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EXPERIMENTING WITH COMMERCIAL WIRELESS MODULES

Wireless *everything*. That is what I am seeing more and more. Practically every electronic product these days has some kind of wireless component or function to it. That's why it makes sense to learn more about wireless. As you are experimenting with electronic products, you may discover some devices you want to imbue with wireless capability.

Adding wireless functionality is easy these days. Transmitter, receiver, and transceiver chips are cheap and plentiful. Plus, these chips are incorporated into complete modules you can buy ready to use. Just add a battery, antenna, and some inputs or outputs. Recently, I was searching for some inexpensive modules to use in a college course lab as demos of basic wireless techniques. I found several, but I ended up with some products from Linx Technologies (**www.linxtechnologies.com**). This company has a wide range of chips, modules, and accessories that use low power, short range wireless in the ISM (industrial-scientific-medical) bands from about 300 MHz to 2.4 GHz. I chose the 900 MHz products.

Anyway, here is the result of my initial experimentation with these modules. Hopefully, this will encourage you to do some wireless experimentation yourself.

SOME WIRELESS BASICS

Most short-range wireless uses the FCC (Federal Communications Commission) designated license-free ISM bands. Some typical frequencies are 315 MHz, 433 MHz, 902-928 MHz, and 2.4 GHz. You can buy ready to use chips or modules for any of these bands. The 315 and 433 MHz frequencies are widely used in things like garage door openers and remote temperature gauges. The 2.4 GHz band is used for everything like Wi-Fi, Bluetooth, ZigBee, cordless telephones, and even your microwave oven. I decided not to use that popular band. Instead, I went for the 902-928 MHz products. These offer good range and the antennas are short. Furthermore, this band does not have as much interference or suffer the effects of multipath fading that is common on the 2.4 GHz microwave band.

As for what is short range, it varies. It can be just a few feet or many hundreds of feet. If you have a clear line of site between transmit and receive antennas with a gain antenna, you can probably extend that to a few miles. Most applications typically involve distances of less than 100 feet. The transmit power is usually low. A power level of zero dBm or one milliwatt is common, but you can get units with up to 100 mW of power if you need a longer range.

The key to ensuring that your wireless installation will work is to do some basic math and calculate the path loss and the range given the specifications of the devices you are using.

Path loss can be calculated with the formula that follows. Just plug in the frequency of operation and the range, and the result will be a path loss in dB.

$$\text{Path loss in dB} = 37 + 20 \log f + 20 \log d$$

The frequency f is in MHz and the range or distance is in miles. If the range is in feet, divide the number of feet by 5,280 to get miles. You can also use this formula:

$$\text{Path loss in dB} = 20 \log (4\pi/\lambda) + 20 \log d$$

Here the wavelength is in meters and the distance d is in meters.

Assume a frequency of 915 MHz and a range of 100 feet. That is 0.018939 miles. Use your scientific calculator to compute this.

dB = 37 + 20 log (915) + 20 log(.018939) =
37 + 59.23 – 34.45 = 61.79 dB

Note: The log of fraction gives a negative number that is the reason for the -34.45 number.

Next, find out what the transmit power is from the module specs. Power is usually stated in terms of dBm or decibels referenced to one milliwatt. Assume 2 mW or 3 dBm. Add the transmit power to the path loss (algebraically) to get the amount of power the receiver will receive at the distance you used.

Received power = 3 - 61.79 = -58.79 dBm

Finally, compare that to the receiver sensitivity figure usually given in –dBm. The larger the number, the better the sensitivity. A sensitivity of -100 dBm means the receiver can detect a signal that small. A sensitivity of -80 dBm is not as good as -100 dBm. That means that in terms of power, -80 dBm is greater than -100 dBm. So, if the received power is greater than the sensitivity figure, the signal will be received. Assume a receiver sensitivity of -70 dBm. Since the received power is greater than the sensitivity figure, you will have a good link.

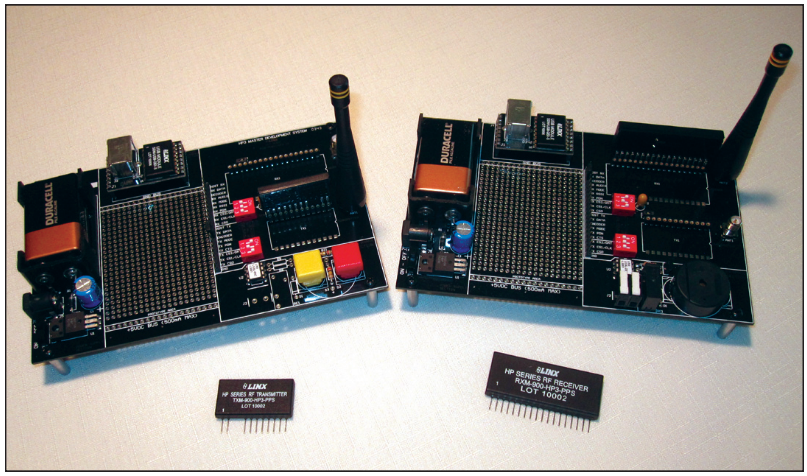
Incidentally, this calculation assumes basic isotropic antennas with a gain of one. If you use a dipole or ground plane, the real power gain is 1.64.

