SPECTRUM COMMUNICATIONS CORP.

S-7R FM REPEATER OR FULL DUPLEX BASE STATION

"Advanced Communications Electronics"

OPERATION AND MAINTENANCE MANUAL

S-7R FM REPEATER
OR FULL DUPLEX
BASE STATION

'Advanced Communications Electronics'

SPECTRUM COMMUNICATIONS CORP.

1055 W. GERMANTOWN PIKE • NORRISTOWN, PA 19403 • USA

(Greater Philadelphia Area)

6/91

S-7R VHF-UHF BASIC REPEATERS

AND FULL DUPLEX LINK TRANSCEIVERS & BASE STATIONS

FCC Type Accepted

Made in U.S.A.

10 -150 Watts

LOW COST

19" RACK MOUNT, OR DESK TOP

shown with Optional Mic

- **100% Solid State** ■ **100% Duty Cycle**
- **10 or 30 Wt. VHF, 10 or 40 Wt. UHF Transmitters. 150W VHF and 100W UHF with SCA100 Power Amplifiers.**
- **Advanced Design Receiver**
- **Heavy Duty 115 or 220V AC Supply. Auto-Switchover to 12VDC Battery Backup, w/Trickle Charger.**
- **Small Size/Light Weight - yet rugged.** *(May be used 'Portable' in Emergencies. Mobile Duplexers available.)*
- **Includes: Basic Panel Controls and AC Pilot Light; Internal Adjustments for Timers, A.F. Levels, etc.; High Stability Crystals.**
- **Options: Local Mic, CW IDer (built-in), Variable TX Power.**

The Spectrum Communictions S-7R Repeater/Base Station line was developed to meet the demand for high quality/high reliability units at a reasonable price. The S-7R line uses advanced, yet conservative designs along with a maximum of ICs and other State of the Art devices for optimum performance, simplicity, and long-term reliability. As with all Spectrum equipment, only the highest quality designs, components and workmanship are used throughout to ensure years and years of superior service. 'Crossband' units are available.

The High Performance Receivers feature an 8 Pole Front End Filter (or optional UHF Helical Resonator Assembly) with a low noise/wide dynamic range RF Amp Stage. Plus, a low noise Preamp is 'built-in' ahead of the RF Stage on 8 Pole Versions for super sensitivity. A Double Balanced Mixer follows the front end and is also a very wide dynamic range device - which, combined with the above, results in excellent Intermod, 'Desense' and Spurious rejection.

Regarding Adjacent Channel Selectivity - the receivers incorporate an 8 Pole First IF Crystal Filter, plus a 4 Pole second IF Ceramic Filter for superior adjacent channel rejection. An advanced design "Hysteresis" Squelch Circuit helps to minimize 'chopping' on weak, fluttery mobile signals, thus making typical weak signal operation much more pleasurable!

The Transmitters are very stable, rugged, and able to withstand high VSWR loads and 100% continuous duty cycle. The RF output spectrum is extremely 'clean', with spurious, harmonics, and "white noise" all very low. Most versions include proportional ovenized oscillators for high frequency stability in varying ambients. On the air, Spectrum Repeaters are famous for superb repeat audio quality - so good, *"It sounds like direct copy"!*

Basic Front Panel Controls are provided, while other adjustments are internal *to prevent tampering by unauthorized personnel.* AC Line Input is protected by a MOV (Metal Oxide Varistor) transient & spike suppressor. 600 ohm Audio Inut/Output is available.

OPTIONS

- **CTCSS/Community Tone Panel** - Single Tone Synthesized Encoder/Decoder **(-PLR)** available "built-in"; or a rack mount Synthesized **(TP38)** Tone Panel may be supplied - up to 38 tones. Many additional features are available with this Tone Panel; e.g., DTMF control. Spcify freq.(s) **DCS** also available.
- **Matching Duplexers** - the very finest "Band Pass/Band Reject" design. #639 for 10W, 136-174MHz Rptr. (#641 for 30W.) #678 for 406-512MHz. (Each Duplexer is carefully tuned and 'checked-out' with your repeater.) The highest quality RG-214/U **"Double Shielded" Duplexer Cables** are also available.
- **FL-4 Helical Resonator Front End,** (for UHF units only) - 4 super sharp 'helicals' greatly increase receiver rejection of strong local signals more than a few MHz away. (-33dB @ ± 5 MHz, -65dB @ ± 10 MHz.) In addition, Intermod spec. is improved by apx. 10dB due to wider dynamic range front end. **Highly recommended where there are many nearby transmitters!**
- **Various IF Filters** - 6, 11**(12 or 14 Pole),** 30KHz. (13KHz Std.)
- **OV-1 Receive Crystal Oven** - Greatly increases RX freq. stability. Especially recommended at UHF in cold ambients.
- **220V, 50-60z Power Supply**
- **Telephone Interconnect/Autopatch and/or DTMF Remote Control, (See Interconnect & TTC300 data sheets.)**
- **Cabinets** - 7" to 6'. (Low Cost to 'Deluxe' - Inquire.)
- **Base Station Antennas & 1/2" or 7/8" 'Hardline' Cable & Connectors. Cavity Filters.**

SPECTRUM COMMUNICATIONS CORP.

1055 W. GERMANTOWN PIKE NORRISTOWN, PA. 19403-3924 U.S.A.

(610) 631-1710 FAX: (610) 631-5017

S-7R PERFORMANCE SPECIFICATIONS

RECEIVER

Sensitivity — 0.2-0.25 μV typ. for 12dB SINAD. 0.3μV max. (0.3 μV typ. with FL-4. 0.35μV max.)

Squelch/COR Threshold — 0.1-0.2 μV nom. Schmitt Trigger 'Hysteresis' Squelch - noise operated.

Selectivity 12 Pole Filter
Std. Fltr. — -6dB @ ±6.5 KHz nom. -75dB @ ±15 KHz nom. >-125dB nom. @ ±25 KHz (20dB Quieting Method) -85dB nom. (EIA RS-204B Method)

Opt. Sharp Fltr. #FL11 (12 Pole) (Only recommended where there is strong local activity at 15-25 KHz) — -6dB @ ±5.5 KHz nom. (20dB Qt. Method) -104dB @ ±15KHz nom. >-125dB @ ±25 KHz nom. -94dB nom. (EIA RS-204B Method) *[Steeper Skirt 14 Pole Fltr. available, #FL10]*

'Desense'/ Overload — With a 1 μV desired signal, 'desense' begins at appx. 50,000 μV @ ±600 KHz. (100,000 μV @ ±1MHz W/FL-4 UHF).

