Usage of Software Defined Radio in DCP Ground Stations

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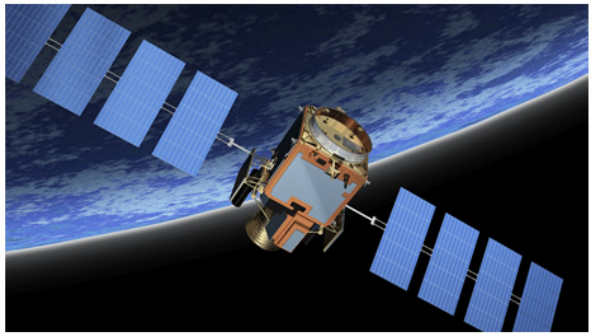
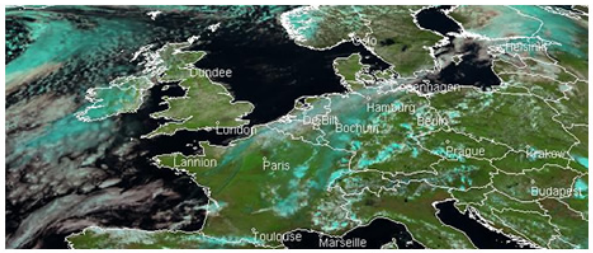




Agenda

- Key Aspects
- Data Collection System
- Direct Reception Ground Station for DCP
- SDR Architecture
- Signal Processing
- Advantages of the SW Approach
- Future Applications

Key Aspects

- Practical application of Software Defined Radio
- Introduction to the application
- Flexibility of the DSR based implementation
- Capture & post-processing capability
- Future-proof nature of SW based processing

Key Aspects

Statement from one of the reviewers:

> *"While not technically novel, this does show an interesting application of SDR technology that will be of interest to people."*

Data Collection System

- DCS – Data Collection System and/or Data Collection Service
- Original system from 1970s
- System for collection of environmental data
  - Meteorological Data Collection
  - Water Management
  - Tsunami Warning Systems
  - Hydro-meteorological Management
- Operation of the DCS by organisations such as
  - EUMETSAT (European Organisation for the Exploitation of Meteorological Satellites)
  - NOAA (National Oceanic and Atmospheric Administration)
  - JMA (Japan Meteorological Agency)
  - ISRO (Indian Space Research Organisation)
  - CMA (China Meteorological Administration)
- Provision of worldwide coverage

Data Collection System

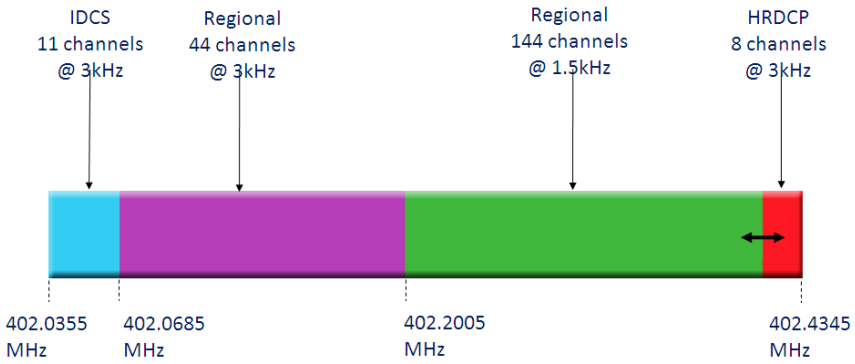
Parameter	100 Baud	GOES 300/1200	HRDCP
Preamble length	Long (7.5s)	Short (0.62s or 0.28s)	Medium (2.0s)
Sync Word	15-bit	15-bit	64-bit
Modulation	Bi-phase-L/PSK	8-PSK	Offset QPSK
Forward Error Correction	None	Trellis code	Concatenated RS(255,223) & R=1/2 Viterbi
End of Transmission detection	31-bit marker	8-bit marker	Message length in FEC protected header.
Error Detection	Parity bits & limited alphabet	Parity (optional)	32-bit CRC
Required E_B/N_0 (approx..)	10dB	12-13dB	6dB
User throughput (bit/sec)	87.5	262.5 or 1050 (parity) 300 or 1200 (no parity)	1049 (~1610 with compression)

Data Collection System

- 100 bps mode used by Eumetsat, JMA and Russian Federation
  - Original global system from 1970s
  - Robust modulation against phase noise and platform movement
  - No Forward Error Correction (FEC) and inefficient bandwidth utilisation
  - No longer supported by NOAA for GOES satellites
- 300/1200 bps used by NOAA
  - Higher spectral efficiency than 100 Baud system
  - Forward Error Correction (FEC)
  - 8-PSK modulation is sensitive to phase disturbances, and FEC is poor with burst noise
- 1200 bps HRDCP used by Eumetsat
  - Similar spectral efficiency to 1200 bps GOES operation
  - Significantly more robust modulation and FEC based on CCSDS recommendations.
  - Designed for binary operation (e.g. data compression) and larger block sizes
  - Can operate at about 6dB lower power than GOES 1200 bps in practice.
- 4800 bps used by India Meteorological Department.
  - Short burst messages sent several times in ‘alert’ mode.
  - Recently added FEC with legacy operations in mind, therefor not following CCSDS recommendations and leading to poorer performance and custom processing requirement

