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MARSIS On-board Software Requirements for Upgrade

Issue 1, Rev 0

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ACRONYM & ABBREVIATION LIST

ADC	Analogue to Digital Converter
AGC	Automatic Gain Control
CM	Contrast Method
DV	Data Volume
ESOC	European Space Operations Centre
FFT	Fast Fourier Transform
OBDH	Mars Express “On-Board Data Handling”
HK	Housekeeping (Telemetry)
ID	Identifier
IFFT	Inverse Fast Fourier Transform
MARSIS	Mars Advanced Radar for Subsurface and Ionosphere Sounding
MEX	Mars Express
OST	Operational Sequence Table
PFS	Planetary Fourier Spectrometer
POR	Payload Operational Request
PT	Parameter Table
PRI	Pulse Repetition Interval
SW	Software
SNR	Signal To Noise Ratio
SPICAM	Spectroscopy for the Investigation of the Characteristics of the Atmosphere of Mars
SC	Spacecraft
SS3	Sub Surface 3
SSM	Sub Surface Mars (New Operative Mode)
SSP	Sub Surface Phobos (New Operative Mode)
TBC	To Be Confirmed
TBD	To Be Defined

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DOCUMENT CHANGE LOG

Issue	Rev.	Date	Changes Description
1	**0**	10/01/2023	First Issue

.

The following documents shall be used as reference background and support information. These documents are herein referred as [RD-XX].

Id	***Document Number***	***Description***
[RD-01]	TNO-MAR-0037-ALS	MARSIS ON BOARD PROCESSING ALGORITHMS
[RD-02]	ANNEX 5_MARSIS_PT_SW_#B2CF8	MARSIS DES PARAMETERS' TABLE
[RD-03]	ID-MAR-0008-INF	MARSIS FLIGHT USER MANUAL

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1 SCOPE AND APPLICABILITY

The Mars Advanced Radar for Subsurface and Ionosphere Sounding (MARSIS) is a powerful instrument for subsurface remote sensing of the Mars planet. Since its debut, about fifteen year ago, many successful observations have been carried out, in particular for the study of Mars south and north polar layered deposits.

At this point of this fruitful mission, having acquired a good knowledge of the Mars environment, it is now necessary and desirable to improve the instrument science performances, mitigating some limitations of the on-board SW, that were required at the beginning of the mission, but which were proven to be excessive and above all limiting.

The main purpose of this document is to define the requirements necessary to update the on-board SW, in order to add two new improved operative modes to the ones already in use. Additional requirements may be found in annexes (mainly details on the algorithms) and in the applicable and reference documents.

It is worth noting that, the existing operative modes will remain unchanged and can continue to be used after loading the updated SW.

The first new operative mode (**SSM**) is related to the observation of Mars. It will be similar to the existing main dual channel sub surface mode (**SS3**). The processing for the first operative channel will remain unchanged, while calculations on the second channel will be modified to extract the most significant data from the full raw data set, discarding what is meaningless or providing poor scientific contribution.

The new second operative mode (**SSP**), will be designed above all to optimize the observation of Phobos which was not originally thought as a target for MARSIS, this means that a very complex on-board SW configuration is required, in order to force the radar to work properly even in this situation. Moreover, actual Phobos observation makes use of valuable SC resources for storing high quantity of useless data, that cannot be eliminated without modifications of MARSIS SW.
The new operative mode will take care of removing these unnecessary data. It will also optimize adaptively the Receiver Gain during the flyby, thereby improving the dynamic range of the receiver of the recorded Science Data. At the same time data-rate on the SC OBDH bus will be strongly reduced, allowing the possibility for MARSIS, PFS and SPICAM to operate simultaneously

.

2 MARS NEW OPERATIVE MODE (SSM)

The operating diagram of the new dual channel operative mode is shown in Fig.2.1. Operations executed on the first radar channel (RX Channel 1) will be equal to the ones performed in existing operative mode SS3. Processing on the second channel will be fully updated with new SW requirements described in this technical note.

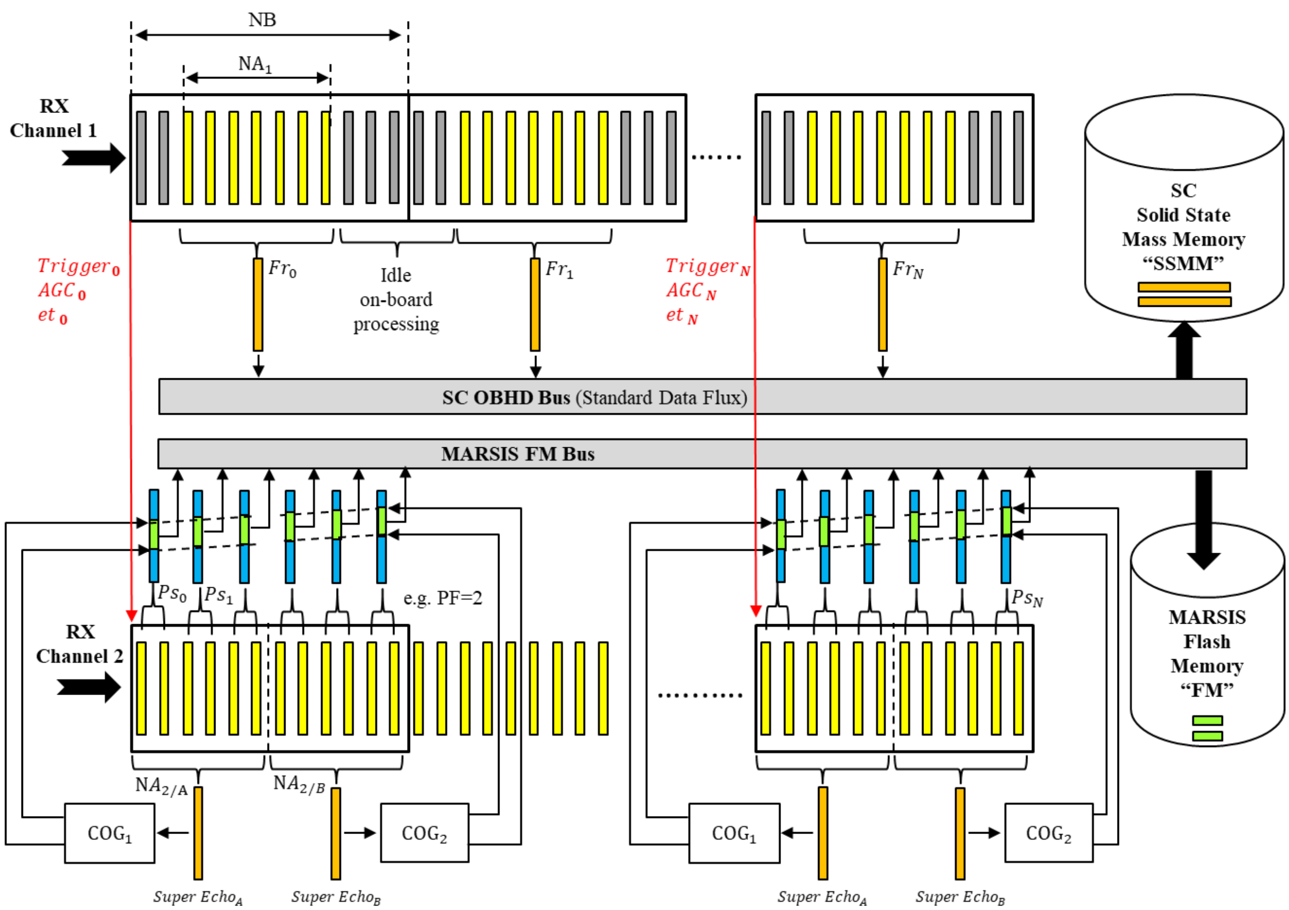

Fig. 2.1 SSM Operative Mode, High level diagram

For the first channel the observation timeline is made of a sequence of frames, where a frame is a group of NB consecutive PRIs, being NB value computed adaptively during the flyby. Within a frame a subset of NA_1 PRIs is used to synthesize a synthetic aperture. As for NB, also NA_1 value is adaptively computed on-board so that a certain amount of PRI’s is always available to calculate the key flight parameters (RX Trigger and Automatic Gain Control ‘AGC’) and to complete the processing of synthetic aperture data. These NB- NA_1 “mute” (no TX/RX activity) PRIs are represented with the grey colour in the top panel of Fig. 2.1. More details can be found in RD-01.

.
The timeline of the second channel is designed to avoid any interruption in the echo collection mechanism, allowing a more uniform observation of Mars. In order to achieve this important science requirement, it was not possible to rely on the “mute” PRIs for the computation of the flight parameters (Trigger, AGC and on-board processing in general). To solve this critical aspect, it has been decided to set the same radar band on both channels, allowing the use of the flight parameters calculated in the first channel also for the second channel. The MARSIS SCET time (et), provided by the SC, necessary to identify the recorded echoes, is reported in the telemetries of both channels every NB PRIs. Synchronization of the two channels RX Trigger values is achieved through the following equation:

$$RX\_TRIG\_CH2\_US = RX\_TRIG\_CH1\_US + TRIG\_OFFSET\_CH2\_US + 450\ [\mu s] \qquad (1)$$

Where:

$TRIG\_OFFSET\_CH2\_US$: Offset extracted from PT, it can assume both positive and negative values in [us]

The recorded echoes (yellow bars of Fig. 2.1) collected by the radar, are flowing constantly on the second channel and before to store them into the limited space of MARSIS internal Flash Memory (FM), it is necessary to perform a significant data volume reduction, that shall be achieved with the following two techniques:

1) Echoes Pre-Summing Technique (blue bars in Fig. 2.1)
2) Receiving Window Resize Technique (green bars of Fig. 2.1)

Appling simultaneously these two techniques will make possible to store into the FM, an entire fly-by of about 30 minutes of data, while the actual design of the on-bard SW permits to store into the FM not more than about 25s of raw unprocessed data.
The first reduction technique (Echoes Pre-Summing) does not present any relevant on-board implementation effort, however the irreversibility of the process, could have a not negligible impact on the scientific content of the data; for this reason it was decided to limit the Presumming Factor (**PF**) to a maximum of seven echoes.
The second reduction technique, Receiving Window Resize, even if more demanding to implement on-board, thanks to its reversibility presents a minor impact on the science data content. For this purpose, a special function, based on the estimation of the Centre of Gravity (COG) of the radar signal, shall be implemented to identify the main contribution of each Range Compressed and Pre-Summed Echoes by the noise, within the Receiving Window and store them into the FM.

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2.1 *FRAME STRUCTURE DEFINITION*

The frame structure for both channels, is computed adaptively during the flyby, according to the following algorithm:

- The space to be covered by the spacecraft during NB pulses is computed first as:

$$\Delta S = \sqrt{\frac{\lambda \cdot H}{2}} + N_0 \cdot \frac{V_{Tan}}{PRF} \tag{2}$$

- Check the computed ΔS:

If $\Delta S < \Delta S_{min}$ ➔ $\Delta S = \Delta S_{min}$ $(\Delta S_{min} = 5.5Km)$

- Evaluate the Frame size NB:

$$NB_{ini} = Int\left[\frac{\Delta S}{V_{Tan}} \cdot PRF\right] \tag{3}$$

- Check the computed NB_{ini}

If $NB_{ini} < NB_{min}$ ➔ $NB_{ini} = NB_{min}$ $(NB_{min} = 160)$

In order to have $\boldsymbol{NB_{ini}}$ multiple of the Presumming Factor **PF**, the following correction shall be applied:

$$NB = \left\lceil \frac{NB_{ini}}{PF} \right\rceil \cdot PF \tag{4}$$

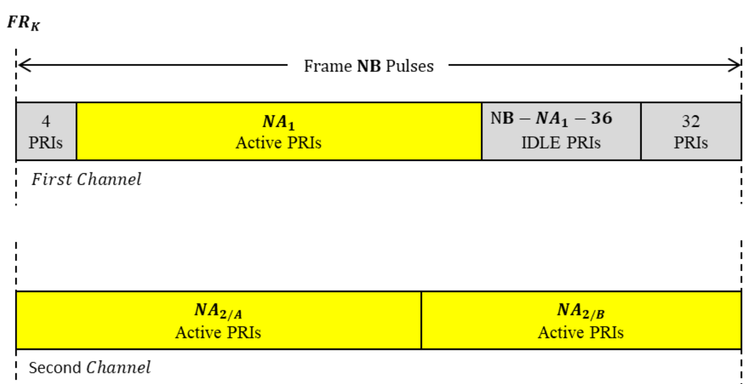

Fig. 2.1.1Frame Structure

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NA₁ PRIs of the first channel shall be used to synthesize a synthetic aperture by coherently processing the radar returns on board. As for NB, NA_1 shall be adaptively computed during the flyby using the following equation:

$$NA_1 = Int\left[\lambda \cdot \frac{H \cdot PRF}{2 \cdot \gamma \cdot V_{Tan} \cdot \Delta S}\right] \quad (5)$$

- Check the computed NA_1:

If $NA_1 > NB - N_0$ ➔ $NA_1 = NB - N_0$

Where

- **PRF** is the Pulse Repetition Frequency equal to 130 Hz.
- $\boldsymbol{N_0}$ is an offset equal to 36 PRIs
- $\boldsymbol{\gamma}$ is corrective frequency dependent parameter set to (1)
- $\boldsymbol{\lambda}$ is the wavelength of the Operative Frequency in use.
- **H** is the SC Altitude
- $\boldsymbol{V_{Tan}}$ is the SC Tangential Velocity

$\mathbf{NA_{2/A}}$ and $\mathbf{NA_{2/B}}$ PRI of the second channel, shall be used to synthesize the two Super-Echoes, inputs to the COG function for the discrimination of the signal by the noise.

$$NA_{2/A} = Int\left[\frac{NB}{2 \cdot PF}\right] \cdot PF \quad (6)$$

$$NA_{2/B} = NB - NA_{2/A} \quad (7)$$

The following Table shows the main frame parameters within a generic flyby:

BND	N Frames	T [min]	Fr dt [sec]	H [Km]	Vt [Km/s]	DS [Km]	NB PRI	NA PRI	IDLE PRI	FRs separation in PRI
B1	917	-14.51	2.70	950.0	3.65	9.93	345	277	32	68
		0.01	1.54	348.2	4.24	6.58	197	132	29	65
B2	1130	-14.51	2.15	950.0	3.65	7.92	275	208	31	67
		0.01	1.29	348.2	4.24	5.5	165	94	35	71
B3	1214	-14.51	1.90	950.0	3.65	7.0	243	177	30	66
		0.01	1.29	348.2	4.24	5.5	165	71	58	94
B4	1257	-14.51	1.73	950.0	3.65	6.37	221	155	30	66
		0.01	1.29	348.2	4.24	5.5	165	56	73	109

Table 2.1.1 Nominal Frame Structure

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2.2 DEMODULATOR (I/Q SYNTHESIS)

The I/Q synthesis shall be applied also for each recorded echo of the second channel, more details can be found in ANNEX 2.

The generic demodulated echo will be represented, in the time and frequency domains, by the following equations:

$$V_t = I(t) + jQ(t) \quad (8)$$

$$V_f = fftshift(fft(V_t)) \quad (9)$$

The high level scheme of Fig.2.1 including also the Demodulation Process is shown if Fig. 2.2.1

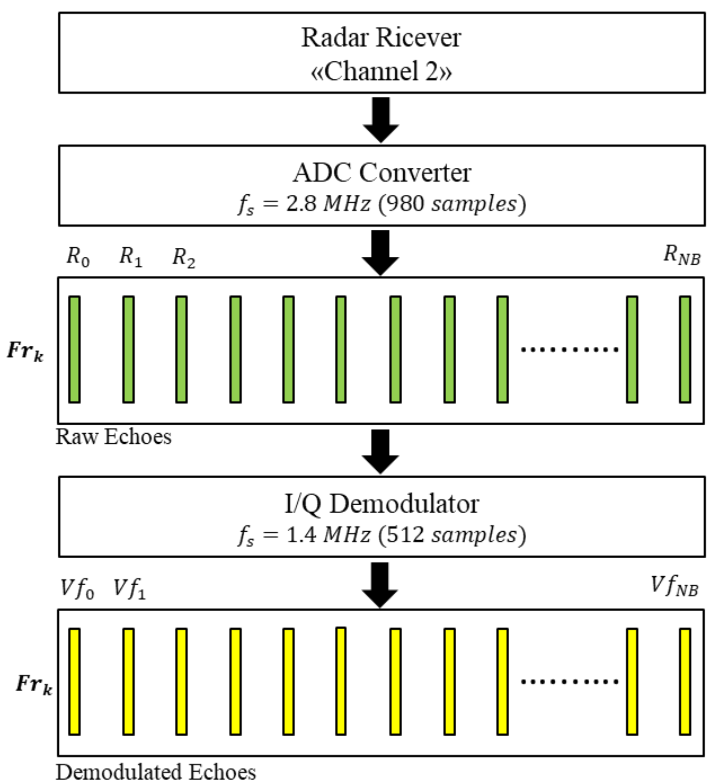

Fig. 2.2.1 Demodulation Process

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2.3 ECHOES PRESUMMING TECHNIQUE

The echo pre-summing technique shall be applied with the following purposes:

1) Science data volume reduction
2) Super-Echo generation process, input to the Centre of Gravity (COG) function

Before summing the echoes, phase compensation w.r.t. the centre frequency shall be carried out to compensate phase displacement, due to satellite radial velocity, accordingly to the scheme of Fig. 2.3.1

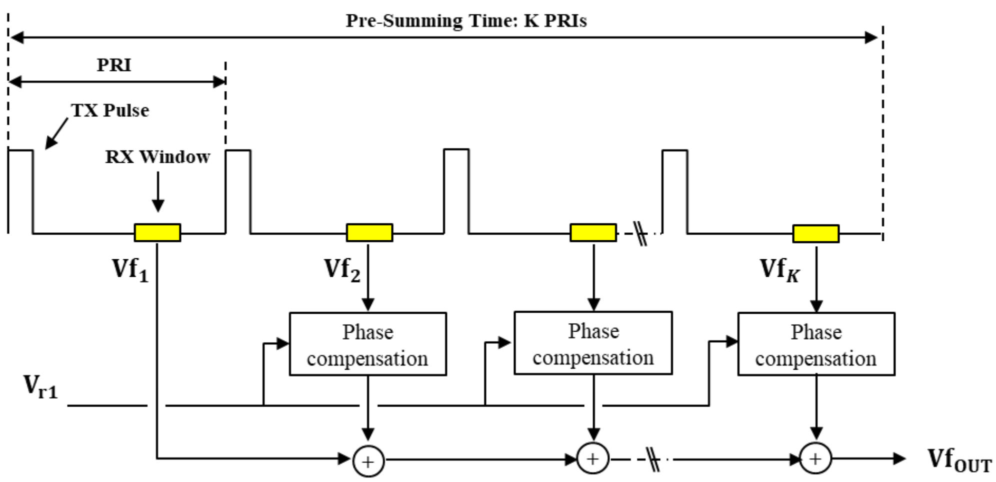

Fig. 2.3.1 Pre-Summing Architecture

Actual phase compensation is a phase increment, computed in accordance with the estimated radial velocity (without considering orbital parameters knowledge inaccuracy). The following equations shall be implemented:

$$Vf_{OUT} = \sum_{N=1}^{K} Vf_N \cdot e^{j\cdot 2\cdot \pi \cdot \varphi \cdot (N-1)} \qquad (10)$$

Being:

K = PF ➔ For the Science Data Volume Reduction task
K = $NA_{2/A}$ ➔ For the **Super-Echo$_1$** generation (input of the **COG$_1$** function)
K = $NA_{2/B}$ ➔ For the **Super-Echo$_2$** generation (input of the **COG$_2$** function)

.
Note that both for Science Data Volume reduction and Super-Echo generation, the radial velocity is constant within the group of PRI to be summed and equal to the radial velocity of the first PRI of the group.

