

How to Define RE Requirements for Radiometer Instruments

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Outline

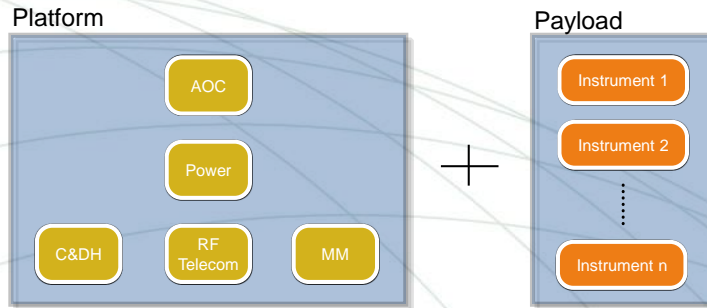
- Spacecraft description
- RE requirement definition
- RE requirement for Radiometers
- Results of a quite conservative requirement
- Conclusions

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Spacecraft description

The Spacecraft is divided in a platform (with several subsystems) plus the payload



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Spacecraft description

The **AOC** subsystem is in charge of the satellite maneuvers. This subsystem use sensors and actuators for orbit tracking and maintenance.

The **Power** subsystem provides from the solar array the energy for each subsystem. Also is in charge for controlling and monitoring each load.

Mass Memory collects all the science data from instruments. This data is downloaded by the RF Subsystem.

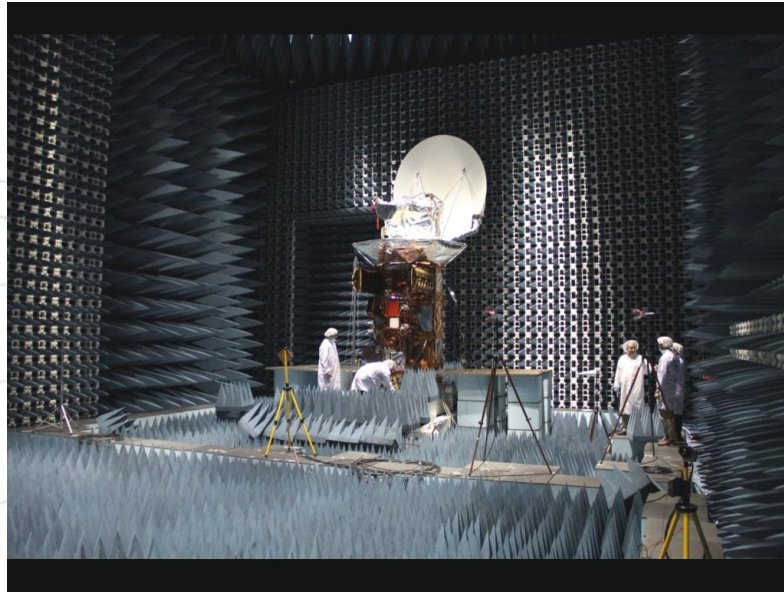
C&DH (Command & Data Handling) subsystem is in charge of receiving and processing all the commands from earth during orbit and to sent the telemetry of the satellite to the earth.

RF Telecom is the RF equipment composed by transmitters and receivers that modulate and demodulate the telemetry and commands who is sent/received to the ground station.

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Spacecraft description



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RE requirement definition

Find who are involved in the electromagnetic environment: implement an **RF Inventory**. This table include all the transmitters and receivers in the spacecraft. It is useful not only to start to define RE requirements but also for PIM analyses purposes.

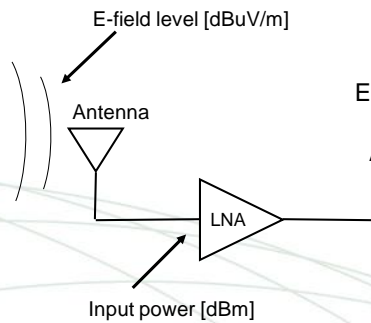
In general for receivers the minimum detectable power at their input is taking in account for this definition plus a margin (6 dB should be enough)

This information in addition with the antenna pattern data the RE requirement could be defined

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RE requirement definition



$$\text{E-field level [dBuV/m]} = V \text{ [dBuV]} + AF \text{ [dBm}^{-1}\text{]}$$

$$AF \text{ [dBm}^{-1}\text{]} = 20 * \text{Log} \left(\frac{9.73}{\lambda * \text{sqrt}(G)} \right)$$

