MOSTDONT
Mode S Transponder in high density operational environment

Presentation of interim results
29.06.2010

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Flight Calibration Services

Contents

- Background, scope of work
- Measurement equipment
- Overview on missions flown
- Signal-in-Space versus Signal-in-Receiver

Background

- In certain areas in Europe Mode S transponders of small aircraft were not detected (“Filser”)
- MOSTDONT WP2100 “Evaluation of the characteristics of the signal in space” is the basis for all analysis and conclusions

Measurements during Flight Inspection

- FCS aircraft “D-CFMD” was used for measurements during ferry and mission flights
- ~100 flight hours with equipment so far
- 3 flight hours with Cessna 172 “D-EMWF” of TU-BS

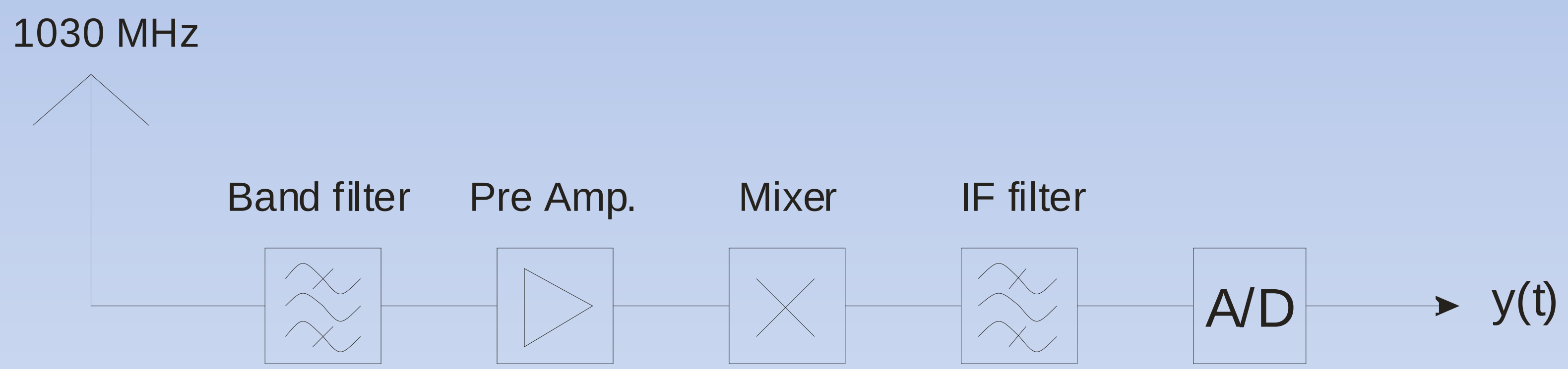
Beech KingAir B300 “D-CFMD”

Measurement equipment (1)

- Signal-in-space can be measured unaltered only with spectrum-analyzer-like equipment having no bandwidth limits
- Any RF and baseband filters to be used in Receivers affect the signal parameters

Measurement equipment (2)

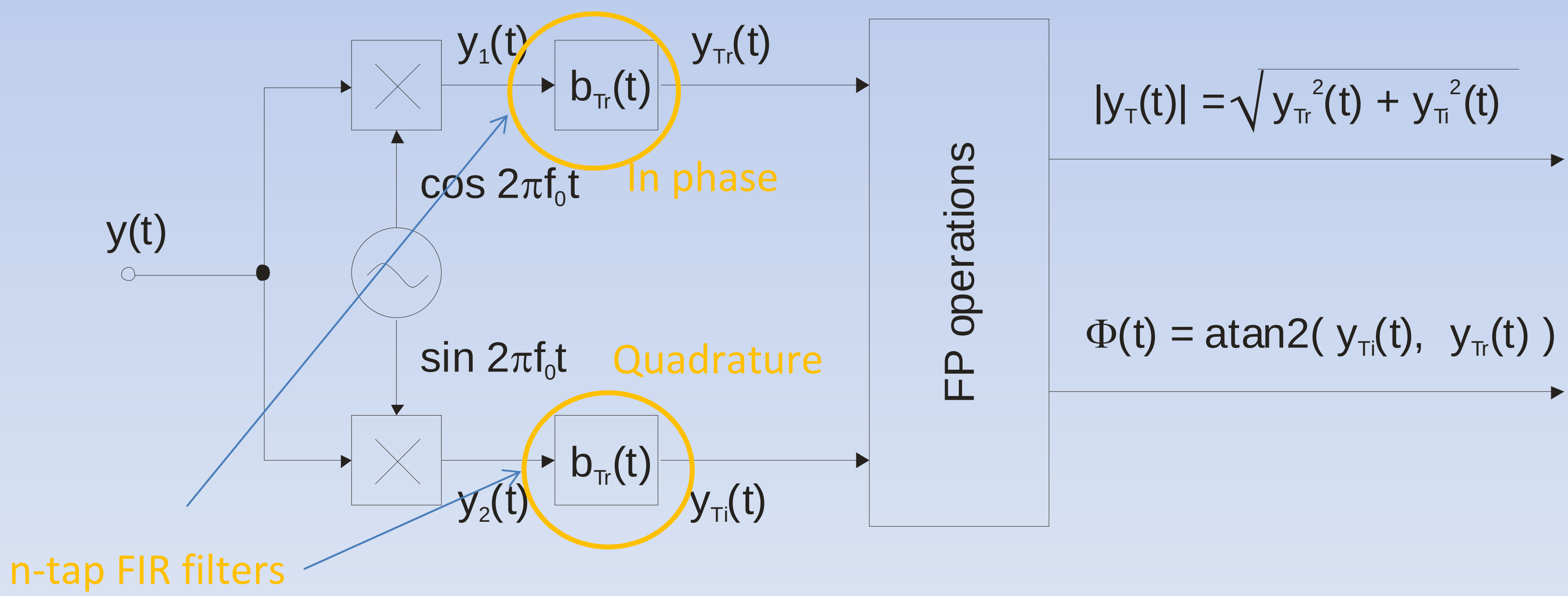
Hardware section of signal processing



- 3dB overall bandwidth at ADC: 10MHz
- y(t) has 14 bits and 105MSps/s at IF 70MHz
- Tolerant Mode S preamble correlator starts recording on hard disk
- 8kB raw IF data is obtained per telegram
- 400GB of raw data collected so far
- Up to 1.5% of time the correlator is suppressed by L band activity

Measurement equipment (3)

Software section of signal post processing



Measurement equipment (4)

- MOSTDONT measurement system (FCS internal name: SISMOS/SSR) is not a spectrum analyzer but a measurement receiver!
- Bandwidth is reduced when signal runs through various sections and filters
- Only a true Spec. Analyzer gives access to SIS measurements due to “infinite” bandwidth
- Constraints of measurement receiver must be considered
- Problems may occur within transponders which inherently have real receivers

Momentary Frequency

When applying a phase reversal from 10° to 170° during the longest ICAO-compliant value 80ns, we have a momentary frequency deviation:

$$\Delta f = \frac{1}{2\pi}\frac{\partial\varphi}{\partial t} = \frac{1^\circ}{360^\circ}\frac{160^\circ}{80ns} = 5.56MHz$$

Reference to interogator by II/SI code

EUR REGIONAL AIR NAVIGATION PLAN

FACILITIES AND SERVICES IMPLEMENTATION DOCUMENT
(FASID)

PART IV

COMMUNICATIONS, NAVIGATION AND SURVEILLANCE (CNS)

SUPPLEMENT
SSR MODE S INTERROGATOR CODE (IC) ALLOCATIONS FOR THE EUR REGION

Edition 1.6

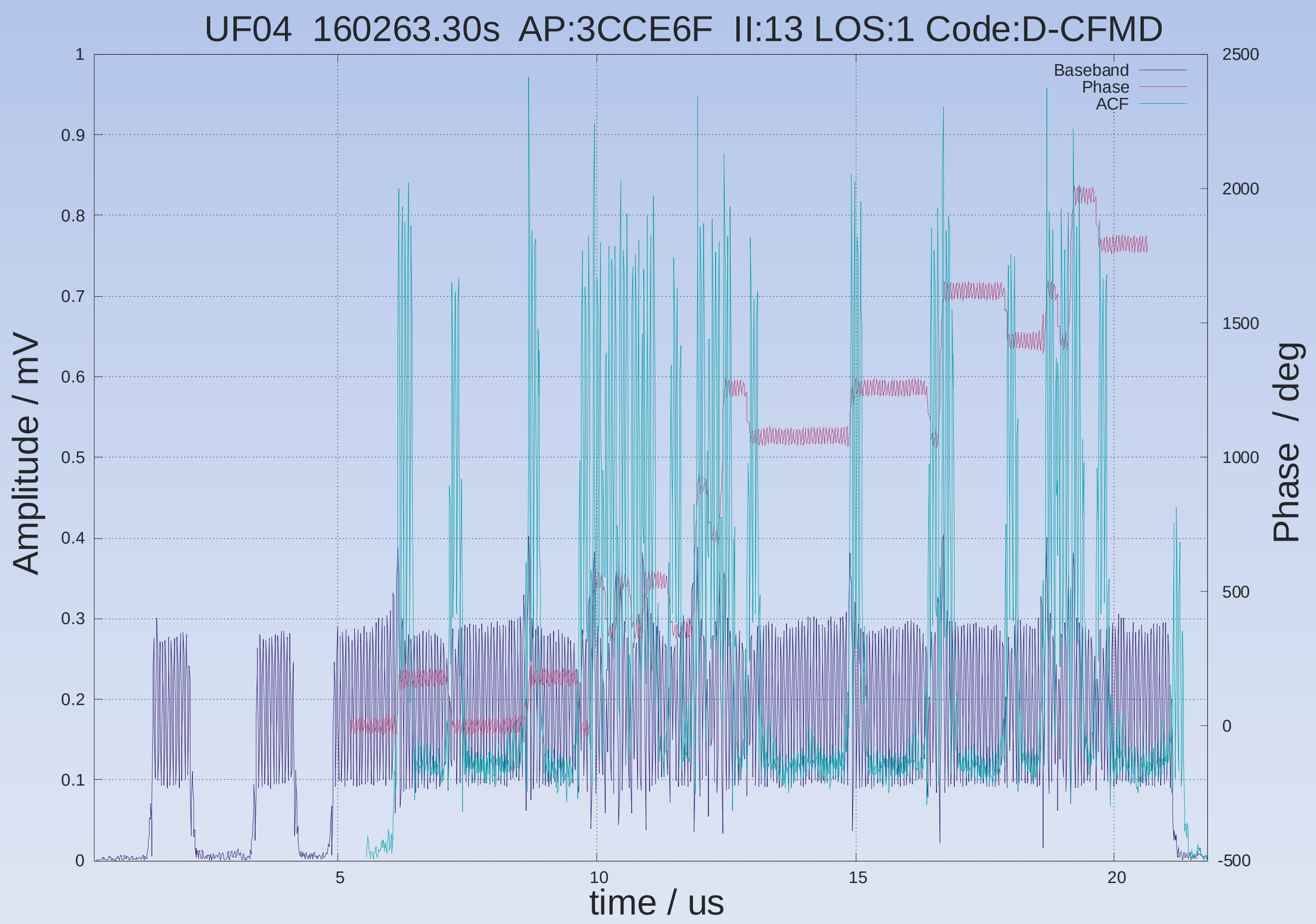
4.16 Code Allocation Status for Germany

MODE S Interrogator Code Allocations as of 06 May 2010 (Cycle 10)

Mode S Station	ALLOCATED CODE			OPERATOR	REMARKS/REFERENCE
	II	SI	Effective Date		
GERMANY					
Auersberg North Cluster main	03		02/07/2008	DFS	MICA/ALLOC358
Auersberg North Cluster fallback	09		02/07/2008	DFS	MICA/ALLOC364
Deister	04		02/08/2007	DFS	MICA/ALLOC271
Deister North Cluster main	03		02/07/2008	DFS	MICA/ALLOC359
Deister North Cluster fallback	09		02/07/2008	DFS	MICA/ALLOC365
Düsseldorf Süd South Cluster main	11		02/07/2008	DFS	MICA/ALLOC352
Düsseldorf Süd					
Büchel	01		02/07/2008	GAF	MICA/ALLOC385
Brockzetel BZ main	13		ad hoc 01/10/2007	GAF	MICA/ALLOC328, Cluster
Brockzetel BZ fallback		13	ad hoc 01/10/2007	GAF	MICA/ALLOC334, Cluster
Döbern DO main	13		ad hoc 01/10/2007	GAF	MICA/ALLOC329, Cluster
Döbern DO fallback		13	ad hoc 01/10/2007	GAF	MICA/ALLOC335, Cluster
Döbraberg DB main	13		ad hoc 01/10/2007	GAF	MICA/ALLOC330, Cluster
Döbraberg DB fallback		13	ad hoc 01/10/2007	GAF	MICA/ALLOC336, Cluster
Elmenhorst EH main	13		ad hoc 01/10/2007	GAF	MICA/ALLOC331, Cluster
Elmenhorst EH fallback		13	ad hoc 01/10/2007	GAF	MICA/ALLOC337, Cluster
Erbeskopf EK, main	13	13	ad hoc 01/10/2007	GAF	MICA/ALLOC332, Cluster
Erbeskopf EK, fallback		13	ad hoc 01/10/2007	GAF	MICA/ALLOC338, Cluster
Großer Arber GA, main	13		ad hoc 01/10/2007	GAF	MICA/ALLOC333, Cluster
Großer Arber GA, fallback		13	ad hoc 01/10/2007	GAF	MICA/ALLOC339, Cluster
Greding	14		05/02/2004	BWB	TRD-Station, MICA/ALLOC077
Erbach	14		ad hoc 07/05/2008	EADS	TRD-Station, MICA/ALLOC395
USH	14		05/02/2004	EADS	TRD-Station, MICA/ALLOC079
Ulm ULM	14		ad hoc 22/03/2007	EADS	TRD-Station, MICA/ALLOC281

Filter effects on phase detection (II 13)

27 tap LP FIR filter, 15MHz passpand,
20MHz stopband, 50dB Att.



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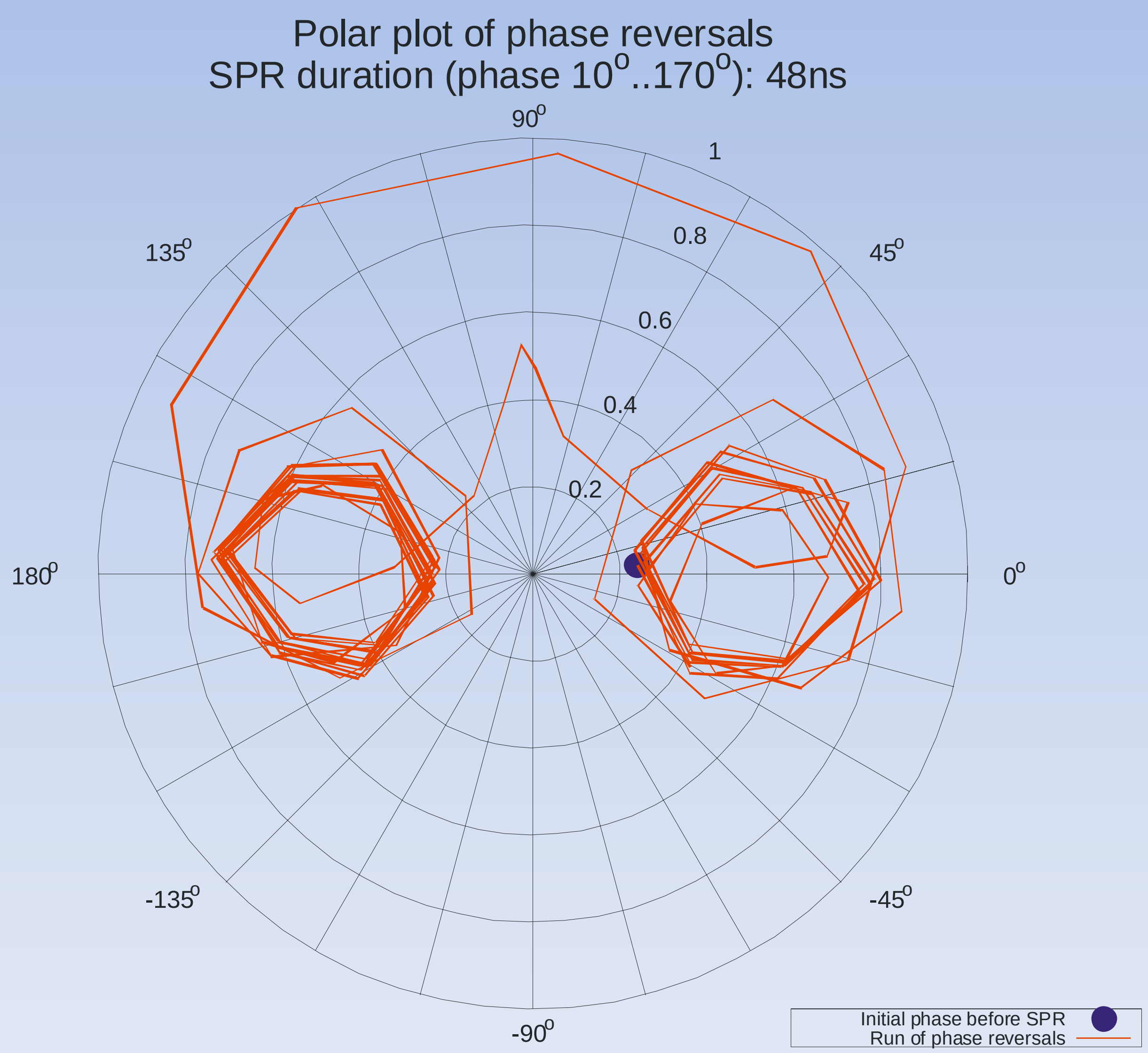
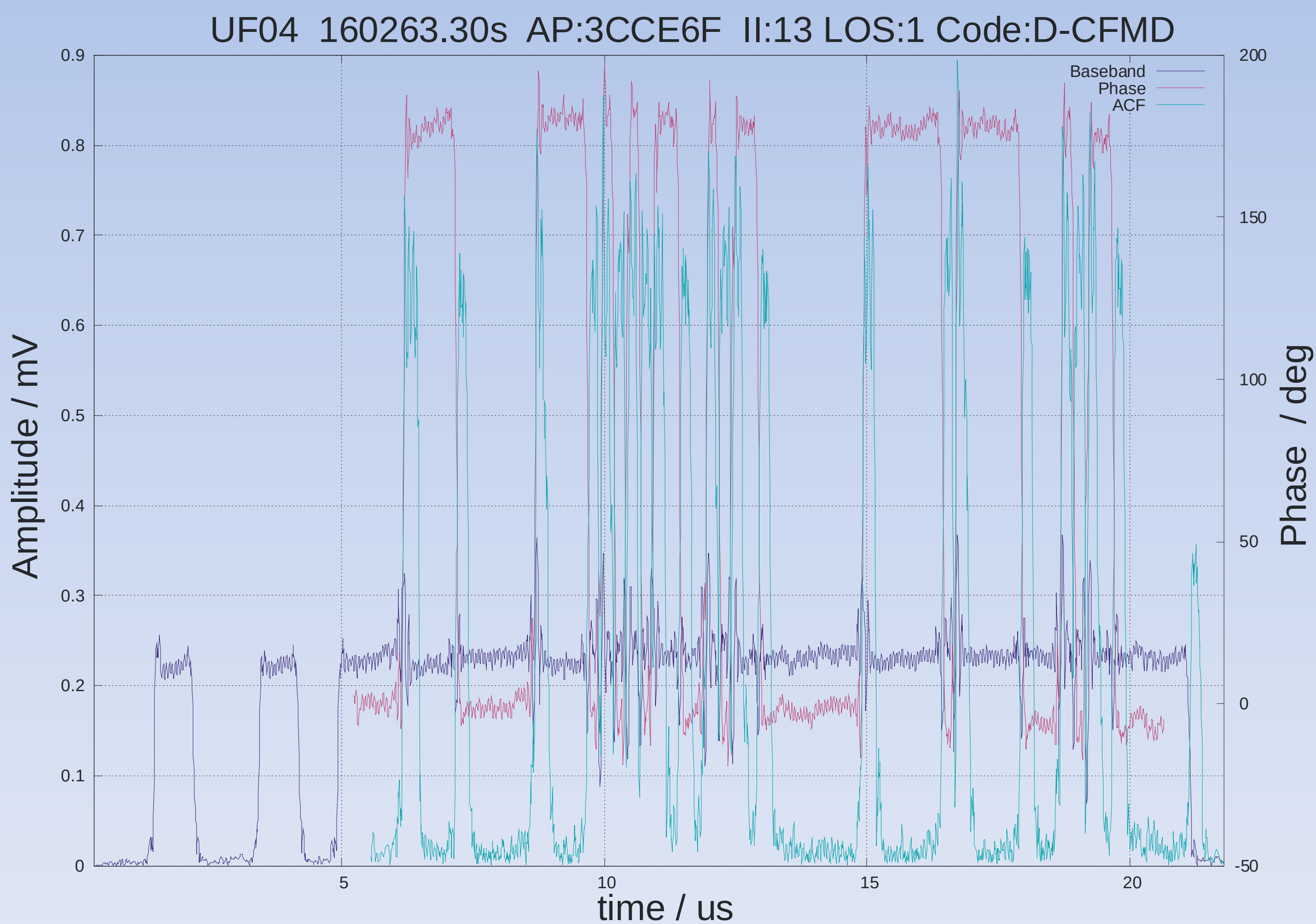


Filter effects on phase detection

28 tap LP FIR filter, 12MHz passpand,
16MHz stopband, 50dB Att.



