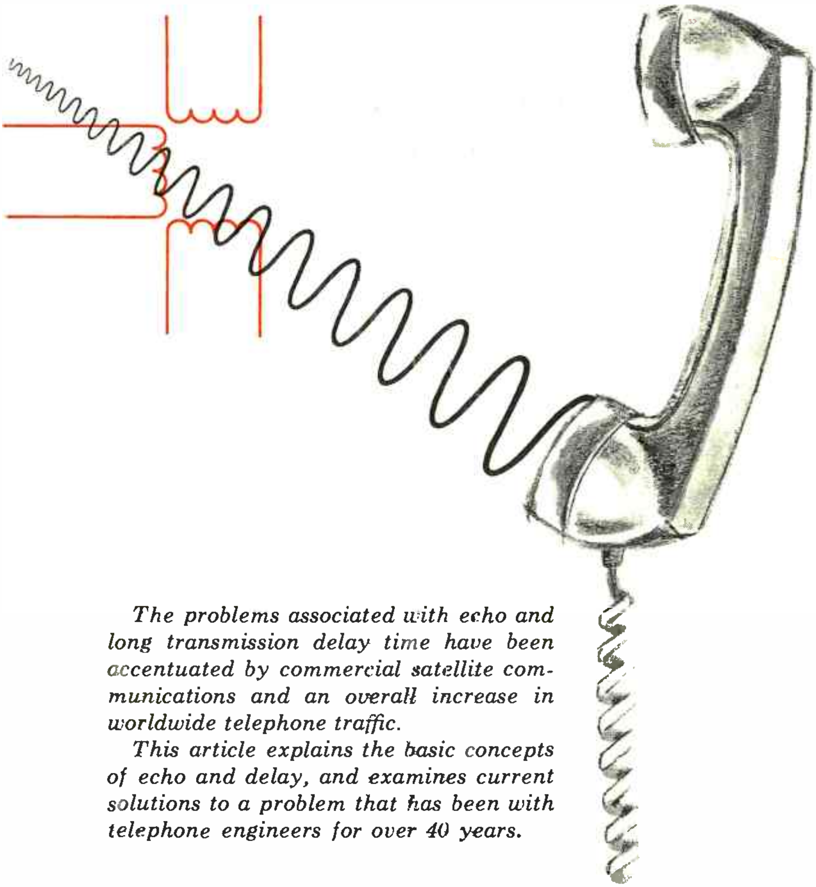
AUGUST, 1966
VOL. 15, NO. 8

the Lenkurt Demodulator

Echo Suppression



The problems associated with echo and long transmission delay time have been accentuated by commercial satellite communications and an overall increase in worldwide telephone traffic.

This article explains the basic concepts of echo and delay, and examines current solutions to a problem that has been with telephone engineers for over 40 years.

Like the acoustic echo heard in a cave, or bounced from the side of a mountain, the echo in a long telephone circuit represents sound energy reflected back from some distant point. Unlike that found in nature, telephone echo is neither a pleasant nor desirable occurrence.

Telephone echo is created primarily at the far end of 4-wire transmission circuits where a junction is made with 2-wire subscriber loops. Because of unavoidable impedance mismatch at this point, energy transfer is not complete and some of the sound is reflected back to the talker. Thus, in the telephone receiver a talker hears his own voice, delayed proportionately to the length of the circuit.

Delay Time

Delay time, the basic factor causing echo to be objectionable, is a function of propagation rate and distance. The faster the propagation, the longer the distance that can be covered without serious degradation of the circuit. The upper limit, however, is the rate at which electromagnetic radiation travels in free space — 186,000 miles per second. And now communications satellites are proving that even this is not fast enough.

Delay is commonly measured in milliseconds (ms), or thousandths of a second. Long one-way delays of, say, 500 ms might be sensed by talkers only as a hesitancy in the response of the other party. But echo returned at a fraction of this time seriously degrades the circuit, and may cause the speaker to stammer, slur his words, or stop talking altogether. In fact, a round-trip echo delay of 45 ms is considered the maximum before some sort of echo suppression must be used. Of course, the speaker's tolerance to echo depends on both echo delay time and loudness. Echo with long delay and of sufficient magnitude is very noticeable.

