VLBA ACQUISITION MEMO #162

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Area Code 508
692-4764

To: VLBA Data Acquisition Group

From: Alan E.E. Rogers

Subject: Improvements in SSB mixer submodule of BBC

1] Removal of phase bias

Difficulty in getting the BBC image rejection to meet specification (26 dB) has prompted another look at the design. If the r.f. phase shift error (from quadrature) is L, the video phase shift error is V and the fractional amplitude imbalance is A the image rejection is given by

$$[(L \pm V)^2 + A^2] / 4 \quad ("+" = \text{USB}, "-" = \text{LSB})$$

If the circuit performed perfectly the image rejection should be limited to 32 dB as a result of the 3 degree phase ripple in the differential phase response of the all pass network (see Acquisition Memo #101 for pole-zero locations). If we add a 0.4 dB (=5%) amplitude imbalance the rejection will be limited to 29 dB. Add a 2 degree r.f. phase imbalance and the rejection will be limited to 26 dB worst case. Since the video phase error oscillates around zero with frequency the worst case rejection should be nearly the same for each sideband. However if the video phase shift is biased it may be possible to adjust the r.f. phase shift so that the image rejection spec. is met for one sideband but is poor for the other sideband. A more careful examination of the circuit shows that there is in fact a phase bias of about 3 degrees at 8 MHz introduced by the feedback compensation capacitors in the 2 highest frequency stages of the all-pass network. This bias can be reduced to an insignificant level by changing the 178 ohm resistor in the highest frequency pole-zero to 162 ohms (or by adding 1.5K in parallel with the 178 ohm).

Figure 1 shows the circuit model used for simulation analysis and Figure 2 shows the phase error (relative to the theoretical differential all-pass action) of the high frequency sections in the path from each mixer.

2] Improved mixer balance

Some SSB submodules are difficult to adjust owing to mismatch between mixers. Mixers from different batches may be poorly matched with as much as 1 dB difference in conversion loss. LMX-113 or LMX-149 mixers can be used. While the circuit and parts list call for LMX-113 it may be that it is easier to achieve a good match with the more expensive LMX-149. Table 1 shows some data for the 2 mixer types. In either case it may be necessary to balance mixer conversion loss by adding a parallel resistor across the output of the mixer with lower conversion loss.

3] Improved r.f. phase quadrature

While the JH-140 hybrids is specified to have less than a 2 degree deviation from quadrature the r.f. quadrature can be degraded by the rather poor match (VSWR $\approx 4:1$) of the mixers. The match can be considerably improved (especially with LMX-149 mixers) by adding 100 ohm resistors to ground in parallel with the mixer L.O. ports. With these resistors in place the relative signal level at the "C" port of the JH-140 is reduced from -6 to -10 dB.

The mounting of the mixers and hybrid is fairly critical. The cutouts should ideally be only very slightly larger than the components to minimize the stray inductance. It is also advantageous to solder the cases to the pc board ground plane at the corners - see Figure 4.

