SECTION 18

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EARTH RESOURCES PROGRAMS AT THE LANGLEY RESEARCH CENTER

PART I. ADVANCED APPLICATIONS FLIGHT EXPERIMENTS (AAFE) AND MICROWAVE REMOTE SENSING PROGRAM

by

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INTRODUCTION

The earth resources activity at the Langley Research Center is comprised of three basic programs as follows:

1. Advanced Applications Flight Experiments (AAFE)
2. Microwave Remote Sensing Program
3. Coastal-Zone Oceanography Program

The three programs are in various stages of implementation, extending from experimental investigations within both the AAFE program and the microwave remote sensing program, to multidisciplinary studies and planning within the coastal-zone oceanography program. From a "significant results" standpoint, the reporting of the three programs is premature. The purpose of this paper is simply to identify the main thrust of the Langley Research Center activity in earth resources.

The coastal-zone oceanography program is not covered in this paper but is reported in a separate paper by W. E. Bressette. Also, the Langley Research Center air pollution program is not construed as an earth resources sub-discipline and is not reported under this meeting.

AAFE PROGRAM

The AAFE program is an Office of Applications program intended to establish strong candidate experiments for future space application missions involving both manned and automated spacecraft. The program consists of the engineering development and demonstration of promising space applications experiments, beginning with the existence of a feasible concept from SR&T investigations, and extending to an interface with flight prototype development.

The Langley Research Center provides the implementation and project management of the AAFE program. The program involves Principal Investigators within industry, universities, other Government agencies, and the NASA Centers. Research Engineers within the Langley Research Center are assigned to each experiment during the AAFE development and experiment demonstration. Further support is also given to AAFE through related SR&T efforts within the Center.

Approximately 25 percent of the AAFE program is comprised of experiments within the earth resources discipline. The remaining experiments are distributed among the space applications disciplines of meteorology, communications, earth physics/physical oceanography, and applications technology. The AAFE/earth resources experiments are listed in Table I. The expected completion dates for the AAFE development and the possible missions which are associated with the experiments are also shown. Of the eight experiments identified, three experiments are entering an experiment demonstration phase and will be further identified with respect to the expected experiment performance and flight plans. The three experiments are the Multichannel Ocean Color Sensor (MOCS) experiment, the Composite Radiometer-Scatterometer (RADSCAT) experiment, and the Sea Surface Temperature Microwave Radiometer experiment.

The performance specifications for the Multichannel Ocean Color Sensor (MOCS) experiment are listed in Table II. The experiment consists of spectrometric measurement of ocean surface for mapping distribution, concentration, and type of organic matter. The instrument developed for this measurement is an electronic multispectral line scanner. A slit image is taken, dispersed spectrally, and read out by an image dissector tube. The instrument has two modules to allow experimental trade-offs to be made between spectral and spatial resolution. The high spectral resolution becomes important in data processing techniques such as second derivative information associated with detecting chlorophyll bands from high altitudes.

The atmospheric effects are of particular concern to the MOCS experiment, and an early phase of the development work included investigating an air-sea optical model. In this effort flight tests with a visible spectrometer, together with boat-gathered ground truth measurements, were made by the Principal Investigator during July, August, September, and October 1971. Spectral reflectance curves were obtained of various water masses overflown for altitudes from 500 to 25,000 ft. On the basis of these data, an extrapolation to the top of the atmosphere was made to indicate the expected spectral radiance obtained from ocean waters from satellite altitude. Results indicate the magnitude of the contrast to be expected from 400 to 700 nanometers and show that the water color signatures should be measurable from satellite altitude. The results are documented in a task report, dated November 15, 1971, to contract NAS1-10908.