Undoubtedly, the commercial satellite system of the future will be built around synchronous satellites whose orbital speed matches exactly the rotational speed of the earth. The satellite appears to "hang" in a stationary location over the equator at an altitude of 22,300 miles. A one-way telephone path through such a satellite is in the order of 50,000 miles, taking into account the geographical distance between ground stations. Delay between New York and London, for instance, is about 265 ms, or over a half-second for round-trip echo. This amount of delay has again accented the problem of echo suppressors.

Signal Path

The telephone path begins with a 2-wire loop from the subscriber's instrument to the local exchange office, and either 2- or 4-wire exchange trunks extending to the toll switching center. Long-haul 4-wire toll trunks eventually are returned to 2-wire subscriber loops at the receiver end of the circuit to complete the path to the called party's telephone. (See Figure 1.) In addition, signals are commonly returned to 2-wire circuits for more economical switching purposes.

Wherever it is necessary to match 2-wire to 4-wire circuits, hybrid transformers are used (Figure 2). Because of impedance irregularities at the hybrid, a certain amount of reflection occurs and echo is produced. Of primary concern is the echo resulting from the mismatch at the far end of the circuit.

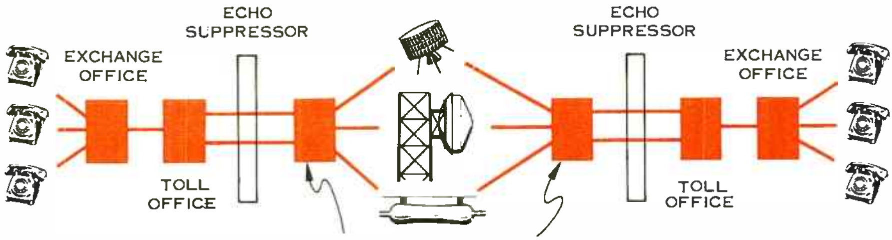


Figure 1. Telephone path through exchange, toll and regional offices. Echo suppressor is located at the beginning of 4-wire toll circuits.

Echo Return Loss

The terms transhybrid loss, return loss, and echo return loss are often used in discussing the operation of hybrid 4-wire terminations. Transhybrid loss is defined as the loss directly across the hybrid on the 4-wire side; i.e., the isolation between the transmit and receive branches of the 4-wire line. The return loss is the transhybrid loss *minus* the losses in the 4-wire to 2-wire paths of the hybrid and serves as a measure of energy returned to the talker. Echo return loss is measured with a known input of voice-weighted noise, between 500 and 2500 Hz. Echo return loss must be greater than 27 dB to meet toll switching requirements. The mean echo return loss at end offices is about 10 dB. (For further discussion, see the *Demodulator*, January 1964.)

It is possible to limit echo in short delay circuits by adding path attenuation. This loss will, of course, reduce the talker's signal as well, but echo returned through the same path will be attenuated twice as much. Until a few years ago circuits with up to 45 ms delay could be accommodated by the insertion of up to 14 dB total one way loss, known as terminal net loss (TNL). Beyond that point, further attenuation interferes seriously with the transmission of speech. Recent upgrading of nationwide service has reduced the amount of attenuation to be placed in high usage trunks. It is now policy to use echo suppressors in circuits having even 20 ms delay, or less.

First Suppressors

Original echo suppressor work began in the 1920's when the first transcontinental telephone systems were being planned. Carrier equipment was not commonly available and most transmission was at voice frequency, having the relatively low propagation rate of about 20,000 miles per second on loaded cable. At that speed a signal would travel a 900-mile circuit from New York to Chicago in 45 ms, or have an echo delay of 90 ms. As trunk lines were expanded across the country, the need for echo suppression became more and more obvious. But before echo equipment approached any degree of sophistication, carrier systems were developed, with their higher frequency increasing the propagation rate to over 110,000 miles per second. At this speed New York to Chicago is only 8 ms, or 16 ms echo delay.

