WELCOME TO

MICROWAVE UPDATE 1986

. . . and welcome to Estes Park, Colorado. We hope you have a very enjoyable stay while you are here. For the radio hams there are of course the technical meetings, the purpose of this conference. For the wives that have come, there are many activities planned. (See the ladies activities sheet). We urge you to acquaint yourselves with the area and take advantage of the many recreational activities which Estes Park and the Rocky Mountain National Park have to offer.

Don Hilliard, WØPW
Coordinator

Norma Hilliard, KAØNEN
Slave to the Coordinator

Did The

Fajuta TWT/S.S

WORZ

MICROWAVE UPDATE '86

28-31 August 1986

Estes Park, CO

	NAME	CALL
1.	Michael C. Laage	NØFZB
2.	Douglas Buhrman	WBØQIY
3.	George Chaney	W5JTL
4.	Elliot Lomer	W7LFX
5.	Mil K Pfeffer	W5LTR
6.	Ray Harland	N6AMD
7.	Margaret Harland	KB6-NLY
8.	GEORGE W. WATSON	WØLOB
9.	LANCE LYMAN	K8IXZ, 9MQAA
10.	RUSS WICKER	W4WD
11.	BILL McCAA	KØRZ
12.	Marty Eichenberger	KDØGT
13.	GARTH FLOURNOY	WØGR
14.	HANS D PETERS	VE3CRU
15.	BILL WESSLUND	WØBJ
16.	CHARLIE JUSTINAK	W7GBI
17.	H. PAUL SHUCH	N6TX
18.	BOB DRYDEN	W9OJK
19.	JACK JACKSON	WB4EFZ
20.	JIM DAVEY	WA8NLC
21.	Gerald Handley	WA5DBY
22.	TERRY TURNER	W5ETG
23.	Merle Cox	W7YOZ
24.	Wes ATCHISON	WA5TKU
25.	Mark Wilson	AA2Z

	NAME	CALL
26.	Bill Olson	W3HQT
27.	Rick Campbell	KK7B
28.	BARRY MALOWANCHUK	VE4MA
29.	Tony R Bubel	K5PIR
30.	Sam Poppini	K2DNR
31.	Walter Reid Fletcher	WB7CJO
32.	Charles Benavides	WA1KIR
33.	JIM STARKEY	WØKJY
34.	Kent Britain	WA5VJB
35.	Ken Erickson	W7JF
36.	CHARLIE CONNER	KØNG
37.	GEORGE DAVID	WØOHP
38.	Dan L Osborne	WB5AFY
39.	RAY FRIESZ	WØHRG
40.	Tom Bishop	KØTLM
41.	Bob Stanley	W9ITB
42.	Dick Raymond	WA7CTY
43.	Thomas J Stebal	WØPNS
44.	Lynn R Hal	WB7UNU
45.	Jerome Doerrie	K5IS
46.	Keith Prussi	KØKE
47.	Jan Hubach	OH1ZAA/NNØY
48.	Al Ward	WB5LUA
49.	[illegible]	KXØO
50.	DAN POND	NØTK
51.	Al Clements	—
52.	HAL BERGESON	WØMXY
53.	PETE SIAS	WBØDRL

NAME	CALL
54. Dean Lewis	WAØTKJ
55. R. Alfred Whiting	K3BRS
56. Ray Ubereckeh	AAØL
57. Don Lund	WAØIQN
58. Gary Breed	K9AY
59. David Chase	KY7B
60. Barry E. Maguire	WB4IZR
61. Geri E. Maguire	WA4UKW
62. MIGUEL A. CZYSCH	LU3DCA
63. James W. Vogler	WA7CJO
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21 October 1986

Dear Microwave Update 86 Attendee:

I hope that your memories of **Microwave Update 86** are still fresh and that the stimulation you experienced is still there. I think most of you had a good time and went home excited about some of the things you heard while attending the conference. That is really the reason Norma and I organized it.

Perhaps it isn't too early to think about **Microwave Update 87.** I'm already considering it. I would like to hear your thoughts about what you would like to hear or see next year. A couple of things have already been suggested. KDØGT suggests having an actual demonstration of how to build and adjust circuits as one of the presentations. Al Clements (from Boulder) suggests having some of you University professors (like Rick Campbell and Paul Schuch) produce some video cassettes on subjects such as solid state power amplifier design or low noise receiving amplifier design for 3.4 and 5.7 GHz. I can hear them groan now, but it is something to think about. Perhaps some of the sessions next year could be video taped and made available to interested persons.

A couple of you offered to give papers next year. This is great. How about some of the rest of you? If you would like to make a presentation, let me know. I can't guarantee that I can use everyone because of the limited amount of time available. But please let me hear from you if you are interested or know of someone who is. You may use the enclosed form if you wish.

With the rapid advances in microwave technology, there should be many new and interesting subjects by next year which we all will want to hear about, or see. The "swap and talk" sessions on Thursday and Friday evenings were just super. One things obviously needed is for some of you to design and build some modules such as preamps, power amps, local oscillators, etc. to sell at these sessions. The ones of you who did this this year can attest to this. (How about all those "this's"). Start planning now for next year. Get some MMIC's and build some amplifiers, etc., etc. GaAs power is going to really come alive in the next year or so. Some of you can take advantage of it and provide some interesting hardware for next year.

3.4 and 5.7 GHz. seem to be getting lots of attention. Perhaps we could use some talks relative to taking the easily developed +10 dbm levels and amplifying to the 100 mw. or 1 watt levels. Avantek plus many others make the devices although the higher power ones are rather expensive by amateur standards. How about it? Let me know.

The program this year was rather full. Some of you mentioned that you appreciated the program in 85 which had more free time. I'll try to arrange the 87 schedule to be in line with these stated wishes.

(over)

The registration fee will be higher next year. This year I didn't make expenses. I am approximately $300 short. I'll make this up next year.

I keep hoping someone out there will start a microwave newsletter. Something like Jack Parker's "VHF Plus". I don't see it happening though. There seems to be a lot of VHF newsletters, etc., but nothing that is really microwave only. How about it out there? The time is really here.

Norma enjoyed getting acquainted with the wives who attended and she had a good time participating in the activities with them. She has also enclosed an evaluation sheet to help her in planning for next year's activities. We would like to make next year's conference even more productive and interesting and solicit your comments in this regard.

73,

Don Hilliard, WØPW

DLH:nh
enclosures

NOISE FIGURE MEASUREMENTS
MICROWAVE UPDATE 1986
ESTES PARK, CO

Equipment - HP8970A - HP346A

CALL	.9	1.3	2.3	3.4	CONV.	PREAMP	TYPE OR DESCRIPTION	GAIN	N.F
WA5VJB	X					X	MGF 1403 - cooled	15.60	.97
	X					X	MGF 1403 - non-cooled	15.55	1.05
VE4MA	X					X	MGF 1402	15.35	.66
W4WD		X				X	HB unknown GA A5	17.1	.75
W7GBI		X				X	WA7CJO-type, MFG 1402	14.6	.82
WB4EFZ		X				X	W6PO-type, MGF 1402	12.75	.38
WØBJ		X					OE9PMJ-type	10.75	9.82
W7JF		X				X	MGF 1402 - "Parabolic"	11.6	.91
KØNG		X				X	MGF 1402 - "Mich. Microwave"	14.15	.61
WØKJY		X				X	MGF 1402 - Two stage	24.9	2.0
		X				X	MGF 1402 - Two stage	15.4	2.3
KK7B		X				X	AT 8140	13.2	6.8
WØBJ		X			X		"Radio Kit"	10.35	19.85
VE3CRU		X			X		LT23S - "SSB"	21.04	1.87
W7CTY		X				X	WA7CJO-type, NE 720	9.66	.68
		X				X	WA7CJO-type, NE 720	19.88	1.59
		X				X	WA7CJO-type, NE 720	14.87	.95
K5PJR		X				X	WA5VJB-type, D2503	12.41	.66
VE4MA		X				X	NE 710	18.88	.41
WA5VJB		X				X	D 2502	17.72	.49
		X				X	MGF 1403	15.50	1.00
K5IS		X			X		MMT-1296, XVTR "Micro Mod"	26.9	4.10
		X			X		MMT-1296, Conv. "Micro Mod"	35.4	3.41
K5LTR		X			X		For Icom, IC-1271A "Angle Linear"	14.3	.93
VE4MA			X		X		MGF 1412 + 2nd stage	27.9	1.63
			X		X		MGF 1402	13.67	1.8

(OVER)

CALL	.9	1.3	2.3	3.4	CONV.	PREAMP	TYPE OR DESCRIPTION	GAIN	N.F
KØRZ			X			X	D2320 - Two Stage - "SSB"	21.8	1.60
W4WD			X			X	D2320 - One Stage - "SSB"	13.06	1.87
KØKE			X		X		Packaged XVTR - "SSB"	22.66	2.9
WA8NLC			X			X	MGF 1402	15.3	1.75
			X			X	NE 720	12.75	2.00
WA5VJB			X			X	MGF 1203	9.18	1.78
WB4EFZ			X			X	W6PO-type	12.6	2.13
KØRZ				X		X	"AMPLICA 304302", WG to Coax	36.8	1.62
KØKE				X		X	"AMPLICA 304301", SMA input	44.8	1.87
				X		X	"AMPLICA 304301", WG to Coax	42.66	1.78
WA5VJB				X		X	"AMPLICA 305329", WG to Coax	52.1	1.97
WA8NLC				X		X	MGF 1402	14.50	1.50
*				2304 MHZ			Noise figure readings appear about 0.8 db. high		

ANTENNA GAIN MEASUREMENTS
MICROWAVE UPDATE'86
ESTES PARK, CO

29 August 1986
KØRZ, WØPW
AAØL, KØKE

CALL	1.3	2.3	3.4	ANTENNA TYPE	GAIN (dbi)	COMMENTS	
KØRZ		X		2' dish, 1 Lb, CC feed	19.5	Sno Sled	H.B.
		X		3' disk Yagi	16.7	Reworked MD5	
		X		1 Lb. Coffee Can feed	10.4		H.B.
WA8NLC		X		13 oz. Coffee Can feed	8.9		H.B.
WA5TKU	X			3 Lb. Coffee Can	5.4		H.B.
W3HQT		X		Pair 45 el. loop yagis	23.8	Down East Microwave	
K5IS	X			45 element loop	14.4		H.B.
KØKE		X		4' dish, 1 Lb. CC feed	24.0	Screened UHF	H.B.
	X			4' dish, folded dipole feed	10.9	Screened UHF	H.B.
W3HQT		X		45 element loop yagi	21.1	Down East Microwave	
KØRZ		X		3' grid dish	25.5	Reworked MDS	
W5LTR	X			44 element yagi	17.9	KLM	
KDØGS	X			45 element loop yagi	16.6	Down East Microwave	
WØKJY	X			24 element loop yagi	15.4		H.B.
	X			3 Lb. Coffee Can	6.1		H.B.
K5IS	X			14 element yagi	7.6		H.B.
KØKE			X	2' dish, soup can feed	19.5	Sno Sled	H.B.
			X	2' dish, 1 lb. CC feed	17.0	Sno Sled	H.B.
KØRZ			X	2' dish, soup can feed	20.5	Sno Sled	H.B.
			X	Soup can feed	7.5		H.B.
Ref. Ant				1296, 2 band horn	6.4		
				2304, 2 dipole	9.8		
				3456, WB5LUA soup can	8.5		
				2304 appears approx. 1 db high			
				1296 appears approx. 1 db low			

Prepared by KØRZ
29 August 1986

MICROWAVE UPDATE 1986 PROGRAM SCHEDULE
28-31 August 1986
Estes Park, CO

THURSDAY - 28 August

1400 - 1600	Registration - pick up Proceedings	
1700 - 1930	Swap session - Noise Figure Measurements	
	Bluegrass jam session	

FRIDAY - 29 August

Morning Session — Lauren Libby, KXØO - Moderator

0800 - 0815	Welcome	Don Hilliard, WØPW
0815 - 0900	"Practical Microwave Transverters"	Rick Campbell, KK7B
0930 - 1130	Antenna measuring; 1296/2304	
1130 - 1300	**L U N C H B R E A K**	

Afternoon Session — George Watson, WØLOB - Moderator

1300 - 1400	"MMIC Update/Cascading MMIC's"	Al Ward, WB5LUA
1400 - 1445	Panel Discussion: "Spectrally Pure Local Oscillators"	Jan Hubach, OH1ZAA
1445 - 1500	**B R E A K**	
1500 - 1545	"432/5760 Transceiver"	Tony Bickel, K5PJR
1545 - 1630	Update on the YU129 1296 Cavity Amplifier	Peter Sias, WBØDRL
1630 - 1900	**D I N N E R B R E A K**	
1915 - 2130	Swap Session - Noise Figure Measurements	

SATURDAY - 30 August

Morning Session — Keith Ericson, KØKE - Moderator

0800 - 0845	"A 5-Band Microwave Transverter"	Paul Shuch, N6TX
0845 - 0930	"Microwave Communications Receivers"	Rick Campbell, KK7B
0930 - 1000	**B R E A K**	
1000 - 1030	"Traveling Wave Tubes"	Tony Bickel, K5PJR
1030 - 1115	"3456 MHz The Easy Way"	Gerald Handley, WA5DBY
1115 - 1330	**L U N C H B R E A K**	

Afternoon Session — Bill McCaa, KØRZ - Moderator

1330 - 1415	"AMSAT Mode-S Transponder"	Bill McCaa, KØRZ
1415 - 1500	"Microwave Outlook"	Kent Britain, WA5VJB
1500 - 1515	**B R E A K**	
1515 - 1600	"Practical Microwave Techniques"	Keith Ericson, KØKE
1830 - 2130	**BARLEEN COUNTRY MUSIC DINNER THEATRE**	

SUNDAY - 31 August STRONGLY SUGGEST YOU DON'T MISS THIS

0800 - 0900	24 GHz. Seminar	Lynn Hurd, WB7UNU
	"Report on very recent operations on 24 GHz. in Oregon and Colorado"	Lauren Libby, KXØO

[The Oregon activity is being conducted on SSB]

MICROWAVE UPDATE 1986 LADIES PROGRAM SCHEDULE

- P R I Z E S -
(AND FOR THE KIDS TOO)

29 AUGUST - FRIDAY

09:45 am - 01:00 pm	Bosch 4-in-1 Kitchen Machine demonstration and lunch. DOOR PRIZES!
02:00 pm - 02:30 pm	Tour of the Pewter Factory. For those of you who went on this tour last year and don't care about going again, you are free to shop or do whatever you choose.
07:15 pm - 08:30 pm	"THE HIDDEN FOREST" Nature film at the Rocky Mountain National Park Headquarters building.

30 AUGUST - Saturday

10:00 am - 12:00	Nature hike in Rocky Mountain National Park
02:00 pm - 03:00 pm	Aerial car ride which will take us to the top of the mountain where we can view the grandeur of the area, feed the wild life and visit the gift shop. ($3 charge)
03:00 pm	Free time
06:30 pm - 09:30 pm	Leave for the Barleen Country Music Dinner Theatre. You will be transported via the Barleen's bus to and from the Theatre. Please BE IN THE LOBBY at 6:30 pm

PLEASE MEET IN THE LOBBY <u>15 MINUTES PRIOR TO POSTED TIMES</u> TO ALLOW FOR LOADING AND TRAVEL TIME.

MICROWAVE UPDATE 1986

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"PRACTICAL MICROWAVE TRANSVERTERS"

BY

RICHARD L. CAMPBELL, KK7B

PRACTICAL MICROWAVE TRANSVERTERS

Richard L. Campbell KK7B
Department of Electrical Engineering
Michigan Tech University
Houghton, MI 49931

When we contemplate building or purchasing equipment for the next higher band, we tend to think of power output, noise figure and IF frequency as the important parameters. Once the equipment is operational, however, another set of parameters becomes important. Many amateur microwave transverters are plagued with frequency drift, unknown operating frequency, mechanical and electrical instabilities that make portable operation impossible, low reliability, unplanned and unsatisfactory packaging, too much receive gain, too little dynamic range, spurious responses and spurious outputs, poor thermal planning, incompatibility with other station equipment and many other faults. A few hours of "engineering" before beginning construction can make the difference between an amateur microwave transverter that barely works and one that far surpasses anything commercially available. Practical techniques and design guidelines to overcome the above list of ills will be discussed. An example 40 W 23 cm transverter and 0.5 W 9 cm transverter will be exhibited and analyzed.

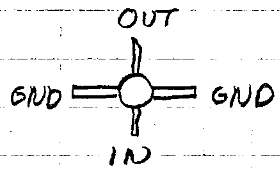
"MMIC UPDATE/CASCADING MMIC's"

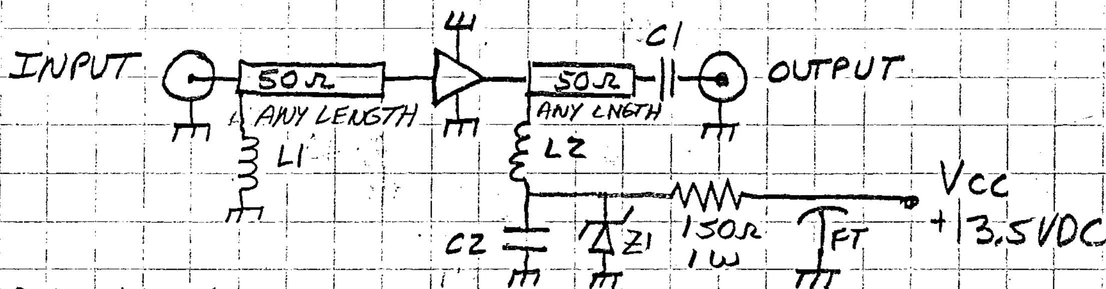
BY

AL WARD, WB5LUA

CGY-40 GaAs MMIC AMPLIFIER

FEATURES
- COST $16[30] ea.
- Pout +17 – +18 dBm 1dB C.P. @ 2304/3456 MHz
  +19.5 dBm SATURATED @ 2304/3456 MHz
- MODERATE GAIN – see table below
- NO TUNING
- G-10 DIELECTRIC MATERIAL
- UNCONDITIONALLY STABLE FROM VHF UP
- NOISE FIGURE UNDER 4dB





PARTS LIST

L1, L2	5 TURNS .075" I.D. S.W.D. #26 GA.
C1	100 pf CHIP CAP
C2	1000pf CHIP CAP
FT	1000pf FEEDTHRU
Z1	1N752 5.6V ZENER – FOR TRANSIENT PROTECTION

OPERATING PARAMETERS

V mmic = 4.5V
I mmic = 60 mA

NEG. BIAS CAN BE APPLIED TO INPUT OF MMIC VIA L1 FOR AGC.

GAIN VS. FREQUENCY

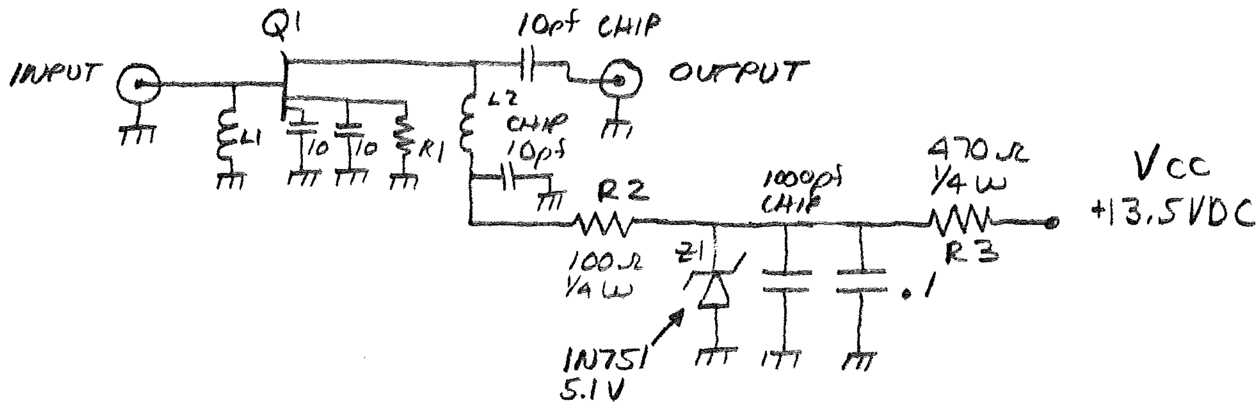
FREQ.	GAIN
902 MHz	9.4 dB
1296 MHz	9.3 dB
2304 MHz	7.5 dB
3456 MHz	5.1 dB
4000 MHz	3.7 dB

DEVICE AVAILABLE THROUGH:
MICROWAVE SEMICONDUCTOR CORPORATION.
201-469-3311

A. J. WARD
8-17-86

3456 MHz GaAs FET PREAMPLIFIER

FEATURES
- LOW COST - DEVICE COST $10[80]
- NO TUNING
- G-10 DIELECTRIC MATERIAL
- 1.2dB NF / 10 dB GAIN

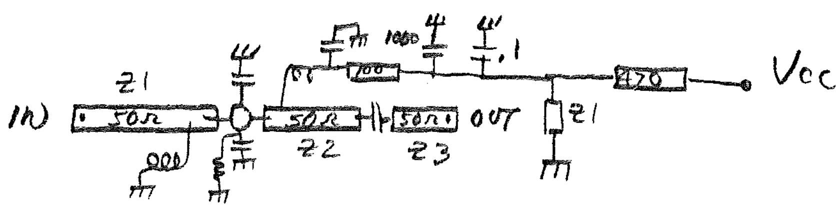


L1 3 TURNS .075" I.D. S.W.D. #26GA

L2 2 TURNS .075" I.D. S.W.D. #26GA

Q1 AVANTEK ATF10135 GaAsFET

R1 3 - 100Ω 1/4 W IN PARALLEL - ADJUST VALUE FOR 15-20mA



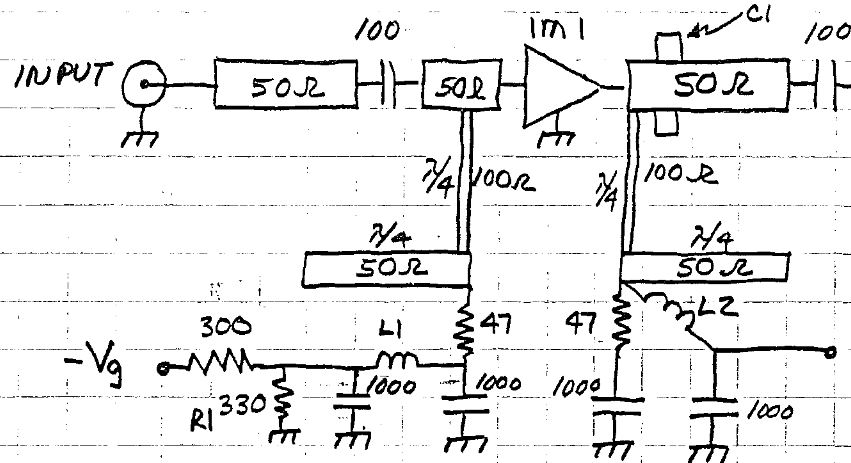
Z1, Z2, Z3 50Ω MICROSTRIPLINE - .1" WIDE ON .062" G10 DIELECTRIC MAKE LENGTH AS SHORT AS POSSIBLE BUT NOT CRITICAL

POWER OUTPUT PERFORMANCE

I_D	V_{DS}	1dB C.P.	SAT. P_o	COMMENT
17mA	3.5V	+10dBm	+12dBm	LOW NOISE BIAS PT.
43mA	3.5V	+13dBm	+15dBm	ADJ. R3
63mA	4.0V	+16dBm	+18dBm	ADJ. R3 and R2

A.J. WARD
6-14-86

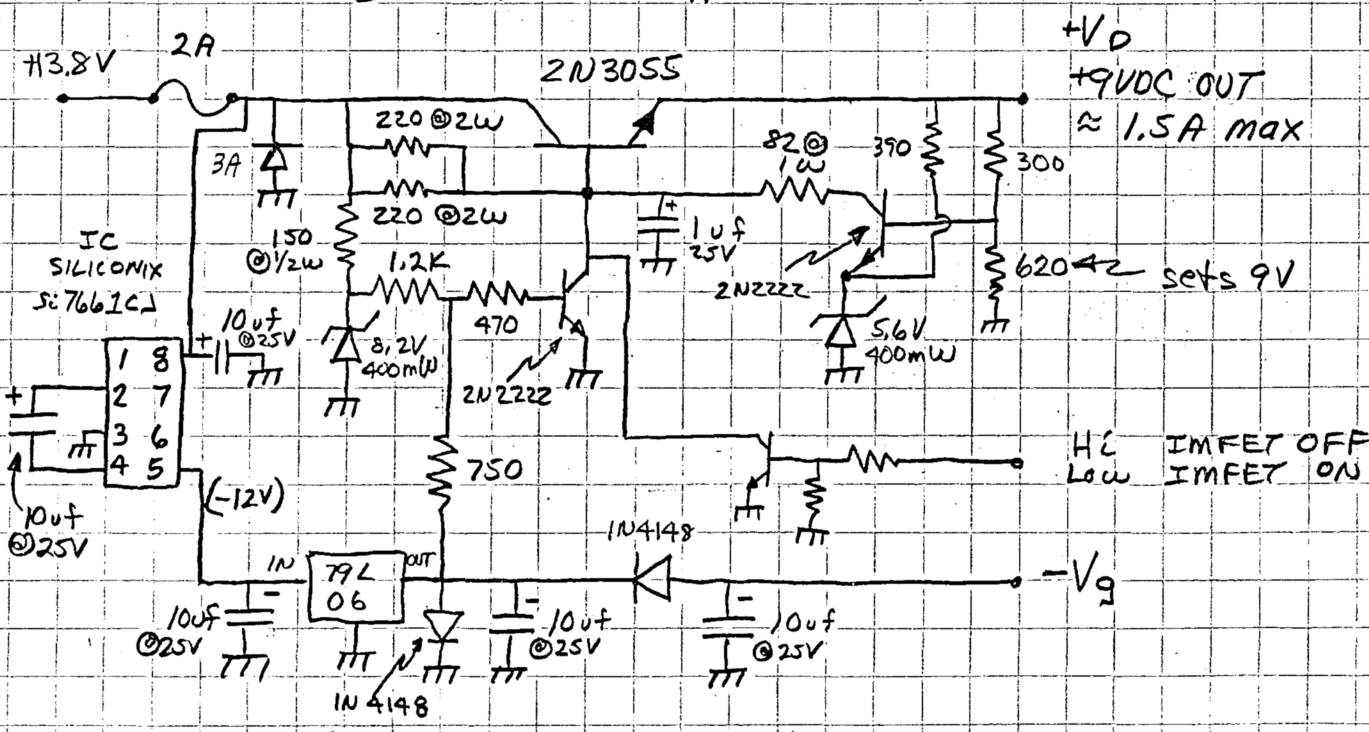
3456 MHz IMFET AMPLIFIER



$V_D = 9\,V$
$I_D = 1.3\,A$
$P_{IN} = 11.7\,W$
$P_O > 4\,W$ @ 1dB C.P.
5.4 W MAX
% ≅ 40 - 43%
G = 11 dB @ 1dB C.P.

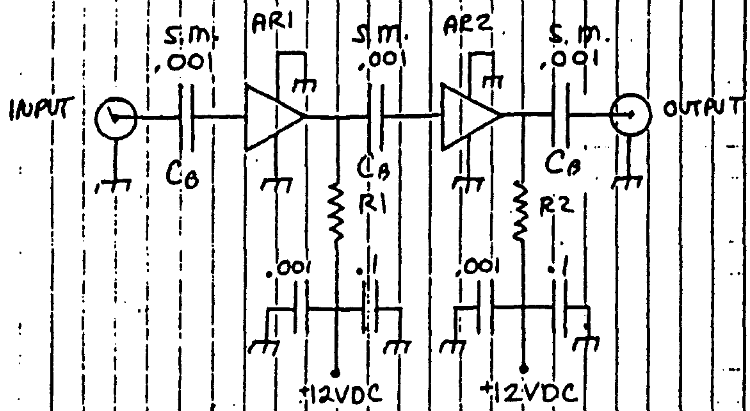
IM1 AVANTEK IM2935-3 IMFET
L1, L2 3 TURNS #28 G, 1/8" I.D. SWD
C1 2 CAPACITIVE STUBS ≈ .1 x .1" SQ ≈ .15" FROM IM1 - ADJ. FOR P_{OUTPUT}
ALL RESISTORS ARE 1/4 WATT CARBON
ALL CHIP CAPACITORS ARE .050" x .050"

- 2 AMPLIFIERS BUILT TO DATE ACHIEVE EQUAL PERFORMANCE



- Sequencing Power Supply built by WA5TNY
- MODIFIED FUJITSU P/S TO ACCOMODATE AVAILABLE DEVICES
- P/S WILL PROPERLY SEQUENCE $-V_g$ ON BEFORE $+V_D$ ON
- R1 CAN BE ADJUSTED TO SET DRAIN IDLING CURRENT TO 900 mA W/NO RF DRIVE

WB5LUA
WA5TNY
8-27-86



AR1 AVANTEK MSA-0204 MMIC

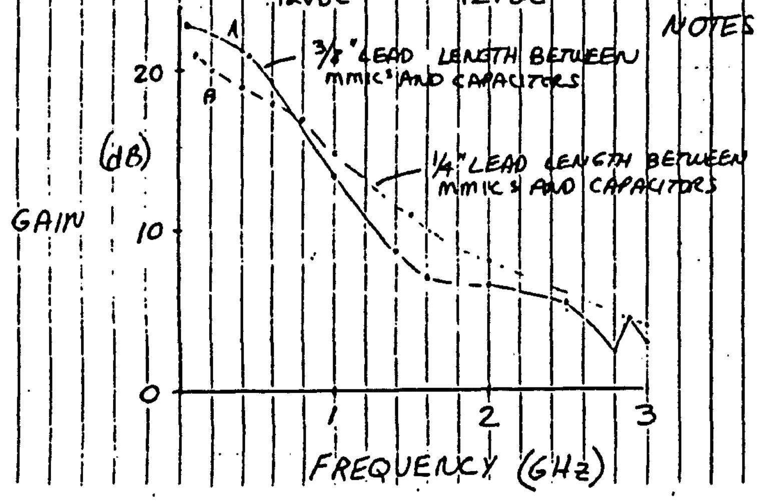
AR2 AVANTEK MSA-0304 MMIC

R1 270 OHM .5 W RESISTOR

R2 220 OHM .5 W RESISTOR

CAPACITORS IN uF.

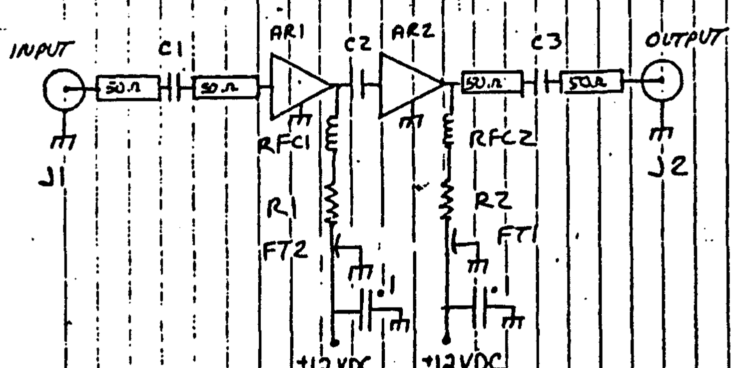
CONNECTORS BNC

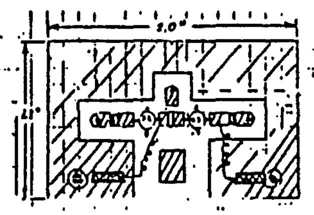


NOTES

1. "DEAD BUG" CONSTRUCTION TECHNIQUES UTILIZED - SEE NOTE
2. .1 uFd BYPASS CAPACITORS ELIMINATE LOW FREQUENCY OSCILLATIONS IN BIAS NETWORK
3. USE OF .1 uFd BLOCKING CAPACITORS ALLOW HF OPERATION DOWN TO 1.2 MHz.

VHF MMIC AMPLIFIER





COMPONENT LAYOUT

- SLASHED AREA IS COPPER
- 50 Ω LINEWIDTHS ARE .100"
- DIELECTRIC IS .062" G-10
- EACH MMIC MUST HAVE BOTH COMMON LEADS GROUNDED TO THE GROUND PLANE ON THE CONNECTOR (BOTTOM) SIDE

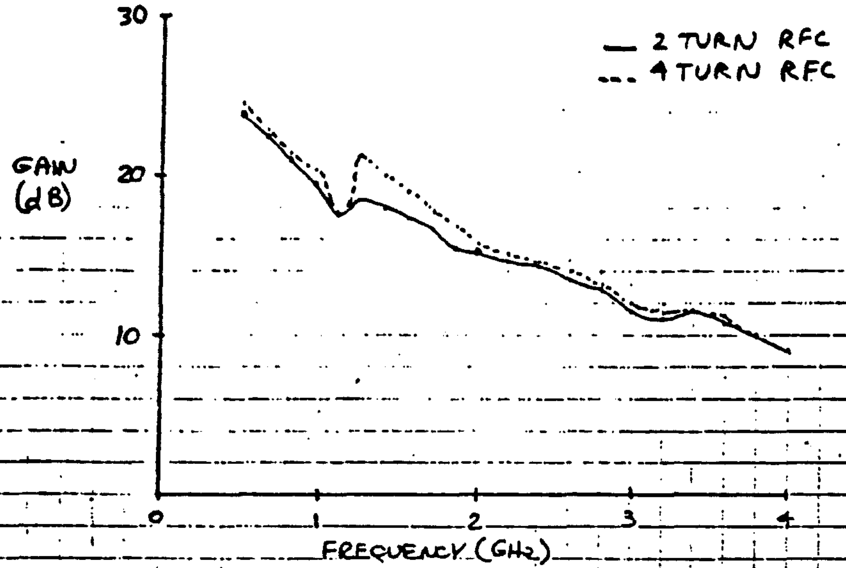
C1, C2, C3	50-100 pf CHIP CAP
AR1, AR2	AVANTEK MMIC
RFC1, RFC2	4 TURNS #28 GUAGE ENAMEL WIRE .125 INCH I.D. SWO.
R1, R2	BIAS RESISTORS - SEE DATA SHEET
FT1, FT2	470 pf FEEDTHROUGH CAP.
J1, J2	SMA CONNECTOR

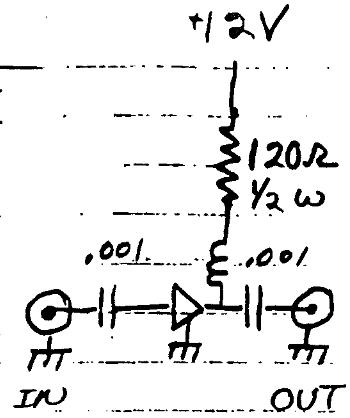
$$R = \frac{V_{cc} - V_{mmic}}{I}$$

MICROSTRIP MMIC AMPLIFIER

WB5LUA

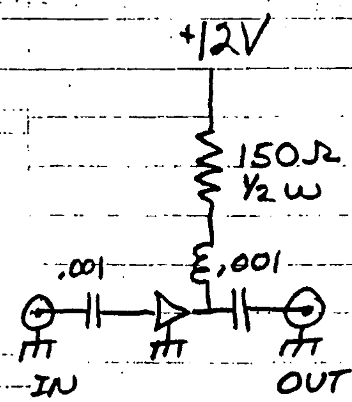
MSA 0835 MMIC AMPLIFIER

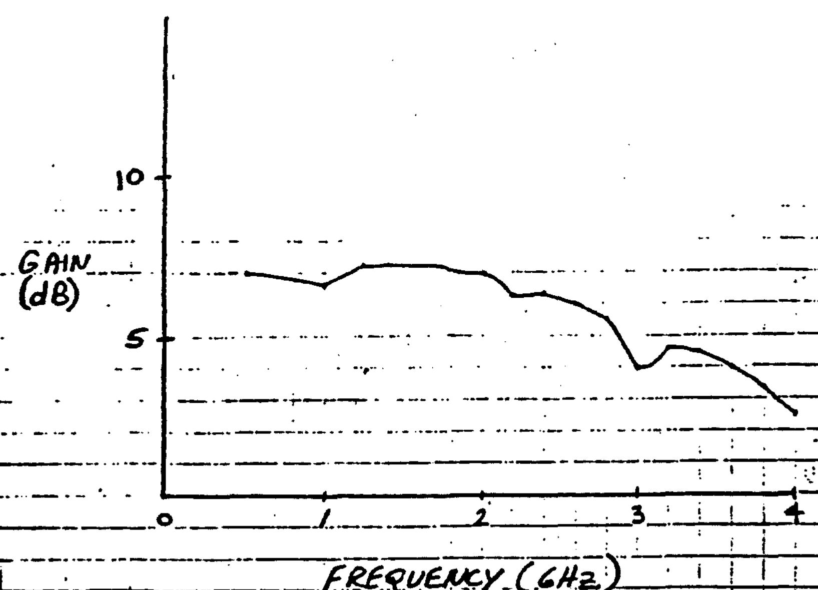




MEASURED PERFORMANCE FOR 2 AND 4 TURN RF CHOKES

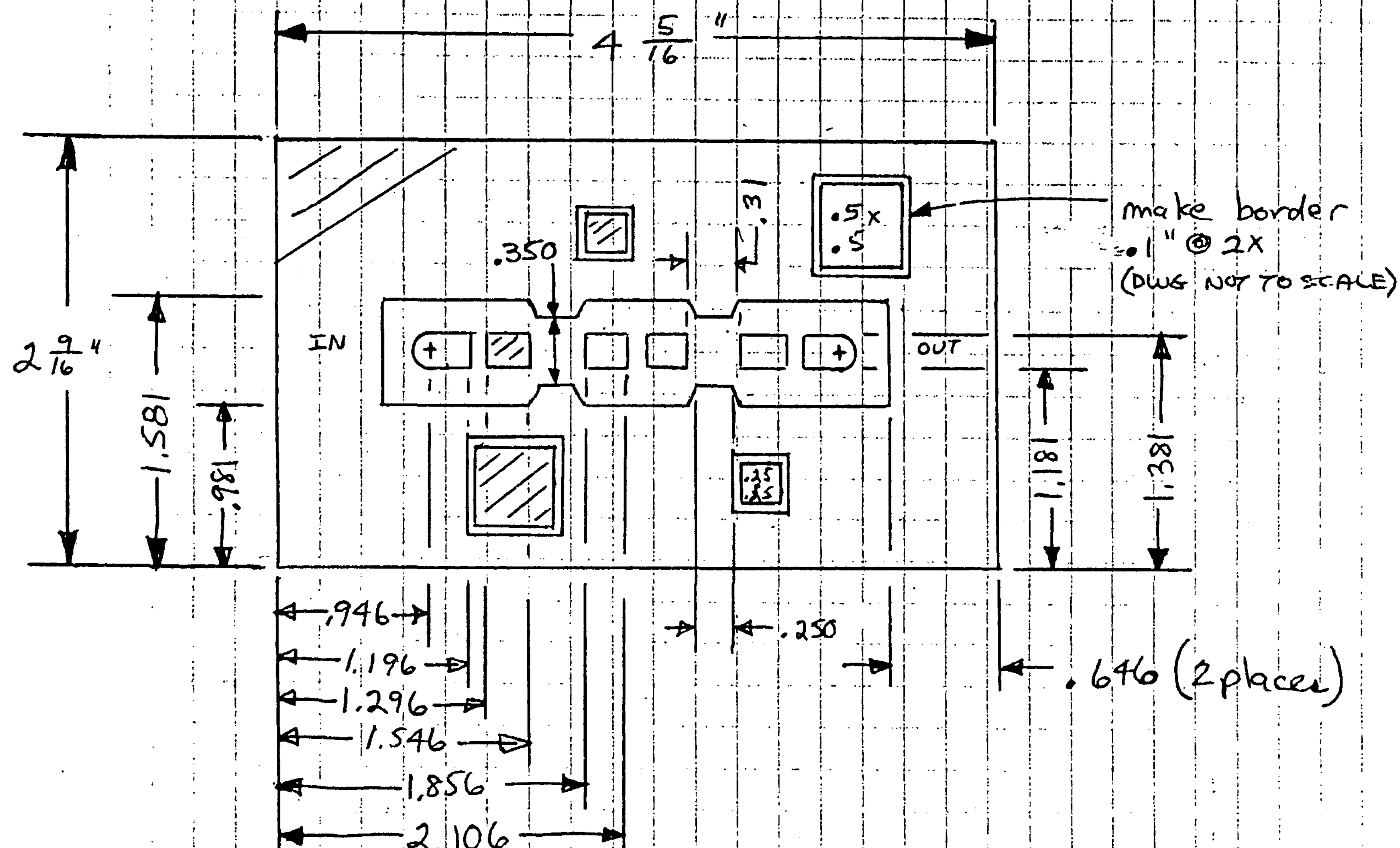
MSA0485 MMIC AMPLIFIER





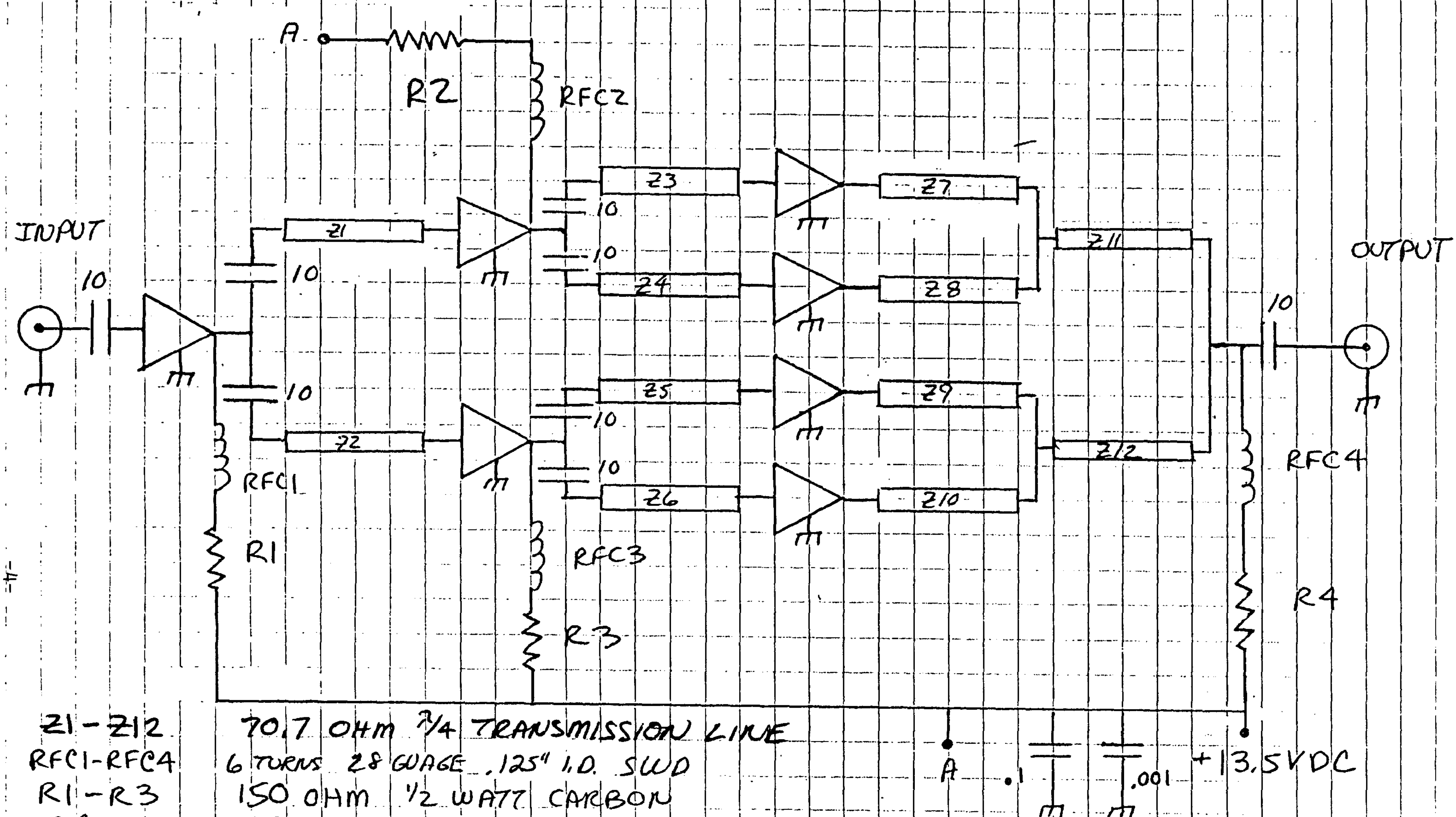
MEASURED PERFORMANCE FOR MSA0485 MMIC AMPLIFIER

WB5LUA
7-14-86



NOTES: 1. DIMENSIONS IN INCHES
2. DIMENSIONS ARE 2X
3. SLASHED AREA IS COPPER
4. $\varepsilon_r = 5.0$, THICKNESS IS .062"