The phase term is given by the following equation:

$$\varphi = \frac{1}{\lambda_{min}} \cdot \left[\frac{2 \cdot V_r}{PRF}\right] \cdot \left[\frac{K \cdot f_s}{N_s \cdot f_{min}} + 1\right] \quad (11)$$

Where:

N is the summation index.
$\boldsymbol{Vf_N}$ is the generic echo after demodulation in the frequency domain.
$\boldsymbol{f_{min}}$ $= -OP\_F - \frac{f_S}{2}$ for the Operative Band B1
$\boldsymbol{f_{min}}$ $= OP\_F - \frac{f_S}{2}$ for the Operative Bands: B2, B3 and B4
OP_F is the operative frequency, to be selected among the Bands: B1, B2, B3 and B4
$\boldsymbol{f_s}$ is the equivalent sampling rate of the I/Q data stream (1.4 MHz)
$\boldsymbol{\lambda_{min}}$ is the correspondent wavelength ($\boldsymbol{\lambda_{min} = \frac{c}{f_{min}}}$)
V_r is the radial velocity of the first echo of the group
$\boldsymbol{PRF}$ is the pulse repetition frequency
K is the FFT bin index ranging from 0 to 511
$\boldsymbol{N_s}$ is the number of complex samples available at the FFT output (512 samples)

Considering the high level scheme of Fig.2.1, the two Pre-Summing tasks to be performed in the frame of the second channel, are shown in the following Fig. 2.3.2

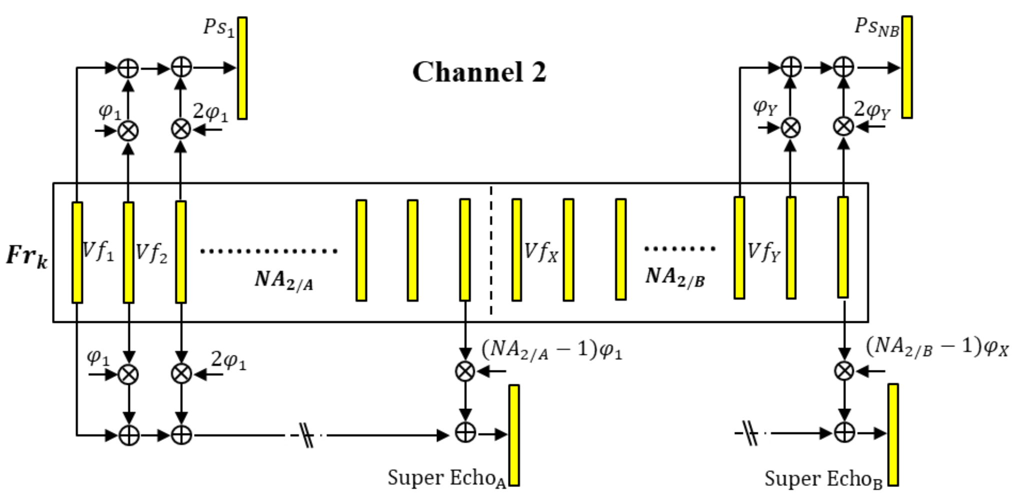

Fig. 2.3.2 Pre-Summing Structure

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2.4 ON-BOARD RANGE COMPRESSION

The range compression will allow a range resolution equivalent to 150 m in vacuum. The Reference Function to be used for the execution of the Range Compression is stored into the Parameter Table (PT), see ANNEX 4 for more details.

The range compression is completed by multiplying sample by sample the resulting Presumming filter by the Reference Function and executing the IFFT, as shown by the following equations:

$$Vf_{RC} = Vf_{OUT} \cdot Ref\_Fun\_f \quad (12)$$

$$Vt_{RC} = IFFT(Vf_{RC}) \quad (13)$$

Where:

$$Ref\_Fun\_f = Ref\_Fun\_Real\_Comp\_f + J \cdot Ref\_Fun\_Img\_Comp\_f \quad (14)$$

The Reference Function Real and Imaginary coefficients are extracted from PT and also reported in ANNEX 4; in paragraph 5.4.1 there are the coefficients for the Reference Function of bands: B2, B3 and B4, while in paragraph 5.4.2, there are the coefficients for the Reference Function of band B1. The number of bits to encode the echo's samples (**ECHO_SAMP_BIT)** will depend on the selected Pre-Summing Factor (PF) and it will be extracted from PT. More details about the signal dynamic as a function of the PF can be found in ANNEX 1. Considering the high level scheme of Fig.2.1, the Echoes Range Compression process is shown in the following Fig. 2.4.1

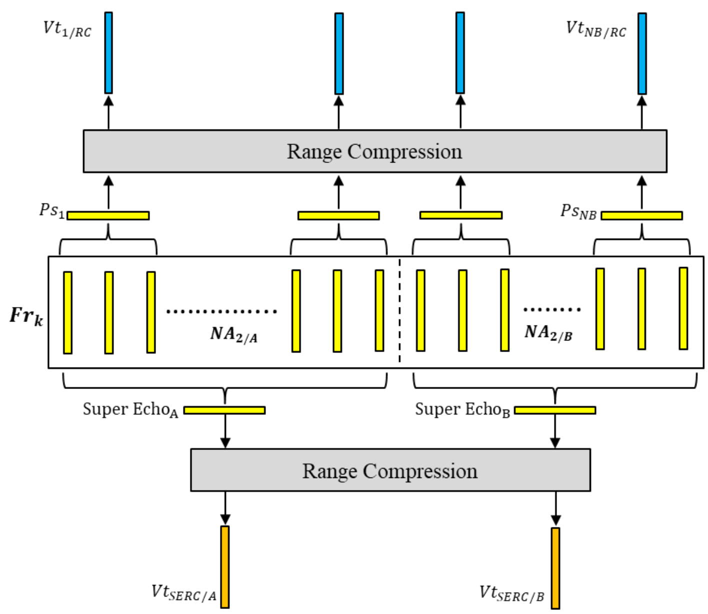

Fig. 2.4.1 Range Compression Structure

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2.5 *RECEIVING WINDOW RESIZE TECHNIQUES*

In order to reduce the Data Volume for the Real and Imaginary components of the Range Compressed echoes to be stored into the FM, it is necessary to reduce the number of the samples representing the signals within the receiving window, from the standard 512 samples to a smaller one.

The following two techniques shall be implemented and it shall be possible to select either one or the other using a specific new flag (**WIN_CUT_TYPE**) inside the Operation Sequence Table (OST).

<u>CENTRE OF GRAVITY (COG)</u>

The first method is based on an algorithm that estimates the Centre of Gravity (COG) of the signal, after the range compression, in the time domain. In detail, as anticipated in section 2.3 (see fig 2.3.2), the algorithm will use the so called Super Echoes to estimate the samples interval to cut out from the full 512 samples receiving window, without altering the relevant radar signal information.
It is worth noting that the signal position within the receiving window is unknown. As shown in fig. 2.1, the trigger of the Tracking Phase performed in the Channel 1 is also used for Channel 2, but this is not sufficient to know with accuracy the signal position. Actually, the final effect of the Tracking is to maintain the signal in a well-defined position in the receiving window, allowing to limit the samples interval to be analysed. It is clear that the task to resize the receiving window, requires a high level of accuracy in the identification of the samples where the signal is located. In order to correctly identify the signal position within the receiving window, it has been developed a dedicated algorithm, described by the high level processing flow diagram of fig. 2.5.1. See ANNEX 3 for more details and some test results.

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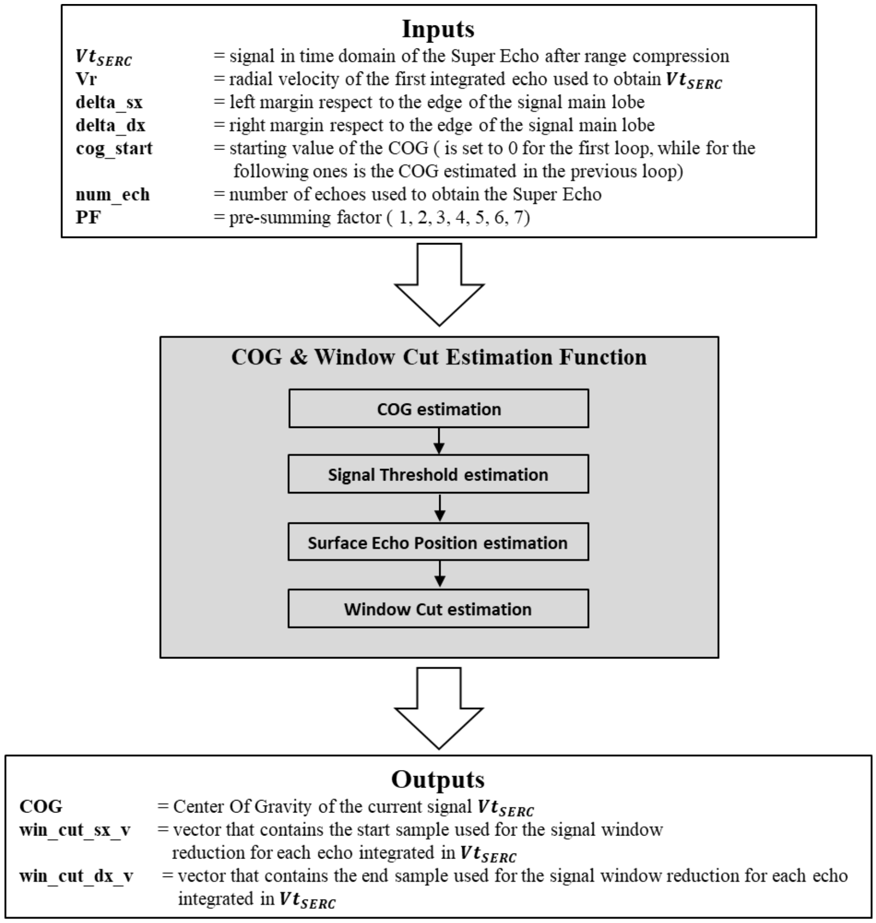

Fig. 2.5.1 COG & Window Cut Algorithm

This algorithm shall be applied separately on both outputs $Vt_{SERC/A}$ and $Vt_{SERC/B}$, as shown in fig. 2.4.1. The first step is represented by the evaluation of the COG, accordingly to the following equation:

$$COG_K = \sum_{i=COG\_START\_IND}^{COG\_END\_IND} i \cdot P_D(i) \Big/ \sum_{i=COG\_START\_IND}^{COG\_END\_IND} P_D(i) \qquad (15)$$

Where:

$\boldsymbol{COG\_START\_IND}$	is the first sample for the computation of the COG, it is extracted from PT.
$\boldsymbol{COG\_END\_IND}$	is the last sample for the computation of the COG, it is extracted from PT.
$\boldsymbol{P_D(i)}$	are the power detected samples.

.
In particular, $P_D(i)$ are the power detected samples (real and imaginary part combined to give the square modulus), as shown by the following equation:

$$P_D(i) = (real(Vt_{SERC}(i)))^2 + (imag(Vt_{SERC}(i)))^2 \quad (16)$$

While Vt_{SERC} represents the signal of the Super Echo after range compression in time domain.

The accuracy of the COG estimation depends on the signal shape. Considering an ideal signal, the COG coincides with the position of main lobe pick.
On the contrary, for a real signal the COG can assume different positions according to the backscattering characteristics of the area observed by the radar.
For echoes reflected by flat surfaces the COG will be very accurate and very close to the signal main lobe, while in presence of rough surface or subsurface layers the COG position will vary according to the magnitude of these phenomena.

The first step of the algorithm consists in the estimation of the COG, that will be used to define the interval where the most meaningful part of the radar signal is supposed to be present.
The second step consists in the evaluation of the mean value of the signal contained in the interval, that shall be considered as a threshold to identify the beginning of the signal itself.
In the third step, the first sample of the interval that is greater than the threshold, can be considered as the edge of the surface echo response. It is now possible to define both the starting and the ending samples of the signal window to cut.
The last step of the algorithm is the window optimization, calculated using the Super Echo and to be used for all the original echoes belonging to the Super Echo itself.

In detail, considering that the Super Echo is evaluated integrating the echoes after a phase compensation, the window cut samples are estimated with reference to the position of the first echo. In order to correctly apply the window cut to the original echoes it is necessary to remove the phase correction.
After this step, each original echo, included in the Super Echo, will have its own window cut. Finally, the receiving window of the real and imaginary components, of the generic range compressed Vt_{RC} (k), will be cut according to the following equation:

$$Vt_{RC\_CUT} = Vt_{RC}(FIRST\_ECHO\_SAMP: LAST\_ECHO\_SAMP) \quad (17)$$

Where:

FIRST_ECHO_SAMP = win_cut_sx_v(k), k=1,…n
LAST_ECHO_SAMP = win_cut_dx_v(k), k=1,…n

.
The value of "n" will be $NA_{2/A}$ or $NA_{2/B}$ (see fig. 2.4.1) according to the related Super Echo. The FIRST_ECHO_SAMP value, shall be also reported in the echo's header, to correctly re-position the signal within the receiving window, once the data will be processed on-ground.

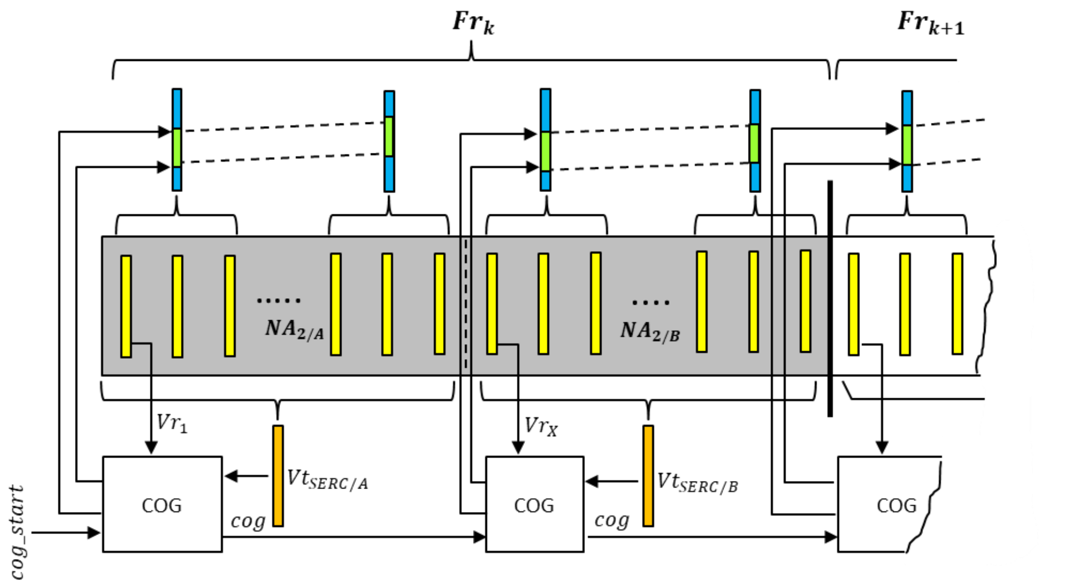

Fig. 2.5.2 Window Cut Algorithm Overall diagram

<u>WIN FIXED RANGE (WFR)</u>

This method consists of selecting a specific segment of the Range Compressed signal, accordingly to the indexes specified by the following parameters, extracted from PT:

$$FIRST\_ECHO\_SAMP = WFR\_START\_IND \quad (18)$$

$$LAST\_ECHO\_SAMP = WFR\_STOP\_IND \quad (19)$$

$$Vt_{RC\_CUT} = Vt_{RC}(FIRST\_ECHO\_SAMP: LAST\_ECHO\_SAMP) \quad . \quad (20)$$

Where:

$\boldsymbol{WFR\_START\_IND}$ is the first echo sample, extracted from PT
$\boldsymbol{WFR\_STOP\_IND}$ is the first echo sample, extracted from PT

Super Echoes generation and COG & Window Cut estimation are not necessary in this case, as shown in Figure 2.5.3

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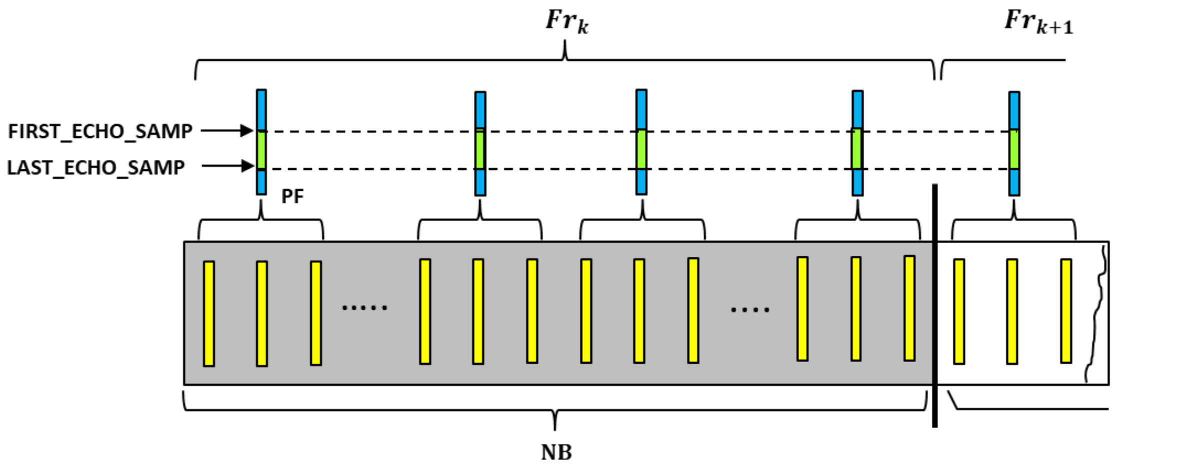

Fig. 2.5.3 Window Cut using WIN FIXED RANGE

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2.6 OST AND P.T. PARAMETERS

OST PARAMETERS FOR SSM (Mode Selection bits = 1110b)

Field	Size (bit)	Format	Bit Position	Bit Configuration	Description
Mode Duration PRI	24	Enum	8 : 31	Same configuration of existing Operative Modes	OPM duration in number of PRI
Mode Selection/DCG Configuration	4+4	Enum	34 : 41	SSM - Band 1 (Param. Value = 224) SSM - Band 2 (Param. Value = 228) SSM - Band 3 (Param. Value = 232) SSM - Band 4 (Param. Value = 236)	Operative mode Identifier and Band Selection
LOL	1	Enum	51 : 51	0 ➔ if Loss of Lock Logic, remain in Tracking. 1 ➔ if Loss of Lock Logic re-start tracking with range polynomial coefficients	Loss of Lock Logic configuration, of channel 1
WIN_CUT_TYPE	1	Enum	55:55	0 ➔ COG Method 1 ➔ WFR Method	Receiving Window reduction method
PF	3	Enum	57 : 59	0 ➔ No Presumming 1 ➔ No Presumming 2 ➔ Presumming Factor = 2 3 ➔ Presumming Factor = 3 4 ➔ Presumming Factor = 4 5 ➔ Presumming Factor = 5 6 ➔ Presumming Factor = 6 7 ➔ Presumming Factor = 7	Presumming Factor
TX_POWER	4	Enum	60 : 63	TX Power Level	Same configuration of existing OPM

