

Turbocharge Your Packet Station!

Forget 1200 baud. Forget 9600, too. N2IRZ shows you how to modify commercially available ham gear for 19200-baud packet operation!

Editor's Note: This month's installment requires experience in modifying equipment and using test equipment.

Last month, we looked at the German packet network and some of the reasons why it's so good. Since we don't face the regulatory restrictions which ensured that only serious network builders could build a network (and since it would *not* be a good idea to ask the FCC for similar restrictions), if we want to build a high-performance network, we have to look at and emulate their *other* advantage: good equipment.

Just what is "good equipment"? After discovering (along with the rest of the world) the wonderful modem designed by James Miller, G3RUH, Henning Rech, N1EOW/DF9IC, designed a 1.2-GHz full-duplex radio for 19200-baud (19k2) backbone operation. The availability and relatively low price of this radio kit, the LinkTRX, made it the most popular radio for that speed in Germany. So, in a short while, most of Germany's backbone links were running at 19k2, and, for reasons discussed last month, they were all dedicated point-to-point links.

TEKK Revisited

Last year, I discussed some suitable radios for 9600-baud (9k6) operation. Among my favorites are those cute little data-only radios from TEKK. They work reasonably well out of the box at 9k6, almost plug-n-play. However, as the baud rate increases, so do the demands upon the radios, making the TEKKs unusable at 19k2 (since they weren't designed for it). This month, we'll take a look at modifications I made to make them useful at this higher speed, specifically modifica-

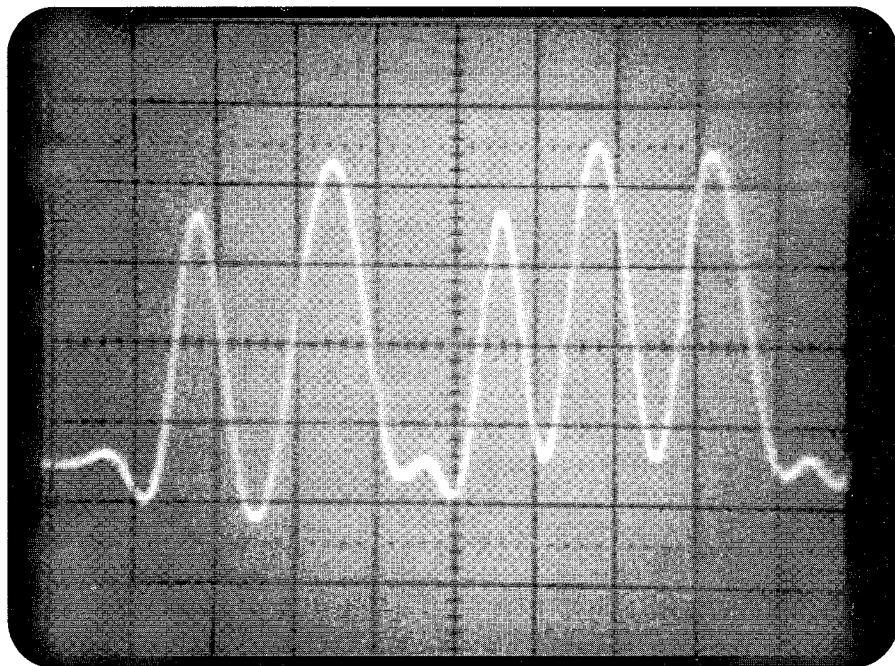


Photo A: A typical data stream. Note how the bits are rounded off, which minimizes the transmitting bandwidth. This is the same data as seen in Photo B, but at about 0.1 mSec/div.

tions to Model KS-900 (T-Net micro). But first, some background information so you'll understand what we're doing.

Eye Patterns

The first topic we have to discuss, albeit briefly, is *eye patterns*. We'll look at this in more detail next month, as we continue our segment on high-speed data, but, for now, here's what you need to know:

Eye patterns are a common yet powerful tool used in data transmission work. Imagine a data stream of ones and zeros, represented by high and low voltages. To reduce the bandwidth of the transmitted signal, the transitions from high to low and vice versa are rounded off somewhat,

so you have a signal that looks kind of like a sine wave with a few teeth missing (see Photo A).

