
**Information technology —
Telecommunications and information
exchange between systems — High-rate
ultra-wideband PHY and MAC standard**

*Technologies de l'information — Téléinformatique — Norme PHY et
MAC à bande ultralarge et haut débit*



Reference number
ISO/IEC 26907:2009(E)

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Published in Switzerland

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Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work. In the field of information technology, ISO and IEC have established a joint technical committee, ISO/IEC JTC 1.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of the joint technical committee is to prepare International Standards. Draft International Standards adopted by the joint technical committee are circulated to national bodies for voting. Publication as an International Standard requires approval by at least 75 % of the national bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO and IEC shall not be held responsible for identifying any or all such patent rights.

International Standard ISO/IEC 26907 was prepared by Ecma International (as ECMA-368) and was adopted, under a special “fast-track procedure”, by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, in parallel with its approval by national bodies of ISO and IEC.

This second edition cancels and replaces the first edition (ISO/IEC 26907:2007), which has been technically revised.

The second edition adds the following for regulatory flexibility:

- an additional TFI code;
- an additional Band Group;
- tone nulling for interference avoidance.

It also

- relaxes the requirement for Band group 1,
- relocates some assigned numbers to Ecma registries on the website,
- adds an information element for Bluetooth.

Introduction

This International Standard specifies the ultra wideband (UWB) physical layer (PHY) and medium access control (MAC) sublayer for a high-speed, short-range wireless network, utilizing all or part of the spectrum between 3 100 MHz and 10 600 MHz, supporting data rates of up to 480 Mb/s.

This International Standard divides the spectrum into 14 bands, each with a bandwidth of 528 MHz. The first 12 bands are then grouped into four band groups consisting of three bands. The last two bands are grouped into a fifth band group. A sixth band group is also defined within the spectrum of the first four, consistent with usage within worldwide regulatory regulations.

A MultiBand Orthogonal Frequency Division Modulation (MB-OFDM) scheme is used to transmit information. A total of 110 sub-carriers (100 data carriers and 10 guard carriers) are used per band. In addition, 12 pilot subcarriers allow for coherent detection. Frequency-domain spreading, time-domain spreading, and forward error correction (FEC) coding are provided for optimum performance under a variety of channel conditions.

The MAC sublayer is designed to enable mobility, such that a group of devices may continue communicating while merging or splitting from other groups of devices. To maximize flexibility, the functionality of this MAC is distributed among devices. These functions include distributed coordination to avoid interference between different groups of devices by appropriate use of channels and distributed medium reservations to ensure Quality of Service. The MAC sublayer provides prioritized schemes for isochronous and asynchronous data transfer. To do this, a combination of Carrier Sense Multiple Access (CSMA) and Time Division Multiple Access (TDMA) is used. A Distributed Reservation Protocol (DRP) is used to reserve the medium for TDMA access for isochronous and other traffic. For network scalability, Prioritized Contention Access (PCA) is provided using a CSMA scheme. The MAC has policies that ensure equitable sharing of the bandwidth.

Taken together, the PHY and MAC specified in this Ecma standard are well-suited to high rate, zero infrastructure communications between a mixed population of portable and fixed electronic devices.

This International Standard is not intended to represent the regulatory requirements of any country or region.

Information technology — Telecommunications and information exchange between systems — High-rate ultra-wideband PHY and MAC standard

1 Scope

This International Standard specifies a distributed medium access control (MAC) sublayer and a physical layer (PHY) for wireless networks.

2 Conformance

Conforming devices implement the MAC sublayer and the PHY layer as specified herein and support:

1. data rates of 53,3 Mb/s, 106,7 Mb/s, and 200 Mb/s for transmitting and receiving;
2. at least one of the band groups;
3. time-frequency codes using both TFI and FFI.

In addition, conforming devices may implement the MAC/PHY Interface as specified in ISO/IEC 26908.

3 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEEE 100, The Authoritative Dictionary of IEEE Standard Terms, Seventh Edition

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NOTE 2 The IEEE standards referenced are trademarks belonging to the Institute of Electrical and Electronics Engineers, Inc.

4 Terms and definitions

For the purposes of this document, the terms and definitions given in IEEE 100 and the following apply.

4.1

access category

AC

label for the common set of prioritized contention access (PCA) parameters that are used by a device to contend for the medium in order to transmit MAC protocol data units (MPDUs) with certain priorities

4.2

beacon group

BG

set of devices from which a device receives beacons that identify the same beacon period start time (BPST) as the device

4.3

beacon period

BP

period of time declared by a device during which it sends or listens for beacons

4.4

beacon period start time

BPST

start of the beacon period

4.5

channel

medium over which cooperating entities exchange information

4.6

data integrity

assurance that the data has not been modified from its original form

4.7

device

entity containing an implementation of this International Standard

4.8

distributed reservation protocol

DRP

protocol implemented in each device to support negotiation and maintenance of channel time reservations binding on all neighbours of the reservation participants

4.9

extended beacon group

union of a device's beacon group and the beacon groups of all devices in the device's beacon group

4.10

frame

unit of data transmitted by a device

4.11

frame protection

security service provided for a frame, including (but not limited to) payload encryption, message authentication, and replay attack protection

4.12

MAC Client

entity above the MAC sublayer that generates MAC service data units for delivery to corresponding entities in other devices, and receives MAC service data units from such entities

4.13

MAC command data unit

MCDU

unit of data exchanged between peer medium access control sublayers in order to manage medium access control functions

4.14

MAC protocol data unit

MPDU

unit of data exchanged between two peer medium access control sublayers using the physical layer

4.15**MAC service data unit****MSDU**

information that is delivered as a unit between medium access control service access points (SAPs)

4.16**message integrity code****MIC**

cryptographic checksum generated using a symmetric key that is typically appended to data in order to provide data integrity and source authentication similar to a digital signature

4.17**neighbour**

any device in a device's beacon group

4.18**network allocation vector****NAV**

indicator, maintained by each device capable of using PCA, of time periods when PCA-based transmission onto the wireless medium will not be initiated by the device, whether or not the device's clear-channel assessment function senses that the wireless medium is busy

4.19**prioritized contention access****PCA**

prioritized CSMA/CA access mechanism used by devices for medium access

4.20**pseudo-random number generation**

process of generating a deterministic sequence of bits from a given seed that has the statistical properties of a random sequence of bits when the seed is not known

4.21**random number generator**

method or design that provides a sequence of bits that is unpredictable

NOTE A cryptographic random number generator is one specific type.

4.22**reservation**

named set of one or more medium access slots (MASs) within a superframe during which a device has preferential access to the medium

4.23**reservation block**

one or more temporally contiguous medium access slots (MASs) within a reservation not adjacent to other MASs in the reservation

4.24**secure frame**

frame in which frame protection is applied

4.25**stream**

logical flow of MSDUs from one device to one or more other devices

4.26

superframe

periodic time interval used in this International Standard to coordinate frame transmissions between devices, which contains a beacon period followed by a data period

4.27

symmetric key

secret key shared between two or more parties that may be used for both encryption and decryption as well as for message integrity code computation and verification

4.28

transmission opportunity

TXOP

interval of time obtained by a device using prioritized contention access (PCA) to initiate transmissions onto the medium

4.29

TXOP holder

device that has successfully contended for a TXOP

4.30

user priority

value assigned to an MSDU by the MAC client that determines the MSDU's transfer priority

5 Notational conventions

The use of the word *shall* is meant to indicate a requirement which is mandated by the Standard, i.e. it is required to support that particular feature with no deviation in order to conform to the Standard.

The use of the word *should* is meant to recommend one particular course of action over several other possibilities, however without mentioning or excluding these others.

The use of the word *may* is meant to indicate that a particular course of action is permitted.

The use of the word *can* is synonymous with is able to – it is meant to indicate a capability or a possibility.

All floating-point values have been rounded to 4 decimal places.

6 Abbreviations and acronyms

AC	Access Category
ACK	Acknowledgment
AES	Advanced Encryption Standard
AIFS	Arbitration Inter-Frame Space
ASIE	Application-Specific Information Element
B-ACK	Block Acknowledgment
BcstAddr	Broadcast Device Address
BM	Burst Mode
BP	Beacon Period
BPOIE	Beacon Period Occupancy Information Element
BPST	Beacon Period Start Time

CBC-MAC	Cipher Block Chaining-Message Authentication Code
CCA	Clear Channel Assessment
CCM	Counter Mode Encryption and Cipher Block Chaining Message Authentication Code
CPE	Common Phase Error
CRC	Cyclic Redundancy Check
CSMA/CA	Carrier Sense Multiple Access with Collision Avoidance
CTS	Clear To Send
DAA	Detect And Avoid
DAC	Digital-to-Analog Converter
DCM	Dual Carrier Modulation
DestAddr	Destination Device Address
DevAddr	Device Address
DME	Device Management Entity
DRP	Distributed Reservation Protocol
EO	Encryption Offset
EUI	Extended Unique Identifier
FCS	Frame Check Sequence
FDS	Frequency-Domain Spreading
FEC	Forward Error Correction
FER	Frame Error Rate
FFI	Fixed-Frequency Interleaving
FFT	Fast Fourier Transform
GF	Galois Field
GTK	Group Temporal Key
HCS	Header Check Sequence
ID	Identifier
IDFT	Inverse Discrete Fourier Transform
IE	Information Element
IFFT	Inverse Fast Fourier Transform
IFS	Inter-Frame Space
Imm-ACK	Immediate Acknowledgment
KCK	Key Confirmation Key
LQE	Link Quality Estimator
LQI	Link Quality Indicator
LSB	Least-Significant Bit
MAC	Medium Access Control
MAS	Medium Access Slot

MCDU	MAC Command Data Unit
McstAddr	Multicast Device Address
MIB	Management Information Base
MIC	Message Integrity Code
MIFS	Minimum Interframe Spacing
MKID	Master Key Identifier
MLME	MAC Sublayer Management Entity
MPDU	MAC Protocol Data Unit
MSB	Most-Significant Bit
MSDU	MAC Service Data Unit
NAV	Network Allocation Vector
No-ACK	No Acknowledgement
OFDM	Orthogonal Frequency Division Multiplexing
OUI	Organizationally Unique Identifier
PAL	Protocol Adaptation Layer
PAN	Personal Area Network
PCA	Prioritized Contention Access
PDU	Protocol Data Unit
PER	Packet Error Rate
PHY	Physical (layer)
PHY-SAP	Physical Layer Service Access Point
PLCP	Physical Layer Convergence Protocol
PLME	Physical Layer Management Entity
PMD	Physical Medium Dependent
PMD-SAP	Physical Medium Dependent-Service Access Point
PMK	Pair-wise Master Key
PPDU	PLCP Protocol Data Unit
PPM	Parts Per Million
PRBS	Pseudo-Random Binary Sequence
PRF	Pseudo-Random Function
PSD	Power Spectral Density
PSDU	PHY Service Data Unit
PT	Preamble Type
PTK	Pair-wise Temporal Key
QPSK	Quadrature Phase Shift Keying
RF	Radio Frequency
RMS	Root Mean Squared

RS	Reed-Solomon
RSSI	Received Signal Strength Indicator
RTS	Request To Send
RX	Receive or Receiver
SAP	Service Access Point
SFC	Secure Frame Counter
SFN	Secure Frame Number
SIFS	Short Interframe Spacing
SrcAddr	Source Device Address
TDS	Time-Domain Spreading
TF	Time-Frequency
TFC	Time-Frequency Code
TFI	Time Frequency Interleaving
TFI2	Time-Frequency Interleaving over 2 bands
TKID	Temporal Key Identifier
TN	Tone-Nulling
TPC	Transmit Power Control
TX	Transmit or Transmitter
TXOP	Transmission Opportunity
UDA	Unused DRP Reservation Announcement
UDR	Unused DRP Reservation Response
UWB	Ultra Wideband
ZPS	Zero Padded Suffix

7 General description

7.1 PHY general description

This International Standard specifies the ultra wideband (UWB) physical layer (PHY) for a wireless personal area network (PAN), utilizing the unlicensed 3 100 – 10 600 MHz frequency band, supporting data rates of 53,3 Mb/s, 80 Mb/s, 106,7 Mb/s, 160 Mb/s, 200 Mb/s, 320 Mb/s, 400 Mb/s, and 480 Mb/s. Support for transmitting and receiving data rates of 53.3, 106.7, and 200 Mb/s shall be mandatory.

The UWB spectrum is divided into 14 bands, each with a bandwidth of 528 MHz. The first 12 bands are then grouped into 4 band groups consisting of 3 bands. The last two bands are grouped into a fifth band group. A sixth band group is also defined within the spectrum of the first four, consistent with usage within worldwide spectrum regulations. At least one of the band groups shall be supported.

This International Standard specifies a MultiBand Orthogonal Frequency Division Modulation (MB-OFDM) scheme to transmit information. A total of 110 sub-carriers (100 data carriers and 10 guard carriers) are used per band to transmit the information. In addition, 12 pilot subcarriers allow for coherent detection. Frequency-domain spreading, time-domain spreading, and forward error correction (FEC) coding are used to vary the data rates. The FEC used is a convolutional code with coding rates of 1/3, 1/2, 5/8 and 3/4.

