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STATUS REPORT ON THE PROTOTYPING ON HIGH RATE DCP FOR MSG

This document is an information paper to CGMS that summarises the activities performed by EUMETSAT for testing in quasi-operational conditions pre-industrialized prototypes (transmitter and receiver) of a High Rate DCP (HRDCP) System using the Meteosat Second Generation satellites. The pre-industrialised HRDCP prototype transmitters have been deployed at the operational Primary Ground Station of MSG (Usingen, Germany) and MTP (Fucino, Italy). The prototype receivers have been installed in the MSG Primary Ground Station. The system has been extensively exercised during the eclipse season of Met-9 in autumn 2007. Delta improvements and minor corrections have been identified and implemented in a new SW release for the TX and RX that has been tested around the eclipse season of Met-9 in spring 2008 and that have confirmed the system characteristics for a potential operational implementation. During the final stages of testing of this final version, particular attention has been given to the cases of moving DCP platforms (e.g. buoys) and adjacent channel interference due to spectral re-growth in commercial HPAs.

Corresponding MSG HRDCP System Specifications have been drafted (TX, RX and overall system) and shall allow presenting to the users of the DCS EUMETSAT regional system the advantages of the new High Rate Data Collection System when compared with the 100 bps operational one, e.g. higher date rate with lower transmission power for reducing battery power requirements, more flexible transmission slots with better characterized system margins allowing reducing the probability of message loss with immediate flagging of post-FEC messages with errors using a CRC.

STATUS REPORT ON THE PROTOTYPING ON HIGH RATE DCP FOR MSG

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 a suitable, CCSDS compliant, 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 was also deployed at the MSG Primary Ground Station site and real life tests with MSG-2 were conducted.

A summary of these initial activities was presented to CGMS-34-in EUM-WP-19. Based on the outcome of all these activities, EUMETSAT identified opportunities for improvement and refined the specifications of the system; this was reported to CGMS-35 in EUM-WP-16. 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 was built in accordance to the revised specifications. The prototype HR DCP transmitters have been deployed at the operational Primary Ground Station of MSG (Usingen, Germany) and MTP (Fucino, Italy) connected at RF level to the spare DCP Transmitter Test chain of the corresponding station. The prototype receivers have been installed in the MSG Primary Ground Station connected at I/F level to a test port within the operational chains. A reference system has been installed in the EUMETSAT Laboratory and used in parallel for specific test reasons under laboratory conditions as well as for serving as reference platform in case of anomaly investigations or special test cases not feasible through the operational DCP transponder (e.g. reception performances under spectral re-growth or under severe adjacent channel interference).

The system has been extensively exercised during the eclipse season of Met-9 in autumn 2007. The tests have covered different system configuration scenarios (e.g. FEC cases for characterising reception performance vs transmitter EIRP under specific channel impairment conditions. The tests results have been analysed and consolidated during the end of 2007. Delta improvements and minor corrections have been identified and agreed with the prototypes' contractor and implemented in a new SW release for the TX and RX that has been tested around the eclipse season of Met-9 in spring 2008. The results of this final version of the S/W for the HR DCP transmitters and receivers has been then used to determine the optimized system configuration allowing to consolidate most of the system parameters and therefore helping in establishing the final system performances for a EUMETSAT MSG HR DCP system.

During the final stages of testing of this final version, particular attention has been given to the cases of moving DCP platforms (e.g. buoys) and spectral re-growth in commercial HPAs.

Based on the analysis of the test results, EUMETSAT has developed the MSG HR DCP System Specification that shall allow presenting to the users of the DCS regional system the advantages of the new HR DCS when compared with the 100 bps operational one, e.g.:

- higher data rate with lower transmission power for reducing battery power requirements,
- more flexible transmission slots with better characterized system margins allowing reducing the probability of message loss with immediate flagging of post-FEC messages with errors by means of a quite powerful CRC artefact,
- increase resilience for channel impairments like phase noise, amplifiers working closer to saturation, signal variations (AM/PM and phase noise) due to platform movements, AM/PM effects introduced by the satellite spinning, satellite eclipses, etc.,
- Engineering Service Channel (ESC), specific field within the message header, allowing the user to independently select a set of platform parameters to be reported.

2 SUMMARY OF THE FINAL PROTOTYPE CHARACTERISTICS

As reported to CGMS-34 in 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 short listed. 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 E_b/N_0 that each modulation scheme suffered for each one of the disturbances listed before. The degradation was measured by comparing the E_b/N_0 value at which BER = 1E-4 and 1E-6 was achieved to the theoretical BPSK performance and ultimately allowed EUMETSAT to decide on SRRC pre-filtered ($\alpha = 0.5$) OQPSK as the most suitable modulation scheme for the potential High Rate DCP implementation in MSG. 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 (because of their spinning characteristics). 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 were added to the revised system specification:

- 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). The selected inner code, has been initially short listed to a few different RS codes: RS(255, 223), RS(255, 239) and RS(204, 188). Interleaving depth from 1 to 5 is considered, but depth is under trade-off between $\Delta E_b/N_0$ 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 final implementation uses a FIR filter bank with 720 taps to “track” the ripple with a sample rate equal to the satellite spinning rate (PLL tracked for allowing automatic compensation). The beacon AM/PM ripple is therefore known every 0.5° of one satellite revolution. The FIR filter reaches “steady” state in about 5 minutes and then it can be reliably used to correct the DCP signal in both AM and PM. All tests results obtained in the Pre-Operational pilot Phase tend to confirm that the degradation exists but it is within system margins and that for worst case scenarios, it is possible to use “regional” beacons (i.e. localised in the vicinity of the troubled platforms) or to bypass the correction if detrimental to reception performance.

Main system specifications of the final prototypes of the HR DCPs TX were detailed in CGMS-35 in EUM-WP-16 but are summarised in Table 1:

TX sequence	2 secs of unmodulated carrier nx32 bytes preamble -0xA05050A0- (n=1,..,4) 8 bytes ASM - 0x034776C7272895B0- DCP message (w/o EOT) 4 bytes CRC
Modulation	BPSK, transmitting "00" (45°), for unmodulated carrier BPSK for preamble and ASM SRRC pre-filtered (α = 0.5) OQPSK for FEC coded, scrambled DCP message
Modulating waveform	NRZ-L
Modulation specifications	As defined by ECSS-E-50-05 Radio Frequency and Modulation Standards.
Channel Bit Rate	2400 bps (1200 bps@ convolutional encoder input)
Coding	None Convolutional, R = ½ (G2 inverted) or punctured coding (R=3/4, R=7/8) RS (255,223), RS(204,188), RS (126,112) with I=1,…,5 Concatenated convolutional and RS codes (as above)
Transmission Slots	3.0 KHz channel

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

3 PRE-OPERATIONAL PILOT PHASE TESTS

Upon validating the HR DCP concept at factory and Lab tests, EUMETSAT has initiated a Pre-Operational Pilot Phase (POPP). The prototype HR DCP transmitters have been deployed at the operational Primary Ground Station of MSG (Usingen, Germany) and MTP (Fucino, Italy) connected at RF level to the spare DCP Transmitter Test chain of the corresponding station. The prototype receivers have been installed in the MSG Primary Ground Station connected at I/F level to a test port within the operational chains. A reference system has been maintained in the EUMETSAT Laboratory and used in parallel for serving as reference platform in case of anomaly investigations or special test cases not feasible through the operational DCP transponder (e.g. reception performances under spectral re-growth or under severe adjacent channel interference).

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 E_b/N_0 conditions are measured along the day, whereas daily change affects the FEC scheme to be used.

This Pre-Operational Pilot phase started in mid August 2007. Since then, the system has been extensively exercised during the eclipse season of Met-9 in autumn 2007 (detailed in Figure 1 and Figure 2).

