Several Uses for EISCAT3D

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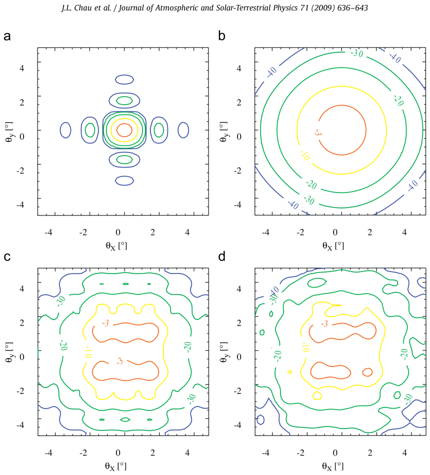
Overview

- Meteor ideas (synthesized beams for statistical studies, simulated "mono-pulse feed" for interferometric angular measurement)
- Space Debris (statistical measurement, passive and active orbital elements determination)
- Planetary radar
- Multi-purpose experiments
- Implications for E3D design, some ideas

Meteors

- Multi-static meteor head echo observations can be used to determine trajectory and correct radar cross-section (a lot of publications by the Swedish group)
- Trajectory could also be estimated using interferometric directional information using several overlapping beams
- Synthesized beams can be used to generate wide and narrow beams (e.g. Chau 2009)
- Both circular polarizations would give more information of the target (e.g. Close 2008)
- A long term data-set would give a better estimate of the global meteoroidal mass flux

Meteors


J.L. Chau et al. / Journal of Atmospheric and Solar-Terrestrial Physics 71 (2009) 636–643
a
b
c
d
θy [°]
θx [°]
-4
-2
0
2
4
-3
-10
-20
-30
-40

Space Debris

- There is considerable interest for surveying the space environment (EU SSA program). This includes space debris, space weather and near earth objects.
- E3D can contribute to all of these
- Passive (using target angular velocities) and active (tracking) orbital element determination for space debris
- Current models predict that space debris is already in a collisional chain reaction that will eventually make near earth orbits unusable (several papers in the ESA Space Debris Conference 2009 proceedings)

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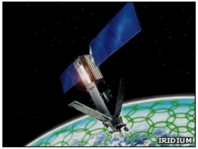
Russian and US satellites collide

US and Russian communications satellites have collided in space in what is thought to be the biggest incident of its kind to date.



Iridium spacecraft provide satellite phone services

The US commercial Iridium spacecraft hit a defunct Russian satellite at an altitude of about 800km (500 miles) over Siberia on Tuesday, Nasa said.

The risk to the International Space Station and a shuttle launch planned for later this month is said to be low.

The impact produced a cloud of debris, which will be tracked into the future.

Since the Soviets launched Sputnik in 1957, it is estimated about 6,000 satellites have been put in orbit.

Satellite operators are all too aware that the chances of a collision are increasing.

The Americans are now following the debris path from the impact. It is hoped that most of it will fall to Earth and burn up in the atmosphere.

> **"The space station does have the capability of doing a debris-avoidance manoeuvre if necessary"**
>
> John Yembrick
> Nasa spokesman

Shuttle launch

The concern is whether the debris will spread and pose any risk to the ISS, which is orbiting the Earth some 435km below the course of the collision.

According to the Washington Post, a Nasa memo said officials

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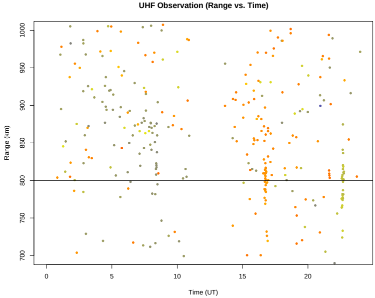
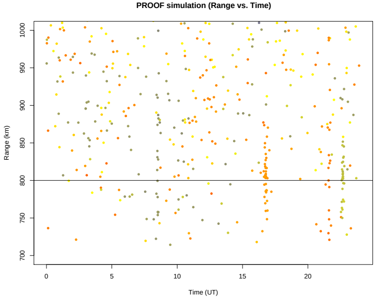
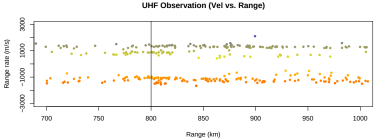
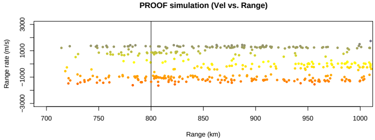
EISCAT Satellite Collision Survey

