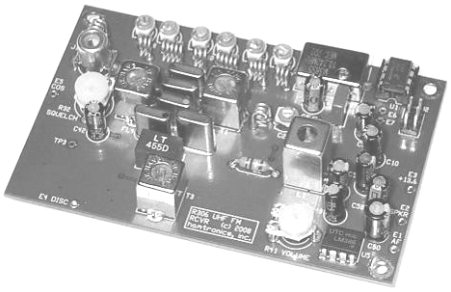
HAMTRONICS® R306 UHF FM RECEIVER: INSTALLATION, OPERATION, & MAINTENANCE



GENERAL INFORMATION.

The R306 is our 6th generation uhf nbfm receiver. It is intended for demanding applications which require exceptional sensitivity and selectivity. It is especially suited for repeaters, audio and data links, and remote control.

The R306 uses triple-tuned circuits in the front end and excellent crystal and ceramic filters in the i-f with steep skirts for close channel spacing or repeater operation. The i-f selectivity, for instance, is down over 100dB at ±12 kHz away from the carrier, which is 40-50 dB better than most transceivers. Low noise fet's and surface mount parts in the front end provide good overload resistance and 0.2µV sensitivity.

The R306 features a positive-acting, wide-range squelch circuit and additional output terminals for low-level squelched audio and discriminator audio as well as COS.

The frequency is programmed in at the factory and is aligned to frequency; so you have no adjustments to do at installation. Volume and Squelch controls are trim pots on the board for compact design. For those applications requiring adjustments on the outside of a cabinet, you may easily replace these pots with suitable panel mount controls.

The frequency reference for the R306 Receiver is a temperature compensated crystal oscillator (tcxo). This provides a temperature stability of ±2ppm over a temperature range of -30°C to +60°C without requiring a crystal oven.

INSTALLATION.

Mounting.

Some form of support should be provided under the pc board, generally mounting the board with 4-40 screws and threaded standoffs to a chassis.

The receiver board relies on the mounting hardware to provide the dc and speaker ground connections to the ground plane on the board; so metal standoffs and screws should be used for mounting.

Electrical Connections.

Power and input audio or data signals should be connected to the solder pads on the pc board with #22 solid hookup wire, which can be extended to a connector or feedthrough capacitors used on the cabinet in which it is installed. Be very careful not to route the wiring near rf components on the board, for instance underneath the board.

Power Connections.

The receiver operates on +13.6 Vdc at about 100 mA peak with full audio. Current drain with no audio is only about 38 mA. A well regulated power supply should be used.

Be sure that the power source does not carry high voltage or reverse polarity transients on the line, since semiconductors in the receiver can be damaged. The positive power supply lead should be connected to the receiver at terminal E3, and the negative power lead should be connected to the ground plane of the board through the mounting hardware. Be sure to observe polarity!

Speaker.

An loudspeaker with an impedance of 8Ω or greater should be connected to E2 with ground return through the mounting hardware. Use of lower impedance speaker or shorting of speaker terminal can result in ic damage. The receiver can also drive higher impedances, such as the 1K to 20K input impedances of repeater controller boards. There is no need to load down the output to 8 ohms.

Antenna Connections.

The antenna connection should be made to the pc board with an RCA plug of the low-loss type made for rf. We sell good RCA plugs with cable clamp. See A5 plug on website.

If you want to extend the antenna connection to a panel connector, we recommend using a short length of RG-174/u coax with the plug and keep the pigtails very short.

We do **not** recommend trying to use direct coax soldered to board or another type of connector. The method designed into the board results in lowest loss practical. When soldering the cable, keep the stripped ends as short as possible.

OPTIONS.

Repeater Use.

E5 provides a COS (carrier operated switch) output which may be connected to a COR module to turn a transmitter on and off. The output level is about 5V unsquelched and 0V squelched. There is a resistor in series with the output to limit current. Therefore, the voltage that appears at the COR board will depend on the load resistance at the input of that board. For best results, be sure that the input resistance of the COR board is at least 47K. If the input resistance is too low, no damage to the receiver will occur; but the squelch circuit hysteresis will be affected.

