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SALINITY SURVEYS USING AN

AIRBORNE MICROWAVE RADIOMETER

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ABSTRACT

The Barnes PRT-5 Infrared Radiometer and the L-Band (1.42 GHz) Channel of the Multifrequency Microwave Radiometer (MFMR) are used to survey the distribution of surface water temperature and salinity. These remote sensors were flown repetitively in November 1971 over the outflow of the Mississippi River into the Gulf of Mexico. Data reduction parameters were determined through the use of flight data obtained over a known water area. With these parameters, the measured infrared and microwave radiances were analyzed in terms of the surface temperature and salinity.

INTRODUCTION

Surface water salinity and temperature measurements are useful to studies of coastal processes such as bay circulation and river outflow. Marine organisms are affected by the salinity and temperature of their water habitat. Marine ecologists and biologists thus need the capability for conducting surveys of salinity and temperature. Also, fish forecasting by the National Fisheries Service of the National Oceanic and Atmospheric Administration (NOAA) requires information on the temperature and salinity of breeding grounds of marine organisms.

Past investigations have shown that the microwave emission of water is affected significantly by changes in the salinity of the water surface layer for microwave frequencies less than 3 GHz(Rfs. 1-3). Thus, the possibility existed for making surveys of the water surface salinity from aircraft through the use of an L-band microwave radiometer. A Multifrequency Microwave Radiometer (MFMR) built by Aerojet General Corporation was installed on the NASA 927 (Lockheed P3A aircraft) in 1969. One channel of the MFMR operates in the L-band at 1.42 GHz. The purpose of this paper is to report on the development of an analysis technique whereby the distribution of surface water temperature and salinity along the flight line may be calculated by computer from MFMR and infrared radiometry (PRT-5) data taken along the flight track of the NASA 927 aircraft.

In order to recover the salinity of the water surface from MFMR measurements, one must consider carefully the effects of a number of other parameters, such as, variations in water surface temperature, absorption and emission by the intervening atmosphere, absorption and emission by the MFMR radome antenna, and waveguide, and departures in the calibration constants from the values determined before the aircraft flight. These considerations are discussed in Section II below.

A computer program was developed to analyze the MFMR and PRT-5 data and to produce profiles of water surface salinity and temperature along the aircraft flight track. The development of the computer program is discussed in Section III below.

The computer program was used with flight data acquired during a flight of the NASA 927 over the outflow of the Mississippi River into the Gulf of Mexico in November 1971. The results of the application of the program are given in Section IV below.

Conclusions and recommendations are presented in Section V below.

THEORETICAL DEVELOPMENTS

EMISSION AND REFLECTION OF WATER

In the determination of salinity from measurements of the microwave emission of water, one needs a computationally simple, mathematical model that may be used to predict the microwave emissive and reflective properties of water, given the observable conditions of the water and trial values of salinity. It is known that the microwave emission of water is affected, in general, by changes in water temperature, water salinity, water surface roughness (wind waves and swell), and by the presence of other materials on the surface, such as sea foam and oil. (Refs. 1-7)

Mathematical models exist for predicting the microwave properties of sea foam and oil on water. These models require, however, a knowledge of the thicknesses of foam and oil, of the dielectric constant of the oil, and of the air-to-water ratio of the foam. These parameters are not available through the use of remotely sensed data. On the other hand, visual or photographic data may be used to determine the presence or non-presence of oil or foam on the water surface. Thus, in the mathematical model, it is assumed that there is no foam or oil on the water surface.

Mathematical models exist also for predicting the effect of water surface roughness on the microwave emission of water. These models require a knowledge of the spectrum of water surface slopes which, in turn, may be inferred from a knowledge of the fetch, duration, and speed of the wind over the water. Again, these parameters are not available from remotely sensed data. Studies (Refs. 4 and 6) have shown, however, that the effect of the water surface roughness is small for viewing angles near nadir and for vertical polarization. In the mathematical model developed for use in this paper, it is assumed that the effects of water surface roughness can be ignored.

With the elimination of the above effects, only the effects of temperature and salinity remain. In order to model the microwave properties of water, it is assumed that the water is a homogeneous, semi-infinite dielectric bounded by a plane surface and overlaid by air. Since the water is an absorbing and emitting medium of large depth, the radiation impinging upon the air-water interface from below is the same as that emitted by a black-body at the temperature of the water. That is, the brightness temperature of the radiation just under the air-water interface is equal to the absolute thermometric temperature of the water.

At the air-water interface, a fraction, r, of the radiation impinging from below is reflected back into the water mass. The rest of the radiation is transferred through the air-sea interface and emerges as emitted radiation. Thus, the brightness temperature of the emitted radiation, T_e ($^\circ$K), is

$$T_e = (1 - r) T_w \tag{1}$$

where T_w is the water temperature ($^\circ$K).

The reflectivity, r, for a flat semi-infinite dielectric of dielectric constant, $\varepsilon'-j\varepsilon''$, is given as (Ref. 2)

$$r_v = \left| \frac{(\varepsilon' - j\varepsilon'') \cos \psi - \sqrt{(\varepsilon' - j\varepsilon'') - \sin^2 \psi}}{(\varepsilon' - j\varepsilon'') \cos \psi + \sqrt{(\varepsilon' - j\varepsilon'') - \sin^2 \psi}} \right|^2 \tag{2}$$

or

$$r_h = \left| \frac{\cos \psi - \sqrt{(\varepsilon' - j\varepsilon'') - \sin^2 \psi}}{\cos \psi + \sqrt{(\varepsilon' - j\varepsilon'') - \sin^2 \psi}} \right|^2 \tag{3}$$

where ψ is the zenith angle of observation and the subscripts v and h refer to vertical and horizontal polarization, respectively.

The microwave radiation directed downward impinging upon the air-water interface is characterized by a sky brightness temperature, T_{sky} ($^\circ$K), which is the sum of the transmitted cosmic background brightness and the katabatic emission by the atmosphere.

A portion of the sky radiation is reflected from the air-water interface toward the observer, such that the total radiation leaving the air-water interface and traveling toward the observer has a brightness temperature of

$$T_o = r T_{sky} + (1 - r) T_w \tag{4}$$

In order to compute the reflectivity for a given angle of observation and polarization, one must be able to specify the dielectric constant, $(\varepsilon' - j\varepsilon'')$ of the water.

