ECE2c Problem set #8:

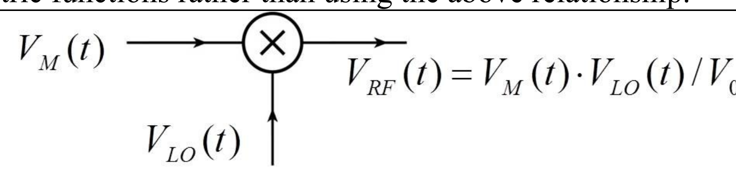
Background: If we have the product of two functions, i.e. $V_C(t)=V_A(t)V_B(t)/V_0$, then

$$V_C(j\omega)=\frac{V_A(j\omega)*V_B(j\omega)}{2\pi V_0}=\frac{\text{convolution of } V_A(j\omega) \text{ and } V_B(j\omega)}{2\pi V_0}$$

$$=\frac{1}{2\pi V_0}\int_{-\infty}^{\infty}V_A(j\omega')\cdot V_B(j\omega-j\omega')d(j\omega')$$

If you are dealing with simple signals (a few sine and cosine waves), it is easier to directly multiply the trigonometric functions rather than using the above relationship.

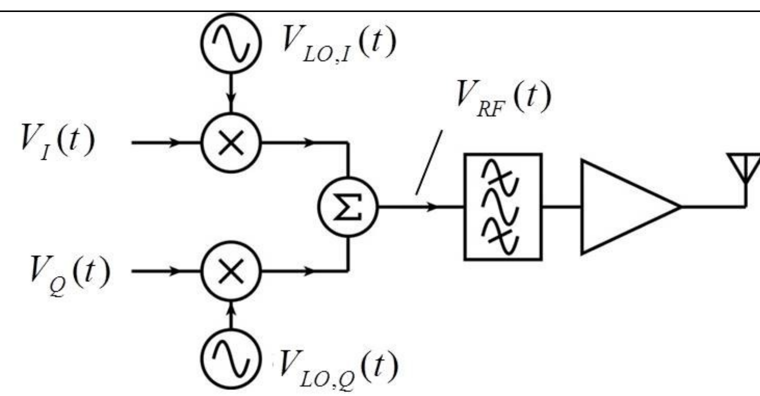
Problem 1: The local oscillator is a 1.6MHz cosine wave of 1 V amplitude. The message $V_M(t)$ is a 100 mV *sine* wave at 1kHz. V_0 is 0.1 Volts



(a) Compute $V_{RF}(t)$. (b) Make a clean graph of this using your favorite computer software. (c) Compute the Fourier Transform of $V_{RF}(t)$. Note carefully the phases of the sidebands. (d) If $V_{RF}(t)$ is delivered to a 50 Ohm load resistor, compute the *power* at each frequency in its Fourier spectrum.

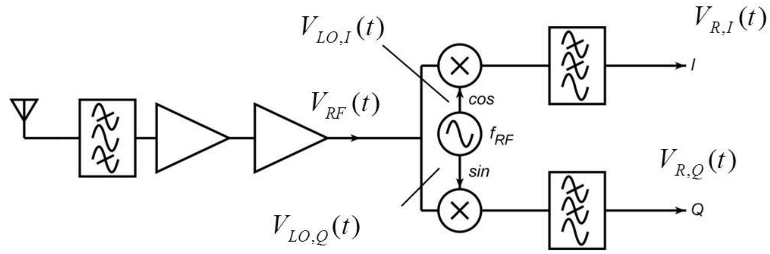
Problem 2: With the same parameters as problem 1, now $V_M(t)$ is a 100 mV *cosine* wave at 1kHz. (a) Again compute the Fourier Transform of $V_{RF}(t)$. Please explain how the sidebands differ in the cases of problem #1 and problem #2.

Problem 3: This is called Quadrature amplitude modulation. QAM is widely used in modern digital wireless links. We will work a simplified case. $V_{LO,I}(t)$ is a 2.4 GHz cosine wave of 1 V amplitude. $V_{LO,Q}(t)$ is a 2.4 GHz *sine* wave of *-1* V amplitude.

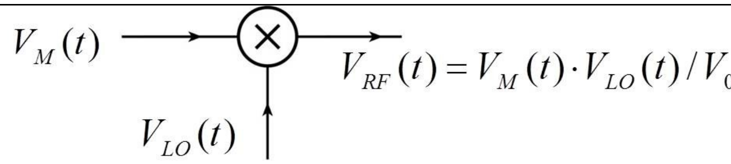


V_0 is 0.1 Volts. $V_I(t)$ is the sum of a 100 mV *sine* wave at 1kHz and a 100 mV *cosine* wave at 2 kHz. $V_Q(t)$ is the sum of a 100 mV *sine* wave at 3kHz and a 100 mV *cosine* wave at 4 kHz . (a) Compute $V_{RF}(t)$ (b) Compute the Fourier Transform of $V_{RF}(t)$. Note carefully the phases of the sidebands. (c) Try to explain in words how a receiver might be able to determine $V_I(t)$ and $V_Q(t)$ from the received signal $V_{RF}(t)$.

Problem 4: Using the parameters of problem 3, here is a receiver for QAM. Again $V_{LO,I}(t)$ is a 2.4 GHz cosine wave of 1 V amplitude. $V_{LO,Q}(t)$ is a 2.4 GHz *sine* wave of *-1* V amplitude. V_0 is 0.1 Volts. (a) Find $V_{R,I}(t)$ and $V_{R,Q}(t)$. (b) Explain the purpose of the indicated low-pass filters.



Problem 5: Returning to problem 1, the local oscillator is again a 1.6MHz cosine wave of 1 V amplitude. The message $V_M(t)$ is a 100 mV *sine* wave at 1kHz, to which we have added a +200 mV DC voltage. V_0 is 0.1 Volts



(a) Compute $V_{RF}(t)$. (b) Make a clean graph of this using your favorite computer software. (c) Compute the Fourier Transform of $V_{RF}(t)$. Note carefully the phases of the sidebands. (d) If $V_{RF}(t)$ is delivered to a 50 Ohm load resistor, compute the *power* at each frequency in its Fourier spectrum. (e) Comment on how much RF power, as a fraction of the total RF power, has been devoted to radiating the 1.6 MHz carrier.