

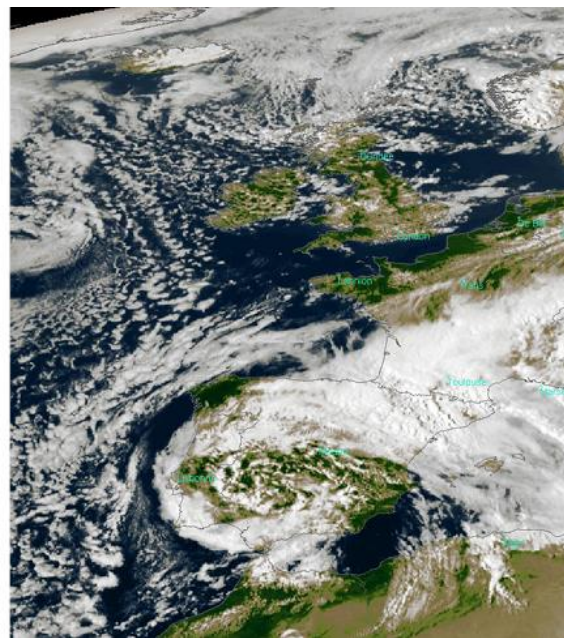


# SCISYS DCP Activities

## Presentation

Dr. Paul Crawford & Thomas Mehr

October 10<sup>th</sup>, 2018

A screenshot of the PLENER software interface, showing a dashboard with various monitoring and control options. The interface includes a sidebar with navigation menus, a main display area with performance metrics, and a process list on the right.

**PLENTER** Dashboard Mission Operations Flight Dynamics Operations Preparation Settings Help

**Monitoring**

- Space-Segment
- Ground-Segment
- Control Centre
- Job-View
- System-CA
- PLENTER-1
- PLENTER-2
- Spacecraft...
- Automation
- Mission Ar...
- FDS
- UI Server
- Logic-View
- Ground Stations

**PERFORMANCE**

system.control.dcp.plenter172.16.102.13

CPU total: 16.54%

Memory total: 67.26%

Disk total: 11.24%

**System**

Uptime: 156 17:37:35

Users: 1

Processes: 126

Load 1: 1.39

Load 2: 1.1%

Load 3: 1.5

**CPU**

Usage: 16.54%

User: 13.6%

Root: 89%

System: 16.54%

**Memory**

Size	Memory	Virtual
1.92 GB	1004.60 MB	
Used: 1.72 GB	164.28 MB	
Free: 75.18 MB	839.32 MB	
Usage: 89.76%	16.4%	11.8%

**PROCESSES**

Process ID	Name	Type	Parameters	Path	Status
5541	0.0 plenler.contr	4	Hitux drad.depender.control-system-manager start	/usr/bin/sh	2
5545	0.0 java	4	-Xmx1024M -Xms1024M -Dlog.dir=/usr/local/embod-2 -Dlog.dir=CORSA-CORSA-CORSA-javacat.org.CORSA -Dlog.dir=CORSA-CORSA-javacat.org.CORSA	/usr/bin/java	2
1654	0.0 main	4	-	/usr/bin/ncp/ncp/main	2
581	0.0 rtpd	4	-i rtp rtp-g	/usr/bin/rtpd	2
626	0.0 wpa_supplicant	4	-i -f /usr/bin/wpa_supplicant.conf -c /usr/bin/wpa_supplicant.conf -i /usr/bin/wpa_supplicant -p /usr/bin/wpa_supplicant	/usr/bin/wpa_supplicant	2
5343	0.0 ranserv	4	-i /usr/bin/plenler-c -ctrl -S -c 0 -idrvhul 2-8-1 -i /usr/bin/plenler-c -ctrl -S -c 0 -idrvhul 2-8-1	/usr/bin/ranserv	2
555	0.0 smartd	4	-i -i never	/usr/bin/smartd	2
899	0.0 cron	4	-i	/usr/bin/cron	2
558	0.0 rsyslogd	4	-i	/usr/bin/rsyslogd	2
529	0.0 avahi	4	-i	/usr/bin/avahi	2
837	0.0 smpd	4	-L50-60-f	/usr/bin/smpd	1
5236	0.0 p4mp	4	-f -i -i -i	p4mp	2
1365	0.0 ping	4	-f -i -i -i	ping	2

**EVENTVIEW**

2017-08-21 20:07:20

2017-08-17 13:04:169

A remote monitoring ca... registered for path "/usr/bin/ncp/ncp/main"

2017-08-08 08:35:713

A new remote monitor... registered for path "/usr/bin/ncp/ncp/main"

2017-08-08 08:35:713

A new remote monitor... registered for path "/usr/bin/ncp/ncp/main"

2017-08-10 04:35:068

A new remote monitor... registered for path "/usr/bin/ncp/ncp/main"

2017-08-10 04:35:068

A new remote monitor... registered for path "/usr/bin/ncp/ncp/main"

2017-08-13 04:31:883

A new remote monitor... registered for path "/usr/bin/ncp/ncp/main"

2017-08-13 04:31:883

A new remote monitor... registered for path "/usr/bin/ncp/ncp/main"

2017-08-13 00:35:950

A new remote monitor... registered for path "/usr/bin/ncp/ncp/main"

2017-08-13 00:35:950

A new remote monitor... registered for path "/usr/bin/ncp/ncp/main"

# Agenda – SCISYS History of DCP Involvement

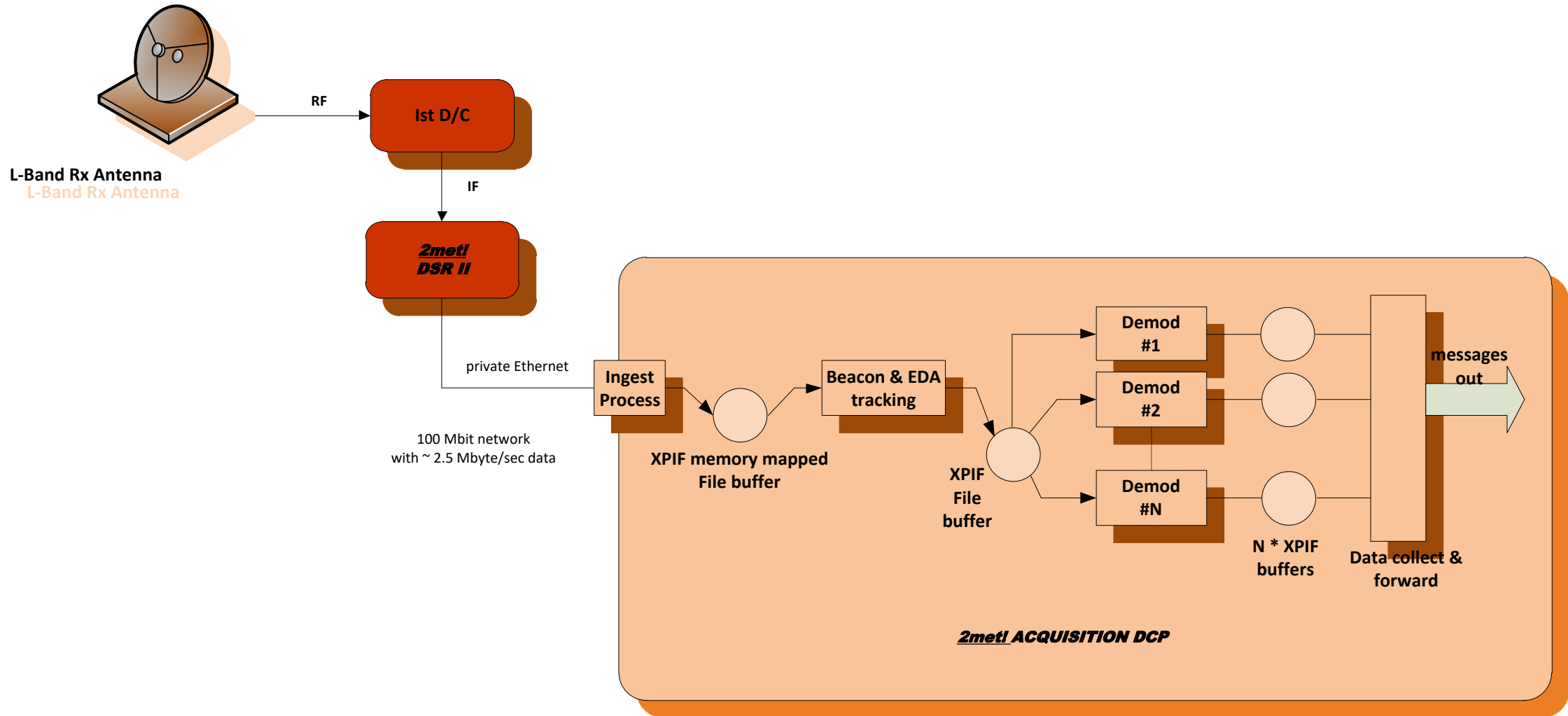
- DRGS (Direct Readout Ground Station)
- HRDCP – Eumetsat Study on New Generation DCP Protocol
- Adaption of DRGS for Eumetsat MTP & MSG
- DRGS & Simulation Tools for Eumetsat MTG
- DCP Transmitter – ESA ARTES-5.1 Project
  - » Transmitter Prototype Development
  - » New Air Radio Interface – now known as “Enhanced DCP”



# DRGS (Direct Readout Ground Station)

## Principle of Operation

# DRGS – Block Diagram

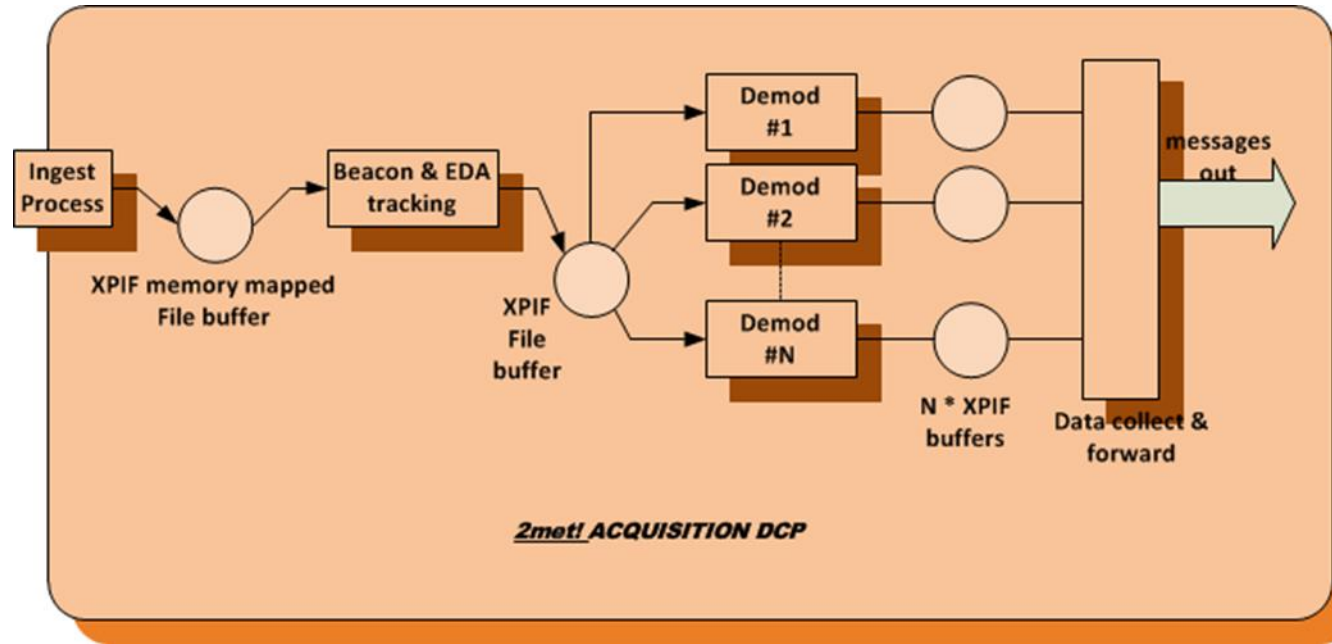


# DRGS – Overview

- Common principle for
  - » MSG/MTP SRDCP (100 Baud) & HRDCP (1200 Baud)
  - » GOES 300 Baud & 1200 Baud
  - » INSAT (4800 Baud)
  - » (EDCP)
- Antenna receives analogue signal in L-band
- Downconversion to 1st IF (140MHz / 70MHz)
- DSRII digitises to complex baseband signal
- Data samples forwarded via Ethernet
- Further data processing performed in software (SDR)

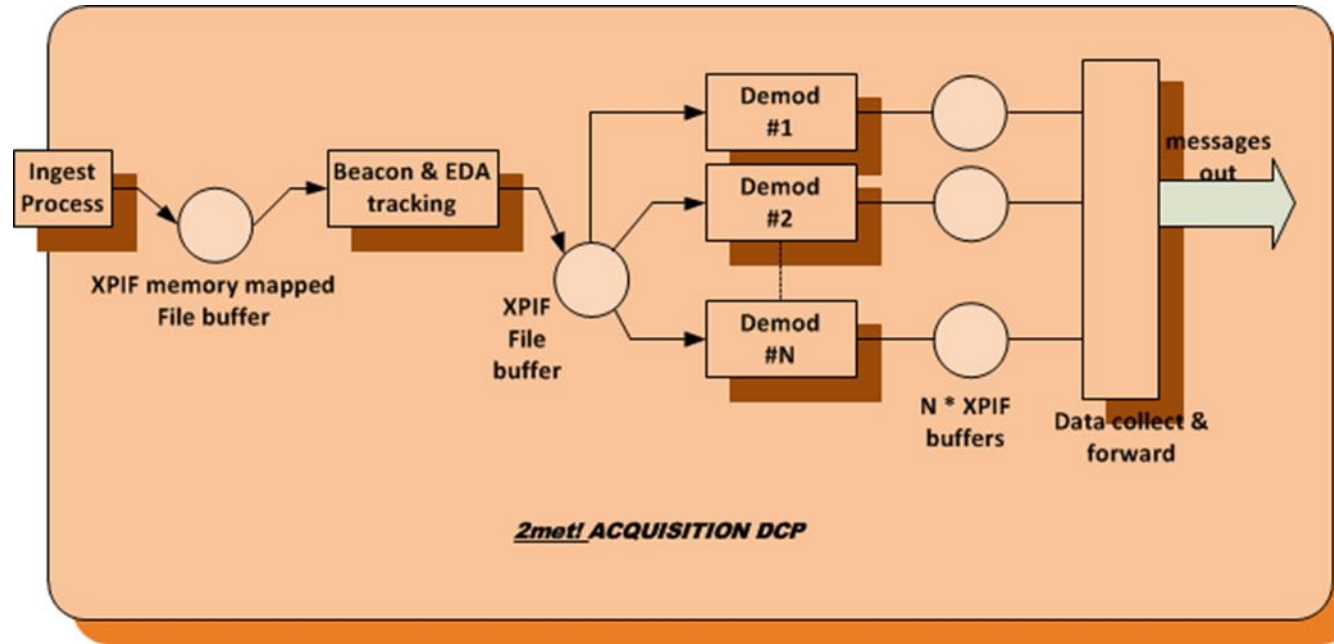
- IF Input 130 – 150 MHz / 70MHz (customization is possible)
- Conversion to final IF of around 13.75 MHz / 10.5 MHz
- Digitization and conversion to a complex baseband signal centered on zero Hz
- Two internal AGC (Automatic Gain Control) systems
- NTP (Network Time Protocol) over Ethernet
- Output
  - » Stream of 16 bit I/Q complex samples
  - » 500 kHz sample rate
  - » Additional monitoring data and time stamping
  - » 2.5 MByte/second

