MFJ 9600 BAUD PACKET MODEM

Compatible with: MFJ-1278 / 1270 / 1270B / 1274 and TNC-2 compatibles

MODEL MFJ-9600
INSTRUCTION MANUAL

CAUTION: Read All Instructions Before Operating Equipment

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Introduction

Thank you for purchasing the MFJ-9600 modem board. This Manual provides installation and operational information for the MFJ Enterprises,Inc. 9600 baud modem, model number MFJ-9600.

The MFJ-9600 modem is based on the G3RUH 9600 baud standard. It was designed to provide affordable 9600 baud packet equipment to support network nodes, local packet users on higher speed channels, and AO-14 UOSAT-D access. This is the standard for medium speed FSK work. The AO-14 satellite now in orbit uses this type of modulation.

It is compatible with the TAPR K9NG/TEXNET and proposed PacketRadio modems, and all implementations of the G3RUH design. Most major packet manufacturers now or will soon support this same modem signal format.

The standard packet VHF/UHF radio data rate is 1200 baud because amateur packet controllers traditionally provide an internal modem for this speed, and the two-tone AFSK audio spectrum suits unmodified voiceband radios comfortably. However, all TNCs can generate much higher data rates, and most FM radios have an unrealized audio bandwidth of some 7-8 kHz or more. So in many cases 9600 baud radio transmission is entirely practical with them.

A key feature of the MFJ-9600 modem design is digital generation of the transmit audio waveform. Precise shaping limits the signal bandwidth and may optionally be used to compensate exactly for the amplitude and phase response of the receiver on dedicated circuits. This results in a "matched filter" system, which means that the received audio offered to the data detector has the optimum charcteristic for minimum errors.

The MFJ-9600 modem design is licensed from James Miller, G3RUH and is in use in dozens of countries worldwide. It is a high performance design using innovative signal processing techniques to limit the occupied bandwidth to significantly less than conventional FSK modems. The design complies with United States Federal Communications Commission (FCC) bandwidth limitations on the 6 and 2 meter amateur bands as well as higher frequencies. The modem must be connected to the radio internally and **may not be suitable for use with all radios. The radio must be a direct FM modulation type, NOT a phase modulation type.**

The MFJ-9600 modem board attaches to a TNC-2 Style "Modem disconnect" header, and obtains its mechanical support and most electrical signals from the header J4 pins. It was designed specifically for the MFJ TNCs and may or may not attach to other brands of controllers.

Chapter 1---Specifications

MODULATION: Direct FM. Audio is applied directly to the radio's transmit varactor. Deviation of +/- 3kHz gives an RF spectrum 20 kHz wide (-60db). Fits standard channels easily. Fully compliant with FCC amateur bandwidth limitations above 50 MHz.

TRANSMIT MODULATOR: 8 bit long digital F.I.R. transversal filter in EPROM for transmit waveform generation with a "brick-wall" audio spectrum. Typically -6 db at 4800 Hz, -50 db at 7500 Hz. Optionally allows compensation for the characteristics of the transmitter and receiver pair to acheive perfect received "eye" pattern. Thirty two transmit waveforms, jumper selectable. Output adjustable 0-8v peak-to-peak.

SCRAMBLER (Randomizer): 17 bit maximal length LFSR scrambler, as used in the K9NG 9600 baud modem and UoSAT-D. Jumper selectable data or BERT (bit error rate test) mode.

RECEIVE DEMODULATOR: Audio from receiver discriminator, 50mv-10v peak-to-peak. 3rd order Butterworth filter, 6kHz. Data Detect circuit for use on simplex (CSMA) links. Independent un-scrambler.

CLOCK RECOVERY: New digital PLL clock recovery circuit with 1/256th bit resolution. Average lock-in time 50 bits (depends on SNR).

OTHER FEATURES: The only set-up is Transmit Audio level. Will run speeds other than 9600 bauds if some filter capacitors are changed. (See the Appendices for details.) Channel calibration and audio loopback capabilities.

The MFJ-9600 circuit board is 3 5/8 " x 4 1/8 " (93 x 140 mm), double sided, plated-through holes, solder masked, with silk-screened legend. It is specifically designed for the MFJ series of TNCs. The board will fit most other TAPR TNC-2 style boards. The current consumption will be about 40 ma. with factory installed CMOS EPROMs and 170 ma. with NMOS EPROMs.Either type of EPROM performs equally well.

Packet Controller Interface

Standard TNC digital TTL connections needed are: Transmit Data, Transmit clock (16x bit rate), Receive data, Data Carrier Detect ("DCD") and GND. Receive Clock is available for those packet controllers which do not have on-board clock recovery. All MFJ packet controllers provide the proper signals. Other TAPR TNC-2 based designs, typified by the TNC-2, PK-80, all Pacomm controllers also provide the proper signals.
See APPENDIX A for specific packet controller hookup information.

Radio Interface

Signal connections required to the radio: Transmit Audio, Receive audio, PTT (radio keying) and Ground. The PTT signal from the packet controller DIN socket must be wired directly to the radio.
The ideal radio link would have a flat DC-8 kHz bandpass. The "better" the transmit and receive specification, the better the received data at the detector, and hence less suceptability to errors. Some apparently horrid receiver responses still offer useable service, but with a typically 2.5 db reduction in performance. A good radio achieves about 1.5 db implementation loss (compared with a perfect link).
Remember that you are pushing most radios to their limit since they were designed for speech where even 100% distortion is still intelligible. A little more finesse is required for data transmission.

Required Receiver Characteristics

NBFM design

* Output from discriminator (essential)
* Response to DC (essential)
* Response no worse than -4 db at 4.8 kHz
* Response no worse than -10 db at 7.2 kHz
* As smooth/flat a phase delay as possible
* As smooth an amplitude response as possible.
* Little change in response with 2kHz de-tuning off-channel
* Symmetric, linear FM discriminator charcteristic

On the whole, most receivers will perform as required. Those with the least complicated IF filtering appear best, especially with 20 Hz channel filters, though 16 kHz is also acceptable. 8 kHz filters for 12.5 kHz channel spacing are too narrow for 9600 baud, but can be used at 4800 baud with +/-1.5 kHz deviation. See Appendix C for details.
Radios with dozens of cascaded tuned circuit IFs tend to be fussy, and, if used, should be properly aligned for good response, particularly linearity, phase delay and mistuning performance.

Required Transmitter Characteristics

* Must generate <u>**true FM**</u>, as linear as possible
* Deviation response DC to 7.2 kHz flat (essential)
* Deviation at 4800 Hz to be +/- 3 kHz peak (maximum)

Transmitters based on Xtal oscillator/multipliers are likely to be the most appropriate. ("Base stations").
Tranceivers (synthesized or not) that have quite separate oscillator sub-systems for generating FM and possibly SSB/CW, which is then mixed with a synthesized source to

produce the final carrier are OK. **Simpler synthesized FM transmitters, where the varactor modulated oscillator is within the synthesis PLL, are generally not usable** as the PLL tracks the modulation, and so get no low frequency response. **Remember you need true** FM, which means a varactor diode pulling the oscillator frequency, **NOT** phase modulating a tuned circuit.

See APPENDIX B for specific radio interconnection information.

Chapter 2 -- Theory of Operation

TNC Interface

The MFJ-9600 has circuitry to allow the unit to be taken out of the 'modem header' circuit of the TNC without physically removing the modem card. The modem is automatically switched in when the command "MODE VP,2400 <RETURN> " is issued when using release 3.3 or later firmware. The command "MODE VP" switches back to 1200 baud.

When using firmwrae 2.3, issue the command MODE VP,9600 <RETURN> to switch to 9600 baud operation. For MFJ-1270, MFJ-1270B, MFJ-1274 TNCs, set Dip SW 8 to ON for 9600 baud operation. Set Dip SW 7 ON for 1200 baud.
300 baud operation is still possible with all MFJ TNCs.

