CGMS

CGMS-35 NOAA-WP-41
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Agenda Item: I/1
Discussed in WG1

# L-BAND FREQUENCY FOR SARAL REAL TIME DOWNLINK

NOAA-WP-41 presents a summary of L-Band frequency for SAREL time downlink for the Argos-4 system. CNES and ISRO are cooperating to launch a satellite with an Argos-3 payload by end 2009. This contribution gives the rational to use the meteorological band 1698-1710 MHz for the real time telemetry downlink of the Argos system. Then it gives the proposed frequency set for L band emitters and insights of potential interference with other systems using the same frequency band.

# L-BAND FREQUENCY FOR SARAL REAL TIME DOWNLINK

## 1. Introduction

CNES and ISRO plan to launch by end 2009 the satellite SARAL (Satellite for ARgos and ALtiKa) with an Argos-3 payload and an altimeter/radiometer payload in Ka band. CNES is responsible for the delivery of the integrated payload module to be integrated on a Small Satellite Bus (SSB) under ISRO responsibility.

Argos is a Data Collection System (NOAA, CNES and Eumetsat cooperation) dedicated to environment already flying on several polar orbits and now in its third generation of instruments. With SARAL, ISRO has recently joined the Argos program. The Argos-3 payload on SARAL is a gap filler mission on a 6am-6pm sun synchronous orbit that will complete the current Argos constellation. The lifetime of the mission Argos-3 on SARAL is 5 years.

The Argos-3 mission requires a Local Mode to transmit in real time the data collected by the Argos instrument and containing the messages to be delivered to the users. This Local Mode is an important mission requirement.

Argos Local Mode data are multiplexed with data from others payloads of meteorological satellites (Metop or POESS) on which Argos instrument are embarked and then transmitted through the HRPT downlink. Local mode data are collected thanks to a ground stations network, around 50 worldwide, through cooperation agreements on a non commercial basis.

On SARAL payload, it is planned to perform the Local Mode transmission through a dedicated L band link called RTTM (Real Time TeleMetry), since no HRPT link is available.

The L-band downlink envisaged for the transmission of the Argos real time data is in the 1698-1710 MHz band, accordingly to ITU-R and SFCG recommendations for non geostationary meteorological satellites.

The rationale to use this meteorological frequency band is the following:

- Argos is a system dedicated to the study and the protection of the environment. Most of Argos applications concern meteorology and oceanography (including location and collection of environmental data from buoys or remote measurement stations, like ocean temperature profiles, currents, salinity, etc.).

- Present Argos real time telemetry (from POES and Metop satellites) is received through HRPT downlinks in L-band 1698-1710 MHz by around 50 ground stations worldwide. To be compatible of existing HRPT ground stations, the downlink on SARAL shall also be in L band.

## 2. Status of the 1698-1710 MHz frequency band

The recommended frequency band for non geostationary meteorological satellite is 1698-1710 MHz accordingly to ITU Recommendation and SFCG Recommendation 11-1R3.

Table 1 below lists the declared frequencies with bandwidths of ITU fillings that are supposed to be used in 2009 (earliest launch date for SARAL) by meteorological satellites on polar orbits. The information contained in the table need to be confirmed, if possible, by agencies responsible of the satellites.

| Satellite | Organisation | Central Frequency (MHz) | Bandwidth (MHz) |
|---|---|---|---|
| NOAA-K (15) | USA | 1702,5 | 4 |
| NOAA-L (16) | USA | 1702,5 | 4 |
| NOAA-M (17) | USA | 1707 | 4 |
| NOAA-N (18) | USA | 1698 | 4 |
| NOAA-N' | USA | 1707 | 4 |
| NPP (NPOESS) | USA | 1707 | 6 |
| SEASTAR | USA | 1702,5 | 2 |
| Metop Redond. | Eumetsat | 1707 | 4 |
| Metop | Eumetsat | 1701,3 | 4 |
| METEOR-3M | Russia | 1700 | 2 |
| METEOR-3M | Russia | 1705 | 4 |
| FY-1 | China | 1700,4 | 4 |
| FY-1 | China | 1708,46 | 2 |
| FY-3 | China | 1,745 | 5,6 |