Studies (Refs. 8 and 9) have shown that the values of ε' and ε'' for water with dissolved salt (NaCℓ) may be predicted for the microwave spectrum through the use of Debye model. That is,

$$\varepsilon' = \varepsilon_\infty + \frac{\varepsilon_s \quad \varepsilon_\infty}{1 + \omega^2 \tau^2} \tag{5}$$

and

$$\varepsilon' = \frac{\omega \tau (\varepsilon_s - \varepsilon_\infty)}{1 + \omega^2 \tau^2} + \frac{\sigma_i}{\omega \varepsilon_o} \tag{6}$$

where ε_∞ is 4.9, ε_s, τ, and σ_i are functions of water temperature and salinity only, and ω is the circular frequency, [$2 \pi \nu$, where ν is the electromagnetic frequency (Hz)].

The values of ε_s, τ, and σ_i for specific water temperatures and salinities as given in Refs. 8 and 9 are given in Table 1. In order to predict the values of ε' and ε'' for any water temperature and salinity, it is necessary to interpolate between the values given in Table 1. Interpolation formulas exist for this purpose and are indicated in Table 2 (Ref. 10).

With these interpolation formulas and the use of Equations 2-6, one has a mathematical model that may be used to predict the emissive and reflective properties of water at 1.42 GHz for any given water temperature, water salinity, angle of viewing and polarization. This model was used to compute the microwave emission for vertical and horizontal polarization, for viewing angles of 0, 30, and 55 degrees, for water salinities of 0, 5, 10, 15, 20, 25, 30, and 35 0/00, and for water temperatures ranging from 0 to 30°C. The results of the calculations are shown in Figures 1-5.

These figures show that salinity has the maximum effect on microwave emission for angles of viewing near 55 deg, for vertical polarization, for warm water, and for salinities in the range from 10 to 35 0/00.

EMISSION AND ABSORPTION BY THE ATMOSPHERE

A mathematical model that may be used to predict the effect of the atmosphere on the transfer of microwave radiation is needed to allow the proper consideration of this effect. For a given aircraft flight, soundings of atmospheric temperature and humidity are available usually through the use of radiosondes released at National Weather Service stations. At 1.42 GHz, the atmosphere is practically transparent for all conditions including clouds and rain (Ref. 9). In the case of rain, however, the surface water would be disturbed and diluted by the rain water. Also the aircraft radome would be covered by liquid water and would create large and unpredictable losses. For these reasons, rainy weather conditions must be ruled out for the measurement of salinity by the MFMR. The emission and transmission of the atmosphere may be computed from the knowledge of the vertical distribution of temperature and humidity in the atmosphere (Ref. 10).

In addition, the effects of refraction and a spherical geometry may be easily included in the calculation. (Ref. 11). As a result, the relationship between the brightness temperature of the radiation impinging upon the MFMR radome, T_b , and T_o , the brightness temperature of the radiation leaving the air-water interface, is

$$T_b = T_o t + T_{atm} \qquad (7)$$

where t is the transmission coefficient for the intervening atmosphere and T_{atm} is the brightness temperature of the radiation emitted by the intervening atmosphere toward the observer.

TRANSMISSION OF SENSOR COMPONENTS

If one neglects the radiation received in the side lobes of the L-band radiometer of the MFMR, then the equivalent radiometric temperature of the radiant power received by the radiometer is given by

$$T_r = \frac{T_b}{L_r L_a L_w} + \frac{(L_r - 1)}{L_r L_a L_w} T_{rd} + \frac{(L_a - 1)}{L_a L_w} T_a + \frac{(L_w - 1)}{L_w} T_w \qquad (8)$$

where L_r is the loss factor for the radome,

L_a is the loss factor for the antenna,

L_w is the loss factor for the waveguide,

T_{rd} is the thermometric temperature of the radome,

T_a is the thermometric temperature of the antenna,

and T_w is the thermometric temperature of the waveguide.

CALIBRATION EQUATION

The microwave radiometer is a linear device such that the output, C (counts)*, is given by

$$C = C_{b\ell} - \frac{T_{b\ell} - T_r}{S} \qquad (9)$$

where $C_{b\ell}$ is the output of the radiometer when the power emitted by the reference load is being monitored, (counts),

$T_{b\ell}$ is the thermometric temperature and equivalent radiometric temperature of the reference load, (°K),

and S is the response of the instrument or scale factor (°K per count).

In the MFMR, the scale factor may be determined before or after a data run by injecting a known amount of argon noise that has an equivalent noise temperature, T_n (°K), and observing the change in output, ΔC (counts). In this case,

$$S = \frac{T_n}{\Delta C} \qquad (10)$$

SUMMARY OF MATHEMATICAL MODELS

Mathematical models were developed above to predict the effects of all measurable parameters and salinity on the output of the MFMR. These models are valid only for the following conditions.

*The output of the MFMR is voltage, however, it is recorded as PCM counts.

1. Smooth water surfaces free from foam and oil

2. Non-raining atmospheres

3. Matched radiometer systems

4. Linear radiometer systems

PROGRAM DEVELOPMENT

DATA AVAILABLE FOR ANALYSIS

The data available for analysis consists of the following:

1. One-second averages of the thermometric temperature of the radome, the antenna, and the waveguide of the MFMR and of the equivalent radiometric temperature of the radiation measured by the L-band radiometer as determined from the calibration equations (Eqs. 9 and 10).

2. Averages taken over 0.792 sec. of the equivalent radiometric temperature of the radiation measured by the PRT-5 infrared radiometer.

3. Radiosonde measurements of atmospheric temperature and humidity from the surface to the 10 mb level (approximately 31 km).

4. Flight logs for the aircraft flight.

5. Location (latitude, longitude, and altitude), attitude (heading, drift, roll, pitch), and speed of aircraft sampled once each ten seconds.

6. Surface measurements of salinity and temperature at selected points under the aircraft surface track.

7. Photographic coverage (10% overlap) along flight line.

8. Scale factors, baseline counts, and baseline temperature used to reduce raw MFMR data to produce data in 1 above.

9. Equivalent argon noise temperature, radome loss factor, and waveguide loss factor.

ADEQUACY OF THE AVAILABLE DATA AND MATHEMATICAL MODELS

In the above it has been noted that some minor effects such as surface roughness and sidelobe contributions have been ignored in the development of the mathematical models. In addition, there is some evidence that there are systematic errors in the values of injected argon noise and of the antenna loss factor for the MFMR. All of these factors could create a significant bias in the data if not properly treated. In order to insure consistency in the analysis and to eliminate the effects of systematic errors, a new set of calibration constants (scale factor and antenna loss factor) are obtained through the use of flight data and the mathematical models. Two portions of the flight data are taken — the first over a stretch of water of known temperature and salinity and the second when the radiometrically cold sky is being viewed.

