VLA TECHNICAL REPORT #15

K AND KU BAND MIXERS

S. Maas

July 1975

TABLE OF CONTENTS

I. THEORY OF OPERATION

The K and Ku band mixers used in the VLA receiver front end are of similar design; both are single diode, externally biased, image enhancement mixers, designed to be cooled to 18 degrees Kelvin to reduce their noise temperatures. Each mixer consists of an input filter, local oscillator filter and diplexer, diode mount and IF output choke. All but the IF choke are waveguide components.

Identical gallium arsenide Schottky barrier diodes are used in each mixer. They are made by the Solid State Device Laboratory at the University of Virginia and have the following characteristics:

Junction capacitance:	.030 pf	(zero voltage)
Whisker inductance:	1.0 nH	
Series resistance:	3.0 Ω	
Case capacitance:	0.15 pf	
Eta (η):	1.055	(293°K)
Eta (η):	5.64	(18°K)
Cutoff frequency:	1767 GHz	(zero voltage)

It is possible, in theory to approach 0 dB conversion loss in a resistive mixer by supplying a purely reactive termination to all diode currents (or voltage components) generated by mixing the received signal with harmonics of the local oscillator[1]. In practice, the impossibility of properly terminating all the mixing products and the effect of diode and package parasitics limit the conversion loss to a few dB at centimeter wavelengths. Usually an attempt is made to optimize the image termination and the products of at most the first two or three LO harmonics[2].

When the mixer has a broadband input, i.e., when the signal and image frequencies are included in the input passband, the minimum conversion loss of the mixer is 3 dB[3]. In this case, half the received signal power is converted to the image frequency and terminated in the source impedance (or radiated). However, if a filter which rejects the image frequency is used at the input, the image frequency components can be reactively terminated and the conversion loss can be less than 3 dB. Such a mixer has reduced image response, and is called an image enhancement mixer.

---

[1] Saleh, A., Theory of Resistive Mixers, The M.I.T. Press, Cambridge, Mass., 1971.

[2] Egami, S., Nonlinear, Linear Analysis and Computer Aided Design of Resistive Mixers, IEEE MTT, Vol. 22, No. 3, p.270.

[3] Saleh, A., idem.

Since it has only one frequency transformation, there is no duality of SSB and DSB noise temperatures in the image enhancement mixer. Consequently, its noise temperature Tm is:

$$Tm = (\frac{1}{G} - 1)T_D$$

where G is the conversion gain (less than unity) and T_D is the effective diode temperature of the mixer.

Image enhancement mixers are particularly useful where the IF frequency is high (>10%) compared to the signal frequency. In this case the image band will be sufficiently well removed from the signal band that an input filter can be designed with low signal loss and high image rejection. In this case, the mixing products of the signal and higher order LO harmonics are not approximately harmonically related, and it becomes more difficult to terminate them optimally. This problem can be avoided by the use of phasing techniques rather than an input filter but this solution increases the complexity of the mixer[4,5].

The K mixer operates between 22.0 and 24.0 GHz; the Ku, between 14.4 and 15.4. The IF frequency for both mixers is 4.5-5.0 GHz. The LO frequencies are approximately the same for both mixers, 17.0-19.5 GHz for the K mixer and 18.9 to 20.4 GHz for the Ku. As a result, a single local oscillator module can be used for both mixers. However, because the LO frequency is greater than the signal frequency in the Ku mixer and less than the signal frequency in the K, different types of input filters must be used. The Ku mixer uses a corrugated waveguide low pass filter with a cutoff frequency approximately 19 GHz. The K mixer uses a short section of waveguide with a 19.6 GHz cutoff frequency as a high pass filter. In both filters, quarter-wave transformers are used at the input to match the standard waveguides to the modified height and width waveguides of the input filter and diode mount.

---

[4]Davis, R. T., "Inexpensive 12 GHz Mixers Developed for Satellite Broadcasting", Microwave, Vol. 14, No. 5, p.9.

[5]Dickens, L. "A New Phased Type Image Enhanced Mixer", 1975 Converence of Microwave Theory & Techniques, Palo Alto, California.

Local oscillator power is coupled into the input waveguide between the input filter and diode mount through the LO diplexer. A direct-coupled cavity bandpass filter is used for the LO filter; the last coupling aperture is in the wall of the input waveguide. The input filter prevents LO leakage from the input port, and the LO filter prevents signal loss through the LO port. A screw in the input waveguide tunes out the reactance of the LO filter junction.

The diode is mounted transversally in the center of the waveguide, in the diode mount. A movable short is positioned in the waveguide behind the diode. The anode (whisker) end of the diode package is secured to the waveguide wall; the cathode is secured in a beryllium copper spring finger contact which serves as the input section of the IF choke assembly.

The IF choke is a coaxial low pass filter of semilumped design. The input is a very low impedance at the signal and LO frequencies; consequently the cathode of the diode appears shorted to the upper waveguide wall at these frequencies, and excellent LO to IF port isolation results. A coaxial tuning stub is located on the IF line between the IF port and the filter output; its position was determined empirically with the aid of a network analyzer and polar display. This stub serves two purposes: (1) to improve the output VSWR of the mixer, and (2) to apply bias to the diode. Bias voltage is applied to one end of this stub. The "short" is in fact a feedthrough capacitor, consisting of an anodized aluminum cylinder slipped over the center conductor. Because of the thin dye coating, it has a high capacitance and large reflection coefficient at the IF frequencies.