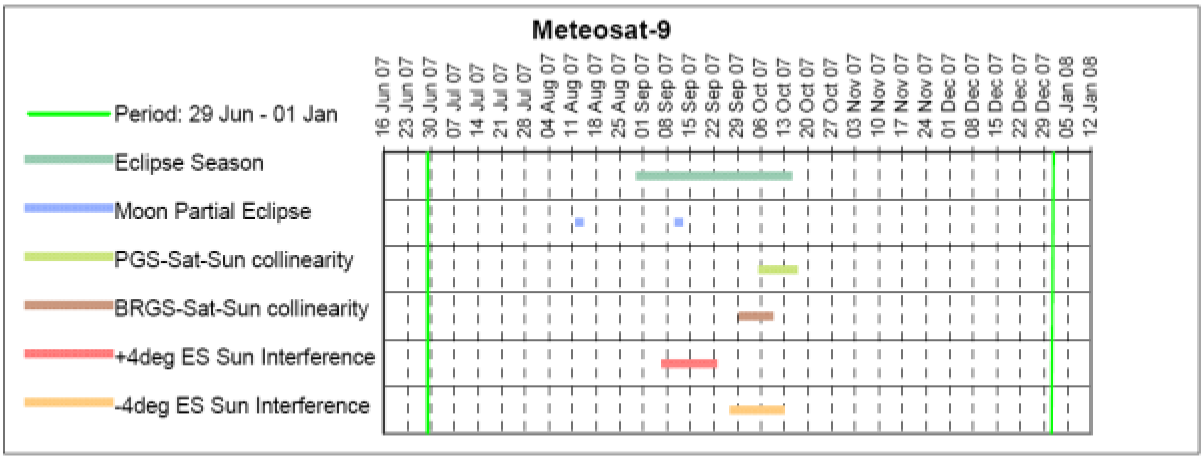


Figure 1 - *Summary of MSG-2 / Meteosat-9 predicted events for Q3/Q4 2007.*

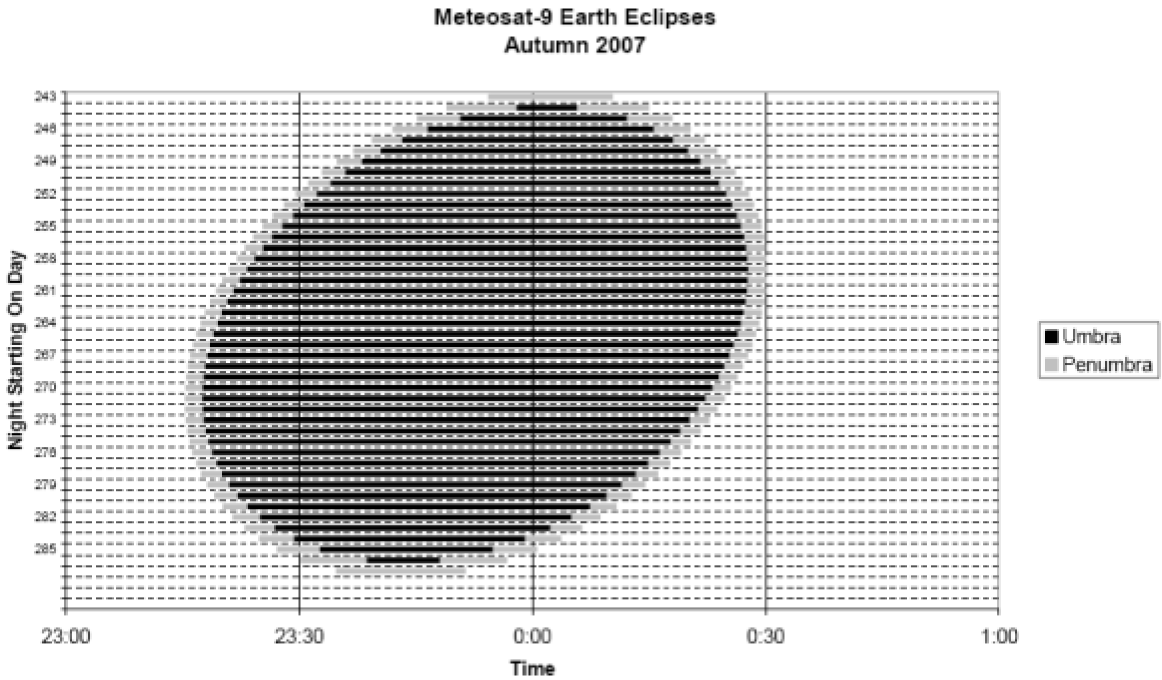


Figure 2 – *Autumn 2007 predicted eclipse period and duration for MSG-2 / Meteosat-9*

The test campaign has covered different system configuration scenarios (e.g. FEC cases for characterising reception performance vs transmitter EIRP under specific channel impairment conditions). The tests results have been analysed and consolidated during the end of 2007. Delta improvements and minor corrections have been identified and agreed with the prototypes' contractor and implemented in a new SW and H/W release for the TX and RX.

A new test campaign, also performed by EUMETSAT, has been organised around the eclipse season of Met-9 in spring 2008 (detailed in Figure 3 and Figure 4). The results of this final version of the S/W for the HR DCP transmitters and receivers has been then used to determine the optimized system configuration allowing to consolidate most of the system parameters and therefore helping in establishing the final system performances for a EUMETSAT MSG HR DCP system.

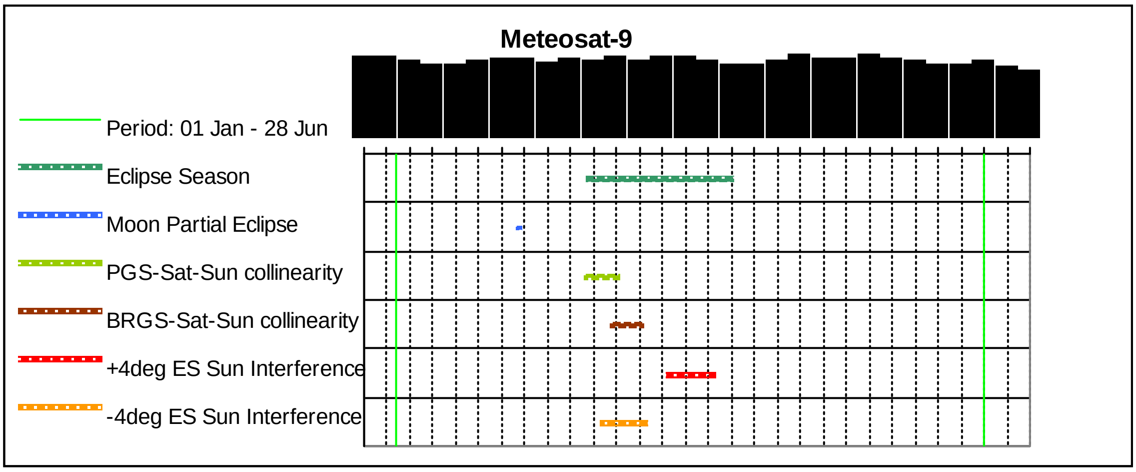


Figure 3 - *Summary of MSG-2 / Meteosat-9 predicted events for Q1/Q2 2008.*

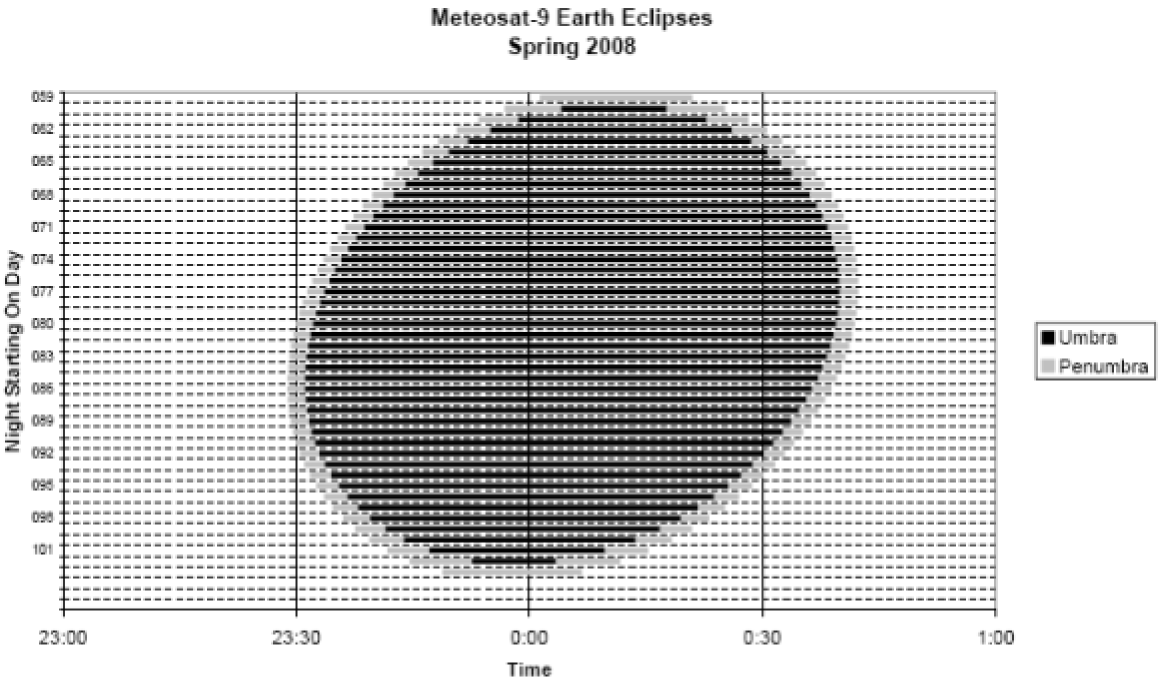


Figure 4 – *Spring 2008 predicted eclipse period and duration for MSG-2 / Meteosat-9*

During the final stages of testing of this final version, particular attention has been given to the cases of moving DCP platforms (e.g. buoys) and spectral re-growth in commercial HPAs.