DETERMINATION OF THE NEW CALIBRATION CONSTANTS FOR THE MFMR

If equations (8) and (9) are combined and rearranged, one obtains the expression,

$$T_b = L_r L_a L_w [T_{b\ell} - S(C_{b\ell} - C)]$$

$$- (L_r - 1) T_{rd} - (L_1 - 1) L_r T_a - (L_w - 1) L_r L_a T_w \qquad (11)$$

The actual output of the radiometer, C, may be obtained from the given values of radiometric temperature through the use of equiations (9) and the old calibration constants.

If T_{bw} is the brightness temperature corresponding to the radiometer reading, C_w, obtained when the known water target is being viewed, and T_{bs} is the brightness temperature of the sky corresponding to the radiometer reading, C_s, then from equation (11),

$$T_{bw} - T_{bs} = L_r L_a L_w S(C_w - C_s) \qquad (12)$$

or

$$S = \frac{T_{bw} - T_{bs}}{L_a L_r L_w (C_w - C_s)} \tag{13}$$

Inserting equation (13) into (11) and solving for L_a, one obtains the expression

$$L_a = \frac{a_1}{a_2} \tag{14}$$

where

$$a_1 = T_b + \frac{(T_{bw} - T_{bs})(C_{b\ell} - C)}{C_w - C_s} + (L_r - 1) T_r - L_r T_a \tag{15}$$

and

$$a_2 = L_r L_w T_b - (L_w - 1) L_r T_w - L_r T_a \tag{16}$$

In equations (14)-(16), one may use either C_w and T_{bw} or C_s and T_{bs} to determine L_a. With the knowledge of L_a, one may obtain the value of the scale factor, S, from equation (13).

The effect of the above determinations is to force the MFMR measurements to agree with the mathematical model at two points, namely, for a selected water point and for a cold sky point. Since all of the radiometric measurements are made for water conditions close to the selected water point, there should be consistency in the values of the derived salinities.

COMPUTATIONAL PROCEDURE FOR OBTAINING SALINITY AND

TEMPERATURE FROM MFMR AND PRT-5 DATA

After receipt of all of the flight data and surface and atmospheric measurement data obtained in support of the aircraft flight, the following procedure was followed:

1. A homogeneous area of water with known water temperature and salinity was selected.

2. From an inspection of the surface measurement and PRT-5 tabulations, the difference between the two temperatures was determined for the selected water area. In general, there will be a fixed difference due to the cool skin of the water, the nonunity value of the emissivity of water, and the absorption and emission of the intervening atmosphere.

3. The radiation properties of the atmosphere were calculated through the use of the Microwave Atmospheric and Oceanic Data Analysis Program (MAODAP). The MAODAP uses radiosonde data taken during the flight (Ref. 12).

4. The salinity and temperature analysis program (STANL) was then employed. In the STANL, the following operations are performed:

   a. Controls cards are read.

   b. Data are read from PRT-5 and MFMR data tapes supplied by the Computing and Analysis Division (CAAD) of NASA Manned Spacecraft Center.

   c. Eleven-second running averages are computed for needed MFMR and PRT-5 parameters.

   d. The new calibration constants are determined by use of the flight data and the Eqs. 13-16.

   e. The salinity and temperature are determined from the MFMR and PRT-5 data through the following procedure:

      (1) First, the microwave radiometric temperatures are corrected for the change in scale factor, that is

$$T'_r = T_{b\ell} + S' \frac{(T_r - T_{b\ell})}{S} \qquad (17)$$

      (2) Second, the PRT-5 infrared radiometric temperature are used with the correction factor in 2 above to determine the water temperature ($^\circ$K).

      (3) Last, the value of salinity is determined through iteration such that the predicted radiometric temperatures agrees with the corrected radiometric temperatures determined in (1) above.

PROGRAM APPLICATION

MISSION 190, FLIGHT 3

Mission 190, Flight 3 was flown over the outflow of the Mississippi River into the Gulf of Mexico (Site 128) on November 11, 1971. Nine data runs were made over Line 1 (see Figure 6) at approximately 242 m (860 ft.) above the water surface. The first eight data runs were made with the MFMR antennas pointing 4.8 deg from nadir in vertical polarization. The last run was made with the antennas pointing 45 deg from the zenith in vertical polarization. The first data run began at the ENE end of Line 1 at 0935 CST; the last data run ended at the ENE end of Line 1 at 1803 CST. Two KA-62 cameras, the Barnes PRT-5 Infrared Radiometer, the MFMR Boresite Camera, the MFMR, and the navigation equipment were used on the NASA 927 (Lockheed P3A) aircraft during the flight, and all sensors functioned normally.

Flight support consisted of a radiosonde released at Boothville, La. (approximately 25 n. miles north of the aircraft flight line), and a surface survey along the aircraft flight line. The surface survey was made through the use of a 65 foot crewboat leased at Venice, La. The surface measurements consisted of *in situ* measurements of salinity and temperature with a Beckman In-Situ Salinometer. The measurements were taken at stations approximately every nautical mile along the flight line. In addition, water samples were taken approximately every ten stations. As originally planned, the surface survey was to take place during a time period centered upon the time interval of the aircraft flight. Unfortunately, the crewboat ran into the dock the evening before the day of the aircraft flight and had to undergo repairs before leaving during the morning of the flight. The accident did not come to the attention of the mission manager since the aircraft crew and sensor operators had left for the airport before the surface survey team arrived at the Gulf Docks in Venice to leave on the crewboat. As a result, the surface survey boat arrived at S. Pass and began the survey at 1157 CST just before the aircraft survey was being completed. The surface survey proceeded toward the WSW end of Line 1 and returned to S. Pass at 1641 CST.

In general, the atmosphere was clear and dry, and surface winds were from the ENE at 5 knots. The radiosonde was released at 1715 CST. The results of the radiosonde sounding are shown in Table 3.

DATA PREPARATION

The water area at the Southwest Pass outflow was selected as the calibration point for the water data, The surface measurements of water surface temperature at this point were compared with the PRT-5 radiometric temperatures, and the radiometric temperature was found to be 3.5 °C lower than the bucket temperature of the water surface.

The MAODAP was used to calculate the microwave parameters of interest for the subsequent analysis. The parameters of interest from the MAODAP program are listed in Table 4.

The analysis program (STANL) developed for the study was then used to determine the new calibration constants and to produce a plot of surface water salinity and temperature along the flight track.

RESULTS

The results of the determination of new calibration constants for the MFMR are listed in Table 5, A significant difference was noted between the old and new values of antenna loss factor, scale factor and injected noise. These differences appear to be the result of a bias in the measurement of injected noise as made by the hot/cold load laboratory calibration procedure.

