ALBERTA RESEARCH COUNCIL
ATMOSPHERIC SCIENCES DEPARTMENT

Garry C. Cardinal

AN S BAND LOW NOISE RECEIVER

11 FEBRUARY 1981

Revised and updated
04 Nov 1986

This report deals with the design of a low noise receiver to be used in the S Band radar located at Penhold Alberta and operated by the Alberta Research Council, Atmospheric Sciences Department.

The low noise receiver is intended to be a series of retrofit replacements and additions to the existing radar receiver which are to improve the receiver performance specifications with particular attention to noise characteristics.

The ultimate goal of this design is to lower the effective noise power at the antenna in order to increase the receiver sensitivity by a minimum of five decibels.

The first part of this report describes the S band receiver system as it existed in the summer of 1980. Total noise figures and noise powers are calculated using the manufacturer's and, where available, the latest measurements made during the S Band microwave tests of 1979.

The second part describes the improvements which are to be undertaken and the resulting system is examined in a comparison to the 1980 system with regard to total noise figures and noise powers.

Appendix I is a discussion of noise power as relating to receiver characteristics. Appendix I includes a listing of the computer program written in BASIC which was used to calculate noise powers.

Appendix II is a discussion of noise figure of cascaded stages. Appendix II includes a listing of the computer program written in BASIC which was used to calculate total system noise figures.

The S Band radar employs a six point seven metre parabolic reflector in conjunction with a dual mode turnstile feedhorn to combine or separate transmitted or returned power into the components right hand circular and left hand circular.

These two components provide the S Band antenna with the capability of transmitting signals of any desired polarization and of discerning the polarization of returned power.

Two waveguide runs couple the antenna to a hybrid assembly. The upper waveguide run carries right hand circular power and the lower waveguide run carries left hand circular power.

The hybrid assembly is comprised of a pair of waveguide hybrids coupled by a ganged pair of variable power dividers. The hybrid assembly routes power from the transmitter to one or both of the waveguide runs and from each of the waveguide runs to one or both of the receivers.

The hybrid assembly affords the receiver system the ability to operate in any one of three primary transmit/receive modes, right hand circular, left hand circular, and linear. This mode flexibility is used extensively during performance evaluations of the receiver system. One of these modes, left hand circular, is the normal operating mode of the antenna.

Left hand circular has been selected as a normal operating mode of the antenna because evidence shows the antenna exhibits slightly more purity in the left hand circular mode than the right hand circular mode.

A linear operating mode is not an operating mode because relatively little information can be extracted about targets when compared to the circular modes. In the linear mode the hybrid asembly splits transmitted power to the right hand circular and left hand circular waveguides. Right hand circular and left hand circular return signals are split to each of the receivers.

A phase shifter at the joint between the hybrid assembly and the lower waveguide run facilitates left hand circular signals being varied in phase by up to three hundred sixty degrees with continuous variability. The phase shifter has the effect of altering the axis of orientation of linear transmitted signals and of altering the apparent axis of orientation of received linear signals.

One of four hybrid assembly ports is shared by the transmitter and the port one receiver through a branch duplexer.

In the normal transmit mode all transmitter power bypasses the port one receiver through duplexer action and enters the hybrid assembly at port one, exits the hybrid assembly at port three, goes through the phase shifter and the lower waveguide run to the turnstile left hand circular port.

In the normal receive mode returned left hand circular power from the turnstile goes through the lower waveguide run and the phase shifter, enters the hybrid assembly at port three, exits the hybrid assembly at port one, and through the duplexer to the port one receiver. Returned right hand circular power from the turnstile goes through the upper waveguide run and enters the hybrid assembly at port four, exits the hybrid assembly at port two, and into the port two receiver.

Both port one and port two receivers are protected from transmitter power by TR cells which present short circuits to high powers but pass low powers to the receivers. The port one TR cell is integral to the branch duplexer. The port two TR cell is coupled to the hybrid assembly port two with a high power isolator. The high power isolator serves to VSWR condition the hybrid assembly port two ensuring that leakage power reflected by the port two TR cell does not couple with the hybrid assembly port four and affect turnstile isolation.

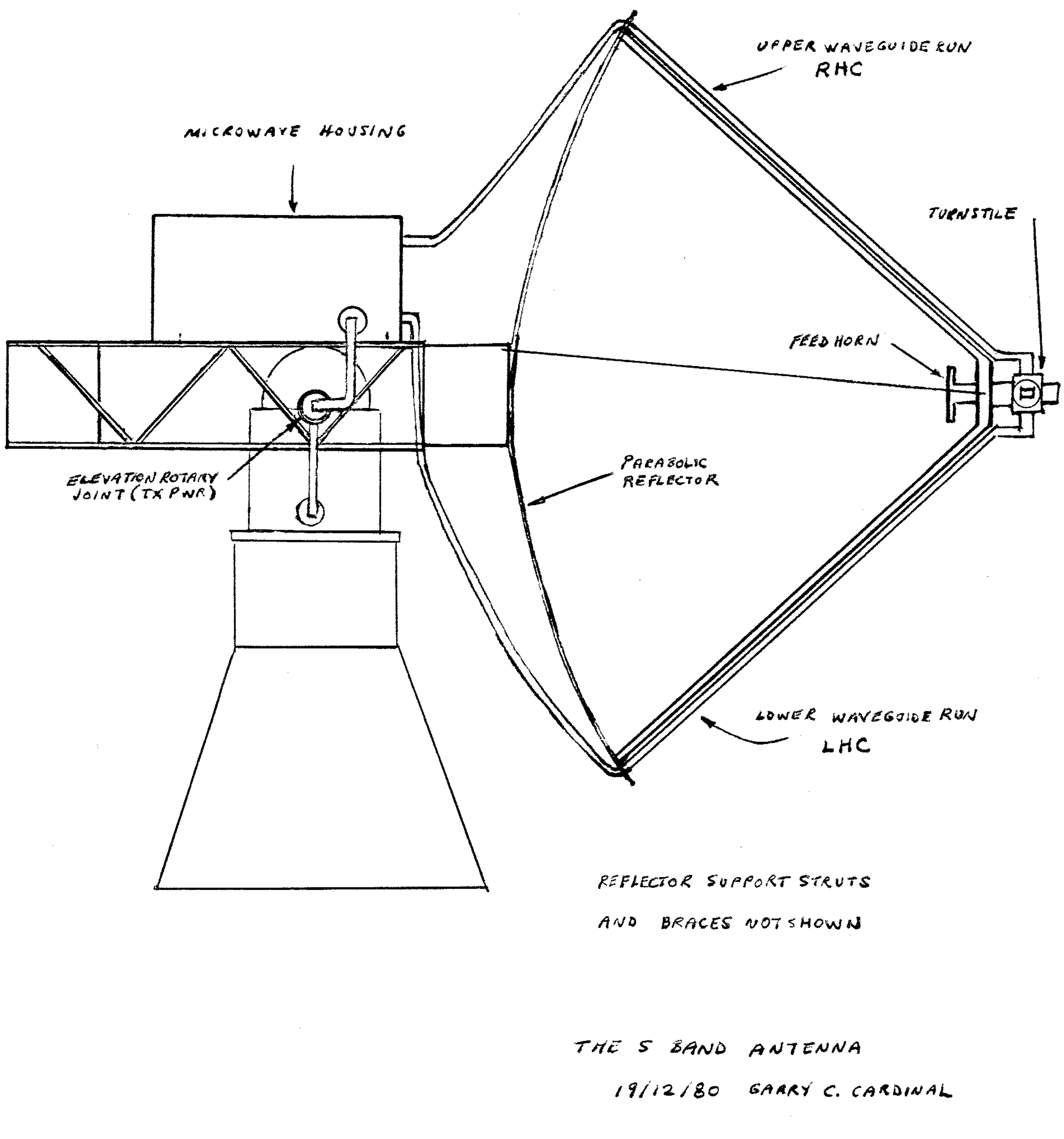
Both port one and port two TR cells are terminated by waveguide to N type transitions. The port one mixer/preamplifier is coupled to the port one transition through a coaxial isolator which prevents the port one mixer/preamplifier VSWR from affecting turnstile isolation. The port two mixer/preamplifier is directly coupled to the port two transition.

Local oscillator power to the two mixer/preamplifiers originates in a solid state phase locked frequency source which oscillates at the sum frequency of IF and RF. The output of frequency source is split by a hybrid power divider. Each of the power divider outputs is attenuated at the power divider by coaxial attenuators and routed to the respective mixer/preamplifier through RG213 coaxial cable.

