COLLISION MANAGEMENT UTILIZING CCD AND REMOTE SENSING TECHNOLOGY

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ABSTRACT

With the threat of damage to aerospace systems (space station, shuttle, hypersonic a/c, solar power satellites, loss of life, etc.) from collision with debris (manmade/artificial), there exists an opportunity for the design of a novel system (collision avoidance) to be incorporated into the overall design. While incorporating techniques from ccd and remote sensing technologies, an integrated system utilized in the infrared/visible spectrum for detection, tracking, localization, and maneuvering from doppler shift measurements is achievable.

Other analysis such as impact assessment, station keeping, chemical, and optical tracking/fire control solutions are possible through this system. Utilizing modified field programmable gated arrays (software reconfiguring the hardware) the mission and mission effectiveness can be varied.

This paper outlines the theoretical operation of a prototype system as it applies to collision avoidance (to be followed up by research).

INTRODUCTION

Orbital debris travels in a wide variety of orbits used by earth orbiting satellites [1]. Orbital debris may orbit the earth for as long as centuries moving in many different direction and velocities (4-20 kps; see figure 1, and tables 1 and 2).

DISCUSSION

With CCD technology the incident light is absorbed by the semiconductor substrate. An electric charge is released. The charge is collected and fixed by electrodes in the vicinity of the absorbing substrate. High resolution is achieved by smaller element-to-element spacing. The channel stop diffusion acts as a sink to prevent the photogenerated charge from spreading laterally (electrodes 5um depth within the semiconductor substrate).

The electrical signal is transferred via a multimode, stepped refracture index profile fiber optic wire (conventional image transfer and short distance data communications) to the analog to digital converter.

A parallel/flash type a/d converter will be used because:

- single integrated circuit package
- comparators can be referenced to a potential from equal resistors
- massive parallelism
- extremely fast

The conversion rate and time for optimum a/d converter performance is >3mhz and <330ns with a recovery setting time of <100ns. Once the signal has been quantized it is sent to the homomorphic processors. Illumination (low frequency) and reflectance (high frequency) gains are applied through a linear shift invariant filter that gives simultaneous dynamic range reduction and contrast enhancement.

From the homomorphic processors the digital signal is sampled. The sampling rate is at least twice the sampling frequency [2]. The sampled signal is sent through a sequential grouping of digital filters/detectors combinations. The system utilizes massive parallelism (MIMD format throughout) along with artificial intelligence (neural networks) for target discrimination. Because the system uses an array format, each element in the array can be configured with 324, 648, or 1296 respectively equating to 1, .5, or .25 degrees of spacing respectively.

Once the signal is detected (range is mathematically determined by amplitude of the target signal), a bit stream is formulated. Triangulation is possible because each array element is hardwired to a specific sector. Because of triangulation high accuracy in tracking is achieved. With the initial detection of the target, the formulated bit stream (localization and range info) is sent to a specified memory location via a shift register. After several readings a doppler shift (rapid changes in target frequency amplitude) as well as velocity (determined by rapid changes in doppler shift) can be determined. The system can be configured to track multiple targets as well as different size and from different locations throughout the array special algorithms are under development). Bit representations for localization, range, doppler shift, and velocity (under development) make up the bit stream. The quantum cryptographic message [3] is sent via fiber optic wire to the main computer to determine collision probabilities. Quantum cryptography coupled with massive parallelism, and artificial intelligence allows for high speed transfer and processing to maintain a near real time format. The quantum cryptographic message that is sent to the main computer allows elements within the bit stream to be interrogated separately (algorithms under development). Various sections of the array have been mathematically determined to pose higher probabilities of collision. The embedded maneuvers (under development) in main memory will be activated by certain elements of the quantum cryptographic code. The maneuvers will encompass slide (left,right),attitude change, or roll about axis (as determined by the aerospace systems design or mission. Once the maneuver is initiated the systems memory repositions itself into the original position.

The data sent to the main computer is stored in memory to be accessed through telemetry monitoring by a ground station [4] or for systems adaptation (learning).

