VLBA ACQUISITION MEMO #176

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

HAYSTACK OBSERVATORY

WESTFORD, MASSACHUSETTS 01886

23 October 1989

Area Code 508
692-4764

To: VLBA Data Acquisition Group

From: Alan E.E. Rogers

Subject: Bandpass simulations for BBC

The BBC bandpass depends on component variations and 3 components in the HiQ section may have to be adjusted (see Acquisition memo #86). Circuit simulation of the component variations is used to provide a better guide for adjustments.

1] Expected component variations

a] NE5539 common mode input resistance
Nominal 1.6M ohm (calculated from bias current of 5 uA across 8 volts)
Max. 400K ohm (from 20 uA max bias current)

b] NE5539 gain (see plot attached) - currently we use the Signetics 5539
Min. 47 dB
Max. 57 dB

c] NE5539 phase delay (see plot attached)
Nominal 72 degrees at 10 MHz
Max. assume 80 deg. (i.e. +10%) no spec. given

d] SD5002N capacitance
Type. Gate node 2.4 pf
Drain node 1.3 pf
Source node 3.5 pf
Transfer 0.3 pf
Max. Add 50% to above values

2] Compensation

a] Input resistance

	RCOM	RL
MIN.	400K	27K
TYP.	1.6M	60K
MAX.	10M	OPEN

b] Gain and phase

	GAIN	PHASE (AT 10 MHz)	C4
MIN.	47dB	80	220pf
TYP.	52dB	72	150pf
MAX.	57dB	72	100pf

Notes: Gain and phase are assumed to be linked with the lowest gain and largest phase delay being poorest and the highest gain and smallest phase delay being best.

c] Switch capacitance

	CAP.	R2 (RC in Dwg. #54120S012)
MIN.	-50%	3000
TYP.	+ 0%	2700
MAX.	+50%	2100

3] Adjustment sequence

It is suggested that R2 be adjusted first to remove any slope on the 1 MHz bandpass. Then adjust RL to correct 62 KHz bandpass and finally adjust C4 to correct 16 MHz bandpass. The tables given above show the expected compensation values. It may also be advantageous to adjust the 180 pf capacitors used for the 16 MHz bandpass.

4] Circuit model

Figure 1 shows the circuit model. The largest and most influential stray capacitance is C3 which is as follows:

Circuit board with components	21 pf
Stray from 10 resistors to ground	13 pf
Stray from 8 source inputs	11 pf
	45 pf

plus some small stray capacitance that depends on the state of the switches. [It should be noted that the substrate (pin 2) of the second switch is floated (through 1M ohm) to reduce the stray capacitance to ground which would be present with an a.c. grounded substrate.] Capacitors C1 and C2 are assumed to be lossless (which is a good approximation for Q>100) and should be a high Q dielectric (eg. CoG).