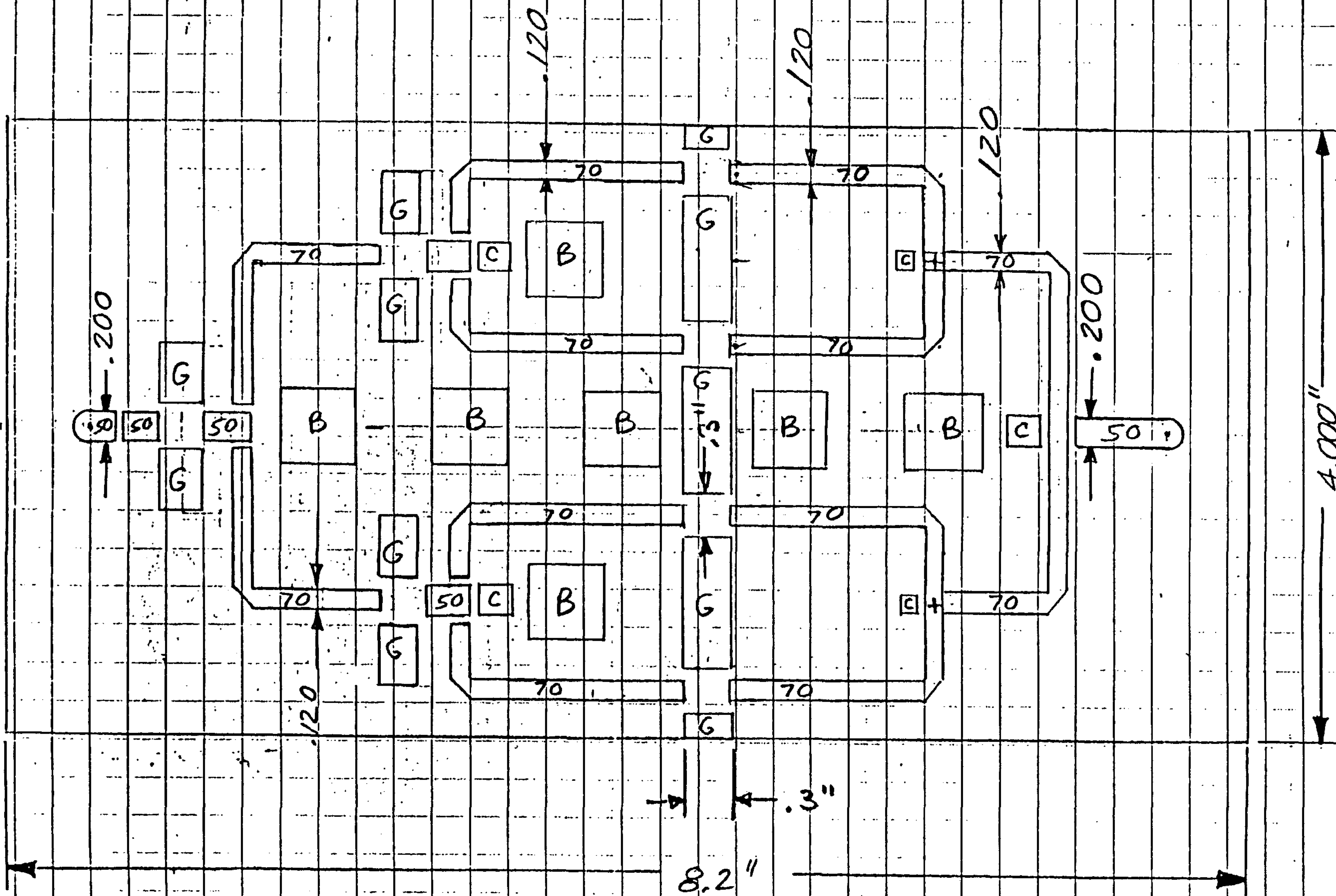
CASCADE MMIC AMPLIFIER
CIRCUIT LAYOUT
A. J. WARD
JAN 6, 1985



Z1 - Z12 70.7 OHM λ/4 TRANSMISSION LINE
RFC1-RFC4 6 TURNS 28 GUAGE .125" I.D. SWD
R1 - R3 150 OHM 1/2 WATT CARBON
R4 30 OHM 2 WATT MINI. CARBON
CONSISTS OF 5 - 150 OHM 1/2 WATT CARBON RES. IN PARALLEL

SCHEMATIC
2.3 GHz MSA-0404 MMIC AMPLIFIER

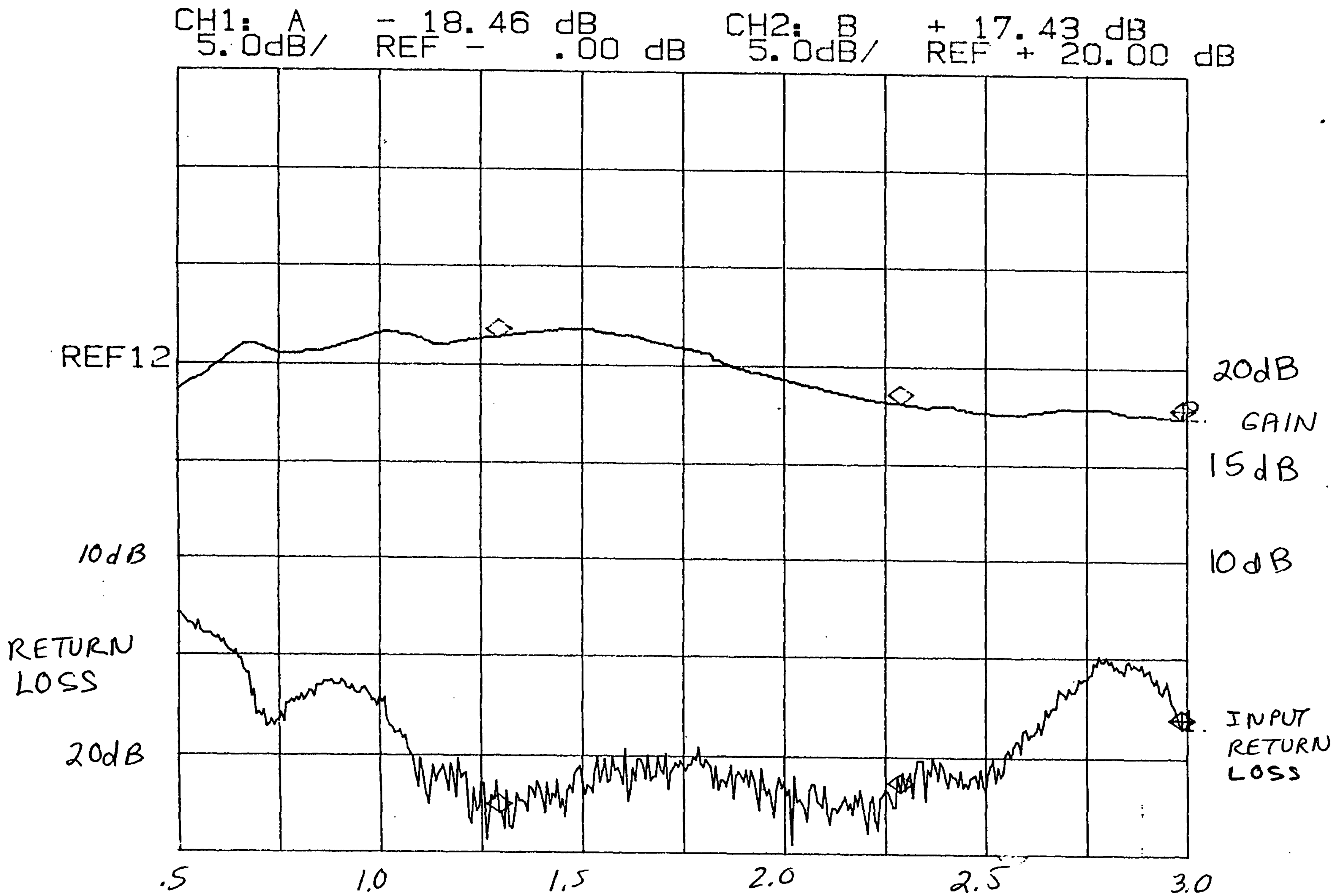
WB5LUA
7-30-86



4-MSA0404
2.3 GHz
AMPLIFIER
A.J. WARD
10-2-85

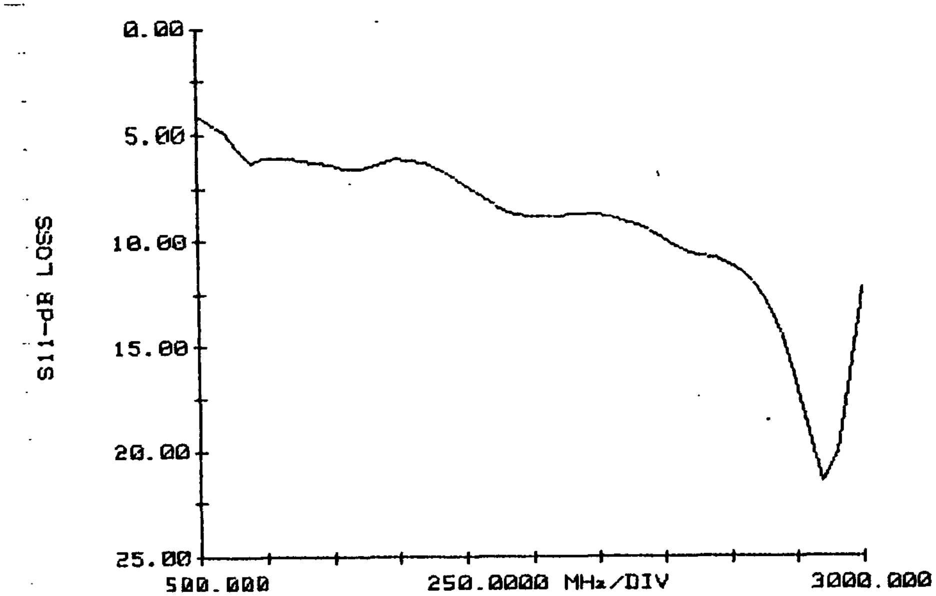
PRINTED CIRCUIT BOARD LAYOUT

MAT'L: DUROID 5880, .031" THICK, $\varepsilon_r = 2.2$
DIMENSIONS: 2X



2.3 GHz MSA-0404 MMIC AMPLIFIER

WB5LUA
7-30-86



OUTPUT PORT RETURN LOSS
OF MSA-0404 AMPLIFIER

WB5LUA

AVANTEK

MODAMP™
MSA-0185, MSA-0285, MSA-0385, MSA-0485
Cascadable Monolithic Silicon
Integrated Circuit Amplifiers
Advanced Product Information
January, 1986

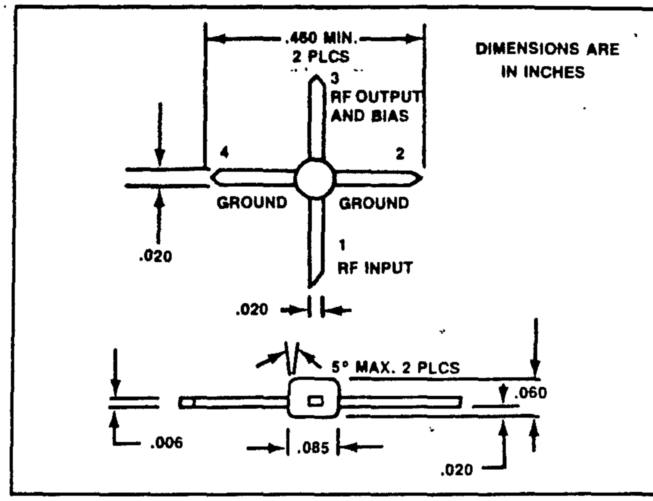
FEATURES

- Low Cost Plastic Packaging
- Cascadable (VSWR<2:1)
- Smooth Single-Pole Gain Rolloff
- Unconditionally Stable

DESCRIPTION

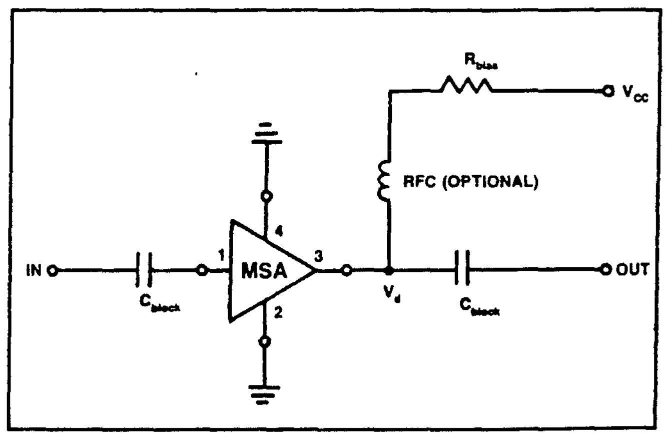
Avantek's MSA-0185, MSA-0285, MSA-0385 and MSA-0485 are a new series of silicon bipolar Monolithic Microwave Integrated Circuits, MODAMPs™, manufactured in a low cost, high performance plastic package. These MODAMPs™ are designed for use as general pupose 50 ohm gain blocks. Typical applications include narrow and broad band IF and RF amplifiers in commercial and industrial applications.

All Avantek MODAMPs™ use nitride self-alignment, ion implantation for precise doping control, and both gold metalization and nitride passivation for high reliability.

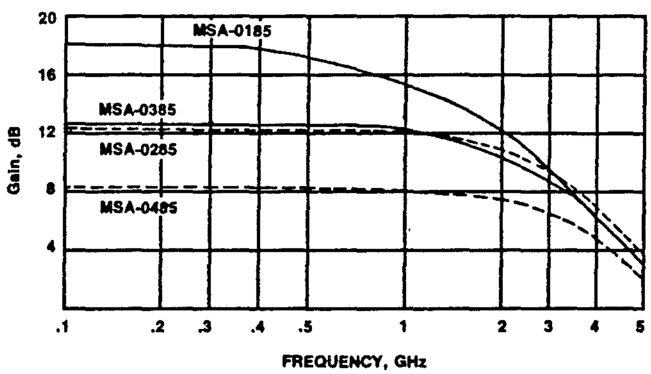


Avantek 85 Plastic Package

Typical Biasing Configuration



Typical S_{21} Gain vs. Frequency



TYPICAL ELECTRICAL SPECIFICATIONS; $T_A = 25°C$

DEVICE	V_{CC} (V)	R_{bias} (Ω)	Typical		Typical @ 500 MHz			Typical $f_{1\ dB}$[1] (MHz)
			I_d (mA)	V_d (V)	$\lvert S_{21}\rvert^2$ (dB)	$P_{1\ dB}$	$NF_{50\Omega}$	
MSA-0185	12	410	17	5	17.4	1.0	5.0	550
MSA-0285	12	280	25	5	12.8	4.0	6.0	1150
MSA-0385	12	200	35	5	12.8	10.0	5.5	1150
MSA-0485	12	140	50	5	8.2	13.0	6.3	2100

NOTE 1: Frequency at which gain is 1 dB less than at 100 MHz.

TYPICAL SCATTERING PARAMETERS, MSA-0185

V_{CC} = 12V, I_d = 17 mA

Freq.	S_{11}		S_{21}		S_{12}		S_{22}	
MHz	Mag	Ang	dB	Ang	Mag	Ang	Mag	Ang
100	.068	163.8	18.46	170.7	.077	4.1	.068	−13.8
500	.062	105.8	17.40	140.6	.084	15.2	.072	−67.7
1000	.065	71.5	15.61	110.7	.102	24.3	.087	−123.8
1500	.036	59.0	13.70	86.6	.127	26.3	.104	−161.2
2000	.059	148.9	12.30	67.1	.157	20.5	.157	−177.2
2500	.096	142.0	10.62	48.8	.180	17.7	.156	154.9
3000	.136	139.3	9.30	33.6	.202	12.0	.145	143.9
3500	.205	129.0	7.89	18.6	.218	5.3	.157	135.3
4000	.279	120.0	6.62	3.1	.246	−4.2	.165	127.3
4500	.335	110.3	5.41	−9.1	.250	−9.9	.159	122.5
5000	.390	99.4	4.26	−20.7	.251	−17.4	.149	124.2
5500	.433	91.1	3.24	−31.0	.256	−22.3	.155	131.0
6000	.479	83.1	2.25	−41.4	.259	−29.6	.174	136.1

TYPICAL SCATTERING PARAMETERS, MSA-0285

V_{CC} = 12V, I_d = 25 mA

Freq.	S_{11}		S_{21}		S_{12}		S_{22}	
MHz	Mag	Ang	dB	Ang	Mag	Ang	Mag	Ang
100	.121	173.5	12.88	174.2	.116	1.4	.126	−7.9
500	.113	154.1	12.75	156.0	.120	4.7	.123	−37.5
1000	.100	130.1	12.47	130.5	.127	6.7	.123	−75.4
1500	.077	120.2	11.75	109.1	.141	9.9	.123	−112.2
2000	.062	126.2	10.99	90.0	.155	8.8	.127	−121.0
2500	.085	147.5	10.35	67.1	.174	5.7	.129	−165.5
3000	.140	146.6	9.35	45.7	.188	−.9	.129	171.2
3500	.207	136.4	8.23	29.6	.199	−5.5	.127	154.8
4000	.273	123.5	7.26	13.6	.207	−10.4	.125	141.7
4500	.344	111.8	6.17	−2.3	.214	−16.9	.123	135.1
5000	.410	101.9	4.90	−16.5	.210	−22.4	.122	135.9
5500	.470	92.4	3.91	−28.9	.222	−27.1	.132	139.7
6000	.516	85.2	2.77	−40.4	.216	−32.5	.165	144.1

TYPICAL SCATTERING PARAMETERS, MSA-0385

V_{CC} = 12V, I_d = 35 mA

Freq.	S_{11}		S_{21}		S_{12}		S_{22}	
MHz	Mag	Ang	dB	Ang	Mag	Ang	Mag	Ang
100	.068	172.1	12.97	174.3	.118	1.2	.154	−10.6
500	.059	156.0	12.78	152.5	.121	5.3	.164	−45.5
1000	.047	145.8	12.40	128.0	.131	9.8	.185	−87.9
1500	.045	172.2	11.75	103.3	.145	11.7	.214	−120.4
2000	.058	173.0	10.80	83.0	.176	10.7	.253	−142.3
2500	.170	174.6	10.25	59.5	.187	5.5	.256	−172.6
3000	.243	157.3	9.10	38.2	.204	−.3	.251	168.0
3500	.319	140.2	7.77	21.4	.214	−6.1	.252	152.4
4000	.386	124.3	6.47	2.9	.219	−13.7	.254	138.4
4500	.456	110.7	5.04	−9.4	.222	−18.4	.237	130.3
5000	.508	99.6	3.90	−23.5	.219	−23.7	.235	125.6
5500	.557	88.7	2.72	−34.0	.225	−26.0	.245	123.7
6000	.596	80.9	1.70	−45.1	.227	−31.2	.265	122.9

TYPICAL SCATTERING PARAMETERS, MSA-0485

V_{CC} = 12V, I_d = 50 mA

Freq.	S_{11}		S_{21}		S_{12}		S_{22}	
MHz	Mag	Ang	dB	Ang	Mag	Ang	Mag	Ang
100	.185	176.9	8.23	175.3	.155	.1	.103	−13.6
500	.180	168.6	8.22	156.5	.156	1.1	.127	−54.4
1000	.173	159.1	8.16	135.1	.161	3.2	.178	−93.9
1500	.174	156.8	8.08	111.7	.170	3.6	.239	−121.4
2000	.190	151.1	7.73	89.6	.186	2.9	.285	−144.8
2500	.240	159.5	7.61	68.7	.204	−.5	.338	−165.2
3000	.313	150.6	6.93	45.9	.221	−5.6	.355	176.2
3500	.391	139.0	5.97	27.3	.226	−10.9	.370	160.5
4000	.465	126.4	4.93	7.8	.250	−22.9	.383	146.9
4500	.524	114.6	3.57	−6.4	.246	−26.1	.385	137.4
5000	.579	105.5	2.39	−21.5	.243	−30.6	.373	129.8
5500	.617	96.6	1.30	−32.3	.242	−32.6	.391	125.1
6000	.643	89.2	.20	−43.7	.242	−38.0	.415	120.8

AVANTEK

3175 Bowers Avenue
Santa Clara, CA 95054-3292
General Offices:
(408) 727-0700

Customer Service & Component
Sales (408) 496-6710
TWX 310-371-8717
Telex 34-6337

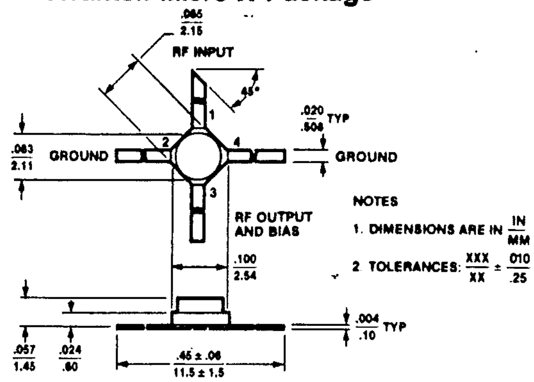
AVANTEK

MODAMP™
MSA-0835 Cascadable Silicon Bipolar MMIC Amplifier
January, 1986

Features:

- DC to 6 GHz Bandwidth
- Low Noise Figure (3.0 dB)
- High Gain (23.5 dB at 1 GHz)
- Smooth Gain Rolloff
- Low Distortion (28 dBm IP_3)
- 100 psec Group Delay
- Bias Flexibility ($V_{CC} \geq 12V$)
- Cost Effective Glass-seal Microstrip Ceramic Package

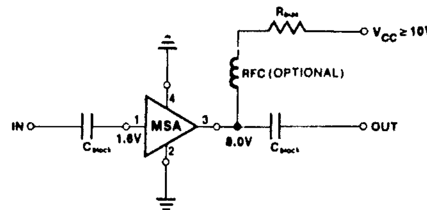
Avantek Micro-X Package



Description

The MSA-0835 is a member of the Monolithic Silicon Amplifier MMIC family of single-stage feedback amplifiers. It is designed for narrow or moderate bandwidth applications that require high gain and low noise. The MSA series is fabricated using nitride self-alignment and ion-implantation to achieve excellent unit-unit uniformity. Use of an external limiting resistor and optional choke allows bias flexibility.

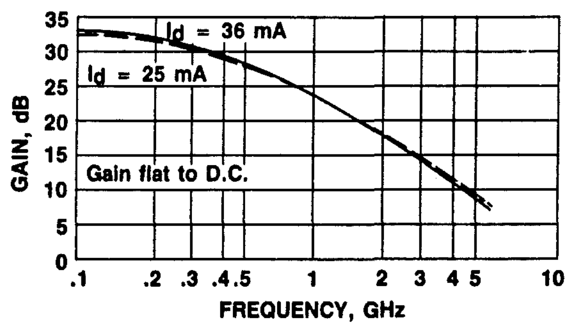
Typical Biasing Configuration



Applications:

- RF and IF Amplifiers
- Frequency Multiplication
- Oscillators up to 6 GHz
- 4 GHz TVRO Amplifiers/Oscillators
- Navigation Receivers
- Cellular Radio Receivers
- Millimeter Wave Receiver IF Amps
- Mobile Receivers
- Secure Communications Receivers

TYPICAL GAIN vs. FREQUENCY



Electrical Specifications: $T_A = 25°C$

Symbol	Parameters/Test Conditions $V_{CC} = 15V$, $R_{bias} = 200\Omega$, $I_d = 36$ mA, $Z_o = 50$	Freq. (GHz)	Units	Min.	Typ.	Max.
$\lvert S_{21}\rvert^2$	Insertion Power Gain	0.1	dB		33	
		1	dB	22	23.5	25
		4	dB	10	11	12
VSWR	Input VSWR	1–6			3:1	
	Output VSWR	1–6			2:1	
NF	Noise Figure at 1 GHz	1	dB		3	
	Noise Figure at 4 GHz	4	dB		5	
$P_{1\,dB}$	Output Power @ 1 dB Gain Compression	1	dBm		12.5	
P_{sat}	Saturated Output Power	1	dBm		16	
IP_3	Third-order Intercept Point	1	dBm		28	
IP_2	Second-order Intercept Point	1	dBm		38	
t_D	Group Delay	1	psec		100	
V_{dtc}	Device Voltage Temperature Coefficient	—	mV/C		−11	

Recommended Maximum Ratings

Parameter	Cont.[1] Oper.	Abs.[2] Max.
Device Current	40 mA	80 mA
Dissipation[3]	350 mW	750 mW
RF Input Power	+16 dBm	+20 dBm
Junction Temperature	150°C	200°C
Storage Temperature	—	200°C

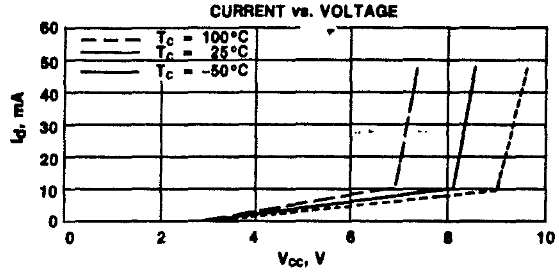
Thermal Resistance: θ_{jc} = 140° C/W

Notes:
1. Maximum for continuous operation.
2. Permanent damage may occur if any of these limits are exceeded.
3. Derate at 7.7 mW/C for Tc ≥ 100°C.

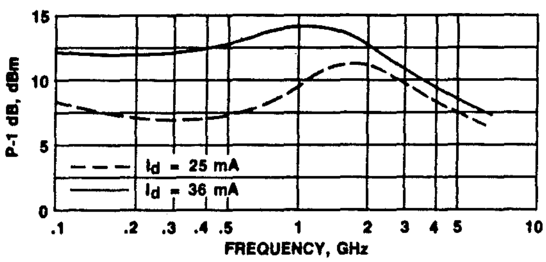
Typical Performance, $T_A = 25°C$

(Unless otherwise noted)

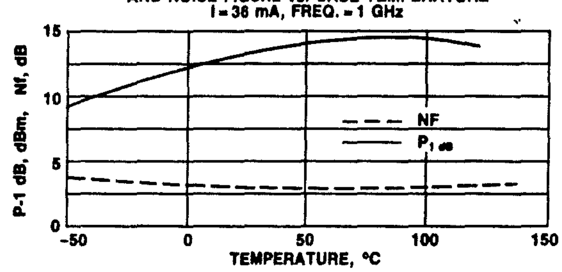
TYPICAL POWER SUPPLY CURRENT vs. VOLTAGE



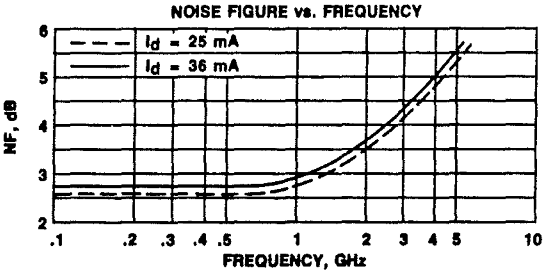
OUTPUT POWER AT 1 dB GAIN COMPRESSION vs. FREQUENCY AND CURRENT



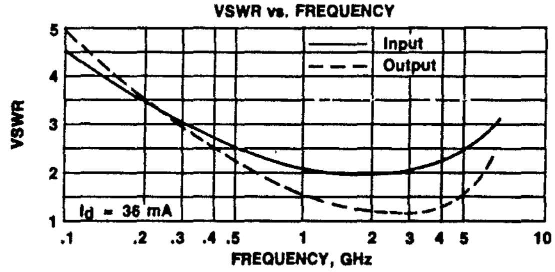
OUTPUT POWER AT 1 dB GAIN COMPRESSION AND NOISE FIGURE vs. CASE TEMPERATURE
I = 36 mA, FREQ. = 1 GHz



NOISE FIGURE vs. FREQUENCY



VSWR vs. FREQUENCY



Typical Scattering Parameters: $T_A = 25°C$, V = 15.0V Typ., Id = 36 mA

Freq. (MHz)	S_{11} Mag	S_{11} Ang	S_{21} dB	S_{21} Ang	S_{12} dB	S_{12} Ang	S_{22} Mag	S_{22} Ang	K
100	0.71	−19	33.2	161	−38.4	42	0.68	−22	.73
500	0.46	−71	28.5	110	−28.9	51	0.40	−85	.69
1000	0.35	−104	23.6	80	−24.7	48	0.24	−127	.83
1500	0.32	−128	20.2	60	−22.1	43	0.16	−154	.90
2000	0.33	−146	17.7	43	−20.2	35	0.11	−168	.93
2500	0.34	−163	15.6	28	−18.8	27	0.07	−177	.96
3000	0.35	−177	14.0	14	−17.9	19	0.05	−151	1.00
3500	0.38	168	12.5	0	−17.0	12	0.06	−121	1.00
4000	0.41	154	11.2	−13	−16.4	5	0.10	−126	1.00
4500	0.43	138	10.1	−26	−15.8	−2	0.14	−130	.97
5000	0.46	121	9.2	−39	−15.2	−8	0.18	−147	.94
5500	0.48	107	8.2	−52	−14.7	−15	0.22	−156	.91
6000	0.50	90	7.2	−66	−14.2	−21	0.23	−170	.90

AVANTEK
3175 Bowers Avenue
Santa Clara, California 95054-3292
(408) 727-0700
TWX 310-371-8717

ADS-1423/R-2-86

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CASCADING DEVICES

Predicting cascaded amplifier performance is merely a matter of understanding a few basic parameters; gain, VSWR, noise figure, 1 dB gain compression, and intercept point. When dealing with transmitter stages, generally all parameters except noise figure are considered important. Since the device noise figure is in the 5-6 dB range the noise level is so low, that other levels in the exciter such as carrier suppression and phase noise are the most dominant factors. In a receiver, all parameters should be considered if good dynamic range is desired. The intent of this section is simply to review these concepts and give several examples. Actual system requirements will be left up to the builder.

GAIN

Gain is a measurement of the difference in power available at the source and power available after the device under test "DUT" is inserted. This is shown in figure 1. To get the most accurate gain measurements possible, the source impedance and the power measuring instrument should exhibit a low VSWR (less than 1.15:1) in reference to the system that we wish to be measuring (50 ohms in our case). Occasionally the source impedance of the generator in use is not 50 ohms resistive. A 6 to 10 dB attenuator can be used on the output of the generator to lower the VSWR. The same may hold true if the detector or power measuring instrument does not have a good VSWR.

Since we are making a gain measurement with the "available power" method (which by the way is the standard accepted industry method) the effect of the DUT input and output VSWR is automatically taken into account with the gain measurement. Included in the gain measurement of the DUT is the mismatch loss which is associated with the VSWR of the DUT. Mismatch loss is calculated by the following equation:

$$M.L. = -10 \log \left[1 - \left(\frac{VSWR - 1}{VSWR + 1}\right)^2\right]$$

If the input and output VSWR's were 1.0:1 then the corresponding mismatch loss would be 0 dB. If we were to improve the input and output device VSWR's, the end effect would be an increase in gain equal to the reduction in mismatch loss at each port. If we were to cascade 2 modules, one with a gain of 6 dB and another with a gain of 10 dB we would expect to see a resultant gain of 16 dB as measured by the gain method described earlier. If the output VSWR of the first DUT and the input VSWR of the second were 1.0:1 then 16 dB of available gain should be measured. If the output VSWR of the first DUT were 1.0:1 and the input VSWR of the second DUT were 1.5:1 then we could calculate the mismatch loss due to the 1.5:1 VSWR and when subtracted from the 16 dB should yield the "actual" gain as measured with our setup.

herefore actual gain should measure 16 dB - .177 dB = 15.823 dB. low to complicate the situation, if the output VSWR of the first)UT was also not 1.0:1 but actually 1.5:1, as an example, :hen the resultant mismatch loss could be nearly .7 dB worst case. laximum mismatch loss will occur at some electrical spacing (L))etween the 2 devices. In contrast to the worst case condition,)t some frequency the VSWR's (which could still be 1.5:1) could ·epresent points on opposite sides of the Smith Chart (R+jx and ?-jx for example) which when mated could actually produce a :onjugate match, a matched condition and as a result minimum oss! As compared to the worst case condition with an electrical ;pacing (L) minimum loss will occur at a spacing a quarter /avelength shorter or longer than (L). As a rule of thumb for /orst case mismatch loss multiply the source VSWR by the load VSWR ınd convert to mismatch loss.

As the frequency of operation of the MMIC increases, the :ffects of mismatch due to VSWR become even more apparent. A :.0:1 source VSWR beating against a 2.0:1 load VSWR can introduce ıp to a 1.94 dB mismatch loss which subtracts from the available ȷain. Keep this in mind as MMIC stages are cascaded.

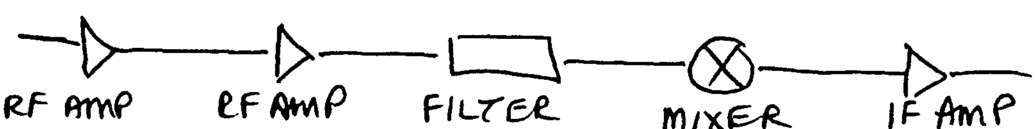
IOISE FIGURE

The noise figure of a cascaded series of devices is readily :alculated from the following formula.

$$NF_{TOTAL} = NF_1 + \frac{NF_2 - 1}{G_1} + \frac{NF_3 - 1}{G_1 G_2} + \frac{NF_4 - 1}{G_1 G_2 G_3}$$

/here noise figure and gain are expressed in unitless ratios. To :onvert from noise figure or gain in dB to a ratio first divide :he number in dB by 10 and take the inverse base 10 log to obtain :he ratio.

As an example let us analyze the noise figure of a 2304 MHz ·eceiving converter whose schematic is shown in figure 2, 2 ISA0835 MMIC's will be used as RF amplifiers driving a bandpass ·ilter into a doublebalanced mixer followed by an IF amplifier.



IF(dB)	4 dB	4 dB			0.5 dB
ìain(dB	13 dB	13 dB	-0.5 dB	-9.5 dB	20 dB

FIGURE 2

In order to simplify the calculation, the loss of the filter ınd mixer can be added to the noise figure of the IF amplifier. herefore, the noise figure at the input to the filter is .5 + 9.5 · .5 = 19.5 dB.

$$NF\ total = \frac{2.51-1}{20} + \frac{11.22-1}{20*20}$$

$$= 2.51 + .0755 + .0255$$

$$= 2.611$$

$$= 4.168\ dB$$

This calculation assumes no additional loss due to mismatch loss as discussed earlier. Mismatch loss can be factored in as additional loss or increase in noise figure of the stage just following the mismatch loss.

COMPRESSION POINT

Calculating 1 dB gain compression of a series of amplifiers is not as straightforward as gain or noise figure. 1 dB gain compression typically occurs several dB after amplifier performance diverges from linearity but does depend on device characteristics. Unless this portion of the gain curve is accurately known it may be hard to determine which stage is actually compressing if in fact two or more stages are compressing simultaneously. The simplest solution is to insure that the only stage that is driven to the 1 dB gain compression point is the output stage. Make sure that each of the driver stages is running at output powers atleast 3 dB and preferably 6 dB lower than its 1 dB gain compression point. The problems associated with cascaded and paralleled devices and its dependence on device gain has been covered in the section on the MSA0404 broadband amplifier. The result of amplifier compression is more easily seen when measuring third order intermodulation distortion products as discussed in the following section.

The concept of intercept point can now be applied to our MMIC amplifier or series of cascaded devices. Intercept point (I.P.) is useful in determining the level of intermodulation distortion (IMD) products generated in amplifiers, mixers, etc. I.P. is the power level at which the amplitude of one of the undesired intermodulation products equals the level of the desired signal. Generally, the second or third order IMD products are of major concern. I.P. can be referenced to the input or output of a device. For amplifiers used for transmit purposes, output I.P. has the most meaning. This is shown in figure 3. Of course in reality I.P. occurs at a point much greater than the device is actually capable of producing power but the separation between the curves in dB for a specific power input or power output level predicts how far down the spurious will be from the desired output. (See Figure 3)

The second order IMD products are described by the equations;

$$F_1 + F_2 \quad 2F_1$$
$$F_1 - F_2 \quad 2F_2$$

The third order IMD products are of prime concern when characterizing linear amplifier performance. They are described by the following equations;

$$2\,F_1 \pm F_2$$
$$2\,F_2 \pm F_1$$

In order to determine the two tone third order intercept point, the following formula can be used without actually plotting the fundamental and third order responses.

I.P.(dBm) = IMD / 2 (dB) + P out (dBm)

Two equal amplitude signals are injected into the device under test and spaced close enough in frequency such that both the fundamental signals and third order signals are in the passband. The output level of one of the two tones is noted as Pout. The output level of one of the third order tones is noted as PImd . The difference in these two levels (Pout - PImd) is the IMD ratio in dB. . Intercept point can now be calculated . Actual measurements on the high power MSA0404 amplifier at 1296 Mhz. yield the following.

I.P. = 40 / 2 dB + 6 dBm = +26 dBm

Making accurate I.P. measurements necessitates having a spectrum analyzer with enough dynamic range such that the amplifier under test is tested at an output power level atleast 10 dB below the actual 1 dB gain compression point. At the same time, the IMD products to be measured should be at a level atleast 10 dB above the spectrum analyzer noise floor to insure that the signal being measured has minimal noise superimposed. These conditions are to say the least tough to meet even under laboratory conditions.

Of major concern over a narrow bandwidth are the $2\,F_1 - F_2$ and $2F_2 - F_1$ products. As an example, for two signals F_1 and F_2 that are separated by 1 kHz the resultant 2 tone third order IMD products are again 1 KHz further removed from the primary signals. This is analagous to an SSB transmitter generating 2 tones separated by 1 kHz producing an additional pair of spurious signals at frequencies 1 KHz further away from the first pair of desired signals. This shows up as "splatter" on an SSB signal.

When working with linear amplifiers used for amplification of SSB signals, the parameter of greatest concern is the level of IMD products below Peak Envelope Power (PEP) output. The maximum PEP output is determined by injecting a single tone into the device and using the resultant output as the reference PEP level. This level is usually set at the top of the spectrum analyzer. See figure 4 The single signal is then replaced by two equal amplitude signals that are at a level 6 dB below the PEP level. This simulates normal speech levels. The two fundamental tones represent average power output that is 3 dB down from PEP output. The third order signals are then measured with respect to PEP output.

Typically when an MMIC amplifier is run up to 1 dB gain compression the 2 tone 3rd order IMD is atleast 27 to 32 dB below the PEP output. For every 1 dB decrease in power output level the 3rd order IMD power level will decrease by 3 dB making the IMD products relative to the desired signal decrease by 3 - 1 = 2 dB. As power out approaches 1 dB gain compression IMD becomes significantly worse.

Let's now calculate the two tone third order IMD with respect to PEP output. The MSA0404 MMIC can be driven to +13 dBm output so this power level will be used as the reference rated PEP output level. According to the data sheet, at 500 Mhz. the intercept point is typically +26 dBm. We then desire the two tone third order IMD at +13 - 6 dB = +7 dBm output power (reference prior discussions on peak versus average power).

Therefore IMD @ + 7 dBm average per tone or +13 dBm PEP

$$2 * (+26 - + 7)$$
$$(2 * 19)$$
$$38 \text{ dB}$$

This concept may be confusing at first but realize that when we are modulating an SSB transmitter and not overdriving it, the total average power in our voice patterns is supposed to be 3 dB down from PEP output.

Measured intercept point data and IMD data is shown in Figure 5 for several MMIC amplifiers. Avantek has specified intercept point generally at frequencies lower than those tested by the author. The MSA 0404 has an intercept point typically +26 dBm at 500 MHz. while the MSA 0835 typically runs +28 dBm at 1 GHz. Intercept point can be expected to decrease in a similar fashion to 1 dB gain compression with increasing frequency. Correllation between measured and calculated IMD levels is not as close as desired but may be due in part to test equipment inaccuracies. Another possibility is the actual shape of the third order response curve. The formulas assume that the response is linear. Since the first order response compresses , the third order response should also. This will tend to decrease the IMD or putting it another way, keep it from getting as bad as the curves and calculations will predict.

The resultant I.P. and IMD for a cascaded series of amplifiers (figure 6) can be calculated with the aid of the following formula.

$$\frac{1}{I.P.} = \frac{1}{I.P._3} + \frac{1}{I.P._2 * G_3} + \frac{1}{I.P._1 * G_2 * G_3}$$

For a 2 stage MSA0404 amplifier running at 1296 MHz,the adjusted I.P. of the amplifier can now be calculated. Assume a 1 dB gain compression point of +13 dBm and an I.P. of +25 dBm for each device. The gain of each device is 6 dB. First convert dBs to ratios and substitute into the formula. Therfore for a 2 stage amplifier

$$\frac{1}{I.P.} = \frac{1}{I.P._2} + \frac{1}{I.P._1 * G_2}$$

$$= \frac{1}{316} + \frac{1}{316 * 4}$$

$$= .003162 + .000791$$

$$= .003953$$

$$I.P. = 252.97$$

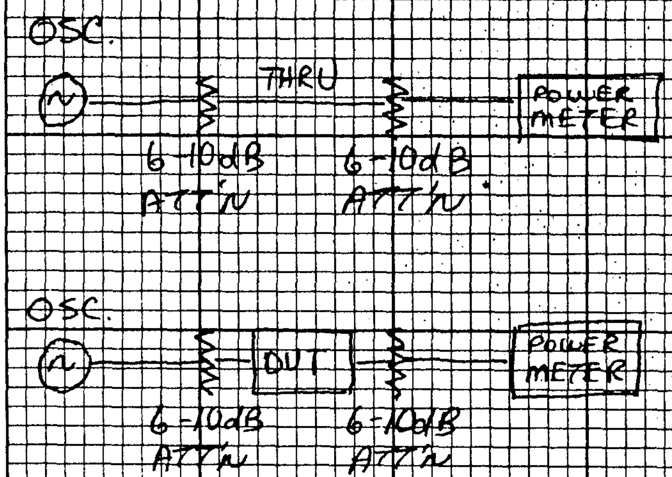
$$I.P. = 24.03 \text{ dBm}$$

Due to each device having only 6 dB gain the intercept point has been degraded 1 dB. If the gain of the output stage had been 10 dB, I.P. would have only been degraded by .41 dB. It's readily apparent that in order to preserve the I.P. of the final stage, greater gain will be required in order to isolate the driver from the final. For the 2 stage amplifier the IMD ratio relative to PEP output at 1 dB gain compression is calculated to be: IMD @ +7 dBm average per tone or +13 dBm PEP

$$IMD = 2(+24-+ 7)$$

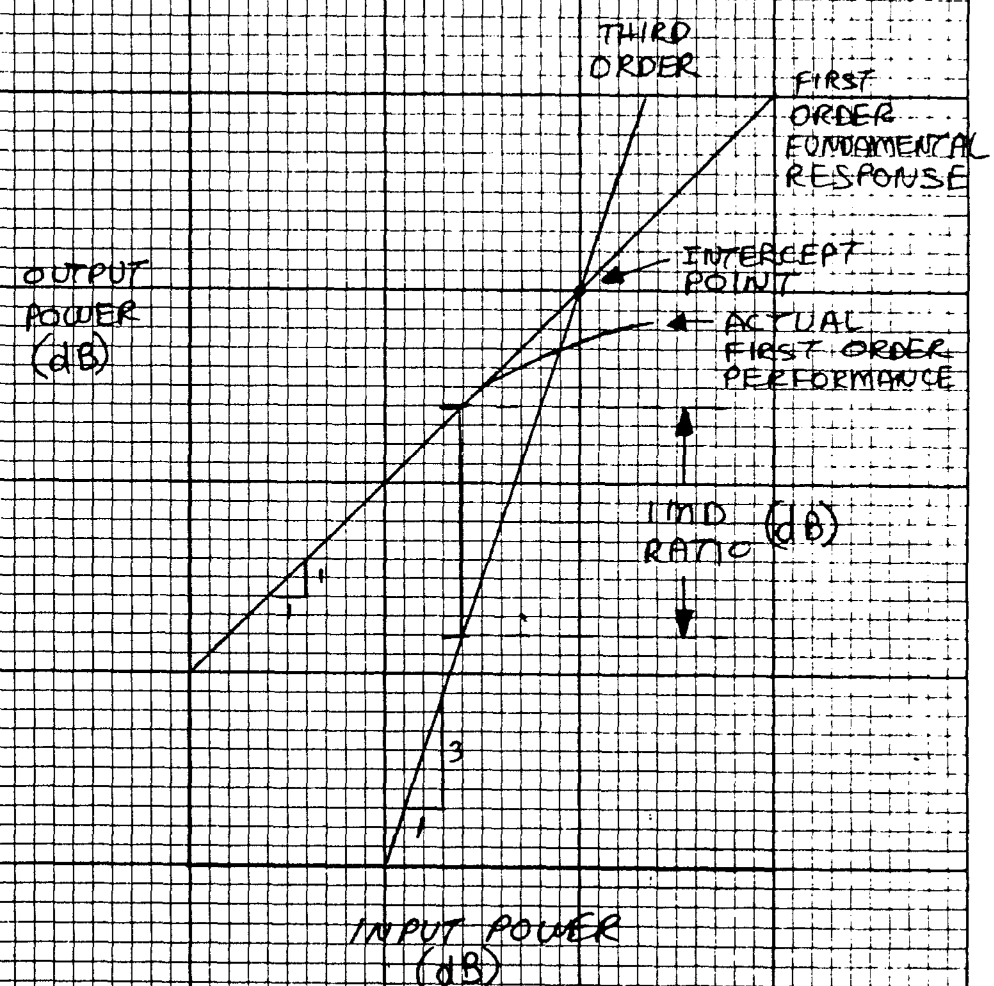
$$= 34 \text{ dB}$$

a degradation of 2 dB over the single MMIC.