Input power = -120 dBm --> -13 dBuV (for 50 ohms load)

$\lambda = 0.15 \text{ m}$ (assuming a S-Band receiver)

$G = 0 \text{ dBi}$ (assuming that the worst case is when the EMI comes in an angle from the antenna boresight equal or greater than 90°)

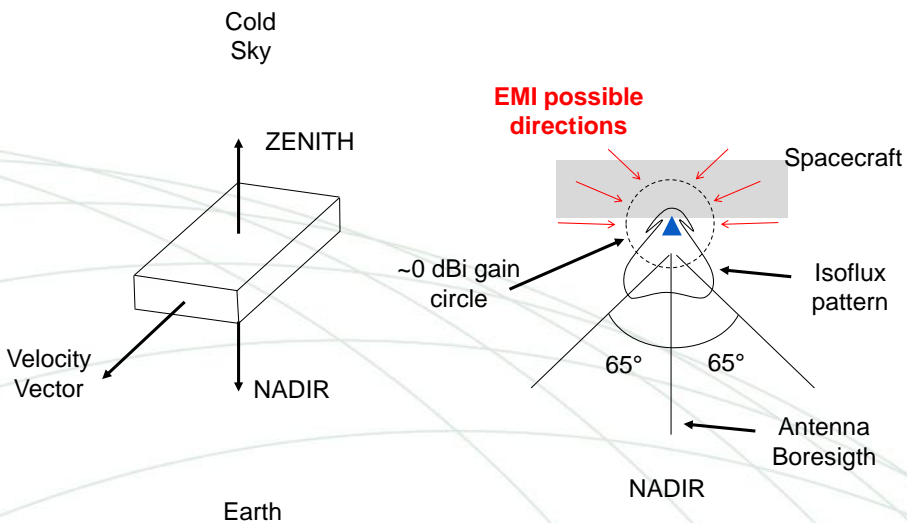
$AF = 36.24 \text{ dBm}^{-1}$

Maximum allowed E-field level = 23.24 dBuV/m

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RE requirement definition



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RE requirement for Radiometers

More important than a receiver threshold for radiometers is the maximum variation introduced by an interference signal with respect to the standard deviation of the noise.

Basically one of the most important figure of merit used to qualify a radiometer is the NE Δ T (Noise Equivalent Delta-Temperature). This figure tell us which is the minimum delta of temperature that the Radiometer can resolve (detection threshold).

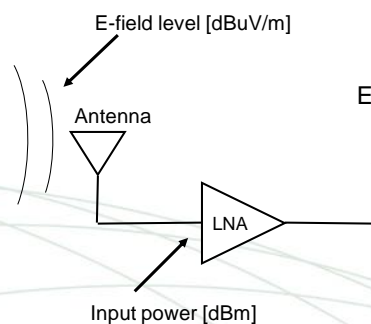
Also this figure tell us which is the amount of "interference power" that should not be overpassed.

$$\Delta T = \frac{P_{EMI}}{\kappa \cdot BW}$$

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RE requirement for Radiometers



$$\text{E-field level [dBuV/m]} = V \text{ [dBuV]} + \text{AF [dBm}^{-1}\text{]}$$

$$\text{AF [dBm}^{-1}\text{]} = 20 * \text{Log} \left(\frac{9.73}{\lambda * \text{sqrt}(G)} \right)$$

Input power = -137.3 --> -30.3 dBuV (for 50 ohms load)

λ = 0.2123 m (in this case the operation frequency is 1413 MHz)

G = 0 dBi (The same assumption can be used as before)

