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COMMUNICATION SEMICONDUCTORS

Wireless Data Modems

FFSK/MSK · GMSK/GFSK · 2/4/8/16-FSK · 4/16/32/64-QAM · V.23

Adaptive Coded Modulation (ACM) features now available in the QAM Function Image™

Product Information Pack

March 2016

Quick Links

- Home
- Introduction
- Evaluation
- Promotion
- Resources
- CMX7164 Overview
- GMSK/GFSK
- Multi-level FSK
- QAM
- V.23

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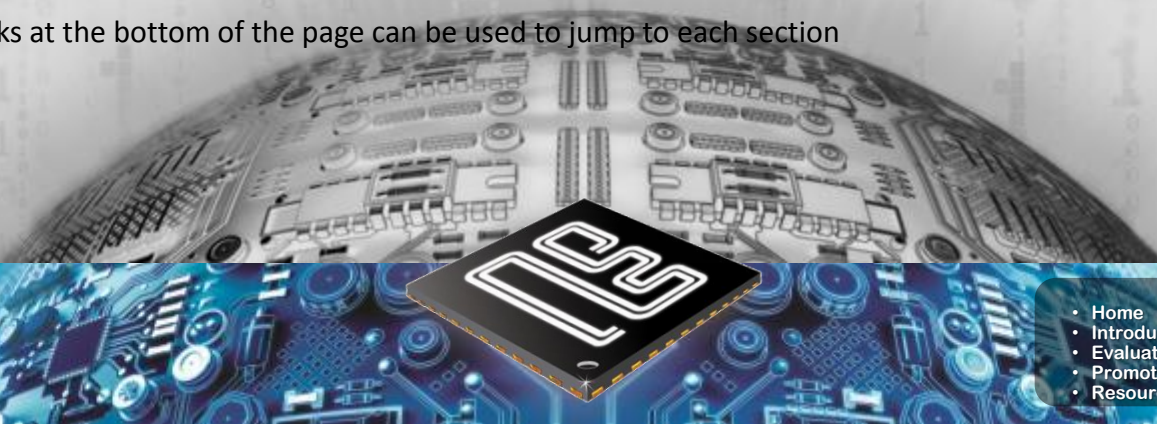
Topics Covered

- Introduction to Wireless data and the benefits of the *FirmASIC*® approach
- CMX7164 product overview
  - QAM Modulation
  - GMSK/GFSK Modulation
  - Multi-level FSK Modulation
  - V.23 Modem
- Evaluation support
- Promotional material
- Resources

Note that the links at the bottom of the page can be used to jump to each section



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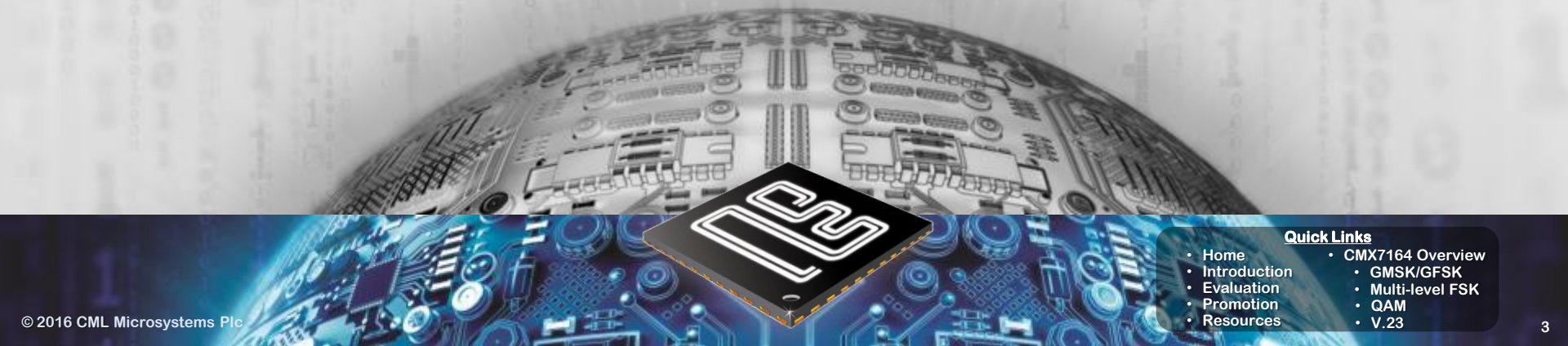
Introduction

Wireless Data Modems



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High performance, proven record

- CML has delivered high performance Wireless Data modem ICs for 30+ years
- RF + modem IC + host µC = end product
- Wide range of modulations, protocol functions, and features
  - GMSK/GFSK, 2/4/8/16-FSK, 4/16/32/64-QAM, V.23 and custom modulations
- Integrated key functions
  - Data pump: Converts bits to and from analogue modulating waveform, no external ADC/DAC required
  - Protocol: Error detection / correction with packet formats for robust, useful data links
  - Auxiliary: ADCs, DACs, digital I/O and clock generation
- High performance - Detect good bits in the presence of noise plus high spectral efficiency
- 'No risk' signal processing performs to datasheet specs
- Low power, small size
- Optimise total solution cost
- ASSP and custom product design opportunities
- High reliability and quality
- Long product life cycle

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Different RF approaches

- Different types of RF transmitters and receivers employ different signal formats
  - Connected modem ICs must support compatible signal formats
  - Different signal formats carry tradeoffs
- RF transmit
  - Direct VCO modulator
  - I/Q modulator
- RF receive
  - Limiter discriminator
  - I/Q demodulator
  - CMX7164 and CMX7163 support direct connection to CML's CMX994/A/E Direct Conversion Receiver Family

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Tx: Direct VCO modulator

- Baseband waveform signal representing data bits drives VCO to develop FM
- Mature technology and widely used for ‘simple’ analogue FM
- Setting FM peak frequency deviation
  - Determined by baseband amplitude and VCO K (modulation sensitivity in frequency change/volts input)
  - K varies so the deviation must be trimmed at time of manufacture
- VCO + synthesiser + reference oscillator = PLL for programmed tuning
- PLLs attenuate (distort) low frequency signal content
  - Must compensate by splitting the input signal and driving both the VCO and its PLL reference oscillator in ‘balanced’ measure
  - Two point modulator ‘balance’ must be trimmed at time of manufacture
- Direct VCO limitations
  - Cannot modulate RF amplitude so only supports constant envelope modulations
  - No precise phase changes = no coherent modulations

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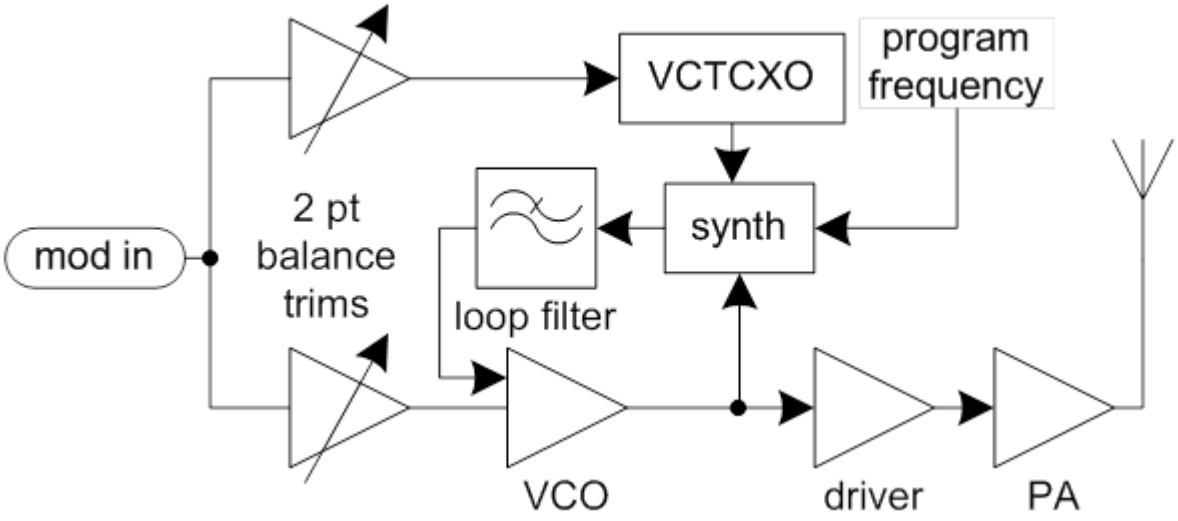
Tx: Direct VCO modulator



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Tx: I/Q modulator

- I/Q modulators convert two baseband (zero IF I and Q) input signals and an RF carrier LO into a modulated RF output signal
- Modulation type is very flexible and determined by the baseband input I and Q signals
  - FM, PSK, QAM, AM
  - Modulations that vary frequency/phase and amplitude for benefits e.g. faster data rate in a given RF channel
  - Readily supports constant envelope modulations e.g. FM
  - Readily supports coherent modulations that require precise signal phase control
  - A modulation that varies amplitude is called “linear” or “non-constant envelope”
- FM peak frequency deviation and modulation bandwidth are determined by baseband input signals
  - Directly determined by modem input I/Q signals, without trimming
- LO generation is similar to direct VCO modulator
- Does not distort low frequency signal content so no two-point modulation balance trimming is required

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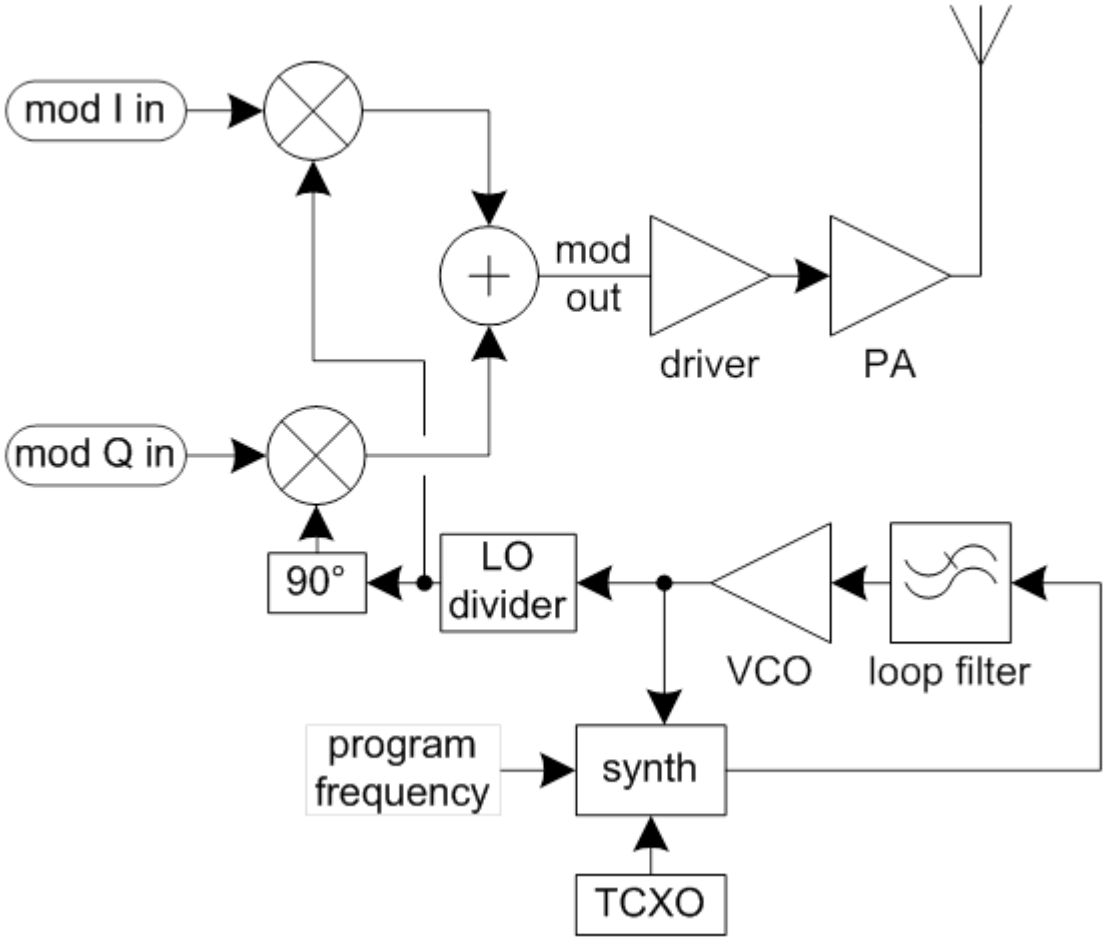
Tx: I/Q modulator



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Rx: Limiter discriminator

- Demodulates RF FM signal into a single baseband output waveform signal
- Mature technology, widely used in dual superhet receiver for analogue FM
  - Two down-mixing stages use fairly high (450kHz, 10.7MHz, etc.) frequency IFs
  - Image reject, 1st IF and 2nd IF filters are discrete and cannot change bandwidth
  - For multiple bandwidth modes must switch multiple IF filters; bulky and expensive
  - Discrete IF filters exhibit group delay distortion, a problem for some modulations
- Limiting amp stage deliberately over amplifies received signal to limit (clip)
  - Removes all amplitude variation so output amplitude fixed at amplifier clipping level
  - Destroys RF signal amplitude information so only ok for frequency mods; cannot support linear modulations
  - Precludes using IF filters after the limiter stage
- FM discriminator dc shift tempco must be compensated by external circuits
- Limiter discriminator limitations
  - Supports only constant envelope modulations
  - Cannot detect precise phase changes = no coherent modulations
  - Requires switching different IF filters to support multiple bandwidth modes

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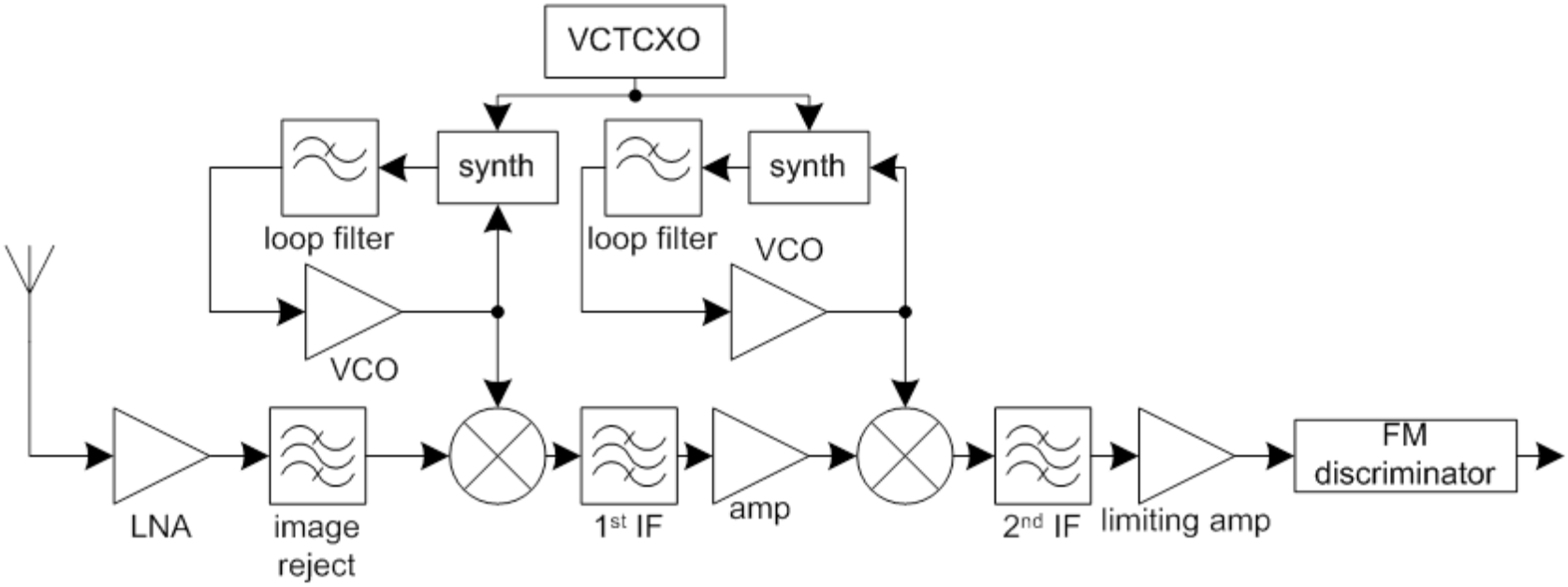
Rx: Limiter discriminator



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Rx: I/Q demodulator

- ‘Demodulates’ RF signal into a related pair of low frequency output waveform signals
  - Does not limit (clip) the Rx signal
  - Output signal is actually mixed-down in frequency and converted to I/Q signal pair format but not yet demodulated
  - IF filtering can thus be done on I/Q output signals, which are low frequency
  - Supports coherent modulations
- External I/Q digital IF filters are relatively easy to implement on I/Q output signals
  - Low I/Q signal frequencies
  - Digital IF filter bandwidth is configurable and virtually free of discrete filter distortions
- No 2nd IF filter or FM discriminator
  - No external circuits to compensate for dc shift tempco
- Supports flexible digital receiver approach
  - Change bandwidth and modulation without switching discrete filters in/out
- LO generation may be similar to limiter discriminator receiver

