KONGSBERG

Report

DCR1200 Brief Summary

Kongsberg Defence & Aerospace AS

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1/1	14.12.2023	All	RIDS from Final Review: - RID AL-03: ToC. - RID AL-04: Removed table of table/figures. - RID EA-01: First and second page.

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Acronyms

16APSK	16-Ary Amplitude and Phase Shift Keying
32APSK	32-Ary Amplitude and Phase Shift Keying
3DES	Triple DES
64APSK	64-Ary Amplitude and Phase Shift Keying
8PSK	8-Ary Phase Shift Keying
AC	Antenna Component
ACM	Adaptive Coding Modulation
AD	Analogue to Digital
ADC	Analogue to Digital Converter
AGC	Automatic Gain Control
AOS	Acquisition of Signal
AWG	Arbitrary Waveform Generator
AWGN	Additive White Gaussian Noise
BER	Bit Error Rate
BERT	Bit Error Rate Tester
BPSK	Binary Phase Shift Keying
BW	Bandwidth
CCSDS	Consultative Committee for Space Data Systems
CLK	Clock
COTS	Commercial Off-The-Shelf
CRC	Cyclic Redundancy Check
DBUC	Digital Baseband Unit Core
DDIF	Data Driven at Intermediate Frequency
DDR2	Double Data Rate type 2 (Random Access Memory)
DMA	Direct Memory Access
DRS	Data Relay Satellite
ECL	Emitter Coupled Logic
EM	Engineering Model
EO	Earth Observation
EQM	Engineering Qualification Model
ESA	European Space Agency
FAR	False Alarm Rate
FD	Frame Descriptor
FEC	Forward Error Correction
FECFS	Forward Error Correction and Frame Synchroniser
FEP	Front End Processor
FFT	Fast Fourier Transform
FIFO	First In First Out
FM	Frame Marker
FPGA	Field Programmable Gate Array
FTP	File Transfer Protocol
FW	FirmWare
Gsps	Giga samples per second
GSTP	General Support and Technology Programme
GUI	Graphical User Interface
HRD	High Rate Demodulator
HRDFEP	High Rate Demodulator and Front End Processor
HSSI	High Speed Serial Interface
HSSIO	High Speed Serial Input Output
I/Q	In-phase / Quadrature-phase

ICD	Interface Control Document
IF	Intermediate Frequency
IKT	Information and Communications Technology (from Norwegian spelling)
ISP	Instrument Source Packet
KDA	Kongsberg Defence & Aerospace AS
KSGS	Kongsberg Space Ground Systems
KSPT	Kongsberg Spacetec AS
LAN	Local Area Network
LED	Light Emitting Diode
LEO	Low Earth Orbit
LLR	Log-Likelihood Ratio
LP	Low Pass
LVDS	Low Voltage Differential Signal
M&C	Monitor and Control
MEOS™[1]	Multimission Earth Observation System
MMI	Man Machine Interface
MR	Multi-Rate
NRT	Near Real-Time
O/B	On Board
O/G	On Ground
PCB	Printed Circuit Board
PCIe	Peripheral Component Interconnect express
PFS	Physical Frame Synchroniser
PIB	Provider Inititated Binding
PL	Physical Level
PLL	Phase-Locked Loop
PN	Pseudo Random
QPSK	Quadrature Phase Shift Keying
RAF	Return All Frames
RAM	Random Access Memory
RCF	Return Channel Frames
RF	Radio Frequency
RMS	Root Mean Square
RTL	Register-Transfer Level
SCCC	Serial Concatenated Convolutional Codes
SFTP	Secure Shell (SSH) File Transfer Protocol
SINR	Signal to Interference plus Noise Ratio
SISO	Soft Input Soft Output
SLE	Space Link Extension
SMA	Connector Standard
SNR	Signal to Noise Ratio
SOW	Statement Of Work
SRCR	Square Root Cosine Rolloff
SRR	Specification Requirement Review
TBC	To Be Confirmed
TBD	To Be Decided
TCP/IP	Transmission Control Protocol/Internet Protocol
TM	Telemetry

[1] *MEOS™ is a registered trademark of Kongsberg Defence & Aerospace AS, in Norway and in other countries.*

UIB	User Inititated Binding
USB	Universal Serial Bus
VGA	Video Graphics Adapter
VHDL	Very High Speed Integrated Circuit (VHSIC) Hardware Description Language
VSWR	Voltage Standing Wave Ratio
XML	Extended Mark-up Language

Table of contents

1. Introduction

This document is the Brief Summary of the DCR1200 Ka-band ground receiver development project.

