FLIGHT AND GROUND TESTS OF A GOES SATELLITE TIME RECEIVER FOR SATELLITE COMMUNICATIONS APPLICATIONS

Roger L. Swanson, Air Force Wright Aeronautical Laboratories,
Wright-Patterson Air Force Base, Ohio and Stephen A. Nichols,
Naval Research Laboratory, Washington, DC

ABSTRACT

A satellite time receiver has been tested by the Air Force Wright Aeronautical Laboratories in various environmental conditions during the past year. The commercial receiver which was designed to work with the National Oceanic and Atmospheric Administration's (NOAA) Geostationary Operational Environmental Satellites (GOES) was purchased from Arbiter Systems, Inc. The test program included operation at low elevation angles (less than five degrees), operation during flight in a military cargo aircraft and long term comparison with laboratory standards.

Modern military spread spectrum communications systems require accurate timing to achieve synchronization. These systems will be deployed on various mobile platforms with attendant start-up problems at remote locations. The GOES satellite time receiver offers an opportunity to provide easy wide area coverage synchronization at low cost.

Two receivers were delivered in December 1979. One was carried to Thule, Greenland in March 1980 where the elevation angle was less than five degrees. Comparisons were made at Thule, Greenland and Goose Bay, Labrador with a Hewlett Packard Rubidium Traveling Clock. Test results from this trip will be presented. The results of long term testing which has been performed at Wright-Patterson Air Force Base to determine the reliability and accuracy for use in testing of potential military communication systems will be presented. The test phase which involves integration into the test aircraft and related test results will be described.

INTRODUCTION

Modern military spread spectrum communications systems require accurate timing to achieve synchronization. These systems will be deployed on various mobile platforms with attendant start-up problems at remote locations. In many spread spectrum communication systems,[1,2,3,4] time is used as a parameter to start or to be a part of the pseudo-random sequence. In the evaluation of prototypes, time accuracy one to two orders greater than required by the prototype, is an aid to the test effort.

Typically, aboard the Avionics Laboratory satellite communications (SATCOM) C135B test aircraft or other flight test aircraft (such as those used to track Apollo or other space launches), a crystal clock, Rubidium or Cesium time/frequency standard has been used. Accuracies experienced in using the Rubidium standard have been excellent (1 to 3 microseconds drift/day). However, as all power is removed from an unattended aircraft, the clock equipped with multiple input AC/DC power supplies and battery pack, are moved to ground power in order to keep time. The threat of power loss, dropping the clock during movement to ground power, the simple hassle of moving 100 pounds of equipment often by hand over good to snowy/ice-covered surfaces leaves much to be desired.

Broadcast time would provide a convenient source if: (1) sufficiently accurate with or without range correction, (2) sufficiently quick to acquire and to produce reliable time, (3) available to the user at his geographical location, and (4) it is a cheap alternative to the portable clock. In addition, a broadcast time might provide a confidence check on a portable clock.

In 1980-83 the Avionics Laboratory's SATCOM test program requires a source of time common both to the flight test aircraft (Figure 1) and the Avionics Laboratory's Rooftop Satellite Facility (Figure 2). HF transmissions do not have the required accuracy; LORAN C and Global Positioning System equipments are not available. The National Bureau of Standard Time (NBS) which the National Oceanic and Atmospheric Administration (NOAA) broadcasts over the Geostationary Operational Environmental Satellite (GOES), should provide an adequate turn on/turn off time source.[5] An accuracy of ±100 microseconds would suffice for the test program.

Two GOES Time System Receivers, Arbiter Systems Model 1060A (Figure 3) and two Model 1036 Broad Coverage Plate Antennas with Preamplifier were bought. One system was installed at the Rooftop Facility and one on the test aircraft.

This satellite time receiver was tested by the Avionics Laboratory at various locations in various environmental conditions during the past year. The results of this testing are presented in this paper.

TEST PROGRAM DESCRIPTION

NBS time signals are transmitted by NOAA from NASA's facility at Wallops Island, Virginia to the GOES satellite at 75 degrees West and 135 degrees West. The downlink signal is a Code Phase Shift Keyed modulation of ±60 degrees on a 468.8375 MHz or a 468.8250 MHz RF carrier respectively. This signal is received by the Arbiter GOES time receiver which derives the satellite's ephemeris and a one second time tick from the signal. The time tick is corrected for range delay through front panel entry of the receiver's latitude and longitude. The receiver delay correction is entered internally and once set correctly should not need to be reset. Figure 4 shows the test concept.

The antenna used was an omni-directional plate antenna with a 20 dB preamplifier mounted directly behind the antenna. The antenna fed 20 feet of RG 214 coaxial cable which connected to the receiver.

The test compared the one second time tick of the GOES receiver and the tick of a Rubidium or Cesium clock, which had been synchronized to the 4950th Test Wing's time shop standard. The time standard accuracy is maintained within ±2 microseconds and is traceable to the Naval Observatory.

The Arbiter GOES receiver contains a digital time interval counter which measures the time difference between the receiver time tick and an external time tick. This difference, up to ±999 microseconds, is converted to an analog equivalent voltage. The convention is that a positive voltage means the external time tick is earlier than the GOES receiver time tick. The Arbiter receiver's time interval counter accuracy was verified before use.

Any time difference was plotted on a strip chart or printed out from a time interval counter. When feasible, receiver AGC voltage and loss of synchronization indications along with UTC were also recorded on the strip chart which was recording the time difference. The test configuration is shown in Figure 5.

LONG TERM TESTING AT WRIGHT-PATTERSON AFB

Ground tests at Wright-Patterson AFB were begun 3 June 1980. Initially, the Hewlett Packard (HP) 5060A Computing Counter was programmed to measure and print out the maximum peak to peak time difference over each 10 minute period. While some data was gathered, this technique proved susceptible to unknown "glitches" which required the program to be reinitiated. This technique was abandoned. By mid-July a strip chart recorder was obtained and the time difference was recorded on the strip chart. Definitive data was not available until 29 July 1980.

From 29 July to 29 August 1980, the strip chart displayed a daily variation of about 160 microseconds peak to peak increasing up to 450 microseconds peak to peak. For a period from 4 August to 14 August 1980 the data was invalid. Figure 6 is a plot of this daily variation. This daily variation was traced to incorrect satellite ephemeris data, which resulted in the wrong range correction. As a result, long term statistics are not available.

The variation stopped at 1430Z, 29 August 1980. Figure 7 is the record of the change. Note the abrupt decrease to the time drift. The step change every two to four minutes is typical of the well behaved range calculation. From 1430Z, 29 August 1980 to 1820Z, 4 September 1980, the peak to peak time variation of the time receiver was 30 microseconds (135 microseconds earlier to 165 microseconds earlier than the Rubidium clock time). The average fixed offset of 150 microseconds was discovered to be an incorrect receiver delay setting. Later calibration of the receiver delay at the 4950th Test Wing's time shop changed the receiver delay from 4265 to 4420 microseconds, moving the receiver time tick 155 microseconds later. This emphasized the necessity of assuring that the correct receiver delay is properly entered into the delay calculation.

The peak to peak variation when the receiver was locked was not more than 30 microseconds for a one week period after removal of the incorrect receiver delay setting. However, there were outages.

Outages during this trial were variable. From 1200Z, 29 July 1980 to 0400Z, 1 August 1980, outage was 53 percent of the 40 hours. From 0400Z, 1 August 1980 to 2359Z, 3 August 1980, outage was 8 percent of the 94 hours. From 2400Z, 3 August 1980 to 1400Z, 14 August 1980, the data is questionable and no results could be gathered. While not certain, many of the outages appear to be caused by local line of sight UHF transmissions. Indeed, the better performance over the weekend, 2-3 August 1980, points to other testings at Wright-Patterson AFB, Ohio as a possible cause of the outages.

However, beginning at 1400Z, 14 August 1980 to 0400Z, 28 August 1980, outages almost disappeared. During the 14 days, individual outages of 40, 10, 30, 10 and 15 seconds occurred. The total outages were 105 seconds, giving an outage rate of .0089 percent.

Beginning 0400Z, 28 August 1980 through 1800Z, 5 September 1980, solar eclipse type outages began, running 26, 33, 41, 50, 56, 60, 143, 125 and 86 minutes for the succeeding days. Total outages were 1920 minutes or 15.5 percent for the eight day period. Figure 8 depicts the availability and the outages experienced at Wright-Patterson AFB.

WORLDWIDE TESTING

From March 1980 through November 1980 the SATCOM test aircraft flew missions to numerous locations in North and South America, the North and South Atlantic, Africa and Europe. This created an opportunity to test the GOES time receiver at these locations. The eastern GOES (75 degrees West) satellite was used for all tests but one. Figure 9 shows the flight test routes.

