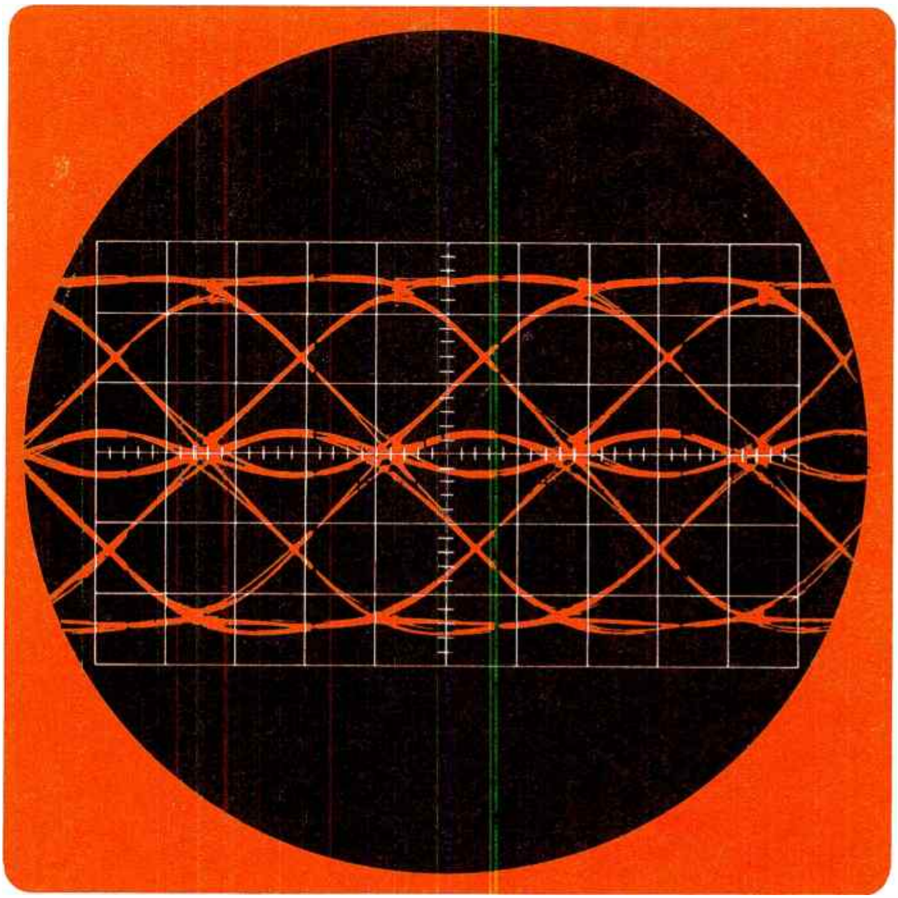
The Lenkurt®

FEBRUARY 1969

DEMODULATOR

Circuit Conditioning Part 2



Amplitude distortion creates unique problems for data transmission over VF facilities.

Even though amplitude and delay distortion are not *necessarily* related and do not *always* appear in the same circuit, their causes are much the same. However, they are still two separate and distinct phenomena – consequently the means for correcting them will also differ.

By definition, amplitude distortion is a variation of loss or gain with frequency. It has two distinguishing characteristics – band edge roll-off and in-band ripple.

Band edge roll-off is usually caused by filters in a voice multiplexing system, or by loaded cable, or by high pass characteristics of transformers and series capacitors. In-band ripple is caused principally by impedance mismatches and their attendant reflection.

Data Distortion

For frequency division multiplexing (FDM) equipment such as the Lenkurt 25B or other low speed data transmission systems, band edge distortion in the voice channel may be so severe that it is impracticable to obtain more data channels by equalization. In-band amplitude ripple or delay distortion, however, is seldom so severe as to affect these low-speed channels. Therefore, equalizers for frequency division multiplexing equipment need only correct the amplitude response at the corners of the channels.

For higher speed data transmission – 1200 bits per second or more – delay distortion usually is controlling, and only moderate amounts of amplitude correction are required. Usually, just enough to correct a general amplitude slope through the frequency band is sufficient.

