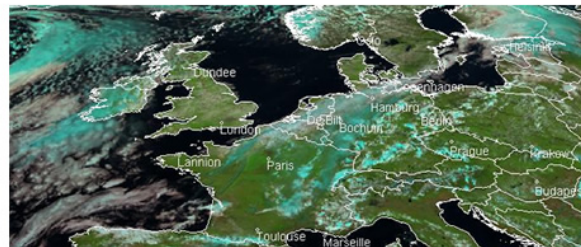
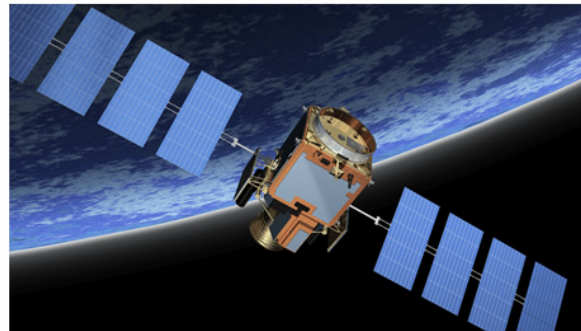




# Usage of Software Defined Radio in DCP Ground Stations

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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

*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

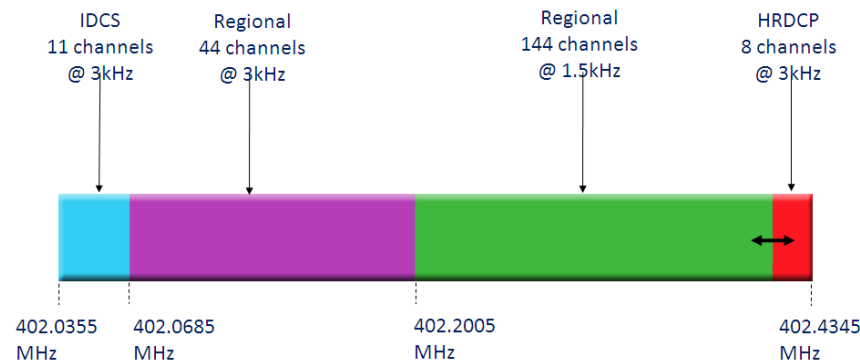
Parameter	100 Baud	GOES 300/1200	HRDCP
Preamble length	Long (7.5s)	Short (0.62s or 0.28s)	Medium (2.0s)
Sync Word	15-bit	15-bit	64-bit
Modulation	Bi-phase-L/PSK	8-PSK	Offset QPSK
Forward Error Correction	None	Trellis code	Concatenated RS(255,223) & R=1/2 Viterbi
End of Transmission detection	31-bit marker	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, therefore not following CCSDS recommendations and leading to poorer performance and custom processing requirement

