VLBA Acquisition Memo # 69

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Area Code 617
692-4765

To: VLBA Data Acquisition/Recorder Group

From: Alan E.E. Rogers

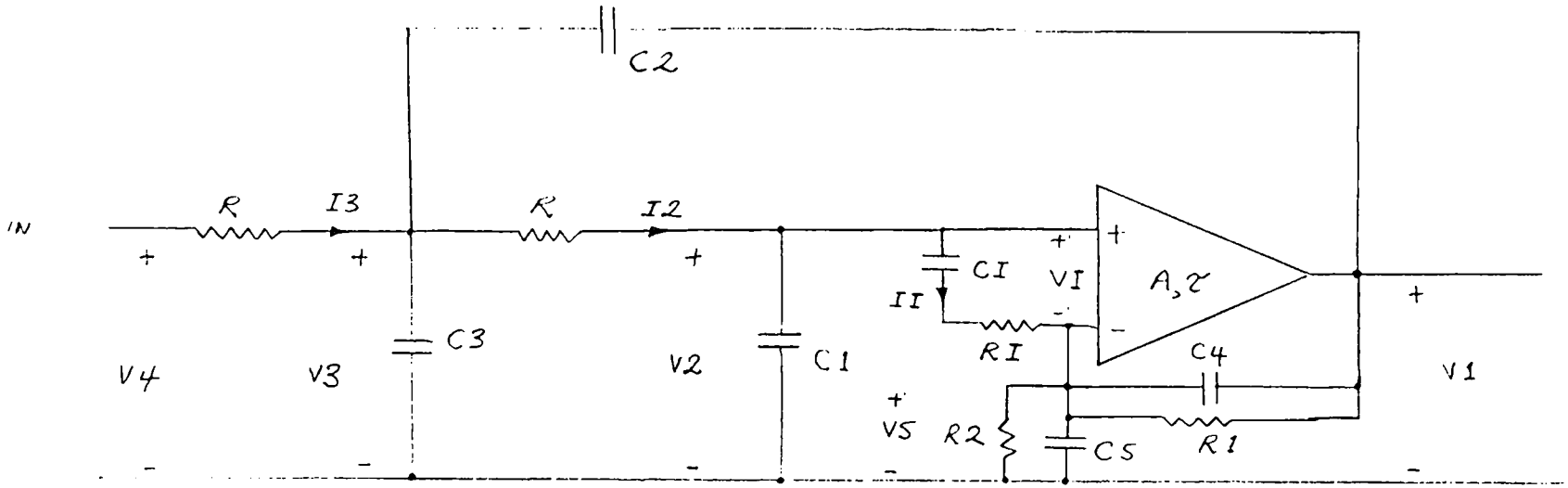
Subject: Active Filter — Sensitivity to Operational Amplifier Performance

The active filter in the VLBA baseband converter has been analyzed on paper and using a simple computer program to simulate the sensitivity to various circuit parameters.

Figure 1 shows the circuit model used for computer simulation. Only the high Q (Q = 2.56) pole pair simulation is shown since the low Q poles are much less sensitive to circuit paramaters. At frequencies below 4 MHz the circuit is insensitive to variations in the operational amplifier gain (since the gain is high and phase shifts are small) and variations in stray capacitance C5. At 16 MHz bandwidth the circuit is quite sensitive to variations in C5 and the operational amplifier gain and delay. The printouts show the sensitivity to various parameter changes. Performance at 16 MHz bandwidth could be improved by using an amplifier with more gain and less delay but at present I have not been able to find anything better than the Signetics NE5539 available at reasonable cost. The lowering of the pole frequencies at 8 MHz bandwidth is compensated by the choice of resistor value for the most significant bit (used for 8 and 16 MHz). The 16 MHz bandwidth, however, is significantly reduced from the nominal 14.4 MHz - see Figure 2 for measured bandpass printout.