II. ASSEMBLY

A. Tuning Stub:

The diode mount will be supplied assembled, but it is necessary to disassemble it to install the diode and preset the tuning stub.

(1) K Mixer:

Remove the screws in the top of the mount. Loosen all the screws in the bias connector and remove the top two. First remove the output connector and radial line choke, then remove the top of the diode mount. Do not try to remove the IF output connector at the same time as the top of the mount, or the soldered connection on the tuning stub may break. Be careful not to scratch the RF short or the bias may be shorted.

The RF short should be set so its edge is 0.065 inches from the end of the teflon SMA connector dielectric. Reassemble the mount in the opposite order to which it was disassembled, being careful not to move the tuning stub.

(2) Ku Mixer:

Remove the six 2-56 flathead screws from the side of the mount. Loosen the four SMA connector screws, and loosen the two 4-40 socket-cap screws recessed in the bottom of the mount. Remove the side plate. Preset the RF short so its edge is 0.050 inches from the end of the bias connector's teflon dielectric. Reassemble and tighten the screws. Be careful not to move or scratch the RF short.

B. Mounting the mixer diode:

No special handling of the diode is necessary; however, it is possible (although difficult) to damage the diode with a static electric discharge, so it is recommended that it be handled as little as possible.

Remove the bottom part of the diode mount by removing the two deeply recessed screws. Cut a few pieces of .004 inch high purity indium (the type used between mechanical connections in the cryogenic system) approximately .050 inches wide by .250 inches long. Insert these into the hole in the diode mount and insert the anode end of the diode so that the indium is wedged between the diode and the mount, and the diode is held firmly. Cut away the excess indium.

Connect an SMA short to the IF output connector, and screw it tight. Carefully reassemble the mount, being certain that the top of the diode fits into the spring fingers in the top half of the mount. Tighten the recessed screws.

Measure the current vs voltage characteristic of the diode, and be certain it is not leaky or shorted, and that the eta (η) is below 1.15. Slowly cool the mount in liquid nitrogen and check the diode characteristic during and after cooling. Cycle the mount two or three times. If no change in the room temperature or cooled diode characteristic is observed, the assembly is acceptable.

C. Assembling the mixer:

Each mixer consists of a diode mount, input filter, LO filter, and spacer. These components are assembled according to the assembly drawings, with the following cautions:

(1) The end of the input filter with the smaller opening mates with the LO filter.

(2) The spacer fits between the LO filter and the diode mount.

(3) The LO filter is completely symmetrical and may be turned 180° about its axis.

(4) The K mixer diode mount is symmetrical, and the mixer may be assembled in such a way that the bias arm points to the right or left as viewed looking into the input waveguide. One mixer of each orientation is needed per receiver.

(5) The Ku mixer diode mount is not symmetrical and should be installed in such a way that the side in which 2-56 flathead screw heads are visible contacts the LO filter.

Install a 4-40 x 5/8 inch socket cap screw and 4-40 locknut in the K mixer LO filter. Use a 4-40 x 3/4 inch socket cap screw and 4-40 x 3/16 inch locknut in the Ku mixer LO filter. Do no screw these tight (they are tuning screws) or damage to the filter will result.

III. TEST AND ADJUSTMENT

3.1 Mixer Test System

A. General:

Two mechanical and three electrical parameters must be adjusted for proper operation of the mixer. These are backshort and tuning screw positions, local oscillator (LO) power level and frequency, and diode bias voltage. The backshort and tuning screw positions are determined with the mixer at room temperature; the mechanical tolerances are such that no significant change in these adjustments occurs as the mixer cools. Furthermore, it can be shown[6] that the diode conductance can be made the same at cryogenic temperatures as at room temperature by a change in bias voltage and LO power level. Consequently it is necessary to readjust only LO power and bias voltage when the mixer is cooled.

The mixer is adjusted at an IF frequency of 4.75 GHz, the center of the 4.5-5.0 GHz output band. It has been determined that the response across the IF band will be adequate.

B. Test System:

The test system is shown in the appendix (4.3). The system provides an uncalibrated oscilloscope display of mixer conversion loss vs frequency at a constant (4.75 GHz) IF frequency, in order to accomplish initial adjustment. Hot (room temperature) and cold loads (77°K) are provided for noise temperature measurement and accurate conversion loss determination. Furthermore, it is possible, using facilities provided in the mixer test set, to measure output VSWR.

The noise diode applies wideband noise to the mixer through an attenuator, for noise level adjustment, and a directional coupler which supplies attenuation and isolation, to improve the VSWR seen by the mixer signal input. The local oscillator signal frequency is swept slowly across the LO band. An isolator is used at the signal generator output to prevent output power variations due to the poor output VSWR of the generator and mixer LO input. An attenuator is used to help adjust LO power. The signal generator may be leveled from its output (sensed by the detector and coupler) or from the mixer bias current as sensed by the mixer test set. The IF noise output is amplified by the mixer test set and applied to a square law detector.

---

[6] S. Weinreb & A. R. Kerr, "Cryogenic Cooling of Mixers for Millimeter and Centimeter Wavelengths", IEEE Journal of Solid State Circuits, Vol. SC-8, No.1 (Feb. 1973), p.58.

The detector output is applied to the oscilloscope vertical input, and signal generator sweep voltage is applied to the horizontal input. The result is a representation of the mixer input passband for a constant 4.75 GHz IF frequency.