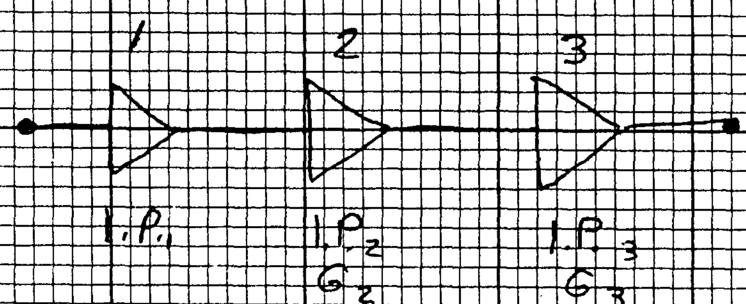
"AVAILABLE POWER" GAIN MEASUREMENT

FIGURE 1



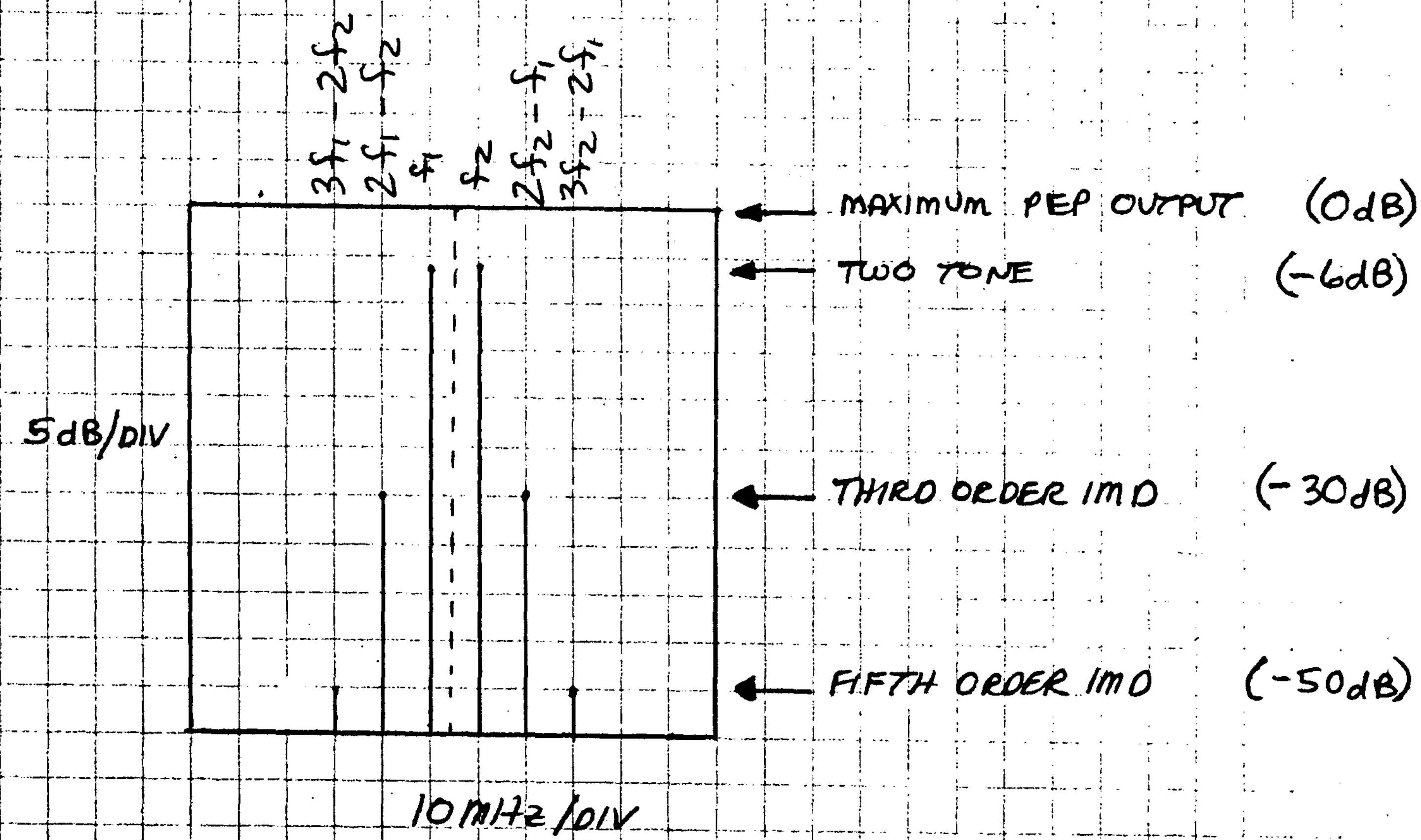
AMPLIFIER IMD PERFORMANCE

FIGURE 3



CASCADED INTERCEPT PERFORMANCE

FIGURE 6



TYPICAL IMD DISPLAY

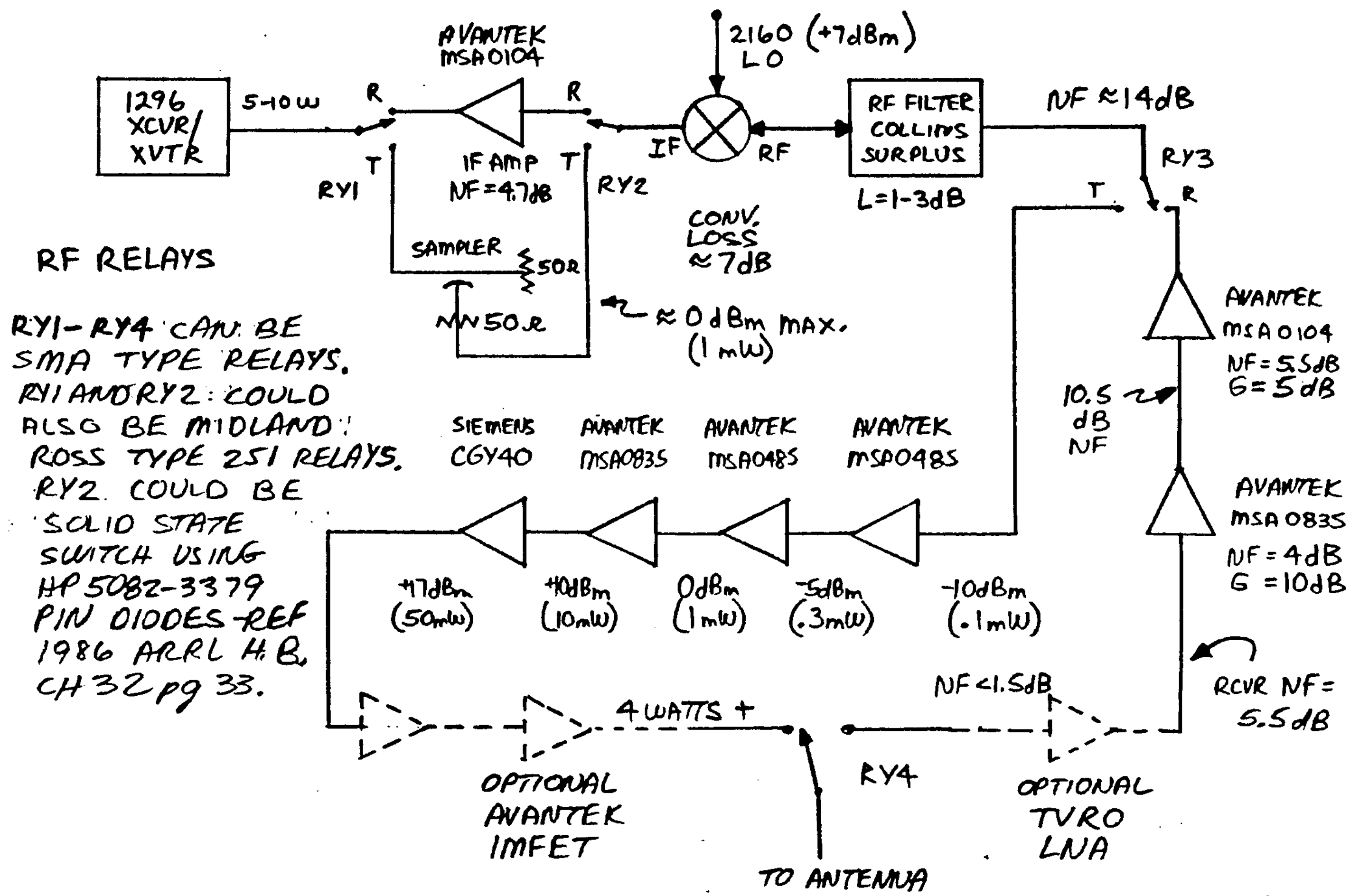
FIGURE 4

DEVICE	1.3 GHz MEASURED I.P. (dBm)	1.3 GHz MEASURED/CALCULATED IMD @ PEP OUTPUT (dBm)	2.3 GHz MEASURED I.P.	2.3 GHz MEASURED/CALCULATED IMD @ PEP OUTPUT (dBm)
MSA-				
0485	+24.5	32/37 @ +12	+18.0	28/24 @ +12
0835	+24.0	28/30 @ +15	+22.0	27/26 @ +15
0404/0404	+24.0	31/36 @ +12	+18.0	28/24 @ +12
7-0404	+26.0	32/30 @ +17 29/28 @ +18	+23.5	27/25 @ +17

3.456 GHz

DEVICE	MEASURED I.P.	MEASURED/CALCULATED IMD @ PEP OUTPUT
0485	+17 dBm	28/22 @ +12
0835	+18 dBm	29/24 @ +12

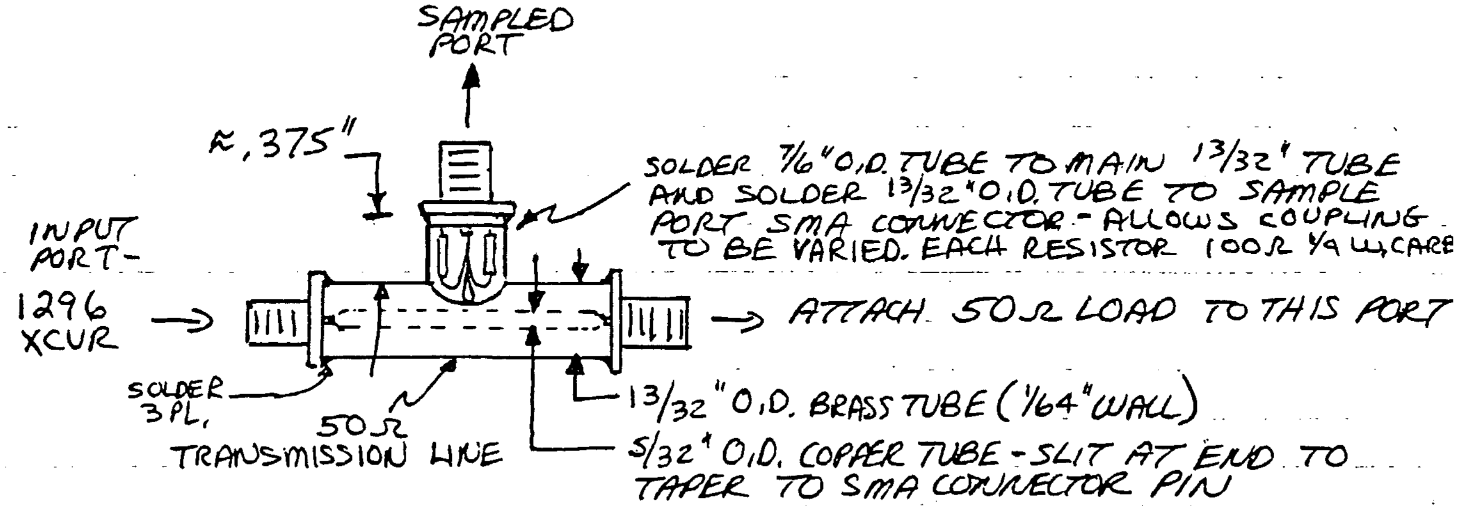
FIGURE 5



3456 MHz TRANSVERTER

WB5LUA
6-4-86

1296 MHz. SAMPLER



- VSWR OF SAMPLED PORT IS LESS THAN 1.25:1.
- VSWR OF INPUT PORT DETERMINED PRIMARILY BY VSWR OF 50Ω LOAD ATTACHED TO END OF TRANSMISSION LINE - USE LOAD THAT CAN HANDLE POWER OF 1296 EXCITER.
- USE 4 HOLE GOLD-PLATED SMA CONNECTORS AT ALL PORTS
- LENGTH OF MAIN TRANSMISSION LINE NOT CRITICAL
- LENGTH OF TRANSMISSION LINE IN SAMPLED PORT LEG SHOULD BE MADE VARIABLE BY USE OF A 13/32" O.D. TUBE SLIDING INTO A 7/16" O.D. TUBE TO OBTAIN REQUIRED POWER (i.e. 0dBm or 1mW). COUPLING LOOP CAN BE ADDED TO RESISTOR LEADS TO ENHANCE COUPLING TO MAIN TRANSMISSION LINE. 2 100Ω RESISTORS ARE WIRED IN PARALLEL AND ARE CONTAINED INSIDE TUBING.

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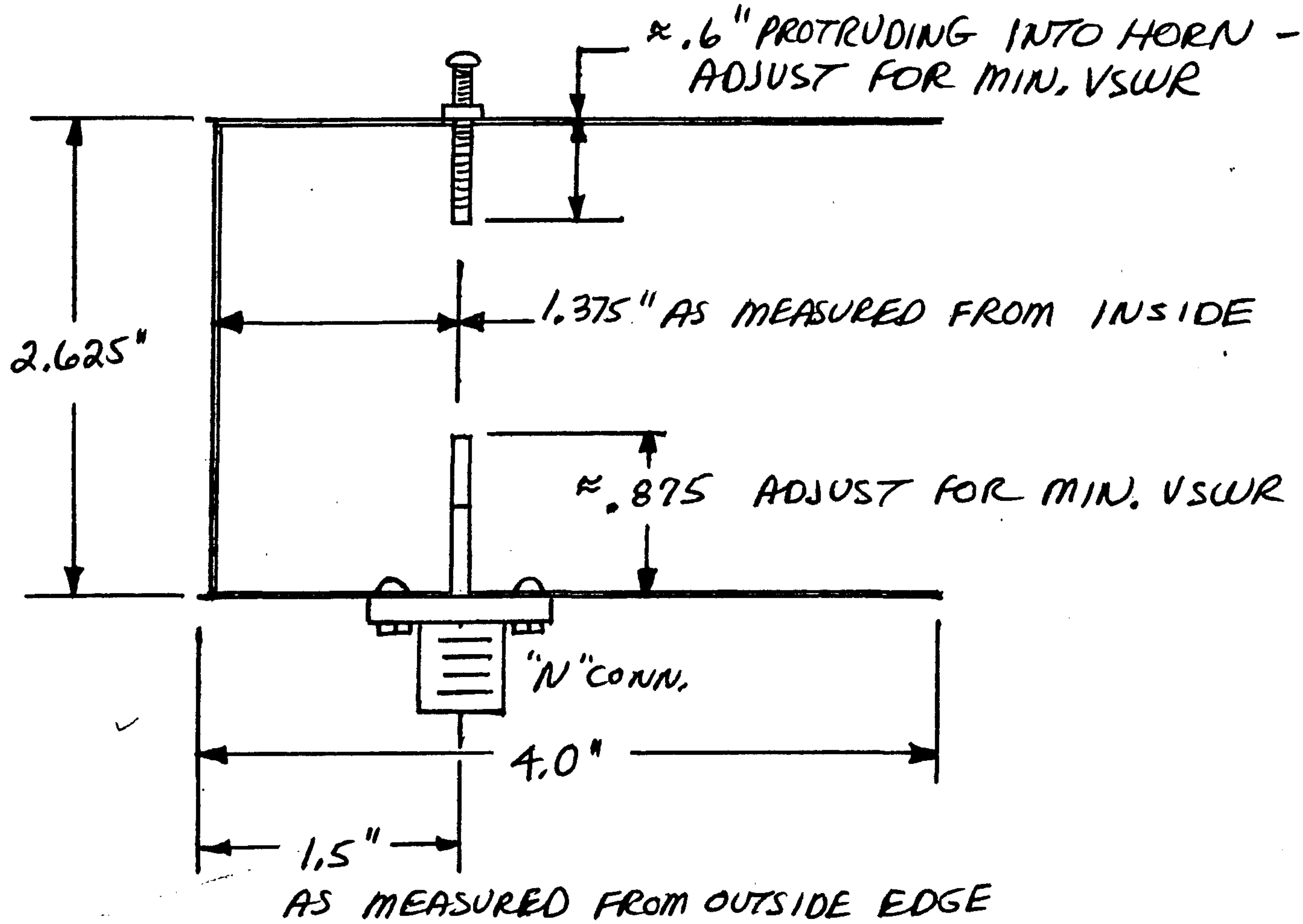
7-14-86

3456 MHz FEEDHORN

OPTIMUM FOR PARABOLIC REFLECTORS WITH F/D RATIO BETWEEN .375 AND .5



MATERIAL:

1. SOUP CAN - RETAIN 1 END OF CAN AS BACK REFLECTOR
2. MONOPOLE MADE FROM HOBBY BRASS MATERIAL ≈ 1/8" O.D. - USE ADJACENT SIZES SO THEY CAN BE TELESCOPED FOR ADJUSTMENT.
3. TUNING SCREW — 8-32 BRASS WITH BRASS NUT SOLDERED TO CAN

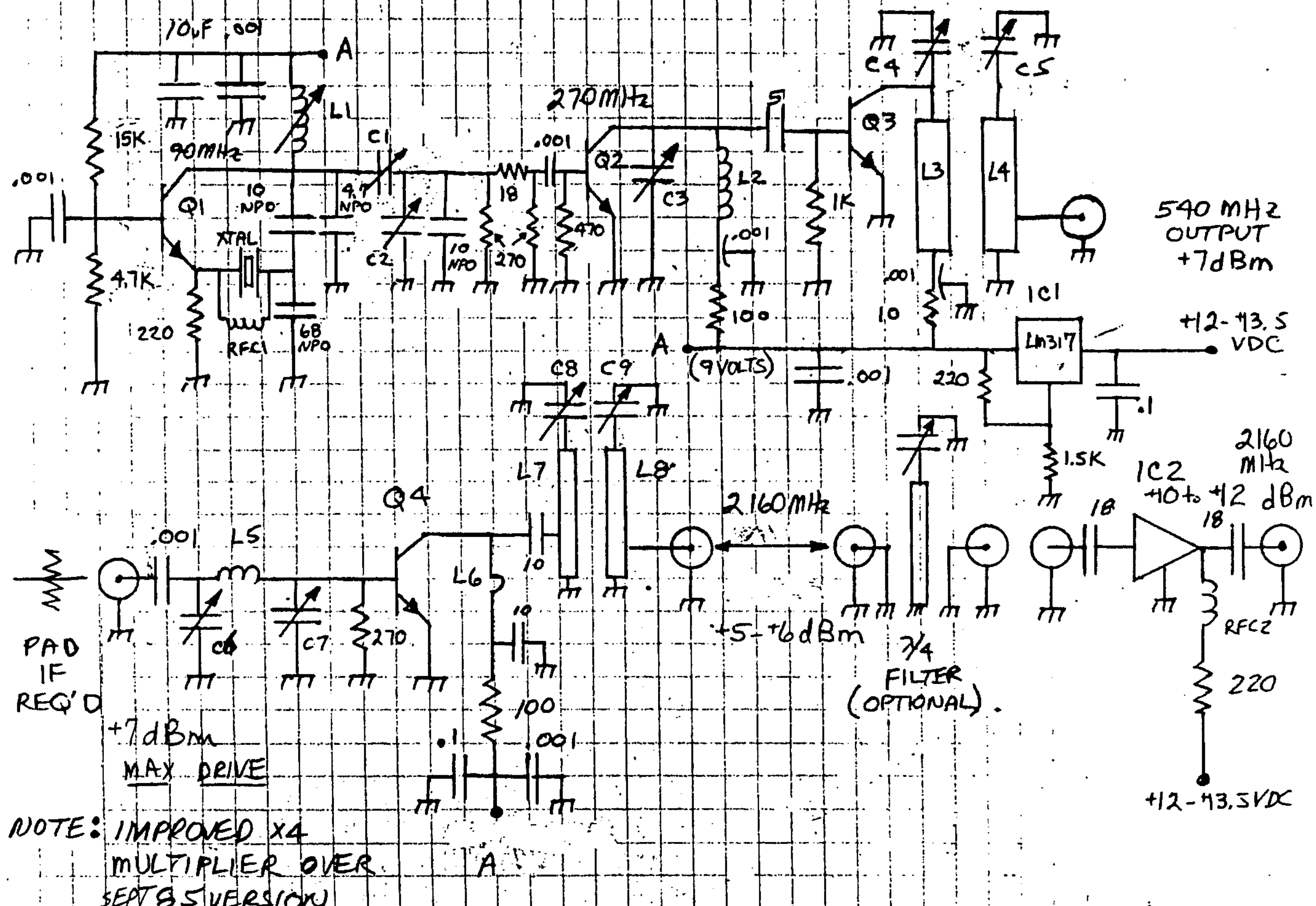
WB5LUA
6-4-86

2160 MHz LOCAL OSCILLATOR

THE CIRCUIT PRESENTED HERE IS AN UPDATED VERSION OF THE ONE CONTAINED IN THE ESTES PARK MICROWAVE CONFERENCE PROCEEDINGS DATED SEPT. 1985. THE TIMES 4 MULTIPLIER FROM 540 to 2160 MHz IS AN IMPROVED HIGHER EFFICIENCY DESIGN. THE 90 MHz OSCILLATOR CIRCUIT WAS ALSO MODIFIED TO IMPROVE TEMPERATURE AND LOAD STABILITY. FOR PRECISE FREQUENCY STABILITY A CRYSTAL OVEN IS STILL SUGGESTED

OPERATING PARAMETERS

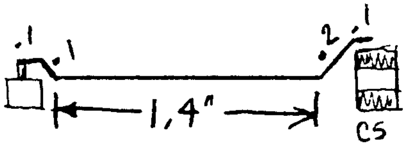
POUTPUT	+12dBm
HARMONICS	> -28dBc w/o λ/4 FILTER > -50dBc w/ λ/4 FILTER
Q2 I_c	5mA
Q3 I_c	25mA
Q4 I_c	25-28 mA



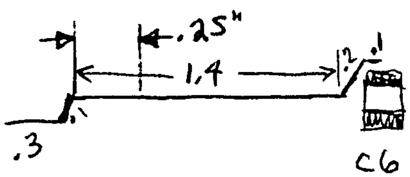
2160 MHz LOCAL OSCILLATOR
FIGURE 2

REVISION B
WB5LUA
7-30-86

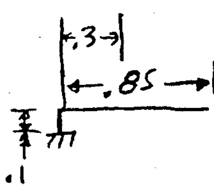
L1	4T #24GA .25" ID COILFORM (W.H.SLUG)
L2	3T #24GA. .125" I.D. S.W.D.
L3	.5 INCH WIDE MICROSTRIPLINE .125 INCH ABOVE GROUNDPLANE - SEE VIEW A
L4	.5 INCH WIDE MICROSTRIPLINE .125 INCH ABOVE GROUND PLANE - SEE VIEW B (L3, L4: SPACE .1" edge to edge; Tap .25" From Ground edge)
L5	2 TURNS #24GA .125" I.D. SWD
L6	1 TURN .125" I.D. MADE FROM LEAD OF 1/4 WATT 100 OHM RESISTOR
L7	.25 INCH WIDE MICROSTRIPLINE .85 INCH LONG AND .1 INCH ABOVE GROUNDPLANE. TAP CAPACITOR .3 INCH UP FROM GROUND - SEE VIEW C
L8	SAME AS L7, TAP OUTPUT .15 INCH UP FROM GROUND - SEE VIEW D. SPACE L7 AND L8 .1 INCH APART EDGE TO EDGE
IC1	LM317 VOLTAGE REGULATOR
IC2	MSA 0404 AVANTEK MMIC
C1-C5	.8-16pf PISTON TRIMMER
XTAL	90 MHz OVERTONE CRYSTAL
RFC1	.38 uH MINIATURE RF CHOKE
Q1, Q2	2N3563, 2N918
Q3	2N3866
Q4	HXTR 3101 (Hewlett Packard)
C6, C7	1.8-6.0 pf MINIATURE CERAMIC VARIABLE CAPACITOR (MOUSER ELECT. P/N 24AA070
C8, C9	.3-3.0 pf MINIATURE PISTON TRIMMER
RFC2	6 TURNS #28 GA .125 INCH ID SWD



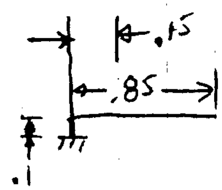
VIEW A



VIEW B



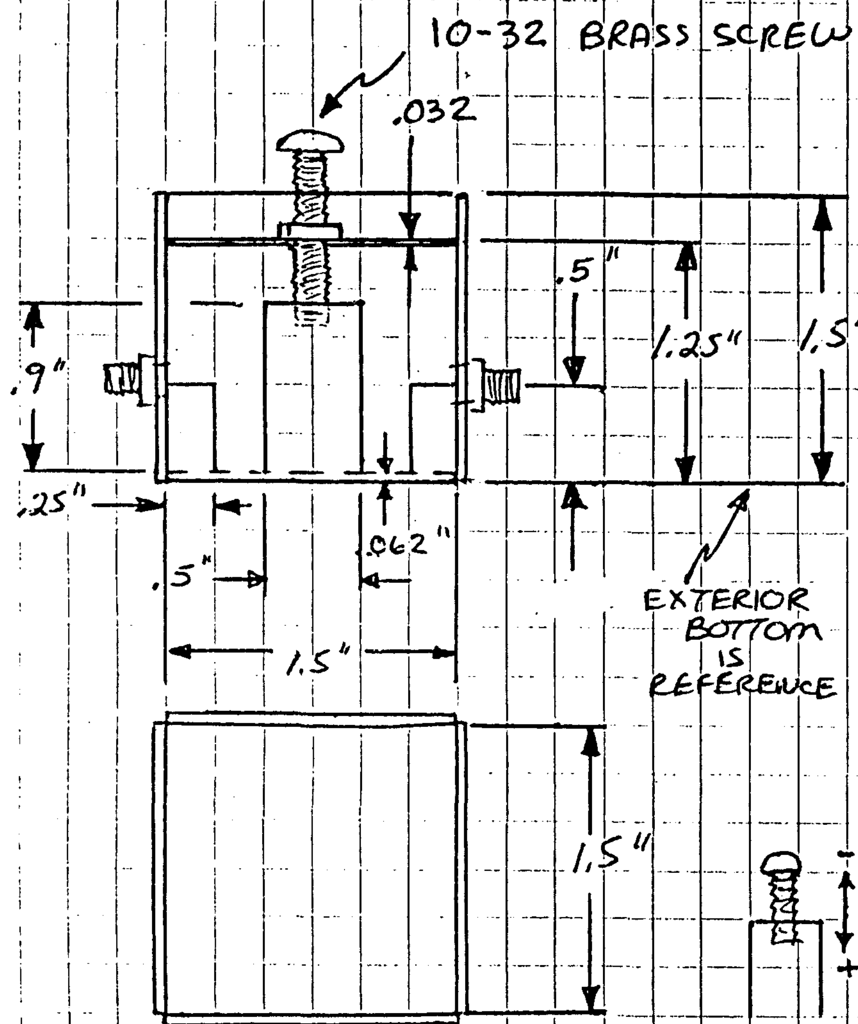
VIEW C



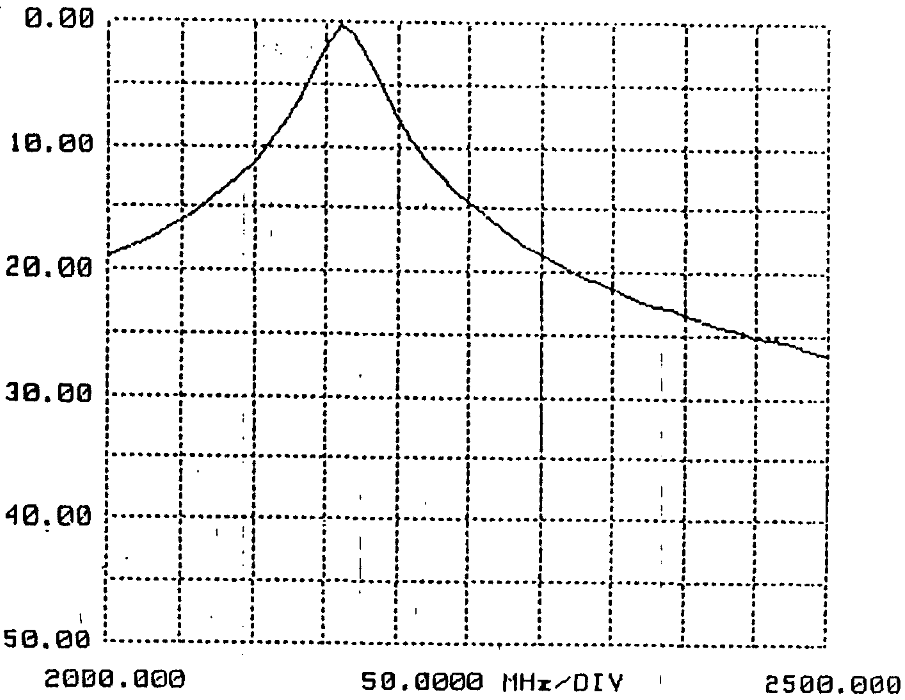
VIEW D

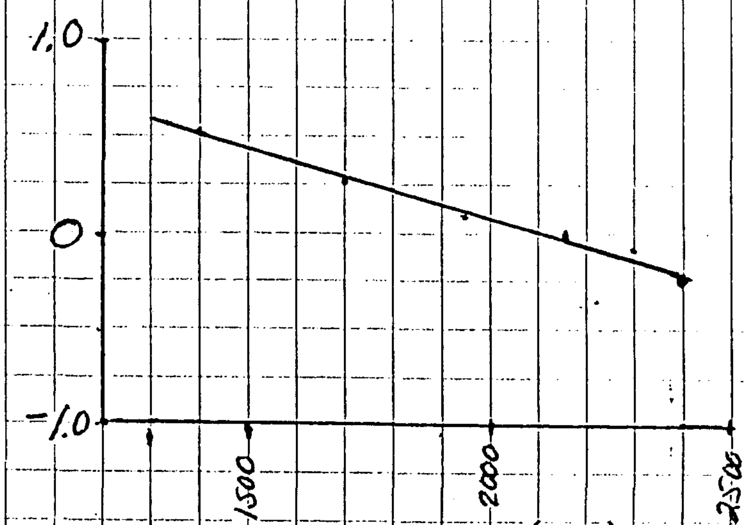
2160 LO
PARTS LIST

REVISION A
WB5LUA
7-30-86



2160 mHz CAVITY FILTER
FIGURE 3

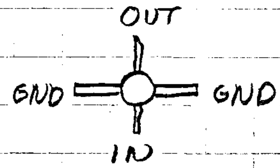


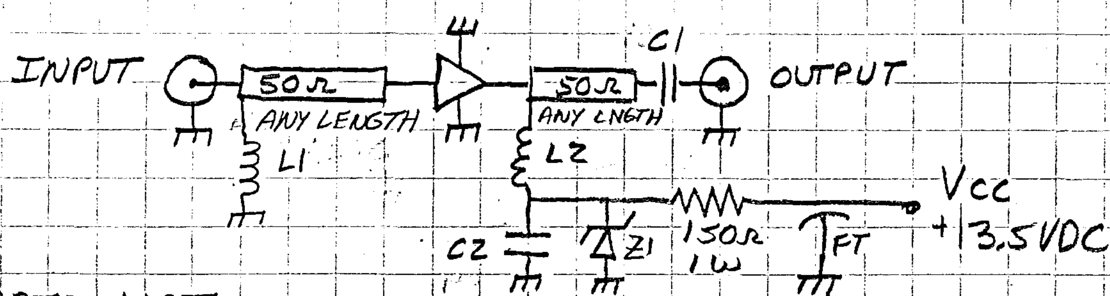


PENETRATION VS. FREQ.

CGY-40 GaAs MMIC AMPLIFIER

FEATURES
- COST $16.30 ea.
- Pout +17 – +18 dBm 1dB C.P. @ 2304/3456 MHz
  +19.5 dBm SATURATED @ 2304/3456 MHz
- MODERATE GAIN – see table below
- NO TUNING
- G-10 DIELECTRIC MATERIAL
- UNCONDITIONALLY STABLE FROM VHF UP
- NOISE FIGURE UNDER 4dB





PARTS LIST

L1, L2	5 TURNS .075" I.D. S.W.D. #26 GA.
C1	100 pf CHIP CAP
C2	1000pf CHIP CAP
FT	1000pf FEEDTHRU
Z1	1N752 5.6V ZENER – FOR TRANSIENT PROTECTION

OPERATING PARAMETERS

Vmmic = 4.5V
Immic = 60 mA

NEG. BIAS CAN BE APPLIED TO INPUT OF MMIC VIA L1 FOR AGC.

GAIN VS. FREQUENCY

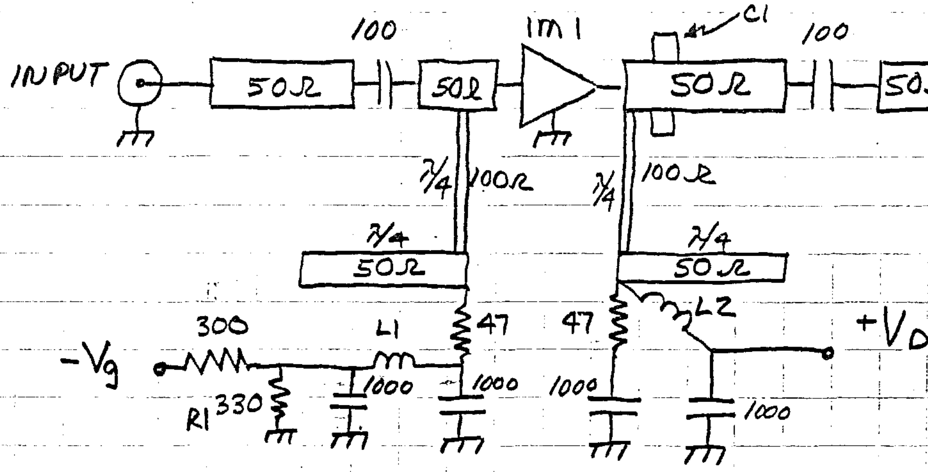
FREQ.	GAIN
902 MHz	9.4 dB
1296 MHz	9.3 dB
2304 MHz	7.5 dB
3456 MHz	5.1 dB
4000 MHz	3.7 dB

DEVICE AVAILABLE THROUGH:
MICROWAVE SEMICONDUCTOR CORPORATION
201-469-3311

A. J. WARD
8-17-86

3456 MHz IMFET AMPLIFIER

Extra



$V_D = 9\,V$

$I_D = 1.3\,A$

$P_{IN} = 11.7\,W$

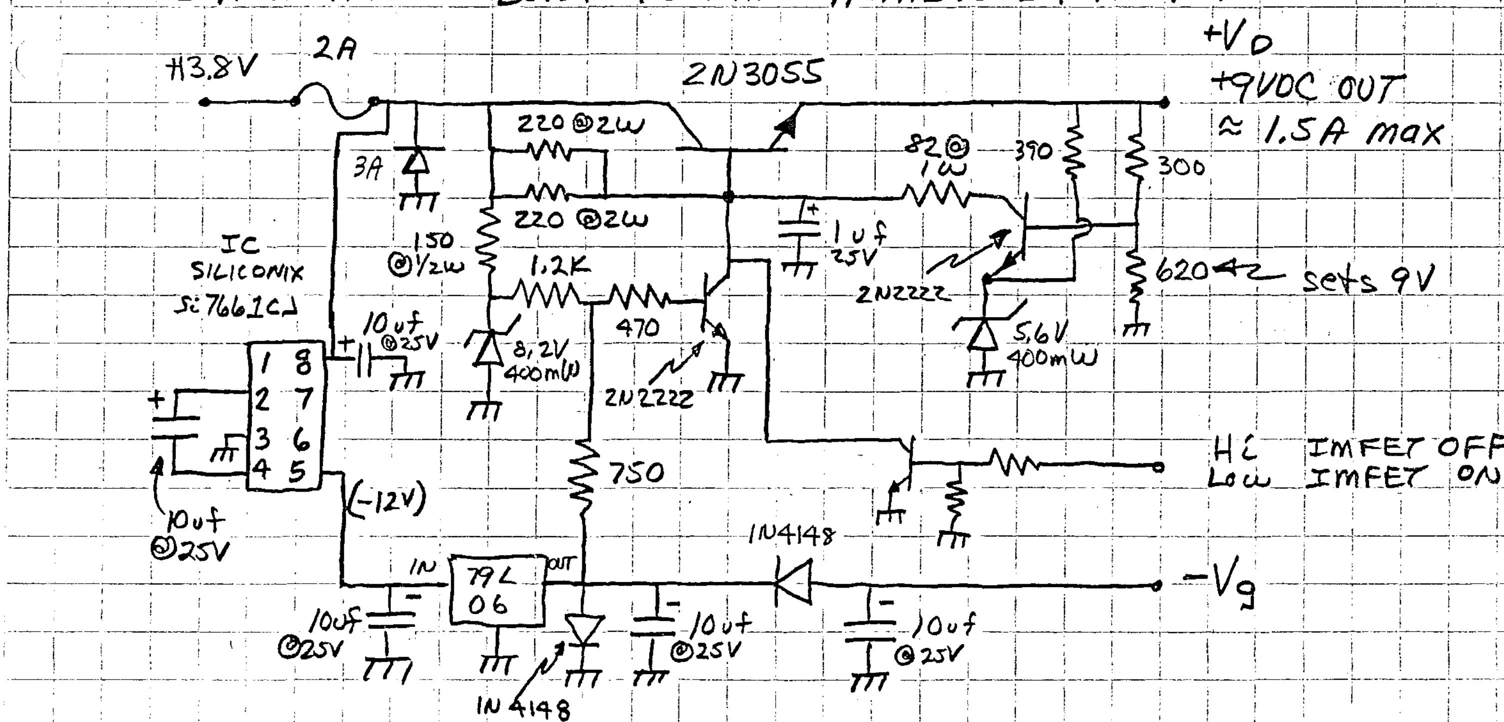
$P_O > 4\,W$ @ 1dB C.P.
5.4W MAX

% ≅ 40-43%

G = 11 dB @ 1dB C.P.

IM1 AVANTEK IM2935-3 IMFET
L1, L2 3 TURNS #28G, 1/8" I.D. SWD
C1 2 CAPACITIVE STUBS ≈ .1 x .1" SQ ≈ .15" FROM IM1 - ADJ. FOR POUTPUT
ALL RESISTORS ARE 1/4 WATT CARBON
ALL CHIP CAPACITORS ARE .050" x .050"

- 2 AMPLIFIERS BUILT TO DATE ACHIEVE EQUAL PERFORMANCE



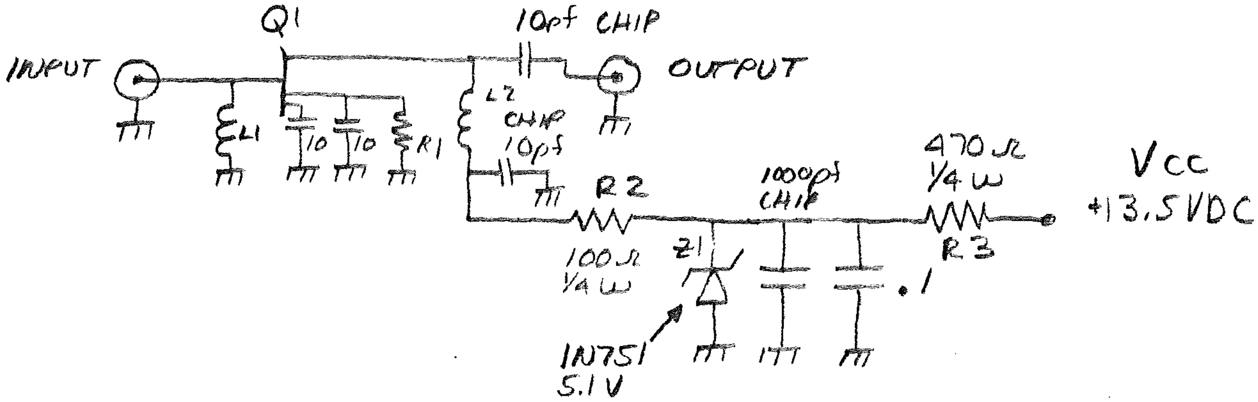
- Sequencing Power Supply built by WA5TNY
- MODIFIED FUJITSU P/S TO ACCOMODATE AVAILABLE DEVICES
- P/S WILL PROPERLY SEQUENCE $-V_g$ ON BEFORE $+V_D$ ON
- R1 CAN BE ADJUSTED TO SET DRAIN IDLING CURRENT TO 900 mA w/NO RF DRIVE

WB5LUA
WA5TNY
8-27-86

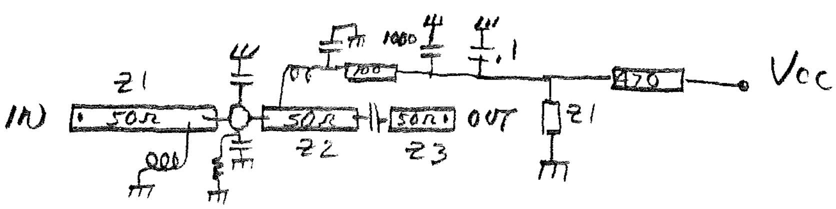
Extra

3456 mHz GAAs FET PREAMPLIFIER

FEATURES
- LOW COST - DEVICE COST $10.80
- NO TUNING
- G-10 DIELECTRIC MATERIAL
- 1.2dB NF / 10 dB GAIN



L1 3 TURNS .075" I.D. S.W.D. #26GA
L2 2 TURNS .075" I.D. S.W.D. #26GA
Q1 AVANTEK ATF10135 GAAsFET
R1 3 - 100Ω 1/4 W IN PARALLEL - ADJUST VALUE FOR 15-20 mA



Z1, Z2, Z3 50Ω MICROSTRIPLINE - .1" WIDE ON .062" G10 DIELECTRIC MAKE LENGTH AS SHORT AS POSSIBLE BUT NOT CRITICAL

POWER OUTPUT PERFORMANCE

I_D	V_{DS}	1dB C.P.	SAT. P_o	COMMENT
17mA	3.5V	+10dBm	+12dBm	LOW NOISE BIAS PT.
43mA	3.5V	+13dBm	+15dBm	ADJ. R3
63mA	4.0V	+16dBm	+18dBm	ADJ. R3 and R2

A.J. WARD
6-14-86

"432/5760 TRANSCEIVER"

BY

TONY BICKEL, K5PJR

432/5760 TRANSCEIVER*

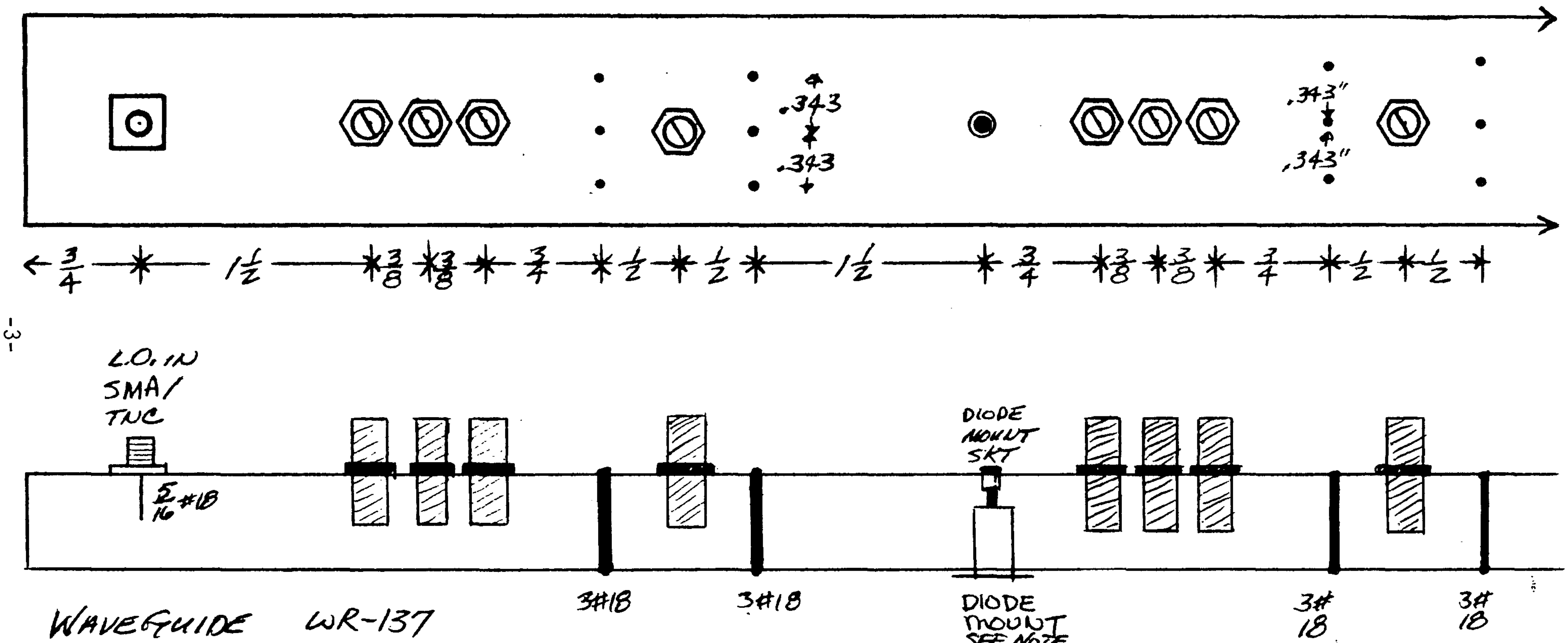
Tony Bickel, K5PJR

This simple 5760 transceiver design will deliver surprising performance, an approximate output of 1 mw SSB, CW, etc., and a noise figure of about 7.5 to 8 db, more than adequate to work any line of sight path as well as a great many scatter paths. It is an excellent base to build from.

Construction is very simple, with all components mounted on the center line with the exception of the filter pins. The filter pins are shown to be symetrical about the center line with the outer two pins offset by .343 inches. This dimension is required to be held as accurate as possible. The remaining dimensions should be held to within a 1/16 inch.

Tuning of the transceiver is also extremely easy. With L.O. source on, tune L.O. filter to maximum mixer current. Reduce L.O. drive to 5 ma. mixer current. "Tweek" L.O. matching screws. These may or may not have any effect, or perhaps only one will have any effect - it depends on many things - output impedence of source, cable, etc. If an attenuator pad is required, install directly on the SMA/TNC fitting.

Tune the signal filter to maximum with either a received signal or from a weak signal source. Tune the diode mount to resonance by peaking the receive signal on 432 MHz. Tune the receive tuning screws on receive only. Some loss in transmit power may be noticed. During transmission, "drive" the mixer to about 10ma.



