FORWARD ERROR CORRECTION PROPOSAL FOR EPOC PHY LAYER

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Broadcom

DVB-C2 VS. BRCM FEC STRUCTURE ON AWGN CHANNEL

- **BRCM FEC**
  - Single LDPC code
  - Codeword size: 12000
  - Code rate 75%
  - Use set-partition LDPC code on 4-LSB's for all QAM constellations
  - Apply both even-bit and odd-bit QAM constellations
  - No need for BCH outer code in AWGN channel (no error floor problem)
  - No Frequency Domain Interleaving
  - Use shortening to provide 0.5 bit/symbol increments (with BCH outer code)

- **DVB-C2 FEC**
  - 6 different LDPC codes (one for each code rate)
  - Code rates: 4/9, 2/3, 11/15, 7/9, 37/45, 8/9
  - Codeword size: 16200
  - Code all QAM symbol bits
  - Need BCH outer code (error floor mitigation)
  - Use interleaving within one LDPC codeword
  - Only on even-bits QAM constellations

PARTIAL BIT CODING

Approach

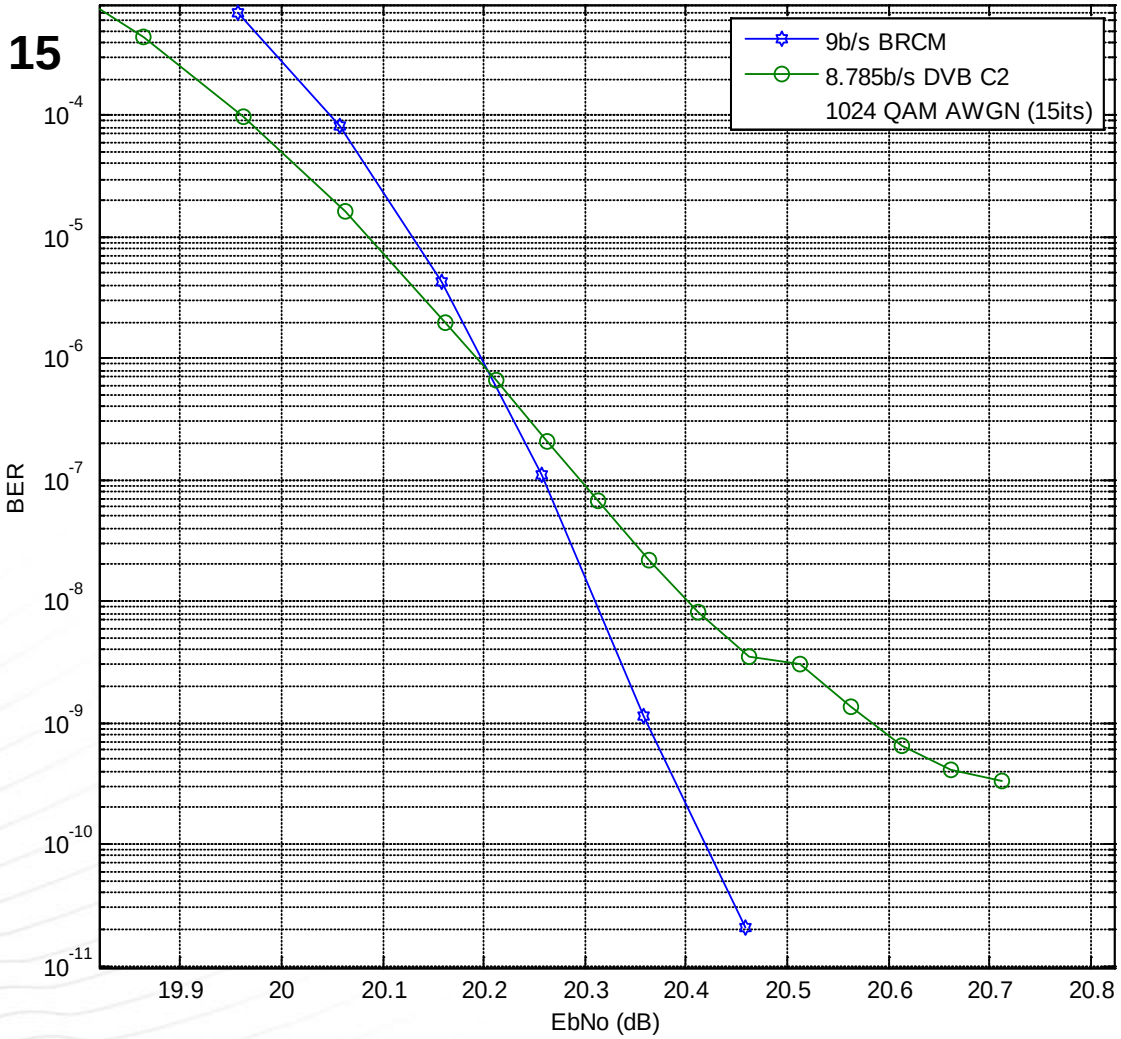
- LDPC Code applied to 4 Least Significant Bits of an QAM symbol
- Uncoded bits use Set Partitioning to maximize distance

