FP-101TA - ASTM V6 Transponder

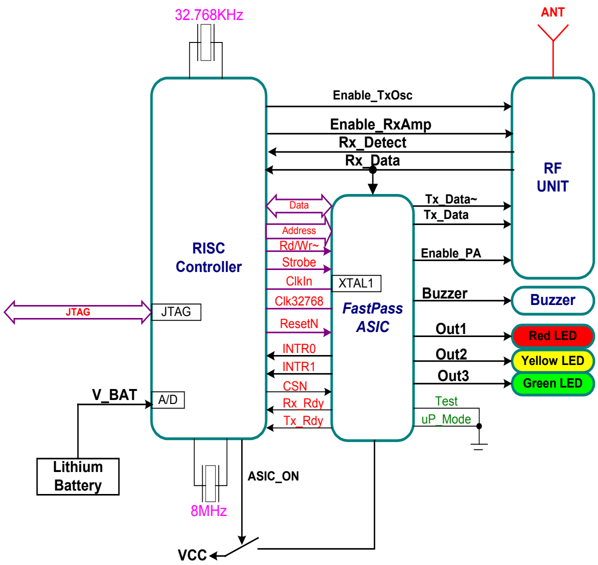
Telematics Wireless' FP-101 software programmable transponder, serves as the in vehicle component of the Cross Israel Highway (CIH) toll collection system.
It is a small size unit that communicates with roadside readers at a data rate of 500 Kb/sec, using ASTM v6 Slotted-Aloha Time Division Multiple Access (TDMA) protocol. It uses ASK modulation and operates in the 902-928 MHz ISM band.
The FP-101 is a read & write transponder providing three levels of programmable memory:

- Factory Programmed
- Agency Programmed
- 256 bits Scratchpad Read/Write

An optional 32 Kbytes on board RAM may be included for additional applications.
The FP-101 transponder has an audible (buzzer) and visual (3 color LEDs) driver interface, enabling various transaction indications.
The FP-101 is powered from an internal, long life, Lithium battery enabling more than 6 years of operation. The unit provides the roadside reader with battery status.

Architecture:

The FP-101 transponder's architecture is based on a RISC and a proprietary ***FastPass***^{TM} ASIC.



This architecture enables the flexibility and programmability of the transponder for future applications and customer specific requirements.

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Transponder Characteristics:

- Slotted Aloha protocol –compatible with ASTM v6.
- Physical Layer compatible with ASTM PS111-98
- Transmit & Receive frequencies within the ISM band 902–928 MHz.
- Transmit and receive data rate of 500 Kb/sec
- Built-in antenna.
- Active Transmitter provides superior immunity to interference.
- Very low spurious and harmonics radiation.
- Driver interface by means of 3 colored LEDs (Green, Yellow, Red) and a buzzer with programmable alarms.
- Long life Lithium battery together with a state of the art power supervision circuitry enable more than 6 years of operation.
- Software programmable
- Programmable Link Validation Sequence Generator.
- Programmable Agency Codes
- Small Size: 88x62x12 (LxWxD) mm.
- Light weight: 55 grams
- Easy mounting/demounting on the vehicle front windshield.
- Performance resistant to vibration, shock, temperatures and humidity prevailing in a vehicular environment.

Applications:

- Toll collection - Lane based and free flow.
- Fee Payments - Drive Through, carwash.
- Parking and curbside parking payments.
- Gas stations and convenience payments.
- Access control to restricted areas, urban centers.
- Border crossing

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REV.	Δ	DESCRIPTION	E.C.N.	DATE	DRAWN	CHECKED
A			010	13/10/02		
B		Revised for FP101A-915		10/2/05	GFK	
C		Revised according to remarks from HL		20/3/05	GFK	

FP101A-915 Transponder Specifications

Electronic Toll and Traffic Management System

FastPass

NAME:				SHEET/OF
FP101A Transponder Specifications	DESIGNED	Z.I	13/10/02	3 / 3
	CHECKED	Z.I	13/10/02	
	APPROVED	A.S	13/10/02	
	Q.A.	G.K	15/10/02	

PROD/PROJ:													
CIH TRANSPONDER	2	1	4	0	0	9	0	0	1	0	0	1	A

1. SCOPE

1.1 This specification defines the protocol and radio air interface requirements for a dedicated short-range communications (DSRC), half-duplex, active, two-way vehicle-to-roadside communications (VRC) equipment.
1.2 This specification meets the requirements of the Electronic Toll and Traffic Management System used by the Cross Israel Highway (CIH).
1.3 This standard defines a means to guarantee accurate and valid message delivery, between moving vehicles randomly entering a communications zone and a fixed roadway infrastructure, for both wide-area (multi-lane, open road) and lane-based applications.
The wide-area protocol permits transactions with several vehicles traveling on a multiple lane roadway without restricting the vehicle to any fixed lane, trajectory or speed. The applications may be characterized by the capability to perform general two-way digital communications with multiple vehicles simultaneously in an open-road operating environment, with minimal implementation restrictions.
The lane-based protocol permits a transaction with a single vehicle traveling on a restricted trajectory. The applications may be characterized by the capability to exchange a short duration, fixed length message with a single vehicle when it passes through a specific location on the roadway. The lane-based protocol is defined to be a subset of the wide-area protocol.

1.4 The VRC equipment is composed of two principal components: a Reader and a Transponder.
1.4.1 The Transponder is intended for, but not restricted to, installation in or on a motor vehicle.
1.4.2 The Reader controls the protocol, schedules the activation of the Transponder, reads from or writes to the Transponder, and assures message delivery and validity. It is intended for, but not restricted to, installation at a fixed location on the roadway.