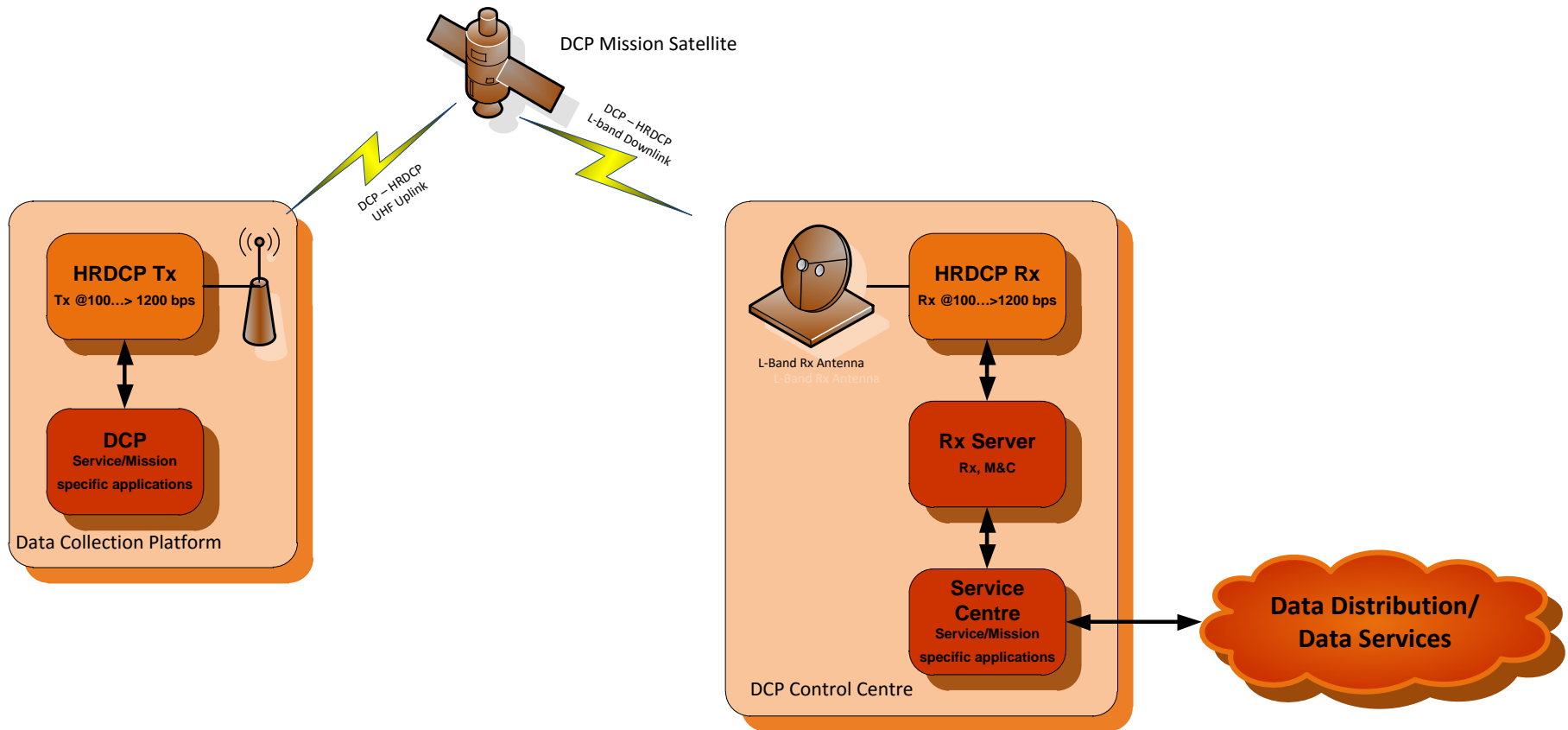
# Data Collection System

- 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



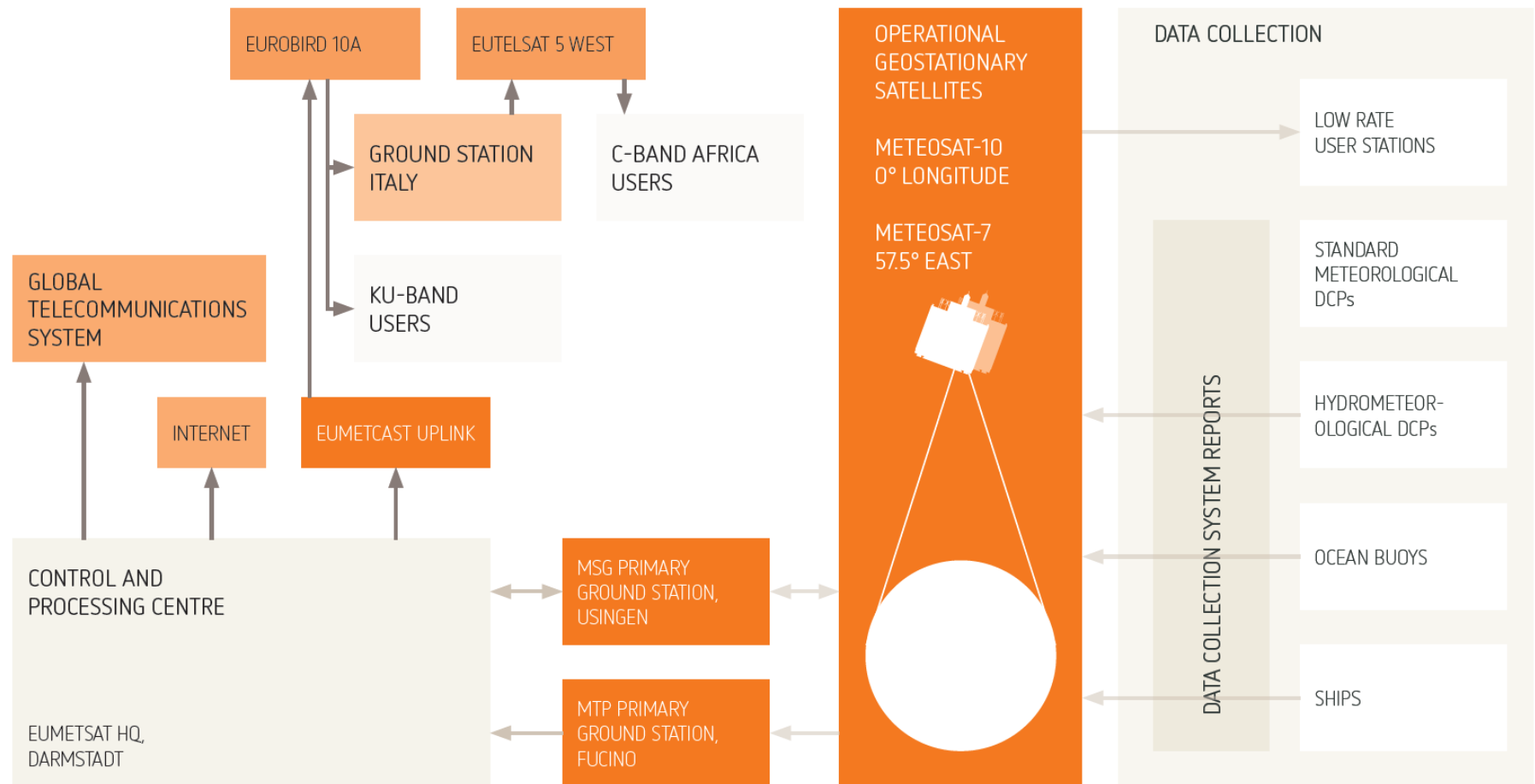


# Data Collection System



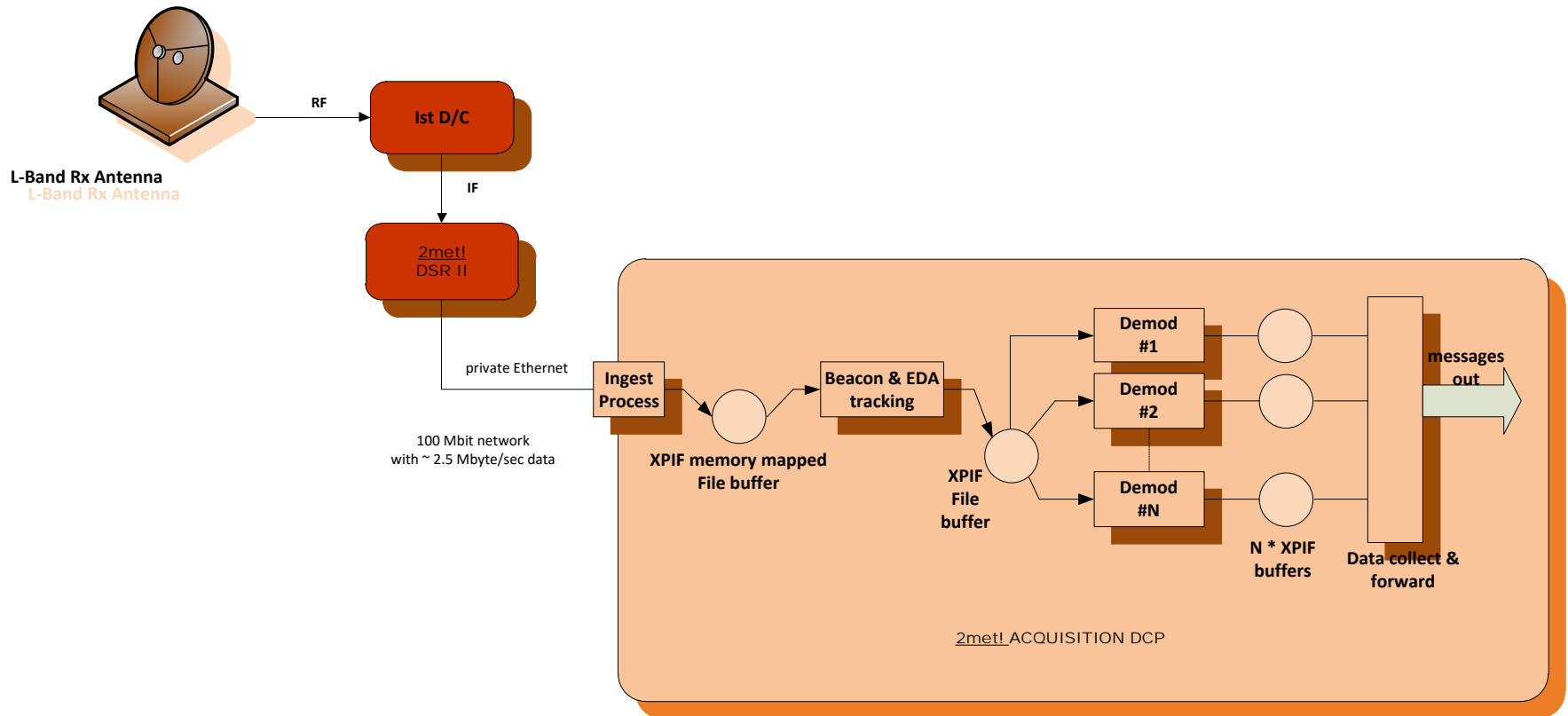
