Commission VII, Working Group 9

A MULTIBAND RADIOMETER AND DATA ACQUISITION SYSTEM FOR REMOTE SENSING FIELD RESEARCH

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ABSTRACT

The specifications of a recently developed prototype multispectral data acquisition system for remote sensing field research will be described. It will consist of a multiband radiometer with 8 bands between 0.4 and 12.5 μm and a data recording module which will record data from the radiometer and ancillary sources. It will be adaptable to helicopter, truck or tripod platforms, as well as hand-held operation. The general characteristics of the system are: (i) comparatively inexpensive to acquire, maintain and operate; (ii) simple to operate and calibrate; (iii) complete with data handling hardware and software; and (iv) well documented for use by researchers. The instrument system will be commercially available and can be utilized by many researchers to obtain large numbers of accurate, calibrated spectral measurements. As such it will be a key element in improving and advancing the capability for field research in remote sensing.

Introduction

Early in the development of remote sensing technology, it was recognized that knowledge of spectral characteristics would be important to improving the accuracy of identification of crops and to the assessment of crop conditions.[1] Much of the early work was performed with laboratory instruments under laboratory conditions using freshly picked leaves or leaves *in vivo*.[2,3,4] However, it was generally understood that the complexity of the spectral and spatial variations of crop spectra would require *in-situ* field measurements.

Photographic techniques have been used to make field measurements of spectra, but they are unsuitable because of their restricted wavelength coverage and the additional steps required to produce meaningful spectra. Airplane mounted multispectral scanner systems have not been widely used to measure spectral reflectance and emittance characteristics in controlled experiments because of the difficulties of operation on an on-call basis, lack of a stable platform, inflexibility of wavelength bands, calibration difficulties, and large costs of operation and data processing. Thus, researchers requiring *in-situ* measurements of spectral characteristics have turned to multiband and continous wavelength techniques.

Initial efforts to obtain in-situ spectra involved extension of laboratory spectrometers to field applications. Further efforts led to the development of rugged, high spectral resolution field spectrometer systems such as the Exotech Model 20C operated by Purdue/LARS[5,6] or the S-191H operated by NASA/JSC.[7] These types of instruments are capable of accurately measuring spectral reflectance and emitted spectral radiance.

Figure 1. Helicopter platform for Spectrometer.

Figure 2. Aerial tower platform for Spectrometer.

They have been used on truck-mounted towers, helicopters, and the Skylab spacecraft. The LACIE Field Measurements Project under the technical direction of Purdue/LARS has produced data from these instruments which are calibrated (and, therefore comparable from time to time and place to place) and registered by wavelength.

Although there will be a continuing need for the high resolution spectral data which these types of systems can provide, these systems cannot economically satisfy the current need. These systems produce large amounts of data for each spectral observation; handling of these amounts of data in the field and processing the data require expertise and resources which are not available to many researchers. The initial purchase price of these systems is beyond the means of almost all researchers and they are expensive to maintain and operate. These factors have limited the number of researchers making accurate spectral measurements and restricted the amount of analysis of spectral data.

At the same time that high spectral resolution systems were being developed several relatively inexpensive multiband instruments became available. However, these instruments cover only the visible and near infrared portions of the spectrum, severely limiting the informational content of the spectral data. An additional limitation is that data handling hardware or software systems are not commercially available for these instruments. And, relatively few investigators are using the instruments in a manner which permits comparable and repeatable measurements to be obtained.

