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The Role of Communications Signal Processing in Storage Systems

Abstract

The role of signal processing in the development of modern digital transmission systems is well established. All transmission systems currently in use rely heavily on signal processing and coding algorithms to deliver the quality of service demanded by the end user. While a digital transmission system delivers data from one location to another, digital storage systems move data in time. Both systems rely on communication channels to transport data spatially or temporally. However, historically these two types of communication channels, the transmission channel and the read/write channel, evolved very differently. Digital communications and coding theory were well understood long before any digital transmission systems were developed. What prevented the earlier deployment of systems such as the global positioning system or the digital cellular telephone system was the absence of the necessary enabling technologies, like digital mapping and very large-scale integrated circuits. Storage systems on the other hand have historically been driven by technological breakthroughs in materials and devices, while the read channels remained poorly understood and underdeveloped.

This situation is changing dramatically as the storage industry faces significant challenges to its ability to continue to grow the storage capacity of its products at the same historical rate, which for hard disk drive products is 40% per year in terms of areal density. Although for different reasons, the situation is fundamentally the same for other storage systems, such as magnetic tape and solid-state drives. The future of storage systems will continue to depend on new materials and devices, but increasingly the channel will be a key component, which will provide the tolerance relief necessary to bring about products approaching the fundamental limits of physics.

Magnetic recording is still today by far the dominant storage technology and therefore a good example to illustrate the increasingly important role of communications signal processing in storage systems. The superparamagnetic limit has already spelled out an end to the current generation of perpendicular magnetic recording on granular media, which will not be able to deliver recording densities much beyond 1 Tb/in². The next generation of magnetic recording systems will rely on new technologies, which are yet to be fully developed, that will avoid running into the superparamagnetic limit until the areal density reaches 10 Tb/in². These include bit-patterned magnetic recording (BPMR), energy-assisted magnetic recording (EAMR), and two-dimensional magnetic recording (TDMR). A fundamental understanding of the communications channel and the development of advanced signal processing and coding algorithms will play a major role in determining which of these three technologies will be able to deliver areal densities of 4 Tb/in² and beyond.

This presentation will provide an introduction to magnetic recording systems spanning three technology generations, with an emphasis on perpendicularly magnetized media, and a preview of the state-of-the-art in signal processing and coding algorithms currently under development for future use in the next generation of hard disk drives. These algorithms include one-dimensional (1D) and two-dimensional (2D) equalizers, multi-dimensional maximum *a posteriori* (MAP) detectors and novel low-density parity-check (LDPC) decoders. Although similar to algorithms used in data transmission channels, they are often more advanced in terms of performance and complexity in order to cope with a far more challenging channel.