# TOWARD OPTICAL ARCHITECTURES IN RADAR SYSTEM DESIGN FOR ULTRALIGHT UNMANNED AERIAL VEHICLES

Alexander Sharp

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School of Electrical and Electronic Engineering

The University of Adelaide

# ABSTRACT

A thesis is presented on the deployment of radar systems on ultra light unmanned aerial vehicles which are compact and lightweight. Deployment upon a small frame presents significant problems due to the size, weight and power (SWaP) requirements of components and which are addressed in this work. Traditional pulsed radar is inadequate due to these considerations and alternatively, a frequency modulated continuous wave (FMCW) radar architecture is proposed. Optical systems, due to their light weight, bandwidth and resistance to interference are a possible implementation for the radar front end. Optical architecture implementations suffer from low signal to noise ratio and low spurious free dynamic range. Employment of an optical architecture for a narrow band radar would be inefficient and its performance would be substandard. Instead a focus on a wide bandwidth is pursued. The advantages of deploying a wide bandwidth, frequency agile radar are its resistance to jamming and the receiver's usefulness as a radar warning receiver. An investigation into optical systems discovers an optical architecture that is highly resistant to environmental changes making it robust, easy to maintain and inexpensive to deploy. A COTS based beam forming array is designed within the optical system. The beam former allows for multiple apertures and multiple beams, a feature previously limited to expensive, complex array architectures. The author presents a COTS based solution for optical mixing, which is both wideband and exploits the linearity of phase modulated optical paths to provide linear mixing. The topology suffers some degradation due to the inherent environmental sensitivity of phase modulated optical fibres. The author presents a means to stabilize the output of the optical mixer, making it suitable for deployment upon an operational platform. The technique can be miniaturized as a new form of optical modulator. This optical front end can be integrated into a full, microwave to digital-at-IF radar. This breakthrough allows the use of millimeter wave carrier frequencies with low IF topologies for digital receivers. Using a low IF eliminates the problems of data overflow and Nyquist sampling limits inherent in available electronic analog to digital converters. Wideband antennas are designed that are compact, light weight and are built from rugged materials. These antennas are simulated to show a 2 – 40+ GHz bandwidth. A series of lower bandwidth 2 -25 GHz antennas are fabricated and the parameters which enable wide bandwidth operation are investigated. The difficulty employing antennas in an array is the creation of grating lobes, through separation of the antennas. The application of medical research in ultrasound shows that an efficient beam former without grating lobes can be created by the use of two different apertures. A Vernier array of two antennas is proposed which increases the effective antenna aperture by a factor of four. A linear 8 port antenna array at the transmitter and an 8 port array at

the receiver becomes a 64 port linear antenna array for the radar, with consequent affect upon the beam width at half power of the array radiation pattern.

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NOTE

Appendix A is a brief excerpt from the US DoD roadmap for UAVS 2005 – 2030

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STATEMENT OF ORIGINALITY

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*Low Noise Wideband Optical Mixing and Optical Up-Conversion*

*Architecture.*

*Alexander N. Sharp* , Bevan D. Bates*†*

**School of EEE, The University of Adelaide, SA 5005 Australia*

*†Defence Science and Technology Organisation, Edinburgh SA 5111, Australia*

*Vivaldi Antennas : Wideband Radar Antennas*

*Simulation and Reality*

*Alexander N. Sharp* , Bevan D. Bates*†*

**School of EEE, The University of Adelaide, SA 5005 Australia*

*†Defence Science and Technology Organisation, Edinburgh SA 5111, Australia*

*Sparse Array Systems for Ultralite UAV Radar*

*Alexander N. Sharp* , Bevan D. Bates*†*

**School of EEE, The University of Adelaide, SA 5005 Australia*

*†Defence Science and Technology Organisation, Edinburgh SA 5111, Australia*

*Email: {alexander.sharp, bevan.bates}@adelaide.edu.au*



*Michael Faraday House*

*Six Hills Way. Stevenage*
*Hertfordshire*
*SG12AY*
*UK*
*Tel: +44 (0) 01438 765647Fax: +44 (0) 01438 765659*