THE WIRELESS MODULES

The wireless devices I bought were part of a whole package called the Master Evaluation/Development System, specifically the Linx Technologies MDEV-HP3-PPS-USB. It comes with two development boards: one for transmit and the other for receive. It also has two each of the transmitter modules (TXM-900-HP3-xxx) and receiver modules (RXM-900-HP3-xxx). The development boards have a USB port on them but you can also get a version for RS-232. Cables and programming software is included. **Figure 1** shows the whole package.

Figure 2 shows the transmit block diagram. It uses a PLL frequency synthesizer programmed by an internal microcontroller for any of the 100 channels in the 902-928 MHz range. A 12 MHz crystal sets the precision and frequency increment at 250 kHz. You can select any of the existing frequencies by programming via the PC, or any of eight frequencies that can be set with a DIP switch on the transmitter development board. The PLL and its VCO act as a frequency multiplier to increase the output frequency into the 902-928 MHz range. Then, a power amplifier boosts the output signal to 0 dBm or in the -3 to +3 dBm range. An output filter gets rid of any pesky harmonics.

The modulation is FSK and you can achieve a data rate up to about 56 kbps. A 28 kHz low pass filter on the data input filters the binary serial data to help restrict the harmonics and the sidebands, and to keep the frequency deviation down to less than 115 kHz. Incidentally, you can also modulate the transmitter with analog signals up to 28 kHz.

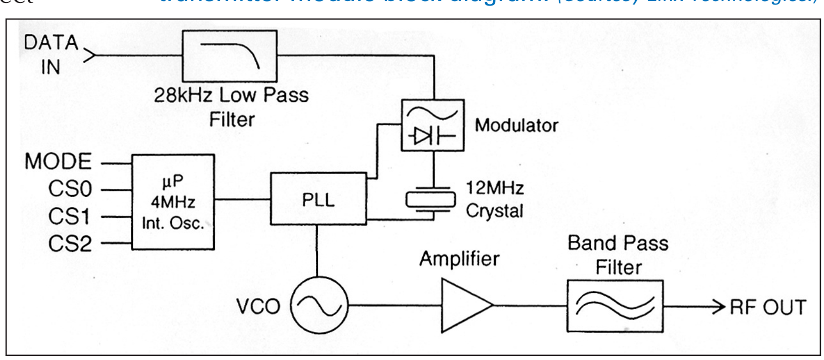


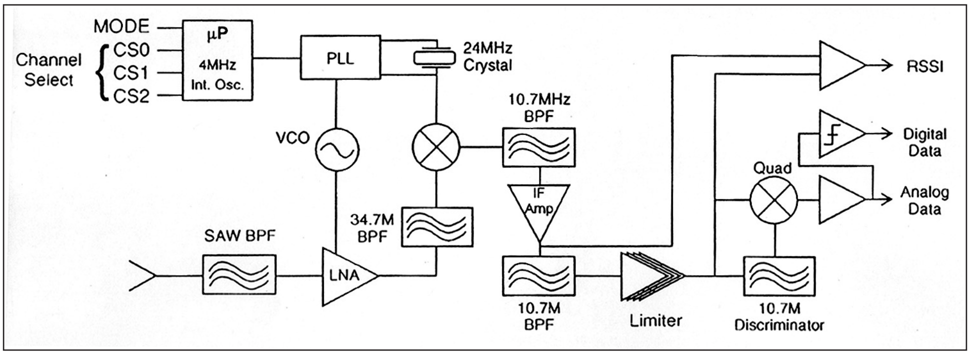
■ FIGURE 1. The Linx Technologies MDEV-HP3-PPS-USB wireless development system. The transmit board is on the left; the receive board is on the right. The transmitter module is on the left and the receive module is on the right. The modules plug into the boards to complete the system. Note the vertical antennas on the right of each board.

You can program the transmitter frequency using the software and USB port on the development board but I just used the DIP switch on the development board. This switch feeds an on-board encoder chip ENC-LS001. It takes the three-bit input code and serializes it into a simple protocol with start and stop bits that the transmitter sends out to the receiver. This eliminates the need for you to create a complex protocol, although you can do that if you want to.

