Multi-modular power and RF miniature connectors

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INTRODUCTION

Axon' Cable was selected, in response to an EMITS ITT, to carry out the development of new, miniaturized connector solutions to carry either higher power (current) or RF signals.
Prior to this project the only space grade connectors available to carry power or coaxial signals were D-SUB connectors. These connectors, developed in the 50's, are widely used in space applications as users have a large choice of contact types (signal, power and coaxial contacts in the same arrangement) and easy integration due to removable contacts. However, the main drawbacks of D- SUB connectors are the weight and the size which are not compatible with the general trends of mass reduction and miniaturization. In addition, D-Sub connectors present some risks of accidental short circuits or bent pins due to the male pins being exposed.
During the 80's, a first step to miniaturization was achieved with the development of micro-miniature ("Micro-D") connectors. Unfortunately, there are currently no micro-miniature connectors with power and coaxial contacts in either the EQPL or the EPPL approved lists.

MICRO-MINIATURE BACKGROUND AT AXON' CABLE

- Axon' cable has been designing and manufacturing all the component parts of the Micro-D system since the early 90's, including wire and cable, twist pin contacts, insulators, seals and shells, giving full control of the whole supply chain for this product range.
  - Axon' is QPL qualified to MIL-DTL-83513 and is in the final stages of QPL approval for the Nano-D range to MIL-DTL-32139.
  - Regarding space applications, Axon' is EPPL2 listed for space grade Micro-D connectors to ESCC 3401/029.

Fig 1: Micro D CBR connector

- In 2010 Axon' carried out a Technology Research project (TRP) for ESA to evaluation the use of nano-D connectors for Space, a key output of which was the creation of the ESCC 3401/086 specification, for which Axon' is also EPPL2 listed.

Fig 2: Nano D connectors

- With Axon's multiple heritages in Micro-D, RF and High Data Rate (HDR) the company undertook, under a CNES Research and Technology (R&T) project, the development of a range of assemblies capable of greater than 10Gb/s per channel. This family subsequently became known as AxoMach.

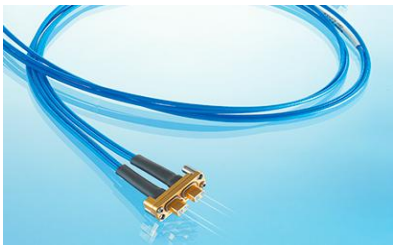


Fig 3: Axomach assemblies.

- Currently, Axon' is developing, under another ESA TRP project, a new generation of SpaceWire connector. The classic 9 way Micro-D has served the SpaceWire user community well for a long time, but as data rates and EMC considerations increase, the limitations of this connector become more evident.
  This new connector is the subject of a separate paper being presented at this SPCD conference.

Fig 4: SpaceWire connectors

CONNECTOR SURVEY

Market Connectors Survey

Within the context of the study Axon' carried out a market survey to see if existing solutions could match the stated needs, and to get information from users as to what they would ideally like for future projects.

QPL D-sub connector shells allow the use of power ESCC 3401-040 D*M contacts or coaxial ESCC3401-004 contacts mixed with signal contacts.
• Coaxial contacts up to 1GHz
• Power contacts from 10 to 40 A
• Straight or 90° solder or crimp versions
• Straight or 90° PCB terminations

