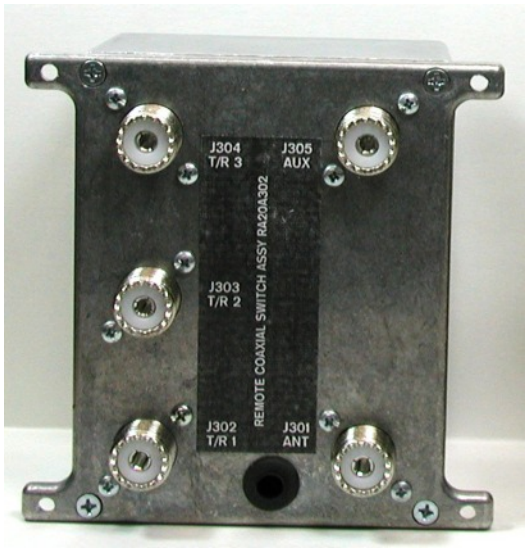
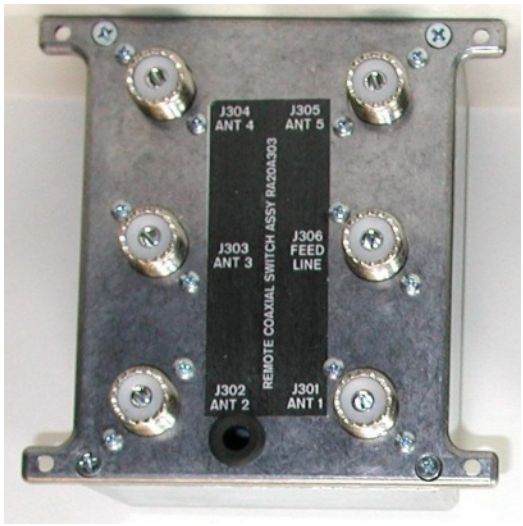
RA-20A-3 REMOTE COAXIAL SWITCH





RA-20A-3 REMOTE COAXIAL SWITCH

This Remote Coaxial Switch selects up to five antenna ports (tower mounted to connect to a single feed line) and three transceiver ports (located in the shack) using shielded cast aluminum enclosures. The Control Unit, conveniently located in the shack, connects to the two RF switch units via small six conductor cables, e.g. CAT-5. This removes bulky coax cables from the desktop. The shack located Transceiver Coaxial Switch can be mounted at any convenient point inside, or at, the station single point ground system.

Features and Applications

- Operates from 13.8 VDC with internal automatically resetting fuse, reverse voltage protection and DC over voltage protection.
- Outputs MOV protected.
- Outputs are current limited electronically to protect wiring and equipment.
- Current sense circuit determines that the remote relay coil is connected before illuminating the front panel LED.
- Each Antenna and Transceiver selection is backlit with a white LED making selected options easy to see at a glance.
- White label areas next to each LED lit selection number provide a space to write the name of the selected antenna or transceiver.
- Antenna port one is on by default, without power or control cables present, thus ensuring at least one antenna is available.
- Antenna selection includes an auxiliary port "AUX" which connects the selected transceiver to an in-shack 50Ω load or another antenna switch.
- Both Coaxial Switch assemblies, RA20A302 and RA20A303, are enclosed in RF tight die-cast aluminum boxes.
- Both Switch assemblies use the same printed circuit board and components.
- Designed to operate from 1.8 MHz to 54 MHz.
- Designed for 50Ω antenna systems at power levels up to 1 kW.
- Tolerable power level depends upon SWR, see detailed information on power vs SWR, see Figure 3.
- Low thru port insertion loss.
- Minimal contribution to return loss (SWR) of the antenna systems.
- High port to port isolation.
- Low control current (less than 100 mA) allows small conductors to be used for distant tower locations.
- Shack mounted Coaxial Switch allows any one of three transceivers to connect to either the common feed line to the tower mounted Coaxial Switch or to an "AUX" port located in the shack.

RA-20A-3 REMOTE COAXIAL SWITCH

Specifications

Remote Switch Assembly RA20A302 AND RA20A303	
Control Inputs (ANT 2 thru 5)	12 to 16 VDC @ 70 mA nominal (ANT 1 requires no current as it is wired to the NC contacts)
Control cable (Note 1)	5 control wires plus ground (Relays are connected to chassis ground)
Insertion loss	Frequency Range — Insertion loss 1.8 MHz to 28 MHz — <0.05 dB 28 MHz to 54 MHz — <0.10 dB
Isolation (port-to-port average all ports)	Frequency — Isolation 1.0 MHz — -77 dB 10 MHz — -63 dB 30 MHz — -50 dB 50 MHz — -43 dB 150MHz — -30 dB
Return Loss (VSWR)	Frequency — RL(dB) — VSWR 1-10 MHz — >45 — 1.01:1 10-20 MHz — 40 — 1.02:1 20-40 MHz — 36 — 1.03:1 40-80 MHz — 28 — 1.08:1 80-160MHz — 17 — 1.33:1
Environmental	Temperature -40 °C to +55 °C Humidity 10% to 90% (non-condensating)
Enclosure	Weather tight die-cast aluminum (internal desiccant for humidity control)
Relays (Note 2)	Contact material — Silver Alloy Contact current — 12A thermal limit Mechanical life — 30,000,000 operations Dielectric — 5000 V_{rms} Contact Opening — 1000 V_{RMS}
RA20A302 Assembly (Transceiver Selection)	Mounted conveniently in or near the shack for "local" remote coax switching. Selects one of three transceivers that then connect to either the feed line or an AUX coax port used to connect a 50Ω load or another antenna switch. Uses same PWB as 303 assembly but without J306.
RA20A303 Assembly (Antenna Selection)	Tower mounted remote coaxial switch connects one of five antenna ports to a common feed line. ANT 1 is connected to the relay's NC contacts so that it will be connected even with loss of power or control inputs.

Control Assembly RA20A301	
Power Requirement	12 to 16 VDC
Input Current	<0.10 Amp @ 13.8 VDC
DC Input Protection	Internal automatically resetting 0.9A PTC fuse Reverse voltage protection Over-voltage and transient protection with 1.5 kW 15V TVS
Control line Protection	16VDC 250A_{pk} MOV
Controls	6 Position Antenna switch (5 antenna plus AUX) 3 Position Transceiver switch Individual LED lit panel indicators for each selection (9 total)
Rear Panel Connectors	J101 — DC Power jack 2.1mm male pin 5.5mm jack J102 — 6 pin female DIN J103 — 0.520" dia.
Control cable (6 conductor or 5 conductor w/ ground) (Note 1)	With Remote Switch Assembly grounded to antenna system Wire Size — Distance 24 AWG — 400 ft 22 AWG — 500 ft 20 AWG — 1400 ft

Notes:

1. Control cable requirement is 5 control wires plus a ground return for a total of six conductors. If permanent ground connection exits from station to tower, it may be used for the ground, with caution.

2. Antenna selection **must not** occur with transmit RF power applied. Relays determine maximum allowed power and SWR based on RF voltage and current presented to the contacts.

Theory of Operation

Control Unit Assy RA20A301

The RA20A301 Control Unit assembly provides clutter free selection of several coaxial interconnects. The **TRANSCEIVER** switch selects one of three transceivers using a "local" Remote Coaxial Switch, Assy RA20A302. This allows coax cable to be routed from the transceivers to the Remote Coax Switch, located at the station's single point ground or other convenient location, without coax cables on the desk.

The second switch, **ANTENNA**, selects one of five antenna ports or an **AUX** port, again without the need for desktop coaxial cables. The antenna selection operates relays in the RA20A303 Assembly that is tower mounted. The **AUX** port is located in the RA20A302 Assembly and is convenient for connecting a 50Ω load to the selected transceiver or expanding antenna selection by connecting to another antenna switch.

