PENTEK

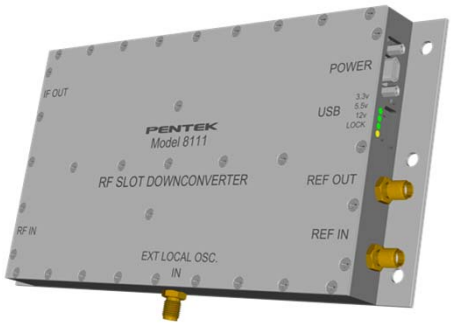
Setting the Standard for Real-Time Digital Signal Processing

Strategies for Pushing Software Defined Radio Closer to the Antenna

SDR-WInnComm 2014 Conference

Seminar Topics

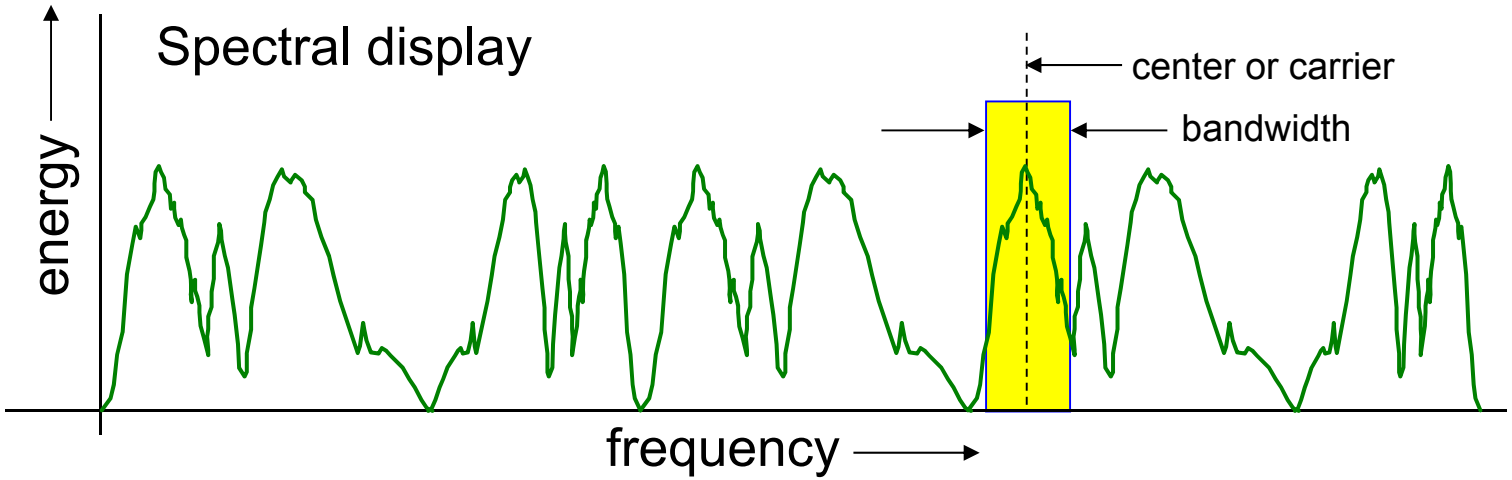
- Strategies for Digitizing RF Signals
- High-Speed A/D Converters
- RF Tuners
- L-Band Tuners

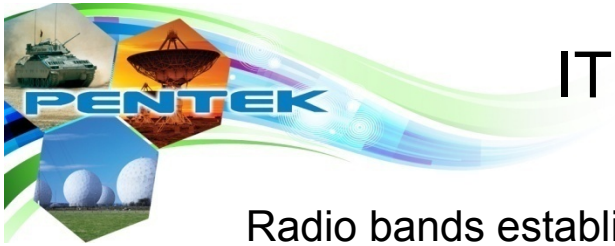


Cobalt Onyx Bandit

RF Signals

- Signals propagate between antennas using RF (radio frequency) signals
  - Different RF signal frequencies have unique characteristics for range, propagation, atmospheric interference, noise, and antenna shapes
- Most of our customers are interested RF signals from 3 MHz up to 40 GHz
  - Suitable for radar, communications, telemetry, SATCOM, etc
- A particular radio signal usually occupies a frequency slice:
  - Center frequency, often called the “carrier” frequency
  - Signal bandwidth: a span or range of signal frequency centered on the carrier





