An HF 50-W Linear Amplifier

If your QRP transmitter operates with 1 to 2 W output, and you have occasionally wished for moderate power increase, this project is for you! With a flick of the switch, you can increase your signal nearly 3 S-units going from 1 to 50 W.

This amplifier project features a complete 50-W unit that covers all ham bands from 160 to 10 m in a compact easy-to-build package. Designed with readily obtainable parts coupled with detailed schematics, parts list, and mechanical drawings make this an attractive project for the moderately experienced builder. This project was designed and built by Rod Blocksome, K0DAS.

The amplifier features internal control circuits to protect it from high antenna SWR and over-drive conditions. The amplifier is designed for excellent linearity and harmonic suppression through the use of negative feedback and a band-switched bank of low-pass filters. A built-in directional-coupler circuit provides metering of the forward and reflected power. And lastly, the amplifier operates from 12 V dc for convenient operation at home, mobile or portable.

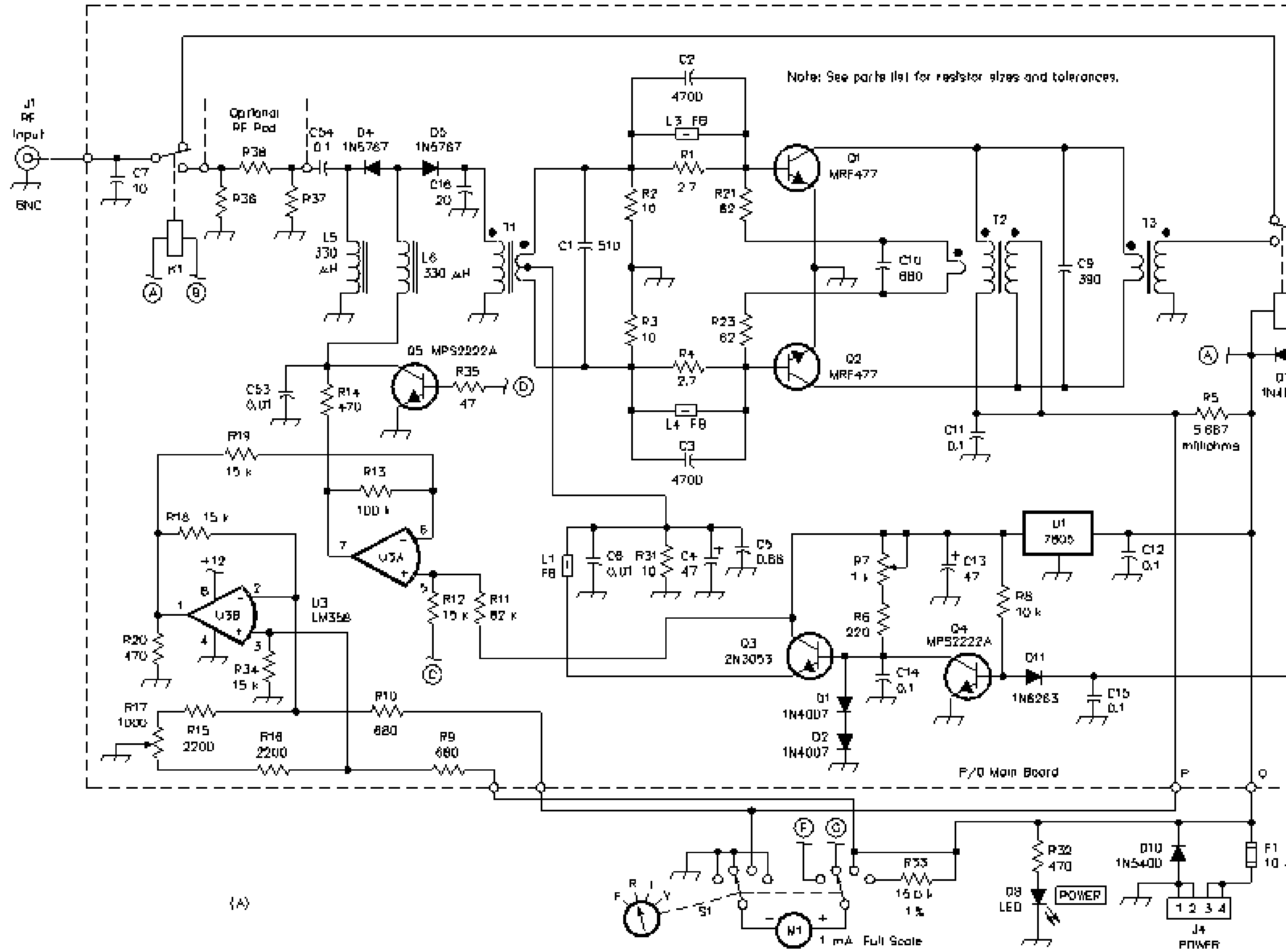
Circuit Design Details

RF Amplifier Circuit

Fig 17.94 is the schematic for the entire amplifier. A basic wideband push-pull RF circuit forms the heart of the amplifier. Motorola MRF477 bipolar transistors were chosen for their high gain and availability in the low-cost TO-220 plastic package. Care was taken to achieve a symmetrical base and collector feed layout on the PC board with this package. The emitters are electrically connected to the mounting tabs which helps reduce the emitter-to-emitter ground impedance in the push-pull circuit. High-gain transistors are necessary to achieve 50 W with only one stage of amplification. Overall amplifier gain must be 15 to 17 dB.

