Development of a new Fast-Lock RF Connector Interface up to W-Band

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The roadmaps of satellite manufacturers and space agencies always include a special focus on “higher frequencies”. X and KU Band had been strongly deployed in the beginning of 2000, then in 2010 a lot of demands appeared in Ka band, and finally Q band around 2020. Therefore, it is quite logical that new developments will focus on the W-Band in the future. This spectrum is not yet overloaded and should allow the offering of a new available bandwidth for operators.

The use of quick-lock connectors, such as SMP-LOCK, in satellite payloads has enabled an important time and cost saving in terms of integration; however, this type of secure and fast interconnection is currently limited to the Ka band and does not meet the technical challenges of the next generation of satellites.

The challenge for both AXON and RADIALL was to combine the 2 above topics: to develop a new fast-lock interconnection and coaxial cable solution which meet the requirements for satellite RF systems up to 110 GHz.

Manufacturing the appropriate cable, ensuring the right dimensions with high precision for each component (center conductor, dielectric) to reduce electrical interferences within the cable as the signals become very sensible to imperfections at high frequencies, was a challenging task.

This development funded by ESA, initiated a collaboration between the 2 manufacturers, who were able to combine their skills to obtain a robust product with the best possible performances. The duration of the project is 24 months and the target is to achieve TRL 4, which means proof of concept technology.

This technical development program contains 5 different activities, defined by the following Work packages. This paper summarizes the outcome of each work package.

WP1: Space Applications of RF Interconnections Review and Requirements

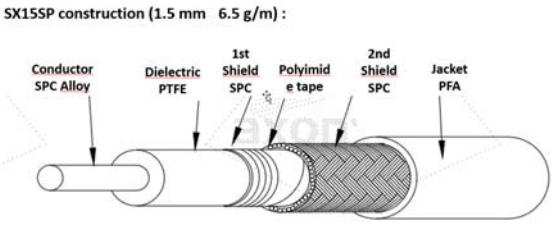
Benchmark &Survey:

The review of existing 110 GHz cable assemblies product offers highlights about fifteen manufacturers with applications mainly dedicated to test and measurement. So far, we didn't really receive any feedback from users and we concluded that there are no space applications on the market yet. All available cable assemblies have 1.0mm connectors, but none of them feature fast-lock system. For the majority of the connectors, the inner contact is not physically maintained. Consequently, deterioration of opposite connectors can happen during use.

In the frame of WP1, we reviewed also all requirements defined by ESA tender to submit our final specifications

WP2: RF Interconnection Design Review and Design Trade-off

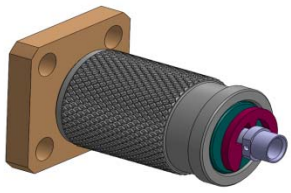
About the cable construction, a deep analysis on all processes to manufacture and prepare a coaxial cable for assembly has been done to select the most appropriate design for a cable operating up to 110 GHz. This is part of Axon know-how which can't be published. At the end of this study, the selected design is applied to the cable called SX15SP with the below construction:



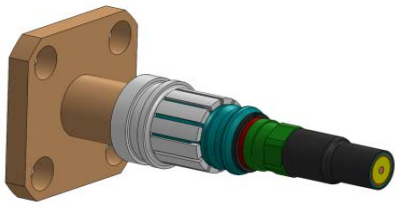
Which fast-lock system is the most appropriate for this need?

3 types of fast-lock systems have been evaluated:

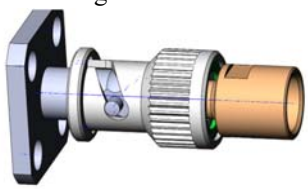
- Push-lock mechanism (in 1 step) : this system is used on NEX10 series (common interface design from Radiall, Rosenberger and H&S)
  Advantages : good compacity, very simple connection with only "push" action, audible click when locked
  Disadvantages : complicated mechanism, high locking forces, design much longer than standards



- Push and lock mechanism (in 2 step): this system is used by Radiall SMP-LOCK and SMPM-LOCK connectors
  Advantages: significant heritage in space, compact
  Disadvantages : locking force sensitivity, not optimized for very high frequencies, 2 steps connection and tool for mating in high density applications



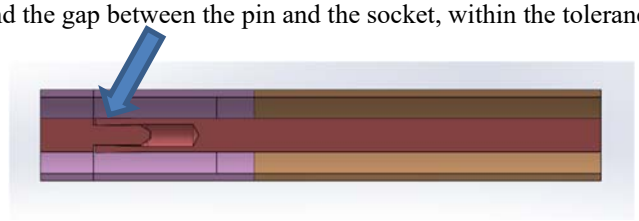
- Push and twist mechanism: this “bayonet” system is used on BNC interface
  Advantages: locking simplicity (axial force and torque), locking safety, locking state visible, simple design
  Disadvantages: twist on cable



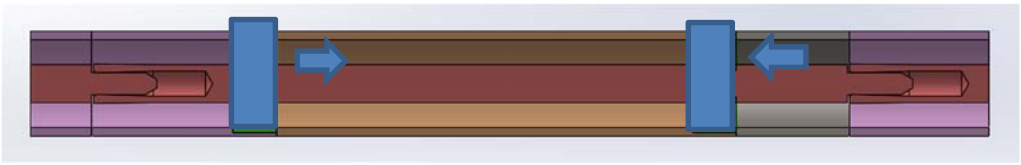
Conclusion: the “push and twist” solution is selected as the best candidate.
To avoid any risk of twist on the cable, an anti-rotation system will be implemented.

