Designation: E 2158 – 01

Standard Specification for Dedicated Short Range Communication (DSRC) Physical Layer Using Microwave in the 902 to 928 MHz Band[1]

INTRODUCTION

FOREWORD

This specification is intended to form a part of a series of standards defining the framework of DSRC link in the North American Intelligent Transportation Systems (ITS) environment. In addition to this specification, Subcommittee E17.51 (and other committees) will issue other standards to form a complete set of standards for the DSRC link.

The Physical Layer Task Group consists primarily of experts from the telecommunications and transport sectors. The most active participating companies and organizations are: equipment manufacturers, systems integrators, toll and turnpike agencies, research consultants, and interested groups and associations.

Recommendations and decisions made by the United States Federal Communications Commission (FCC) and Industry Canada have served as references in the preparation of this specification (refer to Section 2—Referenced Documents).

Additional inputs came from experts from Europe and Japan (see Appendix X1—Bibliography).

This specification is applicable to operations in Canada, Mexico and the US to the extent allowed by national regulatory agencies

INTRODUCTION

DSRC is intended to meet the requirements for many of the applications that need short range communication as defined by the National ITS Architecture and the Intelligent Transportation Society of America. These applications include Advanced Traveller Information Systems (ATIS), Commercial Vehicle Operations (CVO), Advanced Vehicle Control Systems (AVCS), Electronic Toll and Traffic Management Systems (ETTM), Advanced Public Transportation Systems (APTS), and Advanced Transportation Management Systems (ATMS).

This specification comprises requirements for Open Systems Interconnection (OSI) Layer 1 in the 902 to 928 MHz Location and Monitoring Service (LMS) band for DSRC. This specification does not include associated measurement procedures for verification of the requirements. Measurement guidelines will be developed in another document as a separate work item.

The presented requirements distinguish between default and optional parameter values. Procedures for using optional parameters include consideration of upper OSI layers. The elaboration of such procedures will be subject to further work within Subcommittee E17.51.

This specification provides information for onboard equipment based on active as well as backscatter technologies, and allows for interoperability between systems based on both of these technologies. Furthermore, this specification allows for mixed time, frequency, and space division multiple access approaches.

This specification is conceived for the 2+10+2 MHz part, — 902 to 904 MHz, 909.75 to 919.75 MHz, and 919.75 to 921.75 MHz, of the LMS band. The 902 to 904 MHz region is used for unmodulated carriers to provide backscatter capability in this portion of the band. All of these frequencies in the LMS band are currently available for use in the US and Canada.

This specification contains requirements that minimize interference between sites and between active and backscatter systems. The active legacy systems currently operate and will continue to operate uplinks and downlinks on the 915.00 and 915.75 MHz center frequencies. This specification adds the possibility of operating new active downlink center frequencies on and between 915.00 and 918.75 MHz. However, the primary active downlink operating frequencies will be 915 and 918.75

MHz. The backscatter systems operate on all the frequencies between 902 and 904 MHz and 909.75 and 921.75 MHz while using power levels consistent with the out-of-band emissions requirements. However, in order to operate at the power levels allowed in this specification and minimize interference between systems and sites, the following designations have been made. 912.75 and 918.75 MHz will be the primary backscatter downlink operating frequencies just as 915 and 918.75 MHz will be the primary active downlink operating frequencies. The required active uplink frequency is 915.00 MHz. The primary backscatter uplink sideband frequencies are 910.75, 914.75, 916.75, and 920.75 MHz. Fig. 1, shows the ASTM — 902 to 928 MHz ISM Band Utilization.

The above described frequency usage plan enables reduced separation distance between sites for both active and backscatter systems. Multiple active installations, with 918.75 MHz for the active downlink and 915.00 MHz for the active uplink, can be installed with less separation distance than the current 915.00 MHz systems. This is possible because the uplink receiver experiences less interference from a downlink signal that is offset in frequency by 3.75 MHz. In addition, for the backscatter systems, this frequency use plan allows the operation of multiple sets of independent, simultaneously operating, channels of data transfer, which can be very closely spaced. The backscatter operation achieves this by operating one downlink channel at 912.75 MHz, with the uplink sidebands at 910.75 and 914.75 MHz, and another downlink channel at 918.75 MHz with uplink sidebands at 916.75 and 920.75 MHz. The spectral mask attenuation in this specification enables a significant reduction in the interference signal over 4 MHz separation from one downlink (for example, 912.75 MHz) to the adjacent channel uplink receiver (for example, 916.75 MHz). A third uplink sideband set for either downlink can be operated at 901 and 905 MHz with a CW signal at 903 MHz.

This band usage plan allows active and backscatter systems to operate with minimum interference, dual-mode systems to have North American-wide compatibility, and a high density of application deployments in congested areas.

1. Scope

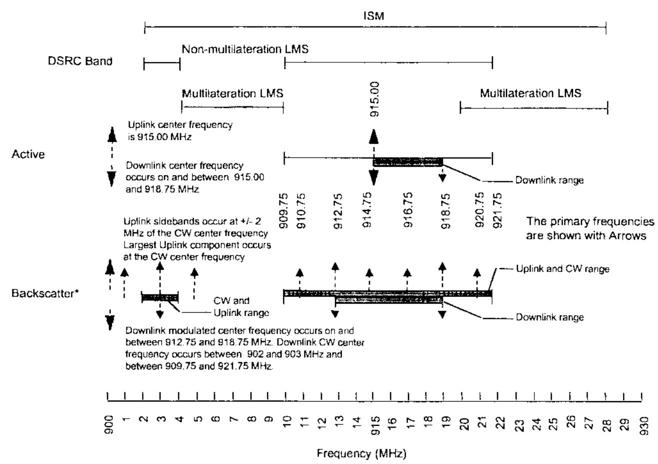
1.1 *Purposes*:

1.1.1 This specification defines the Open Systems Interconnection (OSI) layer 1, physical layer, for dedicated short-range communications (DSRC) equipment, operating in two-way, half-duplex, active and backscatter modes.

1.1.2 This specification establishes a common framework for the physical layer in the 902 to 928 MHz LMS band. This band is allocated for DSRC applications by the FCC in Title 47, Code of Federal Regulations (CFR), Part 90, Subpart M and by Industry Canada in the Spectrum Management, Radio Standard Specification, Location and Monitoring Service (902-928 MHz), RSS-137.

1.1.3 This specification defines an air interface for both wide-area (multi-lane, open road) and lane-based applications that enables accurate and valid message delivery between moving vehicles randomly entering a communications zone and fixed roadside communication equipment. This air interface also enables accurate and valid message delivery between moving or stationary vehicles and fixed or portable roadside communication equipment.

1.1.4 This specification does not include associated measurement guidelines for verification of the formulated requirements in this specification. It is intended that readers will be able to refer to the ASTM standard on Technical Characteristics and Test Methods for Data Transmission Equipment Operating in the 902 to 928 MHz LMS Band for the measurement guidelines, when it is developed.



* Backscatter sidebands are the primary uplink information carriers and can exist outside the band

FIG. 1 ASTM 902 to 928 MHz ISM Band Utilization Plan

1.1.5 This specification does not consider any one specific ITS application, but rather describes a communication means to be used by several ITS applications. This specification also may be used for any non-roadway environment that can utilize this type of dedicated short-range radio communication.

1.1.6 While this specification defines frequencies and power levels that are compatible with the North American regulatory requirements, the technical methodology used in their selection can be utilized in other regions of the world.

1.2 *Equipment*:

1.2.1 The DSRC equipment is composed of two principle components: road-side equipment (RSE) and on-board equipment (OBE) or transponder.

1.2.2 The RSE controls the protocol, schedules the activation of the OBE, reads from or writes to the OBE, and assures message delivery and validity. It is intended for, but not

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[1] This specification is under the jurisdiction of ASTM Committee E17 on Vehicle-Pavement Systems and is the direct responsibility of Subcommittee E17.51 on the Vehicle Roadside Communication.

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restricted to, installation at a fixed location on the roadway.

1.2.3 The OBE communicates with the RSE and is intended for, but not restricted to, installation in or on a motor vehicle.

1.2.4 The RSE must be capable of communicating with closely spaced OBE in the same lane or closely spaced OBE in adjacent lanes.

1.2.5 This specification provides requirements for the communication medium to be used for exchange of information between RSE and OBE. Active, backscatter, and dual-mode technologies are described.

1.3 *Structure*:

1.3.1 This specification defines an open (non-proprietary) architecture using the simplified OSI seven-layer reference model (per ISO 7498). The following sub-section describe the relationships of the OSI layers that support DSRC.

1.3.1.1 The physical layer (Layer 1) is defined as a half-duplex radio frequency medium, in the 902 to 928 MHz band. Layer 1 interfaces with Layer 2.

1.3.1.2 The data link control layer (Layer 2) defines a Time Division Multiple Access (TDMA) messaging protocol in which both the downlink and uplink are completely controlled by the RSE. The data link control layer provides a mechanism to ensure reliable completion of each transaction in the communications zone. This layer includes data organization, sequence control, flow control, error detection and error recovery among other functions. Layer 2 interfaces with Layer 7.

1.3.1.3 The application layer (Layer 7) defines specific functions and message formats to support ITS and other services. Implicit or pre-set message formats may be used. Data encryption, data certification, and manual OBE and RSE authentication may be performed.

1.3.1.4 The functions of the network layer (Layer 3), transport layer (Layer 4), session layer (Layer 5), and presentation layer (Layer 6) are included where necessary in Layer 2 or Layer 7.

1.3.2 The physical layer communications requirements for the signals sent from the RSE in the OBE are accounted for as downlink parameters. The requirements associated with the signals sent from the OBE to the RSE are accounted for as uplink parameters.

1.3.3 Physical layer requirements related to the interface to other DSRC communications layers are accounted for in 4.3.

1.4 The values stated in SI units are to be regarded as the standard.

2. Referenced Documents

2.1 This specification incorporates (by dated and undated reference) provisions from other publications. These references are cited at the appropriate places in the text and publications are listed below. For dated references, subsequent amendments to or revisions of any of these publications apply to this specification only when incorporated in it by amendment or revision. For undated references, the latest edition of the publication referred to applies.

2.1.1 Certain parameters in this specification allow compliance with regulations of the country in which the equipment is used. For the U.S., the regulations are maintained by the Federal Communications Commission and in Canada, the regulations are maintained by Industry Canada. In other countries, contact the regulatory agency for spectrum management to obtain the regulations that apply to this specification. The relevant parameters are marked with an asterisk (*) in the tables and the corresponding regulations are contained in 2.4. These parameters should not be changed without due consideration of the installation country's regulations.

2.2 *ISO Standard:*

ISO 7498 Open Systems Interconnection—Basic Reference Model[2]

2.3 *IEEE Standard:*

IEEE P 1455 Dedicated Short Range Communications Applications for Intelligent Transportation System[3]

2.4 *Government Standard:*

Title 47 Code of Federal Regulations (CFR) Part 90, Subpart M[4]

2.5 *Industry Canada Standard:*

RSS-137, Issue 1 (Provisional), Spectrum Management, Radio Standard Specification, Location and Monitoring Service (902-928-MHz)[5]

3. Terminology

3.1 *Abbreviations:*

3.1.1 *ASTM*—American Society for Testing and Materials.

3.1.2 *AM*—Amplitude Modulation.

3.1.3 *ant*—antenna.

3.1.4 *APTS*—Advanced Public Transportation Systems.

3.1.5 *ASK*—Amplitude Shift Keying.

3.1.6 *ATIS*—Advanced Traveller Information Systems.

3.1.7 *ATMS*—Advanced Transportation Management Systems.

3.1.8 *AVCS*—Advanced Vehicle Control Systems.

3.1.9 *AVI*—Automatic Vehicle Identification.

3.1.10 *Backsc*—Backscatter.

3.1.11 *B.E.R.*—Bit Error Rate.

3.1.12 *CFR*—Code of Federal Regulations.

3.1.13 *contd*—continued.

