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Informal Information Report

ALASKA COLLECTION SAR DATA SUMMARY

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ALASKA COLLECTION
SAR DATA SUMMARY

January 1989

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PREFACE

This report presents a summary of Synthetic Aperture Radar (SAR) data collected in March, 1988 over Alaska and its surrounding seas. The Environmental Research Institute of Michigan (ERIM) and the Naval Air Development Center (NADC) participated jointly in this effort which provided surface truth for comparison with SSM/I ice products. The principle investigators were Drs. Robert A. Shuchman and Andrew Milman. The data collection effort was sponsored by the Office of the Oceanographer of the Navy and the Office of Naval Research, ERIM contract No. N00014-87-C-0726 under the technical guidance of Mr. Charles Luther and Mr. Robert Winokur.

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ABSTRACT

Four synthetic aperture radar (SAR) data collection flights were made over Alaska and the surrounding waters in March of 1988, to obtain SAR images of sea ice and forested areas. The P-3 SAR, that operates at C-, L-, and X-bands, was used. 85 passes were collected over four days. The flights produced imagery of use to oceanographic, glaciological, geological, and botanical studies. This report describes the extent, location, and characteristics of the SAR data collected in this experiment.

1.0 INTRODUCTION

In March 1988, a four-flight SAR experiment was performed in Alaska and its surrounding coastal areas. The four missions were coordinated to coincide with overflights of the DMSP-8 satellite, a meteorological satellite containing a passive microwave radiometer (SSM/I) that uses seven channels (at 19, 22, 37, and 85 GHz; V and H polarization). Data collected by the coincident flights of the P-3 SAR were to be used to validate the sea ice algorithms used by the SSM/I. In order to make valid comparisons, SAR data completely covering ice areas of about 100 km x 300 km were collected on the mission.

Some flights during this mission were also used to collect radar imagery of forested areas of Alaska for use in an ongoing analysis of the radar backscatter of forest stands. Several reflector arrays were placed under tree stands in the Fairbanks, Alaska area and were imaged by the radar. Data collected by these flights are currently being analyzed to study the attenuation and polarization effects of tree canopies. These tree canopy flights are also being used in a calibration analysis of the P-3 SAR. Several calibration targets were placed in open areas and imaged by the radar while it was gathering forest canopy data. The data collected from the calibration arrays will be added to a database of other P-3 calibration data used to establish the linearity and stability of the P-3 radar.

On 18 and 21 March 1988 additional data were collected over northern and southern mountain ranges in Alaska while the P-3 SAR was en route to ice data collection areas. These data will be used in future geological research.

2.0 SYSTEM DESCRIPTION

The P-3 SAR is a three-frequency, polarimetric SAR which is flown aboard a P-3 aircraft which belongs to the Naval Air Development Center. It is a side-looking SAR that operates at X-, C-, and L-bands and can transmit and receive both horizontally and vertically polarized pulses. Four different channels of data, using any combination of frequency and transmitted and received polarization, can be recorded.

The system can operate in three different swath modes. The configurations of these swath modes are illustrated in Figure 1. In single-swath mode (Figure 1a), the radar collects the same range coverage in each channel using four different frequency and polarization combinations. In double-swath mode (Figure 1b), twice the range coverage of single-swath mode is recorded but only two frequency and polarization combinations can be used. In quad-swath mode (Figure 1c), four times the range coverage of single swath mode is recorded but only one frequency and polarization combination can be used. In double- and quad-swath mode there is no range overlap between channels that are contiguous in range.

For any swath modes recorded, the P-3 SAR can operate either in high resolution, with an azimuth resolution of 2.8 m and a range resolution of 1.6 m, or in low resolution, with an azimuth resolution of 2.8 m and a range resolution of 3.2 m. Using low resolution, the range coverage of each channel is 9830 m, and using high resolution, the range coverage of each channel is 4915 m.

The data collected from the four channels are multiplexed and recorded on high-density digital tapes. Also recorded with each data record is an auxiliary block of data describing the radar and aircraft parameters at the time of collection. Any single channel of data can also be recorded optically on the aircraft. A real-time processor on the aircraft also records the image received from a single channel. A summary of the operating parameters provided above for the P-3 SAR is given in Table 1 for ease of reference. A more detailed discussion is given in Appendix A.

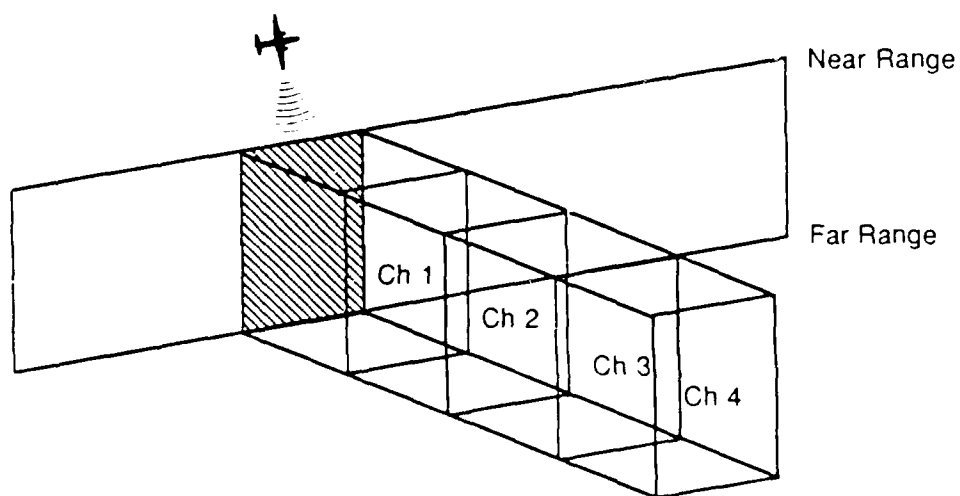


Figure 1a. P-3 SAR swath configuration - single swath mode

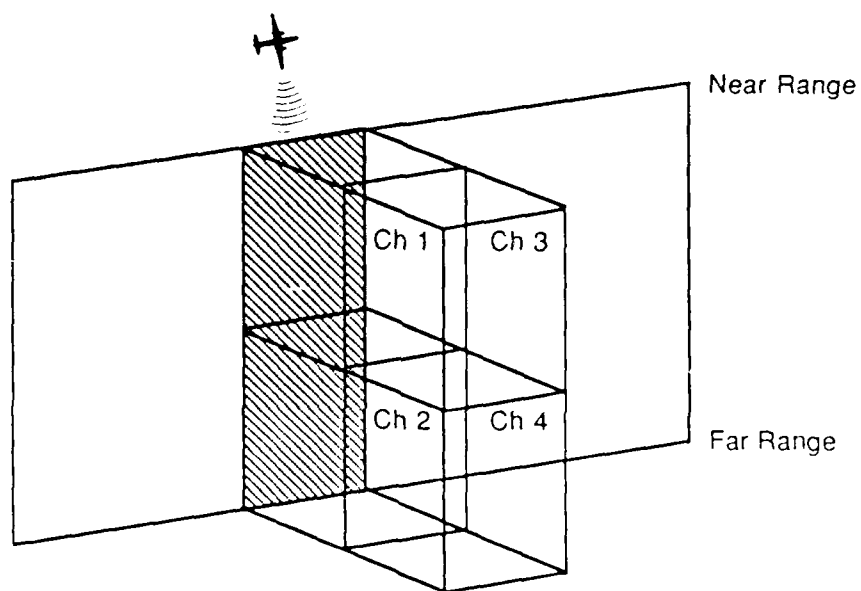


Figure 1b. P-3 SAR swath configuration - double swath mode

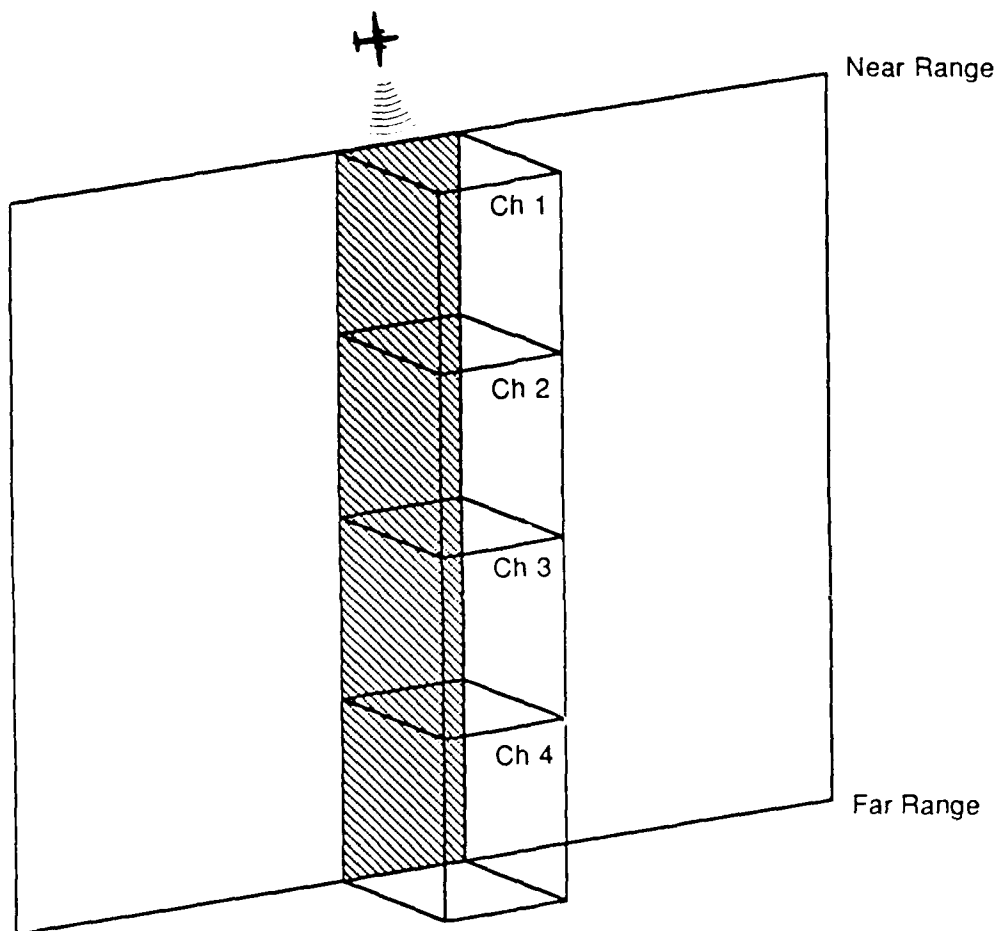


Figure 1c. P-3 SAR swath configuration - quad swath mode

TABLE 1
P-3 SAR OPERATING PARAMETERS

<u>SPECIFICATION</u>	<u>VALUE</u>		
Frequency	X, L, C		
Polarization	VV, HH, VH, HV		
Viewing Direction	left or right		
Processing	real-time, optical, digital		
<u>Swath Width in Range Direction</u>	<u>Single</u>	<u>Double</u>	<u>Quad</u>
Narrow Band (High-Res)	4915m	9830m	19660m
Wide Band (Low-Res)	9830m	19660m	39320m
<u>Resolution</u>	<u>Azimuth x Range</u>		
High	2.8 m x 1.6 m		
Low	2.8 m x 3.2 m		
<u>Center Frequency Beamwidth</u>	<u>Vert. Pol</u>	<u>Hori. Pol</u>	
X-Band	1.7°	1.6°	
C-Band	3.6°	3.45°	
L-Band	8.55°	9.75°	

3.0 MISSION DESCRIPTION

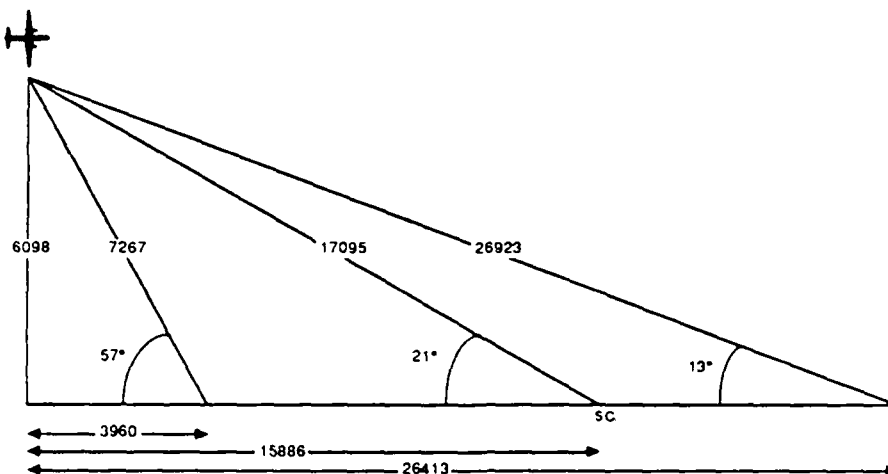
The Alaska collection consisted of four missions which were flown on 18, 19, 21, and 22 March 1988. Eighty-five passes were collected in all.

Two types of data were acquired each day, ice data and calibration data. The ice data were collected in double swath, low resolution mode. The two frequency and polarization combinations used were X-band, HH-polarization, and C-band, VV-polarization. For all ice passes the altitude of the plane was 20,000 feet, providing uninterrupted image coverage from a slant range of 7267 m to 26923 m and from an incidence angle of 38° at near range to 77° at far range. The imaging configuration used in these passes is illustrated in Figure 2. The flight lines for these ice passes were planned to give an overlap of about three kilometers for adjacent passes, so that even with navigation errors, there would be no gaps in the data coverage.

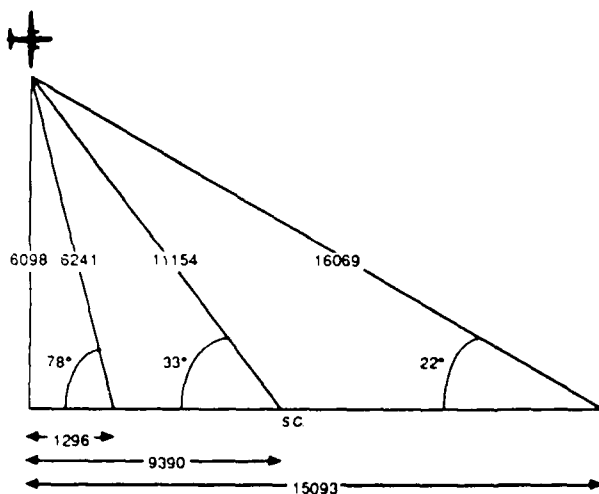
Areas of the Beaufort Sea, Chukchi Sea, and Bering Strait were imaged with these ice passes. The location of these passes is illustrated in Figure 3. Enlargements of each area, in Figure 4, provide ground track location. The SAR data from these ice passes will be processed optically and formed into mosaics to give a synoptic view of the data and for comparison with the SSM/I data, which have very low (25 to 50 km) spatial resolution.