To better understand the following theory of operation refer to the RA20A301 schematic, Figure 5. DC power is provided from either the station DC power source or a dedicated 13.8 VDC power source. If a station has uninterruptible DC power, it should be used to power the switch.

The DC power requirements are listed in **Specifications.** The power connection is via a 5.5mm (2.1mm male pin) coaxial power connector. The total current consumption is 100 mA or less nominal. The internal 0.9A resettable fuse is a PTC device and can pass as much as 4.5A before opening. While it will reset from a reverse voltage connection or overload, the external power source must be capable of withstanding such a fault condition.

Input DC power is protected from reverse voltage, over-voltage and transient conditions by a 1.5 kW, 15V TVS, D101. This is not to imply lightning immunity, but rather appropriate end-use protection in a properly protected station. C111 provides AC stability for the electronics that limit control wire current and determine coil connectivity.

Q104, Q102 and associated components form a 100 mA constant current source. In normal operation, Q104 is a low resistance path from the input DC power. However, in a fault condition (ground fault on a control line) Q102 will be biased on by R102's voltage drop thus lowering (make more positive) Q104 gate voltage. This mechanism will hold Q104 drain current at 100 mA. As soon as the fault is removed normal operation automatically returns. Note the "local" Remote Coaxial Switch control lines do not have this 100 mA constant current feed. If J103 control lines encounter a fault the current will be limited by Z101 to approximately 1.8A, but the fault trip current may reach 4.5A.

When ANT 1 is selected, none of the remote relays will be energized and K301 NC contacts will connect ANT 1 to the feed line. In this case no current flows through Q104, R101 or R102. With no voltage drop across R101 and R102, Q101 will be off and Q101 collector voltage will be near 0V. This allows current flow through D103 and R107, illuminating the ANT 1 LED. Note this is the default condition and may also represent a break in the control cable between the control unit and tower mounted switch assembly.

When antenna selections 2 through 5 are made, the total control current will be that of two relays. K301 is energized to disconnect ANT 1 and secondly the selected relay (K302 through K305) is energized to connect the selected antenna to the feed line. This control current, approximately 70 mA, flows through Q104, R101 and R102 producing sufficient bias to turn on Q101.

When Q101 turns on, its collector voltage will approach +12 VDC, or the incoming DC voltage. D102 will apply this voltage (minus a diode drop) to R107 and D103 ensuring it does not light. Q101 also turns on Q103 by providing base current through R105. When Q103 turns on, it provides a near ground to R108, a common dropping resistor for D105 through D108. Only one of these LEDs will have a path through the selection of S101, from the positive voltage of the current source Q104.

Therefore, for the selected antenna LED to light, S101 must be in the respective position for that antenna and control current must be present in the cable to the remote switch. Otherwise ANT 1 LED will light and indeed ANT 1 will be connected by default. If this occurs in any switch position other than ANT 1, then a fault exists.

The selection process for TRANSCEIVER switch S102 is simply to apply +12 VDC (or incoming DC voltage) to the appropriate remote relay and accompanying LED, D113 through D115. Again the LEDs have a common dropping resistor R109.

The control lines routed to the tower mounted remote switch through J102 have MOV surge protection, Z102 through Z105. ANT 1 control line does not have a dedicated MOV because anytime it is engaged, so is a line with MOV protection. The control lines routed through J103 to the

Theory of Operation

"local" or shack mounted switch have MOV, Z301 through Z305, protection at the remote switch end of the "local" control cable. Also D101 provides common TVS protection for the active line and incoming DC power.

The RA-20A-3 MOV and TVS protection devices are not intended to provide primary lightning protection. Well designed and properly installed station lightning protection must be provided to protect life and property.

The NEC and common sense require all cabling entering a structure have approved surge protection with a ground system that is bonded to the power utility ground. See

http://www.bwcelectronics.com/articles/WP30A190.pdf

For introduction to ARS grounding and lightning protection as well as reference material.

Remote Coaxial Switch Assy RA20A303

Built in a Bud® die-cast aluminum box, the RA20A303 is designed to be tower mounted near the antenna systems that connect to the shack via a common coax feed line. A pack of common desiccant provides condensation control and should be included but kept away from the coax connectors.

The relays, K301 through K305, are sealed PCB mounted power relays, refer to **Specifications** for details. These relays are compact enough to minimize parasitic losses but still robust enough for RF switching duty. Refer to Figure 3 for power vs SWR restrictions. While designed for 50Ω antenna systems and 1 kW transmit power, many factors are involved in determining the actual allowable operating levels.

For instance, an un-modulated RF carrier of 1 kW into a pure 50Ω load produces 224 V_{RMS} and 315 V_{PK}. As well, the RF current will be 4.5 A_{RMS} and 6.3 A_{PK}. Neglecting reactive components, these currents and voltages will increase with load resistance (SWR) above or below 50Ω. For a low resistance antenna of 16.7Ω (3:1 SWR) the current will be 13.5 A_{RMS} which exceeds the relay spec. For a high resistance antenna of 150Ω (3:1 SWR) the voltage will be 672 V_{RMS} and 950 V_{PK}. While this is less than the 60 Hz contact voltage rating, it is in dangerous territory for RF. Also, beware higher reactive voltage and current components will aggravate the situation. **These cautions are common to any RF switch and not unique to RA-20A-3.**

The relay coils are protected by 22V MOVs that serve two purposes. First, is surge protection for EM introduced voltages from lightning or EMP events. Second, the MOVs clamp the reverse voltage spike (from the collapsing magnetic field) when the relays de-energize.

The control cable to the RA20A303 is a non-connectorized pendant. If a connector is desired, for convenience, be sure it will provide reliable contact after exposure to humidity and condensation. A sealed connector is a minimum, but even so trouble may develop after a few years in the weather. I have a sealed Molex® connector up-tower for KA5AZK's station that has been in service since 2008 trouble free. I also used the same connector in our gate operator (unsealed) but protected from the weather - not humidity, that developed trouble within four years.

Remote Coaxial Switch Assy RA20A302

The RA20A302 is almost identical to the RA20A303, using the same components, printed circuit board and die-cast enclosure. Refer to the RA20A302 and 303 schematics, Figure 6. In order to use the same PCB for both switches, the ANT port is identified as the one connected to K301, that is normally closed. Therefore this port is connected to the common for the other four ports and J306 is not installed. J305 is the AUX port and its relay is controlled by S101, ANTENNA, on the control unit. The other three relays, K302, K303 and K304 are controlled by S102, TRANSCEIVER, on the control unit.

The RA20A302 assembly is not needed for the tower mounted remote switch to operate. The RA20A302 **is required** if the AUX or TRANSCEIVER select options are desired.

RA-20A-3 Applications

RA20A302 and 303 configurations.

See Figure 1 for typical application. Remember the switch ratings are based on a 50Ω coaxial system. Antenna tuners should be located on the feed-line side of the "local" remote switch, RA20A302. In cases such as transceivers with built-in tuners, the power and SWR levels should be managed for proper operation. The switch is safe with 200 Watt transmit power at very high SWR levels.

A linear power amplifier may be used either in the common feed line, J301 output, or with each transceiver at the inputs to the RA20A302. Keep in mind the power vs SWR considerations already mentioned.

Another RA-20A-3 switch unit may be connected to the AUX, J305, port to extend the number of antenna selections. Or connected to T/R 3, J304, another RA20A302 assembly can be used to extend the number of transceiver selections to five.

If transceiver and AUX selections are not needed, then the RA20A302 is not required for the selection of five antenna systems using the control unit and the RA20A303 tower mounted assembly.

Coaxial Baluns.

The RA-20A-3 is designed for 50Ω unbalanced coaxial feed lines. For many antenna systems the actual feed point is balanced. Many techniques have been employed to interface coax feed to balanced loads. A complete treatment of these is beyond the scope of this document, but two common and very effective methods will be mentioned.

