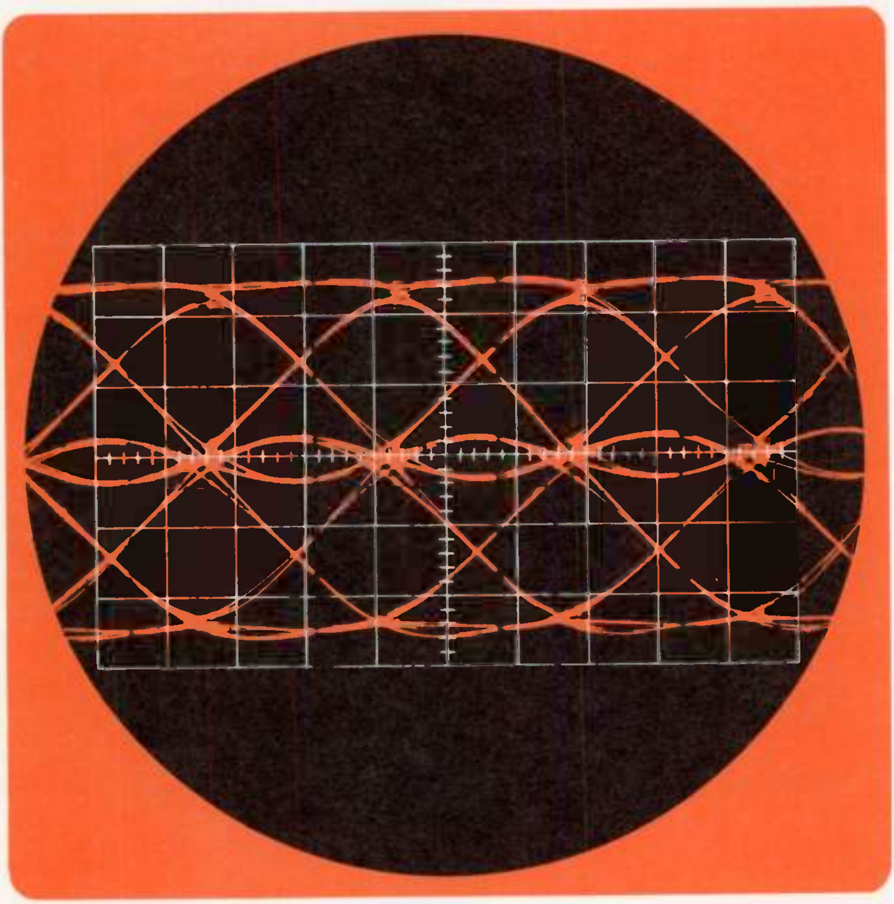
The *Lenkurt.*

JANUARY 1969

# DEMODULATOR

## Circuit Conditioning Part 1



**Data transmission speeds go higher and higher and line quality requirements increase correspondingly.**

Quality, in a communications circuit, is relative. The same circuit may perform flawlessly for voice communications and not handle data traffic at all satisfactorily. Before the recent upsurge in the amount of digital traffic being handled by common carriers, this was not an especially serious problem. But nowadays, data is demanding an increasing amount of the telephone industry's attention. They are faced with the pressing requirement to improve their networks to more efficiently handle digital type traffic.

Since it is not feasible to replace all existing voice-grade circuits or to install whole new networks dedicated to data transmission, the obvious solution is to upgrade existing circuitry.

Two phenomena cause most of the difficulties encountered in attempting to send digital data over voice circuits. They are delay distortion and amplitude distortion. But both can be overcome by proper conditioning of the circuit. The Lenkurt 971B Adjustable Equalizer is designed specifically to cope with problems of distortion in voice circuits intended for data traffic. It corrects for both amplitude and envelope delay distortion, and conditions circuits to meet C–1, C–2, C–3 and C–4 standards.

## Delay Distortion

Delay distortion of electrical signals is a type of distortion caused by the non-linear phase delay-versus-frequency characteristics of a communications circuit.

