# Survey of Common Backside Connections

Tom Roberts

[Summary] The backside connection refers to a microwave transition that is common to many RF/Microwave components and assemblies. This transition forms an interface between the connector and circuit. Often, the backside connection is an area where electrical and mechanical problems can occur. This paper discusses design considerations of some common backside interfaces.

## 1 Introduction

The backside connection interface refers to a microwave transition that aids in the propagation of electromagnetic signals from one transmission line type to another. Ideally, this transition efficiently allows energy to propagate from one point to another with no reflections. Practically, transitions are never perfect and will always produce a small amount of signal reflection. The front side connection, as opposed to the backside connection, is an interface usually defined by a published standard[1] for example. The IEEE-P287 precision coaxial standard only defines the mechanical requirements of the customer facing front side connection interface and does not define the design requirements for everything behind the interface such as slotted center conductor contacts, bead supports, the backside connection interface, etc. The backside connection, just behind the connector, is a location where electrical and mechanical issues can arise in a microwave module component or subassembly.

Some characteristics and requirements that define a good backside connection are: a broadband low reflection transition, ease of assembly and able to withstand mechanical and thermal stress. As described by Oldfield[2] the backside interface becomes more critical at higher frequencies. Achieving the requirements stated above are difficult due to decreased circuit sizes. As a general rule-of-thumb, Microstrip substrate thicknesses need to be kept no greater than 10% of a wavelength at maximum frequency of operation to avoid unwanted mode responses as show by equation 1. The equation shows the maximum usable substrate thickness is inversely proportional to maximum operating frequency and demonstrates the requirement for circuit size reduction. The mechanical features of the coaxial connector also scale inversely with frequency. The connector's diameters need to be small enough to push the coaxial transmission line's TE11 mode above the highest frequency of operation[3].

$$h_{max} = 0.1 * c_0 / (\sqrt{\varepsilon_{eff}} * f_{max}) \qquad (1)$$

Oldfield discusses a 10-mil thick Alumina substrate as an example in describing the difficulty of using this dielectric for a backside transition. A 50-ohm characteristic impedance transmission line on 10-mil thick Alumina requires a 10-mil wide trace. Connecting a center conductor with a diameter equal to the Microstrip trace width onto this trace and making a good electrical connection is not easy due to the small contact area.

There are many options in the design of a Coax-to-Microstrip backside connection on thin film: overlap pin, non-overlap pin, axial pin, soldering, gold ribbon wrap bonding, pressure contact, etc. Each needs to be considered carefully since they can impact electrical and environmental performance, cost and reliability.

## 2 Overlap Backside Pin Connections

### 2.1 Gold Ribbon-Wrap connection

Backside connections using gold ribbon-wrap are common with assemblies having either an integrated or soldered glass fired 50-ohm feedthrough with a protruding pin as shown in the CST Microwave Studio[4] model in Figure 1. The substrate is 10-mil thick Alumina with a 10-mil wide trace. The pin is 12-mils in diameter and 3-mils above the substrate surface. The 0.5 mil thick gold ribbon has circular diameter of 15-mils and is 5-mils from the substrate edge. The ribbon provides a stress relief assuming the ribbon is not taut and a loop remains. A tack bonder is used to bond the ribbon to the top of the pin.

