

KOAXXA SMA RF Interconnects

Innovation & Technology



Kevin E. Weidner - BSME; RF Interconnect Engineering Manager
Daniel Q. Zhu - PhD; Director of Product Development
Claude C. de Lorraine - BS Industrial Technology; MBA; Global
RF Interconnect Product Manager

Preface

This white paper presents a technical overview of TE Connectivity's (TE) new KOAXXA SMA RF interconnect product portfolio. Our KOAXXA SMA product embodies TE's strategic vision for the future of RF connector product design and manufacturing. Innovative product features that are part of the KOAXXA SMA product design have been optimized by using the latest Computer Aided Engineering (CAE) methodology and are validated through extensive testing. Several details are highlighted herein.

Introduction

An Overview of KOAXXA SMA RF Interconnects

TE has developed a new SMA product portfolio under the trademark of KOAXXA. KOAXXA SMA products are designed to provide the best value for our customers with a compelling price structure, optimized performance, and distinguishing features.

A few highlights are as follows:

- IEC-169-15 interface compatible
- Tested and qualified per EIA-364 standards
- 0-18 GHz performance
- >500 durability cycles
- Selective gold plating only at contact interface
- Selective tin plating at PCB and cable center conductor interfaces
- Durable nickel plating on housings

Platform Design

One of the key advantages for the KOAXXA SMA RF product line is its extensive use of platforming. This concept re-utilizes common components and design features are re-used to build many final part configurations and provides several benefits:

Flexible

- Fewer components, improved inventory management
- Smaller lot sizes, lower MOQ's

- Large scale manufacturing and automation enabled

Value

- Minimizes the impact of material headwinds
- Superior performance to price ratio

Customer experience

- Improved lead times
- Quick turn proposals for product extension

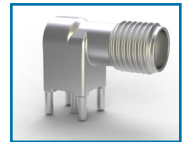
Product Family Features

The Form Factor

One of the things that makes KOAXXA RF interconnects



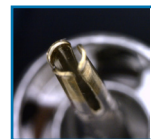
unique is the departure from traditional form factors which are limited by traditional design and manufacturing methods. Typical component manufacturing methods such as screw machining have been



replaced with more efficient manufacturing processes and methods. Included are high-speed stamping and forming, injection molding, die casting, and selective strip-line plating, all of which are utilized to exceed current and future expectations of cost, value, and environmental impact.

The Contact System

TE's RF interconnect design engineers have leveraged both modern contact physics theory and TE's core high speed stamping and forming process technology to achieve more consistent product geometry, manufacturing efficiency, and ultimately best value for our customer. For example, the long standing contact physics rules related to the amount of normal force (F_n) required to provide a "gas tight" contact



interface seal are uniquely achieved. By utilizing a tapered tri-beam socket contact design structure (at left) which is enabled by high speed stamping of strip stock material, the contact system delivers the

appropriate level of F_n to the interface and provides a smooth finish that eliminates any sign of appreciable wear to the contact surfaces. The benefit to customers is that the integrity of the noble metal contact finish is sustained throughout the life cycle of the product.

The Cable Termination System

Flexible termination tooling presents another important value for the RF industry, whether in the field or during production. The KOAXXA SMA product has been designed to



allow customers to use hand held tooling and simple industry typical solder fixtures to insure consistent and reliable cable terminations. For example, tooling similar to TE's long standing "Certi-crimp" hand tool (at left) is used to provide a highly reliable and proven "F-crimp" between the center contact and cable center

conductor. Solder termination of cable center conductors to the KOAXXA SMA center contact is also an option for all cable sizes.



The use of selective tin plating in the solderable zone of the contact makes this easy. TE's PRO-CRIMPER tool (above) or other industry typical "hex crimp" tooling is used to terminate the woven braid shield common to flexible cable types. Semi-rigid and conformable jacket shields are solder terminated using the same industry typical fixtures used for center conductor termination.

The PCB Termination

The KOAXXA SMA interconnect family's PCB-applied products are designed and qualified using the same set of platform contact and dielectric components used on cable applied connectors. This unique synergy between product configurations is another example of the power of platform design.

In the case of the KOAXXA SMA vertical board mount center contact, the selective plating process that allows placement of gold plating only in the mating part interface also allows for selective tin plating only in the PCB termination interface (at left). Also, the stamped and



formed contact, which is essentially a hollow tube, heats up quickly during soldering. This sets the stage for improved solder termination cycle times and lower applied cost. The nickel plated die cast housing is selectively tinned at the PCB termination interface (right). Note: These tinned PCB termination features enable quick and easy hand or wave soldering of the KOAXXA SMA products to PCB's up to 3mm in thickness.



