Transceiver Facility Specification

“Where software defines the radio”

SDRF-08-S-0008-V1.0.0

Approved 28 January 2009
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Executive Summary

This specification is the V.1.0.0 ("Increment 1") of the Transceiver Facility Specification from the SDR Forum, referenced SDRF-08-S-0008.

For radio system integrators, waveform providers, SDR platform providers and radio head manufacturers who seek increased efficiency when integrating waveform applications with target platforms (including radio heads), and who seek increased portability for their waveform applications, the Transceiver Facility Specification V.1.0.0 is an open specification for transceiver subsystems that captures the information needed for interoperability between waveform applications and transceiver subsystems, expressed as generic and abstract requirements for properties and programming interfaces, including the associated real-time issues.

Unlike existing specifications such as OBSAI RP3, CPRI, Vita 49 or DigRF, which focus on interoperability between hardware subsystems, and which do not sufficiently address control and configuration mechanisms, this specification provides a software abstraction that decouples waveform software from the specifics of the transceiver subsystem implementation, while not preventing use of any of the aforementioned standards.

“Where software defines the radio”

Acknowledgment

This specification would not exist without the European Union funded project E3 (End-to-End Efficiency), which has enabled the essential of its content and supported the associated group work effort at SDR Forum level. The decisive contribution of the European Union and the E3 project as a whole to this work is hereby acknowledged.
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*Table 1: Document History*
## Reference Documents

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<th>Author</th>
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*Table 2: Reference Documents*
## Acronyms

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<th>Signification</th>
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<tr>
<td>AGC</td>
<td>Automatic Gain Control</td>
</tr>
<tr>
<td>ALC</td>
<td>Automatic Level Control</td>
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<tr>
<td>API</td>
<td>Application Programming Interface</td>
</tr>
<tr>
<td>CPRI</td>
<td>Common Public Radio Interface</td>
</tr>
<tr>
<td>CPU</td>
<td>Central Processing Unit</td>
</tr>
<tr>
<td>dB</td>
<td>Decibel</td>
</tr>
<tr>
<td>dBFS</td>
<td>Decibel relative to the Full Scale</td>
</tr>
<tr>
<td>FS</td>
<td>Full Scale</td>
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<tr>
<td>HDL</td>
<td>Hardware Description Language</td>
</tr>
<tr>
<td>IF</td>
<td>Intermediate Frequency</td>
</tr>
<tr>
<td>IDL</td>
<td>Interface Description Language</td>
</tr>
<tr>
<td>JPEO</td>
<td>Joint Program Executive Office</td>
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<tr>
<td>JTRS</td>
<td>Joint Tactical Radio System</td>
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<tr>
<td>MAC</td>
<td>Medium Access Control</td>
</tr>
<tr>
<td>MDA</td>
<td>Model Driven Architecture</td>
</tr>
<tr>
<td>MDE</td>
<td>Model Driven Engineering</td>
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<tr>
<td>MHAL</td>
<td>Modem Hardware Abstraction Layer</td>
</tr>
<tr>
<td>OBSAI</td>
<td>Open Base Station Architecture Initiative</td>
</tr>
<tr>
<td>PA</td>
<td>Power Amplifier</td>
</tr>
<tr>
<td>PIM</td>
<td>Platform Independent Model</td>
</tr>
<tr>
<td>PSM</td>
<td>Platform Specific Model</td>
</tr>
<tr>
<td>RF</td>
<td>Radio Frequency</td>
</tr>
<tr>
<td>Rx</td>
<td>Reception / Receive</td>
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<tr>
<td>SCA</td>
<td>Software Communication Architecture</td>
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<tr>
<td>SDR</td>
<td>Software Defined Radio</td>
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<tr>
<td>Tx</td>
<td>Transmission / Transmit</td>
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<tr>
<td>UML</td>
<td>Unified Modeling Language</td>
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<tr>
<td>VHDL</td>
<td>Very high speed integrated circuit Hardware Description Language</td>
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*Table 3: Acronyms*
1.1 - Transceiver Subsystem

This chapter provides the reference definition for Transceiver Subsystem, as applicable within the specification.

The terminology Transceiver derives from the contraction of “transmitter/receiver”.

1.1.1 Definition

The Transceiver Subsystem is the part of a radio chain that transposes, for transmission, baseband signal into radio signal, and, for reception, radio signal into baseband signal.

The terminology Transceiver derives from the contraction of “transmitter/receiver”.

The transposition of baseband signal into radio signal is denoted as the up-conversion. The reciprocal is denoted as the down-conversion.

Tuning is characterizing the signal processing transformations realized by up- and down-conversion.

The baseband signal is a sampled complex signal, with (I,Q) values, denoted $s_{BB}[n]$. The radio signal is a continuous electric signal, denoted $s_{RF}(t)$.

The following figure illustrates the previous definitions:

![Figure 1: Definition of Transceiver Subsystem and key associated concepts](image)

1.1.2 Positioning in Physical Layer

Inside a radio chain, the Transceiver Subsystem is comprised between the Modem and the Antenna Subsystem. It is exchanging the baseband signal with Modem, and radio signal with the Antenna Subsystem. Modem, Transceiver and Antenna are generally considered as parts of the Physical Layer.

Modem

Modem is defined as the part of a radio chain that generates, in transmission, the baseband signal to be transmitted, and that exploits, in reception, the received baseband signal. Implementation of Modem relies on the modulation and demodulation techniques, which explains the selected name.

The Modem scope can not be strictly defined, since has an evident boundary towards the above layers of the radio chain which would be applicable in any case. Additionally, depending on the granularity to which a
certain radio chain is decomposed, several functional modules can take part in the implementation of Modem.

Modem is thus used as the a role taken by the functional modules of the radio chain exchanging baseband signal with the Transceiver Subsystem.

**Antenna Subsystem**

Antenna Subsystem is defined as the part of a radio chain that transforms, for transmission, the radio signal into the transmitted radio wave, and, for reception, the impinging radio wave into the radio signal.

The signal transformation operated by the Antenna Subsystem is evidently conducted thanks to antennas, while the complete subsystem implementation may include additional hardware and control software (e.g. for mechanically directed antennas).

The following figure illustrates previous considerations:

![Figure 2: Transceiver Subsystem within the PHY Layer of a radio chain](image)

1.1.3 Positioning within Radio Set Implementation

1.1.3.1 Implementation concepts

**Reconfiguration Infrastructure**

Reconfiguration Infrastructure is defined as the role taken by parts of the SDR Set which undertakes reconfigurations between the waveform capabilities supported by the Radio Set. It can be compliant with an open reference specification (e.g. SCA Core Framework solutions), or be a proprietary solution.

**Waveform Application**

The Waveform Application is composed of software modules which provide the essential software-defined dimension of the radio capability implementation. The software architectures are often targeted to achieve a high degree of portability for those software modules.

Within the Waveform Application, the Waveform Functional Application denotes the software modules which integrally implement (i.e. without intervention of a particular hardware) functionalities of the considered Waveform Capability. The emergence of high processing power programming capabilities is making implementation of such functionalities in highly portable software modules a tangible reality, even for the most constrained parts of the physical layer processing.

Within the Waveform Application, the Configuration Agent represents the role taken by a software module that accesses the other constituents of the radio capability implementations, in order to dynamically modify or read some configuration properties of those constituents. It typically relays orders provided by a user.
interface or commands retrieved from a remote source. In contrast to the Waveform Functional Application, this software has a strong dependency on the way commands impacting the Transceiver Subsystem are issued, and is not subject to be easily portable across different Radio Sets.

**Platform Functional Support**

The Platform Functional Support denotes the set of Radio Subsystems, such as Transceiver Subsystem, which are provided by the SDR Platform to complement the Waveform Application in order to dispose of a complete Waveform Capability implementation.

The Transceiver Subsystem and the Antenna Subsystem are parts of the Platform Functional Support.

1.1.3.2 **Illustration**

The following figure illustrates the Transceiver Subsystem positioning within a typical radio implementation inside an SDR set:

![Diagram of Transceiver Subsystem and related capabilities](image-url)

**Figure 3: Transceiver Subsystem and related capabilities**

The previous figure is an example that illustrates a typical set of modules and relationships, corresponding to an example of waveform capability implementation. It is recalled that the terminology “waveform” is used by reference to radio communications, but covers a potentially wider scope of radio applications than radio communications only (e.g. spectrum sensing, direction finding, identification friend-foe, …).

The control interaction between MAC and Transceiver Subsystem is underlining that in some cases the control interactions from the Waveform Functional Application to the Transceiver Subsystem are not strictly limited to Physical layer internal interactions.

For simplification purpose, some deployment and configuration interactions between Reconfiguration Infrastructure and Waveform Application components are not represented.

The roles of Reconfiguration Infrastructure and Configuration Agent are presented in conformance with previous definitions. The Transceiver Subsystem and Antenna Subsystem are apperarting as parts of the Platform Function Support.

The presented Waveform Application is composed of one Modem software component, with one MAC software component, the “…” module representing other components of higher layers which are not related to the Transceiver Subsystem.
1.1.4 Internal architecture

There are as many different Transceiver Subsystem implementations as there are radio equipments. The variety in Transceiver Subsystem implementations, architectures, designs and technology is huge, and out of the scope of the specification, which specifically abstracts the implementation choices.

There are nevertheless internal architecture invariants which enable better depictions of Transceiver Subsystems.

A Transceiver Subsystem implementation is composed of a digital segment and an analogue segment separated by a conversion stage. The breakdown between the digital and analogue segment is one essential architectural choice of a transceiver design.

The conversion stage is in charge of transforming the digital signal into analogue signals and vice-versa. It can be positioned at any level between the following extremes: (i) immediately at base-band, for each real component of the complex baseband signal, (ii) directly at the antenna foot.

The digital segment, denoted as Digital Transceiver, is in charge to interact with the Waveform Application, in compliance with the facility programming interfaces. It can undertake a significant part of the signal transformation, when conversion is not happening at baseband level. This part represents the whole lot of the digital segment in the case of antenna foot conversion, often depicted as “genuine” software radio case.

The analogue segment, denoted as Analogue Transceiver, is in charge of exchanging the RF signal with the antenna Subsystem. It undertakes all necessary transformations between the conversion stage and the antenna interface. In most situations the analogue stage will comprise a power amplification stage.

1.1.5 Standard-based implementation solutions

Using standard implementation solutions to provide a complete Transceiver Subsystem can be a relevant option in many industrial cases.

Standards having been identified as typical cases are comprised of OBSAI (or CPRI) in base-stations manufacturing, DigRF in cellular handsets manufacturing, or JTRS JPEO MHAL RF Chain Coordinator in military radios manufacturing.

For illustrative purposes, Annexe 2 graphically presents a certain number of such situations.

1.2 - Rationale for a standard specification

The ongoing development of software-defined radio (SDR) technologies in advanced wireless systems, allowing some or all of the radio implementation to be realized in software and/or HDL code, is creating a need for a further level of standardization between the Waveform Application and the Transceiver Subsystem.

This standard specification shall enable interoperability between Waveform Applications and Transceiver Subsystems.

Expected benefits of such interoperability are (i) increased integration efficiency between a compliant Transceiver Subsystem segment and the Waveform Application parts, (ii) increased portability of a Waveform Applications through different radio platforms with compliant Transceiver Subsystems, (iii) increased openness of Transceiver Subsystems, capable of meeting the needs of a large panel of Waveform Applications with reduced costs.

As a consequence, the standard specification shall specify the Transceiver Subsystem thanks to a generic and abstract approach. Generic signifies that the specification shall be capable to fulfill the needs of the widest possible range of waveform capability, ideally any of them. Abstract signifies that the specification shall propose a characterization of the Transceiver Subsystem which does not make any implementation specific assumptions.
The following figure is summarizing those expectations:

![Figure 4: Key expectations towards Transceiver Subsystem Facility](image)

Meeting the difficult compromise of the often contradictory ambitions of genericity and abstraction requires capturing the fundamental domain concepts which govern radio engineering expertise. As such the Facility elaboration presents similitudes with elaboration of a domain specific language.

### 1.3 - The Transceiver Facility

#### 1.3.1 Overview

The *Transceiver Facility* is the solution proposed by the SDR Forum for definition of a generic and abstract *Transceiver Subsystem* specification conformed to the expectations exposed in the previous rationale.

It is a general-purpose specification applicable to particular development cases. It aims at becoming a largely referenced and implemented standard within the SDR industry.

Its definition is an openly available SDR Forum Specification and follows an open elaboration process conducted by the SDR Forum.
Specification topics

The requirements expressed in the Facility are covering the following topics:

- Structural Concepts
- States & Transitions
- Properties
- Programming Interfaces (used and realized interfaces)
- Real-time requirements
- Reference scenarios

The following figure summarizes what the Transceiver Subsystem Facility is:

```
Transceiver Sub-system Facility

- States & Transitions
- Properties
- Programming Interfaces
- Reference scenarios

- Generic & Abstract specification
- Publicly available
- Openly defined by SDR Forum
```

Figure 5: Overview of the Transceiver Subsystem Facility

1.3.2 Specification levels

The analysis requirements of the Facility (i.e the requirements issued from the analysis process) impact the complete development chain, from the early design phase to the final integration stages. They are valid whatever the implementation choices will be.

To support usage of model-driven engineering and developments, UML concepts are formally required in direct derivation from the analysis requirements.

Reference source code applicable for programming of Waveform Application and Transceiver Subsystems interactions, in a number of popular programming languages such as C, C++, VHDL, etc., are as well specified.

Finally, requirements are expressed to characterize how Transceiver Subsystems compliant with the Facility shall be implemented following the specific constraints of reference SDR standards. The SCA (Software Communication Architecture) is addressed from this perspective.

1.3.3 Features and Common Concepts

The Facility is organized through Features and Common Concepts.

Features

A Feature is an elementary capability of a Transceiver Subsystem for which the Facility is providing a set reference specification items in a dedicated chapter.

Two categories of features are identified:
• **Core features:** Specifying basic and mandatory functionalities of a transceiver, typically Transmit/Receive capability

• **Optional features:** Specifying functionalities which are dependent upon the transceiver type, for example Half/Full Duplex features

This separation of capabilities in Features provides the Transceiver Facility with modularity, extensibility and scalability.

