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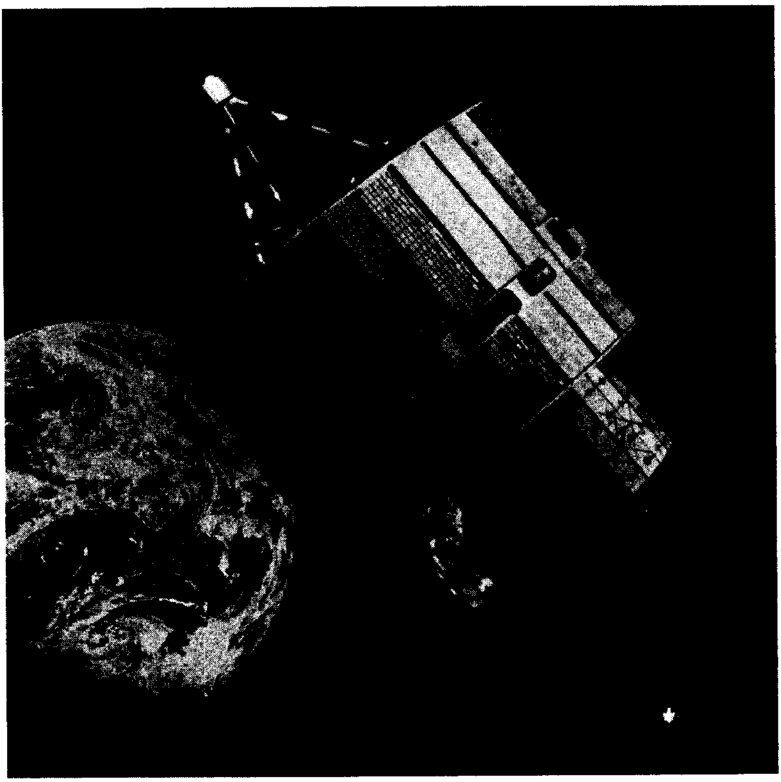
NBS TIME VIA SATELLITES



NATIONAL BUREAU
OF STANDARDS
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NBS TIME VIA SATELLITES

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NBS TIME VIA SATELLITES

As a complement to the present time and frequency services of WWV, WWVH, and WWVB, the National Bureau of Standards (NBS) is now sponsoring a satellite-disseminated time code using the GOES* satellites of the National Oceanic and Atmospheric Administration (NOAA) [1]. The time code is referenced to the UTC(NBS) time scale and gives Coordinated Universal Time (UTC). NOAA considers it a permanent feature of the GOES satellites, intended to serve the GOES users. It may, however, be used by others needing a general purpose time reference. The time code is available to the entire Western Hemisphere from two satellites on a continuous basis.

1. BACKGROUND

The GOES satellites are in orbit 36,000 kilometers above the equator. They travel at about 11,000 kilometers per hour and remain continuously above the same spot on earth. They are thus termed geostationary. Since they always have the same regions of earth in view, they can provide 24-hour, continuous service.

GOES is an operational descendant of NASA's Applications Technology Satellites. Experiments using these satellites clearly demonstrated that earth-synchronous spacecraft are useful for observing environmental conditions. The GOES satellites provide meteorological observations for:

- Continuous storm tracking
- Cloud analysis -- density, temperature, height, wind velocity
- Surface temperature mapping
- Space environment sun/earth interaction
- Collection of rain, snow, flood, Tsunami, earthquake, air/water pollution data

A time code is included in the satellite transmissions to add time and a date to the data collected by the remote sensors, thus making the data much more useful. The time code is part of the interrogation channel which is used to communicate with the remote sensors. The interrogation messages and time code are prepared and sent to the GOES satellites from Wallops Island, Virginia. NBS maintains atomic clocks, referenced to UTC(NBS), at this site to generate the time code.

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*GOES stands for Geostationary Operational Environmental Satellite.

