9. Intrusion Detection Sensors

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Learning Objectives
At the end of this module, you should be able to:
• Discuss the role of intrusion detection sensors
• Identify exterior and interior sensors by classification
• Recognize sensor technologies
• Identify characteristics of a good intrusion detection system design
• Discuss performance characteristics of intrusion detection sensors
Role of Intrusion Detection

- PPS functions
- Detection
  - Exterior intrusion detection
  - Interior intrusion detection
  - Assessment
  - Alarm communication and display
  - Entry control
- Delay
- Response
- IAEA Nuclear Security Series No. 13 recommends an integrated system of detection, delay, and response

Performance Characteristics of Intrusion Detection Sensors

- Probability of Detection ($P_D$)
  - $P_D = P_S \cdot P_A$
  - where
    - $P_S$ is Probability of Sensing
    - $P_A$ is Probability of Assessment
Performance Characteristics of Intrusion Detection Sensors (continued)

- Vulnerability to defeat
  - Bypass: Avoiding the detection volume of the sensor by crawling, jumping, tunneling, or bridging
  - Spoofing: Tricking the sensor into not reporting an alarm
- Methods are dependent on adversary and adversary tactics
  - Given the proper knowledge, tools, and time, every sensor can be individually defeated

Types of alarms
- Real Alarms - Caused by an actual intrusion
- Nuisance Alarms - Occur when the sensor performed properly, but detected something other than a real intrusion attempt
- False Alarms – Generated by the sensor either because of poor maintenance or equipment failure
- All alarms are considered unknown alarms until they have been properly assessed
Exterior Sensor Classifications

• Active or passive
• Covert or visible
• Volumetric or line
• Line of sight or terrain following
• Mode of application
  ▪ Buried line
  ▪ Fence associated
  ▪ Freestanding

Perimeter Features

• Defines the boundary of the Protected Area
  ▪ Well-defined clear zone, typically uses two fences
  ▪ Includes sensors, lighting, assessment, access control, and delay features
  ▪ Detects unauthorized access to the Protected Area
• Protected Area is defined in IAEA NSS-13 as an area inside a limited access area containing Category I or II nuclear material and/or sabotage targets surrounded by a physical barrier with additional physical protection measures
Intrusion Detection Sensors

**Perimeter Sensor Technologies**

- Ported Coax
- Fiber Optics
- Fence Disturbance
- Taut Wire
- E-field or Capacitance
- Active Infrared
- Passive Infrared
- Microwave
- Dual Technology Sensors
- Video Motion Detectors

**Ported Coax Sensor**

- Intruder approaching buried cables causes a change in the field around the cables
Fiber Optic Fence Disturbance Sensor

- Fiber optic sensors are most commonly used as fence disturbance sensors.
- The sensor detects vibrations associated with climbing the fence or cutting the fence.

Fence Disturbance Sensors

- Many different methods are available to detect vibrations on a fence. In addition to fiber optics, the following types of sensors can be used:
  - Inertia switches
  - Strain sensitive cable
  - Geophones
  - Piezoelectric sensors
- Most fence disturbance sensors use an event counter and a time window to minimize nuisance alarms.
Taut Wire Fence

- Horizontal wires are monitored for movements associated with cutting and climbing the fence
- Sensing is accomplished with mechanical switches, strain gages, piezo-electric crystals, resistive rubber, or other materials

Electric Field Sensors

- Some wires transmit a small signal that other wires receive
- Coupling between the wires is changed by a person approaching the sensor
Active Infrared Sensor System

- Multiple beams of infrared light are sent between the transmitters and the receivers
- Transmitters and receivers are stacked in various ways to create an array of beams
- Detection occurs when one or more of the beams is blocked

Passive Infrared Sensor

- Lens divides detector into segments that are monitored for changes in heat energy
- Alarm occurs when changes in heat are detected in more than one segment in a short period of time
Microwave Intrusion Detection Sensor

- Transmitter and receiver are located at opposite ends of the sector
- Transmitter sends a signal to the receiver
- Received signal consists of direct beam and reflected signals
- Alarm occurs when signal is disturbed by the intruder
- Sensors must be overlapped to provide a continuous line of detection

Monostatic Microwave Sensor

- Transmitter and receiver share antenna
- Movement in the detection zone causes a frequency shift in the returned signal
- Used to provide additional coverage
  - In areas near entry portals
  - To supplement bistatic microwaves at overlap areas
  - To cover terrain changes
Dual Technology Sensors