3.1.14 *CVO*—Commercial Vehicle Operations.

3.1.15 *CW*—Continuous Wave.

3.1.16 *DSRC*—Dedicated Short Range Communications.

3.1.17 *E.I.R.P.*—Equivalent Isotropic Radiation Power.

3.1.18 *EM*—Electromagnetic.

3.1.19 *ETTM*—Electronic Toll and Traffic Management Systems.

3.1.20 *f*—frequency.

3.1.21 *FCC*—Federal Communications Commission.

3.1.22 *FDMA*—Frequency Division Multiple Access.

3.1.23 *FSK*—Frequency Shift Keying.

3.1.24 *ITS*—Intelligent Transportation Systems.

3.1.25 *kbps*—kilobits per second (1000 bits per second).

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[2] Available from American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036.

[3] Available from The Institute of Electrical and Electronics Engineers, Inc., 345 E. 47th Street, New York, NY 10017.

[4] Available from Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

[5] Available from Canadian Standards Association, 178 Rexdale Boulevard, Etobicoke, Ontario Canada M9W1R3.

3.1.26 *kHz*—kilohertz (10^3 Hertz).

3.1.27 *kph*—kilometres per hour.

3.1.28 *LMS*—Location and Monitoring Service.

3.1.29 *LSB*—Least Significant Bit.

3.1.30 *M*—modulation order.

3.1.31 *mW*—milliwatt.

3.1.32 *mph*—miles per hour.

3.1.33 *MHz*—megahertz (10^6 Hertz).

3.1.34 *NRZI*—Non Return to Zero, invert on ones encoding scheme.

3.1.35 *OBE*—On-board Equipment, often referred to as a transponder.

3.1.36 *OSI*—Open Systems Interconnection.

3.1.37 *ppm*—parts per million (= 10^{-6}).

3.1.38 *PSK*—Phase Shift Keying.

3.1.39 *RAM*—Random Access Memory.

3.1.40 *Resv*—reserved.

3.1.41 *RF*—Radio Frequency.

3.1.42 *RSE*—Road Side Equipment, often referred to as a beacon.

3.1.43 *SDMA*—Space Division Multiple Access.

3.1.44 *S/I*—signal-to-interference.

3.1.45 *TDMA*—Time Division Multiple Access.

3.2 *Formulas:*

3.2.1 $M=2^k$—number of signal elements (modulation order).

3.2.2 *k*—number of bits per signal element.

3.3 *Definitions of Equipment and Signal Terms:*

3.3.1 *active (system)*—a functionally matched set of OBE and one or more RSE where the OBE generates its own carrier that it modulates to send data to the RSE. The RSE receiver is specifically designed to receive the modulated carrier as defined by this specification.

3.3.2 *backscatter (system)*—a functionally matched set of OBE and one or more RSE where the OBE receives and reradiates the RSE carrier to send its signal. The backscatter OBE generates a sub-carrier that it modulates and then multiplies with the RSE CW carrier to send data to the RSE. The RSE is specifically designed to transmit a CW carrier during the receive phase of the communication sequence and receive the OBE signal resulting from multiplying the modulated sub-carrier with the CW carrier.

3.3.3 *channel*—a designated frequency band for the operation of a signal RF communication link. A channel exists in a system where other bands of operation (channels) are designed in a way that minimizes the possibility of interference between the signals in each band.

3.3.4 *communication zone*—an area in which the signal level is within the OBE operating range.

3.3.5 *compatibility*—the capability of DSRC components (OBE and RSE) that have the characteristics described in this specification, from any vendor, to exchange data properly with the corresponding communication partner components (OBE to RSE, RSE to OBE) from other vendors. Compatibility requires compliance with OSI Layers 2 through 7 documents as well as this specification.

3.3.6 *downlink*—communications from an RSE (usually located at the roadside) to an OBE (usually in a vehicle).

3.3.7 *dual-mode OBE*—an OBE that is capable of communicating with both active and backscatter systems. The OBE can either emit its own modulated carrier or modulate and reradiate a RSE carrier to send its signal.

3.3.8 *dual-mode RSE*—a RSE that is capable of communicating with both active and backscatter OBE. The RSE can receive the active modulated carrier from an active OBE. The RSE can also transmit a CW carrier during the receive phase of a backscatter communication sequence and receive the backscatter OBE signal resulting from multiplying the modulated subcarrier with the CW carrier.

3.3.9 *horizontal range*—distance between the projection of the RSE antenna location in a horizontal plane and the projection of the OBE in the same horizontal plane. Since an RSE antenna is usually mounted above a road surface, on a flat road the horizontal range would be the distance from the place on the road just below the RSE antenna to the place on the road just below the OBE.

3.3.10 *interoperability*—the capability of DSRC components (OBE and RSE) to operate within an integrated system such that data can be exchanged with corresponding communication partner components to accomplish a function or an activity at any co-operating service-provider installation. Activities may include toll payment, in-vehicle sign display, weight station bypass, expedited border crossing, and gate access control, among others described in the ITS architecture. Interoperability requires compliance with OSI Layers 1 through 7 DSRC standard documents as well data exchange and co-ordination between service providers.

3.3.11 *multilateration LMS*—a location and monitoring service that uses the intersection of multiple antenna beam pointing vectors, for an emitter being tracked, to determine the emitter's location.

3.3.12 *non-multilateration LMS*—a location and monitoring service (including DSRC) that uses the location of the receiving station and the characteristics of the link with an emitter being tracked to determine the emitter's location.

3.3.13 *on board equipment (OBE)*—an electronic communications device which is usually attached to or contained in a vehicle. The OBE includes associated transmit and receive (Tx/Rx) components; modulation and demodulation hardware and software; antennas; and user interface buttons, annunciators, lights, and displays. It contains or exchanges information that can be communicated with the RSE over an RF link. It is also referred to as a *transponder* or *tag*. (In this specification an OBE can be either backscatter or active).

3.3.14 *roadside equipment (RSE)*—also referred to as a *beacon*. An electronic communications device (or devices) with associated transmit and receive components, modulation and demodulation hardware and software, and transmit and receive antennas. The RSE is usually found in one of two configurations. One configuration type consists of an electronic communications device with associated transmit and receive components, modulation and demodulation hardware and software, and transmit and receive antennas all contained in one enclosure (or unit). Other configuration types separate the components into an enclosure called a *reader* that contains the associated transmit and receive components, modulation and demodulation hardware and software, another enclosure which contains the transmit and receive antennas, and finally the connecting cabling. For this specification, road side equipment (RSE) refers to both configuration types. The term RSE also includes all the individual sub-components and connecting components need to makeup the roadside DSRC system. RSE transmitters are separated into two classes (A and B) based on carrier tolerance and spectrum mask. Either class may be used in a manufacturer's RSE.

3.3.15 *slant range*—true distance between the RSE and OBE. In roadside applications, the slant range would be the straight-line distance between center of the RSE antenna and the outside of a windshield opposite to the OBE location.

3.3.16 *standard-compliant*—components (OBE or RSE) that meet the requirements described in this specification.

3.3.17 *signal element (symbol)*—distinctly recognizable signal characteristics that can be interpreted as bit indications.

3.3.18 *uplink*—communications from an OBE (usually in a vehicle) to an RSE (usually located at the roadside).

3.4 *Definitions of Bit Coding Terms:*

3.4.1 *Manchester*—as shown in Fig. 2, the "1" bit has transitions from high to low in the middle of the bit. The "0" bit has a transition from low to high in the middle of the bit. Between bits with the same value, a transition is required at the bit boundary (low to high from a 1-1 and a high to low for a 0-0). Between bits with different values (0-1 or 1-0), no transition is required.

3.4.2 *NRZI*—As shown in Fig. 3, NRZI uses no transition at the beginning of the "1" bit, a transition at the beginning of the "0" bit, and a constant level within the bit.

3.5 *Definitions of Downlink Parameters*—Downlink parameters apply to the transmission of data from the RSE to the OBE. For the purpose of this specification the following definitions apply:

3.5.1 *D1 carrier frequencies*—values of the downlink carrier frequencies.

3.5.2 *D1a tolerance of carrier frequencies*—Maximum deviation of the carrier frequency caused by any means, expressed in parts per million (ppm).

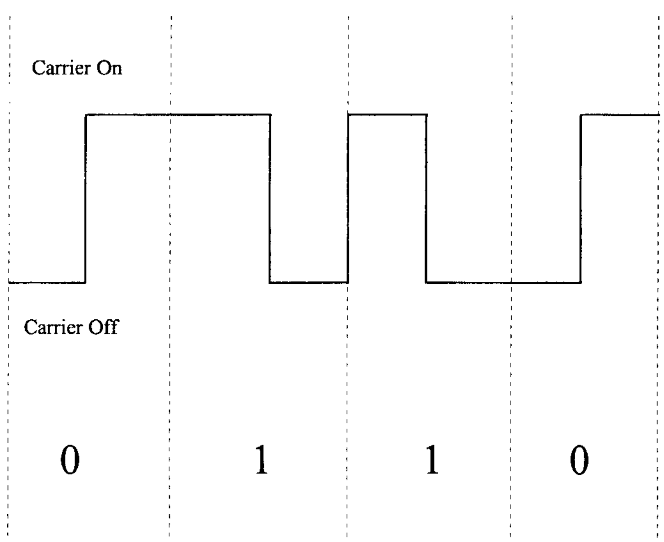


FIG. 2 Manchester AM ASK Coding

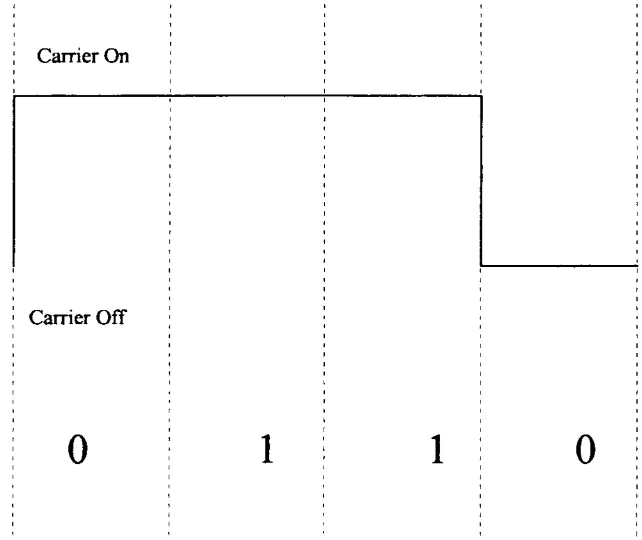


FIG. 3 NRZI AM ASK Coding

3.5.2.1 *Example*—±1 ppm of a 915 MHz carrier allows for the carrier frequency to be in the range of 915 MHz ± 915 Hz.

3.5.3 *D2 RSE transmitter spectrum mask*—maximum power emitted by a RSE transmitter as a function of the frequency.

3.5.4 *D2a RSE transmitter spectrum mask for modulated carriers*—relative power emitted with a modulated carrier by an RSE transmitter as a function of the frequency

3.5.5 *D2b RSE transmitter spectrum mask from unmodulated carriers*—relative power emitted with an unmodulated carrier by an RSE transmitter as a function of the frequency

3.5.6 *D3 OBE minimum operating frequency range*—minimum range of frequencies that must be received by the OBE receiver

3.5.7 *D4 maximum E.I.R.P.*—the maximum peak envelope power transmitted by the RSE referred to an isotropic antenna. The value is normally expressed in dBm, where 0 dBm equals 1 mW.

3.5.8 *D5 antenna polarization*—locus of the tip of the vector of the electrical field strength in a plane perpendicular to the transmission vector. Examples are horizontal and vertical linear polarization and left- and right-hand circular polarization.

3.5.9 *D6 modulation*—keying of the carrier wave by coded data. Some examples are Amplitude Shift Keying (ASK), Phase Shift Keying (PSK), Frequency Shift Keying (FSK), and linear amplitude modulation (AM).