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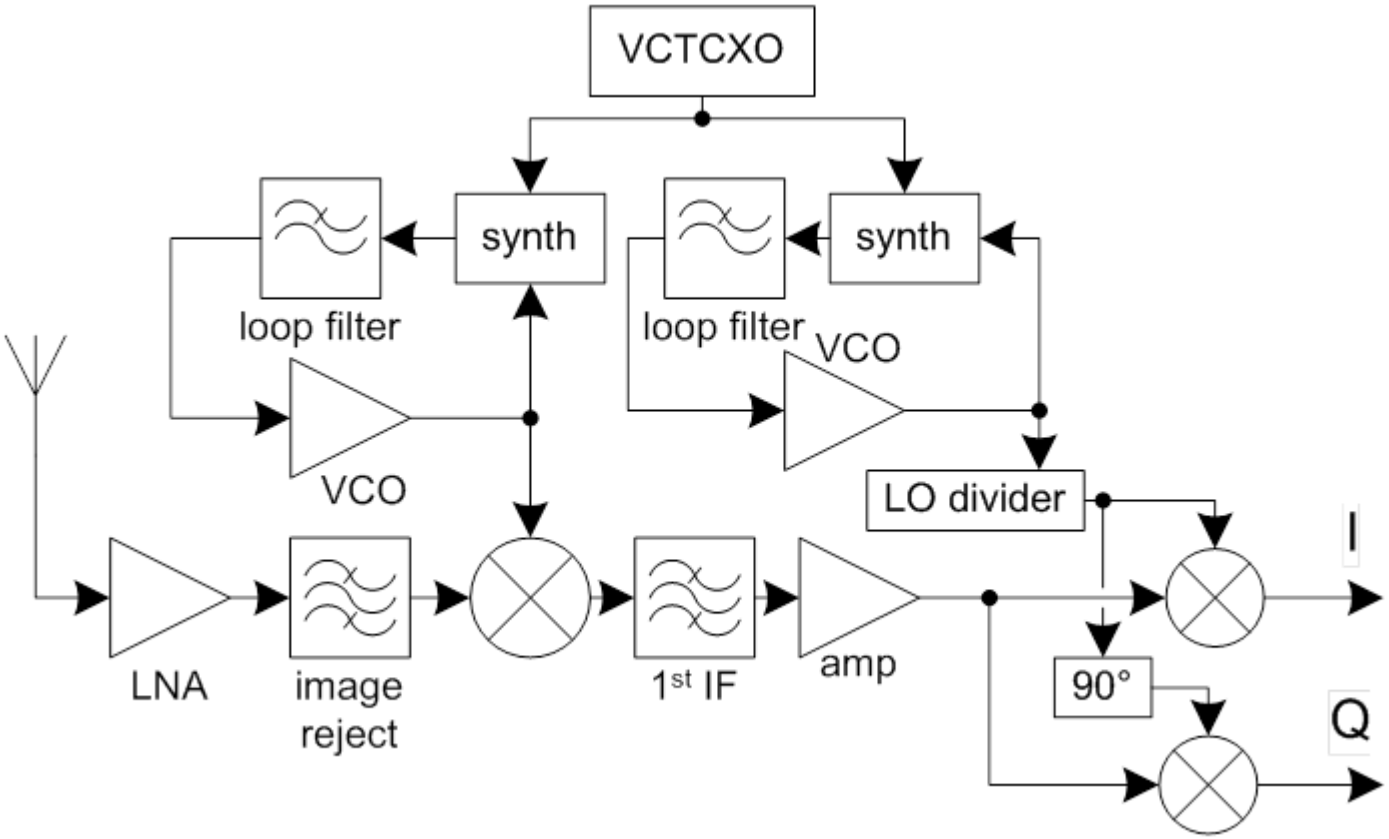
Rx: I/Q demodulator



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I/Q vs. traditional (VCO and limiter discriminator)

- I/Q is flexible
  - Both linear and constant envelope modulations
  - External digital circuits enable modulation type and bandwidth choice under host control
- I/Q eliminates trims; none for peak deviation or two point modulation balance
- I/Q is high performance
  - Supports linear modulations that increase data rate in a given channel bandwidth
- I/Q is a more advanced and capable radio architecture

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Spectral efficiency

- For decades regulatory administrations around the world have provided 25kHz spaced RF channels, which have been very popular
- Rapid growth and pervasive use of wireless communications have exhausted available channels and is limiting wireless use
- A wireless channel is an information pipe; the more narrow the channel the lower its data transfer capacity i.e. less bandwidth = lower data rate
- Existing 25kHz RF channels have not been efficiently used
  - 8kbps in 25kHz is not uncommon yet more efficient modems do much better

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Spectral efficiency

- New regulations are changing the spectrum landscape and forcing channel use at higher data rates
  - FCC part 90 business and industry data modems forced to deliver >=19.2kbps in the 25kHz channels that some applications require
  - Using 6.25kHz channels is sometimes, but not always, given regulatory preference
  - 6.25kHz and or 12.5kHz channels sometimes replace 25kHz ones
  - Some existing 25kHz systems are being forced out of service
- These changes are a global trend occurring in all major regions including: China, Europe, Japan, Korea, USA, and others
- There is a spectrum shortage
  - Available channel bandwidth is not known in advance and is shrinking; users who want a 25kHz channel license may find only 12.5kHz or 6.25kHz is available, yet application data is growing so higher speed links are desired
  - Challenge: Higher speed modulations transmit 'shorter bits' that are more error prone so uncorrected bit error rate usually rises with wireless data rate
- Higher speed
  - Requested by end users
  - Enhances end products and expands applications

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Solution technologies

1. Linear modulation
   - Carries information on wireless link by simultaneously modulating both RF signal frequency/phase and amplitude
   - Significantly increase spectral efficiency by using better modulations
2. I/Q radio architecture
   - Supports both constant envelope and more spectrally efficient linear modulations
   - Enables switching channel spacing (bandwidth) via soft reconfiguration, without multiplexing banks of discrete IF filters
   - Eliminates per-unit trims at time of manufacture
3. Equalisation and enhanced FEC (forward error correction)
   - Mitigates dynamic channel condition changes e.g. fades
   - Counteracts increased uncorrected error rates of high speed modulations
   - Works well under realistic conditions
   - FEC strength choices to suit the application
4. Multiple modulation choices
   - Selected under host control
   - Provide choice of data rate (spectral efficiency) vs. robustness to suit the application
   - Enables higher data rate in same bandwidth or same data rate in less bandwidth
   - Root raised cosine 4FSK and GMSK/GFSK interoperate with legacy systems

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FirmASIC® technology

- *FirmASIC*® IC launched early 2006
- Fixed function experience in a flexible form
- Signal processing + integrated analogue interfaces
- *FirmASIC*® device purchase is standard, off-the-shelf with datasheet specified features and performance
- Simple SPI-like serial host interface
- The difference is to initialise the device by loading a Function Image™ (FI), a small, free file provided by CML
  - FI is loaded via the serial C-BUS (addressed SPI) host interface or an external memory device
  - One datasheet per FI is typical
  - CML can evolve a device's FI to add standard/custom features to suit market/customer needs

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FirmASIC® advantage

- I/Q Tx/Rx radio interfaces directly connect to I/Q RF transceivers
- Digital IF channel filters
- High performance
- Flexibility
  - Support both constant envelope and linear modulations
  - Change modulation bandwidth via host µC command
  - Meet different regional regulations e.g. FCC, ETSI, etc.
  - Feature evolution via FI change, which can be swift
- Aux functions
  - ADCs
  - DACs with RAMDAC
  - Clock synths
  - C-BUS/SPI master
  - GPIO
- 3.3V supply, low power

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FirmASIC® advantage

- Small size
  - RF IC (1 or 2) + *FirmASIC*® + host µC = data terminal
  - SPI master interface to manage connected devices
- Low cost
  - BOM and life cycle
- Delivers *FirmASIC*® datasheet design experience
  - Know what you're getting: FI functions are specified and delivered
  - Low risk
  - Short time to market
  - Enables designer to focus on application development, the real value added

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Products

Wireless data modems

Summary of CML's Wireless data modem ICs

- **CMX7164 - Multi-mode Wireless Data Modem**
  I/Q Rx, I/Q Tx and for some FIs 2-point modulation Tx
    - GMSK/GFSK
    - 2/4/8/16-FSK
    - 4/16/32/64-QAM
    - V.23 Modem
- **CMX7163 - QAM modem**
- CMX7143 - Wireless Data Modem
  LD Rx, 2-point modulation Tx
    - GMSK/GFSK
    - 4-FSK
    - FFSK/MSK
- CMX589 – High speed GMSK/GFSK modem
- CMX469 – FFSK/MSK modem
- Custom modulation schemes for CMX7143, CMX7163 and CMX7164

The remainder of this presentation focuses on the CMX7164/CMX7163

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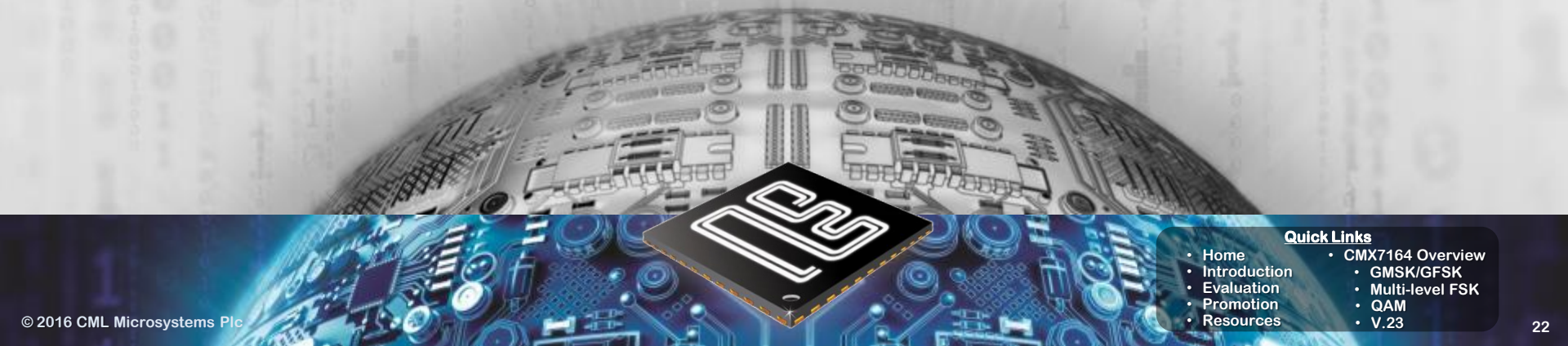
CMX7164

Multi-mode Wireless Data Modem

(GMSK/GFSK · 2/4/8/16-FSK · 4/16/32/64-QAM · V.23)

Adaptive Coded Modulation (ACM) features now available in the QAM Function Image™



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Applications

- High performance narrowband wireless data systems
- Legacy systems using popular CMX7143, CMX909B and CMX919B devices
- M2M systems over dedicated channels
  - High quality of service; long range and no unlicensed channel congestion
  - Point-to-point, multipoint, multicast, broadcast, and mesh network systems
  - Wireless data concentrator hubs and their backbones e.g. smart grid
- SCADA systems
- Mobile data systems - AVL vehicle location and tracking
- FCC part 90 business and industry spectral efficiency system requirements
- Digital SDR (Software Defined Radio) systems
  - Flexible 6.25kHz to 25kHz RF channel spacing fits changing conditions
- General high speed, high efficiency wireless data telemetry
- Digital WLL - wireless telephone links
- Miniature, battery powered, portable, wireless data terminals

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Systems and standards

- Meets the essential parameters of various global regulatory standards
- ETSI EN 300 113
- ETSI EN 301 166
- ETSI EN 300 220
- Various FCC rule parts including Part 90
- ARIB STD-T67
- RCR STD-30
- Different modes support regulations for 5kHz, 6.25kHz, 7.5kHz, 12.5kHz, 15kHz, 20kHz, 25kHz, and other user-selectable channel spacings

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Key features

Solution Technology	CMX7164 Detail
Linear modulation	• Supports spectrally efficient QAM
FM (constant envelope) modulation	• Supports root raised cosine 2-FSK, 4-FSK, 8-FSK and 16-FSK • Supports GMSK/GFSK • V.23 Modem
I/Q radio architecture	• Direct connects to I/Q zero IF radio transceivers • Integrated radio interface codecs (ADC/DAC) • Integrated digital IF filters scale BW with selected data rate
Equalisation and enhanced FEC	• Dynamic equaliser compensates channel response changes • Robust error correcting code supports realistic conditions • Multiple code rates to choose robustness vs. net throughput
Multiple modulation choices Function Images	• 7164FI-1.x - GMSK/GFSK • 7164FI-2.x – 2/4/8/16-FSK • 7164FI-4.x (7163FI-4.x) – 4/16/32/64-QAM • Selectable data rates up to ~96kbps • Data rate selection sets bandwidth to suit requirements

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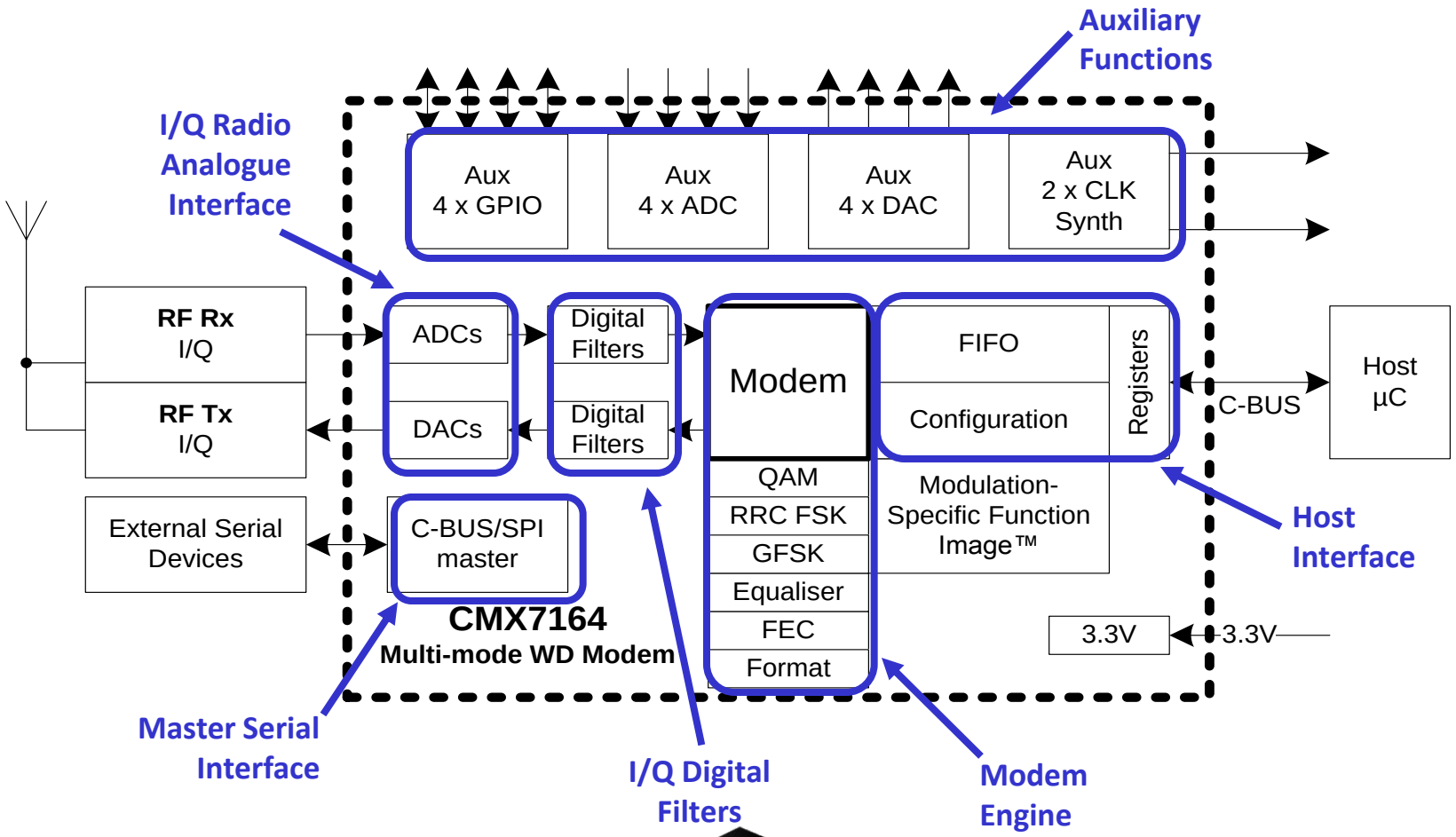
Section overview



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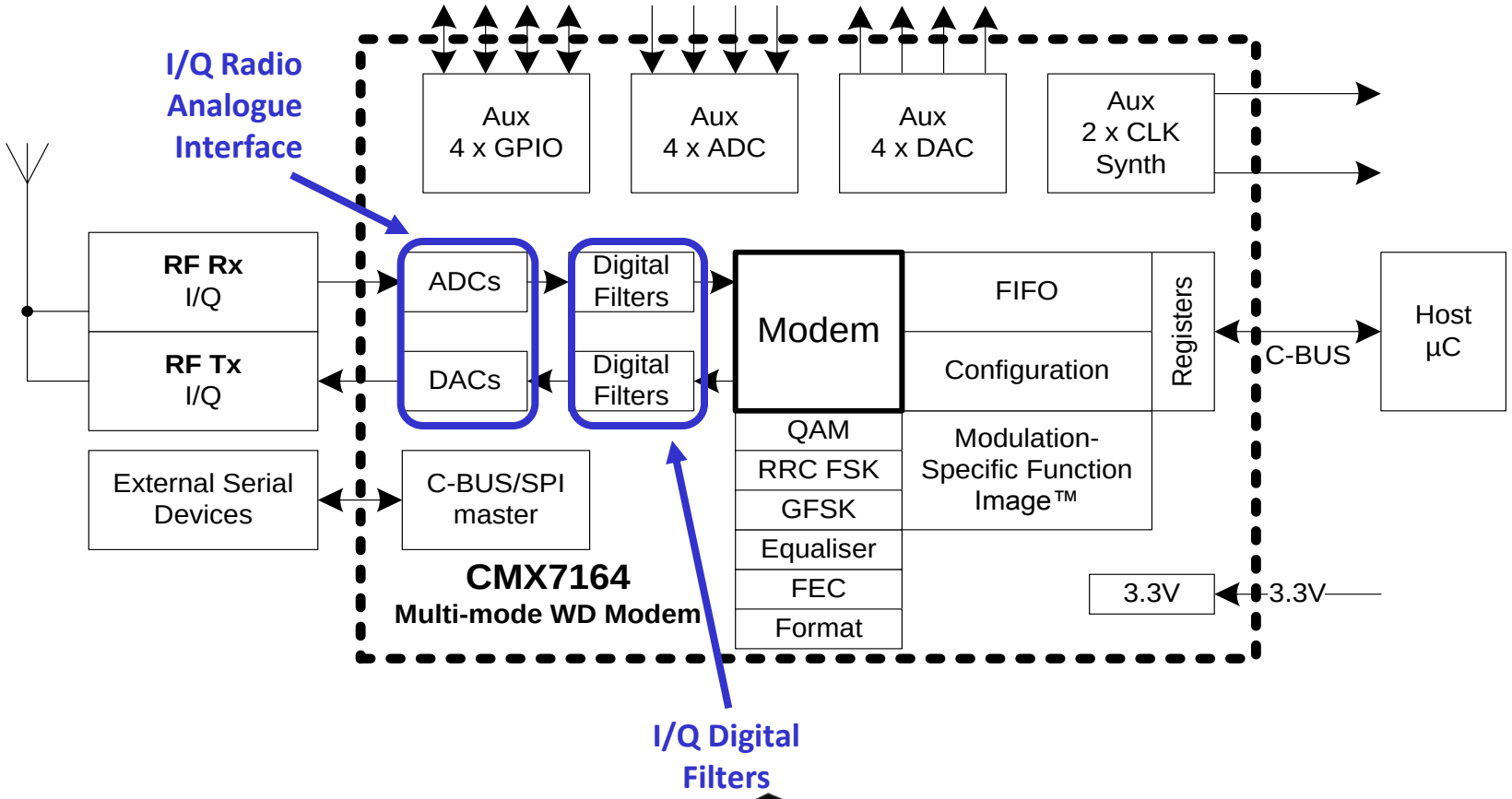
I/Q Radio interface and digital filters