The coded data is then spread using a time-frequency code (TFC). This International Standard specifies three types of time-frequency codes (TFCs): one where the coded information is interleaved

over three bands, referred to as Time-Frequency Interleaving (TFI); one where the coded information is interleaved over two bands, referred to as two-band TFI or TFI2; and one where the coded information is transmitted on a single band, referred to as Fixed Frequency Interleaving (FFI). Support for TFI, TFI2 and FFI shall be mandatory.

Within the first four and the sixth band groups, four time-frequency codes using TFI and three time-frequency codes using each of TFI2 and FFI are defined; thereby, providing support for up to ten channels in each band group. For the fifth band group, two time-frequency codes using FFI and one using TFI2 are defined. For the sixth band group, the FFI channels and one of the TFI2 channels overlap fully with channels in the third and fourth band groups.

A mechanism is provided to allow individual OFDM subcarriers to be nulled. This, together with the choice of frequency bands and of TFI, TFI2 and FFI time frequency codes, provides substantial control over the use of spectrum by the transmitted signal, allowing the PHY to be used in a range of regulatory and radio coexistence scenarios.

7.2 MAC general description

7.2.1 General description of the architecture

As illustrated in Figure 1, the MAC is a sublayer of the Data Link Layer defined in the OSI basic reference model [2]. The MAC service is provided by means of the MAC service access point (MAC SAP) to a single MAC service client, usually a higher layer protocol or adaptation layer. In this Standard the MAC sublayer is represented by a device address.

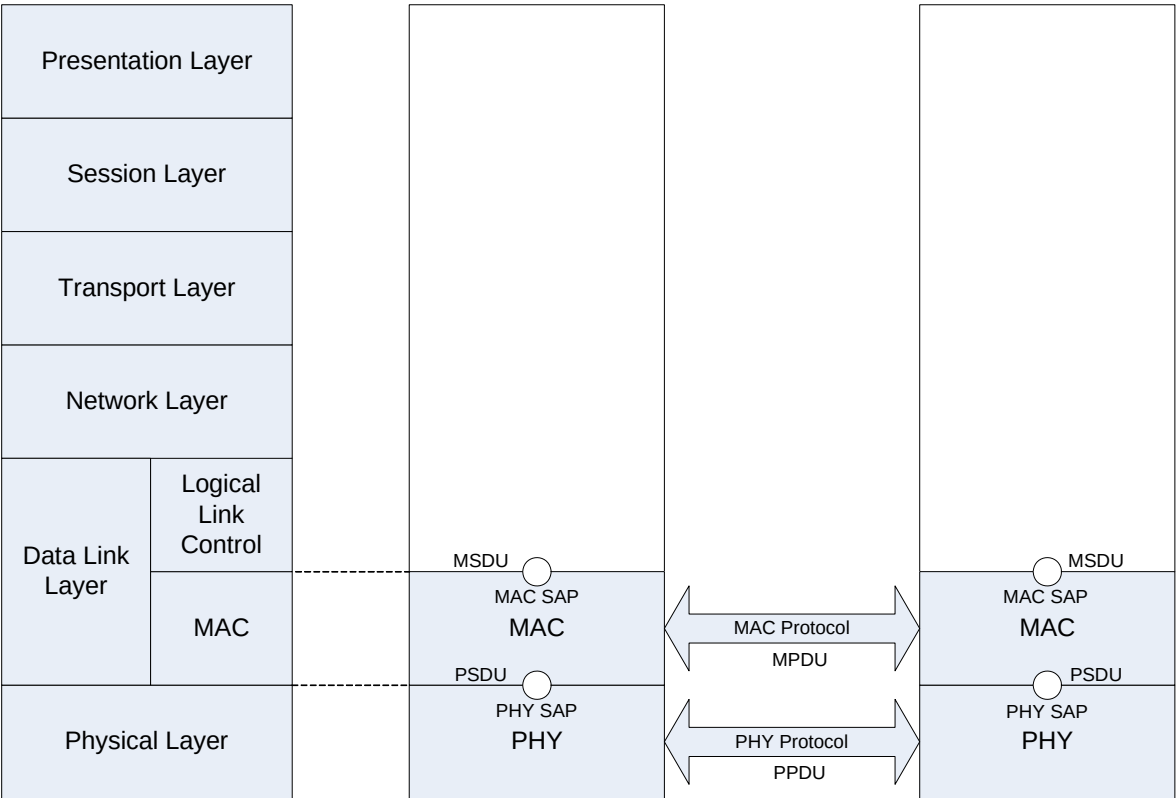


Figure 1 - Architectural reference model

The MAC sublayer in turn relies on the service provided by the PHY layer via the PHY service access point (PHY SAP). The MAC protocol applies between MAC sublayer peers.

7.2.2 Device address

Individual MAC sublayers are addressed via an EUI-48 [1], and are associated with a volatile abbreviated address called a DevAddr. Unicast frames carry a destination DevAddr that identifies a single MAC sublayer.

DevAddrs are 16-bit values, generated locally, without central coordination. Consequently, it is possible for a single value to ambiguously identify two or more MAC entities. This Standard provides mechanisms for resolving ambiguous DevAddrs.

The MAC addressing scheme includes multicast and broadcast address values. A multicast address identifies a group of MAC entities. The broadcast address identifies all MAC entities.

7.2.3 Features assumed from the PHY

A MAC sublayer is associated with a single PHY layer via the PHY SAP as specified in Clause 15.

The MAC sublayer requires the following features provided by the PHY:

- Frame transmission in both single frame and burst mode
- Frame reception for both single frame and burst mode transmission
- PLCP header error indication for both PHY and MAC header structures
- Clear channel assessment for estimation of medium activity
- Range measurement timestamps if MAC range measurement is supported.

Figure 2 defines the structure of a PHY frame.

- There are two types of preamble: Standard and burst.
- The PLCP header including MAC and PHY Headers is protected by a header check sequence (HCS).
- The Frame Payload is followed by its frame check sequence (FCS).

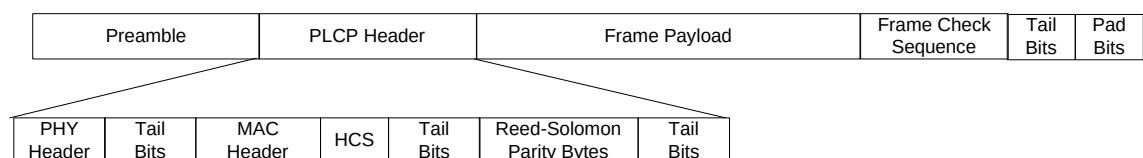


Figure 2 - PHY Frame Structure

Frames are transmitted by the PHY from the source device and delivered to the destination device in identical bit order. The start of a frame refers to the leading edge of the first symbol of the PHY frame at the local antenna and the end of a frame refers to the trailing edge of the last symbol of the PHY frame.

Frame transmission and reception are supported by the exchange of parameters between the MAC sublayer and the PHY layer. These parameters allow the MAC sublayer to control, and be informed of, the frame transmission mode, the frame payload data rate and length, the frame preamble, the PHY channel and other PHY-related parameters.

In single frame transmission, the MAC sublayer has full control of frame timing. In burst mode transmission, the MAC sublayer has control of the first frame timing and the PHY provides accurate timing for the remaining frames in the burst.

7.2.4 Overview of MAC service functionality

The MAC service defined in this Standard provides:

- Communication between cooperating devices within radio range on a single channel using the PHY;
- A distributed, reservation-based channel access mechanism;
- A prioritized, contention-based channel access mechanism;

- A synchronization facility for coordinated applications;
- Mechanisms for handling mobility and interference situations;
- Device power management by scheduling of frame transmission and reception;
- Secure communication with data authentication and encryption using cryptographic algorithms;
- A mechanism for measuring the distance between two devices.

The architecture of this MAC service is fully distributed. All devices provide all required MAC functions and optional functions as determined by the application. No device acts as a central coordinator.

Coordination of devices within radio range is achieved by the exchange of beacon frames. Periodic beacon transmission enables device discovery, supports dynamic network organization, and provides support for mobility. Beacons provide the basic timing for the network and carry reservation and scheduling information for accessing the medium.

7.2.4.1 Logical groups

The MAC protocol is specified with respect to an individual device, which has its own individual neighbourhood. All MAC protocol facilities are expressed with respect to this individual neighbourhood.

In a network formed with fully distributed medium access coordination, logical groups are formed around each device to facilitate contention-free frame exchanges while exploring medium reuse over different spatial regions. In this Standard, these logical groups are a beacon group and an extended beacon group, both of which are determined with respect to an individual device.

7.2.4.2 Control algorithms

MAC protocol algorithms attempt to ensure that no member of the extended beacon group transmits a beacon frame at the same time as the device. Information included in beacon frames facilitates contention-free frame exchanges by ensuring that a device does not transmit frames while a neighbour is transmitting or receiving frames.

To permit correct frame reception, MAC protocol algorithms attempt to ensure that a device's DevAddr is unique within the device's extended beacon group.

7.2.4.3 Channel selection

When a device is enabled, it scans one or more channels for beacons and selects a channel. If no beacons are detected in the selected channel, the device creates its beacon period (BP) by sending a beacon.

If one or more beacons are detected in the selected channel, the device synchronizes its BP to existing beacons in the selected channel. The device exchanges data with members of its beacon group using the same channel the device selected for beacons.

Each device operates in a dynamic environment and under unlicensed operation rules. Thus, it is subject to interference from licensed users, other networks, and other unlicensed wireless entities in its channel. To enable the device to continue operation in this type of environment, each device has the capability to dynamically change the channel in which it operates without requiring disruption of links with its peers.

If at any time a device determines that the current channel is unsuitable, it uses the dynamic channel selection procedure, as described in 17.10, to move to a new channel.

7.2.4.4 Beacon period protection

Each device protects its and its neighbours' BPs for exclusive use of the beacon protocol. No transmissions other than beacons are attempted during the BP of any device. Protection of the device's BP is implicit.

A device may protect an alien BP, detected by reception of a beacon frame unaligned with the device's own BP, by announcing a reservation covering the alien BP in its beacon.

7.2.4.5 The superframe

The basic timing structure for frame exchange is a superframe. The superframe duration is specified as `mSuperframeLength`. The superframe is composed of 256 medium access slots (MASs), where each MAS duration is `mMASLength`.

Each superframe starts with a BP, which extends over one or more contiguous MASs. The start of the first MAS in the BP, and the superframe, is called the beacon period start time (BPST).

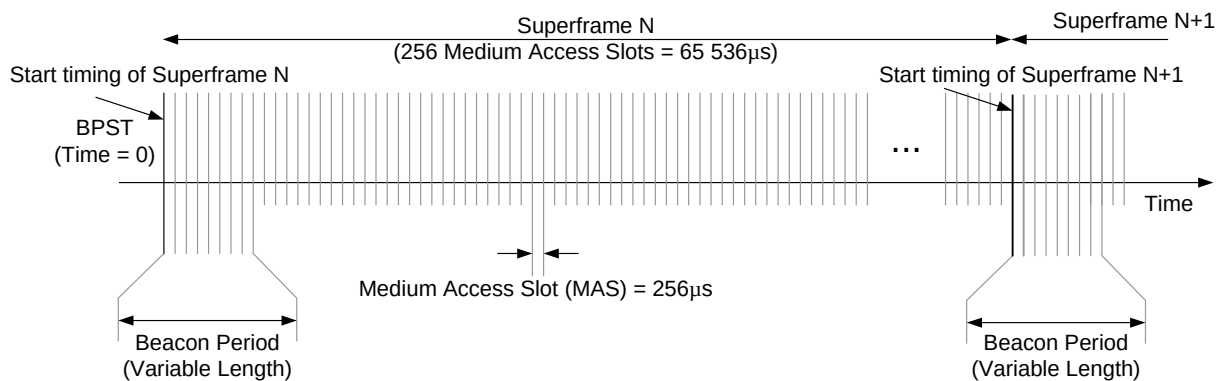


Figure 3 - MAC superframe structure

7.2.4.6 Medium access

The medium is accessed in one of three ways:

- During the BP, devices send only beacon frames, according to the rules specified in 17.2.
- During reservations, devices participating in the reservation send frames according to rules specified in 17.4.
- Outside the BP and reservations, devices may send frames using a prioritized contention-based access method, as described in 17.3.

7.2.4.7 Data communication between devices

Data is passed between the MAC sublayer and its client in MSDUs qualified by certain parameters. MSDUs are transported between devices in data frames. To reduce the frame error rate of a marginal link, data frames can be fragmented and reassembled, as described in 17.6. Fragments are numbered with an MSDU sequence number and a fragment number.

If the source device wishes to verify the delivery of a frame, then one of the acknowledgement policies is used, as described in 17.8. This Standard provides for three types of acknowledgements to enable different applications. The No-ACK policy, described in 17.8.1, is appropriate for frames that do not require guaranteed delivery, or are delay sensitive and a retransmitted frame would arrive too late. The Imm-ACK policy, described in 17.8.2, provides an acknowledgement process in which each frame is individually acknowledged following the reception of the frame. The B-ACK policy, described in 17.8.3, lets the source send multiple frames without intervening ACK frames. Instead, the acknowledgements of the individual frames are grouped into a single response frame that is sent when requested by the source device. The B-ACK process decreases the overhead of the Imm-ACK process while allowing the source device to verify the delivery of frames to the destination.

