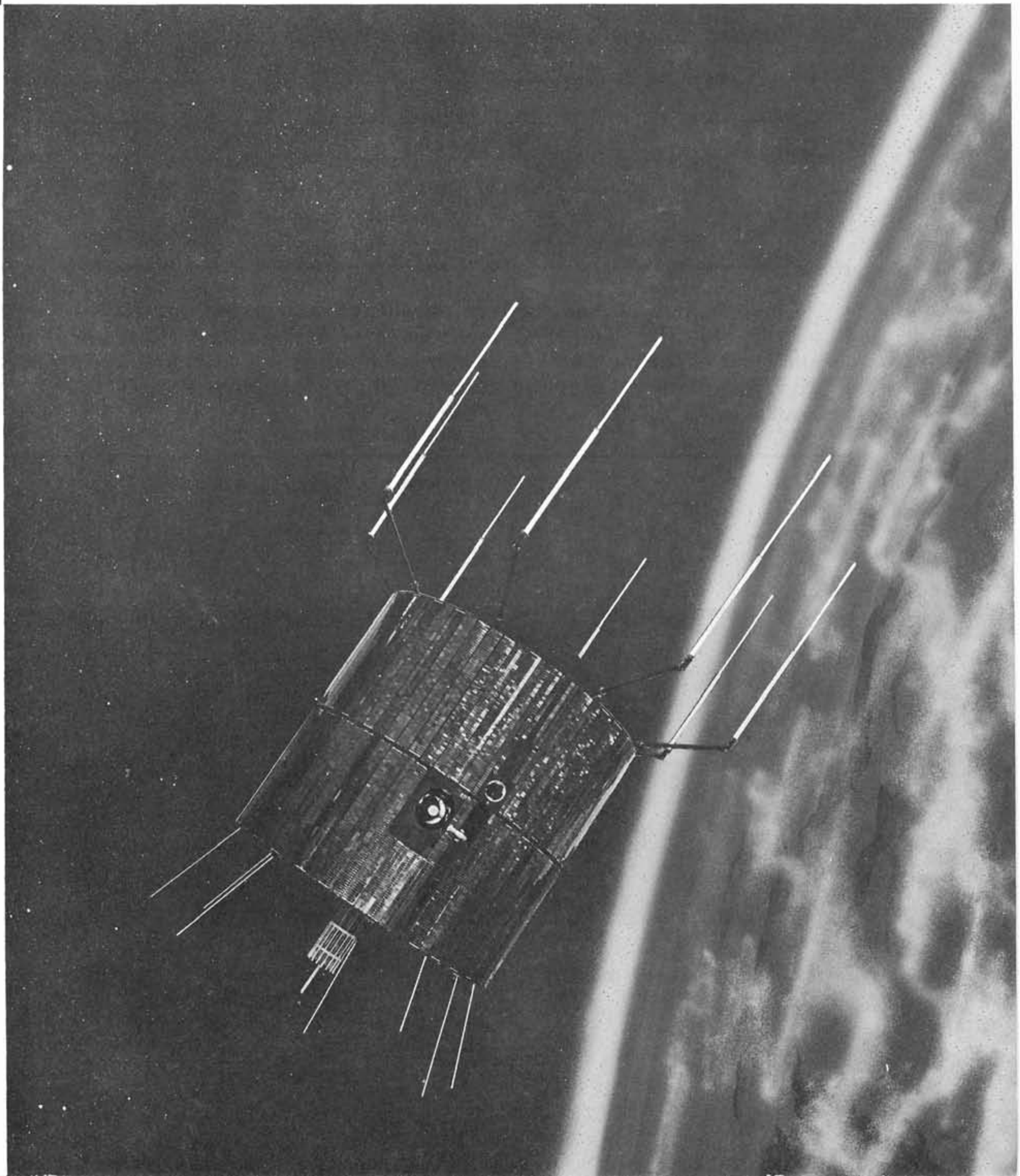
A UNITED STATES
DEPARTMENT OF
**COMMERCE**
**PUBLICATION**

# NBS FREQUENCY and TIME SATELLITE EXPERIMENT



**U.S.
DEPARTMENT
OF
COMMERCE**
National
Bureau
of
Standards
Boulder
Colorado

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This booklet is designed to encourage and assist interested parties to participate with the National Bureau of Standards in satellite frequency and time experiments. For additional information, please contact the Time and Frequency Division, Section 273.01, National Bureau of Standards, Boulder, CO 80302.