However, in a switching network such as Autovon or Autodin, where high speed data is to be transmitted over several tandem switched sections, it is necessary that both amplitude and delay distortion be tightly controlled in each link of the switching system. This is so that the overall characteristics of several sections in tandem (which are the sum of the characteristics of the individual sections) will meet the requirements for data transmission.

In cases like this, the in-band ripple of the amplitude response becomes important and must be equalized. As previously mentioned, this ripple is caused by impedance mismatch; conceivably it could even be caused by imperfect impedance matching of delay distortion correction devices.

Amplitude Equalization

Treatment for amplitude distortion usually accompanies delay equalization. As stated in Part 1 of this issue, the absolute delay within a system cannot be reduced from its total value at the point of origin. But, amplitude correction can be accomplished with gain devices.

The Lenkurt 971B Adjustable Equalizer is designed specifically for the correction of amplitude distortion as a function of frequency as well as delay distortion to enable VF circuits to meet stringent C3 and military DCA requirements for data transmission (as outlined in DCA Circular 330-185-1). See Table 1.

The 971B is usually operated from the receive end of the circuit. An exception would be in cases where intermediate switch locations occur in long-haul circuits that can be separated into shorter segments for switching. In such cases, for purposes of equalization, each segment is treated as a separate circuit.

Correction is accomplished by adding gain or loss in the areas of frequency where distortion exists to flatten the passband. Amplitude-versus-frequency distortion is reduced over a particular frequency range. This, in turn, decreases the distortion of the signals being transmitted in that range or, conversely, increases the data transmission rates.

A good adjustable equalizer system, such as the 971B, generally consists of independent delay and amplitude equalizers. Since the delay systems were described in Part 1 of this article, only the amplitude equalizer will be discussed here.

Basically, there are three methods of amplitude equalization. They involve the use of either "bump" sections, band edge booster sections or cosine sections.

The first method introduces variable compensation shapes (bumps) uniformly across the frequency range

Table 1

TYPE C3 CONDITIONING

Type C3 — For access lines and trunks associated with a Switched Circuit Automatic Network or common control switching arrangement

Access Lines

- The envelope delay distortion shall not exceed:
  - Between 1000 and 2600 Hz, a maximum difference of 110 micro-seconds
  - Between 600 and 2600 Hz, a maximum difference of 300 micro-seconds
  - Between 500 and 2800 Hz, a maximum difference of 650 micro-seconds
- The loss deviation with frequency (from 1000 cps reference) shall not exceed
  - Between 500 and 2800, −0.5 dB to +1.5 dB
  - Between 300 and 3000, −0.8 dB to +3.0 dB
  - (+ means more loss)

Trunks

- The envelope delay distortion shall not exceed
  - Between 1000 and 2600 Hz, a maximum difference of 80 micro-seconds
  - Between 600 and 2600 Hz, a maximum difference of 260 micro-seconds
  - Between 500 and 2800 Hz, a maximum difference of 500 micro-seconds
- The loss deviation with frequency shall not exceed
  - Between 500 and 2800, −0.5 to +1.0 dB
  - Between 300 and 3000, −0.8 to +2.0 dB

NOTE: Conditioning in accordance with the above specifications is limited to:

Each Interexchange or local access line — between the customer's station and switching center

Each trunk — between switching centers

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to be equalized. It is effective for correcting moderate in-band distortion but has the problem of allowing too much interaction among the separate bumps in the line. However the bump method can deal with chosen subdivisions within the band on a one-by-one basis.

In facilities with steeply dropping band edges – such as loaded or submarine cable – equalization is aided by the use of a tuneable high and low frequency booster section with shape controls. Such devices (the Lenkurt 971B is one) are equipped for dealing with slope or band edge drop-off problems. But, unless another equalization technique is used, they cannot cope with mid-band ripples.

Cosine Equalization

Bump section and band edge booster sections are fairly conventional techniques for equalizing data circuits. There is, however, a method used by the Lenkurt Adjustable Equalizer called cosine equalization which is not so common.

Cosine sections introduce a set of harmonically related cosine wave shapes of gain versus the log of the frequency. In general they are considerably more effective than bump shapes for equalizing severe in-band amplitude distortion, especially since they require fewer sections.