1.5 The Reader and antenna equipment must be capable of receiving and decoding data messages from closely spaced transponders in the same lane and/or adjacent lanes. This standard defines a system, which shall communicate and perform reliable message transactions between the Reader and any transponder at speeds up to 200 Km/h, and at spacing between transponders as low as 0.5 meter. Degradation of performance below the specified levels shall not take place within the above speed and spacing requirements.

1.6 This standard defines an open architecture using the simplified OSI 7-layer reference model (per ISO 7498).
1.6.1 The physical layer (Layer 1) is defined as a half-duplex radio frequency medium, not restricted to any operating frequency.
1.6.2 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 roadside Reader equipment. Access to the link is based upon an adaptive Slotted ALOHA scheme to recover from collisions during activation. The protocol permits basic authentication of each transponder and provides a mechanism to assure reliable completion of each transaction in the communications zone.
1.6.3 The network layer (Layer 3), transport layer (Layer 4), session layer (Layer 5), and presentation layer (Layer 6) are eliminated due to the short-range, short-duration nature of the VRC system.

1.7 A summary of operational characteristics is given in Table 1. below

Parameter		Characteristic
Carrier Frequency	Up link	915MHz±400 ppm
	Down link	902 to 928MHz±275 ppm
Carrier Modulation		Unipolar ASK (Manchester Encoded)
Data Bit Rate		500 kbps
Message Data		512 data bits per TDMA packet, single or multi-packet transactions
Technology Type		Two-way Active RF
Protocol		TDMA/Adaptive Slotted Aloha Access

Table 1 - Summary of Characteristics

2. APPLICABLE DOCUMENTS

2.1 **ISO 7498 - OSI** seven layer-reference-model

2.2 **ASTM PS111-98** "Standard Specification for Dedicated Short Range Communication (DSRC) Physical Layer Using Microwave in the 902 t0 928 MHz Band" as applicable to GSM compatible On Board Equipment (OBE) using active technology in a GSM environment (Appendix X4). However, in case of conflict, this specification shall take precedence over the ASTM standard's requirements.

3. TERMINOLOGY

3.1. Definition of Technical Terms:

3.1.1 ***ASK*** - Amplitude Shift Keying
3.1.2 ***AVI*** - Automatic Vehicle Identification
3.1.3 ***CRC*** - Cyclic Redundancy Check
3.1.4 ***Downlink*** - Communications from a Roadside Reader to a Vehicle
3.1.5 ***ERP*** - Effective Radiated Power = peak antenna gain x transmit power
3.1.6 ***EM*** - Electromagnetic
3.1.7 ***FCM*** - Frame Control Message
3.1.8 ***ID*** - Device Identification
3.1.9 ***kbps*** - kilobits per second
3.1.10 ***kHz*** - kilohertz (10^3 hertz)
3.1.11 ***Km/H*** - kilometers per hour
3.1.12 ***MHz*** - megahertz
3.1.13 ***RAM*** - Random Access Memory
3.1.14 ***RF*** - Radio Frequency
3.1.15 ***Uplink*** - Communications from a Vehicle to a Roadside Reader
3.1.16 ***VRC*** - Vehicle-to-Roadside Communications

3.2. Definition of Physical Layer Terms

No Terms

3.3. Definition of Data Link Layer Terms

Reader - A fixed position controller, associated transmits and receives (Tx/Rx) antenna(s), and modulation and demodulation hardware and software.
Byte Order - Numeric fields shall be transmitted most significant bit first. If a numeric field is represented by multiple bytes, the most significant bit of the most significant byte shall be transmitted first. This document represents the most significant, and first transmitted, to the left on a line and to the top of a multi-line tabulation.
CRC - This field is defined as a Cyclic Redundancy Check. Error detection must be performed each time a data message is sent so that the receiving party can ascertain the validity of the data stream. The specified form of the cyclic redundancy check is the CRC-16, with generator polynomial of $x^{16} + x^{15} + x^2 + 1$. This results in a16-bit value transmitted with each data message. The data packet protected by the CRC excludes any preceding header in every case.
Data Packet - The message information, excluding the Header, communicated between the transponder and Reader. Multiple packets may be transferred in each frame, and in multiple frames.
Frame - A cyclic structure consisting of the Message Control Phase, the Transaction Phase with one or four message slots, and the Activation Phase using Slotted ALOHA link access techniques.
Header Code - The Header defines the start of each message and consists of an 8-bit self-synchronization pattern (Selsyn) and an 8-bit start-of-message flag for a total of 16 bits. The Selsyn pattern has binary value of 01010101. The start-of-message flag has binary value of 10001101.
Link Validation - A 7-bit linear sequence generator shall be used to perform link validation. The generator shall be a 7-stage shift register with polynomial $x^7 + x + 1$. Only messages transmitted in the message slots (within the Transaction Phase) shall be validated. All data fields except the Header and CRC shall be included in the validation process. The Reader shall pick a random 64-bit Validation Seed each frame and transmit it in the Frame Control Message. This seed shall be used, along with the message data, by the message source (transponder or Reader) to generate a Validation Check byte. This value shall be calculated for each Slot Data Message transmitted in the frame. The Validation Seed shall be used to initialize the sequence generator by clocking it through the generator. The sequence generator shall be re-initialized by the Validation Seed for each Slot Data Message transmitted in the frame. During reception, data is then clocked through the sequence generator. Following the data, eight additional zeroes are clocked. The output of the sequence generator for these eight bits is the Link Validation Check byte. This is compared to the check byte in the received message to determine validity.
Link Validation Check Byte - An 8-bit field generated by the validation algorithm, and appended to the transmission to validate a received Slot Data Message.
Link Validation Seed - A 64-bit random or pseudo-random number, which initializes the validation algorithm for all message transactions in a given frame. This feature provides uplink playback protection for the Reader.
Slot Command - A field which defines the type of transmission or reception that the transponder will perform during the transaction phase.
Transponder - An electronic device attached to a vehicle and containing information that can be communicated with the Reader.
Transponder ID Number - The code or serial number that uniquely identifies a transponder, as described in section 5.9.8.