# DRGS – SDR Architecture 1



- Stand alone processing packages
  - » Beacon Tracking
  - » EDA Tracking
  - » Demodulation
- Additional: Data Ingest, M&C, Message Dispatch

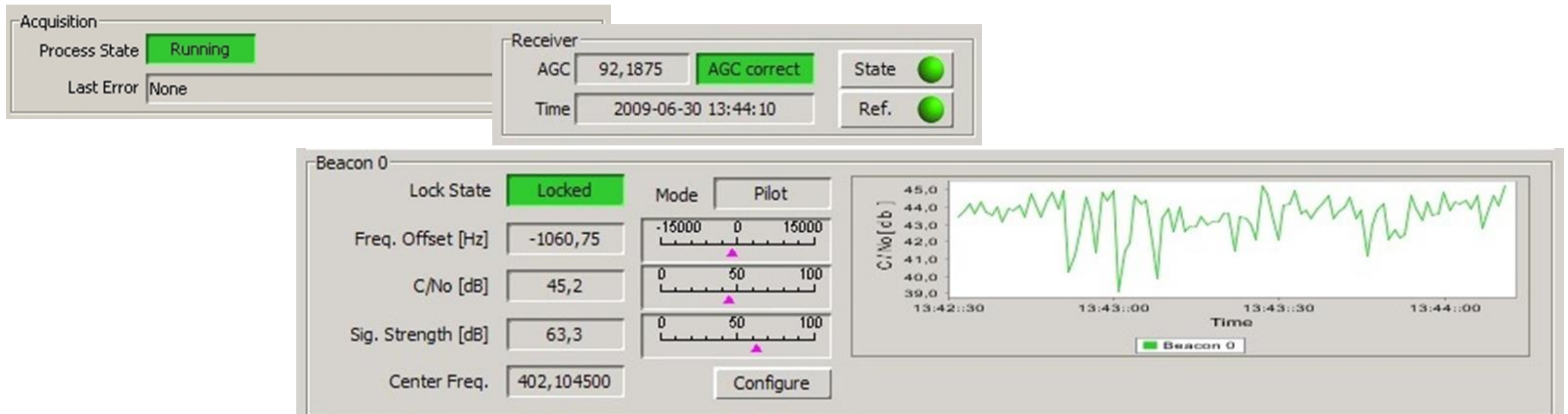
# DRGS – SDR Architecture 2



- Interfaces between “near-real-time” processes
  - » Circular buffers implemented as memory-mapped files
  - » Memory-mapping allows for virtually no disk IO
- Circular buffers
  - » Read simultaneously by one or many processes (Non-blocking)

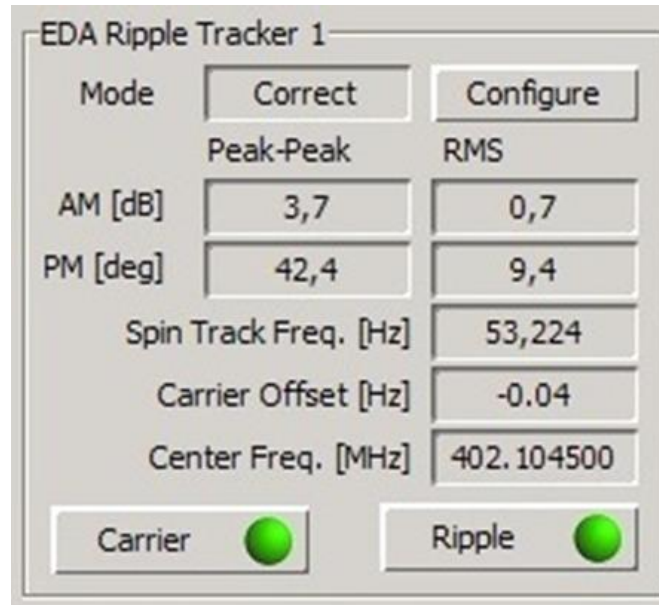
# DRGS - Beacon Tracker

- Frequency correction and amplitude calibration based on a known uplink beacon (pilot) signal
- Support of multiple beacons
- Can also use “message feedback” where properly received DCP transmissions are used for a statistical estimate of those parameters



# DRGS – EDA Tracker

- Adaptive correction of phase and amplitude ripple induced by the Meteosat 1st and 2nd generation Electronically De-spun Array antenna
- This process was added later on EUMETSAT request



EDA Ripple Tracker 1

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

# DRGS – Demodulator

- Performs 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

**Demodulator Details - Demodulator Details - 024**

Demodulator Number: 024  
State: Receiving  
Carrier:  Bitsync:  FrameSync:  SCISYS

**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**

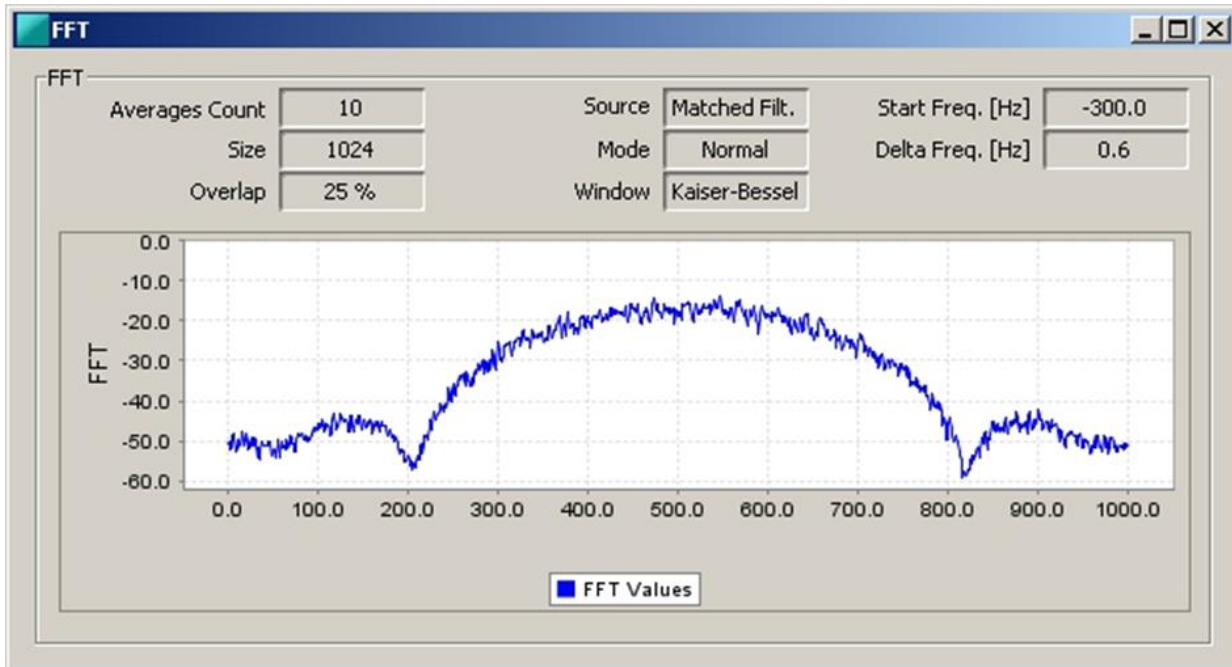
ASM Errors	0	EOT Errors	0	EOT	OK
Parity Errors	0	BCH Errors	0	BCH	OK
CRC	OK	RS Corrections	0	Reed-Solomon	OK
Message Length	OK	DSR-2 AGC	OK	Block Sequence	OK
Freq. Reference	Locked	Beacon	Locked		

2met!

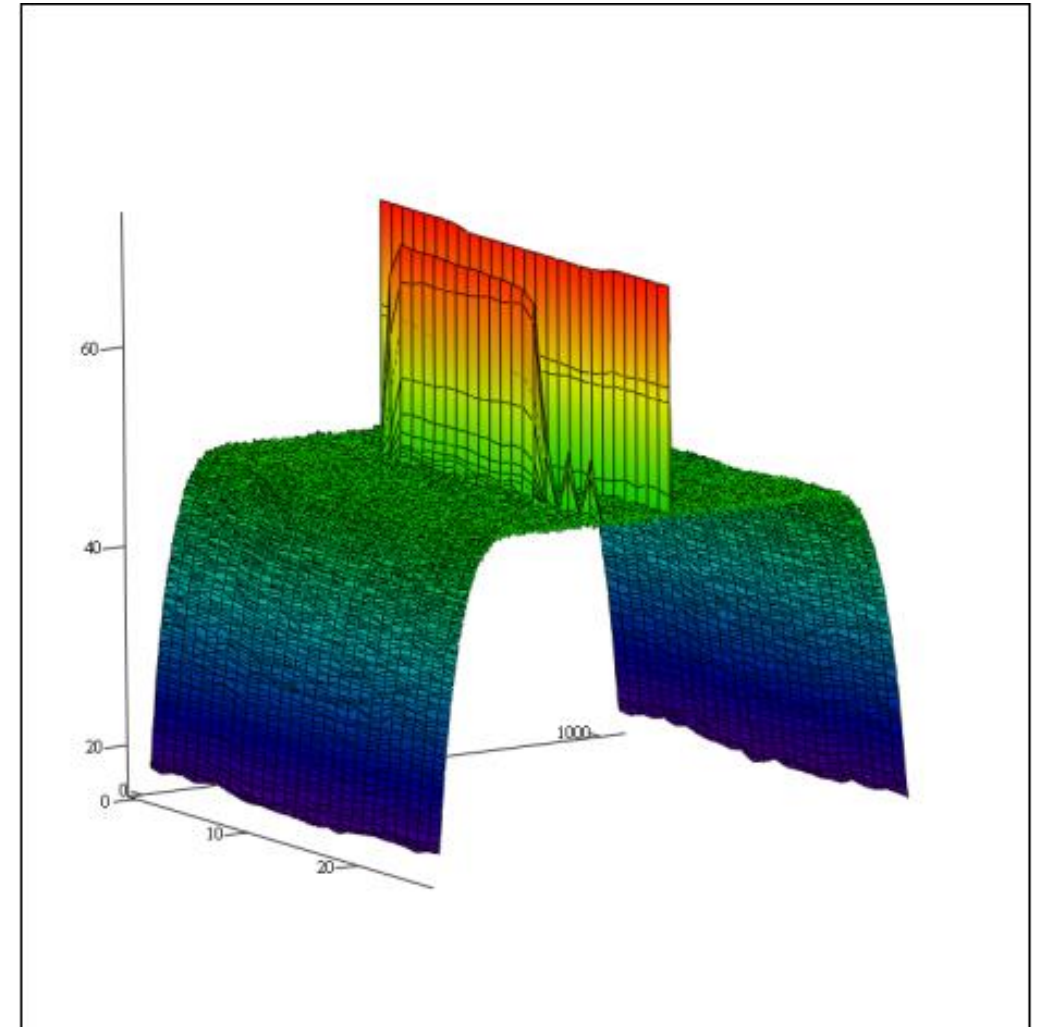
# DRGS – SDR Advantages

- 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 by 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-TX fault, interference, etc.)

## Real-Time FFT



## Retrospective Analysis



mat

# HRDCP – Meteosat High Rate DCP

Eumetsat Study on New Generation DCP Protocol  
Pre-Operational Prototyping Phase

- Shortcomings of legacy SRDCP
  - » Low data rate (100bps)
  - » No FEC → High  $E_b/N_o$  required for acceptable BER
  - » Poor resilience with respect to pulsed interference
  - » Error detection based on parity bits only
  - » Poor data rate to bandwidth ratio
  - » Uses limited alphabet only not suited to binary/compressed data transfer

- Problems with GOES DCP
  - » 8-PSK modulation very sensitive to phase noise or platform movement
  - » Trellis coding needs 7dB  $E_b/N_o$  for 1E-6 BER
  - » Poor resilience with respect to pulsed interference
  - » Typically needs 2-4dB more  $E_b/N_o$  than FEC requirement (due to phase noise and carrier recovery issues)
  - » Error detection based on parity bits
  - » Options for binary mode, RS FEC and compression foreseen, but not yet standardised or implemented

# HRDCP – Goals

- Similar data rates to GOES (1200 Baud in 3kHz channel) but more power efficient (lower  $E_b/N_o$ )
- Robustness w.r.t. phase noise, platform movement, pulsed interference
- Modulation and coding scheme capable to cope also with AM/PM ripple induced by Electronically Despuned Antenna
- Reliable message throughput,  $1E-5$  message failure rate (rather than BER)
- Indication of good/bad status
- Use CCSDS recommendations whenever possible

# HRDCP – Characteristics

- Use of Offset QPSK modulation for reasonable bandwidth efficiency and phase noise tolerance (also BPSK mode available for testing)
- Concatenated FEC system using CCSDS recommended convolution & Reed-Solomon codes, good with pulsed interference
- Binary message system with very robust error checking using a 32-bit CRC, suited to compressed or uncompressed data of any type
- Live tests showed good operation to an  $E_b/N_o$  of 5dB, around 5dB better in practice than the GOES 1200 Baud system (→ only 32% TX power needed)

# HRDCP – Implementation

- Transmitter
  - » Software based design using an Agilent E4403B signal generator with its real time modulation option
  - » Laboratory grade signal purity and stability
  - » Output at 70MHz IF for laboratory tests (receiver input) or at 402MHz as exciter for UHF high power amplifier during live satellite testing
- Receiver
  - » Existing DRGS system with extensions developed for HRDCP use
  - » 4 physical Baud rates (300, 600, 1200 and 2400)
  - » 2 modulation types (BPSK and the preferred OQPSK)
  - » Selection of RS and convolution code combinations

# MTG

## DRGS & Simulation tools for Eumetsat MTG

# MTG – DCP Concept

- Modification of DCP downlink
  - » Not using the “bent pipe” analogue transponder common in L-band
  - » Avoid very demanding phase noise specification in Ka-band
- On-board digitization of UHF uplink (12 bit / 3Msps)
- Digitized data stream multiplexed into the other instrument data streams and transmitted to the Ground Stations in Ka Band
- Signal acquisition, demodulation, decoding and demultiplexing at two redundant Ground Stations
- Ground station diversity to allow for compensation of susceptibility to weather conditions in Ka-band downlink.

