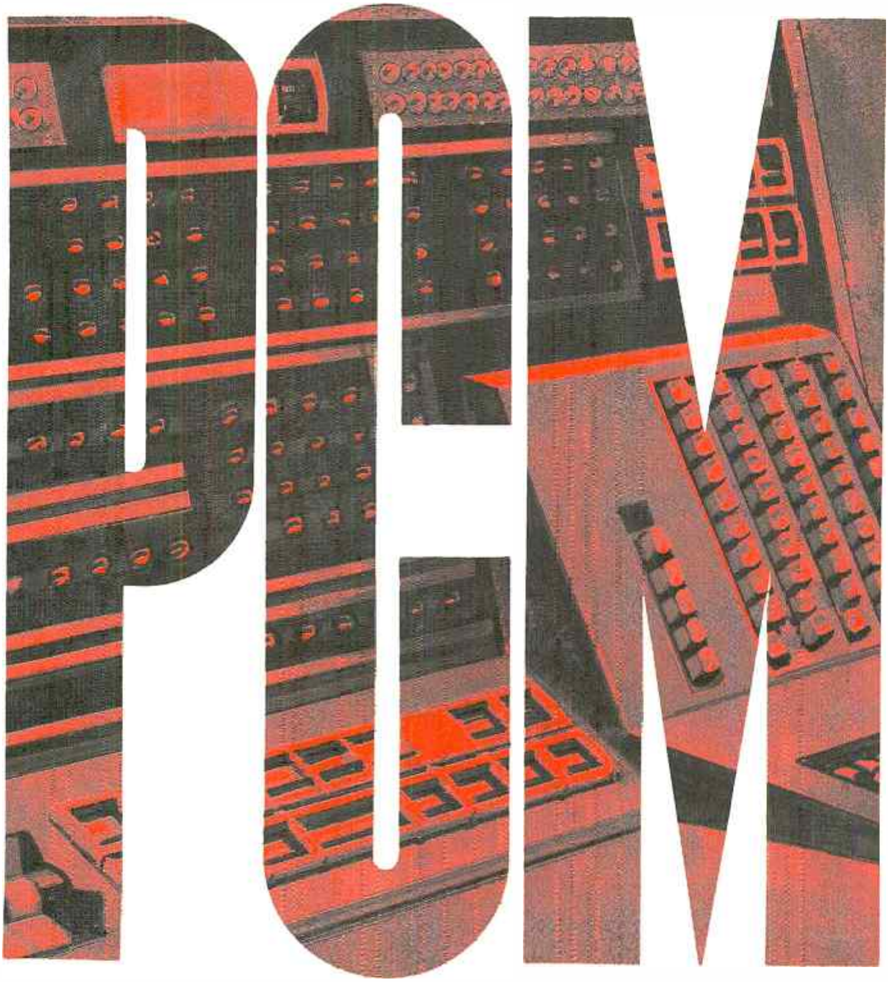
The Lenkurt® DEMODULATOR

APRIL 1968



Part 2

PCM

. . . . New concepts in data transmission, repeatered lines, and switching.

The entire concept of transmitting voice, television, or other analog information using a string of digital pulses – PCM – is unique. Beyond the initial treatment of the signal, so different in itself from frequency division multiplexing, there are many other significant and exciting factors which increase the telephone industry's responsiveness to this new technology.

The data carrying capabilities of PCM, for example, are startlingly high – for a reason. The span concepts of signal routing and repeatered lines themselves are dependent on digital transmission. And the possibility of direct PCM switching, without returning the signal to audio frequencies, is perhaps one of the strongest potentials of all.

Data Transmission

While PCM systems are designed especially for voice transmission, their digital format makes them particularly good carriers of data.

Relatively slow speed data, as would normally occupy no more than one voice channel, will be handled through an existing data modem such as the Lenkurt 26C. While this type of data set is designed to condition data signals for FDM transmission, and therefore has a tonal output, it can work into the T1 system. The data modem output is sampled by the PCM terminal the same as with a voice signal.