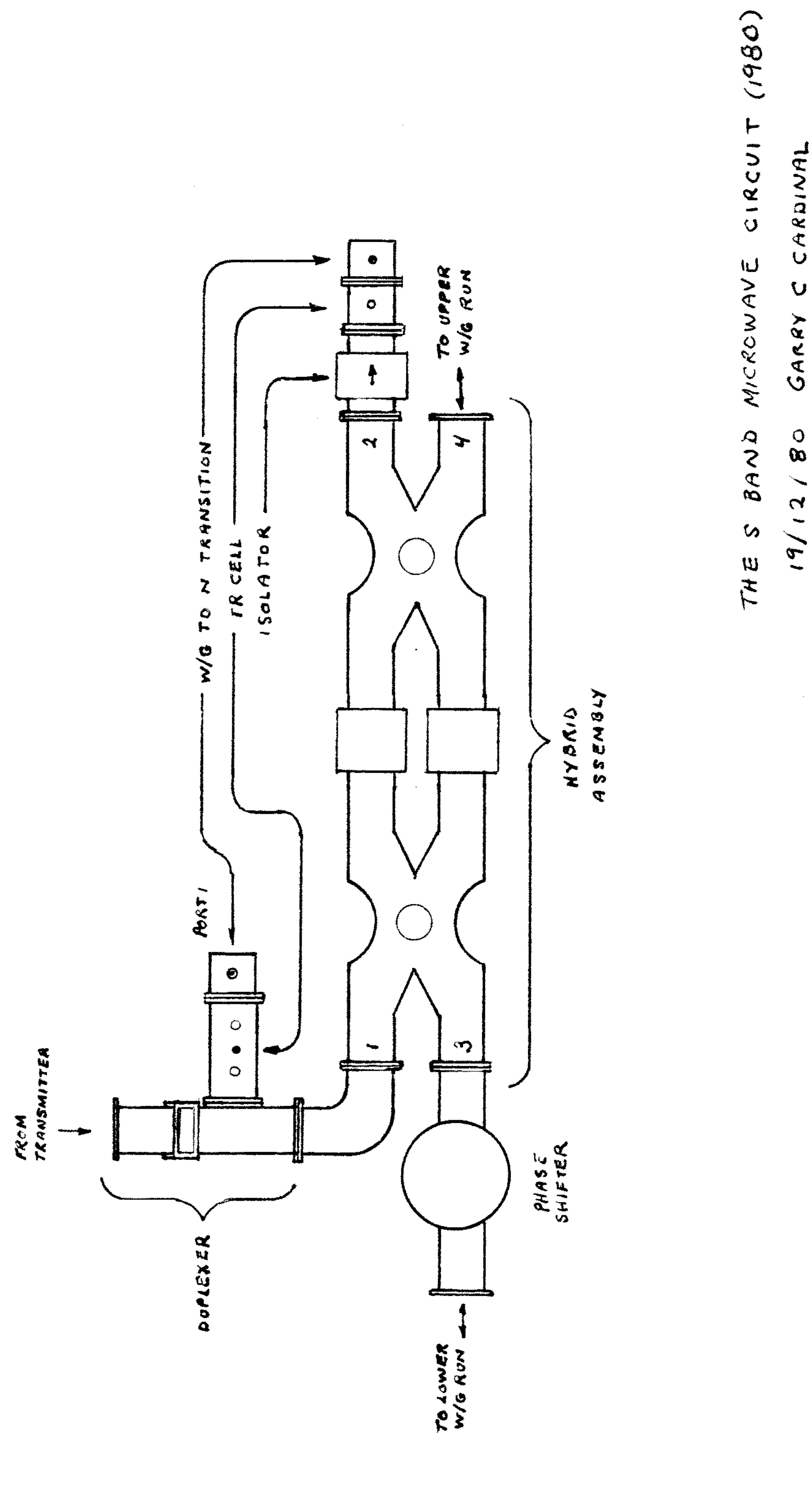
The local oscillator, local oscillator power supply, TR cell keep-alive power supply, mixer/preamplifier power supply, and a power supply voltage - mixer/preamplifier crystal current monitoring meter are all contained in a single chassis. DC power and crystal current monitor lines go to the mixer/preamplifiers via multiconductor sheilded cable with miniature D series connectors on the mixer/preamplifier end only.

The mixer/preamplifiers use discrete mixing diodes which are accessed under screw caps for field replacement. Each mixer/preamplifier has two diodes which are inserted in opposite polarities. Current through the diodes due to local oscillator injection can be monitored by the meter in the LO/power supply/ metering chassis.

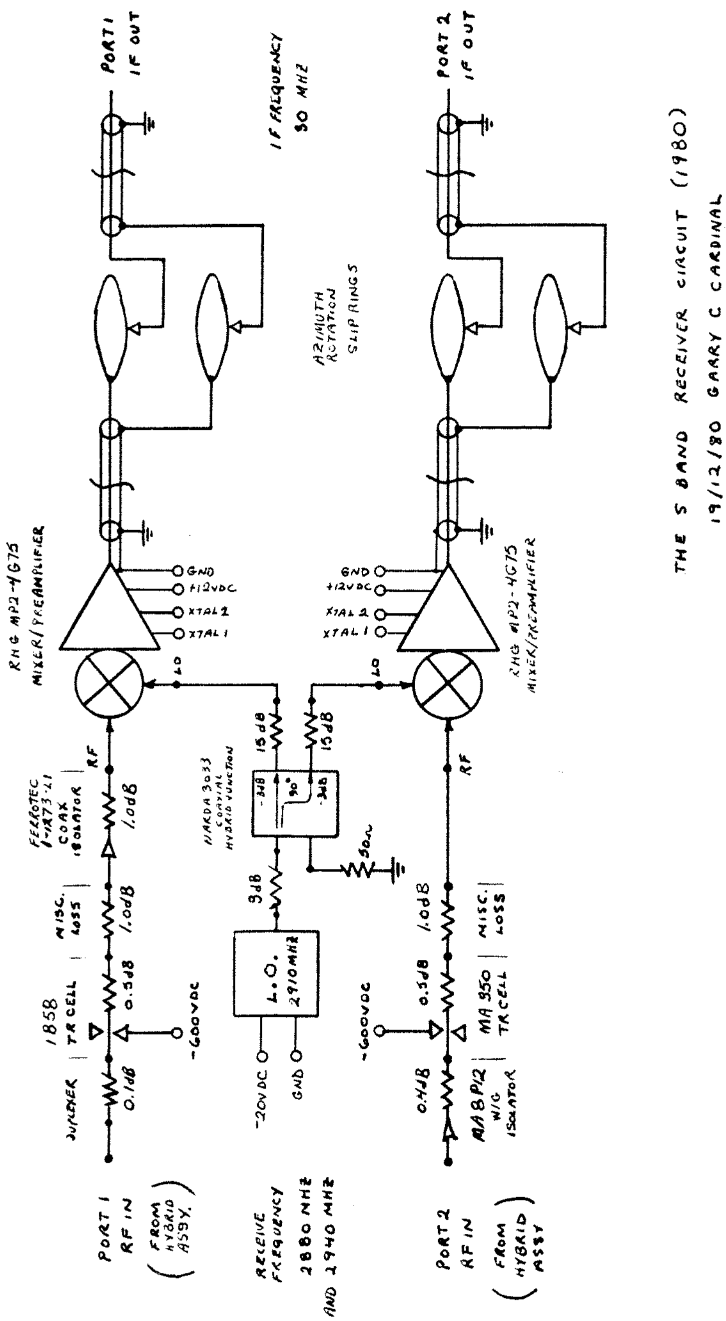
The mixer/preamplifiers are double response heterodyne frequency converters which output both LO+IF and LO-IF products. IF output connectors on the mixer/preamplifiers are BNC type. IF lines carry the mixer/preamplifier output signals to remote signal processing equipment through dual pairs of slip rings.


UPPER WAVEGUIDE RUN
RHC
MICROWAVE HOUSING
TURNSTILE
FEED HORN
PARABOLIC
REFLECTOR
ELEVATION ROTARY
JOINT (TX PWR)
LOWER WAVEGUIDE RUN
LHC
REFLECTOR SUPPORT STRUTS
AND BRACES NOT SHOWN
THE S BAND ANTENNA
19/12/80 GARRY C. CARDINAL

THE ANTENNA



THE MICROWAVE CIRCUIT



THE RECEIVER CIRCUIT

COMPONENT SPECIFICATIONS

ITEM/Spec	(Units)	PORT 1	PORT 2
W/G ISOLATOR		-	MA 8P12
Operating Freq	(GHz)	-	2.7-2.9
Isolation	(dB)	-	>10
Insertion Loss	(dB)	-	< 0.4
VSWR		-	< 1.15
Operating Pwr			
Peak	(MW)	-	1
Average	(KW)	-	1
TR CELL		1B58	MA 350
Operating Freq	(GHz)	2.665-2.965	2.7-2.9
Leakage	(Erg)	< 0.3	< 0.3
Insertion Loss	(dB)	< 0.5	< 0.5
Operating Pwr			
Peak	(KW)	750	50
Average	(W)	750	50
Keep Alive	(VDC)	600 @ 100 uA	600
COAX ISOLATOR		Ferrotec 1-1273-L1 Spec. Not Available	-
MIXER/PREAMPLIFIER		MP2-4G75	Same as PORT 1
Operating Freq	(GHz)	2-4	
Noise Figure	(dB)	7.8	
Responses	(#)	2	
Conv Gain	(dB)	29	
IF Bandwidth	(MHz)	2.4	
IF Frequency	(MHz)	30	
LO Injection	(dBm)	0	
Pwr Sup Reqmt	(VDC)	+12 @ 40 mA	

MEASUREMENTS
(From S Band Microwave Test 1979)

ITEM/Meas	(Units)	PORT 1	PORT 2
LUMPED LOSS			
Hybrid Port to			
Mixer/Preamp	(dB)	2.6	1.9
MIXER/PREAMPLIFIER			
Conv Gain	(dB)	32.8	31.0
IF Bandwidth	(MHz)	2.10	2.22
IF Frequency	(MHz)	30.2	30.0

NOISE POWER CALCULATION

The noise power at the antenna can be calculated using the data presented in previous text for each port of the S Band receiver.

The pertinent specifications for this calculation are:

Operating Temperature - Usually room temperature but for these calculations will be standardized to 26.85 Deg C as the S Band receiver is housed in an aluminum box which is exposed to sunlight.

Noise Bandwidth - The effective bandwidth of the receiver under scrutiny. The receiver is assumed to exhibit a passband which is square. The mixer/preamplifier response curves indicate skirt drop rates in excess of 5 dB/MHz. Thus, the 3 dB bandwidths can approximate square response with little error.

Responses - The number of separate receive frequencies that the receiver under scrutiny will pass to the output. Superheterodyne receivers without frequency preselection or image rejection have two responses. One is the desired receive frequency, the other is parasitic and has the sole effect of passing an extra bandwidth of noise to the IF output.

TERM	ABBREV	UNITS	PORT 1	PORT 2
Temperature	T	Deg C	26.85	26.85
Bandwidth	BW	MHz	2.10	2.22
Responses	#BW	#	2	2

See Appendix I

Anten Noise Pwr	PNA	dBm	-107.60	-107.36

NOISE FIGURE CALCULATION

Total noise figures for each port of the S Band receiver can be calculated using data presented in previous text.

