Adaptive Modem from 4-QAM to 1024-QAM

bc005, "Manero"

The new Binary Core coded modulation scheme (bc005, "Manero") is designed for implementation on low-cost FPGAs, it is extremely compact, highly modular, and it supports all square and cross modulation formats from 4- up to 1024-QAM. The input data can be synchronous (no justification required), or asynchronous. The symbol frequency can be finely and dynamically tuned by means of an all-digital re-sampling filter.

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.
- Tuneable symbol frequency (from 2 up to 56 MHz, with steps of about 200 kHz).
- Only one external clock source required, feeding FPGA, DAC, and ADC.
- Typical clock frequency 80÷120 MHz.
- 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 with mapping by set partitioning, and concatenated Reed-Solomon code.
- User definable service channel for closed-loop communication between transceivers.

Reconfigurability

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. Allowed rates

$$R_{\text{pilot}} = \frac{1}{p+1}$$

  where p is any divisor of 960 with $1 \leq p \leq 48$. For istance for $p = 32$ one pilot is transmitted every 32 data 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 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.

Throughput and applications

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, $R_{\text{RS}} = 241/252$, we obtain

$$\eta = 6.305 \text{ b/2D},$$

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

- An adaptive modulation scheme that switches between 9 modulation formats, $R_{\text{RS}} = 235/252$, and the other parameters defined in the following table.

N	R_{conv}	R_{pilot}	η (bit/2D)
2 (4-QAM)	1/2	–	0.93
2 (4-QAM)	1	–	1.86
4 (16-QAM)	2/3	1/49	3.04
5 (32-QAM)	2/3	1/33	3.91
6 (64-QAM)	2/3	1/17	4.68
7 (128-QAM)	2/3	1/13	5.66
8 (256-QAM)	2/3	1/9	6.07
9 (512-QAM)	2/3	1/9	6.90
10 (1024-QAM)	2/3	1/7	7.45