Triple Design Flaw

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The "triple design flaw" refers specifically to single or bi-parting sliding automatic pedestrian doors actuated on approach by a microwave motion sensor and in which presence detection within the door closing path is nominally afforded by a reflected beam presence sensor. It consists of the following three factors:

1. The fact that the Doppler effect upon which the actuating microwave motion sensor operates goes to zero for horizontal motion in the area directly beneath the sensor and, hence, immediately in front of the door opening. This is a consequence of geometry and the laws of physics that govern electromagnetic (microwave) radiation, which laws cannot be altered by any feature of the internal design of the motion sensor.[1]

2. The fact that, in this design, the edge of the motion sensor detection beam, beyond which motion sensing fails independent of the amount of Doppler effect, is, of necessity, located also directly in front of the door opening; and

3. The fact that, in this design, the presence sensor nominally covering the door closing path is, of necessity, disabled whenever the door is closing.

Details of each of these three factors are provided below.

As a consequence of these three factors, it is possible for slowly moving pedestrians to enter the door closing path and be struck, in direct violation of the intent and letter of the applicable ANSI (American National Standards Institute) A156.10 national standard for power operated pedestrian doors. This is true even for a door that is otherwise operating "normally," and not subject to component failures, maladjustments or external interference, as will be described.

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[1] Rather, it is necessary to adopt a different design that permits the microwave motion sensor to be moved away from the door, concomitantly moving the area of minimal, or zero, Doppler effect safely away from the door opening.

Operation of the microwave motion sensor

Microwave motion sensors are mounted on the center of the vertical face of the door header and operate by transmitting an expanding beam of microwaves generally outward and downward away from the door so as to illuminate an approximately elliptical motion detection zone in front of the door opening. The dimensions of the detection zone that must be achieved are prescribed by the ANSI A156.10 national standard.

First design flaw – The microwave motion sensor establishes in space a set of stationary, invisible, three-dimensional, concentric, spherical "shells" centered on the motion sensor. The separation between the shells is equal to one-half the wavelength of the microwaves.[2] An electronic pulse is generated within the motion sensor for each of the shells penetrated as the pedestrian moves within the detection beam. The motion detection signal is generated when a sufficient number of these pulses is generated within a sufficiently short period of time, typically a fraction of a second. Thus, the pedestrian must move in such a direction and in such a way as to "pierce" the requisite number of shells within a fraction of a second. Failing that, no motion detection signal will be generated.

If the pedestrian moves in a trajectory "around" (transverse to) the sensor, so that no shells are pierced, such motion will ***not*** be detected, even though the motion may be quite rapid and well above the nominal motion detection threshold speed of which the sensor is otherwise capable. In fact, it is only the component of motion directly toward or away from the sensor that results in shells being pierced and, hence, motion detection[3].

An example is provided by horizontal motion directly beneath the sensor. There, there is ***no*** component of motion toward or away from the sensor (no Doppler effect); rather, the motion, being horizontal, is then instantaneously entirely transverse to the sensor. That is, instantaneously around the sensor. Consequently, for horizontal motion in the area directly beneath the sensor, shells are pierced much less frequently than elsewhere,

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[2] For the older X-band (10.525 GHz) microwave sensors, the separation between shells is about 9/16 inch. For the more recent K-band (24 Ghz) presence sensors, the separation is about half this distance.

[3] In fact, some microwave motion sensors are designed to be unidirectional. That is, they contain additional circuitry so that they generate a motion detection signal only for motion toward the sensor, and do not respond to motion away from the sensor. Otherwise, a unidirectional microwave motion sensor can no more respond to transverse motion than can a bidirectional sensor.

and the requisite number of pulses may not be possible within the required fraction of a second for motion detection to occur.

The attached figure illustrates schematically the generation of Doppler pulses for three horizontal trajectories.[4, 5] Note that, for purely geometric reasons, the spacing between the pulses increases as the area directly beneath the sensor is approached. This is a consequence of the laws of geometry and physics and cannot be altered or controlled by any design feature or characteristic within the sensor itself.

Second design flaw – Another characteristic of microwave motion sensors illustrated by the attached figure is the fact that the microwave beam cannot be aimed in such a way as to include the door itself. Otherwise, the motion sensor would "see" the motion of the door as it closes and, not being able to discriminate the door from a pedestrian, would command the door to reopen. Thus, the door would never be able to close.

Consequently, the "edge" of the microwave beam is also, perforce, located directly in front of the door opening in the same area where, independently, the Doppler effect is minimal, or zero. The beam "edge" is the point beyond which the motion sensor signal strength drops so far that motion detection becomes impossible, independent of whether there is otherwise adequate Doppler effect. Furthermore, in this design, the pedestrian is then moving toward the door opening, ***away*** from the core of the motion detection beam where signal strength and detection reliability are greatest.