The RC networks in the base feed to each transistor stabilize the wide variation of the MRF477 base input impedance from 1.8 to 30 MHz. Negative feedback using a low-impedance winding from the collector decoupling transformer also helps stabilize the input impedance and flatten the inherent gain variations of the MRF477 over the HF band.

Wideband RF transformers with a 1:9 impedance ratio couple RF into and out of the push-pull amplifier stage. This wideband transformer is relatively easy to build and provides adequate performance at the 50-W power level. The transformer leakage inductance is compensated with shunt capacitors soldered directly on the low-impedance balanced winding of each transformer.


Note: See parts list for resistor sizes and tolerances.
J1
RF
Input
BNC
C7
10
Optional
RF Pad
R38
R36
R37
K1
C54
0.1
D4
1N5767
D5
1N5767
C16
20
L5
330
µH
L6
330 µH
T1
C1 510
C2
470D
L3 FB
R1
2.7
R2
10
R21
82
R3
10
R23
82
R4
2.7
L4 FB
C3
470D
Q1
MRF477
Q2
MRF477
C10
680
T2
C9
390
T3
C11
0.1
R5
5.687
milliohms
Q5 MPS2222A
R35
47
C53
0.01
R14
470
R19
15 k
R13
100 k
R18 15 k
+12
U3A
U3B
U3
LM358
R12
15 k
R11
82 k
R20
470
R34
15 k
R17
1000
R15
2200
R16
2200
R10
680
R9
680
L1
FB
C8
0.01
R31
10
C4
47
C5
0.68
R7
1 k
C13
47
U1
7805
C12
0.1
R8
10 k
R6
220
Q3
2N3053
Q4
MPS2222A
C14
0.1
D1
1N4007
D2
1N4007
D11
1N6263
C15
0.1
P/O Main Board
P
Q
S1
M1
1 mA Full Scale
R33
15.0 k
1 %
R32
470
D8
LED
POWER
D10
1N5400
F1
J4
POWER
(A)