WAVEGUIDE WR-137

ALL LARGE SCREWS 1/4x20x1"

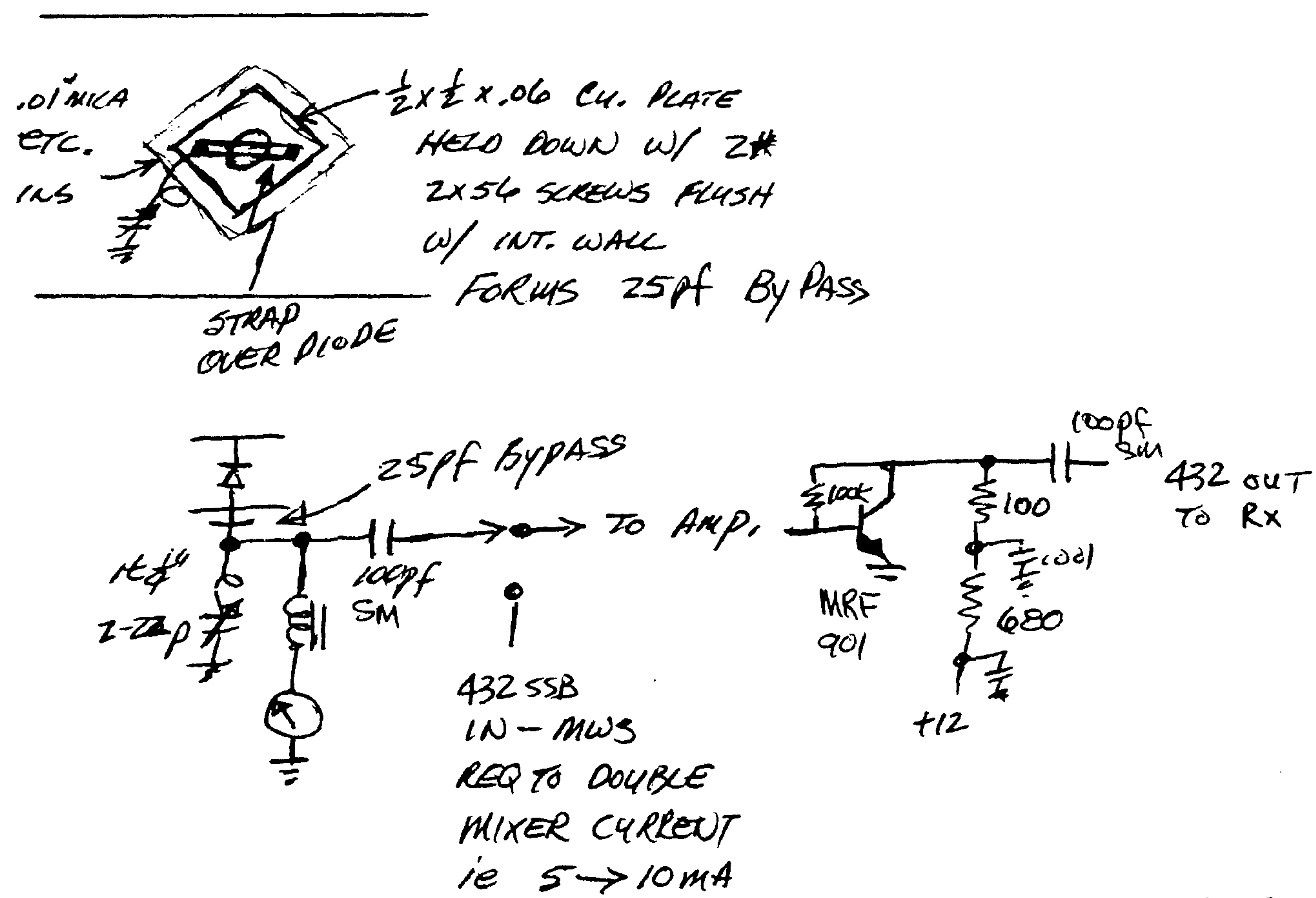
W/ SOLDER NUT & LOCK NUT

K5PJR

432/5760 TRANSVERTER

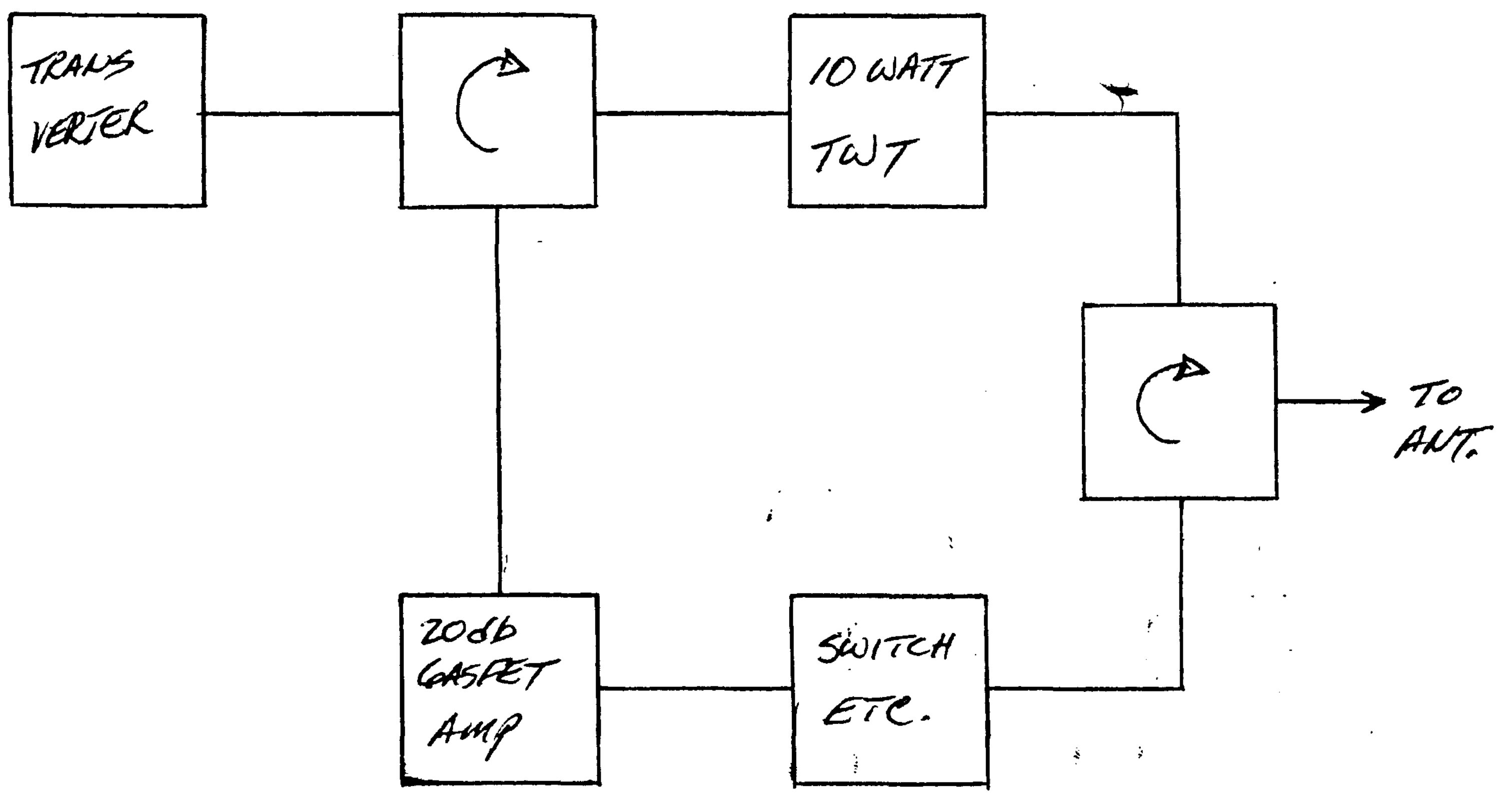
REV #1

FIG.# 1



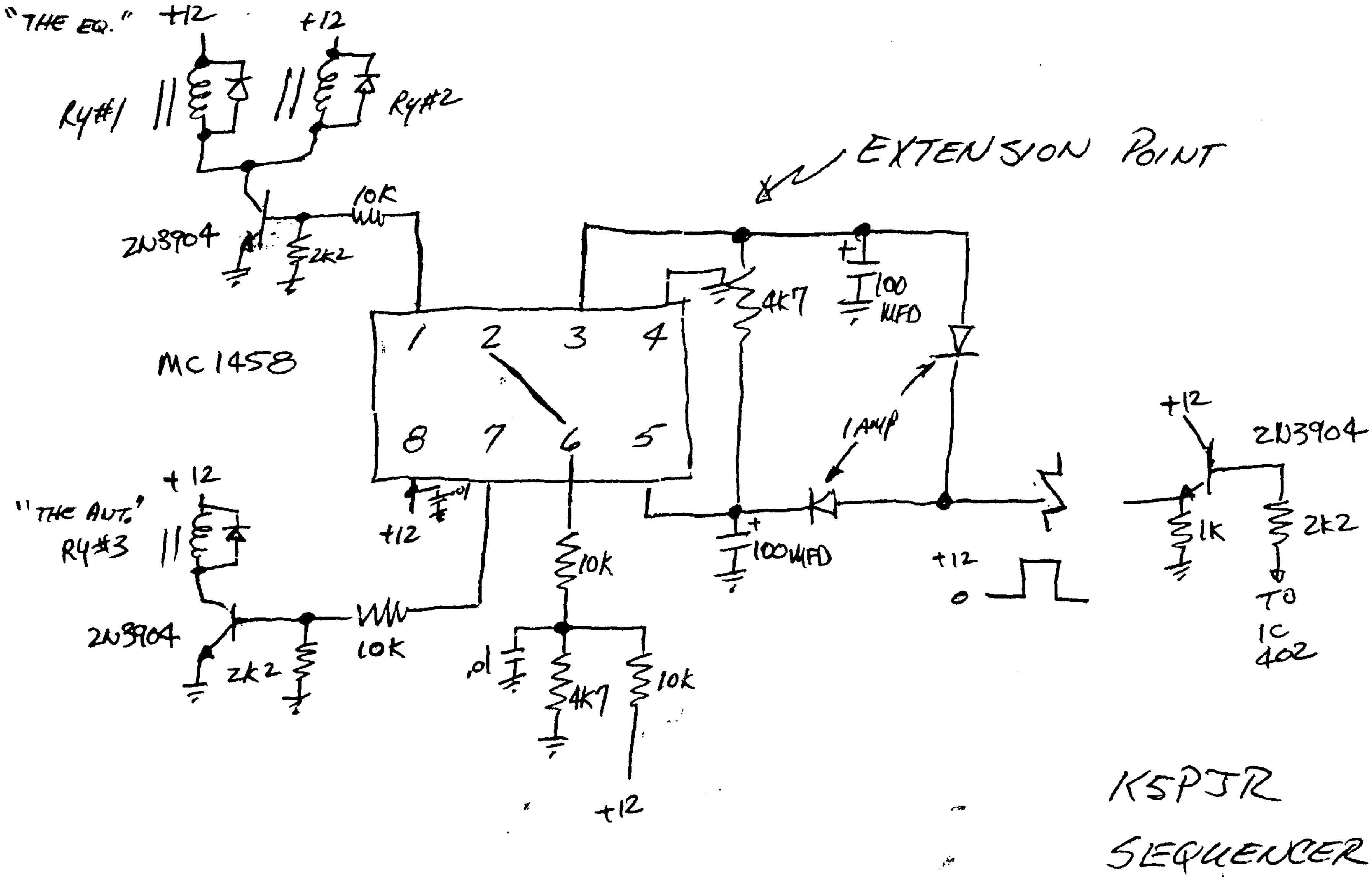
K5PJR
432/5760 TRANSVERTER
DIODE MOUNT &
POST AMP.

FIG. #2



K5PJR
5760 STATION BLOCK

FIG. #3



"THE EQ."
+12
+12
RY#1
RY#2
EXTENSION POINT
2N3904
10K
2K2
4K7
100 MFD
MC1458
1 AMP
+12
2N3904
"THE AUT."
RY#3
.01
10K
100MFD
1K
2K2
TO IC 402
0
4K7
K5PJR
SEQUENCER

FIG#5

"A FIVE-BAND MICROWAVE TRANSVERTER"

BY

H. PAUL SHUCH, N6TX

A FIVE-BAND MICROWAVE TRANSVERTER

by H. Paul Shuch, N6TX

Presented to MICROWAVE UPDATE ´86, Estes Park CO
30 August 1986

Regional UHF conferences serve many important functions. For some, the purpose of such gatherings as the West Coast, Central States and Eastern VHF/UHF Conferences, as well as Microwave Update, is primarily social - an opportunity to renew friendships, meet the old hands and new blood of our avocation, and perhaps to put a face and a handshake to that familiar call which has in the past been merely a fleeting ping or scintillating echo. Others find at conferences an opportunity for technology transfer. At forums such as this one, and in Proceedings such as these, we share our latest innovation with our brethren, glean inspiration from our colleague´s accomplishments, and in so doing, advance the communications art.

For me, the UHF conference represents an opportunity for renewal, a time for recharging the batteries. I never fail to leave such gatherings with newfound enthusiasm, a sense of purpose, and the resolve to go home and accomplish something great. (Whether the ensuing activity lives up to its promise is another issue altogether.) Occasionally, the creative urges are so compelling that they won´t even await my return to six-land. The idea presented herein represents one such project.

One of the truly outstanding technical presentations of this year´s Central States VHF Conference was that by Rick Fogle, WA5TNY, on the subject of 3456 MHz equipment. Though several of the ideas presented by Rick, such as the use of surplus TVRO hardware, were familiar concepts to many of us, his unique conversion scheme struck me as particularly exciting. His mixing of the 2160 MHz LO from an existing 2304 MHz transverter with a 1296 MHz IF, to transmit and receive on 3456 MHz, promised to make my contesting and mountaintopping all the more enjoyable by significantly reducing the weight and volume of hardware needed to achieve multi-band microwave capability. I left St. Louis vowing to repackage my 1296 and 2304 stations into a single, tri-band transverter along the lines Rick had demonstrated.

Have you ever had an idea grab hold of you and shake you so hard that you can´t ignore it? Then you know what it means to have your batteries recharged. In a motel room in Arkansas on the way home from Central States, I awoke in the middle of the night with visions of block diagrams displacing the sugarplums. Repose abandoned, I clutched the ever-present quill and quadrille pad (Don´t leave home without it!) and began scribbling. The results, though perhaps not all that original, were sufficiently satisfying to allow me a good night´s sleep. They are presented in Figure 1, the block diagram for a multiple-conversion transverter covering 1296, 2304, 3456, 5760 and 10368 MHz, all with a 144 MHz IF, using only two Local Oscillators.

This is a "bare bones" transverter for each band. Heterodyne conversion for transmit and receive is accomplished in passive diode mixers (single conversion for 1296 and 2304, double conversion for the higher bands), and neither preamps nor power amps are included in my mountain-topping box. This limits performance severely, with transmit powers in the hundreds of microwatts, and noise figures of 10 to 20 dB. But it also removes from the transverter assembly any requirement for T-R switching. In fact, all the switches shown in the block diagram are involved with changing bands. Of course, you'll probably want to use preamps and power amps for each band, which will require two SPDT coax relays per band (one on the transverter's RF port, the other on the antenna). But that's a topic for another Conference.

Since the transverter uses bilateral mixers for each band (that is, the same mixer for both transmit and receive conversion), T-R switching is unnecessary in the IF port if a two-meter transceiver is used. However, the desired IF injection for transmit service is on the order of 1 to 5 mW, so it is necessary to modify the two-meter rig for very QRP operation. One approach is to install a switch which removes the collector operating potential from the final transistor, and perhaps the driver stage as well. CAUTION: do NOT forget to put this switch in the Low Power position before transmitting! I won't tell you how many mixer diodes I've blown out because of my own carelessness.

The following Sections describe the operation and implementation of the transverter, band by band.

1296 MHz:

The 23 cm transverter section employs a conventional single-conversion scheme with a 2 meter IF. A simple PIN diode switch connects the two meter rig alternately to the 23 cm mixer's IF port, or that of the 13 cm mixer (to be discussed below). LO1 produces 10 to 20 mW at 1152 MHz. I use a 96 MHz overtone crystal oscillator and three MRF-901 multipliers (x2, x2, x3), as described in Ham Radio for December 1979. WA9HUV's synthesizer design from the July and August 1986 issues of Ham Radio would also work quite well. The Wilkenson power splitter shown after the LO in the block diagram permits the same LO chain to be multiplied up for the higher bands (more on this later).

For my 23 cm mixer I use a single-balanced rat-race design etched on fiberglass-epoxy PC board (see Ham Radio for July 1977). Commercial double-balanced mixers in DIP packages are also available at reasonable cost, and work fine, except you can't easily replace their blown diodes (don't laugh - it WILL happen to you some day, probably in the middle of a contest or great band opening!) Not shown in the block diagram, but important, is the image filter in the RF port. I use the 3-pole microstrip design from August 1978 Ham Radio. Cavities, troughs, or interdigital filters also work great.

The band switch in the antenna port is one of WB5LUA's PIN diode TR switches, described in the Proceedings of the 1985 Central States VHF Conference (and, hopefully, in the upcoming ARRL Microwave Handbook as well). With position "A" selected (for Band "A", or 1296 MHz), the transverter is good for about -3 dBm out, and about a 10 dB noise figure. Obviously, preamps and power amps will improve the system performance considerably.

2304 MHz:

The 13 cm transverter section is almost identical to the 23 cm portion just described. For LO2 I use a 1080 MHz board (identical to my 1152 LO chain, but with a 90 MHz crystal) driving a bipolar transistor doubler, with a good filter on its output. WB5LUA's cavity filter, described in the 1986 Central States Proceedings, is perfect. The Wilkenson splitter makes half the LO injection available to the 3456 MHz mixer (see below). In lieu of the oscillator-multiplier approach, the WA9HUV synthesizer mentioned above could also be easily built up for 1080 MHz.

Commercial DIP double balanced mixers are a little more expensive here than at 1296, so I use a scaled down version of my rat-race single balanced design, also etched on glass-epoxy. Not shown, but again important, is an image filter in the mixer's RF port. The same WB5LUA filter used in the LO can be easily tuned up to 2304 MHz and used here. The only thing unconventional in the 13 cm section is the single pole, 3 position switch used to couple the mixer's RF port alternately to the antenna, or the IF ports of the mixers for the two highest bands. I have had good luck modifying WB5LUA's PIN diode switches (like the one used at 1296) for a third pole. Output power and noise figure at 2304, with the naked transverter, are similar to those achieved at 1296 MHz.

3456 MHz:

WA5DBY, WB5LUA, WA5TNY and others have had good success with the conversion scheme mentioned at the beginning of this paper, so who am I to question it? Double-converting from 1296 MHz without any intermediate transmit or receive amplification significantly degrades both noise figure and output power, but it does get me started with a signal on the band. I happened to have a surplus Watkins-Johnson M1G packaged double balanced mixer available, which works great, but at about $200 list, I can't recommend you go out and buy one. Probably a surplus TVRO mixer would be the way to go.

For an image filter in the RF port, I cheat. Running the system barefoot (at all of 50 microwatts out, and over 15 dB noise figure), my antenna is fed with a waveguide horn. The image frequency is (2160 - 1296), or 864 MHz, which is well below the waveguide's cutoff frequency, so why worry about it? The feedhorn is the filter! If you're running amplifiers, you're going to have to filter the mixer's RF port, so use two coax-to-waveguide adapters back to back for the same effect.

5760 MHz:

The IF for the 5 cm band is 2304 MHz, so this transverter, like the one for 3456 MHz, is double conversion. The three position PIN diode switch described previously couples 2304 MHz to the IF port of the 5760 mixer. For this band I used another surplus Watkins-Johnson mixer (an M1H), and again image filtering is accomplished in the waveguide antenna feed, with the 1152 MHz image falling far below waveguide cutoff.

Local oscillator injection for 5760 MHz is accomplished by buffering the 1152 MHz LO1 up to 100 mW (an MMIC can be used here, although I used an MRF-961 discrete bipolar amplifier), splitting that signal in a Wilkenson divider (to provide LO injection for the one remaining band, 3 cm), and multiplying by three in a step recovery diode with a low-pass filter at its input, and a bandpass filter on the output. Since the local oscillator frequency is 3456 MHz, the 5 cm weak-signal calling frequency, it's important to disable the 1152 MHz buffer when not operating on 5760 or 10368. This is accomplished by removing the buffer's DC operating potential in the band-switching circuitry.

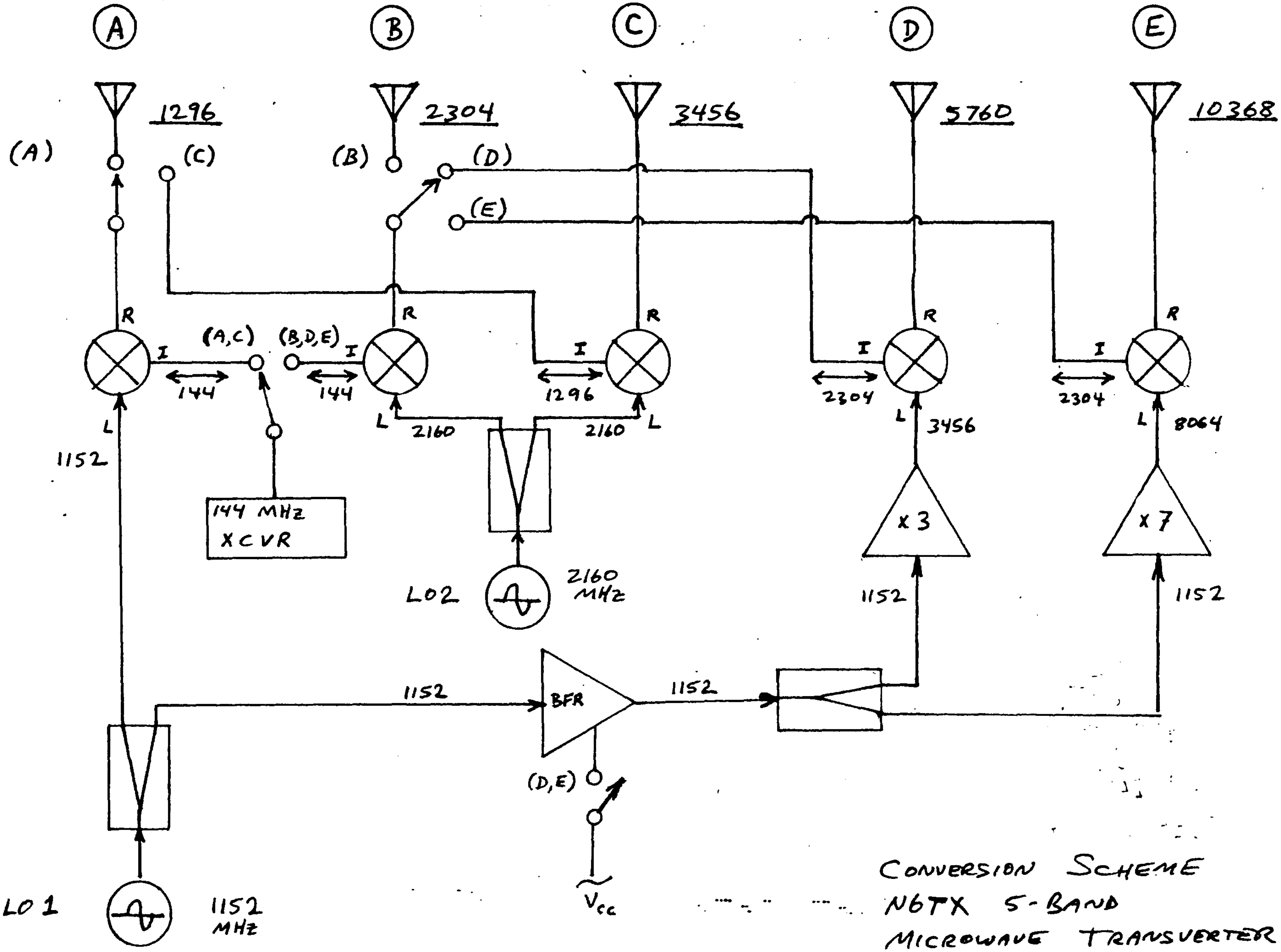
Noise figure and output power of the barefoot 5760 transverter are on a par with the double-conversion 3456 MHz section.

10368 MHz:

This band also employs double conversion with a 2304 MHz IF, and is implemented almost identically to 5760 MHz, except that the LO multiplier is a times seven step recovery diode. The SRD circuit uses a waveguide bandpass filter on the output (the diode is a pretty good comb generator), and was developed by K6UQH, with details pending publication in the ARRL Microwave Handbook. I'm using a waveguide mixer which has poor isolation between the LO and RF ports, so it's necessary to filter the 8064 MHz energy out of the RF port, as well as the 5760 MHz image. An iris-coupled rectangular waveguide bandpass filter is described in the RSGB VHF manual, which should be suitable. Power output at 3 cm is down around 10 microwatts, and noise figure is roughly 20 dB, so GaAs FETs for both transmit and receive are a logical next step.

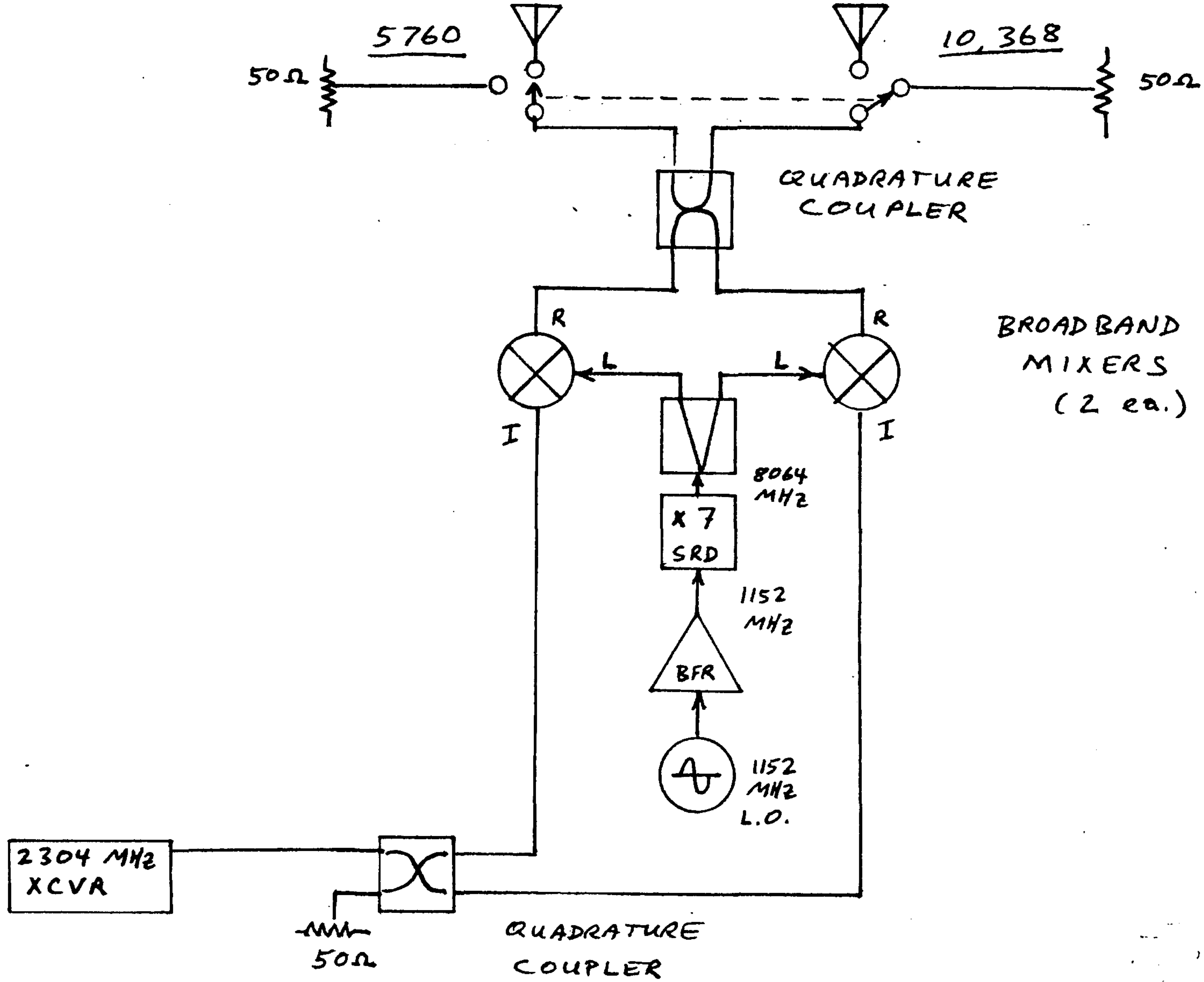
Improving the Higher Bands:

You may have noticed that with a 2304 MHz IF, the image of 10368 MHz falls at 5760 MHz, the C-band weak signal calling frequency. This suggests some interesting possibilities for hardware simplification, as outlined in Figure 2. The idea is to use an image-recovery mixer to generate (and receive) 5760 and 10368 simultaneously, terminating the unused port. I haven't actually tried this yet, but I hope someone attending Microwave Update '86 will take the idea home and make it work. After all, that's why we come to Conferences, isn't it?



CONVERSION SCHEME
N6TX 5-BAND
MICROWAVE TRANSVERTER

– FIGURE 1 –



2-BAND MICROWAVE IMAGE RECOVERY TRANSVERTER – N6TX

— FIGURE 2 —

"MICROWAVE COMMUNICATIONS RECEIVERS"

BY

RICHARD L CAMPBELL, KK7B

MICROWAVE COMMUNICATIONS RECEIVERS

Richard L. Campbell KK7B
Department of Electrical Engineering
Michigan Tech University
Houghton, MI 98831

Amateur receivers for the frequencies above 1000 MHz may take many forms--from very simple diode detectors for test purposes through the average EME station receiver to laboratory receivers using digital signal processing to recover signals 20 dB below those encountered in EME. This talk will cover four topics, each with an example amateur receiver system. The first receiver will be a crystal set capable of receiving signals from an average amateur microwave station at a distance of about 1 mile. The second receiver is part of a simple direct conversion transceiver for line-of-sight paths. Next some aspects of conventional superheterodyne systems will be discussed. Finally, the system currently in use at KK7B for propagation research over obstructed paths (for example--1 mile of dense forest) using digital signal processing will be examined. The practical application of advanced receiving techniques to amateur communications will be discussed.

SIMPLE MICROWAVE COMMUNICATIONS EQUIPMENT
or
WORKING YOUR OWN GRID SQUARE

Rick Campbell KK7B
Merle Cox W7YOZ
Dave Martin KC7NJ

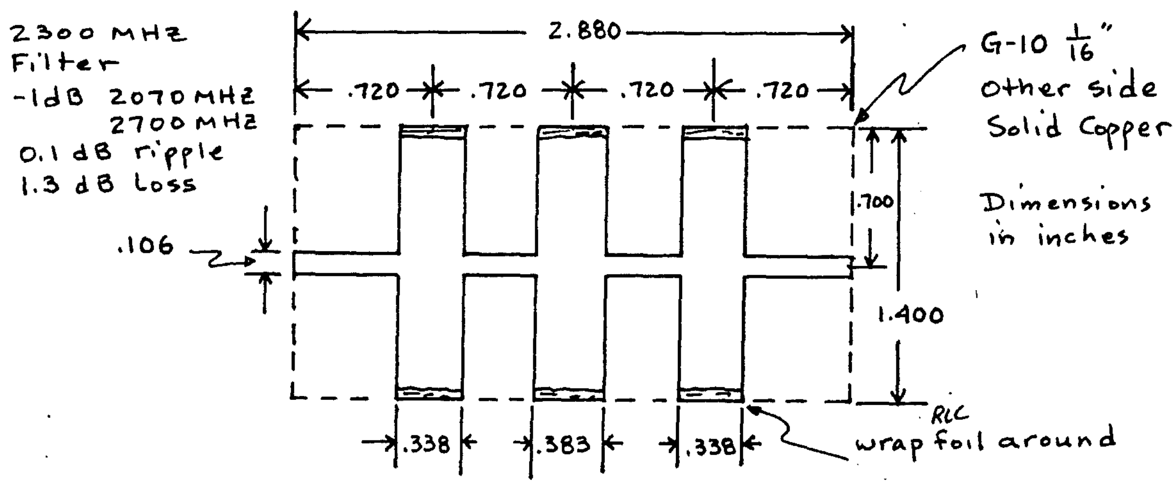
The ARRL defines "capable of real communications" as "able to communicate over at least 1 km" for contest purposes. A typical small 23 cm station, with 10 W output and a 15 dB gain antenna, will generate a field strength of 9 mV/m at 1 km. This is a strong enough signal to be detected using a dipole, diode detector, op-amp audio amplifier, 9v battery and headphones. The same typical small 23 cm station will probably have a noise figure of about 5 dB or less, so a station 1 km away using a dipole will need a transmitter power output of about 500 picowatts (-63 dBm) to be easily heard. A 108 MHZ crystal oscillator with +10 dBm output driving a schottky diode X12 multiplier will produce about -20 dBm at 1296. It is thus possible to engage in "real communications" with a modest 23 cm station using very simple equipment--a crystal oscillator and diode multiplier for transmitting and a diode detector and audio amplifier for receiving.

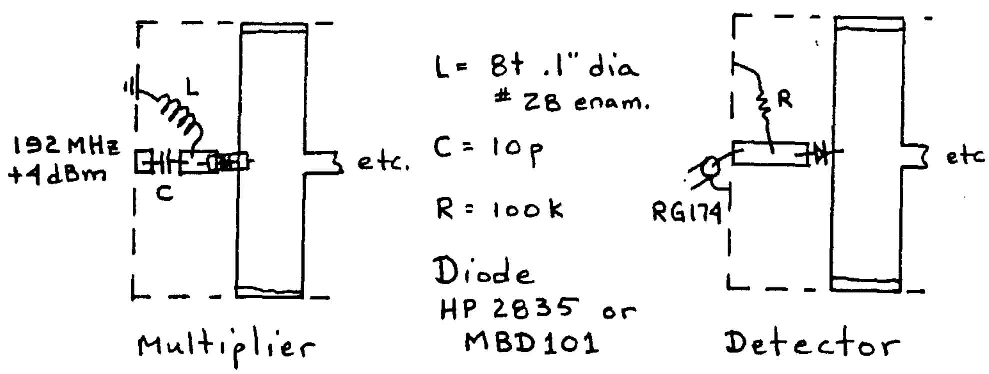
The oscillator--diode multiplier transmitter and diode detector receiver are also useful tools for determining the performance of a conventional microwave station. The diode receiver output can be connected to a microamp meter instead of the audio amplifier for field strength measurements, and the transmitter can be used as a source for receiver and filter testing.

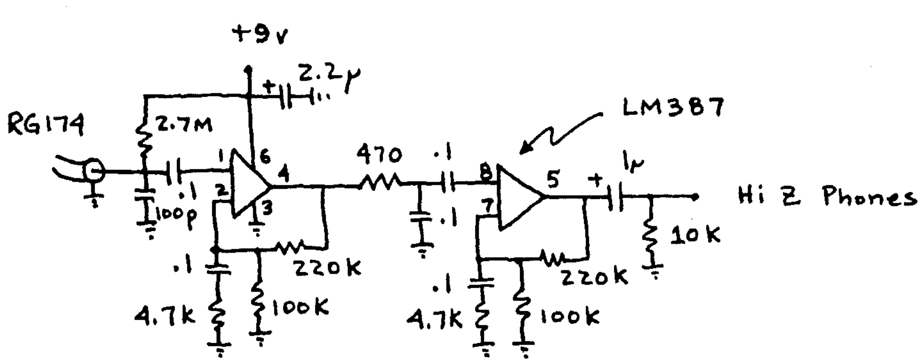
At X-band and up the diode detector receiver becomes very attractive for line-of-sight communications. Of particular interest to radio amateurs are the relatively inexpensive dual band police radar detectors that cover the amateur assignments at 10 and 23 GHz. We have modified several of these radar detectors and conducted tests using a Gunn diode source and 18" dish at 23 GHz with very positive results. Since the receivers are broadband, there is no problem with transmitter drift or critical receiver tuning.

The figures show a low power source and diode detector receiver using printed filters for the 13 cm amateur band. With +4 dBm into the multiplier board at 192 MHz, the 13 cm output is -38 dBm--a good level for short range contacts and receiver alignment and testing. The spurious outputs at 2112 and 2496 MHz are only a few dB down from the 2304 MHz output, so more filtering or a higher input frequency would be needed if amplifiers are added. Receiver sensitivity may be improved if desired by adding several MSA0104 RF amplifier stages.

There are several simple ways of generating MCW signals with conventional equipment. If the IF radio has an AM position on the mode switch, whistling in the microphone works. If the microphone has a touch-tone pad, keying one of the buttons in the SSB mode will generate MCW. If neither of these options is available, a simple two-tone generator fed into the microphone input on SSB works very well.







Detector Amplifier

DIRECT CONVERSION MICROWAVE TRANCEIVERS

Rick Campbell KK7B

During the week prior to the June 1983 VHF Contest a Direct Conversion CW Transceiver was assembled for the 2304 MHz band. The block diagram is shown in figure 1. After a sucsessful contest contact was made, the transceiver was disassembled and the pieces returned to their rightful owners. A few comments are in order:

1. Direct conversion works at microwaves

2. The fundamental limitation on receiver sensitivity is LO phase noise, since the signal frequency is only a few hundred Hz away from the LO frequency.

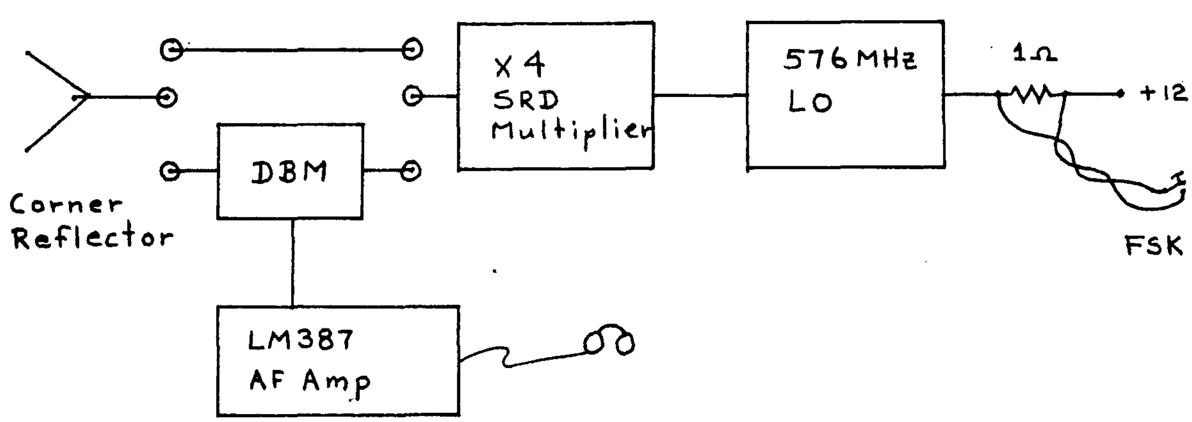
3. RF amplifiers do not generally help, since they amplify the LO phase noise right along with the signal.

4. LO shielding and good LO isolation in a balanced mixer help a great deal.

5. Making the LO tunable will increase phase noise--the LO in figure 1 is not tunable.

6. The sensitivity is about -130 dBw--similar to a superheterodyne system with a 30 dB noise figure.

7. It is a little easier to build a simple transverter (LO, mixer and filter) than a Direct Conversion Transceiver. The simple transverter requires an IF rig, but provides a tunable, SSB or CW system with at least 20 dB better receive sensitivity.



FFT RECEIVERS FOR WEAK CW SIGNALS

Richard L. Campbell KK7B
Department of EE
Michigan Tech University
Houghton, MI 49931

Amateurs involved in weak signal communications have long been aware of the advantages of SSB and CW over wider band modes when signals are very weak. The amount of noise is directly related to the bandwidth--if the bandwidth is cut in half, the noise output drops by 3 dB, everything else being equal. For SSB, best intelligibility for signals in white noise occurs with a bandwidth of about 2.5 kHz, so the noise floor of a perfect receiver (0 dB noise figure) is:

$$-204\ \text{dBw/Hz} + 10\log(2.5\times10^{3}\ \text{Hz}) = -170\ \text{dBW}$$

The ear-brain effective noise bandwidth when listening to weak CW signals in white noise is about 100 Hz, regardless of the receiver bandwidth. For CW with a bandwidth of 100 Hz, the noise floor of a perfect receiver is:

$$-204\ \text{dBw/Hz} + 10\log(100\ \text{Hz}) = -184\ \text{dBw}$$

In order to improve the sensitivity of an already "perfect" CW receiver, it is necessary to use something other than the ear-brain combination for detection.

An attractive way to improve receiver sensitivity by decreasing bandwidth is to use one of the new FFT Signal Analyzers connected to the receiver audio output. FFT stands for "Fast Fourier Transform," the mathematical technique used to perform the filtering operation. It is not necessary to understand the mathematics to take advantage of the FFT Signal Analyzer. What the FFT Signal Analyzer does is to synthesize a large number of very narrow bandwidth filters, all operating at the same time and all on adjacent frequencies. Figure 1 shows the graphical output of a 432 MHz receiver with an FFT Signal Analyzer. Each point of the plot is the output of a 0.6 Hz wide filter centered at the audio frequency plotted along the bottom of the graph. The 512 filters in the graph are 0.4 Hz apart. The receiver noise figure (NF) is 2 dB, so the receiver noise floor is:

$$-204\ \text{dBw/Hz} + 2\ \text{dB NF} + 10\log(0.6\ \text{Hz}) = -204.2\ \text{dBw}$$

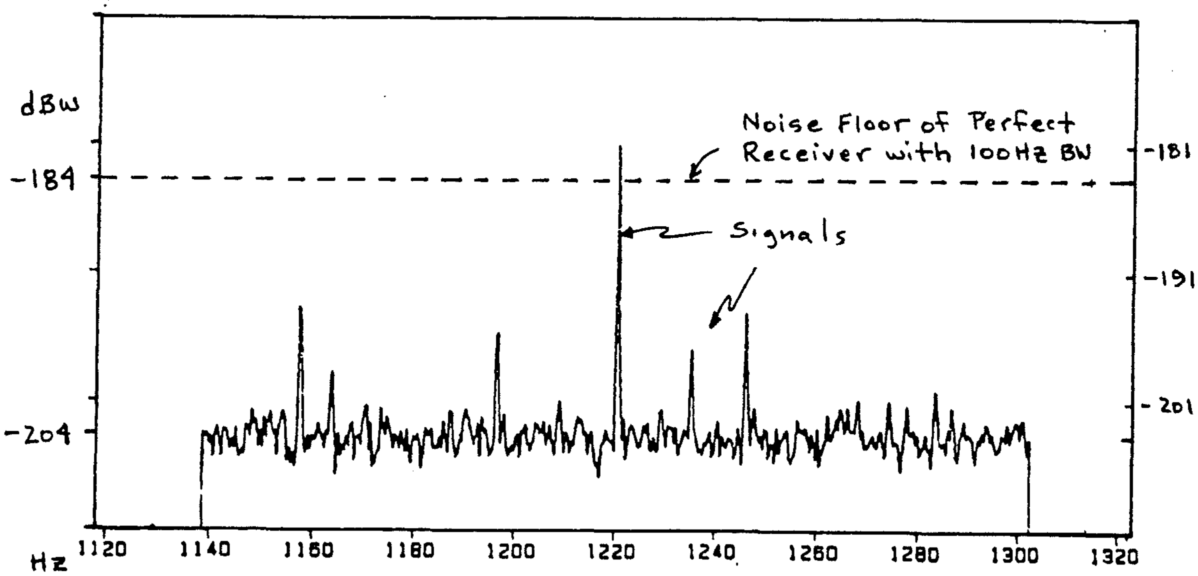
This is 20 dB better than a perfect receiver with a human listener.

The FFT Signal Analyzer is easy to use for improving receiver sensitivity. It is unnecessary to know the exact frequency of the received signal, since there are many filters all operating at the same time--if a signal is anywhere in the receiver passband, it will appear in one of the filter outputs. If the signal drifts, it will simply move to the next filter output. Frequency stability and accuracy requirements are not much different than what is expected of a successful Meteor Scatter or EME station. The 432 signal displayed in figure 1 was transmitted by an IC551 driving a homebrew transverter. The only additional piece of equipment in the station is the FFT Signal Analyzer. There are no special requirements for the transmitter, which means that the FFT analyzer can be used with any CW signal on the band.

There are some disadvantages to using an FFT Signal Analyzer. The first is that narrow bandwidths require slow CW sending speeds--2.5 seconds per dot for the 0.6 Hz bandwidth receiver output shown in figure 1. The Analyzer "listens" for 2.5 seconds and then processes the last 2.5 seconds worth of receiver audio while listening to the next 2.5 seconds. There is about a 4 second delay between starting the analyzer and seeing the first output. The output is also visual rather than audio. The other major disadvantage of the FFT Signal Analyzer is cost. Current models from HP start at about $10,000.

The good news is that FFT Signal Analysis can be performed by a personal computer using Signal Processing software rather than purchasing a dedicated hardware Signal Analyzer. The interface between the receiver and the computer is considerably less complicated than a Packet modem. The author is currently experimenting with PC-Matlab software from The Mathworks on an IBM PC with promising results.

Within a few years it should be possible for single yagi stations running solid state amplifiers to "see" their own echoes from the moon.



"TRAVELING WAVE TUBES"

BY

TONY BICKEL, K5PJR

TRAVELING WAVE TUBES - SOME TERMS

ANODE:	A positively charged element that concentrates and steers the currant flow.
CATHODE:	A negatively charged element that emits electrons
COLLECTOR:	Same as the plate in a tube, it collects the unconverted energy.
DEPRESSED COLLECTOR:	Operating the collector negative with respect to the helix or body of the tube. Slows the "beam" so that more energy may be coupled out.
PPM:	Periodic Permanent Magnet permanent magnets of opposite polarity are placed side by side along the helix to control the electron flow.

