

## Temporal Sensors for Long Range Recognition and Identification

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### Abstract

*Objects within a scene which generate temporal signals (i.e. time varying signals) are easily distinguishable from the natural background. Frequency analysis of temporal signals can lead to the recognition and identification (R&I) of objects. Temporal sensors do not require spatial resolution, this increases the R&I range by a factor of 8 and 16 respectively.*

*Conventional infrared focal plane array (IRFPA) systems generate images by integrating incoming signals onto a storage node in each pixel, these stored signals are then raster scanned and encoded to generate an image. Temporal information is suppressed by this integration process. The aim of this project is to demonstrate a novel focal plane array capable of detecting temporal signals.*

*Keywords: Infrared Focal Plane, Temporal, Sub Pixel Recognition and Identification*

### Introduction

Conventional IRFPA rely on spatial resolution to recognize and identify objects within a scene. The minimum number of pixels required for this process being 8 for recognition and 16 for identification. As the distance to the object increases, the number of pixels that are covered by the image of the object decreases, this corresponds to decrease in the confidence level associated with the output from the recognition and identification (R&I) software (see Fig. 1).

Objects which emit time varying or temporal signals can be R&I by analysing the frequency content of the emitted signal. Sub-pixel R&I can be achieved with temporal techniques as no spatial resolution is required. This increases range at which objects can be identified by up to a factor of 16 compared to conventional IRFPA systems, with partially obscured objects within the scene becoming identifiable (see Fig. 2).

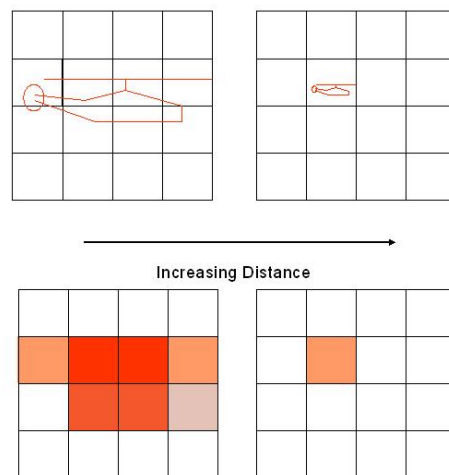


Figure 1: Spatial Resolution shows the effect of increasing distance on array output.

Thermal radiation from objects which emit a temporal signature, such as helicopters, propeller driven aircraft and jet engines; has been analysed to determine the frequency content. Software evaluation has shown that

the fundamental frequency and up to 4<sup>th</sup> harmonic were necessary to R&I objects.

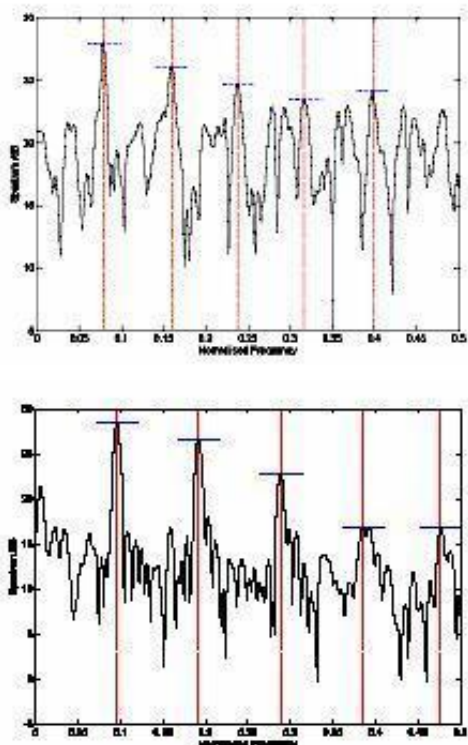


Figure 2 : Frequency Analysis of Two Helicopters Types.

