EMI TIGHT RECTANGULAR CONNECTOR ASSEMBLIES DEVELOPMENT

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INTRODUCTION

One of the main problems of EMC intra-system compatibility is represented by the coexistence of sensitive receivers in different frequency band from DC to some GHz and radiation coming from the on-board equipment and associated harness (data processor, digital clock generator, switching DC/DC converter…), which may generate unwanted interferences in the receiver frequency band.
Earth Observation, Navigation and Telecom spacecrafts shall face the problem of Radio Frequency Interference (RFI). Today the need of on-board processing applications has grown with in particular the development of instruments delivering a huge amount of science data with highspeed links (Example: PLEIADES, TerraSAR-X, GAIA…). High-speed data transmission means fast edge and high Electro-Magnetic Interference (EMI) in a large frequency range. In parallel to high-speed data links, sensitive receivers are mounted on board the spacecraft. Due to their frequency bands and their very high sensitivity levels, they may be disturbed by any radiation coming from close units and associated harness due to harmonics of the high speed links.
In order to ensure the Electromagnetic compatibility at system level, the harness bundle is shielded. This allows to reduce the radiated emissions coming from the high-speed data links and to reduce also the E-field level captured by the sensitive receiver harness. In the current spacecrafts, several options for harness shielding and terminations are used. When the signal is known to be sensitive, the connector uses a backshell associated with an overall braid in order to have a connection over 360°.
However, shielding and overshielding the harness is not enough to prevent radiated emission as it doesn't deal with all potential area of leakage. The junction between chassis and backshell is often left behind and standard space qualified connectors are often used without consideration about the radiated emission performance expected. Shielding effectiveness (SE) above 1GHz of an overshielding harness assembly with EMC backshell is degraded by the presence of slots due to mechanical interfaces between EMC backshell and connectors. The objective of the present paper is to present, newly developed Sub-D and Micro-D EMI rectangular connectors, backshells and accessories that would prevent as much as possible any EMI leakage. Those solutions are developed in the frame of an ESA study handle by ADS Toulouse with AXON and C&K. Solutions will focus only on rear panel mounting as it is the most common case in space application.

UNDERSTANDING THE PROBLEM AND THE ISSUES

Three different slot locations have been identified as sources of RF leakages in a connector assembly (composed of a fix connector, a mobile connector and a backshell). Those three leakage areas will be identified for the rest of the study as respectively (A), (B) and (C): (A) Interface between fixed connector and unit chassis, (B) Interface between the fixed and mobile connector, (C) Interface between the backshell and the mobile connector. Those three locations are identified in Fig. 1.

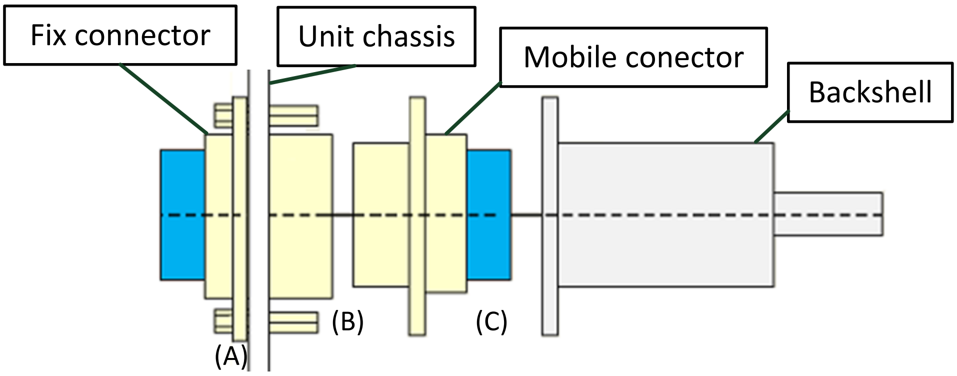


Fig. 1. Leakage location at connector interface level

It is worth noting that locations of leakages can be dealt one by one or together depending on the solution used. For example, interface between fix connector and unit chassis is a leakage area given that interferences generated by the equipment can exit through this area. However, it is possible to suppress this leakage area, as well as the leakage area of the interface between fixed connector to mobile connector, by providing a great conductive contact between the mobile connector and the chassis

At the moment, standard space qualified rectangular connectors and backshells do not guarantee any contact between the chassis unit and the backshell. Random electrical contacts are identified but are not controlled, repeatable and depend on the workmanship.