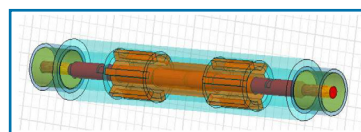
A secondary benefit to the selective tin coated PCB termination features is created by the adjacent nickel plating. As solder wets to the primary nickel plating (which is protected from oxidation by the selective tin coatings) it is also stopped from wicking away from the PCB termination, i.e. solder flow is mitigated when it meets the exposed / oxidized nickel plating outside of the selective tin zones. This provides more consistent solder joint formation which is critical to mechanical strength and RF signal launch from the connector to the PCB.

The RF Wave-Guide Design

Another example of the KOAXXA SMA product platform is found in the design of the primary RF waveguide structure. As noted previously, the connector housing, dielectric, and center contact geometry is proliferated across all configurations of the portfolio.

In RF signal transmission, the voltage standing wave ratio (VSWR) is a leading indicator of interconnect system performance. Also, the insertion loss (IL) is defined as the ratio between transmitted and incident voltages which is a primary measurement of RF cable assemblies:

$$VSWR = \frac{V_{\max}}{V_{\min}} \quad IL \text{ (dB)} = -20 \log \left| \frac{V_{\text{trans}}}{V_{\text{inc}}} \right|$$



In the KOAXXA SMA product design, a 3D connector-mated-pair model structure (at left) was created to perform

HFSS VSWR and IL simulations. In this case, the model

represents a straight cable plug and jack terminated to RG402 cable. The model includes all of the structures of the platform housing, dielectric, and contact that make up the signal propagation path through the connectors. Note: The signal launch planes for the connector mated pair are established at the point where the semi-rigid cable jacket is terminated to the end of each connector. Figures 1 and 2 below show the resultant simulation outputs for VSWR and IL, respectively.

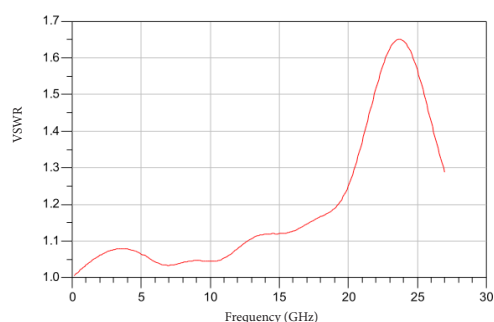


Figure 1: VSWR (simulation)

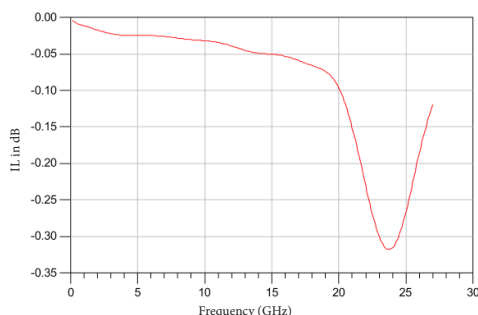


Figure 2: IL Simulation

Product Performance

RF Performance Testing (VSWR and IL)

To validate that we have achieved an optimized design state for RF performance, various tests and measurements are important during all phases of product development and industrialization. The KOAXXA SMA product electrical tests were constructed to measure the RF performance when compared to the simulation shown above and the typical

performance spec of traditional TE SMA products produced using common screw-machining manufacturing techniques.

The VSWR test setup includes a 150mm (6") RG402 cable assembly connected to Port 1 of the network analyzer with the far end terminated to a 50 ohm load. A S11 measurement was taken driven from Port 1 of the analyzer for both the jack and the plug end of the assembly. To minimize the effect of other items in the overall test circuit such as cable and adaptor, time-domain "gates" around the connector mated pair so when the frequency domain measurements are taken the gate structure will allow us to accurately calibrate and subtract unwanted reflections from elements other than the mated connector pair. Figure 3 below shows a nominal VSWR graph over 10 cable assemblies. The KOAXXA SMA product shows excellent performance over the nominal operating range (DC-18GHz) and its usable frequency extended to 28GHz range over which VSWR is below 1.30. Also, shown below in Figure 4 is a nominal IL plot over 10 cable assemblies.