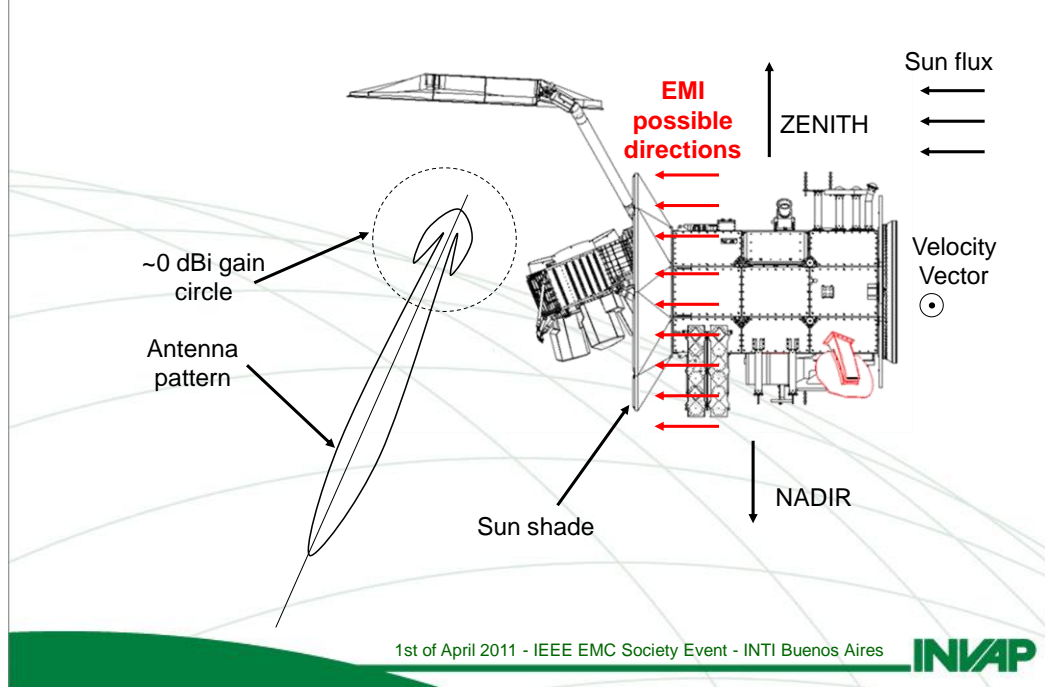
AF = 33.22 dBm⁻¹

Maximum allowed E-field level = 2.92 dBuV/m

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RE requirement for Radiometers



RE requirement for Radiometers

The value adopted by JPL/NASA was 0.05 °K for the Aquarius Radiometer instrument, so:

$$\Delta T = 0.05 \text{ } ^\circ K$$

Taken the equation presented in the previous slide,

Where $\kappa = 1.38 \cdot 10^{-23} \frac{J}{^\circ K}$ is the boltzman constant

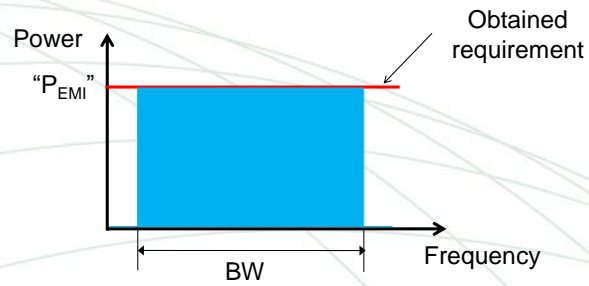
And for this program, $BW = 27 \text{ MHz}$, is the bandwidth of the radiometer.

Giving to us the following result:

$$"P_{EMI}" = 1.863 \cdot 10^{-17} \text{ W} \Rightarrow -137.3 \text{ dBm}$$

RE requirement for Radiometers

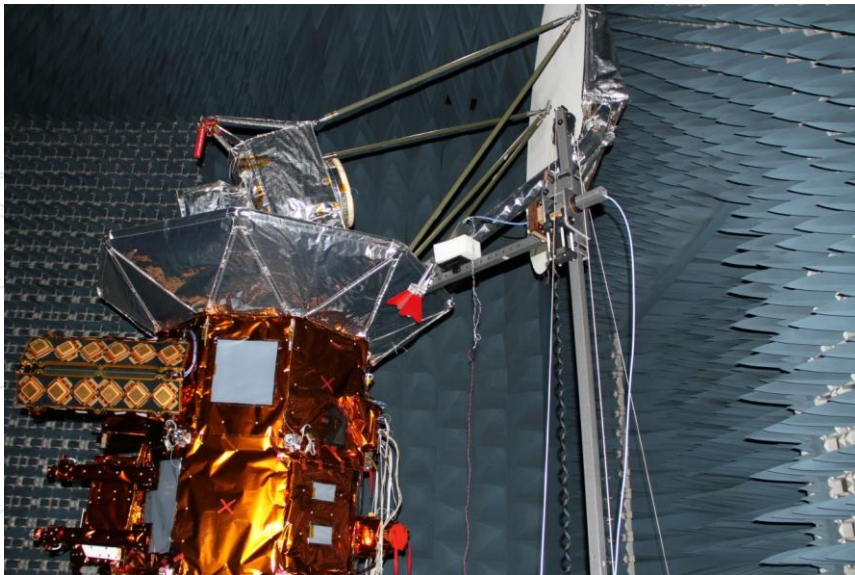
If we add a 6 dB of margin the requirement finally ends in -3 dBuV/m. But which is the actual meaning of this result?