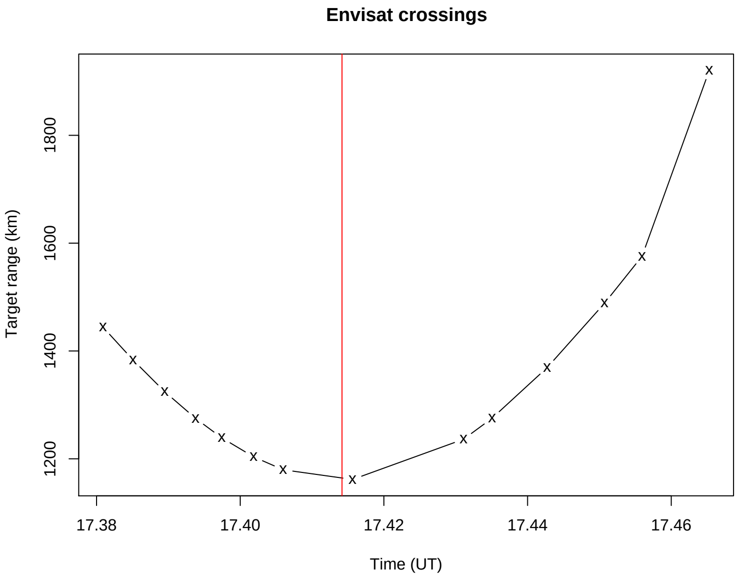




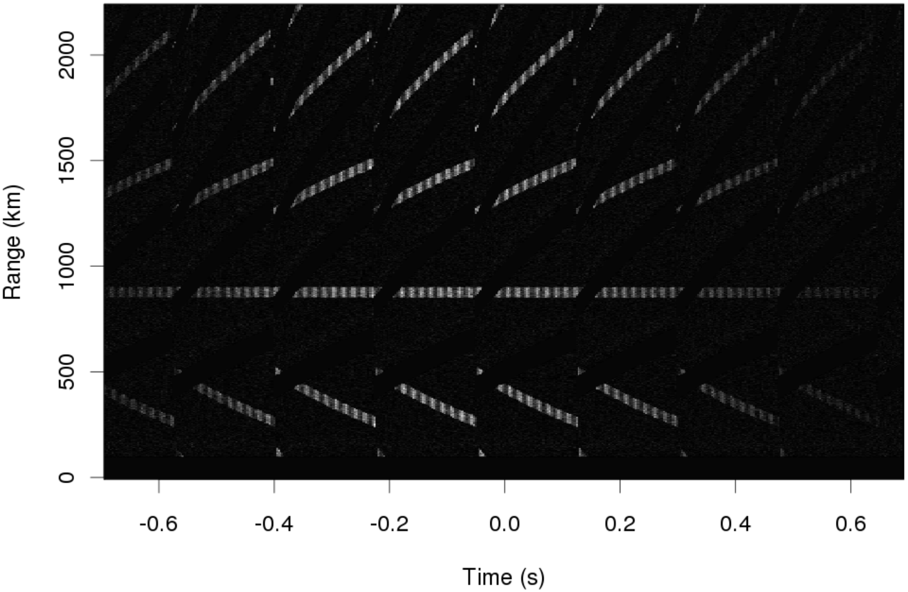




EISCAT tracking test

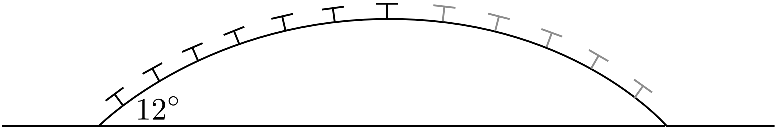


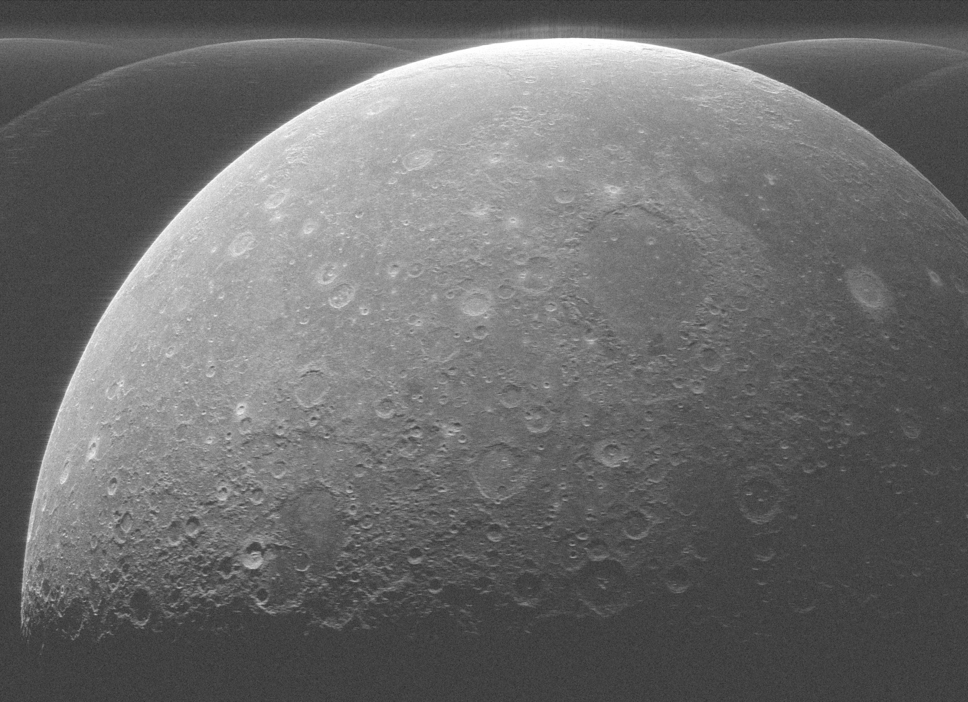
Event 50



Planetary Radar

- The current array design cannot point low enough to allow Lunar or planetary observations
- One idea: use dipole elements and slope array by, say 12°. This would also increase gain at field-aligned direction
