forth across the center frequency. The higher the voltage, the greater the frequency swing.

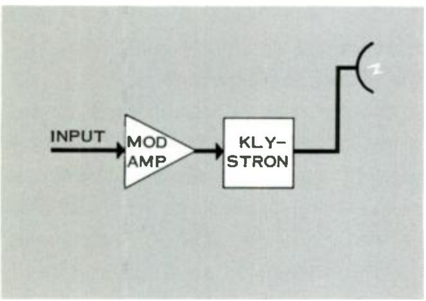

Figure 2. The most basic microwave transmitter consists of a klystron and a modulation amplifier.

A modulation amplifier is normally used ahead of the klystron to increase the amplitude of the input signal so that it can cause enough frequency deviation in the klystron. For example, in a typical system, a 0.36 volt peak-to-peak input to the modulation amplifier produces a 4-Mc deviation in the output of the klystron. This means that if the nominal center frequency is 6000 Mc, the deviation across the frequency band is from 5996 Mc to 6004 Mc.

The Video Receiver

The basic microwave receiver (shown in Figure 3) is only slightly more complex than the basic transmitter. From the receiving antenna the signal goes to a bandpass filter which selects the desired frequency band, rejecting all other frequencies. The signal then goes to a mixer where it is literally "mixed" with another frequency from the local oscillator. One of the results of this mixing or "heterodyning" process is a lower sideband at some intermediate frequency. This intermediate frequency is the difference between the frequencies of the incoming radio signal and the local oscillator signal. For example, if the incoming signal is at 6000 Mc and is mixed with a local oscillator frequency of 5930 Mc, the resulting intermediate frequency will be 70 Mc. This 70-Mc intermediate frequency ("IF") goes to a special low-noise preamplifier. (The other frequencies produced by the mixing process are filtered out.) The IF preamplifier is one of the most critical parts of the system, as far as noise is concerned, because at this point the signal is very weak and any noise added by the amplifier is of the same order of magnitude as the desired signal. Thereafter, noise and signal are amplified together. Thus, special care is taken to avoid introducing noise at the IF preamplifier.

The signal at the IF stage is still frequency modulated, even though it has been translated down from the 6000-Mc radio frequency. The function of the discriminator is to demodulate the signal and return it to its original baseband form. An ideal frequency-modulated wave has a constant amplitude. However, various types of interference and transmission irregularities may cause the signal amplitude to vary. The limiter removes any such unevenness and produces a constant-amplitude FM signal. The recovery of the baseband signal then occurs in the discriminator.

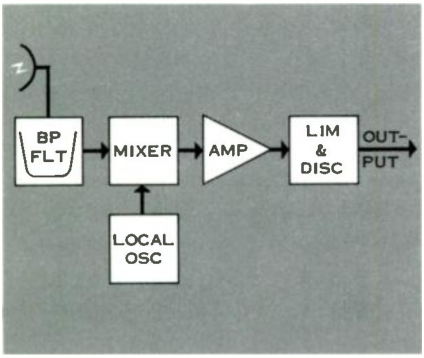

Figure 3. Basic microwave receiver first "heterodynes" the signal down to the 70-Mc intermediate frequency. The discriminator then demodulates the signal, recovering the original baseband frequencies.

Equipment Refinements

The basic equipment described thus far is essentially the same for both TV transmission and message traffic. While this basic system would transmit and receive signals, the quality of transmission would probably not be acceptable by most standards. Therefore, modern transmitters and receivers include a number of auxiliary items whose purpose is to refine the transmission quality. Figures 4 and 5 show simplified block diagrams of a transmitter and a receiver equipped with some of these auxiliary items.

In a message transmission system a technique called "emphasis" is used to overcome some of the effects of noise. This involves a "pre-emphasis" network in the transmitter and a corresponding "de-emphasis" network in the receiver. The effect of emphasis is to improve the signal-to-noise ratio at the more critical high frequencies.

