



N6DC

Vancouver, Washington, USA 98682

Tel: +1-360-253-2181 Fax: +1-360-635-4615

E-Mail: mail@rdfproducts.com Website: www@rdfproducts.com

AR-001

Amateur Radio Application Note

EVALUATING AND IMPROVING THE AMERITRON RCS-8V 5-POSITION REMOTE COAXIAL SWITCH



TABLE OF CONTENTS

<u>SECTION I - INTRODUCTION AND OVERVIEW</u>	1
<u>SECTION II - PERFORMANCE EVALUATION</u>	2
<u>SECTION III - MATERIALS AND WORKSMANSHIP</u>	3
<u>SECTION IV - WEATHER SEALING</u>	4
<u>SECTION V - INDOOR CONSOLE</u>	5
<u>SECTION VI - MULTI-CONDUCTOR CONTROL CABLE AND ADDED CONNECTOR</u>	6
<u>SECTION VII - COMPLETED UNIT</u>	8
<u>APPENDIX A - RETURN LOSS/VSWR CONVERSION CHART</u>	9

LIST OF ILLUSTRATIONS

Figure 1 - RCS-8V Input Return Loss; 0-55 MHz	2
Figure 2 - RCS-8V Input Return Loss; 0-255 MHz	2
Figure 3 - RCS-8V Relay Circuit Board	3
Figure 4 - Improved Ground Terminal	5
Figure 5 - RCS-8V with Added Interface Connector	6
Figure 6 - Interface Connector Inside View	7
Figure 7 - Interface Connector Wire Routing	7
Figure 8 - Completed RCS-8V (Modified, Painted, and Sealed)	8

SECTION I - INTRODUCTION AND OVERVIEW

This Application Note documents my evaluation of and enhancements to the Ameritron RCS-8V 5-position remote coaxial switch. This product comprises two modules, the first being an outdoor mounted relay box containing five RF switching relays and the second being an indoor console that allows the operator to conveniently activate any one of these relays. The RCS-8V thus allows the operator to select any one of up to five outdoor antennas with only one coaxial feedline actually entering the station operating area. A multi-conductor control cable must be separately procured to connect the indoor console to the remote outdoor relay box.

To briefly summarize my findings, I rate it a "4" overall on a scale of 0-5. Breaking this down further, I give it a "5" for performance, but only a "3" for its robustness in an outdoor environment. With the appropriate enhancements presented in this paper, however, I up the overall rating to a "5". These and related issues are discussed in detail in the Sections that follow.

You can visit my N6DC amateur radio website at www.rdfproducts.com/n6dc for possible revisions to this paper as well as additional amateur radio technical articles and other topics of interest.

Also, visit my N6DC vintage radio website at www.rdfproducts.com/N6DC.Vintage.Radio.htm for vintage radio technical articles and related information.

SECTION II - PERFORMANCE EVALUATION

The most succinct performance test of an RF switch is a swept input return loss measurement. For readers unfamiliar with this metric, input return loss is an alternative expression of VSWR with a return loss of 0 dB corresponding to a VSWR of infinity and a return loss of an infinite number of dB corresponding to a VSWR of 1:1. (See the conversion chart in the Appendix at the end of this paper.)

To conduct this test, the active switch output connector was terminated in a very low VSWR 50 ohm load. The return loss bridge was then connected to the input connector and swept return loss was presented as per Figures 1 and 2 (Figure 1 from 0-55 MHz and Figure 2 from 0-225 MHz). The frequency marker intervals for Figures 1 and 2 are 5 and 25 MHz, respectively.

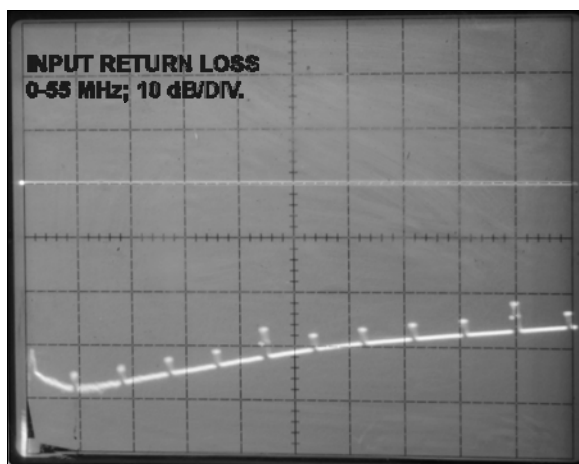
As can be seen from Figure 1, the return loss through 55 MHz (covering the HF amateur bands plus 6 meters) is spectacular. The worst-case return loss (occurring at 55 MHz) is an impressive 26 dB (corresponding to a VSWR of 1.1:1, which is essentially perfect for all practical purposes). Results were very similar for all switch positions.

