The Lenkurt Demodulator

VOL. 14, NO. 9 SEPTEMBER, 1965

Requirements of a HUMAN COMMUNICATIONS CHANNEL

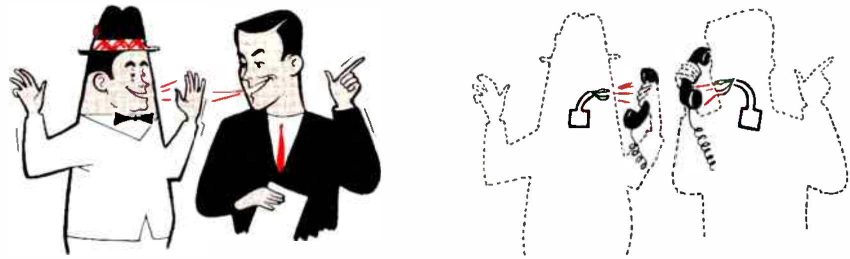
The objective of a human communications channel is to extend our conversational range by permitting direct oral communication between two or more people over some geographic distance. Because the success of such a system is largely subjective, it is necessary not only to make the service easy to use, but to enable the user at each end of the line to communicate in a manner approximating as nearly as possible face-to-face discussion.

With this human factor in mind, it is mandatory that the effects of various interfering factors be judged on a personal basis, not easily correlated in terms of electronic meter readings.

In this article, some of the factors which affect communication are discussed, and an attempt is made to relate these interfering effects to the requirements of a human communications channel.

About this article

This article is a revision of the February, 1959 issue of The Lenkurt Demodulator. It provides a basic introduction to some of the problems of human telephone communications, and is being reissued for the benefit of our new readers.



What we say in face-to-face conversation is emphasized by facial expressions and gestures. In a telephone conversation, we depend upon the voice alone.

A human communication channel (or system) must offer the user more than just a means of transferring information from one point to another. To enjoy wide acceptance as a means of communication, it must present to the user a good "second best" to direct face-to-face conversation, along with being convenient and sufficiently economical. Otherwise, the use of the facility will be restricted to messages which are urgent or absolutely necessary and cannot wait to be mailed or sent by telegraph.

In voice communication, we are not only interested in transmitting information—that is, sounds which can be interpreted as words—but we are also interested in conveying shades of meaning through variations in voice amplitude and inflection. In effect, we wish to capture the feeling of presence that is obtained in face-to-face conversation. The rather extensive use of the telephone as a means of communication indicates to a high degree that this objective has been achieved.

In direct conversation, communication is emphasized in a number of ways: variations in speech amplitude, inflection, facial expressions, and gestures. In a telephone conversation the visual communication is, of course, missing. The listener is forced to rely on word context and voice inflection for the transfer of meaning.

Admittedly, the intelligence alone can be transmitted through a communications system with a minimum of variation in amplitude and in the presence of high noise levels. But while it is possible to get oral information through such a system, this type of low quality communications circuit would certainly not find the wide acceptance that today's telephone industry enjoys.

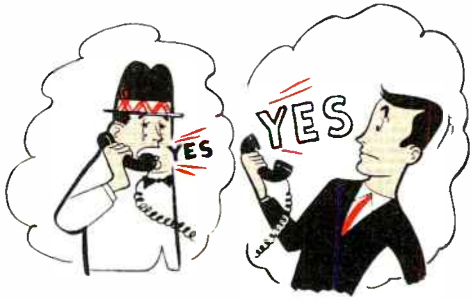
What then is necessary for a successful human communications channel? To answer this question, let's consider some of the things affecting the transmission of voice over a telephone.

In direct face-to-face conversation, the sound intensity (amplitude) and the frequency (pitch) of the sound waves may vary over wide limits. Sound intensities may range from the threshold of hearing (a whisper) to very high levels. However, in a normal conversation the variation is between 30 to 40 db for the usual talker.

But since many different people use the telephone channel, the relationship between the sound intensity ranges of different talkers must be considered. Studies have shown that the intensity range between the weakest syllable of a soft talker and the loudest syllable of a loud talker (that is, the two extremes) is in the order of 70 db. Under the same conversational conditions, the frequency range of sound can vary from about 50 cps to about 10 kc depending on the individual.