Modem Transmit

Outgoing transmit data is clocked into D-type bistable U17a on a high going edge of the TX Clock (P2 pin 3), and then enters a randomizer/scrambler comprising 17 stage shift register U14/U18/U17b and XOR gates U13. So, data in transit through U14 are 8 bits of the TX Data sequence, scrambled. These 8 bits are used to look up a waveform profile for one period of that bit sequence, from transmit EPROM U15. Four samples/bit make up the waveform, and jumpers JP1-4 allow pre-selection of 16 different characteristics. JPROM selects an alternative set of 16 waveform selections.
The EPROM output is passed to digital-to-analog converter (DAC) U19, which generates a discrete staircase-like waveform. This is then smoothed by a four pole "anti-alias" filter and the transmit audio (TA) is output at P5 pin 1 to modulate the FM radio transmitter. If jumper JP5 is set to T (pins closest to EPROM) or OFF (removed), the scrambler generates a repeated sequence of 131071 random bits duration 13.7 sec) which can be used for bit error rate testing (BERT). Jumper JP1-4 set to 1/2 may, in conjunction with a special EPROM, be used to generate higher precision waveforms, those optimized for dedicated radio links.
Jumper JP6 provides for audio loopback testing. Jumper JP7 allows the DAC to be disconnected, and a test signal to be injected at TP2. R4 is the same as the DAC output impedance, 10k ohms. The scrambling polynomial is 1 + X 12 + X 17, one of the eight maximal length generators possible using a one-tap 17 bit shift register.

Modem Receive

Received audio (RA) is passed through a 3 pole low pass filter, and limited by U10 pin 1. It is then sampled by the receive clock (from 11 pin 10) and latched in D-type bistable U5a. Detected data next enters a 17 bit shift register U12/U7/U5b, is unscrambled by XOR gates U6, and sent to the TNC as received data (RX Data) on 1 pin 17. Eight bit shift register U4 is a 1/2 bit delay, and with XOR U6 pin 3 forms a zero- crossing detector (ZCD) that generates one cycle of 600 Hz for each zero crossing of the incoming audio. This ragged "proto-clock" is used by a digital phase locked loop (PLL) to regenerate a continuous received clock (RX Clock). U1/U3 is an up/down counter phase detector, counting up if the proto-clock input at pin 15 is late, DOWN if early with respect to the local clock at pin 10. This counter looks up one of the 256 sinewave profiles (16 steps per cycle) stored in EPROM U2, which is converted to analog by DAC U9, smoothed by C18, and limited to a square wave at U10 pin 2. Thus the recovered clock is pulled into phase with the incoming data at U10 pin 1. Recovered clock and proto-clock are "multiplied" in XOR U6 pin 6 and if in phase, a net DC rise accumulates on C21. Comparator U10 pin 13 senses this, pulling the data carrier detect line (DCD) U20 pin 6 low. An alternative DCD high is available at U10 pin 14. There are test points for receiver monitoring.

Chapter 3 --- Installation

The modem interconnects at connectors S1 (digital) and P5 (power and radio). These mate to J4 and J14 on the 1278 Mother Board, respectfully. For the 1270, 1270B, and the 1274, there is no header at J14. The wires attached to P5 (on the MFJ-9600 board) will have to be hard wired to the Mother Board.

I. INSTALLATION FOR MFJ-1270, MFJ-1270B, AND MFJ-1274

A. Installation of 5-pin I/O.

These units will not have the header pins at J14. The wires from the five pin header I/O connector will have to be soldered to individual components on the Mother Board. The cable comes with connectors at both ends (for 1278 operation) so one end will need to be cut off if you are using the 1270, 1270B, or 1274 TNC. Cut the end that only has the orange, yellow, and green wires. The end that has orange, yellow, green, and two coax cables attached are **NOT** cut.

Prepare the wires by removing 3/32 inch of insulation from the free ends. Tin each of the bare ends with solder to prevent fraying of the wires, and to make it easy to solder to the five locations shown in Figure 1.

The orange wire is connected to ground at the negative end of C12 on the Mother Board. The yellow wire shoild be connected to L2, and the green wire should be connected to the positive end of C10. The coax at Pin 2 of P5 should be connected to Pin 4 of the 5-pin DIN connector on the Mother Board. The coax at Pin 1 of P5 should be connected to Pin 1 of the 5-pin DIN. The shield of the two coax cables should be soldered to ground (Pin 2 of the 5-pin DIN). See Addendum on page 32 of this manual.

Connect each wire to the Mother Board as shown in Figure 1 below.

DCD LED Hookup

You must connect a wire from TP9 on the MFJ-9600 board to the negative lead of the DCD LED on the Mother Board. This must be done whether you have a 1278 or 1270, 1270B, or a 1274 TNC.

Strip 3/32" of insulation from both ends of a five inch wire. Tin each end with solder. Solder one end to TP9 and the other end to the negative end of the DCD LED (left terminal of the LED viewed from front).

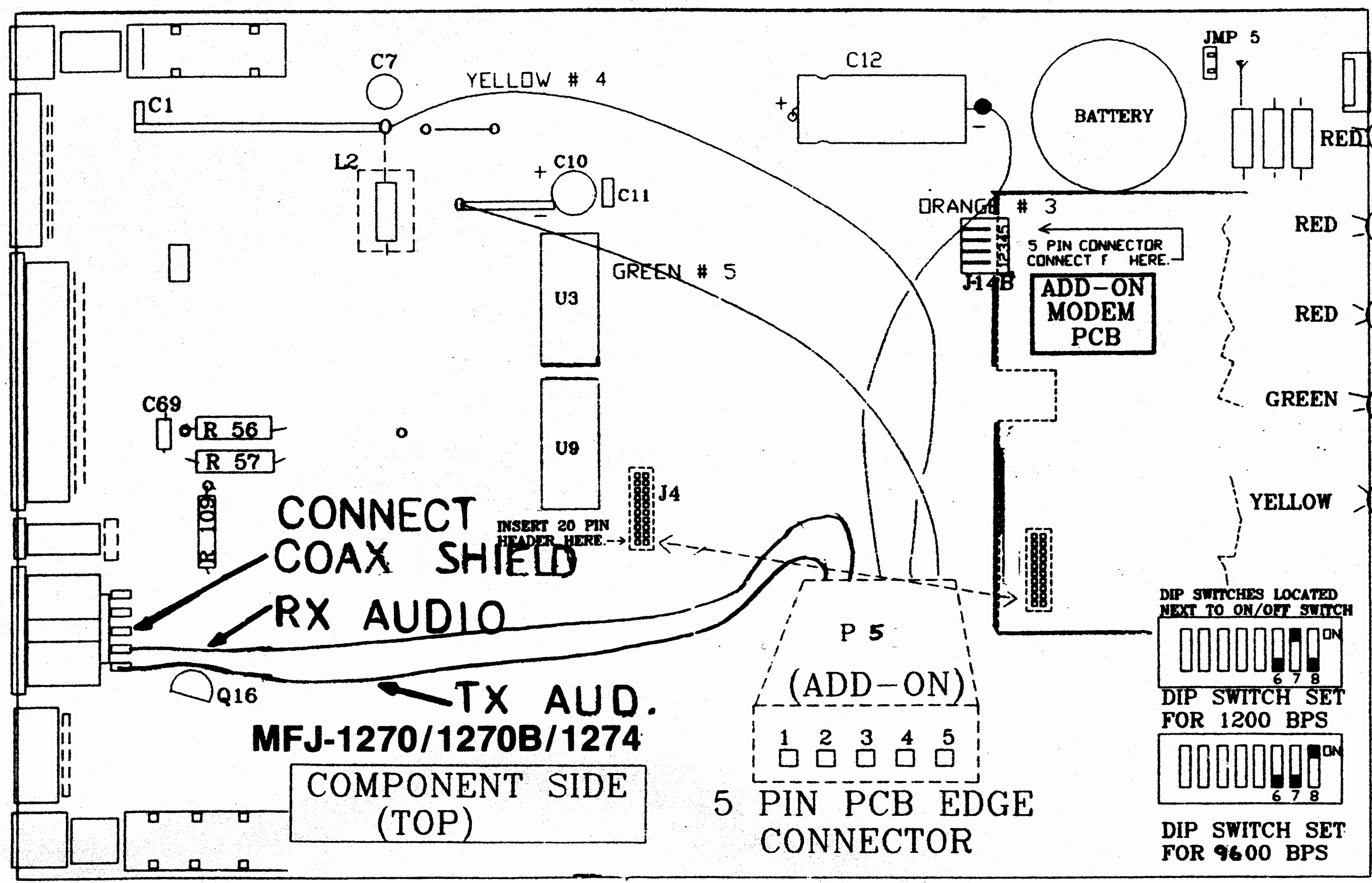

FIGURE 1

B. INSTALLATION OF THE 20-PIN HEADER

NOTE: If the 20-pin header is installed, confirm that pins 1 and 2 of J4 are not shorted together. If they are shorted together, cut the trace between them.

