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STATUS REPORT ON THE PROTOTYPING ON HIGH RATE DCP

This document is an information paper to CGMS that summarises the preparatory activities performed by EUMETSAT for developing pre-industrialized prototypes (transmitter and receiver) of a High Rate DCP System using the Meteosat Second Generation satellites. Based on an evolution of a previous prototype, the design of the pre-industrialized prototypes has focused on enhancing the behaviour of the receivers to the influence of the spinning of the MSG satellites while still using Bandwidth Efficient Modulation schemes and S/W Radio concepts, therefore minimising the dependencies on H/W platforms. After successful Factory and Laboratory tests completion, the prototypes will be deployed at selected locations of the MSG DCP antenna coverage and exhaustively tested in a pseudo-operational approach. This Pre-Operational Pilot Phase has been designed to cover different operational scenarii, as the eclipse season of the MSG satellite, and shall provide complementary information that will allow to consolidate the system specifications of the new EUMETSAT High Rate DCP System by mid 2008.

Status report on the prototyping on High Rate DCP

1 INTRODUCTION

The Data Collection Service (DCS) is a secondary service supported by the Meteosat satellites through a dedicated UHF to L-band transparent communications transponder. The DCS allows users to collect environmental data from sensors in remote locations on the Earth and to transmit those data via the DCS transponder to be received at a central facility. The Meteosat DCS provides an international and a regional service that can be shared by a large number of users as the satellite communications band is separated into multiple FDMA channels and users are assigned pre-defined transmission timeslots in the corresponding FDMA channel. The current DCS standard defines the signal transmission parameters for the Data Collection Platforms (DCPs), which was devised some 25 plus years ago, and uses a PM/SP-L modulation scheme with a data rate of 100bps.

Focusing on the Meteosat Regional service and for taking full advantage of the DCS improvements with the introduction of MSG, EUMETSAT wanted to investigate the feasibility of introducing DCPs transmitting at higher data rates than the old standard. One of the distinctive characteristics of the Meteosat satellites is that they are spin stabilised. The satellite communications antennas used for the DCP signals (in UHF and L-Band) are consequently electronically de-spun (EDA). These EDAs cause phase and amplitude ripple to be introduced onto the DCP signals, with the rate of ripple related to the spin rate of the satellite which is 100 rpm and the different EDA designs. Therefore, whichever modulation scheme is to be used for the high rate DCP transmission, it has to be able to cope with the effects of the EDAs.

For covering all these aspects, EUMETSAT performed a series of technical studies for identifying MSG suitable spectral efficient modulation schemes (or BEM – Bandwidth Efficient Modulation-). After selection of optimal BEM scheme, a proof of concept verification at Lab level was performed with the development of a set of prototypes (transmitter and receiver). Furthermore, this initial set of TX and RX prototypes were also deployed at the MSG Primary Ground Station site and real life tests with MSG-2 were conducted.

Based on the outcome of all these activities, EUMETSAT has identified opportunities for improvement and refined the specifications of the system. The reworked specifications cover two main aspects:

- Enhancement of the Forward Error Corrections (FEC) techniques for improving the probability of message delivery (through the evaluation of concatenated codes).
- Counter-acting the effects on the receiver of the UHF and L-Band satellite antennas spinning (by means of an active de-spinning circuit prior to the demodulator).

A set of receivers and transmitter has been built in accordance to the revised specifications and it is currently under laboratory testing prior to the deployment at remote sites (Usingen and Fucino) for performing pre-operational benchmarking of the different system options under the different operational conditions (e.g. eclipse season, spacecraft manoeuvres, etc).

2 SUMMARY OF THE INITIAL PROTOTYPE CHARACTERISTICS

As reported to CGMS-34 EUM-WP-19, the initial study started with the selection of the candidate modulation schemes to be considered. From an original list selected among the suggested modulation schemes in CCSDS Recommendation 413 (CCSDS 413.0-G-1), only a handful of potential methods were shortlisted. The performances of these candidate modulation schemes were evaluated by using a MATLAB/Simulink model that reproduced the DCS communication link with the perturbations the signals will encounter in a real scenario (such as non-linear power amplifiers, signal multipath, adjacent channel interference, MSG-like satellite transponder including de-spun antenna, additive white Gaussian noise channel, etc).

The comparison between the candidate modulation schemes was based on the observed performance degradation in terms of BER vs Eb/No that each modulation scheme suffered for each one of the disturbances listed before. The degradation was measured by comparing the Eb/No value at which BER = 1E-4 and 1E-6 was achieved to the theoretical BPSK performance. These initial simulations were run at 300 bps without encoding and 1500 bps with convolutional encoding (R = ½, K = 7) and ultimately allowed EUMETSAT to decide on SRRC pre-filtered ($\alpha = 0.5$) OQPSK as the modulation scheme for the potential High Rate DCP implementation in MSG.

3 HIGH RATE DCP 2nd GENERATION PROTOTYPE DETAILS

The exhaustive tests performed with the first generation of HR DCP tests allowed EUMETSAT to confirm the selection of OQPSK as modulation scheme for any future High Rate DCP transmission through the MSG satellites.

Similarly the different laboratory tests helped characterising the performance of the receivers under different satellite spinning conditions and confirmed the positive influence of the selected FEC method (convolutional encoding with Viterbi decoding) for increasing the probability of message reception. Furthermore, the combination of laboratory and field tests also allowed identifying specific system aspects that would benefit from a further improvement in the system specifications.

