Coax Switch Isolation

Amateur radio equipment manufacturers produce switches that are commonly used as "antenna switches", *i.e.,* to switch a single transceiver among multiple antennas. Many hams, however, question whether or not these same switches can be safely used in reverse, or to switch multiple transceivers to a single antenna. If you think about it, this is exactly the condition that is set up at the GCARC Clubhouse, where for example the HF room has a switch of that type used to connect multiple transceivers to the antenna on the tower. Let's talk about it a little bit and explain just *why* this is generally a safe practice.

The important specification of the switch is its isolation between the various ports on the switch. Note first of all that many manufacturers refer to these devices as *"coax switches"* rather than *"antenna switches".* The Alpha Delta model *Delta 2* switch, according to the DX Engineering website, carries two pertinent specifications. The *insertion loss* is stated to be less than 0.10dB, while the *port isolation* or *crosstalk* is stated to be more than 50dB. The MFJ model *MFJ-1702C*, again according to the DX Engineering website, carries the similar specifications of less than 0.20dB insertion loss and more than 60dB of port isolation or crosstalk. The more important specification for this discussion is the port isolation values. It should be noted that these are given as *minimum* isolation values. Are they high enough? Let's see…

Rob Sherwood NC0B, founder of Sherwood Engineering of Denver, Colorado, makes the case that most transceivers are OK with up to 100mW of input power at the antenna port of the radio. In a recent email, he stated that he tests "*receivers up to +20 dBm which is 100 milliwatts. That should be adequate from a damage standpoint."* Thus, in his opinion, and he is a recognized expert in the field, most any radio can safely handle that 100mW or +20dBm input.

To put things into proper perspective, we must first understand some values. That +20dBm value cited above equates to a power level of 100mW. This in turn is equivalent to a value of 93dB over an S9 signal. This is because at HF frequencies, S9 has been defined by the IARU as 73dBm, which is results in a 50µV signal into a 50Ω antenna. In discussing transmitter output levels, the output of a 100W radio equates to +50dBm, while full legal power output of 1500W equates to +62dBm.

If we were to take a more conservative isolation approach, by an order of magnitude, and shoot for 10mW instead of 100mW that the +20dBm limit suggested by Rob would indicate, we are now looking for a maximum of a +10dBm signal crossing between the ports of a switch. At our 100W output, that would mean that we need at least 40dB of isolation, while at 1500W we would need 52dB of isolation.

All that remains is to determine how much isolation is actually provided by some typical coax switches. This can easily be done using a NanoVNA , a couple of jumper cables, and a 50Ω terminator for the open port. We will install the jumper cables and calibrate the NanoVNA to those cables, setting the stimulus for a range of 1MHz to 51MHz, so as to cover the entire HF frequency range. The second channel will be set to the *LogMag* function, and the scaling will be set to *15dB* per graduation.

During the test, I recorded isolation measurements at appropriate frequencies for 160 meters, 80 meters, 40 meters, 20 meters, and 10 meters, as well as recording the insertion loss across the swept range. While I will not show screenshots for every recorded value, I will show them for one of the more interesting test arrangements.

The standard test setup for a two-port switch will have the Channel 0 port of the NanoVNA connected to the “COMMON” port on the coax switch, the Channel 1 NanoVNA port will be connected to the first open port on the coax switch, and the 50Ω terminating load will be connected to the other (or next) switch port. The insertion loss measurement will be made through the switch from the common to the first port, while the isolation measurement will be made when switched to the loaded port.

All of the test results will be listed later in this article. I tested several switches, as listed below:

- Alpha Delta model Delta 2;
- Alpha Delta model Delta 4B;
- MFJ model MFJ-1702;
- MFJ model MFJ-1702C;
- MFJ model MFJ-2702;
- MFJ model MFJ-2703;
- MFJ model MFJ-2704;
- B&W model 595;
- OPEK model CX-5;
- CMS model AS-01;
- Heathkit model HD-1481;
- Heathkit model HD-1234; and
- Daiwa model CS-201A.

One of the common applications of coax switches, especially when used in a series tandem arrangement, is to select one from several transceivers and connect that radio to one of several available antennas. In this arrangement, the “COMMON” port of one switch will be fed into the “COMMON” port of the second switch. Each of the ports of the first switch will then be connected to a different transceiver or transceiver position. Then, each of the ports of the second switch would be connected to a different antenna or antenna system, including, potentially, a dummy load.