Image — -90dB nom. (>-100dB Image with FL-4)

Spurious Response — **VHF:** -85dB nom. **UHF:** -90dB nom.

Intermodulation — -73dB nom. EIA. (-85dB nom. with FL-4)

Modulation Acceptance — 7KHz nom.

I.F. — Double Conversion. High Frequency 21.4MHz 1st IF greatly reduces image response. 455 KHz 2nd IF.

A.F. Output — 2.2W typ. @10% dist. Std. 5W typ. optional.

TRANSMITTER

RF Output @13.8VDC

VHF LOW PWR.	10W Nom. (5W Midband.)	
MED. PWR.	30W Min.	
HIGH PWR.	150W Nom. 136-174MHz. SCA100V option. (#HFW)	
UHF	**406-470 MHz**	**470-512 MHz**
LOW PWR.	10W Nom. (2W avail.)	8W Nom.
MED. PWR.	40W Nom., 37W Min.	30W Min.
HIGH PWR.	100W Nom. SCA100 option. (#HW)	90W Nom.

Final Stage — Emitter ballasted transistor withstands 20:1 VSWR for up to 1 min. without damage. High efficiency heat sink.

Duty Cycle — 100% Continuous duty.

Modulation 16K0F3E — True FM for the ultimate in audio quality. Instantaneous deviation limiting. 5KHz nom. Adj. up to 7KHz. Each unit is factory calibrated for 1:1 input/output deviation, (e.g. 4KHz input dev.=4KHz output dev.) - adjustable. Pre-emphasis per EIA RS-152B. Hum & Noise on the carrier is negligible. *Overall system audio fidelity & quality is excellent—so much so that it's very difficult to tell the difference between 'Direct' and 'Repeat' copy.*

Spurious — -70dB min. -75dB typ.

Harmonics — -65dB nom. Multi-section lowpass filter built-in.

FCC TYPE ACCEPTANCE DESIGNATIONS

Model Series	TX Pwr.	FCC Rule Parts	FCC ID Number
S-7R - VHF	2W	21, 22, 74, 81, 90	B2Y8QRSCT500V-2
	10W		B2Y8QRSCT500V-15
	30W		B2YBQRSCT500V-30
S-7R - UHF	2W	21, 22, 74, 90, 95	B2Y8QRSCT500-2
	10W		B2Y8QRSCT500-10
	40W		B2Y8QRSCT500-40

"Split-Channel" Versions Also Available For 12.5 KHz Channel Spacing. Adj. Chan. Selectivity = -85dB nom. EIA. (6 kHz B.W. IF Filter.)

GENERAL

Frequency Range
VHF Unit 136-174 MHz. 66-88 MHz. 216-240 MHz.
UHF Unit 406-512 MHz

Frequency Stability
Rcvr. ±0.0005% typ. (-20 to +60°C) ±0.001% max. (-30 to +60°C) — **Option** ±0.0003% typ. (-30 to +60°C) w/OV-1 Oven

Xmtr.
VHF: **FCC Type Acc. Unit:** ± 0.0002% max. (-30 to+60°C). Includes OS-18 Proportional Crystal Osc./Oven Module.
Commercial Export/Amateur Unit: ± 0.001% nom. (-20 to +60°C). *Precision Grade Crystals used throughout - on all units.*

UHF: ± 0.00025% max. (-30 to +60°C) **Includes Proportional Solid-State Crystal Osc./Oven circuit. *Superior to common TCXO's.***

Operating Temp. Range — -30 to +60°C

Remote Control — 'Inhibits' xmtr. remotely by shorting transmitter keying line to ground, at rear panel jack.

Timers (All internally adjustable)
"Time Out": 0.5 to 5 min. (typ.)
Carrier 'Hang' Time: 0.1 to 7 sec. (typ.)
ID Time: 0.5 to 10min. typ. (To 30min. max.)

All CMOS Control Logic - For very low current drain.

Local Mic — Optional handheld mic. w/coiled cord. Adjustable Mic. Gain.

RF Connectors — **VHF:** UHF SO239 **UHF:** Type N

Accessory Jack — For Tone Panel, Interconnect/Autopatch, TX Remote Control, DC out to aux. equipment, etc. **Included:** + 5 and +13.8 VDC; RX AF out; Aux. TX AF input, (1 K ohm)—adj. level; Aux. PTT—(gnd to xmit); COR transistor switch—(switches 'LO' with incoming signal); TX Control Line; Ground; CTCSS Tone Input, Output & Trigger.

Panel Size — 5¼"H x 19"W. Depth: 12". **NOTE:** TX Heatsink protrudes 1" above top of panel.

Net Weight — 22 lbs. **Shipping Weight:** 30 lbs.

1 Year Warranty — Covers parts & labor. Spare parts are normally factory stock.

SPECTRUM COMMUNICATIONS CORP.

S-7R REPEATER / BASE STATION

SECTION 1 INTRODUCTION

We would like to take this opportunity to thank you for becoming one of the discerning individuals or organizations to own the Spectrum Communications' S-7R FM Repeater/Base Station. Our company is dedicated to the development of very high-quality products, manufactured in limited quantities, and we anticipate that they will always be in short supply. Onlythe finest quality components and workmanship are used throughout the S-7R. The components are carefully selected and derated for many years of trouble-free operation. The unit is 100% solid-state and is designed for continuous duty, unattended service. The Control/Timer and ID boards use all CMOS ICs for long, reliable life. (No relays are used in the system.) Basic operating controls are provided on the front panel, while audio and timer adjustments, etc. are internal to simplify operation and prevent tampering. A jack is located at the rear and includes provisions for Remote Control, Tone Panel, Autopatch, DC Outputs, AF Inputs and Outputs, etc. Two binding posts are also provided for Automatic Emergency DC Battery Power in the event of an AC power failure. A 115 or 220VAC power supply and an optional "plug-in" digital CW IDer are built-in.

SECTION 2 UNPACKING

Carefully unpack the unit and save the packing material. Locate the optional local mic (if ordered).

In case of damage - be sure to notify the delivering carrier at once. All shipments are insured for full value, and damage is the responsibility of the freight common carrier. Our equipment is carefully packed and shipped in perfect condition, and our responsibility for damage ends when the carton is delivered to the carrier. In case of damage in shipment, please notify the freight carrier and Spectrum within one business day and save the carton and packing material in order to make a claim!

