Mark Spencer, WA8SME, ARRL Education and Technology Program Coordinator

774 Eastside Rd, Coleville, CA 96107; mspencer@arrl.org

Solving Random Noise Issues in TRM-433-LT Data

A number of manufacturers include this tiny transceiver in their UHF data link modules. Here is a way to make it more useful.

I use a number of UHF, Part 15-type, data link modules in ARRL Education and Technology Program projects. These data links are based on Linx RF transmitter, receiver and transceiver ICs that operate on 433 MHz, have an advertised range of 300 feet (optimistic) and are designed to send and receive digital data.

I started a number of years back with using a simple data link to connect a Morse code bug to a transceiver without the interconnecting cables. Since then, I have used these data links in robotics (the Mars Lander simulator) to connect a free-roving robot with students at a ground station in the classroom. I've put them to work in handheld seismometers that students can take on amusement park rides. The links are great for relaying acceleration data to students on the ground. I have also used the data links to receive data collected by Sudden Ionospheric Disturbance (SID) receiver systems that have been detailed in a previous *QEX* article ("SID: Study Cycle 24, Don't Just Use It," Sept/Oct 2008 *QEX*). Lately, I have integrated one of these data links into a CubeSat Simulator to connect a working model of a satellite sending telemetry data to a simulated ground station (Figure 1). This latest project emphasized one limitation of these data links and inspired me to develop a solution.

The Linx series of RF modules use On-Off Keying (OOK) AM modulation to transmit data. Basically, OOK means that when the carrier is present, the receiver output is high to represent the binary state 1 (one), and when the carrier is absent, the receiver output is low to represent the binary state 0 (zero). The early Linx TXM-433-LC/RXM-433-LC transmitter/receiver pair of modules performed well. In an apparent attempt to increase range, the Linx developed the more sensitive TXM-433-LR/RXM-433-LR, but these devices had an irritating flaw: there was no squelch function in the receiver. If no signal was present, the receiver generated a considerable amount of random noise at its output. Software can be written to overlook and negate the random noise, but if you want to send Morse code or simply send control codes to turn a remote switch on and off, the random noise is devastating because it can masquerade as valid data. (The CubeSat Simulator project included sending data via Morse code, just like the real satellites. The random noise made that mode of transmission virtually impossible.)

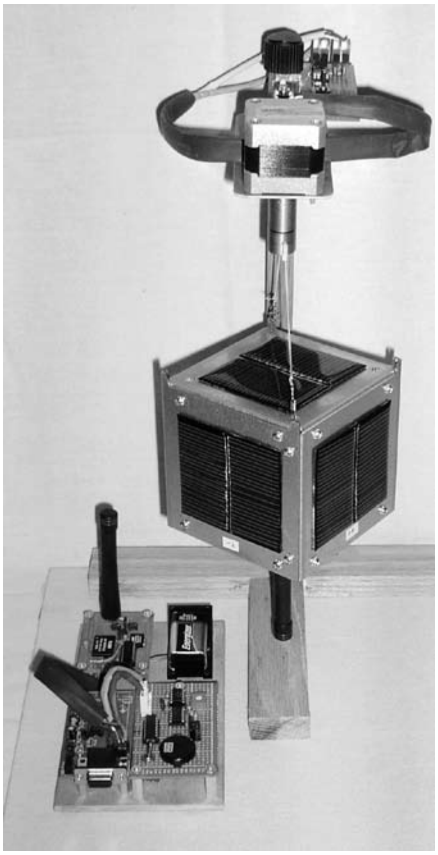

Figure 1 — The CubeSat simulator. A UHF data link connects the satellite to the ground station.

Over time I developed a fairly complex circuit that combined the TX/RX modules along with an antenna changeover device, a squelch circuit, and the gate logic to control all the bits and pieces (Figure 2). I found that it worked fairly well. But as always seems to be the case, just when you get a handle on one technology, the next generation is marketed and it makes the older versions obsolete. Such is the case with the new Linx TRM-433-LT module.

