73 Review

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GRAPES, Inc.
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Alpharetta GA 30239-0871
Price Class: $250, in kit form

GRAPES 56 Kb Modem

We've come a long way from 1200 baud packet.

How would you like to be able to send the equivalent of a standard 5.25" IBM PC floppy disk (360 Kbytes) by packet radio in less than two minutes? How about transmitting telephone-quality digital voice over the air? Sound too good or expensive to be true? Not at all! It's being done right now, with equipment and software available to any interested amateur.

The key is the 56 Kb/s modem designed by Dale Heatherington WA4DSY and distributed by the Georgia Radio Amateur Packet Enthusiasts Society (GRAPES). Since its unveiling at Dayton in 1987, this modem has progressed through the experimental and beta test stages and is now in routine production and use.

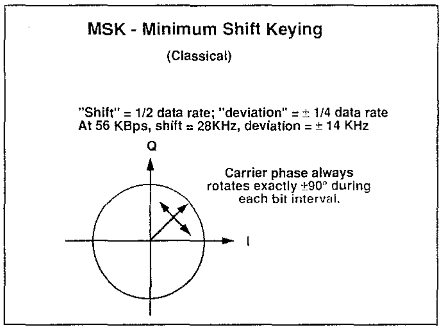

Figure 1. MSK, a form of Frequency Shift Keying (FSK), uses the smallest possible mark/space frequency shift for the data rate in use. This keeps the signal bandwidth to a minimum.

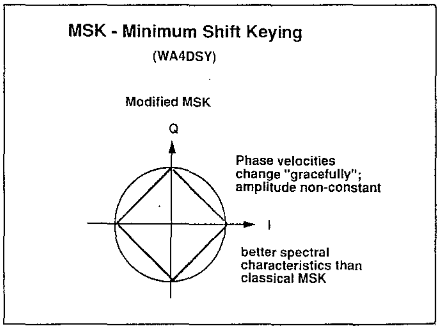

Figure 2. The 56 Kb modem uses a modified form of MSK.

Keying Scheme

The WA4DSY modem uses a modified form of Minimum Shift Keying (MSK) (see Figures 1 and 2). MSK is just a special form of Frequency Shift Keying (FSK), well known to every HF RTTYer. As the name implies, though, MSK uses the smallest possible mark/space frequency shift for the data rate in use, keeping the signal bandwidth to a minimum.

In RTTY terms, the carrier "shift" in Hz is equal to one-half of the data rate in bits per second; at 56,000 bits/sec, the mark/space shift is 28 kHz. In FM terms, the "deviation" of the signal is plus and minus one-quarter of the data rate, or ±14 kHz at 56Kb/s. If you select a different speed in the modem, the shift changes automatically; the transmitted signal is generated digitally in a state machine, so you can't get it wrong!

The WA4DSY Modem Kit

The kit includes three PC boards: transmit encoder, receive decoder, and RF board, plus all necessary board parts except the channel crystals. Unlike virtually all other amateur packet radio modems, the WA4DSY modem is not an add-on to a standard voice transceiver. Instead, it operates with a VHF or UHF transverter (transmit/receive converter) such as those made by Microwave Modules or SSB Electronics. You must buy the transverter separately.

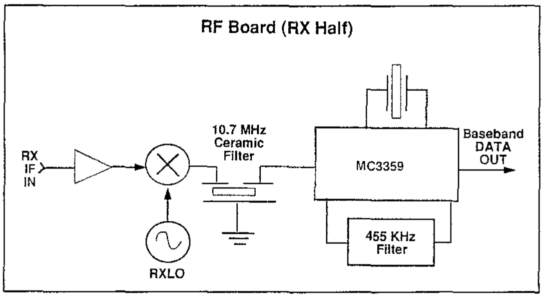

Figure 3. The receive portion of the WA4DSY modem design.

Transverters have the needed bandwidth to pass the high speed modem signal (75 kHz). Also, they are typically cheaper than full-voice transceivers because they lack an audio section, synthesizer, and the other extras that aren't necessary for dedicated packet operation. The RF section of the WA4DSY modem operates near 28 MHz, so you can use it on any band where you can use a transverter designed for a 10 meter transceiver. (Because of FCC bandwidth limits, however, you may only use this modem at full speed on frequencies above 220 MHz in the US. See section 97.69 of the regs.)

The RF modulator produces approximately 1 mW (0 dBm), enough to drive the Microwave Modules transverter, configured for low drive level, to full power. The RF demodulator is sensitive enough to work well when fed directly from a typical receive converter. The transverter must be modified to decrease its transmit/receive switching time, but this is a simple operation involving the removal of a single capacitor.