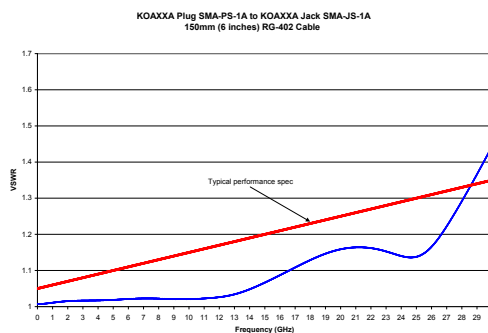


Figure 3: Typical VSWR for a fully mated KOAXXA SMA product with 6" RG402 cable

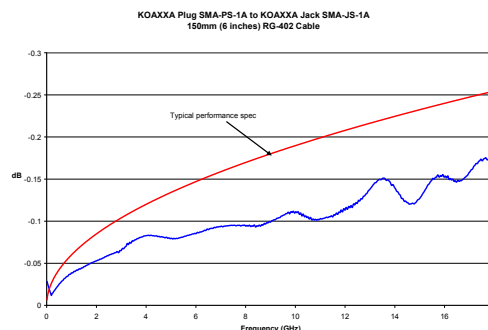


Figure 4: Typical IL for a fully mated KOAXXA SMA product with 6" RG402 cable

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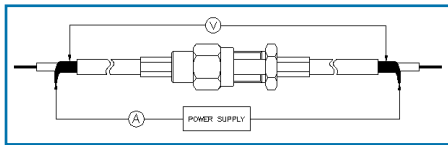
Mechanical Performance Testing

TE recognizes that the KOAXXA SMA product platform concept and manufacturing methods are innovative and represent a departure from typical design and manufacturing methods as described earlier. To give our customers a high level of confidence in KOAXXA product, TE has created a comprehensive mechanical test sequence that includes multiple exposures conducted in series. The test sequence is depicted in Table I:

Mechanical Test Sequence	
Initial Examination of Product	1
LLCR	3, 5, 8
Sinusoidal Vibration	6
Mechanical Shock	7
Mating Torque	2
Durability	4
Final Examination of Product	9

Table I: Mechanical Test Sequence for KOAXXA SMA product

Following the simple product examination step, connector device under test (DUT) pairs are then mated using a prescribed mating torque of 80 – 110 N-cm.



Baseline low level contact resistance (LLCR) measurements are recorded using a 4-wire V-A method (at left). Durability cycles are conducted by hand to insure that all aspects of the contact system and mechanical structure of the connector are evaluated. Following the durability test of 500 cycles, the same DUT's are subjected to Sinusoidal Vibration in 3 mutually perpendicular planes and Mechanical Shock in 3 mutually perpendicular planes. Unmating Torque is recorded after all mechanical exposures. LLCR is the common "response" measurement used to validate stability of product structure and contact systems after exposure and is the final measurement of the sequence. A typical DUT is shown (at right).

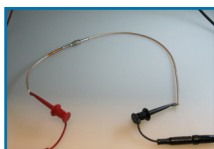


Table II shows the Test Description; Requirements; and Procedure for each test in the sequence above. TE has completed full product qualification of the KOAXXA SMA product and all of the mechanical requirements below are met. The innovations applied by TE's RF connector design team have been fully validated through testing.

Mechanical Tests		
Test Description	Requirement	Procedure
Sinusoidal vibration.	No discontinuities of 1 microsecond or longer duration.	EIA-364-28, Test Condition II, Subject mated specimens to 10 G's between 10 to 500 Hz. 3 hours in each of 3 mutually perpendicular planes. 9 hours total.
Mechanical shock.	No discontinuities of 1 microsecond or longer duration.	EIA-364-27, Condition H. Subject mated specimens to 30 G's half sine shock pulses of 1 milliseconds duration. Three shocks in each direction applied along 3 mutually perpendicular planes, 18 total shocks.
Mating Torque	Required torque 90 N-cm maximum	EIA-364-13, Method A. Produce torque necessary to mate samples.
Durability.	500 cycles	EIA-364-9. Mate and un-mate specimens for 500 cycles at a rate of 12 cycles per minute.
Low Level Contact Resistance.	Center contact: 25 milliohms initial, 10 milliohms delta R; 10 milliohms initial, 15 milliohms delta R.	EIA-364-23. Subject specimens to 100 milliamperes maximum and 20 millivolts maximum open circuit voltage.

Table II: Mechanical Test Sequence for KOAXXA SMA product

Environmental Performance Testing

The KOAXXA SMA product maintains use of all environmentally stable material and plating systems, e.g. nickel, tin, gold. The previously mentioned capability for selective plating limits the amount of expensive gold plating required to insure proper intermateability with other standard products on the market.

