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Improving overall RF system performance by using coaxial splitters, combiners and couplers with integral isolators

Simon Liller

Airbus Defence and Space

Portsmouth, England

Outline

Telecommunication satellites are made up of RF paths routing throughout the payload. Received signals are amplified over the noise floor then routed and manipulated. The requirements can be met by using building blocks of coaxial cables, splitters, combiners, couplers etc, this approach allows flexibility to meet the customer needs, each connection within the RF system introduces a degree of poor matching and signal degradation, RF connections tend to be defined as 50 ohm, but there are tolerances around these parameters and each variation from the ideal impacts the system performance.

Present

The convention for cascaded components in each RF path is to treat them as being effectively isolated by linear accumulating the return losses. The overall return loss is calculated by accumulating the component powers returned at each junction. This simplification does not take into account either the phasing of the returned vectors or more importantly the real mismatch of impedances between components. For instance two transmission line components may have identical impedances and hence return loss. Cascading these components produces no return component at the junction and therefore no change in the coupled return loss. In payload situations the combined return loss will also be a function of frequency and not only be dependent upon the component return losses but also on their complex impedances.

In real life RF systems the accumulated return loss can be significantly lower than the theoretical value, many components have optimum match over a small bandwidth, in fact most coaxial devices are limited by the RF connector performance, and as the system builds up and is routed through coaxial cables, which again can provide less than ideal match, the return loss deteriorates.

Isolators

A common tool for reducing the impact of the poor RF match is to use coaxial Isolators, these devices allows an RF signal in one direction but not in the opposite direction, using magnets to influence the RF path, having the effects of reducing the unwanted reflected signals. Isolators reduce the return loss impact and RF measurement ripple, the additional insertion loss is outweighed by these benefits.

Development

For many years Isolators have been distributed along the RF path, however with each additional external device comes a degree of signal degradation. The development step taken by Airbus Space and Defence has been to incorporate Isolators into some of the common building blocks providing the advantages and reducing the disadvantages of external isolators. Coax combiner, coupler, splitter and dividers can have optimum return loss, providing these devices with better return loss improves the overall system performance, the connecting cable performance may now be the limiting factor.

Proposal

From the initial proposal to flight applications has taken ADS a number of years and involved both Isolator and coax device development. An initial generic specification produced in 2009 was evaluated by a number of suppliers, the breadboard units produced in 2012 proved the concept but also how difficult the integration could be and care required producing compliant units. Flight production was preceded by EM units in 2015, currently a number of suppliers are developing compliant devices. The generic specification defines the RF performance the device shall meet and the environment under which it must operate through the satellite lifetime, and clarifies the quality condition needed for flight use.

Packaging

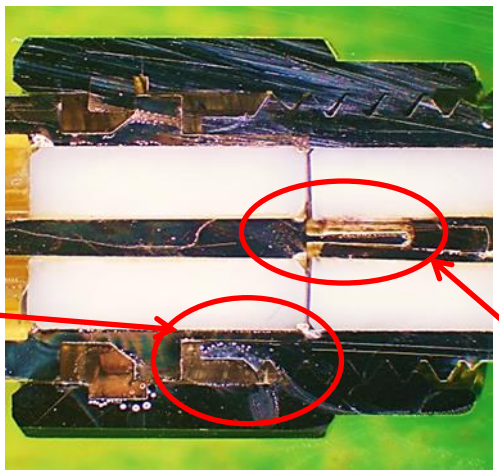
Packaging coaxial isolators within coaxial splitters, dividers, coupler and combiners etc, is not a simple process of enlarging the housing and dropping them in. in order to benefit from the development the internal RF match has to be better than an external RF connection and provide robust and constant performance over lifetime of the payload and under the environmental effects. In fact internally the RF match need not be 50ohm, we are only interested the external connections meet this value. One particular hurdle was the external RF connection through the housing which can be extremely sensitive to machining and assembly variation, individual tuning of each input and output is not efficient for flight production quantities.

RF connectors and Glitch reduction

There is an additional advantage with the development of integrated isolators within the coax device housing, this centre around unwanted RF performance changes due to environmental effects, such as thermal change. Commonly known as glitches this unwanted

RF performance can prove difficult to track and resolve, steps to resolve and remove glitches are beneficial for the payload teams.