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RE requirement for Radiometers

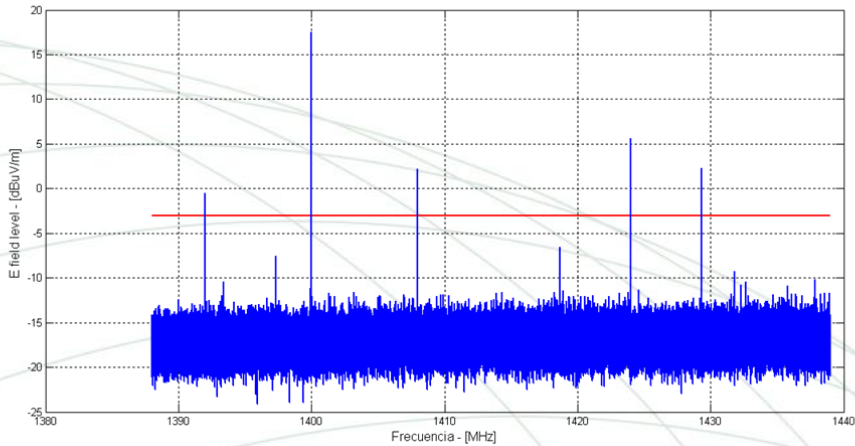


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RE requirement for Radiometers

The following picture shows the result. This is OK or not?

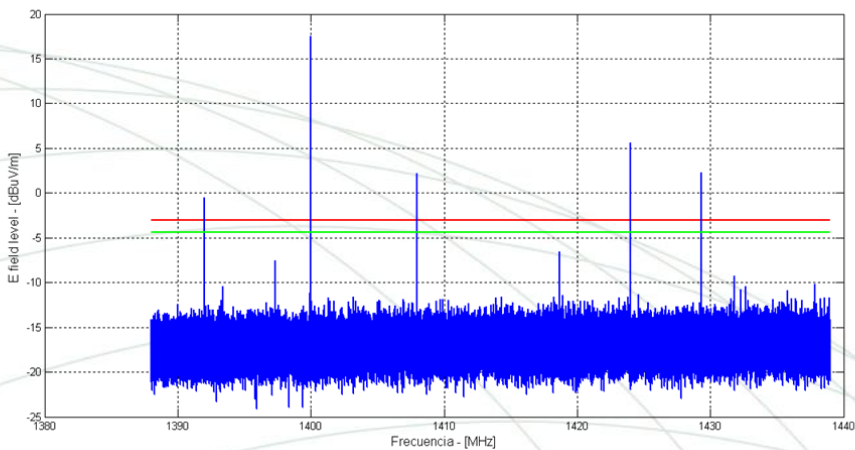


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RE requirement for Radiometers

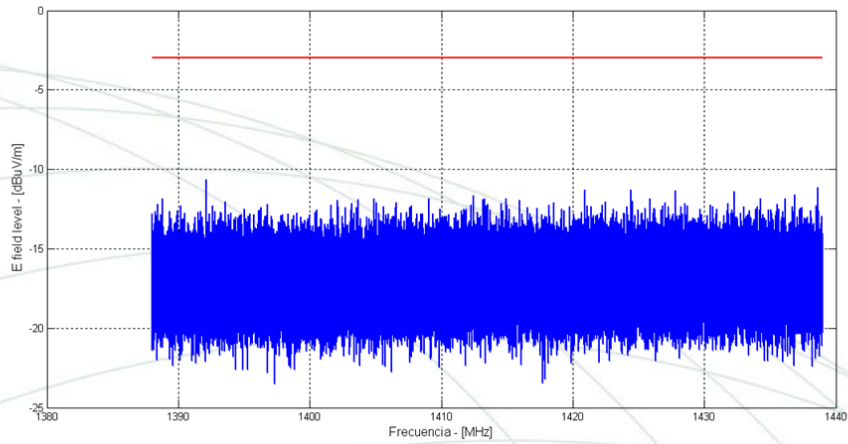
It is OK!!. Actually it is no so different from the case of no interference