If your repeater controller uses discriminator audio, rather than the speaker output, filtered discriminator audio is available at E4. The level is about 2V p-p. *Note that discriminator audio is not de-emphasized or squelched.* If you need audio which is squelched, take it from Repeater Audio terminal E1. Level there is about 1V p-p.

Subaudible Tone Decoder.

To use our TD-5 Subaudible Tone Decoder or a similar module, connect its audio input to DISCRIMINATOR terminal E4. If you want to use it to mute the audio (instead of inhibiting a repeater transmitter as is normally done), connect the mute output of the TD-5 to E1 on the receiver.

Multichannel Operation.

The R306 may be programmed with more than one channel. If you ordered this option, you can change to the first alternate channel by grounding E6 or the second alternate channel by grounding E7. Grounding both terminals selects the third alternate. Ground terminals E8 and E9 are provided if you want to use jumpers, or you can use an external switch of some sort.

ADJUSTMENTS.

Frequency Netting.

All crystals age a little over a long period of time; so it is customary to tweak any receiver back onto the precise channel frequency once a year during routine maintenance. This adjustment is called "netting", which is a term going back to days when all stations on a network would initially adjust their VFOs to all be on the same exact frequency before operating as a net.

The adjustment should be done using an accurate service monitor or frequency counter. Of course, make sure the test equipment is exactly on frequency first by checking it against WWV or another frequency

Table 1. Quick Specification Reference

Frequency Range:
can be supplied from 400 - 470 MHz
Sensitivity (12dB SINAD): 0.2µV
Squelch Sensitivity: 0.15µV
Normal signal bw: ±5kHz deviation
Adjacent Channel Selectivity:
±12 kHz at -100dB! (narrower bandwidth is available as an option)
Modulation Acceptance: ±7.5 kHz
Audio Output: up to 1 Watt (8 ohms).
Operating Power: +13.6Vdc at 38-100 mA, depending on audio level.
Size: 4 in. W x 2.5 in. D

standard.

The channel frequency is trimmed precisely on frequency with a small variable capacitor, which is accessible through a hole in the top of the TCXO shield can. The proper tool is a plastic wand with a small ceramic or metal bit in the end.

To perform this adjustment, it is first necessary to verify that the discriminator is properly adjusted. Do this by connecting a dc voltmeter to TP4. Connect a signal generator set for 10.700 MHz to TP5 (left side of coil L9), and set the level for a relatively strong signal so there is very little white noise. Adjust discriminator coil T2 for 3.3Vdc. Then, reconnect the signal generator to antenna connector J1, and set it for the precise channel frequency. You can also use a strong signal on the air if you are sure it is right on frequency. Adjust the TCXO trimmer capacitor for 3.3Vdc (to match the voltage obtained with the 10.700 MHz signal).

Setting Channel Frequency.

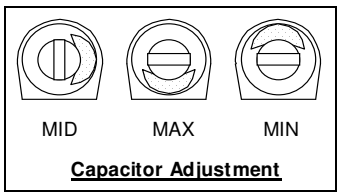
The channel frequency is determined by frequency synthesizer circuits, which use a microcontroller which is programmed at the factory. If you need to change frequency, contact the factory to get another micro programmed for the new frequency settings.

ALIGNMENT.

A complete alignment is needed whenever the frequency is changed by more than about 1 MHz. Alignment ensures that the frequency synthesizer is optimized at the center of the vco range and that all stages are tuned to resonance.

Equipment needed for alignment is a sensitive dc voltmeter, a stable and accurate signal generator for the channel frequency, and a regulated 13.6Vdc power supply with a 0-200 mA meter internally or externally connected in the supply line.

The slug tuned coil should be adjusted with the proper .062" square tuning tool to avoid cracking the powdered iron slugs. Variable capacitors should be adjusted with a plastic tool having a small metal bit. (See website.)