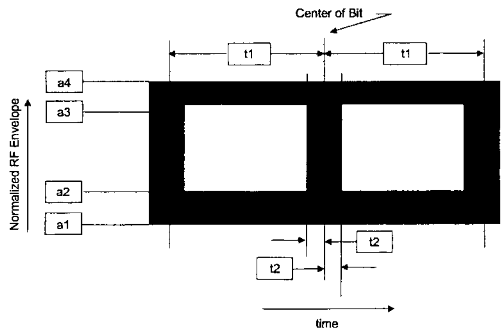
3.5.10 *D6a eye pattern for class A RSE*—description of the acceptable amplitude compared with the time envelope values of the modulated signal created by a class A RSE. See Fig. 4.

3.5.11 *D6b Eye Pattern for Class B RSE*—description of the acceptable amplitude versus time envelope values of the modulated signal created by class B RSE. Refer to D6a.

3.5.12 *D7 Data Coding*—baseband signal presentation, such as a mapping of logical bits to physical signals. Two level schemes include: NRZI, and BI-phase schemes include: Manchester.

3.5.13 *D8 Bit Rate*—number of bits per second.

3.5.14 *D8a Tolerance of Bit Clock*—maximum deviation of



Legend:

a1 - no carrier

a2 - maximum "off" carrier voltage

a3 - minimum "on" carrier voltage

a4 - maximum "on" carrier voltage

a2/a3 - maximum "off" carrier to minimum "on" carrier ratio (maximum "off" voltage / minimum "on" carrier voltage)

a4/a3 – minimum "on" carrier to maximum "on" carrier ratio (maximum "on" carrier voltage / minimum "on" carrier voltage)

t1 - half of bit time

t2 - allowed time variance

Notes: 1) Black area represents permitted normalized envelope of RSE RF data in time.

2) t parameters apply on all vertical edges of the eye pattern.

3) Mask parameters apply to both top and bottom of carrier envelope.

4) t1 tolerance is specified by clock tolerance.

FIG. 4 RSE Eye Pattern

the bit clock expressed in ppm or in percentage (%).

3.5.14.1 *Example*—±100 ppm of 500 kbps allows the bit clock to be in the range of 500 kHz ± 50 Hz. This is the same as ±0.01 %.

3.5.15 *D9 Bit Error Rate (B.E.R.)*—averaged number of erroneous bits related to all transmitted bits. The realized B.E.R. assumes an established link, depends on the application, and does not consider any specific distribution of errors. Within the maximum horizontal range, the effective B.E.R. may be different from the reference value due to time variant and stochastic impacts.

3.5.16 *D9a signal-to-interference (S/I)*—the range of in-band (902 to 904 MHz and 909.75 to 9.21.75 MHz), on-frequency, signal-to-interference ratios over which the OBE must provide a B.E.R. of 10^{-5}, or better, for the downlink communications.

3.5.17 *D9b LMS band interference*—the range of signal-to-interference ratios from non-DSRC LMS band sources, 904 to 909.75 MHz and 921.75 to 928 MHz, over which the OBE must provide a B.E.R. of 10^{-5}, or better, for the downlink communications.

3.5.18 *D9c out-of-band interference*—the range of signal-to-interference ratios from out-of-band interference sources, below 902 MHz and above 928 MHz, over which the OBE must provide a B.E.R. of 10^{-5}, or better, for the downlink communications.

3.5.19 *D10 wake-up process for OBE*—the wake up process within the OBE switches the OBE main circuitry from standby mode (sleep mode) to the active mode.

3.5.20 *D11 OBE receiver operating range*—minimum and maximum signal strengths in which the OBE will respond to the RSE. These two values also specify the minimum dynamic range of the OBE receiver.

3.5.21 *D11a OBE receiver operating range (slow wake-up operation)*—minimum and maximum signal strengths in which the OBE will respond to the RSE while periodically sampling the signal strength. The result of the periodic sampling is a delay in the detection of changing signal strengths and turn on of the full device when entering a RSE communication zone. This is called a slow wake-up operation.

3.5.22 *D11b OBE receiver operating range (Fast wake-up operation)*—minimum and maximum signal strengths in which the OBE will respond to the RSE while continuously sampling the signal strength. The result of the continuous sampling is a rapid detection of changing signal strengths and turn on of the full device when entering a RSE communication zone. This is called a fast wake-up operation.

3.5.23 *D13 preamble/postamble*—the preamble and post-amble are sequences of bits that do not convey information. The preamble is a modulated carrier designed to facilitate notification of an incoming message and synchronization of the receiver with the incoming bit stream. The postamble is designed to facilitate recognition of the end of a message.

3.5.24 *D13a preamble length*—length of the preamble measured in number of bits.

3.5.25 *D13b postamble length*—length of the postamble measured in number of bits.

3.6 *Definitions of Uplink Parameters*—Uplink parameters apply to transmission of data from OBE to RSE. For the purpose of this specification the following definitions apply:

3.6.1 *U1 carrier and subcarrier frequencies*—values of the uplink carrier and sub-carrier frequencies. The subcarrier frequencies are described as the frequency span from the center of the uplink band to the center of the corresponding downlink band.

3.6.2 *U1a tolerance of subcarrier frequencies*—maximum deviation of the subcarrier frequency caused by any means. Normally, it is expressed in percent (%) or in parts per million (ppm) of the subcarrier frequency.

3.6.2.1 *Example*—±0.1 % of a 2 MHz sub-carrier allows for the sub-carrier frequency to be in the range of 2 MHz ± 2 kHz. This is the same as ±1000 ppm.

3.6.3 *U1b use of side bands*—specification of which side-bands may be modulated.

3.6.4 *U1c tolerance of active uplink carrier*—maximum relative deviation of the uplink carrier. Refer to U1a and D1a.

3.6.5 *UC OBE transmitter spectrum mask*—maximum power as function of the frequency emitted by the OBE transmitter.

3.6.6 *U3 RSE receiver RF bandwidth*—nominal bandwidth of the RSE receiver.

3.6.7 *U4 maximum E.I.R.P.*—maximum E.I.R.P. transmitted by the OBE. The backscatter OBE E.I.R.P. shall be measured within a single sideband and at the maximum incident power within the communication zone. The value is normally expressed in dBm where 0 dBm equals 1 mW. All power values are referred to an isotropic antenna.

3.6.8 *U4a antenna beamwidth*—the angle, measured across the center of the antenna beam, at each end of which the signal is 3 dB less than the maximum level.

3.6.9 *U4b vehicle mounted antenna-beam orientation*—the position of the antenna beam relative to the vehicle direction of travel.

3.6.10 *U4c antenna position tolerance*—deviation of the OBE sensitivity as an effect of rotation about the horizontal, vertical, and boresight axes of the OBE.

3.6.11 *U5 antenna polarization*—refer to D5.

3.6.12 *U5a antenna position tolerance*—deviation of the OBE sensitivity as an effect of rotation about the horizontal, vertical, and boresight axes of the OBE.

3.6.13 *U6 modulation*—keying of the carrier or subcarrier wave by coded data.

3.6.14 *U6a carrier modulation (active only)*—keying of the carrier wave by coded data or keying of the carrier wave by the modulated subcarrier. Some examples are Amplitude Shift Keying (ASK), Phase Shift Keying (PSK), and Frequency Shift Keying (FSK).

3.6.15 *U6a sub-carrier modulation (backscatter only)*—keying of the sub-carrier wave by coded data. Some examples are Amplitude Shift Keying (ASK), Phase Shift Keying (PSK), and Frequency Shift Keying (FSK).

3.6.16 *U6c data modulation order (backscatter only)*—number (M) of different amplitude levels for ASK, the number of phase states for PSK, and the number of frequencies for FSK. Normally the carrier is modulated by signal elements. Each signal element represents a combination of k bits that allow the representation of $M=2^k$ different states. The modulation order is equal to M.

3.6.17 *U6d Eye Pattern*—Refer to D6b.

3.6.18 *U6e Sideband Suppression (Backscatter Only)*—Level of suppression of the unused sideband relative to the used side band.

3.6.19 *U6f Sideband Isolation (Backscatter Only)*—Minimum suppression of the sideband modulated with data stream 1 relative to the side band modulated with data stream 2.

3.6.20 *U7 Data Coding*—Refer to D7.

3.6.21 *U8 Bit Rate*—Number of bits per second.

3.6.22 *U8a Tolerance of Bit Clock*—Refer to D8a.

3.6.23 *U9 Bit Error Rate*—Refer to D9.

3.6.24 *U9a Signal-to-interference (S/I)*—The range of in-band (902 to 904 MHz and 909.75 to 921.75 MHz), on-frequency, signal-to-interference ratios over which the RSE must provide a B.E.R. of 10^{-5}, or better, for the uplink communications.

3.6.25 *U9b LMS Band Interference*—The range of signal-to-interference ratios from non-DSRC LMS band sources, 904 to 909.75 MHz and 921.75 to 928 MHz, over which the RSE must provide a B.E.R. of 10^{-5}, or better, for the uplink communications.

3.6.26 *U9c Out of Band Interference*—The range of signal-to-interference ratios from out-of-band interference sources, below 902 MHz and above 928 MHz, over which the RSE must provide a B.E.R. of 10^{-5}, or better, for the uplink communications.

3.6.27 *U13 Preamble/Postamble*—Refer to D13.

3.6.28 *U13a Preamble Length*—The preamble length is measured in number of bits.

3.6.29 *U13b Postamble Length*—The postamble length is measured in numbers of bits.

3.7 *Definitions for Interface Parameters to the DSRC Data Link Layer (Layer 2)*—Parameters defined in this subsection apply to the interface between Layers 1 and 2 of the DSRC link.

3.7.1 *D22 minimum transmission time for OBE wake-up*—Minimum length of time a modulated RSE signal, above the power levels defined in D11(a) and D11(b), must exist to wake-up the OBE.

3.7.2 *D22a OBE time-out*—minimum time that the OBE must stay in a wake-up state without receiving a modulated RSE signal above the power levels defined in D11(a).

4. Requirements

4.1 *Downlink Parameters*:

4.1.1 Table 1 below defines the relevant downlink physical layer or OSI Layer 1 parameters. Compliant devices may be active only, backscatter only or dual mode. Some parameters or values are specifically designated as applicable to either active or backscatter configurations. When not specifically designated as either active or backscatter the parameters or values apply to both. Initialization of any communication shall be performed by using the given default values. On-line negotiations, performed by higher DSRC communication layers, may result in utilization of values in the options column.

