PIRs
from
A to Z

OPTEX

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1. INFRARED ENERGY

A. What is Infrared Energy?

All objects in our everyday world constantly emit Infrared Energy, but because the energy is so weak we rarely notice its existence. While it's easy for us to recognize the heat energy radiated by the sun or a fire, does a wall or a coffee table really radiate heat energy?

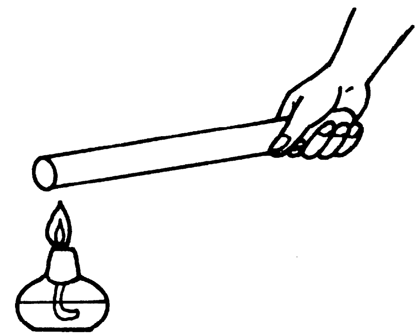
Yes! Absolute zero (-273°C or -460°F) is the point at which electron movement in the atom stops and an object has no heat energy. All substances above absolute zero have electron movement and heat energy. It is the movement of electrons inside the atom which creates Infrared Radiation (IR).

Each material's heat radiation pattern is unique to its own chemical composition and temperature. Even though the IR emissions from the sun and a block of ice are very different, all objects do have a temperature (a heat energy level) and radiate heat energy.

B. The Three Methods of Heat Transfer

There are three ways heat can be transferred. Although IR is only transmitted by radiation, an understanding of the physical processes of Conduction and Convection will improve your understanding of Radiation.

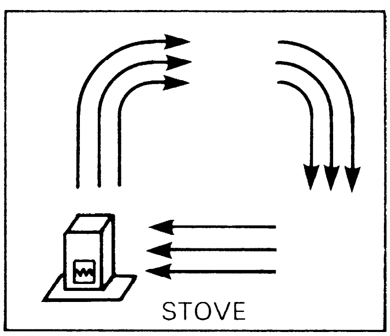
Conduction: The transfer of heat between two parts of a solid object, caused by a temperature difference between the parts.



Example: When one end of a iron pipe is put to a flame, the heat travels inch by inch to the other end.

Figure 1

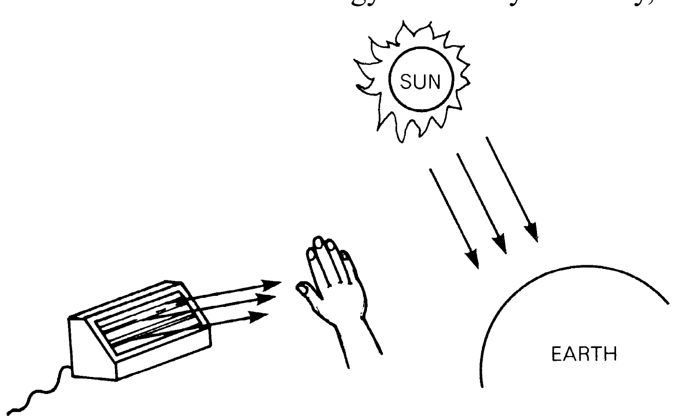
Convection: The transfer of heat by the circulation or movement of the heated parts of a liquid or gas.



Example: When gasses or liquids are heated within a space, the heated particles become lighter and rise up to displace cooler, unheated particles.

Figure 2

Radiation: The transfer of energy emitted by one body, transmitted through space, and absorbed by another body.



Example: IR rays are emitted by all objects above absolute zero and travel at the speed of light until they are absorbed by an object and transfer their heat energy.

Figure 3

Remember the hot pavement heated by the sun? Or, the heat in the light from a fire? All are examples of infrared energy (heat) traveling invisibly through space until it is absorbed by an object and returns to heat: A process known in physics as radiation.

The Random House Dictionary describes radiation as "the complete process in which energy is emitted by one body, transmitted through an intervening medium or space, and absorbed by another body."

C. The Electromagnetic Wave Spectrum

Electromagnetic energy is classified into groups such as Ultra-Violet Rays, X-rays, Visible Light, etc., because energies with similar frequencies (or wave lengths) share similar characteristics.

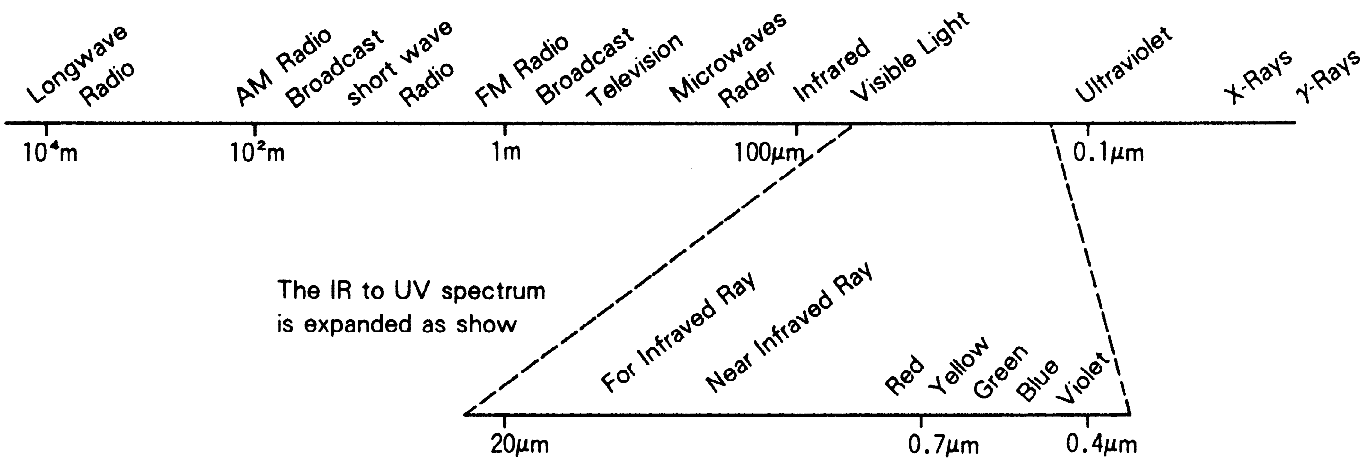


Figure 4

Perhaps, considering some of the similarities between visible light and IR will help explain the nature of IR energy.

-Light and IR both travel by radiation
-They travel at the speed of light (186,300 miles/second)
-They travel to infinity unless blocked by an object
-They both generate heat when absorbed in a material (heat transfer by radiation)

<u>However</u>, Visible Light and IR Energy do have different Reflection, Absorption, and Penetration characteristics.

Infrared rays are part of the Electromagnetic wave, as shown above.
Radio Frequency Signals, X-rays, etc. are Electromagnetic waves, and are distinguished by the length of the wave.

All objects emit some type of electromagnetic wave; but, according to its temperature, the type of wave and power of the wave differ. A human emits a wave that peaks at around 10um of the length of far infrared Rays.