The mixer test set is effectively a 4.75 GHz receiver which can be calibrated to give a direct reading in degrees Kelvin of the noise temperature of a component connected to its input. It is used to measure the noise power from the mixer IF output. Conversion loss is measured by applying a know input noise level change and measuring the output noise level change. The ratio of these is the conversion loss. Output reflection coefficient is determined by measuring the noise power reflected by the mixer where a noise signal is injected through a directional coupler toward the mixer IF output port. The incident noise signal level is simply measured by connecting a short circuit across the test set input port. Mixer noise temperature is determined to be the output noise temperature times the conversion loss factor, minus the noise temperature of the mixer input termination.

It is important that the noise radiated by the test set towards its input be as small as possible, or else a mixer with a poor output VSWR will reflect a significant amount of noise back into the set. To minimize this noise a circulator is used in the input line, and its third port is terminated in a liquid nitrogen cooled load. A a result, less than 150°K is applied to the input port, and a mixer with an output VSWR of 2.0 would cause only a 17 degrees noise increase in the apparent output noise level.

3.2 Adjustment of Mixers

Operation of the mixer test system should be obvious to any competent technician. The signal generator should be adjusted to sweep 17-19.5 GHz for K mixers or 19-20.5 GHz for Ku mixers. The mixer bias should be preset for approximately 0.1 mA with the LO power off. The test set's square law detector need not be calibrated, although is must not saturate. Detector output voltage should be approximately 1.5 volts peak.

The oscilloscope will display the mixer passband and diode current as a function of LO frequency. If the LO is leveled by sensing diode current, the diode current will be constant.

For initial adjustment, the LO power should be leveled in the conventional manner, i.e. with a directional coupler and detector. If the receiver LO will be leveled from diode current, the mixer can be optimized for operation in this mode. In this configuration it is important that the local oscillator be turned off with the ALC loop is opened, or high LO power may be applied to the mixer, resulting in diode destruction.

The mixer backshort, tuning screw, and bias voltage are alternately adjusted until the conversion loss is minimized across the band, and a reasonably flat passband results. There is no simple way to determine the absolute conversion loss at this point. Local oscillator power level has minimal effect on the passband shape, but it does affect conversion loss. It should be adjusted for minimum conversion loss. Diode current will be approximately 8 mA.

Inability to obtain a flat passband or good conversion loss will undoubtedly be traced to a defective diode, improper output tuning stub adjustment, or improper mixer assembly. First test the diode DC characteristics. No leakage should be measurable at 1.0V reverse bias (be sure that any measured leakage is not caused by condensed water in the diode mount). The diode should show a constant change in voltage ($\pm$2 mV per decade of current change, and no series resistance effects below approximately 1 mA). High output VSWR indicates tuning stub misadjustment. Inability to obtain a flat passband may indicate improper assembly.

If the mixer fails to perform well after assembly, tuning stub position, and diode DC characteristic have been checked, a new diode should be tried. Occasionally diode RF characteristics may be poor even though DC characteristics are good.

3.3 Measurement of Mixer Parameters

A. Calibration of the Square Law Detector:

Connect a liquid nitrogen cooled load of known noise temperature to the 4.75 GHz IF input of the test set. Put the meter switch in NOISE position, and turn the CAL/OFF switch off. Alternately adjust the square law detector GAIN and OFFSET precision potentiometers until the digital meter indicates ambient temperature in degrees Kelvin with the LOAD/MIXER switch in LOAD position, and cold load temperature in MIXER position. (A negative sign will appear on the meter, because of the polarity of the detector output voltage).

It may be necessary to adjust the IF GAIN attenuator to achieve suitable readings. When this adjustment has been performed, the meter indicates noise power, in terms of noise temperature, at the IF input port.

Calibration can be checked by switching to LOAD position. If the meter does not indicate ambient temperature, the GAIN potentiometer should be readjusted. It should not be necessary to reset the OFFSET potentiometer more often than once per day if the test set is not turned off.

When the detector has been calibrated the following parameters should be recorded, as they are necessary for analyzing the mixer data. Noise temperature with input terminated in a short circuit, and

(1) CAL/OFF switch OFF ($\triangleq T_{NB}$), and

(2) CAL/OFF switch on CAL ($\triangleq T_{CAL}$).

B. Mixer Measurements:

Noise temperature, conversion loss, and output VSWR can be measured at discrete points in the passband (over a 50 MHz bandwidth) after recording three output noise temperatures using the mixer test set. The LO signal generator is set to the desired frequency, and the following mixer output noise temperatures are recorded:

(1) Noise output with the cold load switched to the mixer input ($\triangleq T_{CO}$).

(2) Noise output with the hot (room temperature) load switched to the mixer input ($\triangleq T_{HO}$).

(3) Noise output with the cold load connected to the mixer input and the output noise diode turned on (CAL/OFF in in CAL position; $\triangleq T_{REF}$).

These three noise temperatures should be recorded at 100 MHz intervals for the Ku mixer and 200 MHz intervals for the K mixer. For each mixer test, the following additional information should be recorded:

(1) Mixer and diode serial numbers

(2) Type of mixer (K/Ku)

(3) Bias voltage

(4) Diode I/V characteristics (measured at 0.1, 1.0, 10.0, 100, 316 microamps, 1.0 and 3.16 mA) at room temperature and 77°K (liquid nitrogen cooled). From this data the diode eta and series resistance can be determined.

(5) T_{NB}

(6) T_{REF}

(7) Hot and cold load noise temperatures (T_{Hi} and T_{ci} respectively).

