Improving Signal-to-Noise Ratio in Oblique Ionosonde Soundings Using New Hardware Capability of the DPS4D Ionosonde

Tobias G.W. Verhulst[1], Bodo W. Reinisch[2], David Altadill[3], Ivan Galkin[4,5], †Alexander Kozlov[4,5], Anna Belehaki[6], Estefania Blanch[3], Stanimir M. Stankov[1]

[1]Royal Meteorological Institute of Belgium & Solar-Terrestrial Center of Excellence [2]Lowell Digisonde International, LLC [3]Observatori de l'Ebre [4]Borealis Global Designs, Ltd [5]University of Massachusetts, Lowell [6]National Observatory of Athens

URSI AT-RASC, Gran Canaria, 2018–06–01

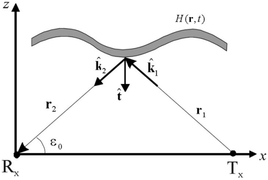
Solar-Terrestrial
Centre of
Excellence

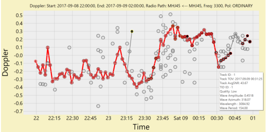
Outline

1. Introduction
    - Oblique, single frequency soundings for TID detection
    - The problem: Sounding cadence
    - The solution: New Tx card for DPS4D
2. The test campaign
3. Results
    - Overall improvement
    - Day-time versus night-time
4. Summary

HF-TID technique in one slide

1. Single frequency digisonde-to-digisonde soundings are performed at five minute intervals.
2. Doppler-shift, angle-of-arrival and range are measured.
3. Clustering and tracking algorithm distinguishes between various propagation modes and interpolates missing data.
4. FAS technique gives the variations in the isodensity contour at the reflection point.
5. Fourier analysis is used to detect TIDs.





For further details, see: Reinisch, Galkin, Belehaki, *et al.*, *Pilot ionosonde network for identification of travelling ionospheric disturbances*, Radio Science (2018); Tech-TIDE project website: www.tech-tide.eu; or the talk by Anna Belehaki in this session.

Problems to solve

The FAS-based detection and characterisation of TIDs works, but can—and should—still be improved.

The data routinely collected—with a five minute cadence—is rather sparse compared to typical TID time-scales (with occasional missing data points).

Also, the windows for the Fourier analysis contain only about 30 data points, and there are border effects that have to be handled (for example by a windowing function).

In summary:

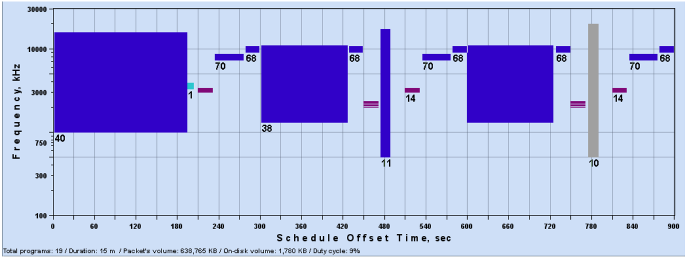
More data, higher sampling rate needed!

But that is easier said than done...

Ionosonde sounding time: precious and scarce

Producing the required D2D measurements involves some logistical and organisational challenges:

- The two (or more!) ionosondes involved have to be synchronised,
- The D2D soundings have to fit in between the other operations, such as the ionograms.



Total programs: 19 / Duration: 15 m / Packet's volume: 638,765 KB / On-disk volume: 1,780 KB / Duty cycle: 9%

The current, day-time operations cycle for the Dourbes digisonde: total of 19 programs in 15 minutes, seven synchronised with EB040, four with JR055—getting very close to 100% of time usage.

New hardware, new sounding options

Question:

How can we improve sounding cadence without sacrificing other soundings?

Answer: shorten the sounding programs, without sacrificing data quality (i.e. signal-to-noise ratio).