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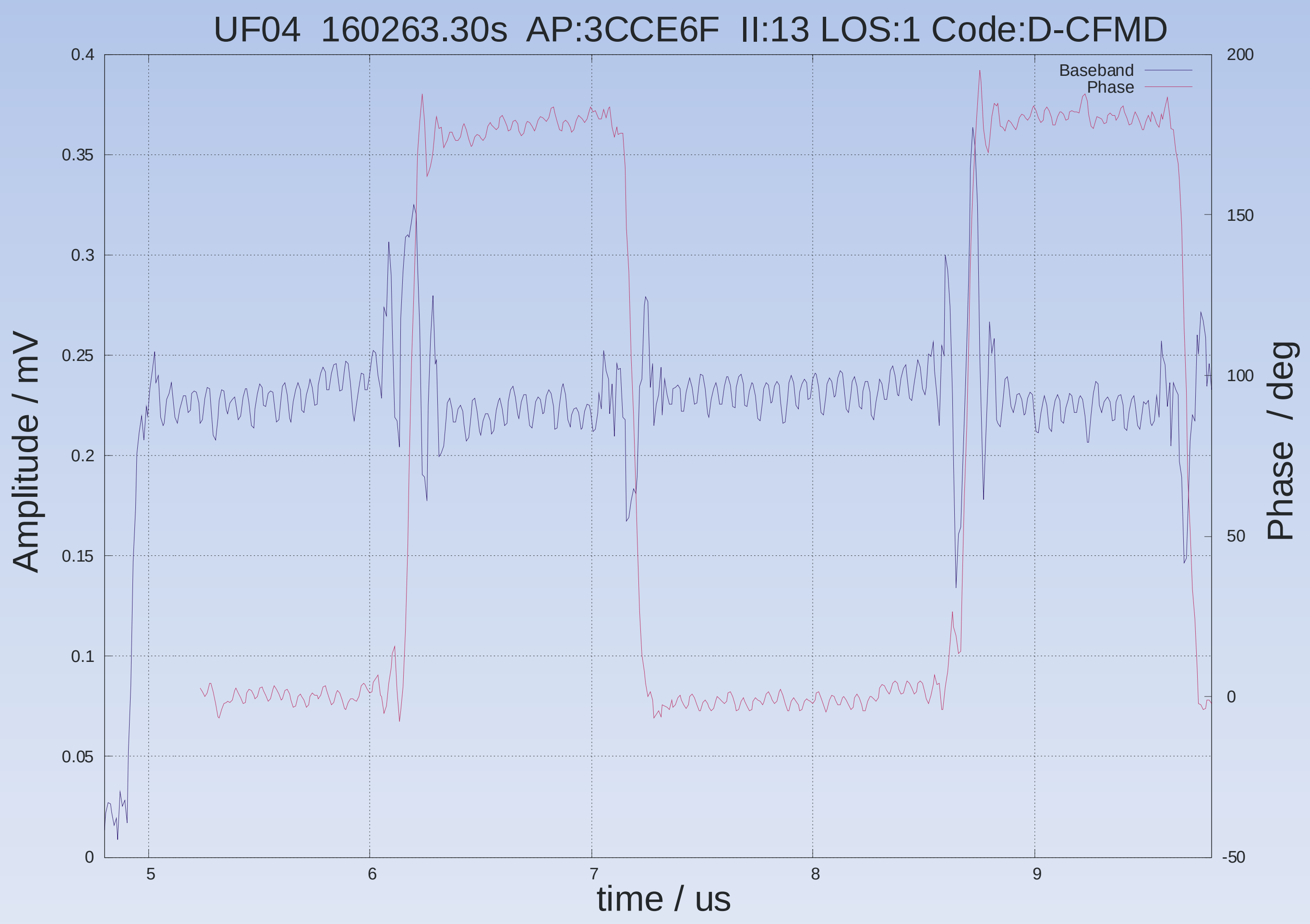

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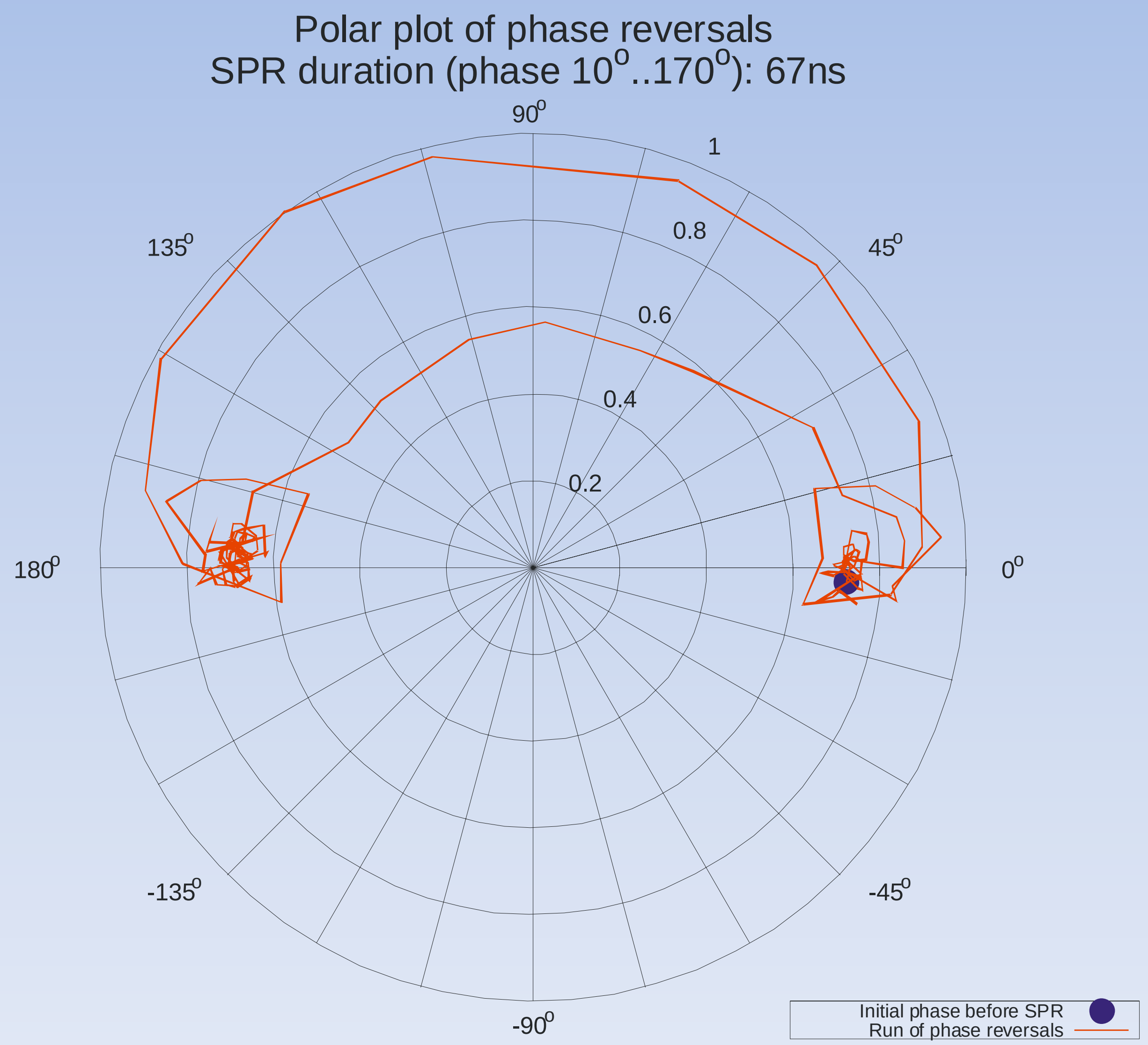
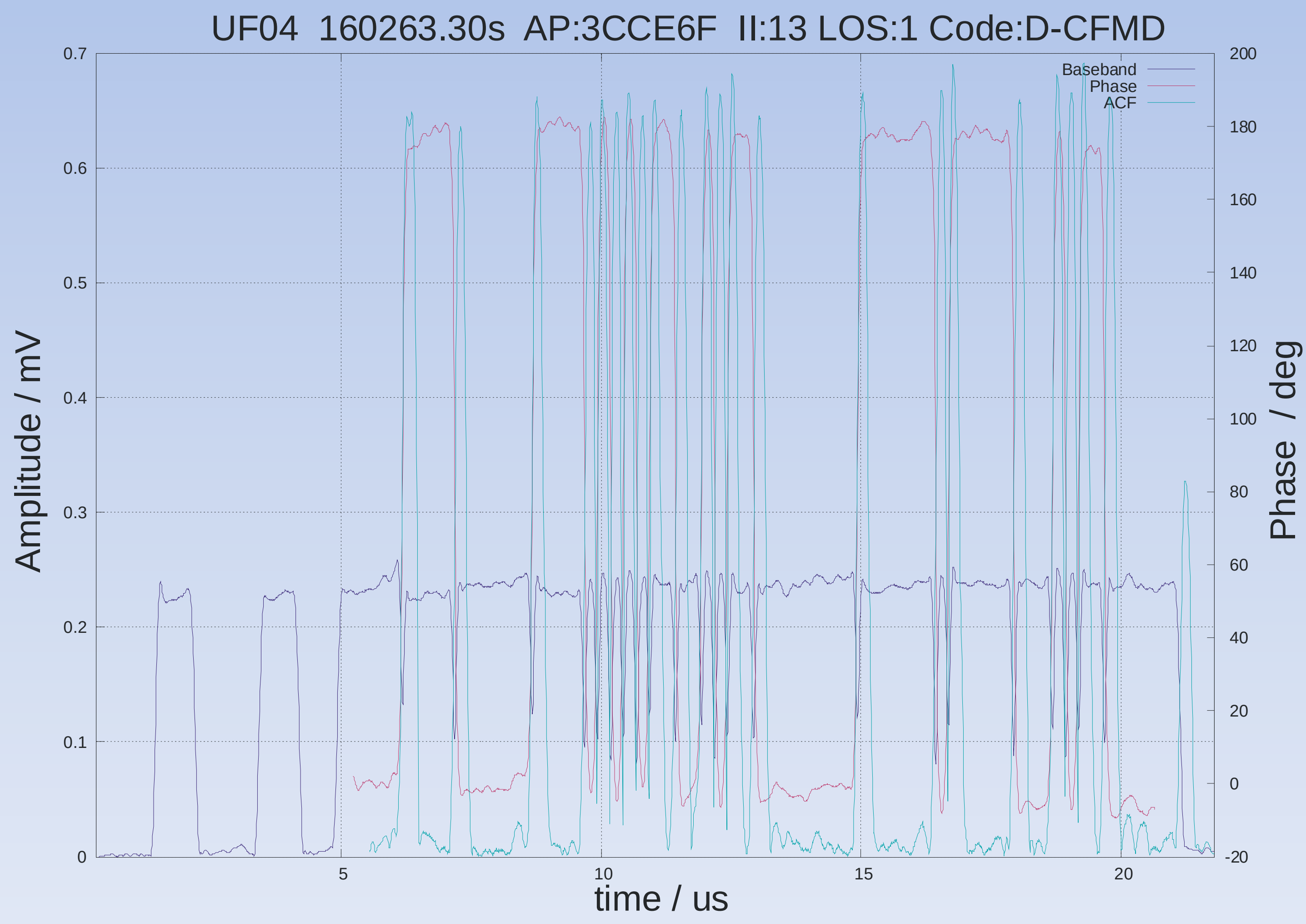


Filter effects on phase detection

32 tap LP FIR filter, 8MHz passband,
12MHz stopband, 50dB Att.



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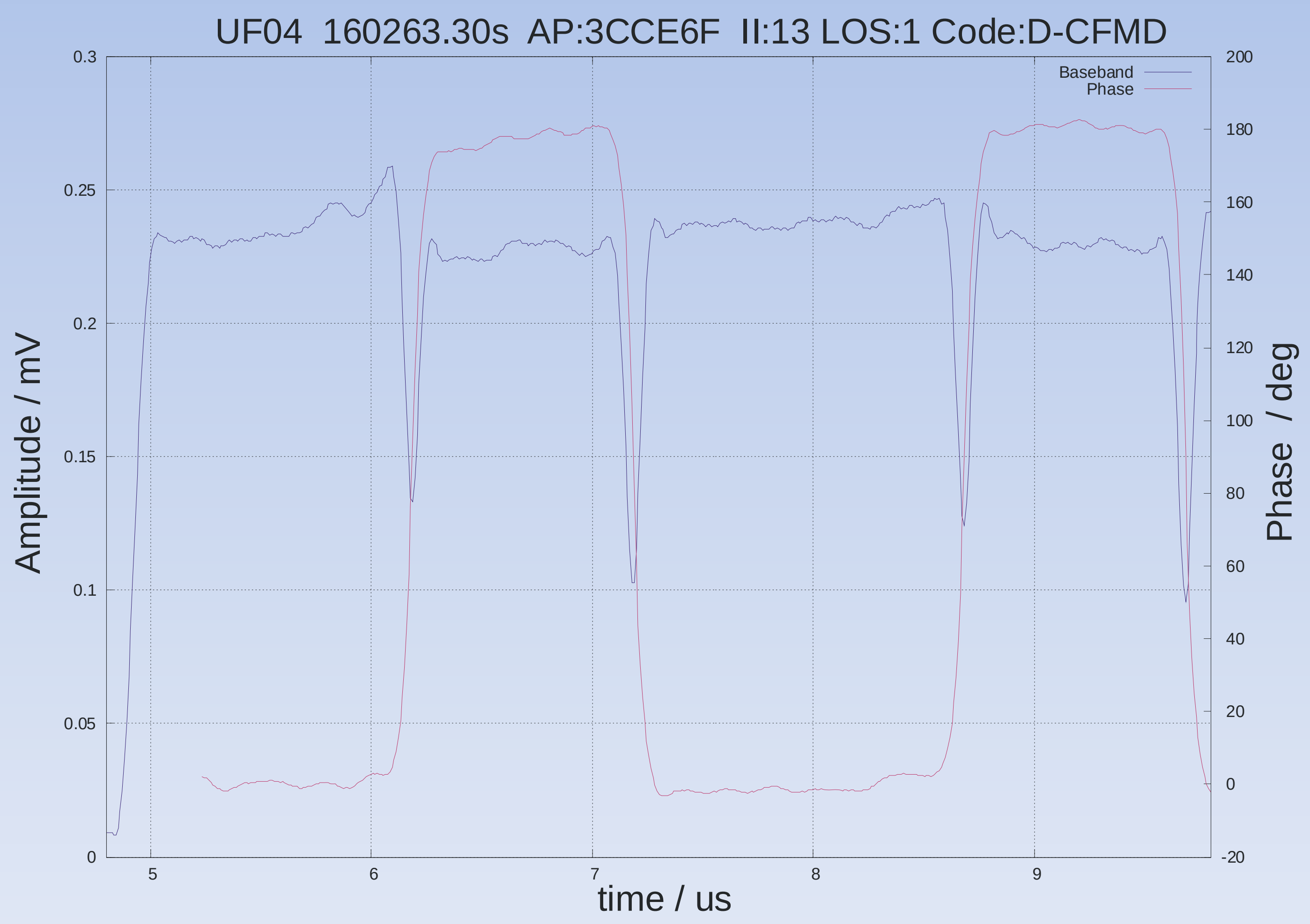
32 tap LP FIR filter, 8MHz passband, 12MHz stopband, 50dB Att.



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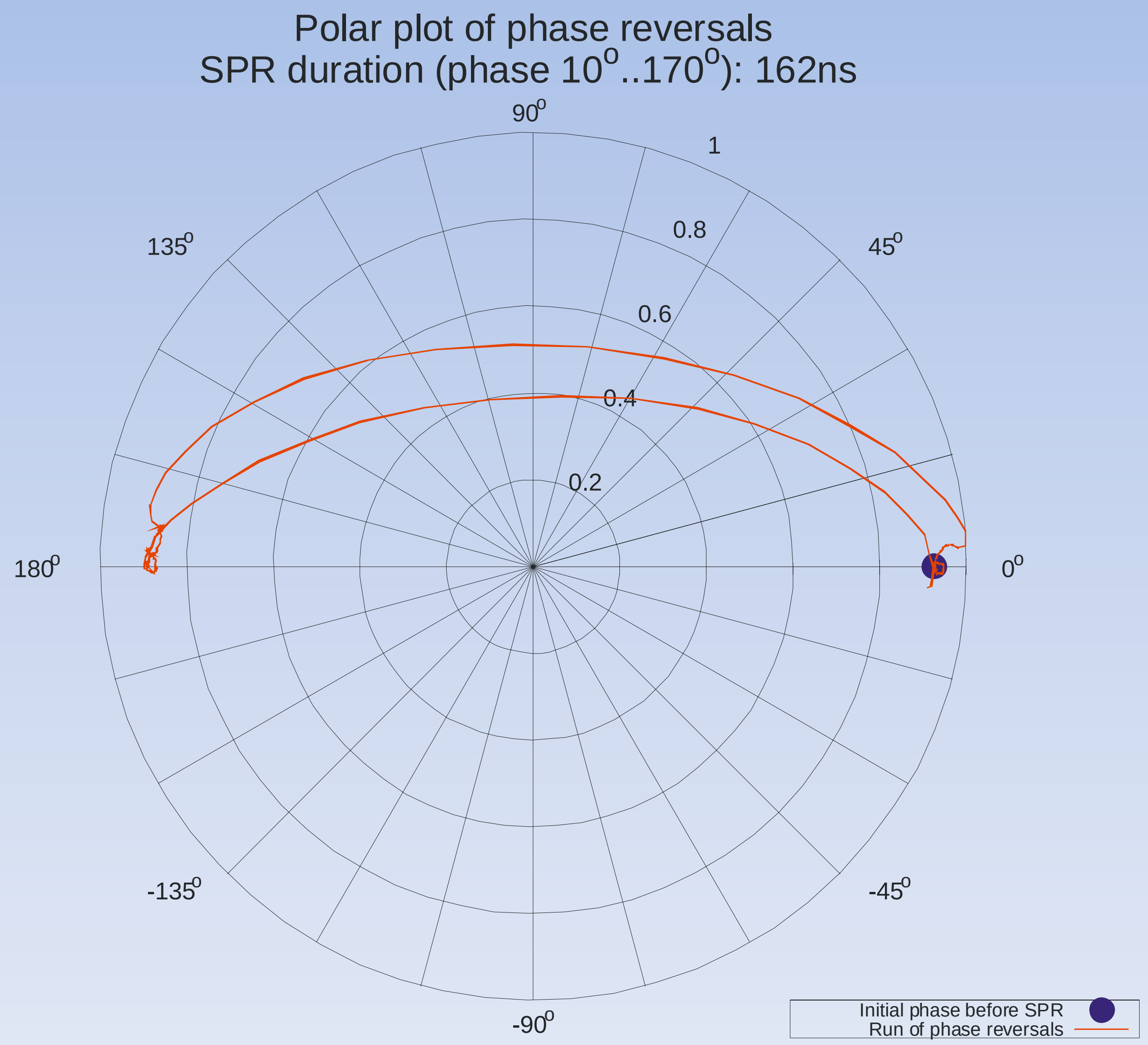
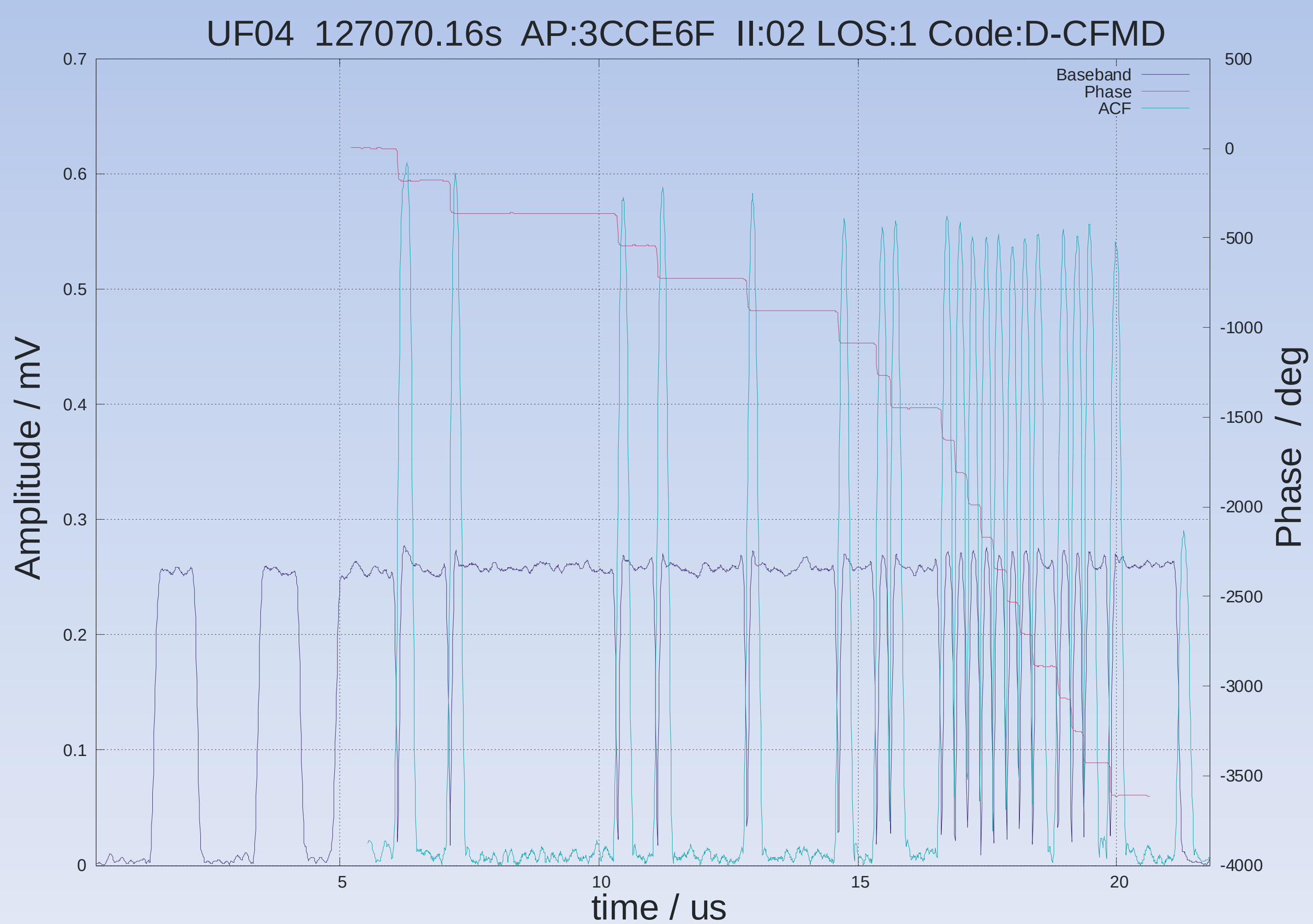