The conversion transducer gain, approximate noise temperature, and output power reflection coefficient can be determined by simple calculations:

(1) Conversion transducer gain:

$$G_T = 10 \log_{10} \left(\frac{T_{HO} - T_{CO}}{T_{Hi} - T_{ci}} \right)$$

(2) Output reflection coefficient magnitude:

$$|\rho| = \sqrt{\frac{T_{REF} - T_{CO}}{T_{CAL} - T_{NB}}}$$

$$\text{output VSWR} = \frac{1 + \rho}{1 - \rho}$$

(3) Approximate noise temperature (for output VSWR <2.0):

$$T_{MXR} = G_T \cdot T_{HO} - T_{Hi}$$

Equations for precise noise temperature and other relations are presented in the Appendix.

C. Final Preparations:

Cement the backshort into position with a dab of Torr-Seal or Miller-Stephenson Epoxy. Tighten the tuning stub locknut. Disconnect the IF output line and connect an SMA short <u>before</u> disconnecting the bias.

MIXER DATA SHEET

DATE ____________

K L.O.	KU L.O.	COLD (T_{CO})	COLD + REF (T_{REF})	HOT (T_{HO})	ΔT_O	L, DB	T_{MXR}
17.2	19.0						
.4	.1						
.6	.2						
.8	.3						
18.0	.4						
.2	19.5						
.4	.6						
.6	.7						
.8	.8						
19.0	.9						
.2	20.0						
.4	.1						
	.2						

Mount S/N ____________

Diode S/N ____________

T_{NB} ____________

T_{CAL} ____________

Temp ____________

Bias ____________

K L.O.	KU L.O.	COLD (T_{CO})	COLD + REF (T_{REF})	HOT (T_{HO})	ΔT_O	L, DB	T_{MXR}
17.2	19.0						
.4	.1						
.6	.2						
.8	.3						
18.0	.4						
.2	19.5						
.4	.6						
.6	.7						
.8	.8						
19.0	.9						
.2	20.0						
.4	.1						
	.2						

Temp ____________

Bias ____________

DIODE CHARACTERISTICS

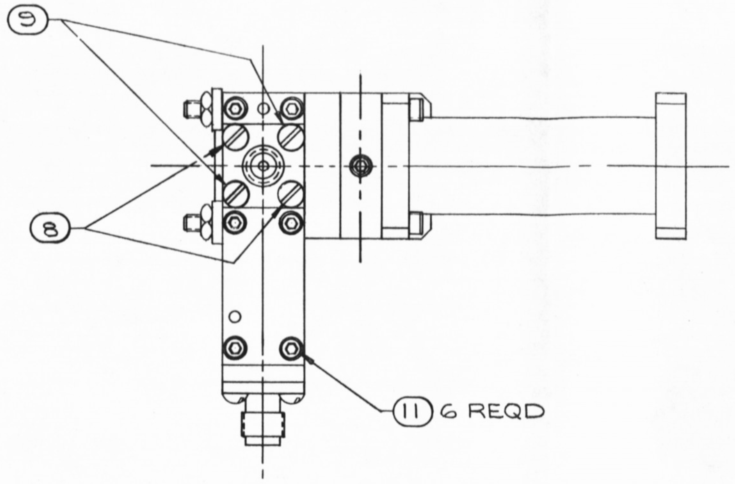
μA	20°K	300°K
	mV	mV
.10		
1.0		
10		
100		
1 mA		
.316 mA		
3.16 mA		
T_{DC}		

