Orthogonal Coding in a MIMO Polarimetric Radar System as a Method to Recover Full Polarimetric Data

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Summary: This abstract serves as a short narrative for a multi-input multi-output polarimetric radar system, where the use of orthogonal waveforms to recover fully polarimetric data is its novel feature for synthetic aperture radar (SAR) imaging of biomass. These waveforms have orthogonal phase codes, and they ride on two different antenna polarizations. These waveforms are modulated by a carrier frequency, and the resulting electromagnetic waves combine together to create an electromagnetic wave with modulated polarization. Two orthogonal codes being transmitted on physically orthogonal channels is the result. The reflected signals can be demodulated to recover both the co-polarized and cross-polarized return signals, allowing the creation of the full Stokes vector with improved estimation accuracy. One of the main advantages in the orthogonal technique is achieving larger swath width. A conventional full pol SAR in spaceborne applications multiplexes in time between two transmit polarizations. Due to azimuth ambiguities in SAR, most spaceborne SARs (if not all) need to trade full pol operation for a reduced swath (~ 50% narrower). A SAR with the orthogonal transmit/receive (T/R) would provide full pol operation with no loss in swath (or coverage). Larger data (2x) volumes would be handled by onboard processors and data compressors. Other advanced radar applications (e.g., MIMO, multi-beam, etc... - which can be implemented with the same SAR architecture) operate entirely using orthogonal T/R techniques. Good isolation among orthogonal channels or beams is key.

I. Introduction

Radar systems must be able to both broadcast and distinguish between polarized signals in order to fully characterize targets and target areas, as the relative return between differently polarized electromagnetic waves on the same target can yield important information about the target. A radar system capable of distinguishing between polarized radar signals returned on their respective polarizations, as well as radar signals that have been modulated by the target and returned on the alternate polarization, is referred to as a dual polarized radar system. Traditional dual polarized radar systems are very expensive however, as dual polarized systems basically require the hardware of two complete traditional linearly polarized radar systems. The method proposed in this paper is for a multi-input multi-output (MIMO) polarimetric radar system utilizing orthogonal coding that is able to reliably produce data comparable with that from a dual polarized radar system. This MIMO polarimetric system can accomplish this data output with a transmit layout only minimally different from a conventional circularly polarized radar system and a receiver layout similar to a conventional dual polarized radar system with some additional digital signal processing. This proposed system is ideal for synthetic aperture radar (SAR) applications, where simultaneous acquisition of both co-polarizations and cross-polarizations replaces the traditional method of alternating transmit polarizations on a doubled PRF. Using a PRF that is half of the alternating polarization method allows the SAR to analyze a much larger swath width.

II. Technical Approach

It can be seen that the Stokes vector, a concise way to completely contain the polarization information of an electromagnetic wave, can be acquired with only the complex measurements of the horizontal and vertical returned signals. The relative phase between the incoming horizontal and vertical channels must be known in order to accurately obtain all of the elements of the Stokes vector.

In order to more fully understand the target, the intensity of the electromagnetic waves transmitted and received on each polarization, known as co-polarized return signals, as well as the intensity of the electromagnetic waves that are transmitted on one polarization and received on the other polarization, known as cross-polarized return signals, must be known. Both the co-polarized and the cross-polarized signals for both polarizations must be known. The Stokes vector of the incident electromagnetic waves on the target is known, and the complex measurements of the horizontal and vertical returned signals are measured by the radar system, thus the Stokes vector of the returned electromagnetic waves of the target are known.

Currently the only way to recover the co-polarized and cross-polarized elements from both polarizations, commonly horizontal and vertical polarizations, is for each of the transmitted polarizations to have some characteristic markedly distinct from the other, such as transmission at a different frequency, or even transmitting the horizontal and vertical polarizations at different times (leading to the creation of a pseudo-Stokes vector due to measurements being taken at different times). These techniques are possible on a dual polarized radar system, due to the system basically being two complete linearly polarized radar systems where the polarization of the two systems is orthogonal to one another.

It is proposed that the markedly distinct characteristic of the signals on the transmitted polarizations be digital coding. More specifically, the two orthogonally polarized electromagnetic waves being transmitted should be modulated by orthogonal codes, so that the modulating waveforms have zero cross-correlation with one another. By modulating the orthogonally polarized carriers with orthogonal codes, this allows carriers of identical frequency to be transmitted simultaneously, while still allowing the co-polarization and cross-polarization elements from both initially transmitted polarizations to be recovered simultaneously at the receiver.

The two cosine waves of identical frequency and $\frac{\pi}{2}$ phase difference to act as carriers on the two transmit polarizations should each be individually modulated by orthogonal codes. This would lead to an electromagnetic wave transmitted from the radar system that would appear at first glance to be circularly polarized, but would in fact have both its vertical and horizontal components modulated by orthogonal codes. The result would effectively be a signal that would have two orthogonal codes being transmitted on two physically orthogonal channels. This would allow the received signal to be analyzed so that the co-polarized and cross-polarized signals from each transmitted polarization can be fully recovered. Due to the co-polarization and cross-polarization elements being distinguishable within the same measurements, the relative phase between the two physically orthogonal channels is preserved, and the Stokes vector for the received signal can be acquired. Due to the system transmitting circular polarization that is actually a combination of two distinct transmit channels, and being able to recover full polarimetric data from two distinct receive channels, the system layout is referred to as MIMO polarimetric.

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