The TRM-433-LT

The TRM-433-LT is a transceiver on a chip that includes virtually all of the features that I had incorporated in my transceiver design at reduced cost (Figure 3)! The random noise issue is still a problem, but there is on-board squelch capability to deal with it. Unfortunately, Parallax, a major manufacturer of RF modules designed around these Linx ICs, ignored the new squelch capability. That meant I had to improvise my own solution, which is detailed in the schematic in Figure 4. Refer to the portion of the schematic that illustrates the TRM-433-LT pinout during the following discussion.

First of all, the TRM-433-LT device is a 12-pin, surface mount device only. The functions of most of the device pins are pretty self

[1]Notes appear on page 00.

explanatory. An external 433 MHz antenna is connected to pin 1, the antenna pin. Voltage (V_{cc} = 3.3 V) is applied to pin 11. The ground pins are pins 2 and 10. The device can be powered down to conserve current through the PDN at pin 9. The TR (transmit/receive) pin is the device PTT; a logic "high" on pin 8 switches the transceiver module into the transmit mode. The DATA line, pin 7, is bi-directional and serves as data in for transmit and data out for receive. The DATA line has a Schmidt triggering circuit that shapes the data output to a square wave. The other pins will require a bit more explanation.

The TRM-433-LT is an FCC Part 15 device, which means that the power output of the transmitter has to be reduced below certain levels to operate in the unlicensed service. The transmitter output power is controlled by the L ADJ at pin 12. The device documentation has a graphic that helps determine a resistance value attached between pin 12 and V_{cc} to control the power. Direct connection of this pin to V_{cc} will produce full power. I chose to use a resistor of 750 Ω between V_{cc} and this pin to bring the power level within Part 15 compliance. The RSSI (pin 4) is the received signal strength indicator line that presents a voltage proportional to the received signal strength. The RSSI line was used in conjunction with the data line to form a squelch circuit in the previous design (Figure 2). Pin 6 outputs the raw received

