INSTITUTE FOR INFORMATION AND COMMUNICATION TECHNOLOGIES

Space radar

A case for space-space radar bands

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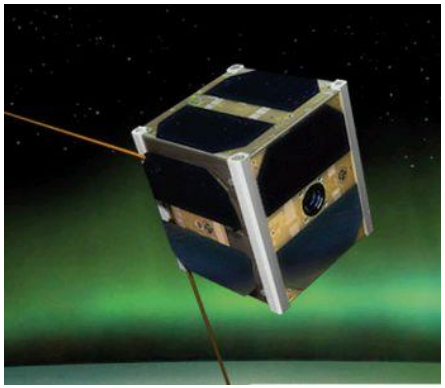
(preliminary presentation 150224)

heig-vd
Haute Ecole d'Ingénierie et de Gestion du Canton de Vaud

Origin of idea

- Phase A of “CubeSat Technology Pre-Developments, QB-50. Active Debris Removal”
  - 100% Swiss project (EPFL, CSEM, RUAG, UAS, MICOS…)
  - Technology research on: debris detection, navigation, propulsion, approach, grappling
  - De-orbiting not considered
- Project close to Cleanspace One
  - Goal: to de-orbit SwissCube



Why space debris radar?

- Project results:
  - 2 mission scenarios (“CADRE”)
  - Preliminary design of a 8U Chaser + 4U target CubeSats
  - Demonstrated usability of radar for long range space debris detection (small debris to km, large to 10s of km)
  - Radar is complementary to lidar and cameras for debris detection/navigation/approach
  - Radar design starting end 2015/2016

In-orbit experiments

- CubeSat Active Debris Removal Experiments
  - 2 proposed, 1 will be selected by ESA (#1)
- CADRE 1 (56 days):
  - Drift/navigation 7km to 25m (4 cycles) + fly around target for observation (15 orbits)
  - Test of short and long range RV sensors (incl. Long/short range radar LRR/SRR), target motion analysis, etc.
- CADRE 2 (11 days):
  - Chaser stays very close to target (<20m), for catching target (with net), study dynamics of tethered system
  - Test of short range detection (esp. short range radar SRR), imaging, attitude control, propulsion
- Launch 2018

Miniature space debris LRR

- X-band was evaluated as best compromise
  - Available COTS parts
  - Wavelength slightly smaller than smallest debris to search
  - Evaluation at 9.5GHz
  - May work from 7 to 14GHz
  - Higher-power FMCW at long distance, low power pulse at shorter distances
- Options rejected (on technical grounds)
  - S and L band: wavelength > object dimension (low cross section, loss of sensitivity) AND antenna size impractical on CubeSat
  - C band: marginal performance
  - Ka band (>22GHz): no COTS power devices currently available, antenna beamforming/mechanical tilting design complex

CubeSat LRR capabilities

- Possible architectures for long range:
  - Digital Beamforming (8° beam width with 2x2U antennas)
  - Analog Beamswitching
  - Single Wide Beam SWB (1U antennas, 25° beamwidth)
- SWB architecture selected for CADRE 1 ➔ gives range only
  - Can detect 4U object at >7 km
  - Can also detect 10m long object at >80km (EnviSat)
  - 50s integration time
  - Compatible with 8U CubeSat requirements
  - Bistatic design

CubeSat LRR summary

- Size is compatible with CubeSat requirements
  - 2 RF+antenna 1U modules on solar panels
  - 1U digital processing board inside body
  - Bistatic design (separate RX and TX)
  - SDR (software-defined-radio) design
- Power consumption and system-compatible with CubeSat
  - Cubesat power requirements ➔ Max 2W RF
  - Digital processing board available for other uses
    - Data compression
    - Image analysis
    - Other navigation tasks
    - Etc.

CubeSat Short Range Radar

- CADRE experiments require a simple collision alarm:

  Low cost, low power, very small

- COTS SRR modules identified during study
  - 24GHz ISM band (150MHz bandwidth)
  - Ground applications: home alarm systems, etc.
  - Miniature (from 25x25mm up)
  - Large detection angle (>90°), 5-10mW RF power
  - Simple analog circuits, with simple range detection capability
  - Could easily be adapted/redesigned for a close space-authorised frequency band

Space radar frequency bands?

