WSMC APPROACH FOR USING GPS TO SYNCHRONIZE REMOTE SITE TIMING

John B. McConnell
Western Space and Missile Center
Vandenberg AFB, CA 93437

Robert L. Baker
ITT-Federal Electric Corporation
Vandenberg AFB, CA 93437

ABSTRACT

The Western Space and Missile Center (WSMC) plans to precisely synchronize timing at remote tracking sites using Global Positioning System (GPS) equipment being developed for the Tri-Service GPS Range Applications Program. The proposed GPS timing systems will provide automated, autonomous, and continuous monitoring of site timing performance and improve WSMC metric support capabilities for ballistic missile and space system test programs on the Western Test Range (WTR). By eliminating the need for portable atomic clocks and allowing replacement of site cesiums with less expensive standards, the proposed timing systems should reduce the cost of timekeeping on the WTR. Initial field demonstration tests are planned in early 1988 at the uprange and midrange tracking sites. This paper discusses the system design, operation, test demonstration plans and schedule.

INTRODUCTION

Highly accurate time transfer employing GPS can be accomplished directly using a fully capable GPS receiver or indirectly using a limited capability receiver tracking a satellite in common-view.[1] WSMC plans to implement the direct time transfer technique using the GPS Reference Receiver/Processor (RR/P) being developed for the Tri-Service GPS Range Application Program.[2,3] The proposed timing system will be a turn-key operation, have the standard RR/P features which include survey and differential modes of operation and meet the most stringent site timing synchronization requirements on the Western Test Range (WTR).

WESTERN TEST RANGE (WTR)

To support testing of space and missile systems, WSMC uses a vast array of test facilities throughout California, Hawaii and other Pacific sites (see Figure 1). WSMC operates the WTR as a national range asset. Key mainland sensors operated by WSMC are located at Vandenberg Air Force Base (VAFB) and Pillar Point Air Force Station (PPAFS). Support further south is provided by the Navy's Pacific Missile Test Center (PMTC) on Point Mugu and San Nicolas Island (SNI). Coverage from the Hawaiian Islands (see Figure 2) is provided by instrumentation operated by Navy, Air Force, and NASA organizations. Downrange support for ballistic operations is provided by the Army's Kwajalein Missile Range (KMR).

CURRENT WTR TIME SYNCHRONIZATION CAPABILITY

A variety of techniques are used to synchronize timing on the WTR.[4] At VAFB and PPAFS, timing is centrally generated by time code generators driven by cesium standards, and distributed via direct lines, microwave and UHF. Cesium standards and time code generators are also used at the telemetry and radar sites. A traveling atomic clock from the VAFB Precision Measurement Equipment Laboratory (PMEL) is used to calibrate the cesium standards on a 90 day or as required basis. PMEL has a Precise Time Reference Station that maintains time synchronization with the United States Naval Observatory (USNO) using the GPS common-view time transfer technique. Timing capabilities similar to those at WSMC are used at PMTC, and USNO provides a correction factor at three month intervals with a portable atomic clock. SNI currently receives primary synchronization via microwave from Point Mugu. PMTC is currently incorporating GPS timing capabilities. Timing at the instrumentation sites in the Hawaiian Islands is generated at each site and the site cesium standards are periodically calibrated by Navy and Air Force traveling atomic clocks. Timing signals at KMR are generated by the Master Timing Center (MTC) on Kwajalein Atoll and distributed to substations on the outer atolls. The MTC is time referenced to the USNO by satellite time transfer on a weekly basis, to two Loran C chains on a daily basis, and certified annually by the USNO flying clock. KMR plans to use the GPS monitor station in the future as the reference. Current techniques typically maintain intersite synchronization on the WTR to better than 10 microseconds.

