CRC **CACTUS Radio, Inc.**

Technical Application Note #6

This Technical Application Note describes the procedure for cleaning and refurbishing the Motorola T-1500 series UHF Cavity.

An excerpt from the Motorola T1500 Series Cavity datasheet has been included at the end of this document. For complete information of the T-1500 Series Cavities and Duplexers, refer to Motorola document 6881102E96 (Old Number 68P81102E96-E).

This Technical Application Note #6 is available in electronic form, in its entirety, that can be read with the Adobe Acrobat Reader application. To obtain an electronic copy of this document, send an e-mail message to Ken Robbins, WA6PYJ, at ken@cactus-intertie.org and request an electronic copy of **Technical Application Note #6 - Motorola T-1500 Cavity Refurbishment Procedure.**

Cleaning and Refurbishing the Motorola T-1500 Series Cavity

This cleaning and refurbishing procedure is being supplied as a courtesy by the Cactus Radio, Inc. There is no Warranty expressed or implied. Use of this procedure is at your own risk. Read this entire procedure prior to attempting to refurbish a cavity.

Supplies Needed

The following supplies will be needed to perform the cleaning and refurbishing operation described in this procedure.

Nose and mouth dust filter
Two (2) pair of household rubber gloves, or medical gloves
Variable speed electric hand drill
Fine bristle wire wheel with ¼ inch shaft
Bench vice
Scribe or awl
Piece of thick cloth to go around the cavity
Coarse emery cloth or 600 grit sandpaper
Tool with a small hook on the end such as a small dental pick
3/8 inch diameter rod about 6 inches long
No oil contact cleaner
Trichloroethylene or denatured alcohol
Clean lint free cloth
"Tefron" or "Tri-Flow", a light oil with a Teflon mix
Miller Stephenson MS-122 TFE "Release Agent Dry Lubricant"
Miller Stephenson MS-171 "Connector Plus"
Tap and Die, 3/8 inch, 40NS TPI

Safety Precautions

Cactus recommends that you take the appropriate safety precautions due to the toxic materials used during the cleaning and refurbishing operation as well as the toxic dust produced during the cleaning and refurbishing process. A breathing filter that covers your nose and mouth should be worn at all times. Household style rubber cleaning gloves and a shop style smock should also be worn.

Disassembly Procedure

This procedure applies to individual Motorola T-1500 cavities only. If you are refurbishing a duplexer, remove all the phase harness cabling and remove the cavities from the rack panel. Be sure you mark and note the location of each individual phase harness cable as you will need to put it back in the exact same location.

Remove all the clamping nuts and panel mounting nuts. Turn the tuning screw counterclockwise several turns such that the threads which were protected inside the cavity show.

Install the fine bristle wire wheel in the electric hand drill and place the drill in the bench vice, drill handle up, at about a 45 degree angle.

Using the wire wheel, polish the exposed threads of the shaft until they are shiny, removing any rust and paint, including the paint dot Motorola puts on. If the threads are not thoroughly cleaned prior to trying to remove it from the cavity housing, it may bind and will need to be cut off and drilled out.

Using a thick lead pencil, on one side of the cavity housing, mark a line across the bottom cover and the center housing of the cavity. This is because the cavity housing is not symmetrical, even though it looks like it is. Remove the bottom cover of the cavity housing by removing the eight (8) screws and sliding the cover off.

Remove the coupling loops, noting their relative positions. There should be a flat washer and a nylon washer under each knurled knob on the outside of the pass-notch style cavities, such as the cavities used in duplexers. The proper assembly order from the outside is knurled knob, split lock washer, nylon washer and then the outside cavity surface. When the cavity is reassembled, these parts must be in this order.

NOTE: A datasheet is included at the end of this document.

Turn the tuning shaft clockwise until it is all the way in. Press down on the tuning sleeve slightly and remove the "C" clip from the bottom of the shaft.

NOTE: The washer under the "C" clip is brass. There are two more identical washers, but they are stainless steel. Do not get the washers mixed up.

Remove the tuning sleeve, the spring and the two (2) stainless steel washers, one on each end of the springs.

By holding the tuning shaft from inside the cavity housing, turn the shaft clockwise until the shaft can be removed from the cavity.

Cleaning Procedure

Lay the spring on a flat surface and note the relaxed length. Stretch the spring until its relaxed length is approximately two (2) inches longer. Remove any foreign material and clean the spring. Clean both stainless steel washers. Clean and polish the brass washer and "C" clip.

Using the wire wheel, polish the entire length of the threads of the tuning shaft until they are shiny, removing any rust and paint. Inspect the threads to ensure there are no spots where it might jam or bind. Use the 3/8" 40 NS die on the shaft if necessary. Use the 3/8" tap on the cavity housing if necessary. For a test, thread the shaft back into the cavity. Make sure it turns freely for the whole length of the shaft. Remove the shaft from the cavity.

Polish the inside of the cavity where the coupling loops make contact using some coarse emery cloth or 600 grit sandpaper. Polish the entire bottom edge of the cavity housing where the bottom cover makes contact. Polish the top flat area above the ridge in the bottom cover where it presses inside the cavity housing.

Using the dental pick tool, gently but firmly bend each of the tines of the finger stock inside the cavity housing where the tuning sleeve makes contact. Bend them inward towards the center of the cavity housing by hooking the loop under each finger one at a time and pulling in and up. Bend them in significantly but gently, as they can be easily broken.

