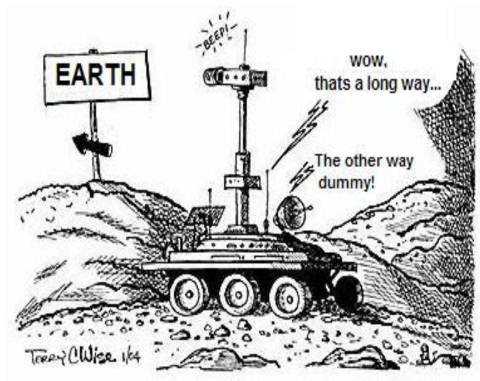
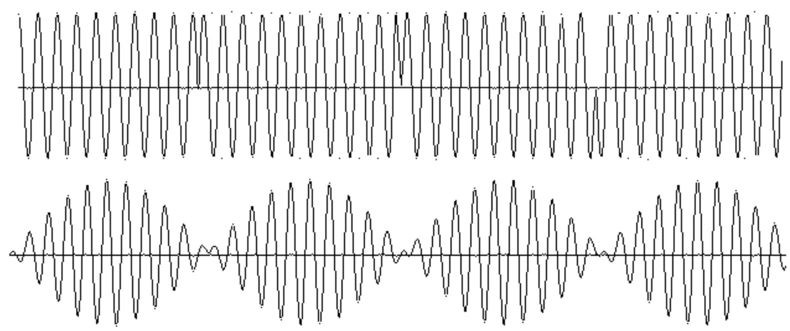
EA467 Communications – Receivers - PSK

(rev-b) Fall 2008



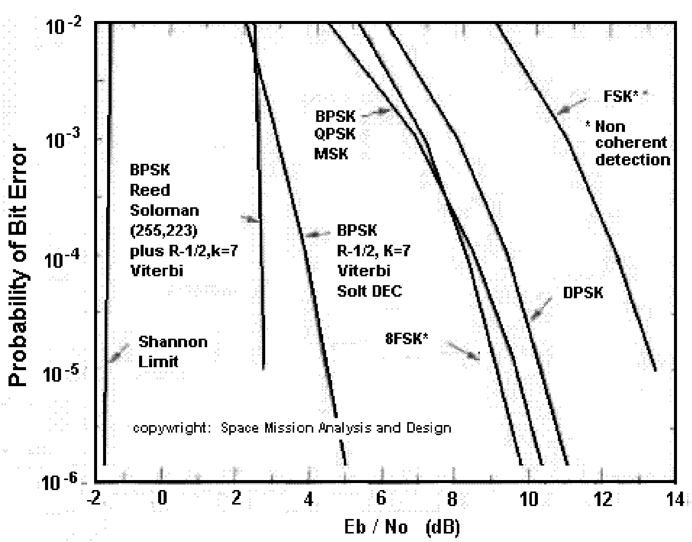
Introduction: In the last lab, you observed FSK signals and demodulation on the PC oscilloscope. The FSK signals were also observed in the time domain, as an example of a shared Time-Division-Multiple-Access (TDMA) channel.

In this lab, you will perform a similar observation of Phase-Shift-Keying (PSK) signals using a low data rate 31 baud narrowband signal. These signals will be sharing a Frequency-Division-Multiple-Access (FDMA) channel. These very low data rates allow for very weak signal detection and are often used on planetary missions due to the large distances involved. The Mars rovers used data rates as low as 10 BPS or so to communicate back to Earth. The lower data rate allows a lower bandwidth which in turn improves the signal to noise ratio.



Normally PSK waveforms are presented as shown in the figure below (top). This is Biphase or BPSK where the 180 degree phase shifts between bits are clearly visible. Because of the sharp transition in the time domain during these phase shifts, the bandwidth of a BPSK signal like this is increased. In this lab, we will be looking at similar signals, but that have been modified to minimize bandwidth. This is done by also applying an amplitude modulation at the bit rate so that the amplitude of the signal is zero at the instant of the 180 degree phase changes. The smooth transitions that result, make these signals occupy less bandwidth in the frequency domain than a normal BPSK signal would occupy.

The bottom line of this figure shows alternating 1's and 0's, but the 180 degree phase shifts are not as easy to see. However, in part C of this lab, you will capture similar waveforms and use cut-n-past to overlay them so that you can clearly see the phase shift in each bit period.