The calibration data were collected in single-swath mode. Most of these passes were recorded with low resolution, but a few passes on 22 March 1988 were recorded using high resolution. All frequency and polarization combinations were attempted, but only X-band and C-band combinations were completely successful. Only two L-band passes were collected due to a radar malfunction. For all calibration passes, the altitude of the plane was 20,000 feet, but slant range and incidence angle coverage varied from pass to pass. The imaging configurations used for these passes are illustrated in Figures 2b through 2h. In all but one configuration (Figure 2b) pre-nadir is also recorded.

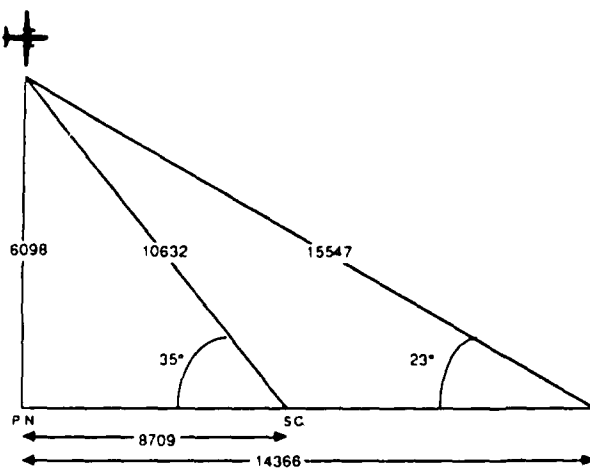
Fairbanks, Alaska, the Chena River area surrounding Fairbanks, and the upper and lower Yukon River Basin areas were imaged with the



(a) Double Swath, Low Resolution

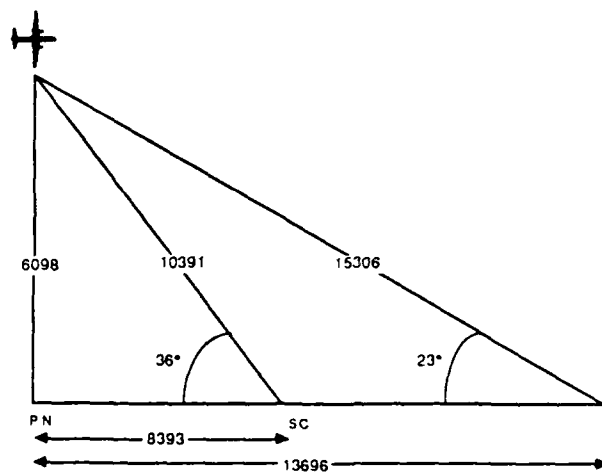


(b) Single Swath, Low Resolution

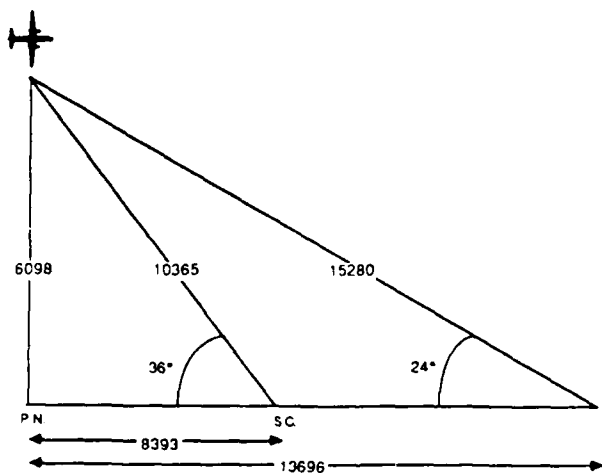


(c) Single Swath, Low Resolution

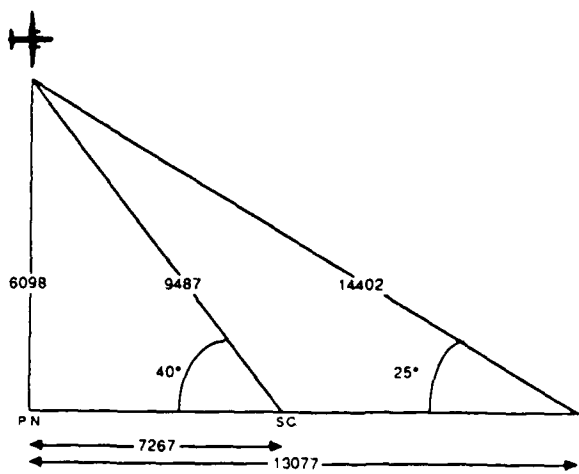
Figure 2a - 2h. P-3 SAR imaging configurations used in the Alaska collection. PN = Pre Nadir, SC = Scene Center



