5.9 GHz DSRC Band Utilization Conceptual Proposals

Prepared for IEEE 802.11 Standard Extension Study Group and ASTM 5.9 GHz DSRC User's Group and Writing Group

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5.9 GHz DSRC APPLICATION FUNCTIONAL CATEGORIES

- ACCESS POINT OPERATIONS
  - ACCESS CONTROL (+ IN/OUT TRACKING)
- TRAFFIC MANAGEMENT
  - PROBE DATA COLLECTION
  - TRAFFIC INFORMATION
  - IN-VEHICLE SIGNING
  - WORK ZONE WARNING
  - HIGHWAY/RAIL INTERSECTION WARNING
  - ROAD CONDITION WARNING
- TRAFFIC SIGNAL INTERFACE
  - INTERSECTION COLLISION AVOIDANCE
  - EMERGENCY VEHICLE SIGNAL PREEMPTION
  - TRANSIT VEHICLE SIGNAL PRIORITY
- ELECTRONIC PAYMENT (In-motion)
  - TOLL COLLECTION
  - PARKING PAYMENT
  - RENTAL CAR PROCESSING
- ELECTRONIC PAYMENT (Stationary)
  - GAS (FUEL) PAYMENT
  - FAST FOOD PAYMENT
  - PHARMACY DRIVE-THRU PAYMENT
- MAINTENANCE
  - DIAGNOSTIC DATA
  - REPAIR-SERVICE RECORD
  - VEHICLE COMPUTER PROGRAM UPDATES
  - MAP and MUSIC DATA UPDATES
- COMMERCIAL VEHICLE OPERATIONS (In-motion)
  - ROLLOVER WARNING
  - MAINLINE SCREENING (WEIGH-STATION CLEARANCE)
  - BORDER CLEARANCE
  - ON-BOARD SAFETY DATA TRANSFER
  - UNIQUE CVO FLEET MANAGEMENT
- COMMERCIAL VEHICLE OPERATIONS (Stationary)
  - DRIVER'S DAILY LOG
  - VEHICLE SAFETY INSPECTION
  - TRUCK TRACTOR-TRAILER INTERFACE
- TRANSIT DATA TRANSFER
  - TRANSIT VEHICLE DATA TRANSFER
  - TRANSIT VEHICLE REFUELING
- RAIL DATA TRANSFER
  - LOCOMOTIVE FUEL MONITORING
  - LOCOMOTIVE DATA TRANSFER
- OTHER DATA TRANSFER
  - VEHICLE REGISTRATION TAG (formerly ELECTRONIC LICENSE PLATE)

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5.9 GHz DSRC APPLICATION RANGE and VEHICLE CATEGORIES

SHORT RANGE CORE APPLICATIONS (FOR ALL VEHICLES)

- ACCESS CONTROL
- PROBE DATA COLLECTION
- TRAFFIC INFORMATION
- TOLL COLLECTION
- GAS PAYMENT
- DRIVE-THRU PAYMENT*
- VEHICLE REGISTRATION TAG (ELP)**
- IDB DATA TRANSFER*
  - DIAGNOSTIC DATA
  - REPAIR-SERVICE RECORD
  - VEHICLE COMPUTER PROGRAM UPDATES*
  - MAP and MUSIC DATA UPDATES*
- RENTAL CAR PROCESSING

APPLICATIONS FOR HEAVY TRUCKS, BUSES, TRAINS, EV (SHORT- EXT RANGE)

- ROLLOVER WARNING
- MAINLINE SCREENING
- BORDER CLEARANCE
- ON-BOARD SAFETY DATA TRANSFER
- UNIQUE CVO FLEET MANAGEMENT
- TRACTOR TO TRAILER DATA TRANSFER*
- DRIVER'S DAILY LOG
- VEHICLE SAFETY INSPECTION
- TRANSIT VEHICLE DATA TRANSFER (gate)
- TRANSIT VEHICLE DATA TRANSFER (yard)
- TRANSIT VEHICLE REFUELING
- LOCOMOTIVE FUEL MONITORING
- TRANSIT VEHICLE SIGNAL PRIORITY

EXTENDED RANGE CORE APPLICATIONS (FOR ALL VEHICLES)

- IN-VEHICLE SIGNING
  - WORK ZONE WARNING
  - HIGHWAY/RAIL INTERSECTION WARNING
- ROAD CONDITION WARNING*
- INTERSECTION COLLISION AVOIDANCE

APPLICATIONS FOR HEAVY TRUCKS, BUSES, TRAINS, EV (EXT & LONG RANGE)

- EMERGENCY VEHICLE SIGNAL PREEMPTION
- LOCOMOTIVE DATA TRANSFER

SHORT RANGE - < 50 ft
MEDIUM RANGE - 50 to 300 ft
EXTENDED RANGE - 300 to 1100 ft
LONG RANGE - 1100 to 3000 ft
CVO - Commercial Vehicle Operations

EV - Emergency Vehicles
THRU - Through
EXT - Extended
ELP -Electronic license Plate
* - New Item Since Last Revision

RED* - Vehicle to Vehicle
RED** - Vehicle to Vehicle and Roadside to Vehicle
GREEN - One-Way Communication from the RSE to the OBE

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SUMMARY OF 5.9 GHz DSRC APPLICATION REQUIREMENTS

- Nationally Compatible
- All Weather Operation
- Two-way (point to point) Communication
- One-way (roadside to vehicle) Communication
- Extremely low latency
- Secure (only authorized users can read transmitted data)
- Reliable (High MTBF and communications performance as indicated in the specific requirements)
- Maintainable (Low MTTR)
- Easy to use
- Scalable (grow from one to multiple lanes of service)
- Widely Installable (few incompatible sites)
- Multimodal (road, rail, aircraft [on the ground] and sea [canal, river, or port])
- Non-Interference with 915 MHz systems
- Non-Interference to incumbent (primary allocation) 5.9 GHz systems
- Minimize interference with secondary allocation 5.9 GHz systems
- Tolerant of inadvertent interference from incumbent 5.9 GHz systems
- Market acceptable cost (< $100 for basic On-Board Equip.)

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SUMMARY OF 5.9 GHz DSRC APPLICATION REQUIREMENTS

Vehicle Location -- Yes.
Lane Discrimination -- Yes.
Traffic Speed -- 0 to 120 mph
Traffic Density -- 3000 v/h/l - (1 to 8 lanes).
Min. OBE longitudinal separation -- 6 ft (motorcycles) / 16 ft (other).
Min. OBE lateral separation -- 3 ft (motorcycles) / 10 ft (other).
RSE Density -- 1 /lane
Communication Modes - one-way and two-way
Transaction Size -- 500 Bits to 10 Mbits.
Max. No. of Messages -- limited by transaction size
Nominal RSE Transmission Range -- 5 to 1100 ft
Nominal OBE Reception Range -- 5 to 1100 ft
Special RSE Transmission Range -- 20 to 3000 ft (Emergency Vehicles and Rail)
Special OBE Reception Range -- 20 to 3000 ft (Emergency Vehicles and Rail)
Communication Zone Size -- 7 to 2980 ft
Nominal Beacon Separation Distance -- 50 to 5500 ft.
Special Beacon Separation Distance -- 50 to 15000 ft.

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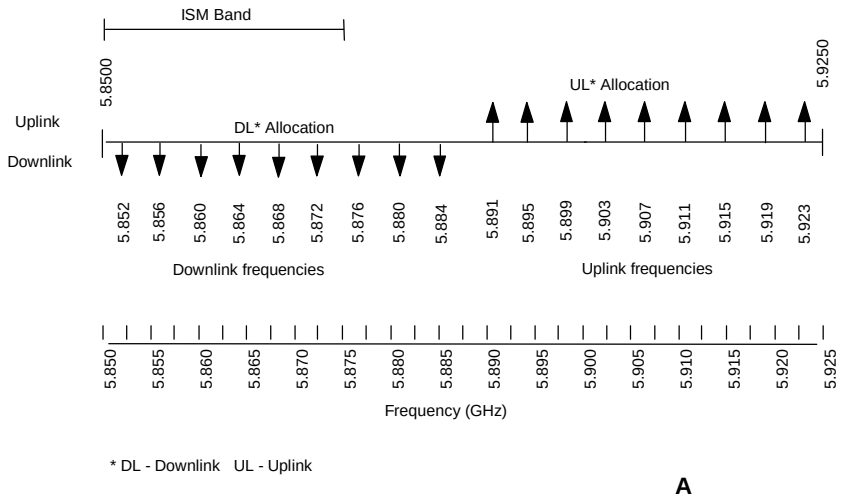
NARROWBAND OPTION 5.850 to 5.925 GHz DSRC BAND



* DL - Downlink UL - Uplink

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NARROWBAND SPECIFICATIONS

NARROWBAND CANDIDATE A - ACTIVE (AM)

- **RSE Maximum EIRP 44.77 dBm (30 W)**
- **OBE EIRP 3 dBm (10 mW) cars / 20 dBm (100 mw) Transit Vehicles / 44.77 (30W) EV**
- **Active**
- **Nominal Modulation - Dual Binary Signaling (OOK with alternating phase shift) downlink (DL) and uplink (UL)**
- **Optional Modulation - None**
- **OBE Sensitivity - -60 dBm (EV -75 dBm) with 15 dB front to back ratio in the antenna**
- **Active RSE Sensitivity - -75 dBm with 20 dB front to back ratio in the antenna**
- **S/I - 14 dB**
- **Vehicle Powered**
- **BW 75 MHz (5.850 - 5.925 GHz)**
- **3 - 4 MHz DL channels and 1 - 12 MHz UL channel or 3 DL/UL channel pairs of 4 MHz w/37 MHz separation**
- **DL Data Rate - 1000 kbps nominal**
- **UL Data Rate - 1000 kbps nominal**
- **Two-way Range - 3 to 305 m (10 to 1000 ft); One-way Range - 3 to 325 m (10 to 1100 ft)**
- **EV Two-way Range - 3 to 2134 m (10 to 7000 ft)**
- **Band Sharing Strategy - Selection of alternate channels for adjacent zones . On-site Frequency Coordination. Isolation of Installations where possible. Use TDMA or CSMA to prevent interference between users in the zone.**
- **3 Channel OBE Estimated Cost - $50 to $100**

ABBREVIATIONS
RSE - Roadside Unit
OBE - Onboard Unit
EIRP - Effective Isotropic Radiated Power
Dist. - Distance
mod - modulated
EV - Emergency Vehicle

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NARROWBAND SPECIFICATIONS

NARROWBAND CANDIDATE B - ACTIVE (PSK)

- **RSE Maximum EIRP 44.77 dBm (30 W)**
- **OBE EIRP 3 dBm (10 mW) cars / 20 dBm (100 mw) Transit Vehicles / 44.77 (30W) EV**
- **Active**
- **Nominal Modulation - DBPSK downlink (DL) and uplink (UL)**
- **Optional Modulation - DQPSK, D8PSK, D16PSK or D16QAM downlink (DL) and uplink (UL) (after initialization)**
- **OBE Sensitivity - -60 dBm (EV -75 dBm) with 15 dB front to back ratio in the antenna**
- **Active RSE Sensitivity - -75 dBm with 20 dB front to back ratio in the antenna**
- **S/I - 12 dB (for DBPSK)**
- **Vehicle Powered**
- **BW 75 MHz (5.850 - 5.925 GHz)**
- **3 to 9 channel pairs: of 4 MHz UL and 4 MHz DL w/37 MHz**
- **DL Data Rate - 1000 kbps nominal (2000, and 4000 kbps optional)**
- **UL Data Rate - 1000 kbps nominal (2000, and 4000 kbps optional)**
- **Two-way Range - 3 to 305 m (10 to 1000 ft); One-way Range - 3 to 325 m (10 to 1100 ft)**
- **EV Two-way Range - 3 to 2134 m (10 to 7000 ft)**
- **Band Sharing Strategy - Selection of alternate channels for adjacent zones . On-site Frequency Coordination. Isolation of Installations where possible. Use TDMA or CSMA to prevent interference between users in the zone.**
- **3 Channel OBE Estimated Cost - $50 to $100**
- **9 Channel OBE Estimated Cost - $150 to $200 ($300 to $500 with optional capabilities)**

ABBREVIATIONS
RSE - Roadside Unit
OBE - Onboard Unit
EIRP - Effective Isotropic Radiated Power
Dist. - Distance
mod - modulated
EV - Emergency Vehicle

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NARROWBAND SPECIFICATIONS

NARROWBAND CANDIDATE C - BACKSCATTER

- **RSE Maximum EIRP 44.77 dBm (30 W)**
- **OBE EIRP -65 to -15 dBm**
- **Backscatter (1.5 MHz subcarrier used in backscatter)**
- **Nominal Modulation (DL)- Dual Binary Signaling (OOK with alternating phase shift) downlink**
- **Nominal Modulation (UL)- QPSK modulated subcarrier that AM modulates the reflected signal**
- **Optional Modulation - 8PSK or 16PSK uplink (UL) subcarrier (after initialization)**
- **OBE Sensitivity - -60 dBm with 15 dB front to back ratio in the antenna**
- **RSE Sensitivity - -90 dBm with 20 dB front to back ratio in the antenna**
- **S/I - Active Downlink: 14 dB**
- **S/I - Backscatter Uplink: 6 dB**
- **Vehicle Powered**
- **BW 75 MHz (5.850 - 5.925 GHz)**
- **3 channel pairs: of 4 MHz UL and 4 MHz DL w/37 MHz**
- **DL Data Rate - 1000 kbps**
- **UL Data Rate - 500 kbps core nominal (1000 and 2000 kbps optional)**
- **Two-way Range - 3 to 90 m (10 to 300 ft); One-way Range - 3 to 325 m (10 to 1100 ft)**
- **Band Sharing Strategy - Selection of alternate channels for adjacent zones . On-site Frequency Coordination. Isolation of Installations where possible. Use TDMA or CSMA to prevent interference between users in the zone.**
- **3 Channel OBE Estimated Cost - $30 to < $80**