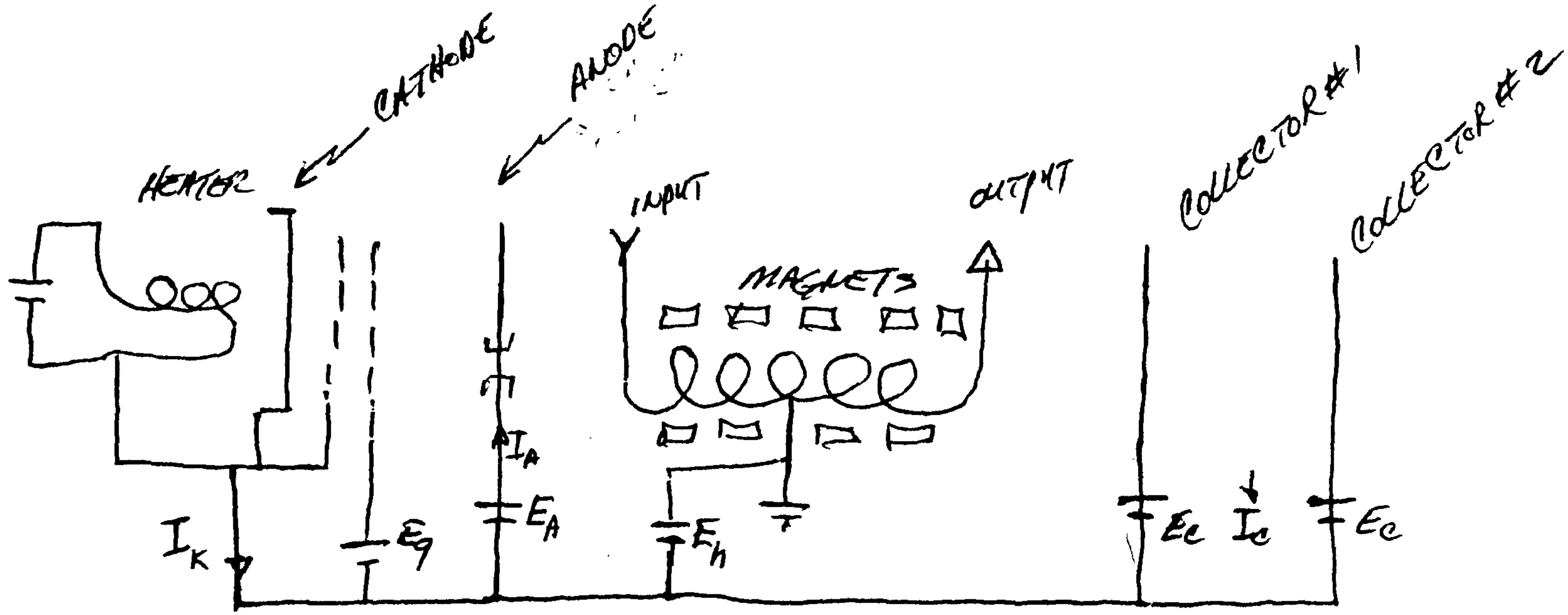


FIG. #6

K5PJR
TWT AMP.

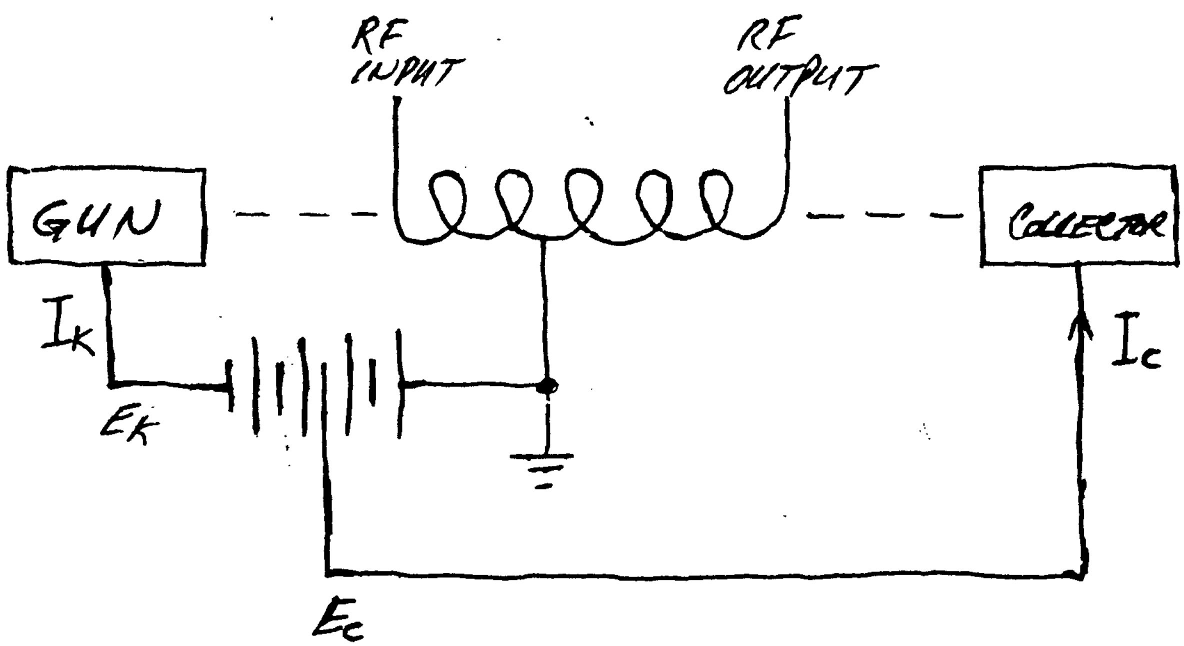


FIG. #7

K5PJR
TWT AMP.

"3456 MHz THE EASY WAY

BY

GERALD HANDLEY, WA5DBY

3456MHZ THE EASY WAY

by
Gerald Handley, WA5DBY

North Texas Microwave Society

INTRODUCTION

Once the microwave enthusiast has mastered 2304MHz, 3456MHz becomes the next mountain to climb. However the time and effort required to get on a new microwave band can be discouraging when one realizes that there are many mountains ahead to climb in the form of even higher frequency bands. A transverter design philosophy has been adopted by some of the members of the North Texas Microwave Society which allows one to get on a new microwave band with a minimum of time and effort. The key to getting on 3456MHz with a minimum of time and effort is to mix the local oscillator (LO) of a 2304MHz transverter with a 1296MHz transceiver.

SYSTEM COMPONENTS

The 3456MHz transverter is composed of the following components:

- LNA
- Waveguide To Coax Transition
- DC Inserter
- Receiver Mixer
- 30 dB Pad
- Transmit Mixer
- 3456MHz Band Pass Filter
- MMIC Amplifier
- T/R Relay
- 2160MHz Local Oscillator

The 3456MHz transverter is designed to be used with a 1296MHz transceiver as its IF. A block diagram of the system is shown in Figure 1.

Receive Transverter

The receive transverter consists of an LNA and a mixer. The LNA is from a satellite TV system. An LNB will NOT work. A used LNA can be purchased from Amateur Electronic Supply for $29.00.

The LNA is connected to an antenna by using a waveguide to coax transition. The waveguide to coax transition was designed using an article numbered 3.2.2 in THE MICROWAVE NEWSLETTER TECHNICAL COLLECTION which is available from the ARRL. The transition can be made out of hobby brass or a printed circuit board material. The transition inner dimensions are the save as the dimensions of the LNA waveguide. A flange is added to the transition and holes punched to match the flange on the LNA. The monopole was mounted in the center of the transition 7/8 inch from the shorted end of the waveguide transition. The dimensions of the waveguide to coax transition are not critical, and it is not necessary to be overly concerned about the accuracy of the dimensions. An illustration of the transition is shown in Figure 2. For better receive sensitivity the LNA can be mounted at the antenna.

A DC inserter was used to provide power to the LNA. A schematic of the DC inserter is shown in Figure 3. Commercial DC inserters are available from satellite TV dealers, but do not perform any better than the one in Figure 3. Some LNA's can be modified to apply power directly to the LNA. The DC inserter showed negligible loss when put in the circuit, and is a more convenient way to power the LNA than trying to modify it. Most LNA's indicate that they are to be powered with more than 12 volts DC; however, they will perform equally well when powered with 12 volts DC.

The receive mixer is a VARI-L DBM-500 SMA connector-equipped microwave double balanced mixer. The L port and R port have a frequency range from 1.7-4.2GHz. The X port has a frequency range from DC-1.5GHz. The noise figure at 3456MHz is about 6dB. All ports have an impedance of 50 ohms. The isolation between ports is about 30dB at 3456MHz. The mixer is available from VARI-L Company, 11101 East 51st Avenue, Denver, Colorado 80239, Phone: (303) 371-1560. The price of the mixer is $95.00 in quantities of 1-9 and $86.45 in quantities of 10-24. The DC inserter and LNA are connected to the mixer R port. The

3456 MHz Transceiver Block Diagram

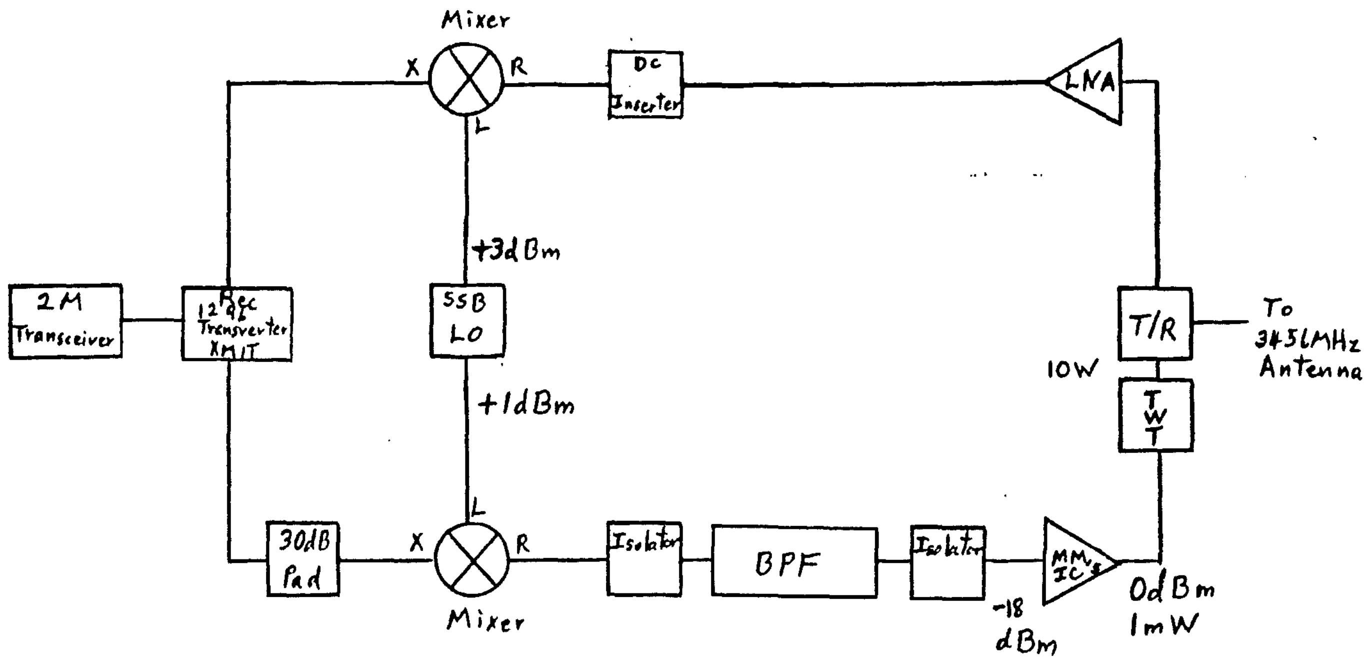
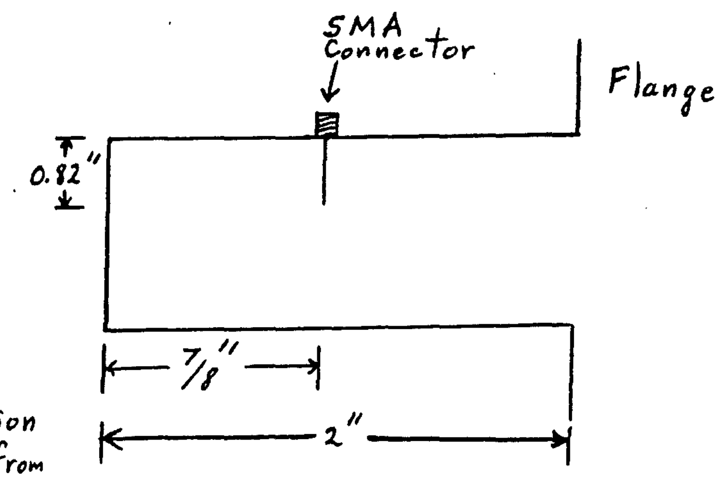


Figure 1

38 dB Rec Gain
1.5 dB System noise figure
1296.100 MHz = 3456.100MHz

Coax to Waveguide Transition



Transition made from hobby brass or PCB material

Solder SMA Connector to Transition
Monopole is #14 copper wire

Figure 2

DC Inserter

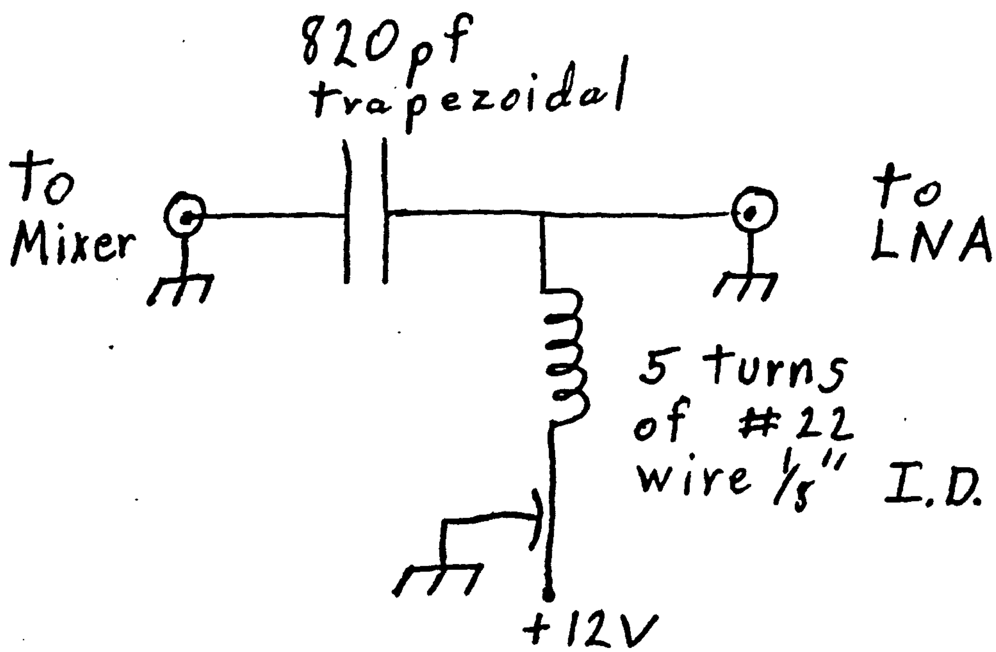


Figure 3

2160MHz LO is connected to the mixer L port. The 1296MHz IF is connected to the mixer X port. It is not necessay to use a band pass filter between the LNA and the mixer because of the selectivity of the LNA.

Transmitting Converter

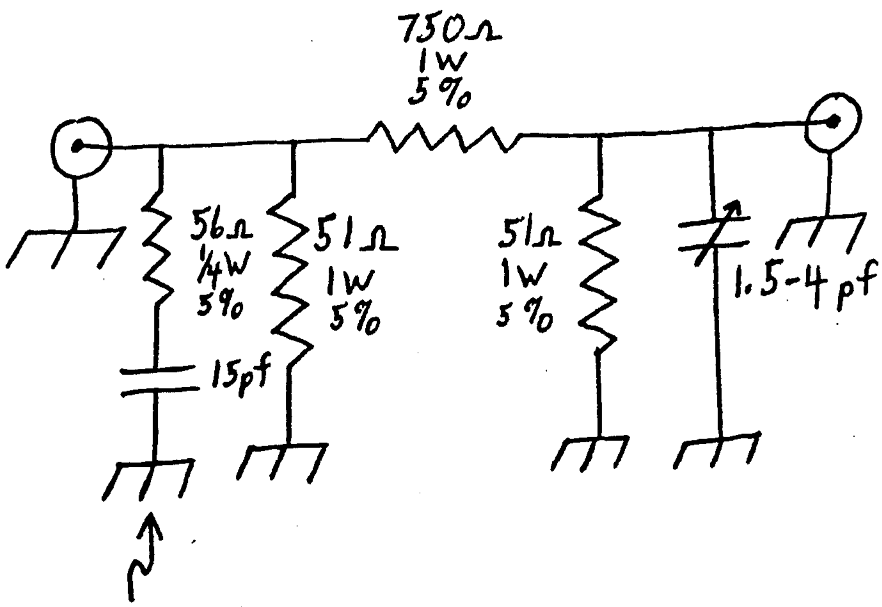
The transmitter uses a separate mixer which is the same type used by the receive converter. The same mixer could be used for both converters by switching it between them. The 1296 IF is connected to the X port of the mixer through a pad to attenuate it to 0dBm. For an IF with 1-2 watts out, a pad of about 30dB is needed. A schematic of a 30dB pad is shown in Figure 4. The L port of the mixer is connected to the 2160MHz LO. The R port of the mixer is connect to the band pass filter and MMIC amplifier.

The band pass filter is commercial filter with SMA connectors which was found in an electonics surplus store. An interdigital filter can be built which will work equally well using the techniques presented in an article by Richard L. Campbell, KK7B, entitled "A Clean Microwave Local Oscillator" in the 1985 1296/2304MHz Conference Proceedings. A diagram of a 3456MHz filter from this article is reprinted in Figure 5 with the permission Richard Campbell. Waveguide band pass filters are also available on the surplus market for 3456MHz and can be used by installing the same type of waveguide to coax transition on each end of the filter that was installed on the LNA. The band pass filter's performance should be checked by sweeping it with a signal generator and observing the output on a spectrum analyzer. The filter can be retuned as necessary to insure its center frequency is 3456MHz and it passband is narrow enough to remove the signal from the 2160MHz LO.

MMIC Amplifier

MMIC's were used for the intermediate amplifier. Amplifiers were built using 0304's, 0404's, 0385's, and 0485's; and the 0404's gave the best performance at 3456MHz. Two amplifiers were used back-to-back and each amplifier contained two 0404's for a total of four 0404's in the intermediate amplifier. The four 0404's had an output of about 0dBm. A schematic of the intermediate amplifier is shown in Figure 6. 50 ohm microstrip printed circuit boards to build a two stabe MMIC amplifier on are available from the North Texas Microwave Society.

30 dB Pad
for 1.3 GHz @1.5W Max



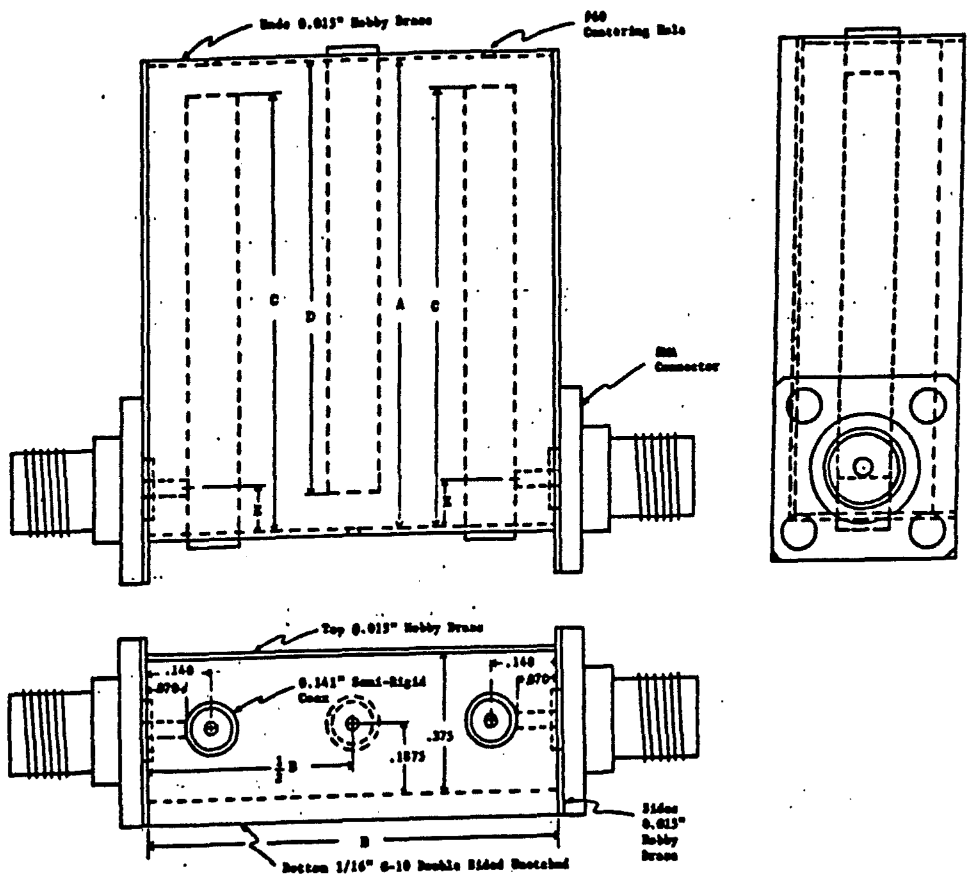
Electronic Finger
Modeled by Collins Radio

Figure 4

3456 MHz

Three Resonator Interdigital Filter

Mechanical Details



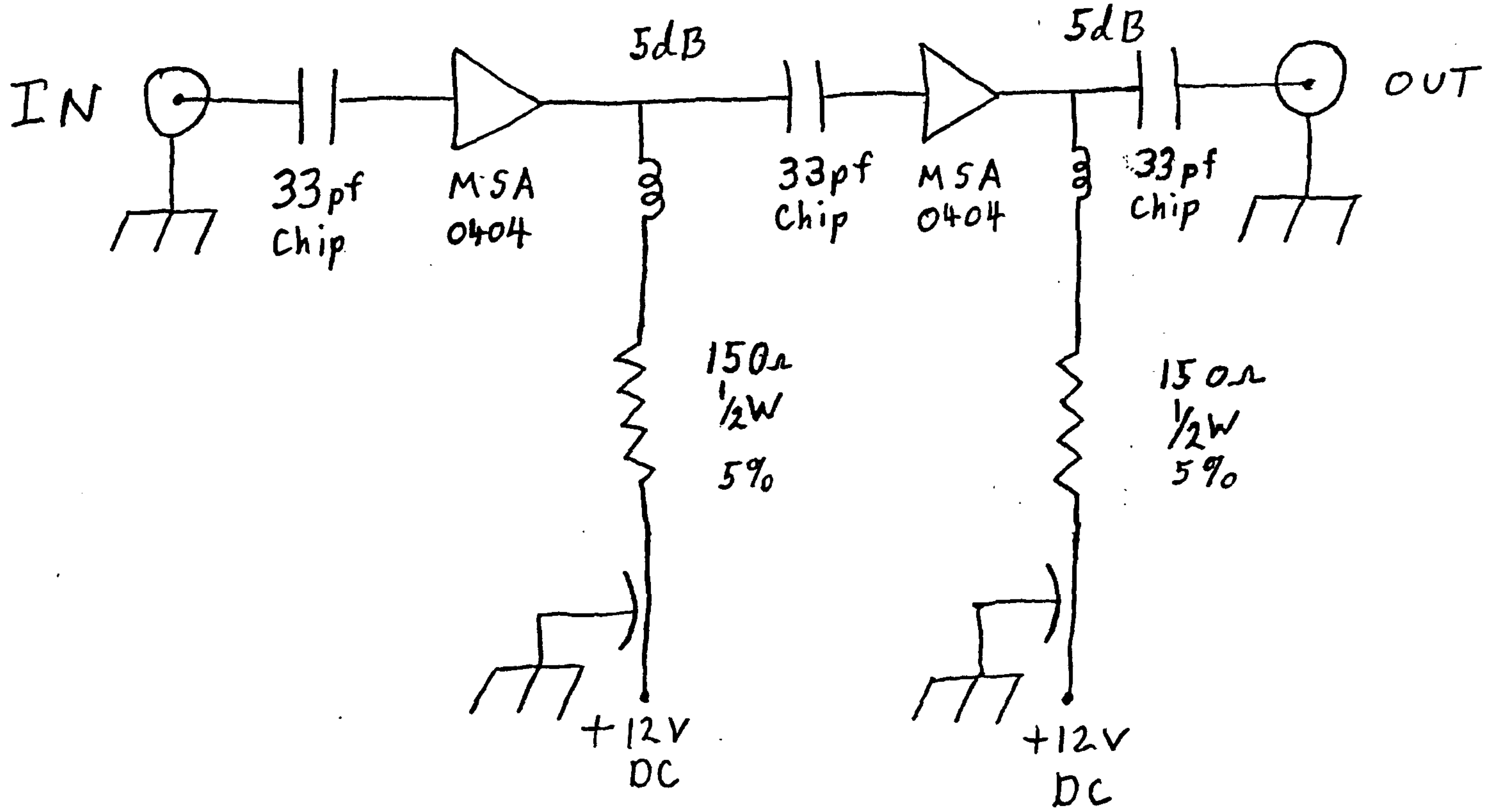
Dimensions in Inches

A	B	C	D	E	Bandwidth
.854	1.034	.764	.745	.127	300MHz

Figure 5

3456 MHz MMIC RF Amp

10 dB Gain
+5 dBm Max Output



Inductors are 3 turns of
#24 wire 1/8" I.D. closewound

Figure 6

Local Oscillator (LO)

The local oscillator is the SSB-Electronic SLO 13 available form SSB distributors for around $100.00. The oscillator needs 12 volts DC and has two BNC connectors which provide 2160MHz at +1dBm on one connector and +3dBm on the other connector. The +3dBm signal was connected to the receiver mixer L port, and the +1dBm signal was connected to the transmit mixer L port. This worked fine since a TWT is being used as the final amplifier and a lot of intermediate power on transmit is not needed. The optimum signal level from each of the two ports on the LO is +7dBm. A single MMIC on the +3dBm signal and two MMIC's on the +1dBm signal can be used to amplify the LO signals to +7dBm. The MMIC amplifier design presented in Figure 5 would work fine in this application.

Another approach would be to run the +3dBm signal through two MMIC's and then through a power divider to the receive converter and the transmit converter. The power divider can be made of two odd 1/4 wavelength multiple pieces of 75 ohm semi-rigid.

T/R Relay

The T/R relay is a Transco SMA microwave relay. This type of relay provides low loss at 3456MHz and is easy to use. The relay switches the feedline from the antenna between the LNA and the final amplifier in the transmitting converter. For better receive sensitivity, the T/R relay and the LNA can be mounted at the antenna.

Connecting System Components

50 ohm 0.141 semi-rigid coax with SMA, BNC, and Type N connectors is used to connect system components. The semi-rigid coax with connectors can be purchased on the surplus market. It is easy to cut the semi-rigid coax to the length needed and remove and reinstall connectors. The shape of a length Semi-rigid coax can be changed slightly, but normally the shape of the shield is distorted when a length of semi-rigid coax is reshaped radically.

IF

Any 1296MHz transceiver can be used as the IF for the 3456MHz transverter. The better noise figure the 1296MHz transceiver has, the better noise figure the system will have since the system noise figure is the sum of the noise figure of the 3456MHz transverter and the noise figure of the 1296MHz transceiver.

FINAL AMPLIFIER

The final amplifier was a TWT which provides 10 watts out with 0dBm of drive. TWT's and solid-state amplifiers for 3456MHz are available on the surplus market but are hard to find. Power GAS FET's can be obtained which can be used as a linear amplifier to provide several watts of output power at 3456MHz.

ANTENNA

A dish antenna is certainly the way to go at 3456MHz. A two foot dish provides the same gain as a 112 element loop yagii. The seven foot dish in the article entitled "The Care and Feeding of a 7 foot Dish", by Gerald Handley, WA5DBY, in the 1985 1296/2304MHz Conference Proceedings was used as the antenna for the 3456MHz system. The dish provides about 33dBi gain at 3456MHz. The dish is a UHF TV antenna made by Channel Master and is available through Trice Electronics for $78.00 in quantities of six or more. The dish has to be covered with 1/4 inch hardware cloth to use it at 3456MHz. Because the beamwidth of the dish is about 3.5 degrees at 3456MHz, a smaller dish in the four foot diameter range might work better. It will take a rotor with very little play to keep the seven foot dish pointed in the desired direction.

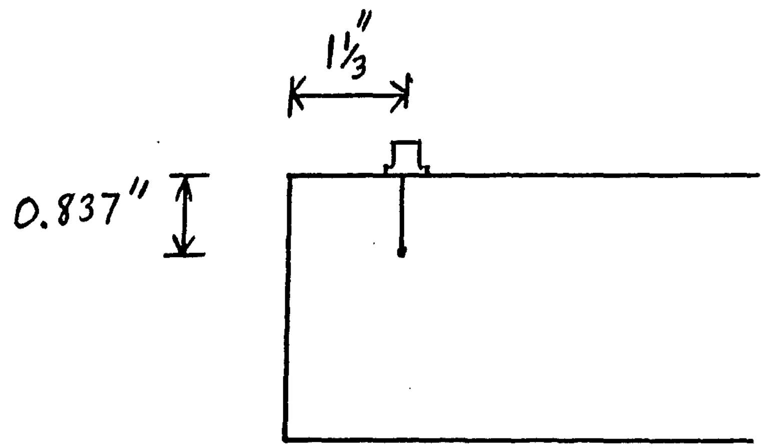
Feed Horn

The 3456MHz feed horn was constructed from a Campbell's soup can using the dimensions shown in Figure 7. The connector is an N connector soldered to the coffee can. The monopole is piece of #14 copper wire with a ball of solder put on the end of it.

Feedline

Unless waveguide is available, the best feedline for 3456MHz is 7/8 inch foam heliax. Foam heliax has the same

3456 FEED HORN



Campbell's soup can

~ 9 dBi

Monopole is #14 copper wire with a ball of solder at its tip.

Figure 7

loss as air heliax at 3456MHz. Larger diameter heliax will have more loss at 3456MHz. Belden 9913 or superflex should be used around the rotor. 7/8 inch foam heliax has about 2.6dB of loss per 100 feet at 3456MHz. Belden 9913 has about 9.8dB loss per 100 feet at 3456MHz. The G-Line would also be a good feed line to use at 3456MHz. For information on the G-Line see the article "How We Put the G-Line to Work" by Warren Weldon W5DFU and Merlin Berrie W5HTZ in the 1984 Central States VHF Society Proceedings.

CONCLUSIONS

3456MHz is an easy band to get on if you are already on both 1296MHz and 2304MHz. The parts for the 3456MHz transverter are available on the used/surplus market. Perfromance on 3456MHz is similar to 2304MHz. The biggest problem on 3456MHz is generating "high power". The system noise figure of the 3456MHz transverter as measured on a HP8970A noise figure meter was 1.5dB and the receive gain was 38dB. 1296.100MHz on the 1296MHz transverter is equal to 3456.100MHz. Most important of all 3456MHz is a fun band to operate on.

FEEDLINE LOSS ABOVE 1 GHz

Attenuation in dB/100ft

Feedline	902	1296	2304	3456	5760
7/8" Air Heliax	1.1	1.4	2.0	2.6	*
7/8" Foam Heliax	1.2	1.5	2.0	2.6	3.2
1/2" Foam Heliax	2.2	2.6	3.8	4.8	6.5
7/8" Hardline	1.5	2.5	3.9	5.1	7.0
1/2" Air Heliax	2.6	2.9	4.0	5.3	7.5
1/2" Hardline	2.9	3.7	5.4	7.1	9.9
Belden 9913	4.2	5.1	7.3	9.8	15.0
RG-214& RG-213 Coax	8.0	10.7	15.9	21.2	30.8
0.141 Semirigid	11.0	13.0	18.0	22.0	30.0
RG-141 Coax	12.0	15.3	22.0	28.4	39.7
RG-58 Coax	17.8	21.0	31.5	40.7	56.9

* Above cutoff

```
1 DIM A(255):DIM B(255)
2 PRINT "{CLR}"
3 POKE 53280,10
4 POKE 53281,13
5 PRINT"{BLUE}"
6 PRINT "    KAIGT PARAMETRIC DESIGN PROGRAM"
7 PRINT "              FOR LOOP YAGI"
8 PRINT "          WRITTEN BY BOB ATKINS"
9 PRINT:PRINT
10 PRINT "      MODIFIED FOR C-64 BY WA5DBY"
11 PRINT:PRINT:PRINT:PRINT
12 INPUT "NUMBER OF ELEMENTS";N
20 A(1)=3.1
21 A(2)=4.05
22 A(3)=5.17
23 A(4)=6.0
25 A(5)=7.78
26 A(6)=9.56
27 A(7)=10.81
28 A(8)=13.12
30 FOR X=1 TO N-8
40 A(X+8)=13.12+X*3.56
50 NEXT
55 PRINT
60 INPUT "FREQUENCY OF USE IN MHZ";F
65 PRINT
70 FC=1296/F
72 FOR X=1 TO N
75 A(X)=A(X)*FC
77 NEXT
80 R1=9.67
90 DE=9.23
110 FOR X=1 TO 11
120 B(X)=8.25
130 NEXT
150 FOR X=12 TO 25
160 B(X)=8.0
170 NEXT
190 IF N>27 THEN GOSUB 600
200 FOR X=1 TO N-2
210 B(X)=B(X)*FC
215 NEXT
220 R1=R1*FC
230 DE=DE*FC
240 INPUT "BOOM DIAMETER IN INCHES";B
245 PRINT
250 INPUT "ELEMENT WIDTH IN INCHES";W
255 PRINT
```

```
260 INPUT "ELEMENT THICKNESS IN INCHES";T
262 PRINT
263 INPUT "OUTPUT TO PRINTER (Y/N)";P$
265 PRINT "{CLR}"
270 B1=B/FC
271 W1=W/FC
272 T1=T/FC
280 IF B1<.5 THEN GOSUB 700
290 IF B1>2.1 THEN GOSUB 700
300 IF T1<.028 THEN GOSUB 750
310 IF T1>.063 THEN GOSUB 750
320 IF W1<.1 THEN GOSUB 800
330 IF W1>.375 THEN GOSUB 800
340 B2=((B1-.5)+(B1-.5)↑2)*2.88
350 FOR X=1 TO (N-2)
360 B(X)=B(X)+(B(X)/100)*B2
365 NEXT
370 DE=DE+DE*B2/100
380 R1=R1+R1*B2/100
390 W2=(.1875-W1)*4.8
400 FOR X=1 TO (N-2)
410 B(X)=B(X)+(B(X)/100)*W2
420 NEXT
422 DE=DE+DE*W2/100
424 R1=R1+R1*W2/100
430 T2=(T1-.028)*(.6/.031)
440 FOR X=1 TO (N-2)
450 B(X)=B(X)+((B(X)/100)*T2)
460 NEXT
470 DE=DE+DE*T2/100
475 R1=R1+R1*T2/100
480 RA=4.5
481 RB=5.5
485 RA=RA*FC
486 RB=RB*FC
495 GOTO 1000
600 FOR X=18 TO N-2
610 B(X)=7.7
620 NEXT
630 RETURN
700 PRINT "BOOM DIAMETER OUTSIDE RANGE OF"
701 PRINT "PARAMETRIC STUDY.  CALCULATION CONTINUES";
702 PRINT "WITH EXTRAPOLATED DATA."
710 RETURN
750 PRINT "MATERIAL THICKNESS OUTSIDE RANGE OF PARAMETRIC STUDY.  ";
751 PRINT "CALCULATION CONTINUES WITH EXTRAPOLATED DATA."
760 RETURN
800 PRINT "ELEMENT WIDTH OUTSIDE RANGE OF PARAMETRIC STUDY.  ";
801 PRINT "CALCULATION CONTINUES WITH EXTRAPOLATED DATA."
810 RETURN
1000 PRINT "{CLR}"
```

```
1005 PRINT "DATA FOR LOOP YAGI FOR USE AT ";F;"MHZ"
1010 PRINT
1020 PRINT "BOOM DIAMETER ";B;"IN"
1030 PRINT "ELEMENT WIDTH ";W;"IN"
1040 PRINT "ELEMENT THICKNESS ";T;"IN"
1042 PRINT"REFLECTING SCREEN ";INT(RA*1000)/1000;" X ";INT(RB*1000)/1000;"IN"
1043 PRINT:PRINT:PRINT
1044 PRINT "ALL DIMENSIONS ARE IN INCHES"
1045 PRINT:PRINT
1046 PRINT "ELEMENT"," DISTANCE"," LENGTH"
1047 PRINT "NUMBER"," FROM"," (CIRCULAR)"
1048 PRINT "      "," SCREEN"
1049 PRINT "------"," ------"," ---------"
1050 PRINT
1051 PRINT "R1",(INT(A(1)*1000))/1000,(INT(R1*1000))/1000
1060 PRINT "DE",(INT(A(2)*1000))/1000,(INT(DE*1000))/1000
1070 FOR X=1 TO N-2
1075 L=(INT(B(X)*1000))/1000
1076 L1=(INT(A(X+2)*1000))/1000
1080 PRINT "D";X,L1,L
1090 NEXT
2000 IF P$<>"Y"THEN GOTO 2095
2001 OPEN4,4
2005 PRINT#4,"DATA FOR LOOP YAGI FOR USE AT ";F;"MHZ"
2010 PRINT#4
2020 PRINT#4,"BOOM DIAMETER ";B;"IN"
2030 PRINT#4,"ELEMENT WIDTH ";W;"IN"
2040 PRINT#4,"ELEMENT THICKNESS ";T;"IN"
2042 PRINT#4,"REFLECTING SCREEN ";INT(RA*1000)/1000;" X ";INT(RB*1000)/1000;"IN"
2043 PRINT#4:PRINT#4:PRINT#4
2044 PRINT#4,"ALL DIMENSIONS ARE IN INCHES"
2045 PRINT#4:PRINT#4
2047 PRINT#4,"ELEMENT","   DISTANCE","CIRCULAR"
2048 PRINT#4," NUMBER","FROM SCREEN","  LENGTH"
2049 PRINT#4,"-------","-----------","--------"
2050 J1=(INT(A(1)*1000))/1000:J2=(INT(R1*1000))/1000
2051 PRINT#4,"      R1";TAB(21-LEN(STR$(J1)));J1;TAB(17-LEN(STR$(J2)));J2
2060 J1=(INT(A(2)*1000))/1000:J2=(INT(DE*1000))/1000
2061 PRINT#4,"      DE";TAB(21-LEN(STR$(J1)));J1;TAB(17-LEN(STR$(J2)));J2
2070 FOR X=1 TO N-2
2075 L=(INT(B(X)*1000))/1000
2076 L1=(INT(A(X+2)*1000))/1000
2078 V1=LEN(STR$(L1))
2079 V2=LEN(STR$(L))
2080 PRINT#4,TAB(6-LEN(STR$(X)));"D";X;TAB(20-V1);L1;TAB(17-V2);L
2090 NEXT
2093 CLOSE 4
2095 PRINT
2096 INPUT "RUN PROGRAM AGAIN (Y/N)";N$
2097 IF N$="Y" GOTO 2
2100 END
```

```
50 REM ENTER QTH IN LINT 185
51 REM ENTER LATITUDE IN LINE 195
52 REM ENTER LONGITUDE IN LINE 240 WITH A MINUS SIGN IN FRONT OF IT
100 PRINT "{CLR}"
110 POKE 53280,14:POKE53281,18:PRINT"{YELO}"
120 PRINT "{CLR}"
185 LET W$="FORT WORTH"
195 LET A=32.4411111111111111111
205 LET A1=A*3.14159/180
240 LET L1=-97.2311111111111111111
700 PRINT"PROGRAM TO FIND BEAM HEADING"
706 PRINT:PRINT:PRINT:INPUT"ENTER OTHER STATION'S CALL SIGN";M$
725 PRINT:INPUT"ENTER LATITUDE OF OTHER STATION";B
745 PRINT:INPUT"ENTER LONGITUDE OF OTHER STATION";L2
756 PRINT:PRINT:PRINT"LATITUDE";B;"/LONGITUDE ";L2
760 GOSUB1000
770 PRINT:PRINT"DISTANCE FROM ";W$;" IS ";D1;" MILES "
772 PRINT"BEARING TO ";M$;" IS ";R2;" DEGREES"
780 PRINT:PRINT:PRINT:PRINT"DO YOU WANT TO RUN THE PROGRAM AGAIN (Y/N)":INPUT T$
795 IF T$="Y" THEN GOTO 120
799 END
1000 L2=-L2
1001 LET L=L2-L1
1003 LET X=0
1010 IF L<-180 THEN GOTO 1025
1015 IF L>180  THEN GOTO 1035
1020 GOTO 1040
1025 LET L=L+360
1030 GOTO 1100
1035 LET L=L-360
1040 IF L<0 THEN GOTO 1100
1045 LET X=1
1100 REM
1110 LET B1=B*3.14159/180
1115 LET L=L*3.14159/180
1119 REM
1120 LET P=COS(L)*COS(A1)*COS(B1)+SIN(A1)*SIN(B1)
1125 LET P1=ATN(SQR(1-P*P)/P)
1130 LET P2=P1*180/3.14159
1134 REM
1135 IF P2<0 THEN GOTO 1145
1140 GOTO 1150
1145 LET P2=P2+180
1149 REM
1150 LET D1=INT(P2*60*1.15152+.5)
```

```
1151 LET D2=INT(D1*1.6093+.5)
1154 REM
1155 LET R=COS(B1)*SIN(L)/SIN(P1)
1160 LET R1=ATN(R/SQR(1-R*R))
1164 REM
1165 LET R2=INT((R1*180/3.14159)+.5)
1168 REM
1169 REM
1170 IF ABS(R)>.999998 THEN GOTO 1500
1175 IF ABS(R)<.00174 THEN GOTO 1160
1180 LET B2=(B+.1)*3.14159/180
1185 LET R3=COS(L)*COS(A1)*COS(B2)+SIN(B2)*SIN(A1)
1190 LET R4=ATN(SQR(1-R3*R3)/R3)
1200 LET R6=COS(B2)*SIN(L)/SIN(R4)
1205 IF X=1 THEN GOTO 1240
1210 IF ABS(R6)>ABS(R) THEN GOTO 1230
1215 LET R2=360-ABS(R2)
1220 GOTO 1700
1230 LET R2=180+ABS(R2)
1235 GOTO 1700
1240 IF ABS(R6)<ABS(R) THEN GOTO 1255
1245 LET R2=180-ABS(R2)
1250 GOTO 1700
1255 LET R2=ABS(R2)
1260 GOTO 1700
1500 IF X=1 THEN GOTO 1530
1510 LET R2=270
1520 GOTO 1700
1530 LET R2=90
1540 GOTO 1700
1600 IF ABS(L)>178 THEN GOTO 1640
1605 IF B<A THEN GOTO 1630
1610 LET R2=0
1620 GOTO 1700
1630 LET R2=180
1635 GOTO 1700
1640 IF B>A THEN GOTO 1630
1645 GOTO 1610
1700 RETURN
```

```
100 POKE 53280,15:POKE 53281,15:PRINT "{BLK}"
150 PRINT "{CLR}"
160 PRINT "               PROGRAM TO FIND"
165 PRINT "   THE GAIN AND BEAMWIDTH OF A DISH":PRINT:PRINT:PRINT
180 INPUT "ENTER FREQUENCY IN MHZ";F:PRINT
190 INPUT "ENTER DIAMETER IN FEET";DI:PRINT
195 INPUT "ENTER F/D";FD:PRINT
197 INPUT "ENTER EFFICIENCY (AS FRACTION)";N
200 H=0:G=0
205 R=DI/2
210 F1=F/1000
212 Y=30/F1
220 H=70/(DI*F1)
225 DI=DI*12*2.54
230 A=(N*9.8696*DI*DI)/(Y*Y)
235 G=10*(LOG(A)/LOG(10))
240 PRINT:PRINT:PRINT:PRINT "GAIN IS =";G;"DBI"
245 R=R*12
250 PRINT:PRINT "3DB BEAMWIDTH =";H;"DEG"
380 PRINT:PRINT:PRINT
390 INPUT "ENTER SUPPORT SPACING IN INCHES";S
393 FP=FD*((DI)/2.54)
395 PRINT "{CLR}"
397 O=0
398 DI=DI/2.54
400 PRINT "X = INCHES FROM CENTER"
405 PRINT "Y = INCHES FROM X"
406 PRINT:PRINT
407 PRINT "   X","   Y"
408 PRINT "-------","-------"
410 FOR X = 1 TO R STEP X
420 Y=INT(((X*X)/(4*FP))*100)/100
421 REM Y EQUALS X SQUARED DIVIDED BY FOUR TIMES THE FOCAL POINT
425 IF X>R THEN 500
430 PRINT X,Y
431 O=O+1:IF O=15 THEN GOSUB 520
432 NEXT
500 INPUT "DO YOU WANT TO START OVER (Y/N)";A$
510 IF A$="Y" THEN 150
515 END
520 INPUT "HIT ANY KEY TO CONTINUE";B$
530 IF B$<>"" THEN GOTO 520 ELSE 540
540 O=0:PRINT "{CLR}":RETURN
```

"AMSAT MODE-S TRANSPONDER"

BY

WILLIAM D. McCAA, JR., KØRZ

AMSAT MODE-S TRANCPONDER FOR PHASE-IIIC

KØRZ 7/20/86

- INTRODUCE MICROWAVE RECEPTION TO THE AMATEUR SATELLITE USER.

- PHASE-IIIC WILL BE LAUNCHED IN THE FALL OF 1987 ON THE FIRST FLIGHT OF THE ARIENNE 4 LAUNCH VEHICLE.