A practical means to obtain spectral data from a wider variety of subjects and to increase the number of researchers who can afford to acquire and analyze such data is to simplify the instrumentation and reduce the amount of data obtained for each observation. To achieve this, a field-rated multiband radiometer system (having a limited, yet sufficient number of wavelength bands) is being developed. It is to be:

- capable of complete spectral coverage (appropriate bands from 0.4 to 2.4 μm and a band at 10.4 - 12.5 μm);

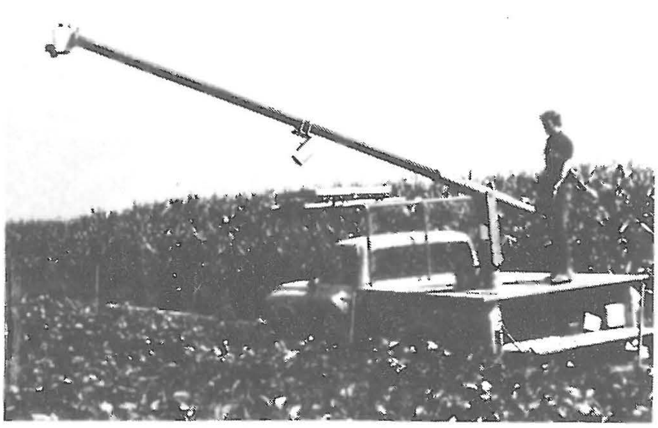


Figure 3. Pick-up truck mounted boom platform for Landsat band radiometer.

Figure 4. Tripod platform for Landsat band radiometer.

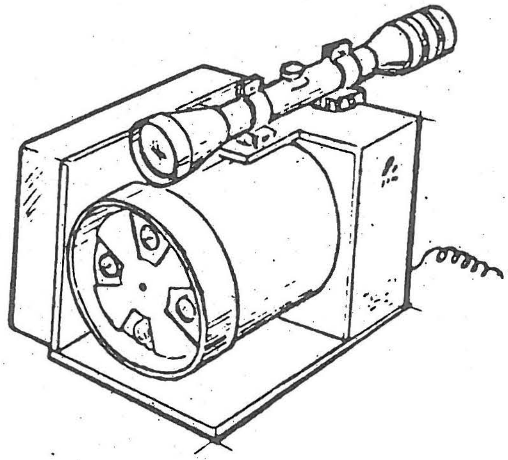
- comparatively inexpensive to acquire, maintain, and operate;
- simple to operate, calibrate, and service;
- rugged, light weight, portable;
- complete with data handling hardware and software; and
- well-documented for use by researchers.

As researchers acquire and use spectral data to gain a better understanding of the spectral, spatial and temporal variation of crops, soils, forests, and water bodies, it is important that acquisition and calibration procedures be standardized to ensure the validity and comparability of the data. Presently, knowledge of acquisition and calibration procedures varies greatly, minimizing the use of shared data and creating problems in the interpretation of data and results. To enable researchers to acquire meaningful calibrated data, the radiometer system will include manuals with considerable emphasis on these topics and case studies of experiments, including experimental design.

Description of the Multiband Radiometer

The multiband radiometer will simultaneously produce analog voltages which are proportional to scene radiance in each of eight spectral bands. The radiometer will be a stand-alone device capable of operation with a variety of data acquisition systems. The prototype radiometer will be capable of operation from 0° to 60°C, when mounted on a tripod, truck, boom, helicopter, or small plane.

Figure 5. Sketch of Multiband Radiometer



To achieve reliability in reflectance measurement, a field calibration procedure using a reference surface is to be employed for the reflective spectral bands.[10] For the thermal channel, direct field comparison with two reference blackbodies at known temperature will be used to establish the thermal radiance scale.

2.1 Specifications and Features of the Multiband Radiometer

Spectral Bands. The prototype unit will be equipped with a standard set of spectral bands which match, as nearly as is practical, the seven bands of the Thematic Mapper multispectral scanner (to be launched in the third quarter of 1981). Filters will be durable and suitable for use under field conditions of temperature and humidity. A summary of the spectral bands is shown in Table 1 and Figure 6.