If the source device does not receive the requested acknowledgement, then it may retransmit the frame, as described in 17.3.7 and 17.4.10 or it may discard the frame. The decision to retransmit or discard the frame depends on the type of data or command that is being sent, the number of times that the source device has attempted to send the frame, the length of time it has attempted to send the frame, and other implementation-dependent factors.

7.2.4.8 MAC frame data rates

MAC beacon frames are intended to be received and interpreted by all devices and hence their frame payloads are transmitted at `pBeaconTransmitRate`, which can be decoded by all recipients. Other frames are exchanged in a more restricted context and their frame payloads may be transmitted at higher data rates if possible. Frame headers are always transmitted at the lowest data rate supported by the PHY.

7.2.4.9 Security

Wireless networks present unique security challenges due to the loss of protection provided by wires and shielding. Distributed wireless networks present additional challenges due to the wide range of applications and use models that they must support. To name a few, eavesdroppers can overhear data exchanges not intended for them, whereas imposters can send forged data not using its own identity, can replay previously transmitted data, and can transmit modified data captured from a previous transmission.

This Standard (Clause 18) defines two levels of security: no security and strong security protection. Security protection includes data encryption, message integrity, and replay attack protection. Secure frames are used to provide security protection to data and aggregated data frames as well as selected control and command frames.

Three security modes are defined to control the level of security for devices in their communications. This Standard allows for a device to use one of the two security levels or a combination of them in communicating with other devices by selecting the appropriate security mode (18.2).

This Standard further specifies a 4-way handshake mechanism to enable two devices to derive their pair-wise temporal keys (PTKs) while authenticating their identity to each other. A secure relationship is established following a successful 4-way handshake between two devices (18.3.1). A 4-way handshake between two devices is conducted based on a shared master key. How two devices obtain their shared master keys is outside the scope of this Standard.

In addition, this Standard provides means for the solicitation and distribution of group temporal keys (GTKs). While PTKs are used for protecting unicast frames exchanged between two devices, GTKs are employed for protecting multicast and broadcast frames transmitted from a source device to a multicast or broadcast group of recipient devices (18.3.2).

A pseudo-random function (18.3.3) is defined based on the message integrity code (MIC) generation by CCM using AES-128 that is defined in ISO/IEC 18033-3:2005. It can be made available to entities outside the MAC sublayer for random number generation.

Secure frame counters and replay counters are set up on a per-temporal key basis to guarantee message freshness (18.4). No specific mechanisms are created in this Standard to address denial of service attacks given the open nature of the wireless medium.

In this Standard, 128-bit symmetric temporal keys are employed based on AES-128 with CCM to provide payload encryption and message integrity code (MIC) generation (18.5).

In general, this Standard specifies security mechanisms, not security policies.

7.2.4.10 Information discovery

The protocols and facilities of this Standard are supported by the exchange of information between devices. Information can be broadcast in beacon frames or requested in Probe commands. For each type of information, an Information Element (IE) is defined. IEs can be included by a device in its beacon at any time and may optionally be requested or provided using the Probe command.

A device uses the MAC Capabilities IE and PHY Capabilities IE to announce information about its support of variable or optional facilities. Declaration of capabilities is especially useful when a device detects changes in its immediate neighbourhood.

7.2.4.11 Support for higher-layer timer synchronization

Some applications, for example, the transport and rendering of audio or video streams, require synchronization of timers located at different devices. Greater accuracy (in terms of jitter bounds) or

finer timer granularity than that provided by the synchronization mechanism described in 17.5 may be an additional requirement. In support of such applications, this Standard defines an optional MAC facility that enables layers above the MAC sublayer to accurately synchronize timers located in different devices. The facility is usable by more than one application at a time.

7.2.4.12 Rate adaptation

A mechanism for data rate adaptation is provided in 17.11. A receiver may use this mechanism to inform a transmitter of the optimal data rate to increase throughput and/or reduce the frame error rate (FER).

7.2.4.13 Power management

An important goal of this Standard is to enable long operation time for battery powered devices. An effective method to extend battery life is to enable devices to turn off completely or reduce power for long periods of time, where a long period is relative to the superframe duration.

This Standard provides two power management modes in which a device can operate: active and hibernation. Devices in active mode transmit and receive beacons in every superframe. Devices in hibernation mode hibernate for multiple superframes and do not transmit or receive in those superframes.

In addition, this Standard provides facilities to support devices that sleep for portions of each superframe in order to save power.

To coordinate with neighbours, a device indicates its intention to hibernate by including a Hibernation Mode IE in its beacon. The Hibernation Mode IE specifies the number of superframes in which the device will sleep and will not send or receive beacons or any other frames.

Power management mechanisms are described in 17.13.

7.2.4.14 Range measurement

A device may contain provisions to support one-dimensional ranging measurements between devices using two-way time transfer techniques. This Standard describes methods in the MAC sublayer to make range measurements in 17.15.

7.2.5 MUX sublayer

In order to enable the coexistence of concurrently active higher layer protocols within a single device, a multiplexing sublayer is defined. This sublayer routes outgoing and incoming MSDUs to and from their corresponding higher layers. The mandatory MUX sublayer is described in Annex A.

7.2.6 MAC policies

It is desirable to allow and facilitate equitable and efficient coexistence of devices with varying medium access requirements. For this purpose, Annex B specifies policies governing sharing of bandwidth. These policies impose, among other things, certain restrictions on the number and configuration of MASs in DRP reservations, and on the location of reserved MASs within a superframe.

7.2.7 Test vectors

To facilitate implementation and interoperability, Annex B provides examples of field encoding in MAC frames and the corresponding octet sequences passed to the PHY SAP. The examples include results from security operation and FCS calculation.

8 PHY layer partitioning

This Clause describes the PHY services provided to the MAC. The PHY layer consists of two protocol functions:

- a. A PHY convergence function, which adapts the capabilities of the physical medium dependent (PMD) device to the PHY service. This function is supported by the physical layer convergence protocol (PLCP), which defines a method of mapping the PLCP service data units (PSDU) into a framing format suitable for sending and receiving user data and management information between two or more stations using the associated PMD device.

- b. A PMD device whose function defines the characteristics and method of transmitting and receiving data through a wireless medium between two or more stations, each using the Ecma PHY.

8.1 PHY function

The PHY contains three functional entities: the PMD function, the PHY convergence function, and the layer management function. The PHY service is provided to the MAC through the PHY service primitives.

8.2 PLCP sublayer

In order to allow the MAC to operate with minimum dependence on the PMD sublayer, the PHY convergence sublayer is defined. This function simplifies the PHY service interface to the MAC services.

8.3 PMD sublayer

The PMD sublayer provides a means to send and receive data between two or more stations.

8.4 PHY layer management entity (PLME)

The PLME performs management of the local PHY functions in conjunction with the MAC management entity.

9 Description of signal

9.1 Mathematical framework

The transmitted RF signal can be written in terms of the complex baseband signal as follows:

$$s_{RF}(t) = \text{Re} \left\{ \sum_{n=0}^{N_{\text{packet}}-1} s_n(t - nT_{SYM}) \exp(j2\pi f_c(q(n))t) \right\}, \quad (1)$$

where $\text{Re}(\cdot)$ represents the real part of the signal, T_{SYM} is the symbol length, N_{packet} is the number of symbols in the packet, $f_c(m)$ is the centre frequency for the m^{th} frequency band, $q(n)$ is a function that maps the n^{th} symbol to the appropriate frequency band, and $s_n(t)$ is the complex baseband signal representation for the n^{th} symbol, which must satisfy the following property: $s_n(t) = 0$ for $t \notin [0, T_{SYM})$. The exact structure of the n^{th} symbol depends on its location within the packet:

$$s_n(t) = \begin{cases} s_{\text{sync},n}(t) & 0 \leq n < N_{\text{sync}} \\ s_{\text{hdr},n-N_{\text{sync}}}(t) & N_{\text{sync}} \leq n < N_{\text{sync}} + N_{\text{hdr}} \\ s_{\text{frame},n-N_{\text{sync}}-N_{\text{hdr}}}(t) & N_{\text{sync}} + N_{\text{hdr}} \leq n < N_{\text{packet}} \end{cases}, \quad (2)$$

where $s_{\text{sync},n}(t)$ describes the n^{th} symbol of the preamble, $s_{\text{hdr},n}(t)$ describes the n^{th} symbol of the header, $s_{\text{frame},n}(t)$ describes the n^{th} symbol of the PSDU, N_{sync} is the number of symbols in the preamble, N_{hdr} is the number of symbols contained in the header, and $N_{\text{packet}} = N_{\text{frame}} + N_{\text{sync}} + N_{\text{hdr}}$ is the number of symbols in the payload. The exact values of N_{sync} , N_{hdr} , N_{frame} , and N_{packet} will be described in more detail in Clause 10.

The potentially complex time-domain signal $s_n(t)$ shall be created by passing the real and imaginary components of the discrete-time signal $s_n[k]$ through digital-to-analog converters (DACs) and anti-alias filters as defined in Figure 4. When the discrete-time signal $s_n[k]$ is real, only the real digital-to-analog converter and anti-aliasing filter need to be used. Clause 10 describes how to generate $s_n[k]$.

Figure 5 shows one realization of the transmitted RF signal using three frequency bands, where the first symbol is transmitted on a centre frequency of 3 432 MHz, the second symbol is transmitted on a centre frequency of 3 960 MHz, the third symbol is transmitted on a centre frequency of 4 488 MHz, the fourth symbol is transmitted on a centre frequency of 3 432 MHz, and so on. In addition, it is apparent from Figure 5 that the symbol is created by appending a zero-padded suffix (ZPS) to the IFFT output, or equivalently, to the OFDM symbol. The zero-padded suffix serves two purposes: it provides a mechanism to mitigate the effects of multi-path; and, it provides a time window (a guard interval) to allow sufficient time for the transmitter and receiver to switch between the different centre frequencies.

A symbol is defined as an OFDM symbol (IFFT output) plus a zero-padded suffix.

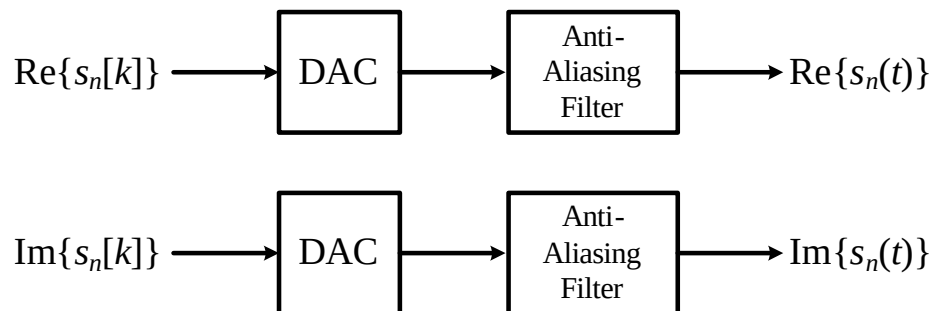


Figure 4 - Conversion from discrete-time signals to continuous-time signals

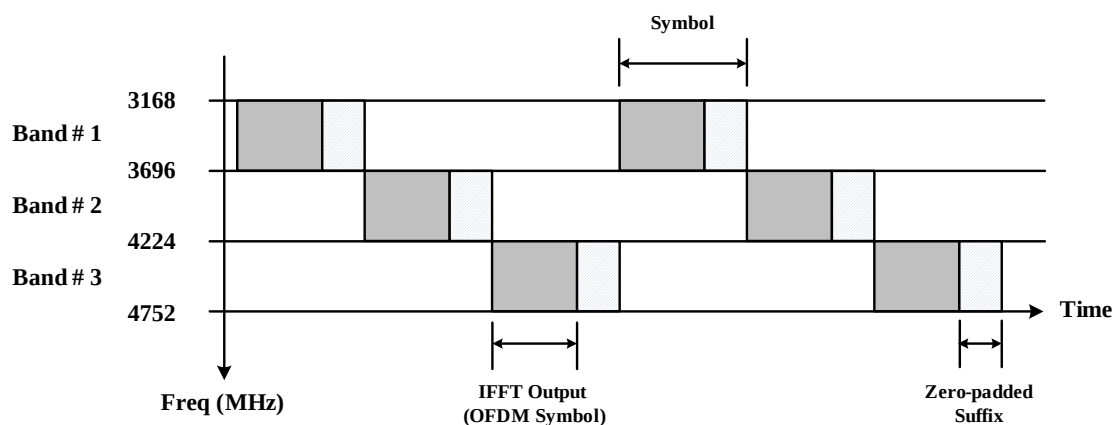


Figure 5 - Example realization of a transmitted RF signal using three bands

9.2 Tone-Nulling

In order to support avoidance of other users of the UWB band, the transmitted signal is sent in the context of a configured array TN of 384 tone-nulling elements. These correspond to the subcarriers of each band within the current band group, so that TN[0 to 127] apply to the subcarriers of the lowest frequency band in the current band group, TN[128 to 255] to the middle band, and TN[256 to 383] to the highest band, if present. See 11.1.2 for a description of bands and band groups.