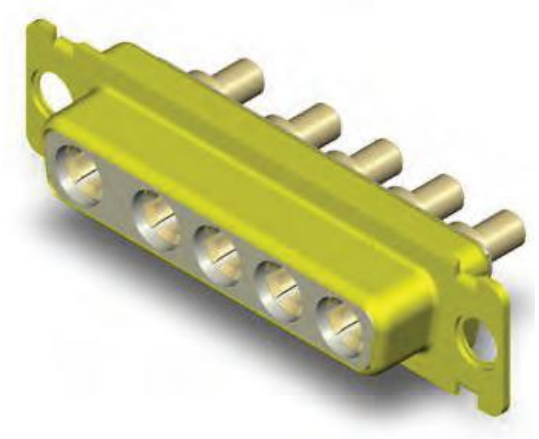


Fig.5: Typical Power D-Sub connector

Conclusions from the Market Survey
At the time of the survey no real need was expressed to have either a mix of signal and coaxial contacts or signal and power contacts. The main interest, following the general trends of miniaturization and weight saving, was to have a qualified version of the Micro-D style - equivalent to the 3W3, 5W5 or 8W8 DSUB arrangements - but smaller and lighter. The need was also expressed to retain the easy "dismount-ability" of contacts possible with the D-Sub but not offered on standard Micro-D connectors.

DESIGN REQUIREMENTS FOR NEW MULTI-MODULAR CONNECTOR (MMCA) FAMILY

From the Statement of Work of the TRP and the responses from the survey, requirements common to both power and coaxial connectors included:

- Small, low mass
- Easy to dismount/interchangeable contacts
- Quick and easy to mate, de-mate and lock
- Rugged (will withstand vibration and shock)
- Reasonably broad temperature capability
- Reasonable cost

Requirements for the Power version:

- A choice of contact sizes for different power handling requirements
- Clear characterization of the current capability and de-rating rules

Requirements for the Coax version:

- Clear characterization of the RF performance over a broad frequency range

MMC AND MMCA PRESENTATION

To achieve the performances in terms of shock/vibration, mechanical robustness and the thermal environment, Axon' based the MMC connector design on the rules and components of Axon's MDSA (space grade) Micro-D connector technology. MDSA connectors are based on both MIL-DTL-85513 and on ESCC3401/029.

There are 2 main sizes of contacts in the range, Size 12 (coaxial & power) and Size 16 (only power), all these parameters giving a large number of possible combinations, with plug or receptacle shells, pigtails or PCB products, standard or panel mount hardware, and the quick disconnect option with the D-Click system.

Axon' offers two variants; one potted variant with non-removable contacts (MMC) and one variant with removable contacts (MMCA). This paper will focus on the removable variants which is available only with the size 12 contacts (power and coaxial). Please contact Axon' for information concerning the potted variants and the size 16 power contact.

Power contacts.

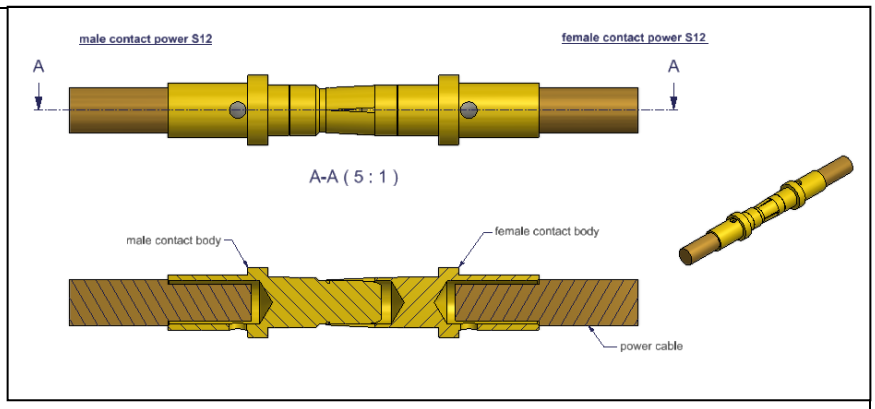
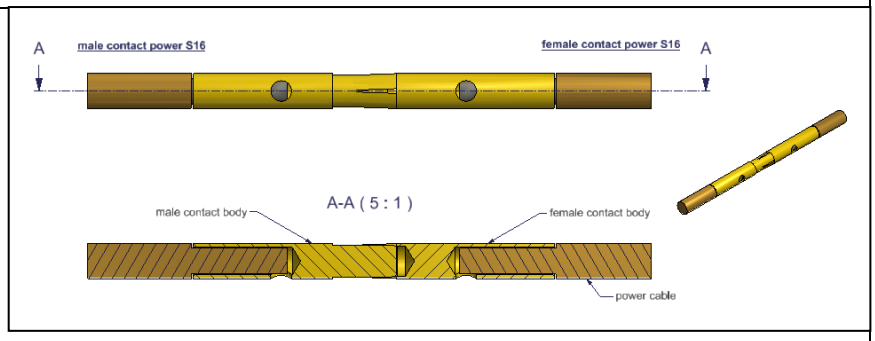
➢ Size 12 (around Ø3mm) This contact is compatible with AWG12: ESCC3901.001.31 AWG14: ESCC3901.001.30 AWG16: ESCC3901.001.29	
➢ Size 16 (around Ø2.2 mm) AWG16: ESCC3901.001.29 AWG18: ESCC3901.001.28	