For higher speeds, special data modems must work directly into the repeatered line and in some cases be able to coordinate with D1 channel banks. Several data banks will be available to meet specific needs and will allow data speeds on the T1 line from 50 to 500 kb/s.

The economy of using the PCM line for data is clear. A 50 kb/s data signal displaces 12 voice channels on an FDM system, but takes only three channels on the T1 repeatered line. And even this efficiency is allowing for data that is not in synchronization with the line rates. If the incoming data rates precisely match the bit rates on the line – 1.5 Mb/s for the T1 – these synchronous signals can be transmitted on a bit-by-bit basis.

However, when asynchronous data must be handled, additional treatment of the information is necessary. Three T1 carrier bits are required for each data bit. The first transmitted bit indicates a data transition has occurred. The second bit carries information on the length of the data bit. The final bit relays the direction of the transition – that is, plus or minus.

Therefore, every time a data bit is received, three successive T1 bits are needed to transmit the information.

The mixture of voice and data signals on a T1 line is not without its own unique problems. The usual 8-digit "word" used to transmit voice is not a natural format for data. For example, if one-half the line bit rate is to be used for data, it seems logical that every other bit transmitted should be allocated to data. In the 8-digit grouping used for voice, this is impossible. But when data is the only

T1 LINE LOADING	NO. OF DATA CHANNELS	MAX. DATA RATE
1/8	8	64 kb/s
1/4	4	128 kb/s
1/2	2	256 kb/s
1/1	1	512 kb/s

Figure 1. Using alternate bits on T1 results in proportionate data loading.

service provided on the line, the most efficient method is to use evenly distributed data bits.

The Western Electric T1WB–1 and T1WB–2 wideband data banks derive data channels in this way, using the appropriate number of alternating bits. Only simple timing changes are necessary to accomplish a variety of data speeds. If the data bank clock is arranged to put a data signal into every eighth bit on a T1 carrier, this channel will have a maximum capability of 64 kb/s. However, this will be standardized as a 50 kb/s channel to match other transmission requirements. Other possible data speeds arrived at in this way are listed in Figure 1.

The T1WB–1 has several possible arrangements depending on the data traffic needs between specific terminals. The T1WB–2 is basically a condensed version, more economical where only 250 kb/s data is transmitted. Other combinations are listed in Figure 2.

Voice With Data

In many cases it will be desirable to mix voice and data on the same line. Since their formats do not coordinate, some conversion will be necessary.

It is possible, for example, to retime the 8-bit word of the standard PCM voice signal to fit into alternate data bits. Or, the reverse can be accomplished by transforming the data stream into 8-bit words. This has been done in a third data bank, the T1WB–3. It will multiplex up to four data channels, using the remaining space for voice transmission. Possible combinations of data and voice are listed in Figure 3.

The T1WB–3 operates in synchronization with the D1 channel bank. Framing bits and the line bit stream for voice channels originate in the D1 and are received and retransmitted into the T1 line by the T1WB–3. In the data bank, a timing network clears pulses from selected voice channels and leaves them clear for data signals.

An additional task must be performed by the data bank in translating the data to the 8-bit format. This is accomplished by storing the data bits and rearranging them into a time sequence proper for the preempted voice channels. The data bits are combined with the retransmitted voice bits and the total digital stream is sent over the T1 line.

Although the data bits occupy the space of a voice channel in the T1WB–3, they are not directly affected by the 8-bit format: the organization of information in the data word bears no relationship to the channel word.

Complementing the three wideband data banks is a single channel modem for speeds up to 500 kb/s. The T1WM–1 will provide more economical service when there is reasonable assurance that additional wideband channels will not be required. The modem could be operated at the customer's location over a dedicated repeatered line.

