CHAPTER XVI: MULTIFREQUENCY TRUCK-MOUNTED RADAR SYSTEM

Peggy E. O'Neill
Hydrological Sciences Branch/Code 974
Laboratory for Hydrospheric Processes
NASA/Goddard Space Flight Center
Greenbelt, MD 20771

John J. Petrella
Department of Electrical Engineering and
Computer Science
George Washington University
Washington, DC 20052

John E. Fuchs
Science Systems & Applications, Inc.
5900 Princess Garden Parkway, Suite 300
Lanham, MD 20706

A. INTRODUCTION

The Hydrological Sciences Branch (Code 974) at NASA Goddard Space Flight Center currently operates a quad-polarized multifrequency truck-mounted radar system in conjunction with Dr. Roger Lang of George Washington University. This radar system consists of L, C, and X band radars which closely approximate the L, C, and X band radars on SIR-C and the L and C band radars on NASA/JPL's airborne AIRSAR system. The truck radar was deployed to Chickasha, Oklahoma in support of the Washita '94 experiment in April (funding limitations prevented its return for the August and October campaigns). Eight days of truck radar data were acquired over four agricultural and pasture sites to complement simultaneous aircraft and SIR-C microwave measurements (Chapters XVII - XIX). These radar data will be used in the following analyses:

1. to investigate and document the capabilities of microwave sensors for soil moisture estimation and for modeling microwave backscatter through vegetation canopies;

2. to examine synergistic effects between active and passive microwave sensors for soil moisture estimation; and

3. to compare microwave data at different scales from different platforms (GSFC truck radar, aircraft AIRSAR and ESTAR, and SIR-C).

The truck radar measurements also directly contribute to the main objectives of our SIR-C investigation, which include determination of the spatial and temporal distribution of soil moisture in a humid-area watershed using SIR-C data, ground measurements, and hydrologic modeling, and the subsequent incorporation of the measured soil moisture patterns in models of larger scale water balance and partial area hydrology.

B. RADAR SYSTEM DESCRIPTION

A 1990 Navstar hydraulic boom truck serves as a mobile staging platform for GSFC's multifrequency radar system (Fig. XVI-1). This vehicle permits stable deployment of sensor packages up to ~ 250 kg in weight to a maximum height of ~ 19 m above the ground with hydraulically driven motion in three planes. The system includes an inclinometer with direct digital readout for boom platform angle, a helium-neon laser for pointing accuracy during external calibration runs, and a portable electrical generator for instrument power at remote sites.

Since its use during the Washita '92 experiment, the GSFC truck radar has been modified to become operational at C and X bands in addition to L band, with a single transmit-receive antenna at each frequency. The L band antenna consists of a 1.2 - m parabolic dish, while smaller horn antennas are used for the C and X band radars. Antenna 3 dB beamwidths range from 9° - 12° depending on frequency and polarization. Table XVI-1 describes some of the characteristics of the truck radar system along with the AIRSAR and SIR-C sensors.

The truck radar system is configured around an HP8719A network analyzer which is mounted on the instrument platform at the end of the boom behind the antennas. Switching between frequencies and polarizations is accomplished by an HP3488A switching unit outfitted with SPDT coaxial switches. Signals are routed to and from the antenna elements by the switching unit and six directional couplers, with bandpass filters installed in the return or received signal path to keep the noise floor on each band as low as possible. An HP8449B 1-26.5 GHz preamplifier is used for all frequency bands, providing uniform amplification of all reflected power from the designated targets. Remote computer control of the ten switches located in the switching unit and the network analyzer is achieved via a pair of HP3702A HP-IB extenders through which all data and control sequences travel. The radar system is operated using a 486-based notebook computer with an IEEE488 interface card and LabWindows software.

C. SET-UP AND CALIBRATION PROCEDURES

Prior to the deployment of the truck radar to the Washita '94 experiment, each radar antenna element underwent extensive testing to determine its beamwidth, gain, and cross polarization characteristics in the antenna test chamber at NASA/Goddard Space Flight Center. The HP8719A network analyzer was also used in conjunction with a standard directional coupler and standard gain horn to measure the reflected power of several known targets. Extensive data were collected on a rectangular flat aluminum plate (area = 0.3825 m^2), a square flat aluminum plate (area = 0.24129 m^2) and an

aluminum sphere (r = 0.1778 m). Distance to chamber targets was 16.75 ± 0.5 m. Measurements were taken in both the time and frequency domains.