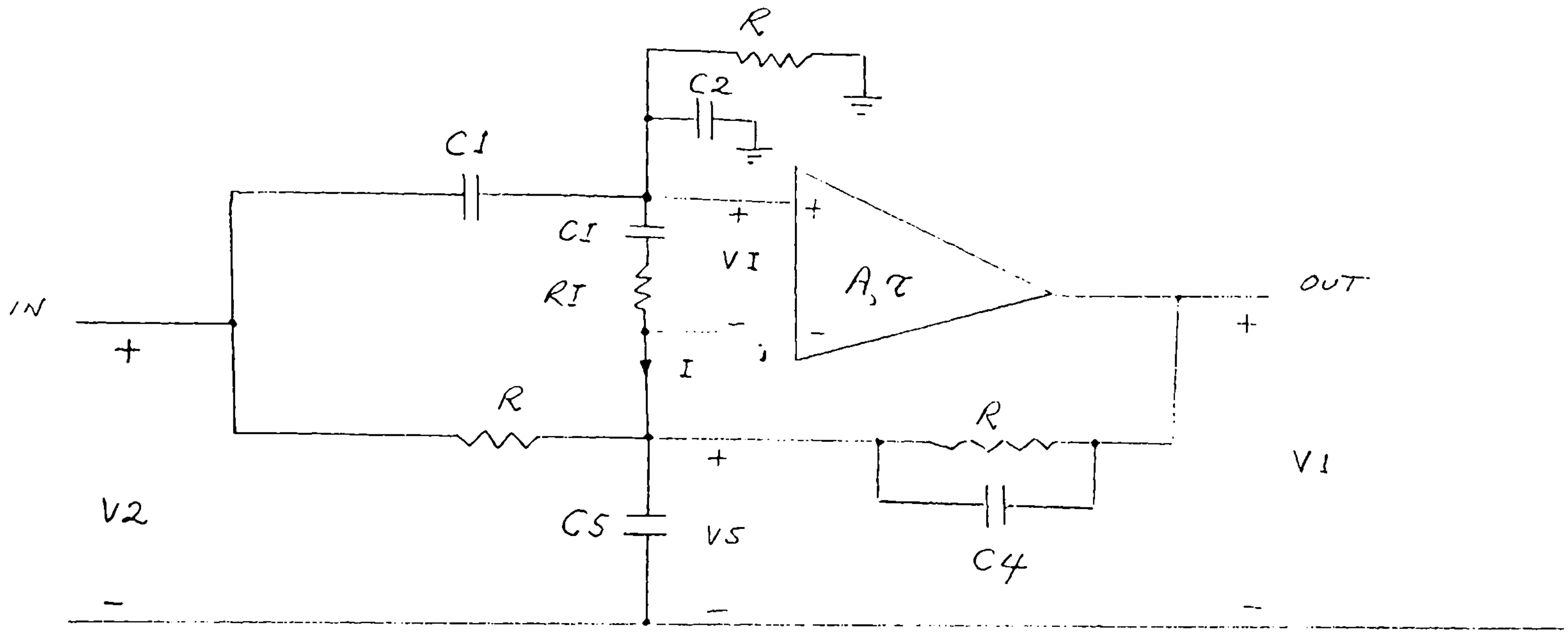
4] Suggested measurement setup and adjustment method

Use sweeper and scope to display both upper and lower sidebands simultaneously with converter bandwidth set to 16 MHz. With converter set to 750 MHz adjust the mixer amplitude balance by placing resistor across mixer output (500 ohm will correct a 0.8 dB imbalance) to minimize unwanted sidebands. With converter set to 950 MHz adjust the input line length for best image rejection and then adjust resistors across the JH-140 hybrid for final trim. Finally check image rejection with computer controlled test procedures. An iterative cycle of adjustment may be needed to achieve better than 20 dB image rejection in the worst case. Achieving 23 dB worst case at any combination of L.O. or r.f. frequency should always be possible - but 26 dB is difficult to achieve in the worst case, and I propose that the specification be changed to 23 dB.

Figure 3 shows the final test results from adjustment of the SSB mixer module in BBC Serial #14. Note that the frequency scale is logarithmic and covers the full video range from 10 KHz to 16 MHz.

Figure 5 shows the revised circuit diagram with notes. At this point more converters need to be examined to see if all the proposed changes are needed, or if they are sufficient to bring all converters to a 23 dB minimum image rejection.

Model for Video Phase Shift Sections in SSB Mixer



Transfer Function V1/V2

C2, C5 are stray capacitance

RI, CI part of H.F. compensation for stability

values: RI = 100 Ω
CI = 100 pf
C2 = C5 = 4 pf
C4 = 12 pf
R = 200 Ω

C1 = determined by pole-zero location (120 pf, 33 pf)
$|A|$ = 30 dB at 16 MHz
τ = 20 ns

Figure 1.