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I/Q Radio interface and digital filters

- Integrated I/Q ADCs and I/Q DACs provide analogue radio interface that can directly connect to zero IF I/Q radio transceivers
- No external ADCs or DACs required
- I/Q ADCs are high dynamic range to support Rx digital IF filter
- Rx (ADC) digital I/Q IF filters provide significant adjacent channel rejection
  - Filter response shape automatically matches selected modulation
  - Linear phase response for negligible group delay distortion
  - I and Q filter path responses are precisely matched
  - Filter bandwidth automatically scales with selected symbol rate
  - Adjacent channel rejection of >58dB may eliminate the need to switch between multiple discrete 2nd IF filters to reduce total BOM cost and size
- Tx DAC path dc offset and gain controls to trim I/Q modulator
- Tx DAC auto-calibrate external CMX998 modulator dc offset (LO suppression)

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New QAM features

- QAM Function Image™ only – 7163/7164FI-4.1.x.x
- 32-QAM modulation
- ACM (Adaptive Coded Modulation) features
  - Command to dynamically change modulation type on a per burst basis
  - User defined formatted blocks: data field size, channel coding and CRC sizes
  - Over-air commands
- Iterative channel coding makes short messages more robust
- User defined CRC polynomials
- Serial port interface (SPI) macros speed external slave device setup
- RSSI and Error Magnitude reporting modes provide better guidance to host ACM decisions

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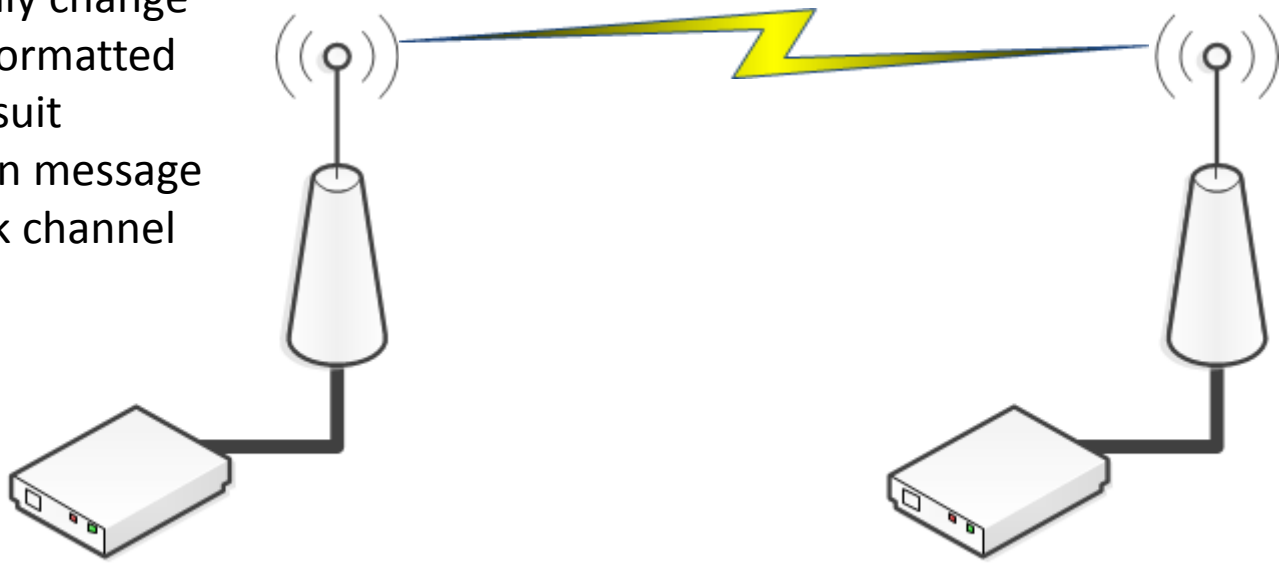
‘Over-air’ commands scenario

Tx host wants to dynamically change selected formatted blocks to suit application message size or link channel quality

Rx host doesn’t know what block format will arrive but must in order to issue the correctly corresponding Rx commands to the CMX7164



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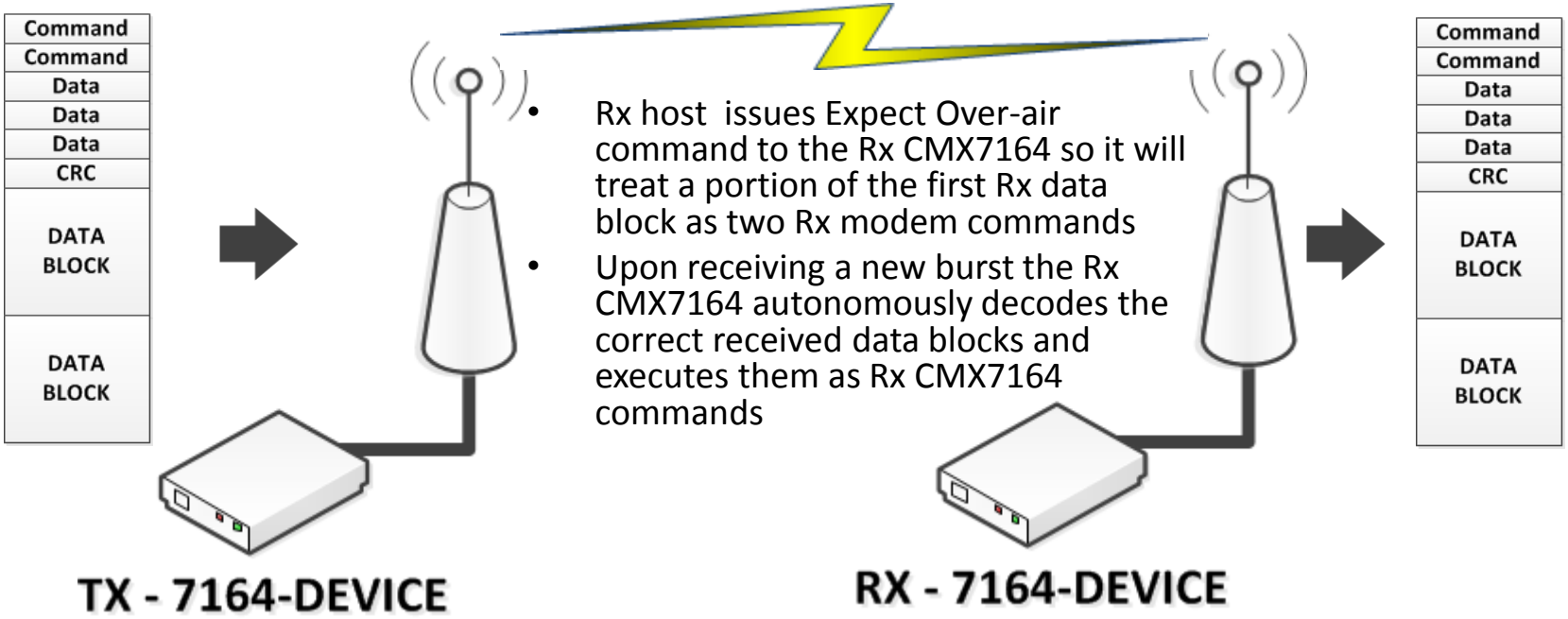
‘Over-air’ commands solution

- **Solution**: Tx host inserts Rx modem command data into first data block
- Rx host commands the CMX7164 to treat a selected portion of the first Rx data block as Rx commands



- Rx host issues Expect Over-air command to the Rx CMX7164 so it will treat a portion of the first Rx data block as two Rx modem commands
- Upon receiving a new burst the Rx CMX7164 autonomously decodes the correct received data blocks and executes them as Rx CMX7164 commands

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New QAM feature benefits

- ACM (Adaptive Coded Modulation) involves dynamically changing Tx burst in response to Tx host's application message size and the link's channel quality. This technique optimizes network performance.
  - Change modulation type on the fly to suit message size and link channel quality. **New Change M-QAM Modulation command** enables quickly changing to any QAM type on a per burst basis.
  - Change block format: Rx must learn the Tx block formats in time to task the Rx CMX7164 to process them correctly. This would require the Rx host to quickly parse and act upon control data in a burst header. **New Rx Expect Over the Air command** enables the Tx host to autonomously control initial Rx CMX7164 commands ***without quick initial Rx parsing by the Rx host***
  - Resolving link channel quality uses Rx CMX7164 RSSI and Error Magnitude metrics. **New, configurable RSSI and EM modes** support developing a more accurate and or timely host view of channel quality.
  - **New user defined formatted blocks (up to 48)** allow the user to tune CMX7164 formatted block 'vocabulary' to best suit his application's message size, robustness, error checking and error correction
  - **New 32-QAM modulation** is an attractive data rate vs. link robustness choice between 16-QAM and 64-QAM
- New iterative channel coding type provides the ability to robustly transport short messages e.g. application control information
- SPI Thru-port macros speed setup and configuration of external C-BUS devices to reduce transition time between Tx and Rx modes

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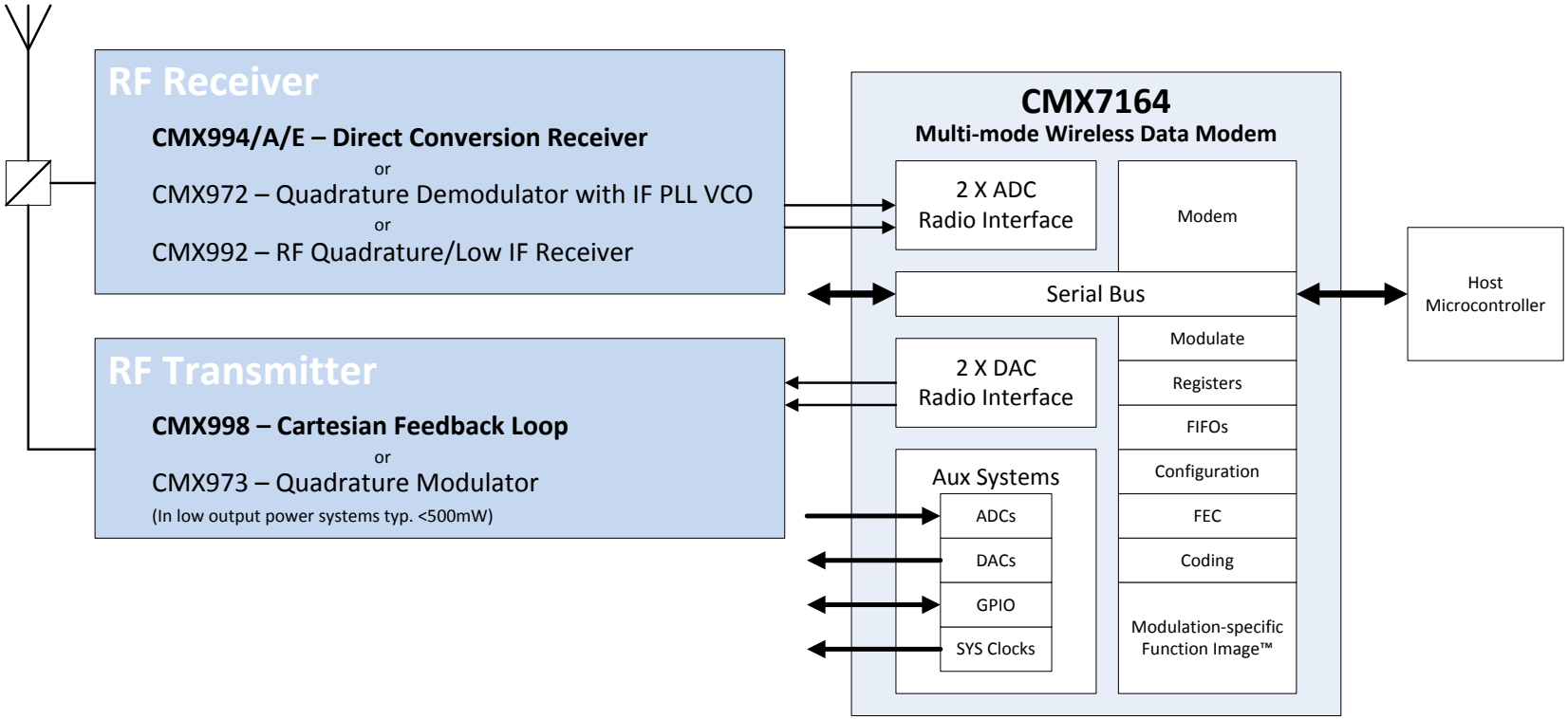
Chip-sets - Linear modulation



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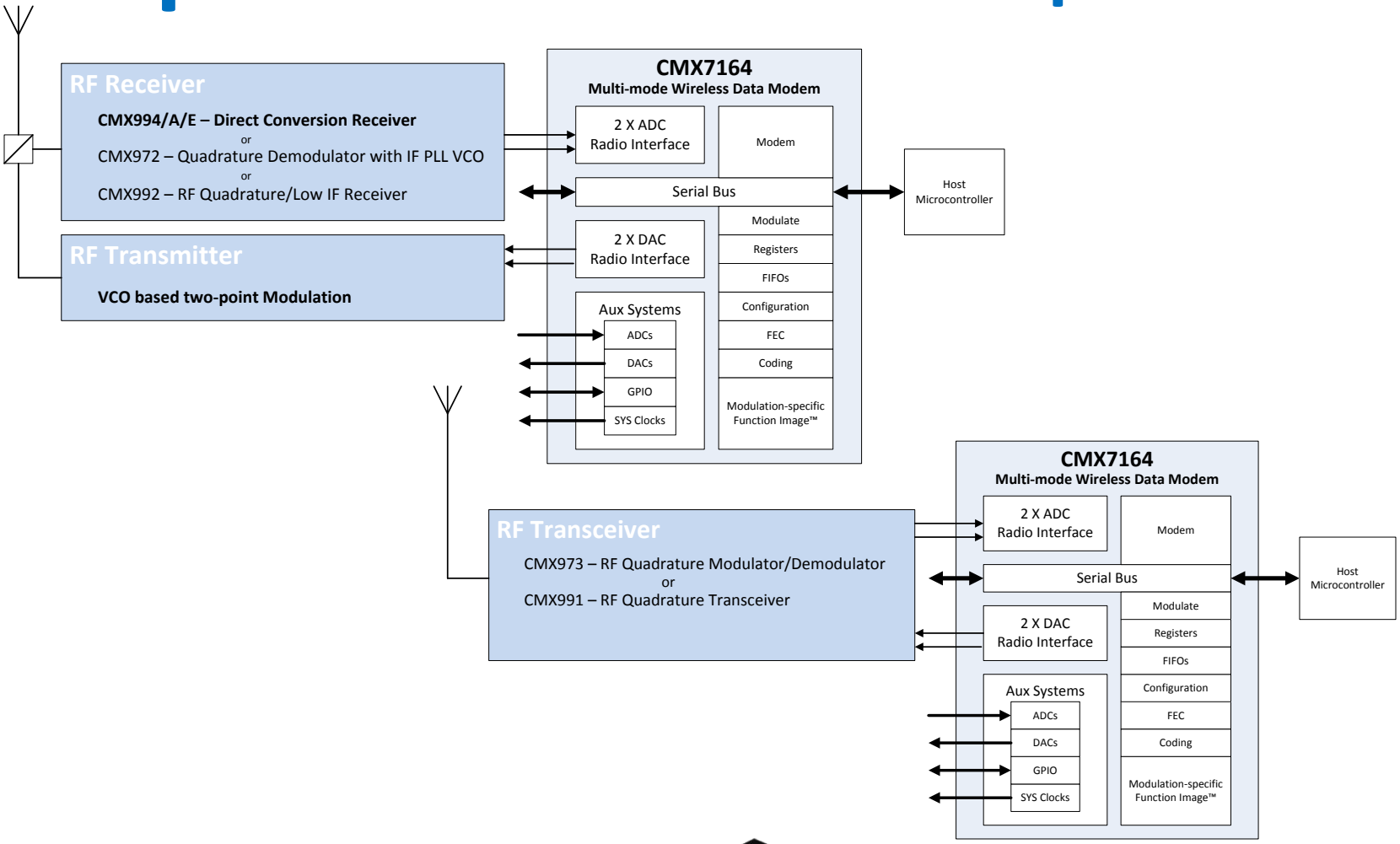
Chip-sets - Constant envelope modulation



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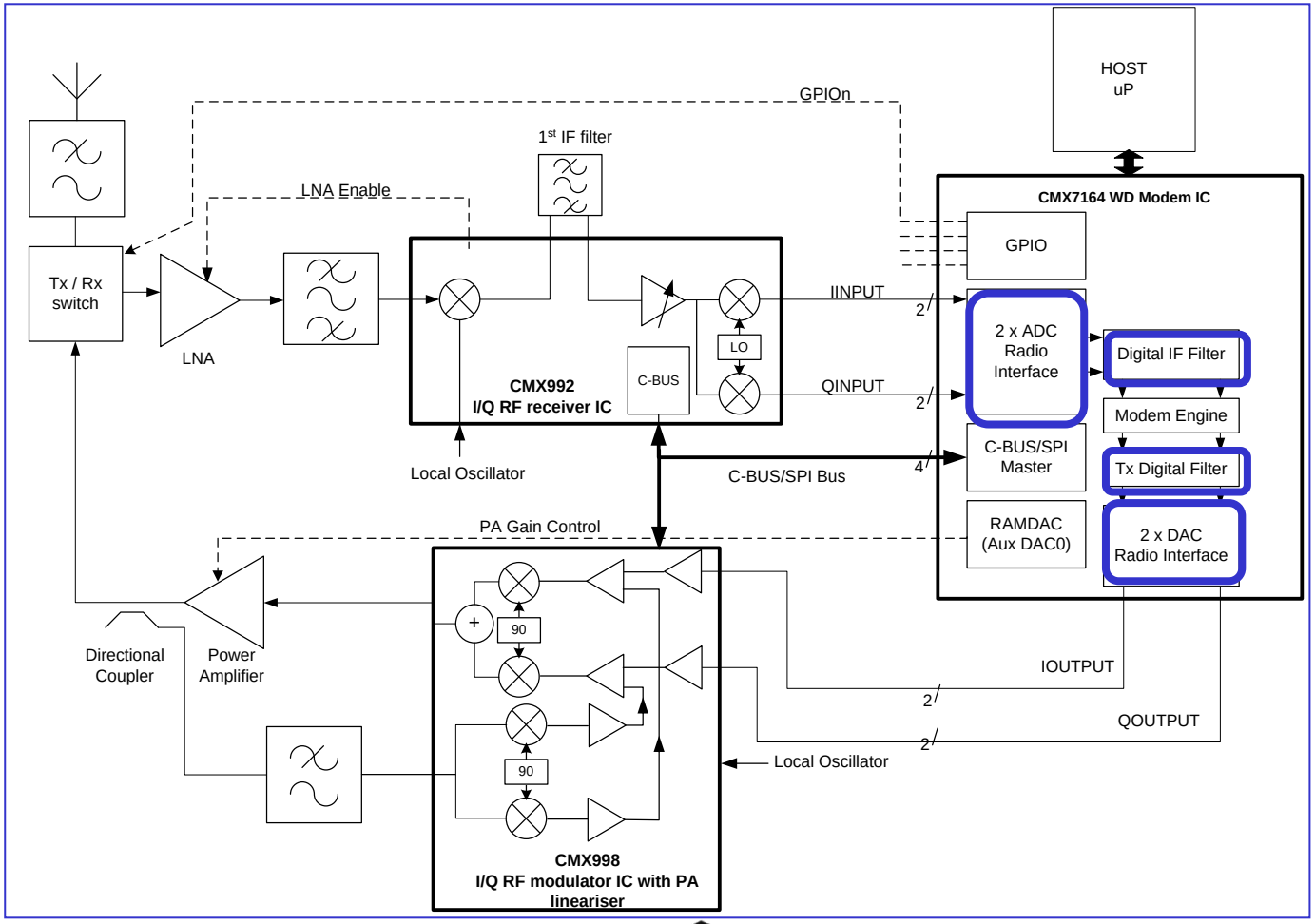
I/Q Radio – CMX992, CMX998