Using an oscilloscope, which shows voltage variations that are too fast for a meter (such as this data signal), you can put the signal on the screen so you can see one or two bits at a time. You then tell the oscilloscope to begin its display (trigger the sweep) every time the receive data clock sends a pulse. In this way, the one and zero bits, as well as the transitions between these levels, are superimposed upon each other, creating a blur of bits. The empty space between these many paths looks like an eye, a flattened oval with pointy ends. That's why it's called an "eye pattern" (see Photo B).

By Don Rotolo, N2IRZ

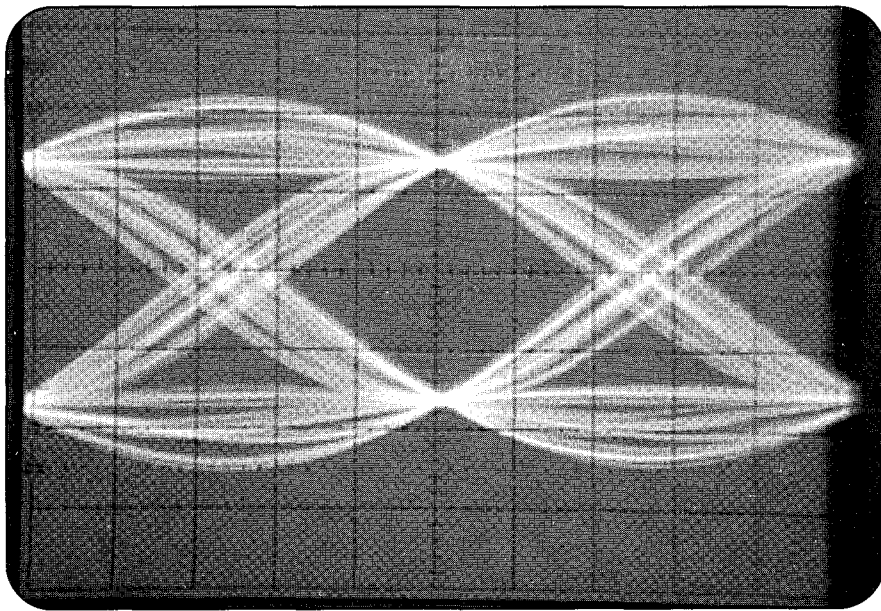


Photo B: An Eye Pattern. Note that all of the signal traces converge into a tiny point at the top and bottom of the display. These are called the decision points, and the goal is to make these as small as possible.

When everything is right, these bits all follow similar paths and converge at the two "decision" points. It's at exactly these points in time that the modem "decides" whether the received signal

represents a zero or a one. If all the bits converge into a very small area, the modem has an easier time deciding, and you have very few bit errors. If the bits are spread out a lot, then you'll see more

"Eye patterns are a common yet powerful tool used in data transmission work."

bit errors. It doesn't take a genius to figure out that lots of bit errors makes for a lousy data link.

When the convergence points spread out vertically, it means there's a lot of noise in the signal, which could also be caused by excessive filtering or other loss of signal. Horizontal spread means the data has excessive jitter in the time axis.

To view an eye pattern, connect an oscilloscope to the test point in the modem just before the data slicer or zero-crossing detector, which is right after the second amplifier in the receive filter. (If you don't have a scope, you're out of luck). Then, you set the scope for external triggering, and trigger off the recovered RX clock signal, which is an output signal from the modem. In a PacComm NB-96 G3RUH-type modem, it's available at TP8; in other brand modems, the operating instructions should mention the correct point.

