NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

GEORGE C. MARSHALL SPACE FLIGHT CENTER

HUNTSVILLE, ALABAMA
June 24, 1964

RING COUPLED FILTER DEVELOPMENT

FINAL REPORT

CONTRACT NAS 8-11507

For the Period July, 1963 to 31 May, 1964

COLLINS RADIO COMPANY
R & D DIVISION B
19700 SAN JOAQUIN ROAD
NEWPORT BEACH, CALIFORNIA

D. L. BISE

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1. PURPOSE

A contract was issued to Collins Radio Company on July 1, 1963, by the George C. Marshall Space Flight Center to determine the practicability of building narrow bandwidth ring coupled mechanical filters employing integral disk-ring elements.

To accomplish the above goal, the program was divided into five areas:

(1) Define mechanical dimensions of the disk-ring elements consistent with machine practices.

(2) Obtain and measure disk-ring elements to determine the distribution of mechanical dimensions.

(3) Define disk dimensions required using mathematical models for mechanical filters.

(4) Compare the results of (2) and (3).

(5) Build and test complete ring coupled filters.

2. ABSTRACT

Work performed under the contract has shown that machined disk-ring elements, because of present day machining tolerance, are not suitable for manufacturing mechanical filters having stringent bandwidth requirements.

3. FACTUAL DATA

3.1 Integral Disk-Ring Elements

Machined disk-ring elements (Figure 1) were received and inspected using high-powered microscopic and comparator type instruments. Distribution of the three most critical dimensions, ring outside diameter, ring thickness and ring height, for the parts of Figure 1, is shown in Figures 2, 3 and 4. Tolerances were generally met with the exception of ring height, which varied ±.002" about a mean. As a result of conferences with our vendors and mechanical engineers, a practical limit on ring tolerances was established at ±.0005".

In order to predict the effect of variations in ring parameters on bandwidth, a study was made of the mechanical filter's analogous electrical circuit (see Appendix 6.1). Through the study, it was learned that for ring tolerances of ±.0005", bandwidth could vary as much as ±13.2%. The allowable variation in bandwidth, to meet the sideband specification (CPN 526-9445-00), was found to be less than ±6%, which corresponds to ring tolerances of ±.0002". Bandwidths of epoxy bonded disk-ring element pairs (Figure 1) varied approximately ±20%, which was a slightly smaller variation than predicted (±26.4%) for tolerances of ±.001". Response curves for five epoxy bonded filters, using the elements of Figure 1, are shown in Figures 7 through 16.

Filters E-1 and E-2 were four disk filters while E-3 through E-5 were five disk filters. Figures 17 and 18 are response curves for a five disk conventional disk and wire edge-coupled filter having approximately the same bandwidth and center frequency as the ring coupled filters. A comparison of spurious plots between the edge-coupled filter and the various ring-coupled filter shows the advantage of the ring coupling technique in reducing spurious. This effect is especially noticeable on the high frequency side of the passband.

Disk-ring elements (Figure 5) were ordered having the coupling ring on one side only. Construction of this type simplified tuning of the disks to the desired frequency and epoxy bonding the elements together. These elements were received with only a few days remaining in the contract and, therefore, were inspected on a sample basis. Sample inspection indicated that tolerances were generally met. These indications were also reflected in the small variation in bandwidth (±9.5%) of several epoxy bonded disk pairs shown in Table I. Response curves for a five disk epoxy bonded filter, using the elements of Figure 5, are shown in Figures 19 and 20.

TABLE I

BANDWIDTHS FOR EPOXY BONDED DISK PAIRS USING THE ELEMENTS OF FIGURE 5

Pair	Bandwidth (KC)
1	2.07
2	2.04
3	2.02
4	1.99
5	1.99
6	1.85
7	1.75
8	1.71
9	1.81

3.2 Separate Disks and Rings

A method of reducing ring tolerances was investigated by using the "A" nickel tubing of Figure 6 as the coupling ring. Bandwidths of several epoxy bonded disk pairs varied less than ±7% about a mean, thus demonstrating the much smaller dimensional tolerances associated with the tubing. Three epoxy bonded filters were constructed. Filter ER-1 (Figures 21 and 22) was a five disk filter while ER-2 and ER-3 (Figures 23 through 26) were eight disk filters. Bandwidths were somewhat wider than filters made from integral disk-ring elements due to the different values of Youngs modulus for Ni-Span "C" and "A" nickel. In the eight disk filters the loss of disk Q, due to epoxy, becomes apparent in the "rounding" of the passband edges.

A technique employing solder to bond disks and rings was also studied. In this technique a small groove, with a mean diameter equal to that of the coupling ring, was machined on the surface of the disk to be bonded and filled with solder. To make disk pairs, two such disks and the ring of Figure 6 were positioned in a jig and placed in an oven, thus melting the solder and forming a bond between disks and ring. Bandwidths of several disk pairs varied ±13.6% about a mean. These pairs, while less consistent in bandwidth, were stronger and more producible than epoxied pairs using the same elements. The increased bandwidth variation in solder bonded pairs must have been caused by bonding inconsistencies because the same type of coupling ring ("A" nickel tubing) was used in both cases. Response curves for six solder bonded filters are shown in Figures 27 through 38. All filters had five disks with the exception of SR-4 (Figures 33 and 34) which used eight disks. Some fabrication problems exist as evidenced by spurious responses in the passband and passband edges (see Figure 29 for example). To alleviate the problem, further work needs to be done in varying the groove width and depth, trying different solder compositions, etc.

One solder bonded filter (SR-3, Figures 31 and 32) was encased, subjected to 20 G's vibration (Paragraph 2.2 of 526-9430/9444-00) and 100 G's shock (Paragraph 2.3 of 526-9430/9444-00) and showed no measurable change in electrical characteristics subsequent to the tests. During vibration, all amplitude modulation, in the frequency range of 55 cps to 2000 cps,was attenuated by greater than 60 db. While no epoxy bonded filters were given shock and vibration tests under this contract, past filters have withstood 50 G's shock and 10 G's vibration with mechanical failure occurring at 20 G's vibration.

4. CONCLUSIONS

With tolerances on machined disk-ring elements held to a minimum, bandwidth variation could still exceed that allowable to meet the sideband specification. Consequently, a low yield rate and high costs would be expected for this type of filter.

Epoxy bonded filters employing separate disks and rings would approach the necessary bandwidth consistency. However, it is doubtful that any epoxy bonded filter, using present bonding techniques, would withstand the shock and vibration requirements. Also, the loss of disk "Q", due to epoxy, would hinder the filter's passband response.

Solder bonded filters using separate disks and rings, while capable of withstanding shock and vibration, would exhibit more bandwidth variation than acceptable to meet the sideband specification. However, some improvement in bandwidth consistency should be possible because it is known that dimensional tolerances account for only half of the total bandwidth variation experienced. The other half must be due to bonding techniques, which should be capable of improvement.

~~Thus~~, through solder bonding techniques, a very rigid and exceedingly strong mechanical filter has been developed. This filter exhibits considerable reduction in spurious responses over conventional edge-coupled mechanical filters. With some additional development, this filter should be capable of mass production to a specification with less critical requirements than the sideband specification.

5. RECOMMENDATIONS

As demonstrated by the preceding work, solder bonded filters using separate disks and rings are exceptionally strong and comparatively easy to build. It is, therefore, recommended that any further study be concentrated in this area. Such a study should include an investigation of the following fabrication problems:

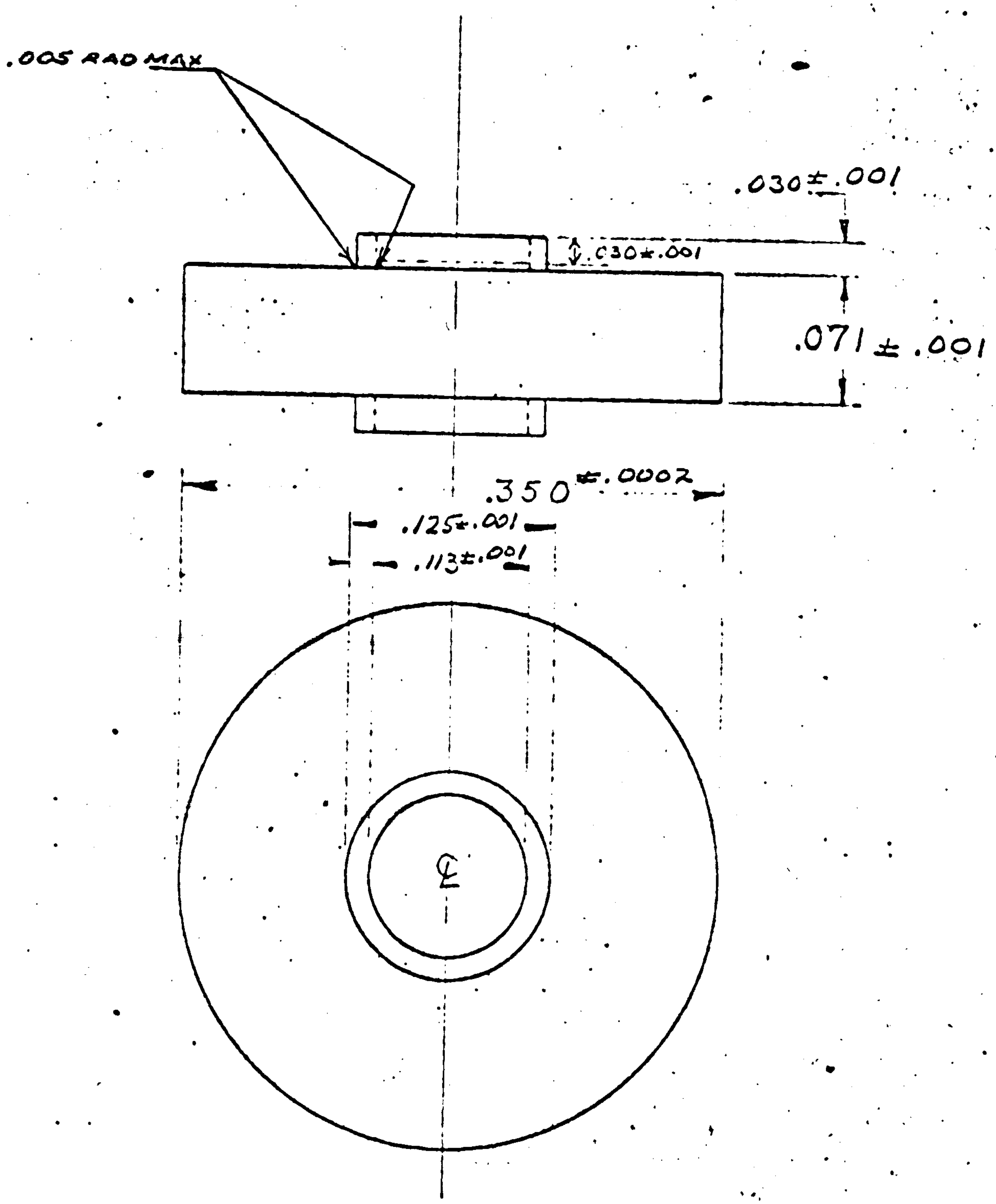
(1) Groove width and depth

(2) Solder composition

(3) Jigging

In addition, design goals should be changed to encompass a filter such as the frequency selectors (CPN 526-9430/9444-00) where bandwidth tolerances are not as critical.

REV



MATERIAL: NI - SPAN C

FIGURE 1

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON FRACTIONS ±1/64 DECIMALS ±.005 ANGLES ±1°	CODE IDENT NO 13499	SIZE A	37-1775-003
	SCALE NONE	WT	SHEET

FD-444 GS (Rev 4-61) SPECIFICATION — CONTINUATION SHEET

FIGURE 2

STATISTICAL QUALITY CONTROL

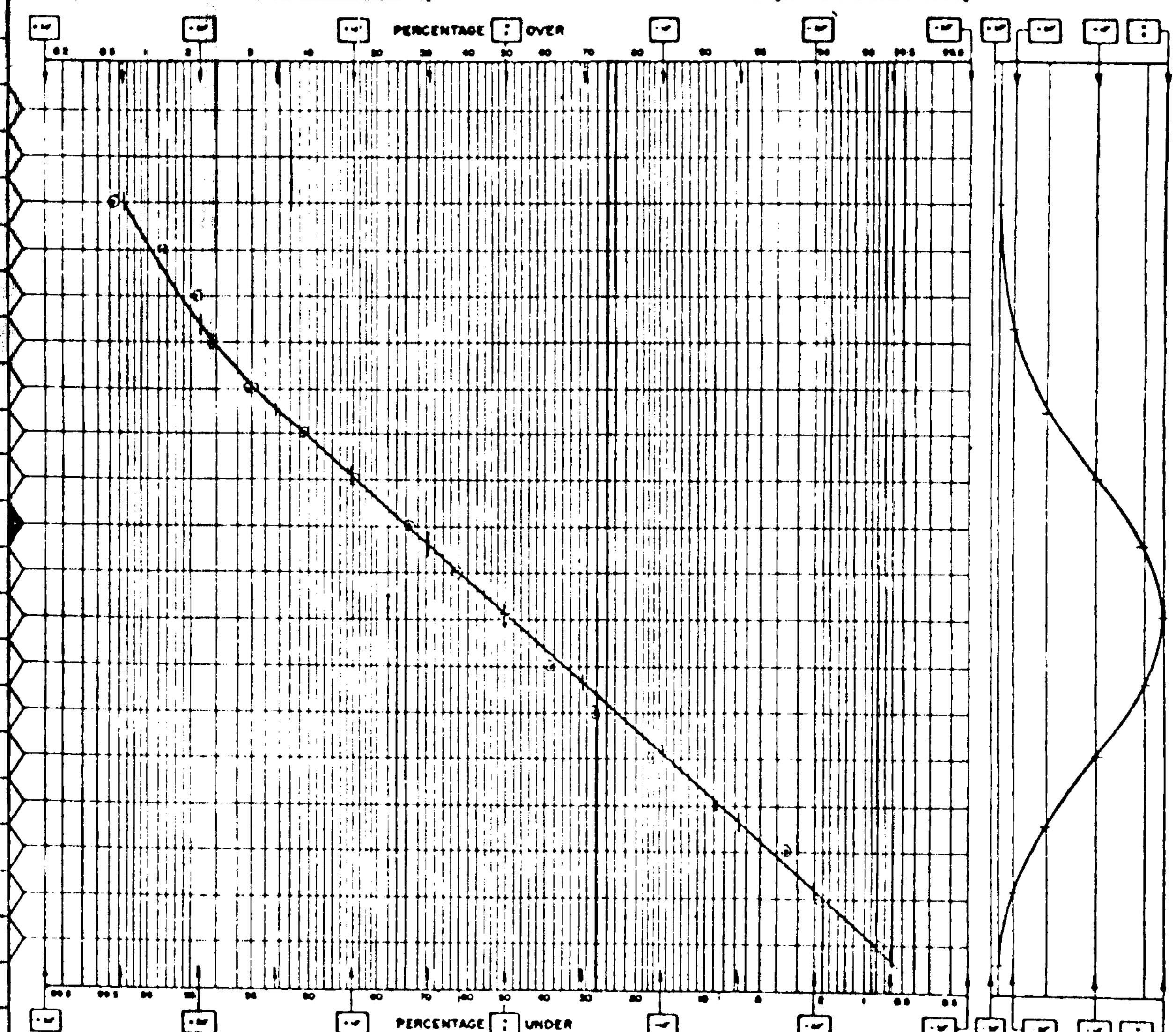
FREQUENCY DISTRIBUTION ANALYSIS SHEET

NORMAL

PART NUMBER	PART NAME	DEPARTMENT OR SUPPLIER	MACHINE	DATE
	O.D. of Coupling Ring (inches)			
BLUEPRINT SPECIFICATION	OPERATION / MATERIAL	CLASSIFICATION / OPERATOR	ANALYST	

1 X	TALLY	2 f	5 Acc. 2	6 5÷4 in % over
.1230	‖	2	2	.53
.1232	|	1	5	1.32
.1234	‖	2	8	2.10
.1236	|	1	11	2.90
.1238	卌 ‖	7	19	5.00
.1240	卌 卌	10	36	9.48
.1242	卌 卌 卌 |	16	62	16.3
.1244	卌 卌 卌 卌 |||	23	101	26.6
.1246	卌 卌 卌 |||	18	142	37.4
.1248	卌 卌 卌 卌 卌 ||||	29	189	49.7
.1250	卌 卌 卌	15	233	61.4
.1252	卌 卌 卌 卌 卌	25	273	71.9
.1254	卌 卌 卌 ‖	17	315	82.9
.1256	卌 卌 卌	15	347	91.3
.1258	||||	4	366	96.4
.1260	‖	2	372	97.9
.1262	|||	3	377	99.2

3 TOTAL	190	
4 DOUBLE TOTAL	380	
$\bar{X}$	.1248	



FX-0372

FIGURE 3

STATISTICAL QUALITY CONTROL

FREQUENCY DISTRIBUTION ANALYSIS SHEET

NORMAL

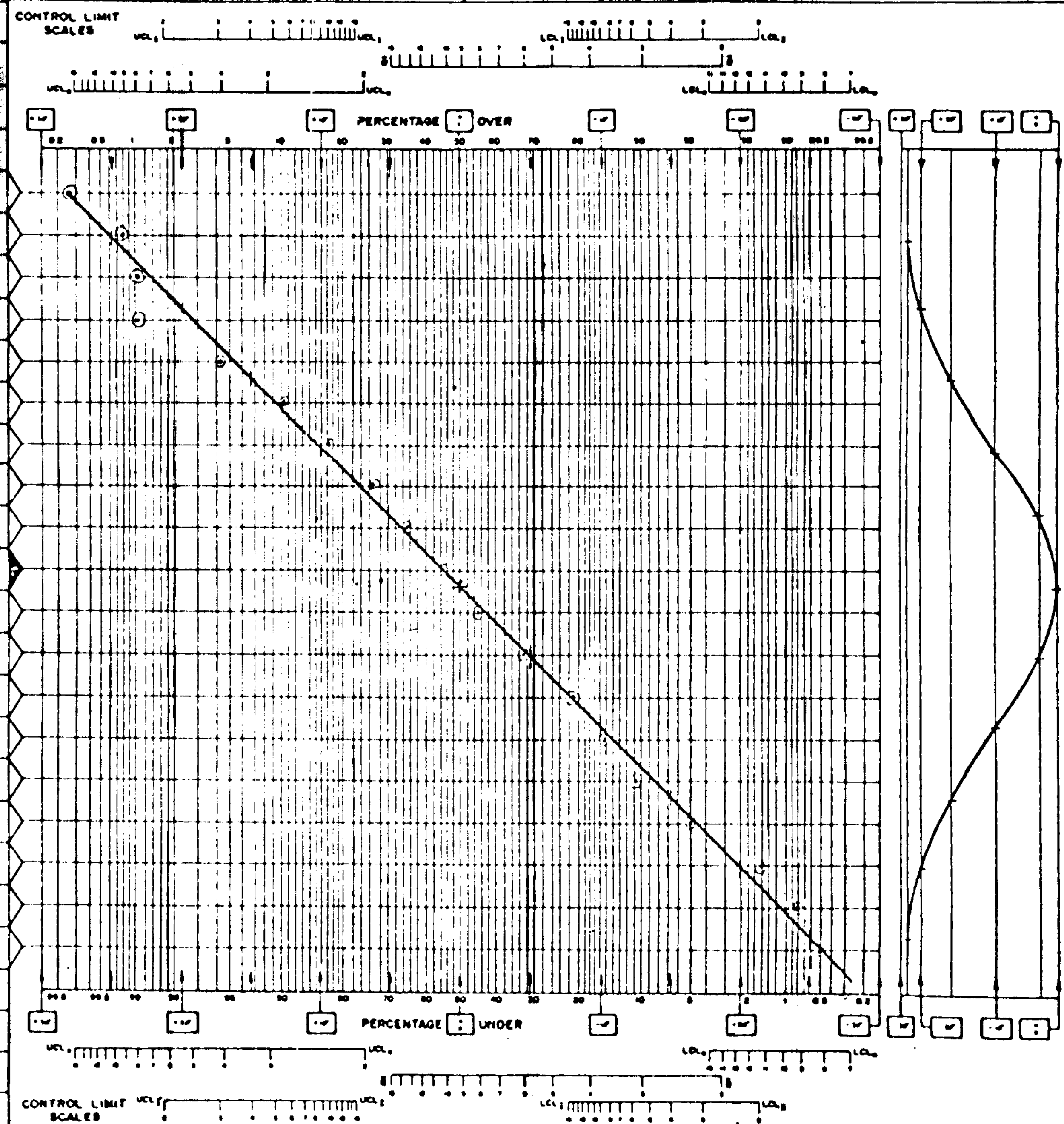
PART NUMBER	PART NAME	DEPARTMENT OR SUPPLIER	MACHINE	DATE
	Thickness Of Coupling Ring (inches)			

BLUEPRINT SPECIFICATION	OPERATION	MATERIAL	CLASSIFICATION	OPERATOR	ANALYST

% UNDER SPECIFICATION	% OVER SPECIFICATION	DISTRIBUTION TYPE	R (FOR CHART CONTROL)

1		2	5	6
X	TALLY	f	Acc. 2	5÷4 = % OVER
.0040	|	1	1	.26
.0042	|	1	3	.79
.0044		0	4	1.05
.0046		0	4	1.05
.0048	卌 卌 ||	12	16	4.21
.0050	卌 卌 |	11	39	10.3
.0052	卌 卌 卌 |	16	66	17.4
.0054	卌 卌 卌 ||||	19	101	26.6
.0056	卌 卌 ||||	14	134	35.3
.0058	卌 卌 卌 卌 ||	22	170	44.7
.0060	卌 卌 卌 |||	18	210	55.2
.0062	卌 卌 卌 卌 卌 |||	28	256	67.4
.0064	卌 卌 卌 |	16	300	78.9
.0066	卌 |	6	322	84.7
.0068	卌 卌 |	11	339	89.2
.0070	卌 卌 |	11	361	95.0
.0072	||	2	374	98.4
.0074	|	1	377	99.2
.0076		0	378	99.5
.0078	|	1	379	99.7

UCL	UCL	3 TOTAL	190	UCL
LCL	LCL	4 DOUBLE TOTAL	380	LCL
PROCESS CAPABILITY	σ	X̄	.0059	R̄



FX-0372

FIGURE 4

STATISTICAL QUALITY CONTROL

FREQUENCY DISTRIBUTION ANALYSIS SHEET

NORMAL

PART NAME: Height of Coupling Ring (inches)

1 X	TALLY	2 f	5 Acc. 2	6 5÷4 in % over
.0272		1	1	.26
.0276		0	2	.53
.0220		0	2	.53
.0284		0	2	.53
.0288		0	2	.53
.0292		8	10	2.63
.0296		9	27	7.11
.0300		13	49	12.9
.0304		14	76	20.0
.0308		16	106	27.9
.0312		19	141	37.1
.0316		31	191	50.3
.0320		30	252	66.4
.0324		21	303	79.8
.0328		9	333	87.6
.0332		9	351	92.4
.0336		8	368	96.9
.0340		1	377	99.2
.0344		0	378	99.5
.0348		1	379	99.7

