ECE 145b first problem set: Radio propagation, architectures, signals

Problem 1: Compare two radio links, one at 1 GHz, one at 38 GHz. The transmitter is 1 km from the receiver. There is a circular obstruction directly between the transmitter and the receiver, 2 meters from the receiver. What area would this circular obstruction be if it were to cover the first Fresnel zone (if this zone is defined according to the definition in the class notes.)

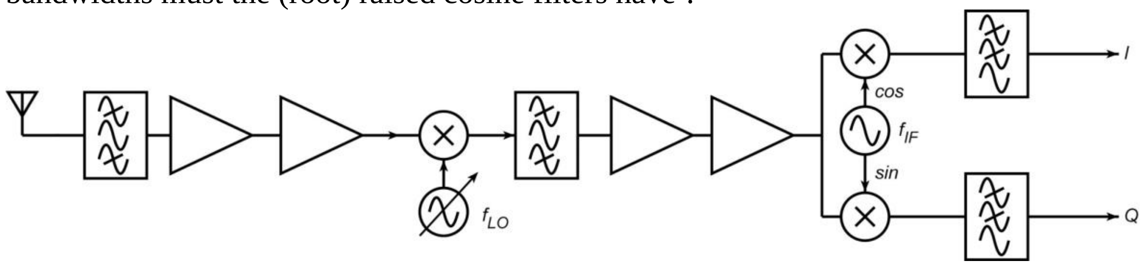
Problem 2: Compare two radio links, one at 1 GHz, one at 38 GHz. The transmitter is 2 km from the receiver. The transmitter has 15 dB directivity, the receiver has 20 dB. In the absence of atmospheric attenuation, what is $P_{received} / P_{transmitted}$ in the 2 cases ? What would $P_{received} / P_{transmitted}$ be if it were raining at 50 mm/hr.? Note that at 1 GHz, with a $\sim f^4$ dependence of rain attenuation with frequency, the rain attenuation over 2 km will be negligible. What are the effective aperture areas of the transmitter and receiver ? What are the angular beamwidths (solid angles, in steradians) of the antennas ? What are the angular beamwidths (normal angles in degrees) if we assume that the beam patterns are circularly symmetric .

Problem 3: If we now assume a *transmitter* (cell phone base station) phased array at 38 GHz, with a array having 4 rows and 8 columns of elements, with each element being 1.5 wavelengths tall and 0.5 wavelengths wide, what is the overall array directivity ? What are the vertical and horizontal beam widths ? What is the vertical and horizontal angular scanning range ? If the beam is scanned *horizontally* by 10 degrees from normal, and scanned *vertically* by zero degrees from normal, what is the relative electrical phase-shift between adjacent elements necessary to do this ? Now assume that we have a 4-element receiver phased array in our cell phone handset, where each element is half-wavelength by half-wavelength. What is its directivity ? If the transmitter and receiver are at 1 km separation, with zero atmospheric attenuation, what would be $P_{received} / P_{transmitted}$? Working in cm instead of wavelengths, what are the dimensions of the array antennas?

Problem 4a: Use this 38 GHz carrier frequency, with a raised-cosine beta factor of zero, and assume that you use QPSK modulation at 500 Mb/s total data rate (bit rate, not symbol rate). Plot the power spectral density (W/Hz) of the resulting transmitted signal. Assume that the total radiated power is 1.0 W. What is the bandwidth of the radiated signal ?

Problem 4b: Repeat problem 4a with 16QAM modulation at 500 Mb/s total data rate (bit rate, not symbol rate). Plot the power spectral density (W/Hz) of the resulting transmitted signal. Assume that the total radiated power is 1.0 W. What is the bandwidth of the radiated signal ?

Problem 5: Assuming the parameters of problem 4a and the block diagram below, if we assume a 30 GHz local oscillator, an 8 GHz IF frequency, and root-raised-cosine filters with $\beta = 0$, make clean plots of the Fourier signal *power* spectrum (a) at the antenna (b) at the output of the first mixer and (c) at the outputs of the I/Q demodulator. What bandwidths must the (root) raised cosine filters have ?



Problem 6: Radio transmission range. We will learn later that the minimum receiver power is $P_{\min} = kTFBQ^2$ where k is Boltzmann's constant, T is the absolute temperature, F is the receiver noise figure , B is the bit rate and Q^2 is the required signal/noise ratio. Simple QPSK without error-correcting codes requires Q=3.1 for 1E-3 bit error rate. If we assume QPSK, a 5 dB receiver noise figure, a 1 Gb/s data transmission rate, and the antenna array dimensions and propagation distance of problem 3, what minimum radiated power is required assuming fair weather ? What would it be if we require, for reliable operation, ten times more received power than the minimum. If it is raining at a 50 mm/hr, and if we still require the 10 dB safety margin how much total transmitted power would be required ? Note that in all cases the output power per transmitter array element is the total output power divided by the number of transmitter array elements.