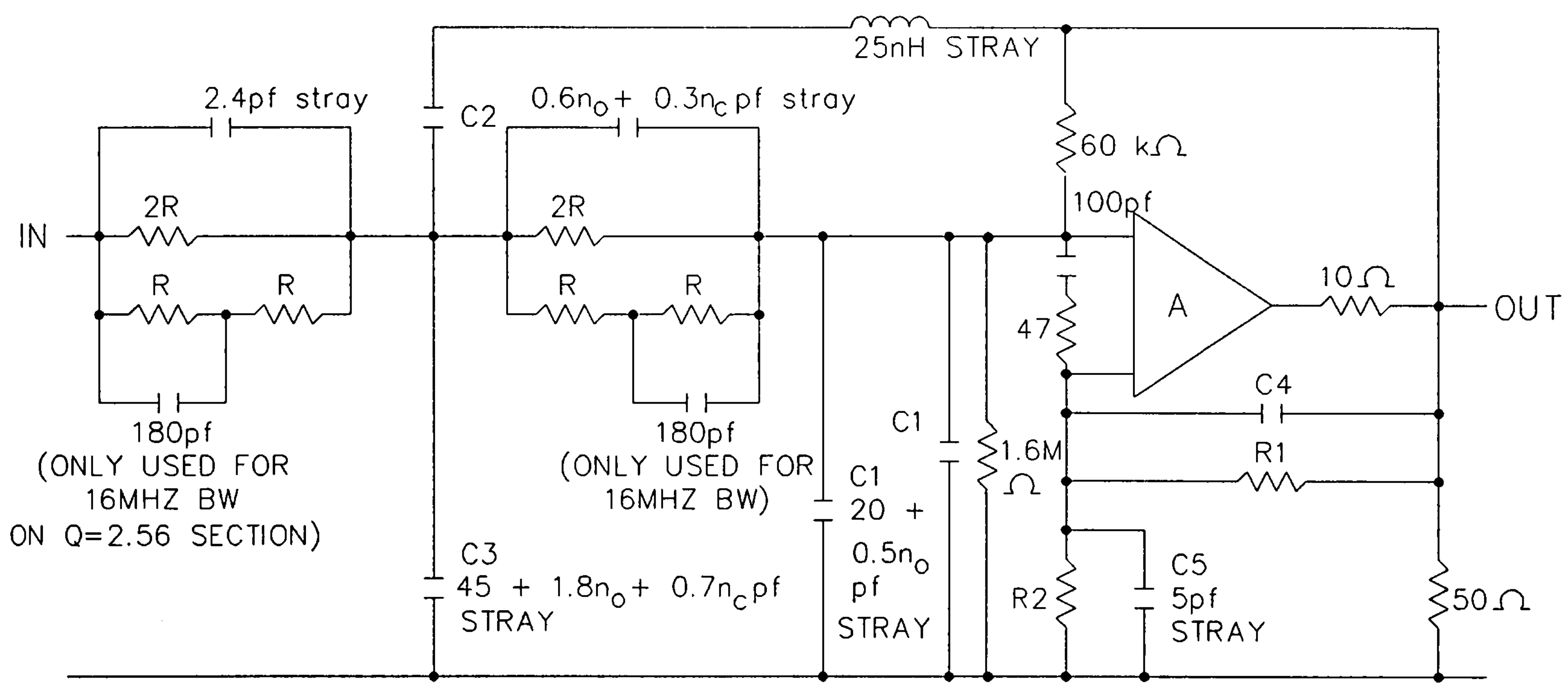
5] Circuit simulations

Figure 2 shows the result of a simulation of all 4 sections of the filter for bandwidths of 16, 8, 1, and 0.625 MHz. The bandpass was calculated for typical component values and for the lowest input impedance, the minimum op.amp. gain and the maximum switch capacitance. Also plotted are the bandpass curves after application of compensating values of RL for input impedance, C4 for op.amp. gain and R2 for switch capacitance. It should be clear from the simulated bandpasses that RL and input impedance affects only narrow bandpass, C4, and op.amp. gain affect only the 16 and 8 MHz bandpasses while R2 and switch capacitance affects all bandpasses. Also shown (curve #8) is the effect of increasing the 180 pf capacitor as well as C4 to compensate for reduced 5539 gain and increased phase delay.

The circuit simulation was written in FORTRAN (unfortunately C doesn't support complex arithmetic). If better simulations are needed it would be desirable to simulate the circuit with actual transistor models for the 5539 using PC-SPICE or other commercial software.

Attachments:
1. Circuit Model
2. Simulation
3. Drawing #54120S012
4. Gain and Phase of 5539
5. Fortran Listing

Attachment 1.



