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Design and Development of Compact Hand Held Target Acquisition Device

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ABSTRACT

A compact, lightweight hand held target acquisition device, comprising of an infra red imager, colour CCD camera, eye safe laser range finder, global positioning system and digital magnetic compass has been developed. The aim was to develop a compact, lightweight, modular and man-portable multi function electro-optical system with a recognition range of 1 km for vehicles and 500 m for human movement enabling day and night time surveillance, target ranging capability, ability to generate coordinates of the operator and estimation of target coordinates. Hand Held target acquisition device operates on 12 V DC, has integrated signal processing for all the sensors and display electronics with a weight of 3 kg. Overview of the system, design methodology, performance modeling, range simulation of both the IR Imager and Colour CCD Camera and field results have been presented.

Keywords: Hand held target acquisition device; IR imager; Global positioning system; Digital magnetic compass; Long wave IR

1. INTRODUCTION

Modern day ground forces that operate in close quarter battles need to be equipped with state of the art electro-optical surveillance systems that provide capability of better tactical target discrimination and reconnaissance during day and night. This visual imagery needs to be supplemented with information from complimentary sensors to ensure accurate location of the intended target. Different systems around the world use separate electro-optical equipment for imaging during the night, day and for ranging and localisation applications. These systems are heavier, power hungry and are not user friendly as they require multiple equipment to be operated simultaneously having manual intervention for estimation of range and localisation parameters from numerous input devices[1,2].

The design and development of a compact, battery operated man-portable multi sensor hand held target acquisition device (HHTAD), useful especially for close quarter battles have been presented. The system has been ergonomically designed for ease of operation to provide surveillance and aiming capabilities. The system has integrated geo-location sensors that provide the coordinates of the operator and those of the target for initiating indirect firing and counter strike measures.

2. SYSTEM DESIGN APPROACH

The specific requirements for close quarter combat is to provide a system that is lightweight, has silent operation with longer operational time on a single battery load providing visual as well as localisation details. To address this requirement, the hand held target acquisition device is designed using five different sensors housed in a single mechanical enclosure. The five sensors are infra red (IR) imager, colour CCD camera, eye safe laser range finder (ELRF), global positioning system (GPS), and digital magnetic compass (DMC). The IR imager provides real time video for day/night surveillance. The colour CCD camera provides day time video. The ELRF provides that range to target. The range data together with the input from the GPS and DMC provide ranging and geo-location capability. The equipment also consists of the signal processing, power supply, display electronics and a key panel for Man Machine Interface.

The signal processing electronics receives range data from ELRF, geo-location and bearing from GPS and DMC respectively and computes location coordinates of the target in real time. The key panel is used to invoke the range and localisation data which is superimposed on real time TI/CCD video. The key panel allows for the selection and adjustment of various parameters such as TI/CCD video output selection, polarity, non uniformity correction, ELRF range estimation, localisation parameter estimation, etc,

Hand held target acquisition device provides surveillance in both the IR region in the 8 μm - 12 μm band as well as in the visible region. A recognition range up to 1000 m for vehicle target and 500 m for human target is obtained.

The equipment is compact, modular, light weight and man-portable with a weight of 3 kg. It offers a four hour continuous operation on a 12V Li ion battery with intelligent power supply management resulting in better performance across different environmental conditions for temperatures from - 30 °C to + 55 °C. The specifications of HHTAD are listed in Table 1.

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Table 1. Specifications of HHTAD

Infrared imager	
Detector, FOV	640 X 480 , 6.6º X 5.2º
Recognition range	≥1 km for vehicle target
Laser range finder	
Range	100 m to ≥ 3500 m
Accuracy	± 5 m
Digital magnetic compass (DMC)	
Resolution	1°
Accuracy	≤ 1°
Global positioning system	Integrated GPS with positional accuracy < 15 m
Colour CCD camera	
FOV(Narrow)	≥ 3° x 1.8°
Display	
Display type	Colour OLED
Data displayed	Range, self and target coordinates
Battery	12 V Lithium Ion
Weight	≤ 3.0 kg

3. SUB SYSTEM DESIGN

Hand held target acquisition device was designed for instant turn on, silent operation, to meet the recognition ranges of 1Km for vehicle targets and 500 m for human target during both day and night surveillance and for obtaining accurate target locations. To meet these requirements the following subsystems were designed.

3.1 Infrared Imager

The infrared imager has been designed using a 640 x 480 elements Uncooled staring focal plane array (FPA) operating in 8 µm - 12 µm wavelength[3]. It provides the IR imagery during day and night.