Capacitor Adjustment

☞***Note:*** *Meter indications used as references are typical but may vary widely due to many factors not related to performance, such as type of meter and circuit tolerances.*

a. Set the SQUELCH pot fully counterclockwise and the VOLUME pot just a little clockwise.

b. Connect speaker and +13.6 Vdc. You should hear white noise.

c. Connect voltmeter to TP1 (insert probe tip in pad on board). Adjust vco coil L1 for +2Vdc. (Although the vco will operate over a wide range of tuning voltages from about 1V to 5V, operation is optimum if the vco is adjusted to 2V.)

d. Connect voltmeter to TP2 (insert probe tip into pad). Adjust doubler variable capacitor C21 for a peak. Note: the peak will be small.

e. Adjust buffer variable capacitor C24 for a peak. This will be just a slight peaking (increase) of the voltage.

f. Adjust C32 and C33 for a peak. Then, re-peak C21, C24, C27, and C33 to ensure they are all at maximum.

g. Connect stable signal generator to TP-2. Set generator to exactly 10.7000 MHz. Use a frequency counter or synthesized signal generator so the frequency is accurate. Set level just high enough for full quieting. At 20 µV, you should notice some quieting, but you need something near full quieting for the test (about 200µV).

h. Connect dc voltmeter to Discriminator pad E4. Adjust discriminator transformer T3 for +2.0Vdc.

💣 *Be careful not to turn the slug tight against either the top or bottom because the winding of the transformer can be broken.*

i. Connect signal generator to J1 using a coax cable with RCA plug. Adjust signal generator to exact channel frequency, and turn output level up fairly high (about 1mV).

j. If necessary, adjust trimmer in TCXO to net the crystal to channel frequency, indicated by +2.0Vdc at Discriminator output terminal pad. The frequency normally will be very close; so you may not need to adjust it at all except to compensate for aging.

Note: There are two methods of adjusting the mixer and front end. One is to use a voltmeter with test point TP-3. The voltage at this point is proportional to the amount of noise detected in the squelch circuit; so it gives an indication of the quieting of the receiver. With SQUELCH control fully ccw, the dc voltage at TP-3 varies from -0.5 Vdc with no signal (full noise) to +0.9 Vdc with full quieting signal. The other method is to use a regular professional SINAD meter and a tone modulated signal.

In either case, a weak to moderate signal is required to observe any change in noise. If the signal is too strong, there will be no change in the reading as tuning progresses; so keep the signal generator turned down as receiver sensitivity increases during tuning.

If you use TP-3 with a voltmeter, the signal can be modulated or unmodulated. If you use a SINAD meter, the standard method is a 1000 Hz tone with 3 kHz deviation.

k. Connect dc voltmeter to TP-3. Set signal generator for relatively weak signal, one which shows some change in the dc voltage indication at TP3. Alternately peak RF amplifier and mixer variable capacitors C29, C30, and C31 until no further improvement can be made. When properly tuned, sensitivity should be about 0.2µV for 12 dB SINAD.

💣 T1 and T2 adjust the crystal filter for minimum distortion. These are adjusted at the factory and should not be disturbed. If you must adjust them, inject a signal exactly on channel frequency with a 1000Hz tone and 5kHz deviation. Adjust alternately for minimum distortion.

THEORY OF OPERATION.

The R306 is a frequency synthesized uhf fm Receiver. Refer to the schematic diagram for the following discussion.

Low noise dual-gate mos fet's are used for the RF amplifier and mixer stages. The output of mixer Q6 passes through an 8-pole crystal filter to get exceptional adjacent channel selectivity.

U4 provides IF amplification, a 2nd mixer to convert to 455 kHz, a discriminator, noise amplifier, and squelch. Ceramic filter FL5 provides additional selectivity at 455 kHz. The noise amplifier is an op amp active filter peaked at 10 kHz. It detects noise at frequencies normally far above the voice band. Its output at pin 11 is rectified and combined with a dc voltage from the SQUELCH control to turn a squelch transistor on and off inside the ic, which grounds the audio path when only noise is present. Inverter Q7 provides a dc output for use as a COS signal to repeater controllers.

The injection for the first mixer is generated by voltage controlled oscillator (vco) Q2. The injection frequency is 10.700 MHz below the receive channel frequency, and the vco operates at one half the injection frequency. The output of the vco is doubled by Q3 and buffered by Q4 to minimize effects of loading and voltage variations of following stages from modulating the carrier frequency. The buffer output is applied through a triple tuned circuit (L4, L5, and L6) to gate 2 of mixer Q6.