TABLE 1 Downlink Parameters

Item Number	Parameter	Values: Default	Values: Options
D1*	Carrier Frequencies (f)	The RSE may be operated anywhere within the 902 to 904 MHz and 909.75 to 921.75 MHz limits of the band, provided that the emissions do not exceed the out of band power limits (refer to D2). Only unmodulated downlink transmissions are allowed in the 902 to 904 MHz range of the band. Class A modulated downlink transmission center frequencies are limited to the range of 915.00 to 915.75 MHz. Class B modulated downlink transmission center frequencies are limited to the range of 912.75 to 918.75 MHz. (These limitations are subject to the regulations of the country in which the equipment is used).	. . .
D1a*	Tolerance of Carrier Frequencies	Active (fixed): ±275 ppm Backscatter (fixed): ±40 ppm Portable and handheld: ±275 ppm	. . .
D2*	RSE Transmitter Spectrum Mask	In-band power: ≤+44.77 dBm Out of band power: ≤-25 dBm transmitter power measured in 100 kHz.	. . .
D2a	RSE Transmitter Spectrum Mask for Modulated Carriers	The in-band emissions shall be attenuated from the peak in-band power by the indicated value of each frequency offset in the classes listed below: Class A: for f ±1.0 MHz: ≥12 dB in 100 kHz for f ±1.5 MHz: ≥20 dB in 100 kHz for f ±2.0 MHz: ≥25 dB in 100 kHz for f ±2.5 MHz: ≥33 dB in 100 kHz for f ±3.0 MHz: ≥40 dB in 100 kHz for f ±3.5 MHz: ≥44 dB in 100 kHz for f±4.0 MHz: ≥48 dB in 100 kHz for f ±4.5 MHz: ≥52 dB in 100 kHz for f ±5.0 MHz: ≥56 dB in 100 kHz for f ±5.5 MHz: ≥60 dB in 100 kHz for f ±6.0 MHz: ≥60 dB in 100 kHz	. . .
D2a	RSE Transmitter Spectrum Mask for Modulated Carriers	Class B: For f ±1.0 MHz: ≥12 dB in 100 kHz for f ±1.5 MHz: ≥20 dB in 100 kHz for f ±2.0 MHz: ≥35 dB in 100 kHz for f ±2.5 MHz: ≥45 dB in 100 kHz for f ±3.0 MHz: ≥55 dB in 100 kHz and have an output power of ≤-25 dBm for f ±3.5 MHz: ≥60 dB in 100 kHz and have an output power of ≤-25 dBm for f ±4.0 MHz: ≥63 dB in 100 kHz and have an output power of ≤-25 dBm (IMPORTANT: Any class may be used in a manufacturer's RSE. Not all classes have to be supported by all RSE.) (Note 1: The resolution bandwidth of the instrument used to measure the peak in-band emission power and the frequency offset in-band emission power shall be 100 kHz and the video bandwidth shall be 100 kHz.) (Note 2: Equipment complying with the different classes will require different separation distances as described in Appendix C.)	
D2b	RSE Transmitter Spectrum Mask for Unmodulated Carriers (Backscatter Only)	The emissions for the backscatter unmodulated carrier shall be attenuated from the peak in-band power by the indicated value of each frequency offset listed below: Co-channel uplink @ 2.0 MHz: ≥60 dB in 100 kHz. Adjacent channel uplinks: ≥80 dB in 100 kHz.	. . .
D3	OBE Minimum Operating Frequency Range	Active Only: All Active OBE must meet the requirements of D11, D11a, and D11b while receiving emissions from RSE operating on or between 915.00 MHz and 918.75 MHz.	. . .

TABLE 1 *Continued*

Item Number	Parameter	Values: Default	Options
		Dual Mode and Backscatter Only: All Dual Mode and Backscatter OBE must meet the requirements of D11, D11a, and D11b while receiving modulated emissions from RSE operating from 912.75 MHz to 918.75 MHz and unmodulated emissions from 902 MHz to 904 MHz and 909.75 MHz to 921.75 MHz.	
D4*	Maximum E.I.R.P.	The maximum E.I.R.P. for each class is limited to the values listed below or a value less than listed if specified by the installation country's governing body. *Class A*: for f = 915.00 MHz only: E.I.R.P ≤+40 dBm *Class B*: for f = 909.75 to 921.75 MHz and not equal to 912.75 or 918.75 MHz: E.I.R.P ≤+40 dBm for f = 912.75 and 918.75 MHz: E.I.R.P ≤+44.77 dBm*	. . .
D5	Antenna Polarization	Limited to the following: Horizontal linear Left-hand circular	. . .
D6	Modulation	Two-level amplitude modulation.	. . .
D6a	Eye Pattern	(see below)	. . .
	a2/a3 - maximum "off" carrier to minimum "on" carrier ratio	0.103	
	a4/a3 - maximum "on" carrier to minimum "on" carrier ratio	1.14	
	t1 - ½ of bit time	1 microsecond	
	t2 - allowed time variance	165 nanoseconds	
D7	Data Coding	Manchester	. . .
D8	Bit rate	500 kbps	. . .
D8a	Tolerance of Bit Clock	±100 ppm	. . .
D9	Bit Error Rate B.E.R.	10^{-6} in a nonfading channel (for reference only)	. . .
D9a	Signal-to-interference	The OBE must provide signal-to-interference ratio of 15 dB and greater for the range specified in D11a and D11b. S/I measurements will be made with a signal strength 2 dB above the OBE sensitivity level.	. . .

TABLE 1 *Continued*

Item Number	Parameter	Values: Default	Options
D9b	LMS Band Interference	The OBE must operate as specified in D11a and D11b with a Signal-to-interference ratio of 8 dB and greater with interference located within the 904 to 909.75 MHz and 921.75 to 928 MHz portions of the LMS band. S/I measurements will be made with a signal strength 2 dB above the OBE sensitivity level.	. . .
D9c	Out of Band Interference	The OBE must operate as specified in D11a and D11b with the following Signal-to-interference ratios with interference at the listed frequency offsets from f - 915 MHz: for greater than f ±13 MHz: S/I = 0 dB and greater for greater than f ±30 MHz: S/I= -5 dB and greater for greater than f ±65 MHz: S/I = -25 dB and greater S/I measurements will be made with a signal strength 2 dB above the OBE sensitivity level.	. . .
D10	Wake-up process for OBE	Slow wake-up operation: ≤50 msec within the power levels specified in D11a Fast wake-up operation: ≤2.0 msec within the power levels specified in D11b (Note: Either of these operations can be requested by the RSE and must be supported by all OBE.)	. . .
D11	OBE receiver operating range	See below	. . .
D11a	OBE receiver operating range (Slow wake-up operating)	Minimum signal strength: None - The OBE may wake-up at any signal strength less than the maximum indicated below and have a downlink B.E.R less than 10^{-5} Required signal strength: Downlink B.E.R. of 10^{-5} at 210 millivolts/meter (-30 dBm with 0 dBi ant.) horizontal signal strength or greater Maximum signal strength: Downlink B.E.R of 10^{-5} at 9377 millivolts/meter (+3 dBm with 0 dBi ant.) horizontal signal strength	. . .
D11b	OBE receiver operating range (Fast wake-up operation)	Minimum signal strength: -Downlink B.E.R. of 10^{-5} at 450 millivolts/meter minimum (-23.38 dBm with 0 dBi ant.)	. . .

TABLE 1 *Continued*

Item Number	Parameter	Values: Default	Options
		Required signal strength: -Downlink B.E.R of 10^{-5} between 450 millivolts/ meter minimum (-23.38 dBm with 0 dBi ant.) and 550 millivolts/meter maximum (-21.63 dBm with 0 dBi ant.) horizontal signal strength (The OBE must not wake-up before the lower signal strength and must wake-up on or before the larger signal strength)	
		Maximum signal level: 9377 millivolts/ meter (+3 dBm with 0 dBi ant.) horizontal signal strength	
D13	Preamble/ Postamble	All data frames shall be preceded by a preamble.	. . .
		A postamble will not be used.	
D13a	Preamble Length and content	The preamble shall be consist of the following set of 8 bits:	. . .
		01010101 B (55 H)	
		(LSB transmitted first)	
D13b	Postamble Length	Not Used	. . .

4.1.2 The parameters marked with an asterisk (*) are subject to legal type approval requirements.

4.2 *Uplink Parameters*:

4.2.1 Table 2 defines relevant uplink DSRC Layer 1 parameters. Compliant devices may be active only, backscatter only or dual mode. Some parameters or values are specifically designated as applicable to either active or backscatter configurations when they only apply to one or the other. When not specifically designated as either active or backscatter the parameters or values apply to both. Initialization of any communication shall be performed by using the given default values. On-line negotiations, performed by higher DSRC layers, may result in utilization of values in the options column.

TABLE 2 Uplink Parameters

Item Number	Parameter	Values: Default	Options
U1*	Carrier and Subcarrier Frequencies	Active,	. . .
		The OBE will generate a carrier of 915.00 MHz.	
		Or	
		Backscatter,	
		The OBE will reflect and modulate the RSE carrier with the modulated subcarriers. The OBE will generate the sub-carriers.	
		Subcarrier Frequency (fsub): 2.0 MHz	
		An active only OBE shall respond with an active carrier. A backscatter only OBE shall respond with a backscattered carrier and subcarriers. A dual-mode OBE shall respond with either mode as requested by the RSE.	
U1a*	Tolerance of Subcarrier Frequencies (Backscatter Only)	±1000 ppm	. . .
U1b	Use of Sidebands (Backscatter Only)	Same data on both sides	Both sidebands can be used independently. These options can be requested by the RSE if supported by the OBE. The possibilities are as follows: Same data in both sidebands Data only in the upper sideband Different data in each sideband.
U1c*	Tolerance of Active Uplink Carrier	±819 ppm	. . .
U2*	OBE Transmitter Spectrum Mask	(1) Out of band power: ≤-25 dBm in 1000 kHz	. . .
		(2) In-band power: Refer to section U4.	
		(3) Emissions in any other uplink channel (Backscatter Only) shall be 20 dB (in 1 MHz) less than the backscatter in-band output.	. . .
U3	RSE Receiver RF Bandwidth	Active: 3 MHz (nominal) Backscatter: 6 MHz (nominal)	. . .
U4*	Maximum E.I.R.P.	Active:	. . .
		The E.I.R.P. shall be 3 ± 3 dBm for a range of 0 to +6 dBm measured as 170 to 350 mV/m at 1 m with a 0 dBi horizontally polarize antenna.	
		Backscatter:	
		Maximum Single Sideband E.I.R.P.: The OBE antenna shall have a (45 to 100 cm^2) delta RF cross section.	

TABLE 2 *Continued*

Item Number	Parameter	Values	
		Default	Options
U4a	Antenna Beamwidth	The OBE transmit and receive antennas shall have a beam width of 140° minimum in elevation and 70° minimum in azimuth. The antenna boresight axis of the OBE transmit and receive antenna field of view is composed of the common bisector of both field of view angles.	. . .
U4b	Antenna Beam Orientation	The antenna boresight axis, in the required mounting position, shall be within ±10° in azimuth from the direction of travel and between 15 and 65° above horizontal.	. . .
U4c	Antenna Position Tolerance	Decrease from maximum sensitivity when the OBE is rotated away from precise orientations as follows: ±15° rotation around the horizontal axis: ≤2 dB ±25° rotation around the vertical axis: ≤2 db ±25° rotation around the boresight axis: ≤2 dB Rotation around any combination of axes: ≤4 dB	. . .
U5	Antenna Polarization	Horizontal Linear	
U6	Modulation	See below	. . .
U6a	Carrier Modulation	Active - Two level amplitude modulation. Backscatter - Multiplication of modulated subcarrier with carrier.	. . .
U6b	Subcarrier Modulation (Backscatter Only)	M-PSK Encoded data synchronized with subcarrier: Transitions of encoded data coincide with transitions of subcarrier.	. . .
U6c	Data Modulation Order	Active: M=2 (500 kbps) only Backscatter: M=2 (options available)	These operations are applicable to backscatter equipment and can be requested by the RSE if supported by the OBE: M = 2 (500 kbps) M = 4 (1000 kbps) M = 8 (1500 kbps)
U6d	Eye Pattern a2/a3 - maximum "off" carrier to minimum "on" carrier ratio	(see below) Active: 0.103 Backscatter: 0.25	. . .
	a4/a3 - maximum "on" carrier to minimum "on" carrier ratio	Active: 1.14 Backscatter: 1.25	
	t1 - ½ of bit time	Active: 1 microsecond Backscatter: 250 nanoseconds	
	t2 - allowed time variance	Active: 165 nanoseconds Backscatter: 45 nanoseconds	
U6e	Side Band Suppression (Backscatter Only)	≤60 dB	. . .
U6f	Side Band Isolation (Backscatter Only)	≤20 dB	. . .
U7	Data Coding	Active - Manchester Backscatter - NRZI	. . .
U8	Baud Rate (Bit rate options are defined in U6)	500 kbaud	. . .
U8a	Tolerance of Bit Clock	±450 ppm	. . .
U9	B.E.R.	10^{-6} in a nonfading channel (for reference only)	. . .
U9a	Signal-to-interference	The RSE must provide a B.E.R of 10^{-5} or better with the signal-to-interference ratios below. Active (class A only): for interference frequencies between 909.75 MHz and 921.75: S/I = 15 dB and greater Active (class B only): for interference frequencies between 912.75 and 918.75 MHz: S/I = 15 dB and greater and for interference on frequencies of 912.75 MHz or less and 918.75 MHz or greater: S/I = -6 dB and greater Backscatter: S/I = 6 dB and greater	. . .
U9b	LMS Band Interference	The RSE must provide a B.E.R of 10^{-5} or better with signal-to-interference ratios of 8 dB and greater from interference located within the 904 to 909.75 MHz and 921.75 to 928 MHz portions of the LMS band.	. . .