During data collection in Oklahoma the network analyzer was set to perform forward gain/loss analysis (S_{21} mode) in the time domain using an IF-bandwidth of 300 Hertz. The reflected power from the target field was gated or filtered in time (Fig. XVI-2) and then transformed to the frequency domain. The gates varied according to incidence angle, with the gate for $\theta = 30^\circ$ and 40° equal to 130 - 180 nanoseconds while the gate for $\theta = 50^\circ$ was 160 - 220 nanoseconds. Internal system calibration at each new measurement site was carried out by connecting high reliability flexible cables (HP85131F) between the two ports on the HP8719A network analyzer. All initial readings after a minimum warm up and stabilization time of 20 minutes were verified to be within manufacturer specifications. External field calibration for both like and cross polarization was accomplished by recording the truck radar response to a target of known backscatter, in this case a large aluminum dihedral corner reflector (side length of 76 cm) mounted on a rotating wooden base. Despite variations in field set-up conditions and sustained winds of 25-30 mph on most days during the April experiment, the radar system was very stable: the network analyzer always powered up to the same level as before in each channel (to within 0.05 dB), and calibration data from the dihedral target never varied by more that 0.1 dB. Cross-polarization data sensitivities of 30 dB above the noise floor at L band and 15 dB above the noise floor at C band were also achieved. The X band data were marginal at incidence angles of 40° and 50° due to noise floor problems.

D. FIELD MEASUREMENTS

During the April field experiment (April 6-16, 1994), field conditions were initially dry, became wet as a result of a heavy rainstorm on the afternoon of 4/10/94 and morning of 4/11/94, and then gradually dried down throughout the remainder of the experimental period (see soil moisture curve in Fig XVI-4).

On each of 8 days of actual data collection the truck radar took measurements at 3 frequencies (L, C, X), 4 polarizations (HH, HV, VH, VV), and 3 angles (30°, 40°, 50°) for 4 test fields which each represented a typical surface cover found in the watershed (pasture field #62, alfalfa field #11, new corn/bare field #12, and winter wheat field #13) (Fig XVI-3). See Chapter III for field descriptions and site characteristics. Average radar backscatter values were obtained by sweeping the radar boom 120° in azimuth across the target fields. 46 data points were collected at each polarization during each 4-minute azimuthal sweep. A new sweep was required for each desired incidence angle and frequency; all sweeps were repeated at L band in order to give 92 samples for averaging.

Normal data collection schedule included truck radar measurements at each of the four test fields on every day. However, due to various logistical considerations, this schedule was sometimes modified. No data were obtained at the winter wheat and pasture sites on April 6, 1994. April 8 was a calibration day at the USDA Lab. On April 10, rain became heavy enough around 12:00 noon to pose a hazard to the truck radar's electrical equipment; measurements at 30° in the winter wheat field #13 and all measurements at pasture field #62 were canceled. April 11 was a down day for the truck

radar due to heavy rain in the morning. Muddy conditions on April 12 prevented truck access to alfalfa field #11 and forced the truck radar to stage on the south side of corn field #12 (instead of its regular staging area on the north side). All remaining measurements followed the normal schedule.

A preliminary comparison of truck radar and SIR-C backscatter values is presented in Figure XVI-4 along with the measured 0-5 cm soil moisture data. Radar backscatter is referenced to the right axis with soil moisture to the left axis. The truck radar measurements are interpolated in angle to match the SIR-C incidence angles, taking local slope crudely into account. With the height of the grass only 3-5 cm, the water content of the vegetation cover in the pasture was very low, on the order of 125 g/m^2. Results indicate that both the truck and Shuttle radars were able to track the changing soil moisture conditions quite well, responding almost identically to the soil moisture dry down in this pasture.

E. DATA TABLES

Calibrated field averages of truck radar backscatter for each of the four test fields are given in Tables XVI-2 through XVI-5. Only L and C band data are included here due to the marginal nature of some of the X band data. Table XVI-6 is a compilation of miscellaneous field notes from the truck radar data sheets.

TABLE XVI-1. Radar System Parameters

	Truck Radar		AIRSAR		SIR-C	
Frequency	X	10.0			X	9.7
(band, GHz)	C	4.75	C	5.3	C	5.3
	L	1.6	L	1.25	L	1.25
			P	0.44		
Wavelength	X	3.0			X	3.1
(band, cm)	C	6.3	C	5.7	C	5.7
	L	18.75	L	24.0	L	24.0
			P	68.1		
Operating Height	up to 18	m	7000-9000	m	215-220	km
Look Angle Range (deg)	10 - 80		20 - 70		17 - 63	
Spatial Resolution* (m)						
azimuth direction	~3		3		4.3	
range direction	~4		6.67		13.3	

* for common operating parameters; single-look resolution

TABLE XVI-2. Washita '94 Truck Radar Data - Calibrated Avg Backscatter (Db)

FIELD #11 ALFALFA
CANOPY HEIGHT: 10-12 INCHES AT START, 14 INCHES AT END RADAR LOOK DIRECTION: 120 DEG AZIMUTH SWEEP CENTERED ON NORTH