3.1 POPP Test results: Autumn/winter 2007 campaign

As depicted in Figure 5, the test campaign of autumn/winter 2007 has covered different system configuration scenarios (e.g. FEC cases for characterising reception performance vs transmitter EIRP under specific channel impairment conditions).

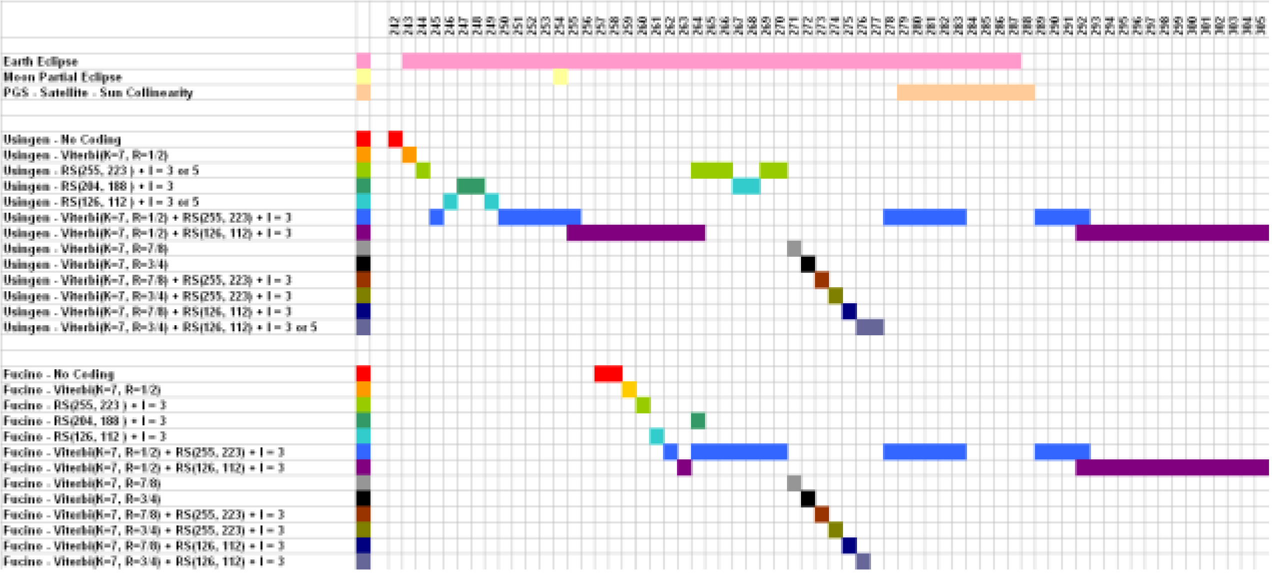


Figure 5 – *HRDCP POPP testing profile for MSG-2 / Meteosat-9 autumn 2007eclipse.*

The following tests have been performed:

Beacon Tracker Performance Test concluding that the unit was able to track the satellite's LO changes even during heavy eclipse conditions, as depicted in Figure 6. The difference in the beacon frequency offset values is caused by the lack of external 10 MHz reference in the HRDCP for POPP receiver unit.

EDA Tracker Performance Test concluding that the use of EDA tracking provides around 1 dB extra margin

HRDCP System performance vs EIRP Test for different FEC scenarios:

- no FEC,
- convolutional/viterbi (K=7, R = ½) ,
- punctured codes (K=7, R = ¾ and 7/8) ,
- Reed-Solomon: RS(255, 223), RS(126, 112) and RS(204, 188) with Interleaving 1, 3 or 5,
- Concatenated Convolutional (K=7, R=1/2) + RS(255, 223) + I = 3, and
- Concatenated Punctured (K=7, R = ¾ and 7/8) + RS(255, 223) + I = 3.

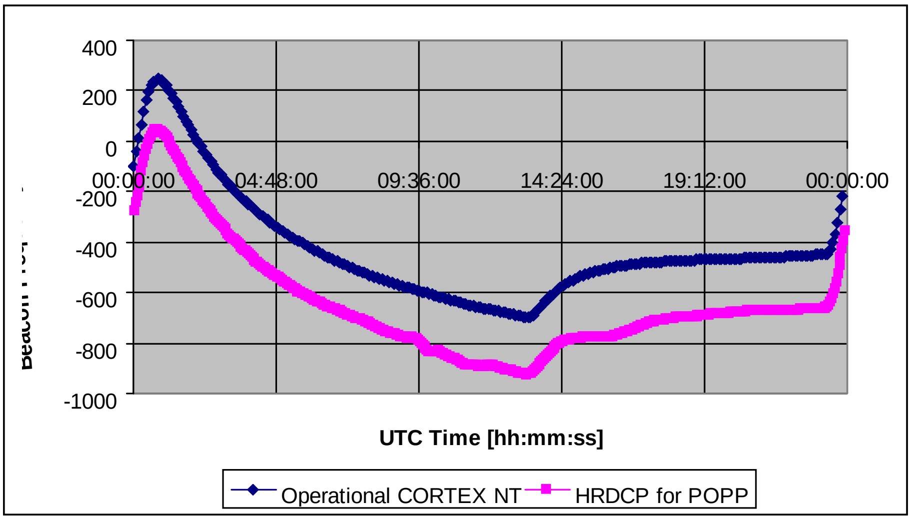


Figure 6 – *Comparison between the beacon frequency offset measured by an operational DCP CORTEX NT unit and by the beacon tracker of the HRDCP receiver for DoY 254.*

FEC Scheme	Minimum EIRP	Comment
1/ No FEC	-	As depicted in Figure 7, beyond a given E_b/N_0 point, the system is no longer AWGN-limited, but phase noise limited (TX, RX and satellite transponder phase noise) as well as AM/PM satellite ripple limited.
2/ Convolutional(K=7, R=1/2)	12.1 dBW	As depicted in Figure 7, the receiver performance is within 1 dB from theoretical curve.
3/ Punctured Convolutional(K=7, R=3/4)	15 dBW	For this SW release, a hard-decision Viterbi decoder was implemented in Matlab, so an extra 1 to 2-dB degradation needs to be accounted for in the results.
4/ Punctured Convolutional(K=7, R=7/8)	> 17 dBW	Same as 3.
5/ Reed Solomon + Interleaving	> 17 dBW	-
6/ Concatenated Convolutional(K=7, R=1/2) + RS(255, 223) + I=3	9.2 dBW	The demodulator unlocked at an unreasonable high Eb/No (~5 dB). Therefore, the minimum EIRP value is limited by the poor PLL performance rather than by the correcting capabilities of the FEC scheme.
7/ Concatenated Punctured Convolutional(K=7, R=3/4) + RS(255, 223) + I=3	9 dBW	Same as 3.
8/ Concatenated Punctured Convolutional(K=7, R=7/8) + RS(255, 223) + I=3	12 dBW	Same as 3.

Table 2 – *Summary of results for several tested FEC configurations.*

Table 2 summarises the results for the given configurations. For each FEC scheme, the minimum value of the transmitted EIRP for 100% successful reception (complete message without CRC errors) is given along with some comments/remarks for a better understanding of the obtained results.