## PAST NBS SATELLITE FREQUENCY AND TIME EXPERIMENTS

The National Bureau of Standards (NBS) has transferred standard frequency and time by satellite since 1967. Participants in the initial experiments both transmitted and listened to time signals via the satellite. More recent experiments required listening only.

All experiments utilized geo-stationary satellites that operated at VHF and UHF frequencies. The two-way time transfer successfully synchronized clocks to five microseconds; one-way time transfers were accurate to between 40 and 100 microseconds, depending on the method of calculating the propagation delay. More details on these experiments will be found in References 1 through 4.

## CURRENT EXPERIMENT

The National Bureau of Standards, operating under NASA's "User Experimental Program," now employs the ATS-3 satellite to relay a frequency and time format similar to that of WWV and WWVH (NBS standard time and frequency stations). It should be stressed that this use of ATS-3 for the dissemination of frequency and time information is experimental and will not continue indefinitely.

The satellite relays voice announcements of the time of day, ticks every second, audio-frequency tones, and a digital time code. Figures 1 and 2 show oscilloscope traces of the tick-plus-tone and the expanded tick from ATS-3 as received in Boulder, Colorado. Broadcasts occur at 1700 to 1715 and 2330 to 2345 GMT (Greenwich Mean Time), in the format shown in figure 3.

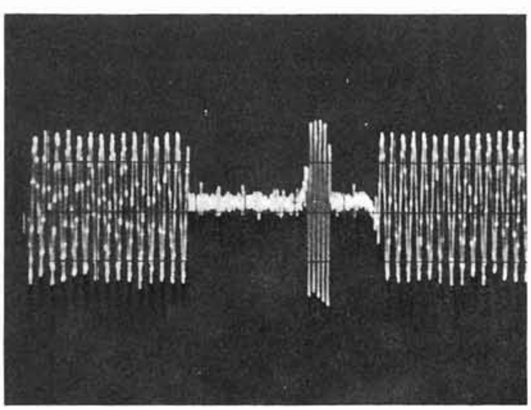

Figure 1.—The "tick," which consists of 5 cycles of 1000-Hz tone, is inserted in a 40-ms "hole" in the continuous tone.

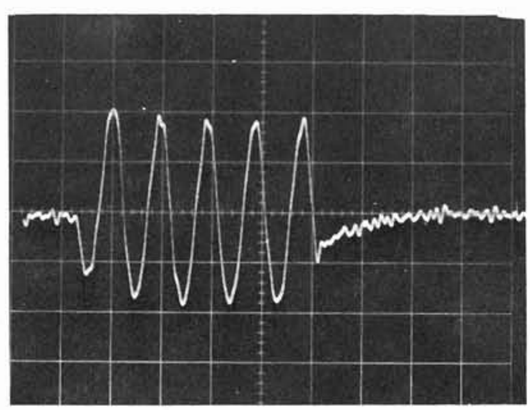

Figure 2. — Expanded display (1 ms/div) of "tick".

