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JPL Field Measurements at the Finney County, Kansas, Test Site, October 1976: Ground-Based Microwave Radiometric Measurements

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Space Administration

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PREFACE

The work described in this report was performed by the Telecommunications Science and Engineering Division of the Jet Propulsion Laboratory.

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Coordination of JPL and JSME experimenters was facilitated by Mr. Ted Buras of the Johnson Space Center (JSC). Drs. Bill Waite of the University of Arkansas and Sri Rao of Kansas University were helpful in organizing and obtaining the JPL ground truth soil samples. Messrs. Jim Beard and Walt Proniewicz of JPL were responsible for the technical operation of the microwave van equipment during the experiment.

CONTENTS

| | | |
|------|---|-----|
| I. | INTRODUCTION ----- | 1-1 |
| II. | INSTRUMENTATION ----- | 2-1 |
| III. | TEST SITE DESCRIPTION ----- | 3-1 |
| IV. | DATA ACQUISITION ----- | 4-1 |
| V. | RESULTS AND DISCUSSION ----- | 5-1 |
| | REFERENCES ----- | 6-1 |
| | APPENDIX. BRIGHTNESS TEMPERATURE DATA (KELVINS) ----- | A-1 |

Figures

| | | |
|------|--|-----|
| 2-1 | JPL Microwave Radiometry Field Van ----- | 2-1 |
| 2-2. | Functional Block Diagram of Measurement System ----- | 2-3 |
| 2-3. | JPL Field Van in Motion With Antennas in Deployed Position ----- | 2-4 |
| 3-1. | Map of JSME Finney County Test Site (JPL Sites in Boldface Numbers) ----- | 3-2 |
| 3-2. | Site 3 ----- | 3-3 |
| 3-3. | Site 7 ----- | 3-3 |
| 3-4. | Site 8B ----- | 3-4 |
| 3-5. | Site 10 ----- | 3-4 |
| 3-6. | Site 12 ----- | 3-5 |
| 3-7. | Site 14 ----- | 3-5 |
| 4-1. | Locations for JPL Soil Samples ----- | 4-1 |
| 5-1. | Brightness Temperature vs. Viewing Angle; Site 8B, 10.69 and 31.4 GHz ----- | 5-2 |

| | | |
|------|--|-----|
| 5-2. | Brightness Temperature vs. Viewing Angle; Site 14, 10.69 and 31.4 GHz ----- | 5-3 |
| 5-3. | Brightness Temperature vs. Viewing Angle; Site 10, 10.69 and 31.4 GHz ----- | 5-4 |
| 5-4. | Brightness Temperature vs. Viewing Angle; Sites 3, 7, and 12, 10.69 GHz ----- | 5-5 |
| 5-5. | Brightness Temperature vs. Viewing Angle; Site 8B, 10.69 GHz ----- | 5-6 |

Table

| | | |
|------|--|-----|
| 2-1. | Radiometer and Antenna Characteristics ----- | 2-2 |
|------|--|-----|

ABSTRACT

Microwave brightness temperature measurement were made at the Finney County, Kansas, test site as part of the Joint Soil Moisture Experiment (JSME) during October 9-14, 1976. These measurements are reported here, with a description of the JPL microwave radiometry van facility. The data will be used with ground truth data from the test site and microwave data from aircraft overflights to investigate the potential of microwave radiometry for soil moisture remote sensing under field conditions.

SECTION I

INTRODUCTION

This document contains the data collected by the JPL Ground Based Microwave Applications Group at the Finney County, Kansas, test site as part of the Joint Soil Moisture Experiment (JSME) during October 9-14, 1976. The purpose of the measurements was to study the dependence of microwave radiometric brightness temperature on soil moisture under field conditions of varying surface roughness, soil temperature, and vegetation cover. Simultaneously with the ground-based measurements, a NASA P3A aircraft carrying the PMIS and MFMR microwave radiometers was flown along three flight lines within the test site. Although footprint size and areal coverage differ considerably between the two systems, it was hoped that a good comparison of the ground-based and aircraft data could be made.

The data presented in this report consist of microwave brightness temperatures obtained over a selected number of fields along the three flight lines within the test site using the JPL microwave radiometry field van. The aircraft data are not available at the present time. Surface truth measurements of the soil moisture, bulk density, and temperature profiles were obtained at the times and locations of the JPL measurements. Soil samples taken for the moisture content, bulk density, and textural analyses were included for processing with the JSME samples from other field locations. This processing is as yet incomplete.

The brightness temperature data are thus presented here without interpretation in terms of soil properties, for the purpose of JSME usage when the remaining data become available. Data pertaining to the meteorological conditions (air speed, temperature, and relative humidity) and soil temperature profiles were collected during the experiment by the JPL Earth Applications and Climatology Group personnel. It is expected that an integration of the microwave emission and thermal inertia models will provide a more effective approach to the remote sensing of soil moisture. The meteorological data from the experiment have been published in a companion report (Ref. 1).

Technical difficulties were encountered with the data processing system during the experiment, which reduced the amount of useful data that could be obtained within the 2-day experiment period. However, the remaining data are presented in what follows, with a detailed discussion of the JPL microwave van instrumentation and data taking procedures, and a description of the field measurements sites.