4. TRANSPONDER PHYSICAL LAYER CHARACTERISTICS

4.1. Physical Requirements

4.1.1. Size

The thickness of the transponder shall not exceed 25mm, the length shall not exceed 90mm. and the width shall not exceed 65mm.

4.1.2. Marking

Each Transponder shall carry a label containing both human and machine readable versions of the public serial number that is encoded into permanent memory within the transponder. The label will also contain the identification of the manufacturer and date of production.

4.1.3. Mounting

Interior mounted transponders should be designed for installation by the end user in the enclosed passenger compartment of a motor vehicle. Ease of attachment is therefore important. The Transponder should be held stationary in it's mounting location by means sufficient to provide reliable attachment, yet easy removal and reinstallation without damage. The attachment method shall be designed to avoid injury to vehicle occupants in the event of a motor vehicle accident. The mounting method employed should make reinstallation of a transponder in an incorrect orientation unlikely. Strip, tab or cup locations should be marked on the transponder or otherwise standardized so that replacement transponders will be correctly attached to any existing mounting.
The transponders shall be designed such that the primary location for the interior transponders would be in the center of the windshield, behind or below the driver's rear view mirror.
Interior mounted transponders shall not be sensitive to minor positioning errors. Transponder positioning shall have a minimum tolerance of ±2 inches and ±20° in any axis from the position specified in the installation instructions for the particular vehicle or type of vehicle.

4.1.4. Physical Security

To discourage theft, interior mounted transponders shall be removable.
Transponder attachments should be inconspicuous.
Transponder case should be difficult to open without an appropriate tool. Any attempt to do so by an unauthorized person, shall cause permanent damage to the case.

4.2. Electrical Requirements

4.2.1. Power

Transponder shall be powered by a long-life, sealed battery contained within the case. (User replacement of the battery is not required).
Any special handling shipping, or disposal requirements for batteries shall be noted in the documentation or packaging of the transponder.

4.2.2. Driver Signaling

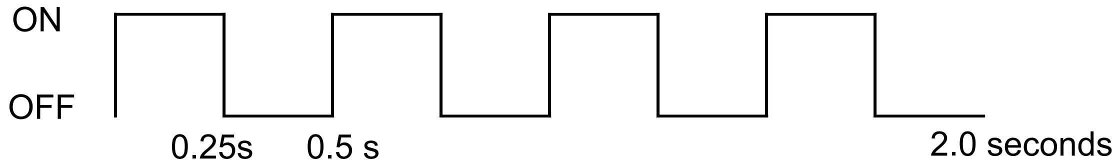
Interior mounted transponders shall provide both audible and visual signaling of transaction status to the motor vehicle operator.
Upon receipt of a Slot Data Message with a driver interface command field set to activate visual or audio signals or bothvisual and audio signals, the transponder shall activate the specified colored visual signal and continuous or intermittent audio signal.

4.2.2.1. Visual Signals

Once activated, indicators shall remain active for 5±0.25 seconds.
The visual indicators shall have luminance of at lest 300 nits (candella/m^2).
Visual indicators shall be arranged Red, Yllow, Green from top to bottom when viewed by the driver.

4.2.2.2. Audible Signals

Audio signals shall have an audio frequency of 4±1 KHz and a minimum sound preasure levvel of 75 dBA at 10 cm.
The continuous adio signal shall be 2±0.1 seconds in duration.
The intermittent audio signal shal be 2±0.1 seconds in duration, and consist of four cycles of 0.5 seconds, 50% on/off duty cycle pattern as shown below.



Intermittent Audio Signal Timing

4.2.3. Transmitter Requirements

Transmitter is SAW oscillator on frequency 915 MHz and amplifier.

4.2.3.1. RF Carrier Frequency

a. The transponder shall transmit at a frequency of 915 MHz.
b. The frequency tolerance shall be 400 PPM.

4.2.3.2. Transmit Field Strength (in band)

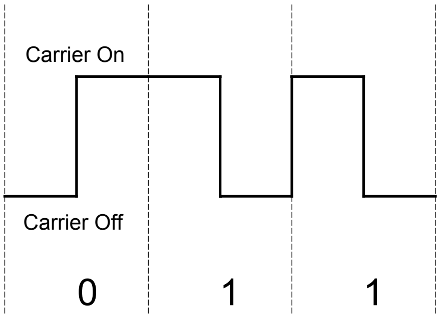
The transponder transmit amplifier and antenna shall operate at a field strength between 120 millivolts/meter to 550 millivolts/meter (-3 dBm to +10 dBm), when measured at one (1) meter along the antenna boresight.

4.2.3.3. Transmit Emissions (out of band)

The transponder emissions at frequencies below 905 MHz shall be less than –45 dBm in a 100 KHz bandwidth.
The transponder emissions at frequencies above 931 MHz shall be less than –52 dBm in a 100 KHz bandwidth.

4.2.3.4. Modulation Scheme

The modulation scheme shall be unipolar amplitude shift keying (ASK) of the RF carrier using Manchester encoding as depicted below. A data bit '1' is transmitted by sending an RF pulse during the first half of the bit period and no signal during the second half. A '0' data bit is transmitted as no signal during the first half of the bit period and an RF pulse transmission during the second half.