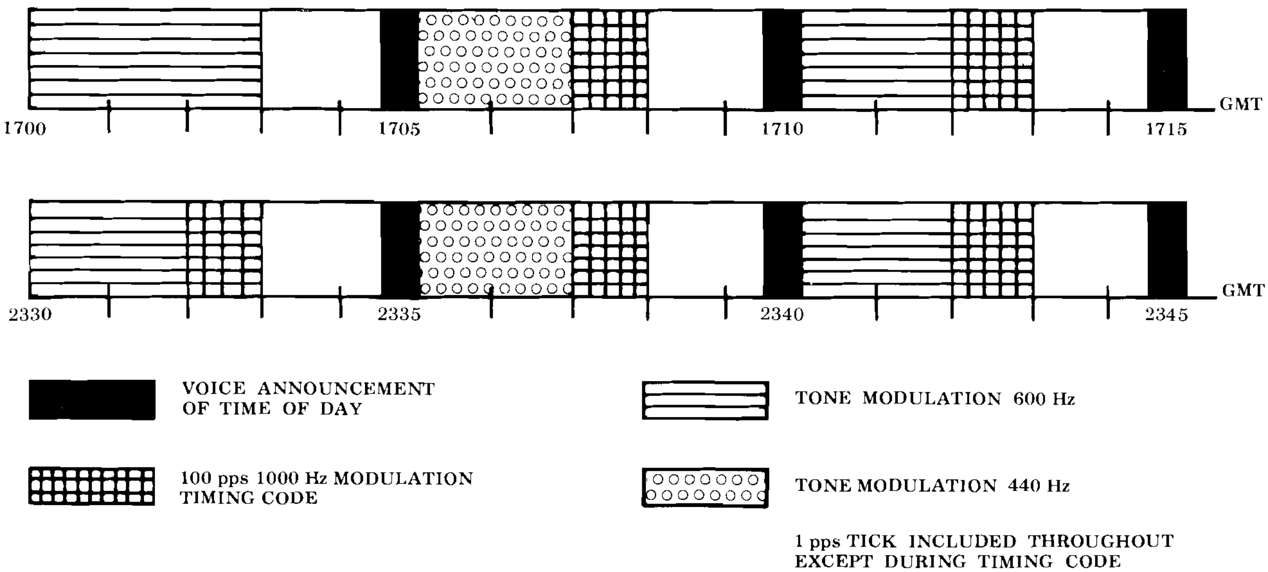


Figure 3. BROADCAST SCHEDULE FROM THE ATS-3 SATELLITE

The two 15-minute broadcast periods occur Monday through Friday, excluding holidays. Being an experimental program, some interruptions to the schedule are expected. Although infrequent, they are necessary to allow NASA to maintain and track the satellite.

August 1, 1972 is the expected cutoff date for these experimental broadcasts, but shortly thereafter, NBS expects to provide a 24-hour experimental service continuing for an indefinite period, using a Department of Commerce satellite.

## RECEIVING EQUIPMENT

The ATS-3 satellite broadcasts on a center frequency of 135.625 MHz (VHF-2.2 meters) with a 30-kHz bandwidth. The broadcast carrier is frequency modulated (FM).

The receiver should have a noise figure of 5 db or less, and the gain of the receiving antenna needs to be about 12 db above isotropic. Signals from the satellite are linearly polarized; thus, if Faraday-rotation effects are to be avoided, the receiving antenna should be circularly polarized in either sense. A linearly polarized antenna is acceptable, but may require rotation about its axis for maximum received signal. A block diagram and photo of a typical receiving system is shown in Fig. 4.

Equipment requirements may be discussed with NBS personnel by calling (303) 447-1000 (499-1000 after November 1971), ext. 3510 or 3281, or by mail.