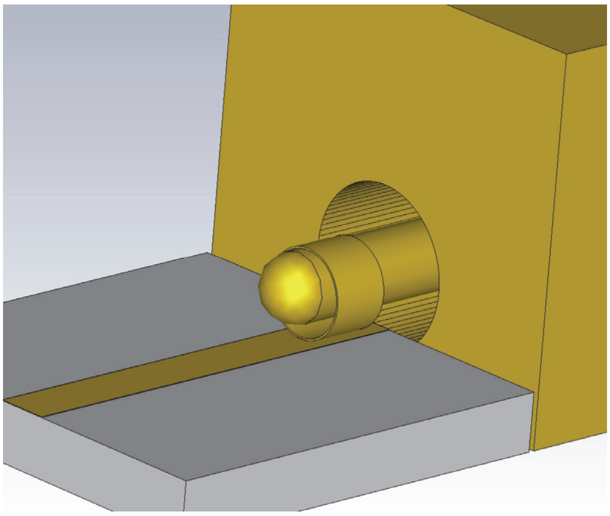

Figure 1 Backside pin overlap on 10-mil thick Alumina using gold ribbon-wrap

Figure 2 shows parametric sweep of the return loss response of the gold-ribbon wrap connection by varying both pin height above the substrate and ribbon diameter. The pin height distance (h) above the substrate was varied 1, and 4-mils and the ribbon diameter (d) varied 13 and 16-mils respectively. Practically, there are a few difficulties implementing this backside connection. For pins that protrude from the backside, it may be difficult to install the substrate *after* the pin is installed into the housing due to the protruding pin. Depending on the assembly the substrate may be required to be installed *before* the pin is installed. There must be enough clearance between the bottom of the pin and the top surface of the housing and 3 to 4-mils clearance is reasonable assuming typical manufacturing tolerances. Finally, controlling the ribbon loop diameter (i.e. the amount of stress relief) and ribbon placement is difficult and can vary from one assembly to the next.

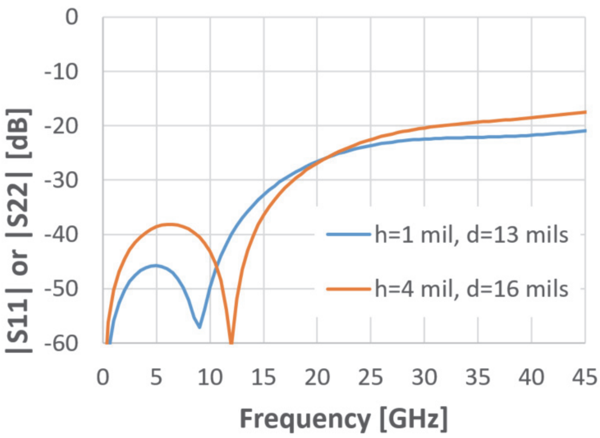


Figure 2 Parametric reflection response of gold ribbon-wrap model

## 2.2 Solder connection

Soldering the backside connection of a hybrid microwave assembly requires flux to be applied and the assembly heated. Unless solder preforms are used, it is difficult to control the amount of applied solder. Excessive solder can cause the backside connection to be capacitive and degrade RF performance. Soldering can also leach gold from thin film circuits making the solder joint brittle, weak and mechanically unreliable. Localized heating cannot be easily performed at the backside connection since the substrate thermal conductivity is usually high for most ceramic substrate materials. The connectors support-bead material(s) melting temperature needs to be taken into account since heat transfer through the pin can potentially melt the bead. Printed Circuit Boards (PCBs), on the other hand, typically make use of edge mount SMA connectors where the pin soldered onto a copper trace with an electroless nickel immersion gold (ENIG) plating barrier. Soldering using localized heat at the connection is performed since the thermal conductivity of the PCB materials is typically low. SMA connectors often use a PTFE support bead material and can withstand high soldering temperatures.

## 2.3 Pressure contact connection

Easily testing and characterizing individual thin-film circuits in a solderless test fixture prior to integrating them in a module assembly is highly desirable. The Anritsu 3680 series Universal Test Fixture[5] (UTF) allows Microstrip or Coplanar Waveguide (CPW) test substrates to be clamped directly into coaxial launchers eliminating the need for carrier blocks or custom test fixtures. In addition, 3680 includes Microstrip calibration standards to calibrate out the fixture.

The center conductor pins on the back side of the UTF's RF connectors make a spring loaded pressure contact with the Microstrip trace. The center conductor pins of the 3680K and 3680V UTFs differ in design as shown in Figure 3. The pin of the K connector contacts the substrate about 4 mils in from the edge of the substrate while the pin of the V connector must make contact at the edge of the substrate. Substrate fab design criteria usually requires the Microstrip trace ends before the edge of the substrate. In such cases, a straight pin may not make contact with the trace. However, at frequencies above approximately 50 GHz, not making contact at the substrate edge results in poor performance.

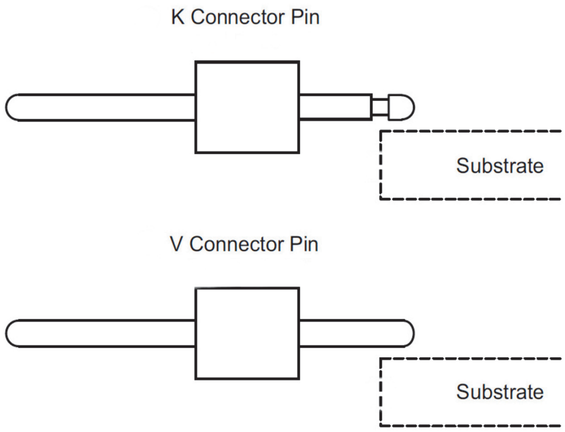


Figure 3 K and V pressure contact pins of Anritsu 3680 Universal Test Fixture (UTF)

Recently, clamp-on edge mount connectors have become available for use with Microstrip or CPW printed circuit boards (PCBs) which also utilize an overlap pressure contact connection. Unlike the 3680 series UTF, removing the effects of these connector fixtures and their backside transition responses is not easy since substrate calibration standards are not provided.