The receiver block diagram is shown in **Figure 3**. It is a superheterodyne using a PLL synthesizer for tuning. The input from the antenna is frequency restricted with a SAW (surface acoustic wave) filter and applied to a low noise (RF) amplifier (LNA). The LNA block also includes a mixer that mixes the incoming signal with a signal from the frequency synthesizer to produce a first intermediate frequency (IF) of 34.7 MHz. The signal is filtered, then sent to another mixer along with a 24 MHz signal from

■ FIGURE 2. The Linx Technologies TXM-900-HP3-xxx transmitter module block diagram. *(Courtesy Linx Technologies.)*





■ FIGURE 3. The Linx Technologies RXM-900-HP3-xxx receiver module block diagram. *(Courtesy Linx Technologies.)*

the crystal oscillator. The mixer output is a 10.7 MHz second intermediate frequency (IF) signal that is filtered — limited to remove any amplitude variations — and sent to the quadrature demodulator where the signals are recovered. A slicer/shaper cleans up the digital signal.

A neat feature of this module is the received signal strength indication (RSSI) circuit. It is a calibrated output that indicates the level of the received signal. It generates a DC signal in the one to three volts range, corresponding to input power levels in the -40 to -110 dBm range. Using this feature lets you actually measure the signal level being picked up.

DEMONSTRATING THE MODULES

To get the boards ready for use, you plug in the transmit and receive modules, screw on the antennas, and install a nine volt battery in each. The battery drives a five volt regulator that supplies power to the modules.

Once you set the frequency on both the transmit and receive boards, are can demo them. Turn on the power switches. Then, press the yellow button on the transmit board that will sound the buzzer on the receive board with a beeping tone. The red transmit button causes a relay on the receive board to close. You can hear it click.

The relay contacts have connectors on the receive board so you can hook them up to control some other device like a light or motor. The relay contacts can handle as much as five amps up to 30 volts DC or 120 volts AC.

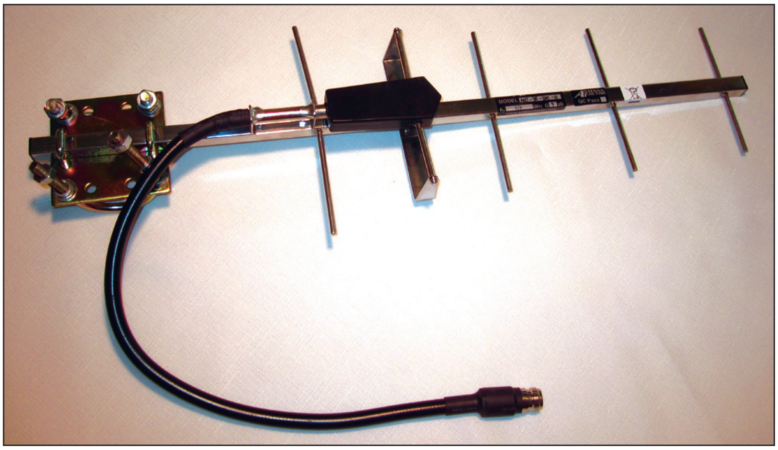
As a next step, you can take the boards outside and test the range. I took the boards out in the street with my wife and tried to estimate the maximum range. Keep the line of site path clear to get the best results. You should easily get several hundred feet. I got 300 feet before a hill cut my line of sight path. (I live in central Texas where it is called the hill country.)

For further experimentation, you can put obstacles between the transmitter and receiver. Walls, trees, cars, whatever. The units still communicate, but the obstacles add considerable extra attenuation to the path thereby shortening the range.

One other demo you can do is check out the RSSI voltage. Get a digital or analog multimeter and connect it up to the RSSI pins on the receiver board. Turn on the units and measure the RSSI voltage over a decent range. The output voltage is roughly linear from about 1.2 volts DC at -110 dBm received power to 2.7 volts at -40 dBm. You could calculate the received power using the formula above, then attempt to verify it with the RSSI reading for a given power and distance. Incidentally, the transmit power is nominally 0 dBm or 1 mW. The specs indicate a possible range from -3 dBm to + 3 dBm so any errors will probably be in transmit power or range measurements.

One final thing I did was to buy an accessory five-element Yagi antenna (**Figure 4**). The antenna is made by Antenna Factor, and is available through Linx. It has a gain of 9 dBi (isotropic gain). It gets that gain by focusing the power in one direction so the effect is that of a transmitter power boost or improved receiver sensitivity. I used the antenna on the receiver. The effect was to greatly increase the range of transmission by a factor of three or more. Not bad. You can note that change on the RSSI reading.

■ FIGURE 4. The Antenna Factor ANT-916-YG5-N Yagi antenna. It has a 50 ohm cable and N-connector. I had to buy two extra cables with different connectors to match up with the SMA connector on the transmit and receive boards.



That is all the time I had for the demos, but I do plan to do more. I particularly want to plot the Yagi antenna pattern by using the RSSI readings as I rotate the antenna horizontally. Should be interesting.

Wireless is fun to play with, but I do admit it is also frustrating at times. Things don't always work as they should, as they seem, or as you want. Mostly, this is due to obstacles in the path like trees or walls, multipath signals developed from nearby reflecting bodies (cars, water tower, etc.), or you personally being too close to either the receive or transmit antennas. So, you need to experiment for best results. Once everything is set up correctly, the communications link is remarkably reliable, almost as good as a wire. **NV**