NOTES: n_o = # open switches, n_c = # closed switches

A HAS GAIN AND PHASE FROM 1985 CATALOG INFO. ON SIGNETICS NE5539

R = 41 Ω FOR 16MHZ (n_o = 1, n_c = 7)
= 92 Ω FOR 8MHZ (n_o = 2, n_c = 6)
= 12.8K Ω FOR 62KHZ (n_o = 8, n_c = 0)

SHOP NOTES: UNLESS OTHERWISE SPECIFIED

1. DIMENSIONS ARE IN INCHES
2. TOLERANCE ON DIMENSIONS
   FRACTIONAL ± 1/64
   DECIMAL .XX ± .01
   DECIMAL .XXX ± .005
   ANGULAR ± 0°30'
3. SURFACE ROUGHNESS PER MIL-STD-10 ✓
4. REMOVE BURRS AND BREAK SHARP EDGES 1/64 MAX.
5. SCREW THREADS PER MIL-STD-9
6. ALL DIMENSIONS TO APPLY BEFORE PLATING OR CONVERSION COATING.

USED ON		
NEXT ASSEMBLY		
WEIGHT		
SCALE	NONE	
CLASSIFICATION		

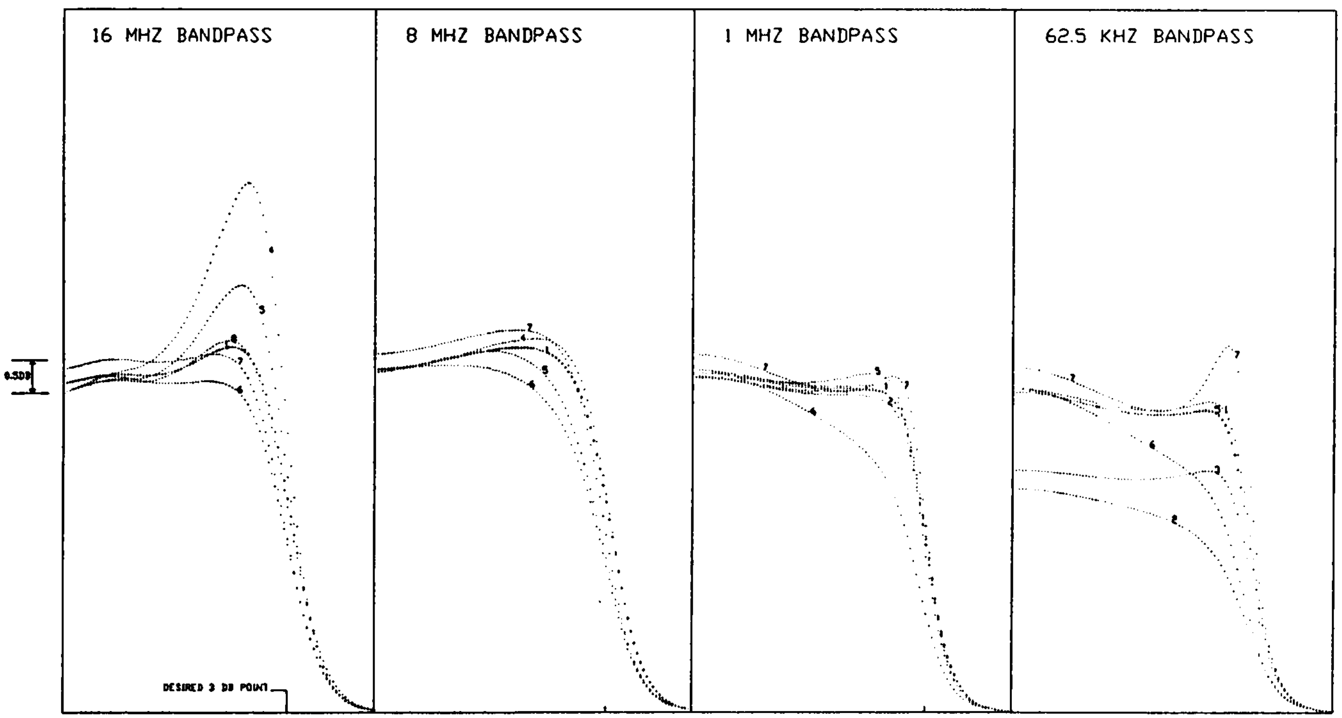
		DATE
DRAWN FOR	A.E.ROGERS	10/89
DRAWN BY	C.KOSTKA	10/89
CHECKED BY		
APPROVALS: PROJECT		
ENGINEER		
MATL. & PROCESS		
STRUCTURES		
THERMAL		
MECH. ANALYSIS		