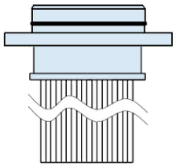
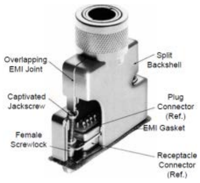
In order to be useful for space application, newly developed EMI connectors are expected to decrease RF leakage in the UHF (300MHz-1GHz), L(1GHz-2GHz), and S(2MHz-4GHz) frequency band by providing a better, and ideally a good 360°, electrical contact at the three identified leakages zones. To be space compatible, a long list of requirements and performance goals have been set and are applicable to the developed Sub-D and Micro-D connectors such as life-time, mating/unmating cycle, outgassing requirement, minimum mass increase and thermal condition. Finally, due to mechanical and space constraint, EMI solution for Sub-D connector may not be compatible for Micro-D connector. For instance, all Micro-D connectors' are machined while Sub-D connectors can be machined or stamped.

EXISTING SOLUTIONS OUTSIDE OF SPACE INDUSTRY

Most standard space qualified connectors guarantee only random electrical contact between A,B and C, but many non-space qualified solutions already exist and would prevent EMI leakage for rectangular Sub-D and Micro-D connectors. The following list is a non-exhaustive state of the art of, non-space qualified, existing EMI connector's solution. It gives leads toward new EMI connectors' designs that could help space applications to reach the cleanliness needed by sensitive receivers. The table 1 shows example of those solutions that are listed arbitrary from 1 to 8.

1. Machined fixed shell with an additional groove, in which a RF gasket can be mounted: The combination of the surface flatness and the installation in between of the RF gasket are leading to a hermetical closure of the slot.
2. EMI Gaskets: Subminiature-D style gaskets are used to provide EMI shielding and environmental sealing between connector flanges and their mating surfaces. (EMI gasket is already space qualified)
3. Machined shell with additional dimples: Once connectors are mated, those dimples are compressed between the fix and mobile connector providing an electrical contact.
4. Rugged shell with mashing: Once connectors are mated, those mashing are compressed with the female connector providing an electrical contact.
5. Filter connectors.
6. Machined aluminum shells with EMI spring: The EMI spring ensures a good electrical contact between the fixed and mobile connector shells.
7. One-piece connector shell: Mobile connector and backshell are gathered together. The cable shield is attached directly onto the one-piece connector shell and secured with a stainless steel BAND-IT clamp.
8. Encompassing backshell: This backshell provides a total enclosure of mated plug and receptacle connectors for optimum electromagnetic interference and meet MIL-STD-461 or TEMPEST requirements.

Table 1: SuB-D & Micro-D existing non space qualified solution

(1) 	(2) 	(3) 	(4) 
(5) 	(6) 	(7) 	(8) 

DEVELOPED MICRO-D AND SUB-D SOLUTIONS

C&K and AXON have developed, within the frame of the study, a total of 12 solutions dealing with at least one area of leakage. For the rest of the paper, C&K and AXON solutions will be identified by: the leakage area they are covering (A or B or C) next to an arbitrary number (see list above). AXON solutions will be identified by an ‘.
C&K has developed following Sub-D solutions in order to prevent leakage in the:

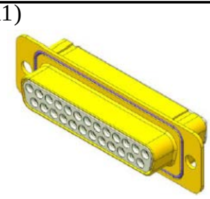
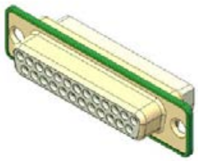
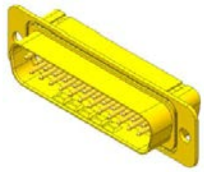
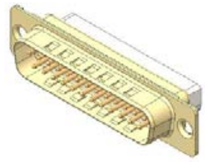
9. Interface between fixed connector and unit chassis:
   - o D*Sub female connector, machined shell with RF gasket in groove (A1).
10. Interface between fixed connector and unit chassis or between the fixed and mobile connector:
    - o Surrounding EMI gasket (A/B1) (this solution is compatible with other developed solution).
11. Interface between the fixed and mobile connector:
    - o D*Sub male connector, machined shell with dimples (B1),
    - o D*Sub Standard male connector with dimples (B2),
    - o D*Sub Standard male connector with bi-material interfacial seal (B3).
12. Interface between the backshell and the mobile connector:
    - o EMI flat gasket between backshell and connector with C&K haloring (C1).
13. Three interfaces:
    - o Encompassing backshell with C&K haloring (ABC1),
    - o D*Sub female connector with integrated absorbing epoxy (ABC2).

AXON has developed following Micro-D solution in order to prevent leakage in the:

14. Interface between fixed connector and unit chassis:
    - o Panel mounting female shell EMI gasket (A1’).
15. Interface between the fixed and mobile connector:
    - o Plug with EMI gasket(B1’),
    - o Plug with EMI spring(B2’).
16. Interface between the backshell and the mobile connector:
    - o Backshell with EMI gasket(C1’),
    - o Plug with integrated funnel and screw(C2’).

However, to be effective, global solutions developed need to deal with all three areas of leakage at the same time otherwise electric field radiated is redirected toward the area left open. To achieve that goal combining solutions is needed. Five global solutions for Sub-d connector and two global solutions for Micro-d connector have been chosen to go under full qualification process. Only two Micro-D global solutions have been chosen due to mechanical constraints between the fix connector, the mobile connector and the backshell.
Table 2 shows for Sub-D and Micro-D a representation of all developed solutions as well as the list of DUTs (Design Under Test).

Table 2: C&K and AXON developed solutions

<table>
<tr><td colspan="12">C&K developed solution</td></tr>
<tr><td colspan="3">(A1)
</td><td colspan="3">(A/B1)
</td><td colspan="3">(B1)
</td><td colspan="3">(B2)
</td></tr>
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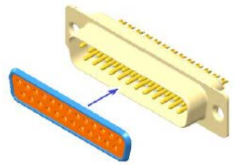</td><td colspan="3">(C1)
</td><td colspan="3">(ABC1)
</td><td colspan="3">(ABC2)
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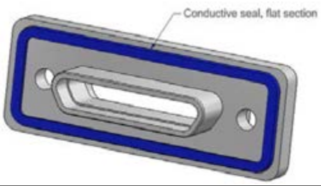
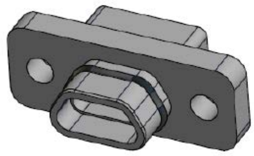
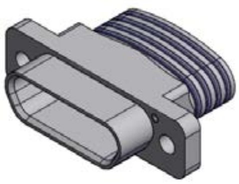
<tr><td colspan="12">AXON developed solution</td></tr>
<tr><td colspan="4">(A1’)
</td><td colspan="4">(B1’)
</td><td colspan="4">(B2’)
</td></tr>
<tr><td colspan="4">(C1’)
</td><td colspan="4">(C2’)
</td><td colspan="4"></td></tr>
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A set of standard fixed connectors, standard mobile connectors and standard backshells have also been manufactured by AXON and C&K. They will be identified with the number 0.
Sub-D DUTs are: A0+B0+C0, A1+B1+C1, A2+B3&A/B1+C0, A2+B2&A/B1+C0, A0+B0+ABC1, ABC2+B0+C0, A0+B1+C1, A1+B0+C1 and A1+B1+C0. Micro-D DUTs are: A0’+B0’+C0’, A1’+B0’+C1’, A1’+C2’, A1’+B1’+C1’ and A1’+B2’+C1’. Five Sub-D DUTs cover all leakage areas while only two Micro-D DUTs cover all three leakage areas.

