On Pilot-Aided Transmission over Doubly Selective Channels

Dr. Phil Schniter

The Ohio State University, Columbus, OH

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Abstract

In this talk, we present recent work on the analysis and design of pilot-aided transmission for doubly selective channels. By pilot-aided transmission (PAT), we mean that known pilots are embedded in the transmission stream and used to obtain a channel estimate at the receiver, after which data detection is performed coherently using the estimated channel. By doubly selective, we mean that the channel has significant time and frequency selectivity. Throughout, we assume the following noncoherent model: the channel's statistics, but not its realizations, are known at both the transmitter and receiver.

The noncoherent capacity of time-selective and frequency-selective channels was recently characterized by Liang and Veeravalli, and the capacity of PAT for frequency-selective channels was recently characterized by Vikalo, Hassibi, Hochwald, and Kailath. Comparing these results, we see that, at high SNR, PAT gives near-optimal performance in that its capacity slope coincides with that of the optimal scheme. Ma and Giannakis have recently analyzed the capacity of a non-superimposed (NSI) PAT scheme for doubly selective channels, but it is not clear how it compares to the optimum noncoherent scheme, nor to other PAT schemes.

We first establish, via simple extension of Liang/Veeravalli, the noncoherent capacity of doubly selective channels, assuming a basis expansion model (BEM) for the channel's time evolution. From this result, it can be seen that the Ma/Giannakis NSI-PAT scheme is suboptimal, even at high SNR. The question remains: do there exist more general (i.e., superimposed) PAT schemes that perform optimally or, if not, better than the Ma/Giannakis scheme? In an attempt to answer this question, we first motivate a general approach to PAT that minimizes the MMSE of Wiener channel estimates. Next, we establish necessary and sufficient conditions for these MMSE-PAT schemes, first for a general class of Rayleigh fading linear channels, and then for the BEM-based doubly selective channel. Several novel superimposed MMSE-PAT schemes emerge from these conditions. Finally, we study the capacity of MMSE-PAT, and find that the superimposed MMSE-PAT schemes can have significant advantages over the NSI ones, especially when the channel's time spread dominates its frequency spread. Unfortunately, though, even the best known MMSE-PAT schemes still fail to achieve the capacity of the noncoherent doubly-selective channel, even at high SNR. We suspect that this is a fundamental property of the doubly-selective channel that is not shared by its time- or frequency-selective counterpart.

Bio

Phil Schniter was born in Evanston, IL in 1970. He received the B.S. and M.S. degrees in Electrical and Computer Engineering from the University of Illinois at Urbana-Champaign in 1992 and 1993, respectively. In 2000, he received the Ph.D. degree in Electrical Engineering from Cornell University in Ithaca, NY.

From 1993 to 1996 he was employed by Tektronix Inc. in Beaverton, OR as a systems engineer. There he worked on signal processing aspects of video and communications instrumentation design, including algorithms, software, and hardware architectures. He is currently an Assistant Professor in the Department of Electrical Engineering at The Ohio State University in Columbus, OH. His areas of research include signal processing for communication systems and wireless sensor networks. He is especially interested in the design of practical communication receivers for doubly dispersive channels.

While pursuing his Ph.D. degree, he received a Schlumberger Fellowship and an Intel Foundation Fellowship. He was awarded the 1999 Prize Paper Award from the IEEE Energy Development and Power Generation Committee for work relating to his M.S. thesis. He received the NSF Career Award in 2003.