ABBREVIATIONS

RSE - Roadside Unit
OBE - Onboard Unit
EIRP - Effective Isotropic Radiated Power
Dist. - Distance
mod - modulated
EV - Emergency Vehicle

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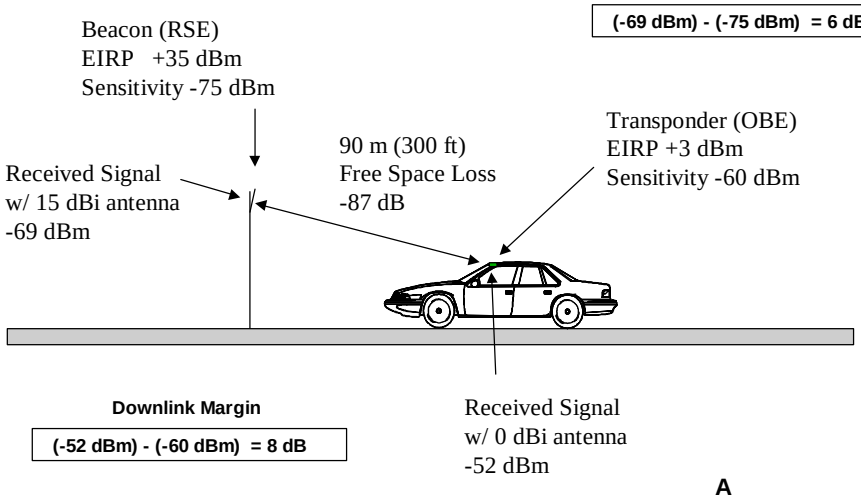
NARROWBAND ACTIVE LINK BUDGET

90 m (300 ft) Two-way Nominal Range
(Uplink Power Limited)

Uplink Margin

(-69 dBm) - (-75 dBm) = 6 dB



Downlink Margin

(-52 dBm) - (-60 dBm) = 8 dB

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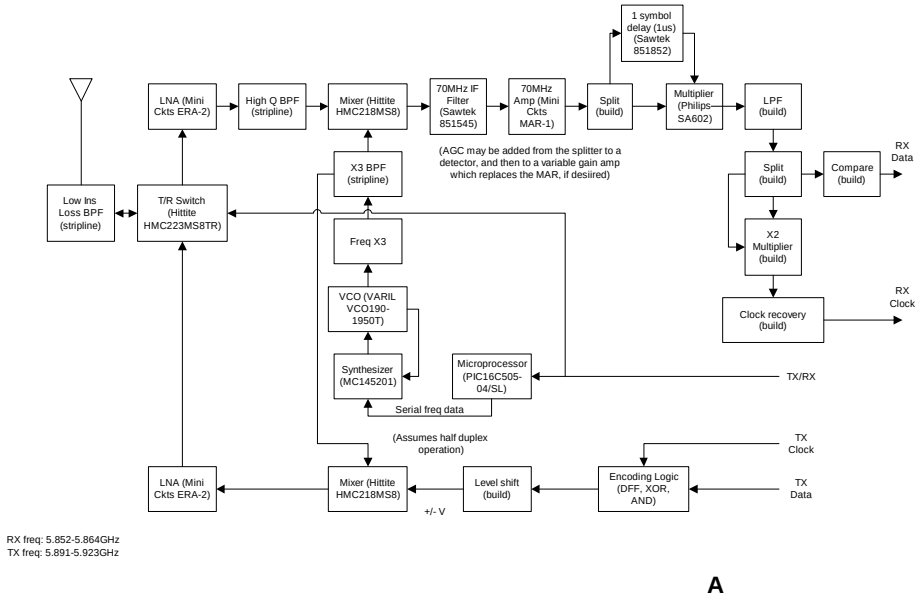
1 Mbit/sec DBPSK Mod/Demod
(Analog)



RX freq: 5.852-5.864GHz
TX freq: 5.891-5.923GHz

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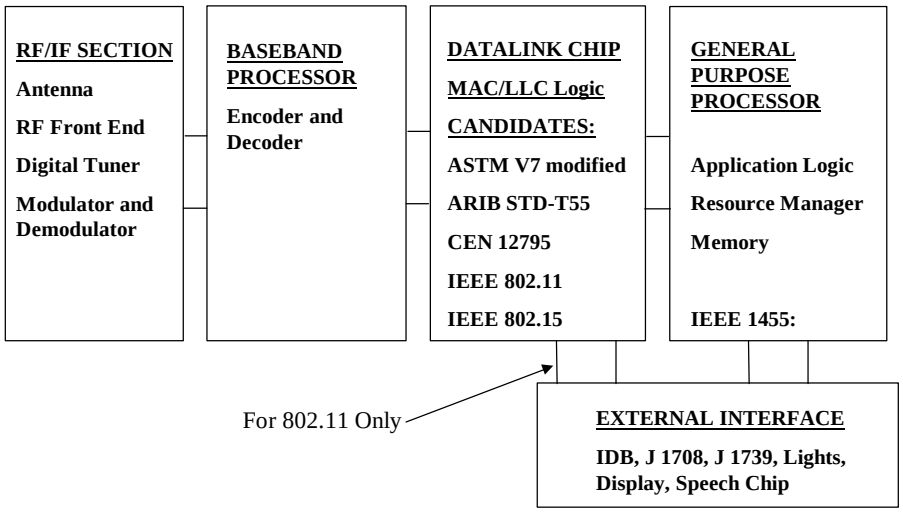
NARROWBAND DSRC OBE DIAGRAM



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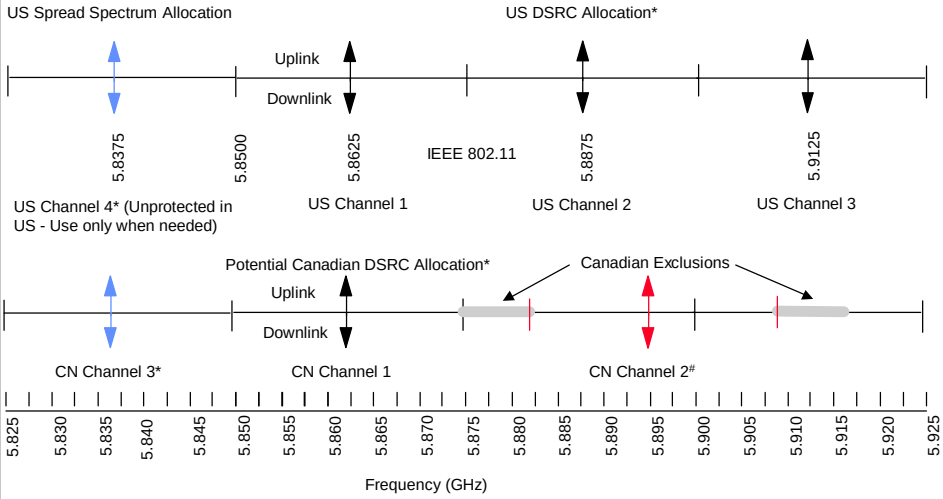
WIDEBAND OPTION
5.850 to 5.925 GHz DSRC BAND



- Channel 2 Substitute for US 2 and 3 when in Canada Only

* - Canadian Channel 3 and Optional US Channel 4

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WIDEBAND SPECIFICATIONS

SPREAD SPECTRUM

- **IEEE 802.11b**
- **RSE Maximum EIRP 20 dBm (100 m W)**
- **OBE EIRP 3 dBm (10 mW) cars / 20 dBm (100 mw) Transit Vehicles**
- **RSE Emergency Vehicle (EV) EIRP 44.77 dBm (30 W)**
- **Active (11 bit code with a chip rate of 11 MHz)**
- **Nominal Modulation - CCK downlink (DL) and uplink (UL) DSS CDMA-TDMA**
- **Optional Modulation - BPSK/QPSK downlink (DL) and uplink (UL) DSS CDMA-TDMA**
- **OBE Sensitivity - -80 dBm with 15 dB front to back ratio in the antenna**
- **RSE Sensitivity - -80 dBm with 20 dB front to back ratio in the antenna**
- **S/I - Active: 4.6 dB**
- **Vehicle Powered**
- **BW 75 MHz (5.850 - 5.925 GHz) + 25 MHz (5.825 - 5.850 GHz) (for Canada and Interference Mitigation)**
- **3 + 1 downlink/uplink channels of 25 MHz each and 1 PN code**
- **Data Rate - 11 Mbps (1, 2 and 5.5 Mbps options)**
- **Two-way Range - 3 to 305 m (10 to 1000 ft); One-way Range - 3 to 325 m (10 to 1100 ft)**
- **Band Sharing Strategy - FDMA for adjacent zones to prevent interference. Use CSMA to prevent interference between users in the zone.**
- **OBE Estimated Cost - $200 to $600**

ABBREVIATIONS

RSE - Roadside Unit
OBE - Onboard Unit
EIRP - Effective Isotropic Radiated Power
Dist. - Distance
mod - modulated
EV - Emergency Vehicle

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WIDEBAND DSRC OBE DIAGRAM

RF/IF SECTION

Antenna

RF Front End

Digital Tuner

Quad IF Modulator/ Demodulator

IEEE 802.11

i.e., Use the narrow band design with additional components back to the first mixer then substitute HFA3724/26

BASEBAND PROCESSOR

DBPSK/DQPSK Modulator and Demodulator/ Encoder and Decoder

CANDIDATES:

IEEE 802.11
IEEE 802.15

i.e., HFA3860/61

DATALINK CHIP MAC/LLC Logic

CANDIDATES:

IEEE 802.11
IEEE 802.15

i.e., HFA3840

GENERAL PURPOSE PROCESSOR

Application Logic

Resource Manager

Memory

IEEE 1455

EXTERNAL INTERFACE

IDB, J 1708, J 1939, Lights, Display, Speech Chip

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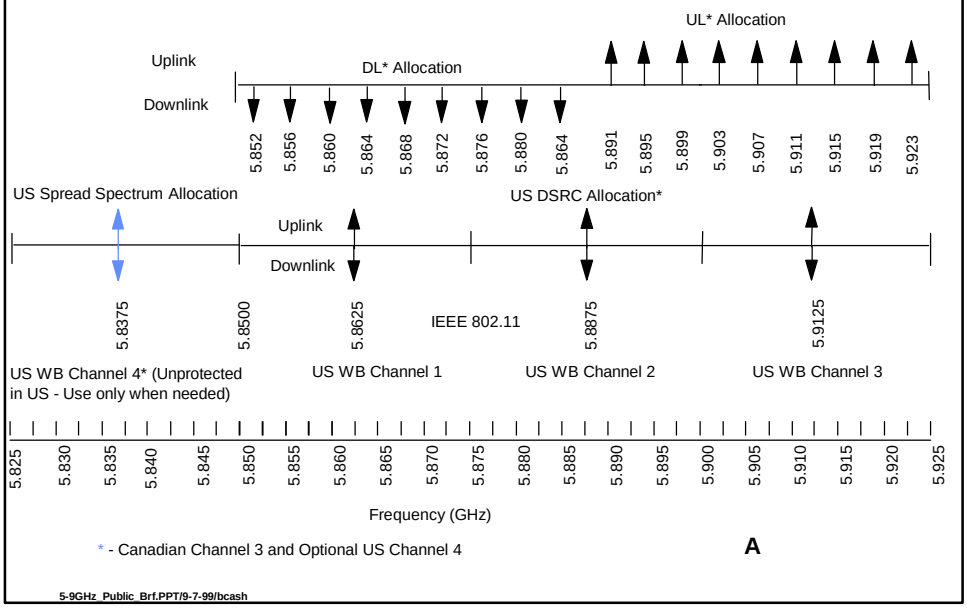
NARROWBAND / WIDEBAND BAND SHARING PLAN 5.850 to 5.925 GHz DSRC BAND