Fig.6: Size 12 and 16 power contacts for MMCA connectors.

Characteristics	Maximum rating	Unit	Applicable for	Connection	Mass in g
Operating temperature range	–65 to 125°C	°C	All		
Storage temperature range	–65 to 125°C	°C	All		
Rated current (for AWG12 wire)	40 (1)	A	Power contact size 12	To be crimped	0.6 Male & 0.9 female (2) & (3)
Rated current (for AWG14 wire)	20 (1)	A	Power contact size 12	To be crimped	
Rated current (for AWG16 wire)	15 (1)	A	Power contact size 12	To be crimped	

Note 1: The current rating can be limited by the cable derating or/and by the PCB.
Note 2: Weight of the contact alone for the Male termination and weight of the contact, spring & CLP for the Female termination
Note 3: For the mass of the complete assembly the cable weight must be added.

Fig.7: Main characteristics of size 12 and 16 power contacts for MMCA connectors.

Coaxial contact.

To achieve optimum performance on the coaxial lines, Axon' designed the sequence of connection to end with the front faces of the 2 dielectrics in contact with each other in the connected position, with a design of the metallic parts (center & outer contacts) to avoid any break in the connection. Linked with this point, Axon' integrated a spring at the rear of the female contact to compensate for any variation in heights or tolerance of the piece parts, while assuring the contact between the two dielectrics in any connected configuration. To optimize the performance of the coaxial lines and contacts, Axon' used CST STUDIO software and carried out many simulations of the design of the components and their relative positions to reach the final contact design. With this software, it is possible to work not just on characteristic impedance but also on the VSWR parameter, and on the global shape of connector, not just section by section.

only size 12 (Ø3 mm) are available

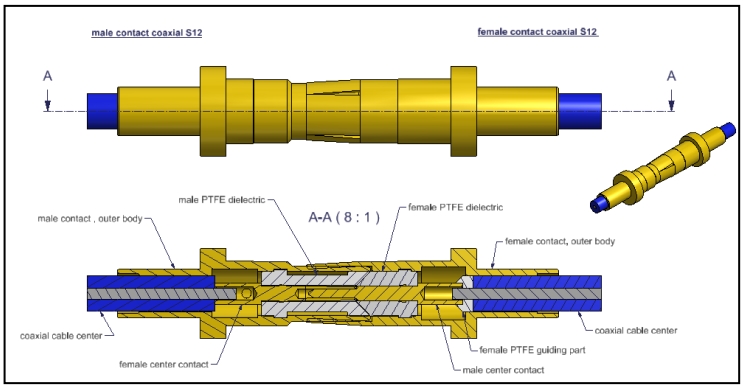


Fig.8: Size 12 coaxial contact for MMCA connectors.

