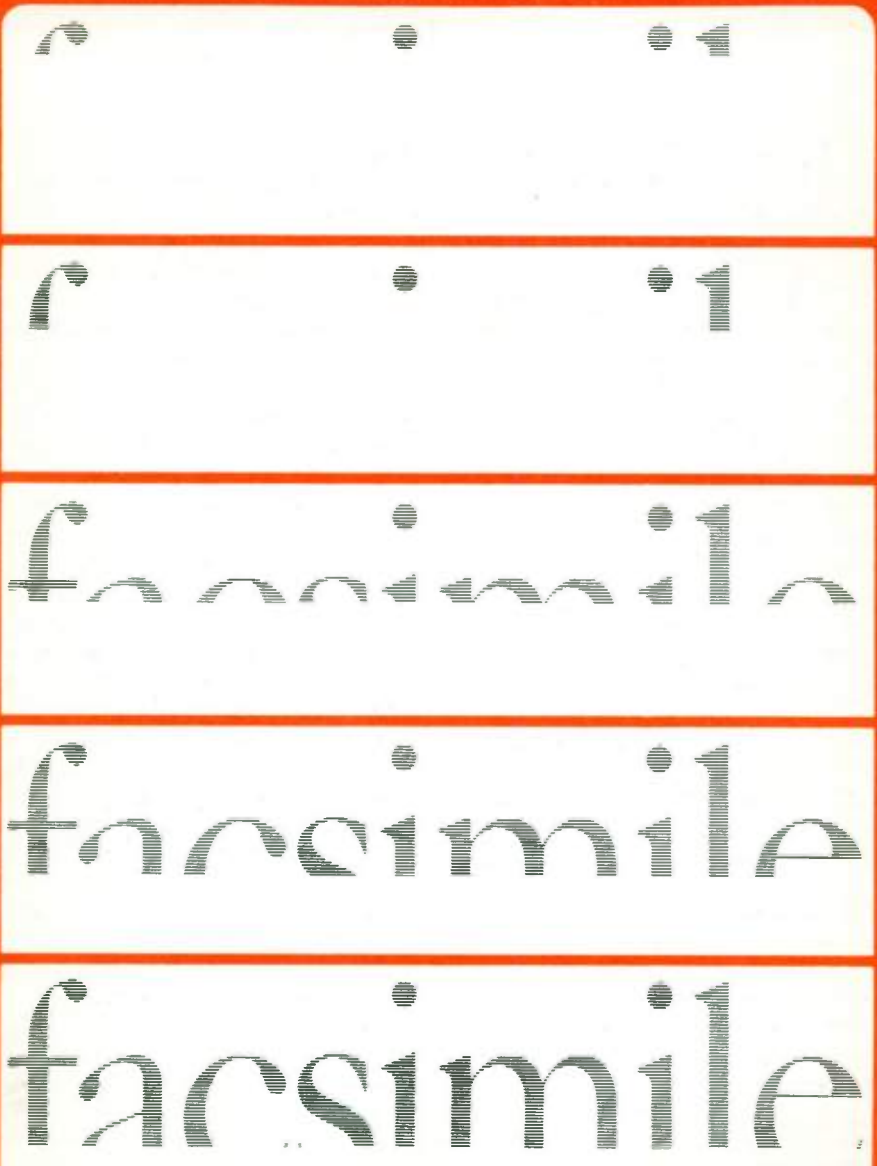
The Lenkurt

SEPTEMBER 1969

DEMODULATOR



facsimile

That old Chinese proverb about a picture being worth a thousand words is no less true in this day of highspeed electronic communications than it was in the early days of paper. As technology improves, the relative value of picture transmission may well exceed that of a thousand words.

The art of sending pictures, maps or whole messages over radio, telephone, telegraph and cable facilities is known as facsimile transmission, or "fax". The basic principles of fax have been understood for almost 100 years. Only in recent years, however, have transmission techniques improved to the point that this unique form of telecommunications can begin to be commercially exploited.

Technological advances in the field of data transmission have, incidentally, made it possible to develop fax systems which significantly reduce transmission time and thereby lower line cost. The expense associated with older transmission techniques has been the most limiting factor in the history of fax. A reduction of common carrier rates, in 1962, considerably improved the commercial outlook of fax, but future advances in data transmission technology will probably have a greater effect.

Background

The early applications of facsimile were essentially limited to the transmission of photographs, telegrams and weather maps. One of the oldest commercial users of fax is Western Union Telegraph Co., presently operating more than 30,000 units for the delivery of telegrams. Thousands of fax equipments are used by the military, weather bureaus and commercial airlines for the recording of weather maps. The advent of weather satellites has made this function more reliable and timely.