To install the 20-pin connector (J4), take the top off the unit, and remove the P.C. Board.

1. Remove the four screws at the sides.
2. Remove the top.
3. Remove the front panel. Remove the two screws holding on the front panel.
4. Remove the four screws holding the P.C. Board to the chassis.
5. Remove the screw and nut holding the voltage regulator to the chassis.
6. Carefully lift the board from the chassis.
7. Turn the board over so the component side is facing down.
8. Carefully cut four traces at the modem header on bottom of board:

1. Cut the trace between pins 1 and 2.
2. Cut the trace between pins 11 and 12.
3. Cut the trace between pins 13 and 14.
4. Cut the trace between pins 17 and 18.

Cut <u>ONLY</u> the traces listed above. Pins 3-4, 5-6, 9-10, and 19-20 should be left shorted. A good magnifying glass is helpful while performing these cuts. It will help prevent your cutting adjacent traces.

Make note of the number progression and location of the pins. Keep in mind the numbers are reversed when the PCB is upside down.

The drawing at Figure 2 will help you locate the header traces to cut. Use solder wick or a solder vacuum device to remove any solder which may be covering any of the 20 pin header holes. Cut the traces between the four points shown in the illustration.

```
                        20           12                 2
Bottom of PC board       o  o  o  o  o  o  o  o  o  o
                            x     x  x              x
                         o  o  o  o  o  o  o  o  o  o
                        19           11                 1

                              solder side view
```

FIGURE 2 - Solder side view of J4 Modem Disconnect Port

Cut at "x".
Insert the 20-pin modem header (supplied) into the printed circuit board. The short side of the header should go into the top (component) side of J4. Solder pins 1 and 20 first to keep the header in place. Solder all pins making sure you adaquately heat the pins and the pc board so that solder flows smoothly. Use a 25-40 watt soldering iron, <u>NOT A SOLDERING GUN!</u> However, too much heat may damage the pc board traces. Heat the trace and the pins long enough for solder to flow into the plated through holes for about a second then remove the heat and the iron. Keep the soldering iron tip clean!

<u>Adding the "Turbo" LED</u>
Included with the MFJ-9600 modem board is the Turbo LED. This LED is for those TNCs without the Turbo LED installed. Mount the Turbo LED on the front panel of the TNC. Solder a wire from the - (short) lead of the LED to pin 15 (ground) of J4 and solder a wire from the + (long) lead of the LED to pin 16 of J4. There is no need to add a current limiting resistor. R16 on the 9600 modem board is the current limiting resistor for the Turbo LED.

II. INSTALLATION FOR MFJ-1278 Rev. 6, 7, and 8

Remove the four screws holding the top cover on the TNC. Remove the cover and set aside. Remove the two screws holding the front face plate, and set it aside. Remove the four screws which hold the Mother Board to the bottom of the chassis.

Carefully lift the P.C. Board from the bottom plate and place on a towel or soft surface COMPONENT SIDE DOWN. Be sure you cause no damage to the components on the top side of the PC board as you perform the installation of the 20-pin header.

These units will not have the five-pin header J14 on the Mother Board. You will need to follow the procedure below to install the MFJ-9600. See Figure 3 below:

DCD LED Hookup

You must connect a wire from TP9 on the MFJ-9600 board to the negative lead of the DCD LED on the Mother Board. This must be done whether you have a 1278 or 1270, 1270B, or a 1274 TNC.

Strip 3/32" of insulation from both ends of a five inch wire. Tin each end with solder. Solder one end to TP9 and the other end to the negative end of the DCD LED (left terminal of the LED viewed from front).

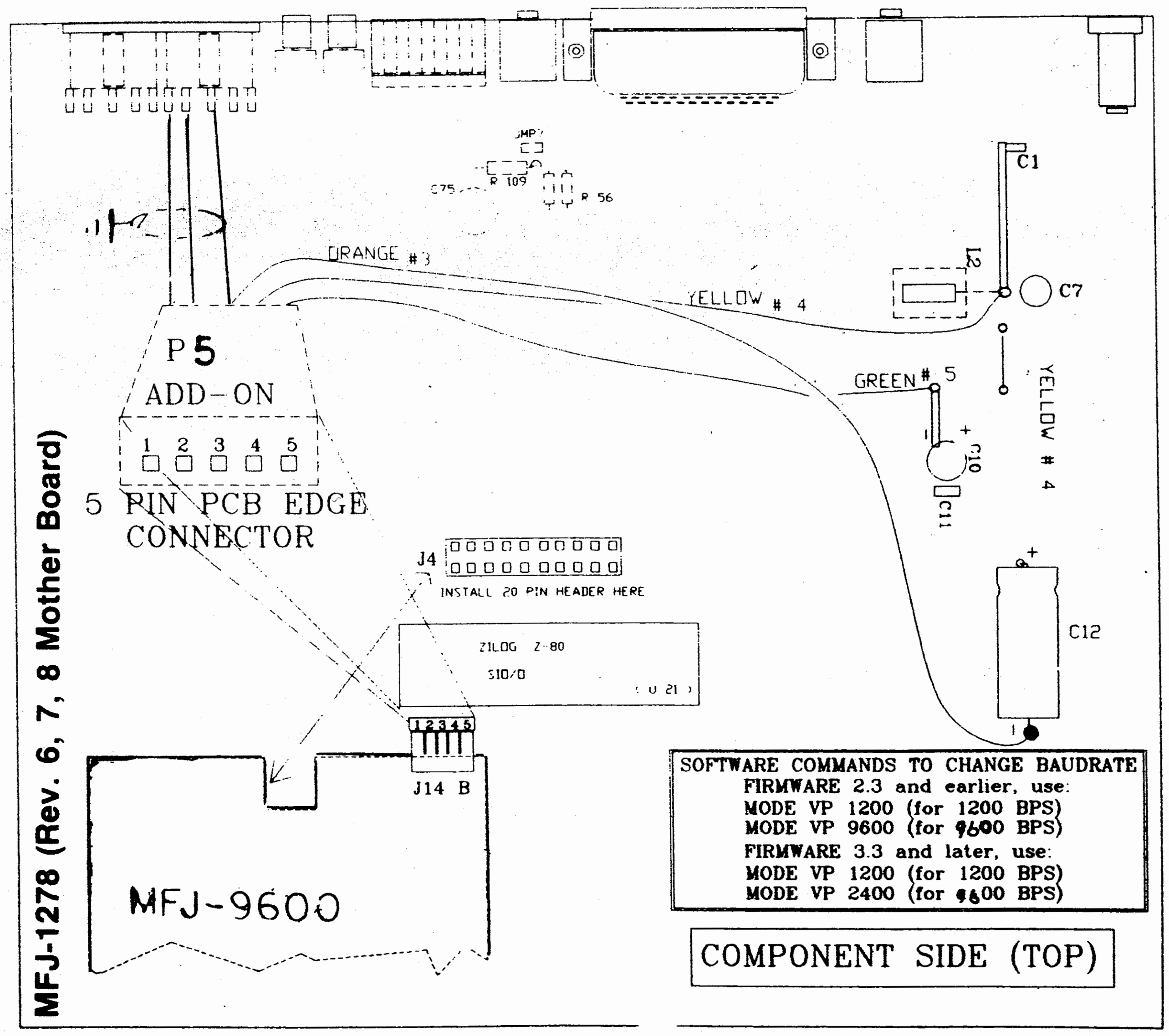

FIGURE 3

A. Installation of the 5-pin I/O Connector

These units will not have the header pins at J14. The wires from the five pin header I/O connector will have to be soldered to individual components on the Mother Board. The cable comes with connectors at both ends (for 1278 operation) so one end will need to be cut off if you are using the 1278 Rev 6, 7, or 8. Cut the end that only has the orange, yellow, and green wires. The end that has orange, yellow, green, and two coax cables attached are **NOT** cut.