Definition of 1.0 mm RF line

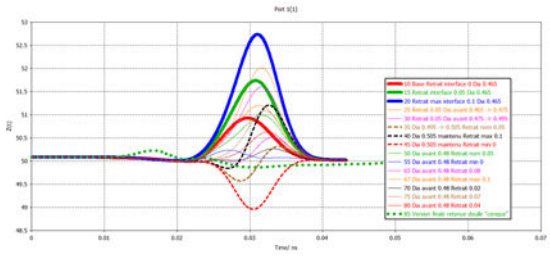
Several hundreds of simulations have been performed to achieve the best RF performances:
Step 1: define the 1.0 mm RF line and interconnection between the pin and the socket: by playing on the shape of socket and the gap between the pin and the socket, within the tolerances given by the IEC standard

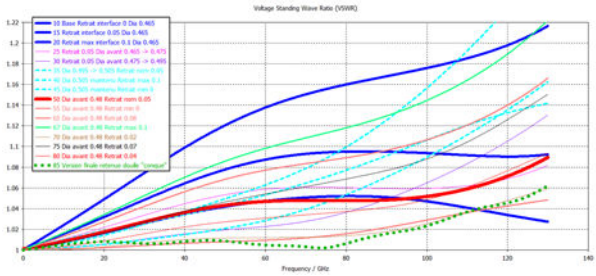


Step 2: define the captivation method of the center contact (dielectric = air)



The shape of the bead used to captivate the contact, the choice of material and their positions influence a lot the RF performances results

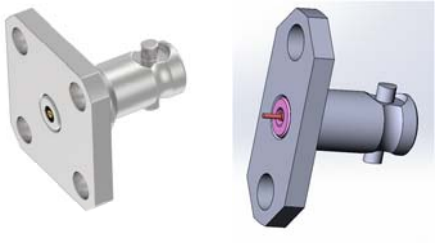




WP3: Development and Manufacturing of the new RF Interface with fast-locking mechanism

- Fast-lock system: spring system to ensure a good pressure between reference planes, the mating and unmating can be done manually, and no risk to damage the cable

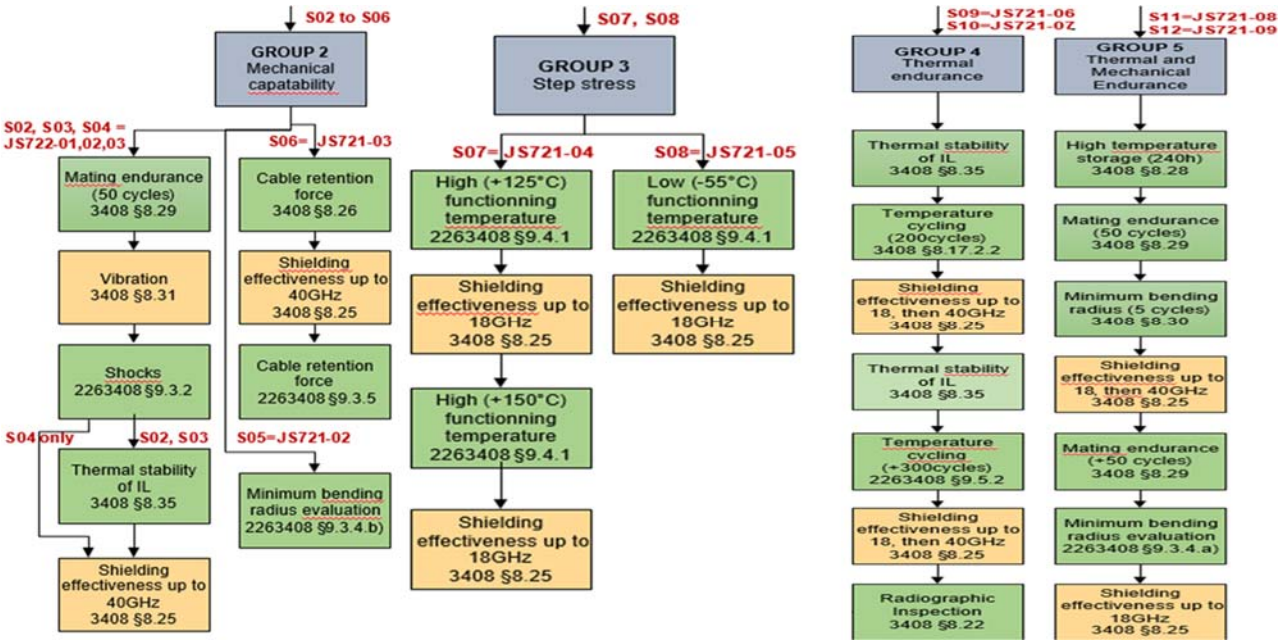
- We developed a truncated flange with cylindrical contact output, diameter 0.25 mm, protruding length 1 mm. (diameter and length can be modified according to the needs of the PCB); and a 4-hole flange with socket contact output.