VSWR remains subdued even into the high VHF bands, measuring near 1.3:1 at 150 MHz and 1.5:1 at 225 MHz. These are still very respectable numbers, and there is no reason not to use the RCS-8V at these frequencies. Although the RCS-8V instruction manual states that the unit is suitable for use at 450 MHz, it was my judgment based on an examination of the circuit board layout and related factors that this unit was not really designed for UHF use.

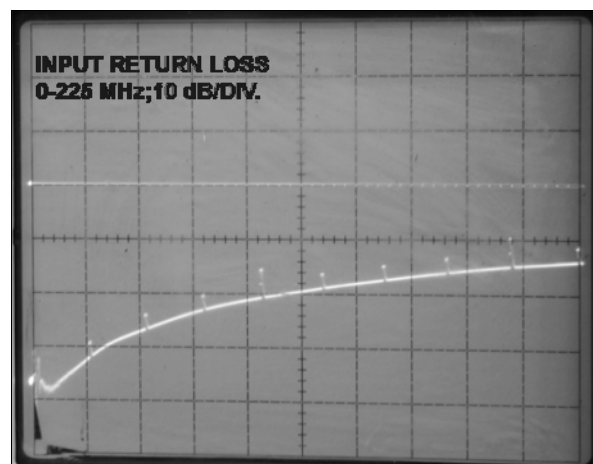
To further clarify this test, my RCS-8V employs SO-239 connectors. It is possible that units employing type-N connectors might exhibit better VSWR performance in the UHF range.

Port-to-port isolation was also very good, measuring 60 dB or better up to 150 MHz and 50 dB or better up to 225 MHz. These numbers were significantly better than I expected.

I did not attempt to measure switch insertion loss. Given that users have reported running this unit successfully at high power levels without it burning up, it is reasonable to expect that dissipative insertion loss is very low. Also, the relay contacts appear to be suitable for the intended application.



**Figure 1 - RCS-8V Input Return Loss;
0-55 MHz**



**Figure 2 - RCS-8V Input Return Loss;
0-225 MHz**

SECTION III - MATERIALS AND WORKMANSHIP

The RCS-8V employs good quality materials and components (notwithstanding the caveats addressed below regarding outdoor weather exposure issues associated with the remote relay box). The circuit boards in both the remote relay box and the indoor console are good quality commercial-grade glass-epoxy boards. The relays and coaxial connectors in the remote relay box are also good quality components that are suitable for the intended application.

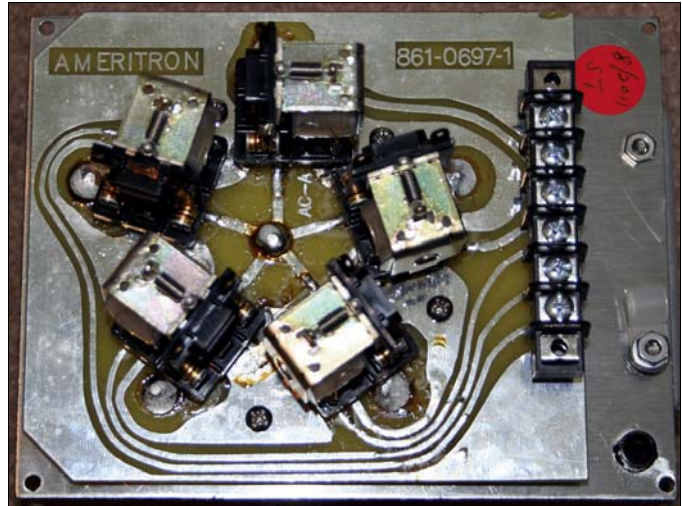


Figure 3 - RCS-8V Relay Circuit Board

Since other users have reported workmanship issues, I checked my unit very carefully with this in mind. On the positive side, I did not find any poorly soldered connections, solder bridges, solder balls, or similar workmanship ills that some users have reported. I did notice that the boards were not degreased (i.e., no effort was made to remove the solder flux), but this is more of a cosmetic issue that does not affect performance in this application (see Figure 3).

