

## FM WIRELESS MICROPHONE

By Len Galasso

This article describes the theory of operation and construction details of a wireless microphone capable of picking up sounds within a 20 meter radius and transmitting them to an ordinary FM radio at distances of up to 2 kilometers. Many uses for this type of device exist ranging from monitoring a baby's room to the surreptitious listening of an adversary's conversations from a remote location. Since the latter is probably illegal without the subject's approval or, at the very least, his knowledge, no recommendation is made one way or another by the author. However, sometimes drastic situations call for equally drastic measures and this device would, if one wanted, fit the bill

The device consists of a two-transistor circuit broadcasting at a wavelength of approximately 3.5 meters and has a possible range of up to 2 kilometers when no obstructions exist between the transmitter and the receiver. However, this rarely being the case, the author has tested prototypes that would transmit within a radius of about 100 meters throughout an ordinary suburban neighborhood. Signal strength was very good until the fringes of the aforementioned radius were encountered at which point the signal would fade out slightly when the author walked past buildings in the transmission path. A standard *Sony FM Walkman* was used as the receiver in the above tests with the sensitivity switch placed in the DX, or *distance* position.

### THE CIRCUIT

Referring to figure 1, the transmitter consists of two transistors Q1 and Q2. Ignoring Q1 for the moment, Q2 is configured as a VCO in the form of a modified colpitts oscillator whose free-running frequency is determined by L1, C5 and C6 and the internal base-to-emitter capacitance of the transistor itself. The latter capacitance is what provides a certain degree of feedback which tends to keep the oscillator running in a stable state. This capacitance is on the order of ten or twenty picofarads and in AF circuitry is insignificant but is very important in this circuit for two reasons, the first of which is the feedback, and the second which will be discussed in a moment.

Parallel-resonant circuit L1 and C5 form the tank circuit which determines, along with the *series-resonant* circuit of L1 and C6, the normal free-running frequency of the oscillator. This frequency is set to be around 87 to 90 megahertz which is located at the bottom of the standard FM broadcast band and was selected so that a normal FM radio could be used as the receiver. This frequency is low enough to not jam normal radio broadcasts which would arouse suspicion in surreptitious situations.

In addition to frequency-determination, the tank also stores the RF energy which will be radiated into space via the 1/16 wave antenna; this size antenna was selected as a compromise between size and emission efficiency. For cases where no antenna can be used, the author has found that running the transmitter without an antenna only requires some retuning of variable capacitor, C6. It must be understood that

this reduces the effective range of the transmitter but this might not be a problem for short-haul transmissions where a small transmitter form-factor is the goal. A 1/4 wave antenna was found to excessively load the VCO to point of circuit destabilization but may be adapted by adding another stage of buffering after the VCO section and driving the antenna this way.

Referring back to figure 1, the signal produced by sound pressure against the electret condenser microphone element is AC-coupled through C1 into Q2; Q1 is configured as a class A amplifier with a signal gain of about 4 to 1. The amplified signal is coupled into the base of Q2 which changes the base-to-emitter junction capacitance in the transistor much like that of a varactor diode used in more sophisticated electronic tuning circuits, the end result being that the base frequency of the oscillator is changed proportionately to the incoming signal's amplitude and frequency. This effect is sufficient to cause frequency modulation to take place thereby imbedding the microphone's signal within the RF carrier which is radiated into space via the antenna.

Power is supplied by either a standard 9-volt alkaline transistor battery or for small space considerations, a miniature 12-volt alkaline electronic lighter battery. The latter is actually a unit of eight watch-cells stacked upon one another and placed into a tiny roll of sheet metal which approximates the size of one "N" cell. Current drain is about 20 milliamps and battery life is very good when the 9-volt transistor battery is used. The electronic lighter battery is good for short transmission cycles and should

only be considered when space is of the utmost and access to the transmitter is available to replace the spent battery.

## CONSTRUCTION

Despite its simplicity, one must bear in mind that this is a VHF circuit and as such its stability (or lack thereof) can be attributed to how it is constructed. Having assembled many prototypes the author can attest to the benefit of the so-called "ugly construction" technique. The latter is a term used by VHF and UHF radio enthusiasts and HAM radio operators which is characterized by point-to-point wiring upon a copper substrate or "ground plane". Its name is attributed to the "rats nest" look to the finished product. Despite its ugliness, short leads and the copper substrate ensure that no ground loops or other forms of circuit loss can contribute to the transmitter's instability.