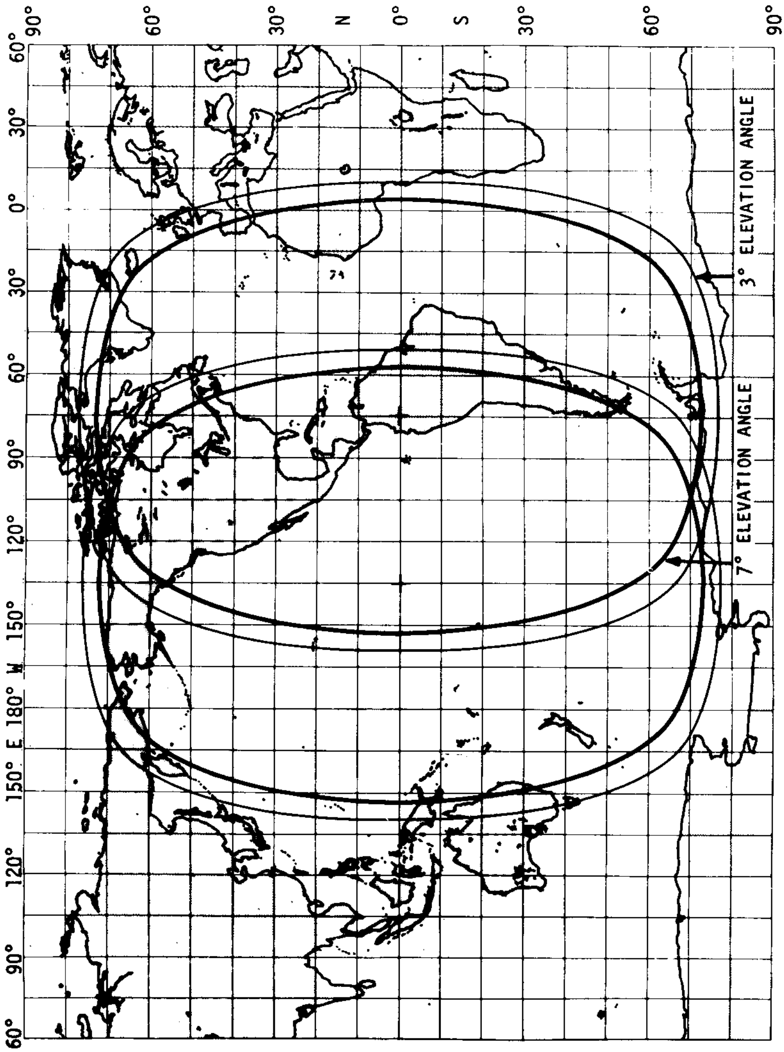

FIGURE 1. COVERAGE OF THE GOES SATELLITES.

2. COVERAGE

There are three GOES satellites in orbit, two in operational status with a third serving as an in-orbit spare. The two operational satellites are located at 135° and 75° West Longitude and the spare is at 105° West Longitude.

The earth coverages of the two operational satellites are shown in figure 1. The heavy oval lines overlap the points on earth where each satellite is 7° above the horizon. The lighter lines represent a 3° elevation angle.

3. SIGNAL CHARACTERISTICS

The signal characteristics are summarized below. The signals phase-shift modulate the carrier and are right-hand circularly polarized. Reception of these signals requires the use of a relatively small antenna and a coherent synchronous digital receiver.

	WESTERN SATELLITE	EASTERN SATELLITE
FREQUENCY	468.8250 MHz	468.8375 MHz
POLARIZATION	RHCP	RHCP
MODULATION	CPSK (± 60°)	CPSK (± 60°)
DATA RATE	100 BPS	100 BPS
SATELLITE LOCATION	135° W	75° W
SIGNAL STRENGTH (OUTPUT FROM ISOTROPIC ANTENNA)	-139 dBm	-139 dBm
CODING	MANCHESTER	MANCHESTER
BANDWIDTH	400 Hz	400 Hz

4. DATA FORMAT

The time code is time-division-multiplexed (interlaced) with interrogation messages. Once every half-second, a time code word, 4 bits, is transmitted (see figure 2). A complete time code is transmitted every 30 seconds, beginning on the half-minute,

