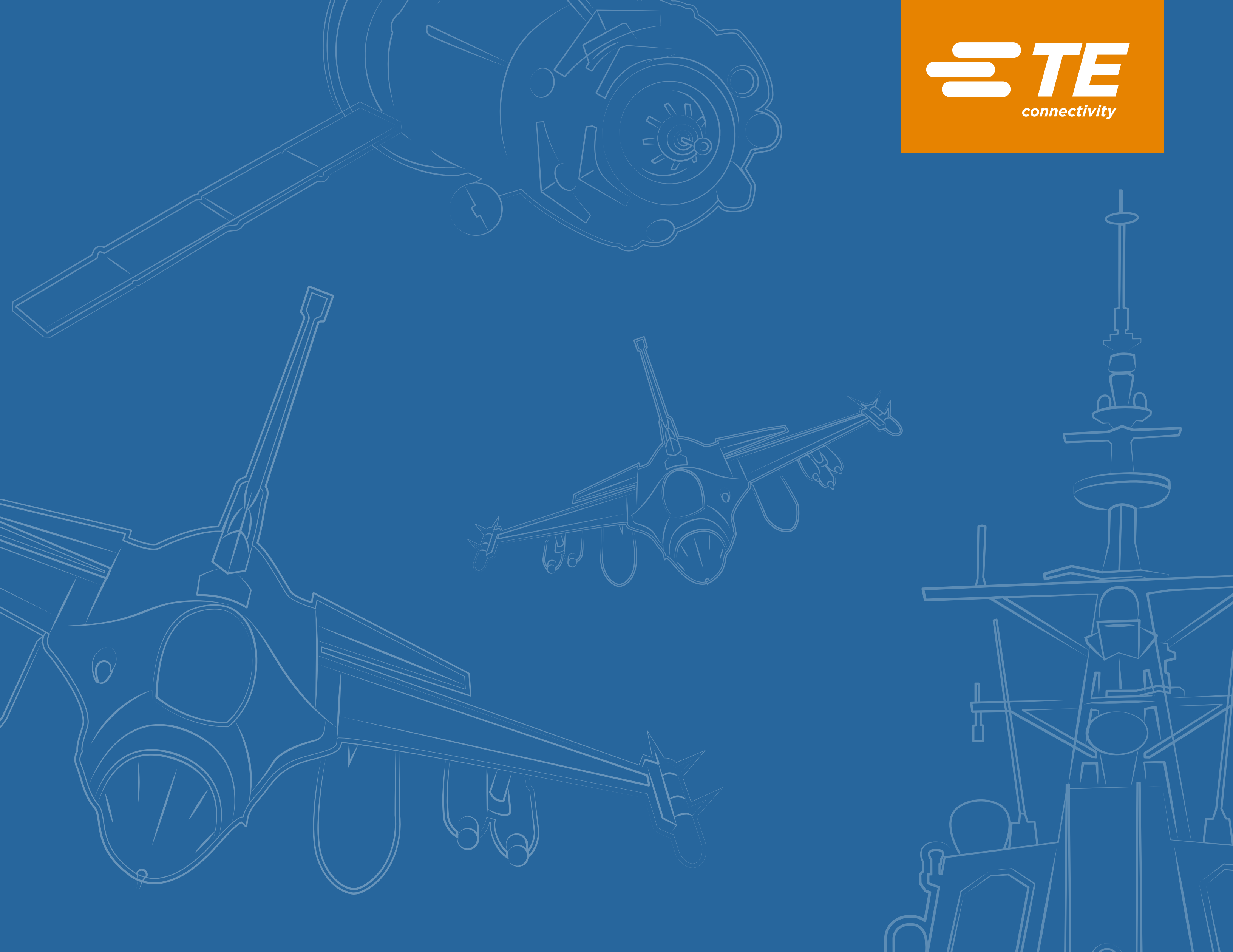

EVOLUTION OF THE NANORF INTERCONNECT

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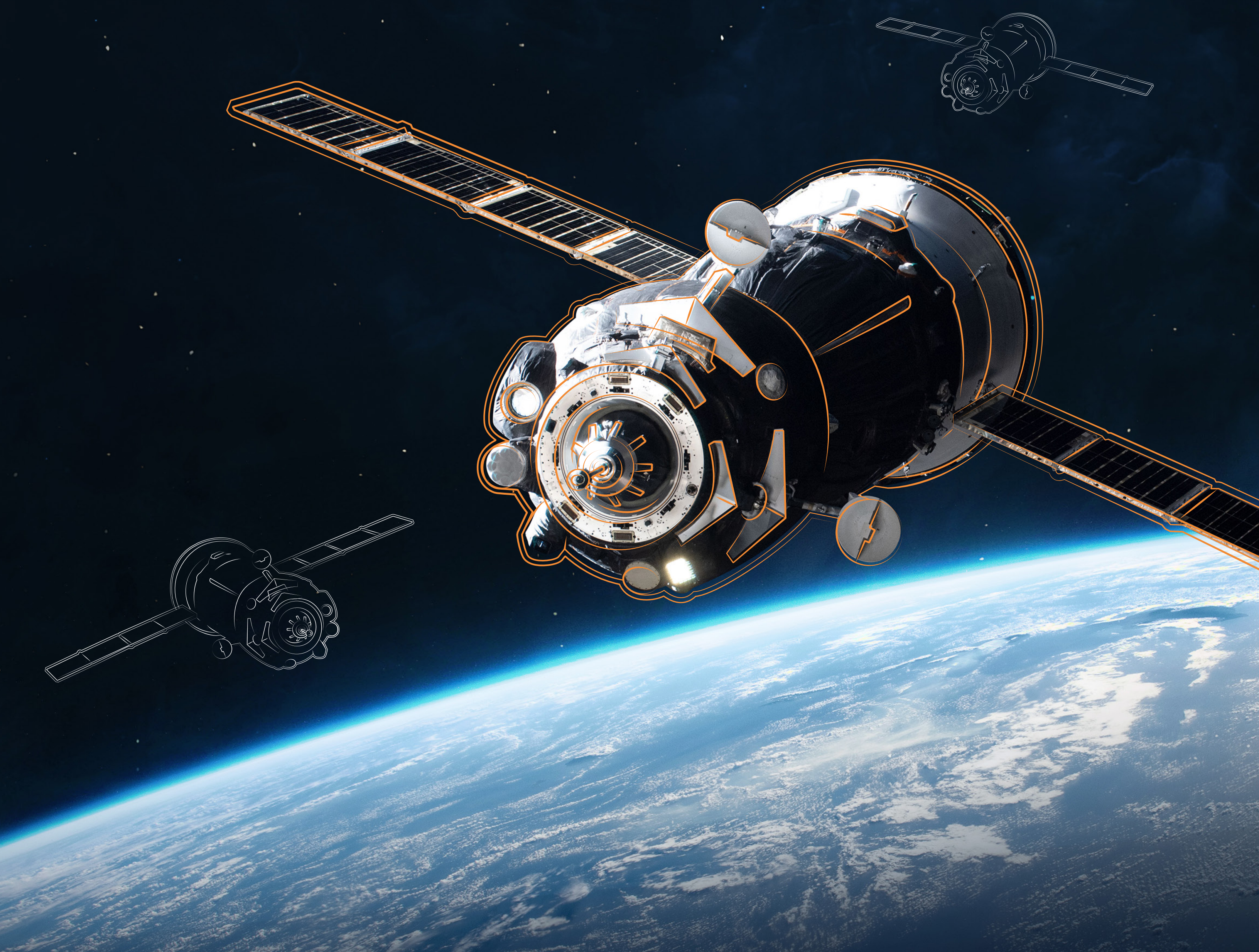
With the growth of OpenVPX system architecture for rugged embedded computing came requirements for RF (radio frequency) signaling in VPX-based products such as tuners, software defined radios, and RF switches. TE Connectivity (TE) developed the original modular multi-position coaxial contact solution defined in VITA 67 standards.

The VPX RF standards and products have evolved significantly within the last 10 years to support new defense systems and technologies for electronic warfare, radar, communications, and SIG-INT (Signals Intelligence). TE has worked closely with leading systems developers and the standards bodies VITA Standards Organization (VSO) and Sensors Open Systems Architecture™ (SOSA) to bring advanced RF interconnect technology to our warfighters.

