GTE LENKURT

DEMODULATOR

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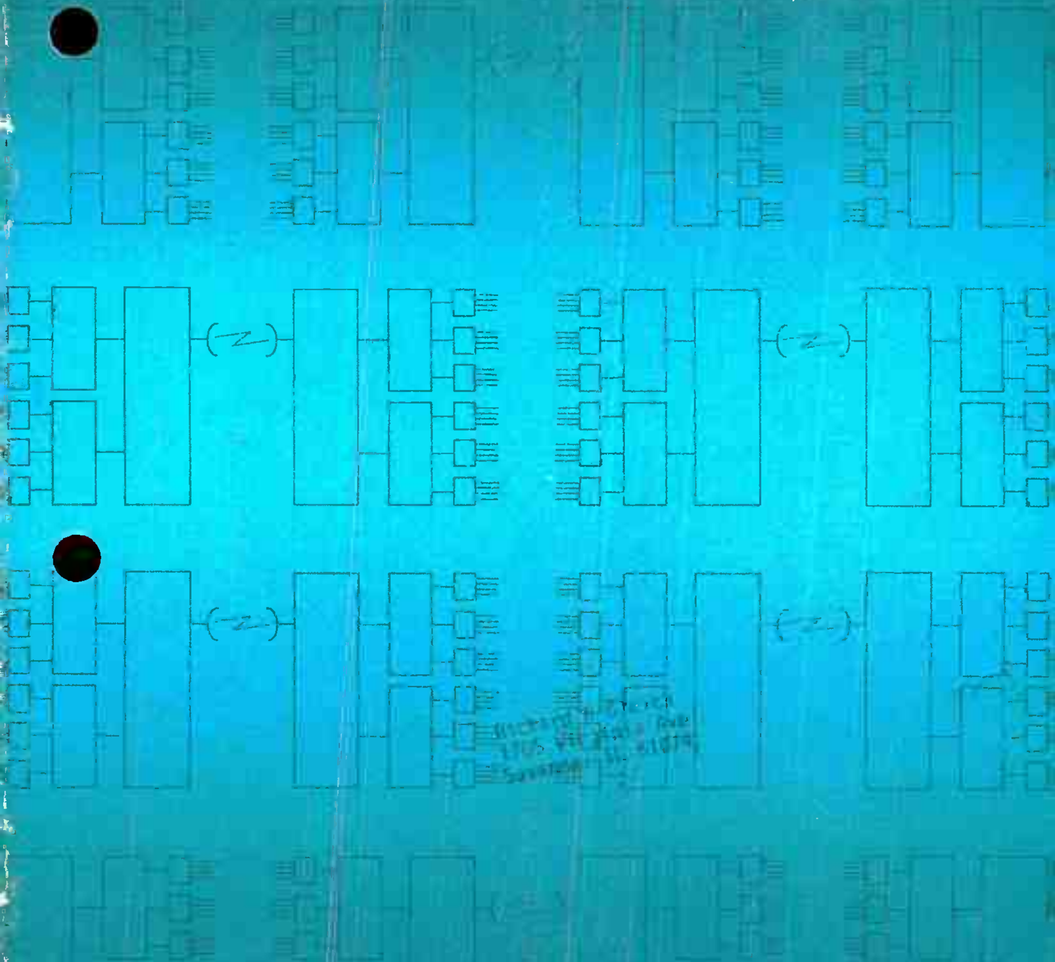

DIGITAL RADIO

Also in this issue: **DATA SET INTERFACES**

For more than a decade vf cable pairs have been the primary transmission medium of pulse code modulation (pcm) carrier. However, the pcm carrier load of the exchange and toll cable plant is nearing its limit in some parts of the world's public telephone networks. Considering the recent sharp rises in the cost of new cable plant construction, network engineers are turning their attention to other pcm transmission media for network expansion. At this time they are finding digital microwave radio to be a very attractive alternative to cable in several areas of the networks.

Modern society is insisting that the channels of human communication convey an ever-increasing mass of information to its destination within an ever-decreasing period of time. Of all the communication media, none is feeling the impact of this social demand more than the telecommunication networks. Although person-to-person telephone conversations still account for the larger volume of traffic, there has been in recent years a phenomenal growth in other types of traffic such as data, telemetry, facsimile, and radio and television network programs.

Most of this traffic is naturally concentrated near the population centers of the world. The trunk circuits in and around these areas frequently tend to be overloaded with traffic. From the early 1960's to the present, pcm cable carrier has helped network engineers reduce this tendency. It has enabled them to load 24 voice circuits onto the vf pairs of exchange and toll cables in place of a single voice circuit or some other type of cable carrier with less channel capacity.