# MTG – DCP Phase Noise

- TX certification phase noise achievable at UHF with 10MHz reference oscillator specification of -90dBc/Hz at 10Hz offset
  - » Good quality TXCO
- L-band around -100dBc/Hz
  - » Exceptional TCXO or good OCXO
- Ka-band equivalent is better than -122dBc/Hz
  - » High performance OCXO
  - » Difficult for space-qualified part

	Frequency (MHz)	L(f) at 10Hz offset (dBc/Hz)	L(f) at 10MHz	Design value (5dB margin)
UHF	402	-52	-84.1	-90
L-band Ground Station	1,680	-52	-96.5	-102
L-band Spacecraft	1,278	-52	-94.1	-100
Ka-band G/S	18,000	-52	-117.1	-123
Ka-band S/C	17,598	-52	-116.9	-122
Ka-band G/S	26,000	-52	-120.3	-126
Ka-band S/C	25,598	-52	-120.2	-126

# MTG – DCP RX Solution

- Proven DRGS software ported to 64-bit Linux OS
- Additional modules created to support MTG data acquisition
  - » Decapsulation of the sampled data from MTG ground stations
  - » Conversion from 12-bit real to 16-bit I/Q format to match DRGS
- Improved user interface to manage hundreds of channels
- DCP-RX systems consist of three servers
  - » CTRL\_SRV for M&C, Beacon Tracking, Message collection and dispatch
  - » PROC\_SRV for demodulation of up to 704 channels
  - » NAS\_SRV for data dumps (operationally not necessary)
- Fewer DCP channels can easily be implemented on a single server system!

# MTG – DCP RX MMIs

### DCP-RX Overview

**Demodulator Status**

177	178	179	180	181	182	183	184	185	186
187	188	189	190	191	192	193	194	195	196
197	198	199	200	201	202	203	204	205	206
207	208	209	210	211	212	213	214	215	216
217	218	219	220	221	222	223	224	225	226
227	228	229	230	231	232	233	234	235	236
237	238	239	240	241	242	243	244	245	246
247	248	249	250	251	252	253	254	255	256
257	258	259	260	261	262	263	264	265	266
267	268	269	270	271	272	273	274	275	276
277	278	279	280	281	282	283	284	285	286
287	288	289	290	291	292	293	294	295	296
297	298	299	300	301	302	303	304	305	306
307	308	309	310	311	312	313	314	315	316
317	318	319	320	321	322	323	324	325	326
327	328	329	330	331	332	333	334	335	336
337	338	339	340	341	342	343	344	345	346
347	348	349	350	351	352				

Group 1 Group 2 Group 3 Group 4

**Platform & Server Monitoring**

**CTRL\_SRV**

dcpr.ctrl  
Mem: 100%  
CPU: 0%  
Disk: 0%

CMCS

**PROC\_SRV**

dcpr.proc  
Mem: 42%  
CPU: 27%  
Disk: 0%

LMCS

**NAS\_SRV**

dcpr.nassrv  
Mem: 0%  
CPU: 0%  
Disk: 0%

WS

dcpr.rwvks  
Mem: 0%  
CPU: 0%  
Disk: 0%

### Processing Chain

**MDAF**

- Enable Link / Disable Link
- IngestTF: Status: Running
- IQConverter: Status: success
- BeaconTracker: Status: Bypass
- Disseminator: Status: Running

**PROC\_SRV**

- Receiver: Status: Running
- Demodulator: Status: Receiving
- MessageExtractor: Status: Running

**CTRL\_SRV**

- Enable Link / Disable Link
- MessageIF: Status: Running
- EFTS: Status: success

DCP-PE

### FFT Tool 1

Averages Count: 391  
Size: 1024  
Overlap: 25 %

Source: Beacon Corr.  
Mode: Normal  
Window: Kaiser-Bessel

Start Freq. [Hz]: 40150000.0  
Delta Freq. [Hz]: 1464.8

**FFT Tool 2**

Averages Count: 10  
Size: 1024  
Overlap: 25 %

Source: Channel Sel.  
Mode: Normal  
Window: Kaiser-Bessel

Start Freq. [Hz]: 402009687.5  
Delta Freq. [Hz]: 15.3

Groups	#	Chan...	Type	ChannelFreq	FreqOffset	EIRP	C	BS	FS	Spacecraft	ProcNum
DemodGroup01	192	192	100 Baud	401.987500	-39.25	25.0	0	0	0	MTG	181
DemodGroup02	193	193	100 Baud	401.989000	-541.11	25.0	0	0	0	MTG	181
DemodGroup03	194	194	100 Baud	401.990500	-393.99	25.0	0	0	0	MTG	181
DemodGroup04	195	195	100 Baud	401.992000	102.74	25.0	0	0	0	MTG	181
	196	196	100 Baud	401.993500	397.47	25.0	0	0	0	MTG	181
	197	197	100 Baud	401.995000	-215.58	25.0	0	0	0	MTG	181
	198	198	100 Baud	401.996500	-408.49	25.0	0	0	0	MTG	181
	199	199	100 Baud	401.998000	-341.16	25.0	0	0	0	MTG	181
	200	200	100 Baud	401.999500	117.77	25.0	0	0	0	MTG	181
	201	201	100 Baud	402.001000	-452.67	25.0	0	0	0	MTG	181
	202	202	100 Baud	402.002500	-359.47	25.0	0	0	0	MTG	181
	203	203	100 Baud	402.004000	195.36	25.0	0	0	0	MTG	181
	204	204	100 Baud	402.005500	360.59	25.0	0	0	0	MTG	181
	205	205	100 Baud	402.007000	41.32	25.0	0	0	0	MTG	181
	206	206	100 Baud	402.008500	384.94	30.2	0	0	0	MTG	181
	207	207	100 Baud	402.010000	-432.85	35.4	0	0	0	MTG	181
	208	208	2400 OQP...	402.011500	-0.11	62.9	X	X	X	MTG	181
	209	209	100 Baud	402.013000	-233.79	40.9	0	0	0	MTG	181
	210	210	2400 OQP...	402.014500	-0.11	62.9	X	X	X	MTG	181
	211	211	100 Baud	402.016000	-512.81	42.9	0	0	0	MTG	211
	212	212	2400 OQP...	402.017500	-0.10	62.9	X	X	X	MTG	211
	213	213	100 Baud	402.019000	-402.66	41.6	0	0	0	MTG	211
	214	214	2400 OQP...	402.020500	-0.10	62.9	X	X	X	MTG	211
	215	215	100 Baud	402.022000	-596.72	43.0	0	0	0	MTG	211
	216	216	2400 OQP...	402.023500	-39.47	40.6	0	0	0	MTG	211
	217	217	100 Baud	402.025000	480.76	38.6	0	0	0	MTG	211

# MTG – DCP RX MMIs

- Menu Area
  - » Permanently visible
  - » Shows status of software units
  - » Offers start of additional displays and tools



# MTG – DCP RX MMIs

- DCP-RX Overview
  - » Divided into several functional parts

The screenshot displays the DCPF-RX Overview MMIs, which are divided into several functional parts:

- Demodulator Status:** A grid showing the status of demodulators across various channels (353-522). The cell for channel 377 is highlighted in green.
- Processing Chain:** A flowchart showing the data processing pipeline. The components and their statuses are:
  - MDAF:** IngestTF (Status: Running), IQConverter (Status: success), BeaconTracker (Status: Bypass), Disseminator (Status: Running).
  - PROC\_SRV:** Receiver (Status: Running), Demodulator (Status: Receiving), MessageExtractor (Status: Running).
  - CTRL\_SRV:** MessageIF (Status: Running), EFTS (Status: success).
- Platform & Server Monitoring:** A section showing the health of various servers and services:
  - CTRL\_SRV:** dcpf.ctrl (Status: OK), CMCS (Status: OK).
  - PROC\_SRV:** dcpf.proc (Status: OK), LMCS (Status: OK).
  - NAS\_SRV:** dcpf.nassrv (Status: OK), WS (Status: OK), dcpf.rwks (Status: OK).

# MTG – DCP RX MMIs

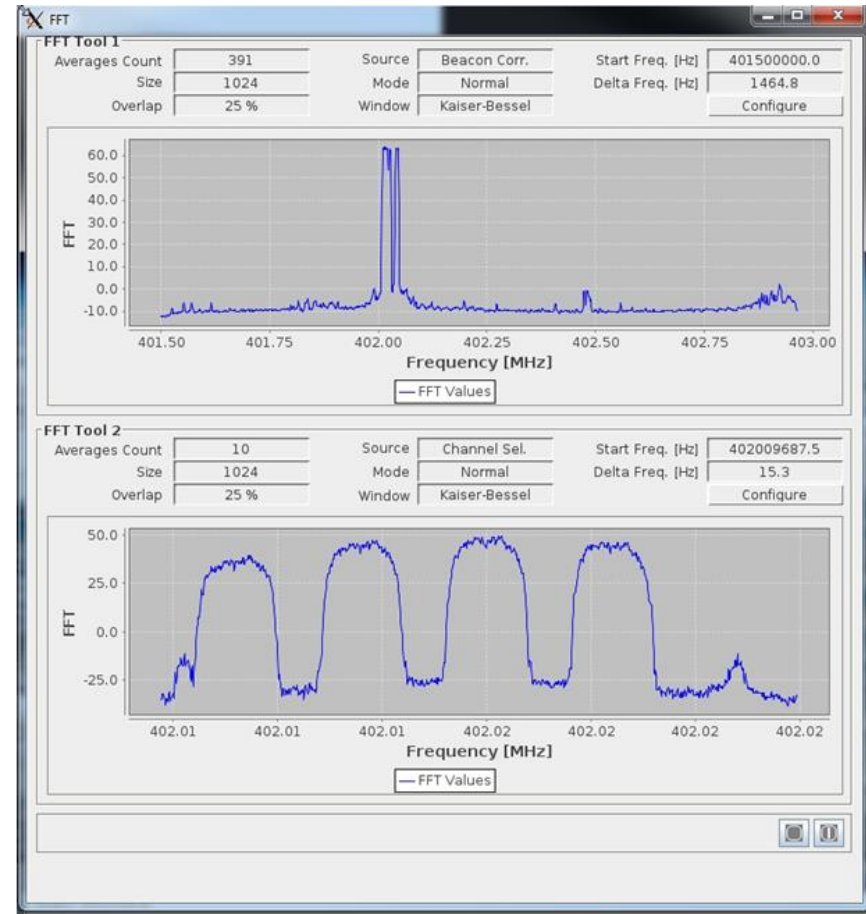
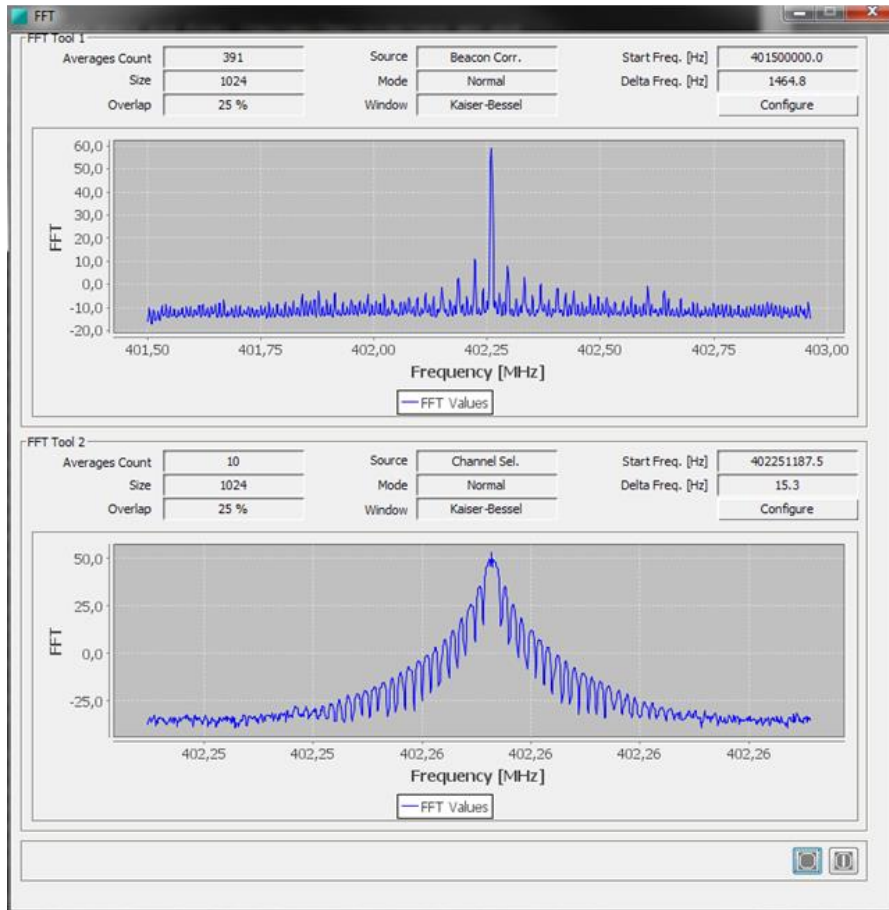
- DCP-RX Overview
  - » Processing Chain: shows the several software units (SUs) from end-to-end
  - » Offers controlling capabilities: enable/disable links, start/stop SUs



