The Lenkurt Demodulator

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The Importance of Controlling Levels

Modern communications systems are remarkable for their efficiency and reliability despite ever-growing complexity. This is a result of careful engineering and excellent planning. An example is Direct Distance Dialing, which is possible only by strict observance of rigid standards for transmission performance. This article discusses one of the most important factors in achieving this performance — the careful control of all voice-frequency and high-frequency levels.

As the name implies, voice frequencies are the frequencies of speech, as spoken and heard. The so-called "high-frequencies" are frequencies above the voice-frequency range to which speech-frequency telephone channels are changed by carrier equipment for transmission. Although these high frequencies might more properly be called low radio frequencies, they are not usually so termed lest they be confused with the very much higher VHF and microwave frequencies commonly used for transmission.

In normal frequency-division carrier practice, many voice-frequency telephone channels, each occupying the approximate range 200 to 3000 cps, are translated to a high-frequency band. Although each channel still occupies the same bandwidth as it did at voice frequencies, it now occupies its own unique portion of the high-frequency band. The entire collection of high-frequency telephone channels may then be transmitted as a single composite signal by metallic circuits, or used to modulate a radio frequency carrier. In this *baseband* signal, each channel contributes to the total signal power. If any channel is set to a level other than specified for it, total baseband power will be shifted a small amount, depending on how many other channels are included in the baseband. If many channels are improperly set, total power may be seriously shifted from the optimum range, causing an increase in noise or intermodulation.

How Improper Levels Affect Quality

Noise is the common enemy of all types of communication. Without noise, communication would be no problem. Amplification would be required only to restore the signal to a comfortable listening level.

All communication methods constantly fight a battle against noise or interference. Although a signal becomes weaker as it is transported from one place to another, noise is everywhere, ready to drown the signal. Regardless of the communication method, amplifiers or repeaters are required to keep the signal stronger than the interfering noise.

Noise represents a threshold. If the signal sinks below this threshold, it can no longer be distinguished. When a signal is transmitted for long distances, attenuation progressively lowers its value until it approaches the level of the interfering noise. Thus, the more a signal is amplified before it is transmitted, the longer the distance it can be transmitted before interference becomes too great. For this reason, signals are transmitted at the highest level permitted by other considerations.

There are several things wrong with transmitting a signal at too high a level. All amplifiers are inherently non-linear. Negative feedback provides great assistance in overcoming non-linearity, but it can't eliminate it entirely. When an amplifier is operated beyond its power handling capability, intermodulation or non-linear distortion rises tremendously. In such a case, the resulting distortion may be worse than the noise which the increased power was supposed to overcome.

Amplifiers of greater capacity, or amplifiers which use large amounts of negative feedback cost much more than smaller amplifiers. In a carrier system, distortion increases noise, not only on the overloaded channel, but on all other channels in the system. Reducing signal level tends to increase noise by lowering the signal relative to background noise.

Economical Design

It may be argued that perhaps equipment manufacturers should use larger, more powerful amplifiers to remove some of the stringency from the performance requirements. The answer lies in economics. In every area, there are literally thousands, even millions of telephones which might have to be connected to any other telephone. In large urban areas, many of these are concentrated in large exchanges. When equipment is concentrated so much, the over-all operating cost may increase radically for even a small increase in operating power.

First there is the matter of power. A relatively minor increase in output power may require several times as much input power due to inefficiencies

Figure 1. Careful control of all transmission levels helps avoid degraded performance or needlessly expensive equipment and installations. This becomes increasingly important as equipment density grows.

in power supplies and amplifiers. The raw power may not cost much, however, the power supplies necessary to convert it to the form required could be very costly. Next, physical space would be increased. Size of the equipment increases and the amount of the heat to be dissipated grows tremendously. Not only must buildings which house equipment be considerably larger, but the cost of supporting equipment such as power supplies, ventilators and batteries increases greatly. An increase in power is indeed costly.

In the case of radio, similar limits may apply. The relative level of each channel determines the frequency deviation of an FM carrier. If levels are too low, frequency deviation is restricted, thus reducing the FM noise advantage.

Increasing the deviation increases intermodulation distortion due to unavoidable non-linearities in the transmitter, receiver IF amplifier and discriminator. In carefully designed radio systems, the narrowest bandwidth suitable to the application is used in order to reduce noise, since residual or threshold noise is directly proportional to bandwidth. Thus, in an FM microwave system, best performance will be obtained by a careful balance between bandwidth, modulation index and frequency deviation. Figure 2 illustrates how noise increases in a typical heavily loaded radio system if frequency deviation is increased or reduced from the specified value.

