Visible Light Communications and Positioning (VLCP)

The automotive use case

White Paper

Intel Corporation

Introduction

The use of positioning sensors in automobiles is becoming increasingly common with the desire to facilitate utility and traffic safety by giving the driver information on the automobiles position relative to the surroundings. Several technologies exist to do this; such as sonar, radar, LIDAR and GPS. Each of these has advantages and disadvantages in regards to cost, complexity and performance. In this white paper we introduce an alternative method, based upon the assumption of automobile LED lighting – either taillights or headlights – that we believe is cost effective, low complexity, offers the promise of high accuracy and uses existing electromagnetic radiators (i.e. automobile illumination lighting).

Vehicular Safety

In a comprehensive report by the US Department of Transportation, a set of high potential beneficial safety applications, enabled by location estimation and vehicular communications, was identified. Examples include emergency electronic brake lighting; forward collision warning system; pre-crash warning; left turn assist and lane change warning systems. In each of these cases, estimating vehicle position very accurately (10's of centimeters to 3m) is critical to improving safety.

Several position estimation technologies exist and each of these has advantages and disadvantages in regards to cost, complexity and performance. For example, GPS does not provide sufficient accuracy for some vehicular positioning applications with the limitation that GPS requires a line-of-sight (LOS) view of the satellites (i.e. tunnels, urban canyons or parking garages can be problematic). Other techniques using detection and ranging can be used to get accurate position, such as LIDAR and RADAR; however, these systems require relatively complex equipment to get accurate location information.

Visible Light Positioning (VLP) for Vehicular Safety

VLP can provide high accuracy, cost effective, relative positioning information about the vehicles in the immediate vicinity which can supplement existing positioning systems such as GPS. The premise of visible light positioning (VLP) is based upon the emergence of automobile LED safety lighting. Today LED taillights are quite common on newer model cars and LED head lighting is emerging. LED lights have a modulation bandwidth due to the fast "on and off" time and can be amplitude modulated (i.e. on/off keyed) – at a rate not perceivable to the human eye – to transmit data waveforms. Figure 1 shows typical LED maximum data rates.

One particular waveform of interest in the VLP case is a ranging waveform, which is the kernel for realizing positioning algorithms. A case in point is GPS which is based upon pseudorandom sequences to determine the time difference of arrival (TDOA) between two signals received from two different satellites with known positions. In a similar manner, VLP uses a simple high rate repetitive on/off keying pattern to measure phase difference of arrival that can then be used to determine relative position. One-way positioning is used in which the light sources transmit a positioning signal and the receiver processes this signal so as to determine the relative position (i.e. similar to the concept behind GPS). No direct cooperation exists between the source and the receiver other than the source needs to transmit the positioning waveform.

In Figure 2, car A amplitude modulates each taillight with a precise frequency RF tone. Meanwhile, each headlight of car B contains a photodetector sensor array behind a lens that receives the signals from the taillights and processes the tone data in order to calculate the relative position between the cars. Tone frequencies that have been investigated range between 20 MHz and 50 MHz. It should be noted that the distances L_A and L_B are known and can be exchanged between the cars.

Figure 3 shows an image array/lens combination that is used to spatially separate multiple light sources. The pixels of the image are identified that are being illuminated by modulated sources and then sources are paired up per vehicle for processing. The processing consists of measuring the phase difference of arrival at the automobile caused by the difference in the propagation path length. In a GPS application this would be known as time difference of arrival (TDOA), which is the basis for multilateration position determination, also known as hyperbolic positioning[1]. A similar principle is used here.

Information is exchanged between vehicles via ranging packets that consist of a visible light communications header and information field, followed by a position ranging field as shown in Figure 4.

[1] http://en.wikipedia.org/wiki/Multilateration

Intel Research

At Intel, we are looking at the connected vehicle. We believe a compelling use case would be the merger of positioning technology to enable automobiles to form a moving map of the traffic around them, and then share this information via a wireless network to provide increased traffic safety as shown in Figure 5. The ultimate goal is to enable intelligent driving systems. To be sure, such a vision will require an infrastructure build out based upon a compelling argument and undoubtedly a regulatory mandate.

Conclusion

In this white paper we've introduced the concept of visible light communications and positioning. Given the assumption of LED auto safety lighting, it is believed high accuracy positioning can be done without deploying additional electromagnetic radiators on the automobile; we just use the already deployed safety lighting.