TABLE 2 *Continued*

Item Number	Parameter	Values: Default	Values: Options
U9c	Out of Band Interference	The RSE must provide a B.E.R of 10^{-5} or better with signal-to-interference ratios from interference at the listed frequency offsets from f = 915 MHz as listed below: for greater than f ±13 MHz: S/I = 0 dB and greater for greater than f ±30 MHz: S/I = -5 dB and greater for greater than f ±65 MHz: S/I = -25 dB and greater	. . .
U13	Preamble/ Postamble	All data frames shall be preceded by a preamble. A postamble will not be used.	. . .
U13a	Preamble Length	The preamble shall consist of the following set of 8 bits: 01010101 B (55 H) (LSB transmitted first)	. . .
U13b	Postamble Length	Not Used	. . .

4.2.2 The parameters marked with an asterisk (*) are subject to legal type approval requirements.

4.3 *Interface Parameters to DSRC Data Link Layer*—See Table 3.

5. Optional Design Characteristics

5.1 *RSE Synchronization*:

5.1.1 *General Description*—This section describes RSE synchronization physical requirements. Synchronization may be used to supplement the provisions in the mandatory part of the specification and thereby reduce interference between closely spaced RSE. RSE synchronization is optional (not a mandatory RSE feature) and may not be supported by all standard-compliant equipment. However, these synchronization physical characteristics shall be utilized when synchronization is implemented in RSE. RSE synchronization involves the step-locked RF transmission of closely located RSEs to avoid the interference created when one RSE is transmitting while one or more RSEs are receiving. There are two modes of operation RS-485 based (Mode 1) and GPS based (Mode 2).

TABLE 3 Interface Parameters Relevant for Communication With DSRC Data Link Layer

Item Number	Parameter	Values: Default	Values: Options
D22	Minimum Transmission Time for OBE Wake-Up	Fast wake-up = Shortest FCM downlink transmission time including all pre-amble and extended header bits. Slow wake-up = 1.1 msec repeated at least every 10 msec Note: 656 µsec and 1.1 msec are the current fast wake-up candidates. The default value will be selected when the length of the shortest frame with a modulated signal is identified in the Datalink layer.	. . .
D22a	OBE Time-Out	100 msec	. . .

5.1.2 *Synchronization Modes*:

5.1.2.1 *Mode 1*—In Mode 1 RSE's synchronize to other RSEs on a peer-to-peer basis. Each RSE is connected to a central electronic hub by a four wire RS-485 connection.

5.1.2.2 *Media*—All interface lines shall be 2 wire twisted pair, 100 ohms nominal impedance.

5.1.2.3 *Input Line*—Each RSE will have 1 incoming control line (Input) with the following parameters.

NOTE 1—Physical Interface: RS 485 (5 volt differential operation), 100 ohm resistive termination.

5.1.2.4 *Output Line*—Each RSE will have 1 outgoing control line (Output) with the following parameters:

Physical Interface: RS-485
States:
Negated -Logical 0 - busy
Asserted -Logical 1 - ready

5.1.2.5 *Topology—Network Configuration*—RSE control lines are connected individually controlled terminals on a central synchronizing device (electronic hub).

5.1.2.6 *Operation*—The RSE initiates the transmission when the input line transitions from the busy (logical 0) to ready (logical 1) state.

5.1.2.7 *Mode 2*—In Mode 2 each RSE interfaces to a GPS receiver co-located with the RSE.

5.1.2.8 *Start of Transmission*—Some multiple of RSE transmissions shall coincide with the GPS UTC 1 s pulse (±µs).

5.1.2.9 *Transmit Repetition*—The time period between GPS UTC pulses shall contain one or more complete RSE transmissions.

5.1.3 *Transmission Synchronization—Accuracy-Mode 1, Mode 2*. Excluding propagation delays, the RF transmissions of each RSE shall synchronize to within 5 µs of the selected transmit time.

5.1.4 *Failure*:

5.1.4.1 *Detectable Failures – Mode 1*—Input not ready when expected (waiting for Ready more than 12 µs).

5.1.4.2 *Detectable Failures — Mode 2*—Loss of GPS signal.

5.1.4.3 *Transmission After Failure Detection*—The RSE shall be configurable to transmit/not transmit RF on synchronization failure.

APPENDIXES

(Nonmandatory Information)

X1. Bibliography

TABLE X1.1 Documents Used as Reference While Preparing This Specification

Number	Author(s)	Title
1	CEN TC278 WG9	DSRC Physical Layer Using Microwave at 5.8 GHz, prENV278/9/#62, December 1995
2	ISO/TC204/WG1 5 Committee of Japan	RTTT's DSRC Standard using Microwave in Japan, 26 September 1996.

TABLE X1.2 Documents That Can Provide Further Insight Into the Evolution of This Specification

Number	Author(s)	Title
1	U.S. Department of Transportation	The U.S. Department of Transportation's Intelligent Transportation Systems (ITS) Standards Program: 1996 Status Report, 1996
2	Architecture Development Team[A]	Standards Requirements Package 1: Dedicated Short Range Communications, June 1996
3	Lee Armstrong	ASTM Project Plan for Dedicated Short Range Communications (DSRC) Standards Development, July 16 1996.
4	ASTM E17.51	Minutes, ASTM E17.51 Subcommittee (DSRC), October 31, November 1, 1996

[A] Rockwell International, Loral and others.

X2. INTEROPERABILITY

X2.1 Interoperability is the capability of components to operate within an integrated system such that data can be exchanged with corresponding communication components from different vendors to accomplish a function or an activity at any co-operating service provider installation. Some activity examples are toll payment, in-vehicle sign display, and access control. Interoperability is the result of building a multilayered and co-ordinated system. First, the system must be stocked with standard-compliant equipment. Second, the modes of interaction must be established so that compatibility exists between appropriate types of equipment. Compatibility, in this context, is the capability of a set of equipment to transfer data between components. This specification supports a system than allows active to active equipment compatibility, backscatter to backscatter equipment compatibility, and both active and backscatter compatibility with dual-mode equipment. Third, compatible application software must be installed in both the OBE and RSE for each interoperable application. And, fourth, administrators of applications that require infrastructure databases or central accounting or both (for example, toll collection) must exchange data so that customers of one area can receive service in any other area.

X2.2 The deployment legacy, RF physical characteristics, and application requirement diversity of DSRC have provided an interoperability challenge similar to that of other systems (for example, AM/FM radio, AMPS/CDMA cellular radio, AMPS/TDMA cellular radio, optical/ion smoke detectors, radar/laser speed sensor detectors, high/low beam headlights, etc.). It is a situation where two technologies or techniques each providing unique benefits are both deployed to provide similar services.

X2.3 The active technology provides relatively long range (5 to 100 m) and good downlink to uplink interference resistance through the use of RSU synchronization. The active systems can achieve large data transfers at high vehicle speeds by using the longer ranges. In addition, the active technology provides effective communications with high throughput at short ranges but must work with throughout limitations because of short range uplink on uplink interference (see next section).

X2.4 The backscatter technology provides a capability to implement fully independent and simultaneous RSE operations in adjacent lanes because of its low uplink on uplink interference. Backscatter also provides the potential for very high communication site throughout, precise communication zone location, and low OBE cost at short distances (5 to 30 m). However, the backscatter systems require more power than the active systems at longer ranges so are limited to smaller ranges (up to 77.8 m) by the band power limit.

X2.5 The selection of system based on the trade-off of advantages and limitations in particular sites or applications and the common capability to adequately service and complete in the toll collection applications market, promotes the deployment of the two types of systems.

X2.6 It is expected that as standard-compliant equipment is deployed, pockets of interoperable active or backscatter applications will develop based on deployment of equipment similar to the legacy systems and the selection of equipment for best application fit. For example, if states such as Florida, Oklahoma, Texas, and California, used different types of backscatter toll systems, it would be possible to use this specification to build an interoperable system based on a single backscatter type. Similarly, if other states such as New York, New Jersey, Maryland, and Pennsylvania deployed different types of active toll systems, it would be just as possible to use this specification to build an interoperable system in this area based on active technology. New active systems could be built so that they would be compatible with the currently deployed active systems and the standard-compliant active systems across the continent. Also, new backscatter systems could be built so that they would be compatible with the currently deployed backscatter systems and the standard-compliant backscatter systems across the continent. This type of regional interoperability works well for localized applications that service mostly commuter traffic. However, for the interstate applications that need full interoperability such as weigh station bypass clearance, road hazard warnings, in-vehicle information systems and others (all OBE communicating with all RSE) this specification enables two approaches.

X2.7 To establish full interoperability between the two types of RSE and the two types OBE described in this specification, the user and the service provider have two choices. The users that require full interoperability could choose to acquire dual-mode OBE or the service provider may choose to operate dual-mode (both active and backscatter capable) RSE.

X2.8 Because the downlink signal format is the same for both modes, either type of RSE can pass data to all OBE. These data usually describe the service being provided and the type of signal response that the RSE needs. The dual-mode OBE will enable a user who travels through multiple service areas, some of which use the active technology and others that use the backscatter technology, to respond with the appropriate signal type at each installation.

X2.9 Alternatively, service providers could install dual-mode RSE if they operate short-range applications in an area where most customers use either active or backscatter OBE but few use dual-mode OBE. The dual-mode RSE are capable of receiving and decoding both active and backscatter OBE responses. These RSE pass the required downlink data and either rapidly alternate between expecting an active or backscatter response or have the capability of receiving either response.

X3. INSTALLATION AND SEPARATION DISTANCE OF DSRC EQUIPMENT

X3.1 Separation distance is the distance between independent, non-synchronized communication sites that allows each to operate without interference. The desired maximum separation distances are 62 m (2500 ft), for sites with a maximum horizontal range of 100 m (300 ft) or less, and 183 m (600 ft), for maximum horizontal ranges of 15 m (50 ft) or less. In addition, the desired lane to lane separation distance between RSE located in adjacent lanes with maximum horizontal ranges of 3 m (10 ft) or less is 3 to 4 m. The installation geometries, RSE classes, RSE antenna gains, operating frequencies, and power levels used by the sites are primary factors that affect this minimum separation distance. This specification includes implementation options that enable both active and backscatter installations to operate within the desired separation distances without interference.

X3.2 These options include a choice of two transmitter classes, class power limitations, a range of operating frequencies, and a transmitter synchronization methodology. Class A is the least restrictive in spectral mask and uses the entire 12 MHz band in its area of influence. Class B equipment occupies 6 MHz of the band and allows a downlink to be offset in frequency from the uplink by 3 to 3.75 MHz for active systems or two channels to operate in the band for backscatter systems. This greatly reduces the interference potential between installations. The Class B equipment is used in locations that include multiple DSRC installations. All these classes can be used at the 3 m maximum horizontal range, with nominal power and antenna configurations, and can have separation distances of much less than 183 m. Near 15 m maximum horizontal range, class A RSE and backscatter class B RSE will not be able to operate within 183 m of each other. But class A RSE will be able to operate within 183 m of other class A RSE, and all class B RSE will be able to operate within 183 m of other class B RSE. For longer, 30 to 100 m, maximum horizontal ranges class A RSE and backscatter class B RSE will not be able to operate within 762 m of each other. But, Class A RSE will be able to operate within 762 m of other Class A RSE, and all Class B RSE will able to operate within 762 m of other Class B RSE.

X3.3 However, these separation distances can be only be obtained if the DSRC system installers and system integrators, whose applications include DSRC equipment, use reasonable power levels and antenna pattern restrictions in order to maximize the interference reduction characteristics of the standard. Table X3.1 describes one set of possible angular E.I.R.P limitations that a DSRC site installer could adopt to minimize interference between DSRC equipment.