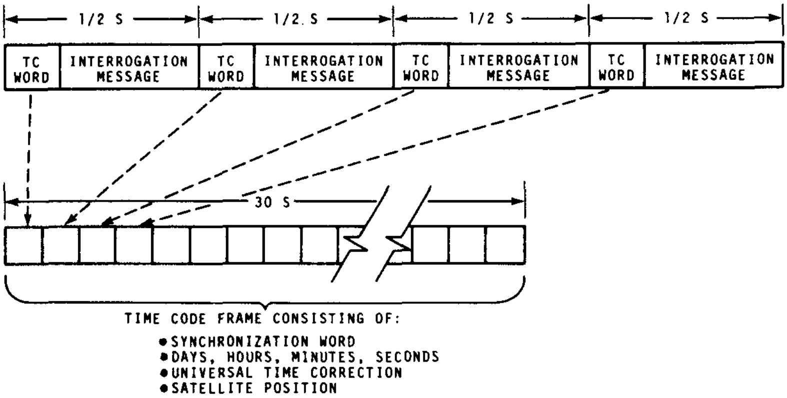

FIGURE 2. INTERROGATION CHANNEL FORMAT.

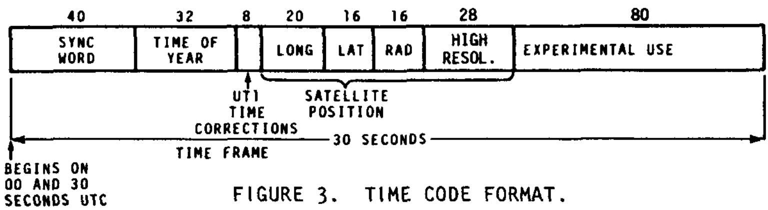

FIGURE 3. TIME CODE FORMAT.

giving day of year, hour, minute, and second. The format is shown in figure 3, beginning with a sync word (40 bits of alternating 1's and 0's), a time-of-year message, UT1 correction, and satellite position.

5. ANTENNA POINTING

Pointing an antenna to either satellite is relatively simple. Because of the large beamwidths of low-gain antennas (<10 dB), pointing into the general direction of the satellite is usually sufficient. However, the antenna must be located so it has an unobstructed path to the satellite. Figures 4 and 5 provide detailed information for antenna pointing with elevation and azimuth angles provided. For example, the pointing directions to the eastern satellite from San Francisco can be obtained from figure 5 as approximately 119° azimuth and 24° elevation.

6. PERFORMANCE

The GOES time code can be used at three levels of performance: uncorrected, corrected for mean path delay only, and fully corrected.