ITU Frequency Bands

Radio bands established by the International Telecommunications Union

Band name	Abbr	ITU	Frequency	Application Spaces
Extremely low frequency	ELF	1	3–30 Hz	Communication with submarines
Super low frequency	SLF	2	30–300 Hz	Communication with submarines, Mains power (50/60Hz)
Ultra low frequency	ULF	3	300–3000 Hz	Communication within mines
Very low frequency	VLF	4	3–30 kHz	Submarine communication, wireless heart rate monitors, geophysics
Low frequency	LF	5	30–300 kHz	Navigation, time signals, AM long-wave broadcasting (Europe and parts of Asia), RFID, amateur radio
Medium frequency	MF	6	300–3000 kHz	AM (medium-wave) broadcasts, amateur radio, avalanche beacons
High frequency	HF	7	3–30 MHz	Shortwave broadcasts, citizens' band radio, amateur radio, over-the-horizon aviation communications and radar, RFID, Automatic link establishment (ALE)/Near Vertical Incidence Skywave (NVIS) radio communications, Marine and mobile radio telephony
Very high frequency	VHF	8	30–300 MHz	FM, television, line-of-sight ground-to aircraft and aircraft-to-aircraft communications, amateur radio, weather radio, PMR, DVB-T, MRI Land Mobile and Maritime Mobile communications
Ultra high frequency	UHF	9	300–3000 MHz	Television broadcasts, microwave communications, radio astronomy, GPS, mobile phones (GSM, UMTS, 3G, HSDPA), FRS & GMRS radios, wireless LAN (Wi-Fi 802.11 b/g/n), Bluetooth, ZigBee, GPS, Land Mobile, amateur radio, DBS, microwave ovens
Super high frequency	SHF	10	3–30 GHz	Microwave communications, wireless LAN (Wi-Fi 802.11 a/n), most modern radars, communications satellites, amateur radio, DBS satellite television broadcasting, WiMAX
Extremely high frequency	EHF	11	30–300 GHz	Radio astronomy, high-frequency microwave radio relay, microwave remote sensing, amateur radio
Tremendously high frequency	THF	12	300–3,000 GHz	Terahertz medical imaging, ultrafast molecular dynamics, condensed-matter physics, terahertz spectroscopy, computing/communications

IEEE Radio Band Nomenclature

- IEEE further designates bands named for applications and wavelengths
- Most of Pentek's customers operate between 3 MHz and 40 MHz

Band	Frequency range	Origin of name
HF band	3 - 30 MHz	High Frequency
VHF band	30 - 300 MHz	Very High Frequency
UHF band	300 MHz - 1 GHz	Ultra High Frequency
L band	1 - 2 GHz	Long wave
S band	2 - 4 GHz	Short wave
C band	4 - 8 GHz	Compromise between S and X
X band	8 - 12 GHz	Used in WW II for fire control, X for cross (as in crosshair)
Ku band	12 - 18 GHz	Kurz-under
K band	18 - 27 GHz	German Kurz (short)
Ka band	27 - 40 GHz	Kurz-above
V band	40 - 75 GHz	
W band	75 - 110 GHz	W follows V in the alphabet
mm band	110 - 300 GHz	mm = millimeter wavelengths

What Do Customers Ask For?

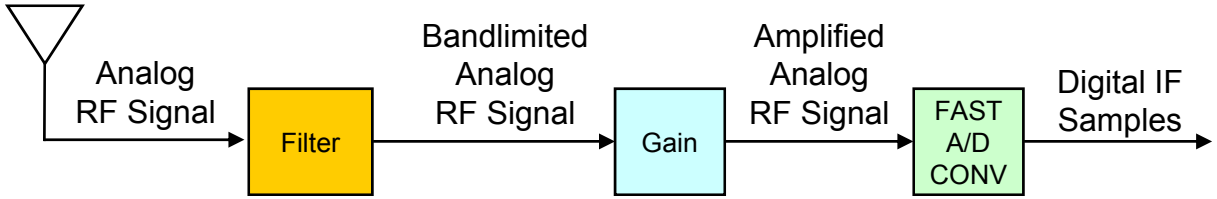
- Customer Requirements – All Over the Map!
  - "I need to build a GSM receiver"
  - "I am trying to capture Galileo satellite signals"
  - "We're working on a new HF direction finder"
  - "I'm coming in with an IF signal at 140 MHz with a 10 MHz bandwidth"
  - "I need to tune a 2 MHz bandwidth signal ranging anywhere between 1100 MHz and 1500 MHz"
  - "I need to receive a lot of different bandwidth signals in the VHF Band"
  - "I've got a Ku band radar and I need to process a 5 MHz pulse waveform"
- Two Key Questions For Any Application
  - What is the center or carrier signal frequency or frequency range?
  - What is the signal bandwidth or bandwidth range?

Getting Closer To The Antenna

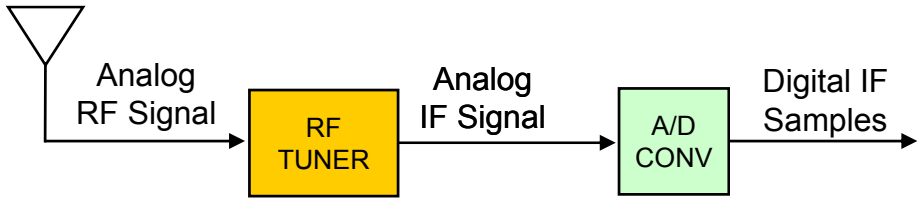
- Most communications and radar systems use DSP for processing the acquired signals
  - Decoding, demodulation, decryption, beamforming, etc.
- Of course, DSP requires digitization of the RF signals
- But, RF antenna frequencies are often much too high for A/Ds !
- What are some strategies?