The fact of minimal, or zero, Doppler effect immediately in front of the door opening, and the fact that the beam edge, where detection reliability is least, is necessarily also located immediately in front of the door opening constitute the first two of the three flaws in the triplet of design flaws.

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[4] The illustration is schematic because the spacing between the concentric shells has been exaggerated in order to make the origin of the effect easier to see and understand. However, the diagram is correct and faithful in every other respect. To adjust the figure to conform with an actual X-band or K-band sensor, it is only necessary to decrease the spacing between the concentric shells.

[5] In the case of the extended and contoured surface of the human body, the totality of the microwaves reflected from all points on the body sums mathematically to create a single equivalent "resultant" reflection point. That is, the microwaves behave as though they had been reflected from the single resultant point, even though they are actually summed over the entire surface of the body. It is for this reason that a single point can be used to illustrate each of the trajectories in the attached figure.

Operation of the infrared presence sensor

The infrared presence sensor nominally covering the door closing path operates by transmitting an expanding beam of near infrared (IR) light directly downward into the door closing path from the underside of the header.[6] When properly adjusted, the beam extends all the way to the jambs on both sides, to, or nearly to, the floor, and to a distance of, typically, 12 to 18 inches on either side of the threshold. That is, the beam expands as it projects downward to a "thickness" of 24 to 36 inches in the direction of travel through the door opening.

Unlike the microwave motion sensor, no shells are established around the sensor, and no pulses are generated or counted within the sensor. Rather, the IR presence sensor simply monitors the strength (intensity) of the IR light reflected back into the sensor from objects that enter its beam. If the intensity of the reflected IR light exceeds a preset threshold, the sensor generates a presence detection signal. Otherwise, there is no presence detection signal.

Third design flaw – Unfortunately, the IR presence sensor cannot discriminate between the presence of the door as it comes closed and the presence of a pedestrian within the door closing path. Consequently, the infrared presence sensor covering the door closing path must be disabled whenever the door is closing. Otherwise, the presence sensor will "see" the presence (not motion) of the door as it closes, causing the door to re-open, with the result that the door can never close. For this reason, the IR presence sensor is *automatically* disabled by design whenever the door is closing.

Consequently, at the very time that presence detection in the door closing path is most needed – when the door is closing – it is not available. This not only represents very poor engineering design, but stands in violation of the ANSI A156.10 national standard, which requires that the door closing path be protected by a presence sensing device to prevent the door from closing on a user. It stands also in contradistinction to the stated intent of the manufacturer that the door should be designed in such a way that it cannot close on a user.

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[6] Near infrared light is located just below the "red" end of the light spectrum visible to humans. It is to be differentiated from "far" infrared, which we perceive as heat, and which is located far below the red end of the visible spectrum. In the presence sensor, the near infrared light is generated by a cluster or bank of light (IR) emitting diodes (LED's).

How accidents result from the triple design flaw

Accidents result from the triple design flaw, even when the door and its sensors are nominally in "perfect working order," in the following way.

First, due to the minimal, or zero, Doppler effect in the area directly in front of the door opening, motion detection by the approach-side microwave motion sensor may be lost just before the pedestrian is about to enter the door closing path. This will occur if the pedestrian moves too slowly, stops, or moves in such a way that the equivalent microwave reflection point happens by chance to follow, rather than pierce, the concentric shells. See footnote 5. To make matters worse, it is characteristic of the design of such sensors that it is much more difficult to re-trigger them[7] once detection has been lost, than it is to sustain motion detection. Therefore, continued, or resumed, motion forward into the door closing path that would otherwise result in sustained detection fails to be detected before the pedestrian enters the door closing path.[8]

Second, the proximal edge of the motion detection beam is, unfortunately, also located just in front of the door opening, and the pedestrian is moving toward the door closing path and away from the core of the motion sensor beam where detection reliability is greatest. Consequently, motion detection may fail, or fail to be reestablished, due to the loss of signal strength at and beyond the beam edge, even if there were otherwise sufficient Doppler effect in this area.

