Adaptive Modem from 4-QAM to 1024-QAM

bc005, “Manero”

The Binary Core coded modulation scheme bc005 (“Manero”) is extremely compact, highly modular, and it supports all square and cross modulation formats from 4- up to 1024-QAM. The modem is well suited for implementation on microwave point-to-point digital radio links and it is compliant with the ETSI EN 302 217-2-2 standard requirements. Typical channel spacings are 3.5-7-14-28-56 MHz (if implemented on low cost FPGAs) and up to 112 MHz (if implemented on high performance FPGAs).

The basic system can be enhanced with asynchronous Cross-Polar Interference Canceler (XPIC) and/or diversity Combiner.

Features

- Eight modulation formats (4-, 16-, 32-, 64-, 128-, 256-, 512-, and 1024-QAM).
- Adaptive modulation switching based on channel measurement and internal service channel signalling.
- Byte interface compatible with both asynchronous and synchronous data flow.
- Finely tuneable symbol frequency.
- Polynomial predistortion.
- TX and RX I/Q impairments recovery (amplitude and phase unbalance).
- Timing recovery with digital re-sampling.
- Carrier recovery with pilot symbols for improved robustness to phase noise.
- Automatic frequency recovery for fast carrier acquisition.
- 20-tap adaptive fractionally spaced equalizer.

- Efficient coding scheme based on punctured convolutional code on the two least significant bits and concatenated Reed-Solomon code.
- Optional asynchronous XPIC and Combiner.
- User definable service channel for closed-loop communication between transceivers.

FEC Reconfigurability and Throughput

The Binary Core bc005 Modem “Manero” provides various synthesis options and dynamically reconfigurable parameters in order to optimize the core to your application. For example

- Optional pilot symbol rate – independently selectable for each modulation format, even in the case of adaptive modulation. The number of pilot symbols in a 960-symbol radio frame, N_{pilot}, can be selected by the user, provided that $N_{\text{pilot}}+1$ is a divisor of 960. A pilot symbol is sent every $960/N_{\text{pilot}}+1$ information symbols.
- Various control loop gains and bandwidths.
- Convolutional code rate – independently selectable for each modulation format, even in the case of adaptive modulation. Allowed rates

$$R_{\text{conv}} = \frac{1}{2}, \frac{2}{3}, \frac{3}{4}, \frac{4}{5}, \frac{5}{6}, \frac{7}{8}, \frac{9}{10}, 1.$$

- Reed-Solomon code rate. Allowed rates

$$R_{\text{RS}} = \frac{k-1}{n},$$

  with $n - k \leq 16$, n and $k-1$ defined by the user.
- The interleaver depth D can be set by the user in the range

$$1 \leq D = \frac{n}{M} \leq 32,$$

  with D and M integers.

The transmission bit rate depends on channel spacing, modulation format, pilot symbol rate, convolutional code rate, Reed-Solomon code rate and user service channel rate. Example throughputs are as follows.

- $N = 7$ (128-QAM), $R_{\text{conv}} = 4/5$, no pilot symbols, $R_{\text{RS}} = 242/252$, we obtain

$$\eta = 6.325 \text{ b/2D},$$

  which is adequate for SDH STM-1 transmission in 28 MHz channel spacing.

- An example adaptive modulation scheme that switches between 8 modulation formats, $R_{\mathsf{RS}} = 235/252$, and the other parameters defined in the following table.

N	R_{conv}	N_{pilot}	η (bit/2D)
4-QAM	1/2	0	0.923
4-QAM	4/5	0	1.481
16-QAM	1/2	0	2.784
32-QAM	3/4	0	4.179
128-QAM	1/2	0	5.576
512-QAM	1/2	29	7.219
1024-QAM	1/2	47	7.978
1024-QAM	1	47	8.865

XPIC and Combiner (Optional)

The adaptive modulation “Manero” can be enhanced with an embedded XPIC/Combiner block, for systems using space diversity and frequency reuse.

- Asynchronous with respect to RF local oscillators.
- 20-tap fractionally-spaced equalization for main, cross-polar, and diversity branches.
- Embedded differential carrier recovery with frequency error compensation for asynchronous operation.
- Fixed delay compensation (e.g., different cable lengths) between main and diversity (cross-polar).
- I/Q delay compensation.
- Maximum tolerable dynamic delay between main and interferer: 4$\times$ symbol time (about 160 ns in 28 MHz channel spacing).
- Combiner performance: 3 dB gain on 10^{-6} BER threshold for balanced input signals.
- XPIC performance is measured using XPIC Improvement Factor (XPIF)

$$\text{XPIF} = \text{C/I}|_{\text{w/o XPIC}} - \text{C/I}|_{\text{with XPIC}},$$

  where $\text{C/I}|_{\text{w/o XPIC}}$ is the Carrier-to-Interferer ratio without XPIC and $\text{C/I}|_{\text{with XPIC}}$ is the Carrier-to-Interferer ratio with XPIC, required to have 1 dB degradation of the 10^{-6} BER threshold (reference: single equalizer, no interferer). Using 128-QAM, 28 MHz channel-spacing, convolutional code rate $4/5$ and Reed-Solomon code rate $242/252$, gives $\text{C/I}|_{\text{w/o XPIC}} = 30$ dB, $\text{C/I}|_{\text{with XPIC}} = 12$ dB, resulting in a XPIF of 18 dB.