NORTHEAST RADIO OBSERVATORY CORPORATION
HAYSTACK OBSERVATORY
WESTFORD, MASSACHUSETTS

CIRCUIT MODEL USED IN SIMULATION

FILE NAME	DWG. SIZE	DWG. NO.	REV.
AER\CIRMDL	A		

Attachment 2.



SEE FIGURE FOR CIRCUIT MODEL
SEE PLOT FOR OP.AMP. GAIN AND PHASE

C1	C2	C4	R1	R2
22 PF	1000 PF	150 PF	220 OHMS	2700 OHMS
100PF	390 PF	47 PF	470 OHMS	2700 OHMS
150 PF	200 PF	47 PF	470 OHMS	3300 OHMS
200 PF	180 PF	47 PF	470 OHMS	3300 OHMS

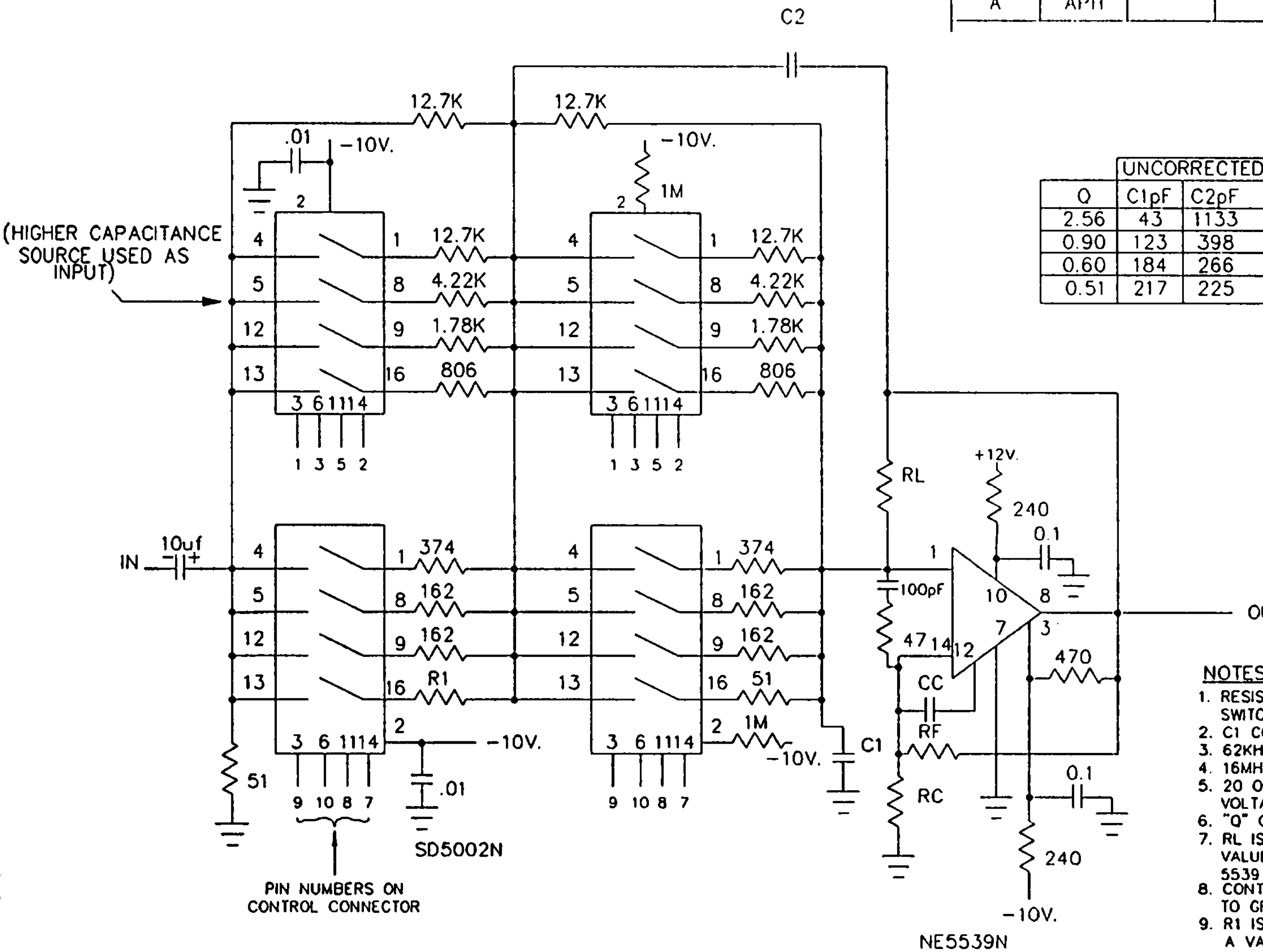
CURVE 1 - NORMAL
CURVE 2 - INPUT IMPEDANCE LOWERED TO 400K
CURVE 3 - RL REDUCED TO 27K TO COMPENSATE
CURVE 4 - OP.AMP GAIN REDUCED 3DB & PHASE INCR.
CURVE 5 - C4 INCREASED TO 220 PF TO COMPENSATE
CURVE 6 - SWITCH CAPACITANCE INCR. 50%
CURVE 7 - R2 ON Q=2.5 SECT. DECR. TO 2100 TO COMP.
CURVE 8 - 180 PF ALSO INCR. TO 270 PF TO COMPENSATE FOR OP.AMP GAIN REDUCTION OF CURVE 4