Attachment (7 pages)

(1) ACTIVE FILTER MODEL USED IN PRG. ACTFL (AEER Aug 86)



Transfer function (V1/V4)

C3 simulates switch + circuit board capacitance

CI, RI Part of H.F. compensation

C5 stray capacitance

A is frequency dependent gain modelled with freq. dependent amplitude plus delay

values:

RI = 50Ω	C3 = 60pF
CI = 50pF	R = 50Ω at 16 MHz BW
C5 = 4pF	|A| = 30 dB at 16 MHz, 36 dB at 8 MHz
R2 = 2.7K	τ = 20 ns
R1 = 200Ω	
C4 = 150pF	
C1 = 43pF	
C2 = 1000pF	

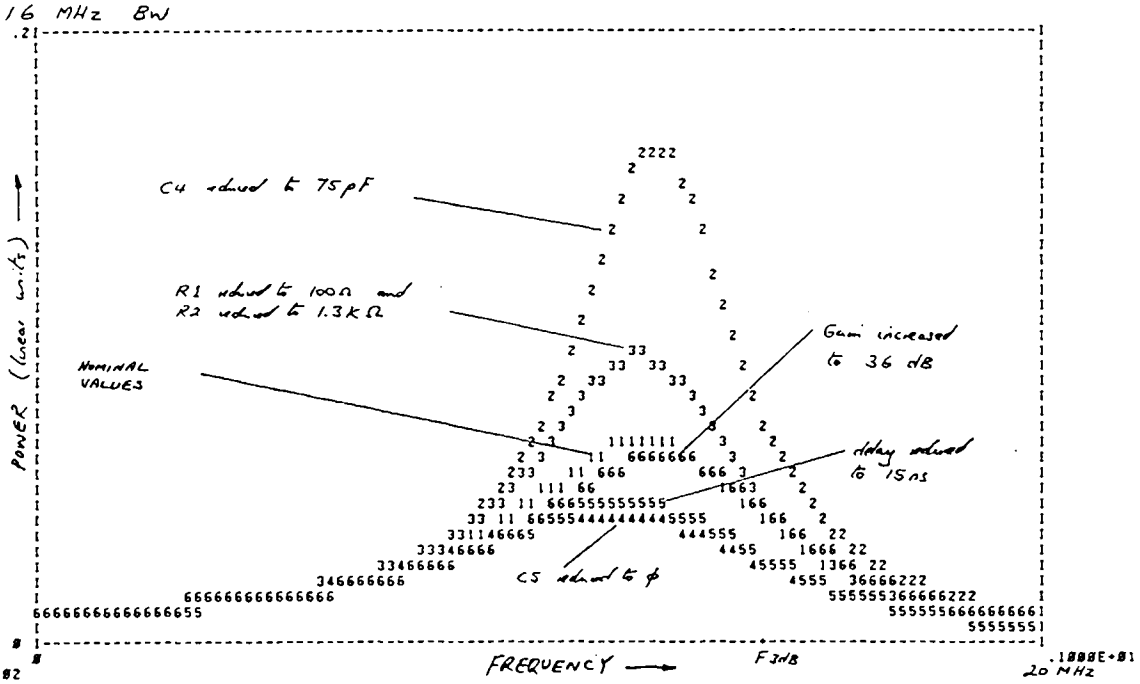
Figure 1.

(2)