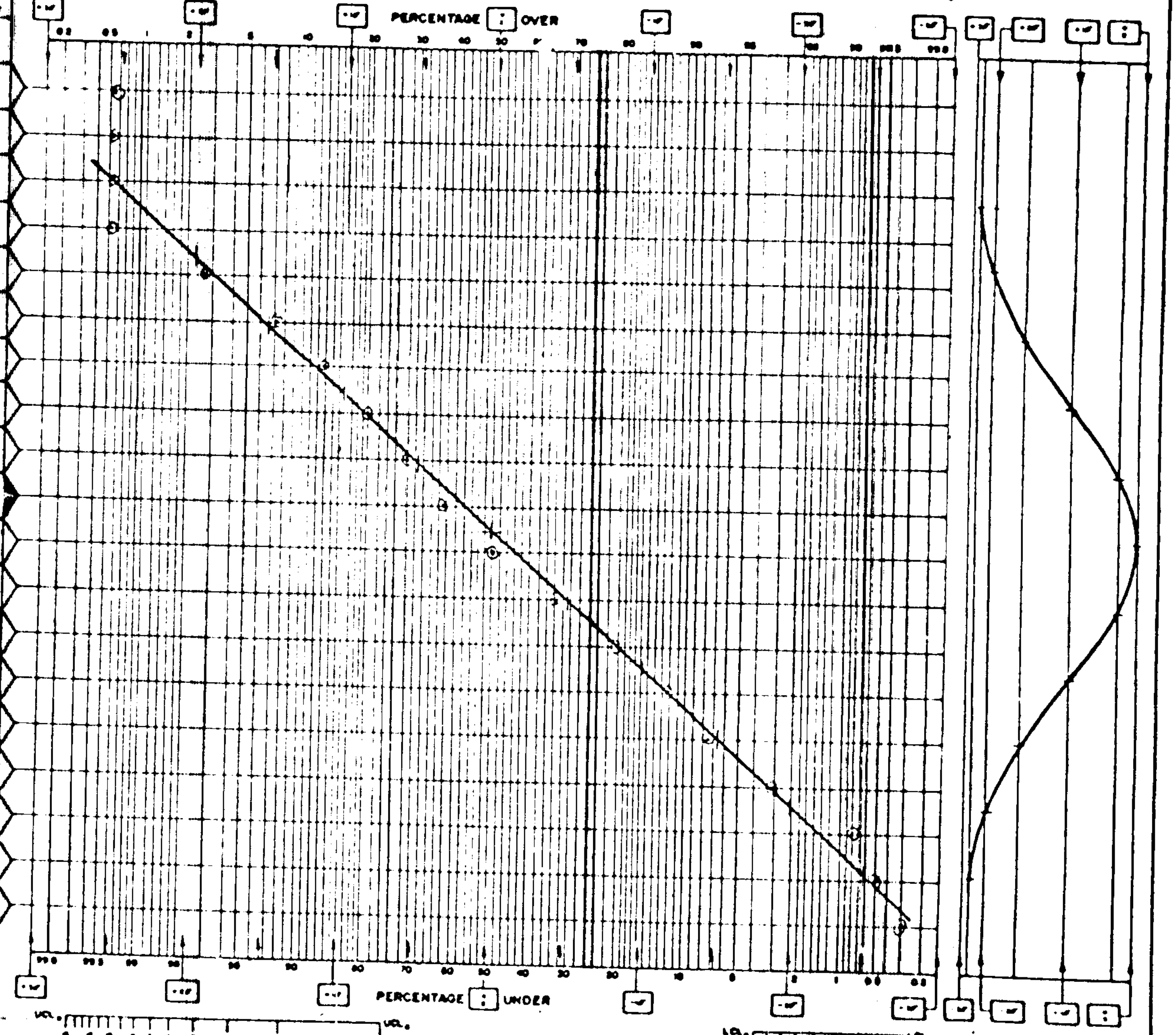
3 TOTAL: 190

4 DOUBLE TOTAL: 380

$\bar{x}$: .0314

CONTROL LIMIT SCALES

PERCENTAGE OVER

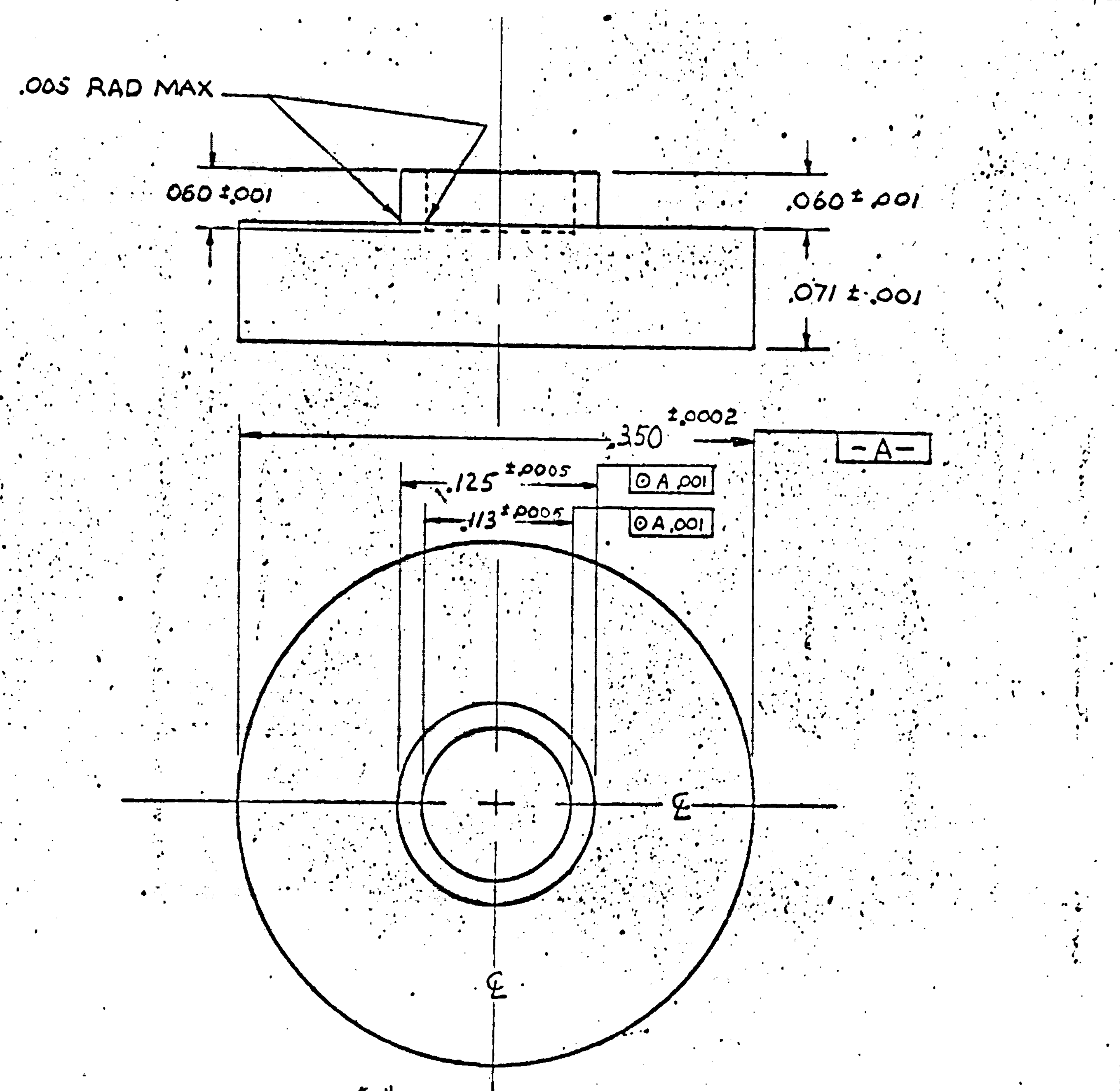


PERCENTAGE UNDER

CONTROL LIMIT SCALES

FX-0372

REVISIONS



MATERIAL: NI-SPAN "C"

QTY REQD	SYM	ITEM	GOV IDENT NO.	COLLINS PART NO.	DESCRIPTION

UNLESS NOTED
DIM ARE IN INCHES
FRACTION $\pm\frac{1}{32}$ DEC .008 ANGLES ±1°

DRAWN DL BISE 3-25-64
CHECK
ENG
APPR

DISK-RING

FIGURE 5

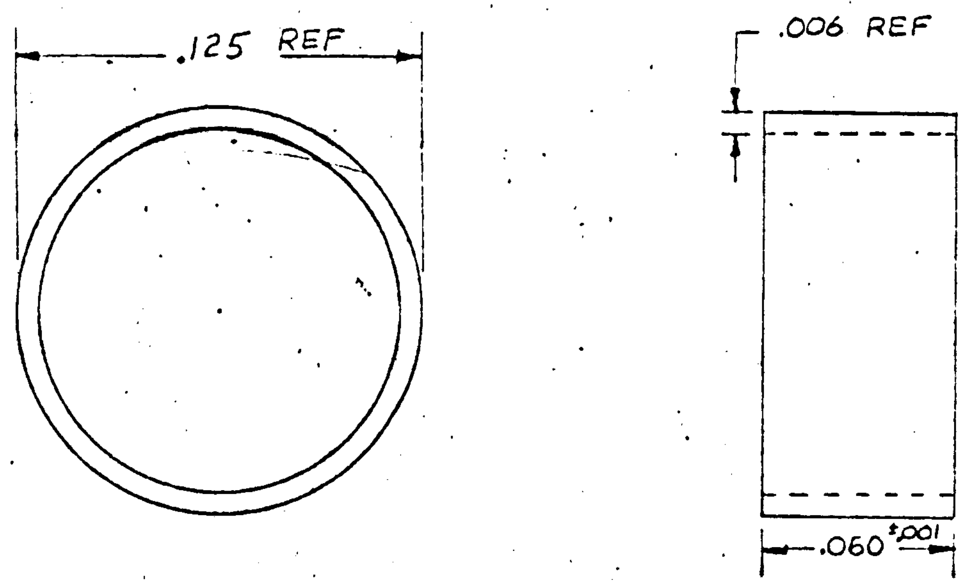
INFORMATION SCIENCE CENTER
COLLINS
NEWPORT BEACH, CALIF.

37-1775-00F

CODE IDENT: 95105 | WT: | SCALE: NONE | SHT 1 OF 1

FORM 864-00

REVISIONS



NOTE:
REMOVE ALL BURRS AND SHARP EDGES

MATERIAL: "A" NICKEL

QTY REQD	SYM	ITEM	GOV IDENT NO.	COLLINS PART NO.	DESCRIPTION

UNLESS NOTED
DIM ARE IN INCHES
FRACTION ± 1/32 · DEC .008 · ANGLES ±1°

DRAWN D.L.BISE 4-1-64
CHECK
ENG
APPR

COUPLING RING

FIGURE 6

INFORMATION SCIENCE CENTER
COLLINS
NEWPORT BEACH, CALIF.

37-1775-006

CODE IDENT: 95105 · WT: · SCALE: NONE · SHT 1 OF

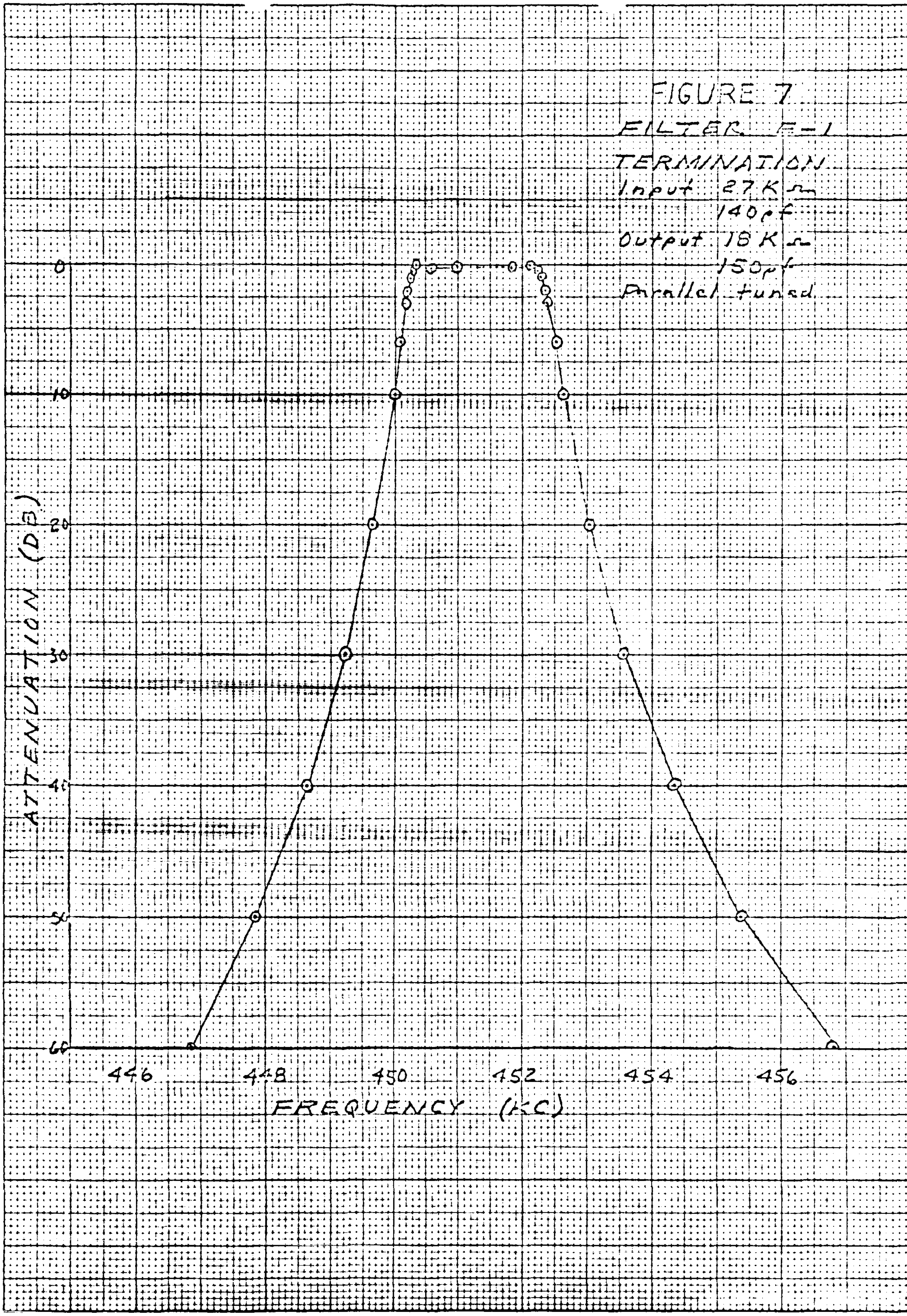


FIGURE 7
FILTER F-1
TERMINATION
Input 27K Ω
140pf
Output 18 K Ω
150pf
Parallel tuned
ATTENUATION (DB)
0
10
20
30
40
50
60
446
448
450
452
454
456
FREQUENCY (KC)

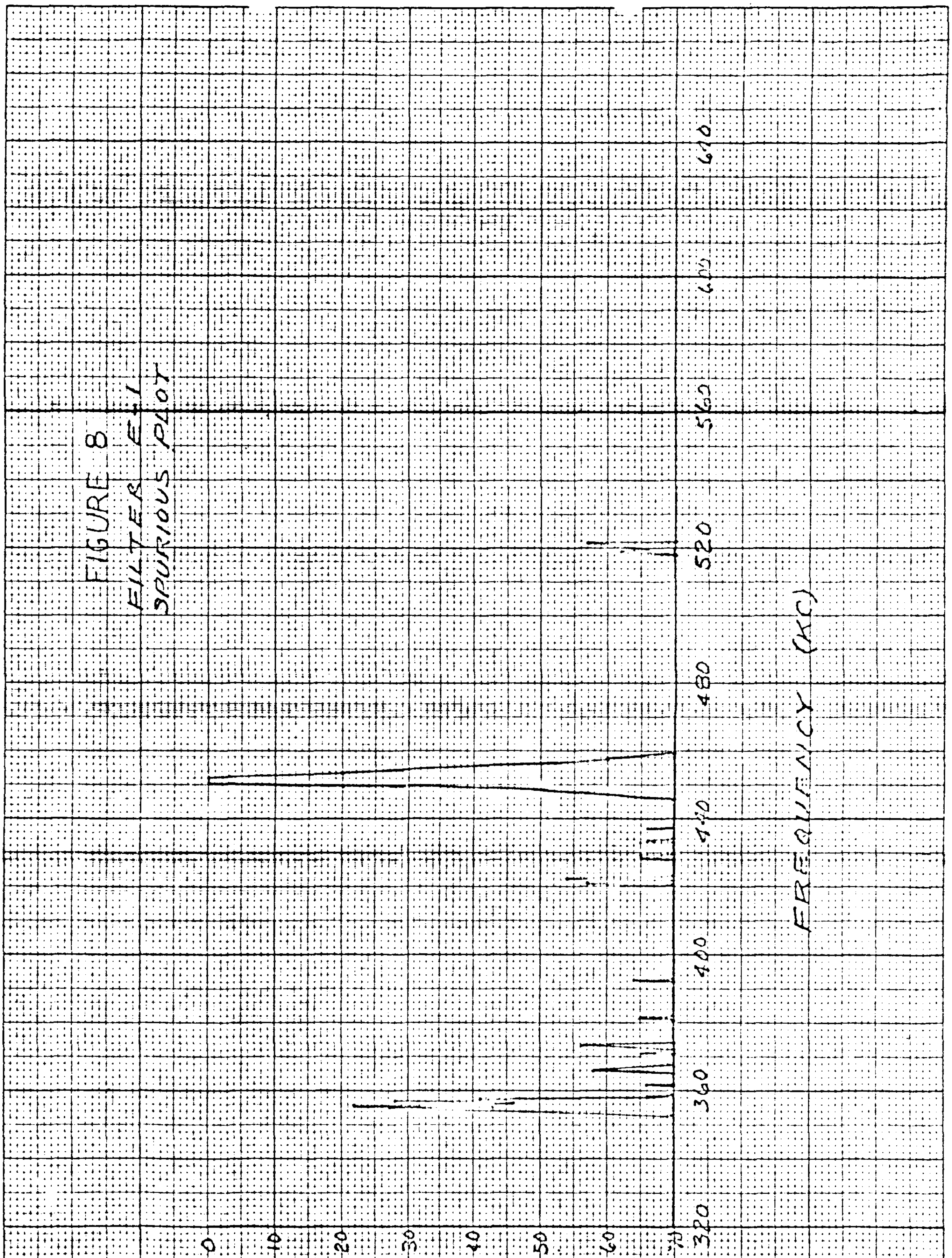


FIGURE 8
FILTER E-1
SPURIOUS PLOT
FREQUENCY (KC)
ATTENUATION (DB)
320
360
400
480
520
0
10
20
30
40
50
60

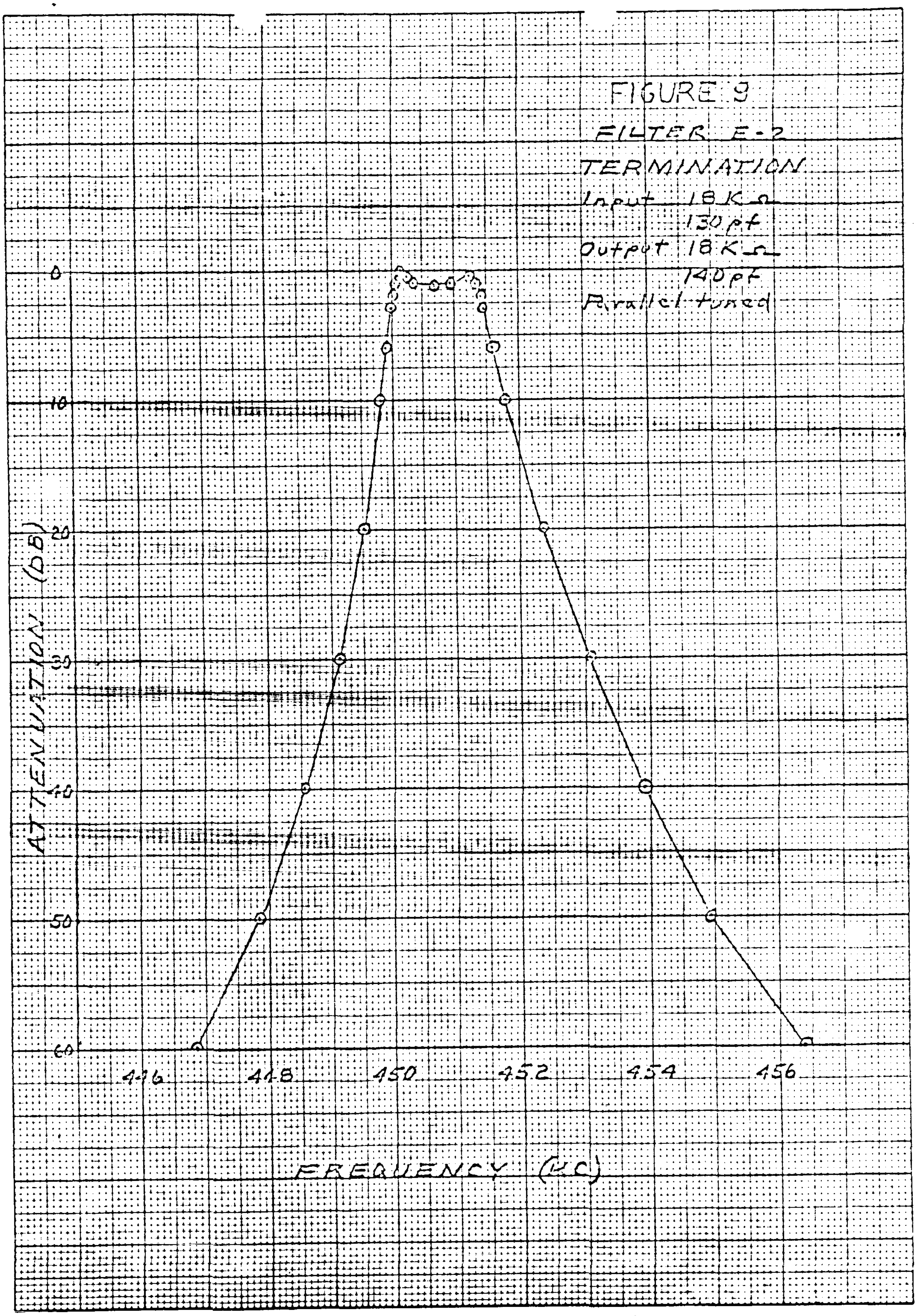


FIGURE 9
FILTER E-2
TERMINATION
Input 18 K Ω
130 pf
Output 18 K Ω
140 pf
Parallel tuned
ATTENUATION (DB)
0
10
20
30
40
50
60
446
448
450
452
454
456
FREQUENCY (MC)

