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the Lenkurt Demodulator

Operating Standards

For Frequency Division Multiplex Systems

Operating standards in the communications industry help to provide an efficient means of linking together hundreds of separate and independent networks throughout the world. They are necessary to achieve uniform performance and to insure high quality transmission. This article mentions the prominent communications agencies that have contributed to standardization, and discusses some of the important characteristics needed to interconnect different frequency division multiplex systems.

One of the most valuable assets of any society is freedom of communication. The unrestricted transfer of information and ideas is vital to promote education, commerce, business, and government operations, and to protect the welfare and security of a free nation.

The vast telecommunications networks that have been developed in the United States and the rest of the free world have indeed become great national resources. These networks carry voice and telegraph messages and a variety of other forms of communications such as data, facsimile, and television, to almost any place in the world. The services provided by these networks must be reliable, economical, and increasingly useful in order to advance user satisfaction.

The enormous success of the communications industry certainly can be attributed to continual improvements made in the quality of service and to the increasing efficiency of equipment and facilities. This, of course, has resulted in lower costs and has permitted almost everyone to fulfill his essential communications needs.

Perhaps one of the most significant factors that has contributed to the progress of communication systems has been the development of universal *operating standards.* To achieve total worldwide communications, thousands of separate networks have to be linked together. It is extremely desirable, therefore, that each of these networks be able to handle the same types of electrical signals. If it is relatively easy to transfer signals from one system to another, the communications services are apt to be more economical and efficient. In a growing and dynamic world, it would certainly be impractical to develop communications networks that, because of technical differences, could not transfer messages to adjacent systems without complicated and expensive conversion equipment. This would be tantamount to railroad systems having tracks of different gauges!

It is also very important that each network preserve the quality of transmission. This means that the performance characteristics of these systems must conform to a *set of rules* which specify standards of operation. In answer to this, many written standards and practices have been developed to cover not only operating problems, but almost every aspect of electrical communications. These standards provide the basis of comparing and evaluating the performance of communications systems. Although the use of such standards often is not obligatory, they are essential and are generally recognized and accepted by the communications industry. The particular standards adopted depend, of course, on the type of system, its intended use, and the performance requirements necessary to interconnect it with other systems.

Who Issues Standards?

In the United States, the most widely used standards or performance objectives are those of the Bell System and the Department of Defense. The Bell System has developed most of the standard practices that are used by the telephone industry to interconnect long-haul multiplex and carrier systems in North America. These standards are contained in publications known as *Bell System Practices (BSP's).*

For the huge worldwide Defense Communications System (DCS), a separate set of standards has been established. Operation of the DCS is controlled by the Defense Communications Agency (DCA) which issues DCS Engineering-Installation Standards to assure uniform high-quality performance of each segment of the system. Where appropriate, these military standards agree with those developed for use by the telephone industry.

There are other agencies and organizations that play a very active role in developing operating standards for carrier and multiplex systems. Prominent among these are the Communication and Signal Section of the American Association of Railroads (AAR) and the Rural Electrification Administration (REA) of the Department of Agriculture. Also, the Electronics Industries Association (EIA) has been very active in helping to standardize the characteristics of digital data signals that are to be transmitted over communications systems.

Another important set of standards used in the development of carrier telephone systems is produced by an organization known as the International Telegraph and Telephone Consultative Committee (CCITT). This body is a branch of the International Telecommunications Union (ITU), located in Geneva, Switzerland. The ITU is an agency of the United Nations.

The CCITT issues recommendations for standardizing international telephone and telegraph circuits. The need for such recommendations developed originally in Europe where many dif-