SECTION II

INSTRUMENTATION

The JPL microwave radiometry field van is shown schematically in Fig. 2-1. The four dual-polarized, Dicke-switched radiometers operate at center frequencies of 0.5 to 1 GHz (tunable), 1.42, 10.69, and 31.4 GHz. During the experiment, the tunable radiometer was operated at a fixed frequency of 0.85 GHz to minimize the radio frequency interference (RFI) observed on the signal. The two lower-frequency radiometers share a 2.4 m parabolic reflector antenna, while lens-loaded horn antennas are used for the two higher frequencies. Antenna and radiometer characteristics are summarized in Table 2-1.

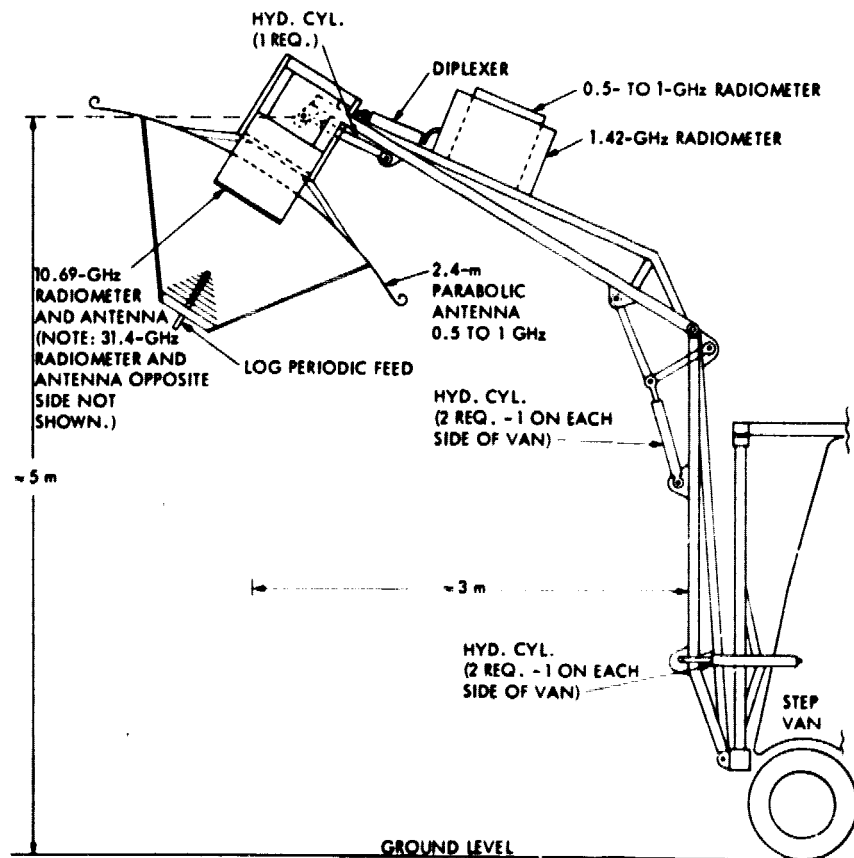


Figure 2-1. JPL Microwave Radiometry Field Van

Table 2-1. Radiometer and Antenna Characteristics

| Center Frequency, GHz | 0.5-1.0 | 1.42 | 10.69 | 31.4 |
|-----------------------|---|------|------------------|------------------|
| Wavelength, cm | 60-30 | 21 | 2.8 | 0.95 |
| Bandwidth, MHz | 60 | 220 | 220 | 220 |
| Polarization | V,H | V,H | V,H | V,H |
| Integration time, s | 2 | 2 | 2 | 2 |
| Flux sensitivity, K | 0.5 | 1.0 | 0.6 | 0.9 |
| Antenna type | 2.4-m parabolic reflector (log-periodic feed) | | Lens-loaded horn | Lens-loaded horn |
| 3-dB beamwidth, deg | 10 | 6 | 7 | 5 |

The radiometer and antenna system is calibrated by a two-point external calibration: viewing clear sky and then microwave absorber at ambient temperature placed in front of the antennas. In addition, instrument temperatures are monitored during the experiment and, together with prior knowledge of the component losses, are used to calibrate out the effects of instrument temperature variations during the experiment. Short-term calibration of the radiometers alone is accomplished by switching between two internal reference loads. It is estimated that an absolute accuracy of 3 K is achieved by this method.

The radiometers and antennas are positioned by a hydraulically operated boom assembly mounted on the front of the van. Under normal operating conditions the antennas are positioned 3.7 m above ground level and 4.6 m from the front of the van. This places the viewing target in the far fields of the horn antennas but in the near field of the parabolic dish. The viewing angle can be continuously varied from 25 deg of nadir to zenith. The van contains the radiometer controls and data processing electronics, including a PDP/8L computer for real-time data reduction. Data output consists of printed copy raw data, calibration data, and calibrated antenna temperatures; this data can be stored on IBM compatible tape for further processing. The antenna temperatures are not yet corrected for antenna pattern effects. A backup system prints out raw data on paper tape, and in addition, the radiometer output levels are displayed continuously on strip chart recorders. A functional block diagram of the system is shown in Figure 2-2.