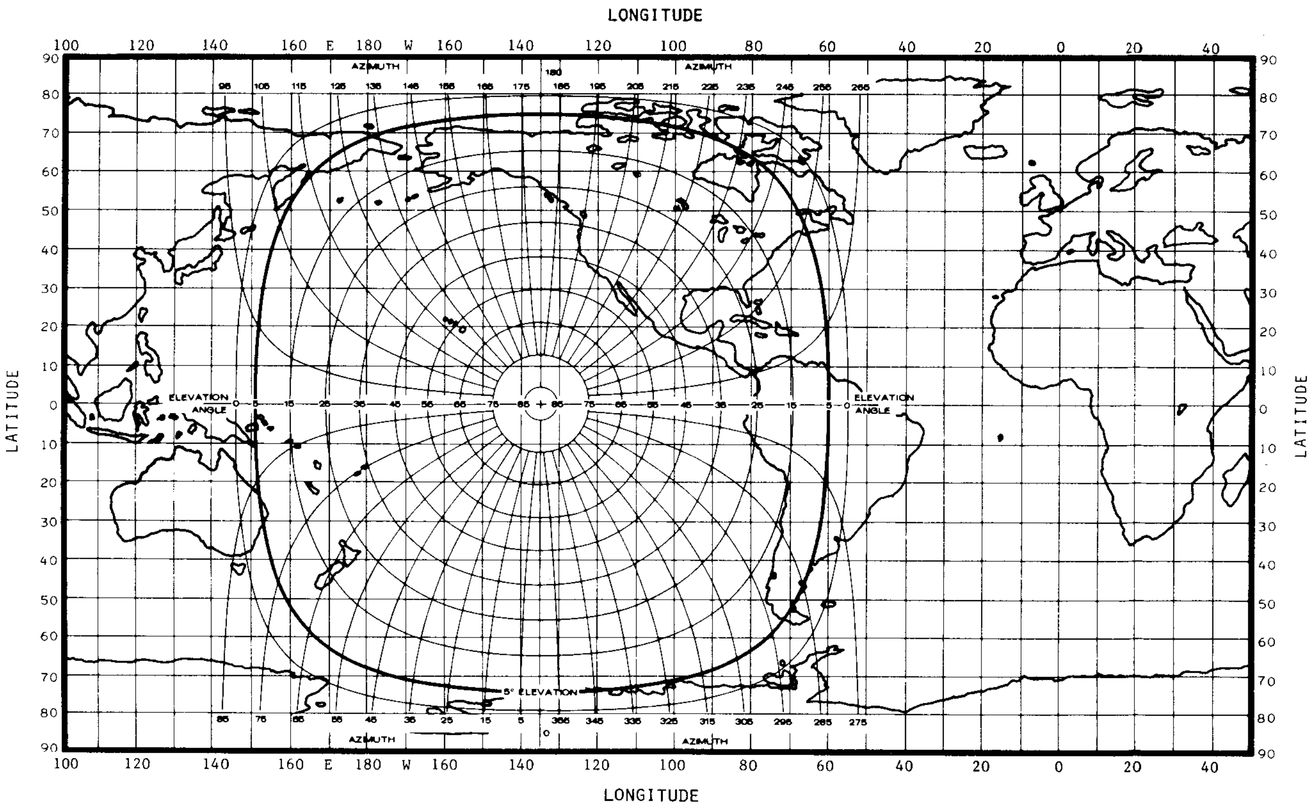

FIGURE 4. WESTERN SATELLITE POINTING ANGLES.

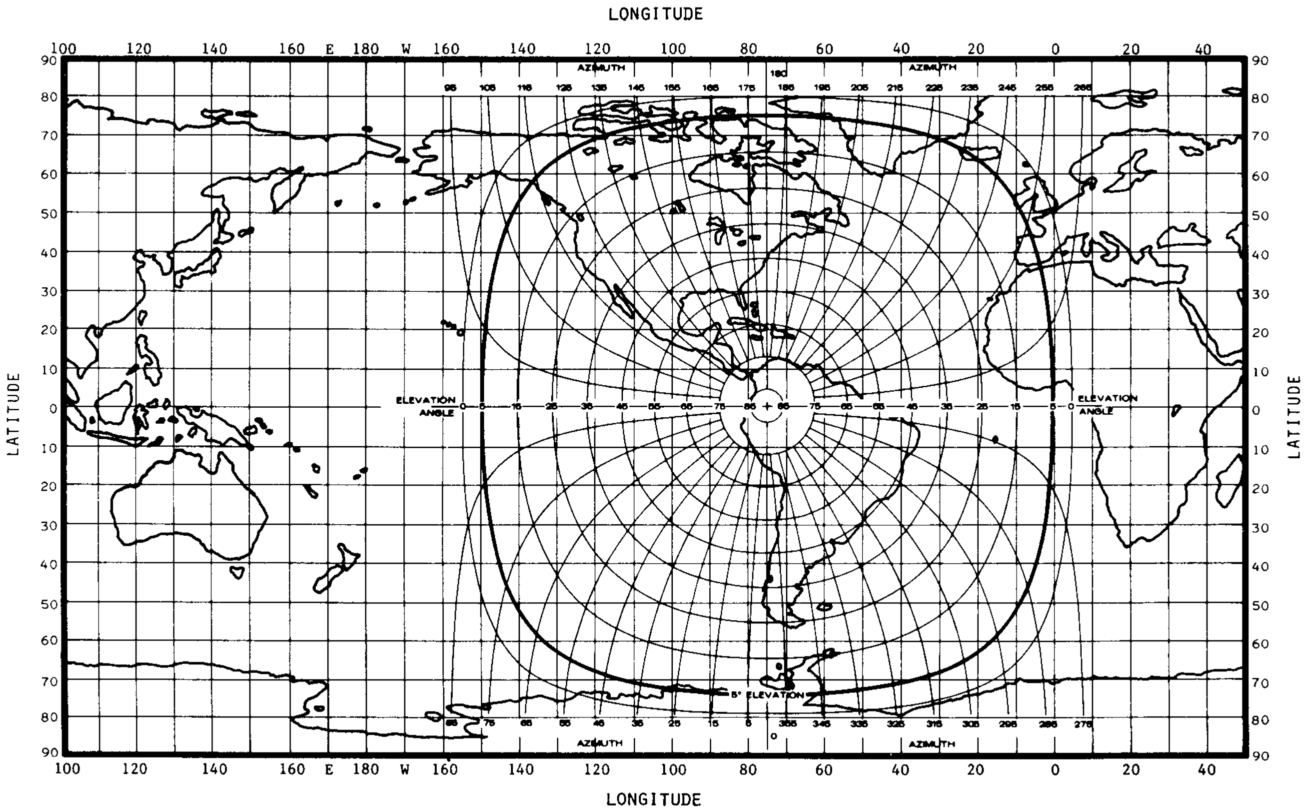

FIGURE 5. EASTERN SATELLITE POINTING ANGLES.