Characteristics	Maximum rating	Unit	Remarks
Operating temperature range	–65 to 125°C	°C	
Storage temperature range	–65 to 125°C	°C	
Rated working voltage sea level	250	Vrms	Note 1 & 2
Frequency range	0-18	GHz	
Impedance	50	Ω	Note 1
RF power	1	W	Note 1
Maximum Insertion losses (note1)	Cable: $(0.7x\sqrt{(F)} +0.030xF)*L + 0.07\sqrt{(F)}$ F in GHz per S12 coax + $0.06\sqrt{(F)}$ F in GHz for a SMA (L=length)	(dB/m)	
Maximum VSWR Contacts only	dc to 6GHz: 1.20; 6GHz to 9GHz: 1.30 ; 9GHz to 18GHz: 1.45		

Note 1: Between inner and outer shields for coaxial contact.
Note 2: Between each contact and between the contacts and the shell.

Fig.9: Main characteristics of size 12 coaxial contact for MMCA connectors.

Example of RF performance on a 2m sample length.

VSWR max= 1.332 up to 18Ghz

IL=6.2dB for 7.6dB.

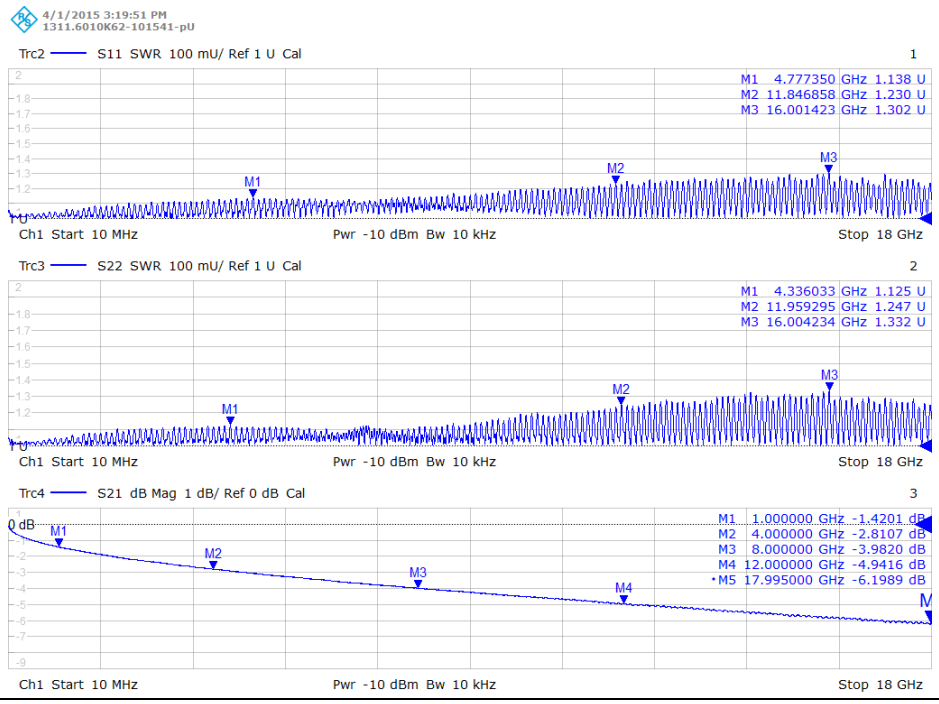


Fig.10: RF performances of size 12 coaxial contact for MMCA connectors.

Shell with removable size 12 power or coaxial contacts.

For the range of S12 removable contacts, Axon' modified the shape of the "D" interface form, to have more space in this area: instead of a symmetrical, trapezoid D, the new shape is that of an elongated, asymmetrical D. It is important to note that the global dimensions and weights remain the same.