Two types of tests, time sync and time comparison, were run. At some locations, before takeoff the receiver was turned on, the antenna set out on a wing and the receiver time output was used to synchronize the aircraft instrumentation clock. The instrumentation clock was then set to free run and a time comparison was made. Synchronization was judged successful if over the next five minutes the time comparison remained less than ±100 microseconds and appeared "well behaved."

At other locations the time comparison measurements were recorded for the length of the stay. Table I lists the locations, the elevation angle to the East (75 degrees West) satellite, and the type of test.

Receiver latitude and longitude at these locations was determined from the appropriate Instrument Flight Approach/airport charts and other surveyed maps as required. Receiver location was determined to within 30 seconds.

REMOTE LOCATION TIME SYNCS

Time synchronization was successful in 26 out of 26 attempts. Twenty-five used the East (75 degrees West) GOES satellite; one synchronization at Omaha, Nebraska used the West (135 degrees West) satellite. The time syncs obtained were then used for each of the missions.

Within the United States, time syncs were obtained at Dayton, Ohio; Omaha, Nebraska; Dallas, Texas; Langley AFB, Virginia; Homestead AFB, Florida. Overseas time syncs were obtained in Greenland, Iceland, Labrador, Canada, England, Senegal, Ascension, Brazil and Peru.

REMOTE LOCATION TIME COMPARISONS

Time comparison measurements were made on three overseas trips: a March 1980 polar trip, a September 1980 equatorial trip and a November 1980 polar trip. Table II is a summary of the time comparisons.

March 1980 Polar Trip

The March 1980 polar trip stopped at Sondrestrom, Greenland; Thule AB, Greenland; Iceland; and Goose Bay, Labrador.

TABLE I

Short Term Testing at Various Locations

Date	Location	Test Type	Elevation Angle to East Satellite
11-14 Mar 80	Offutt AFB, Omaha NE	Time Syncs (3)	36 degrees
24-27 Mar 80	Sondrestrom AB, Greenland	Time Comparison Time Sync (1)	13 degrees
29 Mar 80	Thule AB, Greenland	Time Comparison Time Sync (1)	5 degrees
30 Mar 80	Keflavik NAS, Iceland	Time Sync (1)	5 degrees
3 Apr 80	Goose Bay, Labrador, Canada	Time Comparison Time Sync (1)	27 degrees
5 Jun 80	Dallas Love Field, Texas	Time Sync (1)	44 degrees
27 Jun 80	Langley AFB, Virginia	Time Sync (1)	45 degrees
14-16 Jul 80	Homestead AFB, Florida	Time Syncs (2)	65 degrees
8-9 Sep 80	Lima, Peru	Time Sync (1)	75 degrees
11 Sep 80	Rio de Janeiro, Brazil	Time Sync (1)	45 degrees
12-16 Sep 80	Ascension Island, South Atlantic	Time Comparison Time Sync (1)	20 degrees
17 Sep 80	Dakar, Senegal	Time Sync (1)	21 degrees
18-19 Sep 80	Ramstein AB, Germany	Out of Coverage	Below Horizon
20 Sep 80	Mildenhall AB, England	Time Sync (1)	0 degrees
4-7 Nov 80	Goose Bay, Labrador, Canada	Time Comparison Time Sync (1)	27 degrees
8-11 Nov 80	Sondrestrom AB, Greenland	Time Comparison Time Sync (1)	13 degrees
12-14 Nov 80	Thule AB, Greenland	Time Comparison Time Sync (1)	5 degrees
11 Mar 80 to 14 Nov 80	Wright-Patterson AFB, Ohio	Time Syncs (7)	44 degrees

TABLE II

Location	Time	Event	Hours of Adequate Reception	GOES TIME Variation (μsecs)
Thule, Greenland	27 Mar 2016	Start test, in lock		
	2335	Lost Lock	3:19	26 to 35 early
	28 Mar 1440	Lockup		
	29 Mar 0427	Lost lock	11:47	43 late to 45 early
	29 Mar 1604	Still out, end test	14:66	
Total Test Hours:	43:23			
Availability:	34.8%			
Goose Bay, Labrador	2 Apr 0143	Start test, in lock		
	0432	Solar eclipse	2:49	27 to 37 early
	0536	Lockup		5 to 25 early
	1109	Antenna fell down	5:33	
	1120	(time removed from test hours)		
	3 Apr 0432	Solar eclipse	17:12	10 to 34 early
	0530	Lockup		0 to 12 early
	1003	End test	4:27	
Total Test Hours:	33:09			
Availability:	90.5%			
Ascension Island, South Atlantic	13 Sep 0927	Acquired GOES, synced reference Rubidium to GOES		15 to 35 early
	14 Sep 0424	Solar eclipse, lost lock	18:53	
	0548	Lockup		
	15 Sep 0424	Solar eclipse, lost lock	22:36	
	0550	Lockup		
	16 Sep 0424	Solar eclipse, lost lock	22:35	
	0550	Lockup		
	1600	Rubidium Time Check		
Total Test Hours: 108.27		Other outages during test	4:19	
Availability: 92.1%	2154	End test	16:04	

Table II (continued)

Location	Time	Event	Hours of Adequate Reception	GOES TIME Variation (µsecs)
Sondrestrom, Greenland	9 Nov 0300	Start test, lockup		2 to 18 early
	0737	Out of lock, scintillation	4:37	
	0932	In lock again	23:25	
	10 Nov 0857	Out of lock (antenna blew over)		5 late to 20 early
	2258	Antenna reset		
	2400	In lock	3:19	12 early to 15 late
	11 Nov 0217	Out of lock, scintillation		
	0250	In lock		
	0335	Out of lock, scintillation	0:45	15 late to 44 early
	0557	In lock		10 late to 7 early
	0611	Out of lock, scintillation	0:14	
	1215	In lock		
	1230	End test	0:15	40 to 10 late
Total Test Hours:	57:30 less 16:01 (antenna blew over) = 41:29			
Availability:	78.7%			
Thule, Greenland	11 Nov 2200	Start test, locked up		50 early to 50 late
	Scintillation occurred more than 90% of the test time. Twenty-two outages occurred, ranging from four minutes to 6 hours 22 minutes, totaling 34 hours 24 minutes.			
	14 Nov 1228	End test		
Total Test Hours:	64:28			
Availability:	46.7%			

Thule, Greenland

Time comparison began at 2016Z, 27 March 1980 at Thule, Greenland (elevation angle 4-5 degrees). The antenna was propped up outside the dormitory window and pointed towards the east satellite. After correcting for a 15 microsecond late offset in the Rubidium standard, and a 1.25 microsecond position offset (actual position and Rubidium offset were determined after the data was taken), the time error upon receiver acquisition was 30 microseconds early.

Time reception continued until loss of lock at 2335Z, 27 March 1980, about the time of the solar eclipse. While locked during this 3 hour 19 minute period, the GOES receiver time variation was 21 to 36 microseconds early.

GOES time was reacquired 1530Z, 28 March 1980, retaining lock until 0427Z, 29 March 1980. Peak to peak variation was from 43 microseconds late to 45 microseconds early. This larger spread was due to abnormal step correction (Figure 10) of 23 microseconds early to 42 microseconds late. At the next range correction time the offset returned, stepping from 43 microseconds late to 15 microseconds early. The cause of such an abnormal step is not known.

Total test time was 43 hours 23 minutes. Adequate reception occurred for 15 hours 6 minutes. Availability was 34.8 percent.

Goose Bay, Labrador

Testing at Goose Bay began on 0143Z, 2 April 1980. Outages due to solar eclipse existed from 0432Z and ended 0536Z on 2 April 1980. The peak to peak error during reception was 0 to 37 microseconds early. Total test time was 33 hours 9 minutes with adequate reception occurring 30 hours 1 minute. Availability was 90.5 percent, with outages due to solar eclipses and a nine minute loss of antenna pointing.

During this test a UHF transmission at 235.5 MHz degraded the time accuracy. A 15 microsecond advance of the GOES receiver time was observed to correlate with the transmission (Figure 11). Loss of lock did not occur.

For this trip the receiver (S/N 61) delay was factory set at a nominal 4400 microseconds. The data taken tends to indicate the receiver delay was about 15 microseconds less than it should have been. Calibration at the time shop of the 4950th Test Wing resulted in a delay setting of 4420 microseconds.

September 1980 Equatorial Trip

This trip departed Wright-Patterson AFB, 8 September 1980, for Peru, Brazil, Ascension Island, Senegal, Germany and England. Time syncs were accomplished at all stops but Germany which was out of satellite coverage. Only on Ascension Island were time comparison measurements made.

Ascension Island

GOES Time Receiver S/N 62, which had been on the Rooftop Facility was used for this trip. Its delay setting was 4334 microseconds (nominal 4400 microseconds) which had been set during the August period when the ephemeris was in error. This had the effect of creating a fixed offset in the GOES data of about 65 microseconds early.