In voice-frequency transmission facilities, such distortion is caused mainly by the capacitive and inductive effects of transformers and amplifiers at the low frequencies. At the higher frequencies it is caused by loading coils and line capacitance. In carrier transmission facilities, channel bank, group, supergroup, and mastergroup transformers and filters are the main causes of delay distortion.

Delay distortion is not a problem until it begins to interfere with the ability of the communications receiver to understand the information contained in the signal. In the case of speech transmission, delay distortion has not been a problem, since the human ear is relatively insensitive to variations in phase-versus-frequency relationships.

However, digital signals are quite vulnerable to the effects of delay distortion. Data bits usually originate as rectangular-shaped pulses which are used to modulate a carrier at a particular keying rate for transmission over a communications circuit. The analagous AM or FM signals resulting from this modulation process are composed of many frequencies.

The envelope of these signals results from energy at the fundamental and harmonic frequencies adding together vectorially. If such a signal passes through a circuit with non-linear phase-versus-frequency characteristics, it becomes severely distorted. In fact, the signal energy may "spread out" to the point where adjacent pulses begin to interfere with one another. Under such conditions, the data receiver may not be able to properly detect the information content of each bit, (for example, a binary 1 may be detected as a binary 0, or vice versa).

When considering the cause of delay distortion, it should be noted that an appreciable impedance mismatch between line sections or between the line and office apparatus will influence the distortion characteristics of the facility. The presence of reflected currents sometimes causes an overall distortion much different from that which is indicated by analyzing the individual facility components. This is particularly noticeable at low frequencies or with short lengths of line, where the loss is relatively low, and reflection and interaction effects are consequently greater. In the case of long loaded cable circuits, manufacturing tolerances and subsequent treatment of cables can cause appreciable variation from the delay determined by formula or from typical curves. Another problem is the spacing of load coils which varies from the ideal because of the necessity for spacing coils according to the location of manholes or telephone poles.

## Measurement Techniques

There are two common techniques used to measure delay distortion in communications circuits. One consists of measuring phase shift, either with a phase meter or by means of an oscilloscope Lissajous pattern – a method mainly used in the laboratory. It is a tedious procedure because phase shift-versus-frequency must first be computed and then point-by-point slope measurements made to derive the delay curve.

This method requires accurate frequency measurement and is suitable only when both terminals of the circuit are available at the same location. The method is also occasionally used for transmission circuits where two similar circuits exist so they can be "looped back" to the measuring point. Figure 1 is a curve of frequency-

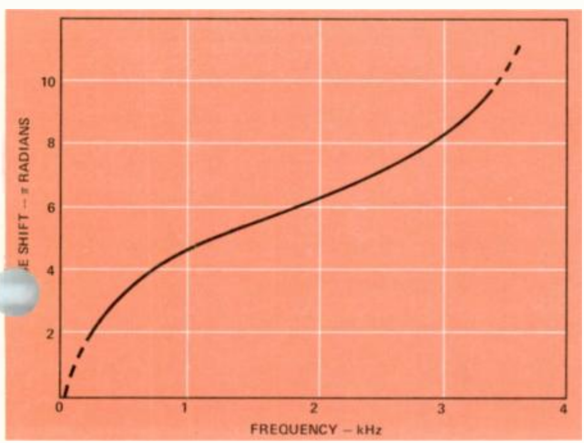



*Figure 1. Frequency/ Phase Shift Characteristic's of Typical Communications Channel.*

versus-phase for a typical communications channel.

The second technique consists of measuring the envelope delay characteristics of a circuit rather than the frequency/phase-shift characteristics and is relatively easy to accomplish.

Envelope delay of a particular frequency is equal to the slope of the phase-frequency curve at the specific frequency. Therefore, envelope delay can be determined by measuring the phase shift of two incremental frequencies and then computing the slope. The degree of resolution of the measurement depends upon the incremental spacing of the two frequencies used to determine the slope characteristics. The closer the spacing the greater the resolution of the measurement.

Measuring the slope at various points throughout the passband of a circuit provides an indirect indication of the phase-versus-frequency characteristics of the circuit.

