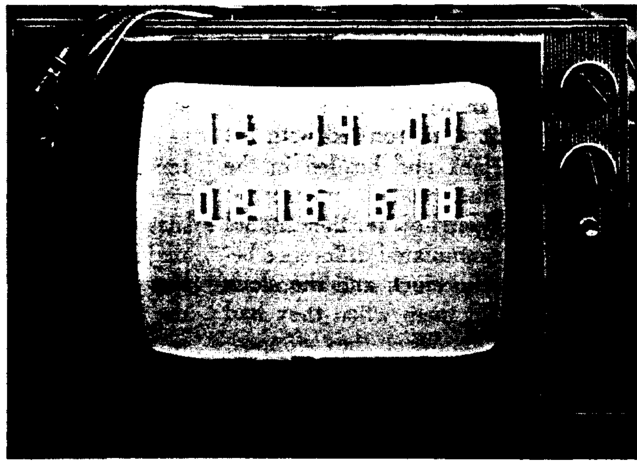
# TIME DISSEMINATION AND CLOCK SYNCHRONIZATION VIA TELEVISION



*A television station with an atomic clock can transmit the time of day with an accuracy of a few microseconds or better to every receiving set within range. An encoder puts the time on the broadcast signal. A decoder at the receiving set makes the time appear as numbers on the TV screen. The top numbers show the time of day at the transmitter, and the bottom numbers give the time difference in nanoseconds between the top line and a clock located at the receiver.*

THE BUREAU (at Boulder, Colo.) has developed an electronic system for synchronizing clocks from coast to coast within a few millionths of a second by means of broadcast signals received on a modified television receiver. Not everyone needs such accuracy, of course, but for those who do the NBS development makes it quick, easy, and convenient. Potential private users include television and radio stations, power companies, airlines, universities, and radio amateurs. Among interested government users are NASA, the military services, the Environmental Science Services Administration, and the Geological Survey.

Required synchronization accuracies vary among organizations. Those who can tolerate millisecond inaccuracies generally use the NBS time and frequency broadcasts of station WWV near Fort Collins, Colo. Others requiring microsecond accuracy commonly carry a portable atomic clock by airplane from location to location synchronizing one clock after another. The flying clock system, besides being expensive, has the disadvantage of being unable to compare all clocks simultaneously. The NBS TV timing system overcomes both the cost and the sequential-synchronization objections to the flying clock system.

The TV system consists of an atomic clock in the broadcasting studio of a television network which puts a time code on the broadcast signal by means of a time-code generator. A decoder at the receiving end picks up the time code, translates it into hours, minutes, and seconds and displays it on the TV screen. Operational tests of the system have been carried on for several months by NBS with the cooperation of KLZ TV, Channel 7 in Denver, and KFBC TV, Channel 5 in Cheyenne.

Two fundamental characteristics of TV signals make it possible to use them to syncronize clocks. First, they always travel at near the speed of light, and second, they travel in the straight lines from transmitters to receivers. Since this is true, distances from one place to another via TV signal can be expressed in microseconds at the rate of about 5000 microseconds per 1000 miles. New York, then, is about 10 000 microseconds from Boulder. It follows that time broadcast from New York will be 10 000 microseconds slower, or behind, the master clock when its is received in Boulder. If a clock in Boulder is to be synchronized with the master clock, it must be set so it is 10 000 microseconds earlier than the time shown on the TV set.

To make this synchronization possible, NBS developed electronics which compares the time received by the TV set with a clock in the same laboratory and displays the difference between them on the TV screen. This line of numbers is updated each second and can show the difference not only in microseconds but in nanoseconds. With such resolution, an observer can tell the distance from transmitter to receiver in feet! (One foot corresponds to one nanosecond.)

Still another innovation that NBS scientists built into the decoder makes it self-checking. If it makes a mistake and comes up with a wrong number, the screen turns red where the numbers appear on a color set, and bars appear in the spaces between numbers on a black and white set.

Recently, Bureau scientists checked the equipment's performance against triangulation points established by the Coast and Geodetic Survey on the plains of eastern Colorado. With the TV transmitting antenna accurately

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**TIME DISSEMINATION** *continued*

fixed as to longitude and latitude, they equipped a van with a TV set and a portable clock synchronized with the transmitter clock and headed in the direction of the geodetic marker. A map showed them how far they should go and the accumulated difference between the studio clock and the clock in the van told them when they had gone far enough. When they stopped, the marker was there.

