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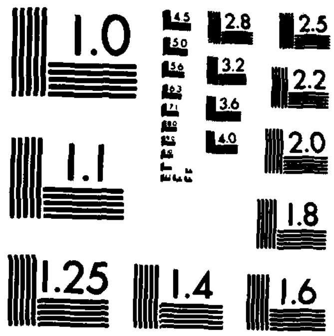

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ELECTRONIC TECHNOLOGY

(Selected Articles)

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THREE CATEGORIES OF APPLICATIONS OF OPTICAL FIBER COMMUNICATION*

Zhang Xu

In addition to two major categories (digital communication and analog communication) of optical fiber communication, there is the application of the third category, short distance data communication. So-called short distance data communication means the data communication of optical fibers used in a local or small range. Here short distance indicates 100 meters, 200 meters, 500 meters or 2 kilometers. Short distance data communication includes two categories of point-to-point (or called fixed point) digital circuits and different types of data trunk line. The fixed point data circuits are divided into low and high speeds. The low code speed ranges from 1 megabit per second to 100 megabits per second with comparatively short transmission distance, from 100 to 500 meters. The data trunk is divided into two types, multidrop line and stellar line. The transmission distance of the multidrop type trunk ranges from 200 meters to 2 kilometers; generally, low code speed is applied from direct current to 1 megabit per second. The stellar trunk line is used over a comparatively short transmission distance

*Refer to D. Personick, N. L. Rhodes, D. C. Hanson, K. H. Chan: Contrasting Fiber-optic-component-design Requirements in Telecommunications, Analog, and Local Data Communications Application, P. IEEE, Oct. 1980, p. 1254.

from 100 to 500 meters; high code speed can be used from 1 megabit per second to 20 megabits per second. This is an overview of the short distance data communication.

Apparently, there are significant differences in performance and design requirements between the third major category and the first two major categories; therefore, an explanation and comparison should be conducted of the characteristics of these categories. With the extensive application of computers in China, the utilization of optical fibers for transmission in short distance data communication should begin to be stressed. The characteristics and requirements of these three major categories of application are briefly explained; this is helpful to clarify the development trend of optical-fiber communication.

I. DIGITAL COMMUNICATION

At the very beginning, the generally termed optical fiber digital communication was tested and applied in interexchange urban telephone lines for transmitting PCM digital signals. Recently, development and expansion of optical fiber communication have been underway for long distance lines and submarine lines. In the presently used 0.85 micron short wavelength, generally the interval between relay stations is greater than 4 kilometers, and code speeds range from 1.5 megabits per second to 400 megabits per second for this type of digital communication. In practice, for digital optical fiber communication over lines between urban telephone exchanges, the most reasonable code speeds range from 30 to 140 megabits per second, the PCM three stage group and four stage group corresponding to 480 and 1920 telephone channels. Exceedingly low code speeds are economically unsound and exceedingly high code speeds are limited by the technique of the devices. Over a long distance optical fiber line, the PCM four-stage group and five-stage group digital signals can be transmitted with a code speed of 400 magabits per second. The signal-to-noise ratio at the receiving terminal is greater than 20 to 30 decibels, enabling it to attain an error rate index of 10^{-9}. The dynamic range of the receiving optical power should be 20 to 50 decibels. For the optical fibers used in this category of digital communication system, the fiber core diameter and covered layer diameter are 50/125 microns; generally, the optical fiber loss is smaller than 4 decibels per kilometer. In the low code speed of optical devices, an LED-PIN combination is used; while in high code speed, an LD-APD combination is used. If an LED is used in transmitters, the code speed is higher than 20 megabits per second; the color dispersion caused by spectral width limits the internal distance of relay stations. Therefore, an LD should be used in high code speeds; this increases the output power by 10 to 20 db. While APD is used in a receiver, the sensitivity at 50 megabits per second of code speed is superior by approximately 15 db than the use of PIN; the interval between relay stations is extended by 2 to 3 kilometers and the dynamic range is greater. In practice, the LD-APD combination is used on lines (between urban telephone exchanges) while transmitting three-stage group PCM signals, and the interval between relay stations is from 4 to 10 kilometers.