In this test, the reference Rubidium standard after 10 hours warm-up was synced to the GOES receiver at the beginning of the test on 0927Z, 13 September 1980. A time check, 1600Z, 16 September 1980, showed the Rubidium to be 81.4 ±2 microseconds early compared to the USAF Eastern Test Range Cesium Time Standard. The peak to peak variation presented in Table II is corrected for 66 microseconds of receiver delay (4400 microseconds nominal - 4334 microseconds receiver setting), and the Rubidium error of 81 microseconds.

GOES receiver time variation during this test was 15 to 35 microseconds early. Solar eclipses occurred for each day, total outage was 4 hours 15 minutes. Other outages totaled 4 hours 19 minutes. Availability was 92.1 percent.

November 1980 Polar Trip

On 4 November 1980 the test aircraft departed for Goose Bay, Labrador, Canada; Sondrestrom AB, Greenland; and Thule AB, Greenland. GOES time receiver trials were run at Sondrestrom AB and Thule AB. Receiver S/N 61 was used. The receiver was calibrated before departure.

To ensure that the receiver delay was correct, the receiver was set up in the time shop of the 4950th Test Wing. Receiver delay was adjusted so that the received time agreed with the shop time standard. Final delay setting was 4420 microseconds.

Sondrestrom, Greenland

Testing began at 0300Z, 9 November 1980 and ended at 1230Z, 11 November 1980. Total hours of testing were 57 hours 30 minutes. Sixteen hours were lost when the antenna blew over, giving a net test time of 41 hours 29 minutes.

Ionospheric scintillation caused 8 hours 51 minutes of outages. Scintillation also caused an unusual drifting of the time tick. Figure 12 shows a normal well behaved time trace and matching receiver AGC. Figure 13 shows the drifting time trace and the AGC during the scintillation.

Signal availability at Sondrestrom was 78.7 percent.

Thule, Greenland

At Thule, Greenland testing began at 2000Z, 11 November 1980 and ended on 1228Z, 14 November 1980. The data was not well behaved with the time variation often ±50 microseconds. The degradation is believed to be due to scintillation. The abnormalities were large step changes (Figure 14), rapid drift (Figure 15) and a random walking of the time trace. This random walk occurred during both heavy scintillation (Figure 16) and mild scintillation (Figure 17). Nine periods of this walking occurred, for a total time of 1 hour 14 minutes.

Scintillation was present for more than 90 percent of the test time. This took its toll in the form of 22 outages, ranging from 0 hours 4 minutes to 6 hours 22 minutes. Variation during lock was ±50 microseconds.

The total outages were 34 hours 24 minutes during a test time of 64 hours 28 minutes.

Signal availability at Thule was 46.7 percent.

FUTURE PLANS

Testing During Flight

For inflight testing, the antenna was to be installed beneath the radome located between the wings (Figure 1). Latitude and longitude would be manually entered from a Litton LTN-51 Inertial Navigation System. Later, automatic entry would be provided.

However, this modification to the aircraft has been delayed until March 1981. Inflight testing will not occur until the Summer of 1981.

Shipboard Testing

One receiver and antenna will be located on the USS Texan during December 1980. Performance while at sea will be evaluated. Particular attention will be given to periods of large rolling or pitching of the ship.

CONCLUSIONS

The GOES Time Transfer System and the Arbiter GOES Time Receiver can satisfy the ±100 microseconds accuracy. When all was working well, accuracy was usually within ±30 microseconds. Good performance was achieved for elevation angles from 2-3 degrees to 75 degrees in temperatures from -20 degrees Fahrenheit (Thule, Greenland) to 95-100 degrees Fahrenheit (Homestead AFB, Florida).

The turn on/turn off feature of this type of system won rapid acceptance among the flight test crew. GOES time syncs were used for 26 flights following a preflight checkout.

However, caution must be observed in the following areas:

(1) The ephemeris data must be correct. The system needs a feedback loop/monitor loop to provide an alarm for discrepancies. For roughly one month the ephemeris which was transmitted was in error.

(2) Receiver delay must be verified and correctly entered before use. To do this using the satellites and an external Rubidium/Cesium quality source is feasible, assuming the ephemeris is good. A minimum of one day of recording the time difference is recommended.

(3) If using the receiver alone, or to set other clocks, a signal quality monitor is recommended. Viewing the demodulated data stream and recording the receiver AGC worked well.

(4) During the trials, ionospheric scintillation did cause outages in the polar regions. Although no outages due to scintillation were experienced in the equatorial regions, other data suggests such outages should occur.[6]

(5) The effects of local interference was readily apparent in the AGC record. Use of this record would increase confidence in a time transfer.

REFERENCES

1. S. A. Nichols, et al, "Interim Test Report of the SEACOM Modem/Radio," NRL Memo Report 4138, 1979.

2. D. G. Woodring, S. A. Nichols, R. L. Swanson, "Timing and Frequency Considerations in the Worldwide Testing of a Spread Spectrum Communication System," 11th Precise Time & Time Interval Planning Meeting, 1979.

3. R. V. Groves, Capt, USAF, "Flight Evaluation of the AN/USC-28 ADM PN Modem," AFAL-TR-75-185, Wright-Patterson AFB OH.

4. A. Johnson, "LES 8/9 Communication System Test Report," AIAA Symposium, April 1978.

5. D. W. Hanson, et al, "Time from NBS by Satellite," Proceedings of the Ninth Annual Precise Time and Time Interval Planning Conference, March 1978, pp. 139-152.

6. A. Johnson, "The Effects of Ionospheric Scintillation Fading on Aircraft-to-Satellite Communications," Air Force Avionics Laboratory Report, AFAL-TR-78-171, 1978.

Figure 1 C135B SATCOM Test Aircraft

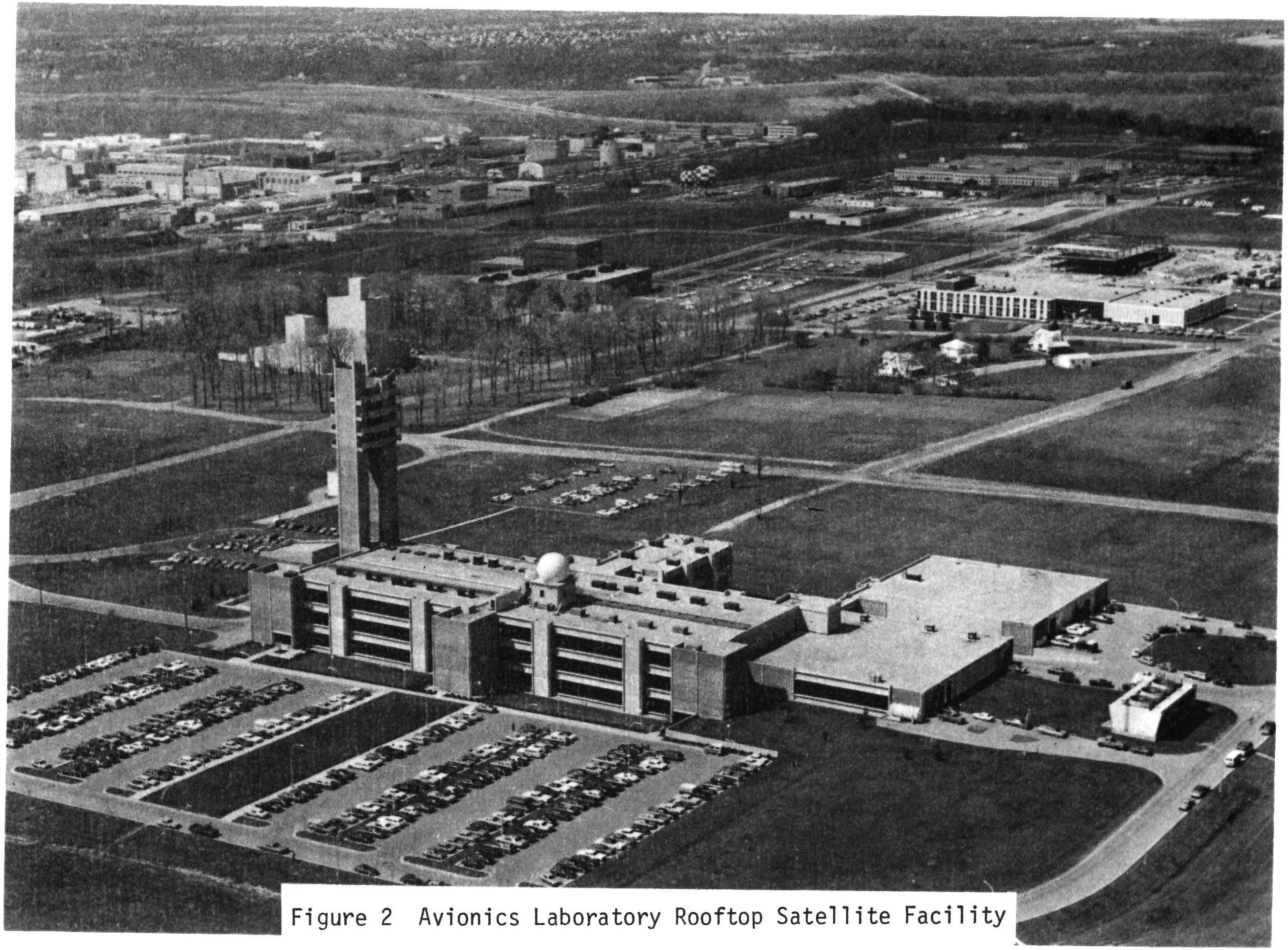
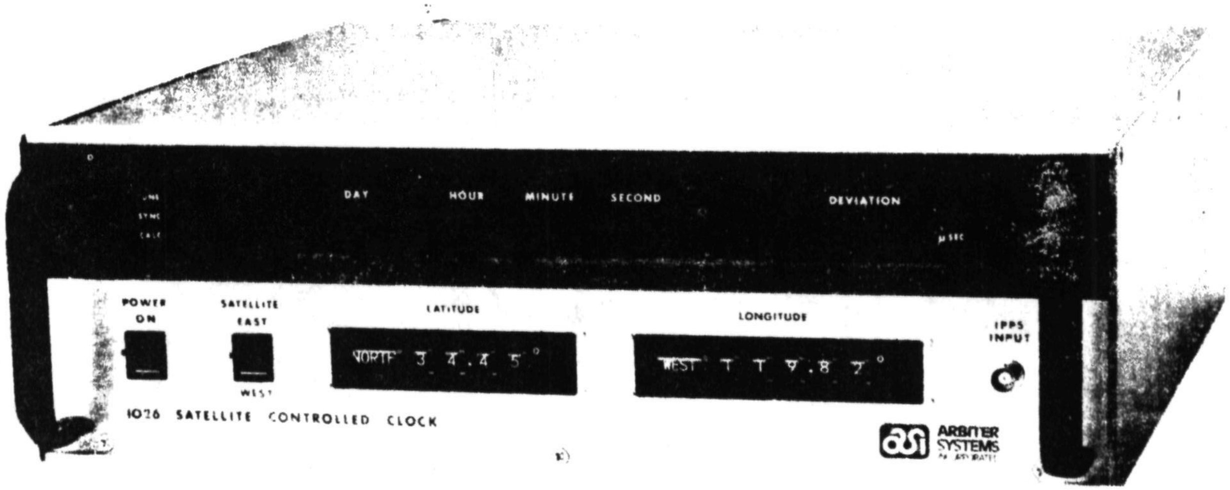