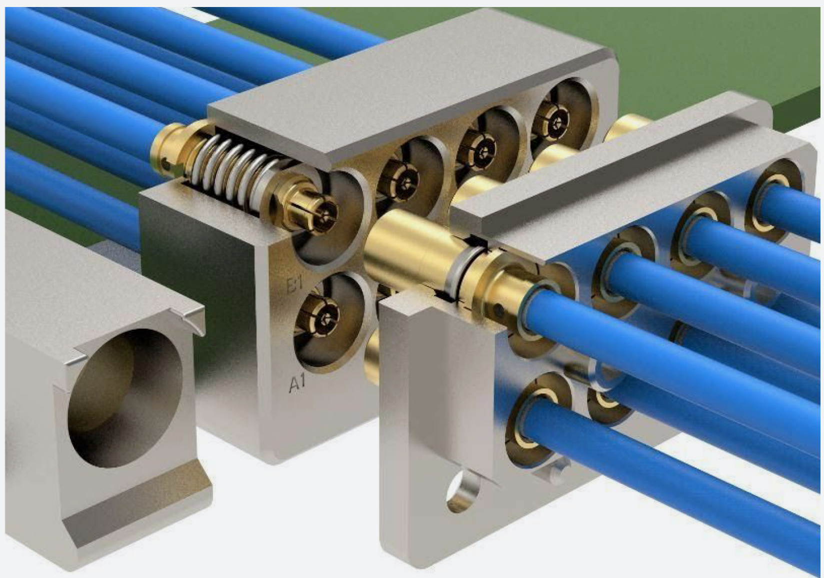


The Evolution of the VITA 67 standards

The VITA 67.1 and 67.2 standards were released in 2012, and defined RF modules populated with contacts based on the SMPM interface in blocks of 4 and 8 contacts for half modules and full modules respectively. Radial float of the contacts within the module cavities provide the alignment required during blind-mating. Contacts are spring-loaded in the plug-in modules (Figure 1), providing axial float under compression to assure that the RF interface is bottomed through the range of plug-in card to backplane tolerances and to maintain the fully-mated position under shock, vibration, and temperature extremes to optimize isolation and RF performance.

FIGURE 1 | CONTACT FLOAT IN VITA 67.2 RF MODULES

VITA 67.2 RF

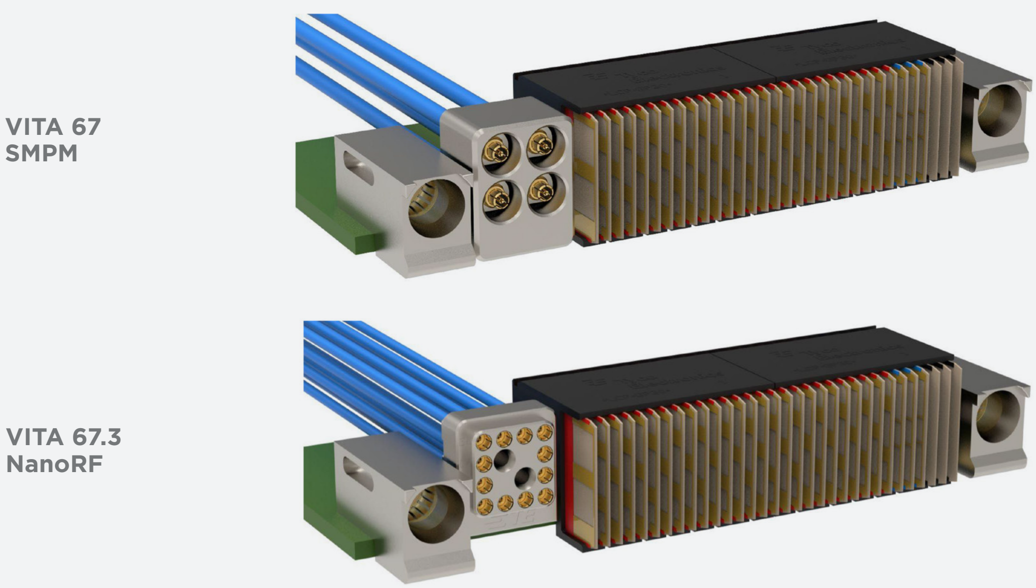


With the release of the VITA 67.3 standard in 2017, the spring-loaded contacts shifted to the backplane and the fixed contacts to the plug-in module. This allowed edge-launching (solder termination) of the RF contacts directly off the plug-in card. This implementation eliminates the need for cables, saving valuable space and eliminating complex cable routing within the tight constraints of a VPX plug-in module. The VITA 67.3 standard also supports a 1” slot pitch versus the original 0.8”, enabling larger RF module interfaces (to add more coax contacts) and allows flexibility in contact positions, so predefined 8 SMPM contacts from VITA 67.2 can increase to 14 SMPM contacts utilizing the same board space within the plug-in module.