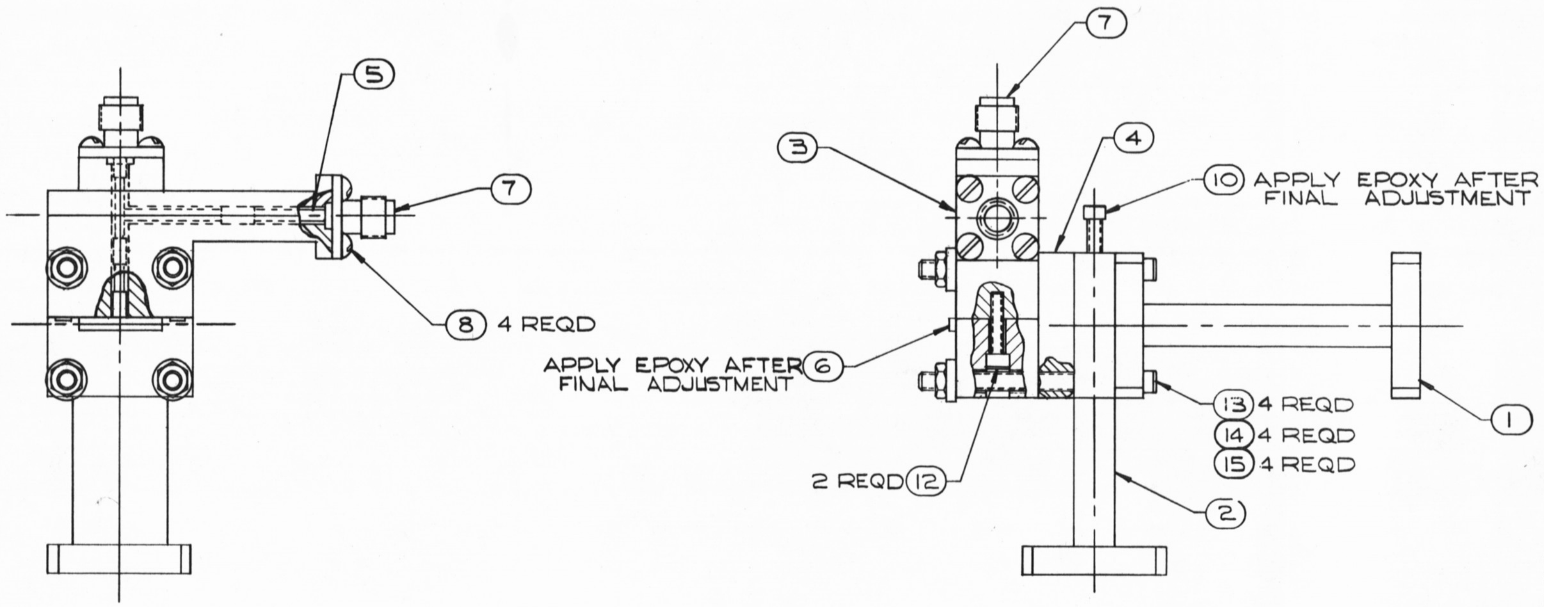
Ambient Temp: ____________

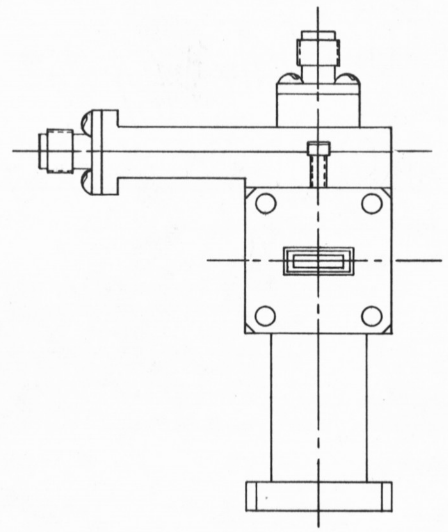
Hot Load (T_{Hi}): ____________

Cold Load (T_{Ci}): ____________

ΔT_i = ____________







ITEM NO.	QTY REQ'D	DRAWING NO.	TITLE
1	1	C13170M16	HIGH PASS FILTER ASSY
2	1	C13170M14	INPUT SECTION ASSY
3	1	D13170M11	DIODE MOUNT ASSY
4	1	B13170M17	SPACER, MIXER
5	1	C13170M12	CENTER CONDUCTOR
6	1	B13170M8-1	BACK SHORT
7	2	OSM 204	CONNECTOR
8	2		#2-56UNC x .125 LG RD. HD SCREW
9	2		#2-56UNC x .375 LG RD. HD SCREW
10	1		#4-40UNC x .750 LG HEX SOC HD CAP SCREW
11	6		#2-56UNC x .125 LG HEX SOC HD CAP SCREW
12	2		#4-40UNC x .375 LG HEX SOC HD CAP SCREW
13	4		#4-40UNC x 1.375 LG HEX SOC HD CAP SCREW
14	4		#4 FLAT WASHER
15	4		#4-40UNC HEX NUT

