Keysight Technologies
Coaxial Electromechanical Switches:
How Operating Life and Repeatability of Keysight's Electromechanical Switches Minimize System Uncertainty

Application Note

KEYSIGHT TECHNOLOGIES

Introduction

Keysight Technologies, Inc. is the global leading designer and manufacturer of coaxial electromechanical (EM) switches, with a long history and proven track record for high performance, quality and reliability. Coaxial EM switches provide the reliability and performance required by automated test systems used in the aerospace and defense and wireless communication industries for signal monitoring and routing purposes. One of the most common applications of coaxial EM switches is mobile handset testing in the wireless communication industry.

According to a research study[1], global mobile handset shipment is on track to reach one billion units shipped in 2006, representing a 22.5% growth over 2005. This impressive growth rate places high emphasis on the reliability and performance of automated test systems (ATS) used for mobile phone testing, of which the EM switch is a major component. Two of the most important considerations when selecting an EM Switch are operating life and repeatability.

This application note describes:

– The operating life of EM switches, the jumper contact mechanism of conventional EM switches, and the Keysight contact mechanism with its wiping-action technology.
– Finally, the effect of repeatability on measurement uncertainty is discussed.

Operating Life of an EM Switch

The operating life of an EM switch can be defined as the number of cycles the switch will complete while meeting all RF and repeatability specifications. The operating life refers to the electrical life of the switch, and not the mechanical life (which is much longer than the electrical life). One life cycle is defined as one closing and opening of the jumper contact (sometimes referred to as switch blade) or one on/off triggering of the electromagnetic coils in the switch. The operating life is very dependant on the jumper contact mechanism, contact resistance, and the material and plating used in all the key RF components of a switch. Keysight coaxial EM switches are produced with meticulous manufacturing processes and stringent quality assurance systems.

Conventional EM Switch Contact Mechanism

Conventional switches function by moving a thick rectangular contact known as a jumper contact (or switch blade) inside the RF housing. The jumper contact is joined by a push rod, generally made of a dielectric material such as Polystyrene (PS) that moves inside an access hole in the RF housing. The tip of the jumper contact is directly pressed onto the flat surface on the tip of the center conductors of the connectors by a mechanical spring force from the actuator.

Figure 1 depicts an open RF line with the jumper contact retracted. Figure 2 depicts a closed RF line where the jumper contact forms a bridge between input and the output port allowing the RF signal to propagate from common port to outer port.

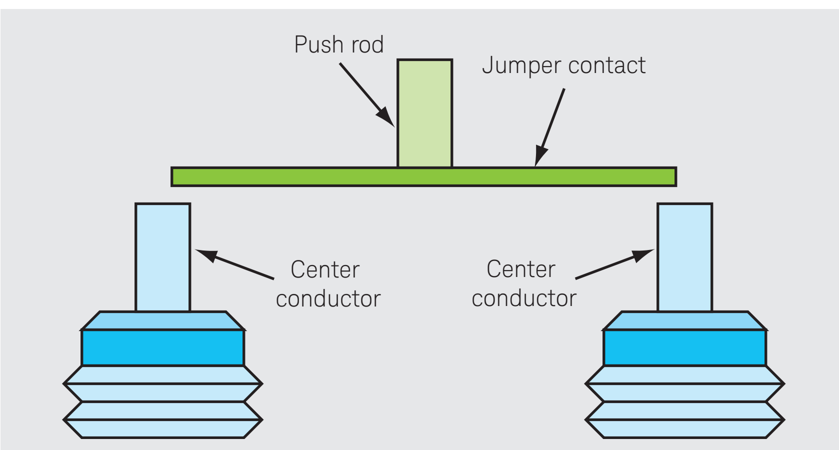

Figure 1. RF line open

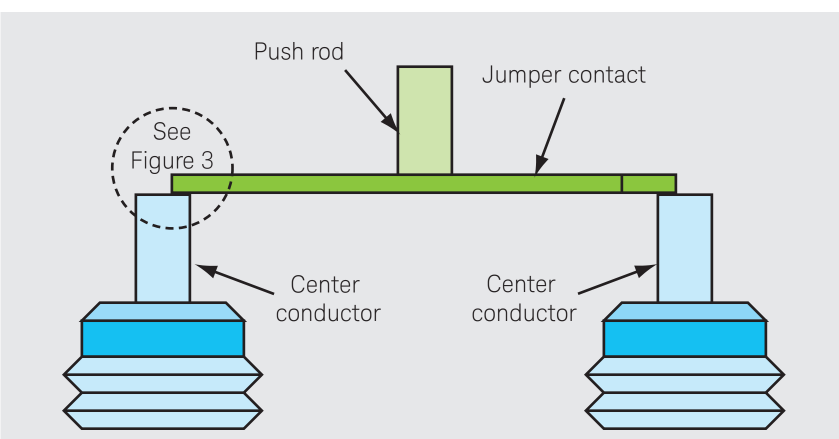

Figure 2. RF line closed

The jumper contact is usually thick and inflexible, as can be seen in Figure 3. The vertical motion of the jumper contact and push rod during opening and closing results in what is sometimes referred to as "frictionless switching", since there is no friction produced between the jumper contact and center conductor.