DATE	TIME (CDT)	FREG	ANGLE	HH	HV	VV	VH
04/06/94	14:48	L	30	-23.99	-31.87	-19.67	-32.10
04/07/94	10:43	L	30	-24.16	-32.76	-21.35	-33.11
04/09/94	09:22	L	30	-24.58	-36.42	-24.31	-36.35
04/10/94	08:54	L	30	-25.73	-35.24	-25.42	-35.40
04/13/94	10:03	L	30	-22.22	-32.42	-21.58	-33.33
04/14/94	09:44	L	30	-23.89	-32.65	-21.95	-33.32
04/15/94	10:14	L	30	-22.39	-34.46	-21.10	-33.66
04/06/94	15:21	L	40	-24.08	-32.28	-20.69	-31.79
04/07/94	11:10	L	40	-24.27	-33.21	-22.29	-33.19
04/09/94	09:45	L	40	-25.49	-35.11	-25.75	-35.29
04/10/94	08:31	L	40	-25.68	-35.31	-24.14	-34.48
04/13/94	09:43	L	40	-22.13	-33.78	-22.68	-33.54
04/14/94	09:23	L	40	-22.50	-32.52	-22.34	-32.96
04/15/94	10:35	L	40	-23.64	-33.85	-22.49	-33.64
04/06/94	15:51	L	50	-23.34	-31.70	-22.58	-31.04
04/07/94	11:36	L	50	-23.97	-34.79	-22.88	-32.79
04/09/94	10:12	L	50	-26.20	-35.70	-23.65	-34.51
04/10/94	08:07	L	50	-25.75	-35.09	-25.24	-35.35
04/13/94	09:17	L	50	-23.66	-34.34	-21.95	-35.57
04/14/94	09:01	L	50	-23.68	-34.40	-22.30	-33.84
04/15/94	10:57	L	50	-23.81	-33.76	-23.87	-33.76
04/06/94	14:59	C	30	-14.53	-21.24	-13.04	-21.32
04/07/94	10:52	C	30	-13.71	-20.32	-12.29	-20.91
04/09/94	09:30	C	30	-15.14	-22.72	-14.97	-20.99
04/10/94	09:01	C	30	-16.29	-23.67	-13.53	-23.64
04/13/94	10:11	C	30	-13.08	-22.00	-12.63	-23.21
04/14/94	09:52	C	30	-12.34	-20.99	-12.71	-21.13
04/15/94	10:23	C	30	-13.15	-22.44	-12.52	-22.46
04/06/94	15:31	C	40	-15.08	-21.62	-13.32	-21.91
04/07/94	11:18	C	40	-17.06	-21.69	-12.83	-20.51
04/09/94	09:54	C	40	-16.04	-22.98	-15.05	-23.80
04/10/94	08:39	C	40	-15.37	-24.65	-14.17	-22.87
04/13/94	09:50	C	40	-15.20	-22.81	-11.78	-24.08
04/14/94	09:31	C	40	-14.36	-22.65	-12.95	-21.42

Table XVI-2. Continued

DATE	TIME (CDT)	FREG	ANGLE	HH	HV	VV	VH
04/15/94	10:44	C	40	-15.66	-22.24	-14.39	-22.27
04/06/94	16:01	C	50	-16.52	-22.05	-13.14	-22.05
04/07/94	11:45	C	50	-15.64	-21.11	-13.67	-20.87
04/09/94	10:20	C	50	-17.42	-22.25	-14.24	-22.77
04/10/94	08:15	C	50	-16.87	-23.41	-16.85	-23.64
04/13/94	09:25	C	50	-15.72	-23.93	-13.61	-21.51
04/14/94	09:09	C	50	-18.58	-23.21	-13.24	-21.96
04/15/94	11:04	C	50	-16.07	-22.59	-15.75	-23.14

TABLE XVI-3. Washita '94 Truck Radar Data - Calibrated Avg Backscatter

FIELD #12 NEWLY EMERGENT CORN 1-2 IN TALL
ROW DIRECTION: EAST - WEST
RADAR LOOK DIRECTION: 120 DEG AZIM SWEEP CENTERED AT 90 DEG TO ROWS

