

(Finnish questions on the other side.) No materials. Basic calculator OK. Prepared by J. Talvitie.

1. Answer briefly to the following questions and justify your answers:
 - a. Mention at least three reasons why modulation is used in communications systems. (2p)
 - b. Describe differences between Fourier series and Fourier transformation concepts. What kind of use case limitations there are for exploiting the concepts? Which one would you choose to study spectral content of a sinusoidal signal? (2p)
 - c. What is the connection between an impulse response and a transfer function in case of LTI (linear time-invariant) systems? What can you say about the amplitude response (consider two-sided spectrum) if you know that the impulse response is real valued? (2p)
2. Explain the concept of distortionless transmission. Given the transmit signal is $x(t)$, and the system is distortionless, how does the received signal $y(t)$ depend on the transmit signal and the properties of the system? Based on this, what kind of transfer function, and thereon amplitude- and phase responses, does a distortionless system have? What kinds of distortions are typically encountered in transmission systems, and how do they affect the signal spectrum? (6p)
3. What is meant by the concept random signal? Why one usually needs to consider such random signals in analyzing and modeling communication systems? In this context, explain briefly what is meant by the following terms or concepts (a) stationarity (strict-sense vs. wide-sense), (b) autocorrelation, (c) white noise, (d) Gaussian noise. (6p)
4. A general bandpass signal can be expressed mathematically as

$$x_{BP}(t) = A(t)\cos(\omega_c t + \phi(t)) = x_I(t)\cos(\omega_c t) - x_Q(t)\sin(\omega_c t)$$

Sketch an example waveform and the corresponding spectrum of this kind of signal. In the above expression, what do the quantities or functions $A(t)$, $\phi(t)$ and ω_c (or f_c) represent physically? Sketch also the spectrum of the corresponding lowpass equivalent signal. What's the time domain expression for this lowpass equivalent signal and how does it describe the waveform characteristics of the original bandpass signal? (6p)

5. (a) Explain what is meant by a Hilbert transformer and how is it related to SSB modulation. Explain also how a real-valued signal can be transformed into an analytic signal (i.e., into a signal which consists of only the positive frequency components of the original signal) using a Hilbert transformer. How is this related to SSB modulation? (3p)
- (b) Compare different linear modulation methods (AM, DSB, SSB and QAM) with respect to transmission bandwidth and power efficiency (mathematical analysis is not required here). (3p)