ISM Band Interference and Locatalite

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Abstract
LocataNet operates in the 2.4GHz ISM band, where there are unlimited number of other transmitter types. It is well known that other radio trilateration systems such as GPS are significantly affected by interference so it can be expected that the performance of LocataNet will also suffer. In this paper, we examine the effects of a common ISM band transmitter, such as Wifi, on LocataNet, and report these effects.

Keywords: Interference, ISM, radio trilateration, WiFi

1 Introduction

LocataNet is a radio trilateration system which employs spread spectrum technology and operate at 2.4 GHz in ISM band [1]. There are unlimited number of transmitters in this band, such as Wifi and Bluetooth, which also employ spread spectrum and thus can significantly interfere with LocataNet signal at a wider band of frequencies; a similar situation that can happen to other trilateration systems such as GPS ([4] and [5]). This paper will examine the effects of Wifi interference on LocataNet.

For this objective an experiment was performed whereby a Wifi transmit signa at various frequency channels, and its effect to the performance of LocataNet is investigated.

In the following the LocataNet and wireless network is described, followed by the description of the experimental set-up, and lastly the results are presented and analysed.

2 Locatanet

A LocataNet is composed of a Locata and five or more Locatalites which are analogous to receiver and satellites in GPS system, respectively, as illustrated in Figure 1. One of these Locatalites is called the master and the rest are called slaves. The master has two antennas; one, labelled Txm_U for sending signal to all slaves, indicated by the finely dashed arrow in Figure 2, and the other, Txm_L, for sending signal to the Locata. The slaves has three antennas, two of which are used for sending signal to the Locata, labelled Tx_L and Tx_U, indicated by the coarsely dashed arrows, and one, labelled Rx, used for receiving signal from Txm_1. The operating frequencies of these antennas are within ISM band and are proprietary information [2].

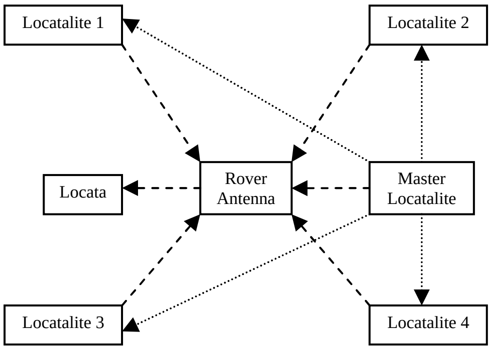

Figure 1: LocataNet configuration

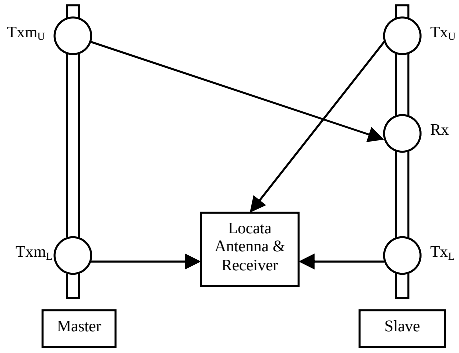

Figure 2: Antenna configuration in LocataNet

The R_x antenna of each slave Locatalite will receive signal from Txm_1 of the master in order for it to follow the latter's clock pace, a state known as time-lock [1]. Further, the signal will be use to compute other parameters including tracking state which described the time-lock status that is given every seconds of LocataNet time system. A tracking status greater than 89 signifies that the Locatalite is tracking the master's clock and a lesser value signifies otherwise.

If the interference at the slave Locatalite receiver is strong enough the Locatalite may not be able to maintain time lock which will cause it to stop transmitting to the Locata and consequently could cause error in the Locata positioning computation. This supports the relevance of investigating interference on slave Locatalite.

3 Access Point

As mentioned above a wireless network, Wifi, was employed to create interference on the LocataNet system. From a computer the data is transferred via an access point (Spark LAN WX-1590) to a laptop which receives the signal using a wireless card (NetGear MA521), thereby forming a wireless network. This access point is in spread spectrum mode and operates in the ISM band from 2400 to 2480 MHz at several selectable carrier frequencies [3].

4 Experiment

The spectrum of Wifi's access point (AP) signal was first gathered by placing an antenna nearest to the AP and connecting this antenna to a spectrum analyser (Anritsu). The spectrum gathering was performed for Wifi's various channels of operation and for the master Locatalite's transmitted signal.