In order to reduce feed line contributions to a balanced antenna's radiation pattern, the feed line should also be balanced. In cases where unbalanced, coax feed, is desired then either an RF choke or a balun should be used to interface the coax to the balanced antenna. Using one or the other of these will reduce or eliminate antenna pattern distortion and RF on the coax shield.

The simplistic, and effective, method is to just coil several turns of the coax feed line into a 6 to 8 inch coil with 5 or 6 turns for 14 MHz and up or 10 turns for 7 MHz and below. Installed at the balanced feed point this forms a common mode RF choke effectively isolating the shield, but not effecting the coax transmission line properties. This coaxial RF choke is simple, requires no extra connectors and is effective.

However, for a dipole or similar wire antenna it becomes important, to reduce static build up, that both halves of the antenna have a ground return . This is easily accomplished with a coaxial balun, see Figure 2. While ferrite core baluns are sometimes used for this application, they tend to be heavy, require a core and have a tendency to saturate or change properties when subjected to high power and SWR.

The coaxial balun provides excellent balance to unbalanced transformation, provides electrostatic ground for both legs of a balanced antenna, requires no core and will not saturate at high power or SWR levels. The description given here is based on an excellent article in "Ham Radio" March 1980 entailed New Class of Coaxial-line Transformers written by George Badger, then W6TC. The only negative is the need to connect the compensation winding to the shield at one end and the center conductor at the other. These are all points that must be water-proofed.

The coaxial balun in Figure 2 can be optimized for the frequency of operation. 50 inches of coax and compensation winding wound into 4.5" coil is ideal for 80 through 10 meters. 100 inches will optimize 160 through 20 meters.

In the early 1980s I had access to a good vector voltmeter that I used to test the 50" version. The balun had excellent amplitude and phase balance, as described in the original article. I did not test ferrite core baluns, but the author did and confirmed IMD products occur under some conditions of power and SWR in these core baluns.

I have used both coaxial baluns and simple feed-line RF chokes with excellent results. I last used ferrite core baluns in 1982 and can not say they were troublesome, but I see no need to use them.

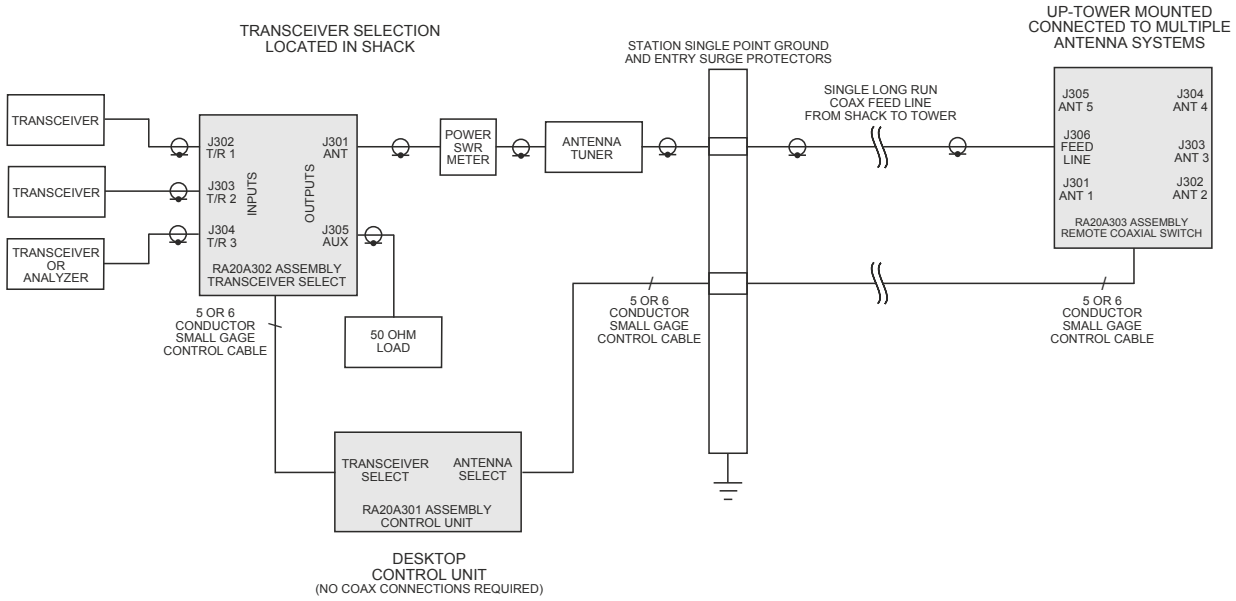


Figure 1. RA-20A-3 typical application. Items to the left of the "station single point ground and entry surge protectors" are located inside the ARS. Items to the right are outdoor coax feed line and remote (up-tower) antenna switch.

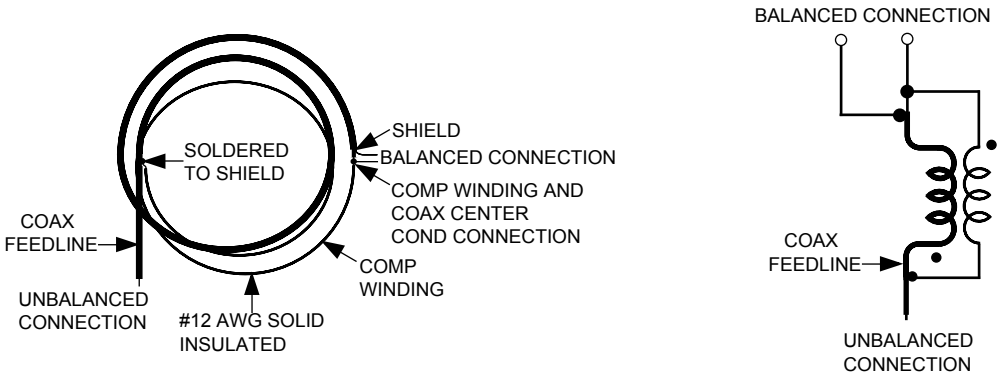


Figure 2. Non-saturating coaxial balun, consisting of 50 to 100 inches of coax and AWG #12 insulated wire wound into 4.5 inch coil. Coax and wire compensation winding wind opposite directions.

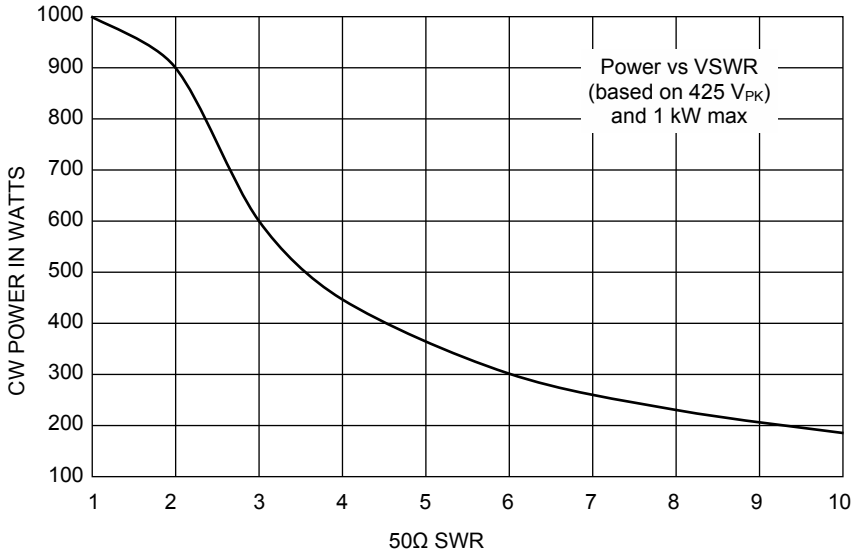


Figure 3. CW power vs SWR based on VSWR. Low impedance SWR does not exceed the relay current rating based on the above curve (that is high ratio of resistance to 50Ω is the more

Isolation From J306 and Return Loss to selected J304							
Frequency (MHz)	Isolation from J306 with J304 selected (dB)					Return Loss (J306 to J304)	
	J301	J302	J303	J305	Avgerage	Return Loss	VSWR
1	75.2	84.5	65.8	82	76.9	>45	1.01:1
10	75.8	66.2	49.8	58.7	62.6	40	1.02:1
30	56	52.2	41	49.1	49.6	36	1.03:1
50	46.4	45.8	36.7	44	43.2	28	1.08:1
150	27.6	35.3	28.5	30.2	30.4	17	1.33:1

Figure 4. Measured prototype data. Note the 150 MHz data is for reference only. The RA-20A-3 is designed to operate from 1.8 to 54 MHz.