TABLE X3.1 Angular E.I.R.P. Mask Recommendations

Angular E.I.R.P. mask for ranges equal to or less than 15 m	***Class A and B:***
	f = 909.75 to 921.75 MHz:
	$\Theta \leq 70°$: $\leq$+40 dBm
	$\Theta < 70°$ and $\leq 87°$: $\leq$+36 dBm
	$\Theta > 87°$ and $<93°$: $\leq$+16 dBm
	$\Theta \leq 93°$: $\leq$+25 dBm
Angular E.I.R.P. mask for ranges greater than 15 m	***Class A and B:***
	f = 909.75 to 921.75 MHz but not equal to 912.75 or 918.75 MHz:
	$\Theta \leq 85°$: $\leq$+40.00 dBm
	$\Theta \geq 85°$ and $<100°$: $\leq$+34 dBm
	$\Theta \geq 100°$: $\leq$+35 dBm
	Class B only:
	f = 912.75 and 918.75 MHz:
	$\Theta < 115°$: $\leq$+44.77 dBm or D4
	$\Theta \geq 115°$: $\leq$+35 dBm

X3.4 In this appendix, separation distances were calculated for example cases to demonstrate how this specification can be used to implement the desired separation distances. The antenna patterns in these calculations are centered on the antenna boresight. Use the antenna boresight as the antenna pointing vector and use straight down as the reference for 0°. In addition, these sample calculations were made using free-space propagation for distances of less than 1000 m and the fourth power distance law for distances greater than 1000 m. The separation distance example case configurations that are described in this section are "downlink on uplink," "downlink on downlink," "uplink on uplink," and "uplink on downlink."

X3.5 *Downlink on Uplink*:

X3.5.1 The downlink on uplink configuration consists of a RSE, in downlink mode, at one site interfering with another site where the RSE is in uplink mode. The downlink signal has the same characteristics in either active or backscatter systems. Therefore, each number under an active category identifies the separation distance required between a RSE receiving an active uplink and another RSE transmitting a downlink of the class designated. And, each number under a backscatter category identifies the separation distance required between a RSE receiving a backscatter uplink and another RSE transmitting a downlink of the class designated. The chart also shows the required separation distances in relation to the difference in frequency between the uplink and the interfering downlink.

X3.6 *Downlink on Downlink*:

X3.6.1 The downlink on downlink configuration consists of a RSE, in downlink mode, at one site interfering with an OBE receiving a downlink signal from a RSE at a second site. This configuration assumes that both downlinks are on the same frequency.

X3.7 *Uplink on Uplink*:

X3.7.1 The uplink on uplink configuration consists of an OBE, in uplink mode, interfering with a RSE receiving an uplink from another OBE. The communicating OBE is in the main lobe of the RSE antenna. The interfering OBE is in the main or side lobe of the RSE antenna forward of the RSE. This section lists the interference with both uplinks on the same frequency and uplinks on different frequencies (channels).

X3.8 *Uplink or Downlink*:

X3.8.1 The uplink on downlink configuration consists of an OBE, in uplink mode, at one site interfering with another OBE receiving a signal from a RSE that is in downlink mode. This configuration assumes that both the uplink and downlink are on the same frequency.

X3.8.2 Tables X3.2-X3.5 illustrate model prediction results. Each table shows separation distances for the two RSE classes in both active and backscatter modes.

X3.8.3 Table X3.2 shows non-synchronized nominal case separation distances calculated for a 3-m maximum horizontal range needing a 6-m slant range capability. The calculations use the following assumptions:

X3.8.3.1 The active and backscatter RSE transmit 27 dBm E.I.R.P. at an antenna pattern elevation of 30° up from vertical and 12 dBm E.I.R.P. at an elevation of 90° up from vertical. (See Fig. X3.1.)

X3.8.3.2 The minimum signal strength for OBE operation is 450 mv/m which is an incident power level of -23.4 dBm with a 0 dBi antenna.

X3.8.3.3 The active and backscatter system slant ranges are 6 m.

X3.8.3.4 The link margin is +3 dBm, which makes the required power level at 6 m -20.4 dBm.

X3.8.3.5 The active system signal-to-interference ratio is 15 dB. The backscatter system signal-to-interference ratio is 6 dB.

X3.8.3.6 The maximum allowed interference level for an uplink receiver is -49.2 dBm for active and -66.3 dBm for backscatter (assuming RSE antenna gain of approximately 10 dB).

X3.8.3.7 The maximum allowed interference level for the downlink receiver is -35.2 dBm.

TABLE X3.2 Calculated Nominal Lane Based Separation Distances for a 3-m Maximum Horizontal Range

NOTE 1—The symbol " - - - -" fills cells which do not represent actual implementations.

Interference Path	Separation Distance in Metres			
Downlink on Uplink	Class A		Class B	
	Active	Back-scatter	Active	Back-scatter
Downlink-uplink separation of <1.0 MHz	9.5	67.5	9.5	67.5
Downlink-uplink separation of ≥1.0 MHz	- - - -	47.8	- - - -	47.8
Downlink-uplink separation of ≥1.5 MHz	- - - -	19.0	- - - -	19.0
Downlink-uplink separation of ≥2.0 MHz	- - - -	- - - -	6.7	3.4
Downlink-uplink separation of ≥3.0 MHz	- - - -	- - - -	<3	<3
Downlink-uplink separation of ≥4.0 MHz	- - - -	<3	- - - -	<3
Downlink on Downlink				
same channel	6.0			
Uplink on Uplink	Active		Backscatter	
Co-channel - no sidelobe attenuation	33.7		12.0	
Co-channel - adjacent lane	3.4		<3	
Adjacent channel -adjacent lane	- - - -		<3	
Uplink on Downlink	Active		Backscatter	
Same channel	- - - -		- - - -	

TABLE X3.3 Calculated Lane Based Separation Distances for a 15-m Maximum Horizontal Range

NOTE 1—The symbol " - - - -" fills cells which do not represent actual implementations.

Interference Path	Separation Distance in Metres			
Downlink on Uplink	Class A		Class B	
	Active	Back-scatter	Active	Back-scatter
Downlink-uplink separation of <1.0 MHz	31.9	480.0	31.9	480.0
Downlink-uplink separation of ≥1.0 MHz	- - - -	339.8	- - - -	339.8
Downlink-uplink separation of ≥1.5 MHz	- - - -	135.3	- - - -	135.3
Downlink-uplink separation of ≥2.0 MHz	- - - -	- - - -	22.6	24.1
Downlink-uplink separation of ≥3.0 MHz	- - - -	- - - -	<3	<3
Downlink-uplink separation of ≥4.0 MHz	- - - -	<3	- - - -	<3
Downlink on Downlink				
Same channel	16			
Uplink on Uplink	Active		Backscatter	
Co-channel	90		31.9	
Adjacent channel	- - - -		<3	
Uplink on Downlink	Active		Backscatter	
Same channel	- - - -		- - - -	

TABLE X3.4 Calculated Lane Based Separation Distances for a 30-m Maximum Horizontal Range

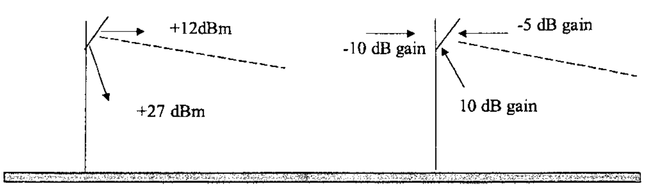
NOTE 1—The symbol " - - - -" fills cells which do not represent actual implementations.

Interference Path	Separation Distance in Metres			
Downlink on Uplink	Class A		Class B	
	Active	Back-scatter	Active	Back-scatter
Downlink-uplink separation of <1.0 MHz	491.3	3198.5	491.3	3198.5
Downlink-uplink separation of ≥1.0 MHz	- - - -	2691.2	- - - -	2691.2
Downlink-uplink separation of ≥1.5 MHz	- - - -	1698.0	- - - -	1698.0
Downlink-uplink separation of ≥2.0 MHz	- - - -	- - - -	347.8	359.5
Downlink-uplink separation of ≥3.0 MHz	- - - -	- - - -	43.8	36.0
Downlink-uplink separation of ≥4.0 MHz	- - - -	20.2	- - - -	14.3
Downlink on Downlink				
Same channel	123.4			
Uplink on Uplink	Active		Backscatter	
Co-channel	174.3		61.9	
Adjacent channel	- - - -		<3	
Uplink on Downlink	Active		Backscatter	
Same channel	- - - -		- - - -	

TABLE X3.5 Calculated Lane Based Separation Distances for a 100-m Maximum Horizontal Range

NOTE 1—The symbol " - - - -" fills cells which do not represent actual implementations.

Interference Path	Separation Distance in Metres			
Downlink on Uplink	Class A		Class B	
	Active	Back-scatter	Active	Back-scatter
Downlink-uplink separation of <1.0 MHz	- - - -	- - - -	- - - -	- - - -
Downlink-uplink separation of ≥1.0 MHz	- - - -	- - - -	- - - -	- - - -
Downlink-uplink separation of ≥1.5 MHz	- - - -	- - - -	- - - -	- - - -
Downlink-uplink separation of ≥2.0 MHz	- - - -	- - - -	- - - -	- - - -
Downlink-uplink separation of ≥3.0 MHz	- - - -	- - - -	562.3	- - - -
Downlink-uplink separation of ≥4.0 MHz	- - - -	- - - -	- - - -	- - - -
Downlink on Downlink				
Same channel	514.6			
Uplink on Uplink	Active		Backscatter	
Co-channel	562.3		- - -	
Adjacent channel	- - - -		- - - -	
Uplink on Downlink	Active		Backscatter	
Same channel	- - - -		- - - -	



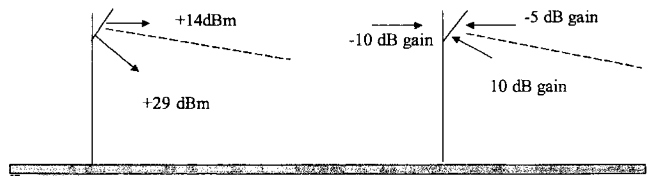
NOTE 1—3 m horizontal range / 6 m slant range.

FIG. X3.1 Power and Gain for Table C2 Separation Distance Example

X3.8.3.8 The RSE antenna gain in the direction of interference is -10 dBi. The RSE antenna sidelobe gain in the direction of an adjacent lane is 0 dBi.

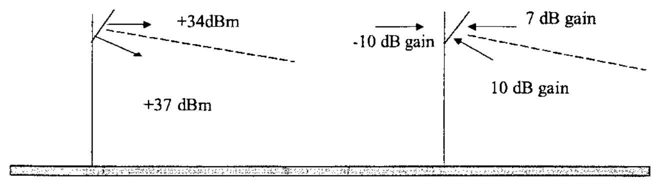
X3.8.3.9 The active OBE transmits with 3 dBm E.I.R.P. The backscatter OBE conversion gain is -2.8 for an OBE antenna RF cross section of 45 cm^2.

X3.8.3.10 The active RSE receiver bandwidth is 6.0 MHz with an RF filter that has 25 dB rejection at 3 MHz removed from the center frequency. The backscatter RSE IF bandwidth is 1.0 MHz.



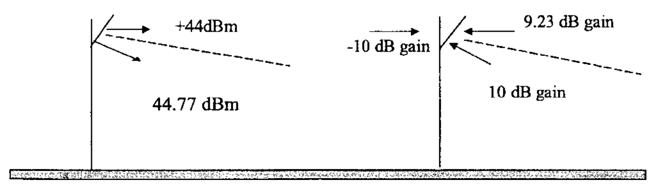
NOTE 1—15 m horizontal range / 16 m slant range.

FIG. X3.2 Power and Gain for Table X3.3 Separation Distance Example



NOTE 1—30 m horizontal range / 31 m slant range.

FIG. X3.3 Power and Gain for Table X3.4 Separation Distance Example



NOTE 1—100 m slant range.