Within this scope, it would be difficult to construct a multichannel transmission system that could include all ranges of sound intensity and frequency without unduly restricting the ultimate channel capacity.

From the listener's point of view the quality of a voice channel can be measured in terms of two parameters, intelligibility and intensity, which together determine the quality of reception of sounds transmitted over the channel. Interestingly enough, intelligibility and intensity are virtually independent of each other over quite a broad frequency range. Most of the speech energy, and hence the intensity, is concentrated in the lower frequencies, while the high frequencies contribute most of the intelligibility. If *no* frequencies below 1000 cps were transmitted, articulation would be about 86 percent perfect, but the received energy content would be only about 17 percent of the original energy. On the other hand, if *only* the frequencies below 1000 cps were transmitted, articulation would be reduced



Restricting the conversational frequency range does not seriously impair telephone communication if normal levels are maintained. Where wide level variations are encountered, communication is seriously affected.

to about 42 percent, while 83 percent of the total energy would be transmitted. This means that any voice channel must include both the low frequencies and the high frequencies. In practice, some compromise is usually necessary because available bandwidth is limited.

For toll circuit engineering, the normal range in talker volume can be considered to be between 0 dbm0 and −31 dbm0, and the *standard* voice channel bandwidth is about 3 kc. Typically, the range of transmitted frequencies is from about 300 cps to about 3400 cps.

The discussion thus far has been concerned with restrictions which may be imposed on speech communication without incurring serious degradation, but has not included any effects which may be encountered during the transmission of speech. When transmission is considered, other factors are introduced that affect the intelligibility and identification of the message signal. These include: (1) level variation, (2) changes in frequency, (3) distortion caused by non-linearities in the circuit, and (4) interference such as noise and crosstalk.

Level Variations

In any transmission medium, the loss in signal strength is not constant, but varies from instant to instant. These variations are a result of changes in circuit loss caused by such things as varying temperature and other weather conditions. This means that unless some type of level control is used, the signal level at the receiver will also vary. The manner in which level control is accomplished depends on the transmission system.

It is desirable to keep level variations which may occur over a short time interval to about 0.25 db. Systems may be expected to drift more than this over a long period of time, but proper routine maintenance usually prevents any serious impairment in transmission quality.

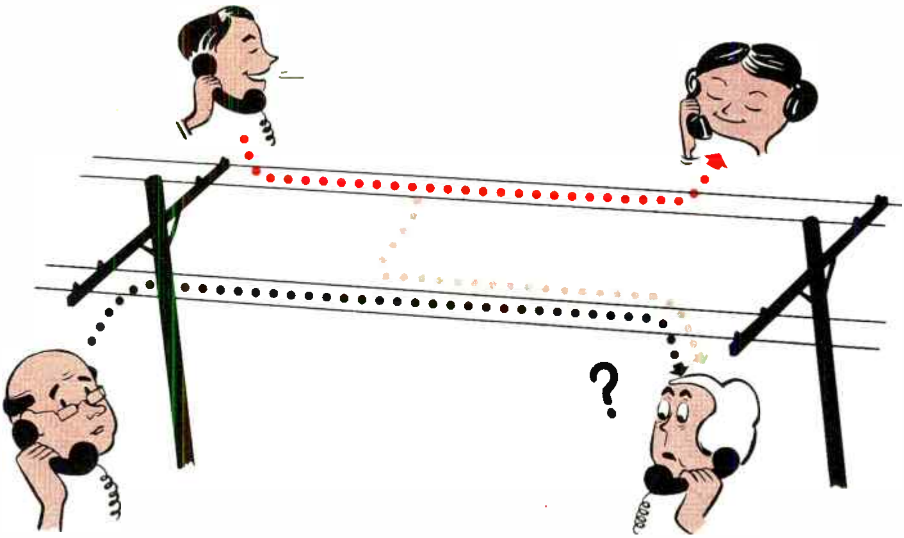
Frequency Stability

The use of oscillators in carrier telephone systems introduces the problem of frequency stability. This problem is commonly associated with the change in frequency of an oscillator over a period of time. But in a telephone circuit, the frequency stability that is of concern is the net change in frequency that occurs between the transmitting and receiving ends of the circuit. The amount of frequency change tolerable is directly related to the amount of change discernable to the ear. Analyses of hearing acuity tests suggest that a certain amount of frequency change, even over a short period of time, can be made without the ear detecting the shift as a different sound.