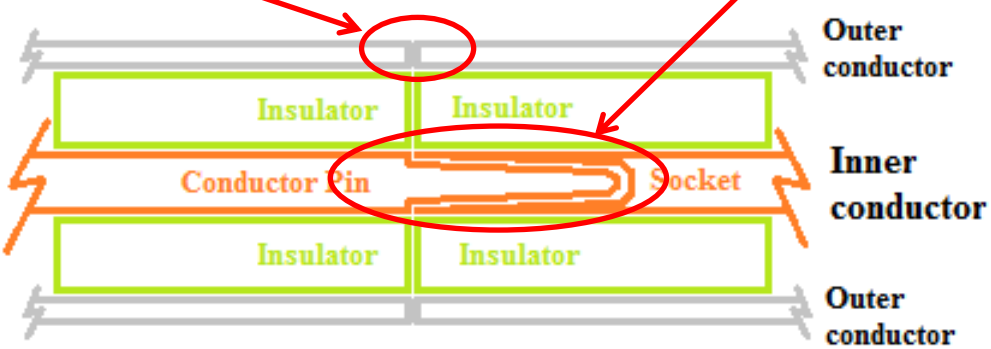
RF connections are made up of an external outer connection and internal centre contact. Typical coaxial connectors rely on external mechanical threads or bayonet to maintain good contact, outer conductors of circular conductors pressed together need significant mechanical change to have an RF effect, but the internal conductor has to deal with tolerance issues, mating and demating, and changes due to thermal pin to socket movement mismatch.



Outer RF connection, mechanically abutted and held with torqued coupling nut, no movement expected

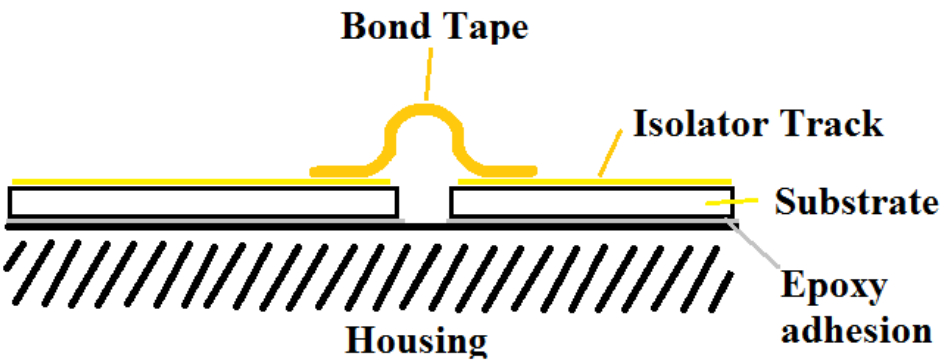
Inner RF connection, pin into socket, sliding joint allows for movement over temp etc

Cross section of mated RF connectors



Schematic of mated RF connectors

This cross-section image and schematic of a mated RF connector, in this case SMA, illustrates the inner and outer RF paths, as described the inner connection is pin onto socket and allows for some movement under different environmental conditions, the outer conductor is conductor ring to ring and whilst held together with correct torque will not change measurably.



Schematic of RF connection between substrates within housing

Integral isolators on substrate joining using bond tapes or solder joints, providing good ground will get good RF connection.

Substrate is bonded to the housing with conductive epoxy eliminating variation over temp this can be assumed to be the outer conductor, the inner conductor is between the tracks on the substrates this uses bond tapes or wires, either bonded or soldered, the loop in the bond tape allows for thermal movement, but since the actual RF length does not change then effects due to environment will have negligible effect.

Integrating a number of devices into a single housing has many advantages, but must be carefully planned and developed, for example even minor interactions can combine to create unwanted signals in the form of cavity resonances. Due to housing height and structure the standing wave with characteristic such that E and H fields are 90 degree out of phase with each other.

Summary

Integrating coaxial Isolators into coaxial devices has proved a good development providing telecom satellite payload teams with improved RF performance, for the mechanical design teams we have also reduced the overall component count. Delivered devices are tested to be compliant to RF system requirements and glitch free. Finally the new products improve quality with fewer connections and pre tested devices, with proven stability under environmental conditions for the designed payload lifetime.