Benefits

- Combined coding and modulation maintains error correction performance (coding gain) with a lower rate (stronger) code for the LSB's with the same overall higher code rate
- LDPC decoder rate is reduced by 4/M for M bit QAM symbols
- Reduction in decoder complexity

PERFORMANCE ON 1024-QAM (AWGN)

- **Max number of iterations: 15**
- **SNR@ 1E-8**
  - BRCM: 20.31dB
  - DVB-C2: 20.4dB
  - Difference: 0.09dB
- **SNR@1E-10**
  - BRCM: 20.41dB
  - DVB-C2: >20.71dB
  - Difference: >0.3dB



ALL QAM CONSTELLATION SUPPORT

Approach

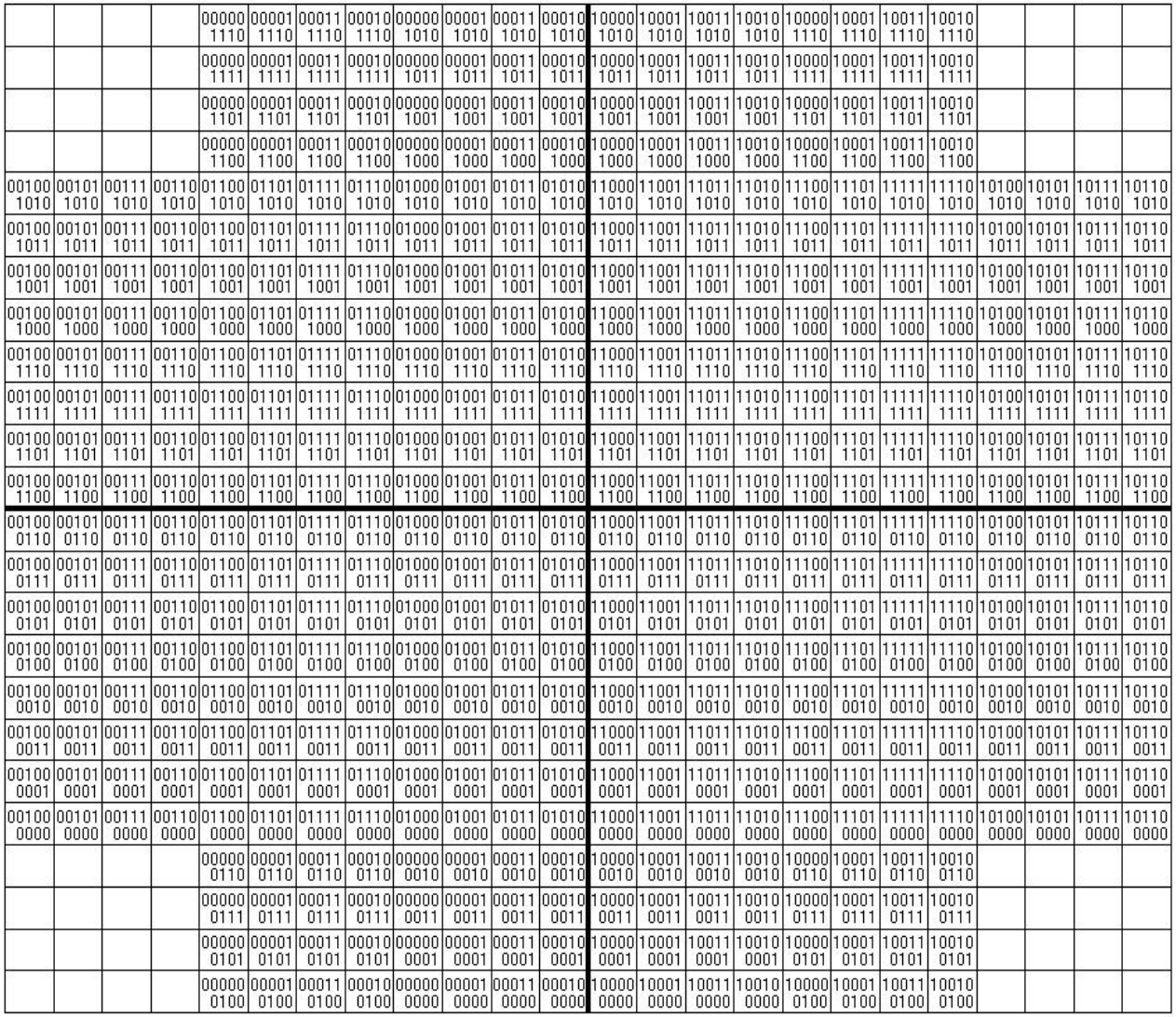
- **Use conventional even (square) QAM constellations**
  - 256-QAM, 1024-QAM, 4096-QAM
- **Add odd (cross) QAM constellations**
  - 512-QAM, 2048-QAM