The transmission of photographs and weather maps requires high resolution and good quality reproduction. Even early fax systems were capable of this kind of performance – quality was not the problem. The problem, until recently, has been providing economical methods for the transmission of large volumes of lesser quality material, such as letters and line drawings. Many similar applications do not require high resolution.

The early uses of fax persisted because of the need to transmit certain kinds of high resolution graphic material from one place to another regardless of cost. Photographs for newspapers, emergency telegrams for people unreachable by phone, and weather maps to chart airline flights are examples of such indispensable services. The use of facsimile as a necessary tool in keeping the public informed was assured by the Federal Communications Commission when

they reserved a portion of the radio spectrum specifically for the transmission of fax by newspapers.

In the light of its present development, it is appropriate to reassess facsimile's role in the field of electronic communications. In a fundamental way, fax provides some unique advantages over other methods of communication. Visual material is often less ambiguous than audio material; most people are better visually-oriented than audio-oriented. Because of this, visual material is not as often misperceived as material which is only "heard". There is also the added benefit of having a readily available permanent record for verification when accuracy is in doubt. Fax material can be more quickly copied for distribution or filing. It can also handle a broad scope of information without the problem of language barriers. Noisy rooms do not impair reception. Fax is as easy to use as a telephone. Another interesting facet is its capacity to transmit legally acceptable documents and signatures.

Low resolution, black and white machines are now being widely manufactured. The availability of these new devices and prognostications of a substantial market, has ushered in a new nationwide business – the facsimile franchising service field which promises to become a booming enterprise. Offices already exist in more than 200 cities across the U.S., making this new service available to any commercial activity wishing to participate. New offices are being opened with each passing week.

There are two types of franchising currently in use. One method has a central office to maintain a pick-up and delivery service to subscribing customers for a monthly rate. The second method invites the franchise holder to establish a secretarial service-type office where anyone desiring to transmit written information presents the information, by person or phone, and is charged on a cost-per-copy basis.

Basic Fax

The principle types of fax are gray-scale and black-and-white. Recently announced color fax is essentially an extension of gray-scale fax technology. All types require a revolving drum, upon which can be attached the copy to be transmitted, and a scanning device which "sees" the copy as it revolves. Line by line the scanner picks up the image, in the form of light impulses, as it sweeps across the page. The received light pattern passes through a precision optical system to a photocell which, in turn, converts the light impulses into an analog signal pattern. Both gray-scale and black-and-white fax can be transmitted over common communications channels by analog means.

Shades of Gray

The signal pattern, or waveform, from a wide-range gray-scale fax system differs from that of a black and white system. A wide-range gray-scale waveform may have an infinite number of tone values between black and white. The waveform produced is a precise electronic representation of the original image on the drum. This kind of waveform is both asynchronous and analog in nature. It is asynchronous because the waveform has not been "sampled" or "clocked" at measured time intervals (see figure 1) and is considered analog because its amplitude varies in direct proportion to the illumination spectrum of the original material. Asynchronous, analog fax systems are well suited for the transmission of pictures and other graphic material where good definition of a wide range of gray tones is necessary.

Good quality gray-scale transmis-

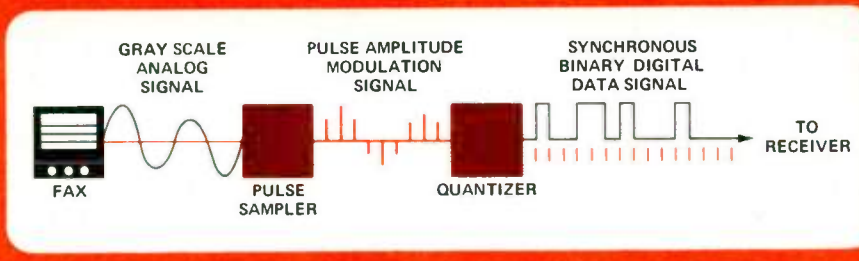


Figure 1. By using a "sampling" device, a continuous, analog signal can be converted into a synchronized, pulse amplitude signal. This signal can further be quantized and encoded into binary digital form.

sion is costly. Since it requires broadband facilities capable of high signal-to-noise ratios.

Fax in Black and White

A simpler system operates only in black and white – no shades of gray. This system employs a scanning device which only registers a black or white impulse and therefore generates a waveform with only two values corresponding to black and white. The digital binary waveform produced by this system is asynchronous and analog in nature because the time interval between two successive transitions corresponds directly to the original image. The application of the word analog is, thus, somewhat less meaningful when it concerns black-and-white systems; its common use is generally reserved for reference to gray-scale systems.

The binary nature of a black and white waveform makes it convenient for this form of fax to take advantage of present and future advances in data transmission techniques.