Table 2.6.1 OST Fields Configuration

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OST PARAMETERS DETAILS

<table>
<tr><th colspan="2">OST fields</th><th>Consiguration</th><th>POR Format</th><th>Note</th></tr>
<tr><td>0
7</td><td>PAD</td><td>NA</td><td>NA</td><td>Field is not in the POR</td></tr>
<tr><td>8
:
31</td><td>Mode Duration in PRI</td><td>Raw Tupe : UNIT
Eng Tupe: NA</td><td>H 774</td><td>Number of PRI</td></tr>
<tr><td>32
33</td><td>PAD</td><td>NA</td><td>NA</td><td>Field is not in the POR</td></tr>
<tr><td>34
:
37</td><td>Mode Selection</td><td rowspan="2">Raw Tupe : UNIT
Eng Tupe: TEXT</td><td rowspan="2">OPM Codes:
SSM - Band 1
SSM - Band 2
SSM - Band 3
SSM - Band 4</td><td rowspan="2">Operative Mode ID a band configuration. The implementation of this field requires an update of the ESOC DB</td></tr>
<tr><td>38
:
41</td><td>DCG Configuration</td></tr>
<tr><td>42
43
44</td><td>Spare</td><td rowspan="2">Raw Tupe : UNIT
Eng Tupe: TEXT</td><td rowspan="2">PIS1B0PIS2B0</td><td rowspan="2">Field not read by SSM mode. It shall be filled anyway to avoid POR format error</td></tr>
<tr><td>45
46
47</td><td>Spare</td></tr>
<tr><td>48
49
50</td><td>Spare</td><td rowspan="6">Raw Tupe : UNIT
Eng Tupe: NA</td><td rowspan="6">0</td><td rowspan="6">SSM reads just the following fields:
-LOL (for channel 1)
-WIN_CUT_TYPE (for channel 2)
-PF (for channel 2)</td></tr>
<tr><td>51</td><td>LOL = Xb</td></tr>
<tr><td>52
53
54</td><td>Spare</td></tr>
<tr><td>55</td><td>WIN_CUT_TYPE</td></tr>
<tr><td>56</td><td>Spare</td></tr>
<tr><td>57
58
59</td><td>PF</td></tr>
<tr><td>60
:
63</td><td>TX Power</td><td>Raw Tupe : UNIT
Eng Tupe: NA</td><td>TX PWR NULL</td><td>TX Power configuration for both Channels</td></tr>
<tr><td>64
:
75</td><td>Spare</td><td>Raw Tupe : UNIT
Eng Tupe: NA</td><td>0</td><td>Field not read by SSM mode. It shall be filled anyway to avoid POR format error</td></tr>
<tr><td>76
:
79</td><td>Spare</td><td>Raw Tupe : UNIT
Eng Tupe: TEXT</td><td>NoFMStore</td><td>Field not read by SSM mode. It shall be filled anyway to avoid POR format error</td></tr>
<tr><td>80
:
95</td><td>Spare</td><td>Raw Tupe : UNIT
Eng Tupe: NA</td><td>0</td><td>Field not read by SSM mode. It shall be filled anyway to avoid POR format error</td></tr>
</table>

Table 2.6.2 OST Fields Details

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PT PARAMETERS

PT Line Number	Parameter	Default Value	Range	Size [bit]	Description
202	ECHO_SAMP_N_BIT_PF_1	8	8 : 15	32bit int	Number of bit to encode the echo's samples after the on-board RC.
203	ECHO_SAMP_N_BIT_PF_2	9	8 : 15	32bit int	Number of bit to encode the echo's samples after the on-board RC.
204	ECHO_SAMP_N_BIT_PF_3	9	8 : 15	32bit int	Number of bit to encode the echo's samples after the on-board RC.
205	ECHO_SAMP_N_BIT_PF_4	10	8 : 15	32bit int	Number of bit to encode the echo's samples after the on-board RC.
206	ECHO_SAMP_N_BIT_PF_5	10	8 : 15	32bit int	Number of bit to encode the echo's samples after the on-board RC.
207	ECHO_SAMP_N_BIT_PF_6	11	8 : 15	32bit int	Number of bit to encode the echo's samples after the on-board RC.
208	ECHO_SAMP_N_BIT_PF_7	11	8 : 15	32bit int	Number of bit to encode the echo's samples after the on-board RC.
209	WFR_START_IND	1	1 : 512	32bit int	First Receiving Window sample in the WFR method
210	WFR_STOP_IND	117	1 : 512	32bit int	Last Receiving Window sample in the WFR method
211	N_SAMP_COG_SX	30	1 : 127	32bit int	N samp Prior COG Index
212	N_SAMP_COG_DX	40	1 : 127	32bit int	N samp Post COG Index
213	COG_START_IND	1	1 : 512	32bit int	First Receiving Window sample for the COG method
214	COG_STOP_IND	117	1 : 512	32bit int	Last Receiving Window sample for the COG method
215	TRIG_OFFSET_CH2	0	[us]	32bit float	Offset to be added to the Second Channel Trigger

Table 2.6.3 Parameter Table New Coefficients

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2.7 SSM DATA MANAGEMENT

The following storage format, shall be considered for the Operative Mode **SSM**: Real and Imaginary components of each processed signal, also equipped with an header, shall be stored into FM as a single stream of bytes, as illustrated in Fig. 2.7.1

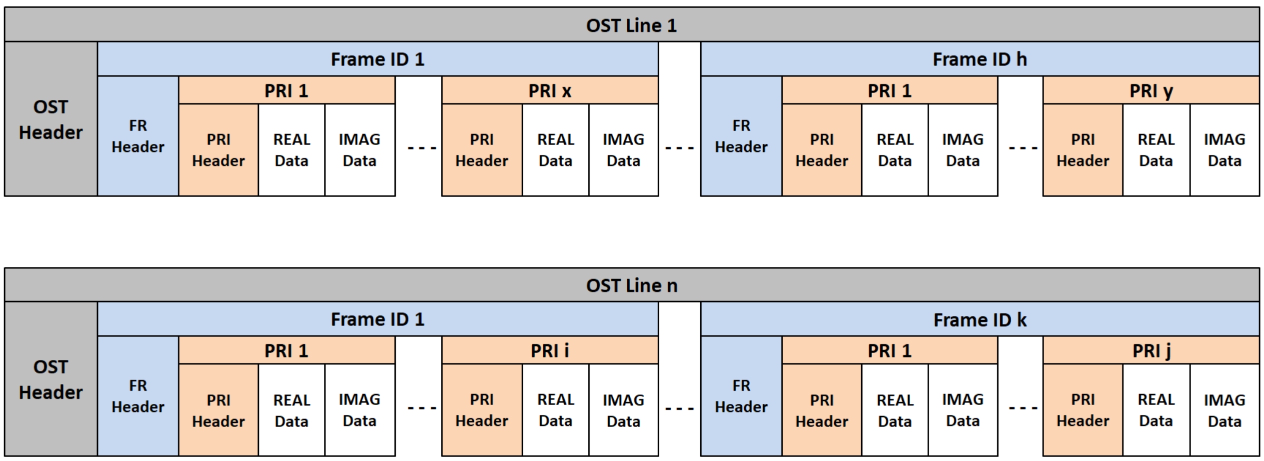

Fig. 2.7.1 SSM FM data format

OST HEADER FORMAT

Field	Size (bit)	Format	Description
OST ID	4	Uint	OST ID number
FRAME_NUMBER	12	Uint	Number of frames in the OST line
Full OST Line	96	bitstream	Full OST line bitstream
SCET 1st PRI of 1st Frame	48	SCET	SCET sampled at the beginning of the Frame (1st PRI of Frame)
On-board computed PRF	32	Float	PRF measured on-board
TRIG_OFFSET_CH2	32	Float	Offset added to the Second Channel Trigger
ECHO_SAMP_N_BIT_PF	4	Uint	Number of bits to encode the echo's samples (it depends on the commanded Presumming Factor)
WFR_START_IND	10	Uint	First Receiving Window sample in the WFR method
WFR_SIZE	8	Uint	Receiving Window size in samples for the WFR method
COG_START_IND	10	Uint	Position of first sample for COG computation
COG_SIZE	8	Uint	Sub-window size in samples for COG computation
N_SAMP_COG_SX	8	Uint	N samp Prior COG Index
N_SAMP_COG_DX	8	Uint	N samp Post COG Index
1st frame MUTE PRI	8	Uint	Number of "mute" PRI at the beginning of 1st frame
Total HEADER size = 288 bits (36 bytes)			

Table 2.7.1 SSM OST Header

.

FRAME HEADER FORMAT

Field	Size (bit)	Format	Description
FRAME_ID	13	Uint	Frame ID number
AGC	3	Enum	AGC attenuation, from 2 to 30dB at 4dB steps
RX TRIGGER	16	Uint	RX trigger expressed as number of 2.8MHz intervals
FRAME_ID_1st half	14	Uint	Frame ID number for **NA_2a sub-frame**
FIRST_SAMP_REC_WIN 1st half	10	Uint	Position of the echo's first sample in the Rec Win for **NA_2a sub-frame**
NUM ECHOES 1st half	8	Uint	Number of echoes in **NA_2a sub-frame**
FRAME_ID_2nd half	14	Uint	Frame ID number for **NA_2b sub-frame**
FIRST_SAMP_REC_WIN 2nd half	10	Uint	Position of the echo's first sample in the Rec Win for **NA_2b sub-frame**
NUM ECHOES 2nd half	8	Uint	Number of echoes in **NA_2b sub-frame**
Total HEADER size = 96 bits (12 bytes)			

Table 2.7.2 SSM FRAME Header

PRI HEADER FORMAT

Field	Size (bit)	Format	Description
ECHO_ID	16	Uint	Echo ID number
Phi0 vRad	32	Float	Radial Velocity used for computation of phi0
Total HEADER size = 48 bits (6 bytes)			

Table 2.7.3 SSM PRI Header

.
The following tables shows the value of the Data Volume and number of orbits that can be stored into the FM, as function of the Pre-Summing factor and the dimension of the Sub Receiving Window to retrieve:

	Receiving Window N Samples 80 (57 us)			**Receiving Window N Samples 70 (50 us)**			**Receiving Window N Samples 65 (46.4us)**		
PF	**DV [Mb]**	**DT [min]**	**NO**	**DV [Mb]**	**DT [min]**	**NO**	**DV [Mb]**	**DT [min]**	**NO**
1	288	13.6	0.5	252.3	15.5	0.5	234.4	16.7	0.6
2	162	24.1	0.8	141.8	27.5	0.9	131.7	29.6	1.0
3	120	32.6	1.1	105.0	27.2	1.3	97.6	40.1	1.4
4	90	43.4	1.5	78.8	49.6	1.7	73.2	53.4	1.8
5	72	54.2	1.8	63.0	62.8	2.1	58.6	66.7	2.3
6	66	59.2	2.0	57.8	67.6	2.3	53.7	72.8	2.5
7	57	69.1	2.4	49.5	78.9	2.7	46.0	85.0	2.9

Table 2.7.4 Data Volume and duration

:

- PF: Presumming Factor
- DV: Total Data Volume (Science DV and Header DV) stored into the FM
- DT: Maximum flyby duration
- NO: Number of orbits that can be stored into the FM

Considering:

- On-board Flash Memory size = 16.7 MB (134217728 bits)
- Nominal duration of an observation (orbit) = 1755 sec (29.25min)

Science Data telemetries sent to SC over OBDH bus for SSM will include just first channel data. That is, no PIS data will be reported, as PIS itself will be skipped in SSM:

SCIENTIFIC DATA IDs				DATA RATE				
Operative Mode	Mode Sel·	Proc. ID & Data Type		bytes per Frame	TM-Pack. number	Dipole-F1 (byte)[2.]		
SSM	1110_b	77_d	11_b	3072	1	512 (8 bit/sa RE)	512 (8 bit/sa IM)	X 3

Table 2.7.5 TM(20,3) Scientific Data field fine structure.

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Auxiliary data for SSM are reported in the following table (note that F2 data will be identical to F1 ones):

First PRI of the Frame – Uint	32 bit
SCET_FRAME – Uint	48 bit
SCET_PERICENTER – Uint	48 bit
SCET_PAR – Uint	48 bit
H(SCET_PAR) – Spfloat	32 bit
VT(SCET_PAR) – Spfloat	32 bit
VR(SCET_PAR) – Spfloat	32 bit
N_o – Uint	32 bit
ΔS_MIN – Spfloat	32 bit
NB_MIN – Uint	16 bit
M_OCOG_F1 – Spfloat	32 bit
M_OCOG_F2 – Spfloat	32 bit
Index_OCOG_F1 – Uint (1...512)	16 bit
Index_OCOG_F2 – Uint (1...512)	16 bit
TRK_Threshold_F1 – Spfloat	32 bit
TRK_Threshold_F2 – Spfloat	32 bit
ini_ind_TRK_Threshold_F1 – Uint (1...512)	16 bit
ini_ind_TRK_Threshold_F2 – Uint (1...512)	16 bit
last_ind_TRK_Threshold_F1 – Uint (1...512)	16 bit
last_ind_TRK_Threshold_F2 – Uint (1...512)	16 bit
ini_ind_FSRM_F1 – Uint (1...512)	16 bit
ini_ind_FSRM_F2 – Uint (1...512)	16 bit
last_ind_FSRM_F1 – Uint (1...512)	16 bit
last_ind_FSRM_F2 – Uint (1...512)	16 bit
Spare (0x0)	96 bit
ΔS(SCET_PAR) – Spfloat	32 bit
NB(SCET_PAR) – Uint	16 bit
NA_1(SCET_PAR) – Uint	16 bit
NA_2(SCET_PAR) – Uint	16 bit
a2_ini_cm_F1 – Spfloat[1]	32 bit
a2_ini_cm _F2 – SpfloatVI	32 bit
a2_opt_F1 – SpfloatVI	32 bit
a2_opt_F2 – SpfloatVI	32 bit
Ref_CA_opt_F1 – SpfloatVI	32 bit

[1] cf. note to the same parameter in SS1.

Ref_CA_opt_F1 – SpfloatVI	32 bit
δt_F1 – Uint (0 in case of FSRM failure, else 1...512)VI	16 bit
δt_F2 – Uint (0 in case of FSRM failure, else 1...512)VI	16 bit
Sf_F1 – SpfloatVI	32 bit
Sf_F2 – SpfloatVI	32 bit
I_c_F1 – Uint (-1 in case of threshold comparison failure, else 1...512)VI	16 bit
I_c_F2 – Uint (-1 in case of threshold comparison failure, else 1...512)VI	16 bit
AGC_SA_for_Next_Frame_F1 – Spfloat (db)	32 bit
AGC_SA_for_Next_Frame _F2 – Spfloat (db)	32 bit
AGC_SA_Levels_Current_Frame_F1 (HW register, binary)VI	8 bit
AGC_SA_Levels_Current_Frame _F2 (HW register, binary)VI	8 bit
RX_Trig_SA _for_Next_Frame_F1 – Uint (μs)	16 bit
RX_Trig_SA _for_Next_Frame_F2 – Uint (μs)	16 bit
RX_Trig_SA_progr_F1 –Uint (HW register)VI	16 bit
RX_Trig_SA_progr_F2 –Uint (HW register)VI	16 bit
ini_ind_OCOG (1...512) – Uint	16 bit
last_ind_OCOG (1...512) – Uint	16 bit
OCOG_F1 – Spfloat	32 bit
OCOG_F2 – Spfloat	32 bit
A_F1 – Spfloat	32 bit
A_F2 – Spfloat	32 bit
C_LoL_F1 – Int	16 bit
C_LoL_F2 – Int	16 bit
(0x0)	16 bit
(0x0)	16 bit
(0x0)	16 bit
Maximum RE output data exp [m = -1; OP_F1; Dipole] – Uint	8 bit
Maximum IM output data exp [m = -1; OP_F1; Dipole] – Uint	8 bit
Maximum RE output data exp [m = 0; OP_F1; Dipole] – Uint	8 bit
Maximum IM output data exp [m = 0; OP_F1; Dipole] – Uint	8 bit
Maximum RE output data exp [m = 1; OP_F1; Dipole] – Uint	8 bit
Maximum IM output data exp [m = 1; OP_F1; Dipole] – Uint	8 bit
Maximum RE output data exp [m = -1; OP_F2; Dipole] – Uint	8 bit
Maximum IM output data exp [m = -1; OP_F2; Dipole] – Uint	8 bit
Maximum RE output data exp [m = 0; OP_F2; Dipole] – Uint	8 bit
Maximum IM output data exp [m = 0; OP_F2; Dipole] – Uint	8 bit
Maximum RE output data exp [m = 1; OP_F2; Dipole] – Uint	8 bit
Maximum IM output data exp [m = 1; OP_F2; Dipole] – Uint	8 bit
(0x0)	8 bit
(0x0)	8 bit
(0x0)	8 bit
(0x0)	8 bit
(0x0)	8 bit
(0x0)	8 bit

(0x0)	8 bit
(0x0)	8 bit
AGC PIS PT VALUE B2	32 bit
AGC PIS PT VALUE B2	32 bit
AGC PIS LEVELS B1	8 bit
AGC PIS LEVELS B2	8 bit
K PIM	8 bit
PIS MAX B1	8 bit
PIS MAX B2	8 bit
Processing_PRF – Spfloat	32 bit
Spare (0x0)	8 bit
Total	**228 bytes**

Table 2.7.6 Auxiliary Data for SSM
(Process ID 77, Science Data Type 11)

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3 PHOBOS NEW OPERATIVE MODE (SSP)

Assuming that Phobos would not be observed by MARSIS, the on-board SW was originally designed and optimized, to operate exclusively on Mars.

However, it was possible to implement a particular parameters configuration of the MARSIS on-board SW, called ‘‘Range Ambiguity,” that allowed to observe also Phobos partially overriding some of the instrument limitations, affecting this particular observation. This parameter configuration is indeed quite complex and presents some additional drawbacks..

This paragraph describes the SW requirements to implement a new operative mode, called **SSP** to improve the instrument performances at observing Phobos, eliminating the drawbacks of the actual method of observation. This new modality shall be optimized for the two main Phobos observation scenarios:

1. Distant Observation Scenario **(DOS)**, when Phobos closest approach is higher than 180 km
2. Near Observation Scenario **(NOS)**, when Phobos closest approach is lower than 180 km

The operative mode **SSP** shall manage continuous raw unprocessed data, after A/D conversion at 980 samples (8bit/sample) per PRI. All science raw data generated during the flyby will be directly moved to non-volatile memory (FM). Dump of the data from FM can be performed in later orbits, and once all the data have been sent to ground, it will be possible to process them with dedicated algorithms.