## 3 Non-overlap Backside Pin Connections

### 3.1 Sliding contact

The backside pin overlap can obstruct the assembly of the substrate if the pin is installed before the substrate. Sliding contacts solve this problem. Sliding contacts are small bondable gold plated copper sleeves with a tab. The sleeve of the sliding contact slides over the center conductor pin which is recessed into the housing. The tab of the sliding contact protrudes from the housing and is bonded to the substrate. The model shown in Figure 4 is an Anritsu K110-1-R[6] sliding contact connected to a 12-mil diameter recessed pin and bonded to a 10-mil thick Alumina substrate with a 10-mil trace. Figure 5 shows typical reflection response of the transition. The sliding contact also provides stress relief since the pin and sleeve can slide during thermal expansion and contraction. The tab of the sliding contact can be made to match the width of Microstrip traces. Sliding contacts can be difficult to mount onto the pin due to their small size. Gold-to-gold gap weld bonding is one way to bond the sliding contact to the substrate trace. Gap weld bonding using flux coated gold-tin preforms between the tab and substrate is another method of attachment. Low temperature solders such as Indium can also be used. For any attachment method chosen, careful process development and environmental qualification is required.

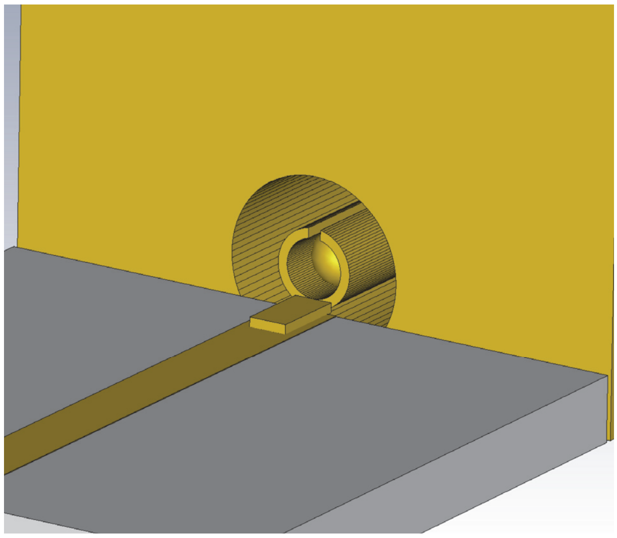

Figure 4 Non-overlaping pin using K110-1-R Sliding Contact on 10-mil thick Alumina