Manchester ASK Coding

4.2.3.5. Data Rate

The data bit rate for all messages shall be 500 Kbps.

4.2.3.6. Emission Bandwidth (null to null)

The maximum null to null emission bandwidth of the transponder shall be 2 MHz.

4.2.3.7. Transmitter Bandwidth (99.9% energy)

The transponder's spectrum bandwidth containing 99.9% of the transmitted energy shall be ±3 MHz.

4.2.3.8. RF Carrier On/Off Ratio

The ratio of power output in the "on-burst" to the power output in the "off-burst" shall be $\geq$19.75 dB.

4.2.4. Receiver Requirements

Receiver is ASK detector and operational amplifier with comparator

4.2.4.1. Receiver Sensitivity

The minimum signal strength for OBE operation is 210 μV/m which is an incident power of –30 dBm with a 0 dBi antenna. At this input level the BER shall be better than 10^{-5}.

4.2.4.2. Interference Susceptibility

4.2.4.2.1. In-Band Susceptibility

a. The transponder bit error rate shall not be degraded when a 918 MHz FM carrier with a 25 KHz modulation bandwidth is present at a signal level of –50 dBm, assuming a 0 dBi dipole antenna.

b. The transponder bit error rate shall not be degraded when a 928 MHz carrier is AM modulated with a 375 KHz square wave is present at a signal level of –50 dBm, assuming a dipole antenna.

4.3. Transponder Characteristics

4.3.1. Antenna Location

The transponder shall establish a communication link with a Reader located at any point in the hemisphere in front of the transponder antenna. Transponders shall meet the performance specified herein when positioned in the front window and maintain a clear line of sight to the Reader antenna.

4.3.2. Antenna Polarization

RF transmissions shall be horizontally polarized. Operational characteristics shall be tested when transmitting in an anechoic environment using a horizontally polarized test antenna.

4.3.3. Transponder Activation

A transponder shall initiate activation in less than 20 milliseconds after entering the Reader communication zone. The area in which the received field strength exceeds the specified transponder threshold defines this zone.

4.3.4. Transponder Data Content

Transponder shall provide three levels of programmable memory:

I. Factory Programmed
II. Agency Programmed
III. Scratchpad Read/Write

4.3.4.1. Factory (Level I) Programming

Factory programmed memory shall contain transponer-unique identification codes that, once programmed, can never be altered without the use of special data and equipment. The identification codes shall be provided as public identification code which can be read out, and a private identification code, usable only for security purposes, and cannot be read ou of the transponder.

4.3.4.2. Agency (Level II) Programming

Agency programmed memory shall be programmable only with access to the private identification code of the transponder. This private identification code shall be provided by the manufacturer only to the purchasing agency approved by DEC. The agency memory shall allow for programming with the agency-unique identifier for Cross Israel Highway tollway and the classification of the vehicle for which the transponder was registered. Memory usage shall allow for multiple agency registration. This memory shall be re-programmable at any time, provided the private identification code is used.

4.3.4.3. Scratchpad (Level III) Memory

General purpose read/write memory shall be provided for use by the Toll Collection system to write to or read from, as required to effect electronic toll transactions. The transponders shall provide a means of message validation before allowing read or write to the scratchpad memory by a reader unit.

4.3.5. Operating Life

Transponders shall provide normal operation as specified herein for a period of at least ten (10) years from the delivery date of the transponder from the factory. This operating life is predicted on the following assumptions: 12 transactions per day, 2 activations for each transaction, 5 seconds in the communications zone, 10 reads in the communication zone, and 1 write. Other combinations could result in a different battery life.

4.4. Environmental

Properly mounted transponders shall not be damaged nor suffer degraded performance due to temperature extremes encountered in the vehicle.
Transponders shall meet all performance requirements in all vehicules, excluding those with metallized windshields.

4.4.1. Humidity

Interior transponders shall operate as specified from 10% to 95% relative humidity, non condensing.

4.4.2. Temperature

Interior mounted transponders shall operate without degradation at ambient temperatures inside the passenger compartment from –40ºC to +75ºC continuous and up to +85ºC for up to ½ hour.