RANGE VERNIER TIME SYNCHRONIZATION REQUIREMENT

WSMC has developed a phase-measuring radar technique called Range Vernier which has been implemented on coherent radars at PPAFS, VAFB, Point Mugu and SNI. Each radar provides extremely precise range increment measurements with a noise level of approximately 0.001 feet. Range Vernier data is used for trajectory reconstruction and will improve the guidance evaluation capability for future ballistic missile programs such as Small ICBM. As shown in Figure 3, the Range Vernier network could provide a test corridor for SDI experiments and Future Military Space Systems.[6,7] In order to fully use the inherent precision of the Range Vernier network, each measurement must be accurately time tagged. WSMC sponsored a study which assessed the sensitivity of pierce-point estimation error to the Range Vernier time tag error.[8] The results are summarized in Figure 4. The study found that current time synchronization via atomic clock does not provide sufficient accuracy to improve pierce-point estimation error and concluded that the timing bias of each radar must be reduced to approximately 30 nanoseconds in order to achieve the full potential of the Range Vernier radar network.

TIMING SYSTEM CONFIGURATION

The proposed timing system configuration for synchronizing the range vernier radar sites is shown in Figure 5. The system is based on the RR/P being developed for the GPS Range Applications Program. The RR/P code and carrier tracks and processes the P-code signals from four GPS satellites on both the L1 (1.57542 GHz) and L2 (1.2276 GHz) frequencies. The Processor, which is operated from a terminal, controls the Reference Receiver, Precision Time Module and Test Signal Source. The Precision Time Module synthesizes a precision local oscillator frequency for the Reference Receiver and adjusts its phase to make the "on time" one-pulse-per-second (1 pps) receiver output coincide precisely with GPS time or Coordinated Universal Time (UTC) time. The Time Interval Counter measures the time intervals between the frequency standard 1 pps output and the Reference Receiver 1 pps output. These time intervals (timing errors) are displayed for realtime monitoring and recorded to allow post test correction of the timing signals. The Test Signal Source provides a capability to calibrate time delays from the antenna to the Reference Receiver 1 pps output. The resulting timing accuracy will be better then ±30 nanoseconds. With common-view satellite tracking, relative accuracies to better then ±10 nanoseconds will be accomplished. These accuracies will be achievable when Selective Availability is in effect.

DEMONSTRATION TEST PLANS

A series of in-plant tests will be conducted in early 1988 to verify system performance including side-by-side and common-view demonstrations. After factory acceptance, tests at a national laboratory are planned. The timing systems will then be installed at Range Vernier radar sites at VAFB and PPAFS, and also at the FPQ-14 radar at Kaena Point, Hawaii. The accuracy of intersite timing synchronization using the direct transfer technique will be evaluated by analyzing data obtained during common-view tracks. Testing opportunities for the current test constellation and the 18 satellite constellation are summarized in Figure 7, 8 and 9 for uprange, midrange and downrange locations. Figure 8 shows the number of satellites above a 5 degree elevation mask angle during 24 hours that can be used for direct time transfer. Opportunities to evaluate intersite synchronization between uprange, midrange and downrange sites using dual frequency and single frequency common-view techniques are shown in Figures 8 and 9 respectively. During site demonstration tests, calibration techniques and procedures will be developed to measure the delay between timing system output and time tag of the radar data. These procedures will be verified using targets of opportunity. These site demonstration tests will also be used to evaluate the effect of masking, EMI and multipath on system performance. Preliminary tests conducted by NSWC shows that multipath can degrade time transfer accuracy.[9]

SUMMARY AND CONCLUSIONS

In summary, current time synchronization on the Western Test Range (WTR) is better than 10 microseconds as referenced to USNO/UTC which is adequate for most timing accuracy needs. In order to achieve the full potential of the Range Vernier radar network for future ballistic missile and space system testing, intersite timing errors must be reduced to approximately 30 nanoseconds. A GPS timing system using equipment under development for the Tri-Service Range Applications Program can meet this accuracy need, has significant advantages over other techniques, and has the potential to reduce the cost of timekeeping in many WTR applications. A series of in-plant and field demonstration tests are planned beginning in early 1988 to validate the accuracy of the planned timing system enhancement project.