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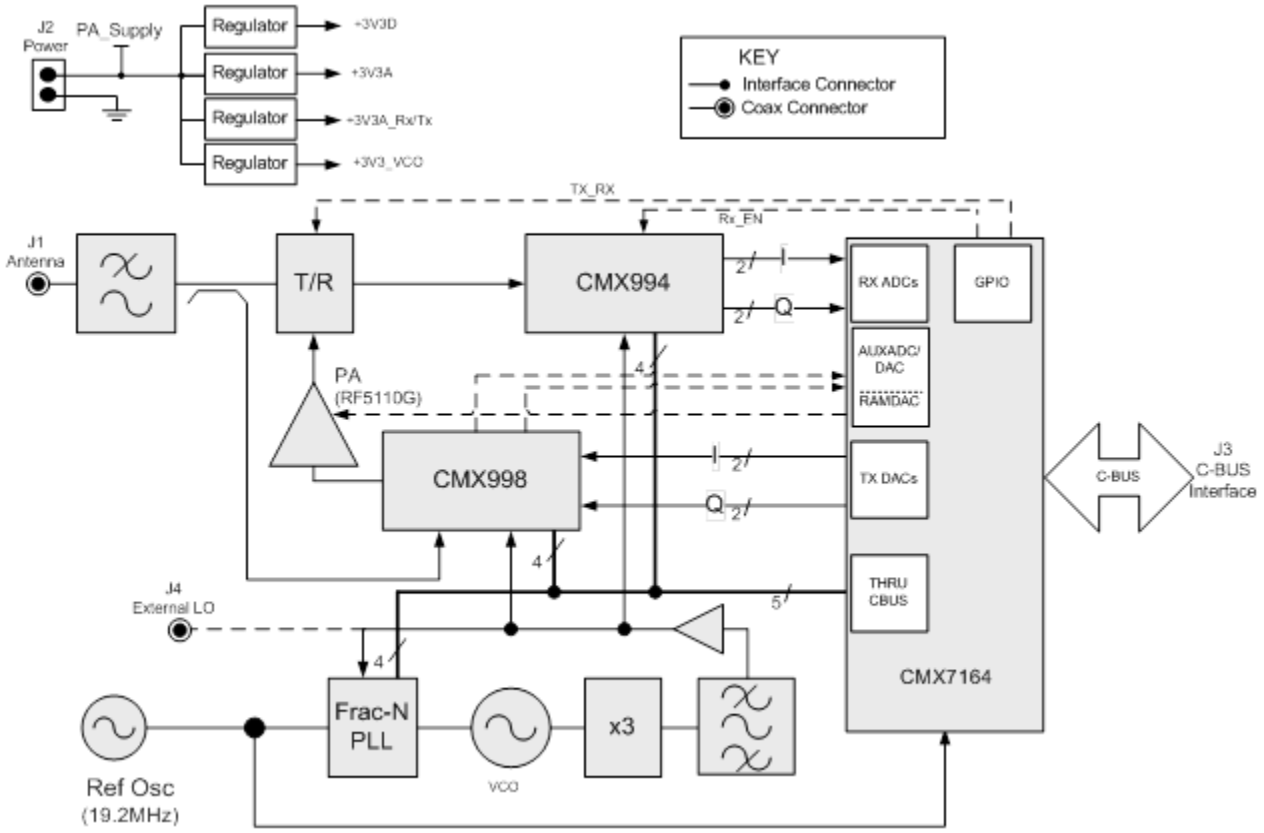
I/Q Radio – CMX994/A/E, CMX998



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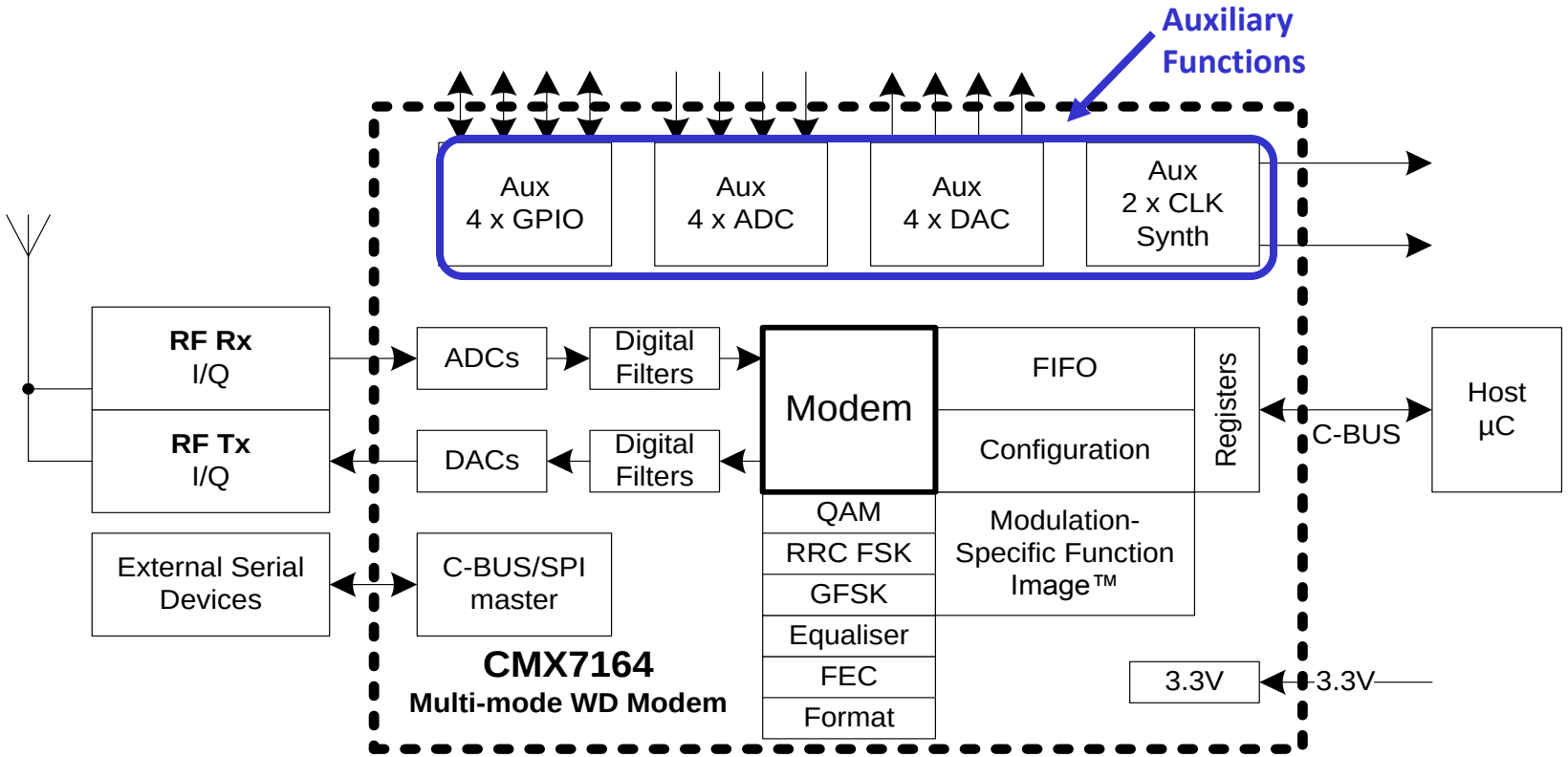
Auxiliary functions



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Auxiliary functions

- End products require auxiliary ADC, DAC and digital I/O functions
- CMX7164 integrates a full suite that minimises total BOM cost and size
- Four Aux 10-bit DACs
  - Autonomous and configurable RAMDAC function develops an attack/decay PA power control signal for ‘smooth’ PA on/off transitions
- Four Aux 10-bit ADCs
  - Configurable averaging and IRQ on configured high/low voltage threshold
  - 6:4 input mux
  - Useful for sampling common external signals e.g. RF detector, temperature sensor, Rx signal level, supply voltage, etc.
- Four GPIO
  - Expands GPIO of host µC
  - CMX7164 sequencing for connected RF circuits e.g. transceiver Tx/Rx switch
- Two system clock generators
  - PLLs develop digital clocks of configurable frequency up to 20MHz

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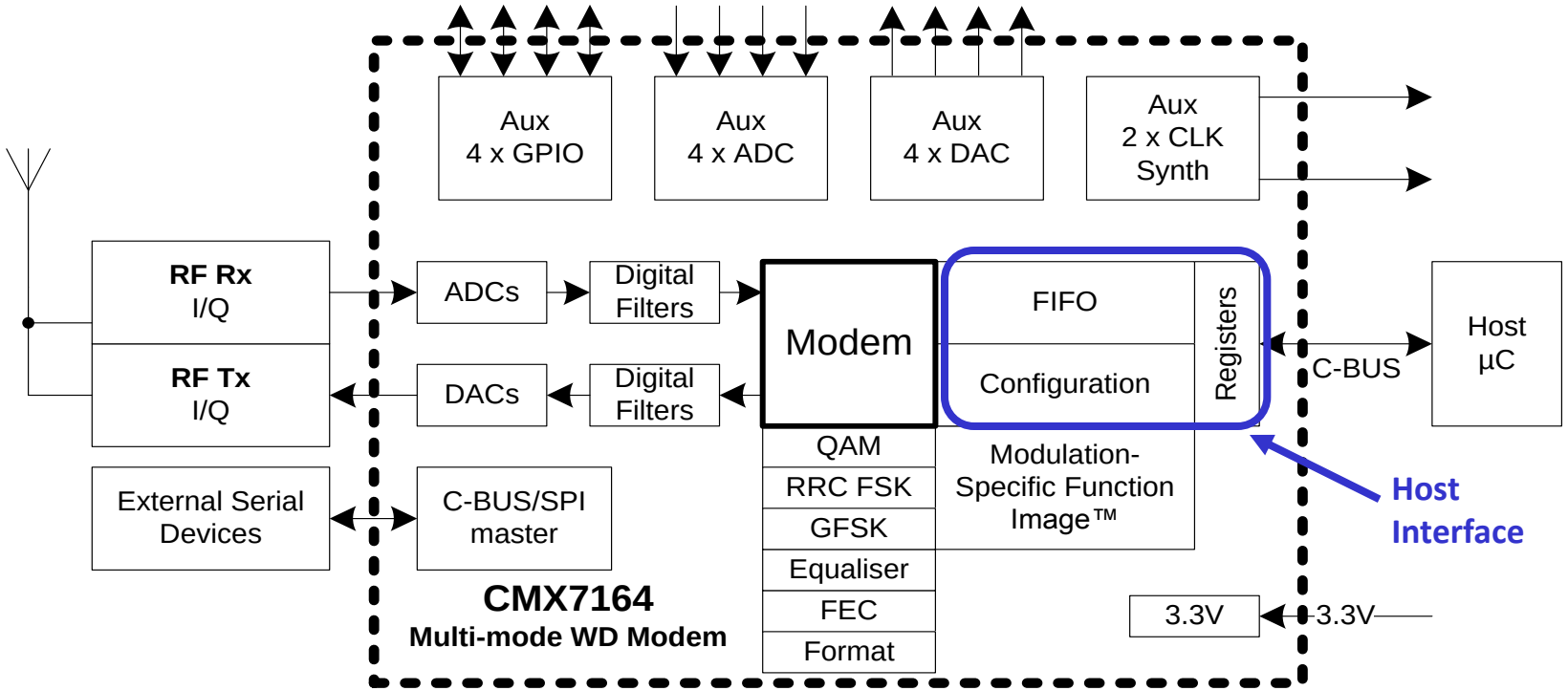
Host interface



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Host interface

- C-BUS serial control interface
  - SPI-like with register addressing
  - For each bus transaction the first ‘Master Out Slave In’ field is a C-BUS command that selects the CMX7164 internal register to be operated upon
  - Small pin count: clock, command data, read data, chip select, IRQ
  - 10MHz clock rate comfortably supports data streams to/from host
- FIFOs
  - Relax host µC interrupt service latency requirements by extending time between host data transfers
  - Reduce host µC interrupt rate by supporting fewer, larger, transfers with host
  - 128 bytes deep on both Tx and Rx
- Streaming C-BUS
  - FIFO registers support multiple reads or writes without repeating C-BUS command
  - Concatenate C-BUS read/write operations without releasing CMX7164 chip select
  - Very efficient FIFO data transfers via low C-BUS transaction overhead
- CMX7164 logical interface provides addressable configuration parameters that ease host driver development

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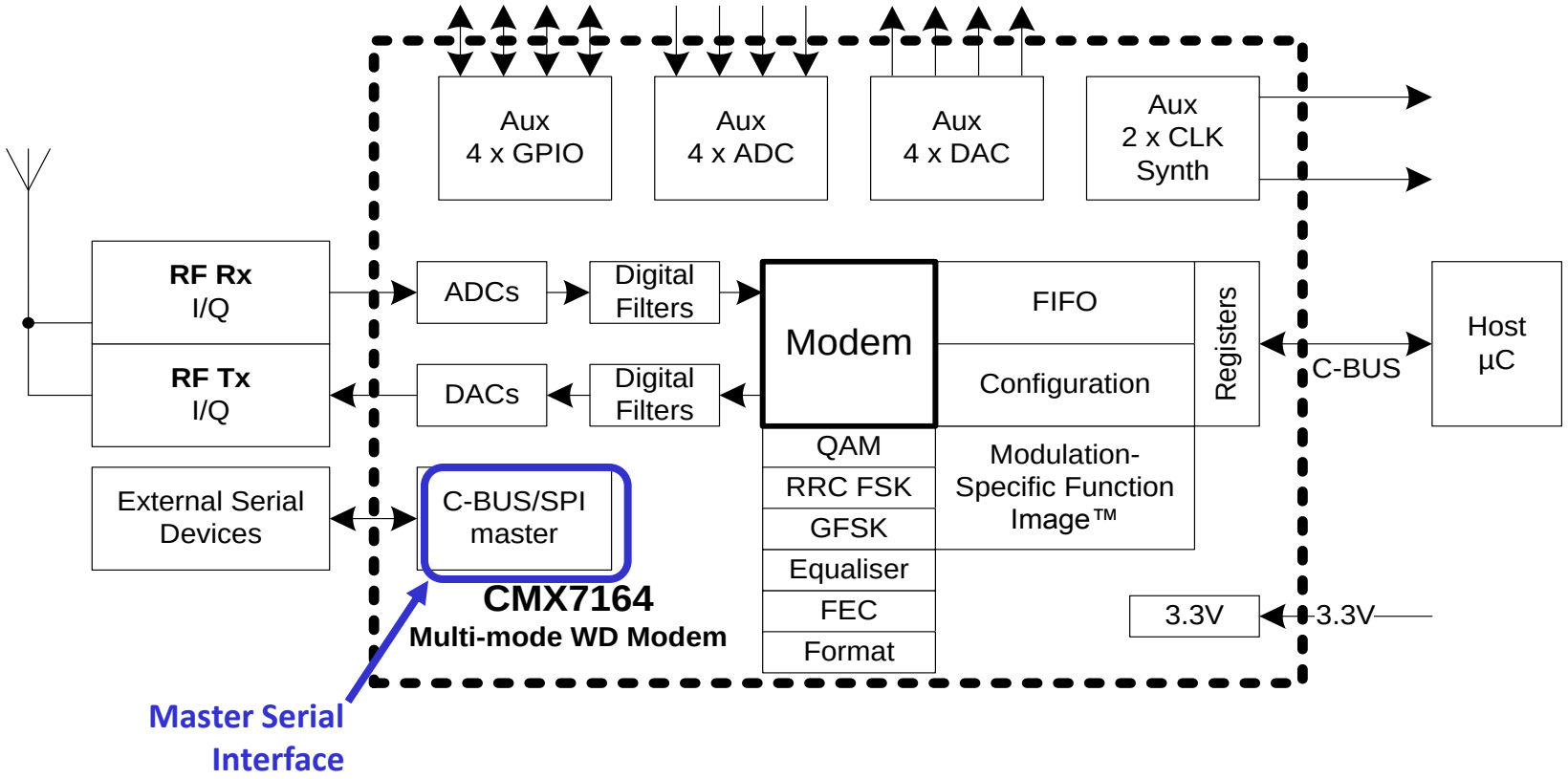
Master serial interface



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Master serial interface

- End products include external RF circuits that work closely with the modem
  - e.g. RF transmitter, RF receiver, LO synthesisers, RF PA, etc.
- C-BUS/SPI Thru port is a master serial interface to efficiently manage connected slaves
- C-BUS/SPI Thru port Talk-through
  - Enables a single host µC serial interface to command both the CMX7164 and external C-BUS/SPI slave devices attached to CMX7164
  - Reduces number of serial interfaces required on host µC
- External RF receiver AGC control
  - I/Q receivers often feature a digitally controlled VGA that must be dynamically managed by the Modem Engine because it directly 'sees' Rx input signal level
  - When so configured, the CMX7164 can autonomously issue C-BUS/SPI commands to adjust external receiver gain according to received signal level

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Modem engine – data pump

- Supports
  - Root raised cosine (RRC) filtered 2/4/8/16-FSK with alpha = 0.2 (can accept custom filter parameters)
  - Gaussian filtered FSK (GFSK and GMSK) with BT = 0.25, 0.27, 0.3 and 0.5 (can accept custom filter parameters)
  - 4/16/32/64-QAM, with RRC filter with alpha=0.2 and 0.35
- Popular legacy narrowband modulations
  - RRC FSK and GFSK/GMSK modulations are established and have been used in a wide range of systems, worldwide
  - New terminal designs require support for both legacy modulations and newer, more spectrally efficient ones
- CMX7164 supports both QAM (higher speed) and legacy modulations
  - Change modulation 'family' by swapping Function Image™ in <0.5s
  - Smooth terminal design migration by supporting new and legacy modulations in a single design
- No external deviation trims required