D. Reflection, Absorption, Penetration

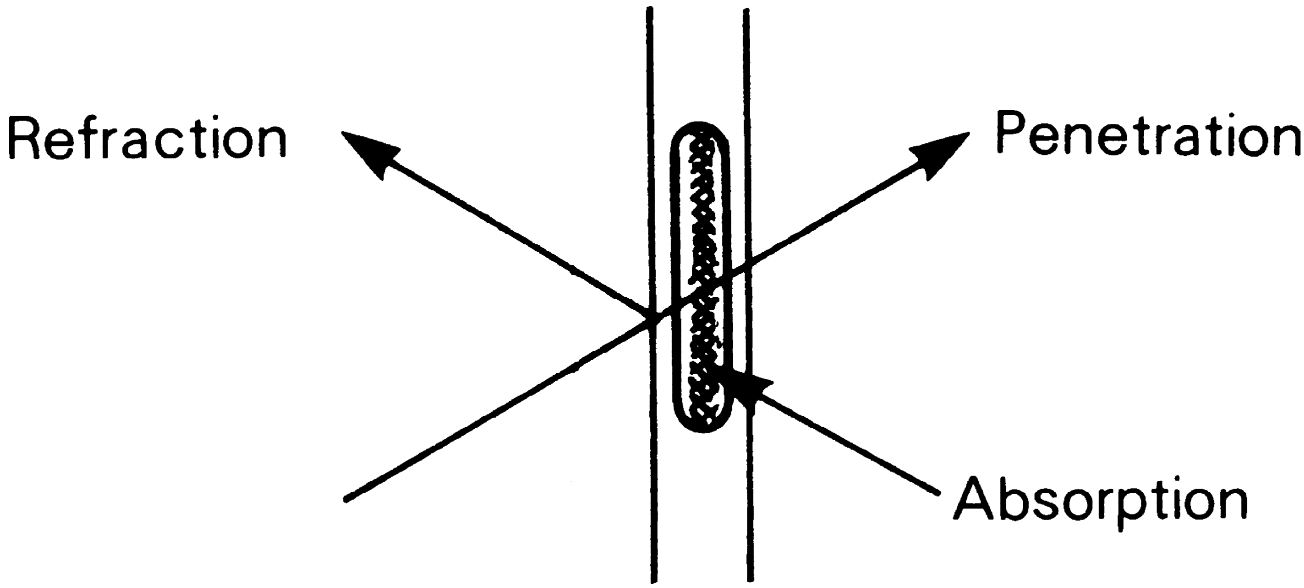


Figure 5

When electromagnetic energy strikes an object, all its energy is either reflected or absorbed by the object, or penetrates through it. The frequency of the energy and the composition of the object will determine the precise amounts of reflection, absorption, and penetration.

When installing or trouble-shooting PIRs it is important to know that Far Infrared Rays cannot penetrate glass, plastic, nor most other ordinary materials; and, that they are reflected by glass, mirrors, and other reflective surfaces.

E. Review

- All objects which have heat radiate IR

- Radiation is described as "the complete process in which energy is emitted by one body, transmitted through an intervening medium or space, and absorbed by another body".

-While IR has many of the same characteristics as light, Far Infrared Rays cannot penetrate glass, plastic, nor most other ordinary materials. Far Infrared Rays, like visible light, can reflect off glass, mirrors, or other reflective surfaces.

2. PASSIVE INFRARED RADIATION DETECTORS

Passive Infrared Radiation detectors (PIRs) detect sudden changes in Far Infrared Radiation levels and produce a corresponding electrical signal. PIR's then compare signals received to the signal characteristics of intruders to improve reliability and reduce false alarms.

While there are many PIRs and a wide variety of designs and features, all units consist of three fundamental components:
Optics, to control the PIR's "vision"
Sensor Elements, which generate electrical signals from IR energy
Signal Processing Circuitry, which evaluates the signal and performs the product's intended function (i.e. trips a relay).

A. Optics

1.) Controlling the PIR's View

Unlike many other detectors, PIRs do not emit energy: they are receivers of far infrared rays. Without an optical system to selectively focus the PIR's "View", PIRs would have just one very wide and insensitive zone.

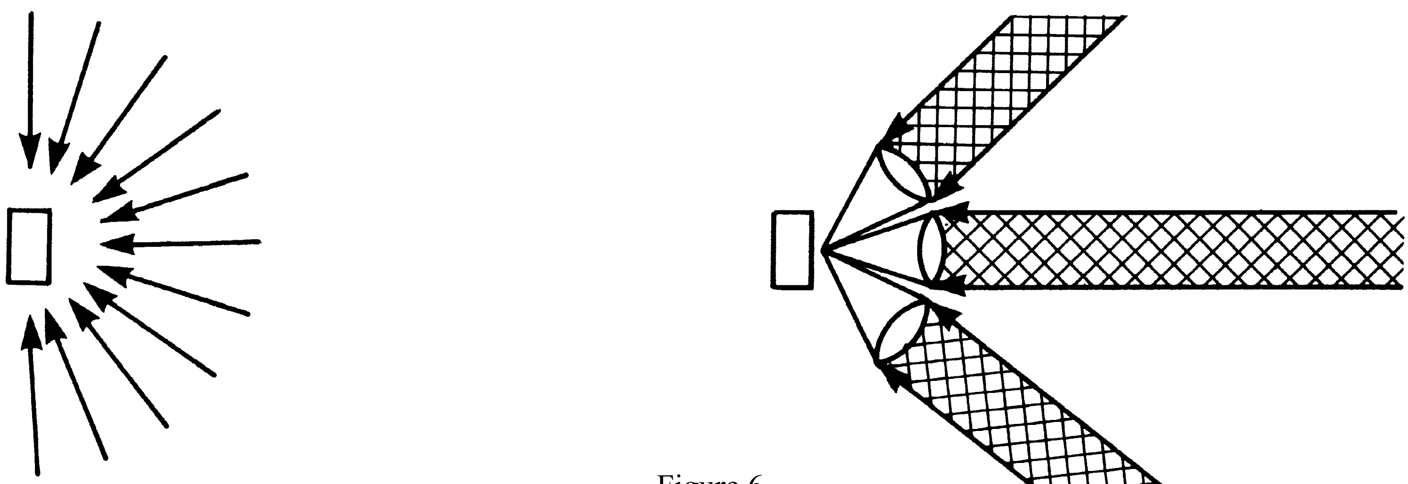


Figure 6

Like a camera without a lens, the PIR would only detect very close objects. Plastic lenses or mirror segments are used to create optic windows which control the PIR's detection area, zone size, and sensitivity.

2.) Detection Zones

Optic windows create detection zones by providing surfaces which receive IR and focus it onto the sensor element. In addition to catching IR energy from selected areas, optic windows also block out IR from unwanted areas.

Because PIRs are not affected by signals from outside the detection zone, narrow beam patterns are often used to provide good trap protection inside an area which has many installation hazards.

3.) Zone Size

Detection zones are created by the same optic principles which are used by cameras. If you are familiar with photography the following information will be easily understood, as the optic window is equivalent to the camera's lens, and the sensor element to it's film.