DCS System block diagram

# Data Collection System



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

# Direct Reception Ground Station for DCP

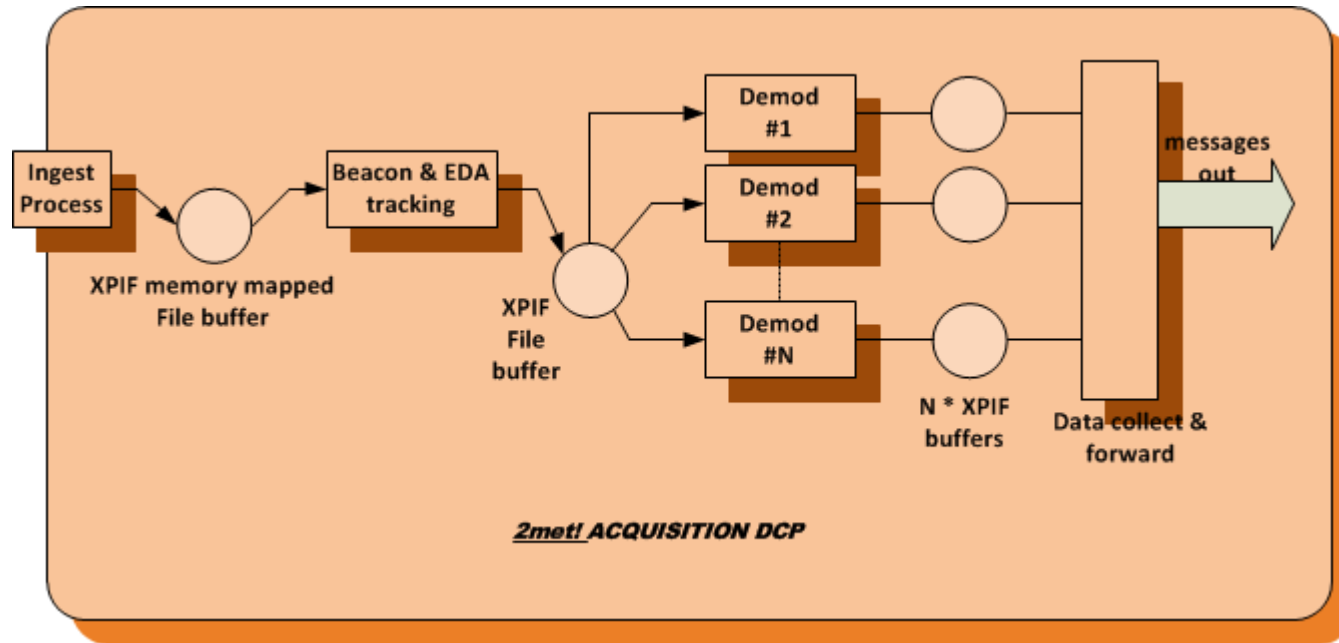