The WA4DSY modem design is highly modular. You can saw the RF board's receive and transmit into halves and build completely independent receivers and transmitters if you wish (e.g., for dedicated, full duplex links). See Figures 3 and 4.

The digital side of the modem provides six interface signals, three each for the transmitter and the receiver. All signals are TTL levels; if the host computer uses RS-232 signals you must either modify it to produce TTL or insert RS-232/TTL level converters.

As standard with commercial high speed synchronous modems, the WA4DSY modem provides both transmit and receive bit clocks. This eliminates the need for a baud rate generator in the host computer interface. It also means you can use older and less expensive HDLC chips like the Zilog SIO without having to provide a "state machine" circuit like that in the TAPR TNC-2 for recovering clock from the receive data stream.

In addition to the data and clock input/output signals, the WA4DSY demodulator also accepts a Request-to-Send (RTS) signal for keying the transmitter, and it provides a Data Carrier Detect (DCD) signal.

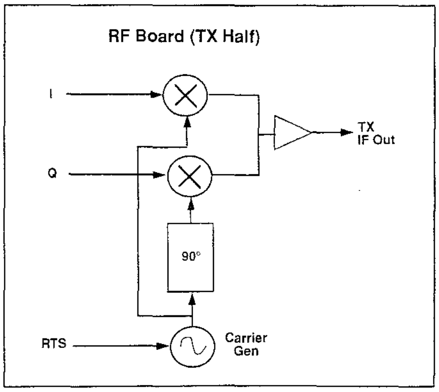

Figure 4. The transmit half of the WA4DSY modem. Since the design is modular, you can saw the RF board in half to set up a completely independent receiver and transmitter section.

Construction and Alignment

The kit provided by GRAPES includes complete documentation and all parts required to populate the three main boards except for the channel crystals (two are required: one for the transmitter and one for the receiver). I found the kit convenient and easy to assemble, particularly after having built two of the early "bare beta board" versions of the modem when I had to scrounge for my own parts! Nothing was missing, and I had the boards together in a weekend. The location of each part was silk-screened into the RF and receive decoder cards.

Although there was no silk screen on the transmit encoder card (see Figure 5), I had no problem putting everything in its place using the parts placement diagrams.

As mentioned earlier, the modem can operate at speeds other than 56 Kb/s. Dale was careful to place all of the speed-determining components on plug-in DIP headers on the transmit encoder and receive decoder cards, so you don't have to unsolder anything to change speeds.

The bandwidth of the receive IF filter on the RF board is fixed, however, so you'd have to do some soldering and recalibrating there if changing speeds. I don't know of too many people, however, who have operated these boards at speeds below 56 Kb/s!

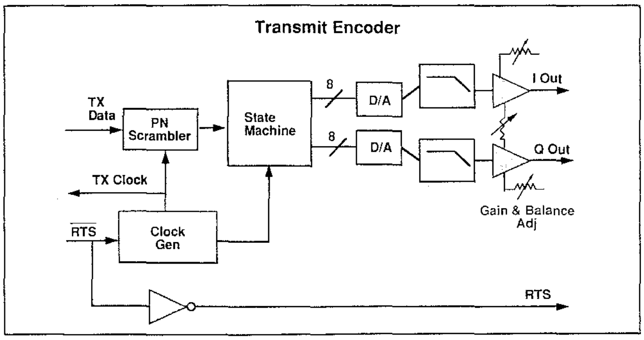

Figure 5. With the parts placement diagrams, it's easy to assemble the transmit encoder.

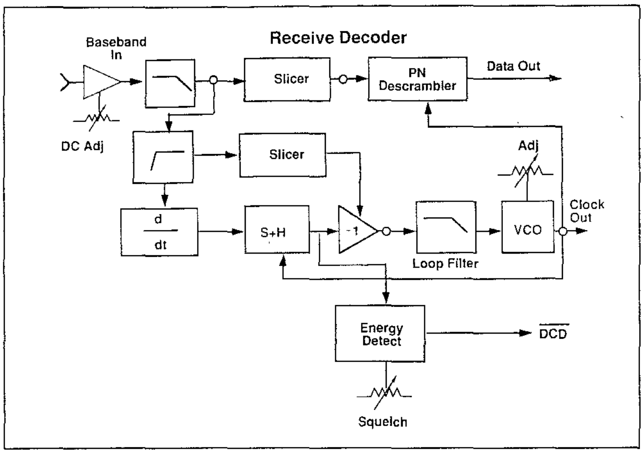

Figure 6. The receive decoder card adjustments are straightforward.

