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High Data Rate HF Communications for BFTN Using Advanced Waveform Techniques

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Background

- Our goal is to utilize advanced techniques such as orthogonal frequency division multiplexing (OFDM) and constant energy modulation (CEM) in high frequency (HF) communications.
- Multi-dimensional CEM improves spectral and energy efficiency especially in nonlinear channels and low received energy levels.
- Study includes effects of various interferences.
- Previous work performed utilized SDR with GNU radio. Our work will utilize the FLEX-6600 radio which has a very programmable user interface.

- Program the FLEX-6600 radio (Fig. 1) to transmit and receive CEM-OFDM over HF and analyze the effects of various interference on constellation, error rate, and non-linear channel.



Fig. 1: FLEX-6600M HF SDR Transceiver and Smart SDR

Multi-Dimensional CEM and OFDM

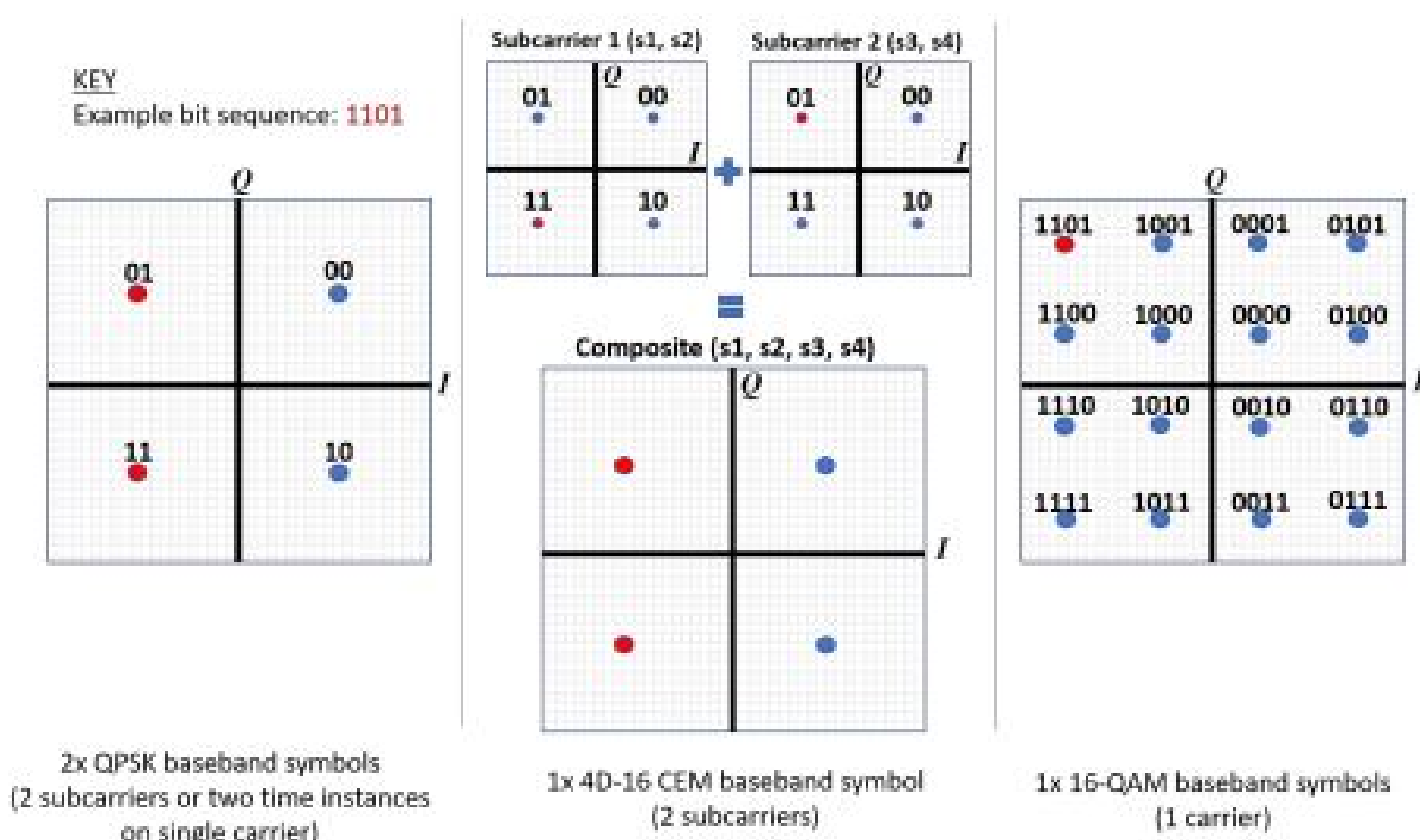


Fig. 2: Modulation constellation comparison between QPSK (left), 4D-16 CEM (center), and QAM16 (right).