Wrap a piece of emery cloth tightly around the 3/8 inch diameter rod and polish the finger stock where it will contact the tuning sleeve. Apply just enough pressure to burnish the finger stock. Be careful not to bend the finger stock back in.

NOTE: When the sleeve is pushed back in the cavity housing, it will push the tines of the finger stock back in firmly, so the point of contact on the fingers will be up a little from where your polishing tool hits it if you go straight in.

Inspect the tuning sleeve. If it is pitted or discolored, clean it with the wire wheel until the entire length is clean. Polish the entire tuning sleeve with the emery cloth.

Clean and polish the coupling loop assemblies. Note the color and location of the paint dots on the pass only loops and re-mark them after cleaning. Clean the two (2) SO-239 connectors with the wire wheel. Polish the bottom of the SO-239 connectors where they will press against the cavity. It is not necessary to remove the paint from the face of the cavity where the SO-239 connectors make contact. The face of the cavity is only part of the current path with Notch Loops. It is not part of the path on voltage notch probes, or in bandpass loops. Polish the flat face of the shorted loops where they will press against the side of the cavity.

All the pieces of the cavity need to be thoroughly washed using a degreaser or other non-water based cleaner that will not leave a residue and which will not damage the paint. Use a good no oil contact cleaner and some Trichloroethylene. Denatured alcohol can also be used.

Put on the household rubber gloves. Spray the tuning sleeve with the no oil contact cleaner. Wipe the tuning sleeve with the lint free cloth. Spray and wipe tuning sleeve again to ensure it is clean. Set the tuning sleeve on a dry piece of the lint free cloth. Remove the household rubber gloves and set aside.

Assembly Procedure

Put on a clean pair of household rubber gloves. Using the “Tefron” lubricate the tuning shaft threads. Thread the tuning shaft into the cavity housing just far enough so that shaft can be turned from the outside after final assembly.

Liberally spray the outside of the tuning sleeve with MS-122 TFE and let it dry. A layer of white Teflon power will be visible after drying. Ensure there is a complete and even layer of the white Teflon power on the outside of the tuning sleeve. Spray the outside of the tuning sleeve again with MS-122 TFE if there is not an even coating.

Liberally spray the tines of the finger stock with MS-122 TFE and let dry. After the MS-122 TFE is dry, lightly spray them with MS-171 and let dry.

Place the cavity housing in the vice with the open end straight up. The tuning shaft should be sticking up, and protruding from the open end of the cavity. Be careful not to damage the cavity by clamping the vice too tightly. Use a thick cloth between the cavity housing and the vise teeth to prevent scratches.

Slide one of the stainless steel washers onto the tuning shaft. Slide the spring over the tuning shaft. Balance the second stainless steel washer on the top of the spring. Carefully pick up the tuning sleeve, handling it only by the (almost) closed end and carefully slide the sleeve over the spring with the washer perched on the end. When you get it on far enough for the washer to contact the end of the tuning sleeve, push the sleeve down another ½ inch to put a little pressure between the washer and the tuning sleeve. Use the scribe to position the inside washer so that it is lined up with the opening in the end of the tuning sleeve and the spring. When the washer is lined up with the opening in the tuning sleeve, press the tuning sleeve down firmly to compress the spring. Carefully press the tuning sleeve straight on into the finger stock, at the same time juggling the end of the sleeve so that the shaft comes through the hole without displacing the washer. The finger stock will resist the sleeve, because it has been pushed out to make more tension. When the shaft is through the sleeve, slide on the brass washer and then snap on the "C" clip.

Carefully lubricate the "C" clip and brass washer with a small amount of "Tefron" or "Tri-Flow". Ensure the lubricant does not run down the side of the tuning sleeve. Carefully spray the tuning sleeve and the finger stock with the MS-122 TFE and let the cavity sit for about 5 minutes.

Remove the cavity from the vice. Install the coupling loops in the cavity housing.

NOTE: Passband Loops, and the Shorted Notch Loops (made with flat strap material) go in the current end of the cavity. This is the end of the cavity that is closest to the front panel, and the nut the tuning shaft goes through.
Open Notch Probes go into the voltage end of the cavity, closest to the rear cover and the "open" end of the tuning sleeve.

Align the reference marking on the bottom cover and the cavity housing and slide the bottom cover onto the cavity housing. There should be some resistance to sliding the bottom cover on. If there is no resistance, remove the bottom cover and slightly bend the sides of the cover until it fits snugly when sliding it on. Install the eight (8) screws.

If you are refurbishing individual cavities, the cavities are complete and ready to be tuned.

If you are refurbishing a duplexer, install the cavities on the duplexer panel. Tune each cavity to the desired transmit or receive pass and notch frequencies. Install the phasing harness. Be sure to install them in the correct position.

NOTE: The change in tuning of both the pass and the notch on a cavity after adding the harness will tell you how close the harness is to the correct lengths. Theoretically, IF the cavities are tuned EXACTLY correctly, by themselves, and the cables are EXACTLY the right lengths, there will be NO change in the tuning when the whole duplexer is harnessed together.

Additional Information:

There is no difference between the 1400 series and 1500 series cavities electrically, as long as they have the correct loops. You can combine all the parts and re-assemble as needed.