However, it is not necessary to use two incremental frequencies to make such a measurement. The usual practice is to transmit an amplitude modulated carrier through the circuit under test, and measure the resulting phase shift of the modulation envelope. The result is the same as measuring the slope of two incremental frequencies, and the measurement concept employs much simpler computational techniques.

When transmitting an amplitude modulated carrier through a circuit, energy at the carrier and upper and lower sideband frequencies will be displaced in time according to the frequency/phase characteristics of the circuit. This is illustrated in Figure 2. It means that the envelope of the signal will shift in phase from the carrier by an amount equal to the mean value of the slopes of the two sidebands (assuming both sidebands are equal in amplitude). The amount of this phase shift is called *envelop delay*.

As a rule, the lower the modulating frequency, the more the envelope phase shift approaches the actual value of the slope of the phase shift at the carrier frequency. It can be assumed in practice that the envelope phase shift of the amplitude modulated carrier is equal to the slope of the frequency/

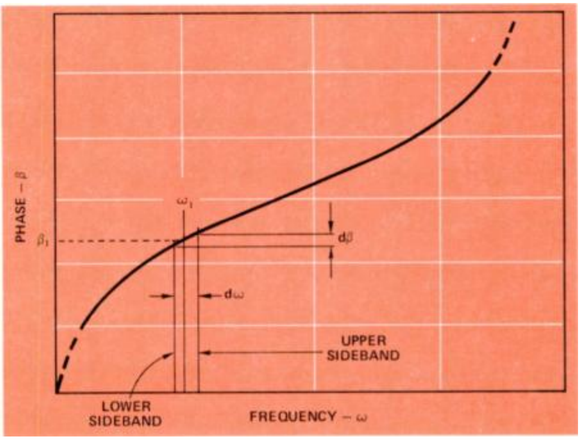



*Figure 2. Envelope Delay at Amplitude Modulated Carrier Frequency $\omega_1$.*

phase curve describing the circuit at the carrier frequency. (See Figure 2). This means that if the amplitude modulated test signal is tuned or swept across the band of interest, the envelope phase shift detected at the receiving end of the circuit provides an indirect measurement of the frequency/phase shift characteristics of the circuit. A curve of envelope delay-versus-frequency for a typical communications circuit is shown in Figure 3.

Delay measuring test sets have been developed to measure envelope delay in communications circuits. An example of such a set is the Sierra Model 340B, shown in Figure 4. The set generates an amplitude modulated carrier that can be manually adjusted or electronically swept over a frequency range corresponding to voice band, standard group and supergroup circuits. The carrier is usually 50 percent amplitude modulated with one of three frequencies.

As mentioned previously, the lower the modulating frequency the more meaningful the measurement. However, variations in envelope delay are difficult to measure accurately if the frequency is too low and a compromise is usually reached. Three modulating frequencies, 25 Hz, 83-1/3 Hz, and 250 Hz, have become somewhat standard throughout the communications industry and are employed in most delay measuring test sets.

The test set also processes the modulated signal after it has traveled through the communications circuit. The phase shift encountered by the envelope with respect to the carrier is measured by a zero-crossing detector. The difference in phase is read directly on a digital display or meter as delay in microseconds. Typically, these test sets are capable of measuring delays as great as 20 milliseconds.

It is important to realize that the absolute envelope delay at a particular frequency is of no immediate concern in equalizing a circuit. It is only the *relative* delay that is important. This is the term used to express delay distortion performance requirements in communications standards. Relative delay is the difference between the envelope delay (in microseconds) measured at some frequency within

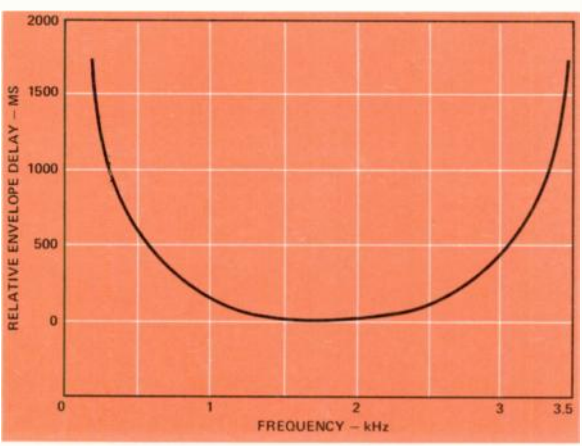



*Figure 3. Typical Relative Envelope Delay – 46A Channel Equipment (Measured With Channel Units Back-To-Back).*