Fax Transmission

In telecommunications transmission there is an inverse relationship between transmission bandwidth and transmission time. This is particularly significant with fax. As bandwidth is increased, the time is decreased, and vice-versa. In general, the bandwidth necessary for fax transmission depends on the required resolution and the speed of transmission.

The relationship between resolution and bandwidth is such that doubling resolution requires four times the bandwidth – if transmission time remains constant. In the future, any significant innovations in effectively reducing transmission costs must reduce both transmission bandwidth and transmission time.

PCM and FAX

A significant new development in the telecommunications industry took place in 1937 with the invention of pulse code modulation (PCM). However, not until the advent of transistors and integrated circuits was this new idea given serious attention. In the 1950's, Bell Telephone Laboratories began to explore the PCM system.

The basic concept of PCM was entirely different from frequency division multiplex (FDM) which has served the industry for so many years. Unlike FDM, which provides frequency separation for all channels, PCM involves switching rapidly from one channel to another – producing a time division multiplex (TDM) system where each channel is allotted a separate time interval.

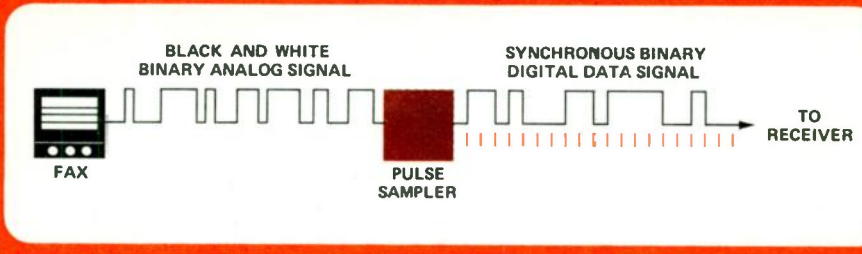


Figure 2. A "sampling" device applied to a black-and-white, binary signal, produces a synchronous, digital binary signal in one step. The binary nature of this mode effectively lowers transmission noise but introduces "jitter".

The Bell System designated their 24-channel time division multiplexing PCM system as T1 carrier. Although primarily designed for voice transmission, the T1 has proven to be ideally suited to the transmission of data or fax.

The use of PCM systems in the telephone network is increasing very rapidly. An example of this growth is the increasing number of Lenkurt's 91A (comparable to Bell's T1) time division multiplex PCM systems now in operation.

Lenkurt's 9003 and 9005 high-speed data terminals are designed for use over 91A (or T1) repeatered lines. Providing data rates of 50 Kb/s (and higher), these data terminals are well suited to the transmission of fax.

The PCM mode of transmission is not greatly troubled by signal distortion caused from noise. It has, however, another kind of distortion problem for black and white fax. When a black and white fax binary wave is synchronized by a sampling pulse it produces an error in the signal pattern which is called "time jitter" (see figure 3). This "jitter" occurs because the sampling pulse rarely takes place at the actual point of transition between black and white. As a result, the synchronized waveform rounds-off the original pattern, causing the intervals to be stretched or compressed, accordingly. The received image may therefore present a slightly fuzzy appearance due to this "time jitter", although legibility is not greatly impaired.

One advantage of binary data transmission is the fact that since there are only two possible waveform pulse values – one or zero, transmission distortion is relatively low and does not increase with distance. The efficiency of this system results from the fact that each positive pulse is regenerated at full amplitude, regardless of signal degradation up to that point. Likewise, every zero pulse is regenerated at zero amplitude.

Data Compression

Another promising field of investigation for bandwidth and time reduction, is the elimination of image redundancy. Nearly all graphic material has a dominant tone-value. For example, a page of typewritten material is essentially white – even when filled with words. This repetition of the same tone, over and over, is redundancy. The conclusion has been logically drawn that if only the non-redundant data could be transmitted (the black letters on a typed page, for example) a reduction in required bandwidth and time might be accomplished. Several