REFERENCES

1. Allen, David W., et al, "Accuracy of International Time and Frequency Comparisons Via Global Positioning System Satellites in Common-View", IEEE Transactions on Instrumentation and Measurement, Vol. IM-34, No. 2, June 1985.

2. Hancock, Thomas P., "NAVSTAR Global Positioning System (GPS) for Range Applications," Proceedings, International Telemetry Conference, Vol. XXI, International Foundation for Telemetering, 1985, pp. 407-425.

3. Luse, James D. and Sanford, Stephen S., "Precise Time from GPS for Department of Defense Test and Training Ranges", To be presented at the Eighteenth Annual Precise Time and Time Interval (PTTI) Applications and Planning Meeting, December 3, 1986.

4. Powers, Linda C., "Timing Facilities at WTR and Supporting Ranges", Technical Note No. OE600-N-84-12 prepared for Western Space and Missile Center by Systems Performance Analysis Department, Federal Electric Corporation, July 1984.

5. Wheeler, Paul J., "Automation of Precise Time Reference Stations (PTRS)," Fifteenth Precise Time and Time Interval (PTTI) Applications and Planning Meeting, 1983, pp 41-52.

6. Lane, Richard, "Future Military Space Systems: Impact on Space Test Ranges" Proceedings, American Institute of Aeronautics and Astronautics 3rd Flight Testing Conference, April 1986.

7. "Test & Evaluation Support Study (A Methodology and Capability Analysis to Support Testing of the Space Based Kinetic Energy Weapon System)", Prepared for Western Space and Missile Center by Program Planning and Analysis Department, ITT/Federal Electric Corporation.

8. Brooks, Richard A., "Range Vernier Timing Error Sensitivity," Technical Note No. OE600-N-85-09, Prepared for Western Space and Missile Center by Systems Performance Analysis Department, Federal Electric Corporation, January 1985.

9. Evans, Alan G., "Comparison of GPS Pseudorange and Biased Doppler Range Measurements to Demonstrate Signal Multipath Effects," Proceedings, 1986 International Telemetering Conference, Volume XXII, pp 795-801.