The author has assembled a prototype on a four-by-three centimeter piece of double-sided, copper-clad epoxy fiberglass circuit board through which a hole had been drilled in each corner to facilitate mounting into some form of enclosure. Each component is soldered vertically, point-to-point, with leads as short as possible; ground connections are made directly to the copper ground-plane using a soldering gun or a soldering iron of at least 30 watts. Standoffs, onto which components are suspended, can be either units specifically designed for this purpose, or as the author has used, high value (22 megohm), quarter-watt resistors. This provides some physical stability to the circuit and lends a method by which to create a VCC rail which can feed the circuit. The end result is that the circuit

is suspended above the ground plane and each component's leads are very short (see Figure 2). This also allows components of various sizes to be accommodated and provides the means to easily replace components which is an aid to experimentation.

*It cannot be stressed more that short leads must be used wherever possible.* This, and the copper substrate will ensure a very stable circuit that will provide drift-free operation over long periods of time. *Never use wirewrap or other types of "neat construction".* These types of construction are very pleasing to the eye but can produce copious amounts of stray capacitance and inductance that form many "accidental" tuned circuits which will affect the stability of the circuit.

Mount the variable capacitor such that the adjustment slot is facing away from the ground plane so it can be tweaked from above through a hole drilled in the enclosure you select. This allows final frequency tweaks to be made after the unit has been assembled and mounted into the enclosure of your choice. The same is true for the microphone element which should be the highest circuit component, thereby allowing it to slightly protrude through the enclosure top.

When selecting an enclosure, select one made of plastic or other non-conductive material or you will find that the tuned circuit will be affected by hand capacitance. An exception to this would be a larger metal enclosure in which the surface is fairly distant from the tank circuit. The author has tried to house the unit in small aluminum "minibox" enclosures without success and

for this reason recommends a plastic enclosure. Another benefit of this material is the ease with which it can be machined: an xacto-knife can be used as a drill bit--a few twirls gets the hole started and the tapered nature of the blade allows the hole to be enlarged as you go. The same knife can also be used to de-burr the holes after the correct size has been achieved.

The circuit card should be mounted to the case using nylon or other non-conductive machine screws or fastened with adhesive from a hot-glue gun. Screws are preferred, since this allows the card to be removed for servicing if that need should ever arise. Figure 3 depicts the author's prototype using a 9V transistor radio battery.

## CHECKOUT AND ADJUSTMENT

After the circuit has been assembled, connect the battery to the unit and set an FM radio to a frequency free of broadcasts at about 88 or 90 megahertz. Solder a stiff piece of wire about 21 cm long directly to the collector of Q2 and let the wire stand as vertical as possible as a temporary antenna. Next tune variable capacitor C5 until the ambient room noise is heard through the radio. Best results are achieved if the radio is monitored through headphones to prevent audible feedback. There might be several capacitor positions which will transmit on the selected frequency but typically, one will be much clearer and louder than the others. When this capacitor position is found, slightly stretching or compressing the windings of L1 will change the frequency

slightly. Be sure to use a non-conductive tweaking tool for C5 or the hand/tool capacitance will change the circuit's frequency when the tool is brought away from the capacitor.

Next mount the circuit and battery in your enclosure after removing the temporary stiff-wire antenna from the circuit. The author has used in his prototype a miniature jack for the antenna connection so that different antenna combinations could be tested or the antenna removed altogether if so desired. Connect the antenna-jack to the collector of Q2 with a heavy gauge wire, strip of grounding braid or short length of *solder-wick*.

The author's antenna was a 21 cm piece of #16 enameled wire soldered into a miniature plug which fit into the enclosure-mounted jack.