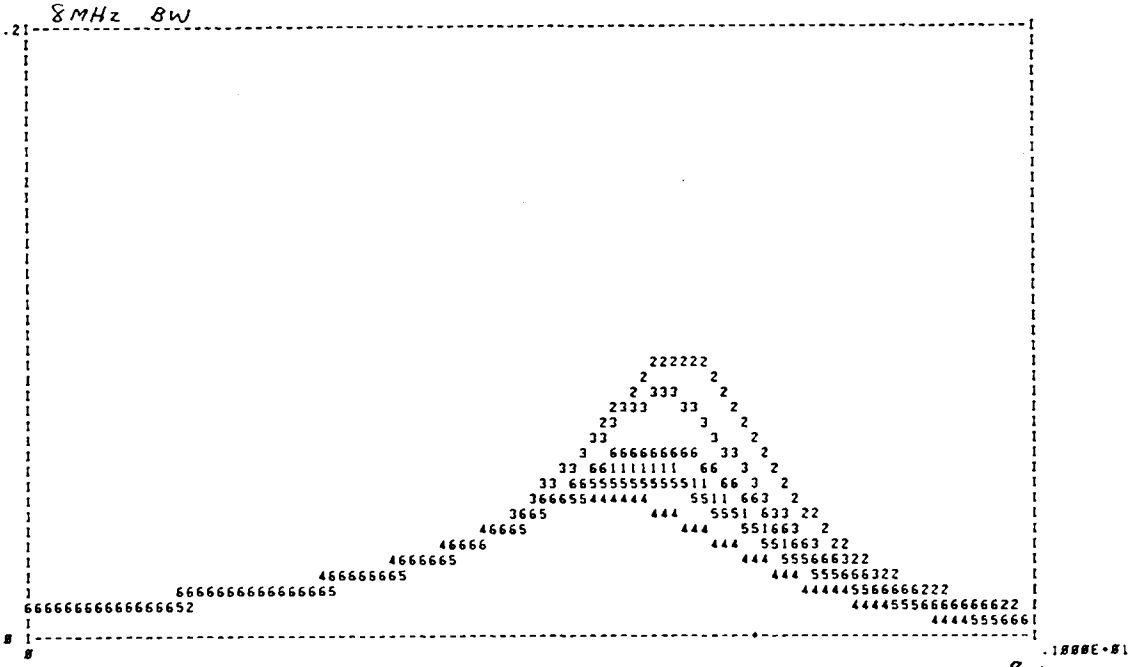
```
  1      FTN66,Y
  2            PROGRAM ACTFL
  3            COMPLEX AI1,AI2,AI3,V1,V2,V3,V4,V5,Z5,Z4,ZI,AA,AII,VI,CONJG
  4            CALL RMPAR(IPAR)
  5            LU=IPAR
  6            PI=3.1415926536
  7            DO 5ØØØ IR=1,9
  8            IF(IR.GT.2.AND.IR.LT.9)GOTO 5ØØØ
  9            CALL VGRPH(Ø.Ø,1.Ø, ØØ.Ø,2Ø.Ø,1)
 1Ø            DO 21ØØ I=1,6
 11            RI=47
 12            CI=5ØE-12
 13            C1=43E-12
 14            C3=6ØE-12
 15            C2=1133E-12 -C3
 16            R=5Ø*(2**FLOAT(IR-1))
 17            C4=15ØE-12
 18            C5=4E-12
 19      C     R1=47Ø
 2Ø            R1=2ØØ
 21      C     R2=12ØØØ
 22            T=2ØE-9
 23            AAA=3Ø*IR
 24            IF(I.EQ.2) C4=C4*.5
 25            IF(I.EQ.3) R1=1ØØ
 26            IF(I.EQ.4) C5=Ø.Ø
 27      C     IF(I.EQ.5) CI=CI*2.Ø
 28      C     IF(I.EQ.5) RI=25
 29            IF(I.EQ.5) T=15E-9
 3Ø            IF(I.EQ.6) AAA=AAA*2.Ø
 31            R2=R1*27*.5
 32            DO 2ØØØ IW=1,1ØØ
 33            W=(IW-1)*2ØE6*2.Ø*PI/(1ØØ.Ø*2**(IR-1.Ø))
 34            V1=CMPLX(1.Ø,Ø.Ø)
 35            ZI=CMPLX(RI,-1.Ø/(W*CI))
 36            Z5=CMPLX(1.Ø,Ø.Ø)/(CMPLX(Ø.Ø,W*C5)+CMPLX(1.Ø/R2,Ø.Ø))
 37            Z4=CMPLX(1.Ø,Ø.Ø)/(CMPLX(Ø.Ø,W*C4)+CMPLX(1.Ø/R1,Ø.Ø))
 38            VI=V1/CMPLX(AAA*COS(W*T),-AAA*SIN(W*T))
 39            AII=VI/ZI
 4Ø            V5=V1*Z5/(Z4+Z5)+AII*(Z4*Z5)/(Z4+Z5)
 41            V2=V5+VI
 42            AI2=V2*CMPLX(Ø.Ø,W*C1)+AII
 43            V3=V2+AI2*CMPLX(R,Ø.Ø)
 44            AI3=AI2+V3*CMPLX(Ø.Ø,W*C3)+(V3-V1)*CMPLX(Ø.Ø,W*C2)
 45            V4=V3+AI3*CMPLX(R,Ø.Ø)
 46            AMP=CABS(V1*V1/(V4*CONJG(V4)))
 47            WW=(IW-1)/1ØØ.Ø
 48            II=48+I
 49            CALL VGRPH(WW,AMP,II,3,2)
 5Ø       2ØØØ CONTINUE
 51            WRITE(6,12ØØ) R,C3,C4,C5,R2,AAA,T,CI,RI
 52       21ØØ CONTINUE
 53            CALL VGRPH(Ø.Ø,1.Ø, ØØ.Ø,2Ø.Ø,4)
 54            CALL VGRPH(Ø,Ø,Ø,6,5)
 55       12ØØ FORMAT(      " R,C3,C4,C5,R2,AAA,T,CI,RI=",9E1Ø.3)
 56       5ØØØ CONTINUE
 57            END
EOF on FMGR file &ACTFL after reading    57 records with approx    1522. chars

R,C3,C4,C5,R2,AAA,T,CI,RI=  .5ØØE+Ø2  .6ØØE-1Ø  .15ØE-Ø9  .4ØØE-11  .27ØE+Ø4  .3ØØE+Ø2  .2ØØE-Ø7  .5ØØE-1Ø  .47ØE+Ø2
```

