S-72.245 Transmission methods in Telecommunication Systems
Tutorial 4

Objectives

- Getting familiar with exponential modulation: line spectrum, phasor diagram and bandwidth estimation. To understand instantaneous phase and frequency.
- To investigate FM modulators and demodulators.

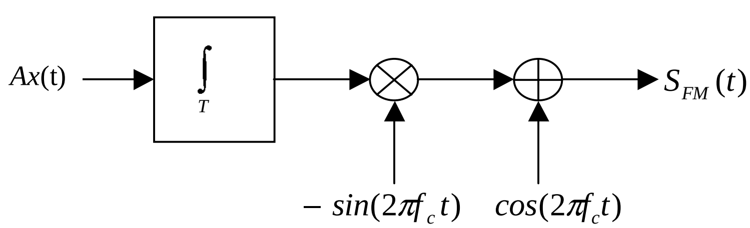
Quizzes

Q4.1 Tone modulation is applied simultaneously to a frequency modulator and phase modulator and the two output spectra are identical. Describe how these two spectra will change when:

a) The tone amplitude is increased or decreased
b) The tone frequency is increased or decreased

Q4.2 Let us consider an FM system with $f_\Delta = 30\,\mathrm{kHz}$. What is the required transmission bandwidth B_T when the modulating signal is an unit-amplitude tone with the tone frequency of $f_m = 0.1, 1.0, \text{ or } 5.0\mathrm{Hz}$? Repeat your inspection for PM system with $\phi_\Delta = 3\,\mathrm{rad}$.

Q4.3 Show (in the time domain), that the system below works as an FM-modulator when A << 1.



Q4.4 An angle-modulated signal, with the carrier frequency $\omega_c = 2\pi \cdot 10^6$ is described by the equation

$$\varphi_{EM}(t) = 10\cos\left[\omega_c t + 0.1 \cdot \sin(2000\pi t)\right]$$

a) Find the average power of the signal
b) Find the respective frequency deviation Δf
c) Find the respective phase deviation $\Delta\phi$
d) Estimate the required transmission bandwidth

Q4.5 Carry out the details to prove the expressions for envelope and phase of unmodulated carrier with additive interference (slide 25).

Matlab assignments

M4.1 A message signal is defined by

$$m(t) = \begin{cases} \text{sinc}(100t), & |t| \le t_0 \\ 0, & \textit{otherwise} \end{cases}$$

where $t_0 = 0.1$ sec. This message modulates the carrier $c(t) = \cos(2\pi f_c t)$, where $f_c = 250\,\text{Hz}$. The deviation constant is $k_f = 100$ .Plot the modulated signal in time and in frequency domain by using Matlab.

M4.2 Demodulate the modulated carrier of M4.1 by using the phase shift FM-detector discussed in the Appendix and sketch the related waveforms in Matlab. Compare the demodulated signal with the message signal and explain possible differences.

Appendix

Phase-shift FM detector

- An approximation for any derivative:

$$d\phi(t)/dt = [\phi(t) - \phi(t-\Delta t)]/\Delta t$$

- Derivative of an FM wave contains message:

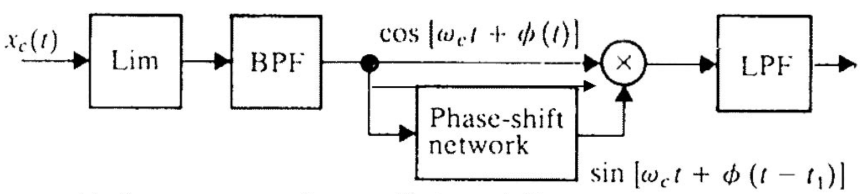
$$d\phi(t)/dt = 2\pi f(t) = 2\pi[f_C + f_\Delta x(t)]$$

- FM-detector can be realized by approximating the derivative:

$$\phi(t) - \phi(t-\Delta t) = \Delta t d\phi(t)/dt$$
$$= 2\pi\,\Delta t[f_C + f_\Delta x(t)]$$

Carrier and modulation are additive

Phase-shift FM detector: circuit realization



- Limiter removes extra amplitude variations
- BPF removes out-of-band components generated in the limiter
- After delay-and-multiply detection carrier components are removed by the last LPF

$$\phi(t) - \phi(t-t_1) = \Delta t d\phi(t)/dt$$
$$= 2\pi\,\Delta t[f_C + f_\Delta x(t)]$$

$$\cos[\omega_c t + \phi(t)]\sin[\omega_c t + \phi(t-t_1)]$$
$$= \frac{1}{2}\left\{\sin[2\omega_c t + \phi(t) + \phi(t-t_1)] - \sin[\phi(t) - \phi(t-t_1)]\right\}$$
$$\sin\underbrace{[\phi(t) - \phi(t-t_1)]}_{\text{small}} \approx \phi(t) - \phi(t-t_1) = 2\pi t_1[f_c + f_\Delta x(t)]$$

LPF removes carrier — detected wave