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DCP-COLLECTED ABSOLUTE TARGET REFLECTANCE SIGNATURES ASSIST ACCURATE INTERPRETATION OF ERTS-1 IMAGERY

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ABSTRACT

Data collection platforms (DCP's) are being used at a Black Hills, South Dakota, test site (MMC 226A) to record radiometric measurements needed to determine solar and atmospheric parameters that affect ERTS-1 multispectral scanner radiance measurements.

A total of 72 channels of analog data are transmitted from an unattended ground truth site via three DCP's at least six times a day. The system has operated with only minor problems since September, sending forth daily measurements of biophysical responses and atmospheric conditions. Comparisons of scene radiance data calculated from ERTS images with that measured on the ground show the image-measured values to be 35 percent higher for the green channel and 20 percent higher for the red channel for the same scene targets. Radiance values for channels 6 and 7 are nearly the same from the ground data and from the imagery.

1. INTRODUCTION

The Forest Service investigation in the Black Hills of South Dakota focuses on monitoring forest stress in the ponderosa pine (Pinus ponderosa Laws.) ecosystem using coordinated data collected from ERTS 1, aircraft, and from ground instrumentation. The cause of the stress being monitored in the Black Hills is a widespread epidemic of the mountain pine beetle (Dendroctonus ponderosae Hopk.). The bark beetle was responsible for over 10,000 infestation spots in the northern Black Hills this past year as identified on high-flight aerial photography obtained in September 1972 after the dead trees were fully discolored. The infestation spots identified ranged in size from single trees to many hundreds of trees with the greatest number of trees occurring in infestations having 11 to 25 trees.

Establishment of an ERTS 1 intensive study site was begun during May 1972 for the purpose of measuring radiometric responses of the principal components of the ecosystem in relation to changing atmospheric and environmental conditions. Our primary concern was to provide closeup spectral radiometric ground truth of the relation between healthy ponderosa pine and the trees which were under stress from attack by the mountain pine beetle. Figure 1 shows the location of the intensive study site in the Black Hills. It was deemed important to monitor spectral radiometric information on two additional ecosystem components--(1) open pastures and grasslands which occupy the majority of nonforest land in the Black Hills and (2) soil and rock outcrops which provide the targets of greatest reflectance contrast with the forest. The rock outcrops provide important control points because they are easily identifiable within the forest on small-scale imagery.

2. METHODS

Many biophysical and atmospheric parameters were measured throughout the test site, but the most important was absolute target reflectance. These data were obtained in terms of scene radiance and irradiance as measured with our RS-2 ERTS-1-matched spectral radiometers shown in Figure 2. One of the 4-channel radiometers was positioned over each of four locations within the study site (over healthy pine, beetle-killed pine, grassland pasture, and rock outcroppings). Each instrument was positioned at the top of an instrument tower in a way that would provide a clear vertical (downward-looking) view of the target from a height of 7 meters (m).

In practice, the RS-2 spectral radiometers provide continuing information of importance in each of the ERTS multispectral scanner (MSS) bands for each of the ecosystem targets. Figure 3 shows the calibrated radiance output at 5 levels for each radiometer detector. Due to the slightly different spectral responsivities of each detector-filter combination, there is a different calibrated radiance for a given neutral density level. For the calibration data (Figure 4), the detector response was measured for each channel as a function of changing target exitance, with target exitance being the energy in watts per unit area of each target. Detector response levels shown in Figure 5 are for unamplified signals from Pin 10 DP detectors with a 10° field-of-view. In operation the output signals from each of the spectral radiometer channels is amplified with a UDT-101 (M) at a gain of 10 before entering the recording system.

In addition to recording target reflectances at each test site with the RS-2 radiometers, additional data collected include net all-wave radiation and upwelling shortwave radiation. At one central location, instruments measure the spectral components of downwelling radiation, atmospheric water vapor content, temperatures, and windspeeds.

Instrumentation data from all four sites are wired into a central data recording facility where sensor signals are amplified and multiplexed for broadcast over the ERTS data collection system (DCS) via three data collection platforms (DCP's) (Figure 6). In all, 72 channels of data are multiplexed over 24 DCP channels. At the same time that instrumentation data enter the DCP buffers they are recorded in parallel on a digital data acquisition system. As the instrumentation laboratory is located within the forest, it was necessary to mount the DCP antennas at the top of a 32 m instrumentation tower, as shown in Figure 7.