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Modem engine – data pump

- Over air signals are a sequence of specific analogue symbols i.e. waveform segments specific to a configured modulation type
- Tx data pump converts binary input data to 'I/Q form' symbols and Rx data pump recovers binary data from 'I/Q form' symbols
- GMSK/GFSK 2FSK and RRC (root raised cosine) 2/4/8/16-FSK are constant envelope so every symbol is transmitted at same RF power
- Different modulation types carry different numbers of bits per symbol (sym)
  - GFSK/GMSK = 1 bit/sym
  - Multi-level FSK
    - 2-FSK = 1 bits/sym
    - 4-FSK = 2 bits/sym
    - 8-FSK = 3 bits/sym
    - 16-FSK = 4 bits/sym
  - QAM
    - 4-QAM = 2 bits/sym
    - 16-QAM = 4 bits/sym
    - 32-QAM = 5 bits/sym
    - 64-QAM = 6 bits/sym

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Unique selling points

- Complete modem baseband system in a small VQFN/LQFP package
- Multiple modulation suites deliver QAM speed and legacy backward compatibility
  - High performance, high spectral efficiency 4/16/32/64-QAM
  - High performance, Constant envelope modulation 2/4/8/16-FSK
  - Gaussian filtered FSK (e.g. GMSK) modulations
  - Telecom modem interconnect V.23
- Small wireless data modem size
  I/Q RF transceiver + CMX7164 + host µC = core of end product
- DSP-free and codec-free design path
  - Single chip baseband modem
  - Soft selectable modulation, symbol rate and FEC suite
  - Software defined radio benefits without the DIY hassle
  - Short time to market
  - Low risk
  - Low cost solution
  - Low power consumption
- *FirmASIC* ® technology enables modulation type swapping and feature evolution
- Combine with high performance CML I/Q RF transmitter, receiver and transceiver devices for smallest, most cost effective total design
  - CMX998 CFBL I/Q modulator linearises external RF PA with high power efficiency
  - CMX994/A/E Direct Conversion Receivers (DCRx ICs) or CMX992/CMX972 dual superhet I/Q RF receive2

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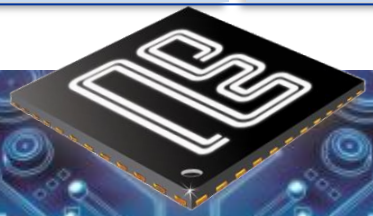
CMX7164 Multi-mode Wireless Data modem

Function Image™ availability

	GMSK/GFSK Packet Data Modem	QAM Packet Data modem	Multi-level FSK Packet Data modem	V.23 Modem
Function Image™	7164FI-1.x.x.x	7164FI-4.x.x.x	7164FI-2.x.x.x	7164FI-6.x.x.x
Basic Configuration	**Half duplex operation** *Differential analogue input and output drivers*			
Modulation Schemes	**GMSK/GFSK** 2,000 to 20,000 symbols/s	**4/16/32/64-QAM** 2, 4 and 6 symbols 2,000 to 20,000 symbols/s	**2/4/8/16-FSK** 1, 2, 4 and 6 symbols 2,000 to 10,000 symbols/s	**V.23** 1200bps
Core Systems	• Up to 16kbps in 25KHz • BT=0.5, 0.3, 0.27 or 0.25 • Flexible packet data protocol • Over-air compatible with FX/MX909B and CMX7143FI-1.x • Two frame sync detectors • Automatic frame sync detect • Rx carrier frequency correction • Receive signal quality metrics	• Up to ~96kbps in 25kHz • ACM features • Flexible packet data protocol • Rate, and robust FEC choices • Channel equalisation • Two frame sync detectors • Automatic frame sync detect • Rx carrier frequency and phase correction • Receive signal quality metrics	• Up to 40kbps in 25 kHz • Flexible packet data protocol • Over-air compatibility with CMX969 for RD-LAP, CMX7143, FX/MX919B 4-FSK (not 2-FSK) • Two frame sync detectors • Automatic frame sync detect • Rx carrier frequency correction • Receive signal quality metrics	• 1200bps • V.23 modulation • Two frame sync detectors • Automatic frame sync detection • Rx carrier frequency detection
ACM Adaptive Coded Modulation		Yes		
Interface	C-BUS serial interface to host microcontroller, SPI master serial interface for external device support			
Auxiliary Systems	Four input 10-bit ADC, Four 10-bit DACs, Master clock PLL, Two system clock outputs, Four GPIO			

Custom Function Images



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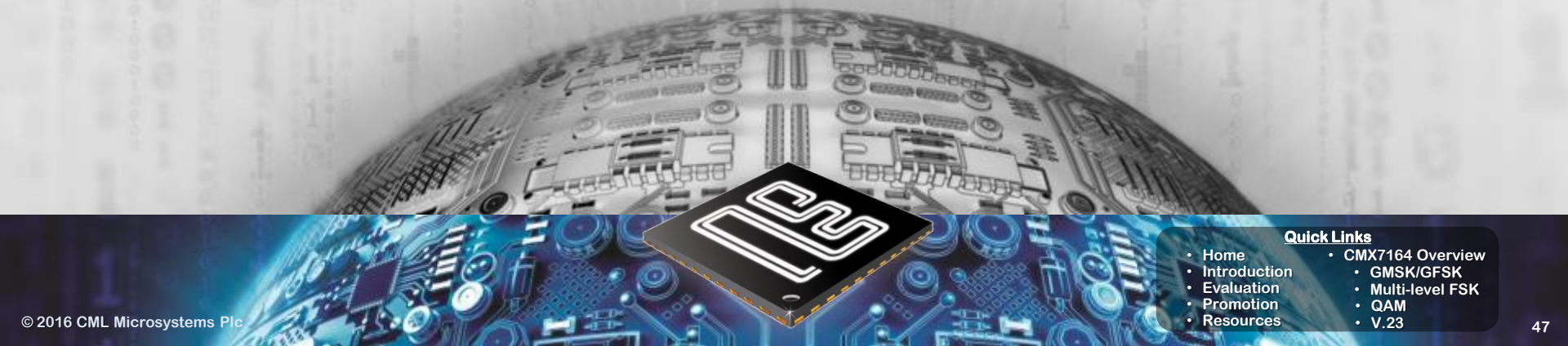
QAM - Modulation

4-QAM, 16-QAM, 32-QAM and 64-QAM

Function Image™ 7164FI-4.x



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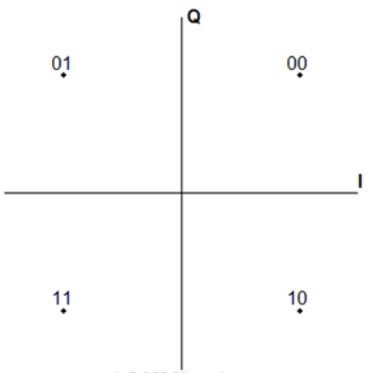
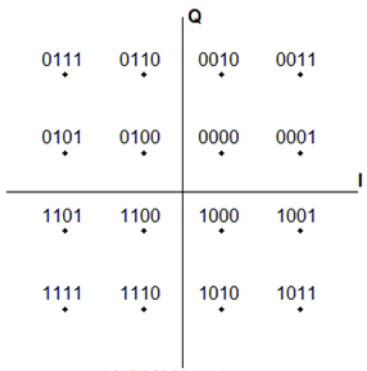
Modem engine – QAM

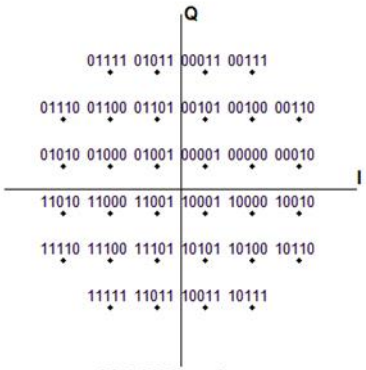
- Function Image™ 7164FI-4. x and 7163FI-4.x
- Modulation using an analogue symbol ‘alphabet’ that represents bits by setting RF carrier phase (angle) and amplitude at one point in time, the symbol sample time
- Yields a constellation of phase and amplitude points e.g. 4-QAM sets phase to 45, 135, 225 or 315 degrees and amplitude of ‘1’ (only at the sample time)



4-QAM Mapping



16-QAM Mapping



32-QAM Mapping

64-QAM Mapping

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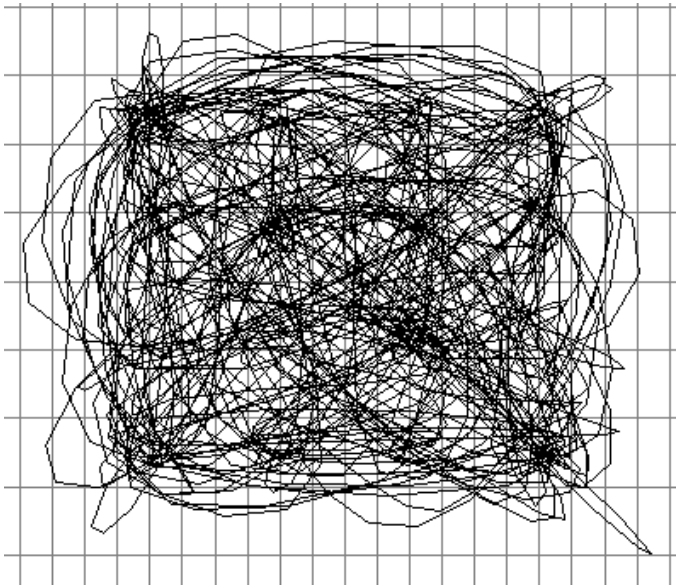
Modem engine – QAM

- In real time, the signal transitions between constellation points as the transmitted symbol changes
- The modulation signal is RRC filtered to reduce modulation bandwidth, so real QAM signals look quite different than QAM constellation diagrams



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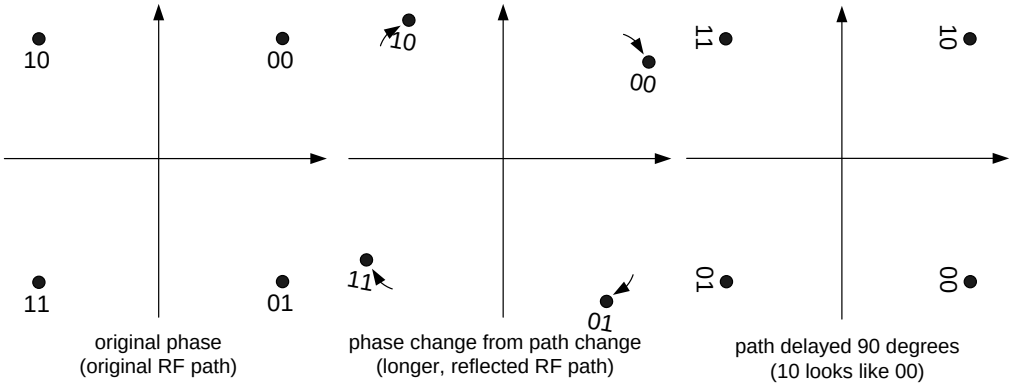
Modem engine – QAM

- Phase is not absolute; it is always relative to what the signal was previously. Changes in the RF path and/or relative frequency errors between transmitter and receiver cause ‘error’ changes in received signal phase, unrelated to the symbols transmitted. Amplitude also changes with path changes (not shown).



- Automatic CMX7164 receive demodulator corrections
  - I/Q receiver dc offset error
  - Relative carrier (e.g. LO) frequency error
  - Channel equalisation for phase and amplitude changes

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Modem engine – QAM

- At same symbol rate, 4/16/32/64-QAM modulations have same bandwidth
  - Simplifies changing QAM type to adjust to changes in channel (RF path) quality
- Configurable symbol rate sets bit rate and determines modulation bandwidth
  - Net raw bit rate = over air rate 'diluted' by 16/18 for equalisation overhead
  - Depending on regulations ~17ksym/sec fits in '25kHz' channel

QAM Variant	Bits per Symbol	Base Over-air Bit Rate (18ksymbols/s)	Raw Mode Over-air Bit Rate (18ksymbols/s)
4-QAM	2	36kbps	32kbps
16-QAM	4	72kbps	64kbps
32-QAM	5	90kbps	80kbps
64-QAM	6	108kbps	96kbps

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Modem engine – Formatting

- Formatted block types support simple design of useful packet structures
- The CMX7164 performs all formatting and ‘de-formatting’ so the host need only select which formats are used
- Typical over air packet field structure, in chronological order left to right

Symbol sync (preamble)	Frame sync	Header block	Intermediate block [0 or more]	Last block

- Formatted blocks include CRC functions for error detection
  - Enables data error check after any error correction has been performed
  - CRC size varies with field and modulation type
  - For QAM and RRC the CRC can span multiple blocks to suit a given application
- Other packet structures constructed from Header, Intermediate and Last blocks are also supported for user flexibility. Three examples:

Symbol sync (preamble)	Frame sync	Header block(s) [1 or more]

Symbol sync (preamble)	Frame sync	Intermed. block(s) [1 or more]

Symbol sync (preamble)	Frame sync	Intermed. block(s) [1 or more]	Last block

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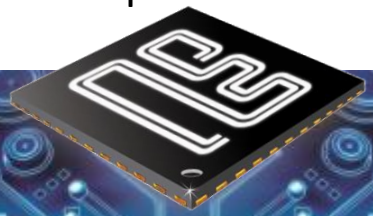
Modem engine – enhanced FEC

- Formatted blocks also include enhanced forward error correction (FEC) to trade off overhead vs. robustness
  - Corrects errors in Rx bits
  - Extends link range with tradeoff of lower link throughput
  - Raw mode (no FEC) is also provided
- FEC, block formatting and CRC are all processed by the CMX7164, without burdening the host
- Each modulation type includes one or more FEC block types that set detailed structure of Header, Intermediate and Last formatted blocks
- QAM provides choice of 12 predefined or up to 48 user defined formatted block types that determine code rate and size of the associated formatted block
- Code rate is the FEC overhead factor that relates net raw bit rate to throughput bit rate after taking FEC code overhead into account
  - Net raw bit rate x code rate = throughput bit rate
  - A code rate of 0.75 means 75% of an FEC coded block's net over air data is host data and the remaining 25% of the over air data is FEC overhead
- For same code rate, larger block size is generally more robust
- User can select the best code for specific needs and link conditions



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Modem engine – QAM, predefined FEC

FEC Block Type	Block Size (bytes)	Code Rate		Formatted Block Size ([n] means # of CRC bytes)		
		4- & 16-QAM	64-QAM	Header	Intermed.	Last
0	15	0.75	0.83	13[2]	15	11[4]
1	60	0.75	0.83	58[2]	60	56[4]
2	33	0.55	0.61	31[2]	33	29[4]
3	37	0.62	0.69	35[2]	37	33[4]
4	44	0.55	0.61	42[2]	44	40[4]
5	176	0.55	0.61	174[2]	176	172[4]
6	73	0.52	0.58	71[2]	73	69[4]
7	292	0.52	0.58	290[2]	292	288[4]
8	88	0.55	0.61	86[2]	88	84[4]
9	352	0.55	0.61	350[2]	352	348[4]
10	104	0.65	0.72	102[2]	104	100[4]
11	416	0.65	0.72	414[2]	416	412[4]

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QAM Performance – predefined formatted blocks

- Performance for 18ksym/s operation was measured with an example receiver
- Depending on specific regulations 18ksym/s roughly fits in a 25kHz channel
- Lower symbol rates would be more robust and reduce error rates
- Signal levels are for mean power
- Results for raw (no FEC) and FEC predefined formatted block types 0, 6 and 7 are shown as examples of none, weak and strong codes. Other FEC formatted block types are provided. (Types 6 and 7 are of same rate but 7 uses a larger block size and is relatively more robust in a fade.)

	Code Rate			
FEC Block Type	**4- & 16-QAM**	**64-QAM**	**Size of Block (bytes)**	**Notes**
0	0.75	0.83	15	Least robust rate
6	0.52	0.58	73	Most robust rate
7	0.52	0.58	292	Most robust rate

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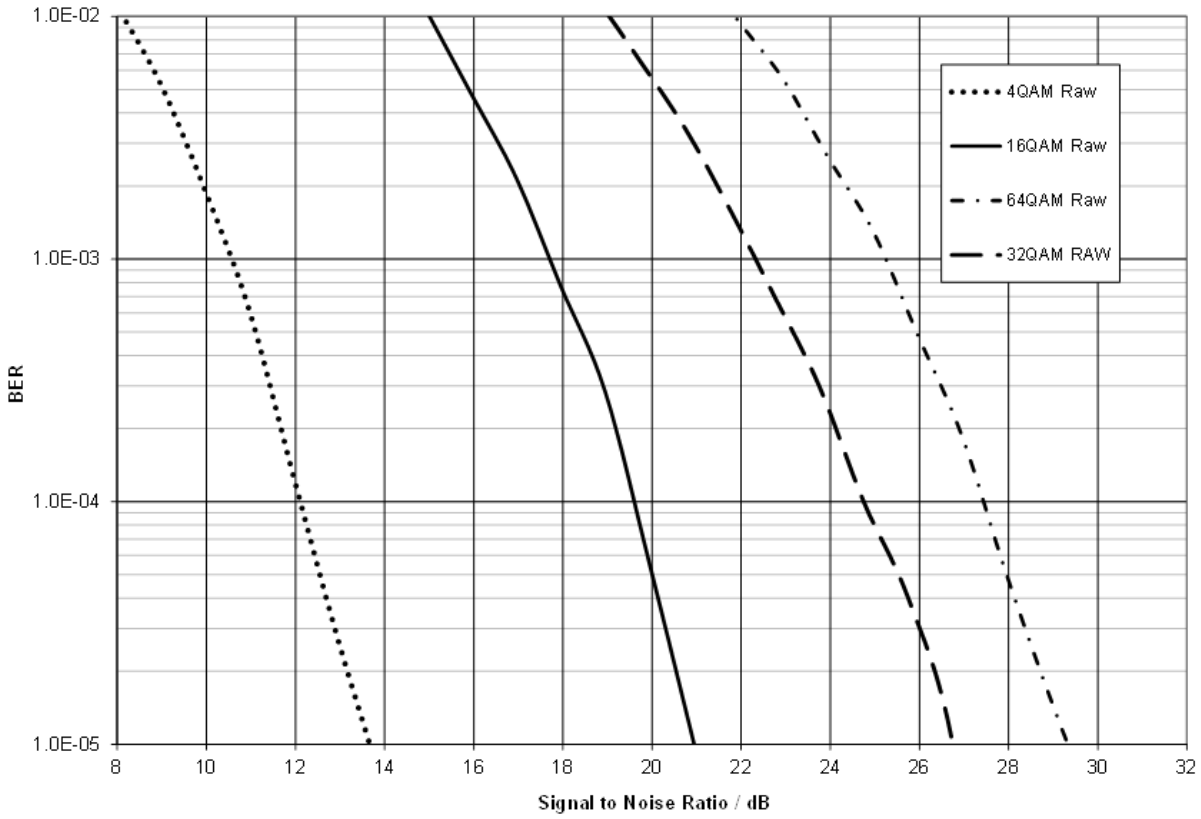
Performance Sensitivity @ 18ksym/sec



BER (bit error rate) vs. SNR curves are commonly used to indicate modem performance. As SNR declines so does signal quality thus BER (bit error rate) increases, which is normal and expected.