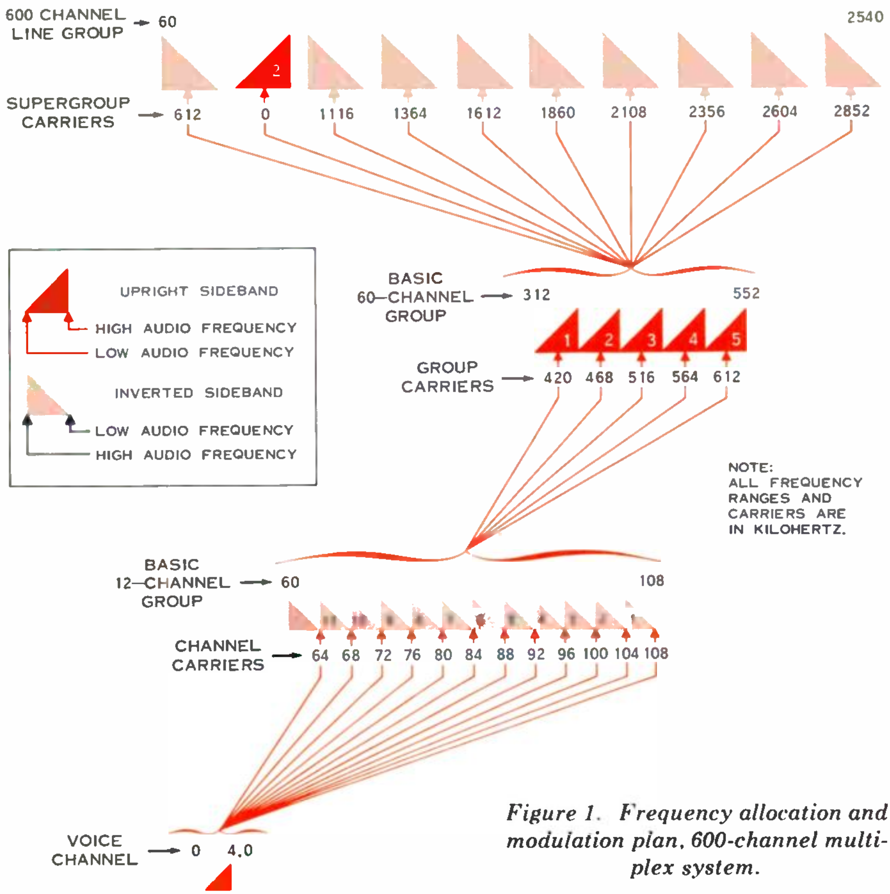

Figure 1. Frequency allocation and modulation plan, 600-channel multiplex system.

ferent telephone administrations had to interconnect at international borders. Unlike other parts of the world, Europe has many dense population centers concentrated in small political divisions. Because of the relatively short distances separating these populated areas, there is a great amount of telephone traffic between them. Therefore, it was necessary to establish an international cooperative organization where the nations involved could get together and agree on universal standards. Such agreements have been very effective in assuring that international circuits of various national telephone administrations and common carriers are compatible. Today, countries all over the world who are interested in promoting and developing international telecommunications networks, are represented in the CCITT.

Frequency Allocation and Modulation Plans

One of the most important aspects of interconnecting frequency-division multiplex and carrier systems is the assignment of frequencies. Each type of carrier and multiplex system employs some type of modulation scheme to shift the voice-frequency signals received from user equipment to some suitable line or baseband frequency range. These schemes are referred to as *frequency allocation and modulation plans*.

Whenever two carrier systems are connected in tandem, signals at the interface point must conform to the technical requirements of the receiving system. Of course, signals at line or baseband frequencies can be simply demodulated to the voice-frequency range and then transferred to the next system. This method, although acceptable, has proven to be rather inefficient in many cases. Extra equipment is needed to demodulate the signals and each additional modulation and demodulation step adds distortion to the signal. What was needed was a standard modulation plan which would allow different carrier and multiplex systems to be interconnected directly at line or baseband frequencies or at some intermediate stage of modulation. This would allow groups of channels to be transferred between systems without the need for extra equipment and unnecessary modulation steps.