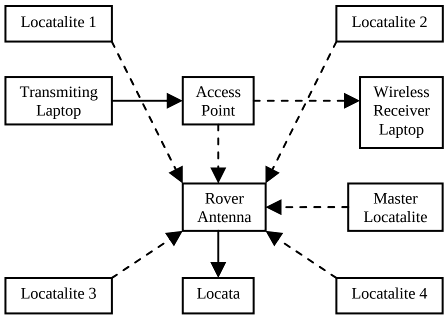

Figure 3: Experimental set-up for Wifi Interference

The experimental set-up for ISM band interference on LocataNet is show in Figure 3. This is composed of the LocataNet and a wireless network which transmit in all directions thereby interfering the signal from the master transmitter to receiver of slave Locatalites.

After all slave Locatalites are time-locked to the master the AP is placed at some far position and then set to transfer data wirelessly thereby interfering the signal from Txm_U. If the time-lock is not lost the position is logged and the access point is displaced towards the Locatalite by an increment of 5 cm.

Considering that the master spectra has centre frequency of 2.4125 GHz which is equivalent to a wavelength of 12.43 cm this increment is enough to observe any variation of system behaviour with respect to the said displacement assuming that reflection is only from a plain ground and that no signal obstructions.

This displacement process is repeated until the access point is in such a position, called boundary, that tracking is lost. Then the data transfer is put off until the Locatalite can recover from the loss. Once recovered, the Wifi is set to another channel and the process above is repeated. The same procedure was applied to other slave Locatalites.

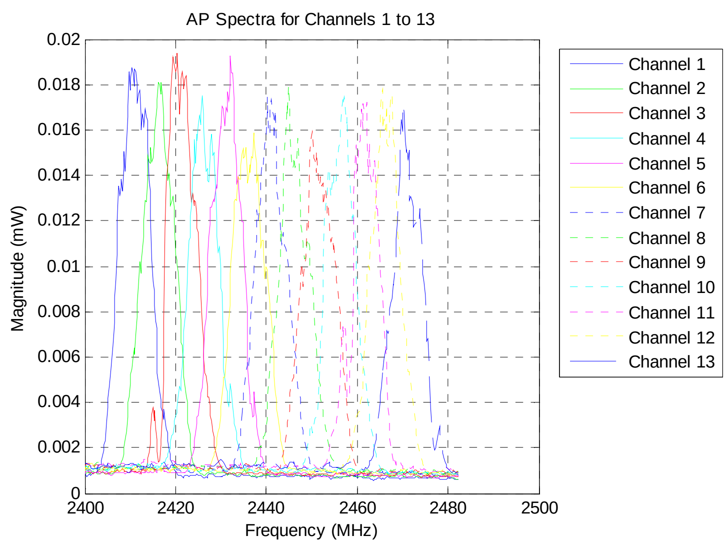

Figure 4: Wifi spectra for different channels

5 Results and Analysis

The measurement on Wifi spectra for channels 1 to 13 yielded a series of spectrum shown in Figure 4 whose bandwidth is 15MHz and centre frequencies are approximately separated by 5 MHz arranged in channel order. The spectrum of master's transmitter is shown in Figure 5 which is around channel 1 and 2 of Wifi's spectrum.