Figure 2 Avionics Laboratory Rooftop Satellite Facility



The Arbiter Systems 1026 Satellite Controlled Clock receives and decodes time signals relayed by the National Oceanic and Atmospheric Administration (NOAA) Geostationary Operational Environmental Satellite (GOES).

These signals, which are continuously available in the covered area and are in synchronism with Coordinated Universal Time (UTC) generated by the National Bureau of Standards, are fully corrected by internal processing circuitry for transmission path delays. The received time in days, hours, minutes and seconds is displayed and is available as multiplexed and IRIG–B formatted data outputs at a rear panel connector. A time corrected one PPS output derived from the satellite signal is provided for user applications. The 1026 incorporates a time interval meter with a 3 digit display that indicates the time difference in microseconds between a user supplied 1 PPS input and the UTC 1 PPS signal. The instrument is designed to operate with a modest antenna in the satellite coverage area that presently includes the North and South American Continents, the Atlantic and Pacific ocean basins and parts of Europe and Africa.

Figure 3 GOES Satellite Time Receiver

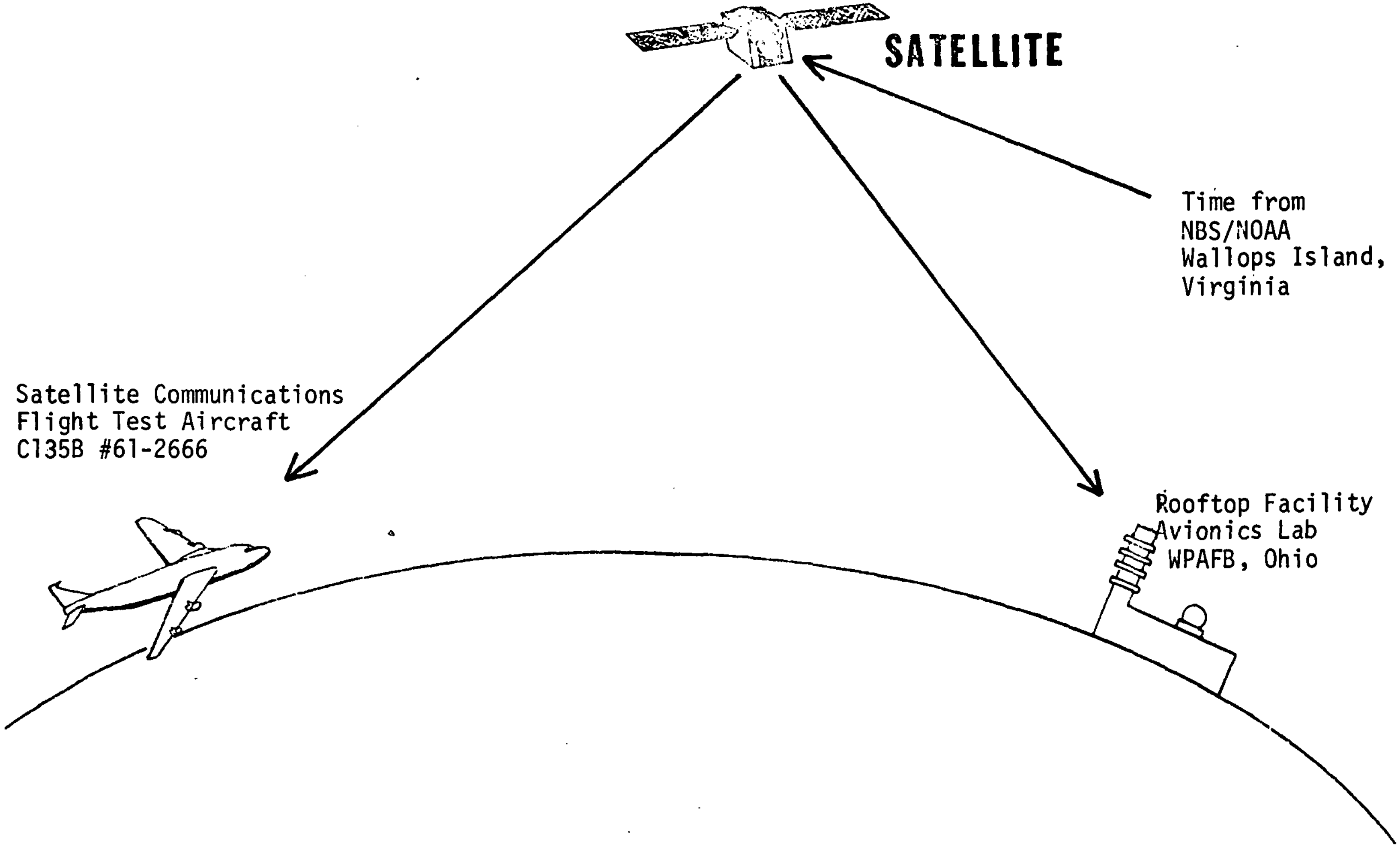


Figure 4 Test Concept for GOES Time Receiver

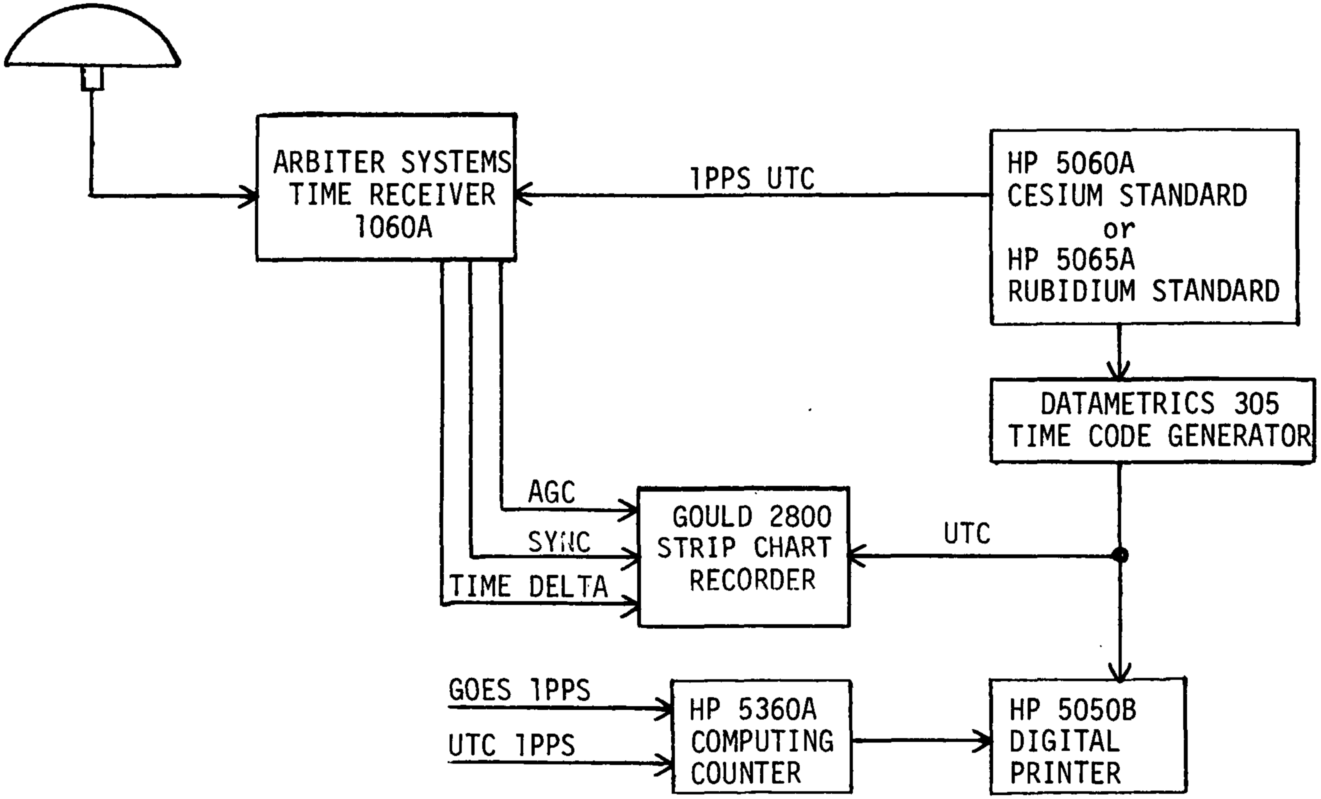


Figure 5 Test Configuration for Time Comparison

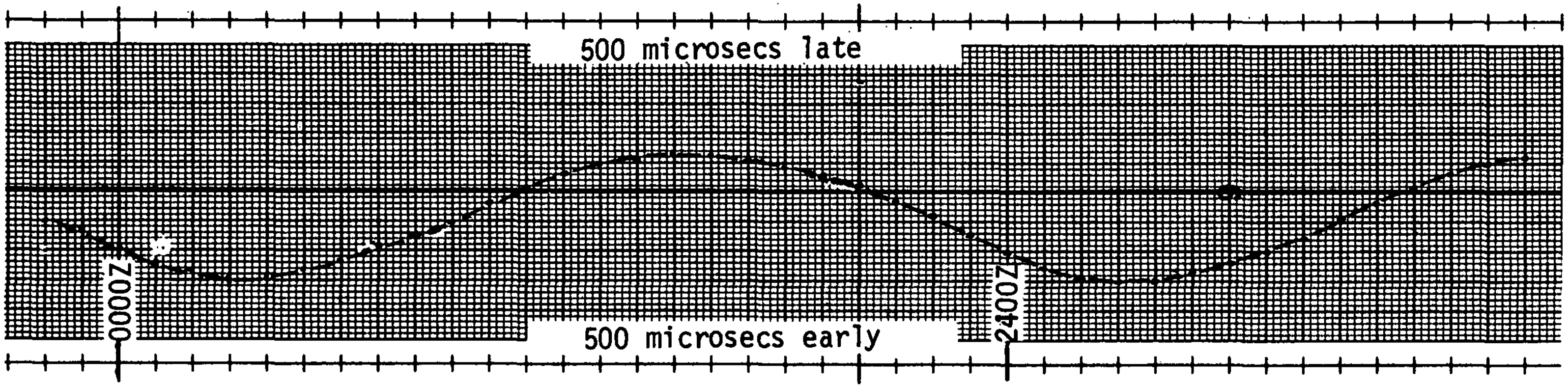


Figure 6 Daily Variation During Incorrect Ephemeris

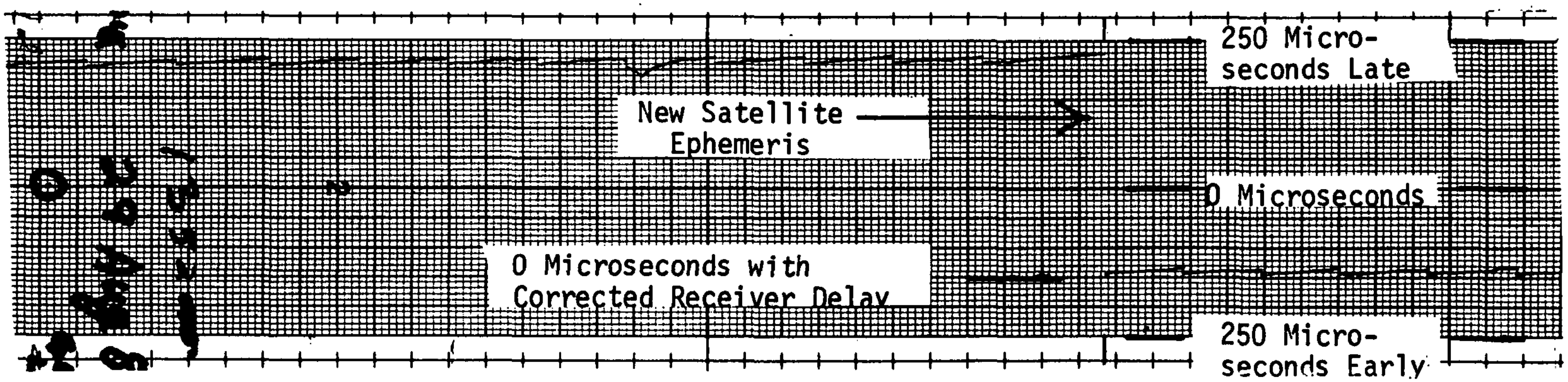


Figure 7 End of Large Daily Variation Due to New Ephemeris Data

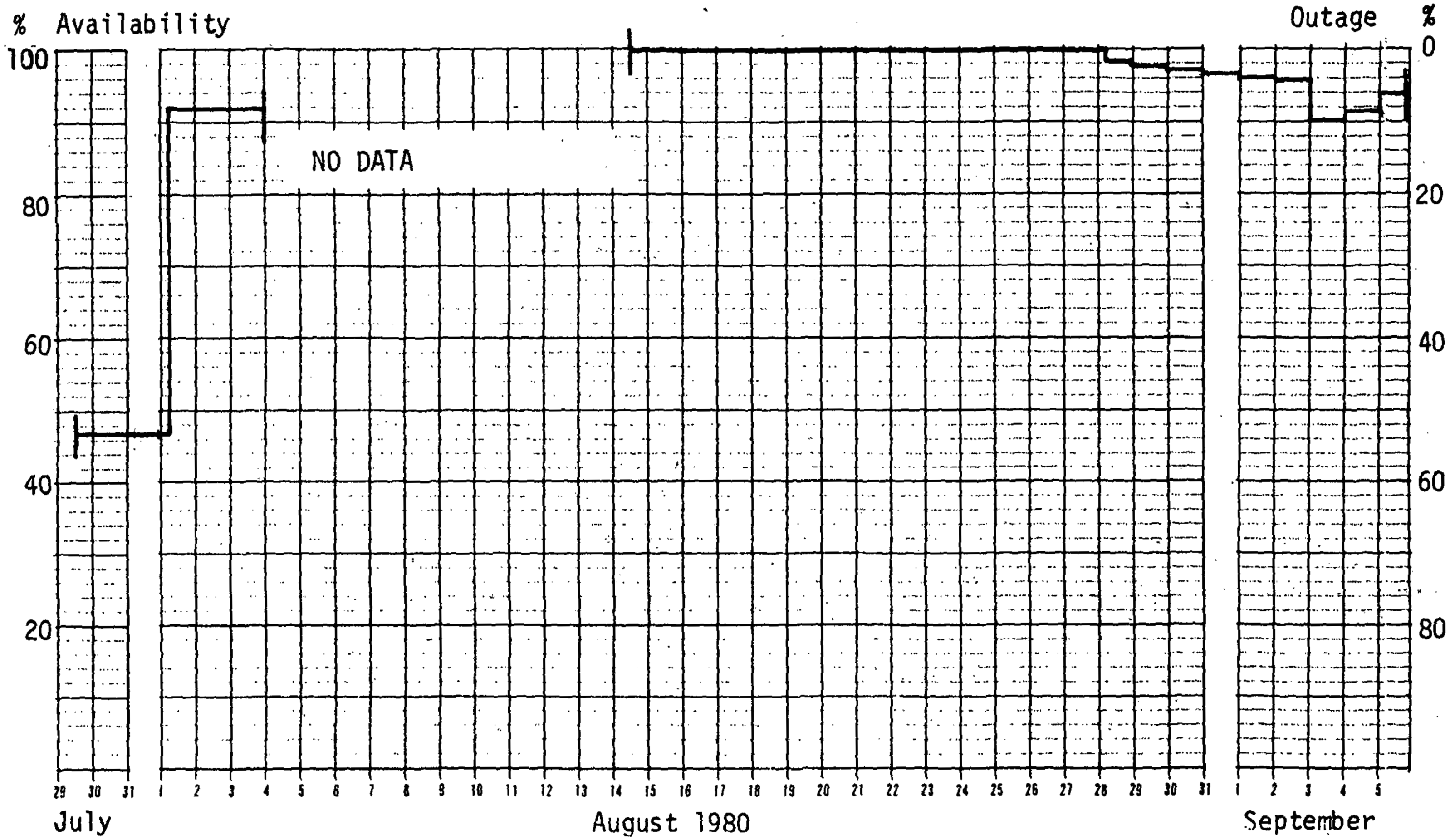


Figure 8 Availability/Outage of GOES Receiver Time at Wright-Patterson Air Force Base