Core and Optional Features include a set of specification items (APIs, attributes, behaviors, etc.) which enable either the waveform or the platform developers to manage the various transceiver interfaces and characterize their performance.

**Example**

| The Feature “Transmit Channel” provides a reference function used by the Waveform Application to notify the Transceiver that a packet of new baseband samples is ready, called `pushBBSamplesTxs()`. Properties attached to the baseband flow exchanged between Waveform Application and Transceiver are the sample rate and the number of coding bits for the stream signal. |

**Common Concepts**

A **Common Concept** is defined as a set of specification items collectively shared between different Features, and captured independently from the Features themselves.

The introduction of Common Concepts avoids duplication of information throughout the specification.

**Example**

| The concept of baseband signal power level is defined in the Common Concept that is used by both the “Receive Channel” and “Transmit Channel” features. |
2 - Specification Assumptions

This chapter defines the specification assumptions as applied by the Facility to express formal requirements.

2.1 - Waveform engineering

The abstract and generic characterization of the Transceiver Subsystem which is realized by the Facility is made through the External Interfaces and Internal Structure of the subsystem, as depicted in following chapters.

These assumptions are intended for engineering of each specific Waveform Capability. They are not addressing matters associated to Transceiver Subsystem implementations, and the issues related to simultaneous support of different waveform capabilities by a given multi-radio Transceiver Subsystem.

Only mono-antenna transceiver capabilities are considered in this chapter, meaning that MIMO or Smart Antenna techniques are not supported by the current specification.

2.1.1 External interfaces

The following figure depicts the external interfaces of a Transceiver Subsystem:

![Figure 6: External interfaces of a Transceiver Subsystem](image)

Programming Interfaces

The Baseband Signal interfaces convey the baseband signal from the Waveform Application (typically its Modem part) to the Transceiver Subsystem. It represents the transceiver input data for transmission and the output data for reception. Typically baseband I&Q samples from a particular waveform travel through this interface.

The Real-time Control interfaces provide data flow control and real-time configuration. Typically the facility provides an API with generic waveform-independent methods configuring transceiver performance and air-interface RF access.

The Baseband Signal interfaces and the Real-time Control interfaces compose the Programming Interfaces attached to the Transceiver Subsystem.

Analogue Interfaces

The RF Signal interfaces convey the radio frequency signal from the Transceiver Subsystem to the Antenna Subsystem. They are the only externally visible Analogue Interfaces presented by the Transceiver Subsystem.
Properties

The Transceiver Subsystem properties are not as such interfaces, but they do correspond to data representations of internal notions of the Transceiver Subsystem which enable the Waveform Configuration to read current values taken by the considered notion or to write desired values to be implemented by the considered notion.

2.1.2 Internal structure

The following figure depicts the internal structure of a Transceiver Subsystem:

![Internal structure of a Transceiver](image)

*Figure 7: Internal structure of a Transceiver*

Transmit and Receive Channels are the core features associated with the Transceiver Subsystem. For a given Waveform Capability, the way they are arranged characterizes three primary possibilities:

- “True” Transceiver: Receive and Transmit Channels core features are both needed
- Receiver (“Receive-only Transceiver”): only Receive Channel core feature is needed
- Transmitter (“Transmit-only Transceiver”): only Transmit Channel core feature is needed

As far as “True” Transceivers are concerned, the following possibilities can then be distinguished:

- Full-duplex Transceiver: Receive and Transmit Channels can be simultaneously activated
- Half-duplex Transceiver: Receive and Transmit Channels shall be exclusively activated

The Facility is based on a baseline specification of the identified core features, complemented by Transceiver-level notions enabling the ability to characterize how they are arranged. Corresponding specifications are provided in §3.

2.1.3 Deployment

Definition of “Deployment”

Deployment corresponds to the implementation-specific mechanisms used to dispose of a Transceiver Subsystem operating in compliance with the needs of a particular radio capability.

Beyond the Transceiver Subsystem, deployment concerns the complete implementation of the considered radio capability. It thus covers the deployment of the different software components of the Waveform Application, and the way they are connected together and with the Transceiver Subsystem itself.

Deployment is primarily introduced to depict the reconfiguration mechanisms of SDR equipment, which triggers deployments in order to evolve from one radio configuration to another.
Deployment typically covers the following steps:

- **Creation:** the expected Waveform Application components are created and the necessary support subsystems (incl. Transceiver Subsystem) are attached to the waveform implementation.
- **Connection:** the connections between Waveform Application components and support subsystems (incl. Transceiver Subsystem) are established.
- **Initial configuration:** initial values of properties of Waveform Application components and support subsystems (incl. Transceiver Subsystem) are set.

Deployment can be based on a proprietary solution or can use a standard solution such as SCA Core Frameworks.

The previous definition encompases non-SDR equipments, for which radio capabilities are implemented using a static deployment mechanism, which deploys once-for-all the associated software, but does not allow reconfiguration.

**Deployment Abstraction**

The Facility assumes a total abstraction of deployment mechanisms, making no assumption on the deployment solution, which is considered as strictly dependent on Transceiver Subsystem implementation choices.

This means in general that SDR or non-SDR implementations are addressed by the Facility.

Furthermore, in the mainstream case of SDR implementations, this abstraction enables to undistinctly address standard-compliant (e.g. SCA) or proprietary solutions.

### 2.2 - Requirements

This chapter explains the different nature of requirements expressed by the Facility.

#### 2.2.1 Abstraction and Genericity

The following chapters detail generally applicable constraints that have to be met by all the requirements expressed in the Facility.

**Abstraction**

Abstraction (of the Transceiver Subsystem implementation) signifies that requirements of the Facility shall be totally independent of any implementation choice of the Transceiver Subsystem.

This applies as well for implementation requirements, meaning that beyond the implementation specific assumptions made (e.g. choice of a particular programming language), no further assumptions dependent on the internal implementation choices may be made.

**Genericity**

Genericity (in front of as many radio capabilities as possible) signifies that requirements of the Facility shall be applicable to the widest possible extent of waveform capabilities.

No additional requirement should be added for the sake of supporting a particular waveform needs, unless the existing requirements would prove not usable by the considered waveform capability.

#### 2.2.2 Functional requirements

##### 2.2.2.1 Requirements Analysis

*Analysis requirements* are the very core of the Facility specification.
They are expressed without any explicit assumption concerning the implementation choices of the Waveform Application and the Transceiver-Subsystem.

Analysis requirements are applicable to any step of engineering activities related to the Transceiver Subsystem and associated Waveform Applications (specification, preliminary design, detailed design, coding, testing, integration, …).

Analysis requirements are expressed in common technical English language, with eventual usage of non-normative technical illustrations to support explanation of the concepts. The principle objective is to achieve as general as possible requirements.

Analysis requirements appear within the core text of the Facility.

2.2.2.2 Modelling requirements

Modelling requirements provide normative UML modelling artifacts to be used in Facility-compliant UML models. Requirements specifically identify the associated modelling artifacts.

Modelling requirements are expressed in UML 2.0. They appear:

- Within the core text of the Facility, distributed in complementary sections next to the analysis requirements to which they correspond
- As a reference model (the Transceiver Facility Reference UML Model) attached to the specification, provided as XMI source file

Some specific UML conventions applied to build the UML artifacts associated with modelling requirements are explained in the rest of the document using specific sections denoted “Modelling Support”. Applicable stereotypes are a typical example of what is captured in such chapters.

Structural stereotypes

Analysis notions and concepts are developed in Features and Common Concepts specifications that are modelled in UML as classes. The following stereotypes are applicable for modelling classes associated with Transceiver structural concepts:

- <<core feature>> applicable to classes modelling core features
- <<feature concept>> applicable to sub-classes aggregated by features
- <<common concept>> applicable to common concepts

2.2.3 Programming language requirements

Programming language requirements provide the normative programming language source code to be used in Facility-compliant software developments (Waveform Application components and Transceiver Subsystem).

Current specification addresses the following programming languages:

- C++
- VHDL
- IDL

Programming language requirements appear:

- Throughout the core document, next to the corresponding Analysis requirements, organized into language-specific sections
- As language-specific annexes to the document core, regrouping all the source code associated to the considered programming languages
- As reference source code, provided as source files for the different programming languages
2.2.3.1 **C++ requirements**

*C++ requirements* address the C++ language. Conformance to C++ reference standard, ISO/IEC 14882:2003, is assumed.

2.2.3.2 **VHDL requirements**

The version of the VHDL language used in this specification is VHDL 93.

The non-exhaustive list of naming conventions is presented in the following table:

<table>
<thead>
<tr>
<th>VHDL constructs</th>
<th>Naming conventions</th>
</tr>
</thead>
<tbody>
<tr>
<td>generic</td>
<td>G_ prefix with name in uppercase and underscore between words</td>
</tr>
<tr>
<td>constant</td>
<td>C_ prefix with name in uppercase and underscore between words</td>
</tr>
<tr>
<td>active low signal</td>
<td>_n suffix</td>
</tr>
</tbody>
</table>

*Table 4: VHDL naming conventions*

The mapping rules between UML, IDL and VHDL constructs are described below:

<table>
<thead>
<tr>
<th>UML constructs</th>
<th>IDL constructs</th>
<th>VHDL constructs</th>
</tr>
</thead>
<tbody>
<tr>
<td>boolean</td>
<td>Std_logic</td>
<td></td>
</tr>
<tr>
<td>short</td>
<td>Std_logic_vector (15 downto 0)</td>
<td></td>
</tr>
<tr>
<td>unsigned short</td>
<td>Std_logic_vector (15 downto 0)</td>
<td></td>
</tr>
<tr>
<td>long</td>
<td>Std_logic_vector (31 downto 0)</td>
<td></td>
</tr>
<tr>
<td>unsigned long</td>
<td>Std_logic_vector (31 downto 0)</td>
<td></td>
</tr>
<tr>
<td>integer of nbBits</td>
<td>Std_logic_vector (nbBits-1 downto 0)</td>
<td></td>
</tr>
<tr>
<td>Package</td>
<td>module M [ ... ];</td>
<td>package P is ... end package P;</td>
</tr>
<tr>
<td>Class</td>
<td>interface I [ ... ];</td>
<td>Entity E is ... end entity E;</td>
</tr>
</tbody>
</table>

*Table 5: UML, IDL and VHDL constructs mapping*

Each Transceiver Feature is described by a VHDL entity, which has to include clock and asynchronous active low reset signals. Other optional signals can be added to the entity by the designer if needed, such as clocks for the following Features or access to FPGA pins (e.g. for LEDs control).

There are three possible implementations of a feature property:

1. It can be implemented as a CONSTANT if its value can not be modified once synthesized (compilation time). The CONSTANT can be defined:
   - a. inside a *Transceiver* PACKAGE if it is desirable to make it accessible for every Feature, or
   - b. inside a feature specific PACKAGE if it is only needed by this feature,
   - c. a constant may be used to configure VHDL generics on the feature entity interface during component instantiation.
2. It can be implemented as a register if its value may be modified during run time. The register can be defined inside of a clocked process inside the architecture of the Feature.
3. It can be data/control signals
   - a. which are declared in the corresponding Feature entity, and
   - b. whose protocol is defined inside the Feature architecture.
Generally speaking, the transfer of information from and to the Transceiver features is based on two phases
1. Up stream or request flow consisting of
   a. Useful data,
   b. Control flow signals in the data direction with a mandatory ‘write’ signal, which means that
      a valid data is ready to be sent,
   c. Other optional signals to include user-defined extensions
2. Down stream or response flow consisting of
   a. Control flow signals in the opposite data direction with a mandatory ‘ready’ signal, which
      means that the next valid data to be sent will be accepted
   b. Other optional signals to include user-defined extensions

2.2.3.3 IDL requirements
To be completed.

2.2.4 Implementation architecture requirements
Implementation architecture requirements provide normative complementary requirements which are
applicable in case the Waveform Application software and the Transceiver Subsystem are developed in
compliance with particular architecture assumptions.
The only case considered in the current specification is SCA compliancy. Others such as Native Simulation
are considered for future evolutions.

2.2.4.1 SCA
To be completed.

2.2.5 Requirements Identification and Numbering
This section summarizes the conventions used within the document for requirements specification.

Requirements identification
The requirements are identified by a unique identifier, composed of the following field:
- Requirement family: General ➞ “GEN_”, Feature ➞ “FEAT_”, Common Concept ➞ “CC_”
- Mnemonic: “<mnemonic>_”
- Requirement number

A mnemonic is a short capital letters string of characters attached to a certain chapter/section of the
specification. The identifiers of the requirements attached to the chapter/section will be using the
chapter/section mnemonic.
The requirement numbering is a three decimal digits number.

Requirement tags
The requirements are tagged by a few words capturing the nature of each requirement. These tags are
intended to facilitate specification ease-of-read and are not normative concepts.

Delimitation of requirements
The beginning of a requirements expression is delimited by an introductive line, containing the identifier of
the requirements and its tag, in conformance with the following arrangement convention:

<IDENTIFIER> & <SPACE> & “[“ & <5 x SPACE> <TAG>

The format of the entry delimitation is in bold red text.
Example: **FEAT\_TXCHAN\_010 [ Example Req.**

The end of a requirement expression is delimited by a conclusive line, containing the identifier of the requirement, formatted as:

```
“] END_”& <IDENTIFIER>
```

The format of the end delimitation is in bold green text.

Example: ] END\_FEAT\_TXCHAN\_010.

**Verification of requirements**

Description of the verification principles for each identified requirement is not in the scope of the *current specification*.

**2.3 - Detailed specification conventions**

Following chapters explain, for different sorts of concepts introduced within the *specification*, general specification conventions applicable to the concerned concepts.

**2.3.1 Classification of Transceiver Characteristics**

**2.3.1.1 Introduction**

The *Facility* introduces many characteristics associated with the *Transceiver Subsystem*. “Characteristic” refers to an information set, simple or structured, quantified or qualitative, which corresponds to a particular notion of the *Transceiver Subsystem*.