DATE	TIME (CDT)	FREG	ANGLE	HH	HV	VV	VH
04/06/94	14:15	L	30	-18.23	-29.45	-16.74	-29.70
04/07/94	10:13	L	30	-17.16	-30.41	-15.48	-30.70
04/09/94	08:57	L	30	-17.77	-30.42	-16.35	-31.04
04/10/94	09:17	L	30	-17.56	-29.75	-16.29	-30.70
04/12/94	10:55	L	30	-14.60	-26.40	-12.88	-24.96
04/13/94	08:11	L	30	-13.71	-27.85	-11.61	-27.62
04/14/94	07:52	L	30	-16.50	-29.80	-14.93	-30.90
04/15/94	08:55	L	30	-17.81	-31.41	-15.99	-30.69
04/06/94	13:46	L	40	-21.67	-32.82	-19.57	-33.17
04/07/94	09:20	L	40	-24.66	-36.52	-24.67	-37.64
04/09/94	08:35	L	40	-19.51	-32.39	-19.48	-32.29
04/10/94	09:40	L	40	-19.05	-32.06	-18.69	-32.70
04/12/94	11:19	L	40	-18.97	-27.68	-14.87	-28.47
04/13/94	08:35	L	40	-17.45	-29.21	-15.68	-28.75
04/14/94	08:13	L	40	-19.87	-31.68	-18.55	-32.18
04/15/94	08:35	L	40	-19.68	-33.99	-18.76	-33.32
04/06/94	12:32	L	50	-18.42	-31.96	-17.51	-33.45
04/07/94	08:55	L	50	-21.19	-33.63	-20.45	-33.41
04/09/94	08:09	L	50	-21.73	-33.32	-21.05	-33.31
04/10/94	10:01	L	50	-23.03	-32.91	-20.94	-32.76
04/12/94	11:43	L	50	-19.26	-27.91	-15.58	-27.36
04/13/94	08:55	L	50	-21.91	-30.87	-18.15	-31.27
04/14/94	08:35	L	50	-21.59	-33.91	-19.52	-33.08
04/15/94	08:13	L	50	-22.17	-34.49	-20.86	-33.75
04/06/94	14:23	C	30	-12.58	-23.04	-9.37	-23.76
04/07/94	10:21	C	30	-11.20	-24.11	-9.68	-22.97
04/09/94	09:05	C	30	-13.22	-25.43	-9.98	-24.33
04/10/94	09:24	C	30	-12.66	-24.64	-11.46	-23.85
04/12/94	11:03	C	30	-5.31	-20.41	-4.39	-19.18
04/13/94	08:20	C	30	-7.87	-23.96	-5.20	-21.85
04/14/94	08:00	C	30	-12.67	-25.84	-8.48	-26.03
04/15/94	09:04	C	30	-11.07	-26.00	-9.45	-24.84
04/06/94	13:55	C	40	-15.66	-25.83	-13.43	-25.67

TABLE XVI-3. Continued

DATE	TIME (CDT)	FREG	ANGLE	HH	HV	VV	VH
04/07/94	09:27	C	40	-15.37	-26.17	-12.57	-25.67
04/09/94	08:43	C	40	-15.84	-26.69	-12.33	-25.23
04/10/94	09:47	C	40	-14.92	-25.53	-11.66	-26.30
04/12/94	11:26	C	40	-11.37	-24.38	-7.34	-23.35
04/13/94	08:42	C	40	-11.59	-26.13	-10.90	-23.99
04/14/94	08:20	C	40	-16.00	-27.05	-14.04	-26.97
04/15/94	08:42	C	40	-15.71	-26.34	-12.11	-27.72
04/06/94	12:45	C	50	-15.10	-23.46	-12.82	-24.75
04/07/94	09:02	C	50	-14.90	-25.13	-14.44	-24.82
04/09/94	08:19	C	50	-15.68	-25.59	-13.77	-24.49
04/10/94	10:09	C	50	-14.75	-24.84	-13.53	-25.20
04/12/94	11:50	C	50	-14.41	-22.61	-11.66	-22.55
04/13/94	09:03	C	50	-16.17	-26.17	-12.68	-25.49
04/14/94	08:44	C	50	-17.07	-28.48	-15.45	-27.43
04/15/94	08:21	C	50	-15.94	-26.84	-11.82	-27.30

TABLE XVI-4. Washita '94 Truck Radar Data - Calibrated Avg Backscatter (Db)

FIELD #13 WINTER WHEAT
CANOPY HEIGHT: APPROX. 14 INCHES
RADAR LOOK DIRECTION: 120 DEG AZIMUTH SWEEP CENTERED ON NORTHWEST