Modem Setup

Alignment of the modem requires an oscilloscope, preferably a dual-trace model. The instructions are fairly clear, and tweaking the transmit encoder card took only a few minutes. The RF card takes a little more work. I was fortunate to have the use of an IFR 1200S Service Monitor to make the alignment of the IF bandpass filter coils in the receiver a two-minute job, but it's not that much harder with just the scope. I did notice something on the IFR's spectrum analyzer while setting the power gain adjustment in the transverter:

If you crank the wick all the way up, the signal sidebands come up noticeably. It's best to sacrifice a few watts to let the transverter have some headroom. The modem signal is a specially modified form of MSK with some deliberate amplitude modulation to reduce the extra sidebands, so you want to operate the transverter in its linear region. If you do this, the spectrum is very clean.

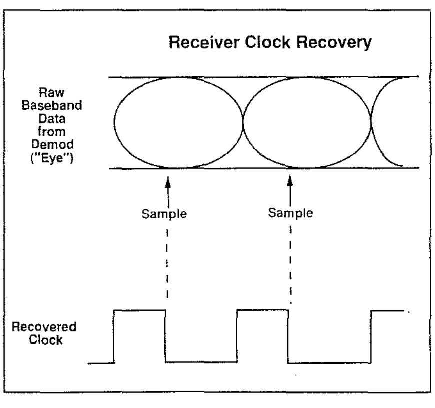

Figure 7. In the clock recovery circuit, the author soldered a miniature 0.1 µF capacitor across the supply and ground pins on the underside of the socket.

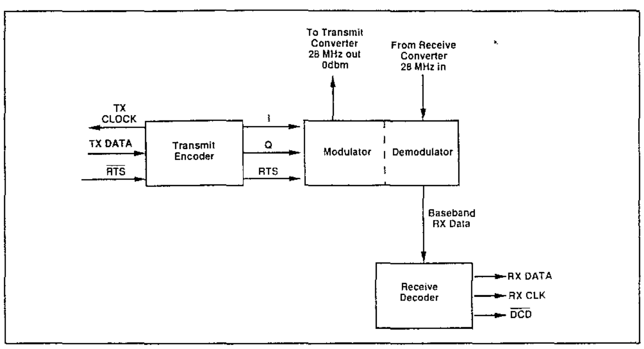

Figure 8. The 56 Kb modem system. The GRAPES kit includes three PC boards: transmit encoder, receive decoder, and RF board, plus all necessary board parts except the channel crystals.

Once the RF board was aligned, the receive decoder card adjustments were very straightforward (see Figure 6). I did have one problem with false triggering in the NE555 IC in the clock recovery circuit (see Figure 7); I fixed this by soldering a miniature 0.1 µF capacitor across the supply and ground pins on the underside of the socket.

Assembly

The GRAPES kit contains no chassis; you have to find one and drill your own holes. I've been using the 10" x 12" x 2" Hammond aluminum chassis, as I can arrange the boards for easy access to the adjustment screws and test points. You can certainly use more compact (or more attractive!) cabinets, if you prefer.

The modem requires a source of ±5V DC, plus whatever the transverter requires (typically +12V DC). I used some small surplus Japanese-made switching power supplies sold by Radio Shack for the bargain price of $5. This was five years ago, and unfortunately they are no longer available. Suitable AC power supplies are certainly available, but if you prefer 12V DC operation, you can use a linear regulator to generate +5V. The modem's −5V requirements are minimal, so a simple charge pump circuit will do just fine.

Up and Running

This modem challenges you to figure out how to move data to and from your computer fast enough! The early experiments in Atlanta with this modem used modified TNC-2s; the mods consisted of beefing up the digital components (CPU, SIO, memory), eliminating the internal Bell 202 modem, and installing a modified copy of the KISS TNC EPROMs. The TNC was then connected to an IBM PC host computer running my TCP/IP package.

This worked, but the serial link between the TNC and host computer was still not fast enough. The cost was unappealing. But if you're interested, the details are included with the modem kit documentation.

Problems and Adaptations

When I obtained my modems a year ago at Dayton, I also picked up a PCPA (PC Packet Adaptor) card from DRSI (Digital Radio Systems, Inc). The PCPA is a plug-in adaptor card for the IBM PC bus that contains a Zilog 8530 HDLC chip, a Bell 202 modem, and associated "glue" parts. Bypassing the modem and RS-232 drivers (a procedure described in the DRSI manual), I was able to connect the PCPA's 8530 chip directly to the modem with a ribbon cable.