Filter effects on phase detection (2)

32 tap LP FIR filter, 8MHz passband,
12MHz stopband, 50dB Att.



Filter effects on phase detection

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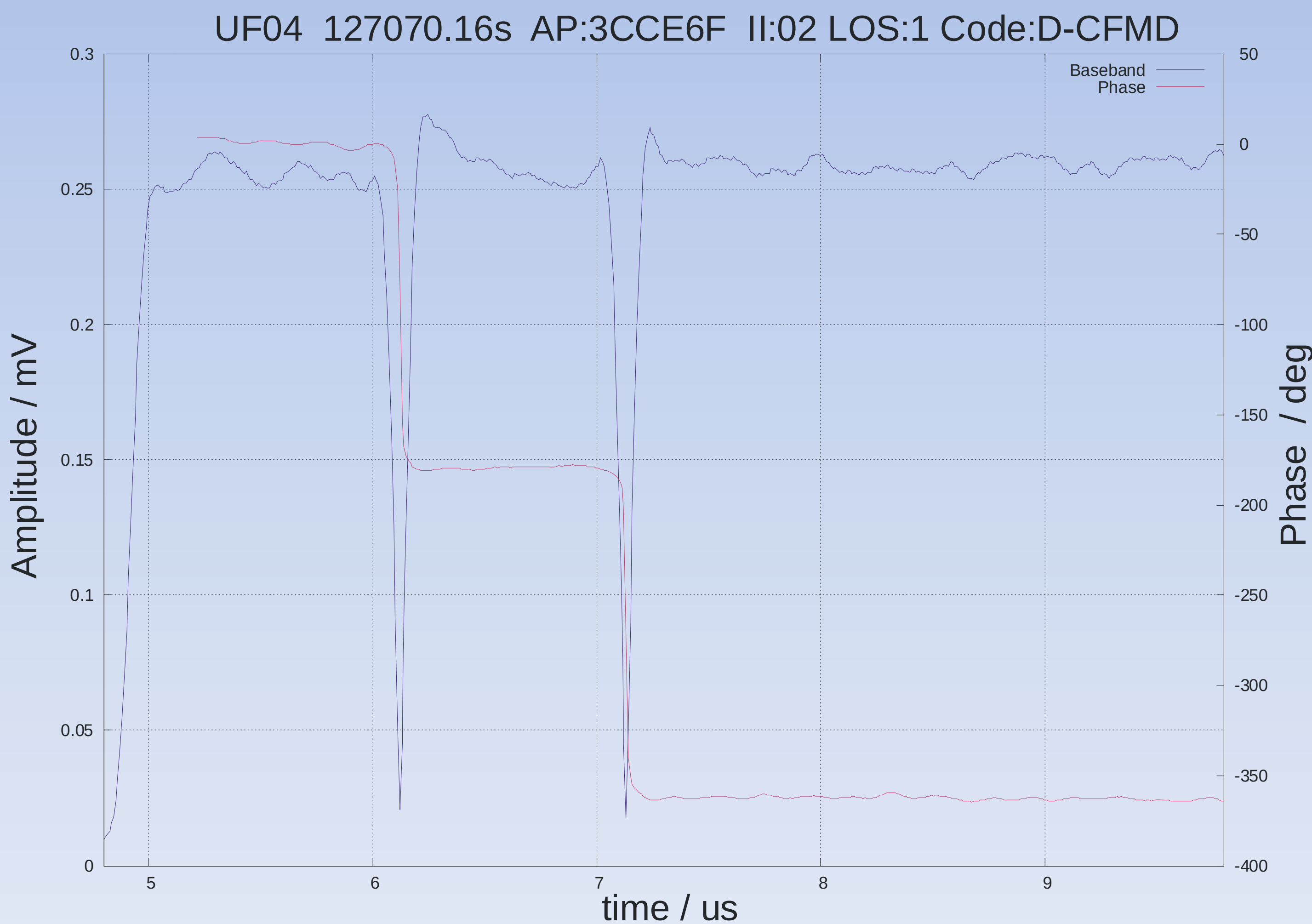
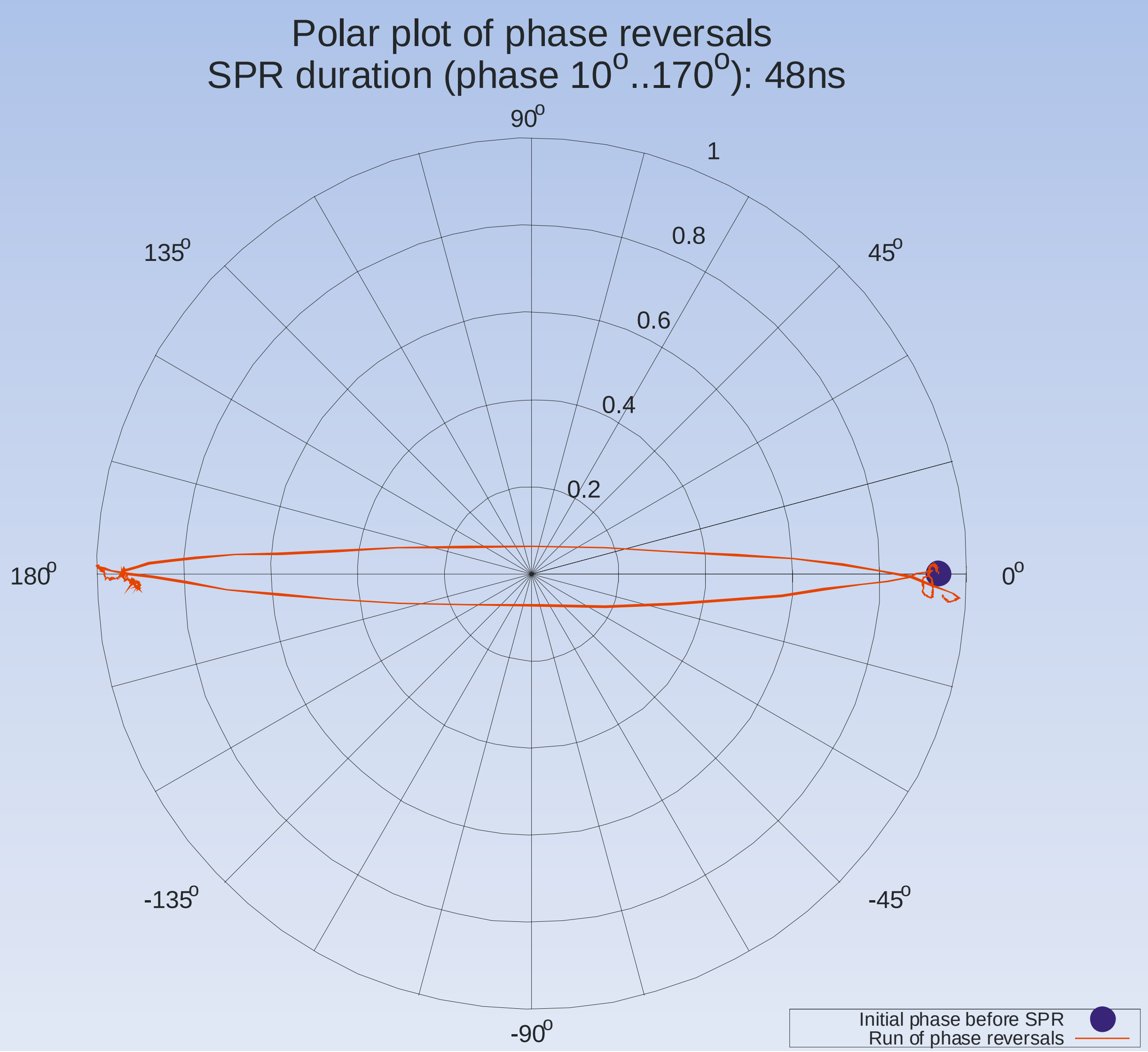


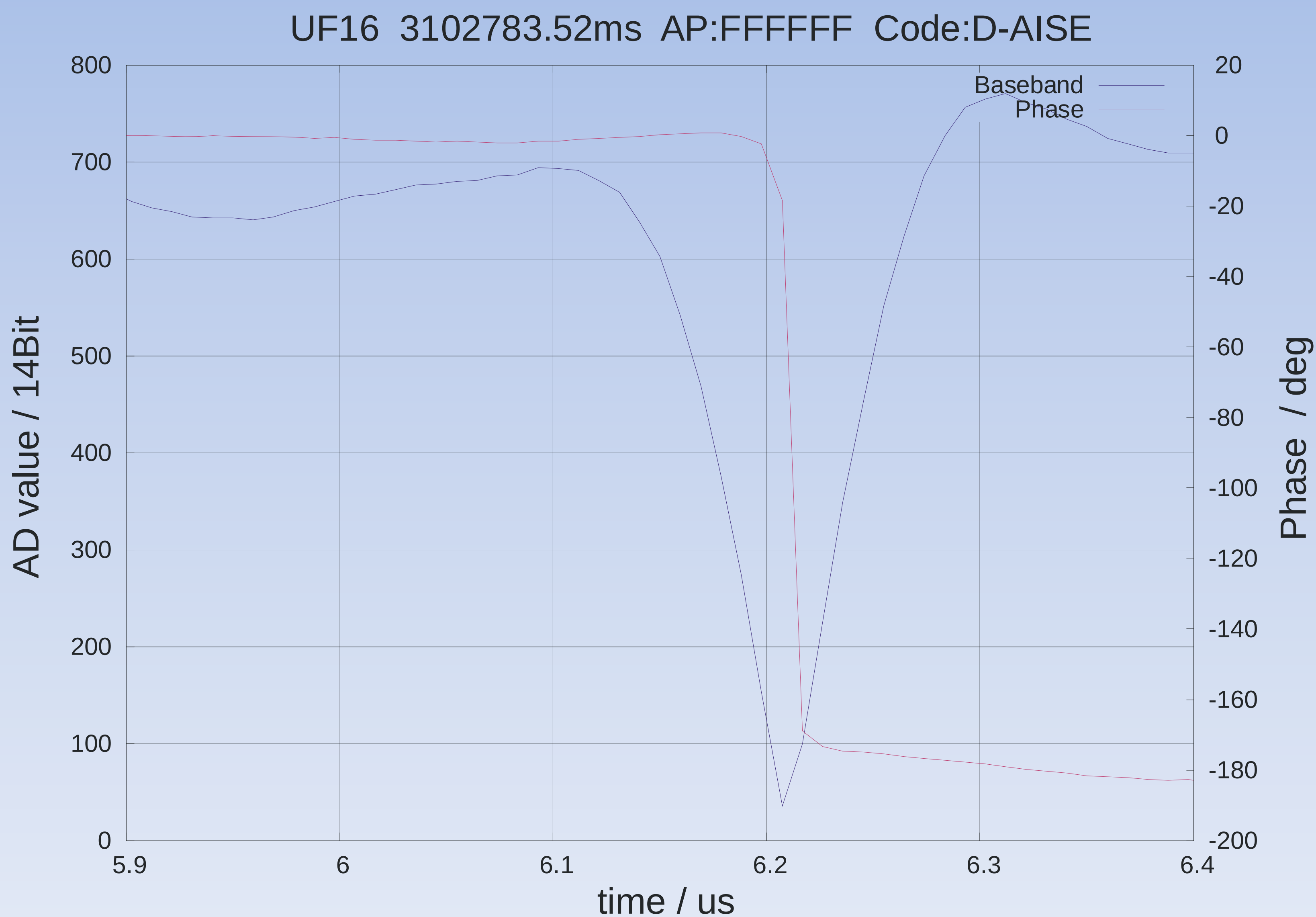
Filter effects on phase detection

32 tap LP FIR filter, 8/12MHz Passb./Stopb.



Examples of Signals-in-Space (1)

Fast SPR within UF16



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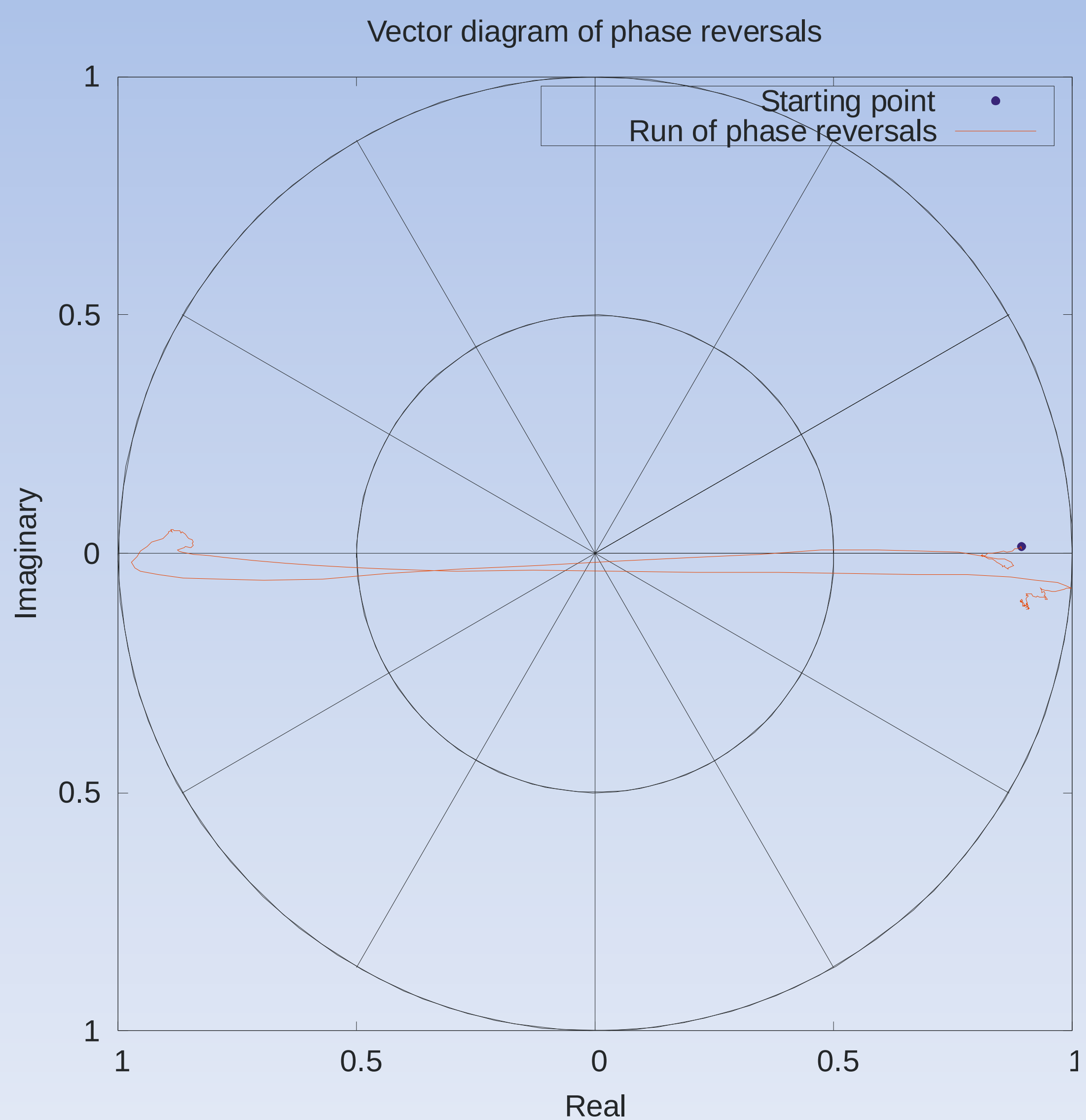
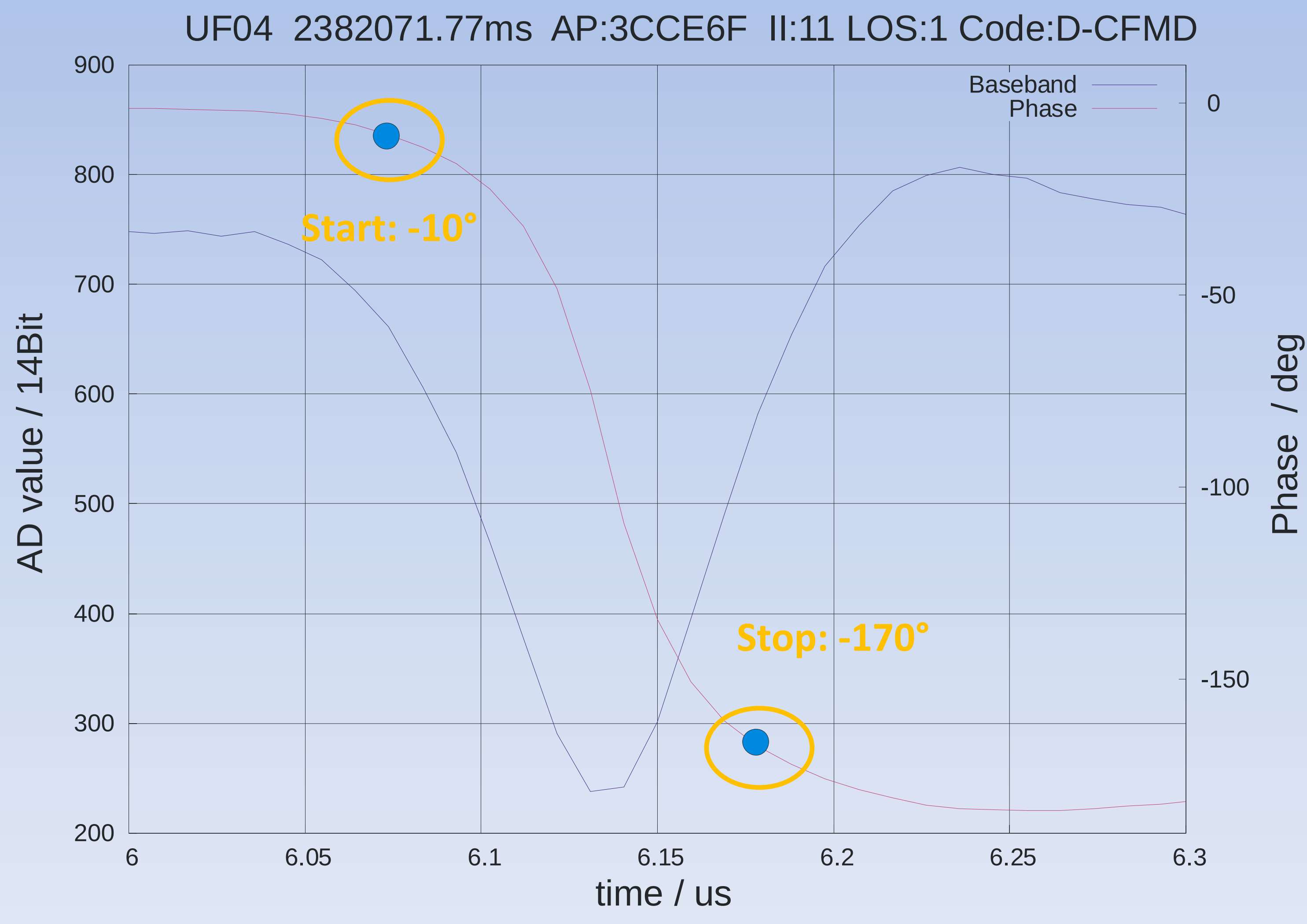