***Table 1 Frequency bands used by meteorological satellites in Low Earth Orbit in the band 1698-1710 MHz***

NOAA K, L, M and N satellites are each one equipped with 3 L band emitters with central frequencies 1698, 1702,5 and 1707 MHz. Only the frequency presently used by the satellite has been indicated in the previous Table. In the same way, Metop has two emitters (nominal and back up), each one with its own frequency.

The Figure 1 shows the spectral occupancy for the satellites listed above.

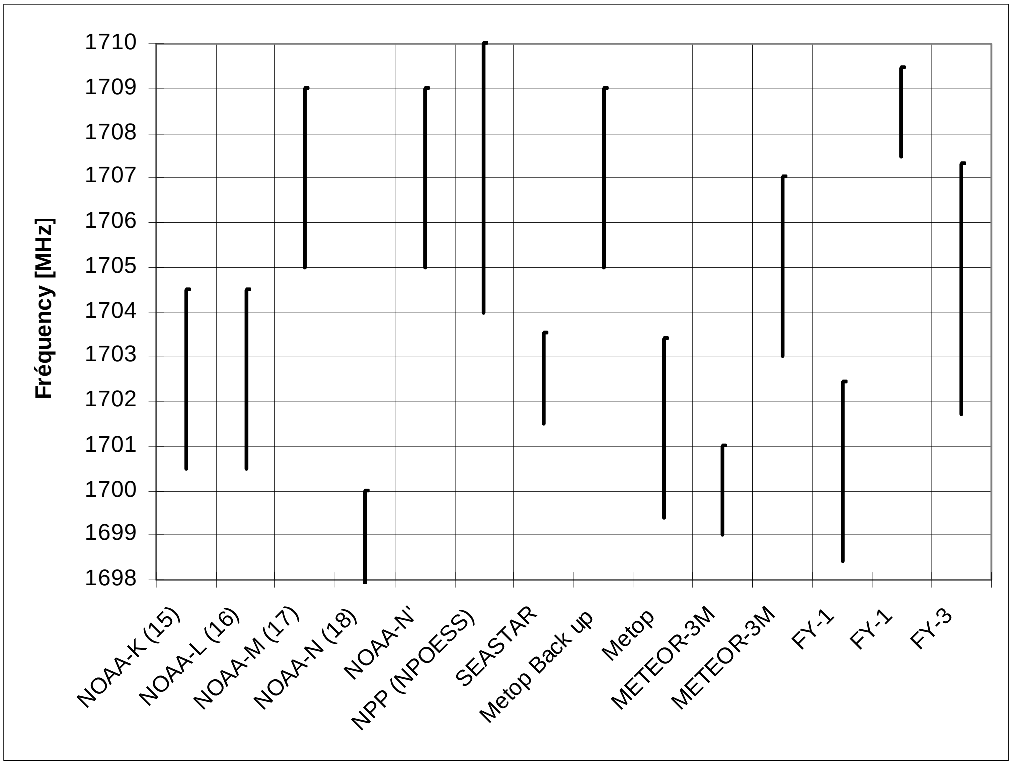


***Figure 1 Frequency bands used by meteorological satellites in Low Earth Orbit in the band 1698-1710 MHz***

## 3. <u>SARAL parameters and assumptions</u>

### 3.1. <u>SARAL orbital parameters</u>

SARAL will be placed on a sun synchronous orbit with a 6am local time of ascending node (LTAN). Orbital parameters have been set up for SARAL simulation.

