A SURVEY OF TIME AND FREQUENCY DISSEMINATION TECHNIQUES

J. L. Jespersen
Frequency-Time Dissemination Research Section
Time and Frequency Division
National Bureau of Standards
Boulder, Colorado 80302

There are a number of common elements which characterize most time and frequency dissemination systems. A simple VLF timing system can be used to illustrate these characteristics. First, suppose there is a sinusoidal signal available at 10.0 kHz and that no other signals are available. A certain positive going zero-crossing of this signal leaving the transmitter at 0000 UT will reach the user at a later time equal to the propagation delay. The user must know this delay because the accuracy of his knowledge of the time can certainly be no better than his knowledge of this delay.

Since all cycles of the signal are identical, the signal is ambiguous and the user must somehow decide which cycle is the "on time" cycle. This means he must already know the time to plus or minus half the period of the signal or ± 50 μs in this case.

Finally, the user may want to use this system, say once a day, for an extended period of time to check his clock. However, it may be that the delay will differ from one day to the next and if he does not know how this value differs from day to day, then his accuracy will be limited by the lack of repeatability of arrival time of the signal. These three characteristics are primarily related to the design of the signal and to the propagation characteristics of the medium. Some important practical considerations are cost to establish and maintain the service, ease of use, and cost to the user.

We can classify time dissemination systems in a number of ways but one useful division is to consider those systems whose carrier frequencies are low enough frequencies to be reflected by the ionosphere and those whose carrier frequencies are at higher frequencies which penetrate the ionosphere. The former may be observed at great distances from the transmitter but suffer from ionospheric propagation anomalies that limit accuracy; the latter (except for long-range groundwave systems such as Loran-C) are restricted to line of sight but suffer little or no deterioration in the signals due to propagation anomalies. The most accurate systems tend to be in the latter category while the former are used by the greatest number of users. Some systems, such as WWV, were built expressly for the purpose of time and frequency dissemination while others, such as Loran-C, a navigation system, can also be used to disseminate time and frequency.

Almost any radio signal with an unambiguous characteristic and which can be observed simultaneously at two locations can be used to synchronize clocks at those two locations. At the present time, TV is used extensively in this way. For example, suppose the arrival time of a synchronization pulse is measured with respect to the clocks at the two locations. If clocks are synchronized then the difference between the two clock measurements will simply be the radial difference in propagation delay as shown in Fig. 1. If this differential delay is known in advance of the measurements, then any difference between the measured differential delay and the known delay is the time difference between the two clocks. Measurements of this sort have shown that TV signals have the potential for disseminating time in the sub-microsecond region.[1,2] This has led NBS[3] to develop an experimental TV time dissemination system which incorporates a code in the transmitted television signal during the vertical blanking interval. Upon reception, this signal is decoded and displayed on a commercial TV set. The top line of the display gives hours, minutes, seconds and the bottom line gives the difference between a local clock 1 pps and the TV 1 pps. (See Fig. 2.) The resolution in the second line of display may be as small as 1 nanosecond.

There are a number of questions and problems for time dissemination which are not resolved. These are largely related to uncertainties concerning the configuration of the electronic systems of tomorrow which depend heavily upon time and frequency techniques. Examples are complex navigation and communication systems which are now being considered by both the civilian and military sectors. It is not clear how these systems could be used to disseminate time, but if there are a large number of independent systems, each generating and disseminating its own frequency and time information, we may find it to be much more **efficient**, in terms of maximizing the communication capacity of the systems, to have one or two systems provide frequency and time information for the others. As an example (which is related to our current experience) consider TV which utilizes a significant portion of its communcation capacity to transmit sync pulses. We have a situation here where inexpensive clocks (or oscillators as they are usually called) have to be synchronized quite often at the expense of channel capacity. On the other hand, if TV sets had synchronization information from some other source, there would be more capacity for communications.

Alternatively, the TV set could have a better oscillator. Of course, the reason that we use inexpensive oscillators in TV receivers is that it is more economical than efficient use of the spectrum. However, the spectrum is a limited natural resource which will become more expensive as greater demands are made upon it. In fact, we might find at some future time that it will be more economical, in terms of spectrum conservation, to use both better clocks and common sources of time and frequency information. We might even go so far as to think of the latter as a time and frequency utility which could be "plugged into" at will.