- If all directions are needed, a mound shaped positioning is possible

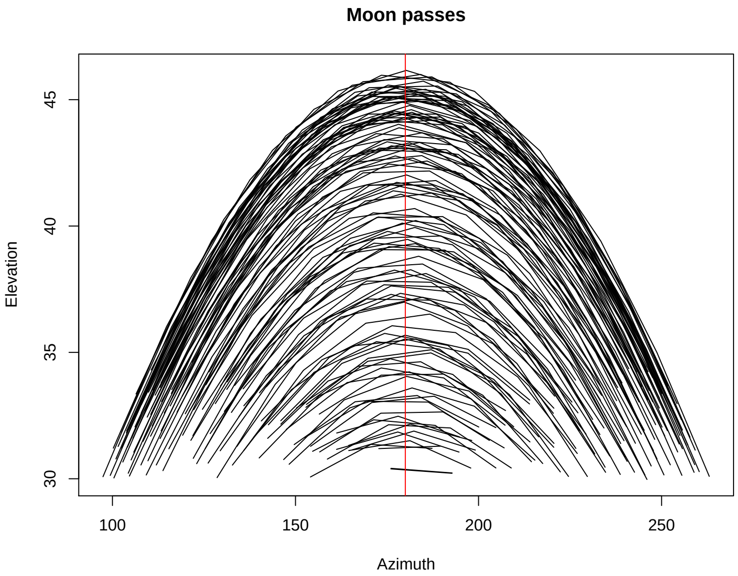




Lunar Radar

- The VHF transmission frequency of $\approx$ 200 MHz means deeper penetration in the regolith (15-150 m, Campbell 2006).
- Lower frequency, clock is less important than with the UHF system
- Both circular / linear receive polarizations are needed
- Phased array allows interferometric observations (e.g. Thompson 1978)