Strategies for Digitizing RF Signals

1. Use a very high-frequency A/D converter
   - Sample rate must be at least twice the signal bandwidth (Nyquist rule)
   - High sample rate A/Ds have fewer bits of resolution
   - Analog gain and/or filtering may be required before the A/D

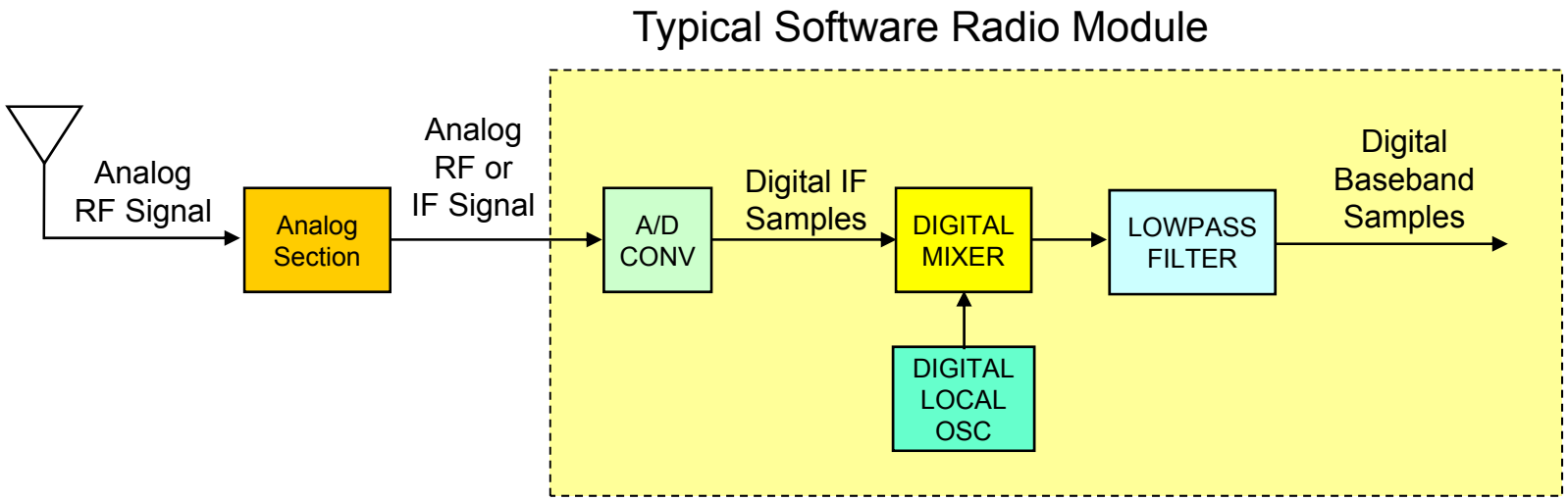


2. Translate the signal band down to a lower IF frequency
   - Requires analog frequency translation (filters, mixer, local oscillator)
   - More expensive and complex analog circuitry
   - Allows use of higher resolution A/D converters



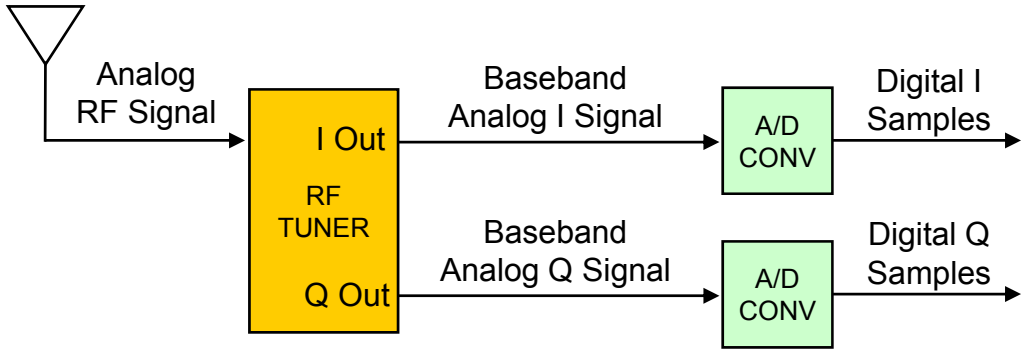
Digital Down Conversion

- Most DSP algorithms need digital baseband samples
  - Complex signal representation is preferred for efficient processing
  - The signal band is centered at 0 Hz, with positive & negative portions
- Digital Downconverters Complete the job
- Digital Mixer and Local Oscillator translate digital IF to baseband
- Digital FIR low pass filter defines the digital IF signal bandwidth