Each tone-nulling element can take the value ONE or ZERO. If the value is ZERO, then the transmitter should take steps to minimize the transmitted signal energy at the frequency of the corresponding subcarrier. If the value is ONE, then the signal is unaffected by tone-nulling. No specific reduction in energy for any tone null is specified in this document. Tone-nulling is an optional feature. Tone-nulling applies to all symbols, including the preamble sequence.

A device shall transmit at least 86 useful tones per band, where useful tones relate to tones containing data, pilot, the preamble or the channel estimation sequence. This limit prevents unacceptable degradation of packet detection performance, and other receive performance. If more tones in a band must be avoided, the entire band cannot be used for transmission.

A device may null additional tones beyond those specified, for instance to improve or preserve symmetry within the transmitted symbols, subject to the constraint that at least 86 useful tones shall be transmitted per band. If additional tones are nulled then this shall be done consistently throughout the packet.

The simplest possible implementation is to set to zero the corresponding values of IFFT inputs, and to generate the sync symbols through the same IFFT process as other symbols.

10 PLCP sublayer

This Clause provides a method for converting a PSDU into a PPDU. During the transmission, the PSDU shall be pre-appended with a PLCP preamble and a PLCP header in order to create the PPDU. At the receiver, the PLCP preamble and PLCP header serve as aids in the demodulation, decoding, and delivery of the PSDU.

10.1 PPDU

Figure 6 defines the format for the PPDU, which is composed of three components: the PLCP preamble, the PLCP header, and the PSDU. The components are listed in the order of transmission. The PLCP preamble is the first component of the PPDU and can be further decomposed into a packet/frame synchronization sequence, and a channel estimation sequence (see 10.2). The goal of the PLCP preamble is to aid the receiver in timing synchronization, carrier-offset recovery, and channel estimation.

The PLCP header is the second component of the PPDU. The goal of this component is to convey necessary information about both the PHY and the MAC to aid in decoding of the PSDU at the receiver. The PLCP header can be further decomposed into a PHY header, MAC header, header check sequence (HCS), tail bits, and Reed-Solomon parity bits (see 10.3). Tail bits are added between the PHY header and MAC header, HCS and Reed-Solomon parity bits, and at the end of the PLCP header in order to return the convolutional encoder to the “zero state”. The Reed-Solomon parity bits are added in order to improve the robustness of the PLCP header.

The PSDU is the last component of the PPDU (see 10.4). This component is formed by concatenating the frame payload with the frame check sequence (FCS), tail bits, and finally pad bits, which are inserted in order to align the data stream on the boundary of the symbol interleaver.

When transmitting the packet, the PLCP preamble is sent first, followed by the PLCP header, and finally by the PSDU. The PLCP header is a codeword of a systematic Reed-Solomon code, appended with tail bits as explained above. As defined in Figure 6, the systematic part of the PLCP header is always sent at a data rate of 39,4 Mb/s. The PSDU is sent at the desired data rate of 53,3 Mb/s, 80 Mb/s, 106,7 Mb/s, 160 Mb/s, 200 Mb/s, 320 Mb/s, 400 Mb/s or 480 Mb/s.

The least-significant bit (LSB) of an octet shall be the first bit transmitted.

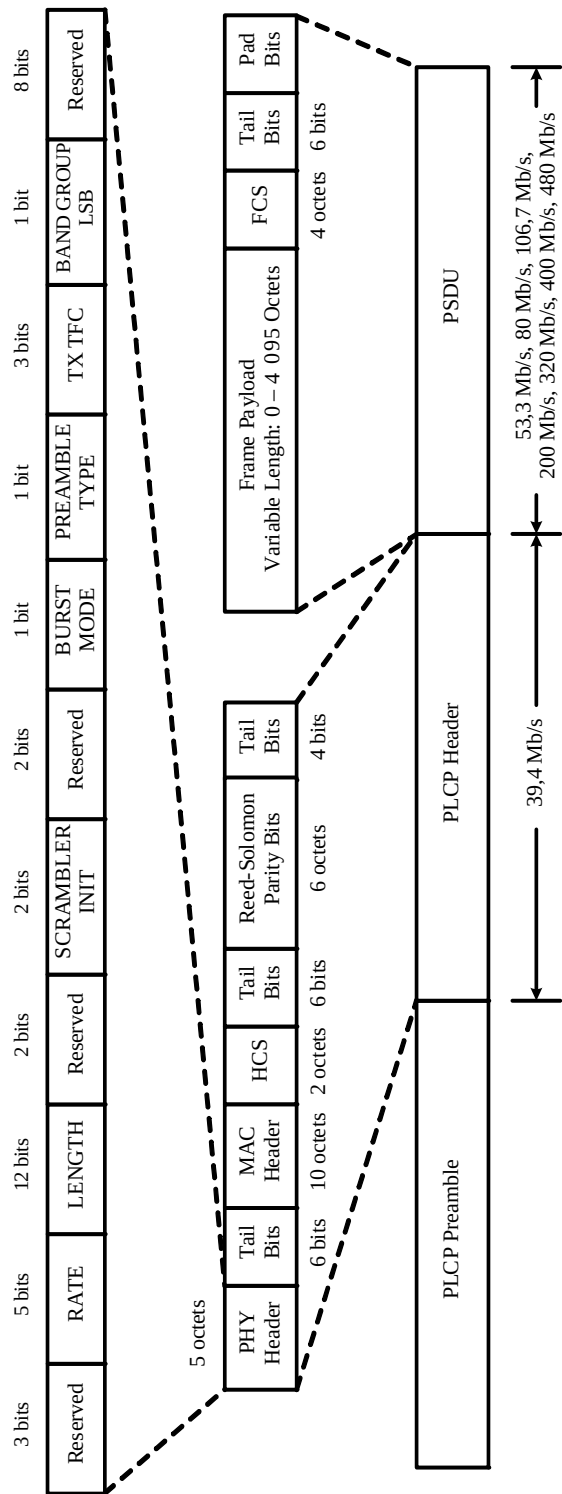


Figure 6 - Standard PPDU structure

10.1.1 PSDU rate-dependent parameters

The PSDU data rate-dependent modulation parameters are listed in Table 1.

Table 1 - PSDU rate-dependent Parameters

Data Rate (Mb/s)	Modulation	Coding Rate (R)	FDS	TDS	Coded Bits / 6 OFDM Symbol (N_{CBP6S})	Info Bits / 6 OFDM Symbol (N_{IBP6S})
53,3	QPSK	1/3	YES	YES	300	100
80	QPSK	1/2	YES	YES	300	150
106,7	QPSK	1/3	NO	YES	600	200
160	QPSK	1/2	NO	YES	600	300
200	QPSK	5/8	NO	YES	600	375
320	DCM	1/2	NO	NO	1 200	600
400	DCM	5/8	NO	NO	1 200	750
480	DCM	3/4	NO	NO	1 200	900

10.1.2 Timing-related parameters

The timing parameters associated with the OFDM PHY are listed in Table 2.

Table 2 - Timing-related Parameters

Parameter	Description	Value
f_s	Sampling frequency	528 MHz
N_{FFT}	Total number of subcarriers (FFT size)	128
N_D	Number of data subcarriers	100
N_P	Number of pilot subcarriers	12
N_G	Number of guard subcarriers	10
N_T	Total number of subcarriers used	122 ($= N_D + N_P + N_G$)
D_f	Subcarrier frequency spacing	4,125 MHz ($= f_s / N_{FFT}$)
T_{FFT}	IFFT and FFT period	242,42 ns (Δ_f^{-1})
N_{ZPS}	Number of samples in zero-padded suffix	37
T_{ZPS}	Zero-padded suffix duration in time	70,08 ns ($= N_{ZPS} / f_s$)

Table 2 - Timing-related Parameters(concluded)

Parameter	Description	Value
T_{SYM}	Symbol interval	312,5 ns ($= T_{FFT} + T_{ZPS}$)
F_{SYM}	Symbol rate	3,2 MHz ($= T_{SYM}^{-1}$)
N_{SYM}	Total number of samples per symbol	165 ($= N_{FFT} + N_{ZPS}$)

10.1.3 Frame-related parameters

The frame parameters associated with the PHY are listed in Table 3, where $\lceil \cdot \rceil$ is the ceiling function, which returns the smallest integer value greater than or equal to its argument.

Table 3 - Frame-related Parameters

Parameter	Description	Value
N_{pf}	Number of symbols in the packet/frame synchronization sequence	Standard Preamble: 24 Burst Preamble: 12
T_{pf}	Duration of the packet/frame synchronization sequence	Standard Preamble: 7,5 μ s Burst Preamble: 3,75 μ s
N_{ce}	Number of symbols in the channel estimation sequence	6
T_{ce}	Duration of the channel estimation sequence	1,875 μ s
N_{sync}	Number of symbols in the PLCP preamble	Standard Preamble: 30 Burst Preamble: 18
T_{sync}	Duration of the PLCP preamble	Standard Preamble: 9,375 μ s Burst Preamble: 5,625 μ s
N_{hdr}	Number of symbols in the PLCP header	12
T_{hdr}	Duration of the PLCP header	3,75 μ s
N_{frame}	Number of symbols in the PSDU	$6 \times \left\lceil \frac{8 \times \text{LENGTH} + 38}{N_{IBP6S}} \right\rceil$
T_{frame}	Duration for the PSDU	$6 \times \left\lceil \frac{8 \times \text{LENGTH} + 38}{N_{IBP6S}} \right\rceil \times T_{SYM}$
N_{packet}	Total number of symbols in the packet	$N_{sync} + N_{hdr} + N_{frame}$
T_{packet}	Duration of the packet	$(N_{sync} + N_{hdr} + N_{frame}) \times T_{SYM}$

10.2 PLCP preamble

A PLCP preamble shall be added prior to the PLCP header to aid the receiver in timing synchronization, carrier-offset recovery, and channel estimation. In this Clause both a Standard PLCP preamble and a burst PLCP preamble are defined. A unique preamble sequence shall be assigned to each time-frequency code (TFC).

The preamble is defined to be a real baseband signal, which shall be inserted into the real portion of the complex baseband signal. Tone-nulling (see 9.2), if implemented, is the applied. The PLCP preamble consists of two portions: a time-domain portion (packet / frame synchronization sequence) followed by a frequency-domain portion (channel estimation sequence).

In this Clause two preambles are defined: a Standard PLCP preamble and a burst PLCP preamble. The burst preamble shall only be used in the burst mode when a burst of packets is transmitted, separated by a minimum inter-frame separation time (pMIFS). For data rates of 200 Mb/s and lower, all the packets in the burst shall use the Standard PLCP preamble. However, for data rates higher than 200 Mb/s, the first packet shall use the Standard PLCP preamble, while the remaining packets may use either the Standard PLCP preamble or the burst PLCP preamble. Support for transmission and reception of burst PLCP preamble is mandatory for all supported data rates above 200Mbps. The preamble type (PT) bit in the PHY header (see 10.3.1.5) describes the type of preamble that shall be used in the next packet.

10.2.1 Standard PLCP preamble

Figure 7 defines the structure of the Standard PLCP preamble. The preamble can be sub-divided into two distinct portions: a packet/frame synchronization sequence and a channel estimation sequence. The packet/frame synchronization sequence shall be constructed as defined in Figure 8:

1. For a given time-frequency code, select the appropriate base time-domain sequence $s_{base}[l]$ from Table 4 through Table 10 and the appropriate Standard cover sequence $s_{cover}[m]$ from Table 21.
2. Form an extended time-domain sequence $s_{ext}[l]$ by appending N_{ZPS} "zero samples" to the length N_{FFT} sequence $s_{base}[l]$.
3. The k^{th} sample of the n^{th} symbol in the Standard preamble $s_{sync,n}[k]$, corresponding to the packet/frame synchronization sequence, is given by:

$$s_{sync,n}[k] = s_{cover}[n] \times s_{ext}[k], \quad (3)$$

where $n \in [0, N_{pf} - 1]$, $k \in [0, N_{SYM} - 1]$, N_{pf} is defined in Table 3 and N_{SYM} is defined in Table 2.

