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FINAL REPORT

ANTENNA TRIPLEXER

by

R. J. Bauer

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Contract NAS 9-4602

NASA Manned Spacecraft Center
Houston, Texas

ADVANCED TECHNOLOGY CORPORATION

1830 YORK ROAD TIMONIUM, MARYLAND

FINAL REPORT

August 16, 1965

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R. J. Bauer

Prepared under Contract NAS 9-4602

by

ADVANCED TECHNOLOGY CORPORATION
Timonium, Maryland

for

NASA Manned Spacecraft Center
Houston, Texas

I. INTRODUCTION

This report describes a development program which will result in the design and fabrication of an antenna triplexer to be used in a small, light weight, personal communications system. The purpose of the triplexer is to allow both duplex and simplex operation utilizing a common antenna and with a minimum of coaxial switching. During the duplex mode of operation the triplexer will allow simultaneous transmission and reception with a single antenna, as shown in the block diagram of Figure 1. The optimum design for such a triplexer is a passive, lumped constant parameter device since this would have the utmost in reliability, would be less subject to environmental conditions, would have minimum size and weight, and would not require any primary power.

The triplexer's electrical and mechanical specifications are:

Lower Passband (Port 2):	259.7 megacycles ±.005%
Middle Passband (Port 3):	279.0 megacycles ±.003%
Upper Passband (Port 4):	296.8 megacycles ±.005%
Impedance:	50 ohms at each port
Insertion Loss in each Passband:	≤ 1.0 db (design goal ≤ 0.5 db)
Isolation between any two ports:	≥20 db (design goal ≥30 db)
Power Handling Capability:	0.5 watts (minimum)
Weight:	≤ 3 ounces (design goal ≤ 2 ounces) excluding external cables
Size:	≤ 3 cubic inches (design goal ≤ 2 cubic inches) excluding external cables

II. RESULTS

Since the three multiplex frequencies have extremely narrow bandwidth requirements, the original triplexer circuit design consisted primarily of m derived filter sections. Following several circuit changes to eliminate as many components as possible while still retaining the desired electrical characteristics, a preliminary breadboard model evolved that is shown in Figure 2. The transmission loss versus frequency plot of this triplexer is shown in Figure 3. At 259.7 Mc the insertion loss was 0.7 db with the isolation of the other two ports being approximately 25 db. At 279.0 Mc the insertion loss of Port 3 was 0.8 db. The isolation of Port 2 (the 259.7 Mc channel) was 29 db, while the isolation at Port 4 (296.8 Mc channel) was 27 db. The insertion loss of Port 4 (296.8 Mc channel) was 0.8 db. The isolations of this port at the 259.7 Mc and 279.0 Mc channels were 31.5 db and 24.5 db, respectively.

After these good results were achieved, the triplexer was repackaged into a much smaller volume using toroids instead of the cylindrical wound inductors that were used on the preliminary breadboard model. A photograph of this unit is shown in Figure 4. After this circuit was tuned-up, it was found that the insertion loss had risen to approximately 1.1 to 1.2 db while the isolation had remained relatively constant at approximately 25 db. These results clearly indicated that the Q of the toroid was not quite sufficient to obtain the required electrical specifications.

Since the unit was very close to meeting the electrical requirements, it was decided not to waste additional effort in trying to further optimize its performance, but rather to go to a final breadboard package that would be slightly less than the required size. Glass variable capacitors and cylindrical wound coils of slightly smaller diameter wire (than that used in the first breadboard model) were utilized in the final breadboard model. Figure 5 shows a photograph of this package. Its size is less than 3 cubic inches, and its weight is less than 3 ounces. It is anticipated that by going to cylindrical wound coils and these high Q subminiature piston trimmer capacitors we can offset the lower Q that would normally result when going to a smaller over-all size package. The subminiature piston trimmer capacitors use 0483 green glass as a dielectric. This glass dielectric increases capacitance approximately 30% and augments the Q approximately 25% in comparison to regular capacitor dielectrics. The Q of these capacitors is approximately 1000 at 20 megacycles, which is a factor of 2 better than any other capacitor of the subminiature type. The insertion loss of this unit at 259.7 megacycles (Port 2) was 0.85 db. The isolation at 279.0 megacycles (Port 3) was 23.0 db while the isolation at Port 4(296.8 megacycles) was 35.0 db. At 279.0 megacycles the insertion loss of Port 3 was 1.0 db. The isolation at 259.7 megacycles (Port 2) was 38.5 db, while the isolation at 296.8 megacycles (Port 4) was 22.6 db. Finally, the insertion loss at 296.8 megacycles (Port 4) was 0.84 db. The isolations at 259.7 megacycles (Port 2) and 279.0 megacycles (Port 3) were 27.4 db and 30.0 db, respectively.

A final model triplexer was then fabricated with a slightly modified layout, and a shield was added to achieve higher isolation between the ports. The unit was constructed using 30 mil aluminum which was then treated with iridite and painted. Figure 6 shows internal and exterior views of the final triplexer model. The external view also shows the various port identifications. In an effort to make this unit as environmental proof as possible it was decided to pot the entire interior with Eccofoam FPH made by Emerson & Cuming, Inc. This is a low dielectric constant foam material which has low loss and very low weight per unit volume. After potting the final unit with this foam, it was discovered that the Q of the circuits had deteriorated substantially. The foam was then entirely removed from the package. To insure mechanical stability without deteriorating the electrical performance the foam was then used at several discrete locations to anchor coil locations. The electrical performance was monitored while this was being accomplished. The interior view of Figure 6 shows the several locations at which foam was used to anchor these coils. After completing this process all of the electrical measurements were repeated to insure that no deterioration in the electrical properties had resulted.

In accordance with the design specifications of the triplexer, coaxial cable lengths were made approximately six inches long.