The pertinent specifications for this calculation are:

Noise Figure - For active devices such as low noise amplifiers or mixer/preamplifiers this specification is supplied by the manufacturer. For passive devices elements in an uninterrupted series can be equated to a single attenuator. The noise figure of an attenuator is, by definition, same as the attenuation.

Gain - Gain is positive for amplification, negative for attenuation.

TERM	ABBREV	UNITS	PORT 1	PORT 2
Stages	#st	#	2	2
Noise Fig 1	NF1	dB	1.9	2.6
Gain 1	G1	dB	-1.9	-2.6
Noise Fig 2	NF2	dB	7.8	7.8

See Appendix II

Total Noise Fig	NFT	dB	9.7	10.4

EFFECTIVE NOISE POWER

The effective noise power at the receiver inputs for each port of the S Band receiver can be calculated using the parameters PNA and NFT. Antenna noise power is the absolute power which will appear at the receiver inputs due to temperature and receiver bandwidth. Noise figure is the ratio of the noise out of a device versus the noise into the same device. Effective noise power simply relates total system noise references to the system input.

TERM	ABBREV	UNITS	PORT 1	PORT 2
Anten Noise Pwr	PNA	dBm	-107.60	-107.36
Total Noise Fig	NFT	dB	9.7	10.4
Effec Noise Pwr	PNE	dBm	-97.20	-97.66

A figure of merit often applied to radar receivers is Minimum Discernable Signal (MDS). MDS is determined by a human operator visually monitoring the receiver output after a logarithmic amplifier. An injected signal of appropriate frequency and pulse width is compared to noise. When the injected signal is decreased in power to the point where signal is just discernable, the power is recorded as MDS.

MDS' in the order of -102 dBm to -107 dBm have been recorded or the S Band receiver. The comparison MDS to Effective Noise Power (Pne) indicates the great sensitivity of the human eye integrating signal from noise. The wide range of MDS measurements indicate the subjectivity involved in arriving at such measurements.

PEAK EFFECTIVE NOISE POWER

A more realistic approach to receiver sensitivity analysis is to locate a threshold power above which noise will not be present a large percentage of the time.

Thermal noise is gaussian in distribution, therefore, the instantaneous amplitude can only be defined in terms of probability. The crest factor for noise is dependent on the percentage of time the noise power can be tolerated to exceed the expected peak value. The table below illustrates.

% TIME PEAK EXCEEDED	CREST FACTOR	CREST FACTOR (dB)
1.0	2.6	4.15
0.1	3.3	5.19
0.01	3.9	5.91
0.001	4.4	6.43

Adding a crest factor of 3.3 (5.19) to the PNE of each port gives:

TERM	ABBREV	UNITS	PORT 1	PORT 2
Peak Eff N Pwr	PNEP	dB	-92.01	-92.47

The following text will examine the improvements which are being undertaken.

No changes will be made to the port two waveguide isolator. Adequate measurements to evaluate it's performance have not been made to date.

TR CELLS

The purpose of a TR cell is to prevent high energy transmitter power from destroying the sensitive components used to detect the faint powers returned by distant targets. TR cells act as waveguide filters which present short circuits to high powers and appear transparent to low level powers.

The port one TR cell is integral to the branch duplexer and must withstand the entire transmitter power at it's input. The port two TR cell is separated from transmitter power by the hybrid assembly which provides more than 20 dB of isolation.

The TR cells presently used are 1B58 for port one, and MA350 for port two. Both devices require a keep alive voltage of 600VDC to sensitize the devices to permit the low spike leakage and breakdown power specification.

The failure characteristics for the present TR cells are that leakage energy increases as the devices age and may deteriorate to the point that damage to following receiver mixer diodes could result. The lifetime of these TR cells is specified as 500 hours with keep-alive voltage applied.

The specifications for 1B58 and MA350 TR cells is identical but for power handling and size. 1B58 tubes are rated for 750KWP input power and are 6.6 inches long. MA350 tubes are rated for 5KWP input power and are 3 inches long.

Retrofit TR cells are available which have long active lifetimes (2000 hours) and do not require keep-alive voltages. These new, passive devices have safe failure characteristics - leakage becomes less as the devices age but recovery times get longer.

Passive TR cell replacements are available for the 1B58 TR tube, but, not the MA350. Passive TR tubes with less power handling capability than the 1B58 are available, but, do not cost less than the 1B58 replacement.

Both 1B58 and MA350 TR tubes will be replaced by VARIAN VDS1014 passive TR limiter tubes.

TR TUBE SPECIFICATIONS

SPECIFICATION	UNITS	1B58	MA350	VDS1014
Operating Freq	GHZ	2.665-2.965	2.7-2.9	2.665-2.965
Operating Pwr				
Peak	KW	750	5	750
Average	W	750	5	750
Insertion Loss	dB	$<$ 0.5	$<$ 0.5	$<$ 0.5
Leakage Energy	ERG	$<$ 0.3	$<$ 0.3	$<$ 0.3
Keep-Alive	VDC	-600 @ 100mA	-600	Not Required
Life Expectancy	HRS	500 Keep-alive	500 Keep-alive	2,000 Operating

MIXER/PREAMPLIFIERS

A Mixer/Preamplifier is a two stage device composed of an RF mixer and an IF preamplifier. The Mixer stage down-converts RF power at the receive frequency (ies) to an easier to amplify IF frequency. The preamplifier stage amplifies the IF frequency signals to higher power levels.

The present mixer/preamplifiers are conventional superheterodyne converters. Two distinct frequencies cause a response to the mixer/preamplifier IF output. The LO-IF frequency is the desired frequency, the LO+IF frequency is an image response which has the sole effect of doubling noise in the receiver.

Low noise amplifiers ahead of the present mixer/preamplifiers would improve receiver noise figure but not to the extent that the 5 dB objective will be achieved. A low noise amplifier with a noise figure of 1.6 dB and a gain of 10 dB would improve overall noise figure by only 4.9 dB.

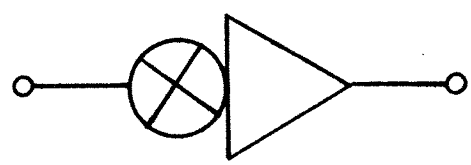
A low noise amplifier ahead of an image rejection mixer/preamplifier will achieve a noise figure improvement of 5.6 dB better than the present mixer/preamplifier. However, the IF bandwidth of the image rejection mixer/preamplifier is 10 MHZ and must be reduced with a bandpass filter to 3.0 MHZ. Overall noise power reduction by this technique will be 7.1 dB for port one and 7.3 dB for port two. Overall system bandwidth will be changed to 3.0 MHZ, an increase of 0.78 MHZ for port one and 0.9 MHZ for port two.

One necessary but easy to overlook subject is the impact of power gain on system performance at the higher signal powers. The question to answer is: Will the power gain used to reduce noise figure at the beginning of a cascaded series cause non-linearities (compression) to signals within the desired dynamic range?

The dynamic range of interest, at the antenna, is from -30 dBm downward as far as possible. Therefore, signals as high as -31.9 dBm (port one) and -32.6 dBm (port two) should be unaffected by compression.

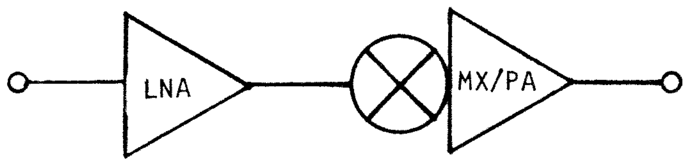
The present mixer/preamplifiers (1980) exhibit 1 dB compression at -20 dBm (port one) and -17 dBm (port two) input powers. Adding 10 dBm of gain ahead of the present mixer/preamplifiers would lower the 1 dB compression points to -30 dBm and -27 dBm. About 2 dB of headroom must be subtracted from the 1 dB compression points to find the maximum uncompressed levels which would be -32 dBm and -29 dBm.

Test data sheets supplied with the image rejection mixer/preamplifiers show that with -21.5 dBm test input powers, compression had yet to occur. With 10 dB of gain ahead of the image rejection mixer/preamplifiers, signal powers of -31.5 dBm would be below compression effects.

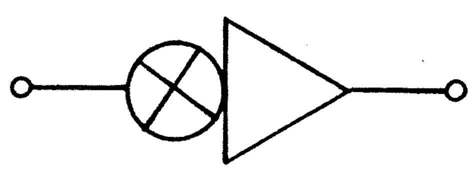


NOISE FIGURE	7.8 dB
IF BANDWIDTH	2.1/2.2 MHZ
POWER GAIN	32.8/31.0 dB
MIXER	Conventional

PRESENT MIXER/PREAMPLIFIERS



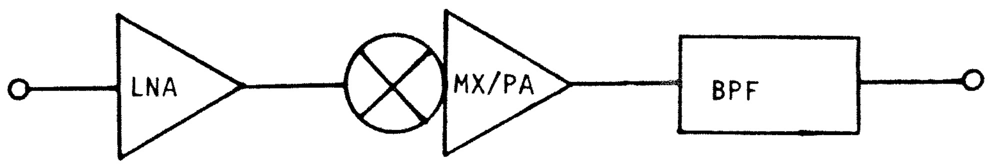
NF	1.6 dB	NF	7.8 dB
PWR GN	10 dB	PWR GN	32.8/31.0 dB
		IF BW	2.1/2.2 MHZ
		MIXER	Conventional



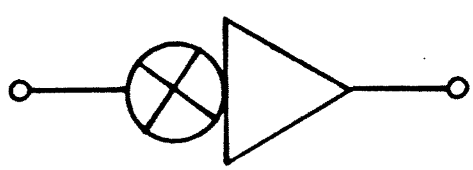
Equivalent Circuit

NOISE FIGURE	2.9 dB
IF BANDWIDTH	2.1/2.2 MHZ
POWER GAIN	42.8/41.0 dB
MIXER	Conventional