DATE	TIME (CDT)	FREG	ANGLE	HH	HV	VV	VH
04/07/94	14:10	L	30	-19.80	-31.24	-19.62	-30.51
04/09/94	11:37	L	30	-19.57	-31.97	-18.99	-30.82
04/10/94	11:59	L	30	RAIN AT NOON			
04/12/94	13:50	L	30	-17.32	-27.41	-16.02	-25.89
04/13/94	11:21	L	30	-18.85	-26.84	-16.10	-27.48
04/14/94	11:05	L	30	-17.58	-27.75	-16.96	-27.32
04/15/94	12:33	L	30	-19.17	-30.43	-18.27	-31.76
04/07/94	13:44	L	40	-23.72	-31.97	-23.48	-33.17
04/09/94	12:01	L	40	-22.41	-32.42	-23.24	-32.27
04/10/94	11:45	L	40	-27.26	-34.64	-26.43	-33.87
04/12/94	13:27	L	40	-19.74	-26.96	-17.66	-26.38
04/13/94	11:42	L	40	-20.97	-28.63	-18.44	-28.17
04/14/94	12:20	L	40	-22.18	-29.78	-19.98	-30.56
04/15/94	12:54	L	40	-23.96	-31.03	-21.24	-32.02
04/07/94	13:19	L	50	-26.40	-31.47	-24.50	-31.45
04/09/94	12:21	L	50	-26.52	-32.89	-25.41	-32.37
04/10/94	11:23	L	50	-25.54	-30.39	-25.60	-31.01
04/12/94	13:03	L	50	-22.18	-27.65	-19.47	-28.17
04/13/94	12:03	L	50	-23.50	-28.78	-21.15	-29.58
04/14/94	12:48	L	50	-25.09	-29.68	-22.84	-29.85
04/15/94	13:13	L	50	-24.55	-29.96	-24.28	-29.23
04/07/94	14:18	C	30	-16.21	-23.50	-14.75	-24.85
04/09/94	11:45	C	30	-16.62	-24.37	-16.91	-21.77
04/10/94	11:59	C	30	RAIN AT NOON			
04/12/94	13:57	C	30	-10.54	-16.57	-11.47	-17.06
04/13/94	11:29	C	30	-12.10	-20.01	-14.30	-19.85
04/14/94	12:07	C	30	-15.78	-21.49	-15.21	-20.84
04/15/94	12:41	C	30	-15.68	-23.44	-17.10	-23.01
04/07/94	13:53	C	40	-16.55	-25.03	-16.61	-24.02
04/09/94	12:07	C	40	-18.55	-25.02	-17.86	-22.89
04/10/94	11:52	C	40	-18.26	-24.84	-18.21	-25.54
04/12/94	13:35	C	40	-11.39	-17.74	-12.47	-17.44
04/13/94	11:49	C	40	-16.38	-22.48	-14.67	-21.22
04/14/94	12:34	C	40	-16.20	-23.43	-17.93	-21.70

TABLE XVI-4. Continued

DATE	TIME (CDT)	FREG	ANGLE	HH	HV	VV	VH
04/15/94	13:01	C	40	-16.94	-23.91	-18.60	-24.23
04/07/94	13:27	C	50	-17.58	-24.73	-16.85	-23.68
04/09/94	12:29	C	50	-16.54	-25.19	-17.16	-24.85
04/10/94	11:30	C	50	-18.61	-23.22	-17.58	-25.58
04/12/94	13:11	C	50	-14.55	-21.94	-15.67	-20.91
04/13/94	12:10	C	50	-16.57	-22.68	-16.89	-21.38
04/14/94	12:55	C	50	-17.17	-25.12	-17.50	-23.35
04/15/94	13:22	C	50	-16.47	-25.48	-17.41	-23.83

TABLE XVI-5. Washita '94 Truck Radar Data - Calibrated Avg Backscatter (Db)

FIELD #62 PASTURE
CANOPY HEIGHT: SHORT GRASS 1-2 INCHES TALL
RADAR LOOK DIRECTION: 120 DEG AZIMUTH SWEEP CENTERED ON WEST; DISK LINES N-S

DATE	TIME (CDT)	FREG	ANGLE	HH	HV	VV	VH
04/07/94	16:41	L	30	-20.99	-32.43	-18.97	-32.03
04/09/94	15:13	L	30	-21.42	-32.02	-19.37	-33.53
04/12/94	09:21	L	30	-15.17	-25.58	-13.19	-25.82
04/13/94	14:21	L	30	-17.32	-29.77	-15.52	-29.26
04/14/94	15:05	L	30	-19.76	-32.06	-17.17	-32.36
04/15/94	15:39	L	30	-20.24	-32.25	-17.62	-32.46
04/07/94	16:11	L	40	-22.41	-34.07	-20.70	-33.76
04/09/94	14:52	L	40	-21.89	-33.66	-20.73	-35.41
04/12/94	08:51	L	40	-17.88	-27.78	-15.47	-27.43
04/13/94	13:59	L	40	-20.50	-31.81	-17.24	-31.82
04/14/94	14:45	L	40	-21.52	-34.64	-19.09	-34.07
04/15/94	15:19	L	40	-22.07	-34.64	-20.83	-34.17
04/07/94	15:50	L	50	-24.27	-35.69	-23.52	-35.27
04/09/94	13:53	L	50	-25.00	-35.79	-24.37	-36.20
04/12/94	08:24	L	50	-19.60	-29.13	-17.42	-28.36
04/13/94	13:35	L	50	-22.21	-31.63	-20.26	-31.76
04/14/94	14:23	L	50	-22.96	-33.33	-21.73	-33.41
04/15/94	14:59	L	50	-23.27	-33.94	-22.33	-34.45
04/07/94	16:49	C	30	-14.95	-24.13	-15.06	-24.77
04/09/94	15:21	C	30	-15.83	-25.16	-15.11	-23.89
04/12/94	09:29	C	30	-9.87	-20.77	-7.43	-21.13
04/13/94	14:28	C	30	-15.63	-26.73	-14.62	-26.73
04/14/94	15:13	C	30	-16.48	-26.48	-14.10	-25.52
04/15/94	15:47	C	30	-16.68	-25.01	-13.09	-24.34
04/07/94	16:23	C	40	-18.54	-26.69	-14.83	-28.83
04/09/94	14:59	C	40	-18.73	-27.42	-15.10	-28.02
04/12/94	08:59	C	40	-11.95	-23.56	-9.40	-22.01
04/13/94	14:06	C	40	-17.28	-26.08	-15.23	-26.78
04/14/94	14:52	C	40	-18.33	-28.52	-17.43	-27.09
04/15/94	15:26	C	40	-16.92	-26.69	-14.90	-25.56
04/07/94	15:58	C	50	-17.65	-26.93	-15.81	-25.51
04/09/94	14:02	C	50	-19.18	-27.72	-15.73	-26.51
04/12/94	08:32	C	50	-15.36	-22.86	-13.14	-22.48
04/13/94	13:44	C	50	-18.21	-26.64	-16.87	-27.01
04/14/94	14:31	C	50	-19.11	-27.33	-17.06	-27.08
04/15/94	15:06	C	50	-17.06	-25.18	-17.09	-26.5

