Astrapi Spiral Polynomial Division Multiplexing (SPDM)

Astrapi® is the leader in a revolutionary method of communication –spiral-based non-periodic communication, which has the potential to be a transformative force in radio communications.

A Breakthrough in Spectral Efficiency

Spiral Polynomial Division Multiplexing (SPDM) exploits a new type of orthogonality in the polynomial coefficient space. Benefits of this approach include remarkably tight and fast synchronization with little or no power/bandwidth devoted to the task; no dependence on sinusoidal orthogonality or frequency alignment; and new and powerful tools to address Peak-to-Average Power Ratio (PAPR) constraints, coherent interference, and other channel impairments. Since Orthogonal Frequency Division Multiplexing (OFDM)-based systems are very sensitive to frequency synchronization and suffer from poor PAPR, Astrapi's SPDM has wide potential applications to solving acute problems related to OFDM implementations.

OFDM Challenges: Compared to single-carrier modulation schemes, OFDM obtains resistance to multi-path interference from increased symbol duration for each individual carrier and the use of a guard interval for each symbol. However, the use of OFDM imposes new problems. OFDM depends on precise carrier spacing and exact amplitude and phase settings for each individual carrier constellation to deliver high throughput data rates. Critical OFDM issues impacting system cost, data rates, and the delivery range include carrier frequency offset and sample clock offset, power consumption, phase noise, and linearity requirements.

1. Carrier Frequency Offset and Sample Clock Offset:
   The last phase of down-conversion in an OFDM receiver involves multiplying the incoming signal with a local oscillator. Since the transmitter and receiver frequency synthesizers are driven by different crystal oscillators, small differences between these two oscillators result in Carrier Frequency Offset (CFO) at the receiver. As the carrier frequency increases, the CFO also increases for the same crystal oscillator. Sampling the demodulated OFDM signal only at the exact symbol interval ensures that there are no contributions except the desired orthogonal basis function. However, even a minor offset of the sample clock will introduce inter-symbol interference (ISI), which will significantly degrade the reception quality.

2. Power Consumption: An OFDM system requires a power amplifier (PA) with a large linear operation zone to address the inherent high PAPR property of the OFDM signal. The high PAPR requirement is proportional to the number of subcarriers. OFDM designed modems are not power efficient. The power amplifier (PA) must be oversized in terms of its average power. So the efficiency of the PA will suffer dramatically since the power consumption is determined by the peak power. As such, PA power consumption is a significant portion of the total required radio power. High power consumption limits the attractiveness of OFDM modulation for portable applications such as PC laptops, tablets, etc. A high PAPR requires the power amplifier to have a high-level compression point which requires high power consumption and a drain on the battery. Approaches to dissipating heat resulting from high peak transmit power increase overall cost.

3. Phase Noise: In practice, the frequency of the Local Oscillator (LO) is not a pure sinusoid. To generate the LO from the free running crystal oscillator, a phase lock loop (PLL)-based frequency synthesizer is used. The PLL tries to detect the phase and generate a voltage to drive a Voltage-Controlled Oscillator (VCO) until a phase lock is achieved. Thus, in the process of phase lock, phase jitter is added to the LO frequency. Compensation of the phase noise levels close to the LO frequency is critical in order to create a low bit rate in an OFDM modem. A small increase in the bit error rate (BER) for each carrier results in a large increase in the cumulative error rate.

4. Interference: Interference from an adjacent transmitter creates throughput-limiting interference in the desired OFDM receiver even when the power levels are much lower. In some instances, the interfering transmitter is located nearer to the receiver than the proper transmitter. Many times an adjacent channel blocker has higher signal power than the desired channel. ..The receiver needs to employ an interference mitigation scheme to suppress or mitigate the effect of the inferring transmitter to achieve higher data rates. Two consequences of interference when using OFDM are difficulty in achieving acceptable noise figure performance for the overall receiver and difficulty in demodulating the desired information signal, perturbed by inference.

The Solution – Spiral Polynomial Division Multiplexing (SPDM)

SPDM uses new mathematics to enable tight low-overhead synchronization, mitigating many OFDM-related problems. SPDM does not depend on sinusoidal orthogonality. New techniques facilitate coherent interference rejection and PAPR control. SPMD can also reduce the need for costly, power-intensive components such as transmit power amplifiers that drive costs higher and increased power consumption.

1. Synchronization: SPDM enables precise and robust synchronization with limited or no power at all allowed on the synchronization signal. The SPDM receiver can identify the correct synchronization phase by examining possible phase shifts of the received amplitude data and finding the message polynomial and message polynomial sub-channel coefficients implied by that phase. A higher degree of accuracy in synchronization with less power enables the SPDM modem to reduce overhead in synchronization signaling.

2. Power Requirements: SPMD provides the ability to reduce PAPR of the power amplifier. For a given data rate, high PAPR increases the transmit power and cost. Aided by SPDM, lower power requirements should enable OEMs to dramatically lower their total cost to manufacture.

3. Interference Mitigation: SPDM offers higher bandwidth and superior interference immunization performance at a lower cost for all power consumption levels. SPMD minimizes coherent interference performance loss. This reduction arises from a novel approach to exploiting dramatically increased waveform design flexibility.

OFDM Challenges	
Synchronization	Minor clock offsets can cause significant degradation in signal reception.
Power Consumption	OFDM designed modems are not power efficient. The power amplifier (PA) must be oversized in terms of its average power
Phase Noise	Phase noise results in Inter-Carrier Interference (ICI) among the OFDM subcarriers. With increase of sub-carriers, ICI power also increases and can lead to a higher BER floor.
Interference	Difficulty in achieving acceptable noise figure performance for the overall receiver and difficulty in demodulating the desired information signal, perturbed by inference
SPDM Solutions	
Synchronization	A higher degree of accuracy in synchronization with less power enables the SPDM modem to reduce overhead in synchronization signaling
Power Consumption	SPMD provides the ability to reduce PAPR of the power amplifier. For a given data rate, high PAPR increases the transmit power and cost.
Phase Noise	SPDM can identify the correct synchronization phase by examining possible phase shifts of the received amplitude data and finding the message polynomial and message polynomial sub-channel coefficients implied by that phase
Interference	SPMD minimizes coherent interference performance loss

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