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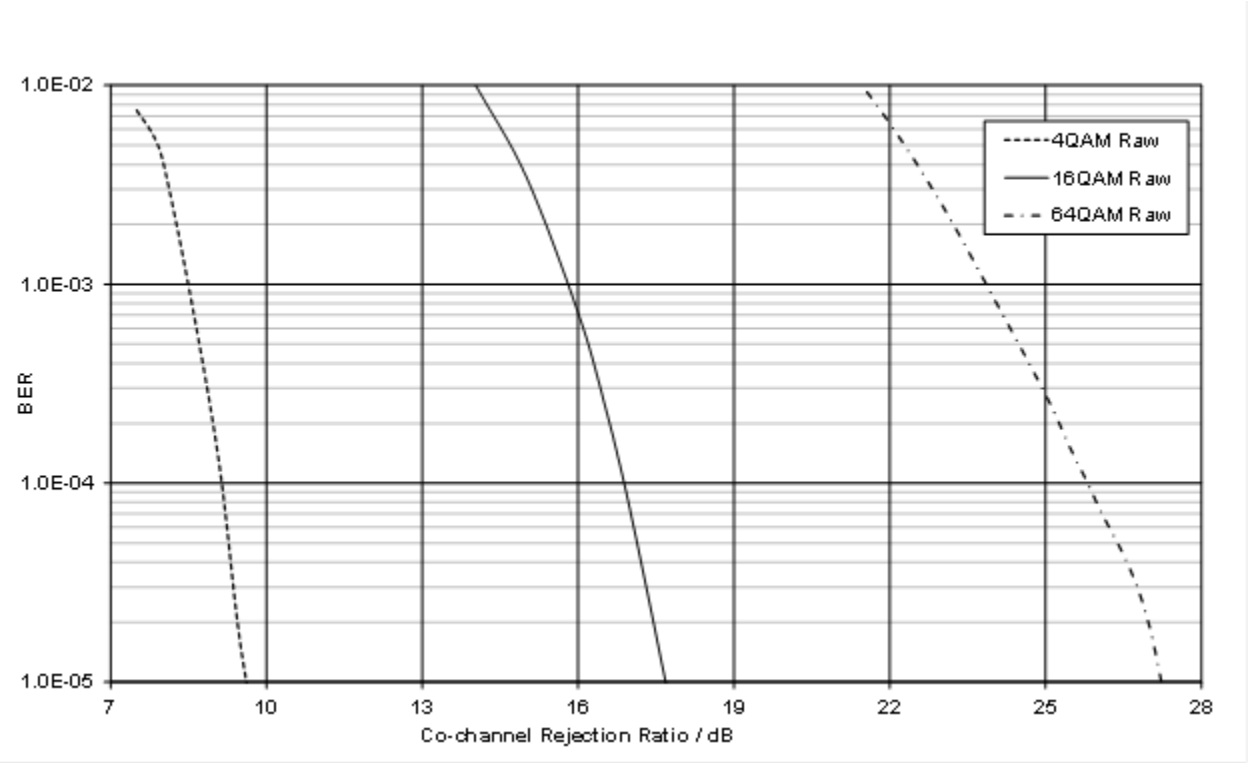
Performance Co-channel rejection ratio



Method based on ETSI EN 300 113 using 400Hz @ 3kHz deviation FM interferer but measured 20dB above sensitivity to resolve CMX7164 device performance independent of thermal noise.

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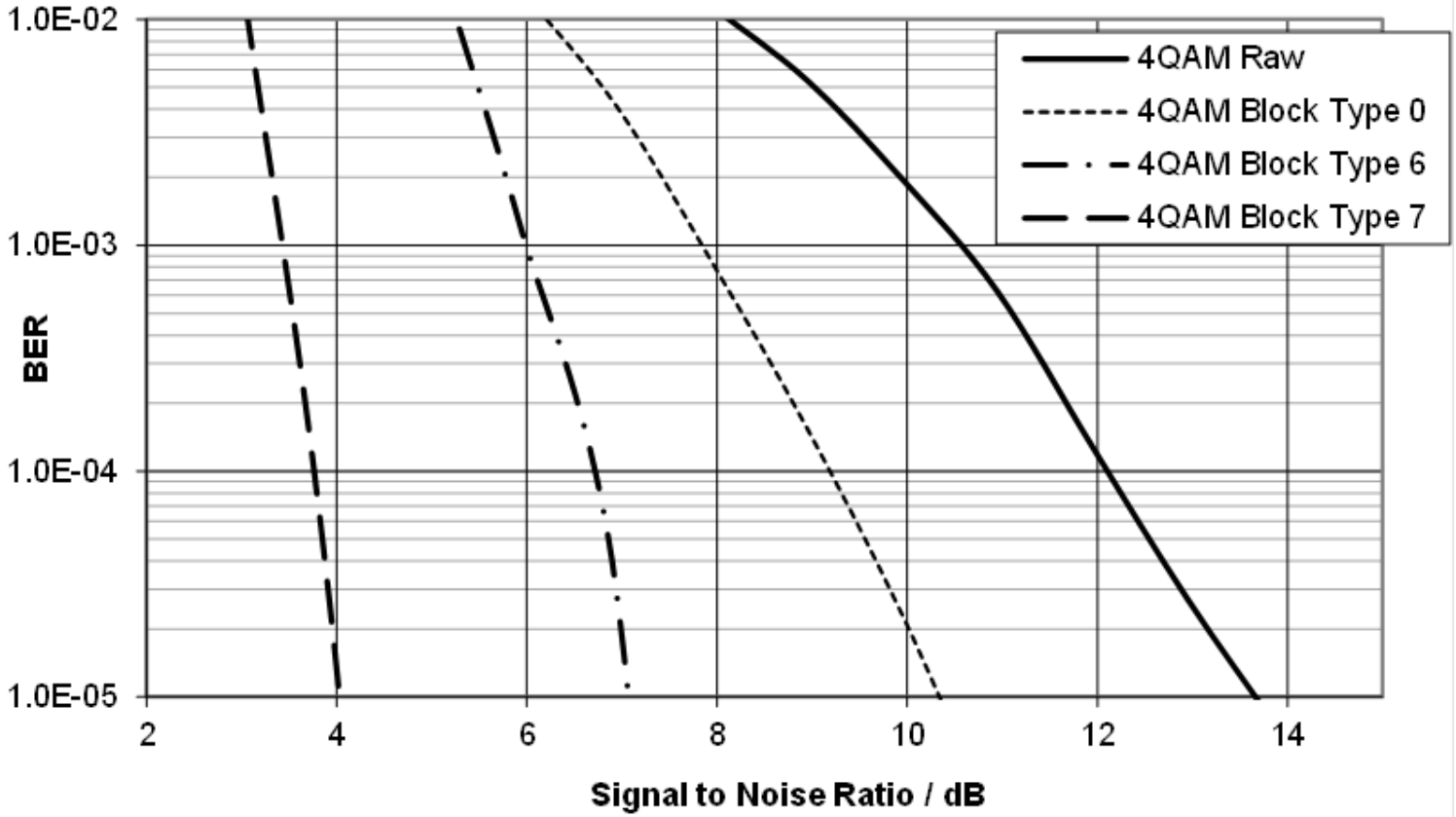
Performance 4-QAM w/wo FEC



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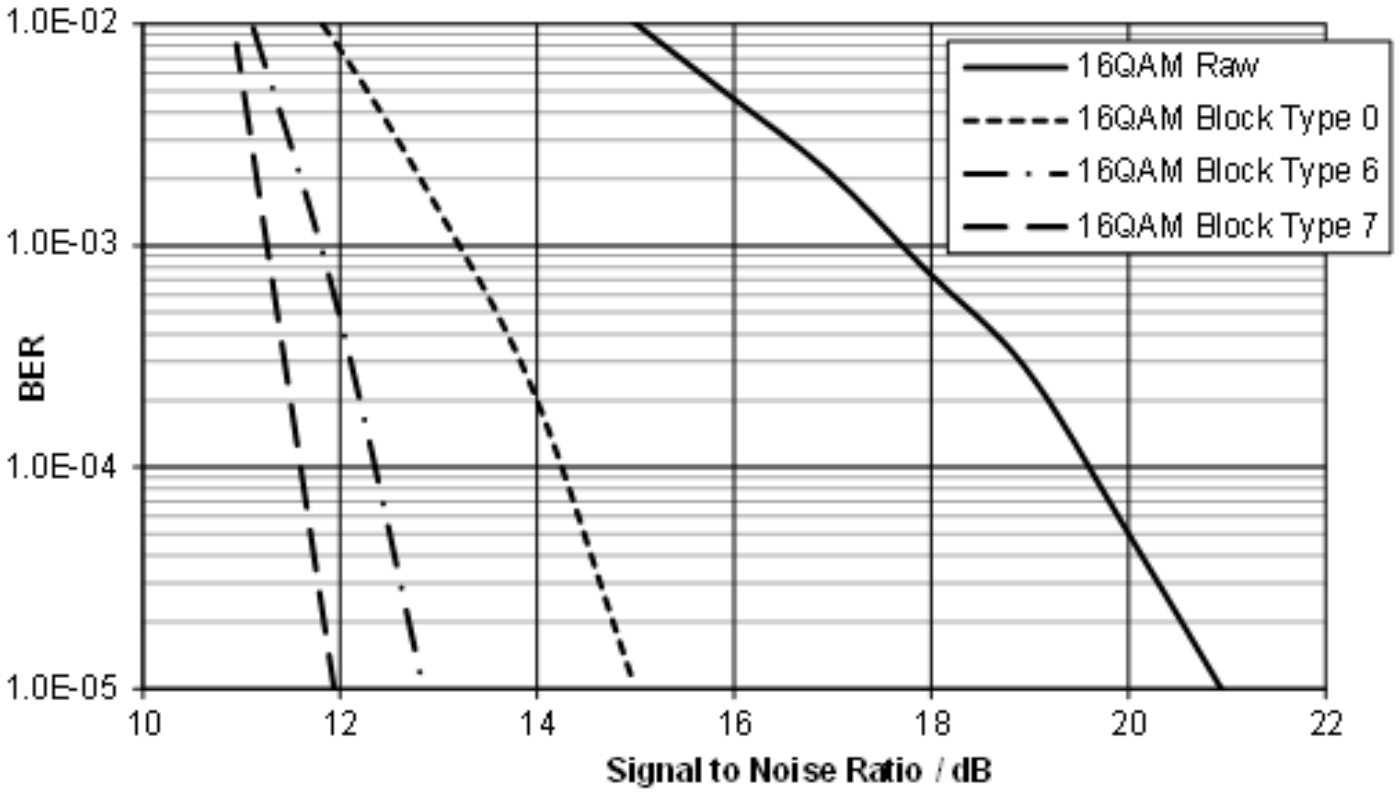
Performance 16-QAM w/wo FEC



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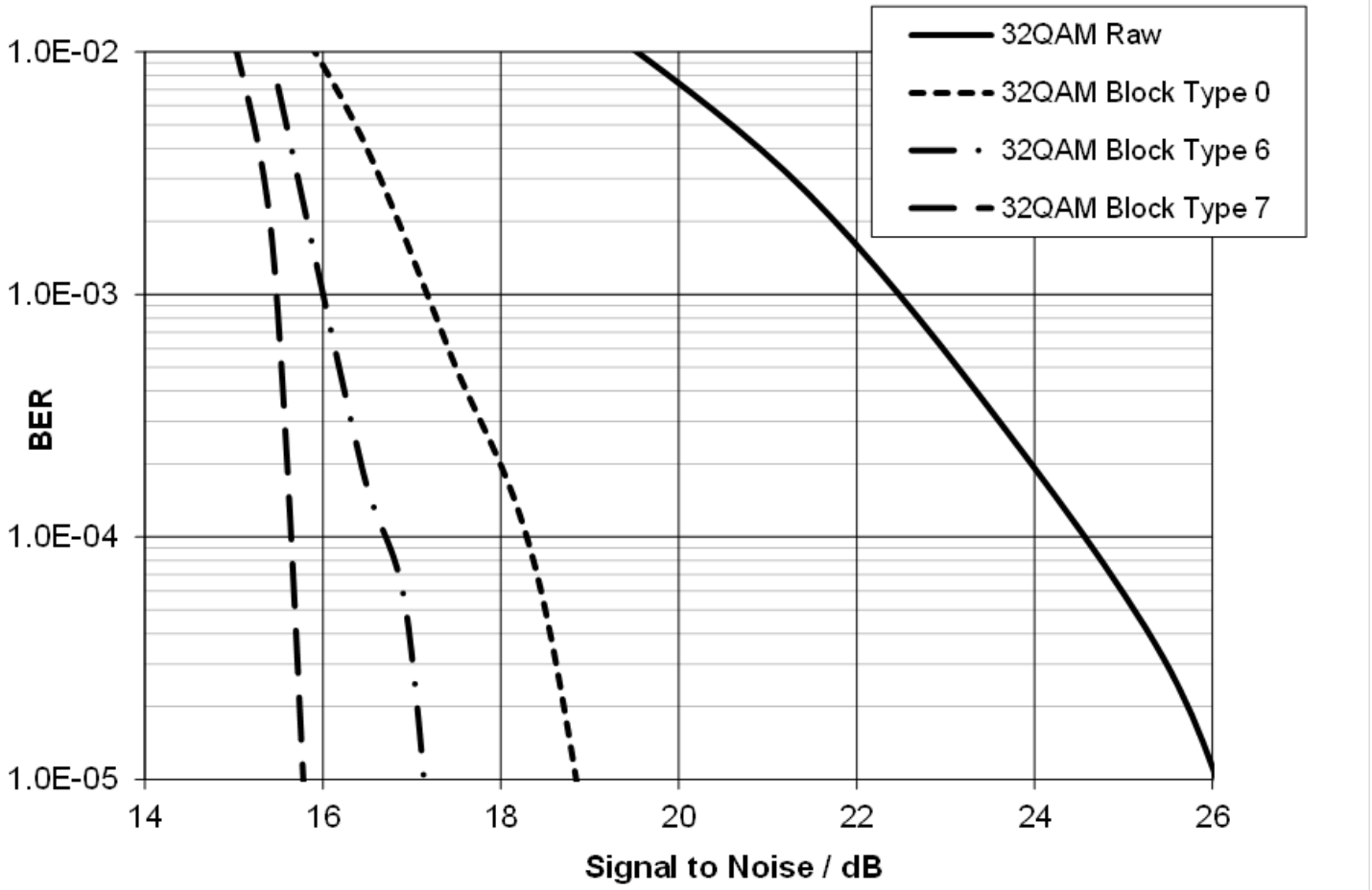
Performance 32-QAM w/wo FEC



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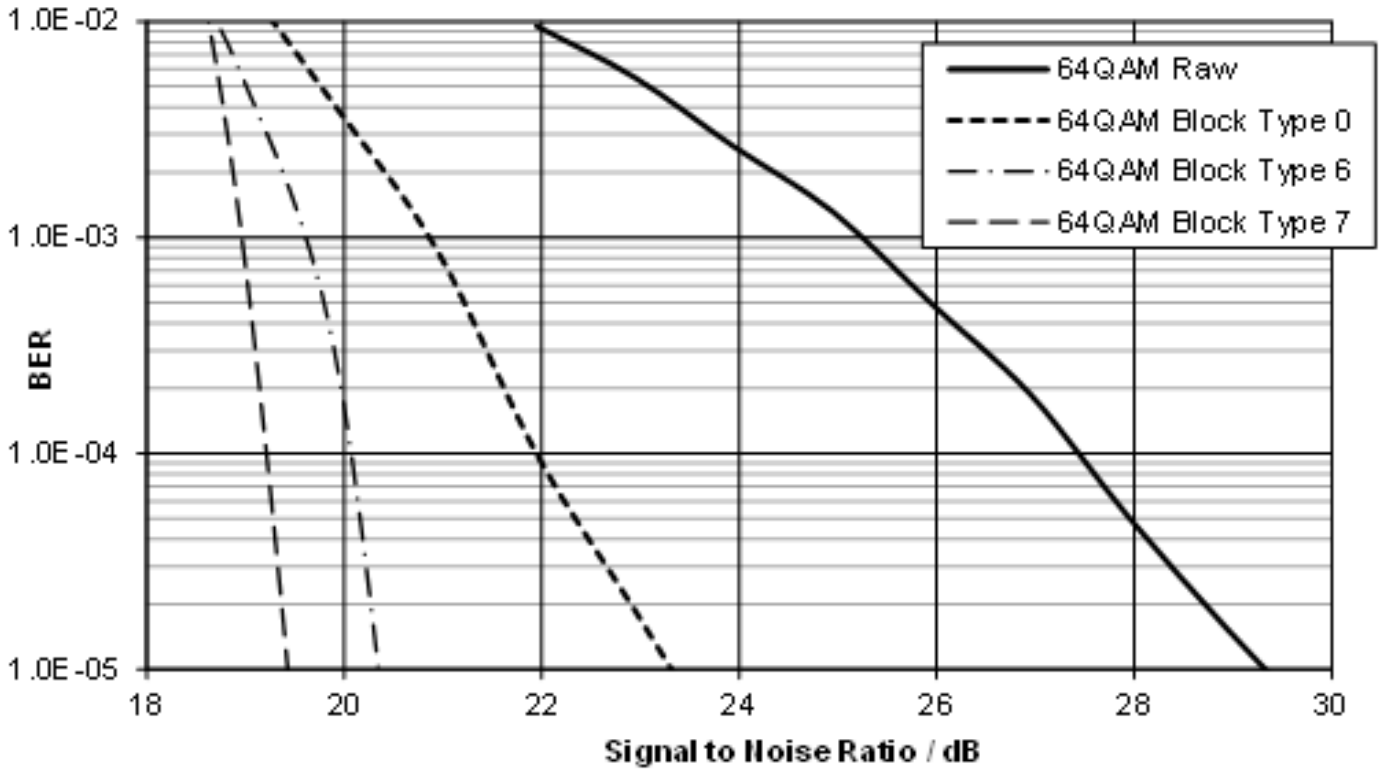
Performance 64-QAM w/wo FEC