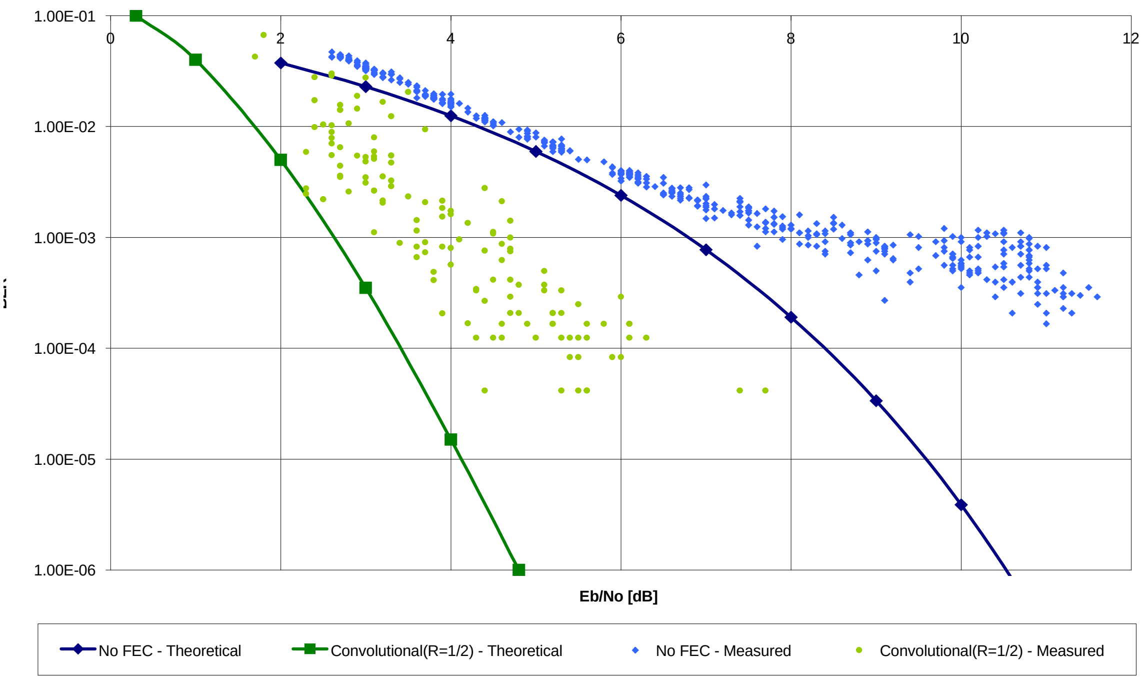


Figure 7 – *HRDCP reception performance when using no FEC and Convolutional(R=1/2) coding.*

Overall, the results show the benefit of a concatenated convolutional implementation approach in terms of transmitted EIRP. Therefore, for the following phases of the tests, only concatenated convolutional FEC configurations have been retained.

Long Term HRDCP System Performance Tests for one FEC scenario:

- o Concatenated Convolutional (K=7, R=1/2) + RS(255, 223) + I = 3.

Table 3 provides the overall summary of the long term reception statistics for the selected case for the HRDCP implementation (concatenated coding with convolutional coding (R=1/2, K=7) as outer code and CCSDS compliant scrambled RS coded blocks using RS (255,223) as inner code. These results are also depicted in Figure 8 and clearly show that below 9.2 dBW of EIRP the system performance is too low (i.e. message reception probability is below 99%), and that if a minimum of 99,5% availability is considered, then TX EIRP > 13 dBW.

Note: For all configurations, the receiver setup used 4 demodulators tuned to the same reception frequency but with different configurations (default and “narrow” PLL, but always the same). The two groups of receivers have been connected as follows: 2 before the EDA tracker and 2 after the EDA tracker. The tests have therefore allowed verification of system performance with and without EDA correction and with two different set of receiver PLL configurations. Nevertheless, no effort has been made in optimising RX configuration (this is left to the necessary system tuning during the operational phase).

HR DCP EIRP [dBW]	TX	RX OK	Probability of Message Reception	PLL / Tracker Config.
13	4808	4805	99.938	Default / Beacon
		4804	99.917	Narrow / Beacon
		4795	99.730	Default / B + EDA
		4781	99.438	Narrow / B + EDA
10.2	5554	5535	99.658	Default / Beacon
		5535	99.658	Narrow / Beacon
		5536	99.676	Default / B + EDA
		5536	99.676	Narrow / B + EDA
9.2	5160	5138	99.574	Default / Beacon
		5141	99.632	Narrow / Beacon
		5138	99.574	Default / B + EDA
		5145	99.709	Narrow / B + EDA
8.2	2897	2833	97.791	Default / Beacon
		2867	98.964	Narrow / Beacon
		2853	98.481	Default / B + EDA
		2875	99.240	Narrow / B + EDA
7.2	1980	487	24.596	Default / Beacon
		1323	66.818	Narrow / Beacon
		941	47.525	Default / B + EDA
		1841	92.980	Narrow / B + EDA

Table 3 – *Long term reception statistics (Probability of Message Reception) vs TX EIRP for the case of concatenated convolutional coding (R=1/2, K=7) and RS (255,223) with I=3.*

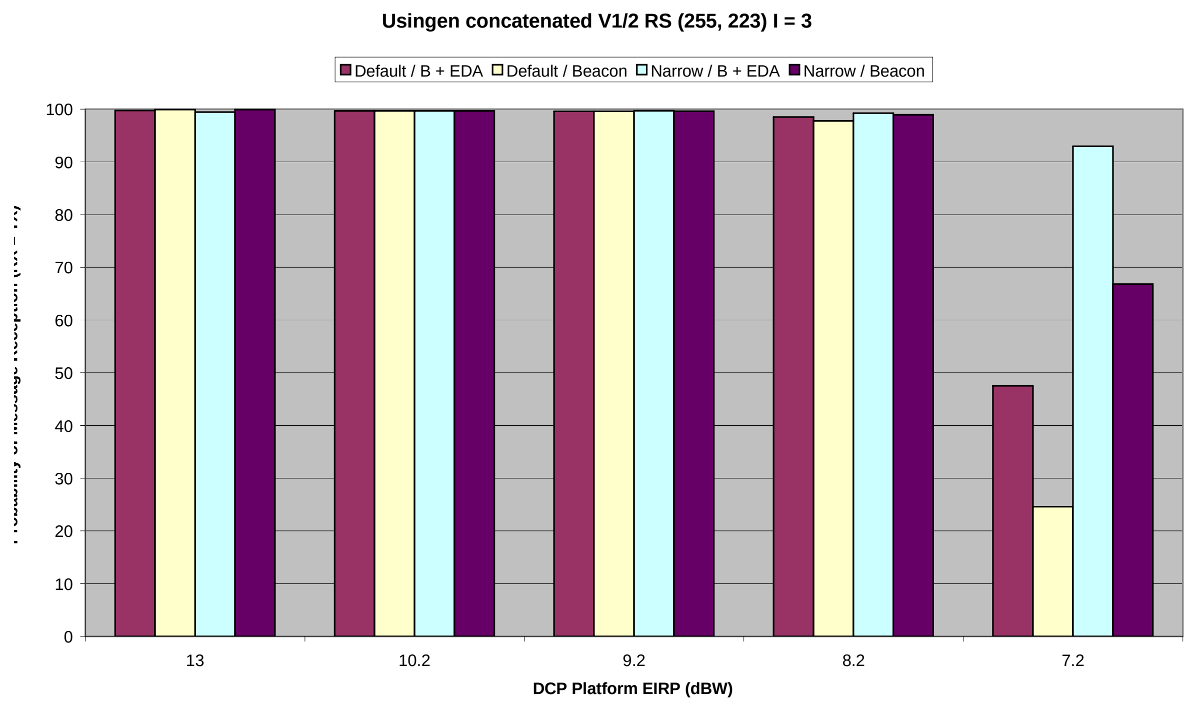


Figure 8 – *Long term reception statistics (Probability of Message Reception) vs TX EIRP for the case of concatenated convolutional coding (R=1/2, K=7) and RS (255,223) with I=3.*

Single Adjacent Channel Interference Tests showed that a minimum channel separation of 2400 Hz was required for a C/I = -10dB for 100% successful message reception. At lower C/I values, no successful reception was achieved.

3.2 POPP Test results: Spring 2008 campaign

Based on the results obtained during the eclipse season of autumn 2007, EUMETSAT decided to work out a refinement of the HRDCP prototype receivers to correct several observed misperformances: the threshold of demodulation was too far (above) from the theoretical values, the degradation caused by the adjacent channel too high, hard-decision off-line punctured decoder had to be used as it was not available on the receiver. Analysis of the source code of this part of the receiver allowed identifying few under-performing functions that were recoded with a more performing set of SW subroutines (and/or libraries). Similarly, a walkthrough the main functions of the S/W of the transmitter was also performed and the small bugs detected during the testing phase were identified and removed. Some H/W modifications were also performed on the receiver units to make them compatible to a 10 MHz external reference and a 70 MHz IF input.