APPENDIX A. Detailed Timing and Flow Figures For VRC Protocol

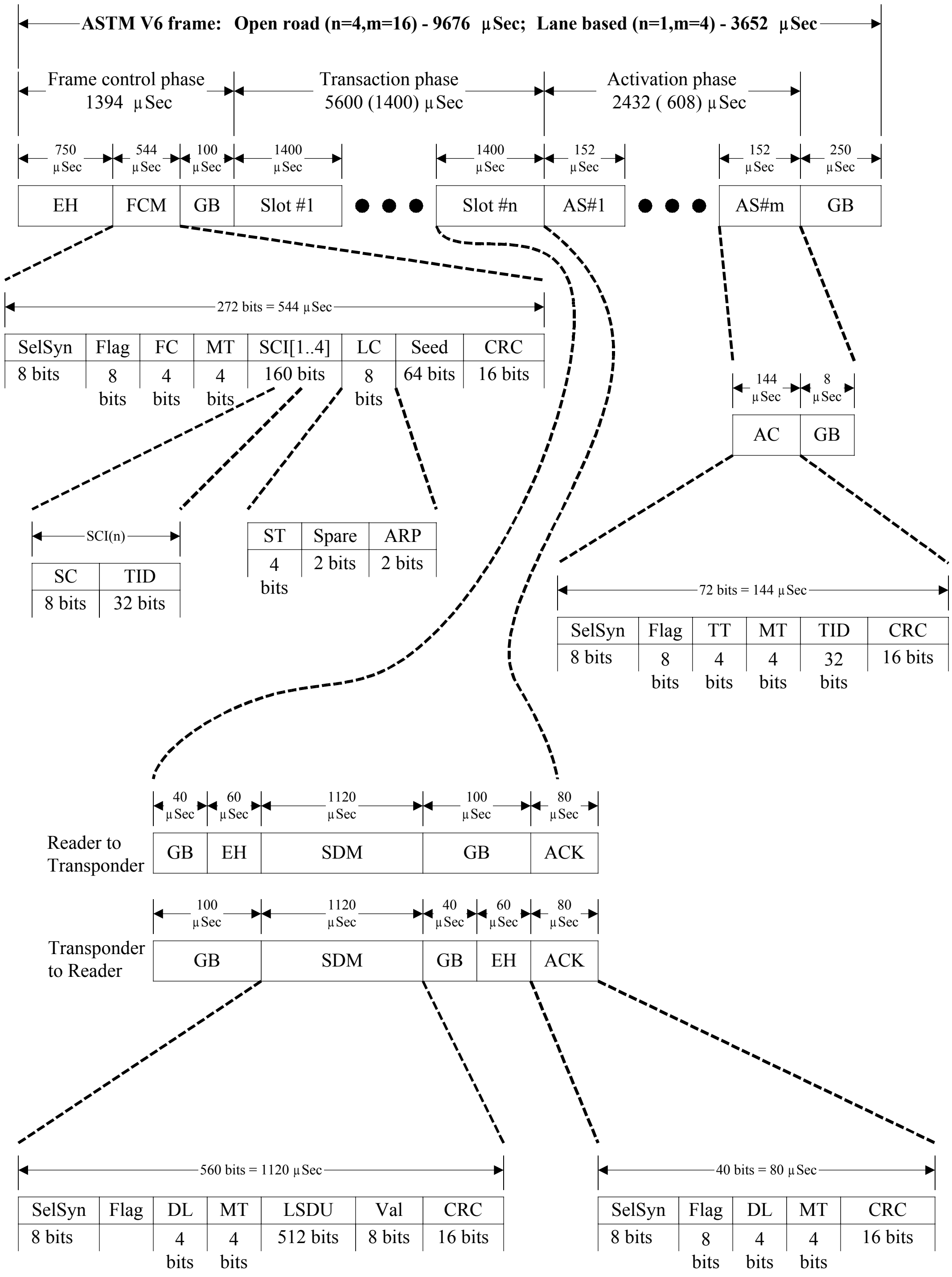