SECTION 3 OPERATING CONTROLS & INSTRUCTIONS

INITIAL SETUP

Connect the Transmitter output to the proper duplexer connector; (or to the transmit antenna cable). Connect the local mic (optional) to the front panel connector. Connect the receiver input. (Normally from a duplexer.) Plug the line cord into a source of 115-120V, 60 Hz power. (Or optional 220 V, 50-60 Hz if unit is so wired.)

MOUNTING/COOLING ← **IMPORTANT !**

The heat sink(s) on the rear panel must be kept open to free air circulation for proper cooling - THEY MUST NOT BE OBTRUCTED! (Especially important on the 30-40 W unit.) The 30 W S-7R must be mounted so that there is a least 2" of open space above and below the housing and behind the heat sinks. Also, on VHF units with the FL-6 Preselector:

note that this module protrudes about 1 3/8" below the bottom of the S-7R, so allow open space below the unit for this. DO NOT operate the 30 - 40 W with the heat sinks against a wall or in a tightly enclosed cabinet, etc.!!

3.2 FRONT PANEL CONTROLS

3.2.1 AC Power - Activates or deactivates the AC line power (lighted switch indicates AC power on.).

3.2.2 Mode Switch - Controls the unit's operating mode. For normal repeater service, this switch should always be left in the OPER position. In this mode, whenever a received signal opens the squelch, the transmitter will be activated instantly, and "repeat" the signal.

3.2.2.1 COR Disable - When the Mode switch is in this position, COR circuitry is disabled. An incoming signal may be monitored on the speaker, but it will not trigger the transmitter. Note that with the COR disabled, the local mic and IDer can still bring up the transmitter. Also, in this mode, the unit may be operated as a full duplex base station.

3.2.2.2 Transmit - Activates the transmitter, but NOT the COR circuits (i.e. not the carrier "hang" or "time-out" timers or IDer). If it desired to check those functions, merely open the squelch control momentarily, and the COR, timer, and ID circuits will be activated.

3.2.3 Monitor Volume - Adjusts the receiver audio level to the front panel monitor speaker. (Has NO effect on repeated audio.) Note that the CW ID is not audible on the local monitor speaker. This control should be set to minimum when the repeater is left unattended.

3.2.4 Squelch - Simultaneously sets both the receiver squelch threshold and the COR trigger point. As the control is advanced clockwise, a stronger signal will be required to trigger the repeater. Since the squelch/COR circuit is VERY SENSITIVE, it is NOT NECESSARY to set this control on the VERY EDGE of THRESHOLD! Normally it should be set at 1-2 divisions BEYOND threshold. This will still be very sensitive, but it will prevent "nuisance triggering" of the machine by extremely weak signals, noise, or other signals which may be present at the repeater site.

Note that this "hysterisis" squelch circuit has a very beneficial effect with weak, fluttery incoming signals, especially at lower settings of the squelch control. If the signal fades BELOW the level necessary to initially "break" the squelch, it would normally "chop-out" of the squelch with most standard receiver designs. However, with this circuit, the signal can fade a few dB BELOW the opening point before the squelch closes. This has the effect of greatly reducing chopping on weak, fading signals - which can be quite annoying. The hysterisis squelch circuit makes operation of the repeater with weak incoming signals much smoother and much more of a pleasure to operate. Note that the amount of hysterisis (i.e. the difference between the squelch opening and closing levels at a given setting) and the "squelch tail" both decrease as the squelch control is advanced.

INTERNAL CONTROLS

3.3.1 TIME-OUT - Sets the transmitter "time-out timer". When the repeater is "timed-out", the transmitter is shut-down after a certain time duration. The time-out may be either on the input (receiver), or output (transmitter) of the repeater per a jumper wire on the CAR-7 Board. When T.O. is on the input, the timer circuit times the duration of the incoming signal and shuts-down the transmitter after the predetermined time interval has elapsed. The timer resets instantly when the incoming signal drops. (In this case, the Hang Time is usually several seconds, and there is no need to let the repeater carrier drop to reset the timer. Repeater users may reset the timer by merely letting up on their mic button for a fraction of a second). When T.O. is on the output, the timer resets when the repeater transmitter carrier drops. In this case, users must let the repeater carrier drop for reset, and hang time is usually fairly short. We recommend T.O. on the input with about 4 second hang time. The repeater will be factory set up for T.O. on the input unless otherwise specified.

3.3.2 HANG TIME - Sets the repeater transmitter's "carrier hang time". (The amount of time the repeater transmitter stays on the air after the received signal drops). Typically set for 4 to 5 seconds.