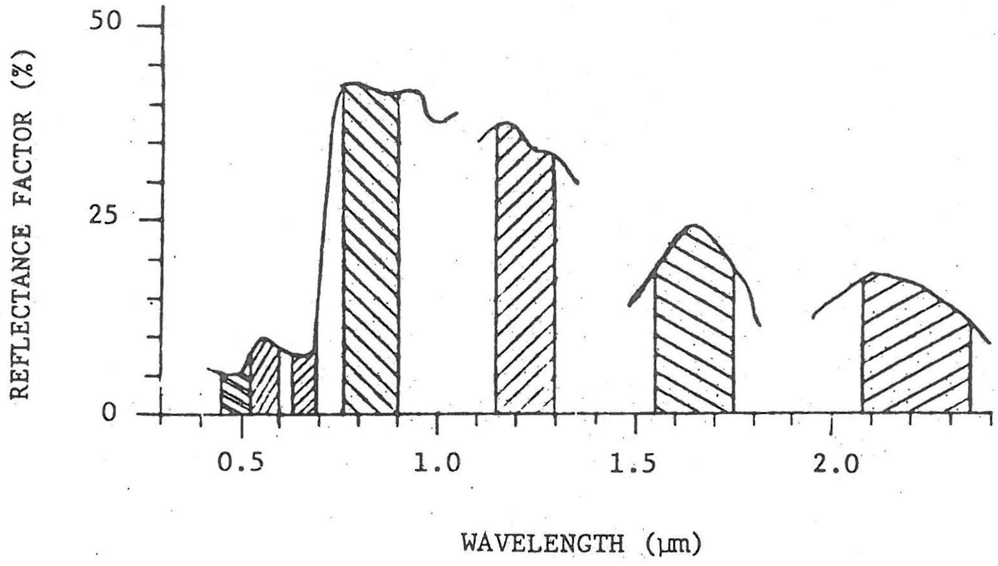


Figure 6. Spectral distribution of passbands superimposed on a typical vegetation spectrum.

Table 1. Spectral Band Specification

Band	50% Response Wavelengths (µm)	Detector	L* $W \cdot m^{-2} \cdot sr^{-1}$
1	0.45 - 0.52	Silicon	31
2	0.52 - 0.60	Silicon	27
3	0.63 - 0.69	Silicon	25
4	0.76 - 0.90	Silicon	45
5	1.55 - 1.75	PbS	16
6	2.08 - 2.35	PbS	6
7	10.40 - 12.50	$LiTaO_3$	8-32
8	1.15 - 1.30	PbS	21

Examination of Figure 6 will show that, while the four Landsat bands (0.5-0.6; 0.6-0.7; 0.7-0.8; 0.8-1.1 m) sample the vegetation spectrum coarsely and over a limited range, the seven Thematic Mapper bands provide complete and rather detailed coverage of the spectrum. Table 1 and Figure 6 show the eighth spectral band (1.15-1.30 m) which was selected by LARS agronomists on the basis of spectrometer studies.

Field of View. The instrument will be equipped with co-aligned fields of view (1°, 15°, and diffuser) which may be exchanged under field conditions (see Figure

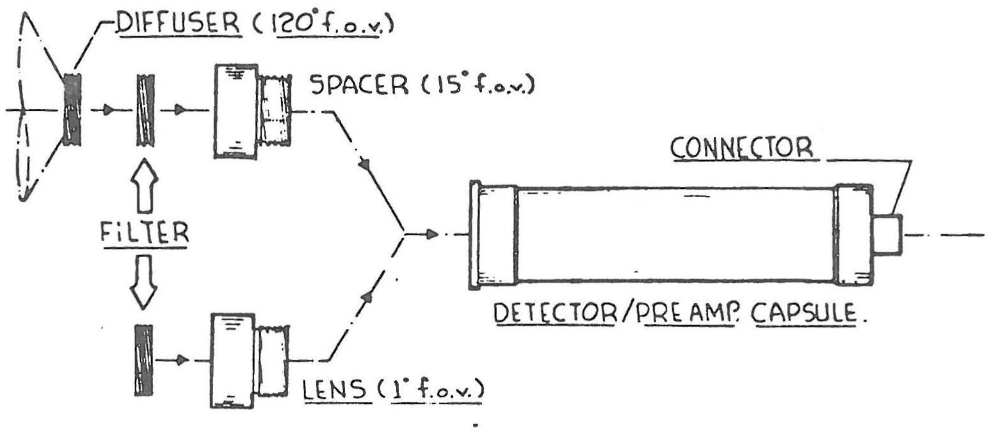


Figure 7. Optical/electronic module of multiband radiometer.

