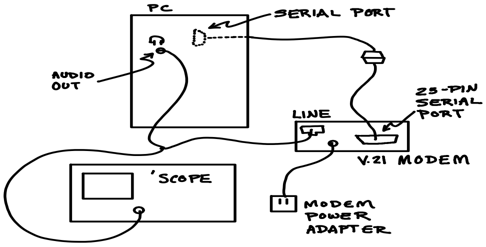
ELEX 3525 : Data Communications
2014 Winter Session

Lab 9 - V.21 FSK Modulator

Introduction

In this lab you will modify your program from Lab 3 so that instead of an RS-232 waveform it generates samples of an FSK waveform that complies with the ITU-T V.21 standard.

To test your program you will output the generated FSK waveform to a telephone-line modem that is hooked up to the PC via a serial port. The modem will demodulate the FSK signal and, if you did everything right, display your name on a terminal emulator running on the PC.



V.21

A copy of the V.21 standard is available on the course web site or from http://www.itu.int/rec/T-REC-V/en/.

Signal Levels

The V.21 modem specification allows a maximum output of 0 dBm and says that typical connections have attenuations of from 5 to 30 dB. You should set the level at the modem input to -6 dBm.

Frequencies

V.21 uses FDD with a different pair of frequencies in each direction. Use the frequencies for the station placing ("originating") the call: 980 Hz for a mark ('1') and 1180 Hz for a space ('0').

Software Changes

Modify the C program you wrote for Lab 3 so that:

- it computes and outputs 8-bit signed samples of a modulated V.21 FSK signal instead of 8-bit signed samples of an RS-232 waveform.
- the data rate is 300 bps instead of 1200 bps (the sample rate should be 9600 Hz)
- your waveform should begin with one second (300 bits) of mark ('1') to allow the modem to detect the carrier
- the FSK modulator only varies the carrier frequency according to the serial interface voltage; note that character format (e.g. start and stop bits) and timing (bit duration) are unchanged

There are various algorithms you can use to compute the sample values for an FSK waveform. Here is the pseudo-code for one method:

```
1. initialize a 'phase' variable to zero
2. for every sample output to the file:
    (a) increment the phase by the phase increment corresponding to the increase in phase per sample for the carrier frequency being generated. This phase increment will depend on whether you are trying to output the mark or space frequency.
    (b) compute the cosine of the phase and scale the value to the range ±127
    (c) write the sample value to the output file ("waveform.txt")
```

You will have to write multiple samples for each bit (how many?).

The hardware implementation of this algorithm is known as a Numerically Controlled Oscillator

(NCO) because it computes the waveform of an oscillator numerically instead of using an analog oscillator circuit.

You will have to determine the appropriate phase increment per sample. (Hints: Frequency is defined as phase difference per time increment. The time increment in this case is the time between samples.) You will have to apply one of two different phase increments depending on whether the mark of space carrier is being generated (which in turn depends on whether you are outputting a 0 or 1).

You can use a `float` value to keep track of the phase and use the function `cos()` to compute the cosine of the phase. `#include` the file `math.h` to include the function prototype for `cos()`. You will have to convert the value from `float` to `signed char` before writing it to the file. The phase variable's value needs to be retained across calls to `writebit()` so the phase variable must either be declared *static* or outside of a function.

The `lab3.c` example should be modified to open the output file in binary mode. Otherwise a carriage return character (0x0d) will be inserted after every linefeed character (0x0a). Use the following syntax for the open: `f = fopen ( "waveform.txt","wb" ) ;`

An incomplete version of the code is available in the file `lab7incomplete.c` on the course web site. You can use this as a reference when writing your own code but you don't have to.

Try to avoid repeating code. Move replicated code to a function and call it as necessary.

Procedure

Compile and run your program to generate the `waveform.txt` file containing the FSK signal using the same software and instructions as in Lab 3. To avoid losing your work, work on your network (`H:`) drive.

Plug the audio cable into the audio output port on the front of the PC. Connect the scope probe ground clip to the yellow lead and the probe to the violet lead.

Load the waveform into Audacity as in Lab 3 and start continous playback. Look at the waveform on the scope and adjust Audacity's volume control (beside the speaker icon) for a signal level of about -6 dBm.

Connect the PC's audio output to the modem's *line* port. You will be supplied a cable that has an RJ-11 jack on one side and bare wires on the other. Polarity does not matter. You can use the scope probe's clips to hold the wires together.

Connect the 9-pin RS-232 cable from the back of the PC to the 9-to-25 pin cable that is normally hooked up to the back of the black "Lab-Volt" chassis on the bench. Connect the 25-pin end of that cable to the RS-232 port on the modem.

Connect the modem's power adapter to the modem and 120VAC power (unplug the Lab-Volt unit if necessary).

Run Teraterm in the same way as for Lab 3 *except* that the baud rate must be set to 300 bps.

Type the following commands in the Teraterm window. These commands will be sent to the modem and configure it for V.21 modulation and then have it "pick up" the phone line and begin receiving data:

- type `ATZ` (followed by Enter) to reset the modem. If the modem receives the command it will respond with "OK".
- type `AT&FLNB15` to: set the factory default settings (F), reduce the modem's speaker level (`L`), disable speed negotiation (`N`), and enable V.21 modulation (`B15`),
- type `ATA` to have the modem go "off-hook" and connect to the phone line input

After a few seconds the modem should detect carrier, print CONNECT and start demodulating the FSK-modulated data and sending the data to the PC over the RS-232 line. You should see your name displayed on the terminal. Take a screen capture for your report.

If the problem is with the waveform you generated, check the frequency and level of your waveforms using the scope. If you trigger on the positive zero crossing you should be able to measure the two periods and compute the frequencies. A known-good test waveform is available in the file `lab9testwaveform.txt` on the course web site. You can use this waveform to confirm whether the problem is with your waveform or somewhere else.

Pre-Lab

What is the power of a sine wave of amplitude A? What amplitude corresponds to a power of -6 dBm if the modem's input impedance is 600 ohms?

What phase increments per sample will result in the V.21 originate mark and space frequencies for a sample rate of 9600 Hz?

How many samples per bit are required for a 300 bps waveform sampled at 9600 Hz?

What will happen if Hyperterm is configured to read more data bits than are generated by your software? Fewer?

Modify your Lab 3 code as described above to generate an FSK signal with the appropriate frequencies and baud rate.

Hand in the answers to the above questions and a printout of your code *before the start of the lab*.

You should try to complete the pre-lab before the lab because you will probably not have enough time to figure out how to modify the code *and* complete the procedure given above during the lab period.

Lab Report

Submit a PDF file with a copy of your modified code including any additional changes you made in the lab and a screen capture showing the Teraterm window with your name displayed.