Characteristics are used during radio capability engineering to define how the *Transceiver Subsystem* shall operate in conjunction with the *Waveform Application* in order to implement the *radio capability* of interest. The notions described thanks to characteristics can indistinctively be constant or transient.

Most characteristics of the *Transceiver Subsystem* are formally defined by the Facility, through specific requirements. The purpose of this section is to define the classification used by the Facility in order to differentiate those characteristics.

The categories of *Notions* and *Constraints* are the first level of differentiation used for discrimination of characteristics.

This Facility defines as *Notions* characteristics of the Transceiver Subsystem which are *observable*. This criteria (the possibility to be *observed* or not) is the fundamental frontier which distinguishes the concept of *Notion* from the concept of *Constraint*.

“Observable” indicates that by using inspection, analysis and/or measurement means, values of the considered characteristics of a specific implementation of a *Transceiver Subsystem* can be inferred. This surely includes externally observable characteristics specified in implementation independent manner, but as well, implementation specific aspects of the considered *Transceiver Subsystem*.

The *Constraints* are defined as non-observable notions, which are typically the design constraints captured in the requirement specifications, which are satisfied by a given *Transceiver Subsystem* implementation, but which are not explicitly defined by measurement. For instance all boundary values of *Notions* are typical of constraints, which the observed notion is complying with, but being by definition impossible to measure by themselves.
2.3.1.2 Notions

Notions are Transceiver Subsystem observable characteristics, sorted by the Facility among three sub-categories:

- Internal notions
- Implicit notions
- Explicit notions

Internal Notions

Internal Notions are Notions answering to the following criterion:

- **Implementation dependency**: one Internal Notion of a Transceiver Subsystem is **dependent** on some implementation assumptions of the Transceiver Subsystem, no matter how minor such assumptions may be.

As a consequence, since the Facility is providing abstraction from the implementation choices, no information relative to a particular value of an internal notion may be considered at any stage of the radio capability engineering, from the design phases to the run-time software exchanges between the Waveform Application and the Transceiver Subsystem.

Internal Notions are nevertheless essential to consider for Waveform Application design, and boundary Constraints are handled in Waveform Engineering to make appropriate design. Internal Notions are typically real-time or signal processing characteristics.

**Examples**

- **Up-conversion Latency** is an “Internal Notion” which defines the time baseband samples need to travel across the Up-conversion chain prior to becoming the radiated RF signal. This value is bounded by the Engineering constraint “Max Up-conversion Latency” and its actual value depends on the particular Transceiver implementation.

- **ConsumptionStartTime** is an “Internal Notion” derived from TransmitStartTime as the instant at which baseband samples should be consumed by the “Up-conversion chain” in order for the RF Transmission signal to be available at the Transceiver output at instant TransmitStartTime.

Implicit Notions

Implicit Notions answer to the following criteria:

- **Implementation independency**: one Implicit Notion of a Transceiver Subsystem is **independent** from any implementation assumptions of the Transceiver Subsystem, no matter how minor such assumptions may be.

- **Not exchanged**: no information relative to an Implicit Notion is exchanged at run-time between the Waveform Application and the Transceiver Subsystem, through programming interfaces or usage of Configuration.

Implicit Notions are thus completely transparent from the Waveform Application point of view, but are essential to be given a well defined value during Waveform Engineering, which will both influence the implementation of the Waveform Application and the Transceiver Subsystem.

Such notions generally remain constant once deployment is completed. The Deployment is in charge to bring the Transceiver Subsystem to support the specified values, as needed by the considered radio capability. The mechanism of **presets** enables to switch during run-time among a predefined constant set of implicit notions.

**Examples**

- **SamplingFrequency** is an example of Implicit Notion. Its frequency in hertz is set once during Transceiver deployment. No waveform is supposed to change it. It remains constant except if a reconfiguration occurs.
Explicit Notions

Explicit Notions answer to the following criteria:

- Implementation independency (as for Implicit Notions): one Explicit Notion of a Transceiver Subsystem is independent from any implementation assumptions of the Transceiver Subsystem, no matter how minor such assumption may be.
- Exchanged: information relative to an Explicit Notion can be exchanged at run-time between the Waveform Application and the Transceiver Subsystem, through programming interfaces or usage of Configuration.

Explicit Notions encompass both static concepts, changed only by means of the configuration functionalities of the waveform application, and very transient concepts characterizing accurate real-time behaviour.

Explicit Notions belong to at least one of the two following sub-categories:

- Configurable
- Programmable

The Facility explicitly identifies which explicit notions are only Configurable, only Programmable, or potentially accessed with both possibilities.

Explicit Notions potentially accessed by both possibilities are in principle accessed using only one of the two possibilities once the engineering choices of the associated radio capability are done.

Configurable notions are accessed by the Configuration part of the Waveform Application (if existing for the considered radio capability), which can read or write associated values through usage of the associated Property. The Facility only identifies the nature of the Property, leaving to implementation choices the way it is implemented by the Transceiver Subsystem and handled by Configuration.

Configurable notions are modified by external agents of the radio capability, typically the end user or a remote configuration manager. The associated configuration mechanism is not strictly bounded from a real-time perspective, what matters is to be reactive in front of the configuration agent needs.

Programmable notions are accessed by the Waveform Functional Application through usage of particular operations of the Programming Interfaces specified by the Facility. Specifically related arguments of the Programming Interfaces are introduced by the Facility.

Programmable notions are typically very transient values automatically accessed in run-time by the Waveform Application software, thus generally answering to specific real-time constraints.

Example

The CarrierFrequency is an Explicit Notion as far as it has a dedicated argument in some waveform programming interface operations i.e CreateTransmitChannel. It may be a static property whose value is set only-once during configuration as in fixed frequencies radios (no need to use the dedicated argument in this case) or a very transient property varying in run-time, typically frequency hopping radios (argument will be used to convey information during run-time in this case).

2.3.1.3 Constraints

Per the definition provided beforehand, constraints are non observable characteristics of the Transceiver Subsystem.

Constraints are assigned values during Waveform Engineering, and implementation phases ensure compliancy with the assigned values. They lead to primary requirements within this specification.
Characteristics inferred from the previous definition are:
- Implementation independency
- Not exchanged

Example
Up-Conversion Latency which describes the elapsed time from the instant baseband samples arrive to the Up-Conversion chain and the instant an RF signal is available at transceiver output is an Internal Notion. This time is dependent on implementation (like any Internal Notion). “MaxUp-Conversion Latency” is the Constraint which limits the value the Notion is allowed to take.

2.3.1.4 Summary table

The following table summarizes the essential criteria answered or not by the categories and sub-categories indentified in the previous chapters:

<table>
<thead>
<tr>
<th>Category</th>
<th>Sub-Category</th>
<th>Observable</th>
<th>Implementation Dependency</th>
<th>Waveform/Transceiver exchange</th>
</tr>
</thead>
<tbody>
<tr>
<td>Notion</td>
<td>Internal</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Implicit</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Explicit</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Constraint</td>
<td>N/A</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Table 6: Differences between Characteristics categories

2.3.1.5 Modelling support

The following stereotypes are defined for modelling support:
- Stereotype <<Constraint>> for constraints
- Stereotype <<Explicit>> for explicit notions
- Stereotype <<Implicit>> for implicit notions

2.3.2 Operations and Programming Interfaces

All information exchanges between the implementations of a Transceiver Subsystem and a Waveform Application are realized thanks to operations. Operations are regrouped into Programming Interfaces.

An operation of the Transceiver Subsystem facility characterizes one possible information exchange mechanism between the Waveform Application and the Transceiver Subsystem.

Operations and Programming Interfaces are primarily defined at analysis level in a strictly implementation-independent approach. The requirements specific to implementation programming languages are then provided as supplements, as detailed in chapter “Programming Languages Requirements”.

This section strictly focuses on the principles applied throughout the Facility for analysis level specification of Operations and Programming Interfaces.

2.3.2.1 Static assumptions

Defining operations

Defining operations consists of providing a complete set of information, as detailed hereinafter.

Each operation is given a specific operation name.
An operation enables information exchanges in a specific direction: from Waveform Application to Transceiver Subsystem, or vice-versa.

Exchanges based on a given operation happen through circulation of elementary messages, each message carrying a structured set of information characterized by the list of arguments of the operation.

The typing of operation arguments is compliant with arguments typing conventions detailed in a later chapter of the specification.

The originator of the information exchanged through an operation has a use relationship with the operation, while the addressee has a realize relationship with the operation.

Bi-directional Programming Interfaces

The Facility considers bi-directional interactions, which means that the Transceiver Subsystem is by principle subject to invoke operations realised by the Waveform Application, additionally to the intuitive case for which the Waveform Application invokes operations realized by the Transceiver Subsystem.

This approach, as surprising as it may appear at first sight, has been identified as the only solution that can characterize the waveform application remaining in a truly implementation abstract mode. For instance, a callback mechanism for reception is specifically software-based, and is at run-time equivalent to a call to a registered method. The Facility is simply specifying the name and prototype of the call back, the registration being part of life cycle designs which are not at analysis level.

Furthermore, this is compliant with the component-based software design paradigm which predominates for standard-based SDR Waveform Application designs.

Example of Realized interfaces

| The flagship example of Used interface if the operation pushBBSamplesRx(), which is enabling a Receive Channel to notify the Waveform Application of the availability of a new packet of baseband samples. |
| This means that a waveform analysis based in the specification shall consider the Transceiver as the caller of this operation, which corresponds to the natural flow of information. This is nevertheless sufficiently disruptive in front of most frequent design approaches where the Transceiver Subsystem is considered as a “slave” system, with the Waveform Application performing all the calls towards the Transceiver, with in particular usage for reception of getSamples() or callbacks registration approaches. |

Simplifying assumptions

A certain number of simplifying assumptions are used for specification of Operations. Those simplifications focus on what is strictly necessary as far as engineering related to Transceiver Subsystem is concerned, in order to facilitate as efficient as possible implementations of the Facility concepts.

Those simplifying assumptions are:
- No return value
- No exceptions
- Types subset

No return value: the operations are not be expected by the originator to bring return values after completion.

No exceptions: the operations are not expected to generate any sort of software exceptions.

Types subset: the types applicable to operation arguments are limited to a certain sub-set in front of the types set classically supported in software engineering. Refer to the chapter on typing conventions for details.

Operations arguments naming convention

The arguments of the interface operations are all preceded by the keyword requested in order to make clear distinction against the characteristics (explicit notions) they refer to.
Specification approach summary

At analysis level, operations are statically specified providing name, direction, and list of typed arguments. The dynamics are specified through identification of what originator and addressee shall do before, during and after operation invocation.

2.3.2.2 Dynamic assumptions

Operations invocation

Invocation of an operation occurs when originator of the operation triggers the information exchange. In doing so the originator provides the values to be carried by the generated message for each of the operations arguments. Some arguments can remain undefined.

Invocation of an operation occurs at the certain invocation time.

Message handling carries the message to the addressee, which is triggered to perform operation execution, which corresponds to the exploitation of the message.

Until the message handling is over, the originator is on hold. The instant when message handling is over is defined as the completion time.

Interaction models

Different strategies can be associated with message handling, and are denoted interaction models.

Interaction models are primarily differentiated by considering the independence of the originator and addressee of the message.

The originator and addressee can be executed on the same thread of control, in which case invocation handling triggers the addressee for operation execution, while the originator is maintained on hold, waits for the operation execution to be over, and only then releases the originator.

The originator and addressee can be executed on different threads of control (i.e. independently), in which case invocation handling triggers the addressee for operation execution, but does not wait for operation execution to start before releasing the originator.

2.3.2.3 Real-time Constraints

Maximum Invocation Duration

Max Invocation Duration is a constraint which can be attached to each interface specified in the Facility. It characterizes the amount of time taken within the caller execution time when an operation is invoked.

Each occurrence of an invocation by the Caller of the operation happens at an instant denoted Invocation Time. The Caller is then on hold until the operation invocation mechanism returns, giving back the hand to let Caller proceed. The instant when the call returns is denoted Return Time. The time elapsed between Invocation Time and Return Time is represented by the Internal Notion Invocation Duration.

Each occurrence of an operation call can have a different Invocation Duration. Whatever the occurrence of an operation invocation, the constraint Max Invocation Duration specifies the maximum value possibly taken by Invocation Duration.

A value for this constraint is defined when accurate real-time engineering is necessary for the considered waveform capability.
A constraint *Max Invocation Duration*, of domain type *Latency*, is specified by the Facility for each defined operation, as depicted in the following figure:

![Diagram showing Max Invocation Duration](image)

*Figure 8: Notion of Max Invocation Duration*

### 2.3.2.4 Modelling support

UML *interfaces* are used to capture the programming interfaces.

UML *operations* are used to capture the analysis *operations* contained in programming interfaces.

### 2.3.3 Types setting conventions

This chapter gives the dispositions applicable, throughout the *specification*, for definition of (i) *Notions* and *Constraints* types and (ii) *Arguments* of programming interfaces operations.

#### 2.3.3.1 Analysis types

**Base types**

Allowed basic types used within the spec are:

<table>
<thead>
<tr>
<th>Base Type</th>
<th>Correspondance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boolean</td>
<td>True / False</td>
</tr>
<tr>
<td>Short</td>
<td>Signed integer, 16 bits min</td>
</tr>
<tr>
<td>Long</td>
<td>Signed integer, 32 bits min</td>
</tr>
<tr>
<td>UShort</td>
<td>Unsigned integer, 16 bits min</td>
</tr>
<tr>
<td>Ulong</td>
<td>Unsigned integer, 32 bits min</td>
</tr>
</tbody>
</table>

*Table 7: Base types*

The specified set of Base types has been taken as a sub-set of CORBA types.
Notice that those types represent an arbitrary design choice. The table above shows a minimum size for the data types. These sizes are common to most of the embedded processors currently implemented in radio equipment but can vary. The minimum has been selected in order to ensure functionality. Nevertheless, depending upon the hardware Short, Long, Ushort and Ulong might be of a larger size and more accurate.