Figure 7 shows the final triplexer with the lengths of coax cable required. The coax cable has a characteristic impedance of 50 ohms (RG-58) and since the triplexer was designed for 50 ohm inputs, the length of coax cable is independent of proper operation of the triplexer.

Figure 8 shows a schematic of the final triplexer. Included in this figure are all the values of inductance and capacitance used, the various coil form diameters and turns of the inductors, and the JFD component numbers of the capacitors.

Figure 9 shows a plot of attenuation versus frequency for each of the three frequency channels of the final triplexer. It will be noted that these curves are very similar to the curves shown in Figure 3 for an early breadboard model.

Table I lists the electrical characteristics of the final triplexer. These measured results are patterned after the requirements listed in the contract; that is, the loss of the coax cable should not be considered as part of the triplexer loss. Although the coax cable losses can be considered negligible when speaking of the isolation losses at the various ports, they do become significant when speaking of the insertion losses, especially with the requirement that the insertion loss be less than 1.0 db. Table I lists the coax losses at the various frequencies and also includes the corrected triplexer loss after this cable loss has been subtracted. Table II presents the mechanical characteristics of the final triplexer.

III. CONCLUSIONS

The final model triplexer has met all of the electrical and mechanical requirements. It has approached (and sometimes surpassed) many of the electrical design goals. Although the triplexer is required to operate only under normal laboratory conditions, it was designed with the intent of trying to meet the environmental conditions listed in the contract Statement of Work.

Based on the study and results obtained on this contract there is one recommendation that can be made for substantially improving the confidence factor of the triplexer operating under extreme environmental conditions. This recommendation would involve investigating the various foam materials that are available so that the unit could be completely potted in foam. This would insure proper operation under extreme environmental conditions of shock, acceleration, acoustics, and pressure. Some further investigations would have to be undertaken to determine the effect of high temperatures on the foam potting material.