Conventional IRFPA's (see Fig. 3) are not suitable for temporal detection due to their low sampling rate. IRFPA operating cycle is split between staring, i.e. collecting incoming signals, and reading the collected data out. While the array is collecting data the incoming signals  $i(t)$  are integrated onto a storage node in each pixel, i.e. as a voltage  $v(t)$  on a capacitor (C).

$$v(t) = (1/C) * \int i(t) * dt$$

The integration of the incoming signals results in all temporal information being suppressed, as the instantaneous relationship between resultant voltage  $v(t)$  and input current  $i(t)$  is unknown.

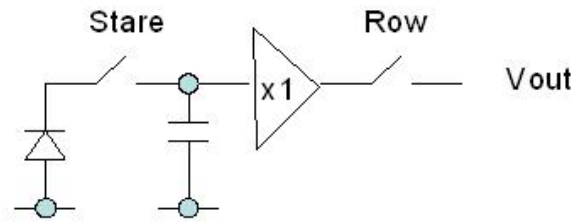


Figure 3: Conventional Pixel Design.

### Design Issues

The major issues which impact on the design of a temporal focal plane array are;

- the method of extracting temporal content.
- the production of imaging and temporal information from the same pixel design.
- the array readout scheme.
- the desired pixel size.
- the power budget.

All these need to be addressed in parallel due to their inter-relationship.

### Imaging / Temporal Information Readout

The output of both imaging and temporal information can be achieved by sequential or simultaneous readout techniques. With sequential readout the input signal is selectively steered to either the temporal or imaging circuits in the pixel. This has the disadvantage that there is a time difference between image and temporal data which could result in an object being missed. With simultaneous processing the input signal is copied to both temporal and imaging circuits. This has the advantage that both processing sections are active at the same time.

### Readout Schemes

The readout of temporal data from a 2D array could be achieved by raster scanning across the array a row at a time (see Fig. 4).

Each pixel has a limited readout time set by the frame rate, stare time and the number of pixels in the array. All pixels need to be readout and analysed for frequency content whether or not they have temporal information. As temporal data is expected on a limited number of pixels, raster scanning the array is a waste of resources.

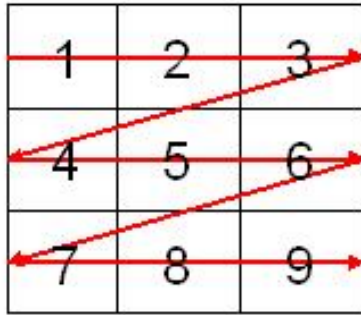


Figure 4: Conventional Raster Scan System read out order 1, 2, 3, 4, 5, 6, 7, 8, 9.

A technique known as “event addressing” seems more applicable [JK], [TS1], [TS2], [TY]. Each pixel waits for a threshold to be exceeded before raising a flag or event (see Fig. 5). When a flag is set, an external processor can then select the pixel and frequency analyse its output signal. The benefit of this approach is that the data rate off chip is reduced to those pixels which are of interest. This comes at the cost of increased complexity in focal plane / support circuitry and the asynchronous nature of the system.



Figure 5: Event Addressing, pixels accessed in order events occur 5, 1, 8.

### Pixel Design

In the proposed design the detector output is simultaneously connected to both the conventional and temporal processing circuits in the pixel. The conventional circuit is readout using raster scan addressing and temporal information is readout using an “event address” system. Figure 6 is a functional diagram of the pixel circuit.

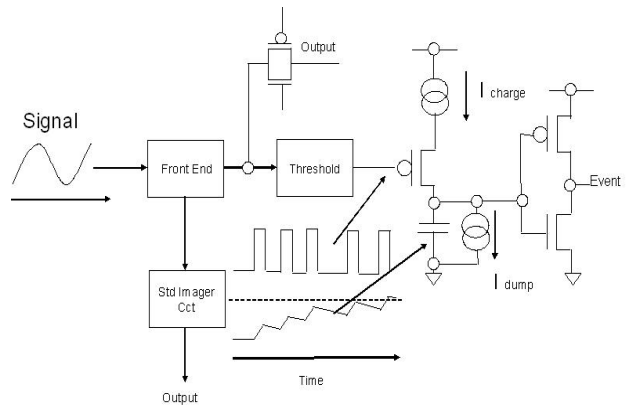


Figure 6: Modified Pixel Circuit.