Fig.11: MMCA connector shape compared to micro D

Male shell with removable female contact (power or coaxial)

A spring has been added at the rear of the female contacts (male shell), to allow dismounting and to accept all the tolerances of the individual parts and contact height differences. The contacts are precisely axially guided into the inserts, but they can slide within the cavity

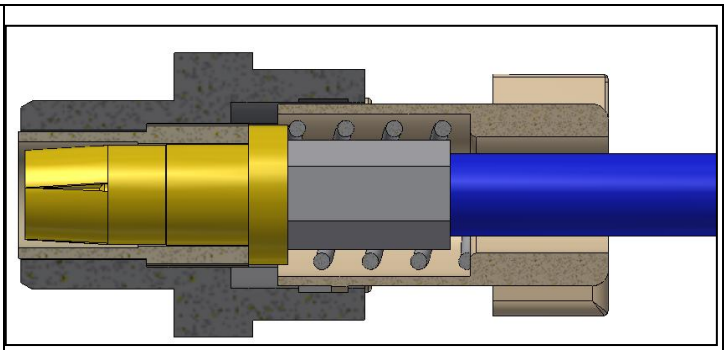


Fig.12: View of MMCA connector with coaxial or power contact.

This spring is combined with a quarter turn system to lock it manually inside the shell. We call this part ‘CLP’ for ‘Contact Locking Part’. Both limits in rotation of the CLP are calibrated by grooves in the surface of the shell and by the CLP lugs. The CLP will be an injected PEEK GF30 part, and universal for all size 12 power and coaxial female contacts.

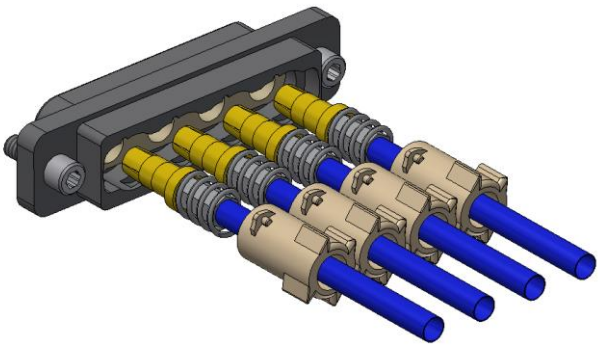


Fig.13: MMCA connector back view

The design of the CLP incorporates a gripping shape for ease of handling, and allows the dismounting of the contacts one by one if needed – please note that the locked position can be visually checked from the rear of the connector, for quality inspection.

Note: The removal of the contact does not need any tooling. This can be done easily by hand.

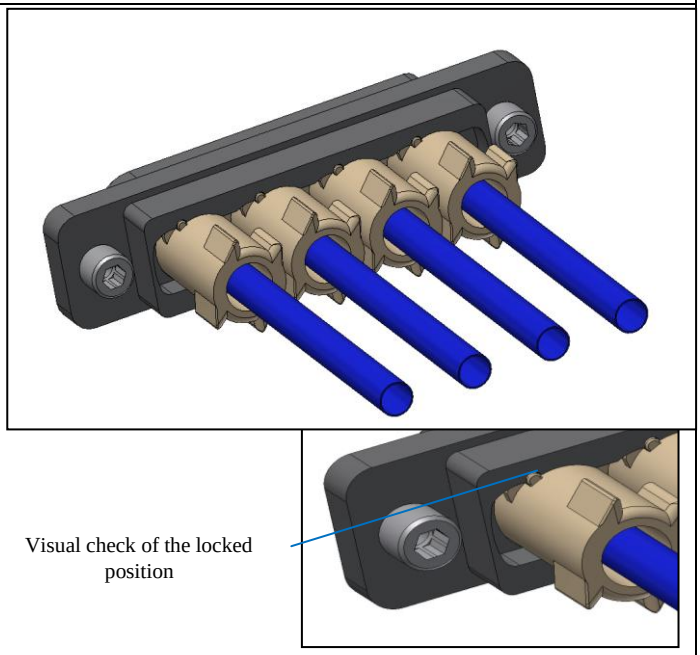
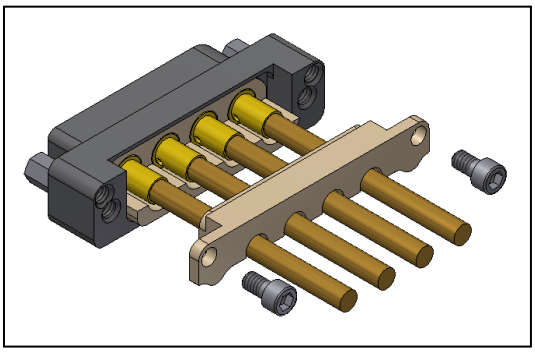
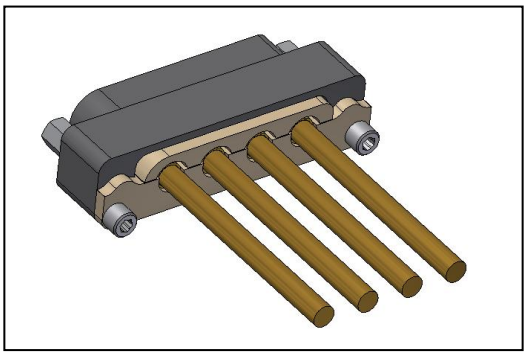