Strategies for Digitizing RF Signals

3. Translate the signal band down to baseband
   - Requires analog frequency translation (filters, mixer, local oscillator)
   - Allows use of higher resolution A/D converters
   - Suffers from analog I/Q imbalance



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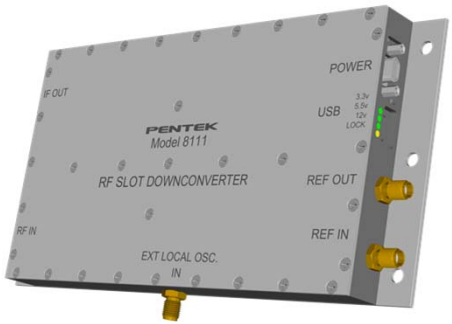
- RF Tuners
- L-Band Tuners

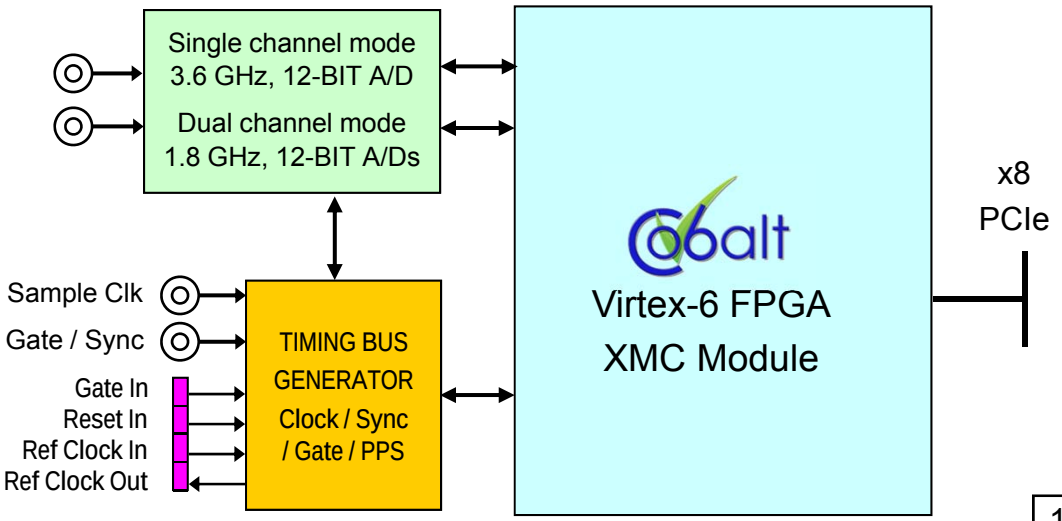
Cobalt Onyx



Bandit

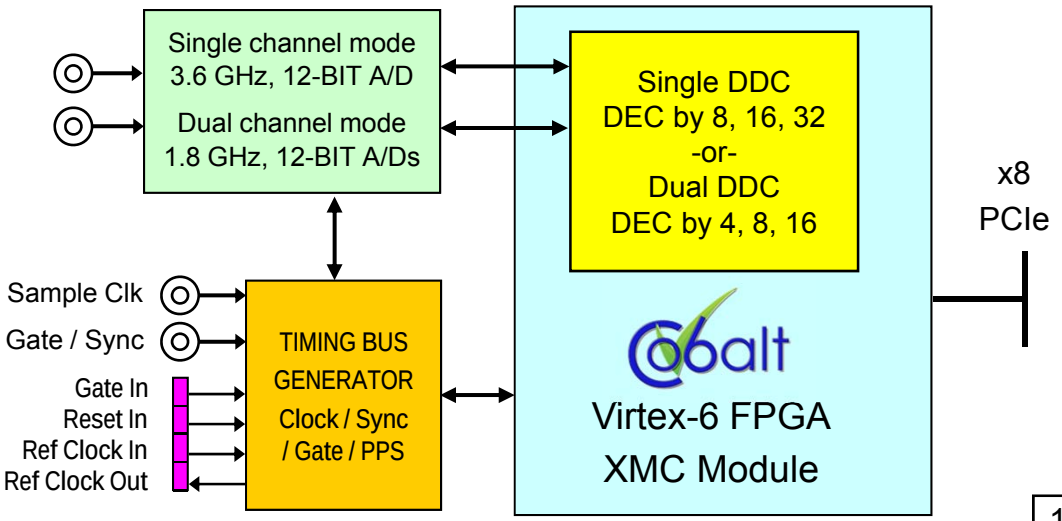
Model 71640 3.6 GHz A/D - XMC Module

- Virtex-6 FPGA
- Industry-standard XMC form factor
- Multi-board, multichannel synchronization
- Single Channel Mode
  - 3.6 GHz 12-bit A/D
  - Usable for RF inputs up to 1.8 GHz
- Dual Channel Mode
  - Two 1.8 GHz 12-bit A/Ds
  - Usable for RF inputs to 2.7 GHz
- Eliminates need for RF tuner
  - May still need amplifier & filter