Data Collection System

- Transmission characteristics
  - » FDMA (Frequency Division Multiple Access), i.e. identification of DCP channels
  - » TDMA (Time Division Multiple Access) for each DCP channel applies, i.e. time slots for DCP systems
  - » DCP channels for so-called self-timed DCPs (alert)
- DCP Band GOES
  - » Approximately 400kHz from 401.701000MHz to 402.099250MHz
  - » Up to 530 channels for 300 Baud DCP at 750Hz spacing
  - » Some sub-bands reserved for 1200 Baud channels
- DCP Band METEOSAT



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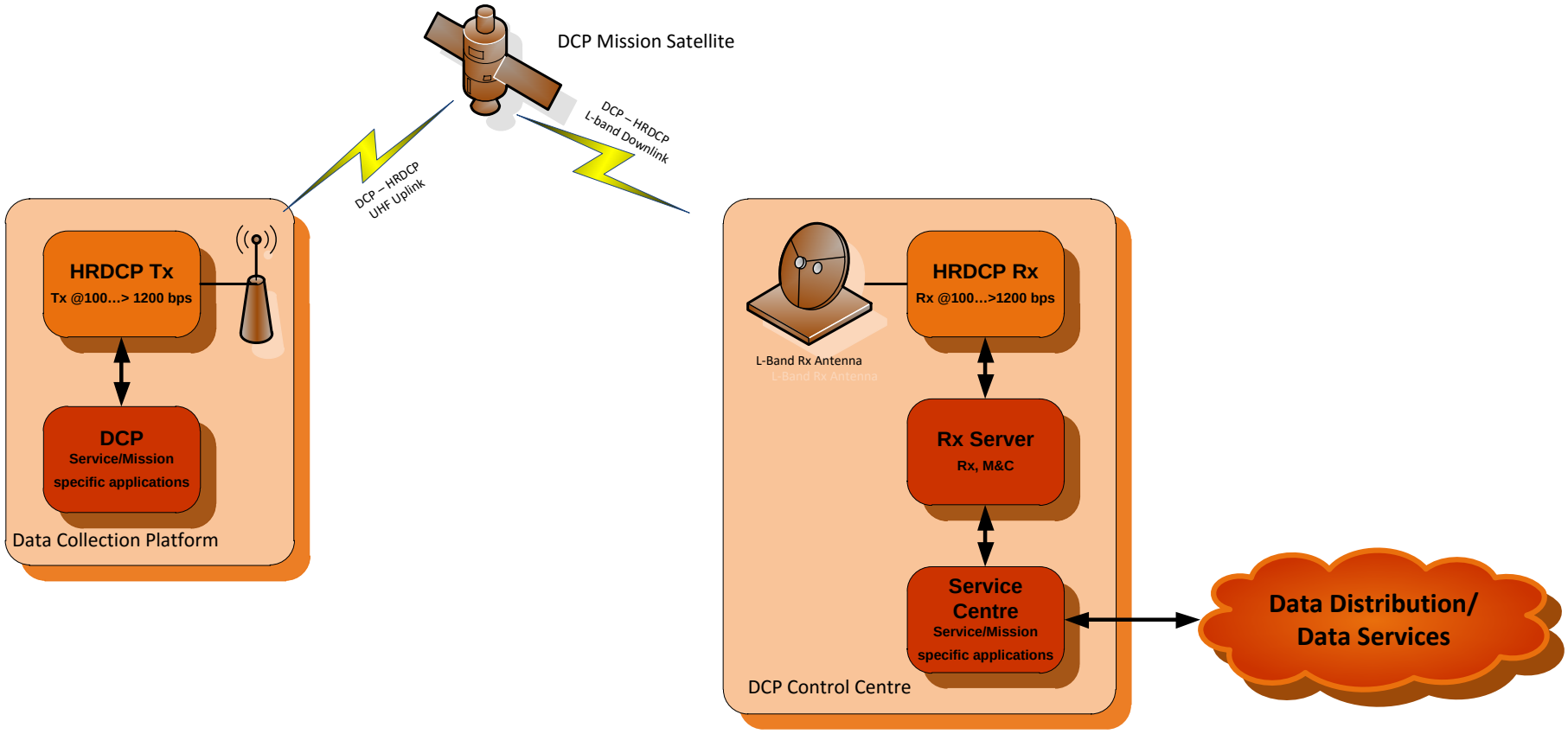
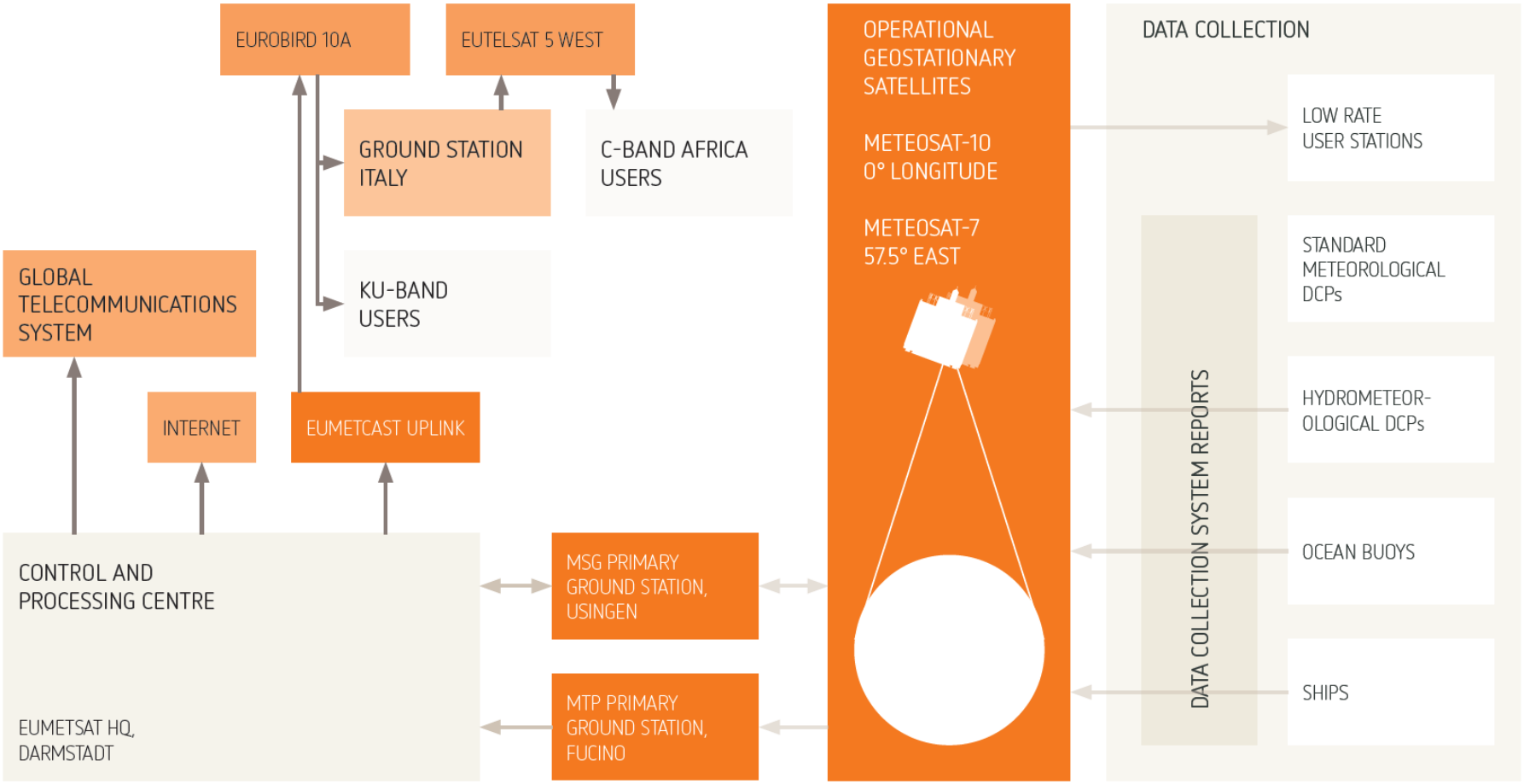
Data Collection System