When symmetrical cables are used for lines between the urban telephone exchanges, generally one stage group PCM signals are transmitted, corresponding to 30 telephone channels; at most, a two stage group is transmitted, corresponding to 120 telephone channels with a relay station installed for every 1.5 kilometers. The competitiveness of the optical fiber digital communication system against the conventional cable is mainly due to its economic soundness while transmitting high stage group PCM signals. In particular, in the case of crowded underground piping and with the requirement of a long-distance interval between relay stations, the optical fiber cable has a clear economic advantage. In the vicinity of high tension power lines and in the area of severe electromagnetic interference with the communication cables, the substitution of optical-fiber cables for the conventional electric cables shows more advantages. First, the PCM signals can be scrambled or compiled into appropriate code types before transmission over an optical fiber cable by randomly separating codes "1" and "0" without long "1" or "0" sequence. Thus, periodic restoration can be obtained at the receiving terminal with the use of alternate current coupling and automatic control increment.

For an ideal digital receiving set, the receiving sensitivity is very high if only a quantum limit is considered. However, in practice owing to limitations of defects in the receiving set, including the light extinction ratio, rise time, and pulse wave forms, the receiving sensitivity takes a loss of 1 to 3 db; in addition, the sensitivity loses another 1 to 3 db because of less-than-ideal quantum efficiency of the detector in the receiving set, and the requirement of greater dynamic ranges. The thermal (agitation) noises in the preamplifier in the receiving set further greatly reduce receiving sensitivity. If a PIN detector is used, the minimum necessary light power of the receiving set should be greater than the quantum limit by approximately 30 db. If an APD detector is used and the bias is so adjusted that the increment is at the optimal value of 50 db, the minimum required light power of the receiving set should be greater than the quantum limit, approximately 15 db. In other words, the loss of maximum sensitivity is 15 db. Then, the output of the preamplifier is approximately 0.5 millivolt and the variable increment amplifier provides an increment of approximately 66 db; the peak value of the output voltage of the amplifier is 1 volt. The light power received at the receiving terminal should not be adjusted to the standard value of the maximum sensitivity, but requires a certain dynamic range, at least 20 db. In practice, when an APD optical receiving set is used, the dynamic range may attain 40 db, including 7 db of allowable variation in light power due to APD increment; the 66 db of the variable increment amplifier corresponds to 33 db in the variation range of the light power. These two amounts (7 and 33 db) add up to 40 db. The power source required by APD provides higher voltage; this causes no difficulties for relay devices installed indoors but poses problems for relay devices installed in manholes. The environmental temperature causes considerable influence on the LD of the light source; even in an air conditioned building, sometime the environmental temperature may rise to 50°C. Transmitters and defect monitors are necessary devices; this adds to costs for the low code speed system. This again indicates an economically unsound posture for optical fiber digital communication used in low code speeds.

It is true that the digital communication is the main stream of rapid development in optical fiber communications. In other words, the importance of optical fiber digital communication is considerably superior to that of optical fiber analog communication, not only in transmitting digital signals over lines between the urban telephone exchanges, but also in transmitting PCM digital signals over long distance lines and submarine lines. This trend coordinates the development of composing the comprehensive operating digital network by using digital transmission and digital exchange of the entire communication network. For the transmission medium of the comprehensive digital network, the optical fiber communication will coordinate with satellite communication, becoming two major types of modern communication transmissions. In land communication and submarine communication, the optical fiber can very possibly replace the conventional electric cable in gradual stages.

It can be expected that the trend of using optical fiber communication in long distance lines and submarine lines is in the use of long wavelength single mode optical fibers; a long wavelength communication system is composed with a long wavelength single mode laser tube (or photo tube) and long wavelength light inspection devices. Since this type of optical fiber has characteristics of very low loss and very low color dispersion, the interval between relay stations can clearly be lengthened; the code speed capacity clearly expanded, and there is even the consideration of using multiple groups and repetitive use of a wavelength.

At present, another trend can be seen; that is, possibly the long distance optical fiber communication uses heterodyne interference testing and FSK (frequency shifting key control), PSK (control by phase shifting key) or a similar modulation method; adopting this method is much superior than the presently used direct inspection (and measurement) and OOK (control by on-off key). It indicates that the development history of optical fiber digital communication will turn a new leaf, as in the case when the interference testing method of modern radio communication replaced the earlier crystal radio receivers. The heterodyne type requires a highly stable frequency and polarization stability; thus, after mixing 200 terahertz (approximation) light frequency transmitted on optical fibers, the frequency is changed to a 2 gigahertz microwave frequency. Once the heterodyne inspection and testing technique becomes a reality in optical fiber digital communication, the sensitivity of the light receiving set can be considerably enhanced by approximately 15 to 25 db. If the loss over a long wavelength optical fiber is 0.2 db per kilometer, the interval of relay stations with a code speed of 400 megabits per second may be 200 kilometers or more. Thus, the potential of optical fibers will be sufficiently more developed with very promising outlook.