WIDEBAND BANK	CHANNEL ARRANGEMENTS
T1WB–1	8 CHANNEL – 50 kb/s
	4 CHANNEL – 50 kb/s 1 CHANNEL – 250 kb/s
	2 CHANNEL – 250 kb/s
T1WB–2	2 CHANNEL – 250 kb/s

Figure 2. Wideband data banks offer a variety of channel options.

Span Concept

The very nature of a digital transmission system allows a new way of looking at the line and the signal it carries between offices. In PCM terminology, a series of regenerative repeaters from one office bay to another is called a "span line".

Using the span concept, it is possible to provide spare lines and fault location on an individual span line basis. And administration for assignment, maintenance, and powering becomes easier. Any span line is just like the next and direct substitution is possible.

In an analog FDM system, losses in the line, at terminals, and in repeater equipment are all cumulative. Therefore, the routing of calls and the design of alternate routes are restricted to some maximum attenuation. The span concept offers some relief from this historic problem. Taking advantage of the new technology, it becomes much less important for trunk routing to be along the shortest distance between terminals.

In practice, span lines between two central offices may be in different cable sheaths and may even follow different geographical routes. But they are indistinguishable in use and in design. The span line is a known quantity to be used as needed, but which remains an independent entity in the system of which it is a part.

With the PCM system that maintains its four-wire nature throughout, a standard loss of about 3 dB can be obtained irrespective of the number of span lines used to complete the route. In the T1 system, span lines may be connected in tandem to a limit of something less than 100 miles.

Fault Location

When trouble occurs in the repeatered line, another unique feature of the PCM system — fault location — makes it possible to identify the exact trouble spot from the central office. First the fault span is taken out of service by patching. A spare span is easily substituted. Then a fault locating test set is used to find the defective repeater.

WIDEBAND BANK	CHANNEL ARRANGEMENTS
T1WB–3	1 CHANNEL – 50 kb/s 21 CHANNELS VOICE
	2 CHANNELS – 50 kb/s 18 CHANNELS VOICE
	3 OR 4 CHANNELS – 50 kb/s 12 CHANNELS VOICE

Figure 3. Versatile T1WB–3 mixes voice and data channels.

The fault locating scheme of the T1 system uses twelve different audio frequencies and an equal number of matching single-frequency filters – one for each repeater site. The audio frequencies are generated in the test set and introduced to the repeatered line as a set of digital pulses. These pulses, which appear as errors to the repeater, actually have within them an audio component (Fig. 4).

The frequency selective filter bridged across the output of each repeater will pick off a specific tone intended to test that repeater. The audio component is looped back to a "fault locating pair" which returns the signal to the testing office. There it can be analyzed and the proper performance of the repeater determined.

In this way a technician working at the exchange can test each repeater in the span without leaving the office. The frequency used determines which repeater housing is being tested; the cable pair selected will determine which repeater within the housing is under scrutiny. The 12 frequencies available make it possible to test 12 different repeater locations, or a total of 300 repeaters if the housings each contain 25 repeaters. If more than this number must be tested from a single office, an additional fault locating pair may be used and the interrogation capacity doubled.

PCM Switching

In its normal operation the regenerative repeater looks at an incoming signal train and literally recreates new pulses in the same sequence as they were originally transmitted. If, instead, the repeater could store the pulses momentarily, and then regenerate them in a different order, a form of switching could be accomplished. For instance, pulses originally representing channel 4 might be regenerated in the time slot allocated to channel 7.

Taken one step further, the device might connect channel 4 pulses from one system to channel 7 slots in another system. This could be used as a trunk switch operating in the PCM mode, without changing information to audio frequency just for the purpose of switching. Such a method of switching could have a decided economic effect on the PCM systems of the future as well as offering some interesting possibilities in plant planning and design.