DRGS block diagram showing main building blocks

## Digitizer (DSR II)

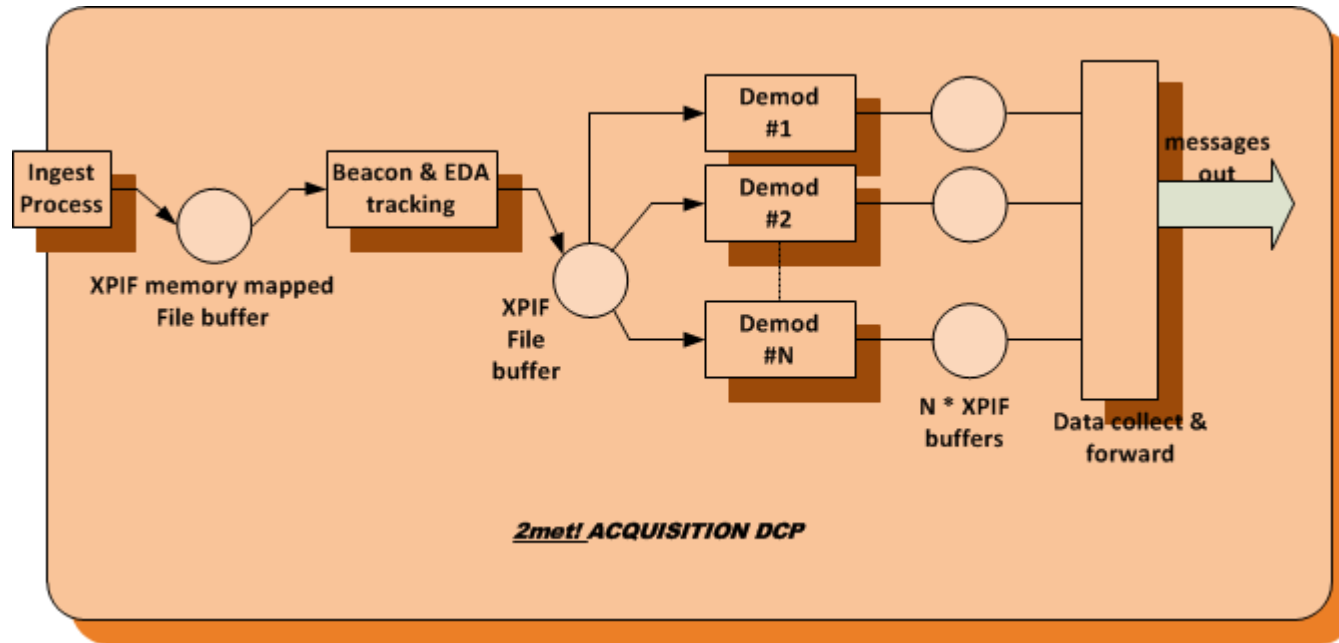
- 1st IF 130 – 150 MHz (customization is possible)
- Conversion to final IF of around 13.75 MHz
- Digitization and Conversion to a complex baseband signal centered on zero Hz
- Two internal AGC (Automatic Gain Control) systems
- NTP (Network Time Protocol) over the Ethernet
- Output
  - » Stream of 16 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