Two satellite images of the Black Hills were selected for the purpose of scene correlations between ground truth data and ERTS MSS scene radiance data. Scene 1047-17175 provides clear coverage of the western Black Hills for September 8, 1972, on MSS channels 4, 5, and 7. Scene 1065-17175 provides partially open coverage of the north-central Black Hills on September 26, 1972, when all channels of the MSS were working well. Figure 8 shows a black-and-white rendition of a 4-channel color composite created on our I^2S color recombiner for the September 26 data.

For the purpose of scene radiance analysis of the ERTS image, microdensitometer scans were made of several transects on each image and all available spectral bands. Scan densities were converted to scene radiance for each 70 mm bulk data scene using calibration data taken from the 15 step wedge on each scene. Several of the scans made on the September 26 scene are shown by the white lines on Figure 1. Radiance data were correlated to scene points using proportional distances from control points which could positively be identified on both the satellite images and the RB-57 small-scale photography.

3. RESULTS

In the past we have received incomplete seasonal radiometric data for the Black Hills because of the large expense in manning test site instruments over long periods of time. It is clear that a significant benefit of ERTS is having the DCS capability for continuously monitoring field instruments and being able to send current and accurate data to our office hundreds of miles away from the remote field site. The minimum of three daytime transmissions of field data seems adequate for monitoring critical biophysical responses and environmental conditions. It seems a simple matter to add a few totalizing circuits to existing instrumentation so as to better utilize the three nighttime data transmissions.

As a result of daily monitoring of Black Hills radiometric instruments we are now beginning to get a clearer picture of spectral energy relationships in the ponderosa pine ecosystem over time. For example, Table 1 shows how albedo of the rock outcroppings was unchanged from September 8 to 26, whereas the albedo of the pasture increased 3 percent. During the same period healthy ponderosa pine showed a 1 percent decrease while bark beetle-killed pine increased by 1 percent. In

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addition to knowing trends, the implication is that we now know for any satellite scene the relation of absolute reflectances between different ecosystem components.

Table 1. The relationship between albedos is shown for four Black Hills, South Dakota, ecosystem components at the time of two ERTS 1 passes in September.

Target	Percent Albedo[1] September 8	Percent Albedo[1] September 26
Healthy pine	11	10
Stressed pine	15	16
Pasture grass	19	22
Rock outcrop	24	24

[1] Albedo is the ratio of upwelling to downwelling shortwave radiation

Scene radiance data obtained from the September 8 imagery of the Black Hills is shown in Table 2.

Table 2. Black Hills scene radiance data for September 8, 1972, are derived from microdensitometer analysis of black-and-white 70 mm bulk data positives for scene 1047-17175.

Target	Scene Radiance (milliwatts/cm^2-SR) MSS Channel[1] 4	5	7
Healthy pine	0.333	0.188	0.847
Stressed pine	0.344	0.229	0.983
Lake	0.339	0.200	0.657
Rock outcrop	0.418	0.270	1.218
Mecadum road	0.394	0.194	0.953
Concrete highway	0.339	0.239	1.062
Mine tailings	0.354	0.249	1.170
New logging road	0.333	0.243	1.014
Tornado area	0.414	0.300	1.206

[1] Imagery received for channel 6 was unusable because of the large number of data dropouts

The 70 mm bulk imagery was fully adequate for extracting the scene radiance signatures of some ecosystem targets such as healthy ponderosa pine and rock outcroppings, using precision microdensitometry. However, even better numbers can be calculated for some of the hard-to-pinpoint targets like bark beetle infestation areas when the 9 1/2-inch black-and-white bulk imagery becomes available.

When it became apparent that we were not going to get ERTS-1 imagery of the Black Hills that was free of clouds over the entire study area during 1972, we settled on the September 26 scene for intensive analysis. We have examined color recombinations of this scene created to optimum illumination levels in our I^2S viewer. The best enhancements of the enlarged color recombination were photographed on color transparency film (Figure 8) and placed in a VARISCAN viewer for scene point correlation. Significantly, we were able to retain good quality ecosystem scene point recognition when the image was enlarged to a viewing scale of 1:32,000 on the VARISCAN screen. This was a useful step in becoming familiar with scene points before measuring the scene radiance with the microdensitometer scans. Table 3 shows the calculated scene radiance for the September 26 imagery of the Black Hills.