When the Bell System began developing its wideband coaxial cable carrier system in the 1930's, considerable thought was given to standardizing single-sideband suppressed-carrier multiplex terminal equipment. One of the results of this effort was the establishment of a standard modulation plan for groups of channels. To accomplish this it was first necessary to standardize the spacing of channel carriers; the Bell System decided on a uniform spacing of 4 kHz. This would permit all channel carriers to be harmonically related to 4 kHz and would allow room to improve the quality of speech transmission with advances in filter design. The next step was to formulate a basic modulation plan that could be used in open-wire and multipair cable systems as well as wideband coaxial cable systems. With 4-kHz channel spacing, single-sideband suppressed-carrier open-wire systems operating with line frequencies above 30 kHz (this would place such systems above the Bell System's 3-channel type C carrier system) could only handle about 12 channels. So it was decided to establish a basic modulation plan for 12 channels. Coaxial cable systems (and later microwave radio systems) were, of course, not limited to 12 channels, but standard 12-channel groups could be used as building blocks to form systems with hundreds of channels by simply using additional stages of modulation. Since the practical lower frequency limit for coaxial cable was about 60 kHz, the standard 12-channel group was established with a frequency range of 60 to 108 kHz.

This standard 60 to 108 kHz 12-channel group has received wide acceptance as the basic building block for long-haul carrier and multiplex systems, and has been adopted by CCITT for use in international circuits and by the DCA for use in the Defense Communications System. Additionally, a standard 60-channel *supergroup*, formed from five 60 to 108 kHz channel groups, has been adopted for use in wideband systems. This supergroup has a frequency range of 312 to 552 kHz.

An example of a frequency allocation and modulation plan for a 600-channel multiplex system is shown in Figure 1. In the first modulation stage for this plan, each voice-frequency input signal modulates one of 12 *channel carriers* spaced 4 kHz apart. The lower sideband signals are selected to provide the standard 60 to 108 kHz 12-channel group. In the second modulation stage, five 12-channel groups each modulate

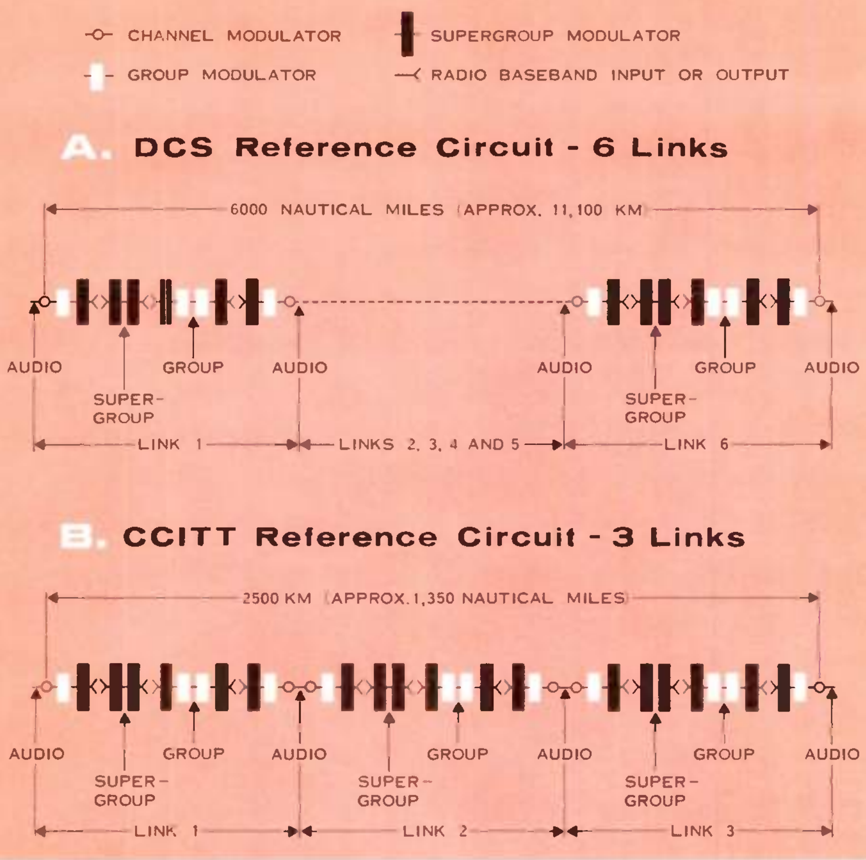

Figure 2. DCS and CCITT reference circuits.

a separate *group carrier* to produce a standard 60-channel supergroup with a frequency range of 312 to 552 kHz. Ten of these supergroups are needed to form the 600-channel system.