References

1. J. Tolman, V. Ptáček, A. Souček, and R. Stecher, "Microsecond Clock Comparison by Means of TV Synchronizing Pulses," IEEE Trans. Instrumentation and Measurement, Vol. IM-16, No. 3, pp. 247-254, September 1967.

2. J. B. Milton, "Standard Time and Frequency: Its Generation, Control, and Dissemination from the National Bureau of Standards Time and Frequency Division," NBS Tech. Note 379, pp. 1-27, August 1969.

3. D. D. Davis, J. L. Jespersen, and G. Kamas, "The Use of Television Signals for Time and Frequency Dissemination," Proc. IEEE (Ltr.), Vol. 58, No. 6 (in press).

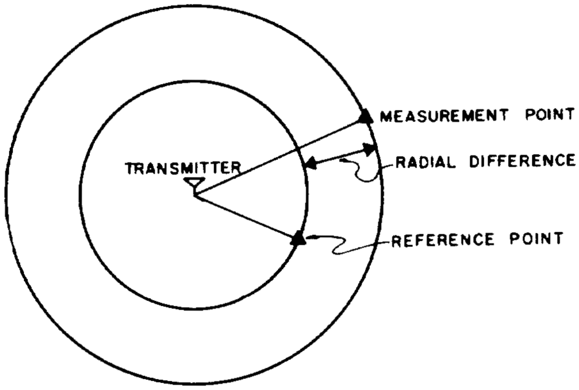

Figure 1. Illustrates use of a TV signal to synchronize clocks at two locations.

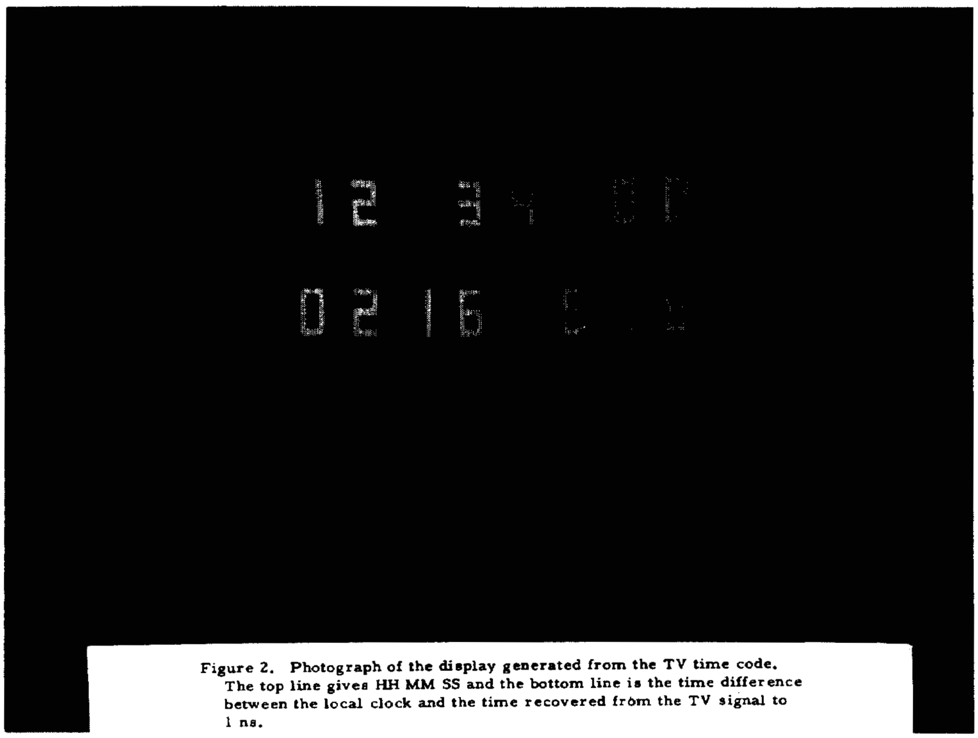

Figure 2. Photograph of the display generated from the TV time code. The top line gives HH MM SS and the bottom line is the time difference between the local clock and the time recovered from the TV signal to 1 ns.