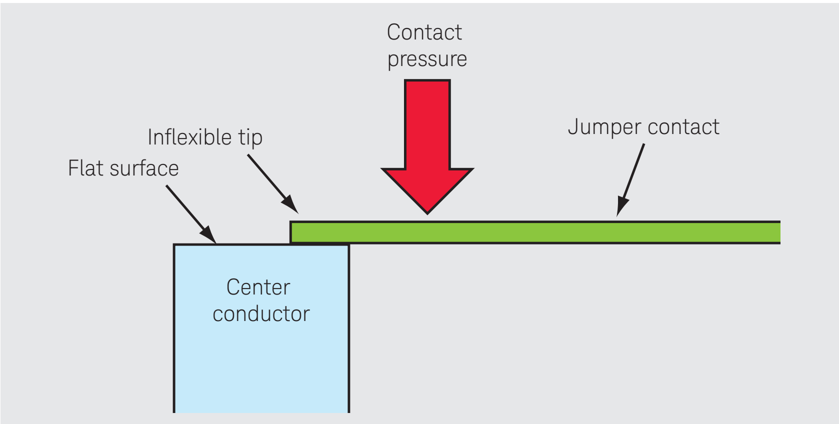

Figure 3. Conventional electromechanichal switch mating configuration

This configuration produces switches that can mechanically actuate for tens of millions of cycles. However, there are some drawbacks.

The continuous impact between the jumper contact and center conductor will gradually result in increasing wear and tear, producing some debris. The debris, along with dirt and contamination accumulated over time remains on the tip. As a result, contact resistance increases over time leading to increased insertion loss. This may or may not result in the switch failing its RF specifications, but will have a significant effect on the insertion loss repeatability of the switch. The random nature of this particle buildup also means that such failure can be intermittent, and may not be detectable. This buildup is the result of an inflexible jumper contact. The particles remain trapped on the surface of center conductor throughout the life of the switch. Switches with designs of this nature usually have loose repeatability specifications or none at all, with possible failures occurring intermittently throughout the lifetime of the switch.

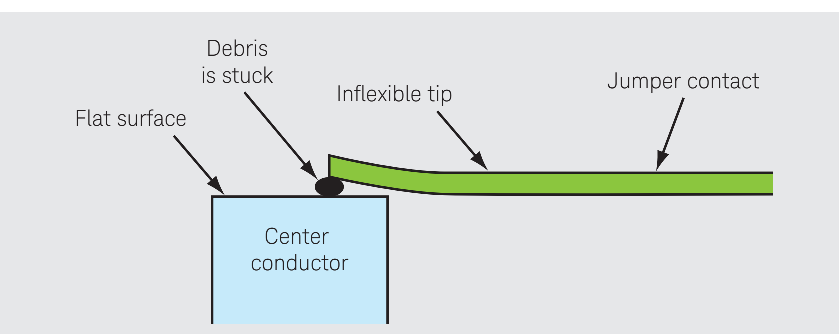

Figure 4. Particle buildup remains trapped between the jumper contact and center conductor

Keysight's EM Switch Contact Mechanism

Keysight's RF electromechanical switches are designed to operate well beyond their specified lifetime within all RF specifications with an insertion loss repeatability of less than 0.03 dB.

To achieve this repeatability specification, it is necessary to have a design that "cleans off" the center conductor tip every cycle, eliminating particle buildup that was prevalent in conventional EM switches design. This is made possible in Keysight switches with a unique "wiping action" mechanism, which is illustrated in Figure 5.

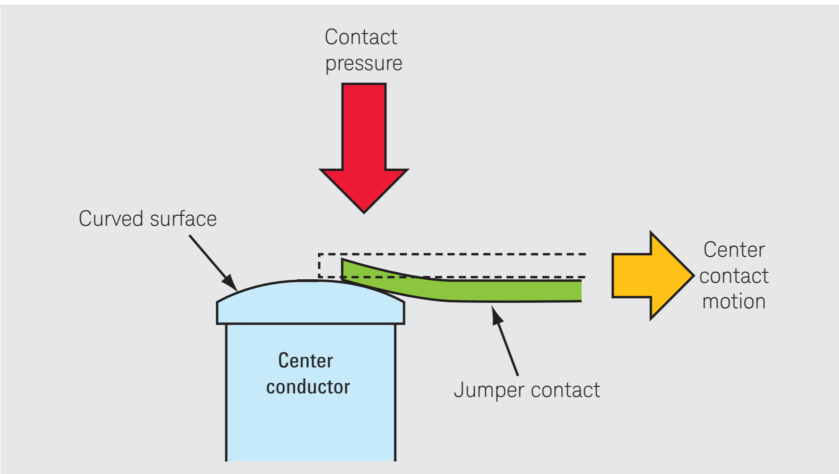

Figure 5. Electromechanical switch mating configuration illustrating microscopic wiping