Set the modem into *Audio Loopback* mode (usually a jumper on the modem

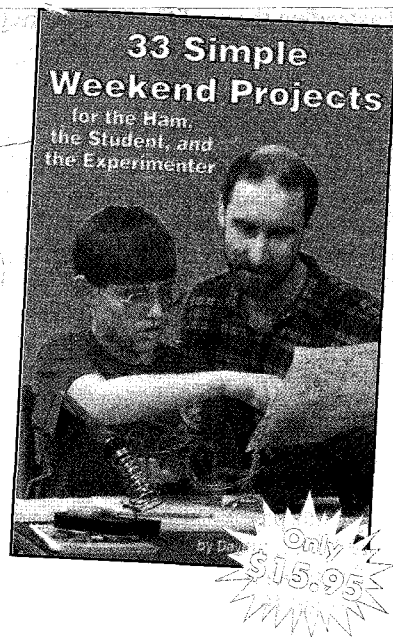
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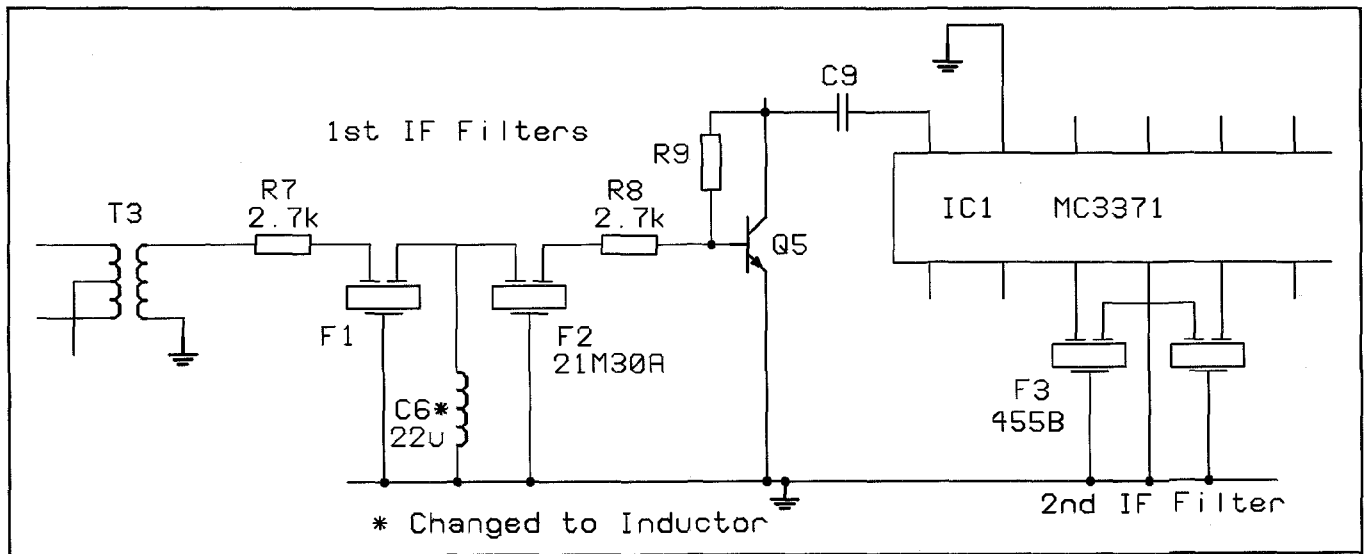


Figure 1: Partial schematic showing the first IF filters of the TEKK KS-900 data radio. Many other radios are similar. Note the input and output resistors, as well as the capacitor between the filters. See the text for the new values of these components.

board) and connect everything. As you speed up the time base to 10 mSec/div, the "eye" should take shape. If it isn't centered, change the trigger slope setting. The vertical setting should be set to whatever it takes to have the signal fill about half the screen. You should see something like Photo B.

The next topic, which is critical to understanding the modifications we're going to make, is IF filtering.

What's an IF?

A radio receiver converts a radio frequency (RF) signal to an *audio* or *base-band* signal by mixing the incoming signal with a local oscillator (LO) frequency. The mixing of these two RF signals creates a number of signals which represent the sum and difference of the two frequencies. The radio then chooses one of these new signals, which is called an *intermediate frequency* (IF), filters and processes it, then demodulates it to recover the originally transmitted signal. Often, this process is repeated one or two more times, and the resulting intermediate frequencies are known as the first IF, the second IF, and so on.

The processing and filtering in the IF stages is what lets you choose just one radio channel from many. By filtering out all the unwanted channels, you're left with what you want. When dealing with data signals, knowing the exact characteristics of any filtering is critical for error-free reception.