* - Canadian Channel 3 and Optional US Channel 4

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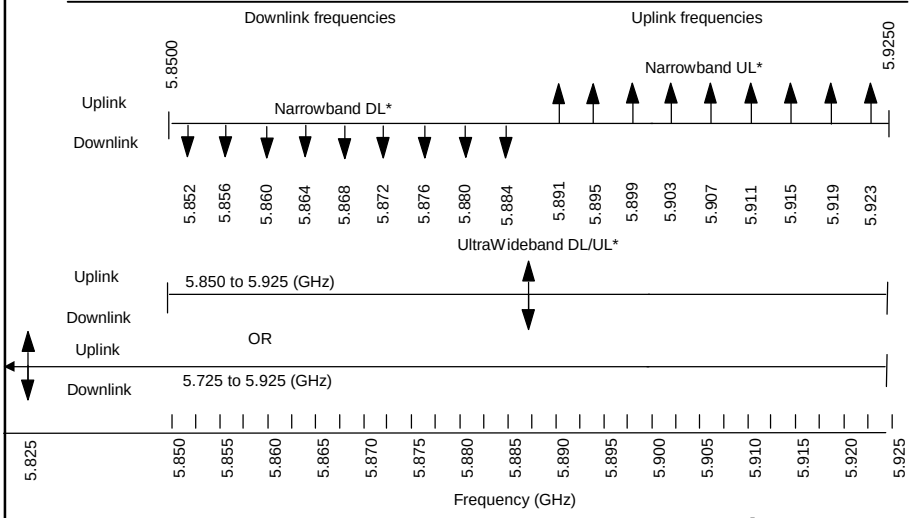
NARROWBAND / ULTRAWIDEBAND BAND SHARING PLAN 5.850 to 5.925 GHz DSRC BAND



* DL - Downlink UL - Uplink

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ULTRAWIDEBAND SPECIFICATIONS

ULTRAWIDEBAND

- **RSE Maximum EIRP 4.5 dBm**
- **OBE Maximum EIRP 4.5 dBm**
- **Nominal Modulation - OOK Nano pulse**
- **OBE Sensitivity - -53 dBm**
- **RSE Sensitivity - - 53 dBm**
- **S/I - Active:11 dB - 20 dB processing gain**
- **Vehicle Powered**
- **BW 75 MHz (5.850 - 5.925 GHz) or 200 MHz (5.725 to 5.925)**
- **1 downlink/uplink channel of 75 MHz or 200 MHz**
- **Data Rate - 1000 kbps (2000 kbps optional)**
- **Two-way Range - 3 m (10 ft)**
- **Lateral Reuse Dist. - 3 m (10 ft) Inline tractor and trailer**
- **Band Sharing Strategy - Operation over an extended band width and in a partially covered mobile environment with very low power levels and directional antennas prevents interfering with other RF links.**
- **Estimated Cost - $100 to $200**

ABBREVIATIONS

RSE - Roadside Unit
OBE - Onboard Unit
EIRP - Effective Isotropic Radiated Power
Dist. - Distance
mod - modulated

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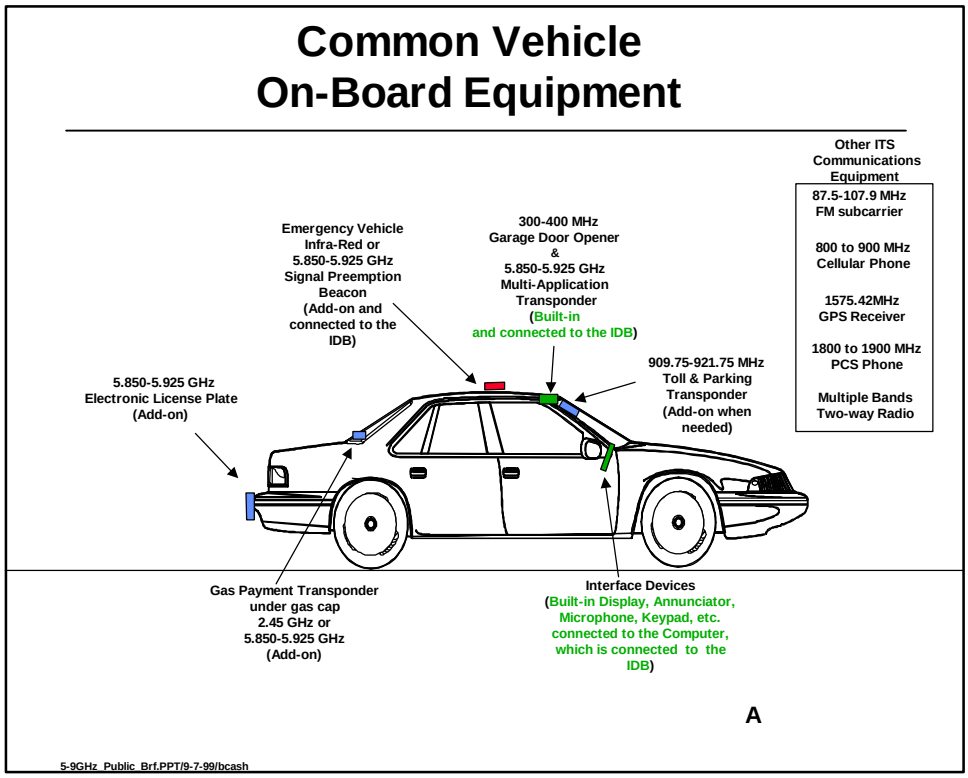
Common Vehicle
On-Board Equipment
Other ITS Communications Equipment
87.5-107.9 MHz FM subcarrier
800 to 900 MHz Cellular Phone
1575.42MHz GPS Receiver
1800 to 1900 MHz PCS Phone
Multiple Bands Two-way Radio
Emergency Vehicle Infra-Red or 5.850-5.925 GHz Signal Preemption Beacon (Add-on and connected to the IDB)
300-400 MHz Garage Door Opener & 5.850-5.925 GHz Multi-Application Transponder (Built-in and connected to the IDB)
909.75-921.75 MHz Toll & Parking Transponder (Add-on when needed)
5.850-5.925 GHz Electronic License Plate (Add-on)
Gas Payment Transponder under gas cap 2.45 GHz or 5.850-5.925 GHz (Add-on)
Interface Devices (Built-in Display, Annunciator, Microphone, Keypad, etc. connected to the Computer, which is connected to the IDB)
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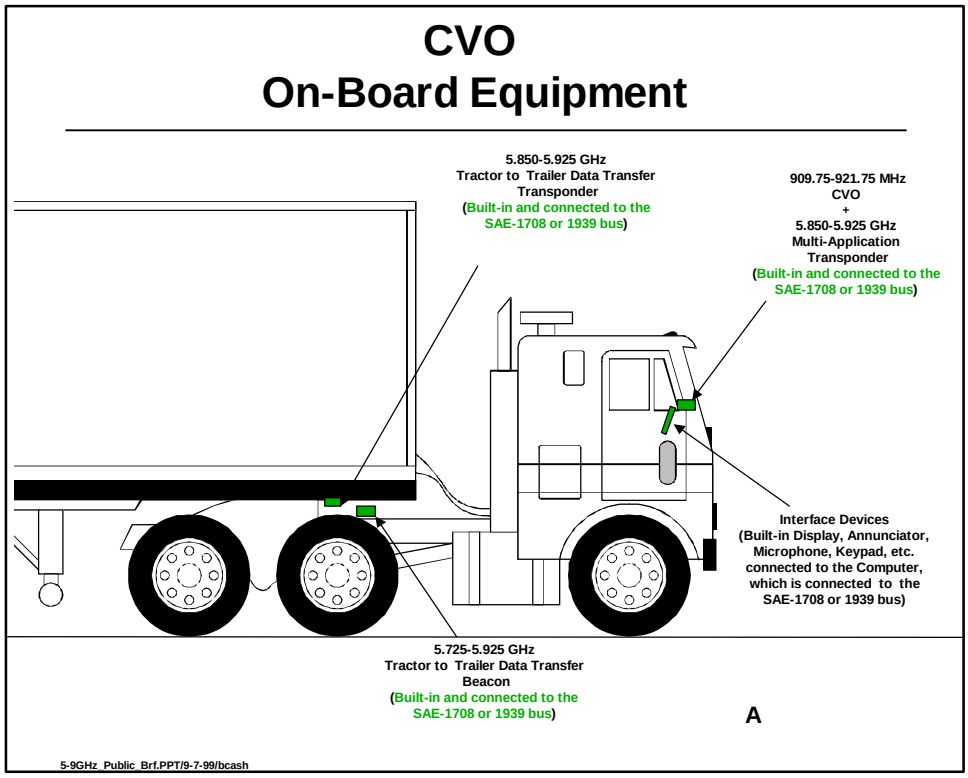
CVO
On-Board Equipment
5.850-5.925 GHz Tractor to Trailer Data Transfer Transponder (Built-in and connected to the SAE-1708 or 1939 bus)
909.75-921.75 MHz CVO + 5.850-5.925 GHz Multi-Application Transponder (Built-in and connected to the SAE-1708 or 1939 bus)
Interface Devices (Built-in Display, Annunciator, Microphone, Keypad, etc. connected to the Computer, which is connected to the SAE-1708 or 1939 bus)
5.725-5.925 GHz Tractor to Trailer Data Transfer Beacon (Built-in and connected to the SAE-1708 or 1939 bus)
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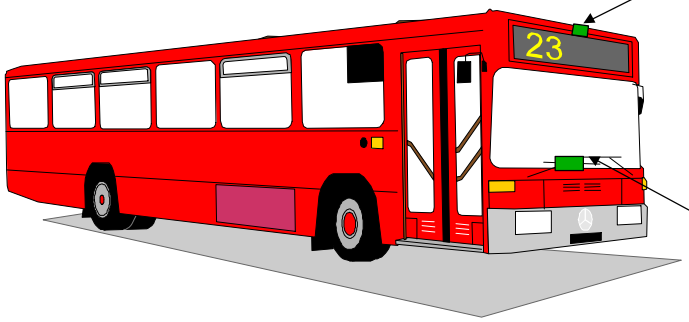
TRANSIT
On-Board Equipment



5.850-5.925 GHz
Multi-Application
Transponder
(Built-in and connected to the
SAE-1708, 1939, or EIA-709
LonWorks interface bus)

Interface Devices
(Built-in Display, Annunciator,
Microphone, Keypad, etc.
connected to the Computer,
which is connected to the
SAE-1708, 1939, or EIA-709
LonWorks interface bus)

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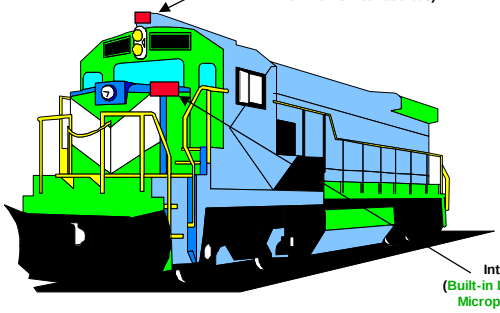
RAIL ENGINE
On-Board Equipment



5.850-5.925 GHz
Multi-Application
Transponder
(Built-in and connected to an
SAE-1708, 1939, or EIA-709
LonWorks interface bus)

Interface Devices
(Built-in Display, Annunciator,
Microphone, Keypad, etc.
connected to the Computer,
which is connected to an
SAE-1708, 1939, or EIA-709
LonWorks interface bus)

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On-Board Equipment (OBE) STRATEGY

Common Equipment Configuration

The type of application requirements range from simple transmit only and receive only to high data rate with overlapping communication zones. It may not be wise to design all devices for the most strenuous requirement if most will not be used that way and the price is more than the average user is willing to pay. The DSRC technique used should be matched to the difficulty of the application implementation as long as a basic national compatibility mode (precursor to interoperability) is included in each device.

Therefore, users should be able to acquire equipment which connects them to the applications they want at an attractive price and have national interoperability. They could then pay more for OBE that implement applications with more demanding requirements. So , if we can require that each application be implemented with one mode nationwide, the following configurations of equipment scale up the capability of a DSRC device from the least demanding to the most while maintaining interoperability with all simpler versions:

OBE TYPES	SHORT RANGE	MED RANGE	EXT RANGE	LONG RANGE	BASIC DATA RATE	HIGHER DATA RATES	DATA TO SPEECH	DISPLAY	VEHICLE BUS CONNECTION
A	X		X*		X		X		
B	X		X*		X		X	X	
C	X		X*		X		X	X	X
D	X	X	X		X		X		
E	X	X	X		X		X	X	
F	X	X	X		X	N	X	X	X
G	X	X	X		W	H	X	X	X
H	X	X	X		X	H	X	X	X

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X* - DOWNLINK ONLY EXT - EXTENDED MED - MEDIUM N - Narrowband limit is 4 Mbps
H - Wideband operation enables 5.5 and 11 Mbps W - No narrowband basic data rate - Wideband only

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On-Board Equipment (OBE) STRATEGY

Special Equipment Configurations

Some devices have special requirements which are not shared by other applications and must be treated separately. Each of these special OBE types need to be interoperable only within its supported applications and may have a different physical layer interface and protocol from the common devices and other special types.