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RE requirement for Radiometers

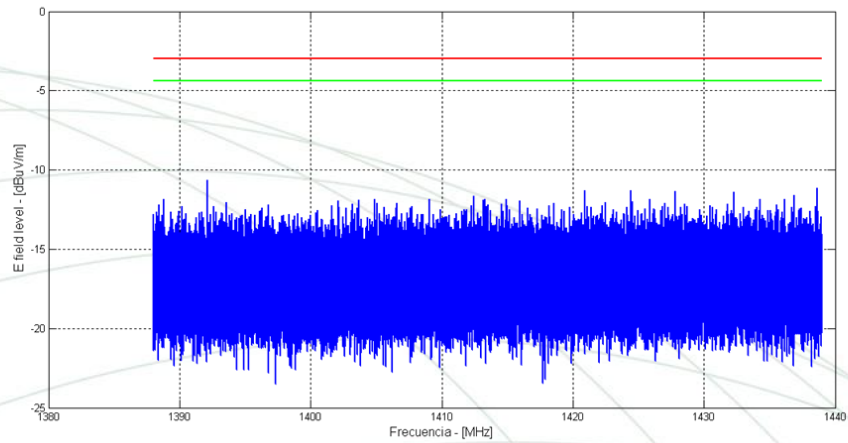


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RE requirement for Radiometers

Clean spectrum (-4.38 dBuV/m) vs interference (-4,36 dBuV/m)



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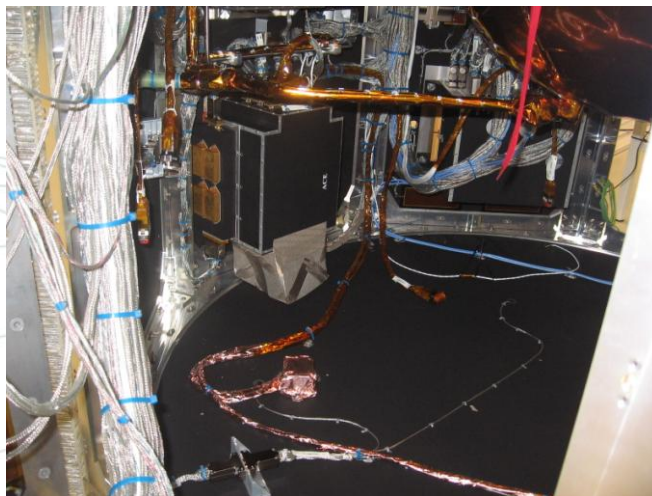
Results of a quite conservative requirement

- Increment of mass. More Kgs in metallic braids and EMI backshells.
- Use of conductive epoxy or sealants, metallic tape, metallic cloth, metallic paints, etc. New materials and consequently additional qualification processes.
- Delta testing over already space qualified equipment. Sniffing for diagnosing the non-conformances.
- Increment on testing time and cost for additional testing equipment for sniffing.
- Delays in integration and functional testing.

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Results of a quite conservative requirement



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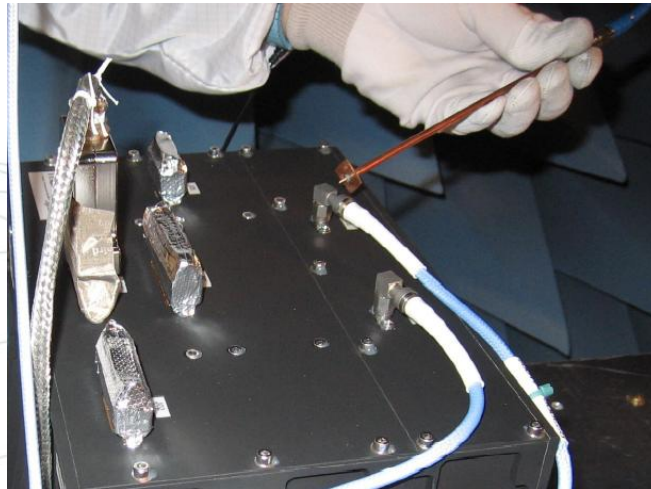
Results of a quite conservative requirement