### **SOME FINAL THOUGHTS**

You will find the transmitter to be both useful, amazingly sensitive to sound and remarkably clear as well as having a long range under fairly ideal conditions. Some other uses for the transmitter might be remote controls for triggering devices or events; replace the microphone stage with a tone generator (perhaps using a 555 timer IC). Or, combine the transmitter with a modem to setup a small wireless computer link . Another use may be to transmit sound programming from, say, a CD player based in the house to remote locations around the house that can be received through the FM radio. In this case, the Q1 stage may be eliminated altogether and the output of the CD (or TV, etc.) coupled via

the headphone jack into the VCO stage through C3.

At any rate, if surreptitious listening is your intended purpose one might consider modifying a standard FM radio to prevent accidental transmission interceptions by persons happening to tune-in to your broadcasts. Before these modifications are discussed it must be noted that the bottom of the FM band is set aside, but not dedicated to, educational broadcasting from local colleges and universities. Often, these educational institutions have amazingly popular followings due to their eclectic programming mix or accessibility to "request lines" and the like. Therefore always be careful for people accidentally tuning in on your broadcasts.

The modifications are neither difficult nor will they render your FM radio useless to standard transmissions. This involves lowering the radio's local oscillator to below the standard 88 megahertz range thereby eliminating most if not all casual FM listeners from capturing your transmissions.

First open the back of your radio and locate the tuning capacitor on the main circuit board; 99 percent of the time this component is made of clear plastic, is somewhat square and will have several small trimmer capacitors located on its back.

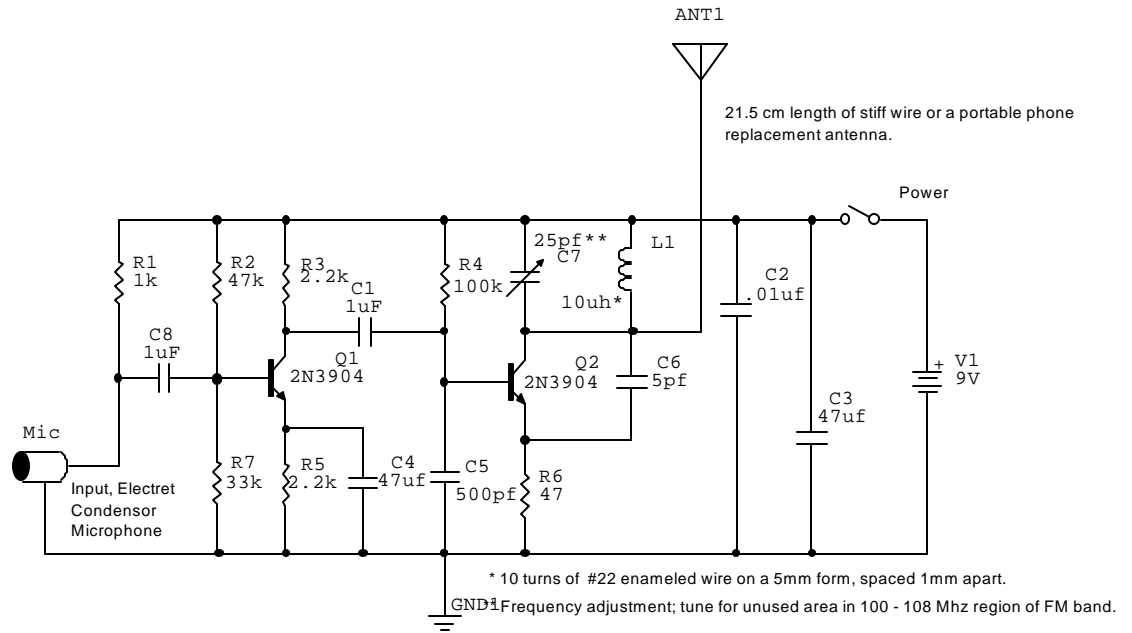
Next, turn on the radio and locate the lowest-frequency legitimate transmission you can by tuning the main capacitor in the normal way. Now, take a non-conductive tweaking tool and locate the oscillator trimmer on the back of the tuning capacitor by slightly tweaking each one, being careful

to note its current position; if the tweak doesn't detune the station, restore its position and move on to the next one. When it is found, change the trimmer to a point that will put the legitimate station *slightly higher*, in terms of frequency, on the main tuning dial. For example, if the station was at 88.9 Mhz, then select an oscillator trimmer position that would put it at say 93.9 Mhz. This effectively will add about four or five Mhz to the bottom end of your radio. Of course you may lose some of the high end of the tuning dial and the actual stations will be slightly skewed along the dial, but it is a small price to pay for having a "clear transmission channel".

