TEST OF LOW-COST OMEGA NAVIGATION OVER ALASKAN AIRWAYS

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ABSTRACT

An airborne survey of OMEGA signal coverage along major airways in the state of Alaska produced records of reception at 10.2 KHz from Hawaii, Japan, Norway, and North Dakota in May, 1975. A low cost OMEGA receiver for general aviation was tested at minimum airway altitudes and relatively high speed, both in and out of clouds of ice crystals. Received signals were monitored and performance measured in terms of accuracy along course and at waypoints.

INTRODUCTION

The Federal Aviation Administration has been testing airborne navigation equipment which receive and process signals in the very low frequency band. The test and evaluation of such equipment poses unique problems due to the characteristics of propogation in VLF, the band of frequencies and the velocity of the test aircraft. Standard test factors such as accuracy and reliability take on new meaning when operating at high-speed over long ranges in a VLF propogation environment. In order to perform such tests aircraft, which are instrumented for testing OMEGA navigation equipment, should also be instrumented for simultaneous airborne monitoring of VLF signals. Combining such data with more readily available static monitor information contributes greatly to the development of performance standards and and to the verification of computed models of VLF propogation.

The purpose of this paper is to describe a series of flight probes, that were flown over Alaska, with a prototype model of a low cost OMEGA Navigation receiver. Alaska became the test site for the following reasons: it has a harsh and varied terrain; it is only partially covered by conventional navigation aids; and, it must somehow support the rapidly expanding use of civil aircraft as a primary mode of transportation. The flight probes were designed to gather preliminary information concerning the quality of OMEGA signal reception along major air routes throughout the state.

Six major test flights were conducted between May 10-18, 1975. The routes were designed to include varied terrain, over-water legs, and the maximum number of established airways. Three additional unscheduled flights were made. Signal outages and malfunctions in the test aircraft interrupted three of the planned flights so that nine flights were made in all.

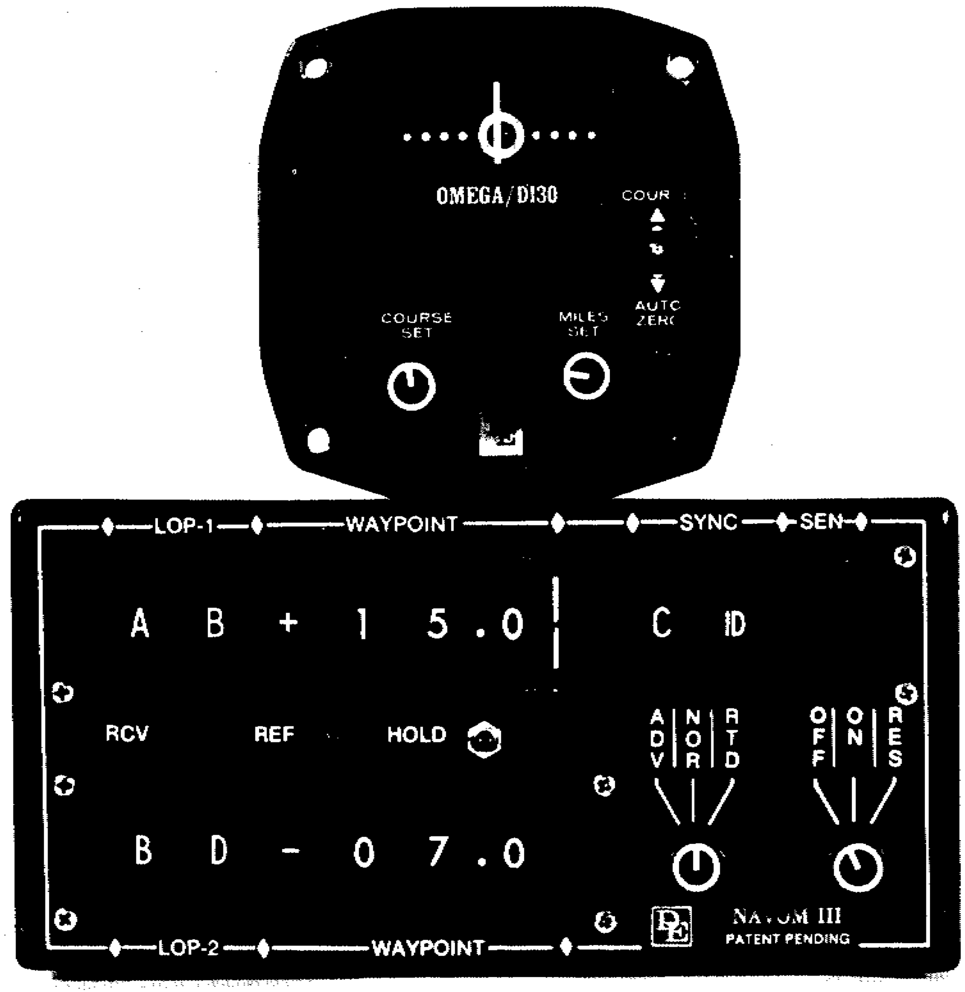
OMEGA Equipment--See Specifications

A low cost OMEGA navigation receiver, which was procured for these tests, was the Dynell Corporation Mark III OMEGA Navigation Set. The equipment is a prototype model that was designed for general aviation operations at maximum speeds of 400 knots under optimum signal conditions. The major units, receiver and indicator, were designed and packaged to standard form factors and cost the Government approximately $3000. The indicator contained a constant sensitivity crosspointer, digital distance display, to/from flag and course/distance set controls.