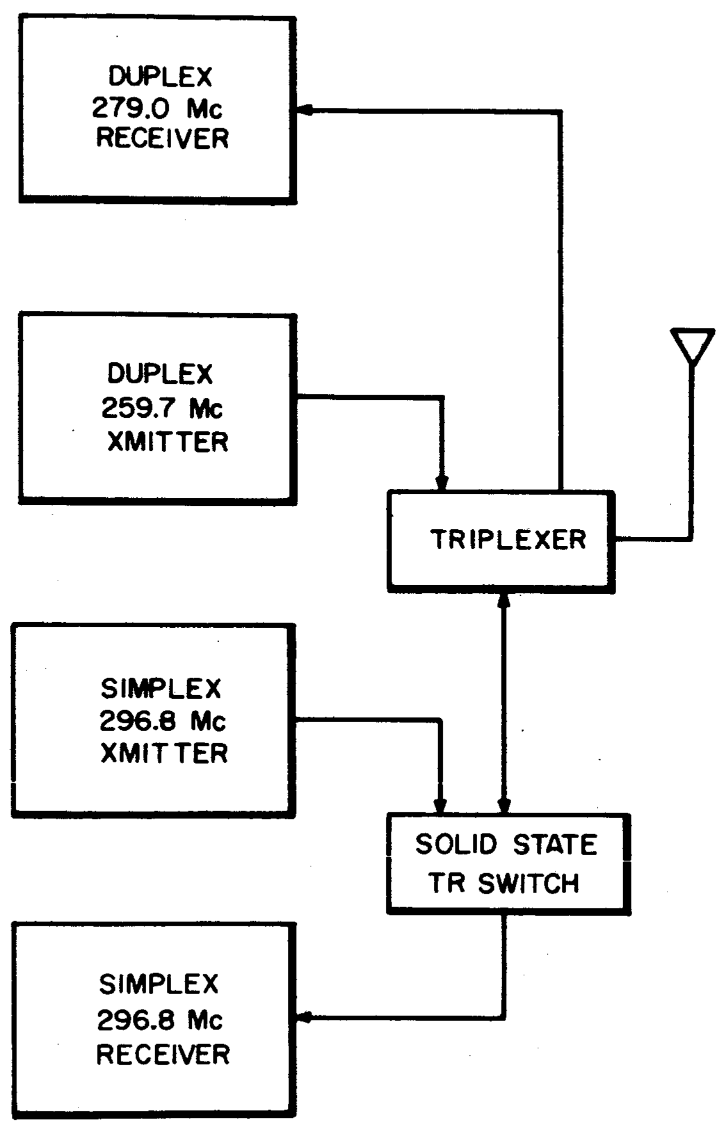


FIG. I —PERSONAL COMMUNICATION SYSTEM

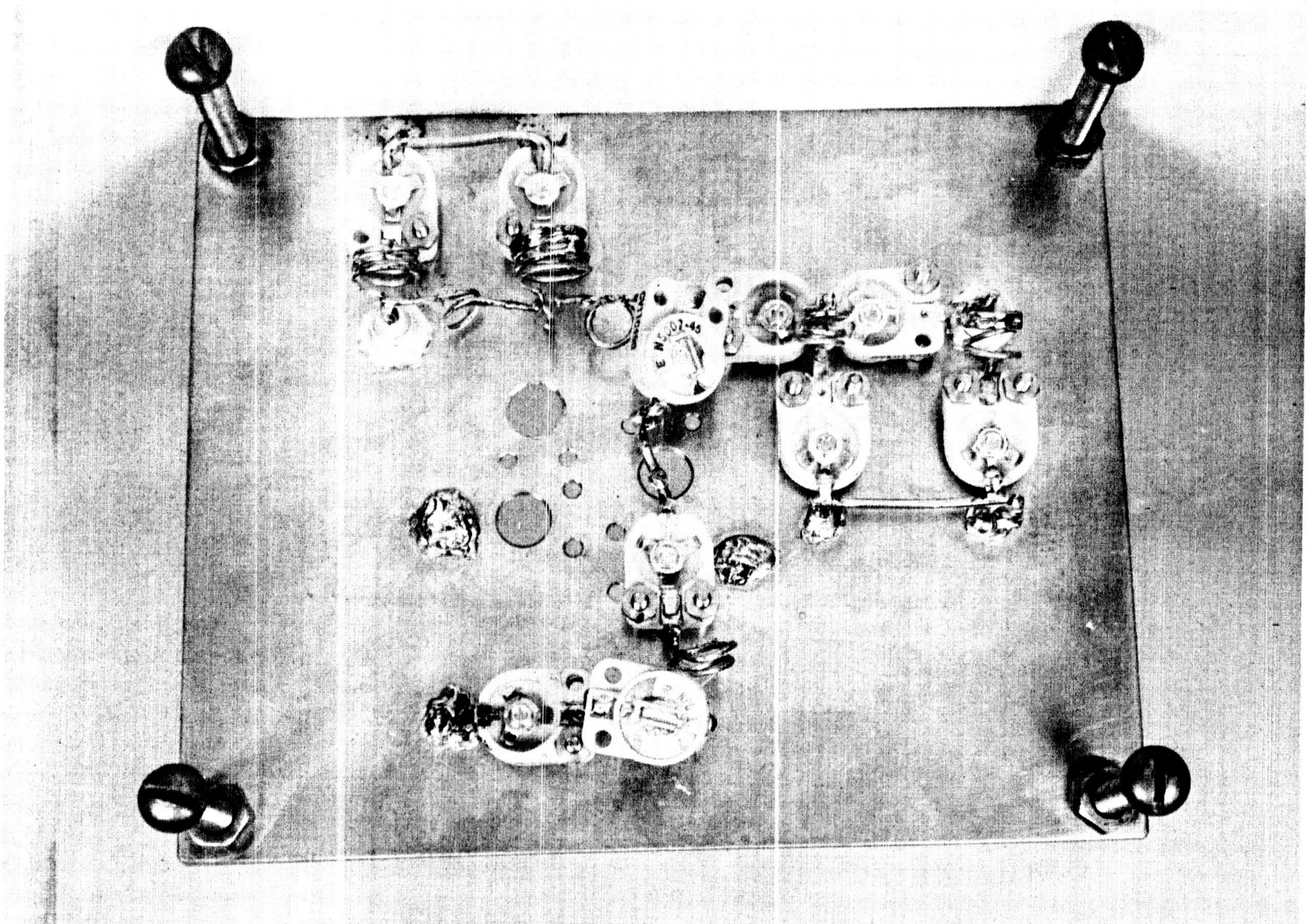