If this radio will be dedicated to work with the transmitter, then you may apply this technique to *radically* lower the radio's oscillator and further ensure security. This being said you must still remember that *anything transmitted on the airwaves is never 100% secure.*

Now close up the radio and retune the transmitter frequency either by re-tweaking C5 or by compressing L1's windings a bit--and there you have it.

The accompanying diagrams should clarify the above text.



**Figure 1.**

## PARTS LIST

<b>RESISTORS (5%, 1/4 watt, carbon film)</b>	
<b>R1</b>	<b>1K</b>
<b>R2</b>	<b>47K</b>
<b>R3, R5</b>	<b>2.2K</b>
<b>R4</b>	<b>100K</b>
<b>R6</b>	<b>47 ohm</b>
<b>R7</b>	<b>33K</b>

<b>CAPACITORS</b>	
<b>12v, electrolytic</b>	
<b>C1, C8</b>	<b>1uf</b>
<b>C2</b>	<b>.01 uf</b>
<b>C3, C4</b>	<b>47uf</b>
<b>ceramic disc unless noted</b>	
<b>C5</b>	<b>500 pf</b>
<b>C6</b>	<b>5 pf</b>
<b>C7</b>	<b>2-25 pf variable</b>

<b>TRANSISTORS</b>
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<b>Q1, Q2</b>	<b>2N3904 or equivalent.</b>
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<b>MISC</b>	
<b>L1</b>	<b>10 turns #22 enameled wire on a 5mm form, spaced 1mm apart.</b>
<b>M1</b>	<b>Electret Condenser element (Radio Shack 270-090)</b>
<b>B1</b>	<b>9V transistor o 12V Electronic Lighter Battery (Radio Shack 23-144 see text)</b>
<b>Enclosure, Switch, etc.</b>	

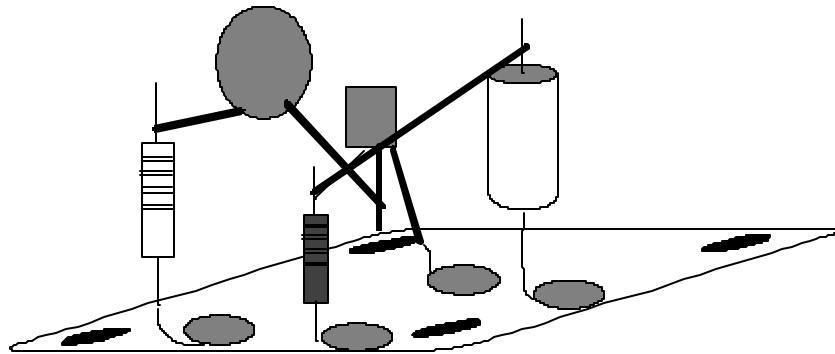


Figure 2

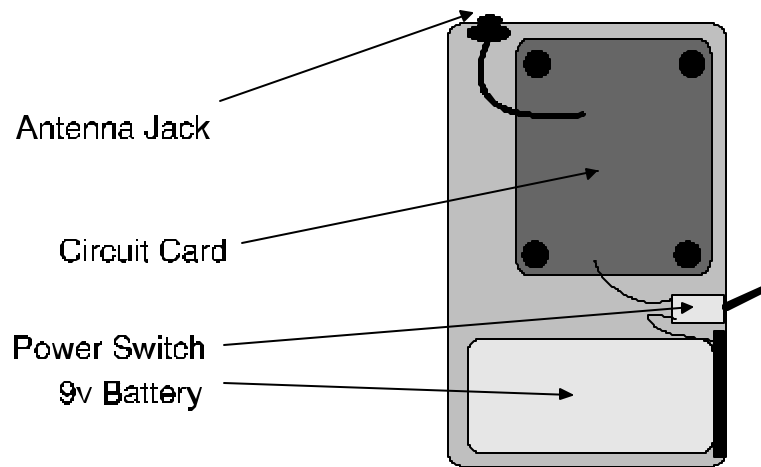


Figure 3