**Composed types**

The *Composed types* possibly used within the specification are limited to the following possibilities:

- Tables of base types
- Structures of base types

**Domain types**

*Domain types* are associated with domain-specific types, applicable for *Notions* and *Constraints*. They are generally attached to physical quantities, and specify the base unit associated.

Types setting makes the association between a domain type and a base type. This shall be used when a numerical representation of a *Notion* or *Constraint* is necessary, or to use an operation attached to the domain type.

A default setting is systematically defined for each domain type. Supplementary settings may be defined.

Unless otherwise specified, any implementation of a given domain type shall be based on the default setting.

The domain types are defined within *Common Concepts*, with the exception of *Timing Types*, presented later in this chapter.

**Types settings for Notions and Constraints**

*Notions* and *Constraints* of the Transceiver are generally first defined using an abstract type, representing the physical value attached to the concept. Then, for the implemented ones, a data type is associated to the concept type.

**Types settings for Arguments**

*Arguments* of programming interfaces operation require a functional definition subject to be translated into programming language data type, since *Waveform Application* software will interact with the *Transceiver Subsystem* according to information carried within the arguments.

### 2.3.3.2 Implementation specific types

For each considered implementation language, the association of base type definitions to types available within the implementation language is defined.

### 2.3.4 States and Transitions

All transitions identified between states are instantaneous.

They are given a specific formal name.

A certain occurrence time can be attached to each transition. Occurrence times of a transition are identified by the formal identifier of the transition it relates to, with “Time” appended. A specific occurrence is identified by its count index.

### 2.3.5 Events Handling

This chapter exposes the concepts used in the *Facility* to specify requirements involving events handling.
2.3.5.1 Events Timely Control

This chapter exposes how the Facility introduces timely control operations, through which the Waveform Application can require internal events of the Transceiver Subsystem to occur at explicitly specified instants.

The timely control operation is invoked at Invocation Time, the Caller being the Waveform Application, the Callee being the Transceiver Subsystem.

Target Event denotes the event attached to such a timely control operation. Target Event Time denotes the effective occurrence time of Target Event, which shall be close to requestedEventTime.

The following concepts are attached to characterization of timely control operations:

- Argument requestedEventTime,
- Constraint Event Accuracy,
- Constraint Min Anticipation.

The argument requestedEventTime, of generic domain type Time, is used by timely control operations to specify at which time Target Event shall happen. Put simply, it is the time at which the Transceiver must fulfill an operation, typically a transmission start/stop or a reception start/stop. Refer to §4.2 Time handling Domain Types for generic domain type Time description.

The constraint Event Accuracy, of domain type Latency, is specified by the Facility to capture the time accuracy to be fulfilled by Target Event Time, which shall belong to the time interval defined by requestedEventTime plus or minus Event Accuracy value.

The constraint Min Anticipation, of domain type Latency, characterizes the anticipation needed for Invocation Time of timely control operations in front of the specified Target Event Time. Invocation Time shall occur before requestedEventTime minus Min Anticipation.

The following figure illustrates the concepts introduced:

![Figure 9: Expression of Timely Events](image)

```
Timely invocation

Invocation Time

Too late invocation

Target Event Time

\(\in [\text{requestedEventTime} \pm \text{EventAccuracy}]\)

Waveform Application

Transceiver Sub-system

controlOperation(…, requestedEventTime)

Invocation

Return

Target Event

Target Event is generated by Transceiver Sub-system in a implementation-dependent fashion.
```

2.3.5.2 Referencing Event Sources

This chapter exposes how reference event sources are identified.
Referencing such event sources is a possibility for timely control operations to request event times, as exposed in common concepts.

**Principle**

Event sources correspond to events of the Transceiver Subsystem which are defined by the specification and thus useful for the engineering of Waveform Capabilities.

The Waveform Application can reference, in control messages, the Event Sources of the Transceiver Subsystem. It may as well reference Event Sources belonging to other radio Subsystems of the Platform Support attached to the Waveform Application.

Platform Support signifies the complete set of Radio Subsystems with which the Waveform Application is interacting in order to implement a certain Waveform Capability. The Transceiver Subsystem is one Radio Subsystem of the Platform Support.

**Examples of Event Sources**

| RF Transmit Start and RF Transmit Stop are event sources attached to a Transmit Channel, while RF Receive Start and RF Receive Stop are attached to a Receive Channel. |

**Event Sources Public Identifiers**

A unique Public Identifier is assigned to each Event Source of the Platform Support. This assignment is specific to each Waveform Capability, and can be different from one Waveform Capability to another. The deployment of the Platform Support is in charge to assign the desired Public Identifiers values.

The Public Identifier values are used by arguments of the control messages sent by the Waveform Application to the Transceiver Subsystem. This enables the Waveform Application to specify accurate real-time behaviors of the Transceiver Subsystem using any available Event Source of the Platform Support. The usable Event Sources may therefore not be limited to those of the Transceiver Subsystem.

The following figure summarizes the principle of Event Sources Public Identifiers:

![Event Sources Public Identifiers](image)

The Public Id assignment is specific to each Waveform Capability

**Figure 10: Event Sources Public Identifiers**
Event Occurences

Event Sources generate Event Occurences.

Each Event Source counts the generated Event Occurences using an unsigned 32 bit value. This enables count values ranging from 1 to 4,294,967,295. the value 0 remaining unused.

Event Occurences count values can be used as arguments in control messages sent by the Waveform Application to specify when particular events shall happen in the Transceiver Subsystem.

2.3.5.3 Last and Next Events

The notion of last and next event of a certain event source is defined relative to the instant when the control operation referring to such events is invoked. Invocation Time and Event Time denote the time of corresponding events.

To enable unambiguous identification of a previous event, the Invocation Time referencing the event shall happen after a margin of time, denoted Real-time Accuracy. Otherwise, guaranteeing that existence of the previous event is taken into account for correct realisation of the control operation is not possible.

Similarly, unambiguous identification of the next event requires Invocation Time to happen with at least Real-time Accuracy before the target Event Time. A constraint of category Min Event Proximity, of domain type Latency, is used to capture the time margin needed between the Invocation Time of any invoked operation and a previous (resp. next) Target Event, where the Invocation Time shall happen at least Min Event Proximity before (resp. after) Event Time.

The formal requirements using Min Event Proximity are specified by the Facility for each concerned timely control operation for a given referenced event source.

The real-time engineering of the Waveform Application shall ensure that the Invocation Time of the timely control operation never falls in the ambiguity period characterized by Min Event Proximity.
3 - Features Specification

3.1 - Transceiver composition

The Transceiver Subsystem can be composed of the following Core Features, as explained in chapter Internal Structure:

- Transmit Channel,
- Receive Channel.

The following implicit notions directly attached to the Transceiver Subsystem are characterizing what is specifically expected in terms of channels composition.

As the Transceiver Subsystem considered by the Facility is attached to a specific radio capability, in total abstraction of the implementation assumption, the aspects covering multi-channel Transceiver Subsystems are not addressed.

FEAT_GEN__010 [ Used “Transmit Channel”]

The implicit notion UsedTransmitChannel, of type Boolean, shall be used to specify if the considered radio capability is requesting usage of a Transmit Channel core feature.

Value True in case a Transmit Channel is needed, False otherwise, may not be left undefined.

] END_FEAT_GEN_010

FEAT_GEN_020 [ Used “Receive Channel”]

The implicit notion UsedReceiveChannel, of type Boolean, shall be used to specify if the considered radio capability is requiring usage of a Receive Channel core feature.

Value True in the case where a Transmit Channel is needed, False otherwise, may not be left undefined.

] END_FEAT_GEN_020

FEAT_GEN_030 [ Half-duplex Transceiver]

The implicit notion HalfDuplexTransceiver, of type Boolean, shall be used to specify if the considered radio capability is requesting usage of a half-duplex Transceiver.

Value True in the case where the Transceiver is half-duplex, False otherwise (full-duplex). Can remain undefined only if a simplex Transceiver is required (i.e. UsedReceiveChannel or UsedTransmitChannel set to False).

] END_FEAT_GEN_030

Note: It is worth noting that the Transmit Channel and Receive Channel are the elementary features of any Transceiver hence their classification as core features. Half-Duplex is an optional feature and it is not elaborated in the current version of the Facility. Other features such as MIMO capability might be also considered as optional and be introduced in future versions of the document. Distinguishing between Core and Optional features, as mentioned in previous chapters, is intended for specification extensibility.
### 3.2 - Core Feature “Transmit Channel”

#### 3.2.1 Principle

For radio transmission, a Transmit Channel of a Transceiver Subsystem is up-converting bursts of input Baseband Signal into bursts of RF Signal. A Transmit Cycle denotes the phase corresponding to the up-conversion of a particular signal burst.

A Transmit Channel implementation is namely composed of the following specific sub-items:

- A Baseband FIFO
- An Up-conversion Chain

The Up-conversion Chain is the signal processing chain which performs the up-conversion and most probably the upsampling and filtering of the burst of Baseband Signal contained in Baseband FIFO, outputting it as a burst of RF Signal.

The programming interface TransmitDataPush enables the samples packets to be pushed by the Waveform Application towards the Transmit Channel. The Transmit Channel takes in charge the packets pushed by Waveform Application, stores them into Baseband FIFO, where Up-conversion Chain consumes them in real-time to upconvert them and generate the RF Signal. The samples need to be available on time in Baseband FIFO for the up-conversion process to start, and need to be continuously stored in Baseband FIFO in a timely manner that prevents signal interruption occurrence.

The programming interface TransmitControl enables the Waveform Application to manage when and how Transmit Cycles shall occur. For each Transmit Cycle, this control is based on specification of when the concerned burst shall start and stop, and through characterization of the applicable Tuning Profile, which characterizes the exact signal processing transformation to be applied to Baseband Signal by Up-conversion Chain on the concerned burst in order to generate the RF Signal.

The following figure summarizes the previous concepts:

![Figure 11: Overview of a Transmit Channel](image)

**Figure 11: Overview of a Transmit Channel**
3.2.2 Overview

3.2.2.1 Programming interfaces overview

The following table provides an overview of the programming interface *TransmitControl*:

<table>
<thead>
<tr>
<th>Signature summary (pseudo-code)</th>
<th>Used by</th>
<th>Realized by</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>createTransmitCycleProfile(</td>
<td>Waveform Application</td>
<td>Transceiver Subsystem</td>
<td>Creation of a Transmit Cycle Profile.</td>
</tr>
<tr>
<td>Time requestedTransmitStartTime,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time requestedTransmitStopTime,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UShort requestedPresetId,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequency requestedCarrierFrequency,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AnaloguePower requestedNominalRFPower)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>configureTransmitCycle(</td>
<td>Waveform Application</td>
<td>Transceiver Subsystem</td>
<td>Configuration of an existing Transmit Cycle Profile.</td>
</tr>
<tr>
<td>Ulong targetCycleId,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time requestedTransmitStartTime,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time requestedTransmitStopTime,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequency requestedCarrierFrequency,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AnaloguePower requestedNominalRFPower)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>setTransmitStopTime(</td>
<td>Waveform Application</td>
<td>Transceiver Subsystem</td>
<td>Specification of the end time of a Transmit Cycle.</td>
</tr>
<tr>
<td>Ulong targetCycleId,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time requestedTransmitStopTime)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Table 8: Overview of programming interface TransmitControl*

The following table provides an overview of the programming interface *TransmitDataPush*:

<table>
<thead>
<tr>
<th>Signature summary (pseudo-code)</th>
<th>Used by</th>
<th>Realized by</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>pushBBSamplesTx(</td>
<td>Waveform Application</td>
<td>Transceiver Subsystem</td>
<td>Notifies availability of a baseband samples packet.</td>
</tr>
<tr>
<td>BBPacket thePushedPacket,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boolean endOfBurst)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Table 9: Overview of programming interface TransmitDataPush*
3.2.2.2 Characteristics overview

Explicit Notions

Explicit Notions defined in §2.3 are observable, implementation independent and exchanged characteristics of the Transceiver Subsystem. The following table summarizes the Explicit Notions related to Transmit Channel:

<table>
<thead>
<tr>
<th>Explicit Notion Name</th>
<th>Defined in</th>
<th>Nature</th>
<th>Exchange Mechanism</th>
<th>Associated Argument</th>
<th>Associated Property</th>
</tr>
</thead>
<tbody>
<tr>
<td>TransmitCycle</td>
<td>Core Feature</td>
<td>Logical</td>
<td>Programmable</td>
<td>targetCycleId</td>
<td>n.a.</td>
</tr>
<tr>
<td>TransmitStartTime</td>
<td>Core Feature</td>
<td>Real-Time</td>
<td>Programmable</td>
<td>requestedTransmitStartTime</td>
<td>n.a.</td>
</tr>
<tr>
<td>TransmitStopTime</td>
<td>Core Feature</td>
<td>Real-Time</td>
<td>Programmable</td>
<td>requestedTransmitStopTime</td>
<td>n.a.</td>
</tr>
<tr>
<td>TuningPreset</td>
<td>Core Feature</td>
<td>Logical</td>
<td>Programmable</td>
<td>requestedPresetId</td>
<td>n.a.</td>
</tr>
<tr>
<td>CarrierFrequency</td>
<td>Common Concept</td>
<td>Signal Processing</td>
<td>Programmable &amp; Configurable</td>
<td>requestedCarrierFrequency</td>
<td>CarrierFrequency</td>
</tr>
<tr>
<td>NominalRFPower</td>
<td>Common Concept</td>
<td>Signal Processing</td>
<td>Programmable &amp; Configurable</td>
<td>requestedNominalRFPower</td>
<td>NominalRFPower</td>
</tr>
</tbody>
</table>

Table 10: Explicit Notions related to Transmit Channel

Implicit Notions

Implicit Notions defined in §2.3 are observable, implementation independent and not exchanged characteristics of the Transceiver Subsystem. The following table summarizes the Implicit Notions related to Transmit Channel:

<table>
<thead>
<tr>
<th>Implicit Notion Name</th>
<th>Defined in</th>
<th>Nature</th>
</tr>
</thead>
<tbody>
<tr>
<td>BasebandFIFOSize</td>
<td>Core Feature</td>
<td>Logical</td>
</tr>
<tr>
<td>MaxPushedPacketSize</td>
<td>Core Feature</td>
<td>Logical</td>
</tr>
<tr>
<td>OverflowMitigation</td>
<td>Core Feature</td>
<td>Logical</td>
</tr>
<tr>
<td>TuningStartThreshold</td>
<td>Core Feature</td>
<td>Logical</td>
</tr>
<tr>
<td>BasebandSignal:...</td>
<td>Common Concept</td>
<td>Signal Processing</td>
</tr>
<tr>
<td>BasebandSamplingFrequency</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BasebandCodingBits</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BasebandNominalPower</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 11: Implicit Notions related to Transmit Channel
Internal Notions

*Internal Notions* defined in §2.3 are *observable* and *implementation dependent* characteristics of the *Transceiver Subsystem*. The following table summarizes the *Internal Notions* related to *Transmit Channel*:

<table>
<thead>
<tr>
<th>Name</th>
<th>Defined in</th>
<th>Nature</th>
<th>Transceiver Design Formulas</th>
</tr>
</thead>
<tbody>
<tr>
<td>TuningDuration</td>
<td>Core Feature</td>
<td>Real-time</td>
<td>$&lt;$ MaxTuningDuration</td>
</tr>
</tbody>
</table>
| TuningStartTime       | Core Feature        | Real-time| $= \text{ConsumptionStartTime} - \text{TuningDuration}$  
|                       |                     |          | $\in [\text{ConsumptionStartTime} - \text{MaxTuningDuration}; \text{ConsumptionStartTime}]$     |
| UpconversionLatency   | Core Feature        | Real-time| $<$ MaxUpConversionLatency                                                                |
| ConsumptionStartTime  | Core Feature        | Real-time| $= \text{TransmitStartTime} - \text{UpConversionLatency}$  
|                       |                     |          | $\in [\text{TransmitStartTime} - \text{MaxUpConversionLatency}; \text{TransmitStartTime}]$     |
| ConsumptionStopTime   | Core Feature        | Real-time| $= \text{TransmitStopTime} - \text{UpConversionLatency}$  
|                       |                     |          | $\in [\text{TransmitStopTime} - \text{MaxUpConversionLatency}; \text{TransmitStopTime}]$        |
| ReactivationTime      | Core Feature        | Real-Time | $= \text{TransmitStartTime}(n) - \text{TransmitStartTime}(n-1)$  
|                       |                     |          | $> \text{MinReactivationTime}$                                                             |
| TxChannelTransferFunction | Common Concept   | Signal Processing | Fits in mask defined by ChannelMask                                                      |

*Table 12: Internal Notions related to Transmit Channel*
Constraints

Constraints defined in §2.3 are non-observable characteristics which constrain the Transceiver Subsystem and/or Waveform Application implementation. The following table summarizes the Constraints related to Transmit Channel:

<table>
<thead>
<tr>
<th>Name of the Constraint</th>
<th>Nature</th>
</tr>
</thead>
<tbody>
<tr>
<td>MaxTuningDuration</td>
<td>Real-time</td>
</tr>
<tr>
<td>MaxUpconversionLatency</td>
<td>Real-time</td>
</tr>
<tr>
<td>MinTransmitStartProximity</td>
<td>Real-time</td>
</tr>
<tr>
<td>MinTransmitStartAnticipation</td>
<td>Real-time</td>
</tr>
<tr>
<td>TransmitTimeProfileAccuracy</td>
<td>Real-time</td>
</tr>
<tr>
<td>MinTransmitStopAnticipation</td>
<td>Real-time</td>
</tr>
<tr>
<td>MinTransmitStartProximity</td>
<td>Real-time</td>
</tr>
<tr>
<td>MaxTransmitDataPushInvocationDuration</td>
<td>Real-time</td>
</tr>
<tr>
<td>MinPacketStorageAnticipation</td>
<td>Real-time</td>
</tr>
<tr>
<td>MinReactivationTime</td>
<td>Real-time</td>
</tr>
<tr>
<td>ChannelMask:...</td>
<td>Signal</td>
</tr>
<tr>
<td>SpectrumMask:...</td>
<td>Signal</td>
</tr>
<tr>
<td>GroupDelayMask:...</td>
<td>Signal</td>
</tr>
<tr>
<td>MaxCycleId</td>
<td>Logical</td>
</tr>
<tr>
<td>MaxTxCycleProfiles</td>
<td>Logical</td>
</tr>
</tbody>
</table>

Table 13: Constraints related to Transmit Channel
3.2.3 Analysis Requirements

The mnemonic used for identification of requirements of Transmit Channel feature is: “TX_CHAN”.

3.2.3.1 Transmit Channel

FEAT_TX_CHAN_ANA_010 [Definition of a “Transmit Channel”

The core feature Transmit Channel shall be used to refer to the capabilities provided by the Transceiver Subsystem component that performs up-conversion of a succession of input Baseband Signal bursts into output analogue RF Signal bursts.

] END_FEAT_TX_CHAN_ANA_010

FEAT_TX_CHAN_ANA_020 [Creation of a “Transmit Channel”

The deployment of a Transmit Channel and all its constituents shall be undertaken by Transceiver Subsystem deployment, following implementation specific choices.

The state of a Transmit Channel just after its creation and any of its constituent shall be state Deployed.

The initialization of the Transmit Channel shall be conducted by deployment.

] END_FEAT_TX_CHAN_ANA_020

The steps setting one Up-conversion Chain into state Deployed are realized by (re)configuration mechanisms proper to the Transceiver Subsystem implementation, which are out of the scope of this specification.

FEAT_TX_CHAN_ANA_030 [Composition of a “Transmit Channel”

The following concepts shall be integrated as constituents of a given Transmit Channel:

- Concept Up-conversion Chain,
- Concept Transmit Baseband Signal FIFO.

] END_FEAT_TX_CHAN_ANA_030

They are defined in their respective definition requirements as specified in the following paragraphs.

3.2.3.2 Transmit Baseband Signal

The Transmit Baseband Signal is the useful signal provided by the Waveform Application to the Transmit Channel in order to be transmitted over the air.

Terms and definitions used in this chapter are based on those presented within Common Concepts Baseband Interface 4.2.4 section.

FEAT_TX_CHAN_ANA_040 [Definition of “Transmit Baseband Signal”

The concept Transmit Baseband Signal shall describe the useful baseband signal sent by the Waveform Application to a Transmit Channel for up-conversion.

] END_FEAT_TX_CHAN_ANA_040

Useful baseband signal corresponds to the signal useful to be transmitted on the antenna, and received by the receiver.
Useful baseband signal can include the following possible information:

- Power rising pattern
- Power falling pattern
- ALC and/or AGC patterns
- Data and eventually WF specifics pattern (sequences for synchronization)

**FEAT_TX_CHAN_ANA_050** [ Implicit Notions of “Transmit Baseband Signal”

A Transmit Baseband Signal shall be characterized using the following notions, defined by common concept Baseband Signal.

- Implicit Notion Baseband Coding Bits
- Implicit Notion Baseband Nominal Power

] END_FEAT_TX_CHAN_ANA_050

**FEAT_TX_CHAN_ANA_060** [ Transmit Baseband Signal configuration

The properties of Transmit Baseband Signal shall be set to values appropriate for the considered waveform during Transmit Channel deployment.

] END_FEAT_TX_CHAN_ANA_060

### 3.2.3.3 Transmit Baseband FIFO

The Transmit Baseband FIFO contains baseband signal samples provided by the Waveform Application in order for them to be consumed by the Up-conversion Chain.

Consumption of baseband samples in the Transmit Baseband FIFO is realized in a packet mode.

The FIFO monitors samples availability in order to raise error notification in case the samples needed by the Up-conversion chain would not be available (underflow situation).

**FEAT_TX_CHAN_ANA_070** [ Definition of “Transmit Baseband FIFO”

The terminology Transmit Baseband FIFO shall be associated with the part of the sub-part of the Transmit Channel where the baseband samples of the bursts pushed by the Waveform Application are stored, waiting to be consumed by the Up-conversion Chain.

] END_FEAT_TX_CHAN_ANA_070

**FEAT_TX_CHAN_ANA_080** [ Implicit Notion “BasebandFIFOSize”

The Implicit Notion BasebandFIFOSize shall be the Ulong value which captures the size of Transmit Baseband FIFO, capturing the maximum number of baseband samples possibly stored inside the Baseband FIFO.

] END_FEAT_TX_CHAN_ANA_080

**FEAT_TX_CHAN_ANA_090** [ Implicit Notion “TuningStartThreshold”

The Implicit Notion TuningStartThreshold shall be the Ulong value which defines the threshold applicable to the number of samples received in the Transmit Baseband FIFO within a transmitted baseband samples burst before Tuning transition is activated.

] END_FEAT_TX_CHAN_ANA_090

Remark: This active phase triggering mode is useful for waveforms having no specific requirement concerning the instant when RFTransmitStart shall happen.
FEAT_TX_CHAN_ANA_100 [ Default value of “TuningStartThreshold”

The Implicit Notion TuningStartThreshold shall have a default value of 0, meaning the Waveform does not use this threshold to set up when RFTransmitStart shall happen.

] END_FEAT_TX_CHAN_ANA_100

Keeping the default value means that Tuning activity starts immediately after first sample has been received, which means further samples must arrive sufficiently fast from the Waveform Application.

FEAT_TX_CHAN_ANA_110 [ Configuration of “Transmit Baseband FIFO”

The properties of Transmit Baseband FIFO shall be set to the values required by the considered Waveform Application during the Transmit Channel deployment.

] END_FEAT_TX_CHAN_ANA_110

Availability deadline and Underflow situations

Any sample of the burst shall be present within baseband FIFO when the up-conversion needs to consume them. An availability deadline is therefore attached to each sample to be transmitted within a cycle.

The availability deadline of the first transmitted sample is equal to ConsumptionStartTime which is derived from the TransmitStartTime and UpConversionLatency. The availability deadline of each next sample is an increment of the baseband signal period per new sample, namely the time between two consecutive samples.

In case any sample to be transmitted would not be available within the FIFO before its availability deadline, the Transmit Channel goes into a SignalUnderflow situation. This is an error situation.

FEAT_TX_CHAN_ANA_120 [ Error “FIFOUnderflow”

During the Active Phase of a Transmit Cycle, an error ERR_FIFOUnderflow shall be generated if the FIFO runs into underflow situation.

] END_FEAT_TX_CHAN_ANA_120

FEAT_TX_CHAN_ANA_130 [ FIFO Underflow TransmitStop

During the active state of a Transmit Cycle, if Baseband FIFO runs into underflow situation, the transmission shall be stopped by initiating a TransmitStop transition, immediately after the last sample pushed into baseband FIFO has been consumed by Up-conversion Chain.

] END_FEAT_TX_CHAN_ANA_130

3.2.3.4 Up-conversion Chain

FEAT_TX_CHAN_ANA_140[ Definition of the “Up-conversion Chain”

Concept Up-conversion Chain shall denote the signal processing chain in the Transmit Channel which undertakes, during periods of time denoted as Active Transmit Cycles, continuous transformation of one input baseband signal burst into the corresponding RF signal burst.

] END_FEAT_TX_CHAN_ANA_140

FEAT_TX_CHAN_ANA_150 [ Constraint “MaxUpconversionLatency”

The constraint MaxUpconversionLatency of type Latency shall be used to characterize the maximum allowed elapsed time between the instant a sample is consumed by the Up-conversion Chain from the Baseband FIFO and the instant this sample is on the RF output.

] END_FEAT_TX_CHAN_ANA_150
This value has to be taken into consideration by the waveform application engineering process. The term *Up-conversionLatency* is used in the following sections as an Internal Notion which is implementation related and does not exceed the above constraint.

**States and Transitions of Up-conversion Chain**

The following figure summarizes the concepts addressed in the following paragraphs:

![Diagram of states and transitions of the Up-conversion Chain]

*Figure 12: States and transitions of the Up-conversion Chain*
FEAT_TX_CHAN_ANA_160 [ States of Up-conversion Chain

The following states shall be implemented by an Up-conversion Chain:

- **Deployed**: Initial state of the chain once deployed according to considered Waveform requirements.
- **Unactive**: The state during which the Up-conversion Chain is not consuming samples within baseband FIFO, and is not outputing any signal at RF level. Automatically reached once Up-conversion Chain is Deployed.
- **Activation**: The transient state during which the Up-conversion Chain has started to consume input baseband signal, while it is not yet outputing the corresponding useful signal at RF level. Arrival of the useful baseband signal at RF level corresponds to the end of the state.
- **Active**: The state during which the input baseband signal is continuously consumed by the Up-conversion Chain, and transformed into the associated RF signal which is being produced by the chain at its output.
- **Deactivation**: The transient state during which Tx baseband signal is not consumed anymore by the Up-conversion Chain, while the previously consumed signal is still being processed by the Up-conversion with associated signal produced. End of this useful signal processing corresponds to the end of the state.

] END_FEAT_TX_CHAN_ANA_160

Activation and Deactivation are transient states which have a duration equal to the Up-conversionLatency, which is the time elapsed between (i) the instant when consumption of a given sample occurs from the Baseband FIFO and (ii) the instant when the corresponding RF signal is transmitted. A Tuning activity, not depicted in the preceding figure, is the step during which the Waveform Application shall configure a Transmit Cycle for the transmission of the next burst.

FEAT_TX_CHAN_ANA_170 [ Transitions between “Up-conversion Chain” states

The instantaneous transitions between states of an Up-conversion Chain shall respect the following list:

- **SamplesConsumptionStart**: transition between states Unactive and Activation
- **RFTransmitStart**: transition between states Activation and Active
- **SamplesConsumptionStop**: transition between states Active and Deactivation
- **RFTransmitStop**: transition between states Deactivation and Unactive

] END_FEAT_TX_CHAN_ANA_170

FEAT_TX_CHAN_ANA_180 [ Timings associated to Up-conversion Chain transitions

The following timings shall be associated with instants when instantaneous transitions of Up-conversion Chain are happening:

- **ConsumptionStartTime**: associated to transition SamplesConsumptionStart
- **TransmitStartTime**: associated to transition RFTransmitStart
- **ConsumptionStopTime**: associated to transition SamplesConsumptionStop
- **TransmitStopTime**: associated to transition RFTransmitStop.