Then I wrote a special software "driver" module for my TCP/IP package that accesses the PCPA's 8530 chip directly, passing data at the full 56 Kb/s rate of the modem. It works, but at a cost: because of the high data rate, the computer has its hands completely full whenever the modem is active, transmitting or receiving. Everything else (keyboard echoing, the time-of-day clock, etc.) momentarily grinds to a halt!

This is not ideal, so work is underway to develop a "smart" card with its own CPU to handle the low-level tasks of talking to a high speed modem, freeing the main CPU for other things. Mike Chepponis K3MC has built a prototype, and my next step is to program it. But until then, we can use the DRSI PCPA and its functional equivalent, the PacComm PC-100. (You can also use a board called the "Eagle card," once sold surplus by the now-defunct Eagle Computer company, if you can get one.)

Packet in the Fast Lane

It should not surprise you that it's VERY easy to get spoiled by 56 Kb packet! Once you've had a taste, there's no going back. Even my 9600 b/s telephone modem seems slow in comparison, and one wonders how anyone could possibly tolerate 1200 b/s!

But to be fair, 56 Kb is not without its problems.

The first problem is probably fairly obvious: There aren't that many people around to talk to yet! The situation here in Northern New Jersey on 220.55 MHz (the local 56 Kb/s channel) is much like 145.01 MHz was back in 1983. Our 56 Kb network presently consists of KA9Q, WB0MPQ, KA9Q-2 (a digipeater/IP switch) and N2AER; we expect N4HY and N7AKR on the air soon. High speed packet is now at roughly the same stage that 1200 baud packet was in the early 1980s, and with luck it'll become as popular.

The keyup delay required by the WA4DSY modem isn't as small as I would like. We're currently running with transmit delays of about 15 milliseconds. This may seem short until you realize that in 15 ms at 56 Kb/s, you can send 100 characters! Many packets aren't this big, even when you include full TCP, IP, and AX.25 protocol headers.

The data carrier detect (squelch) circuit in the WA4DSY demodulator could probably be improved. Although it works reasonably well (better than the DCD circuits in most slow speed packet modems) it can be tricky to adjust and the threshold sometimes varies due to front end desensing. (Perhaps this is an unfair criticism; I live about 500 feet away from a 220 MHz FM repeater.)

High speed operation requires wide bandwidths. As mentioned, the WA4DSY modem occupies about 75 kHz when running at 56 Kb/s; it is generally operated in a 100 kHz channel. This is about five times the bandwidth of an FM voice channel (20 kHz), so five times as much noise enters the modem receiver's passband as compared to a regular FM voice receiver.

Therefore, the 10 watts of 56 Kb/s RF coming out of my transverter is like 2 watts of FM voice RF—not much. Multipath is also a problem (100 kHz is half as wide as a commercial FM broadcast channel.) Beams and good sites help, but sometimes there is no substitute for a power amp.

An aside: The spectral efficiency of a modem isn't measured by its bandwidth alone, but by the ratio of the bandwidth to the data rate. Although the WA4DSY modem requires five times the bandwidth of a standard 1200 baud packet signal, its data rate is 46.7 times faster. This makes it about 9.3 times more spectrally efficient than the latter.

This wide bandwidth also limits us to 220 MHz and up, both a blessing and a curse. It's a blessing because 2 meters really isn't the proper place for serious packet operation because it's too crowded, at least in densely populated areas like New York. It's a curse because propagation isn't as good on the higher bands, and transverters are more expensive. Nonetheless, we'd better get active there in any event, since spectrum theft by other services can strike at any time. If Docket 87-14 is upheld and we are unable to find 100 kHz of space above 222 MHz, my friends and I are going to have to junk some perfectly good transverters.

The availability of high speed modems, interface cards and host computers does not guarantee maximum throughput; careful network engineering is still necessary. But the WA4DSY modem is a major contribution to amateur packet radio, and it has the potential to be as revolutionary as the original Vancouver and TAPR TNCs.

Phil Karn KA9Q works for Bell Communications Research (Bellcore) designing and maintaining internal networks. He is one of the founding fathers of amateur packet radio, as he co-authored the AX.25 protocol specification. Phil is a member of the Board of Directors of the Tucson Amateur Packet Radio (TAPR) group, and is very active in AMSAT. You may contact Phil at 25-B Hillcrest Road, Warren NJ 07060.