In the final stage of modulation, nine of the ten supergroups each modulate a separate *supergroup carrier*, resulting in line frequencies ranging from 60 to 2540 kHz. One of the supergroups (supergroup number 2) is applied directly to the line at the 312 to 552 kHz frequency level.

This particular 600-channel modulation plan is recommended by the CCITT and is standard for use in the Defense Communications System. The Bell System uses a slightly different line frequency range for their type L wideband carrier and multiplex systems. In the type L system, the modulation plan is the same as the one described, through supergroup 8. Supergroups 9 and 10, however, employ carriers of 1860 and 3100 kHz, respectively, resulting in an upper line frequency of 2788 kHz rather than 2540 kHz.

Modulation plans can be expanded to meet the future needs of higher density wideband multiplex systems requiring 2700 or more channels. These expanded plans are formed by additional modulation steps using higher order *master* and *supermaster* channel groups. By adhering to these standard frequency allocation and modulation plans, it is possible to directly interconnect 12-channel, 60-channel, and higher order channel groups of various carrier and multiplex systems, without having to first demodulate the signals down to the voice-frequency range.

For single-sideband suppressed-carrier open-wire carrier systems, the standard frequency allocation and modulation plan provides up to 12 channels. Since open-wire systems are typically 2-wire systems, the frequencies transmitted to the line must be different for each direction of transmission. This establishes what is known as an *equivalent 4-wire* system. The two directions are conveniently referred to as the *east-west* direction and the *west-east* direction.

After the 12 voice-frequency channels have been translated to the 60 to 108 kHz group level, they are then shifted to one of four staggered line frequency allocations. Staggered line frequency allocations are necessary to overcome unacceptable crosstalk where different systems share the same open-wire lead. The four staggered line groups are shown in Table 1.

This open-wire modulation plan is used in the Bell System type J carrier system and is specified standard by the DCA and CCITT.

The standard 60 to 108 kHz group modulation plan is also used in multipair cable carrier systems to provide 12 or 24 channels. The line frequencies for cable systems are also different for each direction of transmission. The DCA prescribes a 12-channel system with line frequencies of 6 to 54 kHz for one direction and 60 to 108 kHz for the other direction.

The standard 24-channel plan used by the telephone industry requires two basic 60 to 108 kHz 12-channel groups. Again the line frequencies are different for each direction of transmission. Typically, the channels in one direction are referred to as the *low line group*, and have a frequency range of 36 kHz to 132 kHz. The channels in the other direction, called the *high line group*, have a frequency range of 172 to 268 kHz.

TABLE 1.

Staggered line frequency allocations for 12-channel open-wire carrier system.

SYSTEM		WEST-EAST	EAST-WEST
DCA	CCITT		
A	SOJ-A-12	36 to 84 kc	92 to 140 kc
B	SOJ-B-12	36 to 84 kc	95 to 143 kc
C	SOJ-C-12	36 to 84 kc	93 to 141 kc
D	SOJ-D-12	36 to 84 kc	94 to 142 kc

Performance Objectives

In order to define standard performance objectives of communications systems, the CCITT, the United States telephone industry, and the DCA have established hypothetical *reference circuits*. These circuits are of a specified length and are composed of a certain number of links. The amount of equipment in each link varies depending on whether the transmission path consists of open wire, cable, or radio. The reference circuits are complete transmission systems interconnecting two audio-frequency terminals. Each link consists of a number of 4-wire, nominally 4-kHz voice-frequency circuits derived from single-sideband suppressed-carrier frequency-division multiplex equipment using standard modulation plans. Such hypothetical reference circuits are very useful in establishing guidelines for the performance characteristics of a communications system.

The CCITT reference circuit, Figure 2A, is 2500 kilometers (1550 statute miles) long and consists of three tandem links with interconnections made at group and supergroup frequency levels. In the United States, the telephone industry uses a reference circuit of 4000 miles, made up of a maximum of seven links. However, from a performance standpoint the two circuits provide essentially the same results.