The new H/W and S/W versions were released just in time for the spring 2008 eclipse season and specific performance tests were repeated. In this case the full testing effort has been focused on the only FEC case retained by EUMETSAT (i.e. concatenated coding with convolutional (R=1/2) / punctured (R=3/4) and RS (255,223) with I=3 and pseudo-randomisation at the level of the RS coded blocks).

The following tests have been performed:

Beacon Tracker Performance Test concluding that the unit was able to track the satellite's LO changes even during heavy eclipse conditions, as depicted in Figure 9. The performance of the beacon tracker implemented in the HRDCP RX was compared to the beacon frequency offset estimates reported by the current operational DCP receivers (NT system). Both values are displayed in Figure 9 for 13 days (DOY 95 to DOY 108). The graph shows that both estimates are very similar (within 10 Hz) even during eclipse.

EDA Tracker Performance Test concluding that the use of EDA tracking provides around 1 dB extra margin. The performance of the amplitude and phase ripple as estimated by the EDA ripple tracker implemented in the HRDCP RX for DOY 095 to 110 is depicted in Figure 10. The estimates during that period fall within the expected values (AM of ~1.5 to 2 dBpp and PM of 35 to 40ºpp). Both amplitude and phase ripple estimates show a clear daily periodic behaviour, stronger in the case of AM ripple that relate to the amplitude and phase stability of the transmitting and receiving chains.

HRDCP System performance vs EIRP Test for different FEC scenarios:

- no FEC,
- Concatenated Convolutional (K=7, R=1/2) + RS(255, 223) + I = 3, and
- Concatenated Punctured (K=7, R = ¾) + RS(255, 223) + I = 3.

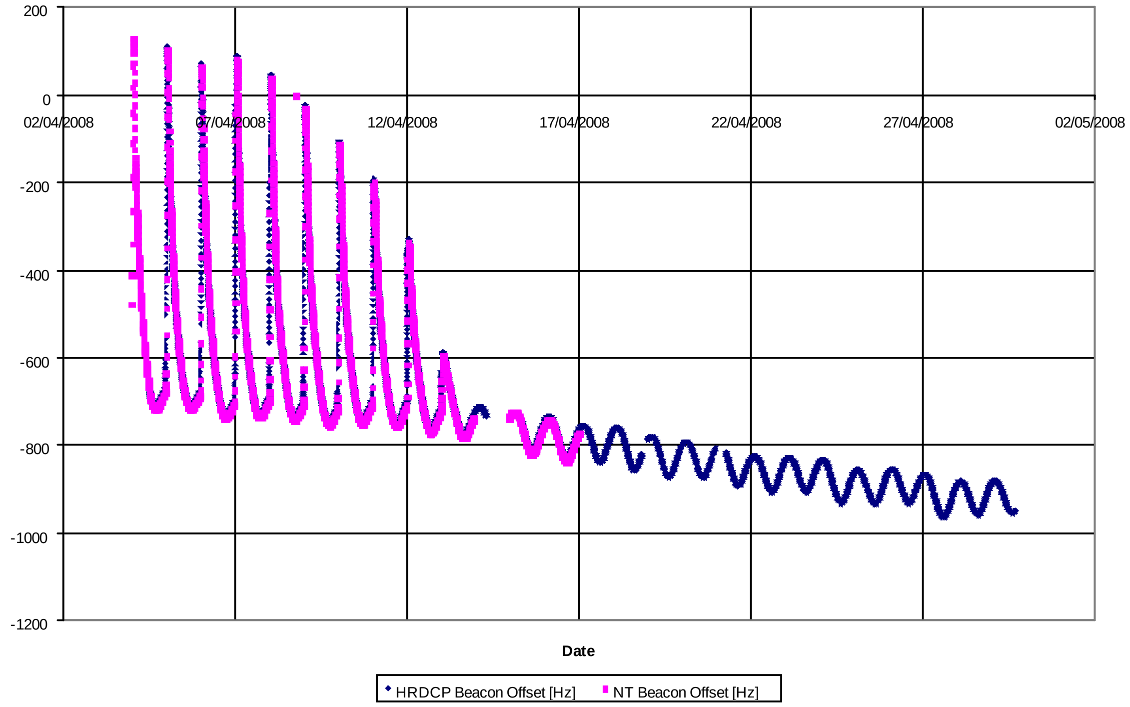


Figure 9 – *Comparison of beacon offset frequency estimates as reported by the HRDCP RX and 100 bps operational DCP system (CORTEX NT).*

Note: There is a gap in the depicted values around 13/04/2008 due to arecording failure

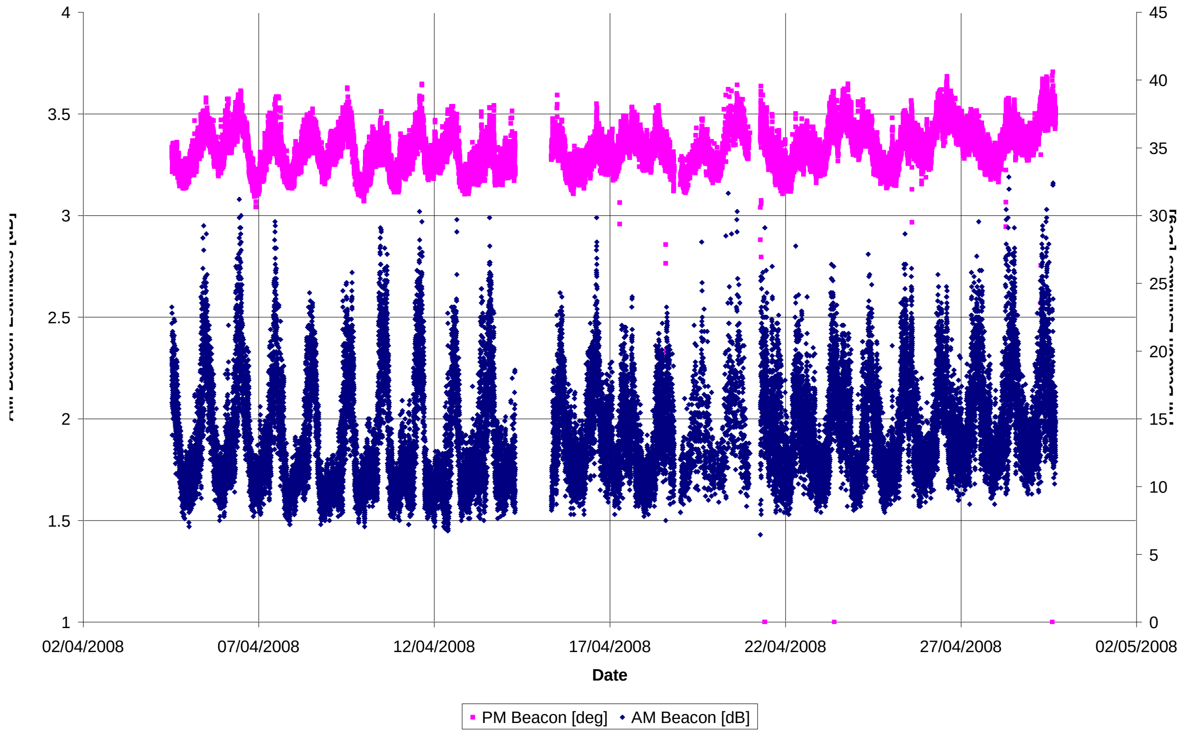


Figure 10 – *Amplitude and phase ripple as reported by the EDA ripple tracker between DOY 095 to 124.*

Figure 11 provides confirmation of the threshold effect created by the system phase noise and AM/PM ripple on the satellite channel when no FEC is applied to the platform data. As an be seen in the figure, the non coded BER is departing from the theoretical curve as the E_b/N_0 increases, showing that, beyond a threshold point, increasing he TX power (i.e. increasing the E_b/N_0 of the signal) has no real effect on the channel BER. For both concatenated cases (R=1/2 and R=3/4) the implementation losses are smaller than 1 dB.

Table 4 summarises the results for the given configurations. For each FEC scheme, the minimum transmitted EIRP value for 100% successful reception (complete message without errors) is given along with some comments/remarks for a better understanding of the obtained results.

Overall, the results confirm the benefit of a concatenated convolutional implementation approach in terms of transmitted EIRP, as already observed in the previous release.

