RTCA, Incorporated
1140 Connecticut Avenue, NW, Suite 1020
Washington, DC 20036-4008 USA

NAVSTAR GPS L5 Signal Specification

RTCA/DO-261
December 14, 2000

Prepared by SC-159
© 2000 RTCA, Inc.

Copies of this document may be obtained from

RTCA, Inc.
1140 Connecticut Avenue, NW, Suite 1020
Washington, DC 20036-4008 USA

Telephone: 202-833-9339
Facsimile: 202-833-9434
Internet: www.rtca.org

Please call RTCA for price and ordering information.

FOREWORD

This report was prepared by Special Committee 159 (SC-159) and approved by the RTCA Program Management Committee (PMC) on December 14, 2000.

RTCA, Incorporated is a not-for-profit corporation formed to advance the art and science of aviation and aviation electronic systems for the benefit of the public. The organization functions as a Federal Advisory Committee and develops consensus based recommendations on contemporary aviation issues. RTCA's objectives include but are not limited to:

- coalescing aviation system user and provider technical requirements in a manner that helps government and industry meet their mutual objectives and responsibilities;
- analyzing and recommending solutions to the system technical issues that aviation faces as it continues to pursue increased safety, system capacity and efficiency;
- developing consensus on the application of pertinent technology to fulfill user and provider requirements, including development of minimum operational performance standards for electronic systems and equipment that support aviation; and
- assisting in developing the appropriate technical material upon which positions for the International Civil Aviation Organization and the International Telecommunication Union and other appropriate international organizations can be based.

The organization's recommendations are often used as the basis for government and private sector decisions as well as the foundation for many Federal Aviation Administration Technical Standard Orders.

Since RTCA is not an official agency of the United States Government, its recommendations may not be regarded as statements of official government policy unless so enunciated by the U.S. government organization or agency having statutory jurisdiction over any matters to which the recommendations relate.

TABLE OF CONTENTS

1 Introduction 1

1.1 Scope 1

1.2 Signal Specification Approval and Changes 1

2 Applicable Documents 3

2.1 Government Documents 3

2.2 Non-Government Documents 3

3 Requirements 5

3.1 Signal Definition 5

3.2 Signal Identification 5
3.2.1 Ranging Codes 5
3.2.1.1 L5-Codes 5
3.2.1.2 Non-standard Codes 8
3.2.2 NAV Data 8
3.2.3 L5 Signal Structure 8

3.3 Signal Characteristics 8
3.3.1 Composite Signal 8
3.3.1.1 Frequency Plan 8
3.3.1.2 Correlation Loss 9
3.3.1.3 Carrier Phase Noise 9
3.3.1.4 Spurious Transmissions 9
3.3.1.5 Phase Quadrature 9
3.3.1.6 User-received Signal Levels 9
3.3.1.7 Equipment Group Delay 10
3.3.1.7.1 Group Delay Uncertainty 10
3.3.1.7.2 Group Delay Differential 11
3.3.1.7.3 GPS Differential Timing 11
3.3.1.8 Signal Coherence 11
3.3.1.9 Signal Polarization 11
3.3.2 PRN Code Characteristics 11
3.3.2.1 Code Structure 12
3.3.2.2 Code Generation 13
3.3.2.3 Q5 Synchronization Sequence 15
3.3.3 Navigation Data 15
3.3.3.1 Navigation Data Modulation 15
3.3.3.1.1 Forward Error Correction 16
3.3.3.1.2 Neuman-Hoffman Code 16
3.3.4 GPS Time and SV Z-Count 17

4 Notes 21

4.1 Acronyms 21

4.2 Definitions 21
4.2.1 User Range Accuracy 21
4.2.2 SV Block Definitions 22
4.2.2.1 Developmental SVs 22
4.2.2.2 Operational SVs 22

4.2.2.2.1 Block II SVs 22
4.2.2.2.2 Block IIA SVs 22
4.2.2.2.3 Block IIA SVs 22
4.2.2.2.4 Block IIR SVs 23
4.2.2.3 Block IIF Operational SVs 23
4.2.3 Operational Interval Definitions 23
4.2.3.1 Normal Operations 23
4.2.3.2 Short-term Extended Operations 23
4.2.3.3 Long-term Extened Operations 23
4.2.4 GPS Week Number 23
4.3 Supporting Material 24
4.3.1 L5 Received Signals 24
10 Appendix I. GPS Navigation Data Structure for Data ID No. 2 25
10.1 Scope 25
10.2 Applicable Documents 25
10.3 Requirements 25
10.3.1 Data Characteristics 25
10.3.2 Message Structure 25
10.3.3 Message Content 25
10.3.3.1 Message Type 1 Clock, Health, and Accuracy Parameters 25
10.3.3.1.1 Message Type 1 Clock, Health, and Accuracy Parameter Content 25
10.3.3.1.1.1 Transmission Week Number 26
10.3.3.1.1.2 SV Accuracy (L5) 32
10.3.3.1.1.3 SV Health (L5) 32
10.3.3.1.1.4 Issue of Data, Clock 33
10.3.3.1.1.5 Short-term and Long-term Extended Operations 33
10.3.3.1.1.6 SV Clock Correction 33
10.3.3.1.1.7 Estimated Group Delay Differential (L1-L5) 33
10.3.3.1.1.8 Estimated L2/L5 Group Delay Differential 33
10.3.3.1.1.9 Estimated L5 Q5/I5 Group Delay Differential 33
10.3.3.1.2 Message Type 1 Clock, Health and Accuracy Parameter Characteristics 33
10.3.3.1.3 User Algorithms for Message Type 1 Clock Data 34
10.3.3.1.3.1 User Algorithms for SV Clock Correction 34
10.3.3.1.3.2 L1/L5 Correction 37
10.3.3.1.3.3 L2/L5 Group Delay Correction 38
10.3.3.1.3.4 L1/L5 Ionospheric Correction 38
10.3.3.1.3.5 L2/L5 Ionospheric Correction 39
10.3.3.1.3.6 L5 Q-code/I-code Correction 39
10.3.3.1.3.7 Example Application of Correction Parameters 39
10.3.3.2 Message Type 1 and 2 Ephemeris Parameters 39
10.3.3.2.1 Message Type 1 and 2 Ephemeris Parameter Content 39
10.3.3.2.2 Message Type 1 and 2 Ephemeris Parameter Characteristics 41
10.3.3.2.3 User Algorithm for Ephemeris Determination 41
10.3.3.2.3.1 Curve Fit Intervals 42
10.3.3.2.3.2 Parameter Sensitivity 45
10.3.3.2.3.3 Coordinate Systems 45
10.3.3.2.3.3.1 ECEF Coordinate System 45
10.3.3.2.3.3.2 Earth-Centered Inertial (ECI) Coordinate System 46
10.3.3.2.3.4 Geometric Range 46
10.3.3.3 Message Type 3 Parameters 46
10.3.3.3.1 Message Type 3 Parameter Content 46