QUALIFICATION OF THE DUTS

Two types of DUTs have been manufactured: “Connectic DUTs” and “Connector assemblies DUTs”. Connectic test vehicles are made of a panel mount connector and a mobile connector equipped with a backshell. Connector assemblies test vehicles are made of 2 panel mount connectors, linked with a 1m long harness made of 2 mobile connectors equipped with backshell, and a shielded cable. The overshielding used is a double layer silver plated copper braid AXODT6SPC grounded with axoclamp. This overshielding has been chosen due to its good performance preventing any harness’s electric field radiations.
Thanks to the two types of DUTs, a full range of different electrical, RF and EMC tests have been performed on them. Following tests are performed on the Connectic DUTs: Voltage Proof (in accordance with IEC Publication 512-2), Insulation Resistance (in accordance with IEC Publication 512-2), contact resistances (in accordance with ESCC Generic Specification N°3401), Transfer Impedance LF(Low Frequency) with triaxial method, and Endurance test (in accordance with ESCC). Following tests are performed on the Connector assemblies DUTs: Voltage Proof (in accordance with IEC Publication 512-2), Insulation Resistance (in accordance with IEC Publication 512-2), Continuity Test, Contact Resistance (in accordance with ESCC Generic Specification N°3401), Transfer Impedance HF(High Frequency) with micro strip method, Shielding Effectiveness, Vibrations (in accordance with IEC Publication No. 512-4), Shock and Bump (in accordance with IEC Publication No. 512-4), Rapid change of temperature (in accordance with IEC Publication No. 512-6), High-temperature storage (in accordance with IEC Publication No. 512-6), and Radiated Emission (in accordance with ECSS-E-ST-20-07C). Fig.2 shows the tests sequence of the two types of DUTs.