Long Term HRDCP System performance tests for two FEC scenarios:

- Concatenated Convolutional (K=7, R=1/2) + RS(255, 223) + I = 3, and
- Concatenated Punctured (K=7, R = ¾) + RS(255, 223) + I = 3.

Table 5 provides the overall summary of the long term reception statistics, with the final prototype S/W version, for the selected case for the HRDCP implementation (concatenated coding with convolutional coding (R=1/2, K=7) as outer code and CCSDS compliant scrambled RS coded blocks using RS (255,223). These results are depicted in Figure 12. For this test, the HRDCP TX was set up in 'continuous' mode to transmit every 60 secs a DCP message of duration 20 secs of PN-generated platform.

FEC Scheme	Minimum EIRP	Comment
1/ No FEC	-	As depicted in Figure 11, beyond a given E_b/N_0 point, the system is no longer AWGN-limited, but phase noise limited (TX, RX and satellite transponder phase noise) as well as AM/PM satellite ripple limited.
2/ Concatenated Convolutional(K=7, R=1/2) + RS(255, 223) + I=3	4.5 dBW	4.5 dB gain with respect to previous release.
3/ Concatenated Punctured Convolutional(K=7, R=3/4) + RS(255, 223) + I=3	7.5 dBW	1.5 dB gain with respect to previous release.

Table 4 – *Summary of results for several tested FEC configurations.*

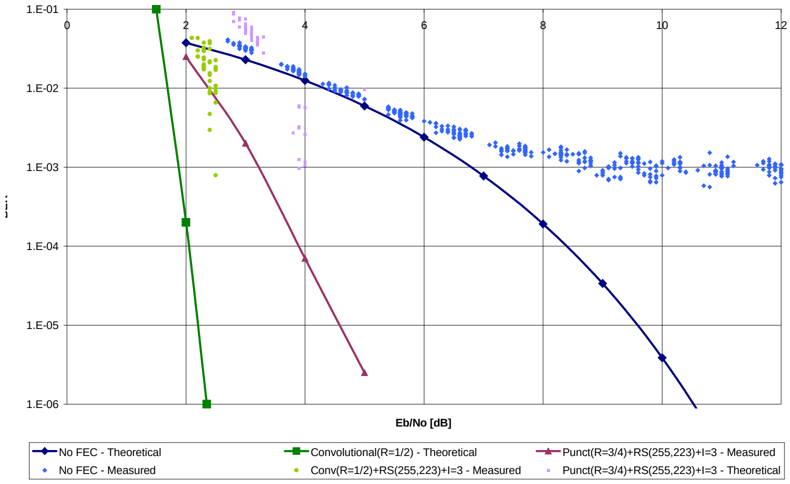


Figure 11 – HRDCP reception performance when using no FEC, Concatenated Convolutional(R=1/2) + RS(255, 223) + I=3, and Concatenated Punctured(R=3/4) + RS(255, 223) + I =3 coding.

DoY	EIRP [dBW]	TX	RX OK	Probability of Correct Message RX	PLL / Tracker Config.
95 to 100	12.5	5636	5636	100.00%	Default / Beacon
			5569	98.81%	Narrow / Beacon
			5632	99.93%	Default / B + EDA
			5565	98.74%	Narrow / B + EDA
100 to 105	8.5	5743	5742	99.98%	Default / Beacon
			5719	99.58%	Narrow / Beacon
			5741	99.96%	Default / B + EDA
			5715	99.53%	Narrow / B + EDA
106 to 109	7.5	5376	5374	99.96%	Default / Beacon
			5373	99.94%	Narrow / Beacon
			5375	99.98%	Default / B + EDA
			5373	99.94%	Narrow / B + EDA
112 to 115	6.5	6871	6871	100.0%	Default / Beacon
			6867	99.94%	Narrow / Beacon
			6869	99.97%	Default / B + EDA
			6869	99.97%	Narrow / B + EDA
115 to 119	5.5	7182	7117	99.09%	Default / Beacon
			7174	99.88%	Narrow / Beacon
			7146	99.49%	Default / B + EDA
			7175	99.90%	Narrow / B + EDA
119 to 123	4.5	5031	4235	84.17%	Default / Beacon
			4995	99.28%	Narrow / Beacon
			4438	88.09%	Default / B + EDA
			5000	99.38%	Narrow / B + EDA
123 to 127	3.5	4768	582	12.20%	Default / Beacon
			3494	73.28%	Narrow / Beacon
			781	16.38%	Default / B + EDA
			4016	84.22%	Narrow / B + EDA

Table 5 – *Final S/W version: Long term reception statistics (Probability of Message Reception) vs TX EIRP for the case of concatenated convolutional coding (R=1/2, K=7) and RS (255,223) with I=3.*

Based on actual traffic measurements on the operational DCP transponder, these results confirm that the Pre-Operational Pilot Phase HRDCP prototypes are performing within margins and that a system implementation needs a minimum transmission power of 6.5 dBW for ensuring a Probability of Message Reception (PMR) better than 99.95 %. It is worth noticing that, due to the characteristics of the selected FEC method, the system performance is not really improved if we increment the transmitted power, it just adds margin to the system link budget.

It is also worth mentioning that, as these figures are obtained using the operational transponder, they reflect the real HRDCP system performance as they already include message losses due to signal interferences (or any other TX/RX problem existing in the operational system).

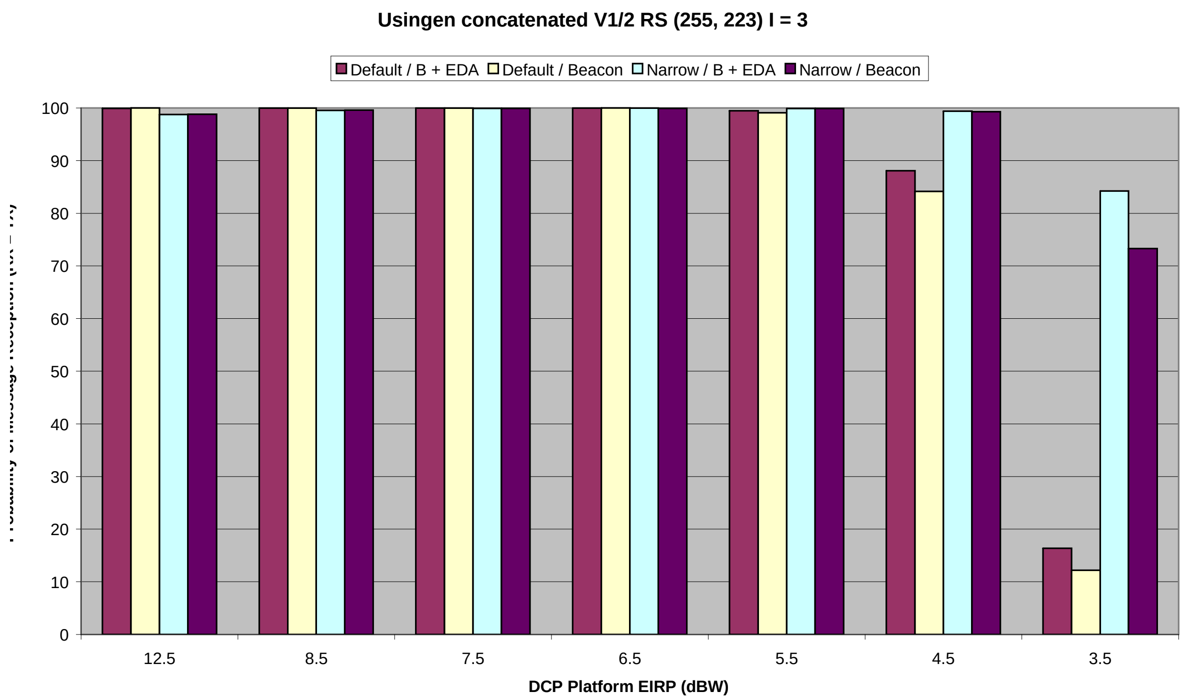


Figure 12 – *Final S/W version: Long term reception statistics (Probability of Message Reception) vs TX EIRP for the case of concatenated convolutional coding (R=1/2, K=7) and RS (255,223) with I=3.*

Similar long term tests were conducted for concatenated punctured (R=3/4) + RS(255, 223) + I = 3 and it was found that a minimum TX EIRP of 9.5 dBW was required for better than 99.95% availability. Although punctured coding R=3/4 permits a 50% increase in data throughput, it requires a 3-dB increase in the transmitted EIRP, a fact that is considered detrimental as the platforms would require bigger solar panels and batteries. Therefore, only convolutional coding R=1/2 has been retained for the final HRDCP specifications

Single Adjacent Channel Interference tests showed that for 100% successful ‘complete and correct’ message reception, a minimum channel separation of 1900 Hz shall be retained (This value allows for current 3000 Hz channelisation as well as for future narrow channelisation of 2250 Hz). If current 3000 Hz channelisation is to be used, then a 1-dB margin in the link budget shall be included due to Eb/No degradation caused by the adjacent channel interferer. If narrow 2250 Hz channelisation is to be used, then 2 to 3 - dB margin in the link budget shall be included due to Eb/No degradation caused by the adjacent channel interferer, as can be seen in Figure 13.