In Keysight's EM switches, the center conductor profiles of the connectors are designed with a spherical mating surface. This mating surface is slightly curved to create a minor downward force and a small movement between the jumper contact and this mating surface. This movement is made possible by a thin and flexible jumper contact design. As the result of this action, there is a slight microscopic wiping between these surfaces. This wiping action continuously cleans the contact area by breaking through the surface films and moving debris away.

The geometry and surface texture (finishing) of the contacting interfaces are very critical in determining the contact resistance and the life of the contacts. The contact resistance during a wipe is influenced by several factors such as normal force, contact geometry, thickness and composition of the contaminating films, and the length of wipe[2]. The use of a thin layer of lubricant along with a smooth surface finishing on the jumper contact and center conductor minimizes the effect of friction during the wiping action, greatly prolonging the life of the contacts.

Figure 6 shows a piece of small debris stuck on the surface of center conductor. The jumper contact is being pressed down by the push rod.

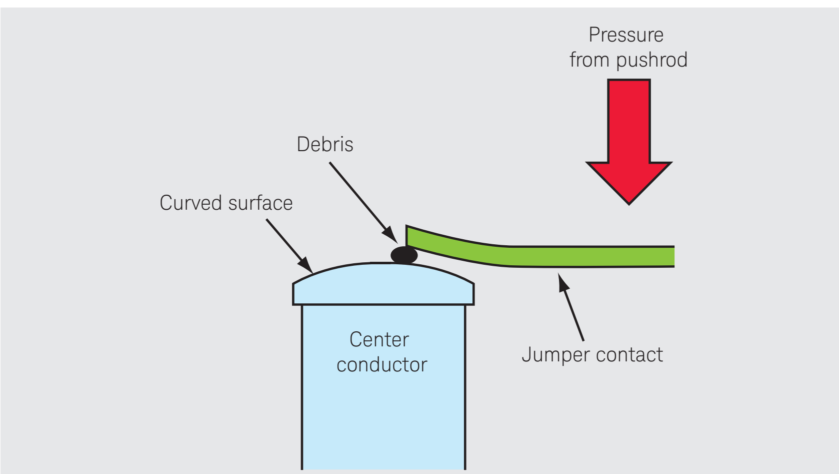

Figure 6. A piece of small debris is stuck on the surface of center conductor

When the pressure is released by the push rod, the jumper contact moves upward and sideways to follow the curved surface of the center conductor. As the result, the tip of jumper contact pushes the debris away from the contact area as shown in Figure 7.

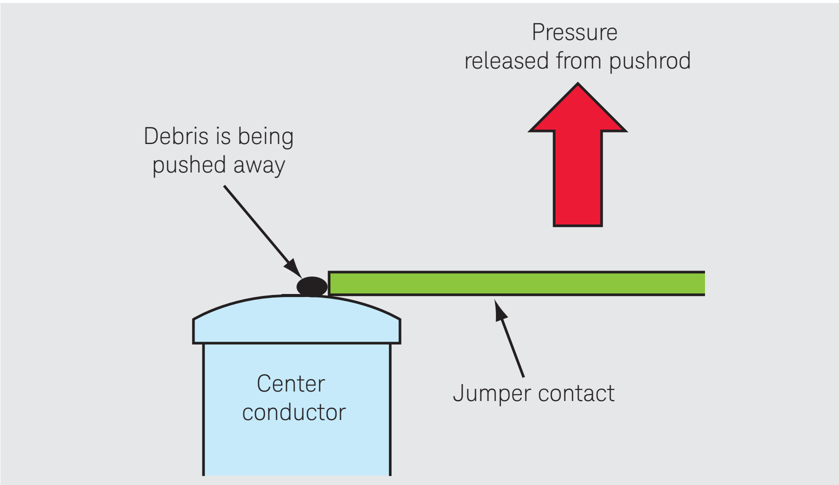

Figure 7. Debris is being push away by wiping process of the jumper contact

The pushrod exerts a constant pressure to mate the jumper contact with the stationary center conductor. This pressure is applied by the magnetic actuating solenoid, and resisted by the spring effect of the jumper contact.