With the dimensions supplied, you can construct your own cables harnesses. We recommend using Teflon PL259's and RG-214. Make sure your measurements are correct. The cable length numbers are from tip of connector pin to tip of connector pin. Make sure you take into account the Motorola way of making a Tee, the male and barrel go on the short leg. There is a minor difference in velocity factor between RG-142 and RG-214, but it's trivial.

Tuning will take you some significant effort. The adjustable probes and loops do not materially impact the pass bandwidth or insertion loss. The sole function of the adjustment is to nudge the re-entrant function where you want it to go – i.e. the notch. Adjusting the spacing between the loops or probes tunes the position of the notch with respect to the pass frequency, and there is very little interaction

Tune the pass frequencies first, and then tune each notch where you want it. Depending on the class of test equipment available, you may need to tune each individual cavity by itself and then hook them into pairs, and then as a whole. If you have a tracking generator class service monitor with sufficient dynamic range in the spectrum display, you can tune the entire assembly all at once in about 20 minutes or less. Hook the generator to one side, then hook the analyzer to the center, and then terminate the other end. Tune first to pass the desired frequency. If the other side is totally untuned, stop there, swap ends and tune the pass of the other side. Then set the generator to the frequency you want to reject, and watch the tracking display to see where the notches are. Move the loops/probes closer together to make the notch closer to the pass, and conversely. The adjustment is very sensitive. Once you think you have it right, tighten down the Knurled nuts and notice the movement. Readjust as you feel necessary. If you are pedantic about it, you can adjust it up to approximately 110 to 120 dB deep notches. The Motorola specification is 80 dB minimum.

Motorola T-1500 Cavity Datasheet Information

For complete information of the T-1500 Series cavities and duplexers, refer to Motorola document 6881102E96 (Old number 68P81102E96-E). The cost of this document from Motorola at the time of this writing is approximately $13.00.

NOTE: The T1500 series Cavities do not provide much out of band attenuation. Do not expect to achieve any significant attenuation of signals above 600 MHz or below 300 MHz.

Theory of Operation

Each resonant cavity, technically a re-entrant quarter-wave resonator, is a very high-Q (low loss) tunable tank circuit. The dimensions of each resonator are designed for minimum loss. The cavities are tuned to the required pass frequency by an adjustment which changes the length of the center conductor. Lower frequencies have more of the center conductor inside the cavity, higher frequencies have correspondingly less. Invar, a material with very low temperature coefficient of expansion, is used for the tuning shaft to minimize detuning due to ambient temperature changes.

Each Resonant cavity is fitted with a specially designed pair of coupling elements (loops or probes). These loops and probes efficiently convert energy from the 50 ohm coaxial cable to the correct mode inside the resonant structure.

When the cavity is not tuned to resonance, most of the energy is reflected. Only a small portion is able to excite the correct mode and reach the output element.

Passband Filters

Each passband cavity filter is provided with a set of adjustable coupling loops to supply varying degrees of selectivity. Coupling loop positions which provide a higher degree of selectivity also result in a higher insertion loss.

Pass-Reject Filters and Duplexers

The input and output coupling elements are placed very close to each other, to take advantage of mutual coupling. That is, a small amount of energy is always being transferred between coupling elements because of their proximity. At one frequency, the energy transferred by mutual coupling cancels the energy transferred across by the resonant mode of the cavity. Thus, at one frequency, there is a reject notch in addition to the selectivity of the cavity. When coupling loops are used, the notch occurs above the pass frequency; when coupling probes are used, the notch is below the pass frequency. The notch frequency is adjusted by changing the physical spacing between the coupling elements.

Cavities are used on each side of a duplexer. The cavities tuned to the lower carrier frequency use the coupling loops to notch out the higher carrier frequency, while cavities tuned to the higher carrier frequency use coupling probes to notch out the lower carrier frequency. Odd quarter-wave coupling is used between cavities to obtain minimum pass frequency bandwidth and insertion loss.

Motorola T1500 Series Model Chart

Model	Description
T1500A	Passband Cavity Filter
T1501AH	Pass-Reject Cavity Filter (reject frequency higher than pass frequency)
T1501AL	Pass-Reject Cavity Filter (reject frequency lower than pass frequency)
T1502A	Two-Cavity Pass-Reject Filter
T1503A	Two-Cavity Pass-Reject Duplexer
T1503AF	Factory Installed Two-Cavity Pass-Reject Duplexer
T1504A	Four-Cavity Pass-Reject Duplexer
T1504AF	Factory Installed Four-Cavity Pass-Reject Duplexer
T1505A	Two-Cavity Passband Filter
T1506A	Three-Cavity Passband Filter
T1507A	Four-Cavity Passband Filter
T1507AF	Factory Installed Four-Cavity Passband Filter