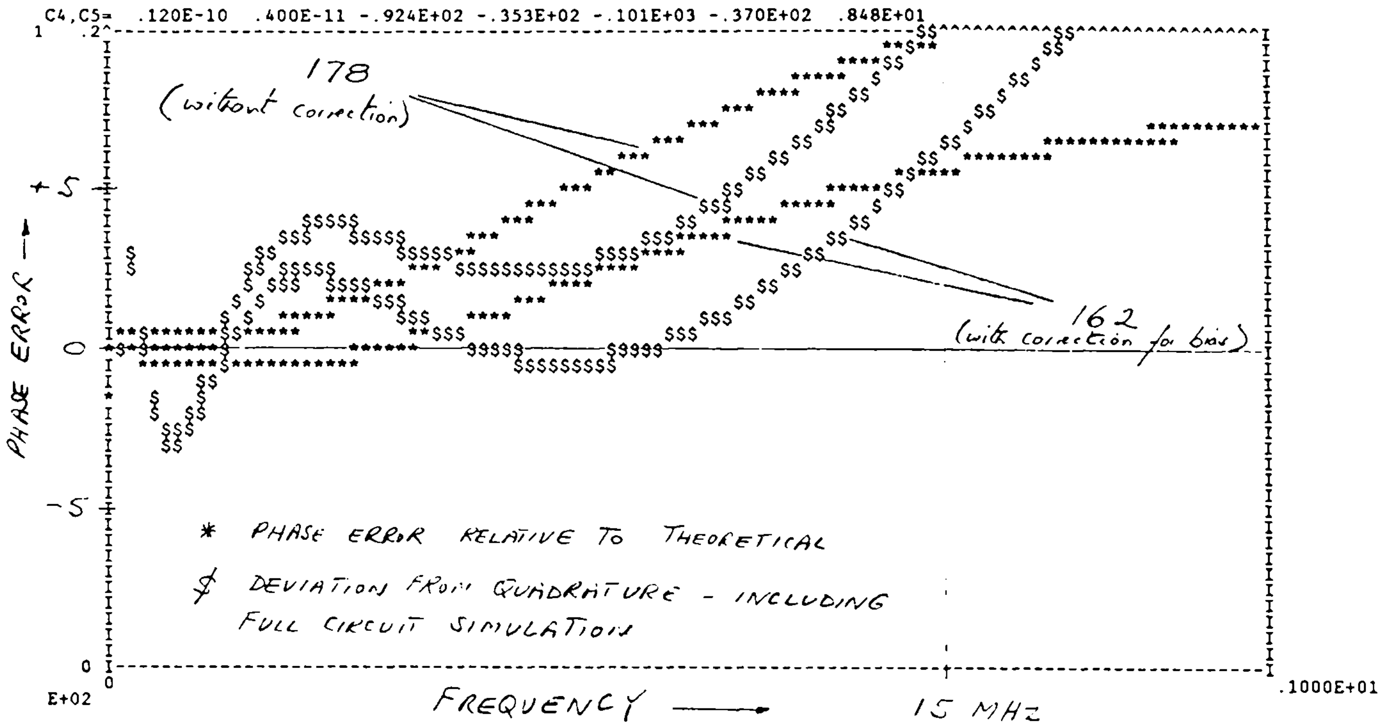

C4,C5= .120E-10 .400E-11 -.924E+02 -.353E+02 -.101E+03 -.370E+02 .848E+01
178
(without correction)
162
(with correction for bias)
PHASE ERROR →
+5
0
-5
* PHASE ERROR RELATIVE TO THEORETICAL
$ DEVIATION FROM QUADRATURE - INCLUDING
FULL CIRCUIT SIMULATION
FREQUENCY →
15 MHz
E+02
.1000E+01

Figure 2

MINI-CIRCUITS

MODEL:LMX-149 — MIXER CONVERSION LOSS

LO POWER : 7 dBm — QUANTITY:5 — DATE :12/10/85

RF POWER :-15 dBm — PROD RUN:F833945-1 — TESTED BY:PN

RF (MHz)	LO (MHz)	UNIT- 1 (dB)	UNIT- 2 (dB)	UNIT- 3 (dB)	UNIT- 4 (dB)	UNIT- 5 (dB)	PRO SPL (dB)	DELTA (dB)
20.000	50.000	5.51	5.47	5.45	5.38	5.37	5.34	.17
100.000	70.000	5.55	5.54	5.55	5.47	5.47	5.42	.13
123.880	93.880	5.62	5.61	5.61	5.50	5.52	5.46	.16
237.760	207.760	5.66	5.67	5.70	5.55	5.59	5.55	.15
346.630	316.630	5.51	5.55	5.62	5.47	5.48	5.48	.15
455.510	425.510	5.25	5.27	5.39	5.25	5.24	5.27	.16
564.390	534.370	5.43	5.53	5.60	5.51	5.51	5.51	.17
673.270	643.270	5.69	6.00	6.01	5.90	5.86	5.90	.32
750.000	720.000	5.67	5.77	[illegible]	[illegible]	5.75	5.81	.32
782.140	752.140	5.56	5.65	5.87	5.76	5.61	5.60	.31
891.020	861.020	5.31	5.61	5.62	5.58	5.46	5.57	.31
[illegible].900	[illegible].900	5.37	5.48	5.62	5.67	5.54	5.77	.30

REMARKS: TESTED USING S-D 1702 SIGNAL GENERTORS. TEST FIX 90-0-09-25. S/N 36382. PROD SAMPLE: RUN F851557-1.