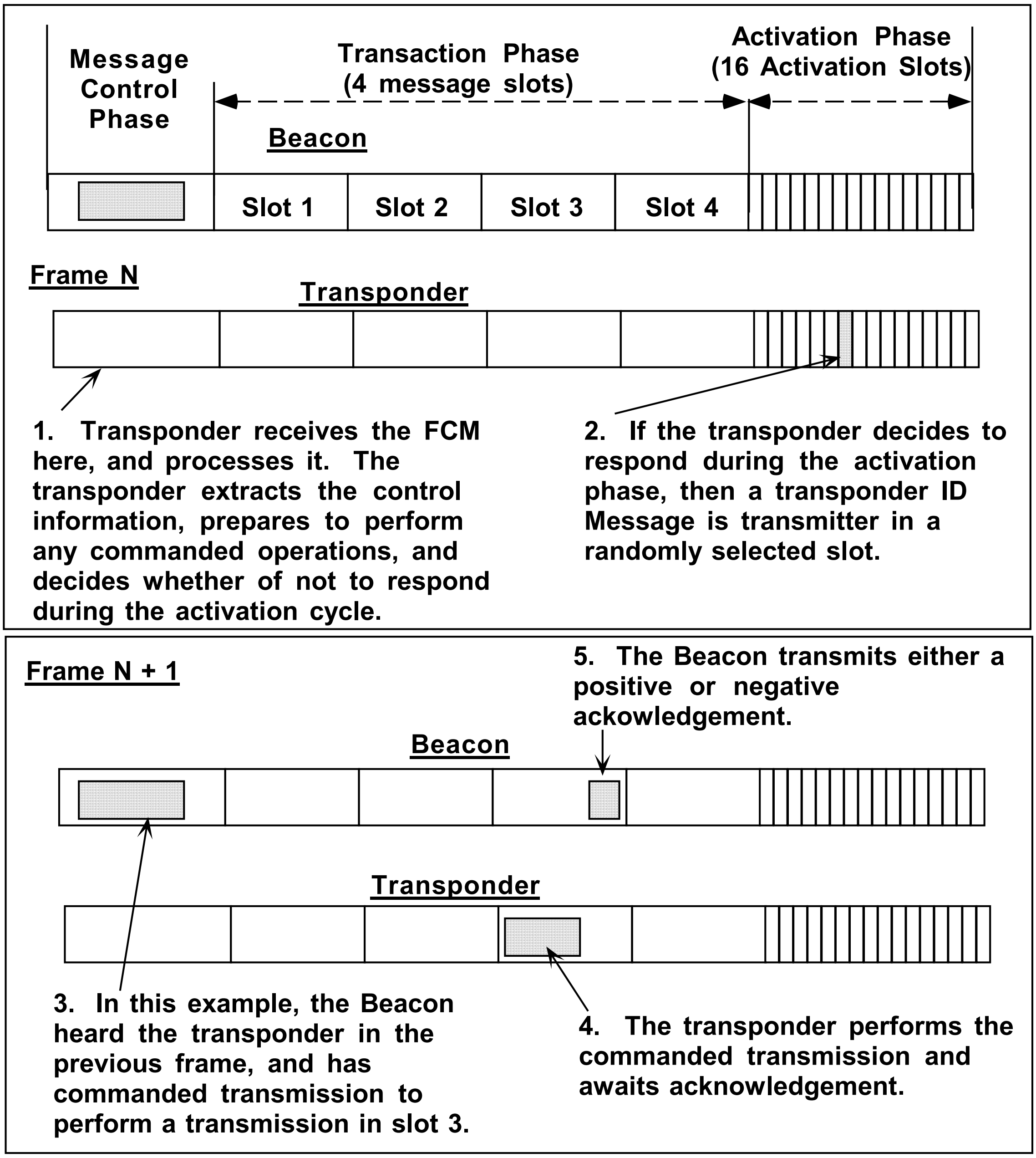
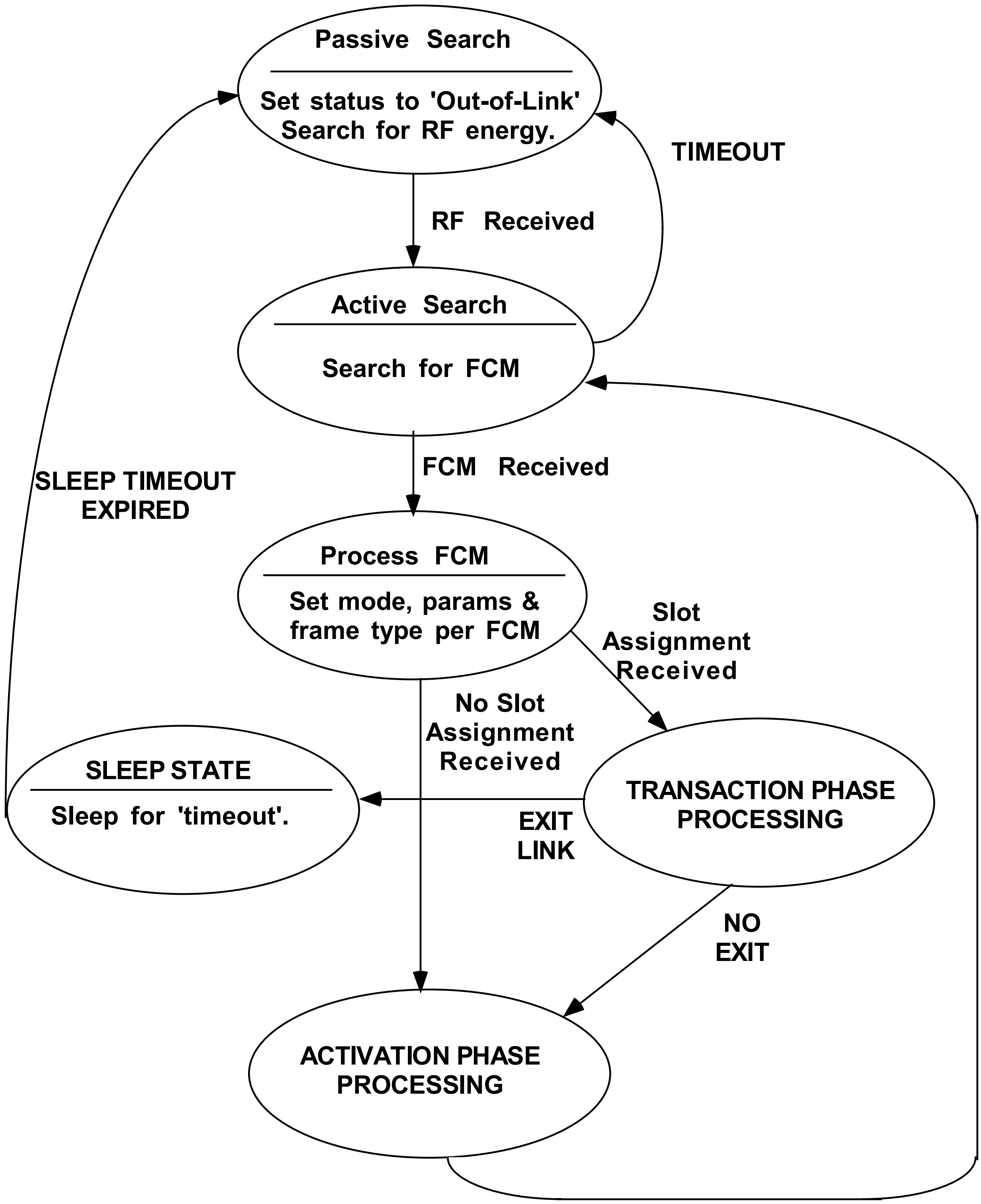


