01QVTLP
Signals and Systems

Final Project: CLEAN UP THE SONG!

Given two reference songs:

- “Imagine” by John Lennon;
- “Mamma mia” by ABBA;

consider only one of the two stereo (R – L) signals.

PART 0: ANALYZE THE AUDIO SIGNAL

1. MEASURE THE SIGNAL
   Show with plots both time and frequency domain characteristics of the two given signals: estimate the occupied bandwidth.

PART 1: REMOVE THE DISTURBANCE

Both songs are affected by the same disturbance. Repeat PART 1 for both songs.

1. ANALYZE THE DISTURBANCE
   Using both time domain and spectral analysis, study the nature of the disturbance, so that you can design a proper filter to remove it. Plot waveform and spectrum of both signals under analysis.
2. USING A BESSEL LOW PASS FILTER
   Consider the low pass Bessel filter with four poles. Applying the bilinear transform method to synthesize a digital filter mimicking the analog transfer function.
   Optimize the filter cut-off frequency maximizing the signal quality, defined as SIR: describe and show with plots the optimization process.
   Plot the transfer function of the optimum filters.
   Show a comparison between the reference signals and the recovered ones.
3. DESIGNING YOUR OWN FILTER
   Design a digital filter capable of eliminating the disturbance by placing two complex conjugate poles and two complex conjugate zeros.
   Optimize zeros and poles positions in the complex z-pan, maximizing the signal quality (SIR): describe and show with plots the optimization process.
   Plot the transfer function of the optimum filters and the position of zeros and poles in the z-plan.
   Show a comparison between the reference signals and the recovered ones.
4. DISCUSSION
   Compare results form Part 1.2 and Part 1.3: discuss the advantages/disadvantages of the two analysed filter families. Discuss also differences between results obtained for the two songs.

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PART 2: SHARE THE CHANNEL

1. ANALYZE THE CHANNEL

   Using the spectral analysis probe the channel that you must share with another signal: plot the channel occupation.

   Try to transmit in the baseband: measure the signal quality (SIR).

2. MULTIPLEXING TWO SONGS

   Assume to apply amplitude modulation to multiplex both songs in the channel: motivate the selection of the carrier frequencies.

   Plot the spectrum of the overall signal transmitted through the shared channel.

3. RECEIVEING WITH A BESSEL LOW PASS FILTER

   Consider as receiver filter the low pass Bessel filters with four poles. Applying the bilinear transform method synthesize a digital filter mimicking the analog transfer function.

   Optimize the filter cut-off frequency maximizing signal quality (SIR): show with a plot the optimization process.

   Plot the transfer function of the optimum filters and of the filtered signal.

   Does the selection of the carrier frequencies have an impact on SIRs?

   Repeat the transmission experiment by considering one song at a time (always together to the signal already present in the given channel).

4. RECEIVING WITH YOUR OWN FILTER

   Consider as receiver filter a custom digital filter based on two complex conjugate poles and two complex conjugate zeros.

   Optimize zeros and poles positions maximizing the signal quality (SIR): show with a plot the optimization process.

   Plot the transfer function of the optimum filters and the position of zeros and poles in the z-plan.

   Show a comparison between the reference signals and the recovered ones.

   Does the selection of the carrier frequencies have an impact on SIRs?

   Repeat the transmission experiment by considering one song at a time (always together to the signal already present in the given channel).