# MTG – DCP RX MMIs

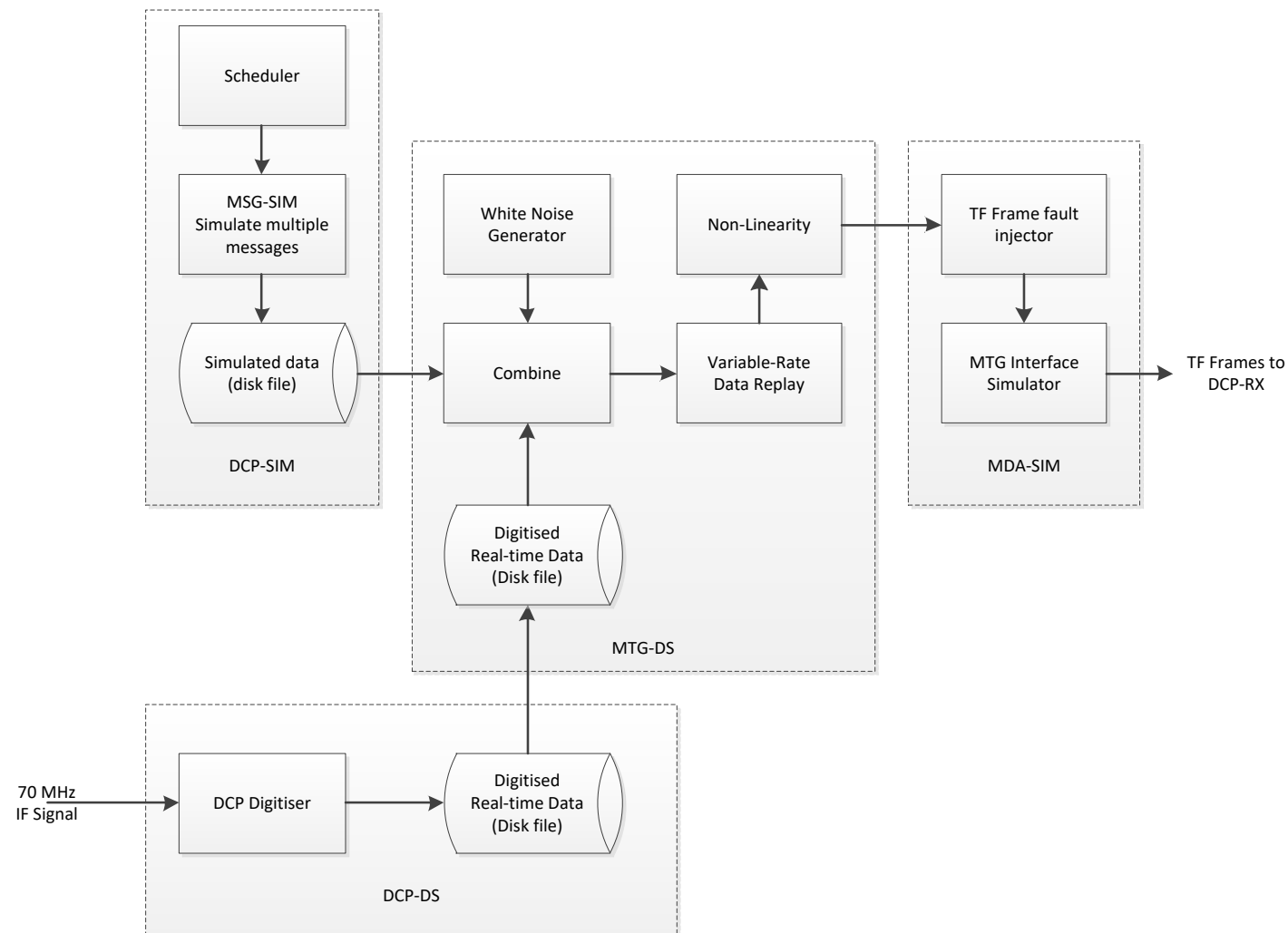
- FFT Tool

- » Shows FFTs, allows to start/stop and reconfigure FFT process
- » Can be used to find problems on the DCP link



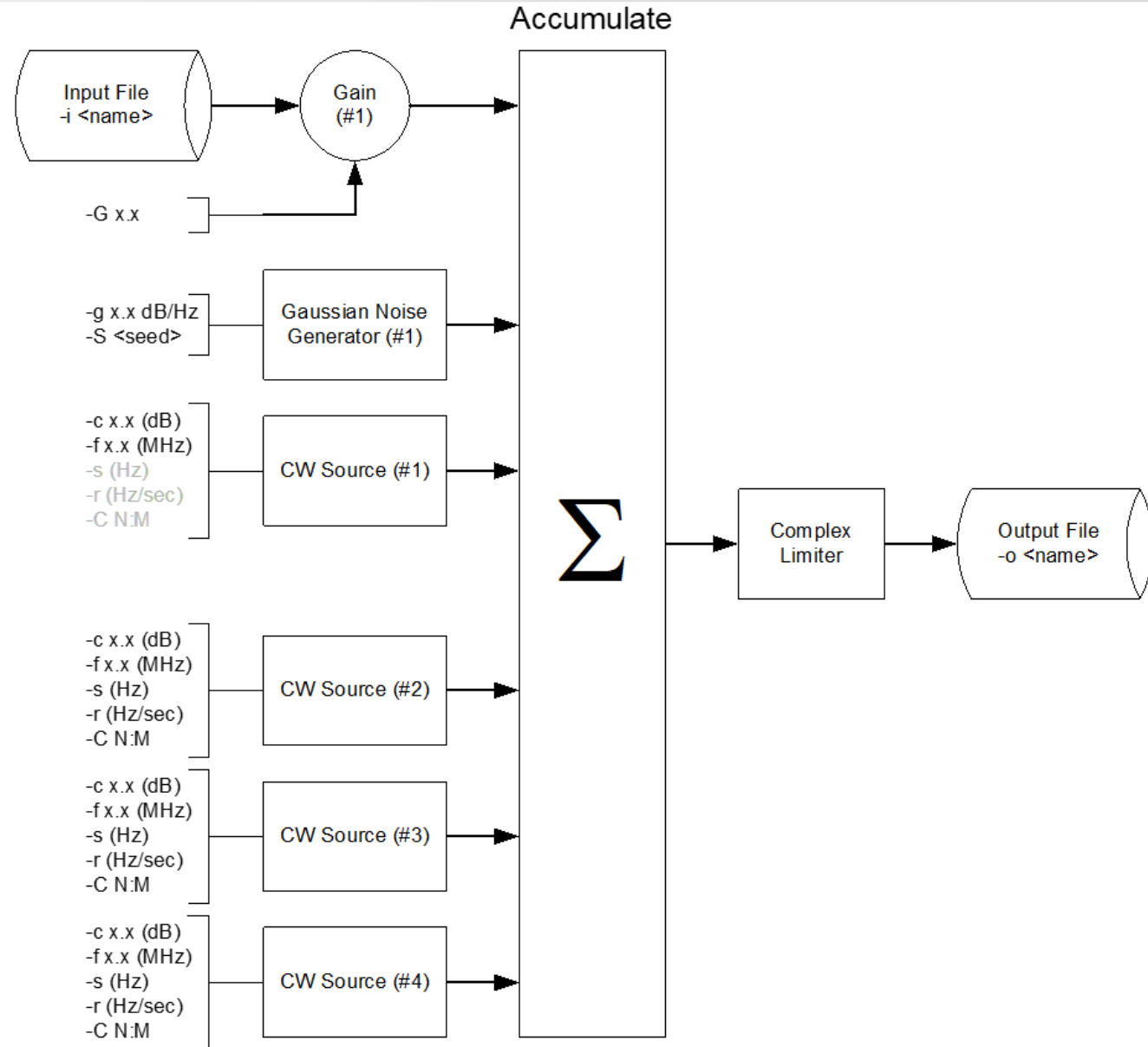
# MTG – Test Concept

- Testing in the absence of the MTG is performed with a test suite provided by SCISYS
- DCP-TST (Test Tools)
  - » **DCP-SIM** - DCP Simulator
  - » **DCP-DS** - DCP Digitiser
  - » **MTG-DS** - MTG Digitiser Simulator
  - » **MDA-SIM** - MTG Mission Data Acquisition Simulator



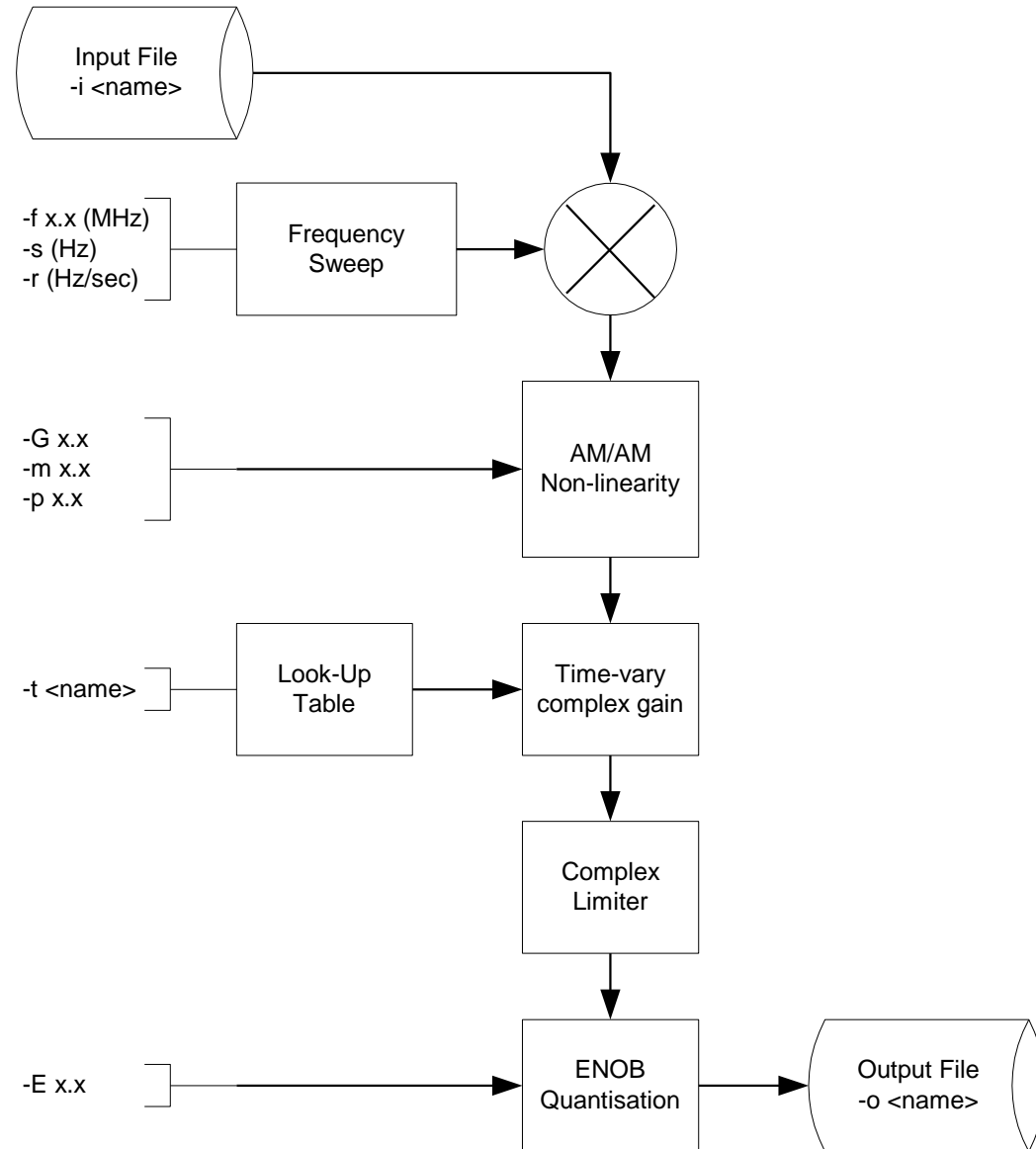
# MTG – Test Concept

## Block Diagram MTG-Combine



# MTG – Test Concept

## Block Diagram MTG-Nonlinearity



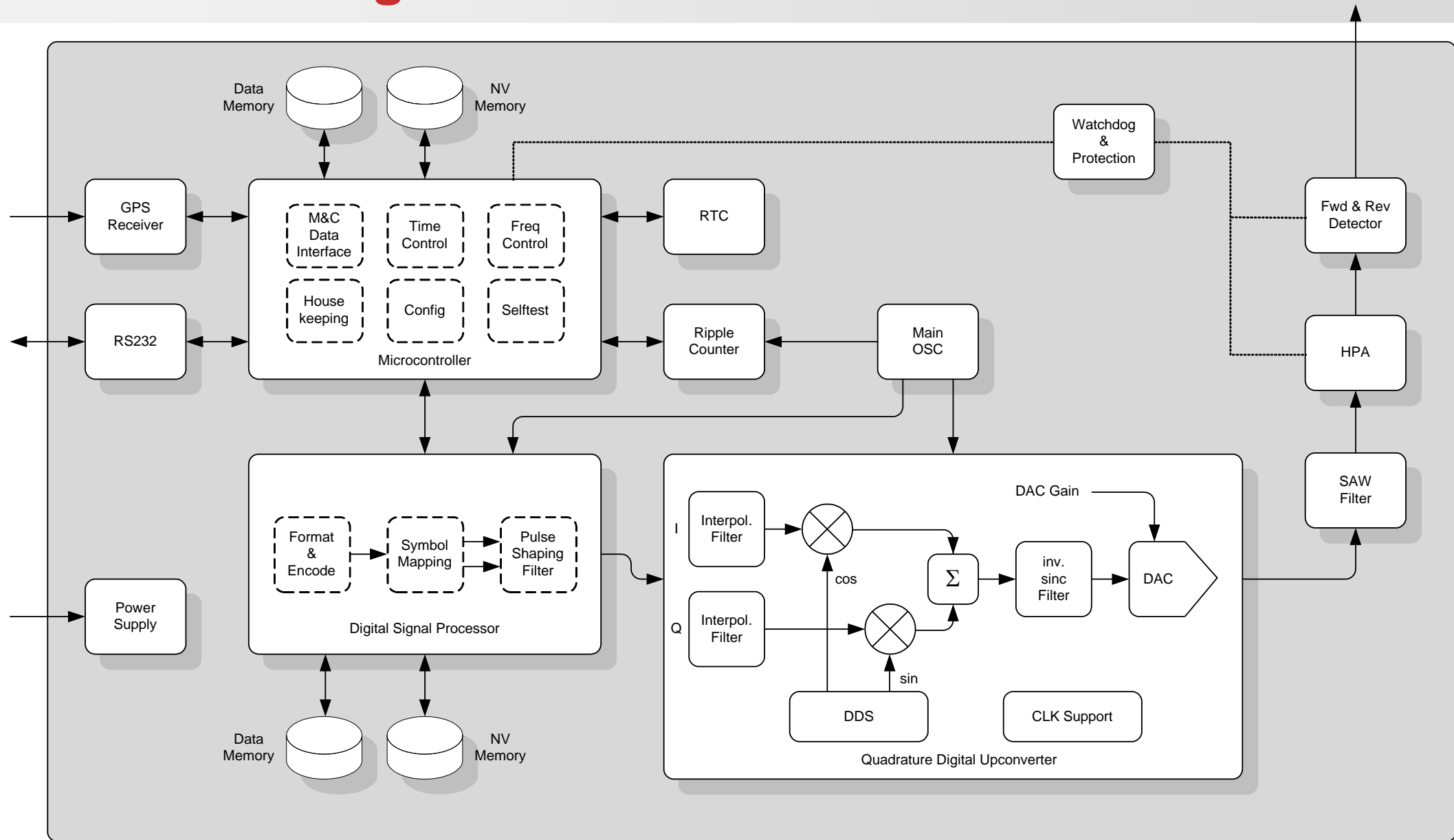
- Possibilities
  - » Generation of complex DCP signals
    - › According to a schedule
    - › Up to 704 DCP signals
    - › Up to one hour repeat pattern
    - › At various power levels and supports ‘error’ cases
  - » Apply
    - › White Gaussian noise
    - › Non-linearity effects
    - › CW signals for pilot or interference simulation
    - › Loss of sample frames
    - › Digital corruption of data for specific demodulator and decoder tests
  - » Further possibilities with appropriate time-varying Look-Up Tables
    - › Apply phase noise
    - › Simulate Ocean Buoy Effects

# Transmitter Prototype Development

# Transmitter Prototype Development – Scope

- Part of Study “High Rate Data Collection Platform Prototype Development” under ESA Contract in ARTES 5.1 Technology Program
- Development of DCP Transmitter Reference Design
  - » Support METEOSAT SR/HR-DCP and GOES-300/1200
  - » Technology / Market Survey
  - » Requirements Analysis & Definition
  - » Architectural & Detailed Design
- Validation of DCP Transmitter Reference Design
  - » Implementation of Engineering Model Prototype (TRL = 5)
  - » Test and Verification
  - » HRDCP Certification