The number of cable pairs available for pcm carrier in most of these densely populated areas is rapidly diminishing. Little, if any, space remains in the underground conduits to accommodate more cable. Since the demand for more circuits continues to rise, engineers are compelled to investigate the various avenues open to them to meet the demand. One possibility is to build more cable conduits, but the construction costs are usually quite prohibitive in the larger cities. Another alternative is to re-engineer the existing cable for 48-channel pcm carrier systems, but this too may require some amount of new construction. Another possibility that currently is being evaluated is the use of optical fibers as the transmission medium. Optical fibers have a very broad transmission bandwidth sufficient to handle several hundred channels of pcm. Also, the empty spaces between copper cables in existing conduits is often adequate for one or more bundles of optical fibers. But transmission over optical fibers is still a developing technology and the cost of such transmission systems is still quite high.

The medium, though, that at the moment seems to be gaining most favor with network engineers is digital radio. In the crowded urban areas as well as other locales, the transmission of pcm over microwave radio has proved to be a most economical method.

Definition

It seems that no universally accepted definition of the term "digital radio" exists. There are those who prefer to limit the use of the term to microwave radios in which one or more properties (amplitude, frequency, and phase) of the radio frequency (rf) carrier are quantized by the modulating signal. In other words, the term is properly applied only to radios whose instantaneous rf carrier can assume one of a discrete set of amplitude levels, frequency shifts, or phase shifts as a result of the modulating signal. This definition contrasts digital with analog radio in which instantaneous variations in the amplitude, frequency or phase of the rf carrier are proportional to the instantaneous amplitude of the baseband signal over its full amplitude range. The rf filters alone in this type of digital radio control the bandwidth of the radiated signal.

Others prefer to expand the definition of the term to include radios in which the intermediate frequency (if) carrier or even the baseband signal is quantized by means of a modem. In such a radio the rf carrier is still quantized, but baseband or if filtering can be used to provide some bandwidth control and thereby reduce rf filtering requirements.

There are still others who contend that the term "digital radio" is aptly applied to any radio that transmits a signal whose informational content is, in whole or in part, digital in format. This definition fits, in addition to those previously mentioned, radios in which the baseband load is a mixture of analog and digital information. In the United States the Federal Communication Commission (FCC) appears to lean toward this definition for type acceptance of digital radios and for assignment of a digital emission designator to a radio. The Commission's rule states: "Digital modulation techniques are considered being employed when digital modulation contributes 50 percent or more to the total peak frequency deviation of a transmitted radio frequency carrier." The Commission goes on to explain that the total peak frequency deviation is determined by adding the deviation produced by the digital modulation signal to the deviation produced by any frequency division multiplex (fdm) modulation used. Thus, in the eyes of the Commission, so-called "hybrid radios" may be considered digital, depending on how much of the peak frequency deviation is produced by the digital modulation signal.

In this discussion, therefore, the term "digital radio" is used to refer to any microwave radio that transmits pcm carrier signals, regardless of how or at what point the signals are inserted into the radio equipment.

PCM Multiplex Hierarchies

The Bell System, when it introduced pcm carrier, established a multiplexing structure and designated it the T carrier system. The framework of this carrier system consists of a multiplexing hierarchy whose several levels are based on the bit rate of the multiplexed line signals. The first level, referred to as T1, is the basic building block of the system and consists of a digital group of 24 channels time-division multiplexed (tdm) to form a 1.544 megabits-per-second (Mbps) line signal (DS-1). The second multiplexing level, T2, combines four T1 line signals to form a 6.312 Mbps line signal (DS-2). Figure 1 tabulates the multiplexing levels of the T-carrier system and the number of T1 lines required to derive them. The T1C multiplexing level, which was introduced after the system hierarchy had been established, is not listed in the hierarchy. This level combines two T1 line signals to produce a 3.152 Mbps signal.

The International Telegraph and Telephone Consultative Committee (CCITT) recommends two basic time division multiplex hierarchies. The one corresponds to the Bell System plan just described and is followed throughout North America. (Japan follows a similar plan, inasmuch as it is based on a DS-1 digital group line rate of 1.544 Mbps, but the line rates of some of the other levels differ from those in the T carrier system.) The other hierarchy, which the CCITT recommends, is based on a digital group of 32 channels (30 voice channels, one signaling channel, and one framing or synchronizing channel) whose line rate is 2.048 Mbps. This plan is prevalent in Europe. The levels and line rates in this hierarchy are also listed in Figure 1.