II. ANALOG COMMUNICATION

Several applications (as follows) can be considered by using optical fiber for transmission of analog signals: (1) single-channel telephone with 4000 hertz as the bandwidth of the acoustical frequency; (2) multiple channel telephone (for example, 2.4 megahertz for bandwidth of main group signals for 600-channel telephone frequency division repetitive use; (3) single-channel television with 5 megahertz as the bandwidth of video-frequency signals; (4) multichannel television signals; and (5) analog remote sounding and remote sensing signals. At present, direct modulation of light intensity is frequently used in analog optical fiber communication; in other words, the output power of the light source continuously fluctuates near the average value of the modulated signal amplitude. The ratio between peak value variation range and the average value is called the degree of modulation. There are two main indexes of analog transmission: one index is the very high signal-to-noise ratio for output of the receiving set, and the other index is the very high linearity for the entire system in order to avoid mutual interference between various frequencies of analog signals.

In analog communication, competition of optical fibers comes from the coaxial cable. We can compare the sigal-to-noise ratio characteristics of these two circuits. It is assumed that the peak voltage value is 5 volts for output to 100-ohm cable from a transmitting terminal of the coaxial cable system. For another assumption, LD is used for an optical fiber transmitter with output light power of 1 milliwatt (0 milliwatt db and 0.5 modulation degree). Under conditions of the same signal bandwidths and the same line loss, the signal-to-noise ratio of the receiving terminal of the coaxial cable system is higher by approximately 40 db than the signal-to-noise ratio of the optical fiber system. If an LED is used in the optical fiber transmitter and the power of incident light to the optical fiber is smaller by 20 db than that of the LD, then the signal-to-noise ratio of the coaxial cable is even higher than that of the optical fiber, approximately 60 db. We can see that for analog lines with a very high requirement on the signal-to-noise ratio, the coaxial cable can easily satisfy the quality index but not in the case of the optical fiber system.

For the several above-mentioned applications, we calculate the allowable line loss (of optical fibers) between transmitter and receiver in ideal quantum limiting conditions. First, for the single channel telephone of 4000 hertz bandwidth, the allowable line loss is 30 db if an LED is used as the light source and the output signal-to-noise ratio of the receiver is required to be 60 db. We can see that transmission is possible but economically unsound. Only in very simple and very cheap equipment, can light fibers be considered for transmitting single-channel duplex telephone signals.

Fro a multichannel telephone (for example, 600 channel FDM main group and 2.4 megahertz bandwidth), the line loss is only allowed to be 15 db if an LED is used for the light source and the output signal-to-noise ratio is required to be 60 db. This indicates that this type of signals can only be transmitted over a short distance optical fiber line. However, if the 600-channel FDM analog signal is transformed into PCM (50 megabits per second) digital signal, the allowable optical fiber loss is 50 db for interval distance between relay stations; in addition, noises and nonlinearity do not accumulate with lengthening of lines. Therefore, for multichannel telephone, analog communication is considerably inferior to digital communication. Only in special conditions, analog signals of multichannel telephone can be transmitted through optical fibers.

For a single television signal with video bandwidth of 5 megahertz, the allowable loss of optical fibers is 10 db if LED is used as light source and the output signal-to-noise ratio of the receiver is required to be 50 db. If the signal-to-noise ratio is required to be 70 db and even an LD is used for the light source, the loss over the optical fiber is only allowed to be 10 db. Apparently, for short distance television transmission (for example, from television camera to video tape recorder or monitor), 50 db of signal-to-noise ratio is perhaps sufficient. In this case, transmission by optical fiber is feasible. If long distance television transmission is required and several relay stations should be installed, the output signal-to-noise ratio of the receiving part in each relay station should be raised to 70 db without lowering the performance index between the two terminals. This requires that the LD is used for the light source and only 10 db is allowed for line loss in each relay sector of the optical fibers. In this situation, it poses difficulties for using an LED as the light source. Conversely, if the transmission distance is not long and LED is still adopted, then relay stations are not installed; the signal-to-noise ratio between two terminals is required to be lowered to 45 db. In this case, the allowable loss of optical fiber line is 15 db. This application is practical and can be propagated. By deduction, if optical fibers are used to transmit multichannel television analog signals, and it is limited to short distance transmission since the bandwidth is doubled, the signal-to-noise ratio cannot be required to be high, only limited to 45 db. For remote sounding and remote sensing signals with low frequency analog modulation, optical fibers are feasible; in addition, the fibers are quite suitable in special environments with development prospects.

