Sensys Networks VDS240 Wireless Vehicle Detection System

Design Guidelines for Freeway & Arterial Applications

P/N 152-240-001-009 Rev D
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Contents

Document Properties

This document is reference material for the Sensys Networks VDS240 wireless vehicle detection system from Sensys Networks, Inc.

P/N 152-240-001-009 Rev D

Regulatory Statements

FCC Compliance Statement

This device complies with part 15 of the FCC rules. Operation is subject to the following two conditions:

(1) This device may not cause harmful interference.

(2) This device must accept any interference received, including interference that may cause undesired operation.

Any changes or modifications to this product not authorized by Sensys Networks could void the EMC compliance and negate the authority to operate the product.

RF Exposure Statement

This device has been tested and meets the FCC RF exposure guidelines. It should be installed and operated with a minimum distance of 20 cm between the radiator of RF energy and the body of users, operators or others.

Improper use or tampering with the device is prohibited and may not ensure compliance with FCC exposure guidelines.

Warnings

No Safety Switching

Sensys Networks **does not** allow its equipment to be used for safety applications such as controlling a mechanical gate or switching a train to avoid a collision.

Lithium Thionyl Chloride Batteries

Sensys Networks uses Lithium Thionyl Chloride batteries in the following products:

- Sensors (VSN240-F, VSN240-T, VSN240-S)
- Repeaters (RP240-B, RP240-BH, RP240-B-LL, and RP240-BH-LL)

Lithium batteries are widely used in electronic products because they contain more energy per unit -weight than conventional batteries. However, the same properties that deliver high energy density also contribute to potential hazards if the batteries are damaged. Improper use or handling of the batteries may result in leakage or release of battery contents, explosion or fire.

Following are the recommendations of the battery manufacturer for proper use and handling of batteries in the Sensys Networks devices mentioned above:

- **DO NOT** charge or attempt to recharge the batteries (batteries are NOT rechargeable)
- **DO NOT** crush or puncture batteries
- **DO NOT** short-circuit the batteries
- **DO NOT** force over-discharge of the batteries
- **DO NOT** incinerate or expose batteries to excessive heating
- **DO NOT** expose battery contents to water
- **DO** dispose of batteries and devices containing batteries in accordance with local regulations

> **Note**: Sensys Networks wireless sensors contain no serviceable parts and should never be disassembled. Installation and removal of sensors from pavement should only be done by trained personnel and care should be taken to insure that the sensor casing is not punctured or crushed.

Additional safety information is available from the battery's manufacturer:

- Sensor battery cell: http://www.able-battery.com/msds/ABLE_MSDS_ER14505.pdf
- Repeater battery cell: http://www.able-battery.com/msds/ABLE_MSDS_ER34615.pdf

Document Control

Sensys Networks continually reviews and revises its technical publications Please address questions, suggestions or corrections to support@sensysnetworks.com.

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CHAPTER 1
Introduction

This document describes how to design a vehicle detection network for common freeway and arterial applications using the Sensys Networks VDS240 wireless vehicle detection system. It provides conceptual information about the Sensys Networks system and presents an approach to making design decisions. This information is primarily intended for traffic system designers, consultants, and engineers. However, installers, dealers and others with an interest in the application of wireless communication technology to the challenges of vehicle detection may also benefit from it.

What's Inside

This document includes the following chapters:

- Chapter 1, *Introduction*, defines the purpose and scope of the document.
- Chapter 2, *System Overview*, describes the components and general operation of a Sensys Networks VDS240 wireless vehicle detection network.
- Chapter 3, *System Design*, provides the design approach recommended by Sensys Networks.
- Supplemental information is provided in an *Appendixes* section.

Other Documents

General and Reference Information

- *Sensys Networks VDS240 Wireless Vehicle Detection System Reference Guide*

Freeway and Arterial Applications

- *Configuration Guidelines for Freeway & Arterial Applications*
- *Installation Guidelines for Freeway & Arterial Applications*

Intersection Applications

- *Design Guidelines for Intersection Applications*
- *Configuration Guidelines for Intersection Applications*
- *Installation Guidelines for Intersection Applications*

Installation Procedures

- *Wireless Sensor Installation Guide*
- *Access Point Installation Guide*
- *Contact Closure Card Installation Guide*
- *Repeater Installation Guide*

Application Notes

- *Installing Sensys Networks Sensors Beneath the Road Surface*

Sensys Networks Management Server

- *SNAPS Server Set Up and Operating Guide*

Readers of this document are encouraged to contact Sensys Networks for the latest technical information, design guides, and best practices.

CHAPTER 2
System Overview

This chapter provides a description of the components of the Sensys Networks VDS240 wireless vehicle detection system and how they work together to perform traffic detection.

Introduction

The Sensys Networks VDS240 wireless vehicle detection system detects the presence and movement of vehicles with magneto-resistive *sensors* mounted in the pavement. The sensors continuously transmit detection data via low power radio communications to *access points* that collect and forward data upstream to local traffic controllers, remote traffic management systems or other applications.

The wireless technology used for communications between a sensor network and an access point is subject to certain physical limitations – notably distance. Thus, it is not uncommon to include one or more *repeaters* in an installation. Repeaters receive data transmissions from sensors and relay them to a designated access point, thereby extending the access point's range.

Vehicle detection data can be forwarded directly to traffic signal control equipment local to the installation, transmitted to remote systems via a wired or wireless connection to an available IP data network, or both.

Remote systems include traffic management centers, advanced transportation management systems, public traveler information systems, or custom applications performing data analysis, reporting, or control operations.