With the push for more I/O and bandwidth through the VPX module-to-backplane interface came the need for higher density contacts. A 3U VPX plug-in module has about 3 inches of space along the edge of the card for interconnect between the guide hardware. With requirements for more high-speed differential pairs, more RF lines, and optical links within the 3U and 6U VPX slot profile spaces came the push for higher density RF and optical modules. The latest draft revision to the VITA 67.3 standard adds higher density RF interfaces NanoRF and SMPS, adding to the legacy SMPM contacts.

TE developed the NanoRF interconnect system to support higher density VPX applications (Figure 2) with a new, very small high frequency contact interface, a robust contact retention design in the multi-position module, and alignment features that assure reliable mating and consistent performance under extreme environments.

FIGURE 2 | **DENSITY ADVANTAGE OF NANORF IN A 3U VPX PLUG-IN CARD**



Design Challenges with Extremely High Density Coax

The need for smaller, higher density coaxial contacts with the ability to support higher frequencies and RF performance presents new design and manufacturing challenges in multi-position solutions that require blind-mating such as VPX.

ALIGNMENT

Accurate contact alignment in blind-mate applications is critical. VPX plug-in modules can be inserted or extracted from slots in the chassis under harsh conditions. From on the ground in a warzone to a fighter jet, misaligned contacts can cause damage leading to critical failures and resulting in costly repairs in an installed chassis. As RF contacts are reduced in size to nanominiature interfaces, the tolerancing to assure alignment becomes challenging.

SIGNAL INTEGRITY

The heart of any new RF connector system is the electrical performance. As the demand increases for contacts with greater frequency range and tighter packing density, the need for precisely tuned and smaller contacts increases proportionally. It is imperative to use state of the art modeling simulation software to accurately predict outcomes that are consistent with design objectives. The slightest changes in impedance above or below 50 Ohms can severely impact electrical performance. Any changes in diameter or material compensation needs to be carefully compensated with small geometric changes.

MANUFACTURABILITY

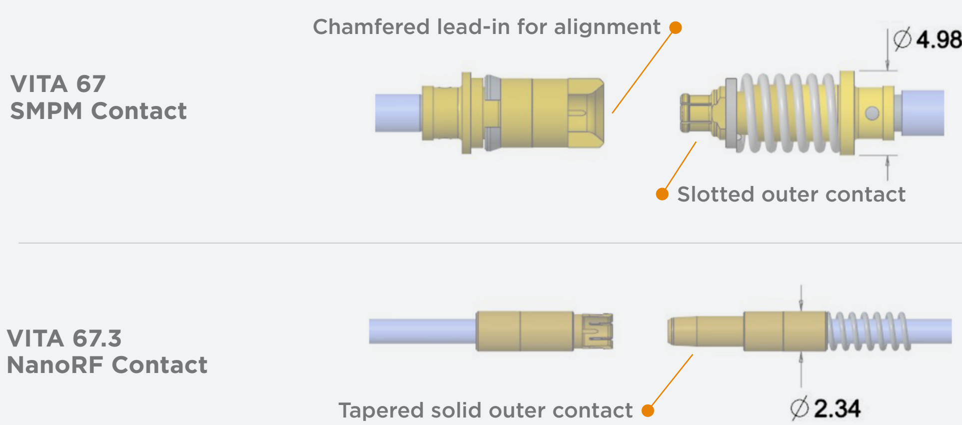
Miniaturization brings manufacturing challenges. When designing high frequency contacts with pins of .010" diameter and smaller, every tenth of a mil (0.0001") has an impact on impedance and fit within the assembly. Machining tolerances get very tight. You need to allow for thickness of plating layers, evaluate fit of components through the full tolerance range, and manufacturing and measurement equipment and processes need the level of precision and repeatability to build consistent quality parts.

Alignment of the NanoRF Interface

The original VITA 67 standards defined contacts are based on the SMPM interface, which relies on the plug contacts to self-align with an expanded chamfer (often called a "catcher's mitt") in the receiving jack. The downside of this approach is the increased wear on the contacts as they mate, and the potential for deformation of the slotted outer body due to repeated engagement with the mating connector chamfer wall. If the outer conductor closes by even a couple mils, the impedance in the interface is reduced and may degrade performance especially at higher frequencies. The effects of this alignment approach on performance is increased with smaller interfaces.