FOR BILL OF MATERIAL SEE A13170Z6

REV.	DATE	DRAWN BY	APPRV'D BY	DESCRIPTION
A	10 JAN 75	H Ward	J. Mann	ITEM 3 WAS C13170M11 RELEASED FOR MICROFILM

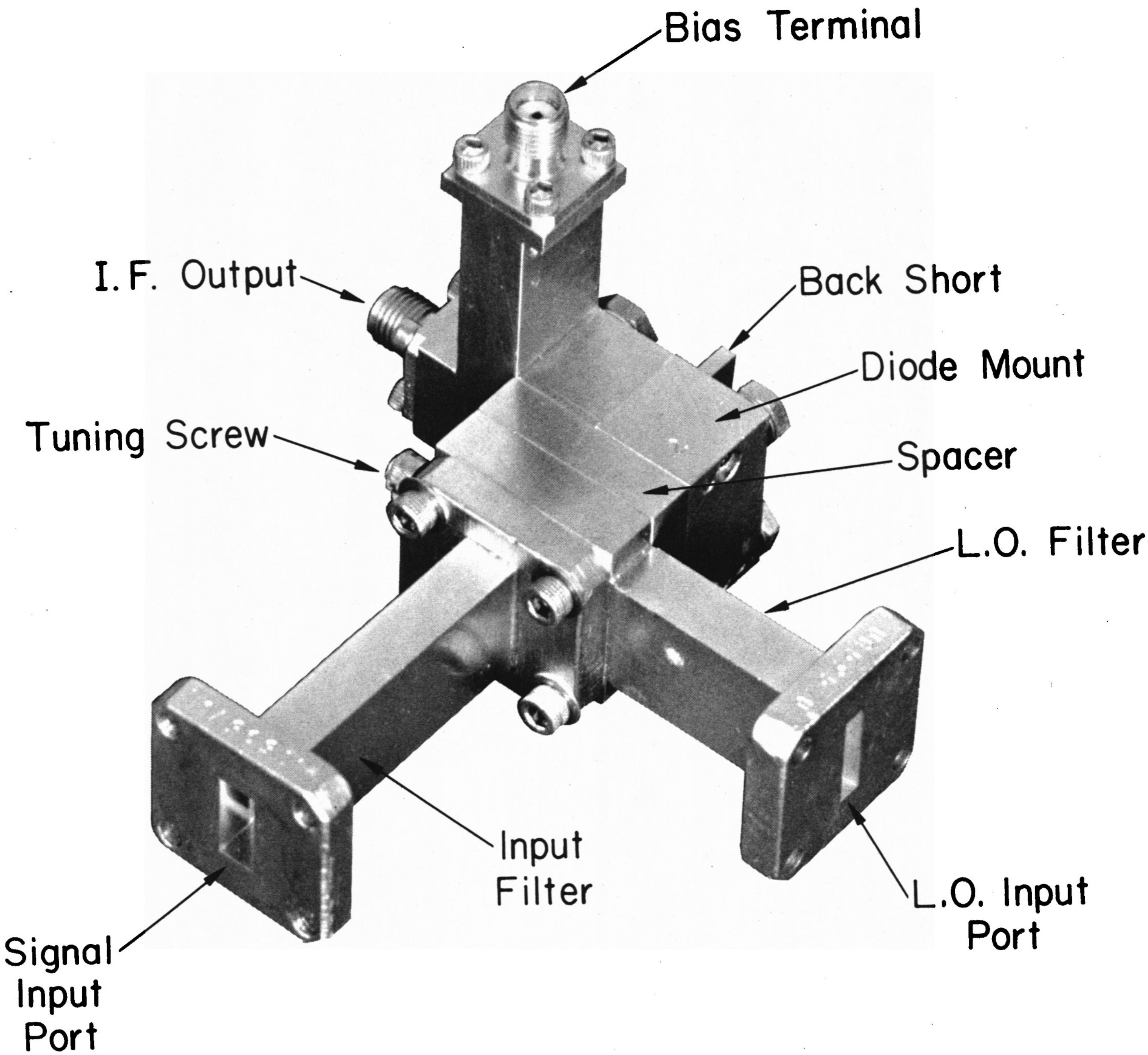
VLA PROJECT: RF COMPONENTS

TITLE: K BAND COOLED MIXER ASSY

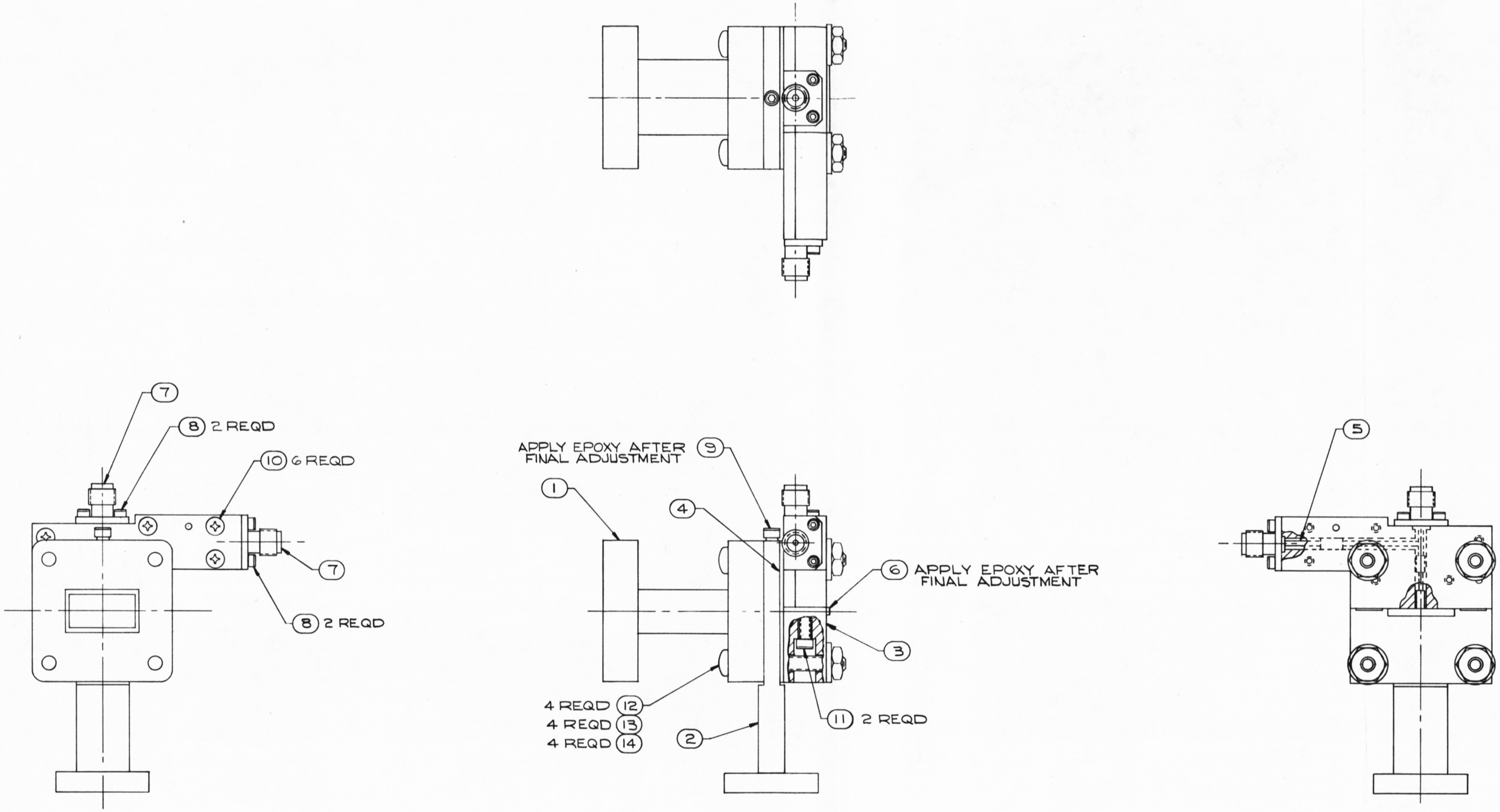
NATIONAL RADIO ASTRONOMY OBSERVATORY
CHARLOTTESVILLE, VA. 22901

DRAWN BY	DATE
Harold Ward	7-24-74
DESIGNED BY M Balister	7-30-74
APPROVED BY M Balister	7-30-74