- THE TRANSPONDER WILL OPERATE IN TWO MODES
  - * FSK BEACON 2400.64 MHZ (400 BAUD)
  - * TRANSPONDER

- TRANSPONDER CHARACTERISTICS
  - * 435.625 MHZ UPLINK (1000 EIRP)
  - * 2401.710 MHZ DOWNLINK, (17 DBWIC)
  - * 30 KHZ. TRANSPONDER BANDWIDTH
  - * MODULATION THRU TRANSPONDER
    - SSB
    - NBFM

- BUILT IN TWO PACKAGES
  - * S-RF MODULE (10 X 2.2 X 3)
    - S-BAND MIXER
    - S-BAND POWER AMPLIFIER
    - 18X MULTIPLIER (126 -> 2264)
  - * S-IF MODULE (13.9 X 4.1 X 1.5)
    - 10 VDC CONVERTER
    - 42 MHZ OSCILLATORS
    - 3X MULTIPLIER (125.8)
    - BEACON GENERATOR (10.64)
    - IHU INTERFACE AND CONTROL
    - IF STAGES (10.7)
    - VHF STAGES

- PROJECT STATUS
  - * FLIGHT UNIT COMPLETED
  - * THERMAL-VACUUM TESTED
  - * 1000 HOURS THANSMIT TIME ON THE BENCH
  - * BOTH SSB AND NBFM SIGNALS PASSED

- 17.1 PERCENT DC TO RF POWER EFFICIENCY
  - * 1.25 WATTS AT 2400 MHZ
  - * 530 MA AT 13.75 VDC INPUT (7.3 WATTS)

- FUTURE TIME SCHEDULE
  - * SATELLITE VIBRATION TEST - GERMANY (WINTER/86)
  - * LAUNCHER INTERFACE - FRANCE (SPRING/87)
  - * LAUNCH - SOUTH AMERICA (FALL/87)
  - * USER AVAILABILITY (WINTER/87)

AMSAT MODE-S TRANSPONDER
by
WILLIAM D. McCAA Jr., KØRZ
June 29, 1986

Background

It is hoped that the addition of an S-band transponder on Phase-3C would help the transition of the average amateur satellite user into the microwave frequencies. The ready availability of good low cost crystal controlled receiving equipment in the MDS (2150-2160 MHz.) service can find immediate application in receiving a Phase-3C transponder in the 2400-2450 MHz. band.

Introduction

The S band output, Mode-S, transponder described herein has been developed for flight in the AMSAT Phase-3C satellite which is scheduled for launch in Mid 1987, on the first flight of the Arienne 4 launcher. Since this transponder is an add on to a Phase-3 type satellite, the power consumption and physical size had to be held to the constraints of the satellite's origional design. Thus power efficiency and size became major design considerations. The transponder's current drain from the satellite's 14.0 VDC buss is 0.54 Amps.

The transponder will operate either in the PSK (400 baud) beacon mode or transponder mode, 30 kHz. bandwidth, usable for both NBFM and SSB and have an EIRP of +17 dBW. The spacecraft S band antenna is a left hand circular 15 turn helix.

The Mode-S transponder uses a portion of the Mode-B transponders receiver. A buffered output at 53 MHz. is taken from the Mode-B receivers first IF after AGC. The Mode-S transponder thus can be operated only when the mode-B receiver is active, while the Mode-S beacon can be operated at any time. The uplink power at 435 MHz. required for access will be the same as that required for mode-B (about 1000 Watts EIRP max.).

Transponder Construction Status

The Mode-S transponder is completed. It has undergone Thermal-vacuum testing in the Phase-3C spacecraft in May, 1986, and is presently being bench operated on extended burn-in.

Link Calculations at 2.4 GHz.

Transmitter output power at antenna	+0 dBW
Spacecraft antenna gain (15 turn helix)	+17 dBic
Spacecraft EIRP	+17 dBW
Free space path loss (40,000 km @ 2.4 GHz.)	-192 dB
Signal level at receive antenna	-175 dBW
Receive antenna gain (1 meter dish @ 50%)	+25 dBic
Signal level at receiver	-150 dBW
Receiver sensitivity (75K, 20 kHz.BW)	-160 dBW
Received signal to noise ratio	+10 dB

INPUT AND OUTPUT FREQUENCIES

The following details the frequencies used in the Mode-S transponder.

INPUT FREQUENCY TO THE S BAND TRANSPONDER (Fin)	435.625 MHz.
Input frequency from Mode-B transponder	53.305 MHz.
Local crystal controlled oscillator (LO1)	42.605 MHz.
Local crystal controlled oscillator (LO2)	41.930 MHz.
IF frequency including filter (IF=Fin-LO1-382.32)	10.700 MHz.
IF FILTER BANDWIDTH	30 KHz.
Beacon injection oscillator (BO)	10.630 MHz.
3XLO2 injection frequency	125.790 MHz.
1st upconversion frequency (FI=3XLO2+IF)	136.490 MHz.
18X3XLO2 injection frequency	2264.220 MHz.
2nd upconversion frequency (Fout=54XLO2+FI)	2400.710 MHz.
OUTPUT FREQUENCY FROM THE S BAND TRANSPONDER (Fout=Fin+56XLO2-382.32=57XLO2+IF)	2400.710 MHz.
BEACON OUTPUT FREQUENCY (FB=57XLO2+BO)	2400.640 MHz.

Modulation

The transponder is a soft limiting type that will be suitable for use by one or two NBFM signal or four simultaneous SSB signals. The nonlinearity introduced by the amplifier and limiter does not limit its usefulness to CW or FM only. Since the received signal to noise ratio will be less than 20 dB, SSB can be used thru the transponder as the intermod products are generally below 20 dB and thus below the received noise level. This technique is being used sucessfully in the Mode-L transponder on OSCAR-10.

General Comments On The Transponder Use

It is necessary to point out that this transponder is intended for purely experimental and educational purposes. Through using it, it is hoped that the satellite users will gain operational and technical experience in receiving microwave frequencies from an amateur radio satellite.

The transponder can be used for normal voice and data communications via narrow band FM, CW or SSB modulation. Doppler shifts can be quite significant, up to 50 KHz. depending where the satellite is in its orbit. Doppler should be a minimun at apogee, and it is planned that the transponder or beacon will operate only at apogee.

Receiving SSB and CW requires less receiver bandwidth than NBFM. With reduced bandwidth, the required receiver sensitivity or antenna size decreases for a given signal to noise ratio. However, SSB and CW reception at 2401 MHz. requires excellent receiver frequency control via a crystal controlled converter. With NBFM modulation, the ground station receiver could use AFC to overcome receiver drift and doppler.

Mechanical Packaging

The transponder is packaged in two separate housings.

PACKAGE 1   S-TX

This module contains the following:
S-Band mixer, S-Band amplifier, and 18X multiplier. It is mounted at the arm end next to Mode-B receiver. Package size is 1Ø.Ø" X 2.23" X 3.ØØ".

PACKAGE 2   S-IF

This module contains the following:
VHF stages, 1ØVDC converter, Beacon generator, 42 MHz. oscillators, 3X multiplier, and IHU interface. It is mounted on top of the Mode-B transmitter. Package size is 13.85 X 4.12" X 1.5".

Development Team

The development of this Mode-S transponder has been shared among many amateurs. The specific task leaders are listed below:

TASK AREA	RESPONSIBLE PERSONS	
Project Coordination, Construction	Bill, McCaa,	KØRZ
S-Band Housing	Ray Uberecken,	AAØL
S-Band Miltiplier, and Mixer	Steve Ernst,	WBØWED
Local Oscillators and 3X Mulitplier	Chuck Hill,	KYØS
VHF Mixers, IF Amp, Control,	Gordon Hardman,	KE3D
Placement, Spacecraft Interface	Jan King,	W3GEY
S-Band RF Power Amplifier	Chip Angle,	N6CA
S-Band Antenna	Hans Van de G.	ZS6AKV

"MICROWAVE OUTLOOK"

by

KENT BRITAIN, WA5VJB

DATA FOR LOOP YAGI FOR USE AT 3456 MHZ

BOOM DIAMETER .5 IN
ELEMENT WIDTH .125 IN
ELEMENT THICKNESS .015 IN
REFLENCTING SCREEN 1.687 X 2.062

ALL DIMENSIONS IN INCHES

ELEMENT	DISTANCE FROM SCREEN	LENGTH (CIRCUMFERENCE)
R1	1.162	3.768
DE	1.518	3.596
D 1	1.938	3.214
D 2	2.25	3.214
D 3	2.917	3.214
D 4	3.585	3.214
D 5	4.053	3.214
D 6	4.92	3.214
D 7	6.255	3.214
D 8	7.59	3.214
D 9	8.924	3.214
D 10	10.26	3.214
D 11	11.594	3.214
D 12	12.93	3.117
D 13	14.265	3.117
D 14	15.599	3.117
D 15	16.935	3.117
D 16	18.269	3.117
D 17	19.605	3.117
D 18	20.94	3.117
D 19	22.275	3
D 20	23.61	3
D 21	24.945	3
D 22	26.28	3
D 23	27.615	3
D 24	28.95	3
D 25	30.285	3
D 26	31.619	3
D 27	32.954	3
D 28	34.29	3
D 29	35.625	3
D 30	36.96	3
D 31	38.295	3
D 32	39.63	3
D 33	40.965	3
D 34	42.3	3
D 35	43.635	3
D 36	44.97	3

Ok

NOTES BY KENT BRITAIN, WA5VJB

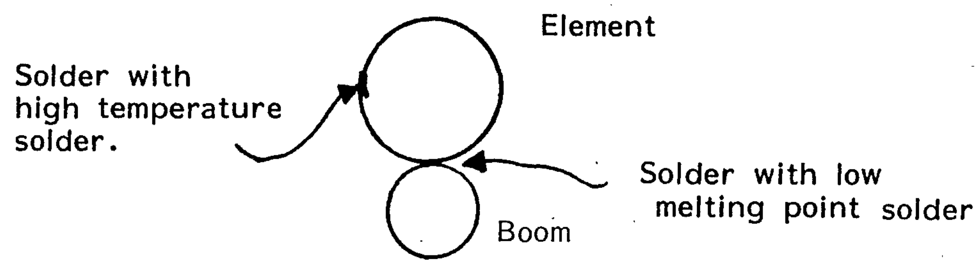
D 37 ⟶ 57 2.95" spaced every 1.34 inches

Boom is 1/2" copper water pipe.

Elements are .015" sheet hobby brass cut on a paper cutter to 1/8" wide.

A second reflector the same size as R_1 was used in place of the screen.

Within each batch of directors (same circumference) some will be a little fat and others a bit thin. Use the fat ones closer to the driven element and the thin ones farther down the boom. This will help maintain the log taper.

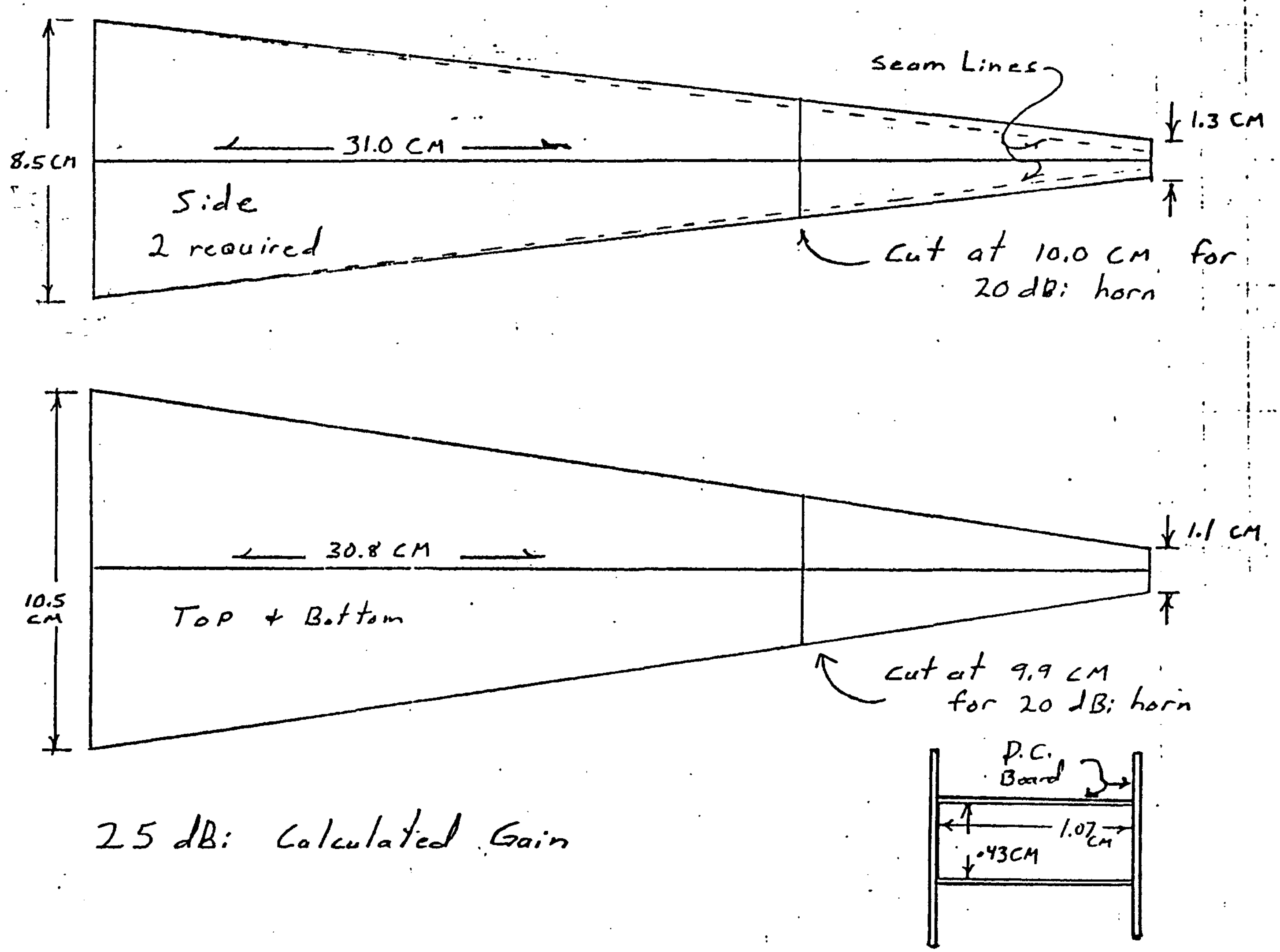


Clamp the boom in a vice just below the last element installed. Using the vice as a heat sink will help keep you from melting off loops while trying to solder on the next one. Also, hold the element by the lap joint with pliers or forecepts while soldering to the boom.

I found I had to back R_1's spacing to 1.1 inches to get an acceptable SWR.

48 element and 60 element versions demonstrated 21.0 dBi and 21.5dBI respectively at the Central States VHF Society antenna contest.

24 GHz Horn



25 dBi Calculated Gain

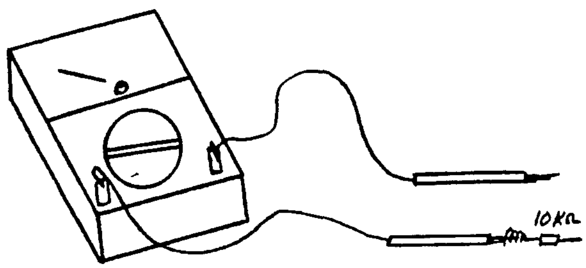
Waveguide Size - Ref: Electronic & Radio Engineering
4th Edition; 1955, McGraw Hill

TESTING GaAs FETS

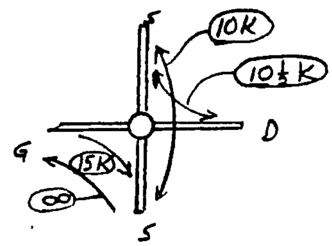
Kent Britain, WA5VJB

When Al Ward, WB5LUA, suggested checking a GaAs FET with an Ohm meter, I gasped!

Use a regular VOM powered by a 1½ volt battery (no 120 VAC powered DVM's!) and a 10 KΩ resistor. Also, don't forget usual static precautions.



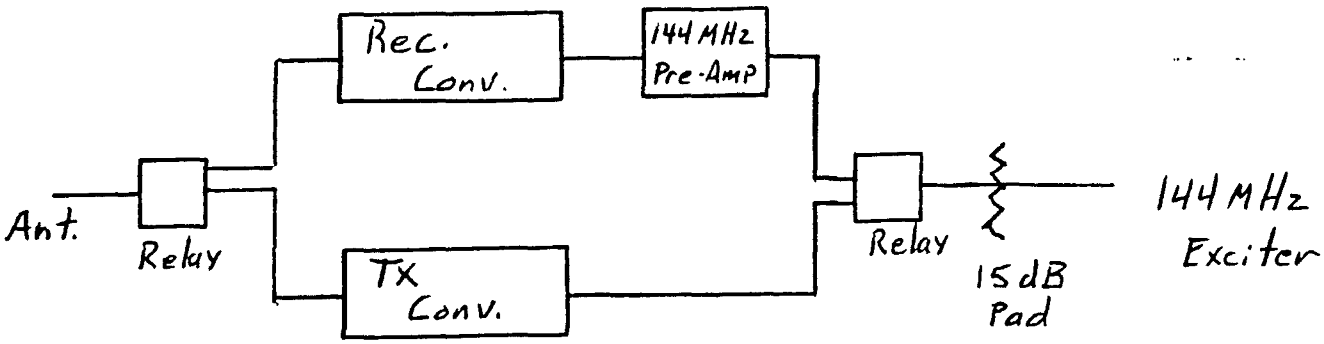
Typical readings



The .01 Ma of current used doesn't bother the gate, and the 1½V is well below all breakdown voltages. With different companies using different designations for the Gate, this test sure can be useful.

PROTECTIVE UHF CONVERTERS

Kent Britain, WA5VJB



Many of the new 10 GHz, 2304 MHz, and 1296 transverters are now using GaAs FET mixers. Brief accidental transmissions back into the receive converters are fatal.

After several friends had lost their Microline 13 cm receive converters, I put an old 2-meter MOSFET pre-amp on the output of my 2304 MHz receive converter. This was followed by a T/R relay and the homebrew 15 dB pad which is now used on both transmitte and receiver.

If you somehow get enough power through the 15 dB pad to blow anything, all you lose is a cheap MOSFET.

"PRACTICAL MICROWAVE TECHNIQUES"

BY

KEITH ERICSON, KØKE

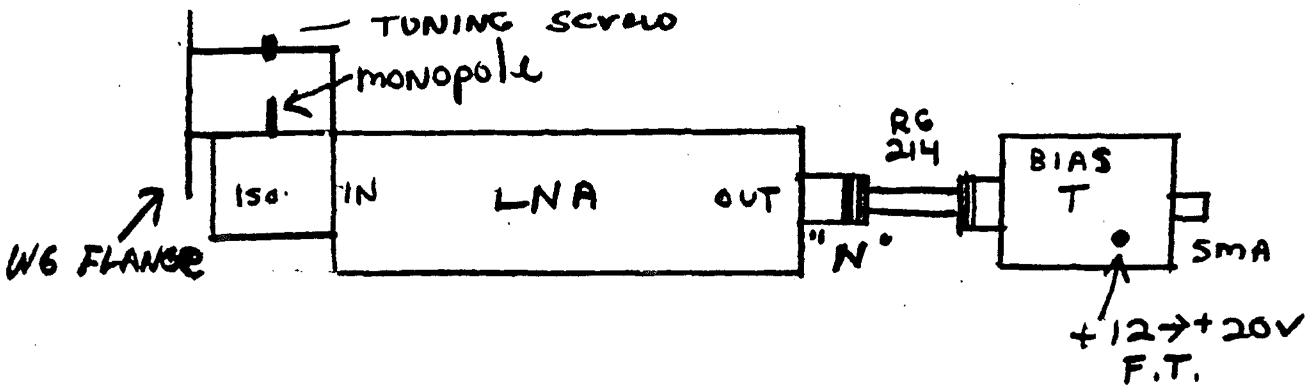
TVRO LAN's ON 3456

Keith Ericson, KØKE.

Many available surplus -- 120° Kelvin = 1.5 db N Figure

35 db gain

isolator on input to maintain impedance match. (If isolator is removed and voltage placed on LNA, it WILL oscillate). i.e., unloaded input



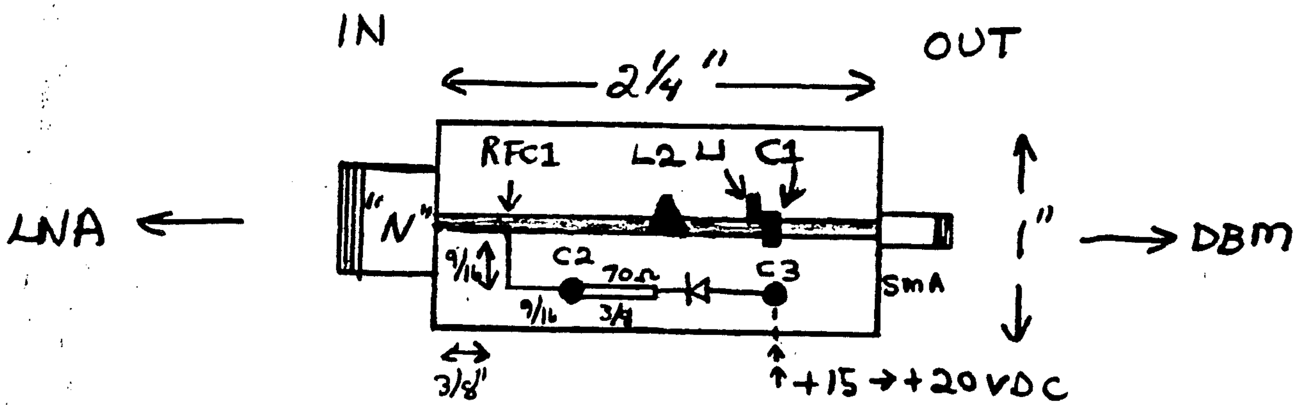
4 stages - 2 gaasfet, 2 bipolar Carefully remove isolate plus WB and drill plus tap for SMA input.

TO USE ON TRANSMITTER!

Feed output of DBM through pad (20 - 25 db of pad) plus filter into LNA. (Output of DBM nominal -10 dbm. I have seen +8 → +10 dbm output in this mode though there appears to be gain compression.

BIAS INSERTION TEE

For use with TRVO LNAs on 3456 MHz. Used to supply voltage up coax to LNA. Use 50 ohm line through



C1 - chip cap for DC isolation -10 pf (blocker)
C2 - Feed through bypass 100 pf
C3 - Feed through bypass 500 pf

L1 - 70 ohm stub 1/8" long for matching
L2 - Reactive matching foil

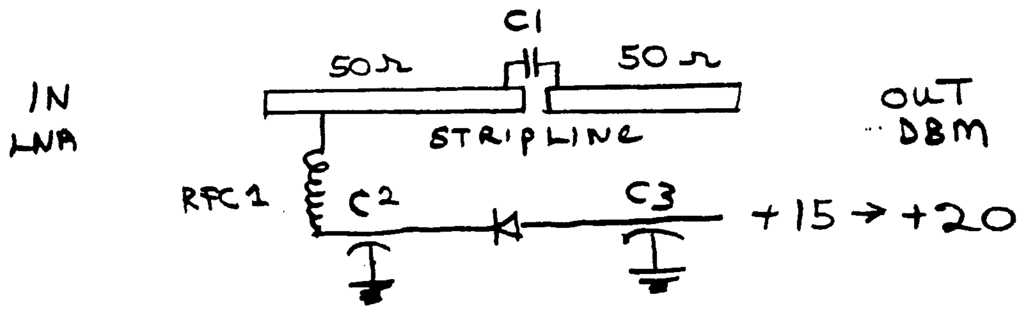
D1 - IN4005 - polarity protection diode.

RFC1 - 1/4λ stub for isolation of RF from D.C.
150 ohm or higher line width, narrow line more X_L

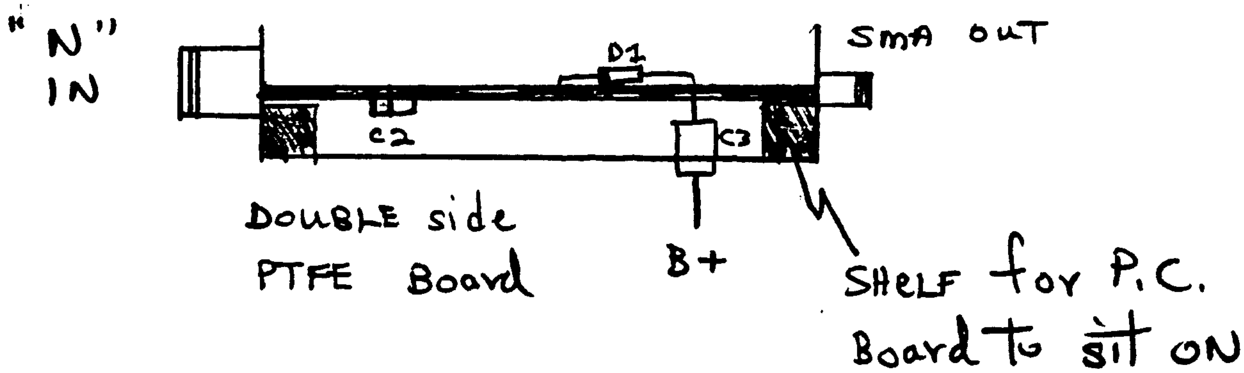
Use 1/32" (.031) teflon board -50 ohm line width .078" double sided.

Insertion loss - .5 db

SCHEMATIC - BIAS TEE



SIDE VIEW



Could be built in small diecast bud box.

Cable Losses at 3456 MHz

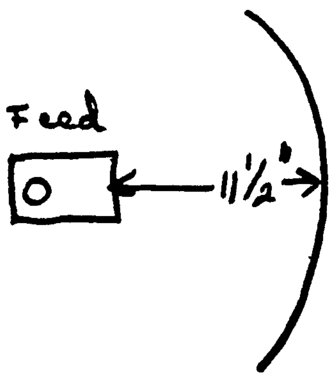
RG213	20 db/100 ft.
RG58	40 db/100 ft.
.141 coax	26 db/100 ft.
1/2" LDF	4.6 db/100 ft.
1/2" Superflex	7.5 db/100 ft.
7/8" LDF	2.6 db/100 ft.
HJ4 1/2" air	5.4 db/100 ft.
HJ5 7/8" air	2.6 db/100 ft.

PRACTICAL 3456 MHz ANTENNA

Preliminary investigations show a snow sled can privde useable gain at this frequenty. 18 --- 20 dbi.

Only approximates a useful surface.

Outer 3" of snow sled rise too steeply. Dish is more like .6 --- .7 f/d if using center 18" dish.

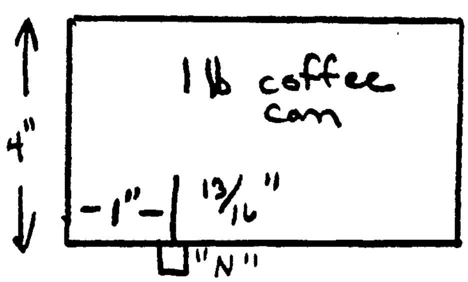


11½" prored best for both feeds

>10 db gain over feed alone.

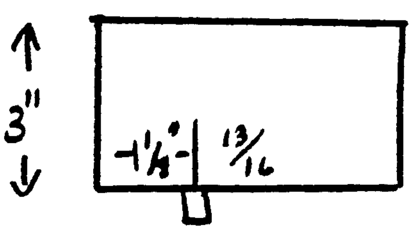
Several feeds tried:

A.



Provides about 2 db more gain than bean can; better illumination, lower side lobes; i.e., cleaner pattern.

B.



Lower gain.

LOOP YAG - 3456 MHz.

DATA FOR LOOP YAGI FOR USE AT 3454 MHZ
BOOM DIAMETER .5 IN
ELEMENT WIDTH .2 IN
ELEMENT THICKNESS .02 IN
REFLECTING SCREEN 1.687 X 2.062

ALL DIMENSIONS IN INCHES

ELEMENT	DISTANCE FROM SCREEN	LENGTH (CIRCUMFERENCE)
R1	1.162	3.741
DE	1.510	3.57
D 1	1.930	3.191
D 2	2.25	3.191
D 3	2.917	3.191
D 4	3.584	3.191
D 5	4.053	3.191
D 6	4.92	3.191
D 7	6.255	3.191
D 8	7.59	3.191
D 9	8.925	3.191
D 10	10.26	3.191
D 11	11.595	3.191
D 12	12.93	3.095
D 13	14.265	3.095
D 14	15.599	3.095
D 15	16.935	3.095
D 16	18.269	3.095
D 17	19.605	3.095
D 18	20.94	3.095
D 19	22.275	2.979
D 20	23.61	2.979
D 21	24.945	2.979
D 22	26.28	2.979
D 23	27.615	2.979
D 24	28.95	2.979
D 25	30.285	2.979
D 26	31.62	2.979
D 27	32.955	2.979
D 28	34.29	2.979
D 29	35.625	2.979
D 30	36.96	2.979
D 31	38.295	2.979
D 32	39.63	2.979
D 33	40.965	2.979
D 34	42.3	2.979
D 35	43.635	2.979
D 36	44.97	2.979

DL6WU ANTENNA DESIGN

Program written by Jerry Haigwood, KY4Z, and Bob Stein, W6NBI - Based on article 'Extremely Long Yagi Antennas' by Gunter Hoch, DL6WU; VHF Communications, 3/82

DESIGNED FOR : KOKE July '86

CENTER FREQUENCY = 2304 MHz

GAIN = 16.7 dBd

DRIVE IMPEDANCE = 200 OHMS (APPROX), WITH FOLDED DIPOLE D.E.

BOOM LENGTH:
REFLECTOR TO
LAST DIRECTOR = 3.95 FT = 47.4 IN. = 120.5 CM

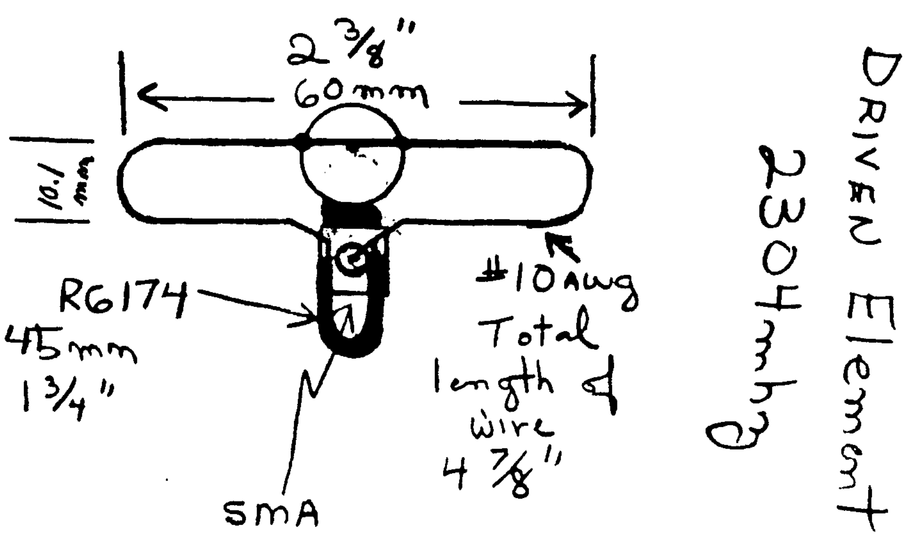
BOOM DIAMETER = 0.375 IN. = 0.95 CM

ELEMENT DIAMETERS:
DRIVEN = 0.102 IN. = 0.26 CM #10 AWG
PARASITIC = 0.102 IN. = 0.26 CM

Elements pass through and are NOT insulated from a metal boom

CUMULATIVE SPACING				ELEMENT LENGTH	
CM	IN.			CM	IN.
Ref	Ref	REFL	-----------¦-----------	6.78	2.668
2.81	1.107	D.E.	=========¦=========	5.96	2.347
3.87	1.524	D 1	---------¦---------	5.91	2.326
6.03	2.374	D 2	---------¦---------	5.82	2.290
8.83	3.477	D 3	---------¦---------	5.73	2.255
12.09	4.759	D 4	---------¦---------	5.65	2.223
15.70	6.180	D 5	---------¦---------	5.58	2.196
19.60	7.715	D 6	---------¦---------	5.52	2.172
23.74	9.346	D 7	---------¦---------	5.47	2.152
28.09	11.061	D 8	---------¦---------	5.42	2.134
32.64	12.849	D 9	---------¦---------	5.38	2.118
37.34	14.702	D 10	---------¦---------	5.34	2.104

42.20	16.616	D 11	---------¦---------	5.31	2.091
47.20	18.583	D 12	---------¦---------	5.28	2.080
52.32	20.600	D 13	---------¦---------	5.25	2.069
57.57	22.664	D 14	---------¦---------	5.23	2.059
62.81	24.728	D 15	---------¦---------	5.21	2.050
68.05	26.791	D 16	---------¦---------	5.18	2.041
73.29	28.855	D 17	---------¦---------	5.16	2.033
78.53	30.918	D 18	---------¦---------	5.14	2.025
83.77	32.982	D 19	---------¦---------	5.13	2.018
89.02	35.046	D 20	---------¦---------	5.11	2.011
94.26	37.109	D 21	---------¦---------	5.09	2.005
99.50	39.173	D 22	---------¦---------	5.08	1.998
104.74	41.236	D 23	---------¦---------	5.06	1.993
109.98	43.300	D 24	---------¦---------	5.05	1.987
115.22	45.364	D 25	---------¦---------	5.03	1.981
120.46	47.427	D 26	---------¦---------	5.02	1.976



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GAIN = 16.7 dBd

DRIVE IMPEDANCE = 200 OHMS (APPROX), WITH FOLDED DIPOLE D.E.

BOOM LENGTH:
REFLECTOR TO
LAST DIRECTOR = 3.95 FT = 47.4 IN. = 120.5 CM

BOOM DIAMETER = 0.375 IN. = 0.95 CM

ELEMENT DIAMETERS:
DRIVEN = 0.102 IN. = 0.26 CM
PARASITIC = 0.102 IN. = 0.26 CM #10 AWG

Elements pass through and are insulated from a metal boom

CUMULATIVE SPACING CM	CUMULATIVE SPACING IN.			ELEMENT LENGTH CM	ELEMENT LENGTH IN.
Ref	Ref	REFL	-----------¦-----------	6.44	2.537
2.81	1.107	D.E.	=========¦=========	5.96	2.347
3.87	1.524	D 1	---------¦---------	5.57	2.195
6.03	2.374	D 2	---------¦---------	5.48	2.159
8.83	3.477	D 3	---------¦---------	5.39	2.124
12.09	4.759	D 4	---------¦---------	5.31	2.092
15.70	6.180	D 5	---------¦---------	5.24	2.064
19.60	7.715	D 6	---------¦---------	5.18	2.041
23.74	9.346	D 7	---------¦---------	5.13	2.020
28.09	11.061	D 8	---------¦---------	5.09	2.003
32.64	12.849	D 9	---------¦---------	5.05	1.987
37.34	14.702	D 10	---------¦---------	5.01	1.973

42.20	16.616	D 11	---------¦---------	4.98	1.960
47.20	18.583	D 12	---------¦---------	4.95	1.948
52.32	20.600	D 13	---------¦---------	4.92	1.938
57.57	22.664	D 14	---------¦---------	4.90	1.928
62.81	24.728	D 15	---------¦---------	4.87	1.918
68.05	26.791	D 16	---------¦---------	4.85	1.910
73.29	28.855	D 17	---------¦---------	4.83	1.902
78.53	30.918	D 18	---------¦---------	4.81	1.894
83.77	32.982	D 19	---------¦---------	4.79	1.887
89.02	35.046	D 20	---------¦---------	4.78	1.880
94.26	37.109	D 21	---------¦---------	4.76	1.873
99.50	39.173	D 22	---------¦---------	4.74	1.867
104.74	41.236	D 23	---------¦---------	4.73	1.861
109.98	43.300	D 24	---------¦---------	4.71	1.856
115.22	45.364	D 25	---------¦---------	4.70	1.850
120.46	47.427	D 26	---------¦---------	4.69	1.845

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DESIGNED FOR : KOKE July '86

CENTER FREQUENCY = 2304 MHz

GAIN = 16.7 dBd

DRIVE IMPEDANCE = 200 OHMS (APPROX), WITH FOLDED DIPOLE D.E.

BOOM LENGTH:
REFLECTOR TO
LAST DIRECTOR = 3.95 FT = 47.4 IN. = 120.5 CM

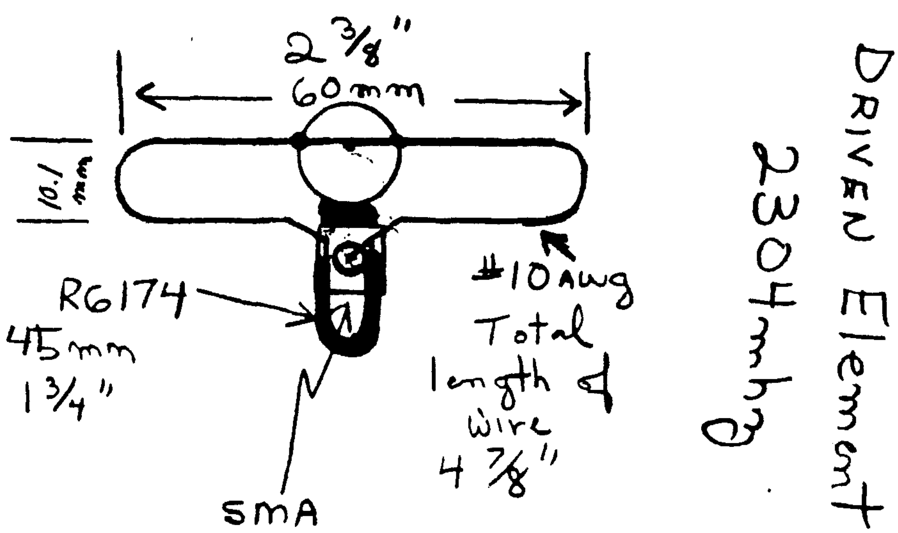
ELEMENT DIAMETERS:
DRIVEN = 0.102 IN. = 0.26 CM
PARASITIC = 0.102 IN. = 0.26 CM #10 AWG

* A non-metallic boom is used ---OR---
elements are mounted on insulators above or below a metal boom *
with metal-to-metal spacing greater than the boom radius

CUMULATIVE SPACING				ELEMENT LENGTH	
CM	IN.			CM	IN.
Ref	Ref	REFL	----------|----------	6.21	2.443
2.81	1.107	D.E.	=========|=========	5.96	2.347
3.87	1.524	D 1	--------|--------	5.34	2.101
6.03	2.374	D 2	--------|--------	5.25	2.065
8.83	3.477	D 3	--------|--------	5.16	2.030
12.09	4.759	D 4	--------|--------	5.08	1.998
15.70	6.180	D 5	--------|--------	5.01	1.971
19.60	7.715	D 6	--------|--------	4.95	1.947
23.74	9.346	D 7	--------|--------	4.89	1.927
28.09	11.061	D 8	--------|--------	4.85	1.909
32.64	12.849	D 9	--------|--------	4.81	1.893
37.34	14.702	D 10	--------|--------	4.77	1.879

42.20	16.616	D 11	---------¦---------	4.74	1.866
47.20	18.583	D 12	---------¦---------	4.71	1.855
52.32	20.600	D 13	---------¦---------	4.68	1.844
57.57	22.664	D 14	---------¦---------	4.66	1.834
62.81	24.728	D 15	---------¦---------	4.63	1.825
68.05	26.791	D 16	---------¦---------	4.61	1.816
73.29	28.855	D 17	---------¦---------	4.59	1.808
78.53	30.918	D 18	---------¦---------	4.57	1.800
83.77	32.982	D 19	---------¦---------	4.55	1.793
89.02	35.046	D 20	---------¦---------	4.54	1.786
94.26	37.109	D 21	---------¦---------	4.52	1.780
99.50	39.173	D 22	---------¦---------	4.50	1.773
104.74	41.236	D 23	---------¦---------	4.49	1.768
109.98	43.300	D 24	---------¦---------	4.48	1.762
115.22	45.364	D 25	---------¦---------	4.46	1.756
120.46	47.427	D 26	---------¦---------	4.45	1.751

172.88	68.063	D 36	---------¦---------	4.91	1.933
178.12	70.127	D 37	---------¦---------	4.90	1.929
183.36	72.190	D 38	---------¦---------	4.89	1.925
188.60	74.254	D 39	---------¦---------	4.88	1.922
193.85	76.318	D 40	---------¦---------	4.87	1.918
199.09	78.381	D 41	---------¦---------	4.86	1.915
204.33	80.445	D 42	---------¦---------	4.86	1.912
209.57	82.508	D 43	---------¦---------	4.85	1.909
214.81	84.572	D 44	---------¦---------	4.84	1.906
220.05	86.636	D 45	---------¦---------	4.83	1.903
225.30	88.699	D 46	---------¦---------	4.83	1.900
230.54	90.763	D 47	---------¦---------	4.82	1.897
235.78	92.826	D 48	---------¦---------	4.81	1.894
241.02	94.890	D 49	---------¦---------	4.80	1.891



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DESIGNED FOR : KOKE July '86

CENTER FREQUENCY = 2304 MHz

GAIN = 19.1 dBd

DRIVE IMPEDANCE = 200 OHMS (APPROX), WITH FOLDED DIPOLE D.E.

BOOM LENGTH:
REFLECTOR TO
LAST DIRECTOR = 7.91 FT = 94.9 IN. = 241.0 CM

BOOM DIAMETER = 0.375 IN. = 0.95 CM

ELEMENT DIAMETERS:
DRIVEN = 0.102 IN. = 0.26 CM
PARASITIC = 0.102 IN. = 0.26 CM *10 AWG

Elements pass through and are NOT insulated from a metal boom

CUMULATIVE SPACING CM	CUMULATIVE SPACING IN.			ELEMENT LENGTH CM	ELEMENT LENGTH IN.
Ref	Ref	REFL	-----------¦-----------	6.78	2.668
2.81	1.107	D.E.	=========¦=========	5.96	2.347
3.87	1.524	D 1	---------¦---------	5.91	2.326
6.03	2.374	D 2	---------¦---------	5.82	2.290
8.83	3.477	D 3	---------¦---------	5.73	2.255
12.09	4.759	D 4	---------¦---------	5.65	2.223
15.70	6.180	D 5	---------¦---------	5.58	2.196
19.60	7.715	D 6	---------¦---------	5.52	2.172
23.74	9.346	D 7	---------¦---------	5.47	2.152
28.09	11.061	D 8	---------¦---------	5.42	2.134
32.64	12.849	D 9	---------¦---------	5.38	2.118
37.34	14.702	D 10	---------¦---------	5.34	2.104

42.20	16.616	D 11	---------¦---------	5.31	2.091
47.20	18.583	D 12	---------¦---------	5.28	2.080
52.32	20.600	D 13	---------¦---------	5.25	2.069
57.57	22.664	D 14	---------¦---------	5.23	2.059
62.81	24.728	D 15	---------¦---------	5.21	2.050
68.05	26.791	D 16	---------¦---------	5.18	2.041
73.29	28.855	D 17	---------¦---------	5.16	2.033
78.53	30.918	D 18	---------¦---------	5.14	2.025
83.77	32.982	D 19	---------¦---------	5.13	2.018
89.02	35.046	D 20	---------¦---------	5.11	2.011
94.26	37.109	D 21	---------¦---------	5.09	2.005
99.50	39.173	D 22	---------¦---------	5.08	1.998
104.74	41.236	D 23	---------¦---------	5.06	1.993
109.98	43.300	D 24	---------¦---------	5.05	1.987
115.22	45.364	D 25	---------¦---------	5.03	1.981
120.46	47.427	D 26	---------¦---------	5.02	1.976
125.71	49.491	D 27	---------¦---------	5.01	1.971
130.95	51.554	D 28	---------¦---------	4.99	1.966
136.19	53.618	D 29	---------¦---------	4.98	1.961
141.43	55.682	D 30	---------¦---------	4.97	1.957
146.67	57.745	D 31	---------¦---------	4.96	1.953
151.91	59.809	D 32	---------¦---------	4.95	1.948
157.16	61.872	D 33	---------¦---------	4.94	1.944
162.40	63.936	D 34	---------¦---------	4.93	1.940
167.64	66.000	D 35	---------¦---------	4.92	1.936

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BOOM LENGTH:
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LAST DIRECTOR = 7.91 FT = 94.9 IN. = 241.0 CM

BOOM DIAMETER = 0.375 IN. = 0.95 CM

ELEMENT DIAMETERS:
DRIVEN = 0.102 IN. = 0.26 CM
PARASITIC = 0.102 IN. = 0.26 CM #10 AWG

* Elements pass through and are insulated from a metal boom *

CUMULATIVE SPACING			ELEMENT LENGTH	
CM	IN.		CM	IN.
Ref	Ref	REFL	6.44	2.537
2.81	1.107	D.E.	5.96	2.347
3.87	1.524	D 1	5.57	2.195
6.03	2.374	D 2	5.48	2.159
8.83	3.477	D 3	5.39	2.124
12.09	4.759	D 4	5.31	2.092
15.70	6.180	D 5	5.24	2.064
19.60	7.715	D 6	5.18	2.041
23.74	9.346	D 7	5.13	2.020
28.09	11.061	D 8	5.09	2.003
32.64	12.849	D 9	5.05	1.987
37.34	14.702	D 10	5.01	1.973

42.20	16.616	D 11	---------¦---------	4.98	1.960
47.20	18.583	D 12	---------¦---------	4.95	1.948
52.32	20.600	D 13	---------¦---------	4.92	1.938
57.57	22.664	D 14	---------¦---------	4.90	1.928
62.81	24.728	D 15	---------¦---------	4.87	1.918
68.05	26.791	D 16	---------¦---------	4.85	1.910
73.29	28.855	D 17	---------¦---------	4.83	1.902
78.53	30.918	D 18	---------¦---------	4.81	1.894
83.77	32.982	D 19	---------¦---------	4.79	1.887
89.02	35.046	D 20	---------¦---------	4.78	1.880
94.26	37.109	D 21	---------¦---------	4.76	1.873
99.50	39.173	D 22	---------¦---------	4.74	1.867
104.74	41.236	D 23	---------¦---------	4.73	1.861
109.98	43.300	D 24	---------¦---------	4.71	1.856
115.22	45.364	D 25	---------¦---------	4.70	1.850
120.46	47.427	D 26	---------¦---------	4.69	1.845
125.71	49.491	D 27	---------¦---------	4.67	1.840
130.95	51.554	D 28	---------¦---------	4.66	1.835
136.19	53.618	D 29	---------¦---------	4.65	1.830
141.43	55.682	D 30	---------¦---------	4.64	1.826
146.67	57.745	D 31	---------¦---------	4.63	1.821
151.91	59.809	D 32	---------¦---------	4.62	1.817
157.16	61.872	D 33	---------¦---------	4.60	1.813
162.40	63.936	D 34	---------¦---------	4.59	1.809
167.64	66.000	D 35	---------¦---------	4.58	1.805

172.88	68.063	D 36	---------¦---------	4.58	1.801
178.12	70.127	D 37	---------¦---------	4.57	1.798
183.36	72.190	D 38	---------¦---------	4.56	1.794
188.60	74.254	D 39	---------¦---------	4.55	1.791
193.85	76.318	D 40	---------¦---------	4.54	1.787
199.09	78.381	D 41	---------¦---------	4.53	1.784
204.33	80.445	D 42	---------¦---------	4.52	1.781
209.57	82.508	D 43	---------¦---------	4.51	1.778
214.81	84.572	D 44	---------¦---------	4.51	1.774
220.05	86.636	D 45	---------¦---------	4.50	1.771
225.30	88.699	D 46	---------¦---------	4.49	1.768
230.54	90.763	D 47	---------¦---------	4.48	1.766
235.78	92.826	D 48	---------¦---------	4.48	1.763
241.02	94.890	D 49	---------¦---------	4.47	1.760

DL6WU ANTENNA DESIGN

Program written by Jerry Haigwood, KY4Z, and Bob Stein, W6NBI - Based on article 'Extremely Long Yagi Antennas' by Gunter Hoch, DL6WU; VHF Communications, 3/82

DESIGNED FOR : KOKE July '86

CENTER FREQUENCY = 2304 MHz

GAIN = 19.1 dBd

DRIVE IMPEDANCE = 200 OHMS (APPROX), WITH FOLDED DIPOLE D.E.