UNCORRECTED

The path delay from point of origin (Wallops Island, Virginia) to the earth via the satellite is approximately 260,000 microseconds. Since the signals are advanced in time by this value before transmission from Wallops Island, they arrive at the earth's surface nearly on time (within 16 milliseconds).

The path delay, as observed at a fixed location, varies in a cyclical fashion during each day because the satellites' orbits are not perfectly circular and their orbital planes are usually slightly inclined with respect to the equatorial plane. The peak-to-peak magnitude of the delay variation depends on the satellite orbit eccentricity and inclination but typically amounts to a few hundred microseconds [2]. Occasional discontinuities or abrupt changes in the path delays may be observed due to satellite maneuver operations performed to control the satellites' orbital positions within certain prescribed limits.

CORRECTED FOR MEAN PATH DELAY

Accounting for the mean path delay to any point on the earth's surface, but ignoring the cyclic (24-hour) delay variation generally guarantees the signal arrival time to ± 0.5 millisecond. For example, the mean delay to San Francisco through the eastern satellite is 130.5 milliseconds downlink (from figure 7) plus 124.5 milliseconds uplink delay, for a total of 255 milliseconds. Since the time is advanced by 260 milliseconds before leaving Wallops Island, the time arrives at San Francisco 5 milliseconds early. Path delay variations of several hundred microseconds during a day will typically be observed as in the "uncorrected" case.

FULLY CORRECTED

As mentioned earlier, the cyclic delay variation is a result of the satellite orbit or path around the earth not being perfectly circular and not in the plane of the equator. The orbit is actually an ellipse and has a small inclination--usually less than 1°. To compensate for these and other effects, the satellite position is included with the time message for correction of path delay by the user.

This correction usually provides path delays accurate to better than ±50 microseconds, except for occasional brief periods when available satellite tracking data may be of reduced quality. The ultimate accuracy of the recovered time depends upon knowledge of user equipment delays and noise levels as well as the path delay. Experience at NBS over a period of several years indicates that the overall accuracy of the received time code from