Moon elevation 2009-2010

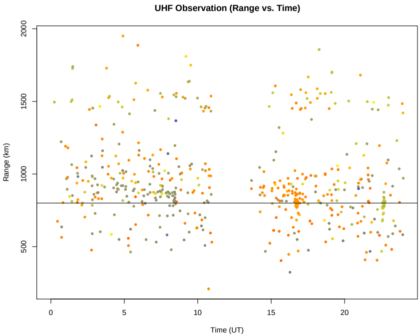


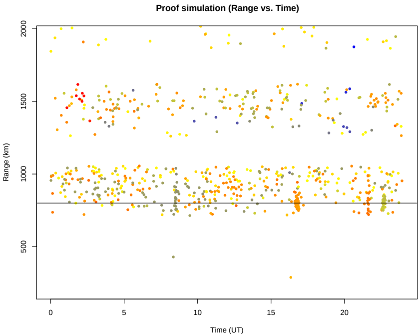
Multi-purpose experiment

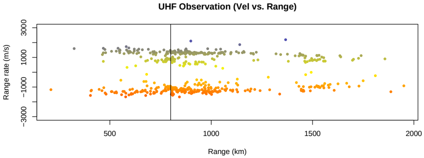
Ideally, the E3D system should give as much bang per euro as possible, by simultaneously measuring:

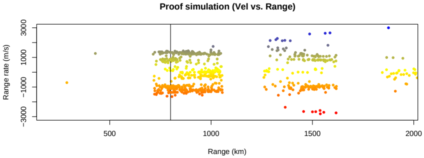
- All regions of the ionosphere
- Meteor head echos (event rate $\approx 1000/\mathrm{h}$)
- Space debris (event rate $\approx 40/\mathrm{h}$)