TABLE XVI-6. Notes from Truck Radar Data Sheets

4-6-94 C-130 overhead at Area 1 at 12:20 pm. Day started cool, clear and sunny, but got warmer by afternoon. Radar data take: t=240 sec, 46 samples/data take, boom height = 40 ft. Corn shoots 1-2 inches tall. Alfalfa is 10-12 inches tall; surface is hard, dry, and flat.

4-7-94 C-130 spotted flying low to southwest at 8:50 am. Day started cool, clear and sunny. Wind picking up. Gate = 130 - 180 nanoseconds for 30° and 40°. Gate = 160 - 220 for 50°. Wind now very strong and gusty. Winter wheat is ~ 14 inches tall with some bare spots. Pasture has short grass, also disk lines (to aid infiltration).

4-8-94 Calibration day at USDA Lab.

4-9-94 Morning gray and overcast with spits of drizzle, but warmer. Still windy with low ceiling of clouds. Skies breaking up with some sun around noon. C-130 spotted at 3:35 PM. Corn in E-W rows.

4-10-94 Gray and overcast; still windy, although less so than previous days. DC-8 overflight scheduled for 11 am. Occasional spits of rain after 9 am. Cool. Rain at ~ noon aborted rest of day's data takes (missed 30° in winter wheat and all of pasture).

4-11-94 Rain since yesterday stopped around noon.

4-12-94 Sunny, windy, cold. Ground is wet from yesterday's rain, but still hard in pasture. Furrows in corn field smoothed out by rain, but ridges still have soil clods. Data taken on south side of corn field and alfalfa skipped due to mud preventing truck access. Getting warmer at noon.

4-13-94 Sunny with high cirrus clouds. Still windy. Temperatures expected in the 80°'s later. Corn field drier than yesterday. Saw space shuttle pass over at 6:24 am.

4-14-94 Sunny, very warm, very windy. Alfalfa ~ 14 inches tall. Some wheat plants starting to sprout grain heads. Soil drier.

4-15-94 Sunny, cooler, VERY WINDY. Corn plants have grown since start of experiment. Corn row spacing averages 30 inches. Strong north wind blowing alfalfa toward radar.

Figure XVI-1. NASA/GSFC truck radar deployed at pasture field #62 in the Little Washita River Watershed.