The acquisition scheme is similar to the one used in operative mode SSM, but the scientific data will be retrieved only from the first Channel, as shown if Fig. 3.1

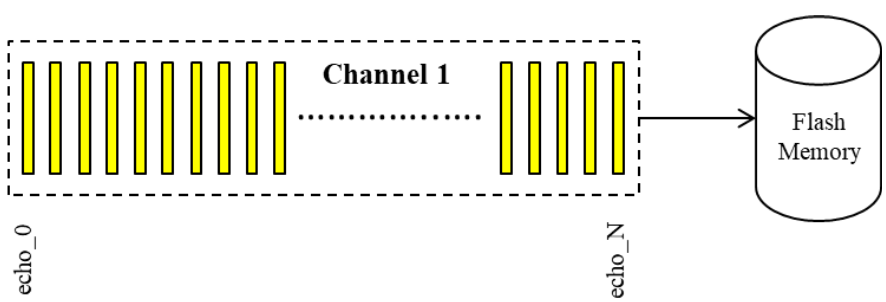

Fig. 3.1 SSP acquisition mechanism

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3.1 SSP MODE REQUIREMENTS

- SSP mode shall not produce any science telemetry on the SC bus (OBDH), this will permit to operate simultaneously: MARSIS, PFS and SPICAM.

- Even if MARSIS only records science data (raw echoes) from channel 1, the instrument transmits two pulses (spaced by 450us) for the **Distant Scenario Configuration** and four pulses (spaced by each other by 450us) for the **Near Scenario Configuration**. The transmission band shall be selected by a proper flag (**DCG Configuration**) inside the Operation Sequence Table (OST).

- The two Observations configuration (Distant Scenario and Near Scenario) shall be selected by a proper flag (**OBS_SCE_CONFIG**) inside the Operation Sequence Table (OST).

- The acquisition process shall be performed on a number of PRI, specified by a proper flag (**Mode Duration**) inside the OST.

- The TX power level shall be configured by a proper flag (**TX Power**) inside the OST. Setting a low level of transmitted power, it will be possible to use the SSP mode, to warm up the instrument, while a Power Null level will be use as IDLE mode.

- The Tracking mechanism of the first channel, shall be selected by a proper setting of the **TRK_SEL** flag inside the OST. Two different modalities can be set:

  TRK_SEL = 0

  The TRIGGERS is fixed, for the entire duration of the OST line. The Trigger value is defined by the specific setting of the **TRIG_SAMP_FIX** filed, inside the OST:

$$RX\_TRIG = \frac{TRIG\_SAMP\_FIX}{2.8}\ [\mu s] \quad (21)$$

  TRK_SEL = 1

  The Trigger will be evaluated on board, based on the use of seventh order polynomial, whose eight coefficients are available from PT:

$$H = a_{h0} + a_{h1}t + a_{h2}t^2 + a_{h3}t^3 + a_{h4}t^4 + a_{h5}t^5 + a_{h6}t^6 + a_{h7}t^7[Km] \quad (22)$$

$$t = T_k/1E3 \quad (23)$$

.

Check the computed altitude (H)

if H < PHO_H_THR

TO_DET_PHO = TO_DET_PHO_A

else
TO_DET_PHO = TO_DET_PHO_B
end

$$RX\_TRIG = \frac{2 \cdot H}{c} \cdot 1E9 \quad + T0\_DET\_PHO \qquad [\mu s] \qquad (24)$$

Where

- H: SC altitude in [Km]
- $a_{h0} - a_{h7}$: PT polynomial coefficients, extracted from PT
- T_k: Time in seconds of the generic $Echo_k$
- C: Light's speed [m/s], extracted from PT
- PHO_H_THR: Altitude threshold parameter in [m]
- TO_DET_PHO: Preset Offset in [us]
- TO_DET_PHO_A/B: Trigger Offset parameter in [us], extracted from PT

- The Recording mechanism shall be selected by a proper setting of the **REC_ENAB** flag inside the OST. This requirement will allow to use SSP in the Slow Power Up technical blocks without recording useless data into the Flash Memory.

- The Automatic Gain Control (AGC) mechanism of the two channels, shall be selected by a proper setting of the **AGC_SEL** flag inside the OST. Two different modes can be set:

  AGC_SEL = 0

  The Attenuator level of the two channels receivers, assume a constant value within the duration of the SSP mode, defined by the **AGC_FIX** field inside the OST and quantised with 4 dB step, from 2 dB to 30 dB.

.

<u>AGC_SEL = 1</u>

The Attenuation level of the receiver, shall be estimated every PRI, based on the algorithm shown in the following Fig. 3.1.1:

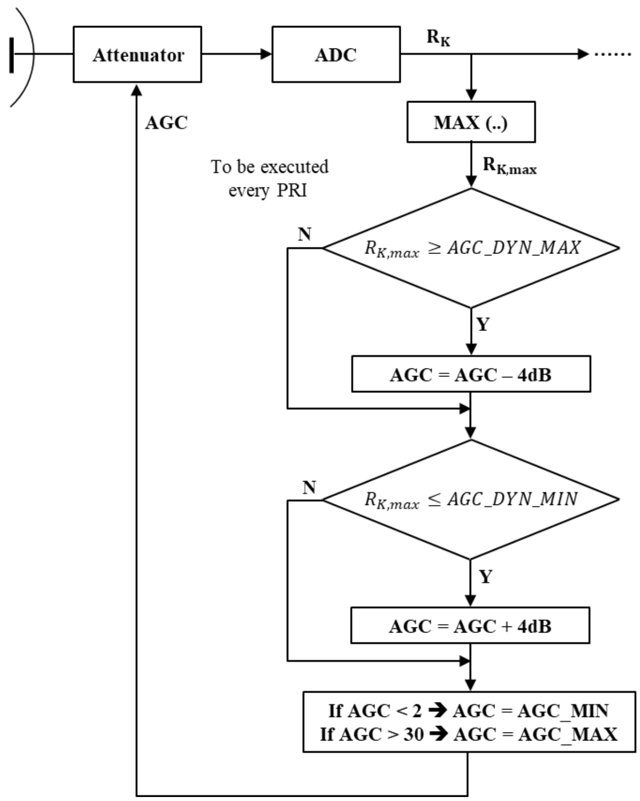

Fig. 3.1.1 AGC Trigger Algorithm

The AGC Trigger Algorithm, compares the maximum value of each echo's amplitude, with the values of two thresholds: AGC_DYN_MAX and AGC_DYN_MIN, in order to increase or decrease the gain of the two radar receivers for the subsequent echo. The AGC level of the first PRI is defined by the **AGC_FIX** field inside the OST. Fig. 3.1.2 shows the Trigger Algorithm mechanism:

Note that, from the analysis of the FM data collected so far by MARSI, we learn that an increase or a decrease of 4dB of the receiver attenuator corresponds about 35 DN of the echo amplitude.

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3.2 ANALYSIS OF OBSERVATION SCENARIOS

In this paragraph will be examined the two observation scenarios, in terms of configuration of the main commanding parameters, in order to build the operative timelines.

DISTANT OBSERVATION SCENARIO (DOS)

When Phobos closest approach is higher than 180 km, the hardware protection mechanism, that precludes any operation when the target range is less than 240 km, can be easily bypassed transmitting two pulses every PRI, and capturing the second generated echo. This configuration shall be enabled setting to “0” the OBS_SCE_CONFIG flag inside the OST line.

In order to capture the second echo and to keep it in the centre of the receiving window, mitigating also a +/-50us (+/- 7.5km) potential inaccuracy of the estimated range polynomial coefficients, it is necessary to add a constant offset of 400us to the Trigger calculated on-board, as shown in Fig. 3.2.1

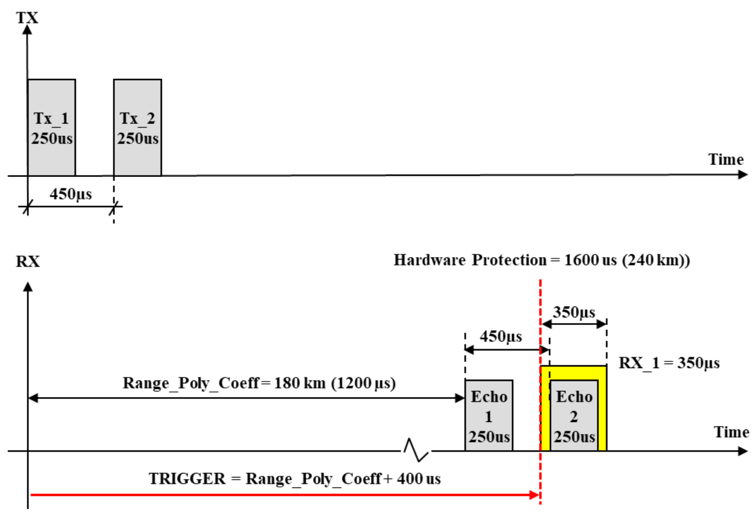

Fig. 3.2.1 Acquisition mechanism when closest approach is higher than 180km

Note that, even if the first echo generated by the transmission of the first pulse, will be always lost, the reception of the second echo produced by the transmission of the second pulse, is always guaranteed during the flyby. In conclusion, the right configuration of the on-board parameters, for the DOS scenario is as follow:

OBS_SCE_CONFIG = 0 (Two transmitted pulses every PRI)
PHO_H_THR = 0
TO_DET_PHO_A/B = 400

.
NEAR OBSERVATION SCENARIO (NOS)

When Phobos closest approach is lower than 180 km, the hardware protection mechanism, that precludes any operation when the target range is less than 240 km, can be easily bypassed transmitting four pulses every PRI, and capturing the fourth generated echo. This configuration shall be enabled setting to "1" the OBS_SCE_CONFIG flag inside the OST line.

In order to capture the fourth echo and to keep it in the centre of the receiving window it is necessary to add a constant offset to the Trigger calculated on-board, whose value depends on the choice that has been set on the duration of the transmitted pulses.

Fig. 3.2.2 shows the case with the nominal duration of the transmitted pulses of 250us and considering the closest flyby to Phobos that is of 45km.

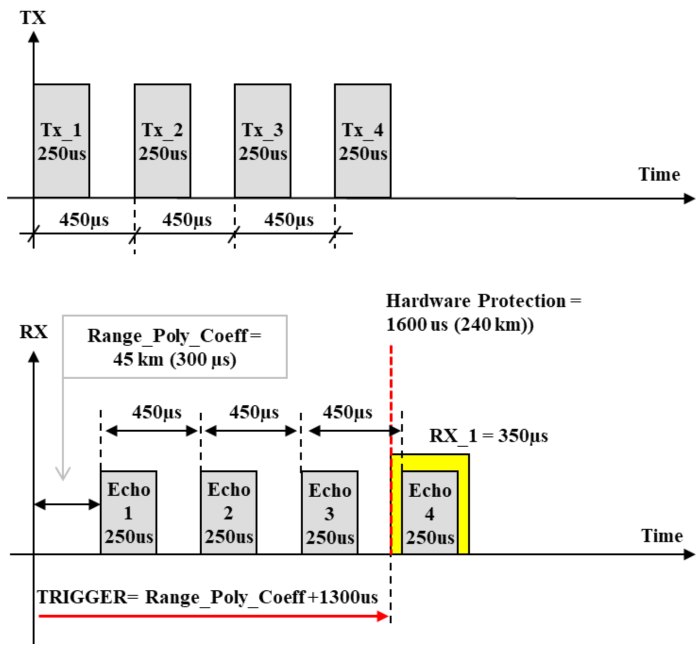

Fig. 3.2.2 Acquisition mechanism when closest approach is lower than 180km and with nominal duration (250us) of TX pulses.

Table 3.3.1 shows the configuration of the main commanding parameters, when Band 3 is selected, to implement the Near Observation Scenario (NOS), with the following TX pulses duration: 30us, 60us, 120us, 150us, 200us and 250us

.

TX Chirp Duration [us]	**TX Chirp Configuration PT Parameters to Load**			**Trigger Offset PT Parameters lo Load**		
	PT Line 518 **0x206**	PT Line 522 **0x20A**	PT Line 526 **0x20E**	PT Line 217 **0xD9**	PT Line 218 **0xDA**	PT Line 219 **0xDB**
30	Default configuration, already on-board			**[+1190us]** 0x4494 0xC000	**[+1190us]** 0x4494 0xC000	**[0]** 0x0000 0x0000
60	0x0000 0x1C02	0x0000 0x8B03	0x0000 0x0544	**[+1205us]** 0x4496 0xA000	**[+1205us]** 0x4496 0xA000	**[0]** 0x0000 0x0000
120	0x0000 0x0E02	0x0000 0x4503	0x0000 0x0A84	**[+1235us]** 0x449A 0x6000	**[+1235us]** 0x449A 0x6000	**[0]** 0x0000 0x0000
150	0x0000 0x0B02	0x0000 0x2E03	0x0000 0x0D24	**[+1250us]** 0x449C 0x4000	**[+1250us]** 0x449C 0x4000	**[0]** 0x0000 0x0000
200	0x0000 0x0802	0x0000 0x6203	0x0000 0x1184	**[+1275us]** 0x449F 0x6000	**[+1275us]** 0x449F 0x6000	**[0]** 0x0000 0x0000
	PT Line 519 **0x207**	PT Line 523 **0x20B**	PT Line 527 **0x20F**	PT Line 217 **0xD9**	PT Line 218 **0xDA**	PT Line 219 **0xDB**
250	0x0000 0x0602	0x0000 0xB503	0x0000 0x15E4	**[+1300us]** 0x44A2 0x8000	**[+1300us]** 0x44A2 0x8000	**[0]** 0x0000 0x0000

Table 3.2.1 SSP Commanding Configuration for the Near Observation Scenario using Band 3

Note that a short duration of the transmitted pulses (30us for example) will allow to better mitigate the potential inaccuracy of the estimated range polynomial coefficients loaded on-board; with a tolerance of +/-160us (24km) but with a loss in term of power of bout 9dB, from the nominal case (250us).
Vice versa a long duration of the transmitted pulses (250us for example) will allow to have a good SNR level, as the radiated power is higher: but with lower tolerance on altitude inaccuracy, +/-50us (7.5km).

3.3 *OST AND P.T. PARAMETERS*

OST PARAMETERS FOR SSP (Mode Selection bits = 1101b)

Field	**Size (bit)**	**Format**	**Bit Position**	**Configuration**	**Description**
Mode Duration in PRI	24	Enum	8 : 31	Same configuration of existing Operative Mode	OPM duration in number of PRI
Mode Selection/DCG Configuration	4+4	Enum	34 : 41	SSP - Band 1 (Param. Value = 208) SSP - Band 2 (Param. Value = 212) SSP - Band 3 (Param. Value = 216) SSP - Band 4 (Param. Value = 220)	Operative mode Identifier and Selected Band
OBS_SCE_CONFIG	1	Enum	53 : 53	0 ➔ Distant Observation Scenario 1 ➔ Near Observation Scenario	Flag to select the Observation Scenario
AGC_SEL	1	Enum	54 : 54	0 ➔ Read receivers attenuator from OST (AGC_FIX) 1 ➔ Receivers attenuator defined on-board	Mechanism to calculate the Receivers attenuator.
TRIG_SEL	1	Enum	55 : 55	0 ➔ Read Trigger from OST (TRIGGER_FIX) 1 ➔ The Trigger is defined on-board	Mechanism to calculate the Trigger
REC_ENABLE	1	Enum	56 : 56	0 ➔ Recording Disabled 1 ➔ Recording Enabled	Mechanism to Enable and Disabled the data recording phase
AGC_FIX	3	Enum	57 : 59	000 (0) ➔ 2dB 001 (1) ➔ 6dB 010 (2) ➔ 10dB 011 (3) ➔ 14dB 100 (4) ➔ 18dB 101 (5) ➔ 22dB 110 (6) ➔ 26dB 111 (7) ➔ 30dB	**AGS_SEL = 0** Level of attenuator to be set for both the channel receivers **AGS_SEL = 1** Level of the first PRI AGC
TX_POWER	4	Enum	60 : 63	Same configuration of existing Operative Mode	
TRIGGER_FIX	16	Enum	80 : 95		Trigger expressed as number of step at $\frac{1}{2.8}$ [μs]. TRIG_SAMP = TRIG_us*2.8 This field is read, only when TRIG_SEL = 0

Table 3.2.1 OST Fields Configuration

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OST PARAMETERS DETAILS

OST fields		Consiguration	POR Format	Note
0 7	PAD	NA	NA	Field not coded in the POR
8 : 31	Mode Duration in PRI	Raw Tupe : UNIT Eng Tupe: NA	H 774	Overwritten existing OPM FM2Ram (ID = 13), originally reserved for RAMtoFM
32 33	PAD	NA	NA	Field not coded in the POR
34 : 37	Mode Selectioin	Raw Tupe : UNIT Eng Tupe: TEXT	OPM Codes: SSP - Band 1 SSP - Band 2 SSP - Band 3 SSP - Band 4	The implementation of this field requires an update of the ESOC DB
38 : 41	DCG Configuration			
42 43 44	P1-B1	Raw Tupe : UNIT Eng Tupe: TEXT	PIS1B0PIS2B0	Field ignored by SSP, however it shall be set the same to avoid POR format error
45 46 47	P2-B2			
48	OBS_SCE_CONFIG	Raw Tupe : UNIT Eng Tupe: NA	0	
49 50	RFS = 00b			
51 52	LOL = 00b			
53	Ch_Sel			
54	Agc_Sel			
55	Trig_Sel			
56	Rec_Enab			
57 58 59	Agc_Fix			
60 : 63	TX Power	Raw Tupe : UNIT Eng Tupe: NA	TX PWR NULL	No changes are required
64 : 75	A2 Abscissa	Raw Tupe : UNIT Eng Tupe: NA	0	Field ignored by SSP, however it shall be set the same to avoid POR format error
76 : 79	Ind echo FM	Raw Tupe : UNIT Eng Tupe: TEXT	NoFMStore	Field ignored by SSP, however it shall be set the same to avoid POR format error
80 : 95	Trigger_Fix	Raw Tupe : UNIT Eng Tupe: NA	0	Discretized in step of 1/2.8 [us]

Table 3.2.2 OST Fields Details

.

PARATER TABLE (PT) PARAMETERS

PT Line Number	Parameter	Value	Unit	Format	Description
198	AGC_DYN_MIN	90	[]	32bit int	raw dada value Lower limit threshold for dynamic AGC
199	AGC_DYN_MAX	127	[]	32bit int	raw dada value Higher limit threshold for dynamic
200	AGC_MIN	3	[]	32bit int	Guaranteed Minimum value of AGC (register setting;3 = 14dB)
201	AGC_MAX	7	[]	32bit int	Guaranteed Minimum value of AGC (register setting;7 = 30dB)
217	TO_DET_SSP_A	-50	[us]	32bit float	Trigger offset parameter
218	TO_DET_SSP_B	-50	[us]	32bit float	Trigger offset parameter
219	PHO_H_THR	0	[m]	32bit float	Altitude threshold parameter

Table 3.2.3 Parameter Table New Coefficients

.

3.4 PHO FLASH MEMORY DATA MANAGEMENT

The following storage format, shall be considered for the Operative Mode **SSP**. FM data shall be stored as single stream of bytes organized as a list of OST Lines, each one of them including a single Frame composed by a variable number of PRI raw data echoes (number of PRI's will be the OST line duration). OST lines and PRI's will be preceded by a short header, as illustrated in Fig. 3.3.1.

