UNIVERSITY of SHEFFIELD
Department of Electronic and Electrical Engineering

EEE 224/227 COMMUNICATION ELECTRONICS

Tutorial Sheet 1: Signals and systems

1. How is the unit step function $u(t)$ related to (i) $\delta(t)$ and (ii) ramp function $r(t)$?

2. For a signal $x(t) = 3u(t) - u(t-2)$, sketch and label

(i) x(t)
(ii) dx(t)/dt
(iii) x(t/2)
(iv) x(2t)
(v) x(1-t)

3. For $x(t) = u(t+2) - 2u(t) + u(t-1)$, sketch and label

(i) x(t)
(ii) $\int_{-\infty}^{t} x(\tau)d\tau$

4. For $x(t) = \delta(t+3) - 2\delta(t-3)$, sketch and label

(i) x(t)
(ii) $\int_{-\infty}^{t} x(\tau)d\tau$

5. Sketch and label $x(t) = e^{-t}u(t) + e^{-t}u(t-2) + e^{t-4}u(t-4)$.

6. Are the following systems with or without memory, causal of noncausal?

(i) y(t)=2u(t)
(ii) y(t)=sin(u(t))
(iii) y(t)=sin(u(t+1))
(iv) $y(t) = e^{t-2}u(t-2)$

7. Is the system represented by $y(t) = 1/x(t)$ linear and time-invariant?

8. An *RC* high-pass circuit has a step response $g(t)=u(t)\exp(-t/RC)$. Sketch and derive an equation for the impulse response

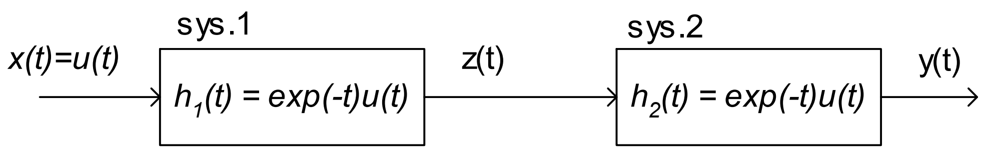
9. A system has an impulse response $h(t)=\exp(-t)u(t)$. Find the unit step response of this system.

10.. Compute and sketch $y[n]=x[n]*z[n]$ where:

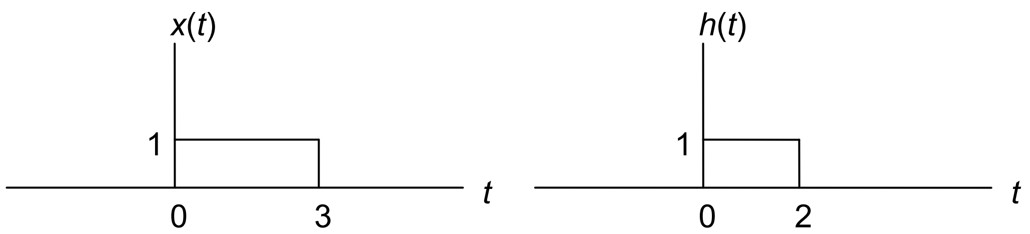
$x[n]$ =1,-1,2 for n =0,1,2
$z[n]$ = 1,2,3,-1 for n = -1,0,1,2
assume that each signal is zero elsewhere.

11. The impulse response of a system is given by $h[n]=-\delta[n-1] + \delta[n]$. By considering the input signal $x[n] = u[n-7]$, show that the system acts as an edge detector.

12. Find the output $y(t)$ for the system shown below when a unit-step input, $u(t)$ is applied.



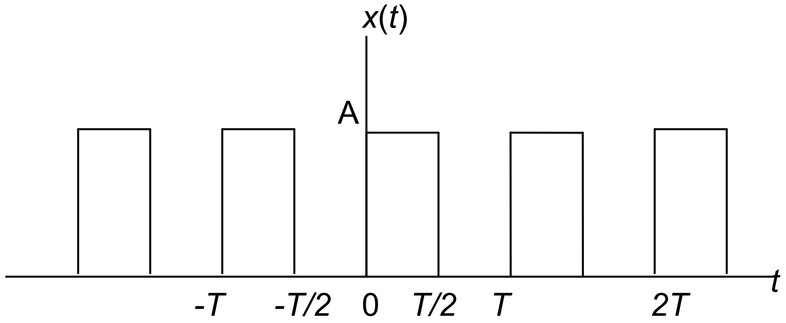
13. Consider the signals $x(t)$ and $h(t)$ shown below. Compute $y(t) = x(t)*h(t)$ using (i) the graphical method (ii) the analytical method and write down the analytical expressions for $y(t)$.