The switch operation not only needs stable contact but also reliable opening and closed contacts[3]. This is provided by a lift-off (extracting) force that exceeded the adherence of the sticking contact, even if there have been metallic bindings formed between the two clean surfaces (namely, the contact areas of jumper contact and the center conductor of connector).

Effect of Repeatability on Measurement Uncertainty

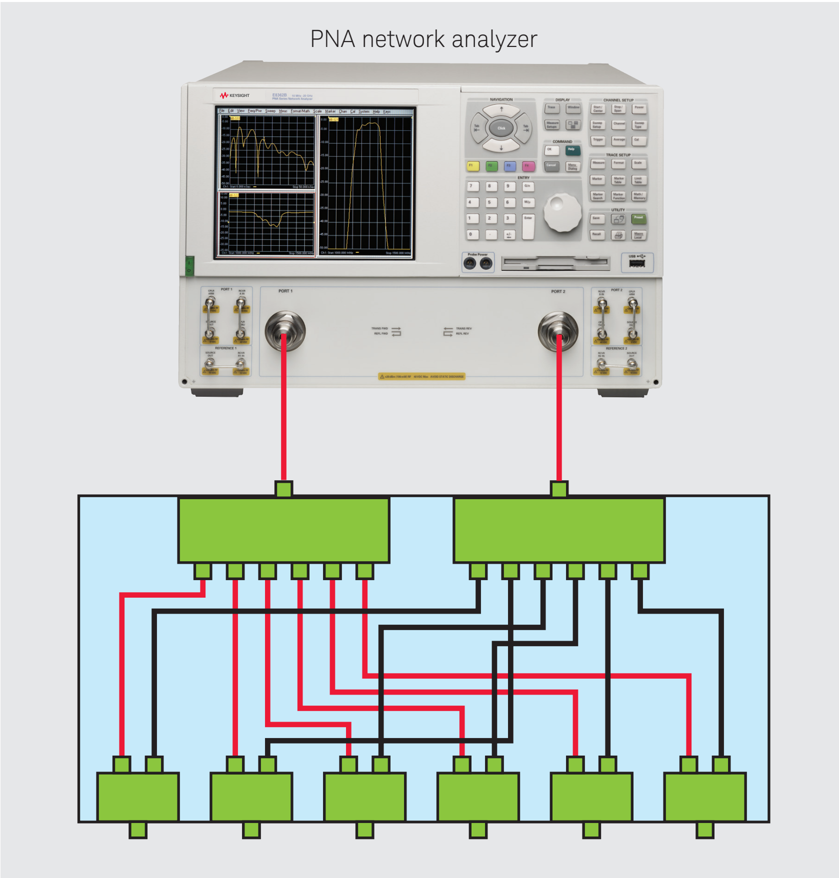

Figure 8. PNA network analyzer with a multi-port test set

The repeatability of a switch has a direct effect on the measurement uncertainty of a test setup. Figure 8 shows a PNA connected to a multi-port test set which is used to test multiple devices. In this example, a total of three 2-port devices can be tested simultaneously, with any port. Since these errors are random and not systematic, root sum square (RSS) is the proper way to calculate the total measurement uncertainty. Here, two scenarios are presented:

Scenario 1

PNA repeatability = 0.01 dB, EM switch repeatability = 0.03 dB
Total measurement uncertainty = $\sqrt{0.01^2 + 0.03^2 + 0.03^2} = 0.044$ dB

Scenario 2

PNA repeatability = 0.01 dB, EM switch repeatability = 0.1 dB
Total measurement uncertainty = $\sqrt{0.01^2 + 0.1^2 + 0.1^2} = 0.142$ dB

It can be seen that the repeatability of the EM switch has a significant effect on the total measurement uncertainty of the system, affecting the accuracy of all measurements made.

Conclusion

Operating life and repeatability are two of the most important considerations when selecting an EM switch. Keysight's EM switches utilize a wiping action design that removes particle buildup to maintain a repeatability specification of 0.03 dB. This is crucial as the repeatability has a significant effect on the total measurement uncertainty of a system.

References

1. IDC Worldwide Quarterly Mobile Phone Tracker, Q3 2006
2. R. Martens, *Effects and Interactions of Design Parameters on Noble Plated Electric Contacts.*
3. J. Schimkat, *Contact Materials for Microrelays,* IEEE 1998

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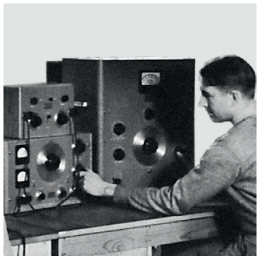
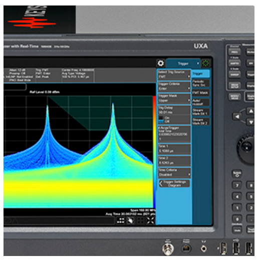


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