There are presently three basic types of exchange switching: manual, electromechanical, and electronic. The electromechanical switch operates in response to the dial pulsing of the

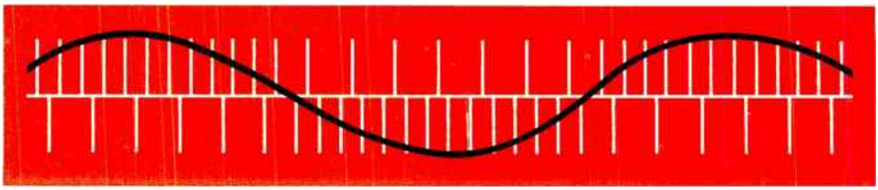
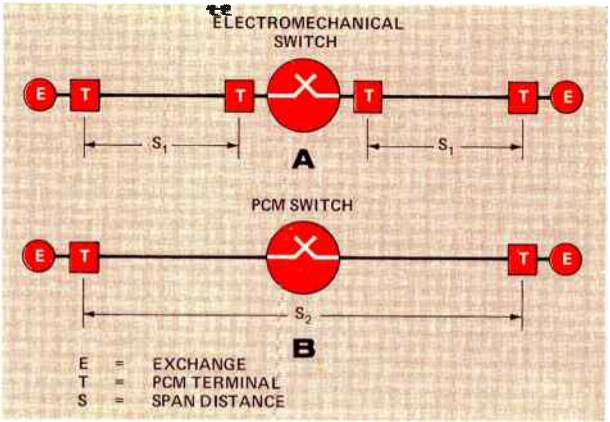


Figure 4. The audio component in the fault locating signal is caused by grouping "error" bits to create one of 12 frequencies.

Figure 5. The distance between terminals, used in figuring prove-in economics, could be lengthened considerably with PCM switching.



subscriber's telephone and is the most common method. Operating at 10 digits per second, the system has been adequate for most applications.

But Direct Distance Dialing within the United States – and soon global dialing – places tighter restrictions on the signaling time available. Tone dialing will help, and the installation of advanced crossbar switching machines offers some relief. But a variation of electronic switching now in operation at several locations lends itself directly to application with PCM switching.

In PCM transmission, the signaling information is contained within the pulse train and therefore arrives at the exchange at the rapid microsecond rate of the PCM signal itself. If electronic switching devices were available to match this speed, all functions could be carried out in phenomenal time. It has been estimated that the entire process of switching might be accomplished in about 100 milliseconds.

Direct PCM switching could offer much more than speed. If signals did not have to be demodulated for switching, considerable economic gain as well as improved signal quality could be achieved. Terminal equipment contributes a large percentage of total system cost. And most degradation in the system takes place at the terminals where signals must be transformed from one form to another. The use of PCM switching could reduce the number of terminal units required.

Prove-in Distance

System planning dictates that the transmission engineer must consider prove-in distances when adding new equipment, especially carrier systems. The cost of carrier equipment versus physical cable, for example, must be compared for a given system. Generally it is less expensive to use physical cable for short distances and carrier equipment for longer routes.

Consider an exchange system (Fig. 5A) linked by PCM and using electromechanical switching at the hub. PCM terminals are required at both ends of the span between the switch and the exchange. Therefore, this span distance must be equal to or more than the prove-in distance if the system is to be economical.

By introducing a PCM switch at the tandem exchange, two terminals are eliminated and the longer span distance between the two far terminals becomes the criteria for prove-in judgment (Fig. 5B).

Two benefits to the operating company become obvious — half as many terminals must be supplied, and many more short-haul exchange routes become eligible for PCM.

In most telephone companies approximately 70 percent of all trunk lines are 10 miles long or less. If the prove-in distance is greater than 10 miles for a typical system, then 70 percent of the facilitites cannot be profitably used with PCM. But PCM switching could effectively double the trunk lengths and produce a sizable increase in the number of trunks available for PCM transmission.

Switch and Delay

The elementary switching function is to detect a new call, absorb signaling information, and set up a path through the exchange to the outgoing system. In PCM switching, routing would involve not only finding a clear circuit leaving the exchange in the proper direction, but would also necessitate matching in time of the two channels.