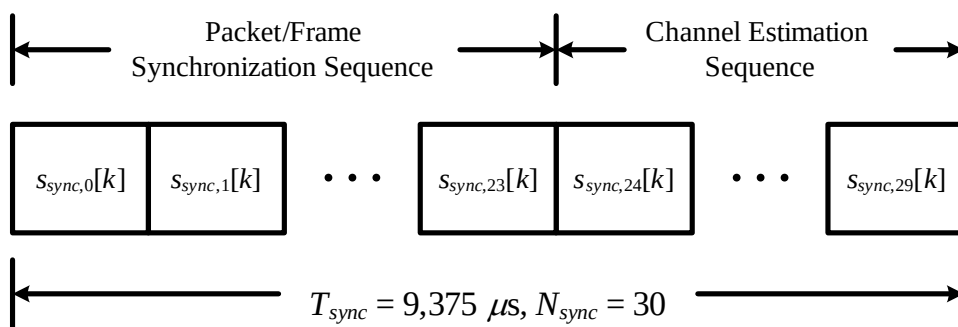


Figure 7 - Block diagram of the Standard PLCP preamble

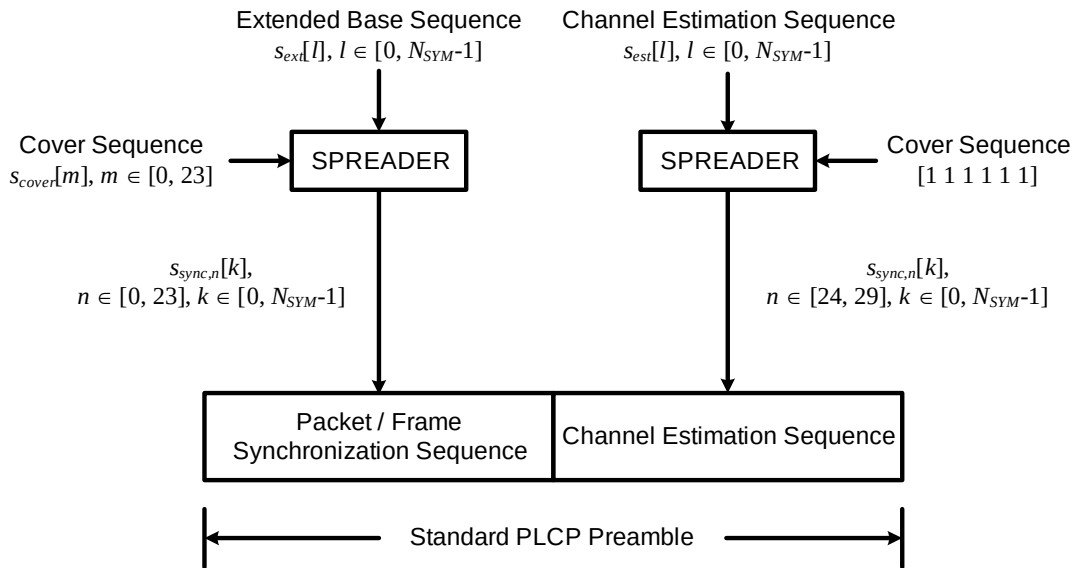


Figure 8 - Block diagram of standard PLCP preamble construction

The channel estimation sequence shall also be constructed as defined in Figure 8. A base channel estimation sequence $s_{est}[l]$ is created by taking the inverse discrete Fourier transform (IDFT) of the frequency-domain sequence defined in Table 23 and appending a zero-padded suffix consisting of N_{ZPS} “zero samples” to the resulting time-domain output. The channel estimation sequence portion of the Standard preamble is created by successively appending N_{ce} periods of the base estimation sequence, or equivalently, spreading the base channel estimation sequence with a sequence of [1 1 1 1 1 1]. Mathematically, the channel estimation sequence portion of the Standard preamble can be written as:

$$s_{sync,n}[k] = s_{est}[k], \quad (4)$$

where $n \in [N_{pf}, N_{sync} - 1]$, $k \in [0, N_{SYM} - 1]$, N_{pf} is defined in Table 3 and N_{SYM} is defined in Table 2.

The packet/frame synchronization sequence can be used for packet acquisition and detection, coarse carrier frequency estimation, coarse symbol timing, and for synchronization within the preamble. Whereas, the channel estimation sequence can be used for estimation of the channel frequency response, fine carrier frequency estimation, and fine symbol timing. The first sample of the first channel estimation symbol, $s_{sync,N_{pf}}[0]$, shall be used as the timing reference point for range measurements, as described in Clause 14.

The time-domain sequences in Table 4 through Table 10 and the frequency-domain channel estimation sequence defined in Table 23 should be normalized (as needed) to ensure that these sequences have the same average power as the PLCP header and the PSDU.

10.2.2 Burst PLCP preamble

The burst PLCP preamble, which is defined in Figure 9, is similar in structure to the Standard PLCP preamble. This preamble can also be sub-divided into two distinct portions: a packet/frame synchronization sequence and a channel estimation sequence. The packet/frame synchronization sequence shall be constructed as defined in Figure 10:

1. For a given time-frequency code, select the appropriate base time-domain sequence $s_{base}[l]$ from Table 4 through Table 10 and the appropriate burst cover sequence $s_{cover}[m]$ from Table 22.
2. Form an extended time-domain sequence $s_{ext}[l]$ by appending N_{ZPS} "zero samples" to the length N_{FFT} sequence $s_{base}[l]$.
3. The k^{th} sample of the n^{th} symbol in the burst preamble $s_{sync,n}[k]$, corresponding to the packet/frame synchronization sequence, is given by:

$$s_{sync,n}[k] = s_{cover}[n] \times s_{ext}[k], \quad (5)$$

where $n \in [0, N_{pf} - 1]$, $k \in [0, N_{SYM} - 1]$, N_{pf} is defined in Table 3 and N_{SYM} is defined in Table 2.

The construction method used to create the channel estimation sequence portion of the burst preamble is identical to the method used to construct the channel estimation sequence portion of the Standard preamble. Mathematically, the channel estimation sequence portion of the burst preamble can be written as:

$$s_{sync,n}[k] = s_{est}[k], \quad (6)$$

where $n \in [N_{pf}, N_{sync} - 1]$, $k \in [0, N_{SYM} - 1]$, N_{pf} is defined in Table 3 and N_{SYM} is defined in Table 2.

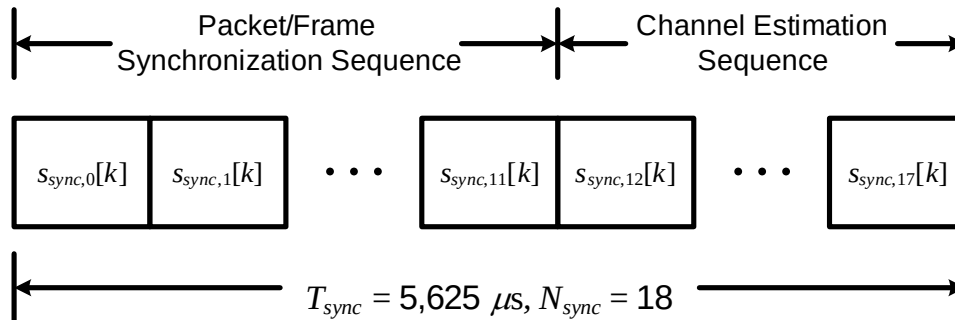


Figure 9 - Block diagram of the burst PLCP preamble

The time-domain sequences for TF codes 1-7, defined in Table 4 through Table 10, have been spectrally flattened for a 4,125 MHz resolution bandwidth. The time-domain sequences for TF codes 8-10, defined in Table 11 through Table 13, have been flattened for a 1 MHz resolution bandwidth. Alternate base time-domain sequences for TF codes 1-7, which are flattened for a 1 MHz resolution bandwidth, are defined in Table 14 through Table 20. Devices using TF codes 1-7 shall use time-domain sequences in Table 4 through Table 10 or the sequences in Table 14 through Table 20.

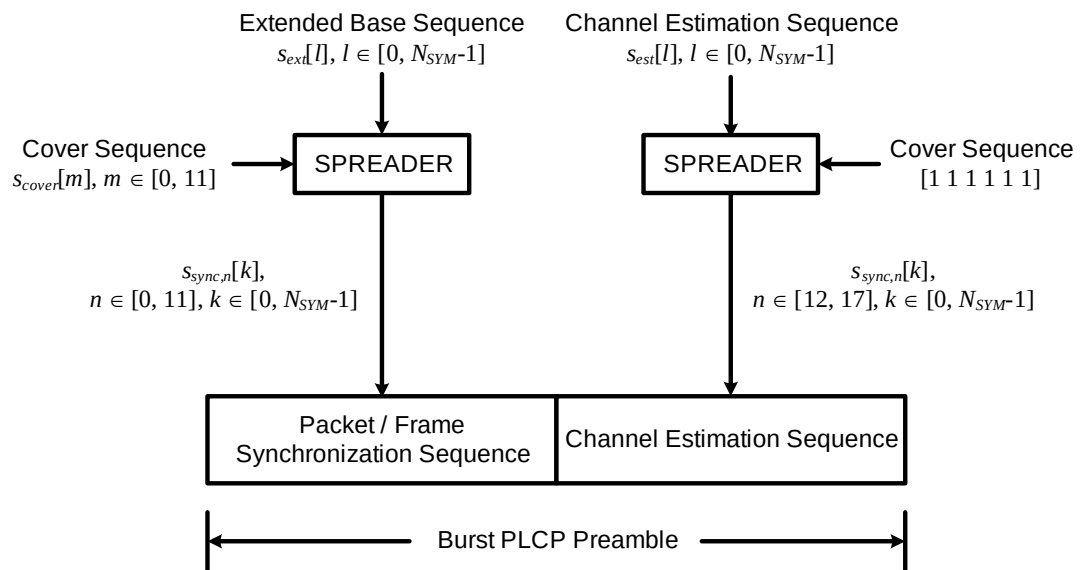


Figure 10 - Block diagram of burst PLCP preamble construction

Table 4 - Base time-domain sequence for TF code 1

l	$s_{base}[l]$	l	$s_{base}[l]$	l	$s_{base}[l]$	l	$s_{base}[l]$
0	0,656 4	32	-0,084 4	64	-0,209 5	96	0,423 2
1	-1,367 1	33	1,197 4	65	1,164 0	97	-1,268 4
2	-0,995 8	34	1,226 1	66	1,233 4	98	-1,815 1
3	-1,398 1	35	1,440 1	67	1,533 8	99	-1,482 9
4	0,848 1	36	-0,598 8	68	-0,884 4	100	1,030 2
5	1,089 2	37	-0,467 5	69	-0,385 7	101	0,941 9
6	-0,862 1	38	0,852 0	70	0,773 0	102	-1,147 2
7	1,151 2	39	-0,892 2	71	-0,975 4	103	1,485 8
8	0,960 2	40	-0,560 3	72	-0,231 5	104	-0,679 4
9	-1,358 1	41	1,188 6	73	0,557 9	105	0,957 3
10	-0,835 4	42	1,112 8	74	0,403 5	106	1,080 7
11	-1,324 9	43	1,083 3	75	0,424 8	107	1,144 5
12	1,096 4	44	-0,907 3	76	-0,335 9	108	-1,231 2
13	1,333 4	45	-1,622 7	77	-0,991 4	109	-0,664 3
14	-0,737 8	46	1,001 3	78	0,597 5	110	0,383 6
15	1,356 5	47	-1,606 7	79	-0,840 8	111	-1,148 2
16	0,936 1	48	0,336 0	80	0,358 7	112	-0,035 3
17	-0,821 2	49	-1,313 6	81	-0,960 4	113	-0,674 7
18	-0,266 2	50	-1,444 7	82	-1,000 2	114	-1,165 3
19	-0,686 6	51	-1,723 8	83	-1,163 6	115	-0,889 6
20	0,843 7	52	1,028 7	84	0,959 0	116	0,241 4
21	1,123 7	53	0,610 0	85	0,713 7	117	0,116 0
22	-0,326 5	54	-0,923 7	86	-0,677 6	118	-0,698 7
23	1,051 1	55	1,261 8	87	0,982 4	119	0,478 1
24	0,792 7	56	0,597 4	88	-0,545 4	120	0,182 1
25	-0,336 3	57	-1,097 6	89	1,102 2	121	-1,067 2
26	-0,134 2	58	-0,977 6	90	1,648 5	122	-0,967 6
27	-0,154 6	59	-0,998 2	91	1,330 7	123	-1,232 1
28	0,695 5	60	0,896 7	92	-1,285 2	124	0,500 3
29	1,060 8	61	1,764 0	93	-1,265 9	125	0,741 9
30	-0,160 0	62	-1,021 1	94	0,943 5	126	-0,893 4
31	0,944 2	63	1,691 3	95	-1,680 9	127	0,839 1

