Implementation of a Cognitive MIMO Radar

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Abstract: With a view to upgrade the Limitations of existing operational conventional radars or during design and implementing of a new radar, Authors worked a lot towards Cognitive MIMO radar. In both the cases, their concepts are first simulated and finally they have designed such cognitive radar. This paper will discuss their development efforts towards simulation and hardware realization.

Index Terms – Multiple Input Multiple Output(MIMO), DDS(Direct Digital Synthesis) Vector Signal Generator (VSG), Orthogonal Frequency Division Multiplexing(OFDM), ALAMOUTI, MMSE. AWG [Arbitrary Waveform Generator]

I. INTRODUCTION
Radar is a remote-sensing system that is widely used for surveillance, tracking, and imaging applications, for both civilian and military needs [1]. But in dynamic condition when the environment changes non linearly the conventional radar system performance degraded. The existence of clutter in open range radar system deteriorates the RCS estimation of the targets. For that reason, radars should incorporate efficient clutter reduction techniques [2]. In order to enhance the radar system performance in terms of clutter, multipath rejection, target detection and high quality imaging etc, some sort of cognition approach needed. The requirement to update estimation of the environmental state as the environment is non-stationary and this leads to requirement of transmitter and receiver adaptively. Therefore the cognitive radar [3] must consist of the following sub-systems:

- The radar continuously monitored the environment and adapted the randomness of the environment and continually updates the receiver with relevant information on the environment.
- Through the receiver signal processing and the feedback path, transmitter gathers the knowledge about the environment and accordingly transmitter applies cognition by utilizing adaptive beam formation, waveform diversity etc.
- The whole radar system should be integrated by a dynamic closed feedback loop encompassing the transmitter, environment, and receiver.
- And also with the advancement of the MIMO technology, it opens up the door to take the challenge of characterization of the target in rich scattering environment through intensive signal processing technique. MIMO radar has significant potentials for fading mitigation, excellent interference rejection capability and jamming suppression [4]. These features leads to the improvement in target detection, parameter estimation, target tracking and recognition performance [5].

II. SIMULATION OF A COGNITIVE MIMO RADAR

The basic Simulation for a MIMO Based Cognitive RADAR is shown in Fig.-1:

A. The choice of basic Radar Waveform
11 bit pulsed barker code with 6% duty cycle is considered to be the basic radar waveform. The 1st part of Fig.-1 in the upper chain of Transmitter section is thus showing the pulsed barker code generation with QPSK modulation.

B. The Recovery
The recovery is also shown in the lower part of Receiver section of Fig. 1.

C. The sub carrier generation and removal part are also shown in Fig. 1.
The ALAMOUTI Encoder with MIMO
Fig. 1: Portion of a Cognitive radar with MATLAB Simulation for Transmitter side barker code generation and Sub-Carrier Generation and Removal of those Subcarriers at Receiver Side and barker code recovery.

Fig. 2: MIMO FRAME Complex Data With 192x1 Zeros and 192x1 Barker Spread Elements combined to form a 192x1 Complex Vector.
The Buffer accepts the 192x1 Complex Vector to accumulate and thereby generating a Complex frame of 384x1 MIMO Baseband Data. This 384x1 Frame is Encoded by ALAMOUTI Encoder and then added with 256x2 Preamble. The two Switching paths alternately passes each segment of Preamble and Alamouti Encoded Data for OFDM Modulation. Each OFDM Branch is carried over the Antennas. Here the scheme is being shown for 2x2 MIMO Based Cognitive RADAR.

Fig. 3: Alamouti encoder and data stream de-multiplexing.

Fig. 4: Antenna 1 Waveform (Tx Side)

Fig. 5: Antenna 2 Waveform (Tx Side)
The data with subcarrier are bundled into two parts and then each packet is transmitted through Antenna after RF modulation. We are proposing two Tx antennas as the configuration is aimed for a 2x2 Adaptive MIMO Radar System. The future works will comprise: (1) the insertion of 2 antennas at the Tx as well at the Rx side followed by its simulation test, (2) the multipath phenomenon (considering clutter) will also be injected in this simulation model, (3) the proper MIMO algorithm (like Alamouti encoding and decoding) is to be realized, (4) the delay measurements after de-spreading to be added.

A. Algorithm and simulation result

In this algorithm, we first stored the environmental data in a buffer and the processed those data through MMSE algorithm to calculate the weight vector. After calculating the weight vectors we convolve those vector with the target return (corrupted by the noise, clutter) in order to reject the clutter effect. The basic block diagram of the algorithm is shown in the figure below.

![Fig.-6: Block diagram for the algorithm (Rx Side)](image)

![Fig.-7: Target with clutter.](image)
Fig. 8: Target without clutter after convolution.

III. Hardware Realization of the Cognitive Radar

As shown in Fig. 9, the transmitter MIMO adaptively will be realized through AWG [arbitrary waveform generator]. Even carrier frequency and receiver adaptively is realized through VSG and VSA respectively. The environment sensing will be through receiver front end and VSA. The Cognitive engine and Knowledge aided processing will be realized through the workstation.

A. Description of AWG Architecture

AWG is one of the modern electronic equipment used primarily for the generation of arbitrary waveform and functions. Waveform memory typically of 32 Mega bytes are very common for e.g., ipod which is very popular multimedia generation and playback system, AWG exploits the memory for the recording and playback of any arbitrary waveform specially, the I-Q baseband waveform. With the use of FM recording mode in ipod, simultaneous recording and playback from memory is possible. In the same way, AWG can be programmed for multimedia communication. For long duration recording and playback, a sequencer is to be introduced as one of the major sub systems. The carrier generation part of the AWG generally, exploits the DDS [Direct Digital Synthesis] technology with a finer resolution of 1 Hz or even less. The old PLL based frequency synthesis is very slow and is replaced by DDS in AWG. AWG, thus achieves the 'Fast Frequency Agility' in its operation. This fast frequency agility feature of AWG can be exploited for real time environment and channel simulation which will help the designer to test his/her system more precisely in the laboratory simulated environment. Sequencer is often extended for introduction of frequency offset, phase offset and gain shifts for creation of such real time environment and channel simulation. Additionally, Simulink RF blocks can be ported to the DDS Block for the creation of 'Digital IF' providing lots of advantages and on line IF processing. DDS based 'Digital IF' signal after multiplied by I-Q baseband signals is generally output through DAC. Both baseband and IF are, thus user programmable using high level language like simulink and system programming may become easy.

B. Description of VSA Architecture

The VSA implements a very different measurement approach than traditional swept analyzers; the analog IF section is replaced by a digital IF section incorporating FFT technology and digital signal processing. The traditional swept-tuned spectrum analyzer is an analog system; the VSA is fundamentally a digital system that uses digital data and mathematical algorithms to perform data analysis. For example, most traditional hardware functions, such as mixing, filtering, and demodulation, are accomplished digitally, as are many measurement operations. The FFT algorithm is used for spectrum analysis, and the demodulator algorithms are used for vector analysis applications. VSA is fully user programmable using Simulink that help a lot to the author for cognitive radar implementation.

IV. CONCLUSION

In this paper we are trying to develop a cognitive radar from basic conventional radar. Using MMSE algorithm and applying with convolution technique perfect detection of target is possible in hostile environment. Further we are trying to extend this developed cognitive radar system towards digital beam forming cognitive radar.
V. REFERENCES


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