Pilot Study on Visibility of Phantom Array and Stroboscopic Effects

Naomi J Miller, FIES, FIALD
Designer/Scientist

Jianchuan Tan, PhD, PMP, LC, WELL AP
Engineer/Scientist

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Scope of Study

• Background
  o Stroboscopic effect and the phantom array are commonly observed phenomena of temporal light modulation (TLM), also called “flicker”.
  o Stroboscopic Visibility Measure (SVM) is a widely used metric to evaluate stroboscopic effect from a light source.
  o There is not a well-established metric yet to evaluate the phantom array effect.

• Goals of this pilot study
  o For stroboscopic effect:
    ▪ Investigate the subjects’ visibility rating scores of stroboscopic effect with respect to wave shape, frequency, modulation depth and duty cycle.
    ▪ Investigate the relationship between subjects’ visibility rating scores and SVM metric values.
  o For phantom array:
    ▪ Investigate the subjects’ visibility rating scores of phantom array with respect to wave shape, frequency, modulation depth and duty cycle.
Stroboscopic effect – Visual patterns
Phantom array effect – Visual patterns

Fixed view on-axis view

Scanning view of continuous (DC) source

Scanning view of TLM source, depending on frequency, modulation depth, duty cycle, etc.
Subjects, Test Setup and Rating Scales

• Subjects
  ▪ Gender
    ▪ Female: 5
    ▪ Male: 6
  ▪ Age range
    ▪ 24 – 66

• Scale of ratings for Stroboscopic Effect
  ▪ 6 – Highly visible stripe pattern
  ▪ 5
  ▪ 4
  ▪ 3
  ▪ 2
  ▪ 1
  ▪ 0 – No stripe pattern visible

• Scale of ratings for Phantom Arrays
  ▪ 6 – Highly visible repeating pattern
  ▪ 5
  ▪ 4
  ▪ 3
  ▪ 2
  ▪ 1
  ▪ 0 – No repeating pattern visible
Test Setup

Test Room 8’-2” x 16’ x 9’ ceiling
10’ viewing distance from subject eye to LED
1.5 – 2 lux at eye, including 0.5 lx ambient light
Visibility of the stroboscopic effect from rectangular waveforms:

- Generally, visibility increases as modulation depth increases.
- Visibility is almost always maximized at 67% - 100% modulation.
- Visibility is very low when frequency exceeds 1000 Hz.
Visibility of the stroboscopic effect from rectangular waveforms:

- Peaks at 90 – 120 Hz, but declines rapidly with frequency
- Greatest at 100% and 67% modulation
- Maximized at 10% and 30% duty cycle
- Barely visible at 1000 Hz at 100% mod, 10% duty cycle
Visibility of the stroboscopic effect from sine waveforms:

- Peaks at 90 Hz, but declines rapidly with frequency
- Studied here at only 100% modulation
- Barely visible at 1000 Hz
This shows that Rectangular Waves are more visible than Sine Waves at equal Modulation Depth for Stroboscopic Effects.
Visibility of the phantom array
• Peaks at 500 – 1000 Hz.
• Interesting dip at 120 Hz.
• Greatest at 100% and 67% modulation
• Maximized at 10% and 30% duty cycle
• Visible on average at 6000 Hz at 100% mod, 10% duty cycle
Visibility of the phantom array
• Peaks at 500 – 1000 Hz
• Studied here only at 100% modulation
• Visible up to 2000 Hz at 100% mod (not studied at higher frequencies)
This shows that Rectangular Waves are more visible than Sine Waves at equal Modulation Depth for Phantom Arrays.
Generally, the rating score increases as SVM increases. We are going to analyze the trends and build a mathematical model to depict the relationship between rating scores in a test and SVM values.
Preliminary Discussion and Summary

Stroboscopic effect
• Most visible at 90-120 Hz, and declines rapidly at higher frequencies
• Probably not visible above ~1000 Hz except in low duty cycle rectangular waves
• More visible from rectangular waves than sinusoidal waves
• More visible with high modulation depths (>50% modulation) and low duty cycles

Phantom array effect
• Interesting drop in visibility at 120 Hz (90 Hz and 250 Hz higher)
• Peaks from 500 to 750 Hz, declines more slowly than stroboscopic effect at higher frequencies
• Duty cycles of 10-30% are most visible when modulation depth is 100%, even at frequencies up to 6000 Hz
• More visible from rectangular waves than sinusoidal waves

Stroboscopic effect most visible from 90 to 250 Hz, the phantom array more visible ≥250 Hz.

If the phantom array is visible, the stroboscopic effect may or may not be.

Stay tuned..................
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Thank You!
Questions?

Naomi J Miller, FIES, FIALD
Designer/Scientist
Naomi.miller@pnnl.gov

Jianchuan Tan, PhD, PMP, LC, WELL AP
Engineer/Scientist
jianchuan.tan@pnnl.gov