A Two-Channel Multiplex Video Remote Sensing System

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ABSTRACT: Video systems offer several advantages over conventional photography for remote sensing, deriving mainly from the instant availability of their output. However, the difficulty of extracting discrete spectral data from a composite video signal and the lack of spectral bands outside the visible region limit the value of common color video systems for agricultural and natural resource applications. Several different multispectral video systems have been developed recently, but very few provide both composite color and easily-extracted individual band output. A new system has been developed consisting of two bore-sighted video cameras fitted with red and near infrared bandpass filters, and a separate multiplexing unit which produces (1) real-time composite color output consisting of a mix of the two channels (red and infrared), (2) output of alternate frames from each channel, and (3) output of a vegetation index image derived from an analog ratio of the two channels.

INTRODUCTION

VIDEO REMOTE SENSING offers a number of distinct advantages over photographic remote sensing, as summarized by Meisner (1986). For practical applications, the first and most important advantage is that video imagery is available immediately. This permits rapid turnaround for applications where the value of the information is short-lived (e.g., agriculture), or where delays in scheduling have significant time penalties (e.g., disaster operations). Second, "live" video images can be used on-board the aircraft for navigation and monitoring system performance. Third, video images can be efficiently recorded and stored on an extremely inexpensive medium (e.g., a two-hour video cassette costing less than $10 can store 216,000 images as video frames). Finally, these analog images either can be interpreted manually from a video monitor, or they can be converted to digital values and analyzed using digital image processing systems. Interest in applications of video imaging in remote sensing is growing rapidly, as evidenced by recent conferences (American Society for Photogrammetry and Remote Sensing, 1988).

To utilize commonly available video cameras for remote sensing applications, the camera must be capable of employing relatively narrow-band filters in the red and near-infrared to assess vegetation condition or amount (Tucker, 1979).

MULTISPECTRAL VIDEO SYSTEMS

Several different approaches have been adopted in the design of multispectral video systems that overcome the limitations of conventional video cameras. The intent generally is to add increased spectral capabilities without sacrificing the fundamental advantages of video: i.e., rapid turnaround, low cost media, and ease-of-use. These conflicting goals have been met with varying success. The following descriptions of the major approaches are drawn largely from Meisner (1986).

Multiple-camera array. The most direct approach has been to employ an array of black-and-white cameras, each fitted with the appropriate filter. The cameras are bore-sighted so that their fields-of-view are coincident, and the signals are electronically synchronized and recorded on separate tape recorders (Nixon *et al.*, 1985), or are multiplexed for recording as a color signal or frame-interleaved band images on a single recorder (Vleck and King, 1985). The signals from these can be analyzed separately or combined in the laboratory.

This design has the advantages of simplicity, multiple discrete band output, and ease of changing filters. Primary disadvantages are associated with the complexity of timing multiple recorders and the lack of a single composite signal (if not multiplexed), and irresolvable problems of parallax at close range.

Internal optical-beam splitter. Based on the design of a conventional color camera, a beam splitter is used to direct light to detectors through appropriate filters. The commercially-available example is designed to produce a false-color infrared output image, either as RGB analog or as a composite signal (Meisner and Lindstrom, 1985).

Advantages are an instantaneous color output and the use of a single lens that eliminates alignment problems. Disadvantages are the difficulty of changing filters and problems of extracting discrete spectral data from the composite signal without a three-channel video recorder.

Filter wheel. Another commercially available system uses filters mounted in a disk which spins in front of a single detector. The output signal is composed of a continuous sequence of single-band images acquired through each filter as the disk rotates (Xybion Electronic Systems, 1985).

Advantages are the use of a single lens, eliminating alignment problems, comparative ease of changing filters, and the production of images in discrete bands. The primary disadvantage is lack of a composite output.

