# Heterodyning with LIGHT

## Optical communications may someday mimic radio

By DIETRICK E. THOMSEN

In many places in the world, optical communications techniques, which use light pulses in glass fibers to transmit information, are being inserted into telecommunications networks. Eventually they may replace the traditional electric circuitry in telecommunications entirely. Systems now in use rely on direct detection of a fairly strong signal by sensors that convert its information into sound, picture or the flipping of a gate in a computer. Lately, however, developments in coherent systems promise to add the advantages of radio receivers to optical systems.

These and other actual and promised communications improvements by optical means prompt the question: Who needs it? The potential information capacity goes far beyond present needs or uses. For an answer the organizers of the recent 1984 Conference on Optical Fiber Communication held in New Orleans invited Ithiel de Sola Pool of Massachusetts Institute of Technology, a specialist in the economy of technology, to give the meeting's keynote speech. De Sola Pool could not attend the meeting, but a videotape of him giving the talk was shown (itself an example of optical communications techniques). (De Sola Pool's death occurred a few weeks after the meeting.)

His answer to the question is, yes. People will learn to use telecommunications in new ways. As the technology provides options, demands will be invented, he suggested. In the future, he hypothesized, one could wander through the stacks of a library, sampling books at random from the shelves, all while sitting in one's own easy chair manipulating one's home computer terminal.

Some of what the technology may provide was addressed by D.W. Smith of British Telecom Laboratories in Martlesham Heath, Ipswich, England. He remarked that the signal detection methods — heterodyning and homodyning — made possible by new lasers and fibers "offer the possibility of improved receiver sensitivity and the selectivity of superheterodyne radio receivers at optical frequencies." This could yield, he says, "exciting new communications possibilities for planned and still unplanned systems."

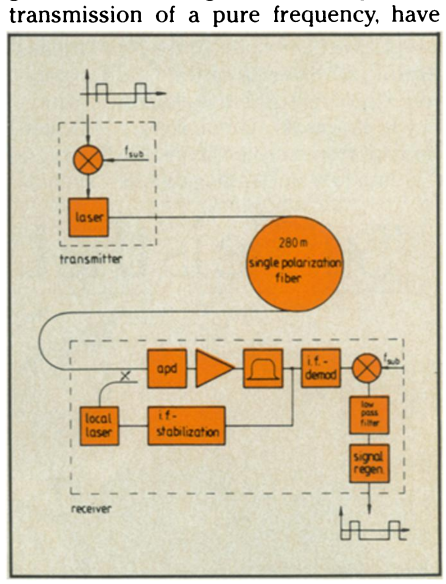
The great advantage of radio receivers is that they can detect and amplify very-weak incoming signals and extract very complex information from them. For example, color photographs have been transmitted to earth from the vicinity of Saturn. All the tones of a symphony plus a moving picture of the orchestra can be transmitted from one side of the earth to another. This is done by combining a strong local signal (from within the receiver) with the weak incoming one.

In the heterodyne case there is a difference between the frequencies of the incoming and local signals. The difference generates a third signal, a beat frequency that varies as the other two alternately reinforce and cancel each other. In the homodyne case the incoming and local signals have the same frequency (either by prearrangement or by tuning until the beats disappear). In either case the combination picks up the modulation of the incoming signal and so delivers its information content in a form strong enough to activate such things as loudspeakers and television tubes.

All the speakers at the session on coherent communications systems stressed that such developments would improve receiver sensitivity by 10 to 30 decibels. As the decibel scale is logarithmic, each decibel means a tenfold improvement in receiver sensitivity. The improvement means longer runs without having to boost the signal with the circuit element called a repeater. The selectivity and tuning that these developments would also bring allow a larger number of transmission channels in the same fiber.

As T. Okoshi of the University of Tokyo points out, there are two kinds of coherence in optics, spatial and temporal. "All heterodyne systems are coherent in the spatial sense," he says. That is, they require a very precise pure frequency of emission. Lasers generally produce a small spread of frequencies; the coherence that originally made lasers famous is phase coherence — everything vibrates up and down at the same time.

Okoshi relates that experimentation on optical heterodyning began in Japan in the 1960s. However, lasers with the required spatial coherence did not exist, and the line of work was dropped. Lately, however, both lasers that are good enough and single-mode fiber, engineered for optimum transmission of a pure frequency, have come into being. The work was restarted in 1979 and continues today.