An engineering model of the MOCS instrument is under construction and flight tests will be performed in June 1972. Assuming a successful checkout of the instrument, the MOCS will be flown on the NASA Convair 990 in June together with a filter-wedge spectrometer from Hovis of Goddard Space Flight Center, and a differential radiometer from Arvesen of Ames Research Center. The joint flight, organized by Goddard Space Flight Center, will seek to determine the relative merits of the three instrument concepts. There is strong interest in an ocean color experiment on future missions such as the Small Applications Technology Satellite (SATS) and the Earth Observations Satellite (EOS).

The performance specifications for the RADSCAT experiment are listed in Table III. The experiment consists of inferring wind speed over the ocean surface through measurement and analysis of radar return signal and radiometer antenna brightness temperature. The RADSCAT instrument operates alternately in an active scatterometer and a passive radiometer mode. In the scatterometer mode, an electromagnetic pulse is transmitted to the ocean's surface where it is scattered by the small scale roughness element or capillary wave portion of the ocean spectrum. The amplitude of the return pulse is a function of the radar frequency, EM wave polarization, viewing angle, and the degree of surface roughness (water waves on the order of one inch length). Since the capillary water waves are in near equilibrium with the local surface wind, the amplitude of the backscattered radar pulse can therefore be used to infer wind speed. The radiometer mode is used to assess the possible contributions of clouds, rain, and surface foam to the overall measurement and analysis.

The multifrequency AAFE RADSCAT will be flown on an NOAA C-130 aircraft during April 1972, followed by flights on the NASA-MSC C-130 aircraft beginning in late June 1972. Both flights will be made over instrumented test sites off the Virginia capes. The antenna will be slewed aft in an along track mode in six steps between nadir and 60° viewing angle. Both radiometer and scatterometer signatures will be correlated with environmental conditions measured by in situ instrumentation. The earlier flights on the NOAA C-130 aircraft are intended to explore the higher wind fields which occur in the spring, prior to the schedule availability of the NASA-MSC C-130 aircraft. Calibration of the RADSCAT will be done at the Wallops Station during March 1972. The instrument will be mounted on a ground pedestal and the scatterometer will be calibrated against test spheres suspended aloft. The radiometer will be calibrated against Hohlraum temperatures and other techniques such as moon tracking, well defined stellar radio sources, and zenith measurement variations with time.

The AAFE RADSCAT instrument will be placed in the inventory of instruments available on the NASA-MSC C-130 aircraft. Future uses of the instrument would include underflight support to the Skylab-S193 experiment.

The performance specifications for the Sea Surface Temperature Microwave Radiometer experiment are listed in Table IV. The experiment consists of a single frequency (S-band) radiometric measurement of brightness temperature for deriving sea surface temperature maps on a global basis.

The relationships between brightness temperature and the effects of environmental parameters such as surface roughness and foaming, sea water salinity, and atmospheric conditions were of particular concern in this AAFE development and were explored by the Principal Investigator in a detailed investigation prior to the design and construction of the radiometer. A summary of the corrections required to the apparent temperature and the uncertainty in deriving the sea surface molecular temperature, as influenced by salinity, roughness, foaming, atmospheric absorption, clouds, and extraterrestrial background is shown in Table V. This information is published in an NASA Contractor Report, NASA CR 1960, dated February 1972.

The microwave radiometer will be test flown off the Virginia capes on an NASA C-54 aircraft operated by Wallops Station beginning in April 1972. Sea truth support will be co-shared with the RADSCAT experiment.

A survey concerning the experimental use of the microwave radiometer is now being conducted among the potential users. First consideration will be given to the continued use of the instrument installed on the NASA-Wallops C-54 aircraft.

MICROWAVE REMOTE SENSING PROGRAM

The microwave remote sensing program is a Supporting Research and Technology effort within the Langley Research Center. A specific goal of the program is to develop precision microwave sensors for day/night, all weather earth observations from satellite and/or aircraft of ocean temperature, ocean roughness, and salinity. The program also provides additional in-house support to the AAFE program.

The microwave remote sensing program involves a range of investigations extending from laboratory and theoretical analysis to systems level testing and evaluation. Descriptions of the investigations follow.