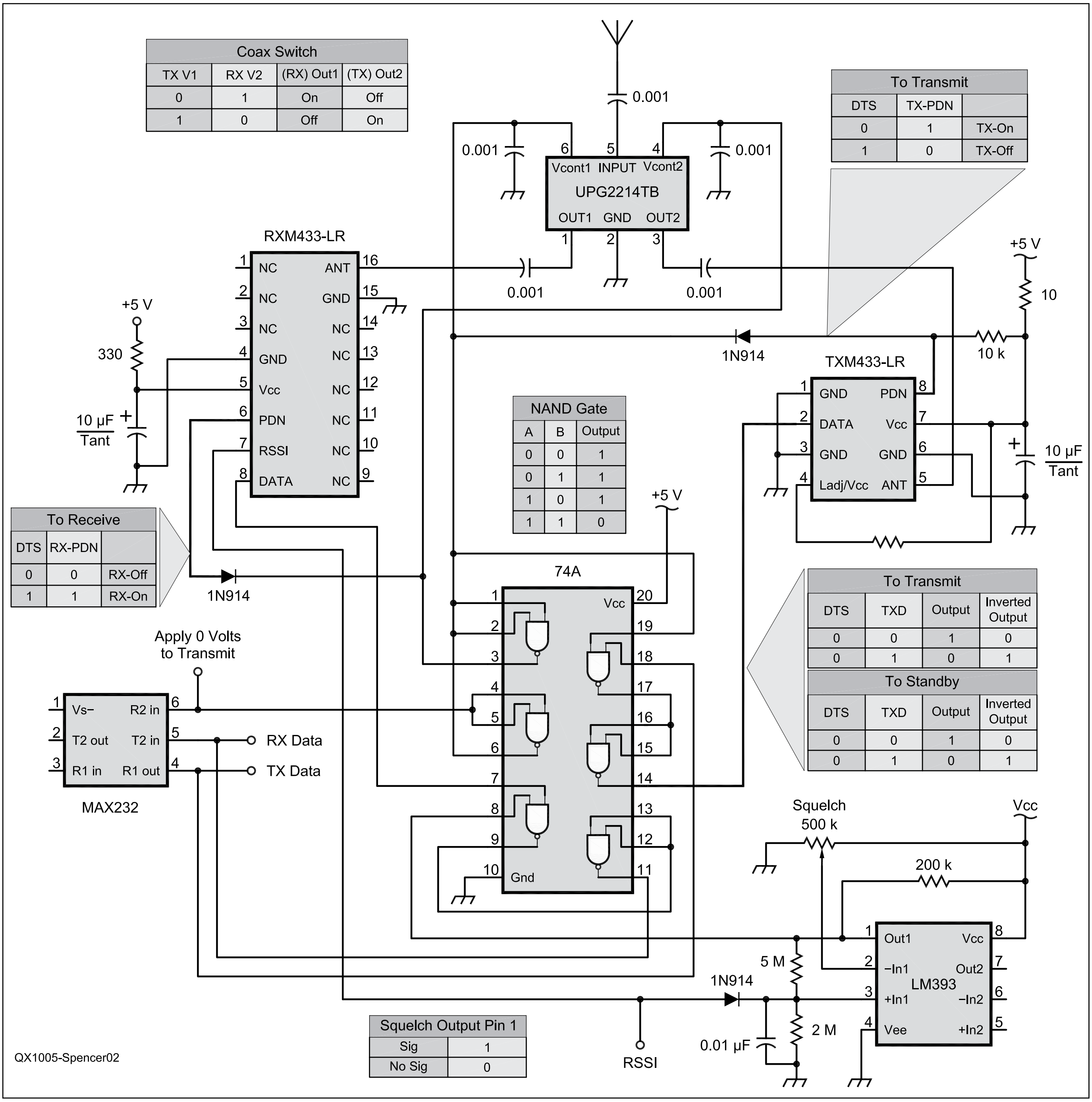

Figure 2 — Data link system circuit diagram using separate transmitter and receiver modules.

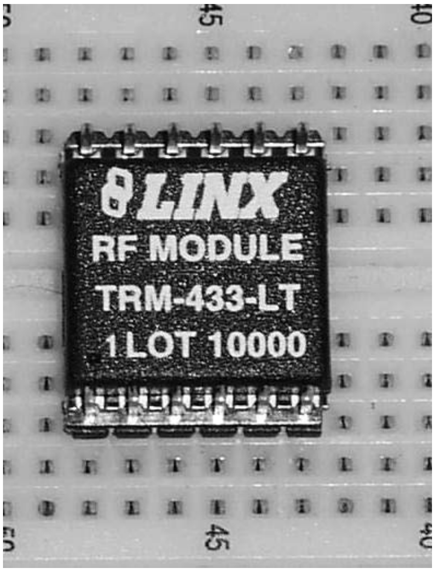

Figure 3 — The Linx TRM-433-LT transceiver module.

