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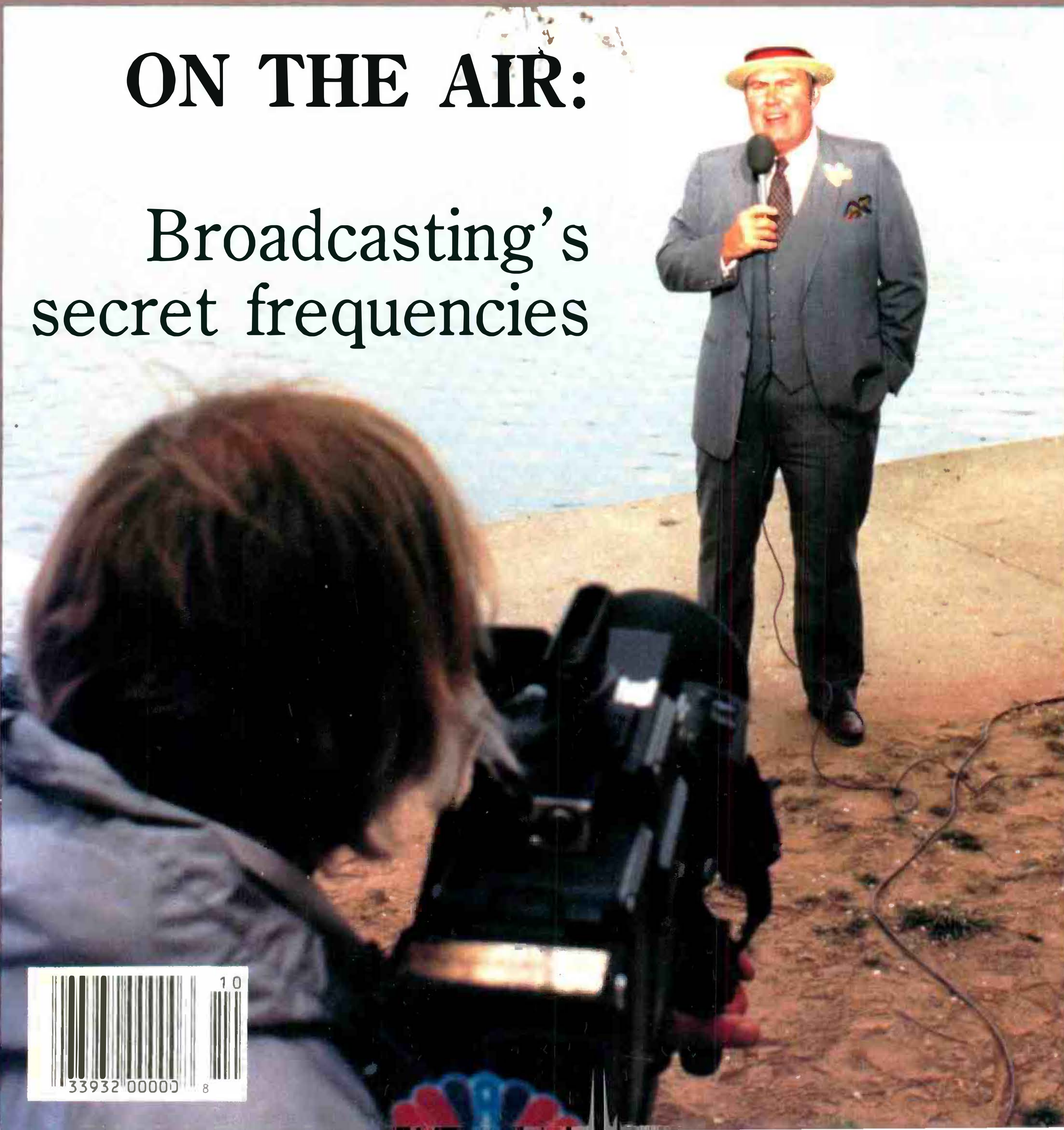
ON THE AIR:

Broadcasting's secret frequencies



Doug DeMaw

P.O. Box 98
Brasstown, NC 28902

A Beginner's Look at
Transmitter Basics

Have you ever experimented with transmitter ciruits? Perhaps now is the time to try your hand at generating RF power. There is nothing difficult about building a small transmitter, and the cost of such a project is minimal if you are willing to work with power levels that are less than a watt or two.