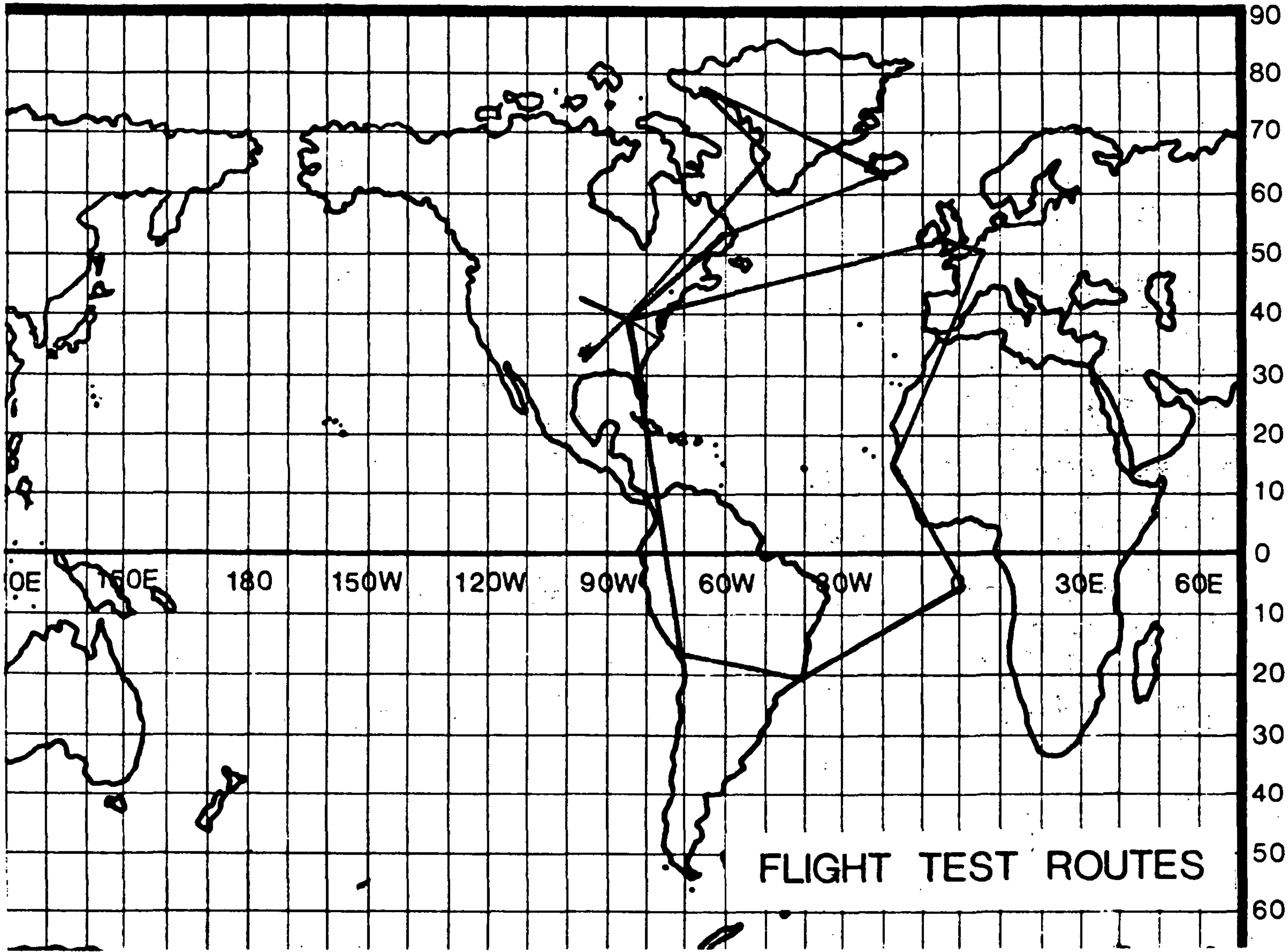


Figure 9 Flight Routes During GOES Time Receiver Testing

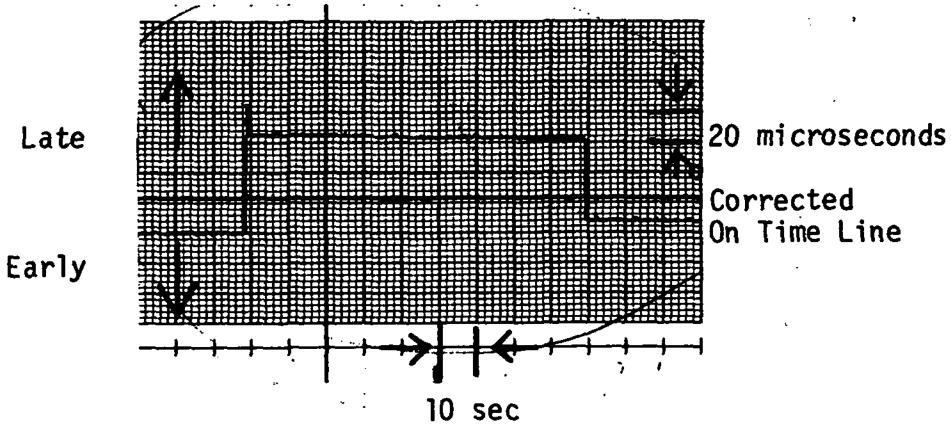


Figure 10 Abnormal Step Change at Thule, Greenland

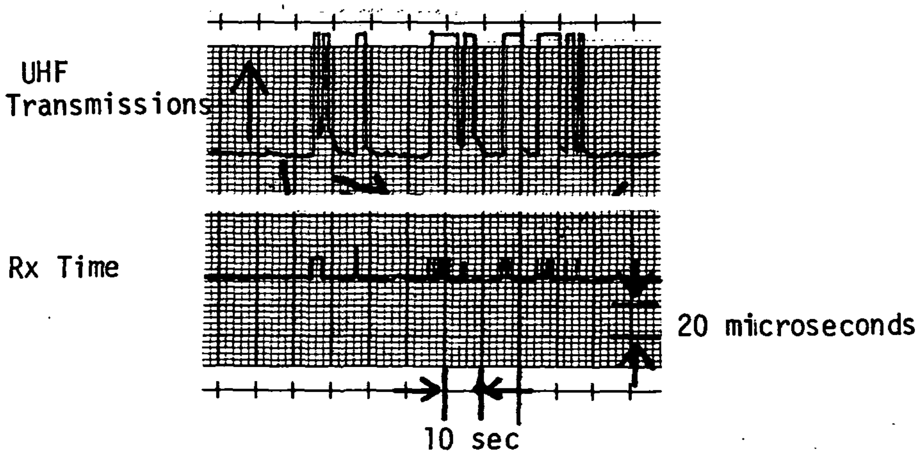


Figure 11 UHF Transmission Effects Upon GOES Receiver Time

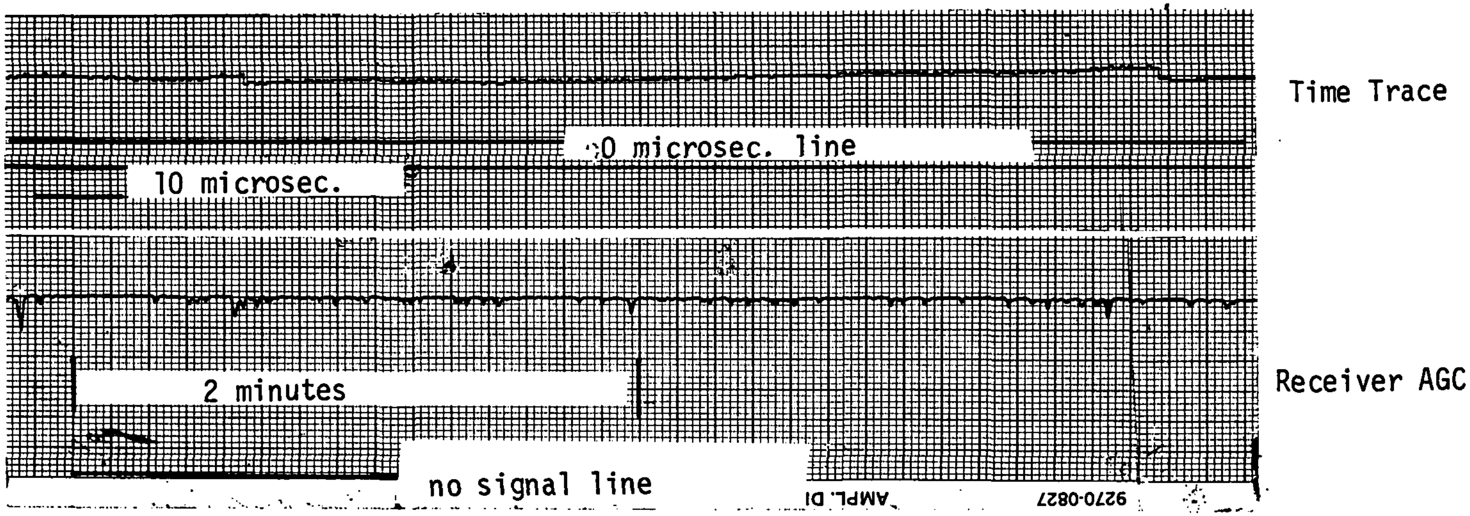


Figure 12 Normal Well Behaved Signal at Sondrestrom AB, Greenland

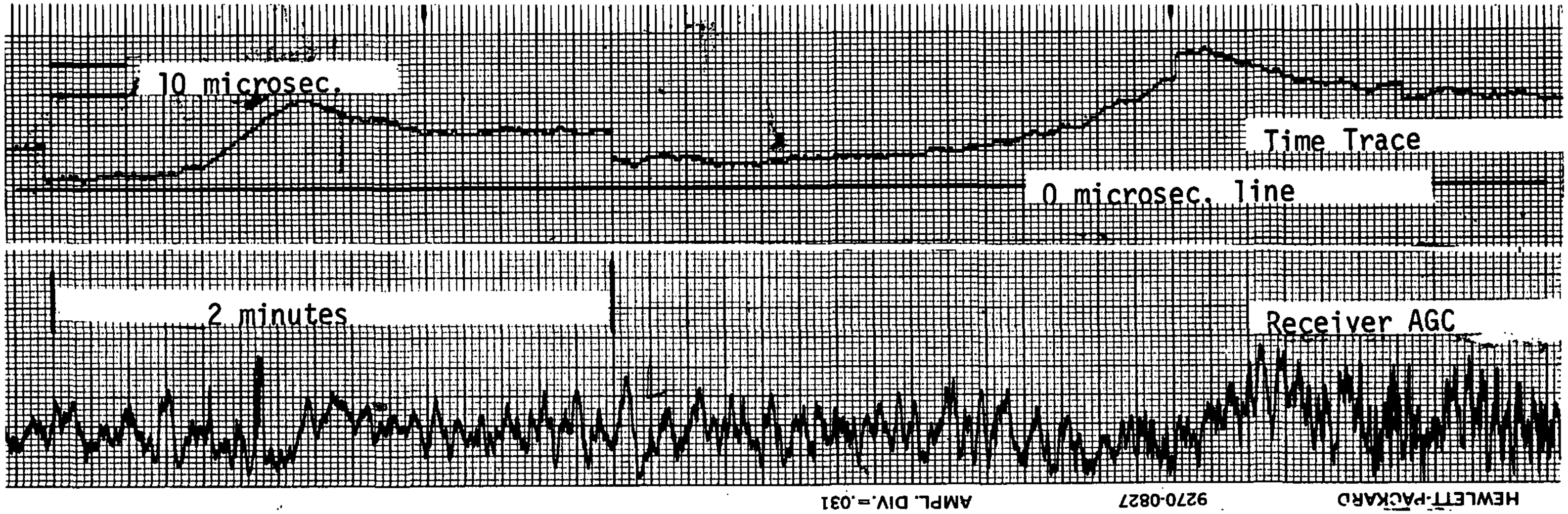


Figure 13 Time Shift during Ionospheric Scintillation

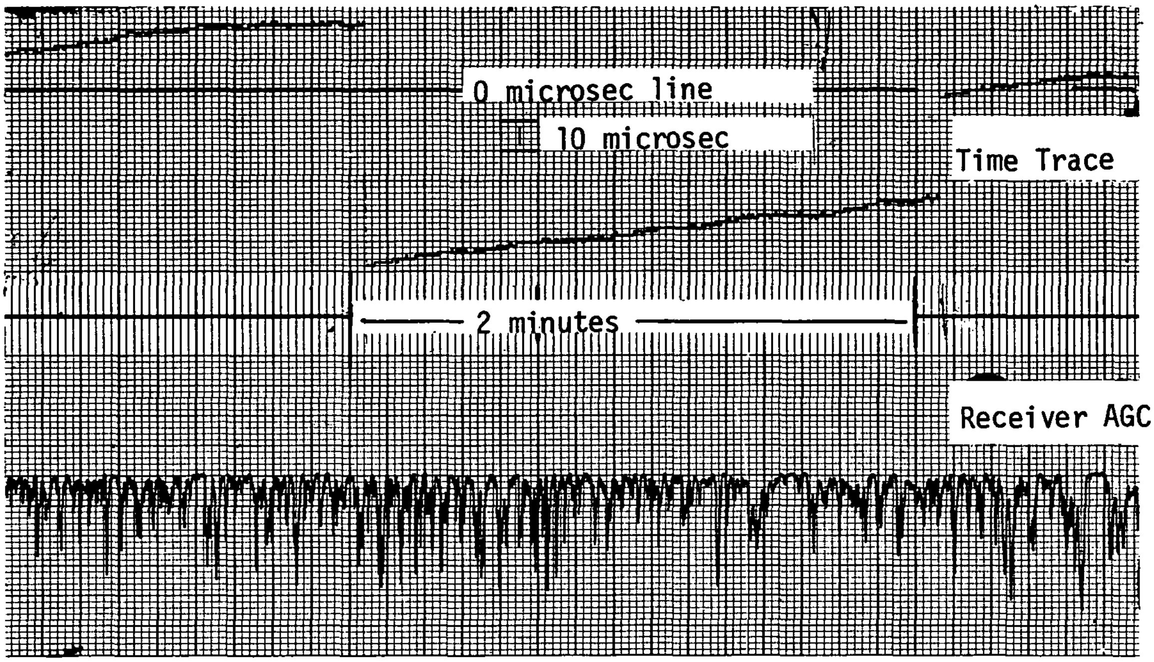


Figure 14 Large Step Change of Time Trace, Thule, Greenland

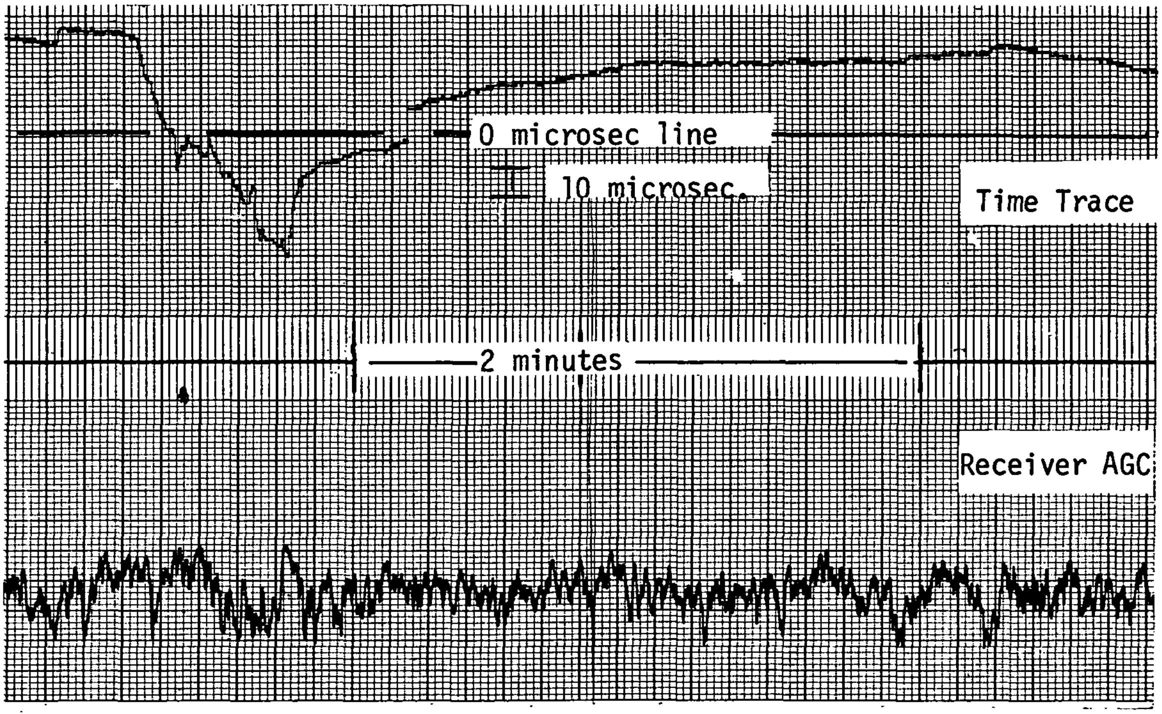


Figure 15 Time Trace Drift During Scintillation, Thule, Greenland

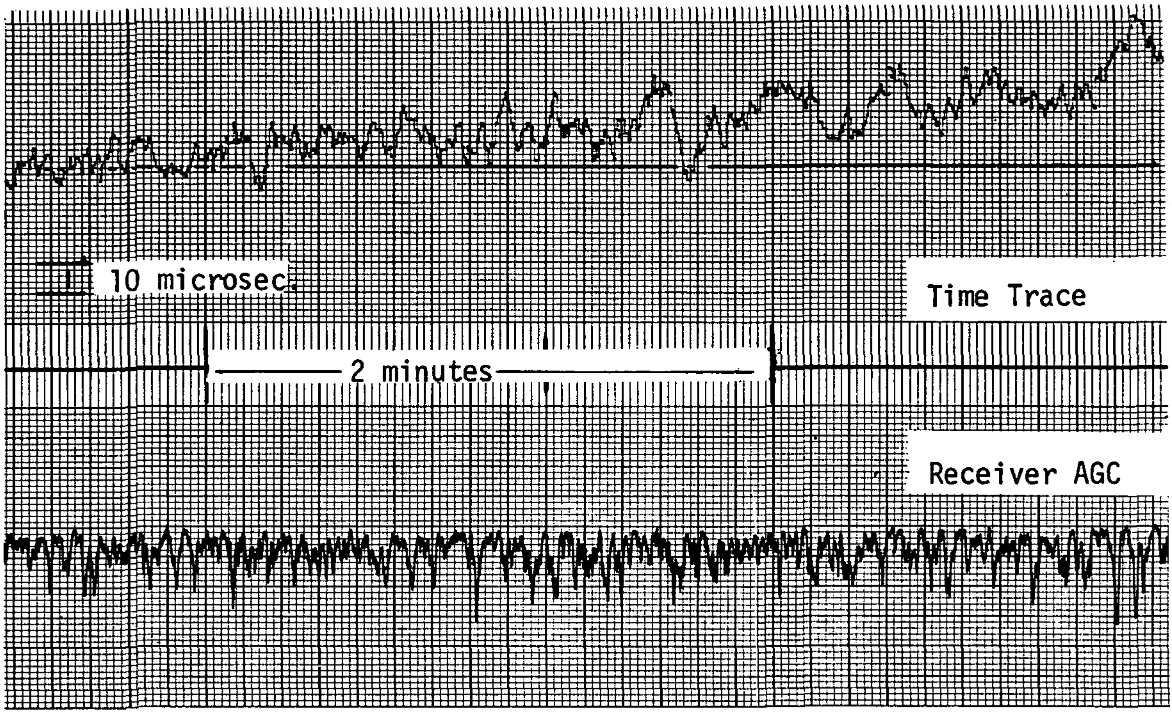


Figure 16 Randon Walk of Time Trace During Heavy Scintillation

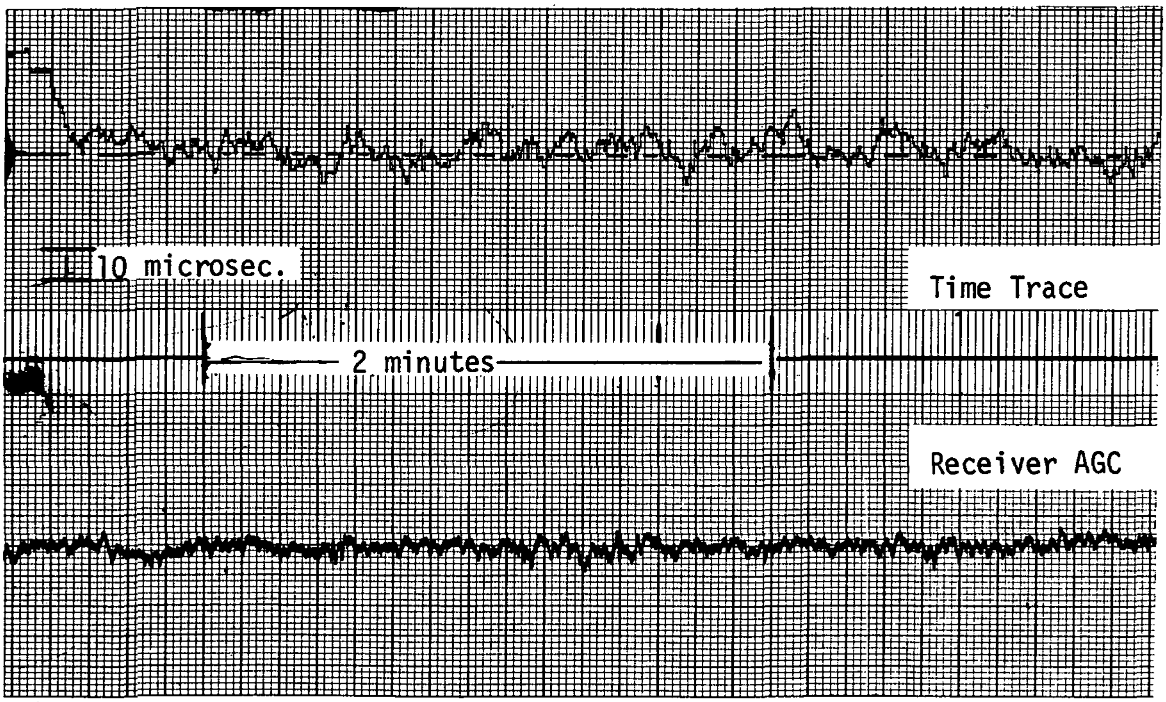


Figure 17 Random Walk of Time Trace During Mild Scintillation

QUESTIONS AND ANSWERS