One reason for mentioning the pcm multiplexing plans is to point out the incompatibility that exists between the two, though some equipment manufacturers, it seems, are investigating "hybrid" multiplexers that would allow the application of radios designed for the T carrier hierarchy to the European hierarchy. A second, and possibly more significant reason, is to point out that the FCC rule regulating the minimum number of voice channels a radio must be capable of transmitting in the frequency bands above 2-GHz does not directly relate to the multiplexing hierarchy. This is readily seen by comparing the data in Figure 1 with that in Figure 2. It should be noted that these channel limitations presently apply only to radios operated in the frequency bands assigned

	LEVEL				
	1	2	3	4	5
BELL T CARRIER					
NUMBER OF VOICE CHANNELS	24	96	672	4032	
LINE BIT RATE (MBPS)	1.544	6.312	44.736	274.176	
DESIGNATION	DS-1	DS-2	DS-3	DS-4	
JAPAN					
NUMBER OF VOICE CHANNELS	24	96	480	1440	5760
LINE BIT RATE (MBPS)	1.544	6.312	32.064	97.728	400.352
EUROPE					
NUMBER OF VOICE CHANNELS	30	120	480	1920	7680
LINE BIT RATE (MBPS)	2.048	8.448	34.368	139.264	560.

Figure 1. The International Telegraph and Telephone Consultative Committee (CCITT) recommends two pcm multiplexing hierarchies based on a 24 or 30 voice channel group.

FREQUENCY RANGE	MINIMUM NUMBER OF VOICE CHANNELS	RADIO CHANNEL BANDWITH
2110 TO 2130 MHz	96	3.5 MHz
2160 TO 2180 MHz	96	3.5 MHz
3700 TO 4200 MHz	1,152	20 MHz
5925 TO 6425 MHz	1,152	30 MHz
10,700 TO 11,700 MHz	1,152	40 MHz

Figure 2. In the United States the Federal Communications Commission (FCC) has established the minimum number of voice channels radios operating in certain common carrier frequency bands must be capable of transmitting.

to Domestic Public Radio Services (common carrier) below 15-GHz. The FCC has not yet set similar limitations on radios operated in the Private Operational-Fixed Microwave Service (industrial) frequency bands. For this reason radio manufacturers currently offer only the "hybrid" type radio to industrial users for digital transmission.

Muldems

Since there is not a total correspondence between the channel limitations imposed by the FCC and the multiplexing levels in the T-carrier family, equipment manufacturers have chosen to design their pcm multiplexers/demultiplexers (muldems) to conform with the T-carrier multiplexing levels. This choice allows them to offer for each multiplexing level a basic muldem that, with only variations in the line interface circuitry, can operate over any of the transmission media capable of handling the frequency spectrum of the signal. But this choice also effectively imposes greater constraints than those already imposed by the FCC on the design of 4-GHz, 6-GHz, and 11-GHz radios. It necessitates placing within FCC bandwidth limitations more than 16 percent more voice channels than the FCC requires. This increase in the number of channels increases the number of bits per Hertz of bandwidth which, in turn, requires the use of more sophisticated modulation and rf filtering techniques in the radio.

The T1 level muldem or pcm channel bank seldom interfaces directly with the radio or baseband equipment except in industrial applications where the baseband is a mixture of digital and analog signals. Even in such applications some type of digital modem serves as the actual interface. The modem usually has at least two, and sometimes four, inputs for T1 lines. The modem, by means of encoding or modulation, produces an output whose spectrum occupies only a certain portion of the baseband. Common carriers make use of similar modems for data-under-voice (duv) applications. The input signals of this modem, however, are made up of combined data rather than voice channels.

Four DS-1 line signals are multiplexed by a T2 level muldem to produce a line signal which contains the minimum number (96) of voice channels that the FCC specifies for microwave transmission in the 2-GHz band. Like the T1 muldem, the T2 interfaces with the radio baseband by way of a digital modem. In order to fit 96 voice channels within the 3.5 MHz rf bandwidth of the radio, the modem must be capable of encoding four bits per Hertz at the baseband. One such modem accomplishes this by using a 7-level modified duobinary encoding technique that some refer to as a partial response filtering technique.

The spectral characteristic of the output signal from this modem allows a vf order wire channel to occupy the first 8-kHz of the baseband spectrum. This composite baseband signal is applied to a standard fdm radio terminal. A block diagram of the basic functions found in this system is provided in Figure 3.

Two types of T3 muldems are available to interface with 4-GHz, 6-GHz, and 11-GHz radios. One type provides seven inputs for T2 line signals; the other provides 28 inputs for T1 lines. The radios themselves must be capable of transmitting two 44.736 Mbps T-3 line signals (DS-3) to satisfy FCC voice channel requirements, assuming the T carrier hierarchy remains intact. The FCC does authorize 20-MHz radio channels in the 11-GHz band; in which case, the radio must be capable of transmitting only one T3 line signal.

The 20-MHz rf bandwidth restriction the FCC places on the 4-GHz radio together with its minimum voice channel requirement has so far disinclined manufacturers from developing a digital radio for this band due to the complexity of the modulator, demodulator, and rf filters in such a radio. Most manufacturers, therefore, are directing their attention and effort toward the design of digital radios for the 6-GHz and 11-GHz common carrier bands. And even in these bands compliance with FCC limitations on channel capacity and rf bandwidth is not easily attained.