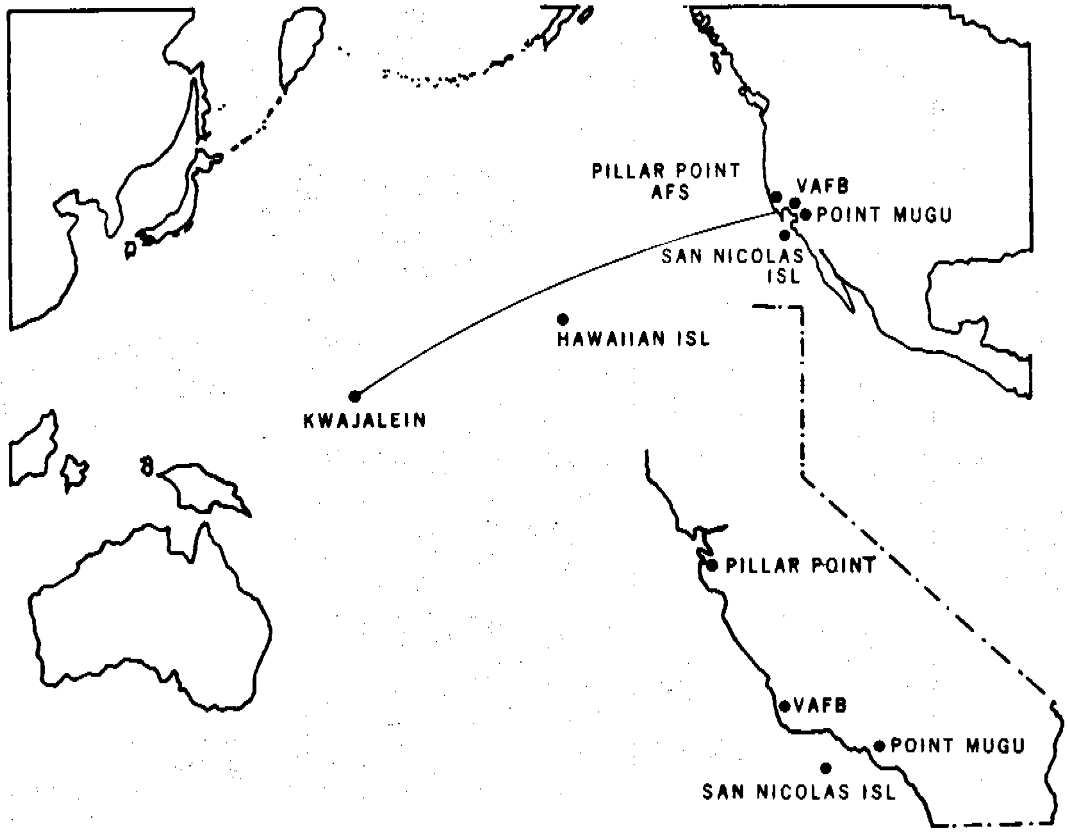

FIGURE 1 WESTERN TEST RANGE

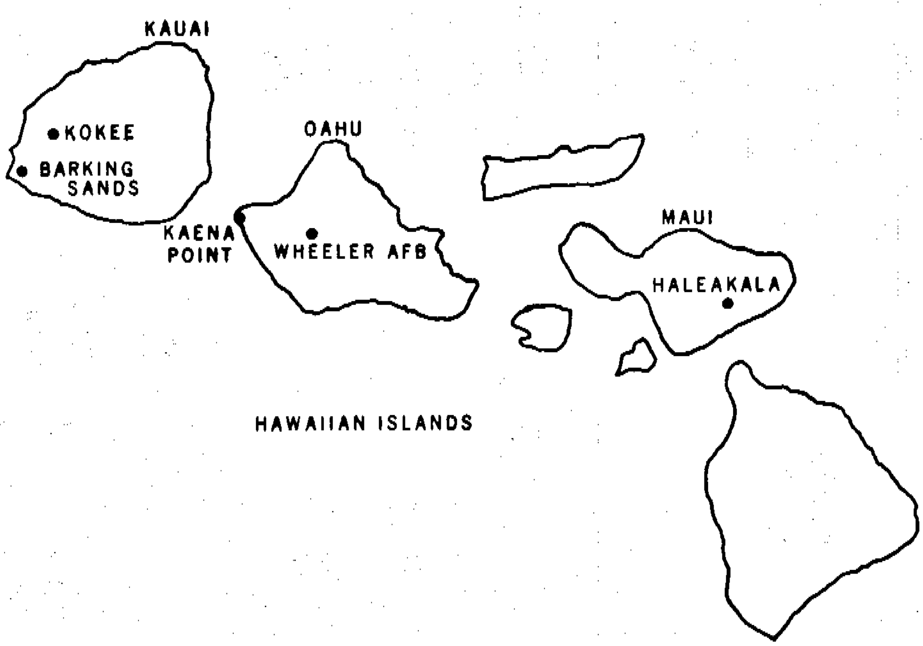

FIGURE 2 MIDRANGE INSTRUMENTATION FACILITIES