Figure 2 - First Breadboard Model

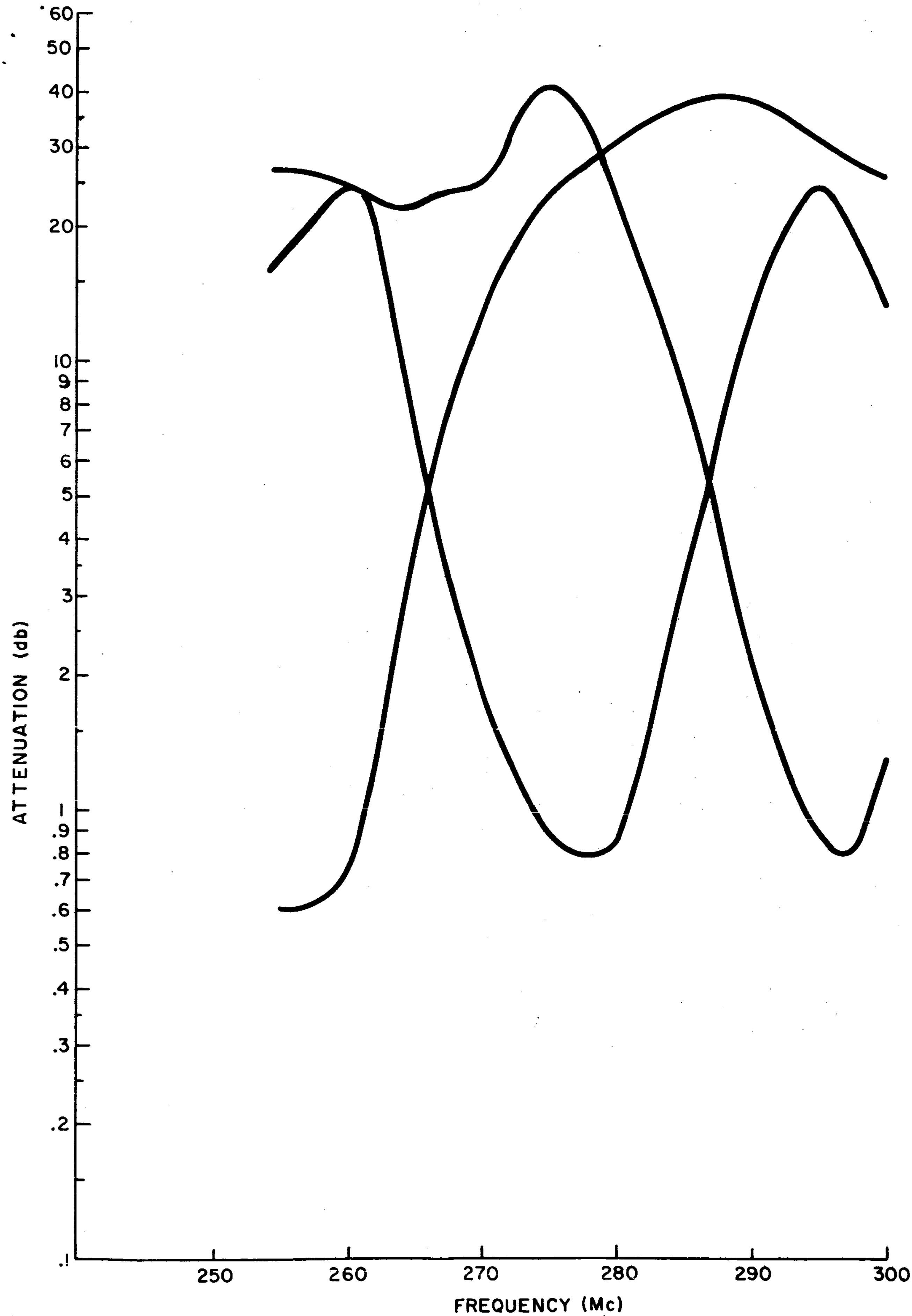