For a 19200-baud G3RUH-type signal, the bandwidth of the IF filters should be

about 30 kHz. Narrower filters remove critical information, causing data errors. Wider filters cause more noise to enter the receiver, lowering the signal-to-noise (S/N) ratio. A low S/N ratio makes the received signal more difficult for the radio to correctly decode.

In a radio such as the TEKK, there are two IF stages, the first at 21.4 MHz and the second at 455 kHz. Some radios use other IF frequencies, such as 10.7 MHz, but the idea is the same. What you need to do is replace the original IF filters, which are 15 kHz wide (good for 9600 baud) with filters that are 30 kHz wide (for 19200). (See Photo C.)

The 455-kHz ceramic filter is fairly common, but you'll still have to search for one. Because you're using it for data, you want one with a 30-kHz bandwidth *and* with its phase delay characteristics optimized for minimum distortion. The ideal choice would be a MuRata-type SFH, which is a six-pole filter with optimized phase characteristics. A reasonable second choice would be a CFW-type, which is the same as SFH except that its phase response isn't optimized. In any case, insist upon a 30-kHz bandwidth, as anything less is just not enough for reliable operations.

The 21.4-MHz monolithic crystal filter is a little less common. Most of the major component suppliers offer something at 10.7 MHz, but I had to special-order the 21.4-MHz version. Again, you must have a 30-kHz bandwidth, and, when you order, ask what the specifications are, at least the input and output impedances, so you can change the resis-

"For a 19200-baud G3RUH-type signal, the bandwidth of the IF filters should be about 30 kHz."

tors accordingly. You'll need two of these filters, but only one of the 455-kHz ceramic filters.

For the 21.4-MHz filters, you have to decide whether you want to use the two-pole or four-pole version. The two-pole is less expensive, and a little more forgiving of off-frequency signals, but it can't filter out adjacent signals as well. The four-pole filter costs about twice the price of a two-pole filter (which makes sense, since it's twice as much filter), but adjacent channel and out-of-band strong signal interference are better suppressed. I chose the two-pole filter because it was immediately available.

This information about IF filters also applies in general to other receivers. For example, a Motorola MITREK in the UHF band uses only a single IF frequency of 10.7 MHz and four two-pole monolithic crystal filters in its receive chain. Replacing these four parts with 30-kHz versions will help this radio work at 19k2, as long as other minor modifications are also made (bypassing *all* of the transmit audio filters, and taking receive audio directly from the discriminator). Without replacing the IF filters, it could never work at a high data rate. I haven't done this yet, but I have a MITREK on my bench and will get around to modifying

Replacement Chart

Following is a replacement guide for the components in the G3RUH modem that must be changed for 19200-baud operation.

Component (NB-96)	Original Value (9600 Baud)	New Value (19k2 Baud)
C26	220 pF	100 pF
C27	.001 μ F	470 pF
C28	.001 μ F	470 pF
C29	.0033 μ F	.0015 μ F
C30	470 pF	220 pF
C31	470 pF	220 pF
C32	1000 pF	470 pF
C18	.0047 μ F	.0022 μ F
C20	100 pF	47 pF
C21	.1 μ F	.047 μ F
R29	100k Ohm	51k Ohm

it sooner or later. I'll let you know how it turns out.

Modifying the TEKK

The first thing I looked at on the TEKK radio was the transmitter. It turns out that there are no modifications necessary for 19K2 operation. While the transmitter isn't perfect, the fraction of a decibel of improvement that might be realized from extensive changes isn't worth it. That kind of improvement can easily be offset by the loss introduced by a single connector in the antenna feedline, so I thought it best to let it be.

That leaves the receiver. When it comes down to it, all that has to be done here is to install wider filters for the first and second IF stages. As mentioned previously, the TEKK uses a first IF of 21.4 MHz and a second IF of 455 kHz.