BOOM LENGTH:
REFLECTOR TO
LAST DIRECTOR = 7.91 FT = 94.9 IN. = 241.0 CM

ELEMENT DIAMETERS:
DRIVEN = 0.102 IN. = 0.26 CM #10 AWG
PARASITIC = 0.102 IN. = 0.26 CM

* A non-metallic boom is used ---OR---
elements are mounted on insulators above or below a metal boom *
with metal-to-metal spacing greater than the boom radius

CUMULATIVE SPACING				ELEMENT LENGTH	
CM	IN.			CM	IN.
Ref	Ref	REFL	----------¦----------	6.21	2.443
2.81	1.107	D.E.	=========¦=========	5.96	2.347
3.87	1.524	D 1	--------¦--------	5.34	2.101
6.03	2.374	D 2	--------¦--------	5.25	2.065
8.83	3.477	D 3	--------¦--------	5.16	2.030
12.09	4.759	D 4	--------¦--------	5.08	1.998
15.70	6.180	D 5	--------¦--------	5.01	1.971
19.60	7.715	D 6	--------¦--------	4.95	1.947
23.74	9.346	D 7	--------¦--------	4.89	1.927
28.09	11.061	D 8	--------¦--------	4.85	1.909
32.64	12.849	D 9	--------¦--------	4.81	1.893
37.34	14.702	D 10	--------¦--------	4.77	1.879

42.20	16.616	D 11	---------¦---------	4.74	1.866
47.20	18.583	D 12	---------¦---------	4.71	1.855
52.32	20.600	D 13	---------¦---------	4.68	1.844
57.57	22.664	D 14	---------¦---------	4.66	1.834
62.81	24.728	D 15	---------¦---------	4.63	1.825
68.05	26.791	D 16	---------¦---------	4.61	1.816
73.29	28.855	D 17	---------¦---------	4.59	1.808
78.53	30.918	D 18	---------¦---------	4.57	1.800
83.77	32.982	D 19	---------¦---------	4.55	1.793
89.02	35.046	D 20	---------¦---------	4.54	1.786
94.26	37.109	D 21	---------¦---------	4.52	1.780
99.50	39.173	D 22	---------¦---------	4.50	1.773
104.74	41.236	D 23	---------¦---------	4.49	1.768
109.98	43.300	D 24	---------¦---------	4.48	1.762
115.22	45.364	D 25	---------¦---------	4.46	1.756
120.46	47.427	D 26	---------¦---------	4.45	1.751
125.71	49.491	D 27	---------¦---------	4.43	1.746
130.95	51.554	D 28	---------¦---------	4.42	1.741
136.19	53.618	D 29	---------¦---------	4.41	1.736
141.43	55.682	D 30	---------¦---------	4.40	1.732
146.67	57.745	D 31	---------¦---------	4.39	1.728
151.91	59.809	D 32	---------¦---------	4.38	1.723
157.16	61.872	D 33	---------¦---------	4.37	1.719
162.40	63.936	D 34	---------¦---------	4.36	1.715
167.64	66.000	D 35	---------¦---------	4.35	1.711

172.88	68.063	D 36	---------¦---------	4.34	1.708
178.12	70.127	D 37	---------¦---------	4.33	1.704
183.36	72.190	D 38	---------¦---------	4.32	1.700
188.60	74.254	D 39	---------¦---------	4.31	1.697
193.85	76.318	D 40	---------¦---------	4.30	1.693
199.09	78.381	D 41	---------¦---------	4.29	1.690
204.33	80.445	D 42	---------¦---------	4.28	1.687
209.57	82.508	D 43	---------¦---------	4.28	1.684
214.81	84.572	D 44	---------¦---------	4.27	1.681
220.05	86.636	D 45	---------¦---------	4.26	1.678
225.30	88.699	D 46	---------¦---------	4.25	1.675
230.54	90.763	D 47	---------¦---------	4.25	1.672
235.78	92.826	D 48	---------¦---------	4.24	1.669
241.02	94.890	D 49	---------¦---------	4.23	1.666

```
9 CLS
10 'THIS PROGRAM CALCULATES THE WIDTH OF A MICROSTRIP LINE
20 'FOR A GIVEN IMPEDANCE OF WILL CALCULATE THE IMPEDANCE
30 'OF A MICROSTRIP LINE OF A GIVEN WIDTH.
40 '
50 'WRITTEN BY C. SWEDBLOM,WA6EXV 12 JUNE 1979
60 'MODIFIED BY DICK KOLBLY, K6HIJ 16 SEPT 1979
70 ' DIELECTRIC CONSTANTS ADDED K6HIJ 10 MARCH 1981
80 ' W=WIDTH OF MICROSTRIP LINE
90 ' H=THICKNESS OF SUBSTRATE MATERIAL
100 ' T=THICKNESS OF MICROSTRIP LINE
110 ' F=FREQUENCY
120 ' E=DIELECTRIC CONSTANT OF SUBSTRATE MATERIAL
130 ' E1=DIELECTRIC CONSTANT AT DC
140 ' E2=DIELECTRIC CONSTANT AT FO
150 ' Z=CHARACTERISTIC IMPEDANCE OF MICROSTRIP
160 ' Z1=CHARTACTERISTIC IMPEDANCE AT DC
170 ' Z2=DESIRED IMPEDANCE
180 ' L=WAVELENGTH
190 ' D1=IMPEDANCE ERROR FACTOR
200 '
210 D1=.0001
220 PI=3.14159265#
230 PRINT "1 OZ CU=.0013 IN, 2 OZ CU=.0027 IN
240 PRINT "(1) AIR             (e=1.00)"
250 PRINT "(2) G10 FIBERGLASS  (e=4.80)"
260 PRINT "(3) TEFLON/GLASS    (e=2.55)"
270 PRINT "(4) REXOLITE        (e=2.54)"
280 PRINT "(5) TEFLON          (e=2.10)"
290 PRINT "(6) FORMICA XX      (e=4.04)"
295 PRINT "(7) DUROID          (e=2.23)"
300 PRINT "(8) OTHER"K:IF K=0 OR K=8 THEN 310 ELSE 320
310 INPUT "TYPE OF MATERIAL AND ER";A$,E
320 IF K=1 THEN A$="AIR":E=1!
330 IF K=2 THEN A$="G10":E=4.8
340 IF K=3 THEN A$="TEFLON/GLASS":E=2.55
350 IF K=4 THEN A$="REXOLITE":E=2.54
360 IF K=5 THEN A$="TEFLON":E=2.1
370 IF K=6 THEN A$="FORMICA XX":E=4.04
375 IF K=7 THEN A$="DUROID":E=2.23
380 IF K<0 OR K>8 THEN 300
390 INPUT "FREQUENCY (GHZ)";F
400 INPUT "SUBSTRATE THICKNESS";H
410 INPUT "LINE THICKNESS";T
420 PRINT "DO YOU WANT"
430 PRINT
440 PRINT "1.  MICROSTRIP WIDTH"
450 PRINT "2.  IMPEDANCE OF MICROSTRIP LINE?"
460 PRINT
470 INPUT X
480 IF X=2 THEN 680
490 INPUT "DESIRED IMPEDANCE=";Z2
500 W=1
510 GOSUB 740
520 GOSUB 820
```

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```
530 PRINT Z
540 R=Z/Z2
550 IF ABS((1-R)/(1+R))<=D1 THEN 620
560 ' CALCULATE NEW WIDTH
570 W=W*R*R
580 GOTO 510
590 '
600 'ADJUST WIDTH FOR THICKNESS OF LINE
610 '
620 GOSUB 1010
630 W=W-W1
640 GOTO 1090
650 '
660 'CALCULATE IMPEDANCE FROM LINE WIDTH
670 '
680 INPUT "LINE WIDTH=";W
690 GOSUB 1010
700 W=W+W1
710 GOSUB 740
720 GOSUB 820
730 GOTO 1090
740 '
750 'SUBROUTINE TO CALCULATE P
760 '
770 IF W/H<=1 THEN 800
780 P=2*PI/((W/H)+2.42-(.44*H/W)+EXP(8*LOG(1-(H/W))))
790 RETURN
800 P=LOG((8*H/W)+W/(4*H))
810 RETURN
820 '
830 'SUBROUTINE TO CALCULATE E1,E2 AND Z
840 '
850 E3=((E-1)/2*(1/SQR(1+(10*H/W))-1))
860 E1=E+E3
870 '
880 'CALCULATE EFFECTIVE ER
890 '
900 ' DISPERSION EQUATION FROM GETSINGER
910 '
920 Z1=60*P/SQR(E1)
930 G=.6+(8.999999E-03*Z1)
940 D=Z1/(2.54*4*PI*H)
950 E2=E+(E3/(1+G*EXP(2*LOG(F/D))))
960 '
970 'CALCULATE IMPEDANCE,Z
980 '
990 Z=60*P/SQR(E2)
1000 RETURN
1010 '
1020 ' SUBROUTINE TO CORRECT LINE WIDTH FOR THICKNESS
```

```
1030 '
1040 IF W/H<.15915 THEN 1070
1050 W1=(T/PI)*(1+LOG(2*H/T))
1060 RETURN
1070 W1=(T/PI)*(1+LOG((4*PI*W)/T))
1080 RETURN
1090 '
1100 'PRINT OUT RESULTS
1110 '
1120 L=(11.811/F)/SQR(E2)
1130 '
1140 'THESE ARE RESERVED FOR PRINT FORMATS
1150 '
1160 PRINT:PRINT:PRINT
1165 LPRINT:LPRINT:LPRINT
1170 LPRINT"  TYPE OF MATERIAL-----------------------------";A$
1180 LPRINT"  DIELECTRIC CONSTANT--------------------------";E
1190 LPRINT"  EFFECTIVE DIELECTRIC CONSTANT----------------";E2
1200 LPRINT"  OPERATING FREQUENCY--------------------------";F;" GHZ"
1210 LPRINT"  IMPEDANCE OF MICROSTRIP----------------------";Z;" OHMS"
1220 LPRINT"  WIDTH OF MICROSTRIP--------------------------";W;" INCHES"
1230 LPRINT"  THICKNESS OF SUBSTRATE-----------------------";H;" INCHES"
1240 LPRINT"  THICKNESS OF MICROSTRIP LINE-----------------";T;" INCHES"
1250 LPRINT"  WAVELENGTH-----------------------------------";L;" INCHES"
1260 LPRINT"  QUARTER WAVELENGTH---------------------------";L/4;" INCHES"
1270 PRINT:PRINT:PRINT
1280 INPUT "ANOTHER RUN";Q$:Q$=LEFT$(Q$,1)
1290 IF Q$="Y" THEN 1300 ELSE END
1300 IF X=1 THEN GOTO 490 ELSE GOTO 680
```

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[redacted]

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5195 E. MISSOURI
DENVER, COLO   80222
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```
100 '   CALCULATION DISTANCE AND BEARING
150 '   BY CARL PINKSTON, WA5TBE
200 '   ADAPTED TO TRS-80 BY BILL KIEBERGER, WA5VAJ
250 CLS
300 PRINT "DISTANCE AND BEARING CALCULATION"
350 AD=37:AM=34
400 AT=AM/60
450 A=AD+AT
500 A1=A*3.14159/180
550 OD=122:OM=18
600 OT=OM/60
650 L1=(OD+OT)*-1
700 INPUT "ENTER DISTANT LONGITUDE(D,M,E/W)";D,M,DR$
750 M=M/60
800 L2=D+M
850 IF DR$="E" THEN 950
900 IF DR$="W" THEN L2=L2*-1 ELSE GOTO 700
950 INPUT "ENTER DISTANT LATITUDE (D,M,N/S)";D,M,DR$
1000 M=M/60
1050 B=D+M
1100 IF DR$="N" THEN 1200
1150 IF DR$="S" THEN B=B*-1 ELSE GOTO 950
1200 GOSUB 1550
1250 PRINT "MILES            KILOMETERS      BEARING"
1300 PRINT D1,D2,R2
1350 INPUT "MORE(Y/N)";A$
1400 IF A$="Y" THEN 250
1450 CLS
1500 STOP
1550 '    THIS SUBROUNTINE PERFORMS ALL CALCULATIONS
1600 L=L2-L1
1650 '    X IS A FLAG FOR TESTING L
1700 X=0
1750 '    BRING L WITHIN RANGE -180 TO +180
1800 IF L<(-180) THEN 1950
1850 IF L>180 THEN 2050
1900 GOTO 2100
1950 L=L-360
2000 GOTO 2200
2050 L=L-360
2100 IF L<0 THEN 2200
2150 X=1
2200 '    CONVERT LAND B TO RADIANS
2250 B1=B*3.14159/180
2300 L=L*3.14159/180
2350 '    COMPUTE THE DISTANCE ANGLE
2400 P=COS(L)*COS(A1)*COS(B1)+SIN(A1)*SIN(B1)
2450 P1=ATN(SQR(1-P*P)/P)
2500 P2=P1*180/3.14159
2550 '    DISTANCE ANGLE MUST BE POSITIVE - IF NOT ADD 180
2600 IF P2<0 THEN 2700
2650 GOTO 2800
2700 P2=P2+180
2750 '    COMPUTE DISTANCE
```

```
2800 D1=INT(P2*60*1.15152+.5)
2850 D2=INT(D1*1.6093+.5)
2900 '     COMPUTE BEARING ANGLE
2950 R=COS(B1)*SIN(L)/SIN(P1)
3000 R1=ATN(R/SQR(1-R*R))
3050 '     CONVERT BEARINGS TO DEGREES ROUNDED TO NEAREST INTEGER
3100 R2=INT((R1*180/3.14159)+.5)
3150 '     DETERMINE WHAT QUADRANT THE BEARING ANGLE IS IN AND ADJUST THE DEGREES

3250 IF ABS(R)>.999998 THEN 4100
3300 IF ABS(R)<.00174 THEN 4350
3350 B2=(B+.1)*3.14159/180
3400 R3=COS(L)*COS(A1)*COS(B2)+SIN(B2)*SIN(A1)
3450 R4=ATN(SQR(1-R3*R3)/R3)
3500 R6=COS(B2)*SIN(L)/SIN(R4)
3550 IF X=1 THEN 3850
3600 IF ABS(R6)>ABS(R) THEN 3750
3650 R2=360-ABS(R2)
3700 GOTO 4750
3750 R2=180+ABS(R2)
3800 GOTO 4750
3850 IF ABS(R6)<ABS(R) THEN 4000
3900 R2=180-ABS(R2)
3950 GOTO 4750
4000 R2=ABS(R2)
4050 GOTO 4750
4100 IF X=1 THEN 4250
4150 R2=270
4200 GOTO 4750
4250 R2=90
4300 GOTO 4750
4350 IF ABS(L)>178 THEN 4650
4400 IF B<A THEN 4550
4450 R2=0
4500 GOTO 4750
4550 R2=180
4600 GOTO 4750
4650 IF B>A THEN 4550
4700 GOTO 4450
4750 RETURN
```

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KEITH R. ERICSON
5195 E. MISSOURI
DENVER, COLO 80222
DM79

```
100 PRINT
110 PI=3.14159
115 CLS
120 INPUT "WHAT IS THE FREQUENCY OF OPERATION (MHZ)";F
140 INPUT "WHAT IS THE TUBE OUTPUT CAPACITANCE (PFD)";C
160 INPUT "WHAT IS THE TUNING CAPACITANCE AT THE TUBE END (PFD)";D
170 PRINT "5 ZO ENTRIES WILL FILL THE SCREEN"
180 INPUT "HOW MANY ZO CALCULATIONS ARE YOU GOING TO TRY";E
200 FOR I=1 TO E
210 PRINT "ZO #";I;: INPUT H(I)
220 NEXT
224 FOR I=1 TO E
226  H=H(I)
230 X=1/(2*PI*F*(C+D)*(.000001))
240 G=ATN(X/H)
250 L=(300*G*39.37)/(2*PI*F)
260 J=H/60 'THE H(ZO) OF A COAXIAL XMISSION LINE IS 60*LN(B/A).
262 JJ=H/120 'THE H(ZO) OF A PARALLEL XMISSION LINE IS 120*LN(2S/D).
270 K=EXP(J)
272 KK=EXP(JJ) 'SEE LINE 262
280 P=K/(1.078)
290 U=(2*PI*F*H)*(C+D)*(.000001)
300 T=(1/2)*(1+(U+1/U)*ATN(1/U))
310 Y=(1/T)*100
320 S=H/X
330 PRINT
340 IF I=1 THEN 342 ELSE 365
342 CLS
343 LPRINT "FREQ ";F;" MHZ";TAB(18);"TUBE C";C;" PF";TAB(35);"TUNING C";D;" PF"
344 LPRINT
350 LPRINT "ZO";TAB(5);"LENGTH-IN";TAB(20);"% BW OF LC";TAB(35);"B/A RATIO";TAB(
49);"H/D RATIO";TAB(63);"2S/D RATIO"
360 LPRINT
365 LPRINT H;TAB(5);L;TAB(20);Y;TAB(35);K;TAB(49);P

;TAB(63);KK
367 LPRINT
370 NEXT I
380 PRINT
390 INPUT "DO YOU WANT B/A AND H/D RATIOS EXPLAINED? Y OR N";W$
410 IF W$="Y" THEN 429 ELSE 450
429 PRINT
430 PRINT "B/A IS RATIO OF INNER DIA. OF OUTER CONDUCTOR TO DIA. OF INNER CONDUC
TOR."
435 PRINT
440 PRINT "H/D IS RATIO OF LENGTH OF WALL OF SQUARE BOX TO  DIA. OF CENTER CONDU
CTOR."
444 PRINT
445 PRINT "2S/D IS RATIO OF 2 TIMES CENTER-TO-CENTER DISTANCE TO CONDUCTOR DIAME
TER."
450 INPUT "DO YOU WANT TO RUN AGAIN? Y OR N ";V$
480 IF V$="Y" THEN 115 ELSE 490
490 END
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```
100 CLS
125 LPRINT "ZO FOR A STRIP OR ROUND CENTER CONDUCTOR BETWEEN GROUND PLANES."
126 LPRINT
127 LPRINT
128 LPRINT
140 INPUT "THE WIDTH OF THE STRIP LINE IN INCHES IS";W1
160 W=W1*2.54
180 INPUT "THE THICKNESS OF THE STRIPLINE IN INCHES IS";T1
200 T=T1*2.54
240 INPUT "THE DISTANCE BETWEEN TOP AND BOTTOM SHIELD IN INCHES IS";B1
242 B=B1*2.54
260 INPUT "THE DIELECTRIC CONSTANT OF THE LINE IS";ER
280 RATIO=W/(B-T)
300 IF RATIO>=.35 THEN 560 'WIDE STRIPLINE CASE
320 T=0
340 ZO=(60/SQR(ER))*LOG((8*B)/(3.1416*W)) 'OHMS
360 INPUT "DO YOU WANT TO TRY A SMALL ROUND CENTER CONDUCTOR-YES OR NO";A$
380 IF A$="YES" THEN 400 ELSE 660
400 INPUT "WHAT DIAMETER CENTER CONDUCTOR DO YOU WANT IN INCHES";D1
420 DO=D1*2.54
440 RATIO=DO/(B/2)
460 IF RATIO =<1 THEN 520
480 PRINT "ENTER CONDUCTOR TOO LARGE IN DIAMETER."
500 GOTO 360
520 ZO=(60/SQR(ER))*LOG((4*B)/(3.1416*DO)) 'OHMS
540 GOTO 600
541 H=(1/(1-T/B))+1
542 J=(1/((1-T/B)^2))-1
560 CF=((.0885*ER)/(3.1416))*((2/(1-T/B))*LOG((1/(1-T/B))+1)-((1/(1/1-T/B))-1)*L
OG((1/(1-T/B)^2)-1))
580 ZO=(94.15)/(SQR(ER)*(((W/B)/(1-T/B))+(CF/.0885*ER))) 'OHMS
600 IF A$="YES" THEN 620 ELSE 660
620 LPRINT "THE CENTER CONDUCTOR DIAMETER IS";D1;"INCHES";DO;"CMS."
640 GOTO 700
660 LPRINT "THE WIDTH OF THE LINE IS";W1;"INCHES";W;"CMS."
680 LPRINT "THE THICKNESS OF THE LINE IS";T1;"INCHES";T;"CMS."
700 LPRINT "THE DISTANCE BETWEEN SHIELD PLANES IS";B1;"INCHES";B;"CMS."
720 LPRINT "THE ZO OF THE LINE IS";ZO;"OHMS"
740 END
```

K0KE
KEITH R. ERICSON
5195 E. MISSOURI
DENVER, COLO 80222
DM79

DL6WU ANTENNA DESIGN

Program written by Jerry Haigwood, KY4Z, and Bob Stein, W6NBI - Based on article 'Extremely Long Yagi Antennas' by Gunter Hoch, DL6WU; VHF Communications, 3/82

DESIGNED FOR : KOKE July '86

CENTER FREQUENCY = 903 MHz

GAIN = 16.6 dBd

DRIVE IMPEDANCE = 200 OHMS (APPROX), WITH FOLDED DIPOLE D.E.

BOOM LENGTH:
REFLECTOR TO
LAST DIRECTOR = 9.65 FT = 115.7 IN. = 294.0 CM

BOOM DIAMETER = 0.875 IN. = 2.22 CM

ELEMENT DIAMETERS:
DRIVEN = 0.250 IN. = 0.63 CM
PARASITIC = 0.250 IN. = 0.63 CM

Elements pass through and are insulated from a metal boom

CUMULATIVE SPACING				ELEMENT LENGTH	
CM	IN.			CM	IN.
Ref	Ref	REFL	-----------¦-----------	16.39	6.453
7.18	2.825	D.E.	=========¦=========	15.23	5.996
9.88	3.890	D 1	---------¦---------	14.21	5.596
15.39	6.058	D 2	---------¦---------	13.99	5.506
22.53	8.871	D 3	---------¦---------	13.76	5.418
30.84	12.142	D 4	---------¦---------	13.56	5.337
40.05	15.768	D 5	---------¦---------	13.38	5.267
50.00	19.685	D 6	---------¦---------	13.23	5.207
60.57	23.847	D 7	---------¦---------	13.09	5.155
71.68	28.221	D 8	---------¦---------	12.98	5.110
83.27	32.783	D 9	---------¦---------	12.88	5.070
95.28	37.513	D 10	---------¦---------	12.79	5.034

107.68	42.394	D 11	---------¦---------	12.70	5.002
120.43	47.414	D 12	---------¦---------	12.63	4.972
133.51	52.562	D 13	---------¦---------	12.56	4.945
146.88	57.827	D 14	---------¦---------	12.50	4.920
160.25	63.092	D 15	---------¦---------	12.44	4.896
173.63	68.358	D 16	---------¦---------	12.38	4.874
187.00	73.623	D 17	---------¦---------	12.33	4.853
200.38	78.888	D 18	---------¦---------	12.28	4.834
213.75	84.153	D 19	---------¦---------	12.23	4.816
227.12	89.419	D 20	---------¦---------	12.19	4.798
240.50	94.684	D 21	---------¦---------	12.15	4.782
253.87	99.949	D 22	---------¦---------	12.10	4.766
267.24	105.214	D 23	---------¦---------	12.07	4.751
280.62	110.480	D 24	---------¦---------	12.03	4.736
293.99	115.745	D 25	---------¦---------	11.99	4.722

DL6WU ANTENNA DESIGN

Program written by Jerry Haigwood, KY4Z, and Bob Stein, W6NBI - Based on article 'Extremely Long Yagi Antennas' by Gunter Hoch, DL6WU; VHF Communications, 3/82

DESIGNED FOR : KOKE July '86

CENTER FREQUENCY = 1296 MHz

GAIN = 17.2 dBd

DRIVE IMPEDANCE = 200 OHMS (APPROX), WITH FOLDED DIPOLE D.E.

BOOM LENGTH:
REFLECTOR TO
LAST DIRECTOR = 7.94 FT = 95.3 IN. = 242.1 CM

BOOM DIAMETER = 0.625 IN. = 1.59 CM

ELEMENT DIAMETERS:
DRIVEN = 0.162 IN. = 0.41 CM #6 AWG
PARASITIC = 0.162 IN. = 0.41 CM

Elements pass through and are NOT insulated from a metal boom

CUMULATIVE SPACING				ELEMENT LENGTH	
CM	IN.			CM	IN.
Ref	Ref	REFL	----------¦----------	11.99	4.719
5.00	1.968	D.E.	=========¦=========	10.63	4.187
6.88	2.710	D 1	---------¦---------	10.52	4.141
10.72	4.221	D 2	---------¦---------	10.37	4.081
15.70	6.181	D 3	---------¦---------	10.21	4.021
21.49	8.460	D 4	---------¦---------	10.07	3.965
27.91	10.987	D 5	---------¦---------	9.95	3.916
34.84	13.716	D 6	---------¦---------	9.84	3.875
42.20	16.616	D 7	---------¦---------	9.75	3.839
49.95	19.664	D 8	---------¦---------	9.67	3.808
58.02	22.842	D 9	---------¦---------	9.60	3.780
66.39	26.138	D 10	---------¦---------	9.54	3.755

75.03	29.539	D 11	---------¦---------	9.48	3.733
83.91	33.036	D 12	---------¦---------	9.43	3.712
93.02	36.623	D 13	---------¦---------	9.38	3.693
102.34	40.291	D 14	---------¦---------	9.34	3.676
111.66	43.960	D 15	---------¦---------	9.30	3.660
120.98	47.629	D 16	---------¦---------	9.26	3.644
130.30	51.297	D 17	---------¦---------	9.22	3.630
139.61	54.966	D 18	---------¦---------	9.19	3.617
148.93	58.635	D 19	---------¦---------	9.15	3.604
158.25	62.303	D 20	---------¦---------	9.12	3.592
167.57	65.972	D 21	---------¦---------	9.09	3.580
176.89	69.641	D 22	---------¦---------	9.07	3.569
186.20	73.309	D 23	---------¦---------	9.04	3.559
195.52	76.978	D 24	---------¦---------	9.01	3.549
204.84	80.646	D 25	---------¦---------	8.99	3.539
214.16	84.315	D 26	---------¦---------	8.97	3.530
223.48	87.984	D 27	---------¦---------	8.94	3.521
232.80	91.652	D 28	---------¦---------	8.92	3.512
242.11	95.321	D 29	---------¦---------	8.90	3.504

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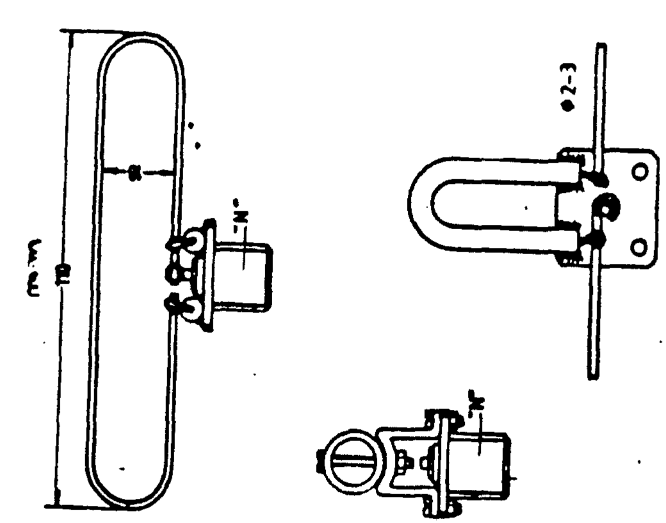


Fig. 4:
23 cm balun arrangement from semi-rigid cable.
Balun length (outer conductor): 80 mm

DL6WU ANTENNA DESIGN

Program written by Jerry Haigwood, KY4Z, and Bob Stein, W6NBI - Based on article 'Extremely Long Yagi Antennas' by Gunter Hoch, DL6WU; VHF Communications, 3/82

DESIGNED FOR : KOKE July '86

CENTER FREQUENCY = 1296 MHz

GAIN = 19.5 dBd

DRIVE IMPEDANCE = 200 OHMS (APPROX), WITH FOLDED DIPOLE D.E.

BOOM LENGTH:
REFLECTOR TO
LAST DIRECTOR = 15.89 FT = 190.7 IN. = 484.4 CM

BOOM DIAMETER = 0.625 IN. = 1.59 CM

ELEMENT DIAMETERS:
DRIVEN = 0.162 IN. = 0.41 CM #6 AWG
PARASITIC = 0.162 IN. = 0.41 CM

Elements pass through and are NOT insulated from a metal boom

CUMULATIVE SPACING				ELEMENT LENGTH	
CM	IN.			CM	IN.
Ref	Ref	REFL	-----------¦-----------	11.99	4.719
5.00	1.968	D.E.	=========¦=========	10.63	4.187
6.88	2.710	D 1	---------¦---------	10.52	4.141
10.72	4.221	D 2	---------¦---------	10.37	4.081
15.70	6.181	D 3	---------¦---------	10.21	4.021
21.49	8.460	D 4	---------¦---------	10.07	3.965
27.91	10.987	D 5	---------¦---------	9.95	3.916
34.84	13.716	D 6	---------¦---------	9.84	3.875
42.20	16.616	D 7	---------¦---------	9.75	3.839
49.95	19.664	D 8	---------¦---------	9.67	3.808
58.02	22.842	D 9	---------¦---------	9.60	3.780
66.39	26.138	D 10	---------¦---------	9.54	3.755

75.03	29.539	D 11	---------¦---------	9.48	3.733
83.91	33.036	D 12	---------¦---------	9.43	3.712
93.02	36.623	D 13	---------¦---------	9.38	3.693
102.34	40.291	D 14	---------¦---------	9.34	3.676
111.66	43.960	D 15	---------¦---------	9.30	3.660
120.98	47.629	D 16	---------¦---------	9.26	3.644
130.30	51.297	D 17	---------¦---------	9.22	3.630
139.61	54.966	D 18	---------¦---------	9.19	3.617
148.93	58.635	D 19	---------¦---------	9.15	3.604
158.25	62.303	D 20	---------¦---------	9.12	3.592
167.57	65.972	D 21	---------¦---------	9.09	3.580
176.89	69.641	D 22	---------¦---------	9.07	3.569
186.20	73.309	D 23	---------¦---------	9.04	3.559
195.52	76.978	D 24	---------¦---------	9.01	3.549
204.84	80.646	D 25	---------¦---------	8.99	3.539
214.16	84.315	D 26	---------¦---------	8.97	3.530
223.48	87.984	D 27	---------¦---------	8.94	3.521
232.80	91.652	D 28	---------¦---------	8.92	3.512
242.11	95.321	D 29	---------¦---------	8.90	3.504
251.43	98.990	D 30	---------¦---------	8.88	3.496
260.75	102.658	D 31	---------¦---------	8.86	3.488
270.07	106.327	D 32	---------¦---------	8.84	3.481
279.39	109.995	D 33	---------¦---------	8.82	3.474
288.71	113.664	D 34	---------¦---------	8.81	3.467
298.02	117.333	D 35	---------¦---------	8.79	3.460

307.34	121.001	D 36	---------¦---------	8.77	3.453
316.66	124.670	D 37	---------¦---------	8.75	3.447
325.98	128.339	D 38	---------¦---------	8.74	3.440
335.30	132.007	D 39	---------¦---------	8.72	3.434
344.62	135.676	D 40	---------¦---------	8.71	3.428
353.93	139.344	D 41	---------¦---------	8.69	3.423
363.25	143.013	D 42	---------¦---------	8.68	3.417
372.57	146.682	D 43	---------¦---------	8.66	3.411
381.89	150.350	D 44	---------¦---------	8.65	3.406
391.21	154.019	D 45	---------¦---------	8.64	3.401
400.53	157.688	D 46	---------¦---------	8.62	3.395
409.84	161.356	D 47	---------¦---------	8.61	3.390
419.16	165.025	D 48	---------¦---------	8.60	3.385
428.48	168.693	D 49	---------¦---------	8.59	3.380
437.80	172.362	D 50	---------¦---------	8.57	3.376
447.12	176.031	D 51	---------¦---------	8.56	3.371
456.44	179.699	D 52	---------¦---------	8.55	3.366
465.75	183.368	D 53	---------¦---------	8.54	3.362
475.07	187.037	D 54	---------¦---------	8.53	3.358
484.39	190.705	D 55	---------¦---------	8.52	3.353

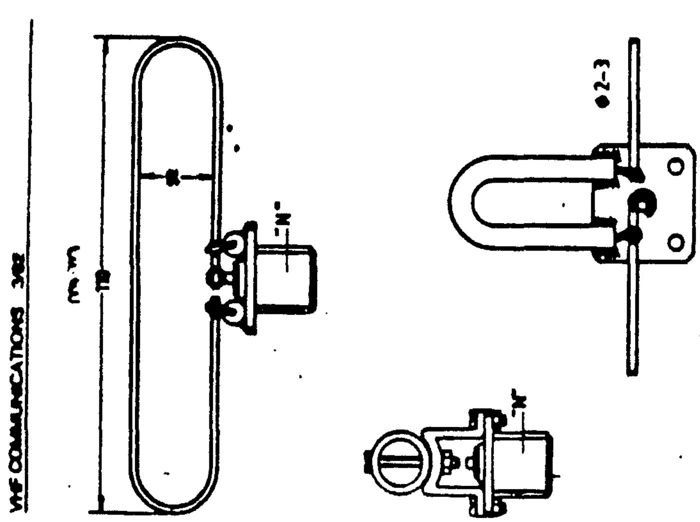


Fig. 4:
23 cm balun arrangement from semi-rigid cable.
Balun length (outer conductor): 80 mm

DL6WU ANTENNA DESIGN

Program written by Jerry Haigwood, KY4Z, and Bob Stein, W6NBI - Based on article 'Extremely Long Yagi Antennas' by Gunter Hoch, DL6WU; VHF Communications, 3/82

DESIGNED FOR : KOKE July '86

CENTER FREQUENCY = 1296 MHz

GAIN = 17.2 dBd

DRIVE IMPEDANCE = 200 OHMS (APPROX), WITH FOLDED DIPOLE D.E.

BOOM LENGTH:
REFLECTOR TO
LAST DIRECTOR = 7.94 FT = 95.3 IN. = 242.1 CM

ELEMENT DIAMETERS:
DRIVEN = 0.125 IN. = 0.32 CM ALUMINUM
PARASITIC = 0.125 IN. = 0.32 CM WELDING ROD

A non-metallic boom is used ---OR---
elements are mounted on insulators above or below a metal boom with metal-to-metal spacing greater than the boom radius

CUMULATIVE SPACING				ELEMENT LENGTH	
CM	IN.			CM	IN.
Ref	Ref	REFL	----------|----------	11.03	4.344
5.00	1.968	D.E.	=========|=========	10.70	4.214
6.88	2.710	D 1	---------|---------	9.72	3.825
10.72	4.221	D 2	---------|---------	9.58	3.771
15.70	6.181	D 3	---------|---------	9.43	3.713
21.49	8.460	D 4	---------|---------	9.29	3.659
27.91	10.987	D 5	---------|---------	9.18	3.612
34.84	13.716	D 6	---------|---------	9.07	3.572
42.20	16.616	D 7	---------|---------	8.98	3.537
49.95	19.664	D 8	---------|---------	8.91	3.507
58.02	22.842	D 9	---------|---------	8.84	3.480
66.39	26.138	D 10	---------|---------	8.78	3.456

75.03	29.539	D 11	---------¦---------	8.72	3.434
83.91	33.036	D 12	---------¦---------	8.67	3.414
93.02	36.623	D 13	---------¦---------	8.62	3.396
102.34	40.291	D 14	---------¦---------	8.58	3.379
111.66	43.960	D 15	---------¦---------	8.54	3.363
120.98	47.629	D 16	---------¦---------	8.50	3.348
130.30	51.297	D 17	---------¦---------	8.47	3.334
139.61	54.966	D 18	---------¦---------	8.44	3.321
148.93	58.635	D 19	---------¦---------	8.40	3.309
158.25	62.303	D 20	---------¦---------	8.37	3.297
167.57	65.972	D 21	---------¦---------	8.35	3.286
176.89	69.641	D 22	---------¦---------	8.32	3.275
186.20	73.309	D 23	---------¦---------	8.29	3.265
195.52	76.978	D 24	---------¦---------	8.27	3.255
204.84	80.646	D 25	---------¦---------	8.24	3.246
214.16	84.315	D 26	---------¦---------	8.22	3.237
223.48	87.984	D 27	---------¦---------	8.20	3.228
232.80	91.652	D 28	---------¦---------	8.18	3.220
242.11	95.321	D 29	---------¦---------	8.16	3.212

DL6WU ANTENNA DESIGN

Program written by Jerry Haigwood, KY4Z, and Bob Stein, W6NBI - Based on article 'Extremely Long Yagi Antennas' by Gunter Hoch, DL6WU; VHF Communications, 3/82

DESIGNED FOR : KOKE July '86

CENTER FREQUENCY = 1296 MHz

GAIN = 19.5 dBd

DRIVE IMPEDANCE = 200 OHMS (APPROX), WITH FOLDED DIPOLE D.E.

BOOM LENGTH:
REFLECTOR TO
LAST DIRECTOR = 15.89 FT = 190.7 IN. = 484.4 CM

ELEMENT DIAMETERS:
DRIVEN = 0.125 IN. = 0.32 CM ALUMINUM
PARASITIC = 0.125 IN. = 0.32 CM WELDING ROD

A non-metallic boom is used ---OR---
elements are mounted on insulators above or below a metal boom with metal-to-metal spacing greater than the boom radius

CUMULATIVE SPACING CM	CUMULATIVE SPACING IN.			ELEMENT LENGTH CM	ELEMENT LENGTH IN.
Ref	Ref	REFL	-----------¦-----------	11.03	4.344
5.00	1.968	D.E.	=========¦=========	10.70	4.214
6.88	2.710	D 1	---------¦---------	9.72	3.825
10.72	4.221	D 2	---------¦---------	9.58	3.771
15.70	6.181	D 3	---------¦---------	9.43	3.713
21.49	8.460	D 4	---------¦---------	9.29	3.659
27.91	10.987	D 5	---------¦---------	9.18	3.612
34.84	13.716	D 6	---------¦---------	9.07	3.572
42.20	16.616	D 7	---------¦---------	8.98	3.537
49.95	19.664	D 8	---------¦---------	8.91	3.507
58.02	22.842	D 9	---------¦---------	8.84	3.480
66.39	26.138	D 10	---------¦---------	8.78	3.456

75.03	29.539	D 11	---------¦---------	8.72	3.434
83.91	33.036	D 12	---------¦---------	8.67	3.414
93.02	36.623	D 13	---------¦---------	8.62	3.396
102.34	40.291	D 14	---------¦---------	8.58	3.379
111.66	43.960	D 15	---------¦---------	8.54	3.363
120.98	47.629	D 16	---------¦---------	8.50	3.348
130.30	51.297	D 17	---------¦---------	8.47	3.334
139.61	54.966	D 18	---------¦---------	8.44	3.321
148.93	58.635	D 19	---------¦---------	8.40	3.309
158.25	62.303	D 20	---------¦---------	8.37	3.297
167.57	65.972	D 21	---------¦---------	8.35	3.286
176.89	69.641	D 22	---------¦---------	8.32	3.275
186.20	73.309	D 23	---------¦---------	8.29	3.265
195.52	76.978	D 24	---------¦---------	8.27	3.255
204.84	80.646	D 25	---------¦---------	8.24	3.246
214.16	84.315	D 26	---------¦---------	8.22	3.237
223.48	87.984	D 27	---------¦---------	8.20	3.228
232.80	91.652	D 28	---------¦---------	8.18	3.220
242.11	95.321	D 29	---------¦---------	8.16	3.212
251.43	98.990	D 30	---------¦---------	8.14	3.204
260.75	102.658	D 31	---------¦---------	8.12	3.196
270.07	106.327	D 32	---------¦---------	8.10	3.189
279.39	109.995	D 33	---------¦---------	8.08	3.182
288.71	113.664	D 34	---------¦---------	8.07	3.175
298.02	117.333	D 35	---------¦---------	8.05	3.169

307.34	121.001	D 36	---------¦---------	8.03	3.162
316.66	124.670	D 37	---------¦---------	8.02	3.156
325.98	128.339	D 38	---------¦---------	8.00	3.150
335.30	132.007	D 39	---------¦---------	7.99	3.144
344.62	135.676	D 40	---------¦---------	7.97	3.138
353.93	139.344	D 41	---------¦---------	7.96	3.132
363.25	143.013	D 42	---------¦---------	7.94	3.127
372.57	146.682	D 43	---------¦---------	7.93	3.121
381.89	150.350	D 44	---------¦---------	7.92	3.116
391.21	154.019	D 45	---------¦---------	7.90	3.111
400.53	157.688	D 46	---------¦---------	7.89	3.106
409.84	161.356	D 47	---------¦---------	7.88	3.101
419.16	165.025	D 48	---------¦---------	7.86	3.096
428.48	168.693	D 49	---------¦---------	7.85	3.092
437.80	172.362	D 50	---------¦---------	7.84	3.087
447.12	176.031	D 51	---------¦---------	7.83	3.082
456.44	179.699	D 52	---------¦---------	7.82	3.078
465.75	183.368	D 53	---------¦---------	7.81	3.074
475.07	187.037	D 54	---------¦---------	7.80	3.069
484.39	190.705	D 55	---------¦---------	7.79	3.065

DL6WU ANTENNA DESIGN

Program written by Jerry Haigwood, KY4Z, and Bob Stein, W6NBI - Based on article 'Extremely Long Yagi Antennas' by Gunter Hoch, DL6WU; VHF Communications, 3/82

DESIGNED FOR : KOKE July '86

CENTER FREQUENCY = 1296 MHz

GAIN = 17.2 dBd

DRIVE IMPEDANCE = 200 OHMS (APPROX), WITH FOLDED DIPOLE D.E.

BOOM LENGTH:
REFLECTOR TO
LAST DIRECTOR = 7.94 FT = 95.3 IN. = 242.1 CM

BOOM DIAMETER = 0.625 IN. = 1.59 CM

ELEMENT DIAMETERS:
DRIVEN = 0.125 IN. = 0.32 CM ALUMINUM
PARASITIC = 0.125 IN. = 0.32 CM WELDING ROD

Elements pass through and are insulated from a metal boom

CUMULATIVE SPACING CM	CUMULATIVE SPACING IN.			ELEMENT LENGTH CM	ELEMENT LENGTH IN.
Ref	Ref	REFL	-----------¦-----------	11.43	4.500
5.00	1.968	D.E.	=========¦=========	10.70	4.214
6.88	2.710	D 1	---------¦---------	10.11	3.982
10.72	4.221	D 2	---------¦---------	9.97	3.927
15.70	6.181	D 3	---------¦---------	9.83	3.869
21.49	8.460	D 4	---------¦---------	9.69	3.816
27.91	10.987	D 5	---------¦---------	9.57	3.769
34.84	13.716	D 6	---------¦---------	9.47	3.728
42.20	16.616	D 7	---------¦---------	9.38	3.693
49.95	19.664	D 8	---------¦---------	9.30	3.663
58.02	22.842	D 9	---------¦---------	9.24	3.636
66.39	26.138	D 10	---------¦---------	9.17	3.612

75.03	29.539	D 11	---------¦---------	9.12	3.590
83.91	33.036	D 12	---------¦---------	9.07	3.570
93.02	36.623	D 13	---------¦---------	9.02	3.552
102.34	40.291	D 14	---------¦---------	8.98	3.535
111.66	43.960	D 15	---------¦---------	8.94	3.519
120.98	47.629	D 16	---------¦---------	8.90	3.504
130.30	51.297	D 17	---------¦---------	8.87	3.490
139.61	54.966	D 18	---------¦---------	8.83	3.477
148.93	58.635	D 19	---------¦---------	8.80	3.465
158.25	62.303	D 20	---------¦---------	8.77	3.453
167.57	65.972	D 21	---------¦---------	8.74	3.442
176.89	69.641	D 22	---------¦---------	8.72	3.431
186.20	73.309	D 23	---------¦---------	8.69	3.421
195.52	76.978	D 24	---------¦---------	8.66	3.411
204.84	80.646	D 25	---------¦---------	8.64	3.402
214.16	84.315	D 26	---------¦---------	8.62	3.393
223.48	87.984	D 27	---------¦---------	8.60	3.384
232.80	91.652	D 28	---------¦---------	8.58	3.376
242.11	95.321	D 29	---------¦---------	8.55	3.368

DL6WU ANTENNA DESIGN

Program written by Jerry Haigwood, KY4Z, and Bob Stein, W6NBI - Based on article 'Extremely Long Yagi Antennas' by Gunter Hoch, DL6WU; VHF Communications, 3/82

DESIGNED FOR : KOKE July '86

CENTER FREQUENCY = 1296 MHz

GAIN = 19.5 dBd

DRIVE IMPEDANCE = 200 OHMS (APPROX), WITH FOLDED DIPOLE D.E.