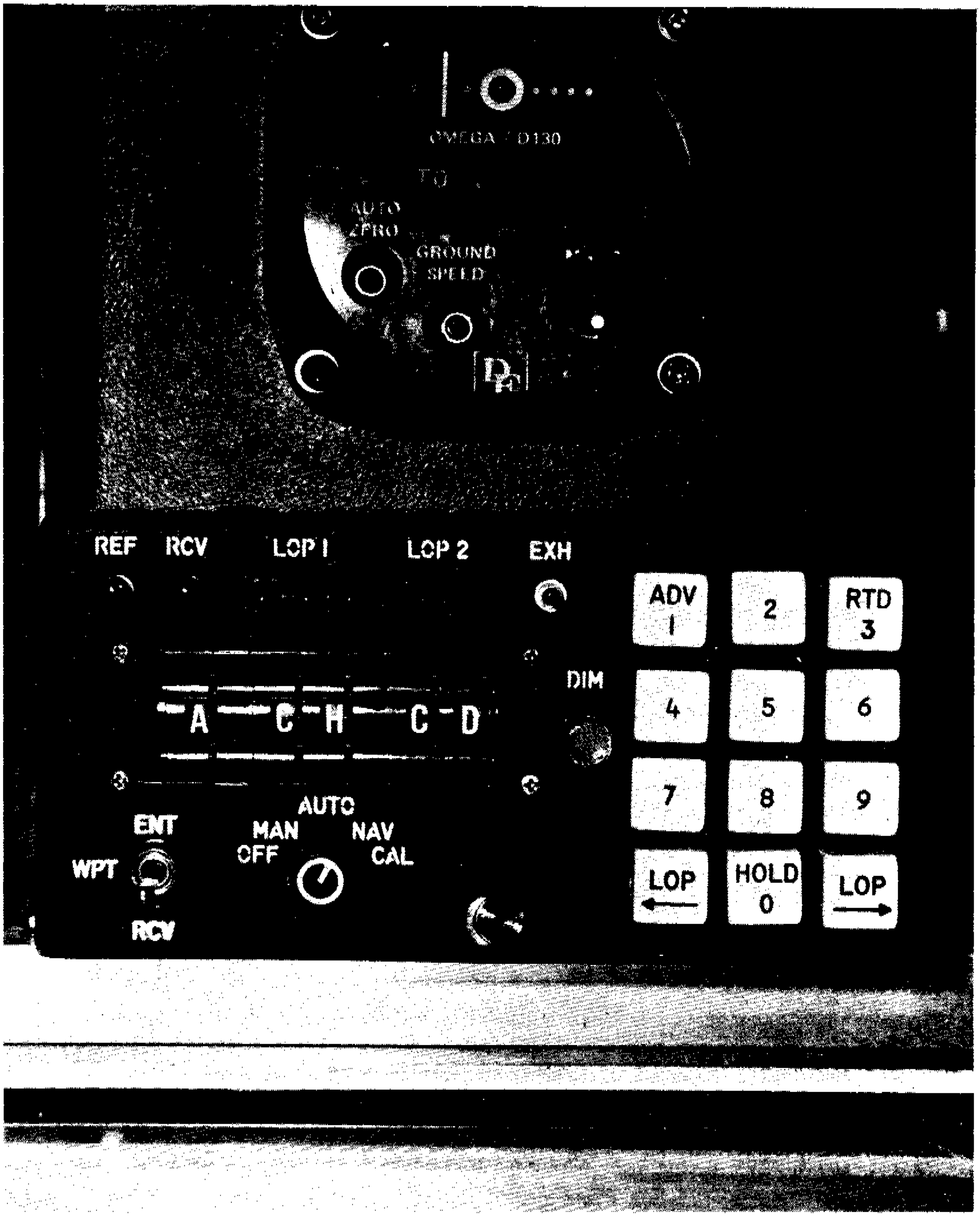
The receiver panel contained all programming switches, synchronization and reset controls. This unit housed three subsystems. These included clock generation and synchronization, phase tracking and error-signal processing circuits.

The Dynell Mark III accepted only single frequency, 10.2 KHz OMEGA navigation signals and did not have provisions for rate-aiding inputs such as compass heading or true airspeed. The system was coupled to an E-field antenna for signal reception. Normally the ADF sense long wire on an aircraft would be coupled to such an equipment in parallel with other avionics. Because of its relatively simple design, the Dynell Mark III was applicable to lower performance aircraft of the general aviation category and not to high performance types. The Dynell receiver did not contain circuitry for diurnal-shift compensation while enroute. The vendor's suggested method of diurnal compensation for large shifts enroute was to modify the manually computed lane crossing on inputs during preparation for each flight. The result of such a refinement would be a flight path, which was not quite linear, but with a minimized end point error. This procedure was not employed for any of the Alaskan test flights.

Operation of the Dynell set was fairly simple. Before flight the receiver was synchronized automatically. The desired destination