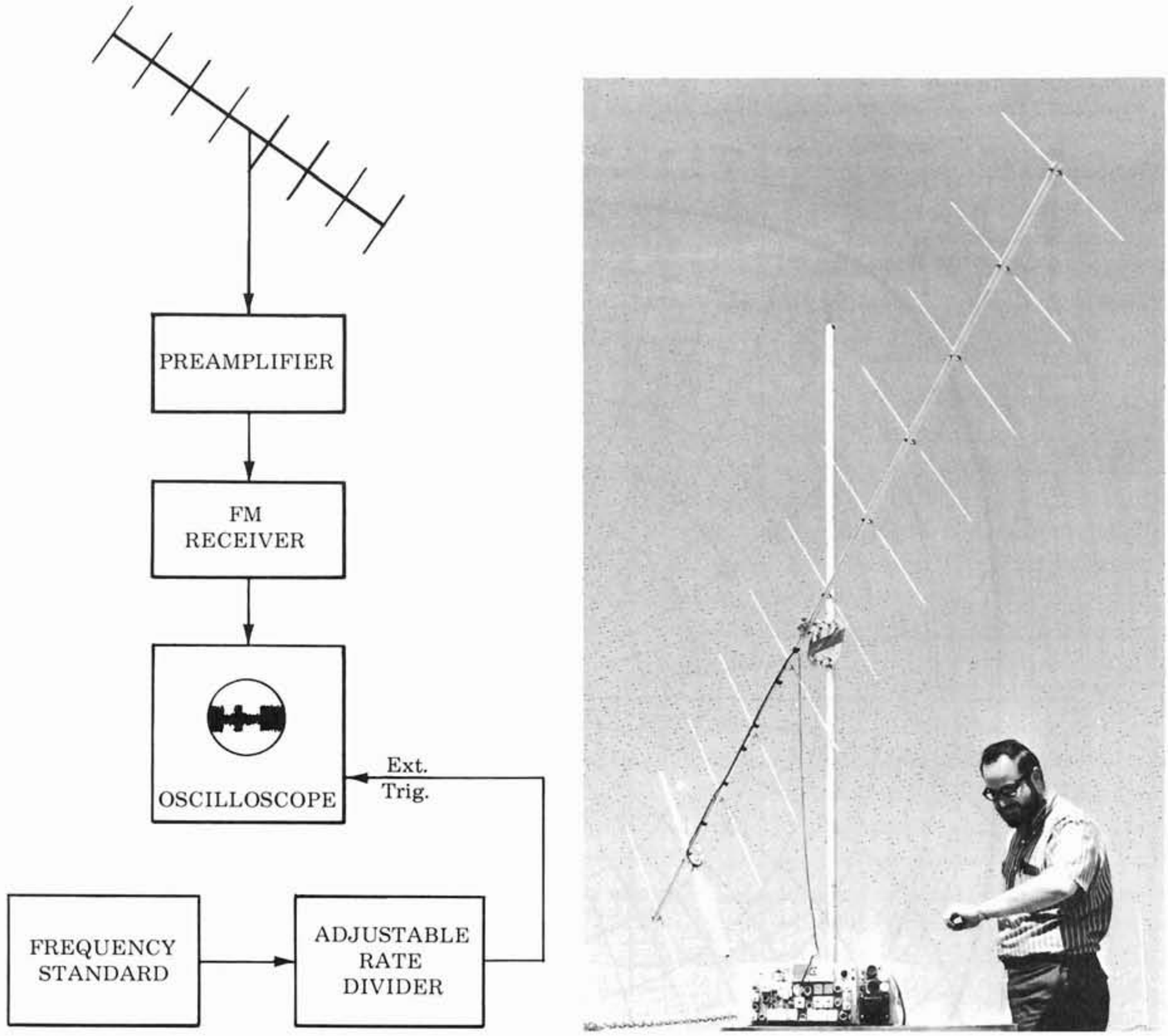


Figure 4. Block diagram and photo of a typical receiver system and antenna.

## SATELLITE LOCATION AND RECEIVING-ANTENNA POINTING DATA

Located some 22,300 miles above the equator at approximately 70 degrees west longitude, the ATS-3 satellite is in a relatively fixed position in the sky at all times. Figure 5 provides data on the satellite's coverage. Contours superimposed on this map provide antenna-pointing data in angles of elevation and azimuth. Once the antenna is properly pointed towards the satellite, it need not be moved. A sample antenna-pointing calculation is also included.