LOW NOISE AMPLIFIERS AHEAD OF PRESENT MIXER/PREAMPLIFIERS



NF 1.6 dB	NF 5 dB	
PWR GN 10 dB	PWR GN 22.5 dB	PWR GN -0.9 dB
	IF BW 10 MHZ	IF BW 3.0 MHZ
	MIXER Image Rejection	



Equivalent Circuit

NOISE FIGURE	2.2 dB
IF BANDWIDTH	3.0 MHZ
POWER GAIN	31.6 dB
MIXER	Image Rejection

LOW NOISE AMPLIFIERS AHEAD OF IMAGE REJECTION MIXER/PREAMPLIFIERS AND IF BANDPASS FILTERS

COMPONENT SPECIFICATIONS

ITEM/Spec	(Units)	OLD RECEIVER (1980)	LOW NOISE RECEIVER
LOW NOISE AMPLIFIER			
Manufacturer		N/A	Miteq
Part Number			AMF 1B2729
Operating Freq	(GHZ)		2.7-2.9
Noise Figure	(dB)		1.6
RF Gain	(dB)		10
Pwr Suppl Reqmt	(VDC)		+11 to +30 @25 mA
Special		N/A	Matched Pair
Gain	(dB)		+- 0.5
Phase	(Degrees)		+- 5
MIXER/PREAMPLIFIER			
Manufacturer		RHG	RHG
Part Number		MP2-4G75	IRR3A22DA
Operating Freq	(GHz)	2-4	2.7-2.9
Noise Figure	(dB)	7.8	5.0
Responses	(#)	2	1
Image Rejection	(dB)	0	20
Conv Gain	(dB)	29	22.5
IF Bandwidth	(MHz)	2.4	10
IF Frequency	(MHz)	30	30
LO Injection	(dBm)	0	+8
Pwr Sup Reqmt	(VDC)	+12 @ 40 mA	+12 @ 5 mA
Special		N/A	Matched Pair
Gain	(dB)		+- 0.5
Phase	(Degrees)		+- 5
BANDPASS FILTER			
Manufacturer		N/A	Texcan
Part Number			3BE30/cc
Center Freq	(MHZ)		30.0
Bandwidth	(MHZ)		3.0
Insertion Loss	(dB)		0.9
SYSTEM			
Noise Figure	(dB)	7.8	2.2
Responses	(#)	2	1
Conv Gain	(dB)	32.8/31.0	31.6
IF Bandwidth	(MHZ)	2.1/2.2	3.0

LOCAL OSCILLATOR/POWER SUPPLY/METERING CHASSIS

The Local Oscillator circuit supplies the mixer/preamplifiers with a CW signal of fixed frequency and fixed power. The two LO power outputs are isolated to preserve the RF to RF isolation between ports.

The power supply circuits provide keep-alive voltages for the TR cells, the DC power to the Local Oscillator, and the DC power to the Mixer/Preamplifiers.

The metering circuit uses a moving coil meter to monitor any one of six test pionts: Local Oscillator power supply voltage, mixer/preamplifiers power supply voltage, port one crystal one current, port one crystal two current, port two crystal one current, and port two crystal two current.

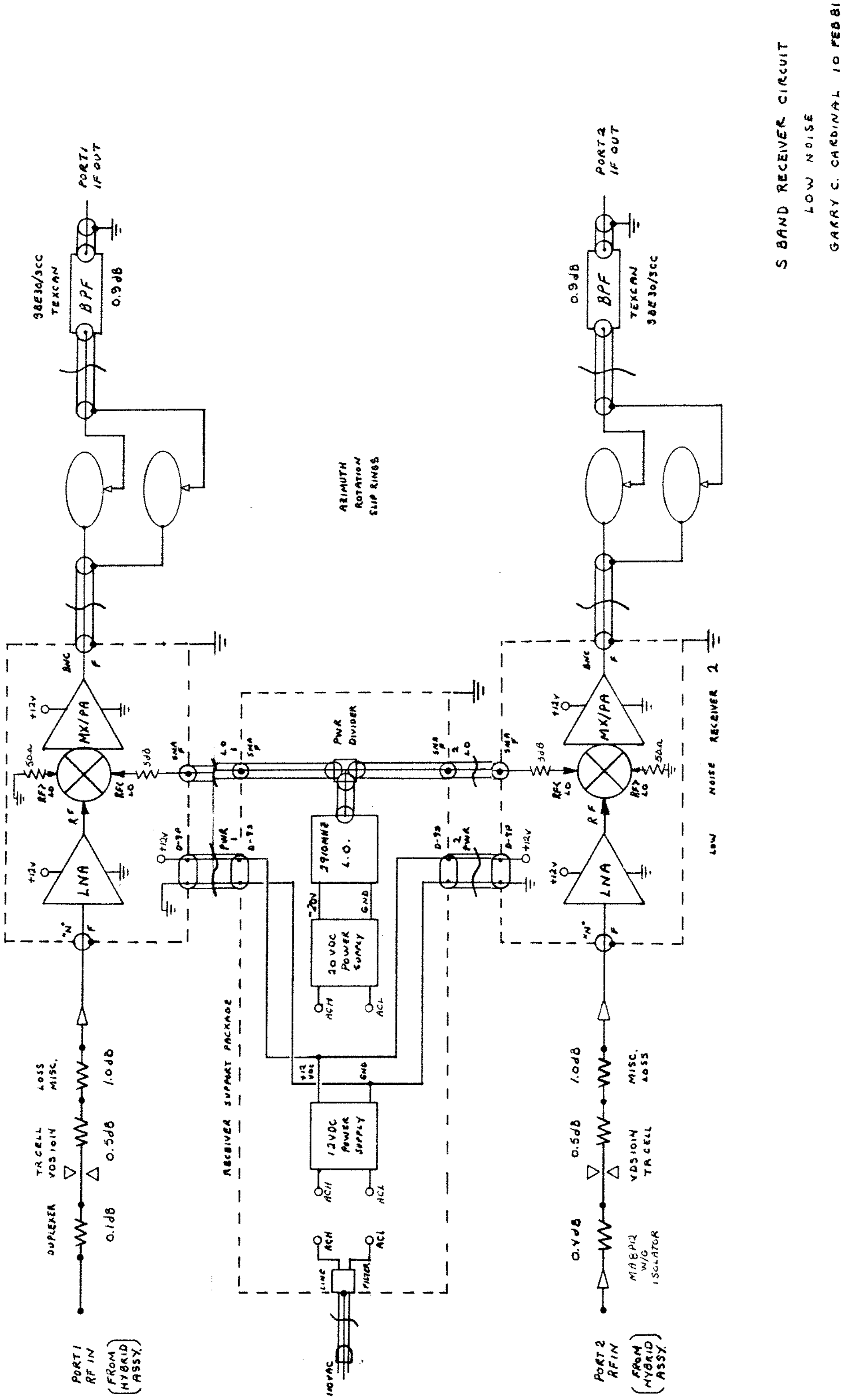
The improvements mentioned on the previous pages necessitate a reevaluation of this chassis since it performs a support function for the improved circuits.

With the use of passive TR cells and image rejection Mixer/Preamplifiers, keep-alive voltages, crystal current monitoring, and special provisions for LO output isolation will all be unnecessary. Power supply monitoring is assumed to be an add-on to the crystal current monitor function and can be replaced by conventional test points.

Extensive modifications must be made to the Local Oscillator circuit to provide the higher power required for the image rejection Mixer/Preamplifiers.

The internal structure of the image rejection Mixer/Preamplifiers provides RF to IF isolation which in addition to the benefit of image rejection, ensures excellent RF to RF isolation between the two ports of the receiver.

A coaxial power divider will split the Local Oscillator power at the LO site. Miniature SMA type cable will route the LO power to each Mixer/Preamplifier site where 3 dB attenuators will reduce the LO power to +8 dBm.



S BAND RECEIVER CIRCUIT (LOW NOISE)

MECHANICAL CONSIDERATIONS

Each Low Noise Receiver will be built into a solid aluminum block with end plates for mounting press fit input and output connectors.

The solid aluminum block will be machined with recesses or steps which will facilitate direct connector to connector coupling of the two subassemblies. A channel will be milled into the aluminum block which will allow routing of a pair of 24 AWG wires from the DC power connector under the Mixer/Preamplifier to the Low Noise Amplifier.

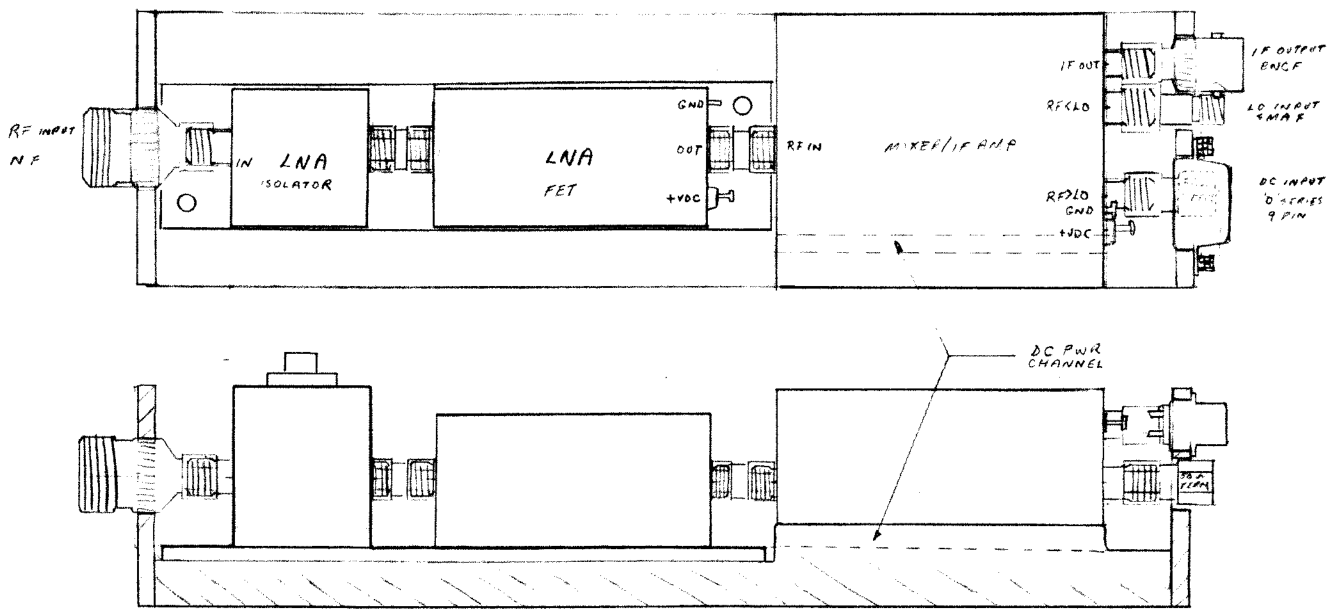
Input and output end plated will be fitted with press-fit connectors to afford ease of disassembly and reassembly in the event that testing or maintenance is required. Press-fit connectors firmly held by end plates which are bolted to the base block of the assembly will isolate the less robust internal connectors from shock, vibration, and/or mishandling.