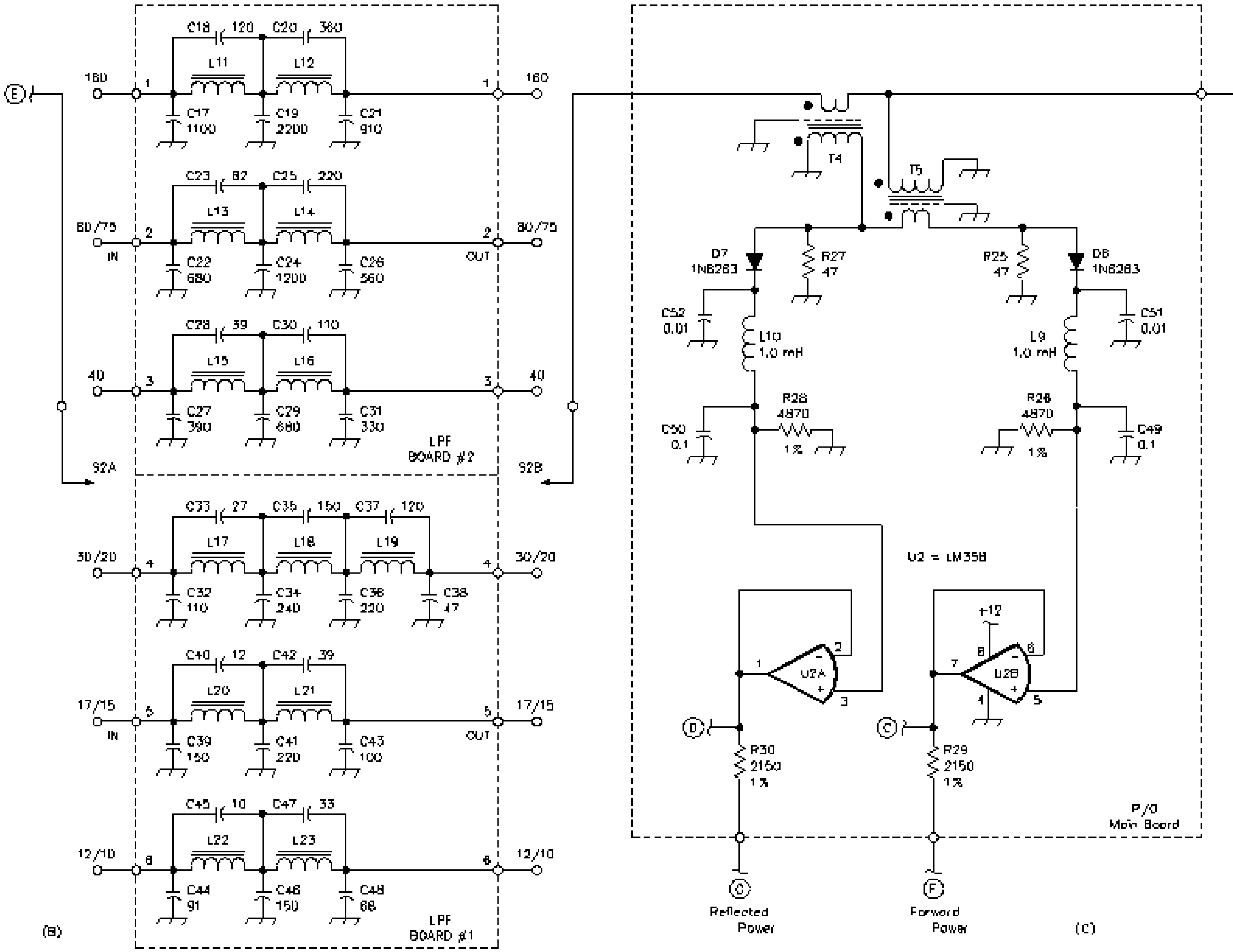


Fig 17.94—A complete schematic for the 50-W linear amplifier. A complete template package with mechanical details is available from ARRL HQ (see text). Resistors are 1/4-W 10% carbon composition units unless otherwise indicated. SM (Silver Mica) capacitors are 5% tolerance. Parts supplier codes: RFP = RF Parts, CCI = Communications Concepts. Look at the Address List in the References chapter for current addresses. The chassis is a 1590E 7.4×4.7×3.1-inch diecast box from Newark (81F3795). Etched circuit boards are available from FAR Circuits for $16 per set (3 boards).