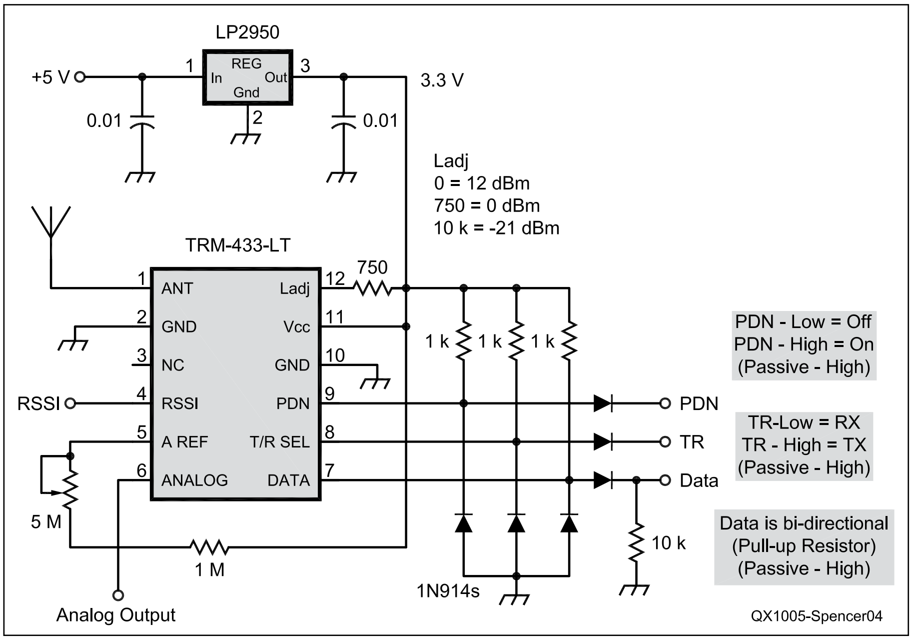

Figure 4 — A TRM-433-LT based data link circuit.

data. The A REF (pin 5) is an added feature of the TRM-433-LT and allows the use of an internal squelch circuit. The threshold level of the squelch is set by varying resistance value between this pin and V_{cc}.

The TRM-433-LT requires CMOS level voltages for V_{cc} as well as the other interconnection pins. The 3.3-V regulator steps down the applied voltage to the appropriate level. The 1 kΩ resistors serve as pull-up resistors to keep the associated I/O pins at V_{cc}. The 1N914 diodes attached to the I/O pins serve two purposes. First, the diodes provide some static discharge protection. Second, the diodes provide isolation between non-CMOS level voltages applied to the pins and the TRM-433. For example, in the static state of the TR pin, it is held high. This puts the transceiver in the transmit mode. If a microcontroller were used to control this device, the controlling pin of the microcontroller would apply 5 V to put the transceiver in transmit mode. The in-line diode isolates the 5 V from the module and allows the pull-up resistor to supply the requisite current. Alternatively, if the transceiver is put in the receive mode, the microcontroller would bring the controlling pin low (ground) and the in-line diode would conduct the pull-up resistor current to ground, grounding the module TR pin.

Testing and Tweaking the Squelch Function

The added squelch appears to solve the random noise issue with these devices. However, there are some unspecified quirks that need to be considered. While the squelch will reduce or eliminate random noise on the data line when there is no signal present, the squelch circuit also affects the Schmidt trigger in the data line. Let me illustrate these quirks with some oscilloscope images under various operating conditions.

In the first test, 100-ms-wide pulses were sent over the data link. The oscilloscope image in Figure 5 depicts what happens. The light gray trace, for reference, is the pulse that is generated by the microcontroller and sent by the transmitter. The receive module data line output, with no squelch circuitry or resistor installed, is the Channel 1 trace. Notice that the receiver data line output is high when the transmitted pulse is high. But also notice that about 40 ms after the pulse goes low, random noise on the receiver data line kicks in. If sending Morse code, or controlling switches, the noise could be a problem.

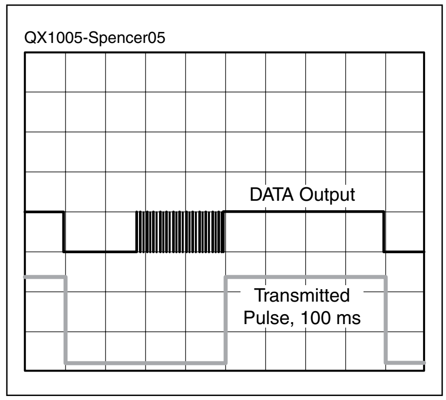

Figure 5 — 100 µs pulses with random noise on receiver data line.

Alternatively, the ANALOG line could be used to mitigate the noise issue. The output of the ANALOG pin follows the raw received signal level without going through the Schmidt trigger circuit in the data line. In Figure 6, the upper trace, Channel 2, shows the action of the ANALOG pin. Note that the ANALOG pin follows the transmitted pulse (the gray reference trace) religiously. One consideration in dealing with the ANALOG pin is that the voltage delta goes from approximately 690 mV when low up to 1.6 V when high (not 0 and 5 V as would be expected). Most comparator or microcontroller devices can distinguish between these two states (voltages). Resistors were added to the squelch circuit to configure the receiver in this test (depicted in the circuit diagram in Figure 4). Note that with the added squelch circuit that the pulse width coming out of the data line pin has been truncated, even though