The innovation of carrier transmission and its characteristically faster propagation speed greatly reduced the pressure on further echo suppressor development. Only years later as coast-to-coast trunks and longer undersea cables were established, did interest in echo suppression again take on new zeal. Even at 110,000 miles per second the round-trip echo delay from New York to London was about 70 ms—far too much to be handled by terminal net loss techniques.

Since it was impossible to reduce delay, impractical to eliminate echo at terminal points, and not feasible to introduce sufficient path loss to suppress echoes without reducing talker volumes to imperceivable levels, only one solution became immediately obvious. It was necessary to block the return path an echo must take. The first echo suppressors did just that, using amplified voice energy to activate a relay shorting the opposite path. More refined versions, such as the Bell 1A echo suppressor, detected relative speech energy between the two paths, and picked the stronger of the two to activate suppressor controls. In this case, rather than shorting the line, the suppressor introduced 40 to 50 dB loss in the return path. Because it was almost impossible for a second speaker to break in on a conversation, the circuit took on the qualities of a "push-to-talk" or simplex operation.

Split Suppressors

Echo suppressors were originally designed to be placed at the midway point of the voice-frequency circuit, but with carrier transmission and ocean cables, this was not feasible. First, suppressors were moved from the midpoint to one end of the circuit. Later, the "split" suppressor allowed one-half of the unit to be located at each end, providing some advantage. In all suppressors, attenuation is maintained after the party stops talking for the period of time necessary for the signal to make its round trip and return to the suppressor. This is called *hangover* time. By using split suppressors, hangover time can be held to a minimum, since one unit is always near the reflection point at the far end. Today, echo suppressors are commonly placed in toll or regional switching offices, and may also be found in future communications satellite ground stations.

One problem inherent in previous suppressors was *lockout.* If circuit switching resulted in two suppressors working in tandem—not at all unlikely, especially with Direct Distance Dialing—it was possible for each talker to take command of the suppressor nearest him, block the opposite

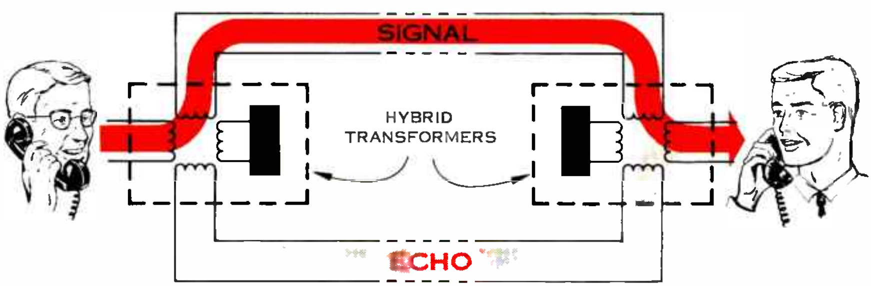


Figure 2. Hybrid transformers are needed at each end of a 4-wire circuit. Reflected energy at this point becomes echo.

path, and thereby prevent any further conversation until one of the parties stopped talking. Split suppressors have also reduced this possibility, but an extension of the problem still exists. A series of echo suppressors introducing individual path losses of about 12 dB could quickly add enough attenuation to reduce speech levels below acceptable values.

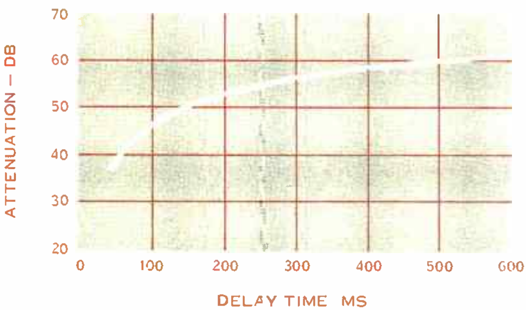


Figure 3. The attenuation needed to suppress echoes to tolerable levels is indicated for the average telephone talker.

