

Infrared telemetry range for fire management

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Abstract

The USDA Forest Service has used airborne infrared systems for forest fire detection and mapping for many years. The transfer of the images from plane to ground and the transposition of fire spots and perimeters to maps has been performed manually. A new system has been developed which uses digital image processing, transmission, and storage. Interactive graphics, high resolution color display, calculations, and computer model compatibility are featured in the system. Images are acquired by an IR line scanner and converted to 1024 x 1024 x 8 bit frames for transmission to the ground at a 1.544 M bit rate over a 14.7 GHZ carrier. Individual frames are received and stored, then transferred to a solid state memory to refresh the display at a conventional 30 frames per second rate. Line length and area calculations, false color assignment, X-Y scaling, and image enhancement are available. Fire spread can be calculated for display and fire perimeters plotted on maps. The performance requirements, basic system, and image processing will be described.

Introduction

Forest fire suppression or management of large fires is a complex operation involving trained professionals in many disciplines and equipment ranging from shovels, pulaskis, and other hand tools to infrared (IR) reconnaissance systems, extensive communications systems, automatic meteorological stations transmitting weather data via satellites, and computerized fire spread models. As technology becomes available, it is applied, where appropriate, to aid the fire staff in achieving and maintaining control of the costly and devastating fires. This paper describes a video image processing system developed for aiding in the transmission, display, and use of infrared images acquired by existing Forest Service airborne IR line scanning systems. The airborne portion will be installed in existing aircraft and the ground portion in a fixed facility at Riverside, California, as part of the Firescope Program.

IR image acquisition

During large on-going forest or wildland fires, airborne infrared reconnaissance is essential for “mapping” or locating the fire perimeter and any fire spots outside the control lines. Visual observation is usually inadequate because of the heavy smoke pall and the need for night reconnaissance in preparation for the next day’s activities. Forest Service planes are using venerable IR line scanners originally supplied by Texas Instruments and modified substantially over the years. Kennedy optics focus radiation from nominal 3-5 micrometer and 8-12 micrometer bands onto their respective detector elements. Time correlation, scaling, combining, and processing of the two signals are followed by unique target discrimination, noise rejection, and false alarm rejection circuitry. The end product is a rapid, wet chemical processed negative film of high quality, clearly showing the terrain features, fire location, and any fire or hot spots, with added target detection and mileage marks. The processed film is also roll-corrected and rectilinearized to assist in the image interpretation and translation to maps. Presently, the IR images must be physically delivered to the fire command post, where tedious manual transposition of the fire location to maps is accomplished by a trained interpreter.

Present airborne infrared image acquisition system

Figure 1 shows a block diagram of the present infrared image acquisition system. Additional features are described in reference 1.

The dual detectors are nominally in the 3 to 5 and 8 to 14 micrometer wavelengths. The actual spectral responses were calculated to provide nearly equal attenuation over the range of atmospheric moisture content likely to be encountered.

The A channel (3-5) and B channel (8-14) signals are processed so that they represent the same instantaneous field of view (IFOV), scaled, combined, and presented to the target detection module (TDM). The background or terrain features are effectively subtracted leaving the signal from a hot target (fire) outstanding for presentation to the TDM circuitry. Pulse height and width discrimination is used; and if the target signal passes the detection criteria, it is retained in a one line memory. The next succeeding line is then compared pixel by pixel; and if the target is again detected at the same pixel location, it is accepted as a valid target. This succeeding line correlation reduces the false target probability but does require at least 100 percent overscan.

The dual channel processing makes possible the detection of very small (0.465 square meter) fires from altitudes of 5,000 meters when using a basic 2 milliradian IFOV system.

The detection of a valid target causes a unique mark to be printed at a known distance from the hot spot on the face of the imagery. A mark is also printed at the end of the image, and a visual alarm can be used in the aircraft at the time of detection.

The terrain (background) features are printed from the B channel signal by an image recorder using a fiber optic cathode ray tube with a rapid wet-chemical film processor.

The roll gyro provides a signal which adjusts the active sweep time to provide a $\pm 10^\circ$ roll correction capability. No correction is made for pitch or yaw variations, or for crabbing with respect to straight line of flight.

Signals from the avionics are used to provide velocity to height (V/H) information and ground mileage indications.

The image recorder rectilinearizes the printed image by using a tangential sweep, beam deflection circuit for the CRT.

The developed imagery is available on board the aircraft in near real time (from a few seconds to a couple of minutes, depending on the V/H). Infrared technicians on the aircraft view the imagery and determine adequate coverage of the fire area, adequate image quality, need for additional flights from different directions or altitudes, and a quick assessment of any area requiring special attention.