SHEET NUMBER | DRAWING NUMBER D13170P2 | REV. A | SCALE: 2/1


Bias Terminal
I. F. Output
Back Short
Diode Mount
Tuning Screw
Spacer
L.O. Filter
Input Filter
L.O. Input Port
Signal Input Port

K BAND MIXER



ITEM NO.	QTY REQ'D	DRAWING NO.	TITLE
1	1	C13170M6	LOW PASS FILTER ASSY
2	1	C13170M4	INPUT SECTION ASSY
3	1	D13170M1	DIODE MOUNT ASSY
4	1	B13170M7	SPACER, MIXER
5	1	C13170M2	CENTER CONDUCTOR
6	1	B13170M8-2	BACK SHORT
7	2	B13170M10	CONNECTOR
8	4		#2-56UNC x .125LG HEX SOC HD CAP SCREW
9	1		#4-40UNC x .750LG HEX SOC HD CAP SCREW
10	6		#2-56UNC x .250LG FLAT HD SCREW
11	2		#4-40UNC x .375LG HEX SOC HD CAP SCREW
12	4		#6-32UNC x 1.125LG RD HD SCREW
13	4		#6 FLAT WASHER
14	4		#6-32UNC HEX NUT

FOR BILL OF MATERIAL SEE A13170Z1

REV.	DATE	DRAWN BY	APPRV'D BY	DESCRIPTION
A	10 JAN '75	H Ward	S. Mau...	ITEM 3 WAS C13170M1 RELEASED FOR MICROFILM

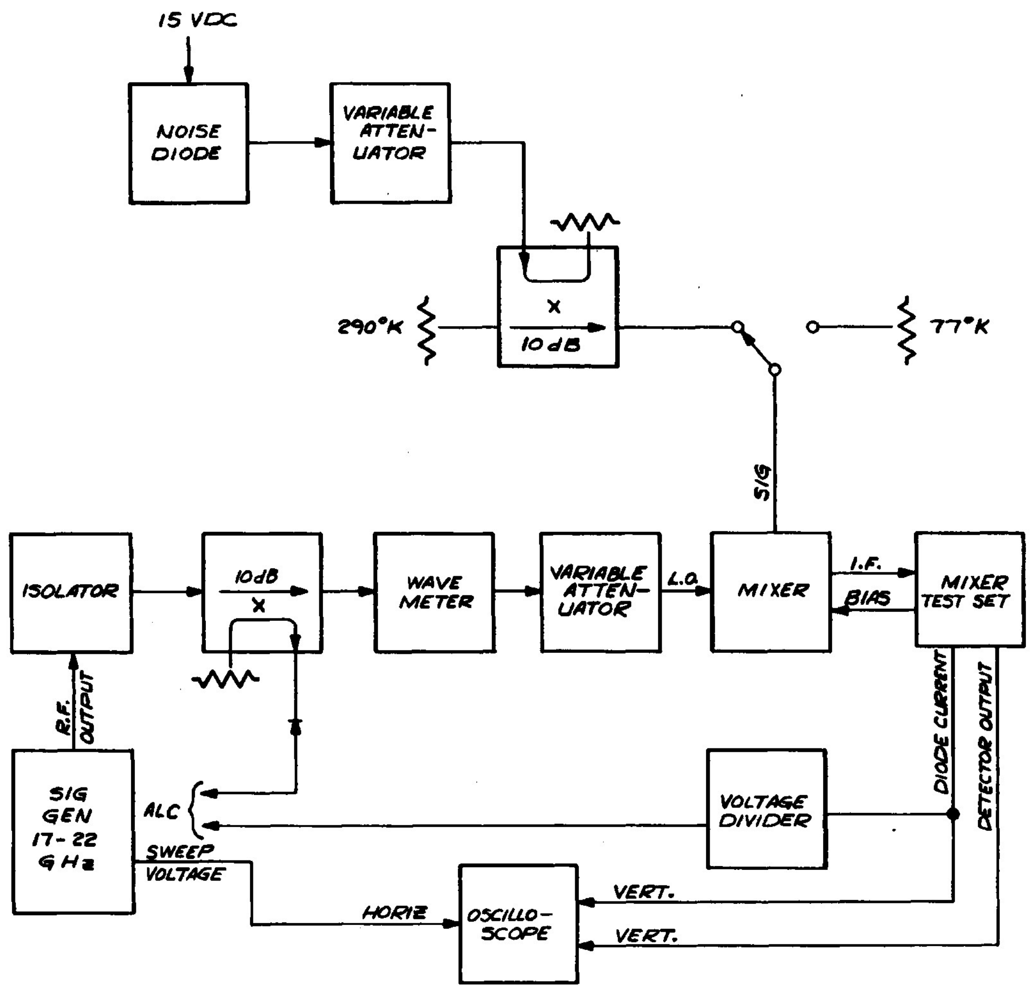
VLA PROJECT: RF COMPONENTS

TITLE: Ku BAND COOLED MIXER ASSY

NATIONAL RADIO ASTRONOMY OBSERVATORY
CHARLOTTESVILLE, VA. 22901

DRAWN BY: Harold Ward — DATE: 6-27-74
DESIGNED BY: M Balister — DATE: 7-23-74
APPROVED BY: M Balister — DATE: 7-23-74