CIRCUIT SIMULATION OF BBC ACTIVE FILTER

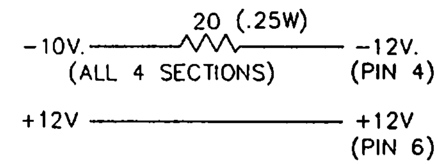
FILE:BANDPAS

Attachment 3.

CHANGE LETTER	DWN BY	CHK'D BY	APP'D BY	DATE	D.C.N. & DESCRIPTION
A	APH			12/87	REMOVED CAP FROM PIN 4 OF SD5002N



Q	UNCORRECTED C1pF	UNCORRECTED C2pF	CORRECTED C1pF	CORRECTED C2pF	RC	RF	CCpF
2.56	43	1133	22	1000	2.7K	220	150
0.90	123	398	100	390	2.7K	470	47
0.60	184	266	150	220	3.3K	470	47
0.51	217	225	200	180	3.3K	470	47



NOTES:

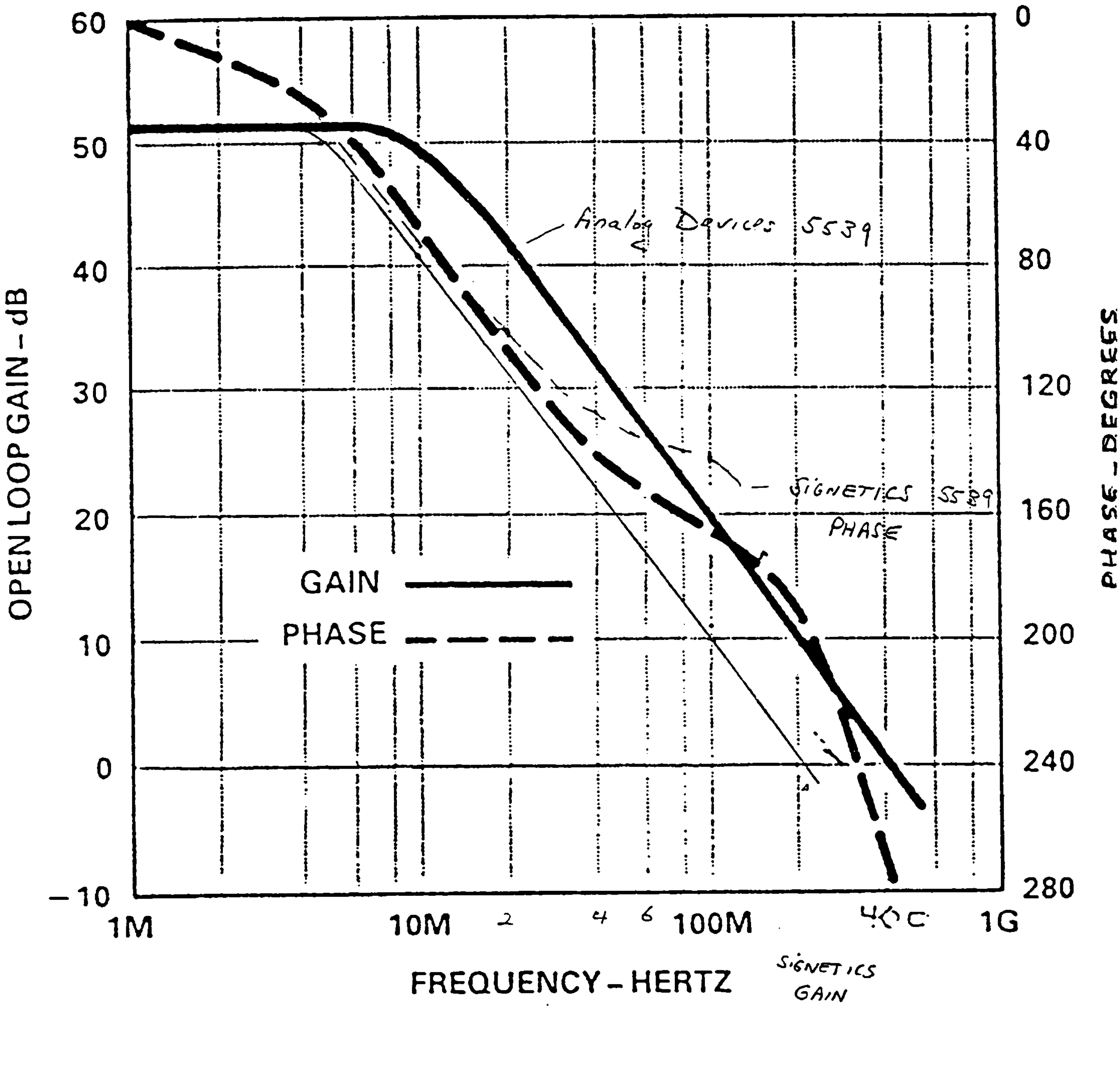
1. RESISTOR VALUES CORRECTED FOR 40 OHMS SWITCH ON RESISTANCE.
2. C1 CORRECTED FOR 20pF TO GROUND.
3. 62KHz BW ALL INPUTS LOW.
4. 16MHz BW ALL INPUTS HIGH.
5. 20 OHM RESISTORS (ON INPUT SECTION) DROP SUPPLY VOLTAGE FOR ALL FOUR SECTIONS.
6. "Q" CORRECTED FOR 40pF TO GROUND USING "RC".
7. RL IS NEEDED ON Q = 2.56 SECTION VALUE APPROX. 20K TO COMPENSATE FOR 5539 INPUT RESISTANCE.
8. CONTROL LINES ARE BYPASSED WITH 0.01uF TO GROUND ON INPUT SECTION.
9. R1 IS 51.1 OHMS EXCEPT ON Q=0.51 FOR WHICH IT HAS A VALUE OF 10 OHMS TO COMPENSATE FOR 50 OHM OUTPUT IMPEDENCE OF SSB MIXER.
10. ON Q=2.56 SECTION 51 OHM RESISTORS HAVE 180pF CAPACITORS IN PARALLEL.
11. 10uf INPUT CAPACTIOR IS ONLY ON Q=2.56 SECTION OTHER SECTIONS HAVE JUMPER.