MINI-CIRCUITS

MODEL:LMX-113 — MIXER CONVERSION LOSS

LO POWER : 7 dBm — QUANTITY:3 — DATE :3-24-8[illegible]

RF POWER :-15 dBm — PROD RUN:F850354-1 — TESTED BY:LB

RF (MHz)	LO (MHz)	UNIT- 1 (dB)	UNIT- 2 (dB)	UNIT- 3 (dB)	STOCK (dB)	SAMPLE (dB)	DELTA (dB)
10.000	40.000	5.75	5.38	5.81	5.80	5.72	.16
50.000	80.000	5.93	6.10	6.05	6.01	5.94	.16
100.000	130.000	5.92	6.03	5.97	5.92	5.89	.14
200.000	230.000	6.02	6.11	6.09	5.99	5.97	.14
300.000	330.000	6.04	6.17	6.11	5.99	5.94	.23
400.000	430.000	5.85	6.01	5.95	5.83	5.75	.26
500.000	530.000	5.83	5.96	5.92	5.79	5.67	.29
600.000	630.000	5.96	6.11	6.06	6.01	5.80	.31
700.000	670.000	6.10	6.28	6.20	6.10	5.86	.42
800.000	770.000	6.04	6.07	6.06	6.13	5.88	.25
900.000	870.000	6.36	6.33	6.18	6.39	6.16	.23
1000.000	970.000	6.76	6.89	6.49	6.82	6.49	.40
1100.000	1070.000	6.64	6.99	6.48	7.29	6.72	.81
1200.000	1170.000	7.24	7.69	7.09	7.63	[illegible]	[illegible]
1225.000	1195.000	7.38	7.80	7.21	8.22	7.51	1.01
1250.000	1220.000	7.94	8.33	7.75	8.81	8.22	1.06
1275.000	1245.000	7.80	8.17	7.63	8.60	8.10	.97