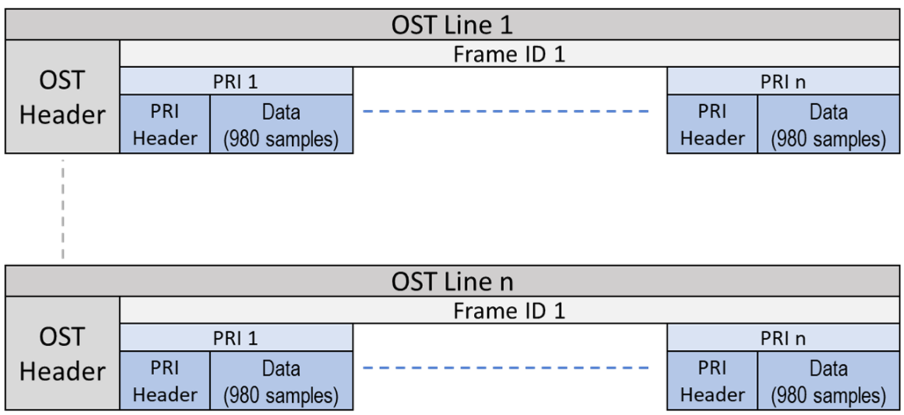

Fig. 3.3.1 SSP FM data format

.

OST HEADER FORMAT

Field	Size (bit)	Format	Description
OST ID	4	Uint	OST Line number
Lost PRI counter	12	Uint	Number of PRI's that were not recorded
Written PRI counter	16	Uint	Number of PRIs with raw data fully recorded
AGC_DYN_PRIs_to_skip	16	Uint	PRI's to be ignored after Dynamic AGC has set a new AGC value
AGC_DYN_PRIs_size	16	Uint	Minimum number of consecutive PRI's with amplitude peak outside of desired range, to trigger an AGC change
Full OST Line	96	bitstream	The full OST line bitstream
SCET 1st PRI of OST Line	48	SCET	SCET sampled at the beginning of the OST line (1st PRI of OST line)
On-board computed PRF	32	Float	PRF measured on-board
TRIG_OFFSET_CH2	32	Float	Offset of the Second Channel Trigger
TO_DET_SSP_A	32	Float	Trigger offset A parameter
TO_DET_SSP_B	32	Float	Trigger offset B parameter
SSP_H_THR	32	Float	Altitude threshold parameter
AGC_DYN_MIN	8	Uint	0-255. Lower limit threshold for dynamic AGC
AGC_DYN_MAX	8	Uint	0-255. Higher limit threshold for dynamic AGC
AGC_MIN	8	Uint	Guaranteed Minimum value of AGC
AGC_MAX	8	Uint	Guaranteed Maximum value of AGC
Total HEADER size = 400 bits (50 bytes)			

Table 3.3.1 SSP OST Header

PRI HEADER FORMAT

Field	Size (bit)	Format	Description
RX Trigger	16	Uint	RX trigger expressed as number of 2.8MHz intervals
AGC	3	Enum	AGC attenuation, from 2 to 30dB at 4dB steps
PRI_Counter	13	Uint	PRI Counter, starting from 1
PRI_Number	16	Uint	PRI Number, starting from 1
PRI_RECEIVED_BYTE	16	Unint	(PRI raw echo bytes + 4) / 2, nominal value is 492
Total HEADER size = 64 bits (8 bytes)			

Table 3.3.2 SSP PRI Header

.
The two parameters: PRI_Counter and PRI_Number apparently identical, have been inserted in order to identify eventually lost PRIs.

In case of not lost PRI, then: PRI_Counter = PRI_Number

In case of lost PRI, then: PRI_Number will assume the value of “0” and immediately after the PRI_Number there will be the PRI_HEADER of the subsequent echo.

DATA

Each echo is represented with 980 samples, each sample (Sample_Value) is coded with 8 bit (integer).

If Sample_Value > 127 ➔ Sample_Value = Sample_Value - 256

.

The maximum duration of the SSP mode and therefore the maximum number of PRI that can be set in OST, is driven by the non-volatile memory (FM) size and given by the following equations:

$$N\_PRI\_MAX = \left\lfloor \frac{FM_{DV_{MB}} \cdot 1E6 - N\_OST \cdot HEADER\_OST}{HEADER\_PRI + ECHO\_SAMPLES} \right\rfloor = 17015\ PRI \quad (27)$$

$$DT\_MAX\_sec = \frac{N_{PRI_{MAX}}}{PRF} = 134\ sec \quad (28)$$

Where:

- FM_DV_MB = 16.7 MB Size of the internal instrument Flash Memory
- HEADER_OST = 50 Bytes Size of the OST header
- HEADER_PRI = 6 Bytes Size the PRI header
- ECHO_SAMPLES = 980 Bytes 980 samples echo (1Byte/sample)
- PRF = 127.267 [Hz] Radar Pulse Repletion Frequency
- N_OST Number of commanded OST lines (typically 1 or 2)

.

4 MARSIS, PLANNING & COMMANDING INTERFACES, REQUEST OF UPDATE

In order to operate the MARSIS radar, with SSM and SSP operative modes, introduced by the new on-board SW, it is necessary to update all the on-ground facilities, in particular: Planning chain and Commanding chain. Regarding the Data Handling facilities, there are not changes to implement. The next paragraphs describe the changes to be implemented.

4.1 PLANNING CHAIN

The new Operative Modes: SSM and SSP shall be handled by the MAPPS tool, in the same way of the existing Operative Modes SS (SS1, SS2, SS3, SS4, SS5). The only differences are in the Data Rate computation and Power consumption, as following highlighted:

Mode: SSM "Variable Data Rate Operative Mode"

Nominal Power: 64 [Watts]

<u>MAPPS Data Rate Model:</u>

The following statement shall be add to the MARSIS Data Rate Model

```
case DM_SSRA_SSM:
      opData = 24576.0; //[bit]
       break;
```

Mode: SSP "Constant Data Rate Operative Mode"

Nominal Power: 64 [Watts]
Data Rate Parameter: 300 [bit/sec] "Constant Data Rate"

```
Orbit Point Rank Instr Activ Start End   Targ  Offdeg Band RDF

21758   NOP      3 SSRA  STBY -10.00 -05.00
21758   NOP      3 SSRA  PREO -05.00 -03.00
21758   NAD-P    3 SSRA  SSM  -03.00  00.00   ---   0       3   1
21758   NAD-P    3 SSRA  SSP   00.00  03.00   ---   0       4   1
21758   NOP      3 SSRA  POST  03.00  05.00
```

Fig. 4.1.1 Example of MIRA timeline with the new OPMs: SSP and SSM

.

4.2 *COMMANDING CHAIN*

The only field, that shall be updated in the ESOC Data Base, to manage the two new Operative Modes: SSM and SSP is: "**Mode and DCG Selection".** The following tables show the new configuration of this filed, in the MARSIS Commands and Sequences files:

.

MARSIS Commands

<table>
<tr><td colspan="6">EDF sections generated from MDB data
$Log: marsis_cmds.edf,v $
Revision 1.121 2021/01/05 15:54:39 msgs_ops
L412
MDB_version: 20201204 "MEX_REL_L412"</td></tr>
<tr><th colspan="3">ESA Configuration Fields</th><th colspan="3">MARSIS Fields</th></tr>
<tr><th>Parameter To be Updated</th><th colspan="2">Extra Parameter Values to be added to the existing ones</th><th>OPMb</th><th>BTX1b</th><th>BTX2b</th></tr>
<tr><td>FMIX0101 "R1[34-41] Mode&DCG Sel."
FMIX0111 "R10[34-41] Mode&DCG Sel."
FMIX0121 "R11[34-41] Mode&DCG Sel."
FMIX0131 "R12[34-41] Mode&DCG Sel."
FMIX0141 "R13[34-41] Mode&DCG Sel."
FMIX0151 "R14[34-41] Mode&DCG Sel."
FMIX0161 "R15[34-41] Mode&DCG Sel."
FMIX0171 "R16[34-41] Mode&DCG Sel."
FMIX0201 "R2[34-41] Mode&DCG Sel."
FMIX0301 "R3[34-41] Mode&DCG Sel."
FMIX0401 "R4[34-41] Mode&DCG Sel."
FMIX0501 "R5[34-41] Mode&DCG Sel."
FMIX0601 "R6[34-41] Mode&DCG Sel."
FMIX0701 "R7[34-41] Mode&DCG Sel."
FMIX0801 "R8[34-41] Mode&DCG Sel."
FMIX0901 "R9[34-41] Mode&DCG Sel."
FMIX1101 "R1[34-41] Mode&DCG Sel."
FMIX2101 "R1[34-41] Mode&DCG Sel."
FMIX2201 "R2[34-41] Mode&DCG Sel."
FMIX4101 "R1[34-41] Mode&DCG Sel."
FMIX4201 "R2[34-41] Mode&DCG Sel."
FMIX4301 "R3[34-41] Mode&DCG Sel."
FMIX4401 "R4[34-41] Mode&DCG Sel."
FMIX8101 "R1[34-41] Mode&DCG Sel."
FMIX8201 "R2[34-41] Mode&DCG Sel."
FMIX8301 "R3[34-41] Mode&DCG Sel."
FMIX8401 "R4[34-41] Mode&DCG Sel."
FMIX8501 "R5[34-41] Mode&DCG Sel."
FMIX8601 "R6[34-41] Mode&DCG Sel."
FMIX8701 "R7[34-41] Mode&DCG Sel."
FMIX8801 "R8[34-41] Mode&DCG Sel."</td><td>224
228
232
236
208(*)
212
216
220</td><td>SSM - Band 1
SSM - Band 2
SSM - Band 3
SSM - Band 4
SSP - Band 1
SSP - Band 2
SSP - Band 3
SSP - Band 4</td><td>1110
1110
1110
1110
1101
1101
1101
1101</td><td>00
01
10
11
00
01
10
11</td><td>00
00
00
00
00
00
00
00</td></tr>
</table>

Table 4.2.1 MARSIS Extra Parameter Values, to be added to the Command file

(*)The value 208 actually present in the ESOC DB, shall be replaced with the new configuration, shown in the table above

.

MARSIS Sequences

<table>
<tr><td colspan="7">EDF sections generated from MDB data
$Log: marsis_seqs.edf,v $
Revision 1.121 2021/01/05 15:54:39 msgs_ops
L412</td></tr>
<tr><th colspan="4">ESA Configuration Fields</th><th colspan="3">MARSIS Fields</th></tr>
<tr><th>Parameter To be Updated</th><th>Parameter Action</th><th colspan="2">Extra Parameter Values to be added to the existing ones</th><th>OPMb</th><th>BTX1b</th><th>BTX2b</th></tr>
<tr><td>VMIX0101 "R1[34-41] Mode&DCG Sel."</td><td>AMIF14A0</td><td rowspan="31">224
228
232
236
208(*)
212
216
220</td><td rowspan="31">SSM - Band 1
SSM - Band 2
SSM - Band 3
SSM - Band 4
SSP - Band 1
SSP - Band 2
SSP - Band 3
SSP - Band 4</td><td rowspan="31">1110
1110
1110
1110
1101
1101
1101
1101</td><td rowspan="31">00
01
10
11
00
01
10
11</td><td rowspan="31">00
00
00
00
00
00
00
00</td></tr>
<tr><td>VMIX0111 "R10[34-41] Mode&DCG Sel."</td><td>AMIF14A0</td></tr>
<tr><td>VMIX0121 "R11[34-41] Mode&DCG Sel."</td><td>AMIF14A0</td></tr>
<tr><td>VMIX0131 "R12[34-41] Mode&DCG Sel."</td><td>AMIF14A0</td></tr>
<tr><td>VMIX0141 "R13[34-41] Mode&DCG Sel."</td><td>AMIF14A0</td></tr>
<tr><td>VMIX0151 "R14[34-41] Mode&DCG Sel."</td><td>AMIF14A0</td></tr>
<tr><td>VMIX0161 "R15[34-41] Mode&DCG Sel."</td><td>AMIF14A0</td></tr>
<tr><td>VMIX0171 "R16[34-41] Mode&DCG Sel."</td><td>AMIF14A0</td></tr>
<tr><td>VMIX0201 "R2[34-41] Mode&DCG Sel."</td><td>AMIF14A0</td></tr>
<tr><td>VMIX0301 "R3[34-41] Mode&DCG Sel."</td><td>AMIF14A0</td></tr>
<tr><td>VMIX0401 "R4[34-41] Mode&DCG Sel."</td><td>AMIF14A0</td></tr>
<tr><td>VMIX0501 "R5[34-41] Mode&DCG Sel."</td><td>AMIF14A0</td></tr>
<tr><td>VMIX0601 "R6[34-41] Mode&DCG Sel."</td><td>AMIF14A0</td></tr>
<tr><td>VMIX0701 "R7[34-41] Mode&DCG Sel."</td><td>AMIF14A0</td></tr>
<tr><td>VMIX0801 "R8[34-41] Mode&DCG Sel."</td><td>AMIF14A0</td></tr>
<tr><td>VMIX0901 "R9[34-41] Mode&DCG Sel."</td><td>AMIF14A0</td></tr>
<tr><td>VMIX1101 "R1[34-41] Mode&DCG Sel."</td><td>AMIF10A0</td></tr>
<tr><td>VMIX2101 "R1[34-41] Mode&DCG Sel."</td><td>AMIF11A0</td></tr>
<tr><td>VMIX2201 "R2[34-41] Mode&DCG Sel."</td><td>AMIF11A0</td></tr>
<tr><td>VMIX4101 "R4[34-41] Mode&DCG Sel."</td><td>AMIF12A0</td></tr>
<tr><td>VMIX4201 "R2[34-41] Mode&DCG Sel."</td><td>AMIF12A0</td></tr>
<tr><td>VMIX4301 "R3[34-41] Mode&DCG Sel."</td><td>AMIF12A0</td></tr>
<tr><td>VMIX4401 "R4[34-41] Mode&DCG Sel."</td><td>AMIF12A0</td></tr>
<tr><td>VMIX8101 "R1[34-41] Mode&DCG Sel."</td><td>AMIF13A0</td></tr>
<tr><td>VMIX8201 "R2[34-41] Mode&DCG Sel."</td><td>AMIF13A0</td></tr>
<tr><td>VMIX8301 "R3[34-41] Mode&DCG Sel."</td><td>AMIF13A0</td></tr>
<tr><td>VMIX8401 "R4[34-41] Mode&DCG Sel."</td><td>AMIF13A0</td></tr>
<tr><td>VMIX8501 "R5[34-41] Mode&DCG Sel."</td><td>AMIF13A0</td></tr>
<tr><td>VMIX8601 "R6[34-41] Mode&DCG Sel."</td><td>AMIF13A0</td></tr>
<tr><td>VMIX8701 "R7[34-41] Mode&DCG Sel."</td><td>AMIF13A0</td></tr>
<tr><td>VMIX8801 "R8[34-41] Mode&DCG Sel."</td><td>AMIF13A0</td></tr>
</table>

Table 4.2.2 MARSIS Extra Parameter Values, to be added to the Command file

(*)The value 208 actually present in the ESOC DB, shall be replaced with the new configuration, shown in the table above

.
The following Figure 4.2.1, shows and example of POR file section, where the two new Operative Modes: SSM and SSP, have been inserted.

```
C ---------------------------------------------------------
C MARSIS Load Operations Sequence Table (OST) with 2 Rows
C ---------------------------------------------------------

H1AMIF11A0 S
H2I UTC    T P 017
H3
H4
H5
S1          MPER 0000021758 -00:09:00
S221-154T10:39:05Z    -iaps-
PVMIX2003 R     D 0
PVMIX2100 R     H 597b
PVMIX2101 E       SSM - Band 3
PVMIX2102 E       PIS1B3PIS2B3
PVMIX2103 R     H 101
PVMIX2104 E       TX PWR MAX
PVMIX2105 R     D 0
PVMIX2106 E       NoFMStore
PVMIX2107 R     H 0
PVMIX2200 R     H 597b
PVMIX2201 E       SSP - Band 4
PVMIX2202 E       PIS1B4PIS2B4
PVMIX2203 R     H 3b
PVMIX2204 E       TX PWR MAX
PVMIX2205 R     D 0
PVMIX2206 E       NoFMStore
PVMIX2207 R     H 0
```

Fig. 4.2.1 Example of POR file with the two new OPMs: SSP and SSM

5 ANNEXES

5.1 ANNEX 1: ON-BOARD SCIENCE DATA BITS ENCODING

This section reports the analysis performed on the dynamics of the raw data, collected so far with the MARSIS internal Flash Memory (FM).
This study allowed the definition of the correct number of bits to properly encode the echo's samples, for each of the two components (Imaginary and Real) after the on-board Range Compression (RC).

An undersizing of the number of bits, could cause irreversible saturation phenomena on the signals, that will be stored into the internal Flash Memory (FM) and then transmitted to the ground.

This statistical analysis, was performed on a congruous number of FM raw data, about 4000 flybys; the results of which are shown from Fig.5.1.1 to Fig. 5.1.4. The following Table 5.1.1, shows the overall conclusion.

PRESUMMING FACTOR	8 BIT ENCODE	9 BIT ENCODE	10 BIT ENCODE	11 BIT ENCODE	RECOMENDATION
2	94% of cases	100% of cases	100% of cases	100% of cases	**9 bit Samples Encoding**
3	82% of cases	99% of cases	100% of cases	100% of cases	
4	75% of cases	96% of cases	100% of cases	100% of cases	**10 bit Sample Encoding**
5	72% of cases	92% of cases	100% of cases	100% of cases	
6	70% of cases	89% of cases	99% of cases	100% of cases	**11 bit Sample Encoding**
7	69% of cases	88% of cases	98% of cases	100% of cases	

Table 5.1.1 Samples Encoding factor overview

.