The following list identifies the devices with unique requirements and capabilities:

OBE TYPES	SHORT RANGE	MED RANGE	EXT RANGE	LONG RANGE	BASIC DATA RATE	LOWER DATA RATES	UNIQUE L1	UNIQUE L2 & L7	VEHICLE BUS CONNECTION
L	O	O	O	X	X		?	?	X
R*	X					X	X^1	X^1	
T*	X				X		X^2	X^2	X

X^1 - Maybe Backscatter
X^2 - Ultrawideband
T* - Tractor to Trailer ONLY
R* - RFID Tag ONLY
O - OPTIONAL
? - Some applications may use a unique layer / others may not
EXT - EXTENDED
MED - MEDIUM

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On-Board Equipment (OBE) ASSIGNMENTS

SHORT RANGE CORE APPLICATIONS (FOR ALL VEHICLES)
OBE - TYPES A,B,C or as indicated

- ACCESS CONTROL
- PROBE DATA COLLECTION
- TRAFFIC INFORMATION
- TOLL COLLECTION
- GAS PAYMENT (R*)
- DRIVE-THRU PAYMENT
- VEHICLE REGISTRATION TAG (ELP)** (R*)
- IDB DATA TRANSFER
  - DIAGNOSTIC DATA
  - REPAIR-SERVICE RECORD
  - VEHICLE COMPUTER PROGRAM UPDATES
  - MAP and MUSIC DATA UPDATES (G/H)
- RENTAL CAR PROCESSING

APPLICATIONS FOR HEAVY TRUCKS, BUSES, TRAINS, EV (SHORT-EXT RANGE)
OBE - TYPES D,E,F or as indicated

- ROLLOVER WARNING
- MAINLINE SCREENING
- BORDER CLEARANCE
- ON-BOARD SAFETY DATA TRANSFER
- UNIQUE CVO FLEET MANAGEMENT (opt G/H)
- TRACTOR TO TRAILER DATA TRANSFER* (T*)
- DRIVER'S DAILY LOG
- VEHICLE SAFETY INSPECTION
- TRANSIT VEHICLE DATA TRANSFER (gate) (G/H)
- TRANSIT VEHICLE DATA TRANSFER (yard) (G/H)
- TRANSIT VEHICLE REFUELING
- LOCOMOTIVE FUEL MONITORING
- TRANSIT VEHICLE SIGNAL PRIORITY (F/G/H/L)

EXTENDED RANGE CORE APPLICATIONS (FOR ALL VEHICLES) OBE - TYPES A,B,C

- IN-VEHICLE SIGNING
  - WORK ZONE WARNING
  - HIGHWAY/RAIL INTERSECTION WARNING
- ROAD CONDITION WARNING
- INTERSECTION COLLISION AVOIDANCE

APPLICATIONS FOR HEAVY TRUCKS, BUSES, TRAINS, EV (LONG RANGE)
OBE - TYPE G,H,L

- EMERGENCY VEHICLE SIGNAL PREEMPTION (L)
- LOCOMOTIVE DATA TRANSFER (G/H/L)

SHORT RANGE - < 50 ft
MEDIUM RANGE - 50 to 300 ft
EXTENDED RANGE - 300 to 1100 ft
LONG RANGE - 1100 to 3000 ft
CVO - Commercial Vehicle Operations

EV - Emergency Vehicles
THRU - Through
EXT - Extended
ELP -Electronic license Plate
T* - Tractor to Trailer ONLY
R* - RFID Tag ONLY

RED* - Vehicle to Vehicle
RED** - Vehicle to Vehicle and Roadside to Vehicle
GREEN - One-Way Communication from the RSE to the OBE

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PROPOSED NARROWBAND DSRC FREQUENCY ASSIGNMENT STRATEGY

Narrowband Frequency Assignment

Each operating frequency and accompanying bandwidth should be designated as a channel and these channels generally assigned to groups of applications.

OBE with several different capability levels will share the spectrum. The capability of the OBE will identify where it can operate.

The basic level OBE(Types A, B, and C) will be able to operate over only the first three narrowband channels to support the core applications. The OBE will rapidly sample each channel (I propose every 3 msec) and start initialization when a valid signal is detected. This will provide a fast initialization time for those applications that require low latency response. These OBE will use the three separate channels to prevent interference between applications (Frequency Division Multiple Access [FDMA]). This channel isolation will allow applications to operate within the co-channel interference range of other applications.

The second level OBE(Types D, E, and F) will be able to operate in all the narrowband channels. These OBE will be capable of sending and receiving over short, medium, or extended ranges and monitoring all the narrowband channels in a way that will enable them to start initialization in any channel within a specified time (I suggest 1 msec) after being exposed to the required communication zone signal level. These OBE will support the applications that use the initial three channels as well as applications that use the other six channels to prevent overcrowding and interference .

The third level includes OBE Types G and H. These OBE are specially designed to communicate with high data rates (5.5 and 11 Mbps) by using the wideband allocation. Type G only implements the wideband high data rate capability. Type H will be able to operate in all the narrowband channels and the wideband channels. These type H OBE will be capable of sending and receiving over short, medium, extended and long ranges in the narrow band and the wideband and monitor all the channels in a way that enables them to initialize in any channel in the required time.

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PROPOSED NARROWBAND DSRC FREQUENCY ASSIGNMENT STRATEGY

Narrowband Frequency Assignment (continued)

The rest of the discussions on this page cover OBE that are configured to meet unique requirements.

The fourth level OBE(Type L) will also be able to operate in all the channels. These OBE will be capable of sending and receiving over short, medium, extended and long ranges and monitor all the channels in a way that enable them to initialize in any channel in the required time. These OBE are specially designed to communicate with high power levels in channels restricted to transit signal priority and emergency vehicle signal preemption because of their extended and long range requirements and overlapping communication zones. The RSE (beacons) implementing theses applications will operate in a synchronized mode and the protocol will provide for a specified number of time slots in each second in which the OBE and RSE in the area can communicate.

The next OBE(Type T) will implement the tractor to trailer interface and be able to operate across several channels in a way that does not interfere with OBE implementing other applications. These OBE will operate using a spread spectrum or ultrawideband method.

Finally, the Type R OBE will implement the applications that require an auxiliary transponder on the vehicle. This transponder must operate at short ranges, over several channels, and at the lowest cost possible. The short range and low power requirements of the applications these OBE implement, along with the assignment to the sparsely used channels, will prevent them from interfering with other applications. In addition, the vehicle registration tag is assigned a channel by itself, because it is a roaming application and can be implemented anywhere on the road. With a separate channel it can operate and not cause interference even if it is initiated in the communication zone of another application.

See the following charts which present a proposed channel assignment for discussion.

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PROPOSED NARROWBAND CHANNEL ASSIGNMENTS

CHANNELS	APPLICATIONS
One - Three	ACCESS CONTROL
One - Three	PROBE DATA COLLECTION
One - Three	TRAFFIC INFORMATION
One - Three	TOLL COLLECTION
Six - Eight	GAS (FUEL) PAYMENT
Five	VEHICLE REGISTRATION TAG (formerly ELP)
One - Three	DRIVETHRU PAYMENT
One - Three (WB Opt)	IDB DATA TRANSFER
One - Three	RENTAL CAR PROCESSING
One - Three	IN-VEHICLE SIGNING
One - Three	WORK ZONE WARNING
One - Three	HIGHWAY/RAIL INTERSECTION WARNING
One - Three	ROAD CONDITION WARNING
Nine	INTERSECTION COLLISION AVOIDANCE
Four	EMERGENCY VEHICLE SIGNAL PREEMPTION
Four	TRANSIT VEHICLE SIGNAL PRIORITY
Six - Eight (WB Opt)	TRANSIT VEHICLE DATA TRANSFER
Six - Eight	TRANSIT VEHICLE REFUELING
One - Three	ROLLOVER WARNING
One - Three	MAINLINE SCREENING
One - Three	BORDER CLEARANCE
One - Three	ON-BOARD SAFETY DATA
Six - Eight (WB Opt)	UNIQUE CVO FLEET MANAGEMENT
Six - Eight	DRIVER'S DAILY LOG
Six - Eight	VEHICLE SAFETY INSPECTION
ALL*	TRACTOR TO TRAILER DATA TRANSFER
Six - Eight (WB Opt)	LOCOMOTIVE DATA TRANSFER
Six - Eight	LOCOMOTIVE FUEL MONITORING

ELP -Electronic license Plate
WB Opt - These applications may use the wideband technique for faster data throughput
* Ultrawideband

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PROPOSED WIDEBAND DSRC FREQUENCY ASSIGNMENT STRATEGY

Wideband Frequency Assignment

The wideband frequencies are used for those applications that need high rates of data transfer in isolated communication areas (Bus Parking Lots, Maintenance Areas, and Service Stations are examples of where this technique can be used).

IT IS NOT BELIEVED THAT THIS APPROACH CAN RESOLVE ALL POSSIBLE INTERFERENCE CONFLICTS BETWEEN APPLICATIONS BECAUSE OF THE LIMITED NUMBER OF CHANNELS. SO IT IS APPLICABLE TO ONLY A FEW APPLICATIONS THAT CAN SHARE SPECTRUM WITH THE NARROWBAND TECHNIQUE THROUGH ISOLATION OF THE COMMUNICATION ZONES.

This equipment is not expected to be adopted in general use for core applications because of its higher price.

These communications links must not interfere with narrowband communication operations located in the surrounding area. If located close to a major emergency route it must accept occasional and brief interference from emergency vehicle operations.

Each operating frequency and accompanying bandwidth should be designated as a channel and these channels generally assigned to groups of applications.

See the following charts which present a proposed channel assignment for discussion.

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PROPOSED WIDEBAND CHANNEL ASSIGNMENTS

CHANNELS	APPLICATIONS
• N/A	• ACCESS CONTROL
• N/A	• PROBE DATA COLLECTION
• N/A	• TRAFFIC INFORMATION
• N/A	• TOLL COLLECTION
• N/A	• GAS (FUEL) PAYMENT
• N/A	• VEHICLE REGISTRATION TAG (formerly ELP)
• N/A	• DRIVETHRU PAYMENT
• One - Four	• IDB DATA TRANSFER
• N/A	• RENTAL CAR PROCESSING
• N/A	• IN-VEHICLE SIGNING
• N/A	• WORK ZONE WARNING
• N/A	• HIGHWAY/RAIL INTERSECTION WARNING
• N/A	• ROAD CONDITION WARNING
• N/A	• INTERSECTION COLLISION AVOIDANCE
• N/A	• EMERGENCY VEHICLE SIGNAL PREEMPTION
• N/A	• TRANSIT VEHICLE SIGNAL PRIORITY
• One - Four	• TRANSIT VEHICLE DATA TRANSFER
• N/A	• TRANSIT VEHICLE REFUELING
• N/A	• ROLLOVER WARNING
• N/A	• MAINLINE SCREENING
• N/A	• BORDER CLEARANCE
• N/A	• ON-BOARD SAFETY DATA
• One - Four	• UNIQUE CVO FLEET MANAGEMENT
• N/A	• DRIVER'S DAILY LOG
• N/A	• VEHICLE SAFETY INSPECTION
• All*	• TRACTOR TO TRAILER DATA TRANSFER
• One - Four	• LOCOMOTIVE DATA TRANSFER
• N/A	• LOCOMOTIVE FUEL MONITORING

A

* Ultrawideband

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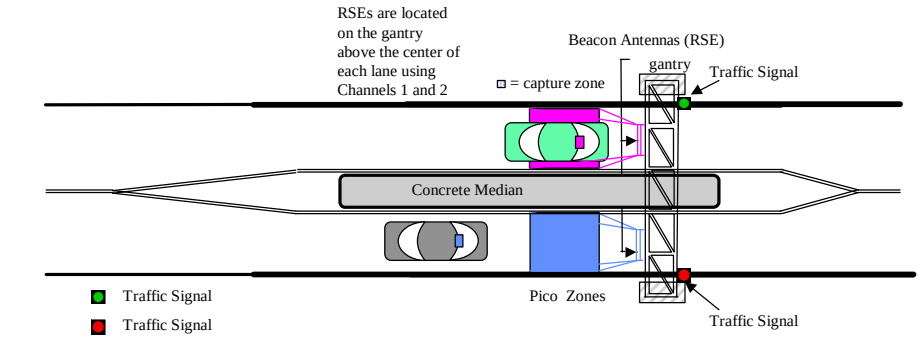
EXAMPLE MICRO/PICO-CELL COMMUNICATION ZONES

TOLL COLLECTION (Lane Based)



Traffic Signal
Traffic Signal
RSE on Channel 1
RSE on Channel 2
OBE on Channel 1
OBE on Channel 2

Note 1: Users must slow down to pay the toll and may proceed only when the light is green.

Not to Scale

Narrowband Channelization

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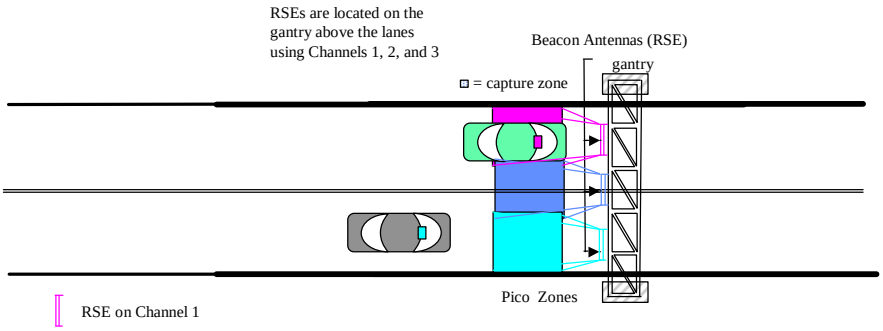
EXAMPLE MICRO/PICO-CELL COMMUNICATION ZONES

TOLL COLLECTION (Open Road)



RSE on Channel 1
RSE on Channel 2
RSE on Channel 3
OBE on Channel 2
OBE on Channel 3

Note 1: Users are allowed to proceed at highway normal speeds while the toll is paid.