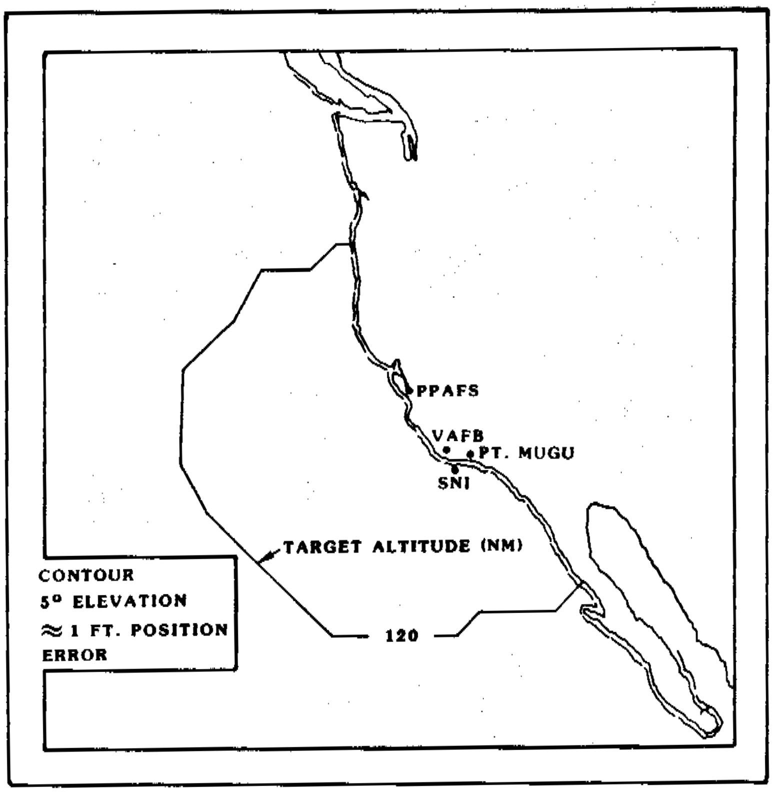

FIGURE 3 RANGE VERNIER NETWORK SPACE EXPERIMENT CORRIDOR

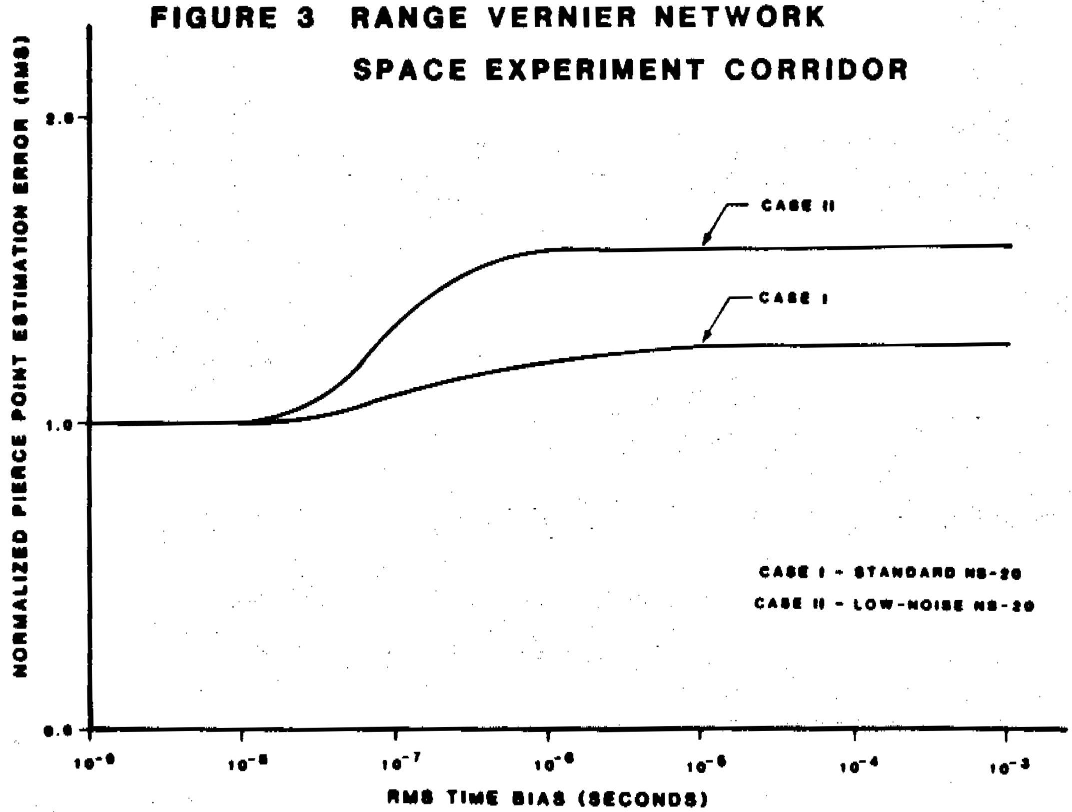

FIGURE 4 RANGE VERNIER NETWORK