FIG. 3 - BREADBOARD TRIPLEXER

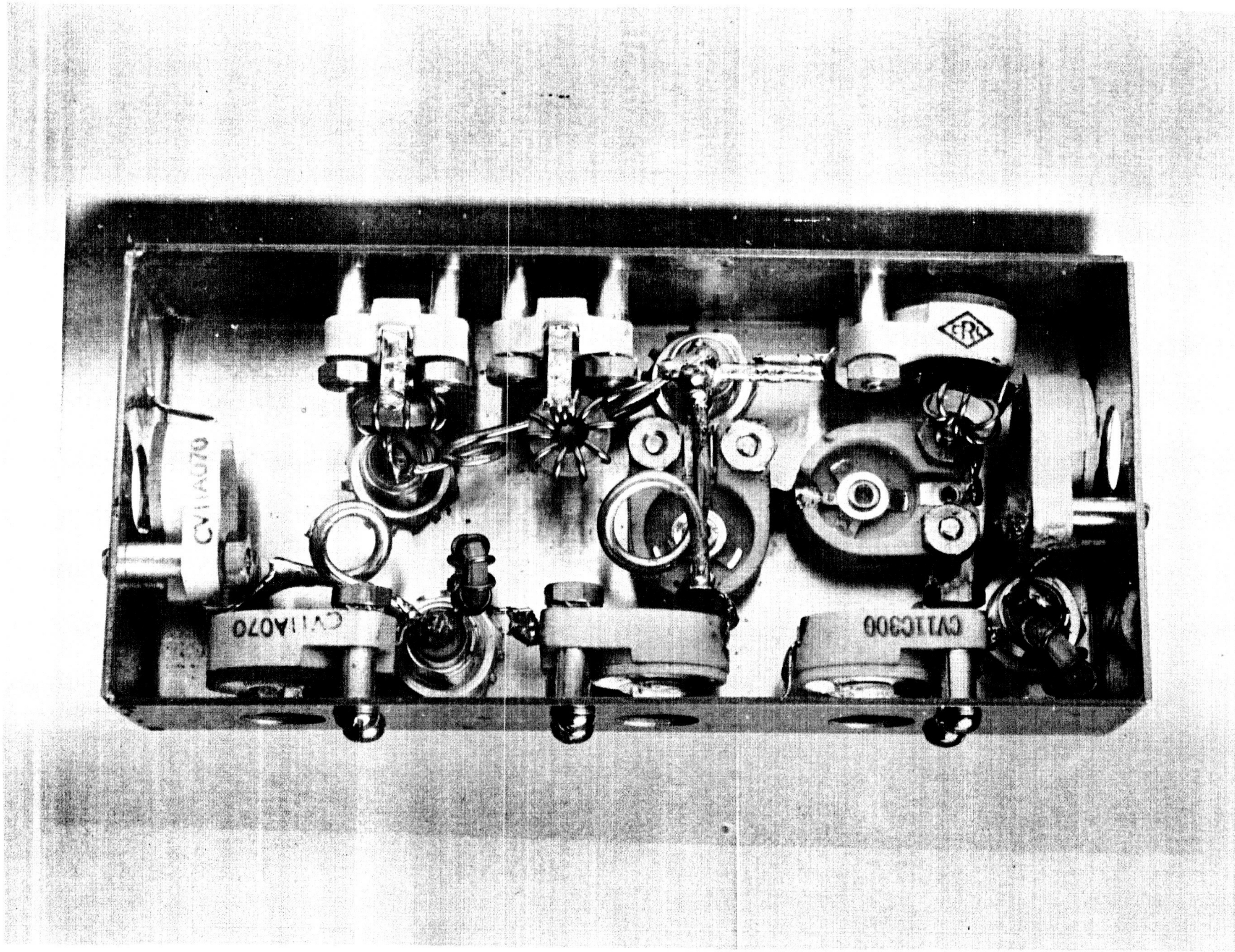
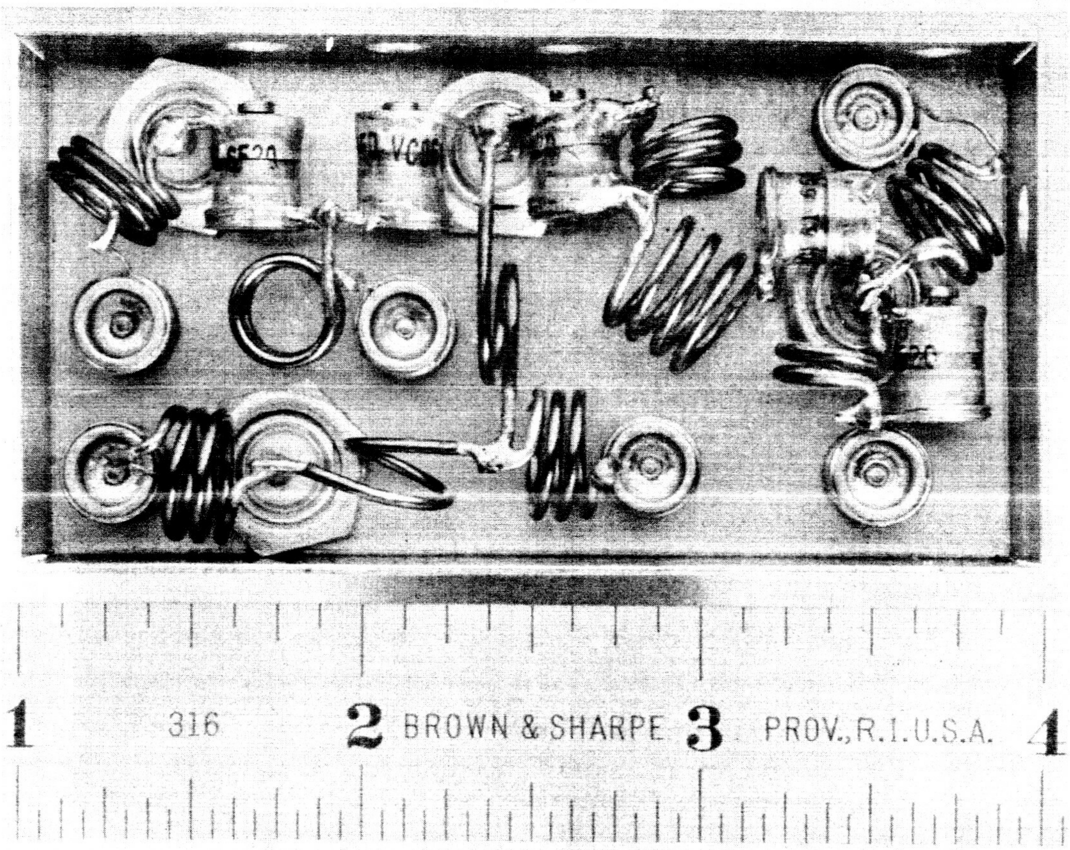