CONCLUSION

The collision avoidance system allows solid state signal processing and imagining through a very basic approach. The three basic functions (CCD) sensing, storage, and transfer are conceptionally simple and allows for many configurations. With the CCD/Remote sensing approach higher element densities and better uniformity of response are obtainable.

Through the use of the array system quantum cryptography [3] and artificial intelligence (neural networks) the system can employ very high speed processing, secure communications, constant reconfiguration for mission purposes, constant telemetry data, and a learning capability (under development) for extended missions. Once the signal is digitized the entire processing can be done within the computer.

REFERENCES

1. McDaniel, Harvey E. Jr. "Space Debris Collection System" Space Studies Institute (at Princeton) conference on Space Manufacturing (1993).

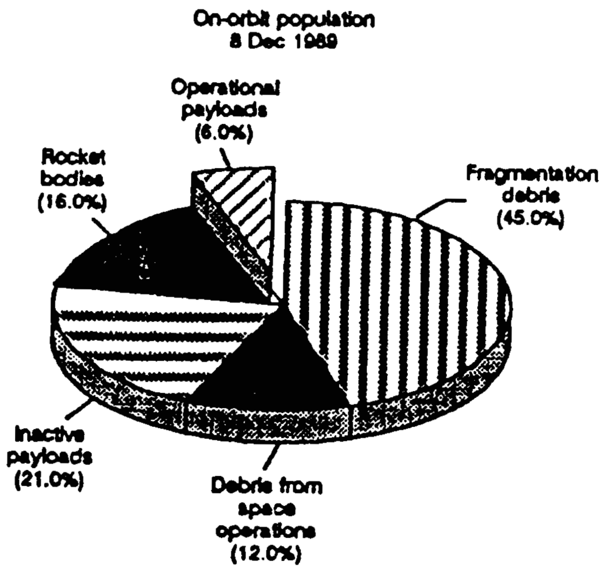
2. Oppenheim, Alan V. and Schafer, Ronald W. "Digital Signal Processing", Prentice Hall, Englewood Cliffs N.J. (1975).

3. Bennett, Charles H., Brassard, Giles, and Ekert, Charles "Quantum Cryptography" Scientific American 1995 special issue.

4. Fortesque, Peter and Stark, John "Spacecraft Systems Engineering" Telecommunications and Telemetry section (1985).

APPENDIX

Figure 1 – Cataloged On-Orbit Population



SOURCE: Nicholas L. Johnson and David J. Nauer, *History of On-Orbit Satellite Fragmentations*, 4th ed. (Colorado Springs: Teledyne Brown Engineering, January 1990), NASA Contract, NAS 9-18208.

Table 1 – Elements of Orbital Debris

- deactivated spacecraft
- spent rocket stages
- fragments of rockets and spacecraft and their instruments
- paint flakes
- engine exhaust particles
- spacecraft rocket separation devices
- spacecraft coverings
- spent Soviet reactors

Office of Technology Assessment, 1990.

Table 2 – Types of Hazardous Interference by Orbital Debris

1. Loss or damage to space assets through collision;
2. Accidental re-entry of space hardware;
3. Contamination by nuclear material of manned or unmanned spacecraft, both in space and on Earth;
4. Interference with astronomical observations, both from the ground and in space;
5. Interference with scientific and military experiments in space;
6. Potential military use.

SOURCE: *Space Debris*, European Space Agency, and Office of Technology Assessment.

Optical Materials for infrared/visible with selected Properties

MATERIAL	R MIN um	R MAX um	Tm K*	Hk um 2/k_g+
Quartz (SiO_2)	0.12	5	174	740-460
Potassium Iodide (KL)	0.25	45	1000	
Cesium Bromide (CsBr)	0.25	80	900	20
Magnesium Fluoride (M_gF_2)	0.11	8		
Calcium Fluoride (C_aF_2)	0.13	12	163	160
Lithium Fluoride (LiF)	0.12	9	1140	100
Silicon (Si)	1.2	15	1690	1150
Germanium (Ge)	1.8	20	1210	
Potassium Chloride (KC1)	0.21	30	1060	