IR Band Selection: There are two types of IR FPAs, cooled and uncooled FPAs[4]. The cooled IRFPAs require the use of a vacuum dewar and cooler assembly operating around liquid nitrogen temperature to provide IR imagery. These tend to be heavier, more power hungry and have acoustic noise associated with the cooler which is not ideal in close quarter combat. Uncooled IRFPAs operate at room temperature and do not require coolers for functionality. Hence they turn on instantly and silently. Uncooled IRFPAs operate in the 8 µm -12 µm wavelength giving the advantages of higher flux, better performance in dusty and smoky environments and less affected by atmospheric changes. The major specifications of the IR FPA are listed in Table 2.

Table 2. IR FPA characteristics

Configuration, pixel pitch	640 X 480, 17 µm
F number	1.0
IR band	8 µm – 12 µm
NETD	<50 mK
Video output	CCIR

IR Optics: The IR imager has been designed based on single field of view (FOV) optics employing only three germanium lenses operating at F/1.4 to optimise the weight and performance of HHTAD. The focal length of the optics is 90 mm and the clear aperture is 65 mm. The optics module has been designed to operate from - 30 °C to + 55 °C. The narrow field of view is covered by electronic zoom.

3.2 Colour CCD Camera

The colour CCD camera features 440,000 effective pixels with a wide dynamic range and 10X optical zoom[5]. The minimum illumination required is 1 lux. and it has an SNR of 50 dB. FOV changeover and focus are controlled over a serial interface. The major specifications of the colour CCD camera are listed in Table 3.

Table 3. Colour CCD Specifications

Image sensor	$\frac{1}{4}$ ” type HAD CCD
Number of pixels	440,000
Optical zoom	10 X
Digital zoom	12 X
Horizontal angle of view	46° to 4.6°
S/N Ratio	50 dB
Input voltage	7 V
Power consumption	3 W
Video output	PAL

3.3 Eye Safe Laser Range Finder

The laser range finder is an Erbium-glass class I eye safe laser that can range targets at a distance of 3.5 km. It works on 12 V DC with a maximum power consumption of 80 W. The major specifications of the ELRF are listed in Table 4.

Table 4. ELRF Specifications

Type	Erbium glass class I eye safe
Range (a) Maximum (b) Minimum	 3.5 km (vehicle target) 100 m
Accuracy	±5 m
Discrimination	50 m
Wavelength	1535 nm

3.4 Global Positioning System

An integrated GPS with a 12 channel receiver working on NMEA protocol automatically produces navigation data without the need for user initiation. The GPS features short reacquisition time of less than 2 s and a positional accuracy of less than 15 m.

3.5 Digital Magnetic Compass

The DMC integrated into HHTAD provides the bearing and elevation data with accuracies of < 0.1°. The data from DMC along with the data from ELRF and GPS is used for estimating target geo-location and localisation parameters[6].

3.6 Signal Processing Electronics

The signal processing electronics provides a combination of low power consumption and high processing power to hand held target acquisition device. It is a single board and is based on Xilinx Virtex 4 FPGA and Blackfin 533 DSP specially designed for real time implementation of video processing algorithms, control over process execution and data handling. The block diagram is as shown in Fig. 1.

The main function of the signal processing electronics are:

- Clock and control signal generation for sensor interface
- Non uniformity corrections (NUC) for IR imager[7]
- Polarity control for IR imager
- Automatics gain control (AGC) for IR imager
- Dynamic range compression
- Reticule generation and display
- Low battery indication
- LRF firing and range estimation
- DMC calibration
- GPS interface
- Geo-location and localisation estimation.
- FOV and focus control
- Electronic zoom
- Text and graphics overlay
- CCIR generation
- VGA video generation
- RS232 communication for operator control and maintenance.

The FPGA is interfaced with the key panel, IR Imager, CCD camera, power supply module and display electronics and the DSP. The ELRF, GPS and DMC are interfaced with the DSP. The FPGA is the master processor and its interface with the key panel controls process execution. The interface of the FPGA with the IRFPA and the colour CCD camera through video decoders allows the FPGA to receive pixel data of the captured images and also to control the implementation of various functions and algorithms on this pixel data. The range, geo-location and bearing data is received from the LRF, GPS and DMC respectively by the DSP. After processing this data for calculation of target location and localisation parameters, the DSP sends these values to the FPGA for overlay on real time video. The video output is available for display in both the standard CCIR-B format and the VGA format. The signal processing electronics is housed in the top cover of the equipment.