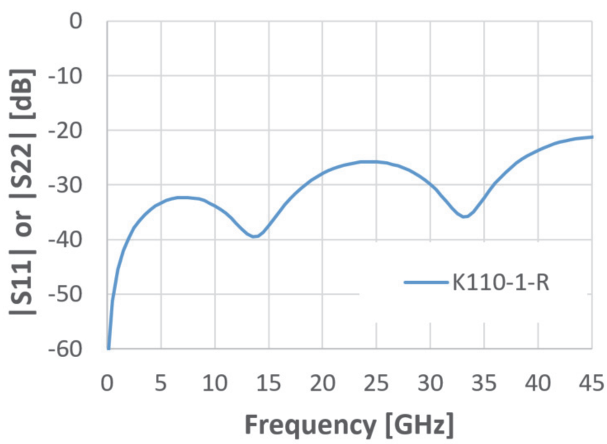


Figure 5 Typical reflection response of Sliding Contact model

### 3.2 "Watermelon Seed" axial contact

An axial contact called a "Watermelon Seed" was introduced in 1996 by Oldfield[7]. The watermelon seed contact is a tapered pin designed to fit inside the backside slotted contacts of a flanged or sparkplug coaxial connector. When axial pressure is exerted on the pin, the tapered pin spreads the fingers of the female slotted contacts causing an opposing longitudinal pressure. This longitudinal pressure by the slotted contacts attempts to expel the contact pin in the same way as squeezing a fresh watermelon seed between your fingers. The tapered contact pin has a flat face that contacts either Stripline or Suspended Substrate with a metalized edge usually fabricated using a gold ribbon wrap-around. Figure 6 shows a 12° angled axial contact. Figure 7 shows an assembly model of a 1.85 mm (V) coaxial slotted contact and tapered axial pin interfacing to a 22.5 mil (h) × 18.6 mil (w) Stripline bar. Figure 8 shows typical reflection response of this compensated transition. The side of the pin protruding out from the end of the slotted contacts is smaller in diameter than the slotted contacts. This feature causes the structure to be inductive and must be compensated for. Sometimes it is difficult to compensate the transition by altering the outer conductor. The pin face diameter can be enlarged to compensate for the small inductance at the end of the slotted contact as shown in Figure 9. Figure 10 shows a capacitively compensated pin installed into a connector and its mating Shielded Suspended Substrate Stripline circuit with gold ribbon wrap in Figure 11. The assembly forms a 3-dB attenuator and its measured response is shown in Figure 12.

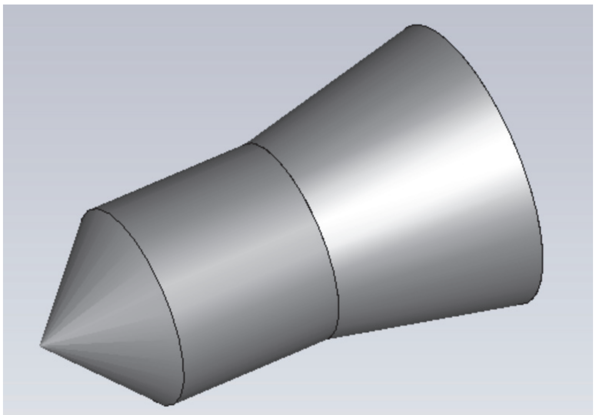

Figure 6 Watermelon seed axial contact with a 12° taper angle

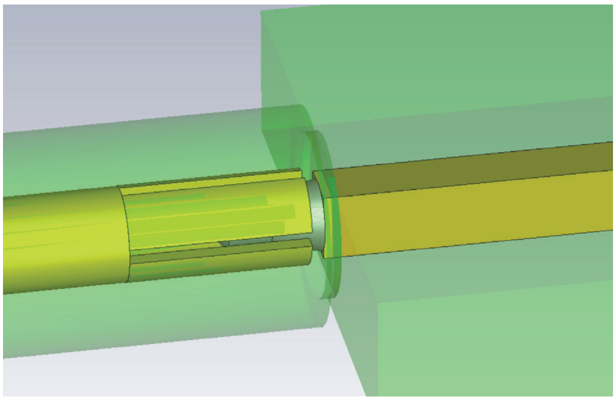

Figure 7 1.85 mm (V) Coax-to-thick Stripline transition using a 12° tapered watermelon seed contact

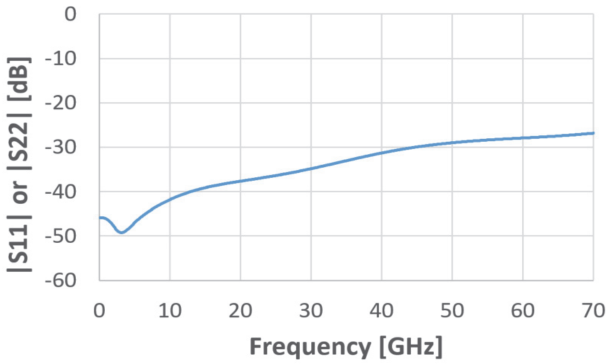


Figure 8 Typical reflection response of compensated 1.85 mm (V) Coax-to-thick Stripline transition using a tapered watermelon seed contact

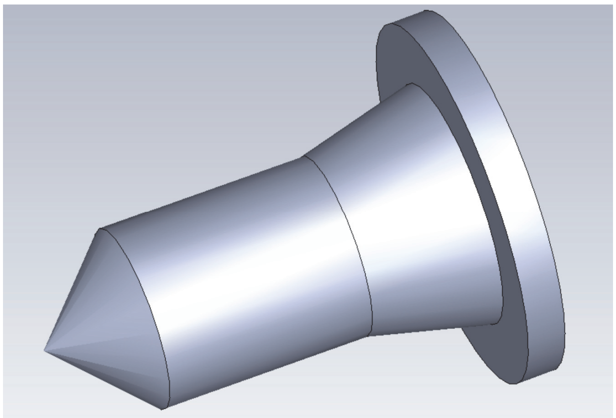

Figure 9 Capacitively compensated pin face of watermelon seed axial contact with a 12° taper angle