Figure 5-1: Frame Structure and Timing



Sample link-entry sequence with a transmission assignment in slot 3.

Figure 5-2: Sample Link Activation and Entry Sequence



Transponder VRC Link Protocol Flow

Figure 5-3a: Top Level Protocol Flowchart

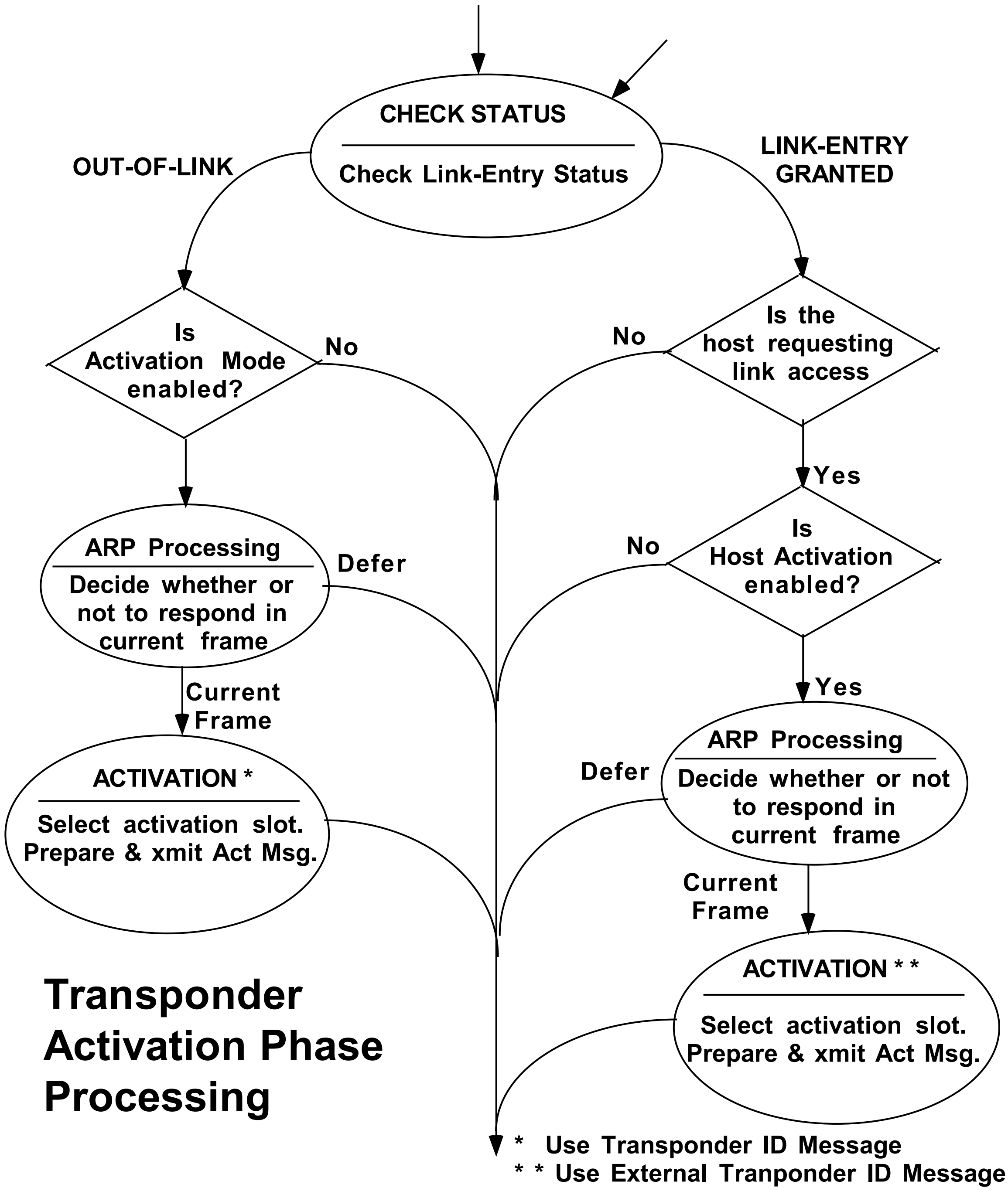


Figure 5-3b: Transponder Activation Phase Processing

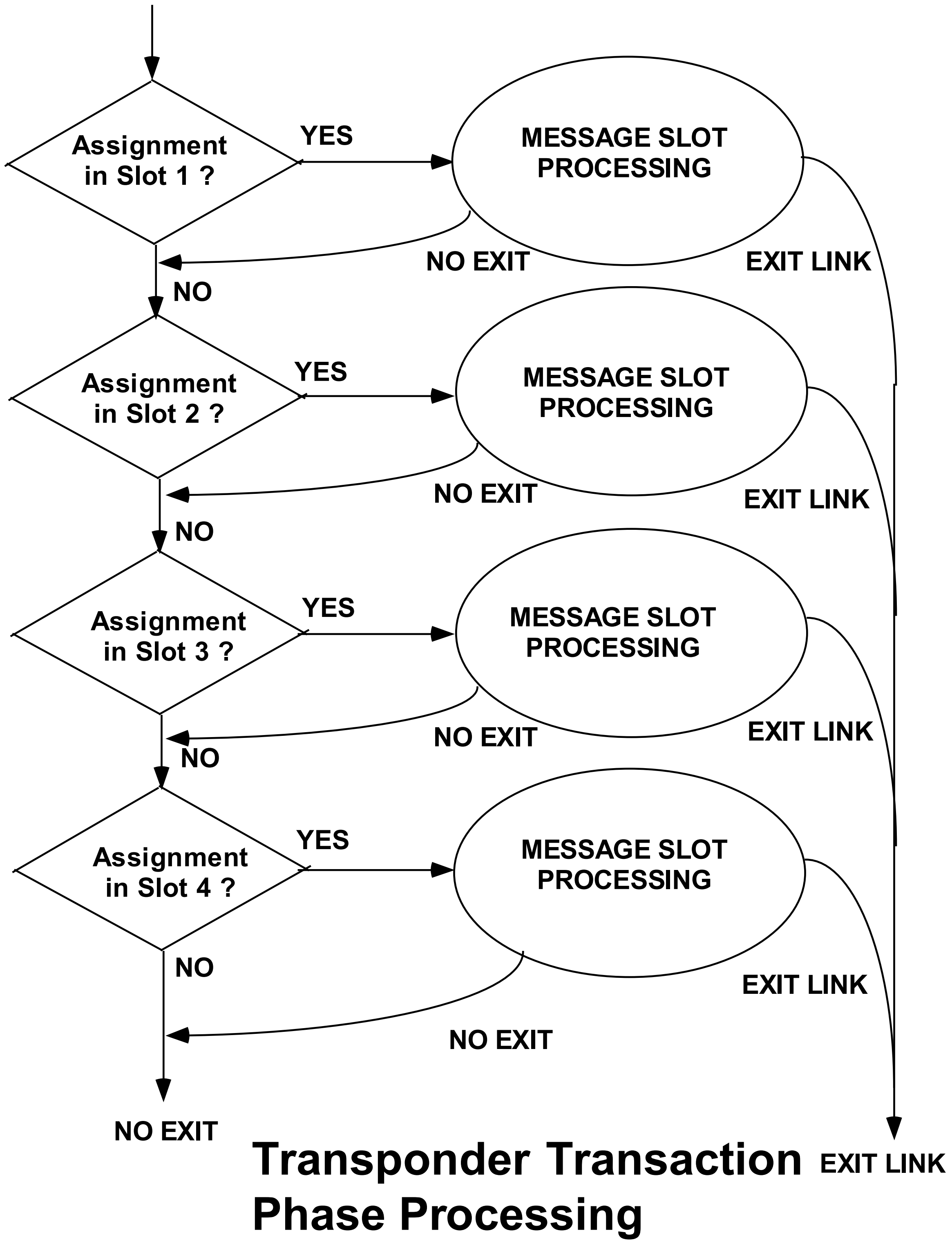


Figure 5-3c: Transaction Phase Processing

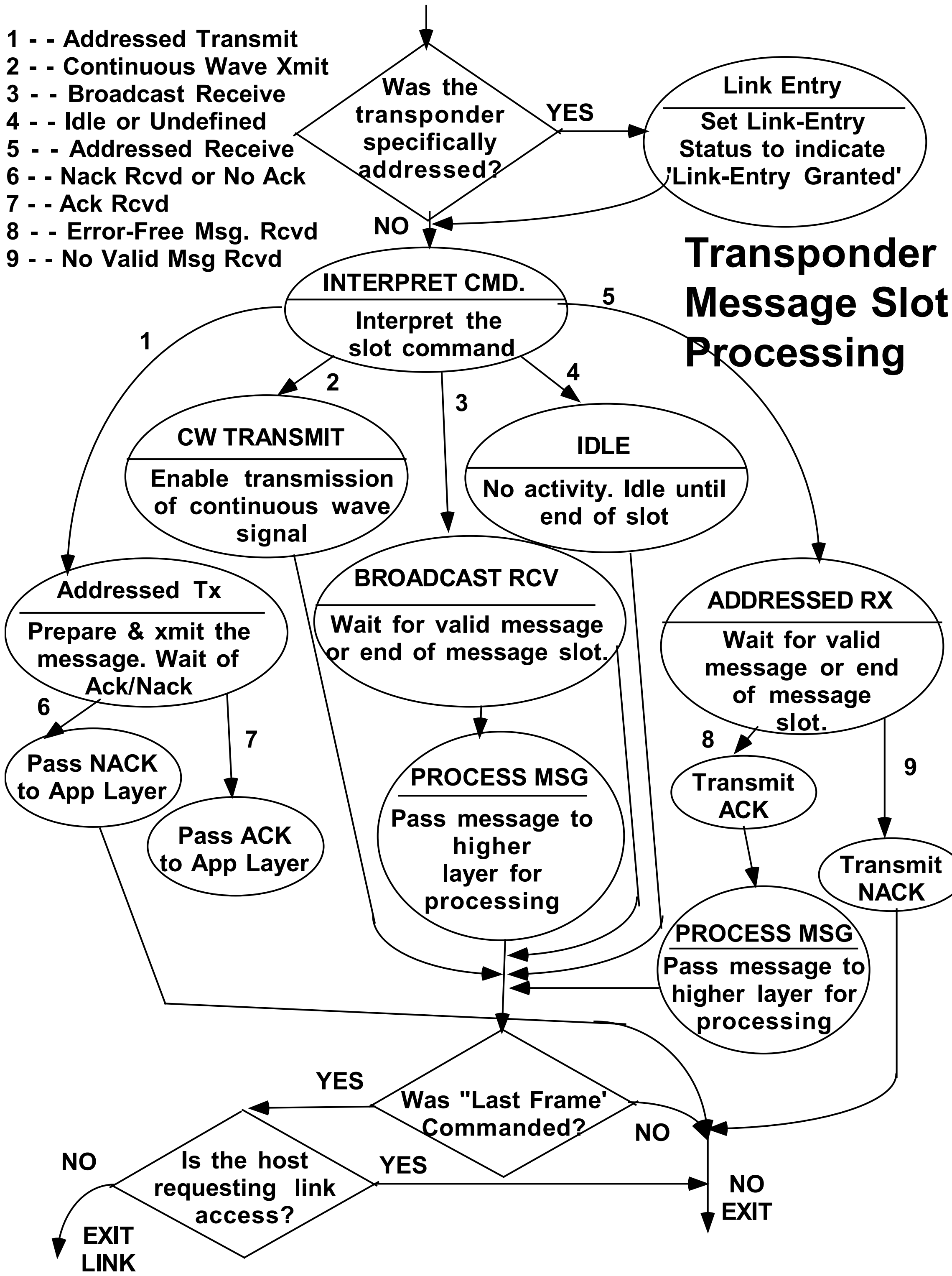


Figure 5-3d: Message Slot Processing