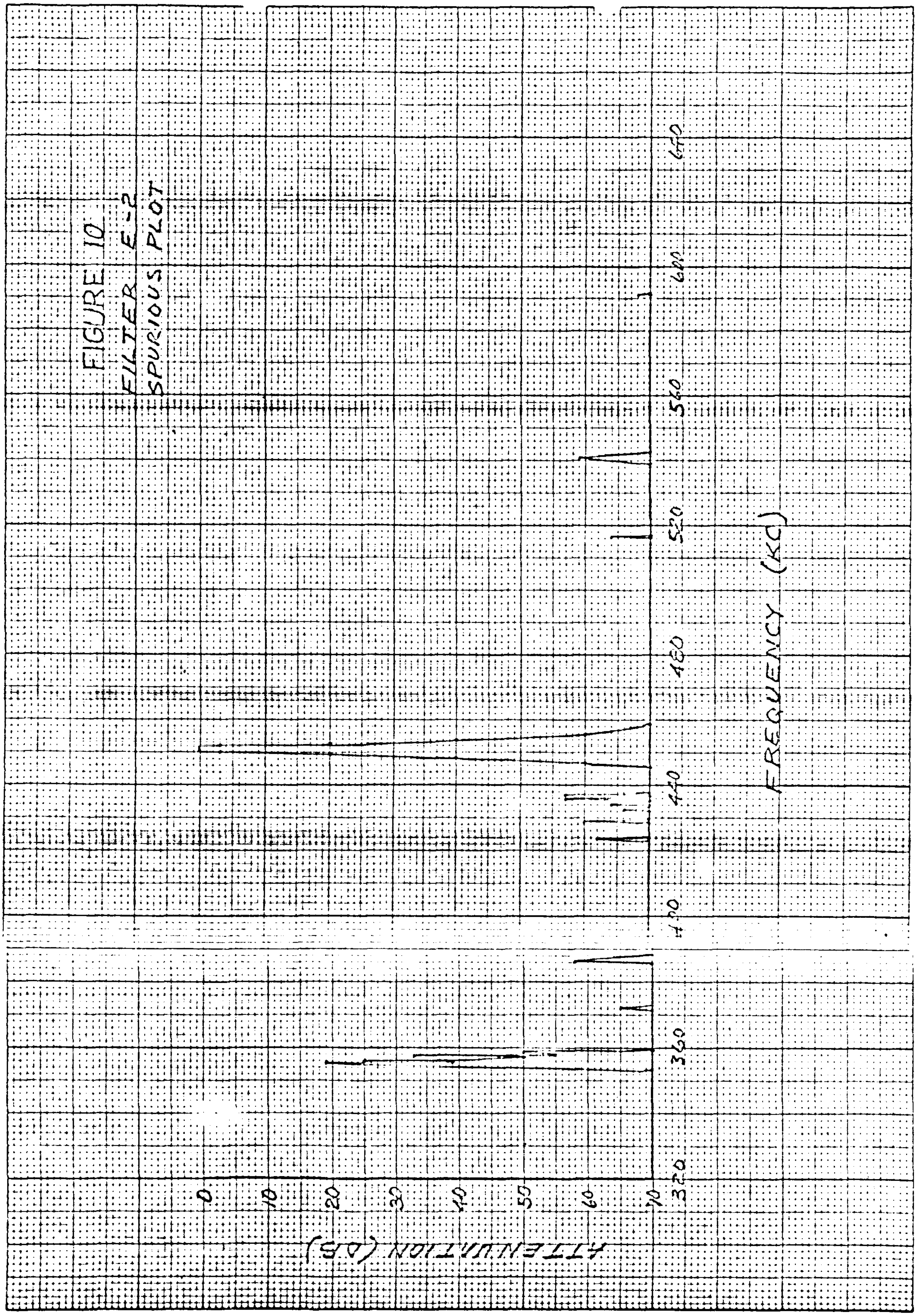


FIGURE 10
FILTER E-2
SPURIOUS PLOT
FREQUENCY (KC)
ATTENUATION (DB)
0
10
20
30
40
50
60
70
320
360
400
440
480
520
560
600
640

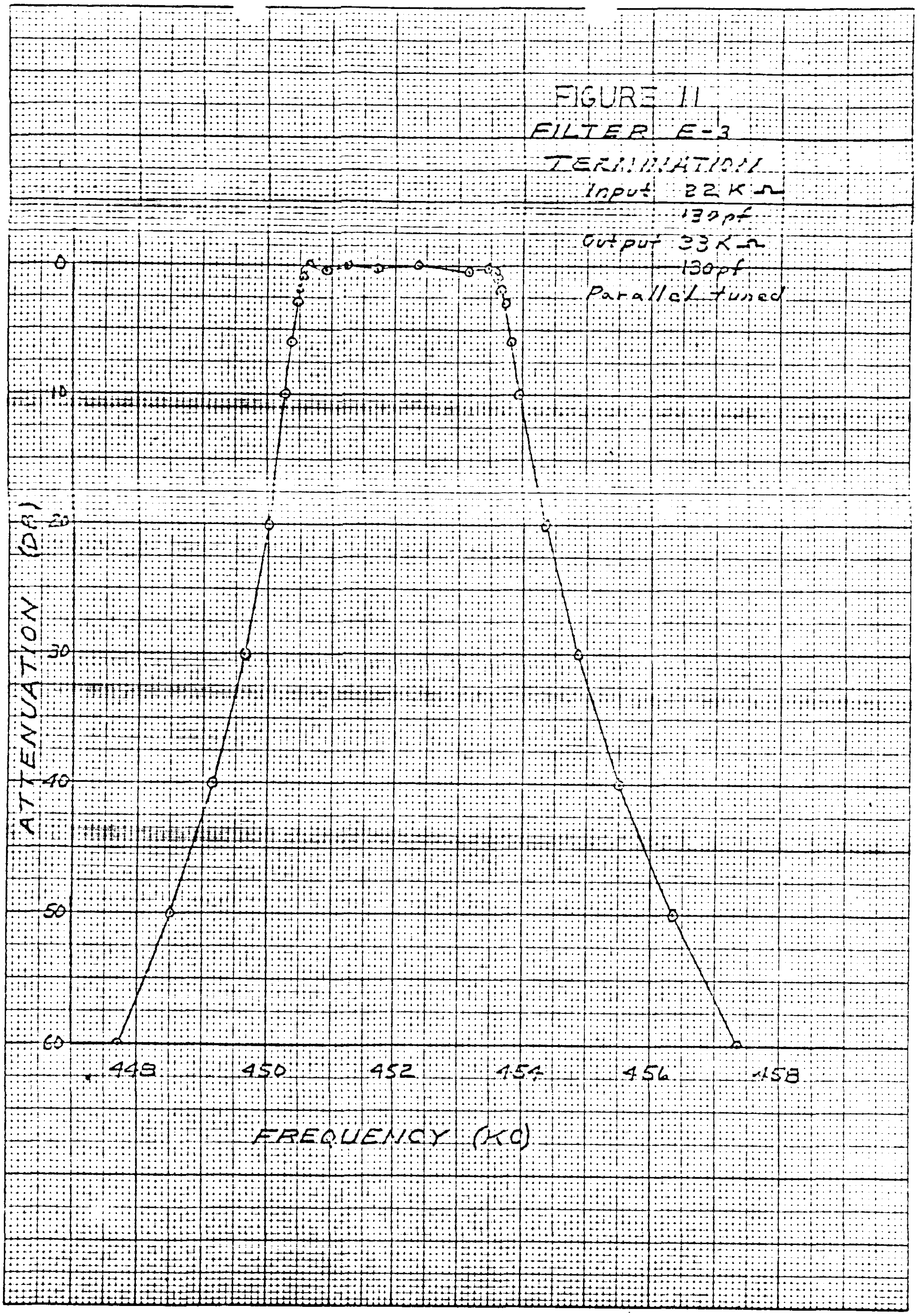


FIGURE 11
FILTER E-3
TERMINATION
Input 22 K Ω
130 pf
Output 33 K Ω
130 pf
Parallel tuned
ATTENUATION (DB)
0
10
20
30
40
50
60
448
450
452
454
456
458
FREQUENCY (KC)

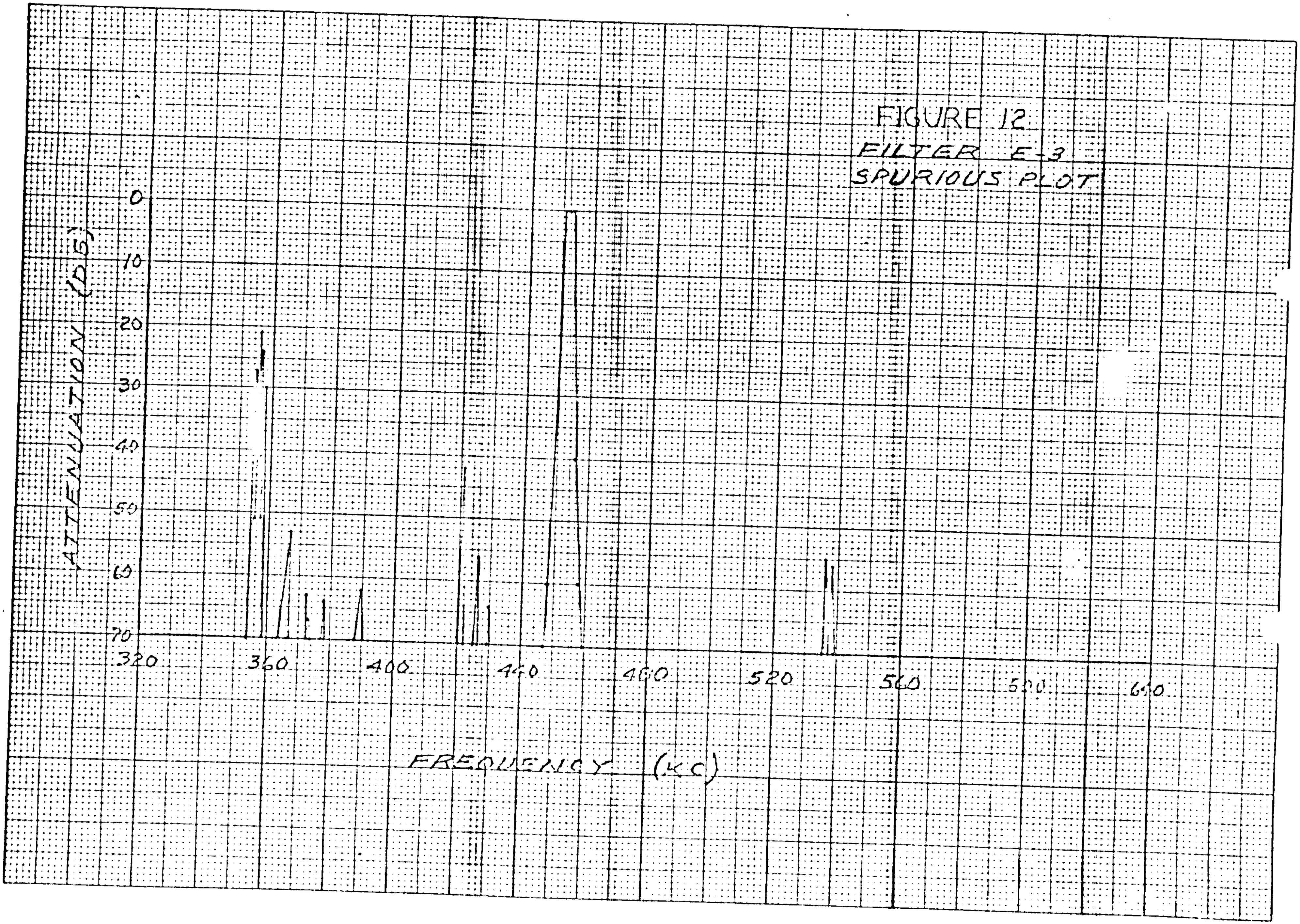


FIGURE 12
FILTER E-3
SPURIOUS PLOT
ATTENUATION (DB)
0
10
20
30
40
50
60
70
320
360
400
440
480
520
560
600
640
FREQUENCY (KC)

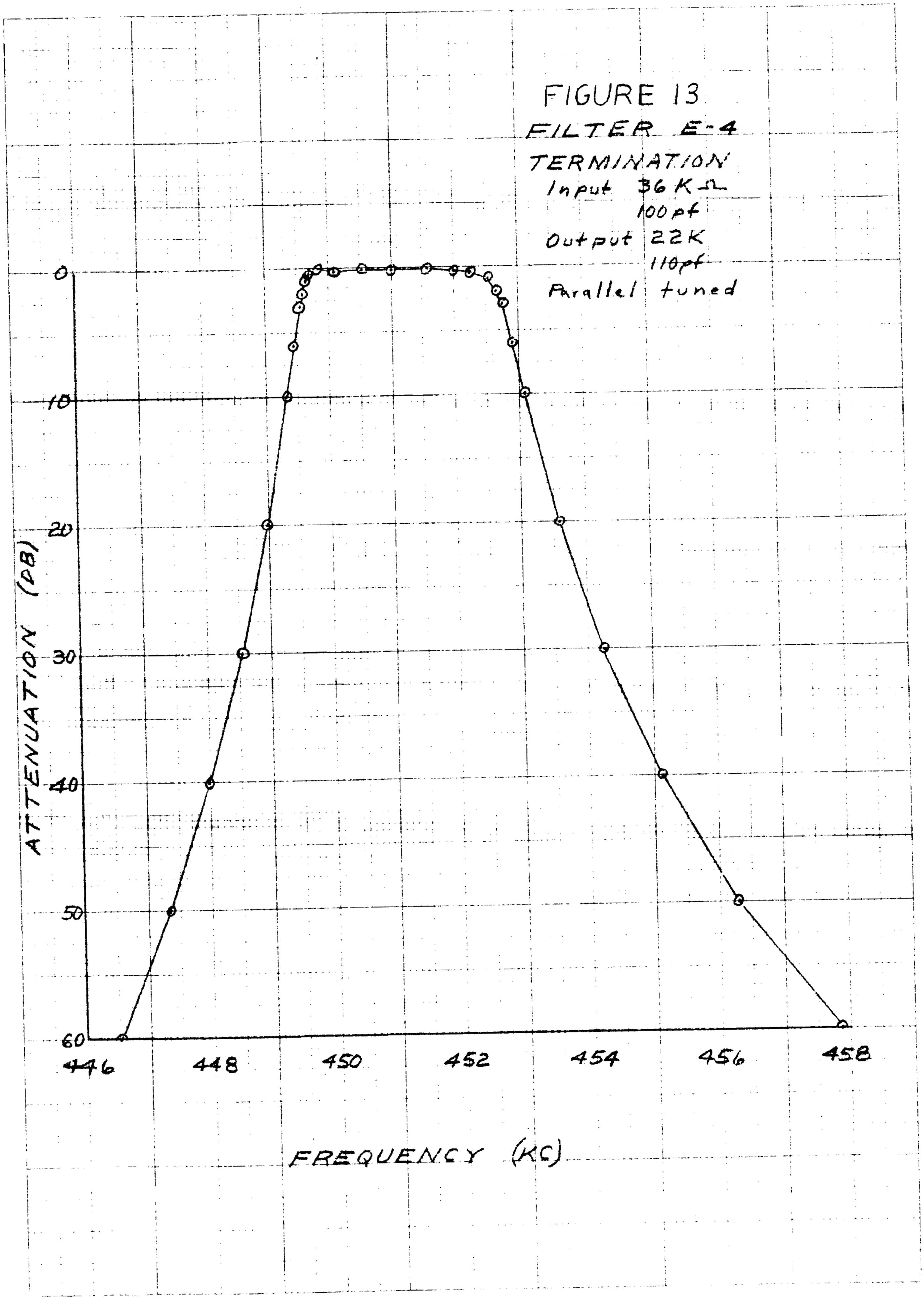


FIGURE 13
FILTER E-4
TERMINATION
Input 36 KΩ
100 pf
Output 22K
110 pf
Parallel tuned
ATTENUATION (DB)
0
10
20
30
40
50
60
446
448
450
452
454
456
458
FREQUENCY (KC)

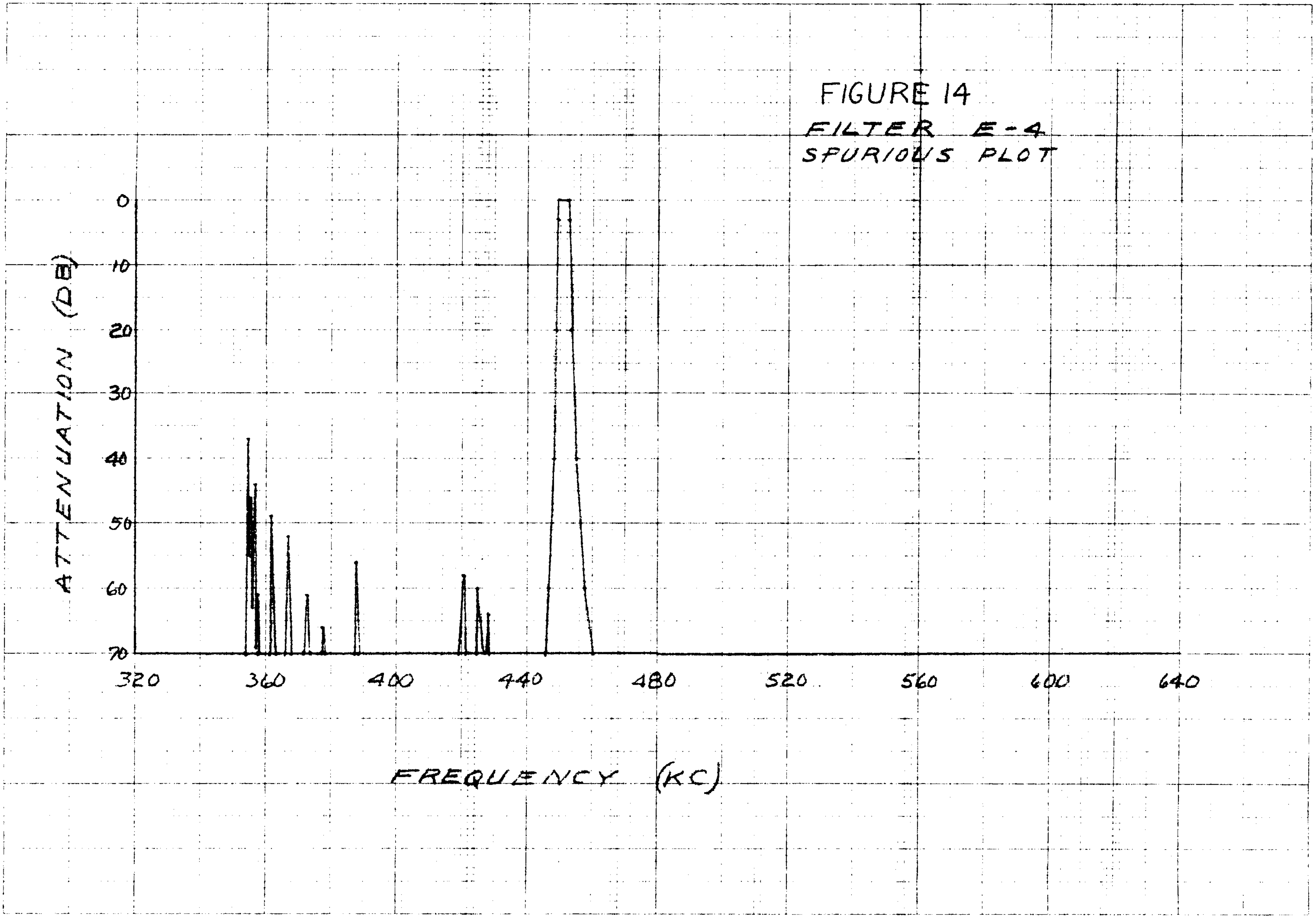


FIGURE 14
FILTER E-4
SPURIOUS PLOT
ATTENUATION (DB)
0
10
20
30
40
50
60
70
320
360
400
440
480
520
560
600
640
FREQUENCY (KC)

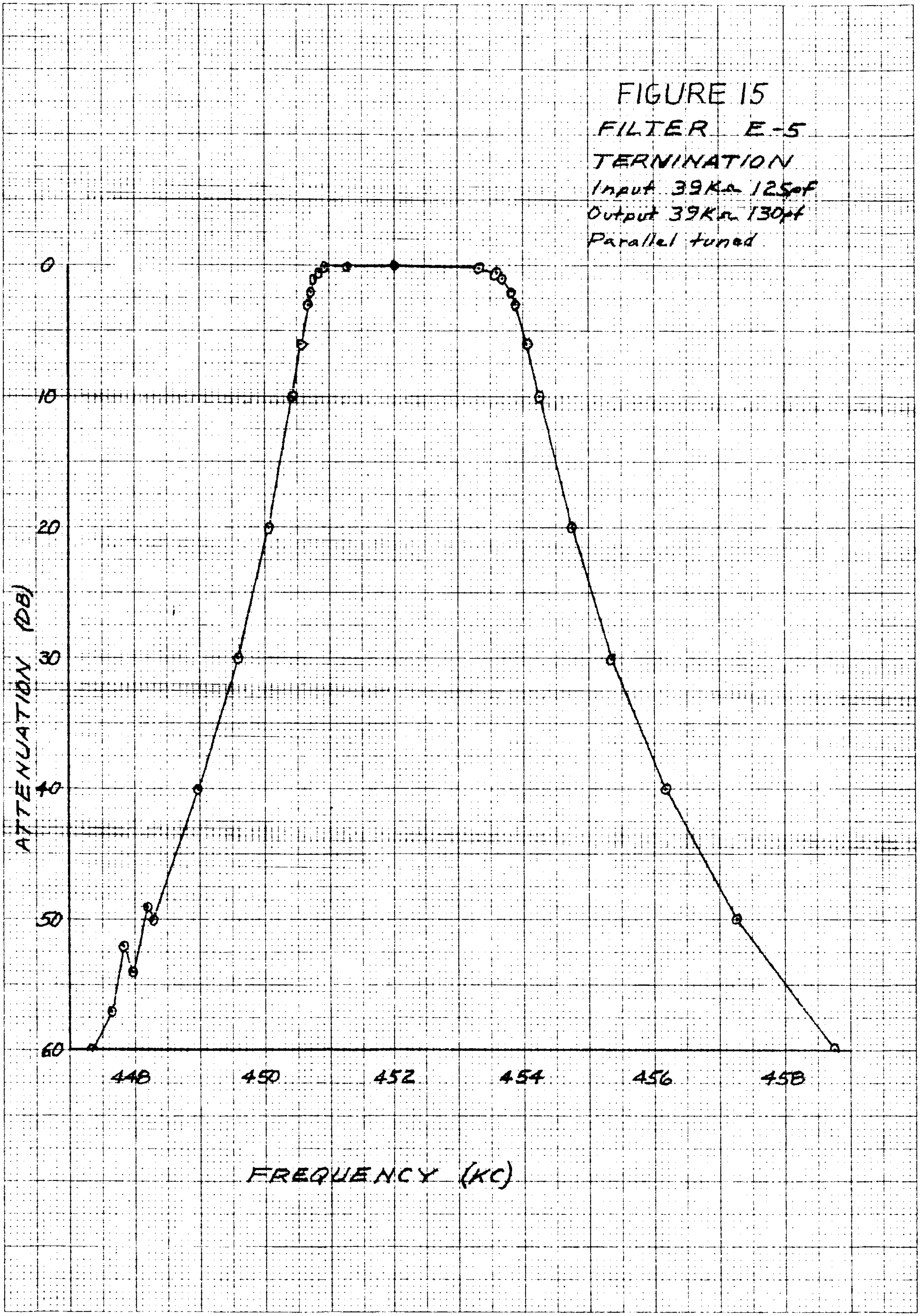
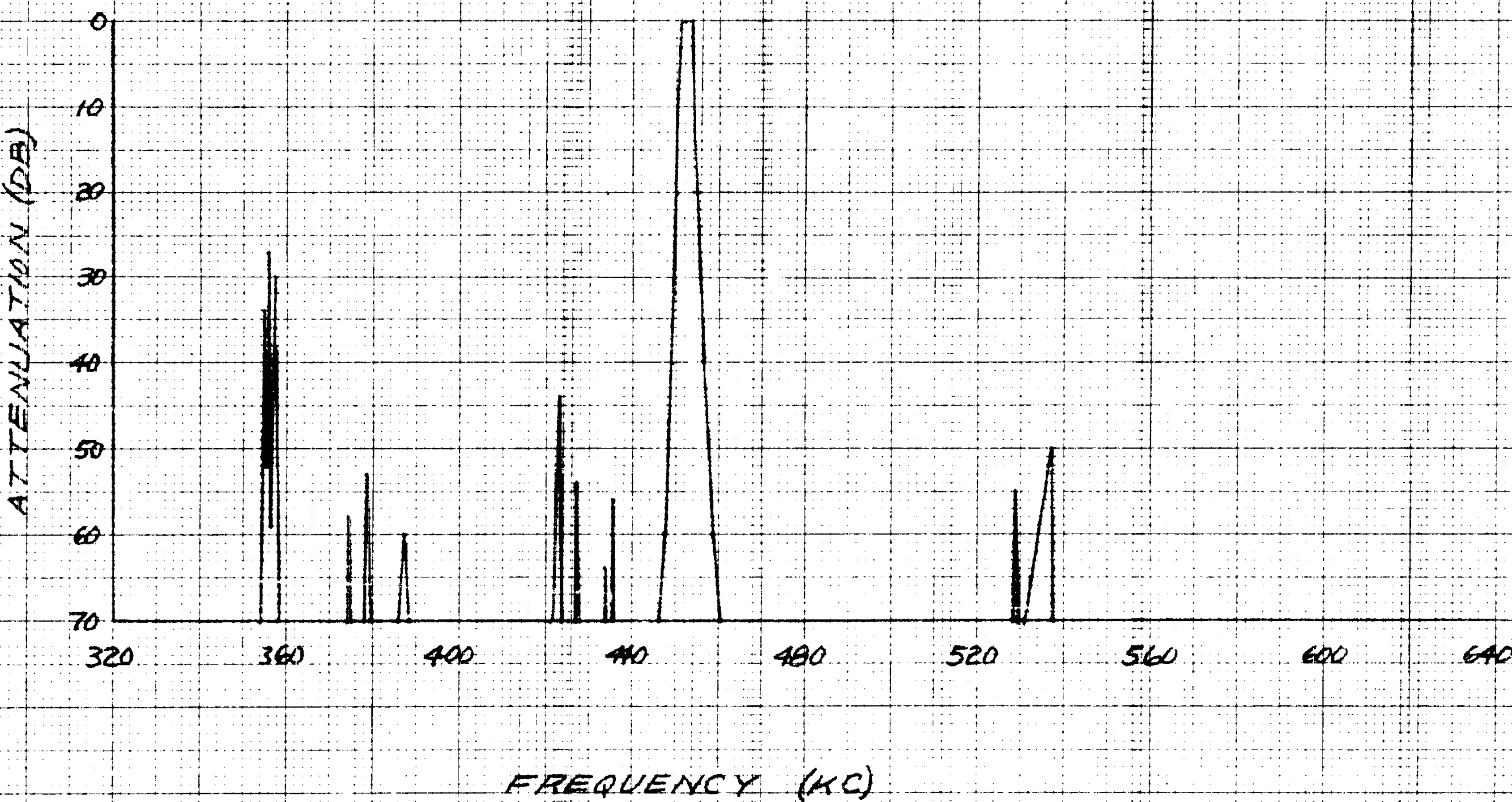