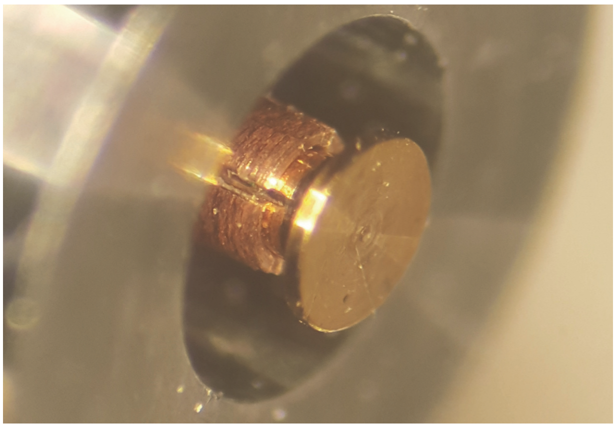

Figure 10 Capacitively compensated watermelon seed pin installed into the backside of a 1.85 mm (V) connector

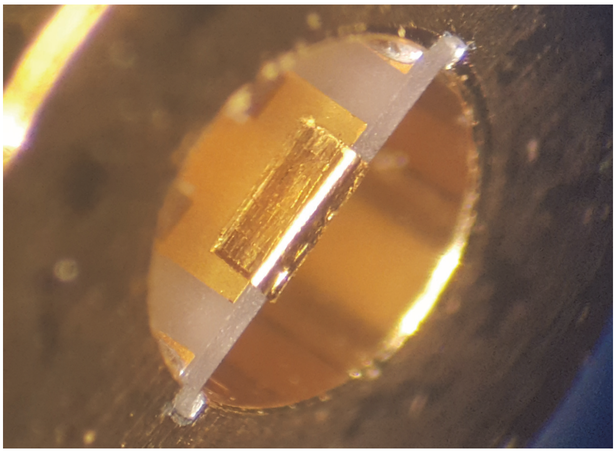

Figure 11 Shielded Suspended Substrate Stripline circuit with gold ribbon wrap-around to contact watermelon seed face

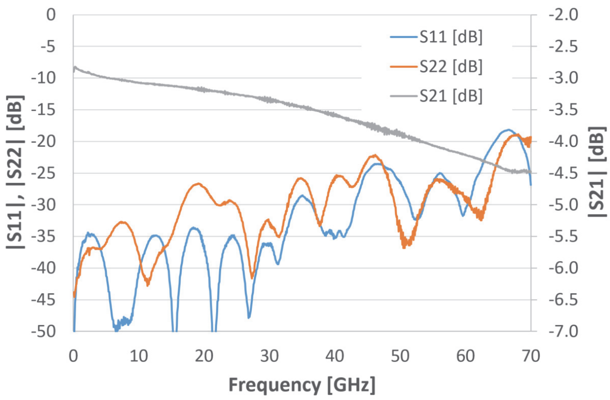


Figure 12 Response of a 1.85 mm (V) coaxial 3-dB atteunuator assembly using Shielded Suspended Substrate Stripline circuit and watermelon seed axial contact

Both taper angle and slotted contact finger thickness are the primary parameters that influence the amount of pressure required to compress the contact. Figure 13 shows how forces can vary significantly with both taper angle and slotted contact finger wall thickness. 50% compression is defined as the compression required to bring the slotted contact end half-way up the tapered portion of the pin. High forces are to be avoided since internal assemblies can physically move with time and temperature.

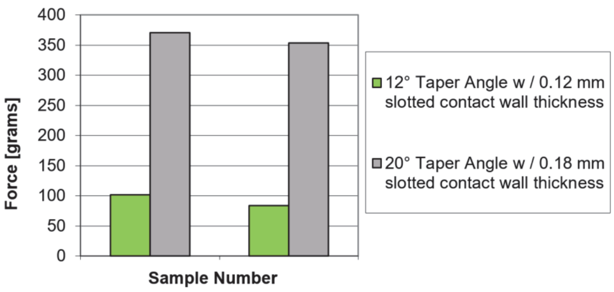


Figure 13 Influence on compression force with taper angle and slotted contact wall thickness. 50% compressed.