C01—510 pF SM, RFP.

C02, C03—4700 pF SM, RFP.

C04, C13—47-µF electrolytic.

C05—0.68-µF disc ceramic.

C06,C08, C51, C52, C53—0.01-µF disc ceramic.

C07, C45—10 pF SM, RFP.

C09, C31—330 pF SM, RFP.

C10, C22, C29—680 pF SM, RFP.

C11, C12, C14, C15, C49, C50, C54—0.1-µF disc ceramic.

C16—20 pF SM, RFP.

C17—1100 pF SM, RFP.

C18, C37—120 pF SM, RFP.

C19—2200 pF SM, RFP.

C20—360 pF SM, RFP.

C21—910 pF SM, RFP.

C23—82 pF SM, RFP.

C24—1200 pF SM, RFP.

C25, C36, C41—220 pF SM, RFP.

C26—560 pF SM, RFP.

C27—390 pF SM, RFP.

C28, C42—39 pF SM, RFP.

C30, C32—110 pF SM, RFP.

C33—27 pF SM, RFP.

C34—240 pF SM, RFP.

C35, C39, C46—150 pF SM, RFP.

C38—47 pF SM, RFP.

C40—12 pF SM, RFP.

C43—100 pF SM, RFP.

C44—91 pF SM, RFP.

C47—33 pF SM, RFP.

C48—68 pF SM, RFP.

D1, D2, D3—1N4007 diodes, CCI.

D4, D5—1N5767 PIN diodes.

D6, D7, D11—1N6263 Schottky diode, CCI.

D8—Red LED indicator Radio Shack.

D10—1N5400 high-current diode.

F1—15A 3AG fuse.

J1—UG-1094 Female BNC RF connector, CCI.

J2—SO-239 Female UHF RF connector, CCI.

J3—RCA Phono jack, female, chassis mount.

J4—P-304-AB 4-pin male Cinch Jones, CCI.

K1,K2 — T90N5D11-12 12V T/R relay Newark (44F8968).

L01, L03, L04—FB43-1801 ferrite bead, Amidon.

L05, L06—330 μH RF choke.

L09, L10—1.0 μH molded choke.

L11-16—T68-2 toroid, μ = 10, Amidon.

L17-L23—T68-10 toroid, μ = 6, Amidon.

M1—RS-270-1754, 2.5-in 1.0 mA meter.

Misc—RG-303 miniature Teflon coax.

P1—S-304-CCT 4-pin female Cinch Jones plug.

Q1,Q2—MRF477 matched pair transistors, RFP.

Q3—NPN transistor, 2N3053.

Q4, Q5—NPN transistor, MPS2222A

R01, R04—2.7-Ω $^1/_2$-W 5%.

R02, R03—10-Ω $^1/_2$-W 5%.

R05—0.005667 Ω, 4.13-in #22 wire.

R06—220 Ω.

R07, R17—1 kΩ variable resistor RS-271-280.

R08—10 kΩ.

R9, R10—680 Ω.

R11—82 kΩ.

R12, R18, R19, R34—15 kΩ, 1%.

R13—100 kΩ, 1%.

R14, R20, R32—470 Ω.

R15, R16—2200 Ω, 1%.

R21, R23—62 Ω $^1/_2$ W, 1%.

R25, R27, R35—47 Ω.

R26, R28—4870 Ω, 1%.

R29, R30—2150 Ω, 1%.

R31—10 Ω.

R36, R37, R38—Optional attenuator resistors. Tables of values appear in the References chapter.

S1—RS-275-1386 8PDT rotary switch.

S2—PA-301 4-inch indexed shaft (Newark 22F651) and 2 PA45 6-position rotary wafers (Newark 22F853).

T1—RF600-9 9:1 RF Input transformer, CCI.