DCS System block diagram

Data Collection System



Data Collection System diagram from EUMETSAT DCP Factsheet as an example of a DCS

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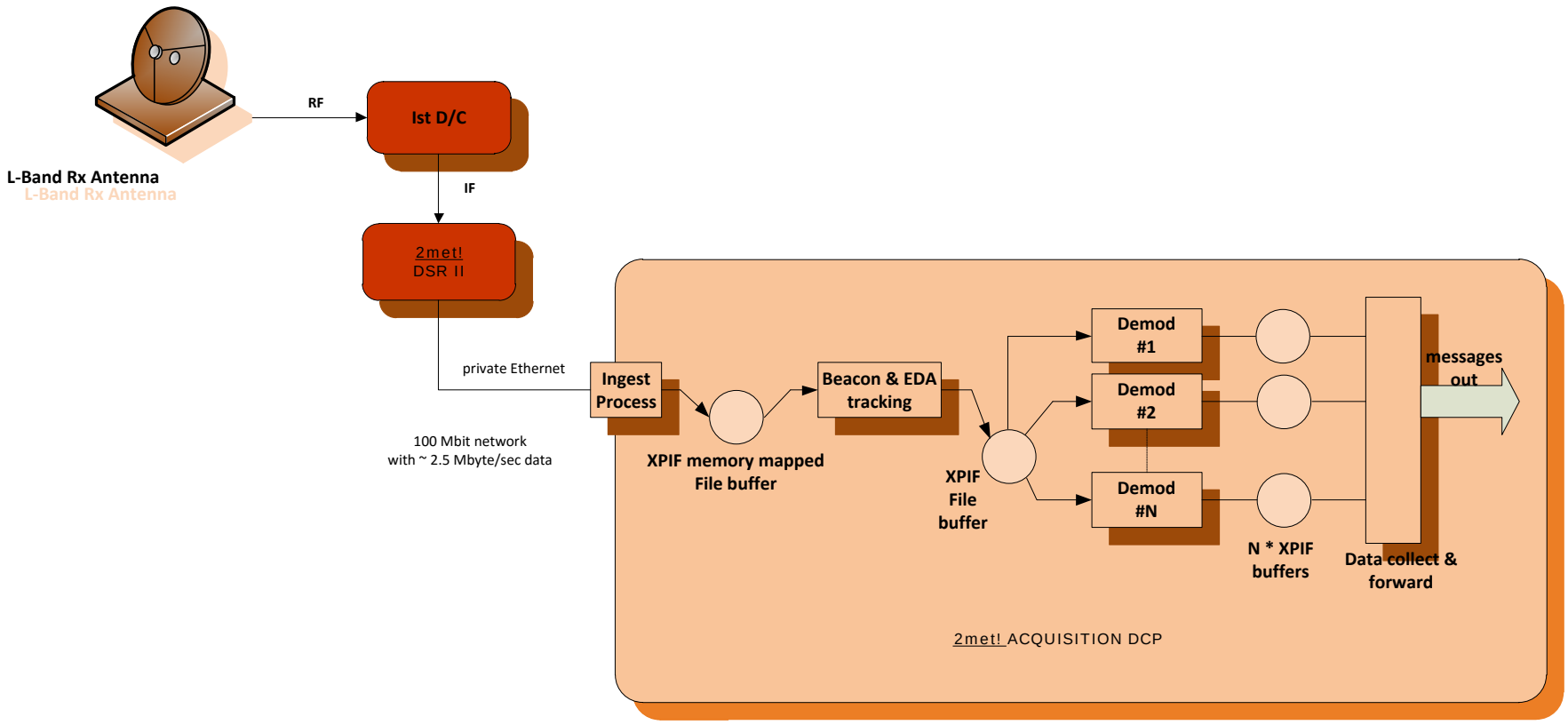
Direct Reception Ground Station for DCP