The plot of surface water salinity and temperature along the flight track during run 8 is shown in Figure 7. The symbols in the Figure indicate the values of surface temperature and salinity obtained by the surface survey that was conducted shortly after the aircraft flight. In general, there is good agreement. The times of passage over the river mouths are indicated by the symbol M and the time of passage over surface foam lines as seen in the photography are indicated by the symbol F .

These data confirm the usefulness of L-band measurements of water microwave emission in determining the surface salinity of water.

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TABLE I.-THE DEBYE PARAMETERS OF AQUEOUS SODIUM CHLORIDE
FOR SPECIFIC VALUES OF TEMPERATURE AND SALINITY
(AFTER SAXTON AND LANE, 1952; SAXTON, 1952)

T_{sea} (C)	Debye Parameter	Salinity (0/00)		
		0.0	28.3	55.5
-10	ε_s	92.3	——	——
	$\tau_s \times 10^{12}$ s	27.5	——	——
	σ_i ℧ m^{-1}	0.0	——	——
0	ε_s	88.2	77.0	69.0
	$\tau_s \times 10^{12}$ s	18.7	17.1	16.4
	σ_i ℧ m^{-1}	0.0	2.44	4.77
10	ε_s	84.2	74.0	66.0
	$\tau_s \times 10^{12}$ s	13.6	12.2	11.8
	σ_i ℧ m^{-1}	0.0	3.45	6.22
20	ε_s	80.4	71.0	63.0
	$\tau_s \times 10^{12}$ s	10.1	9.2	9.0
	σ_i ℧ m^{-1}	0.0	4.44	7.66
30	ε_s	76.7	68.0	68.0
	$\tau_s \times 10^{20}$ s	7.5	7.2	7.1
	σ_i ℧ m^{-1}	0.0	5.22	9.22
40	ε_s	73.1	65.0	58.0
	$\tau_s \times 10^{12}$	5.9	5.7	5.6
	σ_i ℧ m^{-1}	0.0	6.22	10.8

TABLE II.--REGRESSION COEFFICIENTS FOR THE DEBYE PARAMETERS
OF AQUEOUS SODIUM CHLORIDE

Independent variable	Regression coefficients		
	ε_s	$\tau_t \times 10^{12}$ (sec)	$\sigma_i (\mho\ m^{-1})$
constant	0.88195 E 02	0.19390 E 02	————
T_{sea}	-0.40349 E-00	-0.68020 E-00	————
S	-0.43917 E-00	-0.11370 E-00	0.87483 E-01
T_{sea} S	0.43269 E-02	0.58629 E-02	0.45802 E-02
T_{sea}^2	0.65924 E-03	0.95865 E-02	————
S^2	0.16738 E-02	0.11417 E-02	00.25662 E-04
T_{sea}^2 S	-0.92286 E-05	-0.87596 E-04	-0.16914 E-04
T_{sea} S^2	-0.42856 E-04	-0.54577 E-04	-0.37158 E-04
T_{sea}^2 S^2	0.44410 E-07	0.82521 E-06	0.39288 E-06
$\exp(T_{sea})$	————	-0.65303 E-17	————

TABLE III.-RADIOSONDE DATA OBTAINED AT BOOTHVILLE, LA., AT
1715 CST, 11 NOVEMBER 1971, IN SUPPORT OF
MISSION 190, FLIGHT 3, SITE 128

Pressure (mb)	Temperature (°C)	Dew-Point Depression (°C)
1023.5	17.2	5.3
1000.	17.3	5.6
953.	13.5	5.1
939.	13.8	27.0
850.	12.2	28.6
776.	9.4	28.0
500.	-13.4	21.9
400.	-26.9	18.3
314.	-39.4	15.8
200.	-61.7	Dry
171.	-65.4	Dry
159.	-63.8	Dry
128.	-68.4	Dry
121.	-66.1	Dry
100.	-70.6	Dry
95.	-73.0	Dry
50.	-62.5	Dry
41.	-55.3	Dry
23.	-53.5	Dry
17.	-46.2	Dry
13.	-47.6	Dry
10.	-40.5	Dry

TABLE IV.-LIST OF PARAMETERS FROM AMODAP NEEDED
FOR THE ANALYSIS PROGRAM

Parameter	Value
Temperature of selected water area	22.2 °C
Salinity of selected water area	8.0 0/00
Equivalent radiometric temperature of sky (at 45 deg zenith angle)	7.06 °K
Atmospheric transmission factor for intervening atmosphere	0.99982
Emissive brightness temperature of intervening atmosphere	0.1 °K
Sky brightness temperature at surface for the viewing angle of the MFMR	5.15 °K
Zenith angle of viewing	4.8 deg