TIMING ERROR SENSITIVITY

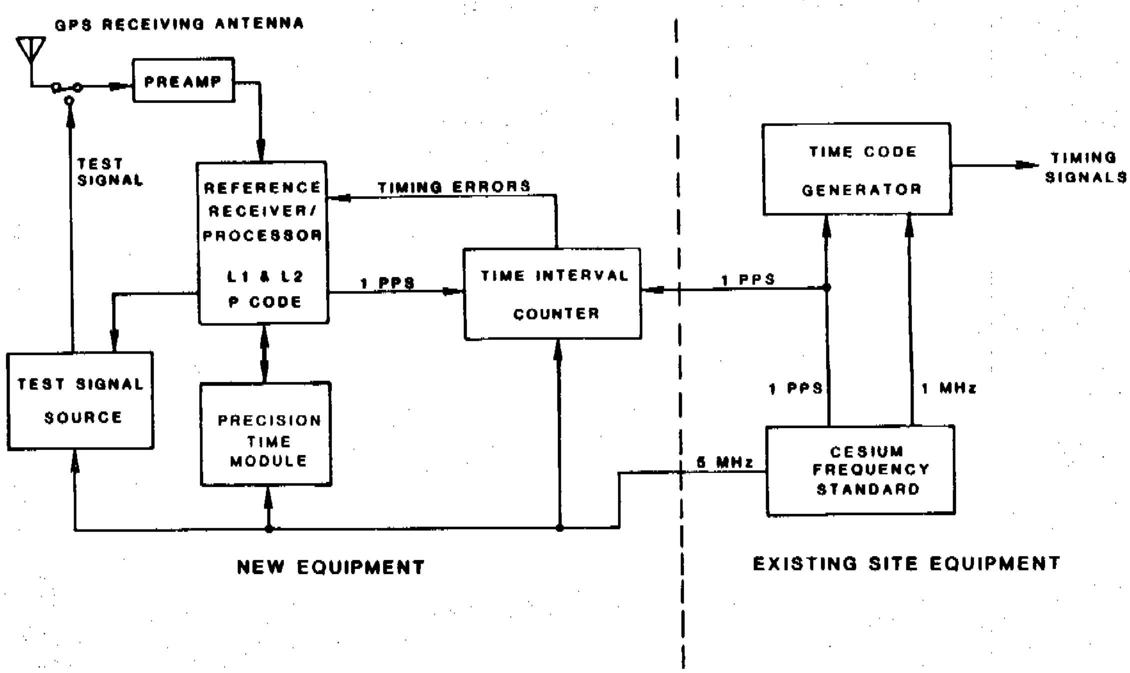

FIGURE 5 WSMC GPS TIMING SYSTEM CONFIGURATION

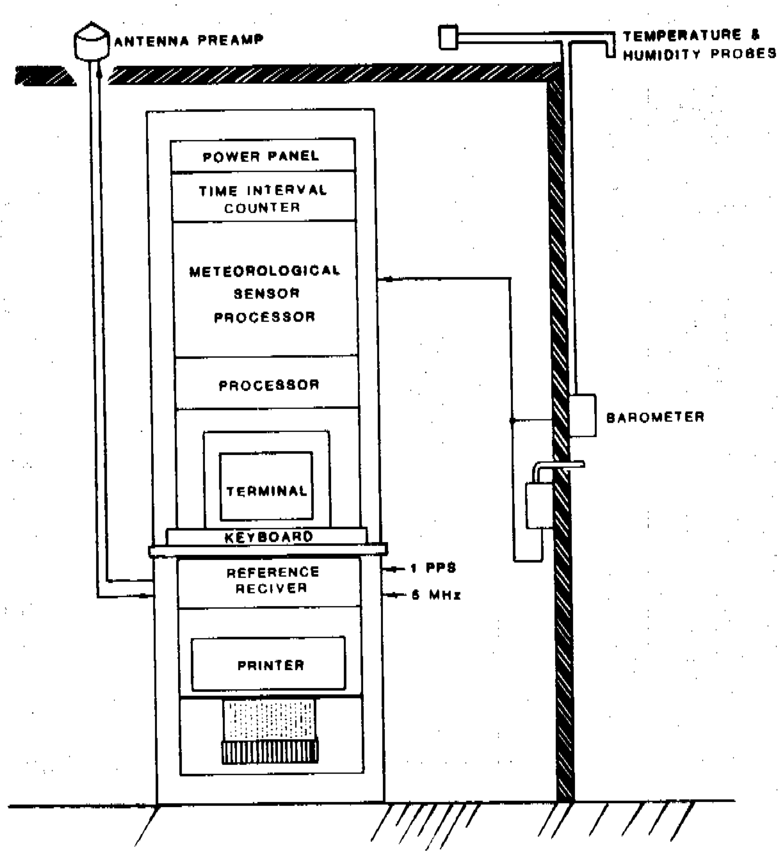