Benefits

- **Provides finer granularity in spectral efficiency choices**
- **Provides finer granularity in SNR threshold choices**

512-QAM MAPPING

BRCM, four coded bits, 512-QAM



Coded bits (LSB's) are grey-coded along each axis

LDPC CODE SHORTENING

Approach

- Use a shortened LDPC codeword for the 4 LSB's as the inner code
- Add a very high code rate BCH outer code over the LDPC information bits and the uncoded bits of the partial bit coded QAM symbols containing the LDPC codeword

Benefits

- Provides finer granularity in spectral efficiency choices
- Only a single LDPC code is used
- Reduction in decoder complexity

BCH OUTER CODE WITH SHORTENED LDPC INNER CODE

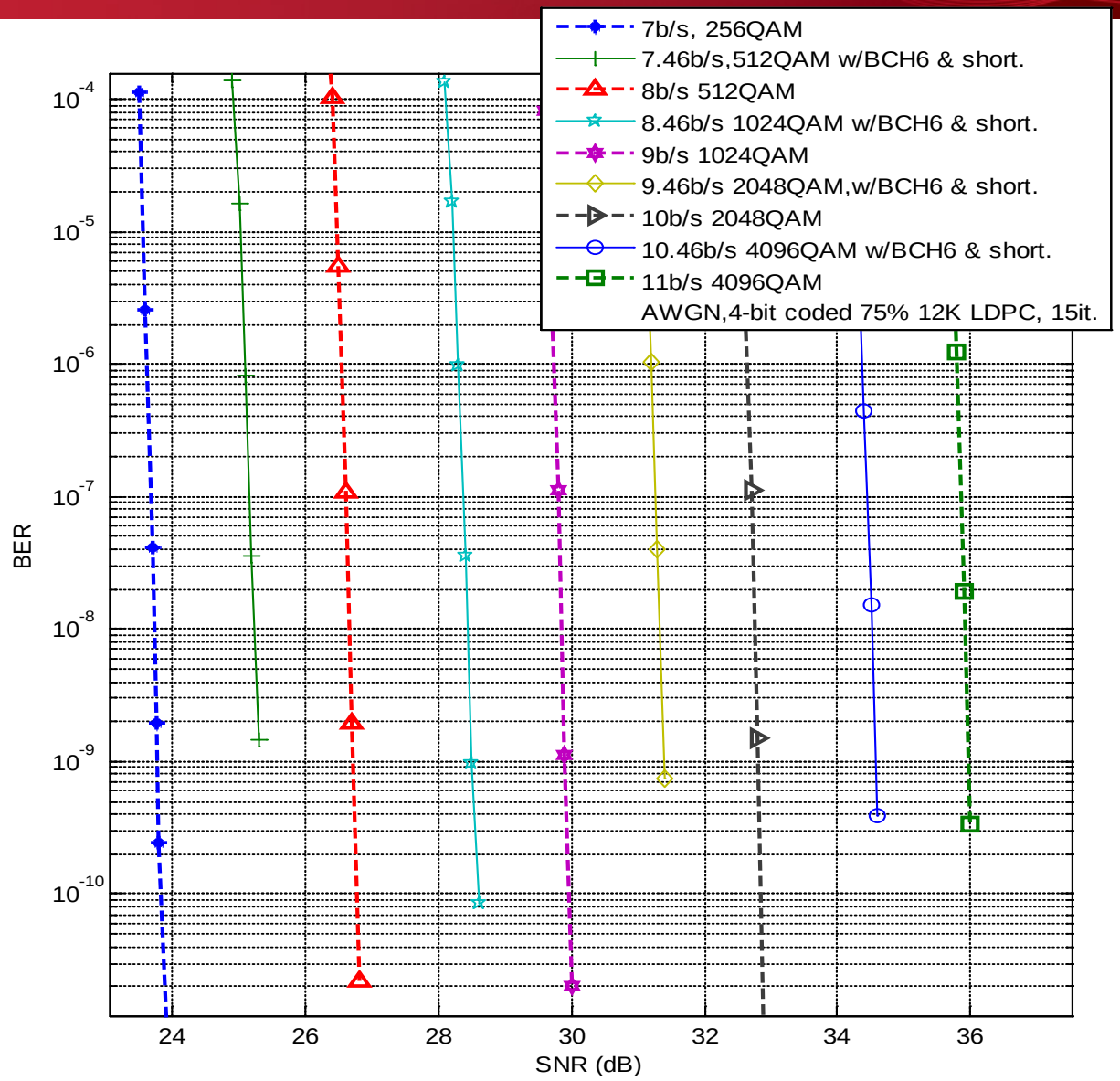
- LDPC inner code shorting size: 4000 bit
- LDPC information bits after shortening: k=9000-4000=5000
- LDPC total bits after shorting: n=12000-4000=8000
- BCH codeword size: k+(n/4)*u (where u = number of uncoded bits/symbol)
- Binary BCH code with working field GF(2^{15})

QAM Symbols				BCH outer code		
Constellation	Symbol size	Number of coded bits	Number of uncoded bits	BCH codeword size	Number of correctable bits	Number of redundancy bits
512	9	4	5	15000	6	90
1024	10	4	6	17000	6	90
2048	11	4	7	19000	6	90
4096	12	4	8	21000	6	90