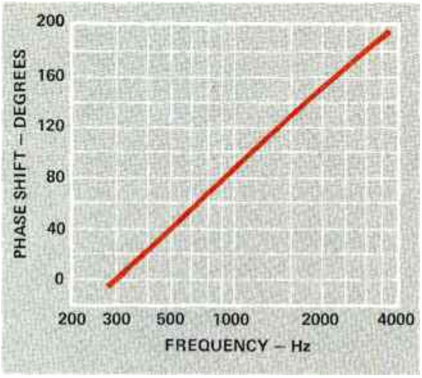


Figure 1. Cosine section phase shift-versus-frequency characteristic – Amplitude Equalizer.

In a conditioning system which employs cosine equalization techniques, the cosine equalizer consists of a number of identical phase-shifting networks connected in tandem. The networks are driven by compound transistors and unity-gain phase splitters the outputs of which are combined in a summing amplifier.

The 971B cosine equalizer provides five cosine shapes of amplitude versus logarithm of frequency. The shapes are continuously variable in amplitude and sign. Combinations of these shapes are used to cancel amplitude variations in the voice band of the circuit.

Figure 1 shows the phase shift/frequency relationship characteristic in a typical cosine stage. This relationship is almost linear. If the output voltage of the first phase shift stage is added linearly to the input voltage, the shift at 300 Hz will be zero and the summed voltage will be double that of the input voltage.

At 3000 Hz though, the phase shift is 180 degrees, and if the two voltages are added their sum will be zero. So, as the frequency is varied between 300 and 3000 Hz a half-cosine curve of the voltage-versus-log/frequency can be obtained. The curve will be on a logarithmic scale because of the logarithmic relationship between phase and frequency.

And, since the phase shift networks are in tandem, the output of the second stage (or section) will go from 0 to 360 degrees as frequency is varied between 300 and 3000 Hz. Output shifts of the next three stages will be 540, 720 and 900 degrees respectively. Consequently the five cosine stages will produce 1/2, 1, 1-1/2, 2 and 2-1/2 cosine curves. All five situations are represented in Figure 2.