FIGURE 15
FILTER E-5
TERMINATION
Input 39KΩ 125pF
Output 39KΩ 130pf
Parallel tuned
ATTENUATION (DB)
0
10
20
30
40
50
60
448
450
452
454
456
458
FREQUENCY (KC)

FIGURE 16
FILTER E-5
SPURIOUS PLOT



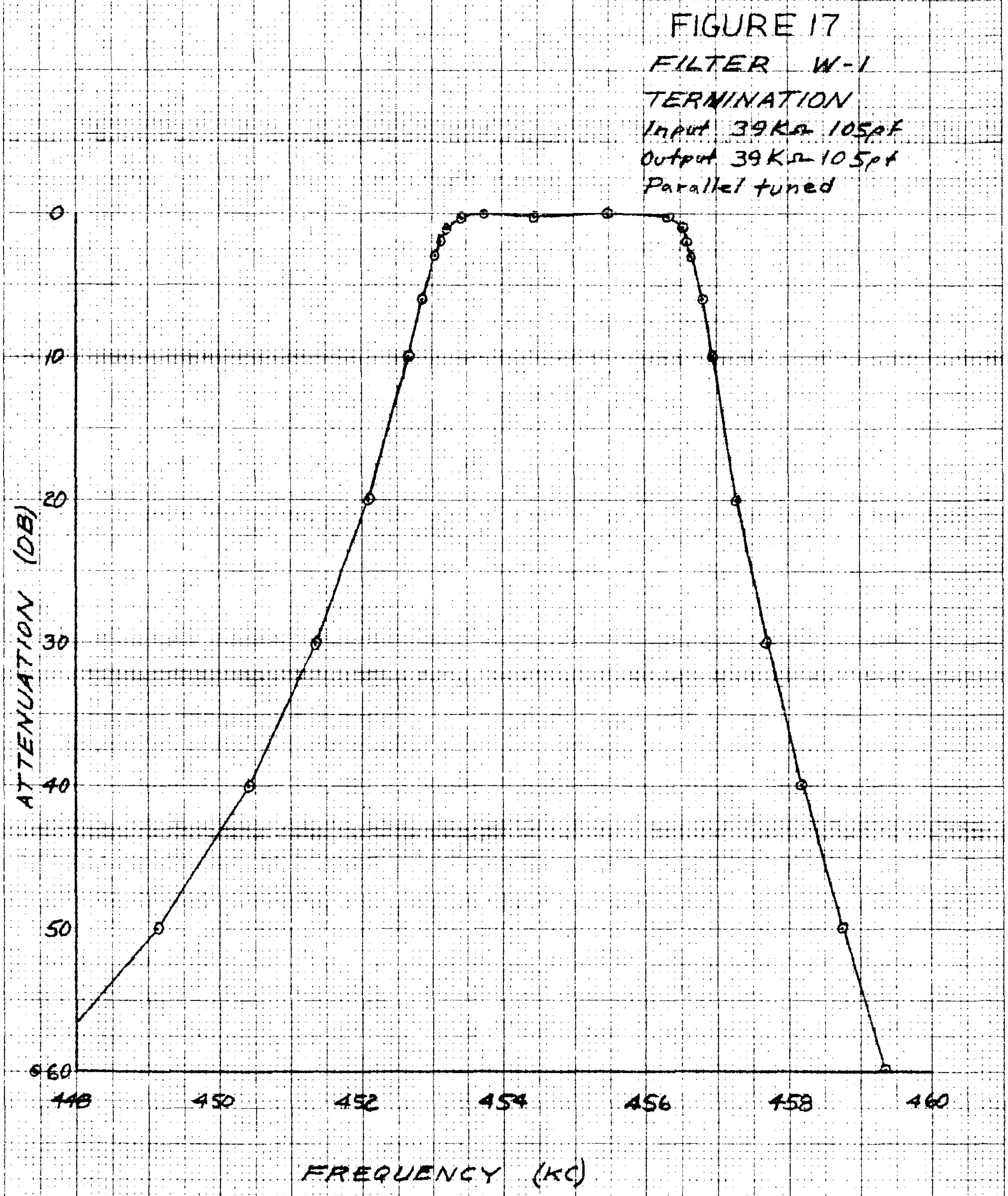
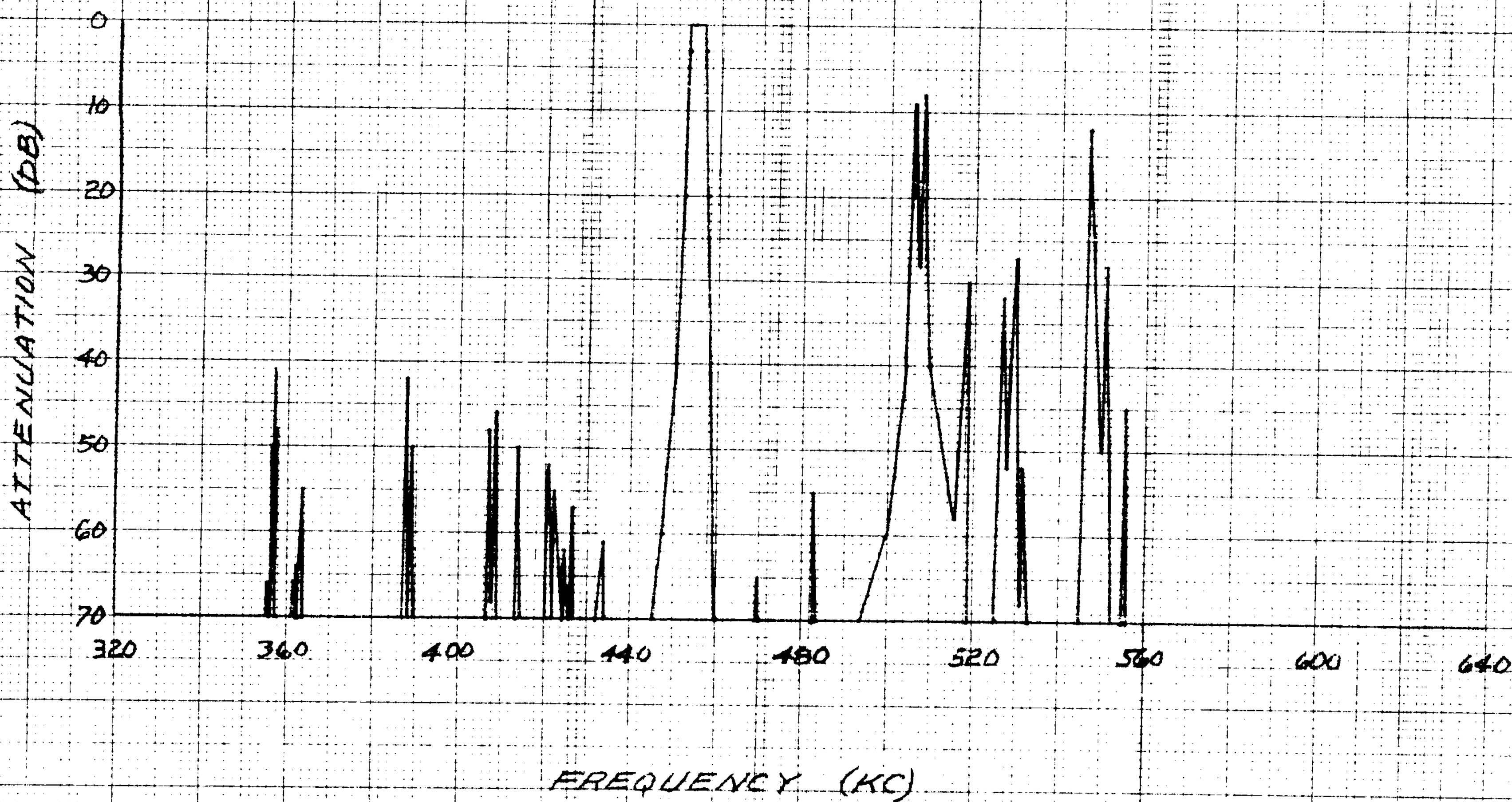


FIGURE 17
FILTER W-1
TERMINATION
Input 39KΩ 105pf
Output 39KΩ 105pf
Parallel tuned
ATTENUATION (DB)
0
10
20
30
40
50
60
448
450
452
454
456
458
460
FREQUENCY (KC)

FIGURE 18
FILTER W-1
SPURIOUS PLOT



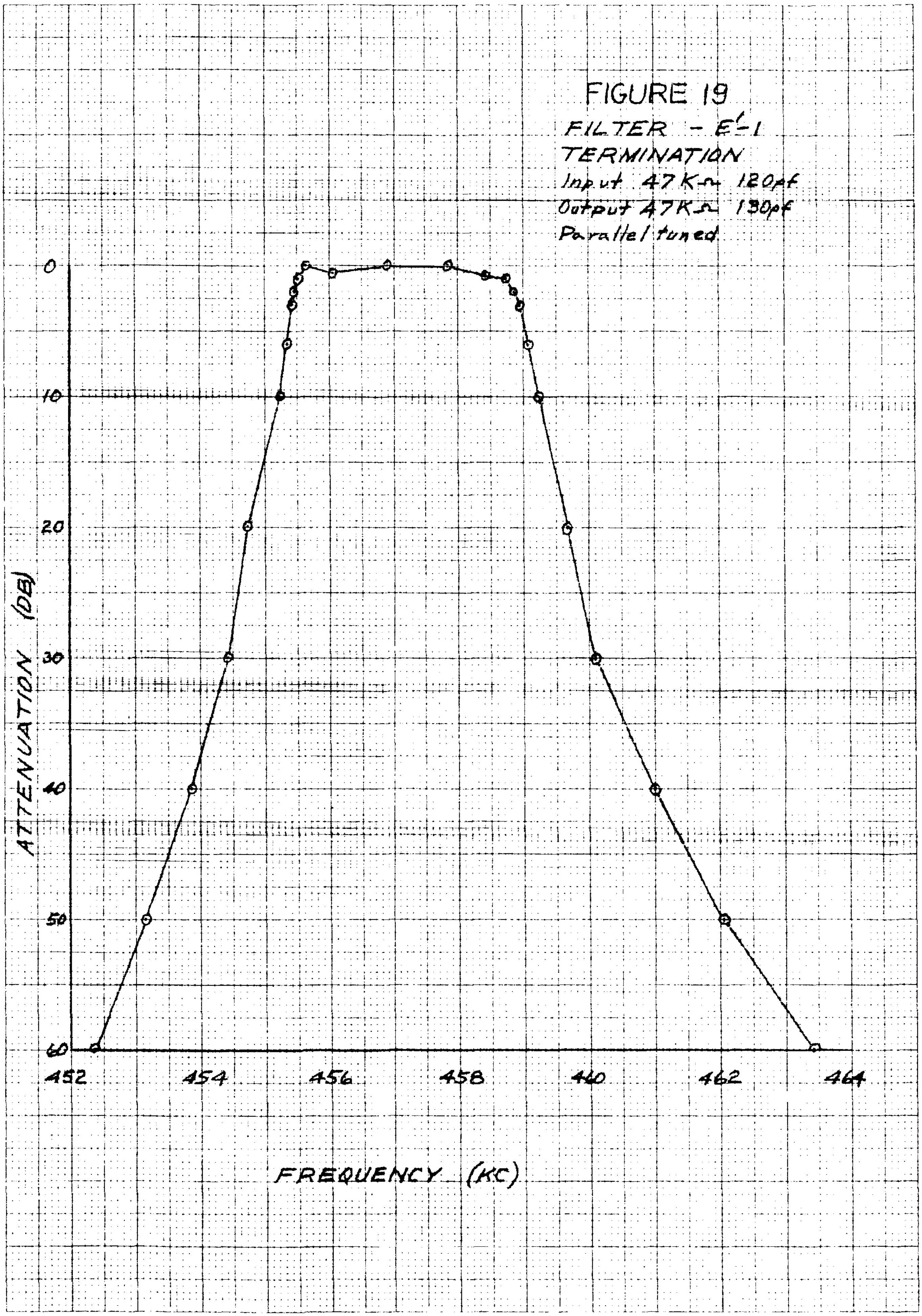
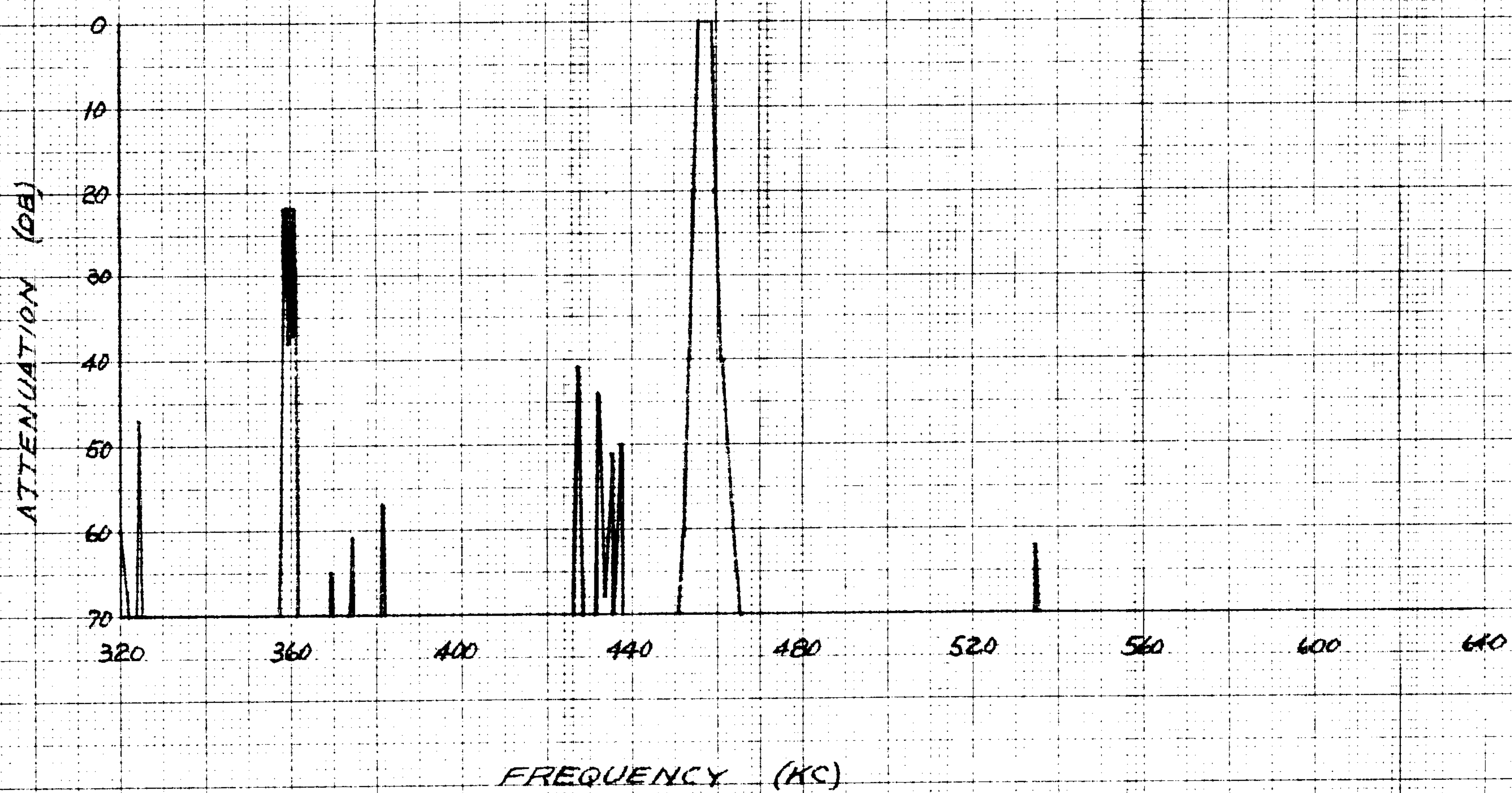


FIGURE 19
FILTER - E'-1
TERMINATION
Input 47KΩ 120pf
Output 47KΩ 130pf
Parallel tuned
ATTENUATION (DB)
0
10
20
30
40
50
60
452
454
456
458
460
462
464
FREQUENCY (KC)

FIGURE 20
FILTER E'-1
SPURIOUS PLOT



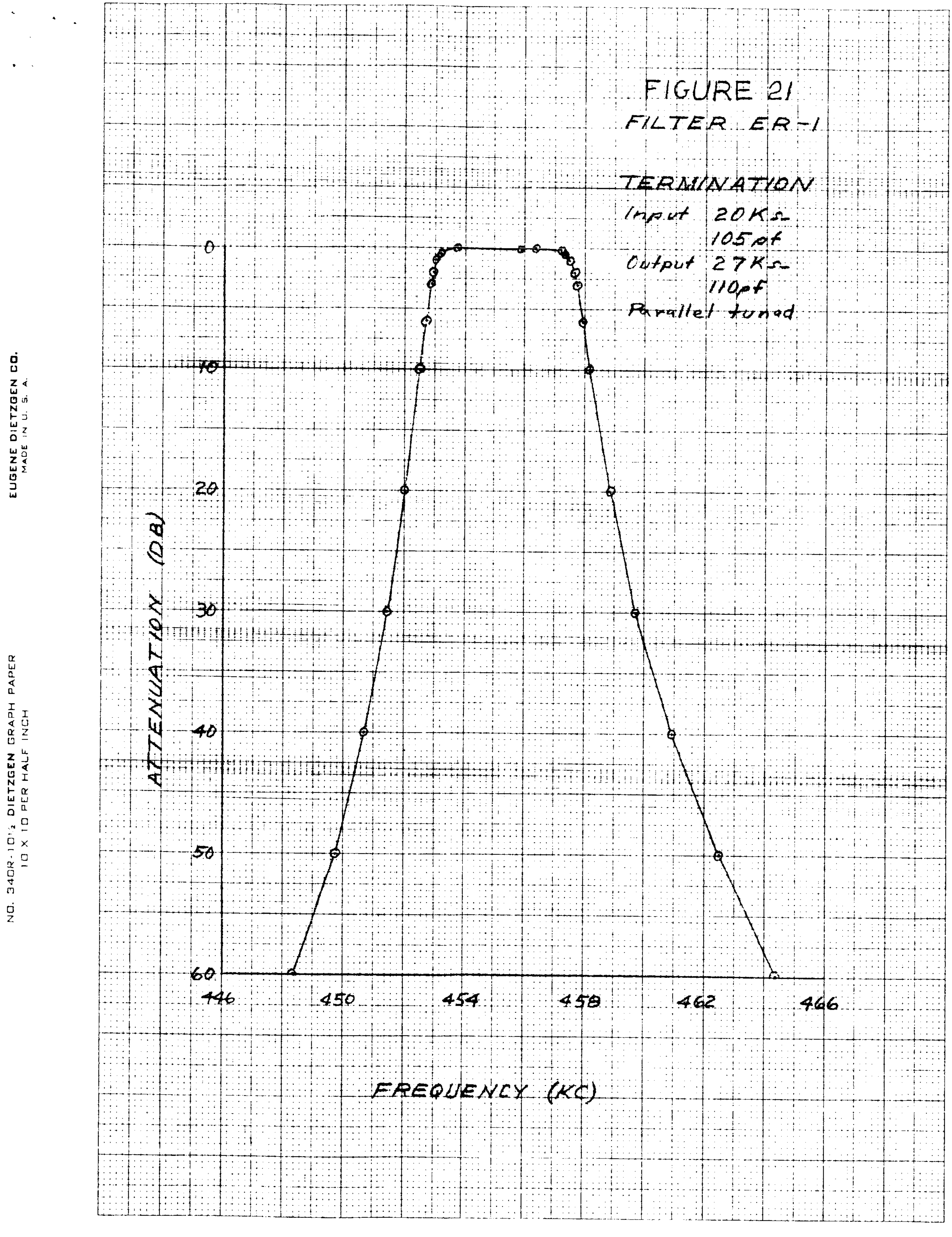
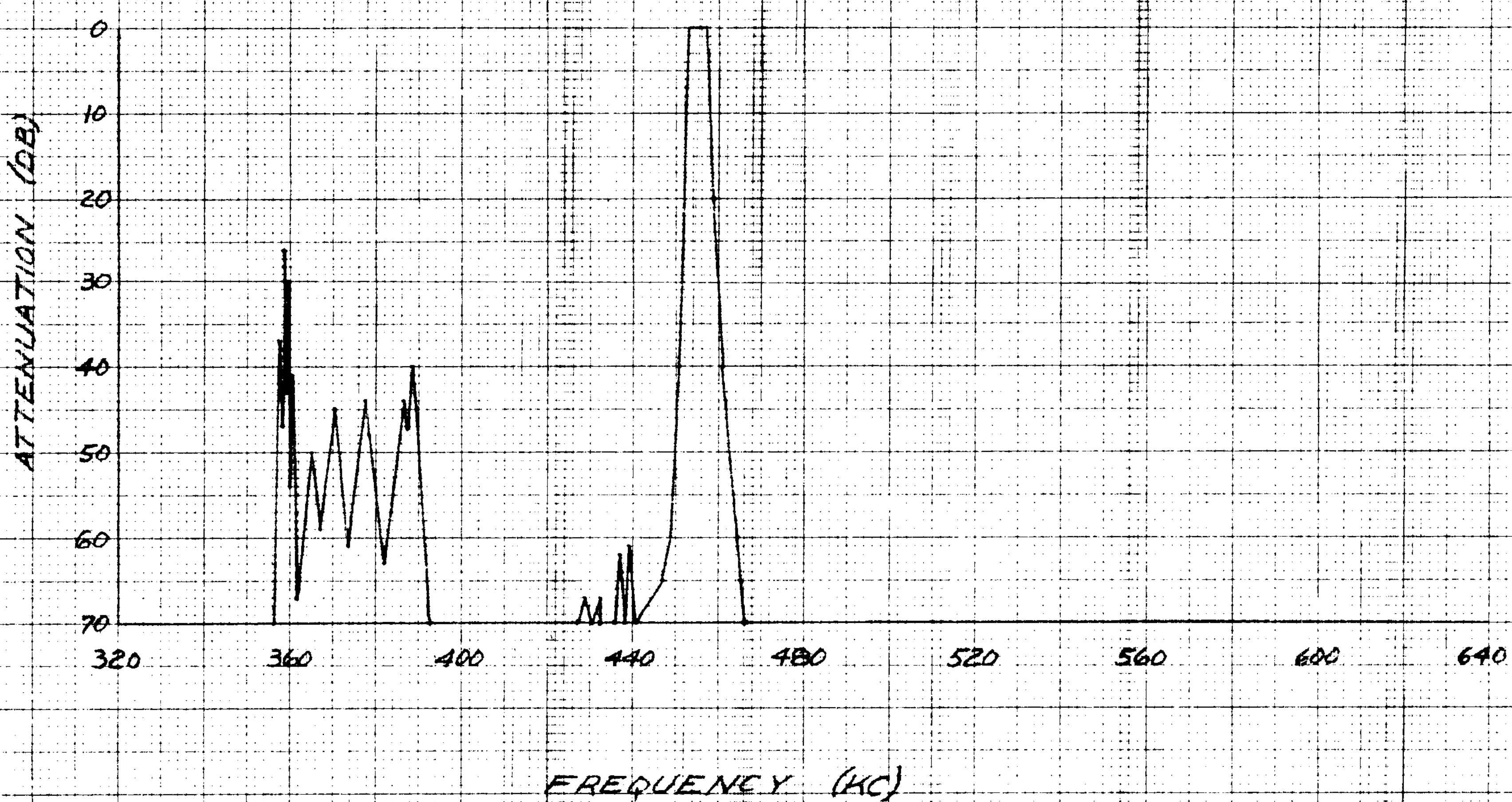