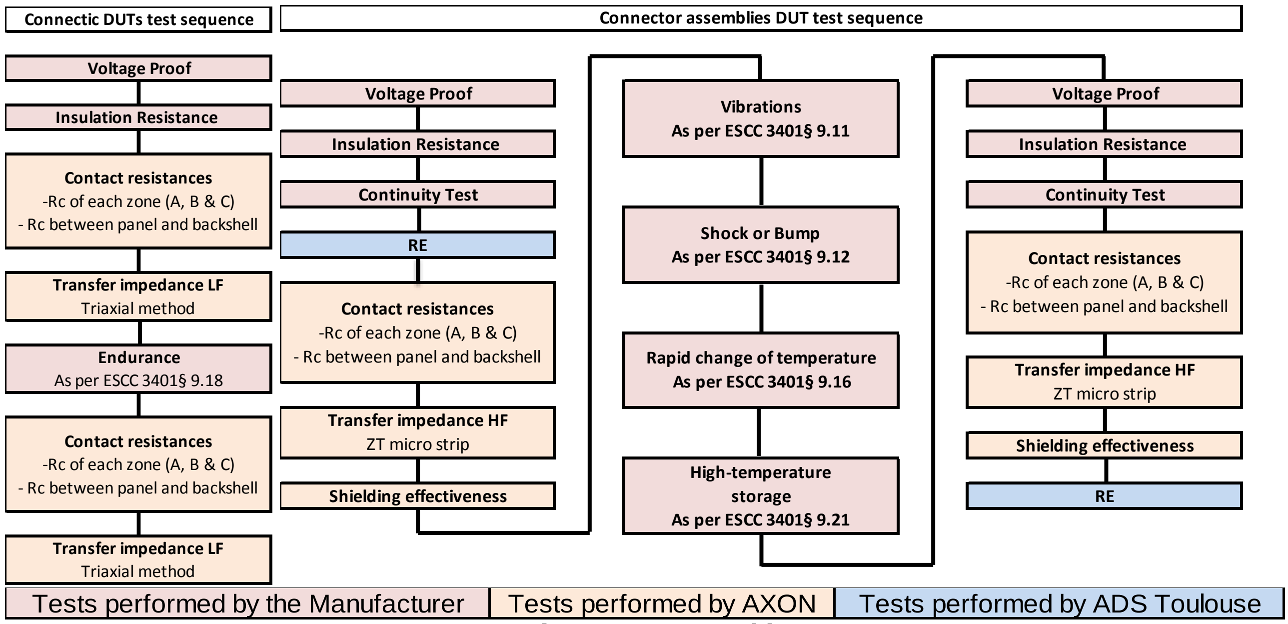

Fig. 2. Connectic DUTs and Connector assemblies DUTs tests sequence

In order to ensure a good understanding and repeatability of the different test results, each DUT has been manufactured in two samples that are going under the full test list.

The EMC success criterion of this study is based on the EMC radiated emission test results performed on Connector assemblies DUTs. In order to be considered successful, the solutions developed have to increase the overall EMI shielding by at least 15 dB in the following frequency range [400MHz-2.5GHz].

To check the overall EMI shielding increase, developed solutions radiated emission levels are compared to the standard solution radiated emission levels. E-Field radiated emissions are generated using a signal generator generating 32MHz harmonics from 416MHz to 2496 MHz. In order to ensure electrical field radiated emission leakage comes from connector areas, all potential openings of the chassis were closed using metallic tape Cho-Foil. Moreover, a high quality overshielding was used in order to prevent radiation from the harness.

Those tests do not fully qualify the developed connectors for space applications according to ESA standards. Some non-critical electrical tests are missing.

RESULTS

Connectic DUTs test campaign is finished. Table 3 displays all criteria of success and test results conclusion for Connectic DUTs. Voltage Proof and Insulation Resistance test were performed successfully on all DUTs. For the Voltage Proof test, the Voltage applied is 1250 Vrms for one minute. During that time the connector shall be monitored for electrical breakdown, flashover, corona discharge, or current leakage in excess of 2 mA. For connector equipped with absorbing epoxy, the Voltage applied is limited to 100V due to the charges in the resin (iron particles). For Insulation Resistance test, the Voltage applied is 500 V. For connector equipped with absorbing epoxy, the Voltage applied is limited to 100V due to the charges in the resin (iron particles).

Endurance test was performed successfully on all Sub-D DUT. Regarding Micro-D DUT, each DUTs is mated and unmated 500 times; except for the DUT (A1'+B2'+C1') with micro-d spring technology, which is limited to 100 cycles. We consider that these results are conforming to what we were expecting.

Table 3: C&K and AXON Connectic DUTs test results

Test performed on Connectic DUTs	Criteria of success	Results
Voltage Proof	No electrical breakdown, no current leakage in excess of ≤ 2 mA...	Compliant
Insulation Resistance	≥ 5000 MΩ / 500 Vdc	Compliant (1)
Contact resistances	≤ 10 mΩ between each mechanical part (mobile connector, fix connector and backshell)	Compliant
Transfer impedance LF	No criteria	Tested
Endurance	No physical damage	Compliant (2)
Contact resistances	≤ 10 mΩ between each mechanical part (mobile connector, fix connector and backshell)	Compliant
Transfer impedance LF	No criteria	Tested

(1) For connector equipped with absorbing epoxy, the Voltage applied is limited to 100V due to the charges in the resin (iron particles).
(2) The results are strictly speaking not compliant with the requirements of the ESA3401/029 specification, but results are compliant with MIL standards requirements.