] END_FEAT_TX_CHAN_ANA_180

FEAT_TX_CHAN_ANA_190 [ Tuning activity

The Tuning activity shall be used to configure the signal processing requirements captured in Tuning Profile. This activity is characterized by the time it starts, TuningStartTime, and its duration, TuningDuration.

] FEAT_TX_CHAN_ANA_190
FEAT_TX_CHAN_ANA_200 [ Constraint “MaxTuningDuration”]
The Constraint MaxTuningDuration shall be used to characterize the maximum allowable constant duration of the Tuning activity.
] END_FEAT_TX_CHAN_ANA_200
It is the boundary for internal notion TuningDuration

FEAT_TX_CHAN_ANA_210 [ Internal Notion “TuningStartTime”]
The internal notion TuningStartTime shall be used to specify the beginning of the Tuning activity. Nominal use of TuningStartTime is described by the relationships below:

\[
\text{TuningStartTime}[n+1] = \text{ConsumptionStartTime}[n+1] - \text{TuningDuration}
\]
\[
\text{TuningStartTime}[n+1] \geq \text{TransmitStopTime}[n]
\]

In rare cases the TuningStartTime[n+1] would be allowed to start before the TransmitStopTime[n], for example in case of duplicated channels for very fast frequency hopping applications.
] END_FEAT_TX_CHAN_ANA_210

The following figure summarizes the definitions introduced in this section:

**Figure 13: Time profile of Transmit Cycle**

FEAT_TX_CHAN_ANA_220 [ Constraint “MinReactivationTime”]
The Constraint MinReactivationTime shall be used to quantify the minimum time elapsed between the TransmitStopTime of one given Transmit Cycle and the TransmitStartTime of the next one.
] END_FEAT_TX_CHAN_ANA_220

**Identification of Current Cycle**
Default event-based time requests are to be based on the notion of “Current” Transmit Cycle.
FEAT_TX_CHAN_ANA_230 [  Definition of the “Current” Transmit Cycle

The notion of current Transmit Cycle shall be applied, for operations invoked by the Waveform Application making event-based time requests, as a function of the instant when the considered operation is invoked by Waveform Application.

] END_FEAT_TX_CHAN_ANA_230

FEAT_TX_CHAN_ANA_240 [  Rule for “Current” Transmit Cycle identification

The current Transmit Cycle shall be the Active Transmit Cycle, if the operation is invoked when a Transmit Cycle is active, or the last Transmit Cycle that finished before invocation.

] END_FEAT_TX_CHAN_ANA_240

Uncertainty of identification of the current Transmit Cycle thus exists when invocation of createTransmitCycle() happens close to the ConsumptionStartTime of a certain cycle. It is up to Waveform Application design to take appropriate assumptions to avoid calls happening within this time zone.

3.2.3.5 Transmit Cycle

A compliant execution by the Up-conversion Chain of a given Transmit Cycle relies upon availability of two sorts of information:

- Control data, captured into the Transmit Cycle Profile
- Input data, denoted as the Transmit Cycle Input Burst

The Transmit Cycle Input Burst is the slice of baseband signal provided by the Waveform Application that the Up-conversion Chain will transform into RF signal during the considered Transmit Cycle, in compliance with the signal processing requirements captured in Tuning Profile and the real-time requirements captured in the Time Profile.

Transmit Cycle Input Burst

FEAT_TX_CHAN_ANA_250 [  Definition of “Transmit Cycle Input Burst”

The Transmit Cycle Input Burst shall denote the un-interrupted slice of baseband signal provided by the Waveform Application for transmission during the considered Transmit Cycle.

] END_FEAT_TX_CHAN_ANA_250

FEAT_TX_CHAN_ANA_260 [  Definition of “Transmit Cycle First Sample”

The Transmit Cycle First Sample shall denote the first sample of the considered input burst.

] END_FEAT_TX_CHAN_ANA_260

FEAT_TX_CHAN_ANA_270 [  Definition of “Transmit Cycle Last Sample”

The Transmit Cycle Last Sample shall denote the last sample of the considered input burst.

] END_FEAT_TX_CHAN_ANA_270

The mechanisms provided to the Waveform Application for provision of the input bursts unambiguously identify the burst first and last samples. This enables synchronization of the Up-conversion Chain operation to meet accurate transmission start and end time requirements.
Transmit Cycle Profile

FEAT_TX_CHAN_ANA_280 [ Definition of “Transmit Cycle Profile”

The concept of Transmit Cycle Profile shall be used to control the Transmit Cycles implemented during the life-time of one Up-conversion Chain. One specific Transmit Cycle Profile instance is created for each specific Transmit Cycle occurrence.

END_FEAT_TX_CHAN_ANA_280

Several Transmit Cycles Profiles may be simultaneously available. The profile corresponding to an Active Phase of the Up-conversion Chain is the only profile active at this time.

FEAT_TX_CHAN_ANA_290 [ Composition of “Transmit Cycle Profile”

A Transmit Cycle Profile shall be composed of a Cycle Identifier, a Time Profile and a Tuning Profile.

END_FEAT_TX_CHAN_ANA_290

Cycle identifier

FEAT_TX_CHAN_ANA_300 [ Explicit Notion “TransmitCycle”

Each created cycle has a unique integer identifier TransmitCycle which shall be set up during creation to a value incremented by one for each newly created Transmit Cycle, starting at 0 (ZERO) for the first created cycle and reaching the value of the constraint MaxCycleId before restarting counter to 0.

END_FEAT_TX_CHAN_ANA_300

FEAT_TX_CHAN_ANA_310 [ Constraint “MaxTxCycleProfiles”

The constraint MaxTxCycleProfiles shall refer to the maximum number of Transmit Cycles simultaneously existing at any time within the Transmit Channel.

END_FEAT_TX_CHAN_ANA_310

Time Profile

The Time Profile is set by the Waveform Application to define time positioning of the Transmit Cycle. It is composed of Explicit Notions TransmitStartTime and TransmitStopTime.

They correspond to the only externally measurable instants attached to a Transmit Cycle which are not dependent on the Up-conversion Chain implementation.

FEAT_TX_CHAN_ANA_320 [ Definition of “Time Profile”

A Time Profile shall be composed of explicit notions TransmitStartTime and TransmitStopTime.

END_FEAT_TX_CHAN_ANA_320

FEAT_TX_CHAN_ANA_330 [ Constraint “TransmitTimeProfileAccuracy”

The constraint “TransmitTimeProfileAccuracy” shall refer to the Event Accuracy associated with the Time Profile explicit notions, namely TransmitStartTime and TransmitStopTime.

END_FEAT_TX_CHAN_ANA_330

FEAT_TX_CHAN_ANA_340 [ Explicit Notion “TransmitstartTime”

The Explicit Notion TransmitStartTime shall be used within Time Profile to contain the Transmit Start Time of the corresponding Transmit Cycle.

END_FEAT_TX_CHAN_ANA_340034
FEAT_TX_CHAN_ANA_350 [   Referenced event source “TransmitStart”

The “TransmitStart” event, associated with the Transmit Start Time explicit notion, shall be the unique Referenced Event Source of the Transmit Channel.
] END_FEAT_TX_CHAN_ANA_350

FEAT_TX_CHAN_ANA_360 [   Explicit Notion “TransmitStopTime”

The Explicit Notion TransmitStopTime shall be used within Time Profile to contain the Transmit Stop Time of the corresponding Transmit Cycle.
] END_FEAT_TX_CHAN_ANA_360

Explicit Notions TransmitStartTime and TransmitStopTime obey accuracy constraints directly imposed by radio link interoperability conventions between transmitting and receiving radio nodes. Low accuracy on those values is requested for waveforms such as fixed frequency AM/FM speech waveforms, while high accuracy is needed for frequency hopping digitally modulated waveforms. TransmitStartTime and TransmitStopTime may be explicitly set by the Waveform Application by means of operations arguments. They belong to the Programmable subtype.

Their values can be measured thanks to external measurements conducted on a transmitting radio set without any knowledge of the Transceiver Sub-system internal implementation.

Implementation-dependent time Internal Notions

Implementation-dependent time Internal Notions necessary for analysis may be derived from the Explicit Notions introduced beforehand, using implementation-dependent durations or latencies:

- ConsumptionStartTime equals to TransmitStartTime less UpconversionLatency
- TuningStartTime equals ConsumptionStartTime less TuningDuration
- ConsumptionStopTime equals TransmitStopTime less UpconversionLatency

Refer to Figure 13: Time profile of Transmit Cycle for a graphical representation of above concepts

Tuning Profile

FEAT_TX_CHAN_ANA_370 [   Definition of “Transmit Tuning Profile”

A Transmit Tuning Profile shall be used to characterize which signal processing explicit notions values shall be applied by the Up-conversion Chain when the Transmit Cycle is activated.
] END_FEAT_TX_CHAN_ANA_370

These explicit notions will be fixed to the requested values and applicable for the complete duration of the Transmit Cycle.

FEAT_TX_CHAN_ANA_380 [   Contents of “Tuning Profile”

The following explicit notions are contained within the Tuning Profile:

- CarrierFrequency
- Nominal RF Power
- Tuning Preset

] END_FEAT_TX_CHAN_ANA_380

From one Transmit Cycle to the next, depending on the deployed waveform needs, the Tuning Profile may be totally different, partially different, or identical.

Examples

In fixed frequency TDD mode with unique channelization, the Tuning Profile is identical from one transmit cycle to another.
In advanced frequency hopping waveforms, the CarrierFrequency or the ChannelMask can be changed from one Transmit Cycle to another, causing different Tuning Profiles.

States and Transitions of Transmit Cycle Profile

The following figure shows how, for Active Transmit Cycle number \( n \) of a given Up-conversion Chain, active states of the corresponding Transmit Channel Profile are defined:

![Diagram of Transmit Cycle Profile and States](image)

**Figure 14: States and Transitions of a Transmit Cycle Profile**

**FEAT_TX_CHAN_ANA_390 [ States of a “Transmit Cycle Profile”**

The following states **shall** be implemented by a Transmit Cycle Profile:

- **Creation**: The Transmit Cycle Profile is created by Transmit Channel.
- **Pre-Activation**: The Transmit Cycle Profile is kept dormant with the possibility for the Waveform Application to update the profile (Time Profile or Up-conversion Profile).
- **Active Phase**: The profile values are taken into account by the Up-conversion Chain to launch the Transmit Cycle of interest, with undefined values completed according to Tuning, and updated to reflect what is effectively implemented during the Transmit Cycle in case they change because of Active Tuning.
- **Post-Activation**: The Transmit Cycle specified by the Transmit Cycle Profile is over, but profile is kept available to let the Tuning of the next Transmit Cycle to re-use previous values
- **Destruction**: The Transmit Cycle Profile is destroyed by the Transmit Channel.

] END_FEAT_TX_CHAN_ANA_390
FEAT_TX_CHAN_ANA_400 [ Transitions of “Transmit Cycle Profile”

The instantaneous transitions between states of a Transmit Cycle Profile shall respect the following list:

- **Created**: transition between states Creation and Pre-Activation
- **ActivePhaseStart**: transition between states Pre-Activation and Active Phase
- **ActivePhaseStop**: transition between states Active Phase and Post-Activation
- **DestructionStart**: transition between states Post-Activation and Desctruction

] END_FEAT_TX_CHAN_ANA_400

FEAT_TX_CHAN_ANA_410 [ Transitions correspondance

The transitions of the Up-conversion Chain for the Active Transmit Cycle # N shall follow the following relationships with the transitions of the corresponding instance of Transmit Cycle Profile:

- **ActivePhaseStart** and **TuningStart(n)** simultaneous
- **ActivePhaseStop** and **RFTransmitStop(n)** simultaneous
- **DestructionStart** after than **TransmitStartTime(n+1)**

] END_FEAT_TX_CHAN_ANA_410

3.2.3.6 Active Phase

**Triggering conditions**

The process leading to the activation of the Transmit Channel Profile starts when the Up-conversion Chain starts the Tuning activity, immediately before state Activation starts.

The triggering condition to start Tuning activity is based on the definition status of TransmitStartTime:

- If **TransmitStartTime** is defined, **TuningStart** will be realized so as to have the resulting **RFTransmitStart** happen at **TransmitStartTime**.
- If **TransmitStartTime** is not defined, **TuningStart** will be realized as soon as the number of baseband samples of the current burst accumulated in Transmit Baseband Signal FIFO has reached **TuningStartThreshold**.

If explicit notion **TransmitStopTime** is set to a defined value when **TuningStart** is happening, the Transmit Cycle is activated for a pre-defined duration. Otherwise, the cycle ending conditions remain to be defined after the cycle has started.

FEAT_TX_CHAN_ANA_420 [ Time-defined transition “StartTuning”

If the Explicit Notion **TransmitStartTime** of the TimeProfile is defined, the Transmit Channel shall initiate a TuningStart transition so as to have the RFTransmitStart happen at the instant specified by value of property **TransmitStartTime**.

] END_FEAT_TX_CHAN_ANA_420

FEAT_TX_CHAN_ANA_430 [ Signal-defined transition “StartTuning”

If the Explicit Notion **TransmitStartTime** of the TimeProfile is not defined, the Transmit Channel shall initiate a TuningStart transition as soon as the number of baseband samples in Transmit Baseband Signal FIFO for the current burst has reached a value superior or equal to the value of Implicit Notion **TuningStartThreshold**.

] END_FEAT_TX_CHAN_ANA_430
FEAT_TX_CHAN_ANA_440 [ Error “ERR_TooLateRequest”

In case the cycle specified by argument targetCycleId has already reached the state Tuning, or went further in the life sequence of the Transmit Cycle Profile, the operation can not be taken into account and an error ERR_TooLateRequest shall be generated.