In particular, the following two aspects have attracted the attention for revising the system specification:

- The UHF and L-Band antenna induced ripple is dominated by two components, a 53.3 Hz (L-Band antenna) and a 26.7 Hz (UHF antenna). Although these components do not influence significantly the system performances in the current 100 bps PM modulated (analogue) DCS, they do have a greater impact on system performance because of using higher order modulation schemes such as OQPSK and as the data rate increases.

- The probability of message reception, although positively improved by the adoption of a traditional convolutional encoder and a Viterbi decoder, could be further enhanced by adopting code block based FEC techniques.

Consequently, the following main modifications have been included in the specification of the system:

- For optimising the influence of Forward Error Correction Techniques, the High Rate DCP message shall be block based and shall allow concatenated coding (as per CCSDS recommendations). Interleaving is considered, but depth is under trade-off between $\Delta Eb/N0$ vs overhead if the message length is below the interleaved size of the blocks.

- The influence of the ripple can be mitigated by applying adequate compensation and correction techniques to the received signal. The concept behind is similar to the one already in use for correcting from satellite DCP transponder LO frequency drifts.

Ideally, if one knew the instantaneous ripple value (both in amplitude and phase), a digital processing artefact could be included in the design of the receiver to remove, prior to demodulation, the amplitude and phase influence of the satellite antennas ripple. Therefore, the ripple would not influence the overall system performance.

In a real world implementation, however, there will always be differences between the estimation of the ripple and the actual value induced on the corresponding DCP signal by the spinning antennas. As there are several possible digital processing system solutions (including a priori and a posteriori estimators), the characterisation of the system performances to these differences is key to the finalisation of the system design.

Using a revised version of the initial High Rate DCP System Specifications, EUMETSAT has teamed with an industrial consortium which has worked in the development of a new set of prototypes for both the transmitter and the receiver. Considering that these new prototypes shall be tested in quasi operational conditions, and that one of the aspects to confirm at system level is the operational functionality of the new system, the use of an already existing commercial solution as the basis to develop on top the new set of TX and receivers has become mandatory. Using already field tested H/W components decreases the uncertainty in the behaviour of the new HR DCPs units while in operational use.

Main system specifications of the new prototypes of the HR DCPs TX are defined in Table 1:

Modulation	SRRC pre-filtered (α = 0.5) OQPSK	
Modulating waveform	NRZ-L	
Modulation specifications	As defined by ECSS-E-50-05 Radio Frequency and Modulation Standards.	
TX sequence	2 secs of unmodulated carrier nx16 bytes Preamble (n=1,…,4) 8 bytes ASM DCP message (w/o EOT) 4 bytes CRC	
Bit Rate	300 bps	1200 bps
Coding	None Convolutional, R = ½, K = 7 RS (255,223), RS(204,188), RS (126,112) with I=1,…,5 Concatenated convolutional and RS codes (as above)	
Transmission Slots	1.5 KHz channel	3.0 KHz channel

Table 1 – *Summary specifications for the prototype High Rate DCP.*

4 CURRENT ACTIVITIES

Upon validating the HR DCP concept at factory and Lab tests, EUMETSAT has initiated a Pre-Operational Pilot Phase (POPP). This Pre-Operational Pilot phase started in mid August 2007 and will continue into early 2008 for covering different MSG system conditions (e.g. autumn 2007 eclipse season).

The Pre-Operational Pilot Phase contemplates the deployment of several HR DCP transmitters and the use of the operational MSG Primary Ground Station at Usingen in Germany for the reception of the HR DCP messages with the prototype receivers. Currently, and because of ease of operations, it is foreseen to deploy two HR DCP transmitters: one in Usingen and one in Fucino (Italy) capitalising on the EUMETSAT infrastructure available at these two sites. Additional sites are under consideration, but given a limited amount of available H/W resources for these prototyping activities, deployment at such additional sites has to be carefully considered.

During the Pre-Operational Pilot phase, two available European regional channels have been assigned for the prototyping activities for each one of the transmitters (for checking also system behaviour for adjacent carrier interference). The system is remotely controlled from EUMETSAT HQ in Darmstadt and daily and weekly schedules are loaded into the transmitters. Typical transmission schedules have a message transmitted every 3 minutes and transmitter settings are changed every hour. This allows collecting 20 measurements per system configuration and helps in enhancing the statistical relevance of the derived measured point for each one of the system configurations. The hourly change in the system configuration normally affects only the transmitted power such as the reception characteristics under different Eb/N0 conditions are measured along the day.

On the receiver side, there is no need for predefined schedules, as the receiving system has been conceived with sufficient S/W receivers to allow permanent assignment of pairs of receivers to the different TX configuration options. Nevertheless, and similarly to the transmitting sites, the receivers are remotely monitored and controlled from EUMETSAT HQ and therefore reconfiguration of the receivers is also possible to EUMETSAT.

The consolidation of the final HR DCP system technical specifications will be done during the Pre-Operational Pilot Phase by gathering information on the system performances with different system configurations. As mentioned above, it is planned that the information gathering effort will take until the end of 2007 to adequately cover all possible system combinations in quasi operational conditions. After consolidation of the gathered system performance results, it is planned to revise the system specifications for the transmitters, receivers and overall system aspects. It is then expected that, by the middle of 2008, EUMETSAT will be in the position to release a consolidated system specification for a new High Rate DCP system through the regional channels in the Meteosat operational satellites.