SHEET NUMBER: — DRAWING NUMBER: D13170P1 — REV. A — SCALE: 2/1



REV.	DATE	DRAWN BY	APPRV'D BY	DESCRIPTION

NEXT ASSY	USED ON

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES: ANGLES ±
3 PLACE DECIMALS (.XXX): ±
2 PLACE DECIMALS (.XX): ±
1 PLACE DECIMALS (.X): ±

MATERIAL:

FINISH:

VLA

PROJECT: FRONT END

TITLE: MIXER ADJUSTMENT SYSTEM BLOCK DIAGRAM

NATIONAL RADIO ASTRONOMY OBSERVATORY
CHARLOTTESVILLE, VA. 22901

DRAWN BY: Harold Ward — DATE: 21 APR 75
DESIGNED BY: — DATE:
APPROVED BY: — DATE:

SHEET NUMBER: — DRAWING NUMBER: C13170B2 — REV. — SCALE

4.5 CALCULATION OF MIXER PARAMETERS

A. Transducer conversion loss factor:

$$L_T = \frac{\Delta T_i}{T_{HO}-T_{CO}}$$

expressed in dB:

$$L_T' = 10 \log_{10} L_T$$

where ΔT_i is the difference between hot and cold load noise temperatures; i.e. $\Delta T_i = T_{Hi}-T_{Ci}$

B. Conversion loss with matched output*:

$$L_M = \frac{\Delta T_i \ (1-|\rho_0|^2)}{(T_{HO}-T_{CO})}$$

where $|\rho_0|$ is defined in (C), below

$$L_M' = 10 \log_{10} L_M$$

C. Output reflection coefficient magnitude

$$|\rho_0| = \frac{T_{REF}-T_{CO}}{T_{CAL}-T_{NB}}$$

D. Mixer noise temperature, T_{MXR}:

$$T_{MXR} = ((T_{CO}-|\rho_0|^2 \ T_{NB}) \cdot L_T)-T_{Ci}$$

E. Effective diode temperature, T_D:

$$T_D = \frac{T_{MXR}}{L_M-1}$$

*NOTE: This quantity is not the available gain of the mixer because a conjugate match does not necessarily exist at the input.

4.6 PARTS LISTS

Quantity	Part No.	Description
1	D13170P1	Cooled Mixer Assembly, "Ku" Band
1	C13170M6	Filter Assembly, Low Pass
2	UG-419/U	Flange, Waveguide
1	C13170M5	L.P. Filter Body
AR	SN60	Solder
1	C13170M4	Injection Filter Assembly
1	UG-595/U	Flange, Waveguide
1	C13170M3	Injection Filter Body,
8	-----	Pins, Cross
AR	SN60	Solder
1	D13170M1	Diode Mount Assembly, Matched Set
2	1/16 dia. x ___LG.	Pin, Dowel
2	1/16 dia. x ___LG.	Pin, Dowel
1	B13170M7	Spacer, Mixer
1	C13170M2	Center Conductor Assembly
1	B13170M9	Sleeve
AR	SN60	Solder
1	B13170M8-2	Back, Short
2	B13170M10	Connector, Altered
2	OSM-204	Connector
4	#2-56 UNC x 1/8" LG.	Hex Socket Head Cap Screw
1	#4-40 UNV x 3/4" LG.	Hex Socket Head Cap Screw
6	#2-56 UNC x 1/4" LG.	Flat Head Screw
2	#4-40 UNC x 3/8" LG.	Hex Socket Head Cap Screw
4	#6-32 UNC x 1-1/8" LG.	Round Head Screw
4	#6	Flat Washer
4	#6-32 UNC	Hex Nut
AR		Resin, Epoxy

P/N AL13170P2

Quantity	Part No.	Description
1	D13170P2	Cooled Mixer Assembly, "K" Band
1	C13170M16	Filter Assembly, High Pass
2	UG-595/U	Flange, Waveguide
1	C13170M15	H.P. Filter Body
AR	SN60	Solder
1	C13170M14	Injection Filter Assembly
1	UG-595/U	Flange, Waveguide
1	C13170M13	Injection Filter Body, Machined
8	-----	Shims, Cross
AR	SN60	Solder
1	D13170M11	Diode Mount Assembly, Matched Set
2	1/16 dia. x ____ LG.	Pin, Dowel
2	1/16 dia. x ____ LG.	Pin, Dowel
1	B13170M17	Spacer, Mixer
1	C13170M12	Center Conductor Assembly
1	B13170M9	Sleeve
AR	SN60	Solder
1	B13170M8-1	Back, Short
2	OSM-204	Connector
2	#2-56 UNC x 1/8" LG.	Hex Socket Head Cap Screw
1	#4-40 UNC x 3/4" LG.	Hex Socket Head Cap Screw
6	#2-56 UNC x 3/16" LG.	Socket Cap Screw
2	#2-56 UNC x 3/8" LG.	Hex Socket Head Cap Screw
4	#4-40 UNC x 1-3/8" LG.	Round Head Screw
4	#4	Flat Washer
5	#4-40 UNC	Hex Nut
AR		Resin, Epoxy