FIGURE 21
FILTER ER-1
TERMINATION
Input 20KΩ
105pf
Output 27KΩ
110pf
Parallel tuned
ATTENUATION (DB)
0
10
20
30
40
50
60
446
450
454
458
462
466
FREQUENCY (KC)
EUGENE DIETZGEN CO.
MADE IN U. S. A.
NO. 340R-10½ DIETZGEN GRAPH PAPER
10 X 10 PER HALF INCH

FIGURE 22
FILTER ER-1
SPURIOUS PLOT



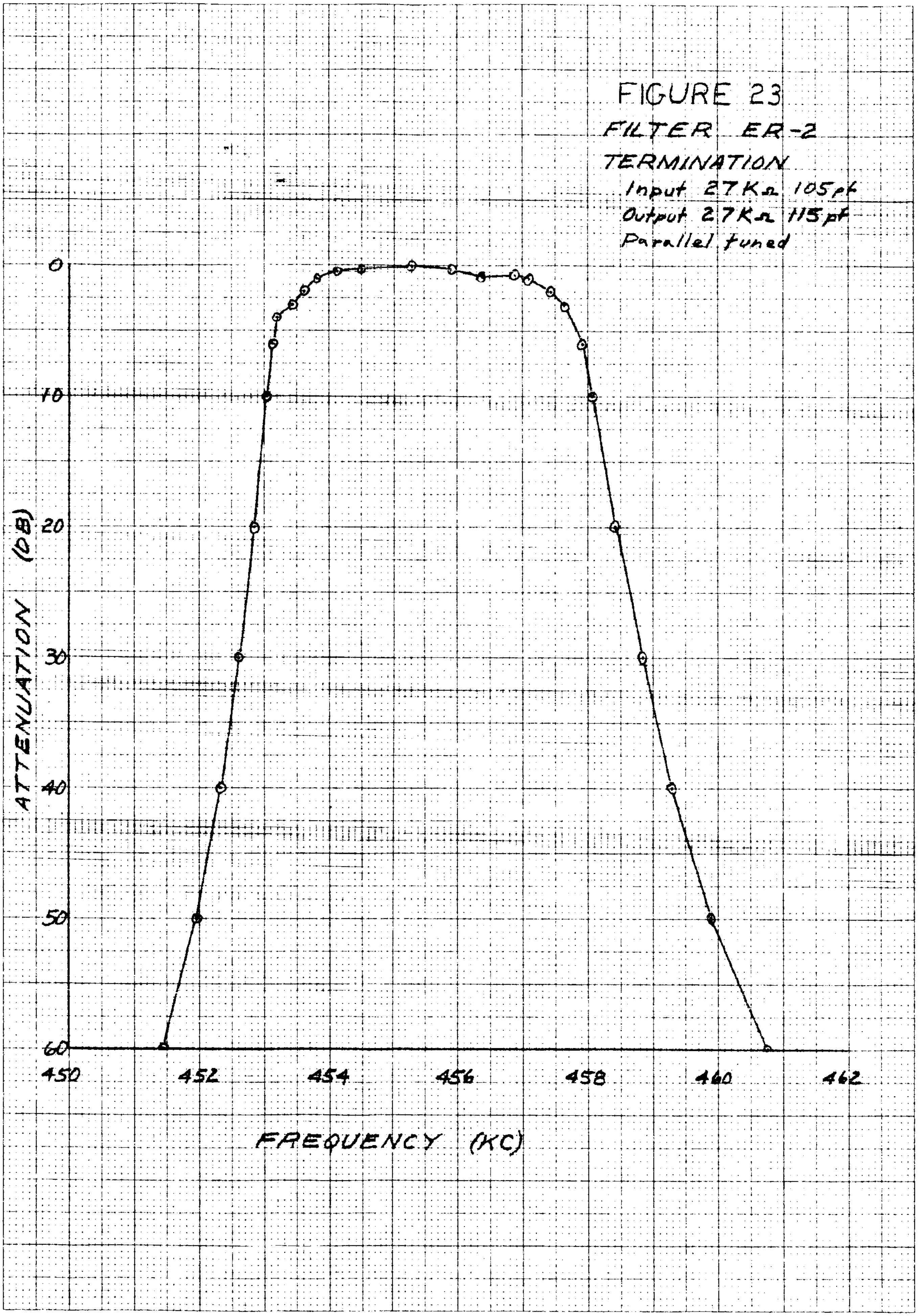


FIGURE 23
FILTER ER-2
TERMINATION
Input 27KΩ 105pf
Output 27KΩ 115pf
Parallel tuned
ATTENUATION (DB)
0
10
20
30
40
50
60
450
452
454
456
458
460
462
FREQUENCY (KC)

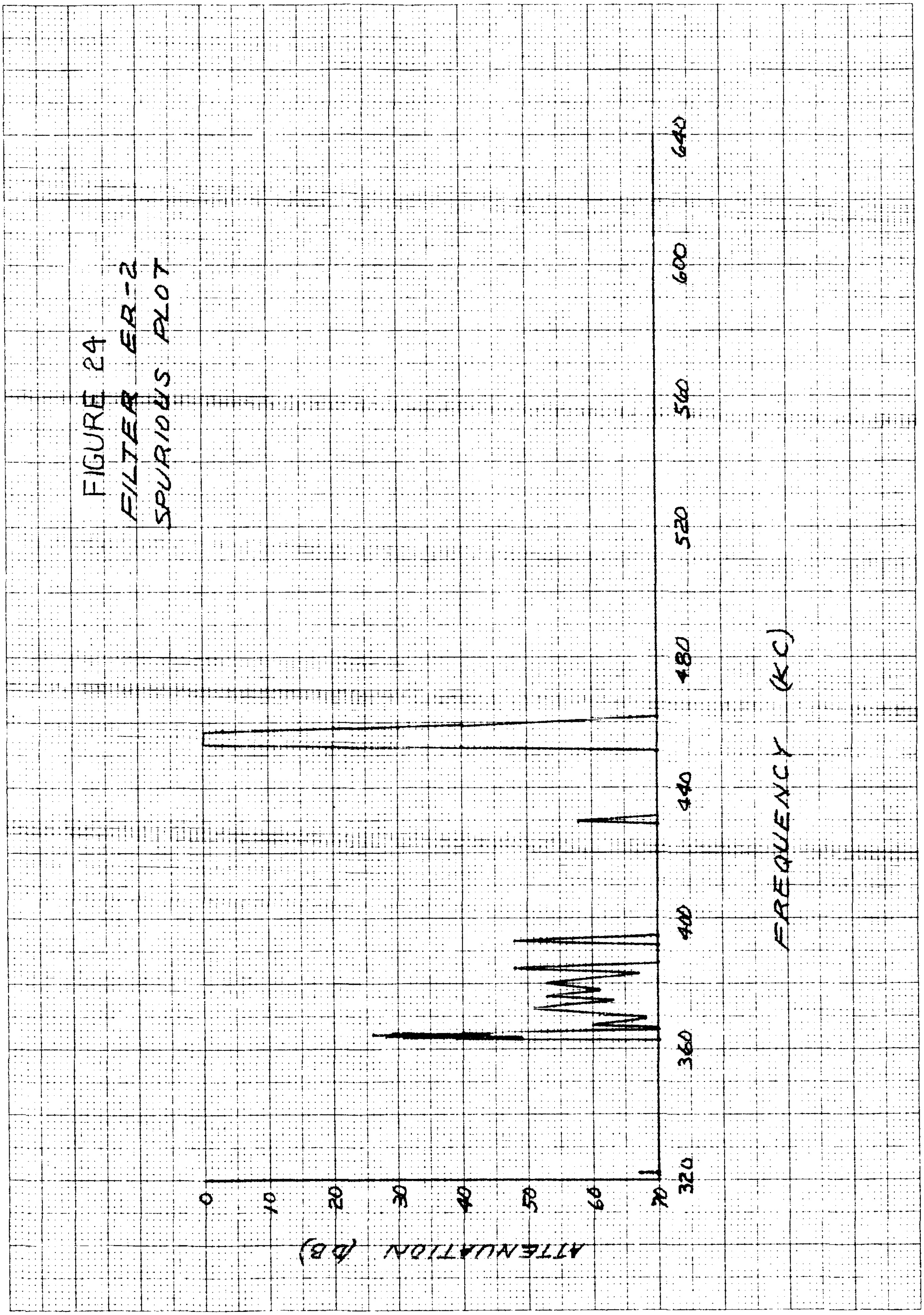


FIGURE 24
FILTER ER-2
SPURIOUS PLOT

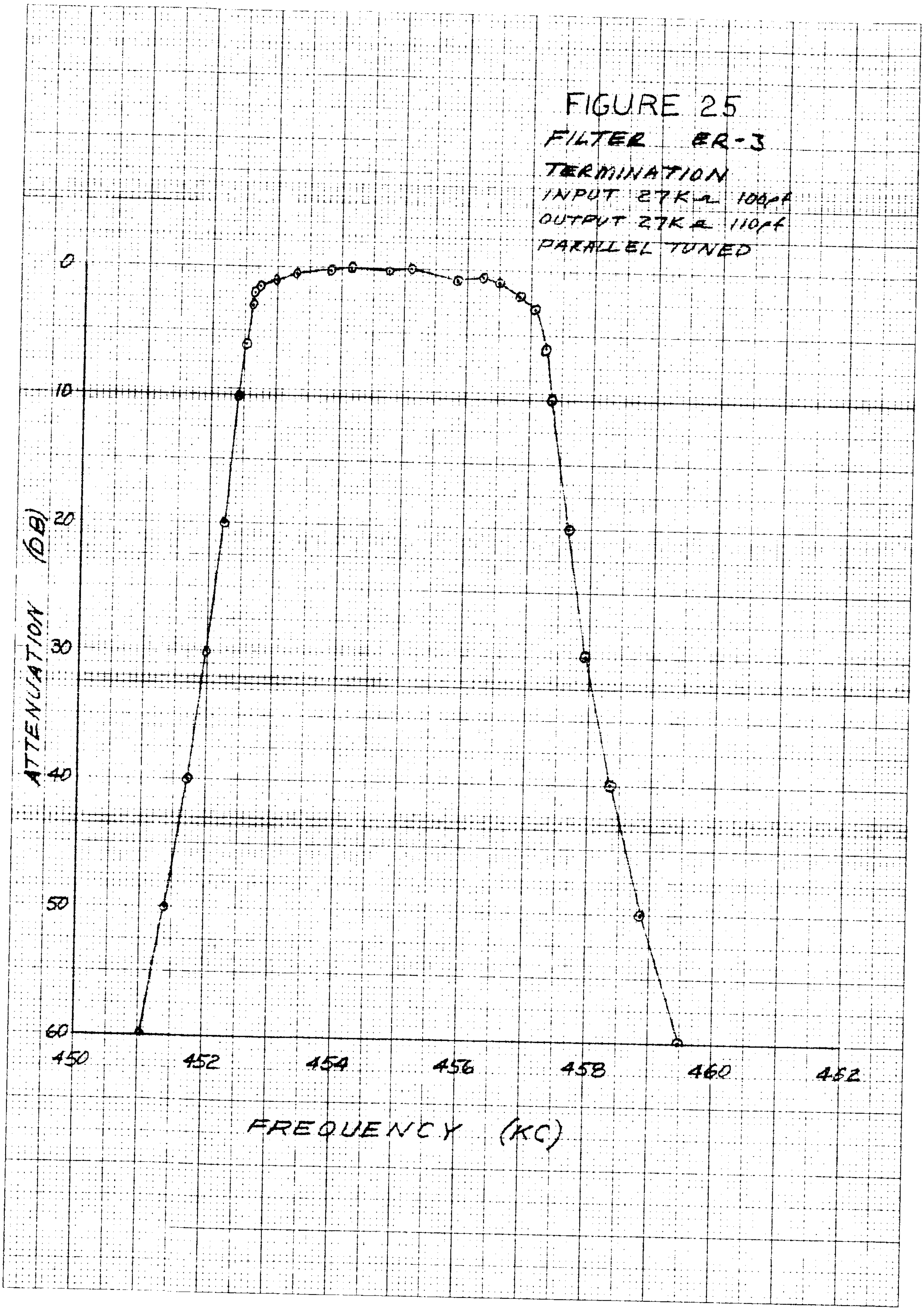
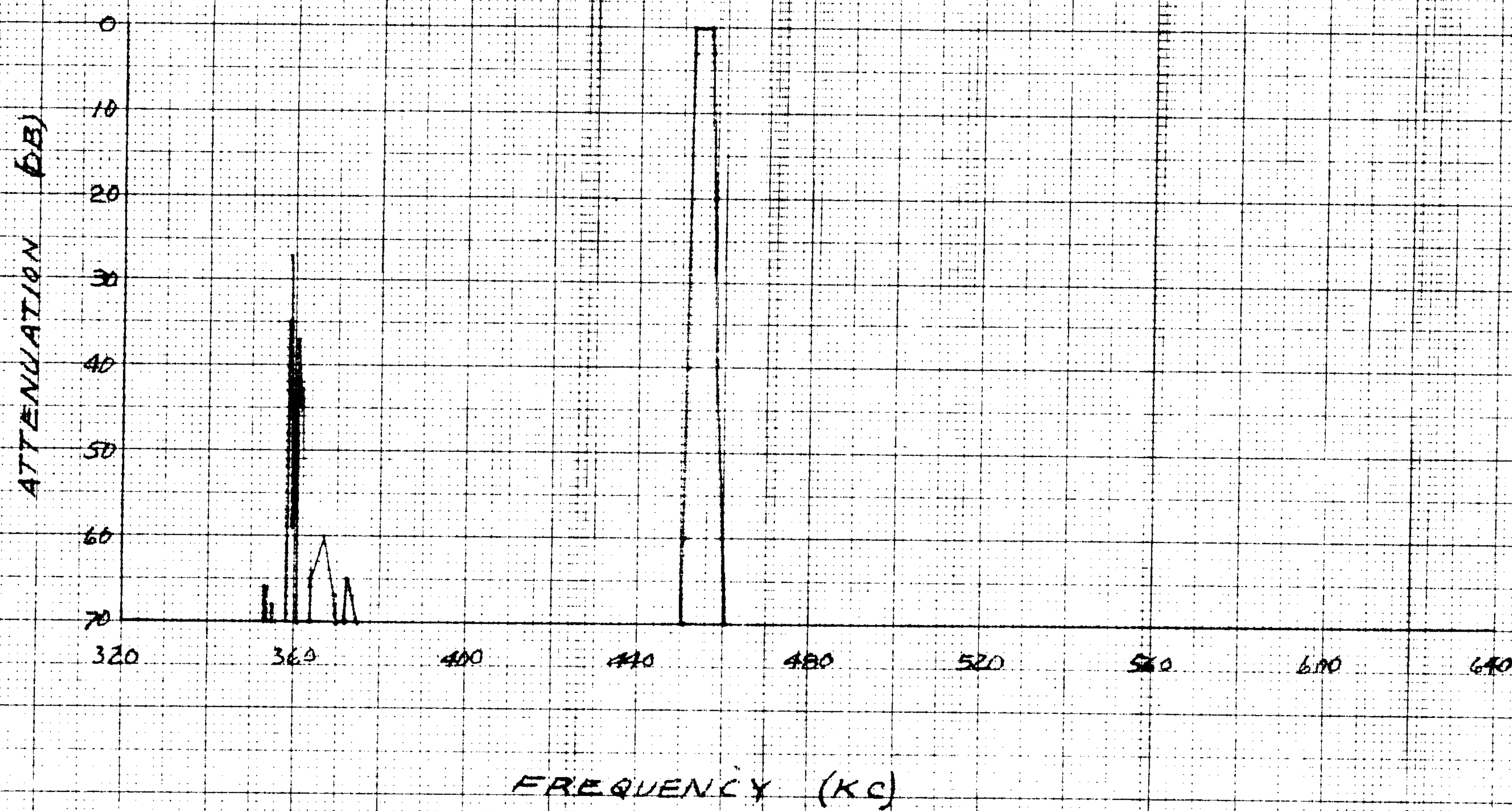


FIGURE 25
FILTER ER-3
TERMINATION
INPUT 27K Ω 100 pf
OUTPUT 27K Ω 110 pf
PARALLEL TUNED
ATTENUATION (DB)
0
10
20
30
40
50
60
450
452
454
456
458
460
462
FREQUENCY (KC)

FIGURE 26
FILTER ER-3
SPURIOUS PLOT



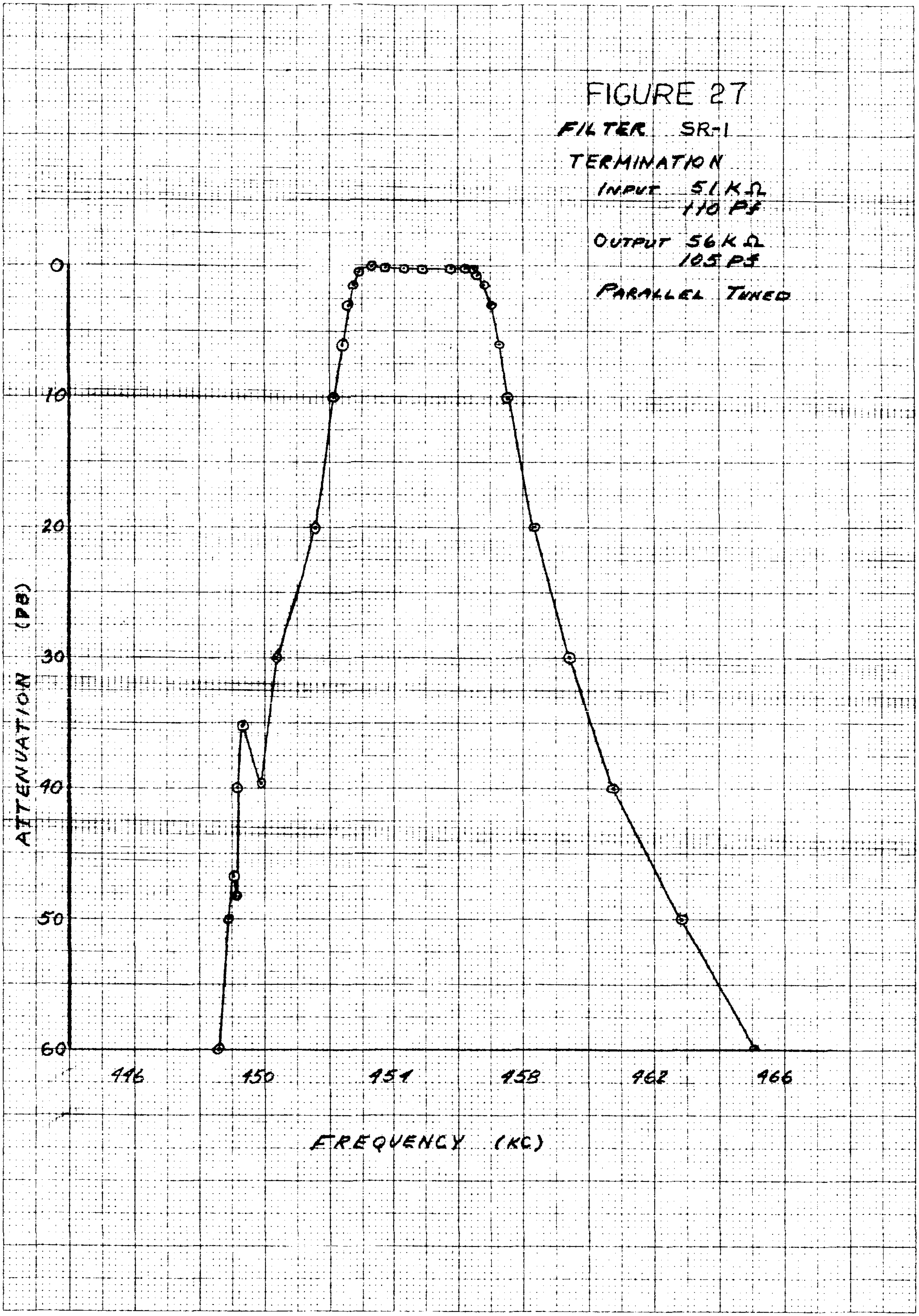
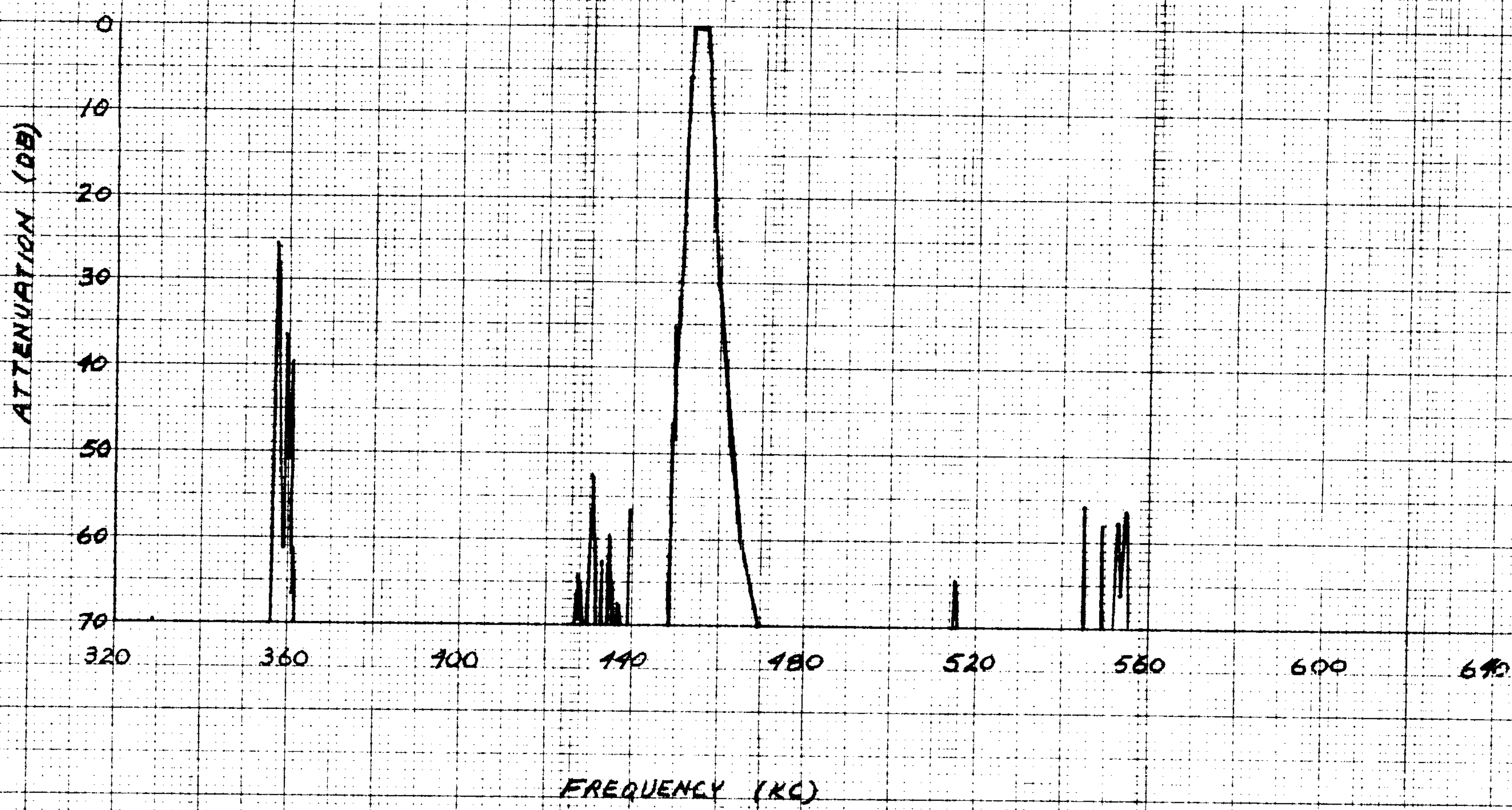