Model 71641 3.6 GHz A/D and DDC

- FPGA Based Digital Down Converter
- Eight parallel poly-phase DDC engines
  - Each running at 450 MHz sample rate
  - Sampling rates Fs = 3.6 GHz or 1.8 GHz
- Tunable from 0 to Fs
  - Translates RF slice down to I+Q baseband
- Output bandwidths 90, 180, or 360 MHz
  - On board FIR filters
- Simplifies system design
  - Provides wide tuning range



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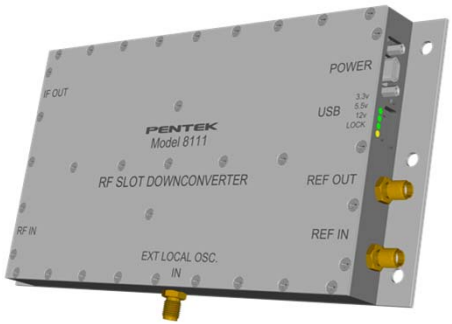
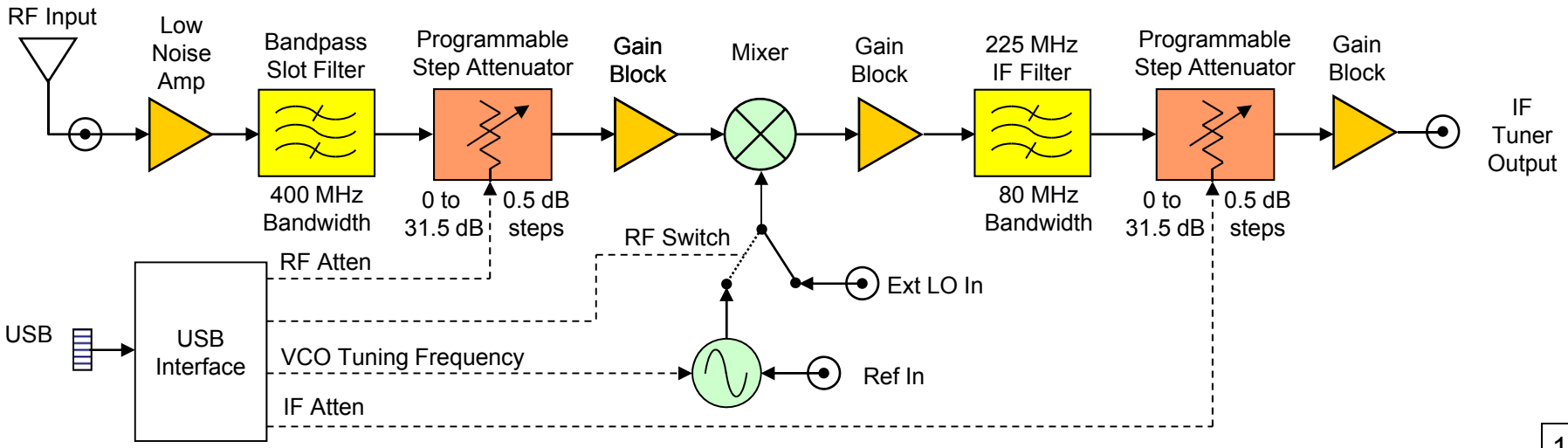