The frequency of the vco stage is controlled by phase locked loop synthesizer U2. A sample of the vco output is applied through the buffer stage and C2 to a prescaler in U2. The prescaler and other dividers in the synthesizer divide the sample down to 5kHz.

A reference frequency of 10.240 MHz is generated by a temperature compensated crystal oscillator (tcxo). The reference is divided down to 5 kHz.

The two 5kHz signals are compared to determine what error exists between them. The result is a slowly varying dc tuning voltage used to phase lock the vco precisely onto the desired channel frequency.

The tuning voltage is applied to varactor diode D1, which varies its capacitance to tune the tank circuit formed by L1/C16/C17. C13

limits the tuning range of D1. The tuning voltage is applied to D1 through a third-order lowpass loop filter, which removes the 5kHz reference frequency from the tuning voltage to avoid whine.

Serial data to indicate the desired channel frequency and other operational characteristics of the synthesizer are applied to synthesizer U2 by microcontroller U1. Everything the synthesizer needs to know about the band, division schemes, reference frequency, and oscillator options is generated by the controller.

+13.6Vdc power for the Receiver is applied at E1. Audio output amplifier U5 is powered directly by the +13.6Vdc. All the other stages are powered through +5V regulator U6 for stability and to eliminate noise. Additional filtering for the vco and buffer stages is provided by capacitance amplifier Q1, which uses the characteristics of an emitter follower to provide a very stiff supply, eliminating any possible noise on the power supply line.

TROUBLESHOOTING.

General.

The usual troubleshooting techniques of checking dc voltages and signal tracing with an RF voltmeter probe and oscilloscope will work well in troubleshooting the R306. DC voltage charts and a list of typical audio levels are given to act as a guide to troubleshooting. Although voltages may vary widely from set to set and under various operating and measurement conditions, the indications may be helpful when used in a logical troubleshooting procedure.

Current Drain.

Power line current drain normally is about 38 mA with volume turned down or squelched and up to 100 mA with full audio output.

If the current drain is approximately 100 mA with no audio output, check to see if voltage regulator U6 is hot. If so, and the voltage on the 5V line is low, there is a short circuit on the +5Vdc line somewhere and U6 is limiting the short circuit current to 100mA to protect the receiver from damage. If you clear the short circuit, the voltage should rise again. U6 should not be damaged by short circuits on its output line; however, it may be damaged by reverse voltage or high transient voltages.

Audio Output Stage.

Note that audio output ic U5 is designed to be heatsunk to the pc board through the many ground pins on the ic.

If audio is present at the volume control but not at the speaker, the audio ic may have been damaged by reverse polarity or a transient on the B+ line. This is fairly common with lightning damage.

If no audio is present on the volume control, the squelch circuit may not be operating properly. Check the dc voltages, and look for noise in the 10 kHz region, which should be present at U4-pin 11 with no input signal. (Between pins 10 and 11 of U4 is an op-amp active filter tuned to 10 kHz.)

RF Signal Tracing.

If the receiver is completely dead, try a 10.700 MHz signal applied to TP-2. Set level just high enough for full quieting. At 20µV, you should notice some quieting, but you need something near full quieting for the test, which requires about 200µV.

You can also connect the 10.700 MHz clip lead through a .01µf blocking capacitor to various sections of the crystal filter to see if there is a large loss of signal across one of the filter sections. Also, check the 10.245 MHz oscillator with a scope or by listening with an hf receiver or service monitor.

A signal generator on the channel frequency can be injected at various points in the front end. If the mixer is more sensitive than the RF amplifier, the RF stage is suspect. Check the dc voltages, looking for a damaged fet, which can occur due to transients or reverse polarity on the dc power line. Also, it is possible to have the input gate (gate 1) of the RF amplifier fet damaged by high static charges or high levels of RF on the antenna line, with no apparent change in dc voltages, since the input gate is normally at dc ground.

Synthesizer Circuits.