Table 3. Black Hills scene radiance data for September 8, 1972, are derived from microdensitometer analysis of black-and-white 70 mm bulk data positives for scene 1065-17175.

	Scene Radiance (milliwatts/cm^2-SR)			
	MSS Channel			
Target	4	5	6	7
Healthy pine	0.154	0.087	0.158	0.392
Stressed pine	0.140	0.093	0.144	0.399
Pasture grass	0.214	0.148	0.239	0.601
Mecadum road	0.213	0.105	0.173	0.440
Rock outcrop	0.316	0.204	0.353	0.920
Open pit gold mine	0.250	0.170	0.311	0.805
Golf course	0.217	0.156	0.244	0.628

The significance of scene radiance calculations on the MSS imagery is illustrated in Table 4 where they are compared to scene radiance measurements made of similar ecosystem targets on the ground which were transmitted to us by the DCS. It is noteworthy that here we are getting the first data which show the effect of atmosphere on radiance values as measured on imagery when compared to that which exists near the ground. Prior to this time we have only had predictions of what should happen with generalized conditions. We see the greatest effect of atmosphere on MSS channel 4 where there is an overall 30 plus percent increase in scene radiance on the satellite imagery. For the infrared channel 7 there is less than 10 percent overall difference in measured values, with the ground-measured radiance being the higher.

Table 4. The relationship is shown between scene radiance data measured on ERTS-1 MSS imagery (scene 1065-17175) and that measured on the ground in the Black Hills by the RS-2 spectral radiometers.

	Scene Radiance (milliwatts/cm^2-SR)							
	MSS Channel							
	4		5		6		7	
Target	ERTS	Ground	ERTS	Ground	ERTS	Ground	ERTS	Ground
Healthy pine	.154	.102	.087	.065	.158	.179	.392	.468
Stressed pine	.140	.093	.093	.101	.144	.135	.399	.506
Pasture grass	.214	.141	.148	.159	.239	.280	.601	.646
Rock outcrop	.316	.219	.204	.199	.353	.358	.920	.999

4. DISCUSSION

From preliminary work with ERTS-1 imagery we look forward with great expectations to receiving one good summertime image of the entire Black Hills test site under full sun conditions. Having already learned to analyze imagery gathered under less than optimum conditions, there is considerable reason for wanting additional good quality coverage so that we can accomplish the goals of the study. Data presented in this report were analyzed from two September ERTS-1 images. One image covered only a small portion of the study area and one MSS channel malfunctioned. The other image was obtained on a cloudy day when the atmospheric water content was high (relative humidity measured at the test site at the time of the satellite overflight was 82 percent). We anticipate few problems in the continued operation of the DCP's and the data collection system.