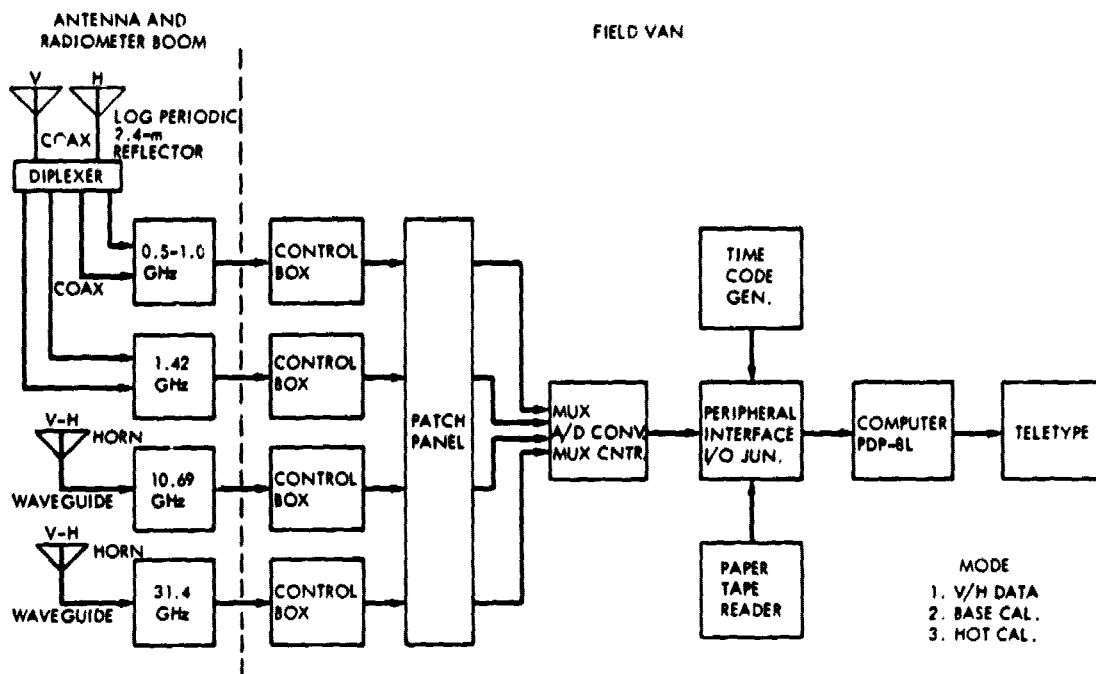


Figure 2-2. Functional Block Diagram of Measurement System

Several redesigns and improvements had been made to the JPL field van prior to the JSME experiment, and in view of the October deadline, these had to be incorporated under a tight schedule. Two technical problems were encountered during the measurements at Finney County which could not be corrected within the experiment time frame. First, it was found that the multiplexer unit was injecting spurious noise into the 1.42-GHz channel and to a lesser extent into the 0.85-GHz channel. Thus the 1.42-GHz data from the experiment could not be used, and the accuracy of the 0.85-GHz data was suspect. Secondly, a switch failure occurred in the 31.4-GHz radiometer at the end of the first day's measurements; thus only data from three field locations was recorded with this channel.

The goals of the experiment required that as many fields as possible be observed by the field van radiometers during the 2 days of aircraft overflights, since the JSME ground truth teams would be operating on these 2 days only. Thus speed in moving from one measurement field site to the next was of importance. Fortunately the terrain was not too rough, and the van could be moved with the antennas in the deployed position, thus minimizing transition time between sites. Figure 2-3 shows the van in motion with the antenna trailer in tow.