PROTOTYPE-DYNELL MARK III OMEGA NAVIGATION RECEIVER



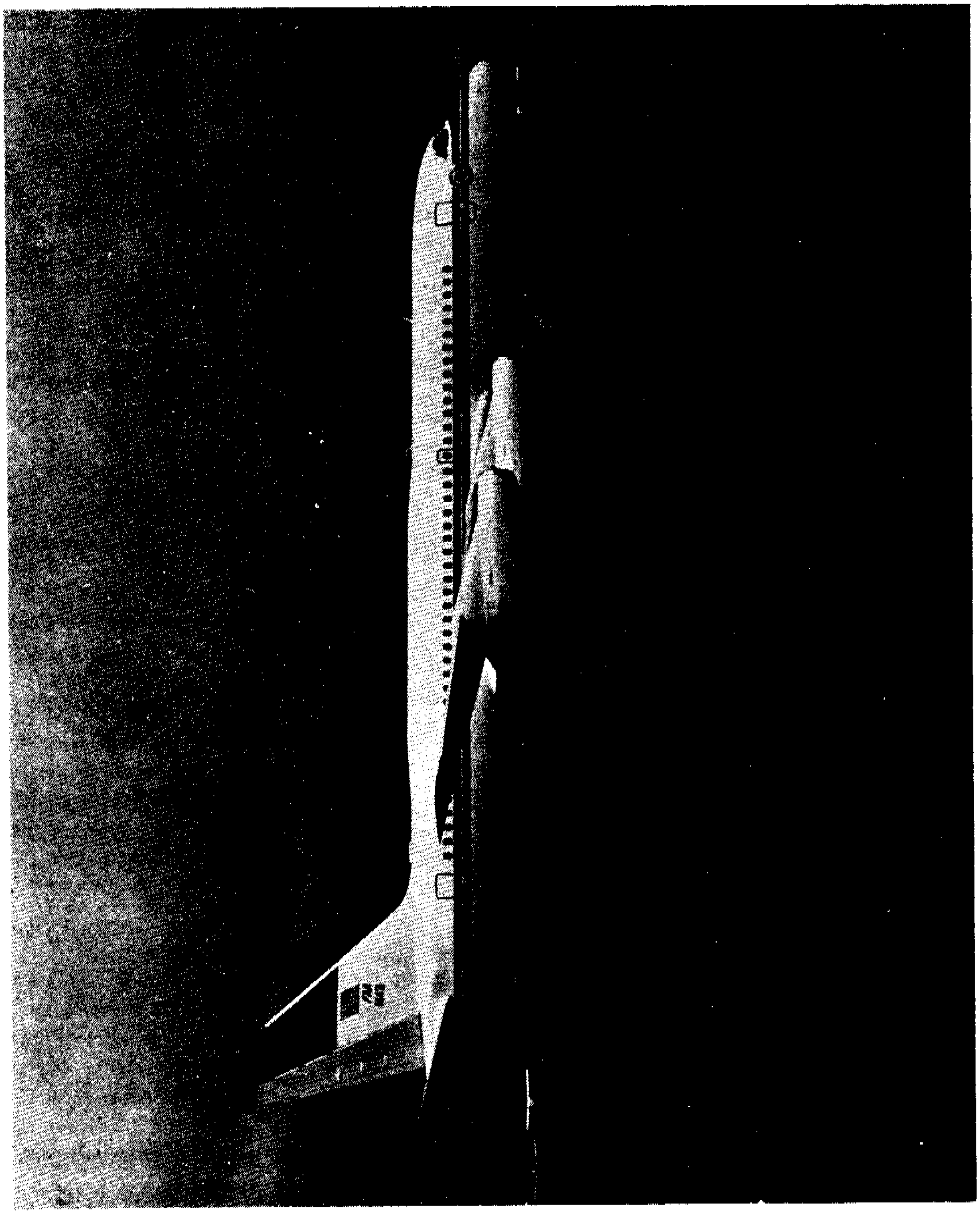
PRODUCTION MODEL-DYNELL MARK III OMEGA NAVIGATION RECEIVER in terms of OMEGA lanes was inserted by operating thumbwheel switches; the Enroute Deviation Indicator (CDI) was zeroed; and known the miles to the destination was set into the digital readout. The entire process, excluding trip computation, took approximately 2 minutes. Simple pre-flight computations established the number of lanes to be traversed for two selected station pairs. The calculated number of lane crossings was the difference between the OMEGA coordinates of the destination and the origin.

In flight the pilot maintained the CDI at zero deflection and the mileage display counted down. When the destination was reached, a flag appeared on the indicator. Simply stated the operation involved synchronizing the receiver to OMEGA transmissions, zeroing all counters, generating a vector, and applying a mileage-scaling factor and end point to the vector. The crosspointer served as a null meter to help the pilot maintain the vector.

TEST BED

Initial planning for flight tests of the low-cost receiver in Alaska had specified installation of the Dynell receiver and related data collection devices in an FAA aircraft, the Douglas Model DC-6B. This aircraft had been selected because of its operating range, relatively low operating speed (240 knots) and the fact that it had long wire E-plane antennas available for OMEGA reception. Flights were conducted in the vicinity of NAFEC and between NAFEC and Anchorage, Alaska, during January 1975. However, the planned flight tests in Alaska had to be cancelled due to a shutdown of the OMEGA Hawaii transmitter. Alaskan tests were rescheduled in May. Unfortunately, the DC-6 was not available and the entire test system had to be reconfigured and installed in another FAA, aircraft Convair Model 880. This jet aircraft was found acceptable after insuring that it could be flown at speeds as low as 250-300 knots during actual test operations in Alaska. Aboard this aircraft there was an inertial navigation system, Litton Model LTN-51. It was used as an onboard positioning reference.

The antennas available on the CV-880 included an ADF E-plane plate sensor, and an active E-plane blade. The blade antenna was selected for all tests in Alaska on the basis of performance comparisons made while enroute to the test area from NAFEC. The primary test



FAA CONVAIR 880 (N-42)

installation which was mounted on a rack in the airplane, consisted of the Dynell Mark III prototype OMEGA navigation receiver, recording interface and incremental magnetic tape recorder. Additional instrumentation included an OMEGA signal monitor and analog pen recorder, a VOR/ DME recording console and a camera installation on the flight deck for photographing the LTN-51 INS position reference. A production version of the Dynell Mark III receiver was also installed on the CV-880. This was to safeguard the mission to Alaska and would have been tested in the event of failure of the prototype Mark III receiver. The indicator of the prototype Mark III system was remotely installed for viewing at the pilots position. Some additional test instrumentation was mounted on test racks on the project test area.

TEST METHODS

Several operational procedures which are described below, were followed for all test flights in Alaska.

All flights except numbers 24, 25 and 26 began and terminated with an overflight of the Anchorage Vortac to secure a datum for data processing. Data collection was terminated and restarted on two occasions when a fuel stop became necessary part way through a planned flight.

The LTN-51 INS and the feasibility model OMEGA receiver were programmed with the same waypoint coordinates inserted in their own respective language. The INS was programmed prior to flight and the OMEGA receiver was programmed with track change information at every waypoint. This information consisted of lane crossing numbers retaining the point of flight origin as reference in the majority of instances.