A typical network is shown in the following figure:

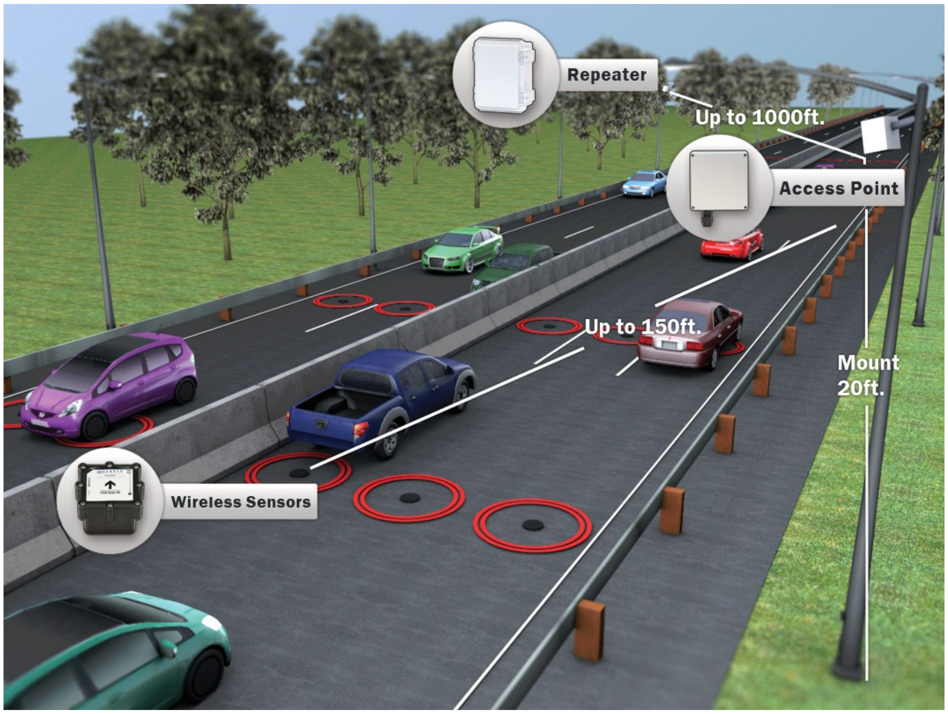


Figure 2.1 – Typical Wireless Vehicle Detection Network

A network replaces traditional copper-based loops with wireless sensors and traditional “home run” cabling with wireless radio transmission. Traffic controller operations are unchanged; they operate in exactly the same manner as they do when used with copper loops, radar, or video systems. Additionally, upstream applications – such as the district front-end processors, traffic control systems, and the like – receive data just as they do from legacy detection solutions (although in many applications, the solution provides additional capabilities).

Network Components

The components of a network are shown in the following figure. (*Note*: some networks may not use all of the components shown.)

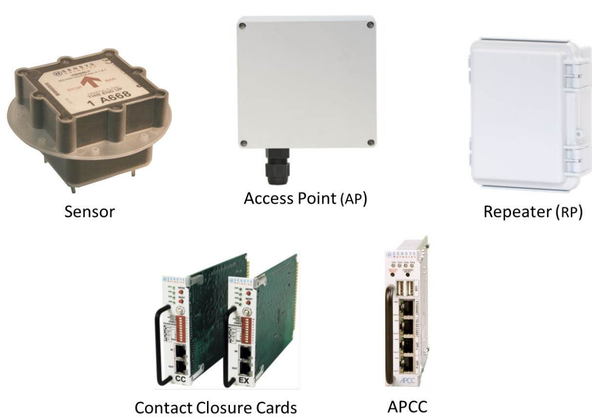


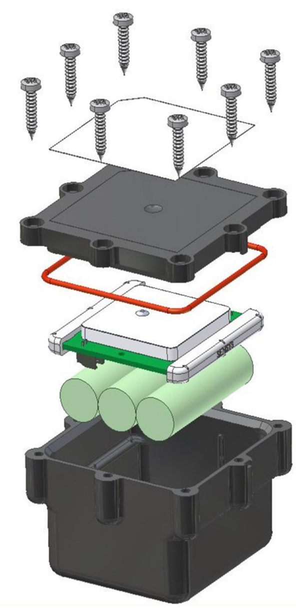
Figure 2.2 – Sensys Networks Components

Sensors are battery-powered magnetometers installed under or on top of the road's surface. Vehicle detection is accomplished by measuring changes in the local magnetic field. Unlike wired loops, sensors do not induce a magnetic field; no current is run through them. An important benefit of this is there can be no “crosstalk” between induced fields as with some wired-loop situations.

Flush-mount sensors are installed in a hole measuring approximately 4” (10 cm) in diameter and 2½” (6.5 cm) deep, cored into the pavement. Since saw cuts are not required, installation can be completed quickly – often in as little as 15 minutes.

Note: Installing sensors at depths other than the nominal depth of 2½” (6.5 cm) voids the product license and warranty unless certified by Sensys Networks, Inc.

Characteristics



- Sealed unit; no user access to internals
- 10 year expected battery life
- Built-in antenna and two-way radio
- Automatic self-calibration
- Unique address per unit
- Software updated via the wireless channel

Sensors are available in two models. Freeway/arterial applications require **F-model** sensors, specifically designed for performing vehicle counts and related detection tasks.

An additional model, the **T-model,** is limited to supporting traffic signal control applications. T-model sensors cannot be used for count applications. The number of sensors in a network is a function of the size of the installation and the detection needs.

Access Point

An access point provides a central point of authority, data collection, and control for a network. An access point and all other components communicating to it (including sensors, access points, and contact closure cards) comprise a network.

Access points are installed at the roadside on an available light, utility or other type of pole, to collect vehicle detection data from sensors and access points. Vehicle detection events are optionally processed and stored by the access point, and optionally forwarded to central traffic management systems, remote traffic information systems, or signal controllers.

Characteristics

- Sealed NEMA Type 4 enclosure; embedded Linux-based microprocessor
- Built-in antenna; 16 channel two-way radio
- Pole mounted; maximum range to sensors: 175 feet (53 m)
- Supports up to 48 sensors (at default settings)
- 2W – 3.5W power consumption
- Built-in Ethernet 10Base-T port
- Optional CDMA/GPRS cellular port (backhaul)
- Unique address per unit
- Software updated via IP-based connection
- Manageable from remote site
- Collects vehicle detection data from sensors and access points
- Forwards detections to traffic signal controllers, district front-end processors, or other traffic management systems
- Optionally calculates and stores statistics describing vehicle detection events
- Master timebase for all network devices
- Central management point for all network devices

Access points are powered via a traffic controller, solar panel or other power source available in the field. Typically there is one access point per network installation.

Repeater

A repeater is an optional system component that extends the range of an access point. A repeater point relays signals between sensors and an access point.