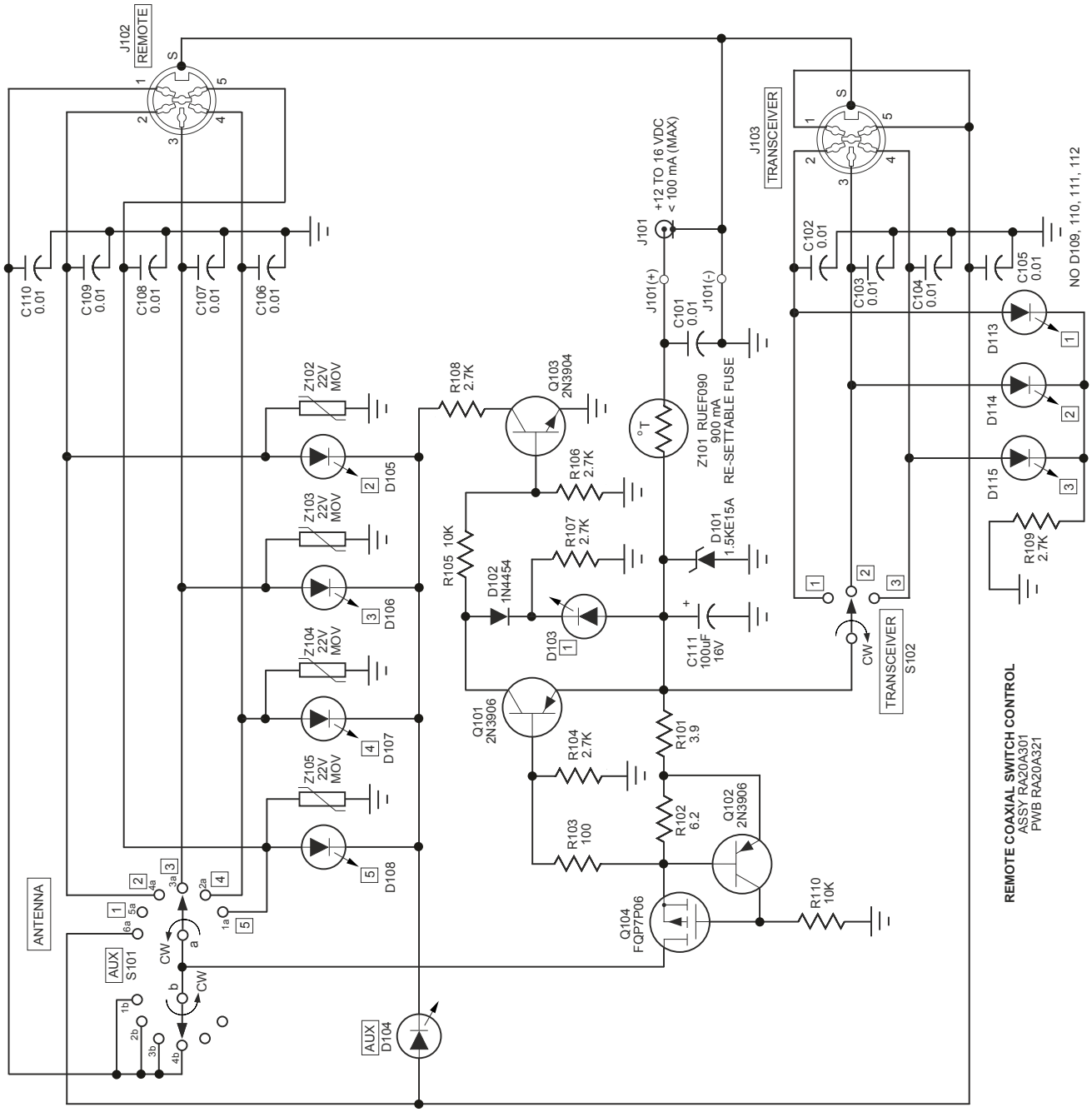


Figure 5. RA20A301 Assembly schematic.

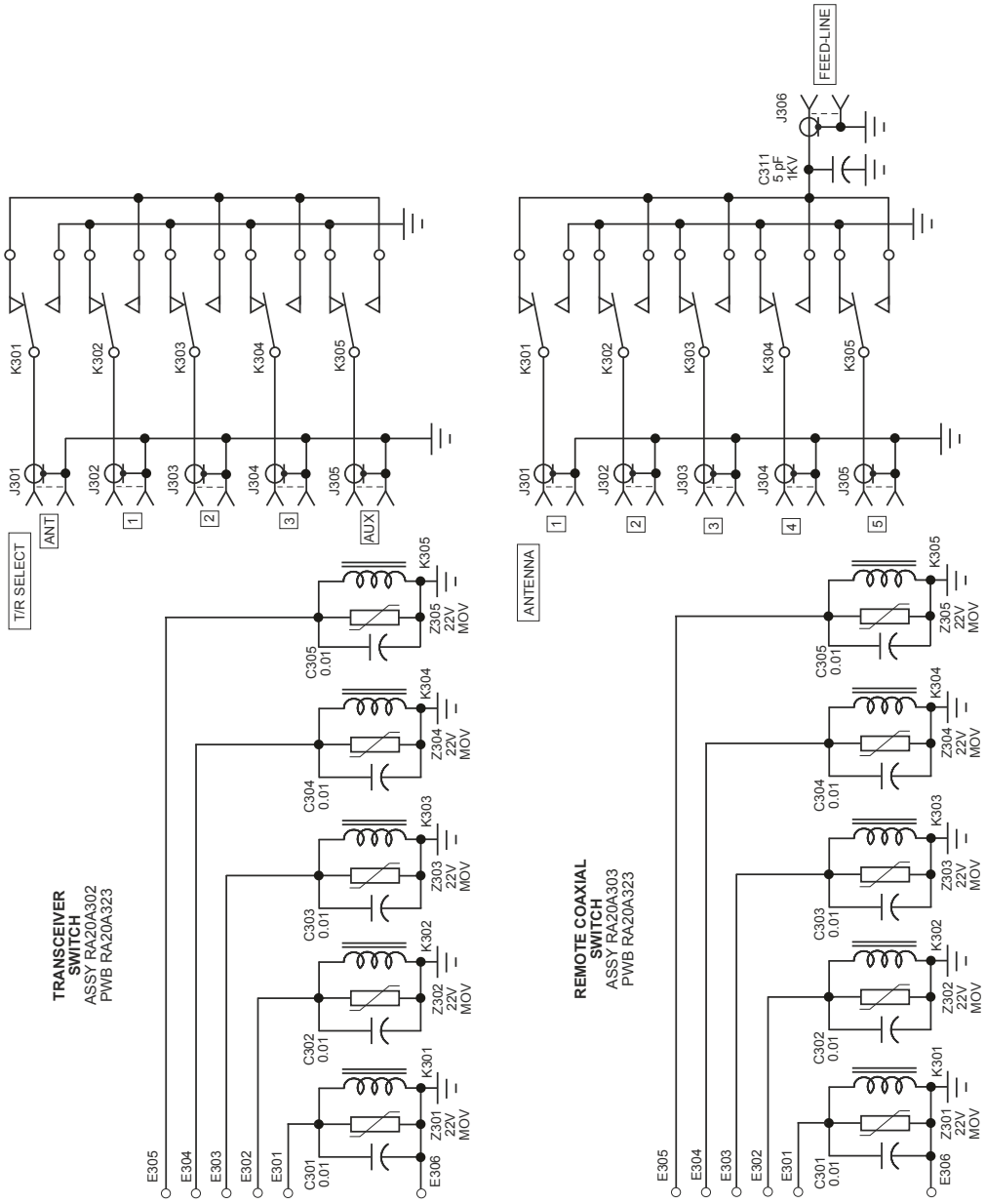


Figure 6. RA20A302 and RA20A303 Assembly schematic.

