A Comparative Evaluation of Joint Versus Sequential Demodulation of Spatially Modulated Underwater Acoustic Telemetry Signals

Daniel B. Kilfoyle
Falmouth, MA

Abstract: Spatial modulation over multiple-input / multiple-output (MIMO) communication channels has been a rich area of research for terrestrial wireless communication and, more recently, underwater acoustic communication. By appropriately including spatial as well as temporal degrees of freedom in the signal design, it has been shown that one can potentially achieve significant capacity gains, reduce power requirements, and increase spectral efficiency. The benefits are analogous to having additional bandwidth and, as such, are well suited for bandwidth-limited conditions, as opposed to power-limited conditions. Spatial modulation uses separate, resolvable propagation paths between a transmitter and receiver array as parallel communication channels and, as such, requires both availability of arrays at both ends of the link and a propagation channel with some level of multipath. The combination of rich, complex reverberation and the inherent bandwidth limitations of the underwater acoustic telemetry channel make it well suited for application of spatial modulation techniques.

This discussion will focus on issues relating to design of the adaptive receiver algorithm for spatially modulated signals. A principal trade-off that has been studied extensively for cellular systems is one between sequential versus joint detection and estimation approaches as exemplified by the well-known D-BLAST versus V-BLAST approaches to space-time coding proposed by Lucent Technologies. While joint detection may improve performance, the added algorithm complexity may impose untenable practical constraints on processor speed and latency.

Results of previous researchers may not be generally applicable to underwater acoustic telemetry channels. Firstly, owing to the extensive temporal and frequency dispersion encountered in typical underwater channels, even conventional receivers have a relatively high degree of complexity with the necessary integration of digital phase-locked loops, decision feedback equalization, and lengthy multi-channel filters. As such, the added complexity may be more bearable. Secondly, cellular channel transfer function matrices are often well characterized by flat Raleigh fading random variables. In contrast, the ocean channel often exhibits substantial levels of spatial coherence and dispersive effects with significant implications for diversity and the need for inter-parallel channel redundancy. Finally, equalization performance rather than ambient noise levels often drives important shallow water applications. The resultant impacts on channel capacity are not well understood. In short, there is a need for an empirical evaluation of sequential versus joint detection for spatially modulated underwater acoustic telemetry signals.

Experimental results will be presented for high frequency (25 – 35 kHz) spatially modulated underwater telemetry signals for a shallow water environment. Specifically, telemetry modem performance in terms of bit error rate and minimum mean square error for receiver structures based on sequential and joint detection will be presented and algorithm complexity will be described in terms of floating point operations per symbol.

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