Telemetry

Telemetry may be defined as measuring from a distance. Typically telemetry consists of measuring one or more parameters, transducing the physical characteristics into electrical signals, processing the signals, multiplexing, transmitting, receiving, demultiplexing, processing, and displaying in a form usable by people. In this system, the temperature of small portions of the earth are measured from a distance, the IR detectors transduce the natural radiation into electrical signals, these are processed and multiplexed into a continuous analog signal. The analog signal is then essentially demultiplexed, processed and displayed on film to the technician. The procedure up to this point is somewhat the reverse of a lot of telemetry applications. That is, rather than measuring parameters on an airborne (or space borne) vehicle and transmitting them to the ground for display where the people are, we are measuring parameters on the ground which are transmitted (by natural radiation) to an airborne vehicle for display where the people are. The reverse procedure continues because we now take the display which is usually the end product and turn it back into an electrical signal for processing, multiplexing, and transmission back to the ground. Thus following the encoding of the displayed images (data), the procedure is somewhat as in conventional telemetry.

Airborne processing and transmission

The new system will provide a rapid means for transmitting the acquired IR images to the ground (rather than relying on physical delivery), speed up the interpretation and transposition to maps, provide image enhancement capability, provide an interactive, high resolution color display, produce color hard-copy prints, and interface with improving fire spread computer models. A block layout diagram of the airborne processing/transmitting system is shown in figure 2.

The IR image strips will be produced on film, as they have been and placed on a light table for viewing by a high resolution monochrome TV camera. The camera will serve as a format converter. The video output of the camera will be digitized into a 1024 x 1024 x 8 bit frame and stored. The frame will then be read out of storage at a 1.544 megabit/second rate and provided as an NRZ signal to modulate the 14.7 GHZ transmitter. The transmitter output is then amplified by a TWTA to provide the necessary carrier power to the antenna. Individual frames will be sequentially stored and transmitted under control of the on-board technician.

Although using a TV camera focused on hard copy images is not a philosophically pleasing means of converting from one signal to another, there are some reasons for doing so at this time: 1) The TV camera is an inexpensive and effective means of getting the image into a composite video format, 2) The IR technicians on the plane can point out or mark areas of special interest, 3) Other information or notes can be placed, in front of the camera for transmission, 4) A permanent hard copy image has been produced for use in the event of a problem anywhere in the transmission or storage links.

Ground reception, processing, storage, and display

A block diagram of the ground receiving station is shown in figure 3. An EMP, Inc. cosecant squared, single axis automatic tracking antenna system including a low noise pre-amplifier will provide the receiver input. The receiver output will be an NRZ signal at 1.544 megabits identical to the transmitter modulating signal. The solid state digital frame store will accept each sequentially transmitted image frame and immediately send it on to the hard disk storage. After receipt of all pertinent frames from the fire, any stored frame may be recalled to the solid state frame storage which will then serve as the refresh memory and drive the high resolution monitor at 30 frames per second.

Color may be assigned to areas of a given temperature or to highlight roads, firebreaks, or other selected features. Proposed firebreaks and projected fire perimeter expansions may be added as color overlays to vividly display the situation as it exists or as it may exist at various times in the future. Crew and equipment positions, hot spots outside the firelines,

intensely hot areas, high value structures, etc., can all be prominently displayed as desired by the fire staff.

The IR images are usually at a different scale than the maps and also the image X and Y scales are not the same. Known points and distances can be identified on the monitor and entered into the controller memory. The processor can then make corrections and plot the fire perimeter and other points or areas of concern on maps at the proper scale and location to accomplish the image-to-map transposition task. A Dunn hard-copier can provide multiple color prints of anything displayed on the monitor for documentation or use at places remote from the system.

A separate video port may be used for remote monitors. A computer port is available for future use in transferring images or data to or from a computer. Image enhancement functions can provide sharper edges, better gray scale utilization, etc. The entire system can also be used for transmission, reception, digitizing, storage, and display of images at standard 525 line resolution, either single frame or at 30 frames per second, if needed.

The digital image processor is described in more detail in reference 2.

Fire image telemetry

Fire image telemetry has been used operationally since 1974 (references 3 and 4). The major difference in the former system and the one described here is the use of a video format which can utilize digital image processing techniques that are available now. Fire telemetry has been used primarily in Southern California and this system will also be used there. The ground receiving station will be at an Interagency Operations Coordination Center in Riverside, California. Subsequent stations may be used in other parts of the country and mobile receiving stations may be used at command posts in various remote locations as required, depending on the results of operational use of the first system.

Conclusion

The telemetry/image processing system described in this paper will provide a new level of display capability and interactions between fire intelligence officers, fire status information, and computer-generated data. The system utilizes technology not previously used or available to the fire staff during active, on-going, large fires. Operational experience will be used to demonstrate the capabilities and usefulness of the system and perhaps identify unexpected uses. The operational experience will also help evaluate the potential for additional systems in other areas of the country and for mobile ground stations at remote fire command posts in the field.