14. Consider a signal $y[n] = 3x[n] + x[n-2]$. Obtain the impulse response and evaluate the response of the system to an input

$$x_1[n] = \begin{cases} 1 & n=0 \\ 1 & n=1 \\ 2 & n=2 \\ 0 & otherwise \end{cases}$$

15. Determine the Fourier Series approximation of the signal shown below



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Tutorial Sheet 2 Amplitude Modulation

1. A transmitter radiates an AM DSB signal with a total power of 5 kW at a depth of modulation of 60 %. Calculate
(a) the power transmitted in the carrier
(b) the power transmitted in each sideband

(4.24 kW, 0.38 kW)

2. A carrier wave represented by 10 cos ($2\pi\ 10^6 t$) V is amplitude modulated by a baseband signal represented by 3 cos ($2\pi\ 10^3 t$) V. Calculate
(a) the modulation index
(b) the upper and lower sideband frequencies
(c) the amplitude of the sidebands
(d) the fraction of the power contained in the sidebands

(0.3, 1.001 MHz, 0.999 MHz, 1.5 V, 4.3%)

3. An AM DSB broadcast station transmits an average carrier power output of 40 kW and uses a modulation index of 0.707 for sine-wave modulation. Calculate
(a) the total average power output
(b) the transmission efficiency
(c) the peak output voltage if the antenna is represented by a 50 Ω resistive load (use P_C not P_T)

(50 kW, 20 %, 3414 V)

4. An AM DSB transmitter develops an unmodulated power output of 1 kW across a 50 Ω resistive load. When a sinusoidal test tone is applied to the input of the modulator, it is found that the spectral line for each sideband in the magnitude spectrum of the output is 40 % of the carrier line. Determine
(a) the modulation index
(b) the peak amplitude of the lower sideband
(c) the ratio of total sideband to carrier power
(d) the total power output
(e) the total average power output if the peak amplitude of the modulation sinusoid is reduced from 5V to 4 V

(0.8, 126.5 V, 0.32, 1.32 kW, 1.2 kW)

5. An AM transmitter has an output of 24 kW when modulated to a depth of 100 %. Determine the power output when
(a) the carrier is unmodulated
(b) after modulation to a depth of 60 %, one sideband is suppressed and the carrier component is reduced by 26 dB

(16 kW, 1.48 kW)

6. Calculate the percentage power saving when the carrier and one of the sidebands are suppressed in an AM wave modulated to a depth of (a) 100 %, and (b) 50 %

(83.3 %, 94.4 %)

7. An AM DSB receiver uses a square-law demodulator. What is the maximum modulation index that may be used if the second harmonic distortion of the modulating signal, produced by the demodulator, is to be no more than 10 % of the fundamental?

(40 %)

8. A carrier of 5 V r.m.s. and frequency 1 MHz is added to a modulating signal of 2 V r.m.s. and frequency 1 kHz. The composite signal is applied to a biased diode rectifier in which the relationship between current and voltage over the range ± 10 V is $i = (5 + v + 0.05\, v^2)$ μA, where v is the instantaneous voltage. Find
(a) the modulation index of the resulting AM DSB signal
(b) the frequency of each component in the diode current

(0.282, 0 Hz, 1 kHz, 2 kHz, 1 MHz, 2 MHz, 0.999 MHz, 1.001 MHz)

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Tutorial Sheet 3 Angle Modulation

1. A 25 MHz carrier is modulated by a 400 Hz sine wave. If the carrier voltage is 4 V and the maximum frequency deviation is 10 kHz, write the equation of this modulated wave for (a) FM, and (b) PM, if the modulation index is numerically identical in each case.

2. The equation of an FM modulated signal is $v = 10 \sin (10^8 t + 3 \sin 10^4 t)$. Calculate
(a) the carrier and modulating frequencies
(b) the modulation index and deviation
(c) the power dissipated in a 100 Ω resistive load.