FILTERS

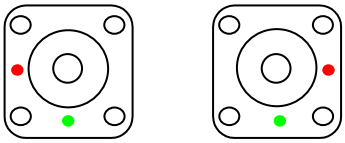
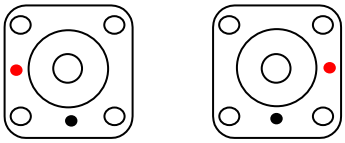
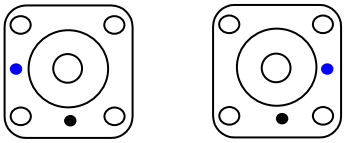
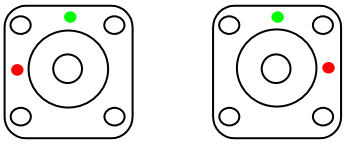
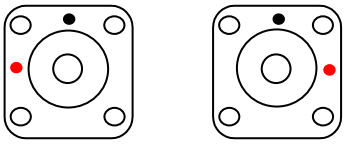
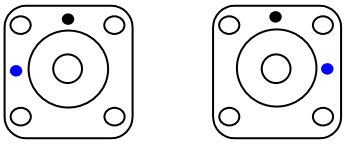
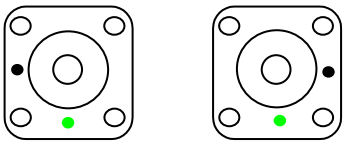
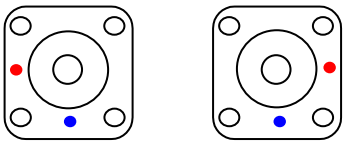
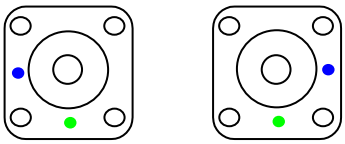
Model Number	T1500A			T1501AL, AH			T1502A		
Freq. Band	406 - 512 MHz			406 - 430 MHz	430 - 470 MHz	470 - 512 MHz	406 - 430 MHz	430 - 470 MHz	470 - 512 MHz
Insertion Loss	0.5dB	1.0dB	2.5dB	0.7dB	0.6dB	0.5dB	1.5dB	1.3dB	1.2dB
Loaded Q	350	725	1750	350			350		
Max Power Input	250 W	125 W	60 W	250 W			250 W		
Min Pass Reject Separation				2 MHz		3 MHz	2 MHz		3 MHz
Min Reject Attenuation				37db @ 2 MHz 52dB @ 5 MHz		40db @ 3 MHz 48db @ 5 MHz	50db @ 2 MHz 72db @ 2 MHz		54db @ 3 MHz 67db @ 5 MHz

DUPLEXERS

Model Number	T1503A, AF		T1504A, AF			T1507A
Freq. Band	406 - 430 MHz	430 - 470 MHz	406 - 430 MHz	430 - 470 MHz	470 - 512 MHz	406 - 512 MHz
Min Freq. Separation	5 MHz		2 MHz		3 MHz	5 MHz
Rx Isolation at Tx	55dB		80dB		85dB	55dB
Tx Noise Suppression at Rx	55dB		80dB		85dB	55dB
Min TX/RX Isolation	45dB		60dB		70dB	55dB
Rx Insertion Loss	0.8dB	0.7dB	1.6dB	1.4dB	1.3dB	2.0dB
Tx Insertion Loss	0.8dB	0.7dB	1.6dB	1.4dB	1.3dB	2.0dB
VSWR Max	1.5:1		1.5:1			1.5:1
Max Power Input	250 W		250 W			125 W

Coupling Loop Positions

(Exterior View)

Insertion Loss	TLE 6881A 406 - 430 MHz		TLE 6882A 430 - 470 MHz		TLE 6883A 470 - 512 MHz	
	Left Hand Loop Position	Right Hand Loop Position	Left Hand Loop Position	Right Hand Loop Position	Left Hand Loop Position	Right Hand Loop Position
½ dB	Top of Cavity 		Top of Cavity 		Top of Cavity 	
1 dB	Top of Cavity 		Top of Cavity 		Top of Cavity 	
2.5 dB	Top of Cavity 		Top of Cavity 		Top of Cavity 	

Cable Kits

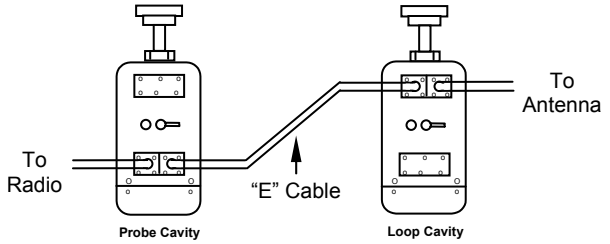
Model Number	406 - 430 MHz	430 - 470 MHz	470 - 512 MHz
T1502A	TKN6535A	TKN6536A	TKN6537A
T1503A	TKN6538A	TKN6539A	TKN6540A
T1503AF	TKN6538A (Qty 2) TKN6531A (Qty 2) TKN6532A	TKN6539A (Qty 2) TKN6531A (Qty 2) TKN6532A	TKN6540A (Qty 2) TKN6531A (Qty 2) TKN6532A
T1504A	TKN6541A	TKN6542A	TKN6543A
T1504AF	TKN6541A (Qty 2) TKN6531A (Qty 2) TKN6532A	TKN6542A (Qty 2) TKN6531A (Qty 2) TKN6532A	TKN6543A (Qty 2) TKN6531A (Qty 2) TKN6532A
T1505A	TKN6544A	TKN6545A	TKN6546A
T1506A	(Qty 2) TKN6544A	(Qty 2) TKN6545A	(Qty 2) TKN6546A
T1507A, AF	TKN6549A	TKN6550A	TKN6551A