Fig.14: MMC CLP concept view

Female shells with removable male contacts (power or coaxial)

On the male contacts (female shell), the removing of the contacts is done by removing a rear section maintained with 2 screws, in order to have a direct access to the contacts. The contacts, which are guided in the inserts, can be replaced or swapped manually, and then the rear section re-installed.	 Fig.15: View of MMCA connector with coaxial or power contact .
The design of the combined parts (connectors shell, plastic insert, rear section and contact body) guarantees the correct contact heights from the front face This rear section can be : - In nickel plated aluminium, for versions with coaxial contacts, to connect the different outer bodies of contacts together - In PEEK for versions with power contacts, to isolate them from each other.	 Fig.16: View of MMCA connector with coaxial or power contact (once closed).

Fast locking hardware: D-click ™

The concept of the D-click hardware system is based on 2 main components:

A) – a waisted guide-pin on the receptacle shells (pigtail or PCB) – can be installed instead of standard jackposts (retrofit possible in most cases)**:**

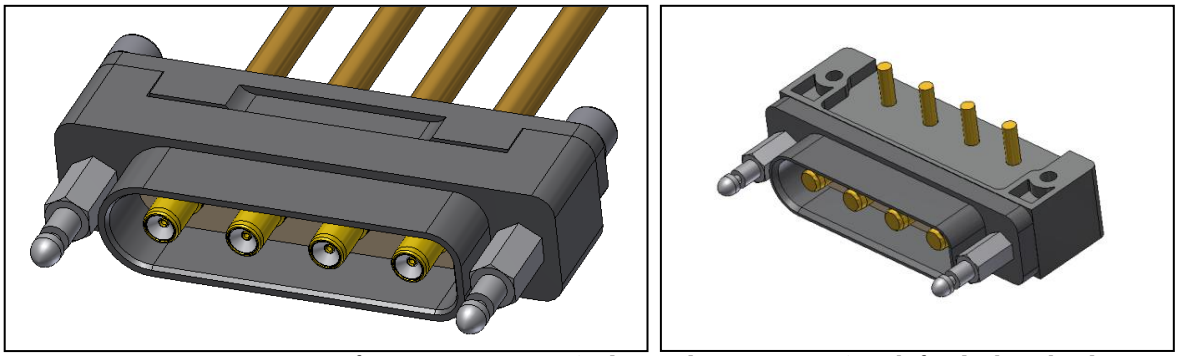


Fig.17: View of MMCA connector (in-line and PCB versions) with fast locking hardware .

B) – Spring clips that are installed on the plug shells, allowing:

- ✓ A simple and easy-to-use mating & locking system,
- ✓ an easy-to-disconnect system by simply pinching/squeezing the two clips together, and pulling the plug connector backwards to disconnect.