- Additional connectors and adaptors have been developed, including screw-in 1.0 mm interface, to allow comparisons between the fast-lock version and the more standard version with a classical nut and threading
- Several samples of cable assemblies 0,5m and 1m long have been manufactured to do evaluations

WP4: Characterisation Tests and Optimisation

An evaluation has been done based on ESCC2263408 and ESCC3408



All tests performed at Axon', except vibrations, shocks and shielding effectiveness measurement up to 40GHz which are done at Radiall.
See below summary of the evaluations results

Technical objectives	Targeted Results	Obtained Results	
Microwave Performance • Bandwidth • Return Loss • Insertion Loss • Shielding effectiveness	Specification • DC-110 GHz • < -13.98 dB • > -23.498 dB at 110 GHz • < -50 dB	Best Results • DC-110 GHz • -17.90 dB • -19.93 dB • -35 dB	Worst Results • DC-110 GHz • -14.94 dB • -21.99 dB • -19.07 dB
Vibrations / Shocks	Sine Vibration : 30G (5-200 Hz)	Success Note : Additional Supports Required	
	Random Vibrations : 38.5G rms 20 to 2000 Hz	Success : No Discontinuity	
	Mechanical shocks : 100 Hz 40G 1000 Hz 900G 4000 Hz 4200G 10000 Hz 4200G	Success : No Discontinuity	

Technical objectives	Targeted Results	Obtained Results
Thermal Stability of Insertion Losses (IL)	IL variation < 0.2 dB/s	Success : max 0.18 db/s
Step Stress/ Operating temperatures	-55; 125°C targeting 150°C	Success : -55 ; 150°C
Minimum bending radius + cold bend	Minimum radius 10mm targeting 5mm	Success : 5mm
mating endurance (end of project)	+50 cycles targeting +100	Success : +100 No considerable damage

Full evaluation of the connector pairs (without cable): minor anomalies identified, which should be solved during industrialization phase.

Group 1

Visual examinations INITIAL
Initial and Final dimensional measurements
Measurement of HF adapters
Measurement of HF connectors
HF subbase measurements
Dielectric Withstanding Voltage / Insulation Resistance
Visual examinations FINAL

Group 2

Measurement of winding torque
Loss of electrical continuity force measurement
Measurement of locking mechanism resistance

Sample A1-1 (couple 1 and 4) / A1-2 (couple 2 and 5) / A1-3 (couple 3 and 6)
(couple = **EPC2202-1000 + EPC2202-1300)**

Sample A2-1 (couple 11 and 12) / A2-2 (couple 13 and 14) / A2-3 (couple 15 and 16)
Couple = **EPC2202-100E**

Sample A3 -1 (couple 7a and 7b) / A3-2 (couple 8a and 8b) / A3-3 (couple 9a and 9b) / Adaptateur Fast Lock 1mm
Couple = **EPC2202-800 for measuring EPC2202-1300**

To conclude this task of work package 5, we wanted to compare RF performances between the fast-lock C/A and traditional screw-in version: for the insertion loss and VSWR, we have a small difference, it's more accurate with screw-in. For RF shielding effectiveness the gap is more significant: with the fast-lock version, even at low frequency the shielding is much lower than expected. And more over the degradation of the performance is significant after several bending on the fast-lock version while it stays stable for the screw-in

WP5: Identification of Limitations, Improvements and Impact on Payload Level

Conclusion of the project:

- Fast-lock system is robust and reliable
- It's easy to use
- We achieve good RF performances up to 110 GHz, except RF leakage
- The solution is very expensive
- There's no market identified in a short term
- In parallel, 110 GHz with 1.0mm interface has been developed, a lot of needs have been identified from T&M market
- Budget higher than expected

RADIALL and AXON have demonstrated together thru this programme that coaxial technology at 110 GHz becomes something concrete and very promising

Roadmap:
To achieve TRL8, a new design phase if improvement of RF leakage is required
Then a solid industrialization phase, including a supplier analysis for mass production capability is necessary. It should be a new project including qualification, creation of specifications, and obviously new investments
Based on market size, RADIALL and AXON wonder if it is relevant to get 2 different interfaces to cover same need? it reduces the volume and increases the costs
Basically the Test and Measurement market needs standardization, reliability and the traditional screw-in version is more relevant.
Even if fast-lock is attractive, the time saving for integration won't compensate the additional costs, whatever is the application or the market

NEXT STEP: it could be more relevant to qualify for space (go to TRL8) a 110 GHz solution with standard 1.0 mm interface (screw-in).

Thanks to Leo Farhat and Joaquin Jimenez for their great support