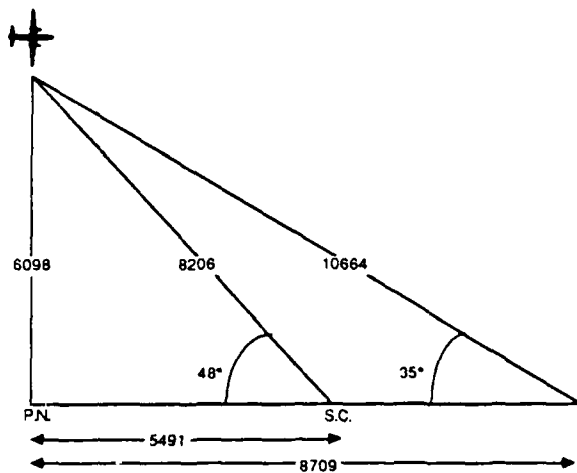
(d) Single Swath, Low Resolution



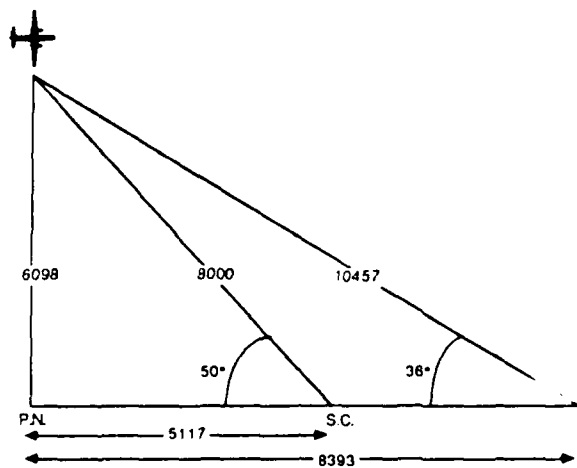
(e) Single Swath, Low Resolution



(f) Single Swath, Low Resolution



(g) Single Swath, High Resolution



(h) Single Swath, High Resolution

ALASKA SURVEY

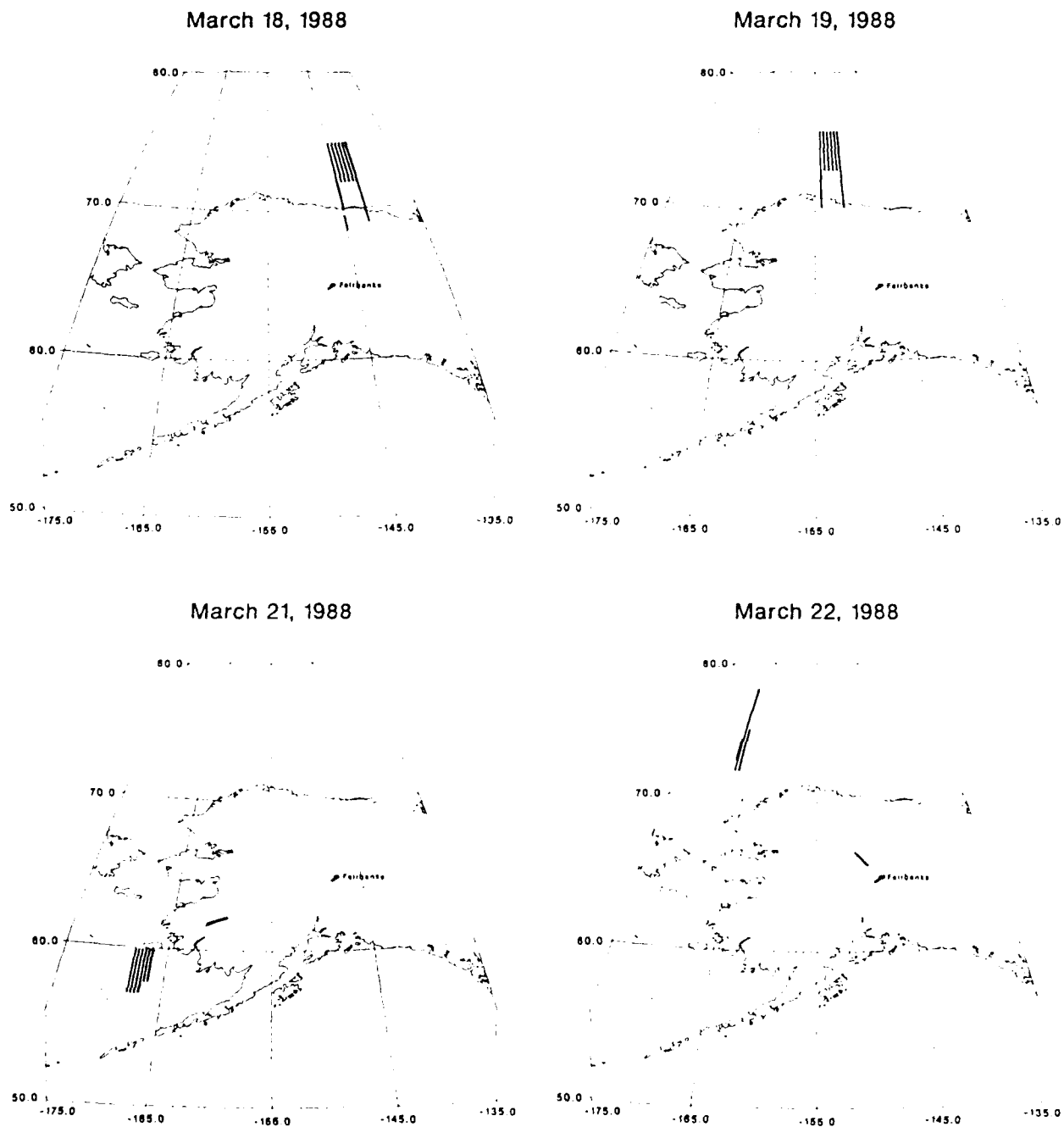


Figure 3. Locations of the Alaska collection passes

ALASKA SURVEY

March 18, 1988

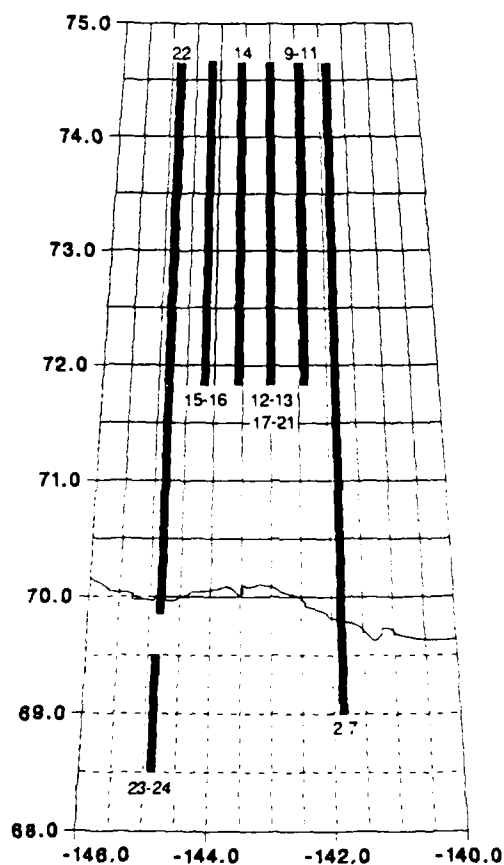


Figure 4a. Detailed locations of the ice data passes on 18 March 1988

ALASKA SURVEY

March 19, 1988

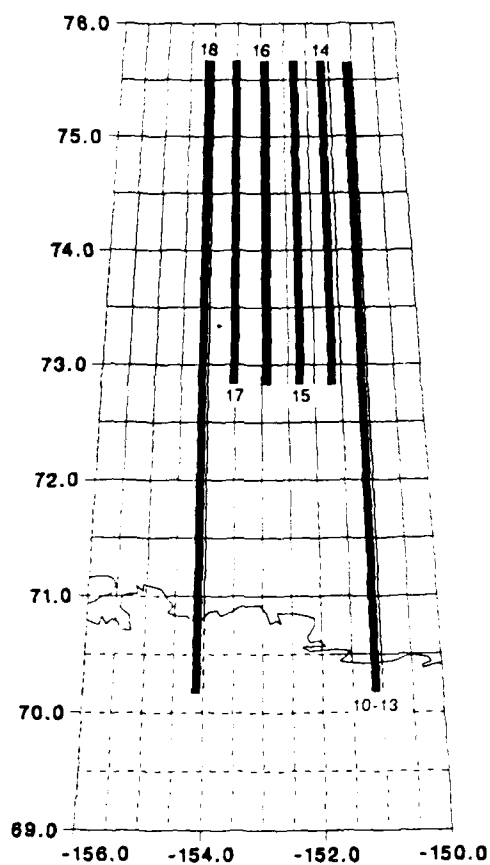


Figure 4b. Detailed locations of the ice data passes on 19 March 1988

ALASKA SURVEY

March 21, 1988

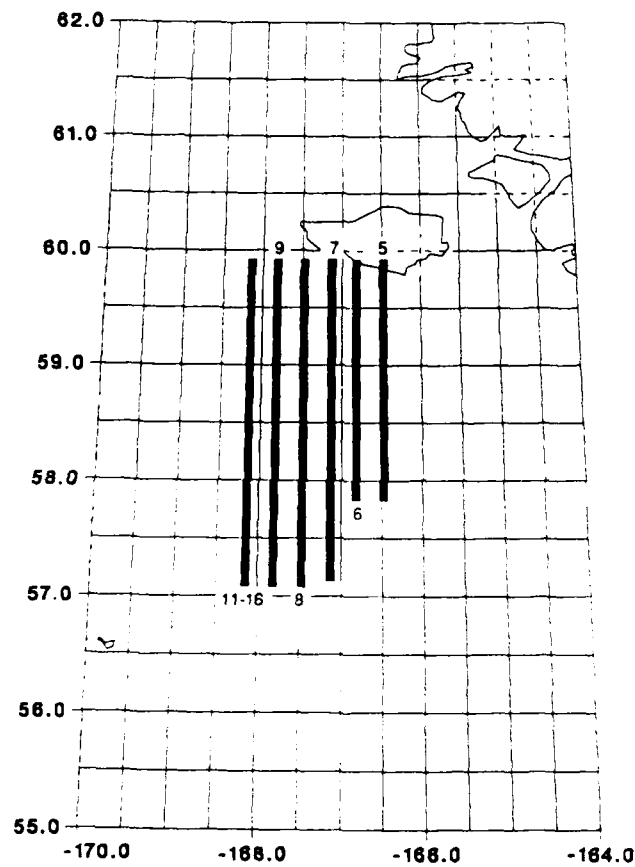


Figure 4c. Detailed locations of the ice data passes on 21 March 1988

ALASKA SURVEY

March 22, 1988

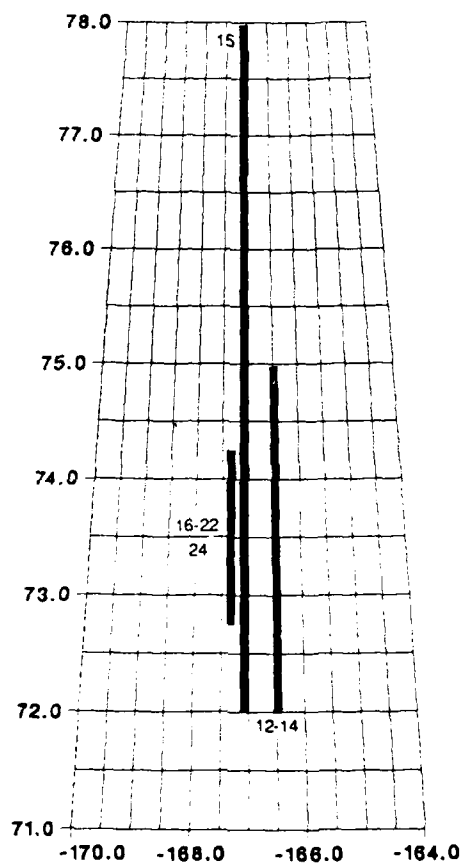


Figure 4d. Detailed locations of the ice data passes on 22 March 1988

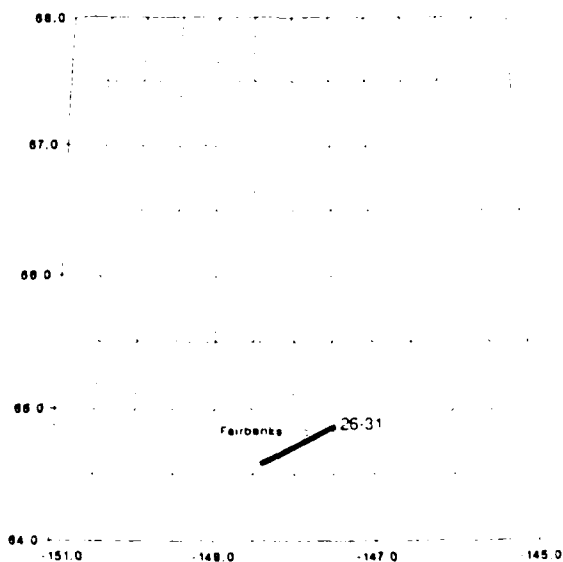
calibration passes. The location of these passes is illustrated in Figure 3; an enlargement of each area in Figure 5 provides ground track location.

The SAR data from these calibration passes are currently being processed digitally to provide calibration for the ice data in this collection and to provide data for an ongoing in-house forestry study.

The radar and aircraft parameters used in the Alaska collection are summarized in Tables 2 through 5. The 'a' tables provide essential aircraft and platform parameters: the start time and stop time of each pass, the start and stop latitude and longitude, altitude, platform heading, platform velocity, and look direction. The 'b' tables provide radar and processing parameters: the near-edge and far-edge slant ranges, the near-edge and far-edge incidence angles, frequency, polarization, swath mode, resolution, attenuation setting, transmitted power, high-density tape number, and optical-film number.

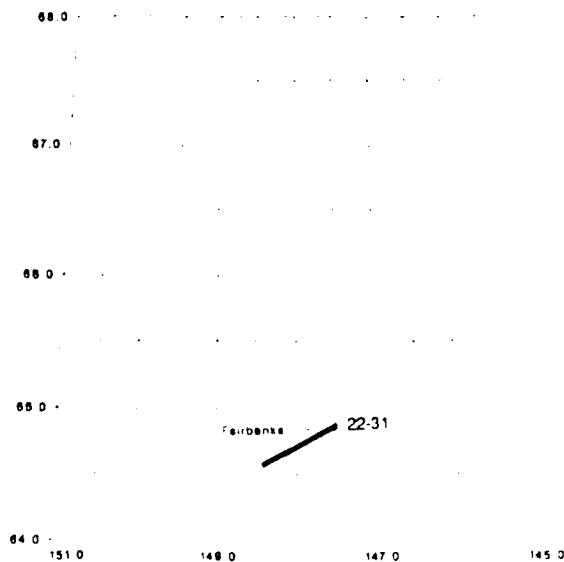
ALASKA SURVEY

March 18, 1988



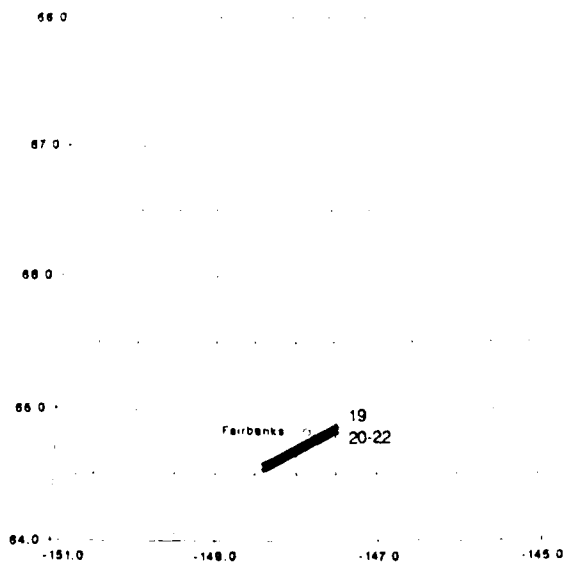
(a)

March 19, 1988



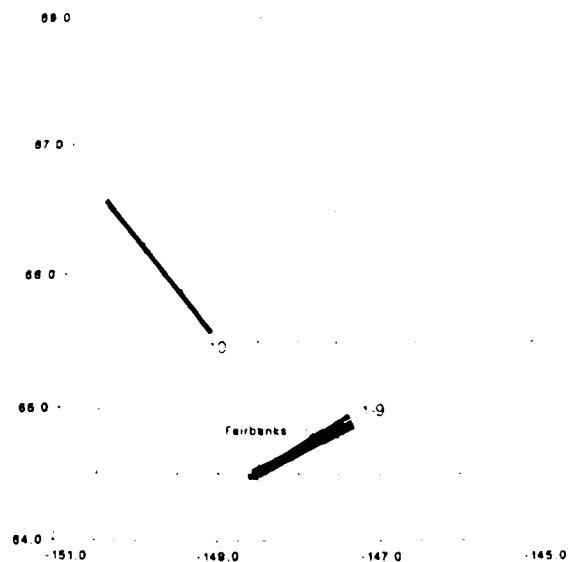
(b)

March 21, 1988



(c)

March 22, 1988



(d)

Figure 5a - 5d. Detailed locations of the calibration data passes on 18, 19, 21 and 22 March 1988

ALASKA SURVEY

March 21, 1988

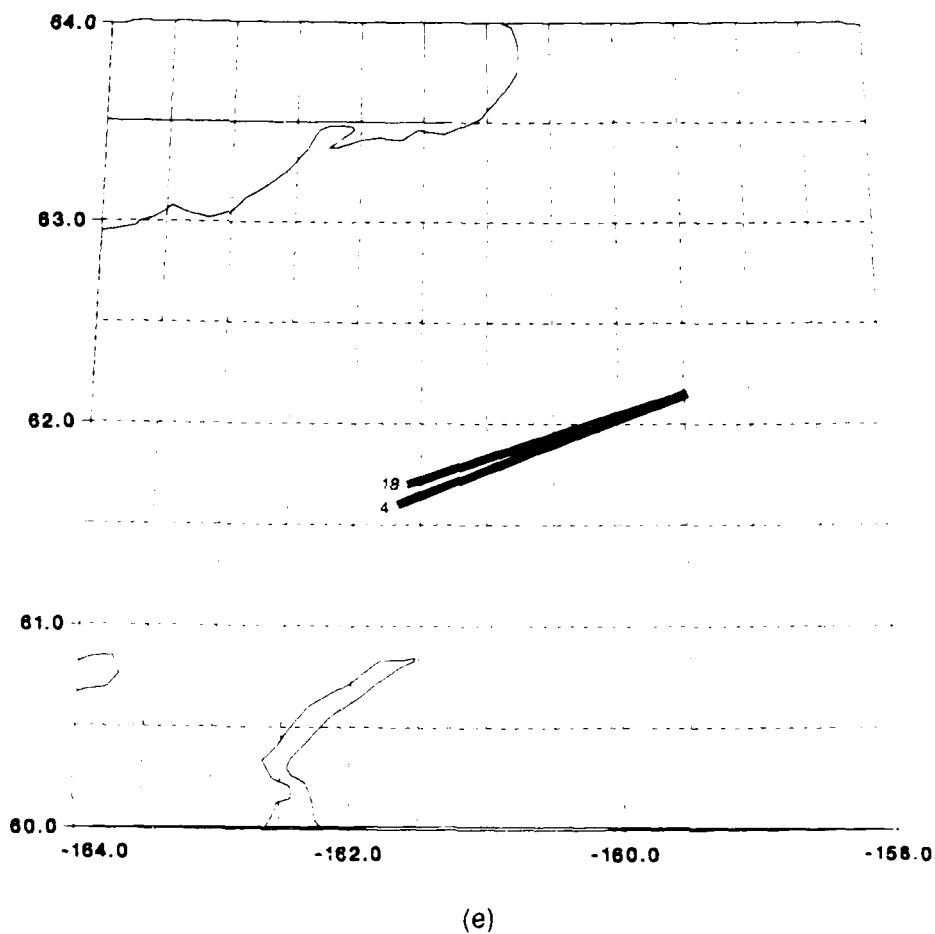


Figure 5e. Detailed locations of land data passes on 21 March 1988

TABLE 2a
SUMMARY OF P3 SAR AND AIRCRAFT PARAMETERS
DURING ALASKA COLLECTION
18 March 1988, Local Time
19 March 1988, UT

AIRCRAFT PARAMETERS

PASS NO.	START TIME (UT)	STOP TIME (UT)	START LATITUDE	START LONGITUDE	STOP LATITUDE	STOP LONGITUDE	ALTITUDE (ft)	SPEED (kts)	HEADING	LOOK
2	02:35:08	02:36:43	69:00.88	141:51.09	74:39.25	141:51.09	20000	247.0	0°	L
3	02:36:43	02:45:12	69:00.88	141:51.09	74:39.25	141:51.09	20000	250.0	0°	L
4	02:45:12	02:47:48	69:00.88	141:51.09	74:39.25	141:51.09	20000	254.0	0°	L
5	02:47:48	03:09:17	69:00.88	141:51.09	74:39.25	141:51.09	20000	254.0	0°	L
6	03:09:17	03:21:39	69:00.88	141:51.09	74:39.25	141:51.09	20000	250.0	0°	L
7	03:21:39	03:40:38	69:00.88	141:51.09	74:39.25	141:51.09	20000	279.0	0°	L
8	03:40:38	03:58:38	69:00.88	141:51.09	74:39.25	141:51.09	20000	279.0	0°	L
9	04:07:57	04:12:01	74:39.62	142:24.44	71:50.36	142:24.44	20000	279.0	180°	R
10	04:12:01	04:28:37	74:39.62	142:24.44	71:50.36	142:24.44	20000	278.0	180°	R
11	04:28:37	04:44:07	74:39.62	142:24.44	71:50.36	142:24.44	20000	284.0	180°	R
12	04:57:26	05:05:28	71:50.36	143:00.04	74:39.62	143:00.04	20000	298.0	0°	L
13	06:06:28	06:32:16	71:50.36	143:00.04	74:39.62	143:00.04	20000	292.0	0°	L
14	06:42:29	08:18:57	74:39.62	143:35.64	71:50.36	143:35.64	20000	282.0	180°	R
15	08:29:48	08:41:20	71:50.36	144:11.24	74:39.62	144:11.24	20000	278.0	0°	L
16	08:41:20	07:08:18	71:50.36	144:11.24	74:39.62	144:11.24	20000	282.0	0°	L
17	07:14:16	07:14:39	74:39.62	143:00.04	71:50.36	143:00.04	20000	283.0	180°	R
18	07:14:39	07:14:45	74:39.62	143:00.04	71:50.36	143:00.04	20000	282.0	180°	R
19	07:14:45	07:14:45	74:39.62	143:00.04	71:50.36	143:00.04	20000	283.0	180°	R
20	07:14:45	07:14:59	74:39.62	143:00.04	71:50.36	143:00.04	20000	283.0	180°	R
21	07:14:59	07:27:02	74:39.62	143:00.04	71:50.36	143:00.04	20000	284.0	180°	R
22	07:49:09	08:51:54	74:39.36	144:48.46	69:50.58	144:48.46	20000	278.0	180°	R
23	08:58:12	08:57:44	69:29.88	144:52.66	68:30.12	144:52.66	20000	274.0	180°	R
24	08:57:44	09:06:00	69:29.88	144:52.66	68:30.12	144:52.66	20000	274.0	180°	R
26	09:57:14	09:58:37	64:51.85	147:28.28	64:34.28	148:24.98	20000	288.0	234°	R
27	09:58:37	09:58:40	64:51.85	147:28.28	64:34.28	148:24.98	20000	287.0	234°	R
28	09:58:40	09:58:42	64:51.85	147:28.28	64:34.28	148:24.98	20000	287.0	234°	R
29	09:58:42	10:00:29	64:51.85	147:28.28	64:34.28	148:24.98	20000	287.0	234°	R
30	10:06:23		64:51.85	147:28.28	64:34.28	147:28.30	20000	350.0	234°	R
31	10:10:45	10:16:58	64:34.29	146:25.01	64:51.67	147:28.30	20000	302.0	54°	L