Dynamic Range. The reflective channels will have adjustable ranges (0.2, 0.5, 1.0, 2.5, 2.0, 3.0 and 5.0) which will be internally adjusted so that radiance of L* (see Table 1) will produce a response of 3 volts in the 0 to 5 volt output range for a gain setting of 1.0. L* is determined to be the nominal in-band radiance of a perfectly diffusing diffuser normal to the irradiance at sea level on a clear day (m=1).[12]

The thermal channel will have a single range of in-band radiances corresponding to blackbody temperatures from -20°C to +70°C which will produce voltages in the 0 to 5 volt range.

Chopping Arrangement. The multiband radiometer will consist of eight modular optical-electronics units centered on a 10.16 cm circle. The front-mounted chopper will limit the entry of radiance flux to the optical modules (see Figure 8). Also, not shown in Figures 5 or 8 is a cover for the chopper-optics region which is installed during normal use.

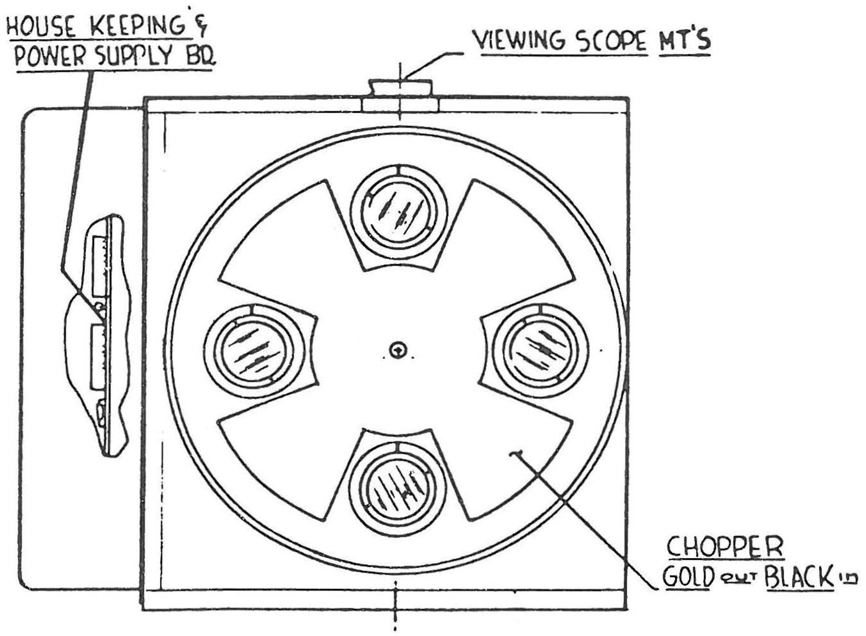


Figure 8. Chopping arrangement for the multiband radiometer.

Modularity. The multiband radiometer will be suitable for reconfiguration in field environments. Detector/preamp capsules 14 cm in length will be plugged into a mother board. Lenses, filters, and spacers will screw into the capsule as indicated in Figure 7.

Controls and Display. The gain of each reflective channel will be selectable by a panel mounted switch. A panel mounted analog meter will display channel output voltages as selected by a panal mounted switch.

Gain Status Signals. On command from an external source (TTL zero) the output from each reflective channel will be switched from data signal to an analog voltage indicating the gain setting of the channel. This feature is useful when the radiometer is mounted on the end of a long boom and for reading the gain of the channel into a data logging device.