Prepare the wires by removing 3/32 inch of insulation from the free ends. Tin each of the bare ends with solder to prevent fraying of the wires, and to make it easy to solder to the six locations shown in Figure 3.

The orange wire is connected to ground at the negative end of C12 on the Mother Board. The yellow wire shoild be connected to L2, and the green wire should be connected to the positive end of C10. The coax at Pin 2 of P5 should be connected to Pin 4 of the 5-pin DIN connector on the Mother Board. The coax at Pin 1 of P5 should be connected to Pin 1 of the 5-pin DIN. The shield of the two coax cables should be soldered to ground (Pin 2 of the 5-pin DIN). See Addendum on page 32 of this manual.

Connect each wire to the Mother Board as shown in Figure 3 on Page 10.

B. Installation of the 20-pin header.

NOTE: If the 20-pin header is installed, confirm that pins 1 and 2 of J4 are not shorted together. If they are shorted together, cut the trace between them.

To install the 20-pin connector (J4), take the top off the unit, and remove the P.C. Board.

1. Remove the four screws at the sides.
2. Remove the top.
3. Remove the front panel. Remove the two screws holding on the front panel.
4. Remove the four screws holding the P.C. Board to the chassis.
5. Remove the screw and nut holding the voltage regulator to the chassis.
6. Carefully lift the board from the chassis.
7. Turn the board over so the component side is facing down.
8. Carefully cut four traces at the modem header on bottom of board:

1. Cut the trace between pins 1 and 2.
2. Cut the trace between pins 11 and 12.
3. Cut the trace between pins 13 and 14.
4. Cut the trace between pins 17 and 18.

Cut <u>ONLY</u> the traces listed above. Pins 3-4, 5-6, 9-10, and 19-20 should be left shorted. A good magnifying glass is helpful while performing these cuts. It will help prevent your cutting adjacent traces.

Make note of the number progression and location of the pins. Keep in mind the numbers are reversed when the PCB is upside down.

The drawing at Figure 4 will help you locate the header traces to cut. Use solder wick or a solder vacuum device to remove any solder which may be covering any of the 20 pin header holes. Cut the traces between the four points shown in the illustration.

```
                        20              12                  2
Bottom of PC board       o   o   o   o   o   o   o   o   o   o
                             x       x   x                   x
                         o   o   o   o   o   o   o   o   o   o
                        19              11                  1

                                solder side view
```

FIGURE 4 - Solder side view of J4 Modem Disconnect Port

Cut at "x".

Insert the 20-pin modem header (supplied) into the printed circuit board. The short side of the header should go into the top (component) side of J4. Solder pins 1 and 20 first to keep the header in place. Solder all pins making sure you adaquately heat the pins and the pc board so that solder flows smoothly. Use a 25-40 watt soldering iron, **<u>NOT A SOLDERING GUN!</u>** However, too much heat may damage the pc board traces. Heat the trace and the pins long enough for solder to flow into the plated through holes for about a second then remove the heat and the iron. Keep the soldering iron tip clean!

<u>Adding the "Turbo" LED</u>

Included with the MFJ-9600 modem board is the Turbo LED. This LED is for those TNCs without the Turbo LED installed. Mount the Turbo LED on the front panel of the TNC. Solder a wire from the - (short) lead of the LED to pin 15 (ground) of J4 and solder a wire from the + (long) lead of the LED to pin 16 of J4. There is no need to add a current limiting resistor. R16 on the 9600 modem board is the current limiting resistor for the Turbo LED.

Installation for MFJ-1278 with Revision 9 Mother Board

Installation of the MFJ-9600 in the MFJ-1278 with Rev. 9 Mother Board is very easy and requires only a brief explanation. Furthermore, it requires very little assembly time.

Locate the illustration which shows the MFJ-1278 Rev 9 installation (Figure 5). Place this drawing nearby for reference as you install the MFJ-9600.

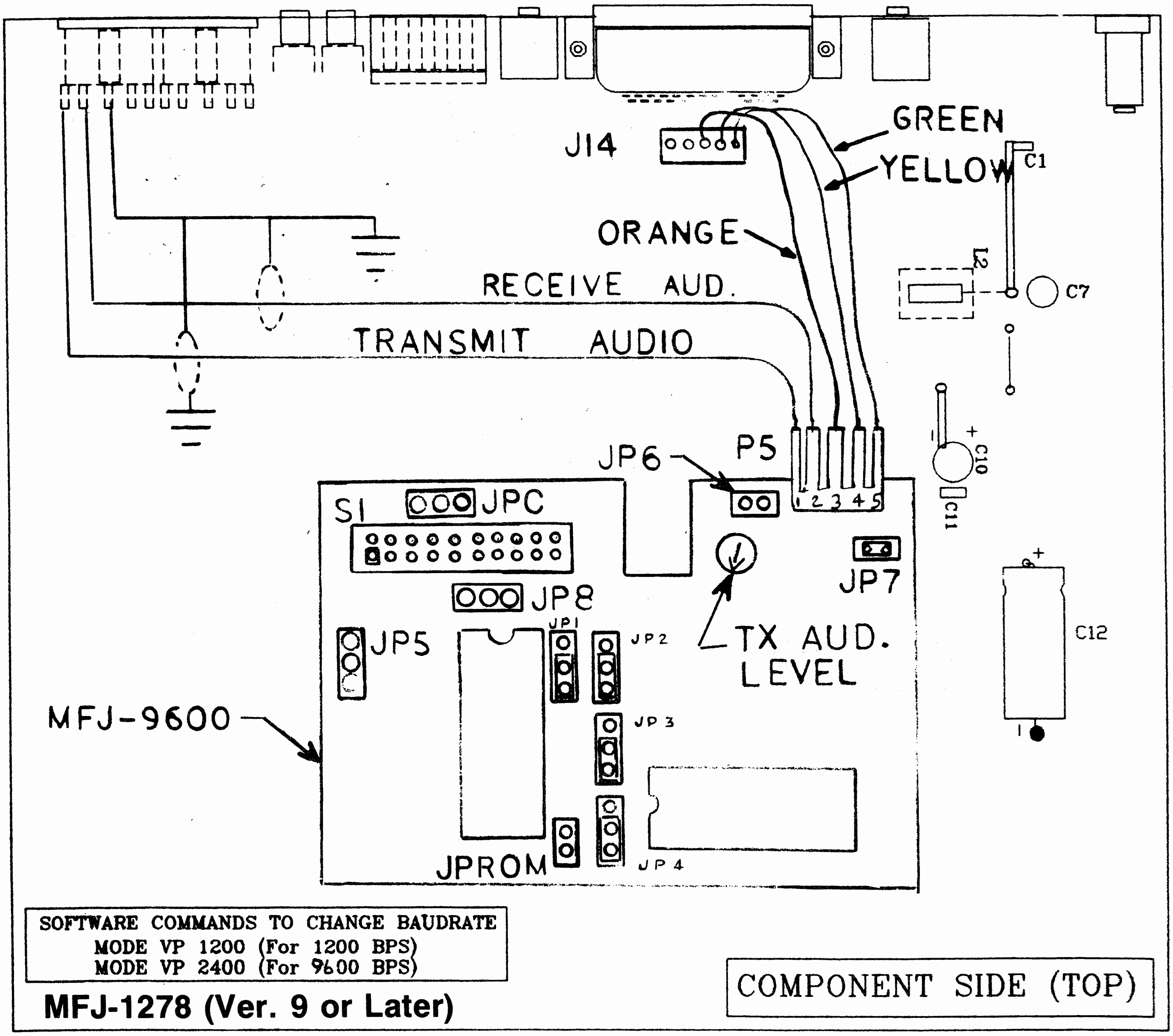

FIGURE 5

To install the MFJ-9600 board in the MFJ-1278 Rev 9:

1. Remove the four side screws.
2. Remove the jumpers on the 20-pin header J4.
3. Using an ohmeter, measure the resistance between pins 1 and 2 of J4. They should not be shorted.
4. Place the plastic spacer through the hole on the right side of the MFJ-9600 P.C.board.
   NOTE: The short side should be on top.
5. Line up pin 1 of J4 with pin 1 of S1 connector of the MFJ-9600 board.
6. Push the MFJ-9600 board down so it is as far down as possible.
7. Insert the 8-32 screw through the hole at the left rear part of the MFJ-9600 board.
8. Tighten down until snug, but DO NOT OVER-TIGHTEN!

Power

Power is applied through the IDC header J5. J5 connects to the 5-pin header (J14) on the TNC motherboard immediately in front of the RS-232 (DB-25) connector. The connector is numbered 1 to 5 from left to right as you face the front of the MFJ TNC with the MFJ-9600 modem board installed.

J5

Pin 1	Transmit Audio	(shielded cable to Radio port pin 1)
Pin 2	Receive Audio	(shielded cable to Radio port pin 4)
Pin 3	Ground	
Pin 4	+ 5 Volts	
Pin 5	- 5 Volts	

Digital Connections

Standard TNC digital TTL connections needed: Transmit Data, Transmit Clock (16x bit rate), Receive Data, Data Detect ("DCD") and GND. Receive clock is available, but not used by most amateur TNCs. See APPENDIX A for specific informtion on interfacing the MFJ-9600 modem to commercially available packet controllers.

Radio Connections

There are four connections to the radio: Transmit Audio (TA), Receive audio (RA), PTT, and ground (GND).

DCD LED Hookup

You must connect a wire from TP9 on the MFJ-9600 board to the negative lead of the DCD LED on the Mother Board. TP9 is just to the left of JMP8 pin 1 and the negative lead of the LED is on the left side viewed from the front. Strip 3/32" of insulation from each end of a five inch wire, tin, and solder in place.

Signal Definitions, Connector S1 - Digital I/O

1 DCD output of MFJ-9600
2 DCD input from TNC (1200),Output to TNC on 9600
3 Shorted to 4 on Mother Board
4 RFDCD from TNC-Tied to pin 3
5 PTT from TNC's SIO (RTS) -Tied to pin 6
6 PTT input to TNC - Tied to pin 5 on Mother Board
7 n/c
8 n/c
9 CTS input to SIO - tied to 5 and 10 through Mother Board.
10 Connected to 5 and 9.
11 Tied to 12
12 TNC 16x TX Clock-Tied to pin 11 through MFJ-9600.
13 RX Clock output of MFJ-9600.
14 RX Clock from TNC - Switched
15 Signal Gnd-Tied to 16
16 Turbo LED output of MFJ-9600. High = Turbo LED ON.
17 RX Data output of MFJ-9600
18 RX Data from TNC - Switched
19 TX Data from TNC-Tied to 20
20 Tied to 19

Description of S1 pins.

Pin 1, DCD

Data Carrier Detect from the MFJ-9600 to the TNC. It goes LOW when the modem recognizes that the received audio is a valid data stream.

Pin 2, TNC Modem DCD

The DCD signal from the TNC's on-board modem. This signal is switched to Pin 1 when the MFJ-9600 is disabled.

Pin 5, SIO RTS output

This signal is output by the SIO chip (U21) every time the TNC has data to transmit. This signal activates the TNC's PTT circuit. This line is always connected to pin 6.

Pin 6, Transmit PTT input to TNC.

Pin 12, Transmit Clock

A signal from the TNC, which provides transmit timing for the MFJ-9600. Its speed must be 16 times the data rate (153.6 kHz for 9600 bauds). Connected to pin 11 to insure it is available to the TNC's on-board modem when the MFJ-9600 is disabled.

Pin 13, Receive Clock

A symetric 9600 Hz clock signal extracted from the received audio, which goes HIGH in the middle of a Receive Data bit. This signal is NOT required by a TNC which has an internal clock recovery system.

Pin 14 , TNC Receive Clock Output

The Received Clock signal from the TNC's on board modem. This signal is switched to Pin 13 when the MFJ-9600 is disabled.

Pin 15 , Ground

Common connection for the digital signals.

Pin 16 , Turbo LED Output

Output of 9600 baud modem to light Turbo LED. This line is low for 1200 baud and high for 9600 baud.

Pin 17, Receive Data

A signal to the TNC; the received data as decoded by the MFJ-9600 modem.

Pin 18, TNC RX Data

A signal from the TNC's on board modem. This signal is swtiched to pin 17 when the MFJ-9600 is disabled.

Pin 19, TNC TX Data

The data from the TNC to be transmitted. It is read by the MFJ-9600 modem on a high going edge of transmit Clock.

Pin 20, TNC TX Data Input

Tied to pin 19 to allow TNC transmit data to reach TNC's on-board modem for transmission when MFJ-9600 is disabled.

Transmitter

PTT is the normal signal obtained from a TNC on its conventional 5 Pin DIN audio connector pin 3, ground pin 2. This signal is not needed by the 9600 baud modem, but it must be wired to the appropriate radio connection. The MFJ-9600 modem does not generate a PTT signal. PTT is generated by the TNC and is available at the 5-pin DIN (Radio Port).

Transmit Audio should be taken from modem P5 pin 1 (TA), directly to the transmitter varactor diode. You CANNOT inject the signal into the Microphone socket. The transmit audio (TA) signal lead MUST be shielded.
Modem adjustment VR1 allows you to set the drive level, which should result in a peak FM deviation of no more than +/- 3 kHz for normal 20 kHz wide channels. The modem should operate properly with deviations between 2.0 and 3.0 KHz.
A signal of up to 8 volts peak-to-peak is available, but if less than 1 volt is needed, it is recommended that a higher level be used, and a simple resistive attenuator be fitted at the transmitter.

IMPORTANT: **The output has been designed for an optimum load of 500 ohms. If you use a higher impedance load, reduce C34 in proportion. This will ensure the correct low frequency response (down to 3 Hz), and hence control any key-up "chirp".**

For example, if the transmitter load is 10k ohms, use a coupling capacitor of 10uf x 500/10000 = 0.5uf. This may be placed in series with C34, and can be conveniently located in the transmitter. There will always be a TX Audio signal, even when the PTT is not active. If possible, the modulated oscillator should remain powered during receive to avoid keying chirp. Chirp will cause the distant receiver to take longer to lock-in.

Receiver

Receive Audio can be brought direct from the receiver FM discriminator, and connected to modem P5 pin 2 (RA). The receive audio (RA) lead MUST be shielded.

A decoupling RC network of time constant not exceeding 10 us is permissible at the discriminator to remove extraneous IF noise, but is not essential. The signal sould be unsquelched (it almost certainly is anyway). You CANNOT use the receiver loudspeaker for this system, though you may monitor reception by ear on it. The signal sounds like a burst of noise. The modem audio input impedance is approximately 50k ohms, AC coupled. In a full-duplex system ONLY, i.e. continuous transmit and receive, modem capacitor C25 may be increased from 0.1 uf to 1 uf. Do NOT alter it for normal simplex service or the modem receive transient performances will be affected, resulting in slow lock-in.