### 3.2. <u>RTTM PARAMETERS</u>

Telemetry data are formatted in CCSDS packets and then in Metop like frames.
Two emitters are embedded. One is the nominal emitter and the other is a back up emitter (cold redundancy). The emitter permanently transmits (always ON).
The data rate is 300 kbits/s (TBC), including CCSDS frame formatting and excluding convolutional coding.
The modulation is direct QPSK with a convolutional (7,1/2) coding. At the modulator output, the signal is filtered by a SRRC filter with a roll off of 1.
The RF output power of the emitter is 0.5 W with permanent transmission during all the mission lifetime.
The bandwidth occupancy is 680 kHz (TBC), Doppler included.
The antenna is quasi recurrent of the one of the HRPT on the Metop program. The expected antenna gain is given in the Figure 2, where θ is the angle with respect to the axis of the antenna. The antenna is right hand circular polarized (RHCP).

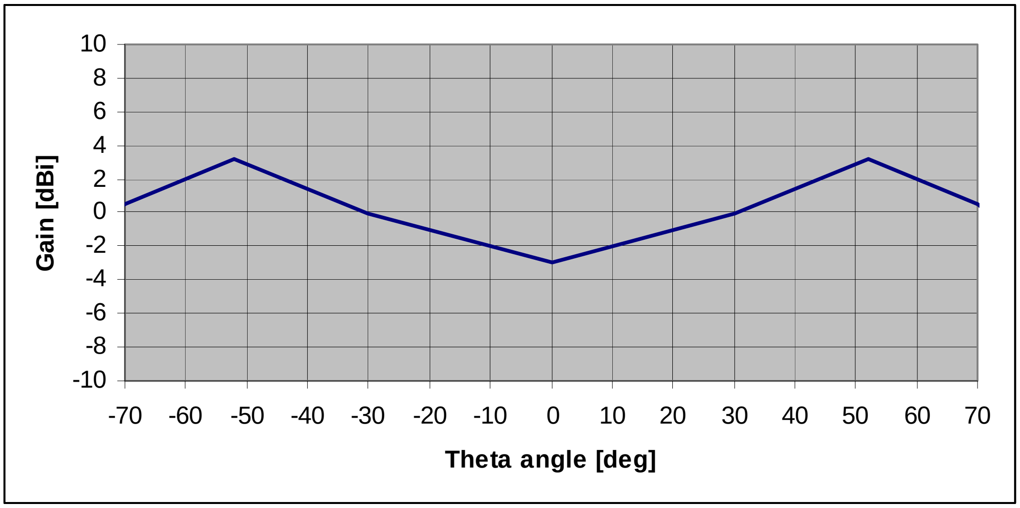


***Figure 2 L band antenna gain***

## 4. Frequency bandwidth selection

The occupancy of the 1698-1710 MHz bandwidth (see Figure 1) does not allow choosing a frequency band without overlapping bandwidths of other existing systems. Therefore the frequency bandwidth for SARAL RTTM shall be chosen in order to limit potential interferences with other systems.

Spatial separation allows the reuse of the frequency. A large difference of local time of ascending node is a significant factor to mitigate potential interference of two systems using the same frequency. In this configuration, only ground stations located at high latitude could encounter some interference issues.

NOAA POES satellites are not maintained in orbit and consequently their ascending nodes drift with the time, whereas Metop is maintained with a local time at 21:30. This parameter is not known for other satellites. Figure 3 gives the predicted drifts of local time for POES satellites for the period from September 2009 to September 2014. The fixed local time of Metop is also indicated. The local time of ascending node of SARAL is 06:00am and will be maintained during the entire mission. Note that Metop and POES satellite have their local time of ascending node in the afternoon whereas SARAL is in the morning.

NOAA POES and Metop frequency sets allow changing the emitting frequency in case of interference with other satellites that could appear, notably due to orbital plan drift.