Look 'L' = Left Look
Look 'R' = Right Look

TABLE 2b
SUMMARY OF P3 SAR AND AIRCRAFT PARAMETERS
DURING ALASKA COLLECTION
18 March 1988, Local Time
19 March 1988, UT

RADAR PARAMETERS																										
PASS NO	NEAR EDGE SLANT RANGE (m)	FAR EDGE SLANT RANGE (m)	NEAR EDGE INCIDENCE ANGLE		FAR EDGE INCIDENCE ANGLE		MODE	FREQUENCY				POLARIZATION				RES ATTENUATION (dB)				TRANSMITTED POWER (dB)				RES	HDDI	FILM
			ANGLE	ANGLE	ANGLE	ANGLE		1	2	3	4	1	2	3	4	1	2	3	4							
2	7267	26923	33°	77°			D	X	X	C	C	HH	HH	VV	VV	8.0	8.0	16.0	16.0	-31.5	-31.5	-39.1	-39.1	L	E332, E233	E333,
3	7267	26923	33°	77°			D	X	X	C	C	HH	HH	VV	VV	4.0	4.0	16.0	16.0	-31.5	-31.5	-39.1	-39.1	L	E332	E333
4	7267	26923	33°	77°			D	X	X	C	C	HH	HH	VV	VV	0.0	0.0	12.0	12.0	-31.4	-31.4	-39.0	-39.0	L	E332, E233	E333
5	7267	26923	33°	77°			D	X	X	C	C	HH	HH	VV	VV	0.0	0.0	8.0	8.0	-31.4	-31.4	-39.1	-39.1	L	E333	E333
6	7267	26923	33°	77°			D	X	X	C	C	HH	HH	VV	VV	0.0	0.0	8.0	8.0	-31.5	-31.5	-39.1	-39.1	L	E333	E333
7	7267	26923	33°	77°			D	X	X	C	C	HH	HH	VV	VV	0.0	0.0	8.0	8.0	-31.5	-31.5	-39.1	-39.1	L	E333	E233
8	7267	26923	33°	77°			D	X	X	C	C	HH	HH	VV	VV	0.0	0.0	8.0	8.0	-31.5	-31.5	-39.1	-39.1	L	E333	E242
9	7267	26923	33°	77°			D	X	X	C	C	HH	HH	VV	VV	0.0	0.0	10.0	10.0	-31.0	-31.0	-38.6	-38.6	L	E233	E242
10	7267	26923	33°	77°			D	X	X	C	C	HH	HH	VV	VV	0.0	0.0	10.0	10.0	-31.0	-31.0	-38.6	-38.6	L	E233	E242
11	7267	26923	33°	77°			D	X	X	C	C	HH	HH	VV	VV	0.0	0.0	8.0	8.0	-30.9	-30.9	-38.5	-38.5	L	E233	E242
12	7267	26923	33°	77°			D	X	X	C	C	HH	HH	VV	VV	0.0	0.0	8.0	8.0	-30.8	-30.8	-38.4	-38.4	L	E244	E242
13	7267	26923	33°	77°			D	X	X	C	C	HH	HH	VV	VV	0.0	0.0	10.0	10.0	-30.8	-30.8	-38.4	-38.4	L	E242	E244
14	7267	26923	33°	77°			D	X	X	C	C	HH	HH	VV	VV	0.0	0.0	6.0	6.0	-31.1	-31.1	-38.6	-38.6	L	E224	E246, 4
15	7267	26923	33°	77°			D	X	X	C	C	HH	HH	VV	VV	0.0	0.0	6.0	6.0	-31.1	-31.1	-38.7	-38.7	L	E187	E188
16	7267	26923	33°	77°			D	X	X	C	C	HH	HH	VV	VV	0.0	0.0	6.0	6.0	-31.0	-31.0	-38.6	-38.6	L	E187	E188
17	7267	26923	33°	77°			D	X	X	C	C	HH	HH	VV	VV	32.0	32.0	32.0	32.0	0.0	0.0	0.0	0.0	L	E188	E188
18	7267	26923	33°	77°			D	X	X	C	C	HH	HH	VV	VV	0.0	0.0	6.0	6.0	-30.9	-30.9	0.0	0.0	L	E188	E188
19	7267	26923	33°	77°			D	X	X	C	C	HH	HH	VV	VV	0.0	0.0	6.0	6.0	-30.9	-30.9	0.0	0.0	L	E188	E188
20	7267	26923	33°	77°			D	X	X	C	C	HH	HH	VV	VV	0.0	0.0	6.0	6.0	-30.9	-30.9	0.0	0.0	L	E188	E188
21	7267	26923	33°	77°			D	X	X	C	C	HH	HH	VV	VV	0.0	0.0	6.0	6.0	-30.9	-30.9	-70.0	-70.0	L	E188	E188
22	7267	26923	33°	77°			D	X	X	C	C	HH	HH	VV	VV	0.0	0.0	6.0	6.0	-31.2	-31.2	-38.7	-38.7	L	E118, E263	E209,
23	7267	26923	33°	77°			D	X	X	L	L	VV	VV	VV	VV	0.0	0.0	32.0	32.0	-31.2	-31.2	-30.5	-30.5	L	E263	E304
24	7267	26923	33°	77°			D	X	X	L	L	VV	VV	VV	VV	4.0	4.0	32.0	32.0	-31.5	-31.5	-30.5	-30.5	L	E263	E304
26	5719	15547	PN	67°			S	X	X	L	L	HH	VV	VV	HH	32.0	32.0	32.0	32.0	-70.0	0.0	0.0	0.0	L	E304	E308
27	5719	15547	PN	67°			S	X	X	L	L	HH	VV	VV	HH	8.0	18.0	14.0	32.0	-30.8	-38.7	-30.8	-30.9	L	E304	E308
28	5719	15547	PN	67°			S	X	X	L	L	HH	VV	VV	HH	8.0	18.0	14.0	32.0	-30.8	-38.7	-30.8	-30.9	L	E304	E308
29	5719	15547	PN	67°			S	X	X	L	L	HH	VV	VV	HH	8.0	18.0	14.0	32.0	-30.8	-38.7	-30.8	-30.9	L	E304	E308
30	5719	15547	PN	67°			S	X	X	L	L	HH	VV	VV	HH	8.0	18.0	14.0	32.0	-30.8	-38.7	-30.8	-30.9	L	E304	E308
31	5719	15547	PN	67°			S	L	L	L	L	HH	HV	VH	VV	30.0	22.0	21.0	30.0	-29.7	-29.7	-29.7	-29.7	L	E304	E308

MODE 'D' = Double Swath
MODE 'S' = Single Swath
RES 'L' = Low Resolution
RES 'H' = High Resolution

TABLE 3a
SUMMARY OF P3 SAR AND AIRCRAFT PARAMETERS
DURING ALASKA COLLECTION
19 March 1988, Local Time
20 March 1988, UT

AIRCRAFT PARAMETERS												
PASS NO	START TIME (UT)	STOP TIME (UT)	START LATITUDE	START LONGITUDE	STOP LATITUDE	STOP LONGITUDE	ALTITUDE (ft)	SPEED (kts)	HEADING	LOOK		
9	02:59:57	03:17:27	70:10.88	151:08.50	75:39.28	151:08.50	20000	257.0	0°	L		
10	03:20:17	03:20:23	70:10.88	151:08.50	75:39.28	151:08.50	20000	257.0	0°	L		
11	03:20:23	03:20:27	70:10.88	151:08.50	75:39.28	151:08.50	20000	258.0	0°	L		
12	03:20:27	03:20:30	70:10.88	151:08.50	75:39.28	151:08.50	20000	258.0	0°	L		
13	03:20:30	03:53:59	70:10.88	151:08.50	75:39.28	151:08.50	20000	258.0	0°	L		
14	04:02:09	04:33:09	75:39.62	151:40.70	72:50.37	151:40.70	20000	344.0	180°	R		
15	04:43:32	05:24:27	72:50.37	152:17.30	75:39.62	152:17.30	20000	280.0	0°	L		
16	05:33:30	06:04:45	75:39.62	152:53.90	72:50.37	152:53.90	20000	331.0	180°	R		
17	06:17:13	06:58:30	72:50.37	153:30.50	75:39.62	153:30.50	20000	244.0	0°	L		
18	07:07:48	08:01:55	75:40.0	154:07.10	70:10.0	154:07.10	20000	244.0	180°	R		
22	09:41:47		84:34.29	148:25.27	84:51.87	147:28.30	20000	295.0	54°	L		
23	09:42:08		84:34.29	148:25.01	84:51.87	147:28.30	20000	297.0	54°	L		
24	09:42:11		84:34.29	148:25.01	84:51.86	147:28.30	20000	297.0	54°	L		
25	09:42:14		84:34.29	148:25.01	84:51.86	147:28.30	20000	297.0	54°	L		
26	09:42:16		84:34.29	148:25.01	84:51.86	147:28.30	20000	297.0	54°	L		
27	09:42:17	09:44:34	84:34.29	148:25.01	84:51.86	147:28.30	20000	297.0	54°	L		
28	10:22:51		84:34.29	148:25.01	84:51.86	147:28.30	20000	312.0	54°	L		
29	10:23:10		84:34.29	148:25.01	84:51.86	147:28.30	20000	316.0	54°	L		
30	10:23:11		84:34.29	148:25.01	84:51.86	147:28.30	20000	316.0	54°	L		
31	10:27:12	1027:52	84:34.29	148:25.01	84:51.86	147:28.30	20000	316.0	54°	L		

Look 'L' = Left Look
Look 'R' = Right Look

Table 3b
SUMMARY OF P3 SAR AND AIRCRAFT PARAMETERS
DURING ALASKA COLLECTION
19 March 1988, Local Time
20 March 1988, UT

RADAR PARAMETERS

PASS NO	NEAR EDGE SLANT RANGE (m)	FAR EDGE SLANT RANGE (m)	NEAR EDGE INCIDENCE ANGLE	FAR EDGE INCIDENCE ANGLE	MODE	FREQUENCY				POLARIZATION				RES ATTENUATION (dB)				TRANSMITTED POWER (dB)				RES	HDDI	FILM
						1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4			
9	7267	26923	33°	77°	D	X	X	C	C	HH	HH	VV	VV	32.0	32.0	32.0	32.0	0.0	0.0	0.0	0.0	L	E122	1
10	7267	26923	33°	77°	D	X	X	C	C	HH	HH	VV	VV	32.0	32.0	32.0	32.0	0.0	0.0	0.0	0.0	L	E122	1
11	7267	26923	33°	77°	D	X	X	C	C	HH	HH	VV	VV	0.0	0.0	8.0	8.0	-31.3	-31.3	0.0	0.0	L	E122	2
12	7267	26923	33°	77°	D	X	X	C	C	HH	HH	VV	VV	0.0	0.0	8.0	8.0	-31.4	-31.4	0.0	0.0	L	E122	2
13	7267	26923	33°	77°	D	X	X	C	C	HH	HH	VV	VV	0.0	0.0	8.0	8.0	-31.4	-31.4	0.0	0.0	L	E122, E116	3
14	7267	26923	33°	77°	D	X	X	C	C	HH	HH	VV	VV	0.0	0.0	8.0	8.0	-30.8	-30.8	-37.9	-37.9	L	E116, E126	3
15	7267	26923	33°	77°	D	X	X	C	C	HH	HH	VV	VV	0.0	0.0	8.0	8.0	-31.8	-31.8	-39.2	-39.2	L	E126, E223	4
16	7267	26923	33°	77°	D	X	X	C	C	HH	HH	VV	VV	0.0	0.0	8.0	8.0	-31.0	-31.0	-38.1	-38.1	L	E303, E221	5
17	7267	26923	33°	77°	D	X	X	C	C	HH	HH	VV	VV	0.0	0.0	8.0	8.0	-32.1	-32.1	-39.4	-39.4	L	E221, E303	6
18	7267	26923	33°	77°	D	X	X	C	C	HH	HH	VV	VV	0.0	0.0	8.0	8.0	0.0	0.0	0.0	0.0	L	E224	8
22	5719	15547	PN	67°	S	X	C	X	L	HH	VV	VV	HH	32.0	32.0	32.0	32.0	0.0	0.0	0.0	0.0	L	E302	8
23	5719	15547	PN	67°	S	X	C	X	L	HH	VV	VV	HH	8.0	18.0	14.0	32.0	-30.0	0.0	-30.0	0.0	L	E302	8
24	5719	15547	PN	67°	S	X	C	X	L	HH	VV	VV	HH	8.0	18.0	14.0	32.0	-30.0	0.0	-30.0	0.0	L	E302	8
25	5719	15547	PN	67°	S	X	C	X	L	HH	VV	VV	HH	8.0	18.0	14.0	32.0	-30.0	0.0	-30.0	0.0	L	E302	8
26	5719	15547	PN	67°	S	X	C	X	L	HH	VV	VV	HH	8.0	18.0	14.0	32.0	-30.0	0.0	-30.0	0.0	L	E302	8
27	5719	15547	PN	67°	S	X	C	X	L	HH	VV	VV	HH	32.0	32.0	32.0	32.0	0.0	0.0	0.0	0.0	L	E302	8
28	5719	15547	PN	67°	S	X	C	X	L	HH	VV	VV	HH	8.0	18.0	14.0	29.0	-30.8	0.0	-30.8	0.0	L	E302	8
29	5719	15547	PN	67°	S	X	C	X	L	HH	VV	VV	HH	8.0	18.0	14.0	29.0	-30.8	0.0	-30.8	0.0	L	E302	8
30	5719	15547	PN	67°	S	X	C	X	L	HH	VV	VV	HH	8.0	18.0	14.0	29.0	-30.8	0.0	-30.8	0.0	L	E302	8
31	5719	15547	PN	67°	S	X	C	X	L	HH	VV	VV	HH	8.0	18.0	14.0	29.0	-30.8	0.0	-30.8	0.0	L	E302	8

MODE 'D' = Double Swath
MODE 'S' = Single Swath
RES 'L' = Low Resolution
RES 'H' = High Resolution