Not to Scale

Narrowband Channelization

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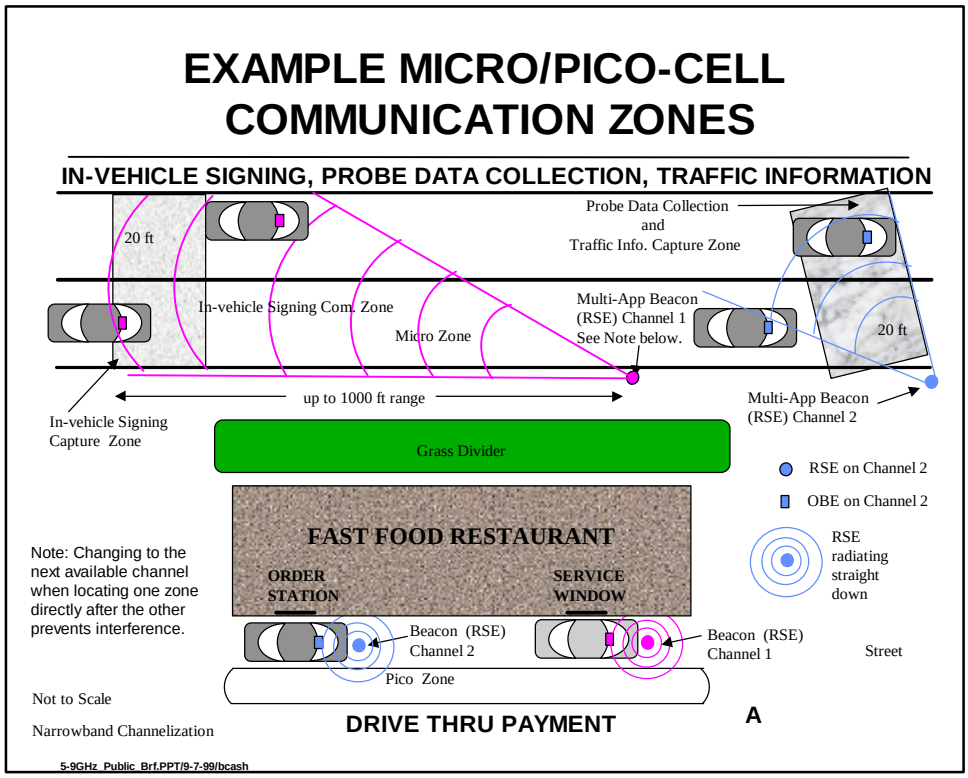
EXAMPLE MICRO/PICO-CELL COMMUNICATION ZONES
IN-VEHICLE SIGNING, PROBE DATA COLLECTION, TRAFFIC INFORMATION
20 ft
In-vehicle Signing Com. Zone
Micro Zone
Probe Data Collection and Traffic Info. Capture Zone
Multi-App Beacon (RSE) Channel 1 See Note below.
20 ft
up to 1000 ft range
In-vehicle Signing Capture Zone
Grass Divider
Multi-App Beacon (RSE) Channel 2
RSE on Channel 2
OBE on Channel 2
RSE radiating straight down
FAST FOOD RESTAURANT
ORDER STATION
SERVICE WINDOW
Note: Changing to the next available channel when locating one zone directly after the other prevents interference.
Beacon (RSE) Channel 2
Beacon (RSE) Channel 1
Street
Pico Zone
Not to Scale
Narrowband Channelization
DRIVE THRU PAYMENT
A
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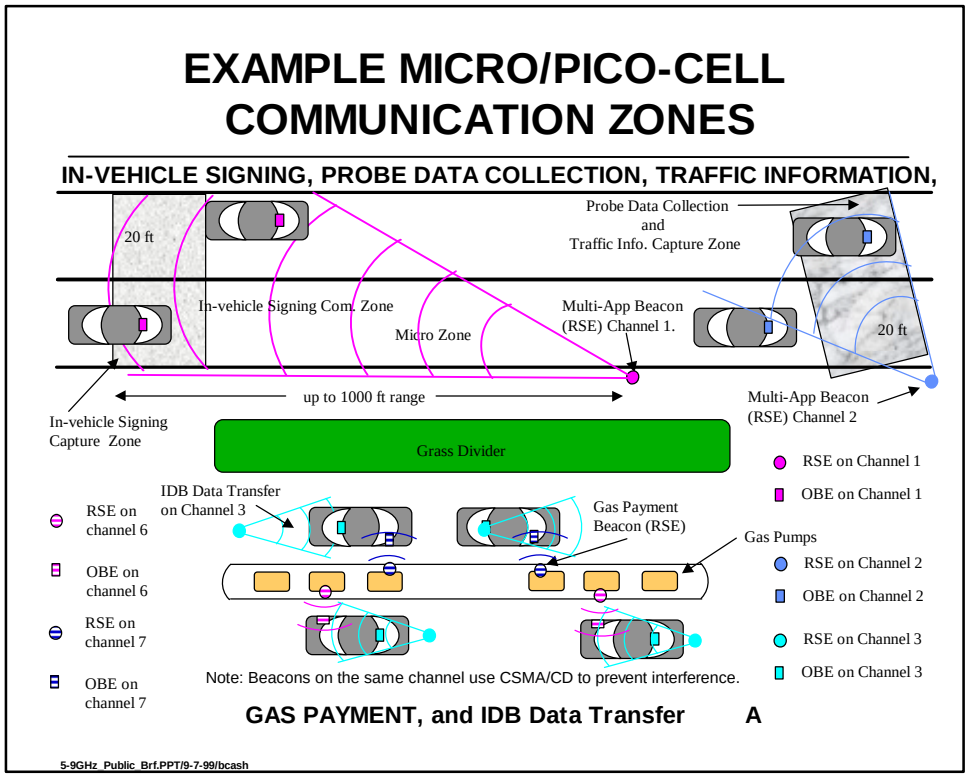
EXAMPLE MICRO/PICO-CELL COMMUNICATION ZONES
IN-VEHICLE SIGNING, PROBE DATA COLLECTION, TRAFFIC INFORMATION,
20 ft
In-vehicle Signing Com. Zone
Micro Zone
Probe Data Collection and Traffic Info. Capture Zone
Multi-App Beacon (RSE) Channel 1.
20 ft
up to 1000 ft range
In-vehicle Signing Capture Zone
Grass Divider
Multi-App Beacon (RSE) Channel 2
RSE on Channel 1
OBE on Channel 1
IDB Data Transfer on Channel 3
Gas Payment Beacon (RSE)
Gas Pumps
RSE on channel 6
OBE on channel 6
RSE on channel 7
OBE on channel 7
RSE on Channel 2
OBE on Channel 2
RSE on Channel 3
OBE on Channel 3
Note: Beacons on the same channel use CSMA/CD to prevent interference.
GAS PAYMENT, and IDB Data Transfer
A
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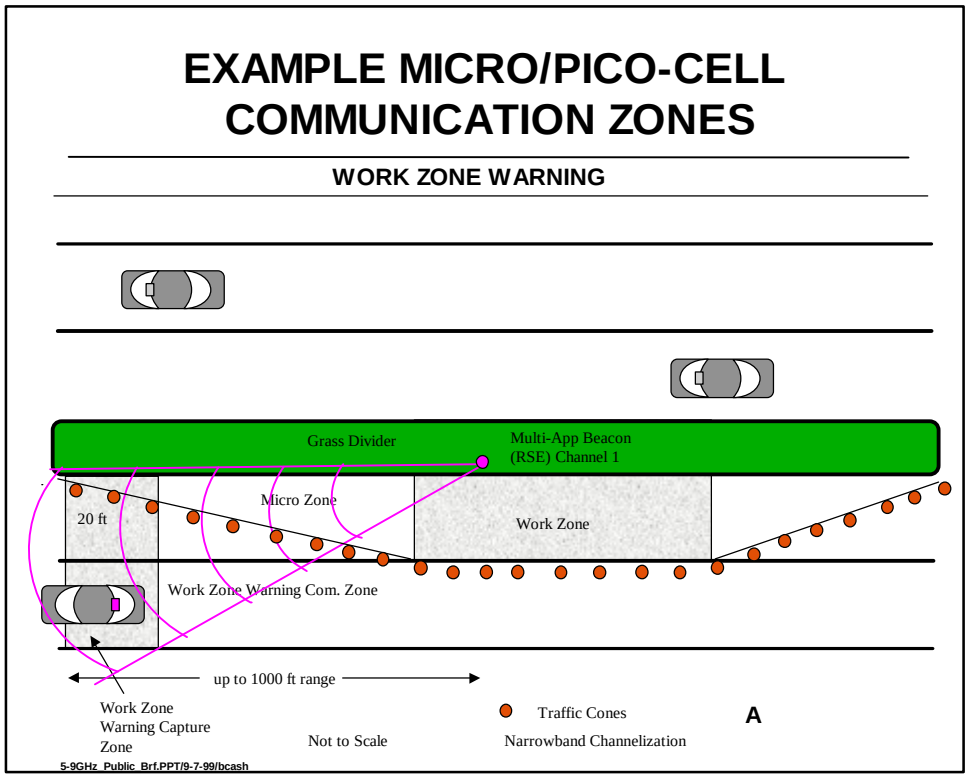
EXAMPLE MICRO/PICO-CELL COMMUNICATION ZONES
WORK ZONE WARNING
Grass Divider
Multi-App Beacon (RSE) Channel 1
Micro Zone
20 ft
Work Zone
Work Zone Warning Com. Zone
up to 1000 ft range
Work Zone Warning Capture Zone
Not to Scale
Traffic Cones
Narrowband Channelization
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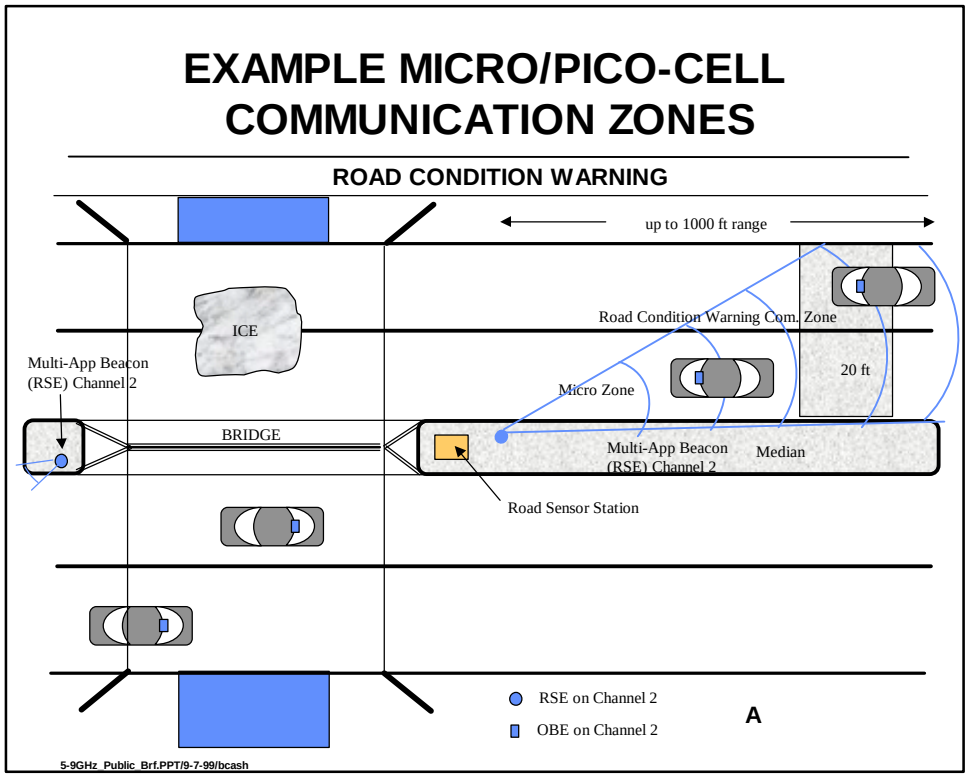
EXAMPLE MICRO/PICO-CELL COMMUNICATION ZONES
ROAD CONDITION WARNING
up to 1000 ft range
ICE
Road Condition Warning Com. Zone
Multi-App Beacon (RSE) Channel 2
Micro Zone
20 ft
BRIDGE
Multi-App Beacon (RSE) Channel 2
Median
Road Sensor Station
RSE on Channel 2
OBE on Channel 2