In analog communication, the major performance index is a high signal-to-noise ratio. As mentioned above, the quantum limiting conditions were assumed; in other words, it is required that noises are mainly limited to quantum noises of the detector, but the thermal noises of the amplifier are not that important. However, we should take note that there are other phenomena possibly limiting the obtainable maximum signal-to-noise ratio. One phenomenon is to use mode noise occurring in the LD and multimode optical fibers. Frequently, the LD emits multiple modes and its radiation pattern varies randomly. However, there are different losses of multimode optical fiber and connectors to different modes; therefore, the output amplitude of the receiver fluctuates, forming mode noises. Not because of mode function and only due to ageing of the LD, the apparent fluctuations of output power can also limit the signal-to-noise ratio to less than 50 db.

In analog television communication, nonlinearity will cause mutual interference between the color subcarrier and the black-and-white portion in the video frequency signals. In multichannel analog communication, if the frequency division repetitive use method is adopted, the nonlinearity produced cross modulation will cause mutual interference between various channels of signals. Hence, the linearity requirement is another major quality index of the analog system of optical fibers. For system nonlinearity, especially nonlinearity of light (source) devices, appropriate measures should be adopted, such as negative feedback and predistortion. However, these measures should be adjusted to the characteristics of light source devices. Besides, other measures can be also considered, such as frequency modulation of subcarriers and pulse modulation. Increasing the bandwidth can be used to lower the requirements of the signal-to-noise ratio and is used to lengthen the interval distance between relay stations and to reduce the effect of mode noises.

Generally speaking, the analog communication is most suitable to a short distance of less than 2 kilometers with bandwidth less than 10 megahertz. The characteristic of the quality index is a high signal-to-noise ratio, between 40 and 70 db. The dynamic range of the received light power is not necessarily too high, and is sufficient at 10 to 20 db. The core diameter of the optical fiber and the outer diameter of the enveloped layer are still the commonly used 50/125 millimeters. Mostly, an LED-PIN combination is used in light devices and line loss of the optical fiber is often less than 10 db.

III. SHORT DISTANCE DATA COMMUNICATION

Short distance data communication is apparently different from the above-mentioned digital and analog communications. First, we deal with cost requirements. As mentioned above, costs of digital and analog communications are calculated on every kilometer-channel. In particular, for digital communication with hour-minute repetitive use, PCM signals of many channels use a single optical fiber; for example, 480 channels of telephone signals are composed of PCM signals of 34 megabits per second, transmitted on a single optical fiber in the same direction. Short distance data communication will be a single channel operation at present or in the near future; that is, a single optical fiber can only transmit one channel of data. Therefore, the cost is calculated on every kilometer-channel. This category of applications stresses, for the time being, not the superior characteristics of high bandwidth capability (of the optical fiber) and low line loss; the application is for the prevention of electromagnetic interference, adaptation to special environments, or for reduction of the number of relay stations for filling limited-space underground piping. However, the application can only be extended in the economic soundness of equipemnt cost as superior to the symmetrical cable.

In order to reduce cost, it is better to use light devices, such as an LED-PIN combination, and to sufficiently adopt the cheap integrated blocks and packaging technique. Larger diameters can be adopted for the optical fiber; for example, the fiber core diameter and the external envelope layer are 100/140 microns and the numerical aperture NA is as large as 0.3, using an light source of greater light emitting surface in order to raise coupling efficiency between the light source and optical fiber and to reduce the accurate density requirement of the connectors. For the shortest distance fixed-point slow code speed data communication, the diameter of the optical fiber can even be as large as 200/230 to 600 microns. Although the increase in cross sectional area of the optical fiber will add to the cost and the fiber is easily broken, generally speaking, large-diameter optical fiber is advantageous to the short distance data communication system. Therefore, the use of an LED-PIN combination of large-diameter optical fiber is advantageous to the short distance data communication system. The use of large-diameter optical fiber and LED-PIN combination are marks of a short distance data communication system. For optical fibers with diameters of 100/140 microns, the loss is lower than 10 db per kilometer and the bandwidth ranges between 10 and 100 megahertz·kilometer. For optical fibers with diameters of 200/230 to 600 microns, the allowable loss is 30 db per kilometer and the required bandwidth is also correspondingly lowered, approximately 10 megahertz·kilometer.