A TWO-CHANNEL MULTIPLEX VIDEO SYSTEM

In January 1988, with support from the National Aeronautics and Space Administration (NASA) and the University of Arizona, we undertook development of a "new" video remote sensing system for monitoring agriculture and natural resources. The system we envisioned would differ from those described above in its ability to produce composite, single-band, and ratio images for use in both research and applications. The design consists of the following elements (Figure 1) :

Cameras: two boresighted, black-and-white, high-resolution (780 pixels horizontal, 488 pixels vertical) Cohu Model 4810 CCD video cameras mounted on a common fixture, with wide-angle lenses (12.5-mm focal length) and removable filters in the red (610 to 690nm) and infrared (780 to 930nm) spectral bands corresponding to those used in the Thematic Mapper. Specifications for the camera system are given in Table 1.

Multiplexer: a real-time video image processing unit between the camera system and video recorder that can:

- modify the contrast of the raw video signals from each camera, as desired;

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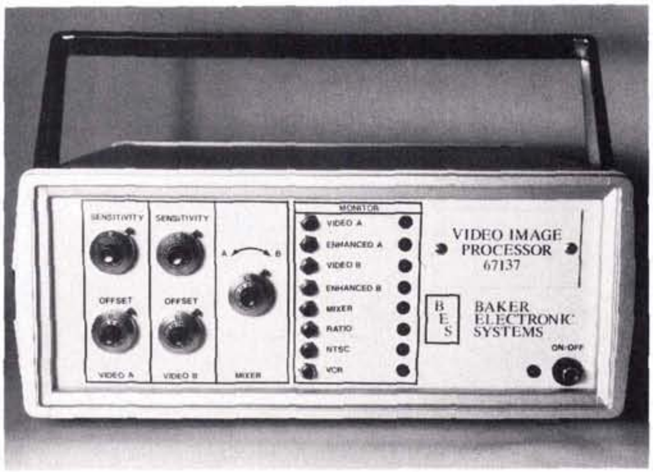
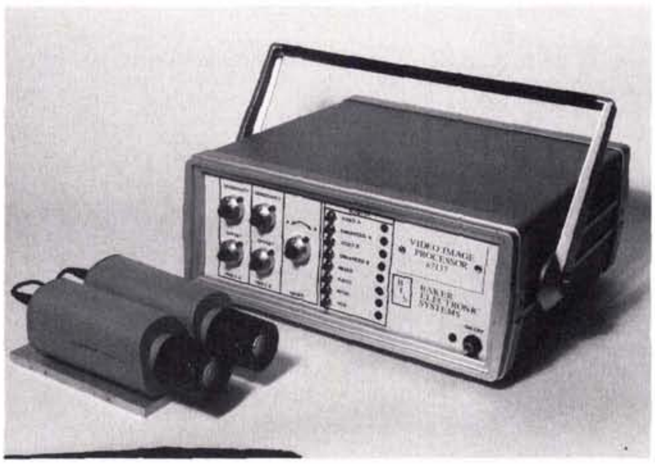
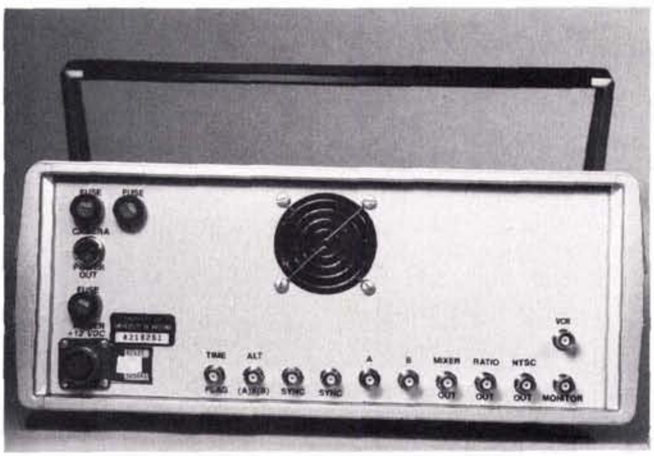


(a)



(b)