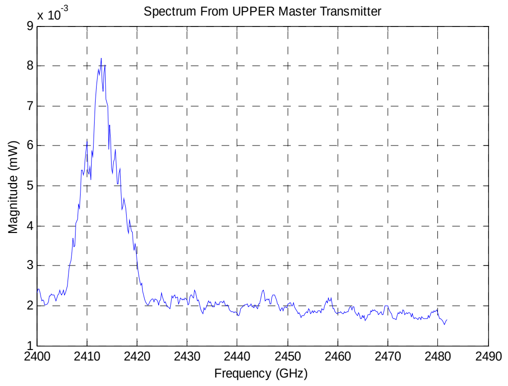

Figure 5 : Spectrum for signal from upper transmitter of the master Locatalite

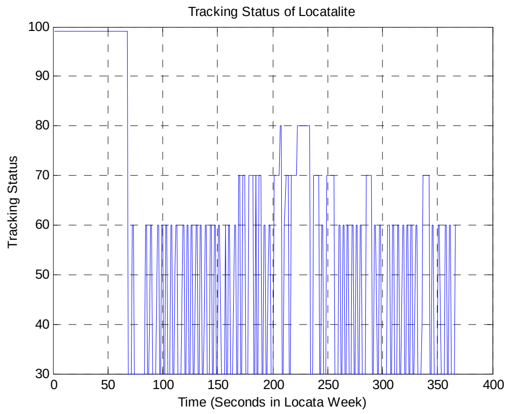

Figure 6: Tracking status of Locatalite prior and during intereference

In the experiment two Locatalites, labelled left and right Locatalite, were tested. A sample tracking status from one of these Locatalites is shown in Figure 6 which, prior to Wifi interference, displays a tracking status greater than 89, denoting time-lock for about 52 seconds (LocataNet time system), and a fluctuating tracking status with value lesser than 90, denoting time-lock loss, after interference was introduced. The figure illustrates the effect of interference on time-lock.

The search for boundary yielded the graph for left and right Locatalites in Figure 7. As mentioned above this has an accuracy of 5cm. It is evident that channels 1 and 2 required the farthest boundary while the rest has decreasing distance with increasing channel number.

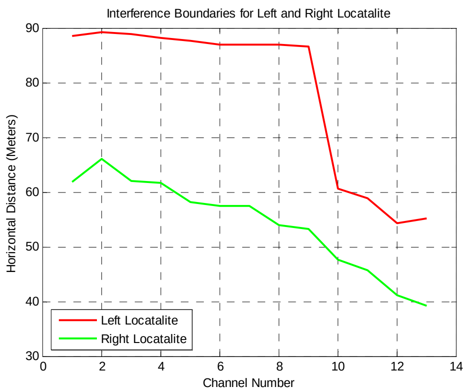

Figure 7: Interference Boundaries for Left and Right Locatalites

The interference on slave Locatalite's received signal is a combination of direct, reflected, refracted, and diffracted waves from the access point antenna. When one of these waves is absent the interference decreases in effectivity. This will require stronger signal, i.e., shorter boundary to achieve the same effectivity as with all types of waves present. In the left Locatalite graph, for the boundary of channels greater than 8, the ground reflected wave is obstructed and the AP is no longer in a position to cause reflection of rays via surrounding objects to the Locatalite receiver antenna. This could explain the sudden drop on the said portion of left Locatalite graph.

Further, when the direction from a boundary to the slave Locatalite receiver is in such a way that the latter's antenna gain is lesser and when diffracted waves dominates these will require stronger signal from the access point, i.e., shorter boundary. The shorter boundary of right Locatalite could be attributed to these factors.

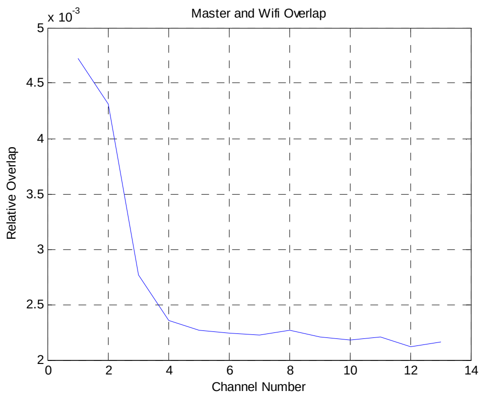

Figure 8: Master and Wifi spectra overlap measure

Let us define the measure of overlap between master and Wifi spectra as,

$$O_c = \frac{\int_{f_0}^{f_1} M(f) W_c^*(f) df}{\int_{f_0}^{f_1} M(\alpha) d\alpha \int_{f_0}^{f_1} W_c(\beta) d\beta} \qquad (1)$$

where $M(f)$ and $W_c(f)$ are the master and Wifi spectra at channel c respectively, and f_0 and f_1 are the two edges of Wifi band, 2.4 and 2.48 GHz respectively. When calculated, Equation (1) yields Figure 8. The proprietary Locatalite signal processing system could be responsible for large difference in graph shapes of Figure 7 and Figure 8, however, the two are similar in the sense of decreasing function with respect to channel number, i.e., increasing frequency away from master's centre frequency.

6 Concluding Remarks

Based on Figure 7 and Figure 8 it was concluded that the relationship of the degree of overlap between Wifi and master spectra and the distance boundary is monotonically increasing.

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