That series tandem switch arrangement will also be tested for insertion loss and port isolation. In this test, a coax “TEE” will be installed on the “COMMON” port of the first switch. This switch will then have Channel 0 of the NanoVNA connected to one leg of that “TEE”, and the other leg of the “TEE” will be connected via coax to the “COMMON” port of the second switch. Channel 1 of the NanoVNA will be connected to one of the open ports on switch 1, and the 50Ω load will be installed to one of the open ports on switch 2. The test signal will be applied from the NanoVNA and the switches will be set to select the cabled port of switch 1 and the loaded port of switch 2. This should let us see the isolation through the combination of switches.

The NanoVNA screenshots at Figure 1 through Figure 5 illustrate the port isolation of this two-switch series connection. While the isolation trace is static, as I paused the sweep for the screenshot captures, the port flag has been moved along the trace to the pertinent frequencies for each of the bands. As was stated earlier, these captures are related to the popular band frequencies as follows:

- Figure 1 – 160 meters;
- Figure 2 – 80 meters;
- Figure 3 – 40 meters;
- Figure 4 – 20 meters; and
- Figure 5 – 10 meters.

Note in each case that the port isolation is shown in the upper-left corner of the screenshot, while the specific frequency at which that isolation is present is shown in the upper-right corner.

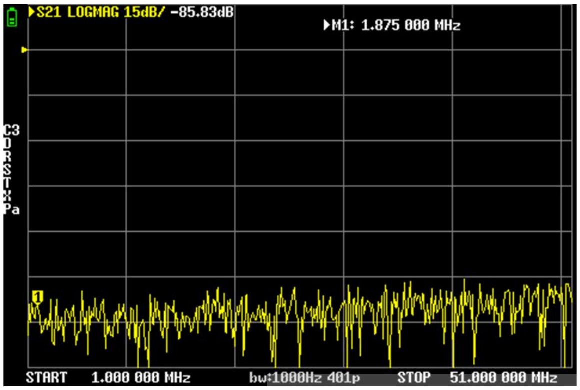

Figure 2 - 160 meters

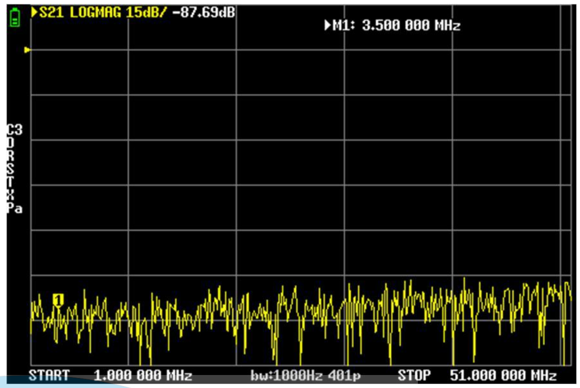

Figure 1 - 80 meters

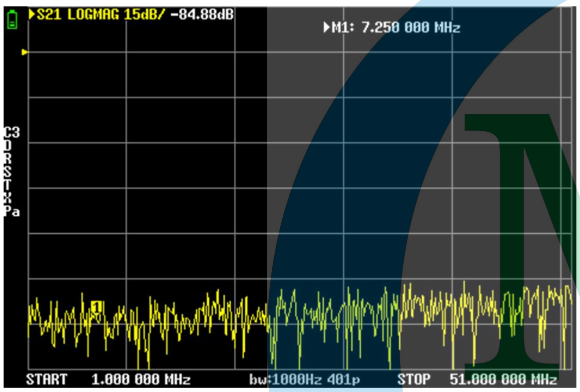

Figure 4 - 40 meters

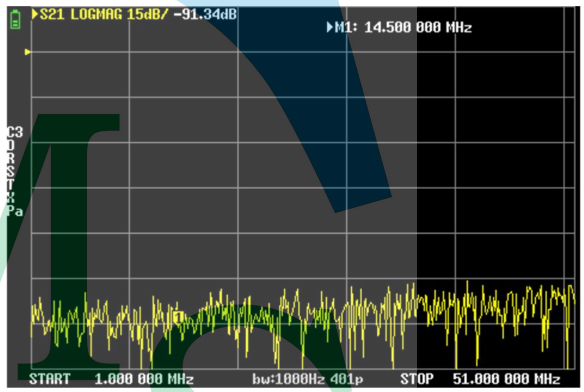

Figure 3 - 20 meters

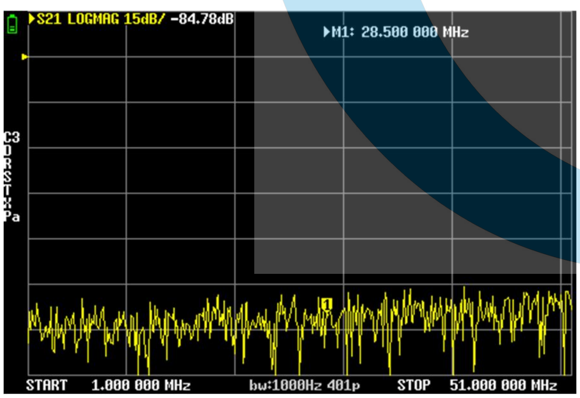

Figure 5 - 10 meters

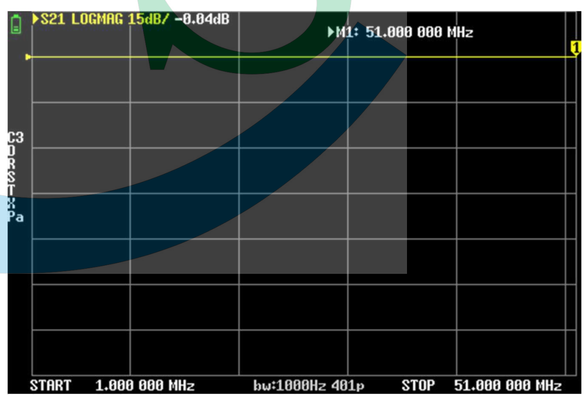

Figure 6 - Insertion loss

Figure 6 depicts the insertion loss across the entire swept frequency range, which was rock steady at -0.04dB. The least amount of isolation was -84.78dB at 10 meters, while the greatest isolation in this test was found to be -91.34dB at 20 meters.

It should, however, be noted that the isolation varied across the swept frequency range, and moving the marker just a short distance would give a different result. At no point, though, was the isolation low enough to be dangerous, because at no point did the isolation drop below our desired minimum.