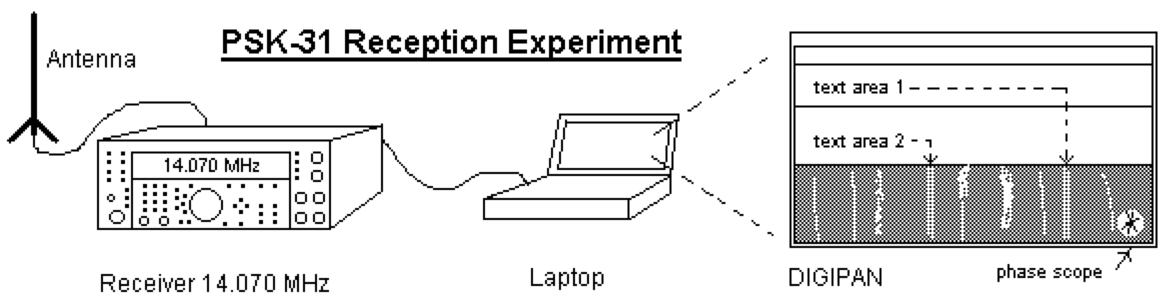


The receiver demodulation process has an impact on the Link Equation since it establishes the threshold of operability of the power received term (Pr) in the receiver. There has to be enough power received with enough SNR to be able to decode a signal. The chart at left shows some of those minimum signals required to achieve various bit-error-rates (BER) for various modulation and coding techniques. BPSK is clearly better than FSK by several dB.

What is the dB advantage on this chart of BPSK over FSK for a bit error rate of 1 out of every thousand bits? ____________

Part A: BPSK Reception on an FDMA Channel

Although satellites with low power over long distances often use PSK instead of the simpler FSK because of the better signal-to-noise link, this does require a more expensive linear receiver and linear transmitter. Another advantage of the narrow bandwidths of BPSK is that more users can fit in the same spectrum of a multiple access transponder. To demonstrate a multiple access Frequency-Division-Multiple-Access (FDMA) shared spectrum, we will use amateur radio signals received from HF combined with our own work station signals. The HF receiver is tuned to a narrow 3 KHz wide spectrum at 14.070 MHz and this is patched via the R-122 patch panel to the sound-card audio input of your workstation PC as shown below. This single 3 kHz radio channel is where the international BPSK operators hang out. On this PSK band, weak transmitters as low as 5 watts are frequently heard around the world using PSK at 31 baud. Deep space probes also operate at very low data rates as low as 10 baud because the lower the baud rate the less the bandwidth, the less the noise and the better the signal to noise ratio for a given spacecraft power (but the longer it takes to download appreciable data).



This BPSK experiment also demonstrates the concept of FDMA or Frequency Division Multiple Access. FDMA is a means for multiple users to share a single transponder or channel by separating the signals in the frequency domain. This is in contrast to TDMA observed in the FSK section of this Lab previously.

To receive and display the BPSK signals, you will use the free downloadable DIGIPAN software that uses the PC sound card for BPSK demodulation and also displays the receiver spectrum, a phase vector scope, and the recovered data. The small phase vector scope in the lower right corner displays the instantaneous phase of the signal. Since BPSK-31 operates on 180 degree phase shift, you can see the quality of the decoding on this 360 degree phase scope. Good decoding will show green vectors near 0 and 180 degrees. Noise will cause errors in amplitude and phase that are visible in the recovered text and phase vector scope closer to 90 and 270 and are shown in yellow and red.

Lab Procedure: There are five DIGIPAN stations so each group can operate independently. Each station has the left work station set up as a BPSK Transmitter and the right station as the BPSK receiver.

1. The 14.070 MHz receiver in the rack by the consoles in R-122 is connected to the signal patch panel in the front of the classroom via a 13k resistor and is distributed to all receive workstations. All of the transmit workstations are similarly patched via individual 13k resistors to all receivers.
2. Set the receive audio level into your DIGIPAN software by clicking on CONFIGURE and WATERFALL DRIVE. Your PC speaker will be emitting the sound as well. You can adjust its level with the volume control on the speaker on the front of the PC and also by the PC’s VOLUME slider. First adjust the WATERFALL DRIVE for a good modulation on the spectrum waterfall display (seeing some quiet blue and some yellow noise levels, but not too much noise). The spectrum displayed is from 0 to about 3000 Hz and represents a typical single voice bandwidth channel. PSK-31 signals will have two clear peaks or “tracks” representing the width of the modulated waveform in the frequency domain. You can decode a signal by clicking on it. As you first click on a strong signal, watch the vector scope as the phase-lock-loop acquires the signal and gets into phase lock…

3. Receiver RF tuning must be very precise because of the very narrow bandwidth of each signal. But by eye you can easily find and click on a signal. Each PSK-31 signal looks like a "railroad track" showing the two sidebands of the PSK signal. Here is what to look for and document:

   - The number of signals, their frequency in the transponder and their individual bandwidth?
   - The purity of each signal (do any of them overmodulate and develop +/- sidebands which consume extra spectrum?
   - What happens to other weak signls when a strong one begins transmitting?
   - What is the overall bandwidth of this broadband multi-user FDMA transponder?
   - How many potential FDMA signals can fit in this transponder?

4. You can see where these signals are originating, by watching for 4-to-6 character call signs in upper case that have a single numeral for the 2nd or 3rd character. Then use the USA map and World map provided on the back of Bruninga's desk to identify the location or country of origin. Try to find at least 3 decodable call signs.. Usually they are preceded by "de" which in teletype means "from". Other abbreviations: CQ(seek you), K (over), SK(out), QTH(location), 73(bye) and 88(love&kisses).