Cable Kit Details

Model Num	Cable Kit	Part Number	Color Code	Length (RG-142 B/U)
T1502A	TKN6535A	1-84459A13	Blk, Red	14 ¼”
	TKN6536A	1-84459A23	Blk	13 3/8”
	TKN6537A	1-84459A19	Brn, Grn	11 ¾”
T1503A	TKN6538A	1-84459A18	Brn, Blu	6 3/8”
		1-84459A04	Org	9 ¾”
	TKN6539A	1-84459A12	Red, Yel	5 ¾”
		1-84459A06	Grn	8 ¾”
	TKN6540A	1-84459A05	Yel	5 ¼”
		1-84459A16	Blk, Blu	8”
T1504A	TKN6541A	1-84459A18	Brn, Blu	6 3/8”
		1-84459A04	Org	9 ¾”
		1-84459A14	Blk, Yel	10 ½”
		1-84459A15	Blk, Grn	9 3/8”
	TKN6542A	1-84459A12	Red, Yel	5 ¾”
		1-84459A06	Grn	8 ¾”
		1-84459A04	Org	9 ¾”
		1-84459A07	Blu	8 ½”
	TKN6543A	1-84459A05	Yel	5 ¼”
		1-84459A16	Blk, Blu	8”
		1-84459A15	Blk, Grn	9 3/8”
		1-84459A20	Brn, Yel	7 7/8”
T1505A & T1506A	TKN6544A	1-84459A15	Blk, Grn	9 3/8”
	TKN6545A	1-84459A07	Blu	8 ½”
	TKN6546A	1-84459A20	Brn, Yel	7 7/8”
T1507A	TKN6549A	1-84459A15	Blk, Grn	9 3/8”
		1-84459A04	Org	9 ¾”
	TKN6550A	1-84459A07	Blu	8 ½”
		1-84459A06	Grn	8 ¾”
	TKN6551A	1-84459A20	Brn, Yel	7 7/8”
		1-84459A16	Blk, Blu	8”

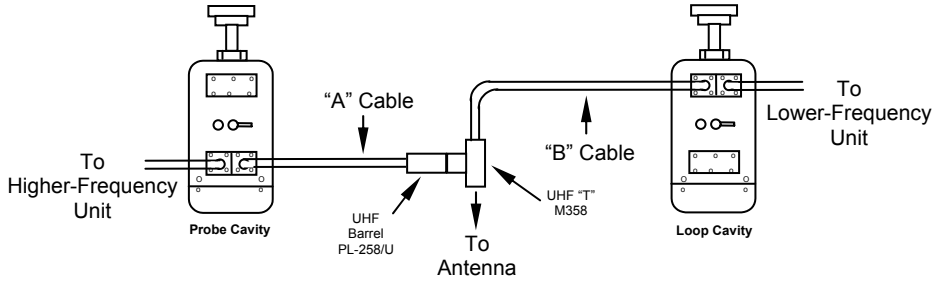
Model T1502A

Freq Range	Cable Kit	"E" Code
406 - 430	TKN6535A	Blk-Red (14 ¼")
430 – 470	TKN6536A	Black (13 3/8")
470 - 512	TKN6537A	Brn-Grn (11 ¾")



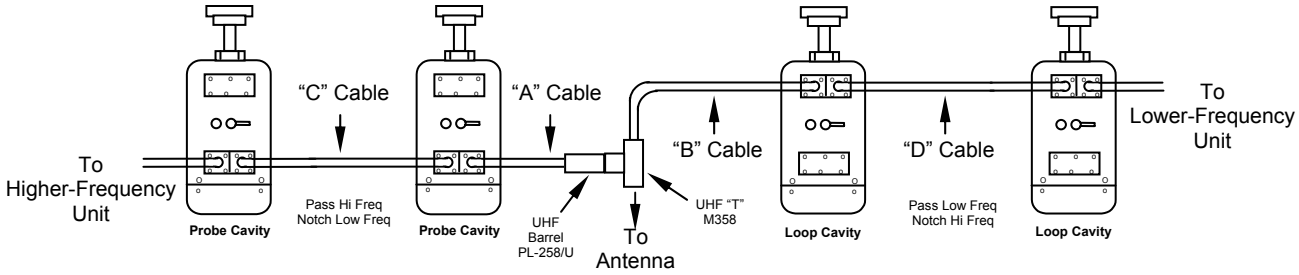
Model T1503A

Freq Range	Cable Kit	"A" Code	"B" Code
406 - 430	TKN6538A	Brn-Blu (6 3/8")	Org (9 ¾")
430 – 470	TKN6539A	Red-Yel (5 ¾")	Grn (8 ¾")
470 - 512	TKN6540A	Yel (5 ¼")	Blk-Blu (8")



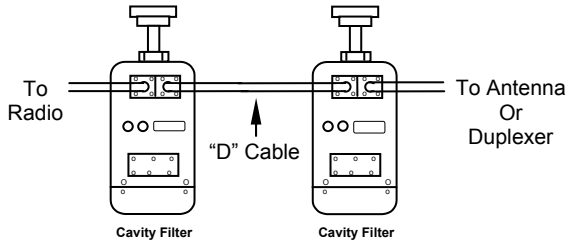
Model T1504A

Freq Range	Cable Kit	"A" Code	"B" Code	"C" Code	"D" Code
406 - 430	TKN6541A	Brn-Blu (6 ¾")	Org (9 ¾")	Blk-Yel (10 ½")	Blk-Grn (9 3/8")
430 – 470	TKN6542A	Red-Yel (5 ¾")	Grn (8 ¾")	Org (9 ¾")	Blu (8 ½")
420 - 450		6 1/16"	9 ¼"	10 1/8"	8 15/16"
470 - 512	TKN6543A	Yel (5 ¼")	Blk-Blu (8")	Blk-Grn (9 3/8")	Brn-Yel (7 7/8")