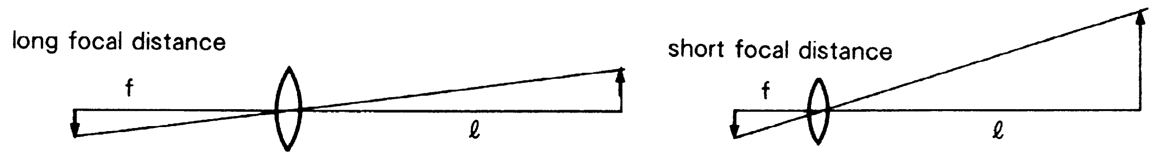


Figure 7

A detection zone's height, width and shape are determined by the sensor element, the focal length (f), and the distance from the detector where the zone is measured (l). Notice that the angle (or rate) of the zone's expansion is determined solely by the focal length of the detector. Like a long range lens on a camera, a long focal length creates a narrow field of view for the PIR; while a short focal length creates a large zone more quickly.

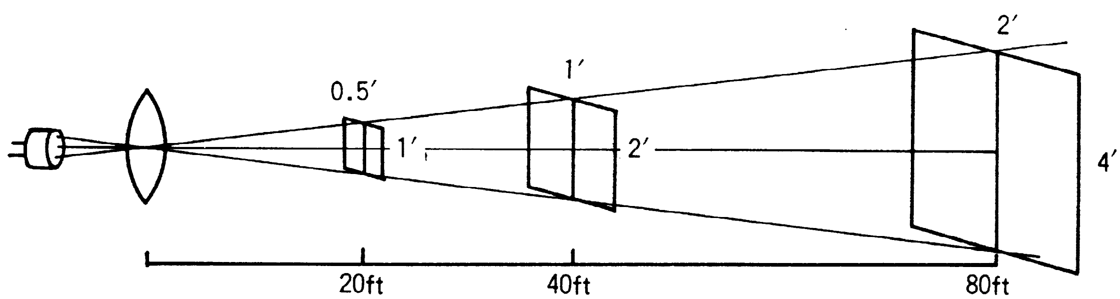


Figure 8

Detection zones become larger at a constant rate. A zone which is 2' x 1' at 40 feet from the detector is 1' x .5' at 20 feet, and 4' x 2' at 80 feet.

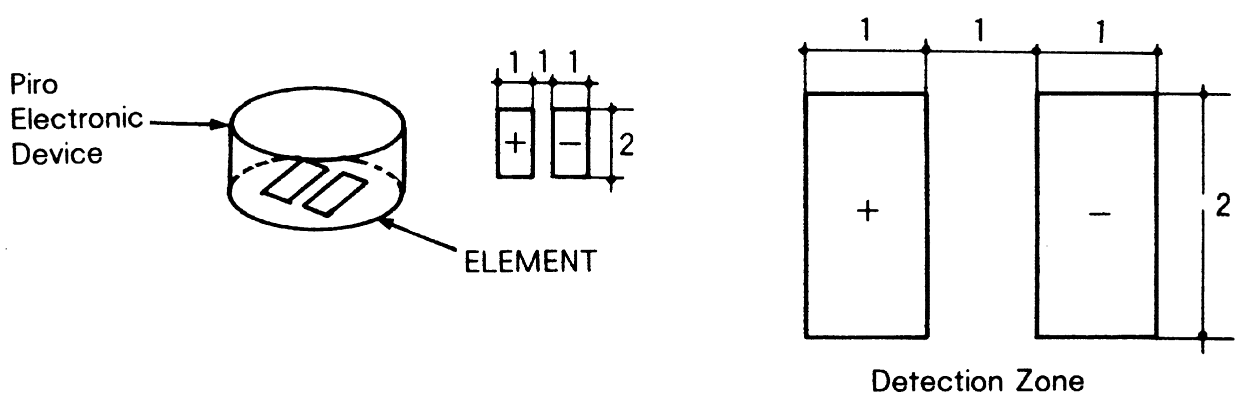


Figure 9

A zone's shape is determined by the shape of its sensor element.

4.) Zone Size and Sensitivity

As shown below, detection zones should be the size of the intended target. Compared to smaller zones, a human size zone is just as sensitive to human (or larger) targets and less sensitive to small disturbances such as mice, balloons, or heating vents.

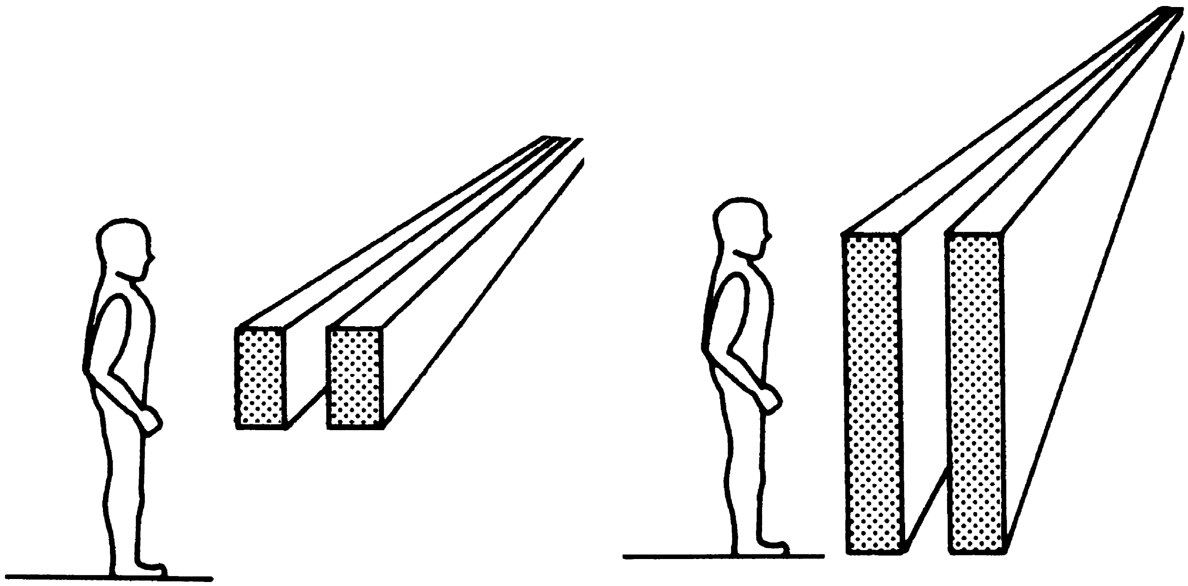
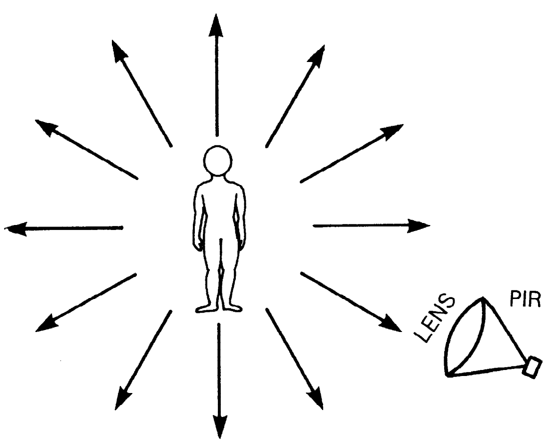


Figure 10

5.) Catching Infrared Radiation (IR)

Round, triangle, square, big, or small, the size and shape of the optical window has no relationship to the size or shape of the zone.

