EA467 Comm Lab – FSK and PSK part-1 (rev-a) Fall 2008

Elements: Bits, Baud rates, and ASCII. FSK and BPSK signals. TDMA and FDMA channel access methods. Noise bandwidth.

Introduction: Now that you have completed all the elements in the Link Equation, you understand how to calculate the RF signal power available at a receiver from a signal coming from a distant transmitter. This lab will address the demodulation of the RF waveform into useable signals. This demodulation process also has an impact on the Link Equation since it establishes the threshold of operability of the power received term (PR) in the receiver. There has to be enough power received with enough SNR to be able to decode a signal. The chart below shows some of those minimum signals required to achieve various bit-error-rates (BER) for various modulation and coding techniques.

This lab will demonstrate two common modulation methods used in space communications. These are Frequency Shift Keying FSK as used on most of our USNA satellites and Bipolar Phase Shift Keying, BPSK, used on the PCSAT2 and RAFT multi-user HF transponders. Some modulation methods are better than others as shown in the figure above (from SMAD). Notice that FSK requires the most SNR (Eb/No), but it is also the simplest and used in many applications such as all of our USNA satellites, PCSAT1/2, ANDE, RAFT and MARScom. BPSK needs less Eb/No by 4.5 dB or so but requires significantly higher quality linear receivers and stability which adds to cost.
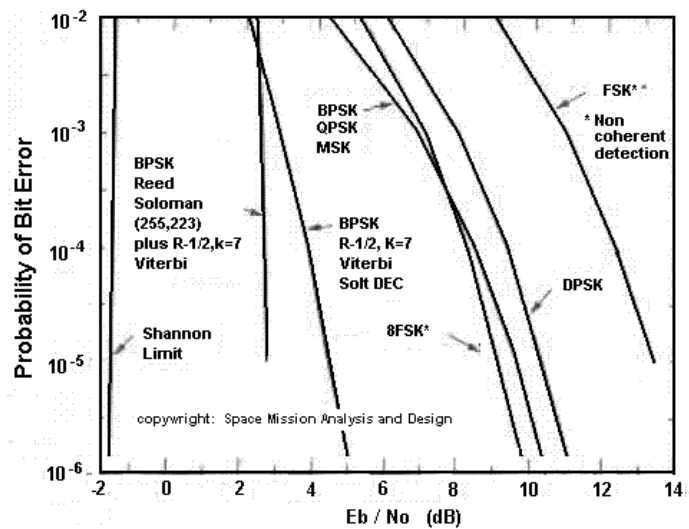

This lab uses your LABsat comm system to gain experience with these two modulation methods. During this lab period, you will first explore FSK demodulation.

FSK Demodulation. FSK Data Receiver on a TDMA Channel:

Many spacecraft communication systems use FSK; some of the user channels on UFO and many amateur satellites are good examples. The USNA LabSats, RAFT, ANDE and the PCSATs all transmit telemetry and user packets periodically using the AX.25 packet radio protocol using FSK. Packet digital communications is the name for "bursty" types of data exchange where many stations can share a channel or transponder in the Time domain. This is called TDMA for Time Division Multiple Access which you observed in the previous GO-32 Lab.

 In this lab you will set your LABSAT for data reception of telemetry from a prototype of the ParkinsonSAT Ocean Buoy. Also, to keep the channel busy, each of your LABsat TNC's is also set to a 10 second telemetry rate. This will provide plenty of activity on the channel and also let you see how TDMA works (Time Division Multiple Access).