*Figure 4. Envelope Delay Test Set*

(Courtesy Sierra Electronic Operation, Philco–Ford Corp.)

the band of interest and a reference delay and frequency established within the same band.

In performance standards, envelope delay distortion is usually expressed as a maximum difference in envelope delay (in microseconds) between two frequencies within the passband of the circuit. For example, the envelope delay standards for a telephone trunk circuit might read:

> "Envelope delay distortion shall not exceed:
> 80 microseconds between 1000 and 2600 Hz.
> 250 microseconds between 600 and 2600 Hz.
> 500 microseconds between 500 and 2800 Hz."

This means that the difference in envelope delay (in microseconds) between any two frequencies between 1000 and 2600 Hz cannot exceed 80 microseconds, and so on. Using a delay measuring test set, the envelope delay characteristics of a circuit can be determined very quickly to see if they meet these requirements.

Such a test can be accomplished by tuning the amplitude modulated carrier to a series of discrete frequencies across the band of interest (i.e. 1000 to 2600 Hertz), and manually recording the relative envelope delay reading at each frequency on the receiver of the test set.

Alternatively, the carrier can be electronically or manually swept across the band of interest and the envelope delay information recorded on an X–Y recorder or viewed on an oscilloscope.

Subtracting the minimum delay reading from the maximum delay reading provides a measure of the envelope delay distortion for the particular passband. If the difference between 1000 and 2600 Hz is greater than 80 microseconds, then the delay performance of the circuit will not meet the standards described in the example and the circuit must be equalized.

## Delay Equalization

It is not always necessary to measure the delay characteristics of a circuit to equalize it for data. There is a technique for equalizing a circuit known as the "eye pattern" method which is useful when conditioning a circuit for a particular data modem.

With this method, a data modem such as the Lenkurt 26C which has its own test pattern generator is placed in the circuit with the modulator generating a random data pattern. An oscilloscope is connected to the data receiver (or demodulator) and synchronized with the receiver clock. The overlapping traces viewed on the oscilloscope provide an indication of the amount of phase distortion present in the signal.

Equalizers can be added to the circuit and adjusted until the distorted eye pattern improves. This technique, although it does not assure that the circuit is equalized to certain specified limits, does provide the fastest adjustment to optimum setting for the particular data modem involved.

The job of equalizing a telephone circuit for data transmission has been greatly improved through the use of delay measuring test sets and variable equalizers. Most of the delay measuring test sets provide analog output voltages that are proportional to the carrier frequency and envelope delay detected in the receiver. These voltages are used to drive an oscilloscope or an X–Y recorder to provide a visual display of the relative envelope delay-versus-frequency characterisitics of a circuit. Such visual information is extremely helpful when attempting to equalize a circuit.

There are several methods of setting up delay test sets to measure the envelope delay characteristics of a circuit such as *loop back*, *end-to-end with return reference*, and *end-to-end*, as shown in Figure 5.

The loop-back method is used primarily in the laboratory or in factory tests to measure the envelope delay characteristics of a circuit when both ends are available at the same location. The end-to-end with return reference method generally provides the most accurate measurement of a circuit because of better synchronization between the transmitter and receiver of the test set.

The first step in equalizing a circuit with a delay measuring test set is to establish the test arrangement. The end-to-end method is generally the most convenient.

In such an arrangement, an operator is required at each end of the circuit with an order wire facility so that the operators can talk to each other. At the transmit end of the circuit the terminal equipment is removed and the delay test set transmitter connected in its place. The test set receiver is then connected to the opposite end of the circuit. An X–Y recorder can be connected to the receiver to facilitate equalizing the circuit.