MR. GEORGE PRICE, Austron

As an operational experiment, or an operational procedure on-board an aircraft to get time to 30 microseconds are you able to use it with a commercially available piece of equipment, and if so then what do you have to add to it to make those measurements?

MR. SWANSON:

Yes, we use the Arbitors System Model 1060 receiver which cost about $5,000 and the plate antenna that went with it. For our time comparison measurements we carried a HP 5065 rubidium and battery pack, which was synchronized at the time shop at Wright-Patterson.

We used two techniques. One being the Hewitt-Packard computing counter, with its time interval device and print out. We used that to verify the digital comparitor that is inside the Arbitors receiver which creates an analog voltage with the resolution of plus or minus a microsecond.

We confirmed that that did work and then relied upon a strip chart as the recording device running the pulse from the rubidium into the Arbitor time comparer circuit and taking the analog equivlent and voltage out onto the strip chart.

At the same time then we also recorded one minute time hacks from the UTC time from the rubidium or from the Arbitor, just to keep track of where we were in the strip chart.

MR. PRICE:

But, to make an operation -- a day to day type of experiment a day to day type of measurement, on-board an aircraft could you do it with just the Arbitor receiver and the antenna and nothing else?

MR. SWANSON:

I would not want to do that with any great confidence, no. The restriction being that you don't know whether you have had local interference or not. I would feel much more comfortable having just a nice crystal running along side of it. Such that I could plot a small, very slow trace and say, obviously I am 500 microseconds off from what I was a minute ago and therefore, I won't accept the time off the GOES receiver now.