10.3.3.3.1.1 Universal Coordinated Time (UTC) Parameters 47
10.3.3.3.1.2 Ionospheric Data 47
10.3.3.3.1.3 SV Health (L1/L2) 47
10.3.3.3.1.4 Code(s) on L2 Channel 47
10.3.3.3.2 Algorithms Related to Message Type 3 Data 50
10.3.3.3.2.1 Universal Coordinated Time (UTC) 50
10.3.3.3.2.2 Ionospheric Model 51
10.3.3.4 Message Type 4 Almanac Parameters 55
10.3.3.4.1 Message Type 4 Almanac Parameter Content 55
10.3.3.4.1.1 Data ID and SV ID 55
10.3.3.4.1.2 Almanac Data 55
10.3.3.4.1.3 SV Health (L1 and L2) 55
10.3.3.4.1.4 SV Health (L5) 56
10.3.3.4.1.5 Anti-Spoof (A-S) Flags and SV Configurations 56
10.3.3.4.1.6 Almanac Reference Week 56
10.3.3.4.2 Algorithms Related to Message Type 4 Data 62
10.3.3.4.2.1 Almanac 62
10.3.3.4.2.2 Almanac Reference Time 63
10.3.3.4.2.3 Almanac Time Parameters 63
10.3.3.5 Message Type 5 64
10.3.4 Timing Relationships 64
10.3.4.1 Paging and Cutovers 64
10.3.4.2 SV Time vs. GPS Time 64
10.3.4.3 Speed of Light 64
10.3.4.4 Data Sets 65
10.3.4.5 Reference Times 67
10.3.5 Data Frame Parity 69
10.3.5.1 Parity Algorithm 69

MEMBERSHIP 71

TABLE OF FIGURES

Figure 3-1. Generation of Codes 12
Figure 3-2. Modulation of Signals 13
Figure 3-3. XA Shift Register Generator Configuration 14
Figure 3-4. XB Shift Register Generator Configuration 14
Figure 3-5. Relative Phases Between the XA and XB Sequences 15
Figure 3-6. Convolutional Encoder 16
Figure 3-7. Convolutional Transmit/Decoding Timing Relationships 17
Figure 3-8. Time Line Relationship of a Six-Second Message 19
Figure 10-1. Message Type 1 Format 27
Figure 10-2. Message Type 2 Format 28
Figure 10-3. Message Type 3 Format 29
Figure 10-4. Message Type 4 Format 30
Figure 10-5. Message Type 5 Format 31
Figure 10-6. Sample Application of Correction Parameters 40
Figure 10-7. Ionospheric Model 52

TABLE OF TABLES

Table 3-I. Code Phase Assignments 6
Table 3-II. Composite L5 Transmitted Signal Phase 10
Table 3-III. Received Minimum L5 RF Signal Strength 10
Table 10-I. Message Type 1 Clock, Health and Accuracy Parameters 35
Table 10-II. Ephemeris Data Definitions 41
Table 10-III. Ephemeris Parameters 42
Table 10-IV. Elements of Coordinate Systems 43
Table 10-V. UTC Parameters 48
Table 10-VI. Ionospheric Parameters 49
Table 10-VII. Almanac Parameters 57
Table 10-VIII. L1/L2 NAV Data Health Indications 58
Table 10-IX. Codes for Health of SV L1/L2 Signal Components 59
Table 10-X. L5 NAV Data Health Indications 60
Table 10-XI. Codes for Health of SV L5 Signal Components 61
Table 10-XII. IODC/IODE Values and Data Set Lengths 66
Table 10-XIII. Reference Times 68

1 Introduction

1.1 Scope

This Signal Specification defines the requirements related to the signal interface between the Space Segment (SS) of the Global Positioning System (GPS) and the GPS Navigation Users for the L5 Navigation Signal.

1.2 Signal Specification Approval and Changes

RTCA is responsible for the basic preparation, approval, distribution, and retention of the Signal Specification.

Notes:

1. *The U.S. Department of Defense (DoD) will generate a GPS Interface Control Document (ICD) based on this document (after approval of this document by the U.S. Interagency GPS Executive Board). To facilitate conversion to an ICD, this document follows the section numbering convention and section titles used by previous DoD GPS ICDs.*

2. *The L5 signal design, as documented in this document, is complete. However, specific values for various low-level requirements remain to be specified based upon space vehicle (SV) design tradeoffs that will be conducted by the Block IIF contractor under the constraints imposed by high-level performance requirements. Notes are included in sections of this document that include a low-level requirement with a value to-be-determined.*

©2000 RTCA, Inc.