Strebel et al.

*Circuitry used in Berlin experiment on television transmission by optical fiber.*

The goals, according to Okoshi, are first to improve by heterodyning, then to continue by coherent modulation. The goal of the first stage is to get detection sensitivity down to the shot noise limit, the level of noise naturally produced by the electronic structure of the material. This has actually been surpassed by at least one Tokyo experiment. There are three kinds of modulation: amplitude shift keying (ASK), frequency shift keying (FSK) and phase shift keying (PSK).

Heterodyning with ASK should improve signal sensitivity by 10 to 25 decibels (dB) over direct detection schemes with intensity modulation, Okoshi suggests. FSK heterodyne should give about 3 dB more sensitivity and PSK heterodyne another 3 dB more. Homodyning with ASK or PSK, if it can be achieved, will give yet another 3 dB over the corresponding heterodyne systems.

Milestones of recent progress listed by Okoshi include: the first ASK heterodyne system (using one laser to provide both signals) at the University of Tokyo in 1981; the first FSK system and the first optical heterodyne system using two lasers at Musashino Electrical Communications Laboratory near Tokyo, in May 1982; the ASK heterodyne system that surpassed the practical shot noise limit by 1 dB at the University of Tokyo in September 1982; the first PSK heterodyne system at the French CNET laboratory in October 1982 and in Feburary 1983, the first PSK homodyne system at British Telecom.

All but one of these experiments involved virtually no distance between transmitter and receiver — the single exception, the French PSK experiment, went 3.9 kilometers. They were done at various wavelengths from 0.633 micrometers to 1.523 micrometers, but for a number of technical reasons 1.5 seems the wave of the future. More recently distance experiments have been done. At the New Orleans meeting M. Shikada of the NEC Corporation Optoelectronics Research Laboratory in Kawasaki, Japan, reports ASK heterodyne transmission over 30 kilometers at a data rate of 100 megabits per second. (One bit is a digital information unit, a yes or no or a digit of a binary number; a megabit is one million bits.) Shikada says the experiment convinces him and coworkers that 150-km ASK heterodyne transmission using distributed feedback laser diodes (as the experiment did) and low loss fibers is possible without repeaters.

B. Strebel, representing a group from the Heinrich-Hertz-Institut für Nachrichtentechnik (Heinrich Hertz Institute for Communications Technology) in Berlin, describes an experiment that used a two channel transmitter and a tunable heterodyne receiver. A special fiber that preserves the polarization of the light was necessary to keep all the coherences in order. The fiber was only 280 meters long, but the transmission carried a television test picture (a very complex collection of information) with good image fidelity. It involved a transmission rate of 70 megabits per second with a bit error rate of less than one in a billion.

British Telecom has been experimenting with the longest lines in heterodyne systems. They are actually laid out over the Suffolk countryside in a triangle with corners at Martlesham Heath, Ipswich and Woodbridge. There is a total of 109 km of fiber, and over this they have sent a 142 megabit per second PSK signal with a receiver sensitivity of $^{-}$56 decibel-meters, a 14-dB improvement over direct detection. In January 1984 they succeeded in coupling the phases of two 1.5 micrometer lasers over a 30-km fiber, an indication that long-distance homodyne transmission may be feasible.

To support his economic and sociological argument, de Sola Pool made an analogy with the history of paper. Until the mid-nineteenth century paper was made from rags. The scarcity of the raw material limited the uses. People were so used to the situation that when it became possible to make paper from wood pulp, they wondered whether there was a market for cheap paper.

It soon appeared. Periodicals blossomed. Newspapers, which had been one or two folded sheets concentrating on politics and shipping news, began to cover sports, fires, murders and other human interest stories; to publish fiction, poetry and advice columns. Paper bags and paper packaging were invented. Businesses began to use paper for multiple copies of documents as they had not done before.

It will be the same with increased telecommunication capacity, de Sola Pool suggested. New uses will be invented. Today, he pointed out, telecommunications are used mainly to transmit or retrieve information that one already knows is there and wants for a specific purpose.

But the possibility of "electronic browsing" through libraries — or other forms of random retrieval — he suggested, may soon become a reality. □