Let's examine some fundamentals that may be applied to transmitter design for low, medium or high frequency. Although many of the principals we will discuss are useful also at VHF and UHF, there are some design rules that are very special at those higher frequencies. We will discuss them another time.

I chose the AM broadcast band in order to provide a test frequency that is available to all persons: You do not need an FCC license to operate in the AM band, provided you comply with the stipulations set forth in Part 15 of the rules. Notably, the antenna (inclusive of the feed line) cannot exceed 3 meters in length. Also, the maximum DC input power to the last stage of the transmitter cannot exceed 0.1 W (100mw). Finally, you may not cause interference to any licensed AM broadcast frequency.

Select a transmitting frequency that is not apt to interfere with the reception of local stations. Best results are usually obtained when we use the high end (1200 - 1600 kHz.)

How Far Can the Signal Carry?

My experience while using 100 mw of dc input power, indicates 1/4 of a mile is typical for solid reception. But, I have copied it as far as 1/2 mile when using a good portable radio. The limiting factor is the short antenna. The 3 meter restriction limits the overall antenna length to only 10 feet. Use of a loading coil in the antenna is prohibited, since the wire on the coil must be counted as a part of the overall antenna length.

Uses for a 100-mw BC-Band Transmitter

There are some practical applications for a transmitter of this type. For example, a modulator can be added to permit the use of a microphone. The transmitter can then be used as a crib monitor for a baby's room, as an intercom (two units needed) or as a phono transmitter. The latter application would enable you to modulate the transmitter with a tape deck or turntable, permitting you to listen to your favorite music while working in your garden or yard on a portable radio.

Our circuit example this month shows how we may use a tone modulator to generate MCW (modulated continuous wave) allowing you to employ the transmitter for code practice with a nearby friend.

Analyzing the Transmitter Circuit

Figure 1 shows the schematic diagram of our study project. Q1 is the heart of the system. This bipolar transistor operates as a Pierce crystal oscillator. Y1 is a crystal for the frequency of your choice. It should be selected in accordance with the earlier discussion of this subject. C1 and C2 are feedback capacitors. They ensure oscillation of Y1. C1 may be varied in value to assure reliable oscillation of Y1.

Some crystals are less active than others, and this may require experimentation with the value of C1. You will find that C1 values between 27 and 100 pf are typical for crystals in the 1000-1600 kHz range.

Generally, the collector of a Pierce oscillator has an RF choke or a resistor in place of T1 (Fig. 1). I use a broadband toroidal transformer in this part of the circuit. It allows me to use a secondary winding to feed energy to the base of the amplifier transistor, Q2. The primary of T1 acts as an RF choke, since it is not tuned to the operating frequency. Q1 and Q2 operate continuously. The tone modulator is keyed instead of the RF stages.

A Class-C amplifier (Q2) follows the crystal oscillator. A low-impedance secondary winding is used on T1 to provide a match between the collector of Q1 and the base of Q2. The Q2 base presents an impedance between 10 and 25 ohms, depending upon the level of the base drive.

You will note that R1 is shown in dashed lines. It is an optional component, and is used only if Q2 has a tendency to self-oscillate. The range of resistance values for R1 is between 10 and 33 ohms, typically. The smaller the ohmic value of R1 the lower the output power from Q2, since a greater part of the driving power from Q1 is dissipated in R1. Use the highest R1 value that ensures Q2 stability.

The collector impedance of Q2 at 70 mw is 1028 ohms. This is derived from Z(ohms) = $Vcc^2/2Po$, where Vcc is the collector to emitter voltage, and Po is the transmitter output power. We have assumed an efficiency of 70% for Q2, which equates to approximately 70 mw of output power. The collector of Q2 is tapped toward the +12-V end of L1 in order to prevent the collector load impedance from degrading the Q of tuned circuit C3/L1. This aids the stage efficiency and reduces harmonic output currents. The 10-ohm series resistor at the bottom end of L1 serves as a protective device for Q2. In the event thermal runaway or self-oscillations should occur causing Q2 to draw excessive current, the resistor will limit the current.

Note that the 3-meter-long antenna connects to the top of L1 via a 0.1 uF blocking capacitor. The latter component prevents the +12-V line from short-circuiting, should the antenna wire come in contact with the circuit ground. Another 0.1 uF capacitor is present between the top of L1 and the stator of C3. This prevents short-circuiting the +12-V line should the rotor and stator plates of C2 come in contact with one another.