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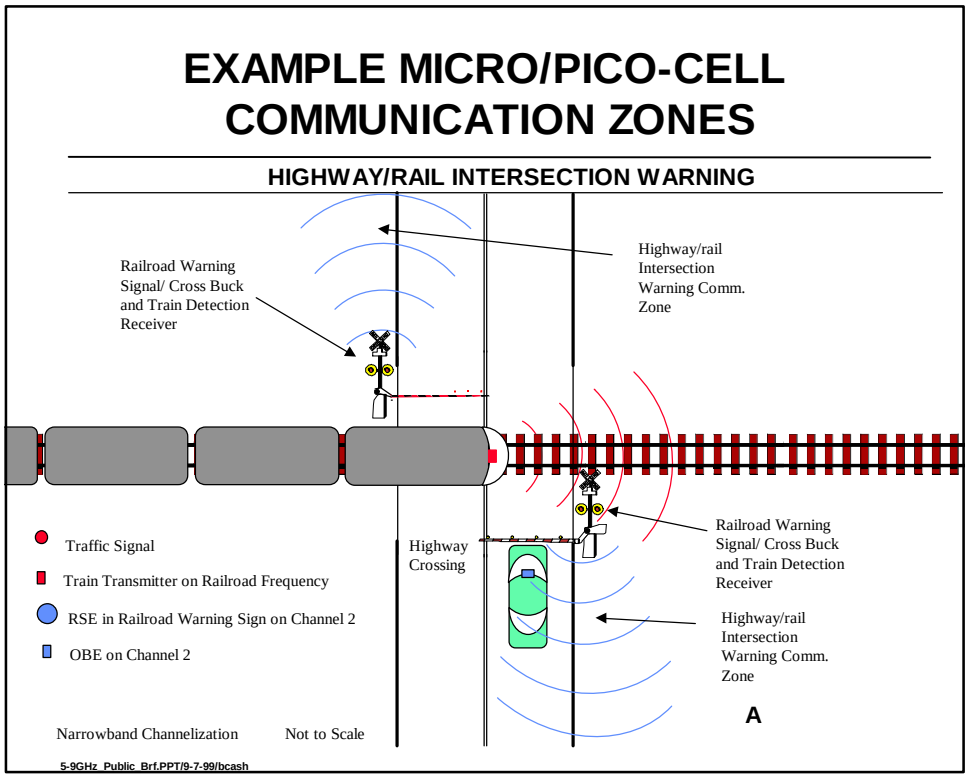
EXAMPLE MICRO/PICO-CELL COMMUNICATION ZONES
HIGHWAY/RAIL INTERSECTION WARNING
Railroad Warning Signal/ Cross Buck and Train Detection Receiver
Highway/rail Intersection Warning Comm. Zone
Traffic Signal
Train Transmitter on Railroad Frequency
RSE in Railroad Warning Sign on Channel 2
OBE on Channel 2
Highway Crossing
Railroad Warning Signal/ Cross Buck and Train Detection Receiver
Highway/rail Intersection Warning Comm. Zone
Narrowband Channelization
Not to Scale
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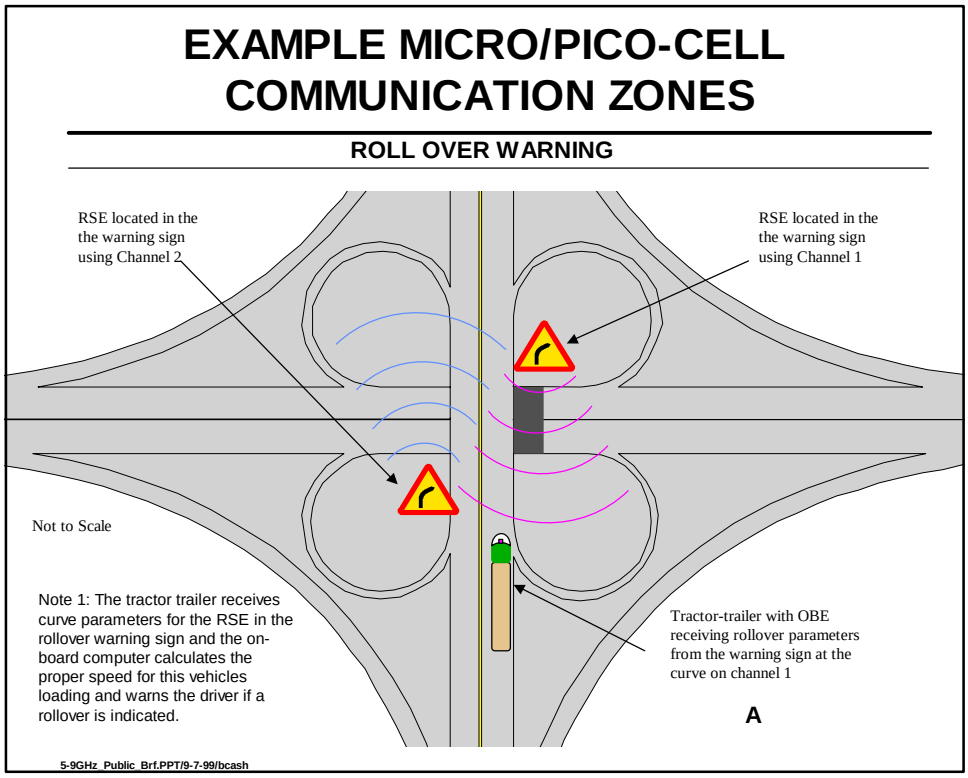
EXAMPLE MICRO/PICO-CELL COMMUNICATION ZONES
ROLL OVER WARNING
RSE located in the the warning sign using Channel 2
RSE located in the the warning sign using Channel 1
Not to Scale
Note 1: The tractor trailer receives curve parameters for the RSE in the rollover warning sign and the on-board computer calculates the proper speed for this vehicles loading and warns the driver if a rollover is indicated.
Tractor-trailer with OBE receiving rollover parameters from the warning sign at the curve on channel 1
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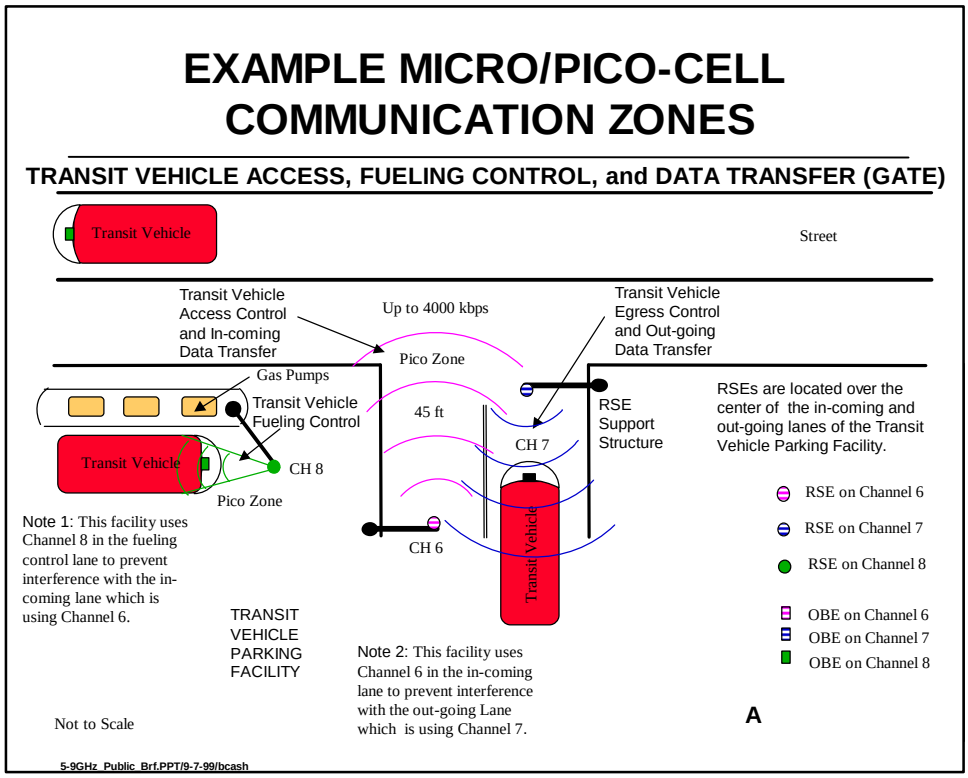
EXAMPLE MICRO/PICO-CELL COMMUNICATION ZONES
TRANSIT VEHICLE ACCESS, FUELING CONTROL, and DATA TRANSFER (GATE)
Transit Vehicle
Street
Transit Vehicle Access Control and In-coming Data Transfer
Up to 4000 kbps
Transit Vehicle Egress Control and Out-going Data Transfer
Pico Zone
Gas Pumps
Transit Vehicle Fueling Control
45 ft
RSE Support Structure
RSEs are located over the center of the in-coming and out-going lanes of the Transit Vehicle Parking Facility.
Transit Vehicle
CH 8
CH 7
Pico Zone
CH 6
Transit Vehicle
RSE on Channel 6
RSE on Channel 7
RSE on Channel 8
Note 1: This facility uses Channel 8 in the fueling control lane to prevent interference with the in-coming lane which is using Channel 6.
TRANSIT VEHICLE PARKING FACILITY
OBE on Channel 6
OBE on Channel 7
OBE on Channel 8
Note 2: This facility uses Channel 6 in the in-coming lane to prevent interference with the out-going Lane which is using Channel 7.
Not to Scale
A
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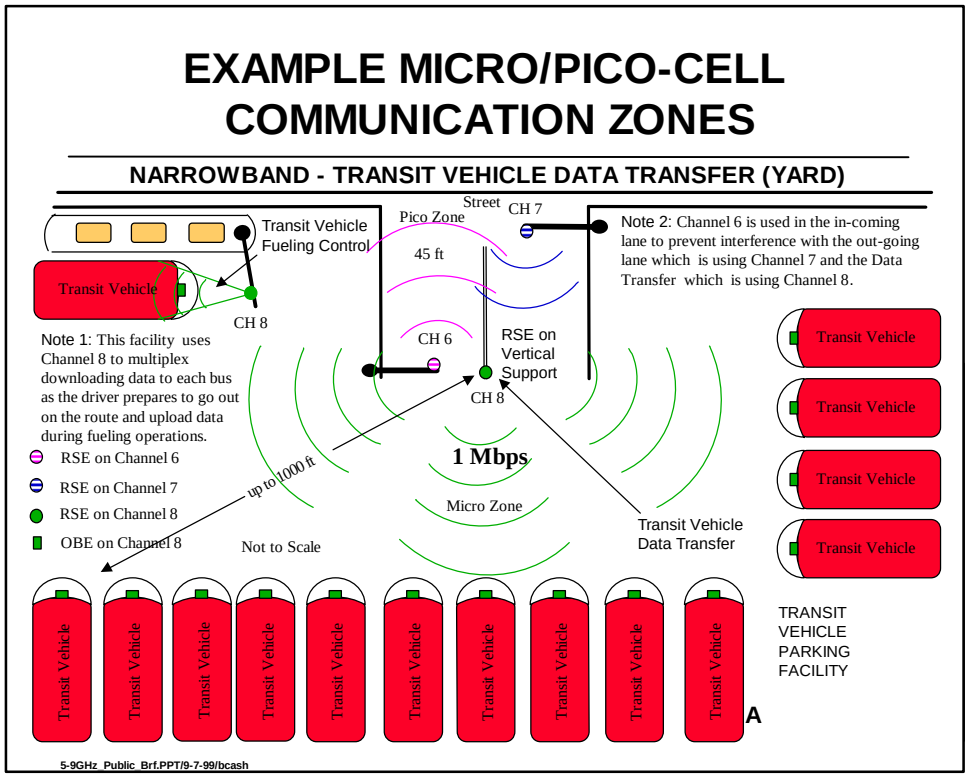
EXAMPLE MICRO/PICO-CELL COMMUNICATION ZONES
NARROWBAND - TRANSIT VEHICLE DATA TRANSFER (YARD)
Street