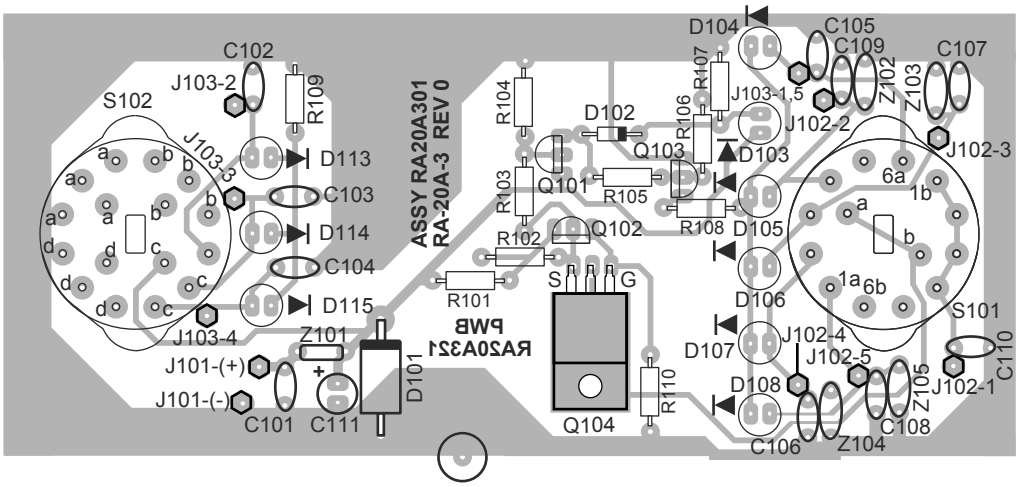


Figure 7. RA20A301 Assembly component locator.

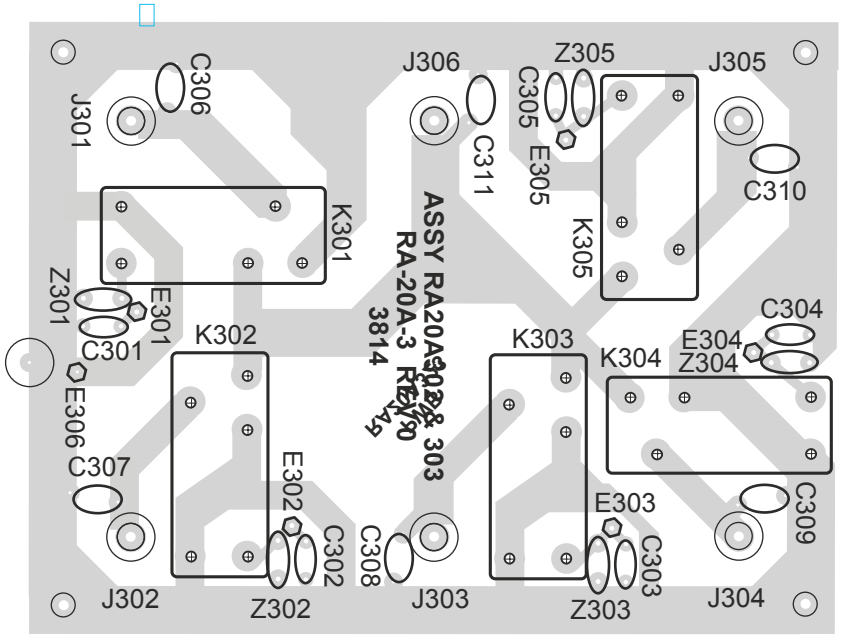


Figure 8. RA20A302 and RA20A303 Assembly component locator.

RA-20A-3 Construction

RA20A301 Assembly

The prototype control unit was built in a shop made 0.050" 5052-H32 aluminum enclosure. See

http://bwcelectronics.com/articles/WP40A190.pdf

for methods I use to fabricate custom enclosures. Also, see Figure 9 for the front and rear panel overlays, included at full size. The panel is 2.50" x 5.50" and the rear panel overlay is exact size. The front panel is the same size, but the overlay has extended coverage in all dimensions. The extra material allows the overlay to wrap around all edges of the front panel.

The front panel should be drilled using Figure 10 pattern. The panel overlay is printed on either paper or white polyester film. If paper is used it should have several coats of lacquer applied before attaching to the aluminum panel. The white LEDs illuminate the white (actually clear) numbers located over the holes drilled in the aluminum panel.

I expect anyone copying this design will select their own control unit enclosure from standard product offerings; therefore, patterns for the prototype enclosure are not included in this document. If desired, a full size pattern for the two piece enclosure used is available upon request to

sales@bwcelectronics.com

which includes cut, bend and drill marks. This pattern can be attached to an aluminum sheet with spray adhesive and used for fabrication without the need to measure and mark.

The RA20A321 printed circuit board is available from Far Circuits or the above email. It is FR4, etched, drilled, solder platted with legend. The two rotary switches, S101 and S102, are PCB pin switches mounted to the board. The switch shafts use two control nuts each to mount the entire assembly to the front panel using only the switch bushings.

D105-108 and D113-115 are mounted with their base 0.45" above the PWB surface. The two each control nuts are adjusted so the LEDs just reach the front panel.

J101 through J103 are chassis mount connectors located on the rear panel. These connectors and their mounting are not critical and can be modified to suit the builder's preferences.

RA20A302 and RA20A303 Assembly

These two assemblies are essentially identical. The 302 assembly does not use J306 or C311 and has a different panel overlay. Otherwise they use the same components and layout.

Circuit board is RA20A323 and also available.

Built in Bud® die-cast aluminum boxes these two units require very little fabrication. See Figures 11 and 12 for full size drill templates. **Templates install inside the cover - mirror image of panel overlays.** Once drilling is complete, use acetone to remove the spray adhesive and paper pattern. Clean metal contact is required for the coax connectors. The appropriate panel overlay, also in Figures 11 and 12, should be attached with spray adhesive prior to installing the coax connectors.