Two end plates will be required for each Low Noise Receiver assembly, an RF input end plate, and an IF output/LO input/DC input end plate. RF input will be via a press-fit N type female connector. IF output will be via a press-fit BNC type female connector.

A pair of holes in the IF end plate will allow access to both RF›LO and RF‹LO inputs. The used LO input will be connected to the LO supply cable through a miniature 3 dB attenuator. The unused LO input will be terminated by a miniature precision load. Both LO input access holes will be sized to give a close fit to the miniature attenuator. This close fit is intended to mechanically couple potentially damaging forces to the IF end plate.

DC input to each receiver assembly will be through a 9 pin D series miniature connector which will be mounted on the IF end plate. The DC power connectors will be fitted with screw-lock fasteners which will prevent the loss of DC power due to unintentional cable disconnection.

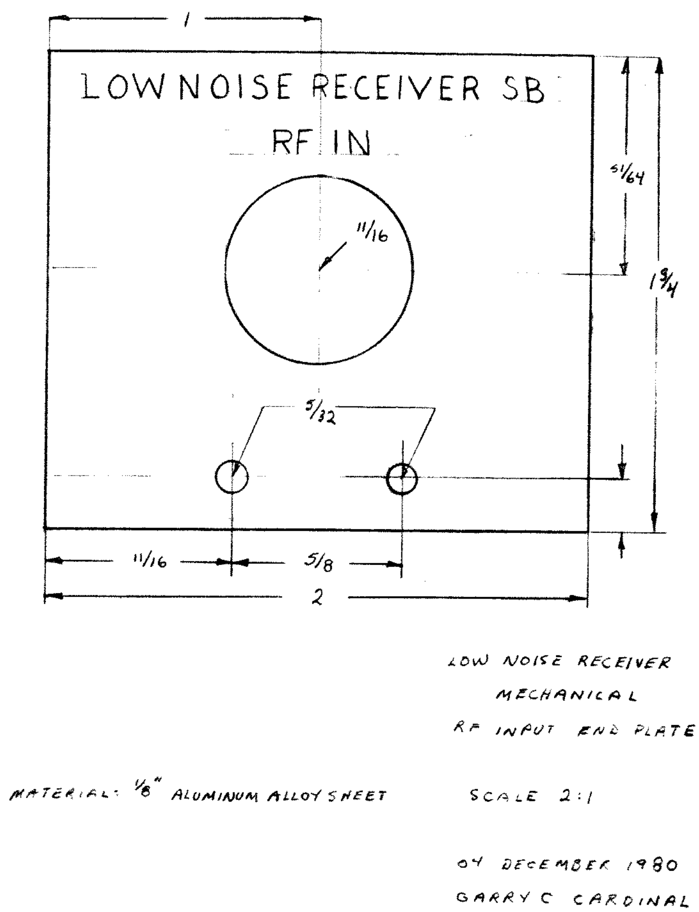
Low Noise Amplifier and Mixer/Preamplifier +12VDC and GND leads will terminate separately at the DC power connector. Both Low Noise Amplifier and Mixer/Preamplifier DC inputs will be shunted by a 15V zener diode and a 10 uF tantalum capacitor.



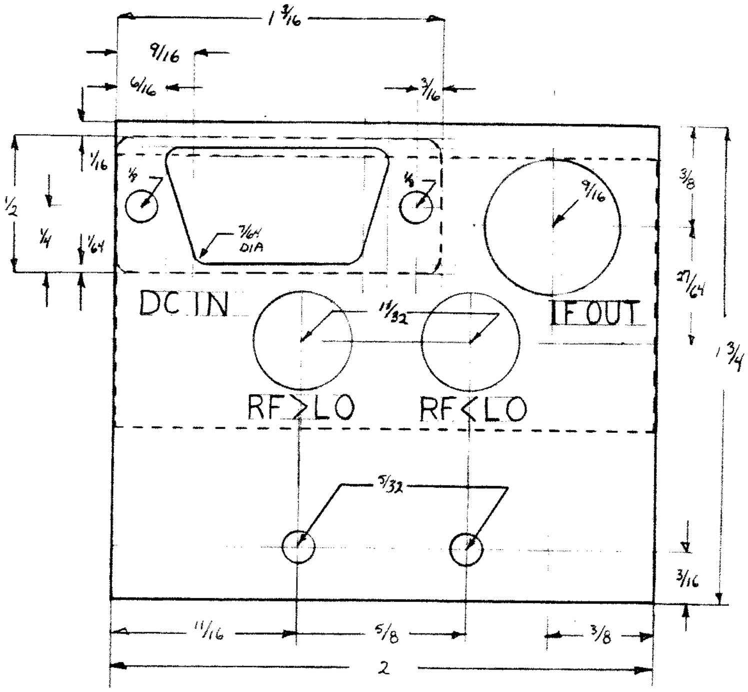
S BAND LOW NOISE RECEIVER
PREAMPLIFIER ASSEMBLY

24 NOV 80 J.C.

-MECHANICAL-
TOP AND SIDE



-MECHANICAL-
RF INPUT PLATE



LOW NOISE RECEIVER
MECHANICAL
IF OUTPUT END PLATE

MATERIAL 1/8" ALUMINUM ALLOY SHEET

SCALE 2:1

04 DECEMBER 1980
GARRY C. CARDINAL

-MECHANICAL-
IF OUTPUT PLATE

PARTS LIST
ELECTRICAL

1	Low Noise Amplifier with SMA I/O connectors MITEQ AMF 1B 2729 (Port 1 Ser 29356, Port 2 Ser 29357)
1	Low Noise Mixer/Preamplifier with SMA I/O connectors RHG IRR3A22DA (Port 1 Ser 14-816-1A, Port 2 Ser 14-816-1B)
1	Attenuator with SMA Male to SMA Female ends 3 dB Weinschell 3M-3
1	Adapter with press-fit mounting N female to SMA male
2	Adapter SMA male to SMA male
1	Adapter with press-fit mounting SMA male to BNC female
1	Connector D series 9 pin male ITT DEM-9P
1	Screwlock fasteners ITT D20418-2
2	Diode, zener 1N4744
2	Capacitor, tantalum 10uF 35 VDC
20cm	Wire, stranded, 24AWG, PVC Red
20cm	Wire, stranded, 24AWG, PVC Black

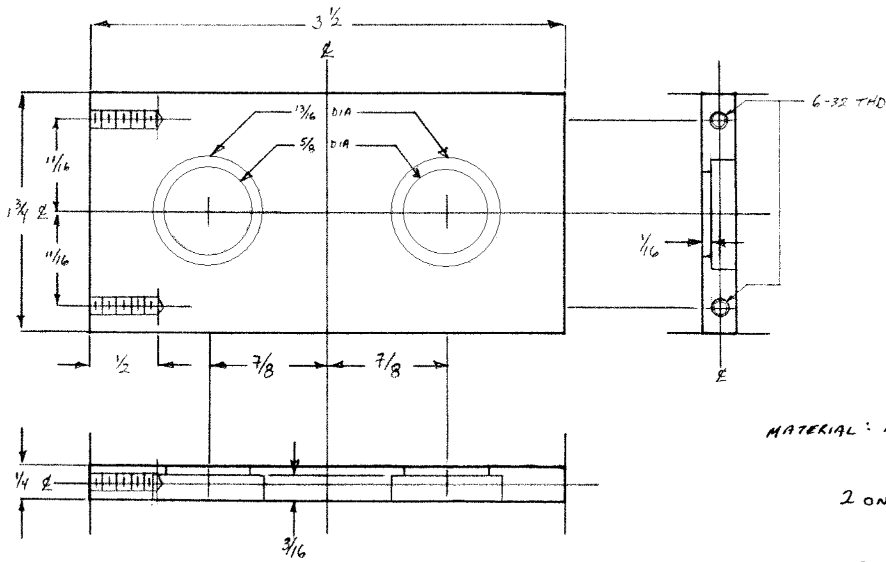
PARTS LIST
MECHANICAL

1	Base plate
1	RF input end plate
1	IF output end plate
1	Mounting bracket
	Assorted screw fasteners

MECHANICAL CONSIDERATIONS

The IF outputs of the Low Noise Receivers connect to the Logarithmic Amplifiers with very long coaxial cables and must pass through a set of slip rings. In order to maximize the benefit of filtering on the IF lines from the Low Noise Receivers the bandpass filters will be located in close physical proximity to the Logarithmic Amplifiers.