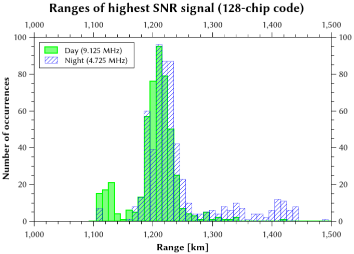
For this purpose, LDI developed a new transmitter card for the DPS4D. This new Tx card provides two new options for the transmitted waveform, using spreading codes of 64 or 128 chips (compared to the old 16 chips).

The new hardware was installed in the Dourbes digisonde at the beginning of 2018, and a campaign organised to test the performance of the new capabilities.

The test campaign

For some days, we ran both the old and new programs for D2D soundings on the Dourbes–Roquetes link. Every five minutes, both soundings are performed immediately after each other, so we can assume the ionosphere is identical for both soundings.

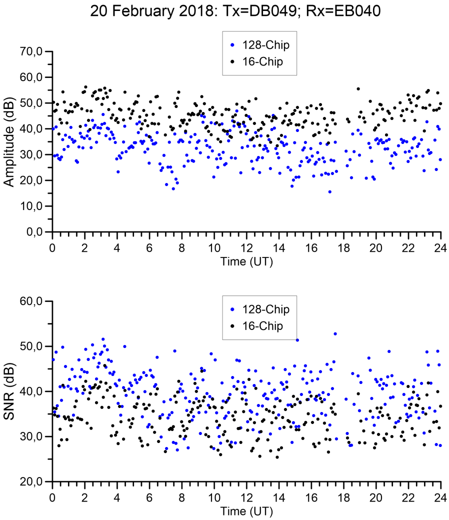
We select the echo with the highest SNR. This is not always the 1F2 signal, but that is not a problem for us here.



Two phases of testing (frequencies: 9.125 MHz (day), 4.725 MHz (night)):

1. Comparing 16-chip using 2048 integrated repeats (40 sec.) to 128-chip with 1024 repeats (20 sec.),
2. Comparing both with 1024 integrated repeats (20 sec. integration time).

Phase 1: different integration times



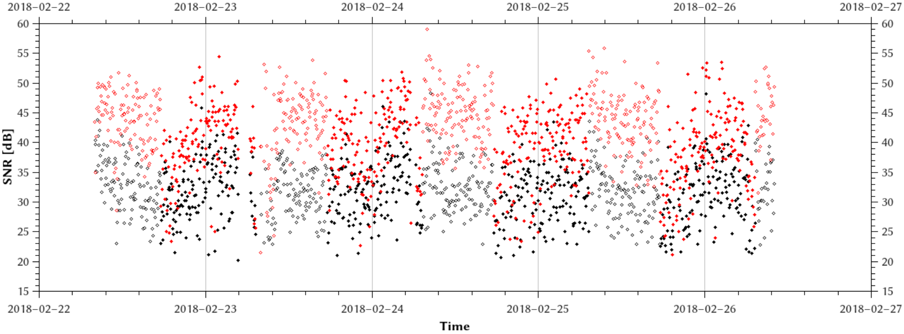
One day of highest SNR signals with 40 seconds integration time for the old sounding program, 20 seconds for the new one.

The amplitudes for the new program are somewhat lower (but this is probably due to a problem with the Rx gain).

Nevertheless, the new, shorter program not only matches the old SNR, but even somewhat improves on it.

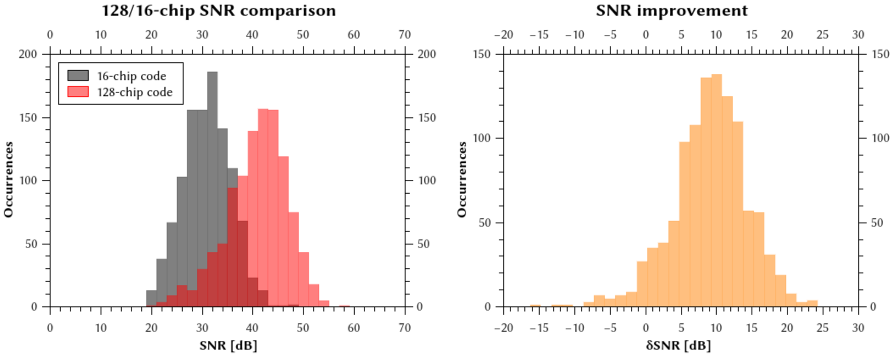
Phase 2: equal length soundings

Here, we perform soundings with both waveforms using 1024 integrated repeats for each (about 20 seconds). The experiment lasted about four (geomagnetically quiet) days.