The terminals to which jumper wire W1 is connected may be opened for the purpose of metering the dc current taken by Q2. You may insert a milliammeter at the W1 jumper point. The collector current for Q2 should be 9.1 ma for 100 mw of dc input power. This is based on 11 volts, collector to emitter, at Q2 (there is a 1-V drop across the 10 ohm protective resistor).

In the event the current for Q2 is low, add a turn of wire to the secondary of T1. If the current is too high for the legal 100 mw power level, remove a turn from the T1 secondary winding. The drive to Q2 may be increased or decreased slightly in this manner. You may also reduce the drive to Q2 by adding the appropriate value of resistor to the circuit at R1.

C3 tunes L1 to resonance at the Y1 crystal frequency. Do this with the antenna connected to L1, as the 10 foot wire adds stray capacitance to the C3/L1 tank circuit. Tune for maximum output power by monitoring the signal with an AM receiver. There will be a small dip (reduction) in Q2 collector current when the tuned circuit is resonant. You may use a dc milliammeter to determine resonance. Connect it in place of jumper W1.

Tone-Modulator Circuit

A 741 op amp is used as a tone oscillator. It is labeled U1 in Fig. 1. It generates a tone of roughly 1000 Hz. The transmitter (Q1 and Q2) operate continuously, but U1 is keyed on and off to produce MCW. The keying is accomplished by PNP switch Q3. You can eliminate Q3 and simply key the +12-V line to R2. This will require that the key jack be isolated from the circuit ground with insulating washers.

The form of modulation used in Fig. 1 is called *base modulation*. Normally, a solid-state AM transmitter has the modulation

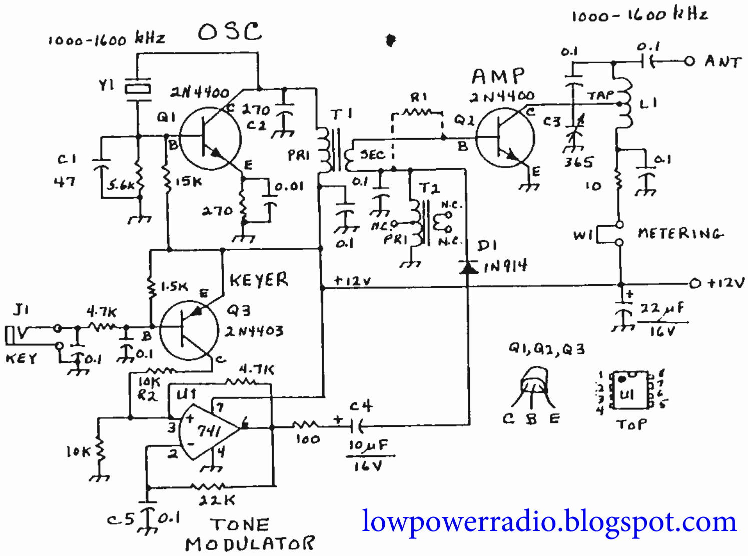


Fig. 1 -- Schematic diagram of a 100-mw transmitter for use in the standard AM broadcast band. Fixed-value capacitors are disc ceramic. Polarized capacitors are electrolytic or tantalum. Resistors are 1/4-W carbon-composition units. Decimal-value capacitors are in uF. Others are in pF. K = 1000.

- C1,C2,C4 -- see text.
- C3-- Air variable capacitor or mica trimmer.
- D1-- Small-signal switching diode, 1N914 or equiv.
- J1-- Two-circuit phone jack.
- L1-- 82-uH inductor. Use 90 turns of no. 28 enam. wire, closewound, on a 1 inch piece of 3/4 inch PVC pipe.
- R1-- See text.
- T1-- Broadband toroidal transformer. Primary has 1 mH of inductance. Use 44 turns of no. 28 enam. wire on an Amidon Assoc. (12033 Otsego St., N. Hollywood, CA 91607) FT-50-43 ferrite toroid. Secondary has 10 turns of no. 28 enam. wire over primary winding. Toroid core has 0.5 inch OD and permeability of 850.
- U1-- 8 pin DIP op amp, type 741.
- W1-- Jumper wire.
- Y1-- Fundamental crystal, surplus computer type, for frequency of your choice (see text).

applied to the collector circuit of the driver and PA stages.