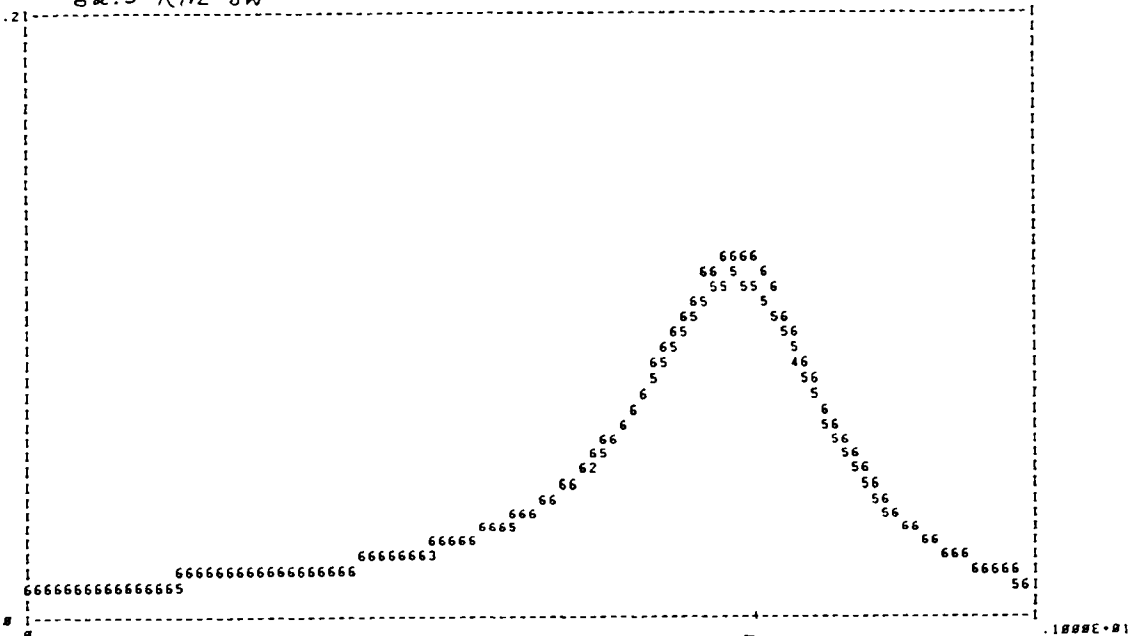
16 MHz BW



8MHz BW



62.5 KHz BW