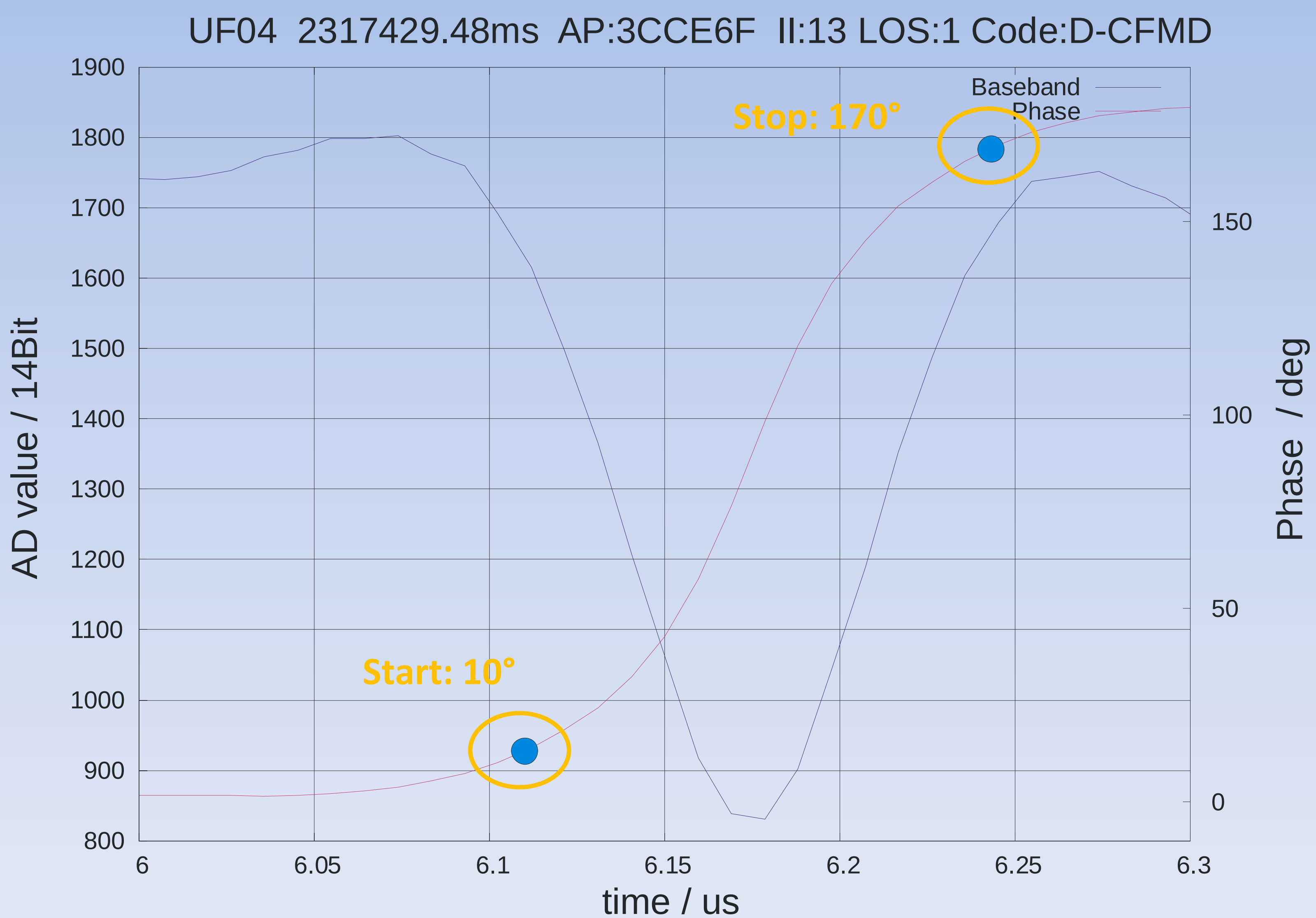
Examples of Signals-in-Space (2)

“Slow SPR” having round edges within UF04 of II11



Examples of Signals-in-Space (2)

"Slow SPR" having round edges within UF04 of II13



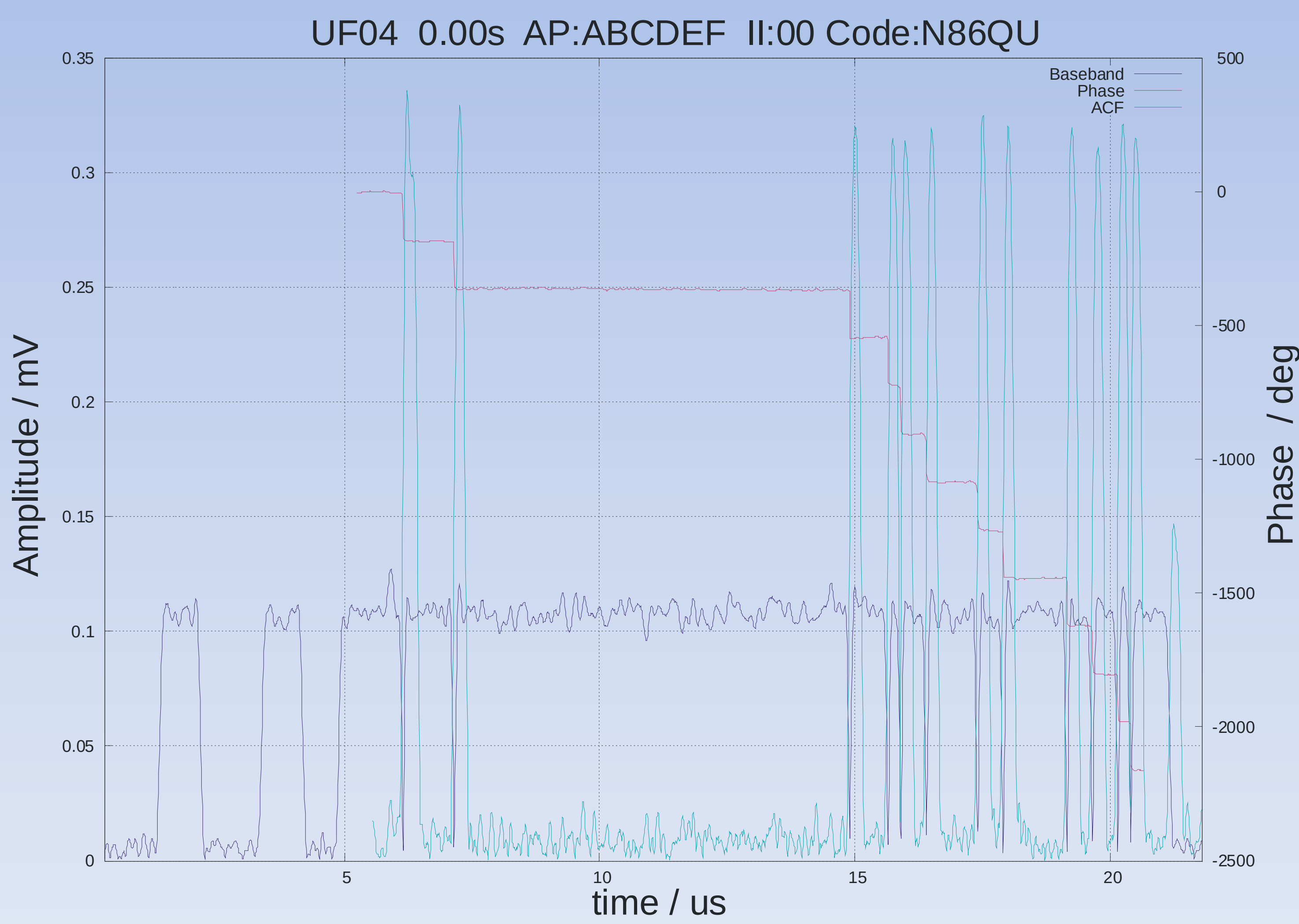
Intermediate statements

Argumentation chain

- Attempts to comply with “no AM” requirement leads to using I/Q modulator in some interrogator types
- The spectrum requirements are preserved, but SPR duration is increased to 30ns or more
- Simple RF switches performing 0°-180° steps are much quicker!
- Any kind of RF or IF or baseband LP filter decreases amplitude during phase reversals
- Lower amplitude means lower S/N when I and Q start to change signed amplitude
- The edges of phase curve get round
- The true SPR point in time gets fuzzy
- The start of the bit clock may be shifted artifically

Transponder Tester (1)

IFR 6000



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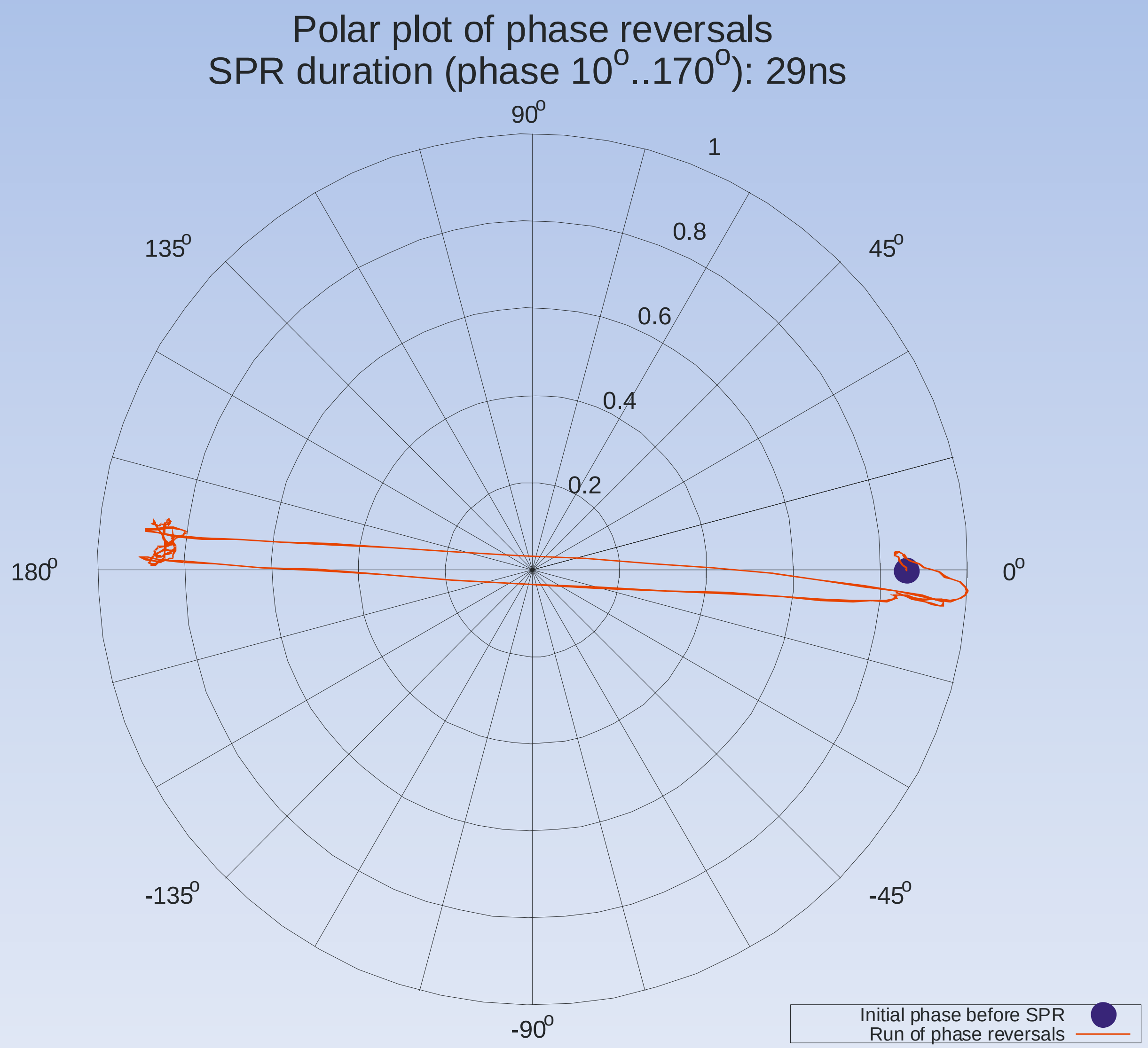
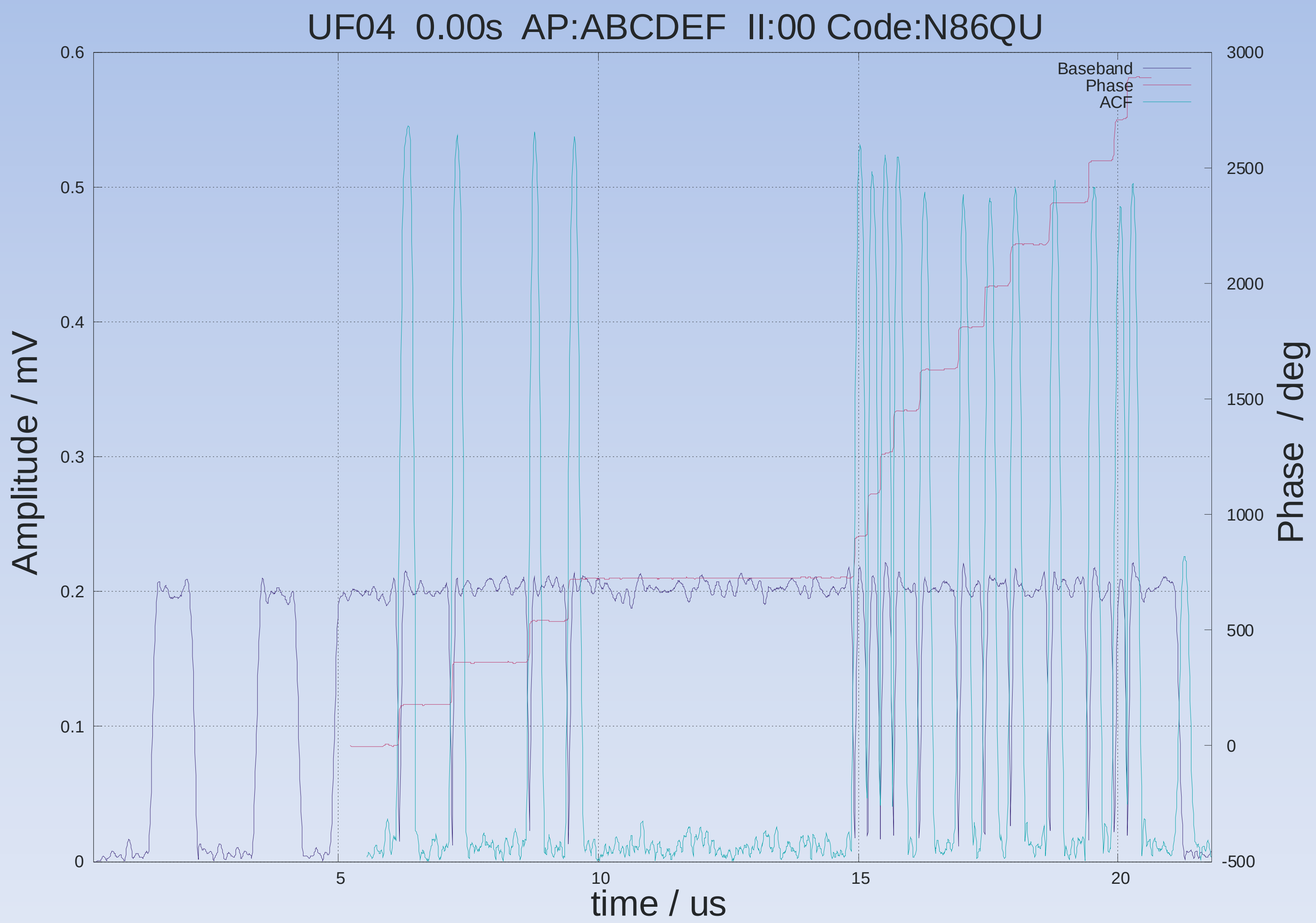


Transponder Tester (2)