I reached out to several different companies to obtain switches for the testing that I did. Of the companies that responded, I included their products. I will point out, however, that MFJ had said in an e-mail that they would decline to provide their model MFJ-1702, stating that the switch was not one that they would like to see in this comparison. The MFJ-1702C is an upgraded version of the base MFJ-1702 model, and is therefore slightly more expensive, and would be shipped instead of the base

MFJ-1702. However, when the shipment from MFJ arrived, both the MFJ-1702 and the MFJ-1702C were in the package, so both were tested and compared. The MFJ-27*xx* series of switches is what they their *"rhino"* switches.

The tables below show the results for each of the switch models tested. Included for each model, where available, is the company's specifications for insertion loss and port isolation.

Table 1 - Insertion loss and port isolation measured values

Model	Insertion Loss Specification	Port Isolation Specification	Measured Insertion Loss	Measured Port Isolation				
				160 meters	80 meters	40 meters	20 meters	10 meters
Delta 2	<0.10dB	>50dB	-0.026dB	-77.25dB	-72.38dB	-70.94dB	-80.17dB	-86.24dB
Delta 4B	<0.10dB	>50dB	-0.02dB	-78.89dB	-73.79dB	-73.84dB	-80.32dB	-84.82dB
MFJ-1702	<0.20dB	>60dB	-1.14dB	70.60dB	-62.64dB	-56.36dB	-49.95dB	-43.11dB
MFJ-1702C	<0.20dB	>60dB	-0.02dB	-92.37dB	-85.08dB	-87.07dB	-86.83dB	-79.39dB
MFJ-2702	<0.10dB	>60dB	-0.03dB	-90.24dB	-81.70dB	-89.02dB	-81.61dB	-70.94dB
MFJ-2703	<0.10dB	>60dB	-0.02dB	-77.96dB	-76.31dB	-83.04dB	-85.66dB	-67.26dB
MFJ-2704	<0.10dB	>60dB	-0.09dB	-90.53dB	-79.04dB	-83.85dB	-78.078dB	-62.43dB
595	unspecified	>50dB	≈ -60dB to -23.88dB	-85.72dB	-76.43dB	-64.82dB	-52.21dB	-40.47dB
CX-5	unspecified	≤50dB	-0.36dB	-58.03dB	-52.02dB	-46.24dB	-40.41dB	-34.10dB
AS-01	<0.10dB	>50dB	-0.05dB	-85.91dB	-86.18dB	-76.82dB	-70.03dB	-58.72dB
HD-1481	<0.20dB	unspecified	-0.41dB	-49.71dB	-43.63dB	-37.53dB	-30.64dB	-24.44dB.
HD-1234	unspecified	unspecified	-0.08dB	-89.92dB	-75.75dB	-79.68dB	-73.79dB	-61.70dB
CS-201A	<0.20dB	60dB	-0.37dB	-63.29dB	-61.86dB	-59.54dB	-49.21dB	-46.83dB