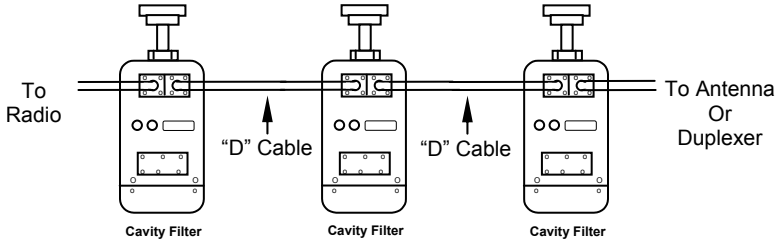
Model T1505A

Freq Range	Cable Kit	"D" Code
406 - 430	TKN6544A	Blk-Grn (9 3/8")
430 – 470	TKN6545A	Blu (8 ½")
470 - 512	TKN6546A	Brn-Yel (7 7/8")



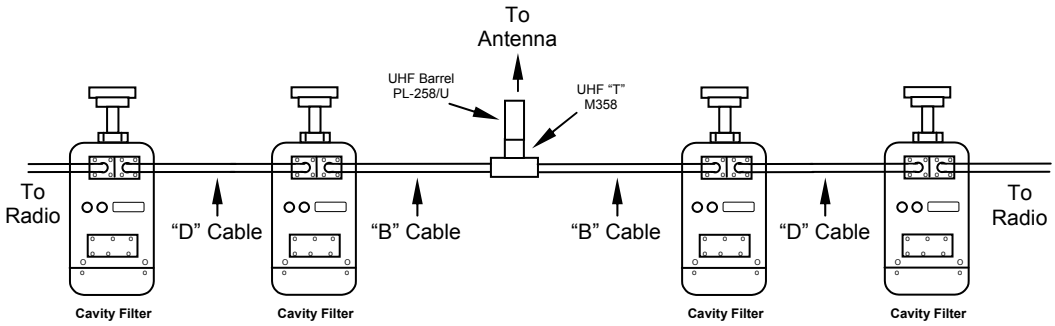
Model T1506A

Freq Range	Cable Kit	"D" Code
406 - 430	TKN6544A	Blk-Grn (9 3/8")
430 – 470	TKN6545A	Blu (8 ½")
470 - 512	TKN6546A	Brn-Yel (7 7/8")