FIGURE 27
FILTER SR-1
TERMINATION
INPUT 51 K Ω
110 PF
OUTPUT 56 K Ω
105 PF
PARALLEL TUNED
ATTENUATION (DB)
0
10
20
30
40
50
60
446
450
454
458
462
466
FREQUENCY (KC)

FIGURE 28

FILTER SR-1

SPURIOUS PLOT



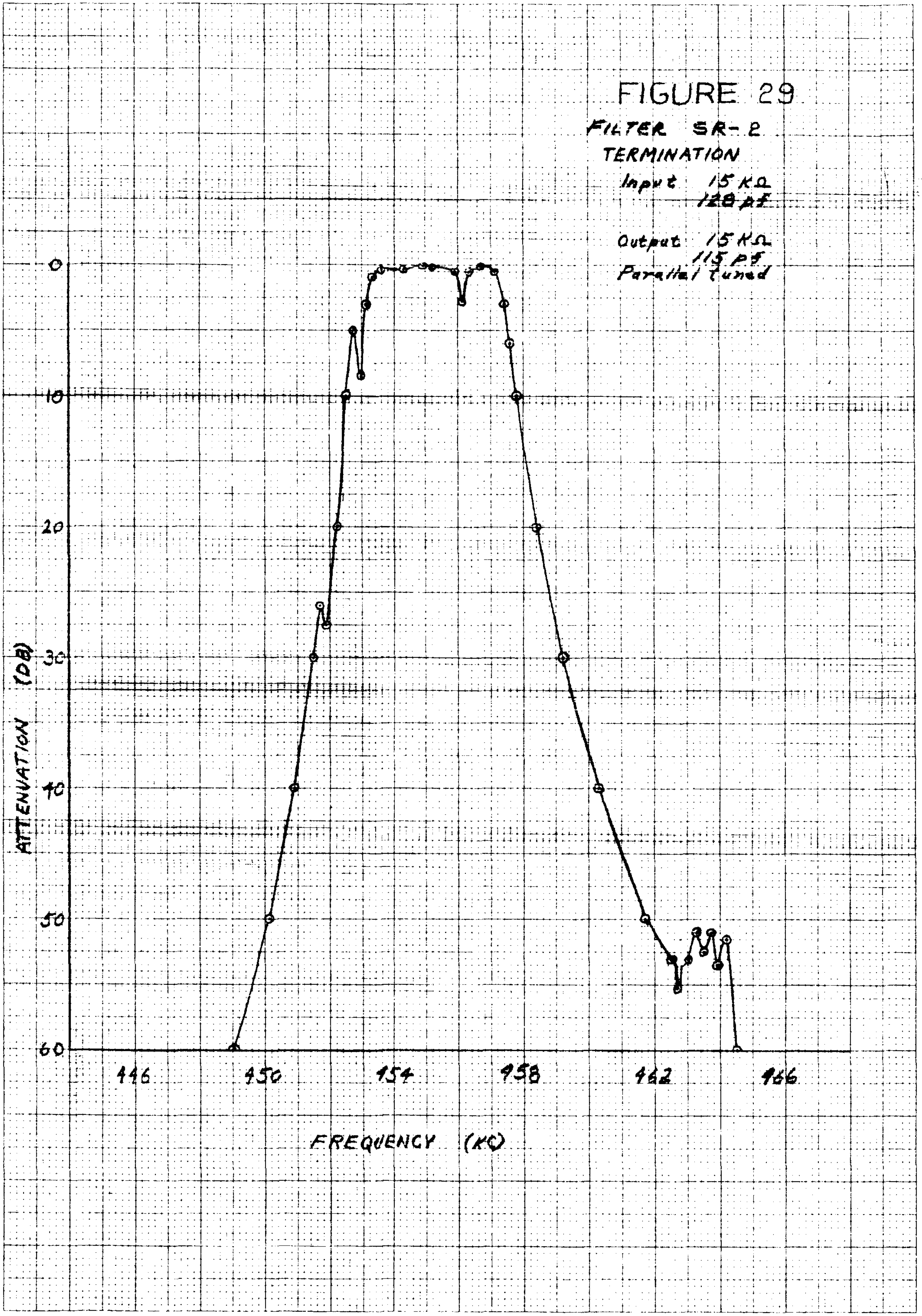


FIGURE 29
FILTER SR-2
TERMINATION
Input 15 KΩ
128 pF
Output 15 KΩ
115 pF
Parallel tuned
0
10
20
30
40
50
60
ATTENUATION (DB)
446
450
454
458
462
466
FREQUENCY (KC)

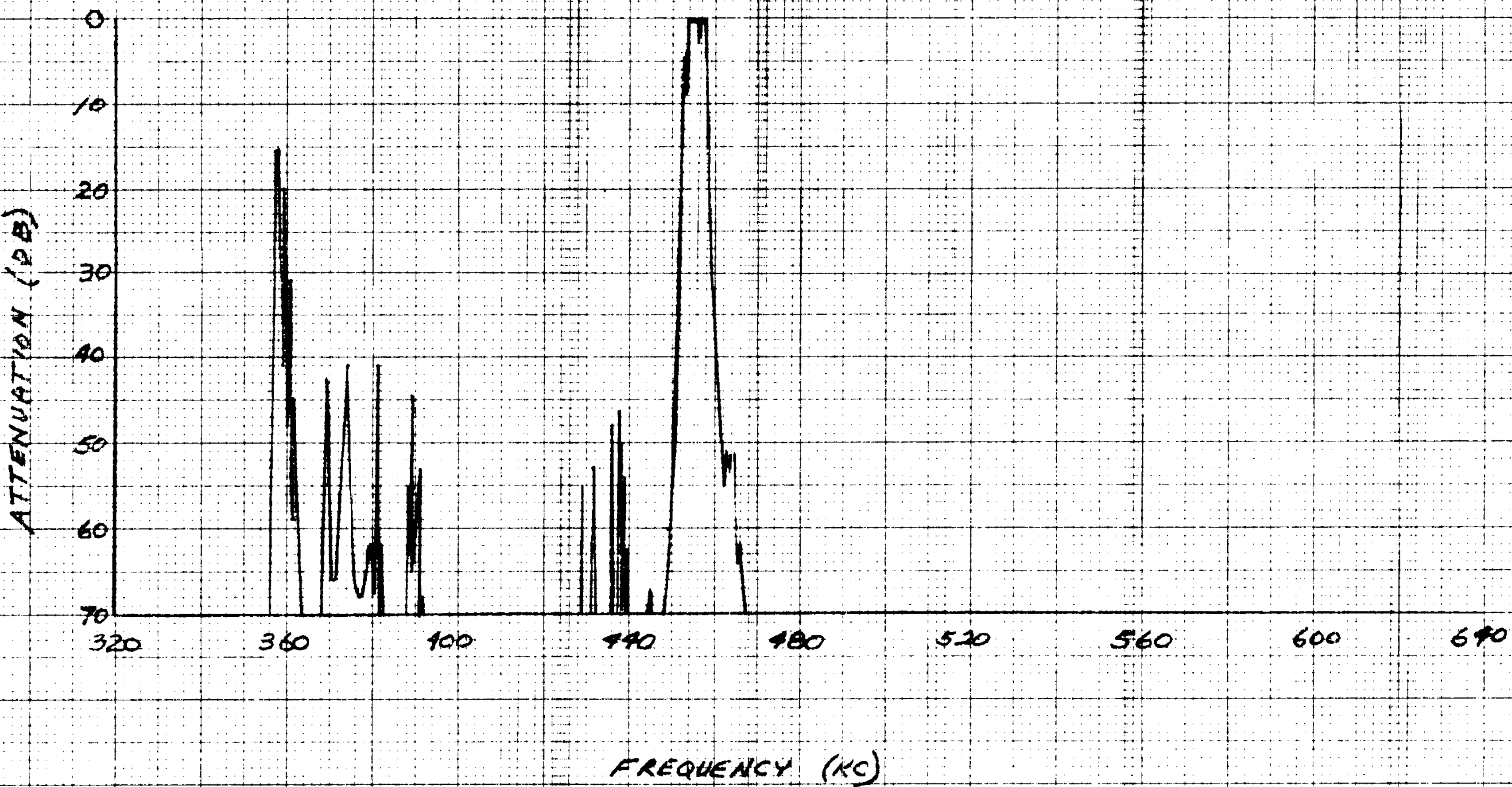


FIGURE 30
FILTER SR-2
SPURIOUS PLOT

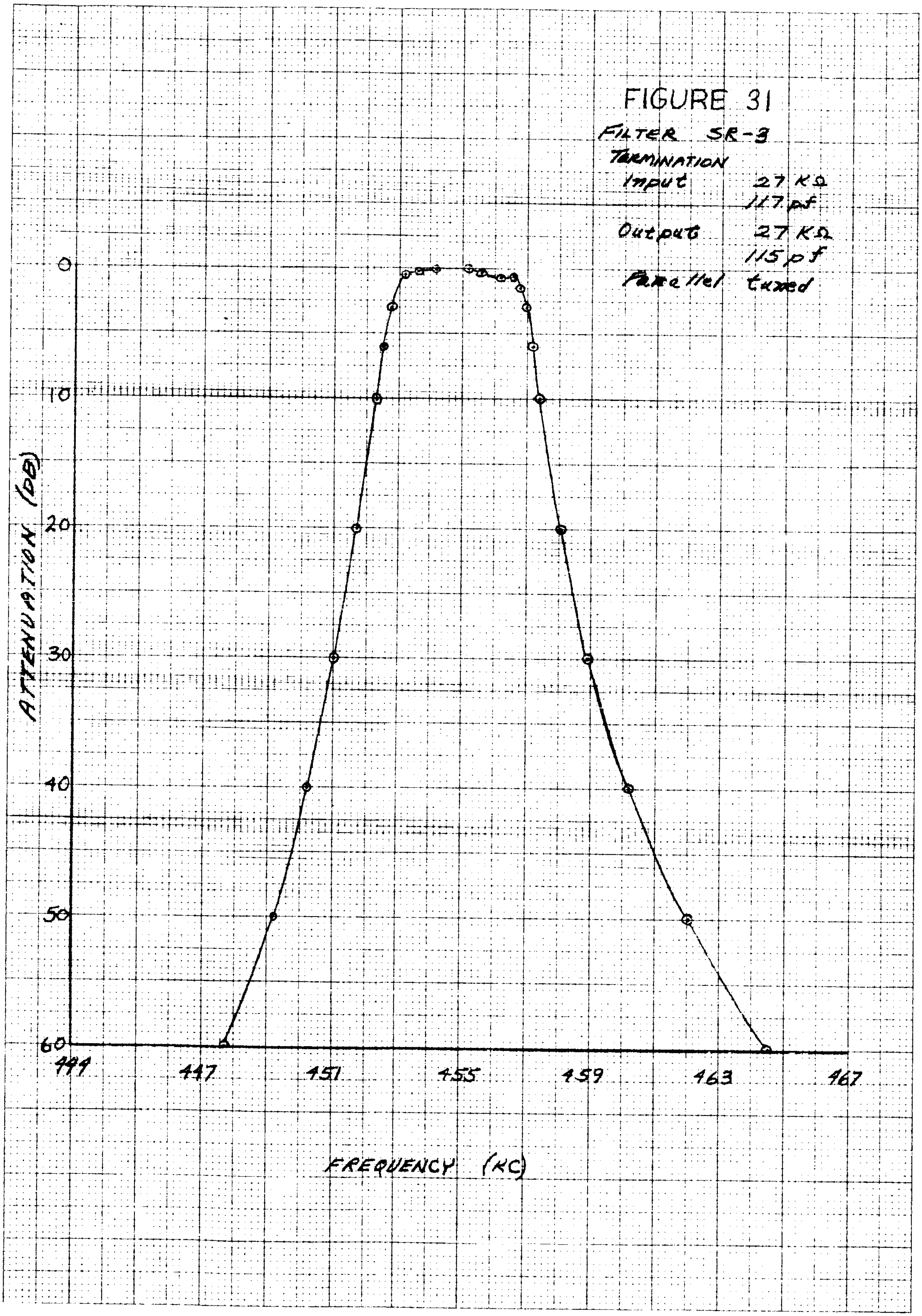
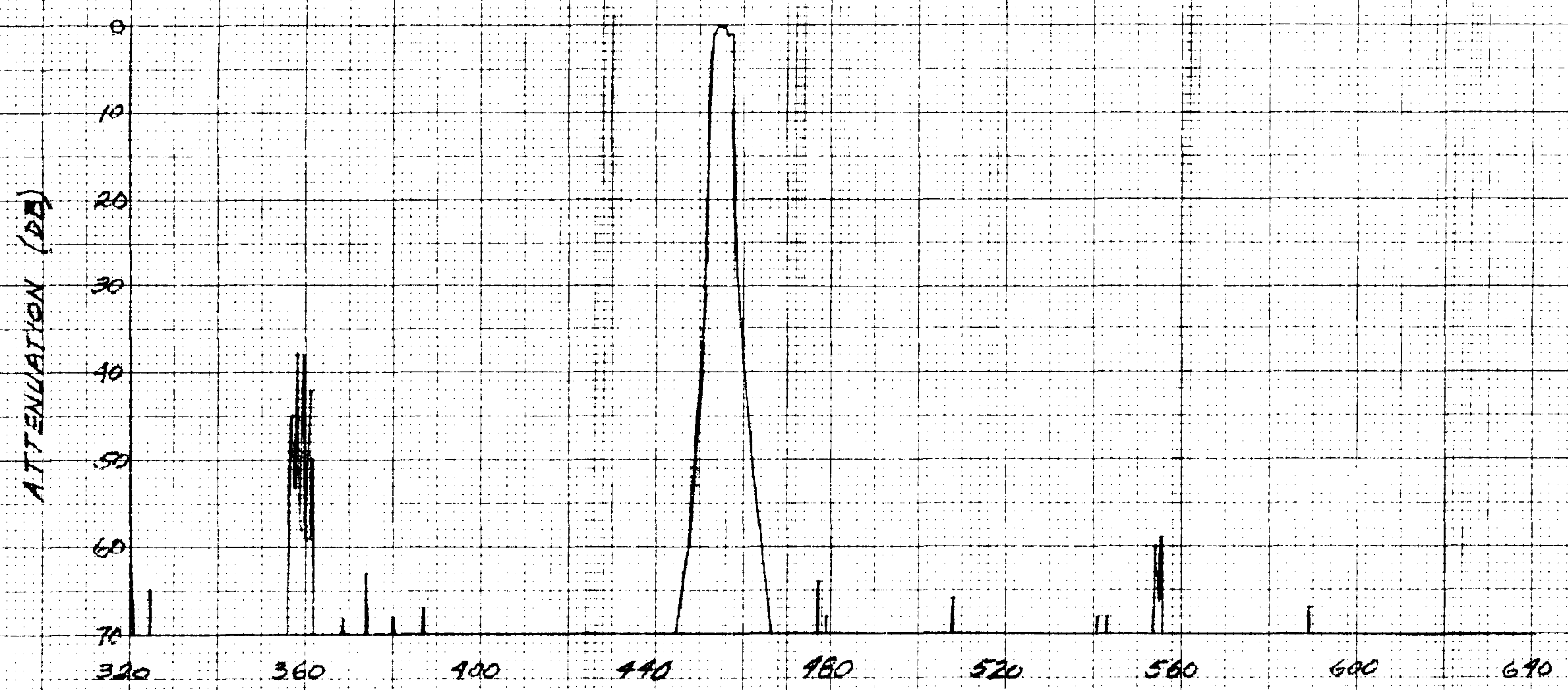
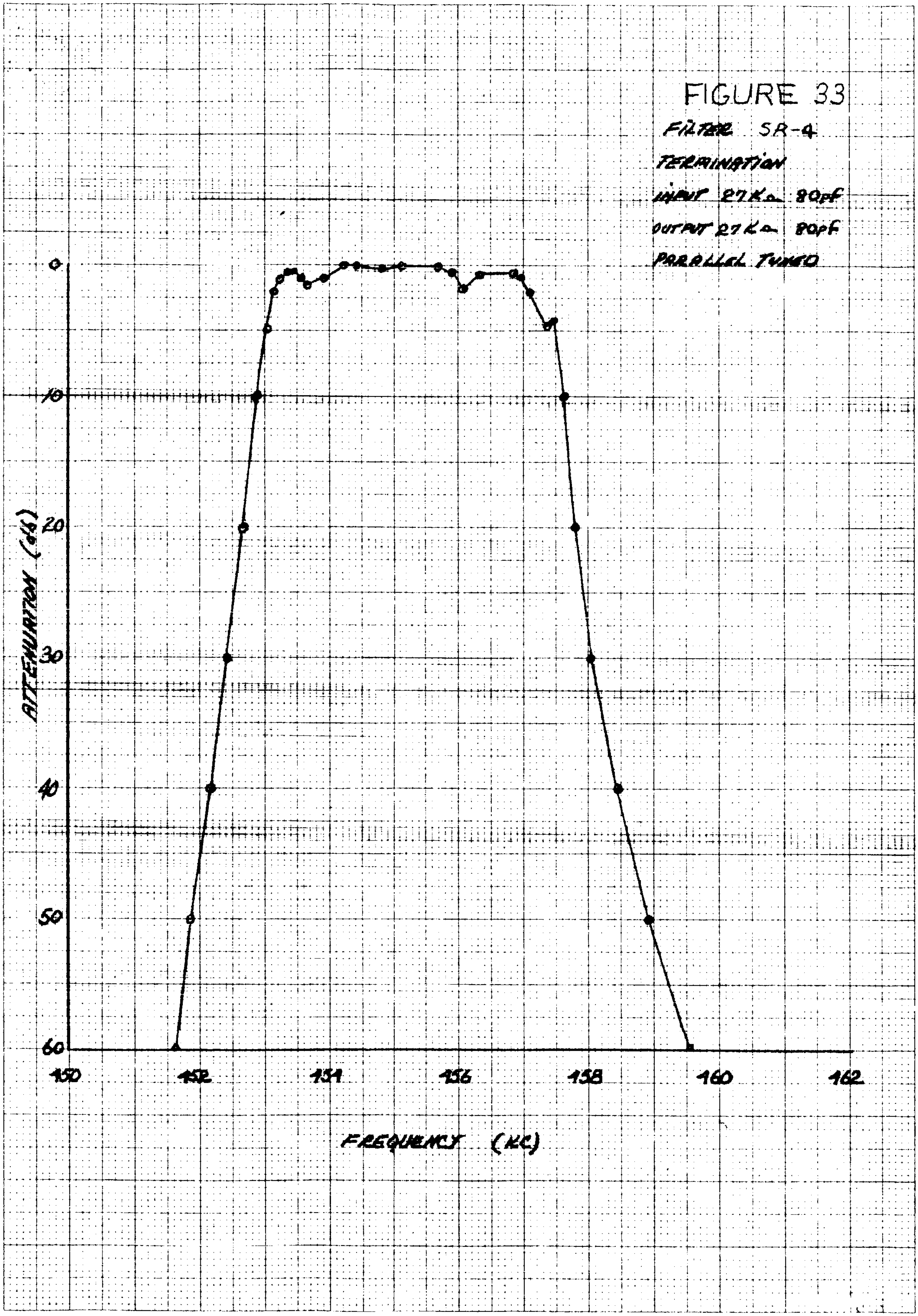


FIGURE 31
FILTER SR-3
TERMINATION
Input 27 KΩ
117 pf
Output 27 KΩ
115 pf
Parallel tuned
0
10
20
30
40
50
60
ATTENUATION (DB)
444
447
451
455
459
463
467
FREQUENCY (KC)

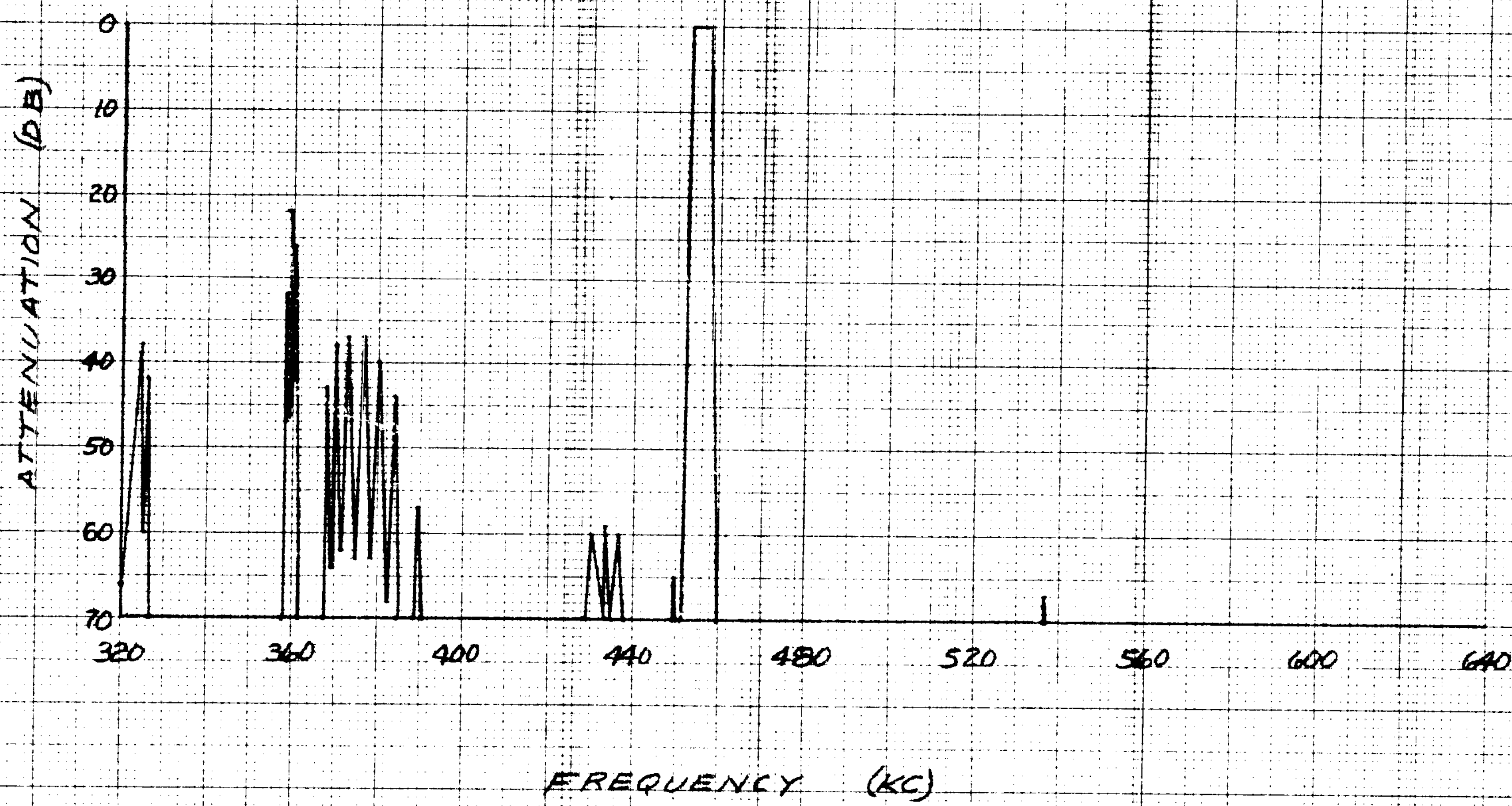
FIGURE 32
FILTER SR-3
SPURIOUS PLOT





NO. 340R-10½ DIETZGEN GRAPH PAPER
10 X 10 PER HALF INCH
EUGENE DIETZGEN CO.
MADE IN U. S. A.

