Appendix B

Examinations

There were 3 examinations.
Examination problems and their solutions are given in this appendix. Students were allowed to bring one letter-size sheet (two-pages) of a summary note for each exam.

(a) Midterm Examination 1 was 120 minutes long, and the average score of the class of 45 students was 67 points out of the total of 110 and the standard deviation was 21.

(b) Midterm Examination 2 was 120 minutes long, and the average score of the class of 45 students was 72 points out of the total of 110 and the standard deviation was 24.

(c) The Final Examination was 120 minutes long, and the average score of the class of 45 students was 80 points out of the total of 110. It was a non-cumulative third examination.
1. (30 points) The following three problems are unrelated to one another.

(a) State the reason that a nonlinear channel can cause inter-channel interference (cross-talk) in frequency-division multiplexing.

(b) Arrange DSB-LC, DSB-SC, SSB and VSB in the decreasing order of the bandwidth required for transmission.

(c) A baseband video signal is to be generated according to the specifications given below. Determine the bandwidth of the signal, specifying clearly the assumption you have made in your computation. (You can ignore the time needed for horizontal and vertical retraces.)

<table>
<thead>
<tr>
<th>frames per second</th>
<th>30</th>
</tr>
</thead>
<tbody>
<tr>
<td>scan lines per frame</td>
<td>900</td>
</tr>
<tr>
<td>aspect ratio</td>
<td>16 : 9</td>
</tr>
</tbody>
</table>

(The U.S. high definition TV standard adopts the aspect ratio of 16 : 9.)

(d) Find the Hilbert transform $\hat{x}(t)$ of $x(t) = Am(t)\cos(2\pi f_c t)$, where $m(t)$ is bandlimited to $W$ Hz and $f_c \gg W$. Simplify the result as much as possible.

2. (25 points) A message signal $m(t)$ is given as follows:

$$m(t) = AW\text{sinc}(\pi Wt) + 2AW\text{sinc}(2\pi Wt),$$

where $A > 0$ and $W > 0$. (Note that $\text{sinc}(\alpha) = \sin(\alpha)/\alpha$.)

(a) Find the spectrum $M(f)$ of signal $m(t)$ and plot it carefully.

(b) Specify the band of the spectral occupancy of $m(t)$.

(c) Find the energy contained in signal $m(t)$.

(d) Find the spectrum $Z(f)$ of signal $z(t)$, where $z(t)$ is the analytic signal associated with $m(t)$.

(e) Plot the signal $x(t) = \text{Re}\{A_c z(t)e^{j2\pi f_c t}\}$ in the frequency domain, where $z(t)$ is the signal in (d). Assume that $f_c \gg W$. 

3. (25 points) A DSB-LC AM signal \( x(t) \) is generated by a periodic message signal \( m(t) \) given below.

\[ x(t) = (A_c + m(t)) \cos(2 \pi f_c t). \]

(a) Find and plot the normalized message \( m_n(t) \) for \( t \in [-2, 2] \) ms.
(b) Express the modulation index in terms of \( A_m \) and \( A_c \).
(c) Plot \( x(t) \) in the case that the modulation index is 50%.
(d) Express the power efficiency in terms of \( A_m \) and \( A_c \).
(e) Compute the average power of \( m(t) \).

4. (30 points) You are asked to design a DSB-SC AM system with the following nonlinear system whose input-output relationship is given by \( v_o(t) = kv^3_i(t) \), where \( k \) is a positive constant.

\[ v_i(t) \rightarrow \text{Nonlinear system} \rightarrow v_o(t) \]

Answer the following when the input \( v_i(t) \) is the sum of a sinusoid \( A \cos(2 \pi f_0 t) \) and a message \( m(t) \) bandlimited to \( W \) Hz, i.e., \( v_i(t) = A_c \cos(2 \pi f_0 t) + m(t) \).

(a) Find the output \( v_o(t) \) of the system for input \( v_i(t) \). Arrange the terms in the increasing order of frequency.
(b) Find the expression for \( V_o(f) \) and plot it in the frequency domain. Specify important frequencies.
(c) Devise a method to extract a DSB-SC signal from \( v_o(t) \), specifying, in terms of \( f_0 \) and \( W \),
   (i) the condition necessary for the extraction, and
   (ii) the center frequency of the resulting DSB-SC signal.