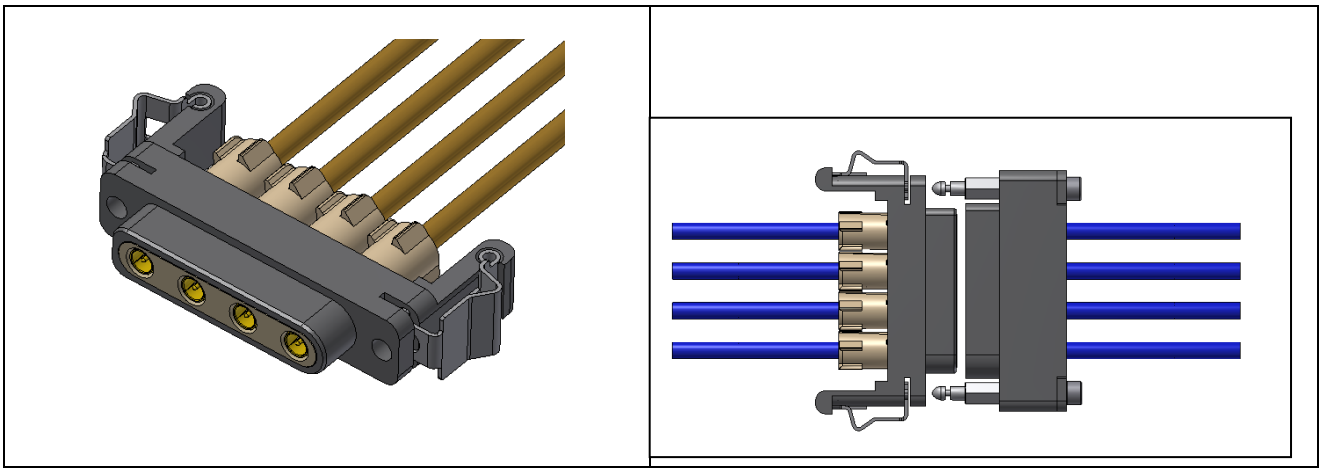


Fig.18: View of MMCA connectors with fast locking hardware .

Power Condensed Board Right/90° (CBR) connector design

For the structure of the PCB connectors, a rear tray in Liquid Crystal Polymer (LCP) is used:

- to hold and guide the contact pins down to the PCB in the correct board layout
- to fix the connector to the PCB. The connector is fixed to the tray by a pair of screws and either free nuts or pre-installed threaded inserts.

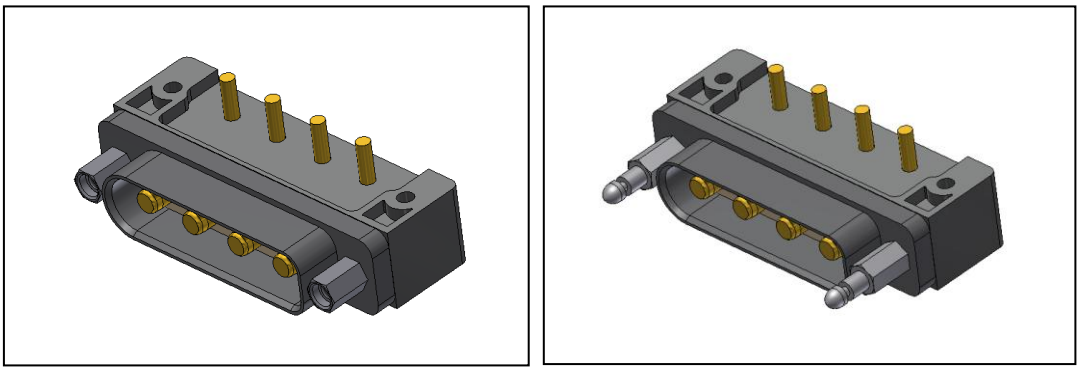


Fig.19: View of MMCA connectors for PCB connection (CBR version) .

Power contacts on CBR connectors are single piece right angle contacts with the same front face as the normal female pigtail contact; the rear section is composed of a large diameter pin bent at right angles.