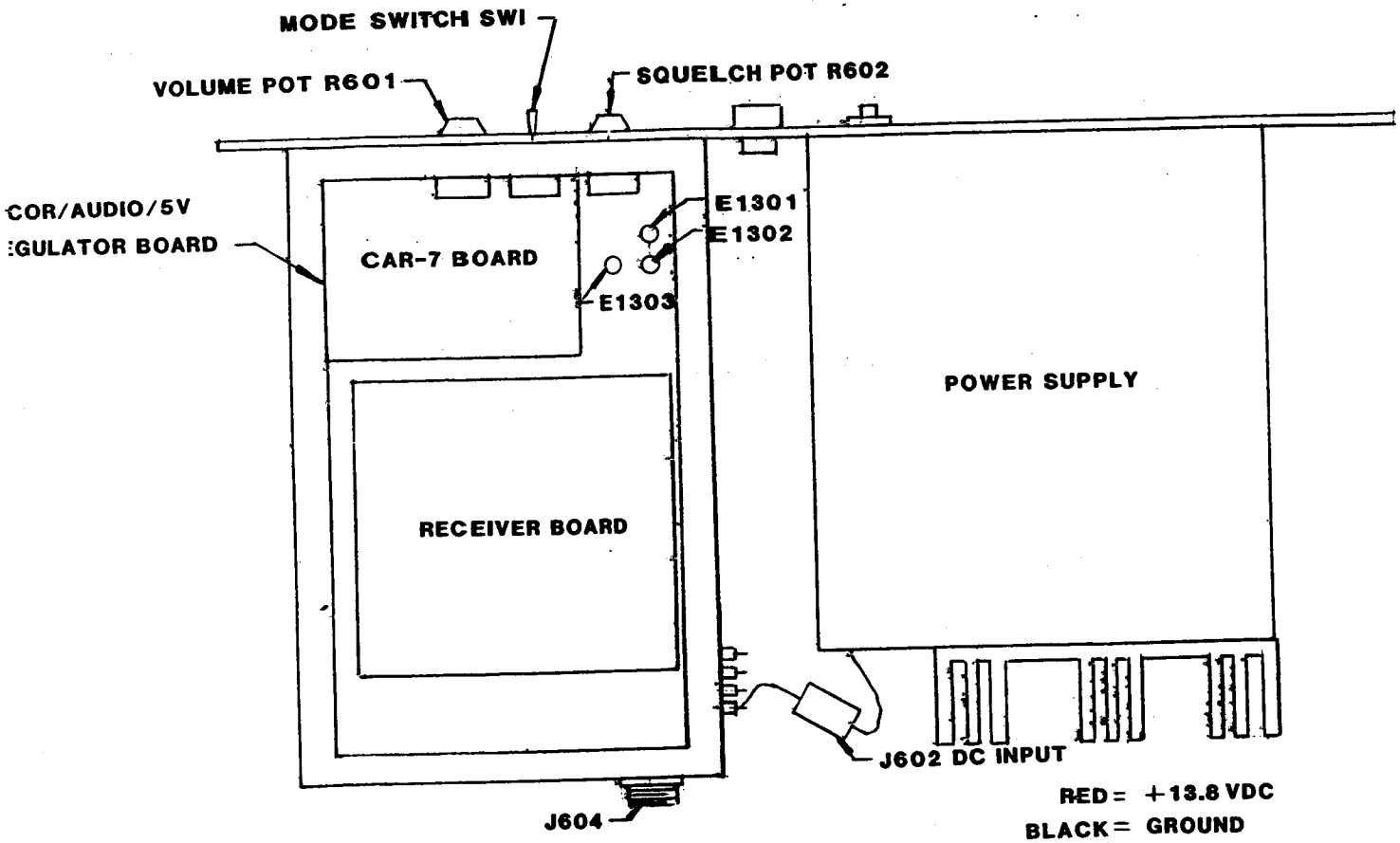
3.4 REAR PANEL JACKS

3.4.1 EXTERNAL 12V DC INPUT - (EMERGENCY BATTERY POWER). J608 (Red and Black Binding Posts, on Power Supply unit) This DC input is provided so that the unit may be operated on an external source of DC power, such as a car or truck battery, should there be a failure in AC line power. Assuming a 12 V battery is connected to the terminals, when the built-in AC power supply's output voltage drops below 11 V, the battery current conducts through a diode to power the repeater until AC is restored. The switching action is instantaneous, reliable, and 100% solid state - no manual switches or relays are required.

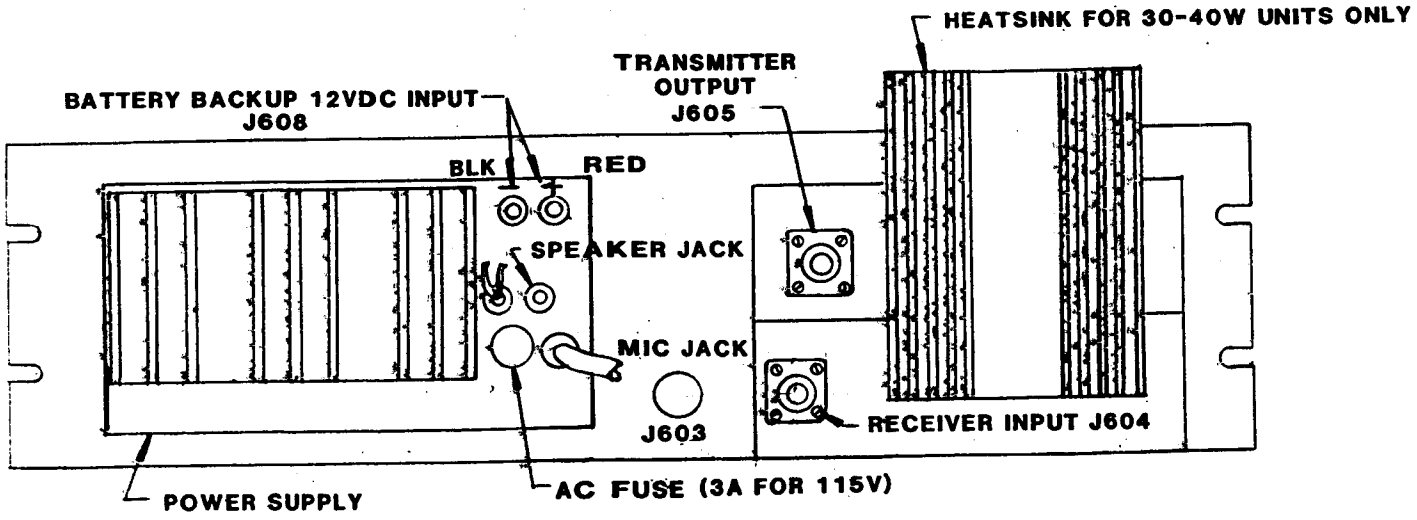
When the unit is operating normally on its built-in AC power supply, about 100mA of current is delivered to the battery as a trickle charge. Note: This is not enough to charge a discharged battery - only enough to "float" a fully charged battery and prevent self-discharge. When the battery is discharged, it must be disconnected and charged from a standard battery charger.

The Red terminal is the +12 V input. Black is the ground or - terminal. The input is fused with an internal 8 A fuse. If the 12 V leads are reversed, the reverse voltage protection diode will conduct very heavily and blow the fuse - thus protecting the repeater from damage. When operating on battery power, the 30 W unit will draw about 5 A of current while transmitting.

S-7R CHASSIS LAYOUT



BOTTOM VIEW



REAR VIEW

(7A for 40W UHF unit. Approximately 2.2A for 10W units.) At least a 70 Amp-Hour battery is recommended. Keep the battery leads as short as possible (6 feet maximum) and use at least #12 wire (#8 or #10 preferred), since voltage drop will be appreciable with thinner gauge wire.

In normal operation, the battery voltage must not exceed 13.8 V or improper operation could result. If it is desired to run the unit strictly on an external DC Power Supply, unplug the AC line cord, and in this case only, the external DC voltage may be as high as 14.2 V.