Third, in order to close the door, the infrared presence sensor covering the door closing path is automatically disabled. Thus, it is possible for a pedestrian to enter the door closing path undetected after the IR presence sensor has been disabled. Being then out of the motion sensor beam, or in the area where motion detection is unreliable and can fail, there is no sensor remaining that is capable of detecting the presence of the pedestrian in the door closing path, and nothing to prevent the door from closing on the user.[9]

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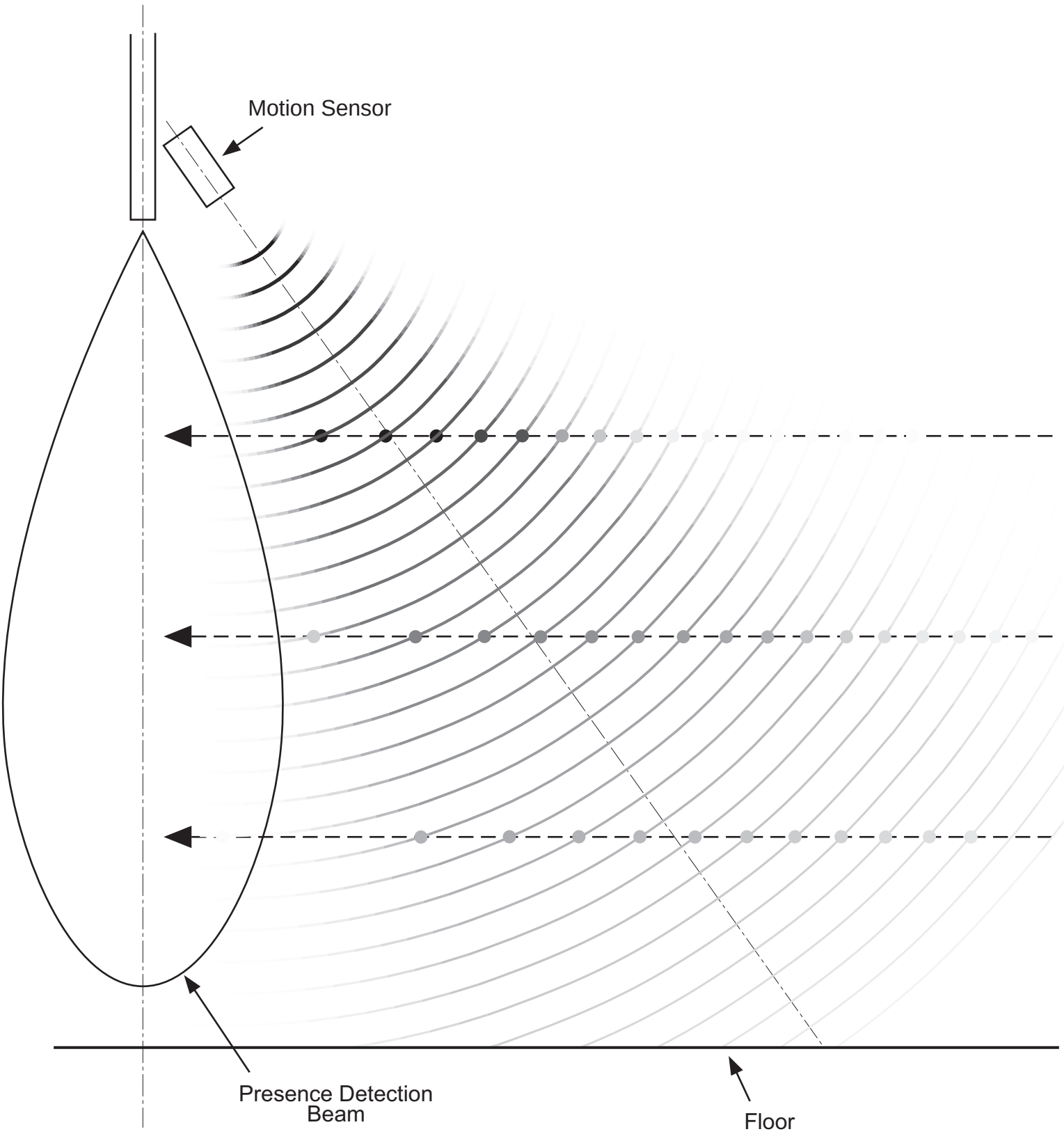
[7] That is, to re-establish motion detection.

[8] This is due to the difficulty of re-triggering motion detection, as opposed to sustaining it, and is aside from the question of whether there is otherwise adequate Doppler effect or motion sensor signal strength, due to the beam edge effect, to re-trigger the motion sensor.

[9] A "hold open time delay," which is usually set at the minimum value allowed by the ANSI A156.10 national standard, keeps the door open for an additional interval before the door closing sequence begins. The minimum value allowed by ANSI A156.10 – 1.5 seconds – is, unfortunately, often not sufficient to permit a slow moving user to clear

the door closing path before the closing sequence begins.


Motion Sensor
Presence Detection Beam
Floor