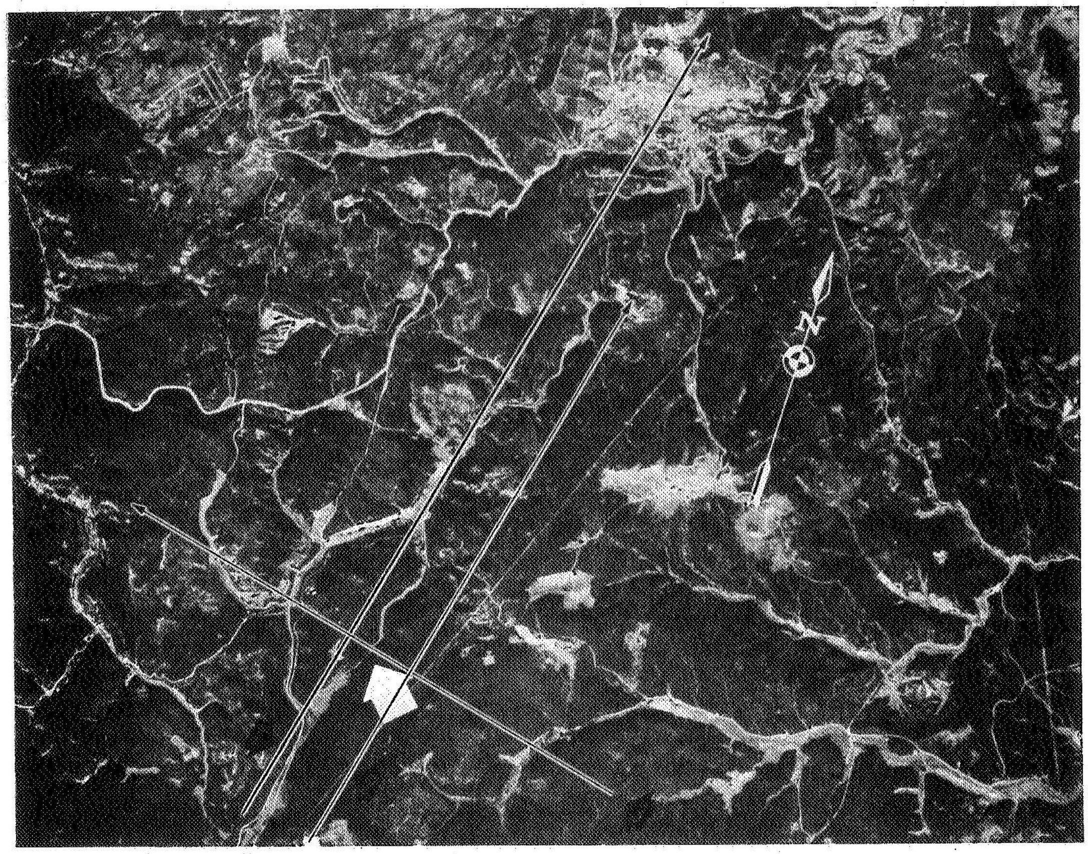

FIGURE 1. A PORTION OF THE BLACK HILLS FORESTRY TEST SITE SHOWS SOME OF THE MICRODENSITOMETER SCAN LINES

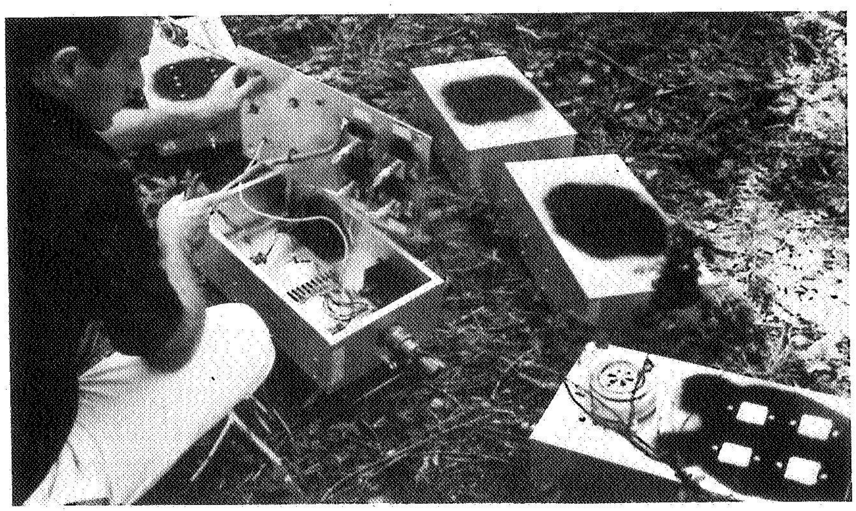

FIGURE 2. RS-2 SPECTRAL RADIOMETERS

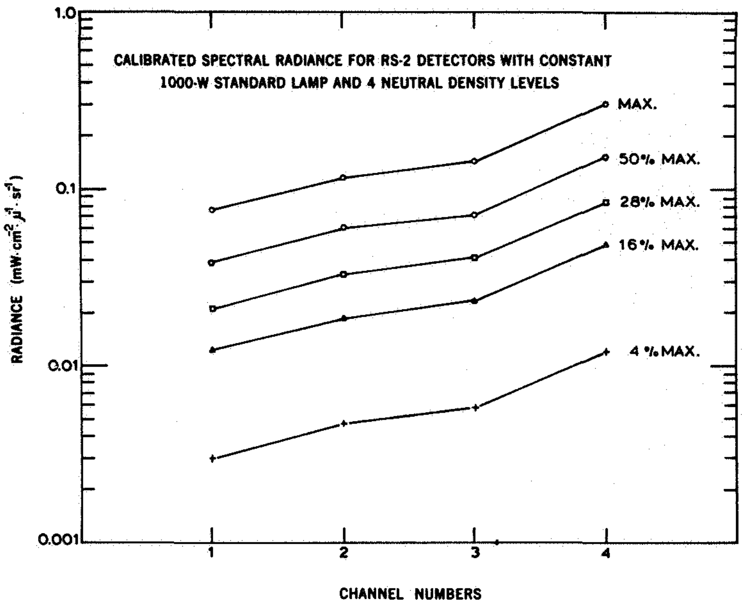