C- 54120S012 A

DWG. LAST CHANGED 10/31/88

NOTES:

ELECTRONIC NOTES: UNLESS OTHERWISE NOTED: RESISTORS: CAPACITORS: INDUCTORS:	USED ON	DRAWN FOR: A.E.ROGERS	DATE: 7-87	NORTHEAST RADIO OBSERVATORY CORPORATION HAYSTACK OBSERVATORY WESTFORD, MASSACHUSETTS
		DRAWN BY: A PHILBROOK	7-87	BASEBAND CONVERTER ACTIVE FILTER SECTION
		CHECKED BY:		
	SCALE NONE	APPROVAL PROJECT		AER\ACTFILT — DWG. SIZE C — DWG. NO. 54120S012 — REV. A
	CLASSIFICATION	ENGINEER:		



Attachment 4.

```
FTN66,Y
$FILES (2,2)
      PROGRAM ACTFL
      COMPLEX AI1,AI2,AI3,V1,V2,V3,V4,V5,Z5,Z4,ZI,AA,AII,VI,CONJG,U,YR
      DIMENSION IESCQ(2)
      QDATA LASET/@E@(s0p7v16H@&l3E@&l4C@&a1L_/
      QDATA IESCE/@E_/
      QDATA IATQ/@/
      DATA IESCQ/1,015400B/
      CALL RMPAR(IPAR)
      LU=IPAR
      PI=3.1415926536
      U=CMPLX(1.0,0.0)
      OPEN(88,FILE='ACTFL::57::400')
      WRITE(88,70)
   70 FORMAT("0",/,"SECTION",/,"2",/,"ENTITIES")
      IRR=0
      DO 5000 IR=1,9
          IDUM=IXQ(LASET,IATQ,IESCQ,0)     !Exchange @ for <ESC>
          IF(IR.EQ.1.OR.IR.EQ.9.OR.IR.EQ.5)
                CALL EXEC(2,12,LASET(2),-LASET)    !Laserjet setup
      IF(IR.GT.2.AND.IR.LT.9.AND.IR.NE.5) GOTO 5000
      CALL VGRPH(0.0,1.0, 00.0,20.0,1)
      IRR=IRR+1
      DO 2100 I=1,8
      IF(IR.NE.1.AND.I.EQ.8) GOTO 2100
      RI=47
      AL=25E-9
      CI=100E-12
      C11=18E-12
      RL=60E03
      RCOM=1.6E06
      ANOPEN=8
      R=50*(2**FLOAT(IR-1))
      IF(IR.EQ.1) THEN$ R=38 $ ANOPEN=1 $ ENDIF
      IF(IR.EQ.2) THEN$ R=90 $ ANOPEN=3 $ ENDIF
      IF(IR.EQ.5) ANOPEN=7
      CSCA=1.0
      IF(I.EQ.6.OR.I.EQ.7) CSCA=1.5
      C5=5E-12
      CP1=0.3E-12*CSCA*ANOPEN+0.3E-12*(8.-ANOPEN)
      CP2=0.6E-12*CSCA*ANOPEN+0.3E-12*(8.-ANOPEN)
      WRL=4.5E6*2.*PI
      IF(I.EQ.2.OR.I.EQ.3) RCOM=400E03
      IF(I.EQ.3) RL=27E03
      C11=C11+0.5E-12*ANOPEN
      C3=34E-12+1.3E-12*CSCA*ANOPEN+0.7E-12*CSCA*(8.-ANOPEN)
     .+0.5E-12*ANOPEN+11E-12*CSCA
      DO 2000 IW=1,100
      W=(IW-1)*20E6*2.0*PI/(100.0*2**(IR-1.0))
      AAA=400.0
      IF(W.GT.WRL)AAA=AAA*((WRL/W)**1.5)
