A Practical Guide to Microwave Switch Selection for ATE Systems

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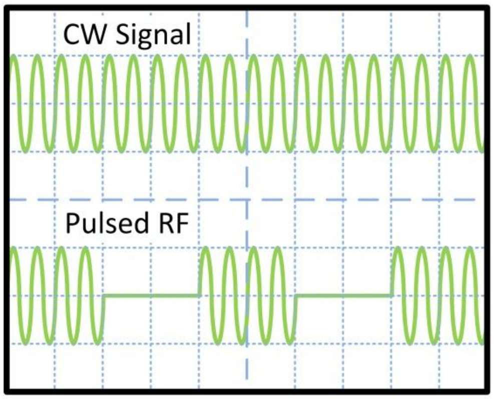
Application Note

We at Giga-tronics ASCOR frequently spend time with our switching solution customers discussing microwave relay selection, and verifying that we are in agreement with our customer on the definition of terms. There are a number of important selection criteria for Microwave relays and below are some suggestions for how to select one over another.

1. **Frequency Range** – This is probably the most simple and basic requirement. The microwave relays are going to be the most expensive element in your switching design, and the price increases with frequency, so you should select the relay which supports the frequency range you need and not overdesign. On the other hand, if your company is developing a new higher frequency product, it can be far more expensive to replace low frequency relays with new higher frequency relays, so having some idea of your company's direction could save money in the long run.

2. **Power Level, CW or Pulsed** – Power level for microwave switches is all about heat dissipation and how it affects the mechanical portions of the switch. There is more of an impact with higher Frequencies. For example, one popular switch will handle 100 Watts of power at 1 GHz, but is derated down to about 20 Watts at 18 GHz. The take away here is that if your Unit Under Test (UUT) puts out any significant amount of power, then you might be well served to take the signal through an attenuator first (if possible) so as not to overload the switches or to burden your design with a requirement for high power switches. High power microwave switches are available, but the price increases dramatically.



3. **Reliability** – this is another one of those criteria which increases along with price. There are microwave relays with life ratings ranging from 1 million cycles up to 10 million cycles. Clearly, the 10 million cycle relay will be priced higher. The real question is what do you need for your application? For customers in high volume production environments, the cost of downtime will easily justify the extra expense of the higher reliability relays. On the other hand, a recent customer purchased a switching system to automate a software validation

process that was only going to be used a few times a year. The cost of automation made sense for them, but the added cost of higher reliability relays did not.

4. **Low PIM** – PIM stands for Passive Intermodulation. PIM is essentially unwanted modulation between different frequency components of the test signal itself. The modulation occurs in non-linear components in your switching system such as cables, connectors and switches. The non-linear elements are caused by junctions of dissimilar metals or metaloxide, contaminated junctions or loose connectors. If PIM is a concern in the test plan, then you had better be specifically looking for components which are rated for low PIM. Like the other parameters and ratings, the low PIM devices are more expensive.

5. **Connector Style** – Most relay manufacturers support the common microwave connector styles such as SMA, SMB, SMC, Type-N, TNC and BNC. The important point is that you know what you need. Like the relays themselves, the different connector styles are rated for different levels of power and frequency, so this needs to be considered as part of the design. A common "safe bet" is to match the connectors used on the UUT itself. One personal note is the choice of material. Connectors on ATE are subjected to an inordinate amount of use and abuse. My personal preference is to use harder materials on the test system elements such as passivated stainless steel and softer material such as gold plated brass for the cable connectors. In this way you ensure that the wear is concentrated in the replaceable external cable assemblies instead of the switching box in the test system.

Figure 1 - SMA Connector

Figure 2 - Type-N Connector

6. **VSWR** – Voltage Standing Wave Ratio is an indication of how efficiently your test signal passes through your switching system without portions of the signal bouncing off impedance discontinuities and creating reflective signals that add or subtract with your test signal, creating amplitude inaccuracies. Unfortunately, every component like connectors and switches has a contribution to VSWR. It's best to have some indication from your test plan of how much VSWR from the test system can be tolerated and then selecting components accordingly.

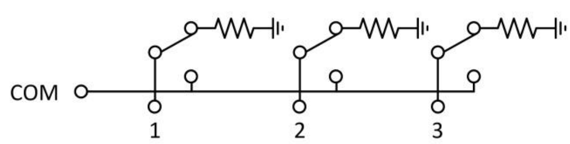
7. **Isolation** – this is an indication of how much of a signal on one input port can couple into an adjacent input port. Anything between 70 to 110 dB is typical depending on the frequency. This implies that if you have an input signal at +30 dBm on input #1 of your switch, you

could measure -40 to -80 dB on input #2. In cases where the switch does not have active signals on its various input ports at the same time, it is probably a non-issue. On the other hand if a high power UUT output is connected to one port and a highly sensitive input is connected to another port, then isolation could be a specification you should be concerned about. This is not frequently a concern in an ATE environment since UUT input signals typically come from stimulus instruments, and UUT output signals typically go to measurement instruments and so there is a natural separation of signals in the switching system design.