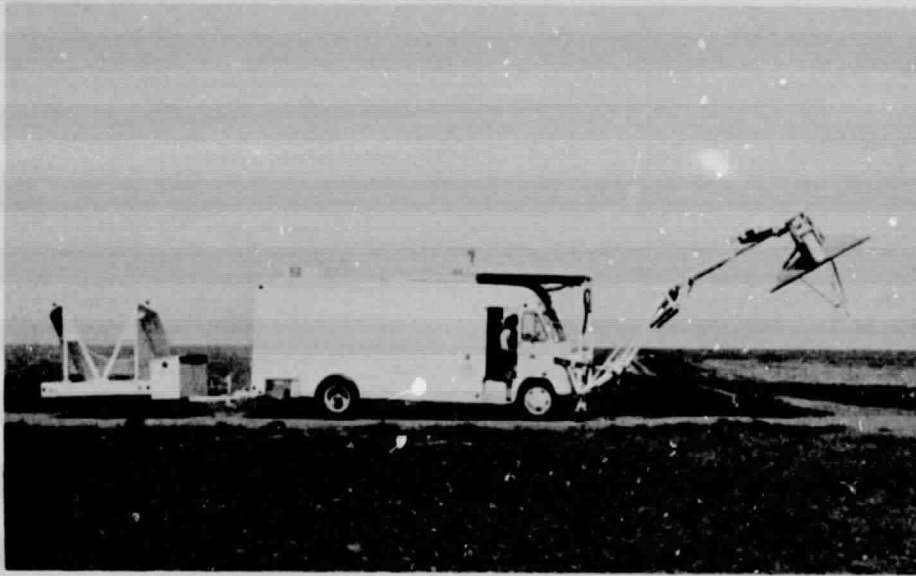


Figure 2-3. JPL Field Van in Motion With Antennas in Deployed Position

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SECTION III

TEST SITE DESCRIPTION

The Finney County, Kansas, test site is shown in Fig. 3-1. Flight lines 1, 2, and 4 were flown with the NASA aircraft on October 13 and 14. Six field locations were chosen along these flight lines for the ground-based microwave measurements. These are marked in Fig. 3-1. The numbering of the site corresponds to the convention adopted in the companion report (Ref. 1-1). The individual sites are shown in detail in Figs. 3-2 to 3-7 and are described as follows:

- Site 3: (Fig. 3-2). Wheat stubble field. Western edge of field Q (just east of field 129a), looking east. Wheat stubble, dry, yellowed, 25 to 50 cm high, some upright, some matted down, with 5-10% green volunteer wheat. Underlying surface quite smooth.
- Site 7: (Fig. 3-3). Newly planted wheat field. Western edge of field 38b, looking east. New winter wheat, 5-8 cm high. Furrows transverse to viewing direction.
- Site 8B: (Fig. 3-4). Newly planted wheat field. Western edge of field 50d, looking east. Newly planted, no wheat visible. Furrows transverse to viewing direction.
- Site 10: (Fig. 3-5). Newly planted wheat field. Eastern edge of field 30a, looking west. Newly planted, no wheat visible. Furrows transverse to viewing direction close in, and along viewing direction further out.
- Site 12: (Fig. 3-6). Mature milo field. Southwest corner of field 26 looking northeast. Solid, unharvested milo with heads of reddish brown grain, 1-1.5 m high.
- Site 14: (Fig. 3-7). Newly planted wheat field. Eastern edge of field 18, looking west. Newly planted winter wheat, 10-13 cm high. Furrows diagonal to viewing direction close in, and along viewing direction further out.

In choosing these sites, an attempt was made to find a number of bare fields with furrows running either along or transverse to the viewing direction. Sites 7, 8B, 10, and 14 satisfied this condition quite well, although in general no field had furrows entirely in one direction; rather they were ploughed in different directions in different areas of the field. Furrow orientation is expected to have a significant effect on the brightness temperatures; thus correlation of aircraft data (larger antenna footprints encompassing several furrow directions) with the ground-based data may prove to be difficult. Site 12 was chosen to measure the response from a fully developed milo field, and site 3 was selected to study the effect of sparse vegetation over an underlying relatively smooth surface.