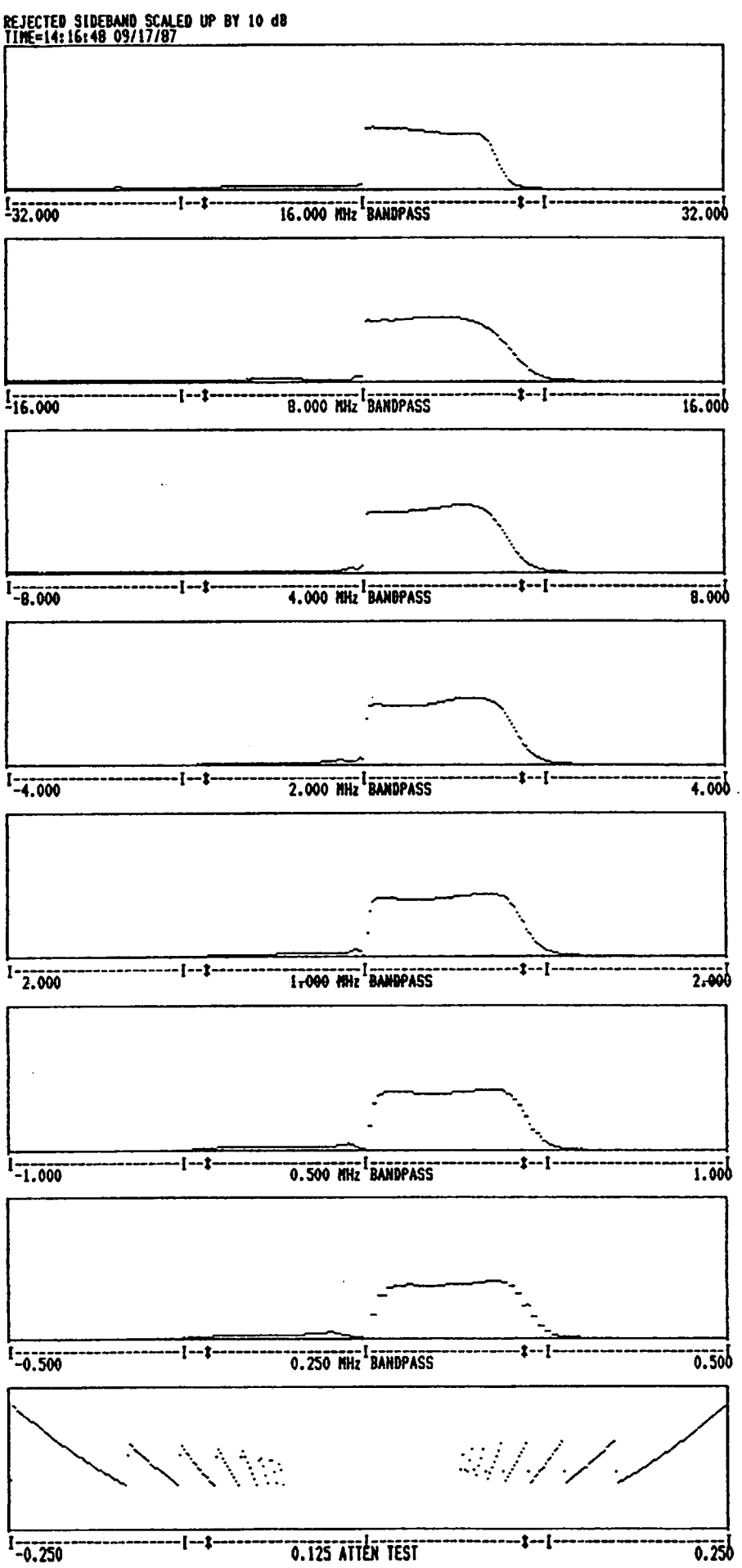
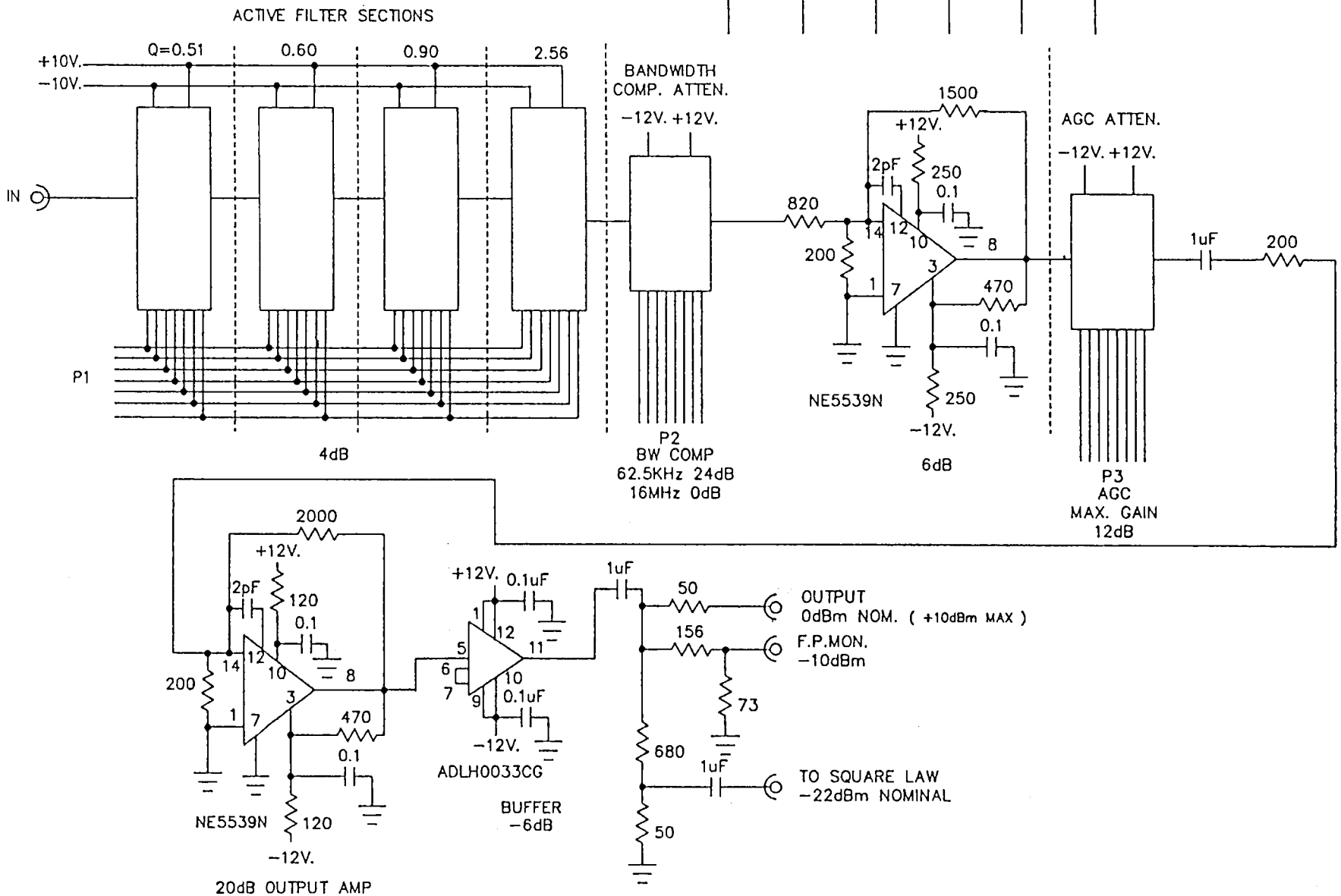