The pilot flew the test routes using OMEGA course deviation and distance-to-go for aircraft guidance. The only exceptions to this procedure were, made just prior to waypoint passage and where OMEGA navigation was not possible. A constant heading was maintained prior to approaching a waypoint in order to allow time to insert new lane information into the OMEGA receiver. Waypoint passage was marked by conventional navigation aids. At this point a track change was made in the OMEGA receiver.

All flights were flown in standard air routes at published minimum enroute altitudes and at ground speeds of approximately 300 knots.

All flights were accomplished during daylight hours, commencing at approximately 1000 local time. Anchorage time in May was GMT − 9 hours.

FLIGHT ROUTES

Dynell Flight 21 (AL Test #1) May 10, 1975

Airway	to Waypoint	Distance, nmi	M. E. A. ft.
V438/456	Big Lake	26	2000
V456	Gulkana	133	10000
V456	Northway	109	11000
V444	Big Delta	121	8000
V444	Fairbanks	77	5000
V438	Big Lake	202	10000
V438/456	Anchorage	26	2000

This initial relatively short flight in the southeast central portion of the state demonstrated operation and signal reception over high ranges and deep valleys. The legs from Northway to Fairbanks were flown in a valley with high ranges between the aircraft and the coastline. Close observations were made of the signal received from Norway in order to detect any degradation as the flight proceeded eastbound toward the Canadian Border. This flight was flown with only team members aboard in order to shakedown equipment and optimize team effort. Signal reception from OMEGA Stations A, C, D and H was recorded.

Dynell Flight 22 (AL Test #2) May 12, 1975

Airway to	Waypoint	Distance, nmi	M. E. A., ft.
V440	McGrath	187	11000
V440	Nome	273	8000
V506	Bethel	242	8000
V506	King Salmon	198	8000
V456	Kenai	204	13000 to 5000
V456	Anchorage	43	2000

During this flight to the western portion of the Alaskan mainland, reception of OMEGA signals A, C, D and H was verified over and adjacent to high ranges and along and over the water segment. There were no indications of RF interference. The airways flown along the west coast of the mainland were on the edge of the VOR/DME network.

Dynell Flight 23 (AL Test #3 May 13, 1975

Airway to	Waypoint	Distance, nmi	M. E. A., ft.
V436	Talkeetna	69	3000
V436	Nenana	141	10000
V504	Bettles	152	7000
V504	Dead Horse	211	10000 to 7000
A15	Pt. Barrow	177	-6000 Actual
	Cape Lisburne	240	-6000 Actual
	Kotzebue	143	-6000 Actual
V498	Galena (fuel)	192	8000

Dynell Flight 23 (AL Test #3) May 13, 1975 (continued)

Airway to	Waypoint	Distance, nmi	M. E. A., ft.
V498	McGrath	112	6000
V440	Anchorage	187	10000

This flight was the longest one of the series requiring a fuel stop at Galena. The flight covered most of the North Slope area after crossing over the Brooks Range. Some areas did not have Navaids other than non-directional beacon (NDB) equipment. Signal coverage from OMEGA A, C, D and H was monitored with A signals displaying a dramatic increase in quality as we progressed northbound.

OMEGA Demonstration Flight May 14, 1975

Airway to	Waypoint	Distance, nmi	M. E. A., ft.
V438/456	Big Lake	26	2000
V438	Fairbanks	202	10000
V438	Big Lake	202	10000
V438/456	Anchorage	26	2000

This flight was a demonstration of OMEGA navigation for the Director, Alaskan Region, and members of his staff. Operation of low cost OMEGA and all related systems onboard were demonstrated and explained. Multiwaypoint operations and functions of the controls were examined. OMEGA signals A, C, D and H were monitored.

Dynell Flight 24 (AL Test #4) May 15, 1975

Airway to	Waypoint	Distance, nmi	M. E. A., ft.
V456	Kenai	43	2000
V456	King Salmon	204	13000
V456	Cold Bay	287	14000
	Adak	536	14000

This test provided information on OMEGA signal coverage in the Aleutian Chain between Cold Bay and Adak. A 536 nmi. course was flown over water originating at Cold Bay and terminating at Adak. The Tacan at Adak was inoperative during the test period.

Dynell # Flight 25 (AL Test #5) May 16, 1975

Airway	to	Waypoint	Distance, nmi	M. E. A., ft.
		Approx. 300 nmi NE of Adak		13000 actual
		Return to Adak		13000 actual

This flight was planned to provide a single leg that was 793 nautical miles long for navigation testing over the Bering Sea enroute to Anchorage. The flight was aborted when a problem developed in the LTN-51 reference. A turn of 180 degrees was initiated in the OMEGA test systems. Proper operation of OMEGA during the inbound leg was confirmed by Adak Radar at a distance of 50 nmi. The LTN-51 problem was resolved after landing and the test flight was reinitiated.

Dynell Flight #26 (AL Test 5A) May 16, 1975

Airway	to	Waypoint	Distance, nmi	M. E. A., ft.
		King Salmon	793	13000
V456		Kenai	204	13000
V436/456		Anchorage	43	2000

This flight, the fifth of the planned series, demonstrated operation of a low-cost OMEGA on a single-leg that was 793 nmi. flight over water. OMEGA signals A, C, D and H were monitored and/or utilized for Dynell navigation.