SDX 2000



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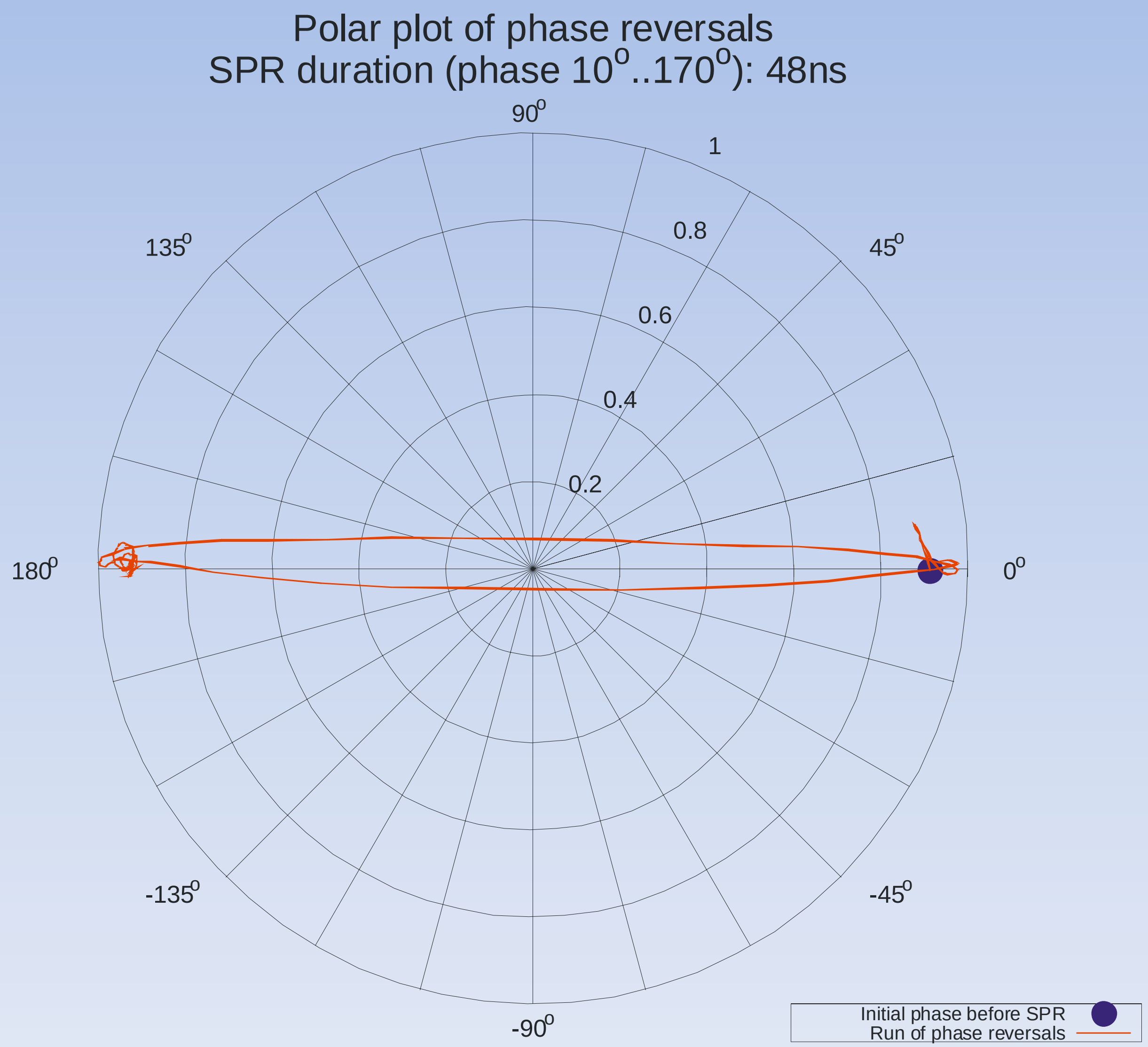
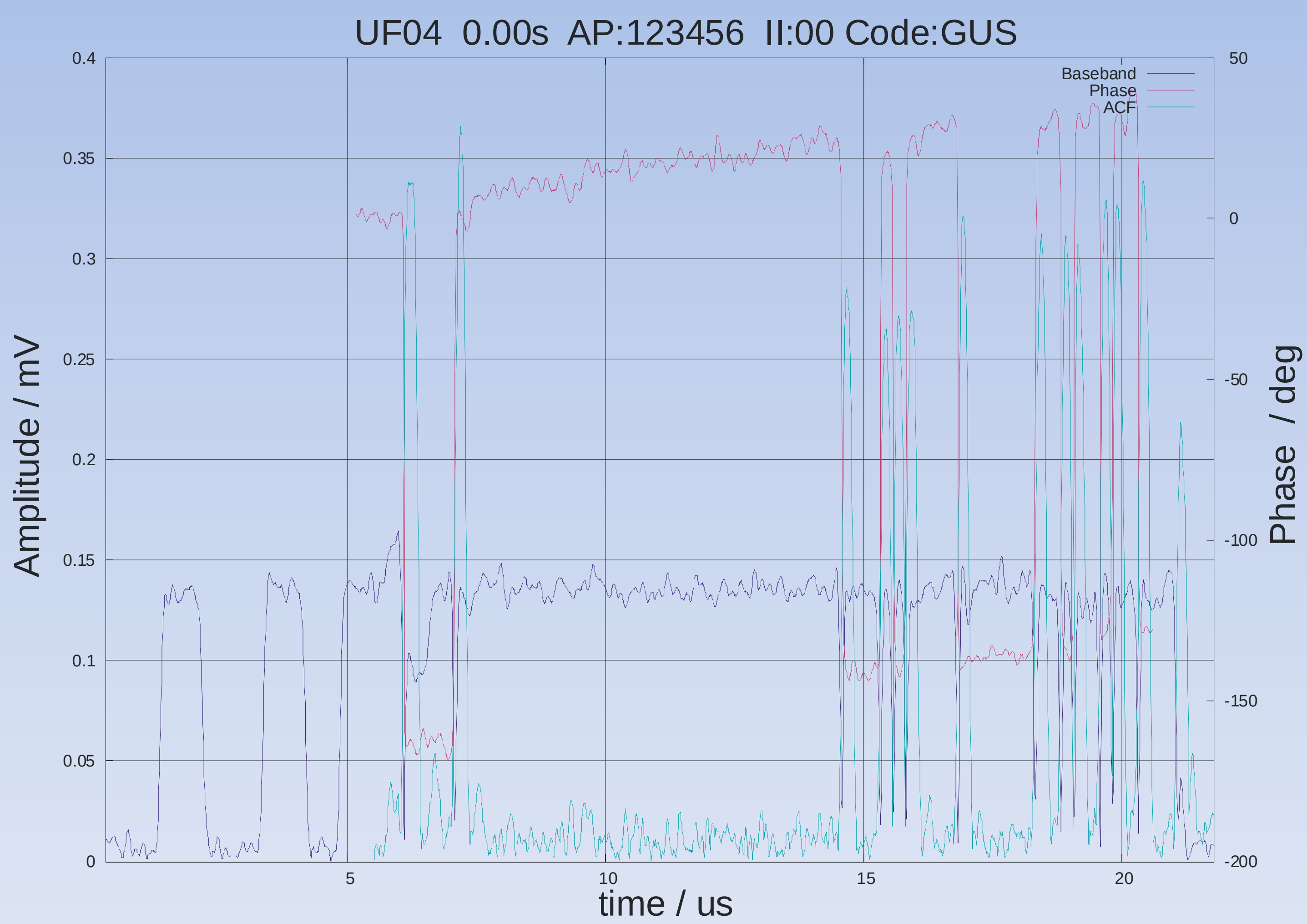
SDX 2000



Transponder Tester (3)

TIC T-48



Transponder Tester (3)

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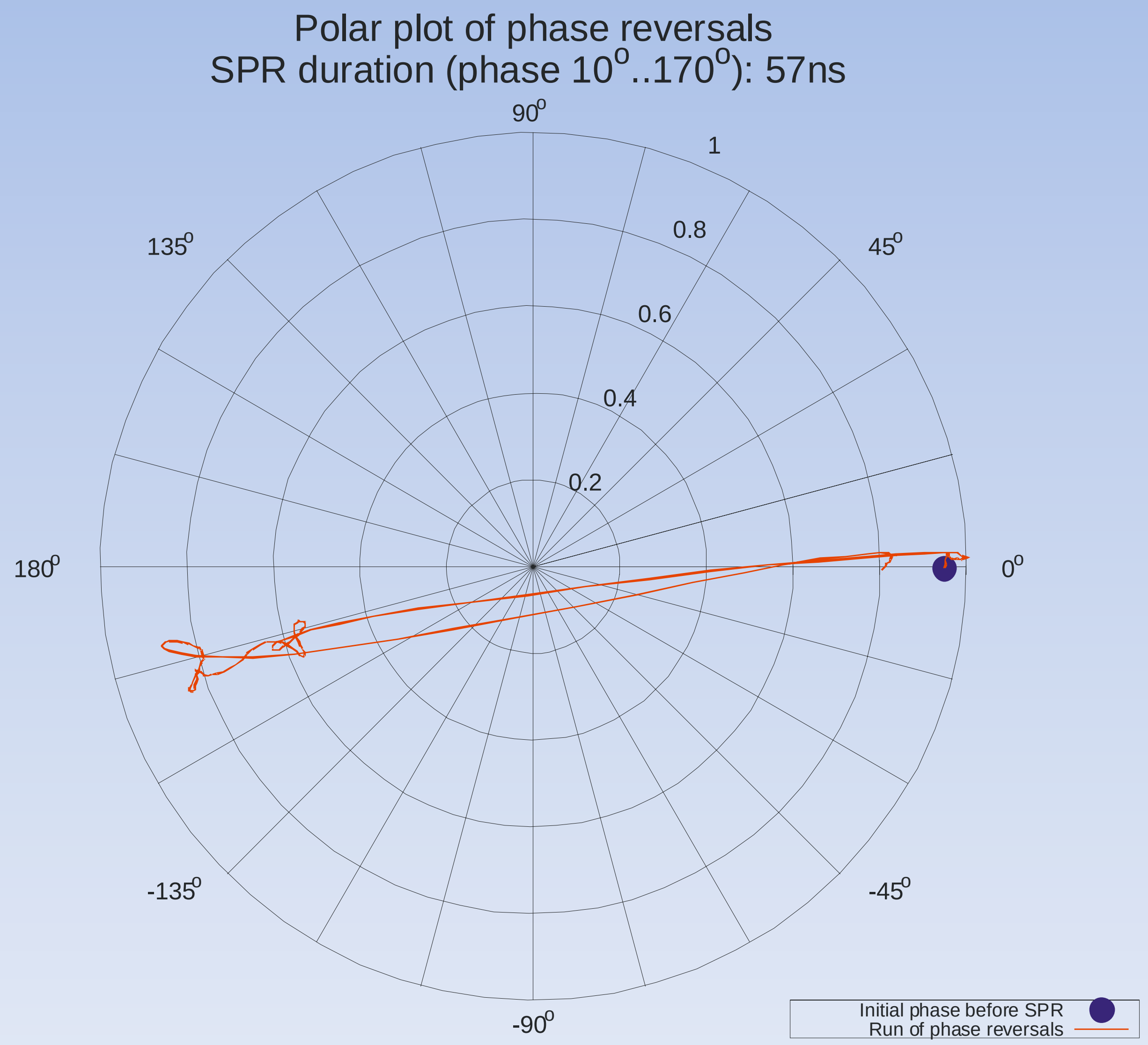
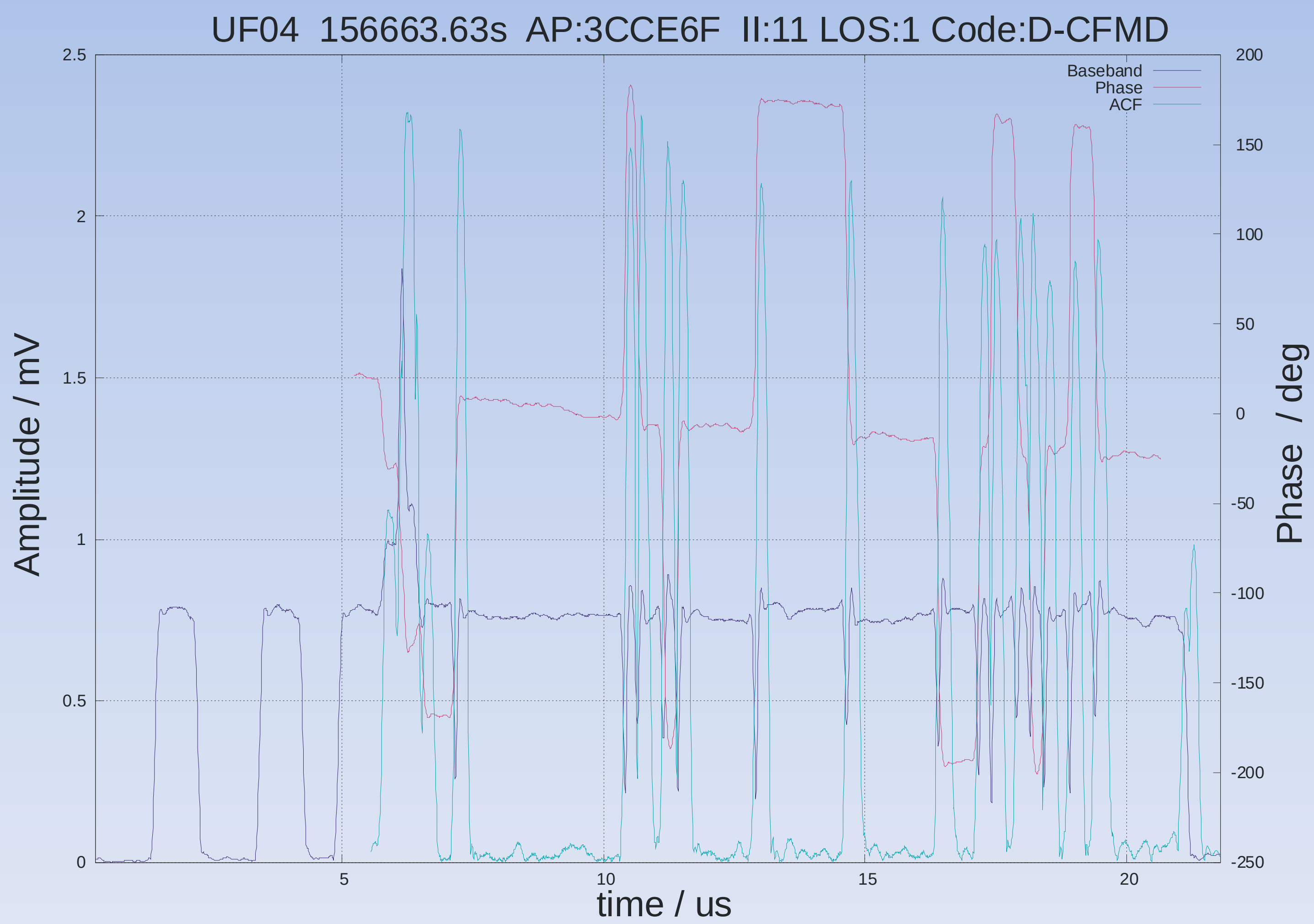


Interrogation UF04 with SLS

Transmitted by Munich ASR



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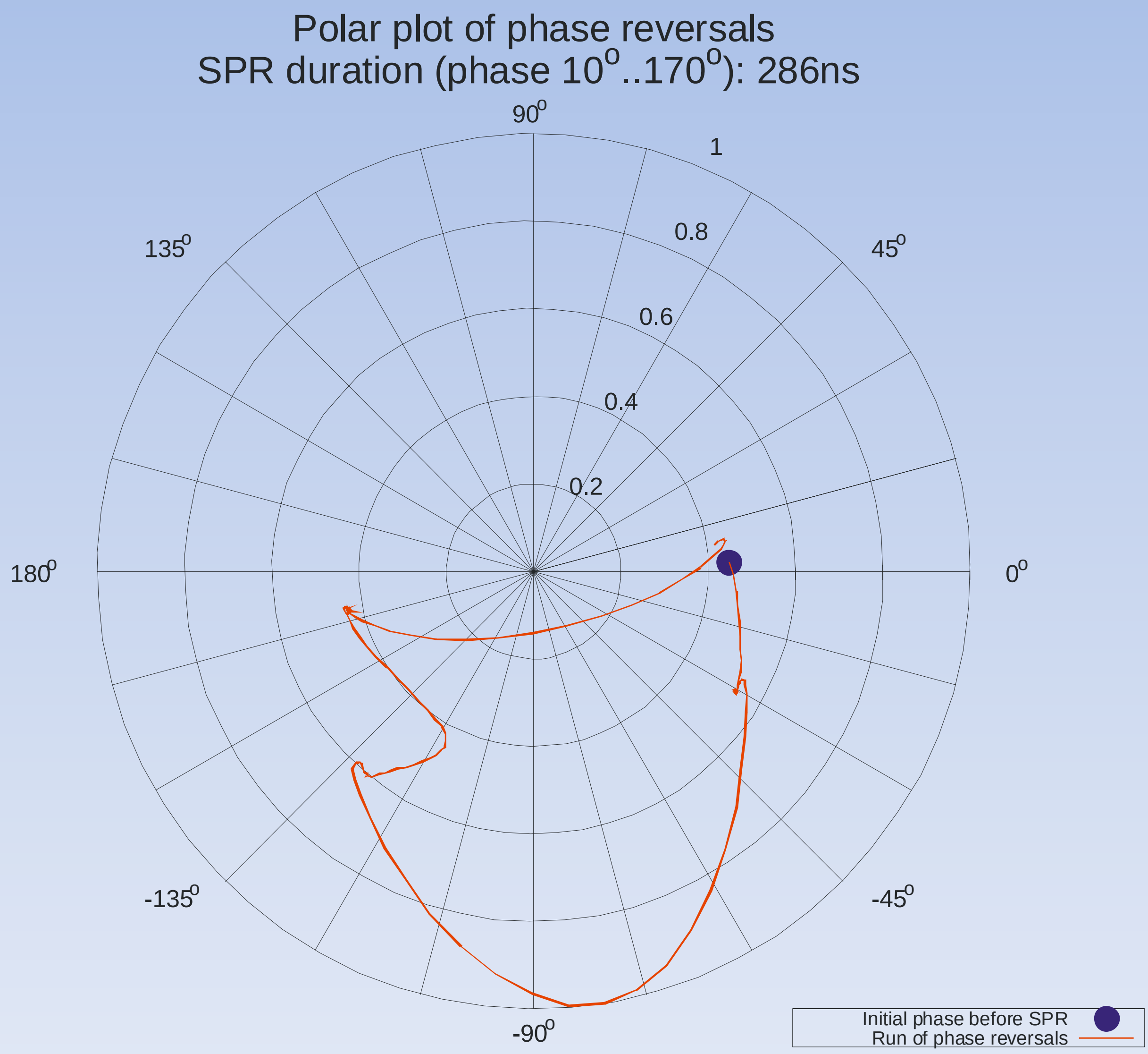
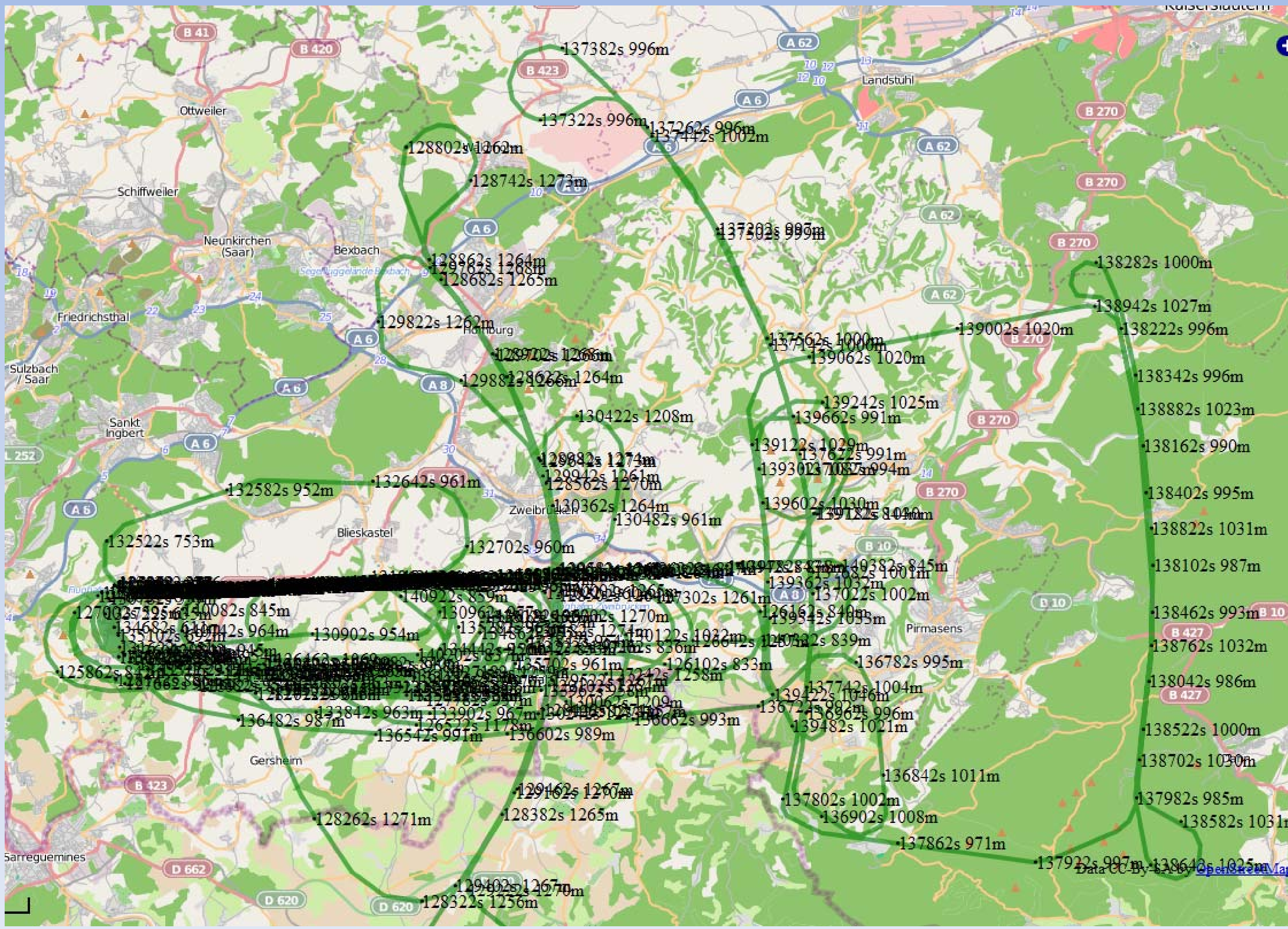