Figure 3-2. Site 3



Figure 3-3. Site 7

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Figure 3-4. Site 8B

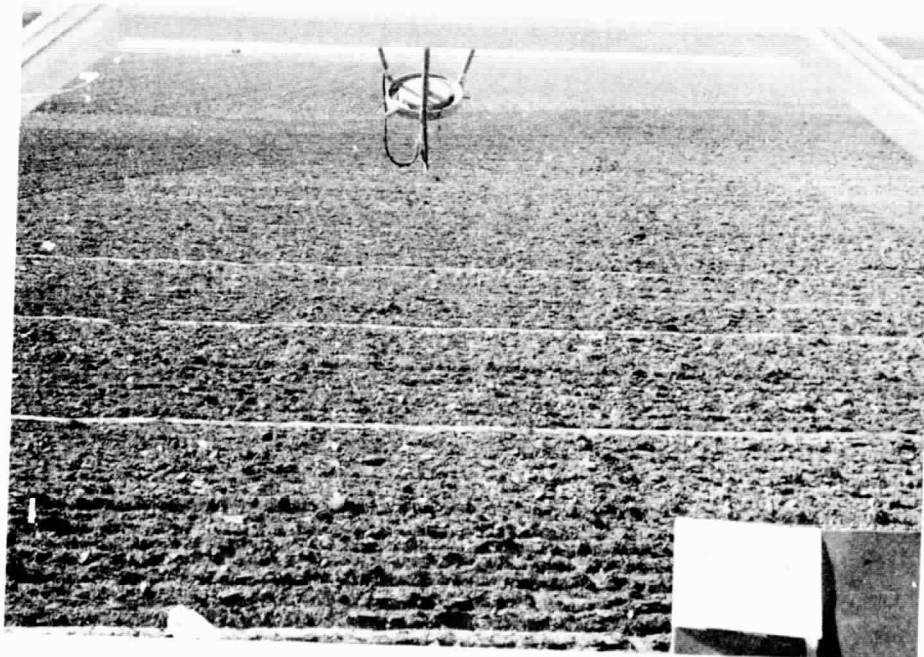


Figure 3-5. Site 10

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Figure 3-6. Site 12

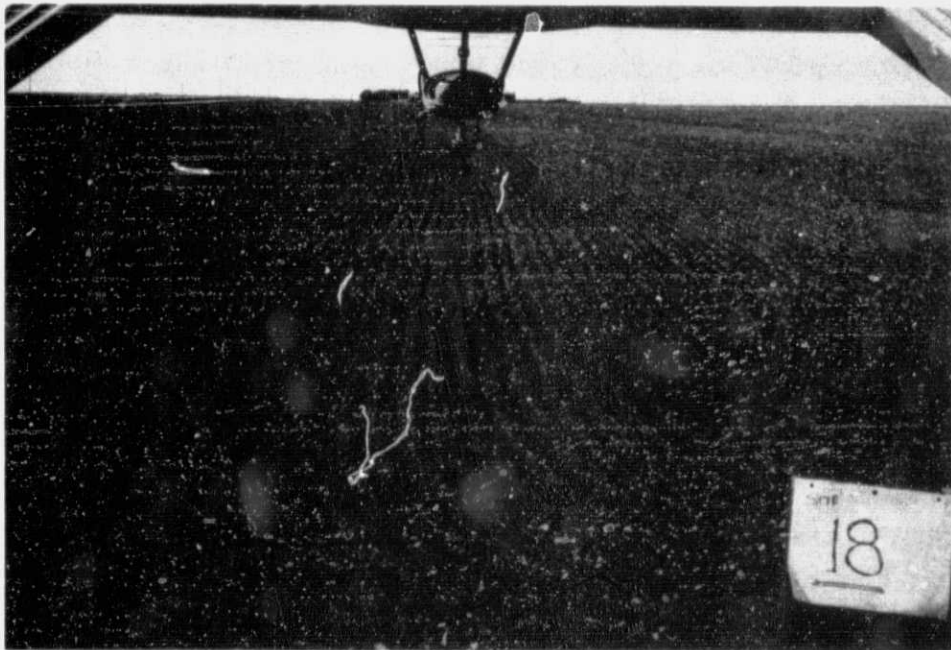


Figure 3-7. Site 14

The furrowed fields could be described as having a two-scale surface roughness. The furrows were 25 cm from peak to peak and 10 cm deep from peak to trough. The soil itself was cracked and crumbly, thus giving a fine-scale roughness to the furrows.

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SECTION IV

DATA ACQUISITION

At each site, the radiometry van was positioned at the edge of the field, so that at the lowest incidence angle of 25 deg, the antenna footprints were about 6 m from the edge of the field. Before each set of measurements, the antennas were rotated towards zenith for a clear sky calibration. They were then directed towards the ground, and data was taken at successive angles of 25, 35, 40, 45 and 55 deg from nadir. The lowest angle used was 25 deg in order to avoid shadowing by the 2.4-m reflector dish. At each angular position, for each frequency, ten 2-s samples of data were taken for both polarizations. At the beginning and end of each set of measurements, the radiometers were switched to their hot and cold (reference) loads for an internal calibration. The resulting data are in the form of calibrated antenna temperatures and have not been corrected for the effects of antenna pattern and atmospheric effects, although these are expected to be small.

A JSME ground truth team was assigned to the JPL van, and at each site soil samples were obtained at two locations just outside the antennas' fields of view. These locations are shown diagrammatically in Fig. 4-1. The sampling procedure was the same as that used for obtaining the JSME samples from other field locations and consisted of taking core samples, dividing them into depth increments, and placing them in sealed containers. These samples are being analyzed for moisture content, bulk density, and texture. Thermocouple probes were also placed in the soil at nearby locations to record the temperature profile during the radiometric measurements. These are reported in Ref. 1.

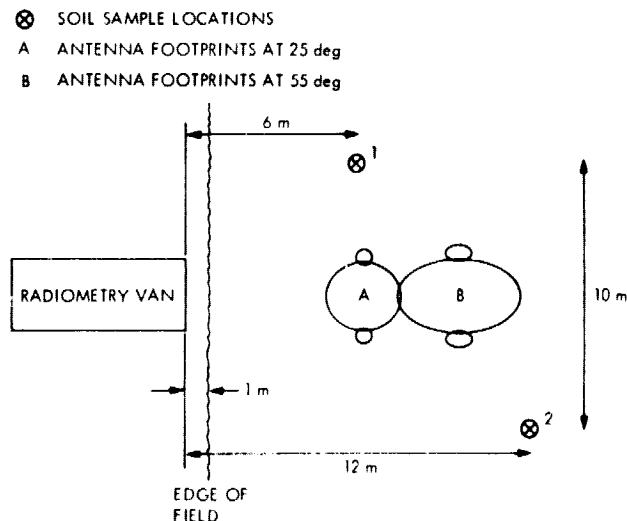


Figure 4-1. Locations for JPL Soil Samples

Because of the fixed position of the microwave van, a different area of the site was viewed at each angular position of the antennas. This should present no problem, providing the soil moisture, temperature, and surface condition were fairly homogeneous over the viewing area. In Fig. 3-7, however, it can be seen that whereas at large incidence angles the furrows of site are along the viewing direction, at low incidence angles the furrows have curved in a diagonal direction. This should be taken into account in the data interpretation.