A wave tank has been constructed and will be used to isolate and independently study parameters such as wave spectrum, salinity, temperature, and surface composition, all of which influence RF scattering and emission from water. The wave tank will also be used as a test bed to develop and calibrate sea truth instrumentation such as measurement of capillary waves.

Rigid surfaces, having a characteristic roughness which can be mathematically modeled, have been constructed for in-house experimental studies of RF scattering from rough surfaces. This technique will allow correlations between analytical and experimental results concerning RF scattering theory.

Advanced radiometer components, such as image line waveguides and associated computer design programs, are being developed to reduce internal losses and waveguide size for application in high precision radiometers. Low noise radiometer antennas, which exhibit maximum beam efficiency and minimum insertion loss, are also being developed. One such design, a corrugated horn, is also being investigated as an unfurlable concept for satellite application at S-band frequencies.

At the systems level, measurements of radiometric signatures are currently being made with a four frequency group of microwave radiometers located on a railway bridge at Buzzard's Bay in Massachusetts. Measurements are being made at .75 GHz, 1.4 GHz, 4.0 GHz, and 7.5 GHz, in conjunction with supporting sea truth and meteorological data. The measurements are taken at both vertical and horizontal polarizations and at a variable view angle from -30° through 160°. A photograph of the antennas mounted on the Buzzard's Bay bridge is shown in Figure 1. The antennas are shown in the upward-looking, stowed position.

The Buzzard's Bay radiometer investigations are intended to establish the relationship between observed radiometric signatures and ocean surface condition parameters. Information will be gathered through June 1972, a data bank established, and the data statistically analyzed. A recent computer plot of uncalibrated data taken with the Buzzard's Bay 1.4 GHz radiometer is shown in Figure 2. The increase in brightness temperature near nadir is due to reflections from the bridge.

CONCLUDING REMARKS

The earth resources program at the Langley Research Center continues as a modest effort, strongly oceanographic oriented, and characterized as entering a measurement and data analysis phase. Contributions from these SR&T and AAFE efforts, in terms of systems design, interpretive information, and confidence in specific remote sensing techniques and associated experiments, are anticipated during the current year.

TABLE I.- AAFE/EARTH RESOURCES EXPERIMENTS

Experiment Title and Investigator	Expected Completion	Possible Mission
• Fast Response, Hybrid Multispectral Processor (Kreigler; Univ. of Michigan)	Feb 74	Ground Equip.
• Earth Observation Scanning Spectro-Radiometer (Goldberg; NASA-GSFC)	Dec 74	EOS-B
• Earth Surface Mapping, Microwave Hologram Radar (Zelenka; Univ. of Michigan)	Nov 73	EOS-C
• Luminescense Detection, Fraunhofer Line Discriminator (Hemphill; USGS)	July 73	SATS
• Multichannel Ocean Color Sensor (MOCS) (White; TRW)	Dec 72	SATS
• Composite Radiometer-Scatterometer (RADSCAT) (Pierson; NYU)(Moore; U. of Kansas)(Tomiyasu; GE)	Oct 72	Skylab Support
• Sea Surface Temperature, Microwave Radiometer (Hidy; North American Rockwell)	May 72	EOS-C
• Sea-Ice Mapping Radiometer (Gloersen; NASA-GSFC)	Dec 72	EOS-A

TABLE II.- PERFORMANCE SPECIFICATIONS

MULTICHANNEL OCEAN COLOR SENSOR (MOCS)