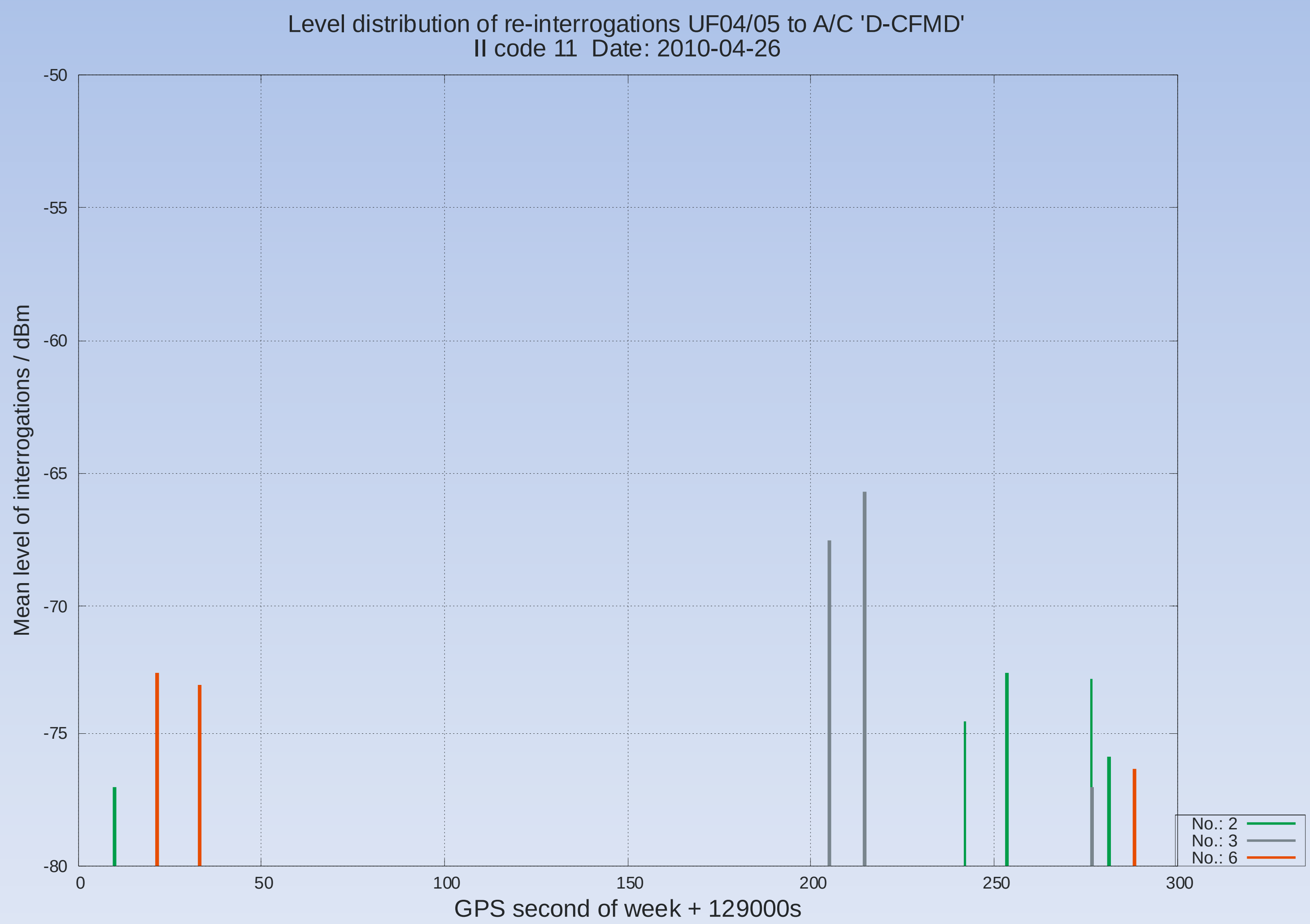
Typical ILS inspection flight pattern

Saarbrücken ILS



Re-Interrogation UF04

Transmitted by German South Cluster II11



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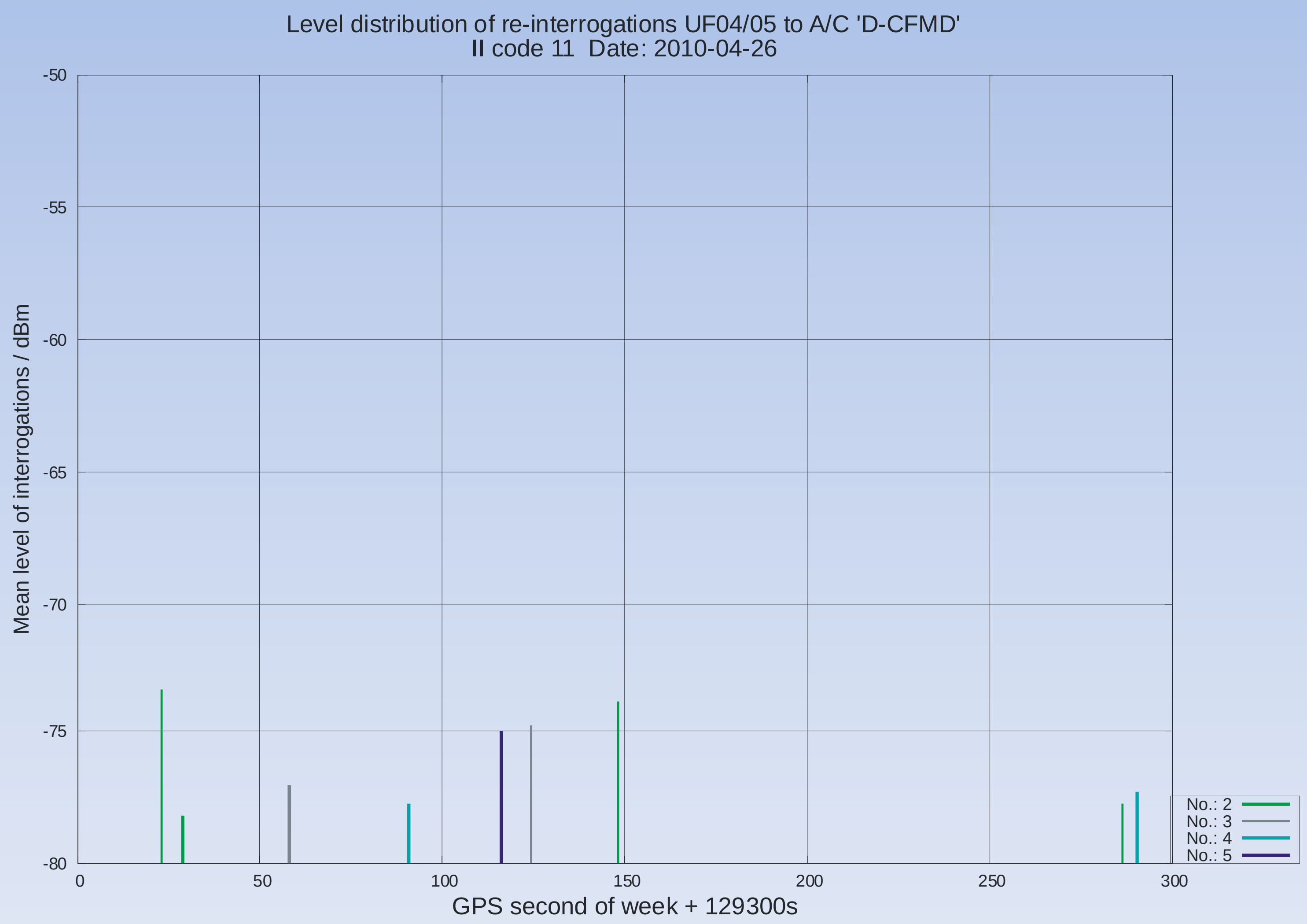

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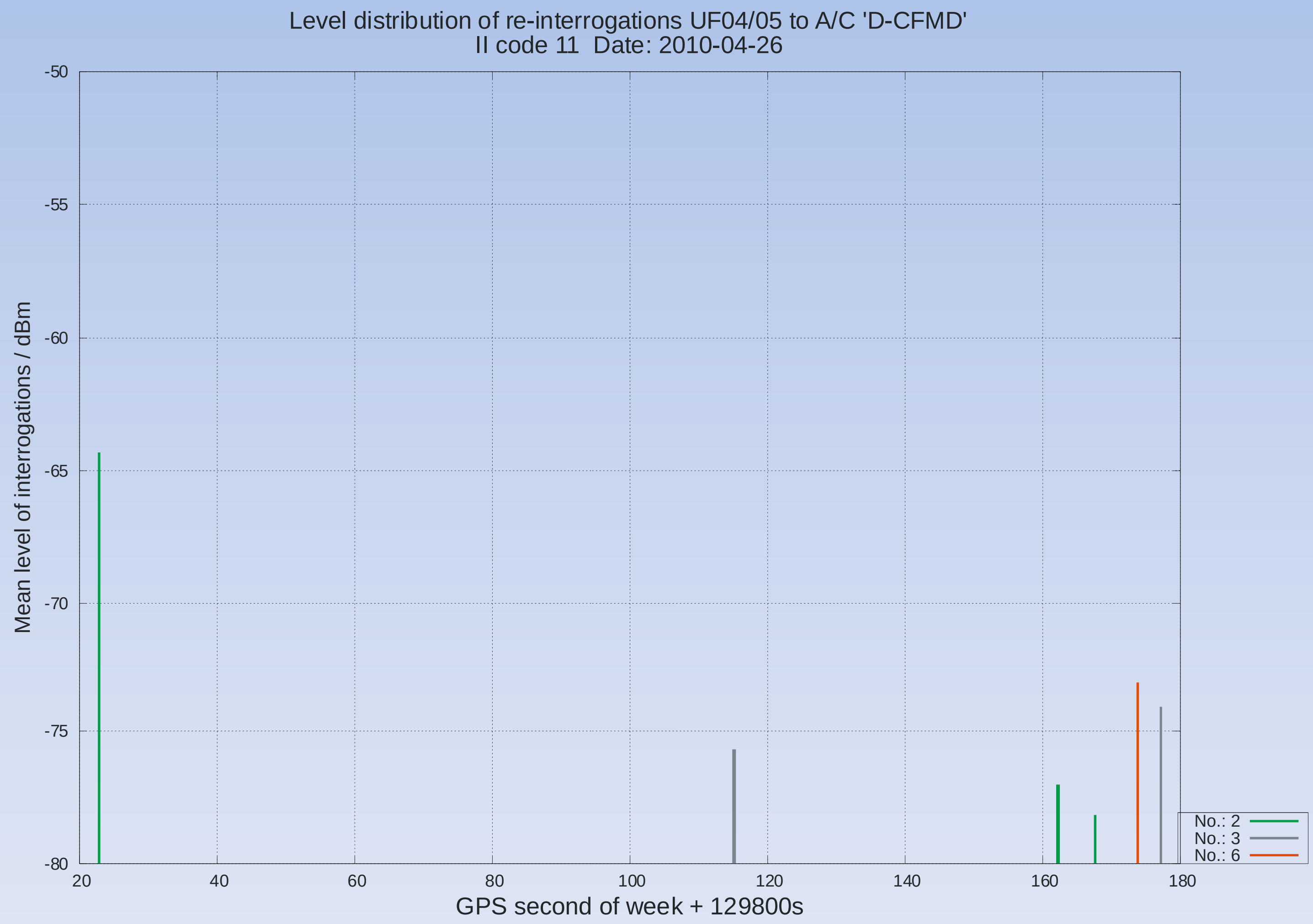
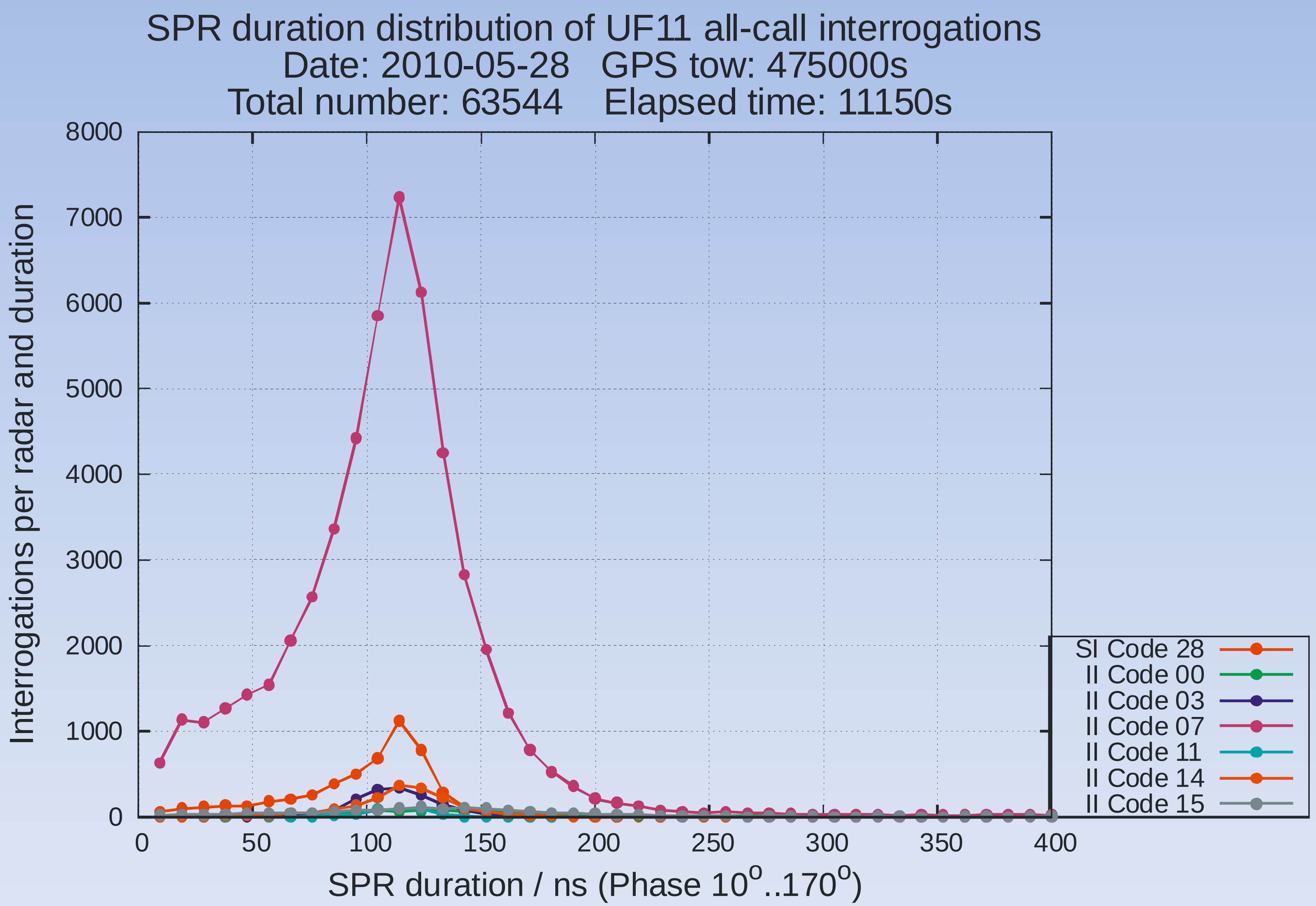


SPR duration measured through Amsterdam flight

Note: This is not Signal-in-Space, but Signal-in-Receiver SPR duration!



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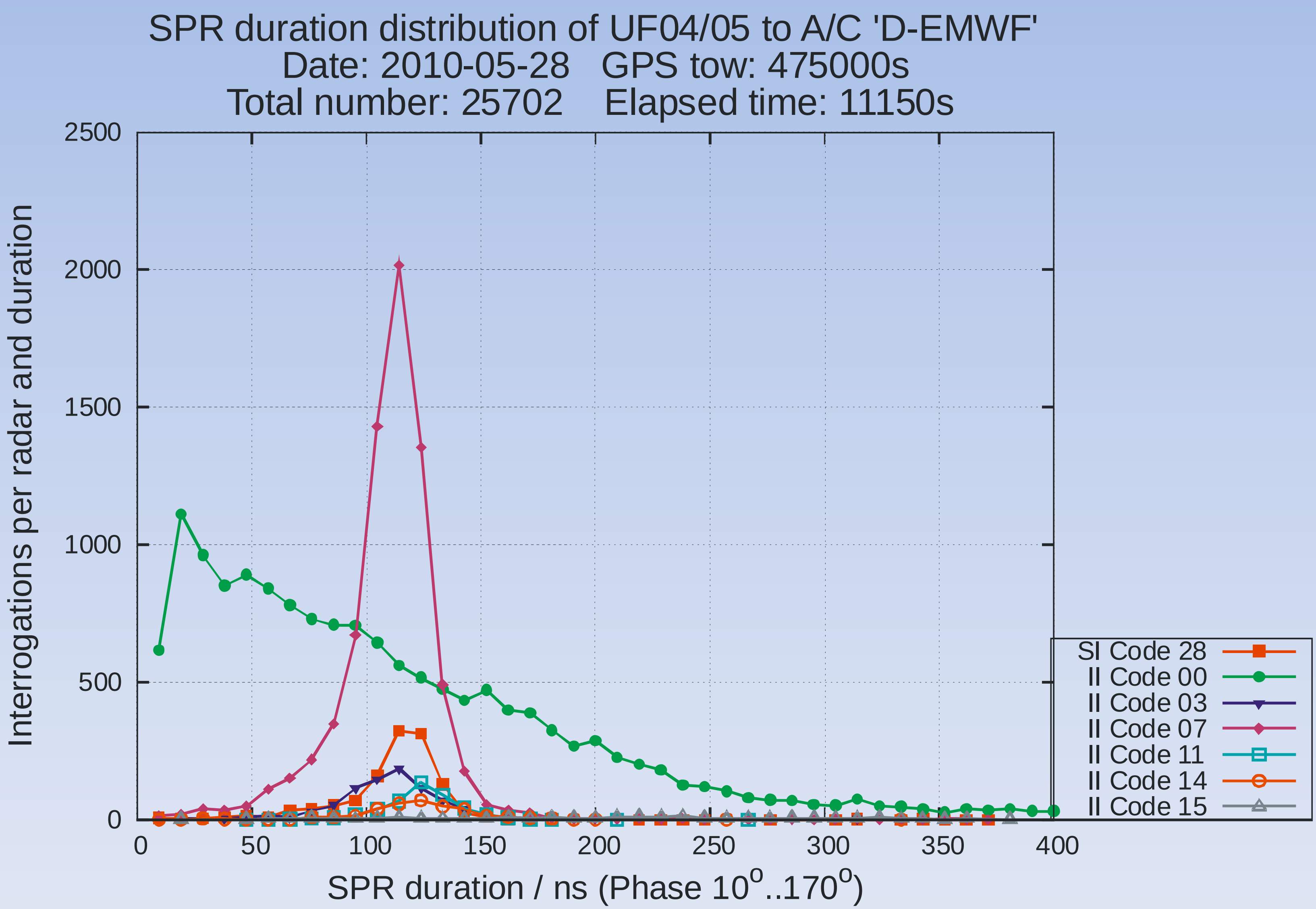