Since the van could be moved from one field site to another with antennas in the deployed position, less than an hour was required for preparation and measurements at each site.

SECTION V

RESULTS AND DISCUSSION

The radiometric data are tabulated in the appendix and plotted in Figs. 5-1 to 5-5. The following brief comments can be made concerning the results.

The fields within the test site appeared to be fairly homogeneous in terms of their near-surface moisture content. This meant that not much useful information could be obtained from these sites concerning the dependence of brightness temperature on soil moisture content over the full range of possible moisture contents. In this respect the Kansas test sites were not ideal for an independent ground-based study. However, useful information was obtained concerning the effects of roughness and diurnal temperature variations.

The 31.4-GHz data show little dependence on angle, indicating that small-scale roughness is the dominating surface feature at this wavelength. The variations in brightness temperatures from one field to the next follow quite closely the variations in the soil surface temperatures. Thus the surface soil moisture contents appear to be fairly uniform (and dry) over the sites observed.

The 10.69-GHz data from the unvegetated fields show a greater dependence on angle, with some difference between vertical and horizontal polarizations. The larger roughness scale of the furrows appears to be having an effect at this frequency. The difference between polarizations is greater for the longitudinal furrows of site 14 than for the transverse furrows of sites 8B, 10, and 7. Figure 5-5 presents data from site 8B at four different times on the same day, showing the effect of soil temperature variations.

The greatest angular dependence is found for site 3. The specular nature of the underlying surface is quite visible through the sparse, dry stubble. For the mature milo field (site 12), at large viewing angles, mostly the heads and stalks of the plants are being observed, whereas at the lowest viewing angle, areas of the underlying soil can be seen from more directly overhead. The stalks and soil are significantly cooler than the exposed bare soil fields.

A more detailed discussion can be presented when the soil moisture content data becomes available.

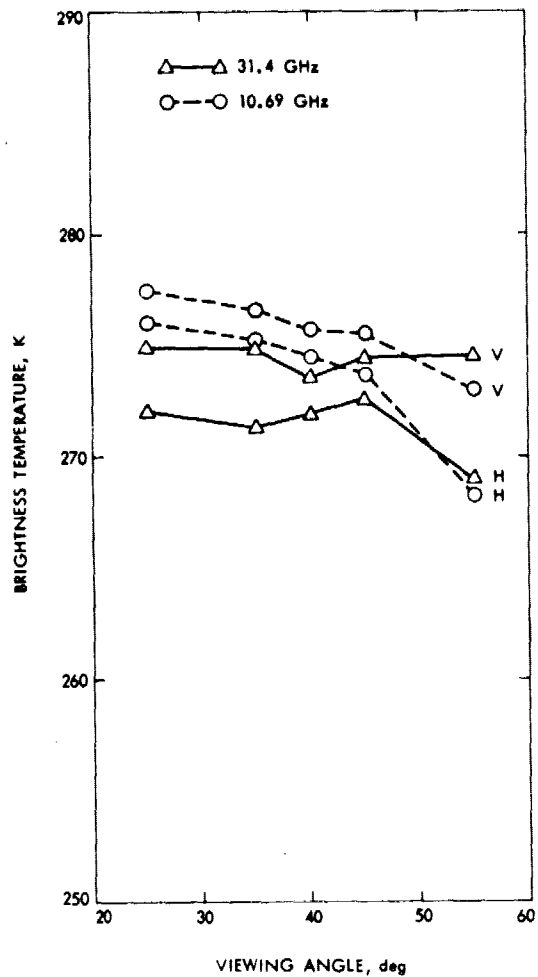


Figure 5-1. Brightness Temperature vs. Viewing Angle; Site 8B, 10.69 and 31.4 GHz

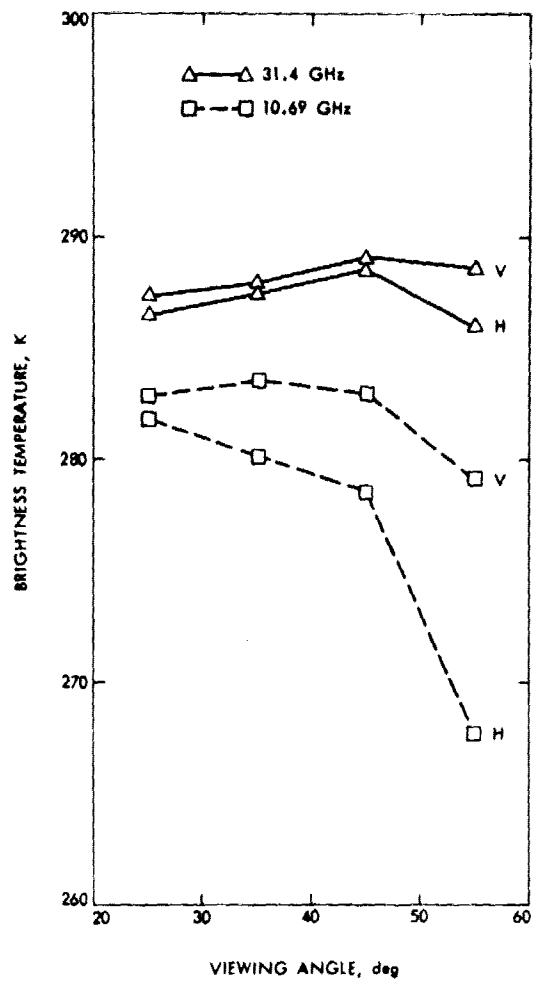


Figure 5-2. Brightness Temperature vs. Viewing Angle; Site 14, 10.69 and 31.4 GHz