Transfer Impedance LF with triaxial method tests was successful as no criterion of success was explicitly present. However, good information regarding the potential improvements in EMI shielding can be deduced from this test. Using transfer impedance results, the two best Sub-D DUTs seem to be the A0+B0+ABC1 DUT (Encompassing Backshell) and the A1+B1+C1 DUT. The A0+B1+C1 DUT, which presents one leakage area open, also seems to show great results. This result is quite far from the expected performance from DUTs not dealing with every leakage area. This great performance could be due to good random contact between the chassis and the fix connector assuring a good contact. Impact of the operator seems non negligible.
For Micro-D, transfer impedance measurement shows overall a small improvement. Moreover, one measurement shows that a high variance between samples can be found. It is the case for the A1'+B1'+C1'DUT, the first sample has a better transfer impedance by at least a factor 2. Another measurement, which confirm C&K sample test results analysis, also shows that performance of the connectors is dependant of the way screw locks are locked.
No major impact from endurance test is seen on all DUTs.

Connector assemblies DUTs test campaign is ongoing. Results will be exploited and presented during the SPCD. First radiated emission tests have been performed with one sample per DUT for Sub-D connectors and two samples per DUT for Micro-D connectors. Two samples of Sub-D connector per DUT will be tested afterward the environmental tests. According to the first results from connector assemblies DUTs radiated emission test, the A0+B0+ABC1 DUT (Encompassing Backshell) seems to be the most effective EMI solution with a global improving of the shielding of more than 20dB [400MHz-2.5GHz] (see Fig.3). A1+B1+C1 DUT shows also good results with an improvement of 15 to 20dB in most of the frequency band (see Fig.3). Moreover, similarly to the result with the connectic DUTs sample, A0+B1+C1 DUT, which presents one leakage area open, also seems to present really good results.
Micro-D connector DUT, as expected, shows smaller improvement. It is due to smaller mechanical hazard in Micro-D assembly than in Sub-D assembly. More random contacts are already present for Micro-D connectors. Both A1'+B1'+C1' and A1'+B2'+C1 DUTs show good results that need to be confirmed with the second radiated emission test campaign.

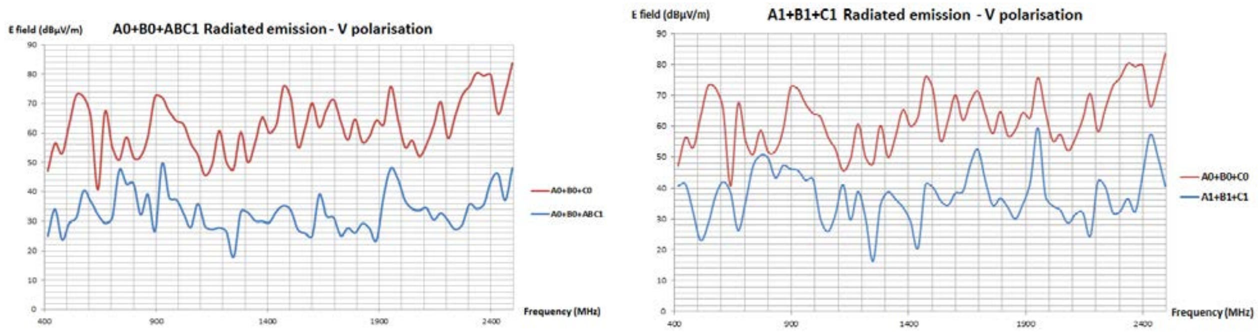

Fig. 3. Radiated emission improvement in V polarisation from the standard technologies to the C&K AO+B0+ABC1 DUT and to the A1+B1+C1 DUT

CONCLUSIONS

New Sub-D and Micro-D connectors, backshell and accessories, that deal with EMI leakage at connector level, have been developed by AXON and C&K. Such solutions should be implemented in chassis and harness design in order to lower as much as possible radiated emission coming from high frequency fast edge signal inside units. Those solutions are recommended when radiated requirements are challenging.

The importance of the know-how has also been identified in the course of the different test campaigns. When performing a mating/unmating cycle, one connector assembly can achieve different level of performance even without going under any aggression.

Some of the EMI connector technologies, developed by AXON and C&K, fulfill the goal of reducing the EMI by more than 15dB. The rest of the test campaign results will be presented during the SPCD presentation.