Dynell Flight #27 (AL Test #6) May 18, 1975

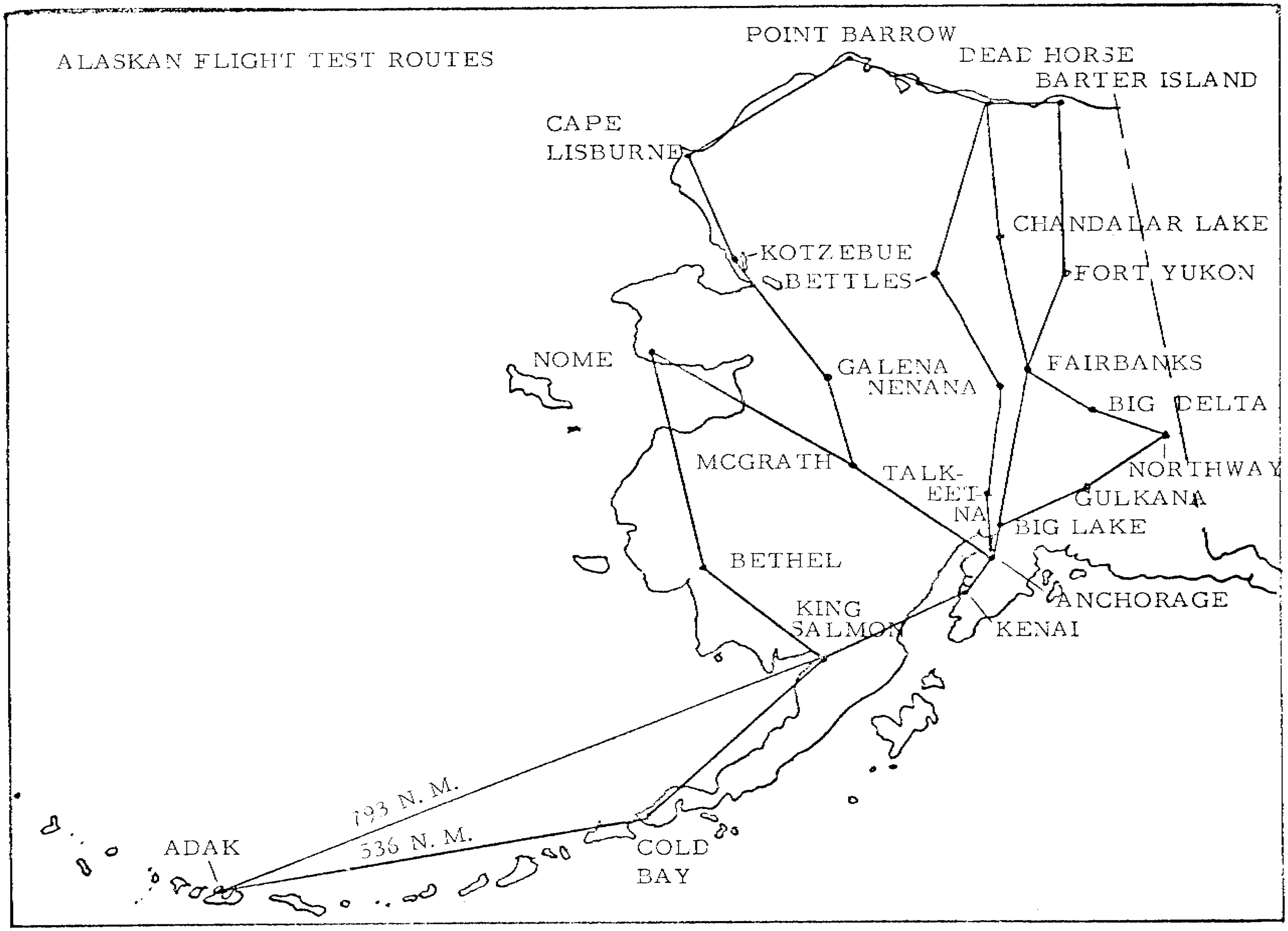
Airway	to	Waypoint	Distance, nmi	M. E. A., ft.
V438/456		Big Lake	26	2000
V438		A point approx. 100 nmi. north of Anchorage		10000

This flight was aborted approximately 100 nmi. north of Anchorage because of an unscheduled outage of the OMEGA Station at Hawaii. Rather than lose data legs enroute, while waiting for Hawaii to resume transmission, an unknown factor, the test was terminated. Prior to turning back to Anchorage, pilot confirmed that enough flight time remained on N-42 to repeat the test. Signals from Hawaii were received again prior to landing at Anchorage. Telephone contact was made with OMEGA Hawaii which confirmed that approximately 30 minutes outage had been due to component failure. The test was rescheduled next day; the planning included the alternate selection of station pairs in case that Hawaii should again prove unreliable.

Dynell Flight #28 (AL Test #6A) May 19, 1975

Airway to	Waypoint	Distance, nmi	M. E. A., ft.
V438/456	Big Lake	26	2000
V438	Fairbanks	202	10000
V347	Chandalar Lake	164	11000
A15	Dead Horse	163	10000
	Barter Island	98	10000 act.
B26	Fort Yukon	217	12000
V438	Fairbanks	127	8000
V438	Big Lake	202	10000
V438/456	Anchorage	26	2000

This test was the last of the planned series conducted in Alaska. The course was designed to traverse the remainder of the North Slope east of Prudhoe Bay and the airway roughly paralleling the Canadian border between Barter Island and Fairbanks. In addition, this route provided a repeat leg over V438 between Fairbanks and Anchorage for data comparison.


ALASKAN FLIGHT TEST ROUTES
POINT BARROW
DEAD HORSE
BARTER ISLAND
CAPE
LISBURNE
CHANDALAR LAKE
KOTZEBUE
BETTLES
FORT YUKON
NOME
GALENA
NENANA
FAIRBANKS
BIG DELTA
MCGRATH
TALK-
EET-
NA
NORTHWAY
GULKANA
BIG LAKE
BETHEL
ANCHORAGE
KING
SALMON
KENAI
793 N. M.
536 N. M.
ADAK
COLD
BAY

DATA COLLECTION TECHNIQUES

The low-cost OMEGA receiver was connected interfacing it to an incremental digital tape recorder. The sampling rate was 1.3 seconds Records were synchronized to the OMEGA transmission format. A delay after the start of the "A" pulse was introduced in order to secure records of the relative amplitudes of received OMEGA signals. Unfortunately, a defective integrated circuit in the recorder prevented collection of amplitude information and LOP 1 lane counts. Other parameters were recorded successfully. These included course deviation, distance-to-go, LOP 2 lane counts, weak signal warning, to/from flag, and reset/auto zero switch functions. Despite the loss of magnetic tape signal data a permanent record of received relative signal amplitude was obtained by monitoring the detected envelope of the OMEGA receiver continuously with a strip chart recorder.