REMARKS: TESTED USING HP 8662A SIGNAL GENERTORS. STOCK RUN F840408-2 *TEST FIX 90-0-09-01 SAMPLE DATED 2-G3[illegible]*

Table 1. Comparison of LMX-149 and LMX-113 Mixers

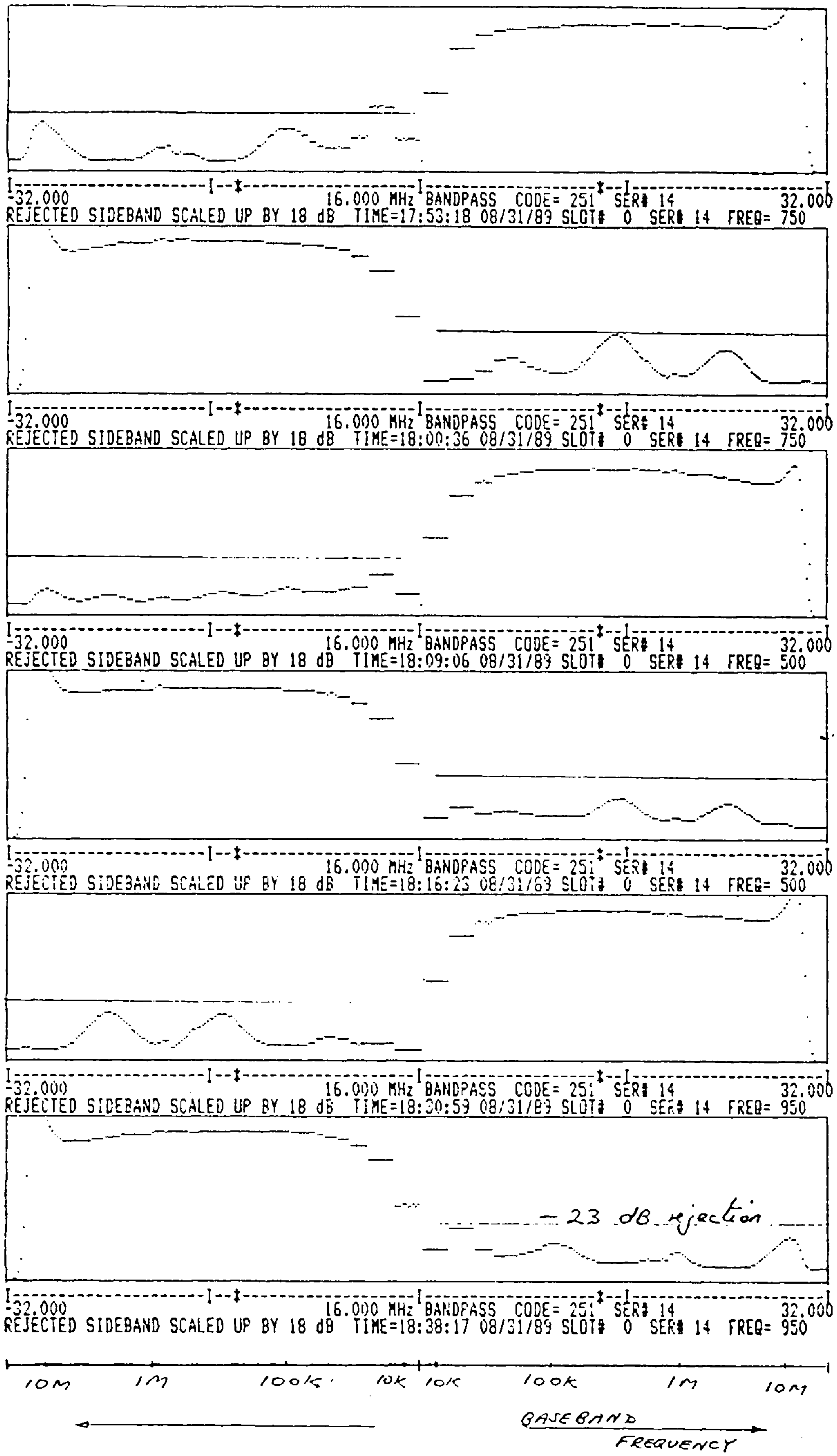

-32.000
16.000 MHz BANDPASS CODE= 251 SER# 14
32.000
REJECTED SIDEBAND SCALED UP BY 18 dB TIME=17:53:18 08/31/89 SLOT# 0 SER# 14 FREQ= 750
REJECTED SIDEBAND SCALED UP BY 18 dB TIME=18:00:36 08/31/89 SLOT# 0 SER# 14 FREQ= 750
REJECTED SIDEBAND SCALED UP BY 18 dB TIME=18:09:06 08/31/89 SLOT# 0 SER# 14 FREQ= 500
REJECTED SIDEBAND SCALED UP BY 18 dB TIME=18:16:23 08/31/89 SLOT# 0 SER# 14 FREQ= 500
REJECTED SIDEBAND SCALED UP BY 18 dB TIME=18:30:59 08/31/89 SLOT# 0 SER# 14 FREQ= 950
REJECTED SIDEBAND SCALED UP BY 18 dB TIME=18:38:17 08/31/89 SLOT# 0 SER# 14 FREQ= 950
-23 dB rejection
10M
1M
100K
10K
10K
100K
1M
10M
BASEBAND
FREQUENCY

Figure 3.

