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The Applicability of a Motorcycle Headlamp Modulator as a Device for Enhancing Daytime Conspicuity

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ABSTRACT

Considerable research is needed before any positive steps are taken to further the general use of modulated high-beam headlamps as motorcycle conspicuity aids. Such research cannot proceed satisfactorily without rigorous measurements of the visual characteristics of a modulating device, which have so far been lacking. The purpose of this paper is to provide an example of such measurements and, in particular, to report on the measurements of the relevant photometric characteristics of the Q-Switch modulating device. The results of these measurements demonstrate that the device falls within the specifications recommended by the authors for an extended flashing-signal code to be used by motorcyclists and moped riders, and clearly show that measurements in field conditions will form an essential part of any future conspicuity program based on lights.

Flashing light signals are used extensively in the road environment. On vehicles they are used as turning indicators, hazard warning lights, and emergency vehicle identifiers. On the highway they are used to indicate roadside hazards, temporary construction work, railway crossings, and so forth. These diverse applications have the common purpose of alerting a road user immediately and certainly to an uncommon situation that is potentially hazardous or requires distinctive identification.

The use of flashing signals in the road environment has been reviewed by the authors (1). They proposed a coherent code of flashing signals for the traffic environment that encompasses and extends their applications to allow for the use of a modulated light device to enhance the conspicuity of motorcyclists, bicyclists, and moped riders. The problem of motorcycle conspicuity is widespread and important in many different countries (2-4), resulting in several investigations of the efficacy of headlamps, daytime running lights, and motorcyclist's clothing as aids to frontal conspicuity. The potential contribution of modulated lights is substantial. There have been some reports of promising conspicuity response effects from the use of modulated headlamps on motorcycles from Olson et al. (5).

Olson et al. compared many different types of conspicuity aids for day and night conditions, including low-beam, modulated high-beam, and reduced-intensity (10 percent) low-beam headlamps and various garments for conspicuity enhancement. They found that the modulated high-beam headlamp was the most effective daytime conspicuity aid evaluated. However, no details of the characteristics of the device were given.

Considerable research is needed before any positive steps are taken to further the general use of these devices as conspicuity aids. Such research cannot proceed satisfactorily without rigorous measurements of the visual characteristics of the modulating devices, which have so far been lacking. The purpose of this paper is to provide an example of such measurements and, in particular, to report on the measurements of the relevant photometric
characteristics of the Q-Switch manufactured by Do-Tech, Inc., North Carolina, and used by Olson et al. (5). The results demonstrate that the device falls within the specifications recommended by the authors (1) for an extended flashing-signal code to be used by motorcyclists and moped riders, and clearly show that measurements in field conditions will form an essential part of any future conspicuity program based on lights.

PERCEPTION OF FLASHING LIGHTS

The authors (1) reviewed the current Australian specifications for flashing lights for vehicle and highway use and concluded that the specification of frequencies within the range of 0.8 to 2.0 Hz is somewhat arbitrary. This specification reflects the lack of knowledge of the effect such frequencies have on the visual system. The terminology used in the literature to describe the types of flashing signals is inconsistent and can lead to considerable confusion. The following definitions (also shown in Figure 1) are suggested as a classification of the various forms of flashing signals on the basis of their visual appearance and physical characteristics (these definitions are only suggested and may need to be modified in the light of empirical evidence):

Modulating signal—a signal that fluctuates continually and regularly between two levels of intensity (or luminance), neither one of which is zero (Figure 1a).

Pulsating signal—a signal that fluctuates from one level of intensity-to-zero. The fluctuations may or may not appear to decrease to zero depending on a number of factors (e.g., frequency and adaptation level) (Figure 1b).

Interrupted signal—a steady signal that is periodically turned off (electrically switched or physically occluded) at intervals. There are two types of interrupted signals: (a) those in which the light pulses are separated by sufficiently long, off periods for the individual pulses to be regarded as independent of one another, and (b) those in which the light pulses cannot be regarded as independent of one another. The off-period criterion is at least 300 to 400 msec. This term is normally, but not necessarily, applied to regular pulse frequencies (Fig. 1c).

Stroboscopic signal—a signal with a large ratio of intensity-to-pulse time and a pulse duration of less than 10 msec. The pulse interval is measured between intensity levels that are 1 percent of the peak intensity (see Figure 1d).

The following physical properties must be specified to uniquely describe a flashing light.

- Frequency of modulation,
- Pulse shape and intensity,
- Pulse-to-cycle fraction,
- Angular size, and
- Color.