# DCP-TX Block Diagram



- Microcontroller
  - » Scheduling / Timing
  - » User Interface
  - » Power Control
- Baseband Processing in Software (DSP)
  - » Interpolation up to Moderate Sample Rate
  - » Flexibility (Software Defined)
  - » Formatting, Encoding, Pulse Shaping
- I/Q Modulation and Up-Conversion (QDUC)
  - » Final Interpolation, Digital Modulation, Up-Conversion
  - » Carrier NCO Generation, Clock Control
  - » Degree of Integration / Optimisation (FPGA) → low power
  - » LO Leakage, I/Q Imbalance (both better than analogue)

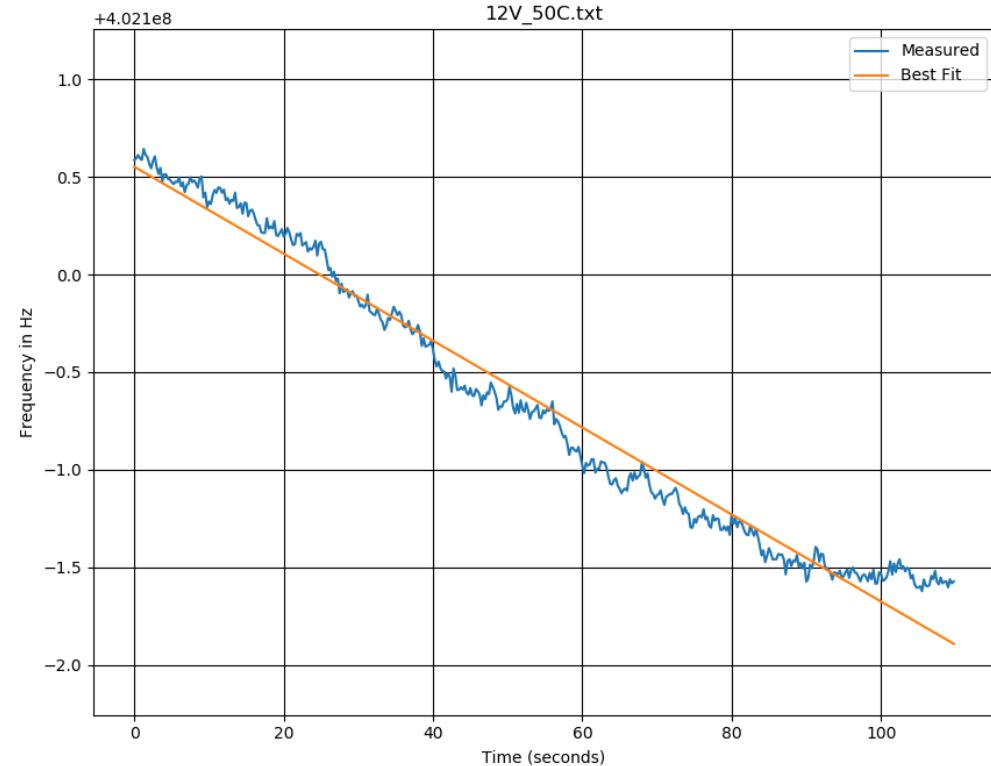
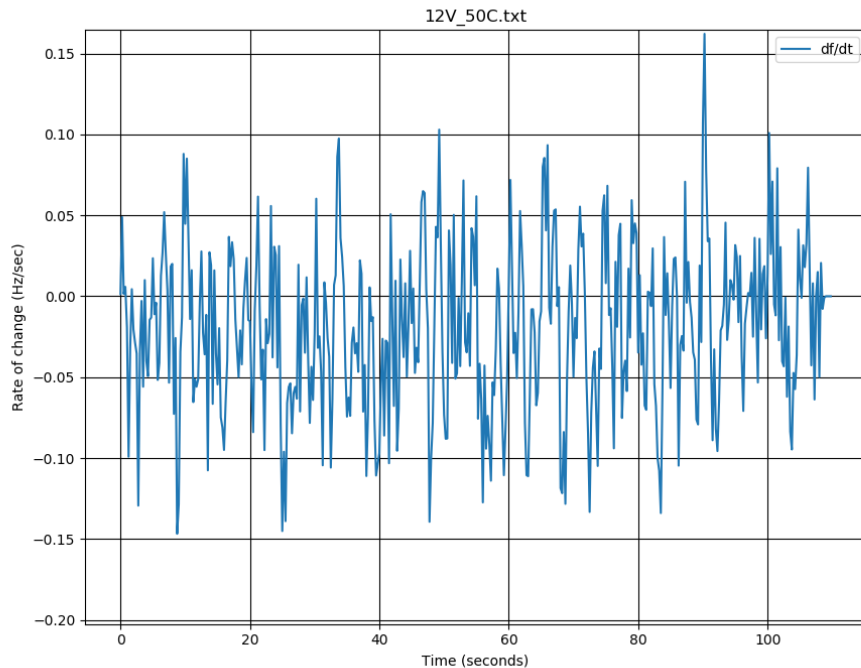
- TCXO
  - » Power Consumption
  - » Phase Noise
  - » Frequency Stability
  - » Size
- Frequency / Time Correction (GPS, Temperature)
  - » Timeliness Requirement (+/- 250ms)
  - » Frequency Accuracy (125Hz @ 400MHz → ~ 0.3ppm)
  - » Frequency Drift during Transmission (1Hz/s)
  - » Operating Temperature Range (-40°C ... +50°C)

# DCP-TX Main Design Drivers

- Frequency Stability / Drift
- Timelines of Transmissions
- Phase Noise
- Low Power Consumption
- Flexibility
- Low Cost
- Maintenance Free
- Operating Temperature / Voltage Range

# Frequency Stability / Drift

- TCXO Stability:  $\pm 0.5\text{ppm}$
- Additional Temperature LUT
- GPS Correction for slow changing effects (e.g. ageing)



Less than 5Hz drift during 110s transmission  
Less than 5Hz drift during > 20 hours of operation  
Rate of change <  $\pm 0.2\text{Hz/s}$

# Timeliness of Transmission

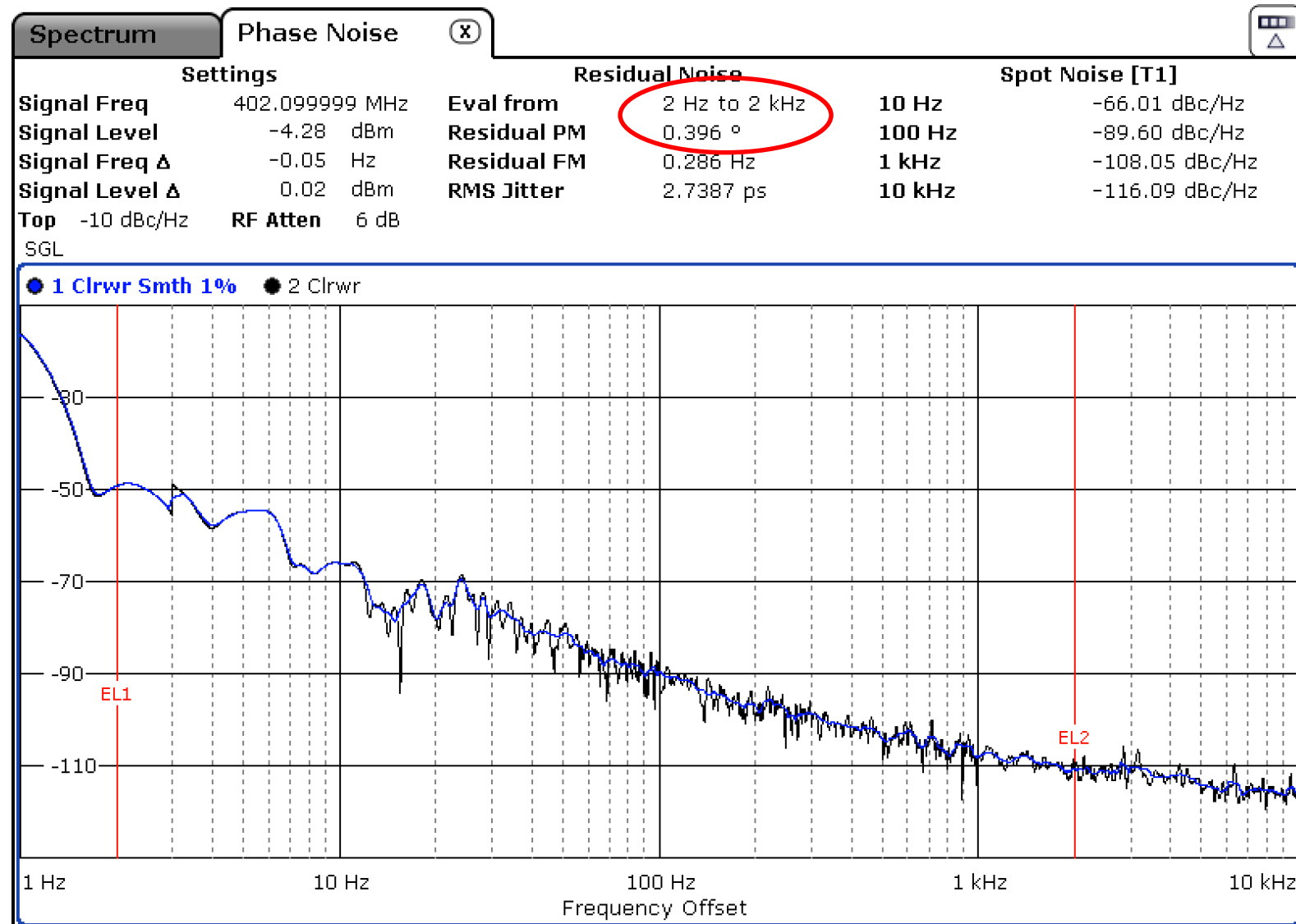
- Requirement:  $\pm 250\text{ms}$

The screenshot shows the 'Demodulator Details - 002' window. At the top, the Demodulator Number is 002 and the State is Active. There are three status indicators: Carrier (off), Bitsync (off), and FrameSync (off). The 'General' section includes: Channel 2, Channel Type 18, Modulation Index 0.0, Channel Freq. 402.002500 MHz, Freq. Offset -10.45 Hz, EIRP 10.7 dBm, Eb/No 30.0 dB, Viterbi Eb/No 12.6 dB, and Spacecraft MTG. The 'Last Message' section shows: DCP Address 162096C4, Type Binary, Msg. Length 665 Bytes, Carrier Lock Time 24 Apr 2018 05:42:01.003, Bitsync Lock Time 24 Apr 2018 05:42:03.054, Freq. Stab. 0.01 Hz/s, B/R Freq. Off. 0.0001 Bits/s, Freq. Offset -0.23 Hz, Worst Case -0.08, Worst Case -0.0023, EIRP 40.2 dBm, Carrier Unlock Time 24 Apr 2018 05:42:18.338, and ASM (FSS) Detection Time 24 Apr 2018 05:42:03.229. The 'Last Error Report' section shows: ASM Errors 0, Parity Errors 0, CRC OK, Message Length OK, Freq. Reference Locked, EOT Errors -1, BCH Errors 0, RS Corrections 0, DSR-2 AGC OK, Beacon Locked, EOT OK, BCH OK, Reed-Solomon OK, and Block Sequence OK. A red arrow points from the 'Carrier Lock Time' field to the text 'Verified by Receiver Time Tags' in the list below.

- GPS Corrected RTC
- Verified by Receiver Time Tags

# Phase Noise

- Spec: 2° RMS when integrated from 2Hz to 1kHz
- → -53dBc/Hz @ 10Hz offset from 400MHz carrier



# Low Power Consumption

- Initial Requirement: max. 10mA @ 12V Idle Power
- Benchmark: 3mA @ 12V Idle Power
- Idle power dominates overall power budget
  - » Microcontroller Power Saving Modes
  - » Voltage Islands controlled by  $\mu\text{C}$
- → 3.5mA @ 12V in Idle Mode

# Flexibility / Costs / Maintenance

- Flexibility
  - » Same hardware for legacy and new air interface
  - » All missions supported by single firmware
- Costs
  - » Usage of “standard” COTS components
  - » Single side populated PCB
  - » Automatic calibration possible
- Maintenance
  - » Fully digital design
  - » No manual adjustments/ re-calibration necessary
  - » No serviceable parts

# Testing

- Laboratory Tests over Full Voltage / Operating Temperature Range
- METEOSAT HRDCP Certification Test
  - » Blind Test (formatting & encoding)
  - » Laboratory Tests
  - » Long Run Test over Satellite
- Simulations

# Delta to Production Unit

- Minor Hardware Improvements to Main PCB
- Better GPS Module
- Operation for long periods without GPS Lock
- Automatic Calibration and Production Tests
- HPA Improvements
- Long Term Tests
- Data Logger Interface

# New Air Radio Interface

Enhanced DCP (EDCP)

# EDCP – Scope

- Part of Study “High Rate Data Collection Platform Prototype Development” under ESA Contract in ARTES 5.1 Technology Program
- Definition of New Air Interface
  - » Analysis of DCP System Scenarios
  - » Survey
  - » Possible Fields of Improvement
  - » Analysis of Compatibility Aspects
  - » Requirements Definition
  - » Architectural & Detailed Design (common hardware)
- Prototype Validation (Proof of Concept)
  - » Implementation of Engineering Model Prototype (TRL < 5)
  - » Design and Implementation of Receiver
  - » Test, Simulation and Verification

# EDCP – Background

- Definition of a new air interface to extend the appeal of the DCP system to both new and existing users
- Potential new options constrained by existing space-side assets
  - » Current and planned DCP transponders on GEO satellites of Eumetsat, NOAA, JMA, etc.
- Conducted a survey of existing and potential new users to find out what aspects are important
- Survey was send to 31 possible participants
- Received 19 responses
- Discussed with Eumtesat who proposed the EDCP name

# EDCP – Additional Resources

- Web pages relating to EDCP are:
  - » ESA project web page: <https://artes.esa.int/projects/hrdcp>
  - » SCISYS web page for DCP: <https://www.2met.com/hrdcp/>
- Document bundle available on request from SCISYS with:
  - » End user survey results
  - » Analysis of survey results
  - » Technical note on data link layer and alert concepts
  - » Extract from final test report covering EDCP simulation
  - » ESA project final report
  - » Eumetsat summary document presented to CGMS

# EDCP – Survey Results

- Almost all suggestions for new use-cases of the DCP system involve movement
  - » Animal tracking & Distress beacons are examples where low power/speed is appropriate.
  - » Aircraft, Ship and Logistics/Transport are examples where current (or higher) speed operation is appropriate.
- Other questions relating to movement tolerance showed a very strong interest
- The question of data integrity, something already greatly improved with HRDCP over other systems, was one that also drew strong support
- Only other strong opinion was that standby power consumption is an important factor
- SCISYS DCP Activities