The originally supplied first IF filters (there are two) are type 21M15B, meaning 21.4-MHz center frequency, Monolithic, 15-kHz bandwidth, and four poles (denoted by "B"). To replace them, I selected a type 21M30A, which has a 30-kHz bandwidth and only two poles (denoted by "A"). If you can find, and afford, the four-pole version (21M30B), it might be a better choice, as it has better adja-

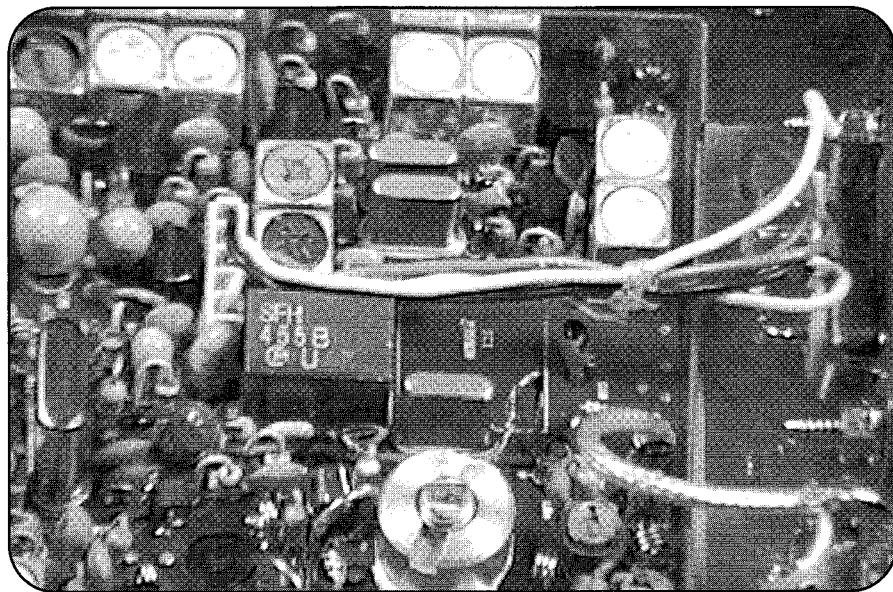


Photo C: Typical IF filters. The small metal ones that look like crystals are the first IF filters, the larger plastic one is the 455-kHz second IF filter. These are the parts that were removed from the radio.

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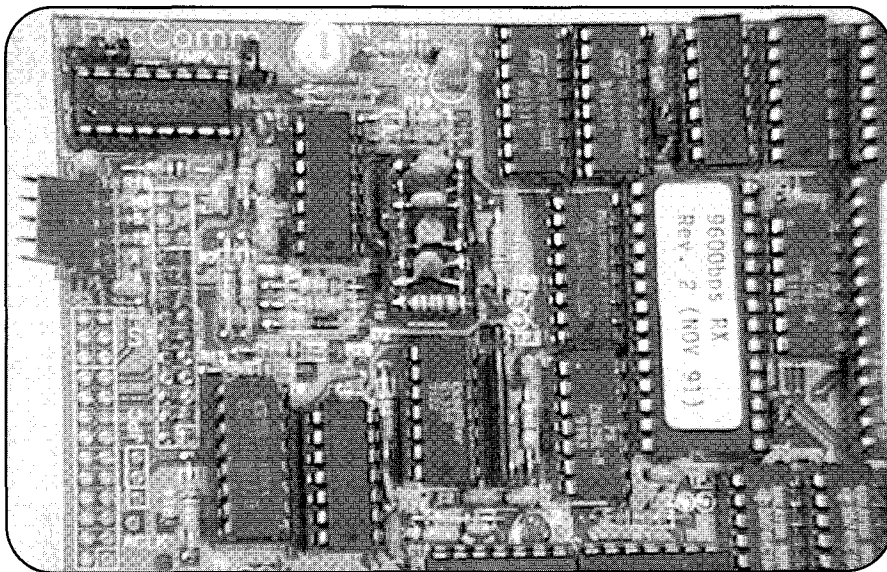


Photo D: The PacComm NB-96 G3RUH-type data modem. The eye pattern is taken from TP4 and the scope is triggered from TP8. The components that have to be changed are all shown, as is the output level adjustment potentiometer.

cent signal rejection than the two-pole version. But use whichever you can find.