The optical window catches IR and focuses it onto the sensor elements. Its size determines how much IR it can catch.



IR rays are emitted in all directions, becoming less concentrated with distance.

Figure 11

Because they collect more IR energy, large windows produce stronger and more clearly defined signals than small windows and are particularly desirable for long range applications.

6.) Zone Definition

Using high quality lenses or mirrors and creating a sharp focus onto the sensor element will produce clearly defined detection zones. Clearly defined detection zones are important because they provide clear signals and high sensitivity.

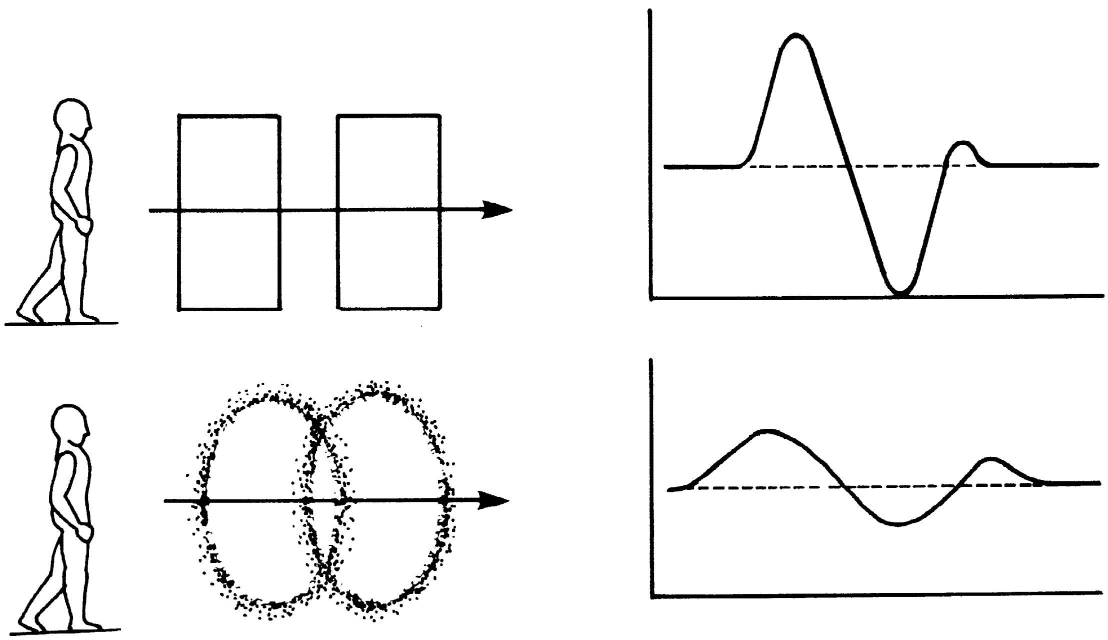


Figure 12

High zone definition also makes walk testing easier and helps installers avoid potential causes of false alarms.

7.) Review

- An optical mechanism is a basic component of any PIR detector.

- The optical design determines the PIR's field of view, the expansion angle of the zone, and the zone's size at any given distance.

- Optics also determine the PIR's ability to catch IR energy and the amount of infrared energy delivered to the sensor element. This can have a significant effect on the unit's overall sensitivity and stability.

B. The Sensor Element

1.) Pyroelectric Elements

PIR's focus IR energy onto pyroelectric elements which absorb the energy and transfer it into heat. When the amount of IR energy they receive changes, the elements change temperature and create an electrical signal.

Explained more simply: the heating and cooling of the pyroelectric elements creates electrical signals which are processed by the detector.

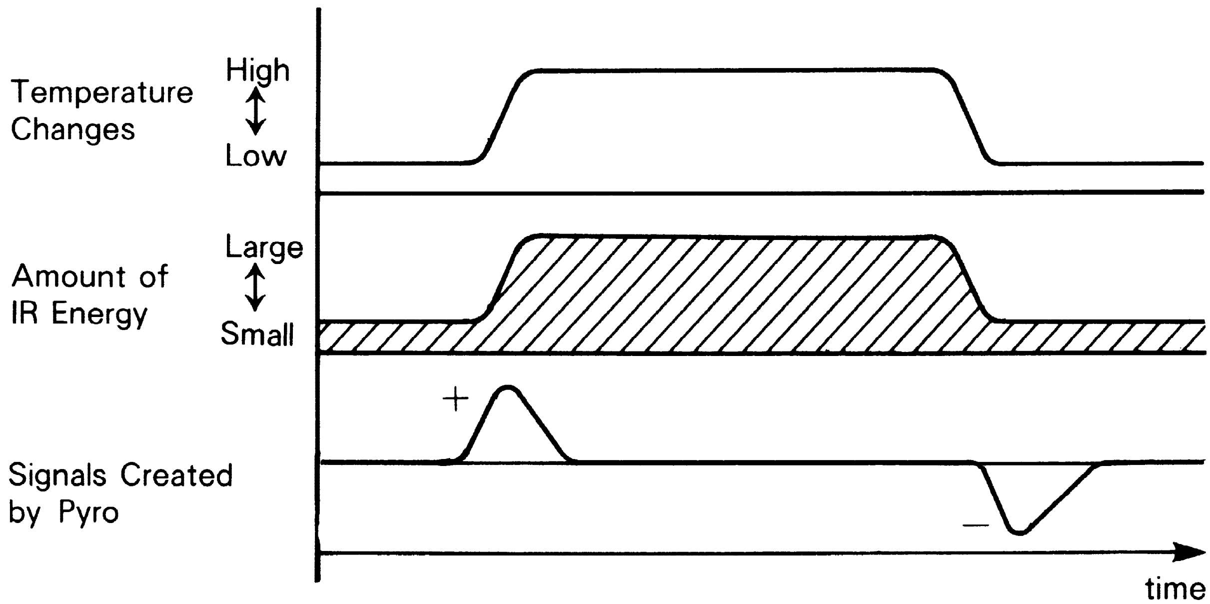


Figure 13

Pyroelectric elements only create electrical signals during temperature changes. When the pyroelectric elements do not change temperature, they do not generate a signal.

2.) PIRs Detect Sudden Temperature Changes

While PIRs do detect sudden temperature changes, the objects that they detect usually haven't changed temperature.

Before we proceed, please look down at the floor and slowly move a white paper across your field of view approximately ten inches from your eyes. Notice that while the floor doesn't change color, you do see a sudden color change.

3.) Zone Size and Target Speed

Because the sensor element creates an electrical charge only during a change in temperature, PIR detectors are less sensitive to fast moving objects at short distances and to slow moving objects at long distances.