The FCC has not yet placed the same restrictions on radios operating in the common carrier band above 15-GHz that it has placed on those operating below 15-GHz. At present the FCC allocates to radios in these higher bands rf bandwidths sufficient to accommodate the line signal (DS-4)

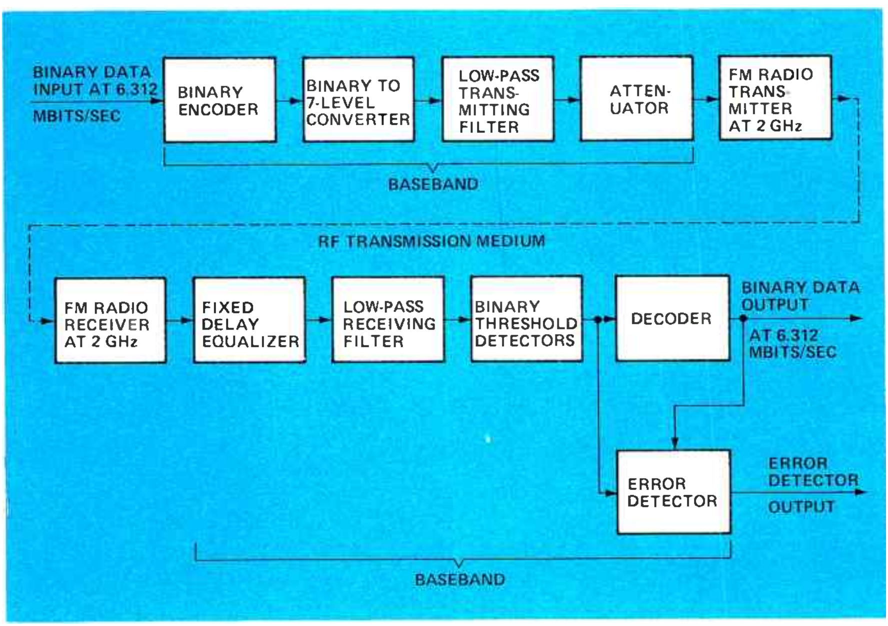

Figure 3. Block diagram of a 7-level modified duobinary digital transmission system over a 2 MHz FM radio.

of a T4 muldem. Test systems of radios operating in these higher bands exist in the United States, Great Britain, and Japan, but certain inherent properties of these systems make them less attractive than 6-GHz and 11-GHz systems. Less transmitter output power, greater path attenuation from rain and fog, and more critical antenna orientation are some of the major drawbacks of these systems.

Other digital multiplexers than those just described are available, but they are generally not considered for voice channel applications in the common carrier radio frequency bands because they do not conform to the T-carrier multiplexing hierarchy.

Modems

In order to transmit the digital output signal of one or another multiplexer over radio, the signal must be modulated onto the radio carrier at the transmitter and demodulated from the carrier at the receiver. The device that performs this modulation and demodulation function is commonly called a modem. The modem, as mentioned previously, may interface the radio equipment at the baseband, intermediate frequency, or radio frequency level. The modulation schemes most frequently used in digital radio modems is some form of frequency shift keying (FSK) or phase shift keying (PSK), the latter seeming to be the most popular.

The primary function of a modem is to encode one or more bits of the digital input signal into a *symbol* signal whose bit content determines the modulating effect it is to have on the amplitude, frequency, or phase of the carrier. The number of bits encoded into each *symbol* signal is constant and each of the bits encoded may have a binary value of 1 or 0. Each different combination of bit values that may be encoded into a *symbol* signal corresponds to a logic level within the encoder. Thus, a two-bit-per-symbol encoder requires four logic levels to encode all possible combinations of bit values. A three-bit-per-symbol encoder requires eight logic levels. The logic level the encoder assigns a particular bit combination defines a discrete amplitude, frequency, or phase produced in the carrier at the moment of modulation. Some of the many types of digital modulation techniques now being used in digital radio modems are listed in Figure 4. Lest some confusion arise over the fact that modified duobinary encoding makes use of seven logic levels to encode two bits per symbol, it should be noted that three

TYPE OF MODULATION	NUMBER OF LOGIC LEVELS	NUMBER OF BITS PER SYMBOL
AMPLITUDE (AM)	2	1
FREQUENCY–SHIFT KEYING (FSK)	2	1
SEVEN LEVEL MODIFIED DUOBINARY	7	2
2 PHASE–SHIFT KEYING (2PSK)	2	1
4 PHASE –SHIFT KEYING (4PSK)	4	2
8 PHASE–SHIFT KEYING (8PSK)	8	3
16 PHASE–SHIFT KEYING (16PSK)	16	4
QUADRATURE PARTIAL RESPONSE SIGNALING AM (QPRS AM)	16	4

Figure 4. Various digital modulation techniques are used in order to meet the spectral efficiencies required by the FCC in digital radio transmission.

of the four bit combinations can each be represented by either of two logic levels. The fourth combination is represented by only one level.