Chapter 3 --- Operation

Jumper Settings

Nine jumpers are provided on the modem PCB to configure the system, and allow user experimentation. Positions for NORMAL operation are shown:

Jumper	Function	Normal Position	Result
JP1-4	Transmit Waveform	2/3	Uncompensated
JP5	Data/BERT Mode	D	Data Mode
JP6	Audio Loopback	OFF (removed)	No loopback
JP7	Transmit DAC connect	ON	Connected
JPROM	Alt Transmit Waveform	OFF (removed)	
JP8	Enable DCD LED for 9600	1/2	LED enabled

The transmit waveform EPROM contains a variety of general compensation waveforms. The normal selection should be used in most all cases and certainly for AO14 (UoSAT-D) access and general purpose terrestrial packet work.. If difficulty is experienced with a particular radio, try each of the transmit settings to find the most optimum one. Note that the selection compensates for the DISTANT receiver - not your local receiver. The receivers your link uses may not be exactly compensated by the EPROM contents. Nevertheless, most NBFM radios' responses are quite similar, and one selection should be found acceptable. You should examine the received "eye" diagram while the sender tries different JP1-4 combinations. At least one of them will be "best". Repeat for the other transmit/receive combination.
Obviously, this is more easily tried out with all radios in one room. You may well find the "loopback" selection is useful.
You may also calibrate a radio channel. This would be most appropriate for a dedicated network link with limited signal margin. It is vital that the radios are tuned to the correct frequency. If they are mis-tuned by more that 2-3 kHz, distortion will be apparent in the received signal, which will rapdily degrade performance. Some receivers have AFC, which will be helpful if it pulls in within 50 ms and also does not try to track the data and so impair the link's low frequency performance.

Optimum TNC Settings

These are a matter for individual experimentation. TXDELAY = 3 can be used on a full duplex link and also for audio loopback testing. More efficient use of the channel can be made if packets are long and concentrated, so set MAXFRAME = 7, FULLDUP ON, and PACLEN = 0. Sometimes it's better to use a SENDPAC character other than $OD . In some instances data is sent faster from terminal to TNC if ECHO = OFF. Better still, use TRANSPARENT mode.

The command to move from 1200 or 300 baud to 9600 baud is:

MODE VP,9600 <RETURN> for firmware release 2.3.

or

MODE VP,2400 <RETURN> for firmware release 3.3 or later.

To return to 1200 baud, type MODE VP <RETURN> (the default for mode VP is 1200 baud so there is no need to put in 1200.

To return to 300 baud, type from the cmd: prompt, MODE HP,300.

On the 1270, 1270B, and the 1274 TNCs, set DIP SW 6 ON for 300 baud, DIP SW 7 ON for 1200 baud, and DIP SW 8 ON for 9600 baud operation.

Chapter 4 --- Follow up Support

Follow up Support

You are invited to contact MFJ Enterprises, Inc. with any technical inquiries about this modem. Or you may choose to contact the modem's designer at the address below. Be sure to include a self addressed envelope and 4 International Reply Coupons if corresponding with Mr. Miller.

Packet messages cross the Atlantic in about three or four days, so a packet message put in at your local 2-meter BBS will probably reach Mr. Miller within a week. That's about as quick as the postal service.

James R. Miller G3RUH
3 Benny's Way, Coton, Cambridge, CB3 7PS, England
E-mail: g3ruh@amsat.org
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CHAPTER 5- Troubleshooting and Test

Modulator (Transmit section)

1. Install jumpers JP1-4 on 2/3 side (toward JPROM), JP5 OFF, JP6 OFF, JP7 ON, JPROM OFF. Set VR1 to mid position.
2. Switch power OFF then ON, and install JP5 on T (pins nearest EPROM).
3. Check that a 9600 Hz pulse train is obtained at test point TP0, and then trigger the scope from this, time base 20 us/div.
4. Examine TP2. You should see a rather coarse "eye" pattern at an amplitude of about 2 volts peak-to-peak. Examine the signal at JP6 (left), and you should see a smooth "eye". Vary VR1 and note that the amplitude changes.
5. Try changing jumpers JP1-4 to positions 2/3 and OFF (removed), and observe the variety of waveforms. (Do NOT install any of the jumpers in the 1/2 position).
6. Whenever you power up in test mode, always remove and replace JP5 on T (pins nearest EPROM). If you don't do this the scrambler can jam, and no transmit Audio will be generated.

Demodulator (Receive section)

1. Install jumpers JP1-4 on 2/3 (Nearest JPROM), JP5 OFF, JP6 ON, JP7 ON, JPROM OFF. Set VR1 to mid position.
2. Switch power OFF then ON, and install JP5 on T (pins nearest EPROM). The modem is now in audio loopback and BERT mode.
3. Examine TP4, the received "eye" point. If the correct selection has been made from the transmit EPROM U15 (JP1-4 as required, and JPROM OFF), you should see a perfect eye waveform.
4. Now use the other trace of the scope to view the received clock (RX Clock) at TP8. This should show a LOW going edge at the same moment as all the eye traces converge to a point. There may be a little jitter, and possibly a slight displacement.
5. Momentarily remove JP6, put your finger on TP4, and the Receive clock will drift. Replace JP6 and the clock should pull again.
6. Examine RX Data at TP6. With JP5 on T (pins nearest EPROM) the signal should be LOW. With JP5 OFF it should be HIGH. With JP6 OFF it will go completely random. With JP6 OFF you should also notice the DCD LED on the TNC extinguish.

TNC Digital Loopback

1. Install jumpers JP1-4 on 2/3 (nearest JPROM), JP5 on T (pins nearest EPROM), JP6 ON, JP7 ON, JPROM OFF. Set VR1 to mid position.
2. Examine RX Data at TP6. With a TNC-2 type of packet controller you should see "flags", one bit in eight, i.e. 00010000 or 11101111 repeated (Not all TNCs do this; some will simply show high or low).
3. Set FULLDUP - ON at the TNC, and MYCALL to your callsign.
4. Now type CONNECT MYCALL, and you should get the ***CONNECTED to MYCALL message. Type "test" and you should get a repeat of "test". Now disconnect. Observe data at TP6 during this test.
5. Experiment a bit; try CONNECT MYCALL VIA MYCALL MYCALL, MYCALL, etc. When you have finished, don't forget to remove JP6, and set FULLDUP OFF.

EYE Diagrams

The "eye" diagram is a simple yet powerful way of deciding whether or not the received audio is of satisfactory quality. You can see what a **good** eye looks like using audio loopback. Install the modem on the TNC. Disconnect the radio. Install jumpers JP1-4 on 2/3 (nearest JPROM. This is the "loopback" selection 0), JP5 on D (pins away from EPROM), JP6 ON, JP7 ON, JPROM OFF. Set VR1 to mid position. Trigger the scope from TP0, timebase set to 1 ms/div. Apply power to the TNC. Put a probe on TP4, the "Eye" point. At this slow speed the waveform looks rather like familiar digital "data" but with sloping edges, and a little overshoot.

Now gradually speed up the timebase to 20us/div. See how the data bits become superimposed, fusing into a characteristic "eye", the diamond shape in the center of the screen. Notice the traces converge at two distinct points, one high corresponding to a "1" bit, the other low for a "0" bit. It is at these points the modem samples the audio to detect a "1" or a "0".

Also shown is the RX Clock waveform from TP8.

The goodness of this convergence is an indication of the way the modem will perform. Vertical scatter at the sample point reduces the systems tolerance to noise, because some bits pass closer than others to the "1" decision threshold. This scatter is "self- noise", and adds to any real noise present.