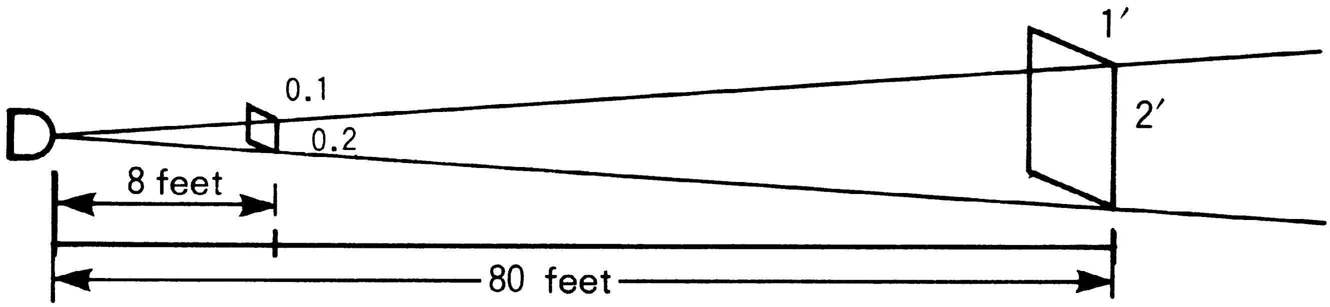


Figure 14

Figure 14 shows that if a long range PIR produced a 2 x 1 foot zone at 80 feet, the zone would be only 2.4 x 1.2 inches at 8 feet and 1.2 x 0.6 inches at 4 feet.

A person walking into such a small zone would fill it so quickly that the actual duration of the temperature change would be too short to produce a significant signal.
Similarly, if a zone is too large, a person might enter it so slowly that a trigger strength signal is not produced.

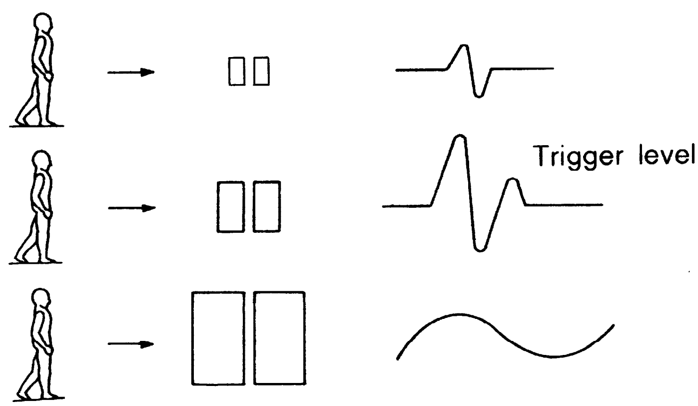


Figure 15

Here again, human sized detection zones provide the best detection performance. Well designed long range detectors often have extra short range zones in order to insure sufficient sensitivity close to the detector.

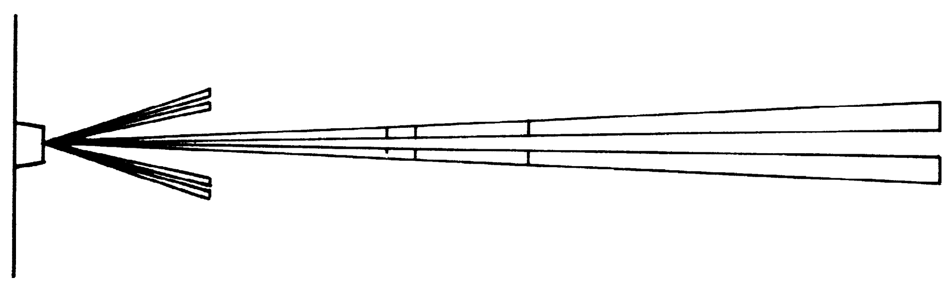


Figure 16

4.) The Dual-Opposed Sensor Element

Detectors which use just one pyroelectric element, will generate signals in response to any change in IR levels. This type of detector would be too sensitive to background temperature changes, drafts on the detector, and other environmental disturbances. The development of the Dual-Opposed Sensor Element (Dual Element) has significantly reduced the effect of these false alarm causes.

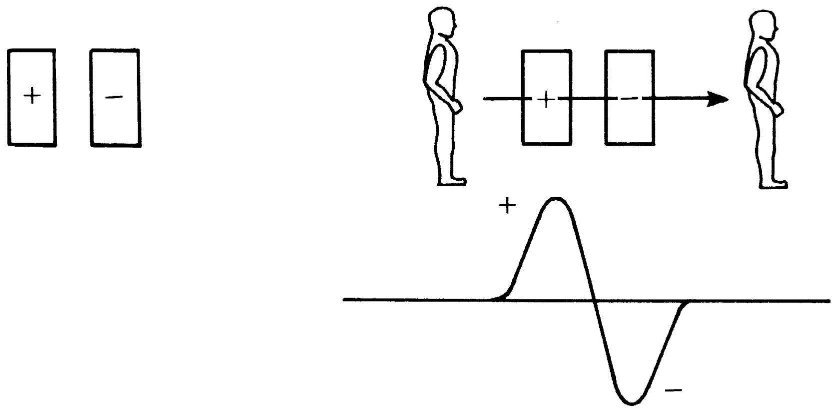


Figure 17

Dual element detectors combine two elements in one detector: each with opposing charges. Each element creates a signal (either positive or negative) when it changes temperature; but, when both are affected simultaneously, the positive and negative charges cancel and no signal is generated. Because of their superior performance, virtually all PIR detectors sold today utilize the concept of dual opposed elements.

This characteristic of dual elements suggests an important installation tip about aiming detection patterns.

Dual element detectors are more sensitive to movement across detection zones (alternating + and - signals) than to movement towards the detector (simultaneous + and - signals). This characteristic is most noticeable in high temperatures (when background and target temperatures are similar).

5.) Quad Element PIRs

There are many Quad Element PIRs available today. While each manufacturer has their own unique design, all quad units utilize the two fundamental concepts which were introduced by the Dual Opposed Element:

A) Using multiple elements creates additional channels of information and can increase the detector's "logic" capabilities.

B) Opposing positive & negative charges are used to cancel simultaneous signals.

Keeping these two concepts in mind, you should be able to evaluate the advantages and disadvantages of each manufacturer's design.

6.) Review

- The IR emissions from any material changes when the material changes temperature.

- Pyroelectric elements create an electrical signal when they change temperature. When their temperature remains stable, they do not generate any electrical signal.

- PIRs do not detect infrared levels, they detect changes in infrared levels.

- Dual pyroelectric elements generate positive and negative signals which cancel each other when the elements change temperature simultaneously. This significantly reduces false alarms caused by room temperature changes.

- Dual element detectors are more sensitive to movement across the detection zone than to movement towards the detector.

C. Signal Processing Circuitry

1.) Pre-Amp Sensitivity

The efficiencies of a PIR's first two fundamental components, the Optical System and the Sensor Element, combine to determine its pre-amp sensitivity level.

Given the same change in infrared level, PIRs with high pre-amp sensitivity generate stronger electrical signals than detectors with low pre-amp sensitivity. Sending a stronger signal to the amplifier allows for less amplification and distortion of the signal.

2.) The Amplifier

The signal produced by the sensor element is extremely weak (30 picofarads) and too susceptible to interference and distortion to be reliably processed. Before it can be evaluated by the signal processing circuitry, the signal must be amplified (often up to 2000X to 4000 X).

3.) Signal-to-Noise Ratio

Electrical Engineers refer to unwanted signals as noise. Whether these signals are caused by electrical circuitry; environmental temperature changes; false targets; electrical disturbances; or any other source, they are unwanted "noise" for PIR detectors.