Besides watermelon seed pin angle and slotted contact wall thickness, there are many other critical electrical and mechanical design considerations to take into account in the successful development of these contacts such as: contact pin surface finish, contact pin plating, DC contact resistance, operational temperature, friction between parts etc. Further discussion of these considerations is beyond the scope of this article. One of the main advantages of the watermelon seed axial contact is it requires no bonding or soldering for the connection. In addition, the connection is blind-mate with fast assembly times and with few errors in manufacturing.

### 3.3 Bellow axial contact

Bellow flexible gold plated contacts have been developed by Servometer[8]. These axial contacts are manufactured from a proprietary flexible metal FlexNickel®, a cobalt-nickel alloy with a gold plated finish. Bellow contacts have a relatively low compression force compared to watermelon seed contacts where compression forces due to the slotted contacts can be high if the taper angle is large. The 2000 series bellows from Servometer do not need to be soldered to the backside coax pin. Bellow contacts have low DC resistance and wide operating temperature range. Bellow contacts can be prohibitively expensive and in many microwave component assemblies this can make them impractical.

## 4 Single-bead vs. Dual-bead assemblies

A dual-bead connector assembly is shown in Figure 14. This backside connector configuration uses an Anritsu K102F-R sparkplug connector, a K100 glass bead and a K110-1-R sliding contact. The two beads are: 1) the K100 glass bead and 2) the bead supporting the center conductor of the K102F-R connector. This configuration is mechanically very rugged with excellent reliability. Any mechanical movement (perpendicularly or axially) at the front side of the K102F connector does not translate movement at the backside interface due to the rigid glass bead structure. Hermiticity is another benefit provided by the soldered-in glass bead.

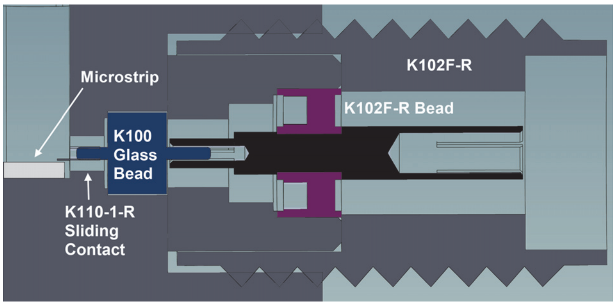


Figure 14 Dual bead assembly using Anritsu K102F-R, K100 Glass Bead and K110-1-R sliding contact

A single-bead configuration is shown in Figure 15. This assembly removes the glass bead and replaces it with a pin connecting the sliding contact with K102F-R center conductor. Single-bead assemblies typically have improved reflection responses compared to dual-bead assemblies. On the other hand, these assemblies are not hermetic and are not as mechanically rugged as the dual-bead designs. Occasionally a dual-bead design will incorporate two precision machined plastic beads to achieve good mechanical and electrical performance and is an alternative to the glass bead assembly shown in Figure 14. For any new connector and backside assembly, especially single-bead assemblies, careful qualification[9] is necessary.

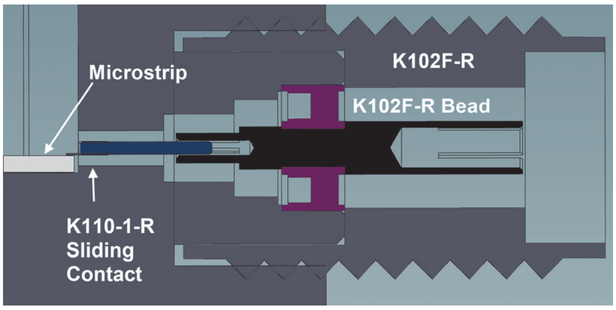


Figure 15 Single bead assembly using Anritsu K102F-R, pin and K110-1-R sliding contact

## 5 Conclusions

There are design considerations worth emphasizing for any backside connection: 1) thermal expansion and contraction must be allowed for 2) transition inductances and capacitances must be minimized 3) the design must be manufacturable 4) the substrate, backside interface and connectors must be sized to reduce unwanted modes and 5) the assembly must be able to withstand mechanical shock and vibration. These considerations should be carefully examined in the design phase before any hardware is fabricated with further qualification as hardware becomes available.

The backside interface and connector assembly plays a critical role in establishing good RF performance from the front side connector interface to the internal circuit. As frequencies increase, internal circuits, backside interfaces and connector assemblies necessarily become smaller to prevent unwanted modes from propagating. At higher frequencies, transition design and manufacture becomes more difficult and has a greater impact on overall module or sub-assembly performance.

## References

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## Author

Tom Roberts
Service Infrastructure Solutions
US Division
Measurement Business Division

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