Figure 4 - Second Breadboard Model
(using some toroid inductors)



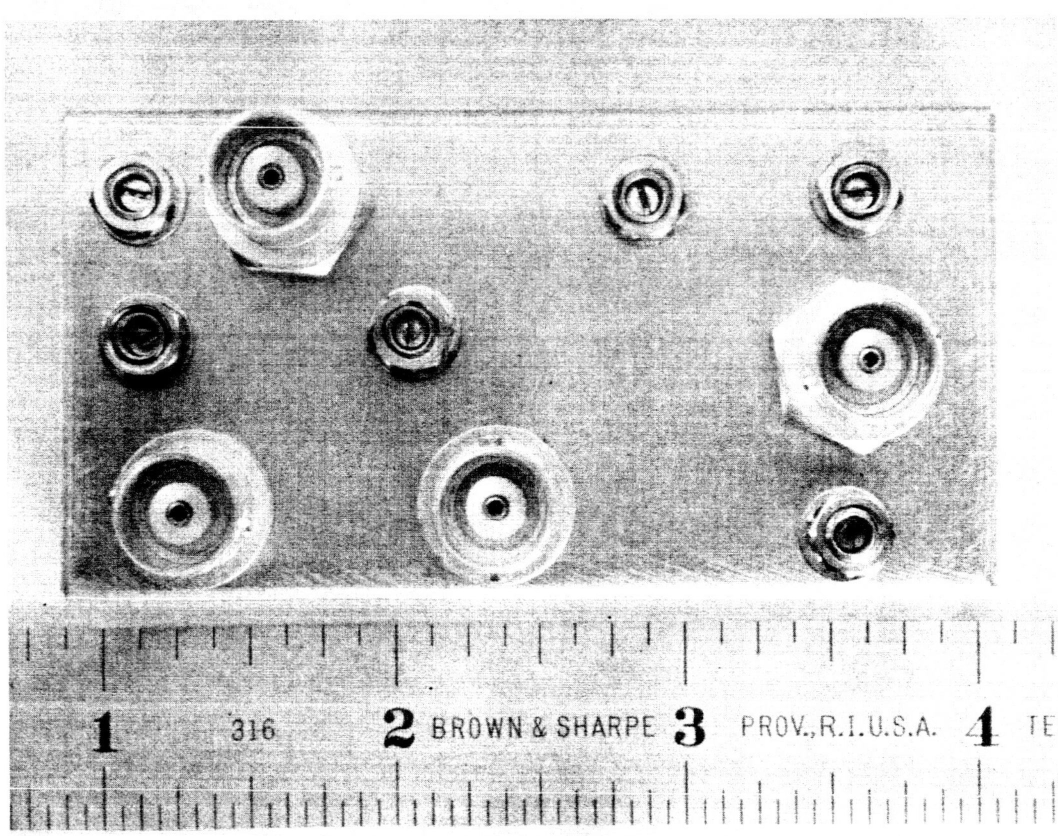
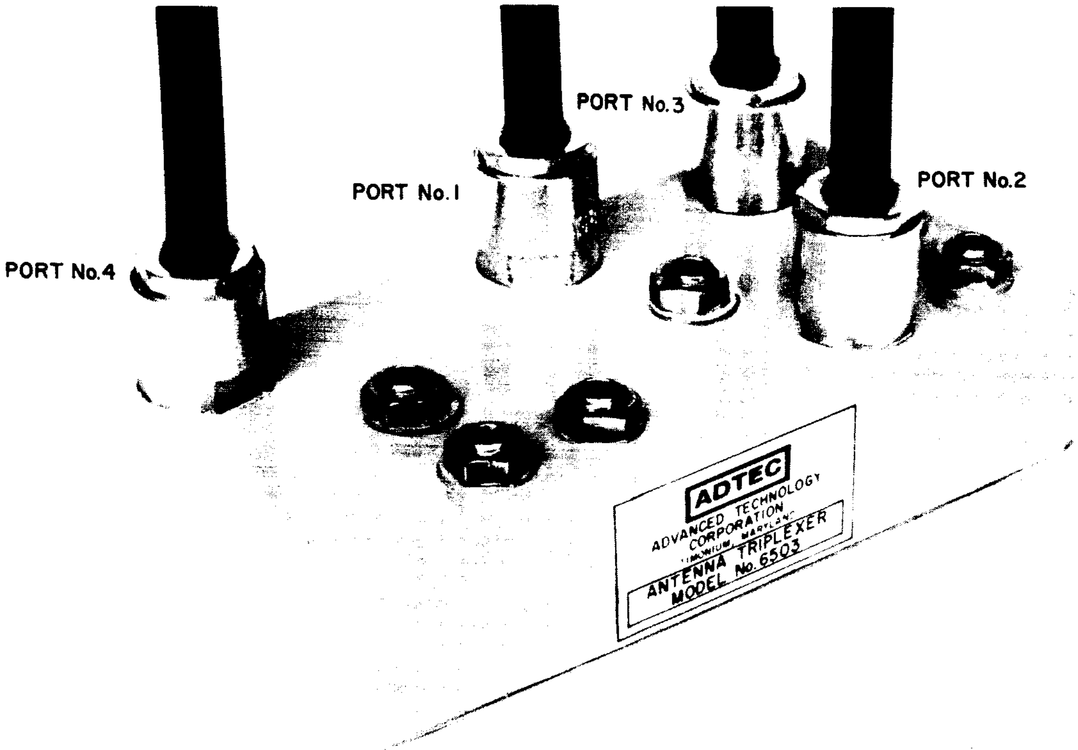
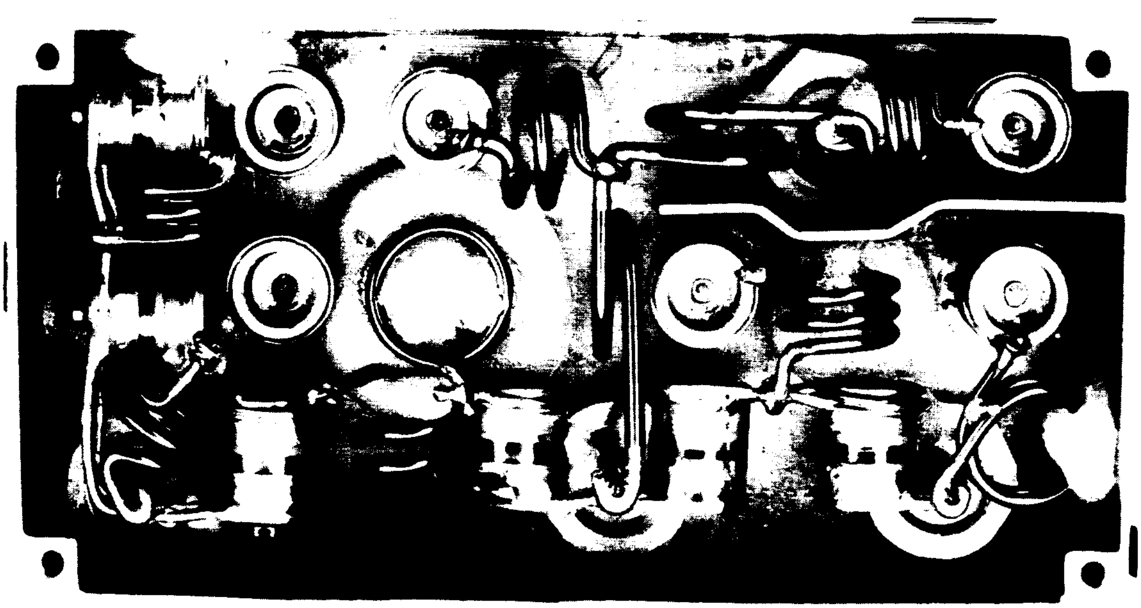