DRGS block diagram showing main building blocks

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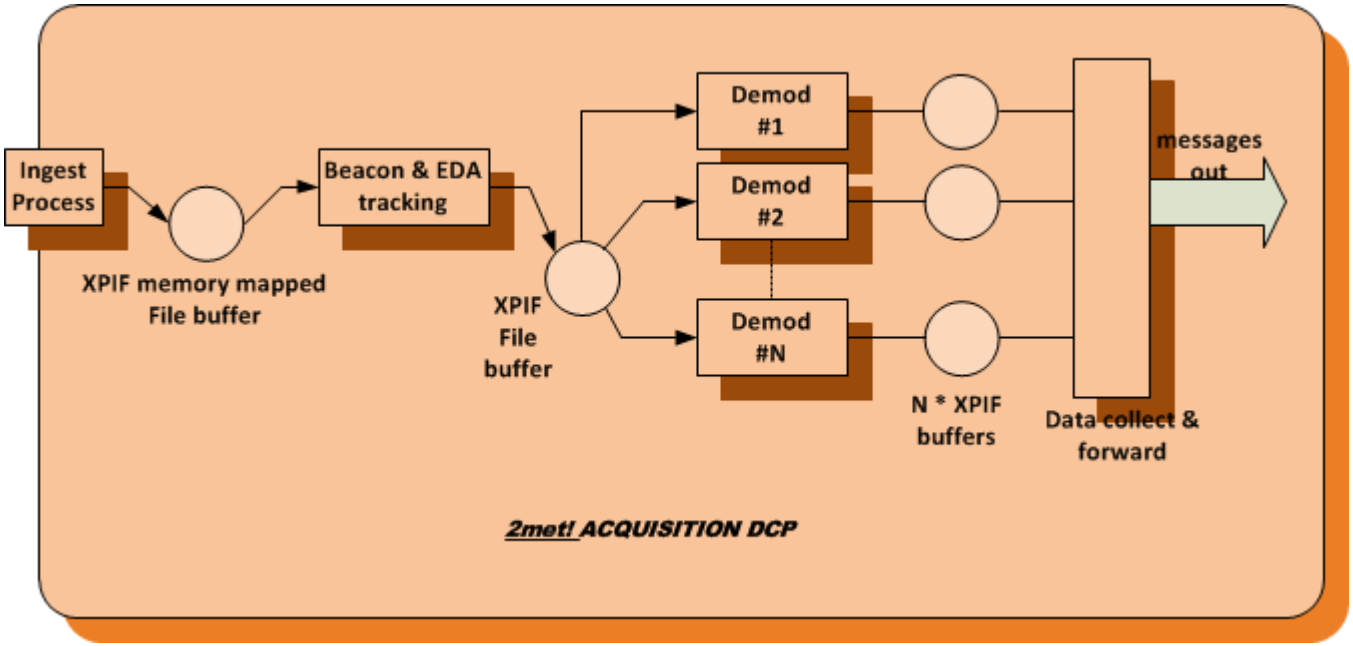
Direct Reception Ground Station for DCP

Digitizer (DSR II)

- 1st IF 130 – 150 MHz (customization is possible)
- Conversion to final IF of around 13.75 MHz
- Digitization and Conversion to a complex baseband signal centered on zero Hz
- Two internal AGC (Automatic Gain Control) systems
- NTP (Network Time Protocol) over the Ethernet
- Output
  - » Stream of 16 bit I/Q complex samples
  - » 500 kHz sample rate
  - » Additional monitoring data and time stamping
  - » 2.5 MByte/second

SDR Architecture



- Orchestration of SW by the Acquisition Service
- Signal Processing for
  - » Beacon & EDA tracking
  - » Demodulation and Decoding
- Additional Processes for
  - » Data Ingestion
  - » Monitoring & Control and
  - » DCP Message Dispatch