Table 2 - Analytics based on Table 1 values

Model	Insertion Loss Spec	Measured Insertion Loss	Insertion Loss Variation from Spec	Port Isolation Spec	Port Isolation Analysis				
					Maximum	Minimum	Range	Average	Average Variation from Spec
Delta 2	<0.10dB	-0.026dB	-0.074dB	>50dB	-86.24dB	-70.94dB	15.30dB	-77.40dB	27.40dB
Delta 4B	<0.10dB	-0.02dB	-0.08dB	>50dB	-84.82dB	-73.79dB	11.03dB	-78.33dB	28.33dB
MFJ-1702	<0.20dB	-1.14dB	0.94dB	>60dB	-70.60dB	-43.11dB	27.49dB	-56.53dB	26.53dB
MFJ-1702C	<0.20dB	-0.02dB	-0.18dB	>60dB	-92.37dB	-79.39dB	12.98dB	-86.15dB	26.15dB
MFJ-2702	<0.10dB	-0.03dB	-0.07dB	>60dB	-90.24dB	-70.94dB	19.30dB	-82.70dB	22.70dB
MFJ-2703	<0.10dB	-0.02dB	-0.08dB	>60dB	-85.66dB	-67.26dB	18.40dB	-78.05dB	28.05dB
MFJ-2704	<0.10dB	-0.09dB	-0.01dB	>60dB	-90.53dB	-62.43dB	28.10dB	-78.78dB	28.78dB
595	(unspecified)	≈ -60dB to -23.88dB	*N/A*	>50dB	-85.72dB	-40.47dB	45.25dB	-63.93dB	13.93dB
CX-5	(unspecified)	-0.36dB	*N/A*	≤50dB	-58.03dB	-34.10dB	23.93dB	-46.16dB	-3.84dB
AS-01	<0.10dB	-0.05dB	-0.05dB	>50dB	-86.18dB	-58.72dB	27.46dB	-75.89dB	25.89dB
HD-1481	<0.20dB	-0.41dB	0.21dB	(unspecified)	-49.71dB	-24.44dB	25.27dB	-37.19dB	*N/A*
HD-1234	(unspecified)	-0.08dB	*N/A*	(unspecified)	-89.92dB	-61.70dB	29.22dB	-76.17dB	*N/A*
CS-201A	<0.20dB	-0.37dB	0.17dB	60dB	-63.29dB	-46.83dB	16.46dB	-56.15dB	-3.85dB

In almost all of the switches tested, the non-connected (or unselected) ports are grounded internally within the switch, helping to improve the isolation of the switch. Some of the switches also claim to provide lightning protection, some with replaceable protection elements. All of the switches include some mounting scheme so that the switch can be installed to a wall or a panel.

The second table provides some analytics based on the collected test results. The first item of note is the variation between the measured insertion loss and the factory-provided insertion loss specification. This analysis data is presented in the column headed *"Insertion Loss Variation from Spec".* The next analytic derived is the aggregate data related to the port isolation specification and the measured values, manipulated to derive certain values such as the minimum isolation measured, the maximum isolation measured, the isolation range, the average port isolation afforded by the switch, and the variation of that average from the factory specification provided as regards port isolation.

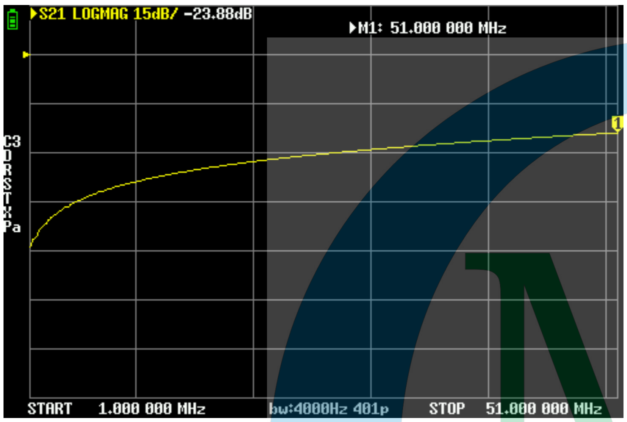

Figure 7 - Insertion loss of B&W model 595 switch

One switch in particular is very interesting in light of its extremely high insertion loss values. The B&W model 595 tested out with insertion losses that would certainly convince me not to use this switch. Figure 7 shows a screenshot of the insertion loss test for this switch. I could cause the insertion loss to drop to a reasonable level by pulling out on the switch knob, but in its natural position, the insertion loss is unacceptable. Each grid graduation vertically is 15dB, with 0dB being at the gridline with the yellow pointer at the left edge. Thus, if one counts down the grid lines, the 1MHz end of the sweep range, or the 160-meter area, has an insertion loss approaching 60dB. This test was run on a brand-new switch, so the loss cannot be blamed on switch age or condition. It would appear to be a function of the switch design.