# SDR Architecture

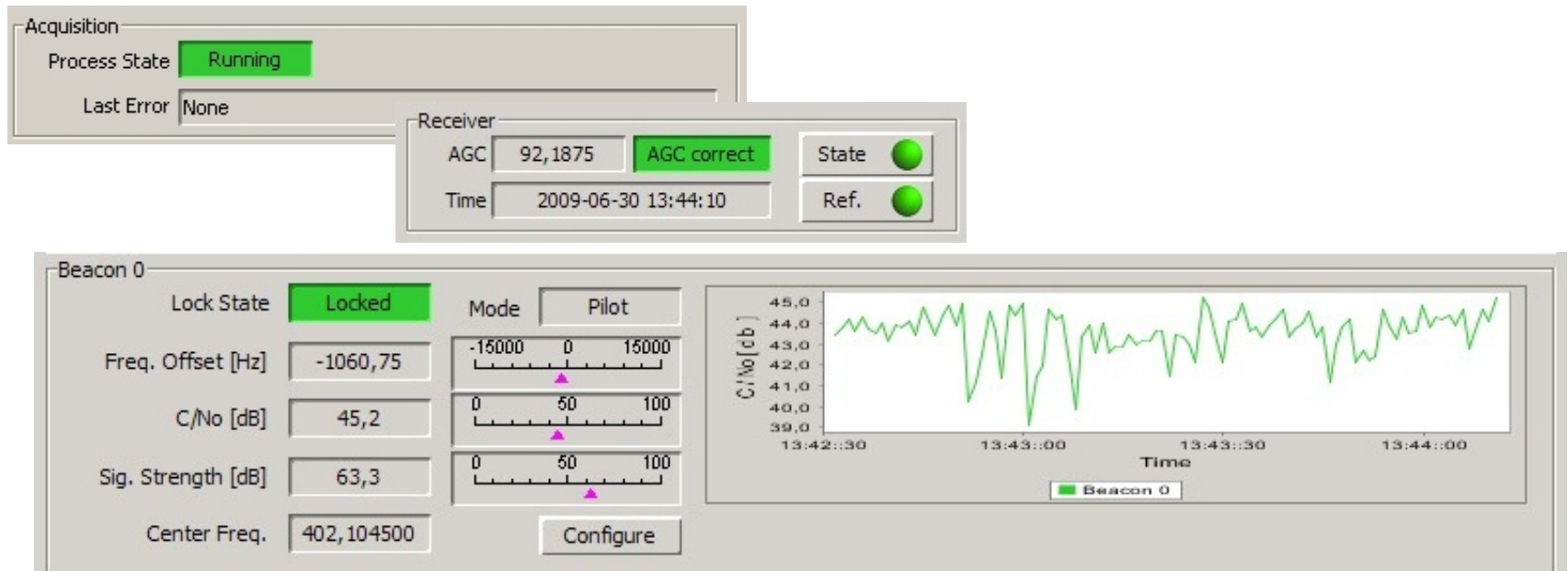


- Interfaces between “near-real-time” processes
  - » Circular buffer implemented as a memory-mapped file
  - » Memory-mapping allows for virtually no disk IO
- Circular buffers
  - » Written by one previous process
  - » Read simultaneously by one or many processes
  - » Non-blocking, so rogue process won't impact on others

# Signal Processing

- Beacon Tracker

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



# Signal Processing

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

The screenshot shows a software window titled "EDA Ripple Tracker 1". It contains several input fields and buttons. At the top, there are two buttons: "Correct" and "Configure". Below these are two columns of input fields. The first column is labeled "Peak-Peak" and the second is labeled "RMS". The input fields are: AM [dB] (3,7), PM [deg] (42,4), Spin Track Freq. [Hz] (53,224), Carrier Offset [Hz] (-0.04), and Center Freq. [MHz] (402.104500). At the bottom, there are two buttons: "Carrier" and "Ripple", each with a green indicator light.

Mode	Correct	Configure
Peak-Peak		RMS
AM [dB]	3,7	0,7
PM [deg]	42,4	9,4
Spin Track Freq. [Hz]	53,224	
Carrier Offset [Hz]	-0.04	
Center Freq. [MHz]	402.104500	
Carrier	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Ripple	<input type="checkbox"/>	<input checked="" type="checkbox"/>



# 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

The screenshot displays the 'Demodulators' GUI. At the top, the 'State Overview' section shows 'Receiver' (green circle), 'Acquisition' (green bar), 'Running' (green bar), and 'Beacon' (green bar). The '2met!' logo is visible. The 'Demodulator States' section shows a 4x10 grid of buttons numbered 001 to 040. Button 024 is highlighted in green. Below this is a table with columns: #, Channel, Type, ChannelFreq, FreqOffset, EIRP, C, BS, FS, Spacecraft, and ProcNum. The table lists demodulators 021 through 030. A 'Groups' list on the left shows 'DemodGroup03' selected. At the bottom left, there are 'Leaf' and 'Value' buttons.

**Demodulator States Grid:**

001	002	003	004	005	006	007	008	009	010
011	012	013	014	015	016	017	018	019	020
021	022	023	024	025	026	027	028	029	030
031	032	033	034	035	036	037	038	039	040

**Demodulator Data Table:**

#	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

The screenshot displays the 'Demodulator Details - Demodulator Details - 024' window. At the top, the 'Demodulator Number' is 024, and the 'State' is 'Receiving'. Three status indicators (Carrier, Bitsync, FrameSync) are shown as green circles. The SCISYS logo is in the top right corner.