Now as an example, change jumpers JP1-4 to select another transmit waveform. You will see the eye change somewhat,

with scatter at the sample point, as well as some asymmetry. However if this audio were passed through its matched transmitter/receiver combination it would convolve back to the ideal shape. It is this compensatory feature of the modem which contributes mainly to its high performance.
When using a real radio link, trigger the scope from TP8, the Receive lock. It will add lateral jitter due to the clock recovery process, and give a more valid (and stationary) eye.

JUMPERS and CONNECTORS

JP1-4 Transmit Waveform Select

NOTE: JP1-4 are three pin headers. The pin of each jumper closest to JPROM is pin 3, the center pin is 2, and the pin farthest from JPROM is pin 1. The transmit waveform generator uses a look-up table of values stored in EPROM U15. Depending on the contents of this EPROM, and the selections of JP1-4, a variety of transmit waveform characteristics may be acheived to suit differing radio channels.

JPx Position	Function (x = 1, 2, 3, or 4)	
OFF(removed)	Transmit Waveform Selection	bit x = 1
2/3	Transmit Waveform Selection	bit x = 0
1/2	Transmit Waveform uses DATA	bit x + 8

In the standard configuration, the generator operates on a span of 8 data bits at once via shift register U14. A 27256 EPROM can hold up to 32 different waveform characteristics in 2 banks of 16, selected by jumper JPROM.

Bit x 4321	TxWaveform Selection	Bit x 4321	Waveform Selection
0000	0	1000	8
0001	1	1001	9
0010	2	1010	10
0011	3	1011	11
0100	4	1100	12
0101	5	1101	13
0110	6	1110	14
0111	7	1111	15

Alternatively, it could hold eight charcteristics operating on 9 data bits (JP1 = 1/2) and so on, up to one charcteristic spanning 12 data bits (JP1, 2, 3, 4 = 1/2).

Non-standard or customized EPROMs are supplied with linking information on their data sheet.

JP5 Data/BERT Mode Select

NOTE: JP5 is labeled with designations of D(ata) and T(est), but these labels are hidden by the nearby IC socket. Position T is the postion closest to the nearby EPROM, while position D is that position closest to the JP5 label and the edge of the circuit board.

BERT = Bit Error Rate Testing. In BERT mode, the transmitter generates specific sequence of 131071 pseudo-random bits. At the receiver, after unscrambling, the received data (RX Data) should be constant 0 or a constant 1. However, if a received bit is corrupted, then there will be burst of exactly 3 pulses on Receive Data. These are easily counted, and provide an accurate measure of the channel quality. If there are N counts in T seconds, the channels bit error rate is (N/3) (T*9600). For example a count of 30 in 10 seconds would equate to an error rate of approximately 1 in 10000 bits (10E-4).

JP5	Position	Function
D	Normal	DATA
T	BERT mode	all 0
OFF (removed)	BERT mode	all 1

NOTE: If the modem is powered up with JP5 set for a BERT mode, the transmit scrambler can jam, and no transmit audio will be generated. Remove and replace the jumper as required. The NORMAL position of JP5 is on D (pins nearest board edge).

JP6 Audio Loopback

Installing JP6 connects the transmitted analog audio signal to the modem receiver input. This allows a modem performance check to be carried out without radios. The NORMAL position of JP6 is OFF.

JP7 Transmit DAC Connect

Removing JP7 disconnects the transmitter waveform generator. This allows a test source to be connected to test points TP2 and TP3. You would do this to perform radio checks. The NORMAL position of JP7 is ON.

JP ROM Transmit Waveform Select

JP ROM should be OFF (removed) for transmit waveform selections 0-15, and ON for selections 16-31. See JP1-4.

Test Points

Five test points facilitate monitoring:

Test Point	Function	Ground
TP0	9600 Hz Sync	TP1
TP2	Transmit audio inject	TP3
TP4	Receive "Eye" Point	TP5
TP6	RX Data	TP7
TP8	RX recovered Clock	TP7

TP0: 9600 Hz Sync
This is a high going 5 volt pulse of duration 1/16th bit, at 9600 hz. It should be used as a "sync" to trigger a scope when examining the waveform.

TP2: Transmit Audio Inject
With JP7 removed this point allows a test audio signal to be injected into the transit system. In this way the radio may be checked, and radio transmitter/receiver combination can be checked/calibrated.

TP4: Receive "eye" Point
This point allows the received audio to be examined just prior to the data detector. The characteristic trace of numerous bits superimposed resembles an "eye". This analog signal is sampled on the low going edge of Receive Clock (TP8). The desired trace has symetry, an open "eye", with all trajectories converging to a spot at the sample point, once per bit.

TP6: Receive Data (RX Data)
This is the 5 volt TTL signal sent the the TNC. In data mode this will be essentially random. In BERT mode it will be high or low, punctuated by any errors. (See notes on JP5).

TP8: Receive Recovered Clock (RX Clock)
This is a 5 volt TTL symetric 9600 Hz clock signal recovered from the received audio. It goes HIGH mid-bit.

NOTE:
Receive Clock will take the frequency of the transmitter. It will only be identical with TP0 in Audio Loopback Mode (see notes on JP6).

Connectors

Power Supply / Radio Interface

P5	Function
5	Minus 5-volt
4	Plus 5-volt dc input
3	GROUND
2	Receive Audio (RA) output
1	Transmit Audio (TA) Output

Radio Connections

The radio connections are made via P5.

Transmit Audio (TA), P5 Pin 1. This MUST be the center conductor of a coax (shielded cable).

The audio signal to the transmitter, used to modulate the varactor diode to generate true FM. The level is adjustable by VR1 from 0 to about 8 volts peak-to-peak. The cable MUST be shielded.

Receive Audio (RA), P5 Pin 2

The audio signal direct from the receiver's FM discriminator. A level exceeding 50mv is sufficient, but a probe on TP4 should show clipping. The cable MUST be shielded.

Power Connections

The radio and power connections are made via P5.

Vcc (+5 vdc), P5 Pin 4
+5 vdc input to the MFJ-9600.

Vdd (-5 vdc), P5 Pin 5
- 5 vdc input to the MFJ-9600.

Power Ground, P5 Pin 3
Common for Vcc and Vdd. An alternative to S1, Pin 25.

Appendix A - Packet Controller Interfacing

1. Plug in the MFJ-9600 modem board at J4 of the motherboard. Insure pin 1 of the header is in pin 1 of the socket S1.

2. Carefully align the 20-pin header of J1 with the pins sticking up from the MFJ TNC motherboard.

3. Plug in the MFJ-9600 modem board at J5. Insure pin 1 of the header is in pin 1 of the socket S1.

4. Attach wires coming from the plug (J5) attached to P5 on the MFJ-9600 modem board as follows:

   a. P5 pin 5 to - 5 volts.
   b. P5 pin 4 to + 5 volts.
   c. P5 pin 3 to ground.
   d. P5 pin 2 to radio discriminator (RA).
   e. P5 pin 1 to radio varacter (TA).

Appendix B, Radio Interfacing

Perfect Modulation with the FT726R
by James Miller G3RUH

Inject your modem TXaudio directly to the transmitter varactor in the SAT unit via J04 pin 2.

1. Remove the main lid; remove the SAT unit lid.
2. Locate J04 which is a 3 wire connector in the front left-hand corner.
3. Unplug J04, and inject your audio on pin 2, ground on pin 1, using a screened cable.

FT736 & 9600 Baud Operation
by James Miller G3RUH

These notes tell you where to get FM RX audio direct from the discriminator, and where to modulate the FM TX varactor directly. These mods are non-destructive and take no more than a few minutes. The signal bypass the "DATA SOCKET" for high grade FM operations. The RX mod is suitable for:

* UOSAT-D 9600 baud downlink and terrestrial links
* 1200 baud AFSK/FM Standard Packet - BUT IT'S UNSQUELCHED.