Each of these physical properties has an effect on the visual appearance of the light and all of the properties interact with one another. The appearance of the flashing light is also affected by the level of background luminance, the presence of other lights, and the location of the flashing light in the visual field.

If flashing lights are to be used in the road environment, it must be ascertained whether they are to be seen under threshold conditions or supra-threshold conditions, because quite different effects are apparent in the two regimes. Flashing lights used to warn of roadside hazards should be visible from as great a distance as possible and therefore should be first seen in the threshold regime. Flashing lights on vehicles are generally seen at much closer distances and are often a means of enhancing the vehicle's conspicuity; they should therefore be viewed under supra-threshold conditions. It must also be decided whether the sequence of flashes is independent or interacting. The authors (1) suggest that if the period between flashes is greater than 350 msec, the flashes can be regarded as independent.

The appearance of supra-threshold flashing lights is shown in Figure 2 as a function of frequency.

![Intensity vs. time graphs](image)

**FIGURE 1** Examples of wave shapes for (a) modulating, (b) pulsating, (c) interrupted, and (d) stroboscopic signals, as defined in text.

The frequency regions in current use are as follows:

- Frequency range of AS1742, AS1165, SAEJ590e, DR404 (21, and DR902.
- Frequency of Q-Switch motorcycle headlamp (4 Hz).
- Frequency range of the variable-rate Cyberlite.

**FIGURE 2** Relationship between brightness of a pulsating or interrupted signal and its frequency.

The brightness enhancement effect strictly applies to the 6- to 18-Hz frequency range in which the observer is aware of a steady intensity component and a fluctuating component. (The maximum enhancement occurs at about 10 Hz.) Below approximately 4 Hz, the observer is aware of the dark phases between the light pulses (a different visual phenomenon) and the
More work is also needed to understand the percep­
toralist was more often in error. Foldvary concluded
eral fields of vision and to assess the use of other
conspicuity of the interaction between several modu­
devices can be advocated unequivocally, much more
1962, Foldvary found significant differences between
accidents (13). In an analysis of accidents involving
"APPLICATION TO MOTORCYCLISTS
Evidence from accident statistics shows that motor­
cyclists are over-represented in certain types of
accidents (13). In an analysis of accidents involving
motorcycles in Victoria, Australia, from 1961 to
1962, Foldvary found significant differences between
the ratio of motorists to motorcyclists in different
types of accidents (14). In accidents involving an
error of right-of-way, turning, or signaling, the
motorist was more often in error. Foldvary concluded
that the lack of conspicuity of the motorcycle and
rider was the major contributing factor to these
types of accidents. Other more recent studies have
also reinforced the problems that motorcycles have
with poor frontal visibility during the daytime (15–
18). A flashing light would be expected to enhance
the daytime conspicuity of motorcyclists for the
reasons outlined earlier. The expansion of the
flashing-signal code suggested by the authors might
then accommodate the use of modulation devices to
enhance motorcycle conspicuity without any detri­
mental effect on the current use of flashing signals
by highway authorities. Another advantage of using a
unique code for motorcycles is that it will readily
identify them as a specific class of vehicle.

PHOTOMETRY OF THE Q-SWITCH HEADLAMP MODULATOR:
RESULTS AND DISCUSSION

The Do-Tech Q-Switch is one of several commercially
available headlamp modulators. It creates a modula­
tion that lies within the frequency range of 3 to 8 Hz.
Q-Switch was used to provide a concrete example of
the photometric properties of a headlamp fitted
with such a modulator. Olson et al. (5) used the
device to obtain positive conspicuity results for
several motorcycle configurations in highway condi­
tions; however, no details of the photometric
characteristics of the device were provided.
The headlamp employed for the Australian Road
Research Board tests was a sealed-beam Stanley
40 (12 V, 40 W/3.4 W) fitted to a 1979 Honda
1048-ml CBX. This is a large machine which, because
of its ample power generation capabilities, does not
require the reductions in current effected by the
use of a modulated headlamp to sustain daylight use
of the headlamp. The photometric measurements were
made in a dark tunnel and the results are given in
the following sections.

Lamp Voltage Versus Engine Speed

The photometric properties of the modulated headlamp
were best measured while it was off the motorcycle
because the positioning and mounting accuracy of the
headlamp is greatly reduced when it is actually on a
motorcycle. Nevertheless, it is obviously important
to gauge the performance of the headlamp on a motor­
cycle. Therefore, the lamp voltage at the lamp
terms was then measured with the headlamp mounted
on the motorcycle as the engine speed was held at a
number of values ranging from idling to 5,500 rpm or
92 Hz (5,500 rpm corresponds to approximately 120
km/hr in top gear on this machine). Subsequent
photometric measurements carried out at a known lamp
current from a stabilized power supply could then be
related back to engine speed. The results of lamp
voltage as a function of engine speed are given in
Figure 3.