FIG. X3.4 Power and Gain for Table X3.5 Separation Distance Example

X3.8.3.11 The attenuation of a class B signal at 918.75 MHz by the active receiver is 21 dB. The attenuation of a class B signal at 917.75 MHz by the active receiver is 3 dB.

X3.8.3.12 The measurement of a signal over 6 and 100 kHz along the center frequency is 5 dB greater in 6 MHz. The measurement of a signal over 100 kHz and 1 MHz, is 9 dB greater in 1 MHz at offsets from the center frequency greater than 1 MHz.

X3.8.3.13 Both the RSE communicating and interfering antennas are mounted 6.1 m high on level ground with the interfering antenna pointed at the back of the communicating antenna.

X3.8.3.14 The horizontal distance between the RSE and closest OBE position in the adjacent lane is 3 m, which puts the adjacent lane communication zone in the RSE receiver antenna side lobe.

X3.8.3.15 The active uplink occurs on the center frequency of the signal. The information of the backscatter uplink is carried on both side bands of the return signal ±2 MHz away from the downlink CW signal. Downlink-uplink separation from an active uplink is the difference in frequency between the interfering signal and center of the active uplink signal. Downlink-uplink separation for a backscatter uplink is the difference in frequency between the interfering signal and center of the closest side band of the uplink signal.

X3.8.3.16 Uplink on downlink interference is prevented by the using the datalink layer protocol timing and sound installation engineering.

X3.8.4 Table X3.1 shows non-synchronized separation distances calculated for a 15-m maximum horizontal range needing a 16-m slant range capability. The calculations use the same assumptions as Table X3.2 except:

X3.8.4.1 The active and backscatter RSE transmit 29 dBm E.I.R.P. at an antenna pattern elevation of 60 degrees up from vertical and 14 dBm E.I.R.P. at an elevation of 90 degrees up from vertical. (See Fig. X3.1).

X3.8.4.2 The minimum signal strength for OBE operation is 210 mv/m which is an incident power level of -30 dBm with a 0 dBi antenna.

X3.8.4.3 The active and backscatter system slant ranges are 16 m.

X3.8.4.4 The link margin is +3 dBm, which makes the required power level at 16 m -27 dBm.

X3.8.4.5 The maximum allowed interference level for uplink receiver is -57.75 dBm for active and -81.3 dBm for backscatter.

X3.8.4.6 The maximum allowed interference level for the downlink receiver is -41.8 dBm.

X3.8.4.7 For OBE uplink on uplink calculations, all lanes and OBE are in the RSE antenna main lobe.

X3.8.5 Table X3.4 shows non-synchronized nominal case separation distances calculated for a 30-m maximum horizontal range needing a 31-m slant range capability. The calculations use the same assumptions Table X3.2 except:

X3.8.5.1 The active and backscatter RSE transmit 35 dBm E.I.R.P. at an antenna pattern elevation of 65° up from vertical and 32 dBm E.I.R.P at an elevation of 90° up from vertical. (See Fig. X3.1.)

X3.8.5.2 The minimum signal strength for OBE operation is 210 mv/m which is an incident power level of -30 dBm with a 0 dBi antenna.

X3.8.5.3 The active and backscatter system slant ranges are 31 m.

X3.8.5.4 The link margin is +3 dBm, which makes the required power level at 31 m -27 dBm.

X3.8.5.5 The maximum allowed interference level for uplink receiver is -63.5 dBm for active and -86.8 dBm for backscatter (assuming RSE antenna gain of approximately 10 dB).

X3.8.5.6 The maximum allowed interference level for the downlink receiver is -41.5 dBm.

X3.8.5.7 For OBE uplink on uplink calculations, all lanes and OBE are in the RSE antenna main lobe.

X3.8.6 Table X3.5 shows non-synchronized separation distances calculated for a 100-m maximum horizontal range needing a 100-m slant range capability. The calculations use the same assumptions as Table X3.2.

X3.8.6.1 The active RSE transmit 44.77 dBm E.I.R.P. at an antenna pattern elevation of 80° up from vertical and 44 dBm E.I.R.P. at an elevation of 90° up from vertical. (See Fig. X3.1.)

X3.8.6.2 The backscatter RSE transmit 44.77 dBm E.I.R.P. at an antenna pattern elevation of 80° for a range of 77.8 m. The backscatter separation distance is not shown because the maximum power level did not enable the 100 m range.

X3.8.6.3 The minimum signal strength for OBE operation is 210 mv/m which is an incident power level of -30 dBm with a 0 dBi antenna.

X3.8.6.4 The active system slant range is 100 m.

X3.8.6.5 The link margin is +3 dBm, which makes the required power level at 100 m -27 dBm.

X3.8.6.6 The maximum allowed interference level for the active uplink receiver is -73.7 dBm.

X3.8.6.7 The maximum allowed interference level for the downlink receiver is -41.9 dBm.

X3.8.6.8 Only greater than or equal to 3 MHz frequency separations can occur because only 912.75 and 918.75 MHz downlink frequencies can be used at this power level.

X3.8.6.9 For OBE uplink on uplink calculations, all lanes and OBE are in the RSE antenna main lobe.

X4. GSM ENVIRONMENT OPERATION

X4.1 Background

X4.1.1 The body of this specification describes the requirements for operation in North America, where cellular phone frequencies and DSRC frequencies are adequately separated. In parts of the world where GSM cellular is deployed, cellular phone frequencies and DSRC frequencies can overlap and the specifications in Section 4 are not wholly operable.

X4.1.2 Outside of North America, it is possible to use different frequencies in the 900 MHz band and still meet the intent of the specification. This appendix defines a set of requirements that allows for the comparable operation of a 900 MHz DSRC system with a 900 MHz GSM cellular phone system.

X4.1.3 Section X4.2 lists the DSRC operational requirements that will allow DSRC equipment to be compatible with a 900 MHz GSM cellular phone system environment. The requirements section of this appendix shifts the frequencies of operation and adds some additional interference requirements. The parameter item numbers and modified with "GSM-" placed in front of the parameter code to distinguish them from the requirements listed in the body of this specification. Otherwise, the definition of the parameters remain the same as listed in Section 3.

X4.2 Requirements for a GSM Environment

X4.2.1 *Downlink Parameters*:

X4.2.1.1 Table X4.1 below defines the relevant downlink Physical Layer or OSI Layer 1 parameters for operation in a GSM environment. Compliant devices may be active only, backscatter only or dual mode. Some parameters or values are specifically designated as applicable to either active or backscatter configurations. When not specifically designated as either active or backscatter the parameters or values apply to both. Initialization of any communication shall be performed by using the given default values.

TABLE X4.1 Downlink Parameters

NOTE 1—The parameters marked with an asterisk (*) are subject to legal type approval requirements.

Item Number	Parameters	Values: Default	Options
GSM-D1*	Carrier Frequencies (f)	The RSE may be operated from 920.00 to 928.00 MHz, provided that the emissions do not exceed the out of band power limits (refer to D2). The Class A modulated downlink transmission center frequency shall be 925.00 MHz. Class B modulated downlink transmission center frequencies are limited to the range of 922.75 to 928.00 MHz. (These limitations of the country in which the equipment is used).	. . .
GSM-D1a*	Tolerance of Carrier Frequencies	Same as D1a.	. . .
GSM-D2*	RSE Transmitter Spectrum Mask	In-band power: ≤+44.77 dBm Out of band power: ≤-35 dBm transmitter power measured in 100 kHz.	. . .
GSM-D2a	RSE Transmitter Spectrum Mask for Modulated Carriers	The in-band emissions shall be attenuated from the peak in-band power by the indicated value at each frequency offset in the classes listed below: Class A: Same as D2a.	. . .
	RSE Transmitter Spectrum Mask for Modulated Carriers	Class B: Same as D2a.	. . .
GSM-D2b	RSE Transmitter Spectrum Mask for Unmodulated Carriers (Backscatter Only)	Same as D2b.	. . .
GSM-D3	OBE Minimum Operating Frequency Range	Active Only: All Active OBE must meet the requirements of GSM-D11, GSM-D11a, and GSM-D11b while receiving emissions from RSE operating on or between 925.00 MHz and 928.00 MHz. Dual Mode and Backscatter Only: All Dual Mode and Backscatter OBE must meet the requirements GSM-D11, GSM-D11a, and GSM-D11b while receiving emissions from RSE operating from 922.00 MHz to 928.00 MHz.	. . .
GSM-D4*	Maximum E.I.R.P.	The maximum E.I.R.P for each class is limited to the values listed below or a value less than listed if specified by the installation country's governing body. Class A: for f = 925.00 MHz only: E.I.R.P ≤+40 dBm Class B: for f = 922.00 to 928.00 MHz and not equal to 922.00 or 928.00 MHz: E.I.R.P ≤+40 dBm for f = 922.75 and 928.75 MHz: E.I.R.P ≤+44.77 dBm*	. . .
GSM-D5	Antenna Polarization	Same as D5.	. . .
GSM-D6	Modulation	Same as D6.	. . .
GSM-D6a	Eye Pattern	Same as D6a.	. . .
GSM-D7	Data Coding	Same as D7.	. . .
GSM-D8	Bit rate	Same as D8.	. . .
GSM-D8a	Tolerance of Bit Clock	Same as D8a.	. . .
GSM-D9	Bit Error Rate B.E.R.	Same as D9.	. . .
GSM-D9a	Signal-to-interference	Same as D9a.	. . .
GSM-D9b	DSRC Band Interference	The OBE must operate as specified in GSM-D11a and GSM-D11b with a Signal-to-interference ratio of 8 dB and greater with interference located within the 915 to 920 MHz and 930 to 935 portions of the spectrum. S/I measurements will be made with a signal strength 2 dB above the OBE sensitivity level.	. . .
GSM-D9c	Out of Band Interference	In addition to the out of band interference requirements of D9c the OBE must provide a B.E.R. of 10^{-5} or better with GSM interference levels as listed below: GSM frequency less than 915 MHz: -10 dBm and less GSM frequency greater than 935 MHz: -20 dBm and less	. . .
GSM-D10	Wake-up process for OBE	Same as D10	. . .
GSM-D11	OBE receiver operating range	Same as D11	. . .

TABLE X4.1 *Continued*

Item Number	Parameters	Values: Default	Options
GSM-D11a	OBE receiver operating range (Slow wake-up operation)	Same as D11a.	. . .
GSM-D11b	OBE receiver operating range (Fast wake-up operation)	Same as D11b.	. . .
GSM-D13	Preamble/Postamble	Same as D13.	. . .
GSM-D13a	Preamble Length and content	Same as D13a.	. . .
GSM-D13b	Postamble Length	Not Used	. . .

X4.2.2 *Uplink Parameters*:

X4.2.2.1 Table X4.2 defines relevant uplink DSRC Layer 1 parameters for operation in a GSM environment. Compliant devices may be active only, backscatter only, or dual mode. Some parameters or values are specifically designated as applicable to either active or backscatter configurations. When not specifically designated as either active or backscatter, the parameters or values apply to both. Initialization of any communication shall be performed by using the given default values. On-line negotiations, performed by higher DSRC layers, may result in utilization of values in the options column.

