Recent advances and results of MWL FS and MWL GT verification and tests

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This work is performed under ESA contract 16242/02/NL/JS
Outline

- Activities with RF EGSE
  - Updates, connections, calibrations…
- GT Activities and Tests
  - TWO GT assembled, connections, tests, some selected results
- FS Verification and Tests
  - AM / PM calibrations
  - Dynamic PLL response & Bump calibration
  - RF Sensitivity (tests ongoing)
  - RF Interference Test (tests ongoing)
  - Dynamic Doppler verification, to come
Recent advances and results of MWL FS and MWL GT verification and test.

RF EGSE Activities

Simultaneous Multiple connections
1. Pair FM <-> GT #3
2. Pair EM <-> GT #2

Cables firmly installed
Well-defined interfaces at boxes

Calibration & Verification
- RF signal amplitudes
- Frequency and range settings
- AM/PM characterisation

Reproducible and long-term stable signals

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EM set-up and connections, ELT mockup

- EM serves as representative test-bed, for any HW, SW and FW tests and verifications
- Various break-out boxes and extenders for simplified module access
- It is paired with the GT development and test stand, for GT design and verification.
- Connected to RF-EGSE for non-zero Doppler tests
GT #2 in test environment

- One Ku-Transmitter
- Two Ku-Receiver Channels
- One S-Receiver Channel
- S-Band delay monitor (loop)

- Ku-Loop is closed externally at the antenna
Calibrate for AM/PM
“NO” AM/PM in receivers

- Earlier attempts poor, severely limited by instrumentation

- New: Use AM/PM-free attenuators
  - Ku-Band (TESAT): Rotary-Vane WG attenuator (used for TWT AM/PM tests)
  - S-Band: Evanescent-mode attenuator

- Observation: “Receivers exhibit virtually NO AM/PM“ for carrier phase (why? see block diagramme below…)

- Calibrate RF-EGSE for AM/PM using MWL receivers together with these attenuators

- Result:
  **RF-EGSE is calibrated wrt AM/PM, for code and carrier**

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**Impressive:**
Delay does not change, despite physical length is changing
“Divider problem”, phase continuity solved

- A “Divider problem” has been identified during last end-to-end test (E-2-E)
- DLL ON/OFF was necessary to recover from possible SEU effects
- Problem solved using DLL-FPGA reload without module switching (requiring a small SW & FW change)

As result:
- NO module-switching required any more during nominal operations
- All RF synthesisers & dividers run continuously, incl Test-loop carrier oscillator
- Full phase continuity is ensured, for code and carrier, during a full operation period
Ongoing Tests:
Example: RF Interference Test

- On-Going verification tests, example: CDMA interference test
- Script-based
- Automatic data recording, semi automated test evaluation, ongoing
Ongoing Tests:
RF Sensitivity & Interference

- RF test levels have changed since last E-2-E test to better account for unfavorable locations (i.e. Tokyo) and rain
  - Requirement
  - Acquisition: starting at 5° up to 10°
  - Tracking above 10° (no carrier cycle slips)
- Rx receiver lock-in sensitivity has been increased by 8 dB since E2E, which does not change noise levels!
- Lock-in algorithm and lock detector performance required changes to FW and SW, FPGAs
- New tests ongoing to adapt to the new situation
- Preliminary results promising
- Caution:
  - published results are taken under different configurations
  - new set of data being acquired
FM RF Sensitivity
very preliminary ongoing

FM Code sensitivity approaching – 123 dBm

Test:
15 acquisitions at each RF signal level
Then change range and amplitude

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**FM Phase continuity vs RF EGSE under realistic Doppler conditions**

January 2019

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**FM Code – minus - Carrier, reproducible between lockins**

### Frequency vs. Time

- **Data Source:** FS-CAL Dop
- **Average:** No Averaging
- **Averaged Samples:** None
- **Min Value:** -353.9964 Hz
- **Max Value:** 313.9988 Hz
- **Average:** 43.099 Hz
- **Std Dev:** 263.4981 Hz
- **Data Length(s):** 419
- **Peak To Peak:** 624 6799 Hz
- **2 Sigma:** 526.9574 Hz
- **Scale:** 0.0094 Hz/s

### Phase vs. Time

- **Data Source:** FS-C02 Abs
- **Data Source B:** FS-082 Par1
- **Data Source C:** FS-572 Par1
- **Data Source D:** FS-CA2 Ins
- **Averaged Samples:** No Averaging
- **Min Value:** -629.3202 ps
- **Max Value:** 578.3388 ps
- **Average:** -34.159 ps
- **Std Dev:** 125.8696 ps
- **Data Length(s):** 11996
- **Peak To Peak:** 1207.640 ps
- **2 Sigma:** 251.3368 ps
- **Scale:** 500 ps / div
FM to RF EGSE stability signal -105 dBm, max amplitude

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Achieve carrier cycle identification within 10..20 s, at high amplitude

TDEV: Code Phase
10E-12 @ 10 s

TDEV: Carrier Phase
9E-14 @ 10 s
Thermal stability, code phase

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Thermal stability, carrier phase

Carrier Phase
Temperature: 3 Kpp

TDEV: Carrier Phase degraded

Code

Carrier
GT #3 Stability using TLT
System Overview, telemetry

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FM to GT2 Doppler Test
“long cables” 150 ns el. Length
de-synchronisation

Doppler shape, code and
carrier

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Code minus carrier after code ambiguity removal and carrier cycle identification
Shall be straight line

2-way carrier phase:
De-Synchronisation due to
• Short cables to FM
• Long cables to GT2
FM to GT2 2-way Test
TestDLL Bump due to relative acceleration

Solution:
Calibrate for bump in non-dispersive conditions,
i.e. on ground
Using code minus carrier, see slide 11
Wanted signal: low, -119 dBm
Interfering signal: high, -97 dBm
Difference: 22 dB

Minor interference effect only for long tau within measurement uncertainty
### Summary & Conclusions

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<tr>
<td><strong>1. Phase Continuity</strong></td>
<td>OK, full ops period</td>
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<td><strong>2. AM/PM</strong></td>
<td>OK, negligible</td>
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<td><strong>3. Code Dynamics (PLL bump)</strong></td>
<td>OK, to be calibrated</td>
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<tr>
<td><strong>4. Signal delay, carrier</strong></td>
<td>understood</td>
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<tr>
<td><strong>5. Signal delay, code</strong></td>
<td>understood</td>
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<td><strong>6. RF sensitivity</strong></td>
<td>ongoing (OK \text{ prelim})</td>
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<td><strong>7. CDMA interference</strong></td>
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<td><strong>8. Internal EMC/EMV</strong></td>
<td>ongoing (OK \text{ prelim})</td>
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<td><strong>9. GT shows matching performance</strong></td>
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Further Tests related to performance excerpt

1. Realistic GS Szenario (FS with RF EGSE), formerly E-2-E test
   - „Full set“ of GS active, GS handover test
   - Full Doppler & Range simulation
   - Verify scaling (equal phase-time on all measurements)
     • Essential to determine ionosphere
   - Doppler stress test (15% higher than expected maximum)

2. Two-Clock Test (FS vs GT)
   - Realistic clock drifts, absolute scaling
   - unambiguous time transfer after interruptions

3. ELT-Operations

4. Signal delays (see Luigi‘s talk)
   - Very much reduced effort, based on instrument‘s own measurements
   - More accurate, because signal detectors are always the ones used in operations.