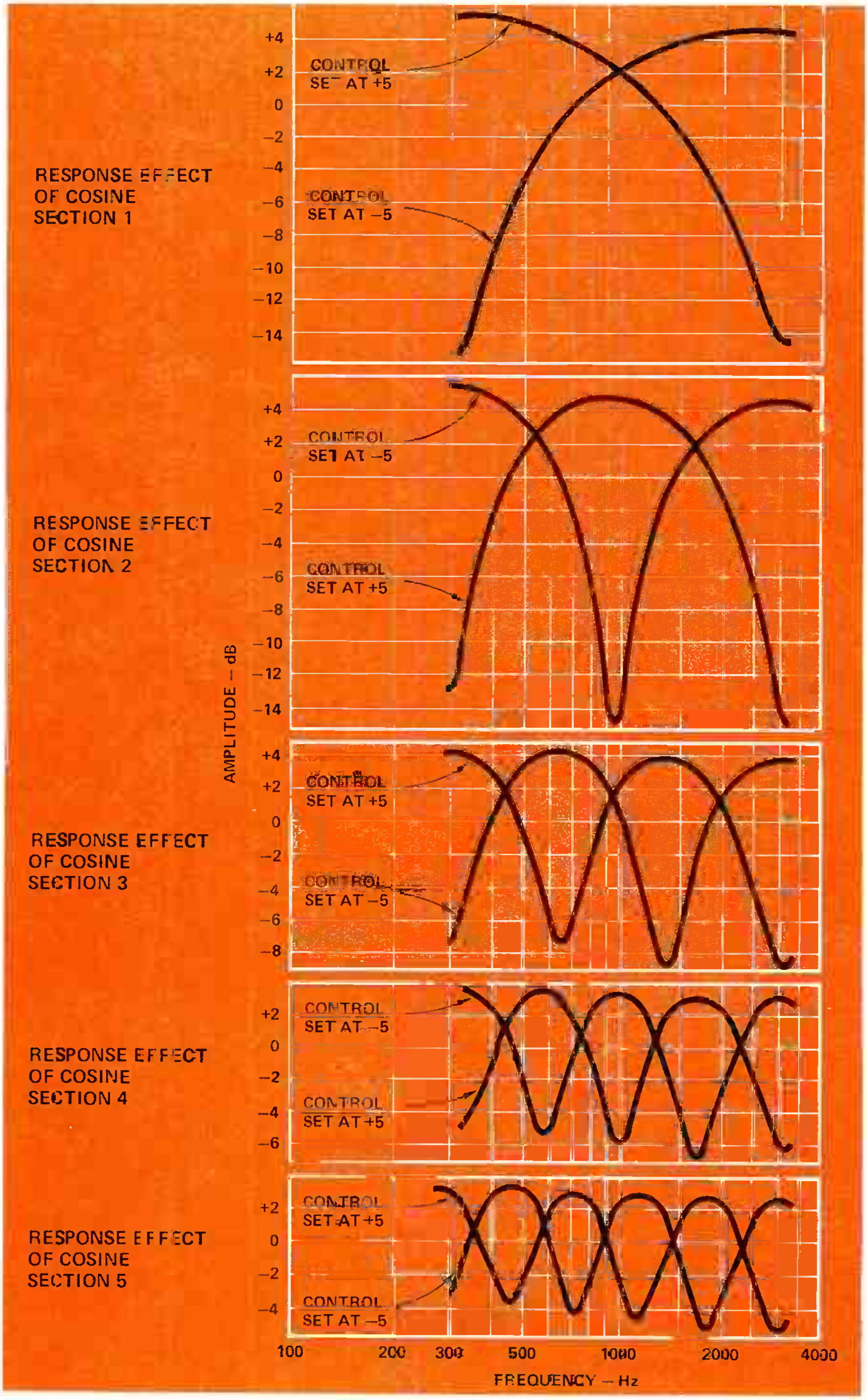
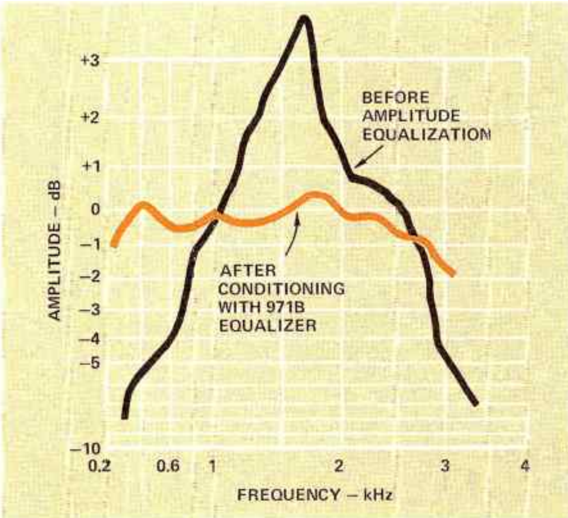


Figure 2. Response effects of Lenkurt 971B's five cosine sections

Figure 3. Actual amplitude distortion condition — before and after equalization. End-to-end measurement of VF circuit consisting of four links of 46A Carrier and one link of 3-kHz submarine cable.



Measurement Techniques

Equipment for measuring amplitude distortion is basically an oscillator and a VTVM; whereas an envelope delay test set is used for determining delay distortion. There are also some differences in technique.

Whereas the reference point for delay measurements was arbitrarily set at zero microseconds on the test set, a specific frequency — usually 1 kHz with a 0 dB reference point — is chosen for amplitude measurements. Consequently, values of distortion throughout the passband may appear as both plus and minus figures with respect to the reference level. But just as with delay measurements, a reference point is provided to which distortion in other portions of the band may be compared. From this comparison, it can be determined whether or not equalization is feasible or even required.

Absolute values of minimum distortion and loss within a system are not directly related to the problem of correcting for relative distortion and its effect on a signal. Even though they may not be of immediate concern to the equalizer system, absolute values are important for purposes of comparison, particularly in parallel circuits. In such cases, the circuit with the lowest distortion and loss figures is "built out" of the network by the equalizer to the value of the circuit having the highest figures.