One issue I did notice that was serious enough to warrant remedial action was that three of the five machine screws securing the relay board to the hex support spacers were not fully tightened down. I tightened them to correct this, but then noticed that this caused the relay circuit board to warp. To correct this, I heated the solder on some of the SO-239 coaxial connector center pins while pushing the board downward to allow the board to properly seat itself on these connector pins.

This may have been an assembly error, or possibly the result of a defective or improperly built assembly fixture. My guess is that the machine screws in question were not fully tightened down by intent to prevent the board from warping. I think that it is important that these screws be fully tightened since they provide the primary conductive RF ground path between the circuit board and the connector plate. Given the weather sealing issues discussed below, it is probable that these loose screws would eventually develop high resistance ground paths that could impair performance.

SECTION IV - WEATHER SEALING

The instructions call for the RCS-8V to be mounted so that its six SO-239 connectors face downward. While this technically makes the unit splash-proof for most installations, the unit is not weather sealed. Although the unit has sufficient sealing under these circumstances to keep out direct rain and prevent insect nesting, it is not sufficient to protect its components from the effects of prolonged weather exposure. I am almost certain this vulnerability to moisture and water intrusion is the reason for some of the latent failures reported by some users. Also, I noticed that the relay board does not have a solder mask. While a solder mask is not essential for equipment intended for operation in a weather protected environment, it does provide an additional margin of corrosion protection if the circuit board is exposed to weather. Finally, the five relays, though rugged, are unsealed open-frame types that are not designed to hold up well to prolonged weather exposure.

Although the instruction manual specifically states that the unit should not be “air sealed”, I believe that this unit has inadequate weather sealing for long term outdoor use. For reliable operation, the unit should be fully sealed with RTV (silicone sealant) to achieve adequate protection against moisture and water intrusion. As per Figure 8, I applied Permatex Part 66B RTV (available in many auto parts stores) along all four panel edges (where they abut the plastic box) and also on all 13 exposed screw heads and the 24 pop-rivets (securing the SO-239 connectors). I also applied RTV along the SO-239 connector bodies (where they protrude from the panel) and at the multi-conductor cable entry hole (although I subsequently changed direction on this and installed a cable connector as discussed below).

Prior to mounting my RCS-8V on my tower, I installed protective weather caps on the unused SO-239 connectors and suggest that readers do likewise. (See Section VII and Figure 8.) Finally, although the plastic enclosure appears sturdy enough, the instruction manual makes no mention of its ability to withstand prolonged exposure to UV (ultra-violet) radiation from the sun. Since most plastics do not hold up well to prolonged UV exposure, I applied a protective paint coating to be on the safe side. For readers intending to mount their units in a permanently shaded location (e.g., underneath a roof eave), painting is unnecessary.

On a related note regarding UV issues, similar considerations apply to the multiconductor control cable outer plastic sheath. Although the most elegant solution is to employ a cable specifically designed for sunlight exposure, this is probably impractical for most installations. The more realistic solution is to place as much of the cable run as possible in a shaded area and then inspect the exposed sections periodically with the expectation that portions of the cable may eventually have to be replaced.

Also, be advised that the plastic and nylon cable ties commonly used to secure cables can likewise be vulnerable to UV radiation. I use black nylon cable ties that are specifically rated for UV exposure.

SECTION V - INDOOR CONSOLE

I was mostly favorably impressed with the indoor console (control unit). This unit is compact, presentable, functional, and its controls and indicators are well laid-out.

I did find a minor issue that might be of concern to some users. As per Figure 4, the control cable connects to the indoor console via a 5-lug terminal block. Although this well accommodates the five relay control lines, the ground (common) wire is intended to be connected to one of the two 6-32 machine screws securing this terminal block to the rear-panel. The problem with this arrangement is that when the nut is loosened to



Figure 4 - Improved Ground Terminal

fasten the control cable ground wire, the 6-32 machine screw upon which this nut is installed becomes loose and can fall back into the control box if it is pushed too hard.

This is not a problem as long as it is recognized and taken into account. Once the wire is attached and the nut tightened, everything is satisfactory. Even so, I decided to improve this by adding a second 6-32 nut along with a #6 lock washer to firmly secure the 6-32 machine screw to the terminal block and rear-panel. This modification required that the original 6-32 x 1/2" machine screw be replaced with a longer (5/8" or 3/4") screw.