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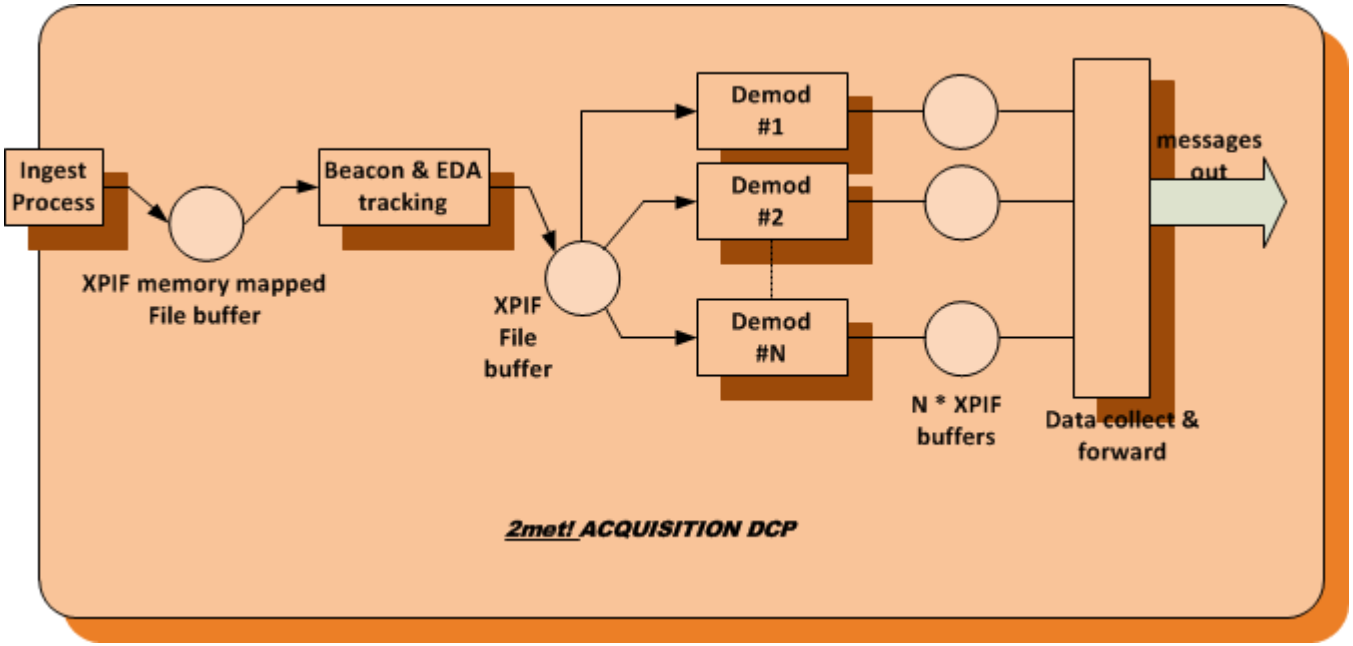
SDR Architecture



- Interfaces between “near-real-time” processes
  - » Circular buffer implemented as a memory-mapped file
  - » Memory-mapping allows for virtually no disk IO
- Circular buffers
  - » Written by one previous process
  - » Read simultaneously by one or many processes
  - » Non-blocking, so rogue process wont impact on others

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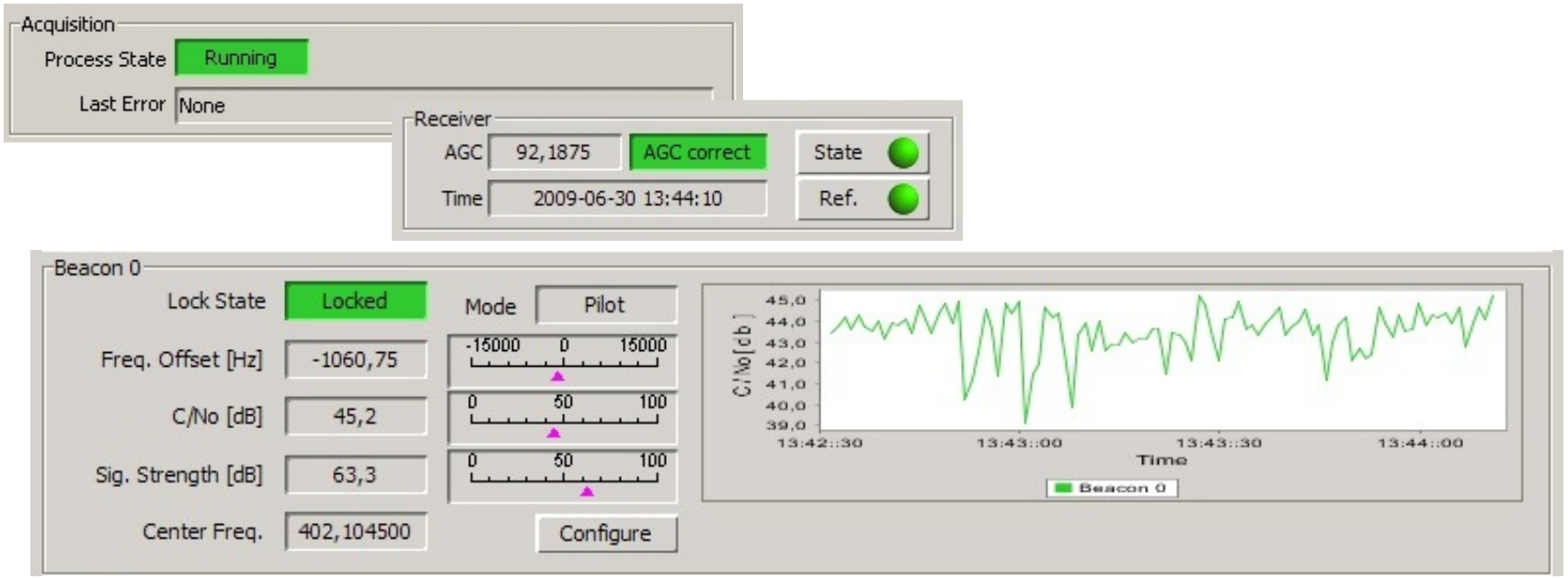
Signal Processing