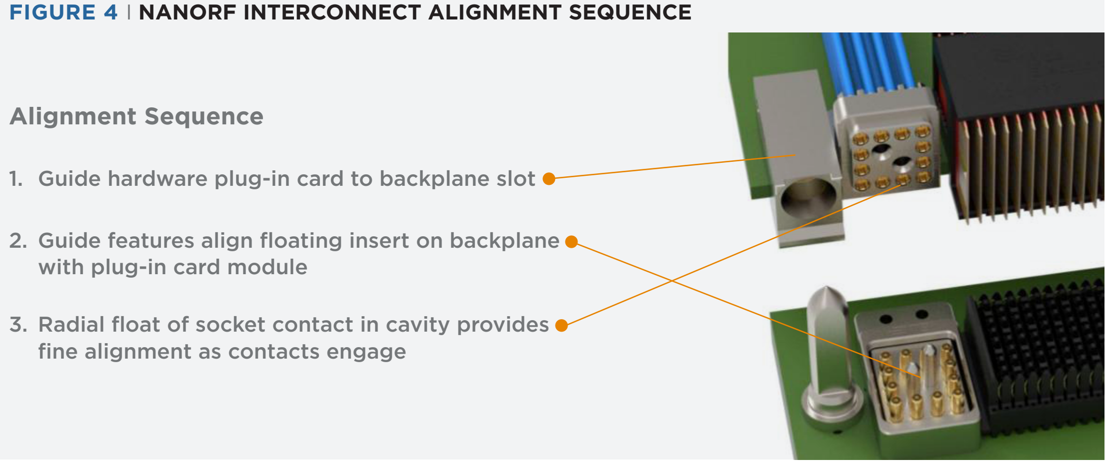
NanoRF uses features in the module system to pre-align the coax contacts before they engage to help minimize wear of the interface. The contacts are a more traditional pin and socket style with a solid tube as the plug contact's outer conductor which helps prevent deformation and improves isolation over a slotted structure (Figure 3).

FIGURE 3 | CONTACT FEATURE COMPARISON: SMPM AND NANORF



In VPX embedded computing architecture, the NanoRF modules are positioned on the plug-in card and backplane per VITA 67.3 requirements. The plug-in card is initially aligned with the backplane slot by the VPX guide hardware (refer to Figure 4).

FIGURE 4 | NANORF INTERCONNECT ALIGNMENT SEQUENCE



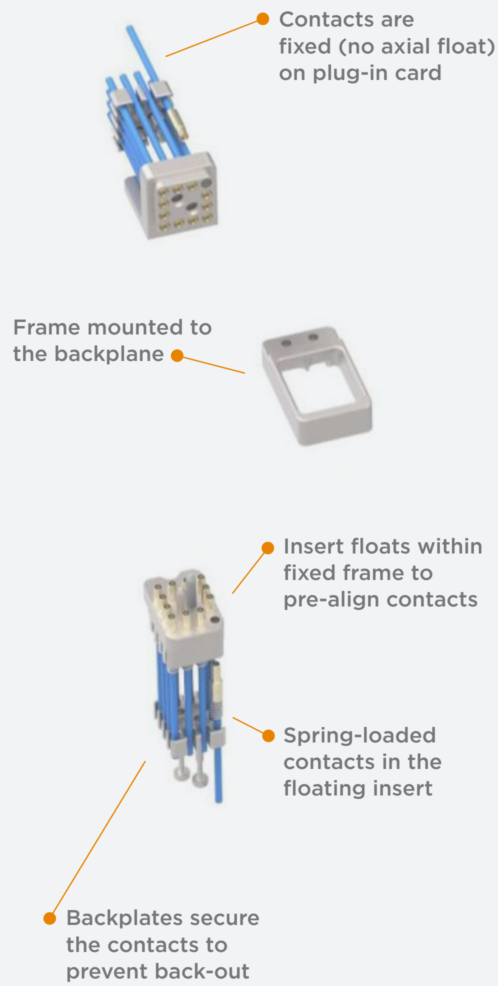
The next sequence of alignment utilizes the guide features of a floating machined insert which has the contacts captured within it. This insert is nested within a fixed frame mounted to the backplane. The floating insert design for the backplane modules was adopted from TE's VITA 66 optical modules where it is used to precisely align the optical fibers in MT (Mechanical Transfer) ferrules. In NanoRF, the floating insert on the backplane aligns with the RF module on the plug-in card, pre-aligning the array of coax contacts before they start to engage.