I also noticed that the aluminum chassis was slightly warped with the result that only three of the four rubber feet made contact with the operating table. As my first attempt to correct this, I removed the top cover and bent the chassis to eliminate the warp. However, when I reinstalled the top cover the problem reappeared.

Upon further examination, I found that the some of the six top cover screw holes were out of alignment with their corresponding chassis screw holes. As a result, the chassis warps when the top cover is installed and the screws are tightened.

To correct this, I drilled-out the top cover screw holes to provide a looser (and thus more forgiving) fit. These holes can be drilled-out to up to 3/16" without them being visible when the screws are re-installed. (They can also be drilled-out to even larger diameters if appropriate flat washers are added to cover up visible portions of the holes.) Be sure to use masking tape to prevent the drill shards from scratching the top cover finish. This corrected the problem, but just barely.

If drilling out the top cover screw holes fails to completely correct the problem, larger rubber feet with flat bottom surfaces can be installed and then one of them shimmed as required with Mylar tape. Although my unit did not require shims, I added larger rubber feet (3M SJ-5023 large tapered square; 0.30" x 0.81") with flat surfaces to elevate the chassis slightly. Rather than removing the existing four smaller rounded feet, I just mounted the new larger feet adjacent to the originals.

Finally, the indoor console is very light with the result that it can be inadvertently pushed out of position on the operating table. To correct this, I weighted it down by installing a piece of scrap lead inside the box to add heft.

SECTION VI - MULTI-CONDUCTOR CONTROL CABLE AND ADDED CONNECTOR

The RCS-8V requires a multi-conductor control cable that connects between the indoor console and the remote relay box. This required (but not supplied) accessory must be a 6-wire cable (if all five relays are to be used). As per the cover page photo and Figure 3, this cable is intended to be inserted into the RCS-8V through a plastic grommet and then wired to the terminal block.

I do not regard the shifting of the burden of supplying this cable to the user as a product deficiency. The manufacturer could make a reasonable argument that since some users will require longer cables than others and some users will require cables with more conductors than others, there is no economical one-size-fits-all solution. Furthermore, since this cable is a significant cost item, it is reasonable that the manufacturer would want to shift the selection and cost of this cable to the user as a custom after-market accessory.

Since it is awkward and inconvenient to route a very long cable from the remote relay box down the tower and into operator's console, most users would likely want to have a convenient means of disconnecting the cable from the relay control box.

One solution is to install an in-line connector junction. To explain, the multi-conductor cable exiting the relay control box would first be cut to any convenient short length. Next, in-line mating connectors would then be wired, one at the end of this short cable and the other to the mating end of the longer cable routed to the indoor console. This would not only simplify cable installation, but would also allow a convenient means of disconnecting the relay control box should it need to be moved or taken down for maintenance.



Figure 5 - RCS-8V with Added Interface Connector

Since this connector junction would be exposed to weather, it would have to be adequately sealed against moisture and water intrusion. Since most users would likely prefer to use inexpensive connectors, they would need to be supplemented with a rubber boot or other means of weather protection.

For maximum convenience, I decided to install a chassis-mount waterproof connector directly on my RCS-8V remote relay box panel as illustrated in Figure 5. As per Figure 6, it was necessary to cut away a corner of the relay circuit board to make room for this connector. (I was able to do this neatly and conveniently using tin snips.) The selected location was chosen so as to be convenient for installing the connector and one that would cause no change in unit performance.

With the connector installed, I then soldered six insulated color-coded wires to the connector and routed them appropriately to the relay control terminal block as per Figures 6 and 7. To keep the wire bundle away from the "hot" RF circuitry, I installed two hex spacers and 4-40 machine screws as support standoffs. I then used 4" nylon cable ties to secure the wire bundle to the 4-40 machine screws and then used additional cable ties to keep the wires

tightly bundled.

Since the addition of this cable connector eliminated the need for the cable entry grommet, I removed this grommet, reamed out the hole to ½", and installed a ½" plastic hole plug as per Figure 5. I then weather sealed the hole plug with RTV as per Figure 7. Users who attempt to do this should be careful not to position the hole plug too close to the panel edge. To this end, I had to "drift" the original hole inward slightly from both panel edges before reaming it out.