# EDCP – Design Constraints

- Largely due to re-use of existing space-side hardware and coexistence with existing DCP users
- Bandwidth
  - » 3000Hz current HRDCP option
  - » Meteosat use currently low so more theoretically possible
  - » 2250Hz for GOES maximum likely
  - » GOES major market
- EIRP
  - » Significantly more than legacy/HRDCP a problem for DC power and possibly spacecraft transponder loading
  - » Significantly less a risk for interference lock problems
- Complexity / Licensing
  - » Wide adoption important for DCS approval, so other manufacturers need easy deployment

# EDCP – Design Study

- Considered wide range of modulation formats
- Coherent modulation considered necessary for good power efficiency
- Analysed models for system phase noise
  - » Oscillators in TX / transponder/ RX
  - » Ocean buoy movements
  - » Ionospheric effects similar
  - » Transport effects simpler (just consider Doppler limit for road / rail / aircraft cases)
- Analysed performance in terms of phase noise tracking for coherent demodulation
- Analysed FEC performance

# EDCP – Design Choices

- Speed around 400 Baud (in 2250Hz channel)
- Proposed modulation is Pi/2 BPSK
  - » Good phase noise tolerance
  - » Low peak to average should ease HPA design
- Also implemented standard BPSK
  - » Same good phase noise tolerance
  - » Low risk as already supported in receiver
- FEC system adapted from HRDCP
  - » Easy implementation for existing manufacturers of HRDCP TX
  - » Has choice of RS code block for better power efficiency with short messages
  - » Has symbol interleaver for better phase noise tolerance
  - » Pilot symbols for advanced tracking in future demodulators
- Data link layer (frame format) same as HRDCP

# EDCP – Performance Simulation

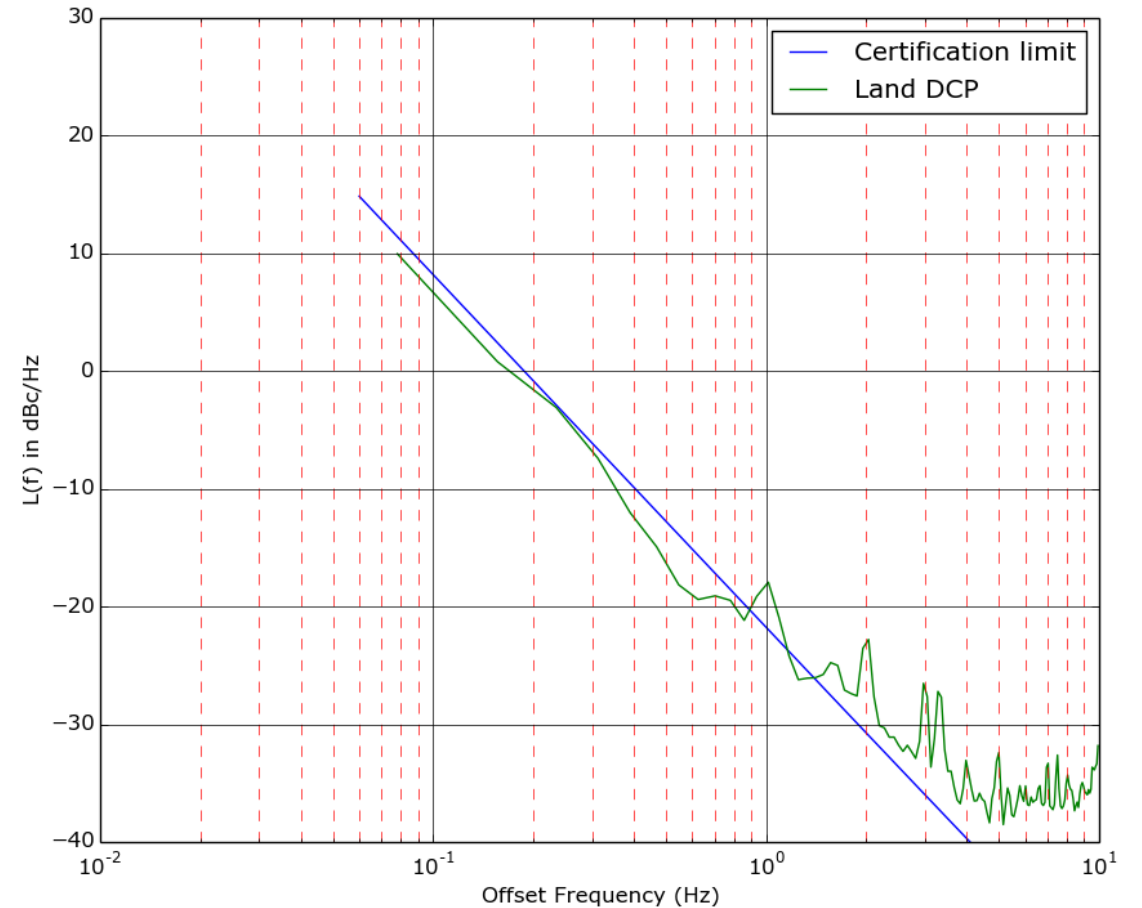
- Used same software demodulator as Eumetsat use for their DCP facility
- Simulation tool chain included:
  - » Gaussian additive noise
  - » Interference from fixed or sweeping/pulsed CW sources
  - » FM and AM effects based on an example ocean buoy message in 15 m/s wind speed storm conditions
- Simulation included legacy systems and EDCP proposal
- ESA project phase noise modelling limited:
  - » Observed ocean buoy effects used
  - » Movement and oscillator noise combined

# EDCP – Further Simulation

- SCISYS supporting masters student Thilo Moldenhauer
- Masters project looking as modelling phase noise and ocean movement effect for use in such simulation tools
- Aim to model:
  - » Land case dominated by oscillator noise
  - » Sea case based on oscillator noise and Pierson-Moskowitz Wave Spectrum
- Some preliminary results from Sep 2018 included here
- Testing with Thilo Moldenhauer also resulted in some minor bug-fixes for the simulation tool chain
- Amplitude effects due to multipath reflection are **not** covered here!
  - » AM effects were used in ESA study based on recorded data

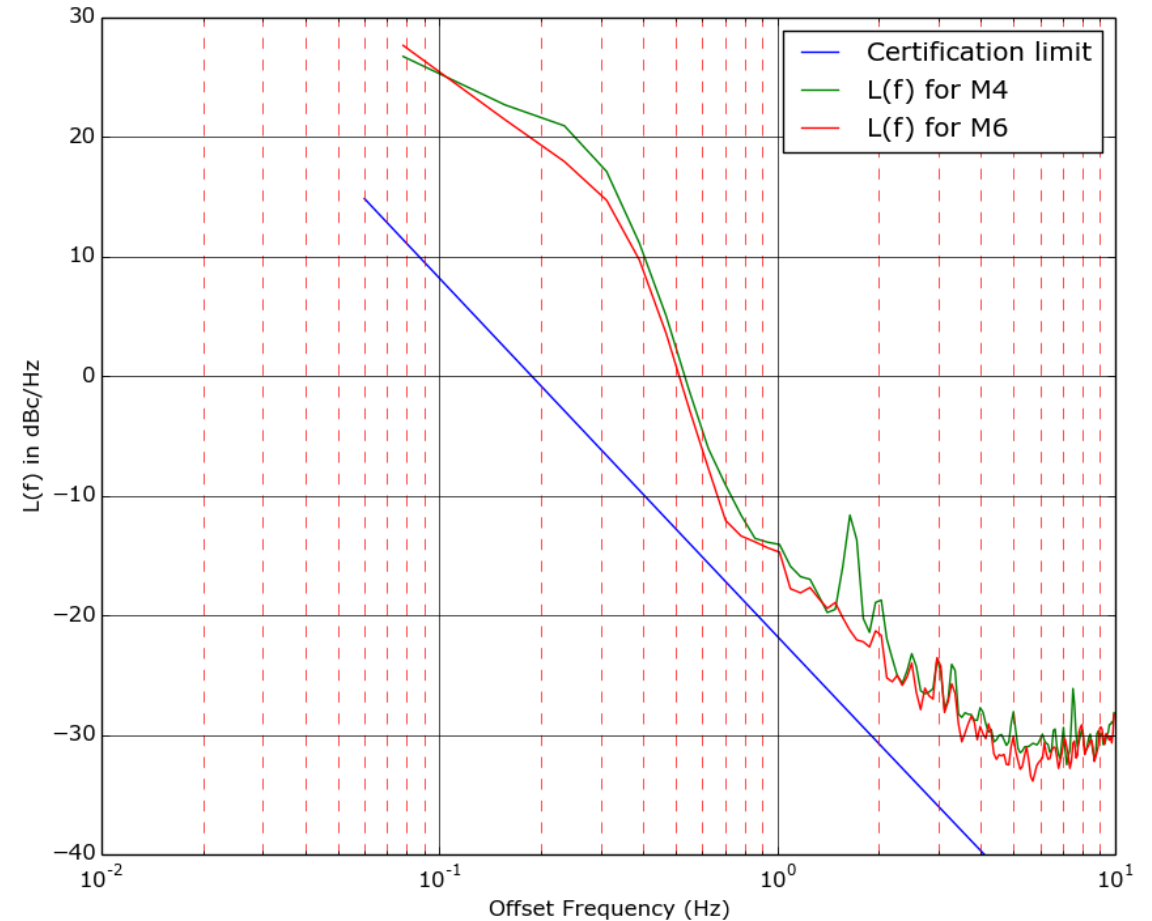
# EDCP – Land Model Observation

- Observed phase noise spectrum from a known land-based DCP transmitter
- Overall results show combined TX, quiet ionosphere, satellite, and RX performance
- Close to the Eumetsat/NOAA certification limit for typical oscillator with a  $1/f^3$  spectrum
- Normally TX are 5dB or so better



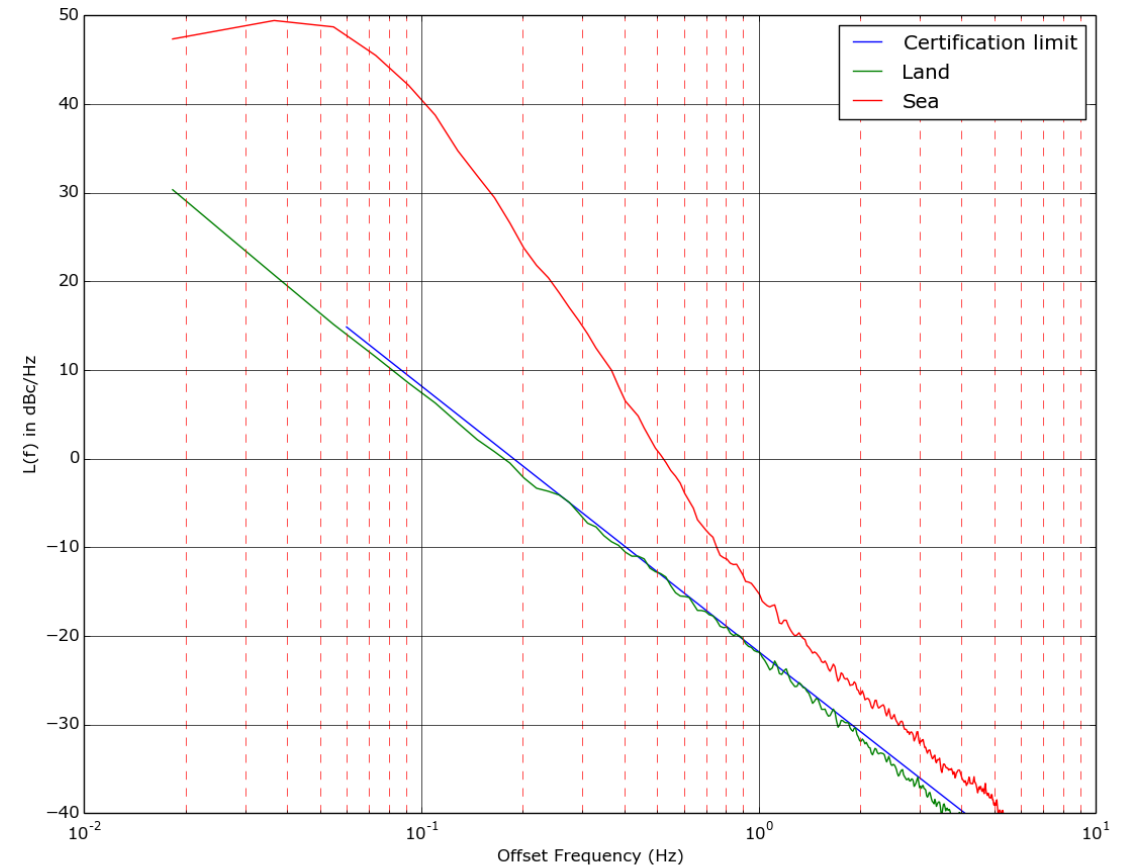
# EDCP – Sea Model Observation

- Observed phase noise spectrum from known sea buoy operated by Irish Marine Institute
- Data from storm 4th Feb 2008
- Wind speed around 15 m/s (Beaufort scale 7 “near gale”)
- Above  $\sim 0.7\text{Hz}$  show elevated oscillator-like noise
- Below  $\sim 0.7\text{Hz}$  show greatly elevated noise due to wave motion