- Beacon Tracker
  - » Performs frequency correction and amplitude calibration based on a known uplink beacon (pilot) signal.
  - » Software supports a 2nd beacon (when available) for redundancy.
  - » Also can use “message feedback” where DCP transmissions are used for a statistical estimate of those parameters.



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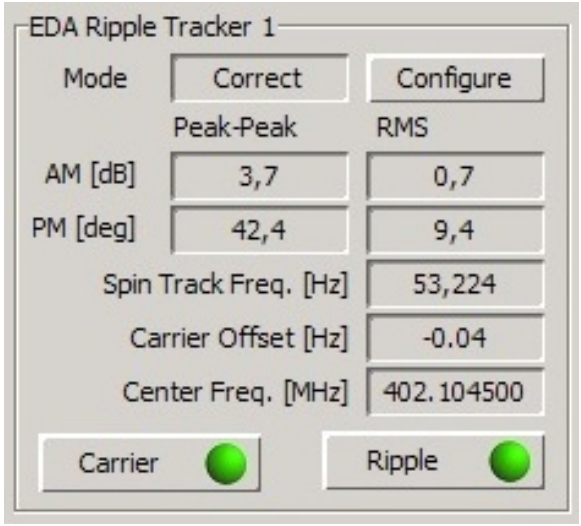
Signal Processing

- EDA Tracker
  - » Adaptively corrects for the phase and amplitude ripple of the Meteosat 1st and 2nd generation Electronically De-spun Array antenna.
  - » This process was added later on EUMETSAT request



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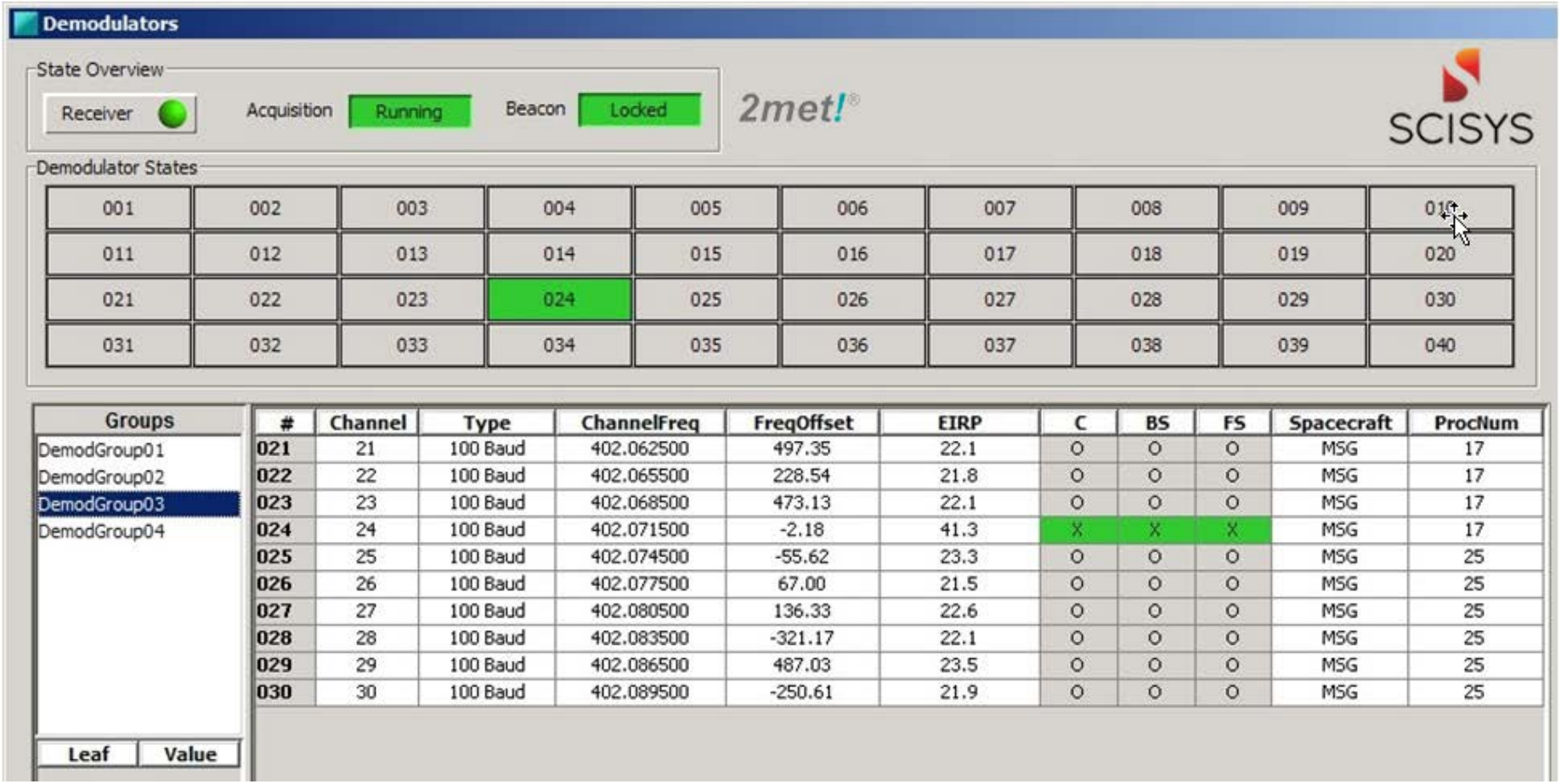
Signal Processing

