**EE 445S Real-Time Digital Signal Processing Laboratory – Prof. Brian L. Evans**

**Lab 5 Instructions Part 2**

**1. Simulation of Receiver (Matlab)**

* Generate 2000 symbols and get the baseband transmitted signal using “rcosflt”, all the specifications are the same with Task 2 in Instructions Part 1.
* Assume we know exactly the symbol clock information in the receiver, sample the transmitted signal to recover the symbol.

(Hint: the delay in the transmitted signal is 4\*20=80 samples, so your sampler should start from the 81st sample in the transmitted signal)

* Compare the original symbols and recovered symbols and compute the error probability and show it in report. Since there is no additive noise in the channel, the error probability should be extremely low.

**2. Symbol clock recovery: Filter design (Matlab)**

* Please refer to slide 3 for the block diagram for the symbol clock recovery system.
* There are 2 different filters in this system: Pre-filter B() and band pass filter H().
* We will use 2nd order Butterworth IIR band pass filters with a sampling rate of 48 kHz for both the filters.
* The pre-filter B() has a center frequency of fsym/2 = 2400/2 = 1200 Hz. The 3 dB BW = 120 Hz.
* The band pass filter H() has a center frequency of fsym = 2400 Hz. The 3 dB BW = 240 Hz.
* Using fdatool, design both these filters and obtain the coefficients for both these filters.

**3. Symbol clock recovery: Implementation (Code Composer)**

* Modify the code you have developed in Task 5 of Instruction Part 1.
* Pass the **PAM output** (output from the filter bank, within the inner loop) to the **right** channel. This portion of the code is unchanged.
* Pass this output to a new function which you will write. Call this function **clock\_recover**.
* Within this function, implement the algorithm as shown in slide 3, i.e., Pre-filter -> Square -> Post band – pass filter -> Scale. The scaling is done to ensure that the input and output are in the same range of values. Please figure out an appropriate scaling level.
* For the pre-filter and post band – pass filter IIR filters, please use the code for Lab 3 (IIR Biquad).
* Take the output of this function and pass it to the **left** channel. This is the “recovered” clock.
* **Do not run the code yet!** Task 4 and Task 5 are test tasks to run this code.

**4. Symbol clock recovery: Testing (Code Composer)**

*Dotting Sequence Test*

* Make sure the audio codec is set to a sampling rate of 48 kHz.
* To test the code you wrote in Task 3, first comment the code which calls the scrambler code that generates the symbol.
* Now, generate a “dotting sequence”, i.e. an = (-1)n \* d where d = 1000, an is the symbol that is fed into the bank of filters and n is a running index for the outer loop that goes on forever.
* Do not use *pow* function. Instead, simple *if* constructs should do.
* As mentioned in Task 3, pass the PAM output to the **right** channel and the recovered clock output to the **left** channel. Observe both the channels on the oscilloscope and show the screenshot in report.

**5. Symbol clock recovery: Testing (Code Composer) (Contd.)**

*Scrambler Test*

* Make sure the audio codec is set to a sampling rate of 48 kHz.
* Now, uncomment the code which calls the scrambler code that generates the symbol, scale the symbols by 1000 as in Task 4.
* Comment out the “dotting sequence” code from Task 4.
* As mentioned in Task 3, pass the PAM output to the **right** channel and the recovered clock output to the **left** channel. Observe both the channels on the oscilloscope and show the screenshot in report
* **In Lab Report:** Make a note of your observations in this table.

|  |  |  |  |
| --- | --- | --- | --- |
| **Task** | **Pattern** | **Tone frequency** | **Tone amplitude** |
| **12** | **Dotted Sequence** |  |  |
| **13** | **2 – PAM** |  |  |

**6. Theoretical error probability (Matlab)**

* Please perform point 8 on Tretter’s Slide 11-33. This is the error probability for M – level PAM.
* Please read the section from slides 11-17 to 11-22 to understand the formulation for Pe.
* Please plot all the three graphs on the same plot with appropriate labeling of axes and legends.
* You will find the *erfc* function in Matlab to be useful. There is a relationship between the Q function and the *erfc* function. Please refer to Slide 14-25 of the **course notes** **(Lecture 14: Matched Filtering and Digital PAM).**