One of the most expedient methods of measuring amplitude distortion involves the use of level tracers such as the Siemen's REL 3 K 211G. A level tracer provides an oscilloscope trace pattern of the pass-band amplitude condition. Hence, the effects of adjustments made on the equalizer can be readily seen and adjustment results can be recorded for reference. In this method, one level tracer's generator is used at the transmitting end of the line as a sweep signal source. The receiving portion of a second level tracer is connected to the output of the equalizer at the line's receiving terminal. The tracer is then adjusted to track the sweep of the transmitting unit. The result is a calibrated amplitude-versus-frequency curve of the pass band.

By using a level tracer in conjunction with an adjustable equalizer such as the Lenkurt 971B, off-line amplitude equalization is possible. This is done by placing a mirror image of the trace (inverse tracing) before the cathode ray tube of the level tracer and matching to it the shape of the equalizer circuit. This technique is used when, for some reason or another, end-to-end alignment is not possible.

Alignment for Amplitude Equalization

Just as with delay equalization, three basic pieces of equipment are required – an adjustable equalizer and two sweep level tracers.

The level tracers are connected to each end of the circuit and their controls are set for the desired transmit/receive levels as determined by the particular system requirements. Requirements differ widely depending upon the particular transmission facility being equalized.

To determine the system's general amplitude response characteristics, the line response should be first observed and recorded off the level tracer without the equalizer in the circuit.

The five cosine equalizer section controls are then adjusted to get the best possible (flat) response across the entire pass band. These controls are especially effective for minimizing in-band amplitude ripples. Each cosine section introduces a distinct positive or negative shape whose amplitude is directly proportional to the control knob setting.

At the start, each cosine control should be varied in both directions from its zero setting to determine the relative effect on the response for that particular section. Experimentation is usually necessary to determine the various combinations of cosine control settings which will best equalize the circuit.

From a simple operational point of view, it is not really necessary to know what each term is accomplishing except for a general understanding. This is because cosine shapes, up to the third or fourth terms, can be reckoned reasonably accurately from the gain/frequency response on the level tracer.

For higher terms, reduction of the total gain spread over the whole band usually provides sufficient adjustment standards. But when adjusting the cosine sections sequentially, if a point is reached where no appreciable reduction in gain spread is noted, this and all higher order sections should be left at zero. A new combination is then started by setting the first section at a new level.

In obtaining the desired amplitude response, it may be necessary to juggle the high and low booster sections and the 0 dB, 1000 Hz reference values during alignment since cosine adjustments can change the high and low end response.

But if all goes well, and the desired amplitude response is obtained, the line should then be ready and capable of carrying digital information as well as analog signals.

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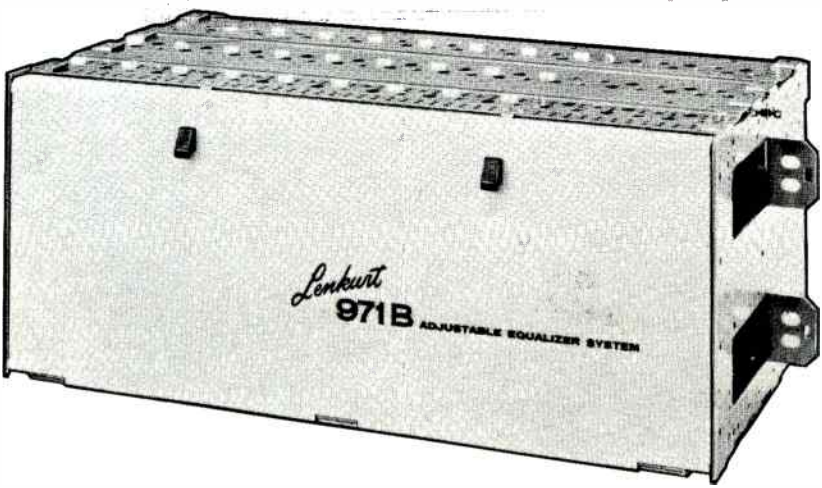

DISTORTIONLESS DATA

To send digital data over voice circuits — error free — is a snap with the Lenkurt 971B Adjustable Equalizer.

This little system does a big job. It compensates for both delay and amplitude distortion — quickly and easily.

For more information on this or other Lenkurt communications systems, call or write Lenkurt, Dept. C720.

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