* Values will be available pending future processing

TABLE 4a
SUMMARY OF P3 SAR AND AIRCRAFT PARAMETERS
DURING ALASKA COLLECTION
21 March 1988, Local Time
22 March 1988, UT

AIRCRAFT PARAMETERS

PASS NO	START TIME (UT)	STOP TIME (UT)	START LATITUDE	START LONGITUDE	STOP LATITUDE	STOP LONGITUDE	ALTITUDE (ft)	SPEED (kts)	HEADING	LOOK
4	03:03:34	03:17:21	62:08:60	159:28:89	61:35:84	161:39:74	20000	294.0	242°	R
5	03:56:38	04:29:46	59:54:78	168:28:57	57:06:19	166:28:57	20000	312.0	180°	R
6	04:38:12	05:11:41	57:05:19	168:48:57	59:54:78	168:48:57	20000	298.0	0°	L
7	05:20:43	06:53:10	59:55:0	167:08:6	57:08:6	167:08:6	20000	298.0	180°	R
8	06:02:04	06:34:26	57:05:19	167:28:57	59:54:78	167:28:57	20000	318.0	0°	L
9	06:41:17	07:12:39	59:54:78	167:48:57	57:06:19	167:48:57	20000	331.0	180°	R
10	07:21:01	07:27:20	57:05:19	168:08:57	59:54:78	168:08:57	20000	328.0	0°	L
11	07:30:09	07:30:11	57:05:19	168:08:57	59:54:78	168:08:57	20000	328.0	0°	L
12	07:30:11	07:30:18	57:05:19	168:08:57	59:54:78	168:08:57	20000	329.0	0°	L
13	07:30:18	07:30:21	57:05:19	168:08:57	59:54:78	168:08:57	20000	329.0	0°	L
14	07:30:21	07:30:29	57:05:19	168:08:57	59:54:78	168:08:57	20000	329.0	0°	L
15	07:30:29	07:30:34	57:05:19	168:08:57	59:54:78	168:08:57	20000	330.0	0°	L
16	07:30:34	07:52:30	57:05:19	168:08:57	59:54:78	168:08:57	20000	330.0	0°	L
18	08:41:23	08:42:26	61:42:09	161:35:82	62:08:65	159:28:94	20000	311.0	62°	L
19	09:33:47	09:39:28	64:34:38	148:25:15	64:51:95	147:28:45	20000	328.0	54°	L
20	09:45:59	09:46:39	64:49:94	147:28:46	64:32:36	148:25:10	20000	287.0	234°	R
21	09:46:39	09:47:27	64:49:94	147:28:46	64:32:36	148:25:10	20000	287.0	234°	R
22	09:47:27	09:52:51	64:49:94	147:28:46	64:32:36	148:25:10	20000	289.0	234°	R

Look 'L' = Left Look
Look 'R' = Right Look

TABLE 4b

RES 'L' = Low Resolution
RES 'H' = High Resolution

MODE 'D' = Double Swath
MODE 'S' = Single Swath

TABLE 5a
SUMMARY OF P3 SAR AND AIRCRAFT PARAMETERS
DURING ALASKA COLLECTION
22 March 1988, Local Time
23 March 1988, UT

AIRCRAFT PARAMETERS										
PASS NO.	START TIME (UT)	STOP TIME (UT)	START LATITUDE	START LONGITUDE	STOP LATITUDE	STOP LONGITUDE	ALTITUDE (ft)	SPEED (kts)	HEADING	LOOK
1	04:17:33	04:26:16	64:54.23	147:18.86	64:31.40	148:34.46	20000	279.0	234°	R
2	04:30:44	04:30:58	*	*	*	*	*	*	*	*
3	04:35:04	04:35:40	64:29.42	148:34.45	64:52.85	147:18.94	20000	296.0	54°	L
4	04:35:40	04:35:43	64:29.42	148:34.45	64:52.85	147:18.94	20000	299.0	54°	L
5	04:35:43	04:35:44	64:29.42	148:34.45	64:52.85	147:18.94	20000	299.0	54°	L
6	04:35:44	04:40:45	64:29.42	148:34.45	64:52.85	147:18.94	20000	299.0	54°	L
7	04:51:51	04:53:10	64:51.20	147:21.30	64:27.76	148:36.67	20000	254.0	234°	R
8	04:53:10	05:01:16	64:51.20	147:21.30	64:27.76	148:36.67	20000	256.0	234°	R
9	06:07:58	06:13:55	64:28.42	148:34.43	64:51.85	147:18.96	20000	287.0	54°	L
10	06:32:22	06:48:14	65:33.72	149:07.28	66:34.13	150:33.27	20000	297.0	330°	R
12	07:10:23		72:00:38	166:29.80	74:59.60	166:29.80	20000	311.0	0°	L
13	07:18:57		72:00:38	166:29.80	74:59.60	166:29.80	20000	314.0	0°	L
14	07:58:34	07:44:55	72:00:38	166:29.80	74:59.60	166:29.80	20000	314.0	0°	L
15	07:52:38	08:27	77:59.60	167:04.80	72:00.38	167:04.80	20000	314.0	180°	R
16	08:39:16	08:56	72:45.19	167:19.62	74:14.80	167:19.62	20000	316.0	0°	L
17	09:04:14		74:14.80	167:19.62	72:45.19	167:19.62	20000	322.0	180°	R
18	09:08:30	09:21	74:14.80	167:19.62	72:45.19	167:19.62	20000	324.0	180°	R
19	09:34:14	09:51	72:45.19	167:19.62	74:14.80	167:19.62	20000	320.0	0°	L
20	09:59:34	10:17	74:14.80	167:19.62	74:45.19	167:19.62	20000	327.0	180°	R
21	10:25:39		72:45.19	167:19.62	74:14.80	167:19.62	20000	326.0	0°	L
22	10:28:32	10:42:14	72:45.19	167:19.62	74:14.80	167:19.62	20000	327.0	0°	L
24	10:49:40	11:06:09	74:14.20	167:19.62	72:45.19	167:19.62	20000	329.0	180°	R

Look 'L' = Left Look
Look 'R' = Right Look

* Values will be available pending future processing

TABLE 5b
SUMMARY OF P3 SAR AND AIRCRAFT PARAMETERS
DURING ALASKA COLLECTION
22 March 1988, Local Time
23 March 1988, UT

RADAR PARAMETERS

PASS NO	NEAR EDGE SLANT RANGE (m)		FAR EDGE SLANT RANGE (m)		NEAR EDGE INCIDENCE ANGLE		FAR EDGE INCIDENCE ANGLE		MODE	FREQUENCY				POLARIZATION				RES ATTENUATION (dB)				TRANSMITTED POWER (dB)				RES	HDDI	ETIM				
	1	2	1	2	1	2	1	2		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4							
1	5452	15280	15280	15280	PN	66°	66°	66°	S	X	C	X	C	X	C	C	HH	VV	VV	HH	11.0	21.0	13.0	20.0	-29.2	-35.3	-29.2	-35.3	L	E179, E317	E317	1
2	5452	15280	15280	15280	PN	66°	66°	66°	S	X	C	X	C	X	C	C	HH	VV	VV	HH	32.0	32.0	32.0	32.0	0.0	0.0	0.0	0.0	L	E179, E317	E317	1
3	5452	15280	15280	15280	PN	66°	66°	66°	S	X	C	X	C	X	C	C	HH	VV	VV	HH	11.0	21.0	13.0	20.0	-29.2	0.0	0.0	0.0	L	E179, E317	E317	1
4	5452	15280	15280	15280	PN	66°	66°	66°	S	X	C	X	C	X	C	C	HH	VV	VV	HH	11.0	21.0	13.0	20.0	-29.2	-70.0	-29.2	-70.0	L	E179, E317	E317	1
5	5452	15280	15280	15280	PN	66°	66°	66°	S	X	C	X	C	X	C	C	HH	VV	VV	HH	11.0	21.0	13.0	20.0	-29.2	-70.0	-29.2	-70.0	L	E179, E317	E317	1
6	5452	15280	15280	15280	PN	66°	66°	66°	S	X	C	X	C	X	C	C	HH	VV	VV	HH	11.0	21.0	13.0	20.0	-29.2	-70.0	-29.2	-70.0	L	E179, E317	E317	1
7	5543	10457	10457	10457	PN	54°	54°	54°	S	X	X	X	X	X	X	X	HH	HV	VH	VV	11.0	6.0	6.0	13.0	-29.5	-29.5	-29.5	-29.5	H	E179, E317	E317	1
8	5543	10457	10457	10457	PN	54°	54°	54°	S	X	X	X	X	X	X	X	HH	HV	VH	VV	11.0	6.0	6.0	13.0	-29.5	-29.5	-29.5	-29.5	H	E179, E317	E317	1
9	5452	15280	15280	15280	PN	66°	66°	66°	S	C	C	C	C	C	C	C	HH	HV	VH	VV	20.0	14.0	14.0	20.0	-35.2	-35.2	-35.2	-35.2	L	E179, E317	E317	1
10	4574	14402	14402	14402	PN	65°	65°	65°	S	X	C	X	C	X	C	C	HH	HH	VV	VV	4.0	16.0	4.0	16.0	-29.5	-35.2	-29.5	-35.2	L	E154	E154	2
12	7267	26923	26923	26923	33°	77°	77°	77°	D	X	X	C	C	X	C	C	HH	HH	VV	VV	0.0	0.0	6.0	8.0	-70.0	-70.0	0.0	0.0	L	E165	E165	3
13	7267	26923	26923	26923	33°	77°	77°	77°	D	X	X	C	C	X	C	C	HH	HH	VV	VV	0.0	0.0	8.0	8.0	-31.0	-31.0	-38.3	-38.3	L	E165	E165	3
14	7267	26923	26923	26923	33°	77°	77°	77°	D	X	X	C	C	X	C	C	HH	HH	VV	VV	0.0	0.0	8.0	8.0	-31.0	-31.0	-38.3	-38.3	L	E165	E165	3
15	7267	26923	26923	26923	33°	77°	77°	77°	D	X	X	C	C	X	C	C	HH	HH	VV	VV	0.0	0.0	8.0	8.0	-31.0	-31.0	-38.3	-38.3	L	E271, E272	E272	4
16	5748	10884	10884	10884	PN	55°	55°	55°	S	X	X	X	X	X	X	X	HH	HV	VH	VV	0.0	0.0	0.0	0.0	-30.2	-30.2	-30.2	-30.2	H	E272, E273	E273	5
17	5748	10884	10884	10884	PN	55°	55°	55°	S	C	C	C	C	C	C	C	HH	HV	VH	VV	22.0	32.0	32.0	32.0	0.0	0.0	0.0	0.0	H	E273	E273	5
18	5748	10884	10884	10884	PN	55°	55°	55°	S	C	C	C	C	C	C	C	HH	HV	VH	VV	16.0	10.0	10.0	16.0	-34.3	-34.3	-34.3	-34.3	H	E273	E273	5
19	5748	10884	10884	10884	PN	55°	55°	55°	S	X	C	X	C	X	C	C	HH	HH	VV	VV	8.0	20.0	8.0	20.0	-30.2	-34.4	-30.2	-34.4	H	E204	E204	6
20	5748	10884	10884	10884	PN	55°	55°	55°	S	X	C	X	C	X	C	C	HH	HH	HV	HV	8.0	20.0	4.0	15.0	-30.3	-33.9	-30.3	-33.9	H	E204	E204	6
21	5748	10884	10884	10884	PN	55°	55°	55°	S	X	C	X	C	X	C	C	VV	VV	VH	VH	10.0	20.0	4.0	15.0	-30.8	-34.8	-30.8	-34.8	H	E234, E247	E247	7
22	5748	10884	10884	10884	PN	55°	55°	55°	S	X	C	X	C	X	C	C	VV	VV	VH	VH	2.0	15.0	0.0	10.0	-31.0	-34.8	-31.0	-34.8	H	E234	E234	7
24	5748	10884	10884	10884	PN	55°	55°	55°	S	X	X	X	X	X	X	X	HH	HV	VH	VV	7.0	4.0	4.0	7.0	-30.9	-30.9	-30.9	-30.9	H	E247	E247	7

MODE 'D' = Double Swath
MODE 'S' = Single Swath
RES 'L' = Low Resolution
RES 'H' = High Resolution

* Values will be available pending future processing

4.0 REFLECTOR ARRAYS AND GROUND TRUTH

Reflector arrays were deployed during the collection in order to calibrate the radar and to analyze the radar attenuation of tree stands. Reflectors were set up at the three sites along the Chena River that are illustrated in Figure 6. At sites A & B, which were clear of any trees, three 60-cm trihedrals were placed on sandbars near the river. Many reflectors were placed at Site C. Four 50-cm dihedrals and four 60-cm trihedrals were placed on a sandbar outside the forests, while twelve of the 60-cm trihedrals, four 90-cm trihedrals, and six 120-cm trihedrals were placed in stands of alder, poplar, and mixed poplar and spruce.

Also at Site C, maps of tree stems within 10 m of each reflector were created. Each map included information about the distance from reflector, angle, diameter, height, and species of the trees. Dielectric properties of the tree trunks, branches, and needles were measured. Additional ground truth data were also collected throughout the Chena River area.



Figure 6. Map of ground truth and calibration array areas. Sites A, B, and C are illustrated

5.0 SAMPLE IMAGES

Figures 7 through 11 present examples of data collected during this mission. Figure 7 is a digitally processed image of Fairbanks, Alaska and the surrounding area. The image was recorded at C-band frequency and VV polarization. Fort Wainwright can be seen in the upper left corner. On the right side of the image the Fairbanks International Airport is flanked by the Chena River on the bottom and the Tanana River at the top. The image coverage is 9830 m in slant range and 19907 m in azimuth.

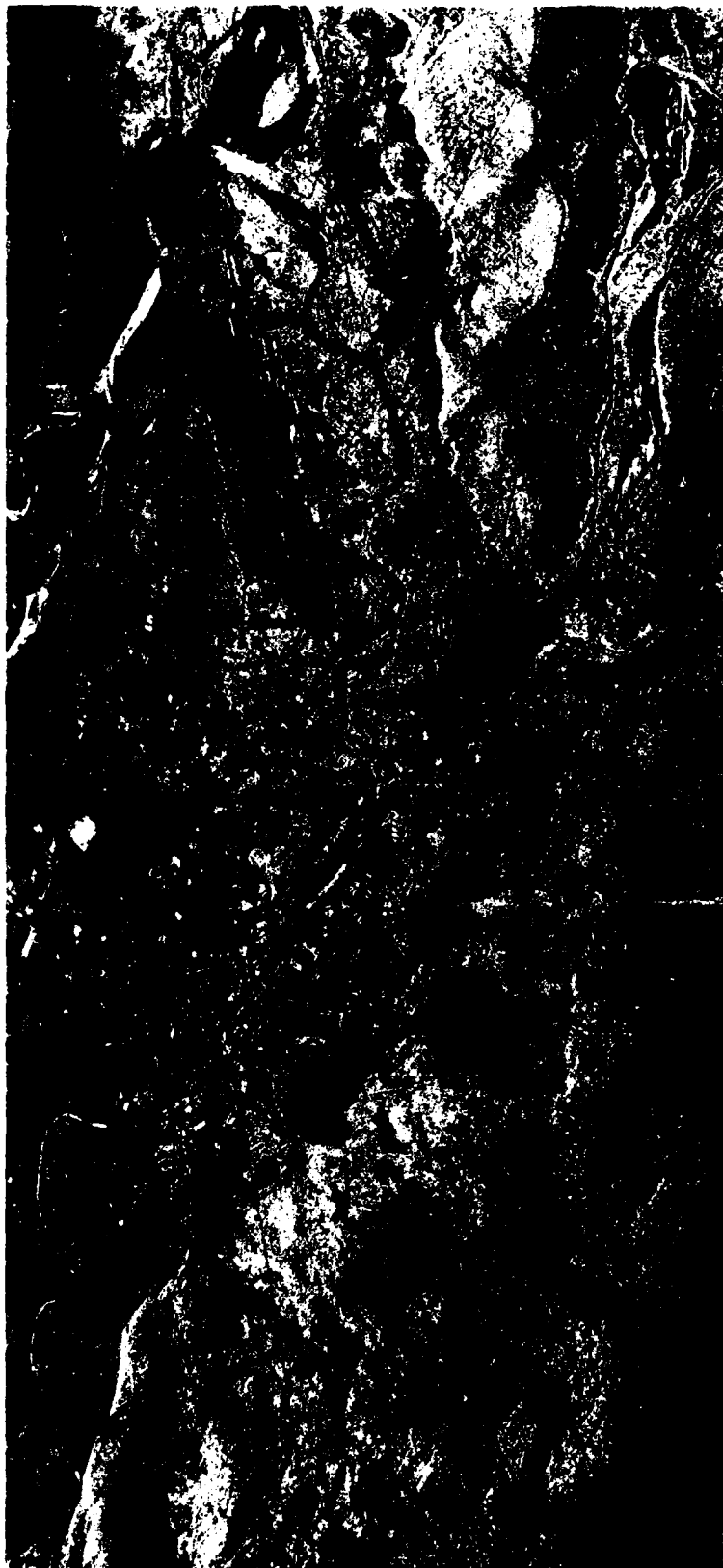
Figure 8 is a mosaic of two digitally processed images of ice data. These data, collected on 18 March 1988, were recorded using C-band frequency and VV polarization. Dark patches of ice in the scene are first-year ice and light patches of ice are multi-year ice. Fissures can be seen in the first year ice as light lines. The area covered by this double swath image is 19660 m in slant range and 6636 m in azimuth. The image has not been radiometrically corrected.