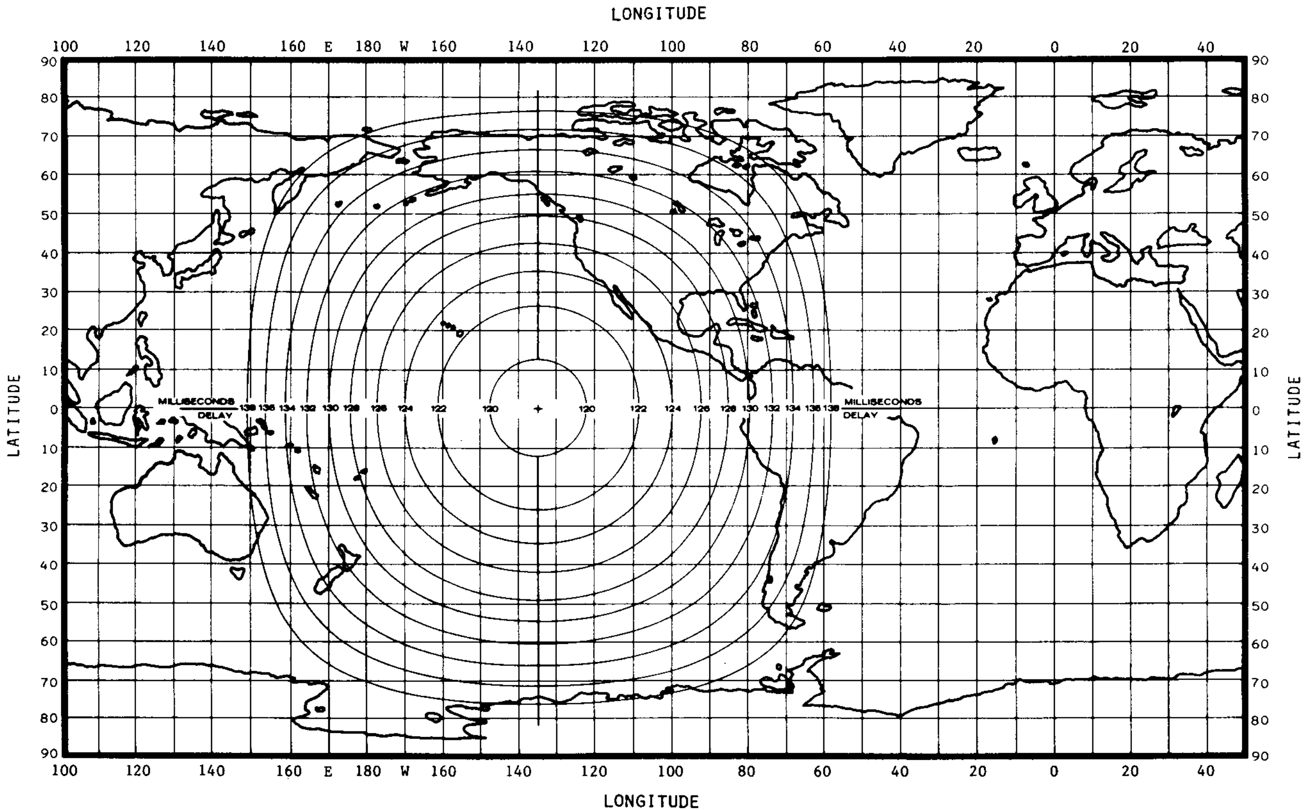

FIGURE 6. WESTERN SATELLITE MEAN DELAYS.

For total delay, add 133.5 ms to downlink delays shown.