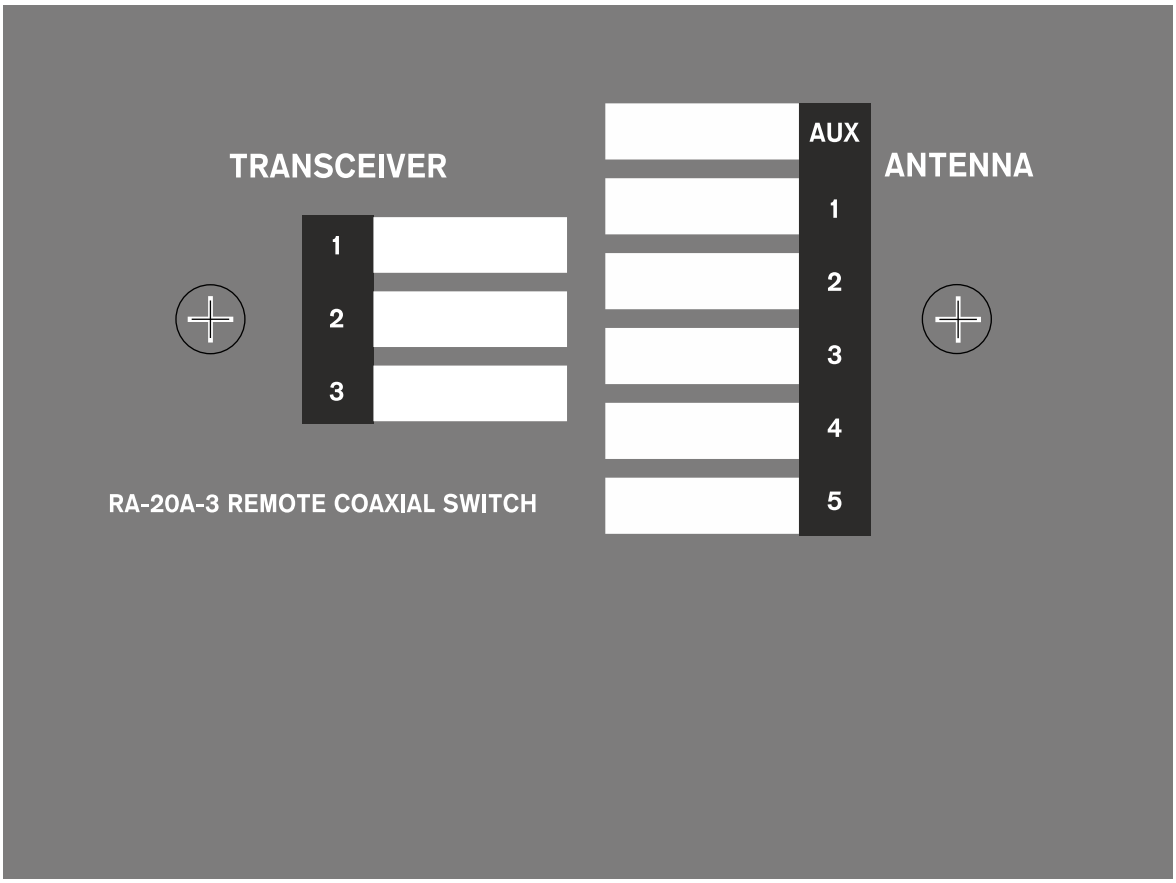
Carefully clean the inside of the cover with acetone to remove all adhesive residue. The cover must be clean prior to mounting the coax connectors.

The circuit board components should be installed and short lengths of solder braid should be soldered to the foil near each coax connector hole in the board. These will need to reach through to the top of the board and solder to the coax connector's center pin - after the board is mounted to the four corner 0.187" 4-40 standoffs.

The control cable enters through a rubber grommet. Each conductor solders to the appropriate circuit board pad. Strain relief should be provided at the grommet. The grommet should be sealed with a weather-seal of choice. If a connecter is desired in the control cable, see **Theory of Operation** for comments on doing so.

The completed assembly should be tested with the control unit prior to mounting up-tower. A common bag of desiccant should be attached between the circuit board and the connector panel, but not in contact with connectors. Once tested, mount the assembly up tower with the connectors facing down. Do not support long lengths of coax from the connectors, but rather provide mechanical support for all coax cables connected to the switch assembly.

The RA20A302 assembly is mounted in the shack wherever it is best suited. It can be mounted on the station's single point entry ground or elsewhere in the shack, but it does not provide any surge or lightning protection, the switch is an inappropriate location for such. So, ensure station protection is properly designed and installed per NEC and local codes.



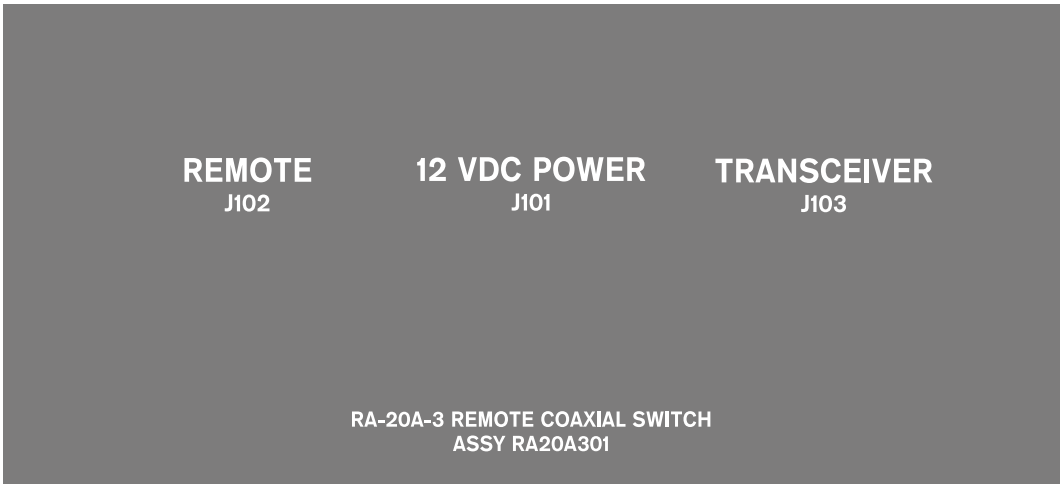


Figure 9. RA20A301 front and rear panel overlays. The rear panel overlay is the same size as the panel, whereas the front panel has additional material to wrap around all edges of the front panel.

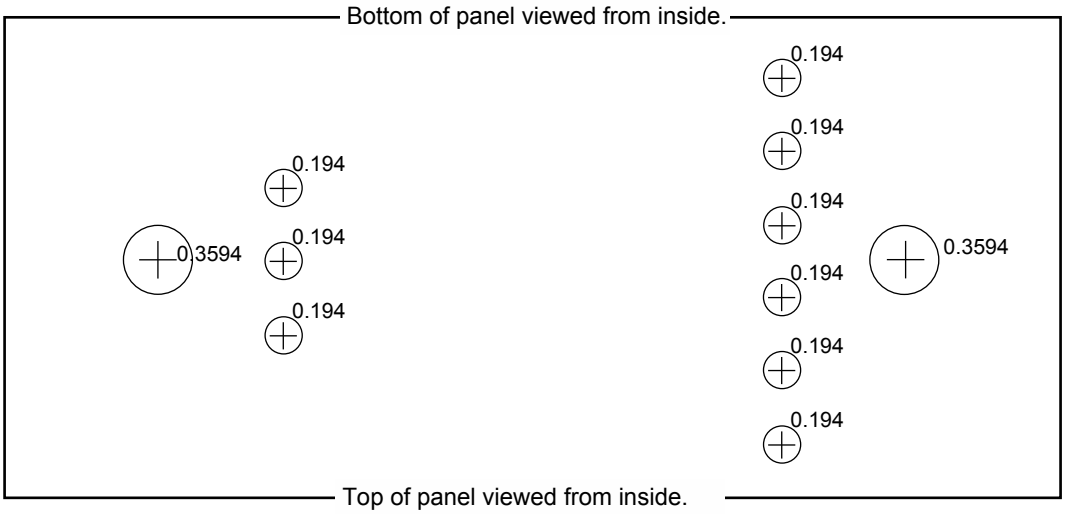
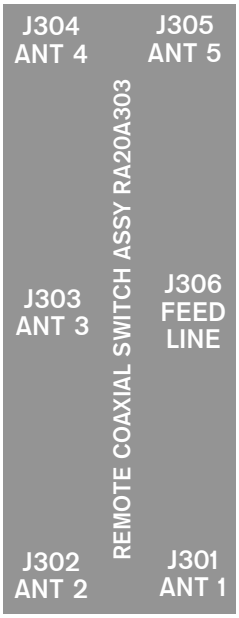


Figure 10. RA20A301 Front Panel drill pattern. Note this is inside view and upside down from the outside panel view. The prototype was fabricated from a single sheet of aluminum so the bend and drill markings are for inside operations.