Figures 9a through 9c are representative of the ice data collected during the Alaska survey. Each of these images, collected on 21 March 1988 over the Bering Sea, was recorded using C-band frequency and VV-polarization. Each image covers approximately 9830 m in slant range and approximately 26,542 m in azimuth. In Figure 9a, dark patches of first-year ice and light patches of multiyear ice float in a matrix of crushed ice material. Small, dark, worm-like features in the center of the left side of the image may be open water or newly-frozen leads. In Figure 9b, the upper half of the image contains several large floes of multiyear ice while the lower half of the image contains mostly smaller first-year ice floes. Large dark areas in the upper right quadrant of the image are newly frozen leads and the light linear features on these areas are probably wind streaks caused by the deposition of blowing snow. A large, light, linear feature in the lower right hand corner of the image may be a fissure or pressure ridge. The predominant ice type in Figure 9c is first-year ice. The first-year ice is contained mainly

in large floes throughout the image. A small amount of multiyear ice floats in a matrix of crushed ice material in the upper right side of the image.

Figures 10a through 10d are digitally processed images of fully polarimetric X-Band data collected over calibration sites A and B along the Chena River. The use of multi-polarization analysis enhances subtle differences in the forested and river bed areas of this region which would not be detected by dual polarization methods alone. The area covered by each of these images is 9830 m in slant range and 6636 m in azimuth. These images have not been radiometrically corrected.

Figure 11 is a digitally recorded and optically processed image of the Franklin and Romanzof mountain ranges in North Alaska. This C-band VV-polarization image, collected on 18 March 1988, was created by mosaicing the near and far swaths of a double swath pass together. No radiometric correction has been applied to the data. The image represents an area of approximately 19660 m in slant range and 53000 m in azimuth. Preferential erosion can be observed in the dark striations on the left side of the image.



FAIRBANKS, ALASKA

DATE= 22-MAR-88
 PASS= 8
 41.2722-41.24179
 FLIGHT DIRECTION
 C-100

ALT= 20147 FEET

PERMANENT TO 66.7 DEGREES
 RSP= 4.86 METERS
 RSP= 4.8 METERS
 FORESIGHT ANGLE= 25 DEGREES
 PRT 516-518

LEFT LOOK

HOG= 54 DEGREES

Figure 7. C-Band image of Fairbanks, Alaska, collected 22 March 1988



Figure 8. C-Band image of ice, collected on 18 March 1988

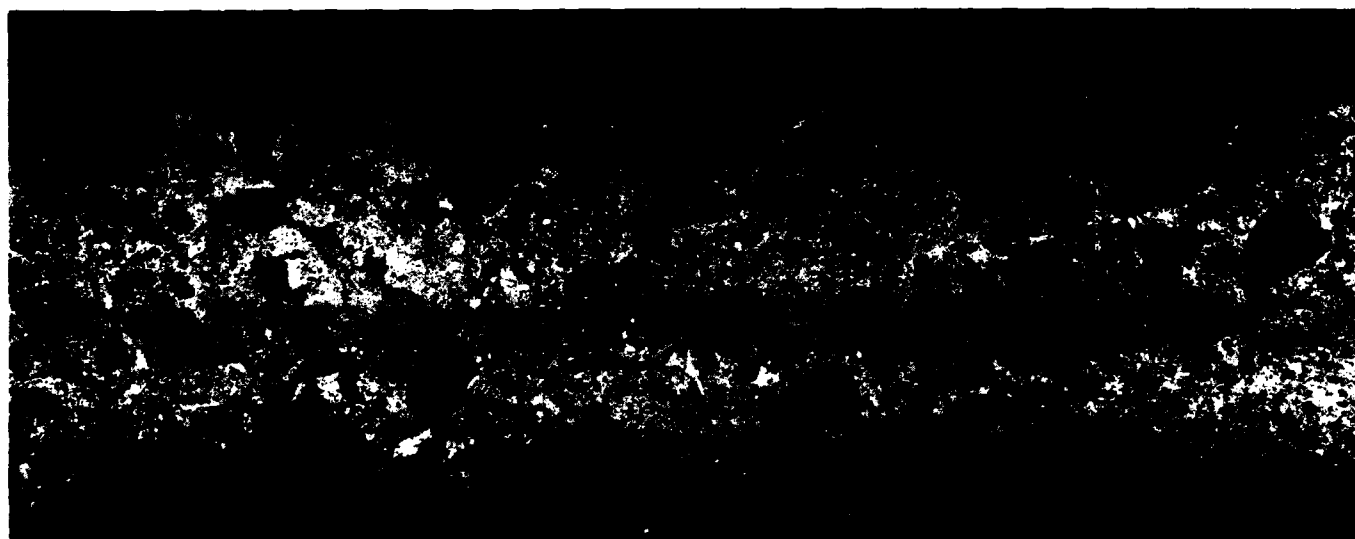


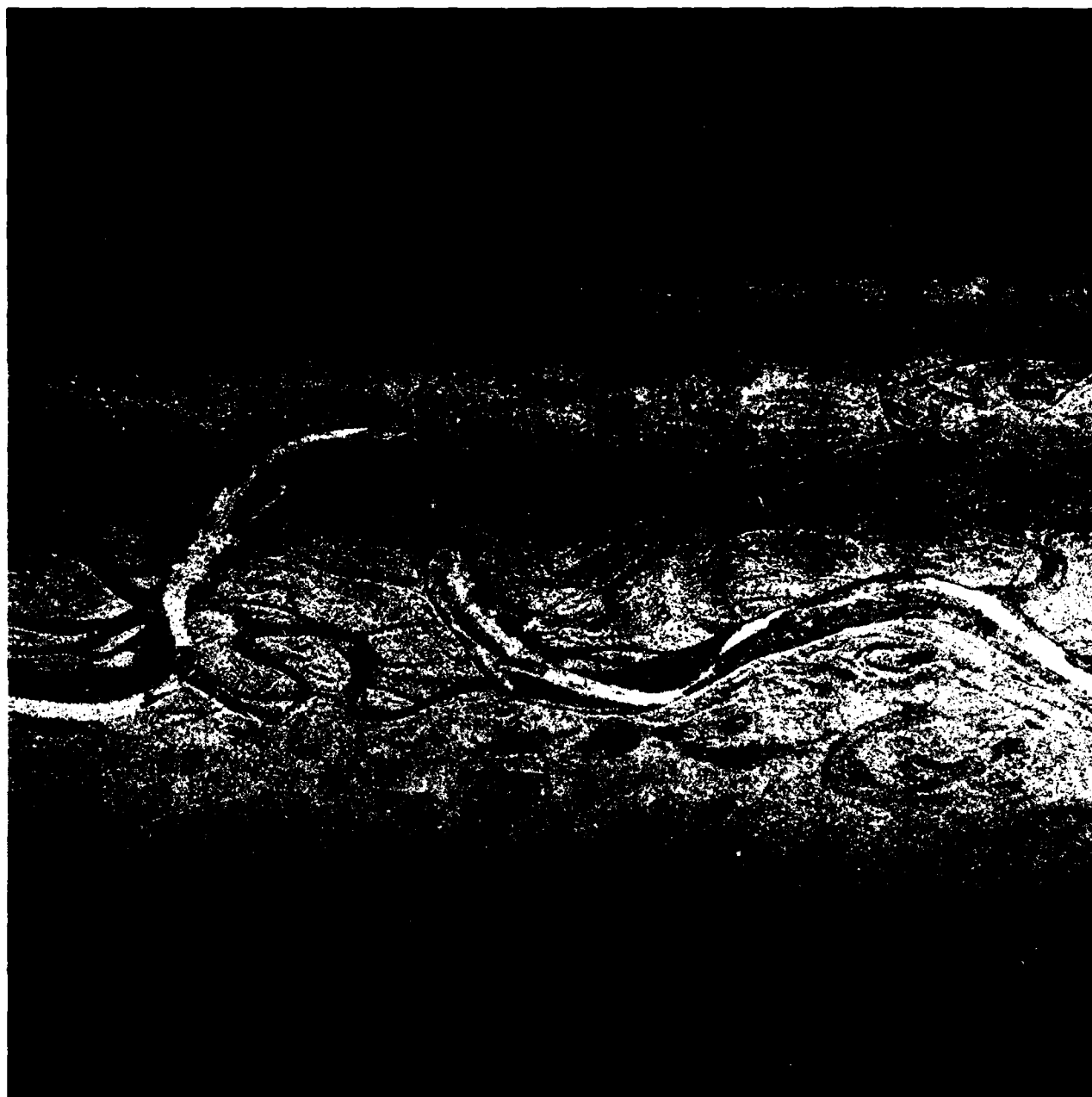
Figure 9a. C-Band image of ice, collected on 21 March 1988



Figure 9b. C-Band image of ice, collected on 21 March 1988



Figure 9c. C-Band image of ice, collected on 21 March 1988



ALASKA FOREST
DOF# 22-MAR-88
PASS 22
9:50:02-9:50:50
- FLIGHT DIRECTION
- 180°

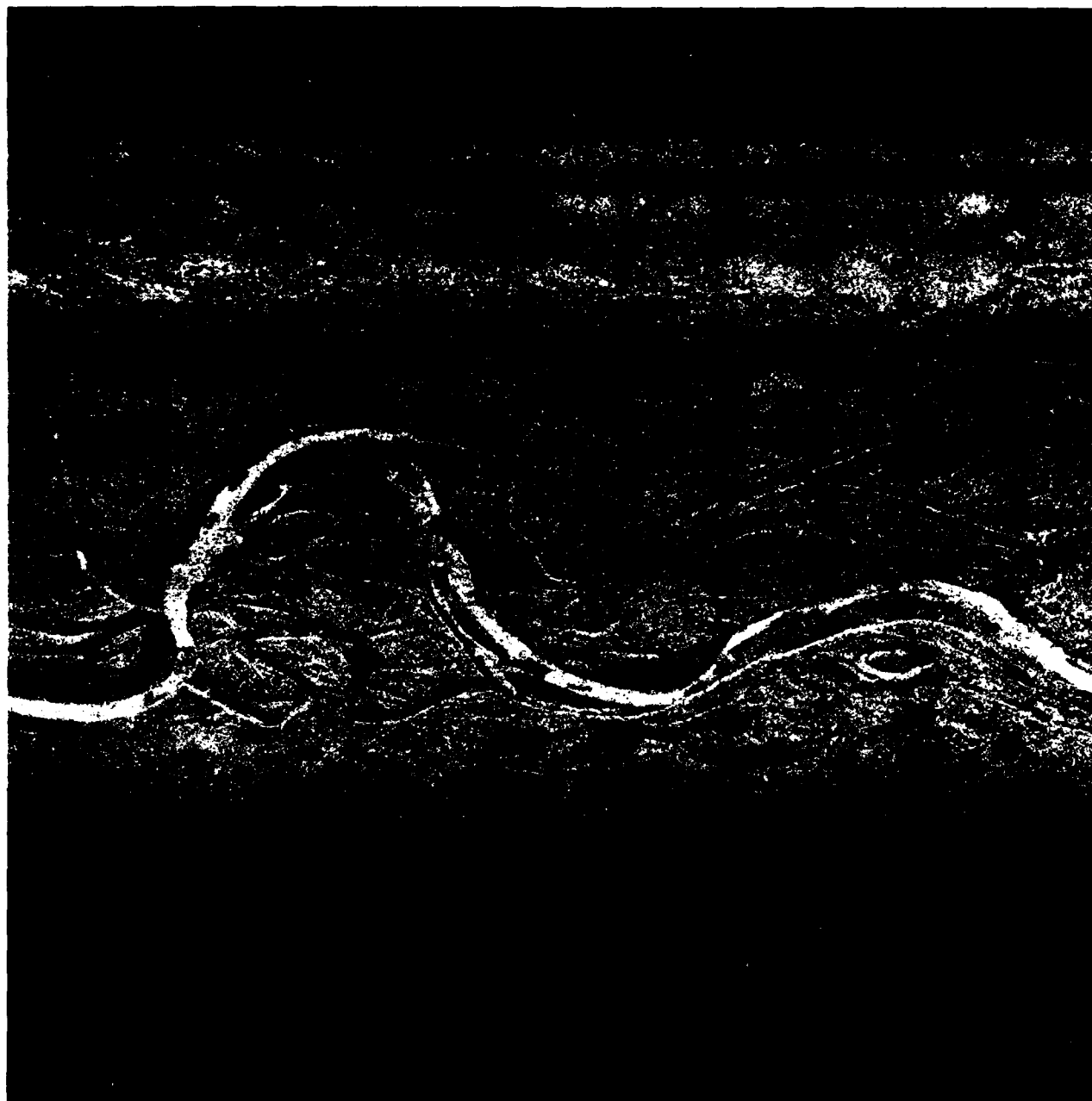
ALT# 20106 FEET

HOG# 234 DEGREES

CAL ARRAY
PRENDIR TO 66.4 DEGREES
AZSP# 1.62 METERS
RGSP# 2.4 METERS
BORESIGHT ANGLE# 25 DEGREES
PST 363

RIGHT LOOK

Figure 10a. X-Band image of the Chena River, Alaska, collected on 22 March 1988, using VV-polarization