References

1. John R. Warren, "Infrared Applications for Forest Fire Management," Proceedings of the Fourteenth International Symposium on Remote Sensing of Environment, April 1980.
2. W. K. Pratt, "Systems Architecture of the VICOM Intelligent Image Processing Display System," SPIE Proceedings, 1981.
3. John R. Warren, "Telemetering Infrared Imaging from Aircraft to Fire Camp", Fire Management, Fall, 1975.
4. John R. Warren, "Telemetry Applications in Wildland Fire Control", ITC Proceedings, 1975.

INFRARED FIRE SURVEILLANCE SYSTEM

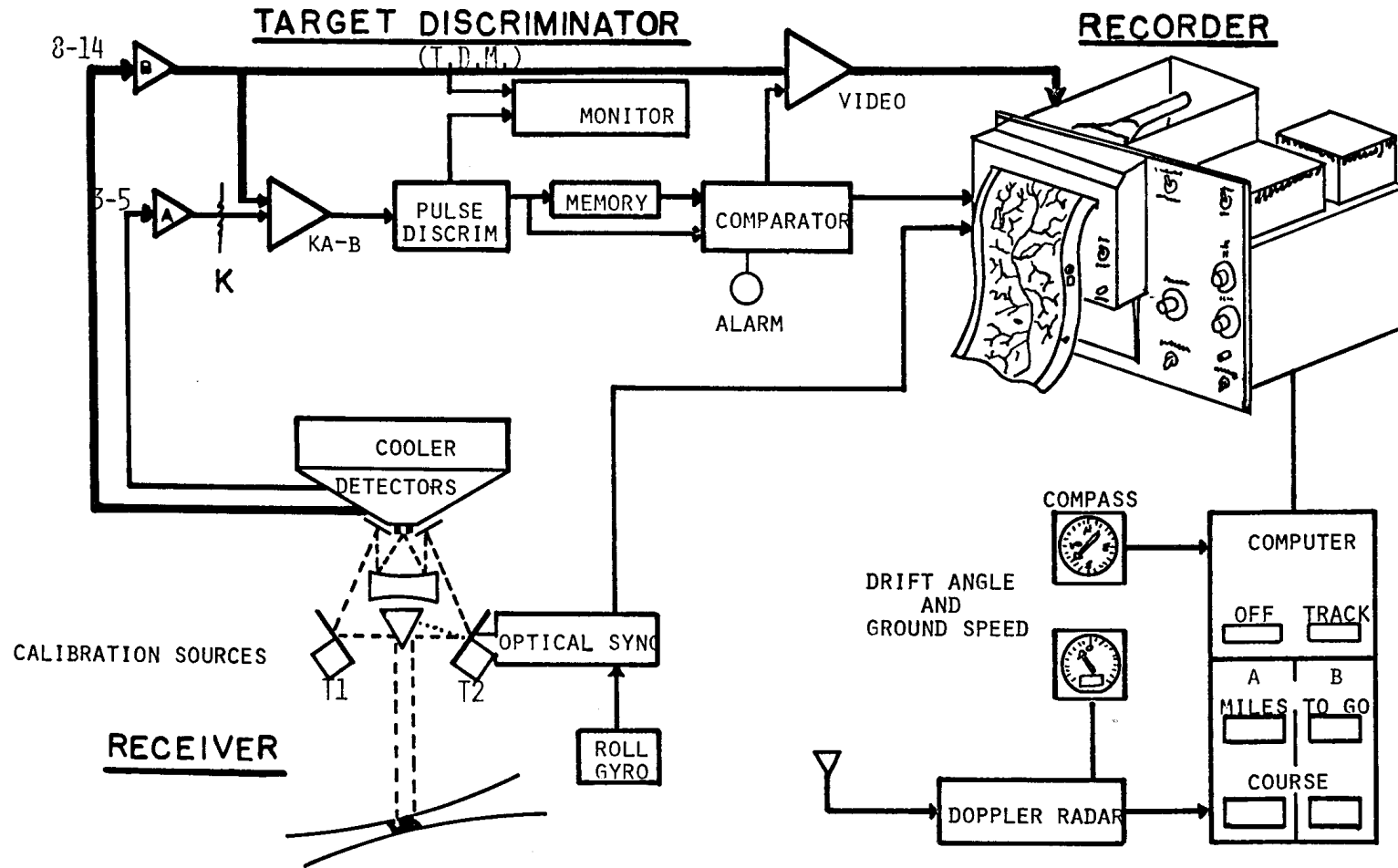


FIG. 1 INFRARED SYSTEM BLOCK DIAGRAM

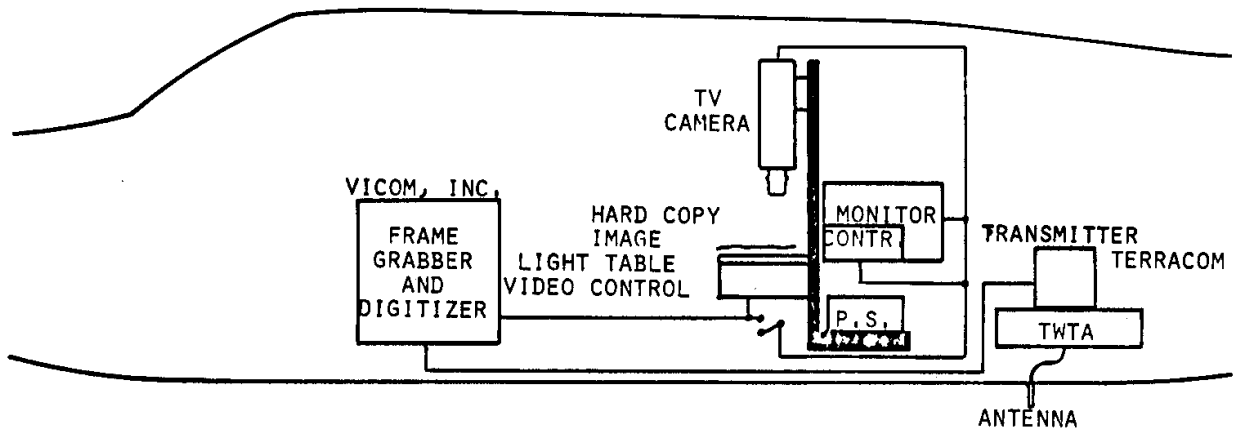


FIG. 2 AIRBORNE PROCESSING/TRANSMITTING SYSTEM LAYOUT

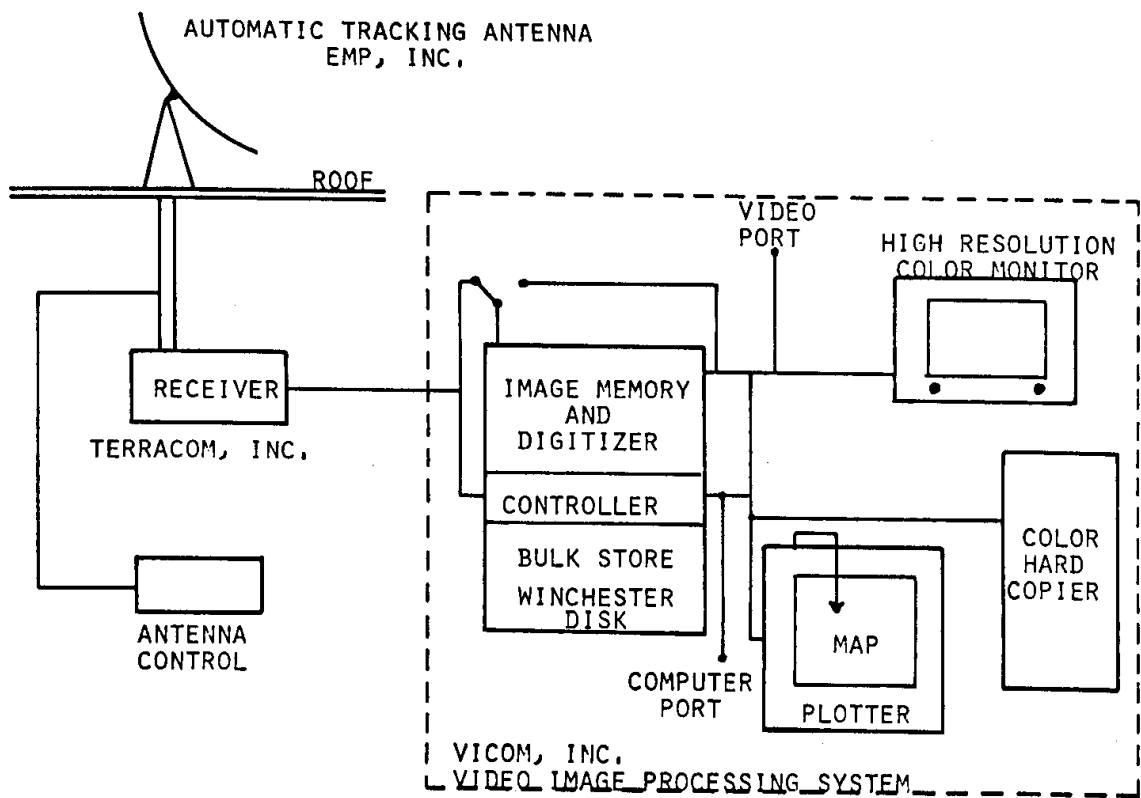


FIG. 3 GROUND-RECEIVING STATION BLOCK DIAGRAM