changes during a mission, but are confined to within the allocated pointing loss budget (assumed 2 dB of pointing loss). Therefore, the effect of Earth image size variations on the required optics system design is minimal.

Table (1) summarizes the operable IR camera update rates and FOV-per-pixel for meeting an assumed 2 dB of pointing loss allocation. The calculated maximum bias error, NEA and downlink beam fullwidth-at-half-maximum (FWHM) at the wavelength of 1064 nm is also summarized in this table.

References:
[1] H. Tsou, T. Y. Yan, “Maximum likelihood based extended-
Results

Figure 2 shows an example of the measured bit-error rate performance of the GM-APD-based receiver as a function of the incident photon flux, measured at the input fiber facet of the fiber-coupled APD. For this demonstration, the GM-APD was biased at 47V at a temperature of -40C, giving a dark count rate of 4.28 kHz and a detection efficiency of 28%. An error floor of $\sim 4 \times 10^{-2}$ is observed in the uncoded data. This error floor is a consequence of the noise characteristics of the detector—for gated-mode PPM, there is a finite probability that the detector will register a dark count before the incident pulse arrives. Such detection events will cause errors that cannot be mitigated by increasing the optical power incident on the receiver. No such error floor is observed when the 1/2-rate turbo code is employed. In this case, the receiver output is error-free for received powers in excess of 1.8 dB PPB (1.5 PPB). This performance represents a 6.9 dB penalty from the optimal capacity for this channel. The 5.5-dB penalty introduced by the 28% detection efficiency of the GM-APD accounts for most of measured penalty in performance. The remaining 1.4-dB penalty is due to coding and implementation losses. Note that after accounting for losses due to detection efficiency, the receiver provides error-free performance with -3.7 dB detected PPB, or, 2.34 bits per detected photon.

Summary

In summary, we have demonstrated a photon counting optical communication link using commercially-available Geiger-mode APDs operating at a wavelength of 1.55 µm. A receiver sensitivity of 1.5 incident PPB was demonstrated using high-efficiency PPM modulation together with a 1/2-rate turbo code. To the best of our knowledge, this is the most sensitive optical receiver reported to date. Moreover, this demonstration shows that even with current limitations in the detection efficiency of photon-counting detectors, photon-counting receivers can perform better than competing technologies in terms of overall receiver sensitivity.

References


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