3.4.2 ACCESSORY JACK J601 - This jack is provided for convenience in interfacing the unit to other auxiliary equipment and for test purposes. See Table 1 for the pin configurations.

PIN 1 - AUXILIARY AUDIO INPUT TO THE TRANSMITTER. (Level Adjust pot R343 is on the CAR-7 COR/Audio Mixer/5 V Regulator Board.) Maximum input sensitivity is 100mVp-p (36 Vrms) for ±5 KHz transmitter deviation with a 1 KHz tone. Use shielded wire to Pin 1 and use Pin 9 for shield ground. Useful for autopatch, signaling, or any other application which requires voice or tone audio to modulate the S-7R's transmitter.

PIN 2 - RECEIVER AUDIO OUTPUT. (High Impedance Line), after squelch gate. Maximum output level: 0.7 Vp-p (0.25 Vrms) w/1 KHz tone @ +/- 5 KHz deviation. Do not load down this terminal with low impedance loads. Use at least a 10K ohm load impedance or greater. (10K ohm pot, etc.) Shielded wire is required for connection to this point. Use Pin 9 for ground.

PIN 3 - COR SWITCH. This is an open collector transistor switch which is triggered by the COR - (switches ON -- or Low -- when there is an incoming signal to the receiver). Useful for autopatch and many other applications.

PIN 4 - AUXILIARY PTT INPUT. Ground this pin to trigger the transmitter remotely (may be grounded through the collector of an NPN switching transistor such as a 2N2222A, or through relay contacts, etc.). Triggering the transmitter for any length of time via Pin 4 will not cause the transmitter to "time out". (However, if the transmitter is "timed out" due to Receiver/COR activity, then the Aux. PTT Input will not key the transmitter.

PIN 5 - REMOTE TRANSMITTER/COR DISABLE. Used to remotely shut down the S-7R's transmitter;(actually the COR trigger line is shorted to ground). This may be accomplished with a set of relay contacts or an open collector transistor switch. (The maximum voltage at this point is 5VDC and the maximum current into a short is 1.2 mA.) The transmitter is disabled while this point is shorted to ground.

PIN 6 - RECEIVER COR OUTPUT. (High Impedance Point.) This output can be used to trigger a repeater or link transmitter, (via a COR board, "Controller", etc.) Note that this IC output can only switch high impedance loads. It can "source" (supply) up to 5mA max. (It cannot directly switch relays, lamps, etc. Interface circuitry, such as a transistor switch, must be used if the currents to be switched exceed the above limits.) The output "High" state voltage is approx. 7 VDC; and the "Low" state voltage is approx. 0.1 VDC. When the Squelch is open, the COR output state will be "Low". When the Squelch is closed, the COR output will be "High".

PINS 7 & 8 - +5 and +13.8 VDC OUTPUTS to power auxiliary equipment, (1/2 A max. @ 13.8V, and 0.1A max. @ 5V, unless a heat sink is added to the 5V regulator IC on the CAR-7 board.

PIN 9 - CHASSIS GROUND.

PIN 10 - CTCSS TONE INPUT. For Community Tone Panel use. Connects directly to the transmitter's High Z CTCSS Tone Input.

PIN 11 - CTCSS Trigger. For Community Tone Panel use. Connects to the Receiver's Squelch/COR Trigger Input. (When this point is grounded, the receiver will be squelched. When "open", squelch operation is normal.)

PIN 12 - CTCSS RECEIVER TONE OUTPUT. Unsquelched output from Discriminator/De-emphasis point. Used as tone input for Community Tone Panel or Controller.

SECTION 4 INSTALLATION & OPERATION

4.1 DUPLEXERS, WHITE NOISE, "DESENSE", ETC.

We recommend a good quality duplexer with approximately 90 dB isolation and silver-plated cavity center conductors. Duplexers with a Bandpass/Bandreject response are highly recommended! Each repeater transmitter is carefully checked on a spectrum analyzer before it is shipped, and white noise is at least 90 dB down @±.6 MHz (VHF units)* Spurious outputs are at least 70 dB down. Note that transmitter "white noise" is low level wideband noise that is generated in *all* types of oscillator, multiplier and amplifier stages. This noise will be found to varying degrees in *all* transmitters. If not properly filtered out by the duplexer, this noise can mask weak received signals. [* -90dB min. @ ±5MHz for UHF units.]

System performance may be computed as follows, (for 30 W unit):

+45 dBm	30 W Output (Note: 0dBm = 1mW)
-90 dB	White noise is 90 dB below carrier
-45 dBm	Absolute Level of Noise
-90 dB	Duplexer isolation to receiver port
-135 dBm	Level of white noise at receiver port

This is *below* minimum detectable signal level of the receiver.

Transmitter white noise is best checked with a steady, weak signal into the repeater system (20 to 30 dB of quieting) with duplexer and antenna connected. Listen on the local monitor speaker, and alternately flip the Mode Switch to COR Disable while listening for an increase in noise which may mask the weak signal. (Reduce Hang Time to zero.) If an increase in noise is heard when the transmitter is activated, it is most likely *not "desense"* as is commonly believed, but transmitter white noise getting back into the receiver due to insufficient isolation in the duplexer. The extremely wide dynamic range of the Spectrum receiver *precludes true desensitization* of the receiver due to overload by the transmit carrier *unless* the duplexer is greatly out of tune, or, where two antennas are used and there is insufficient separation. (80 dB minimum - 100 ft. vertical separation min. recommended.)

4.1.1 DUPLEXER TUNING - If transmitter white noise is a problem, the duplexer may have to be tuned slightly into your system since different cable lengths and antenna VSWR can affect cavity tuning. (Antenna VSWR must be *under* 1.4:1 for a duplexer to operate properly.) If cavity tuning is required, carefully tune the "Transmitter" notches for minimum noise on the weak signal, consistent with maximum power out to the antenna. Note: *Only double shielded* coax cable should be used in the system - such as RG-9B/U or RG-214/U. *Do not* use the commonly available "loose braid" coax such as "RG8 Type". Keep cables at least one foot apart. It is recommended that the cavity tuning rods be measured or marked, so that you can return to the original settings if required. Refer to Duplexer Tuning Instructions for more specific information, if nesessary.