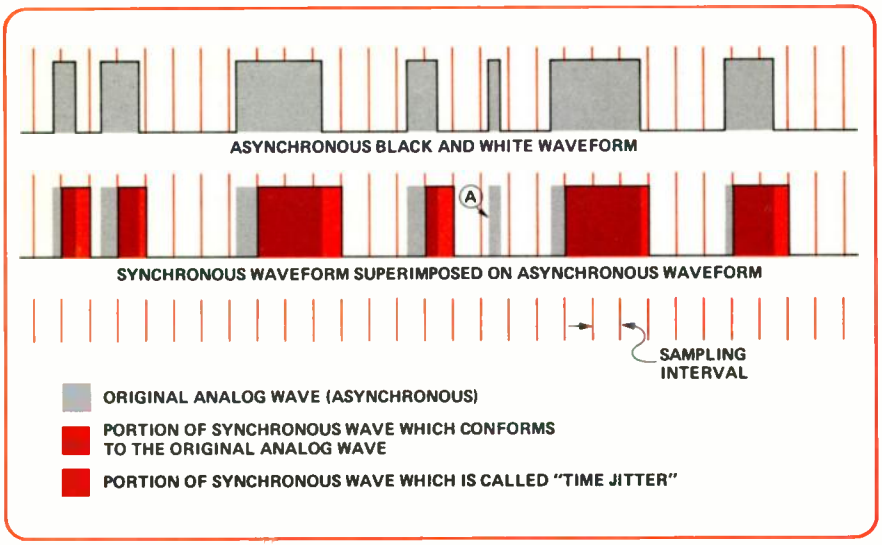


Figure 3. When a black and white analog waveform is synchronized by sampling pulses (vertical red lines), a certain amount of distortion occurs which is called "time jitter". This jitter results from the fact that the sampling eliminates changes in the original waveform which take place between pulses. The entire interval between pulses will read either "up" or "down" depending on the location of the original waveform at the time of the last pulse. Obviously, some complete white-to-black-to-white (and vice versa) changes can take place between pulses and therefore be completely eliminated from the synchronized wave (A).

techniques are being explored to eliminate redundancy and some methods are presently in use. One system of this type encodes the location of black-white and white-black transitions and transmits this information through digital transmission systems such as Lenkurt's type 26C or 26D data modems. Using Lenkurt's 26D, speed improvements as high as four to one have been achieved.

Present Applications and Future Possibilities

Early uses of facsimile have been enhanced and new uses are constantly being explored. Effective techniques for removing redundancy promise to place facsimile within the reach of many new applications.

Significant improvements in facsimile technology have reawakened the interest of police authorities around the globe.

Police departments which have installed facsimile systems are finding their use indispensable in communication of fingerprints and "mug" shots. There has long been a need for rapid identification of suspected criminals. Court imposed restrictions on police detention practices served to highlight this need. Rapid and positive identification not only makes it easier to identify wanted criminals, it has the added benefit of facilitating the release of innocent persons.

The Chicago and Los Angeles police departments have had, for some time, operational facsimile systems using

high resolution data transmission equipment. This application requires good quality gray-scale reproductions and 200 line per inch resolution – twice the resolution of a typical copying machine.

The newspaper industry represents one of the largest single markets for facsimile transmission systems. Many newspapers are now making use of various available devices for this purpose. It has been found desirable to provide high resolution of this large format material with wide-range gray-scale. It is necessary that newspaper pages be transmitted at very high resolution rates, on the order of 1000 lines per inch, to maintain sufficient standards of quality of half-tone picture material. Perhaps a system could be devised to transmit newspaper printed material at about 200 lines per inch, then slow down for half-tone picture material at 1000 lines per inch.

Facsimile systems have been used to transmit full size newspaper proof sheets from the main plant to remote satellite printing plants where the transmitted page is converted into a photographic negative which is then used for direct reproduction. At the present state of technological development, this application is still relatively expensive.

The future of facsimile transmission in the newspaper industry is very promising. Elaborate systems have been proposed which would require complete microwave networks capable of transmitting a standard newspaper page at 1000 lines per inch resolution within time limits of about four minutes per page between plants.

The Wall Street Journal already achieves fast service to parts of California and other Western states by using facsimile to transmit page proofs. Many banks are now using facsimile to speed stop-payment notices on checks by transmitting the notice from the bookkeeping office to the main banking office. Manufacturing companies are using facsimile equipment as an adjunct to their teleconferences in order to provide charts and diagrams so that each participant has precise references for the topics of discussion.

Courtesy of Dacom, Inc.

Figure 4. This black and white fax system transmitter produced by Dacom, Sunnyvale, California, makes use of Lenkurt's 26D data modem.

It has been reported that there are over 18,000 current users of facsimile systems. This list includes railroads, hospitals, schools, airlines and general business. It can be safely predicted that as new advances are made in compression techniques, bandwidth requirements will be reduced, costs will drop and new applications will become virtually endless.

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INTRODUCING LENKURT'S NEW 26D DATA SET.

Lenkurt's 26D, using the Modified Duobinary technique, transmits 4800 bits per second on a single conditioned voice channel without the need for automatic equalization. Eliminating the DC component from the transmitted signal, the Duobinary technique compresses required bandwidth, therefore concentrating more transmitter power in the useful part of the spectrum. As a result data errors are significantly reduced, allowing more throughput and effectively lowering transmission costs. For additional information, write Lenkurt Department C134.

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