Lastly, there is radial float and a lead-in chamfer to assure that the coax contacts are precisely aligned as they engage. With a contact post of .010" diameter, this sequence of alignment features is critical to the repeated reliability of blind-mating and with minimal wear under harsh environments.

With miniaturization of the coax contact interfaces, a traditional contact design with a retention clip that snaps into in a module cavity must be toleranced much tighter. The bearing surface for the clip against the cavity shoulder is then reduced, lowering the pushout forces of the contact.

With NanoRF, the contacts are retained in the module cavities with a backplate that is screwed into the machined module (Figure 5). This captures the contacts and retains them securely in position under compression. The backplate also acts as a strain relief for the soldered section of the cable termination so a cable bend can be applied directly behind the backplate minimizing risk of fracturing the solder joint.

FIGURE 5 | NANORF ASSEMBLY



Signal Integrity

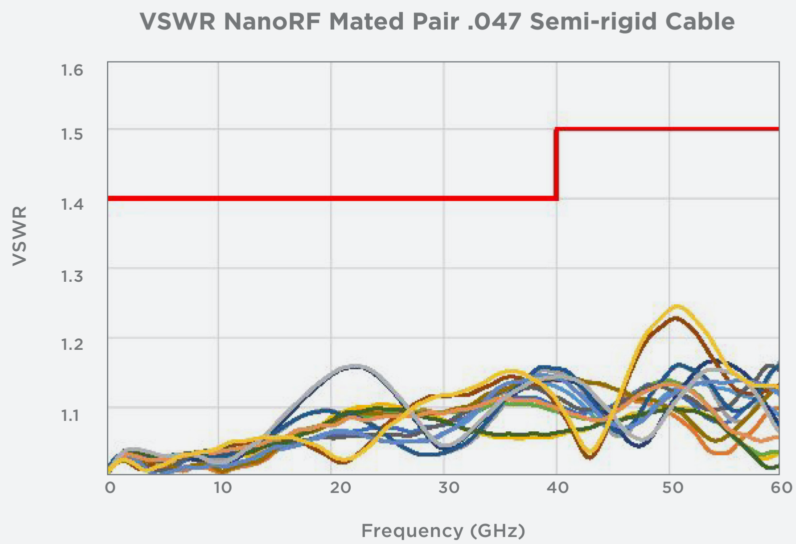
The NanoRF interface and contact structure has been developed through numerous iterations of electrical modeling to ensure signal integrity. Contact geometries have been tuned for performance, to the extent that the center contact beams have tapered diameters as machined resulting in a consistent outer diameter and matched impedance in the mated condition. Cable transition into the contact is included in the electrical models to optimize the termination. Precision tolerances help assure that performance is consistent from lot to lot in machining and assembly.

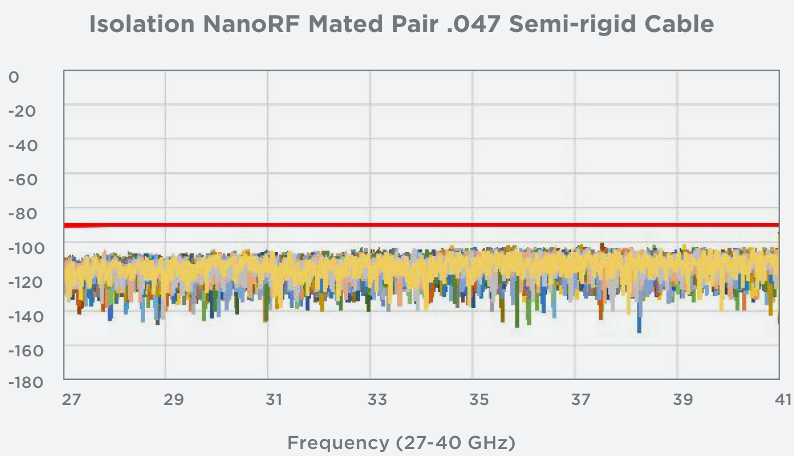
The pin contact has a solid body; no slots that will contribute to RF leakage at the interface. The contacts are captured within a machined module to provide excellent isolation over 100dB through 40 GHz.