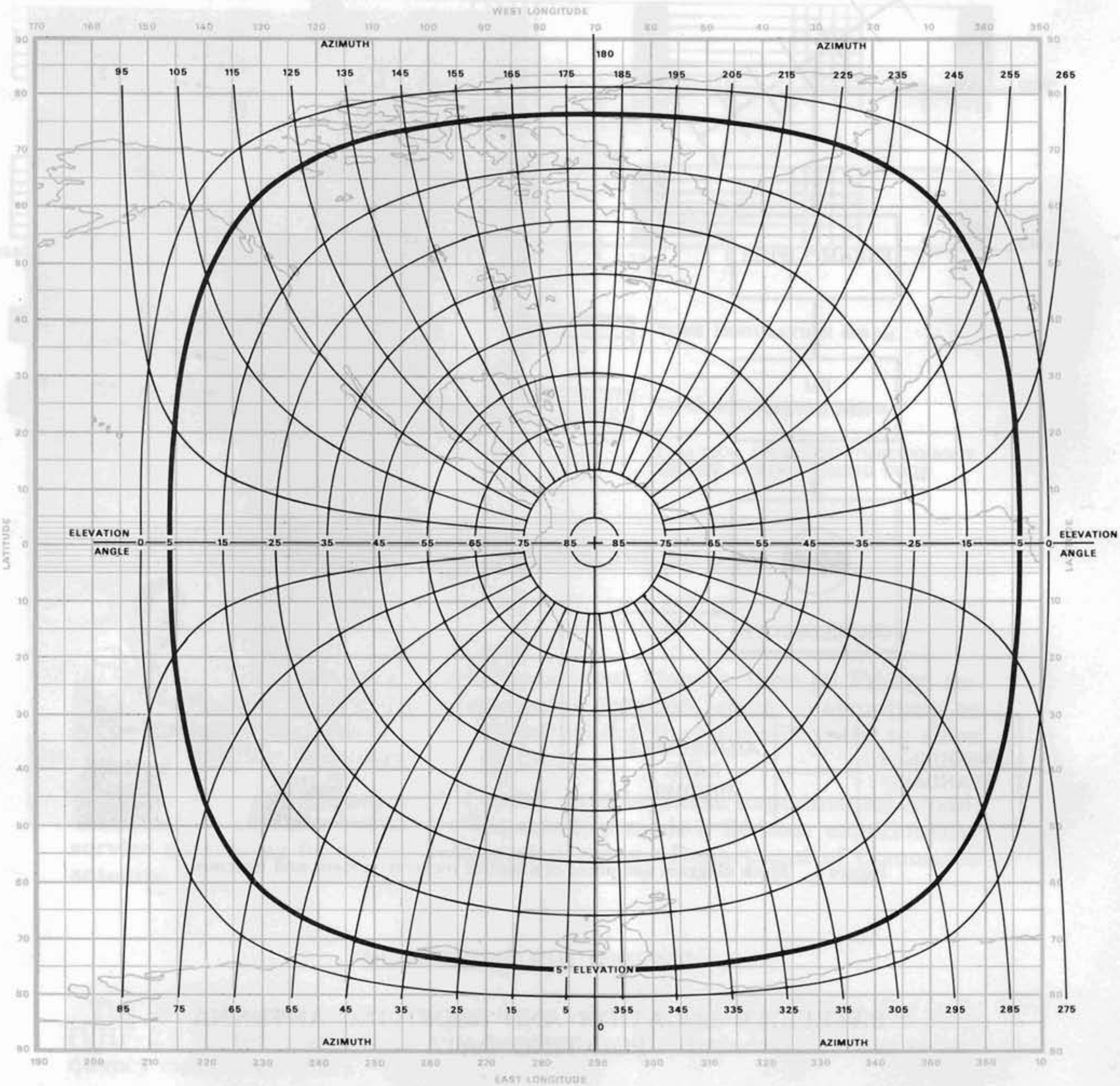


Figure 5. ANTENNA-POINTING DIAGRAM

To aim an antenna in Washington, D.C. (located at 77°W, 39°N), for example, the map shows the proper angles to be 45° elevation above horizontal, and 168° azimuth.