Removing the first IF filters from the TEKK pc board was a bit difficult. The board is small and there's a lot of ground plane around the filters. This draws away all the heat, making unsoldering difficult. The ideal solution would be to use a vacuum desoldering station, but I don't have one since they're expensive. I ended up buying a desoldering iron from Radio-

Shack (a real bargain, on sale at the time for half price, \$5), which did the job wonderfully for me.

After replacing the first IF filters, it was time to deal with the second IF filter. I used a type SFH455B from MuRata. This one was a little easier to replace, but that little desoldering iron really let me do a clean job and save the old component.

After the components were changed, I tried a test transmission on the bench,

looking for the ideal eye pattern. I noticed that it was much less than optimum, so, after resetting the transmit deviation and frequency, I started tweaking the matching sections near the first IF filters. Some slight improvement in the eye pattern can be achieved by readjusting the quadrature coil, the slug closest to the second IF filter, but you must keep rechecking these items as you progress. Photo D shows these components and adjustments.

Since the new crystal filters have a different input and output impedance from the originally installed filters, I had to change the input and output resistors. Unfortunately, I didn't have the manufacturer's information handy, so I had to use trial and error to come up with a value of 2.7 k. If you have the specs, the resistances should match the filter's impedance. If not, just plug in resistors until the eye pattern looks best. Refer to Figure 1.

At that point, the eye pattern wasn't all that bad, but it wasn't perfect. I tried tweaking the center filter capacitor and, when I removed it, the eye got better. After more trial and error, I ended up going with some negative capacitance (a 22- μ H inductor).

It's important to understand that each crystal filter is different. While there might not be much variation within a manufacturer's lot, filters from different manufacturers can vary widely. This means that the values I used for match-