(15.9 MHz, 1.59 kHz, 3, 4.77 kHz, 0.5 W)

3. Starting with an oscillator working near 500 kHz and using a maximum frequency deviation not exceeding ± 30 Hz at that frequency, calculate the following for an Armstrong system which is to yield a centre frequency of exactly 97 MHz with a deviation of exactly 75 kHz
(a) starting frequency
(b) exact initial deviation
(c) frequency of the crystal oscillator
(d) amount of frequency multiplication n_1 and n_2

(several schemes are possible)

4. In the absence of an input signal, the carrier output from a distortionless frequency modulator
has a frequency of 12 MHz and an amplitude of 5 V peak. An input signal causes a frequency deviation of 25 kHz per volt. Derive an expression for the modulated wave at the output when
the signal v = 1.5 sin (6280t) V is applied at the input. Hence deduce

(a) the peak phase deviation of the modulated carrier
(b) the peak frequency and phase deviation if the signal frequency is halved
(c) the peak frequency deviation if the signal amplitude is doubled

V_{FM}=5cos(24π*10^6t-37.5cos(6280t)
(37.5rads, 37.5kHz 75rads, 75kHz)

5. Describe the operation of a varactor diode frequency modulator. An oscillator operating at 100 MHz has a 75 pF capacitor in its tuning circuit. What total capacitance swing must the varactor supply to allow the modulator to have a 80 kHz peak deviation?

(± 0.12 pF)

6. An FM signal has a total bandwidth of 165 kHz when the modulating signal is a 10 kHz tone. Estimate the maximum carrier frequency deviation.

(50 kHz)

7. An FM transmitter is modulated with a single sine wave. The output for no modulation is 100 W into a 50 Ω resistive load. The peak frequency deviation of the transmitter is carefully increased from zero until the first sideband amplitude in the output is zero. Under these conditions determine

(a) the average power at the carrier frequency
(b) the average power in all the remaining sidebands
(c) the average power in the second order sidebands

(16 W, 84 W, 32 W)

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Tutorial Sheet 4 Pulse Modulation and Receivers

1. Several speech channels are to be transmitted over a radio link using time-division pulse position modulation. Using the information given below, estimate the maximum number of channels which may be transmitted

Channel sampling frequency	8 kHz
Pulse width	2 μs
Pulse shift	± 3 μs
Minimum adjacent channel pulse separation	2 μs

(12)

2. Eight data signals are sampled and time-multiplexed using PAM. The time-multiplexed signal is then passed through an ideal low-pass filter. If six of the data signals are band-limited to 3.3 kHz and the other two to 10 kHz,
(a) what is the minimum sampling frequency if all channels are to be sampled equally ?
(b) for this sampling rate, what is the minimum bandwidth of the low-pass filter ?
(c) what would be the minimum bandwidth requirement if the data signals were frequency-multiplexed using SSB ?
(d) In the above sampling format, the low data rate inputs are sampled much more often than necessary. A narrower transmission bandwidth could be obtained, for example, by sampling the 10 kHz signals three times more often than the 3.3 kHz signals. Devise a new sampling scheme to achieve this and repeat the calculations of (a) to (c) for the new scheme.

(160 kHz, 80 kHz, 39.8 kHz, 80 kHz, 40 kHz)

3. A continuous data signal is quantised and transmitted using PCM. If each data sample at the receiver must be known to within ± 1 % of the peak-to-peak full-scale value, how many bits must be transmitted to represent each data sample ?

(6)

4. A data signal consists of a series of binary pulses occurring at the rate of 100 bits / sec. This signal is to be transmitted over a telephone line, binary 1 being sent as a 1.5 kHz tone and binary 0 as a 2.8 kHz tone.
(a) What is the bandwidth of the transmitted signal ?
(b) If the data rate is increased to 1000 bits / sec, what are the required upper and lower cut-off frequencies of the line in order that it might transmit this signal ?

(1.5 kHz, 3.8 kHz, 500 Hz)

5. A superhet receiver for a radar is tuned to a signal frequency of 2.80 GHz and has a local oscillator frequency of 2.86 GHz. A second identical receiver, located nearby, has its local oscillator set at the image frequency of the first receiver and interference results.

(a) What is the I.F. of the first receiver ?
(b) To what signal frequency is the second receiver tuned ?
(c) If the receivers were to be redesigned, what should be the minimum I.F. to prevent interference problems in the 2.8 - 3 GHz radar band ?

(60 MHz, 2.86 GHz, 200 MHz)

6. A receiver, of the double superhet type, receives signals from a weather satellite at 136 MHz. The receiver first and second I.F.s are 30 MHz and 10 MHz, respectively. The first local oscillator operates below the signal frequency and the second operates above the first I.F. Determine the image frequencies.