Camera Boresight. The instrument will be equipped with a mount suitable for boresighting a 35mm camera to 0.3^{o} of the optical axis.

Camera Control. A camera control signal will be fed, through the input cable, to a jack on the exterior of the electronics case to enable remote camera operation.

Low Battery Warning Signal. The multiband radiometer will provide a TTL zero signal when the battery is judged to be too low for accurate operation.

System Temperature Signals. Several temperature monitoring devices will be imbedded in the prototype multiband radiometer for monitoring system temperatures.

Electronic Filtering. Each channel will be equipped with 4 Hz and 20 Hz filters which are internally selectable.

Measurement Precision. The performance of the reflective channels is limited by demodulation noise and gain draft due to temperature changes. Detector temperatures will be monitored and analog compensation will be used to limit the relative limit of uncertainty in reflectance measurement to 1% (silicon) and 2% (lead sulfide) for a 5 Celsius degree step in temperature imposed for 20 minutes (20 Hz filter).

The thermal channel will also be compensated and the temperature of the chopper monitored to produce an NEΔT of less than 0.5 Celsius degrees for the above conditions.

Weight and Volume. $15.24 \times 20.32 \times 13.65$ cm^3
Less than 3 Kg (production system)
3.5 Kg prototype.

Power. The instrument will be powered by any 12 volt battery and protected for vehicular battery operation. Two separate 12 volt rechargeable batteries which may be carried in a "fanny pack" will be supplied. A charger will be provided to recharge the batteries. Battery life will be greater than 3 hours in continous service.

Cables. Connecting cables, 1.2m and 15m will be provided for hand-held and boom operation, respectively.

3. Description of the Data Recording Module

The Data Recording Module (DRM) will digitize, format, and store data in a solid state memory. The DRM will accept analog signals from the multiband radiometer and other sources as appropriate to the measurement situation. It will operate under the same environmental conditions as the multiband radiometer.

The main function of the DRM is to record the data from the multiband radiometer and other data channels within 2.5 milliseconds - corresponding to 15 cm at 61 meters per second. Additionally, the unit will provide a suitable interface for a printing calculator to allow on-site evaluation of system performance and to provide a means for analysis of limited quantities of data (typically, a H.P. 97S will require about 30 seconds to process a single observation (all channels) to the desired final form and print the results. The principal transfer mechanism will be 16 bit parallel with handshake which is well suited for entry to many micro-processors and computers. A parallel to serial conversion may be required for some systems but can be easily accomplished external to the DRM.

3.1 Specifications and Features of the Data Recording Module

Data Acquisition

Data Inputs: 15 single ended channels
>10 MΩ input impedance
Resolution: 12 bits
Accuracy: 1 bit ($0^{o}C$ to $60^{o}C$)
Stored Data (4K increments to 64K - 16 bit static RAM with data retention battery)
Year, Day of Year, Time, Observation Number (auto advance), up to 15 channels of data and radiometer channel gain (optional), will be recorded for each observation.
Data Retention: 30 days

Data Output

Display: Memory contents
Transfer: Memory contents direct to parallel input port on digital computer or translating device. Memory contents may be directed to printing calculator such as the Hewlett-Packard 97S for on-site computation of reflectances, radiances, and temperatures.

Control Functions

Intervalometer Action. Based on internal clock, adjustable timing intervals for acquisition of data and activation of camera from 0.1 to 10 seconds will be provided.

Data/Gain Status control for radiometer gain interrogation
Low Battery Warning - Audible
Channel Over-Range Warning - Audible
Remote Activation of Acquisition
Observation Number (6 BCD characters) available for use by data back camera

Power

The instrument will be powered by any 12 volt battery and protected for vehicular battery operation. Two separate 12v rechargeable batteries will be supplied. Battery life will be greater than 3 hours in continous service. A charger will be supplied to recharge the batteries. Batteries will be external to the logger case.