**General**

Channel	24	Channel Freq. [MHz]	402.071500	Eb/No [dB]	20.3
Type	100 Baud	Freq. Offset [Hz]	86.00	Viterbi Eb/No [dB]	0.0
Modulation Index [°]	57.4	EIRP [dBm]	40.1	Spacecraft	MSG

**Last Message**

DCP Address	12AA03C4	Freq. Stab. [Hz/s]	-0.42	Worst Case	-1.22
Type	Pseudo Binary	B/R Freq. Off. [Bits/s]	-0.0040	Worst Case	0.0103
Msg. Length [Bytes]	637	Freq. Offset [Hz]	-1.26	EIRP [dBm]	38.5
Carrier Lock Time	30 Jun 2009 13:45:59.966	Bitsync Lock Time	30 Jun 2009 13:46:05.030		
Carrier Unlock Time	30 Jun 2009 13:46:58.551	ASM (FSS) Detection Time	30 Jun 2009 13:46:07.355		

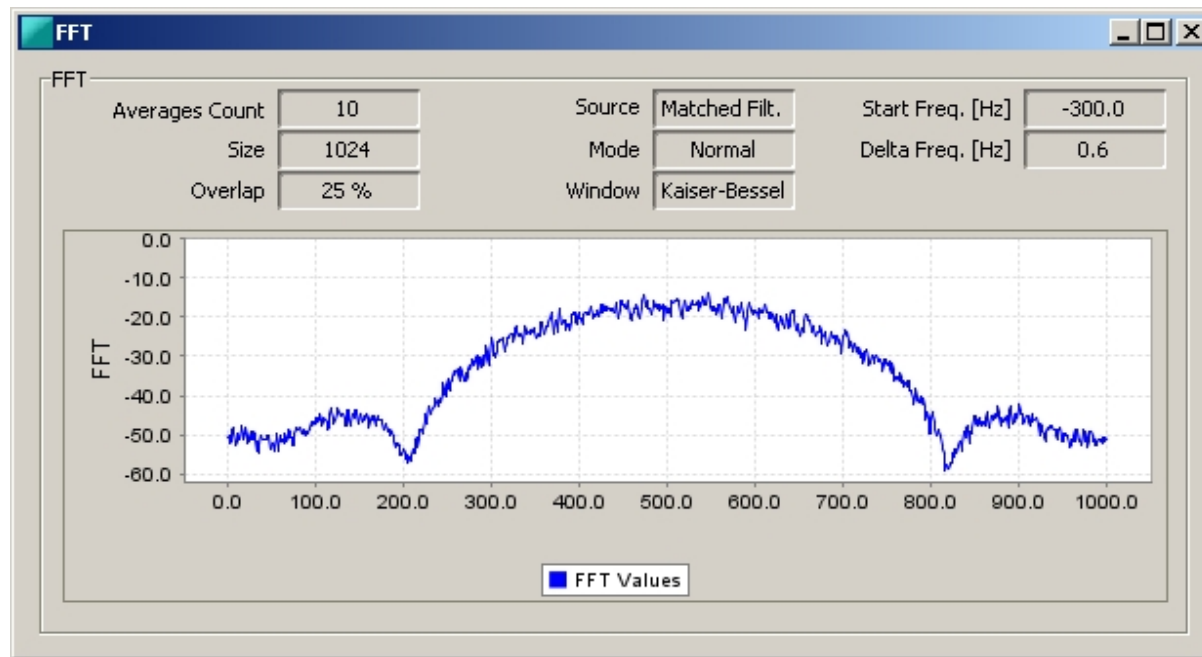
**Last Error Report**

ASM Errors	0	EOT Errors	0	EOT	OK
Parity Errors	0	BCH Errors	0	BCH	OK
CRC	OK	RS Corrections	0	Reed-Solomon	OK
Message Length	OK	DSR-2 AGC	OK	Block Sequence	OK
Freq. Reference	Locked	Beacon	Locked		

The 2met! logo is located in the bottom right corner of the window.

# Signal Processing

- Analysis FFT GUI



# 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!**

# The End



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