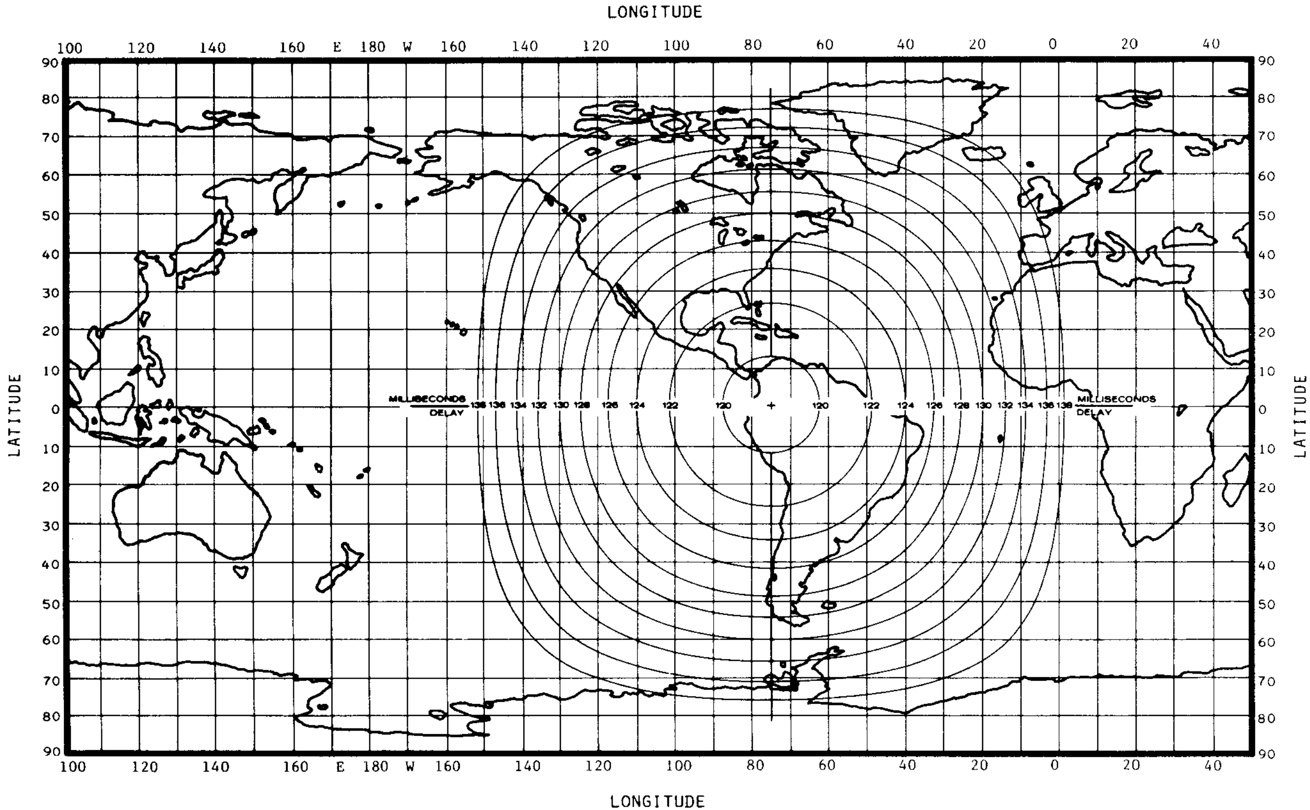

FIGURE 7. EASTERN SATELLITE MEAN DELAYS.

For total delay, add 124.5 ms to downlink delays shown.

either GOES satellite, when corrected, normally remains well within ±100 microseconds with respect to the UTC(NBS) time scale [2].

7. EQUIPMENT

Figure 8 shows one antenna used by NBS with satisfactory results. The antennas can be of small size and pointed in the general direction of the satellite. The NBS-designed receiver in figure 9 is completely automatic, requiring no tuning or auxilliary equipment to operate. Commercial versions of this equipment are now available. A list of manufacturers may be obtained from Time and Frequency Services, 524.00, NBS, 325 Broadway, Boulder, CO 80303.

8. PRECAUTIONS

INTERFERENCE

Since the GOES time code is transmitted outside the spectrum reserved exclusively for time and frequency broadcasts, it cannot be considered an NBS service in the same sense that WWV, WWVH, and WWVB are services. The "land-mobile" services and the GOES interrogation channels use the same frequency allocations (468.8250 and 468.8375 MHz), which means the time code may suffer interference from land-mobile transmissions. This is particularly true in urban areas where there is a high density of land-mobile activity. The satellite frequency allocations are secondary to the land-mobile services. Therefore, any such interference must be accepted by the time signal users. Complaints to the FCC will not result in any adjustments in favor of such users.

Because of the spacing of frequency assignments to the land-mobile users, there is far less interference to the eastern satellite signals than to the western satellite signals. Therefore, the eastern satellite should be used by those users situated in large urban areas.

OUTAGES

Although the GOES satellites transmit continuously, there may be interruptions during the periods of solar eclipses. The GOES satellites undergo spring and autumn eclipses during a 46-day interval at the vernal and autumnal equinoxes--i.e., March 1 to April 15 and September 1 to October 15. The eclipses vary from approximately 10 minutes at the beginning and end of eclipse periods to a maximum of approximately 72 minutes at the equinox.

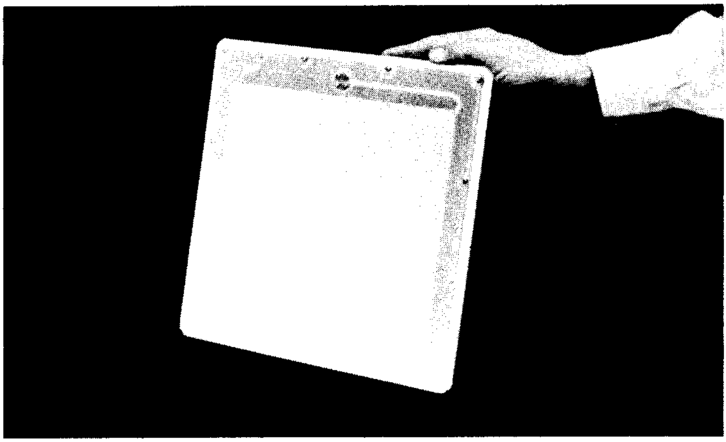

FIGURE 8. ANTENNA USED BY NBS TO RECEIVE GOES TIME CODE.