FSK Data Receiver System
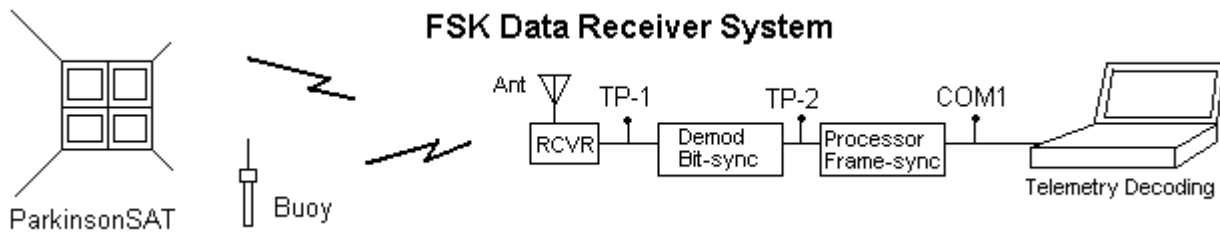
In the diagram above, the ground station receiver receives the VHF telemetry FSK signals as a pair of shifting audio tones (test-point-1) representing bits of 1's and 0's. The terminal node controller (TNC) then amplifies and demodulates the tones into individual bits (test-point-2) and then synchronizes these bits to the data clock in the Bit-Sync circuitry. Next, the Frame-Sync circuits lock onto the special flag bytes that signal the start and end of each packet. This then allows the frame sync to parse out all of the 8 bit bytes and send the resulting characters onto the PC for display (COM1 port).
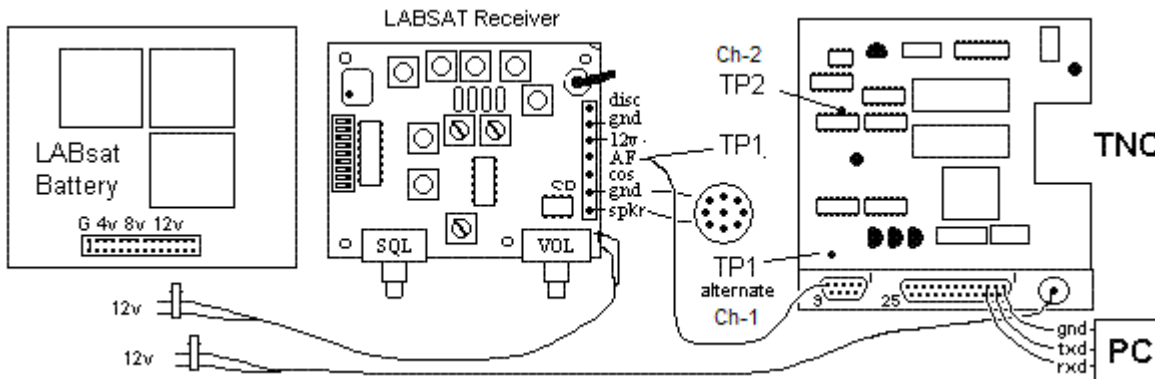

Lab Period: Assemble the various components above to begin to integrate your spacecraft FSK receiver as shown above. This year we will not use the full size receivers, but the smaller black transceivers so that they can also Transmit telemetry as well as receive it. So the receiver image above does not match your workstation this year. Perform the following setup tasks.

1. **Mechanical:** Connect the Radio Transceiver speaker and mic audio connector (a dB-9 connector) to the back of the TNC. Connect the PC o'scope probe channel-1 black lead to the TNC case and the red clip to the output of the receiver which is really the small "alternate TP1" pin in the back right corner of the TNC as shown above.

2. **PC Oscilloscope:** Bring up your PC oscilloscope under Programs or on the desktop - PC-Lab2000SE. Set channel-1 to 1 volt per division and the time base to 1 millisecond. Click on the RUN button. Turn on the Receiver volume control and verify that the oscilloscope shows the receiver noise and maybe some occasional tones. Adjust the Ch1 slider to the top half of the O'scope display and adjust the receiver volume control to fill about half the display.

3. **Terminal Node Controller (TNC):** Next connect the battery power lead to the TNC on the back. Connect the COM1 serial port wires of your PC to the serial port pin sockets on the back of the TNC. Connect the Receive Data (RXD)(red or brown) to pin 3, the Transmit Data (TXD)(white or yellow) wire to pin 2 and Ground (GND)(black) wire to pin 1 as shown.

4. **PC Terminal Program:** On the desk top you should find a shortcut to the serial port program called HYPERTERM that is included in all Microsoft PC's under the Accessories folder. We have made a shortcut labeled 9600com1 (red telephone Icon). Bring it up and then turn on the TNC. Now the TNC will decode any FSK data received and you should be able to see it on the PC terminal window. Hit a few ENTER keys to verify that the TNC responds with its *cmd:* prompt. Do not type any other commands!

5. **FSK Discriminator:** Connect the channel-2 o'scope black ground clip to the TNC chassis and the red probe to the discriminator output at TP-2 shown above. It is the top of a small resistor sticking up off of the discriminator chip. Observe the received waveform and data on the oscilloscope.

6. **OPERATION:** You want to try to capture a waveform similar to that shown in the figure below. When you hear a new data burst, quickly toggle-off the RUN button to try to capture the trace. Notice that the discriminator output is always trying to make sense out of the incoming noise, so there are always transitions. But these transitions will only "square-up" to true data when the sinusoidal alternating tones appear on the receiver output (ch 1).