Following is a checklist of things to look for if the synthesizer is suspected of not performing properly.

a. Check the output frequency of the vco buffer with a frequency counter or spectrum analyzer.

b. Check tuning voltage at TP1. It should be about +2Vdc. Actual range over which the unit will operate is about +1Vdc to just under +5Vdc. However, for optimum results, the vco should be tuned to allow operation at about +2Vdc center voltage.

c. Check the operating voltage and bias on the vco, doubler, and buffer.

d. Check the 10.240 MHz TCXO signal at pin 1 of the synthesizer ic (actually best to check at pad next to pin 1; avoid trying to probe surface mount ic leads which are close together). A scope should show strong signal (several volts p-p) at 10.240 MHz.

e. The data, clock, and latch enable lines between the microcontroller and synthesizer ic's should show very brief and very fast activity, sending data to the synthesizer ic shortly after the power is first applied or a dip switch setting is changed. Because this happens very fast, it can be difficult to see on a scope. Use 1mSec/div, 5Vdc/div, and normal trigger on rising pulse.

Microphonics, Hum, and Noise.

The vco and loop filter are very sensitive to hum and noise pickup from magnetic and electrical sources. Some designs use a shielded compartment for vco's. We assume the whole board will be installed in a shielded enclosure; so we elected to keep the size small by not using a separate shield on the vco. However, this means that you must use care to keep wiring away from the vco circuit. Having the board in a metal enclosure will shield these sensitive circuits from florescent lights and other strong sources of noise.

Because the frequency of a synthesizer basically results from a free running L-C oscillator, the tank circuit, especially L1, is very sensitive to microphonics from mechanical noise coupled to the coil. You should minimize any sources of vibration which might be coupled to the Receiver, such as motors.

Excessive noise on the dc power supply which operates the Receiver can cause noise to modulate the synthesizer output. Various regulators and filters in the Receiver are designed to minimize sensitivity to wiring noise. However, in extreme cases, such as in mobile installations with alternator whine, you may need to add extra filtering in the power line to prevent the noise from reaching the Receiver.

Typical Dc Voltages and Signal Levels.

Tables which follow give dc levels measured with a sensitive dc voltmeter on a sample unit with 13.6 Vdc B+ applied. All voltages may vary considerably without necessarily indicating trouble. Signal levels at significant points are also given. The charts should be used with a logical troubleshooting plan. All voltages are positive with respect to ground except as indicated.

Use caution when measuring voltages on the surface mount ic. The pins are close together, and it is easy to short pins together and damage the ic. We recommend trying to connect meter to a nearby component connected to the pin under question.

Table 2. Typical Audio Voltages

Audio Test Point	Normal Level*
U4-9 (Discriminator)	1.5V p-p audio
E4 (Disc Output)	1V p-p audio
E1 (Repeater Output)	600mV p-p audio
U4-11 (noise ampl output)	1.5V p-p noise
CW lug Vol Cont R32	300mV p-p audio
U5-3 (af ampl input)	0 to 100mV p-p (depends on volume control)
U5-5 or E2 (speaker ampl output)	0 to 5V p-p audio

* Readings taken with strong input signal with 1000Hz modulation at ±3kHz deviation.

Table 3. Typical Test Point Voltages

TP1	Tuning V.	Normally set at +2Vdc
TP2	Inj. Level	+0.25Vdc
TP3	Sig. Level	Varies from -0.5Vdc to +0.9Vdc depending on noise quieting with signal.
TP4	Freq.	Varies with frequency of input signal. Voltage at this point normally is adjusted for +2.0Vdc with a signal exactly on frequency. Can vary a little without being a problem.

Table 4. Typical Xstr DC Voltages

Xstr	Stage	E(S)	B(G1)	C(D)	G2
Q1	dc filter	4.0	4.7	4.8	-
Q2	vco	0.95	1.6	3.8	-
Q3	doubler	0	0.68	2.6	-
Q4	buffer	0	0.74	2.7	-
Q5	RF ampl	0	0	4.8	2.4
Q6	Mixer	0.25	0	5	1.0
Q7	sq. open	0	0	5	-
	sq. closed	0	0.65	0.15	-