RA-20A-3 REMOTE COAXIAL SWITCH



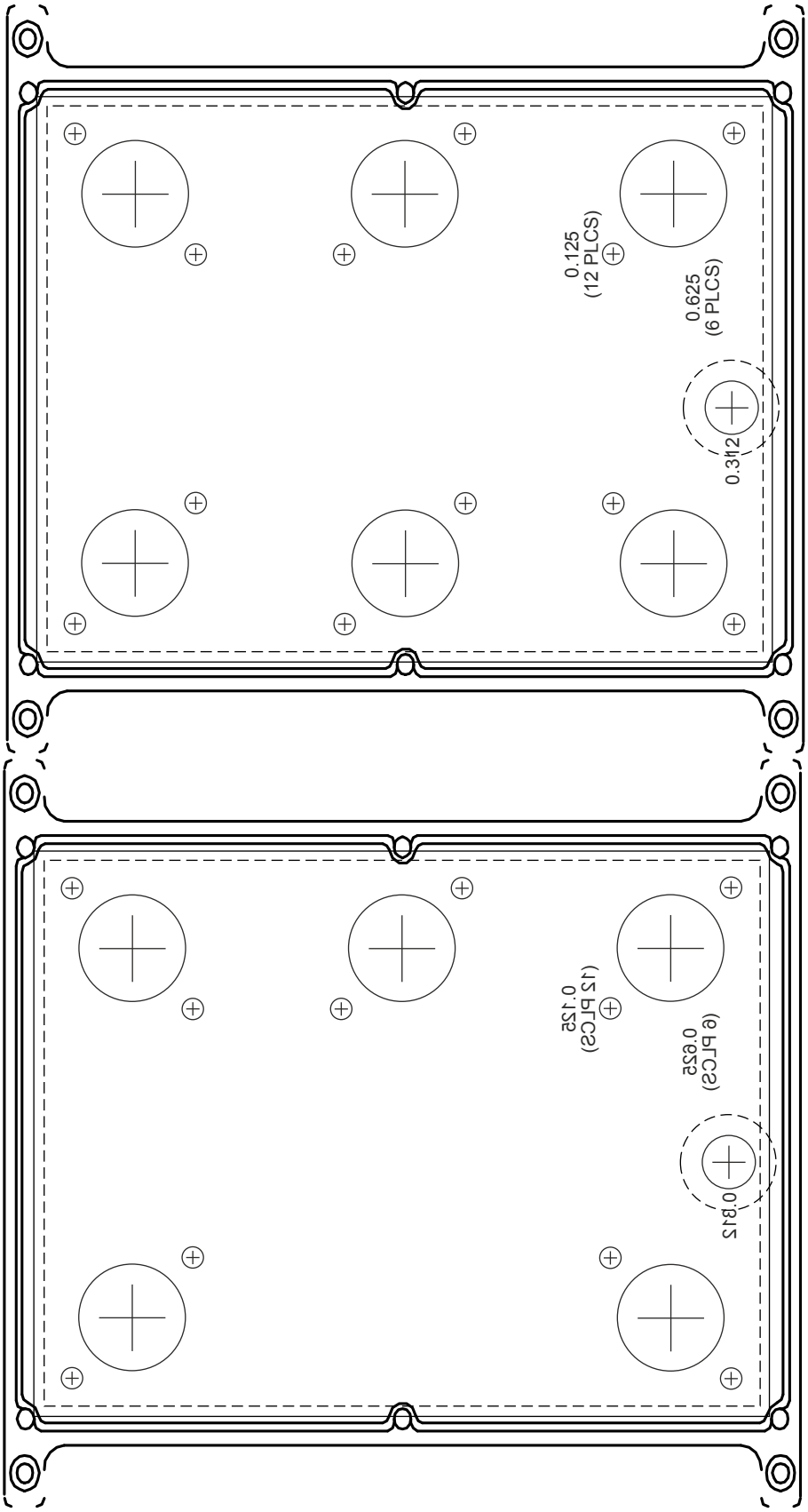


Figure 12. RA20A303 drill template and panel overlay.

Figure 11. RA20A302 drill template and panel overlay.

Note: Drill templates attach to the **inside** of the covers. The overlays attach to the **outside** of the covers.

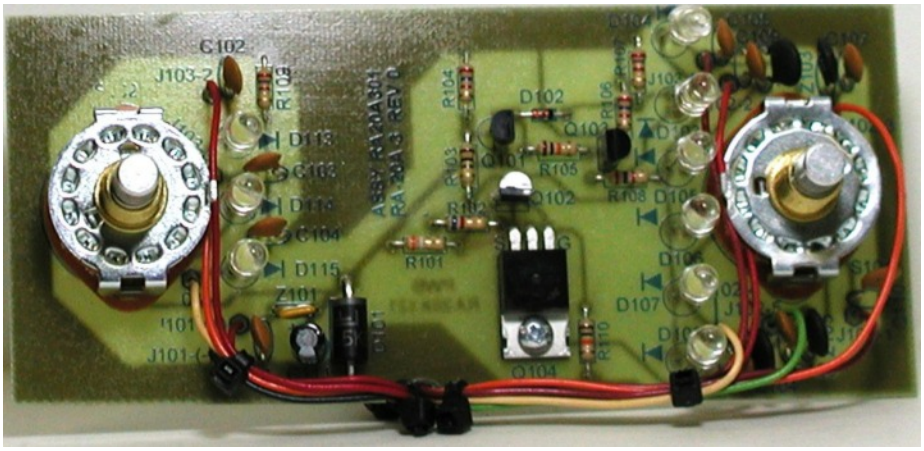


Figure 13. RA20A301 Assembly showing installed components and wiring. The base of the LEDs should be 0.45" above the PWB.

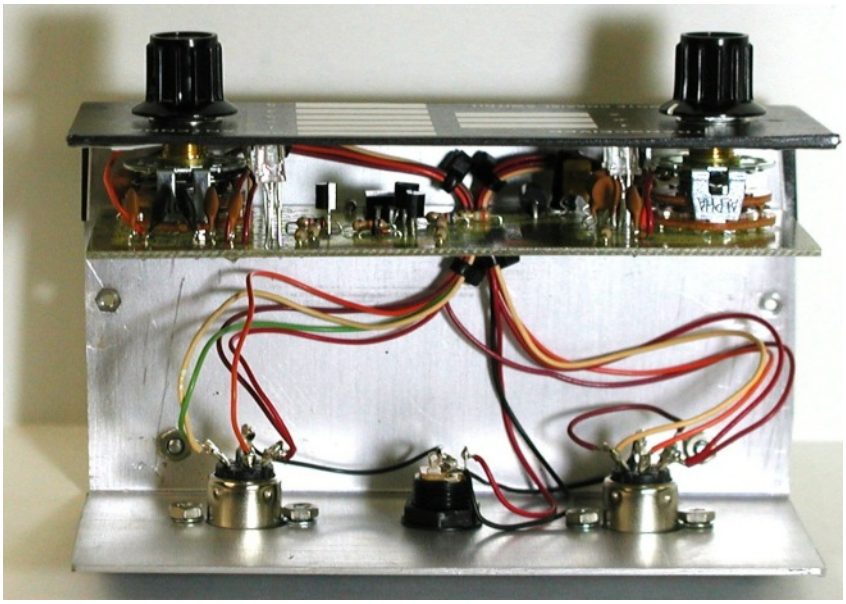


Figure 14 RA20A301 installed into the shop-built enclosure.

Figure 15 RA20A301 Rear panel showing the connectors.