REJECTED SIDEBAND SCALED UP BY 10 dB
TIME=14:16:48 09/17/87
-32.000
16.000 MHz BANDPASS
32.000
-16.000
8.000 MHz BANDPASS
16.000
-8.000
4.000 MHz BANDPASS
8.000
-4.000
2.000 MHz BANDPASS
4.000
2.000
1.000 MHz BANDPASS
2.000
-1.000
0.500 MHz BANDPASS
1.000
-0.500
0.250 MHz BANDPASS
0.500
-0.250
0.125 ATTEN TEST
0.250
REJECTED SIDEBAND SCALED UP BY 10 dB
TIME=16:53:12 09/17/87

Figure 2

CHANGE LETTER	DWN BY	CHK'D BY	APP'D BY	DATE	D.C.N. & DESCR



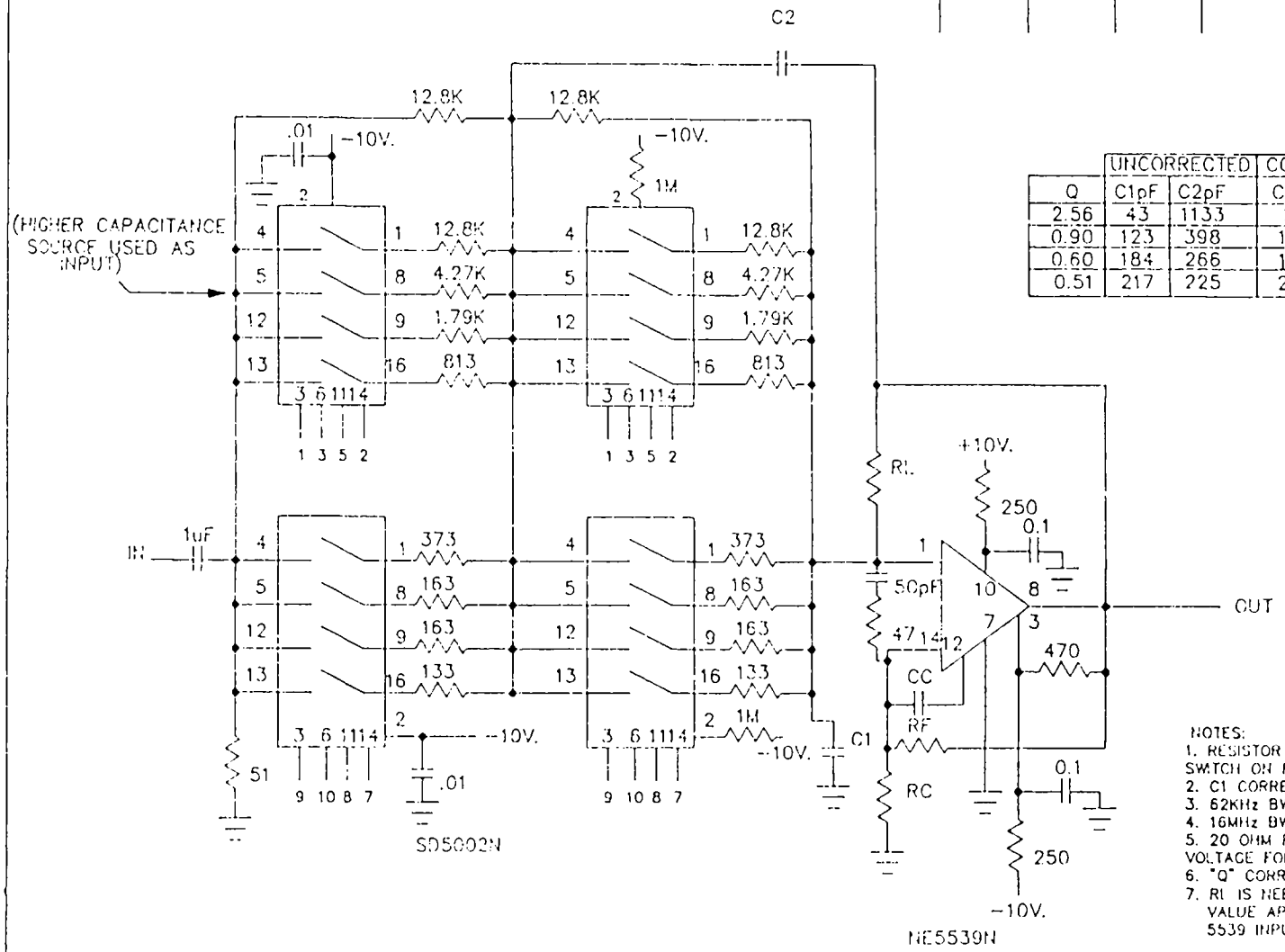
C- 54120S003

NOTES:

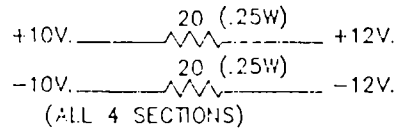
1. DASHED LINES INDICATE SEPARATE PC BOARD SECTIONS.
2. SEE DRAWINGS 54120S012, 54120S001, AND 54120S004 FOR CIRCUITS OF ACTIVE FILTER, BANDWIDTH COMP., ATTEN. AND AGC.

ELECTRONIC NOTES: UNLESS OTHERWISE NOTED: RESISTORS: CAPACITORS: INDUCTORS:	USED ON	DRAWN FOR: A.E.ROGERS	DATE: 9-85	NORTHEAST RADIO OBSERVATORY CORPORATION HAYSTACK OBSERVATORY WESTFORD, MASSACHUSETTS	