Table 5 - Base time-domain sequence for TF code 2

l	$s_{base}[l]$	l	$s_{base}[l]$	l	$s_{base}[l]$	l	$s_{base}[l]$
0	0,967 9	32	-1,290 5	64	1,528 0	96	0,519 3
1	-1,018 6	33	1,104 0	65	-0,919 3	97	-0,343 9
2	0,488 3	34	-1,240 8	66	1,124 6	98	0,142 8
3	0,543 2	35	-0,806 2	67	1,262 2	99	0,625 1
4	-1,470 2	36	1,542 5	68	-1,440 6	100	-1,046 8
5	-1,450 7	37	1,095 5	69	-1,492 9	101	-0,579 8
6	-1,175 2	38	1,428 4	70	-1,150 8	102	-0,823 7
7	-0,073 0	39	-0,459 3	71	0,412 6	103	0,266 7
8	-1,244 5	40	-1,040 8	72	-1,046 2	104	-0,956 4
9	0,314 3	41	1,054 2	73	0,723 2	105	0,601 6
10	-1,395 1	42	-0,444 6	74	-1,157 4	106	-0,996 4
11	-0,969 4	43	-0,792 9	75	-0,710 2	107	-0,354 1
12	0,456 3	44	1,673 3	76	0,850 2	108	0,396 5
13	0,307 3	45	1,756 8	77	0,626 0	109	0,520 1
14	0,640 8	46	1,327 3	78	0,953 0	110	0,473 3
15	-0,979 8	47	-0,246 5	79	-0,497 1	111	-0,236 2
16	-1,411 6	48	1,685 0	80	-0,863 3	112	-0,689 2
17	0,603 8	49	-0,709 1	81	0,691 0	113	0,478 7
18	-1,386 0	50	1,139 6	82	-0,363 9	114	-0,260 5
19	-1,088 8	51	1,511 4	83	-0,887 4	115	-0,588 7
20	1,103 6	52	-1,434 3	84	1,531 1	116	0,941 1
21	0,706 7	53	-1,500 5	85	1,154 6	117	0,736 4
22	1,166 7	54	-1,257 2	86	1,193 5	118	0,671 4
23	-1,022 5	55	0,827 4	87	-0,293 0	119	-0,174 6
24	-1,247 1	56	-1,514 0	88	1,328 5	120	1,177 6
25	0,778 8	57	1,142 1	89	-0,723 1	121	-0,880 3
26	-1,271 6	58	-1,013 5	90	1,283 2	122	1,254 2
27	-0,874 5	59	-1,065 7	91	0,787 8	123	0,511 1
28	1,217 5	60	1,407 3	92	-0,809 5	124	-0,820 9
29	0,841 9	61	1,819 6	93	-0,746 3	125	-0,897 5
30	1,288 1	62	1,167 9	94	-0,897 3	126	-0,909 1
31	-0,821 0	63	-0,413 1	95	0,556 0	127	0,256 2

Table 6 - Base time-domain sequence for TF code 3

l	$s_{base}[l]$	l	$s_{base}[l]$	l	$s_{base}[l]$	l	$s_{base}[l]$
0	0,404 7	32	-0,967 1	64	-0,729 8	96	0,242 4
1	0,579 9	33	-0,981 9	65	-0,966 2	97	0,570 3
2	-0,340 7	34	0,798 0	66	0,969 4	98	-0,638 1
3	0,434 3	35	-0,815 8	67	-0,805 3	99	0,786 1
4	0,097 3	36	-0,918 8	68	-0,905 2	100	0,917 5
5	-0,763 7	37	1,514 6	69	1,593 3	101	-0,459 5
6	-0,618 1	38	0,813 8	70	0,841 8	102	-0,220 1
7	-0,653 9	39	1,377 3	71	1,536 3	103	-0,775 5
8	0,376 8	40	0,210 8	72	0,308 5	104	-0,296 5
9	0,724 1	41	0,924 5	73	1,301 6	105	-1,122 0
10	-1,209 5	42	-1,213 8	74	-1,554 6	106	1,715 2
11	0,602 7	43	1,125 2	75	1,534 7	107	-1,275 6
12	0,458 7	44	0,966 3	76	1,093 5	108	-0,773 1
13	-1,387 9	45	-0,841 8	77	-0,897 8	109	1,072 4
14	-1,059 2	46	-0,681 1	78	-0,971 2	110	1,173 3
15	-1,405 2	47	-1,300 3	79	-1,376 3	111	1,471 1
16	-0,843 9	48	-0,339 7	80	-0,636 0	112	0,488 1
17	-1,599 2	49	-1,105 1	81	-1,294 7	113	0,752 8
18	1,197 5	50	1,240 0	82	1,643 6	114	-0,641 7
19	-1,952 5	51	-1,397 5	83	-1,656 4	115	1,036 3
20	-1,514 1	52	-0,746 7	84	-1,198 1	116	0,800 2
21	0,721 9	53	0,270 6	85	0,871 9	117	-0,007 7
22	0,698 2	54	0,729 4	86	0,999 2	118	-0,233 6
23	1,292 4	55	0,744 4	87	1,487 2	119	-0,465 3
24	-0,946 0	56	-0,397 0	88	-0,458 6	120	0,686 2
25	-1,240 7	57	-1,071 8	89	-0,840 4	121	1,271 6
26	0,457 2	58	0,664 6	90	0,698 2	122	-0,888 0
27	-1,215 1	59	-1,103 7	91	-0,795 9	123	1,401 1
28	-0,986 9	60	-0,571 6	92	-0,569 2	124	0,953 1
29	1,279 2	61	0,900 1	93	1,352 8	125	-1,121 0
30	0,688 2	62	0,731 7	94	0,953 6	126	-0,948 9
31	1,258 6	63	0,984 6	95	1,178 4	127	-1,256 6

Table 7 - Base time-domain sequence for TF code 4

l	$s_{base}[l]$	l	$s_{base}[l]$	l	$s_{base}[l]$	l	$s_{base}[l]$
0	1,154 9	32	-1,238 5	64	1,309 5	96	-1,009 4
1	1,007 9	33	-0,788 3	65	0,667 5	97	-0,759 8
2	0,735 6	34	-0,795 4	66	1,258 7	98	-1,078 6
3	-0,743 4	35	1,087 4	67	-0,999 3	99	0,669 9
4	-1,393 0	36	1,149 1	68	-1,005 2	100	0,981 3
5	1,281 8	37	-1,478 0	69	0,660 1	101	-0,556 3
6	-1,103 3	38	0,887 0	70	-1,022 8	102	1,054 8
7	-0,252 3	39	0,469 4	71	-0,748 9	103	0,892 5
8	-0,790 5	40	1,506 6	72	0,508 6	104	-1,365 6
9	-0,426 1	41	1,126 6	73	0,156 3	105	-0,847 2
10	-0,939 0	42	0,993 5	74	0,067 3	106	-1,311 0
11	0,434 5	43	-1,246 2	75	-0,837 5	107	1,189 7
12	0,443 3	44	-1,786 9	76	-1,074 6	108	1,512 7
13	-0,307 6	45	1,746 2	77	0,445 4	109	-0,747 4
14	0,564 4	46	-1,488 1	78	-0,783 1	110	1,467 8
15	0,257 1	47	-0,409 0	79	-0,362 3	111	1,029 5
16	-1,003 0	48	-1,469 4	80	-1,365 8	112	-0,921 0
17	-0,782 0	49	-0,792 3	81	-1,085 4	113	-0,478 4
18	-0,406 4	50	-1,460 7	82	-1,492 3	114	-0,502 2
19	0,903 5	51	0,911 3	83	0,423 3	115	1,215 3
20	1,540 6	52	0,845 4	84	0,674 1	116	1,578 3
21	-1,461 3	53	-0,886 6	85	-1,015 7	117	-0,771 8
22	1,274 5	54	0,885 2	86	0,830 4	118	1,238 4
23	0,371 5	55	0,491 8	87	0,487 8	119	0,669 5
24	1,813 4	56	-0,609 6	88	-1,499 2	120	0,882 1
25	0,943 8	57	-0,432 2	89	-1,188 4	121	0,780 8
26	1,313 0	58	-0,132 7	90	-1,400 8	122	1,053 7
27	-1,307 0	59	0,495 3	91	0,779 5	123	-0,079 1
28	-1,346 2	60	0,970 2	92	1,292 6	124	-0,284 5
29	1,686 8	61	-0,866 7	93	-1,204 9	125	0,579 0
30	-1,215 3	62	0,680 3	94	1,293 4	126	-0,466 4
31	-0,677 8	63	-0,024 4	95	0,812 3	127	-0,109 7

Table 8 - Base time-domain sequence for TF code 5

l	$s_{base}[l]$	l	$s_{base}[l]$	l	$s_{base}[l]$	l	$s_{base}[l]$
0	0,957 4	32	0,840 0	64	0,585 9	96	-0,852 8
1	0,527 0	33	1,398 0	65	0,305 3	97	-0,697 3
2	1,592 9	34	1,114 7	66	0,894 8	98	-1,247 7
3	-0,250 0	35	-0,473 2	67	-0,674 4	99	0,624 6
4	-0,253 6	36	-1,717 8	68	-0,890 1	100	0,768 7
5	-0,302 3	37	-0,847 7	69	-0,813 3	101	0,796 6
6	1,290 7	38	1,508 3	70	0,920 1	102	-1,280 9
7	-0,425 8	39	-1,436 4	71	-1,084 1	103	1,102 3
8	1,001 2	40	0,385 3	72	-0,803 6	104	0,425 0
9	1,770 4	41	1,567 3	73	-0,310 5	105	-0,161 4
10	0,859 3	42	0,029 5	74	-1,051 4	106	0,754 7
11	-0,371 9	43	-0,420 4	75	0,764 4	107	-0,669 6
12	-1,346 5	44	-1,485 6	76	0,730 1	108	-0,392 0
13	-0,741 9	45	-0,840 4	77	0,978 8	109	-0,758 9
14	1,535 0	46	1,011 1	78	-1,130 5	110	0,670 1
15	-1,280 0	47	-1,426 9	79	1,325 7	111	-0,938 1
16	0,695 5	48	0,303 3	80	0,780 1	112	-0,748 3
17	1,720 4	49	0,775 7	81	0,786 7	113	-0,965 9
18	0,164 3	50	-0,137 0	82	1,099 6	114	-0,919 2
19	-0,334 7	51	-0,525 0	83	-0,562 3	115	0,392 5
20	-1,724 4	52	-1,158 9	84	-1,222 7	116	1,286 4
21	-0,744 7	53	-0,832 4	85	-0,822 3	117	0,678 4
22	1,114 1	54	0,633 6	86	1,207 4	118	-1,090 9
23	-1,354 1	55	-1,269 8	87	-1,233 8	119	1,114 0
24	-0,729 3	56	-0,785 3	88	0,295 7	120	-0,613 4
25	0,268 2	57	-0,703 1	89	1,099 9	121	-1,546 7
26	-1,240 1	58	-1,110 6	90	-0,020 1	122	-0,303 1
27	1,052 7	59	0,607 1	91	-0,586 0	123	0,945 7
28	0,119 9	60	0,716 4	92	-1,228 4	124	1,964 5
29	1,149 6	61	0,830 5	93	-0,921 5	125	1,454 9
30	-1,054 4	62	-1,235 5	94	0,794 1	126	-1,276 0
31	1,317 6	63	1,175 4	95	-1,412 8	127	2,210 2

Table 9 - Base time-domain sequence for TF code 6

l	$s_{base}[l]$	l	$s_{base}[l]$	l	$s_{base}[l]$	l	$s_{base}[l]$
0	1,294 7	32	-0,997 3	64	1,070 3	96	0,951 6
1	-0,818 8	33	0,854 8	65	-0,862 5	97	-1,259 3
2	0,900 7	34	-0,696 3	66	0,698 6	98	0,459 4
3	0,778 6	35	-0,687 4	67	1,098 9	99	1,303 8
4	0,630 1	36	-0,501 5	68	0,460 0	100	0,109 0
5	-0,128 3	37	0,700 3	69	-0,655 9	101	-0,508 2
6	-0,797 2	38	0,358 2	70	-0,608 7	102	-1,818 1
7	-0,389 7	39	0,577 2	71	-0,420 6	103	-0,774 7
8	1,179 4	40	0,742 1	72	-0,845 4	104	0,767 8
9	-1,259 2	41	-0,676 6	73	1,031 7	105	-1,534 2
10	0,813 6	42	0,624 2	74	-0,762 4	106	0,491 4
11	0,887 2	43	0,424 1	75	0,061 9	107	0,719 7
12	0,579 7	44	0,589 1	76	-0,731 1	108	0,335 3
13	-1,230 4	45	-0,904 5	77	1,363 4	109	-1,583 2
14	-0,562 8	46	0,162 5	78	-0,137 9	110	-0,994 7
15	-0,827 2	47	-0,510 5	79	0,840 1	111	-1,032 9
16	-1,541 8	48	-1,418 7	80	1,637 1	112	-1,966 9
17	1,280 4	49	1,516 9	81	-1,020 1	113	0,994 6
18	-1,152 4	50	-0,958 0	82	0,924 3	114	-1,327 3
19	-0,984 6	51	-1,123 7	83	2,093 1	115	-1,557 2
20	-0,917 8	52	-0,678 2	84	0,451 1	116	-0,874 6
21	1,183 4	53	1,355 7	85	0,076 8	117	0,057 9
22	0,429 3	54	1,022 9	86	-1,797 4	118	1,226 9
23	0,902 1	55	0,949 0	87	-0,468 5	119	0,449 7
24	1,115 2	56	1,630 8	88	1,472 7	120	-1,475 1
25	-0,982 8	57	-0,932 5	89	-1,338 7	121	1,389 7
26	0,789 1	58	1,146 1	90	0,777 9	122	-0,992 2
27	0,939 1	59	1,167 5	91	2,008 0	123	-1,295 0
28	0,594 4	60	0,816 3	92	0,302 6	124	-0,683 9
29	-0,837 6	61	-0,155 1	93	-0,426 3	125	1,211 3
30	-0,532 0	62	-0,865 7	94	-1,975 1	126	1,055 9
31	-0,633 5	63	-0,369 6	95	-0,842 1	127	0,814 7