For voice circuits, a frequency stability (end-to-end) in the order of ±3 to ±5 cps provides a very good circuit. In actual operation, frequency shifts approaching ±15 cps may occur over a long time period without seriously impairing the quality of the voice circuit. However, the increased use of switched networks and dial-up connections for data transmission has necessitated much greater frequency control, measured usually in fractions of a cycle.

Crosstalk

Wherever telephone circuits follow adjacent paths, they are susceptible to crosstalk interference. Crosstalk may be produced by inductive or capacitive coupling in parallel lines, or at junctions, producing unwanted signals in the disturbed circuit. Generally, three



Excessive crosstalk interferes with the desired conversation, and reduces the privacy of this means of communication.

types of crosstalk are considered to exist: (1) intelligible crosstalk, which is in the same frequency range, but lower in amplitude than the original or desired signal, (2) unintelligible crosstalk, which is translated in frequency, or appears in the disturbed circuit in an inverted order, and (3) babble, which is crosstalk from a number of sources, either intelligible or unintelligible. With babble, the resulting sound has an apparent syllabic rate, but because of the number of interfering signals, does not appear as intelligible crosstalk. Babble is normally evident during the busy-hour periods and is similar to noise.

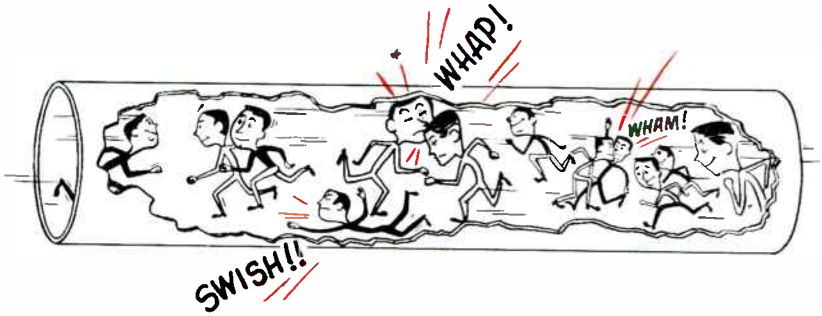
Crosstalk performance could be readily calculated if it were only necessary to measure coupling between two circuits. However, the magnitude of crosstalk in the disturbed cricuit will vary depending on talker volumes in the disturbing circuit, or circuits. Other factors which change the interfering effect of crosstalk are variations in subscriber loop losses, and the masking effect of circuit and room noise. In addition, the reactions of different people to a given crosstalk volume will vary widely. The total range of tolerance is about 30 db. These are among the factors considered in determining the crosstalk index, often used in establishing grades of performance for telephone circuits.

Noise

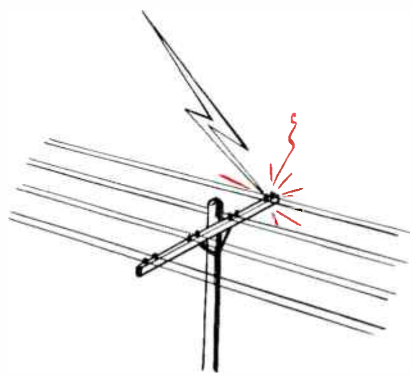
Another type of interference that is important in telephone communication is noise. Any type of interfering signal may be classified as noise. However, crosstalk, which is included in this broad definition, is generally treated as a separate problem.

Types of interference which may affect voice communication include: (1) thermal noise, (2) impulse noise, and (3) extraneous tones. The disturbing effect of these types of noise is generally less than that of crosstalk because in most instances no recognizable syllabic pattern is discernible. However, the disturbing effect on any one circuit will depend upon the type of noise and its frequency distribution. Many types of noise are man made, and can be eliminated, or at least reduced in magnitude.