- Reduces the number of nuisance alarms
- "AND" output
- Allows sensitivity to be set higher than for individual sensors
- Example:
  - Monostatic microwave and passive infrared

Video Motion Detectors (VMD)

- VMD monitor a scene for changes and movement
- Early systems divided the screen into small blocks in the field of interest
- Newer systems can
  - Analyze individual pixels
  - Detect when an intruder
    - Crosses a certain line
    - Enters a certain area
    - Travels in a certain direction
### Conditions That Can Adversely Affect Exterior Sensors

- **Extreme weather**
- **Animals and other nuisance sources**
- **Terrain, soil, and ground covering**

### Exterior Sensor Classification

<table>
<thead>
<tr>
<th>Sensor Type</th>
<th>Passive or Active</th>
<th>Covert or Visible</th>
<th>LOS or Terrain Following</th>
<th>Volumetric or Line Detection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buried Line</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ported Coax Fiber Optic Cables</td>
<td>A</td>
<td>C</td>
<td>TF</td>
<td>VOL</td>
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<tr>
<td>Fence Associated</td>
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<tr>
<td>Fence Disturbance</td>
<td>P</td>
<td>V</td>
<td>TF</td>
<td>L</td>
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<tr>
<td>Sensor Fence</td>
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<td>TF</td>
<td>L</td>
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<tr>
<td>Electric Field</td>
<td>A</td>
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<td>TF</td>
<td>VOL</td>
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<tr>
<td>Freestanding</td>
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<td>Active Infrared</td>
<td>A</td>
<td>V</td>
<td>LOS</td>
<td>L/VOL</td>
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<td>Passive Infrared</td>
<td>P</td>
<td>V</td>
<td>LOS</td>
<td>VOL</td>
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<tr>
<td>Bistatic Microwave</td>
<td>A</td>
<td>V</td>
<td>LOS</td>
<td>VOL</td>
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<td>Dual Technology</td>
<td>A</td>
<td>V</td>
<td>LOS</td>
<td>VOL</td>
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<tr>
<td>Video Motion</td>
<td>P</td>
<td>C</td>
<td>LOS</td>
<td>VOL</td>
</tr>
</tbody>
</table>

*LOS= Line of Sight*
Extended Detection

- Used to extend detection beyond Protected Area into Limited Access Area and possibly beyond
- Areas covered may
  - Be natural terrain with native vegetation and not well lighted
  - Contain more wildlife
- Alarm assessment may require thermal cameras or dispatch of patrols
- Contributes to Defense-in-Depth
- May be used as a compensatory measure to adapt to changes in threat and can help detect stand-off attacks

Seismic and Magnetic Sensors

- Seismic Sensors
  - Designed to detect footsteps
  - Types
    - Geophones
    - Pressure filled tubes
    - Buried fiber optics
- Magnetic Sensors
  - Detect intruders carrying weapons, tools, keys, or other metallic objects
  - Magnetic sensors are not commonly used in perimeter applications, because the detection range cannot be well controlled
Extended Detection Technologies

- Used to cover areas outside perimeter
  - Radar
    - Long-, medium-, and short-range
  - Laser Radar
  - Scanning Thermal Imagers
  - Unattended Ground Sensors

Interior Sensors

- Used to provide detection for protection against sabotage and unauthorized removal
  - Protected Areas
  - Inner or Vital Areas
- Help provide Detection in Depth
- Useful for detecting Insider activity
  - Can help enforce the Two Person Rule
- In addition to providing detection for access to nuclear materials, interior sensors are also used to protect sensitive information
9 - Intrusion Detection Sensors

Classification of Interior Sensors

- Active or passive
- Covert or visible
- Volumetric or line
- Mode of application
  - Boundary penetration
  - Interior motion
  - Proximity

Simple Magnetic Door Switch

- Switch mounted to door frame
- Magnet moves with door
- Detects opening of door

Switch Unit

Magnet Unit

(Door Closed)

(Door Opened)

Non-Mag =
Balanced Magnetic Switch (BMS)

- Balanced magnetic switch contains a bias magnet in the switch housing
- Complex magnetic switch contains multiple reed switches and multiple magnets

