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ECEN 5634
Lab 9 Report

Q0: The largest dimension of the antenna is 9.02 cm, so the far field distance at our chosen frequency of 9.4 GHz is $r = \frac{2d^2}{\lambda} = \frac{2*(0.0902^2)}{0.0319} = 51$ cm. The maximum power transmitted is 26 dBm or 398 mW, and the power density at the edge of the far field when transmitting this power would be $S_R = \frac{P_T G_T}{4\pi r^2} = \frac{(398\ mW)*10}{4\pi*(51\ cm)^2} = 0.121\ \frac{mW}{cm^2}$, which is 0.5% of the occupational safety limit in Canada. Therefore, it does not pose any danger at the far-field. If we assume that the power density across the aperture is constant, then we find that it is $\frac{398\ mW}{(5.3\ cm)(7.3\ cm)} = 10.29\ \frac{mW}{cm^2}$, which is also less than the occupational safety limit. However, because the power may not actually be distributed evenly at the aperture, it is probably best to avoid the area right in front of it if transmitting maximum power.

Part I

Q1: We expect to see a 1 kHz square wave on the oscilloscope, because the input to the oscilloscope is the output of the IF amp/demodulator, which is the demodulated IF signal (the 1 kHz square wave that we are sending).

Figure 1: Oscilloscope display of IF amp/demodulator output for modulated 1 kHz square wave sent.

Part II

Q2: We know that the output voltage of a Schottky diode is proportional to the input RF power (from Lab 3). By Joule's Law, power is proportional to voltage squared, so we expect the IF power to be proportional to the LO power squared.

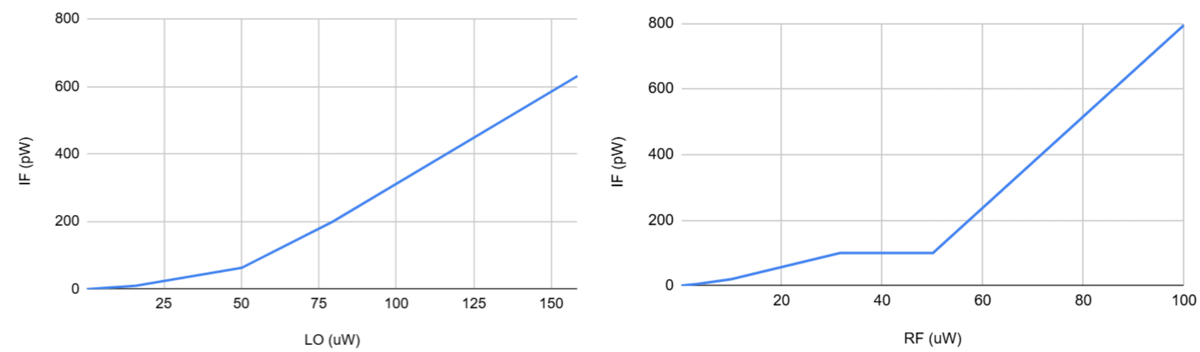

Figure 2: IF vs LO power while RF maintained at 0.0316 mW (left) and IF vs RF power while LO maintained at 0.0501 mW (right).

Q3: The behavior of the IF power in the two graphs above is more or less the same. This is because to the mixer, it does not matter where the power is coming from. Power from both ports will be mixed in the same way, and the power of the IF signal will be proportional to the product of the RF and LO powers squared. The only difference between the two graphs is that the one on the right is steeper overall, which I think is due to the fact that the constant variable (LO power) is kept at a higher value compared to the graph on the left (where it is RF power).

Part III

Q4: The largest dimension of the antenna is 9.02 cm, so the minimum far field distance at 9 GHz is $r = \frac{2d^2}{\lambda} = \frac{2*(0.0902^2)}{0.0333}$ = 49 cm.

Q5: If transmit power is kept constant, then received power is inversely proportional to distance between the antennas. Therefore, we have $P_{R1}r_1^{\ 2} = P_{R2}r_2^{\ 2}$. If we set P_{R1} = -15 dBm = 0.0316 mW, $r_1 = 0.5\,m$, and P_{R2} = -60 dBm = 0.000001 mW, then we can solve for r_2 as $r_2 = \sqrt{\frac{0.5^2*0.0316}{0.000001}}$ = 89 m, which is the maximum distance between the two horns to detect a signal.

Q6: We turned the variable attenuator to 27 dB before we observed that the signal and noise amplitudes were equal at 50 cm. If we turned it back to 0 dB, then the received power would increase by a factor of $10^{2.7}$=501.2. Therefore, we could increase the distance by a factor of $\sqrt{501.2} = 22.39$ to have SNR = 1, which would be a maximum distance of 22.39*(0.5 m) = 11.19 m.

Q7: The distance that the signal travels has increased by a factor of $\frac{1}{cos(\theta)}$, which means that the transmitted power must increase by a factor of $\frac{1}{cos^2(\theta)}$ to receive the same amount of power at the receiving horn. With the previous settings, we measured P_T = -13.1 dBm = 0.049 mW. If the angle was $\theta = \frac{\pi}{4}$, for example, then the required power would increase to P_T =$\sqrt{2}^{2} * 0.049\,mW = 0.098\,mW$.

Part IV
Q8: With the 1 kHz signal, we were able to hear a single tone, and with the phone connected, we were able to hear its music. We found that the best quality sound was not when the IF power was maximized, as the noise became very loud and the lower tones became somewhat tinny.