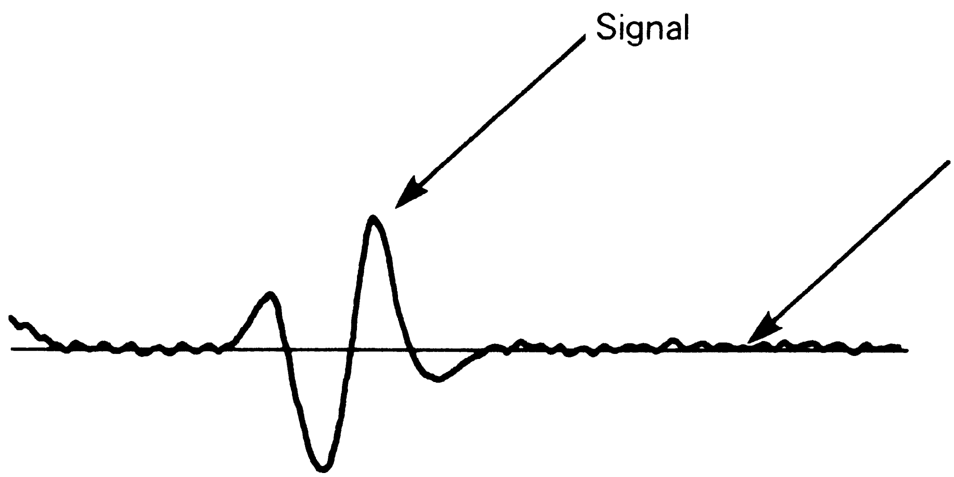


Figure 18

A low signal to noise ratio offers poor contrast between noise levels and target signals, leaving the detector more easily affected by RFI, white light, and other disturbances.

A high signal to noise ratio can achieve a greater separation between noise levels and the trigger level; thus providing greater immunity against false alarms.

4.) Trigger Level

When the electrical signal from the amplifier exceeds a predetermined magnitude, the trigger level detector is activated. (Because many detectors today use "Time-Frame Pulse Count", this does not necessarily mean that the relay is activated.)

While a high trigger level can reduce false alarms caused by noise signals, it also reduces sensitivity to an intruder. A high signal-to-noise ratio allows PIR detectors to be both sensitive and stable.

5.) Noise Reduction Circuitry

Some PIRs utilize special circuitry to filter out unwanted 'popcorn-noise' signals. This circuitry rejects signal patterns which are uncharacteristic of human intruders.

6.) Time-Frame Pulse Count

Time-Frame Pulse Count (pulse count) uses a counter to record a specified number of trigger strength signals, within a specified amount of time, before activating the relay. If the required number of signals are not registered within the time frame, the counter returns to zero.

7.) Sensitivity Adjustment

Some PIRs offer a sensitivity adjustment which controls the PIR's amplifier gain level (the amount the amplifier magnifies the pre-amp signal). For example, if the amplifier level were increased by 20%, the targetable temperature contrast would change from 5°F to 4°F.

Because increased amplification makes the PIR more sensitive, and allows it to detect objects at greater distances, this feature is often called a "range adjustment". This inexact term can lead the installer into forgetting that the detector's sensitivity increases, too.

Sensitivity adjustments should be used with caution; they increase the detector's sensitivity to the sources of false alarms as well as intruders. Likewise, using amplifier gain to reduce false alarms also reduces sensitivity to an intruder.

8.) Review

- Good optical design and high quality sensor elements produce high pre-amp sensitivity.

- High pre-amp sensitivity allows less amplification of the signal and 'noise' signals.

- Detectors with a high signal to noise ratio are more stable and reliable.

- Sensitivity adjustments should be used with caution.

D. Conclusion

All PIRs are not the same. While to the uninformed they may appear to be just 'white boxes with red lights', in reality there are a great number of design considerations involved in manufacturing a product that is both sensitive and stable. The performance of any particular PIR is not a matter of chance, but the end result of a long series of design considerations.

While sensitivity and stability might appear to be mutually exclusive goals, many technologies have been developed which do not require a sacrifice of one for an improvement in the other. In fact, it can be argued that improving the stability of PIRs permits increased sensitivity.

In addition to developing and applying new technologies, careful consideration and execution of basic design principles are necessary to achieve the highest performance levels in PIR detection.

3. PIR INSTALLATION

A quality PIR detector, installed properly, will provide over a decade of trouble-free, false alarm free, service.

This success is only possible when the installer knows he will live with the system for the next ten years: that he'll be the one to test; trouble shoot; service and repair; and add on additional devices. And, of course, that he'll be called at 2:00 AM if there's a problem.

Quality equipment and installation techniques allow this time to pass quickly and profitably.

A. Site Selection

1.) Location

PIRs are trap detectors and are placed in areas an intruder is likely to enter; or, which contain objects of high value. In homes, these are generally the living room, master bedroom, and hallways or walkways. In commercial and industrial applications, PIRs are often placed in office computer rooms, hallways and aisles, warehouse and storage areas, and rooms with much glass (such as the store front or reception area.).

Before you begin installing a PIR detector, its wires, or even the control panel, you should review the system's layout to be sure that the best location has been selected for the PIR.

2.) Survey

Surveying the detection area with your eyes at the exact location selected for the PIR is the professional way to avoid the most common installation mistake; poor site selection.

Don't be too shy to use this technique. Auto Repairmen look at cars, Doctors look in throats, Accountants look at bank books, and Alarm Installers look at the PIR's field of view. Before you drill, put your eyes at the same height as the PIR and take one last look at its field of view.

Good site selection will reduce the need for aiming, masking, or even moving PIRs, to avoid false alarms.

B. Installation Hazards

Air Turbulence & Drafts

PIRs do not "see" air temperature (not even air from overhead heaters or air conditioners, or inside drafty warehouses).

Objects changing temperature inside a detection zone (such as heating vents or air conditioners) or objects being blown around inside the detection area (hanging signs, or balloons) can be seen by a PIR detector and can cause false alarms.

Drafts blowing directly on a PIR at a close distance, could change its temperature quickly enough to cause a false alarm.

Unsealed wire knock-outs, especially on surface mount installations, will cause false alarms. Always seal wire knock-outs with silicone. Even in well constructed buildings, temperature and atmospheric pressure differences between indoors and outdoors can cause walls to breathe and create wind currents inside the PIR. This type of draft can change the pyroelectric element's temperature and cause a false alarm. Additionally, winds can frequently gust at over 50-60 mph, sealed wire knock-outs keep drafts from entering PIRs.

RFI Wires and Antennas

Wires connecting the control panel and PIR are essentially antennas which lead RFI to the PIR. The longer the wire, the better the antenna.

Using twisted wire reduces RFI related problems. In trouble areas, RFI rejection can be further enhanced by applying 30 microfarad capacitors at the detector and/or the control panel.