It is important to understand that the absolute delay within a circuit cannot be reduced. Equalizers correct,

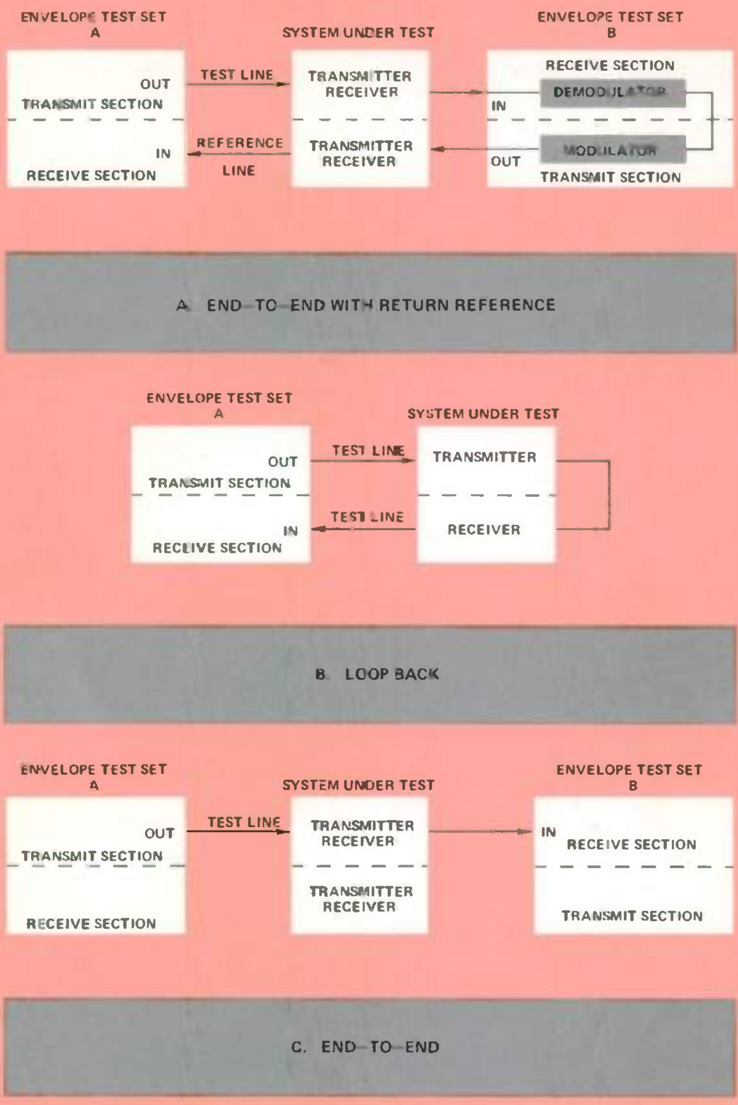



*Figure 5. Envelope Delay Test Sets, Test Arrangements*

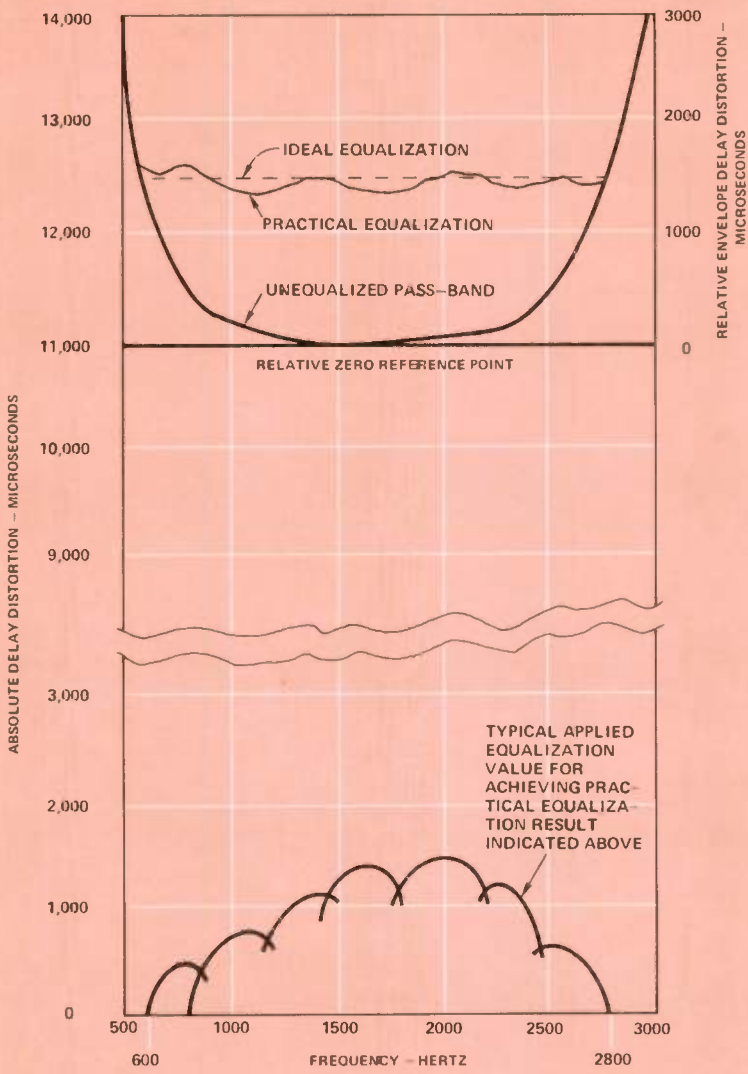



*Figure 6. Relationship of Relative Envelope Delay Distortion To Absolute Delay Distortion.*

at a specific point in the circuit, for relative values of delay (and associated amplitude) distortion across the passband. This point is usually at the receiving end of the circuit. Fundamentally, relative delay distortion is corrected by adding extra delay to those areas in frequency where the signal distortion value is low. This effectively flattens the passband by setting the overall distortion levels, across the band, at the value of the worst (highest) condition. Even though system end-to-end absolute (total) delay has been increased slightly for certain frequencies, the conditioned signal will display very little effect from these forms of distortion.

Relative delay distortion is usually determined by establishing, individually, the lowest respective delay value and corresponding frequency within the passband as the reference point and comparing the values at other frequencies with this point of reference. For most applications, the reference point is arbitrarily set at zero microseconds of delay. In this way, measurements made at