1.1. Purpose

The purposes of this document are:

- Present a brief overview of the technologies developed in the DCR1200 project
- Present an overview of the achieved results

1.2. Scope

This document summarizes the project's key objectives and goals, and presents the results achieved.

1.3. Intended audience

This document is intended for the customer (ESA) personnel involved in the project, KDA project management, and the KDA project team.

1.4. Conventions used in this document

- Agency:

Indicates the European Space Agency (ESA)

- Conventional Coding and Modulations:

Coding and modulations supported by the current HRDFEP V5 product, not including CCSDS SCCC and DVB-S2

- SCR500:

KDA's currently existing Single Channel 500 Msps Receiver prototype developed for Ka-band

- DCR1200:

Dual Channel 1200 Msps Receiver prototype developed in this project.

- HRDFEP:

The commercial receiver product is called the HRDFEP: High Rate Demodulator and Front End Processor. The commercialization of the DCR1200 prototype has resulted in a new HRDFEP version: HRDFEP V12

- Modem:

Encoder, transmitter, receiver and decoder unit

2. Documents

2.1. Applicable documents

A-1.		

2.2. Referenced documents

R-1.	DCR-TS-KSPT-ESA-17126	DUAL CHANNEL RECEIVER Technical Specifications Issue/revision: 1/3 Date: 2018-12-20
R-2.	GSTP-FR-KSPT-ESA-17119	Prototype of a 26 GHz Receiver for EO Final Summary Report Issue/revision: 1/1 Date: 30 May 2017
R-3.	CCSDS 131.2-B-1	"Flexible Advanced Coding and Modulation Scheme for High Rate Telemetry Applications", Blue Book, Issue 1. March 2012
R-4.	ETSI EN 302 307 V1.3.1	"Digital Video Broadcasting (DVB); Second generation framing structure, channel coding and modulation systems for Broadcasting, Interactive Services, News Gathering and other broadband satellite applications (DVB-S2)"
R-5.	KSGS-QA-23037	MEOS™ Capture HRDFEP High-Rate Demodulator & Front-End Processor V12 MAX1200 X4 Product sheet Issue/revision: 1/1 Date: June 2023
R-6.	KSGS-QA-22065	MEOS™ Capture HRTG

		High-Rate Test Data Generator & Transmitter V12 Product sheet Issue/revision: 1/0 Date: May 2022

3. Objective

3.1. Need for Ka-Band

The ongoing migration of satellite downlinks from X-band to Ka-band is motivated by several factors. Among these, the saturation of the X-band and the need for more bandwidth to support higher data rates seem to be the most important.

It is commonly known and accepted that future missions will not only require higher data rates to transfer increasing data volumes, but also more power efficient protocols and techniques. While the available bandwidth is clearly a limiting factor, so is also the amount of available power on the spacecraft per transmitted bit. This drives the need for highly efficient and standardized protocols as an enabler for future satellite programs to reach their goals.

To address this, ESA has chosen to implement and prototype transmitter and receiver technology using the CCSDS SCCC protocol for Ka-band. KDA has taken part in this development with the Single Channel Receiver for 500 Msps (SCR500) prototype. The SCR500 has previously been tested and verified in combined transmitter/receiver tests with Tesat Spacecom's TeTra transmitter for CCSDS SCCC.

3.2. Need for Higher Data Rates

For Earth Observation satellite missions, the development of more advanced onboard instruments, higher resolution data, and a general desire for increasing data amounts to support more and better science, are all pointing at the need for higher data rates. Likewise, for satellite communication links the desire for more bandwidth reflects a continuous increase in user needs.

The Copernicus program is an example of how the need for satellite-to-ground bandwidth is increasing.

A receiver that can make use of the full 1.5 GHz bandwidth in two channels with opposite polarization is needed for maximum exploitation of the available bandwidth.

As a response to this, KDA has developed the Dual Channel Receiver for 1200 Msps per channel (DCR1200).

3.3. Goal

The objective of the project has been to develop technology to receive, demodulate and decode data from a Ka-band downlinks, which can be used directly in commercial products in support of Copernicus and other satellite programs, for data rates up to 10 Gbps.