3.7 Power Supply Electronics

The power supply electronics is based on an 8-bit microcontroller, that generates all the power supplies for the IR imager, ELRF, colour CCD camera, GPS, DMC, signal processing and display electronics and is housed in the bottom cover of HHTAD. The power supply module also switches between the TI and colour CCD camera images on the video output as per the user selection from the key panel. It also provides the features of low battery indication and reverse polarity protection.

3.8 Display Electronics

The display module consists of an organic light emitting device (OLED) of resolution 800 x 600 pixels for displaying

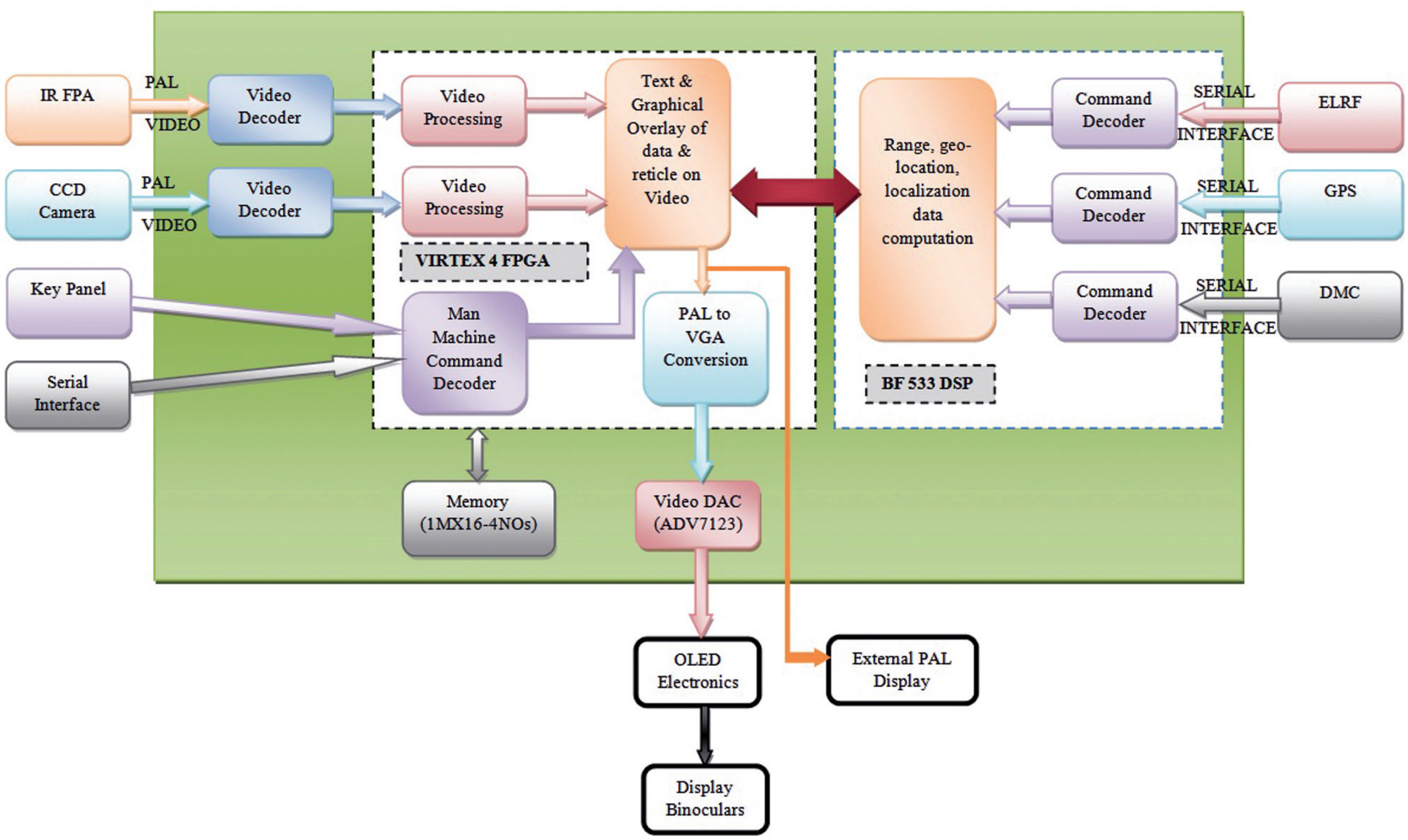

Figure 1. Block diagram of signal processing electronics.

the real time video output[8]. It provides the user with a high intensity, monochrome image of the IR Imager and colour image of the CCD Camera.