Table 10 - Base time-domain sequence for TF code 7

l	$s_{base}[l]$	l	$s_{base}[l]$	l	$s_{base}[l]$	l	$s_{base}[l]$
0	0,814 7	32	-0,842 1	64	-0,369 6	96	-0,633 5
1	1,055 9	33	-1,975 1	65	-0,865 7	97	-0,532 0
2	1,211 3	34	-0,426 3	66	-0,155 1	98	-0,837 6
3	-0,683 9	35	0,302 6	67	0,816 3	99	0,594 4
4	-1,295 0	36	2,008 0	68	1,167 5	100	0,939 1
5	-0,992 2	37	0,777 9	69	1,146 1	101	0,789 1
6	1,389 7	38	-1,338 7	70	-0,932 5	102	-0,982 8
7	-1,475 1	39	1,472 7	71	1,630 8	103	1,115 2
8	0,449 7	40	-0,468 5	72	0,949 0	104	0,902 1
9	1,226 9	41	-1,797 4	73	1,022 9	105	0,429 3
10	0,057 9	42	0,076 8	74	1,355 7	106	1,183 4
11	-0,874 6	43	0,451 1	75	-0,678 2	107	-0,917 8
12	-1,557 2	44	2,093 1	76	-1,123 7	108	-0,984 6
13	-1,327 3	45	0,924 3	77	-0,958 0	109	-1,152 4
14	0,994 6	46	-1,020 1	78	1,516 9	110	1,280 4
15	-1,966 9	47	1,637 1	79	-1,418 7	111	-1,541 8
16	-1,032 9	48	0,840 1	80	-0,510 5	112	-0,827 2
17	-0,994 7	49	-0,137 9	81	0,162 5	113	-0,562 8
18	-1,583 2	50	1,363 4	82	-0,904 5	114	-1,230 4
19	0,335 3	51	-0,731 1	83	0,589 1	115	0,579 7
20	0,719 7	52	0,061 9	84	0,424 1	116	0,887 2
21	0,491 4	53	-0,762 4	85	0,624 2	117	0,813 6
22	-1,534 2	54	1,031 7	86	-0,676 6	118	-1,259 2
23	0,767 8	55	-0,845 4	87	0,742 1	119	1,179 4
24	-0,774 7	56	-0,420 6	88	0,577 2	120	-0,389 7
25	-1,818 1	57	-0,608 7	89	0,358 2	121	-0,797 2
26	-0,508 2	58	-0,655 9	90	0,700 3	122	-0,128 3
27	0,109 0	59	0,460 0	91	-0,501 5	123	0,630 1
28	1,303 8	60	1,098 9	92	-0,687 4	124	0,778 6
29	0,459 4	61	0,698 6	93	-0,696 3	125	0,900 7
30	-1,259 3	62	-0,862 5	94	0,854 8	126	-0,818 8
31	0,951 6	63	1,070 3	95	-0,997 3	127	1,294 7

Table 11 - Base time-domain sequence for TF code 8

<i>l</i>	<i>sbase[l]</i>	<i>l</i>	<i>sbase[l]</i>	<i>l</i>	<i>sbase[l]</i>	<i>l</i>	<i>sbase[l]</i>
0	-1,541 8	32	1,599 1	64	1,272 4	96	-1,085 3
1	-1,869 3	33	0,981 5	65	1,182 6	97	-1,157 8
2	0,737 6	34	-0,397 2	66	-1,062 4	98	0,500 2
3	0,705 3	35	-0,635 9	67	-0,870 3	99	0,783 7
4	-0,389 4	36	0,995 2	68	0,678 5	100	-0,540 0
5	0,151 3	37	-0,720 2	69	-0,960 8	101	0,428 9
6	-0,880 5	38	0,776 5	70	0,480 1	102	-0,610 1
7	-0,377 9	39	-0,565 1	71	-0,794 7	103	0,417 0
8	-1,961 0	40	-0,850 1	72	-0,835 3	104	-1,676 4
9	-2,446 4	41	-0,726 7	73	-0,782 2	105	-1,307 0
10	1,854 8	42	0,799 5	74	0,495 3	106	1,419 8
11	1,366 2	43	0,710 0	75	0,506 8	107	1,120 1
12	-0,356 1	44	-0,365 7	76	-0,389 2	108	-1,063 0
13	0,681 6	45	1,182 5	77	0,345 5	109	1,633 5
14	-0,874 5	46	-0,220 9	78	-0,337 1	110	-0,419 7
15	0,145 1	47	0,913 3	79	0,232 7	111	1,450 9
16	-1,292 6	48	1,355 6	80	-0,401 3	112	1,400 5
17	-1,922 8	49	1,378 1	81	-0,382 6	113	1,318 7
18	2,112 7	50	-0,867 7	82	0,422 4	114	-1,205 1
19	1,323 3	51	-0,601 8	83	0,122 6	115	-1,234 3
20	-0,149 2	52	0,749 4	84	-0,253 4	116	0,635 4
21	0,852 0	53	-1,151 0	85	0,504 9	117	-0,932 8
22	-0,309 7	54	0,385 6	86	-0,047 4	118	0,556 5
23	0,618 9	55	-0,823 5	87	0,319 7	119	-0,883 4
24	-0,492 3	56	-1,225 2	88	1,722 4	120	0,627 8
25	-0,970 4	57	-0,861 1	89	1,415 6	121	0,559 1
26	1,804 2	58	0,908 0	90	-1,265 0	122	-0,975 9
27	0,807 6	59	0,931 2	91	-1,249 4	123	-0,744 2
28	-0,041 8	60	-0,848 6	92	0,955 6	124	0,416 7
29	1,186 9	61	1,274 6	93	-1,622 7	125	-1,174 9
30	0,246 4	62	-0,450 0	94	0,454 0	126	-0,086 5
31	1,049 1	63	1,081 8	95	-1,370 0	127	-1,138 2

Table 12 - Base time-domain sequence for TF code 9

<i>l</i>	<i>sbase[l]</i>	<i>l</i>	<i>sbase[l]</i>	<i>l</i>	<i>sbase[l]</i>	<i>l</i>	<i>sbase[l]</i>
0	-0,450 4	32	1,503 3	64	0,795 4	96	1,319 6
1	-0,020 4	33	0,580 0	65	0,398 4	97	0,305 1
2	0,603 8	34	-1,132 4	66	-0,711 4	98	-1,417 7
3	0,003 7	35	0,885 8	67	0,311 2	99	0,435 8
4	0,545 4	36	-0,964 2	68	-0,584 5	100	-1,275 8
5	0,697 5	37	-1,750 0	69	-0,906 4	101	-1,653 4
6	0,985 9	38	-1,439 5	70	-0,695 6	102	-1,753 1
7	-0,303 2	39	0,815 0	71	0,374 1	103	0,552 2
8	1,038 8	40	-0,606 2	72	-0,398 1	104	-0,855 4
9	1,170 3	41	-1,347 9	73	-0,835 9	105	-1,237 7
10	-0,773 3	42	0,782 5	74	0,634 3	106	0,166 7
11	1,322 4	43	-1,343 7	75	-0,758 1	107	-1,573 9
12	-1,313 8	44	1,837 4	76	1,334 8	108	0,686 1
13	-1,396 5	45	1,434 8	77	0,690 2	109	1,013 4
14	-1,136 2	46	1,623 3	78	1,518 3	110	-0,074 2
15	1,104 8	47	-1,328 4	79	-1,070 4	111	-0,655 5
16	-0,363 5	48	0,946 1	80	1,325 0	112	-1,243 8
17	-0,886 9	49	1,293 5	81	1,020 8	113	-0,379 8
18	0,327 4	50	-0,317 1	82	-0,364 3	114	0,805 1
19	-0,691 7	51	1,464 7	83	1,406 8	115	-1,059 8
20	1,343 3	52	-1,265 1	84	-0,864 2	116	0,196 9
21	1,040 0	53	-1,289 4	85	-1,837 7	117	1,102 1
22	1,127 8	54	-0,210 3	86	0,060 4	118	0,073 9
23	-0,899 2	55	0,903 5	87	0,411 5	119	-0,008 6
24	0,916 0	56	1,076 7	88	1,693 3	120	-1,573 2
25	1,021 1	57	0,403 2	89	0,332 6	121	-0,606 3
26	-0,195 5	58	-1,128 7	90	-1,309 5	122	1,057 5
27	1,066 2	59	1,006 6	91	1,283 9	123	-0,819 0
28	-0,675 2	60	-0,369 2	92	-0,732 7	124	0,840 0
29	-0,987 6	61	-0,937 7	93	-1,962 3	125	1,708 4
30	0,160 0	62	-0,663 5	94	-0,870 1	126	0,751 4
31	0,413 7	63	0,284 2	95	0,192 7	127	-0,250 7

Table 13 - Base time-domain sequence for TF code 10

<i>l</i>	<i>sbase[l]</i>	<i>l</i>	<i>sbase[l]</i>	<i>l</i>	<i>sbase[l]</i>	<i>l</i>	<i>sbase[l]</i>
0	-0,809 9	32	1,028 7	64	-0,091 1	96	-0,704 8
1	0,816 6	33	-1,775 5	65	0,038 7	97	0,163 2
2	0,398 2	34	-2,049 8	66	-0,458 7	98	1,589 6
3	0,825 9	35	-1,220 7	67	0,142 6	99	1,053 1
4	-0,763 4	36	1,113 5	68	0,737 7	100	-1,793 1
5	0,160 7	37	-1,505 3	69	-0,685 3	101	0,573 8
6	-0,649 1	38	0,700 0	70	0,152 5	102	-1,422 5
7	0,006 2	39	1,746 8	71	0,818 2	103	-1,475 1
8	0,339 3	40	0,528 4	72	1,092 1	104	0,682 5
9	-1,080 1	41	-0,089 1	73	-0,464 2	105	-1,705 3
10	-1,385 2	42	-1,588 6	74	-1,231 7	106	-1,138 5
11	-0,541 0	43	-0,876 9	75	-1,270 4	107	-1,284 0
12	0,663 0	44	1,466 2	76	1,869 0	108	0,291 5
13	-1,148 5	45	-0,545 1	77	-0,557 7	109	-1,058 3
14	0,113 1	46	1,070 8	78	1,686 5	110	0,393 5
15	1,172 7	47	1,476 5	79	1,141 3	111	0,771 8
16	0,822 7	48	-0,832 1	80	-0,564 0	112	-0,086 3
17	-0,429 8	49	1,271 6	81	1,686 9	113	-0,459 3
18	-1,778 5	50	0,387 8	82	1,690 4	114	-0,853 3
19	-1,382 6	51	1,135 1	83	1,388 6	115	-0,223 6
20	1,538 5	52	-0,477 3	84	-0,604 9	116	0,330 8
21	-0,579 1	53	0,423 9	85	1,370 8	117	-0,670 4
22	1,416 8	54	-0,720 4	86	-0,530 6	118	-0,172 9
23	1,144 5	55	0,116 2	87	-1,365 7	119	0,740 0
24	-1,294 2	56	0,465 7	88	0,040 4	120	0,220 6
25	1,520 8	57	-0,564 4	89	0,411 1	121	-0,182 5
26	1,332 4	58	-1,311 7	90	1,228 4	122	-1,356 7
27	1,542 7	59	-0,656 9	91	0,348 9	123	-0,694 7
28	-1,066 3	60	0,590 8	92	-1,041 0	124	0,658 6
29	0,365 6	61	-0,639 9	93	1,100 2	125	-0,306 6
30	-1,089 1	62	0,663 8	94	-0,246 7	126	0,482 3
31	-0,434 0	63	1,218 3	95	-1,372 0	127	0,876 6

Table 14 - Alternate base time-domain sequence for TF code 1

<i>l</i>	<i>sbase[l]</i>	<i>l</i>	<i>sbase[l]</i>	<i>l</i>	<i>sbase[l]</i>	<i>l</i>	<i>sbase[l]</i>
0	0,720 5	32	0,054 5	64	-0,227 3	96	0,379 9
1	-1,552 6	33	1,048 5	65	1,104 4	97	-1,174 6
2	-1,260 4	34	1,181 0	66	1,158 1	98	-1,701 1
3	-1,564 0	35	1,358 3	67	1,521 1	99	-1,431 9
4	0,972 3	36	-0,535 5	68	-0,895 4	100	0,966 6
5	1,366 4	37	-0,366 3	69	-0,352 3	101	0,796 3
6	-1,068 0	38	0,805 2	70	0,741 1	102	-1,071 0
7	1,428 1	39	-0,835 7	71	-0,926 7	103	1,327 7
8	0,972 2	40	-0,514 7	72	-0,315 7	104	-0,675 4
9	-1,368 0	41	1,141 6	73	0,666 7	105	0,907 4
10	-0,820 3	42	1,116 5	74	0,471 0	106	1,069 9
11	-1,297 5	43	1,027 9	75	0,490 8	107	1,087 0
12	1,035 9	44	-0,880 0	76	-0,410 6	108	-1,195 6
13	1,398 5	45	-1,653 8	77	-1,072 5	109	-0,727 8
14	-0,781 3	46	0,994 9	78	0,631 5	110	0,427 0
15	1,338 8	47	-1,629 9	79	-0,926 8	111	-1,194 4
16	1,046 2	48	0,247 4	80	0,467 0	112	0,051 9
17	-1,054 8	49	-1,196 4	81	-1,165 5	113	-0,737 2
18	-0,491 7	50	-1,310 9	82	-1,218 4	114	-1,162 6
19	-0,897 3	51	-1,610 9	83	-1,327 9	115	-0,921 0
20	0,961 4	52	0,900 0	84	1,113 6	116	0,377 9
21	1,297 4	53	0,419 1	85	0,953 1	117	0,177 5
22	-0,489 5	54	-0,834 1	86	-0,813 9	118	-0,631 0
23	1,2113	55	1,0763	87	1,2429	119	0,5395
24	0,9397	56	0,4772	88	-0,4808	120	0,1006
25	-0,5617	57	-1,0323	89	1,0782	121	-0,6751
26	-0,2846	58	-0,9790	90	1,6726	122	-0,4944
27	-0,2956	59	-0,9650	91	1,3107	123	-0,7774
28	0,8050	60	0,8004	92	-1,2466	124	0,3183
29	1,2805	61	1,6412	93	-1,1728	125	0,4327
30	-0,2843	62	-1,0196	94	0,9184	126	-0,5049
31	1,0961	63	1,5773	95	-1,6176	127	0,4425