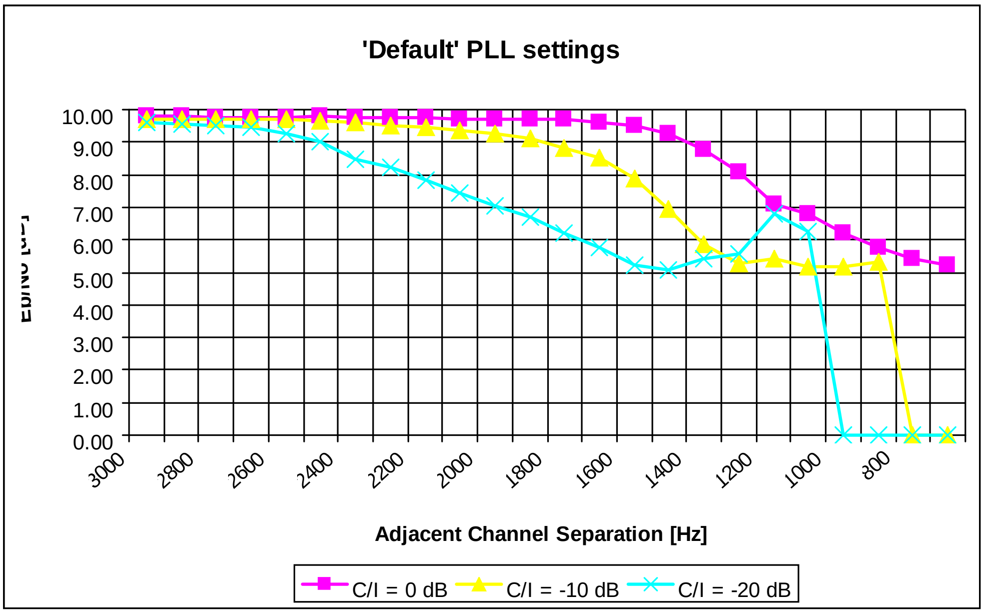


Figure 13 – *Eb/No degradation due to adjacent channel interference using saturated HPA as a function of C/I and adjacent channel interference.*

3.2.1 Impact of platform movement (buoy platforms)

The Pre-operational Pilot Phase has explored the potential of use of the new prototypes not only for fixed platforms but also for moving ones such as ocean buoy platforms. The case of a buoy platform has been simulated on a “fixed” HRDCP signal by re-creating the AM/PM ripple values derived from the signal received by the 100 bps DCP operational system in Usingen, Germany, for a 24h period on 4th Feb 2008 from the M4 and M6 platforms from the Irish Marine Institute. The related period correlates to some storm weather off the west coast of Ireland with wave height in the 4-6m range and wave period in the 8-10s range. This results in a modified DCP signal as depicted in Figure 14 for the amplitude (EIRP) of the signal, Figure 15 for the frequency of the signal and Figure 16 for the associated phase noise (this includes not only the effect of buoy movement but also the overall channel phase noise and the phase noise of the transmitting platform). As shown in these figures, the amplitude of the DCP signal can vary more than 4 dB suddenly and the overall received signal phase noise is clearly outside the certification mask (dotted line in Figure 16). The AM/PM ripple modified HRDCP signal has been transmitted with different EIRP values and has then been used to derive the additional degradation induced by the movement of the transmitting platform (like the buoy platform under heavy see conditions).

The overall system performance, under these additional degraded conditions, has been found to need 4 dB of additional EIRP for reaching minimum system performance.

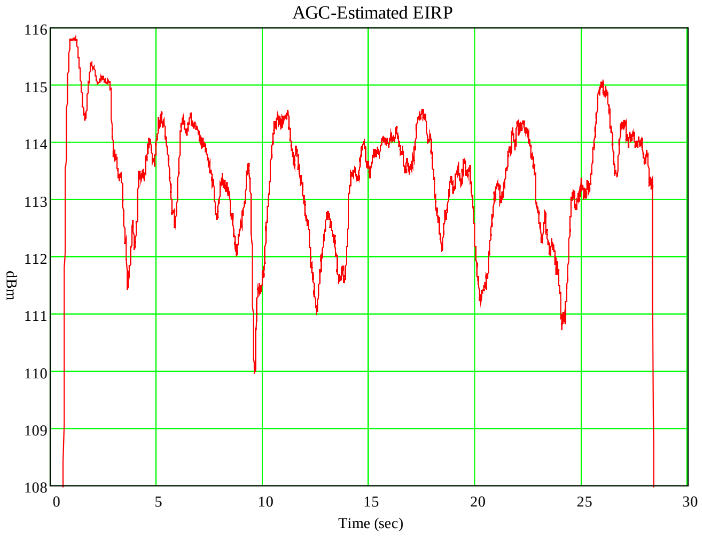


Figure 14 - *AM (EIRP) profile derived from an ocean-buoy platform.*

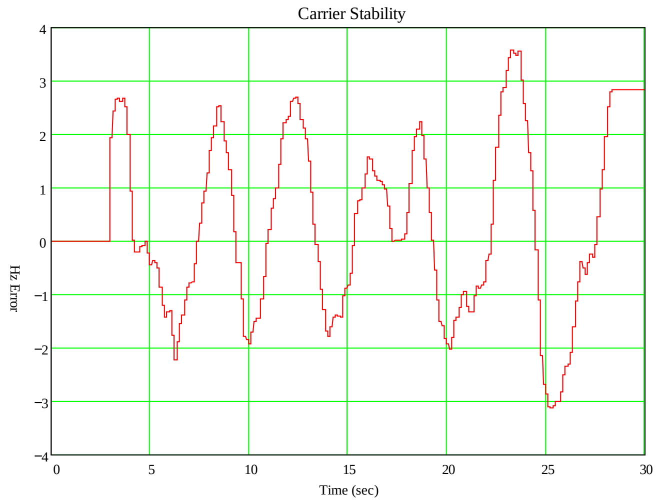


Figure 15 - *FM profile derived from an ocean-buoy platform.*

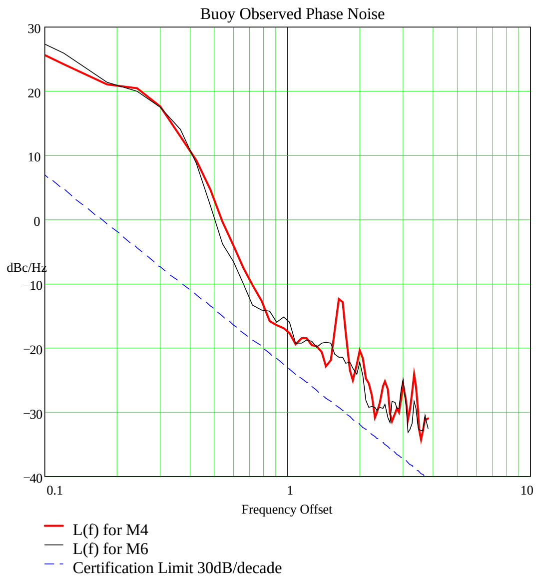


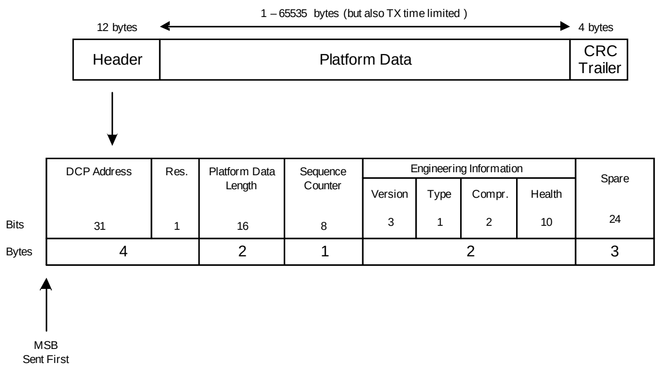
Figure 16 – *Phase Noise spectrum profile derived from an ocean-buoy platform.*