The TX mod is suitable for:

* FO-20/PACSAT uplink (1200 bps Manchester FM)
* UOSAT-D 9600 baud uplink direct FSK and terrestrial links
* 1200 baud AFSK/FM Standard Packet.
* FT736 - FM Direct from Discriminator

Detected FM direct from the receiver discriminator is available from the RX UNIT at the junction of R91 and C83. These components are shown in the top right-hand corner of the schematic. Proceed thus:

1. Disconnect FT736 from the mains electricity. (Safety).
2. Remove top cover only.
3. RX Unit is the vertical module on the left.
4. Locate R91 which is about 25mm from the top, 50mm from the radio rear. The resistor is "on-end", and near a couple of glass diodes.
5. Scrape any paint off R91's free end and wet with solder.
6. Your RXaudio lead should be a fine screened cable; connect the inner to R91, and the outer braid to a ground point (e.g. can of T009)
7. Route the cable out though any convenient aperture in the case.
8. The discriminator sensitivity (FM Normal) as about 6 kHz/volt.

Important notes on 9600 Baud Use

Some FT736 receivers are fitted with an LFH12-S IF filter for FM. (CF01 at the top front of the RX Unit). This is a 12 kHz bandwidth filter which is a little too narrow for 9600 bps FSK operation. It is recommended you change this to 15 kHz or better still for UOSAT-D use, 20 kHz bandwidth which will allow more tolerance for doppler shift, and give a far better "eye". Suitable filters are: LFH-15S or CFW455E, and LFH-20S or CFW455D. The first of these is a Yaesu spare part, and is often already fitted.

FT736 DIRECT VARACTOR FM MODULATION

Refer to the circuit diagram; inject your TXaudio at the junction of R32/C29 on the TX Unit. The signal level at this point should be 800 mV peak-peak, and will give +/- 3 kHz deviation. DO NOT EXCEED THIS LEVEL.

Set Mic Gain to min.
Modulating the FM transmitter this way you get an LF response down to 18 Hz (at which point the associated synthesiser PLL begins to track the modulation), and an HF response which is flat to some 10 kHz.

Proceed thus:

1. Disconnect the FT-736 from its power supply. (Safety).
2. Remove top cover only.
3. TX Unit is the module flat on the left (not the one tucked down the side vertically).
4. R32 is just to the left of the rectangular shielded enclosure. The resistor is "on end". Scrape any paint off the free leg.
5. Your TXaudio lead should be a fine screened cable; connect the inner to R32, and the outer braid to the adjacent enclosure.
6. Route the cable out though any convenient aperture in the case.
7. 9600 BAUD FSK MODEM: Adjust TXAudio level with VR1

Other Radios

John Branegan GB7MAC of Scotland reports in the September 1990 issue of the AMSAT Journal various connections of popular radios and 9600 baud modems. You must run a wire (preferably shielded coax) from the FM Discriminator to the input of the modem. The location for this wire is as follows for the following radios:

FRG 9600 UHF Rx: A sheilded coax from pin 9 of IC MC3357 FM discriminator on N. FM unit F268201 (accessory board near middle of Main Board), to Record socket at back of receiver, replaceing existing R53 feed.

Kenwood R2000: A shielded coax is connected from the FM discriminator on the IF unit at the commonpoint of R207, R209, R210, C200, and C202 to a spare position on the Receiver (Rx) back plate.Icom 451 UHF Tranceiver: For 9600 bps reception wire a shielded coax from pin 9 of IC7 MC3357, to one of the spare terminals at the rear of the transceiver.

Icom R7000: A sheilded coax comes from the FM discriminator on the IF unit at the common point of R97 and R96, to a spare position on the rear back plate of Rx. Yeasu FT221R 2m Tranceiver: Used for 2m reception tests of uplink to UoSAT-Oscar 14 by taking Rx audio out from card PB-1463 (FM IF) connection 2, via a shielded coax to one of the relay sockets on the back panel after first disconnecting the original output.

Appendix C, MFJ-9600 Alternate Data Rates

The MFJ-9600 modem design is not sensitive to the data speed. The only changes that need to be made are time constants in the audio filters and the time constant in the Lock Detect Filter.

	4800 Baud	9600 Baud	19200 Baud
C26	470pf	220pf	100pf
C27	.0022uf	.001uf	470pf
C28	.0022uf	.001uf	470pf
C29	.0068uf	.0033uf	.001uf
C30	.001uf	470pf	220pf
R*	220k	100k	51k

R* is RS2 on the MFJ-9600 modem card, a SIP resistor pack. You can either cut the traces to that section of the SIP or leave the value unchanged.

Addendum

If the 9600 bps external modem is to be used on a dedicated radio, i.e., you are not going to run anything but 9600 baud packet on this radio, there are a couple of modifications that will optimize the efficiency:

1) First- remove Q5.
2) Put a shorting wire from the Q5 emitter pad to the Q5 collector pad.

   This modification will make the TX audio present at all times 9600 baud is selected. This will reduce keying "chirp".

3) Instead of tying the TX and RX audio lines to the radio port connector, use TX and RX audio should go directly to the radio varactor and discriminator. These lines will have to be extended for this purpose. Use shielded cable and be careful not to short the shield and the center conductor together.

   This modification will lessen any interference that might be caused by ther presence of the TNC 1200 baud audio.

FULL 12 MONTHS WARRANTY

MFJ Enterprises, Inc. warrants to the original owner of this product, if manufactured by MFJ Enterprises, Inc. and purchased from an authorized dealer or directly from MFJ Enterprises, Inc. to be free of defects in material and workmanship for a period of 12 months from date of purchase provided the following terms of this warranty are satisfied.

1. The purchaser must retain the dated proof-of-purchase (bill of sale, cancelled check, credit card or money order receipt, etc.) describing the product to establish the validity of warranty claim and must submit the original or a machine-reproduction of such proof-of-purchase to MFJ Enterprises, Inc. at the time of warranty service. MFJ Enterprises, Inc. shall have the discretion to deny warranty without dated proof-of-purchase. Any evidence of alteration, erasure, or forgery of proof-of-purchase shall be cause to void any and all warranty terms immediately.
2. MFJ Enterprises, Inc. agrees to repair or replace at MFJ's option without charge to the original owner any defective product provided the product is returned postage prepaid to MFJ Enterprises, Inc. with a personal check, cashier's check or money order for **$4.00** covering postage and handling.
3. MFJ Enterprises, Inc. will supply replacement parts free of charge for any MFJ product under warranty upon request. A dated proof-of-purchase and a **$4.00** personal check, cashier's check or money order must be provided to cover postage and handling.
4. This warranty is **NOT** void for owners who attempt to repair defective units. Technical consultation is available by calling (601) 323-5869.
5. This warranty does not apply to kits sold or manufactured by MFJ Enterprises, Inc.
6. Wired and tested PC board products are covered by this warranty provided **only the wired and tested PC board is returned.** Wired and tested PC boards installed in the owner's cabinet or connected to switches, jacks, cables, etc. sent to MFJ Enterprises, Inc. will be returned at the owner's expense unrepaired.
7. Under no circumstances is MFJ Enterprises, Inc. liable for consequential damages to person or property by the use of any MFJ product.
8. **Out-of-Warranty Service:** MFJ Enterprises, Inc. will repair any out-of-warranty product provided the unit is delivered prepaid. All charges will be shipped COD to the owner.
9. This warranty is given in lieu of any other warranty express or implied.
10. MFJ Enterprises, Inc. reserves the right to make changes or improvement in design or manufacture without incurring any obligation to install such changes upon any of the products previously manufactured.
11. All MFJ products to be serviced in-warranty or out-of-warranty should be addressed to **MFJ Enterprises, Inc., 921A Louisville Road, Starkville, Mississippi 39759, USA** and must be accompanied by a letter describing the problem in detail along with a copy of your dated proof-of-purchase.
12. This warranty gives you specific rights, and you may also have other rights which vary from state to state.