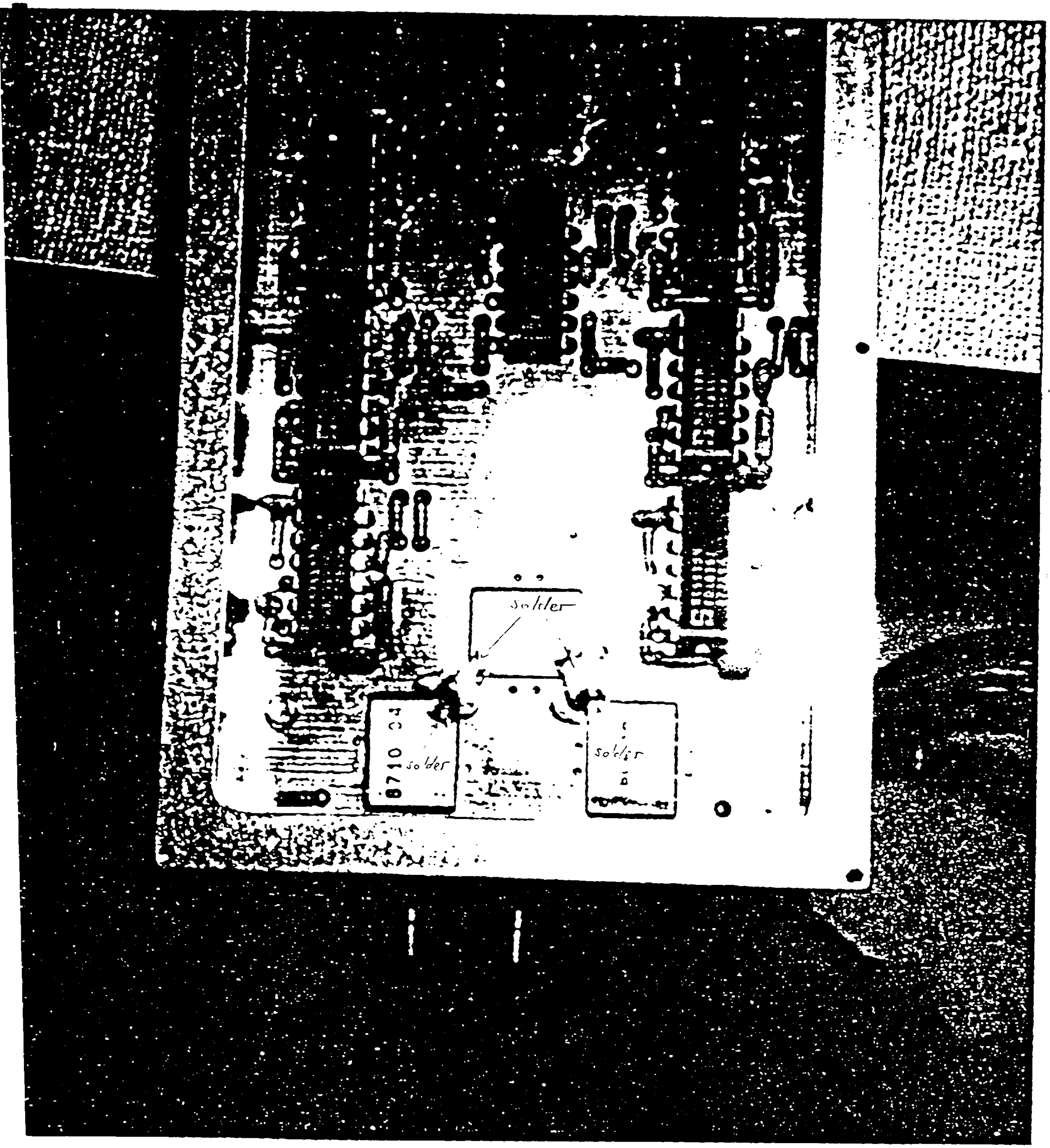
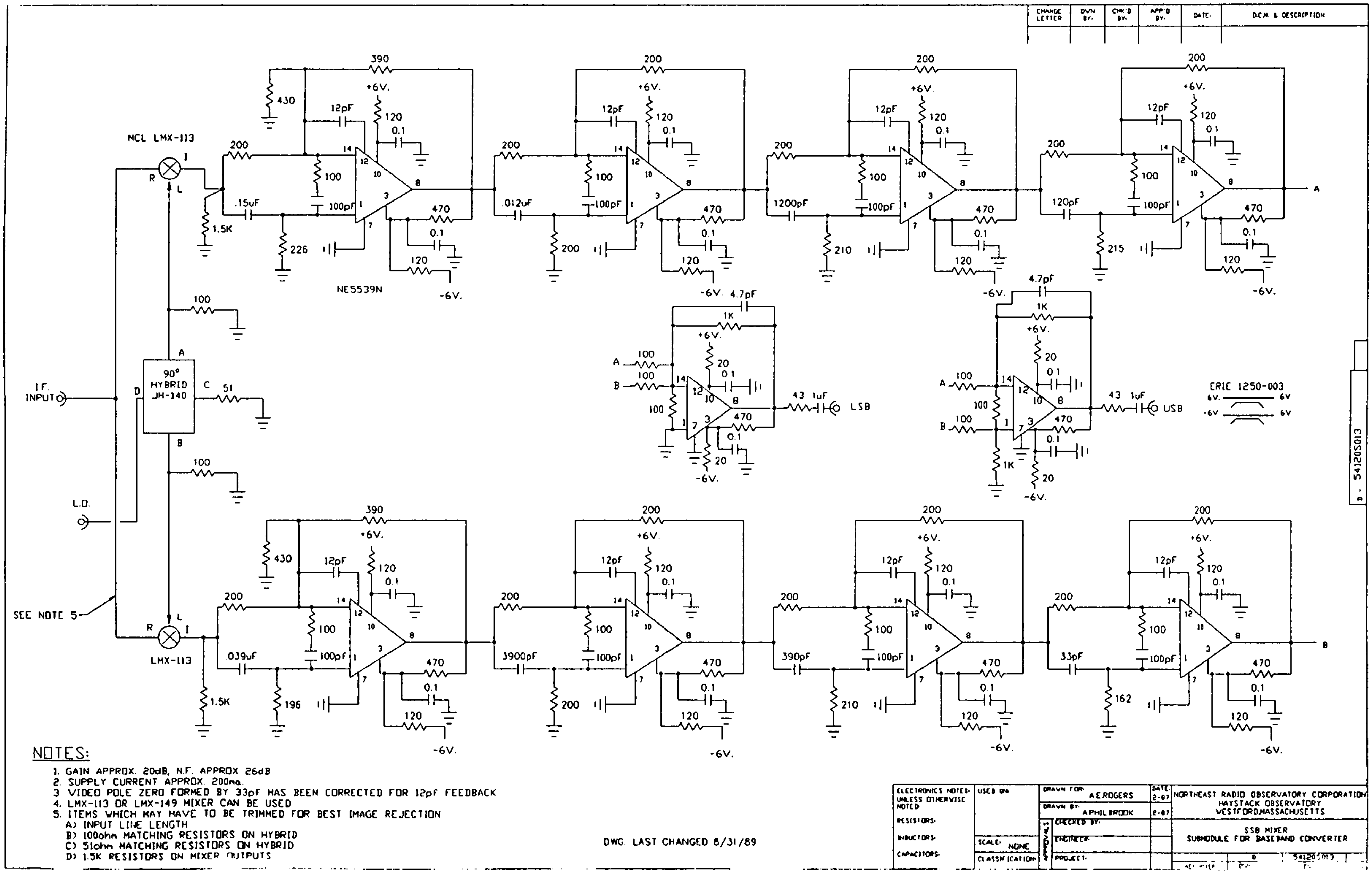