Figure 5 - Final Breadboard Model



EXTERNAL VIEW



INTERNAL VIEW

FIG. 6 - FINAL MODEL OF ANTENNA TRIPLEXER

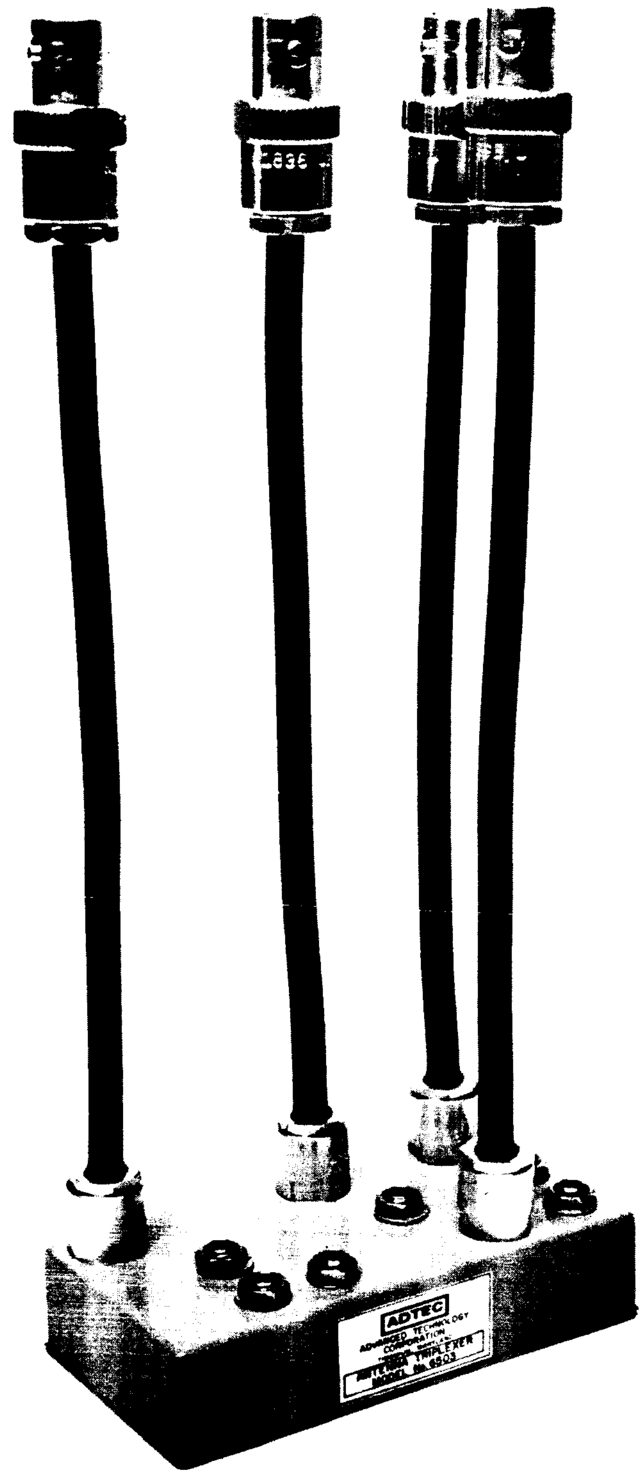
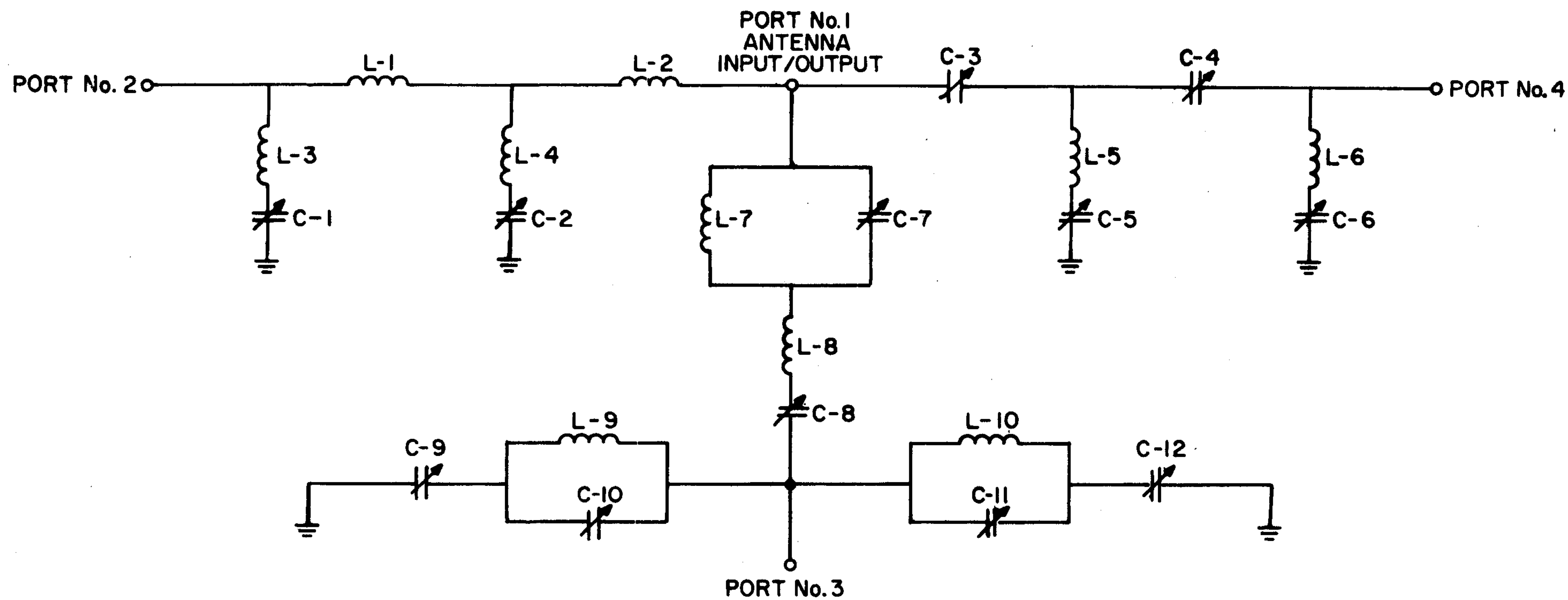


FIG. 7 -ANTENNA TRIPLEXER WITH COAXIAL CABLES



L	μh INDUCTANCE	FORM DIA.	TURNS	WIRE SIZE	C	JFD
1	.019	5/16	1	16	1	VC - 951
2	.019	5/16	1	16	2	- 951
3	.052	9/32	3	18	3	- 961
4	.028	9/32	2	16	4	- 961
5	.045	1/4	3	18	5	- 951
6	.033	9/32	2	18	6	- 951
7	.027	13/64	2	18	7	- 961
8	.088	5/16	4	18	8	- 961
9	.028	1/4	2	18	9	- 951
10	.028	1/4	2	18	10	- 961
					11	- 961
					12	- 951