(76 MHz, 50 MHz)

What other signal frequencies received will cause 2^{nd} IF image problems?

(56 MHz, 156 MHz)

7. When a superhet receiver is tuned to 555 kHz, its local oscillator provides the mixer with an input at 1010 kHz. What is the image frequency?
The antenna of the receiver is connected to the mixer via a tuned circuit whose loaded Q is 40. What will be the image-frequency rejection ratio in dB ?

(1465 kHz, 39.1 dB)

8. A superhet receiver having an r.f. amplifier and an I.F. of 450 kHz is tuned to 15 MHz. Calculate the Qs of the r.f. and mixer input tuned circuits, being identical, if the receiver's image rejection ratio is to be 120.

(88)

9. A standard 4 kHz telephone channel actually transmits voice frequencies between 300 and 3400 Hz. If the desired signal-to-noise ratio for the channel is 32 dB, what is the information carrying capacity ?

(32.953 k bits / sec)

10. A system has a bandwidth of 4 kHz and a signal-to-noise ratio of 28 dB at the input to the receiver. Calculate
(a) its information-carrying capacity
(b) the capacity of the channel if its bandwidth is doubled, while the transmitted signal power remains constant.

(37.219 k bits / sec, 64.455 k bits / sec)

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Tutorial Sheet 5

1. A non-linear circuit has an output voltage v_o which is related to its input voltage v_i by

$$v_o = 0.5v_i + 0.1v_i^2$$

v_i contains a carrier of 1 V p-p at 100 kHz and a tone of 0.7 V p-p at 5 kHz. Write down an expression containing all the frequency components and their amplitudes in v_o and draw its spectrum.
v_o is now passed through an ideal low-pass filter of passband 65 to 135 kHz. Show that the signal spectrum is now a full AM one with m = 0.14.
Now find the largest values of modulation tone and frequency which can be used without producing distortion or interference in the filter output.

(5 V p-p)

2. For an envelope detector, with a full AM input, answer the following:
(a) What is the maximum CR value at f_m = 1 kHz for m= 0.1, 0.3 and 0.9 ?
(b) Find values of m for which CR = 1 / ω_m and 0.
(c) CR values seem to be independent of f_c. What assumption has been made to cause this to be true and under what circumstances is it invalid ? What happens then ?
(d) For f_m = 10 kHz and f_c = 1 MHz find the largest and smallest CR values useable.
(e) For the results in (a), assign actual values for C, R, C' and R', explaining your choice of values.

(1.58×10^{-3}, 5.06×10^{-4}, 7.7×10^{-5}, 1, 0.707, 0, 1.59×10^{-5})

3. An FM signal having the following characteristics is applied to the input of a superhet radio receiver:
Carrier centre frequency = 90 MHz
Frequency deviation = ± 75 kHz
Baseband is from 30 Hz to 15 kHz
If the receiver has an IF of 10.7 MHz, calculate:
(i) the extreme values of the modulation index
(ii) maximum Carson bandwidth
(iii) local oscillator frequency
(iv) the probable practical IF bandwidth.

(2500, 5, 180 kHz, 79.3 MHz, 225 kHz)

4. N binary coded signals, each having n digits per sample, are time-multiplexed together. Calculate the overall signal bandwidths for the following conditions:

(i) $n = 8$, $N = 12$, all telephone channels

(ii) $n = 6$, $N = 400$, all telephone channels

(iii) $n = 8$, telephone channels. Find N and the frame rate if the overall bit rate is 2.048 Mbs.

(iv) Baud rates of 100, 300, 2400 and 9600.

(v) Bit lengths of 16, 125 and 1024 μs

(768 kHz, 19.2 MHz, 32, 125 μs, 100 Hz, 300 Hz etc, 62.5 kHz, 8 kHz, 976.6 Hz)

5. An analogue signal is limited to an amplitude range of 0 - 5 V.

(i) Calculate the quantisation intervals when digitised with 4, 6 and 8 bits per sample.

(ii) Sketch the form of the digital signal for the largest and smallest signal voltages and also for the middle 2.5 V one at 6 bit quantisation

(iii) What voltages do the following digital samples represent:

10000000, 01000000, 00011010, 11100101

(iv) For a 6 kHz baseband bandwidth, calculate the minimum PCM bandwidth required for 8 and 12 bit quantisation.

(5/15V, 5/63V, 5/255V, 2.5098V, 1.2549V, 0.5098V, 4.4902V, 96 kHz for 8 bit, 144 kHz for 12 bit)