Space Debris

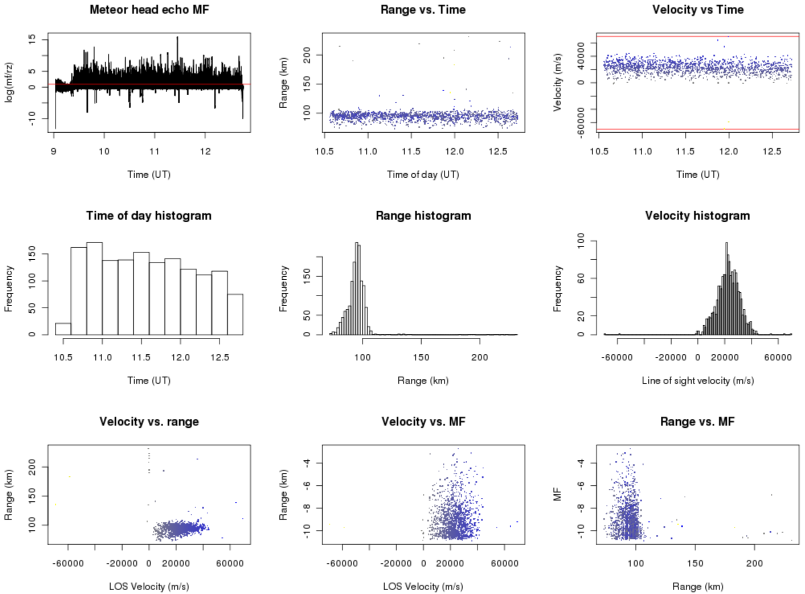




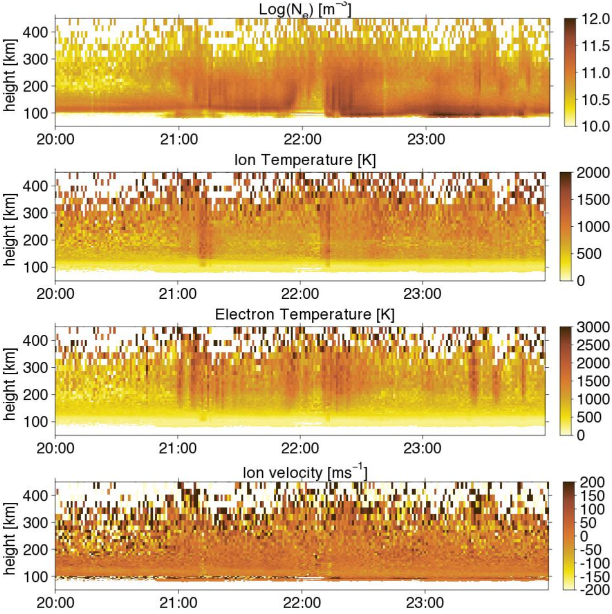


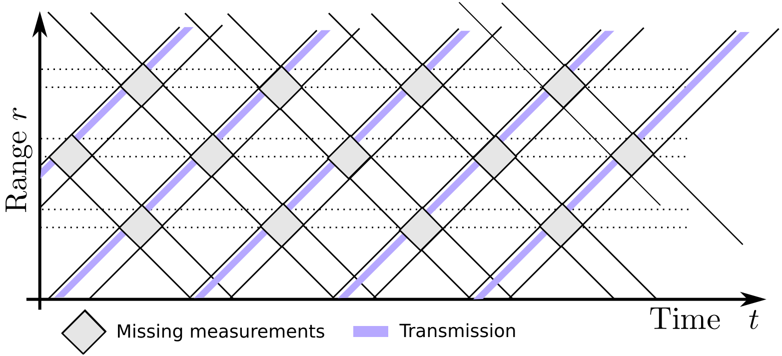


Meteor head echos



Plasma parameters





Range r
Time t
Missing measurements
Transmission

Uniform IPP missing ranges

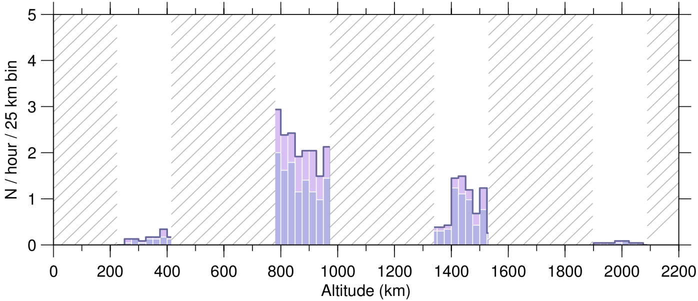
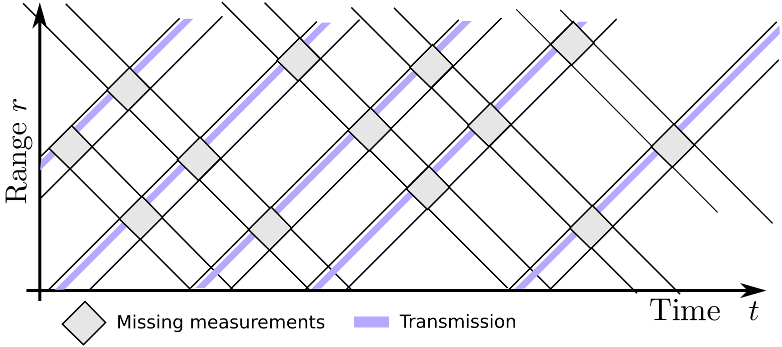


Figure 6: **Event rate v altitude.**

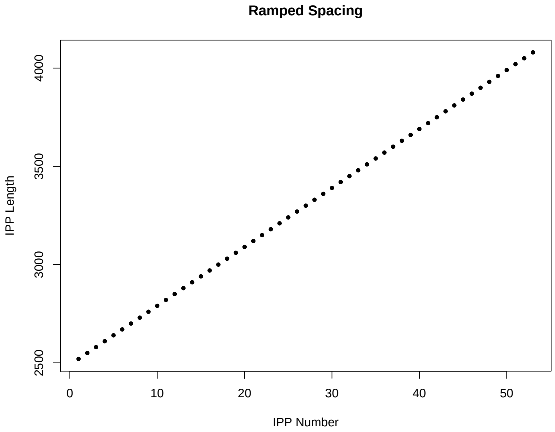
At EISCAT 30-50% ranges blocked by transmission and ground clutter.