Repeaters are used when the *distance* between sensors and the access point exceed the practical limits of wireless radio, or the *angle* of the devices to one another results in poor signal reception. These conditions can be found at large intersections, in ramp management applications, or advance detection situations.

Characteristics

- Sealed NEMA Type 4 enclosure
- Battery powered (minimum two year expected life)
- Built-in antenna; 16 channel two-way radio

- Pole mounted; maximum range to sensors: 175 feet (53 m)
- Supports up to 10 sensors (at default settings)
- Maximum range to access point : 1,000 feet (305 m)
- Unique address per unit
- Software updated via the wireless channel

Repeaters are particularly useful for mid-block detection or similar uses. The number of access points in a given network is a function of the detection requirements and where the other components are installed.

Contact Closure Card

A network can be interfaced to traffic signal controllers such as the CalTrans Type 170, Type 2070 ATC and NEMA TS-1 and TS-2 controllers via a hardware interface card installed into the controller cabinet. The interface is called a contact closure (CC) master card.

Characteristics

- Installs directly into controller shelf
- Occupies one or two controller slots depending on configuration
- Wired connection to access point (carrying power and channel signal)
- Emulates two or four channel loop amplifier cards
- Supports up to 15 sensors per channel
- Individually configurable channels
- Supports pulse or presence modes and delay or extension modes
- Supports visual and audible channel status indicators
- Can be configured and managed remotely
- Unique address per unit
- Software updated via wired access point connection

Additional sensor or channel capacity can be provided by a contact closure expansion (EX) card. Expansion cards use the same form factor as master cards and are daisy-chained to a master card by front-panel cables. Up to 63 expansion cards can be used per contact closure master card.

A contact closure master card is required to interface an access point to a traffic controller; there is one CC card per access point. The number of expansion (EX) cards is determined by the detection requirements of the application and the controller's programming regarding input channels.

AccessBox

An AccessBox is a small, three-port junction device used with contact closure cards. It provides a wired port for IP-based access to the access point for the purposes of device management, configuration or data collection. An AccessBox is required for each contact closure master (CC) card; they are not used with EX cards.

Access Point Controller Card (APCC)

The Sensys Networks Access Point Controller Card (APCC), is a second generation controller card that maintains low power consumption, supports multiple radios, and allows for additional communication and processing power. The APCC, which is compatible with all of Sensys Networks VDS240 Wireless Vehicle Detection System products, receives and processes data from the sensors. The APCC then relays the sensor detection data to a roadside traffic controller or remote server traffic management system.

Contact Closure Expansion Card

Additional capacity (to handle more sensors or controller channels) is provided by a contact closure expansion card (EX card). EX cards use the same form factor as APCC cards and are daisy-chained to a CC interface on the APCC on the front-panel RJ45 jacks or backplane connectors. Up to 63 EX cards can be used per APCC card.

Types of APCC Configurations

The APCC single-slot configuration consists of dual APCC radio ports, Sensys Networks Expansion (EX) port, and contact closure interface via backplane to a traffic controller. It also has dual USB 2.0 full speed host ports and 10/100Base-T network access. The APCC dual-slot configuration adds an SD memory card, real-time battery-backed clock, dual serial (DB9) interface, or an optional built in cellular modem.

APCC System

The minimum APCC system consists of an APCC and one SPP radio. The system can also consist of multiple SPP radios and an isolator that offers electrical isolation up to 1500V, surge protection up to 1500V, and AC power cross protection.

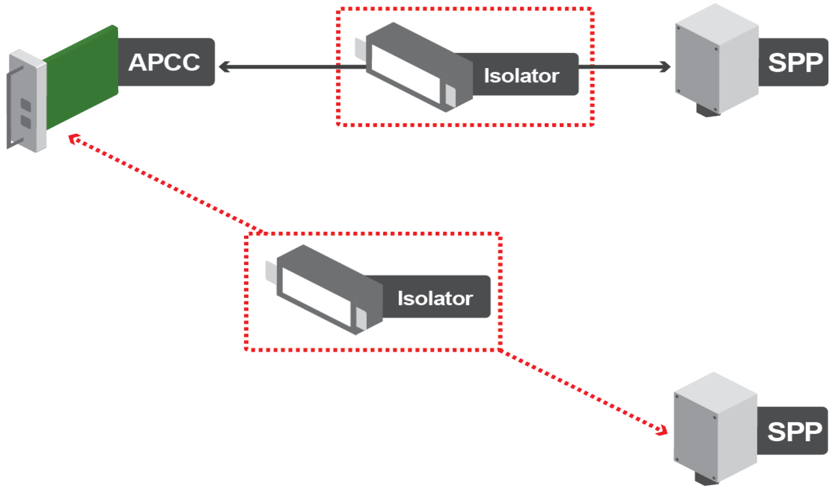


Figure 2.3 – APPC system configuration

APCC Serial Port Protocol (SPP) Digital Radio

The APCC, along with the SPP, maintains two-way wireless links to an installation's sensors and repeaters, establishes overall time synchronization, and transmits configuration commands and message acknowledgements.

Isolator

The isolator is an optional component that provides the following services:

- connects an SPP to the APCC
- isolates and routes power from the controller backplane to the SPP
- provides a wired port for IP network access (suitable for network configuration, management and data acquisition)
- extends the communication for the APCC to and from the SPP at RS422 distance

Network Operations

The basic operating principles of a network are depicted in the following figure.