4.2 TRANSMITTER TUNING FOR MINIMUM WHITE NOISE

If the duplexer has been tuned and some white noise remains, it may be necessary to tune the repeater transmitter for minimum noise. Again, this should be done with a weak, steady received signal which is monitored on the local speaker while the MODE Switch is flipped between OPER & COR Disable. The coils and the various trimmer caps should be carefully tuned for minimum white noise consistent with maximum output power, (preferably with a Bird wattmeter, or equivalent, at the output of the duplexer). The coils should be tuned ±1 turn, or ±2 turns, and the effect noted. *If there is no effect, return to the original setting.* If necessary, the ceramic trimmers may be adjusted - a fraction of a turn only. Driver and final amp trimmers are adjusted for a maximum output consistent with minimum white noise and minimum current.

If all else fails, any remaining white noise can normally be eliminated by the addition of one or more cavities (notch type) to the *transmit* side of the duplexer. This will pass the transmit carrier, but notch-out white noise on the receive frequency.

4.3 HIGH POWER AMPLIFIERS

If it is desired to add an amplifier to the repeater transmitter's output, with 70-150 W output, one additional cavity (notch type) may be required in the Transmit side of the duplexer. It is a little recognized fact that transmitting amplifiers (like receiving pre-amps) have gain, *and a noise figure* - which is typically about *30 dB* for solid state amps! In other words, while the amplifier will provide 5 to 8 dB of gain, it will also increase white noise by about 30 dB. If this is a problem, the only solution is an additional transmitter *notch* cavity, which will supply about 30 dB of increased filtering of white noise between transmitter and receiver.

4.4 INCREASING RECEIVER REJECTION OF "OUT-OF-BAND" SIGNALS

The Spectrum Receiver incorporates one of the "sharpest" and widest dynamic range front-end designs on the market, but even so, if the repeater antenna is located at a site with many nearby VHF/UHF transmitters, additional front-end filtering may be required to prevent spurious mixing products (a filter should be planned into the system in advance in this case). Transmitters within ±20 MHz will usually be the biggest problem. Remember - most duplexers have *little or no out of band rejection* - only a notch on the transmit frequency, so do not rely on the duplexer for out of band filtering; *with the exception of the Bandpass/Band-reject type* which is supplied by Spectrum Communications Corporation.

If spurious received signals or "desense"/front-end overload is a problem due to nearby transmitters, (sometimes producing extreme received levels of *several hundred-thousand microvolts!*), the usual solution is a good quality cavity *filter* in the receiver input line. In general, a Bandpass Filter is recommended as this will greatly attenuate everything beyond about ±5MHz. For "closer-in" interference, or where there is only 1 interfering signal, a "Notch Type Filter" is usually preferable. Contact Spectrum Communications Corporation for further details. Our FL-6 VHF (or FL-4 UHF Helical Resonator) Preselector is highly recommended to "filter out" strong signals more than 4MHz away.

4.5 "TOWER & GUY WIRE NOISE"

In some repeater installations, there may be a problem with intermittent "crackling noises" on the repeater signal, (particularly on weak received signals), especially when there are high winds. This noise has been traced to poor and intermittent metal to metal connections on the antenna tower or nearby metal objects - such as guy wire connection points, tower leg joints, supporting mast intermittently touching the tower's top collar, rusty joints, etc. These metal objects pick up RF from the repeater's transmitted signal, and when moved slightly, will *arc* microscopically to any other metal object touching it. The arc, (which is a very low level effect), produces wideband RF noise which is radiated, picked up by the repeater's antenna, and heard in the receiver - which is, of course, then re-transmitted.

One stubborn case was traced to a point where a rusty steel supporting mast passed through the collar at the top of a tower, only a few feet below the repeater antenna. The cure to the intermittent connection, which produced a heavy static on windy days, was rather unique. The tower collar was packed with automotive lithium "chassis lubricant"! This grease is very lossy at VHF, and effectively 'shorted out' the poor connection, and eliminated the noise from that source.

The solution to these intermittent joints is to either bond or insulate the poor connections. Bonding involves either clamping, soldering, or welding the connections together. Wire braid, copper strap, heavy wire, etc. may be used. Any materials which can rust *must not* be used since rusty joints are the *worst* offenders. Once bonded, the connections should be waterproofed with a material such as the commonly available "Silicon Rubber". As an alternative, the connections may be insulated. Guy wires should be insulated with ceramic compression insulators only about 1" from each tower leg. Any wire or metal objects within about 50' of the antenna should not touch each other! Also, beware of "noise" on the repeater's output due to intermittent cable or antenna connections! Some fiberglass encased 6dB gain base station antennas are known to become *internally intermittent* after as little as 2 years service - thus producing a terrific noise on the transmitted signal! (Check for intermittent VSWR.)

SECTION 5 SPECIFICATIONS

5.1 RECEIVE CRYSTAL INFORMATION

Receive Frequency	Equation
30-50MHz	Crystal Freq. = Rcve. Freq. + 21.4MHz
66-88MHz	Crystal Freq. = Rcve. Freq. - 21.4MHz
136-151.000MHz	Crystal Freq. = $\frac{\text{Rcve. Freq. + 21.4MHz}}{2}$
151.001-174MHz	Crystal Freq. = $\frac{\text{Rcve. Freq. - 21.4MHz}}{2}$
216-250MHz	Crystal Freq. = $\frac{\text{Rcve. Freq. + 21.4MHz}}{3}$
406-512MHz	Crystal Freq. = $\frac{\text{Rcve. Freq. - 21.4MHz}}{6}$

Non Oven Crystals must be designed for maximum "pullability". HC-25/U Case. 3rd Overtone, Parallel Resonant, w/15 pf Load Cap., Rs 30 ohms max. Calibration Tolerance: ±0.001% @ 23°C. Temp. Tolerance: ±0.0005% from -20 to +60°C. Temp. Cycle & Age for at least 5 days.

NOTE: SOME CRYSTAL MANUFACTURERS CANNOT MAKE 3rd OVERTONE CRYSTALS ABOVE 75MHZ. INORDER TO AVOID PROBLEMS, WE HIGHLY RECOMMEND THAT ALL REPLACEMENT CRYSTALS BE ORDERED FROM SPECTRUM COMMUNICATIONS.