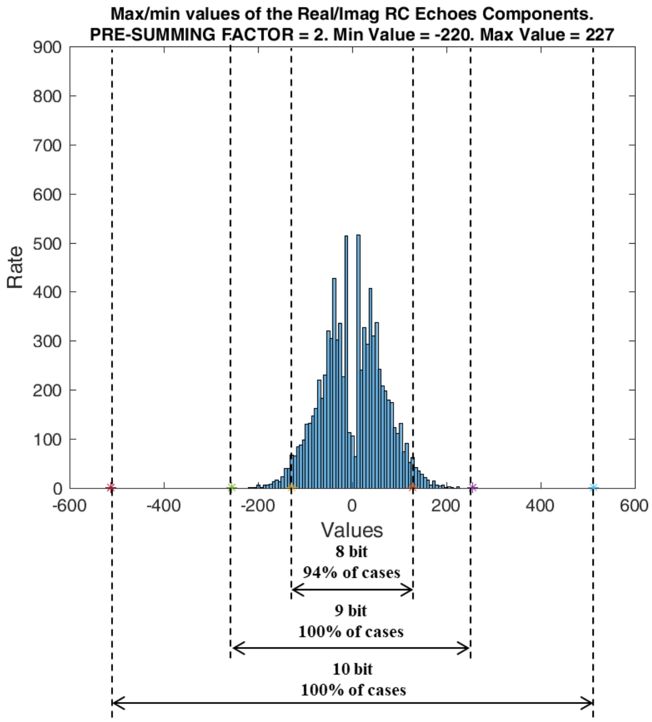

Fig. 5.1.1 Max/min values distribution (PF = 2)

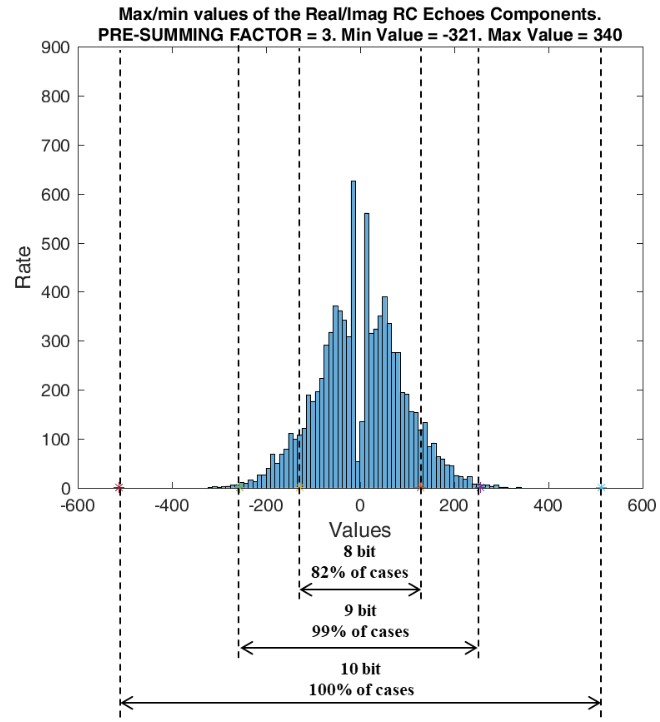

Fig. 5.1.2 Max/min values distribution (PF = 3)

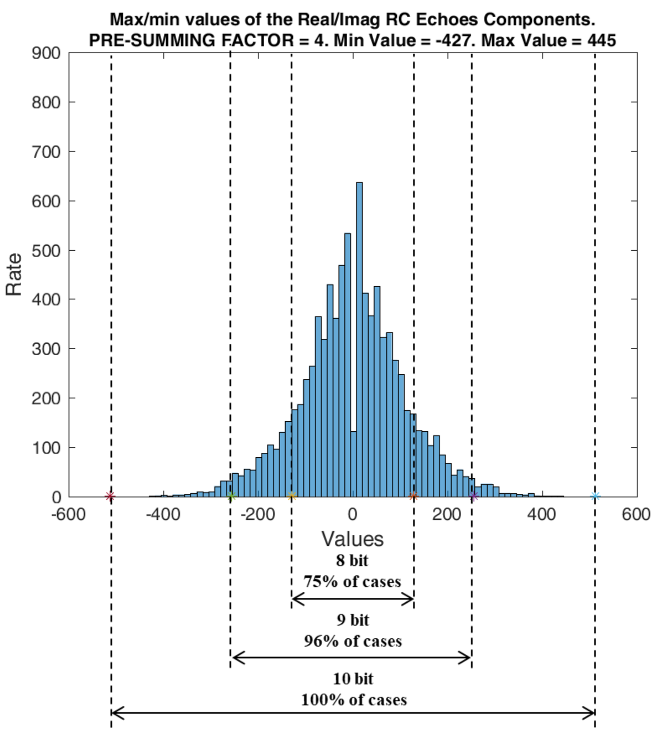

Fig. 5.1.3 Max/min values distribution (PF = 4)

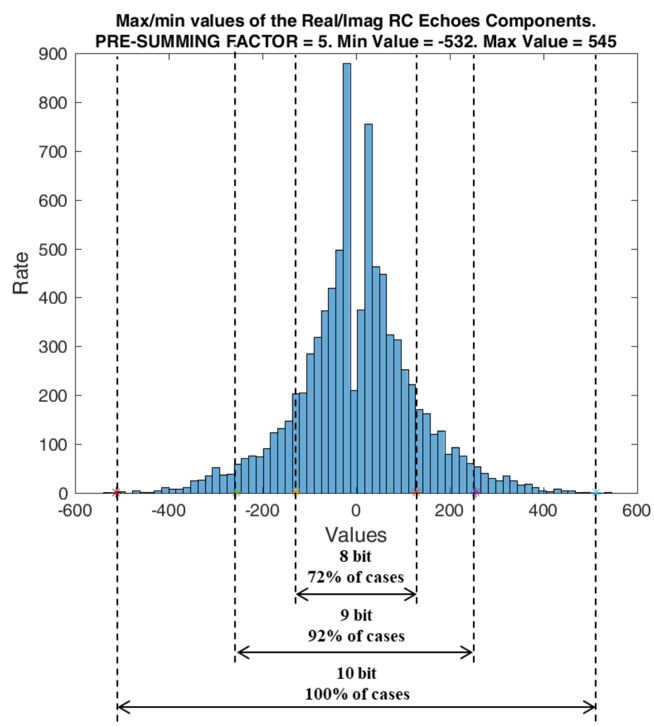

Fig. 5.1.4 Max/min values distribution (PF = 5)

.

5.2 *ANNEX 2: DEMODULATOR (I/Q SYNTHESIS)*

The I/Q synthesis shall be based on the direct quadrature synthesis method shown in figure 2.1.1 starting from the real data stream available at the A/D converter (980 samples) output for each received echo. All collected echoes by both channels (yellow bars of Fig. 2.1) will be demodulated, with the following procedure:

This process is also described in **[RD-01]** but with the right values of the FIR filter coefficients, reported in table 2.1.1.

$$V(t) = I(t) + jQ(t) \tag{29}$$

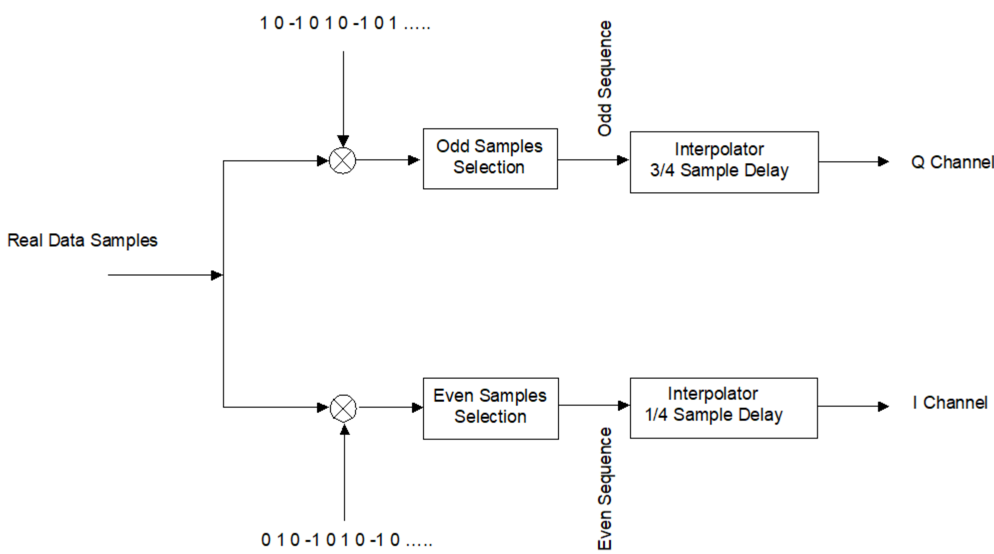

Fig. 5.2.1 I/Q Synthesis

<u>Odd Samples Synthesis</u>
The real data stream of each received echo shall be multiplied by the basic pattern [1 0 -1 0] and odd samples selected to generate the “odd sequence”.

<u>Even Samples Synthesis</u>
The real data stream of each received echo shall be multiplied by the basic pattern [0 1 0 -1] and even samples selected to generate the “even sequence”.

.

<u>Q Syntheses</u>

The “odd sequence” shall be filtered by a ¼ sample interpolator. The interpolator is implemented as a 8 taps FIR filter whose weighting coefficients are reported in the second column of table 2.1.1. The FIR filter structure is shown in figure 2.1.2

<u>I Synthesis</u>

The “even sequence” shall be filtered by a ¾ sample interpolator. The interpolator is implemented as a 8 taps FIR filter whose weighting coefficients are extracted form P.T. and the default values are reported in the third column of table 2.1.1. The FIR filter structure is shown in figure 2.1.2

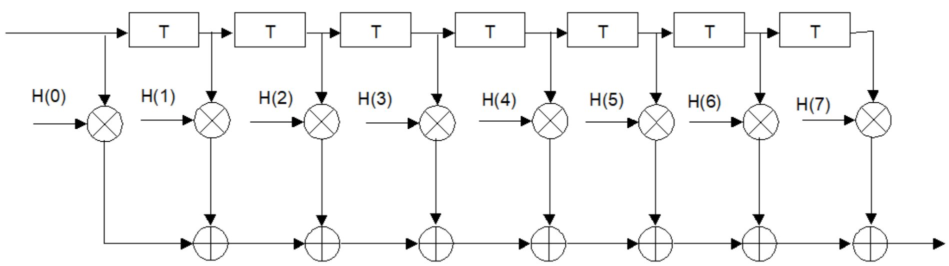

Fig. 5.2.2 FIR filter

	¾ Interpolator	**¼ Interpolator**
H(0)	-0.005660847	-0.015062067
H(1)	0.030040974	0.053058197
H(2)	-0.088921657	-0.149882026
H(3)	0.281224221	0.893889519
H(4)	0.893889519	0.281224221
H(5)	-0.149882026	-0.088921657
H(6)	0.053058197	0.030040974
H(7)	-0.015062067	-0.005660847

Table 5.2.1 FIR filter coefficients

The generic demodulated echo, will be represented in the time and frequency domains with the following equations:

$$V(t) = I(t) + jQ(t) \quad (30)$$
$$V(f) = fftshift(fft(V(t))) \quad (31)$$

.

5.2.1 On-Board Function Demodulator

```
function [I_ob,Q_ob] = MI_FUN_CERTIF_OnBoard_Demod_IQ_01(V)

% V(1,980) Input Signal

n=size(V,2); % Signal's samples

TAPS=8;
fir_I=[-0.005660847 0.030040974 -0.088921657 0.281224221 0.893889519 -0.149882026
0.053058197 -0.015062067];

fir_Q=[-0.015062067 0.053058197 -0.149882026 0.893889519 0.281224221 -0.088921657
0.030040974 -0.005660847];

Delay_I = zeros(1,TAPS); Delay_Q = zeros(1,TAPS);
I_chan = zeros(1,512); Q_chan = zeros(1,512);

j=1; qc=1; ic=1;

for i = 1:(n/4)
    Q_chan(qc) = V(j)*1.0;  qc=qc+1;j=j+1;
    I_chan(ic) = V(j)*1.0;  ic=ic+1;j=j+1;
    Q_chan(qc) = V(j)*-1.0; qc=qc+1;j=j+1;
    I_chan(ic) = V(j)*-1.0; ic=ic+1;j=j+1;
end

qc=1; ic=1; di=1; dq=1; fq=1; fi=1;

for i = 1:(n/2)
    f13 = 0;
    f0  = Q_chan(qc);
    qc=qc+1;
    f1 = I_chan(ic);
    ic=ic+1;

    f12 = 0;
    Delay_Q(dq) = f0;
    Delay_I(di) = f1;

    f8 = 0;
    f0 = Delay_Q(dq);
    dq=dq+1;
    f4 = single(fir_Q(fq));
    fq=fq+1;

    f9 = 0;
    f5 = single(fir_I(fi));
    fi=fi+1;
    f1 = Delay_I(di);
    di=di+1;
```

.

```
    for x = 1:(TAPS-1)
        f13 = f1 * f5;
        f9 = f9 + f13;
        f5 = single(fir_I(fi));
        fi=fi+1;
        f1 = Delay_I(di);
        di=di+1;
        f12 = f0 * f4;
        f8 = f8 + f12;
        f0 = Delay_Q(dq);
        dq=dq+1;
        f4 = single(fir_Q(fq));
        fq=fq+1;
    end

    f12 = f0 * f4;
    f8 = f8 + f12;
    f8 = f8 + f12;
    f13 = f1 * f5;
    f9 = f9 + f13;
    f9 = f9 + f13;
    Q_chan(qc-1) = f8;
    I_chan(ic-1) = f9;

    Delay_Q(8) = Delay_Q(7);
    Delay_I(8) = Delay_I(7);

    Delay_Q(7) = Delay_Q(6);
    Delay_I(7) = Delay_I(6);

    Delay_Q(6) = Delay_Q(5);
    Delay_I(6) = Delay_I(5);

    Delay_Q(5) = Delay_Q(4);
    Delay_I(5) = Delay_I(4);

    Delay_Q(4) = Delay_Q(3);
    Delay_I(4) = Delay_I(3);

    Delay_Q(3) = Delay_Q(2);
    Delay_I(3) = Delay_I(2);

    Delay_Q(2) = Delay_Q(1);
    Delay_I(2) = Delay_I(1);

    di=1; dq=1; fq=1; fi=1;
end

Q_ob = single(Q_chan);
I_ob = single(I_chan);
```

.

5.3 ANNEX 3: RECEIVING WINDOW RESIZE TECHNIQUE

A more detailed diagram of the signal window resize function is shown in fig. 5.3.1.

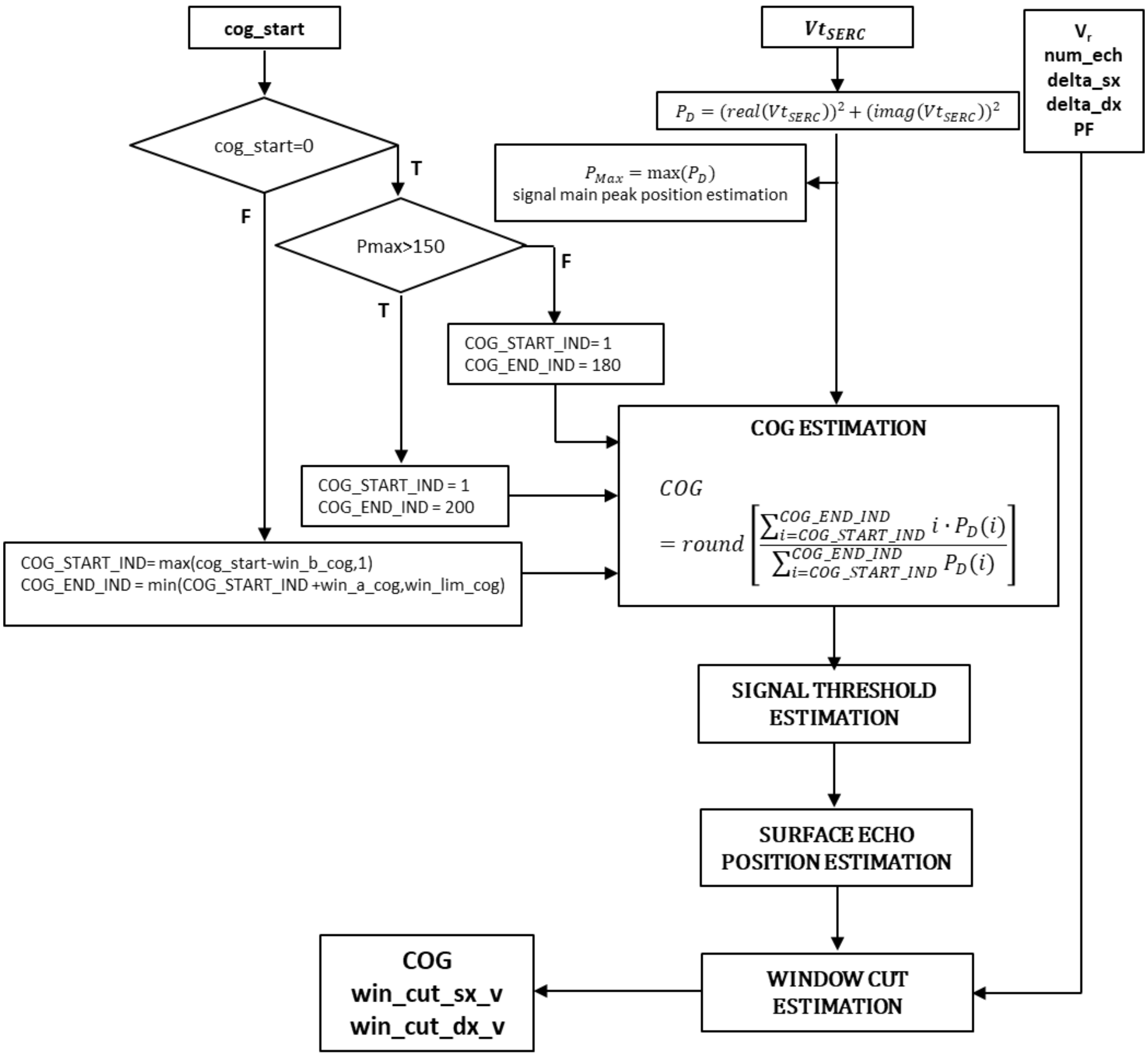

Fig. 5.3.1 Signal window resize diagram

.

In the following figures are represented some results obtained applying the window resize algorithm. The upper radargram shows the original echoes after range compression and the lower part of the figures shows the same radargram after Window Resize. In the last cases the samples selected by the algorithm are untouched, while the others are set to zero and appear black. During these test was applied a resized window of 70 samples, distributed as follows: 8 samples before the surface echo edge and 62 samples after.

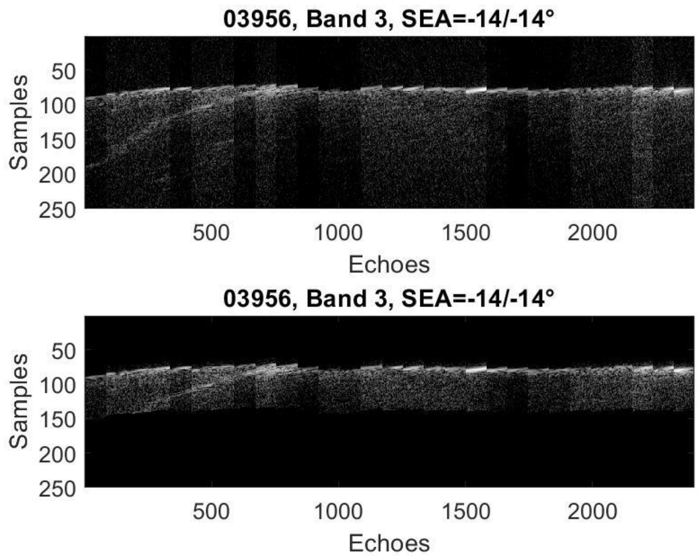

Fig. 5.3.2 Orbit 3965 Raw Echoes from FM
“Resize Window Test Results”

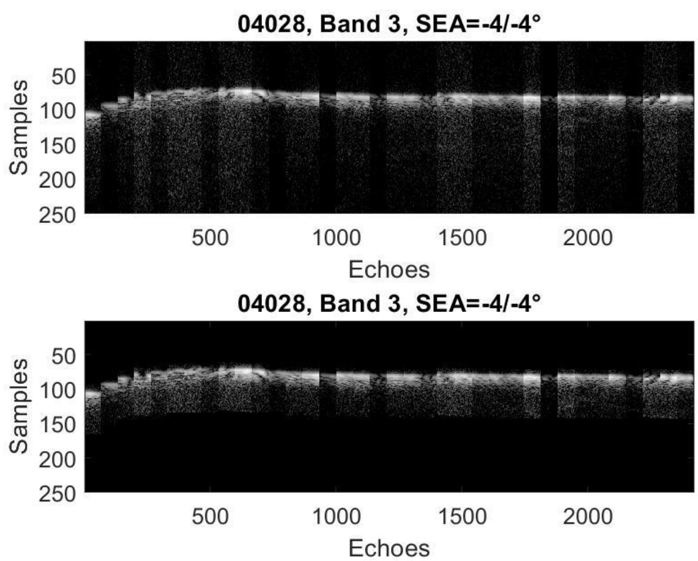

Fig. 5.3.3 Orbit 4028 Raw Echoes from FM
“Resize Window Test Results”

.