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KOAXXA SMA product utilizes an innovative signal contact system with lower normal force than screw machined contacts. This reduces plating wear from mated surfaces that drives the need for thicker plating. TE has validated the environmental performance per the test sequence depicted in Table III:

Environmental Test Sequence			
Initial Examination of Product	1	1	1
Insulation Resistance	2, 6	2, 4	2, 4
Withstanding Voltage	3, 7		
Thermal Shock	4		
Humidity-Temperature Cycling	5		
Temperature Life (Heat Age)		3	
Mixed Flowing Gas			3
Final Examination of Product	8	5	

Table III: Environmental Test Sequences for KOAXXA SMA product

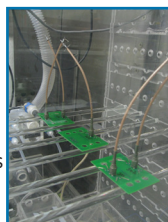
The KOAXXA SMA product is subjected to 3 different environmental test sequences. Each test sequence targets specific aspects of the overall connector design, material selection, and plating systems to insure a comprehensive evaluation. The test sequence that subjects the DUT to



thermal shock (at left) and Humidity Temperature cycling validates that the connector dielectrics maintain adequate insulative properties. The test sequence that subjects the DUT

to Temperature Life is aimed at validating there is no “stress relaxation” of the active beam contact system, or crimp zone of the contact. The test sequence that exposes the DUT to mixed flowing gas (MFG, below right) is designed to validate the integrity of the connector noble metal (gold in this case) plating systems, and the overall interface design, i.e. normal force, wiping action, etc.

Table IV shows the test description, requirements and procedure for each test in the sequence above. TE has completed full product qualification of the KOAXXA SMA product and the environmental requirements below are



met. Our approach to contact design has been validated through testing. In this case, it is clearly demonstrated that the use of sufficient but lowered normal force maintains a “gas tight” seal at the critical contact interface. It is also demonstrated that the use of selective gold plating place only in the contact interface is the right approach to modern contact design and manufacturing.

Mechanical Test Sequence		
Test Description	Requirement	Procedure
Thermal shock	Shall meet visual requirements, show no physical damage	EIA-364-32C, Subject mated specimens to 5 cycles between -55 and +85 C
Humidity-temperature cycling	Shall meet visual requirements, show no physical damage	EIA-364-31B, Condition III. Subject mated specimens 10 cycles between 25 °C and 65 °C at 95% RH.
Temperature life	LLCR measured on center contact only	EIA-364-17B. Subject mated specimens at 85 °C for 1000 hours.
Mixed flowing gas	LLCR measured on center contact only	EIA-364-65A. Subject mated specimens to environmental class IIA for 14 days.
Low Level Contact Resistance.	Center contact: 25 milliohms initial, 10 milliohms delta R; 10 milliohms initial, 15 milliohms delta R.	EIA-364-23. Subject specimens to 100 milliamperes maximum and 20 millivolts maximum open circuit voltage.
Insulation resistance.	5000 megohms minimum	EIA-364-21. 500 volts DC, 2 minute hold. Test between signal and ground.
Withstanding voltage.	Connector for flexible cable: 750 volts; Connector for Semi-rigid: 1000 volts	EIA-364-20, Condition I. Apply volts AC (rms) at sea level. One minute hold with no breakdown or flashover

Table IV: Detailed Environmental Test for KOAXXA SMA product

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Cable Termination Performance Testing – F crimp & soldering

The KOAXXA SMA interconnect product family's cable-applied products are designed and qualified using common coaxial cable termination methods such as crimping and soldering. For example, the KOAXXA cable-applied plug and jack, designed for termination to RG402 cable are terminated by soldering the cable center conductor and jacket to the connector. This method of cable termination is common across the RF connector cable assembly industry and enables RF performance as shown in the Figures 3 and 4 above.

With KOAXXA SMA product, another example of TE innovation is the termination of flex cable center conductors like RG316 and RG58A using TE's proven F-crimp technology (see Figure 5 below). Coupled with TE's use of stamped and formed contacts, F-crimping provides a "cold weld" of the cable conductor strands to the contact crimp barrel. This cold weld provides a high reliability electrical connection identical to that used in other critical applications such as RF cable harnesses used in automobiles and industrial appliances.

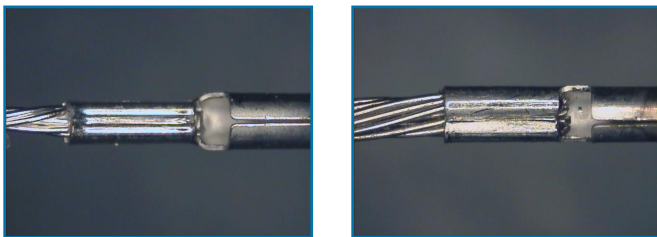


Figure 5: F-crimp termination to RG316 (left) & RG58A (right)

During the actual contact to cable center conductor termination process these width and height values are measured for quality control. To ease market transition to KOAXXA SMA, the cable braid is crimped to the connector using industry standard hex crimp sizes. Table V shows the cable compatibility matrix with the KOAXXA SMA connectors and the corresponding termination options. There is no difference between KOAXXA RF interconnects and traditional SMA interconnects in terms of cable type support and termination methods. "Instruction Sheets" that provide specific tooling information and process steps are available on

the KOAXXA SMA product web site.