CH 7
Pico Zone
Transit Vehicle Fueling Control
45 ft
Note 2: Channel 6 is used in the in-coming lane to prevent interference with the out-going lane which is using Channel 7 and the Data Transfer which is using Channel 8.
Transit Vehicle
CH 8
CH 6
RSE on Vertical Support
Note 1: This facility uses Channel 8 to multiplex downloading data to each bus as the driver prepares to go out on the route and upload data during fueling operations.
CH 8
1 Mbps
RSE on Channel 6
RSE on Channel 7
RSE on Channel 8
OBE on Channel 8
up to 1000 ft
Micro Zone
Transit Vehicle Data Transfer
Not to Scale
Transit Vehicle
TRANSIT VEHICLE PARKING FACILITY
A
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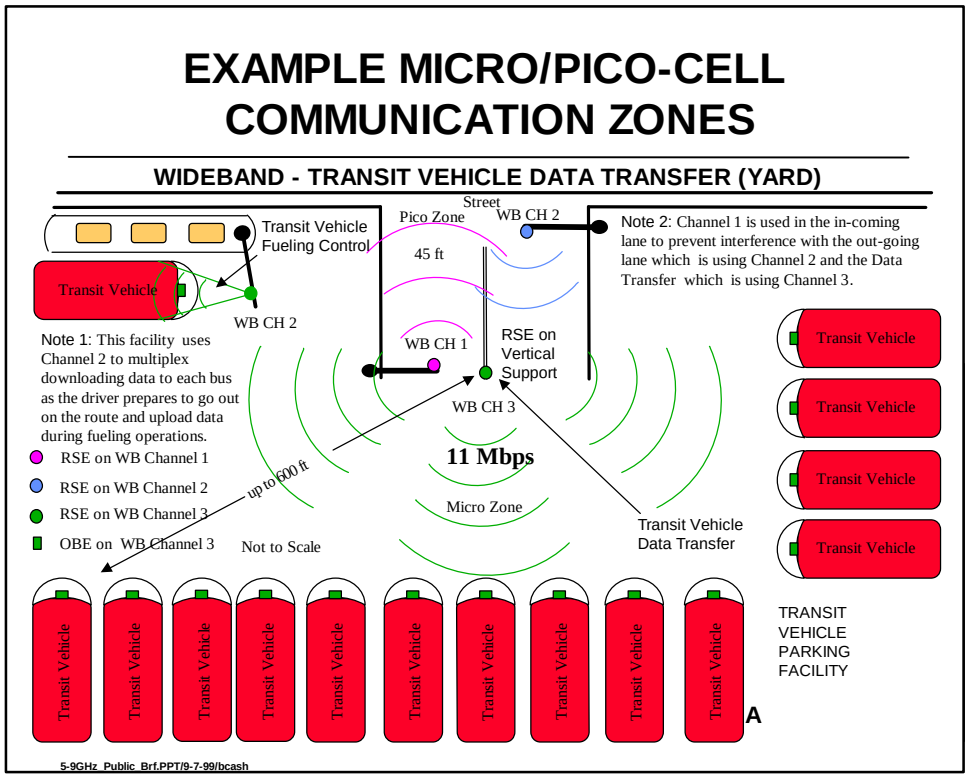
EXAMPLE MICRO/PICO-CELL COMMUNICATION ZONES
WIDEBAND - TRANSIT VEHICLE DATA TRANSFER (YARD)
Street
Pico Zone
WB CH 2
Transit Vehicle Fueling Control
45 ft
Transit Vehicle
WB CH 2
Note 2: Channel 1 is used in the in-coming lane to prevent interference with the out-going lane which is using Channel 2 and the Data Transfer which is using Channel 3.
Note 1: This facility uses Channel 2 to multiplex downloading data to each bus as the driver prepares to go out on the route and upload data during fueling operations.
WB CH 1
RSE on Vertical Support
WB CH 3
11 Mbps
RSE on WB Channel 1
RSE on WB Channel 2
RSE on WB Channel 3
OBE on WB Channel 3
up to 600 ft
Micro Zone
Not to Scale
Transit Vehicle Data Transfer
Transit Vehicle
Transit Vehicle
Transit Vehicle
Transit Vehicle
TRANSIT VEHICLE PARKING FACILITY
A
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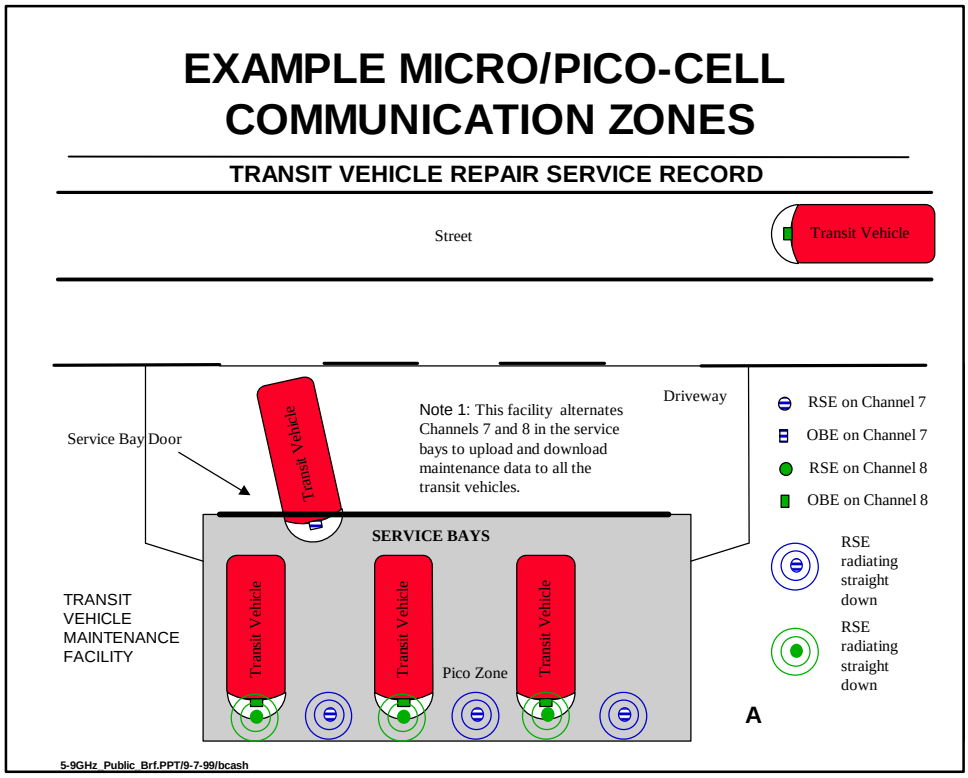
EXAMPLE MICRO/PICO-CELL COMMUNICATION ZONES
TRANSIT VEHICLE REPAIR SERVICE RECORD
Street
Transit Vehicle
Driveway
Service Bay Door
Transit Vehicle
Note 1: This facility alternates Channels 7 and 8 in the service bays to upload and download maintenance data to all the transit vehicles.
RSE on Channel 7
OBE on Channel 7
RSE on Channel 8
OBE on Channel 8
SERVICE BAYS
RSE radiating straight down
RSE radiating straight down
TRANSIT VEHICLE MAINTENANCE FACILITY
Transit Vehicle
Transit Vehicle
Transit Vehicle
Pico Zone
A
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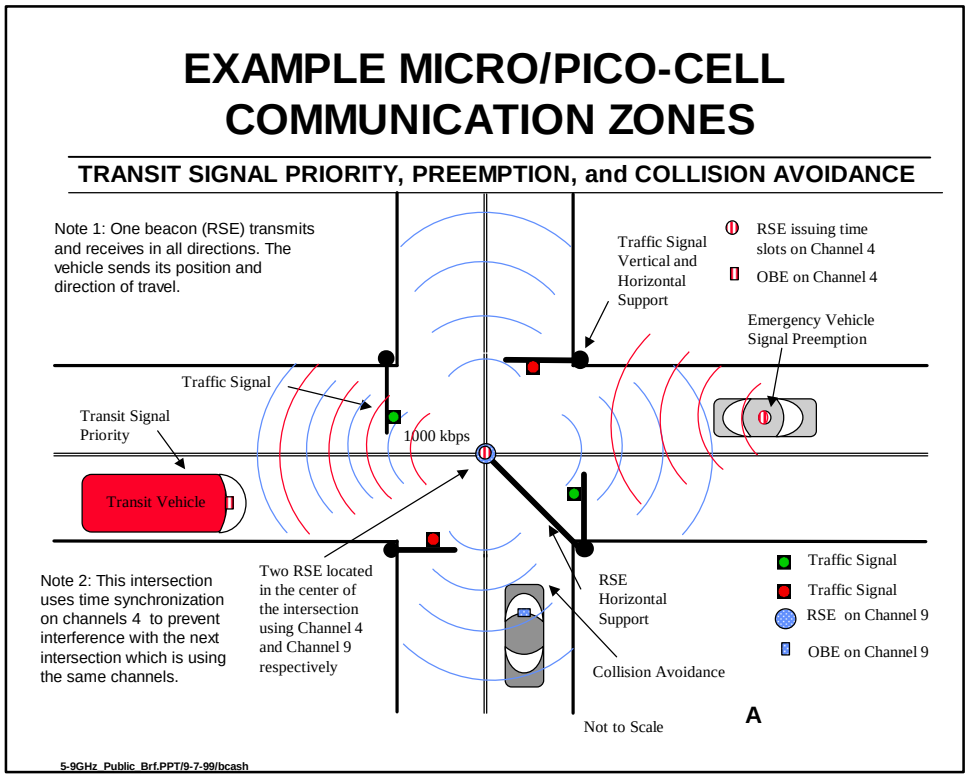
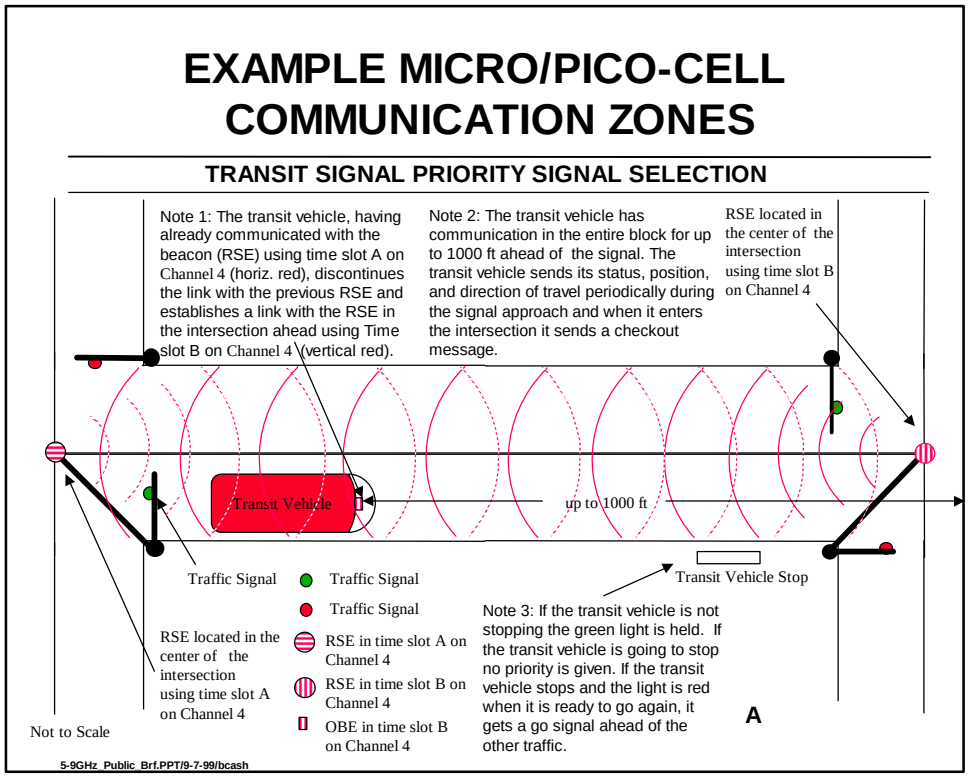
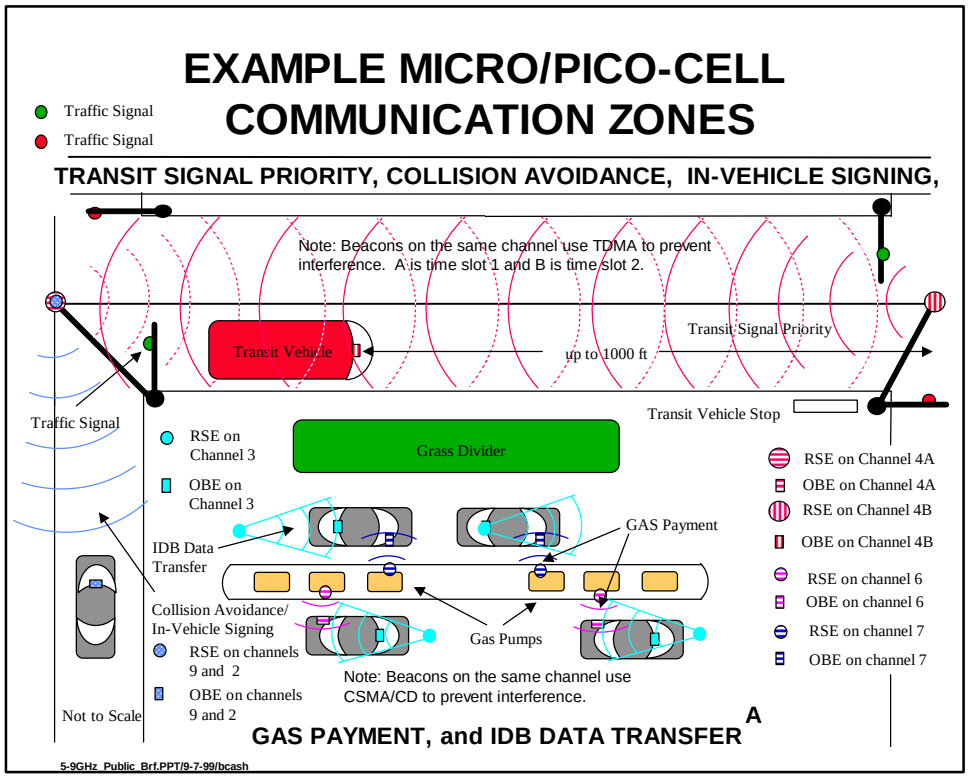
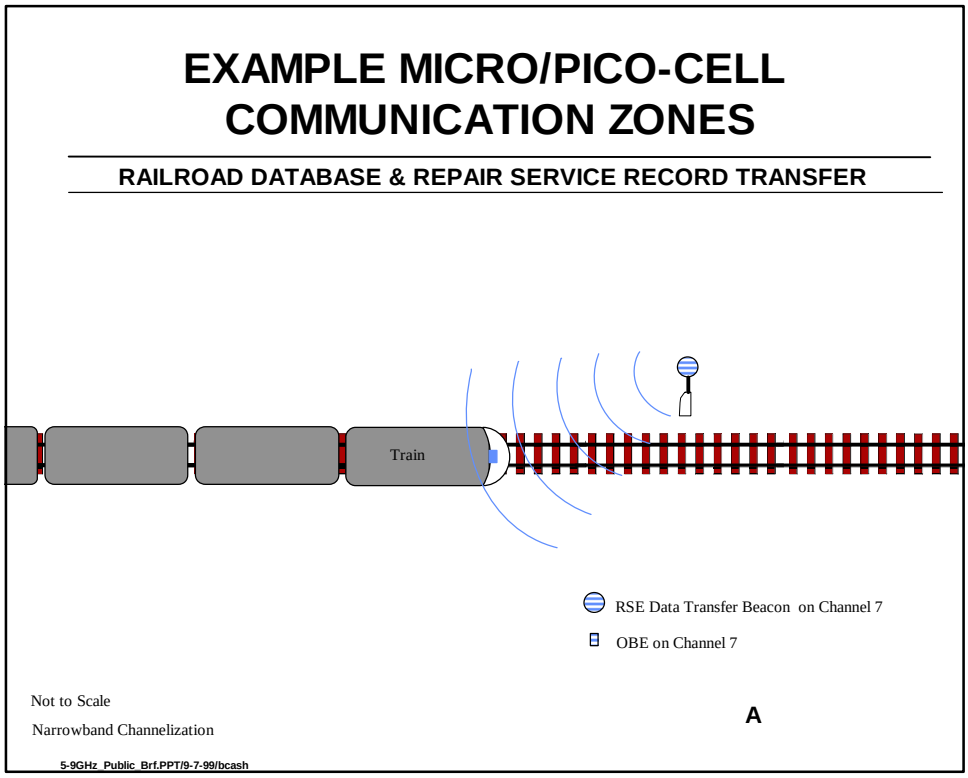