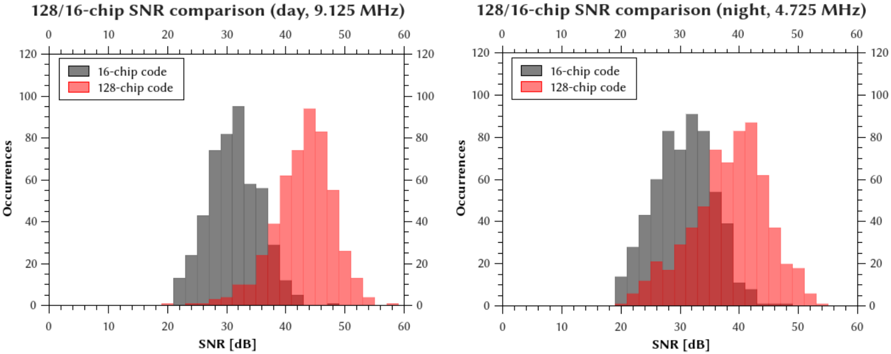
It is evident that the 128-chip code (red) gives a higher SNR than the 16-chip code (black). There also seems to be a slight difference between day-time (open symbols) and night-time (solid symbols).

SNR improvement statistics



Waveform	Signal-to-noise ratio
16-chip code	32.0 ± 4.7 dB
128-chip code	41.8 ± 5.9 dB
Improvement	9.8 ± 5.3 dB

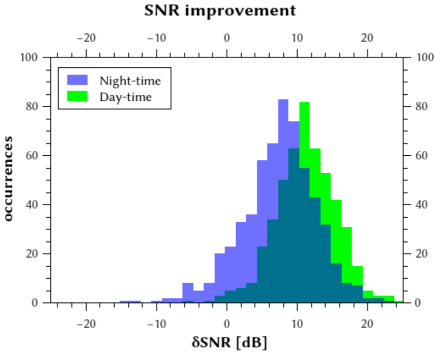
Day-time and night-time

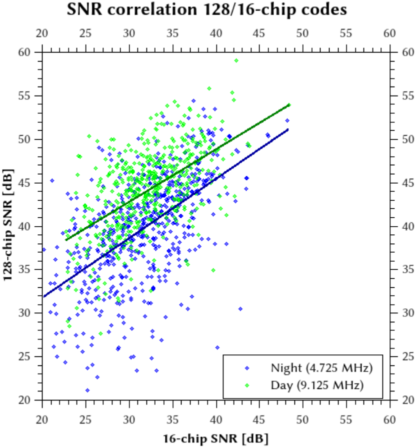


	SNR 16-chip code	SNR 128-chip code
Day	32.2 ± 4.3 dB	44.0 ± 5.0 dB
Night	31.7 ± 5.0 dB	39.3 ± 6.3 dB

The 16-chip codes had a similar performance throughout the day, but the improvement is larger in day-time.

SNR improvement: day & night





On average, δSNR (day) is 11.9 dB, δSNR (night) is 8.1 dB. Note: night-time distribution not completely symmetrical.

Summary

1. Because digisonde scheduling time is limited, soundings must be shortened to allow high cadence of various modes of operations.
2. We tested the new hardware for oblique, single frequency soundings. Even with shorter integration times, the SNR is improved.
3. With the same integration time, SNR can be improved by about 10 dB.
4. The improvement is bigger during day than during night, which might be due to the different ionospheric radio noise environments.
5. There are a number of cases, mostly at night, where the new sounding mode provides worse SNR; this may need some further investigation.

The end, thank you!