Enhancing Multibeam Satellite Communications through Selective Precoding

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Abstract (should be within 1st page)

As global demand for faster internet and higher data capacity grows, satellite communication systems must evolve for greater efficiency. Traditional satellites use a single wide beam, limiting bandwidth per user. Modern systems adopt multibeam technology, dividing coverage into smaller regions with focused beams. This allows frequency reuse and increases total capacity, but as beams become denser, interference becomes a major challenge, often degrading performance. This interference can be managed by precoding, which adjusts each beam's signal based on channel state information (CSI). While traditional precoding mitigates interference, it assumes all interference is harmful. In reality, some is constructive and can improve signal quality. This work challenges that paradigm by strategically exploiting constructive interference. We first introduce a low-complexity CSI management method that uses only the sign of signal components, significantly reducing overhead. Building on this, we develop a selective precoding scheme that classifies symbols as constructive or destructive, applying precoding only to the latter. This approach substantially reduces computational complexity while maintaining robust performance, even with channel coding, making it ideal for resource-constrained LEO satellites. Furthermore, our method inherently enhances physical-layer security by controlling the nature of interference at specific user locations. This dissertation delivers a more efficient, robust, and secure framework for satellite communications, accelerating their readiness for 6G and global broadband deployment.