Aperiodic IPP experiment



Multi-pulse codes [Farley, 1972], Simple Difference covers [Clinger and Ness, 1976], ATC [Uppala and Sahr, 1996, 1994], Jicamarca [Chau et al., 2004], SMPRF [Pirttilä and Lehtinen, 1999], PPATC [Virtanen et al., 2008, 2009]

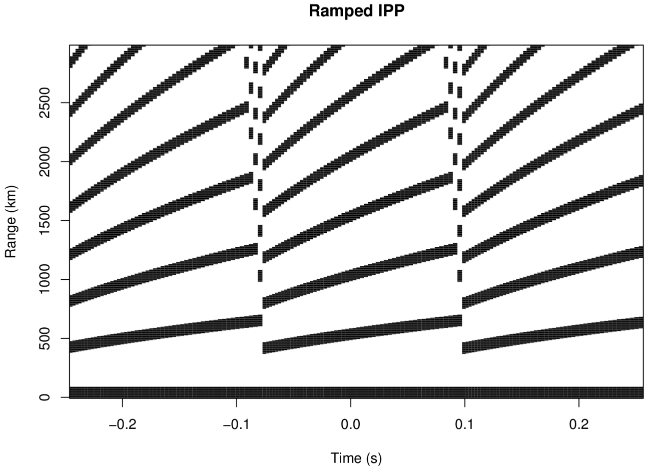
Ramped IPP timing



- Duty-cycle locally variable

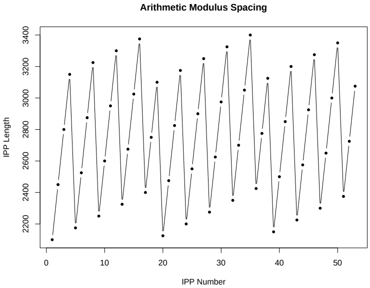
$$\mathrm{IPP} = \{a, a+k, a+2k, \cdots, a+(N-1)k\}$$

Ramped IPP timing



TX and ground clutter is black

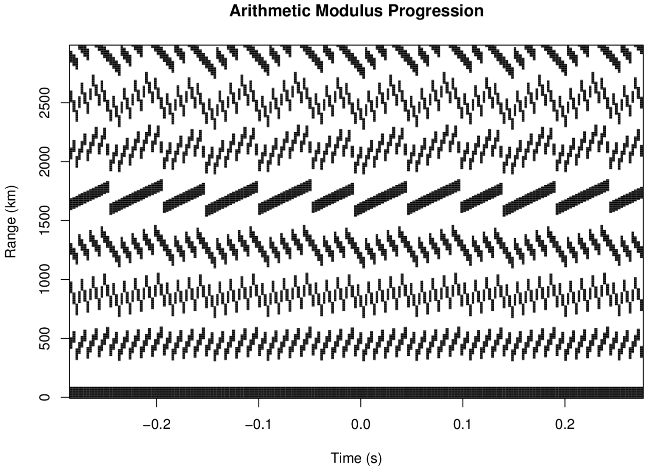
Arithmetic Modulus Timing



- [Uppala and Sahr, 1996]
- Duty-cycle less variable locally
- More evenly spaced

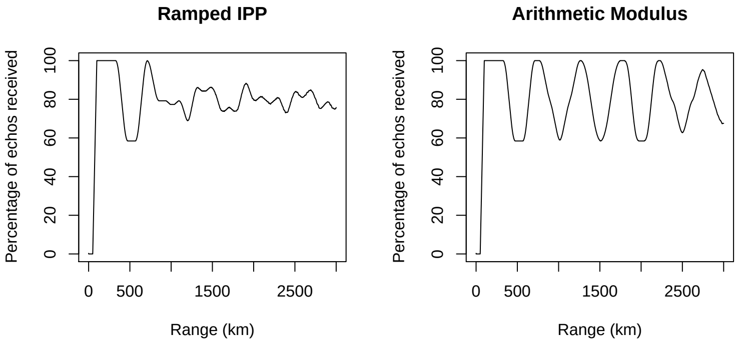
$$\mathrm{IPP} = \{a, a+(k \mod p), a+(2k \mod p), \cdots, a+((N-1)k \mod p)\}$$