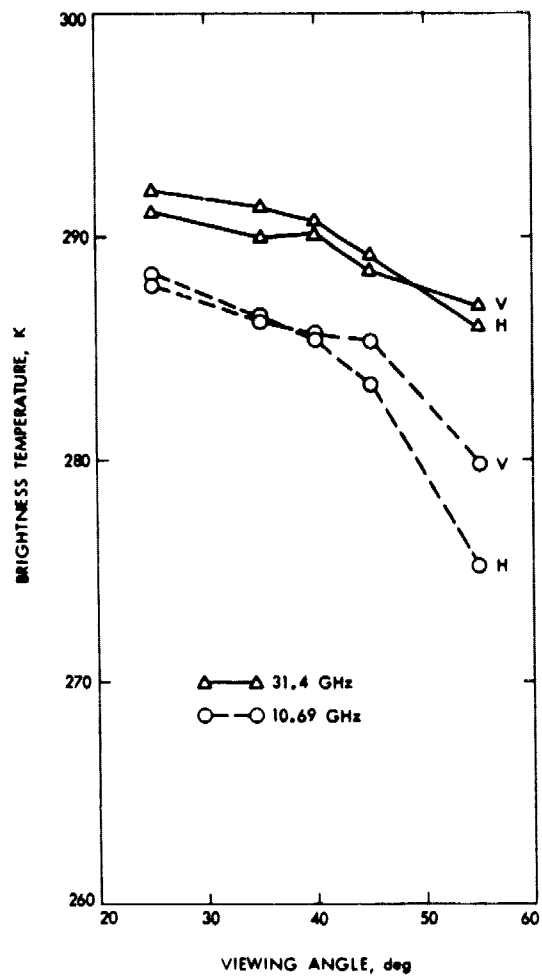


Figure 5-3. Brightness Temperature vs. Viewing Angle; Site 10, 10.69 and 31.4 GHz

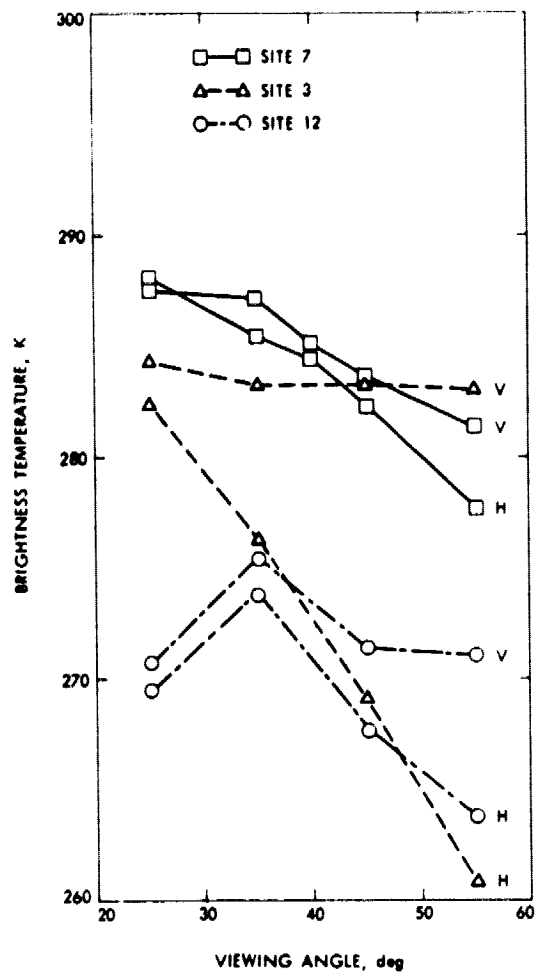


Figure 5-4. Brightness Temperature vs. Viewing Angle; Sites 3, 7, and 12, 10.69 GHz

