Beat Flicker – A Temporal Light Artefact due to Multiple Sources of Time Modulated Light

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Introduction

Metrics of temporal light artefacts (TLAs) are tools meant to quantify the magnitude of the impact of temporal modulated light generated by light sources. However, just assigning a TLA metrics to a light source is not necessarily an easy task. For example, a luminaire containing two drivers operating on different frequencies could generate a superposition light intensity waveform, resulting in some TLA values at one moment, and different TLA values at another moment, here a phenomenon called *beat flicker*. In the present work, waveforms as such, both authentic and simulated, are investigated with respect to several TLA metrics. The objective is to draw attention to the challenge of presence of beat flicker, which might arise in the case of a single luminaire or for that matter in the case of an entire lighting environment containing several light sources.

Method

Both authentic and simulated superposition waveforms (20 s. duration) are investigated. In the authentic case, two ceiling luminaires with slightly different frequencies of pulse width modulation are investigated (see Figure 1). Light intensity variations from the lamps are recorded at a sample rate of 100.000 S/s, using a photodiode and an amplifier. Figure 2 shows the waveforms from the two individual lamps and two examples of how the superposition of the two individual waveforms looks at different positions in time.

In the simulated case, two subcases of waveforms are investigated: sinusoidal and square. In each subcases, two waveforms are combined, one with frequency f and the other with frequency f+Δfreq. A frequency f = 500 Hz is selected as a starting point, and four different cases of Δfreq is investigated: 0 Hz (equals a single waveform), 0.2 Hz, 1 Hz and 10 Hz. Figure 3 shows examples of a resulting superposition waveforms of two combined square waveforms (here 500 Hz and 500.2 Hz), at two positions in time separated by 2 ms.

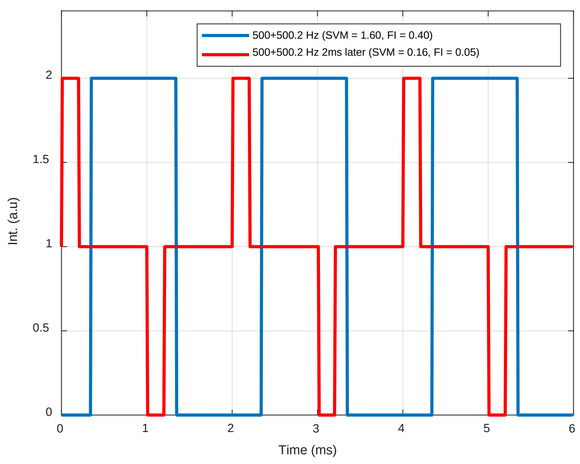

Figure 3 – Superposition of two square shaped waveforms of 500 Hz and 500.2 Hz, at two different positions in time, generating different TLA values (shown in the legend).

The waveforms are analysed with respect to stroboscopic visibility measure (SVM), flicker index (FI) and modulation depth (MD), at different starting positions in time. The duration the measurement window is 1 s.

Results

The frequency difference between the two lamps in the authentic case is two big to notice any major beat flicker. However, it is observed that both the SVM and FI are lower for the combined light of the two lamps, compared to the values from the two lamps individually. I.e. it is possible to combine waveforms with slightly different frequencies to deliberately achieve lower TLA values.

Due to limited space, only the results from the simulated square waveforms and with respect to SVM are presented here. Figure 4 shows the time resolved SVM for combined waveforms with four different cases of Δfreq. As can be seen, the SVM is constant at both low and high Δfreq (0 Hz and 10 Hz respectively), but at different values (1.72 and 1.04, respectively). Hence, it is possible to achieve a lower SVM value if one combine two waveforms with a frequency difference greater than 10 Hz. Actually, a thorough investigation shows that the SVM value stabilizes already at a frequency difference of 2 Hz. In the case of using two square waveforms with the frequencies of 500 and 500.2 Hz the SVM value will oscillate between 1.73 and 0.16 (indicated by the red curve) with a period time of 5 seconds. In such a case, it is therefore a high risk of measuring a lower SVM value than the highest occurring.

Conclusions

It is shown that light originating from a multiple light source luminaire could in some cases give rise to temporal variations in TLA metric values, due to the phenomenon in this paper called beat flicker.

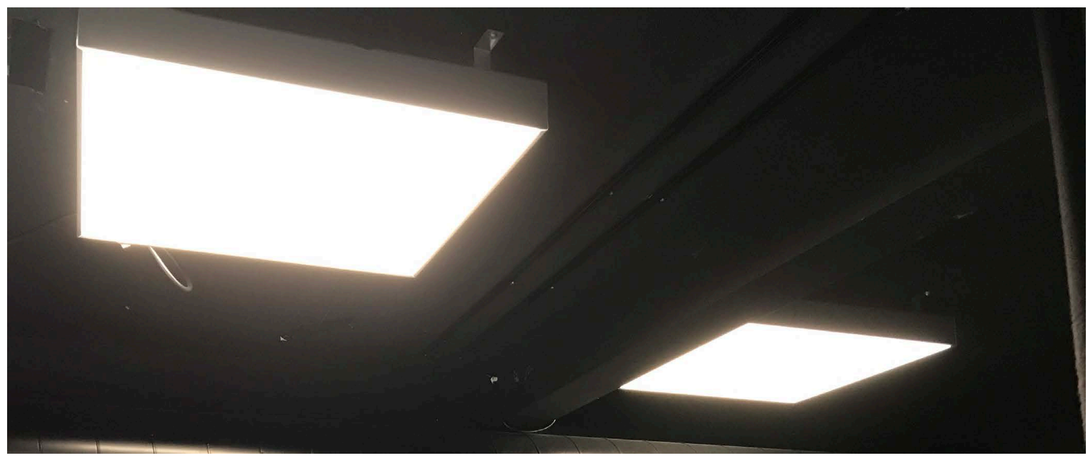

Figure 1 – Two 60x60 cm ceiling LED lamps in a facility at DTU used as an authentic example. The lamps are dimmable using pulse width modulation, however using slightly different frequencies. The left lamp (lamp 2) exhibit 551.8 Hz and the right lamp (lamp 1) exhibit 546.7 Hz.