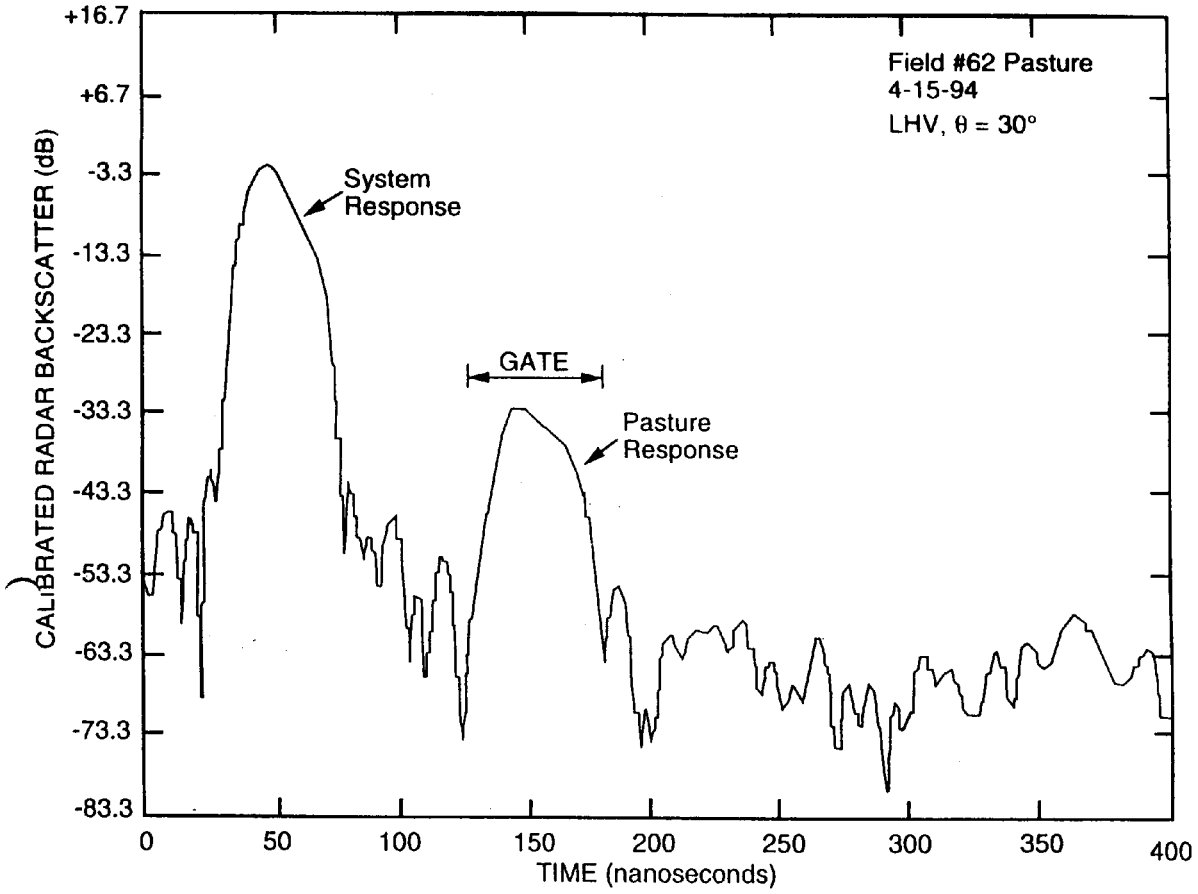

Figure XVI-2. Time domain response of truck radar over pasture field #62 which was used to determine gate setting for backscatter measurements in the frequency domain. The cross polarization sensitivity of 30 dB above the noise floor is evident.