A threshold is applied to the temporal signal which produces a series of pulses. Each pulse switches a known charge onto a capacitor. If the voltage on this capacitor exceeds a threshold level an event is triggered. A constant current is removed from the capacitor; this discharges the capacitor should the temporal activity go below a set level.

When an event occurs, a “true” voltage is applied to the row and column lines which pass through the pixel circuit (see Fig. 7). The row and column state gives the position of the pixel in the array. However, multiple events can generate false addresses. These can be rejected by accessing the each potential pixel and checking for an event.

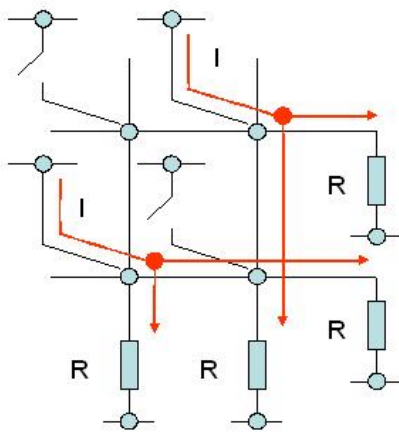


Figure 7: Readout Circuit, highlighting generation of “true” and “false” events.

The readout cycle will consist of three phases for temporal detection;

- phase one, after detecting an event shift registers will be loaded with row and column states. These will then be readout to off focal plane processing to generate a table of possible addresses of events within the array.
- phase two, these addresses will then be loaded into a random access register so that the status of the flag at each location can be checked. Should a flag be set “true” the address is stored, if not it is deleted.
- phase three, the detector at a stored address can then be connected, in turn, to post-processing for detailed frequency analysis.

Assuming that only a limited number of pixels will detect temporal signals, the generation of a large number of “false” events is not an issue. This readout scheme has been simulated successfully. The time delay (i.e. latency) between an event being triggered, its location being confirmed and connection to post-processing is 10µs. The latency between an event being triggered, location being checked and connection to post-processing is dependent on the number of pixels detecting temporal signals.

Two potential methods of further reducing the number of pixels that need to be analysed for temporal content;

- the output from pixels in a windowed area are combined into one output channel (see Fig. 8).

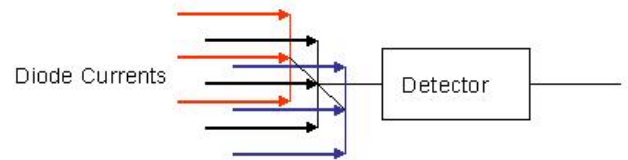


Figure 8: Combining Inputs.

- post-processing of the “true” event data and selection of a target pixel (see Fig. 9).

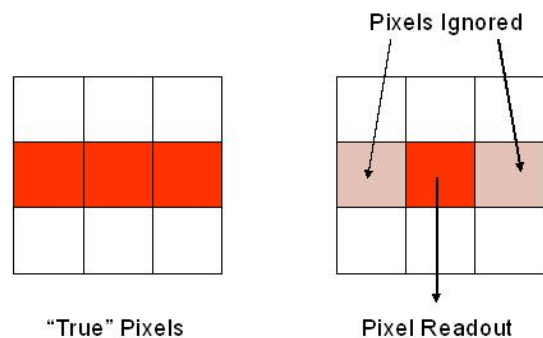


Figure 9: Selecting Target Pixel

## Conclusions

Spatial information is not required for temporal R&I. A temporal sensor will increase the range at which objects can be successfully identified by a factor of 8. Analysis of data has shown that fundamental and up to 4<sup>th</sup> harmonic are required to uniquely R&I a target.

A 2D array capable of detecting the temporal content in a scene has been designed. The array is capable of producing both conventional and temporal images.

## References

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