- Demodulators
  - » Performs the frequency selection, filtering and demodulation of DCP messages.
  - » In turn calls a decoder program to implement the various Forward Error Correction systems used in the different DCP standards.
  - » Spread over multiple processes to allow multiple core CPUs and/or distributed systems to be used effectively.
- Data Collection
  - » Combines all processes to have single point (network socket) for access.

Signal Processing

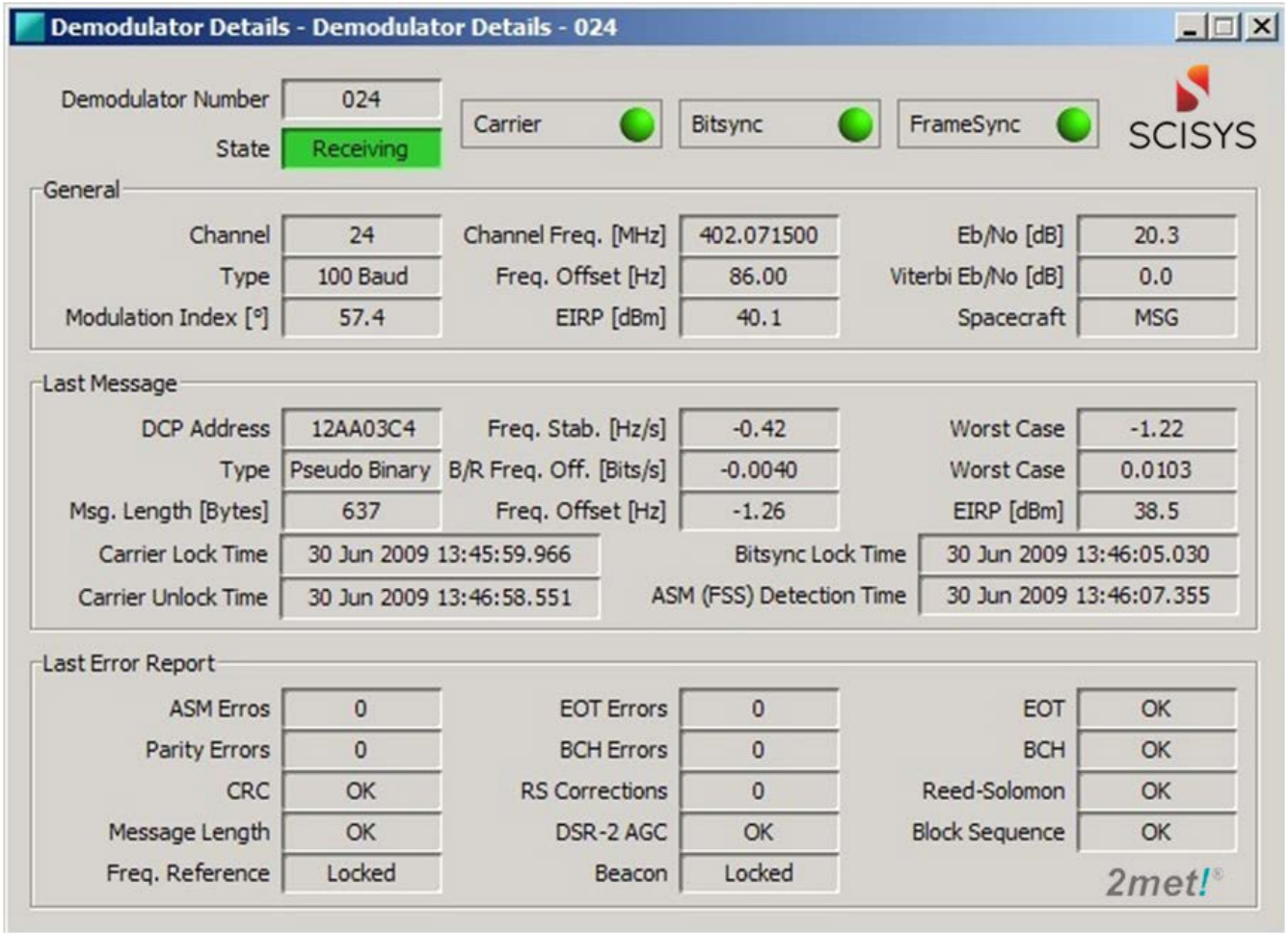
- Demodulator Overview GUI



#	Channel	Type	ChannelFreq	FreqOffset	EIRP	C	BS	FS	Spacecraft	ProcNum
021	21	100 Baud	402.062500	497.35	22.1	O	O	O	MSG	17
022	22	100 Baud	402.065500	228.54	21.8	O	O	O	MSG	17
023	23	100 Baud	402.068500	473.13	22.1	O	O	O	MSG	17
024	24	100 Baud	402.071500	-2.18	41.3	X	X	X	MSG	17
025	25	100 Baud	402.074500	-55.62	23.3	O	O	O	MSG	25
026	26	100 Baud	402.077500	67.00	21.5	O	O	O	MSG	25
027	27	100 Baud	402.080500	136.33	22.6	O	O	O	MSG	25
028	28	100 Baud	402.083500	-321.17	22.1	O	O	O	MSG	25
029	29	100 Baud	402.086500	487.03	23.5	O	O	O	MSG	25
030	30	100 Baud	402.089500	-250.61	21.9	O	O	O	MSG	25

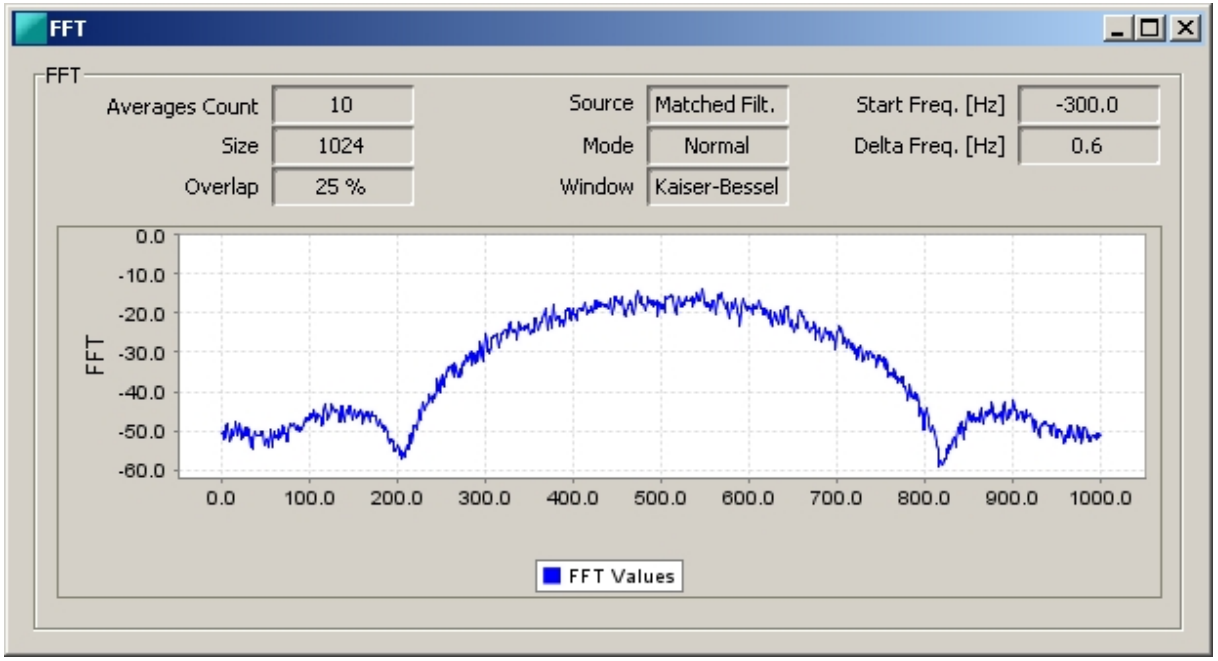
Signal Processing

- Demodulator Detailed View GUI



Signal Processing

- Analysis FFT GUI



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Advantages of the SW Approach

- Very little hardware dependency
  - » Several types of “receiver” can function as the digitizer.
  - » Provision of spares and long-term support much easier.
- Scalable by design
  - » Number of demodulators limited by total CPU performance of server(s) used.
  - » With time CPU performance gets cheaper!
- Upgradable
  - » New features and bugs fixable with simple software update
  - » Roll-back also simple.
- Analysis support
  - » Can capture the IF signal to disk in real-time for later analysis.
  - » Allows investigation of failed DCP messages to determine possible causes (DCP fault, interference, etc).

Future Applications

- Meteosat Third Generation
  - » Modification of DCP downlink
  - » On-board digitization
  - » Digitized data stream multiplexed into the other instrument data streams and transmitted to the Ground Stations in Ka Band
- Study “High Rate Data Collection Platform Prototype Development” under ESA Contract
  - » ARTES 5.1 Technology Program
  - » Specification of a preliminary New Generation DCP Air interface
  - » Development of a Prototype DCP Transmitter
  - » Development of a test receiver based on existing SDR system

SOMETIMES
GREAT IDEAS
WANT MORE
ATTENTION!

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The End

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