When designing a short distance data communication system, interfaces should be designed between the communication system on one hand, and the computer and peripheral equipment on the other. The interface frequently uses standard digital devices, such as TTL. Hence, for the light terminal devices of the optical fiber system, either for transmitting or for receiving, the power source should be limited to +5 volts. If ECL is used for high code speed communication or stellar trunk line equipment, the power source should be -5.2 volts. Low voltage of the power source is another characteristic of an optical fiber system for short distance data communication. Thus, the voltage of the power source is lowered; this will cause difficulties in obtaining wider dynamic range in receiver design, higher sensitivity and elimination of power source interference.

In short distance data communication, communication between fixed points at a code speed of higher than 9600 bits per second is frequently used in a single large building or between several adjacent buildings. Most short distance data communication requires the product of bandwidth and distance to be smaller than 10 megabits per second·kilometer. However, as mentioned above the application of optical fiber data communication requires the product of bandwidth and distance to be between 300 and 500 megabits per second·kilometer. These two products differ quite widely; this is also the reason that appreciable differences exist in dimensions of optical fibers, kinds of light devices, and circuit design.

In the category of fixed point communication, the variation of light power received by the receiver is only due to variation of output power coupling of the transmitter, variation of the optical fiber, variation caused by ageing and environments, and variations in the allowable range of length of the optical fiber. Once a light system is installed, the increment of the light receiver only needs to be adjusted within a very small range; in other words, the requirement of dynamic range of fixed-point communication is comparatively small, generally smaller than 20 db. In receivers of a stellar data trunk line, the requirement of dynamic range and the requirement of the fixed-point system are similar. Only in the case of a multidrop type data trunk does the line length vary to a greater extent; the receiver should be used to inspect and measure light power transmitted from transmitters of different distances. Hence, the requirement of dynamic range is possibly greater, even 40 db.

There is another problem for short distance data communication receivers--the problem of capture time. The capture time is the time required from the static state to attaining stability in receiving the data group. In applications of the category of fixed point communication, receivers always receive signals from a single transmitter; hence, measures of automatic increment control, direct current feedback, and alternating current coupling can be used to attain significant improvement in dynamic range and sensitivity of receivers. When useful data are not transmitted, continuous null codes can be transmitted to keep the receiver stable at its operation point. Conversely, this is not the case for applications in the data trunk category. For receivers of multidrop communication, not only should wider dynamic range exist, but also the data should be captured quickly within several digits of the code. This can avoid the reduction of trunk efficiency by requiring a longer training sequence. In order to obtain quick capture time, it is impossible to use automatic increment control and dc feedback. In addition, the ac coupling capacitance is limited to a minimum value, thus lowering sensitivity and bandwidth capacity. Therefore, the difficult problems confronted in the design of a data trunk receiver are high code speed, high sensitivity, wide dynamic range, and quick capture time.

Comparison of Application and Categorization of Optical Fiber Communication

性 (a) 能	(b) 应用分类			
	(c) 数字通信 -PCM-		(d) 模拟传输 -TV-	(e) 短距数据通信 -数据-
	(f) 市话局间	(g) 长途干线	(h) 短 · 距	(i) 定点和母线
传输距离 (j)	2~10 公里 (aa)	>50 公里 (aa)	<2 公里 (aa)	0.1-0.5-2 公里 (aa)
码速或带宽 (k)	30~50 兆比特/秒 (ab)	400 兆比特/秒 (ab)	6 兆赫 (ac)	0-1-10 兆比特/秒 (ab)
码速·距离乘积 (l)	300~500 兆比特/秒·公里 (ad)			10 兆比特/秒·公里 (ad)
光波长 (m)	0.85 微米 (ae)	1.3~1.55 微米 (ae)	0.85 微米 (ae)	0.85 微米 (ae)
信噪比，误码率 (n)	(af) 25 分贝, 10^{-9}		50 分贝 (af)	20 分贝, 10^{-7} (af)
动态范围 (o)	20~50 分贝 (af)		20 分贝 (af)	20~50 分贝 (af)
捕获时间 (p)				几位码，不能用锁相环 (母线要快些) (ag)
模式 (q)	多模 (ah)	单模 (ai)	多模 (ah)	多模 (ah)
纤芯直径 (r)	50/125 微米 (ae)	5/125 微米 (ae)	50/125 微米 (ae)	100/140, 200/300 微米 (ae)
数值孔径 (s)	0.2		0.2	0.3
损耗 (t)	<4 分贝/公里 (aj)	<1 分贝/公里 (aj)	<4 分贝/公里 (aj)	<10~30 分贝/公里 (aj)
带宽 (u)				>10~100 兆赫·公里 (ak)
光器件 (v)	LD-APD	LED-PIN/FET(GaAs)	LED-PIN/FET(Si)	LED-PIN
调制和检测 (w)	OOK 调制 直接检测 (al)	FSK 或 PSK 调制 外差相干检测 波分多路合用 (am)	连续调制 直接检测 (an)	OOK 调制 直接检测 (al)
电源 (x)			(ap)	5 伏低电压 (av)
成本计算 (y)	每一通路公里 (ao)		每一通路公里或每一线路公里	每一线路公里 (aq)
特点 (z)	多局结构，缩短用户线，短波长或是长波长 (ar)	各种业务都数字化，电视数字化。中继站间隔长 (as)	(at) 中继站信噪比要求极高。用 LED 时，光纤损耗限于 15 分贝。可传输遥测遥感模拟信号。	带宽-距离乘积小 (au)