Weight and Volume

The logger will be light enough to hand carry with the radiometer. Battery and logger may be strapped to user and comfortable to carry.

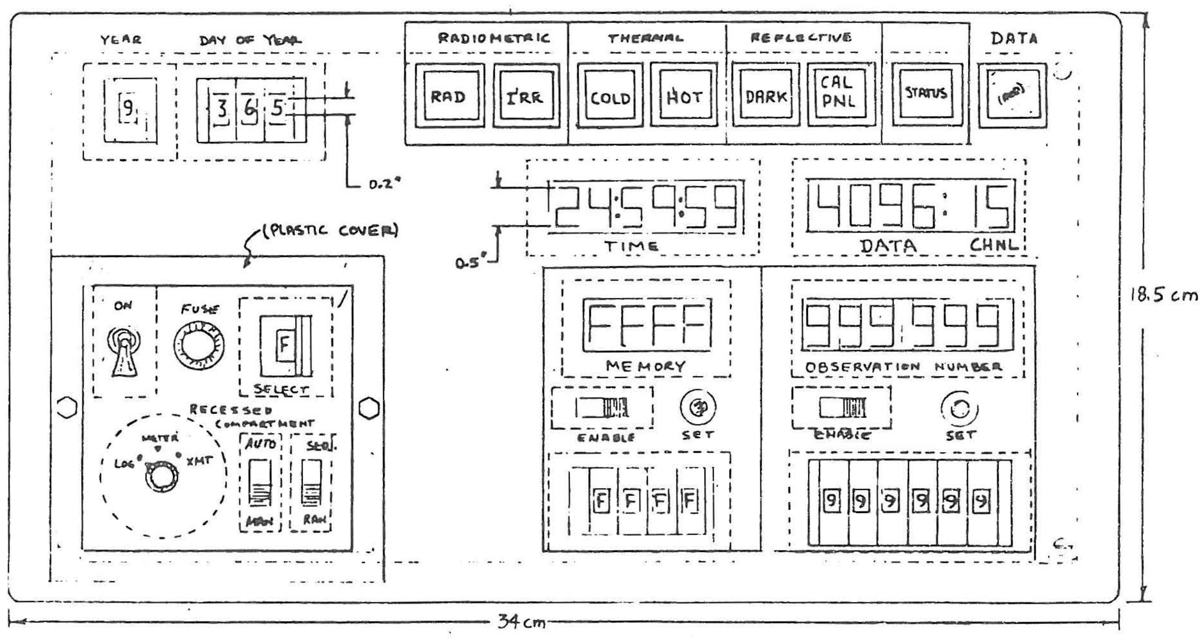


Figure 9. Sketch of Front Panel of Data Recording Module.

Conclusion

The research required to produce durable solutions to the problems of the second generation of remote sensing technology must effectively deal with more subtle, second-order effects in the reflectance characteristics of earth surface features. Such research must be well designed and be performed on the appropriate geographic scale over an adequate period of time. It is felt that this instrument system will enable researchers to perform a significant portion of this needed research.

A prototype radiometer is being prepared by Barnes Engineering Co., Stamford, CT, USA with delivery scheduled for July 1980. Following laboratory and field tests of the prototype radiometer and data logger system (prepared by Purdue) specifications for production units will be completed in fall 1980. Commercial availability of both units is planned in early 1981.

Acknowledgements

The authors wish to thank Blaine Blad, University of Nebraska; Ray Jackson and Craig Weigand of USDA; Robert Sadler, Exotech, Inc.; Robert Buckley, Barnes Engineering Company; Richard Juday and Mickey Trichel, EOD, NASA, Johnson Space Center for their assistance and direction in the formulation of the system details. Special acknowledgement is made to Robert B. MacDonald, NASA, Johnson Space Center and Roger M. Hoffer, LARS, for their participation in the development of the concept. This research work was performed under NASA contract NAS-9-15466.

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