After the information has been switched out of an incoming pulse train, a finite amount of delay would be necessary to fit the signal into the proper time slot of the outgoing circuit. Preference would be given to switching situations where the incoming call could go out on the same channel, thus requiring no delay. Fixed delay lines would provide the proper delay for moving pulses into the time slots of any of the other 23 channels.

Fitting nicely into the span concept, PCM switching could increase the company's ability to give the customer substantially uniform quality communication regardless of the distance and the number of switching stages involved.

PCM Compatibility

The nationwide telephone network — giant machine that it is — must grow and change while it continues to operate. Any new technology, such as PCM, must work with existing facilities. This means that PCM transmission must be carried out over present cable and work through the exchange as it is today. The first PCM systems of the T1 class have been introduced in just that way.

If PCM switching is adopted, it will be added to the existing system. It is possible — perhaps even economically advisable — that the PCM switching will be called on to work with FDM systems. Local converters could change FDM audio signals to PCM and back again for the purpose of switching. These converter units would be relatively simple devices, free of complicated synchronization problems in that both ends of the conversion would be made in the same office.

Conceivably, PCM techniques could be extended to the subscriber level. This would not only open the way to increased wideband service available at the home and office, but have a strong effect on PCM switching, making possible a complete integrated telephone network.

Perhaps only with the eventual installation of the transcontinental T4 coaxial system will an entirely new PCM facility be established. But it too will have to coexist with other systems, accepting PCM-coded FDM supergroups, and pulse streams from other PCM systems, the T1 and T2.

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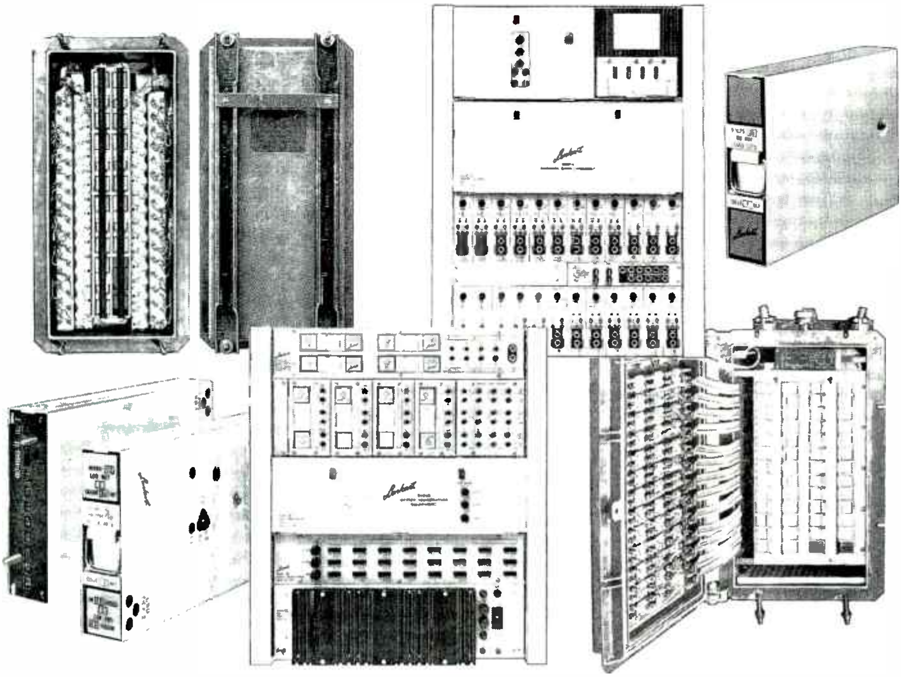

The **Lenkurt 91A Cable Carrier System** is completely compatible with the Western Electric T1 system. In addition, several advanced design features are unique to the 91A — all detailed in a new product brochure, available by writing Lenkurt, Dept. B720.

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