Normally, telephone traffic will affect frequency deviation. Increased number of channels in use and loud talkers will increase frequency deviation. As the number of channels increases, the level variations that may be encountered reduce, as shown in Figure 3. Individual talkers vary in loudness from instant to instant and from channel to channel. Variations tend to average out with time. For fairly large systems, signal loading is very predictable. Although individual variations among telephone users tend to average out, and are taken into account in system design, optimum performance of the system still depends on coming as close as possible to the design value for the various components that make it up. It is very similar, in principle, to walking on top of a very narrow fence — deviating in either direction may prove dangerous.

Even though the radio equipment may be carefully adjusted to achieve proper deviation, it still requires that individual channels be held at a specified level. Where very many channels are transmitted over a single radio or carrier path, each channel exerts its own effect on the performance of the entire system. Adjustment of equipment has a much more serious effect on performance than speech variations.

Crosstalk

Another important performance consideration that is strongly affected by signal level is crosstalk. In cable or wire

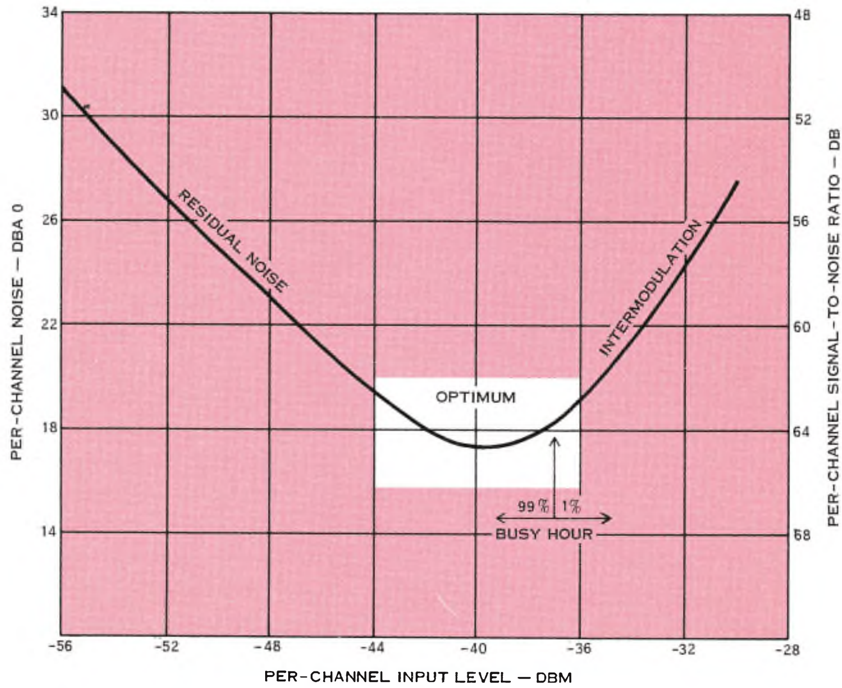


Figure 2. Typical noise performance of heavily loaded non-diversity microwave system. Only careful control of all channel and system levels permits consistent operation within optimum zone. Arrow indicates typical level exceeded only 1% of busiest hour (264 channels, no signaling tones).

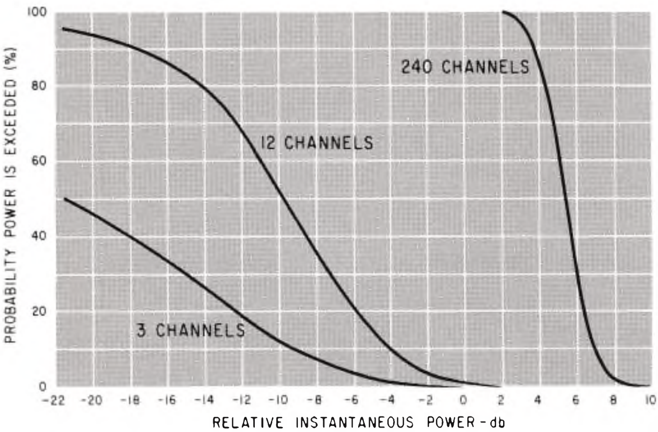


Figure 3. Baseband power distribution expected from different numbers of channels. Note that the 3-channel system has a 22-db maximum probable range, while 240-channel system has less than 8-db range.

circuits, signals on one pair are coupled into adjacent pairs by induction. This crosstalk is a function of length of path, strength of the interfering signal, coupling between pairs, and transmission frequency. Within a carrier system, crosstalk may occur because of the inability of channel filters to *completely* reject out-of-band signals.