The backplane contacts are spring-loaded in the backplane insert providing axial float to take up the tolerances between the plug-in card and backplane which in VPX systems can vary by +/- .020". This axial float assures that the RF contact interface is always bottomed for excellent isolation and RF performance through shock, vibration, and temperature extremes.

The result is an extremely clean signal propagation as can be seen in the VSWR performance and isolation between adjacent signals verified to be nearly noise-free (see Figure 6 below).

FIGURE 6 | NANORF INTERCONNECT TEST RESULTS



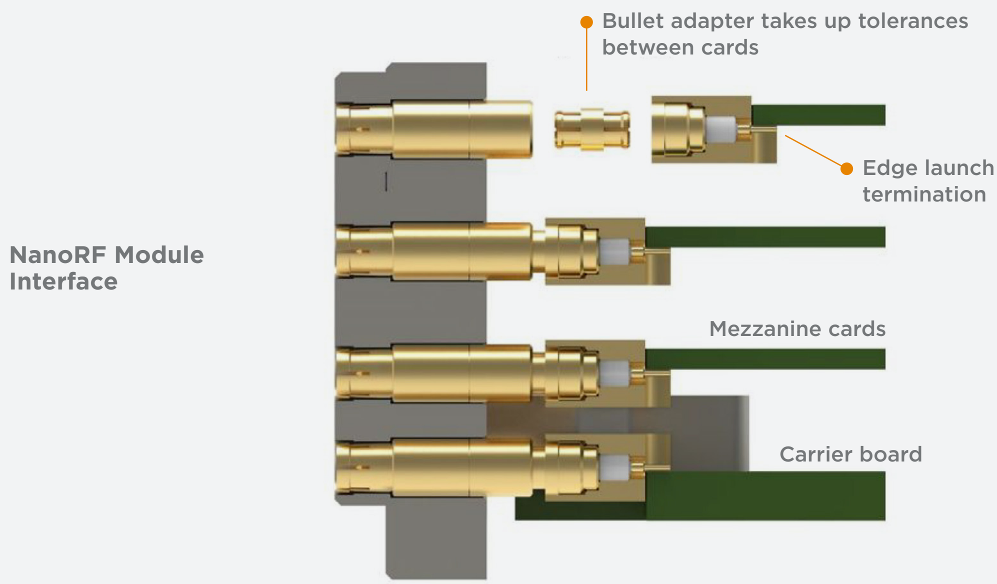


NanoRF contacts are designed to support standard cable sizes of .047" and .086" – with semi-rigid, conformable or flexible RF cables. While .047" diameter cables offer the highest density and allow .110" spacing between contacts, .086" cables have lower insertion loss and generally are more phase stable supporting backplane contacts at .155" spacing. In VPX applications, cables in the plug-in module are generally very short and require tight bend radii for routing around components so .047" cables fit the application. Backplane cables are generally longer so .086" cabled contacts are only offered on the backplane side for lower loss and better phase stability under vibration and temperature fluctuations. An adapter kit can be used to populate an .047" cabled contact on the backplane in a module cavity that supports .086" cabling, bringing flexibility to the implementation.

Eliminating Cables in a Plug-In Module

Initially released as a cable-to-cable solution, NanoRF is evolving to include edge launch designs. VITA 67.3 defines the fixed contact on the plug-in card side of the interface and thereby allows contacts to be soldered directly to the board. And not only terminated to the carrier board, but also to mezzanine cards stacked above it. Several NanoRF modules developed in alignment with the SOSA™ Technical Standard, have been configured with contact row heights that can align with stacked mezzanine cards, bringing unprecedented RF contact density in computing modules with no internal RF cables. With multiple rows of contacts launching off separate boards, tolerances between the contacts add up. Bullet adapters are used to take up the stack-up of tolerances between the cards and contacts within the cards and bring the entire array of contacts into precise position at the module plate interface (Figure 7).