FIGURE 6 WSMC GPS TIMING STATION CONCEPT

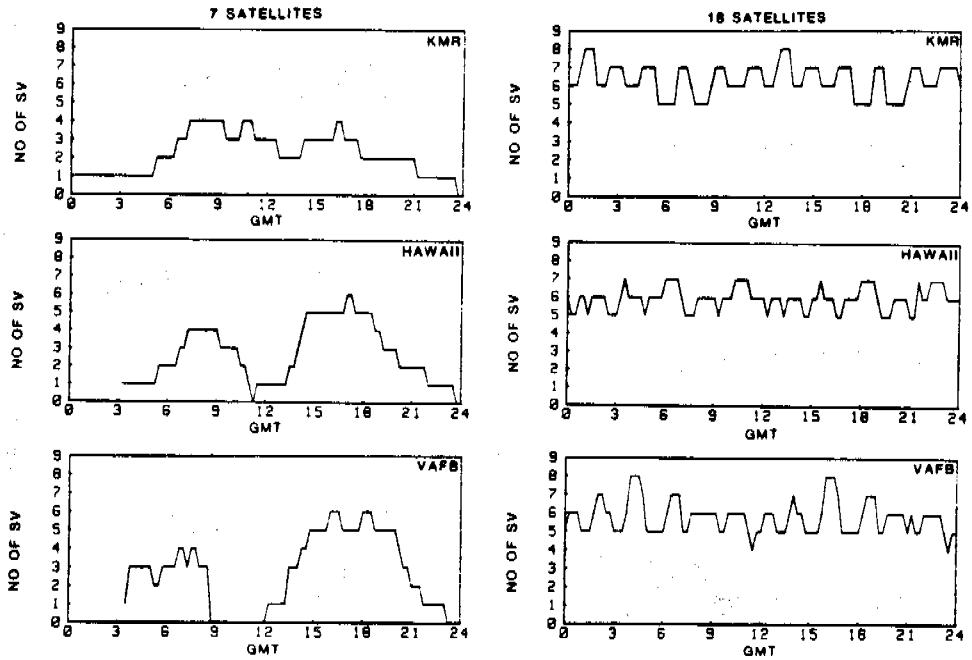

FIGURE 7 GPS SATELLITE COVERAGE ABOVE 5° ELEVATION

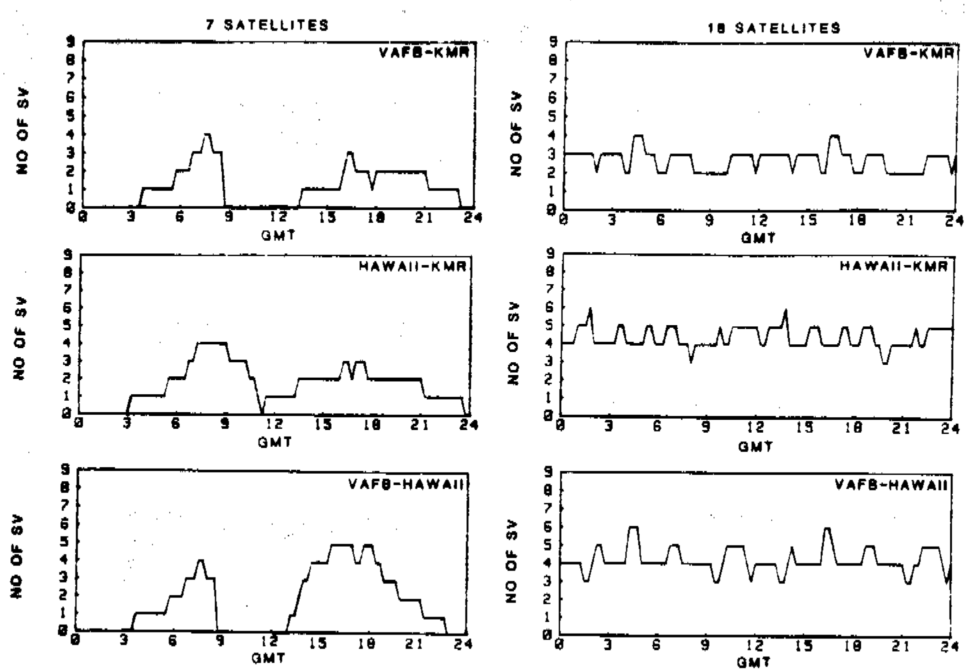