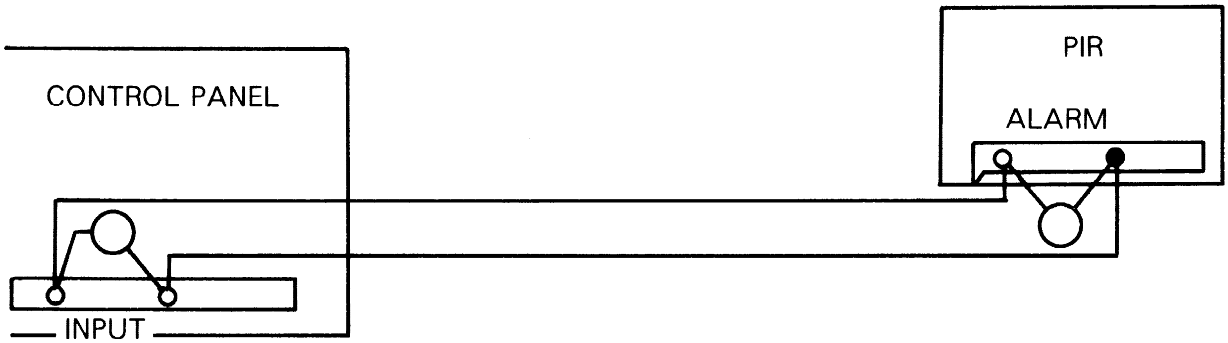


Figure 19

Glass

While some frequencies of electromagnetic energy pass through glass (i.e. visible light), the far infrared rays utilized by a PIR detector do not. A PIR detector will not detect objects such as a person or a car through glass.

Glass changes temperature quickly and some PIRs might react to the temperature change exterior windows experience. Similarly, sunlight hitting the floor below a window might change the floor's temperature too quickly for the PIR to adjust. However, a good PIR that is installed at least 50% of its rated distance away from a window, should not have difficulties compensating for these disturbances.

But, before you aim a PIR at a window, consider these next two installation hazards.

Visible Light

Visible light penetrates glass and turns into heat when it is absorbed by an object. Even reflected visible light can cause many PIRs to false alarm when it shines directly into the detector.

Reflection

Reflection can also cause false alarms. While visible light usually penetrates glass, IR energy is reflected by glass. Glass, mirrors, and highly polished metal reflect IR and create detection in unexpected areas.

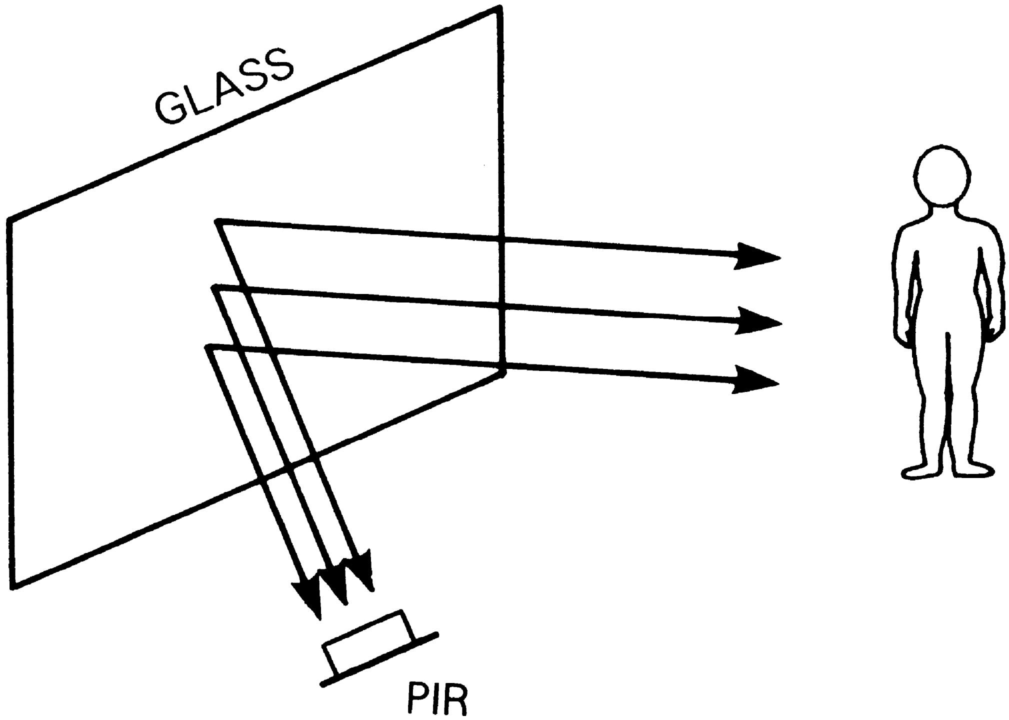


Figure 20

While aiming a PIR at glass can't really be forbidden, considering the complications it creates, it definitely should be avoided.

Insects & Dirt

Sealing the wire knock-out also keeps out dirt & insects. Insects walking across the sensor element look like king kong and dirt accumulation will reduce sensitivity.

Installations in restaurants; bars; grocery stores; and other areas where food is present, require the installer to make an extra effort to completely seal the PIR. If you don't, you will be back.

Small Animals

Rodents and birds have a stronger affect on the PIR the closer they are to it.

Moving Objects

Objects moving within the detection zone, such as hanging signs, balloons, or curtains, can cause false alarms. While they might appear to be "room temperature", in fact they can provide enough of a temperature contrast (especially if the PIR is facing an exterior wall) to cause a false alarm. As with small animals, the closer these objects are to the PIR, the more effect they will have.

Pets

PIRs can often be adjusted to create pet alleys. Pet alleys provide detection zones which shoot straight across the room, without touching the floor.

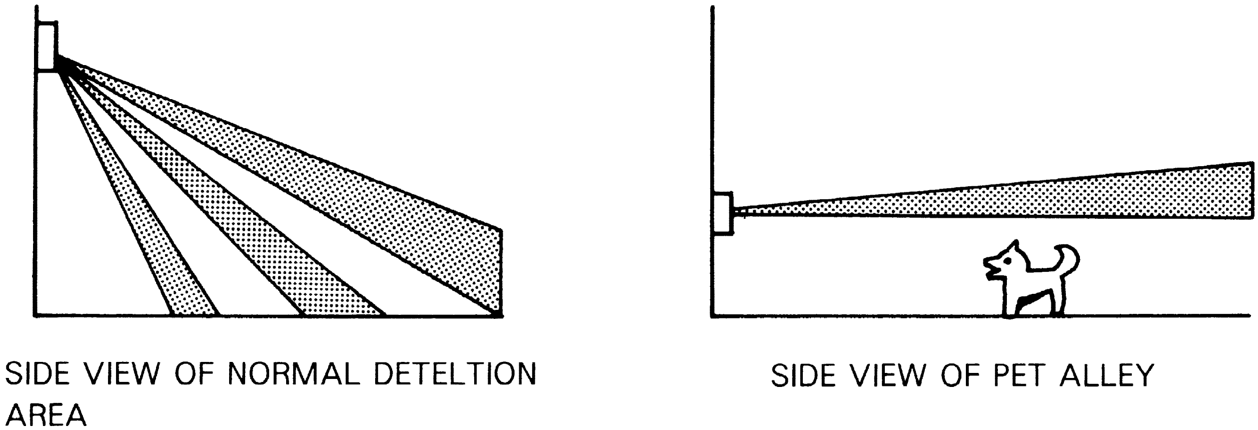


Figure 21

Pet alleys are most successful with animals which tend to stay on the floor and are not overly active.