4 SYSTEM SPECIFICATIONS FOR THE EUMETSAT MSG HR DCP SYSTEM

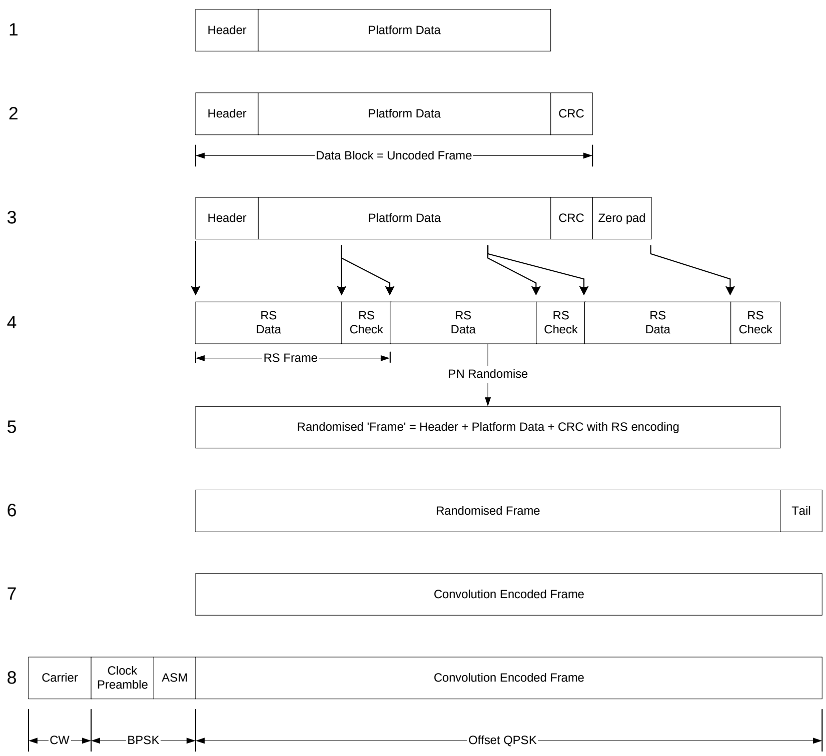
Based on the results of the Pre-Operational Pilot Phase, EUMETSAT has drafted a HRDCP System Specification that is currently under internal evaluation. Main characteristics are detailed below:

DCP Message format: The HRDCP message format is broken down in the following parts:

a) header with the DCP address and engineering information,
b) platform data field, and
c) trailer with an overall CRC computed according to 0x04C11DB7 polynomial.



HRDCP Data construction: The construction of the overall transmitted waveform consists of an unmodulated carrier with a duration of 0.5 secs, preamble clock and frame synchronisation modulated in BPSK, followed by the FEC protected 'header + platform data + CRC' modulated in OQPSK, as depicted below.



Data formats: Binary data channel

FEC: CCSDS compliant concatenated coding using RS (255,223) with I=3 plus convolutional encoding (R=1/2, K = 7) with G2 inverted, as defined in CCSDS recommendations (G1 on I and G2 on Q channels).

Preamble: The preamble shall be of the 32-bit pattern 0xA05050A0 repeated to make a total of 128 bits.

ASM: A 64-bit long Attached Synchronisation Marker (ASM), 0x034776C7272895B0 shall be attached to the left of the incoming data.

Encoder Flush: A 1-byte tail sequence, value 0x80, shall be attached at the end of the HRDCP frame to flush the K=7 convolutional encoder to end the trellis in the all zero state.

Modulation Characteristics:

1. The modulator shall produce a BPSK-like signal from a NRZ-L baseband waveform during the clock preamble and ASM. *(The phase values for the BPSK-like constellation shall be 45º for 0 and 225º for 1, instead of the traditional 0º and 180º.)*
2. The modulator shall automatically switch to SRRC (=0.5) OQPSK signal from a NRZ-L baseband waveform for the rest of the message.

Bit Rate: The data rate at the input of the SRRC-OQPSK modulator shall be 2400 bps. *(The effective data rate, when operating in BPSK mode, shall be half the value.)*

System EIRP (min, max): 10-20 dBW (minimum step of 1 dB)

System TX Phase Noise: 2° rms integrated/measured using the certification test set.

Frequency mask: The OQPSK modulated signal shall fall within the following spectral emission mask (to be measured at the HPA output at the worst operating point in terms of bandwidth):

Frequency Relative to Carrier		Relative Power Spectral Density wrt to Centre Frequency
3000 Hz Channelisation	*2250 Hz Channelisation*	
1500Hz	*1125Hz*	0 dB (constant limit)
-1500Hz to -3000Hz & 1500Hz to 3000Hz	*-1125Hz to -2250Hz & 1125Hz to 2250Hz*	-25 dB (constant limit)
-3000Hz to -7200Hz & 3000Hz to 7200Hz	*-2250Hz to -6450Hz & 2250Hz to 6450Hz*	-60 dB tapering to -25dB
Beyond 7200Hz	*Beyond 6450Hz*	-60 dB (constant limit)

Table 6 – *Suggested HRDCP transmission frequency mask.*

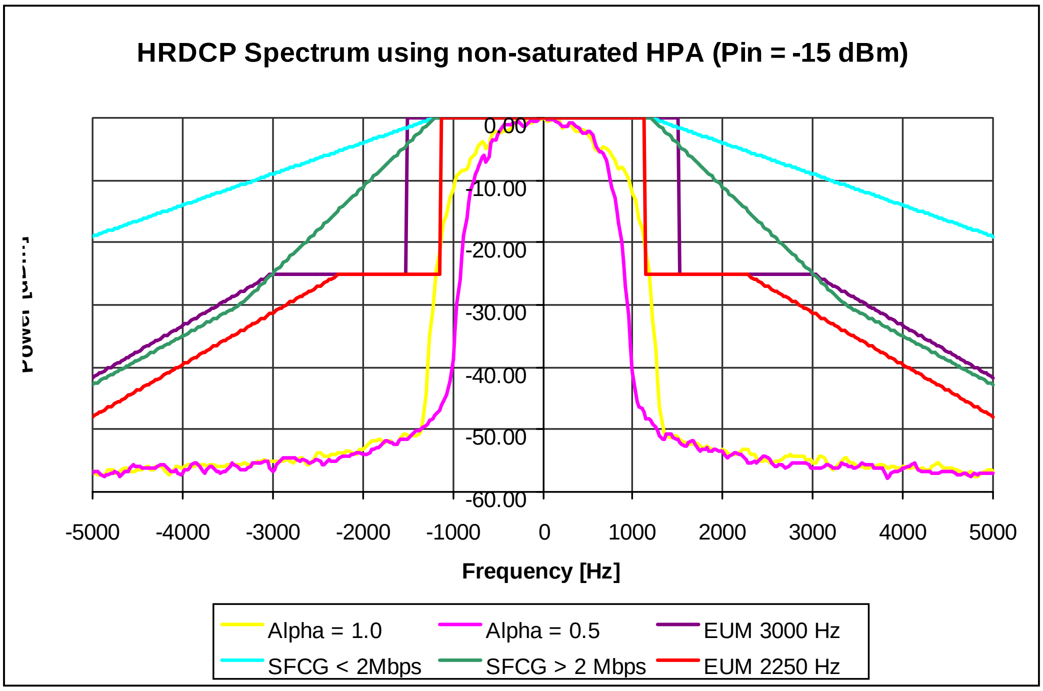


Figure 17 – *Comparison between EUMETSAT HRDCP frequency masks, SFCG masks and transmitted OQPSK spectra.*

<u>**Frequency slots:**</u> Initially 3KHz, consideration being given for 2250 Hz.

<u>**Frequency Stability:**</u> Better than125 Hz

<u>**Time slots:**</u> variable from 10 to 60 secs in 5 secs steps.
(The time slot assigned to a given HRDCP platform will depend on the amount of data to be transmitted.The minimum block size length is 1530 bytes, which leads to a minimum transmission message duration of 5.1 seconds. The message is preceded by0.5 secs of unmodulated carrier, preamble and ASM and protected with 0.5 secs guard bands at the beginning and end of the message. Thus, minimum transmission duration is 6.85 secs).

<u>**Time Stability:**</u> Better than 0.25 secs.