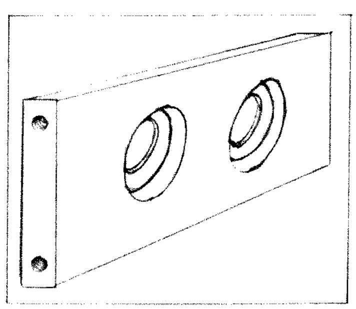
The coaxial bandpass filters will be mounted together behind a 1.75" high 19" rack mount panel. The filters will be held in place using special mounting brackets fitted with rubber grommets to electrically isolate the filters from chassis ground.



MATERIAL: 1/4" THICKNESS ALUMINUM

2 ONLY PIECES REQUIRED.

SCALE 1:1 UNITS INCHES



S BAND COAXIAL FILTER
MOUNTING BRACKET
13 MAY 1983 d.c.

-MECHANICAL-
S BAND COAXIAL FILTER MOUNTING BRACKET

PARTS LIST
ELECTRICAL

2	Coaxial Filters 30.0 MHz center frequency, 3.0 MHz bandwidth Texcan 3BE30/cc

PARTS LIST
MECHANICAL

2	Mounting bracket, aluminum
4	Rubber grommet, to fit 0.625" dia hole
1	19" panel 1.75" height, aluminum
	Assorted screw fasteners

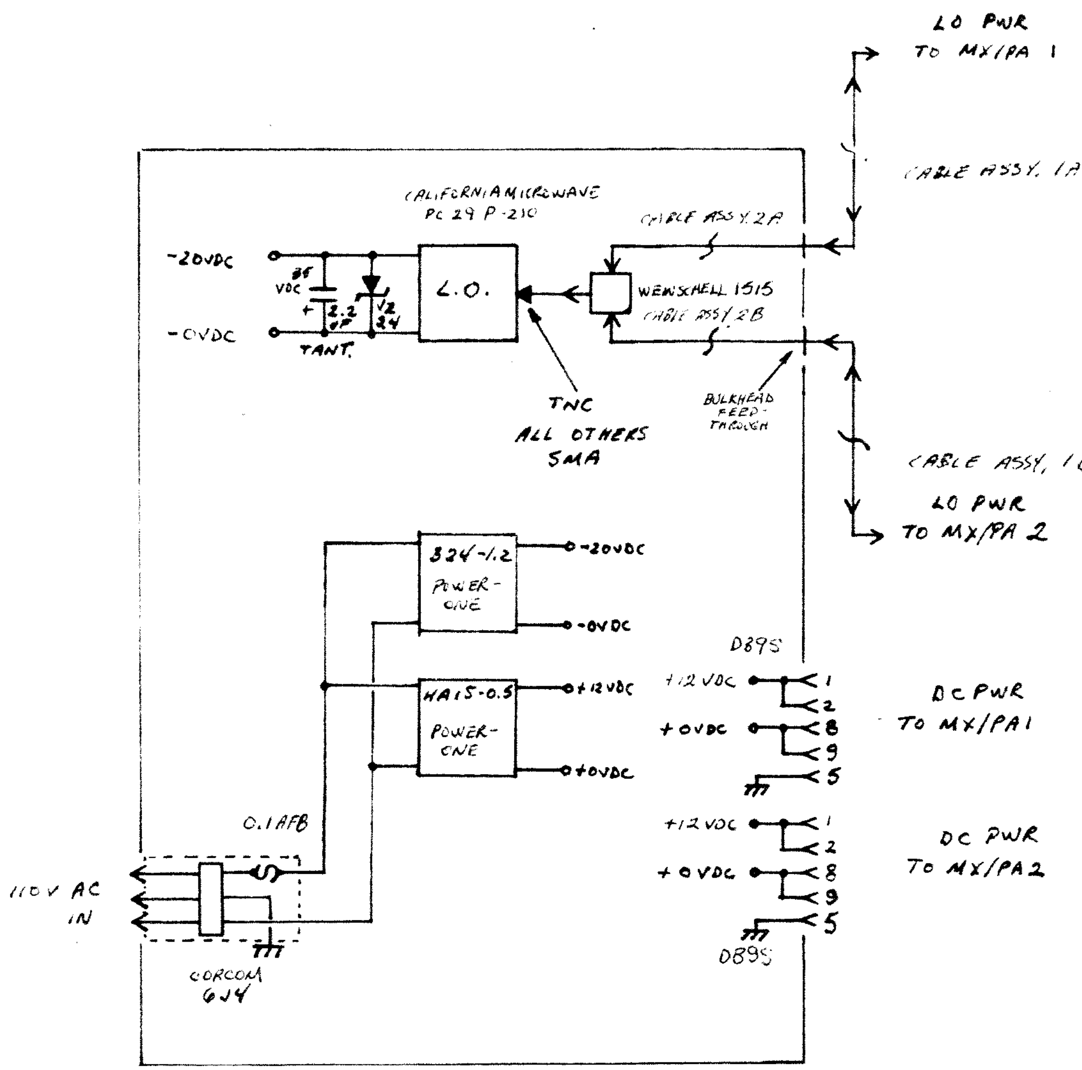
MECHANICAL CONSIDERATIONS

The Receiver Support Package will be built onto an aluminum plate which will mount on the interior wall of the S Band microwave housing. The unit will be unenclosed to allow inspection, testing, and removal of any subassembly with a minimum of tools.

All hazardous voltage carrying terminals, connectors, and solder joints will be shielded with heat shrinkable tubing.

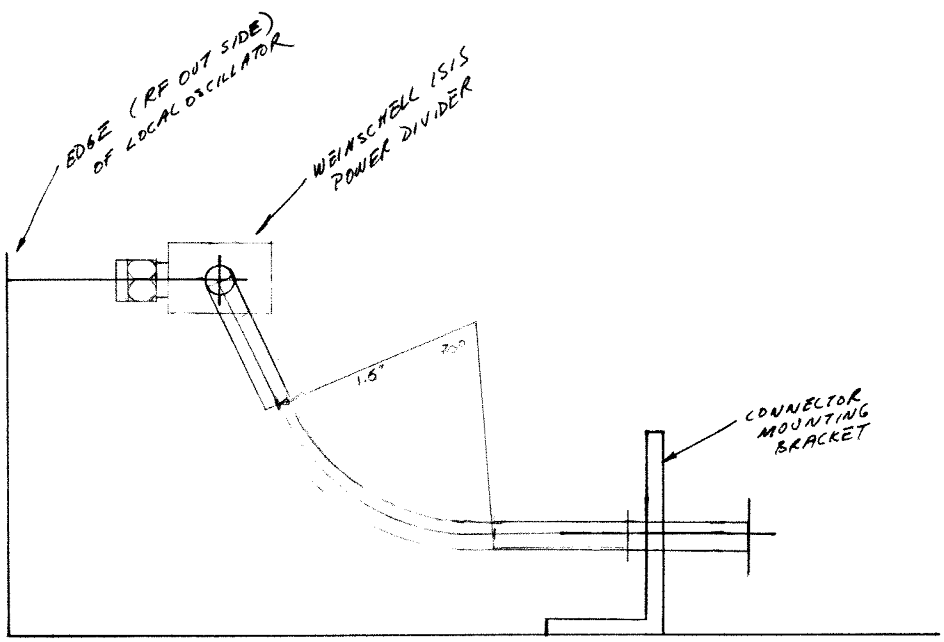
A single horizontally mounted bracket will be fastened to the aluminum plate and will be used to mount all input and output connectors. All input and output connectors will face downward to prevent dust accumilation on unused or open connectors.

Studs projecting from the mounting plate will provide support and fastening provisions for the subassemblies and will facilitate removal of any subassembly through forward access.



S BAND RECEIVER SUPPORT PKG.
3 NOV 81
S. C.