		DRAWN BY: A.PHILBROOK	9-85	BASEBAND FILT/AMP (BASEBAND FILTERS & BW GAIN & AGC)	
		CHECKED BY:			
	SCALE	APPROVAL PROJECT		C	54120S003
	CLASSIFICATION	ENGINEER:		AER\FILTAMP DWG. SIZE	DWG. NO. REV.

CHANGE LETTER	DWN BY	CHK'D BY	APP'D BY	DATE	D.C.N. & DESCRIPTION



	UNCORRECTED		CORRECTED				
Q	C1pF	C2pF	C1pF	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



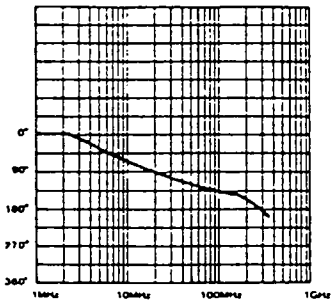
NOTES:
1. RESISTOR VALUES CORRECTED FOR 40 OHMS SWITCH ON RESISTANCE.
2. C1 CORRECTED FOR 20pF TO GROUND.
3. 62KHz BW ALL INPUTS LOW.
4. 16MHz BW ALL INPUTS HIGH.
5. 20 OHM RESISTORS (ON INPUT SECTION) DROP SUPPLY VOLTAGE FOR ALL FOUR SECTIONS.
6. "Q" CORRECTED FOR 40pF TO GROUND USING "RC".
7. RL IS NEEDED ON Q = 2.56 SECTION VALUE APPROX. 20K TO COMPENSATE FOR 5539 INPUT RESISTANCE.