5.2 TRANSMIT CRYSTAL INFORMATION

Transmit Frequency	
66-88MHz	Xtal. Freq. = $\frac{\text{TX Freq. (MHz)}}{8}$
136-174MHz	Xtal. Freq. = $\frac{\text{TX Freq. (MHz)}}{8}$
216-250MHz	Xtal. Freq. = $\frac{\text{TX Freq. (MHz)}}{12}$
406-512MHz	Xtal. Freq. = $\frac{\text{TX Freq. (MHz)}}{24}$

VHF UNITS without OV-1 Crystal Oven	Fundamental mode, parallel resonant, w/32 pF Load Cap., Rs less than 25 ohms. Calibration Tolerance: ±0.001% @ 23°C. Temp. Tolerance: ±0.0005% from -20 to +60°C. HC-25/U Case.
VHF OV-1 Crystal Oven Units; And All VHF FCC Type Accepted Units	As Above, except: Calibration Tolerance: ±0.001% @ 65°C. Temperature Tolerance: ±0.0003% from +50 to +80°C. HC-18/U Case.
UHF UNITS (With "on-board"oven)	Fundamental mode, parallel resonant, 32pF Load Capacity, R_S less than 25 ohms. HC-18/U Case. Calibration Tolerance ±0.001% @ +50°C. Temp. Tolerance ±0.0002% from +40 to +60°C. Turning Point +50°C.

All Crystals must be designed for max. "pullability". Temp Cycle & Age for at least 5 days.

5.3 GENERAL

ALSO SEE "PERFORMANCE SPECIFICATIONS" ON DATA SHEET

Control Logic & Timers	Fully Solid State CMOS logic. (TTL compatible.) No Relays. "Time-Out" may be triggered on repeater input, (received signal); or repeater output (xmtr. carrier drop)-simple jumper wire change. CMOS circuitry assures extremely good long term reliability - and its super-low current consumption is very beneficial when operating on battery power.
CMOS CW IDer (OPTIONAL)	Factory Programmed Memory is contained in a PROM IC chip. Adjustable code speed, tone pitch, timing cycle, and AF output level. 250 bit memory - sufficient for any call sign.
Local Mic (OPTIONAL)	High quality ceramic or dynamic mic with coiled cord & 4 pin plug. Adjustable Mic Gain.
AC Power Supply	110-125 V, 60Hz; (or optional 220 V 50-60Hz) supply Although normal DC current consumption (30W TX) is about 5 A, the supply is rated for 9 A for extremely high reliability. AC line input is protected by a MOV transient & spike suppressor and a fuse.

SECTION 6 CIRCUIT DESCRIPTION

6.1 RECEIVER

6.1.1 VHF UNITS: The receiver front end consists of an RF preamplifier and an RF amplifier stage. The transistors used for this application provide low noise figure while simultaneously giving high gain, and very wide dynamic range. Eight "HI Q" resonators are intermixed before, and after the RF transistors for excellent rejection of 'out of band' signals.

UHF UNITS: The receiver front end consists of an RF Preamplifier stage followed by a second RF Amplifier stage. The transistors used for this application are designed to provide an extremely low noise figure, while simultaneously giving high gain and very wide dynamic range. Eight L-C resonators are intermixed before, between, and after the two RF transistors. The optional FL-4 Helical Resonator front end assy. consists of 4 true copper cavities with a single RF stage. The 'Helicals' are far sharper to conventional L-C circuits and are about 60dB down at ±10MHz. Also, dynamic range is improved since only one RF stage is used. These tuned circuits provide extremely good rejection of strong signals more than a few MHz away - which could otherwise overload the front end. Shield partitions are used between each tuned circuit in order to obtain optimum skirt selectivity characteristics. The output of the RF amplifier stages is fed to a true Double Balanced Mixer which converts the UHF input signal down to the 21.4MHz IF frequency. This type of mixer is used due to its extremely wide dynamic range characteristics and its simplicity of operation. Note that they are widely used in microwave receiver applications because of their superior performance. Double Balanced Mixers are well known for their excellent strong signal handling capabilities - which lead to very low spurious response, 'desense', and overload.

6.1.2 The Local Oscillator (LO) chain consists of a third overtone crystal oscillator stage (Q104) which operates in the 65-85MHz range. Q104's collector output is filtered by the L110/C128 tank circuit, and its output is fed to the base of the Q105 multiplier circuit. The multiplier's output is filtered by a "double tuned" filter which consists of L111 and C131 plus L112 and C135. This signal is fed to the base of Q106, a second multiplier stage whose output is similarly filtered by another double tuned filter consisting of L113 and C137 plus L114 and C141. For 136-174MHz units, Q105 is a doubler stage and Q106 is an amplifier.

For 216-250MHz units, Q105 is a tripler and Q106 an amplifier. For 406-512MHZ units, Q105 acts as a tripler, Q106 a doubler. The multiplier chain's RF output is filtered by a double tuned filter in order to reduce spurious outputs which would lead to spurious responses in the receiver. On UHF boards, the signal is now fed to the base of an amplifier stage, Q107. The signal at Q107's collector is again filtered by a very sharp triple tuned filter which consists of L115 and C143, plus L116 and C145, plus L117 and C147. The final output is at a level of approximately 5mW, (the relatively high level required by the mixer). The L.O. output frequency is always exactly 21.400MHz above the desired receive frequency for 136-151.000MHz and for 216-250MHz receivers. The L.O. output frequency is exactly 21.400MHz below the desired receive frequency for 151.001-174MHz and for 406-512MHz receivers. This is done to minimize problems with the image response. A L.O. output test point is provided at TP1, and a frequency counter or spectrum analyzer may be connected to this terminal.

6.1.3 The first mixer (M101) is immediately followed by a 4 Pole first IF crystal filter (FL101 and FL102) which begins to filter out off channel signals before they reach the IF amp. stages. This filter network is followed by Q103, the first IF amplifier stage, which provides about 30dB of gain. Q103's output is tuned by the L120 and C153 tank circuit, and fed to a second 4 Pole crystal filter (made up of two 2 Pole crystal filter elements, FL103 and FL104) which adds further adjacent channel selectivity. A 21.4 MHz IF frequency is used in this design since it places the image 42.8 MHz away from the desired receive frequency. This image is extremely well attenuated by the very sharp filters in the receiver front end stages. This high frequency IF is far superior in this respect to the commonly used 10.7 MHz IF stages.