	SPACECRAFT	AIRCRAFT
ALTITUDE	500 NM	15,000 Ft.
CROSS-TRACK SWATH WIDTH	150 NM	4,500 Ft.
ANGULAR FIELD OF VIEW	17.1°	17.1°
SPECTRAL RANGE	400-700 Nanometers	400-700 Nanometers
SPECTRAL RESOLUTION:		
(a) Modular Package MP-5	5 Nanometers	5 Nanometers
(b) Modular Package MP-15	15 Nanometers	15 Nanometers
GROUND RESOLUTION		
(a) Modular Package MP-5	3 x 1 NM	90 x 30 Ft.
(b) Modular Package MP-15	1 x 2 NM	30 x 60 Ft.
S/N (500 NANOMETERS, SCENE IRRADIANCE 1400 W/M^2-MICRON)	110	110
WEIGHT	15 lb.	20 lb.
POWER CONSUMPTION	7.5 Watts, 28 VDC	7.5 Watts, 28 VDC

TABLE III.- PERFORMANCE SPECIFICATIONS

COMPOSITE RADIOMETER SCATTEROMETER (RADSCAT)

FREQUENCY: 9.3 GHz 13.9 GHz

POLARIZATIONS: V V; V H
H H; H V

ANTENNA: 44-1/2" Dia. (S 193 Design)
ANTENNA BEAMWIDTH: 1.5° (Half Power)
ANTENNA SCAN: 0° (Nadir) to 60°, Six Steps

SCATTEROMETER TRANS. POWER: 1 Watt Peak
SCATTEROMETER MEASUREMENT RANGE: +10 DB to -35 DB
SCATTEROMETER MEASUREMENT ACCURACY: $\pm$ 1 DB (RMS Error)
SCATTEROMETER OPERATING ALTITUDES: 2 K Ft.; 10 K Ft.; 18 K Ft.

RADIOMETER, BRIGHTNESS TEMP. RESOLUTION: $\pm$ 1° K
RADIOMETER OPERATING ALTITUDES: Any

WT. (ANTENNA, GIMBAL, RF SUBSYSTEM): 300 Lbs.

TABLE IV.- PERFORMANCE SPECIFICATIONS

SEA SURFACE TEMPERATURE MICROWAVE RADIOMETER

FREQUENCY: 2.65 GHz
BANDWIDTH: 100 MHz

POLARIZATIONS: Circular; V; H

ANTENNA: Multimode Horn, Square Aperture
(35.5 cm Side, Limited by C-54 Installation)

ANTENNA BEAMWIDTH: 20.5° (Half Power)

TEMPERATURE ACCURACY:

Molecular Absolute	± 1° K (after corrections)
Brightness Absolute	± .3° K
Resolution	± .1° K

RADIOMETER TYPE: Modified Dicke With Precision
Nulling Feedback

POWER: 20 Watts
WT. (WITHOUT ANTENNA): 30 Lbs.

TABLE V.- SEA SURFACE TEMPERATURE MICROWAVE RADIOMETER

Contributions to Apparent Temperature and Corrections to be Applied

Effect	Contribution: Correction Required	Contribution: Uncertainty in Molecular Temperature	Remarks
Salinity	$\Delta T_B = +1.0^\circ$	$\pm 0.3^\circ K$	Correction derived from known spatial and temporal salinity variations in sea.
Roughness, Foaming	$\Delta T_B = \sim 3^\circ K$	$\pm 3^\circ K$	Corrections derived from knowledge of sea state and wind conditions can reduce T_B uncertainty to $\sim 1^\circ K$.
Atmospheric Absorption	$+2.4^\circ K$	$\pm 0.5^\circ K$	Contribution due mainly to oxygen absorption.
Extraterrestrial Background	$+3.0^\circ K$	$\pm 0.3^\circ K$	Excludes strong isolated radio sources near galactic center.
Clouds	$\pm 0.5^\circ K$*	$\pm 0.1^\circ K$	Corrections derived from extent and thickness of cloud cover.

*For cloud layer 1 km thick containing 1 gm liquid water per cubic meter.