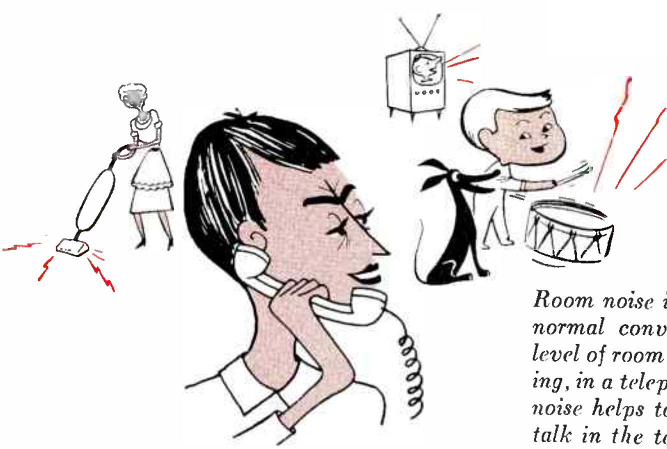
Since noise cannot be entirely eliminated, objectives for noise amplitude



One source of random noise is from thermal motion of the conduction electrons in a resistor.



Lightning is another source of noise which can affect telephonic communication.



Room noise is present even during a normal conversation. While a high level of room noise is always distracting, in a telephone conversation room noise helps to mask noise and crosstalk in the telephone circuit.

and frequency distribution have been established. For example, in many toll applications, the overall objective for end-to-end connections is to maintain total noise (including crosstalk) at 20 dbrnc0, as measured at the subscriber terminal under normal busy-hour conditions. This total value is then divided into separate objectives for subscriber loops, terminal equipment noise, various types of line noises, and crosstalk.

Distortion

Distortion is the general term used to describe any change in waveform of a signal. Even where noise and crosstalk requirements are met, distortion may reduce the intelligibility and identification of the speaker. The three basic types of distortion are: (1) amplitude distortion, (2) frequency distortion, and (3) delay distortion.

Amplitude distortion is caused by non-linearities in the circuit and is often called non-linear distortion. This type of distortion is characterized by the generation of harmonics which are multiples of the speech frequencies being transmitted. Depending upon the point in the circuit at which the non-linearity exists, these harmonics may appear as crosstalk in other carrier telephone channels. Because of the possible interfering effects, amplitude distortion is kept to a minimum in carrier equipment design.

Frequency distortion, unlike amplitude distortion, does not generate harmonics, but simply appears as selective attenuation of some frequencies with respect to the overall frequency spectrum. If frequency distortion appears within a voice channel and is excessive, the effect is readily apparent. Where low frequencies are greatly attenuated, the resulting speech will sound "tinny"; if the high frequencies are greatly attenuated, the resulting speech will have a "booming" sound.

Delay distortion is the result of differences in the propagation velocities between the various frequencies in a complex wave. For speech circuit, delay distortion is not a problem because the ear is relatively insensitive to phase variation. However, on voice-frequency circuits used for high-speed data transmission, delay distortion is an important factor.

Conclusion

While many of the factors affecting the transmission performance of a telephone circuit may be readily measured, it is difficult to correlate these figures meaningfully to the satisfaction of the user. The telephone user remains subjective in his evaluation of the human communications channel. As advances are made in techniques and equipment, so will the user raise his standards in demanding better and more complete service. Only through continual review can the telephone industry insure that it is in agreement with the user on what he expects of his telephone.

Lenkurt Electric Co., Inc.
San Carlos, California

Bulk Rate
U.S. Postage
Paid
San Carlos, Calif.
Permit No. 37

MR. E. A. GARCIA
CHIEF OPERATOR
% MILWAUKEE ROAD DEPOT
SAVANNA, ILL.

R-24948 6B

RETURN REQUESTED

IN-BAND SIGNALING

Versatile new signaling units expand the capability of the Lenkurt 927A In-Band Signaling System to meet the needs of any multiplex or 4-wire facility. This new system provides for E and M signaling with and without pulse correction, loop start and ground start foreign exchange (FEX) with pulse correction, automatic ringdown, and loop dial with pulse correction. Trouble-free solid-state circuits cut maintenance to a minimum. The technical characteristics of this versatile new signaling system are described in Form 927A-P4, available on request from the Sales Promotion Manager.

LENKURT ELECTRIC San Carlos, California, U.S.A.

SUBSIDIARY OF
GENERAL TELEPHONE & ELECTRONICS GT&E

Lenkurt Offices

San Carlos	New York City
Atlanta	Washington, D.C.
Dallas	Chicago

The Lenkurt Demodulator is a monthly publication circulated free to individuals interested in multi-channel carrier, microwave radio systems, and allied electronic products. Permission to reproduce material from the *Demodulator* will be granted upon request. Please address all correspondence to the Editor.