Observe that D1 is in the audio line to the base of Q2. It passes only the positive audio pulses while blocking the negative half of the square-wave output from U1. This causes Q2 to be forward-biased by the positive audio pulse, causing upward swings of output power from Q2. Modulation is applied across an audio inductor, T2 which is the primary of a transistor radio audio-output transformer. The T2 primary winding provides a dc return path for the secondary of T1, but it prevents the audio pulses from being lost to ground at the cathode end of D1. The center tap of the T2 primary and the secondary winding are not used.

The modulation level from U1 may be reduced by making C4 smaller in value. It is possible to use as little as 0.1uF of capacitance at C4, depending upon the exact output level from U1. Use only enough modulation to provide a clean, well modulated output signal from Q2. You may change the pitch of the tone by experimenting with the value of C5. Smaller values provide a higher frequency.

Voice Modulation May be Used

You can transmit music or voice information by replacing U1 of Fig. 1 with a circuit that is suited to use with a microphone or tape-deck output. Fig. 2 illustrates the changes necessary.

In Fig. 2 I have shown part of Fig. 1 to indicate how the modulator changes are made. The keying transistor of Fig. 1 has been deleted. An audio-amplifier IC, U1, has replaced the op amp of Fig. 1. R1 of Fig. 2 is the audio-gain control. It determines the modulation percentage of the transmitter. It is adjusted for minimum received-signal distortion, consistent with a high modulation percentage. A low-impedance microphone (600-1000 ohms) or the output of a tape deck may be plugged into the mike jack at the lower left of Fig. 2.

Construction Notes

This project can be built easily on perforated circuit board, or you may elect to use the one-shot board technique that we considered in last month's article. I suggest you build this circuit one stage at a time, commencing with Q1 of Fig. 1. Get the oscillator running and checked out, then add Q2 and ensure that both stages are functioning correctly. The modulator and keying circuit are added last. You can use the dead-bug (IC on its back construction method when wiring U1. Use an IC socket for this purpose. This will enable you to use the 741 or LM386 later, for other projects.

All RF and component leads must be as short as practicable. Long leads introduce unwanted stray inductance, and this can cause low stage gain and self oscillations.

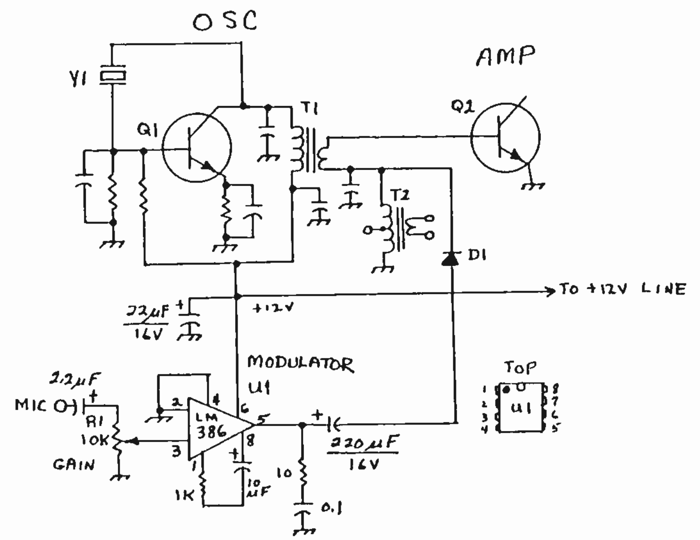


Fig. 2 -- Schematic diagram that shows the changes to the Fig. 1 circuit for using voice or music transmissions. Q3 of Fig. 1 is eliminated. R1 is a linear or audio taper carbon control. U1 is a National Semiconductor Corp. Audio amplifier Ic, 8 pin DIP.

You may use transistors other than 2N4400s for Q1 and Q2. For example, 2N2222As are good substitutes. Any NPN transistor that has characteristics similar to a 2N4400 or 2N4401 will perform nicely in the circuit of Fig. 1.

Closing Remarks

This month we have examined a simple type of transmitter as part of your learning process. Build one of the circuits in this article. You will gain valuable experience, and have fun too. Be sure to connect an earth ground to the circuit ground; it will improve the signal coverage.

Do not attempt to increase the range of this transmitter by using a long antenna or increasing power output. A long antenna can't be attached to L1 of Fig. 1 without ruining circuit performance. Also, any violation of the FCC part 15 rules will be discovered in short order, and "The Man" will be knocking at your door! Observe the FCC rules and have fun.

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