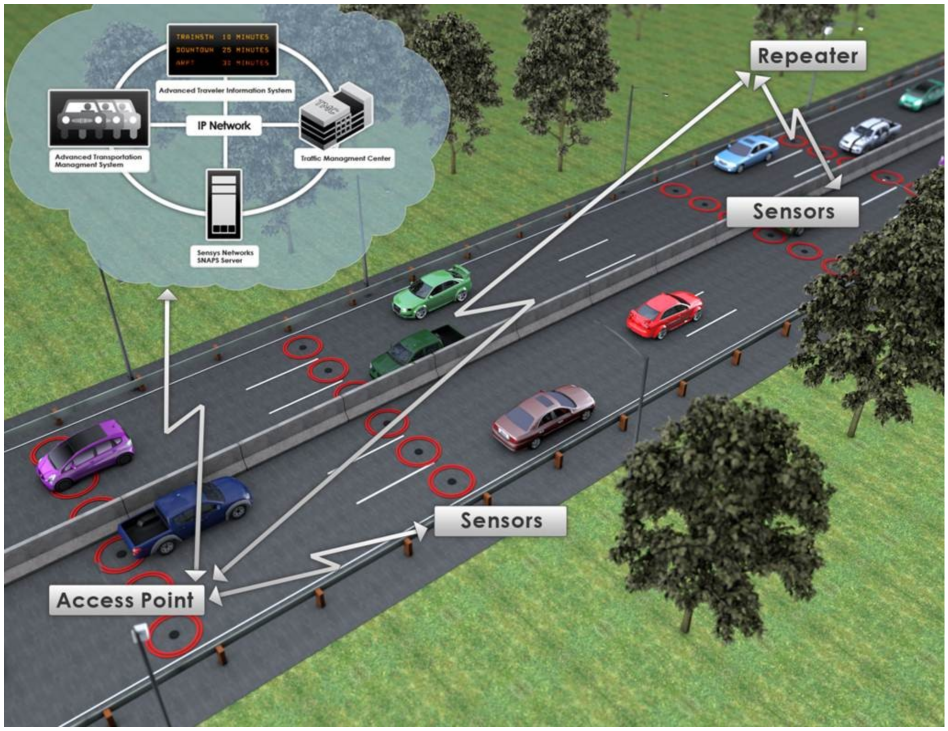


Figure 2.4 – Simplified Network

Pavement mounted sensors detect the presence or passage of vehicles. Detection events are transmitted by wireless radio to an access point or, if used, a repeater. The access point may store the events, forward them to a local traffic controller, backhaul them to another system, or any combination of the foregoing.

The key point is, that when compared to wired loops, the loop is replaced by one or more wireless sensors and the "home run" is replaced by wireless RF communications. The operations of traffic signal controllers or traffic management systems are unchanged.

Understanding Vehicle Detection

Wireless sensors passively measure changes in the Earth's magnetic field. They do not use electrical current to induce a field. Additionally, sensors automatically recalibrate to the environment over time, eliminating the need to manually tune or adjust them.

Events

Vehicles are detected by inference. Algorithms in the sensor's firmware make decisions based on changes detected in the local magnetic field and user-supplied parameters. Detecting a vehicle is reported as a *detection event*.

Modes

The behavior of a sensor is dictated by its *mode* – an instruction given to a sensor that directs how it will operate. Freeway and arterial applications require the use of *Count* mode, while intersection applications may use any of 16 different *Stop Bar* modes.

Modes are assigned via network management software, and can be assigned individually to sensors resulting in a high degree of customization to the needs of the application.

> **Note**: In certain rare situations overhead or buried power lines may interfere with vehicle detection. Testing of the environment using a reserved detection mode may be required if conditions such as this exist at or near the site of the detection system.

Detection Zones

The area around a sensor in which changes in the local magnetic field are detected is known as the sensor's *detection zone*. Generally speaking, this area is composed of two parts – the *Detection* zone and the *Intermediate* zone – as shown in the following figure:

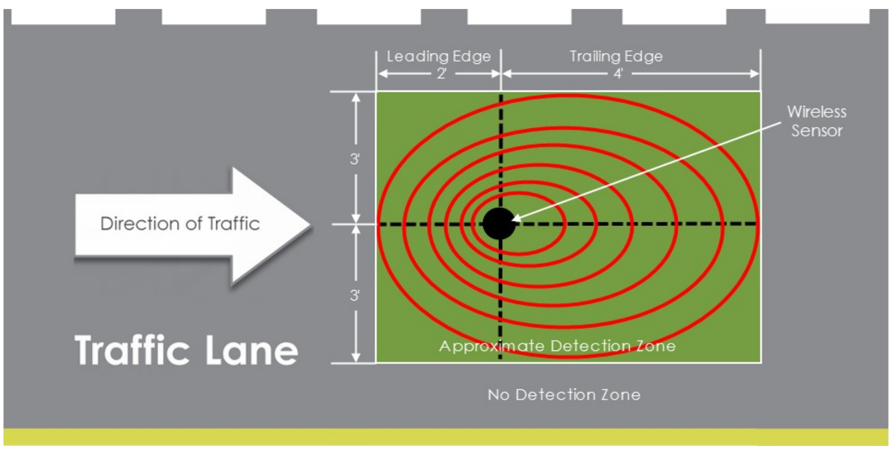


Figure 2.5 – Approximate Sensor Detect Zone and Intermediate Zone Shown For Default Count Mode Settings

The *Detect Zone* is the area immediately surrounding the sensor, in which vehicles are likely to be detected with high probability. The *Intermediate Zone* is an area surrounding the Detect Zone in which vehicles may or may not be detected depending on their size and type. Detection of vehicles outside the Intermediate Zone is not likely. The detection zone can be adjusted by the operating mode of the sensor.

Understanding Event Data Collection

Sensors automatically transmit their vehicle detection events to an access point or repeater on a predetermined wireless radio channel. Repeaters relay the data from the sensors they service on a second wireless channel.

Antenna Orientation

All components use the same directional antenna. With regard to access points and repeaters, the strongest signal comes from the front of the device, in a pattern radiating approximately 60° from either side of the centerline as represented in the following figure.

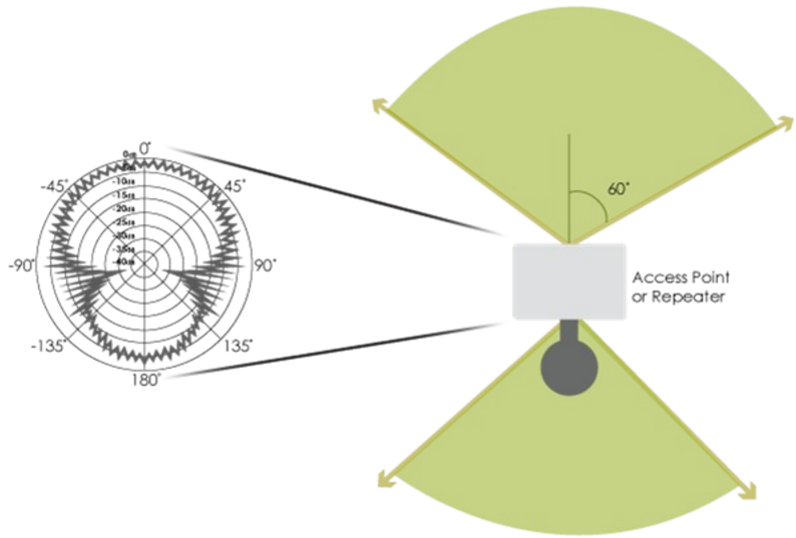


Figure 2.6 – Antenna Beam Pattern

A more limited pattern radiates from the back of the device which can, in certain applications, yield adequate RF performance. With regard to installed sensors, the primary signal energy radiates straight upward. Signal strength radiating in the opposite direction is not useful.