FIGURE 3. CALIBRATED SPECTRAL RADIANCE FOR RS-2 DETECTORS

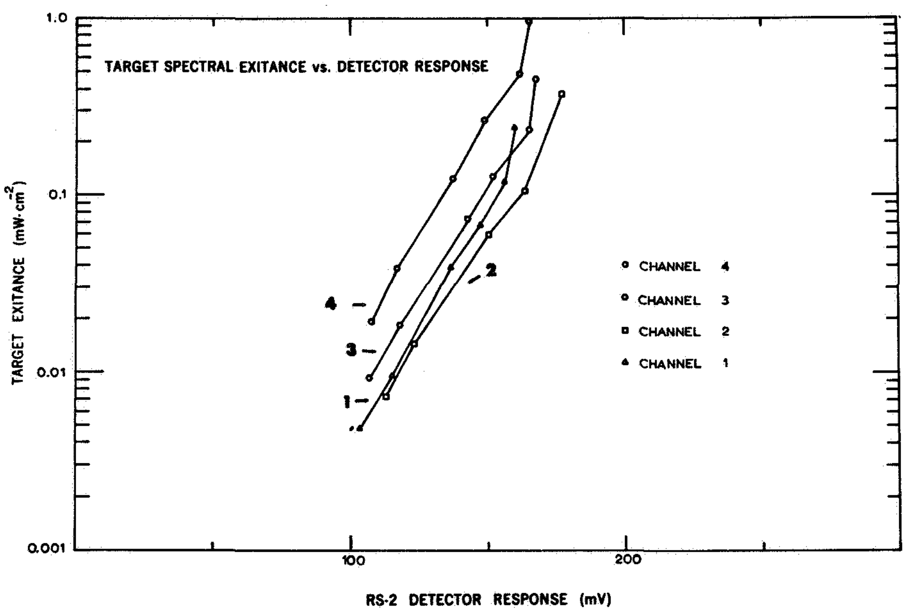

FIGURE 4. TARGET EXITANCE VERSUS DETECTOR RESPONSE FOR RS-2 RADIOMETERS

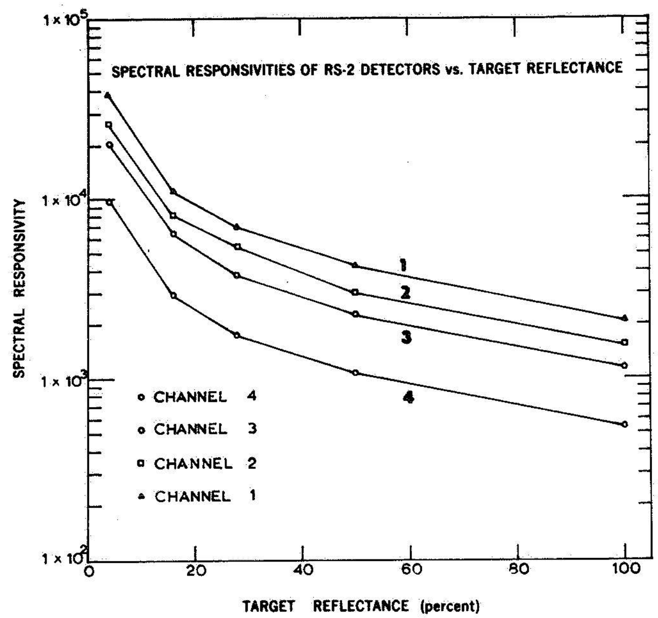

FIGURE 5. SPECTRAL RESPONSIVITIES OF THE RS-2 DETECTORS FOR FIVE LEVELS OF ABSOLUTE TARGET REFLECTANCE