The DCS reference circuit for wideband systems is shown in Figure 2B. This hypothetical circuit is 6000 nautical miles long and consists of six tandem links each approximately 1000 miles long and interconnected on a 4-wire basis at the audio-frequency level. Each link is divided into three sections of equal length and consists of wire or radio facilities plus necessary repeaters and frequency division multiplex equipment.

Through the use of these hypothetical reference circuits, it is possible for various manufacturers to develop multiplex equipment with uniform performance capabilities. In addition to the type of multiplexing and associated frequency allocations and modulation plans, the reference circuits are used to define and standardize other circuit characteristics such as noise objectives, power levels, impedances, pilots, and signaling in order to interconnect groups of channels at carrier frequencies.

Power level is a very important factor which must be considered when establishing guidelines for interconnecting multiplex systems. The amount of power required at the voice-frequency input and output circuits of multiplex systems is determined by the needs of the subscriber or user equipment, or the switching center in the communications system. In the United States, the standard used to set the levels for speech transmission is a 1000-Hz test tone at a level of 0 dBm0. The CCITT specifies an 800-Hz tone for the same purpose.

Both the Bell System and the DCA have standardized the input level of speech signals at −16 dBm and the output level at +7 dBm with a balanced circuit impedance of 600 ohms. These levels result in a net gain of 23 dB from the input of the multiplex transmit channel to the output of the distant multiplex receive channel. The CCITT also recommends a voice-frequency circuit impedance of 600 ohms, but has not specified any standard voice-frequency power levels.

Conclusion

The development of universal operating standards for carrier and multiplex systems has certainly been a tremendous help in advancing worldwide international communications. Such standardization has made it possible to transfer groups of channels at carrier frequencies directly from one communications system to another. This has resulted in communication services with greater efficiency, better quality, and lower costs.

Direct Distance Dialing in the United States is an excellent example of what can be achieved through the use of operating standards for communications transmission equipment. With the advent of worldwide multiple-access communications satellites the need for universal standards for interconnecting carrier and multiplex systems will certainly become more and more significant.

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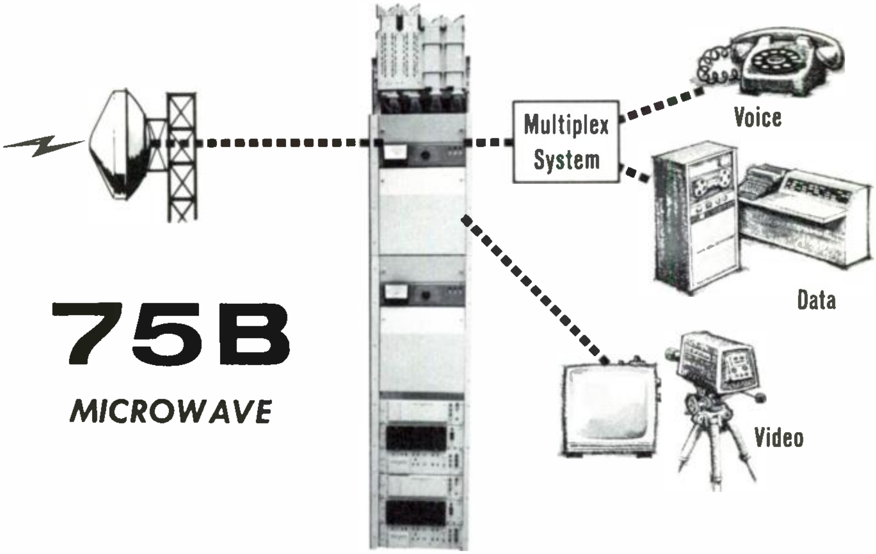

The Lenkurt 75B microwave radio is a high-performance wideband system designed for heavy-density long-haul routes. Operating in the industrial, broadcast auxiliary (STL), and international bands between 6425 and 7125 MHz, it can handle more than 960 voice channels or a color TV signal. Superior system noise performance is achieved using I-F heterodyne repeaters and traveling wave tube amplifiers with five watts output. For more information about the outstanding features of the 75B, write Lenkurt, Dept. B720.

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