      IF(I.EQ.4.OR.I.EQ.5.OR.I.EQ.8) AAA=AAA*0.7
C     TO CORRECT FOR LOADING
      IF(IR.EQ.1) AAA=AAA*0.35
      PHI=((W/(WRL))**0.5)*0.9*0.9
      IF(I.EQ.4.OR.I.EQ.5.OR.I.EQ.8) PHI=PHI*1.1
      V1=U
      DO 2001 IS=1,4
      IF(IS.EQ.1)THEN$ C1=22E-12$C2=1000E-12$R1=220$C4=150E-12$R2=2700
      ENDIF
      IF(IS.EQ.2)THEN$ C1=100E-12$C2=390E-12$R1=470$C4=47E-12$R2=2700
      ENDIF
      IF(IS.EQ.3)THEN$ C1=150E-12$C2=220E-12$R1=470$C4=47E-12$R2=3300
      ENDIF
      IF(IS.EQ.4)THEN$ C1=200E-12$C2=180E-12$R1=470$C4=47E-12$R2=3300
      ENDIF
      C1=C1+C11
      RLL=RL
      IF(IS.NE.1) RLL=1.0E20
      IF(I.EQ.5.AND.IS.EQ.1)C4=220E-12
      IF(I.EQ.8.AND.IS.EQ.1)C4=220E-12
      IF(I.EQ.7.AND.IS.EQ.1)R2=2100
      CA=1.0E-14
      IF(IS.EQ.1.AND.IR.EQ.1)CA=180.0E-12
      IF(IS.EQ.1.AND.IR.EQ.1.AND.I.EQ.8)CA=270.0E-12
      ZI=CMPLX(RI,-1.0/(W*CI))
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      Z5=U/CMPLX(1.0/R2,W*C5)
      Z4=U/CMPLX(1.0/R1,W*C4)
      VI=V1/CMPLX(AAA*COS(PHI),-AAA*SIN(PHI))
      AII=VI/ZI
      V5=V1*Z5/(Z4+Z5)+AII*(Z4*Z5)/(Z4+Z5)
      V2=V5+VI
      AI2=V2*CMPLX(1.0/RCOM,W*C1)+AII+(V2-V1)/CMPLX(RLL,0.0)
      YR=CMPLX(1./(R*2.0),0.)+U/(CMPLX(R,0.)+(U/CMPLX(1./R,W*CA)))
      V3=V2+AI2/(YR+CMPLX(0.0,W*CP2))
      AI3=AI2+V3*CMPLX(0.0,W*C3)+(V3-V1)/CMPLX(0.0,W*AL-1./(W*C2))
      V4=V3+AI3/(YR+CMPLX(0.0,W*CP1))
 2001 V1=V4
      AMP=CABS(CMPLX(1.0,0.0)/(V4*CONJG(V4)))
      WW=(IW-1)/100.0
      II=48+I
      CALL VGRPH(WW,AMP* 4.,II,3,2)
      WRITE(88,91) (IW/10.0+(IRR-1)*10),AMP*4.,I
   91 FORMAT("0",/,"TEXT",/,"8",/,"0",/,"10",/,F7.3,/,"20",/,F7.3,
     ./,"40",/,"0.02",/,"1",/,I1)
 2000 CONTINUE
      WRITE(12,1200) R,C3,C4,C5,R2,AAA,T,CI,RI
 2100 CONTINUE
      CALL VGRPH(0.72,0.0,42,3,2)
      CALL VGRPH(0.0,1.0, 00.0,20.0,4)
      CALL VGRPH(0,0,0,12,5)
 1200 FORMAT(      " R,C3,C4,C5,R2,AAA,T,CI,RI=",9E10.3)
 5000 CONTINUE
      WRITE(88,6000)
 6000 FORMAT("0",/,"ENDSEC",/,"0",/,"EOF")
      ENDFILE 88
      END
EOF on file &ACTFL after     108 records with     3506 chars:    2 pages
```