Christmas Project Report: Optical Smart-card Data Transfer

Introduction

This project is intended to investigate and construct a system capable of communicating with a smart card in a room, without the need for contact or holding the card still while communication occurs. A data transport layer has already been developed, so this project will focus on the optical system and filtering necessary to complete a physical communications layer.

We plan to use an infrared emitting strip light used for security cameras as a light source. The smart cards would contain a retro-reflector (an optical device that reflects incoming light in the direction from whence it came) and a liquid crystal shutter to modulate the returning light beam.

This system has a number of challenges: it is a low-bandwidth system, with extremely low signal levels, and a high background noise level (typically from fluorescent lights).

The diagram below shows the system in use.

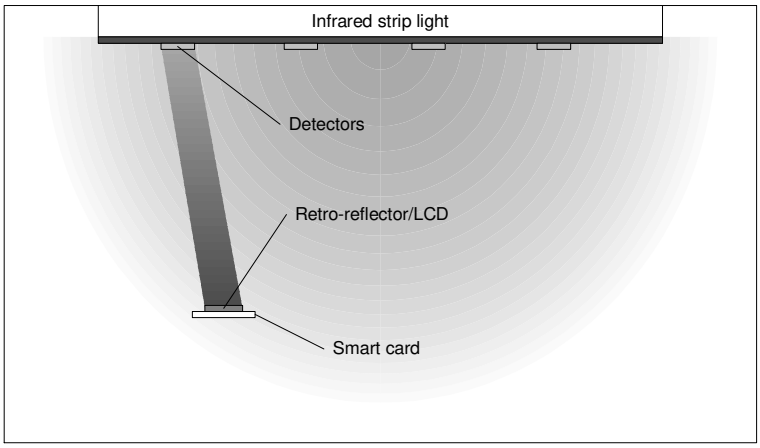

Figure 1: Schematic of optical system

The first step was to determine the link budget necessary for the detectors. Many hundreds of measurements were taken of the light profile of the strip light, to obtain the minimum intensity expected at the detector for a given position of the retro-reflector. These measurements also give an insight into the optimum position of detectors placed on the strip.

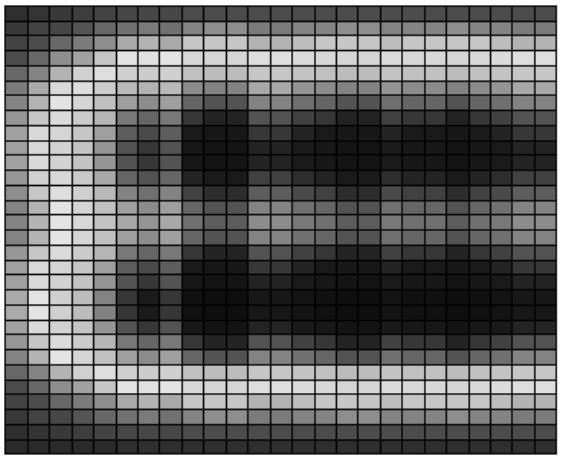

Figure 2: Surface plot of light output intensity

A Matlab program was then developed to estimate the power received by the detectors. This takes into account:

- Emitted power from the strip light;
- The reflectivity of the retro-reflector at varying angles;
- The expected coverage of the photo-detector.

The expected minimum intensity of light is approximately 10nW/cm^2.

Detection

The next step is to look at the detection of the returned signal. This signal may be as low as 10nW, and so detection will be difficult. There is a lot of noise present in the system, notably from fluorescent lights, which produce a great deal of noise at approximately 100Hz, and at harmonics thereof.

We considered the possibility of using a strip-style detector, such as a solar cell, but this has potentially very low bandwidth – solar cells are used for power, not communication, and as such their bandwidth is very low. Little real data is available for these, too. We will be able to use multiple photo-detectors instead to increase our coverage.

One possible technique for improving would be to use a carrier wave (modulated at the light source). This would allow coherent detection to be used, which would significantly improve the bit-error rate. However, after tests, it was found that the strip does not respond to variation in the input voltage, which indicates the presence of electronic circuitry in the strip itself (probably a DC-DC converter).

Extensive filtering will therefore have to be used to recover a usable signal with a low bit-error rate (BER). In order to achieve our goal of a BER of 10^{-9}, a signal-to-noise ratio of approximately 12:1 is required.

We will be using Manchester encoding for the signal, as this is easier to detect (no long periods of the 'off' state) than other methods, and clock recovery for this encoding scheme is well-established.

Plan

Week	Action
8th week MT	Complete tests on light strip
9th week MT	
0th week HT	Build testing rig with retro-reflector
1st week HT	Spectrum sampling
2nd week HT	System design
3rd week HT	Finalise design of system
4th week HT	PCB layout
5th week HT	PCB fabrication
6th week HT	Board population
7th week HT	Testing
8th week HT	