3.4. KDA Starting Position

The following two technologies represented the starting point for the DCR1200 development:

- SCR500: CCSDS SCCC receiver prototype, max 500 Msps
- HRDFEP V5 COTS product: Conventional ground receiver, max 500 Msps

From this starting point, the DCR1200 extends the capabilities and performance far beyond the limits of the already existing technologies. This includes far higher bandwidths and symbol rates, additional waveforms including DVB-S2, dual channels with interference cancellation, as well as a fully matching transmitter at IF frequency for test purposes or operations.

The DCR1200 development is a major leap forward.

3.5. Experience

At the time when the project started, KDA had 30-40 years of experience from the satellite ground systems business. Development of operational systems ranging from data receivers and processors to control systems, as well as operational support, represented the wide basis of experience within KDA.

3.6. Deliverable Technology

The initial assumption was that both the transmitter and receiver hardware would be hosted together in a separate physical crate, connected to a standard HPE host computer via a local network cable. It was assumed that the hardware would require too much physical space and consume too much power to be integrated inside a standard HPE computer. During the project it became clear that this assumption was not correct.

The implemented solution to be delivered to ESA consists of one receiver and one transmitter.

4. Key Requirements and Design Goals

The following is an overview of the key requirements and design goals of the DCR1200 project.

4.1. Waveforms/Standards

The DCR1200 shall support all the following waveforms/standards:

- CCSDS SCCC: All 27 ModCods
- DVB-S2: All 28 ModCods
- Conventional modulations and coding, convolutional coding and block coding

4.2. Bandwidth, Symbol- and Bit Rates

The DCR1200 shall provide:

- Dual channels, each with a bandwidth of at least 1.5 GHz
- Symbol rates up to 1200 Msps per channel
- Bit rates up to 10 Gbps

4.3. Implementation Losses

The DCR1200 shall:

- Minimize implementation losses in both the transmitter and the receiver

4.4. Interference Cancellation

The combination of 4.1, 4.2, and 4.3 implies that the DCR1200 receiver shall have:

- Active cross-channel interference cancellation to allow high-order modulations/ModCods to be used

4.5. Transmitter

The transmitter has specifications matching the receiver.

The transmitter is suitable as a test transmitter, and is also capable of supporting operational data transmission.

The transmitter supports:

- Dual channels with the same bandwidths and symbol rates as the receiver
- All the above waveforms: Conventional, CCSDS SCCC, DVB-S2
- Programmable signal distortions to reflect real-world degradations in satellite-to-ground downlinks for testing and verification
- Test data transmission from files on disk, with selectable fill data patterns

4.6. Commercialization

The DCR1200 project shall develop the technology for COTS modem products in support of future missions for very high data rates:

- Receiver: MEOS^{TM} Capture HRDFEP V12
- Transmitter: MEOS^{TM} Capture HRTG V12

V12 is the next generation of KDA's high-rate modems, i.e., the successor of the V5 version.

These products are:

- Rack-mountable in a standard 19" rack; i.e., physically compliant with the constraints in terms of power, cooling and physical dimensions
- Modular and scalable for various data rates and number of channels

5. Conclusion

The project has implemented a system with the following capabilities:

- 1200 Msps symbol rates in two parallel channels
- A linear design with analog bandwidth greater than the 1.5 GHz Ka-band
- Minimal implementation losses
- A peak bit rate for CCSDS SCCC of ~13 Gbps

This is a very powerful combination, challenging any other RF-based solution for high-rate satellite communications.

A number of decision points were made throughout the project, with the option of terminating parts of the development in case they were deemed to be technically unfeasible, or just modifying the technical requirements. With the exception of the transition from a Coherent Cross Polarization Interference Cancellation filter (C-XPIC) to a Non-Coherent implementation (NC-XPIC), no part of the original requirements have been omitted or cancelled at these decision points.

The developed technology is highly relevant for current and future space programs with high demands for space-to-ground and/or ground-to-space data capacities and high bandwidth efficiency.

ACM is a desirable capability for such high-rate systems. With seamless and lossless transitions from any ModCod to any other ModCod and generation of SNR as a signal quality metric, this is supported.

Conclusively, the DCR1200 development project can be summarized as follows:

1. The objective described in section 3 has been fulfilled
2. The key requirements and design goals listed in section 4 are met
3. The technical specifications have been met, with few exceptions

Work continues to meet all final requirements and resolve the exceptions in item 3.

Furthermore, the technologies developed have been successfully commercialized as the COTS products MEOS^{TM} Capture HRDFEP and MEOS^{TM} Capture HRTG, supporting the Copernicus program's requirements, as well as the requirements of other high-rate satellite missions for Ka-band. The commercial value and potential of both products is very high.

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