TABLE V.–CALIBRATION CONSTANTS FOR THE MFMR

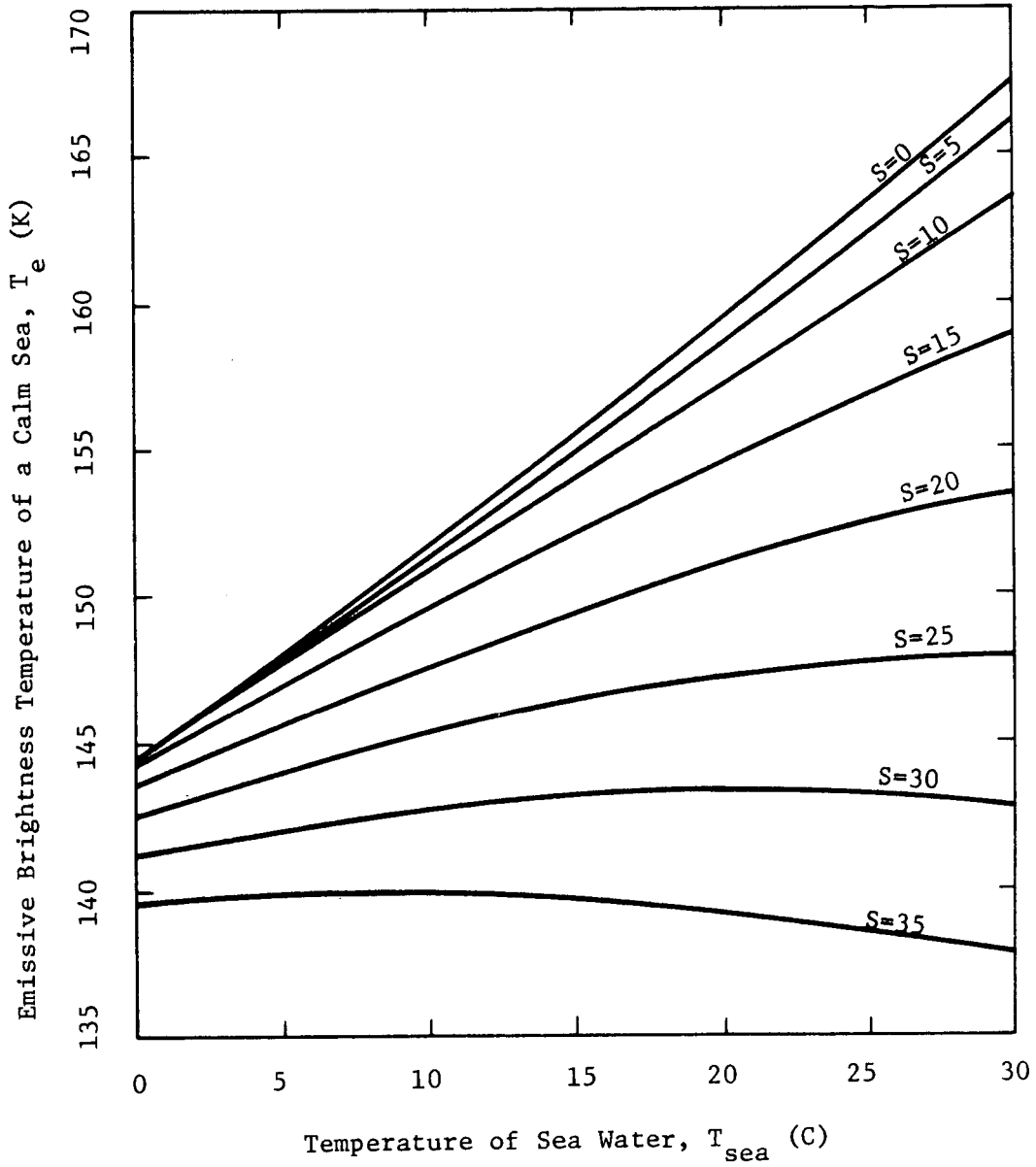| Parameter	Old Value	New Value
Radome loss factor	1.10786	1.10786
Antenna loss factor	1.600	1.509
Waveguide loss factor	1.0423	1.0423
Scale factor	0.5875 °K/cnt	0.49588 °K/cnt
Injected noise	133.0 °K	112.3 °K