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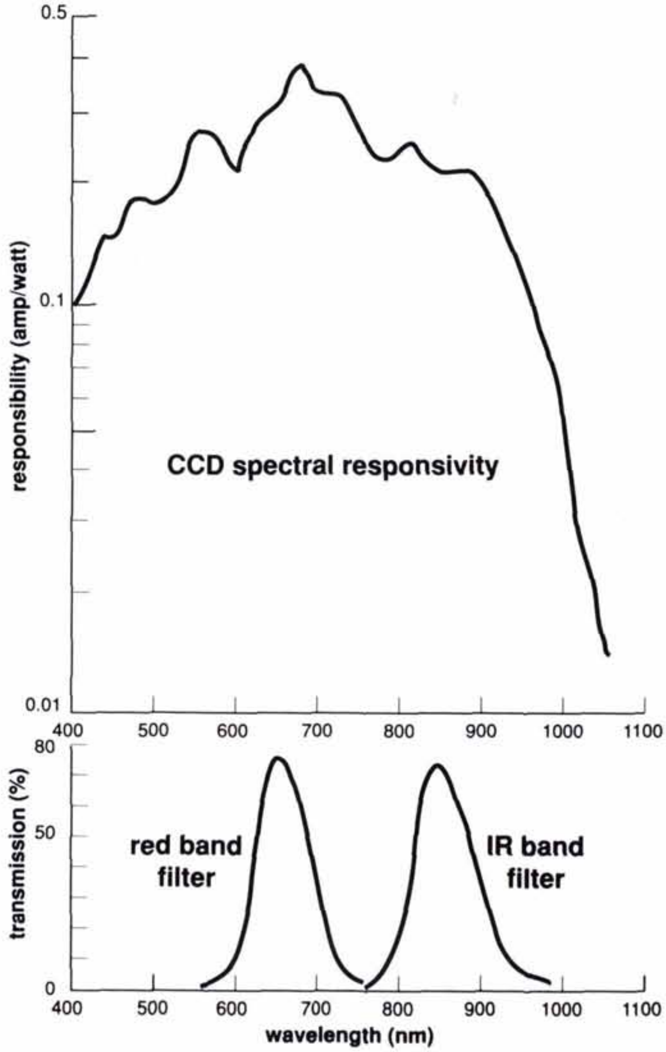

(d)

FIG. 1. The two channel multiplex video remote sensing system (a). Dials on the left side of the control panel permit the two input channels to be enhanced separately and mixed in any proportion. A set of dip switches is used to assign colors in the output composite image, and to switch the numerator and denominator of the vegetation index processor, if desired (b). Jacks for each of the seven possible outputs are on the rear of the unit (c). Power requirements of the camera and multiplexer are approximately four amps and are met by rechargeable, portable gel-pack batteries, allowing full 2-hour recording. The camera spectral sensitivity (Texas Instruments, 1985) and filter transmission curves (Andover Corporation, 1988) are presented in (d).

- mix the individual video signals to yield a single composite color signal composed of any desired combination of raw or enhanced camera signals, or other processed outputs (see option d; Plate 1);