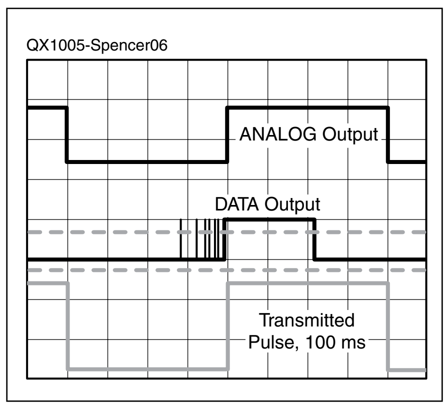

Figure 6 — The transceiver with the squelch circuit active. ANALOG output above, DATA output in the middle and transmitted pulses at the bottom for reference.

the squelch was opened up to un-squelch the receiver (as indicated by the presence of noise). The manufacturer's documentation alludes to this characteristic this way: "It should also be noted that squelching will cause some bit stretching and contracting, which could affect PWM-based protocols."

In Figure 7, the receiver is squelched. Note that the noise is gone, but the pulse width out of the data line is further truncated while the ANALOG pin faithfully follows the transmitted pulse width.

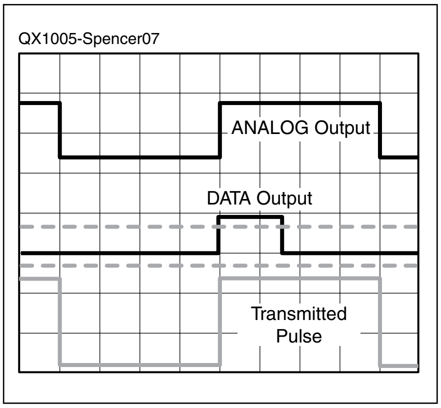

Figure 7 — The squelched transceiver results in truncated DATA pulses.

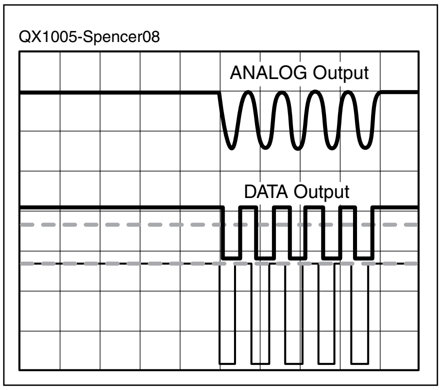

Figure 8 — 4800 baud data. The DATA line is being shaped by the Schmidt trigger. The ANALOG line is raw data.

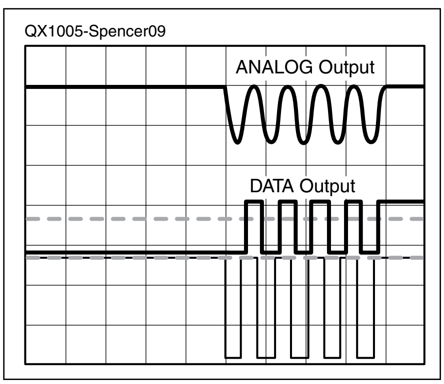

Figure 9 — 4800 baud data with 50 ms between bytes. Notice that the "mark" state is lost in the data line.

In Figure 8, serial data was transmitted at 4800 baud. Again, the gray trace is the reference and depicts the data that is being generated for transmission by a microcontroller. The Channel 1 trace is the output of the receiver presented on the data line. Other than a minor delay, the waveform is religiously reproduced. The upper trace is the output of the ANALOG pin. Notice that the output waveform is not shaped. Although it may be usable, it is not as well formed as the Schmidt trigger shaped wave on the data line. In the tests that I did with 9600 baud, the waveform contraction that was mentioned in the documentation started to be evident and could make the use of 9600 baud and above marginal when the receiver is squelched.