[Key on following page]

Key [of table on the preceding page]: (1) Characteristics; (b) Application categories; (c) Digital communication; (d) Analog transmission; (e) Short distance data communication -data-; (f) Between urban telephone exchanges; (g) Long distance trunk; (h) Short distance; (i) Fixed points and trunk; (j) Transmission distance; (k) Code speed or bandwidth; (l) Product of code speed and distance; (m) Light wavelength; (n) Signal-to-noise ratio, rate of error codes; (o) Dynamic range; (p) Capture time; (q) Mode; (r) Diameter of fiber core; (s) Numerical aperture; (t) Loss; (u) Bandwidth; (v) Light device; (w) Modulation and inspection-measurement; (x) Power source; (y) Cost calculation; (z) Features; (aa) Kilometers; (ab) Megabits per second; (ac) Megahertz; (ad) Megabits per second·kilometer; (ae) Microns; (af) db; (ag) No locking phase mode for several-digit code (faster capture time required for the trunk); (ah) Multimode; (ai) Single mode; (aj) db/km; (ak) Megahertz·kilometer; (al) OOK modulation and direct inspection and measurement; (am) FSK or PSK modulation, heterodyne phase interference inspection and measurement, and wavelength division suitable for use in multigroup; (an) Continuous modulation and direct inspection and measurement; (ao) Every channel kilometer; (ap) Every channel kilometer or every line kilometer; (aq) Every channel kilometer; (ar) Multi-exchange configuration, shortening of users' line, short or long wavelength; (as) Digitalization of various operations, digitalization of television, and long interval between relay stations; (at) Very high requirement of signal-to-noise ratio of relay stations. When using LED, the loss of optical fiber is limited to 15 db. Remote sounding, remote sensing analog signals can be transmitted; (au) Small product of bandwidth and distance; (av) Low voltage, 5 volts.

In applications of short distance data communication, the design of light transmitters and receivers should differ significantly from the other two categories. For data communication of low code speed, since competition is required against the conventional electrical cable, the equipment cost should be especially lowered by adopting integrated circuits as much as possible. Furthermore, since the low code speed data frequently use asynchronous transmission, the transmitters and receivers should be able to respond to dc; that is, from dc to 1 megabit per second. Hence, the amplifier in a receiver should use dc type coupling. For high code speed data communication of over 1 megabit per second, the equipment cost may be slightly higher. High code speed transmission frequently uses synchronous communication. The code types transmitted on a line undergo transformation without containing a dc component. Hence, dc response by the equipment is not required.

In practice, the data trunk requires the organizing of an appropriately multiple-terminal communication network and corresponding distribution system. Then, considerations can be given to use of microcomputers for control. This is an important development direction for short distance data communication.

ELECTRONIC CALIPER

[translated by] Luo Yanfu

In Sweden, a new digital caliper was developed with a high accuracy of 0.01 millimeter or 0.005 inch.

The liquid crystal display of this type of caliper can show units in English or in the metric system. When conducting multiple measurements in a continuous sequence, all data of each measurement can be stored. When the caliper is used to measure a work piece, two legs of the caliper can be moved flexibly. In the processing of digital reading, no parallax exists.

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