- CEM uses a multi-dimensional constellation that is constrained by a constant energy (Fig. 2). Multiple subcarriers are assigned different symbols in the OFDM manner (Fig. 3).
- An added benefit of CEM-OFDM is that degraded channels can be mitigated by turning off subcarriers.

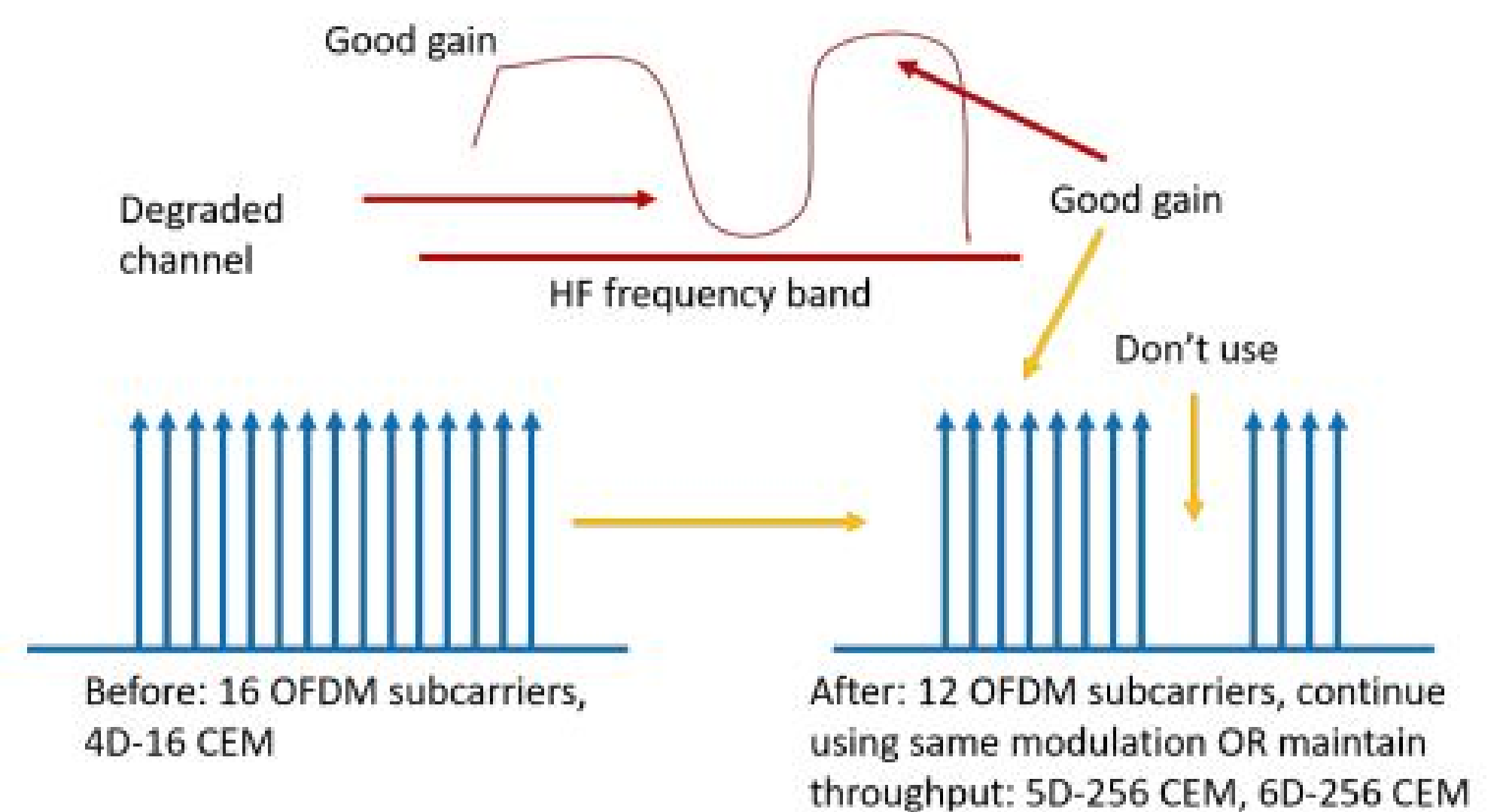


Fig. 3: Mitigated HF channel removes unusable OFDM subcarriers.