Figure 4. Improved grounding of hybrid and mixers using solder connection to ground plane

Figure 5.


NCL LMX-113
LMX-113
NE5539N
I.F. INPUT
L.O.
90° HYBRID JH-140
SEE NOTE 5
LSB
USB
ERIE 1250-003
NOTES:
1. GAIN APPROX. 20dB, N.F. APPROX 26dB
2. SUPPLY CURRENT APPROX. 200ma.
3 VIDEO POLE ZERO FORMED BY 33pf HAS BEEN CORRECTED FOR 12pf FEEDBACK
4. LMX-113 OR LMX-149 MIXER CAN BE USED
5. ITEMS WHICH MAY HAVE TO BE TRIMMED FOR BEST IMAGE REJECTION
A) INPUT LINE LENGTH
B) 100ohm MATCHING RESISTORS ON HYBRID
C) 51ohm MATCHING RESISTORS ON HYBRID
D) 1.5K RESISTORS ON MIXER OUTPUTS
DWG. LAST CHANGED 8/31/89
DRAWN FOR: A.E.ROGERS 2-87
DRAWN BY: A.PHILBROOK 2-87
NORTHEAST RADIO OBSERVATORY CORPORATION
HAYSTACK OBSERVATORY
WESTFORD,MASSACHUSETTS
SSB MIXER
SUBMODULE FOR BASEBAND CONVERTER
SCALE: NONE