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- ▼ **Topic 8: Signal Transmission - Demodulation**

**8.1 Demodulation****8.2 Analysis of Mixing using Cosines**

Week 4 Quiz due Nov 23, 2015 at 15:30 UTC

**8.3 Analysis of Mixing using Complex Exponentials**

Week 4 Quiz due Nov 23, 2015 at 15:30 UTC

**8.4 Filtering**

Week 4 Quiz due Nov 23, 2015 at 15:30 UTC

**8.5 Non-ideal Effects****8.5 QUIZ QUESTION 1** (1/1 point)

Suppose the frequencies of the cosines used to be modulated by the baseband signal and to demodulate the received signal are *not* identical. Which of the following is/are true?

☐ After demodulation, the two copies of the signal at baseband obtained by multiplying by the complex exponentials at positive and negative frequencies cancel each other.

☒ After demodulation, the two copies of the signal at baseband obtained by multiplying by the complex exponentials at positive and negative frequencies are not aligned at zero. ✓

☒ The received signal at baseband is a distorted version of the original baseband signal. ✓

☐ No signal appears at the baseband.



*Note: Make sure you select all of the correct options—there may be more than one!*

**EXPLANATION**

Suppose that the frequency of the modulating cosine is  $f_1$  and the frequency of the demodulating cosine is  $f_2 \neq f_1$ . After multiplication, there is a cosine at  $f_1 - f_2$ . This leads to two complex exponentials at  $\pm(f_1 - f_2)$ , rather than a single component at zero frequency. This gives two copies of the original signal slightly displaced from each other. When combined, this leads to distortion in the original signal.

*You have used 1 of 2 submissions*

**8.5 QUIZ QUESTION 2** (1/1 point)

Suppose that at the transmitter, the signal to be transmitted,  $m(t)$ , modulates the carrier  $\cos(2\pi f_0 t)$ . Suppose that the received signal  $x(t) = m(t) \cdot \cos(2\pi f_0 t)$  is demodulated by mixing with a signal that has a slight phase offset with respect to the carrier,  $\cos(2\pi f_0 t + \frac{\pi}{4})$ . Thus, after mixing, the signal is given by

$$d(t) = m(t) \cdot \cos(2\pi f_0 t) \cdot \cos(2\pi f_0 t + \frac{\pi}{4})$$

Assume that after mixing, the signal is low pass filtered to remove the components introduced by mixing at  $2f_0$  and  $-2f_0$ .

Week 4 Quiz due Nov 23,  
2015 at 15:30 UTC

### 8.6 Lab 4 - Modulation

Lab due Nov 23, 2015 at  
15:30 UTC

▶ MATLAB download  
and tutorials

▶ MATLAB Sandbox

Which one of the following is true about the recovered signal at baseband.

☐ It disappears.

☐ It has a spectrum that is the sum of two copies of the original spectrum that are shifted slightly in frequency in opposite directions.

☒ It is equal to the original signal  $m(t)$ , only scaled by approximately 0.35. ✓

☐ It is equal to the original signal  $m(t)$ , only flipped in sign.

#### EXPLANATION

Since  $\cos(A + B) = \cos(A)\cos(B) - \sin(A)\sin(B)$

$$\begin{aligned} d(t) &= m(t) \cdot \cos(2\pi f_0 t) \cdot \cos(2\pi f_0 t + \frac{\pi}{4}) \\ &= m(t) \cdot \cos(2\pi f_0 t) \cdot \left( \cos(2\pi f_0 t) \cos(\frac{\pi}{4}) + \sin(2\pi f_0 t) \sin(\frac{\pi}{4}) \right) \\ &= m(t) \left( 0.5 \cos(\frac{\pi}{4}) + 0.5 \cos(2\pi(2f_0 t)) \cos(\frac{\pi}{4}) + \cos(2\pi f_0 t) \sin(2\pi f_0 t) \sin(\frac{\pi}{4}) \right) \end{aligned}$$

Since  $\cos(A)\sin(B) = 0.5 \sin(A + B) + 0.5 \sin(A - B)$  and  $\sin(0) = 0$ ,

$$\cos(2\pi f_0 t) \sin(2\pi f_0 t) = 0.5 \sin(2\pi(2f_0 t)).$$

Thus,

$$d(t) = 0.5 \cos(\frac{\pi}{4})m(t) + m(t) \cdot (0.5 \cos(2\pi(2f_0 t)) \cos(\frac{\pi}{4}) + 0.5 \sin(2\pi(2f_0 t)) \sin(\frac{\pi}{4})).$$

The second term is removed by filtering, leaving only

$$d(t) = 0.5 \cos(\frac{\pi}{4})m(t) \approx 0.35m(t)$$

*You have used 2 of 2 submissions*

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