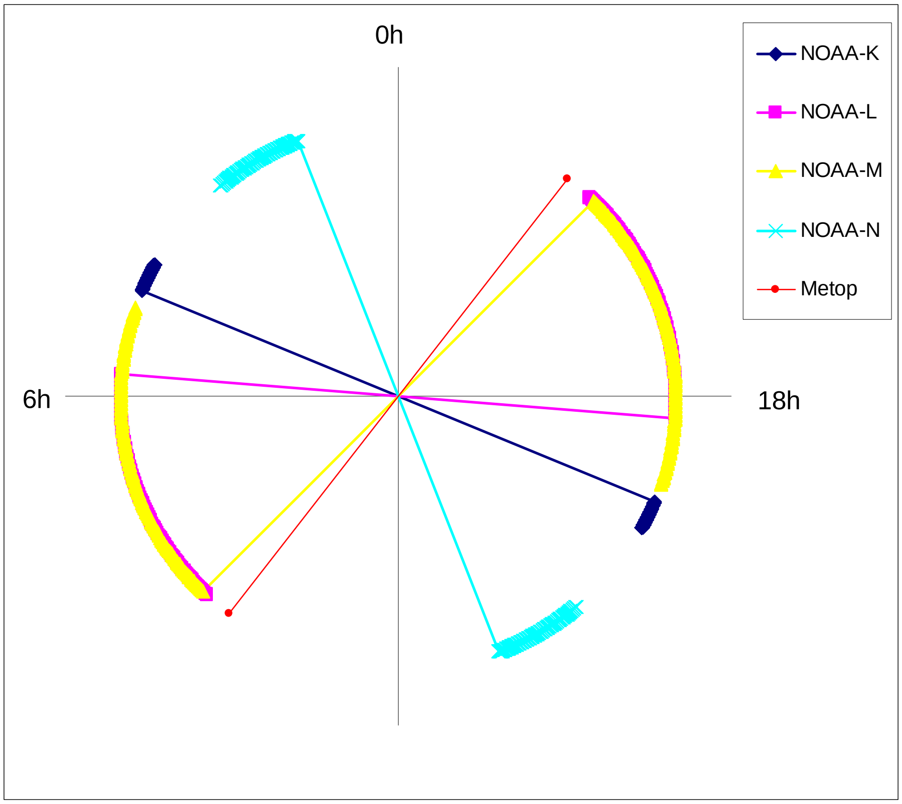


***Figure 3* Local time of POES satellites and Metop**
***(lines mark the positions at end 2009)***

According to Figure 3, main drivers can be identified to chose or reject SARAL RTTM potential frequencies:

- NPOESS bandwidth shall be avoided since NPOESS-C2 (LTAN 17:30) and SARAL orbital plans will be close one to each other. Interference configuration would not only occur with high latitude ground station but also with medium or low latitude ground station.

- Frequencies of Metop and NOAA-N satellites can be reused for SARAL because SARAL, NOAA-N and Metop will be placed in separate orbital plans. If located at medium latitude, a ground station is not in visibility, or with a large angular separation, of both SARAL and Metop or NOAA-N.

The frequency bandwidth B1 = 1698-1698,680 MHz is proposed for SARAL RRTM because it limits the overlap with other frequencies than NOAA-N, which is in another orbital plan. In particular, B1 minimizes the overlap with FY-1 frequency.
The frequency bandwidth B2 = 1702,72-1703,4 MHz is also proposed for SARAL RTTM. This bandwidth is within Metop emitter and out of FY-1 down frequency band. B2 is located at the edge of Seastar and Meteor-3M for which deeper analyses might be done.
Interference issues can be mitigated by using several frequencies, as on NOAA or Metop satellites. The frequency bands of SARAL will be configurable between B1 and B2. This setting will allow changing the frequency in case of interference with other systems.

## 5. Analyses of interferences

Analyses have been conducted in order to evaluate the occurrences of potential interferences with other meteorological systems using the same frequency bands: NOAA-N for SARAL bandwidth B1 and Metop for SARAL bandwidth B2.
Maintaining the local time of ascending node is difficult to simulate and in particular it can not be done for the long period of the mission (2009-2014). Nevertheless, because statistical results are expected, simulations have been performed on the basis of orbital parameters at present time.
Geometrical analyses have been first performed with a ground station located in Svalbard with a minimum elevation of 5 degrees for a 1,8m diameter dish (assuming a 3dB beamwidth of 6,8 degrees). This ground station is representative of the worst case configuration.
The following cases have been considered:

- Case 1: Metop as the victim and SARAL as the interferer,
- Case 2: NOAA-N as the victim and SARAL as the interferer.