Cobalt Onyx Bandit

Model 8111 Tuner - Bandit Slot Receiver

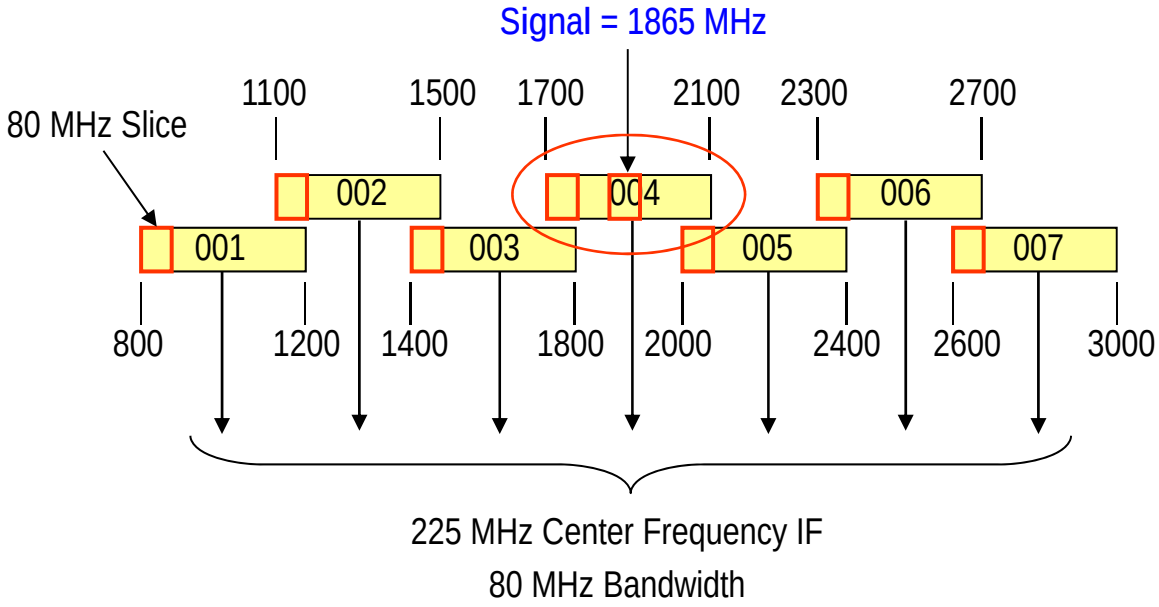
- Each model has a different 400 MHz tuning range
- Tuning ranges overlap by 100 MHz to ensure coverage
- Mixer tunes across the 400 MHz input RF band
- Down converts RF input to 225 MHz IF center frequency
- Delivers 80 MHz bandwidth slice centered at 225 MHz IF
- USB control interface
- Free ReadyFlow BSP for Windows and Linux

Input Signal Range (Slot)		
Model	Min	Max
8111-001	800 MHz	1200 MHz
8111-002	1100 MHz	1500 MHz
8111-003	1400 MHz	1800 MHz
8111-004	1700 MHz	2100 MHz
8111-005	2000 MHz	2400 MHz
8111-006	2300 MHz	2700 MHz
8111-007	2600 MHz	3000 MHz



Seven 8111 Models to Choose From

- Pick the correct 8111 model based on the input RF frequency Range
- Set the tuning LO frequency to translate an 80 MHz slice of the RF input frequency down to 225 MHz
- Covers any RF input from 800 MHz to 3000 MHz
- Example:
  - For 1865 MHz RF Input, select 8111-004 (1700 – 2100 MHz)
  - Set LO to 1865 – 225 = 1640 MHz
- Done!



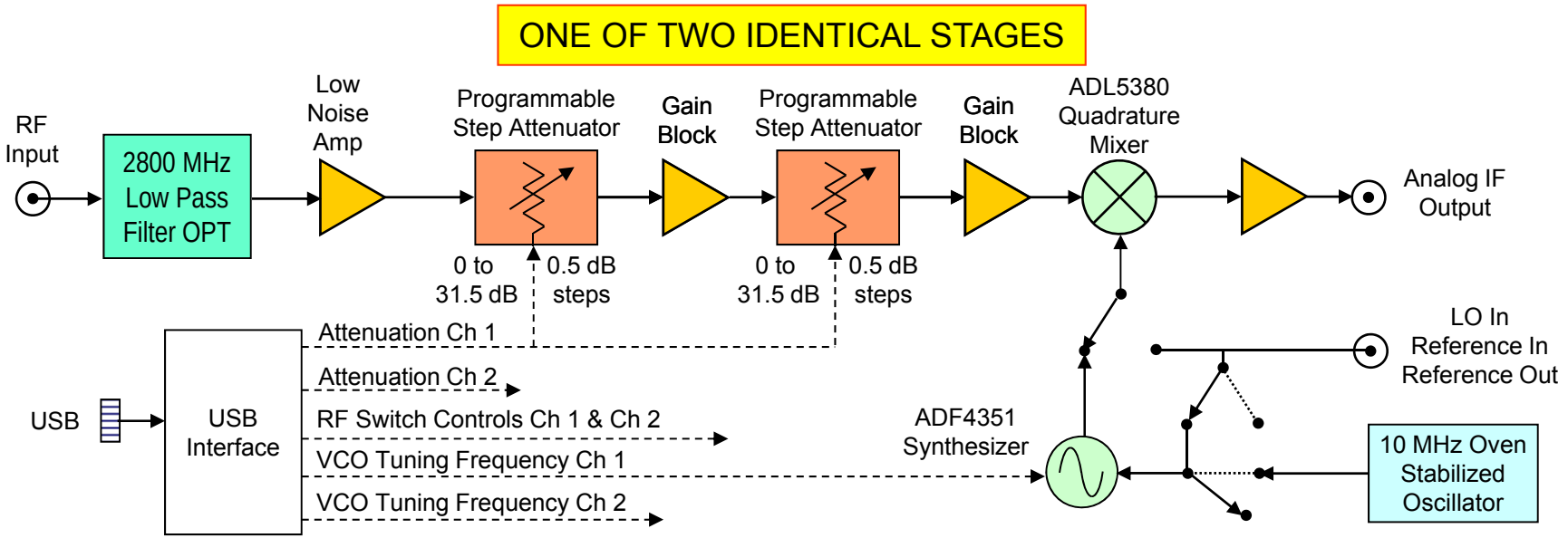
Model 8111 A/D Compatibility

- The 225 MHz IF frequency was chosen for Pentek A/D compatibility
- Three different baseband sampling and under-sampling modes
- All A/D modules below will digitize the full 80 MHz bandwidth of the 8111
- Many models include DDCs