In either a carrier system or non-carrier transmission system, crosstalk is increased when *differences* in level exist between channels. In the carrier system, this is increased by less-than-perfect filter characteristics. If a circuit level is too low, it must be amplified more, thus amplifying the low-level crosstalk along with the signal. If the level is set too high, the increased signal is more strongly coupled to adjacent cable or wire pairs. In the case of carrier, the increased signal is more able to partially overcome the rejection characteristics of adjacent channel filters.

Even where all circuits are at the same level, crosstalk may become objectionable if levels are too high. For instance, consider a path operated at a net loss of 3 db. That is, transmitting levels may be 0 dbm and incoming signals are at -3 dbm. If we assume a near-end crosstalk coupling loss of 70 db between the adjacent pairs, crosstalk will appear at -67 dbm, or about 15 dba of crosstalk noise (in the case of voice measurements). If constant residual noise in the system is about 17 dba, crosstalk will be masked and will not be objectionable.

Now, if it were desired to increase transmitting levels to +10 dbm in order to permit a longer transmission section, still keeping the -3 dbm receive level, near-end crosstalk noise will become 25 dba and be quite objectionable. If residual noise were higher, higher transmission levels might be acceptable because crosstalk would be masked. Equally important is the problem of coordinating levels between different systems operated on a frequency-staggered basis. Improper level coordina-

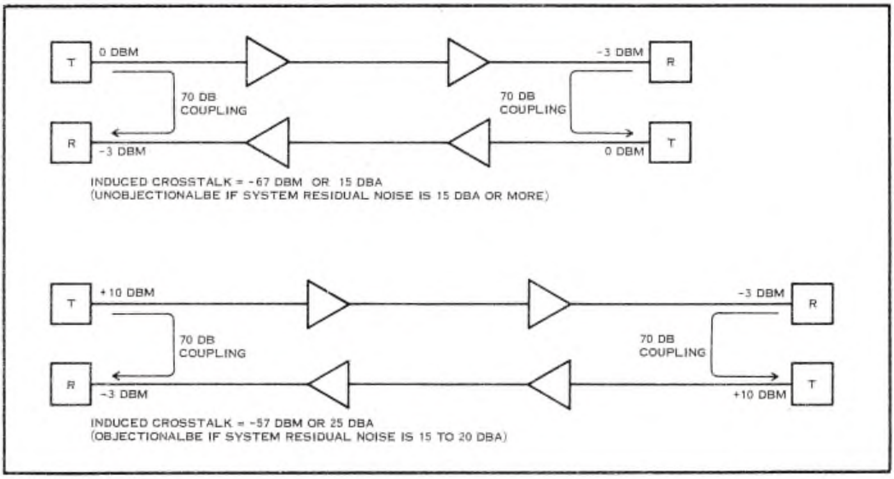


Figure 4. Near-end crosstalk occurs in systems operating on same frequencies or at voice frequency. Here, length of span, crosstalk coupling are controlling if levels are kept equal. Crosstalk increases if levels are not kept equal in the two systems.