ALASKA FOREST

DOF= 22-MAR-88
PASS 22
9:50:02-9:50:50
FLIGHT DIRECTION
X-HH

ALT= 20106 FEET

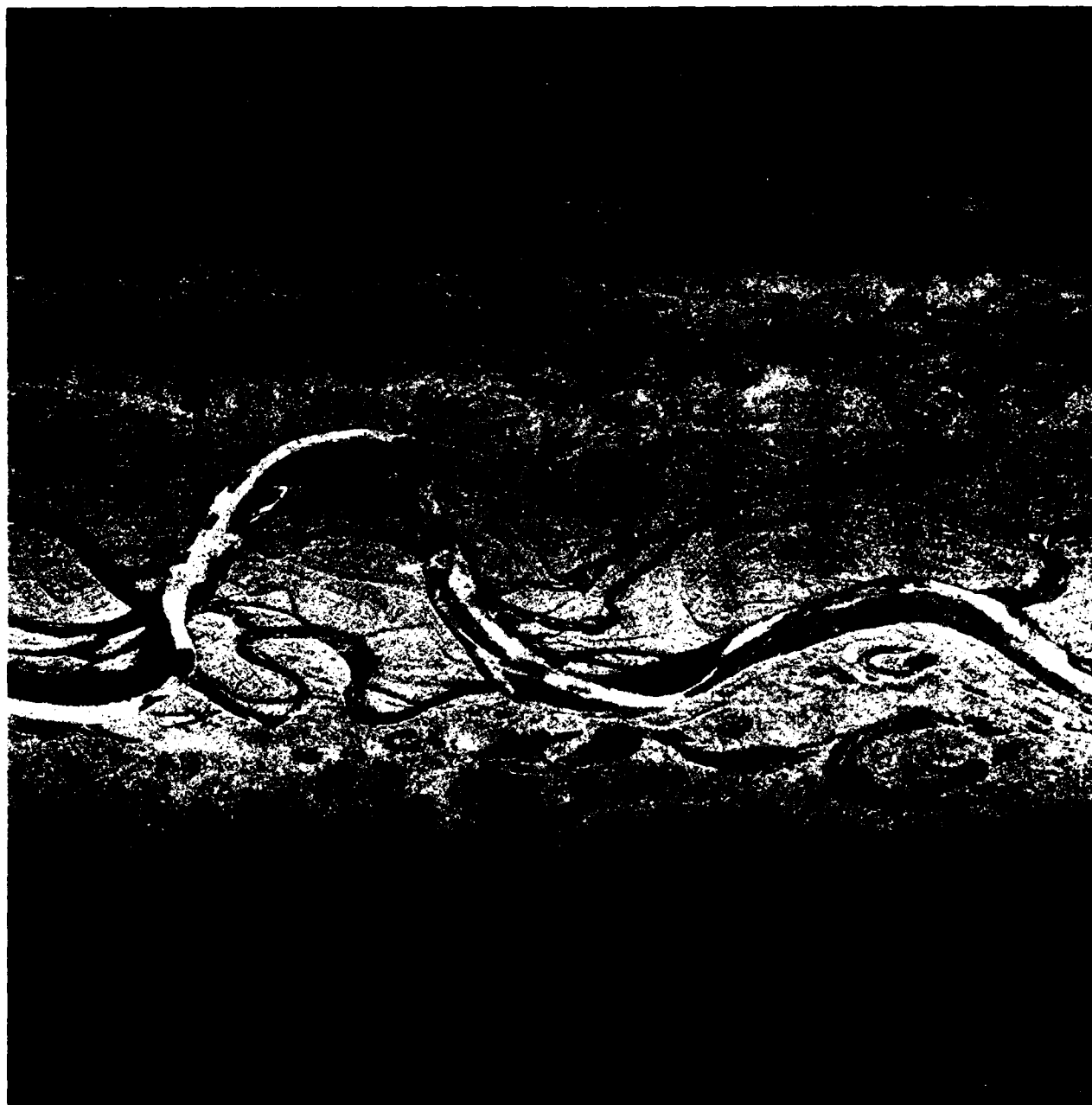
CAL ARRAY

PRENADIR TO 66.4 DEGREES
AZSP= 1.62 METERS
RGSP= 2.4 METERS
BORESIGHT ANGLE= 25 DEGREES
PST 360

HOG= 234 DEGREES

RIGHT LOOK

Figure 10b. X-Band image of the Chena River, Alaska, collected on 22 March 1988, using HH-polarization



ALASKA FOREST

DOF= 22-MAR-88
PASS 22
9:50:02-9:50:50
- FLIGHT DIRECTION
Z-HW

ALT= 20106 FEET

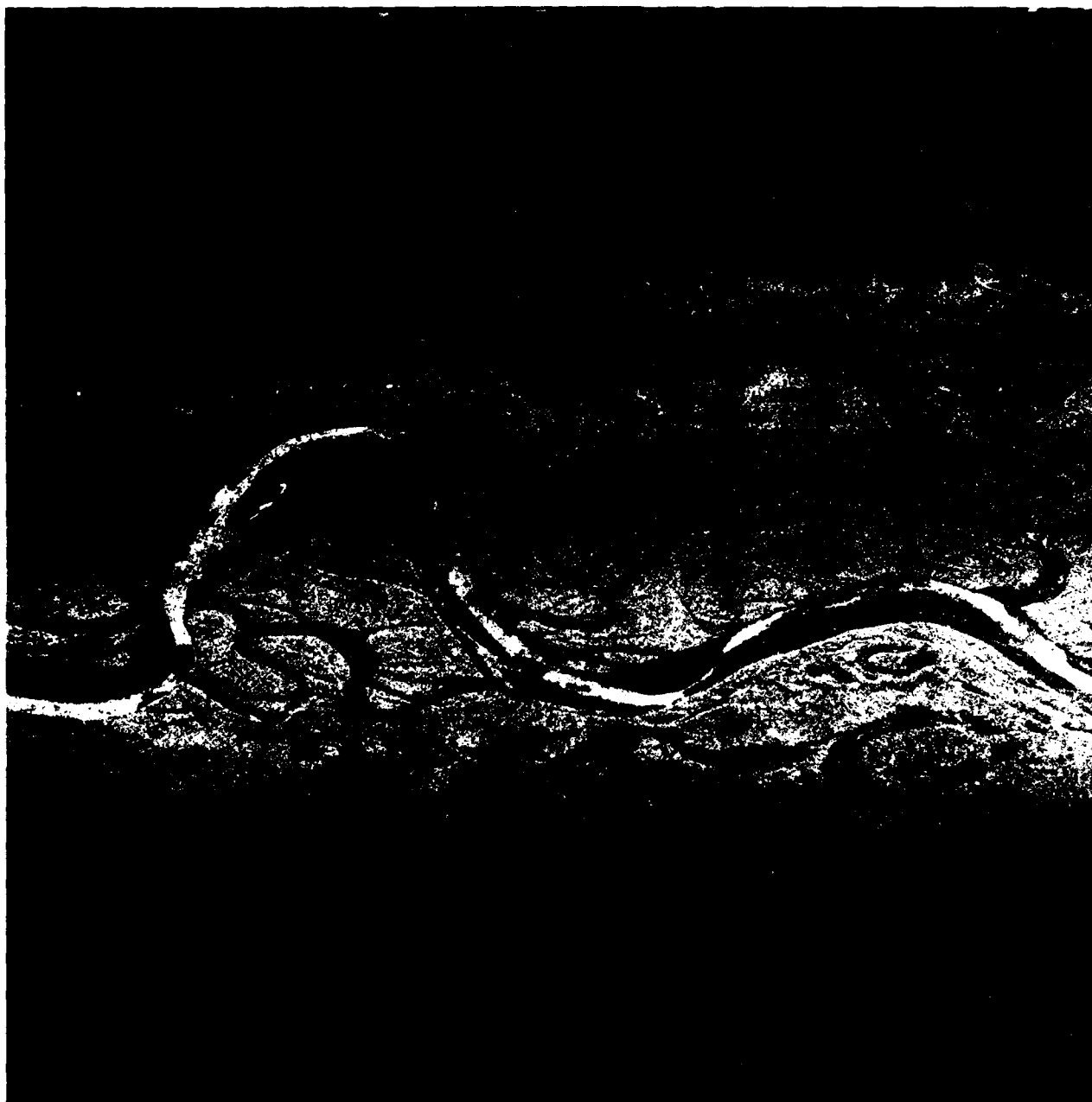
CAL APPAY

PRENADIR TO 66.4 DEGREES
AZSP= 1.62 METERS
RGSP= 2.4 METERS
BORESIGHT ANGLE= 25 DEGREES
PST 361

HCG= 234 DEGREES

RIGHT LOOK

Figure 10c. X-Band image of the Chena river, Alaska, collected on 22 March 1988, using HV-polarization



ALASKA FOREST
DOF= 22-MAR-88
PASS 22
9:50:02-9:50:50
- FLIGHT DIRECTION
X-VH

ALT= 20106 FEET

CAL ARRAY

PRENADIP TO 66.4 DEGREES
AZSP= 1.62 METERS
RGSP= 2.4 METERS
BORESIGHT ANGLE= 25 DEGREES
PST 362

HDG= 234 DEGREES

RIGHT LOOK

Figure 10d. X-Band image of the Chena River, Alaska, collected on 22 March 1988, using VH-polarization

11



Figure 11. C-Band image of the Franklin and Romanzof mountain ranges,
Alaska, collected on 22 March 1988

APPENDIX A

POLARIMETRIC X/L/C-BAND SAR

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Abstract

A new triband polarimetric synthetic aperture radar (SAR) has been developed for remote sensing applications and has been installed in a U.S. Navy P-3 aircraft. Pulses are transmitted at either X-, C-, or L- band. They may be transmitted at either horizontal (H) or vertical (V) polarization and received at either horizontal or vertical polarization. Transmit and receive polarization, as well as frequency band, may be switched pulse-to-pulse. Up to four different waveforms may be interleaved, e.g., $X_{HH} L_{HV} X_{VV} C_{VH}$ or $X_{HH} X_{HV} X_{VH} X_{VV}$ (full-polarimetric mode). A digital synthesizer produces the FM-chirp pulse. The pulse is emitted from a new triband antenna that is kept perpendicular to the aircraft ground track by means of a three-axis, servo-driven positioner which compensates for aircraft pitch, roll and yaw. Received pulses are digitized, preprocessed and recorded to high-density digital tape. Test flights began in late October, 1987 and preliminary imagery has been obtained.

Introduction

A SAR system, called the P-3/SAR, has been installed in a U.S. Navy P-3 aircraft and operates at X-, C- and L-bands with the capability of recording HH, HV, VH and VV polarizations. An earlier description was provided [1]. The system is a fully focused side-looking SAR capable of looking out either side of the aircraft. Operating center frequencies are 9.35 GHz, 5.30 GHz and 1.25 GHz. The system data are recorded in several forms. High-density digital tape (HDDT) is the primary recording medium. The data are also recorded on photographic film for subsequent optical processing. A real-time image formation processor records image data on heat-developed film or paper.

Figure 1 is a photograph of the P-3 aircraft. The radome aft of the wing contains the antenna and pedestal.

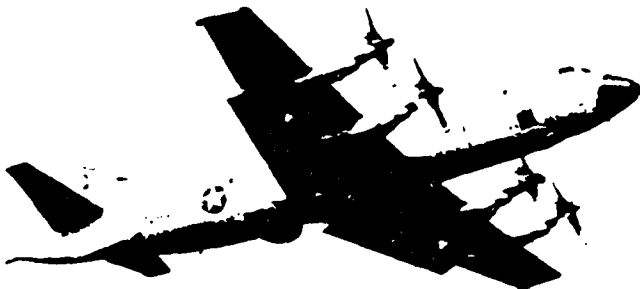


FIGURE 1. P-3 AIRCRAFT

Operating Modes

The P-3/SAR has five operating modes, summarized in Figure 2. For each mode, the figure illustrates the number of frequency/polarization combinations, the pulse repetition frequency (PRF) per combination, the number of range bins per pulse, the presum factor (data are presumed via a presum filter before being written to tape) and the corresponding data recording rate, tape speed and time to record a full tape. The rate of recording data to tape is

$$r = 2nfrNb/P$$

where

n = number of frequency/polarization combinations
 f_r = PRF
 N = range bins per pulse
 b = bits in the A/D converter = 6
 P = presum factor.

The factor of 2 is to account for both I and Q.

The Single-Swath Multiplex Mode employs any four frequency/polarization combinations, except that (1) at least two different frequency bands must be used because of the transmitter duty-cycle limitation, and (2) each band must have a uniform PRF within the overall waveform. The PRF per combination is 2 kHz at a ground speed of 350 knots. (PRF is proportional to ground speed producing a constant value of pulses per unit ground distance). Four thousand ninety-six range bins per FM-chirp pulse are processed. These are presumed to a data rate one-sixth that which would result from no presuming. An example for this mode is shown in Figure 3.

The Double-Swath Multiplex Mode is similar except that for each pulse, the number of range bins is doubled to 8192. The number of frequency/polarization combinations is halved, to two, and the presum factor remains the same at six. Thus, the data recording rate is the same. An example is given in Figure 3. The Quadruple-Swath Multiplex Mode is completely analogous with one frequency/polarization combination, 16,384 range bins per pulse, a presum factor of six and the same data recording rate. An example is shown in Figure 4.

The Single-Swath Polarimetric Mode is similar to the Single-Swath Multiplex Mode except that all pulses are from the same frequency band and all four polarization combinations (HH, HV, VH, VV) are employed. This enables the full polarization scattering matrix to be recorded. Because of the transmitter duty-cycle limit of two percent, the PRF per combination is limited to 1 kHz instead of 2 kHz. The presum factor is reduced to three, again resulting in the same data recording rate. An example is given in Figure 4.