A similar technique is used in television transmission (where it is often called "pre-distortion"). The technique is much the same for both message and video channels, but the reasons for using it are quite different. It provides a high-frequency noise advantage when used for message traffic. However, low-frequency noise interferes with a television signal much more than high-frequency noise. Therefore, emphasis offers little *noise* advantage to video transmission. Instead, emphasis is used to improve the quality of color transmission. (Standard practice is to engineer a video link for color transmission, even though initial plans may only call for it to handle black and white signals.) Intermodulation between the color subcarrier and the low-frequency components of the video signal is produced by the transmission variations in the system. The unwanted products of this intermodu-

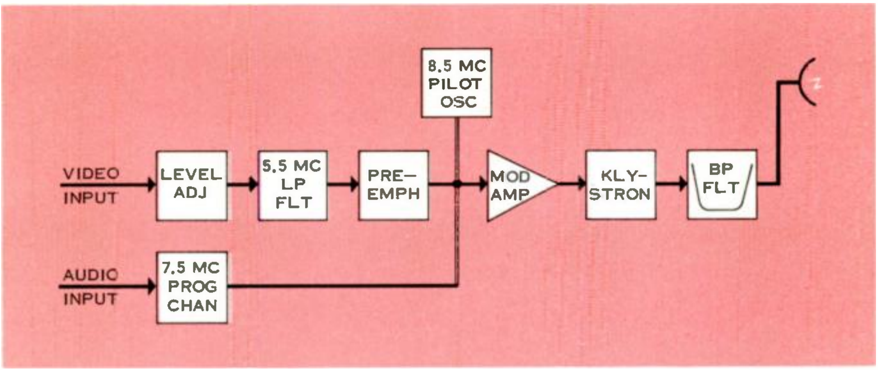

Figure 4. Performance of the basic transmitter shown in Figure 2 is improved by adding auxiliary items. The program channel carries the audio portion of a television signal or can be used for other services.

lation are of such a frequency that they interfere with the color information. Emphasis reduces the amplitude of the intermodulation products by reducing the low-frequency components of the signal. The result is better color performance.

Another refinement to the basic microwave system is the addition of a pilot-frequency oscillator to the transmitter and a pilot-frequency detector at the receiver. With the addition of these two items a single-frequency pilot tone is transmitted at all times, even when no signal is applied to the system. This permits a continuous check of both equipment and propagation path continuity, even under "no-signal" conditions.

Further refinement often consists of level adjustment facilities. The standard interface video signal has an amplitude of 1 volt peak-to-peak. Most transmitters are designed to accommodate this level. A signal at any other level must be adjusted. A lower-amplitude input signal goes through an amplifier, while a signal of higher level goes through an attenuation pad.

Level adjustment in the receiver normally takes the form of additional amplifiers. An intermediate-frequency amplifier often follows the IF preamplifier to provide a fairly high-level signal for the limiter and discriminator. A baseband amplifier placed after the de-emphasis network provides the proper output level for the baseband signal.

An important part of most microwave systems for video transmission is the "clamper" at the output of the receiver. Ideally the baseband frequency response of such systems would extend down to dc on the low-frequency side. However, it is not practical to extend the response below a few cycles per second. Therefore, no dc reference potential is included in the video signal. The *relative* amplitudes of the different