256 TO 4096-QAM AND SHORTENING WITH BCH T=6

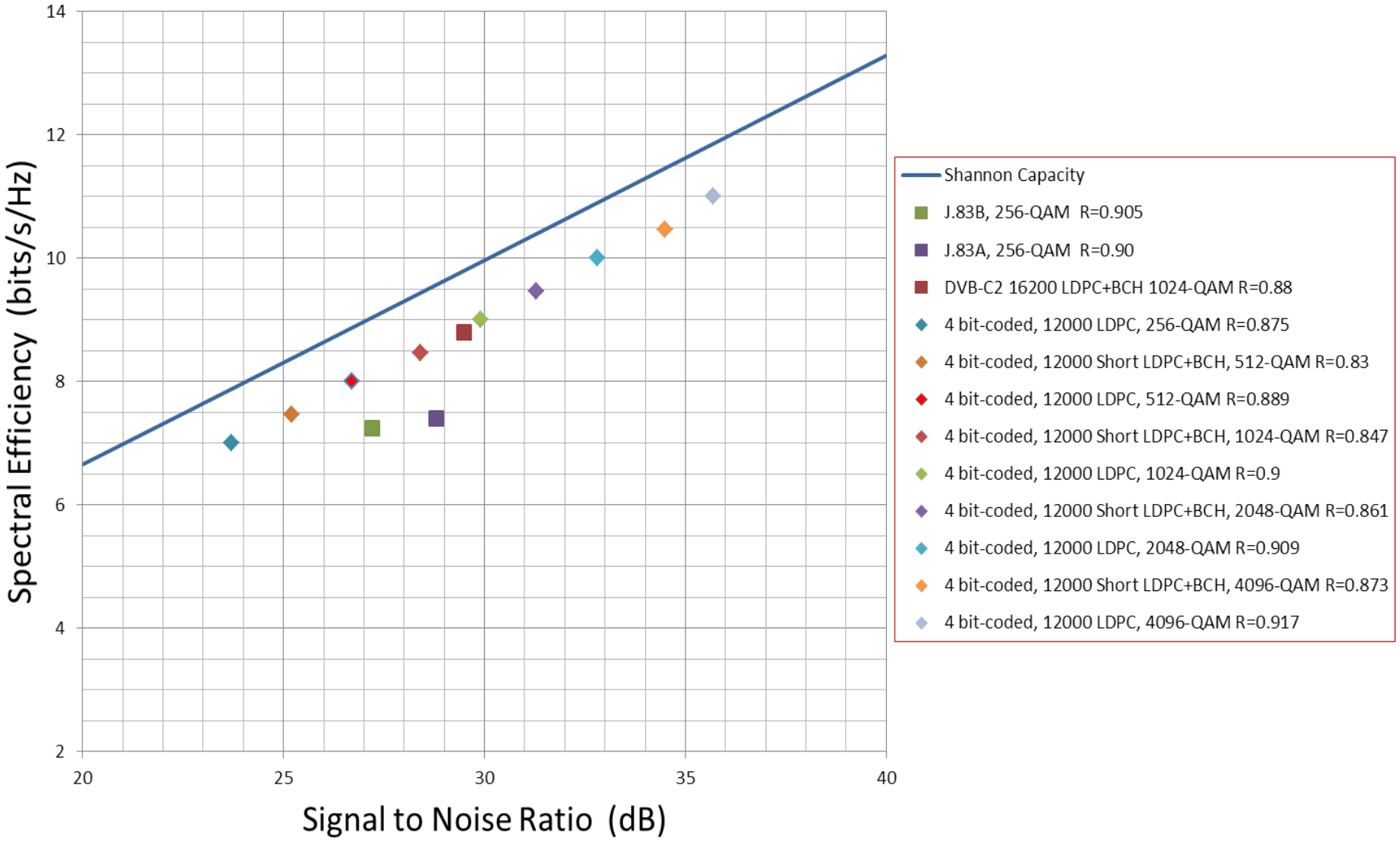
QAM symbol size	coded bits	uncoded bits	Shorten size	BCH correction t	BCH codeword size	BCH check bits	# Max iterations	Overall rate	Bits/ symbol	b/s distance to the previous one	SNR @10^{-8} BER (dB)	SNR distance to the previous one
8	4	4	0	0	0	0	15	0.875	7		23.7	
9	4	5	4000	6	15000	90	15	0.828	7.46	0.46	25.2	1.5
9	4	5	0	0	0	0	15	0.889	8	0.54	26.7	1.5
10	4	6	4000	6	17000	90	15	0.846	8.46	0.46	28.4	1.7
10	4	6	0	0	0	0	15	0.9	9	0.54	29.9	1.5
11	4	7	4000	6	19000	90	15	0.86	9.46	0.46	31.3	1.4
11	4	7	0	0	0	0	15	0.909	10	0.54	32.8	1.5
12	4	8	4000	46	21000	90	15	0.871	10.46	0.46	34.5	1.7
12	4	8	0	0	0	0	15	0.917	11	0.54	35.9	1.4

256 TO 4096-QAM AND SHORTENING WITH BCH T=6 PERFORMANCE CURVES



Max 15 iterations on Full and Shortened LDPC code

SPECTRAL EFFICIENCY OF QAM WITH FEC



CONCLUSIONS

- An LDPC Forward Error Correction approach is proposed with partial bit coding using set partitioned coded modulation
- Even and Odd QAM constellations supported for finer SNR Threshold granularity
- Codeword shortening supports variable code rates with a single LDPC code for finer spectral efficiency granularity
- Reduced decoder memory size with 12000 bit LDPC code
- Reduced decoder rate with 4-bit per QAM symbol partial bit coding
- Reduced decoder complexity with a single LDPC code
- Spectral Efficiency granularity in 0.5 bits/symbol increments
- SNR Threshold granularity in ~1.5 dB increments
- Better performance with lower complexity and greater flexibility

THANK YOU