One modem currently being developed, using 8 PSK modulation techniques to modulate an IF carrier, is shown in Figures 5 and 6. The modem has a 90 Mbps transmission rate which provides sufficient capacity to accommodate two standard 44.736 Mbps DS-3 signals. A multiplexer is used to

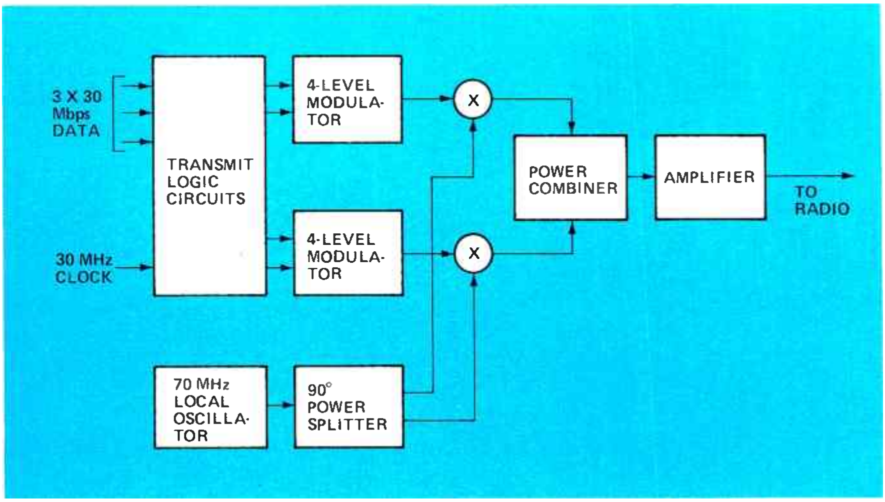

Figure 5. Block diagram of a modem transmitter in which 8 PSK modulation is used to modulate a 70 MHz intermediate frequency carrier.

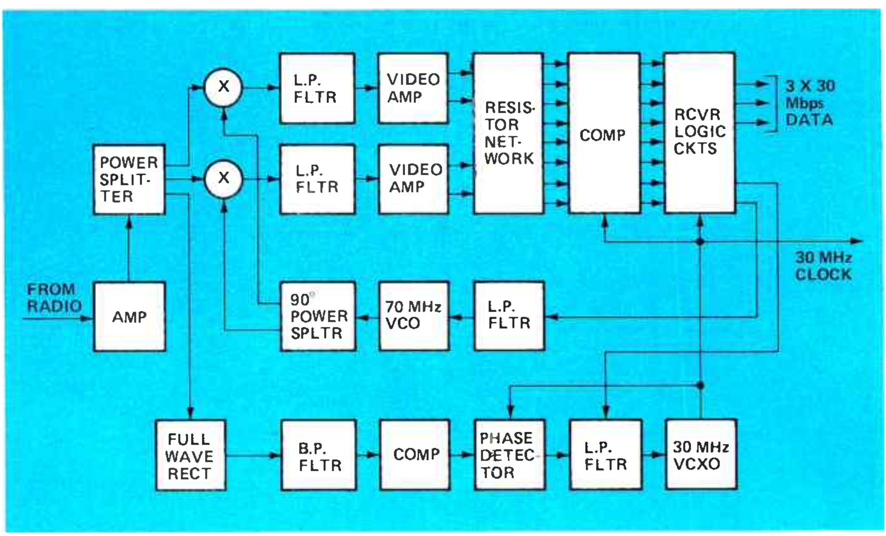

Figure 6. Block diagram of a modem receiver in which a 90 Mbps signal is recovered from a 70 MHz intermediate frequency carrier.

derive from the two DS-3 signals the three 30 Mbps data inputs and 30 MHz clock input into the modem. By using 8 PSK type modulation the modem can transmit the 90 Mbps of information within FCC bandwidth requirements for 6-GHz and 11-GHz digital radios.

Another method being used to transmit 90 Mbps of information within FCC radio channel bandwidths is antenna cross-polarization. This method requires two radio transmitters to operate at the same frequency over the same path. One radio transmits one DS-3 signal in a horizontally polarized plane; the other transmits another DS-3 signal in a vertically polarized plane. In a system of this kind four logic levels of encoding in the modem are sufficient to confine the modulated carrier within FCC bandwidth limitations.

Conclusions

In certain parts of the world's telecommunication networks digital microwave radio is supplanting cable as the transmission medium for pcm carrier. In the United States FCC rules and regulations as well as the Bell System pcm hierarchy place definite constraints on digital radio designs. The propagation path environment adds other design constraints to the equipment. A future *Demodulator* article will review these constraints and other important aspects of digital radio.

