University Defence Research Collaboration in Signal Processing

Edinburgh Consortium White Paper

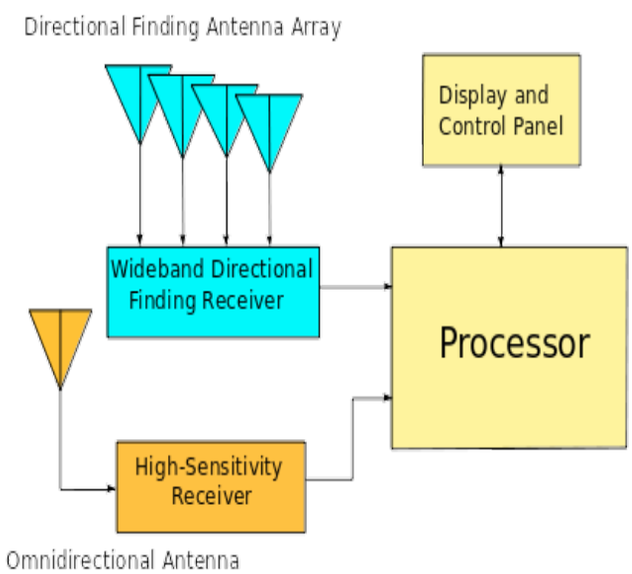
A Low Complexity Sensing System for Ultra Wideband Radar Electronic Surveillance

Introduction

There is a need in electronic surveillance to monitor a wide frequency band where Radar signals and communication signals may occur. Early solutions used instantaneous frequency measurements to detect and categorise radio frequency (RF) signals. However, such systems have limited sensitivity and cannot sort multiple signals simultaneously. Recently, digital receivers have been employed due to their ability to process a wider range of signals. However, size, weight and power (SWAP) requirements impose limitations on the sampling rates and hence, the bandwidths that are viable for such technology. Currently, there are no computationally simple systems that are able to monitor wide frequency bands at sampling rates that are substantially below the minimum sampling rate
required to avoid aliasing (the Nyquist rate).

Current Approaches

Modern Radar electronic surveillance (ES) is based on the digital processing of signals. However, the input Electro Magnetic waves are sensed with some analog sensors, which need to be digitised before processing in the digital processing unit, i.e. digital computer. Ultra high speed analog to digital converters (ADC) are very power hungry. As a result, current technologies are based on using one or some low rate ADCs to simultaneously monitor desired frequency ranges.



Two scenarios are possible:

a) Using as many ADCs as the ratio of the full frequency band to the low rate ADCs or

b) Using time sharing techniques

The former needs many ADCs, which makes the actual implementation expensive and power hungry and the latter misses some part of the frequency spectrum, when it only investigates a fraction of spectrum at a time. The latter is the most commonly used technology which suffers from missing short-time events, i.e. short radar pulses and lower processing gain.

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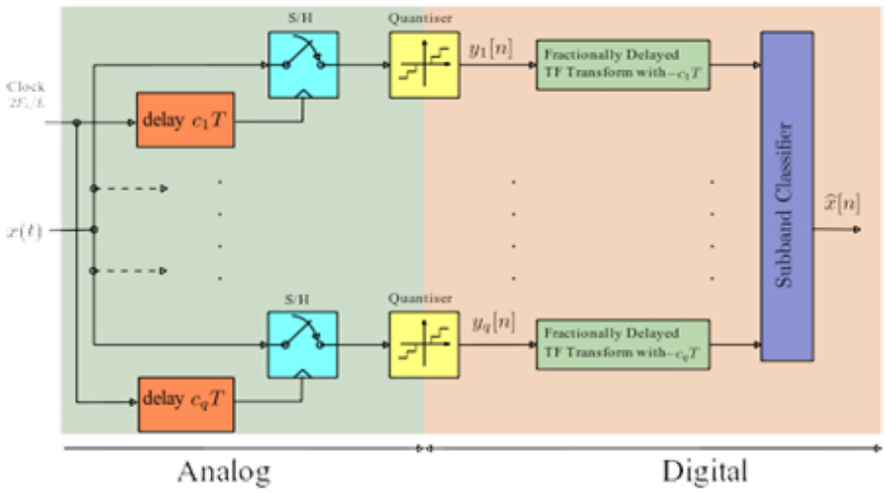
Technology

We have developed a novel technique which uses only a small number of ADCs to monitor a wide band frequency spectrum, this number can be as low as two. The proposed technique, LoCoMC which stands for Low Complexity Multicoset, is inspired by the Compressive Sampling (CS) paradigm, which has revolutionised our earlier assumptions on signal digitisation. A schematic of the proposed system is presented here, which includes a bank of delayed ADCs with distinctive delay factors, followed by some digital processing techniques to combine the information of the different channels. As the final goal of the Radar ES system is to detect, identify and classify incoming EM Radar pulses, we have also proposed a new post-processing unit to detect the pulses in a harsh noisy environment. The new technique can identify the pulses and pass the information to a post-classification unit. We have shown that LoCoMC is superior to the time-sharing schemes, particularly in comparison with a method called Rapidly Swept Super-heterodyne Receivers (RSSR). The features of LoCoMC can be listed as follows:



- Smart compression sensing algorithm
- Parallel Time Frequency transforms on each multicoset sampling strategy
- Novel structured sparse model
- A few multicoset channels are required

LoCoMC is suitable for SWAP implementation, as it needs only a few ADCs and synchronization of ADCs is possible in digital domain. The benefits of using LoCoMC over other sub-Nyquist methods are:

- Practical and fast acquisition, detection and analysis system for electronic surveillance of Radar and communication signals
- Computationally simple non-iterative algorithm
- Explicit optimisation of sampling strategies
- Simple online calibration and compatible with a wide variety of Time Frequency transforms

The algorithm has been tested with industrial level simulation signals and its Technology Readiness Level (TRL) is currently three.

References:

[1] A Low-complexity Sub-Nyquist Sampling System for Wideband Radar ESM Receivers , M. Yaghoobi, M. Lexa, F. Millioz and M. E. Davies, IEEE Conference on Acoustics, Speech and Signal Processing, Florance, Italy, May 2014.

[2] A Computationally Efficient Multi-coset Wideband Radar ESM Receiver, M.Yaghoobi and M. E. Davies, NATO Specialist Meeting on Compressed Sensing, Tallinn, Estonia, May 2014.

[3] An Efficient Implementation of the Low-Complexity Multi-Coset Sub-Nyquist Wideband Radar Electronic Surveillance, M.Yaghoobi, B. Mulgrew and M. E. Davies, Sensor Signal Processing for Defence (SSPD), Edinburgh, September 2014.