Antenna orientation is a direct contributor to the quality of RF signal reception in the field. The optimal orientation is where the devices face each other. When devices must be oriented differently, be certain to assess the impact on the RF signal strength. (See the *RF (Radio Frequency) Performance Monitoring* section.)

Range

The radio transmitter used in equipment is subject to certain limitations in terms of the proximity of the devices to one another.

Range to Sensors

Generally speaking, the distance between access points and sensors is a function of mounting height of the access point. The same is true for repeaters-to-sensor distances.

Best practice guidelines are provided in the following table:

Height of Access Point or Repeater Relative to Road Surface	Maximum Recommended Range to Sensor
16 feet (5 meters)	100 feet (30 meters)
20 feet (6 meters)	150 feet (45 meters)
30 feet (9 meters)	175 feet (50 meters)

Table 1: Best Practices For Proximity of Sensors to Access Points and Repeaters

Repeater Range to Access Point

Repeaters may be located up to 1,000 feet (305 m) from an access point. Be certain that a line of sight exists between the devices, and that the devices face each other as much as possible.

RF (Radio Frequency) Performance Monitoring

Wireless radio communications can be impeded by transient local interference and the physical environment in which the equipment operates. The communication protocol developed by Sensys Networks provides two important benefits in this area:

- Automatic detection and handling of RF communication errors
- Automatic, continuous measurement of RF communication efficiency

All devices comply with a message acknowledgment protocol so that data not received due to communication errors is automatically resent.

Additionally, two metrics – RSSI and LQI - characterize radio communication efficiency and provide a means for evaluating radio performance in the field.

RSSI (Received Signal Strength Indicator)

RSSI characterizes the power loss in a received radio signal. For example, a signal with an RSSI value of -60dBm is considerably stronger than a signal with an RSSI value of -80dBm. Typical RSSI values found in the field will range from -50dBm (excellent) to -95dBm (the far edge of RF coverage).

For reliable communications, RSSI values (in the absence of vehicles) must be in the ranges shown in the following figure.

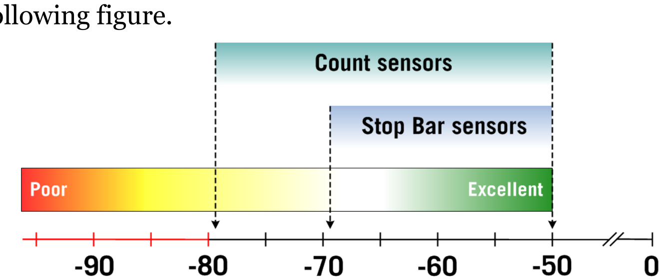


Figure 2.7 – Required RSSI Ranges by Application

Typically, count applications can tolerate a weaker signal than intersection applications. Therefore, sensors in count mode should exhibit RSSI values greater than -79dBm; sensors in stop bar applications should exhibit RSSI values greater than -69dBm.

LQI (Line Quality Indicator)

LQI is an indicator of link error rate or signal-to-noise ratio (SNR). LQI values conform to the scale given in the following figure.

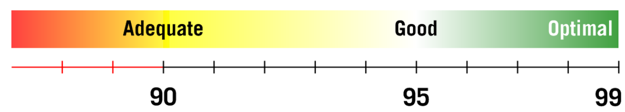


Figure 2.8 Acceptable LQI Values

For reliable performance, LQI values must be at 90 or above. Poor LQI in the presence of strong RSSI is indicative of local ISM band interference (for example, a nearby Wi-Fi modem). Use an alternative RF channel to improve performance.

Displaying RSSI and LQI

RSSI and LQI are displayed in TrafficDOT, the network management program from Sensys Networks.

Use TrafficDOT to validate the communication efficiency of a network at a point in time – for instance, at installation. To evaluate the communication efficiency of a network over a longer period of time, use the automated daily network diagnostic report.

Understanding Event Data Processing

As vehicle event data is collected by an access point, any combination of the following types of additional processing may occur.

Forward Detections to Traffic Controller

A detection network can be interfaced to a local traffic controller with a contact closure (CC) card. Controllers receive signals in exactly the same fashion as they do from copper loops, radar or video-based systems. Reprogramming the controller is not required.

Backhaul to Traffic Management Center

Vehicle detection data (or statistical summaries) can be backhauled to the TMC via either of the following interfaces:

- Ethernet (10baseT)
- Cellular modem (GPRS or CDMA)

These interfaces support IP-based communications, and also enable remote management of the access point and the other devices on the network. (*Note*: using these interfaces does not conflict with legacy backhaul technology that may exist at a given controller.)

Calculate Statistics

Vehicle detections can be used to calculate statistics such as volume, occupancy, and speed. Statistics can be computed on a *per-lane* or *per-vehicle* basis. The statistical process may execute on the access point or other platform.

Store Event Data

Vehicle detections may be stored on the access point for periodic download. Storage requirements depend on the application requirements and the configuration of the network. Typical installations may store over one month of detection data.

CHAPTER 3
System Design

The Sensys Networks VDS240 wireless vehicle detection system can be configured to meet the requirements of many different traffic management situations. This chapter presents the recommended process for designing networks used in freeway and arterial count applications.

Getting Started

Prior to installing any components in the field, develop a a site design document. The purpose of a site design document is to minimize the thought, effort, and time required to install the equipment and achieve acceptable detection performance. Experience has shown that a design document, augmented by equipment that has been labeled and pre-configured, can reduce overall installation time by as much as 50%.