FIGURE 34
FILTER SR-4
SPURIOUS PLOT



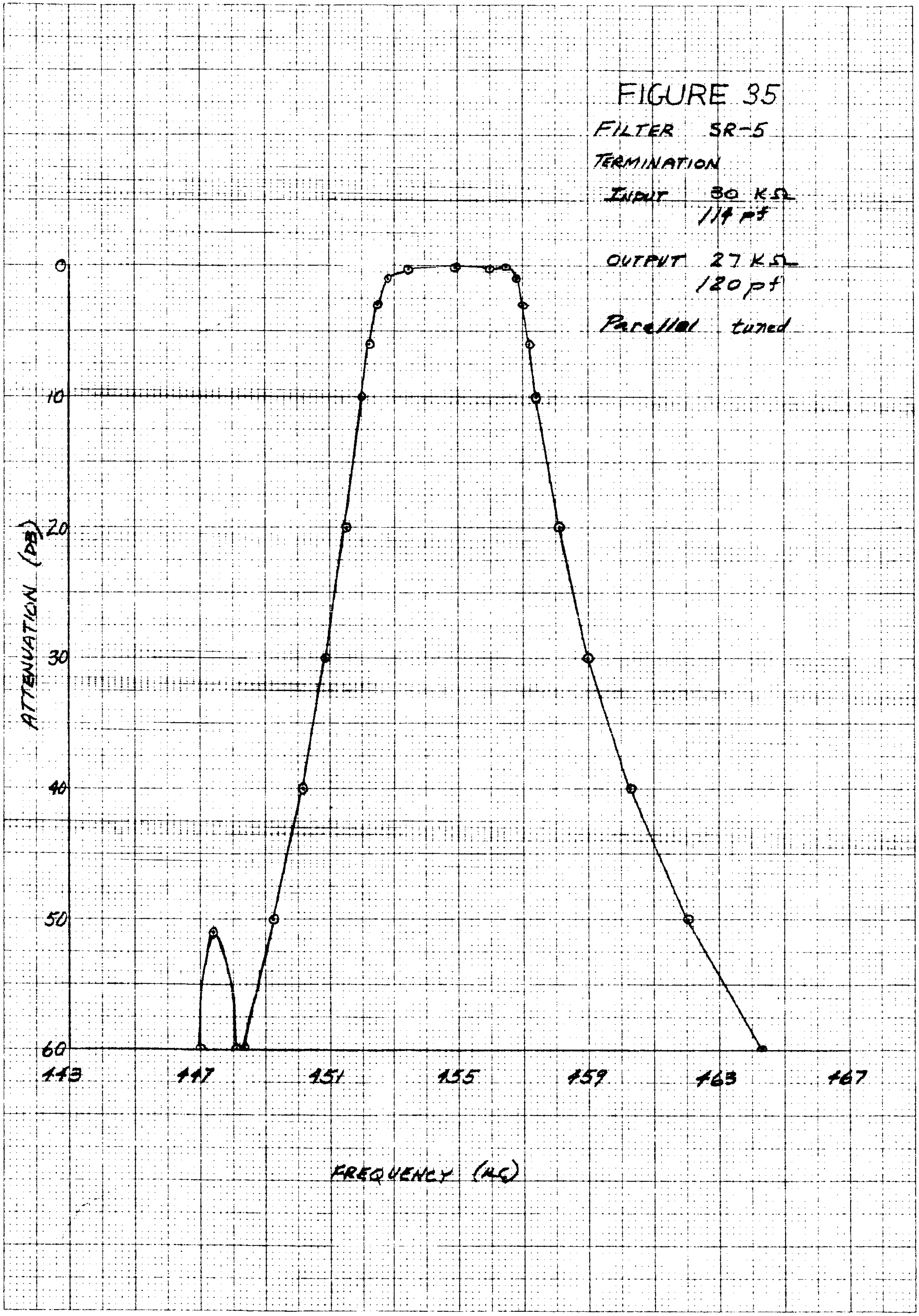


FIGURE 35
FILTER SR-5
TERMINATION
INPUT 30 KΩ
114 pf
OUTPUT 27 KΩ
120 pf
Parallel tuned
ATTENUATION (DB)
0
10
20
30
40
50
60
443
447
451
455
459
463
467
FREQUENCY (KC)

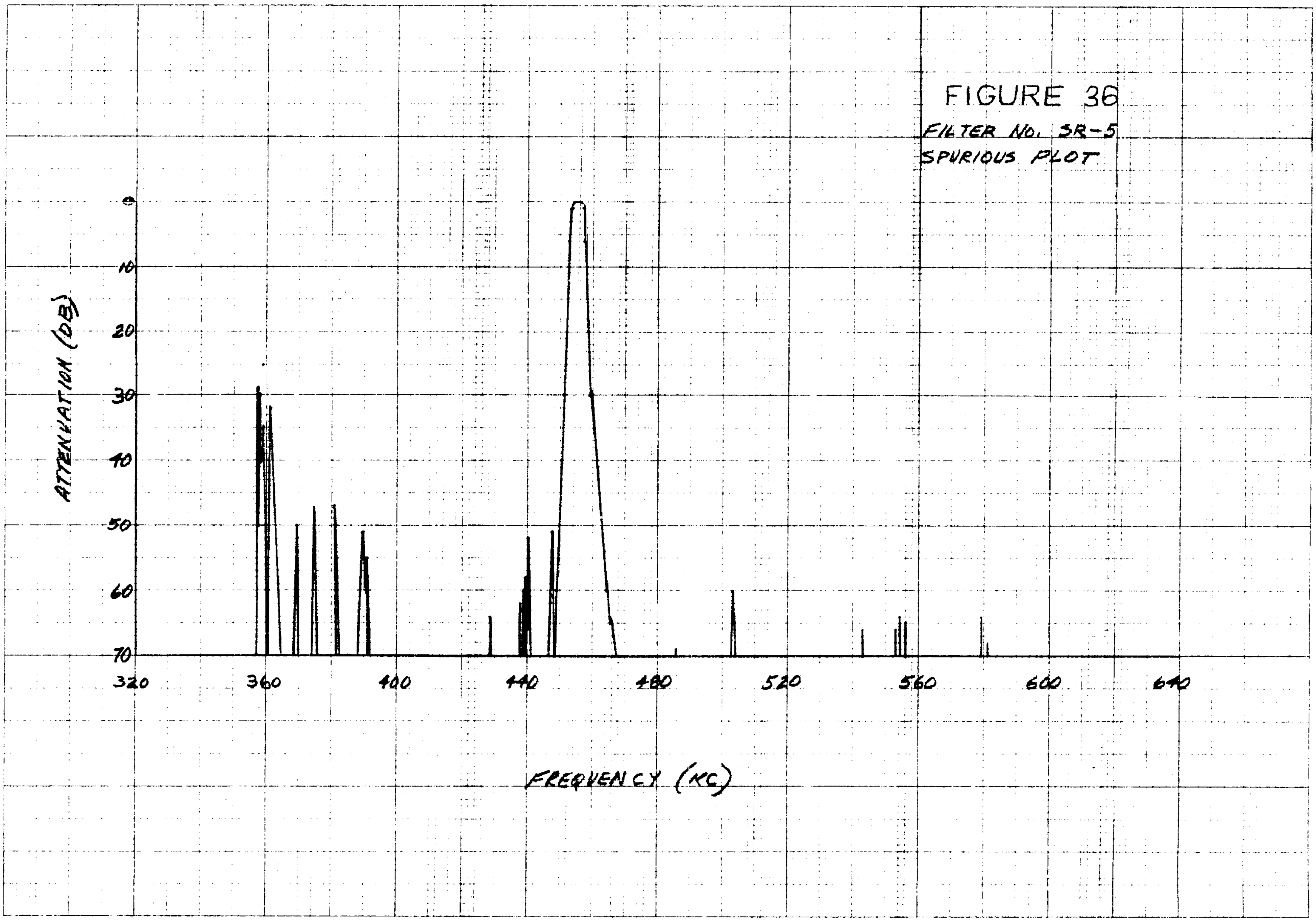
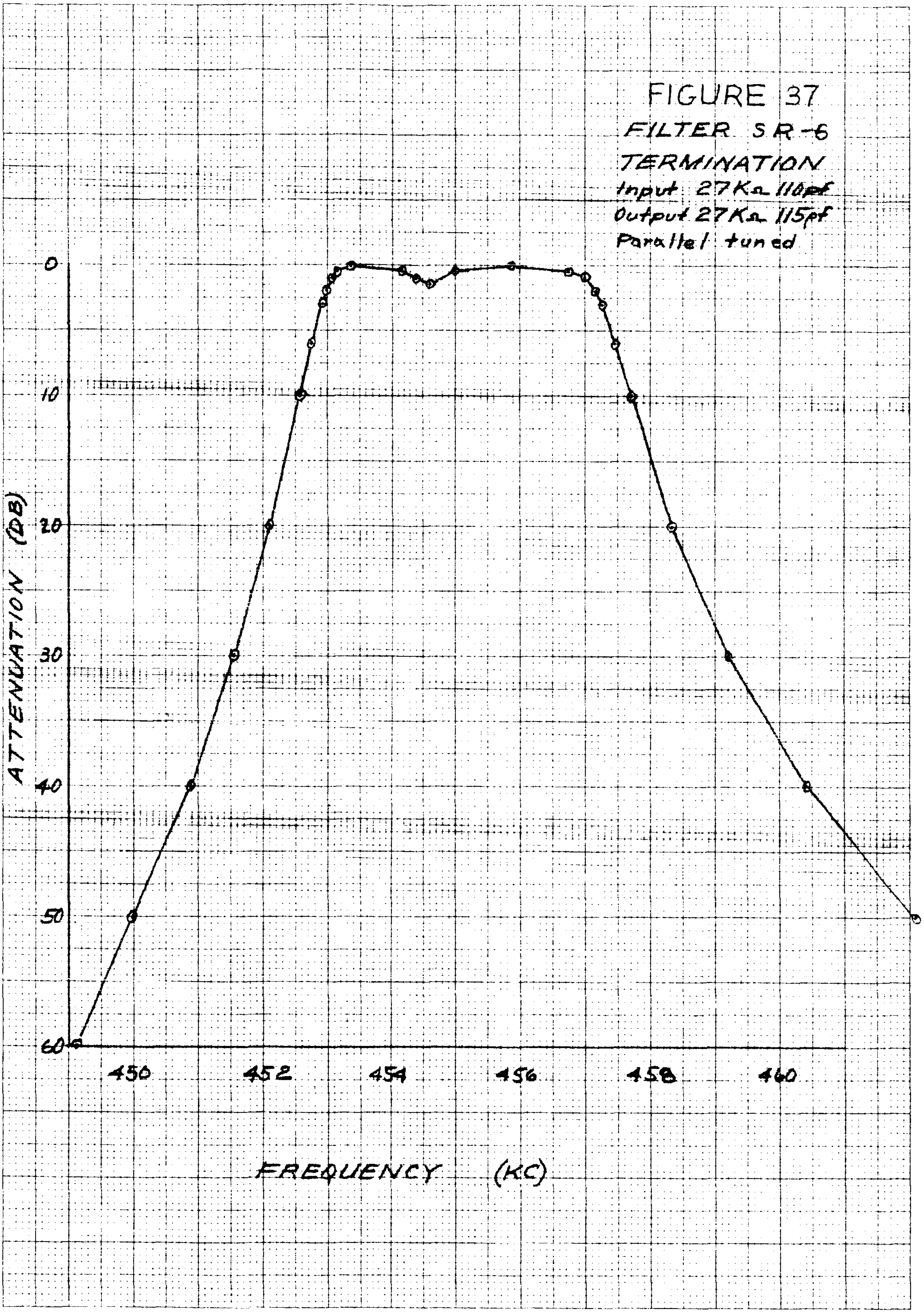
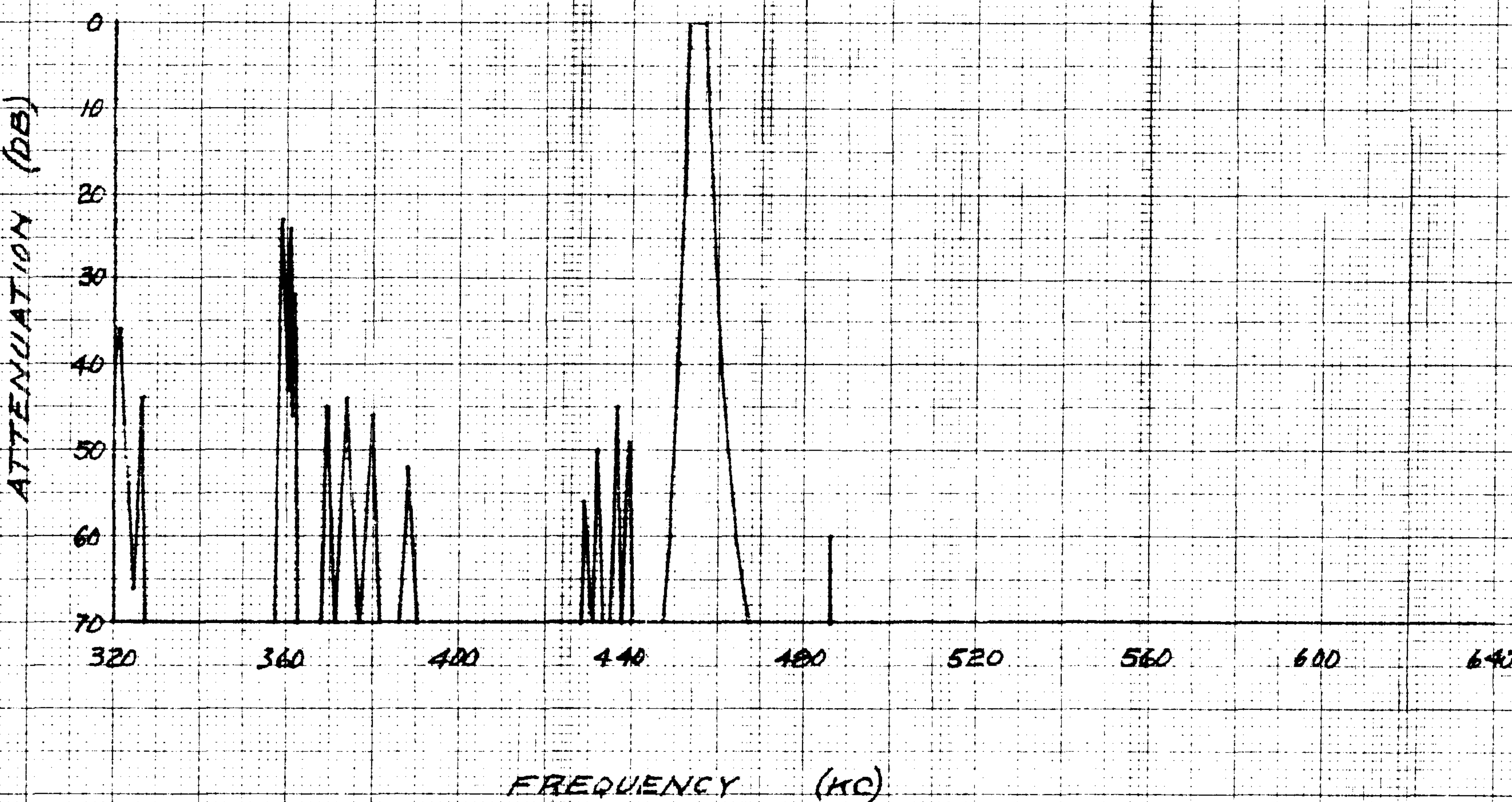


FIGURE 36
FILTER No. SR-5
SPURIOUS PLOT
ATTENUATION (DB)
0
10
20
30
40
50
60
70
320
360
400
440
480
520
560
600
640
FREQUENCY (KC)



NO. 340R-10', DIETZGEN GRAPH PAPER
10 X 10 PER HALF INCH
EUGENE DIETZGEN CO.
MADE IN U. S. A.

FIGURE 38
FILTER SR-6
SPURIOUS PLOT



6. APPENDICES

6.1 Parameter Study of Mathematical Model for Mechanical Filters

6.2 **Sideband Filter** Specification 526-9445-00

6.3 Frequency Selector Filter Specification 526-9430/9444-00

6.1 Parameter Study of Mathematical Model for Mechanical Filters

In order to predict the effect of variations in ring parameters on bandwidth, it was necessary to investigate the mechanical filters analogous electrical circuit. In the circuit of Figure I, inductance is analogous to a spring and capacitance is analogous to a mass. If this circuit is designed on an image parameter basis, the element values are defined as follows:

$$(1) \quad L_R = \frac{2\,R_n}{\omega_1 + \omega_2} = \frac{2\,R_n}{2\omega_1 + BW}$$

$$(2) \quad L_D = \frac{R_n\,BW}{2\omega_1^{\,2}}$$

$$(3) \quad C_D = \frac{2}{R_n\,BW}$$

Where:

L_R = equivalent inductance of the coupling ring

L_D = equivalent inductance of the disk

C_D = equivalent capacitance of the disk

ω_1 = lower cutoff frequency

ω_2 = upper cutoff frequency

$BW = \omega_2 - \omega_1$

R_n = design impedance

Substituting the expression for R_n obtained from (3) into (1) we find:

$$(4) \quad L_R = \frac{4}{C_D(2\omega_1 + BW)BW}$$

The coupling inductance L_R in the electrical analogy can also be expressed in terms of the mechanical dimensions:

$$(5) \quad L_R = \frac{l_R}{A_R E}$$

Where:

A_R = cross sectional area of coupling ring

E = Youngs Modulus

l_R = total length of coupling ring (spacing between disks)

From Figure II, it can be shown that:

$$(6) \quad A_R = \pi\ T_R\ (D_R - T_R)$$

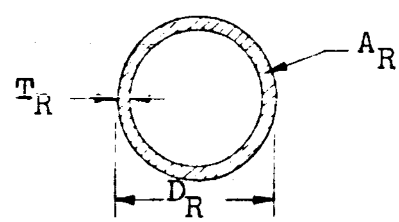


Figure II Cross Sectional View of Coupling Ring

For $D_R >> T_R$

$$(7) \quad A_R \cong \pi\ T_R\ D_R$$

Combining equations (4), (5) and (7)

$$(8) \quad \frac{4}{C_D\ (2\omega_1 + BW)BW} \cong \frac{l_R}{\pi E\ T_R\ D_R}$$

Figure III shows a plot of equivalent mass versus normalized distance from the center of a disk of radius a, vibrating in a two nodal circle flexural mode.[1] The two points of discontinuity represent the nodal circles where the velocity is zero. The coupling ring is placed at:

$$\frac{r}{a} = \frac{.119}{.350} = .340$$

For very small variations in r ($\Delta r \leq .001''$) we can approximate the curve with a straight line in the region of interest.

$$(9) \quad C_D = Meq \cong 246\ D_R - 27.4 \quad \text{for } .124'' \leq D_R \leq .126''$$

Substituting (9) into (8) and letting $K = 4\pi E$ we have:

$$(10) \quad \frac{K}{(246\ D_R - 27.4)\ (2\omega_1 + BW)BW} \cong \frac{l_R}{T_R\ D_R}$$

To find $\frac{dBW}{BW}$ (the fractional change in bandwidth) from equation (10), treat l_R as the dependent variable and write:

$$(11) \quad l_R \cong \frac{K\ T_R\ D_R}{(246\ D_R - 27.4)\ (2\omega_1 + BW)BW}$$

With l_R expressed as a function of three independent variables we can find the total derivative of l_R as a function of the partial derivatives of l_R and the total derivatives of the independent variables.

$$(12) \quad dl_R = \frac{\partial l_R}{\partial T_R}\ dT_R + \frac{\partial l_R}{\partial D_R}\ dD_R + \frac{\partial l_R}{\partial BW}\ dBW$$

Taking the partial derivatives and dividing both sides of the equation by l_R we have:

(1) Roshan Lal Sharma "Axially Symmetric Vibrations of a Thick Circular Disk" Collins Radio Company (unpublished)

$$(13)\quad \frac{dl_R}{l_R} \cong \frac{dT_R}{T_R} - \frac{27.4}{246\, D_R - 27.4}\,\frac{dD_R}{D_R} - \frac{2\omega_1 + 2BW}{2\omega_1 + BW}\,\frac{dBW}{BW}$$

Solving equation (13) for $\frac{dBW}{BW}$ and letting $BW = 2\pi\ 3$ KC, $\omega_1 =$ $2\pi\ 455$ KC and $.124'' \leq D_R \leq .126''$ we find:

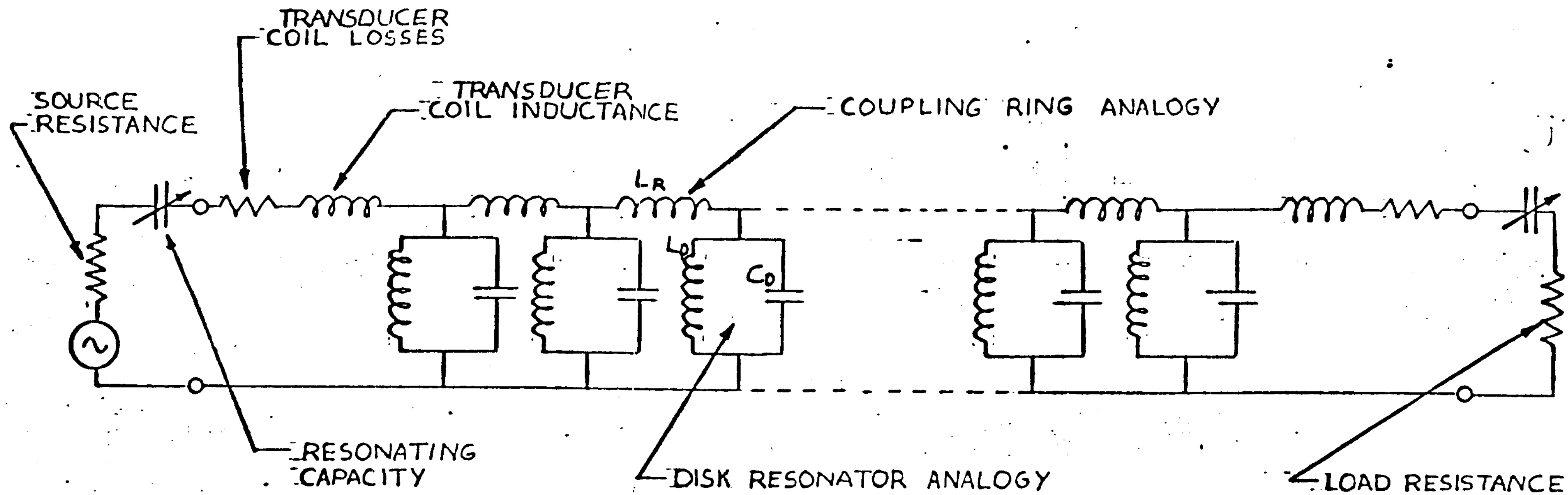
$$(14)\quad \frac{dBW}{BW} \cong \frac{dT_R}{T_R} - 8\,\frac{dD_R}{D_R} - \frac{dl_R}{l_R}$$

We now have an expression for the fractional change in bandwidth in terms of the fractional changes in ring dimensions. Considering dimensional tolerances of ±.001, the possible variation in bandwidth would be:

$$\frac{dBW}{BW}\ (\%) \cong \pm \left[\frac{.001}{.006} + 8\,\frac{(.001)}{.125} + \frac{.002}{.060}\right] 100 = \pm 26.4\%$$

If all ring tolerances were reduced to a machining practical limit of ±.0005", the possible variation in bandwidth would be:

$$\frac{dBW}{BW}\ (\%) \cong \pm 13.2\%$$



MECHANICAL FILTER ELECTRICAL ANALOGY

FIGURE I

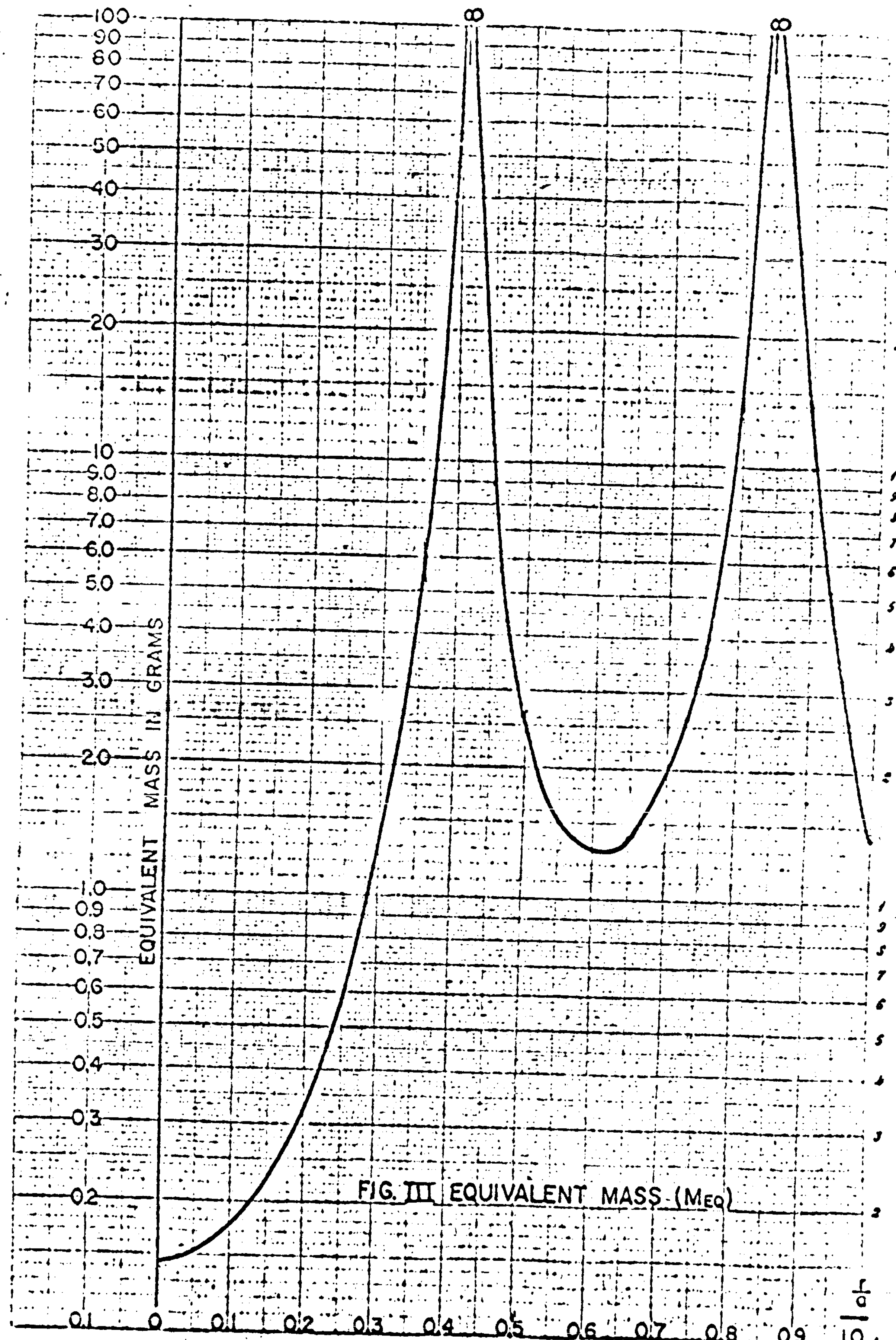


FIG. III EQUIVALENT MASS (M_{EQ})

6.2 Sideband Filter Specifications 526-9445-00

APPLICATION		QTY REQD		REVISIONS			
NEXT ASSY	USED ON	NEXT ASSY	FINAL ASSY	SYM	DESCRIPTION	DATE	APPROVAL
				A	CD-00489; Added P/N 526-9445-021.	26 OCT 1962	
				B	CD-04447; Changed location of decal on dwg. sheet 5.	1 FEB 1963	2-20-63
				C	REV. PARA(a) UNDER 526-9445-011, CD 03899	10 OCT 1963	

Description: This specification covers the requirements of a 455 KC carrier, upper sideband selector, mechanical.

REFERENCE ONLY

JUN 25 1964

QTY REQD	SYM	ITEM NO.	PART NUMBER	PART NAME	CODE IDENT	GOV'T IDENT NO.	SPECFICATION
1	5A	1	526-9445-003	MECH. FILTER			

LIST OF MATERIALS OR PARTS LIST

UNLESS OTHERWISE SPECIFIED	DWG BY	FILTER, MECHANICAL F455Z-10	COLLINS RADIO COMPANY NEWPORT BEACH CALIF
DIMS ARE IN IN. TOLERANCES ON FRAC ± DEC ± ANGLES ±	CHK BY R. Moret		
	ENGR		
MATERIAL —	ENGR L. Viles		CODE IDENT NO 95105
	APPROVE.	SCALE	DWG SIZE A — 526-9445-00
FINISH —	DATE WRITTEN 11 May 1962	WT	SHEET 1 OF 5

*When part number appears as 526-9445-009, Military Inspection is required.

When part number appears as 526-9445-011, the requirements shall be changed as follows:

(a) Paragraph 1.2., the 1.5 db at -25°C is changed to read 1.5 db at 0°C, and THE 1.7 db AT +85°C IS CHANGED TO READ 1.7 db AT +60°C.

(b) Paragraph 1.3.2., the -25°C is changed to read 0°C and +60°C, paragraph 1.3.3. is deleted.

(c) Paragraphs 2.2, 2.3. and 2.4 are deleted.

When part number appears as 526-9445-021, the requirements shall be changed as follows:

(a) Para. 1.2. The peak to valley ratio shall not exceed 3.0 db from 0°C to +50°C, other requirements shall be deleted.

(b) Para. 1.3.1. The frequency shall be 455.12 max. and 457.80 min. at 3.0 db down. Other requirements shall not change.

(c) Para. 1.3.2. Temperature shall be changed from -25°C to 0°C. The frequency shall be 455.18 max. and 457.80 min. at 3.0 db down. Other requirements shall not change.

(d) Pára. 1.3.3. Temperature shall be changed from +85°C to +50°C. The frequency shall be 455.18 max. and 457.80 min. at 3.0 db down. Other requirements shall not change.

(e) Para. 1.4. The insertion loss shall not exceed 10 db.

(f) Para. 1.5. The spurious response shall not exceed 35 db from 400 kc to 500 kc. Other requirements shall be deleted.

(g) Para. 1.6. The -25°C and +85°C requirements shall be changed to 0°C and +50°C.

REFERENCE ONLY

JUN 25 1964

(h) Delete paragraphs 2.2, 2.3 and 2.4.

1. ELECTRICAL REQUIREMENTS.-

1.1 Impedance.- The filters shall be used and tested in a circuit that presents 600 ohms resistive input and output impedance. The filters will be series resonated, no limits being placed on the value of resonating capacity needed. (Nominal value 140 uuf.) The resonating capacity shall not be varied when running temperature tests.

REV C

1.2 Peak to valley ratio.- The peak to valley ratio in the passband shall not exceed:

1.0 db at +25°C
1.5 db at -25°C
1.7 db at +85°C

1.3 Selectivity.- The bandpass characteristics shall be as follows:

1.3.1 +25°C

DB Down From Peak Response	Frequency	Frequency Tolerance
65	453.34	Min.
3	455.00	Min.
1.2	455.12	Max.
1.2	457.80	Min.
3	458.30	Max.
65	459.67	Max.

1.3.2 -25°C

DB Down From Peak Response	Frequency	Frequency Tolerance
65	453.34	Min.
3	455.00	Min.
1.5	455.18	Max.
1.5	457.80	Min.
3	458.30	Max.
65	459.67	Max.

REFERENCE ONLY
JUN 25 1964

1.3.3 +85°C

DB Down From Peak Response	Frequency	Frequency Tolerance
65	453.30	Min.
3	455.00	Min.
1.7	455.18	Max.
1.7	457.60	Min.
3	458.30	Max.
65	459.67	Max.

1.4 Insertion loss.- The insertion loss shall not exceed 6 db in the passband. The insertion loss is the difference in voltage (db) across the load with the filter in the circuit and the filter (including capacity) out of the circuit.

1.5 Spurious response.- Any response outside the normal passband shall not exceed the following limits when measured from the level of maximum response within the passband at 25°C.

From 400 KC to 405 KC	65 db attenuation
From 405 KC to 430 KC	30 db attenuation
From 430 KC to 440 KC	50 db attenuation
From 440 KC to 453.34 KC	65 db attenuation
From 459.67 to 475 KC	65 db attenuation
From 475 KC to 485 KC	60 db attenuation
From 485 KC to 500 KC	65 db attenuation

1.6 Passband.- The passband is defined as 455.12 KC to 457.80KC at +25°C and 455.18 KC to 457.80 KC at -25°C and +85°C.

2. ENVIRONMENTAL REQUIREMENTS.- (Not included in Para. 1.)

2.1 Low temperature storage.- The filter shall be fully operable in its normal temperature range after -80°F exposure for 24 hours.

2.2 Vibration.- The filters shall be tested in accordance with Method 204, Test Condition C, Part 2 of MIL-STD-202A dated October 24, 1956, with the exception that the peak acceleration shall be 20 G and that they are to be vibrated in any one direction perpendicular to the length of the filter.

2.3 Vibration modulation.- During vibration, with a 456.5 KC input signal of amplitude such that the filter output is 1 volt RMS, the output shall be monitored to detect modulation. If modulation appears on the test signal, its amplitude shall not exceed the following limits referenced to a 1 volt RMS, RF, 100 percent modulated signal.

From 55 cps to 800 cps	50 db attenuation
From 800 cps to 1,000 cps	35 db attenuation
From 1,000 cps to 2,000 cps	30 db attenuation

2.4 Shock.- The filters shall be capable of withstanding shock, 100 G for a seven (7) millisecond duration, consisting of five (5) blows in each of two (2) directions, in each of three (3) perpendicular planes. This test shall be performed in accordance with Method 202A of MIL-STD-202A, dated 24 October 1956, and the filters shall exhibit no permanent degradation of electrical performance.

3. RECOMMENDED OPERATING PARAMETERS.-

3.1 Signal input voltage.- 0 to 1 volt RMS.

3.2 Direct current.- Shunt feed is necessary to eliminate DC current in transducer coils. DC current in transducer coils will alter the electrical characteristics of Para. 1.

4. MECHANICAL REQUIREMENTS.-

4.1 Construction.- Hermetically sealed.

4.2 Case.- Cartridge brass; see Sheet 4 for dimensional details.

4.3 Finish.- Nickel plate, Type VI, Class 2, in accordance with the latest version of QQ-N-290.

4.4 Nameplate.- A suitable metal foil or decalcomania nameplate shall be attached to the filter and shall include the following data:

Collins Type
Serial Number or Date Code Stamp
Collins Part Number

Silk screening or rubber stamped identification data may be used in lieu of a nameplate. The nameplate shall remain firmly attached and legible after subjection to the environmental tests of Para. 3.

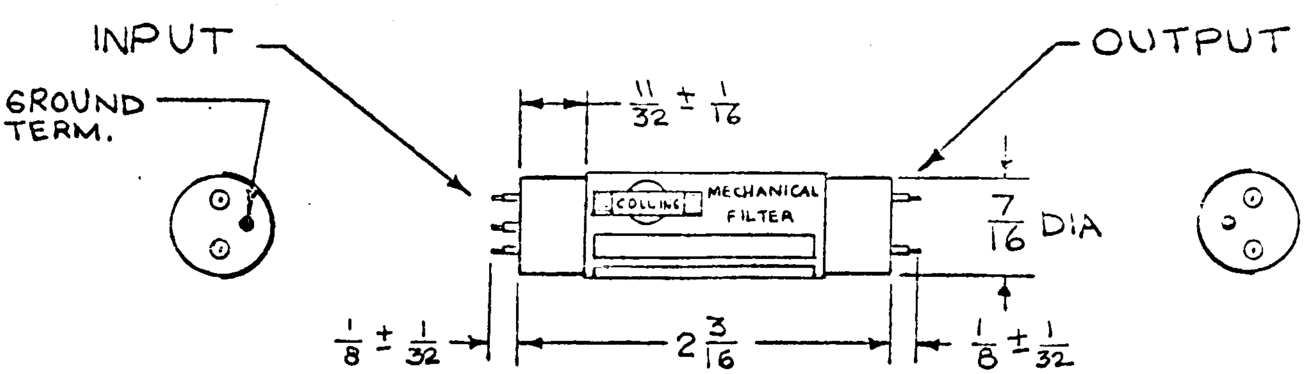
5. PRODUCTION TEST REQUIREMENTS AT COLLINS RADIO COMPANY.-

5.1 Production inspection tests.- All units shall be tested for the following:

1. Visual Inspection for mechanical requirements and workmanship.
2. Electrical requirements of Para. 1.
3. Environmental requirements of Para. 2.

REFERENCE ONLY

JUN 25 1964



UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON FRACTIONS ±1/64 DECIMALS ±.005 ANGLES ±1°	CODE IDENT NO. 95105	SIZE A	526-9445-00
	SCALE NONE	WT	SHEET 5

6.3 Frequency Selector Filter Specifications 526-9430/9444-00

REVISIONS

SYM	DESCRIPTION	DATE	APPROVED

REFERENCE ONLY

JUN 25 1964

Description: MECHANICAL FILTER
f_c KC CENTER FREQUENCY SELECTOR

VENDOR	CODE IDENT. NO.	VENDOR P/N
COLLINS RADIO CO., NEWPORT BEACH, CALIF. SSA		

CLASS 2B	CAL CHANGE 3 MAY 1962	SOURCE CONTROL DRAWING	ENGRG PN 082-0123/0137-526 082-0160/0174-526

	NAME	DATE
PREP BY	Kirtley J.	26 April 1962
CHK BY	[signature]	4-26-62
PROJ CHK	[signature]	4/26/62
PROJ ENGR	[signature]	4-26-62
DWG DATE	11 May 1962	

COLLINS RADIO COMPANY
NEWPORT BEACH, CALIFORNIA

FILTER, MECHANICAL

CODE IDENT NO.	SIZE	
95105	A	* 526-9430/9444-00
SCALE NONE	WT	SHEET 1 of 4

1.0 Electrical Requirements (-25°C to +85°C)

	ELECTRICAL CHARACTERISTICS	NOM.	TOL.
1.1	Center Frequency (KC) (1)	f_c See	Table
1.2	Frequency Response (KC)	See 1.	2.1
1.3	Passband (2)	See 1.	8
1.4	Passband Response Variation (db)	2.0	Max.
1.5	Insertion Loss (db) (3)	5 to 8	
1.6	Spurious Response Atten. (db)		
	400.0 KC to f_c -34.74 KC	45	Min.
	f_c -34.74 KC to f_c -4.74	50	Min.
	f_c +4.74 KC to f_c +34.74 KC	50	Min.
	f_c +34.74 KC to 540.0 KC	45	Min.

1.2.1 Additional Selectivity and Attenuation Data

Frequency (KC)	db	Atten. Tol.
f_c +0.2	2.0	Max.
f_c -0.2	2.0	Max.
f_c +4.74	50	Min.
f_c -4.74	50	Min.

REFERENCE ONLY

JUN 25 1964

* When part number appears as 526----009, Military Inspection is required.

* When part number appears as 526----011,
Paragraph 1.0 and 2.1, the operating temperature range is 0° to +60°C;
Paragraphs 2.2 and 2.3 are deleted.

1.7 Note 1 Center Frequency, by definition, is f_c KC. (See Table I)

1.8 Note 2 Passband, by definition, is the frequency band between f_c -0.2 KC and f_c +0.2 KC.

1.9 Impedance: The filters shall be used and tested in a circuit that presents 600 ohms resistive input and output impedance. The filters will be series resonated, no limits being placed on the value of resonating capacity needed. (Nominal value 140 uuf.) The resonating capacity shall not be varied when running temperature tests.

1.10 Note 3 Insertion Loss: The insertion loss of the filters in the circuit described in Paragraph 1.9 shall not exceed 8 db measured at the center frequency, but shall be 5 db or greater.

2. ENVIRONMENTAL REQUIREMENTS:

2.1 Operating Temperature Range: The above electrical requirements shall be met over the operating temperature range of -25°C to +85°C.

2.2 Vibration: The filters shall be tested in accordance with Method 204, Test Condition C, Part 2 of MIL-STD-202A dated October 24, 1956, with the exception that the peak acceleration shall be 20 G and that they are to be vibrated in any one direction perpendicular to the length of the filter.

REV

2.2.1 Vibration Modulation: During vibration, with a center frequency (f_c) input signal of amplitude such that the filter output is 1 volt RMS, the output shall be monitored to detect modulation. If modulation appears on the test signal, its amplitude shall not exceed the following limits referenced to a 1 volt RMS, RF, 100 percent modulated signal.

From 55 cps to 800 cps	40 db attenuation
From 800 cps to 1,000 cps	35 db attenuation
From 1,000 cps to 2,000 cps	30 db attenuation

2.3 Shock: The filters shall be capable of withstanding shock, 100 G for eleven (11) millisecond duration, consisting of five (5) blows in each of two (2) directions in each of three (3) mutually perpendicular planes. The test shall be performed in accordance with Method 202A, of MIL-STD-202A, dated 24 October 1956, and the filters shall exhibit no permanent degradation of electrical performance.

REFERENCE ONLY

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3. MECHANICAL REQUIREMENTS:

3.1 Construction: Hermetically sealed.

3.2 Case: Cartridge brass; see figure for dimensional details.

3.3 Finish: Nickel plate, Type VI, Class 2, in accordance with the latest version of QQ-N-290.

3.4 Nameplate: A suitable metal foil or decalcomania nameplate shall be attached to the filter and shall include the following data:

Collins Type
Serial Number or Date Code Stamp
Collins Part Number

Silk screening or rubber stamped identification data may be used in lieu of a nameplate. The nameplate shall remain firmly attached and legible after subjection to the environmental tests of Para. 3.

4. PRODUCTION TEST REQUIREMENTS AT COLLINS RADIO COMPANY:

4.1 Production Inspection Tests: All units shall be tested for the following:
1. Visual Inspection for mechanical requirements and workmanship.
2. Electrical Requirements of Para. 1.
3. Environmental Requirements of Para. 2.

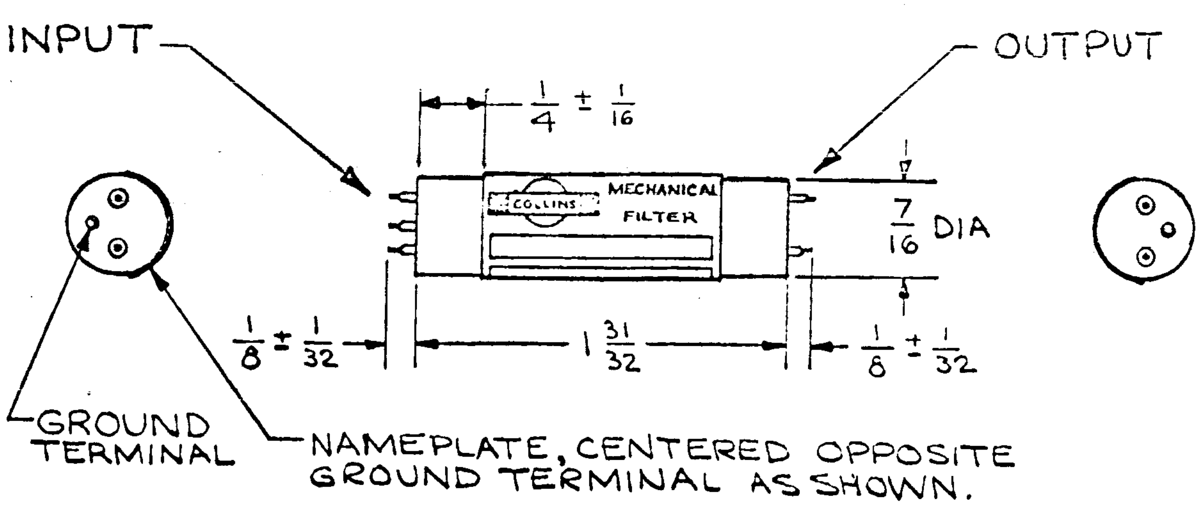
REV

TABLE I

f_c (KC)	Collins Part Number	Collins Type No.
459.74	526-9430-00	F459Y-20
464.48	526-9431-00	F464Y-20
469.22	526-9432-00	F469Y-20
473.96	526-9433-00	F473Y-20
478.70	526-9434-00	F478Y-20
483.44	526-9435-00	F483Y-20
488.18	526-9436-00	F488Y-20
492.92	526-9437-00	F492Y-20
497.66	526-9438-00	F497Y-20
502.40	526-9439-00	F502Y-20
507.14	526-9440-00	F507Y-20
511.88	526-9441-00	F511Y-20
516.62	526-9442-00	F516Y-20
521.36	526-9443-00	F521Y-20
526.10	526-9444-00	F526Y-20

REFERENCE ONLY

JUN 25 1964



UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON	CODE IDENT NO.	SIZE	
FRACTIONS ±1/64 DECIMALS ±.005 ANGLES ±1°	95105	A	* 526-9430/9444-00
	SCALE NONE	WT	SHEET 4 of 4