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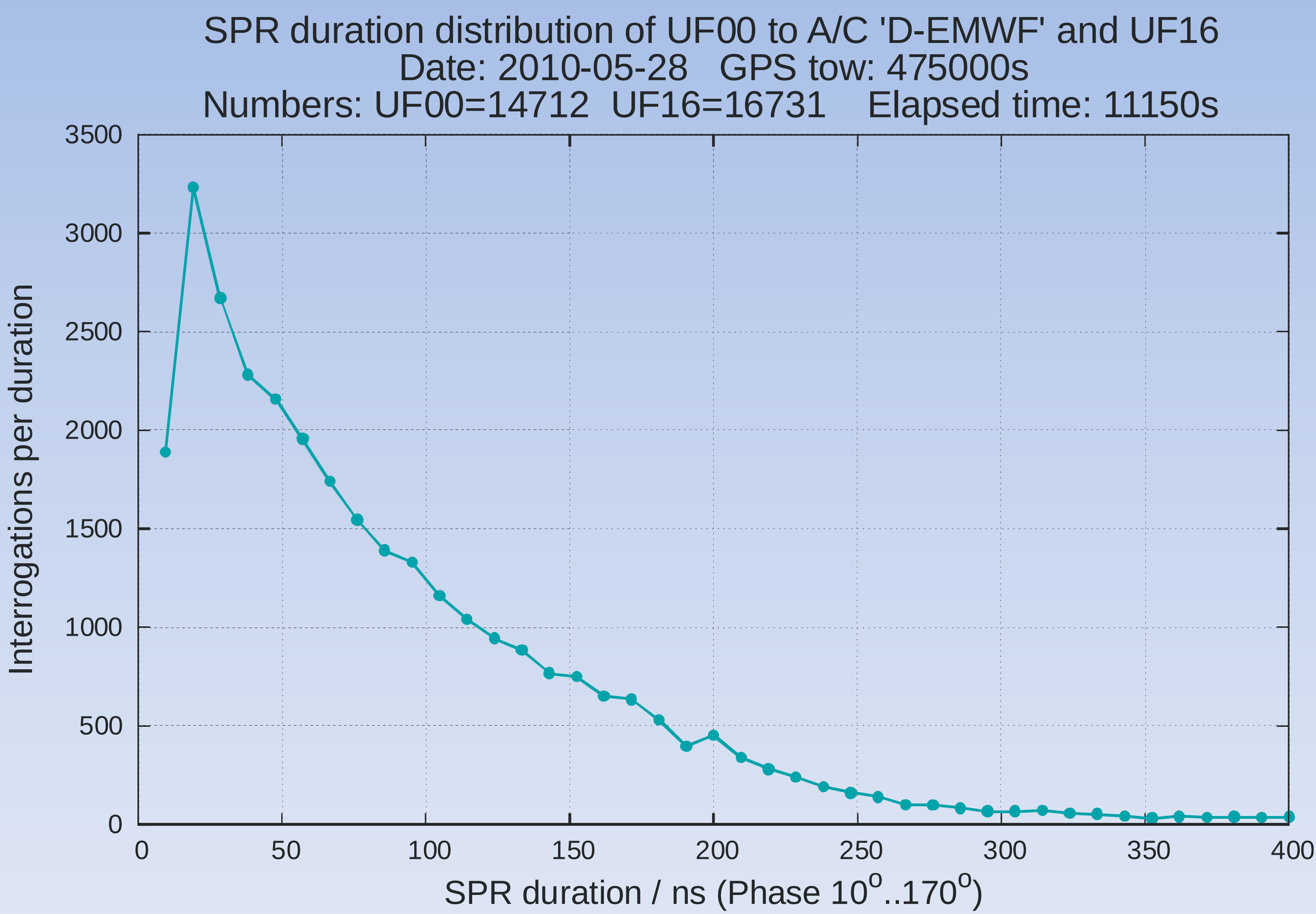
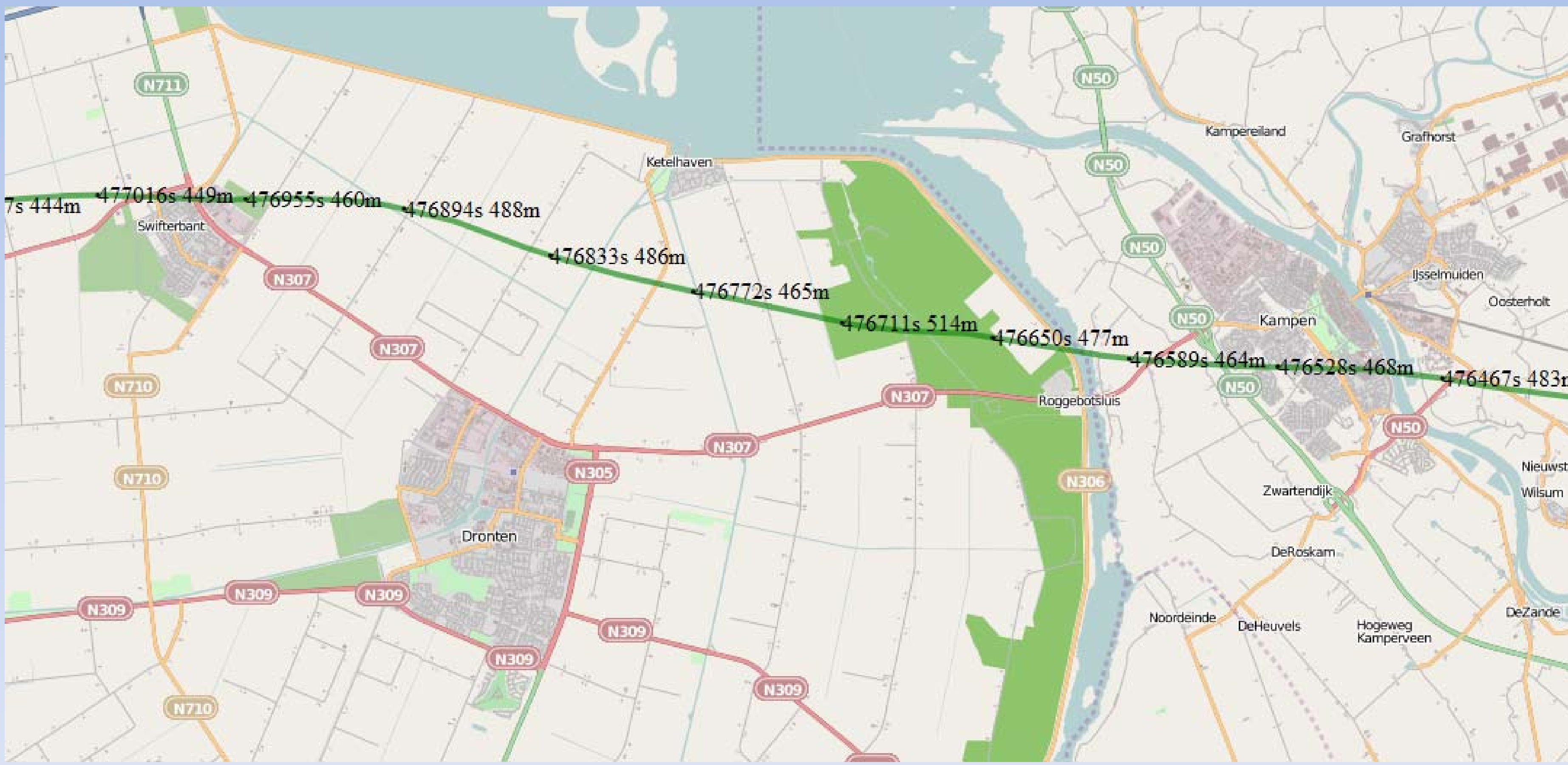


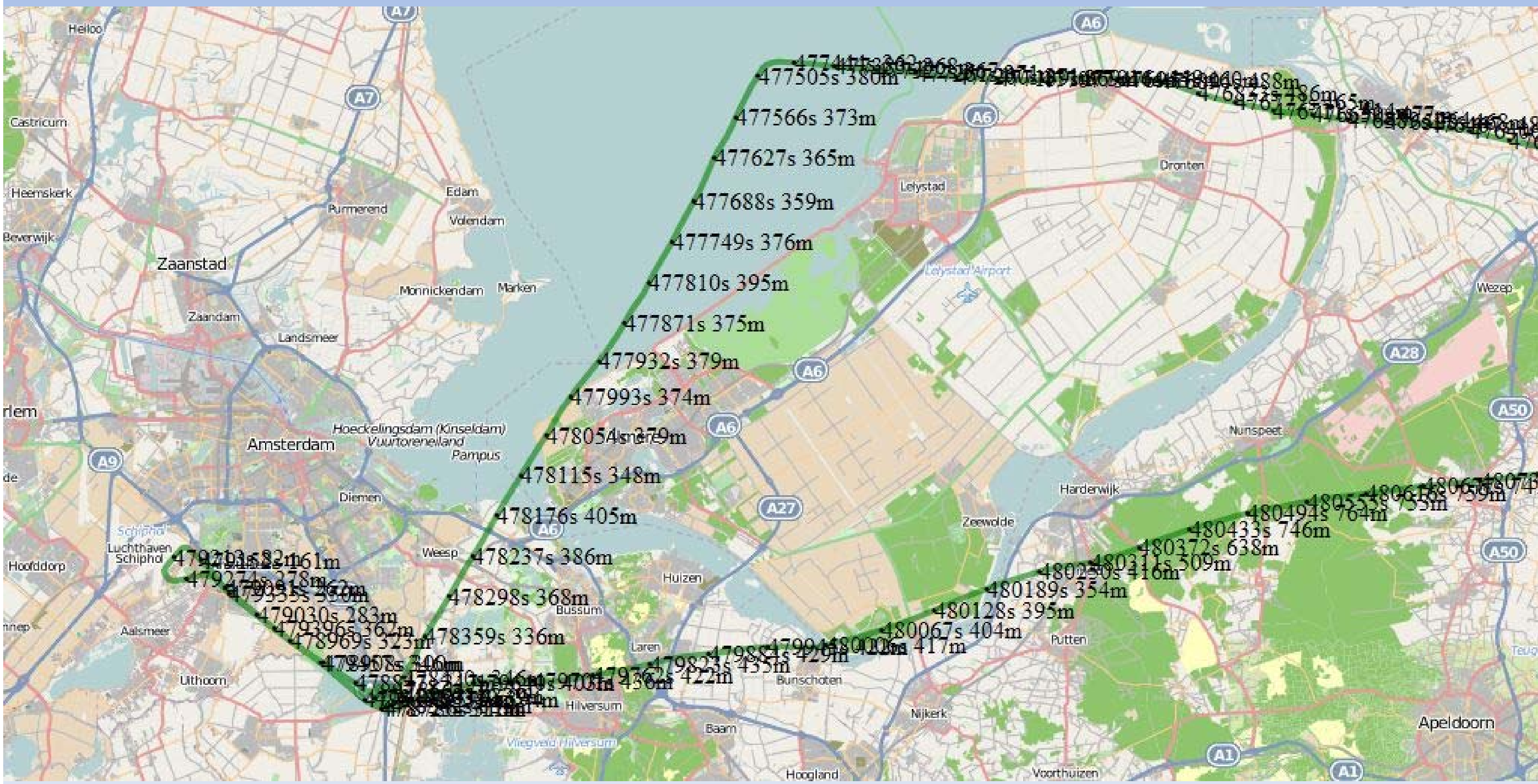
Re-Interrogation UF04

Transmitted by LVNL Cluster II07



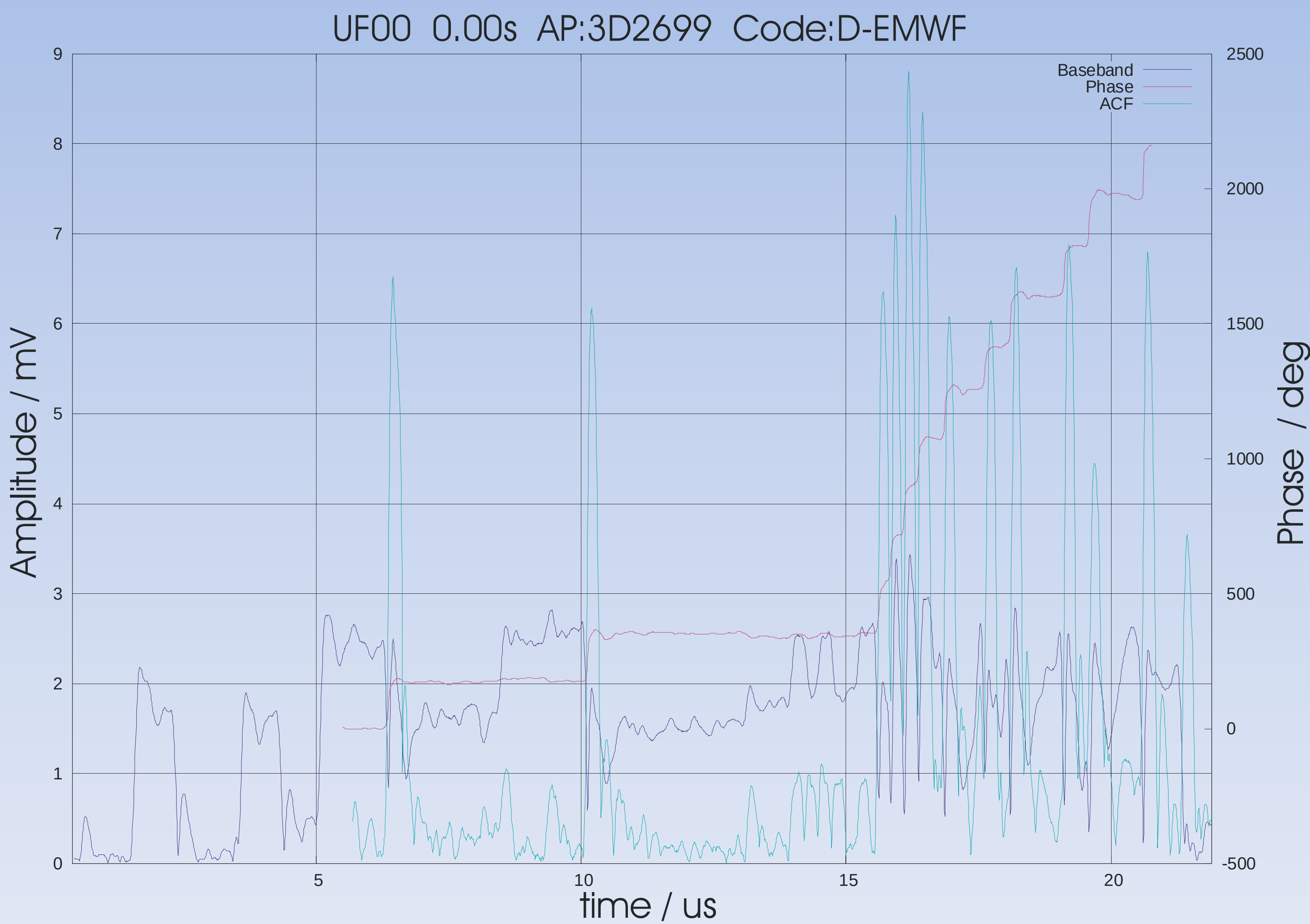
Multipath-rich Interrogation UF04

Transmitted by AMS MLAT II00



Multipath-rich Interrogation UF04

Transmitted by AMS MLAT II00



Multipath-rich Interrogation UF04

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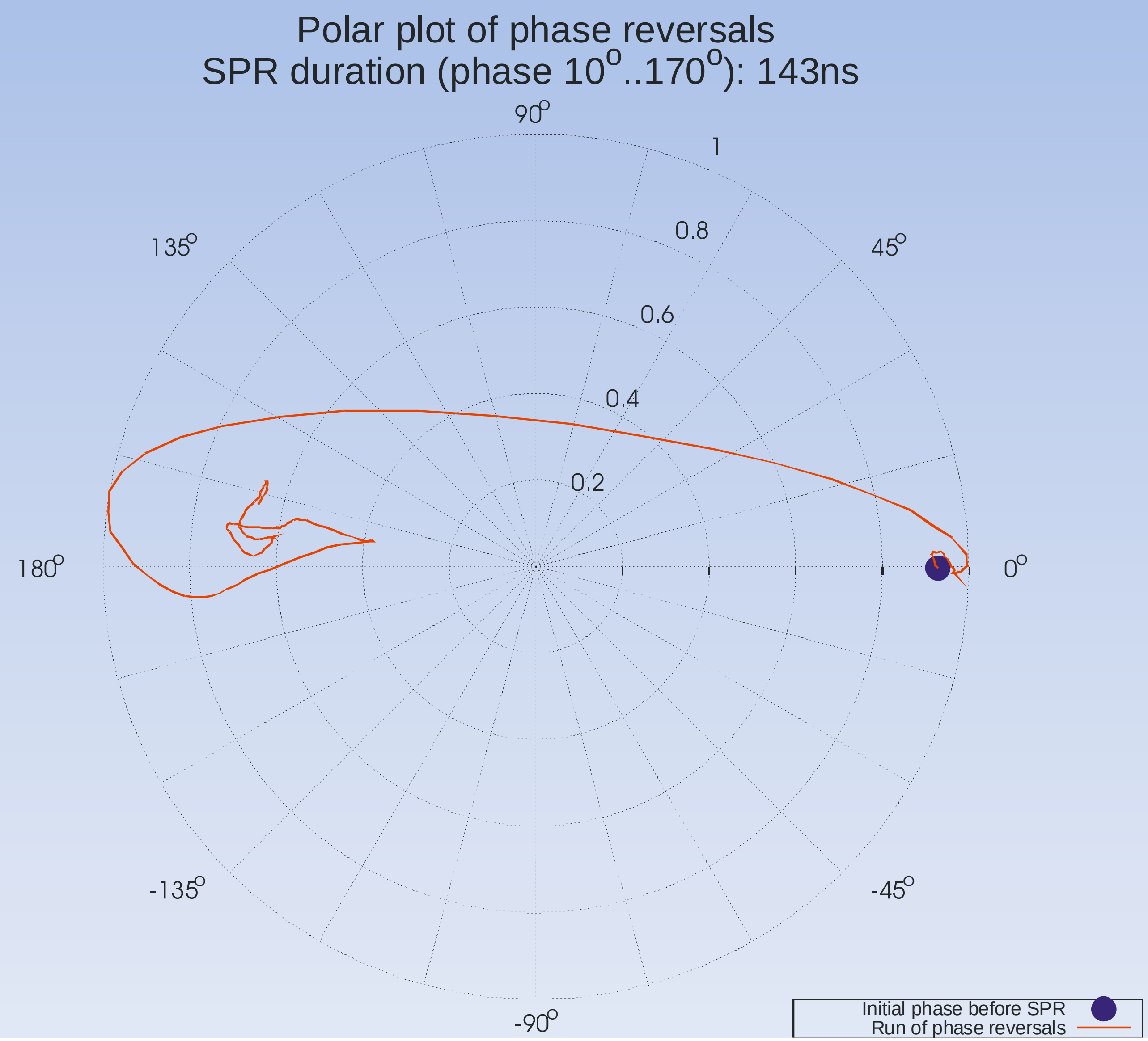
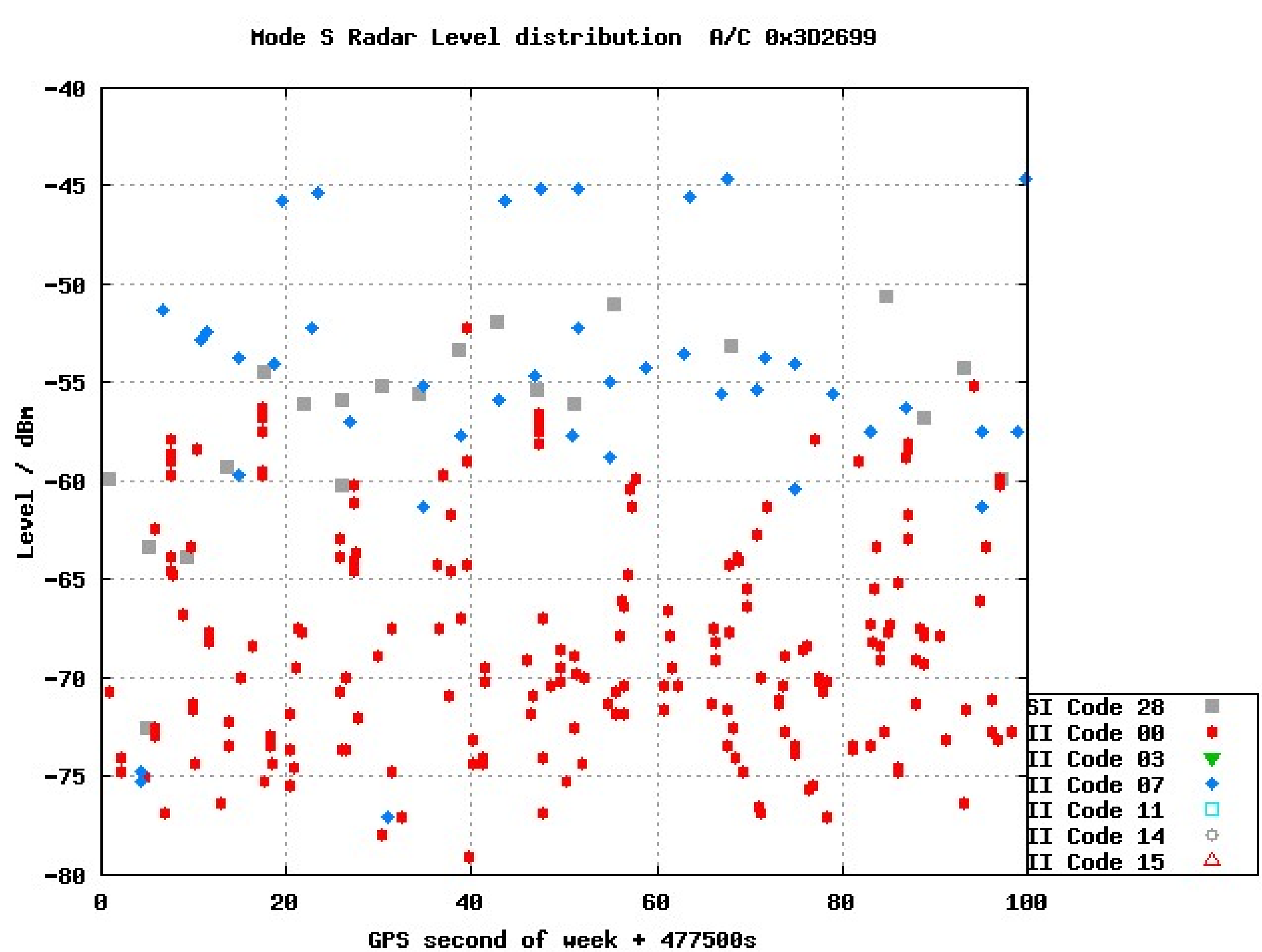
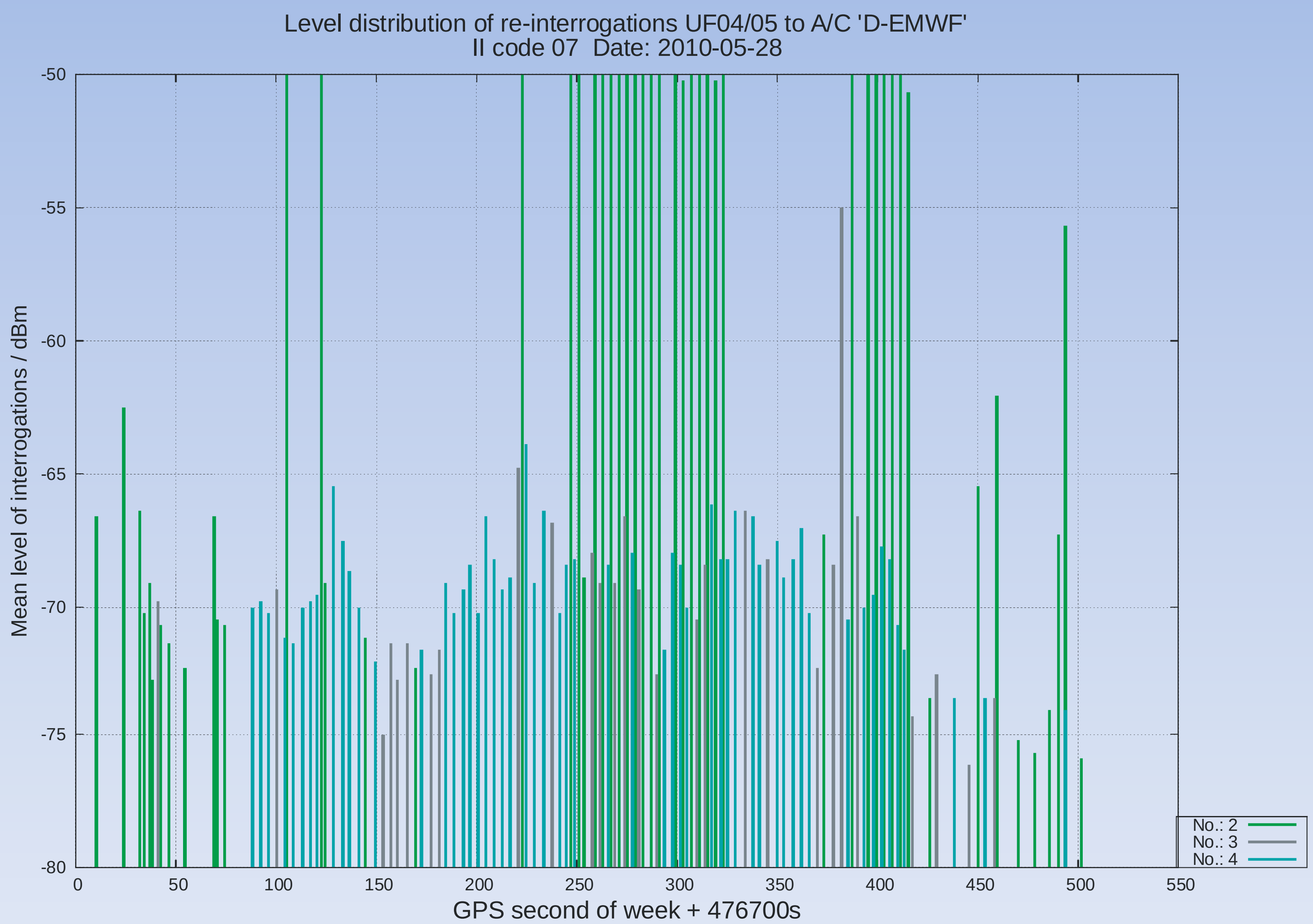