] END_FEAT_TX_CHAN_ANA_440

Setting applicable profile

FEAT_TX_CHAN_ANA_450 [ Precedence rules for Tuning explicit notions definition

For each up-conversion processing explicit notion of any given Transmit Cycle, except the first one, the values applicable by the Up-conversion shall be determined during state Tuning in compliance with the following precedence rules, sorted in decreasing order:

- Last value set by a call during the state Idle
- Value set during the call to createTransmitCycle()
- Value applied for the considered property on the previous Transmit Cycle, if defined

] END_FEAT_TX_CHAN_ANA_450

3.2.3.7 Post-Activation

Triggering conditions

State Post-Activation of the Transmit Channel Profile corresponds to when the Up-conversion Chain has finished its state Deactivation and is back to state Unactive.

Entering into state Post-Activation is entirely based on the triggering conditions which push the Up-conversion Chain into state Deactivation.

- If TransmitStopTime is defined, SignalConsumptionStop will be realized so as to have the resulting RFTransmitStop happen at TransmitStopTime.
- If TransmitStopTime is not defined, availability of the last burst sample will trigger transition SignalConsumptionStop.

The usage of operation setTransmitStopTime() with an undefined requestedTransmitStopTime value is another possibility for SignalConsumptionStop trigger introduced previously.

FEAT_TX_CHAN_ANA_460 [ Time-defined transition “SignalConsumptionStop”

If the explicit notion TransmitStopTime of the TimeProfile is defined, the Transmit Channel shall initiate a transition SignalConsumptionStop so as to have the RFTransmitStop happen at the instant specified by value of TransmitStopTime.

] END_FEAT_TX_CHAN_ANA_460

FEAT_TX_CHAN_ANA_470 [ Signal-defined transition “SignalConsumptionStop”

If the explicit notion TransmitStopTime of the TimeProfile is not defined, the Transmit Channel shall initiate a SignalConsumptionStop transition as soon as the last sample of the burst is available within Tx Baseband Signal FIFO.

] END_FEAT_TX_CHAN_ANA_470

FEAT_TX_CHAN_ANA_480 [ Useless samples discarding

The Tx Baseband Signal FIFO shall discard the samples transmitted by the Waveform Application within the current burst which would exceed the last sample effectively consumed by the Up-conversion Chain in respect of the specified TransmitStopTime.

] END_FEAT_TX_CHAN_ANA_480
The destruction of a given *Transmit Cycle Profile* shall not be realized by the Transmit Channel until the next *Transmit Cycle* has reached its transition *RFTransmitStart*.

This requirement enables the *Tuning* of the next cycle to be able to re-use the previous *Tuning Profile* for undefined properties.

**Error “Too Short Burst”**

When the last sample of a burst is consumed and consumption shall continue because *ConsumptionStopTime* is not yet reached, the *Transceiver Subsystem* shall generate an error *Too Short Burst*.

### 3.2.3.8 Transmit Control

#### `createTransmitCycleProfile()`

**Purpose**

The operation `createTransmitCycleProfile()` enables to request the creation by the *Up-conversion Chain* of a specific *Transmit Cycle Profile*. It aims at performing a systematic call for any necessary *Transmit Cycle*.

**Syntax**

The operation `createTransmitCycleProfile()` shall be implemented by the Transmit Channel and be used by the Waveform Application in order to request the creation of a particular *Transmit Cycle Profile*.

**Argument “requestedTransmitStartTime”**

The argument `requestedTransmitStartTime` of type *TimeRequest* shall be used to request an initial value for the explicit notion *TransmitStopTime*.

**Constraint “MinTransmitStartProximity”**

If the argument `requestedTransmitStartTime` is an Event-based Time, it shall respect the *Min Event Proximity* constraint specified by “MinTransmitStartProximity”.

**Constraint “MinTransmitStartAnticipation”**

The constraint *MinTransmitStartAnticipation* of type *Latency* shall be used to characterize the minimum allowed elapsed time between the instant the `createTransmitCycleProfile()` operation is invoked and the target Transmission start time.

**Argument “requestedTransmitStopTime”**

The argument `requestedTransmitStopTime` of type *TimeRequest* shall be used to request an initial value for the explicit notion *TransmitStopTime*.
The argument requestedTuningPresetId of type UShort shall be used in order to indicate the PresetId value of the Tuning Preset to be applied on the considered burst.

The requirements associated with Tuning Presets are provided in Common Concepts.

The argument requestedCarrierFrequency of type Frequency shall be used to request a value for tuning explicit notion Carrier Frequency.

The argument requestedNominalRFPower of type Frequency shall be used to request a value for tuning explicit notion Nominal RF Power.

Semantics

The Transmit Channel shall set the initial values of the corresponding explicit notions in TransmitCycleProfile to the values specified by passed arguments.

If argument requestedTransmitStartTime is defined by the Waveform Application, the Transmit Channel will start the Active Phase according to the specified time. If the initial value of TransmitStartTime was left undefined, the Active Phase may not start until the value is further set.

If argument requestedTransmitStartTime is set to a defined value by the Waveform Application, the operation invocation which corresponds with internal notion TransmitStartAnticipation shall happen before the corresponding TuningStartTime respecting the MinTransmitStartAnticipation real-time constraint.

The Transmit Channel shall generate an error ERR_TooManyCreatedTxProfiles if creation of the Transmit Cycle Profile would cause a number of created profiles exceeding the value of constraint MaxTxCycleProfiles.

Usage of domain type Absolute Time Request format shall be available as a type possibility for argument requestedTransmitStartTime.
Usage of domain type “Event-based Time Request” shall be available as a type possibility for argument requestedTransmitStartTime.

The default Event Source for event-derived expression of requestedTransmitStartTime shall be the TransmitStartTime of the current Transmit Cycle.

For the first Transmit Cycle of the Transmit Channel lifetime, since there is no available pre-existing Transmit Cycle, the current Transmit Cycle is not defined so event-based approach can not be used.

The default event occurrence for event-derived time requests

The default event occurrence for event-derived expression of requestedTransmitStartTime shall be the last occurrence.

Purpose

This operation is the way a Waveform Application can set the Up-conversion profile during its state Pre-activation.

Syntax

The operation configureTransmitCycle() shall be implemented by the Transmit Channel and be used by the Waveform Application in order to set the value of the properties of a previously created Transmit Cycle.

The Transmit Cycle for which the requested properties values are applicable shall be identified by the argument targetCycleId of type ULong, which specifies the Cycle Identifier of the target Transmit Cycle.

The argument requestedTransmitStartTime of type TimeRequest shall be used to request an initial value for the explicit notion TransmitStartTime.

The constraint MinTransmitStartAnticipation of type Latency shall be used to characterize the minimum allowed elapsed time between the instant configureTransmitCycle() operation are invoked and the target transmission start time, when the argument requestedTransmitStartTime is specified.
FEAT_TX_CHAN_ANA_700 [ Argument “requestedTransmitStopTime”]

The argument requestedTransmitStopTime of type TimeRequest shall be used to request an initial value for the explicit notion TransmitStopTime.

] END_FEAT_TX_CHAN_ANA_700

FEAT_TX_CHAN_ANA_710 [ Argument “requestedCarrierFrequency”]

The argument requestedCarrierFrequency of type Frequency shall be used to request a value for tuning explicit notion Carrier Frequency.

] END_FEAT_TX_CHAN_ANA_710

FEAT_TX_CHAN_ANA_720 [ Argument “requestedNominalRFPower”]

The argument requestedNominalRFPower of type Frequency shall be used to request a value for tuning explicit notion Nominal RF Power.

] END_FEAT_TX_CHAN_ANA_720

Errors

FEAT_TX_CHAN_ANA_730 [ Error “Unknown Target Cycle”]

In case the cycle specified by argument targetCycleId is not created, the operation can not be taken into account and an error Unknown Target Cycle shall be generated.

] END_FEAT_TX_CHAN_ANA_730

setTransmitStopTime()

Purpose

The operation setTransmitStopTime() is intended to allow setting the explicit notion TransmitStopTime value for a Transmit Cycle.

FEAT_TX_CHAN_ANA_740 [ Operation “setTransmitStopTime()”]

The operation setTransmitStopTime() shall be implemented by the Transmit Channel and be used by the Waveform Application in order to set the TransmitStopTime of the considered Transmit Cycle.

] END_FEAT_TX_CHAN_ANA_740

FEAT_TX_CHAN_ANA_750 [ Argument “requestedTransmitStopTime”]

The argument requestedTransmitStopTime shall be available in operation setTransmitStopTime() in order to enable the Waveform Application to specify when the transition RFTransmitStop shall happen.

] END_FEAT_TX_CHAN_ANA_750

FEAT_TX_CHAN_ANA_760 [ Defined “requestedTransmitStopTime”]

If argument requestedTransmitStartTime is set to a defined value by Waveform Application, the Transmit Channel shall deactivate the Transmit Cycle in respect of the specified value.

] END_FEAT_TX_CHAN_ANA_760
FEAT_TX_CHAN_ANA_770 [ Undefined “requestedTransmitStopTime” (instant Deactivation)

If argument requestedTransmitStartTime is set to undefined by Waveform Application, the Transmit Channel shall immediately turn the current Transmit Cycle into Deactivation state, discarding the unused baseband samples eventually stored into Tx Baseband Signal FIFO for the aborted burst.

] END_FEAT_TX_CHAN_ANA_770

FEAT_TX_CHAN_ANA_780 [ Constraint “MinTransmitStopAnticipation”

The operation setTransmitStopTime() shall be called with an anticipation relatively to the requestedTransmitStopTime at least equal to value of constraint MinTransmitStopAnticipation, of type Latency.

] END_FEAT_TX_CHAN_ANA_780

FEAT_TX_CHAN_ANA_790 [ Error “ERR_TooLateRequest”

If the operation setTransmitStopTime() is invoked after TransmitStopTime – MinTransmitStopAnticipation, the Transmit Channel is not able to guarantee correct application, and an error ERR_TooLateRequest shall be generated.

] END_FEAT_TX_CHAN_ANA_790

3.2.3.9 Transmit Data Push

Overview

The programming interface Transmit Data Push enables the Waveform Application to push packets of baseband samples towards the Transmit Channel.

The programming interface relies on: (i) a single operation, pushBBSamplesTx(), (ii) the data pushed by the Waveform Application, denoted as The Pushed Packet.

pushBBSamplesTx() is used by the Waveform Application to: (i) notify the Transmit Channel of availability of a new packet of samples, (ii) indicate if the pushed packet is the last packet of the transmitted burst.

The Pushed Packet structure is defined by common concept Baseband Packet. It must be prepared by Waveform Application prior to the pushBBSamplesTx() notification. The samples are stored by the Waveform Application in conformance with specific packets contents requirements.

Once pushBBSamplesTx() is called, the Transmit Channel undertakes packets handling activities. First, it has to take in charge the pushed packet, copying its content into an internal memory zone. Second, it has to store the corresponding data into the Baseband FIFO.

The way a Transmit Channel implementation takes in charge the pushed packet and stores it into the Baseband FIFO is implementation dependent. Most reactive implementations will take in charge and store in baseband FIFO the pushed packet into one single data copy. More complex designs may exist, especially...
when the digital part of the Transceiver Subsystem is distributed over different digital signal processing units.

### The Pushed Packet

#### Structural requirements

**FEAT_TX_CHAN_ANA_810** [ Definition of “The Pushed Packet” ]

A data construct denoted The Pushed Packet, of type Baseband Packet, shall be used to contain the Baseband Signal samples to be pushed.

) END_FEAT_TX_CHAN_ANA_810

**FEAT_TX_CHAN_ANA_820** [ Creation of “The Pushed Packet” ]

The Pushed Packet shall be created by the Waveform Application.

) END_FEAT_TX_CHAN_ANA_820

**FEAT_TX_CHAN_ANA_830** [ Visibility on “The Pushed Packet” ]

The Pushed Packet shall be visible by the Waveform Application with write rights and be visible by the Transmit Channel with read rights.

) END_FEAT_TX_CHAN_ANA_830

**FEAT_TX_CHAN_ANA_840** [ Destruction of “The Pushed Packet” ]

The Pushed Packet shall be destroyed by the Waveform Application.

) END_FEAT_TX_CHAN_ANA_840

#### Packets ordering requirements

This section specifies a certain number of requirements applicable to packets content.

**FEAT_TX_CHAN_ANA_850** [ Packets burst alignment ]

The pushed baseband samples shall be aligned with the Transmit Cycles Input Bursts, which means no packet contains samples belonging to two different input bursts.

) END_FEAT_TX_CHAN_ANA_850

**FEAT_TX_CHAN_ANA_860** [ Sequential bursts transmission ]

The pushed baseband samples packets shall be transmitted one burst after the other.

) END_FEAT_TX_CHAN_ANA_860

**FEAT_TX_CHAN_ANA_870** [ Ordered packets pushes ]

The pushed baseband samples packets shall not be interverted within a given burst.

) END_FEAT_TX_CHAN_ANA_870

#### Packets identification

The first packet of a burst is defined as the packet where first sample is the first transmitted sample of the burst.

The last packet of a burst is defined as the packet where last sample is the last transmitted sample of the burst.
A packet containing all the samples of a given burst is at the same time the first and last packet of the burst. The last packet of a burst is therefore systematically followed by the first packet of the next burst.

```
pushBBSamplesTx()
```

**Syntax**

**FEAT_TX_CHAN_ANA_880 [ Operation “pushBBSamplesTx()”**

Operation `pushBBSamplesTx()` shall be used by the Waveform Application and realized by the Transmit Channel, in order to: (i) notify the Transmit Channel of availability of a new packet of samples, (ii) indicate if the pushed packet is the last packet of the transmitted burst.

] END_FEAT_TX_CHAN_ANA_880

**FEAT_TX_CHAN_ANA_890 [ Argument “thePushedPacket”**

The argument `thePushedPacket`, of type `BBSamplesPacket`, shall contain information enabling to access to the pushed packet.

] END_FEAT_TX_CHAN_ANA_890

The pushed packet content shall have been prepared by the Waveform Application to contain correct signal before invocation. The size of the pushed packet is determined by the value of argument `requestedPacketSize` set during the Transmit Cycle creation or profile configuration.