Unheated Areas

The quality of a PIRs components and design determines its stability at different operating temperatures and during sudden changes in operating temperature. A high quality PIR detector should not have difficulty in unheated indoor environments.

Blockage

Far infrared energy is relatively weak and does not penetrate most materials. Sometimes PIR zones can be blocked by furniture, walls, and doorways and sensitivity is lost.

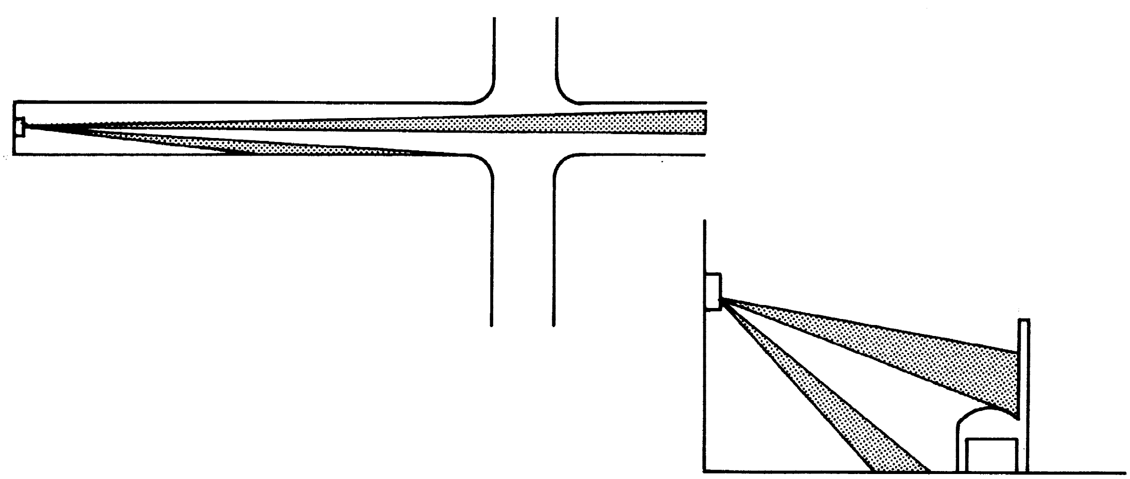


Figure 22

C. Room Size

Obviously smaller rooms do not turn up the amplifier level; but, smaller zones are easier to affect. The relationship between zone size and sensitivity suggests that increased caution be used when installing a PIR in a room less than half the PIR's rated range.

D. Terminating the PIR's Zones

Before installation, it is also important to consider the terminating point of a PIR's zones.

1. Detection area is blocked by walls, floors, or furniture.

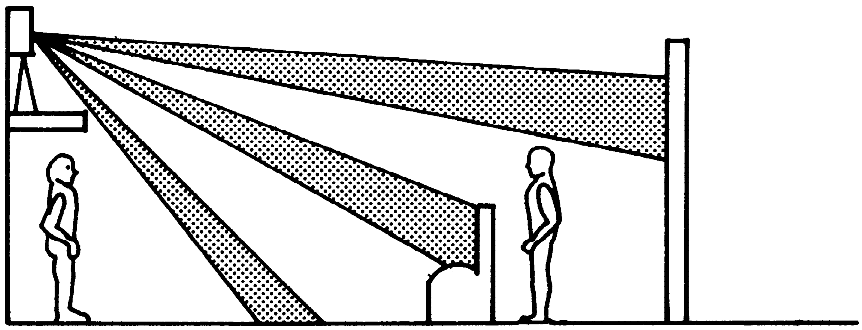


Figure 23

The detection area will be less than the rated range when the zone is blocked.

2. PIRs can detect from beyond their rated detection range.

A PIR is a receiver of IR energy (not a transmitter) and it can receive from an infinite distance. Unless the zone is terminated by something within the PIR's rated range, the zones will continue to expand; creating large and unreliable detection areas which may lead to false alarms.

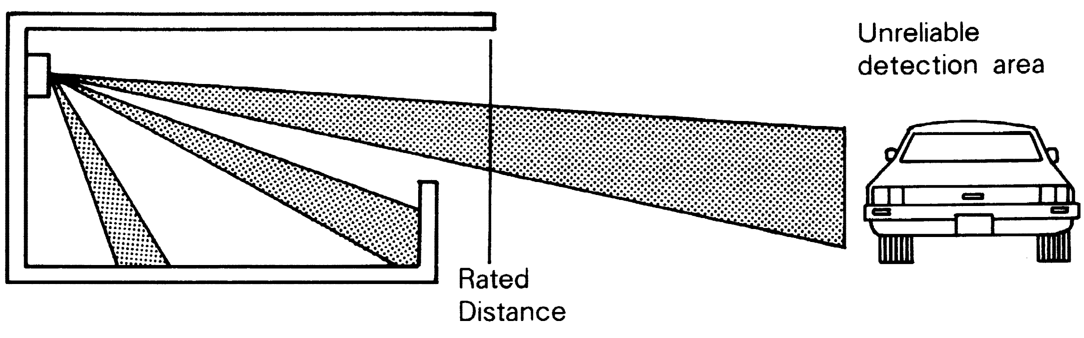


Figure 24

<u>Figure</u>

Even when the walk test shows no detection beyond the rated range and the installation goes for months without a false alarm, an especially cold day or large object can create a strong enough signal to cause a false alarm. "Gee, I didn't think it would pick-up that far" is heard too often by all PIR manufacturers.

PIRs can receive from an infinite distance, it is only a question of how strong of a signal is received.

3. Rated detection range is assured even when PIR's don't terminate within their rated range.

E. Masking PIR Detectors

Proper site selection and aiming are the two quickest and easiest ways to avoid false alarms. While masking PIRs has no negative effect on the performance of the detector, it is usually avoided because it is time consuming.

Many manufacturers provide precut masking segments, but virtually any material can be used. Be very careful when masking mirrors, because the masking cannot be removed without damaging the mirror.

IMPORTANT: Always conduct walk tests to confirm that unwanted detection has been completely eliminated.

Masking detection zones does not affect the sensitivity of the remaining zones.

F. Installation

Install according to the manufacturers instructions.

Walk test to confirm the desired detection has been achieved and there is no unwanted detection (often we are too busy checking detection in important areas to notice that we are also detecting in unwanted areas). As mentioned earlier, sealing the wire knockout with silicone is necessary. If this is not done, the PIR is not properly installed!

Remembering that you will come back in the next 1-2 years to inspect, service, or upgrade this system: label all wires and zones; record the total system current draw; each line's current draw; and the resistance of each loop. Doing this is professionalism, and it earns us respect from our customers, our coworkers, and our competitors.

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OPTEX accepts no liability for the use, or misuse of ideas presented in this brochure. We strongly encourage readers to discuss these concepts with us, and conduct tests in a controlled workshop environment, before applying any of this information to actual field installations.

We welcome your questions, comments, or suggestions.

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