Compiling Site Design Materials

At the outset, spend a few minutes collecting information to accurately document the installation site's general location and environment. Consider acquiring:

- the address of the site, major cross streets, map references, GPS co-ordinates, or road-marker designations
- the identifiers of all traffic controllers involved in the project (if any)
- a satellite image (obtained from Google Maps, Google Earth, or similar source)

Developing a Schematic

Next, rough out a schematic of the site on a white board, drawing program or sketch pad. Identify and mark the following:

- lanes of traffic
- key approaches
- traffic controller locations

An example satellite image and resulting schematic are shown in the following figure.

Figure 3.1 – Satellite Image and Road Schematic (from Google Maps)

While the availability of geographic information has never been better, nothing compares to an actual site visit. Schedule a site survey if possible.

Documenting the Application Requirements

Begin the system design by documenting the general requirements of the vehicle detection network. Most applications require some or all of the following:

- Vehicle counts
- Advance detection
- Intersection signal control
- Occupancy or speed measurement

Sensys Network Design Steps

The design process recommended by Sensys Networks consists of the four steps shown in the following figure. Consideration of each step is required, however, the *backhaul* step may not be applicable to every application.

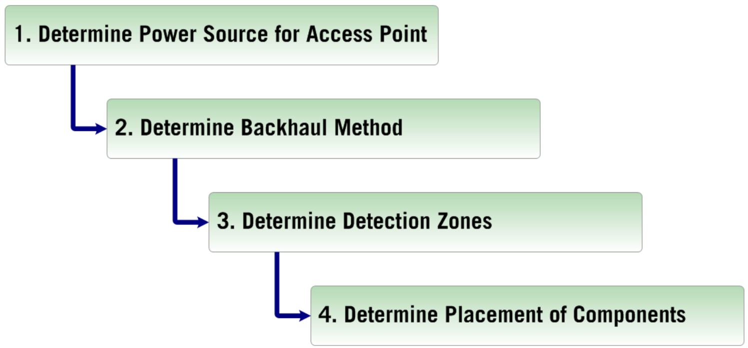


Figure 3.2 – Sensys Networks Design Steps

In the sections that follow, each step is discussed and the design factors applicable to each are identified.

Step 1: Supplying Power to an Access Point

The first design step considers powering the access point from an external source.

Design Factors

- Power reaches an access point via an 4-pair CAT5 or better, outdoor rated Ethernet cable, terminated with male RJ45 connectors, through an integrated bulkhead connector.
- Power sources may include:
  - 12 – 24 VDC from a traffic controller detector rack or input file
  - 10 – 20 VDC from a low-voltage source such as a solar panel
  - Available Power-over-Ethernet (PoE) device such as a local area network hub, switch, or router
  - 120 VAC outlet

  When an access point is powered from the controller rack, a *contact closure card* and a *AccessBox* are required. Otherwise, an industry standard PoE enabled device is used.
- An access point without an integrated cellular modem draws approximately 2 W of power; when equipped with a cellular modem, an access point draws approximately 3.5 W.
- The length limit of standard Ethernet compatible, outdoor rated, 4-pair CAT5 cable is 100 meters (328 feet). This is the maximum supported distance between an access point and its power source.

- The cable must be terminated with male RJ45 connectors according to the TIA/EIA 568-B specification.

Step 2. Designing the Data Backhaul Method

Vehicle detection data may be optionally backhauled to a remote site such as a district traffic management center. To do so, the backhaul method must be determined.

Design Factors

Detection data may be backhauled via any of the following methods:

- Over a legacy TMC link if such exists at the site. The components are not involved if this method is used.
- Via TCP/IP over a wired, Ethernet network to which the access point has been connected.

  When this method is used, an IP address for the access point is required. Additionally, the network connection is made with either a PoE device or AccessBox depending on how the access point is powered.
- Via TCP/IP over a cellular data modem integrated with the access point.

  An integrated data modem is an optional feature of the access point. Additionally, when this method is used, a connectivity type (GPRS/CDMA) must be chosen, a compatible SIM card acquired, and the coverage area of the selected wireless carrier should be validated against the location of the site.

Step 3. Determining the Detection Zones

This design step considers two aspects: (*i*) the size and shape of the sensor's detection zones and (*ii*) the number of sensors and the relationship of one sensor to another.

Design Factors

- Freeway/arterial count stations and advance detection applications require sensors that operate in *count* mode.
- The default *count* mode detection zones are effective for virtually any freeway/arterial count and advance detection application.
- A single sensor in the middle of a lane is sufficient for count, occupancy or advance detection applications.
- Two sensors, placed in the same lane and separated by approximately 20 feet (6 meters) are required to perform speed and classification measurements.

Measuring Speed and Vehicle Classification

Speed and classification rely on *sensor pairs*. A sensor pair consists of two sensors in the same lane, installed in “single file”. The *leading* sensor is, when traffic moves in the normal direction, the sensor that is first crossed over. The *trailing* sensor is the sensor normal traffic crosses over second.

During installation it is essential to keep notes of the sensor IDs of the leading and trailing sensors and the exact distance between each pair member. Without this data, speed and classification calculations may be unreliable.

Step 4. Placing the Components

The final design step involves selecting installation locations for the equipment that maximize detection performance and promote acceptable operations over time.

Design Factors

Sensors

- Place sensors in the middle of the area typically occupied by a loop.
- Sensors may be placed up to 75 to 175 feet (23 to 50 meters) away from an access point or repeater depending on the mounting height of the latter.

Access Points

- Mount an access point at least 16 feet (5 meters) above the road surface; greater height normally supports more distance between the access point and sensors. (See *Table 1*.)
- Orient the front of the access point so that its bulkhead connector is facing downward and the access point faces its sensors.
- When operating with default settings, an access point supports up to 48 sensors, of which 20 may be repeated.
- When operating with default settings, an access point supports up to 15 access points.
- Maintain a line of sight between the access points and its sensors and/or access points.
- Use a distance of 328 feet (100 meters) or less between an access point and its power source.

Repeaters

- Install a repeater at least 16 feet (5 meters) above the road surface; greater height normally supports more distance between the access points and sensors. (See *Table 1*.)
- Orient the front of the repeater so that it faces slightly downward toward its sensors and faces its access point.