The specification provided for the OPEK model CX-5 switch is very interesting in that it makes a strange departure from the norm. Usually, the port isolation is specified as being some value that is *greater than* a specified *minimum*. The OPEK switch is specified as having a port isolation value that is *less than or equal to* a *maximum* of 50dB. This is rather unfortunate, as we have already seen that 50dB is the approximate minimum isolation desired for a one-hundred-watt transmitter. This means that the OPEK switch was, before any testing is done, already considered to be unusable for our purposes. It can only be hoped that the specification provided is a typographical error. It is a fact, however, that the specification listed in this article is that provided at multiple websites of vendors that offer the OPEK switch in their product lines.

The testing of the OPEK switch told a somewhat different story. First of all, it must be noted that this switch does *not* ground the unselected port positions. This lack of port grounding immediately reduces the port isolation provided by this switch. With this condition in mind, it is now easier to understand why the specification is given as a maximum isolation rather than as a minimum value. While this switch was not the worst of the lot as regards insertion loss, it certainly was the worst when it comes to port isolation. Remember, though, that both of these factors are important when selecting a suitable coax switch.

As a point of interest, and through curiosity and a desire to see the comparison, I also included in this test series my own 6-port remote antenna switch (CMS model AS-01). I had anticipated the insertion loss to be less than 0.1dB and that the minimum port isolation would be 50dB. Testing showed that these anticipated values were in fact valid. I do not know why I did not do this type of testing at the time that I built the device, but I did not. Had I done so, I would have included the data in the article that I wrote on the topic and that can be found on the *Builds & Reviews* page of my website, www.ad2cs.com. Of course, the port isolation in my switch is helped by the fact again that the unselected ports are grounded. This is almost a solid necessity in order for good port isolation to be achieved in a coax switch.

I should mention that my homebrew switch was one of only two remote switches that were in the test mix, with the second remote unit being the Heathkit® model HD-1481switch. In most cases, remote switches are designed and intended to be used in an antenna farm and not so much as a transmitter selection device, but I wanted a comparison of this unit to be included.

As it turned out, the HD-1481 is clearly not suited for use as a transmitter selector, but only as an antenna selector. The maximum port isolation measured was a mere -49.71dB at 160 meters, below the 50dB target isolation value that we like to see if we follow Rob Sherwood's recommendations for maximum crosstalk power. This value, however, is above the 40dB threshold that we had set by reducing our accepted input power, as was the -43.63dB port isolation measured at 80 meters. Port isolation at all of the other frequencies tested were below the 40dB threshold, however. Further, the insertion loss was at least twice the design maximum per the specifications offered in the HD-1481 manual.

At this point, I would like to discuss a slight change that I had cause to make in the test regime. The problem is that the maximum dynamic range of the NanoVNA-H4 is listed as being only 70dB in the 50kHz to 300MHz frequency range, and indications were that the port isolation values were up against and beyond that limit. As a result, I switched out the NanoVNA for my HP 8752 benchtop VNA, which has a 100dB maximum dynamic range in the frequency ranges of interest. It is with the 8752 that the higher port isolation values were verified. The interesting thing is that the values measured there were almost identical to those measured with the NanoVNA-H4, despite being beyond the stated limits of that instrument. It is because the measured values were virtually the same that I chose to go ahead and use the NanoVNA screenshots in this article. Rest assured that the values are accurate, as they were all verified with the 8752. This says quite a bit about the capabilities of the NanoVNA-H4.

Having run these test series several times, making very sure that the results were accurate, it can safely be stated that many of the coax switches commonly used by amateur operators are for the most part safe for use as described in the opening of this article. However, not all of the switches tested proved to be completely safe, with the level of safety afforded being dependent upon the frequency of the signal applied and/or the quality and design of the switch. As such, care must be taken when using one of the "conditional" switches. It may simply be wisest to stay with one of the switches that tested well. There are enough of those switches to provide an array from which to choose. As is usually the case, those switches that came in at the lowest price points also came in the worst in the testing, a clear-cut illustration of the old adage that one gets what one pays for.