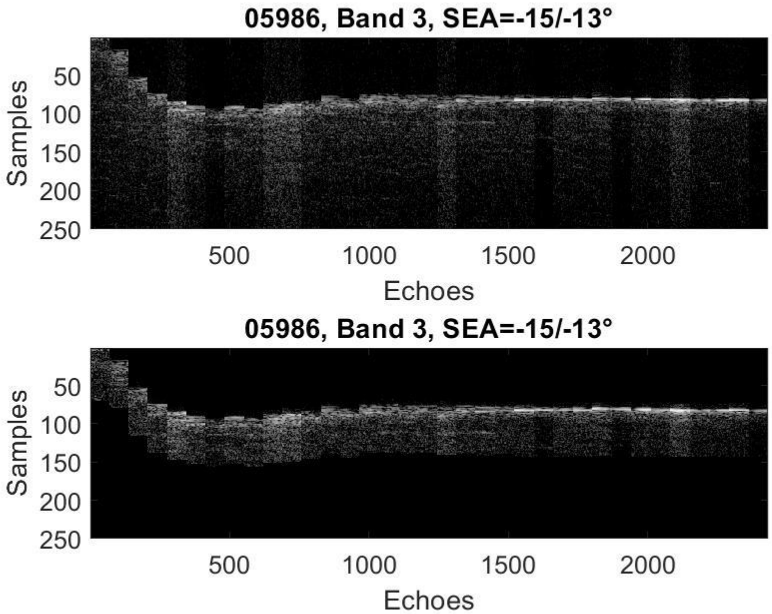

Fig. 5.3.4 Orbit 5986 Raw Echoes from FM
"Resize Window Test Results"

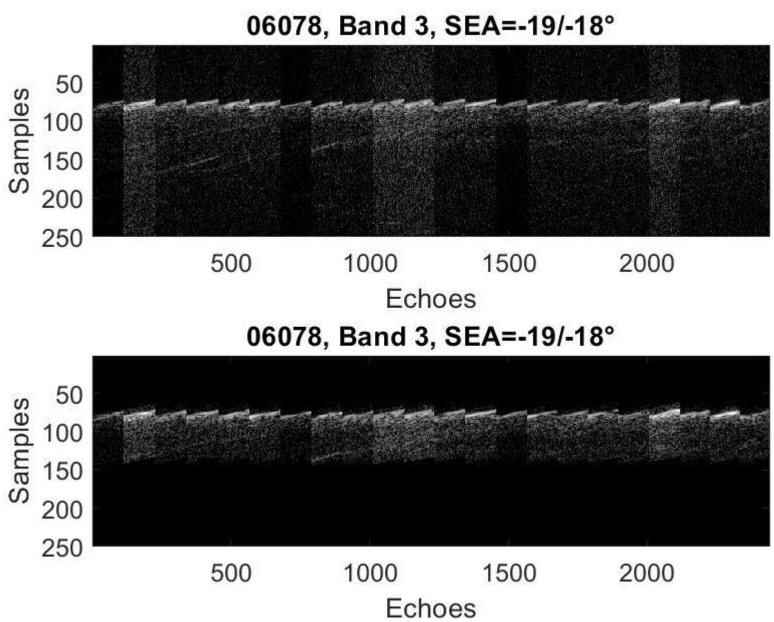

Fig. 5.3.4 Orbit 5986 Raw Echoes from FM
"Resize Window Test Results"

.

```
function [win_cut_sx_v,win_cut_dx_v,COG] =
Fun_Test_COG_v05(signal,delta_sx,delta_dx,cog_start,Vr,num_ech,PF)

% ----------------------------- Descrizione -------------------------------

% Funzione per individuare, in modo approssimato il fronte di salita del segnale.
% La funzione esegue prima un Loop di COG, per stimare il baricentro del segnale.
% Successivamente, usa i valori del COG per delimitare un intervallo in cui stima
% il valore medio del segnale. Tale valore è usato come soglia per individuare,
% approssimativamente, il fronte di salita del segnale. In pratica, viene
% considerato come fronte di salita del segnale, il primo campione che supera la
% soglia.

%% INPUT
% Vettore Segnale in tempo complesso: signal(512,1)
% Numero di campioni da tagliare a sinistra del fronte di salita: delta_sx
% Numero di campioni da tagliare a destra del fronte di salita: delta_dx
% COG stimato nel loop precedente (zero per il primo loop di una OST): cog_start
% Velocità radiale del primo eco, degli N componenti il segnale: Vr
% Numero di echi integrati nel segnale di ingresso: num_ech
% Fattore di pre-summing applicato ai dati da inviare alle FM: PF

%% OUTPUT
% Vettore che individua l'estremo di sinistra della finestra di taglio:
win_cut_sx_v(1,num_ech/PF)
% Vettore che individua l'estremo di destra della finestra di taglio:
win_cut_dx_v(1,num_ech/PF)
% Campione che individua il baricentro del segnale in input: COG

%% PARAMETRI
winbcog             =   60;                  % delta da sottrarre al valore di COG
per stimare COG_START_IND dal 2nd Loop
winacog             =   130;                 % delta da aggiungere al valore di COG
per stimare COG_END_IND dal 2nd Loop
winlimcog           =   130;                  % campione limite per stimare il COG
dal 2nd Loop
winbfss             =   60;                   % delta da sottrarre al valore di COG
per calcolare l'inizio dell'intervallo in cui si stima la soglia per individuare il
fronte di salita del segnale
winafss             =   60;                   % delta da aggiungere al valore di
start_rx1 per calcolare la fine dell'intervallo in cui si stima la soglia per
individuare il fronte di salita del segnale
wintot              =   delta_sx+delta_dx;      % dimensione totale della finestra di
taglio
fs                  =   1.4e6;                % Sampling frequency of the reference
functions
c                   =   3e8;
PRF                 =   127.27;
PRI                 =   1/PRF;
```

.
```
%% INIZIALIZZAZIONE VARIABILI
dim                     =   size(signal);
%% INIZIALIZZAZIONE VETTORE RIFERIMENTO FINASTRA DI TAGLIO CON FATTORE DI PRE-
SUMMING
vetnumec                =   1:PF:num_ech;
delta                   =   round(((2*Vr*PRI*vetnumec)/c)*fs);
%% STIMA POTENZA DEL SEGNALE
PD                      =   real(signal).^2+imag(signal).^2;

%% COG LOOP
% Questo loop serve per individuare, approssimativamente, il
% baricentro del segnale.
% Nel primo loop il COG è calcolato in un intervallo fisso 1-180.
% Tranne nel caso in cui il massimo del segnale sia oltre il campione 150.
% In questo caso, l'intervallo è 1-200.
% Dal secondo loop, il COG viene stimato in un intervallo ridotto, a cavallo
% del baricentro stimato nel loop precedente, della dimensione di 130
% campioni.

if cog_start==0
    COG_START_IND          =   1;          % campione start 1st Loop COG
    [~,P]               =   max(PD);% Check sulla posizione del massimo del primo eco
(introdotta nella versione 02)
    if   P(1,1)>150
        COG_END_IND =   200;        % campione end 1st Loop COG
    else
    COG_END_IND       =   180;        % campione end 1st Loop COG
    end
else
    COG_START_IND     =   max(cog_start-winbcog,1);        % campione start per gli
altri Loop COG
    COG_END_IND       =   min(COG_START_IND+winacog,winlimcog);  % campione end per
gli altri Loop COG
End

%%
temp                    =   0;
temp1                   =   0;
for i = COG_START_IND:COG_END_IND
    num1                =    (i*(PD(i,1)));
    temp                =   temp+num1;
    temp1               =   temp1+PD(i,1);
end
COG                     =   round((temp/temp1));

%% Front Surface Sample
% Questo loop serve per individuare, approssimativamente, il fronte di
% salita del segnale
% A partire dai valori stimati dal COG, si considera un intervallo di 60
% campioni a cavallo del baricentro, attualmente -50/+10.
```

.

```
% Si stima il valore medio di questi 60 campioni che, molto probabilmente,
% racchiudono la maggior parte dell'energia del segnale.
% Il valore medio viene considerato come una soglia per discriminare il
% segnale utile dal rumore.
% In pratica, il primo campione che supera tale soglia, viene considerato
% come indicativo del fronte di salita del lobo principale del segnale.

buffer              =   PD;
start_rx1           =   max(COG-winbfss,1);
stop_rx1            =   start_rx1+winafss;
buffer1             =   buffer(start_rx1:stop_rx1,1);
thresh              =   mean(buffer1);
pos1                =   find(buffer1>thresh);
pos2                =   pos1(1,1)+start_rx1;
wincutsx            =   max(pos2-delta_sx,1);
%%
wincutdx            =   wincutsx+wintot-1;
if wincutdx>=dim(1,1)
    wincutsx        =   dim(1,1)-wintot+1;
    wincutdx        =   dim(1,1);
end

%% RIMOZIONE DELLA COMPENSAZIONE DI FASE DALLA FINESTRA DI TAGLIO
win_cut_sx_v        =   wincutsx+delta;
win_cut_dx_v        =   wincutdx+delta;
x+delta;
```

.

5.4 ANNEX 4: ON-BOARD REFERENCE FUNCTIONS

```
function [ Ref_Fun_Real_Comp, Ref_Fun_Imag_Comp ] = OnBoardRefFunGenerator(BND)

% Description: Ideal Chirp generator to be used for the MARSIS on-board compression
%
% Input: BND = Transmitted band (1,2,3,4)
%
% Output
%    Ref_Fun_real_comp: [512x1] Real component of the ideal_chirp
%    Ref_Fun_imag_comp: [512x1] Imaginary component of the ideal_chirp
%
% Parameters
%    B   :  Radar Band (1MHz)
%    fs  :  Equivalent sampling rate of the I/Q data stream (1.4MHz)
%    Ns  :  Number of samples (512)
%    tau :  Tx Pule length (250us)

% ------------------------- PARAMETER DEFINITION  -------------------------
B    = 1e6;
fs   = 1.4e6;
Ns   = 512;
tau  = 250e-6;
% ------------------------ SIGNAL TIMING DEFINITION -----------------------
dt = 1 / fs;

t  = dt * ( ( 1 : Ns ) - 1 );
% ---------------------- REFERENCE FUNCTION DEFINITION ----------------------
chirp                      = exp( pi .* 1i .* B ./ tau * ( t - tau/2 ).^2 );

chirp( t > tau )           = 0;

ideal_chirp                = conj( transpose( fft( chirp ) ) );

ideal_chirp                = ideal_chirp ./ sqrt( sum( abs( ideal_chirp ).^2 ) );

ideal_chirp               = fftshift(ideal_chirp);

If BND == 1

      ideal_chirp = conj(ideal_chirp(end:-1:1,1));

end


Ref_Fun_Real_Comp      = real(ideal_chirp);

Ref_Fun_Imag_Comp      = imag(ideal_chirp);
```

.

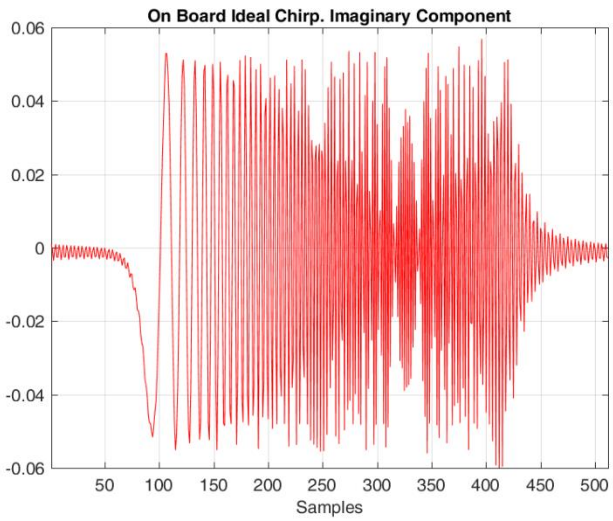

Fig. 5.4.1 On-Board Ideal Chirp (Imaginary Component)

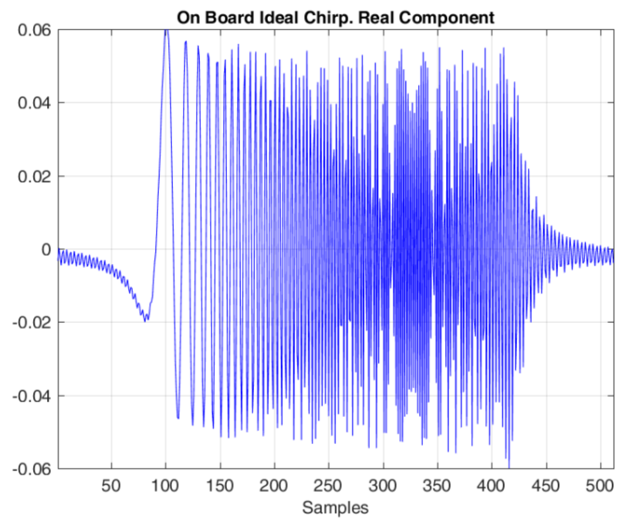

Fig. 5.4.2 On-Board Ideal Chirp (Real Component)

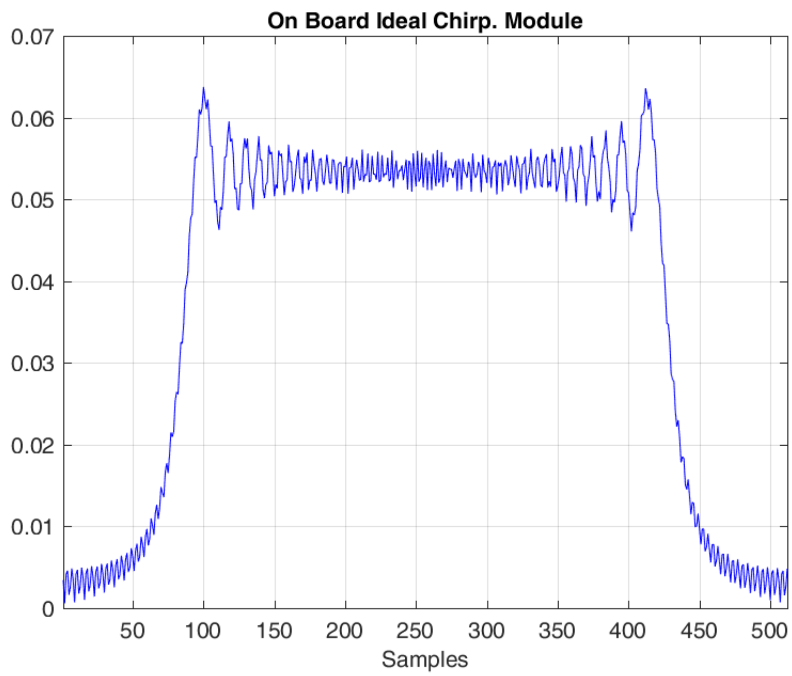

Fig. 5.4.3 On-Board Ideal Chirp (Module)

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5.4.1 *ON-BOARD REFERENCE FUNCTION COEFFICIENTS FOR BANDS: B2, B3 AND B4*

Reference Function Real Component	**32 bit float (HEX)**	**Reference Function Imaginary Component**	**32 bit float (HEX)**
-0.00489436894096521770	0xBBA060F1	-0.00244200885189165130	0xBB200A1C
-0.00262435291562209460	0xBB2BFD55	0.00147403056770454750	0x3AC13442
-0.00003023729789808469	0xB7FDA61A	-0.00216466693143469370	0xBB0DDD15
-0.00440365020672655190	0xBB904C7E	-0.00311435518390244800	0xBB4C1A35
-0.00359206387159877140	0xBB6B68D4	0.00118067503407080190	0x3A9AC0E1
-0.00008109424879259408	0xB8AA1124	-0.00129233220997643880	0xBAA96379
-0.00376780577245703140	0xBB76ED4A	-0.00353729237907209410	0xBB67D1EB
-0.00440533981874041780	0xBB905AAB	0.00064629818496069076	0x3A296C56
-0.00042535354587646605	0xB9DF01FC	-0.00047466509653947383	0xB9F8DC78
-0.00307905904916605300	0xBB49CA09	-0.00368449230747163080	0xBB717785
-0.00500525038242014690	0xBBA40315	-0.00005780370793273049	0xB8727242
-0.00102393529919905970	0xBA863591	0.00020480186752279951	0x3956C015
-0.00243059437961607850	0xBB1F4A9B	-0.00355974481449883260	0xBB694A9B
-0.00536005454597082360	0xBBAFA365	-0.00084771777369892914	0xBA5E3960
-0.00181575874349304950	0xBAEDFEC0	0.00068171507408799372	0x3A32B51F
-0.00190741453663713540	0xBAFA0236	-0.00319486167264537320	0xBB5160E2
-0.00546705134322509390	0xBBB324F3	-0.00163613886465773590	0xBAD673B5
-0.00272542920830484360	0xBB329D1D	0.00091618406316255202	0x3A702C12
-0.00157853660900103490	0xBACEE6E6	-0.00264495463334651210	0xBB2D56F9
-0.00535152510259262300	0xBBAF5BD8	-0.00234147334392315140	0xBB197367
-0.00367200606646092290	0xBB70A609	0.00089534364877147539	0x3A6AB57E
-0.00149124063289468200	0xBAC375BB	-0.00198167702881884250	0xBB01DF06
-0.00506303574739457900	0xBBA5E7D2	-0.00289594935237795550	0xBB3DC9F7
-0.00457796171927770100	0xBB9602B9	0.00063305281300373155	0x3A25F374
-0.00166786289130457330	0xBADA9C31	-0.00128519823995148310	0xBAA87418
-0.00466955847018796570	0xBB990318	-0.00325199667448227780	0xBB551F73
-0.00537746294847804130	0xBBB0356D	0.00016686732356031896	0x392EF91B
-0.00210536434916441980	0xBB09FA27	-0.00063578226471910405	0xBA26AAA0
-0.00425017506195825200	0xBB8B450D	-0.00338636596491700710	0xBB5DEDCB
-0.00602321299664487510	0xBBC55E5F	-0.00044732520244834286	0xB9EA86F8
-0.00277763115187557850	0xBB3608EA	-0.00010585957486870768	0xB8DE00ED
-0.00388714384353505560	0xBB7EBF73	-0.00330171414073178030	0xBB586192
-0.00649127289048855890	0xBBD4B4BE	-0.00114241990547112080	0xBA95BD40
-0.00364020576921791040	0xBB6E9084	0.00024658109828053194	0x3981478E
-0.00365821639820931980	0xBB6FBEAF	-0.00302566693497428960	0xBB464A44
-0.00678351387828494530	0xBBDE483D	-0.00184824656504436160	0xBAF240DD
-0.00463692872647112910	0xBB97F160	0.00038258432847389733	0x39C89599
-0.00363002460701224720	0xBB6DE5B4	-0.00260765777244865130	0xBB2AE53C
-0.00692761356298510300	0xBBE30108	-0.00250001319679060960	0xBB23D742
-0.00570781029901190960	0xBBBB0895	0.00028428107161742656	0x39950B8F
-0.00385323463867482190	0xBB7C868C	-0.00211411472716877250	0xBB0A8CF5
-0.00697476551629100120	0xBBE48C92	-0.00304636527051630690	0xBB47A587
-0.00679735733312269480	0xBBDEBC5D	-0.00004592962733608523	0xB840A48F
-0.00435996223011012910	0xBB8EDE03	-0.00162281204946453200	0xBAD4B489
-0.00699548937476807040	0xBBE53A6B	-0.00345656325531414150	0xBB628782
-0.00786254525284381040	0xBC00D1E7	-0.00058923817474685952	0xBA1A771A