8. **Insertion Loss** – this is simply how much of your signal is not going to make it through the switch. All microwave components have insertion loss, including the connectors and cables. Insertion loss also increases with frequency. In order to make accurate power measurements, you must have a plan for compensating for these losses. In my opinion, the next criteria, repeatability, is probably more important to getting accurate measurements than insertion loss itself. The only exception might be in the case of extremely small signals which could fall below the measurement instrument's dynamic range, if there is excessive insertion loss in the signal path. Read on.

9. **Repeatability** – this is the repeatability of insertion loss. As previously mentioned, all components will have some insertion loss, but how frustrating will it be if that number is different every time you close the switch? Some manufacturers offer exceptionally good repeatability on the order of ±0.03 dB. This may or may not be an important criteria depending on your application, but if accurate power level measurements are required, then this could be something worth considering. I have often heard test engineers state that they don't care about switch insertion loss because they intend to measure it and subtract it out. What if the switches have poor repeatability and if there are several of these switches in the path? Suddenly you have a significant contribution to your measurement uncertainty.

10. **Termination** – simply explained, in the case of a 1x6 microwave switch, any signal entering one of the 6 input ports is directed to a 50Ω termination whenever that port is not selected. This is particularly useful in cases where multiple UUTs are being tested, and all of the UUTs are active at the same time. A simple example of this would be RF Oscillator testing. The test plan may require the units to remain on over an extended period of time for stability, but during the testing cycle the active inputs from the five unused ports might interfere with some of your measurements. Use of a terminated relay will help to prevent this crosstalk. One caution here. Because of the additional switching elements, adding termination usually has a large impact on price, often doubling the cost of the relay.

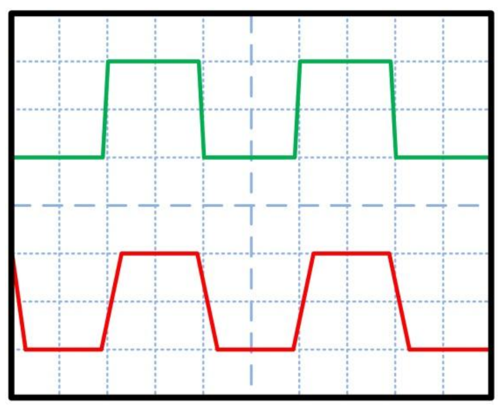


11. **Phase or path length matching** – this is less of a switch selection criteria but can be an important element of designing a switching system. In some test plans the phase relationship between two signals is very important and must be measured. This is particularly important with high speed digital signals. The only way phase matching can be accomplished is by carefully maintaining cable lengths to excruciatingly tight tolerances, testing the overall phase match and further trimming the cable lengths within the system to create a matched set of path lengths. Giga-tronics ASCOR has extensive experience with this.

12. **Latching vs. non-latching** –Latching relays remain in their last known position until they receive an electrical signal to change. Conversely, non-latching or fail safe relays will return to their normally open position upon a loss of power. If you were testing a high power transmitter, and the connection from its output to a high power load were through a switch, I would probably want the switch to be of the latching variety. This way, in the event of a power glitch or sag, which does not shut down the UUT, you know that the transmitter will still be operating into a load. If you were to use a non-latching relay, the transmitter could end up operating into an open circuit.

13. **Environmental Shock and Vibration** – simply put, the microwave relay is a mechanical device and as such will be affected by shock and vibration. If you need the relay to maintain its electrical specifications in conditions other than standard Lab ambient conditions, then you had better review the environmental specifications for the particular relay you have selected.

14. **Pulsed Digital signals** – We are seeing more and more crossover between the classic CW or Pulsed RF application and newer high speed digital signal applications. Here's the really important "take away" on high speed digital signals: the highest frequency components are not in the pulse repetition frequency (PRF) but rather in the rising and falling edges. Those edges have some very high frequency components hidden in them, and if you don't provide enough bandwidth in your switching system, it behaves like a low pass filter, slowing down those edges and making it impossible to take an accurate rise time or pulse width measurement. Just to put some reality into it, consider a pulsed DC signal with a 1 µs PRF and 100 ps rise time. The bandwidth for the PRF is 1/PRF or 1 MHz, very easy to accommodate. On the other hand, the formula popularly used for edge bandwidth is BW=0.35/RT. In our example, the 100 ps edge requires a switch rated for 3.5 GHz, and a faster edge like 10 ps will require a 35 GHz Switch. Therefore, some of these digital signals are more challenging from a switching perspective than the traditional RF signals.



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