One year simulations have been conducted with a simulation step of 10 seconds.
Table 2 gives statistics for a ground station located in Svalbard. The Svalbard ground station is in view of one of the satellite during approximately 11% of the time, whatever the satellite. In the period when the ground station has an active link to Metop or NOAA-N, SARAL is also in visibility during approximately 13,3 %.
Then two geometrical configurations are analysed with respect to the main lobe of the ground antenna:

- Configuration 1: the interferer (SARAL) remains out of the main lobe of the ground station antenna tracking the victim satellite (either Metop or NOAA-N). This configuration should not lead to damageable interference because the gain antenna gives sufficient isolation.
  Assuming a worst case with 1st lobe 17dB below the victim signal and 9dB of EIRP level difference (worst case combining RF output power and antenna pattern of Metop and SARAL), the signal level of SARAL is 26 dB lower than Metop signal.
- Configuration 2: the interferer SARAL is within the main lobe of the ground station antenna pointing towards the victim satellite. This configuration is the limiting worst case for potential interference risk.

To evaluate the occurrence of configuration 2, the cumulative distribution of the separation angle between SARAL and victim satellite has been estimated for a ground station located in Svalbard. Assuming an antenna 3dB beamwidth of 6,8 degrees (1,8m diameter) for a ground station in Svalbard, the probability for both SARAL and victim satellite to be in the main antenna lobe, (i.e. interferer and victim with an angular separation below 6,8 degrees) occurs during around 0,7 % of common visibility duration
For information and comparison, the case of a victim satellite with a sun synchronous orbit with LTAN at 05:30pm, i.e. close to SARAL LTAN, has also been analysed.

| Ground station: Svalbard | | SARAL (potential interferer) | Case 1 : Metop (victim) | Case 2: NOAA-N (victim) | SSO Satellite at 5:30pm (victim) |
|---|---|---|---|---|---|
| A | Visibility over the year | 10,57%<br>(55536 min) | 10,90%<br>(57312 min) | 11,23%<br>(59071 min) | 10,84%<br>(57004 min) |

| | | | | | |
|---|---|---|---|---|---|
| B | Fraction of visibility duration, with SARAL also in visibility (common visibility) | N/A | 13,33% | 13,35% | 13,27% |
| C | Fraction of common visibility (victim+SARAL) while SARAL is in the main lobe of the antenna | N/A | 0,75% | 0,70% | 0,00% |
| | = A*B*C, over the year | N/A | 57 min | 53 min | 0 min |

***Table 2 Statistics for a ground station located in Svalbard***

Similar analyses have been conducted for a ground station located in Toulouse, shown in Table 3 below.

| Ground station: Toulouse | | SARAL (potential interferer) | Case 1 : Metop (victim) | Case 2: NOAA-N (victim) | SSO Satellite at 5:30pm (victim) |
|---|---|---|---|---|---|
| A | Visibility over the year | 3,60% (18903 min) | 3,78% (19888 min) | 3,87% (20842 min) | 3,72% (19576 min) |
| B | Fraction of visibility duration, with SARAL also in visibility (worst case) | N/A | 3,55% | 1,83% | 10,42% |
| C | Fraction of common visibility (satellite+SARAL) while SARAL is in the main lobe of the antenna (worst case) | N/A | 0% | 0% | 1,58% |
| | = A*B*C, over the year | N/A | 0 min | 0 min | 32 min |

***Table 3 Statistics for a ground station located in Toulouse***

For frequency bands B1 and B2 respectively, results are similar to Metop and NOAA-N respectively in terms of occurrence of potential risk of interferences. This risk is rare and only concerns ground stations located at high latitude. For Svalbard and for both Metop and NOAA-N, the risk is less than 57 minutes for more than 57000 minutes of visibility every year. For Toulouse, the risk to have both interferer and victim satellites in the main antenna lobe is null due to the difference of LTAN.