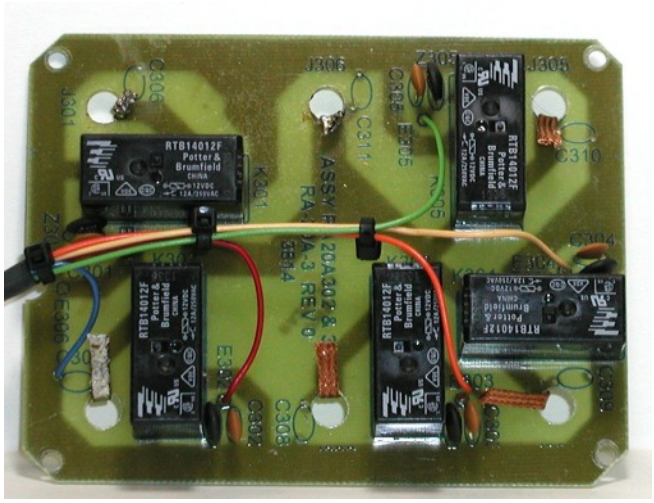


Figure 16. Assembly RA20A303 shown with components and wiring. Note solder braid protruding through clearance holes for the coax center pin. Short strips of braid (approximately 0.60" long solder to the back-side foil after being formed through the holes.

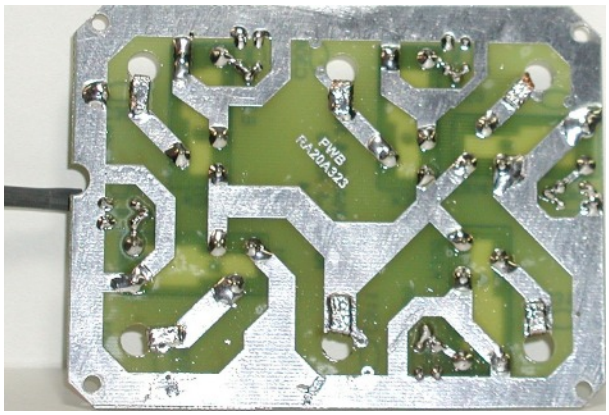


Figure 17. Foil side of PWB RA20A323. Note the solder braid attachment to the foil. Also note the solder flux has been removed and the board coated with clear lacquer.

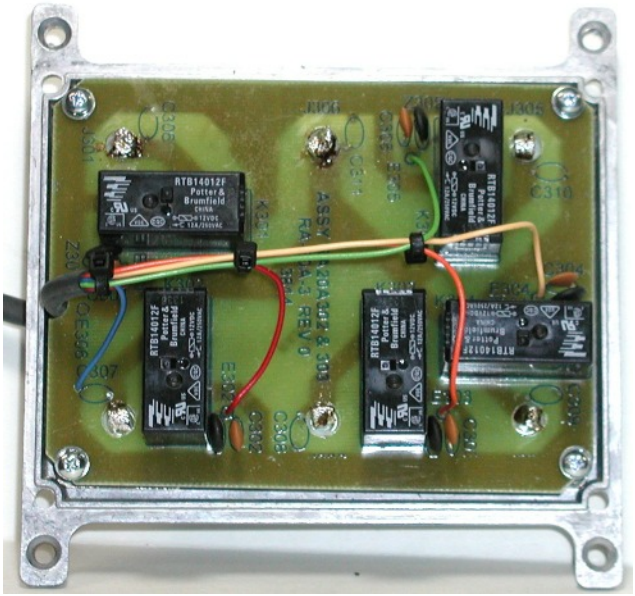


Figure 18. RA20A303 PWB mounted onto the front cover of the die-cast box. Note the solder braid soldered to the coax connector center pins.

COAXIAL RF SWITCH RA-20A-3 LIST OF MATERIAL										
RA-20A-3 ASSEMBLIES COMPONENT DESIGNATORS			VALUE OR TYPE	DESCRIPTION	PART NUMBER	QUANTITY PER				SUPPLIER
RA20A301	RA20A302	RA20A303				301	302	303	TOT	
C101-C111	SAME AS RA20A303 EXCEPT NO C311, J306	C301-C305	0.01uF 100V	CERAMIC DISK	594-D103M29Z5UH6UJ5R	11	5	5	21	MOUSER
C112			100uF 16VDC	ALUMINUM ELECTROLYTIC	647-UVR1C101MDD	1			1	UNLESS
D101,			1.5KE15A	15V TVS	576-1.5KE15A	1			1	NOTED
D102			1N4454	SILICON SWITCHING DIODE	512-1N4454	1			1	OTHERWISE
D103-D108, D113-D115			LED T-1 3/4	BRIGHT WHITE	941-C503DWANCBBDB152	9			9	
J101			DC POWER JACK	2.1 MM CHASSIS MTG	163-4302-E	1			1	
J102, J103			DIN CONNECTOR	6 PIN, FEMALE, CHASSIS	161-0006-E	2			2	
P102, P103			DIN CONNECTOR	6 PIN, MALE	171-0276	2			2	
P101			DC PWR PLUG & PIGTAIL	2.1 MM FEMALE	172-4203	1			1	
Q101, Q102			2N3906	PNP SMALL SIGNAL	512-2N3906BU	2			2	
Q103			2N3904	NPN SMALL SIGNAL	512-2N3904BU	1			1	
Q104			FQP7P06	P-CH POWER MOSFET	512-FQP7P06	1			1	
R101			3.9, 5%, 0.25W	CARBON FILM	291-3.9-RC	1			1	
R102			6.2, 5%, 0.25W	CARBON FILM	291-6.2-RC	1			1	
R103			100, 5%, 0.25W	CARBON FILM	291-100-RC	1			1	
R104,106-109			2.7K, 5%, 0.25W	CARBON FILM	291-2.7K-RC	5			5	
R105, R110			10K, 5%, 0.25W	CARBON FILM	291-10K-RC	2			2	
S101			2P 6POS ROTARY SWITCH	PCB PIN, PANEL MTG	105-SR2512F-26NS	1			1	
S102			4P 5POS ROTARY SWITCH	PCB PIN, PANEL MTG	105-SR2512F-43NS	1			1	
Z101			900 mA FUSE	RESETTABLE THERMAL	650-RUEF090	1			1	
		J301-J306	SO-239 UHF	CHASSIS MTG	601-25-7350		5	6	11	
		K301-K305	SPDT RELAY	12VDC, 360 OHM, PCB PINS	655-RTB14012F		5	5	10	
Z102 - Z105		Z301-Z305	22V MOV	DISK	871-B72207S1140K201	4	5	5	14	
			4.68X3.68X2.06 ENCLOSURE	DIE-CAST ALUMINUM	563-CU-5234		1	1	2	
			CONTROL ENCLOSURE	ALUMINUM	SHOP MADE	1			1	
			RA20A301 FRONT PANEL	OVERLAY		1			1	
			RA20A301 REAR PANEL	OVERLAY		1			1	
			RA20A303	OVERLAY				1	1	
			RA20A302	OVERLAY			1		1	
			0.25" PAN HD PHILLIPS	4-40 ZINC	90272A106		4	4	8	MCMASTER
			0.312" PAN HD PHILLIPS	4-40 ZINC	90272A107	11	10	12	33	MCMASTER
			0.25" HEX NUT	4-40 ZINC	90480A005	9	10	12	31	MCMASTER
			0.25" HEX SPACER	4-40 ALUMINUM	91780A712 (4-40)		4	4	8	MCMASTER
			#4 LK WASHER	4-40 ZINC	91113A005	9	6	8	23	MCMASTER
			#4 PRESS-IN NUT	4-40 SS	94674A485	2			2	MCMASTER
			RUBBER GROMMET	0.375"	534-735		1	1	2	
			RUBBER FEET	0.375" RECESSED BUMPER	534-720	4			4	
			KNOB W/ SKIRT	1/4 SHAFT	506-PKA50B1/4	2			2	
			CONTROL NUT	3/8 - 32NEF	652-H-38-11	2			2	
PWB					RA20A321	1			1	FAR
		PWB			RA20A323		1	1	2	FAR
11/17/2014						93	58	65	158	