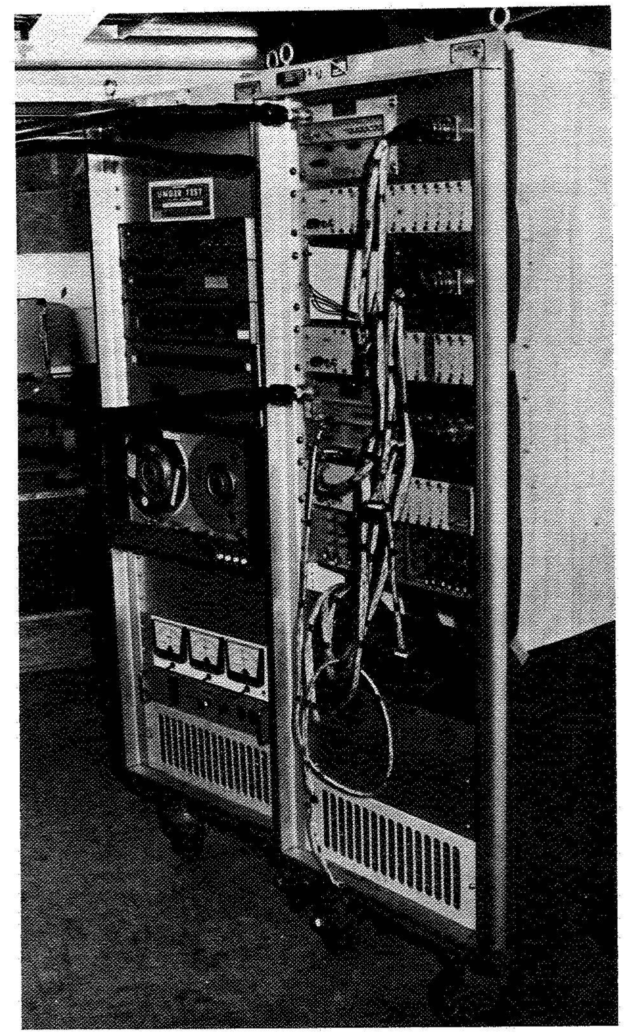

FIGURE 6. DIGITAL DATA ACQUISITION SYSTEM (left) DCP AND MULTIPLEXER CONSOLE (right)

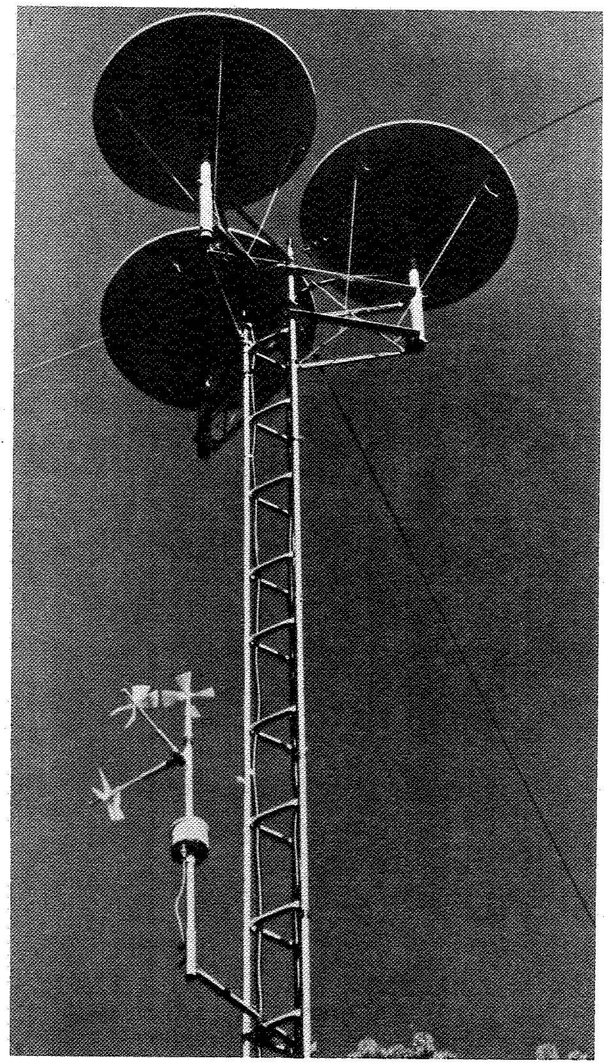

FIGURE 7. DCS/DCP TRANSMIT ANTENNA TOWER

FIGURE 8. FOUR CHANNEL COMPOSITE OF ERTS SCENE 1065-17175 AT SCALE OF 1:100,000