Stop action photography was employed at a 1 minute sampling rate to record present position in latitude and longitude from the INS display while the aircraft was being navigated by OMEGA steering and distance to go information.

VOR/DME position information was recorded continuously whenever signals were available at a flight inspection recording console. This data was gathered to describe coverage available with the conventional navaid systems and to maintain a check on the performance of the LTN-51 inertial navigation system as a position reference.

DATA PROCESSING TECHNIQUE

The total process for reducing and compiling the data collected during the Alaskan tests will include the following: total usage of all INS present position samples for position reference purposes, correlation of VOR/DME data with OMEGA/INS samples, correction factors to compensate for INS drift error and referral to published announcements concerning station outages and anomalies during the period of test flights.

Total processing and analysis of all information gathered in Alaska was not complete at this writing. In order to provide an approximate measure of low-cost OMEGA accuracy under good signal reception conditions in Alaska random samples of data were processed and are expressed here in terms of comparative cross-track and along-track errors. Cross-track error information was developed by first converting a sample of CDI deflection voltage to nautical miles, offsetting the INS present position for that time frame and finally comparing the resultant position to a computed great circle track from waypoint to waypoint. Along-track error is the difference between the reading of OMEGA distance-to-go and the computer distance between the corrected present position and the destination waypoint.

DATA SAMPLES

Alaska Test #1 May 10, 1975

GMT	Waypoint	OMEGA Distance	Comparative Error nmi Cross-track	Along-track
	Anchorage			
193756		14.0	2.0R	-1.1
	Big Lake			
194756		101.0	1.2R	2.6
195256		77.0	0.7R	1.5
195756		51.0	0.8R	-0.1
200256		28.0	2.8R	0.2
	Gulkana			
201656		70.0	1.1R	-0.3
202156		47.0	0.0	1.2
202656		22.0	0.0	0.0
	Northway			
203756		93.0	0.2R	0.1
205356		9.0	1.2L	0.9
	Big Delta			
205956		53.0	2.4L	-2.9
	Fairbanks			
211756		172.0	0.4R	-0.3
212256		150.0	2.8R	2.2
212756		127.0	5.4R	2.3
213256		102.0	2.7R	0.5
213756		81.0	3.5R	3.2
214256		57.0	2.0L	3.7
214856		25.0	1.7R	1.1
215156		11.0	2.0R	1.9

Alaska Test #2 May 12, 1975

GMT	Waypoint	OMEGA Distance	Comparative Error nmi Cross-track	Along-track
	Anchorage			
194659		51.0	0.2L	1.0
194959		35.0	0.0	-0.9
195159		26.0	0.9R	0.5
	McGrath			
201159		192.0	6.0R	1.2
201559		174.0	7.0R	2.8
202559		127.0	6.7R	5.9
	Nome			
205558		221.0	0.2L	-2.1
210058		194.0	1.7R	-4.2
211058		139.0	6.8R	-9.0
211558		112.0	7.7R	-10.5
	Bethel (reset)			
214358		187.0	0.8R	6.2
214958		151.0	0.5R	-0.2
215458		121.0	0.0	-5.5
215958		93.0	6.6L	-8.8
220458		78.0	1.1R	1.1
220958		50.0	1.7R	-3.1
221558		17.0	1.8R	-8.1
	King Salmon (reset)			
223658		139.0	1.7R	-2.7
224158		115.0	2.9R	3.5
224657		92.0	2.5R	2.9
225157		69.0	2.5R	2.7
225657		44.0	4.8R	1.0
230057		22.0	2.7R	1.4

Alaska Test #3 May 13, 1975

	Anchorage			
193357		7.0	0.5L	0.3
	Talkeetna			
194557		91.0	2.0L	3.4
200057		19.0	3.3L	3.7

Alaska Test #3 (continued)

GMT	Waypoint	OMEGA Distance	Comparative Error nmi Cross-track	Along-track
	Nenana			
201557		102.0	0.9L	4.4
205757		76.0	0.3L	3.5
202557		53.0	0.1R	6.0
203157		23.0	0.5L	6.1
	Bettles			
204157		186.0	3.7L	8.5
205557		115.0	5.9L	4.9
210556		69.0	6.4L	5.7
211556		21.0	6.5L	3.4
	Dead Horse			
213556		102.0	2.7R	3.9
214556		55.0	3.7R	6.4
215356		14.0	2.0R	4.6
	Point Barrow			
220956		169.0	8.4R	-7.6
222056		114.0	8.4R	-7.6
222556		91.0	8.5R	-5.7
223556		42.0	9.0R	-4.3
224056		17.0	8.7R	-5.2
	Kotzebue (reset)			
233156		116		-1.4
233556		97		-2.0
234056		75		-0.6
225556		21		6.0
	Galena			
012450		93		6.0
013050		64	.05L	-4.7
013550		40	1.3R	0.6
014050		14	2.0R	-0.3
	McGrath			
015050		153	1.0L	-0.2
015550		134	0.13L	4.8
020550		86	1.0R	3.7
022150		9	1.6R	-0.4

Alaska Test #4 May 15, 1975

GMT	Waypoint	OMEGA Distance	Comparative Error nmi Cross-track	Along-track
	King Salmon (reset)			
201600		280.0	1.3R	5.5
205500		81.0	5.0R	0.6
	Cold Bay (reset)			
211500		515.0	0.3L	2.1
212500		461.0	1.5R	0.7
214500		350.0	0.0	-6.9
223000		120.0	1.8L	-1.5