## FREQUENCY AND TIME BROADCAST ACCURACY

Frequency and time signals originate and are transmitted to ATS–3 from the Time and Frequency Division of NBS, in Boulder, Colorado. They are related to the NBS time system which generates Coordinated Universal Time (UTC, also known as GMT or Z-time).

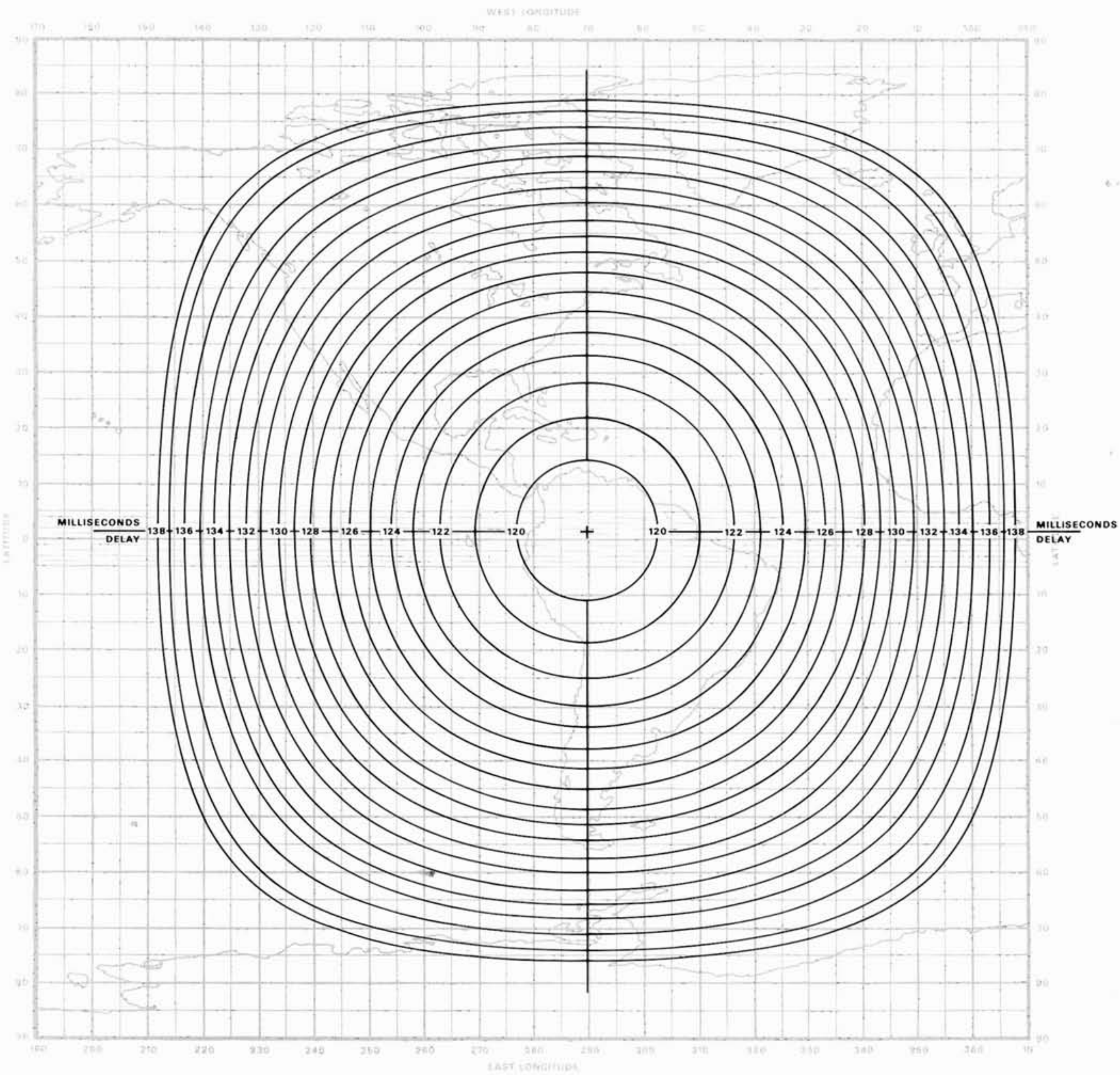


Figure 6. DELAY CONTOURS: 1700-1715 GMT

Sample calculation of delay for a receiver in Washington, D.C.:

| | |
|---|---|
| Delay from Boulder to satellite | 128.1 milliseconds |
| Delay from satellite to Wash., D.C. | 124.5 milliseconds |
| | Total delay 252.6 milliseconds |