T2—FT50B-43 ferrite core.

T3—RF800-9 9:1 RF Output transformer, CCI.

T4,T5—T68-2 toroid core, μ = 10; 4 required, 2 per transformer.

U1—7805 5-V regulator, RS276-1770.

U2,U3—LM358 dual op amp.

XF1—HPK fuse holder, CCI.

Low-Pass Filter Circuit

The nine ham bands between 1.8 and 30 MHz are filtered for harmonics at the output of the amplifier by six low-pass filters (see **Table 17.6**). All harmonics must be at least 40 dB less than the fundamental to comply with FCC requirements. The filters must meet several additional design requirements besides harmonic reduction. A compact layout was needed to keep the overall amplifier reasonably small. Standard-value capacitors were used along with toroidal inductors. The use of toroids eliminates stray magnetic coupling between filter sections without elaborate shielding. Only two different cores and one wire gauge are used in the filters.

The six filters are mounted on two PC boards located on either side of the rotary band switch. This arrangement minimizes stray inductance associated with switching leads to the desired low-pass filter. The result is a filter assembly with very low passband insertion loss, low SWR in the passband and adequate stop-band harmonic attenuation. Elliptic function filters fulfill these requirements nicely. They also offer advantages in trouble shooting with simple ham shack test equipment.

All nine HF ham bands, except for the 30-m band, can be adequately filtered using only six, two-section elliptic filters. The 30-m band is separated from the 40 and 20-m bands far enough that a two-section elliptic filter will not provide adequate harmonic suppression. The solution requires either seven two-section filters or a three-section filter (with a steeper roll off) for the 30 and 20-m bands. The latter was chosen because it is more cost effective.

The main amplifier board contains T/R relays that bypass the amplifier during receive. The relays are controlled by an external PTT line to allow transceiver operation. By simply disconnecting the PTT line or the 12 V dc power, the amplifier is automatically bypassed to allow QRP transceiver operation. The low-pass filters are placed between the antenna and the T/R relays for two reasons: the filters provide some measure of receiver protection from strong out-of-band signals, and placing the T/R relays on a PC board connected with microstrip transmission line eliminates expensive coaxial relays and associated cable interconnects.

Table 17.6—Low-Pass Filter Coil Data

Notes:

1. All inductors wound with AWG #22 enameled wire

2. Toroidal Cores: Red = T-68, μ = 10 Black = T-68, μ = 6

3. Number of turns refers to the number of times the wire passes through the center of the core.

4. The coverage angle refers to the arc of core circumference occupied by the winding; that is 90° means that one quarter of the core is covered by the winding, with the turns evenly spaced within that area.

5. Inductance is given in μH.

6. The wound cores are mounted with the winding away from the board ground plane (except band-6 cores are mounted with the winding next to the board, minimum lead length).

Ref	*L(μH)*	*Core*	*Turns*	*Coverage*
L11	4.68	Red	28	300°
L12	3.94	Red	25	270°
L13	2.40	Red	19	270°
L14	1.97	Red	17	250°
L15	1.34	Red	14	200°
L16	1.12	Red	11	150°
L17	0.579	Black	11	250°
L18	0.435	Black	9	180°
L19	0.371	Black	8	180°
L20	0.450	Black	9	90°
L21	0.375	Black	8	180°
L22	0.320	Black	6	60°
L23	0.260	Black	5	45°

Stop-band pole frequencies (frequencies with high peak attenuation):

Band	*F1 (MHz)*	*F2 (MHz)*	*F3 (MHz)*
1	4.06	6.78	
2	7.76	12.3	
3	15.7	19.7	
4	20.3	25.3	36.9
5	41.7	68.8	
6	54.2	78.0	

Directional Coupler Circuit

Accurate measurement of forward and reflected power is required for a good control circuit to protect the RF devices from accidental destruction. A broadband directional coupler requiring no alignment or tweaking is incorporated in the amplifier design. The circuit is simple and low cost but the key to its performance is symmetry and careful adherence to the physical layout. RF voltage detector circuits on both forward and reflected power ports of the directional coupler provide the signals for the protection circuits and for the front-panel meter.