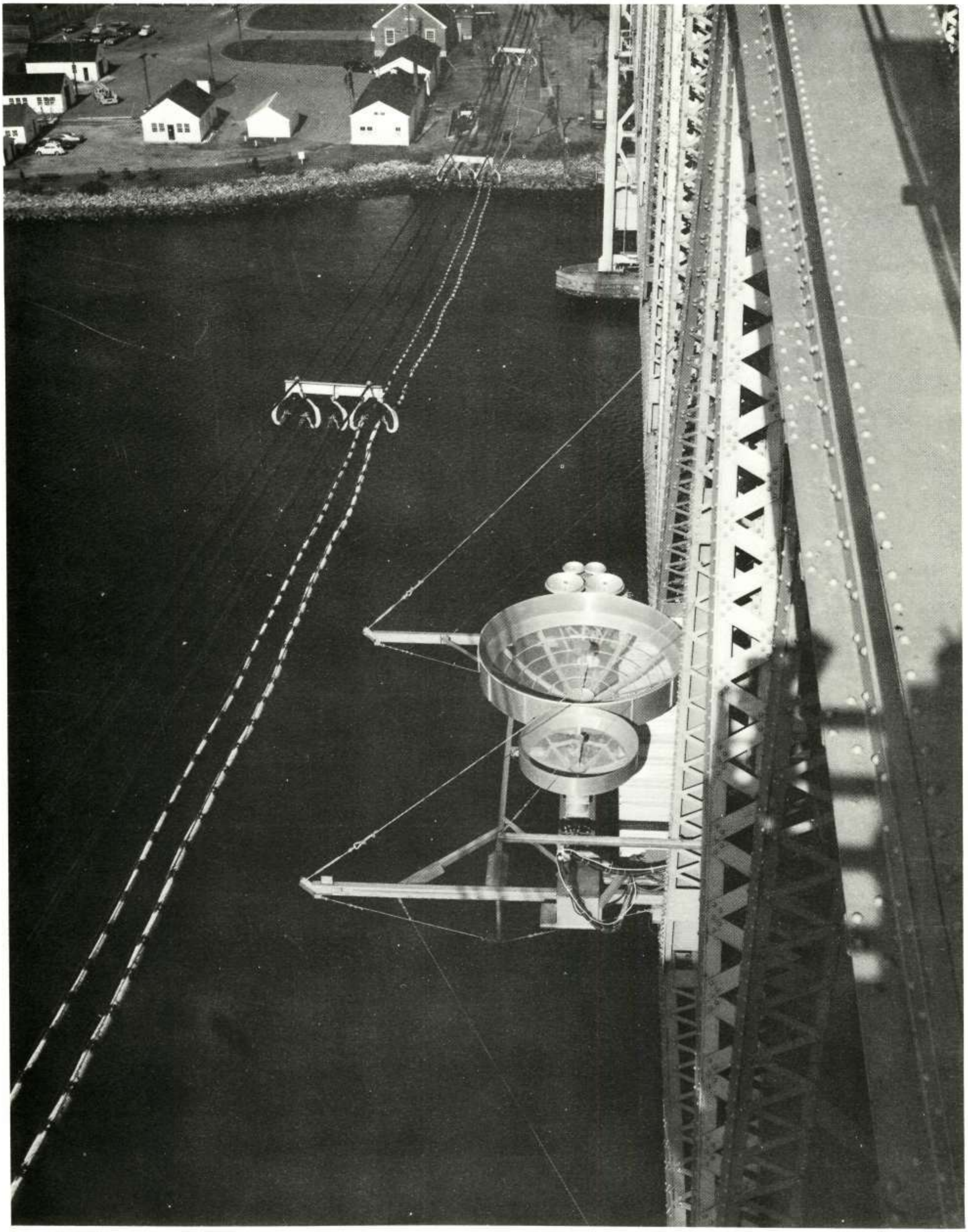

Figure 1.- Microwave radiometers located on the Buzzard's Bay Bridge in Massachusetts.