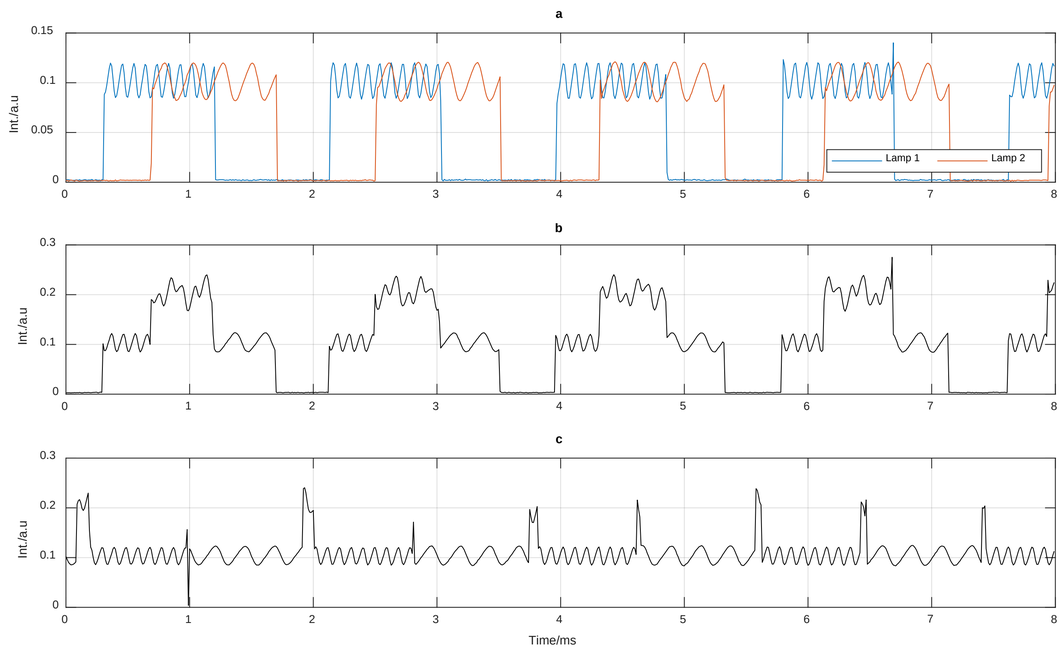

Figure 2 – a) Separated light intensity waveforms from lamp 1 @ 546.7 Hz and lamp 2 @ 551.8 Hz. b) Superposition of the two waveforms in a. c) Superposition of waveforms about 130 ms later compared to b.

It is observed that it's possible to combine waveforms with slightly different frequencies to deliberately achieve lower TLA values. Weather this is a good strategy or not is too early to tell, since it cannot be excluded that the resulting temporal modulated light could have a non-visual effect on humans. One important conclusion is that in order to fairly assess TML, it is necessary to make a more thorough investigation of the waveform in question. The presence of beat flicker could be difficult to detect using hand held TLA measurement devices, and should be taken into consideration when standards of measurements procedures of TLAs are being constructed. If temporal variations of a TLA value are observed, it is recommended to declare the highest occurring value.

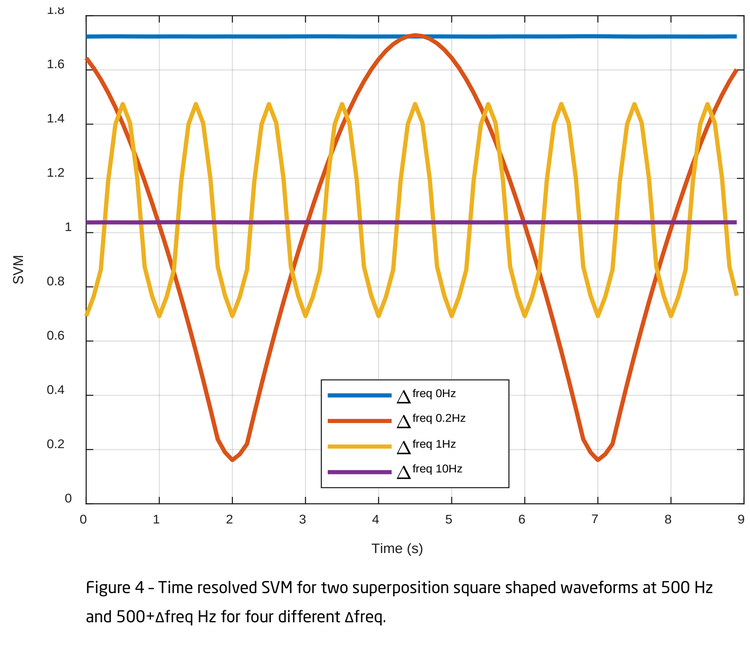

Figure 4 – Time resolved SVM for two superposition square shaped waveforms at 500 Hz and 500+Δfreq Hz for four different Δfreq.

Acknowledgment

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