MODE	No. Freq/Pol Combinations = n	PRF ^a per Freq/Pol Combination = f_R (Hz)	Range Bins/Pulse = N	Presum Factor = P	Nominal ^b Recording Rate = $r = \frac{2nf_R Nb}{P}$ (Mbits/sec)	Nominal ^b Tape Speed $v = \frac{r}{n_1 \rho}$ (in/sec)	Nominal ^b Tape Time $t = \frac{l}{v}$
Single-Swath Multiplex	4	2000	4096	6	65.5 (71)	61.6 (86.2)	35.4 (25.3)
Double-Swath Multiplex	2	2000	8192	6	65.5 (71)	61.6 (86.2)	35.4 (25.3)
Quadruple-Swath Multiplex	1	2000	16384	6	65.5 (71)	61.6 (86.2)	35.4 (25.3)
Single-Swath Polarimetric	4 ^c	1000 ^c	4096	3	65.5 (71)	61.6 (86.2)	35.4 (25.3)
Single-Swath No Presum	1	2000	4096	1	98.3 (106.5)	92.4 (129.3)	23.6 (16.9)

a - PRF is proportional to ground speed. Values given are appropriate for 350 knots.

b - Actual values, given in parentheses, are slightly different due to "second-order" effects such as record format, auxiliary data, etc.

c - Transmitter duty cycle is 4000 pulses/sec x 4 μ sec/pulse = 1.6 percent. Limit is 2 percent, preventing higher PRF.

b = bits in A/D = 6

n_1 = no. tracks = 28

ρ = tape density = 38,000 bits/in-track

l = tape length = 10,888 ft = 130,656 in.

88-20020

FIGURE 2. OPERATING MODES

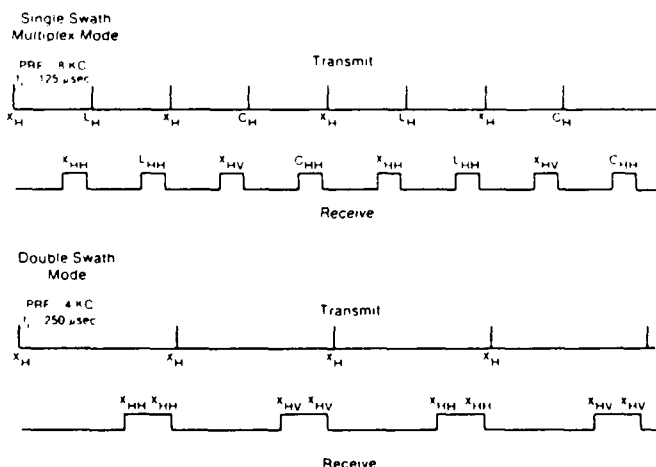


FIGURE 3. MODE TIMING DIAGRAM

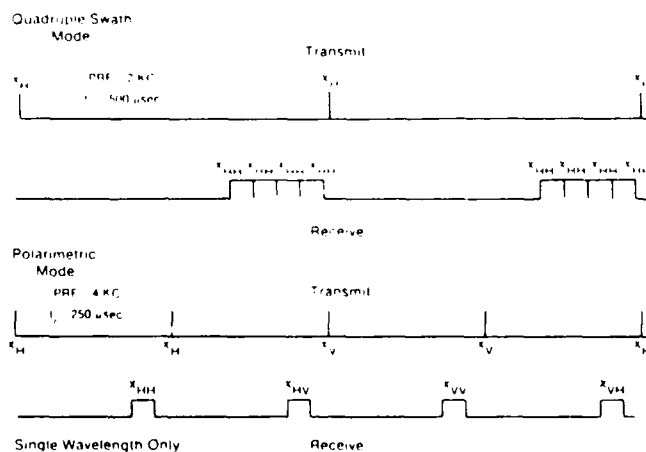


FIGURE 4. MODE TIMING DIAGRAM

The Single-Swath No-Presum Mode provides a capability for recording all of the Doppler data spatially filtered by the antenna beam. No additional azimuth filtering is applied to this data in the preprocessor. In this case, only one frequency/polarization combination can be used and the presum factor is one. The data recording rate is 1.5 times that for the other modes.

Subsystem Configuration

Figure 5 shows a simplified block diagram of the P-3/SAR system.

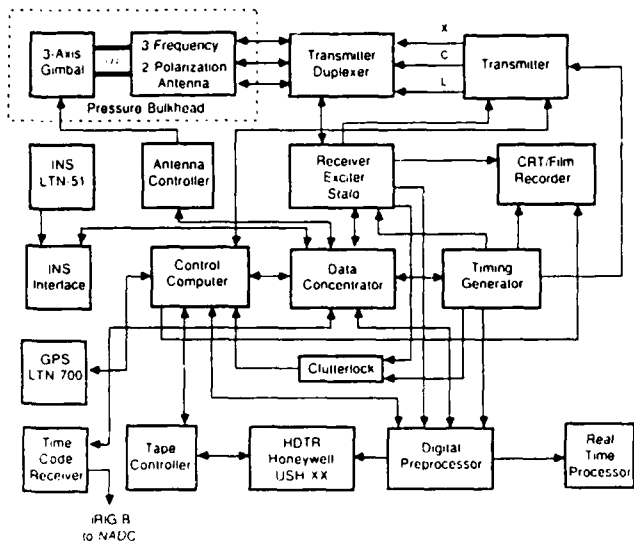


FIGURE 5. SYSTEM BLOCK DIAGRAM

The Inertial Navigation System (INS), a Litton LTN-51, performs several important functions for the radar system. It steers the aircraft via the autopilot during mapping, it points the antenna to 90 degrees from the ground track, it provides aircraft rotation data to the antenna gimbal systems for compensation of pitch and roll, and it provides aircraft lateral translation sensing for motion compensation of the radar data. Integrated INS three-axis accelerations are digitized in the INS interface and are input to the data concentrator. This computer resolves these inputs from the INS coordinate system into the radar coordinate system (along-track, cross-track, vertical) and then computes the velocity component along the radar beam. This beam velocity is scaled to radar wavelength and converted to phase corrections.

The linear FM chirp waveform is generated within the Receiver/Exciter/STALO using a digitally synthesized waveform generation technique described by Gallaway, et al. in another paper in these Proceedings. The chirp data points are stored in a PROM, then loaded into a RAM. The data points are read out of the RAM at the clock rate to produce the digital chirp waveform. This waveform is converted to an analog signal, then filtered and up-converted to the desired RF carrier frequencies for transmission. One feature of this technique is the capability to alter the chirp waveform data points in the PROM to compensate for range dimension hardware phase errors.

The chirp waveform is input to the transmitter where it is amplified by a traveling wave tube (TWT) amplifier. The X-, C- and L-band TWTs are manufactured by Hughes, Litton and Varian, respectively. A four microsecond pulse is transmitted for each band. The pulse repetition frequency (PRF) is proportional to ground speed to provide constant azimuth spatial frequency sampling. PRF is 8 kHz for a ground speed of 350 knots. The maximum transmitter PRF for any band is 4 kHz with the maximum transmit duty cycle equal to 2 percent for each band.

The amplified chirp waveform is passed to the Transmitter/Duplexer where a high-power switch selects the transmit polarization.

A triband (X-, C-, L-bands) dual-polarization antenna, developed by Chu Associates of Littleton, Massachusetts, is used for this system. The X- and C-band capability is provided by a dual, feed-on-focus shaped reflector based on the work of L.J. Chu [2]. The L-band capability is provided by a crossed-element Yagi array mounted on top of the X-C band reflector. This antenna is mounted on a new three-axis gimbal pedestal developed by Kintec Corporation of St. Petersburg, Florida. This gimbal system provides stabilization of the antenna with attitude reference data from the INS.

Backscattered signals are collected by the antenna and passed through the Transmitter/Duplexer where a switch selects the receive polarization. The Transmitter/Duplexer includes a transmitter power monitor capability which continually monitors average transmitter power. In addition, an injection port for amplitude-controlled synthetic targets is provided. This gives an end-to-end test capability for pre-flight and post-flight testing and system calibration.

The signal is then sent to the receiver which provides down-conversion of the X- and C-band RF channels to the L-band IF, band-limits the signals to support the desired range resolution and then amplifies the signals with minimal addition of noise. A digital phase shifter and frequency synthesizer within the receiver provide the motion compensation correction for the received signals based on the inputs from the INS.

The Receiver/Exciter/STALO provides complex I (in-phase) and Q (quadrature) analog video signals to the Digital Preprocessor, and real analog-video signals to the CRT/film recorder and clutterlock units.

The Digital Preprocessor performs A/D conversion of the I and Q analog video signals, buffers these signals to reduce the data rate, performs 6:1, 3:1 or no pre-sampling of the input signals depending on the radar mode, and then formats the data for high-density digital tape recording (HDDTR) on the Honeywell AN/USH-XX 28 track tape recorder. The two-channel A/D converter required to digitize the complex radar video utilizes two 6-bit high-performance A/D converter circuits built at ERIM.

The AN/USH-XX HDDTR 28 tracks are utilized as follows: 24 tracks for four 6-bit complex video words, one track for auxiliary data (128 16-bit words per frame), one track for frame synchronization, and two tracks for error correction. Four thousand ninety-six complex words make up a frame of data.

The Digital Preprocessor also provides presumed I and Q digital video to the Real-Time Processor (RTP). The RTP performs single-channel, image-formation processing in real time. The output is displayed on a

VISOR hardcopy thermal paper recorder. This RTP provides capability for real-time check of the general navigation and also a coarse check on the system operation.

The CRT/Film Recorder provides a capability for recording one channel of video data on silver halide film for subsequent ground processing in an Optical Processor.

The clutterlock unit uses a low-frequency spectrum analyzer to measure the Doppler frequency centroid of the radar returns spatially filtered by the antenna beams. A cross-track velocity analog is developed from this Doppler frequency centroid; it is input to the Data Concentrator velocity filter to remove INS velocity biases.

The system computer consists of two HP 9000 Series 320 computers and peripherals to (1) provide operator control of the radar system signals, (2) perform the motion compensation computations, (3) provide an operator/display interface, and (4) concentrate data for auxiliary data recording and other functions. The Control Computer and associated monitor serve as the operator interface. This computer does all of the slower functions such as mode control, line navigation, system monitoring, etc. The Data Concentrator performs the motion compensation computations, converts the roll, pitch and yaw INS measurements into antenna stabilization and pointing commands, filters and combines the different sources of velocity measurements (INS, GPS and clutterlock), and assembles the auxiliary data for recording on the HDDTR.

The Time Code Receiver uses the GOES satellite data as a time base for comparing radar events with other data collection equipment events. This is distributed to other systems within the P-3.

The Global Positioning System (GPS) receiver provides an independent measure of aircraft position and velocity. The aircraft position (latitude and longitude) is used for manual update of the INS to improve the general navigation capabilities. The GPS velocities are resolved into along-track and cross-track velocities. The along-track velocity is used for setting the system PRF. The cross-track velocity is used as an input to the velocity filter to reduce INS biases. These inputs will be used when GPS data is available.

The system output products are (1) high-density digital tapes from the Honeywell AN/USH-XX HDDTR, (2) signal film cassettes from the CRT/Film Recorders, (3) a Control Computer printout which includes mode parameters, pass parameters, flight geometry and operator comments, and (4) 9-inch paper format real-time imagery from the VISOR recorder. The high-density digital tapes are played back in an ERIM facility where computer compatible tapes are generated for subsequent image-formation processing. The signal film data is chemically processed, then used in the optical processor to expose an image film.

Images are processed in one of three ways:

Optical-Optical: Raw video data from the on-board optical film recorder are processed via Fourier optics to produce imaging. This is the fastest processing method.

Digital-Optical: Data from the high-density data tape (HDDT) are transformed to video data on film, in the same format as that produced by the optical film

record, and then processed via Fourier optics to produce imagery. This can provide a quick look at the contents of an entire HDDT.

Digital-Digital: Data from the HDDT are processed via computer to produce imagery. This is the most precise method for analyzing a specific frame but is not generally suited to an overview of an entire flight.

Results

The first test flight of the P-3/SAR flight, designated as an engineering flight, occurred on 28 October 1987. The aircraft took off from Willow Run Airport near Ann Arbor, Michigan and was flown to the Straits of Mackinac and back twice, at an altitude of 15,000 feet. At the time, permission to transmit at L- and C-bands had not yet been received. Therefore, transmission was planned at X-band only. Data were collected at X_{HH} and X_{HV} .

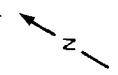
Figure 6 shows "digital-digital" images of Saginaw, Michigan, taken at X_{HH} and X_{HV} . For each image, the gray scale was chosen to reveal maximum detail; thus, one cannot compare relative brightness between the two images. In general, the X_{HH} image contains many more sharp, specular reflections, for example in the region of the Saginaw Fair Grounds. It is interesting to note the return from the railroad tracks at both X_{HH} and X_{HV} . The long north-south portion of the tracks is essentially parallel to the aircraft flight path; there is also a set of tracks approximately perpendicular to the flight path. At X_{HH} , where the transmitted and received electric vectors are parallel to the flight path, the "parallel" tracks produce a brighter return than the "perpendicular" tracks. At X_{HV} , the perpendicular tracks are brighter than the parallel tracks.

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References

- [1] A. Kozma, A. Nichols, R. Rawson, R. Shackman, C. Haney and J. Schanne, Jr., "Multifrequency-Polarimetric SAR for Remote Sensing," in Proceedings of the IEEE Geoscience & Remote Sensing Society, 8-11 September 1986, pp. 715-719.
- [2] Silver, J., Microwave Antenna Theory and Design, McGraw-Hill, 1949, pp. 497-500.



Railroad
Bridge

I-675

Johnson
Street

Genesee
Avenue

SAR
Look
Direction
↑

Aircraft
Flight
Direction
→

Saginaw
High School

Saginaw
Fairgrounds

GMC Grey Iron
Foundry

I-675

Veis Memorial
Park

Chevrolet Plant

Railroad Tracks

Genesee Avenue

X_{HH}

X_{HV}

FIGURE 6. P-3 SAR IMAGES OF SAGINAW, MICHIGAN

Biographies



Dr. Roger J. Sullivan received the B.S. and Ph.D. degrees in physics from the Massachusetts Institute of Technology. Prior to joining the Environmental Research Institute of Michigan in 1986, he was at System Planning Corporation 1973-1986 and the Illinois Institute of Technology Research Institute 1969-1973.



Mr. Alan D. Nichols received the B.S. and M.S. in electrical engineering from the University of Iowa and the University of Michigan respectively. Mr. Nichols has been with the Environmental Research Institute of Michigan since 1979. Prior to this period he spent 1972 through 1979 at McDonnell Aircraft Company and 1961 through 1972 at Conductron Corporation.



Mr. Robert F. Rawson received the B.S. degree in electrical engineering from the University of Michigan. He has been on the staff of the Environmental Research Institute of Michigan since 1961.

Mr. Charles W. Haney received the B.S. in physics at St. Joseph's University and performed graduate studies at Columbia University. He has been at the Naval Air Development Center since 1963.

Mr. Joseph J. Schanne, Jr., received the B.S. degree in electrical engineering from Drexel University in 1985. He has been at the Naval Air Development Center since then.

Mr. Francis P. Darreff received the B.S. and M.S. degrees in electrical engineering from Drexel University in 1962 and 1967 respectively. He has been at the Naval Air Development Center since he was a co-op student.