Table 15 - Alternate base time-domain sequence for TF code 2

<i>l</i>	<i>sbase[l]</i>	<i>l</i>	<i>sbase[l]</i>	<i>l</i>	<i>sbase[l]</i>	<i>l</i>	<i>sbase[l]</i>
0	0,808 0	32	-1,357 7	64	1,574 2	96	0,512 7
1	-0,858 1	33	1,104 1	65	-1,014 4	97	-0,418 3
2	0,410 3	34	-1,263 9	66	1,133 5	98	0,136 9
3	0,375 0	35	-0,829 2	67	1,298 4	99	0,617 9
4	-1,145 3	36	1,555 8	68	-1,581 0	100	-1,128 7
5	-1,203 7	37	1,135 2	69	-1,624 1	101	-0,649 2
6	-0,910 0	38	1,455 2	70	-1,227 0	102	-0,842 0
7	-0,138 3	39	-0,475 8	71	0,383 4	103	0,197 1
8	-0,910 3	40	-0,982 1	72	-1,222 5	104	-0,981 6
9	0,121 1	41	1,027 7	73	0,841 8	105	0,606 6
10	-1,080 7	42	-0,431 4	74	-1,357 3	106	-1,118 0
11	-0,798 4	43	-0,753 7	75	-0,845 7	107	-0,402 0
12	0,277 5	44	1,572 6	76	1,000 6	108	0,392 6
13	0,053 4	45	1,721 6	77	0,811 4	109	0,463 3
14	0,441 9	46	1,240 9	78	1,147 8	110	0,511 7
15	-0,888 5	47	-0,211 7	79	-0,571 5	111	-0,304 1
16	-1,406 6	48	1,626 2	80	-0,811 7	112	-0,915 6
17	0,581 5	49	-0,667 7	81	0,719 9	113	0,597 2
18	-1,386 9	50	1,115 7	82	-0,321 3	114	-0,437 6
19	-1,099 4	51	1,461 4	83	-0,887 7	115	-0,795 9
20	1,091 4	52	-1,385 2	84	1,568 8	116	1,187 9
21	0,675 0	53	-1,359 6	85	1,198 4	117	0,981 7
22	1,158 7	54	-1,163 2	86	1,176 0	118	0,942 4
23	-1,043 6	55	0,809 0	87	-0,248 2	119	-0,316 8
24	-1,349 9	56	-1,202 3	88	1,469 5	120	1,279 4
25	0,845 2	57	1,005 6	89	-0,849 4	121	-0,850 0
26	-1,359 5	58	-0,810 6	90	1,453 4	122	1,264 8
27	-0,936 7	59	-0,895 5	91	0,887 5	123	0,608 9
28	1,311 1	60	1,166 8	92	-0,955 6	124	-0,825 9
29	0,897 8	61	1,618 6	93	-0,921 2	125	-0,954 4
30	1,337 7	62	0,932 7	94	-1,075 1	126	-0,937 3
31	-0,842 0	63	-0,313 3	95	0,606 1	127	0,345 4

Table 16 - Alternate base time-domain sequence for TF code 3

<i>l</i>	<i>sbase[l]</i>	<i>l</i>	<i>sbase[l]</i>	<i>l</i>	<i>sbase[l]</i>	<i>l</i>	<i>sbase[l]</i>
0	0,484 2	32	-1,036 8	64	-0,749 8	96	0,292 2
1	0,776 1	33	-1,058 0	65	-1,040 8	97	0,650 5
2	-0,455 5	34	0,795 7	66	1,112 1	98	-0,723 8
3	0,641 1	35	-0,816 0	67	-0,893 1	99	0,833 9
4	0,232 9	36	-0,852 2	68	-1,019 1	100	0,923 1
5	-0,921 0	37	1,680 5	69	1,678 1	101	-0,688 5
6	-0,757 2	38	0,962 6	70	0,839 7	102	-0,369 0
7	-0,815 4	39	1,457 5	71	1,654 4	103	-0,920 6
8	0,384 6	40	0,253 5	72	0,158 3	104	-0,252 6
9	0,672 6	41	0,934 7	73	1,215 0	105	-1,099 8
10	-1,027 0	42	-1,167 6	74	-1,537 7	106	1,728 9
11	0,454 9	43	1,188 7	75	1,487 0	107	-1,364 2
12	0,293 6	44	1,097 9	76	0,997 7	108	-0,934 3
13	-1,397 7	45	-0,738 5	77	-0,752 6	109	0,948 9
14	-1,020 9	46	-0,566 2	78	-0,930 2	110	1,075 4
15	-1,268 6	47	-1,275 6	79	-1,243 8	111	1,461 9
16	-0,791 5	48	-0,249 7	80	-0,667 7	112	0,480 8
17	-1,518 5	49	-1,020 3	81	-1,303 6	113	0,823 0
18	1,084 6	50	1,199 2	82	1,721 9	114	-0,909 0
19	-1,913 5	51	-1,229 1	83	-1,717 1	115	1,090 2
20	-1,517 2	52	-0,553 1	84	-1,259 9	116	0,799 8
21	0,650 1	53	0,257 7	85	0,884 6	117	-0,188 4
22	0,640 4	54	0,784 8	86	1,025 3	118	-0,351 7
23	1,247 0	55	0,697 2	87	1,541 2	119	-0,605 6
24	-1,002 5	56	-0,067 2	88	-0,460 7	120	0,672 4
25	-1,319 8	57	-0,666 1	89	-0,896 2	121	1,187 4
26	0,512 4	58	0,402 0	90	0,846 5	122	-0,893 7
27	-1,301 7	59	-0,728 4	91	-0,909 2	123	1,234 2
28	-1,058 1	60	-0,243 8	92	-0,670 0	124	0,862 8
29	1,403 4	61	0,575 5	93	1,378 7	125	-1,105 9
30	0,784 4	62	0,491 9	94	0,979 7	126	-0,856 4
31	1,376 1	63	0,614 4	95	1,240 7	127	-1,188 7

Table 17 - Alternate base time-domain sequence for TF code 4

<i>l</i>	<i>sbase[l]</i>	<i>l</i>	<i>sbase[l]</i>	<i>l</i>	<i>sbase[l]</i>	<i>l</i>	<i>sbase[l]</i>
0	0,942 3	32	-1,005 4	64	1,325 4	96	-0,968 7
1	0,787 9	33	-0,672 2	65	0,764 0	97	-0,724 5
2	0,563 4	34	-0,628 5	66	1,428 5	98	-1,030 7
3	-0,587 3	35	0,948 1	67	-0,986 5	99	0,640 9
4	-1,103 8	36	0,989 5	68	-1,016 8	100	0,935 5
5	0,996 1	37	-1,371 7	69	0,691 0	101	-0,469 3
6	-0,861 1	38	0,727 0	70	-1,069 7	102	1,032 3
7	-0,171 3	39	0,364 0	71	-0,770 7	103	0,930 0
8	-0,609 3	40	1,504 4	72	0,797 4	104	-1,427 2
9	-0,320 9	41	1,105 5	73	0,353 0	105	-0,854 4
10	-0,768 2	42	0,952 6	74	0,274 1	106	-1,407 2
11	0,330 1	43	-1,303 8	75	-1,072 8	107	1,275 8
12	0,316 6	44	-1,856 8	76	-1,382 3	108	1,529 2
13	-0,156 5	45	1,791 1	77	0,750 2	109	-0,794 1
14	0,402 8	46	-1,518 1	78	-1,081 9	110	1,506 0
15	0,190 9	47	-0,390 8	79	-0,535 4	111	1,105 2
16	-1,030 3	48	-1,693 6	80	-1,579 3	112	-0,866 8
17	-0,746 2	49	-0,943 1	81	-1,217 7	113	-0,407 1
18	-0,412 3	50	-1,686 6	82	-1,612 4	114	-0,506 1
19	0,915 7	51	1,059 8	83	0,522 1	115	1,187 0
20	1,491 8	52	1,029 6	84	0,852 9	116	1,466 0
21	-1,388 6	53	-1,061 6	85	-1,174 5	117	-0,730 6
22	1,216 7	54	1,090 1	86	0,993 5	118	1,152 4
23	0,378 8	55	0,613 1	87	0,509 1	119	0,663 2
24	1,695 3	56	-0,630 7	88	-1,407 9	120	0,857 7
25	0,911 6	57	-0,458 3	89	-1,164 9	121	0,773 3
26	1,267 0	58	-0,146 6	90	-1,266 2	122	0,980 3
27	-1,203 2	59	0,546 4	91	0,732 9	123	-0,123 5
28	-1,222 2	60	1,047 6	92	1,308 0	124	-0,345 9
29	1,584 7	61	-0,873 5	93	-1,176 9	125	0,663 1
30	-1,079 1	62	0,658 9	94	1,255 5	126	-0,526 2
31	-0,621 8	63	-0,071 7	95	0,758 0	127	-0,139 5

Table 18 - Alternate base time-domain sequence for TF code 5

<i>l</i>	<i>sbase[l]</i>	<i>l</i>	<i>sbase[l]</i>	<i>l</i>	<i>sbase[l]</i>	<i>l</i>	<i>sbase[l]</i>
0	0,780 5	32	0,953 5	64	0,580 6	96	-0,873 9
1	0,599 4	33	1,154 5	65	-0,048 3	97	-0,369 7
2	1,439 2	34	1,248 8	66	1,033 7	98	-1,300 3
3	-0,049 2	35	-0,520 4	67	-0,732 5	99	0,725 3
4	-0,306 2	36	-1,576 9	68	-0,660 4	100	0,460 1
5	-0,111 9	37	-0,840 0	69	-0,721 5	101	0,768 0
6	1,131 8	38	1,498 2	70	0,841 7	102	-1,228 5
7	-0,237 9	39	-1,389 5	71	-0,883 9	103	0,953 8
8	1,031 0	40	0,320 6	72	-0,750 7	104	0,327 3
9	1,988 8	41	1,517 5	73	-0,351 0	105	-0,084 8
10	0,996 9	42	-0,161 2	74	-0,904 8	106	0,612 9
11	-0,284 8	43	-0,497 1	75	0,691 8	107	-0,672 7
12	-1,435 0	44	-1,556 1	76	0,860 1	108	-0,482 7
13	-0,718 9	45	-0,850 2	77	0,893 3	109	-0,787 0
14	1,715 6	46	1,057 5	78	-1,163 2	110	0,783 8
15	-1,344 0	47	-1,485 2	79	1,322 7	111	-1,052 2
16	0,458 2	48	0,295 9	80	0,802 4	112	-0,547 2
17	1,635 8	49	0,644 0	81	0,758 7	113	-1,000 2
18	-0,157 4	50	-0,265 5	82	1,268 8	114	-0,615 5
19	-0,105 9	51	-0,650 2	83	-0,452 5	115	0,378 0
20	-1,378 3	52	-1,106 0	84	-1,153 3	116	1,491 3
21	-0,583 5	53	-0,937 3	85	-0,812 5	117	0,665 2
22	0,907 6	54	0,452 5	86	1,129 1	118	-0,995 8
23	-1,153 4	55	-1,319 1	87	-1,175 2	119	1,114 6
24	-0,804 7	56	-1,120 1	88	0,356 8	120	-0,442 1
25	-0,148 1	57	-1,248 6	89	1,305 5	121	-1,421 3
26	-1,349 8	58	-1,427 9	90	0,160 4	122	-0,132 4
27	1,113 0	59	0,739 3	91	-0,509 9	123	0,694 3
28	0,487 8	60	1,176 8	92	-1,480 4	124	1,781 6
29	1,227 5	61	1,073 5	93	-0,961 0	125	1,114 4
30	-1,197 5	62	-1,730 1	94	0,942 5	126	-0,884 9
31	1,461 6	63	1,605 8	95	-1,540 2	127	1,708 3