FIGURE 8 COMMON VIEW GPS SATELLITES ABOVE 5° ELEVATION

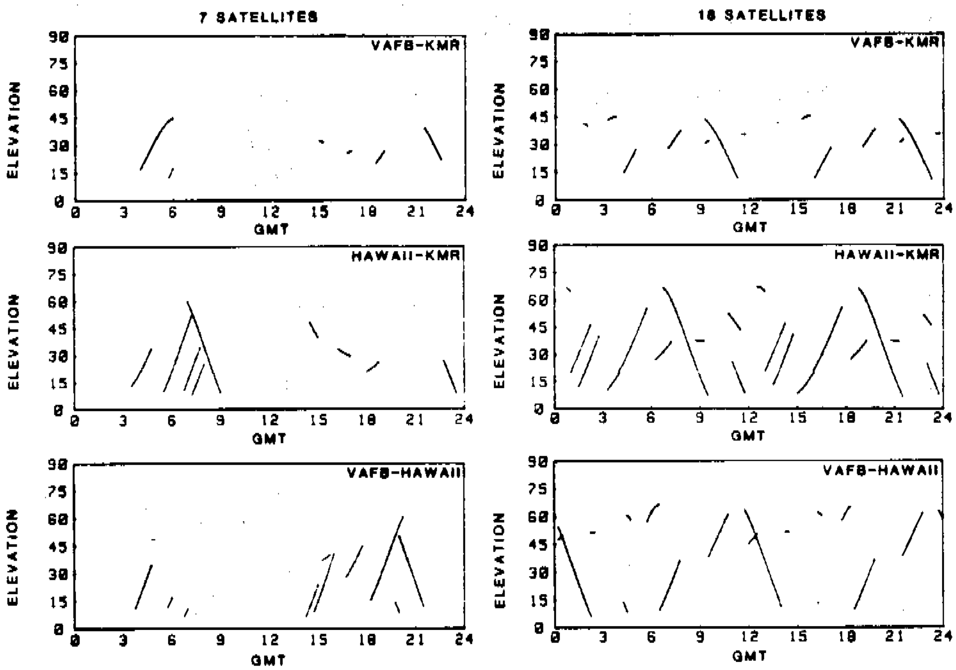

FIGURE 9 COMMON VIEW GPS SATELLITES WITHIN 10° SAME ELEVATION