discrete frequencies within the passband of the circuit will all read as positive numbers. Occasionally, the point of zero reference is set at a specific frequency, such as 1500 Hz. In this event, values of distortion throughout the passband may appear both as positive and negative numbers with respect to the reference point. Figure 6 shows the relationship between relative and absolute delay distortion.

The February, 1969 DEMODULATOR, Circuit Conditioning, Part 2, will discuss amplitude distortion and the means for coping with it.

# The Lenkurt Demodulator...

an informative technical periodical circulated monthly to technicians, engineers, and managers employed by companies or government agencies who use and operate communications systems, and to educational institutions. . . .

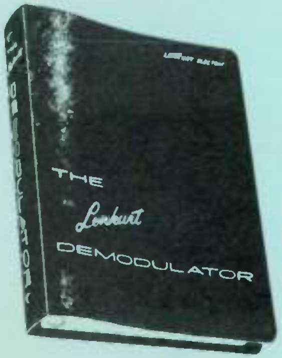
**. . . with our compliments.**

Each issue features an interesting and instructive article on a subject dealing with the science of telecommunications.

If you are interested — and qualify — we will gladly place your name on the mailing list. Simply fill out and mail the attached postcard.

**the Editor**

## Binder




A special binder is available for storing issues of **The Lenkurt Demodulator.** These binders are covered in durable, embossed Lexide; each binder holds 24 issues. The cost is 60 cents for one binder, or 50 cents each for two or more, postpaid.