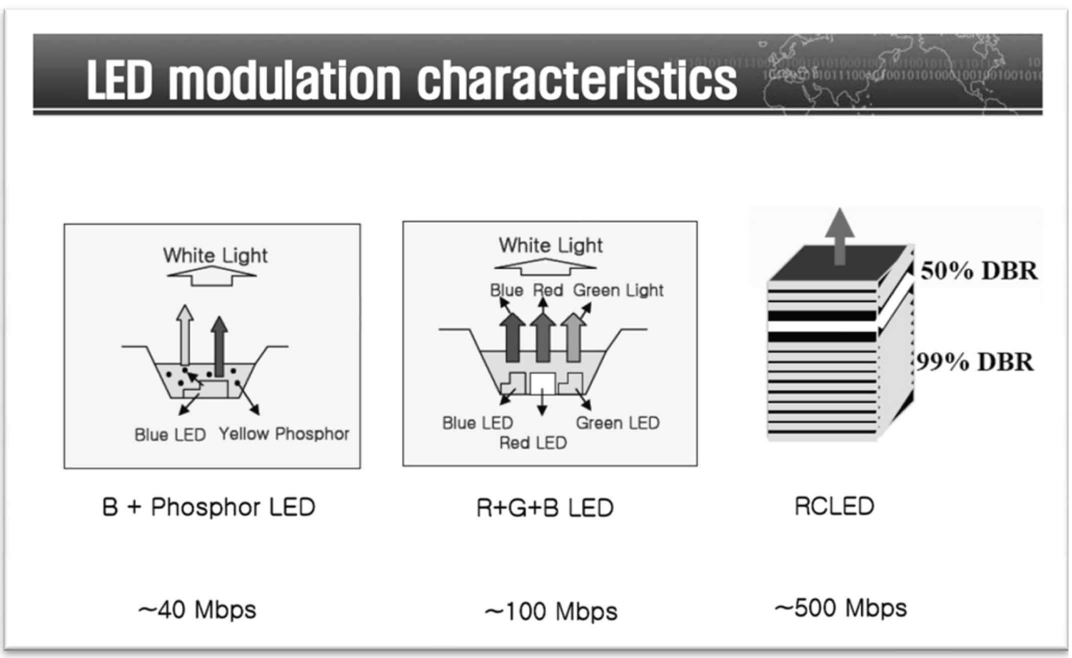

Figure 1 – Typical LED modulation characteristics

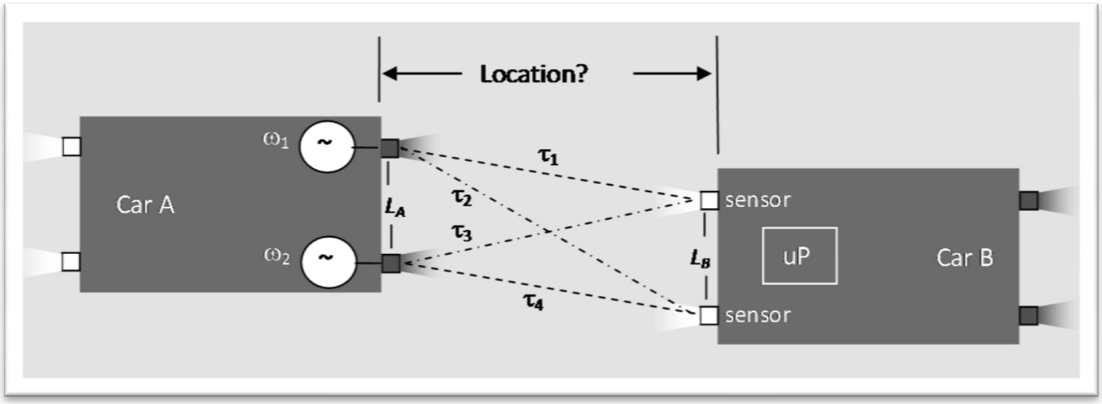

Figure 2 - One-way ranging between automobiles *(ref. Intel patent application)*

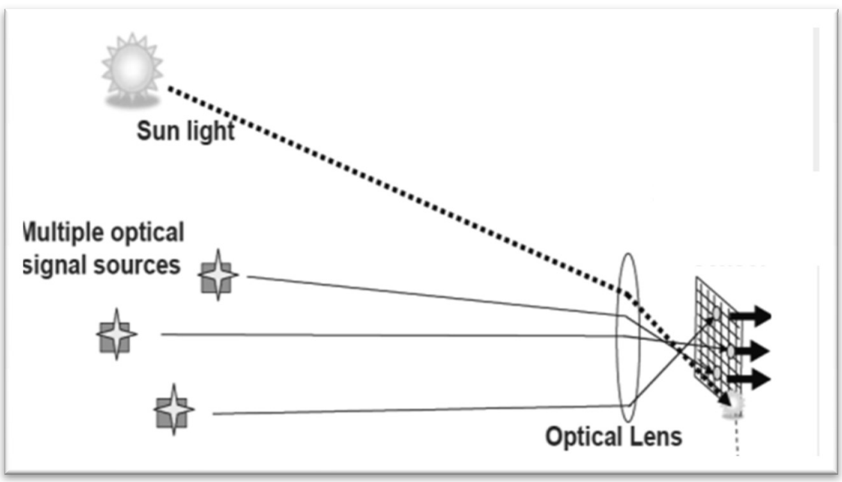