- Repeaters may be installed in *tandem* to accommodate distances or obstructions.
- Use a distance of 1,000 feet (305 meters) or less between a repeater and its access point (or tandem repeater).
- Maintain a line of sight between the repeater and its access point (or tandem repeater).
- When operating with default settings, a repeater may support up to 10 sensors.

Design Examples

In the field, there is an almost infinite variety of traffic management requirements – many more than can be discussed here. This section includes diagrams and design notes for very common freeway/arterial applications for the purposes of illustrating design techniques. Apply the techniques to your design as needed.

Design examples are provided for:

- four lane count station
- four lane count station with speed detection
- eight lane count station
- simple advance detection
- advance detection with long distance and counts

Four Lane Count Station

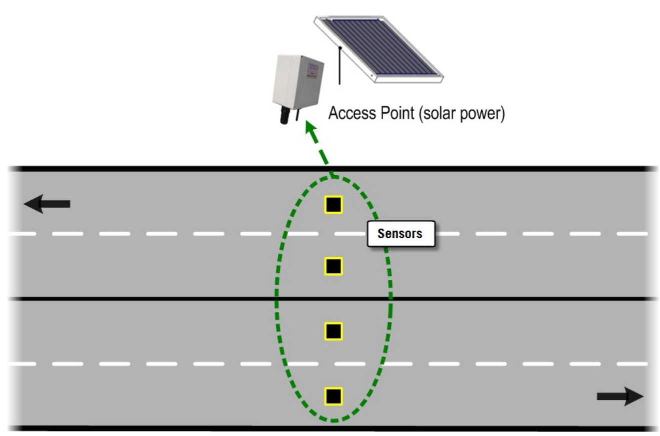


Figure 3.3 – Four Lane Count Station

Required Components

- (1) Access point supporting low input voltage and backhaul by cellular modem
- (4) Flush mount sensors operating in count mode

Design Notes

- Number of sensors and deployment array are within distance limits
- Single sensor per lane for count applications
- Access point powered by low voltage solar panel through PoE injector
- Access point uses carrier cellular network for data backhaul
- Access point serves as a node on enterprise IP data network to deliver backhauled count data and receive remote management commands

Four Lane Count Station With Speed Detection

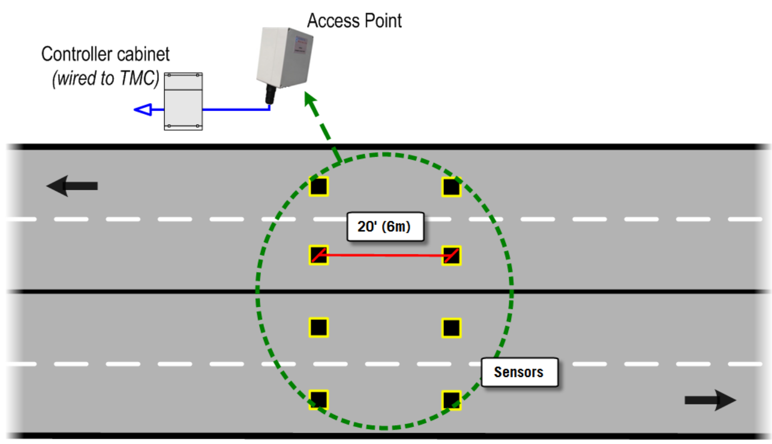


Figure 3.4 – Four Lane Count Station Performing Speed Detection

Required Components

- (1) Access point hosts speed statistics process
- (8) Flush mount sensors operating in count mode

Design Notes

- Number of sensors and deployment array are within distance limits
- Vehicle counts performed by leading sensors
- Four sensor pairs (formed from sensors in the same lane) used in speed calculations
- Trailing sensors placed 20 feet behind leading sensors
- Access point powered by available 120 VAC outlet in nearby traffic controller cabinet
- Legacy controller link to TMC provides backhaul

Eight Lane Freeway Count Station

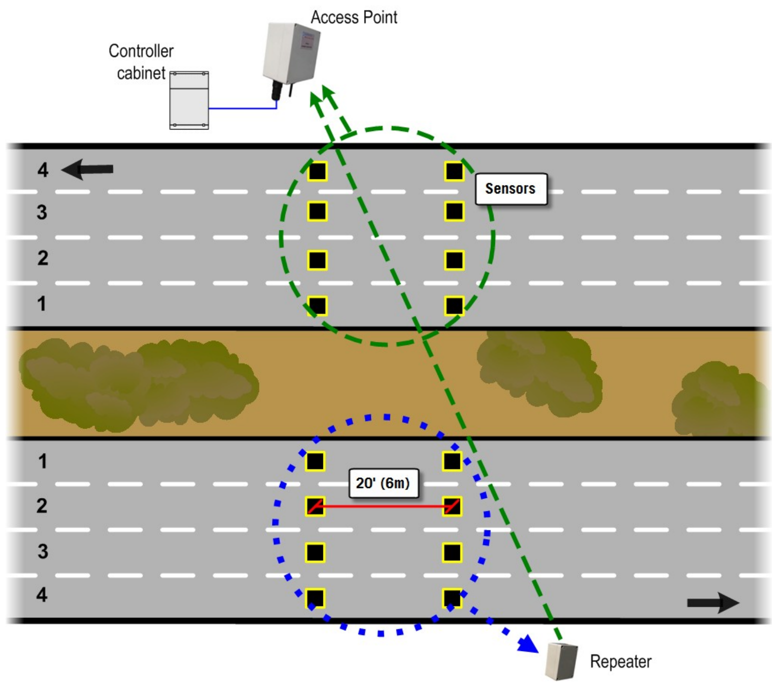


Figure 3.5 – Eight Lane Freeway Count Station With Repeater

Required Components

- (1) Access point hosts speed statistics process and cellular modem backhaul
- (16) Flush mount sensors operating in count mode
- (1) Repeater

Design Notes

- Sensors across the median strip are beyond supported distance from the access point
- Access point services close-in sensors and access point on channel "1" (shown in green)
- Repeater reaches far sensors on channel "2" (shown in blue)
- Access point to access point distance within 1,000 feet; line of sight is achieved through local vegetation; optimal orientation
- Calculation of speeds occurs independently from wireless radio communications
- Access point powered by controller cabinet
- Access point backhauls data via carrier cellular network
- Colors/line dot patterns denote discrete radio channels