Headlamp Intensity at Different Lamp Voltages

The headlamp was mounted in a goniometer and posi­
tioned so that the photometer recorded the maximum
intensity on high beam. The power supply was stabili­
ized and the lamp voltage was monitored at the lamp
terms. The intensity of the headlamp was found
for a range of voltages from 10 to 14 V for both
high- and low-beam conditions. The results are shown
in Figure 4.

Measurement of Modulated Headlamp Intensity

On Motorcycle

The modulated headlamp intensity was measured while
the headlamp was attached to the motorcycle because
the very approximate positioning of the headlamp in
FIGURE 3 Lamp voltage (measured at lamp terminals) as a function of engine speed (measured by tachometer).

FIGURE 4 Headlamp beam intensity at the straight-on position as a function of lamp voltage for high-beam (HB) and low-beam (LB) conditions.

FIGURE 5 Oscilloscope trace recording of modulated headlamp intensity with headlamp mounted on a goniometer for a time base of 100 msec per division.

FIGURE 6 Output waveform of the headlamp modulator device.

during the off period of the duty cycle, the lamp filament received short duration pulses that would promote a slower drop of filament temperature than would otherwise occur. This would also have the effect of extending the life of the bulb. The measured frequency of the input waveform was 4.26 Hz.

The current drain of the modulation device was about 200 mA, which is negligible in comparison with the 4 to 6 A drawn by the headlamp bulb. The long-term reliability of the device has been tested independently by the Electrical Testing Laboratories, New York, who certified no degradation in performance after 2 million pulses (i.e., 6 to 7 years of average use in the United States).

It is instructive to look at another, quite different motorcycle and headlight combination. This motorcycle [a Yamaha RZ350 (K), which is a type of RZ250, a popular model in the key novice rider category] had a much smaller engine capacity and the headlamp had a much higher rating (12 V, 60 W/5.5 W).

Under laboratory conditions and with a stabilized power supply, the steady-state intensity at 12.15 V was 31 600 cd on high beam compared with 21 700 cd for the first headlamp test. Of course, the frequency of the modulated headlamp intensity and the ratios of the maximum and minimum modulated intensities to the steady-state intensity are determined almost completely by the Q-Switch and thus remain the same as in the first test (64 percent and 21 percent, respectively). It was not possible to measure the steady-state high-beam intensity for the battery-only condition because the current drain was so great that the light output rapidly decreased. Consequently, the low-beam intensity would probably have better results in this combination.

Another feature of the small motorcycle and high-
rated headlamp combination was that the lamp voltage varied rapidly over a narrow range of engine speed from idling to 2500 rpm (42 Hz), which resulted in considerable variation of light intensity at these low engine speeds. It was also apparent that at low rpm levels, which are typical of a stationary machine awaiting a turn, the dipped beam was delivering a higher intensity than the main beam.

It should be noted that both machines were in as-new condition. The two examples of motorcycle and headlamp combinations serve to forcefully illustrate the need to combine rigorous photometric data with the results from experiments of behavioral responses. Field results differ substantially from laboratory measurements. The point of application of all such conspicuity enhancement measures is field performance on real machines.

SUMMARY
Positive on-road conspicuity effects have been reported by Olson et al. (5) using a proprietary device: the Q-Switch headlamp modulator. Considerable research is needed before any positive steps are taken to further the general use of such modulation devices as conspicuity aids. In particular, experimental field work is needed to quantify the effect on conspicuity of the interaction between several modulated headlamps and between a modulated headlamp and other flashing signals in the road environment. A greater understanding of the peripheral and foveal perception of modulated lights at suprathreshold intensities is also needed. Such research cannot proceed satisfactorily without rigorous measurements of the visual characteristics of such modulating devices, which have so far been lacking. An example of such measurements was provided in this paper by examining the Q-Switch device photometrically.

The maximum and minimum values of the intensity waveform were 64 percent and 21 percent of the steady-state value, respectively. The frequency of the modulation was 4.20 Hz and the waveform was close to triangular. This device lies within the range of specifications suggested by the authors (1) for the enhancement of the daytime conspicuity of motorcyclists. These results complement the on-road conspicuity results of Olson et al. (5) and provide a reference for permissive or regulatory considerations.

The results clearly show that measurements in field conditions, with a typical distribution of motorcycles of different ages, will form an essential part of any future lighting-based conspicuity program.

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