EXAMPLE MICRO/PICO-CELL COMMUNICATION ZONES
TRANSIT SIGNAL PRIORITY, PREEMPTION, and COLLISION AVOIDANCE
Note 1: One beacon (RSE) transmits and receives in all directions. The vehicle sends its position and direction of travel.
Traffic Signal Vertical and Horizontal Support
RSE issuing time slots on Channel 4
OBE on Channel 4
Emergency Vehicle Signal Preemption
Traffic Signal
Transit Signal Priority
1000 kbps
Transit Vehicle
Two RSE located in the center of the intersection using Channel 4 and Channel 9 respectively
Note 2: This intersection uses time synchronization on channels 4 to prevent interference with the next intersection which is using the same channels.
RSE Horizontal Support
Collision Avoidance
Traffic Signal
Traffic Signal
RSE on Channel 9
OBE on Channel 9
Not to Scale
A
5-9GHz_Public_Brf.PPT/9-7-99/bcash


EXAMPLE MICRO/PICO-CELL COMMUNICATION ZONES
TRANSIT SIGNAL PRIORITY SIGNAL SELECTION
Note 1: The transit vehicle, having already communicated with the beacon (RSE) using time slot A on Channel 4 (horiz. red), discontinues the link with the previous RSE and establishes a link with the RSE in the intersection ahead using Time slot B on Channel 4 (vertical red).
Note 2: The transit vehicle has communication in the entire block for up to 1000 ft ahead of the signal. The transit vehicle sends its status, position, and direction of travel periodically during the signal approach and when it enters the intersection it sends a checkout message.
RSE located in the center of the intersection using time slot B on Channel 4
Transit Vehicle
up to 1000 ft
Traffic Signal
Traffic Signal
Traffic Signal
Transit Vehicle Stop
RSE located in the center of the intersection using time slot A on Channel 4
RSE in time slot A on Channel 4
RSE in time slot B on Channel 4
OBE in time slot B on Channel 4
Note 3: If the transit vehicle is not stopping the green light is held. If the transit vehicle is going to stop no priority is given. If the transit vehicle stops and the light is red when it is ready to go again, it gets a go signal ahead of the other traffic.
Not to Scale
A
5-9GHz_Public_Brf.PPT/9-7-99/bcash


EXAMPLE MICRO/PICO-CELL COMMUNICATION ZONES
Traffic Signal
Traffic Signal
TRANSIT SIGNAL PRIORITY, COLLISION AVOIDANCE, IN-VEHICLE SIGNING,
Note: Beacons on the same channel use TDMA to prevent interference. A is time slot 1 and B is time slot 2.
Transit Vehicle
up to 1000 ft
Transit Signal Priority
Transit Vehicle Stop
Traffic Signal
RSE on Channel 3
OBE on Channel 3
Grass Divider
RSE on Channel 4A
OBE on Channel 4A
RSE on Channel 4B
OBE on Channel 4B
GAS Payment
IDB Data Transfer
RSE on channel 6
OBE on channel 6
RSE on channel 7
OBE on channel 7
Collision Avoidance/ In-Vehicle Signing
RSE on channels 9 and 2
OBE on channels 9 and 2
Gas Pumps
Note: Beacons on the same channel use CSMA/CD to prevent interference.
Not to Scale
A
GAS PAYMENT, and IDB DATA TRANSFER
5-9GHz_Public_Brf.PPT/9-7-99/bcash


EXAMPLE MICRO/PICO-CELL COMMUNICATION ZONES
RAILROAD DATABASE & REPAIR SERVICE RECORD TRANSFER
Train
RSE Data Transfer Beacon on Channel 7
OBE on Channel 7
Not to Scale
Narrowband Channelization
A
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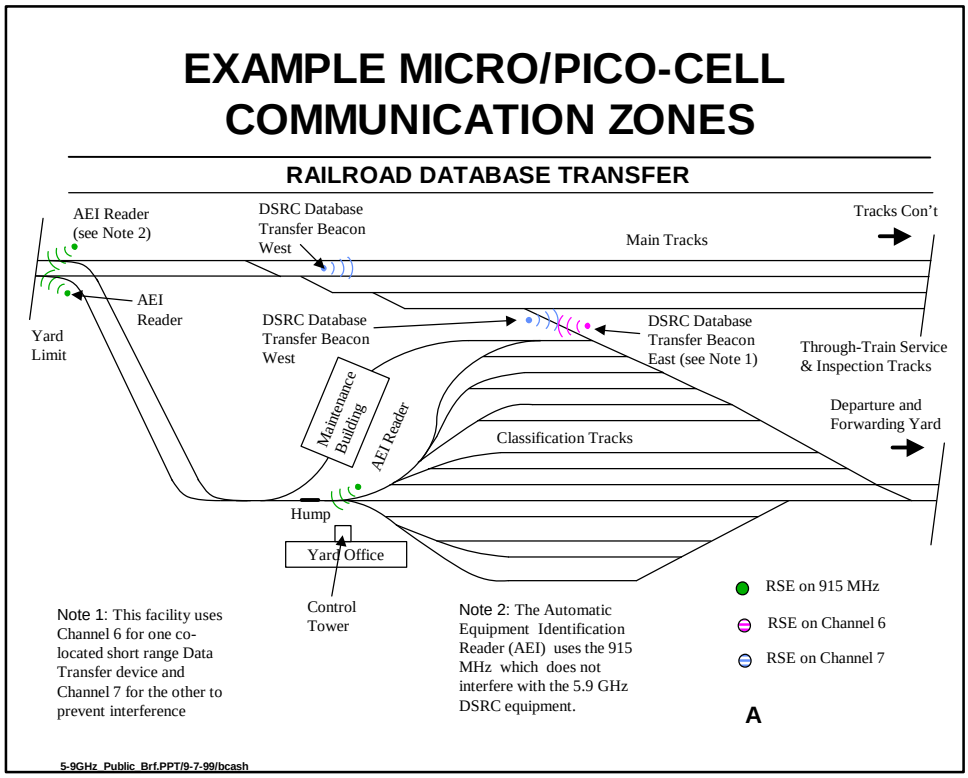
EXAMPLE MICRO/PICO-CELL COMMUNICATION ZONES
RAILROAD DATABASE TRANSFER
AEI Reader (see Note 2)
DSRC Database Transfer Beacon West
Main Tracks
Tracks Con't
AEI Reader
Yard Limit
DSRC Database Transfer Beacon West
DSRC Database Transfer Beacon East (see Note 1)
Through-Train Service & Inspection Tracks
Maintenance Building
AEI Reader
Departure and Forwarding Yard
Classification Tracks
Hump
Yard Office
Control Tower
Note 1: This facility uses Channel 6 for one co-located short range Data Transfer device and Channel 7 for the other to prevent interference
Note 2: The Automatic Equipment Identification Reader (AEI) uses the 915 MHz which does not interfere with the 5.9 GHz DSRC equipment.
RSE on 915 MHz
RSE on Channel 6
RSE on Channel 7
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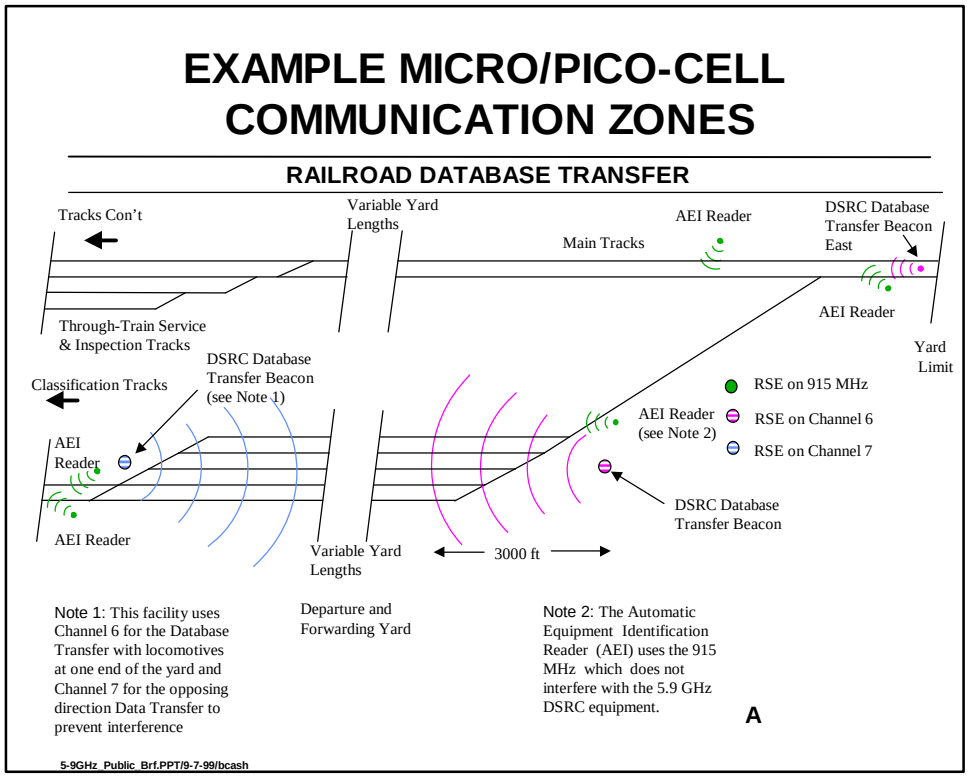
EXAMPLE MICRO/PICO-CELL COMMUNICATION ZONES
RAILROAD DATABASE TRANSFER
Tracks Con't
Variable Yard Lengths
AEI Reader
DSRC Database Transfer Beacon East
Main Tracks
AEI Reader
Through-Train Service & Inspection Tracks
Yard Limit
Classification Tracks
DSRC Database Transfer Beacon (see Note 1)
RSE on 915 MHz
RSE on Channel 6
RSE on Channel 7
AEI Reader (see Note 2)
AEI Reader
DSRC Database Transfer Beacon
AEI Reader
Variable Yard Lengths
3000 ft
Departure and Forwarding Yard
Note 1: This facility uses Channel 6 for the Database Transfer with locomotives at one end of the yard and Channel 7 for the opposing direction Data Transfer to prevent interference
Note 2: The Automatic Equipment Identification Reader (AEI) uses the 915 MHz which does not interfere with the 5.9 GHz DSRC equipment.
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SUMMARY OF 5.9 GHz DSRC PHYSICAL LAYER OPTIONS

- **AM / OOK ACTIVE w/3 Channels and separate frequency DL/UL**
  - **Possible low cost solution for core applications**
  - **Low channel isolation (could allow interference between applications)**
- **DBPSK ACTIVE w/3 Channels and separate frequency DL/UL**
  - **Viable solution for core applications**
- **DBPSK ACTIVE w/9 Channels and separate frequency DL/UL**
  - **Viable solution for all* applications**
- **BACKSCATTER w/3 Channels and separate frequency DL/UL (AM / OOK)**
  - **Possible low cost solution for core applications**
  - **Low channel isolation (could allow interference between applications)**
- **DSSS ACTIVE w/4 Channels and same frequency DL/UL (High Data Rate Opt)**
  - **Possible limited application solution (not enough channels for all).**
  - **Most nearly off-the-shelf solution**
- **ULTRAWIDEBAND w/1 Channel and same frequency DL/UL (Tractor-Trailer Opt)**
  - **Totally viable for tractor to trailer application**

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* - Excluding the tractor to trailer application

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SUMMARY OF 5.9 GHz DSRC DATALINK LAYER CANDIDATES

- **ASTM V7**
  - **Acceptable to all parties**
  - **Significant development costs (design chips from scratch)**
- **ARIB STD-T55**
  - **Not acceptable to all parties**
  - **Less implementation cost (existing chip designs)**
- **CEN 12795**
  - **Not acceptable to all parties**
  - **Less implementation cost (existing chip designs)**
- **IEEE 802.11**
  - **Suitability not fully explored**
  - **Low implementation cost (available off-the-shelf chips)**
  - **Cost to interface to IEEE 1455**
- **IEEE 802.15**
  - **Suitability not yet explored**
  - **Low implementation cost (potential off-the-shelf chips)**
  - **Cost to interface to IEEE 1455**

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