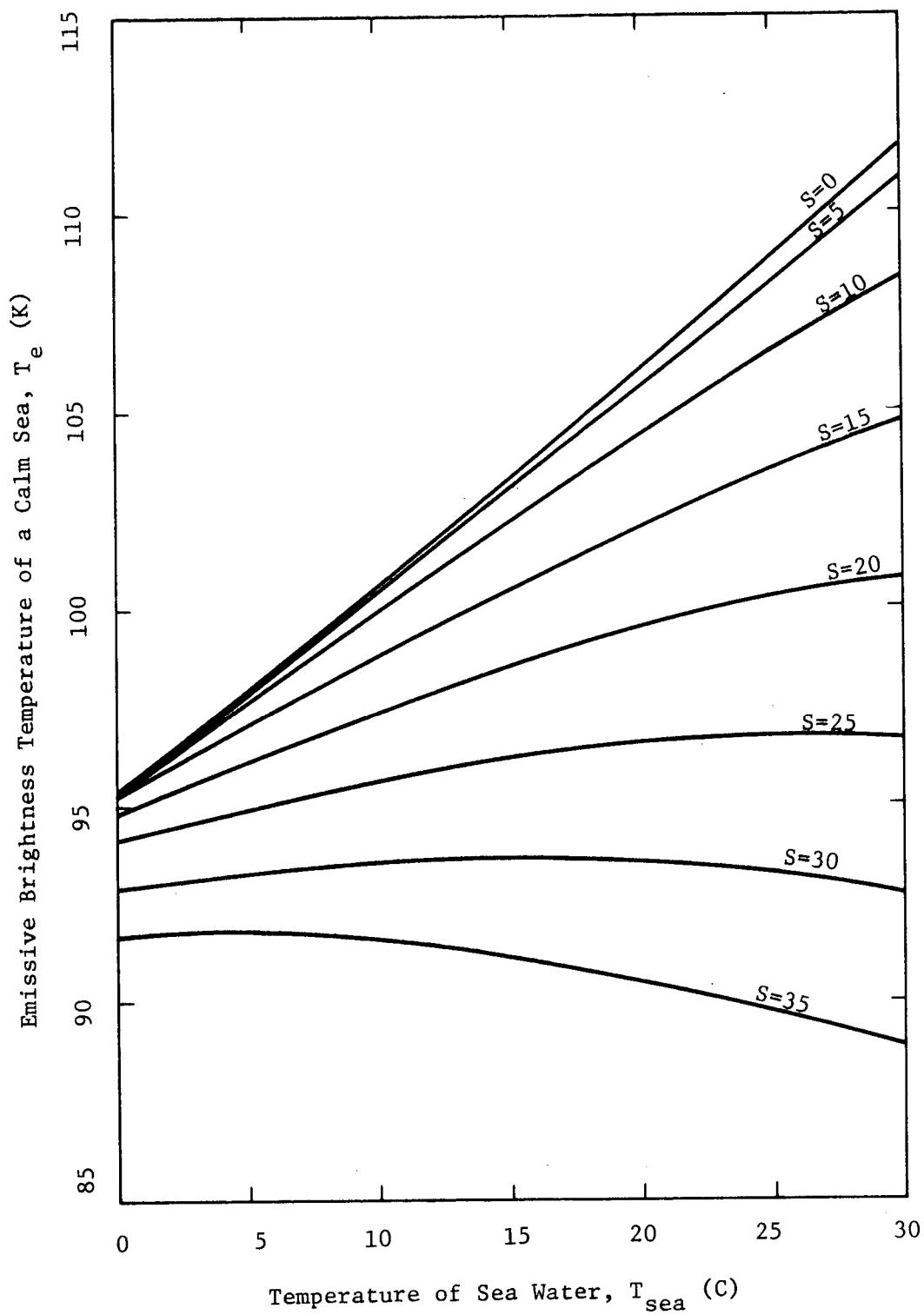
Fig. 1. Microwave emission of a calm sea: $\nu = 1.42$ GHz, $\theta_a = 0$ deg, vertical or horizontal polarization.
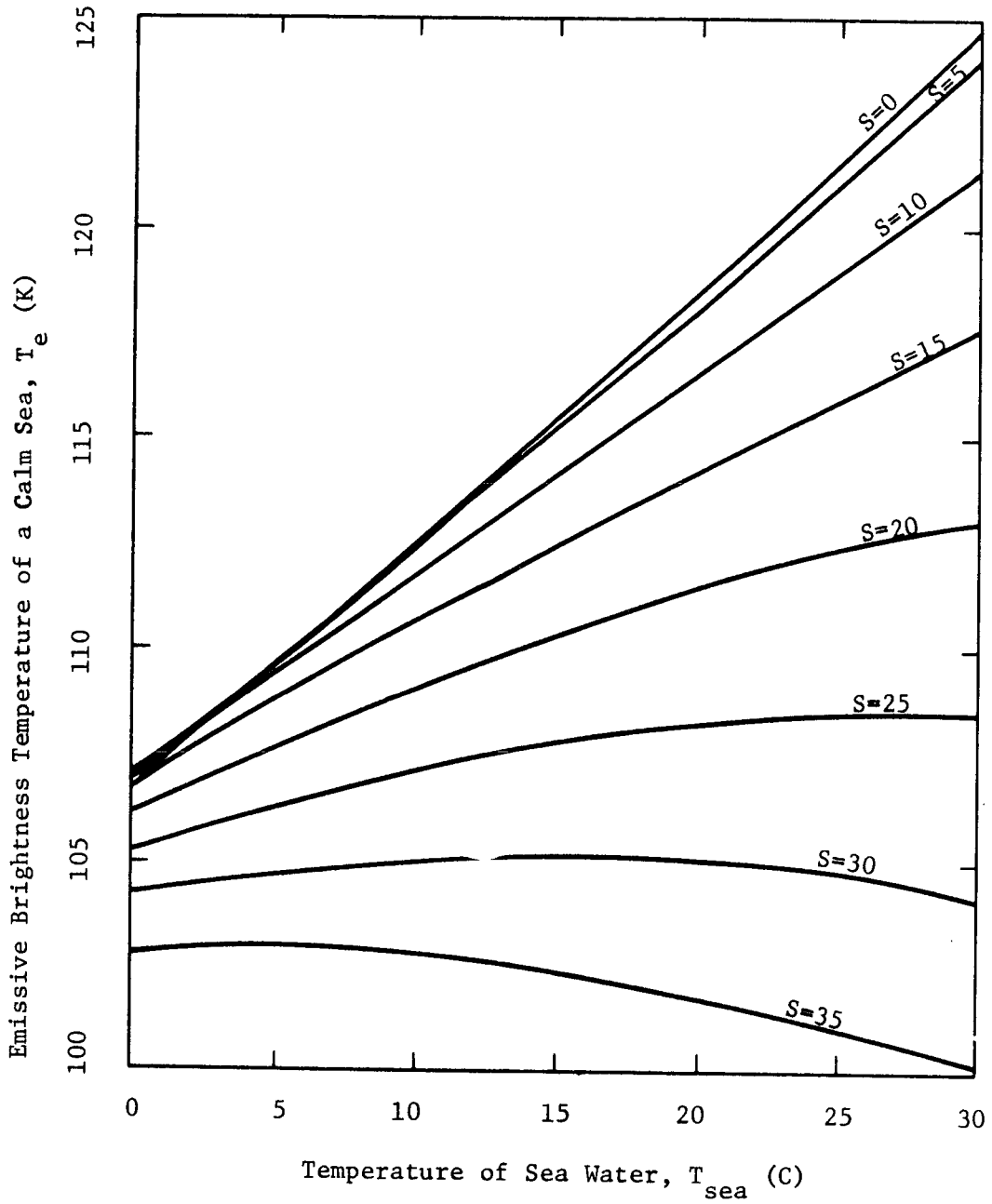
Fig. 2. Microwave emission of a calm sea: $\nu = 1.42$ GHz, $\theta_a = 30$ deg, vertical polarization.