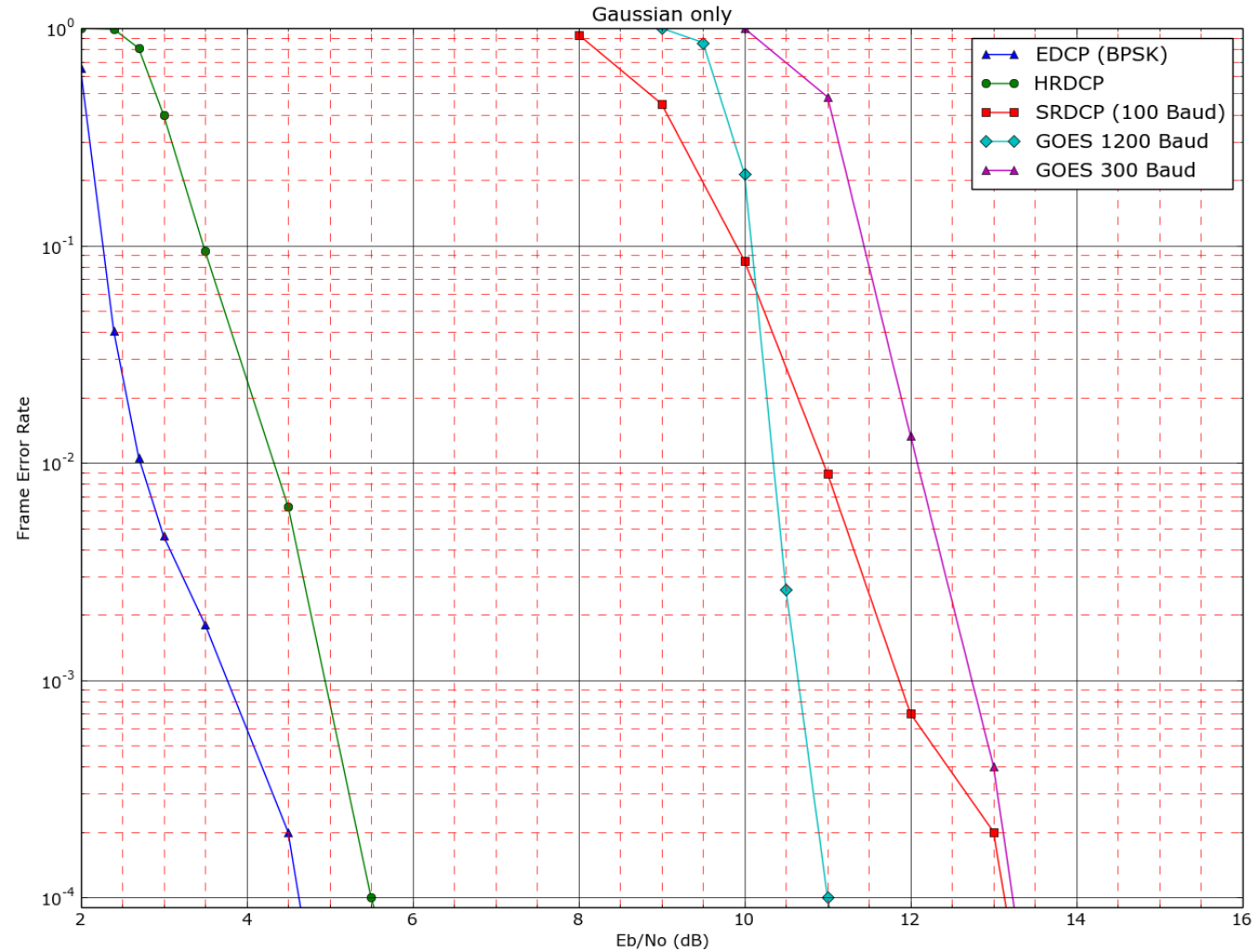


# EDCP – Sea Model Simulation

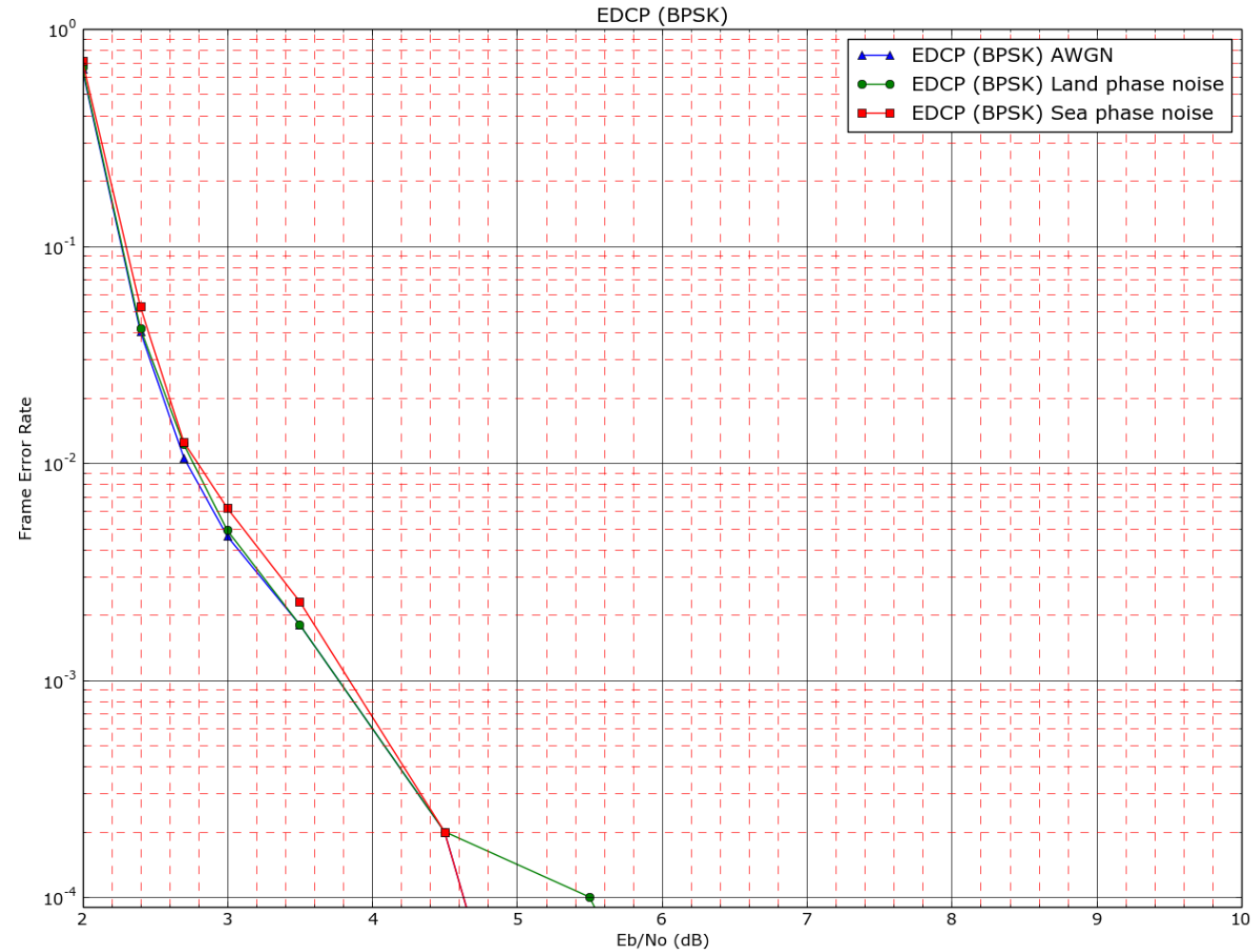
- Land case simply the  $1/f^3$  oscillator model meeting certification limits
- Sea case has certification model at +5dB and Pierson-Moskowitz Wave Spectrum
- Planned P-M spectrum slightly modified to account for estimated buoy platform resonance around 0.35Hz



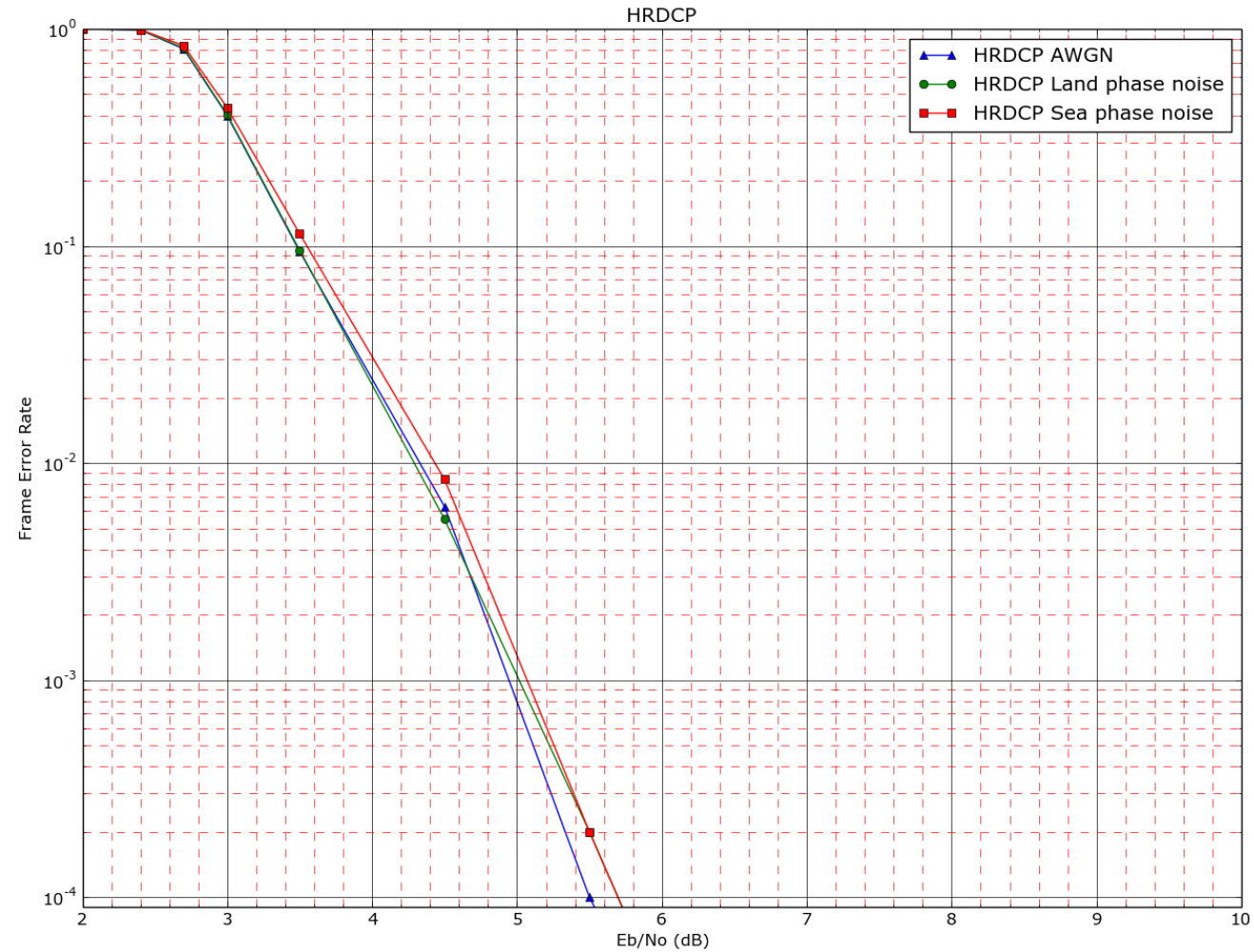
# EDCP – AGWN Results (10k messages of 600 bytes)



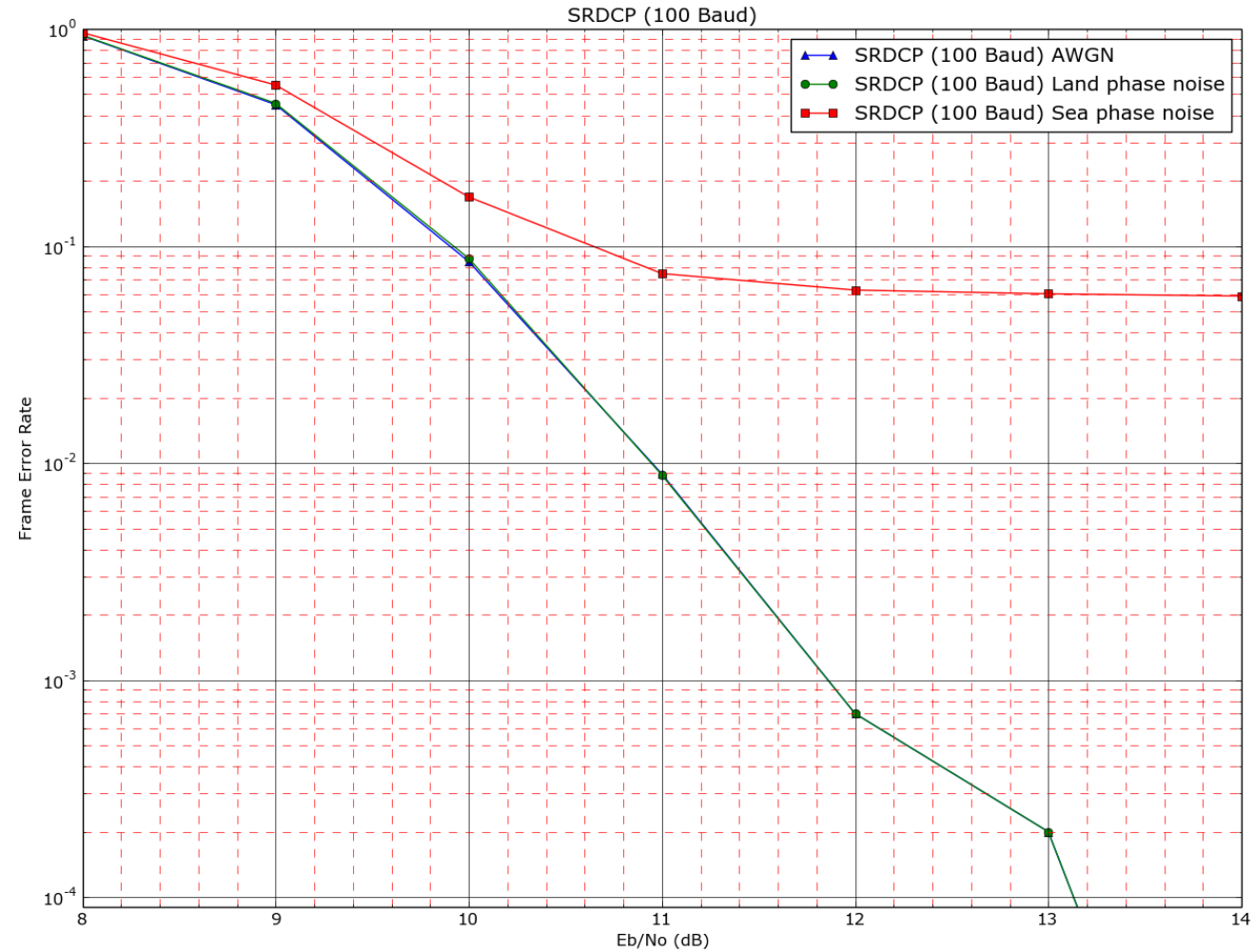
# EDCP – Phase Noise Tolerance (EDCP BPSK)