Power Board Straight/Vertical (BS) connector design

The design of the BS style connector is basically identical to that of the CBR, except:

- the shape of the tray which is in a straight/vertical style
- the shape of the power contacts which are also straight.

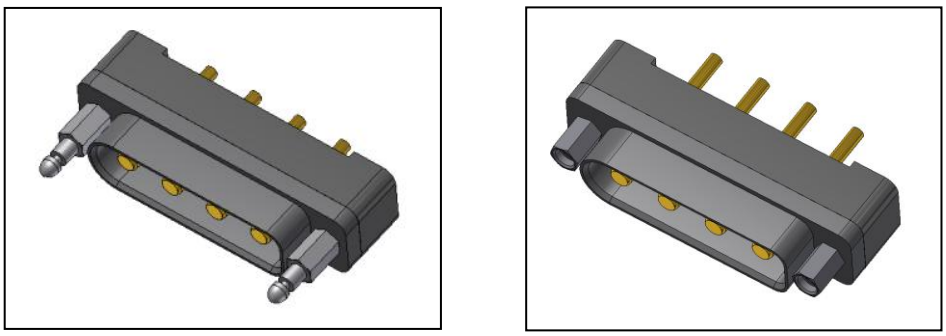


Fig.20: View of MMCA connectors for PCB connection (BS version) .

Extensive evaluation.
As part of the overall TRP study a large Evaluation Test Plan (ETP) has been performed and this has generated a great deal of data to justify the use of these connectors on space programs.
Below is a brief summary of the test plan and report.

Group 1: Electrical and storage. for all samples
-Electrical test (dc resistance, insulation, DWV, RF performances…).
-Storage at very low temperature -120°
-Storage at maximum temperature +125°C
Group 2: Mechanical and rapid temperature cycling

- Random vibration levels and duration: According to the future ESA basic evaluation test plan for assemblies: Project ESCC2263xxx according to MIL-STD-202, test method 214

Envelope: Grms = 38.5
20 to 60 Hz +6dB / Octave; 60 to 400 Hz 2g2/Hz, 400 to 800 Hz -6dB / Octave, 800 to 1000 Hz 0.5g2/Hz, 1000 to 2000 Hz -6dB / Octave, Duration: 360s in each of the 3 mutually perpendicular axes.

- Shocks: According to future ESA basic evaluation test plan for assemblies (ECC2263xxx according to MIL-STD-202, test method 213)

Shape of shock pulse: Half-sine, Peak acceleration: 1500g, Duration of pulse: 0.3ms, Number of shocks: 18 (3 shocks in each direction along the 3 perpendicular axes of the test specimen).

Group 3: Mechanical and thermal endurance.
Mechanical: 1000 mating cycles
Endurance: 2000 hours at +125°C.

Group 4: Power and RF performance versus temperature & RF leakage.
RF performances for coaxial versions: RF leakage, IL and VSWR) at low (-65°C) and high temperature (+180°C).
Power performance for power version: Dc resistance and insulation at low (-65°C) and high temperature (+180°C).

Group 5: Overload in voltage and ampacity
Overload ampacity under ambient pressure and under vacuum with temperature.
This allows to state on the maximum rated level of current admissible in low (-65°C) and high temperature (+180°C).

Provisional heritage, at the time of writing this paper, a major customer has selected MMC for use on a large number of satellites.

CONCLUSION

In conclusion we can say that the overall objectives of the ESA TRP were achieved:

- The new MMC connectors are smaller in mass and size and have higher contact density than previously possible in space approved connectors
- The connectors are simple, quick and easy to mate, lock and de-mate
- The contacts are interchangeable, and are very quick and easy to dismount and swap
- The power current rating goes up to 40A+ in TVAC or space conditions
- The coaxial RF performance is good to 18GHz
- An extended Evaluation Test has been carried out on MMC and MMCA connectors, results available
- A specification according to ESCC has been issued and is available. ESA Qualification will follow.
- Crucially, the MMC connector has already been selected by a major customer for many satellites