6.1.4 The 21.4 MHz first IF signal is fed to U101 which is a multi-purpose second IF IC. This IC performs the functions of second LO and mixer (down to the 455 KHz second IF frequency.) This mixer is also doubly-balanced to reduce spurious responses. The second LO operates at a frequency of 21.855 MHz. U101 also includes 455 KHz second IF Amplifier and Limiter Stages, as well as the FM Quadrature Detector, and high frequency (35 KHz) Squelch Noise Amp. The second mixer's output at U101 pin 3 is filtered by a 4 Pole ceramic filter which provides additional skirt selectivity for excellent adjacent channel rejection. Its output is fed to pin 5, which is the Limiter Amplifier input. The amplifier's output is at pin 7 and feeds the FM Detector. The detected FM output is internally amplified and appears at U101 pin 9. The audio output is coupled to the 35 KHz high frequency noise amp. and active bandpass filter, the input to which is U101, pin 10. Pin 11 is the Noise Amp. output. The amplified noise is fed to a detector circuit composed of C175, R150, diode CR108 and bias resistor R151. This circuit rectifies the high frequency noise and converts it to a negative DC voltage which is proportional to signal quieting in the FM receiver; and this negative voltage drives the bias voltage across C175 down as the noise increases (weaker, or no signal).

6.1.5 Front panel squelch pot R602 sets the squelch threshold point by setting the voltage at which diode CR108 begins to conduct, thereby setting the maximum voltage across C175. R154 sets the dynamic range of the squelch circuit and mainly affects the signal level required to open the squelch when R602 is fully clockwise (tight squelch). The voltage across C175 directly triggers the squelch gate built into U101. Pin 12 is the squelch trigger terminal, and pin 14 is the gating terminal. This terminal is open when an incoming signal is present and goes to ground in the absence of signal. Pin 14 is connected through zener diode CR102 to the base of Q112. With no incoming signal Q112 is turned on causing Pin 2 of U104 to go to a high positive level. This biases U104 off. When U101 detects a signal above the squelch level, Pin 14 of U101 becomes an open circuit and Q112 is biased off by R171, allowing normal operation of U104. Pin 13 of U101 is the COR output which is high with no signal and low when signal is present. This pin is connected to Pin 3 of U102A through R149. When the COR line is high (no signal) U102A is biased off. The result of these circuits is complete silencing of both the repeat audio and the monitor speaker when the receiver is squelched. There is 100mV of hysterisis at pin 12, and this circuit allows the squelch to close at a weaker incoming signal level than the level required to open the squelch initially.

This feature allows the squelch to remain open though the signal may fade a few dB into the noise, and reduces squelch chopping effects on weak, fluttery mobile signals.

6.1.6 The audio output from the FM detector at pin 9 U101 is deemphasized by the R145/C178 network at 6dB per octave roll off per EIA specifications, and connected to the AF Preamp input at pin 3 of U102A. A CTCSS tone output point is provided at terminal E109. Op Amp stage U102A is an audio amplifier with a gain of about three times, and is gated on/off by the squelch at Pin 3. Pin 3 is also the audio input. (Gain is measured from junction R145/C178 to terminal E110.) The AF Preamp's audio output Pin 4 is connected to the front panel Monitor Volume pot. Audio from the monitor volume pot is fed to pin 1 of U104, the audio power amplifier IC. U104 drives the front panel monitor speaker so that incoming signals may be monitored. Transistor switch Q112 gates U104 for squelch action, thereby eliminating any idleing white noise from this stage.

6.1.7 Q111 is a voltage regulator stage, and supplies regulated 9 VDC to all of the appropriate points on the board. Zener diode CR114 sets the 10V reference voltage on the base of Q111.

NOTE - Part/Terminal Numbering System

Receiver - 100 Series
Transmitter - 200 Series
Power Supply, COR, A.F. Mixer - 300 Series
ID - 400 Series
Main Chassis - 600 Series

6.2 TRANSMITTER

6.2.1 VHF UNIT: Initial FM signal generation is accomplished at Q202 and its supporting circuitry. This stage is a modified Clapp oscillator with the 18 MHz crystal operating on the inductive slope of its parallel resonance curve. The collector circuit of Q202 is resonated at the second harmonic of the crystal frequency, (third harmonic on 220 MHz versions), by a double-tuned filter, and is applied to the base of Q203, a frequency doubler. FM modulation is affected by "modulating" the crystal load capacitance with varactor diode CR203. A steady-state D.C. bias for CR203 is provided by R217, and the modulating audio signal is superimposed on this voltage through C209.

6.2.2 Modulating audio for CR203 is pre-emphasized by R203 & C201 and is applied to IC201A where it is amplified by a factor of 10. The output of IC201A is applied to "back-to-back" diodes CR201 and CR202 which cause the audio signal to be limited to a maximum value of about 1.4 Vp-p. The limited audio signal is next applied to a 3 section RC lowpass filter which removes most of the high order harmonic distortion produced by the limiting process. The output of the lowpass filter is fed to IC201B for further amplification, and is finally connected to the varactor modulator through Deviation Pot R212.

6.2.3 The RF drive to Q203, now at 36 MHz (55 MHz in 220 MHz versions), is doubled in frequency and is filtered by another double tuned circuit before being applied to the base of Q204. Q204 is another frequency doubler, and the 72 MHz drive at its base (110 MHz in 220 MHz versions), is multiplied in the collector circuit to 144 MHz (220 MHz), the final output frequency. The signal is again filtered in a double-tuned circuit, and is fed to the base of pre-driver Q205. The signal is further amplified by Q206, and is applied as drive to the Class "C" amplifier chain consisting of Q207 and Q208. Power output from Q208 (about 10-12 watts in 220 MHz versions) is finally applied to a 2 section harmonic filter, and is routed to the RF output of the board.

The 13.8 VDC input is applied directly to Class "C" stages Q207 and Q208, and also to audio stage IC201. Oscillator stage Q202 is run continuously from a 9 volt zener diode regulator for maximum stability. Grounding the PTT input to Q201 causes Q201 to turn on, applying +13.5 volts to the doubler and pre-driver stages. The RF output of exciter board is next applied to the final amplifier board. The final amplifier is Q209 (or Q210), an emitter ballasted RF power transistor. It is designed with sufficient heat-sinking to provide a nominal output of 30 Watts in continuous service when operated into a proper 50 ohm load. The power transistor is capable of withstanding open and shorted load conditions for short periods of time, but this should be avoided, since certain VSWR conditions can cause excessive heat build-up in the amplifier and possibly damage the device. The RF output is passed through a 3 section (2 section on 220 MHz) lowpass filter which greatly attenuates all harmonics.