The geodetic-marker test was just one of many made by NBS to determine the reliability of the TV timing system. Not only the electronics of the encoder and decoder are involved, but also the stability of television signals themselves. Tests on the latter involved paths between Washington, D.C., and Boulder, Colo., and between New York and Boulder.[1] These tests proved that in a month's time the microwave paths were repeatable (and therefore predictable) within one or two microseconds. Day-to-day variations are less than half a microsecond. Local broadcasts are stable within nanoseconds.

The future of the TV timing system is still a matter of speculation, but its potential is well defined. Just three master clocks in the studios of the major networks in New York could serve 70 percent of the population of the United States. The time signals would ride on waves carrying the regular programs at no extra cost in getting them to users. For those not interested in timing, TV programs would come through unaffected by the time signals. The only cost to a user with a TV set would be for a decoder. Parts for the prototype decoder cost $400. The cost of a commercially built unit is unknown, but even if it were 10 times the cost of the parts, the proposed system would be thousands of dollars cheaper than any other synchronization equipment of comparable accuracy.

On the negative side, regular transmission paths might be interrupted, e.g., if a storm knocks out a relay station, then the signal would have to take a different route. Perhaps alternate routes could be determined in advance and the correction factor precalculated to overcome this possibility. Another drawback is the practice of local stations taping network programs for release at a more convenient time. There still would be a sufficient number of live broadcasts to keep laboratory clocks adequately calibrated.

Actual value of the system will be determined by additional operational tests. The U.S. Naval Observatory at Washington, D.C., and NASA's Goddard Space Flight Center in Greenbelt, Md., will conduct such tests this summer with equipment supplied by NBS Boulder Laboratories.

[1] Davis, D. D., Jesperson, J. L., and Kamas, G., The use of television signals for time and frequency dissemination, IEEE Proc. Letters, June 1970.

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**MECHANICAL SHOCK** *continued*

beam and then is split and each half passed through a polarized screen before detection. The two screens differ in plane of polarization by 90 degrees, so that at any instant the phases of light in each channel differ by 90 degrees. Photodetectors in each fringe presentation sense fringe movement as a change in light intensity at their apertures.

The two photodetector signals are amplified and fed to a single-sideband carrier-insertion circuit to modulate a locally generated 60-MHz signal. The resulting signals drive a frequency-sensitive discriminator; the polarity of its output indicates the direction and its magnitude the velocity of the motion. Since acceleration is differentiated velocity, the discriminator output can be differentiated electrically to yield an analog of acceleration. In tests this signal was found to agree closely with the output of an accelerometer for frequencies of interest.

The principal uncertainties in the velocity measurement are attributable to the electrical calibration of the discriminator and final voltage measuring device.

### Use of System

An accelerometer whose sensitivity is to be determined is mounted with the target reflector on the shock motion generator table. The instantaneous outputs from both the accelerometer and the velocity-measuring system are measured during shock by high-speed voltage sensing instruments and converted to computer-compatible form by analog-to-digital converters. The digital outputs are sent to an on-line computer, which stores the instantaneous voltage readings in its magnetic core memory. At the end of the shock pulse, the computer executes a program employing a Fourier transform of both the acceleration and velocity signals. The velocity signal is mathematically differentiated to obtain a reference acceleration signal. The two acceleration signals, one from the accelerometer and the other from the interferometer, are compared to obtain the sensitivity factor of the accelerometer being calibrated. Phase information also is calculated as part of the calibration process.

The system will be capable of calibrating accelerometers for various pulse shapes, peak acceleration amplitudes and pulse widths ranging from 15 *g* at 50 milliseconds to 10 000 *g* at 200 microseconds. This optoelectrical shock system will enable the Bureau to add the calibration of shock accelerometers to its services during 1970.

[1] Ballard, L. D., Epstein, W. S., Smith, E. R., and Edelman, S., Optical FM System for Measuring Mechanical Shock, Nat. Bur. Stand. (U.S.), J. Res. 73C (Engr. and Instr.), Nos. 3 and 4, 75–78 (July–Dec. 1969).