The characters were sent in Figure 8 with 5 ms spacing. I stretched the time between characters to 50 ms in Figure 9. Notice that the noise that was evident in the unsquelched configuration is gone, but also notice that the mark state is lost. This data stream has been corrupted due to the loss of the start bit. This problem was also alluded to in the device documentation: "This prevents low amplitude noise from causing the DATA line to switch, reducing the hash during times that the transmitter is off or during transmitter steady-state times which exceed 15 ms." Translating this sentence, it means that if the transmit state is static too long (on or high too long), the Schmidt trigger will shut down and bring the data line to the low state. This characteristic effectively sets the minimum usable baud rate of these modules.

So what's the bottom line? If you are going to send control pulses or Morse-code-like data, use the ANALOG line. If you are going to send serial data, use baud rates between 300 and 4800 baud and the DATA line. Slower baud rates will be affected by the transmitter "steady-state" caveat and baud rates faster will be affected by the bit "contraction" issue.

Circuit Construction

The data link transceivers were initially built on prototyping boards. Later, formal circuit boards were designed and procured to make circuit duplication easier. I mentioned that the TRM-433-LT is available only as a surface-mount device. It seems that as my eyesight gets less acute, and my grip gets a bit shakier, the components get smaller! At least this device is still large enough that you have a chance to hand wire it. One technique I found effective is to hold header pins in a proto-board and solder the device to the header pins as illustrated in Figure 10 and Figure 3. The rest of the components for the circuit are through-hole components (Figure 11). I use wire wrap wire to make the inter-

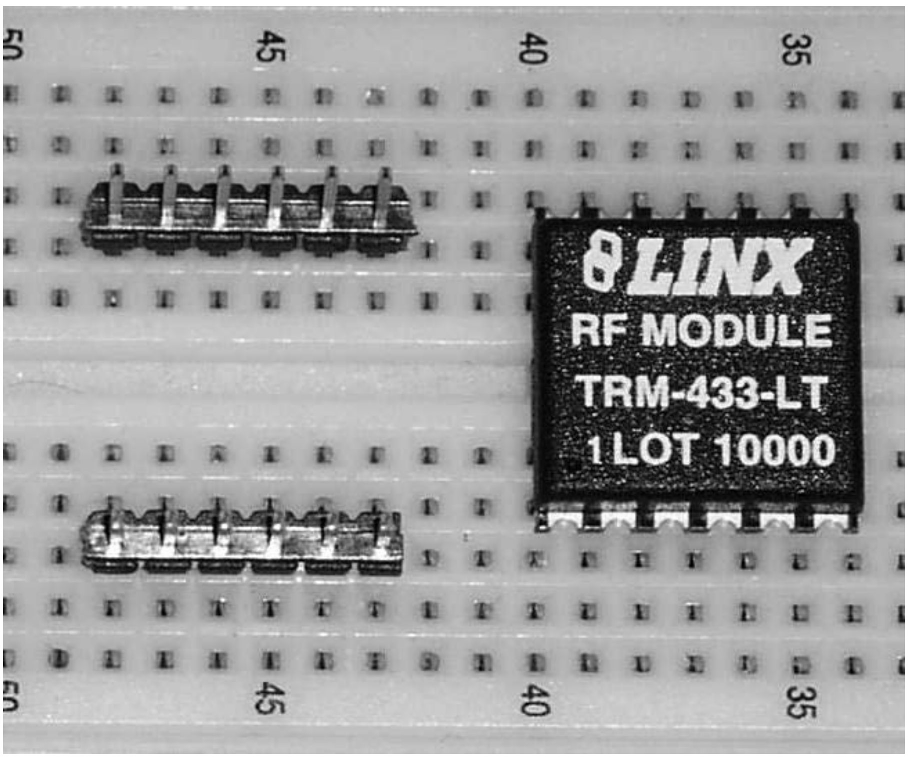

Figure 10 — Use header pins soldered to the SMD device to make it manageable.