Table 5. Typical IC DC Voltages

U2-1	2.3	U2-7	5
U2-2	2.1	U2-8	1.7
U2-3	5	U2-9	0
U2-4	5	U2-10	0
U2-5	0 - 4.5	U2-11	0
U4-1:	5	U4-10:	0.8
U4-2:	4.5	U4-11:	2
U4-3:	4.8	U4-12:	0.5 (with
U4-4:	5	sq. just closed)	
U4-5:	3.8	U4-13:	
U4-6:	3.8	0V (sq. open),	
U4-7:	3.8	5V (sq. closed)	
U4-8:	5	U4-14:	0
U4-9:	2 (Varies	U4-15:	0
w/ freq.)		U4-16:	1.8
U5-1:	1.4	U5-6:	13.6
U5-3:	0	U5-7:	7
U5-5:	6	U5-8:	1.4

Table 6. Typical Synthesizer Levels

Data signals from microcontroller U1: Latch enable (LE), clock, and data signals are constant stream of 5V pulses which can be observed with scope set for dc input with 1mSec/div horizontal scan.

U3 TCXO output is approx sine wave signal of 2.5V p-p.

PARTS LIST FOR R306 UHF FM RECEIVER.

Caution: static sensitive part. Use appropriate handling precautions to avoid damage.

Ref Desig	Value (marking)
C1	0.1µf
C2	2pf
C3	100pf
C4	0.1µf
C5	100µf electrolytic
C6	0.15µf mylar (red)
C7	.01µf
C8	.001µf
C9,C10	100µf electrolytic
C11	0.1µf
C12	390pf
C13	5pf
C14	390pf
C15	100µf electrolytic
C16	12pf
C17	47pf
C18	7pf
C19	220pf
C20	100pf
C21	4.5pf variable (white)
C22	2pf
C23	100pf
C24 **	4.5pf variable (white)
C25	220pf
C26	5pf
C27,C28	100pf
C29 **	4.5pf variable (white)
C30	4.5pf variable (white)
C31 **	4.5pf variable (white)
C32 **	4.5pf variable (white)
C33	4.5pf variable (white)
C34	.0047µf
C35-C37	.001µf
C38	7pf
C39	4pf
C40	7pf
C41	.001µf
C42	0.47µf electrolytic
C43	0.1µf
C44,C45	.001µf
C46,C47	.01µf
C48	0.1µf
C49	10µf electrolytic
C50	220µf electrolytic
C51	0.1µf
C52	68pf
C53	220pf
C54-C56	0.1µf
C57	100µf electrolytic
C58	1µf electrolytic
D1	BB132 varactor diode
D2,D3	MMBT3904 used as diode
FL1-FL4	10.7MHz crystal filter (matched set of 4)
FL5	455kHz ceramic filter
J1	RCA Jack
J2	6-pin header
L1	1½ turn slug-tuned (brn)
L2	0.22µH RF choke (red-sil-red-red)
L3,L4	2¾ turn air wound coil
L5	3¾ turn air wound coil
L6	4¾ turn air wound coil
L7,L8	2¾ turn air wound coil
L9	4¾ turn air wound coil
L10	2¾ turn air wound coil
Q1	MMBT3904
Q2-Q4	MSC3130
Q5,Q6	BF998 dual gate mos fet (note: source is wide lead)
Q7	MMBT3904
R1	27Ω
R2	15K
R3	150K
R4	10K
R5	1K
R6,R7	27Ω
R8,R9	10K
R10	180Ω
R11	27Ω
R12	10K
R13	3.9K
R14	470Ω
R15	47Ω
R16	470Ω
R17	10K
R18	3.9K
R19,R20	100K
R21	27Ω
R22	2.2K
R23	330K
R24	22K
R25	27Ω
R26	47Ω
R27	270Ω
R28	330K
R29	15K
R30	2 MEG
R31	47K
R32	100K pot
R33	68K
R34	100K
R35	510K
R36	4.7K
R37	680Ω
R38	1K
R39	22K
R40	100K
R41	100K pot
R42	47K
R43	10Ω
T1,T2	10.7MHz IF xfmr (T1005)
T3	455kHz IF transformer (T1003)
U1	MC9RS08KA1 µP
U2	LMX1501A
U3	10.240MHz TCXO
U4	MC3361BP (smt type)
U5	LM386N-1
U6	78L05 regulator (smt type)
XU1	8 pin ic socket
Y1	10.245 MHz crystal

** Note: C24, C29, C31, and C32 each have 1pf capacitor tack soldered across pads on rear of board.