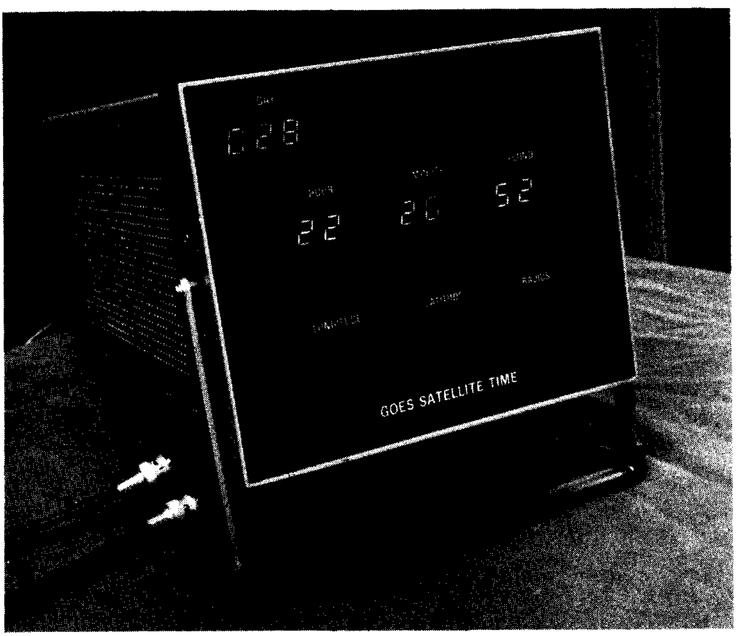

FIGURE 9. GOES TIME CODE RECEIVER.

Under operating procedures in effect since January 1983, NOAA transfers the time code dissemination function from the operational east and west satellites to the spare satellite (105° W longitude) for two-hour periods each day during the eclipse periods. These two-hour periods are scheduled from 0400-0600 UTC for GOES/East and 0800-1000 UTC for GOES/West. During these times, the position data transmitted in the time code message may not be correct for the spare satellite, resulting in erroneous computed values for the path delay for receivers operating in the "fully-corrected" mode. Outputs from receivers operating in the "uncorrected" mode may also be shifted significantly during these periods since the path delay through the spare satellite will normally be substantially different. Depending on the beamwidth characteristics and pointing of the antenna used, the transfer of the time code to the spare satellite during eclipse periods may result in loss of signal. NBS is currently considering revised procedures during eclipse operations which may alleviate some of these problems. Any future changes will be announced in the NBS Time and Frequency Bulletin (available monthly upon request to Time and Frequency Services, 524.00, NBS, 325 Broadway, Boulder, CO 80303).

There are no regularly scheduled time code outages for equipment maintenance. Continuous, reliable operation is assured by the use of triply-redundant time code generation systems at NOAA's Wallops Island, Virginia, facility. In the event of any problems in the overall GOES time code distribution system that can affect users, appropriate messages are provided by NBS via the following two channels:

- NBS Time and Frequency Bulletin (monthly); and

- USNO (U. S. Naval Observatory) Automated Data Service, Washington, DC. The USNO system may be accessed 24 hrs/ day by telephone using any of a variety of standard data terminals operating at 300 or 1200 baud with even parity. A brief status report for the GOES time code system may be obtained by the following procedure:

  1) Access the USNO system by dialing (202) 653-1079 (commercial); 653-1079 (FTS); or 294-1079 (Autovon).

  2) After responding to the prompt asking for your identification (e.g., name and organization), request the NBS GOES status file by typing "@NBSGO" followed by a carriage return; and

  3) At the conclusion of the status message, type a Control-D to disconnect.

9. FOR FURTHER INFORMATION

For further information on the GOES time code system or operational procedures, contact: R. E. Beehler, 524.00, NBS, 325 Broadway, Boulder, CO 80303.

10. REFERENCES

[1] Hanson, D. W., D. D. Davis, and J. V. Cateora, "NBS Time to the Western Hemisphere by Satellite," Radio Science, Vol. 14, No. 4, pp. 731-740 (July-August 1979). (Reprints not available.)

[2] Beehler, R. E., "GOES Satellite Time Code Dissemination," Proc. 14th Annual Precise Time and Time Interval (PTTI) Applications and Planning Meeting, Washington, DC (Nov. 30-Dec. 2, 1982), in press. (Reprints not available.)

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