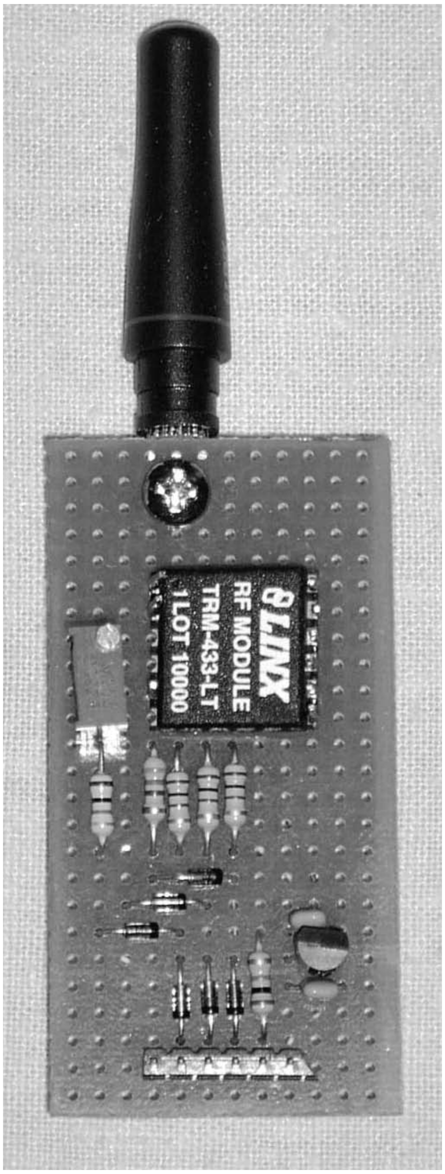

Figure 11 — The hand-wired data link module on a prototyping board.

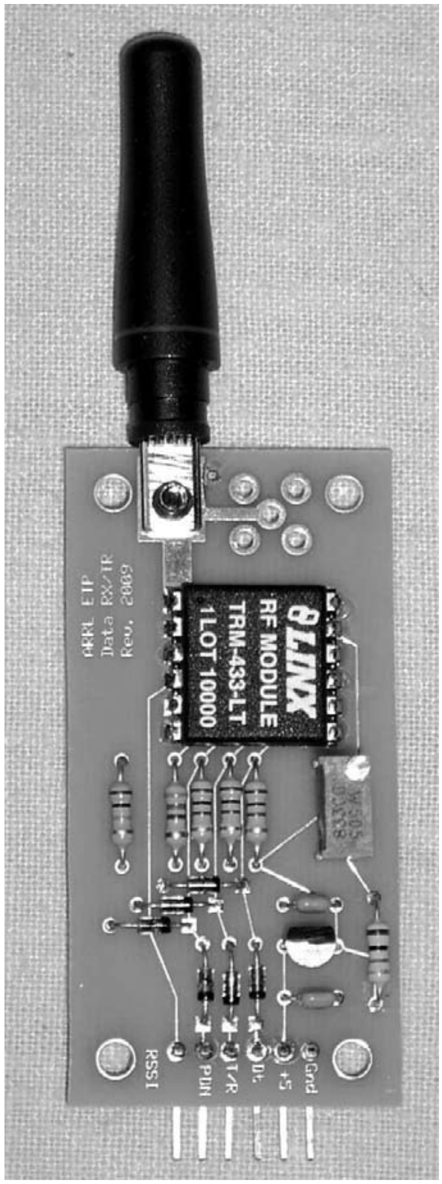

Figure 12 — The formal circuit board module.

connection between components.

The final circuit board version of the transceiver is shown in Figure 12. It makes a tiny, yet flexible, package.

Summary

The Linx TRM-433-LT transceiver is easy to adapt to data link applications. With a minimum of ancillary components, you can control the power output of the transmitter section and squelch the receiver noise when no signal is present. There are, however, some trade-offs when squelching the receiver due to the effect the squelch circuit has on the output waveform at the DATA pin. But knowing these limitations, you can easily work around them. Take a look around your shack and I'll bet you will find a number of applications for use these handy modules.

Mark Spencer, WA8SME, is an ARRL member and the ARRL Education and Technology Program Coordinator.