-SCHEMATIC-

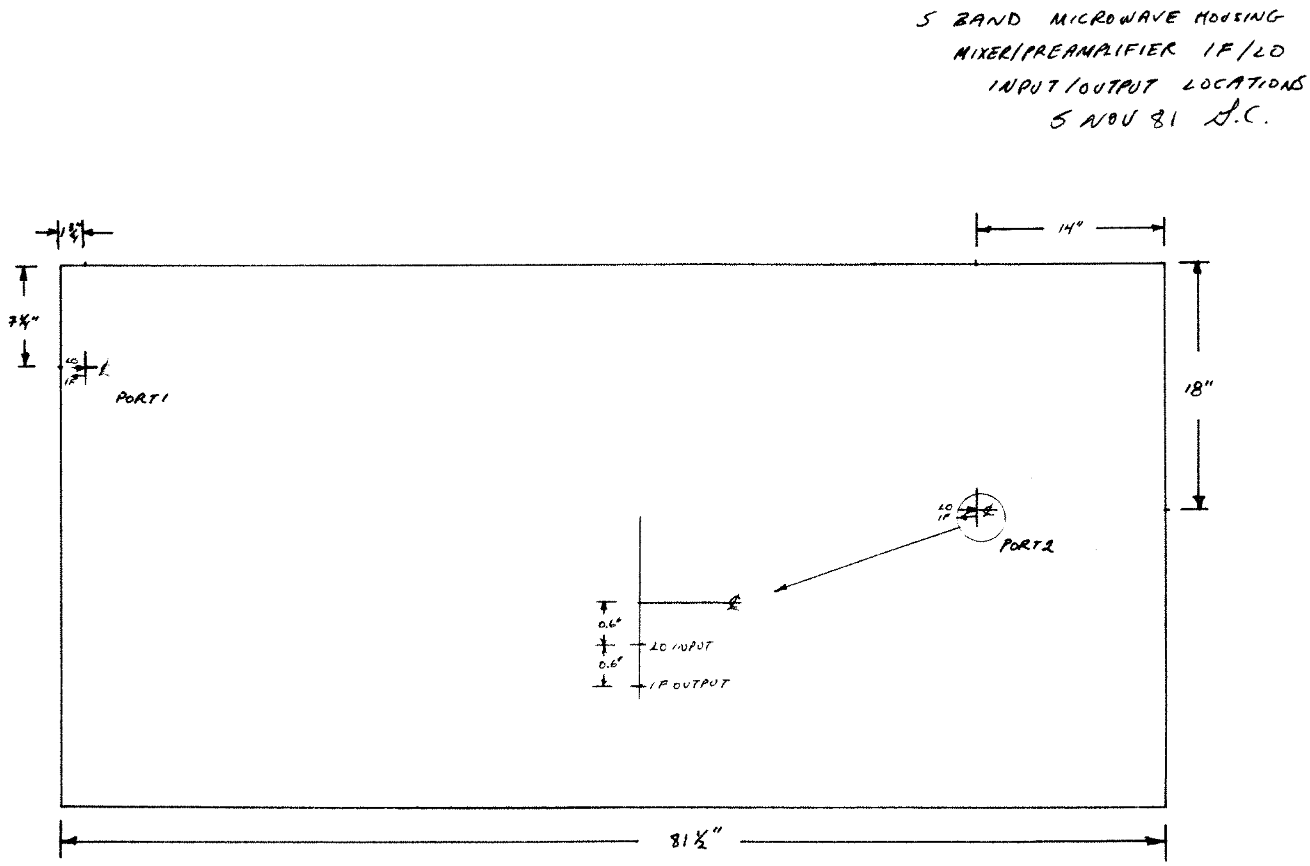


Cable length = $2'' + 3.2\pi \times 70/360'' + 0.92 = 4.875''$

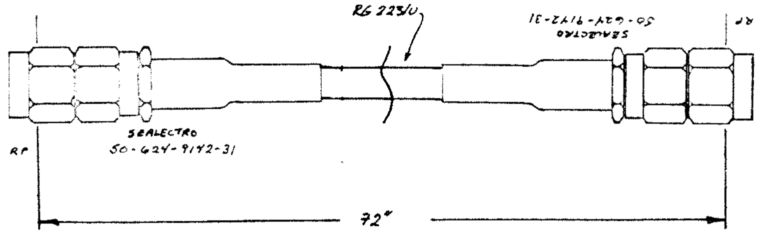
SBAND RECEIVER SUPPORT PACKAGE
CABLE RUN LO POWER DIVIDER
TO CONNECTOR MOUNTING
BRACKET.

5 NOV 81 S.C.

-MECHANICAL
CABLE RUN FROM LO PWR DVDR TO CONNECTOR MTG BRKT

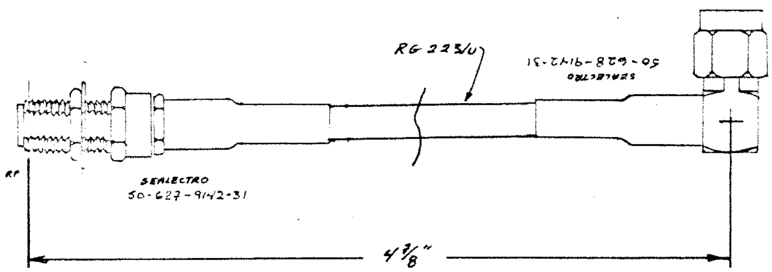


-MECHANICAL-
MIXER/PREAMPLIFIER IF/LO INPUT AND OUTPUT LOCATIONS



CABLE ASSEMBLY 1

NOT TO SCALE



CABLE ASSEMBLY 2

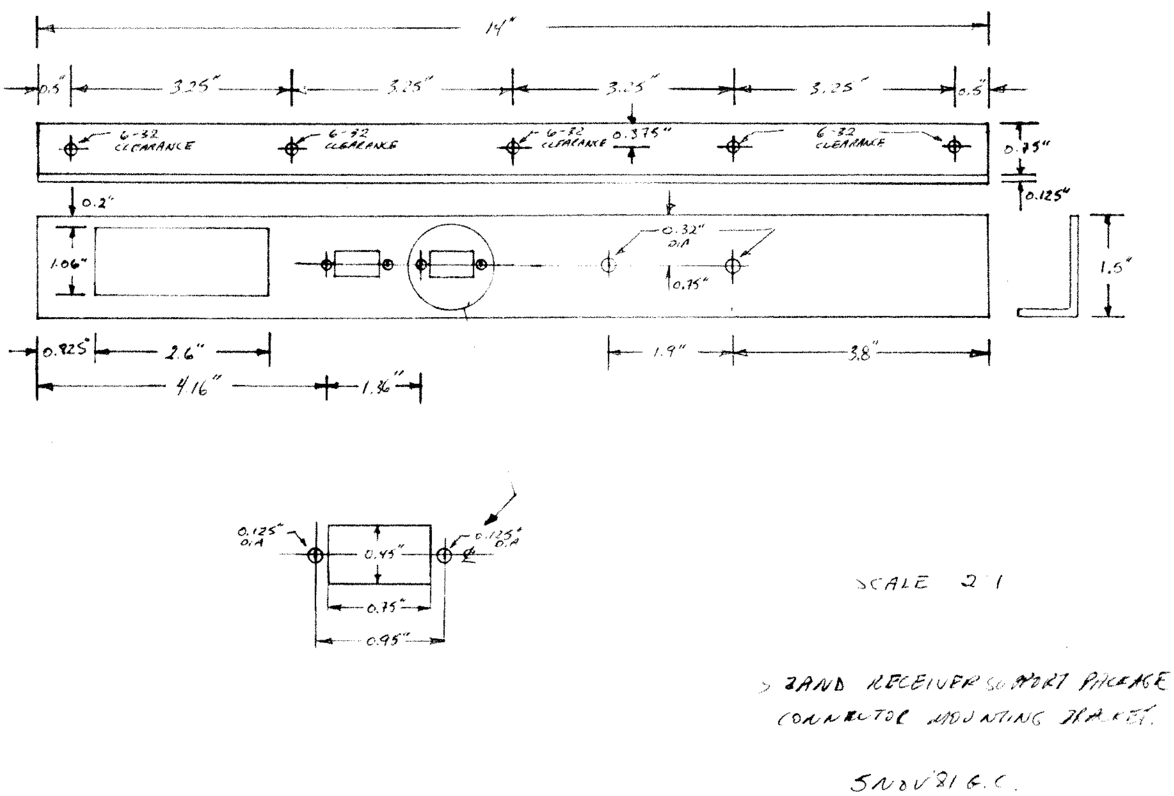
NOT TO SCALE

2 REQUIRED OF CABLE ASSEMBLY 1
2 REQUIRED OF CABLE ASSEMBLY 2

CABLES ARE TO OPERATE AT 3.0 GHZ
POWER LEVELS NOT TO EXCEED +20 dBm

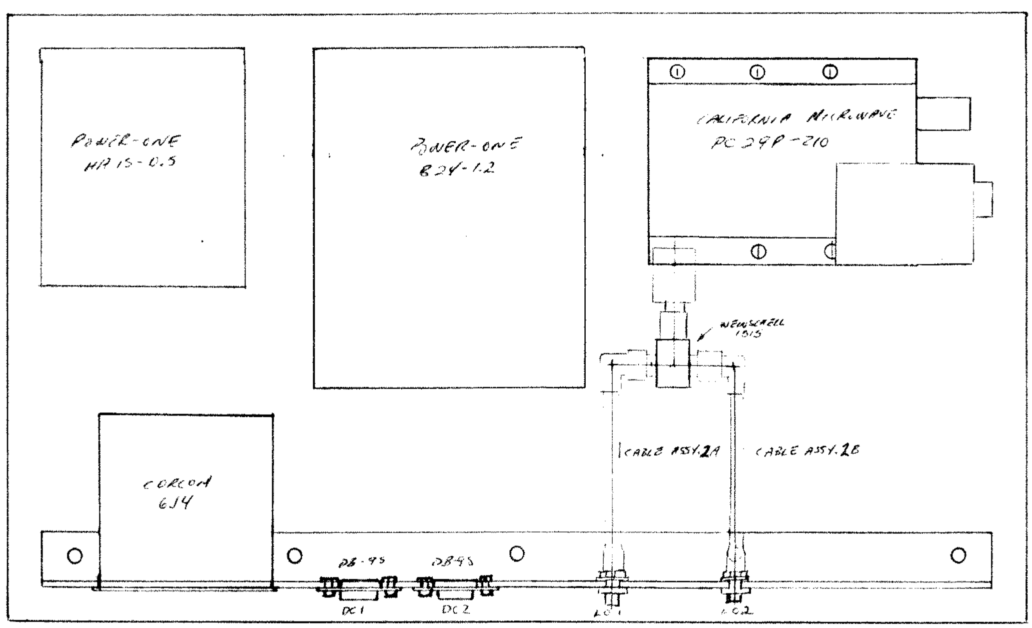
S BAND RECEIVER LOW NOISE
LOCAL OSCILLATOR CABLES
18 DEC 81 S.C.