BOOM LENGTH:
REFLECTOR TO
LAST DIRECTOR = 15.89 FT = 190.7 IN. = 484.4 CM

BOOM DIAMETER = 0.625 IN. = 1.59 CM

ELEMENT DIAMETERS:
DRIVEN = 0.125 IN. = 0.32 CM Aluminum
PARASITIC = 0.125 IN. = 0.32 CM Welding Rod

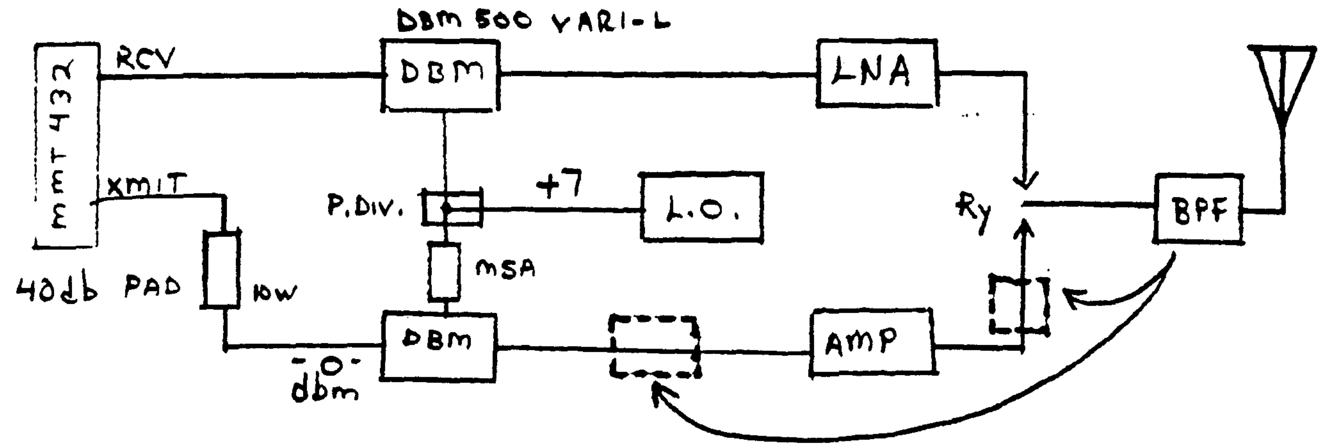
Elements pass through and are insulated from a metal boom

CUMULATIVE SPACING				ELEMENT LENGTH	
CM	IN.			CM	IN.
Ref	Ref	REFL	----------¦----------	11.43	4.500
5.00	1.968	D.E.	=========¦=========	10.70	4.214
6.88	2.710	D 1	--------¦--------	10.11	3.982
10.72	4.221	D 2	--------¦--------	9.97	3.927
15.70	6.181	D 3	--------¦--------	9.83	3.869
21.49	8.460	D 4	--------¦--------	9.69	3.816
27.91	10.987	D 5	--------¦--------	9.57	3.769
34.84	13.716	D 6	--------¦--------	9.47	3.728
42.20	16.616	D 7	--------¦--------	9.38	3.693
49.95	19.664	D 8	--------¦--------	9.30	3.663
58.02	22.842	D 9	--------¦--------	9.24	3.636
66.39	26.138	D 10	--------¦--------	9.17	3.612

75.03	29.539	D 11	---------¦---------	9.12	3.590
83.91	33.036	D 12	---------¦---------	9.07	3.570
93.02	36.623	D 13	---------¦---------	9.02	3.552
102.34	40.291	D 14	---------¦---------	8.98	3.535
111.66	43.960	D 15	---------¦---------	8.94	3.519
120.98	47.629	D 16	---------¦---------	8.90	3.504
130.30	51.297	D 17	---------¦---------	8.87	3.490
139.61	54.966	D 18	---------¦---------	8.83	3.477
148.93	58.635	D 19	---------¦---------	8.80	3.465
158.25	62.303	D 20	---------¦---------	8.77	3.453
167.57	65.972	D 21	---------¦---------	8.74	3.442
176.89	69.641	D 22	---------¦---------	8.72	3.431
186.20	73.309	D 23	---------¦---------	8.69	3.421
195.52	76.978	D 24	---------¦---------	8.66	3.411
204.84	80.646	D 25	---------¦---------	8.64	3.402
214.16	84.315	D 26	---------¦---------	8.62	3.393
223.48	87.984	D 27	---------¦---------	8.60	3.384
232.80	91.652	D 28	---------¦---------	8.58	3.376
242.11	95.321	D 29	---------¦---------	8.55	3.368
251.43	98.990	D 30	---------¦---------	8.53	3.360
260.75	102.658	D 31	---------¦---------	8.52	3.353
270.07	106.327	D 32	---------¦---------	8.50	3.345
279.39	109.995	D 33	---------¦---------	8.48	3.338
288.71	113.664	D 34	---------¦---------	8.46	3.332
298.02	117.333	D 35	---------¦---------	8.45	3.325
307.34	121.001	D 36	---------¦---------	8.43	3.318

316.66	124.670	D 37	---------¦---------	8.41	3.312
325.98	128.339	D 38	---------¦---------	8.40	3.306
335.30	132.007	D 39	---------¦---------	8.38	3.300
344.62	135.676	D 40	---------¦---------	8.37	3.294
353.93	139.344	D 41	---------¦---------	8.35	3.289
363.25	143.013	D 42	---------¦---------	8.34	3.283
372.57	146.682	D 43	---------¦---------	8.33	3.278
381.89	150.350	D 44	---------¦---------	8.31	3.272
391.21	154.019	D 45	---------¦---------	8.30	3.267
400.53	157.688	D 46	---------¦---------	8.29	3.262
409.84	161.356	D 47	---------¦---------	8.27	3.257
419.16	165.025	D 48	---------¦---------	8.26	3.253
428.48	168.693	D 49	---------¦---------	8.25	3.248
437.80	172.362	D 50	---------¦---------	8.24	3.243
447.12	176.031	D 51	---------¦---------	8.23	3.239
456.44	179.699	D 52	---------¦---------	8.21	3.234
465.75	183.368	D 53	---------¦---------	8.20	3.230
475.07	187.037	D 54	---------¦---------	8.19	3.226
484.39	190.705	D 55	---------¦---------	8.18	3.221

3456 TRANSMITTER OPTIONS



Alternate locations for BPF - needed only on transmitter side so image does not fall in TVRO, Terrestial microwave bands.

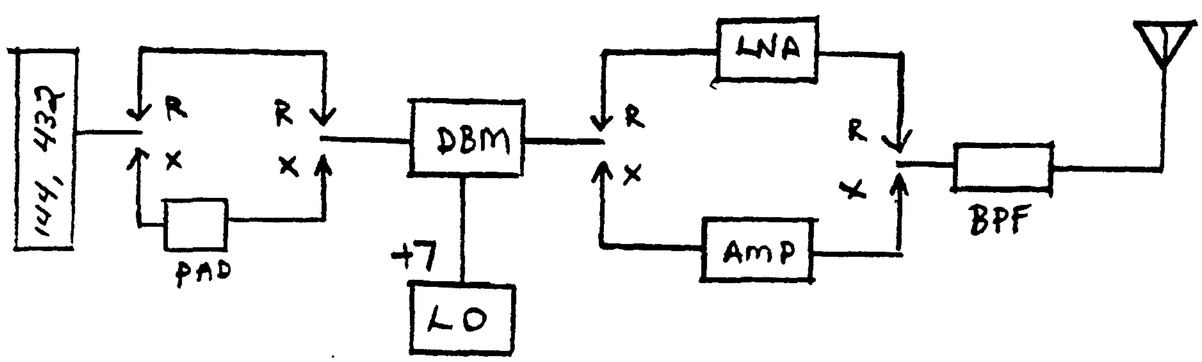
Image - 3891 + 435 = 4326 MHz.
Image - 3600 + 144 = 3744 MHz.

LNA will provide some receiver selectivity.

While this scheme requires a 2 DBMs, it does eliminate several relays.

Circulator may be used in place of relay if power out is low (i.e., mws)

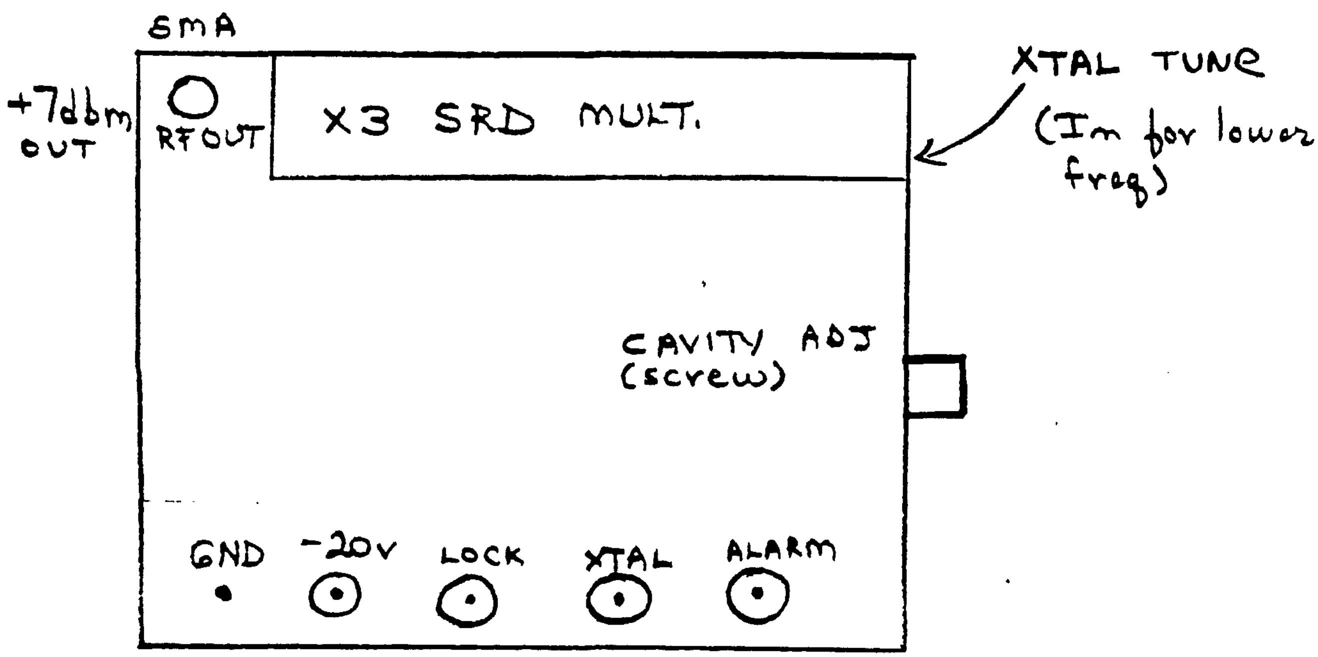
MSA needed to boost L.O. power to transmitter mixer. 4-5 db gain is adequate after power split



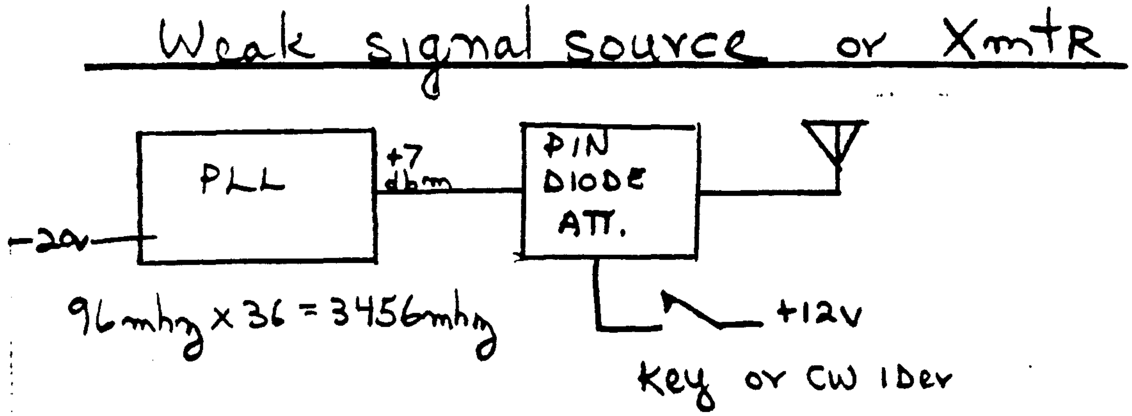
P.L.L. SOURCE FOR LOCAL OSCILLATOR 3456 MHz. TRANSVERTER

Adjust cavity resonance to correct harmonic by tuning screw.

IN - raises cavity frequency
OUT - lowers cavity frequency



1. 4" L x 3" H x 2¼" W
2. Dielectrically tuned cavity at 1297 MHz phased locked to 108.08333 MHz crystal.
3. 1297 MHz x 3 = 3892 MHz L.O. - 3456 = 435 MHz I.F.
4. Power -20V (sometimes -19 V or +20 V) at 450 ma.
5. Manufacturers - CTI, Frequency West



Voltage biases on PIN diode for low loss, allowing signal through. (See WB5LUA PIN diode switches in other Conference notes).

Recrystaling for output on 3456 will require retuning of X3 multiplier (7 tuning screws under cover by SMA output). Power drops to -17 dbm without returning but will tune to 3456 MHz and +7 dbm out.

2. 3600 MHz L.O. for 144 MHz out
   100 MHz x 36 = 3600 MHz.

3. Some units use TO can-type crystal. Newer units use HC25 type crystal.

4. Crystal fits into oven.

5. Voltmeter can be used to indicate phase lock by measuring voltage on lock output.
   A - 8V indicates UNLOCK
   B -16V indicates LOCK

   Peak for maximum MINUS voltage out by turning cavity adjust screw. You will also hear a faint relay clock when you achieve lock.

6. Voltmeter should be used to peak XTAL TUNE - output should be +1 → +1.5V. Crystal tuning will also affect lock.

7. Main Osc. cavity is capacitively coupled to SRD multiplier. Multiplier may be removed making PLL useful in 1 GHz. region. Power may be capacitively coupled out of unit by mounting SMA connector over hole in the main cavity. As much as +20 dbm is available that way at 1 GHz.

8. Other units available use a X5 SRD multiplier into the 6 GHz. region from 1.5 GHz., making them useful for 5760 MHz.

   96 MHz x 12 = 1152 x 5 = 5760

   Multiplier modules should be interchangeable making the same unit useful on both bands. Further, units are available using a basic cavity oscillator in the 2 GHz. range which use a X5 multiplier to get to 10-11 GHz.

   108 MHz x 20 = 2160 MHz (X5) = 10,800 MHz.
   10,800 MHz - 432 MHz = 10,368 MHz.

9. Lockup of PLL also indicated by alarm output
   A. Ground output (low resistance) indicates UNLOCK
   B. Open circuit (high resistance) indicates LOCK

10. Low SSB phase noise output

   -70 dbC/Hz at 100 Hz.
   -95 dbC/Hz at 1 KHz.
   -105 dbC/Hz at 10 KHz.

11. Very clean output - no discernable spurs on spectrum analyzer; i.e., (1) frequency output!

3456

DO YOU WISH INFORMATION ON DISH SIZES
1 TO 50 FEET ? Y
THE FREQUENCY IS 3456MHZ

DIAMETER	GAIN IN DBI	3DB BEAMWIDTH
1	18.2714747	20.2546296
2	24.2920746	10.1273148
3	27.8138998	6.75154321
4	30.3126745	5.06365741
5	32.2508748	4.05092593
6	33.8344997	3.37577161
7	35.1734355	2.89351852
8	36.3332744	2.5318287
9	37.3563249	2.2505144
10	38.2714747	2.02546296
11	39.0993284	1.84132997
12	39.8550996	1.6878858
13	40.5503417	1.55804843
14	41.1940354	1.44675926

PRESS <RETURN> TO CONTINUE

DIAMETER	GAIN IN DBI	3DB BEAMWIDTH
15	41.7932999	1.35030864
16	42.3538743	1.26591435
17	42.8804531	1.1914488
18	43.3769248	1.1252572
19	43.8465467	1.06603314
20	44.2920746	1.01273148
21	44.7158606	.964506173
22	45.1199283	.920664983
23	45.5060314	.880636071
24	45.8756995	.843942901
25	46.2302749	.810185185
26	46.5709416	.779024217
27	46.8987499	.750171468
28	47.2146353	.72337963
29	47.5194346	.698435504

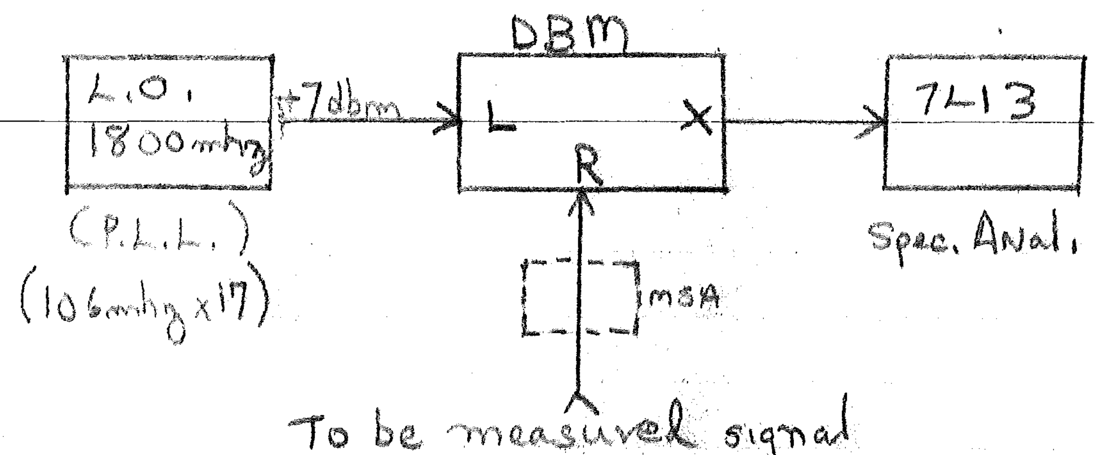
PRESS <RETURN> TO CONTINUE

DIAMETER	GAIN IN DBI	3DB BEAMWIDTH
30	47.8138998	.675154321
31	48.0987086	.653375149
32	48.3744742	.632957176
33	48.6417535	.613776655
34	48.901053	.595724401
35	49.1528356	.578703704
36	49.3975247	.562628601
37	49.6355092	.547422422
38	49.8671466	.533016569
39	50.0927668	.519349477
40	50.3126745	.506365741
41	50.5271518	.494015357
42	50.7364605	.482253086
43	50.9408438	.471037898
44	51.1405282	.460332492

PRESS <RETURN> TO CONTINUE

Extend the Frequency Range of a Spectrum Analyzer

In my case I have a Tektronix 7L13 which covers 0-1.8 GHz. The technique is to downconvert 1.8 GHz - 3.6 GHz to 0-1.8 GHz. by using a mixer and a 1.8 GHz Local oscillator. In practice this works quite well, sensitivity + linearity are determined by the mixer used - (Vari L - DBM 500)



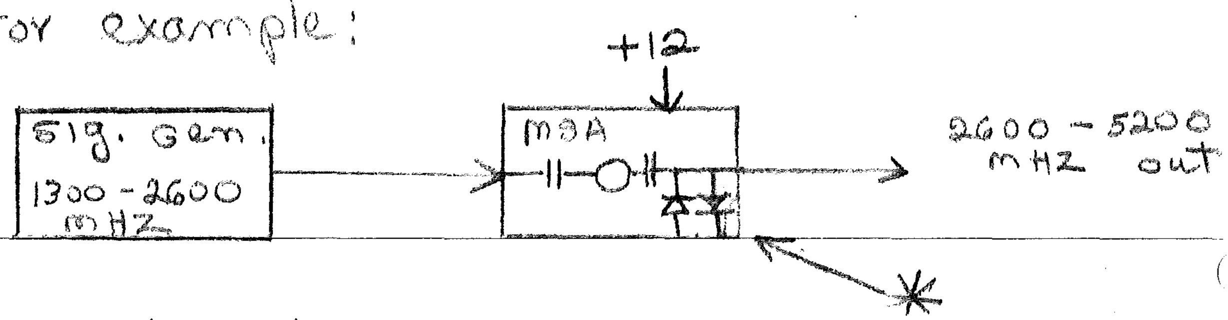
If needed an MSA preamp can be used. With this technique - 2304 mhz will appear at 504 mhz, 3456 mhz will apper at 1656 mhz. You may see some mixing artifacts go backwards across the display. This is the price you pay for no image filtering ahead of the mixer. It's real advantage is for a way to peak filter response, measure stage gain etc. Don't rely on it for harmonic measurement.

KØKE

EXTENDING YOUR SIG. GEN.

USING the nonlinearity characteris
of diodes can be used to advantage
when you run out of frequency
for the next band you wish to
conquer.

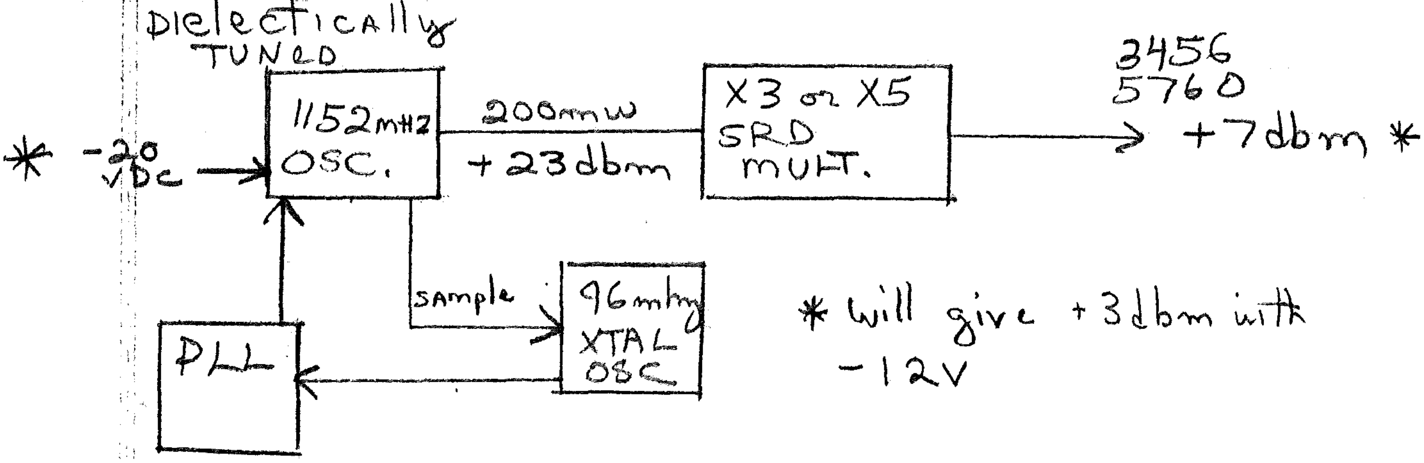
For example:



Back to back IN914, IN4554 type diodes across MSA 01→04 output will create HARMONICS useable well into the GHZ region.
I now have a useable sig source at 3456 mhz that is tuneable!
This was used to retune a combline filter from 3700 mhz down to 3456. This filter has a 25 mhz bandwidth and was tuned in very small stepped increments. The key was a variable freq. source. A DBM also could be used as a freq. doubler but this was infinitely easier!

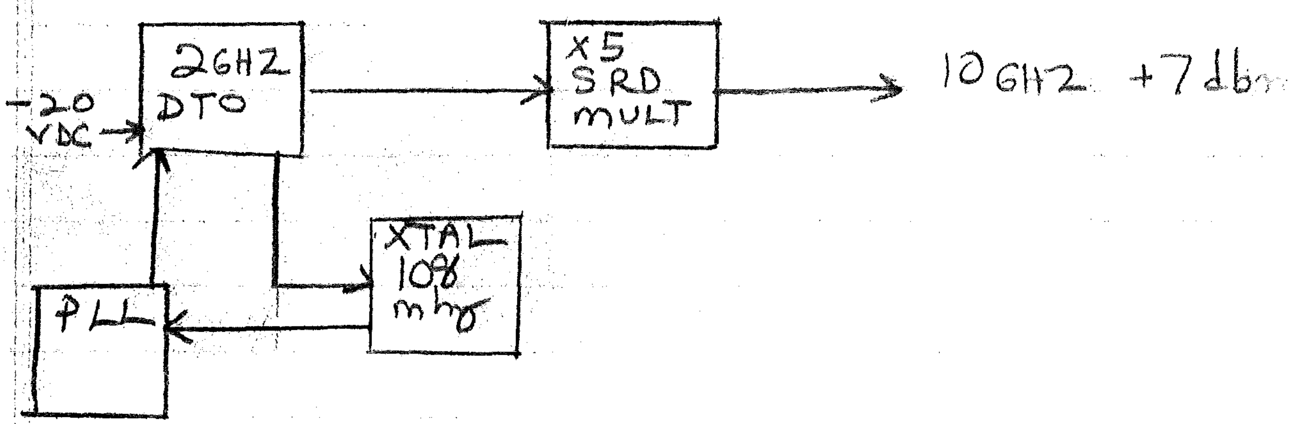
KØKE 8/86

3 GHZ + 5 GHZ Sources



Tune 1GHz osc to multiples of 96 mhz
i.e. 9th, 10th, 11th, 12th, 13th harmonic
Range will be 1000 mhz - 1200 mhz
Output will be x 3 (or x 5)
27th, 30th, 33rd, 36th, 39th harmonic
of 96 mhz or 45th, 50th, 55th, 60th etc
if x5.

10 GHZ Sources



Tune 2GHZ osc to 18th, 19th, 20th, 21st harmonic
Range should be 1900 - 2200 mhz
Output will be 90th, 95th, 100th, 105th harmon
of XTAL freq (108 mhz)

KØKE

Mode S RCVING

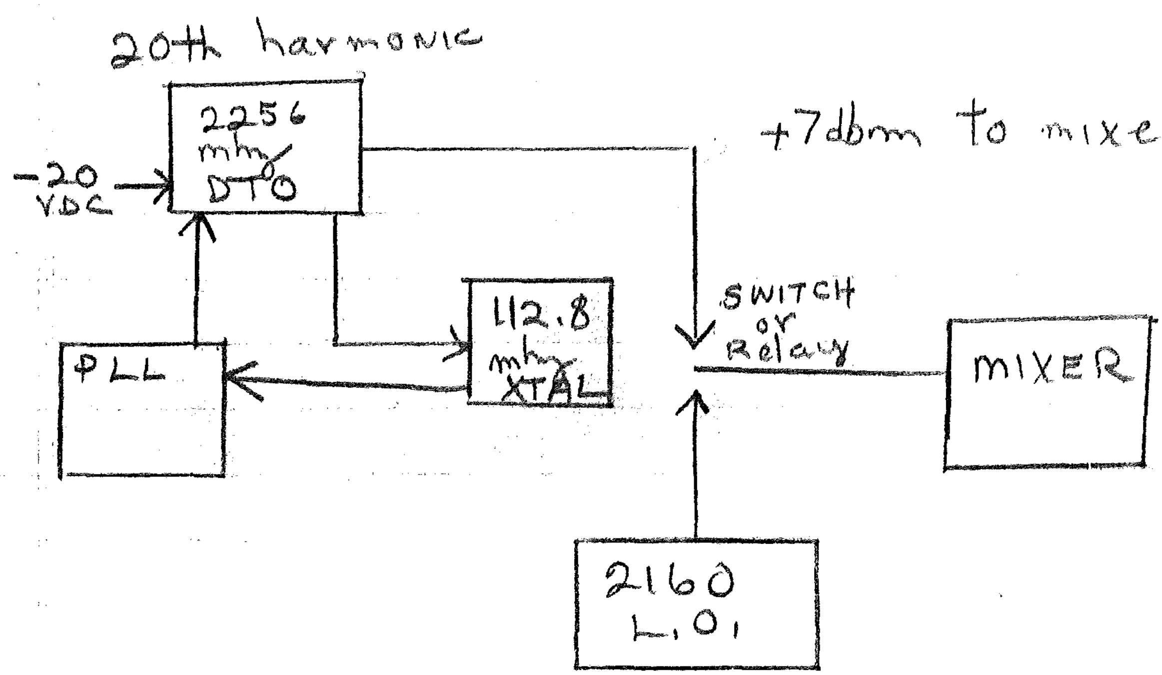
2256 mhz L.O. freq

144 mhz = 2400 mhz
145 mhz = 2401 mhz

Output channel – 2400.710 (144.710)
Beacon 2400.640 (144.640)

PLL Source

112.8 mhz x 20 = 2256 mhz
(10 ghz source, x5 multiplier removed.
+7 dbm out for L.O. use with
XVTR (SSB)



21st harmonic 107.4285714 mhz

KØKE 8/8

F9FT 55 el yagi

Element lengths computer optimized by K1FO + KØKE

STOCK F9FT ≈ 21 dbi, Comp opt yagi ≈ 23 dbi

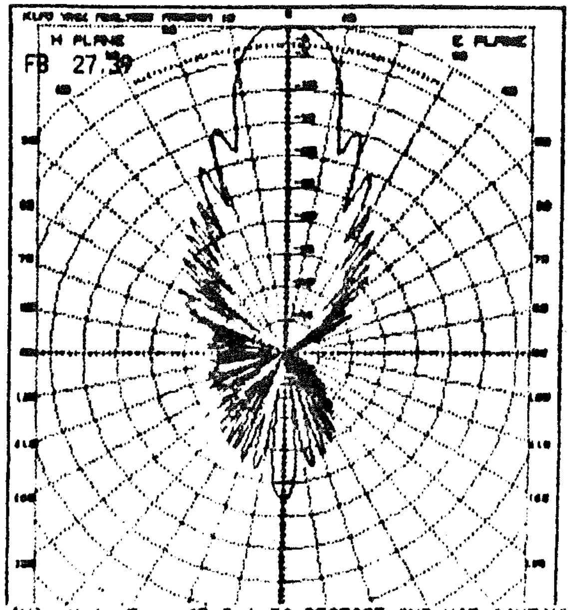
R	4.531	4 17/32	D24	3.313	3 5/16	D49	3.125
DE			D25	3.281	3 9/32	D50	3.125
D1	4.141	4 9/64	D26	3.266	3 17/64	D51	3.094
D2	4.031	4 1/32	D27	3.266	"	D52	3.094
D3	3.953	3 61/64	D28	3.266	"	D53	3.094
D4	3.828	3 53/64	D29	3.266	"	D54	3.063
D5	3.75	3 3/4	D30	3.234	3 15/64	D55	3.063
D6	3.75	3 3/4	D31	3.203	3 13/64		
D7	3.703	3 45/64	D32	3.203	"		
D8	3.672	3 43/64	D33	3.203	"		
D9	3.609	3 39/64	D34	3.203	"		
D10	3.516	3 33/64	D35	3.188	3 3/16		
D11	3.516	"	D36	3.188	"		
D12	3.516	"	D37	3.188	"		
D13	3.5	3 1/2	D38	3.188	"		
D14	3.469	3 15/32	D39	3.188	"		
D15	3.406	3 13/32	D40	3.156	3 5/32		
D16	3.406	"	D41	3.156	"		
D17	3.406	"	D42	3.156	"		
D18	3.406	"	D43	3.156	"		
D19	3.391	3 25/64	D44	3.156	"		
D20	3.344	3 11/32	D45	3.156	"		
D21	3.344	"	D46	3.125	3 1/8		
D22	3.344	"	D47	3.125	"		
D23	3.344	"	D48	3.125	"		

Measured 22.4 dbi at C. States VHF Conf, .8 db over stock F9FT

If you use #8 AWG (.128) wire for elements ~~shorten all dims by 3 mils~~ use #30 drill to slightly enlarge plastic to accept element

All dimensions assume use of .125 aluminum welding rod less GAIN

K6MIE_57E 55 Dir 1 Ref
FREQ 1296.0 GAIN dBd 20.77 FB 27.39



r new info, Elspace(X), Elength(Y), Nel, Freq OR R=1 TO RESTART AND HIT CONTINU

Step | Continue | RUN | Print All | Clr Tab / Set Tab | Display /clns | System Any char | Caps Recall

Element #	Millimeters	Inches	Color code
Reflector	115	4" 17/32	Black
Driven element	102	4" 1/64	(none)
Director 1	99	3" 57/64	Brown
Director 2	98	3" 25/32	Red
Director 3	95	3" 47/64	Orange
Director 4	94	3" 45/64	Yellow
Director 5	93	3" 21/32	Green
Director 6	92	3" 5/8	Blue
Director 7	91	3" 37/64	Violet
Director 8 thru 14	7 x 90	7 x 3" 39/64	White
Director 15 thru 21	7 x 89	7 x 3" 1/2	** Black
Director 22 thru 27	6 x 88	6 x 3" 15/32	** Red
Director 28 thru 34	7 x 87	7 x 3" 27/64	** Orange
Director 35 thru 41	7 x 86	7 x 3" 25/64	** Yellow

57 ELEMENT 1296 MHz YAGI BASED ON F9FT 55 el SPACINGS
ELEMENT LENGTHS OPTIMIZED BY K1FO

CUMULATIVE ELEMENT SPACINGS

0	1.375	2.4062	3.6875	6.2812	8.9687	11.625	14.75
18.3125	21.875	25.4375	29	32.5625	36.125	39.6875	43.25
46.8125	50.375	53.9375	57.5	61.0625	64.625	68.1875	71.75
75.3125	78.875	82.4375	86	89.5625	93.125	96.6875	100.25
103.8125	107.375	110.9375	114.5	118.0625	121.625	125.1875	128.75
132.3125	135.875	139.4375	143	146.5625	150.125	153.6875	157.25
160.8125	164.375	167.9375	171.5	175.0625	178.625	182.1875	185.75
189.3125	0	0	0				

ELEMENT LENGTHS (1/8 in. diameter elements)

	4.53125	0	4.140625	4.03125	3.953125	3.828125	3.75	3.75
7	3.703125	3.671875	3.609375	3.515625	3.515625	3.515625	3.5	3.46875
15	3.40625	3.40625	3.40625	3.40625	3.390625	3.34375	3.34375	3.34375
23	3.34375	3.3125	3.28125	3.265625	3.265625	3.265625	3.265625	3.234375
31	3.203125	3.203125	3.203125	3.203125	3.1875	3.1875	3.1875	3.1875
39	3.1875	3.15625	3.15625	3.15625	3.15625	3.15625	3.15625	3.125
47	3.125	3.125	3.125	3.125	3.09375	3.09375	3.09375	3.0625
55	3.0625	0	0	0				

"A 2.3 GHz FEED FOR .43 f/d REFLECTORS"

BY

DONALD L. HILLIARD, WØPW

A 2.3 GHz FEED FOR .43 f/d REFLECTORS

by

Donald L. Hilliard, WØPW

One of the more common f/d (focal length/diameter) ratios used in designing parabolic reflectors is .43, the reasons for which are several. It is not the purpose of this description to discuss these reasons, but to describe a linear feed that is efficient. It can be seen (ref. Figure 1) that the -10 db beamwidth for a feed antenna should be 120°. It is commonly believed that -10 db edge illumination is a good compromise, all factors considered. Therefore, for uniform illumination, a good antenna should have equal E and H plane patterns of 120° at -10 db. The "two half wave dipoles spaced a half wavelength, one quarter wavelength above a one square wavelength reflector" design is one that approximately meets this criteria.

The described design uses a quarter wavelength split 4:1 balun to support the two dipoles and phasing line assembly. This balun and dipole assembly are constructed from small pieces of 1/64" wall brass tubing, commonly referred to as "hobby brass tubing", which is available at most hobby supply stores and some hardware stores.

The balun assembly should be assembled first. Solder the 1.3 inch length of 3/16" OD tubing to the center pin of the UG-58 connector. Then solder the slotted length of 15/32" OD tubing to the UG-58, making certain the 3/16" tube is centered. Once this balun assembly is done, it can be mounted through a 5/8" diameter hole to the reflector plate with four 4-40 1/8" screws.

The phasing line/dipole assemblies can be soldered in place on the balun assembly as shown in Figure 3.

If constructed exactly as described, the VSWR should be good. If equipment is available to accurately measure VSWR, two variables that can be adjusted are element lengths and spacing above the reflector.

EXAMPLE : 96" REFL.

$$h = \frac{D^2}{16f}$$

$f = 41.28"$

$h \approx 14"$

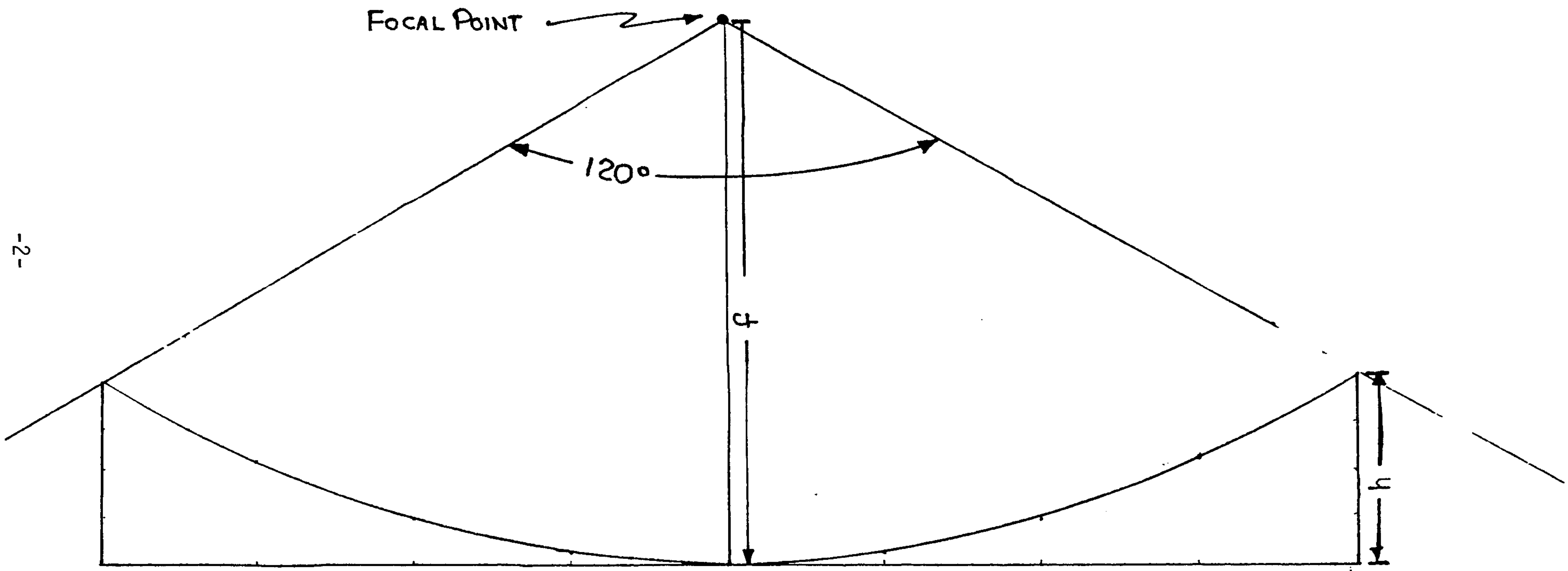
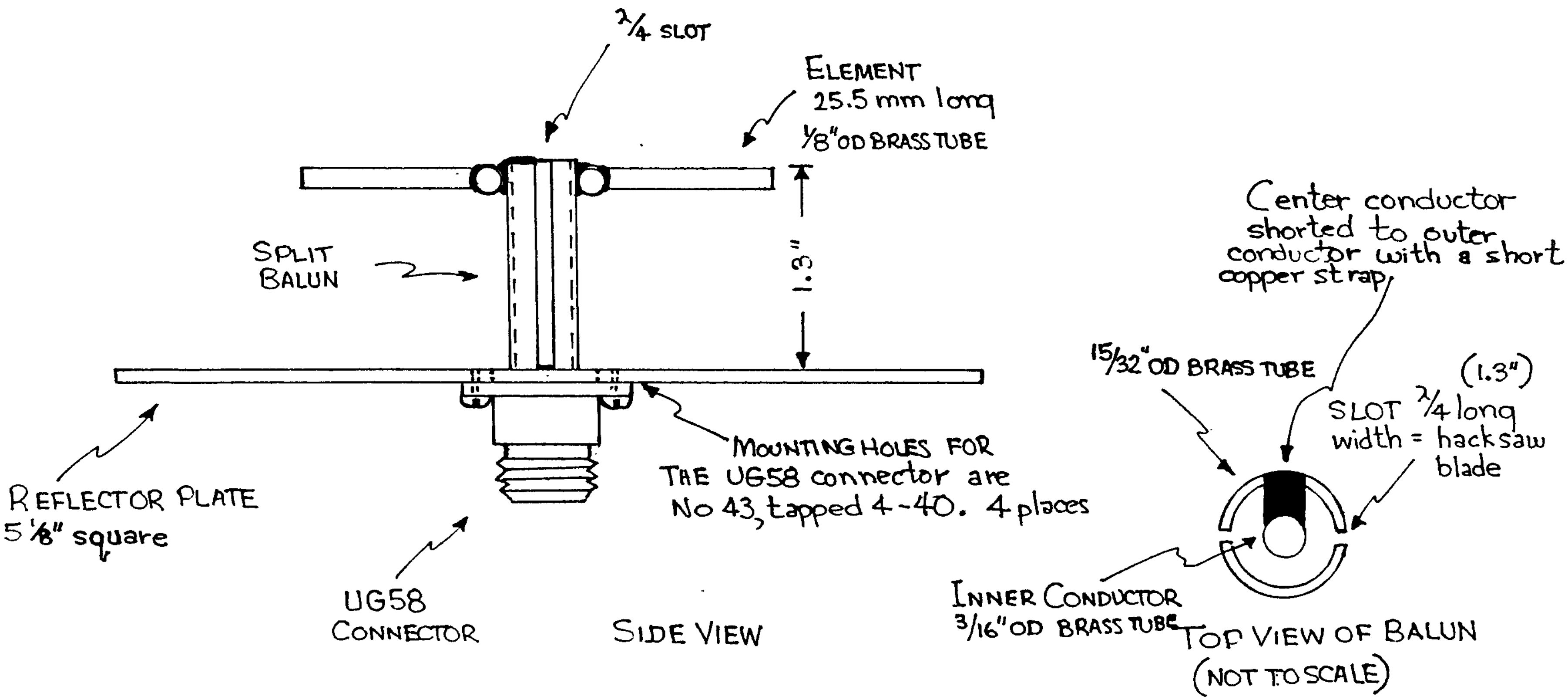


FIGURE 1

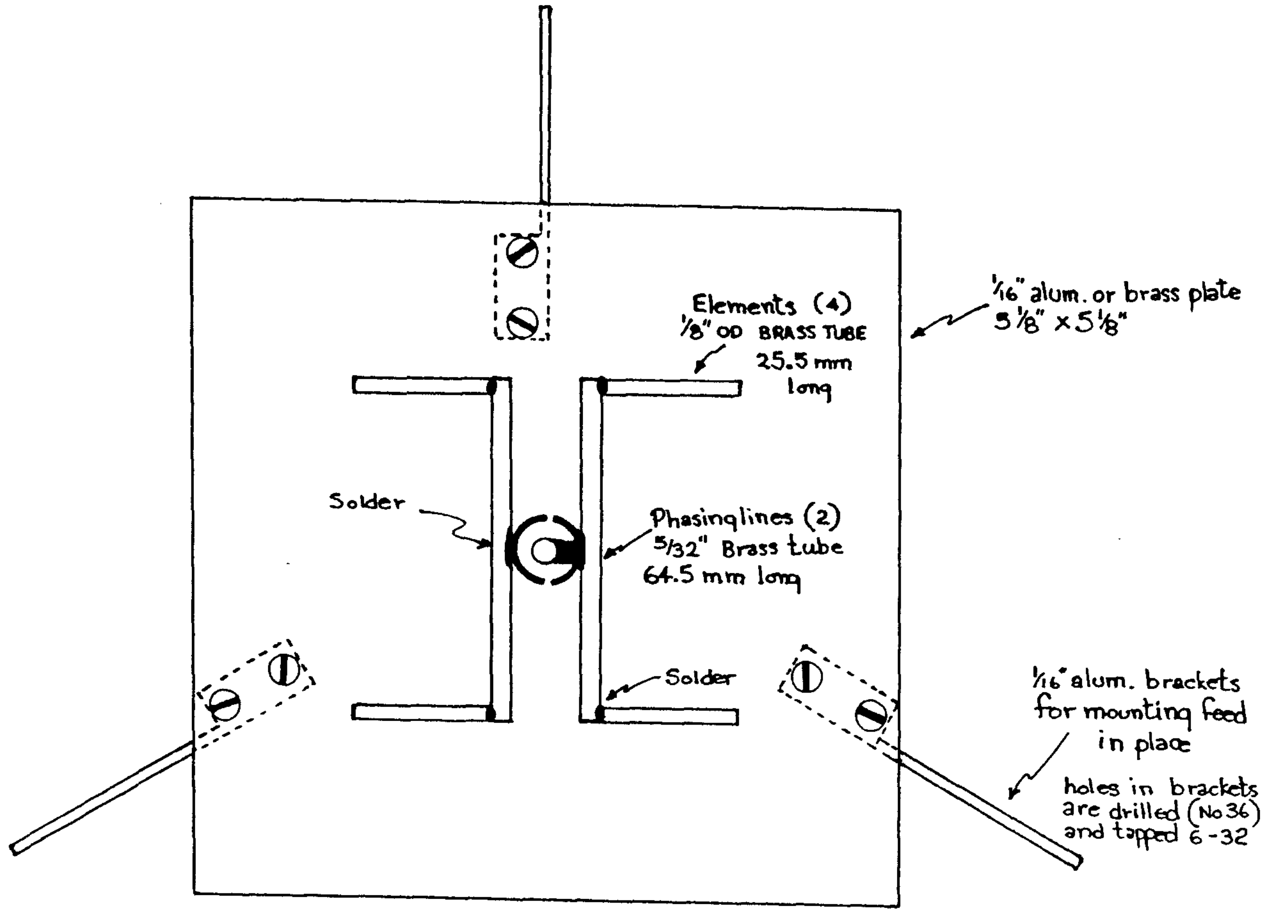
-3-



2.3 GHz. FEED FOR .43 f/d Reflectors

FIGURE 2

D. Hilliard 7/86



2.3 GHz. FEED FOR .43 f/d Reflectors

Top view.

FIGURE 3

D. Hilliard 7/86