With the benefit of hindsight, it seems that a ½" hole plug is somewhat large for this application and a smaller one would have been more convenient. Alternatively, this hole could be plugged with a suitable nut and bolt combination weather sealed with RTV.

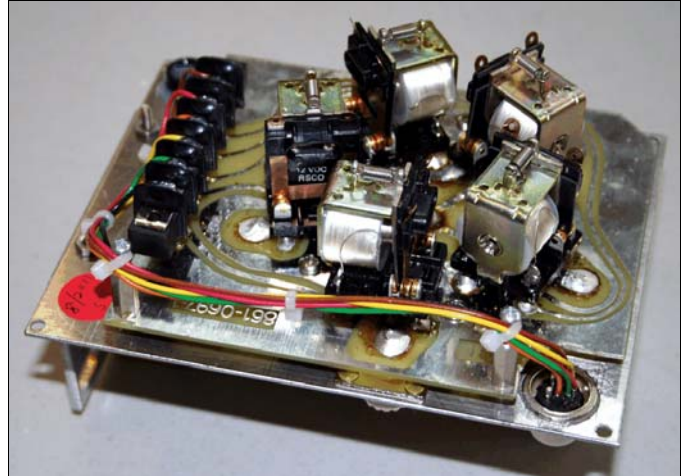


Figure 6 - Interface Connector Inside View



Figure 7 - Interface Connector Wire Routing

Although I used a high-quality IP-66 rated waterproof connector, most users would likely prefer a less expensive and easier to find alternative. A good candidate would be an 8-pin microphone plug and jack. These are widely used as microphone connectors for amateur radio equipment, are inexpensive, and are available from many sources. Although they are not waterproof, they can be adequately weather sealed using an appropriate combination of RTV, O-rings, and rubber boots.

SECTION VII - COMPLETED UNIT

My fully modified, painted, and sealed RCS-8V remote relay box (configured to select between two antennas) is shown in Figure 8. I painted the plastic enclosure by first applying a self-etching spray primer and then finished up with spray paint. Since the unit will not be readily visible, it is not necessary that the paint job be of cosmetic quality - a functional protective coating is adequate.

As also shown in Figure 8, I used modified PL-259 mating connectors as weather caps to seal the unused SO-239 connectors. To construct these, I first solder-sealed the PL-259 tips. Next, I poured Permatex Part 66B RTV into the connector body necks to water seal them. Next, I screwed the PL-259 connectors fully onto a mating SO-239 connector (serving as a holding fixture) and placed 1" lengths of 3/4" diameter adhesive heat shrink tubing over the PL-259 necks and shells. Finally, I applied heat from a heat gun to shrink the tubing to seal the PL-259 connectors.



**Figure 8 - Completed RCS-8V
(Modified, Painted, and Sealed)**

Since the PL-259 neck and shell are bonded together with the shrink tubing, the connector cannot be fully screwed onto the mating RCS-8V SO-239 connector. I screwed it down until it met resistance and then used Part 66B RTV to seal the PL-259 shell to the SO-239 connector threads for a full weather seal. If it is necessary to remove the PL-259, simply unscrew it with sufficient force to break the RTV seal. Once the PL-259 is removed, the residual RTV on the SO-239 connector threads can be peeled away.

When I mounted this unit on my tower and connected the three coaxial cables, I applied Part 66B RTV to the PL-259/SO-239 connector junctions as well. I am confident that this weather sealing and other enhancements will extend the service life of the RCS-8V by many years.

APPENDIX A - RETURN LOSS/VSWR CONVERSION CHART

<u>Return Loss, dB</u>	<u>VSWR</u>	<u>Return Loss, dB</u>	<u>VSWR</u>
0.0	Infinite	16	1.38
6.0	3.01	17	1.33
8.0	2.32	18	1.29
9.0	2.10	19	1.25
10	1.92	20	1.22
11	1.78	25	1.12
12	1.67	30	1.07
13	1.58	35	1.04
14	1.50	40	1.02
15	1.43	Infinite	1.00

Conversion Equation:

$$RL = -20 \cdot \log\left[\frac{(VSWR-1)}{(VSWR+1)}\right]$$

where:

RL is the return loss in dB,
VSWR is the voltage standing wave ratio,
and common (base 10) logarithms are employed.

<>