Alaska Test #5A May 16, 1975

	Adak (reset)			
002848		793.0	0.2L	5.7
004748		706.0	0.5R	8.7
025139		73.0	5.1R	2.7
	King Salmon (reset)			
031539		156.0	2.9L	4.4
033539		57.0	0.7R	4.6

Alaska Test #6 May 18, 1975

	Anchorage			
190356		11		-4.7
190656		6		-5.0
	Big Lake			
190956		200.0		-2.2
191255		183.0		-5.1
191555		168.0		-5.9
192055		142.0		-6.8
192555		116.0		-7.0
	Abort 100 mi north of Anchorage			

Alaska Test #6A May 19, 1975

	Anchorage			
191255		9.0	1.1L	-0.8
	Big Lake			
192855		129.0	3.7L	1.3
194055		66.0	0.2L	1.3
	Fairbanks			
200155		121.0	0.9L	6.8
202055		26.0	0.1R	5.5

Alaska Test #6A (continued)

GMT	Waypoint	OMEGA Distance	Comparative Error nmi Cross-track	Along-track
	Chandalar Lake			
202555		163.0	0.6R	6.3
	Dead Horse			
211055		33.0	0.8R	-0.9
	Barter Island			
213055		150.0	0.45R	1.9
215055		46.0	3.8R	1.3
	Fort Yukon			
220555		105.0	3.5L	6.5
221555		56.0	4.4L	6.1
	Fairbanks			
223055		181.0	0.3L	5.0
224555		106.0	0.7L	5.7
225555		60.0	2.2L	8.4

DATA ANALYSIS

In general reception of signals from OMEGA stations transmitting from Norway, Hawaii, North Dakota and Japan were of high quality during VFR conditions on all flights in Alaskan airspace. The Norwegian Station was unusable from west of a line through White Horse, Canada, to another line passing south of the Yakatut-Sitka area along the Pacific Coast. Station pairs AD and AC were processed on all flights for programming Dynell Mark III navigation alternate pairs CH and CD were considered but the reliability of Japan's station had not yet been established. As expected, recordings during flight through snow showers and dense clouds were characterized by high noise levels and impaired signal reception. The effect on OMEGA Navigation depended upon the density of the snow or clouds and aircraft speed. These effects, characteristic of operation with E-plane antennas, would have been less noticeable had the tests been conducted in a test bed of performance more nearly representative of the more numerous types of general aviation aircraft flown in Alaska.

The low-cost OMEGA set performed well considering the severity of the demands made on it for navigation. Although some trip initializations were performed enroute (transfer of origin) over waypoints, the majority of test flights retained Anchorage as origin. This resulted in long duration legs with many waypoint calibrations enroute. The manual waypoint calibrations are a source of human errors which tend to accumulate. Errors in the distance along the track appeared more likely to be long than short of actual distance and more likely to occur than errors in course deviation indication.

Dynell Flight 21 (AL Test #1)

The flight was initiated and terminated over the Anchorage Vortac with six waypoints enroute. The westward portion indicated a decrease in Norway signals but had not affected the OMEGA navigation. The flight through the clouds near Gulkana did not impede OMEGA navigation. The end point error at Anchorage was less than 1 nmi. on distance and course deviation pointer.

Dynell Flight 22 (AL Test #2)

Heavy snow showers and ATC diversions were encountered after leaving Anchorage. The distance error was 8 nmis. approaching McGrath. The error increased to 20 nmi. by the time we flew over Bethel. Several cloudy areas were encountered enroute. The course deviation indicator remained usable from Anchorage to Bethel. A reset (transfer of ORIGIN) was initiated over King Salmon for flight to Anchorage. The end point error was approximately 20 nmi. in distance and crosspointer. Some of this error is attributed to the quality of the airborne mark over King Salmon.

Dynell Flight 23 (AL Test #3)

OMEGA navigation from Anchorage to Cape Lisburne was satisfactory. Waypoint marks indicated minimal accumulated error. The leg from Lisburne to Kotzebue was unusable because of difficulty in marking Cape Lisburne. A reset was accomplished over Kotzebue for flight to Galena. The end point error was 10 nmi. and approximately 1 nmi. on crosspointer. Heavy snow showers were encountered enroute. A reset was initiated at Galena for flight to Anchorage. The end point error was less than 1 nmi. on distance and crosspointer.

Dynell Flight 24 (AL Test #4)

Heavy clouds with signal reception problems prevented OMEGA navigation between Anchorage and King Salmon. Resets were accomplished at King Salmon and Cold Bay. The end point error at Adak was approximately 4 nmi. in distance and 2 nmi. on cross-pointer.

Dynell Flight 25 (AL Test #5)

The flight originated and terminated at Adak. OMEGA reception and navigation was excellent throughout flight. The end point error was 1 nm. in distance and crosstrack.

Dynell Flight 26 (AL Test #5A)

Severe signal drop out was experienced 190 nmi. out from Adak. Signals returned but project power was interrupted shortly after. An airborne restart over an INS checkpoint enabled OMEGA navigation for the last 270 nmi. to King Salmon. Error at this point was approximately 2 nmi. in distance and 1 mile in crosstrack.

Dynell Flight 27 (AL Test #6)

The flight was aborted 100 nmi. north of Anchorage due to an unscheduled outage of OMEGA Hawaii.

Dynell Flight 28 (AL Test #6A)

error was 10 nmi. in distance and 3 nmi. on crosstrack. Some of this error was accumulated during waypoint operations ; clouds were encountered for a short period of time. The detected signal recording also indicated two Hawaii signal problems for periods of less than four OMEGA epochs while on the North Slope.

SUMMARY

The low-cost OMEGA receiver is relatively simple to operate. Pre-flight planning by the user is necessary but not excessively time consuming. The equipment appeared to be adequate as a VFR ONLY supplemental enroute system when operated in the CV-880 test bed. It is likely that signal interference, due to penetration of ice clouds and snow showers when using an E-plane antenna, would be substantially decreased or avoided during flights at lower air-speeds typical of light aircraft. However, the antenna seems to remain the weak link in low-cost OMEGA navigation avionics.