FIGURE 7 | NANORF EDGE LAUNCH APPLICATION

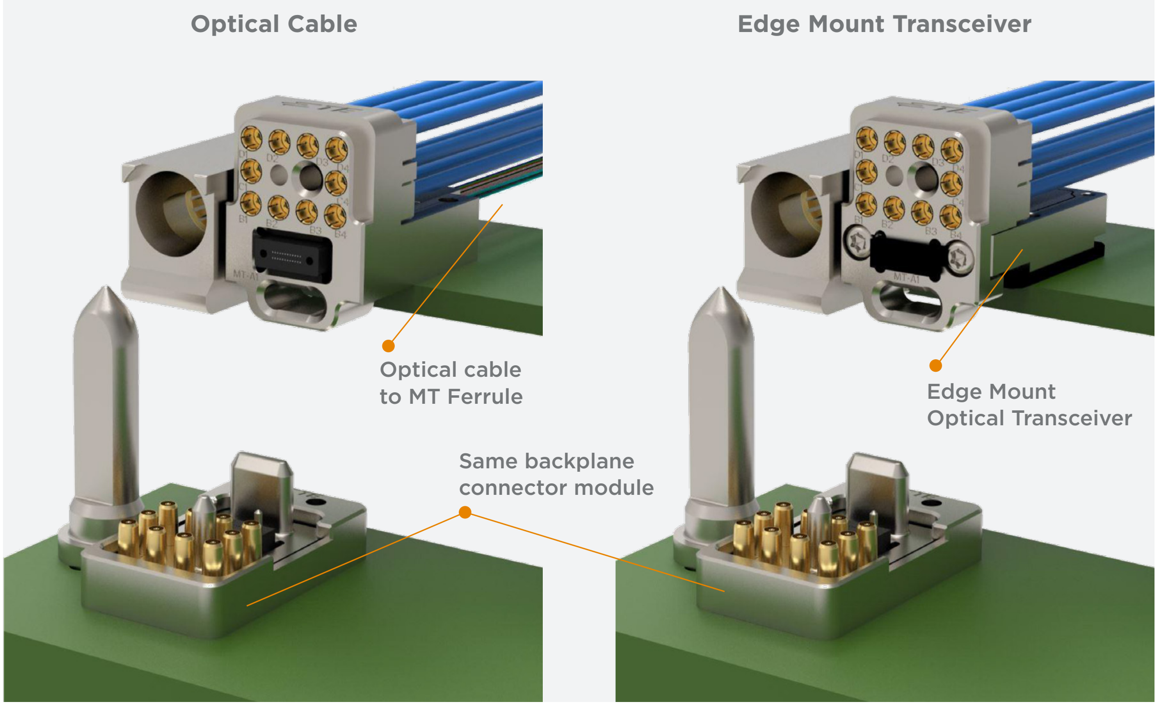


Integration of RF and Optics

NanoRF VITA 67.3 modules use the same floating insert design on the backplane for alignment as VITA 66 optical modules. This enables the integration of RF contacts and optical termini in the same connector module, sharing common guide features to align both the RF contacts and the optical MTs. This capability brings significant density advantages. In applications where both RF and optical signals need to be supported, incorporating these into one machined connector module instead of side by side modules saves valuable board space in a VPX plug-in card (Figure 8).

The MT interface can be from an optical cable that is routed from a mid-board transceiver, or it can be the interface of an edge mounted transceiver. The edge mount transceiver does the electrical to optical conversion at the edge of the card, freeing up space that would otherwise be taken by a mid-board transceiver and eliminates the need to route optical cable within the plug-in module. The RF/optical hybrid modules are designed to support both optical implementations with the same mating interface – this brings versatility and flexibility in the design of the plug-in module as they can mate to the same backplane slot.

FIGURE 8 | NANORF HYBRID RF/OPTICAL MODULES: OPTICAL CABLE VS EDGE MOUNT TRANSCEIVER



The Future of the NanoRF Interconnect

The NanoRF interconnect system has been developed for VPX systems to provide excellent RF performance, achieve extremely high density, survive harsh environments, and build in flexibility for use in multiple RF and IF (intermediate frequency) applications, including those requiring optical links. Integrating precision alignment features and a robust contact design into a module system has led to a product that successfully passed extreme vibration and temperature testing and brings unprecedented density to the VPX plug-in module interface.

This NanoRF technology can be carried over to I/O connectors, suitable for packaging high density RF in Micro-D and M38999 connectors, for internal cabling or box-to-box communications. Radar arrays can leverage the size and performance of NanoRF for the RF interfaces between stacked boards, with a rugged bulletized implementation. Point-to-point NanoRF cabling can solve routing challenges in tight spaces.

Look to TE Connectivity as the NanoRF technology expands into other RF interconnect solutions.