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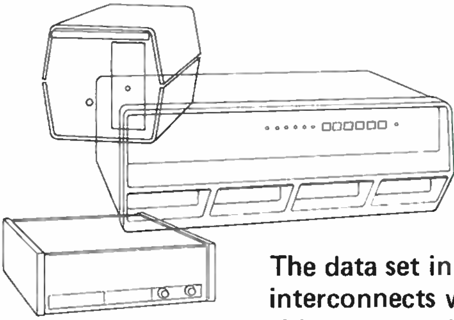

DATA SET INTERFACES

The data set in a data communications system interconnects with some type of business machine on one side and communication facilities on the other. These two points of interconnection are called interfaces. Over the years different agencies and organizations have worked to reach agreement on what characteristics the interfaces should have.

An interface is that point where two different pieces of equipment or two different parts of a system interconnect. There are several points in a data communications system that equipment manufacturers and users commonly designate an interface. Two of the interface points most often encountered in a data communications system lie on either side of a piece of equipment variously called the data modem, data set, data subset, data communication equipment, or data circuit-terminating equipment. One interface is the point where circuits in the data circuit-terminating equipment (DCE) interconnect with circuits in the data terminal equipment (DTE). The DTE may be one of various pieces of equipment in which data transmission originates or terminates such as a computer, teleprinter, punched-card reader, data display terminal and other similar devices. The designation commonly assigned to this point is the "data interface." The other interface is the interconnect point between the DCE and the transmission medium. The medium is normally a two- or four-wire metallic circuit furnished by the telephone company or other supplier of carrier facilities. This point is ordinarily referred to as the "communication interface." Figure 1 is a simplified layout of a data communication system in which these two interface points are identified.

As is true of the interconnect points between other pieces of electronic equipment, each of the two DCE interfaces just mentioned must have specific and well-defined electrical and mechanical characteristics for proper mating and operation of the equipment on either side of the interface points. Since one manufacturer seldom supplies both the DTE and the DCE or the DCE and the transmission facility, the user must have some assurance that the two pieces of equipment can be interconnected and operate together. But the two suppliers often are unknown to one another. In order to give the user the assurance he desires, the suppliers might be obliged to spend a considerable amount of time and money becoming acquainted

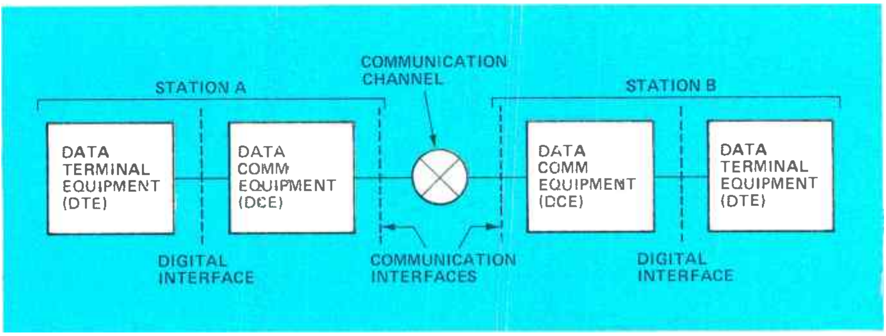

Figure 1. The data set in a data communication system ordinarily interfaces with the data terminal equipment and the communication channel.

with one another and arriving at some agreement on the type of interface to be supplied.

Fortunately, there is another avenue of approach ordinarily followed in dealing with this type of situation.

Early in the growth of the data communications community many of its members, frequently finding themselves confronted with similar equipment interface problems, expressed a common interest in drawing up standards for the interconnection of equipment in a data communication system. Rather than form a new standards organization, interested individuals sought and received recognition and association with other nationally and internationally established standards organizations. Within these organizations they set up committees to define equipment interface parameters to which user and manufacturer alike could assent.

The first data equipment interface standard to be published and to receive widespread acceptance in the United States was the Electronic Industries Association (EIA) Standard RS-232 bearing the title, "Interface between Data Terminal Equipment and Data Communications Equipment Employing Serial Binary Data Interchange." This standard has undergone three revisions since its release in 1960, the current revision being RS-232-C. New generations of equipment offering more sophisticated modes of operation ordinarily dictated the need for a revision. Each revision demonstrated the interest of industry in keeping the standards current and abreast of the changes occurring in the state of the art.

The current revision of the standard places the interface or interchange circuits into four general categories: ground or common return, data circuits, control circuits, and timing circuits. All the circuits are unbalanced having a common signal return path. Figure 2 is a presentation of an interchange equivalent circuit. Each circuit contains a driver or signal source and a terminator or signal sink. One of these circuit elements is located in the DTE, the other in the DCE. Their location is determined by the direction of signal flow in the particular circuit.