Figure 3 - Multiple source separation at the receiver using a lens and image array

Figure 4 - Ranging packet with auxiliary data transmission

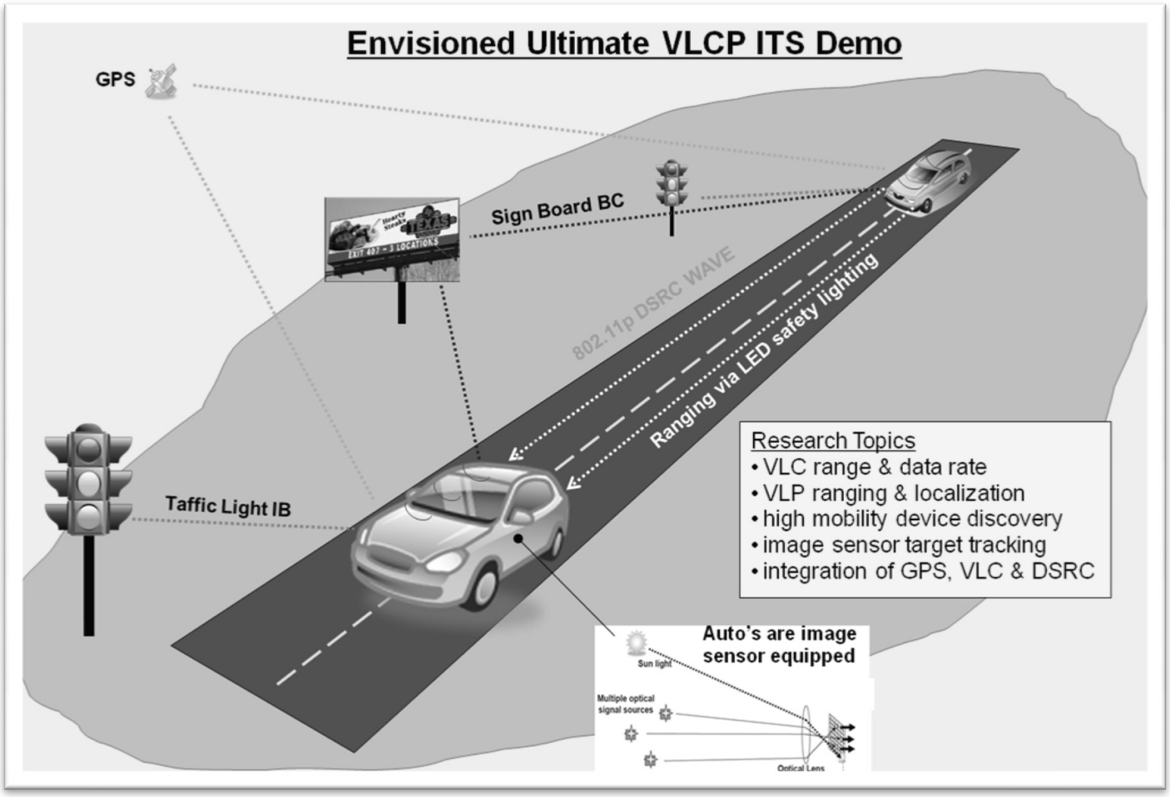

Figure 5 - The vision for a compelling VLCP use case