TABLE X4.2 Uplink Parameters

Item Number	Parameter	Values: Default	Options
GSM-U1*	Carrier and Subcarrier Frequencies	Active, The OBE will generate a carrier of 925.00 MHz. Or Backscatter, The OBE will reflect and modulate the RSE carrier with the modulated subcarriers. The OBE will generate the sub-carriers. Subcarrier Frequency (fsub): 2.0 MHz An active only OBE shall respond with an active carrier. A backscatter only OBE shall respond with a backscattered carrier and subcarriers. A dual-mode OBE shall respond with either mode as requested by the RSE.	. . .
GSM-U1a*	Tolerance of Subcarrier Frequencies (Backscatter Only)	Same as U1a.	. . .
GSM-U1b	Use of Sidebands (Backscatter Only)	Same as U1b.	. . .
GSM-U1c*	Tolerance of Active Uplink Carrier	Same as U1c.	. . .
GSM-U2*	OBE Transmitter Spectrum Mask	Same as U2.	. . .
GSM-U3	RSE Receiver RF Bandwidth	Same as U3.	. . .
GSM-U4*	Maximum E.I.R.P.	Same as U4.	. . .
GSM-U4a	Antenna Beamwidth	Same as U4b.	. . .
GSM-U4b	Antenna Beam Orientation	Same as U4b.	. . .
GSM-U4c	Antenna Position Tolerance	Same as U4c.	. . .
GSM-U5	Antenna Polarization	Same as U5.	. . .
GSM-U6	Modulation	Same as U6	. . .
GSM-U6a	Carrier Modulation	Same as U6a	. . .
GSM-U6b	Subcarrier Modulation (Backscatter Only)	Same as U6b	. . .
GSM-U6c	Data Modulation Order	Same as U6c.	. . .
GSM-U6d	Eye Pattern	Same as U6d.	. . .
GSM-U6e	Side Band Suppression (Backscatter Only)	Same as U6e.	. . .
GSM-U6f	Side Band Isolation (Backscatter Only)	Same as U6f.	. . .
GSM-U7	Data Coding	Same as U7.	. . .
GSM-U8	Baud Rate (Bit rate options are defined in U6).	Same as U8.	. . .
GSM-U8a	Tolerance of Bit Clock	Same as U8a	. . .
GSM-U9	B.E.R.	10^{-5} in a nonfading channel (for reference only)	. . .
GSM-U9a	Signal-to-interference	Active (class A only): for interference frequencies between 920.00 MHz and 930.00: S/I = 15 dB and greater Active (class B only): for interference frequencies between 922.00 and 928.00 MHz: S/I = 15 dB and greater and	. . .

TABLE X4.2 *Continued*

Item Number	Parameter	Values Default	Options
		for interference on frequencies of 920.75 MHz or less and 930.00. MHz or greater: S/I = -6 dB and greater Backscatter: S/I = 6 dB and greater	
GSM-U9b	LMS Band Interference	The RSE must provide a B.E.R. of 10^{-5} or better with signal-to-interference ratios of 8 dB and greater from interference located within the 915 to 920 and 930 to 935 MHz portions of the spectrum.	. . .
GSM-U9c	Out of Band Interference	In addition to the out of band interference requirements of D9c the OBE must provide a B.E.R. of 10^{-5} or better with GSM interference levels as listed below: GSM frequency less than 915 MHz: -10 dBm and less GSM frequency greater than 935 MHz: -20 dBm and less	. . .
GSM-U13	Preamble/Postamble	Same as U13.	. . .
GSM-U13a	Preamble Length	Same as U13a.	. .
GSM-U13b	Postamble Length	Not Used	. . .

X4.2.2.2 The parameters marked with an asterisk (*) are subject to legal type approval requirements.

X4.2.2.3 *Interface Parameters to DSRC Data Link Layer*—See Table X4.3.

TABLE X4.3 Interface Parameters, relevant for communication with DSRC Data Link Layer

Item Number	Parameter	Values Default	Options
GSM-D22	Minimum Transmission Time for OBE Wake-Up	Same as D22	. . .
GSM-D22a	OBE Time-Out	Same as D22a	. . .

X5. LEGACY SYSTEMS NON–INTERFERENCE AND CO-SITE OPERATION

X5.1 Background

X5.1.1 Legacy systems are those DSRC operating designs that existed before the adoption of this specification. These include the California Code of Regulations Title 21, Interagency Group (IAG), ISO 10374 (ATA), and Raytheon (Hughes) wide area TDMA compliant designs. This specification was designed to minimize the interference between legacy systems and the standard–compliant systems, as well as minimize the changes necessary to make the transition from legacy systems to the standard–compliant systems.

X5.1.2 Since the transition may take several years, many installations may have a combination of standard–compliant systems along with legacy systems. It is also possible, that over time, installations will need to use different designs of legacy systems at a site to service customer bases with more than one type of tag. With some transmission timing and separation considerations, the standard–compliant systems can operate with the legacy systems and different designs of the legacy systems may operate together. This appendix defines a set of parameters that optimize the utility of operating different types of legacy systems and standard–compliant systems at the same DSRC site. Setting the legacy systems to these parameters at a multiple system installation should increase the number of lanes or rate of vehicles serviced or both over not using these parameters.

X5.1.3 In addition, since the OBE only respond when properly interrogated, it is also possible to use any combination of the Title 21, IAG, ISO 10374, Hughes, and ASTM standard-compliant types of backscatter and active OBE in a vehicle at the same time. Only the type being communicated with should respond with data. This technique may be useful to vehicle operators that travel through DSRC service areas that do not use the same type of equipment and have not installed multiple types of RSE at the sites.

NOTE X5.1—It may be possible for vehicles needing nationwide compatibility with Legacy RSE to use two OBE (one Title 21/ATA multimode and one ASTM v6 / IAG multimode). As new RSE compliant with this specification is brought online, it would be necessary to add a third "compliant" OBE or replace one or both of the original OBE with units that implement both legacy and compliant modes.

X5.1.4 Section X5.2 of this appendix lists selected DSRC operational requirements from Section 4 of that will optimize the legacy DSRC equipment operation, together or with standard-compliant equipment at the same site. The parameter item numbers are modified with "L-" placed in front of the parameter code to distinguish them from the requirements listed in the body of the specification. Otherwise, the definitions of the parameters remain the same as listed in Section 3.

X5.2 Guidelines for Co-Site Operation of Legacy and Standard-Compliant Systems

X5.2.1 *Downlink Parameters*:

X5.2.1.1 Table X5.1 below defines the relevant downlink Physical Layer or OSI Layer 1 parameters for operation of different types of legacy systems or legacy and standard–compliant systems at the same site (in other words, "co-site operation”). The devices that this section applies to may be active only, backscatter only, or dual mode. Some parameters or values are specifically designated as applicable to either active or backscatter configurations. When not specifically designated as either active or backscatter the parameters or values apply to both. Initialization of any communication shall be performed by using the given default values. Only those parameters that may be variable in the legacy systems and affect co-site operation are listed below. All parameters refer to both standard–compliant and legacy systems unless otherwise indicated. Options refer to choices of default configurations.

TABLE X5.1 Downlink Parameters for Co-Site Operation

Item Number	Parameter	Values	
		Default	Configuration
L-D1*	Carrier Frequencies (f)	Legacy and standard-compliant RSE may be operated within the 902 to 904 MHz and 909.75 to 921.75 MHz limits of the band, provided that the emissions do not exceed the out of band power limits (refer to D2). Only unmodulated downlink transmissions are recommended in the 902 to 904 MHz range of the band. Class A modulated downlink transmission center frequencies should be limited to 915 MHz with synchronized emissions. Active Class B modulated downlink transmission center frequencies should be limited to 918.75 MHz. Backscatter Class B modulated downlink transmission center frequencies should be limited to 912.75 MHz and 918.75 MHz. (These limitations are subject to the regulations of the country in which the equipment is used).	Any combination of legacy and standard-compliant techniques can operate on the same frequency and site by designating specific slots of airtime to each technique.
L-D1a*	Tolerance of Carrier Frequencies	Active (fixed): ±275 ppm	. . .
		Backscatter (fixed): ±40 ppm	
		Portable and handheld: ±275 ppm	
L-D2*	RSE Transmitter Spectrum Mask	In-band power: ≤44.77 dBm	. . .
		Out of band power: ≤-25 dBm transmitter power measured in 100 kHz.	
L-D2a	RSE Transmitter Spectrum Mask for Modulated Carriers	The in-band emissions should be attenuated from the peak in-band power by the indicated value at each frequency offset in the classes listed below:	
		Class A:	
		for f ±1° MHz: ≥12 dB in 100 kHz	
		for f ±1.5 MHz: ≥20 dB in 100 kHz	
		for f ±2.0 MHz: ≥25 dB in 100 kHz	
		for f ±2.4 MHz: ≥33 dB in 100 kHz	
		for f ±3.0 MHz: ≥40 dB in 100 kHz	
		for f ±3.5 MHz: ≥44 dB in 100 kHz	
		for f ±4.0 MHz: ≥48 dB in 100 kHz	
		for f ±4.5 MHz: ≥52 dB in 100 kHz	
		for f ±5.0 MHz: ≥56 dB in 100 kHz	
		for f ±5.5 MHz: ≥60 dB in 100 kHz	
		for f ±6.0 MHz: ≥60 dB in 100 kHz	
L-D2a	RSE Transmitter Spectrum Mask for Modulated Carriers	Class B:	. . .
		for f ±1.0 MHz: ≥12 dB in 100 kHz	
		for f ±1.5 MHz: ≥20 dB in 100 kHz	
		for f ±2.0 MHz: ≥35 dB in 100 kHz	
		for f ±2.5 MHz: ≥45 dB in 100 kHz	
		for f ±3.0 MHz: ≥55 dB in 100 kHz and have an output power of ≤-25 dBm	
		for f ±3.5 MHz: ≥60 dB in 100 kHz and have an output power of ≤-25 dBm	
		for f ±4.0 MHz: ≥63 dB in 100 kHz and have an output power of ≤-25 dBm	

TABLE X5.1 *Continued*

Item Number	Parameter	Values	
		Default	Configuration
		(Note 1: The resolution bandwidth of the instrument used to measure the peak in-band emission power and the frequency offset in-band emission power shall be 100 kHz and the video bandwidth shall be 100 kHz.)	
L-D2b	RSE Transmitter Spectrum Mask for Unmodulated Carriers (Backscatter Only)	The emissions for the backscatter unmodulated carrier should be attenuated from the peak in-band power by the indicated value at each frequency offset listed below: Co-channel uplink @ 2.0 MHz: ≥60 dB in 100 kHz. Adjacent channel uplinks: ≥80 dB in 100 kHz.	. . .
L-D3	OBE Minimum Operating Frequency Range	Active Only: Active OBE should be able to receive emissions from RSE operating on or between 915.00 and 918.75 MHz. Backscatter Only: Backscatter OBE should be able to receive modulated emissions from RSE operating on 912.75 and 918.75 MHz and unmodulated emissions from 902 to 904 MHz and 912.75 and 918.75 MHz.	
L-D4*	Maximum E.I.R.P.	The maximum E.I.R.P for each class should be limited to the values listed below or a value less than listed if specified by the installation country's governing body. Class A: for f = 915.00 MHz: E.I.R.P ≤+40 dBm* Class B:	

TABLE X5.1 *Continued*

Item Number	Parameter	Values	
		Default	Configuration
		Active Only: for f = 918.75 MHz: E.I.R.P ≤+40 dBm* Backscatter Only: for f = 912.75 and 918.75 MHz E.I.R.P ≤+40 dBm*	
L-D5	Antenna Polarization	Limited to the following: Horizontal linear Left-hand circular	

X5.2.1.2 The parameters marked with an asterisk (*) are subject to legal type approval requirements.

X5.2.2 *Uplink Parameters*

X5.2.2.1 Since the characteristics of legacy OBE are not adjustable, Table X5.2 defines one relevant uplink DSRC Layer 1 parameter to identify OBE that will optimize the operation of legacy and standard-compliant systems at the same site. The devices that this section applies to may be active only to backscatter only. The parameters and values are specifically designated as applicable to either active or backscatter configurations. Initialization of any communication shall be performed by using the given default values.

X5.2.2.2 The parameters marked with an asterisk (*) are subject to legal type approval requirements.

TABLE X5.2 Uplink Parameters for Co-Site Operation

Item Number	Parameter	Values	
		Default	Options
L-U1*	Carrier and Subcarrier Frequencies	Active, The OBE should generate a carrier of 915.00 MHz. Or Backscatter, The OBE will reflect and modulate the RSE carrier with the modulated subcarriers. An active only OBE shall respond with an active carrier. A backscatter only OBE shall respond with a backscattered carrier and subcarriers.	