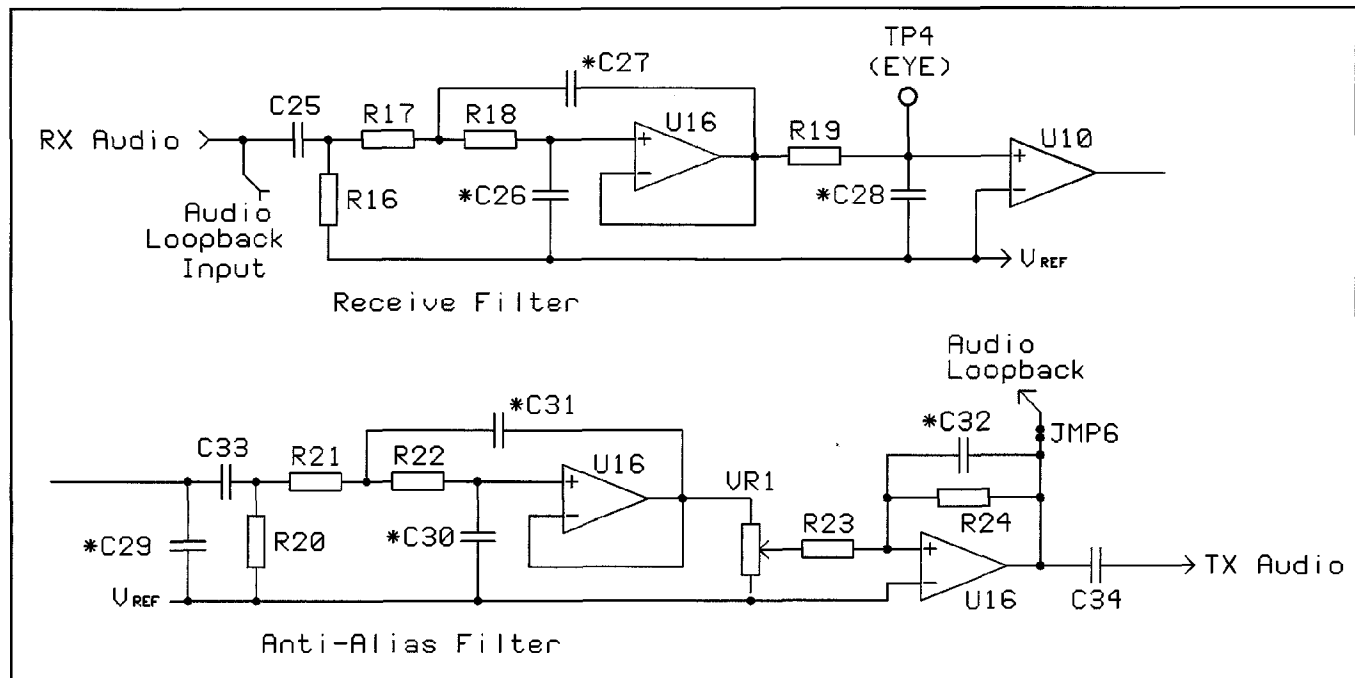


Figure 2: Partial schematic of a G3RUH modem, with the components to be changed marked with an *. All of the values shown must be reduced by half, so it might be easier to simply put a capacitor of the same value in parallel with the original.

ing to the filters are not universal: you'll have to determine the best value for the specific radio you're working on.

Aside from needing a good variety of resistors, inductors, and capacitors, the trial and error part went well, considering that there are only three components involved. Of course, I was constantly adjusting the deviation, frequency, and quadrature coil, always looking for the best eye pattern. The goal, of course, is to come as close as possible to a perfect eye pattern. However, that's about all there is to the modification, and the same technique applies to almost any crystal-controlled radio.

Modifying the G3RUH Modem

This whole process assumes that you already have your G3RUH-type modem modified for 19k2 operation. I happen to use PacComm NB-96 modems, though all of the modems available today work just as well. The G3RUH modem is kind of unique, in that changing the baud rate only involves changing the value of a few filter capacitors. If you don't make the change, it won't work.

The NB-96 manual states that all of the components you need to change are on a component header for easy modification. Unfortunately, that isn't entirely true: some are on the pc board. In comparing the NB-96 with G3RUH's original design, I noticed that PacComm has taken some liberties on which components needed to be changed. I suppose you could get away with only changing the components on the header, but I didn't want to take the chance.

Figure 2 shows all the components that need to be changed, and their new values (which are always half the 9k6 values) are shown in the "Replacement Chart." Don't forget to set the radio baud rate in the TNC to 19200 after changing these components! For the capacitors mounted on the board, I found it easier to just tack-solder a capacitor of the same value beneath the board. For the rest of the changes, invest a dollar in a new component header.

If you're using a different brand of modem, the owner's manual should cover this modification. If not, contact the manufacturer for help.

Ready to Try It?

So, there you have it. Even if you don't go out and modify all of your rigs for

higher speed, at least you can say you know what's involved and how to do it. The two keys to high-speed packet are IF filtering and eye patterns. Once you understand the concept of eye patterns, and learn to use them to your advantage, you'll find them to be a very powerful tool for analyzing data transmissions.

If you do nothing else, find someone with an oscilloscope (or buy one, they're available used for under \$200) and check the eye patterns on all your higher-speed links. Who knows, maybe you'll finally fix that flaky link once and for all! Finally, if you seem to be doing the modi-

fication right but can't get the eye pattern to look good, don't despair—we'll take a closer look at eye patterns next month.

Well, once again, I've run out of space for this month. Next month, aside from more on eye patterns, we'll describe the construction of a simple test transmitter for data signals. When you want to fool around with IF filtering, as we did this month, this handy little gizmo really makes life easier. I also want to say thanks to everyone who writes, because it really is good to hear from you.


Until next month, 73 and remember to have fun.

Resources

21.4-MHz Monolithic Crystal IF filters, 30-kHz bandwidth, are available from International Crystal Manufacturing Co., Inc., P.O. Box 26330, Oklahoma City, OK 73126-0330; Phone: (800) 725-1426.

455-kHz ceramic filters, optimized for data use, are manufactured by MuRata Erie North America, 2200 Lake Park Drive, Smyrna, GA 30080; Phone: (800) 394-5592 or (770) 436-1300. Call for the name of a local distributor.

TEKK radios are manufactured by TEKK Incorporated, 226 Northwest Parkway, Kansas City, MO 64150; Phone: (816) 746-1098. Call for the name of a local distributor.




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