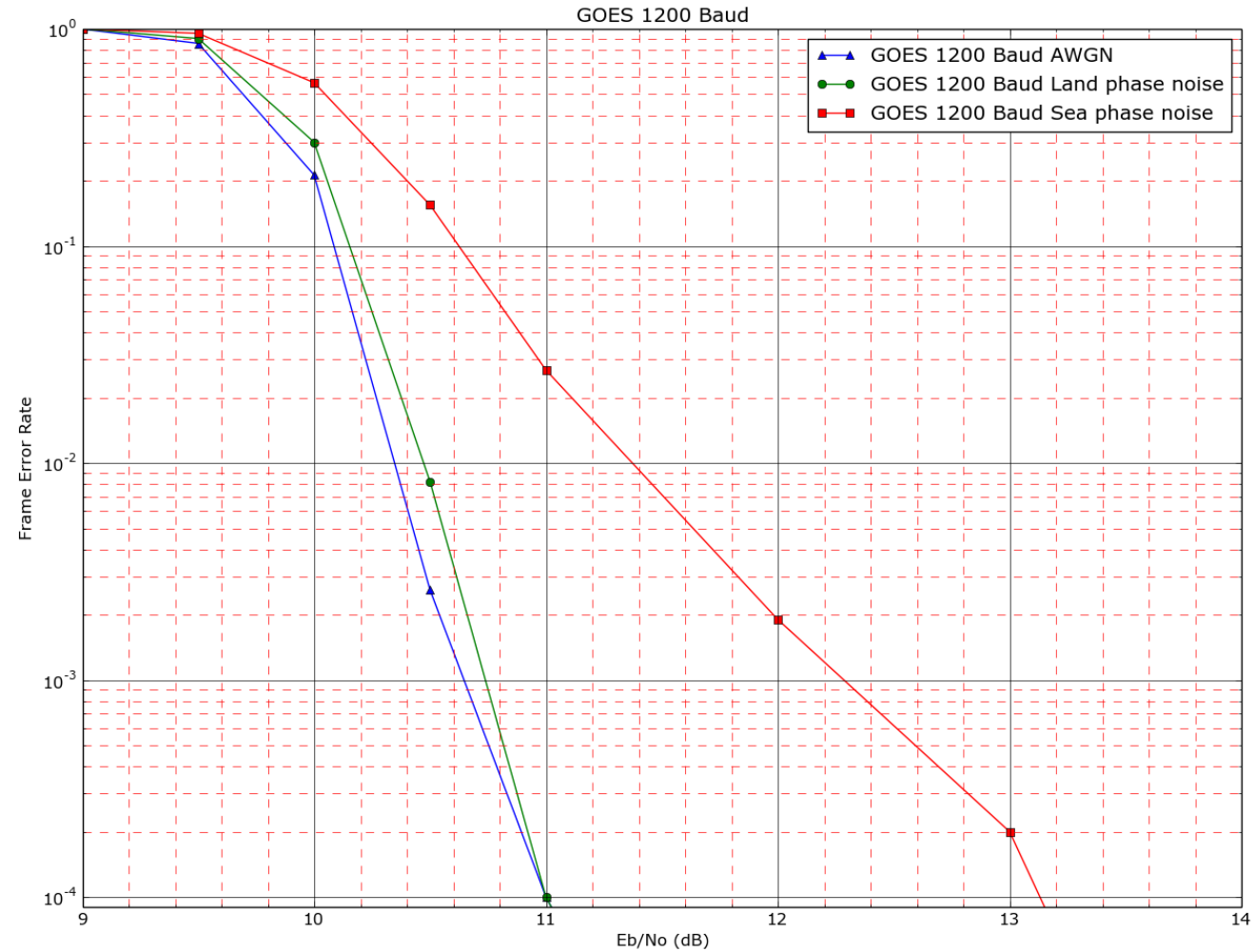
# EDCP – Phase Noise Tolerance (HRDCP – default 5Hz PLL)



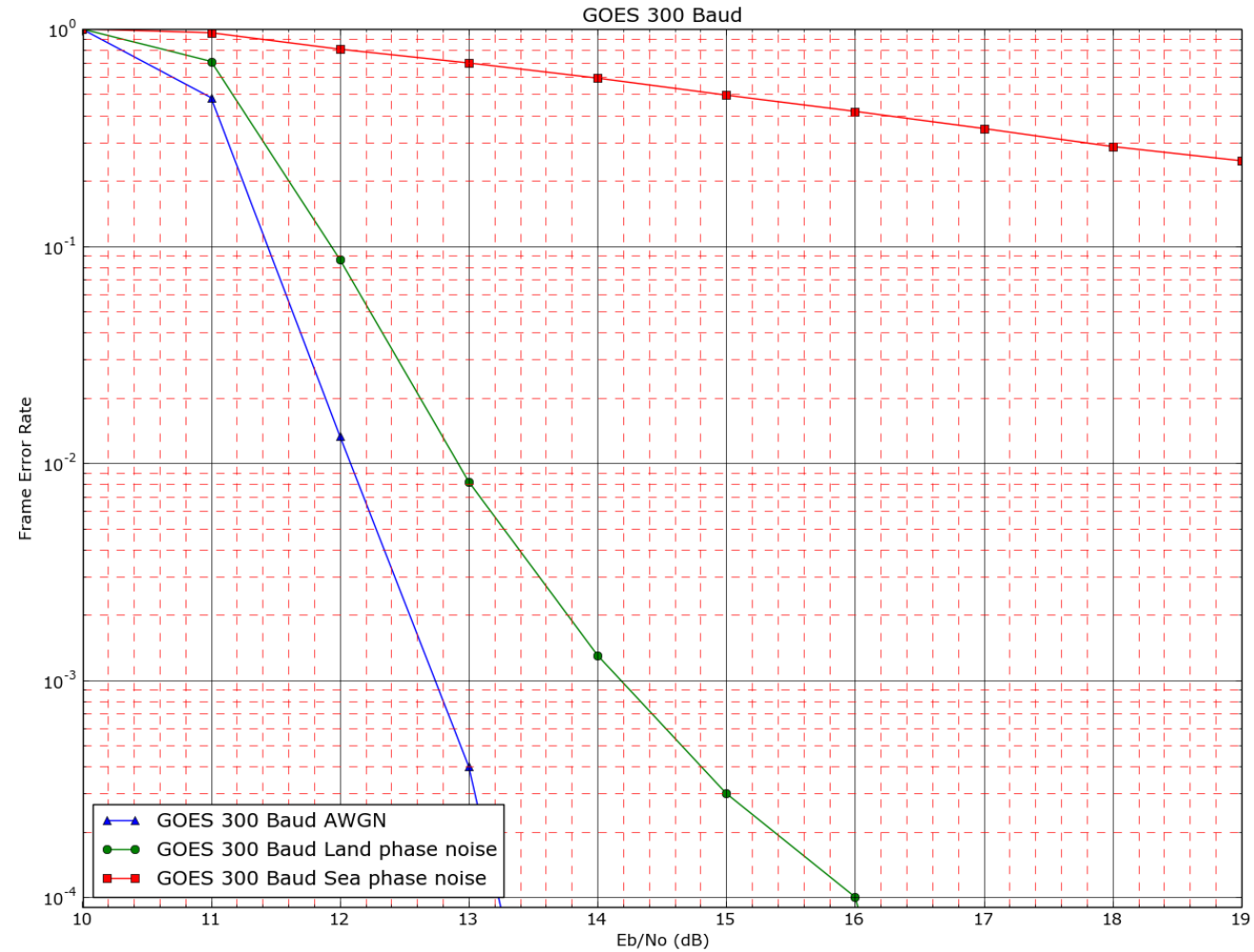
# EDCP – Phase Noise Tolerance (SRDCP – default 2Hz PLL)



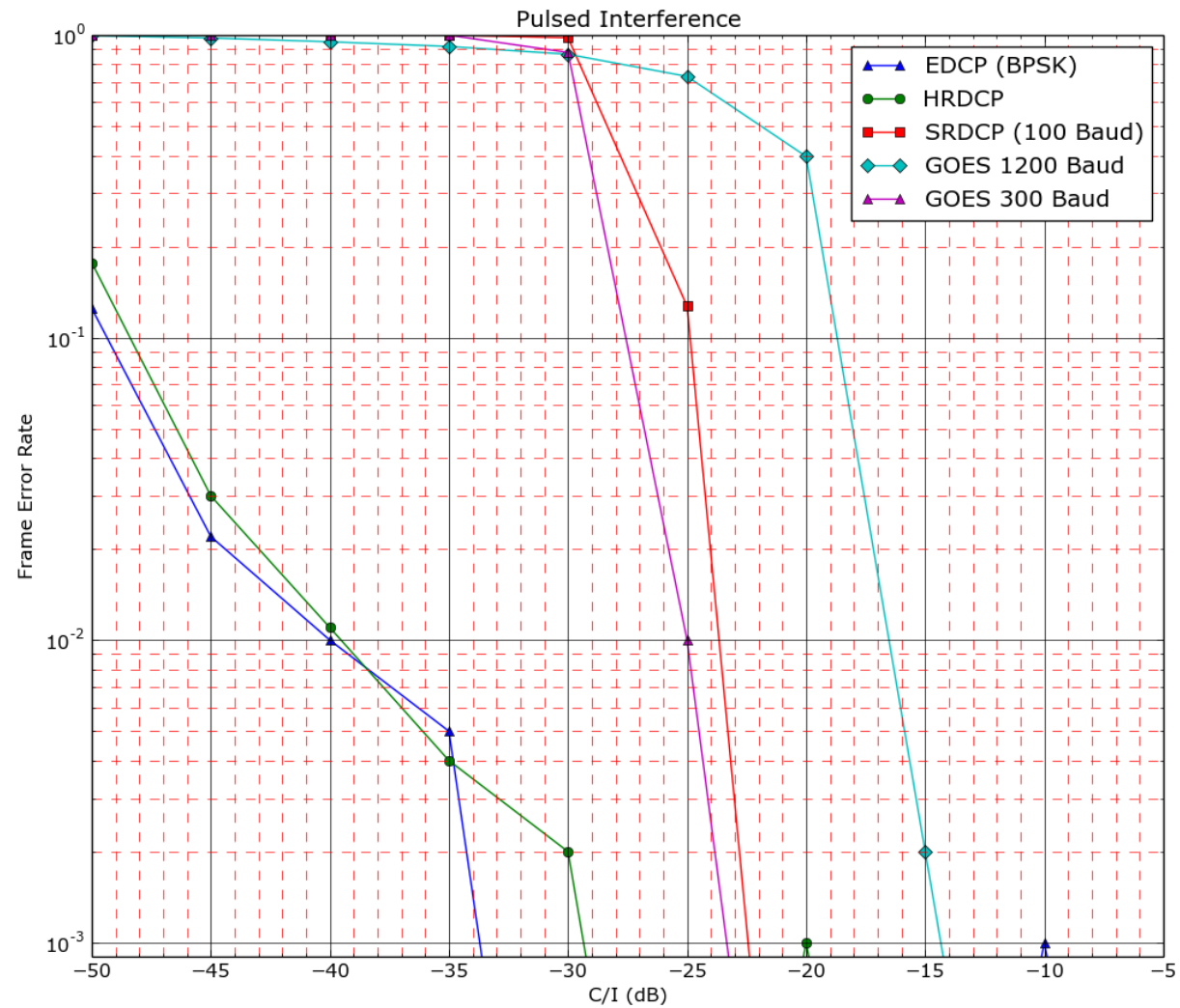
# EDCP – Phase Noise Tolerance (GOES 1200 Baud)



# EDCP – Phase Noise Tolerance (GOES 300 Baud)



# EDCP – Pulsed Interference Results (1k messages)



# EDCP – Simulation Results

- Gaussian case shows that EDCP & HRDCP have around 6dB advantage over SRDCP and GOES systems
- EDCP only implemented with ESA project's 2250Hz choice
- New “sea model” revealed bit-slip problem for SRDCP demodulator
- HRDCP tracking default values can be improved
- EDCP (BPSK) better than HRDCP, even with such improvements!
- EDCP  $\text{Pi}/2$  results showed more work on demodulator needed (theoretical performance is same as BPSK)
- EDCP AM/FM results within 0.25dB of Gaussian-only performance
- Interference results show EDCP and HRDCP to be much better than SRDCP/GOES as expected

# EDCP – Summary of Systems

Parameter	100 Baud	GOES 300	GOES 1200	HRDCP	EDCP (ESA)	EDCP (1.5kHz)	EDCP (750Hz)
CW Duration	5.0s	0.5s	0.25s	2.0s	1.0s	1.0s	1.0s
Clock & Sync Time	2.65s	0.12s	0.03s	0.16s	0.218s	0.31s	0.768s
Clock Pattern	250 bits	3 bits	3 bits	128 bits	128 bits	128 bits	128 bits
Sync Word Length	15-bit	15-bit	15-bit	64-bit	64-bit	64-bit	64-bit
Mod (Preamble)	Bi-Phase-L / PSK	BPSK	BPSK	BPSK	BPSK (also $\pi/2$ )	BPSK (or $\pi/2$ ?)	BPSK (or $\pi/2$ ?)
Mod (Data)	(same as preamble)	8-PSK	8-PSK	Offset QPSK	(same as preamble)	(same as preamble)	(same as preamble)
Symbol Rate	100	150	600	1200	880	620	250
Filtering	3 pole Bessel	RRC $\alpha = 1.0$	RRC $\alpha = 1.0$	RRC $\alpha = 0.5$	RRC $\alpha = 1.0$	RRC $\alpha = 1.0$	RRC $\alpha = 1.0$
Channel Spacing	1500Hz	750Hz	2250Hz	3000Hz	2250Hz	1500Hz	750Hz
Primary FEC	None	R=2/3 Trellis	R=2/3 Trellis	Concatenated R=1/2 Viterbi, RS(255,223), l=3	Concatenated R=1/2 Viterbi with choice of RS block size	Concatenated R=1/2, Viterbi with choice of RS block size	Concatenated R=3/4, Viterbi with choice of RS block size
Other FEC		Symbol interleave dropped in V2	Symbol interleave dropped in V2		1 in 12 pilot symbols and symbol block interleaver	1 in 12 pilot symbols and symbol block interleaver	1 in 12 pilot symbols and symbol block interleaver
End of Transmission	31-bit marker	8-bit marker	8-bit marker	Message length in header.	Message length in header.	Message length in header.	Message length in header.
Error Detection	Parity & alphabet	Parity (optional)	Parity (optional)	32-bit CRC	32-bit CRC	32-bit CRC	32-bit CRC
$E_b/N_o$ for 1E-3 FER (noise only)	11.5dB	13dB	10.6dB	5dB	4dB	4dB ?	5dB ?
User throughput after overheads	87.5 bit/s	263 bit/s (parity) 300 bit/s (none)	1050 bit/s (parity) 1200 bit/s (none)	1049 bit/s	355 bit/s	251 bit/s	152 bit/s
Binary Support	No	Not yet	Not yet	Yes	Yes	Yes	Yes

# EDCP – Conclusions from ESA Project

- Simulation results very promising
- Implemented and tested on engineering model hardware
- Developed under ESA project for 2250Hz channel slot to fit both Eumetsat HRDCP and GOES 1200 Baud allocations
- Discussion for modifications to use 1500 Hz channel slots (SRDCP) and possibly 750 Hz slots (GOES 300 Baud)
- Additional work on BPSK  $\text{Pi}/2$  demodulator desirable
- Additional optimisation of demodulator for legacy missions desirable
- Wider discussion within DCP community on data link layer / common header ideas

# EDCP – Way forward?

- Feedback from DCS community!
- Selection of EDCP options:
  - » Channel spacing(s) to be supported: 750 / 1500 / 2250Hz?
  - » Modulation mode BPSK or  $\pi/2$  BPSK
  - » Standard header ideas?
  - » Message authentication?
- Improve simulation tools
  - » Turn masters project in to usable verified tools for phase noise modelling
- Further demodulator work:
  - » Fix  $\pi/2$  mode to match BPSK performance
  - » Implement pilot symbol tracking, or drop this feature?
  - » General optimisation for legacy missions
- Live testing over Eumetsat MSG, also with NOAA, JMA?

**Thank you for your  
Attention!**

# Contact us

We are happy to help.

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