Q9: The AM demodulator can only demodulate the FM signal if we are operating near the edge of the filter where there is a steep slope, implying that a change in frequency correlates with a change in amplitude. Therefore, we got the best quality of sound when we were on the steepest part of the filter on either side of the notch. If we are directly in the middle then we are not able to demodulate the signal anymore because we lose the monotonic scaling relationship between frequency and amplitude.

Part V
Q10: The demodulation still works without an LO because the RF carrier that is sent with the signal performs its function. It does not matter whether this signal is generated locally or enters the mixer at the same port as the modulated signal. Either way, the two inputs are mixed and the signal with the information is downconverted. Port 1 is fitted terminated with a short so that the reflection coefficient is -1, which means that the incoming signal and reflected signal will cancel out. This eliminates any extraneous signals that are reflected from ports 2 and 3, if either of them is not perfectly matched.

Q11: We sent a QPSK modulated signal between the SDRs. We found that although the received signal had some noise, the symbols were still distinguishable. We then held the polarizer between the antennas and rotated it. When it was horizontal, there was no change in the received signal. As we rotated it, the received signal gradually reduced in amplitude to 0 when the polarizer was vertical.

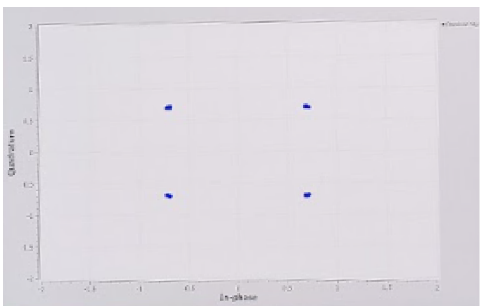

Figure 3: Transmitted constellation.

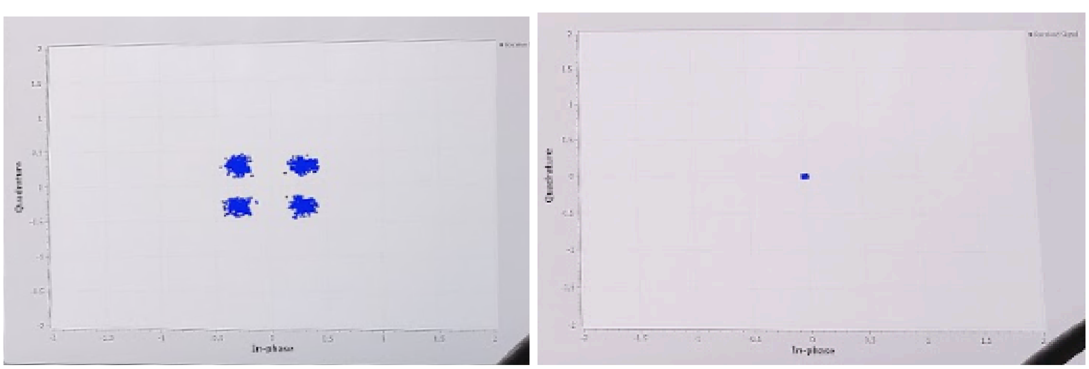

Figure 4: Received constellation with polarizer held horizontally (left) and vertically (right).

Q13: Finally we experimented with multipath fading. We found that as we moved the reflector closer to the antennas, shortening the overall length of the reflected path, that the received signal would periodically increase to maxima and decrease to minima. The minima were achieved when the additional distance of the reflected path resulted in that signal being out of phase with the line-of-sight one so that they destructively interfered. The maxima were achieved when the reflected signal reached the antenna with the same phase as the line-of-sight signal, so they added together to be greater than just the line-of-sight signal.

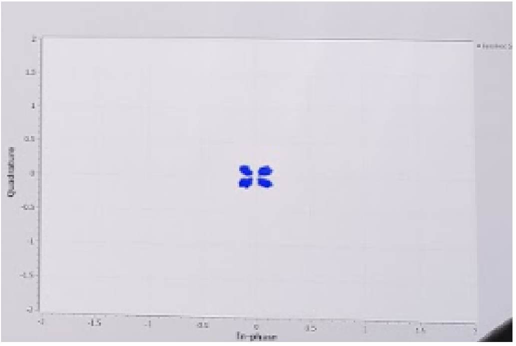

Figure 5: Received signal with horns misaligned and no reflector.

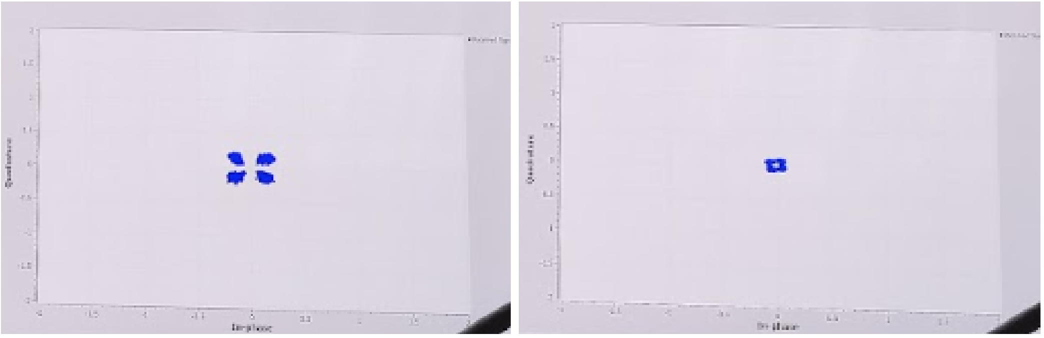

Figure 6: Received signal with reflector placed to achieve multipath constructive interference (left) and destructive interference (right).