Advance Detection – Simple Case

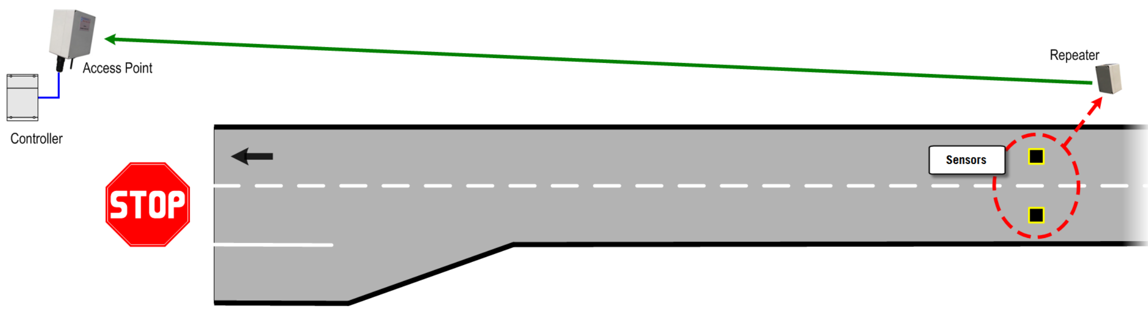


Figure 3.6 – Simple Advance Detection

Required Components

- (1) Access point powered by available PoE device inside cabinet
- (2) Flush mount sensors operating in count mode
- (1) Repeater

Design Notes

- Advance detection sensors are beyond supported distance limits to the access point
- Repeater services the sensors (access point services no sensors directly)
- Access point to access point distance within 1,000 feet; line of sight is achieved
- Repeater is oriented to face sensors and the access point
- Access point powered by controller cabinet
- No backhaul requirement
- Colors/line dot patterns denote discrete radio channels

Advance Detection – Two Levels With Counts

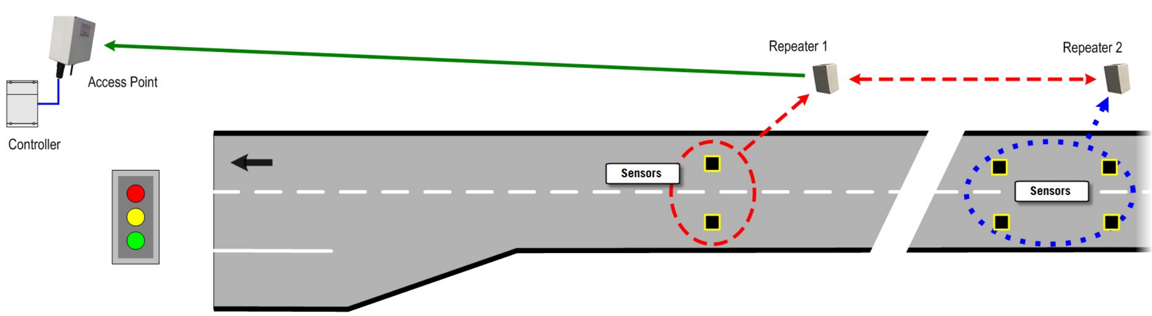


Figure 3.7 – Two-level Advance Detection With Counts

Required Components

- (1) Access point powered by controller rack through contact closure card
- (6) Flush mount sensors operating in count mode
- (1) Repeater
- (1) Contact closure master (CC) card installed in controller rack

Design Notes

- Advance detection sensors are beyond supported distance limits to the access point
- Repeater #1 services close-in sensors
- Four sensors are located beyond the reach of Repeater #1
- Repeater #2, in tandem with Repeater #1, services the far end sensors
- Repeater #1 is oriented to face sensors and the access point; line of sight is achieved
- Repeater #2 is oriented to face sensors and Repeater #1; line of sight is achieved
- Backward emanating RF energy of Repeater #1 is used to to reach Repeater #2
- Three RF channels are used (shown in green, red and blue)
- Repeater #1 uses its “sensor channel” to reach sensors and Repeater #2
- Repeater #2 uses its “access point channel” to reach Repeater #1
- Access point receives cabinet power through contact closure card
- Access point backhauls data via carrier cellular network
- Colors/line dot patterns denote discrete radio channels

Finishing the Design

A design is complete when it reflects the designer's intention with regard to the four essential design considerations:

- Designating the power source for the access point
- Selecting the data backhaul method (if needed)
- Designing the detection zones
- Selecting installation locations for all devices

Treat the design as a *baseline*. Site conditions such as vegetation, local wireless transmitters, scarcity of assumed resources, and other factors may influence the way the network is ultimately installed. Adjust and change the baseline as needed while retaining the overall objective.

Appendixes

Appendix 1 – Design Worksheet

SENSYS Networks

Freeway & Arterial Detection Network Design

Site Location

Designer

Project

Date **Page** **of**

Network Purpose *(Select all that apply)*

- ☐ Vehicle counts
- ☐ Lane occupancy
- ☐ Vehicle speeds
- ☐ Advance detection
- ☐ Other: ____________

Contacts

Access Point

ID Location Orientation *(Specify N, NE, etc.)* Channel *(Specify 0 – 15)*

Power source *(Select one)*

- ○ 120 VAC
- ○ Legacy PoE device
- ○ Solar panel
- ○ Controller *(Requires Sensys Contact Closure card)*

Backhaul *(Select one)*

- ○ None
- ○ Ethernet
- ○ Cellular modem
  - ○ CDMA ○ GPRS
  - Carrier

IP Address

(Optional; specify an address if the Access Point is part of an enterprise IP network.)

Repeaters *(Use additional sheets if necessary)*

ID	Location	Orientation *(Specify N, NE, E, etc.)*	Uplink channel *(Specify 0 – 15)*	Downlink channel *(Specify 0 – 15)*

Sensors *(Use additional sheets if necessary)*

Total Sensors in network:

	ID	Mode *("Mode B")*	Lane Description	Sensor Location	Position *(Specify only for sensor pairs)*	Separation	Repeater ID *(if used)*	Channel *(0 – 15)*
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								