## Reprint Book

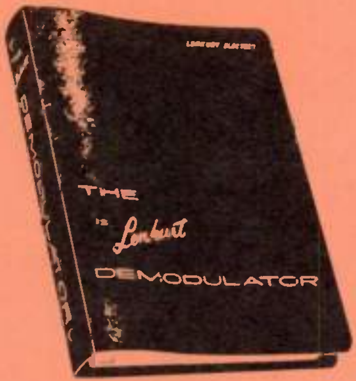

The 32 most-requested articles from the first seven years of **The Lenkurt Demodulator** have been compiled into book form.

The attractive, cloth-bound book is titled **Carrier and Radio Articles Selected from The Lenkurt Demodulator**, and costs $2.50, postpaid.

NEW BOOK AVAILABLE
74 ARTICLES
$5. POST PAID

**A convenient order envelope will be sent with your first issue of**

**THE LENKURT DEMODULATOR**




# *To Our Readers...*

Regrettably, increased costs force us to change the price of the *Demodulator* three-ring binder. In an effort to make the price equitable to *all* of our subscribers, we have decided to set the new price at $1.00 each to both domestic and overseas readers. This will cover both the higher cost to us as well as the increase in mailing and handling charges.

New subscribers will be interested to know that one binder will handily accommodate two full years' issues of the *Demodulator.*

**The Editor**

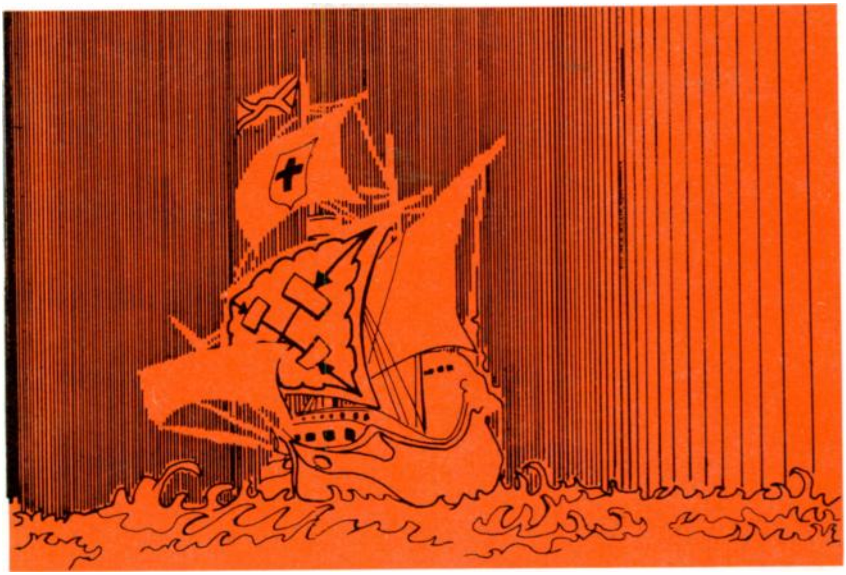
LENKURT ELECTRIC CO., INC.
SAN CARLOS, CALIFORNIA 94070

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

RETURN REQUESTE

MR. PHILIP E. FRAZIER 567
UNIV. OF CALIF. RADIATION LAB.
BLDG. 88, ROOM 113
BERKELEY, CAL 94720

# OUR SHIP IS IN



At long-last, the Demodulator reprint book, *Selected Articles from the Lenkurt Demodulator*, is available again. The quality and value are the same, and so is the price – $5.00 domestic and APO/FPO, $7.50 foreign. Reprint books and any other information about the "Demod" can be obtained by writing Lenkurt, Dept. A134.

LENKURT ELECTRIC
GENERAL TELEPHONE & ELECTRONICS

SAN CARLOS, CALIFORNIA, U.S.A.
**VIDEO, VOICE & DATA**
*TRANSMISSION SYSTEMS*

**Lenkurt Offices**
San Carlos
Stamford, Conn.
Falls Church, Va.
Chicago
Atlanta
Dallas

The Lenkurt Demodulator is circulated monthly to technicians, engineers and managers employed by companies or government agencies who use and operate communications systems, and to educational institutions. Permission to reprint granted on request.