FSK Modulation, TDMA Channel Sharing and Baud Rate
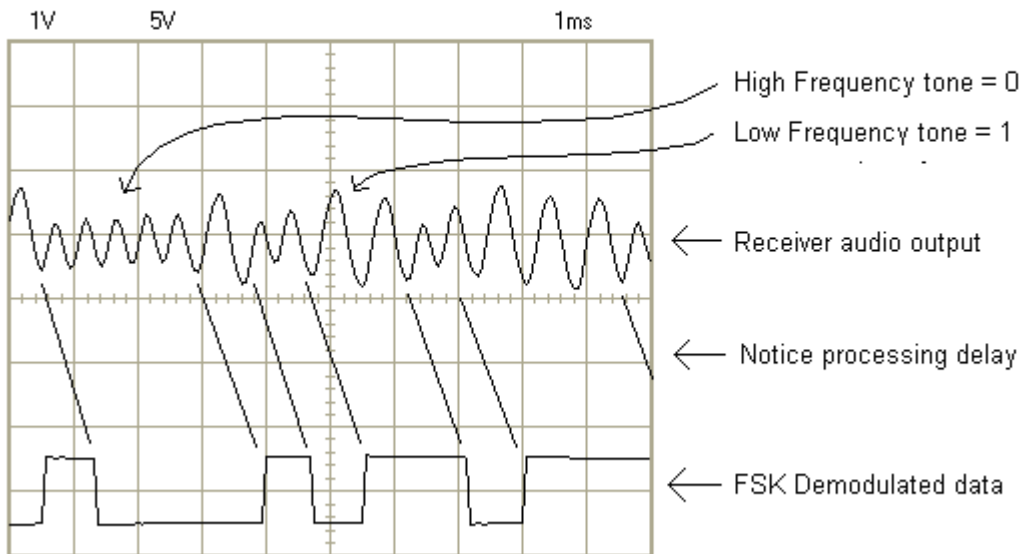
Observations: Notice that the noise coming out of the receiver (ch 1) is quite high in level when there is no signal. This noise is called white noise, because it contains components of all of the frequencies in the receiver's bandwidth. As we observed in the previous receiver's lab, this noise will "quiet" when a signal is present depending on the SNR. And then the modulation tones can easily be seen.

Notice the changes between the two tones correspond to the changes in the data stream which represent the one's and zeros. There is not a one-for-one correspondence between the number of cycles in the tone and the number of data bits. It is only the presence of one tone or the other that represents the ONE or the ZERO in the data.

Waveform Capture: Capture the waveform by clicking on the RUN button to save the data bursts' analog waveform consisting of two alternating sinusoidal tones. This is frequency-shift keying (FSK) where one tone represents a digital 1 and the other tone represents a digital 0. You should be able to save the image on the PC oscilloscope similar to the one above into a file and Email it to yourself for your report.

Make sure you get a nice capture that shows lots of 1's and 0's and at least a continuous string of several 1's or several 0's in a row, because then it is easier to see the difference between the tones.

In-Lab, Post Lab: Now determine the following learning points from this waveform and data capture. This will give you a pretty good understanding of data transmission, demodulation, and decoding. Do this while in the lab so that if your data capture does not grab a good representative sample, you can do it again until you get a good capture. Also, be sure you actually capture data and not just noise.

The discriminator does not know the difference between data and noise at this point in the data decoding process, since the decision of determining if the 1's and zeros mean anything comes later when the bits are sync'ed to a data clock and checked for bytes in the frame-sync part of the TNC.

1. Estimate the frequency of each of the two analog tones represented by estimating the period of the sinusoid waveform.

2. Observe that the data is in bursts (TDMA). From your capture, look for the smallest bit width and assume that is a single bit wide. Estimate the approximate data rate (bits/sec) from that observed bit width.

3. Estimate (by what you hear by ear) the data packet length (audible signal length). With that duration, estimate the number of 8-bit words probably included in the packet.

4. Observe the ASCII equivalent of the FSK data words on the PC serial port displayed by the HYPERTERM software terminal program. Record one of these telemetry frames. There should be several different types of data being received. A Buoy Beacon Text, and a Telemetry packet similar to the one shown below. Copy and paste will work.   Notice the number of bytes (characters) in each telemetry packet. Later in the Telemetry Lab, we will decode these bytes into meaningful telemetry.

BUOY>APRS:T#SSS,111,222,333,444,555,11111111

Post-Lab:

Answer the questions above and discuss the advantages and limitations of this FSK digital transmission type used by LabSat and our satellites. Think bandwidth and speed.   If each buoy was transmitting once every 30 minutes, how many buoys like this could share the TDMA channel.   How can they avoid collisions? Explain what is happening (and why) at each stage of the process (use the waveforms as support).

Laboratory Report: Use the standard lab format for your report. Describe the set-up, discussing data and results and answering questions and writing conclusions.

➢ Briefly describe the laboratory setup for each section of the laboratory procedure above, including block diagrams where appropriate.

➢ Complete all tasks in each section. Complete the analysis and discuss the results by making comparisons between measurements and theory where appropriate. Use figures and plots to support your conclusions.

➢ Summarize your results and observations.