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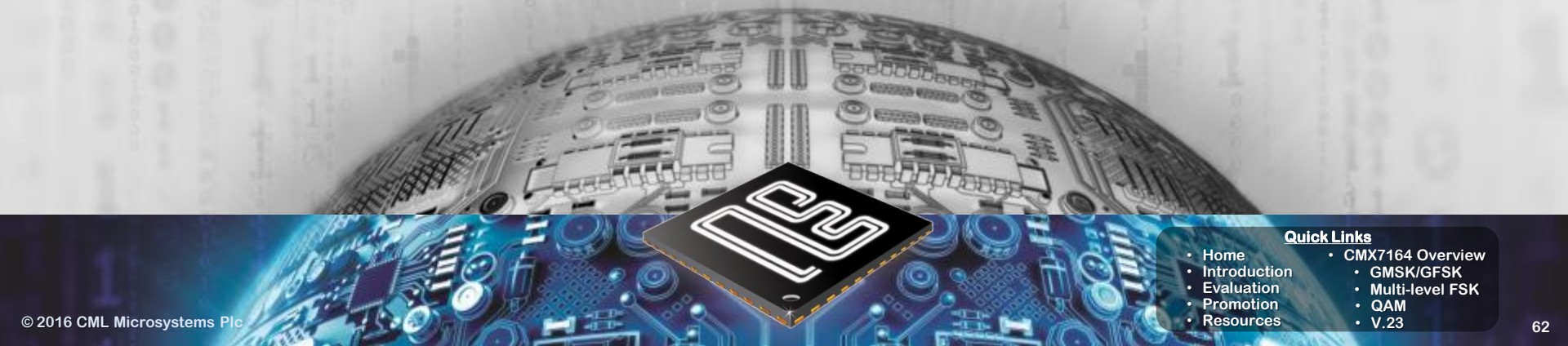
GMSK/GFSK - Modulation

Function Image™ 7164FI-1.x



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GMSK/GFSK Modem

- Function Image™ 7164FI-1.x
- Constant envelope modulation (no requirement for PA linearisation)
- Robust modulation supporting up to 20kbps
- Raw data mode
- Packet data modes
- Flexible frame structure
- Complete Tx/Rx filtering
- ‘Air compatible’ with CMX909B

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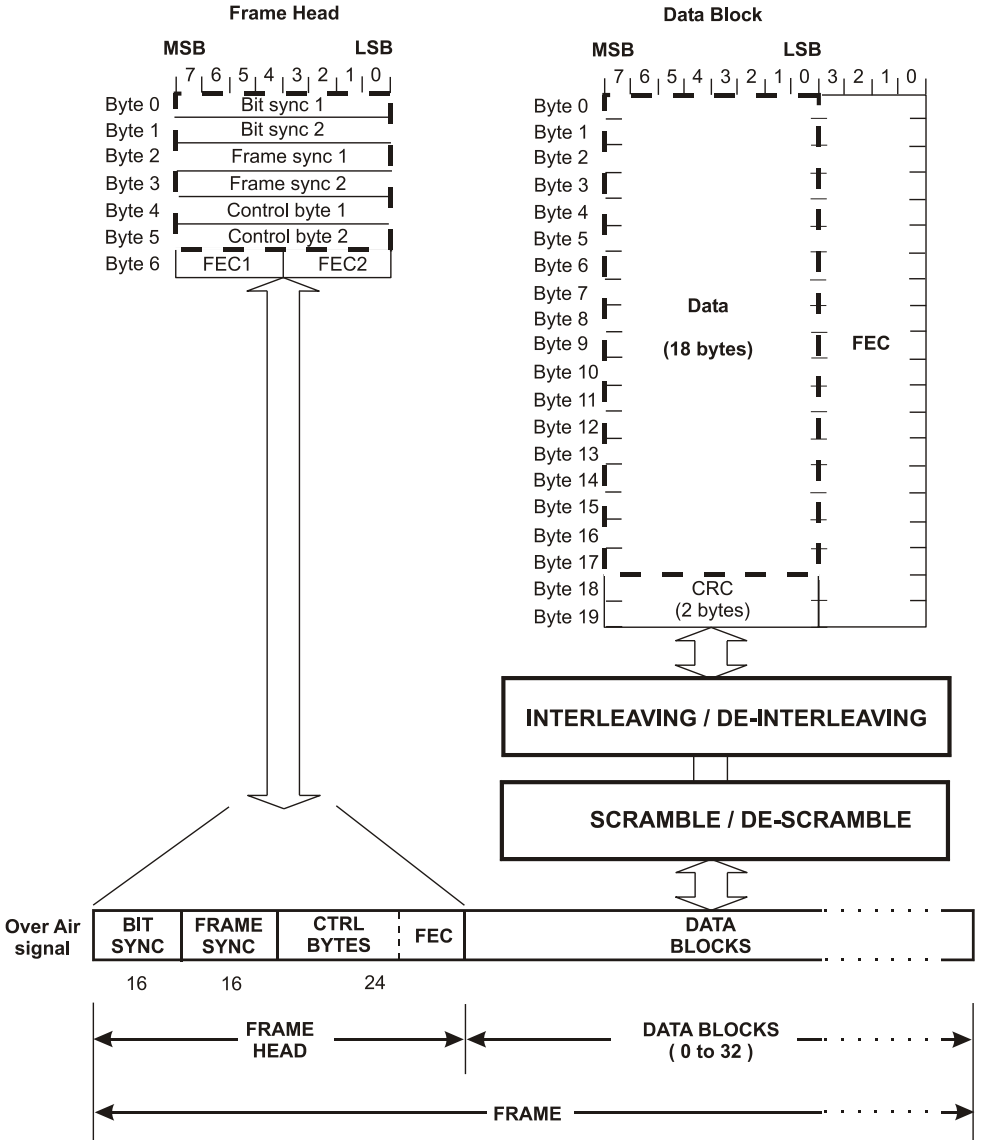
GMSK/GFSK data coding



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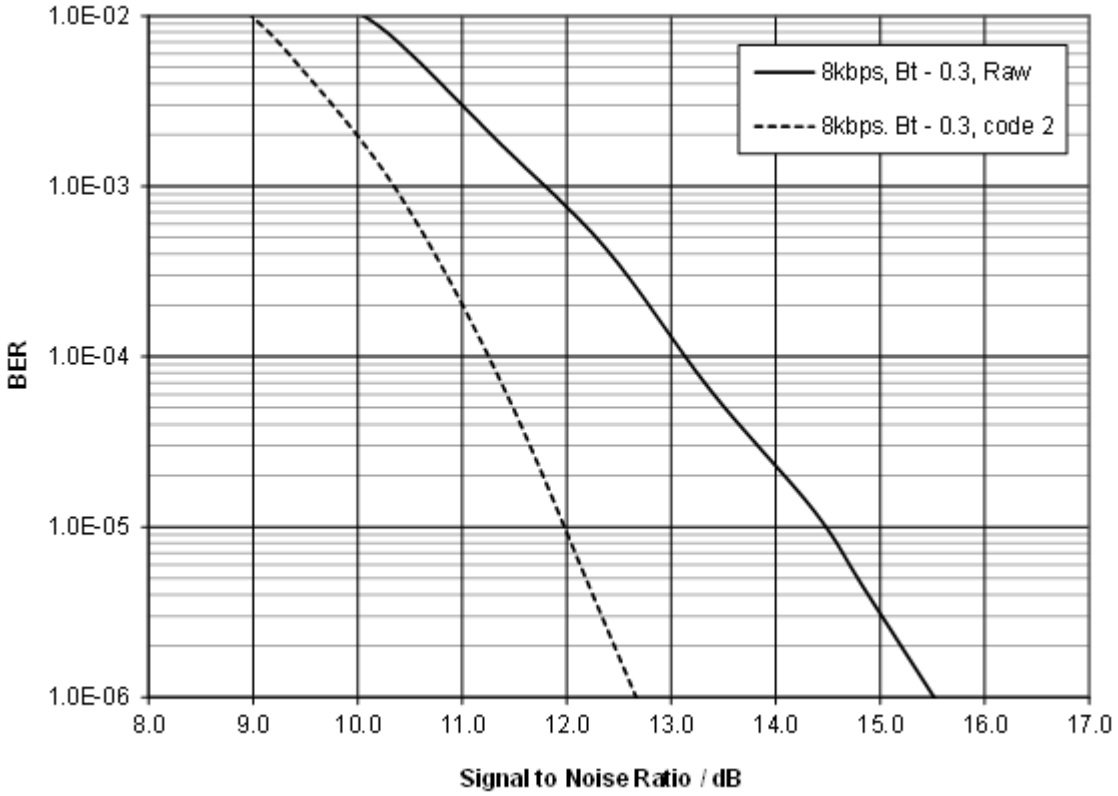
Performance GMSK/GFSK w/wo FEC



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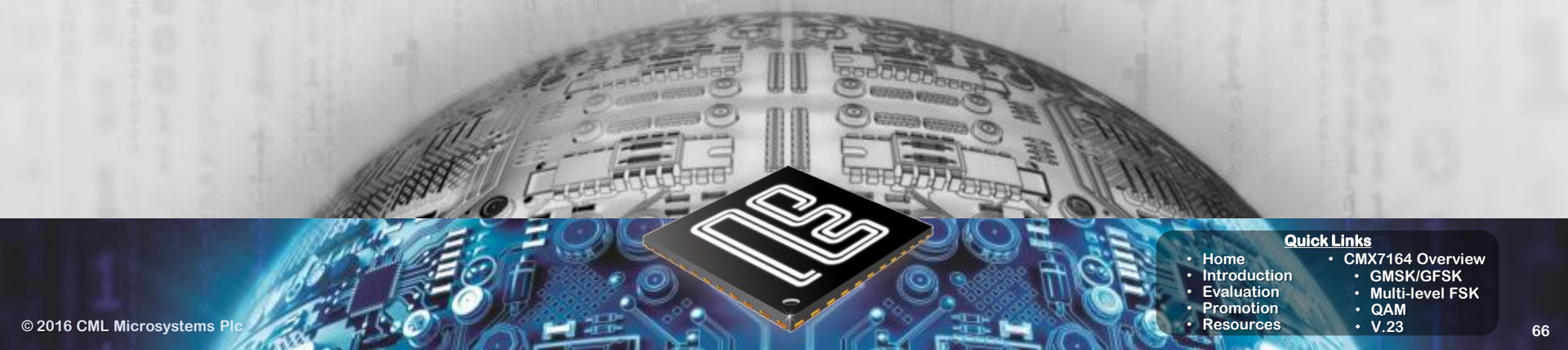
FSK- Modulation

2-FSK, 4-FSK, 8-FSK and 16-FSK

Function Image™ 7164FI-2.x



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2/4/8/16-FSK Modem

- Function Image™ 7164FI-2.x
- Constant envelope modulation (no requirement for PA linearisation)
- Raw data mode (2/4/8/16-FSK)
- Packet data modes (4/8/16-FSK with flexible frame structure
  - Header, Intermediate and Last data block types
  - Multiple size choices for each
- Complete Root Raised Cosine pulse shaping Tx/Rx filtering
- 4-FSK 'Air compatible' with FX/MX919B and CMX969
- 4-FSK modulation offers a good robust data channel up to 20kbps in 25kHz
- 8/16 FSK modulation provides increased data through-put up to 40kbps
  - Coding schemes are included that can be selected based on individual channel performance and requirements.
  - An Auto Modulation Detection mode is also provided, enabling backward compatibility with existing 4-FSK systems.

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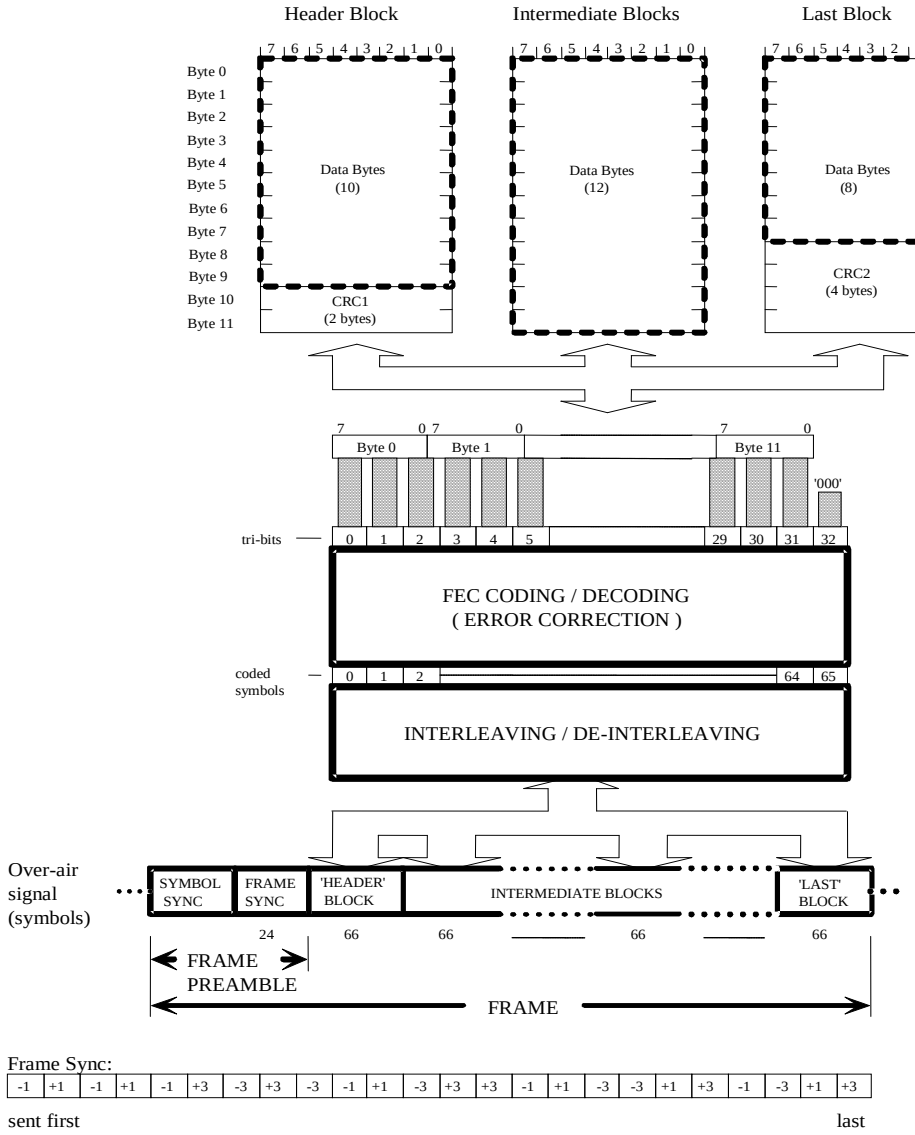
4/8/16-FSK data coding



Symbol Sync : at least 24 symbols of '..+3 +3 -3 -3 ...' sequence

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Formatted Block Coding

Formatted Block Types, Sizes and Rates for 8-FSK

			User(CRC) bytes for a:			Total bytes
Block Size	Block Size (Bytes)	Coding Rate	Header Block	Inter Block	Last Block	(excluding frame/symbol sync.)
0	12 bytes	2/3 (high rate) 1/2 (low rate)	10(2)	12	8(4)	18 bytes + 6 bits (high rate) 24 bytes + 6 bits (low rate)
1	24 bytes	2/3 (high rate) 1/2 (low rate)	22(2)	24	20(4)	36 bytes + 6 bits (high rate) 48 bytes + 6 bits (low rate)
2	36 bytes	2/3 (high rate) 1/2 (low rate)	34(2)	36	32(4)	54 bytes + 6 bits (high rate) 64 bytes + 6 bits (low rate)
3	48 bytes	2/3 (high rate) 1/2 (low rate)	46(2)	48	44(4)	72 bytes + 6 bits (high rate) 96 bytes + 6 bits (low rate)

Formatted Block Types, Sizes and Rates for 16-FSK

			User(CRC) bytes for a:			Total bytes
Block Size	Block Size (Bytes)	Coding Rate	Header Block	Inter Block	Last Block	(excluding frame/symbol sync.)
0	12 bytes	3/4 (high rate) 9/16 (low rate)	10(2)	12	8(4)	17 bytes (high rate) 22 bytes (low rate)
1	24 bytes	3/4 (high rate) 9/16 (low rate)	22(2)	24	20(4)	33 bytes (high rate) 43 bytes (low rate)
2	36 bytes	3/4 (high rate) 9/16 (low rate)	34(2)	36	32(4)	49 bytes (high rate) 64 bytes (low rate)
3	48 bytes	3/4 (high rate) 9/16 (low rate)	46(2)	48	44(4)	65 bytes (high rate) 85 bytes (low rate)

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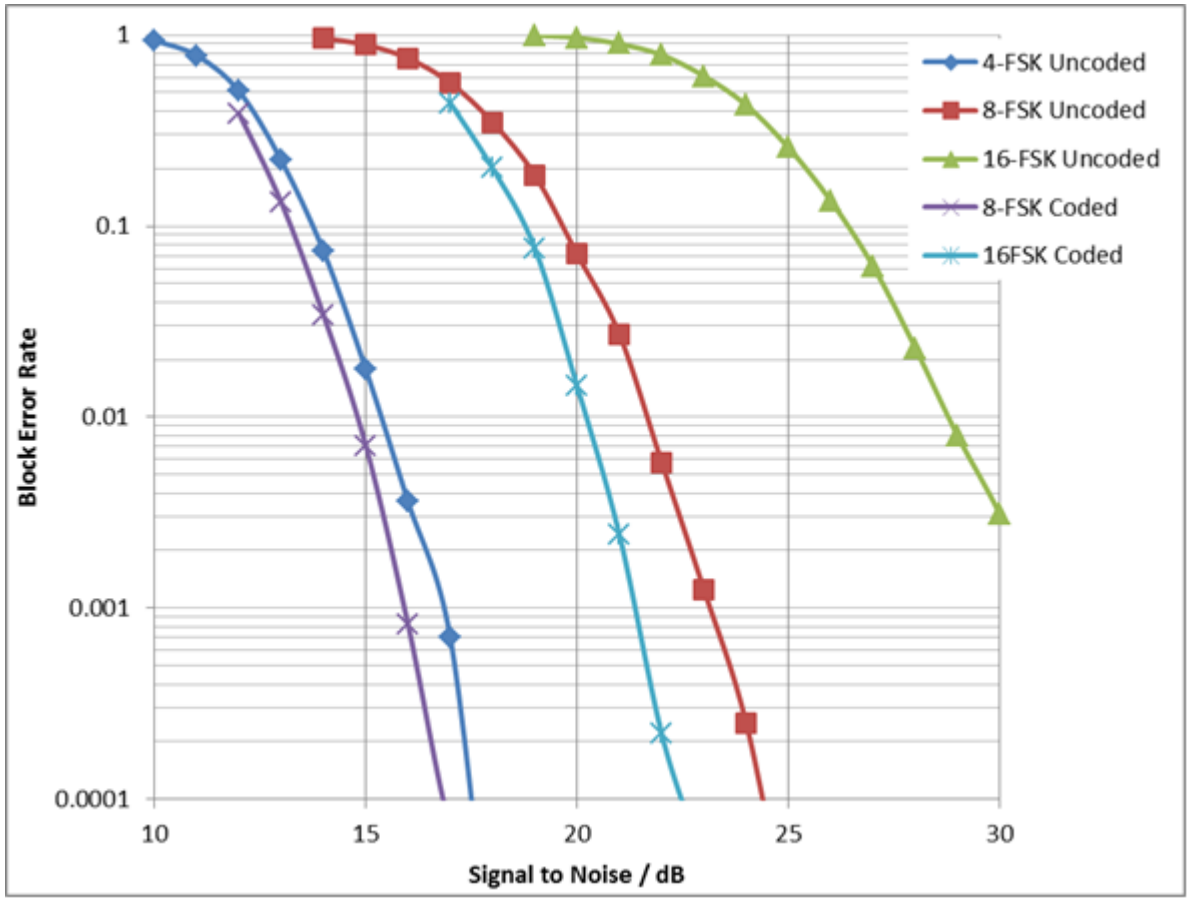
Performance 4/8/16-FSK w/wo FEC