-MECHANICAL-
LOCAL OSCILLATOR CABLES



-MECHANICAL-
CONNECTOR MOUNTING BRACKET

S BAND RECEIVER SUPPORT PACKAGE
ASSEMBLY
5 NOV 81



SCALE 2:1

-MECHANICAL-
ASSEMBLY TOP VIEW

PARTS LIST
ELECTRICAL

1	Microwave frequency source, Phase locked, TNC output connector California Microwave PC 29 P-210
1	Power divider, SMA male input, SMA female output Weinschell Engineering 1515
1	Adapter TNC male to SMA female
2	Adapter SMA female to SMA female, bulkhead feedthrough
2	Cable assemblies, SMA male rt ang to SMA male, 12.5 cm length
1	Power supply, -20VDC Power-One HB 24-1.2
1	power supply, +12VDC Power-One HA 15-0.5
1	Line filter/Fuse/Connector 120VAC Corcom 6J4
1	Line cord 120VAC Corcom 1245
1	Connector D series 9 pin female ITT DEM-9S
1	Screwlock fasteners ITT D20418-2
60cm	Wire, stranded, 24AWG, PVC Red
90cm	Wire, stranded, 24AWG, PVC Black
30cm	Wire, stranded, 24AWG, PVC White
15cm	Wire, stranded, 24AWG, PVC Green

PARTS LIST
MECHANICAL

1	Base plate
1	Connector bracket
8	Standoff, nickel plated brass, 6-32 thread, 1.27 cm length
	Assorted screw fasteners

PARTS LIST
INTERCONNECTING CABLES

2	Connector D series 9 pin male ITT DEM-9P
2	Connector D series 9 pin female ITT DEM-9S
4	Screwlock fasteners ITT D 20419
3.7m	Cable, 2 conductor, shielded Belden 8420-50
2	Cable assemblies, SMA male to SMA male, 1.83m length
4	Adapter, SMA male to SMA female rt ang

-NOISE POWER-

	PORT 1 (1980)	PORT 2 (1980)	PORT 1 (LNR)	PORT 2 (LNR)
TEMPERATURE C:	26.85	26.85	26.85	26.85
BANDWIDTH MHZ:	2.10	2.22	3.00	3.00
RESPONSES 1,2:	2	2	1	1

See Appendix I

EFFECTIVE NOISE POWER :	-107.6 (PNA1)	-107.36 (PNA2)	-109.06 (PNALNR1)	-109.06 (PNALNR2)

-NOISE FIGURE-

	PORT 1 (1980)	PORT 2 (1980)	PORT 1 (LNR)	PORT 2 (LNR)
#STAGES:	2	2	3	3
NF1:	2.6	1.9	1.6	1.9
G1:	-2.6	-1.9	-1.6	-1.9
NF2:	7.8	7.8	1.6	1.6
G2:	N/A	N/A	10	10
NF3:	N/A	N/A	5.0	5.0

See Appendix II

TOTAL NOISE FIGURE :	10.4 (NFT1)	9.7 (NFT2)	3.81 (NFTLNR1)	4.11 (NFTLNR2)

-EFFECTIVE NOISE POWER-

	PORT 1 (1980)	PORT 2 (1980)	PORT 1 (LNR)	PORT 2 (LNR)
EFFECTIVE NOISE POWER :	-97.20 (PNE1)	-97.66 (PNE2)	-105.25 (PNELNR1)	-104.95 (PNELNR2)

-PEAK EFFECTIVE NOISE POWER-

	PORT 1 (1980)	PORT 2 (1980)	PORT 1 (LNR)	PORT 2 (LNR)
PEAK EFFECTIVE NOISE POWER :	-92.01 (PNEP1)	-92.47 (PNEP2)	-100.06 (PNEPLNR1)	-99.76 (PNEPLNR2)

THERMAL NOISE

Thermal noise is related to the agitation of matter in a resistance. How violently this matter is agitated is directly proportional to temperature. Nyquist describes the relation with the equation:

$$Vt = 4KTBR$$

Vt = open circuit noise voltage (Vrms)
K = Boltzman's constant (1.38054x10^-23 Joules/Deg K)
T = absolute temperature (Deg K)
B = noise bandwidth (Hz)
R = resistance of interest (Ohms)

The absence of a frequency component in the above equation implies that the noise is white, uniform in spectrum. A more exact expression must be used at extremely high frequencies and extremely low temperatures. The noise spectrum becomes significantly non-white if the ratio f/T exceeds approximately 10^8. The S Band f/T ratio is approximately 10^7.

NOISE POWER

The thermal noise voltage in the equation described previously is the open-circuit noise voltage. If a load is connected, ie. if the resistance of interest is part of a matched transmission line, the available noise power generated is described by the equation:

$$Pn = KTB$$

Pn = noise power (W)
K = Boltzman's constant (1.38054x10^-23 Joules/Deg K)
T = absolute temperature (Deg K)
B = noise bandwidth (Hz)

Noise power may be expressed in Watts or dBm. To convert Watts to dBm:

$$Pn\ (dBm) = 30 + 10\ LOG\ Pn\ (Watts)$$

Absolute temperature expressed in degrees Celsius is:

$$T\ (Deg\ K) = T\ (Deg\ C) + 273.15$$

Noise bandwidth is the total bandwidth which will be affected by the thermal noise. The term assumes a square response which is closely approximated by most mixer/preamplifier bandpass characteristics.

Conventional superhererodyne receivers without frequency preselection have two IF output products called responses. The responses correspond to the receive frequencies RF + IF and RF - IF.

The effective noise bandwidth of such a receiver is double it's IF bandwidth. Image rejection mixer/preamplifiers do not have this effect since they are single response receivers.

Noise bandwidth, in terms of receiver parameters, is:

B = BW#BW

B = noise bandwidth (Hz)
BW = IF bandwidth of receiver (Hz)
#BW = number of responses received

Combining all these noise power equations results in the equation:

Pn(dBm)=30+10LOG(1.38054x10^-23[T(Deg C)+273.15]BW#BW)

This equation is specifically intended for use with receivers and removes the ambiguities of the simpler equation.

Below is a listing of a computer program written in BASIC which was used to calculate noise powers in the main text.

```
10 "PN (DBM)":  INPUT"T (C)?";A,"BW (MHZ)?";B,"IRR
    (Y/N)?";C$
20 IF C$="Y"C=1:GOTO40
30 C=2
40 X=90+10*LOG(1.38054E-23*(A+273.15)*B*C)
50 PRINT"PN (DBM) = ",X
60 END
```

NOISE FACTOR

Noise factor compares the noise performance of a device to that of an ideal, noiseless, device and is defined:

$$F = \frac{\text{Noise power out of actual device}}{\text{Noise power out of ideal device}}$$

The noise ower output of the ideal device is due to thermal noise and can be found using the equation:

$$Pn = KTaB$$

An arbitrary temperature can be assigned to the actual device which describes the actual device as an ideal device operating at a high temperature. Thus the equation:

$$Pne = KTsB$$

The noise contribution by the actual device in terms of temperature is therefore:

$$Te = Ts - Ta$$

Te = effective temperature of actual device
Ts = sum temperature of ambient and effective temperatures
Ta = ambient temperature at which device operates

Noise factor is therefore the ratio:

$$F = \frac{Ts}{Ta} \quad \text{and,} \quad \frac{Ta+Te}{Ta}$$

Given noise factor and ambient temperature:

$$Te = Ta\,(F-1)$$

The effective noise temperature of a number of amplifiers in cascade can be shown to be:

$$Te\,(Total) = Te1 + \frac{Te2}{G1} + \frac{Te3}{G1\,G2} + \ldots$$

Te1 = noise temperature of first amplifier
G1 = power gain of first amplifier

In the same regard Friis shows the noise factor of a number of amplifiers to be:

$$Ft = F1 + \frac{F2-1}{G1} + \frac{F3-1}{G1\ G2} + \ldots$$

NOISE FIGURE

Noise factor is related to the most often specified figure of merit for amplifiers, noise figure by the equations:

$$NF = 10\ LOG\ F, \quad F = 10^{(NF/10)}$$

Gain can be expressed linearly as a power ratio or logarithmically as decibels:

$$G\ (dB) = 10\ LOG\ G, \quad G = 10^{(G\ (dB)\ /\ 10)}$$

NOISE FIGURE OF CASCADED STAGES

Substituting the logarithmic forms of F and G into Friis' equation yields:

$$NFT = 10LOG\left(10^{(NF1/10)} + \frac{(10^{NF2/10})-1}{10^{(G1/10)}} + \frac{(10^{NF3/10})-1}{10^{(G1/10)}\ 10^{(G2/10)}} + \ldots\right)$$

which is the equation used to calculate total noise figures in the BASIC computer program listed at the end of this appendix.

Receiver noise temperature and noise figure ratings apply to a specific terminating impedance. Therefore comparisons of noise figures must be limited to those of the same specific terminating impedance.

Noise temperature and noise figure ratings, unless stated, do not imply or compensate for VSWR conditions.

```
100 "NF#STGS":  INPUT"NUMBER OF STAGES?";Z
105 IFZ>5GOTO100
106 IFZ<2GOTO100
110 INPUT"NF1?";A(1),"G1?";A(2),"NF2?";A(3)
120 IFZ=2GOTO180
130 INPUT"G2?";A(4),"NF3?";A(5)
140 IFZ=3GOTO180
150 INPUT"G3?";A(6),"NF4?";A(7)
160 IFZ=4GOTO180
170 INPUT"G4?";A(8),"NF5?";A(9)
180 Y=1
190 FORY=1TO(2*Z-1)
200 A(Y)=10^(A(Y)/10)
210 NEXTY
220 X=A(1)+(A(3)-1)/ A(2)
230 IFZ>2LETX=X+(A(5)-1)/(A(2)*A(4))
240 IFZ>3LETX=X+(A(7)-1)/(A(2)*A(4)*A(6))
250 IFZ>4LETX=X+(A(9)-1)/(A(2)*A(4)*A(6)*A(8))
260 X=10*LOGX:PRINT"NFT =",X
270 END
```

The Alberta Hail Project Radar Systems
S.K. Leung, Alberta Research Council ASD 77-4

A Variable Polarization Antenna
L.E. Allan, R.C. Markell, and G.C. McCormick, NRC ERB-768
June 1967

Electronic Communication Systems
Kennedy, McGraw-Hill, 78-109251 34050 1970

Noise Reduction Techniques in Electronic Systems
Henry W. Ott, John Wiley and Sons Pub. TK 7867.5 087 1976

A Guide to Basic Pulse-Radar Maximum-Range Calculation
L.V. Blake, Naval Research Laboratory 6930 Dec 1969

A Quiet Mixer
Don Neuf, Reprint Microwave Journal Vol 16 5 May 1973

ADVICE

Steven Block, AVANTEK, Santa Clara, California

Marty Markson, RHG ELECTRONICS, Deer Park, New York

Dave Hollinka, MITEQ, Haupage, New York

Philip Loreti, VARIAN, Beverly, Massachusetts