Careful placement on the aircraft of new types of E-plane plates or noise cancelling antenna units may be expected to help solve this problem.

OMEGA signal reception from Norway, Hawaii, North Dakota and Japan provided adequate coverage of Alaska with respect to geometry. For all practical purposes the world-wide OMEGA system was found to be complete in Alaska since there were several station pairs available for primary and alternate use. Station outages appear to be a deminishing problem based on these and previous OMEGA test efforts. Signals received during all test flights were usable except after penetrating dense clouds or when a station outage occurred. The test series flown can only be considered a minimal probe in assessing the characteristics and reliability of OMEGA signals. Continuous monitoring at various points in Alaska would provide more thorough and complete information regarding OMEGA propogation and the natural phenomena which affect it.

Mark III OMEGA Airborne Navigation System Specifications

Dimensions	
Receiver Unit (DR-30)	6"W x 3"H x 13"D
Indicator Unit (DR-30)	3.5"Dia. x 5"D
Weight	
Receiver Unit	4.5 lbs.
Indicator Unit	1.5 lbs.
Prime Power (total)	+12 Vdc, 1A
Operating Temperature	$-20^{\circ}C$ to $+60^{\circ}C$
Maximum Aircraft Speed	Approximately 400 knots
Navigation Range	
Single Leg Flight	Approximately 1000 nmi.
Multiwaypoint Flight	Unlimited
Navigation Readouts	
CDI Meter	Sensitivity nominally 4 files full scale
Miles to go	3 digit display to 999 nmi.
To/from Flag	Indicates designation arrival
On Ground Setup Time	Approx. 2 minutes with destination number predetermined
Antenna Coupler	Provided as required

QUESTION AND ANSWER PERIOD

MR. SAKRAN:

Charley Sakran, Navy.

Could you describe briefly how the problem of diurnal propagation corrections is accounted for in this set?

MR. MOORE:

I can be very brief about that. There is no diurnal compensation built into this set. I neglected to mention that. It is mentioned in the paper, though. The only method prescribed by the vendor to compensate for diurnals expected enroute would be to offset your preliminary computations to account for the changes expected during a flight. This would produce a flight path that would be slightly non-linear, but would reduce your end point error.

MR. SAKRAN:

Thank you. Could you also describe how you decided what an adequate signal was during the flight? What criteria was used?

MR. MOORE:

The equipment had a weak signal indicator, and we were monitoring with some Tracor equipment, doing some tracking of the pair selected, and the indications on the Omega receiver would correspond to slewing or would break track. The distance to go would freeze. This induced the 20 mile error. I believe that occurred in two snow cloud periods over a period of quite a bit of time. The end point error was 20 miles, or approximately two lanes. The correspondent did not seem to be affected as much. I believe it just goes dead when it loses signal, and you get a red light telling you you don't have any more signals left.

MR. SAKRAN:

Was there any indication of interfering noise, other than precipitation static, specifically onboard-aircraft-generated noise with the E-Field antenna?

MR. MOORE:

No, sir. Our problem appeared to be mainly a charge buildup. There were noticeable increases in noise level for very short periods of time after takeoff, which did not affect Omega navigation. The effects of cloud penetration were obvious. They appeared and disappeared when the visibility decreased and increased. I didn't notice any problems with onboard equipment. The equipment -- by the way, I didn't mention it -- is a 12-volt system and draws about one ampere of power, so I didn't notice any interference on the aircraft.

MR. BARSZCZEWSKI

Barszczewski, National Research Council.

In Canada we have some data on operation in the eartern part of Arctic and Omega. We have been operating there for the last five years, and it is just not there. In particular, on low level. If you go below 5000 feet with Greenland completely masking Norway, we get Foresport, that is about the only thing we get there.

Do you have any data on signal strength versus altitude?

MR. MOORE:

No, sir. All of the flights in Alaska were flown at the minimum enroute altitudes for the benefit of the type of aircraft we were testing for, and one of the ideas of flying at low levels was to get into the depressions in Alaska, for instance between Norway and Fairbanks there is quite a valley of depression area. The peaks to the right and left were higher than the altitude of the aircraft. I have no information to correlate altitude with signal strength at this time.

I can say that a subsequent flight flown in September at jet speeds in the same aircraft using an automatic Omega set at altitudes far above the minimum enroute altitudes produced approximately the same signal coverage results.

DR. REDER:

I would like to make two comments; in fact, part of it the gentleman already answered, and that is the effect of Greenland, as we all know, is that it cuts off Omega signals practically completely. That is how he lost it on the way down. But, as far as Alaska is concerned, you don't have any problems, and there is another advantage for Alaska and that is that the diurnal shift of most of the Omega signals being used there is relatively small. In summer you have almost none; in winter you have almost none; and the paths from Hawaii and Japan are short. So this is one advantage of Alaska, probably the only one.

Oh, excuse me. I forgot the oil.

MR. MOORE:

All of the test flights flown in Alaska were started at approximately 1000 local time. That is GMT minus 9, so I believe the diurnal shift effects were minimal at that time.

DR. REDER:

On the precipitation static, if one could use ferite loop sticks, or loops anyway, that will drastically reduce precipitation noise.

MR. BARSZCZEWSKI:

Regarding your loops, now there is a set built by Canadian Marconi, and they started to operate with the loop. What happens, you pick up tremendous noise from the aircraft engines, from spark plugs, and so on, and so they went to the E-antenna just for that reason. So you can have one or the other, but you can't have them both.

DR. REDER:

Well, maybe the airplanes should be changed. What altitude did you fly?

MR. MOORE:

The minimum altitudes ranged from 6,000 feet on the north slope to 13,000 feet east of Anchorage.