Arithmetic Modulus Progression



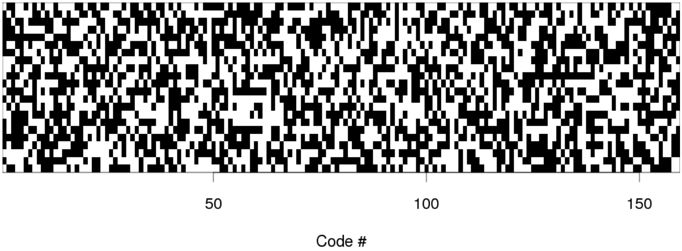
TX and ground clutter is black

Radar efficiency comparison



- Ramped IPP has less oscillation of efficiency
- Arithmetic Modulus coding has bands of 100% efficiency

The Spade09 Experiment: Coding



- Ramped IPP
- Coding optimized for ionospheric work
- Random code group, 159 codes, 53 IPPs
- 15 μs baud length
- 22 bauds

Why random coding?

Measurement equation:

$$m = Ax + \xi \tag{1}$$

Maximum likelihood solution:

$$x_{ML} = (A^H A)^{-1} A^H m \tag{2}$$

- A random transmission code is rarely optimal for a single echo, but under the asumption of target stationarity, it approaches an optimal coding with enough repetitions. $A^H A \approx I$ (Sulzer 1986)
- In the case of incoherent scatter, our random code is 0.01% less than optimal in terms of estimation variance.

Implications for E3D

- Planetary radar is not possible without south facing low elevation pointings (preferably down to 65° zenith angle)
- Several simultaneous beams should be possible, in order to determine angular position of space debris, meteors, and to enable interferometric Lunar observations
- Proper ionospheric plasma parameter estimation requires detection of space debris and meteors, so that they can be removed in amplitude domain, a general operating mode of the system should optimally be able to estimate all of these.

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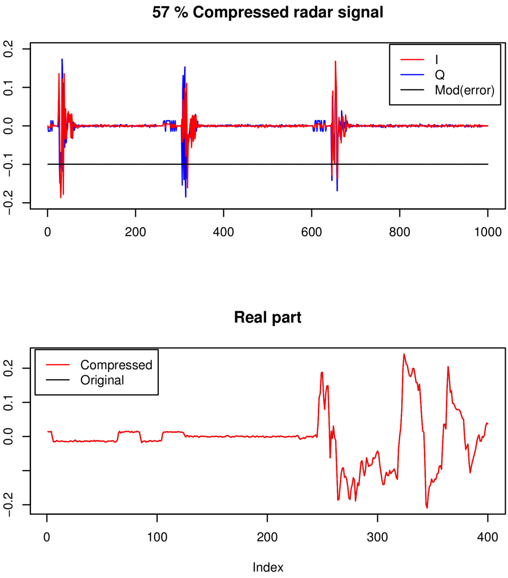
Raw Voltage Data Compression



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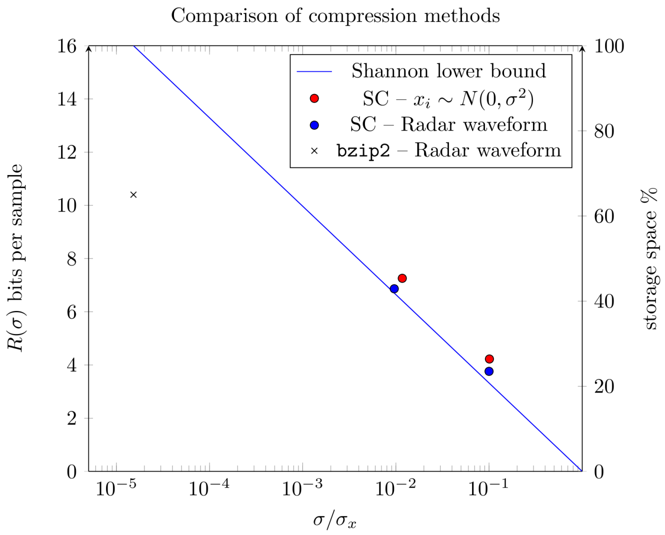

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