- Actually none!
  - Navigation in space using *primary* radar for detection of passive targets is a new subject. Existing systems rely on active target *(secondary* radar) *:* ATV, PROBA…)
  - Only earth-space or space-earth for passive targets
- Short term (latest end 2015)
  - In order to design the radar, we must find «frequency niches» where LRR could be authorised in the 7-14.5GHz range, ideally 300MHz wide (100MHz min)
  - SRR: 23GHz?
  - Extension of currently defined services?
  - CADRE radar may be under the «space research» umbrella?
- Long term (past 2019: WRC-19?)
  - Define a new service (space radionavigation) in bands X/Ku/Ka?
  - Space-to space radar

Space radar frequency bands?

- Definitions (ITU-RR)
  - Radiodetermination: (1.9) The determination of position, velocity and/or other characteristics of an object, by propagation properties of radio waves. (+…Satellite-service 1.41, radar 1.100, primary radar 1.101)
  - Radionavigation: (1.10) Radiodetermination used for the purposes of navigation (including obstruction warning)
  - Radiolocation: (1.11) Radiodetermination used for purposes other than those of radionavigation.
- Service to look for in ITU-RR, Swiss RIR…:
  - Space-space versions of the above? ➔ none found!

Space radar frequency bands?

- Preliminary work with Swiss OFCOM/BAKOM
  - Taking in account technical and regulatory criteria
  - Considering LEO spacecraft only
  - LRR bands selected, by order of (technical) preference:

1. 9.3-9.5/9.8GHz (space tracking, non-interference)
2. 14.1-14.3GHz, clauses 1.41 ➔ 1.40 ➔ 1.10
3. 5.01-5.03GHz: BW and frequency too small!

  - SRR band: 22.55-23.55Ghz inter-satellite band

(Other possibilities may exist!)

Space radar frequency bands?

- X band LRR
  - 9.5-9.8GHz Non-interference 5.476A. Clause 5.475A: could be extended down to 9.2GHz if more than 300MHz BW required (but not likely).
  - TU-RR clauses 1.23 (space tracking?), 5.475A etc (non-interference). **But** 1.136: primary radar excluded?
- Ku band LRR
  - 14.0-14.25GHz, clauses 1.41 (radiocom) ➔ 1.40 (radiodet) ➔ 1.10 (radionav). VSS uplink primary. 5.484A and 9.12?
- Ka band SRR
  - 22.55-23.55GHz inter-satellite band. 5.338A Non-interference to RA 22-23.15GHz (atm. H_20?)➔ use only 23.15-23.55: range resolution issues!

Outlook for space radar

- Beyond debris detection: Radar as a navigation instrument
  - For deep-space craft (small or big)
  - Docking assistance
  - Asteroid approach and landing
  - Altimeter (not new!)
- Beyond X-band: Ka band to be used in the future for LRR?
  - Inter-satellite service?
  - No COTS devices yet for CubeSat design
  - Better beaming and directivity (requires beamforming)
  - More complex design, less power-efficient
- Evaluation of interference to other services, taking in account :
  - Typical cubesat antenna characteristics (SRR and LRR)
  - Fixed antenna orientation during operation (attitude control)
  - RF power vs. Range
  - Study in X, Ku and Ka bands
  - EO as well as deep space

Who are we?

- Applied aR&D group active in:
  - Space comms!
  - RF and microwave circuits
  - Internet of Things, low power embedded systems
  - Biomedical applications of EM waves
  - Biomedical applications of ultrasound
- Our philosophy:
  - We love to do “things” that really work!
  - Hands-on approach, business, entrepreneurial
  - Close contacts with industry partners (CH, FR, DE)
  - We don’t publish scientific papers (at least, usually)
  - Innovation:
    - Putting together “things” that never were together before
    - New applications of our technologies
  - “end-result” partner in H2020 and other international projects

Questions?

welcome!

- Looking forward to talk with you:

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