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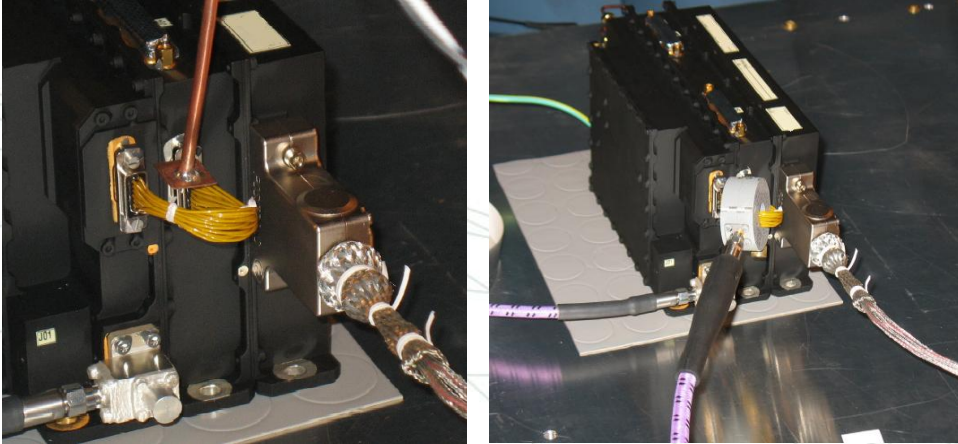
Results of a quite conservative requirement



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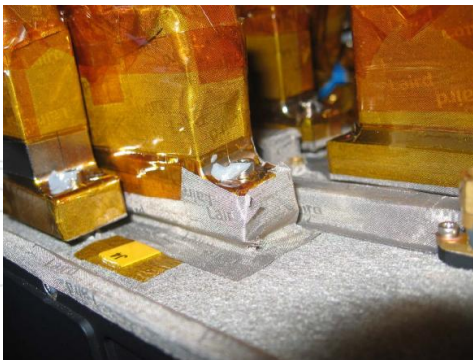
Results of a quite conservative requirement



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Results of a quite conservative requirement



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Results of a quite conservative requirement



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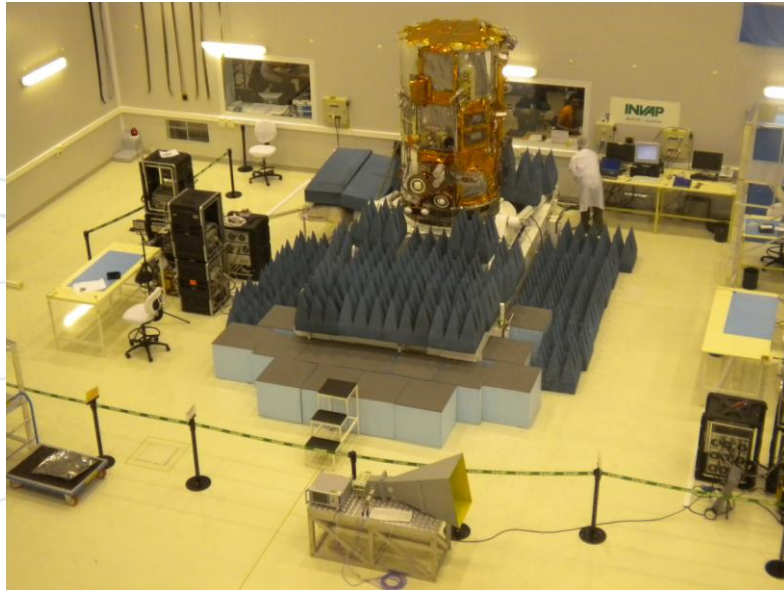
Results of a quite conservative requirement



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Results of a quite conservative requirement



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Conclusions

- A plain RE requirement is not enough.
- The integrated value should be taken in account for the case of appearing non conformances. This is helpful when the impact to solve the problem will be too high.
- The measurement setup when it is possible should maintain a quite margin between the plain requirement and the spectrum analyzer noise floor.
- Usually it is tempting to define a RE requirement in conservative way but the impact can be important not only because the cost but also due to the schedule. Therefore follow standard philosophies regarding margins.
- Take care, even with all of this everything will fail !! So have aluminum tape just in case.

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