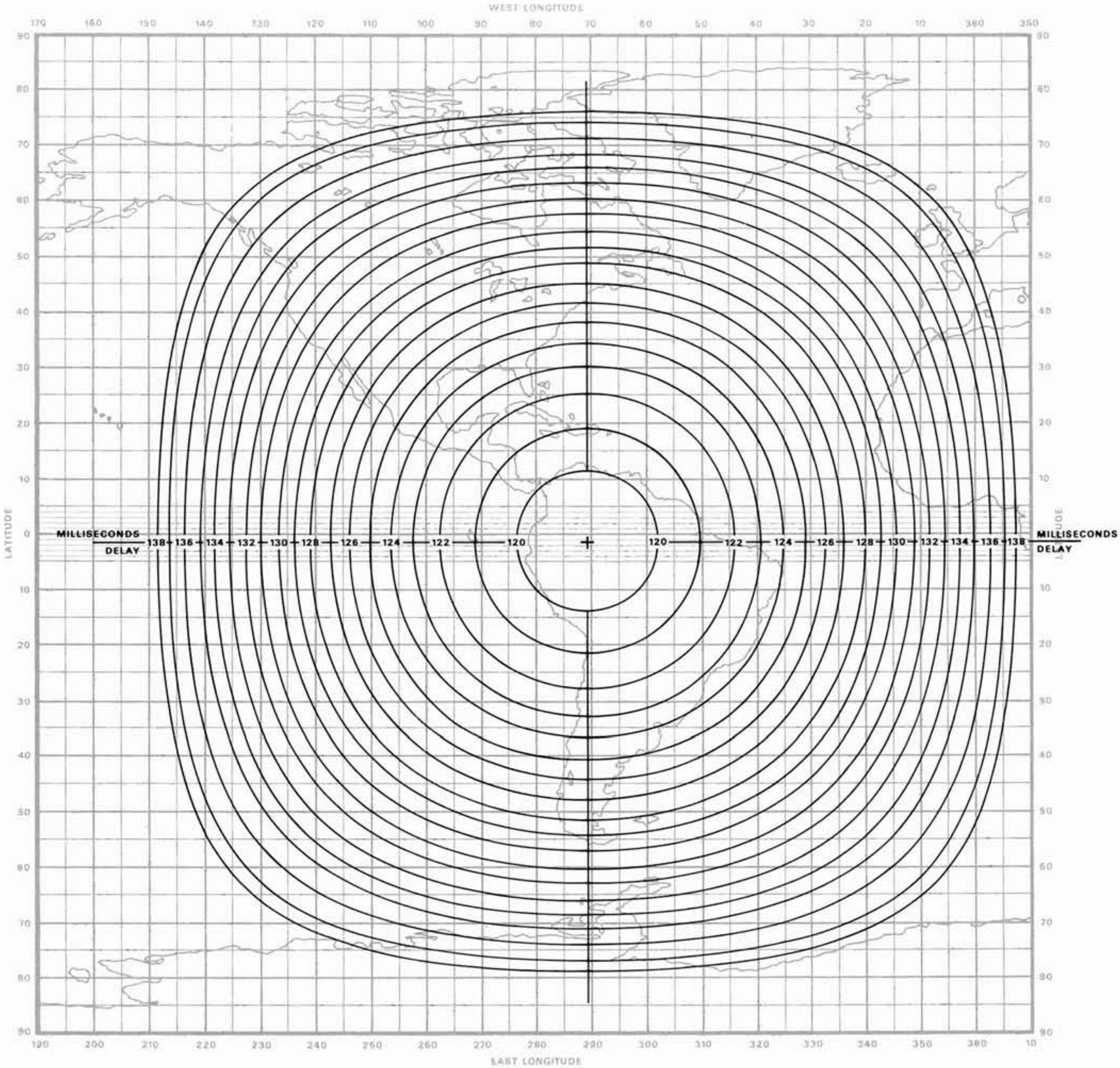


Figure 7. DELAY CONTOURS: 2330-2345 GMT

Because of the distance travelled and transponder/receiver delays, the relayed signals arrive back on earth about ¼ second after transmission. Thus, listening to the voice announcements and 1-pps ticks provides time accurate to better than one second. For more precise clock setting, the well-known oscilloscope technique of alining the beginning of a received 5-ms, 1000-Hz tick with the scope trigger from a local clock may still be used (see Ref. 5). This technique can provide a few milliseconds accuracy in this satellite service.

Frequency can be obtained from the 1000-Hz, 440-Hz, and 600-Hz modulations, or by time synchronization over a period of days.

The delay, from the NBS laboratories in Boulder through the satellite and back down to the user, may be calculated from the maps and delay contours in figures 6 and 7. These contours are accurate to a few milliseconds. Monthly updating may be required, for which new contours will be furnished to the user upon request. The contours shown here apply to the months of October and November 1971.

## REFERENCES


1. Jesperson, J. L., Kamas, G., Gatterer, L. E. and MacDoran, P. E., Sattellite VHF Transponder Time Synchronization, Proc. IEEE, **56**, No. 7, 1202-1206 (July 1968).

2. Gatterer, L. E., Bottone, P. W. and Morgan, A. H., Worldwide Clock Synchronization Using a Synchronous Satellite, IEEE Trans. Instr. and Meas., **IM-17**, No. 4, 372-378 (December 1968).

