OPTICAL COMMUNICATIONS TUTORIAL PROBLEMS: SET 2

1. An InGaAs LED (Bandgap $W_g = 0.95$eV, conversion efficiency $\eta = 0.053$) has a measured total harmonic distortion of 25dB for a peak sinusoidal input current of 50mA. The LED is biassed at 50mA and used in a two-channel frequency division multiplexed system carrying two signals: a 1kHz tone on a subcarrier at 1MHz and a 2kHz tone on a subcarrier at 2MHz. AM/IM is used as the modulation format, with the carrier modulated at 100% and the subcarrier at 50%. All of the power is received by a photodiode with a responsivity $\rho = 0.5$ A/W. Plot the spectrum of the current at the photodiode.

2. A PIN photodetector has a responsivity of 0.5 A/W and a 2nA dark current. The load resistance is 2000 ohms and the system bandwidth 50MHz. The temperature is 40 degrees Celcius. (a) At what value of received optic power is the thermal noise equal to the shot noise? (b) What is the signal-to-noise ratio at this power level? (c) What is the value of the shot-noise power at this value of the received optic power? Repeat for an APD having a gain of 100 and an unamplified dark current of 2nA.

3. The optcal power reaching a receiver is measured to be 1μW. The detector has a responsivity of 0.5 A/W and a dark current of 4nA. The temperature is 27 degrees Celcius, the receiver bandwidth 500MHz and the load resistance 50 ohms. (a) Compute the signal-to-noise ratio. (b) Compute the thermal-noise-limited SNR. (c) Compute the shot-noise-limited SNR. (d) What value of photodetector gain is needed to make the actual SNR just 5dB less than the quantum limit? Assume that the APD has negligible excess noise.

4. Consider a heterodyne receiver for a digital system. The photodetector has 2nA of dark current and a responsivity of 0.5 A/W. The temperature is 27 degrees Celcius, the load resistance 100 ohms, the IF bandwidth 500MHz and the received optic power is constant at 5nW when a binary "1" is received. (a) How much local-oscillator power is required to make the SNR just 1dB less than the quantum limit. (b) If this were not a heterodyne system, then the receiver's bandwidth could be as small as 250MHz. For this case determine the signal power required to achieve a SNR equal to that found in part (a).

5. A laser diode has a RIN of -135 dB/Hz. A receiver has a bandwidth of 1GHz and a received average power of 20μW. (a) compute the laser noise power at the receiver. (b) Compute the average laser noise current if the detector has a responsivity of 0.3 A/W.

6. Consider a transimpedance amplifier. The feedback resistance is 10KΩ and feedback capacitiance is 0.2pF. The diode capacitance is 5pF and the responsivity 0.5 A/W. If the incident optic power is 0.5μW, (a) Compute the receiver's output voltage, (b) Compute the receiver's 3dB bandwidth, (c) Compute the rms thermal noise current generated in the feedback resistor at 300K, (d) Compute the signal current, (e) Assuming negligible dark current and an amplifier noise figure of 4dB, compute the output SNR.

Design Problems

A. Transmit a video signal having a 4.5MHz bandwidth over a 10km path using analogue modulation. The SNR at the receiver must be 48dB or better.

B. Repeat problem A using digital modulation to achieve a bit-error-rate of 10^{-9} or better.

C. Transmit a 2Gbps NRZ signal over a 100km path without the use of repeaters. The error rate should be better than 10^{-9}.

D. Transmit a voice signal with a 4kHz bandwidth over a 100m length with a SNR of 30dB.

E. Transmit simultaneousely three channels over a 4km path: one for voice (4kHz bandwidth, SNR 25dB), one for video (4.5MHz bandwidth, SNR 40dB) and one for data (10Mbps data rate, BER 10^{-9}).