Nyquist Zone	Sample Rate Fs	Pentek A/D Models	Density (Chans/slot)	A/D Bits Resolution
1	≥550 MHz	71630	1	12
		71650-012, 71640, 71641	2	
2	300 MHz	71650, 71651, 7158	2	12
		71650-014, 71651-014, 7156	2	14
3	180 MHz	71620, 71621	3	16
		71660, 71661, 71662, 7150, 7151, 7152, 7153	4	

Model 7120 2 Ch RF Tuner PMC/XMC

- Two completely independent RF Tuner Channels
- Convenient PMC/XMC form factor for VME, cCPI, VPX, PCIe, AMC, etc.
- Input frequency range: 500 MHz to 2800 MHz
- About 54 dB Spurious Free Dynamic Range
- Internal Oven Controller 10 MHz Reference
- PMC or XMC connector is used for power only – USB for control
- Requires external IF filter: determines IF frequency & bandwidth to 390 MHz



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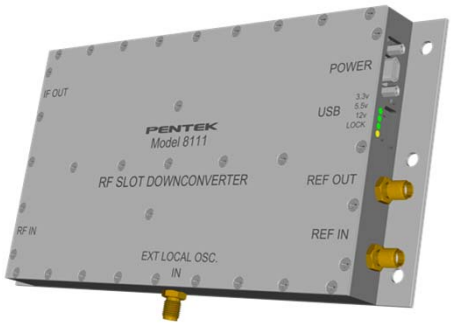
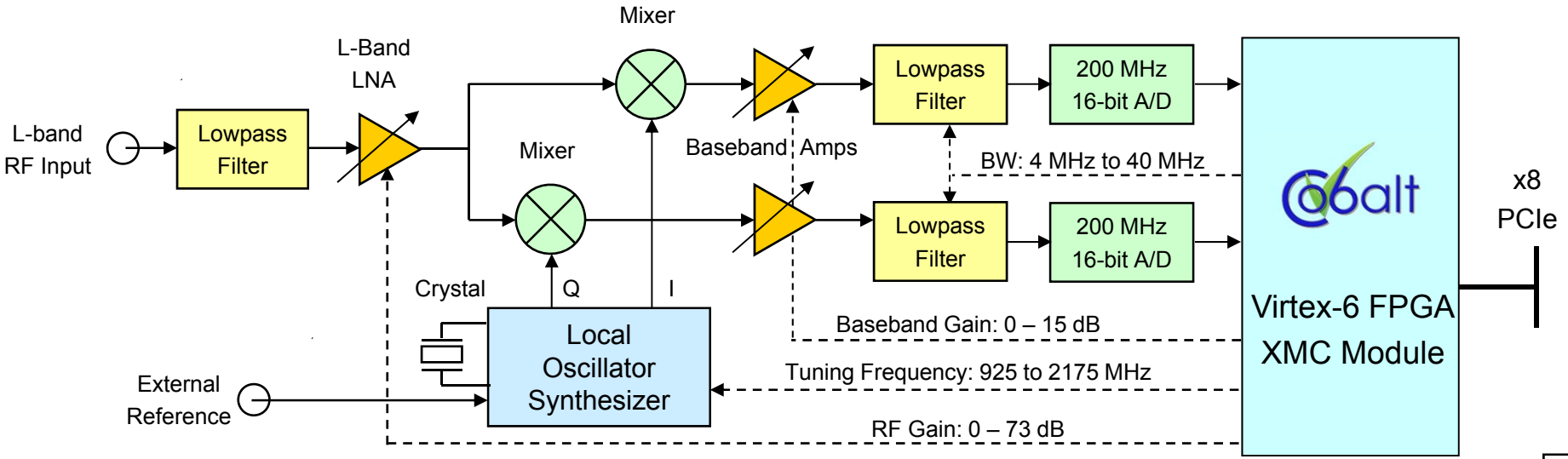