Compatibility with Competitor Product

TE's design engineers have used the IEC-169-15 interface standard to insure that KOAXXA SMA product is compatible with other standard SMA products on the global market. Compatibility has also been verified by conducting product performance testing of KOAXXA SMA product when mated to various competitor products. In the following examples the competitor products, identified as "Competitor A" and "Competitor B", are well-known global suppliers of SMA products. Note: Components for these competitor products were manufactured using typical screw machine processes.

Durability / LLCR Testing

500 cycle durability testing of KOAXXA SMA plugs and jacks mated with similar competitor products was conducted. Sample sets included 3 mated pairs each. Delta (Δ) LLCR values were recorded throughout the testing. Figure 6 below shows a summary of this testing.

VSWR Testing

VSWR testing of KOAXXA SMA plugs and jacks mated with similar competitor products was conducted before, during, and after 500 cycle durability testing. Figure 7 below shows an example plot summary of this testing.

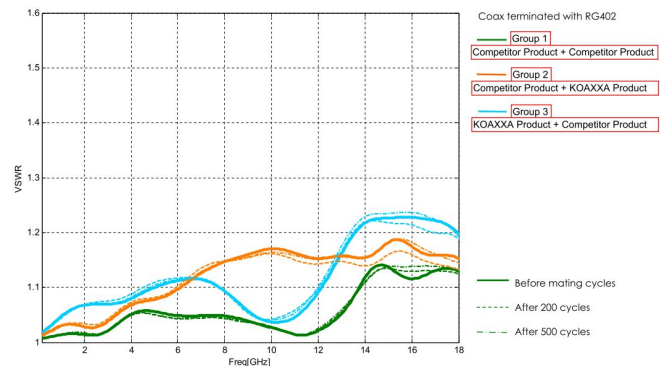


Figure 7: VSWR Test Plot Summary

Cable Group	Cable Description	Crimp		Solder	
		Center Contact	Outer Braid	Center Contact	Outer Braid
1A	RG402 Semi Rigid, RG402 Conformable	No	No	Yes	Yes
1B	RD316 (Double Braid), K0225D	Yes	Yes	Optional	No
1C	RG405 Semi Rigid, RG405 Conformable	No	No	Yes	Yes
1D	RG178, RG196	No	Yes	Yes	No
1F	RG174, RG188, RG316	Yes	Yes	Optional	No
1G	RG58, RG141, RG223, RG400, RG142	Yes	Yes	Optional	No

Table V: Cable termination compatibility matrix

LLCR: Average Delta (Δ) R						
Brand	After 100X(Δ R)		After 200X(Δ R)		After 500X(Δ R)	
	Signal	Ground	Signal	Ground	Signal	Ground
"Com-petitor A"	0.17	0.61	0.20	0.00	0.01	0.19
"Com-petitor B"	0.01	0.86	0.06	0.08	0.04	0.11

Figure 6: Durability & LLCR Test Summary Table

Conclusion

The RF market has seen rapid expansion in the last few decades. This growth continues to be fueled by increased global consumer demands for new technologies, such as cloud computing, broadband mobile internet and smart energy metering and grid communications. But as these markets expand, expectations of the performance and economic sustainability of RF interconnect solutions are changing to meet future global and emerging market requirements, customers' system design and application requirements, and regulatory oversight. To stay ahead of these growing expectations, companies that provide RF interconnect solutions must rethink their approach and seek a supplement: a modern, viable, and economically sustainable RF solution to fill the gap.

With testing of the KOAXXA SMA product portfolio, this paper provides evidence to show that this next generation of

RF interconnect products can fulfill the market's performance requirements. The paper validates this claim by including rigorous test data on mechanical, electrical, environmental and termination performance. Finally, this white paper provides a high level, brief insight into the new manufacturing processes behind the KOAXXA RF products that build on TE's 40+ year RF interconnect manufacturing tradition.

References

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- [2]. IEC-169-15: "Radio-frequency connectors - Part 15: R.F. coaxial connectors with inner diameter of outer conductor 4.13 mm (0.163 in) with screw coupling "Characteristic impedance 50 ohms (Type SMA)", 1979.
- [3]. M. Scheggia, et. al.: "RF product platforming", TEchCon2011.