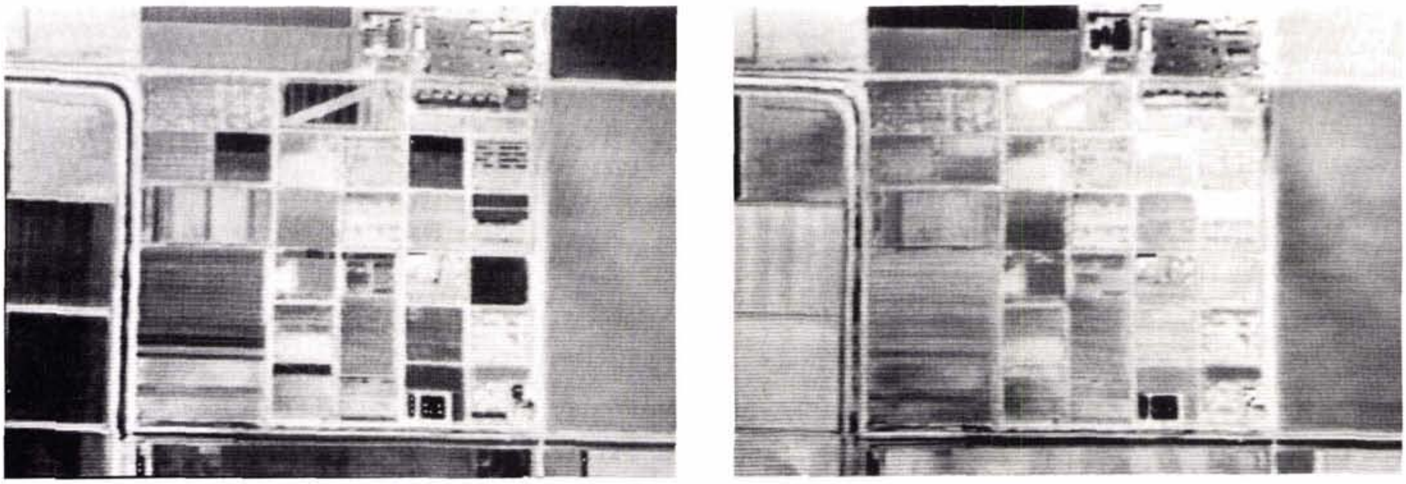

FIG. 2. Images produced by the red and infrared cameras. One multiplexer output consists of alternating frames from each camera which are recorded on a single tape recorder. These frames can be digitized later and processed in a digital image processing system.

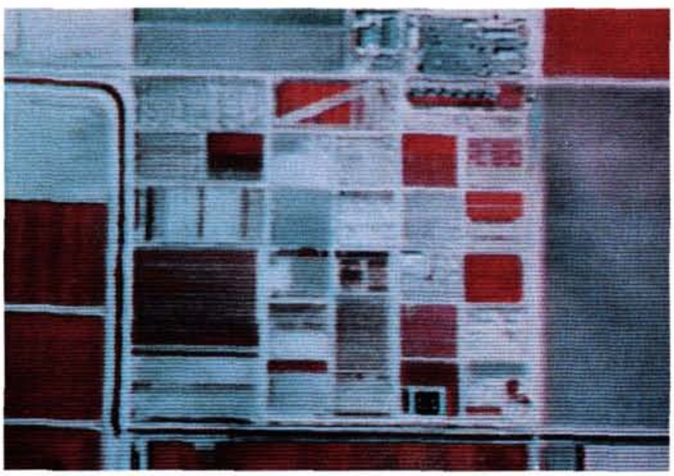

PLATE 1. False color composite image created by a user-selectable mix of the red and infrared signals (infrared video channel displayed as red, red video channel displayed as green and blue).

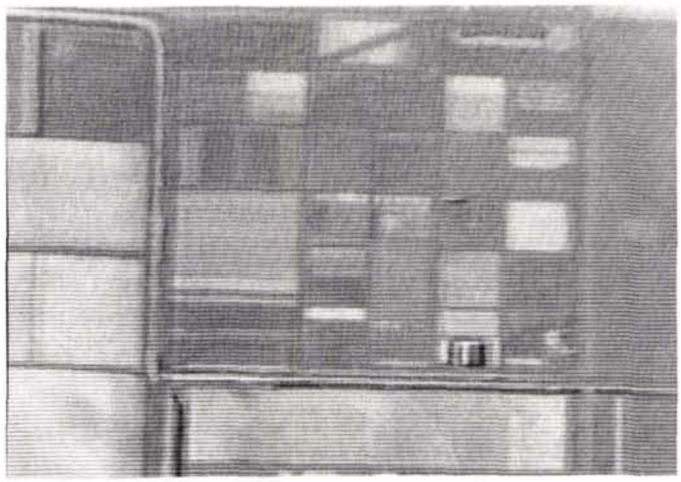

FIG. 3. A vegetation index image. The outputs of the red and infrared image are combined according to the general form $(A-B)+0.5/2(A+B)$. Because of the possibility of negative values, a strict NDVI form is not possible in the analog combination.

- generate a single output signal of alternating frames from each raw video input signal (Figure 2); and
- perform a continuous ratio of the difference and sum of two video input signals yielding a single ouput signal comparable to the normalized difference vegetation index (Tucker, 1979; Figure 3.)

In addition to a video monitor output, the system is capable of producing seven different output signals simultaneously (raw and enhanced signals from each camera, NTSC color composite, alternate bands, and vegetation index). Any one or all of these signals can be displayed or recorded during operation, provided appropriate equipment is available.