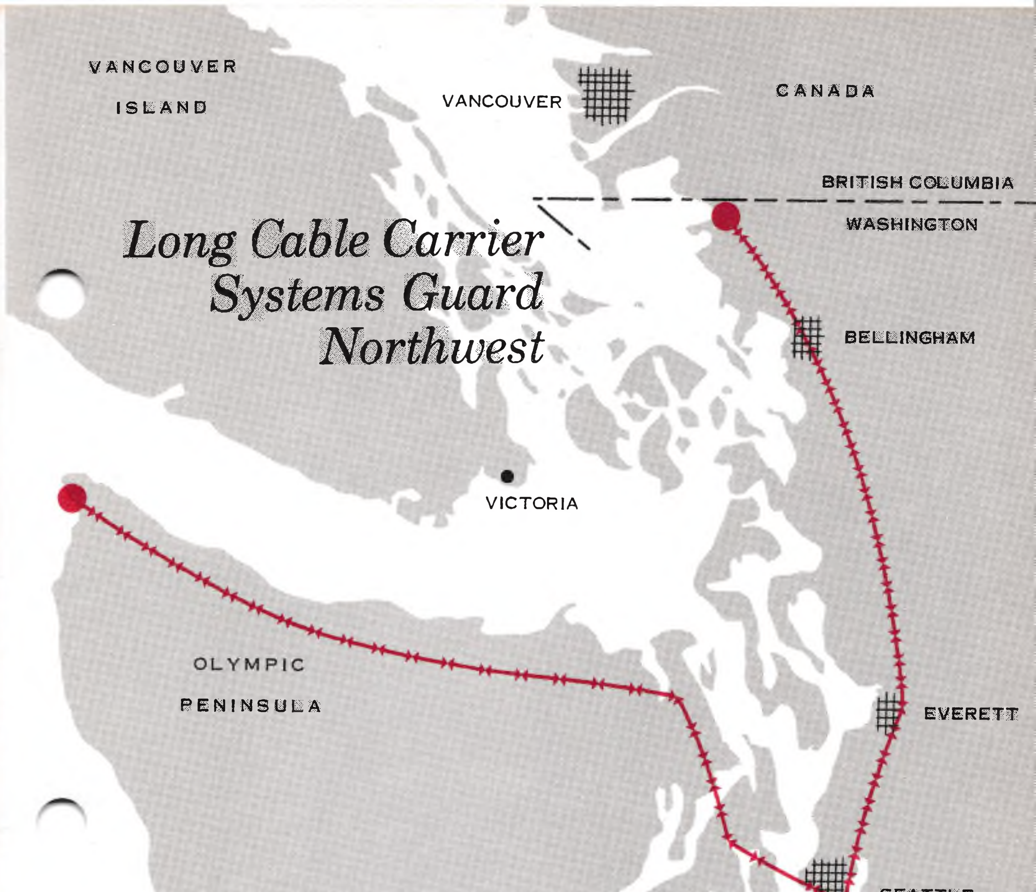
tion will introduce problems of far-end crosstalk.

Uniformity

Telephone service must be based on the assumption that any telephone might be connected to any other telephone, regardless of how great the distance between them. Furthermore, it is very desirable that the long call be comparable in quality to the local call. Since very long spans exist between some areas, it is very important that extraordinary pains be taken to operate the transmission equipment at its highest quality. For this reason, telephone systems attempt to bring all signals to certain standard levels, then adjust all equipment to maintain those levels as closely as possible. This permits either the local caller or the very distant caller to be connected to a given subscriber with very little difference between the loudness or the clarity of the two calls.

With the advent of direct distance dialing, this has become far more important than before. In order to provide the vast number of possible connections that might be demanded, direct dialing equipment automatically seeks the shortest path to the destination. However, if the short path is occupied, the equipment automatically finds another route. Thus a call between two points one hundred miles distant may travel over a transmission path of a hundred miles or a thousand miles! Since the longer path must be nearly as good as the short path, there should be no perceptible decrease in the signal level. Good practice had previously tolerated several db net loss in a path to reduce "singing" due to feedback. Under the direct dialing plan, net loss must be carefully restricted to very small values. This is difficult, if not impossible, unless levels are most carefully maintained at the design value. •

Long Cable Carrier Systems Guard Northwest



Two unusually long cable carrier systems are helping secure the Pacific Northwest against surprise attack. SAGE radar sites at two extreme northwest tips of the United States employ the carrier systems to supply continuous data to a control center south of Tacoma, Washington.

One system, connecting a radar near Neah Bay, with the control center, spans 218 miles and uses 40 repeaters. The other system employs 30 repeaters to cover 178 miles. Both systems consist of Lenkurt 45BN terminals and a combination of Western Electric N and Lenkurt 45BN repeaters.

On each of the systems, tests of the compandored voice circuits showed less than 8 dba noise. The non-compandored SAGE data channels were metered at 30 to 35 dba. When the systems were patched together to provide a path of 396 miles and 70 repeaters, voice circuits measured 12 dba, and data channels 33 to 38 dba.

The systems were installed by Lenkurt's E. F. & I. ("Engineer, Furnish, and Install") group and the Pacific Telephone and Telegraph Co. ●

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New Microwave Publications Available

Performance characteristics and specifications for the new Lenkurt 74A2 6,000 mc microwave system are described in the latest edition of *Form 74A-P4.*

Equipment Considerations and Ordering Procedures (Form 74A2-EE) is available to those who are planning to buy or install 74A2 microwave. This publication provides such details as rack dimension details, system layout recommendations, panel specifications, and ordering information.

Either publication may be obtained by writing Lenkurt or Lenkurt distributors on your company letterhead.

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