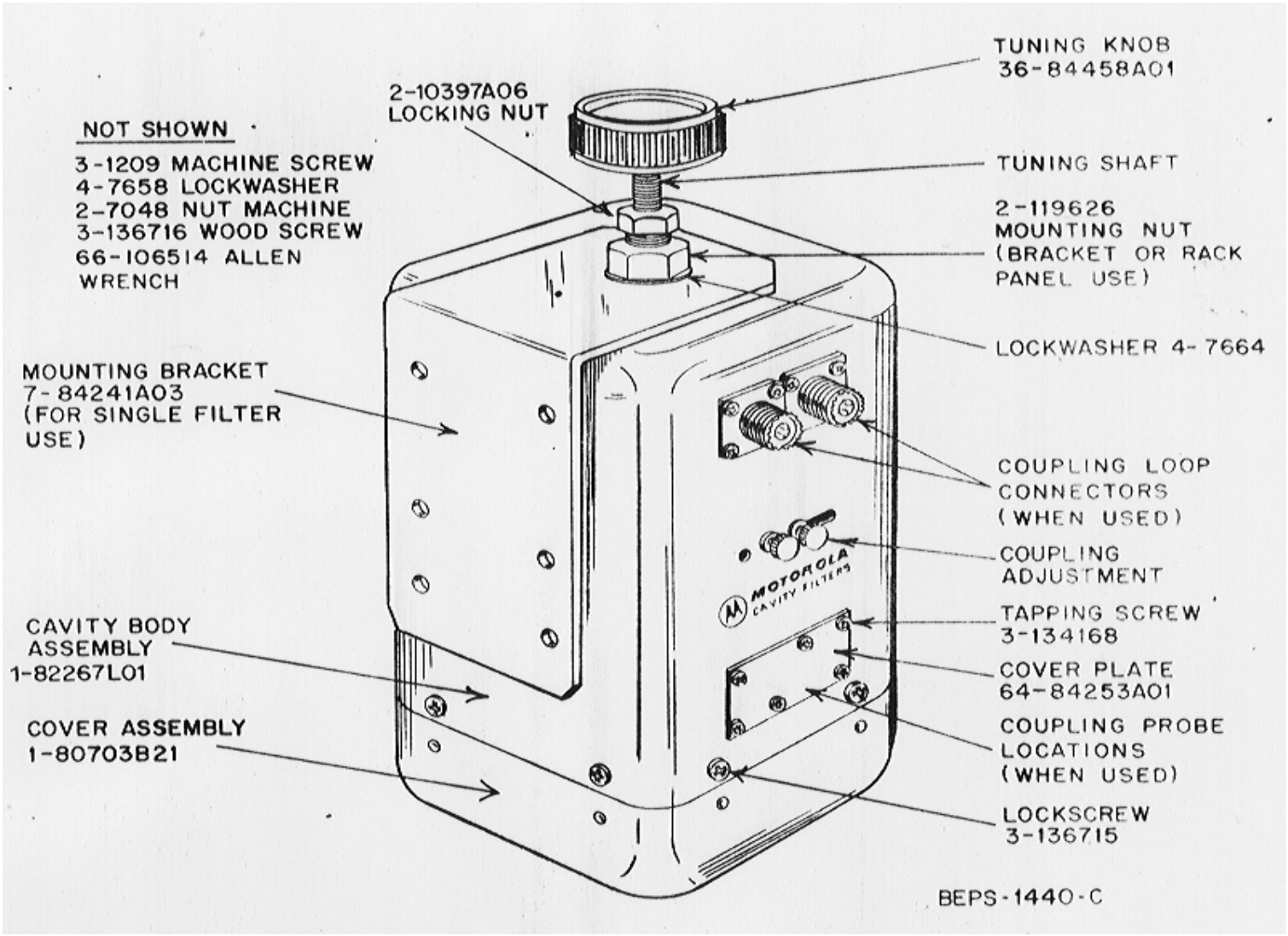


Model T1507A

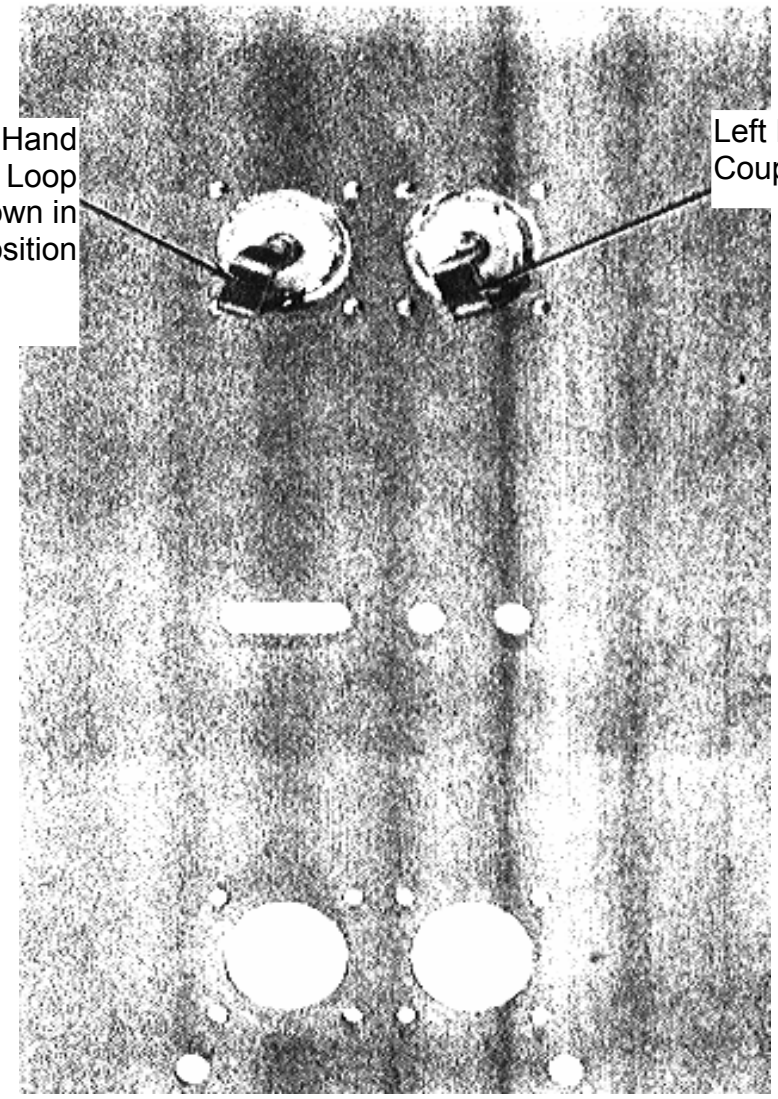
Freq Range	Cable Kit	"D" Code	"B" Code
406 - 430	TKN6549A	Blk-Grn (9 3/8")	Org (9 ¾")
430 – 470	TKN6550A	Blu (8 ½")	Grn (8 ¾")
470 - 512	TKN6551A	Brn-Yel (7 7/8")	Blk-Blu (8")