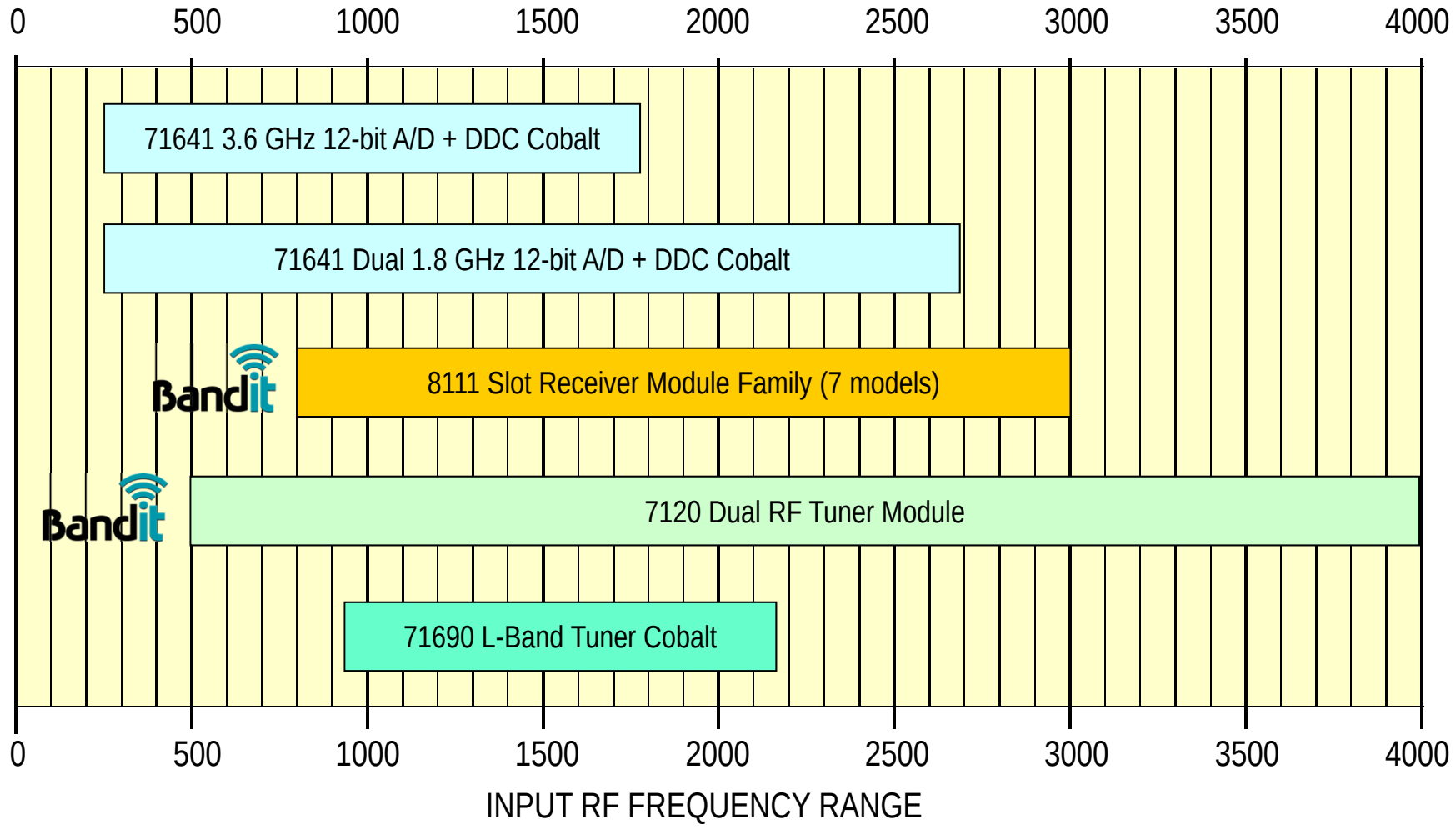
Bandit

Model 71690 L-Band Tuner XMC Module

- Low noise programmable gain input amplifier
- Local oscillator synthesizer programmable 925 MHz to 2175 MHz
- Baseband lowpass filter programmable 4 to 40 MHz bandwidth
- Two 200 MHz 16-bit A/Ds for I + Q
- Cobalt Virtex-6 for control and signal processing
- x8 PCIe interface to system bus
- ReadyFlow BSP for Windows and Linux



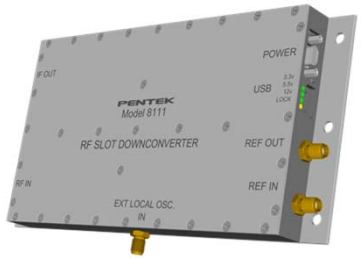
RF Frequency Range Coverage



Pushing SDR Closer to the Antenna

- Two Important Factors
  - RF center frequency and signal bandwidth
- Other Important Factors
  - Signal amplitude (determines gain needed)
  - Out of band signals (determines filtering)
  - Dynamic Range
- Multiple strategies – Multiple products
  - High Speed A/Ds
  - Analog Downconversion to IF
  - Analog Downconversion to baseband
- RF Frequency coverage to 4 GHz
- Signal Bandwidth coverage to 390 MHz
- Attractive pricing compared with alternative solutions or custom, in-house designs

Cobalt



Bandit

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