Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

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Abstract: The forthcoming standard IEEE 1789 addresses modulation frequencies for lighting and signalling LEDs. In this contribution I provide an overview of the IEEE-1789 PAR scope and currently proposed minimum modulation frequencies for LEDs. Potential implications for IEEE 802.15.7, draft D0, are discussed.

Purpose: Helping TG 802.15.7 decide on modulation frequencies for the forthcoming standard.

Flicker definition according to IEEE 1789

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Motivation for this contribution

- Modulation-frequency recommendations in IEEE 802.15.7 baseline draft (f ≥ 200 Hz, Section 5.7) based on literature study conducted by SG (802.15-08-0261-01-0vlc)

- TG IEEE 1789 commissioned to draft recommendations for modulation of LEDs. Main focus: flicker.

- This contribution: summary of current state of IEEE 1789 discussions and their implications for VLC modulation frequencies

Brief history of IEEE 1789

- Approval of PAR September 2008
- Expected submittal to RevCom: December 2010
- Chapter draft on biological effects of flicker in December 2009 [Wilkins, 2009] → basis for this presentation

IEEE-1789 PAR scope

1) Define the concept of modulation frequencies for LEDs and discuss their applications to LED lighting.

2) Describe LED lighting applications in which modulation frequencies pose possible health risks to users.

3) Discuss the concept of dimming of LEDs by modulating the frequency of driving currents/voltage.

4) Present recommendations for modulation frequencies for LED lighting and dimming applications to protect against known adverse health effects.

Hazards of flicker according to TG IEEE 1789

- Immediate effects (few seconds of exposure): mostly epileptic seizures (1 in 4000 individuals)
- Long-term effects: malaise, headaches, reduced acuity of vision, … (pervasive)
- Goal of TG IEEE 1789: avoid both

Critical modulation frequencies

- ## Immediate effects: 3 $\rightarrow$ ~70 Hz

- ## Long-term effects: ~ 70 Hz $\rightarrow$ $f_{cut-off}$

- ## Value of $f_{cut-off}$ pending
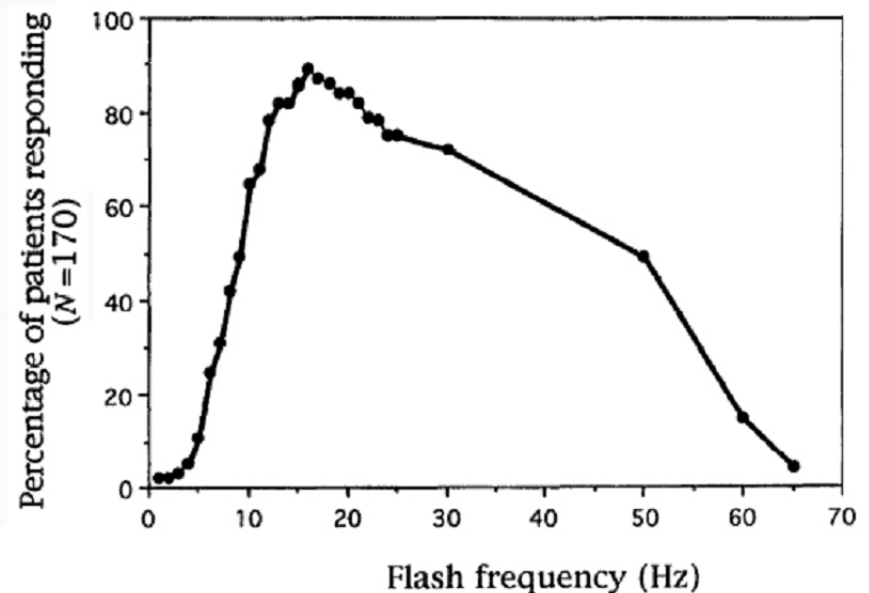
Percentage of patients with photosensitive epilepsy responding to repetitive flashes [Harding, 1994]

Recommended values for cut-off frequency

- Electrical currents from retina show response up to 100-160 Hz
- Highest perceivable value for $f_{cut\text{-}off}$ (sensitivity to spatial patterns): 5.4 kHz (spatial frequency {1.7 krad^{-1}} x radial velocity of eye movement {3.1 rad/s}).
- My personal opinion: derivation of questionable fidelity
- Recommended value for cut-off frequency expected to reside between f_{min} = 160 Hz and f_{max} = 5.4 kHz

Escalator stair tread [Wilkins, 2009]

Implications for IEEE 802.15.7: modulation frequencies

- Modulation frequencies for PHY I and II ≥ 200 kHz >> f_{max} → no issues
- Might restrict "super-low" modulation frequency proposed by CASIO (802.15-09-0801-0007)
- Lowest line rate (idle + data + off) currently set to 200 Hz → potential non-adherence to IEEE 1789
- Issue: final decision on $f_{cut-off}$ might not be available well before December 2010
- Notice: modulation circuits operating at frequencies below 20 kHz might generate audible sound

Implications for IEEE 802.15.7: colour-packet scheme

- Change in radiant colour in order to visualise VLC communication state to user(s) [see Section 7.7.4 of D0]

- Aggregated time of colour packets long enough to be perceivable, i.e. > 10 ms

- Too short aggregation times for (quasi-) periodic changes in colour might induce epileptic seizures

- Recommendation: colour-packet aggregation time always > 1/(3 Hz) = 333 ms

My recommendations

- IEEE-802.15.7 stakeholders: decide about whether to adopt these recommendations
- If yes:
  - Implications for
    - Lowest line rate in idle situations
    - Shortest aggregation time for colour-packet scheme
    - Super-low modulation frequency (if included into standard)
  - Discuss VLC use case with TG IEEE 1789

References

- Wilkins, Lehman, Veitch, Bhattacharya, Bergman, Wolfman (Photosensitive-Epilepsy Subcommittee of IEEE PAR1789), "Biological Effects and Health Hazards from Flicker, Including Flicker that is too Rapid to See," Internal document of IEEE PAR1789, December 2009

- G. F. A. Harding and P. Jeavons, "Photosensitive Epilepsy," Mac Keith Press, 1994