CAPACITANCE RANGE OF ALL CAPACITORS 1.2 - 16 μfd

FIG. 8 - SCHEMATIC OF FINAL TRIPLEXER

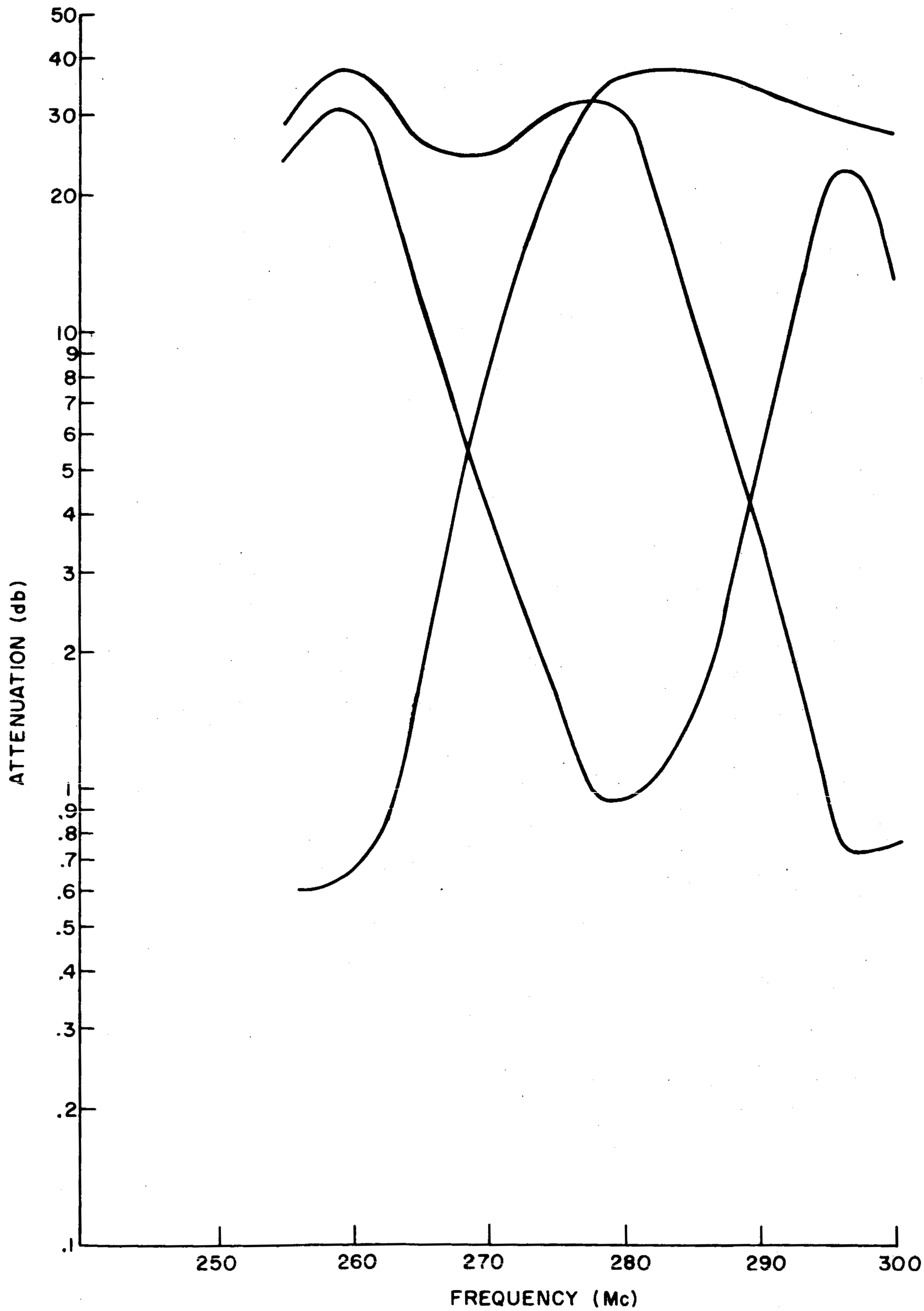


FIG. 9 — FINAL TRIPLEXER

Insertion Loss and Isolation Loss Results

		Triplexer Requirements	Measured Results: Triplexer plus Cable Loss	Cable Loss	Triplexer Loss
Freq. 259.7 Mc	Port 1 to Port 2	≤ 1.0 db	.80	.15	.65 db
	Port 1 to Port 3	≥ 20 db	30.6	neg.	30.6 db
	Port 1 to Port 4	≥ 20 db	37.5	neg.	37.5 db
Freq. 279.0 Mc	Port 1 to Port 2	≥ 20 db	35.0	neg.	35.0 db
	Port 1 to Port 3	≤ 1.0 db	1.10	.16	.94 db
	Port 1 to Port 4	≥ 20 db	32.0	neg.	32.0 db
Freq. 296.8 Mc	Port 1 to Port 2	≥ 20 db	29.0	neg.	29.0 db
	Port 1 to Port 3	≥ 20 db	22.4	neg.	22.4 db
	Port 1 to Port 4	≤ 1.0 db	.90	.17	.73 db

Impedance Results

		Impedance
Freq. 259.7 Mc	Port 1	$48\ \underline{/+7.8^{\circ}}$ ohms
	Port 2	$50\ \underline{/-7.8^{\circ}}$ ohms
Freq. 279.0 Mc	Port 1	$53\ \underline{/+14^{\circ}}$ ohms
	Port 3	$45\ \underline{/+5.6^{\circ}}$ ohms
Freq. 296.8 Mc	Port 1	$56\ \underline{/-17.8^{\circ}}$ ohms
	Port 4	$48\ \underline{/+3^{\circ}}$ ohms

TABLE I - FINAL TRIPLEXER ELECTRICAL RESULTS
(ADTEC MODEL 6503)

Size (excluding cables and connectors):

Length	-	3.06 inches
Width	-	1.56 inches
Height	-	0.63 inches

This results in an over-all volume of 2.71 cubic inches. The over-all size requirement was a volume less than 3 cubic inches with a design goal of 2 cubic inches.

Weight:

Total weight of triplexer, including all connectors and coax cables	-	6.14 ounces
Weight of four coax connectors (UG-89B)	-	2.33 ounces
Weight of four coax cables	-	0.83 ounces
Weight of triplexer, excluding cables and four coax connectors	-	2.98 ounces

The design requirement was for a triplexer weight (excluding cables and connectors) of less than 3 ounces with a design goal of 2 ounces.

TABLE II - MECHANICAL CHARACTERISTICS OF FINAL TRIPLEXER