C- 54120S012

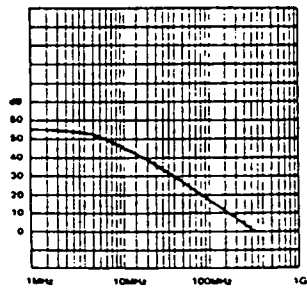
NOTES:

ELECTRONIC NOTES: UNLESS OTHERWISE NOTED RESISTORS: CAPACITORS: INDUCTORS:	USED ON	DRAWN FOR: A.E.ROGERS	DATE: 8-85	NORTHEAST RADIO OBSERVATORY CORPORATION HAYSTACK OBSERVATORY WESTFORD, MASSACHUSETTS	
		DRAWN BY: A.PHILBROOK	8-85	BASEBAND CONVERTER ACTIVE FILTER SECTION	
		CHECKED BY:			
SCALE	APPROVAL	PROJECT ENGINEER		C	54120S012
CLASSIFICATION				DWG SIZE	DWG NO REV

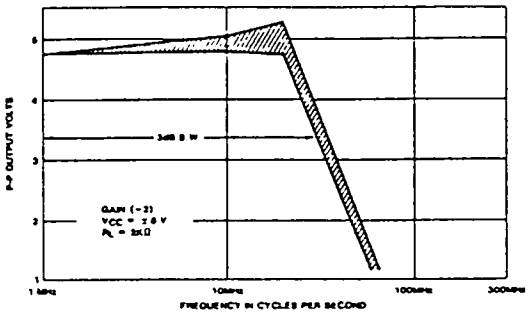
NE5539 OPEN LOOP PHASE



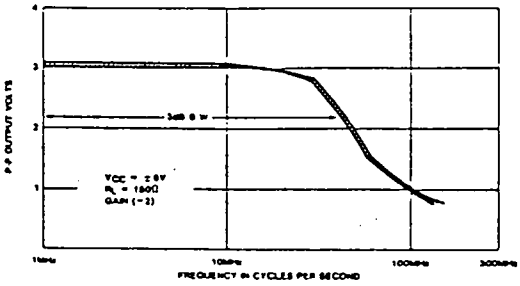
NE5539 OPEN LOOP GAIN



POWER BANDWIDTH (SE)

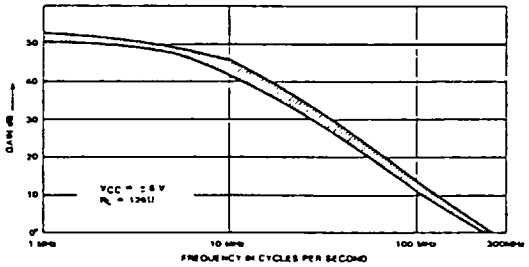


POWER BANDWIDTH (NE)

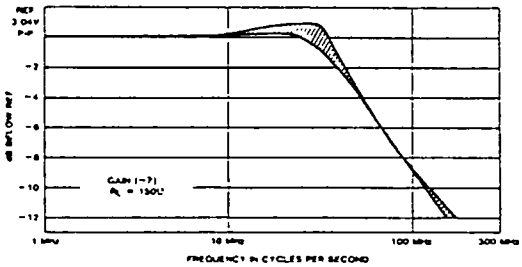


$e_o(rms) = 0.22$ volts r.m.s. $\approx$ 1 p-p into ... for

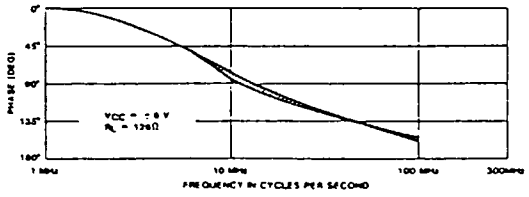
SE5539 OPEN LOOP GAIN vs FREQUENCY



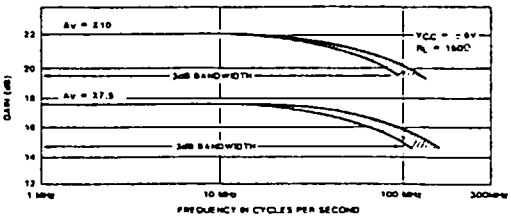
POWER BANDWIDTH



SE5539 OPEN LOOP PHASE vs FREQUENCY



GAIN BANDWIDTH PRODUCT vs FREQUENCY



NOTE

Indicates typical distribution $-55°C \leq T_A \leq 125°C$

(7)