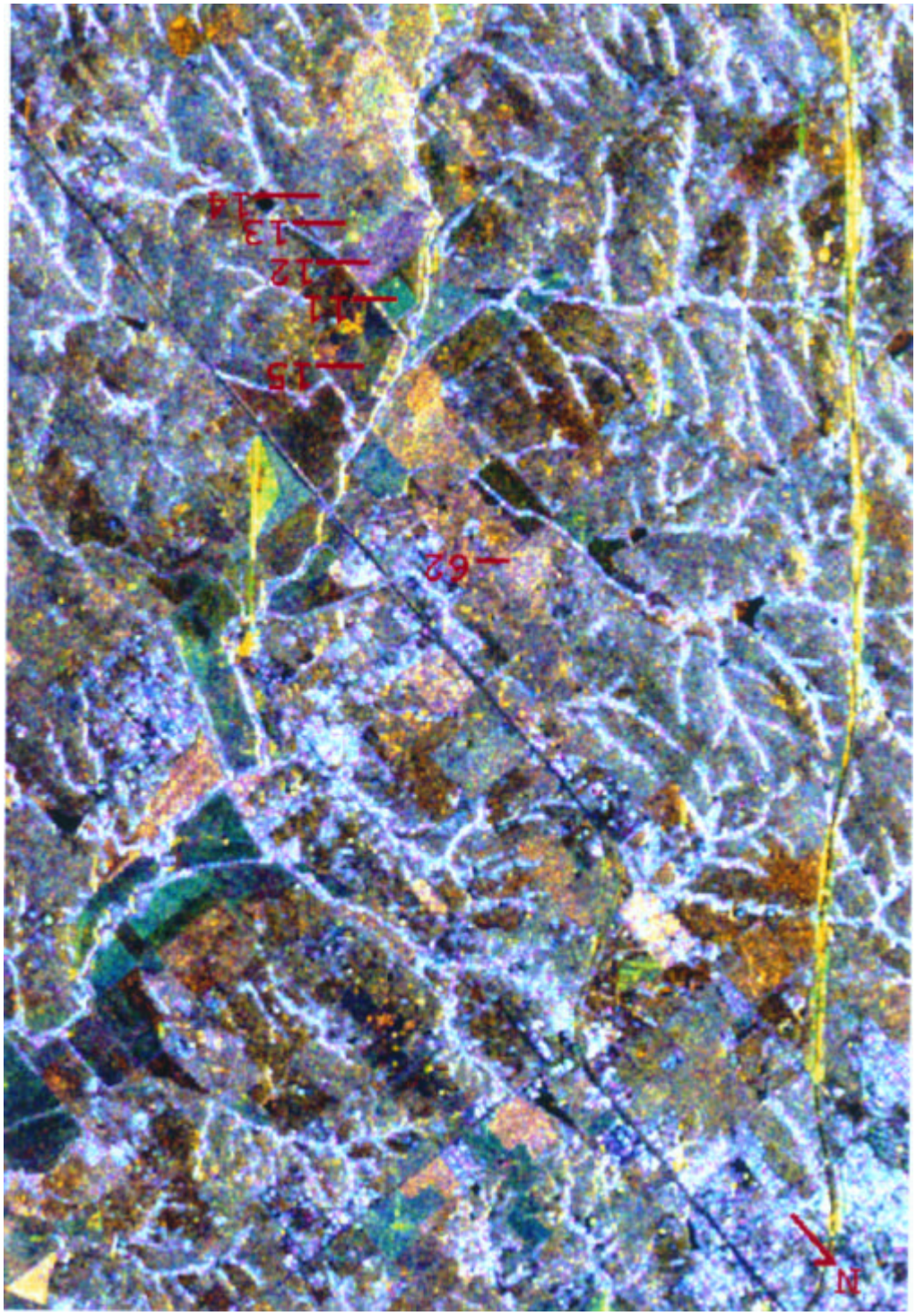

Figure XVI-3. SIR-C L band radar image from April 11, 1994 showing pasture field #62 and Area 1 test fields. Data are multi-look complex converted to ground-range format. LHH channel is in green, LVV in red, and LHV in blue.

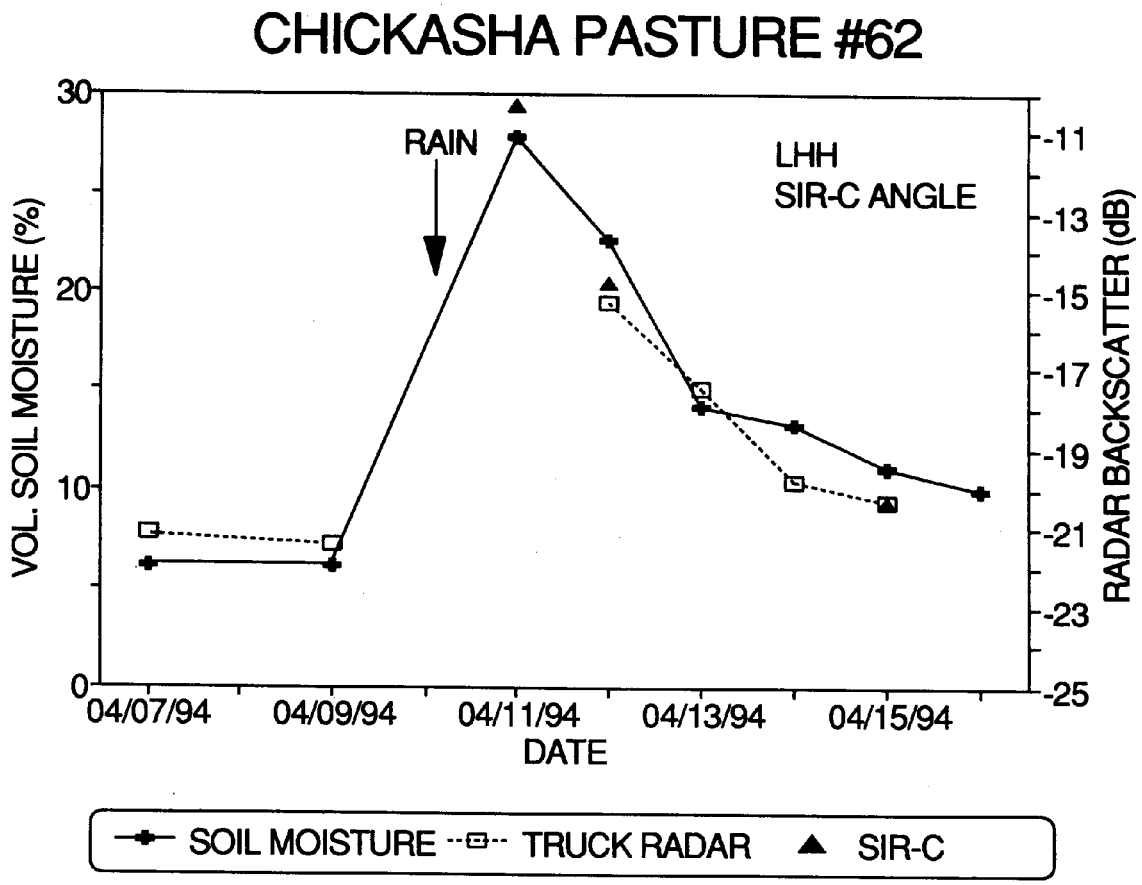

Figure XVI-4. 0-5 cm soil moisture curve and associated LHH truck radar and SIR-C backscatter values for pasture field #62 during the April experiment.