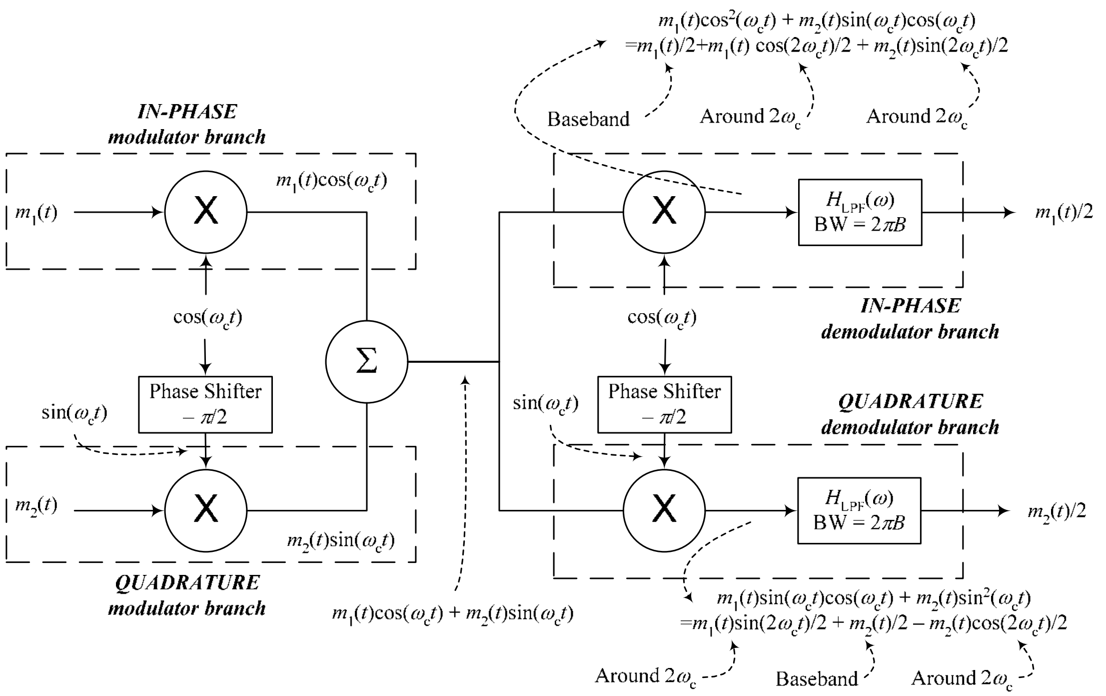
Quadrature Amplitude Modulation (QAM)

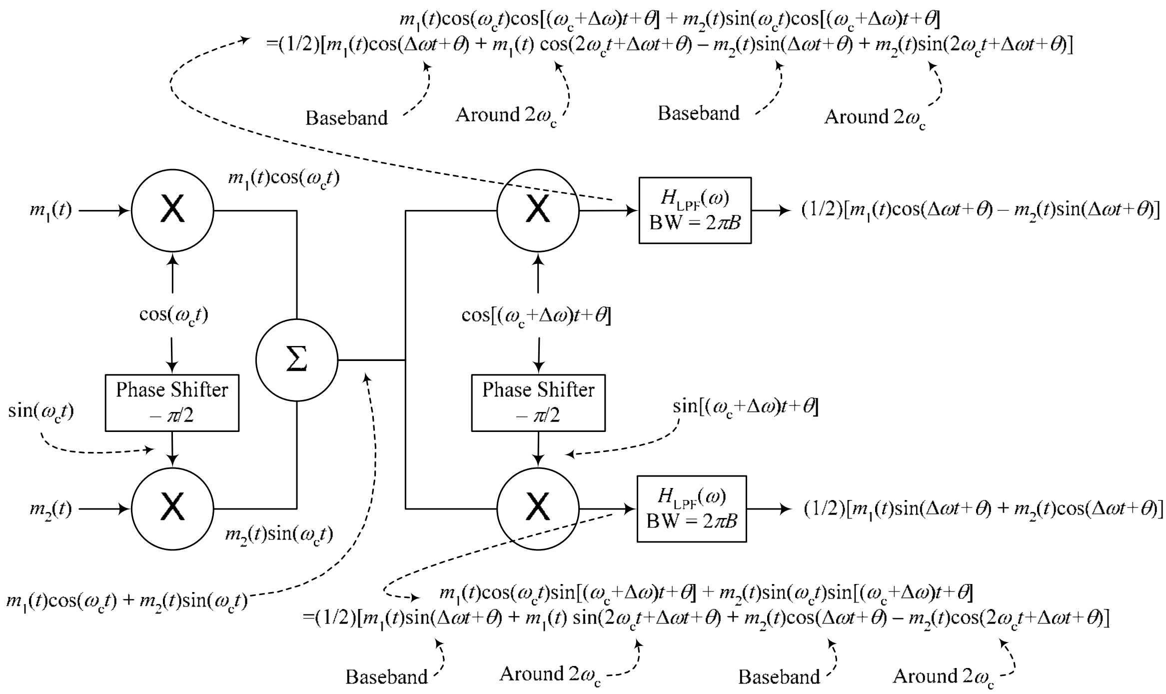
If you noticed, you would see that so far we have always used a carrier that is $c(t) = \cos(\omega_C t)$ to modulate the message signals both in AM and DSBSC. There is nothing special about using a cosine instead of a sine carrier. In fact, we can transmit two signal using the same carrier frequency but using $\cos(\omega_C t)$ for one of the message signals and $\sin(\omega_C t)$ for the other signal. These transmitted signals if transmitted over the same channel would not interfere with each other and can be demodulated.

Consider the following block diagram of a Quadrature Amplitude Modulation (QAM) and Demodulation system:



QAM Modulator/Demodulator

The modulator/demodulator system shown above clearly is able to modulate and demodulate two different signals without any interference. However, if the generation of the carrier at the demodulator had even small phase or frequency errors, the demodulated signals will interfere at the outputs. The following figure illustrate what happens when the carrier at the demodulator has a small frequency error $\Delta\omega$ (must be a small value much less than ω_c) and/or a small phase error θ.



QAM Modulator/Demodulator with Demodulator Carrier Phase and/or Frequency Error

If the carrier at the receiver has a small frequency error $\Delta\omega$ (but a phase error θ=0), we see that the two output signal become

$$
\begin{aligned}
r_1(t) &= \frac{1}{2}\left[m_1(t)\cos(\Delta\omega t) - m_2(t)\sin(\Delta\omega t)\right] \\
r_2(t) &= \frac{1}{2}\left[m_1(t)\sin(\Delta\omega t) + m_2(t)\cos(\Delta\omega t)\right]
\end{aligned}.
$$

Clearly, in this case, the output signals are not purely either of the two message signals but a combination. The ratio of message 1 to message 2 at the different outputs changes as a sinusoid with a frequency equal to the frequency error $\Delta\omega$.

If the carrier at the receiver has a phase error θ (but a frequency error $\Delta\omega$ = 0), we see that the two output signal become

$$
\begin{aligned}
r_1(t) &= \frac{1}{2}\left[m_1(t)\cos(\theta) - m_2(t)\sin(\theta)\right] \\
r_2(t) &= \frac{1}{2}\left[m_1(t)\sin(\theta) + m_2(t)\cos(\theta)\right]
\end{aligned}.
$$

In this case, the output signals are not also mixed signals of the two messages. However, the ratio of the two messages in each output is a constant.