Glass Break Sensors

- Acoustic glass break sensors
  - Mount on ceiling or wall
  - Respond to low frequency impact and higher frequencies of glass breaking
- Vibration glass break sensors
  - Mount directly on glass pane
  - Respond to vibration of breaking glass
- Magnetic switches are sometimes used to detect window opening
Boundary Sensors

- Break wire sensors sometimes used to detect penetration through a vent or window screen
- Vibration sensors mounted on walls to provide early warning of attempted penetration
- Jiggle switches, inertia switches, piezoelectric sensors can be used
- Many fence disturbance sensors, including fiber optic sensors, can also be used

Active Infrared

- Can be used across windows and doors to detect penetration or entry
- Detects a break in one or more beams of infrared light
  - Multiple transmitters and receivers form a vertical fence
  - Pulsed synchronous techniques can reduce interference and attempted defeat from external light sources
- May be used with entry control systems to ensure only one person entered
Microwave Sensors

- Used to provide volumetric detection within a room
- Monostatic configuration
  - Single antenna or two antennas located in the same housing used to transmit and receive
  - Detection is based on the Doppler frequency shift between the transmitted and received signal caused by an object moving within the energy field
  - Most sensitive to movement toward or away from sensor

Monostatic Microwave Actual Walk Test Detection Data

- Actual data can vary depending upon direction, size, and speed of intruder
Passive Infrared Sensors

- Detects changes in thermal energy
  - Pyroelectric detector converts changes in thermal energy to an electrical signal
  - Lens or mirror focuses energy onto pyroelectric detector
    - Determines field of view (detection volume)
    - Segmented to create multiple detection areas
  - Most sensitive across field of view

Passive Infrared

- Many varieties of detection patterns are available
- Range from a narrow curtain detection pattern to a 360-degree ceiling mounted version
Passive Infrared Sensor Walk Test Pattern

- Movement is towards the sensor
  - Least sensitive direction

Dual Technology Sensors

- Combines passive infrared and microwave technologies into one sensor unit
  - "AND" configuration
    - Both sensor technologies must detect motion
    - Combined $P_D$ is less than each individual sensor
    - Reduces nuisance alarms
  - "OR" configuration
    - Either technology can generate an alarm output
    - Higher $P_D$
    - Higher nuisance alarm rate – either technology can generate nuisance alarms
Dual Technology Walk Test Patterns

- Microwave Pattern
- IR Pattern

Sensor Location

AND

Capacitance Proximity Sensor

- Capacitance Proximity Detector
- Ungrounded Metal Objects
- Electrical Connection
- Ground Strap
- Insulation Blocks
Features of Good Interior Intrusion Detection System

- High $P_D$
- Low nuisance alarm rate
- Uses protection-in-depth
- Detects tampering
- Is properly installed: No loose mountings, wiring in conduit, proper location for sensors
- Well maintained
- Regularly tested

Example Sensor Layout
Protection-in-Depth

Building
- Boundary detection (walls, windows doors)
- Volumetric detection (rooms, halls)
- Proximity detection (target)

Perimeter
May have some combination of:
- Volumetric sensors
- Line sensors
- Buried sensors

Early Warning
(outside perimeter)

Features of Good Perimeter Sensor System

- Continuous line of detection
- Protection-in-depth
- Complementary sensors
- Clear zone
- Sensor configuration
- Site-specific system
- Tamper indication
- Integration with
  - Assessment system
  - Barrier delay
- Maintenance and testing program
Sensor Selection Considerations

- Application
- Operating principle
- Detection capabilities
- Conditions for unreliable detection
- Typical defeat methods
- Major causes of nuisance alarms

Schematic of a Perimeter System

Limited Area

Protected Area

Communications
And Display
(CAD) Box

Power
Cabinet

Taut Wire

High Pressure
Sodium Lights

CCTV

Sector Length
~100 m

IR

MW

IR

IR

MW

IRD
Example Perimeter System

Summary

• Performance characteristics
  ▪ $P_d$, nuisance alarm rate, vulnerability to defeat

• Sensor classifications
  ▪ Passive or active; covert or visible; line of sight or terrain following; volumetric or line detection; and by application

• Exterior technology includes
  ▪ Buried line sensors, fence-associated sensors, freestanding sensors

• Interior technology includes
  ▪ Boundary penetration, interior motion, and proximity

• Designers should consider
  ▪ Design goals, effects of physical environmental conditions, and interaction of system with a balanced PPS