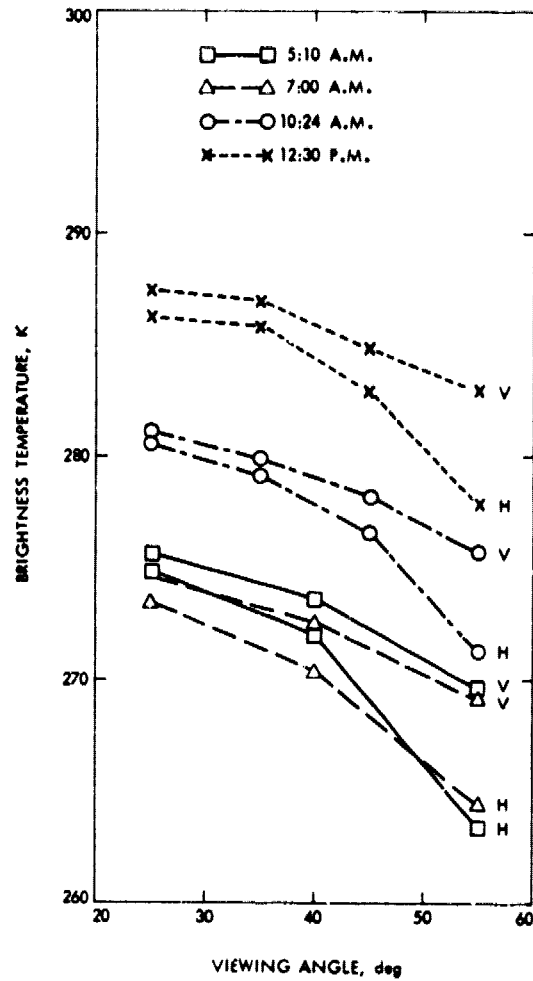


Figure 5-5. Brightness Temperature
vs. Viewing Angle;
Site 8B, 10.69 GHz

REFERENCES

- 1-1. Kahle, A. B., J. Schieldge, and H. N. Paley, JPL Field Measurements at the Finney County Kansas Test Site, Oct., 1976: Meteorological Variables, Surface Reflectivity, Surface and Subsurface Temperature. Publication 77-1, Jet Propulsion Laboratory, 1977.

APPENDIX

BRIGHTNESS TEMPERATURE DATA (KELVINS)

31.4 GHz (vertical polarization)

| Date | Time | Site | 25 deg | 35 deg | 40 deg | 45 deg | 55 deg |
|-------|------|------|--------|--------|--------|--------|--------|
| 10/13 | 1020 | 8B | 274.9 | 274.8 | 273.5 | 274.5 | 274.6 |
| 10/13 | 1200 | 14 | 287.4 | 288.0 | | 289.2 | 288.7 |
| 10/13 | 1345 | 10 | 291.2 | 290.0 | 290.2 | 288.3 | 286.8 |

31.4 GHz (horizontal polarization)

| Date | Time | Site | 25 deg | 35 deg | 40 deg | 45 deg | 55 deg |
|-------|------|------|--------|--------|--------|--------|--------|
| 10/13 | 1020 | 8B | 272.1 | 271.4 | 272.0 | 272.6 | 269.0 |
| 10/13 | 1200 | 14 | 287.4 | 287.6 | | 288.6 | 286.0 |
| 10/13 | 1345 | 10 | 292.2 | 291.3 | 290.8 | 289.1 | 285.9 |

10.69 GHz (vertical polarization)

| Date | Time | Site | 25 deg | 35 deg | 40 deg | 45 deg | 55 deg |
|-------|------|------|--------|--------|--------|--------|--------|
| 10/13 | 1020 | 8B | 277.4 | 276.6 | 275.6 | 275.5 | 272.9 |
| 10/13 | 1200 | 14 | 282.8 | 283.6 | | 283.0 | 278.9 |
| 10/13 | 1345 | 10 | 287.8 | 286.2 | 285.7 | 285.3 | 279.8 |
| 10/13 | 1600 | 7 | 287.5 | 287.2 | 285.0 | 283.6 | 281.3 |
| 10/14 | 0510 | 8B | 274.7 | | 273.7 | | 269.7 |
| 10/14 | 0700 | 8B | 274.6 | | 272.7 | | 269.1 |
| 10/14 | 1024 | 8B | 281.2 | 279.8 | | 278.2 | 275.7 |
| 10/14 | 1137 | 12 | 270.7 | 275.5 | | 271.3 | 271.1 |
| 10/14 | 1230 | 8B | 287.4 | 287.0 | | 284.9 | 283.0 |
| 10/14 | 1350 | 3 | 284.4 | 283.2 | | 283.4 | 283.0 |

10.69 GHz (horizontal polarization)

| Date | Time | Site | 25 deg | 35 deg | 40 deg | 45 deg | 55 deg |
|-------|------|------|--------|--------|--------|--------|--------|
| 10/13 | 1020 | 8B | 276.0 | 275.2 | 274.5 | 273.6 | 268.2 |
| 10/13 | 1200 | 14 | 281.8 | 280.1 | | 278.6 | 267.7 |
| 10/13 | 1345 | 10 | 288.4 | 286.3 | 285.3 | 283.2 | 275.1 |
| 10/13 | 1600 | 7 | 288.0 | 285.4 | 284.4 | 282.2 | 277.6 |
| 10/14 | 0510 | 8B | 274.8 | | 272.0 | | 266.3 |
| 10/14 | 0700 | 8B | 273.5 | | 270.5 | | 264.4 |
| 10/14 | 1024 | 8B | 280.6 | 279.1 | | 276.6 | 271.2 |
| 10/14 | 1137 | 12 | 269.3 | 273.9 | | 267.7 | 263.8 |
| 10/14 | 1230 | 8B | 286.3 | 285.9 | | 283.0 | 277.8 |
| 10/14 | 1350 | 3 | 282.4 | 276.4 | | 269.1 | 200.9 |