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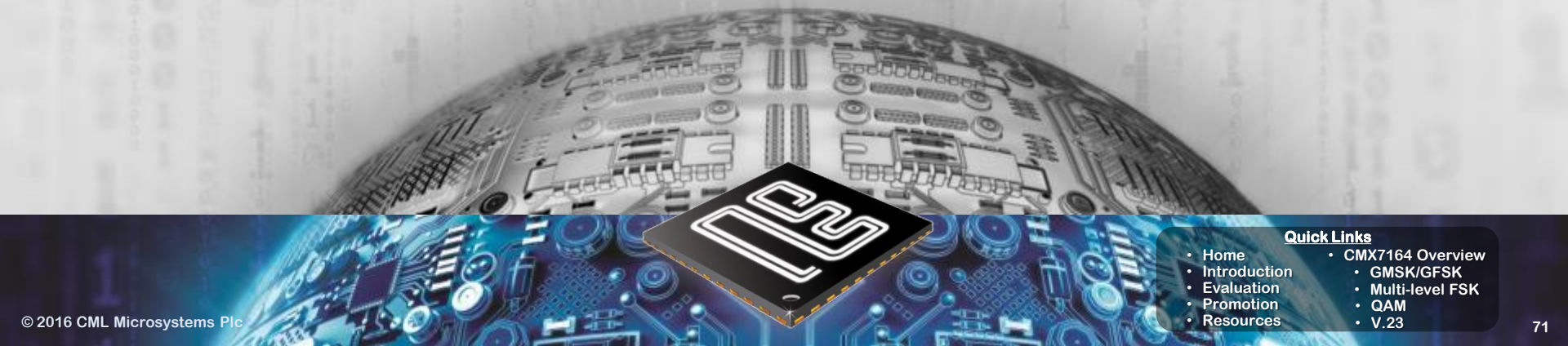
V.23 - Modem

Function Image™ 7164FI-6.x



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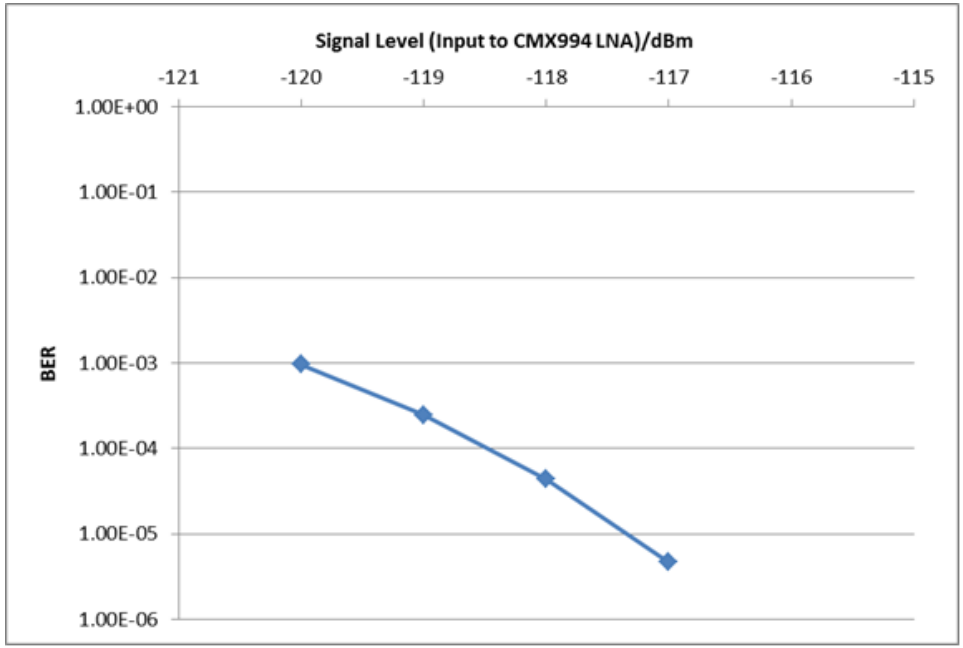
V.23 Modem

- Function Image™ 7164FI-6.x
- Compatible with ITU-T V.23
- Over-air bit rate 1200bps
- Raw data mode
- Formatted data mode
  - Tx adds start, stop and parity bits
  - Rx removes start, stop and checks parity
  - Data transfer in blocks of 1 to 8 bytes
- Tx interface - Two-point modulation or I/Q
- Rx interface – Zero IF I/Q receiver



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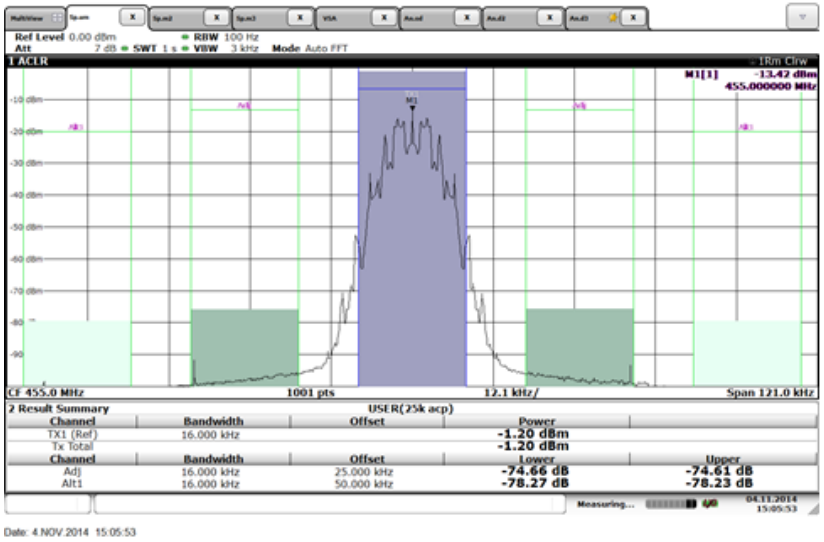
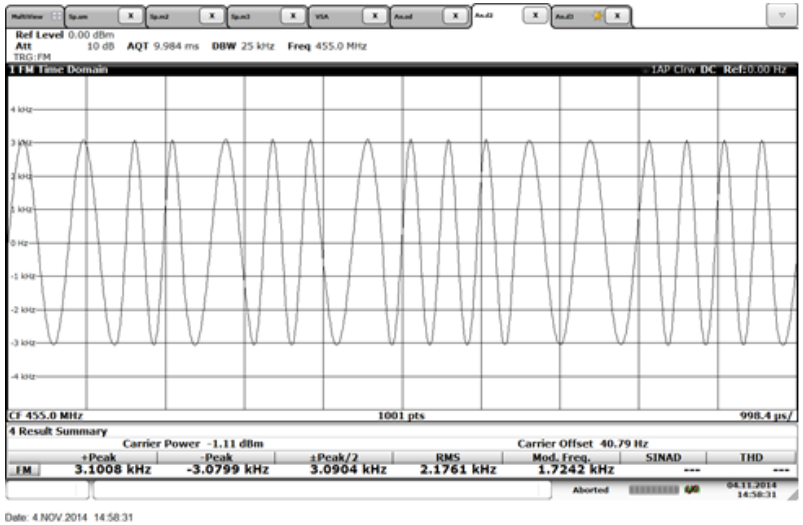
V.23 Modem



Modulation Spectrum (Peak deviation = 3.0 kHz)



V.23 1200bps I/Q Modulation

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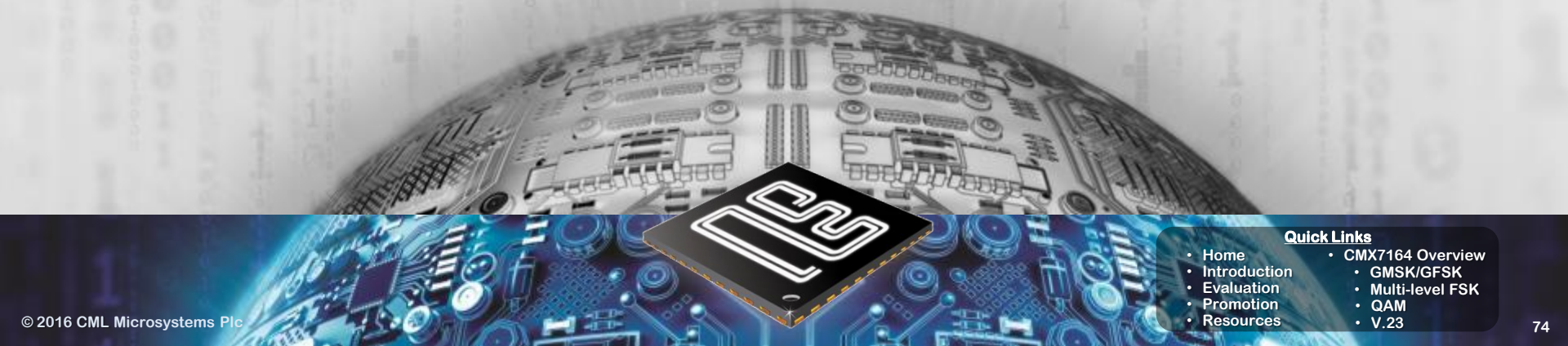

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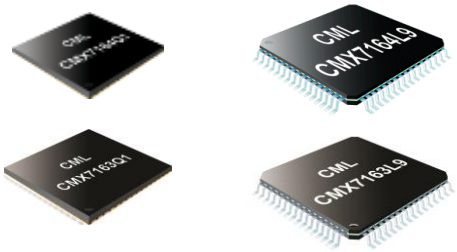
Evaluation resources

- Ordering information
  - Product
    - CMX7164Q1, CMX7164L9
    - CMX7163Q1, CMX7163L9



  - Evaluation support
    - PE0601-7164 – CMX7164 EvKit
    - PE0601-7163 – CMX7163 EvKit
    - DE9941 – SDR Demonstrator for Linear Radio Systems
    - PE0003 – Universal interface board

PE0003
Universal Interface Board

DE9941
SDR Demonstrator

PE0601-7164
CMX7164 Evaluation Kit

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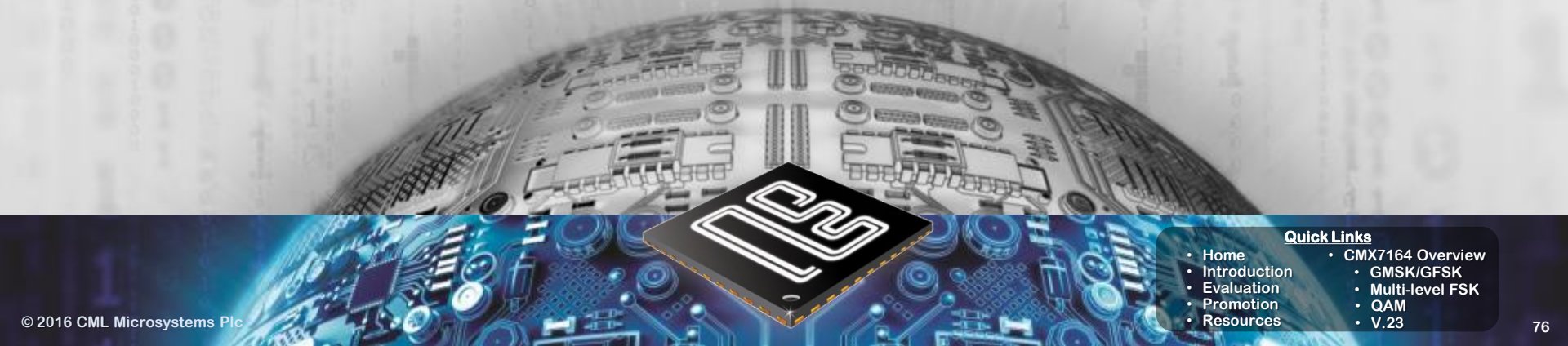
Promotion material



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CMX7164 Multi-mode Wireless Data Modem

Press release

Maldon, Essex - CML Microcircuits, a leading innovator and provider of low-power semiconductors for global wireless data and two-way radio communications markets, has added Adaptive Coded Modulation capabilities to its CMX7164 Multi-mode Wireless Data Modem, QAM modulation suite.

Adaptive Coded Modulation (ACM) features allow modulation type and block format to change on the fly to dynamically select data block size, coding rate and CRC size. Over-air commands enable a Tx host to select optimum modulation type and coding per burst to suit application message size and link channel quality. They can also relax required Rx host parsing speed. SPI Thru-Port macros speed serial slave control for shorter Tx/Rx mode transitions.

The CMX7164 covers both constant envelope and linear modulation schemes including: GMSK/GFSK, 2/4/8/16-level FSK, 4/16/32/64-QAM and V.23 to provide the ideal platform for customer-specific modulation schemes. Together these features make the CMX7164 a truly universal Wireless Data Modem solution.

Combining the CMX7164 with one of CML's RF building blocks enables the highest integration and performance radio data modem application to be developed.

The DE9941 demonstrator/evaluation board is available and enables the CMX7164, CMX994E Direct Conversion Receiver and CMX998 Cartesian Feedback Loop Transmitter to be demonstrated/evaluated.

The CMX7164 is available now, offering low power 3.3V operation in small VQFN/LQFP packaging.

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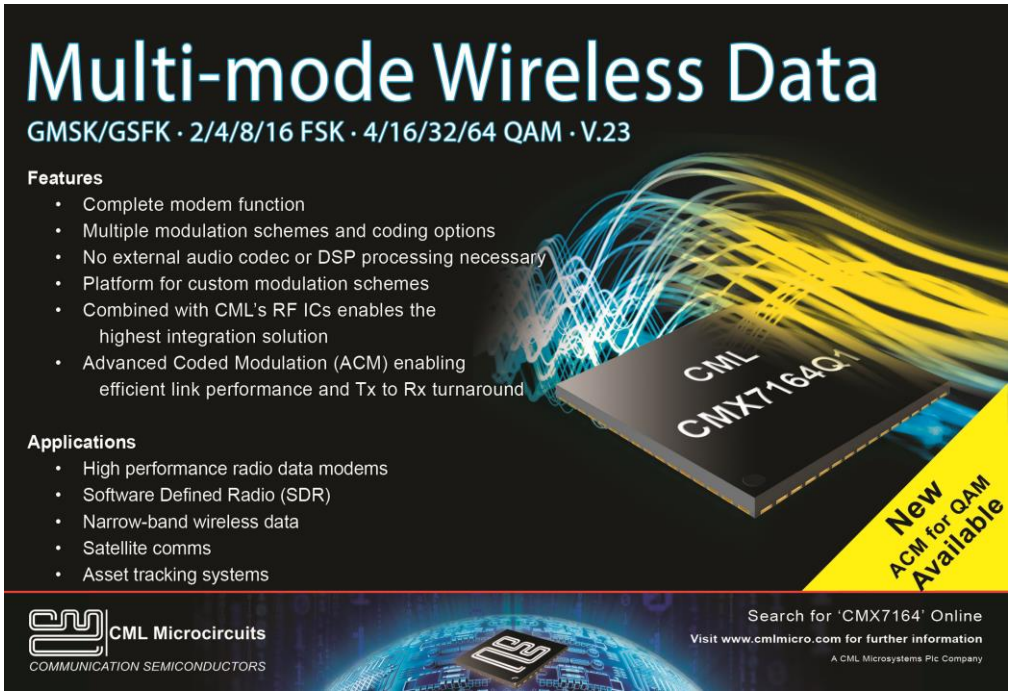
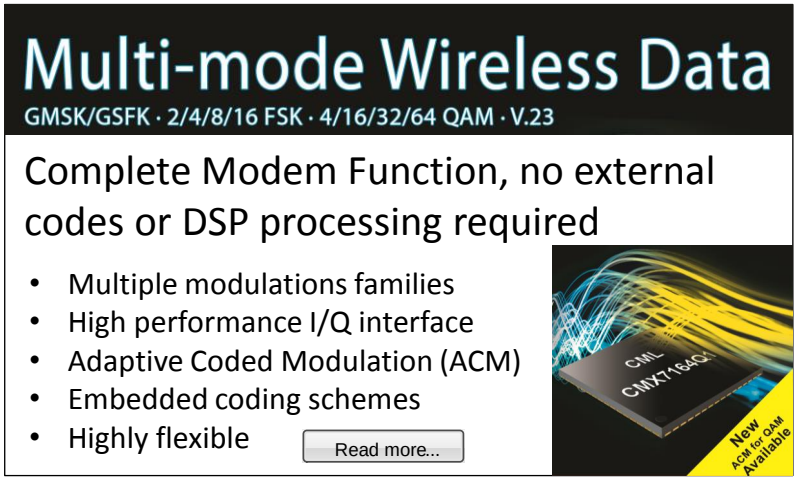
Promotion material





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Information resources

- CML website www.cmlmicro.com
  - Product Overview
  - Product Datasheet
  - Evaluation kit user manual
    PE0601-7164 (PE0601-7163) and DE9941 SDR WD Modem Demonstrator
  - Application notes and scripts for the PE0002
- CML Technical Portal http://www.cmlmicro.com/TechnicalPortalLink.aspx
  (Registration and product specific authorisation required)
  - Complete product datasheet and user manual
  - Function Images
    7164FI-4.x(4/16/32/64-QAM), 7164FI-2.x(2/4/8/16-FSK), 7164FI-1.x(GMSK/GFSK) and 7164FI-6.x(V.23)

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