The standard does not designate a specific electrical connector to be used at the interface, but it does state that it is to be a pluggable type, of which the female part is associated with the DCE and the male part with the DTE. The connector is to be equipped with

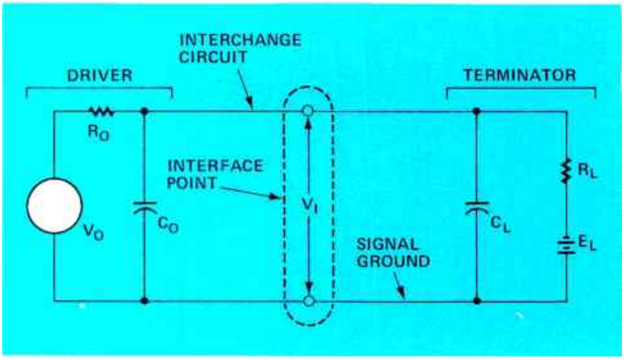

Figure 2. Interchange circuits as defined by EIA Standard RS-232-C consist of a driver and a terminator operating in an unbalanced mode.

at least twenty-five consecutively numbered pins. The circuits defined in the standard are each given a specific pin number assignment.

RS-232-C also recommends that the length of cable interconnecting the equipment not exceed fifty feet, though it does permit longer cables provided that the total load capacitance (C_L) measured at the interface point does not exceed 2500 picofarads. This limitation on cable length arises from the electrical characteristics of the interface circuits and certain interface signal parameters as defined by the standard.

Shortly after the release of RS-232 in the United States, the International Telegraph and Telephone Consultative Committee (CCITT) issued Recommendation V.24, and, some years later, Recommendation V.28, which together set forth data interface standards nearly identical to those in RS-232, for use by its world members.

These three documents and their several revisions have until now served their respective adherents well. But the advances in integrated circuit design for DTE and DCE applications, and user demands for higher data signaling rates and increased cabling distances between equipment have convinced standards groups of the need to draw up totally new interface standards.

New Versus Old

The new data or digital interface standards are no longer contained in a single document as they are in RS-232. Those involved in the development of the new series of interface standards determined that the electrical characteristics of the interface should be defined in general-purpose documents, so that the scope of their application could be broadened to include any interconnection of binary signals between voice or data equipment. EIA subcommittee TR30.1 issued in 1975 two standards, RS-422 and RS-423, that specify those characteristics. RS-422 establishes the electrical characteristics of balanced voltage digital interface circuits; RS-423, of unbalanced circuits. CCITT has issued corresponding recommendations for the international community.

EIA subcommittee TR30.2 was given the task of drawing up new standards defining the mechanical and functional characteristics of the digital interface between the DTE and the DCE. That standard, RS-449, has just recently been released.

Some of the important differences between the new EIA standards and RS-232-C are the following:

(1) Two connectors, a 37-pin and a 9-pin, replace the 25-pin connector commonly used in RS-232-C appli-

cations. The physical dimensions and mechanical features of the connectors are now clearly defined. The 37-pin connector accommodates all the interchange circuits except secondary channel circuits; the 9-pin connector accommodates them.

(2) Depending on the digital signaling rate, the cabling distance between the DTE and the DCE can be extended beyond the RS-232-C fifty foot limit to slightly more than 200 feet. The maximum signaling rate, for which the standard is applicable, has been extended from 20,000 bits per second (bps) to 2,000,000 bps.

(3) RS-449 defines ten exchange circuits not previously included in RS-232-C. Three circuits formerly defined in RS-232-C do not appear in RS-449. Most of the new circuits provide control and status functions for different operating modes of the equipment.

(4) The new standard establishes an entirely new set of circuit names and associated mnemonics.

(5) The electrical characteristics of the interface have been completely revised so that the basic components of the circuit, the generator and receiver, can be implemented in integrated circuit technology. The electrical parameters of these components are specified such that both balanced and unbalanced type circuits may be used within the same interface connection. In fact, RS-449 classifies the interchange circuits into two categories. Category I circuits may be balanced or unbalanced, depending on the data signaling rate; Category II circuits are always to be unbalanced.

The two EIA subcommittees that developed the new standards gave close attention to the selection of parameter values that would facilitate the interconnection of new RS-449 equipment with the older RS-232-C equipment without costly retrofits. Jointly they issued an application note that provides guidance for implementing this type of interconnection.

Communication Interface

In most countries the supplier of the carrier facilities solely determines and controls the interface between the data set and the carrier facilities. But in the United States the Federal Communications Commission (FCC), following a recent denial of an appeals hearing by the Supreme Court, has taken the definition of this interface under its jurisdiction. In Part 68 of its Rules and Regulations the FCC has determined that all data sets connected to the public switched telephone network after a certain date, yet to be determined, shall be registered by the FCC or shall be connected to the network through a protective device registered by the FCC. In the past the telephone company has required that customer-owned data sets be connected to the public network through a data access arrangement (DAA) furnished by the telephone company. The DAA provided electrical isolation between the customer's equipment and the network to safeguard the telephone company's equipment and personnel from exposure to hazardous voltages that might be generated in the customer's equipment. The DAA also limited the signal level applied to the loop thereby removing the possibility of excessively high-level signals disrupting service to other telephone company customers.