Lenkurt 931B

In developing the 931B Echo Suppressor, Lenkurt design engineers were able to include the desirable feature of bi-directional operation — both parties talking at the same time — and minimize speech clipping at the beginning, and speech chopping in the middle of conversations. All modern echo suppressors have since adopted this bi-directional mode of operation.

The 931B suppressor has two modes of operation, allowing it to discriminate between single-party talking and two-party talking. With only one subscriber talking the suppressor is in Mode 1, and blocks echo by inserting 60 dB loss in the return path. Mode 2 provides for two-party talking by only partially suppressing echoes in both paths, on the assumption that echoes of short duration will be masked by the speech signals of the other party.

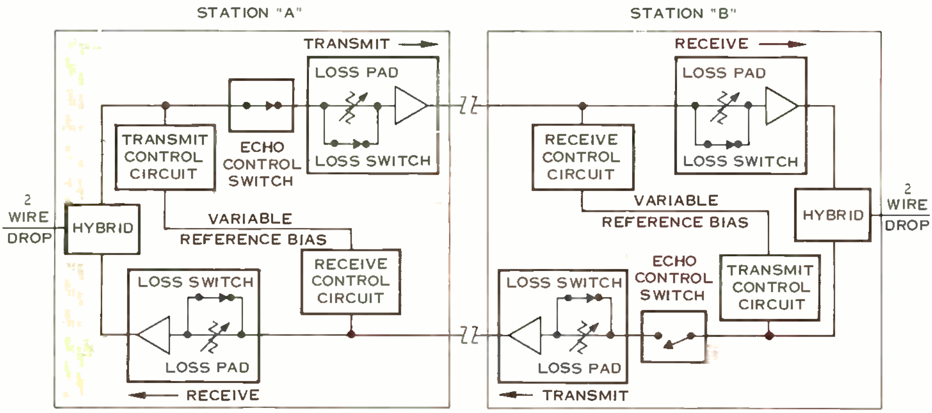
Mode 1

Block diagrams of the Lenkurt echo suppressor in both modes are shown in Figure 4. Identical units are placed at each end of the communications link, and contain two variable-gain amplifiers, an echo control switch, and associated control circuits. To analyze the set's operation, assume Station A is talking. A's voice operates the transmit control circuit closing both loss switches, producing a no loss, or unity gain condition in the transmit path. The echo control switch is normally closed.

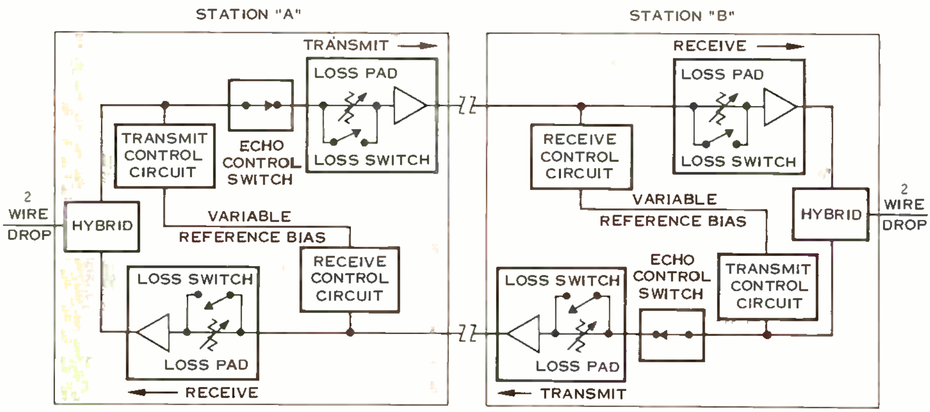
At Station B, the signal operates the receive control circuit, opening the echo control switch. The loss switch remains closed and the signal arrives at the second talker unattenuated by the suppressor. The echo signal, reflected at the hybrid, is sensed by the transmit control circuit at Station B, but because of loss in the hybrid, lacks the energy to overcome the variable reference bias supplied from the receive path and is blocked by the echo control switch.

