S-72.245 Transmission methods in Telecommunication Systems

Tutorial 3

Objectives

- To understand bandpass systems and lowpass equivalents
- Getting familiar with AM and DSB modulation and their properties
- To understand linear transceiver techniques: Topics in modulator and non-coherent/coherent detector techniques

Quizzes

Q3.1 Topic: baseband and bandpass systems: Signal definitions, frequency spectrums and related transformations: (a) What is the relationship of bandwidth and fractional bandwidth?
(b) Why lowpass signal presentation is used, any practical application? (c) Show a block diagram of a system capable of making lowpass to bandpass transformation. (d) Briefly describe how fiber optical cables can be used for baseband and bandpass communications?

Q3.2 DSB is also called as DSB-SC (double-sideband-suppressed-carrier modulation). Explain the meaning of **suppressed.** On **suppressed** point of view compare AM and DSB modulation method by drawing their spectrum for tone modulation and for some more general form of signal spectra.

Q3.3 Show that any scheme that can be used to demodulate DSB can also demodulate AM. Is the reverse also true? Explain.

Q3.4 A message *m(t)* is defined by

$$m(t) = \begin{cases} 1, & 0 \le t \le \frac{t_0}{3} \\ -2, & \frac{t_0}{3} < t \le \frac{2t_0}{3} \\ 0, & otherwise \end{cases}$$

This message DSB modulates the carrier $c(t) = cos 2\pi f_c t$, and the resulting modulated signal is denoted by *u(t)*. It is assumed that $t_0 = 0.15s$ and $f_c = 250Hz$.

a) Obtain the expression for *u(t)*.
b) Derive the spectra of *m(t)* and *u(t.)*
c) Demodulate the modulated signal *u(t)* and recover *m(t)*. Draw the circuit diagram for the demodulator!

Hints: $F[\prod(\frac{t}{\tau})] = \tau sinc\ f\tau$

Q3.5 Design in block diagram for a DSB modulator by using a non-linear element with $v_{out} = a_1 v_{in} + a_3 v_{in}{}^3$. What is the condition on f_c in terms of the modulating signal $v_i(t)$ bandwidth *W*?

Hints: consider $v_i(t) = x + \cos\omega_0 t$

Matlab assignments

M3.1 According to the description in Q3.4, write MATLAB program to evaluate and plot modulating signal *m(t)* and modulated signal *u(t)* in time and frequency domains.

M3.2 According to description in Q3.4, write MATLAB program to evaluate and plot demodulated output signal *z(t)* in time and frequency domains. What is the relationship of lowpass signal presentation to results of this simulation?

M3.3 Consider a tone modulated AM-signal signal. Verify by MATLAB that the lowpass to bandpass conversion equations, as explained below, apply. How the role (function) of unit-step function can be realized in practice?

Transforming bandpass signal to lowpass signal

- This means **demodulation** of the bandpass signal:

  $$v_{bp}(t) = v_i(t)\cos(\omega_c t) + v_q(t)\cos(\omega_c t + \pi/2)$$

  take this to frequency domain by using **modulation theorem**:

  $$v(t)\cos(\omega_c t + \phi) \leftrightarrow \tfrac{1}{2}\left[V(f - f_c)\exp j\phi + V(f + f_c)\exp - j\phi\right]$$

$$\Rightarrow V_{bp}(f) = \underbrace{\left[V_i(f - f_c) + V_i(f + f_c)\right]/2}_{V_i(f)} + j\underbrace{\left[V_q(f - f_c) - V_q(f + f_c)\right]/2}_{V_q(f)}$$

now inspect this by setting $f = f + f_c$

$$V_{bp}(f + f_c)\big|_{rem} = \left[V_i(f) + \cancel{V_i(f + 2f_c)}\right]/2 + j\left[V_q(f) - j\,\cancel{V_q(f + 2f_c)}\right]/2$$

and we note that $V_{lp}(f) = V_{bp}(f + f_c)\big|_{rem} = V_i(f)/2 + jV_q(f)/2$

e.g. $V_{lp}(f) = V_{bp}(f + f_c)u(f + f_c)$

unit step function removes the terms as shown above

References

1. A. Bruce Carlson: Communication Systems IV ed
2. B. P. Lahti: Modern Digital and Analog Communication Systems third ed