The video image processor contains a 12-volt DC power supply to provide the necessary power forms to operate the internal modules. An RS-170 sync generator provides signals to synchronize the CCD cameras. The unit accepts two video inputs, which are passed through routing electronics to a pair of enhancer modules, prior to signal mixing and processing. The enhanced signals are mixed and the resultant signal along with the two original camera signals are made available to an NTSC encoder. The red, green, and blue color encoder inputs are available for user selection, providing the user with many color combinations of NTSC color video (Figure 1b).

TABLE 1. CAMERA SPECIFICATIONS

CCD resolution	754 pixels by 488 lines (11.5 micrometre CCD elements)
Exposure time	1/60 second
Full signal level	0.032 ft-candles at CCD
Signal-to-noise	50dB peak signal to RMS noise
Typical exposure settings	$f/8$, 1.3 neutral density in red band, 1.0 neutral density in IR band

All electronics are packaged in a small, portable enclosure, utilizing plug-in boards for ease of maintenance. Front panel controls have been kept to a minimum but, where potentiometers are used, 10-turn locking counter dials are used to allow repeatable specific system set ups (Figure 1b).

The two-color to three-color transformation is similar to that successfully used for displaying real time images of Jupiter and Saturn from the Pioneer 10 and 11 spacecraft (Baker, 1975). The

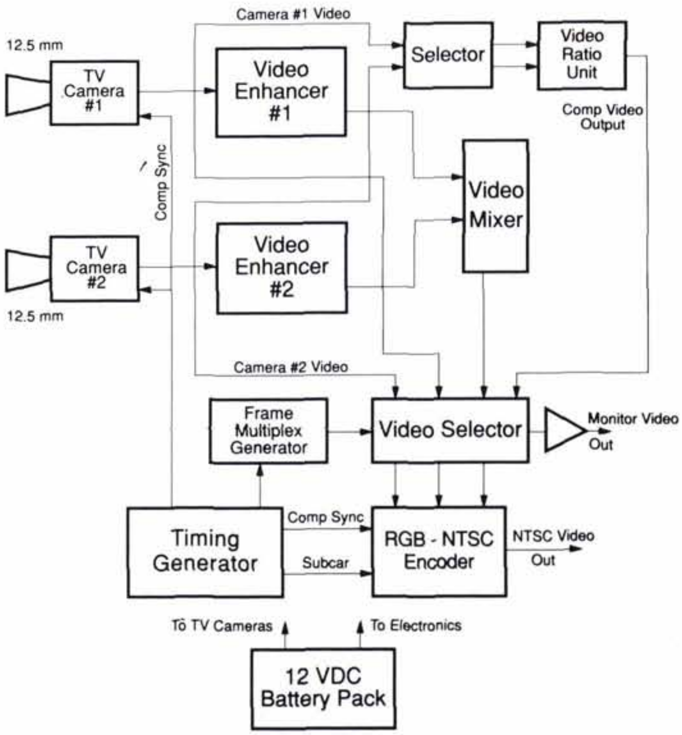

FIG. 4. Two-channel video camera remote sensing system.

third, synthesized spectral band is a linear combination of the other two bands.

APPLICATION AND ANALYSIS

The system is currently being evaluated in two sets of applications. In one, color-infrared video images are manually interpreted to map the extent of recession agriculture along the Senegal River (Marsh *et al.*, 1990). In the other, the video imagery provides high-resolution aerial data for a multi-agency program that requires a large multi-sensor (satellite, aircraft, and field) database for the Maricopa Agricultural Center in central Arizona (see Plate 1 and Figures 2, and 3).

Color infrared images are interpreted manually on a conventional color monitor. Alternate frame images are digitized on a microcomputer (Compaq Plus PC) equipped with a frame-grabber. Simple image manipulation tasks can be performed on the Compaq using XICAS2 software (Xybion Electronic Systems, 1987). More complex image processing is done on a Compaq 386 system using the PC ERDAS image processing system (ERDAS, 1988; Figure 4).

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