Protection Circuit

A PIN diode attenuator in series with the RF input controls the amount of drive applied to the MRF477s. The PIN diodes are normally biased "on" offering very little attenuation to the RF drive signal. However, if excessive reflected power or excessive collector current without proper output power is present, the PIN diodes are proportionally biased off reducing the RF drive to a safe level. The operator is made aware of these conditions by the front-panel meter and can take steps to correct the situation.

Construction

For etching patterns, filter information, construction tips and check-out procedure, see Chapter 30, **References**, to obtain a template package. The etching pattern and filter details are crucial to successful construction of this amplifier.

Conclusion

The 50-W HF amplifier just described is a low-cost, reproducible design that will give the builder years of reliable operation. Its performance is equal to, or better than, available commercial units (see **Fig 17.96**). If a higher power level is desired, the advanced amateur should have no trouble modifying this design for a 100 or 150-W version. The low-pass filter assembly and directional coupler were tested at 150 W with no signs of degraded performance. A finned heat sink will definitely be required at these higher power levels.

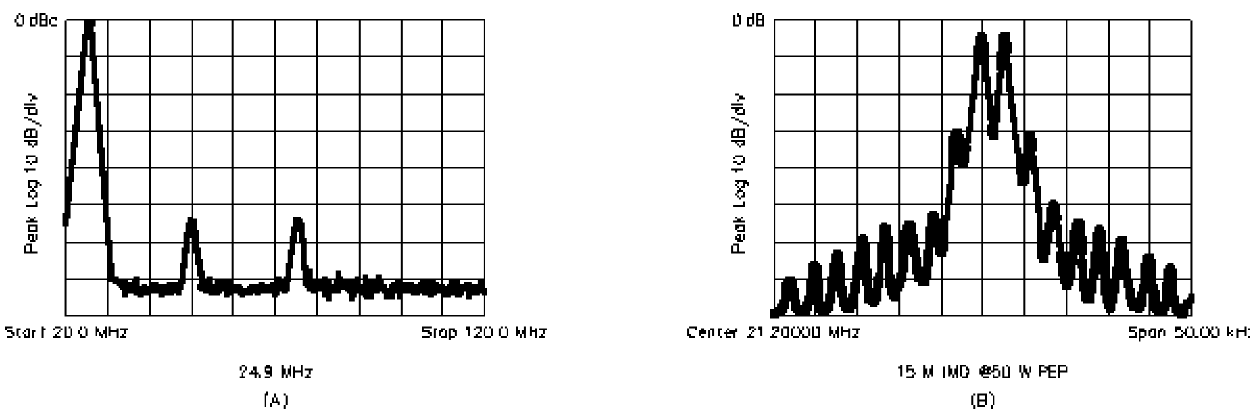


Fig 17.95—Worst-case spectral plots for the 50-W amplifier. A shows 50-W power output on 24.9 MHz. All harmonics and spurious emissions are at least 52 dB below the peak fundamental output. This amplifier meets current FCC spectral-purity requirements. B shows two-tone IMD for 50-W output at 21.2 MHz. The third-order products are approximately 34 dB below PEP output.

References

1. E. Wetherhold, W3NQN; "Elliptic Low-pass Filters for Transistor Amplifiers," January 1981 *Ham Radio*, p 20.

2. H. Granberg, Motorola Application Note AN762 "Linear Amplifiers for Mobile Operation." Published in Motorola *RF Device Data Manual*.

3. N. Dye and H. Granberg, *Radio Frequency Transistors, Principles and Practical Applications*, Butterworth-Heinemann, 1993.

4. Amidon Associates, *Iron-Powder and Ferrite Coil Forms* (application information included with their catalog of products).