3. Hanson, D. W. and Hamilton, W. F., One-Way Time Synchronization via Geostationary Satellites at UHF, IEEE Trans. Instr. and Meas., **IM-20**, No. 3, 147-153 (August 1971).

4. Hanson, D. W. and Hamilton, W. F., Clock Synchronization from Satellite Tracking, IEEE Trans. Aerospace and Electronic Systems, **AES-7**, No. 5 (September 1971).

5. Hewlett Packard Application Note 52, Frequency and Time Standards, (1965).


Reprints of the first four articles are available from NBS upon request.

SOMETHING ABOUT NBS

The National Bureau of Standards is under the U.S. Department of Commerce. NBS goals are to strengthen and advance the nation's science and technology and to facilitate their effective application for public benefit. Part of this goal is attained by disseminating time-and-frequency standards to the nation.

Time and frequency are unique standards among the many maintained and distributed by NBS. Unlike other standards of length, mass, etc., that must be distributed via secondary standards carried to and from laboratories, time and frequency can be transmitted directly via radio waves to the users. Radio station WWV and other NBS facilities accomplish part of this task, but a need exists to extend and improve this service. The proposed system offers a large improvement in the Bureau's ability to disseminate accurate standards. Although not intended to provide full-time service to all possible users, it will supply a service to a large segment of the U.S. public.



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