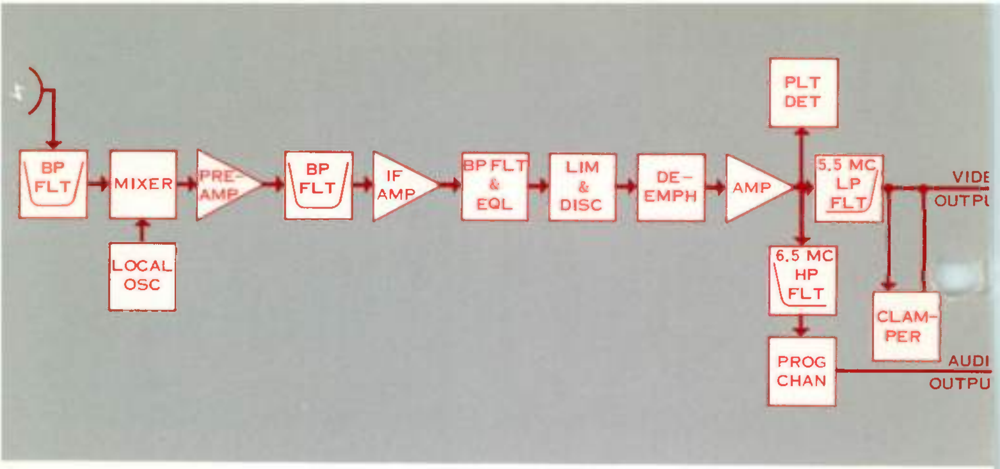

Figure 5. Receiver performance is also improved by adding auxiliary items. Particularly important in television transmission is the clamper, which provides a dc reference to maintain constant picture brightness.

frequency components in the video signal are accurate, but the whole signal may move up or down in relation to a constant dc reference. The result is a brightening or darkening of the whole TV picture as seen on the viewer's screen. The clamper is a device which provides the necessary dc reference potential. Thus, when a clamper is used, the brightness of the viewer's picture remains constant regardless of any variations in the transmission.

Bandpass filters inserted in the IF section before and after the IF amplifier limit the bandwidth of the IF signal, removing extraneous signal components outside the desired frequency band.

An equalizer in the IF stage also improves performance. Since different frequencies are delayed by different amounts as the signal passes through the system, the time relationship between the frequency components is altered, with the result that the demodulated video signal is distorted. The equalizer's function is to adjust the time relationship between the various frequency components in the IF band. The effect is better reproduction of the transmitted signal.

The Audio Signal

The audio signal may be carried on the same microwave system as the video signal by means of a program channel. The program channel is a separate FM transmitter which accepts an audio signal with a bandwidth of about 15 kc (enough bandwidth to give high-fidelity reproduction of both music and speech). In a typical arrangement such as that shown in Figures 4 and 5, the program channel carrier is centered on 7.5 Mc. This puts it well above the frequency range of the video signal, and it is simply bridged onto the transmission path near the input to the transmitter. In other words, the signal from the program channel is frequency-division multiplexed above the video signal. A common arrangement uses a lowpass filter (5.5 Mc in the illustration) ahead of the program channel insertion point. This lowpass filter "cleans" a slot for both the program channel and the pilot frequency, removing any unwanted interference from the frequencies above the video baseband.

At the receiver both the pilot frequency and the program channel are "picked off" just ahead of a similar lowpass filter. This lowpass filter removes the pilot and program frequencies from the video output. A highpass filter keeps the video signal out of the program channel.

For an "off-the-air" pickup such as that used for community antenna television systems, the program channel would not normally be used to carry the audio portion. In a standard broadcast signal the audio is transmitted 4.5 Mc above the video carrier. When such a signal is picked up by the receiving antenna, both the audio and the video portions can be transmitted through the normal transmission path without separating the audio signal. In such a case, a program channel may be used for other purposes, such as transmitting the signal from an FM broadcast station. In fact, two or three program channels with carriers at different frequencies may be used to transmit FM broadcast signals.

Conclusion

A typical microwave system for television transmission is capable of handling 960 voice channels in place of the single video channel. In both cases, the baseband is about four megacycles wide, and the power-handling requirements are approximately the same. Both arrangements use the same basic system. The difference is in the baseband treatment and the auxiliary items.

Such things as the emphasis networks and the various filters, used in both types of systems, are similar versions of essentially the same item. On the other hand, the clamper used for a video system has no application in a message system because no dc reference is required for message traffic. However, one auxiliary item developed for television transmission can be very useful in a message system. This is the program channel, which can also be used for wide-band data service.

Individual systems differ, of course. The attempt here has been to explain how a basic system operates, then to describe a few of the auxiliary items that tailor the system to carry a specific type of traffic. Microwave systems designed for television transmission are basically the same as those designed for message transmission. Their general purpose is even the same — to provide satisfactory service to the user, without distracting noises in one case and without brilliantly colored "snow" in the other case.

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