Fig. 3. Microwave emission of a calm sea: $\nu = 1.42$ GHz, $\theta_a = 55$ deg, vertical polarization.
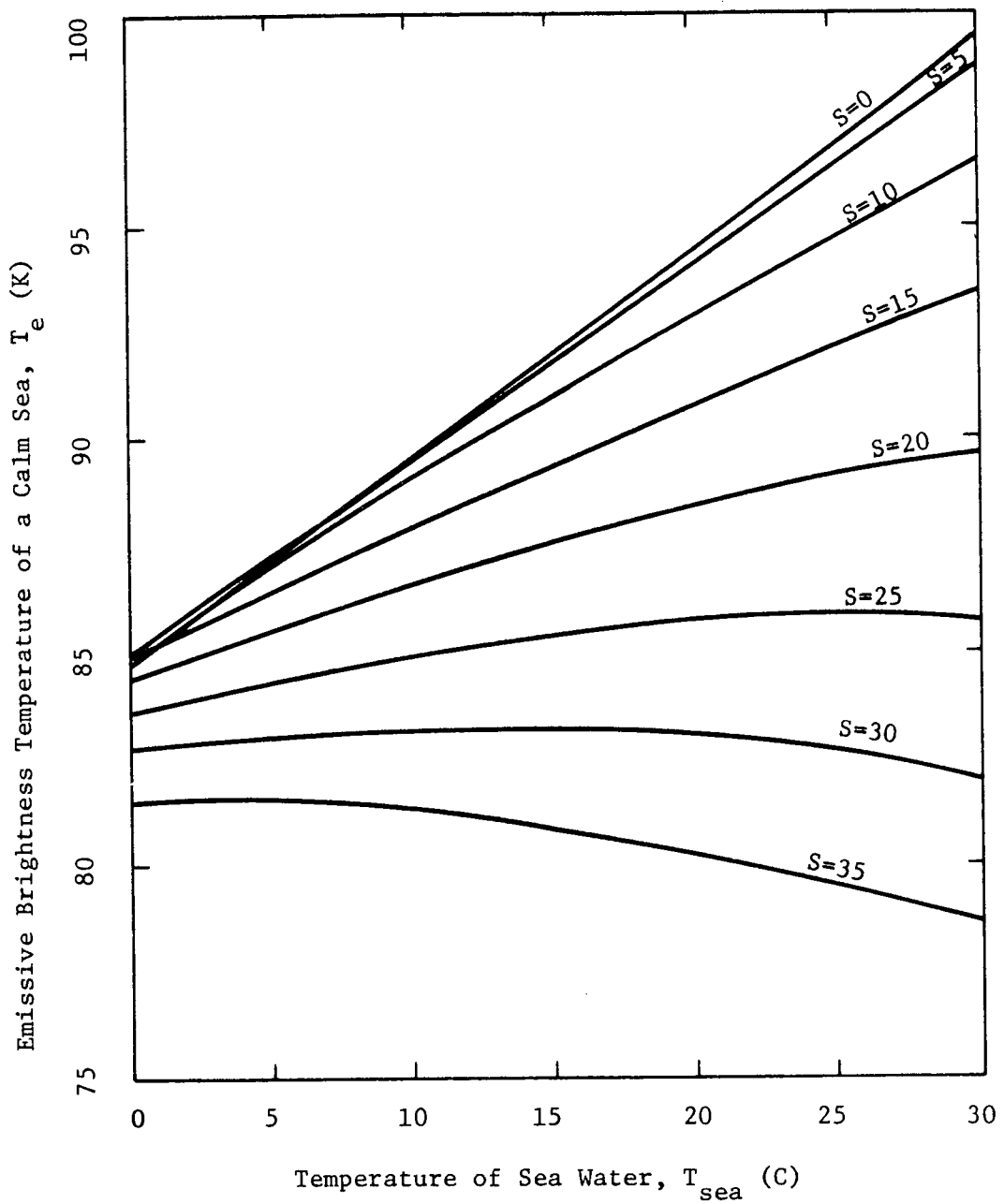
Fig. 4. Microwave emission of a calm sea: $\nu = 1.42$ GHz, $\theta_a = 30$ deg, horizontal polarization.
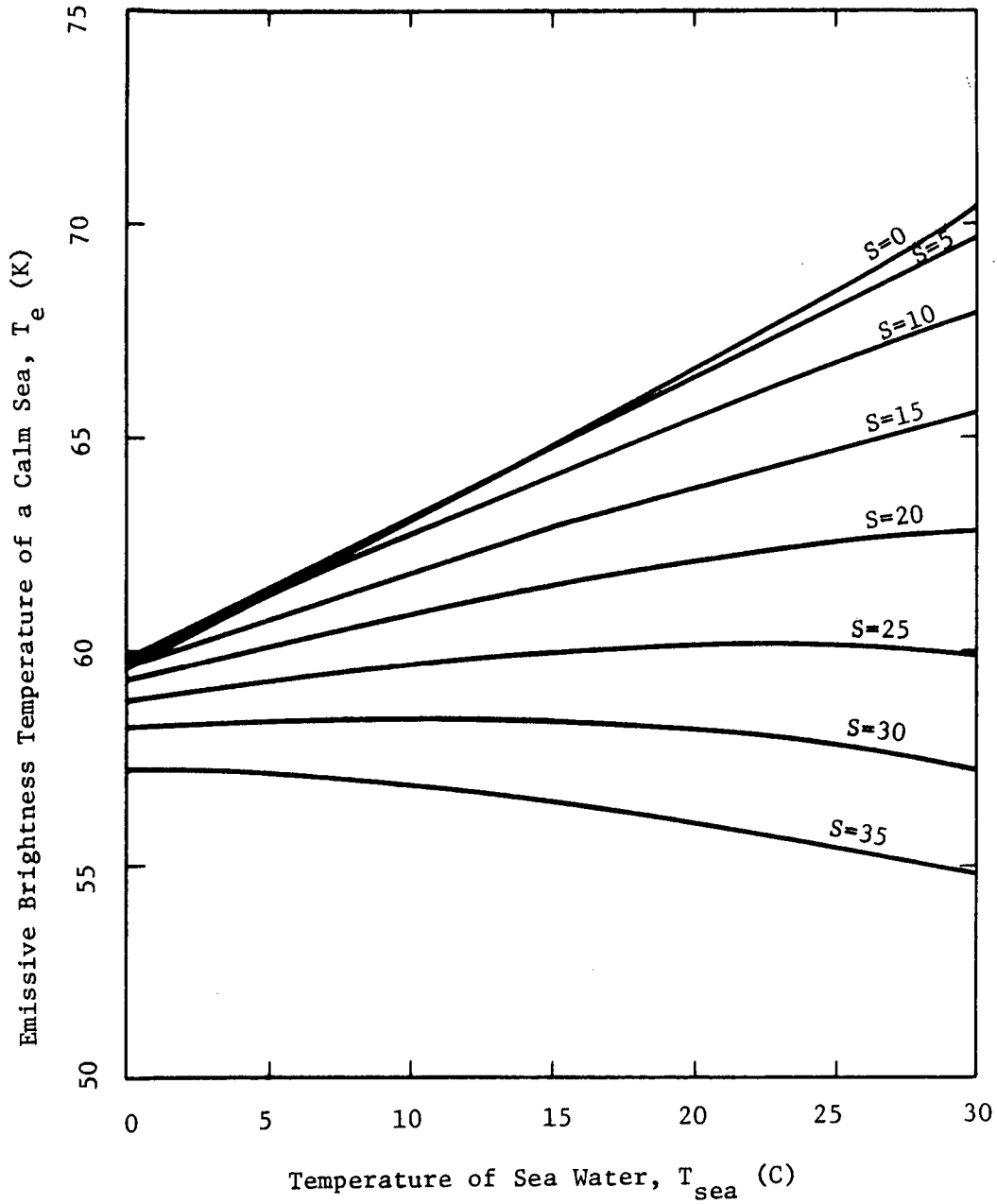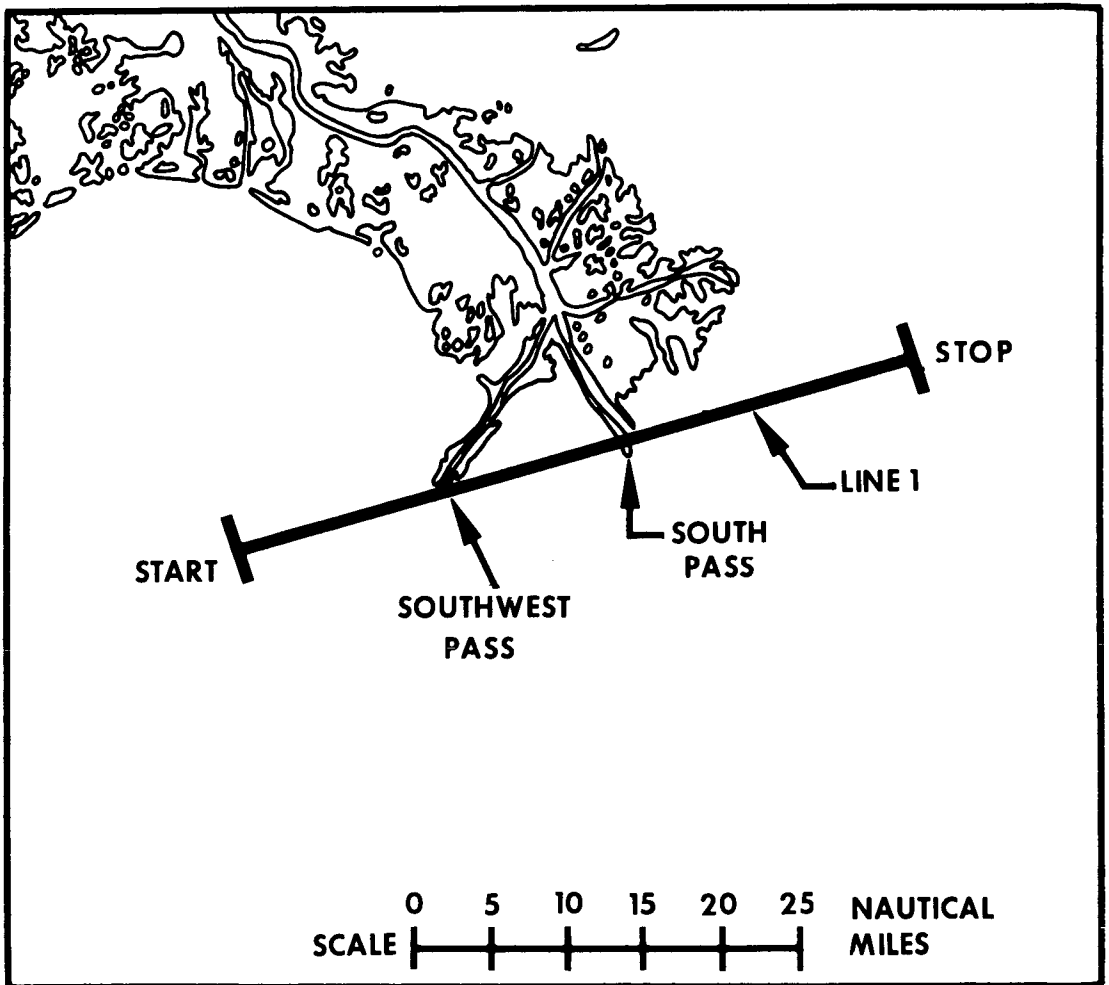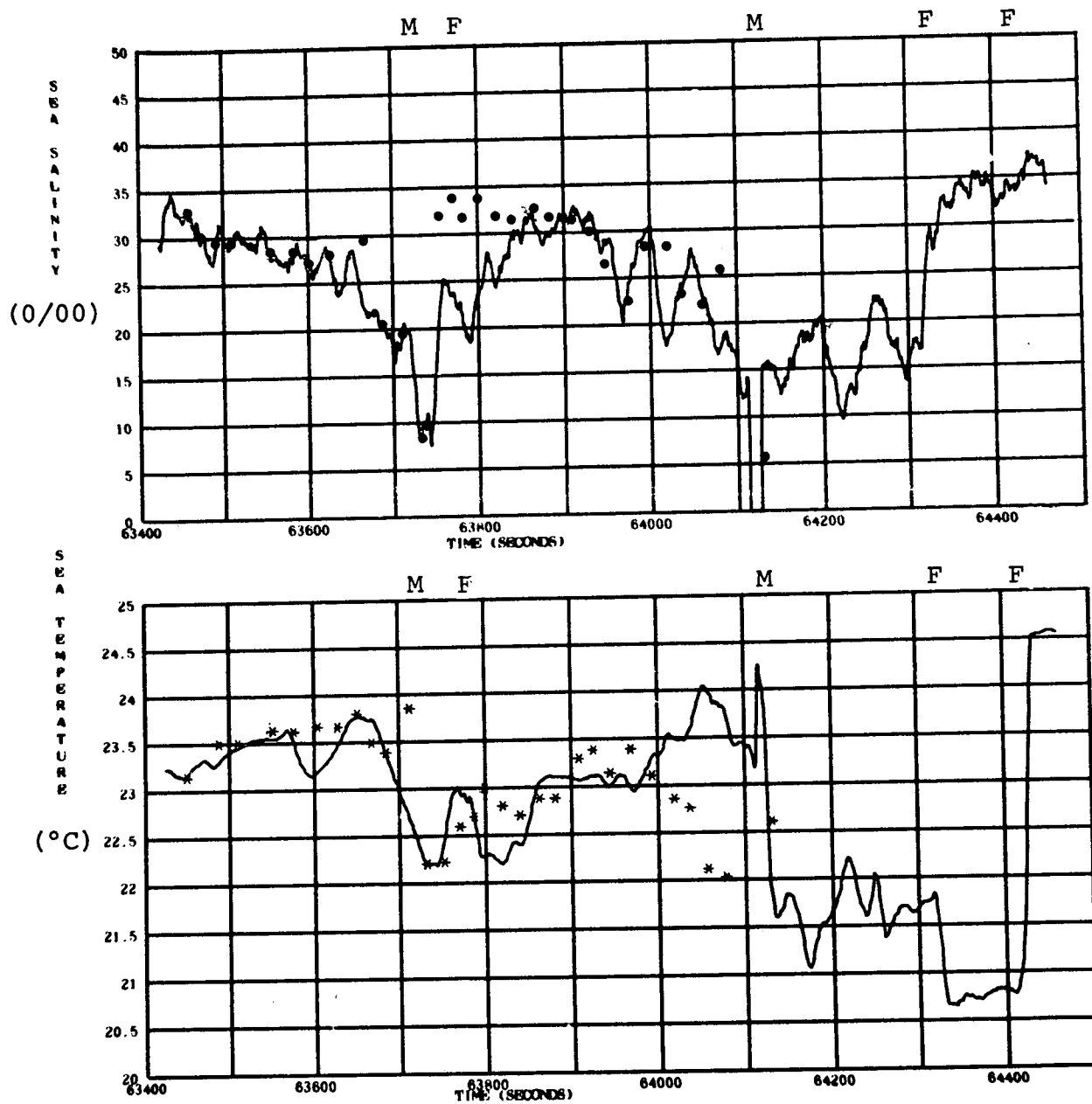
Fig. 5. Microwave emission of a calm sea: $\nu = 1.42$ GHz, $\theta_a = 55$ deg, horizontal polarization.

FLIGHT LINE FLOWN DURING MISSION 190, FLIGHT 3, NOVEMBER 11, 1971

MISSISSIPPI DELTA SITE 128

Fig 6. Flight line flown during mission 190, flight 3, site 128, November 11, 1971.

- • Surface salinity measurement (0/00)

- ∗ Surface Temperature measurement (°C)

Fig 7. Results of mission 190, flight 3, run 8,
over site 128, line 1.