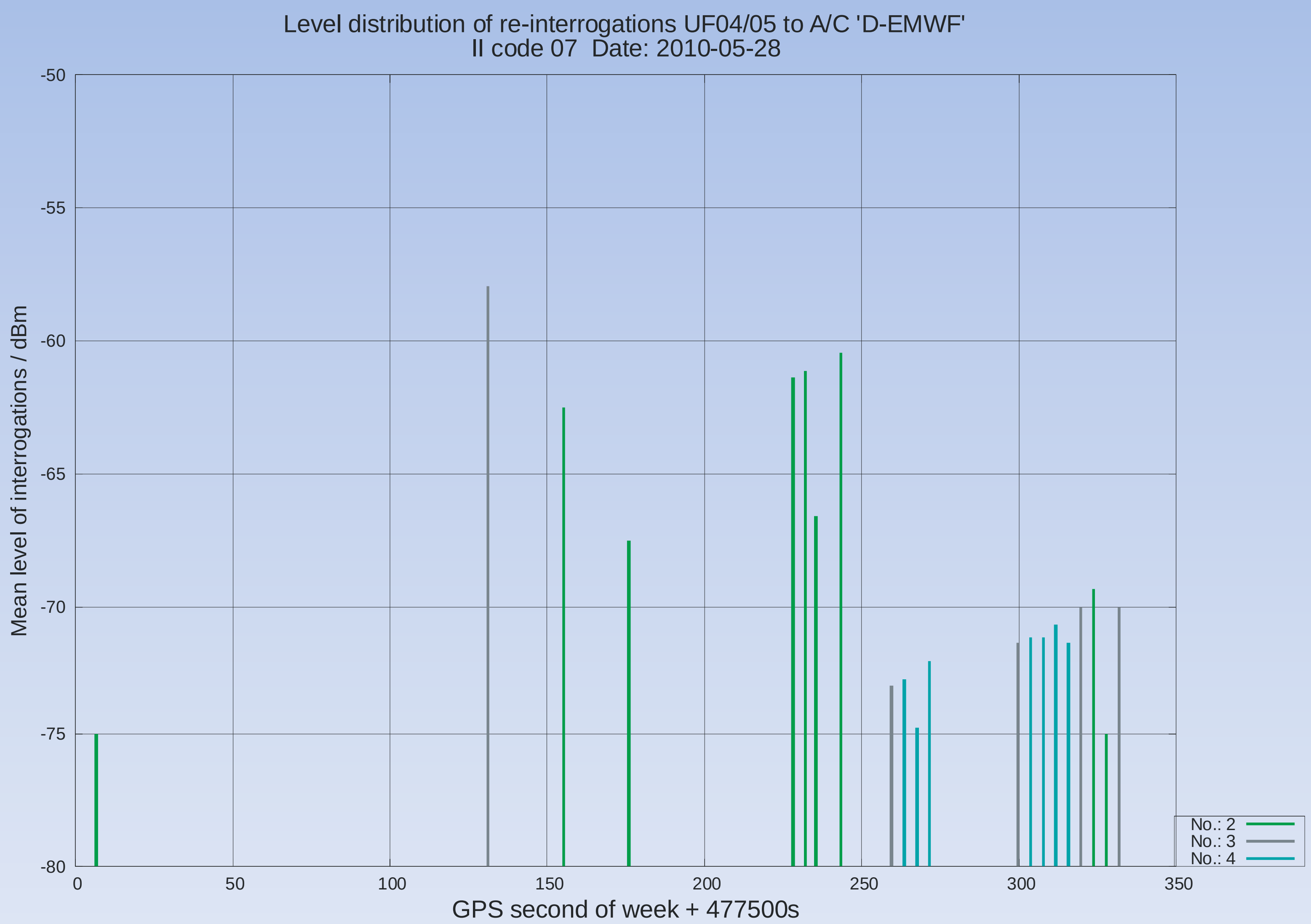
Radars interrogating us in AMS TMA



Radar Re-Interrogation of identical UF04/05 telegrams measured through Amsterdam flight

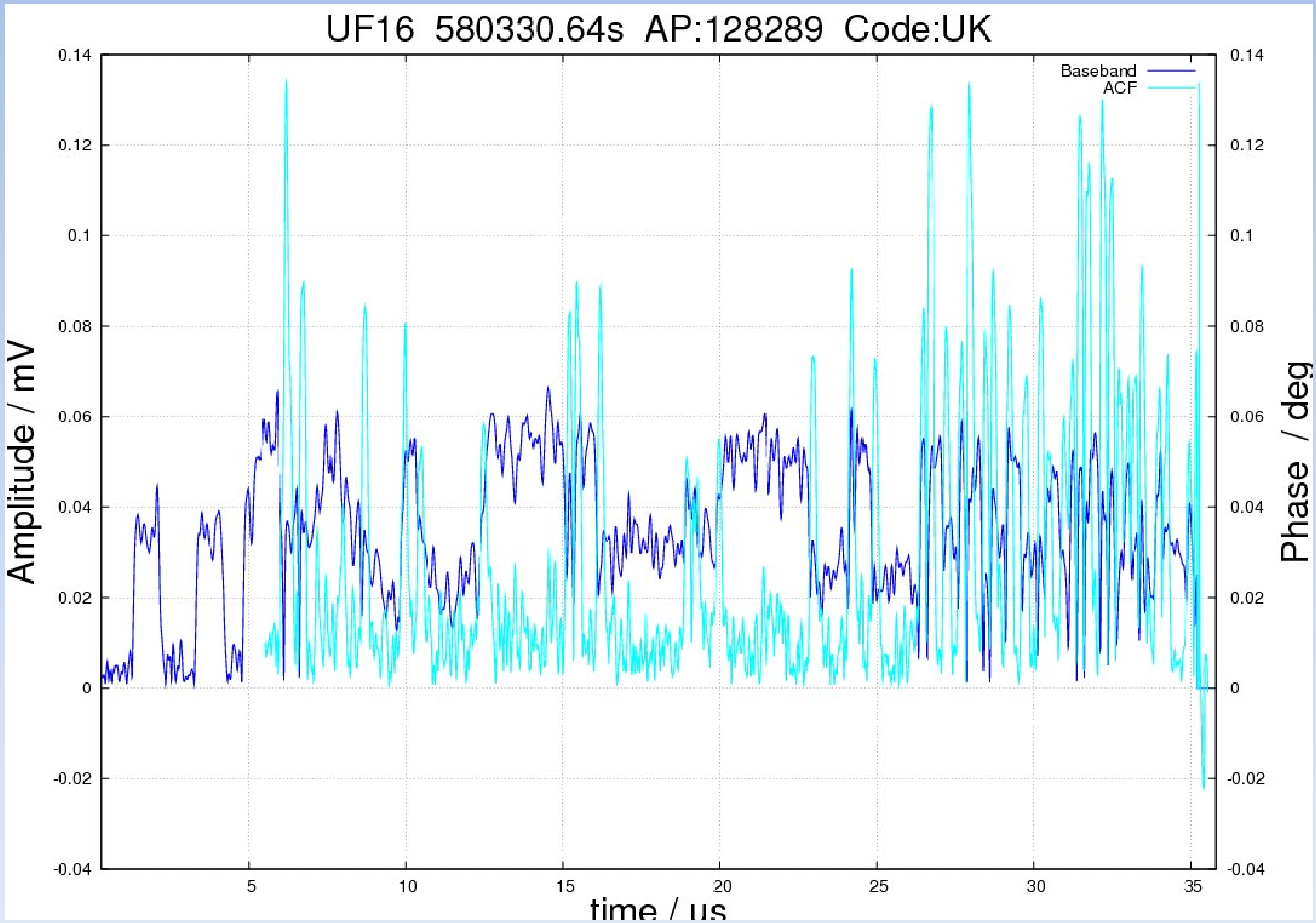


Radar Re-Interrogation of identical UF04/05 telegrams measured through Amsterdam flight



Interrogation UF16

Poor level stability



Interrogation UF16

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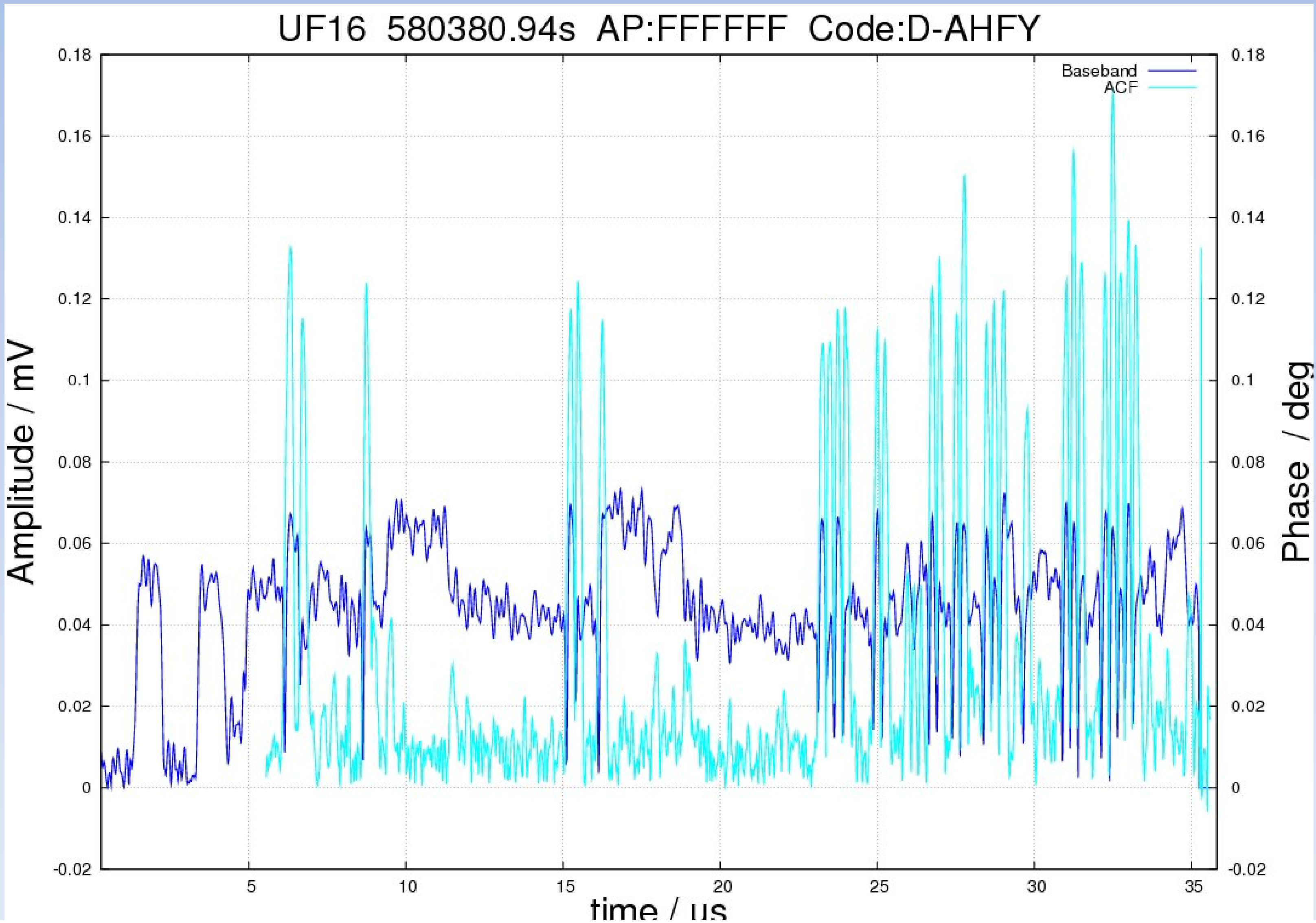
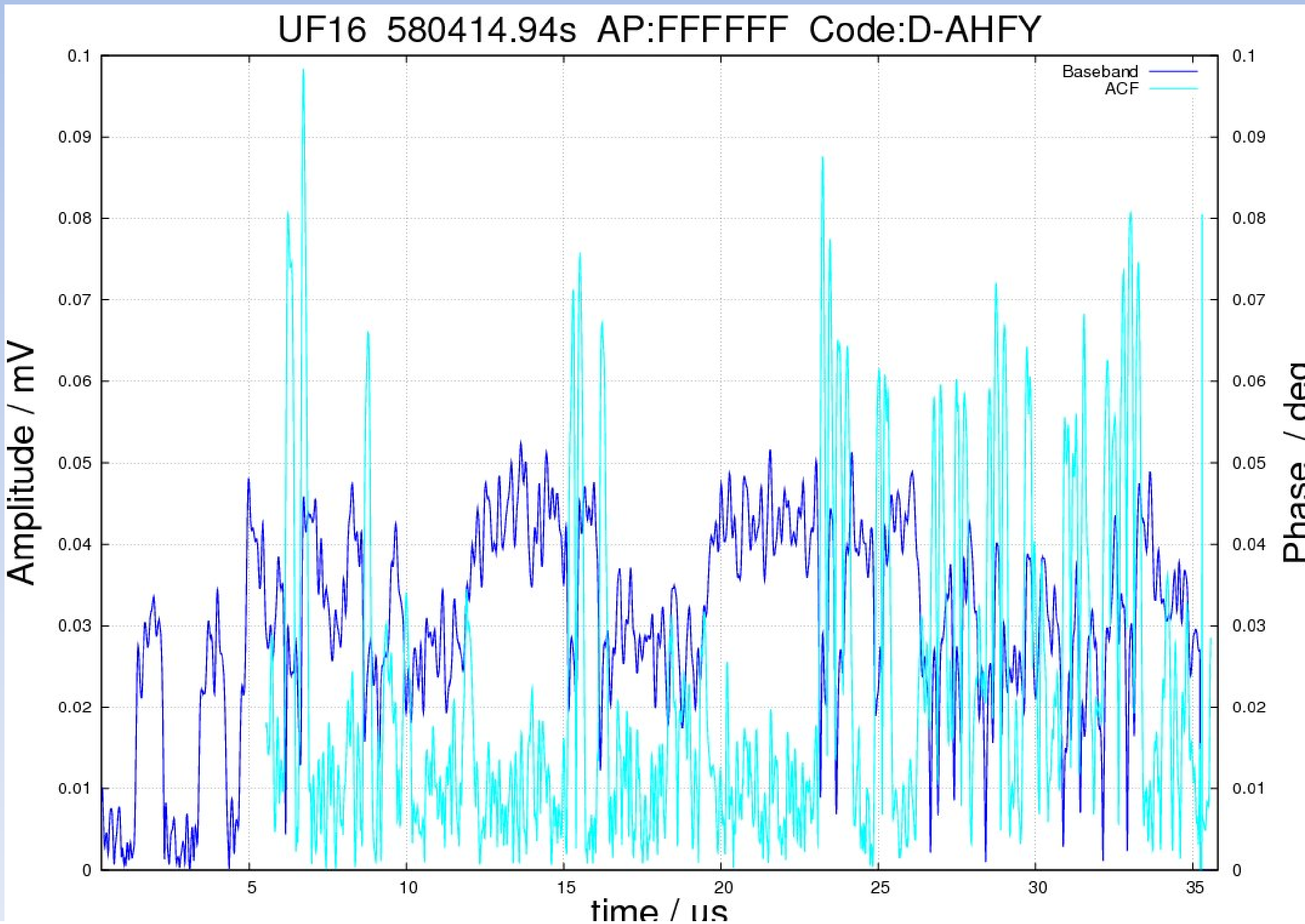


Interrogation UF16

Poor level stability



Conclusions to be drawn so far

- Statement “Too slow phase duration of signal-in-space” of certain interrogator types is <u>not</u> Feasible for the signal-in-space!
- But: There is a difference in phase durations
- Depending of type of DPSK demodulator detection of interrogation may fail

Conclusions to be drawn so far (2)

- One radar interrogator type (II02) has fast switching phase like ACAS and transponder test sets, all others apply IQ modulation
- Transponders of D-CFMD and D-EMWF get mostly along with this interrogation, but:
- Frequent re-interrogations occur at low altitude (D-EMWF) having low levels, probably due to reply on 1090MHz was not accepted: this may be critical for non-diversity installations!
- ACAS interrogations mostly have short SPR durations, but level continuity within telegram is sometimes weak
- Need for DFS/LVNL radar data to solve some issues within runtime of MOSTDONT!

Conclusions to be drawn so far (3)

- I/Q modulators comply with ICAO spectrum and AM-free requirements but may fail with certain transponders
- Phase reversal duration of test sets behave like ACAS interrogators and interrogator of type „II02“ (Luxemburg)
- Recorded bandpass signals can be used to test transponders in a pseudo-real environment
- DPSK demodulation should accumulate energy of whole chip length, not only seek for momentary phase reversal 0°-180°