-0.00516366851807407120	0xBBA933FD	-0.00121741742243231060	0xBA9F91C0
-0.00707405950667756250	0xBBE7CD83	-0.00372657247738308020	0xBB743982
-0.00887961783034075730	0xBC117BD1	-0.00131739033045263690	0xBAACAC48
-0.00626139416975946080	0xBBCD2C61	-0.00098345882102737064	0xBA80E766
-0.00730204911956849540	0xBBEF4607	-0.00388426110162791520	0xBB7E8F16
-0.00984884667961802990	0xBC215D0E	-0.00220283684152675070	0xBB105D78
-0.00763769050699527730	0xBBFA4597	-0.00100711619841217730	0xBA840136
-0.00777120655291156470	0xBBFEA59A	-0.00399439623922258430	0xBB82E36C
-0.01079615398177362900	0xBC30E25A	-0.00323226682348661580	0xBB53D470
-0.00926884903967494130	0xBC17DC5E	-0.00137839795676486930	0xBAB4AB5C
-0.00856516242314755810	0xBC0C54E5	-0.00416464281535199300	0xBB88778E
-0.01176986343895761700	0xBC40D662	-0.00442389885570226330	0xBB90F65A
-0.01112478682558425800	0xBC3644BC	-0.00220027315778208510	0xBB103275
-0.00974802599931605570	0xBC1FB62F	-0.00455408126517997760	0xBB953A67
-0.01282944370145244800	0xBC523296	-0.00584884196175556110	0xBBBFA7A4
-0.01316386777485822200	0xBC57AD43	-0.00360480576732873350	0xBB6C3E9A
-0.01134539658114676300	0xBC39E20A	-0.00538527742212680220	0xBBB076FB
-0.01402054113701791200	0xBC65B669	-0.00765576762919400150	0xBBFADD3B
-0.01531269728722198600	0xBC7AE21B	-0.00577527612448476560	0xBBBD3E87
-0.01330946737762461800	0xBC5A0FF3	-0.00695831068652483580	0xBBE4028A
-0.01532678576633102900	0xBC7B1D32	-0.01009433952830352700	0xBC2562BA
-0.01741876932806955800	0xBC8EB1CE	-0.00896756844624568670	0xBC12ECB5
-0.01545548191411885500	0xBC7D38FD	-0.00965777645567915570	0xBC1E3BA6
-0.01658520043131394100	0xBC87DDAF	-0.01352320799727291900	0xBC5D9072
-0.01916117377355599400	0xBC9CF7E4	-0.01351119642148744400	0xBC5D5E10
-0.01735559854464986000	0xBC8E2D54	-0.01392767359470093200	0xBC6430E5
-0.01735407771020728800	0xBC8E2A23	-0.01836876426071976800	0xBC967A17
-0.01991119238467864100	0xBCA31CCC	-0.01974636944089512600	0xBCA1C323
-0.01818887894174009800	0xBC9500D8	-0.02016122887369326700	0xBCA52929
-0.01674385821482084500	0xBC892A6A	-0.02496995125611006800	0xBCCC8DC8
-0.01856818031735184600	0xBC981C4B	-0.02782024490254483800	0xBCE3E748
-0.01659421231615529300	0xBC87F095	-0.02841967940010914400	0xBCE8D063
-0.01328797195260715500	0xBC59B5CB	-0.03321586156781437800	0xBD080D5A
-0.01348427577160955600	0xBC5CED26	-0.03724645920352089000	0xBD188FBE
-0.01068458166550736500	0xBC2F0E62	-0.03789237323969435500	0xBD1B3508
-0.00506658962317605220	0xBBA605A2	-0.04190954566417400700	0xBD2BA958
-0.00275005543824105800	0xBB343A46	-0.04619968646879182800	0xBD3D3BE1
0.00144495952383675650	0x3ABD64CB	-0.04613450126892940800	0xBD3CF787
0.00952723994286559620	0x3C1C1823	-0.04798942750888504600	0xBD44908F
0.01472835577689001600	0x3C714F33	-0.05080573053999611100	0xBD5019AB
0.02027501842208167700	0x3CA617CB	-0.04851219878725718200	0xBD46B4BA
0.02997503225332343400	0x3CF58E32	-0.04624561552635304100	0xBD3D6C0A
0.03706423628595961800	0x3D17D0AB	-0.04530029942619825300	0xBD398CCE
0.04239364199166555800	0x3D2DA4F4	-0.03897800186167867100	0xBD1FA765
0.05100553607906800600	0x3D50EB2E	-0.03088860932019985700	0xBCFD0A1B
0.05683057761284828600	0x3D68C72E	-0.02458568296076824000	0xBCC967EA
0.05830412456469916100	0x3D6ED04E	-0.01375588317996242500	0xBC61605B
0.06119257252966656800	0x3D7AA510	-0.00040293571599511405	0xB9D3411D
0.06096589242020368500	0x3D79B75F	0.00981461383708665330	0x3C20CD79
0.05418412638564015100	0x3D5DF02C	0.02186627949571650100	0x3CB320E9
0.04711968658937240600	0x3D410092	0.03535277881207665700	0x3D10CE13
0.03780813757479674400	0x3D1ADCB4	0.04313739921126936300	0x3D30B0D7
0.02199531324616442100	0x3CB42F83	0.04847185476456500300	0x3D468A6C
0.00639717937180264880	0x3BD19F6E	0.05297348159107299900	0x3D58FAB8
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0.00134213809591311780	0x3AAFEAAE	-0.00254283757612959720	0xBB26A5BC
-0.00442477360264114960	0xBB90FDB0	-0.00360374518234512920	0xBB6C2CCF
-0.00314708914400936960	0xBB4E3F64	0.00198524588944732750	0x3B021AE6
0.00134995571081805360	0x3AB0F0FF	-0.00139260002715809450	0xBAB687E7
-0.00350497449169646920	0xBB65B3B6	-0.00414294146376503830	0xBB87C183
-0.00411202770293031540	0xBB86BE30	0.00129259442707274070	0x3AA96C45
0.00099116489432346500	0x3A81E9F9	-0.00032860227349915583	0xB9AC4840

-0.00252363306291757000	0xBB256389	-0.00432286349808919370	0xBB8DA6CE
-0.00478533237713168160	0xBB9CCE47	0.00039583106553664439	0x39CF878B
0.00032457793023018378	0x39AA2C1C	0.00054852690004332755	0x3A0FCB04
-0.00159580993330398540	0xBAD12A7E	-0.00415669471085295360	0xBB8834E1
-0.00513349258359317980	0xBBA836DB	-0.00059670060180340445	0xBA1C6BE6
-0.00056642915912882342	0xBA147C6A	0.00116441265272177540	0x3A989F34
-0.00082290593249562192	0xBA57B848	-0.00369049349274404910	0xBB71DC34
-0.00515830632306776400	0xBBA90702	-0.00157582335053615010	0xBACE8BDB
-0.00158360627069145990	0xBACF9102	0.00147610582197159490	0x3AC179E4
-0.00028407690126272062	0xB994F028	-0.00299654712201004050	0xBB4461B7

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5.4.2 ON-BOARD REFERENCE FUNCTION COEFFICIENTS FOR BAND: B1

Reference Function Real Component	32 bit float (HEX)	Reference Function Imaginary Component	32 bit float (HEX)
-0.00028407690126272062	0xB994F028	0.00299654712201004050	0x3B4461B7
-0.00158360627069145990	0xBACF9102	-0.00147610582197159490	0xBAC179E4
-0.00515830632306776400	0xBBA90702	0.00157582335053615010	0x3ACE8BDB
-0.00082290593249562192	0xBA57B848	0.00369049349274404910	0x3B71DC34
-0.00056642915912882342	0xBA147C6A	-0.00116441265272177540	0xBA989F34
-0.00513349258359317980	0xBBA836DB	0.00059670060180340445	0x3A1C6BE6
-0.00159580993330398540	0xBAD12A7E	0.00415669471085295360	0x3B8834E1
0.00032457793023018378	0x39AA2C1C	-0.00054852690004332755	0xBA0FCB04
-0.00478533237713168160	0xBB9CCE47	-0.00039583106553664439	0xB9CF878B
-0.00252363306291757000	0xBB256389	0.00432286349808919370	0x3B8DA6CE
0.00099116489432346500	0x3A81E9F9	0.00032860227349915583	0x39AC4840
-0.00411202770293031540	0xBB86BE30	-0.00129259442707274070	0xBAA96C45
-0.00350497449169646920	0xBB65B3B6	0.00414294146376503830	0x3B87C183
0.00134995571081805360	0x3AB0F0FF	0.00139260002715809450	0x3AB687E7
-0.00314708914400936960	0xBB4E3F64	-0.00198524588944732750	0xBB021AE6
-0.00442477360264114960	0xBB90FDB0	0.00360374518234512920	0x3B6C2CCF
0.00134213809591311780	0x3AAFEAAE	0.00254283757612959720	0x3B26A5BC
-0.00195854837092499820	0xBB005AFD	-0.00237732015453657850	0xBB1BCCD0
-0.00516477544876639290	0xBBA93D46	0.00272881162922770190	0x3B32D5DC
0.00094134907458474763	0x3A76C4DD	0.00366048230719680930	0x3B6FE4B3
-0.00064478965986575752	0xBA29071A	-0.00239480453613117590	0xBB1CF227
-0.00561496120564506950	0xBBB7FDB5	0.00157894404271687030	0x3ACEF492
0.00015892419909567298	0x3926A4E3	0.00461879123431211710	0x3B97593A
0.00067275942596055761	0x3A305C1E	-0.00199521825747071790	0xBB02C235
-0.00568490360240835650	0xBBBA486D	0.00024925831714201337	0x3982AEE2
-0.00095409892654334770	0xBA7A1C7E	0.00529477551028345680	0x3BAD7FCB
0.00185952852852733570	0x3AF3BB6C	-0.00117427926084838850	0xBA99EA46
-0.00531397880561894960	0xBBAE20E2	-0.00113714192565155270	0xBA950C26
-0.00230854306284977150	0xBB174AEC	0.00558120269894075290	0x3BB6E285
0.00277947965665063190	0x3B3627EE	0.00003055983838747099	0x38002D60
-0.00447943929269916180	0xBB92C842	-0.00243840668274593630	0xBB1FCDAC
-0.00378221021727593400	0xBB77DEF5	0.00539783594151693570	0x3BB0E054
0.00330754245558233370	0x3B58C35A	0.00154015037733229330	0x3AC9DEDF
-0.00320152255748812000	0xBB51D0A2	-0.00350534747655845400	0xBB65B9F8
-0.00522820684794216530	0xBBAB5160	0.00470084344104458080	0x3B9A0988
0.00334168544845048900	0x3B5B002D	0.00323737812842204080	0x3B542A31
-0.00154502427623298970	0xBACA8269	-0.00419402642952786470	0xBB896E0B
-0.00648580448410762760	0xBBD486DF	0.00348944635380756850	0x3B64AF31
0.00281348904784962770	0x3B386283	0.00497435357758347140	0x3BA2FFE6
0.00038292031352642842	0x39C8C2B1	-0.00437838672273185150	0xBB8F7891
-0.00739289288460782090	0xBBF24014	0.00180909650526412990	0x3AED1F34
0.00169617628163235150	0x3ADE523B	0.00658248906314786930	0x3BD7B1EB
0.00243875541028942170	0x3B1FD386	-0.00396172457960652750	0xBB81D15A
-0.00779888347331826170	0xBBFF8DC6	-0.00024923422733963267	0xB982ABA6
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0.00445168587080486520	0x3B91DF72	-0.00288583967896048010	0xBB3D205B

-0.00757681009188840730	0xBBF846E3	-0.00255374414627969810	0xBB275CB7
-0.00218097266677231940	0xBB0EEEA6	0.00870784062339683040	0x3C0EAB54
0.00623537306723078930	0x3BCC5219	-0.00113682492680905510	0xBA950183
-0.00663335874111712150	0xBBD95CA5	-0.00494023860373706170	0xBBA1E1B9
-0.00476499164172765330	0xBB9C23A5	0.00889646703603649660	0x3C11C27C
0.00760116451859620210	0x3BF91330	0.00125335441076325800	0x3AA44798
-0.00491563516176049980	0xBBA11356	-0.00722380672224740530	0xBBECB5AE
-0.00759845290421697250	0xBBF8FC71	0.00832274011842086200	0x3C085C1A
0.00837176304477181900	0x3C0929B8	0.00421012196613127030	0x3B89F510
-0.00241364007618102790	0xBB1E2E29	-0.00921306673681563520	0xBC16F267
-0.01051459910204122000	0xBC2C456C	0.00689519921253682090	0x3BE1F11F
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0.00084233752758717324	0x3A5CD050	-0.01072632903386872900	0xBC2FBD7C
-0.01334095318671759700	0xBC5A9403	0.00456317280542293740	0x3B9586AA
0.00755212961564119810	0x3BF777DA	0.01136870167093388200	0x3C3A43CA
0.00478985308723485060	0x3B9CF433	-0.01160933003663348900	0xBC3E350F
-0.01592014882147625000	0xBC826AF8	0.00131727494058265000	0x3AACA869
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0.00934784995398028720	0x3C1927B9	-0.01175490156165184300	0xBC4097A1
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-0.01994118266684757500	0xBCA35BB0	-0.00776500236521368140	0xBBFE718F
-0.00056200316511314109	0xBA135364	0.02343900939807036200	0x3CC0032A
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-0.02140142621488831000	0xBCAF520B	-0.01343705583848347000	0xBC5C2718
-0.00490896723062268610	0xBBA0DB66	0.02760935944575124100	0x3CE22D05
0.02596606494243525900	0x3CD4B6C8	-0.00794191023998333000	0xBC021EC9
-0.02273253861209982600	0xBCBA3996	-0.01967452520138411900	0xBCA12C78
-0.00969284989414815130	0xBC1ECEC2	0.03201237272781797000	0x3D031F67
0.03235852149176303400	0x3D048A5E	-0.00599767842300306770	0xBBC4882C
-0.02434544312947821800	0xBCC77018	-0.02621379516847650200	0xBCD6BE50
-0.01439428842683548500	0xBC6BD605	0.03690432057319971400	0x3D1728FC
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-0.02685924722637492900	0xBCDC07EC	-0.03256779370205528000	0xBD0565CE
-0.01815350397803935900	0xBC94B6A8	0.04257257483459780900	0x3D2E6094
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-0.03102433502599793700	0xBCFE26BF	-0.03783178676396491800	0xBD1AF580
-0.01964624374920780400	0xBCA0F128	0.04911386592541879700	0x3D492B9E
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-0.03743996688635380100	0xBD195AA6	-0.04044018290695194900	0xBD25A49A
-0.01707403601100663400	0xBC8BDED9	0.05598528408304769000	0x3D6550D3
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-0.05831683954653661700	0xBD6EDDA3	-0.00832046028292294030	0xBC08528A
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0.01959041774444488000	0x3CA07C15	-0.04949272715977619300	0xBD4AB8E2
-0.05019344539947501200	0xBD4D97A4	0.01810336142059567800	0x3C944D80
0.04316176239985273400	0x3D30CA63	0.02550522159727507500	0x3CD0F053
-0.01277968002042965100	0xBC5161DC	-0.04542216210990979200	0xBD3A0C96
-0.02422059960680382800	0xBCC66A47	0.04151903683419909400	0x3D2A0FDD
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-0.04191464893089800300	0xBD2BAEB1	-0.01973551687397042900	0xBCA1AC60
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-0.04729340292397275100	0xBD41B6BA	0.02271080199440517200	0x3CBA0C00
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-0.02642631347289005300	0xBCD87BFF	-0.04797416229361240600	0xBD44808E
-0.01603054065258762200	0xBC83527A	0.05583799899418706600	0x3D64B662
0.04849030949584678300	0x3D469DC6	-0.02830708905131470300	0xBCE7E444
-0.05614414247959793900	0xBD65F766	-0.01011274272237247200	0xBC25AFEA
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0.00222092632413756990	0x3B118CF5	-0.05210255655909128100	0xBD55697D
-0.03418508776413541800	0xBD0C05A9	0.03961980097422325400	0x3D22485F
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-0.04497230295761292500	0xBD3834E0	-0.01690890231179433000	0xBC8A8489
0.02662353908076174300	0x3CDA199B	0.04092344461324147500	0x3D279F57
-0.00125848431224854630	0xBAA4F3B9	-0.04824391308761198600	0xBD459B68
-0.02859261952426540500	0xBCEA3B11	0.04437005703253087800	0x3D35BD60
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-0.05449965149535739700	0xBD5F3B06	-0.01117794502916789200	0xBC3723B3
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0.04446675780134331400	0x3D3622C6	0.02008187415283223300	0x3CA482BE
-0.03267888143166210200	0xBD05DA4A	-0.03613982383364688200	0xBD14075A
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-0.03733440350551010800	0xBD18EBF5	0.04205604780254416200	0x3D2C42F6
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-0.02431409180024535600	0xBCC72E58	-0.04208507967142476700	0xBD2C6167
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-0.04313174693645379500	0xBD30AAEA	0.03193768230944442300	0x3D02D116
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-0.04898393007294320900	0xBD48A35F	0.01083838756565048100	0x3C31937E
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-0.04302649390852408800	0xBD303C8C	-0.03169250242176242100	0xBD01CFFF
0.03428035736691531500	0x3D0C698F	0.03992848572426990100	0x3D238C0D
-0.02807511008648117000	0xBCE5FDC5	-0.04038277551278437300	0xBD256868
0.02327956882934523200	0x3CBEB4CB	0.04569971508503281600	0x3D3B2F9F
-0.01877565397191462800	0xBC99CF66	-0.04780447300214949600	0xBD43CE9F

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-0.01691476735486036100	0xBC8A90D6	0.05277777741610527300	0x3D582D82
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-0.02017936419031707600	0xBCA54F31	0.04831509277362221200	0x3D45E60B
0.02106053726386602700	0x3CAC8725	-0.04796088481202302100	0xBD4472A1
-0.02281117964313359900	0xBCBADE82	0.05037171555535002700	0x3D4E5292
0.02214184796686876800	0x3CB562D2	-0.04641061191311671200	0xBD3E190D
-0.01880943912437827600	0xBC9A1640	0.04803468208521247100	0x3D44C003
0.01433182986545940600	0x3C6AD00D	-0.04745620752289653900	0xBD426170
-0.01147170704193271700	0xBC3BF3D3	0.05286480458803193700	0x3D5888C3
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