Cavity Filter Parts Location Detail

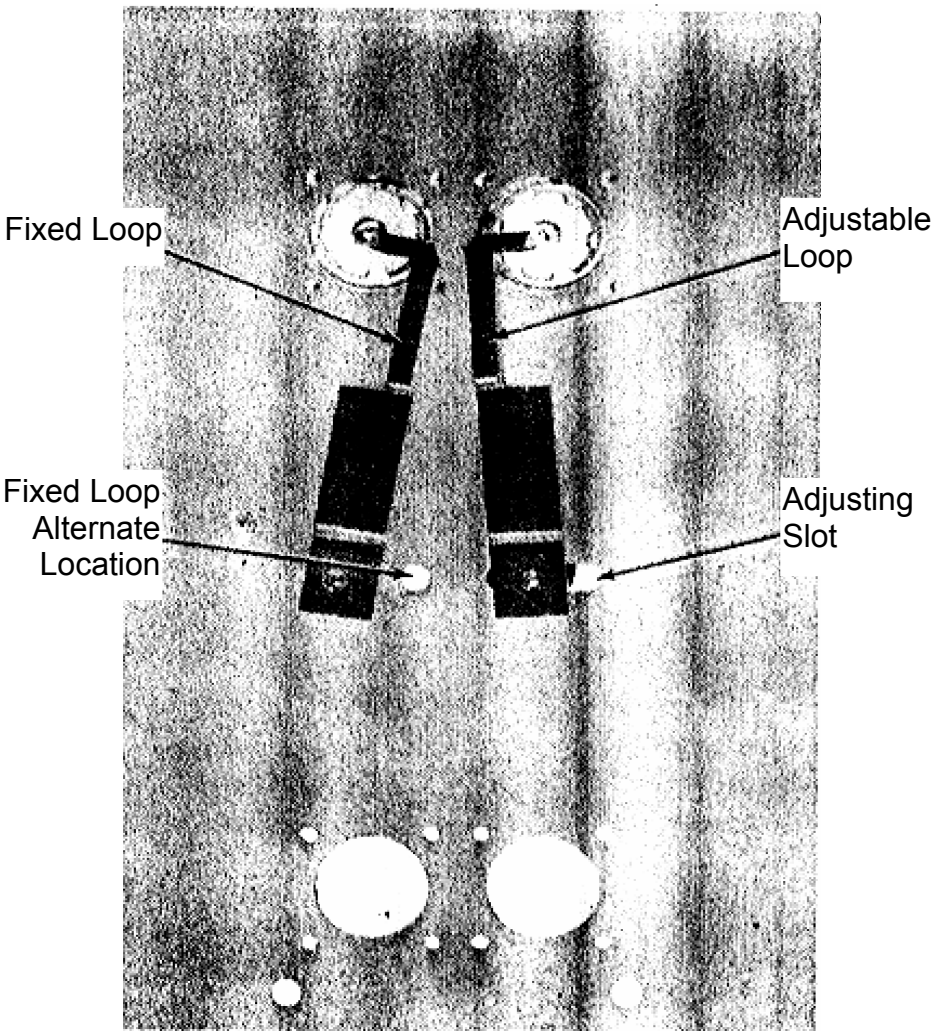


Pass Coupling Loop Locations
(Interior View)



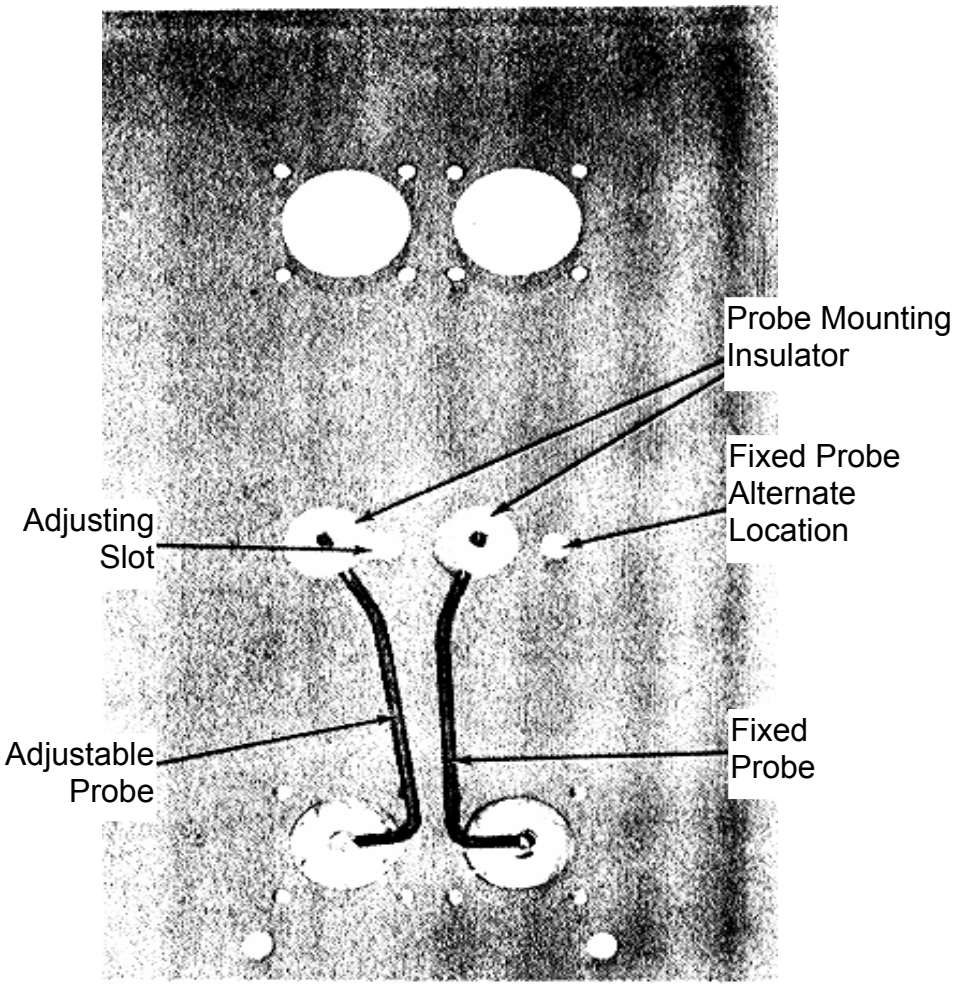
Cavity Filter

Notch Coupling Loop Locations
(Interior View)



Loop Cavity

Notch Coupling Probe Locations
(Interior View)



Probe Cavity