3.9 Key Panel

The key panel consists of one 3-way switch for switching on the equipment and selection of TI or CCD. Additionally four push buttons and two 4-way switches are located on the top and back side of the equipment to control all other functionality. The key panel allows the user to navigate through an on screen menu to select and adjust parameters such as contrast, brightness, FOV change, focus change, ELRF firing, selection of either IR or colour CCD imagery, etc.

4. SYSTEM PERFORMANCE AND RESULTS

Performance of the system was simulated using NVThermIP software[9] and range simulation results for IR Imager for vehicle and human targets based on TTP model[10] are given in Fig. 2. MTF[11] results of the IR channel are presented in Fig. 3.

The minimum resolvable temperature difference (MRTD)[12] values for the IR channel were also simulated in the NVThermIP software and the values obtained are listed in Table 5.

Figure 4 shows the snapshot of video output with the image and graphics overlay on IR channel. Figure 5 shows the snapshot of video output with the image and graphics overlay on CCD channel. Figure 6 shows the picture of hand held target acquisition device.

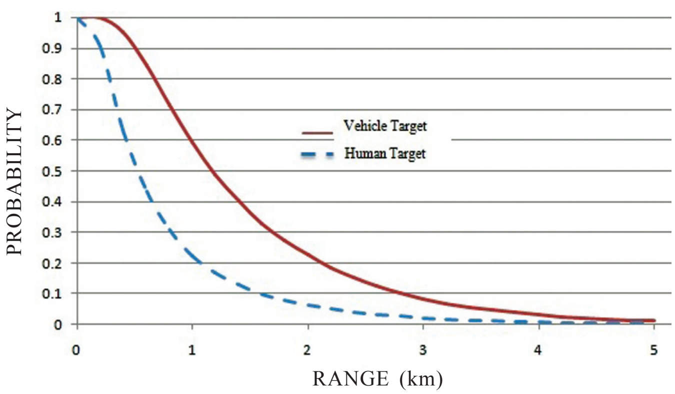

Figure 2. IR imager range simulation results for vehicular and human targets.

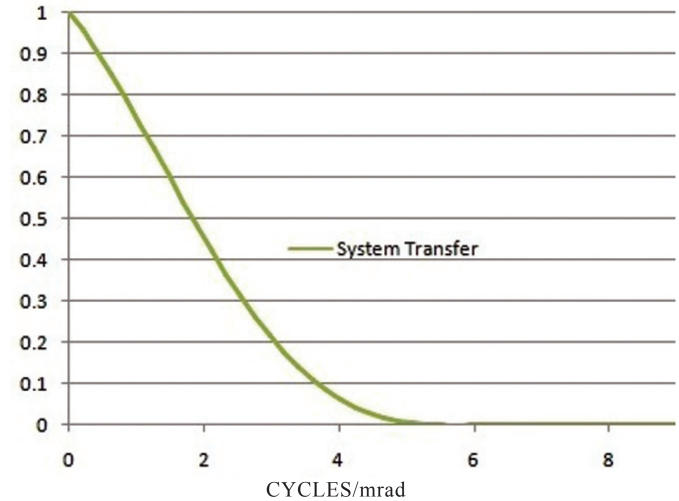

Figure 3. IR imager MTF.

Table 5. Simulated values of MRTD for IR imager

Spatial frequency (cy/mrad)	MRTD (°C)
0.96	0.05
1.5	0.08
2.4	0.13
3.0	0.2

5 CONCLUSION

The design of the hand held target acquisition device (HHTAD) has been presented. HHTAD is a compact, modular and lightweight equipment that offers recognition ranges of 1Km for vehicle targets and of 500 m for human targets and meets the requirement of instant power on and silent operation.

We are in the process of developing network capability to enable video transmission. HHTAD will be integrated over this network to enable long distance video transmission. We

Figure 4. IR video output.

Figure 5. CCD video output.

Figure 6. Hand held target acquisition device.

are also designing an advanced version of HHTAD based on higher format 1024x768 IR detector and high sensitivity colour CCD Camera.

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CONTRIBUTORS

Ms Eyneen Altaf, obtained her BTech in Electronics and Communication from NIT Srinagar in 2003. She has been working in IRDE for the past 10 years. Her area of interest is infrared signal processing.
Her contribution in the current study, is responsible for signal processing design, implementation and product realisation for HHTAD.

Dr Ajay Kumar, obtained his MTech and PhD from IIT Kanpur and IIT Roorkee in 1996 and 2006 respectively. He heads the Image Processing Group in IRDE and has been working there for the past 25 years. His area of research is electro-optical image processing.
His contribution in the current study, is responsible for system engineering, architecture definition and overall system development for HHTAD