Bit Error Rate (BER) Results

- Each constellation for CEM considers the maximum number of bits transmitted, dimensions, energy constraint, and the largest minimum squared Euclidean distance between symbol vectors.
- The BER worsens when the distance between each symbol is shorter and as more symbols are added for the same dimension.
- 4D-16 CEM is similar to QPSK.
- All variations for 4D CEM performed better than QAM16 after 3dB Eb/No.
- CEM is effective in reducing the BER and increasing the data throughput for the same allocated bandwidth.

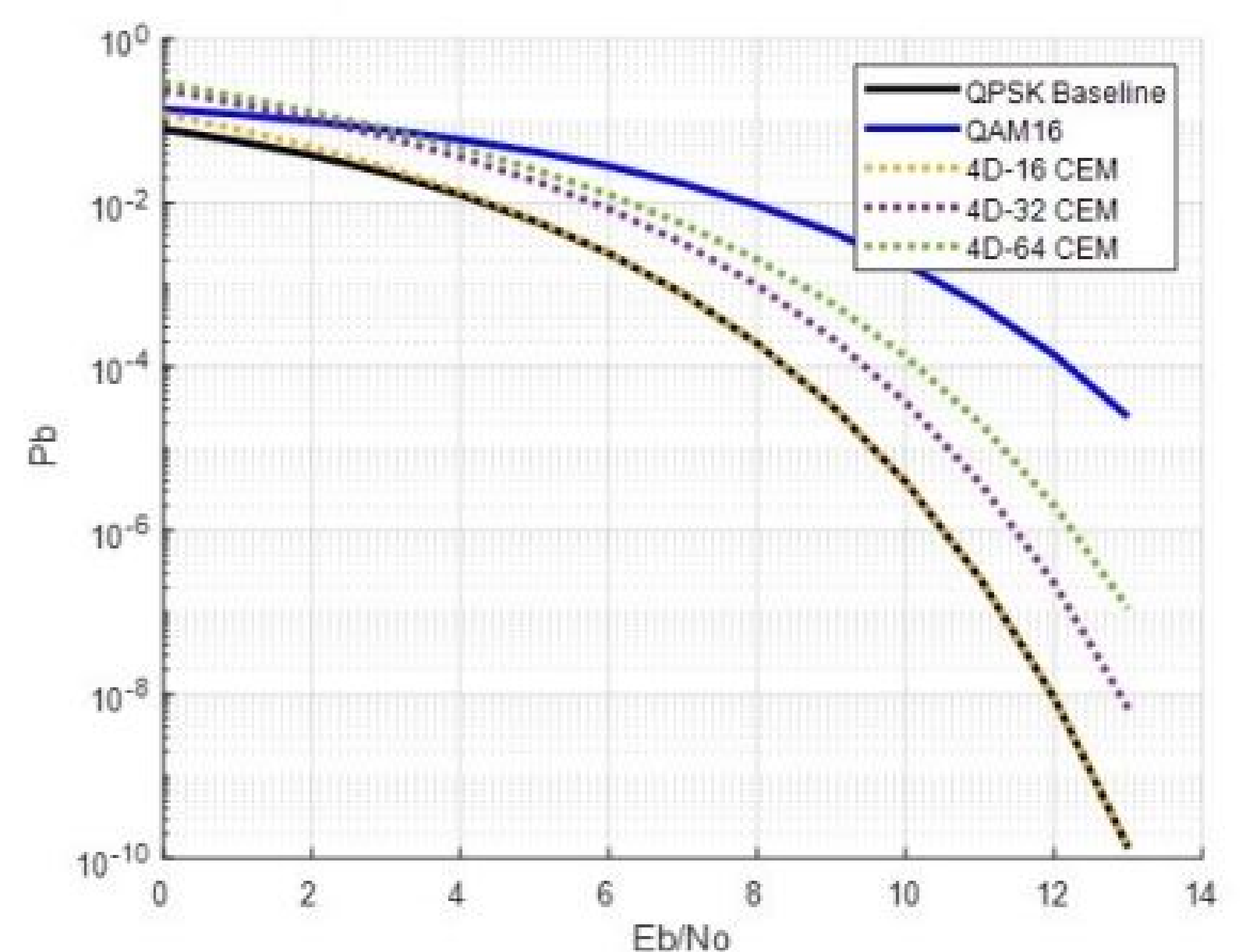


Fig. 4: BER response comparison between QPSK, QAM16, 4D-16 CEM, 4D-32 CEM, and 4D-64 CEM.

Recommendations for Future Works

- Utilize OFDM and CEM for HF over-the-horizon communications using the FLEX-6600M or with current naval platforms. Incorporate CEM-OFDM agility in other communications systems to improve data throughput.



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