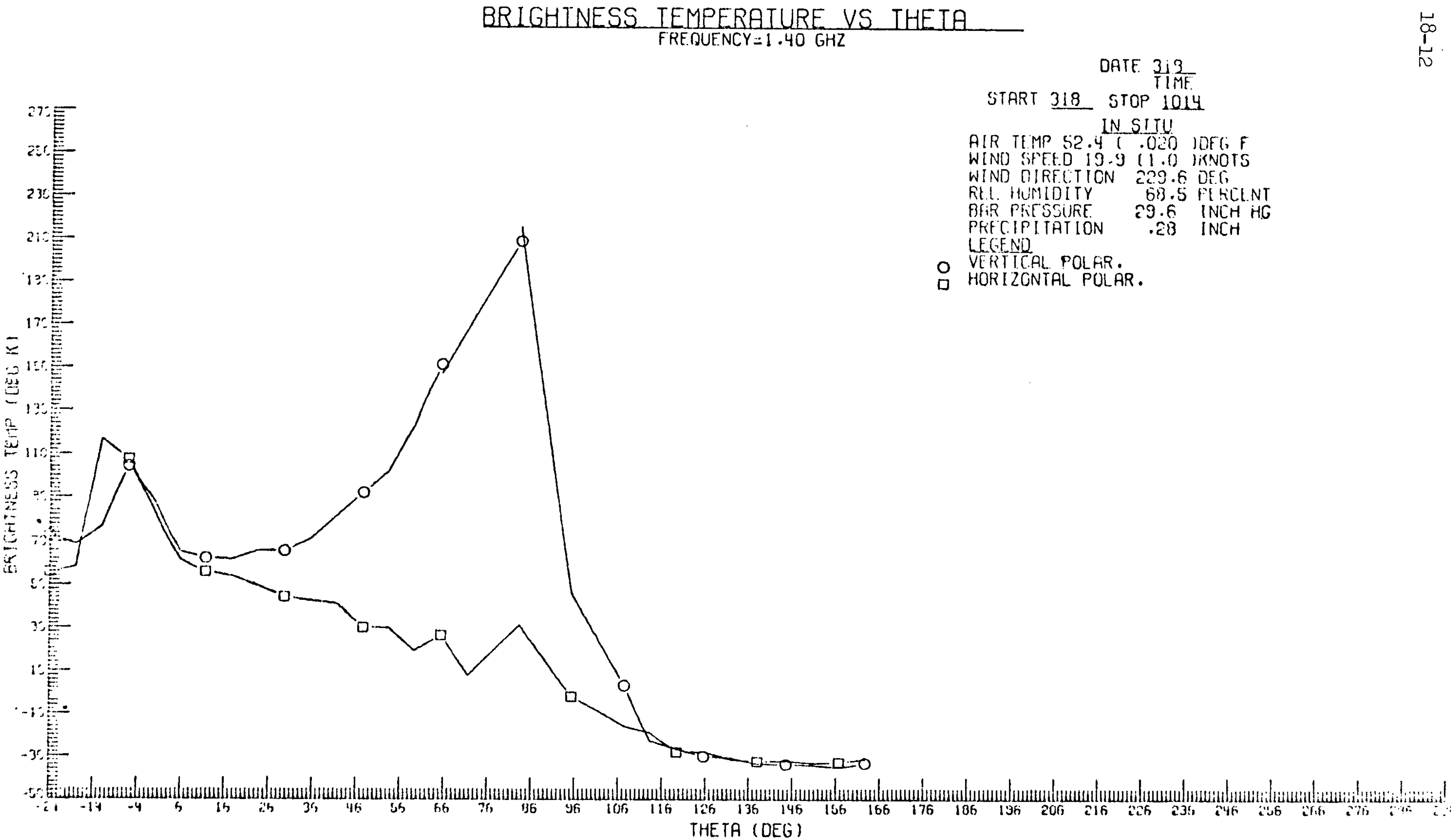

Figure 2.- Computer plot of uncalibrated data taken with the Buzzard's Bay 1.4 GHz radiometer.