The SARAL bandwidth B1, overlapping NOAA-N bandwidths, minimizes the interference risk with other systems and shall be chosen for the nominal RTTM frequency. The SARAL bandwidth B2 overlapping Metop downlink frequency shall be chosen for the back up frequency.

## 6. <u>Conclusion</u>

Candidate frequency bands have been identified for SARAL in order to minimize the risk of interference with other systems:

1. B1 = 1698-1698,680 MHz,

2. B2 = 1702,72-1703,4 MHz.

B1 shall be the nominal frequency band whereas B2 shall be the backup frequency band. Emitters embedded on SARAL could be configured either at frequency band B1 or B2.

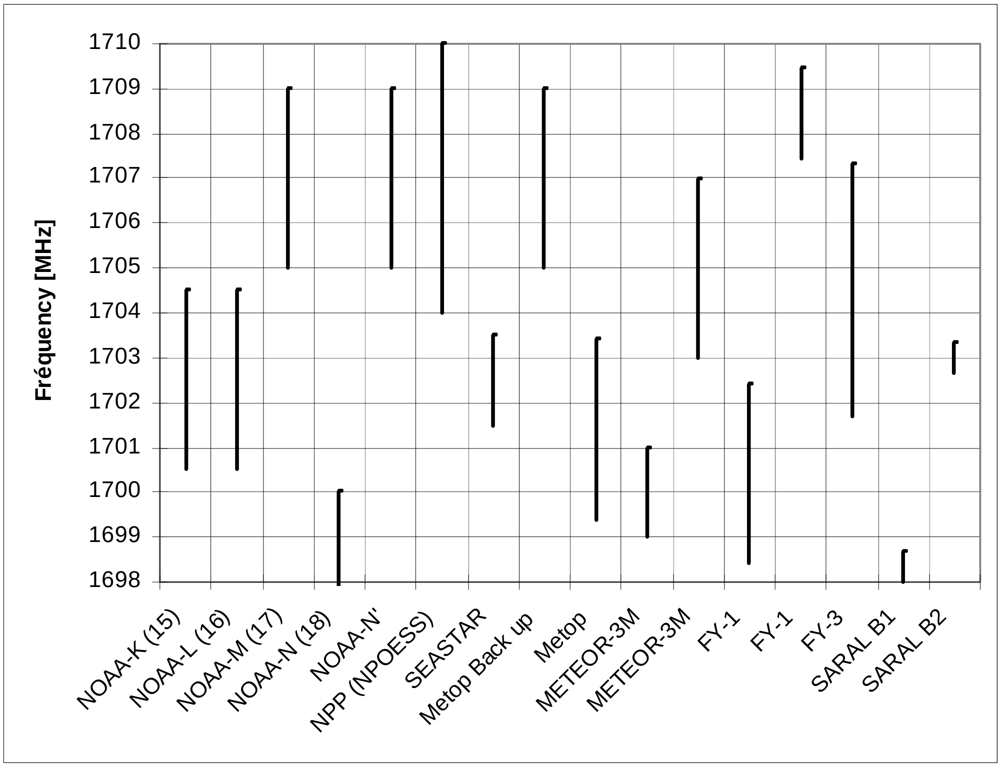


***Figure 4 Frequency occupation with SARAL bandwidths***

CNES plans to engage the frequency declaration of B1 and B2 frequency bands by the end of the year, based on figures presented above. Analyses have been conducted mainly for Metop and POES satellites because of available parameters on the satellites and associated RF link. Analyses with other systems should be done if necessary, but should lead to similar results since the orbital parameters are comparable.

## ACTION REQUIRED

The SFCG members are then invited to consider the frequency declaration of the new L band frequency for SARAL real time downlink and propose some recommendations for the future co-ordinations.

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# 7. Appendix

## 7.1. Ground stations network expected for SARAL