5. Most stations will also exchange a GridSquare to easily document their location. You can decode these on the green Grid-Square map also in the back.

Part B. Transmitting BPSK:

There may be few signals on the air, or there may have been some space weather that knocks out HF propagation. To be sure we have some signals, we have configured your left hand PC to transmit BPSK-31. To Transmit, plug the audio cable into the headphone jack on the front of the PC speaker. Then click on the Digipan frequency in the waterfall where there is a station you want to contact, or a clear frequency where you want to call CQ. Once you have clicked on the desired frequency, then click TX on the lower part of the display to shift from RX to TX and back. Your station should now become a transmitting station and its tone will appear on all other consoles while transmitting.

You can either type fresh text, or use some of the pre-loaded preambles and post-amble buttons across the top of the display. You use the CQ button to call others in the classroom on your frequency. Your stations identification are by rows (1-3) and right to left (A,B,C,D). Similarly, you have to watch for new signals on the air, and quickly click on them on your receiver to capture their text.

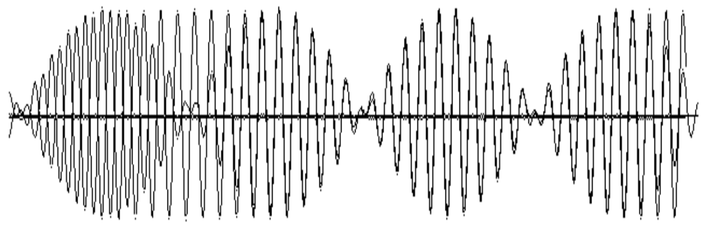
Your goal is to observe the performance of the BPSK system, quality of signals in the vector scope, operations of the FDMA channel while having a 2-way contact with all other stations in the room. Each of you has a callsign already loaded into the DIGIPAN software.

Post Lab: Write up your observations and comments… Based on the bandwidth you observed, comment on the number of signals possible on this FDMA channel, the number you saw, the quality of the signals, the phase shift used, the relationship between the vector scope observations and quality of data recovery. How much bandwidth is used by each signal. How much "guardband" should be allowed between signals. What kind of impact did noise make on the signal? What happened to everyone on the channel when a strong signal drove up the AGC level (Automatic Gain Control) on the receiver ?

This transponder channel is 3 KHz wide, which is the same bandwidth as a standard voice channel. But since an individual PSK-31 user only uses about 60 HZ of bandwidth, he has to contend with less noise power. Knowing that SNR is limited by noise bandwidth, how much better performance in dB can the BPSK-31 user expect over the same channel as a 3 KHz voice user? This improvement makes his 5W transmitter perform as well as what power level for the Voice user using the same channel bandwidth?

Part C. Waveform Capture:

We want to capture the BPSK-31 waveform like that shown on page 1 for analysis. As discussed, it is difficult to see the 180 degree phase shift that is occurring at each of the transitions between bits in this BPSK because this BPSK does amplitude waveshaping at the crossover points to minimize occupied bandwidth. By only doing phase shifts between bits in the waveform while the carrier is at zero amplitude, time domain transients and therefore bandwidth are reduced.



To make it easy to see the phase shift, you will capture an idle waveform from your transmitter with no data and then one with data. Then bring them into paint, and do a cut of the plain waveform and paste it over the modulated waveform (with Paint set for transparent paste).. By eye, it will be easy to see the bits that have the 180 degree phase shift from those that do not. Perform the following steps on your Transmitting PC:

1) Disconnect the transmit cable from the headphone jack if still connected. Select a tone down around 1000 Hz. Then click transmit. You should hear it on your speaker. Plug in the short audio cord with stripped ground and white wires.

2) Bring up the PC oscilloscope PS-2000E and connect the Channel 1 probe to the ground and white wire of the audio cable. Set the O'scope to 10 ms time base and the amplitude to a comfortable display. You should see a clear pattern of envelopes of energy at a 31 Hz rate superimposed on the 1000 Hz carrier you selected.

3) Now you will clean up that display for better analysis. Go back to RX and change your selected frequency down to around 500 Hz or so. This will make the carrier easier to see on the waveform. Select transmit again.

4) Now capture this null waveform which is alternating one's and zeros and save it.

5) Without touching anything else or changing any settings, click on one of the transmit texts and while it is playing capture another waveform.

6) Bring these into paint, and using transparent cut and paste, see if you can overlay one on top of the other. You should clearly be able to see where the bits are in phase and 180 degrees out of phase.

Laboratory Report: This completes the Transmitter and Receiver lab series. Use the standard lab format for your report which will include the TX/RX lab where you learned about receiver parameters, the FSK lab where you learned about demodulating FSK into bits, bytes and words, and then the GO-32 operations lab where you actually received data from a satellite on a shared TDMA channel. This final BPSK lab demonstrated how phase shift keying can also be used for very weak signal links and also for FDMA channel sharing. Describe the set-up, discussing data and results and answering questions and writing conclusions according to each section of the lab.

- 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.