Mode 2

Mode 2 occurs when B attempts to interrupt A's conversation. B's speech energy is high enough to operate the transmit control switch on his end of the circuit. This results in closing of the echo switch, and the opening of loss switches in both paths at Station B. Similar action occurs as B's signal arrives at Station A. In Mode 2, with both parties talking, each speech signal is attenuated by two losses, and each echo signal reduced by four losses. These losses may be strapped in 1-dB



MODE 1



MODE 2

Figure 4. Simplified diagram of Mode 1 (uni-directional) and Mode 2 (bi-directional) operation of the Lenkurt 931B Echo Suppressor.

steps up to 6 dB, depending on the length of the circuit. If set for 6 dB, the talker's signal is reduced a total of 12 dB, while echo is suppressed 24 dB — this in addition to loss in the hybrid and other circuit losses.

The hangover time in the operation of the echo control switch is a compromise between echo and speech chopping. In Mode 1, the echo control switch at Station B is open as long as A is talking. When A stops talking the switch must be closed to allow B to talk. The time period before this happens is known as receive hangover and is set at 40 ms in the 931B.

In Mode 2, A is talking and B interrupts. The echo control switch at Station B closes to allow B's conversation to be transmitted. If B stops talking but A continues, the switch must again open to block any echo signal to A. If this time, known as transmit hangover, is too short chopping will result; if it is too long, A will hear a few moments of "trailing" echo. Transmit hangover is set at 85 ms in the Lenkurt echo suppressor as an adequate compromise.

In addition, it should be noted that since all operations consist of a *change* in attenuation rather than the actual opening and closing of the circuit, the recycling time between modes is not critical.

The Bell 3A echo suppressor operates similarly, using rectified speech energy through a differential detector to activate mechanical relays. During Mode 2 operation echo attenuation is introduced by a speech compressor, inserting loss in the receive path proportional to the level of the incoming signal.

Data Disabler

With the increasing use of voice circuits for data transmission, it is necessary to provide some means of removing the suppressor from the circuit. This is accomplished with a disabling circuit activated by the transmission of a continuous tone between 2000 and 2250 Hz for approximately 400 ms. Both paths are then held open for data until there is no signal for at least 100 ms. The suppressor then reverts to normal action. Note that echo delay presents no problem in one-way transmission, such as data or television.

Long delay and echo have been the subject of a number of recent tests performed by General Telephone and Electronics Laboratories, Bell Telephone Laboratories, Stanford Research Institute in Palo Alto, California, and others. Interestingly, talkers participating in the experiments became "sensitized" to the problems associated with exceptionally long delays, say of 1200 ms, and thereafter tended to be less tolerant of circuits with shorter delay. However, typical delays of 600 ms found in operating communications satellites apparently have not produced sensitizing to any noticeable degree and most customers find such service fully acceptable.

The Future

Authorities expect that round-trip delays longer than 600 ms must be avoided in future worldwide telephone links by limiting satellite systems to one hop. The practice in coming years may very well be to use satellites for only a portion of an around-the-world conversation, relying on conventional land circuits for the remainder of the path.

Generally, results of experimental testing and of actual performance in operating systems demonstrate that modern echo suppressors have satisfactorily eliminated undesirable qualities found in earlier models. Equipment such as this will be a necessary standard in all long telephone systems of the future, especially when distances are amplified by commercial and military communications satellites.

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

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 periodical circulated to technicians, engineers, and managers employed by companies or government agencies who *use and operate* communications systems, and to educational institutions. Job title, company affiliation, and nature of business must be indicated on subscription requests. Each issue features an instructive article on a subject dealing with the science of telecommunications. Permission to reprint articles may be obtained by writing THE EDITOR.

LITHO IN USA