Now, according to Part 68 of the Rules and Regulations, the equipment manufacturer is obliged to include isolation and level control circuits for

Program Resistor Auto adjusts output of MODEM

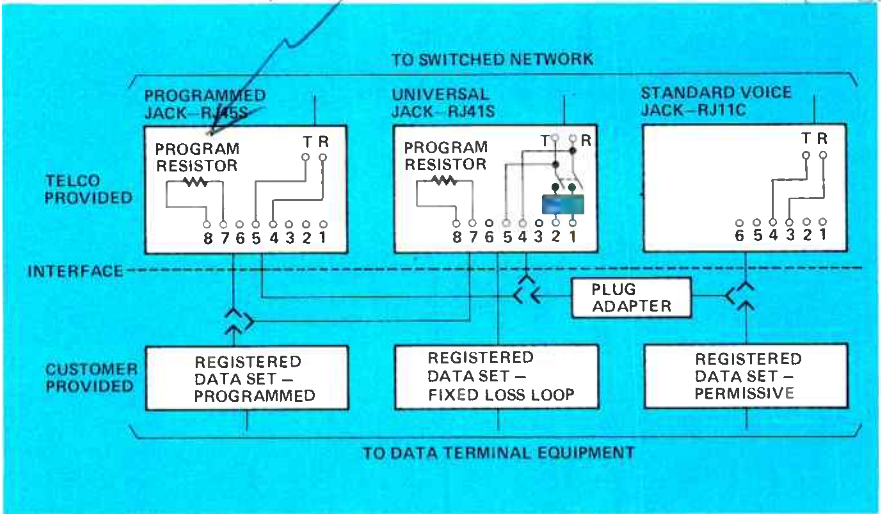

Figure 3. Part 68 of the FCC Rules and Regulations defines three classes of registered data sets based on output signal power of the data set.

network protection in his equipment, if he expects to register it with the Commission. Prior to connecting registered equipment to the telephone network, the customer must notify the telephone company of the particular line(s) to which the connection is to be made and shall provide to the company the FCC registration number and ringer equivalence number of the registered equipment. Based on this information, the telephone company is to install on each line one of three standard jacks to which a corresponding standard plug furnished with the registered equipment is connected. Figure 3 presents the three standard jacks and the three classes of data sets that may be connected to one or another of the jacks.

The FCC registration program is primarily set up to insure that the transmitted signal level received on the customer's loop at the telephone central office does not exceed –12 dBm. To make certain that registered data equipment when connected to the network conforms to this signal power requirement, the FCC restricts the output power of each class of data set. The maximum output data signal level that a permissive type data set can transmit is –9 dBm. The average attenuation of a business loop is 3 dB. The permissive type data set, therefore, can interface with the network through any one of the three standard jacks without the need for additional attenuation in the jack box. However, a 6-pin to 8-pin adapter must also be used when the data set is connected to a universal or programmed jack.

The Commission limits the output power of a data set registered as a fixed-loss-loop type to –4 dBm maximum. This type of data set may be connected to the network only through a universal jack which has provision for a pad to insert up to 8 dB of attenuation in the loop. The telephone company at the time of jack installation is to measure the loop loss and determine the amount of additional attenuation that must be inserted in the loop by means of the pad in order not to exceed the −12 dBm signal power limit.

The programmed type data set may be connected to the network through either a programmed or universal jack. The output power of this data set may vary in 1 dB steps from 0 dBm to −12 dBm. The telephone company, based on loop loss measurements made at the time of installation, inserts a program resistor in the jack box against which the data set programs its output signal level. The FCC does not specify how the data set is to sample the value of the resistor in order to set its output signal to the correct level, but the telephone company does suggest one method of implementing the resistor into the output circuit of the data set.

In those systems where a customer chooses to use an unregistered data set, the data set may be connected to the public telephone network only through a registered protective device. The protective device interfaces the network in exactly the same manner as a registered data set—through one of the standard jacks previously mentioned. How the data set is to interface with the protective device has not yet been defined by any standards organization. However, EIA subcommittee TR41.4 is currently developing a standard for this interface that is expected to be published late in 1978.

Standards organizations throughout the world are continually developing new standards in an effort to keep pace with the exploding technology. Increased cooperation between the various groups is resulting in the development of standards that are more universally acceptable. There is growing hope that one day a single set of standards can be drawn up that will meet everyone's requirements.

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