**FEAT_TX_CHAN_ANA_900 [ Argument “endOfBurst”**

The argument `endOfBurst`, of type `Boolean`, shall be used to indicate that the pushed packet is the last packet of the current Transmit Cycle Input Burst.

Value `True` if the packet is the last packet, `False` or `undefined` otherwise.

] END_FEAT_TX_CHAN_ANA_900

**Semantics**

**FEAT_TX_CHAN_ANA_910 [ pushBBSamplesTx() Post-Invocation**

When return of `pushBBSamplesTx()` returns, the samples values contained in the pushed packet shall have been taken into account by the Transceiver Subsystem.

] END_FEAT_TX_CHAN_ANA_910

The Waveform Application is then free to handle in any way the pushed packet, since return from invocation means the useful data have been taken into account by Transmit Channel. Among possibilities, one can quote that the same pushed packet can be re-used for the next push, that it can be destroyed with another one being created for the next push, that a pair of packets may be alternately used in flip-flop.

**FEAT_TX_CHAN_ANA_920 [ pushBBSamplesTx() Post-Invocation for defined TransmitStopTime**

When the `TransmitStopTime` of a burst is explicitly set, the Transmit Channel shall discard any pushed samples in excess from the Baseband Burst limit set by `TransmitStopTime` value.

] END_FEAT_TX_CHAN_ANA_920
Realt-time Constraints

**FEAT_TX_CHAN_ANA_930** [ Constraint “MaxTransmitDataPushInvocationDuration”]

The constraint “MaxTransmitDataPushInvocationDuration”, of type Latency, shall be used to identify the Max Invocation Duration to be met by pushBBSamplesTx implementations.

As noted in §2.3, the Max Invocation Duration of an operation corresponds to the time difference between:

- The instant when an operation invocation occurs
- The instant when an operation return occurs

The constraint may remain undefined if the real-time constraints of the radio capability do not justify it. 

Max pushBBSamplesTx Invocation Duration is generally assigned a unique value, taking into consideration the maximum packet size used by the waveform application.

**FEAT_TX_CHAN_ANA_940** [ Constraint “Min Packet Storage Anticipation”]

The constraint Min Packet Storage Anticipation, of type Latency, shall be used to identify the Minimum Anticipation to be guaranteed in order to have a packet stored in Baseband FIFO before the target time.

The target time to be considered takes into account the consumption start time of the considered burst and the relative time shift between the first sample of the burst and the samples in the pushed packet.

Arguments Boundaries

**FEAT_TX_CHAN_ANA_950** [ Implicit Notion “MaxPushedPacketSize”]

The implicit notion MaxPushedPacketSize, of type Ulong, shall be used to set the maximum packet size sent through the operation pushBBSamplesPacket().

**FEAT_TX_CHAN_ANA_960** [ Error “ERR_Oversized Pushed Packet”]

In case the size of a pushed packet exceeds the property MaxPushedPacket Size, the Transmit Channel shall generate the error ERR_Oversized Pushed Packet.

Overflow mitigation

Two overflow mitigation options can be selected:

- Caller Blocked: The Transceiver Subsystem will block the waveform application until there is sufficient space in the FIFO to copy the pushed packet.
- No Overflow: Reaching overflow is corresponded to an error, so the Transceiver Subsystem is requested to generate an error.

**FEAT_TX_CHAN_ANA_970** [ Implicit notion “OverflowMitigation”]

The enumerated implicit notion Overflow Mitigation shall be used to set the applicable overflow mitigation option.

The possible values are: (i) Caller Blocked and (ii) No Overflow. Undefined corresponds to Caller Blocked.
FEAT_TX_CHAN_ANA_980 [ Caller Blocked Overflow Mitigation

When implicit notion Overflow Mitigation is set to CallerBlocked, the Transceiver Subsystem shall block the Waveform Application execution until sufficient room is available within Baseband FIFO to complete copy of the pushed packet. The constraint Max Invocation Duration is not applicable in this scenario.

] END_FEAT_TX_CHAN_ANA_980

This is the default mode since it does not require any supplementary dependency between the Waveform Application and the platform. This occurs at the expense of handling trivial synchronization mechanisms. It is therefore believed to be the optimal solution.

FEAT_TX_CHAN_ANA_990 [ No Overflow Overflow Mitigation

When implicit notion Overflow Mitigation is set to No Overflow, the Transceiver Subsystem shall raise an error in case an overflow of the FIFO occurs. The samples in excess are not copied into baseband FIFO.

] END_FEAT_TX_CHAN_ANA_990

This mode can be used in cases where waveform design is considering overflow case shall not occur. Two mainstream design paradigms can justify usage of such an option:

- Synchronization events provide the Waveform Application with information which shall avoid overflow situation.
- Flow control mechanisms enable the Transmit Channel to stop the Waveform Application when the Tx Baseband Signal FIFO fill level becomes critical, and to restart it once room is available again. This corresponds to feature AsyncControlMechanisms of [Digital IF Initial Submission].
3.2.3.10 Analysis Requirements Summary

The following table provides an overview of the Analysis requirements of Transmit Channel:

<table>
<thead>
<tr>
<th>Identifier</th>
<th>Tag</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEAT_TX_CHAN_ANA_010</td>
<td>Definition of a “Transmit Channel”</td>
<td>Transmit Channel</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_020</td>
<td>Creation of a “Transmit Channel”</td>
<td>Transmit Channel</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_030</td>
<td>Composition of a “Transmit Channel”</td>
<td>Transmit Channel</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_040</td>
<td>Definition of “Transmit Baseband Signal”</td>
<td>Transmit Baseband Signal</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_050</td>
<td>Implicit Notions of “Transmit Baseband Signal”</td>
<td>Transmit Baseband Signal</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_060</td>
<td>Transmit Baseband Signal configuration</td>
<td>Transmit Baseband Signal</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_070</td>
<td>Definition of “Transmit Baseband FIFO”</td>
<td>Transmit Baseband FIFO</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_080</td>
<td>Implicit Notion “BasebandFIFOSize”</td>
<td>Transmit Baseband FIFO</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_090</td>
<td>Implicit Notion “TuningStartThreshold”</td>
<td>Transmit Baseband FIFO</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_100</td>
<td>Default value of “TuningStartThreshold”</td>
<td>Transmit Baseband FIFO</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_110</td>
<td>Configuration of “Transmit Baseband FIFO”</td>
<td>Transmit Baseband FIFO</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_120</td>
<td>Error “FIFOUnderflow”</td>
<td>Transmit Baseband FIFO</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_130</td>
<td>FIFO Underflow TransmitStop</td>
<td>Transmit Baseband FIFO</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_140</td>
<td>Definition of the “Up-conversion Chain”</td>
<td>Up-conversion Chain</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_150</td>
<td>Constraint “MaxUpconversionLatency”</td>
<td>Up-conversion Chain</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_160</td>
<td>States of Up-conversion Chain</td>
<td>Up-conversion Chain</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_170</td>
<td>Transitions between “Up-conversion Chain” states</td>
<td>Up-conversion Chain</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_180</td>
<td>Timings associated to Up-conversion Chain transitions</td>
<td>Up-conversion Chain</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_190</td>
<td>Tuning activity</td>
<td>Up-conversion Chain</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_200</td>
<td>Constraint “MaxTuningDuration”</td>
<td>Up-conversion Chain</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_210</td>
<td>Internal Notion “TuningStartTime”</td>
<td>Up-conversion Chain</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_220</td>
<td>Constraint “MinReactivationTime”</td>
<td>Up-conversion Chain</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_230</td>
<td>Definition of the “Current” Transmit Cycle</td>
<td>Up-conversion Chain</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_240</td>
<td>Rule for “Current” Transmit Cycle identication</td>
<td>Up-conversion Chain</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_250</td>
<td>Definition of “Transmit Cycle Input Burst”</td>
<td>Transmit Cycle</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_260</td>
<td>Definition of “Transmit Cycle First Sample”</td>
<td>Transmit Cycle</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_270</td>
<td>Definition of “Transmit Cycle Last Sample”</td>
<td>Transmit Cycle</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_280</td>
<td>Definition of “Transmit Cycle Profile”</td>
<td>Transmit Cycle</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_290</td>
<td>Composition of “Transmit Cycle Profile”</td>
<td>Transmit Cycle</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_300</td>
<td>Explicit Notion “TransmitCycle”</td>
<td>Transmit Cycle</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_310</td>
<td>Constraint “MaxTxCycleProfiles”</td>
<td>Transmit Cycle</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_320</td>
<td>Definition of “Time Profile”</td>
<td>Transmit Cycle</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_330</td>
<td>Constraint « TransmitTimeProfileAccuracy »</td>
<td>Transmit Cycle</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_340</td>
<td>Explicit Notion “TransmitStartTime”</td>
<td>Transmit Cycle</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_350</td>
<td>Referenced event source « TransmitStart »</td>
<td>Transmit Cycle</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_360</td>
<td>Explicit Notion “TransmitStopTime”</td>
<td>Transmit Cycle</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_370</td>
<td>Definition of “Transmit Tuning Profile”</td>
<td>Transmit Cycle</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_380</td>
<td>Contents of “Transmit Profile”</td>
<td>Transmit Cycle</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_390</td>
<td>States of “Transmit Cycle Profile”</td>
<td>Transmit Cycle</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_400</td>
<td>Transitions of “Transmit Cycle Profile”</td>
<td>Transmit Cycle</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_410</td>
<td>Transitions correspondence</td>
<td>Transmit Cycle</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_420</td>
<td>Time-defined transition “StartTuning”</td>
<td>Active Phase</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_430</td>
<td>Signal-defined transition “StartTuning”</td>
<td>Active Phase</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_440</td>
<td>Error “ERR_TooLateRequest”</td>
<td>Active Phase</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_450</td>
<td>Precedence rules for Tuning explicit notions definition</td>
<td>Active Phase</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_460</td>
<td>Time-defined transition “SignalConsumptionStop”</td>
<td>Post-Activation</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_470</td>
<td>Signal-defined transition “SignalConsumptionStop”</td>
<td>Post-Activation</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_480</td>
<td>Useless samples discarding</td>
<td>Post-Activation</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_490</td>
<td>Desctruction start time</td>
<td>Post-Activation</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_500</td>
<td>Error TooShortBurst</td>
<td>Post-Activation</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_510</td>
<td>Operation “createTransmitCycleProfile()”</td>
<td>Transmit Control</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_520</td>
<td>Argument “requestedTransmitStartTime”</td>
<td>Transmit Control</td>
</tr>
</tbody>
</table>
Table 14: Overview of Transmit Channel Analysis requirements

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEAT_TX_CHAN_ANA_530</td>
<td>Constraint “MinTransmitStartProximity”</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_540</td>
<td>Constraint “MinTransmitStartAnticipation”</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_550</td>
<td>Argument “requestedTransmitStopTime”</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_560</td>
<td>Argument “requestedTuningPresetId”</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_570</td>
<td>Argument “requestedCarrierFrequency”</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_580</td>
<td>Argument “requestedNominalRFPower”</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_590</td>
<td>TransmitCycleProfile initialization</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_600</td>
<td>Constraint “MinTransmitStartAnticipation”</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_610</td>
<td>Error “ERRTooManyCreatedTxProfiles”</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_620</td>
<td>“requestedTransmitStartTime” using AbsoluteTimeRequest format</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_630</td>
<td>“requestedTransmitStartTime” using event-based format</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_640</td>
<td>Default event source for event-derived time requests</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_650</td>
<td>Default event occurrence for event-derived time requests</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_660</td>
<td>Operation “configureTransmitCycle()”</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_670</td>
<td>Target cycle identification in “configureTransmitCycle()”</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_680</td>
<td>Argument “requestedTransmitStartTime”</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_690</td>
<td>Constraint “TransmitStopAnticipation”</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_700</td>
<td>Error “ERRTooLateRequest”</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_710</td>
<td>Constraint “MaxTransmitControlInvocationDuration”</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_720</td>
<td>Definition of “The Pushed Packet”</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_730</td>
<td>Visibility on “The Pushed Packet”</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_740</td>
<td>Desctruction of “The Pushed Packet”</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_750</td>
<td>Packets burst alignement</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_760</td>
<td>Ordered packets pushes</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_770</td>
<td>Operation “pushBBSamplesTx()”</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_780</td>
<td>Argument “thePushedPacket”</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_790</td>
<td>Error “ERR_Oversized Pushed Packet”</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_800</td>
<td>Implicit notion “Overflow Mitigation”</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_810</td>
<td>Caller Blocked Overflow Mitigation</td>
</tr>
<tr>
<td>FEAT_TX_CHAN_ANA_820</td>
<td>No Overflow Overflow Mitigation</td>
</tr>
</tbody>
</table>
3.2.4 Modelling Requirements

3.2.4.1 Transmit Channel interfaces

The following class diagram involves the interfaces realized by the Transmit Channel, between the Waveform Application and the Transceiver Subsystem:

```
Figure 15: Transmit Channel involved interfaces
```

**FEAT_TX_CHAN_MOD_010** [Transmit Control interface]

*Transmit Control* is the interface used to control the Transmit Channel behaviors according to the Waveform needs. This interface **shall** include the following operations:

- createTransmitCycleProfile()
- configureTransmitCycle()
- setTransmitStopTime()

Definitions of operations and behaviors of their realizations by the Transmit Channel core feature are specified in the baseline requirements of the Transmit Channel.

)` END_FEAT_TX_CHAN_MOD_010`

**FEAT_TX_CHAN_MOD_020** [Transmit Data Push interface]

*Transmit Data Push* is the interface used for transferring baseband samples from the Waveform Application to the Transceiver Subsystem. This interface **shall** include the following operation:

- pushBBSamplesTx()

Definition of this operation and associated behaviour of its realization by the Transmit Channel core feature are specified in the baseline requirements of the Transmit Channel.

)` END_FEAT_TX_CHAN_MOD_020`
Note: Signatures of the operations are not provided for better visibility. Specification of the operations is depicted in paragraph Baseline Requirements of this chapter.

3.2.4.2 Transmit Channel composition

FEAT_TX_CHAN_MOD_030 [Transmit Channel modelling elements 1]

Transceiver Subsystem model involving feature Transmit Channel shall use the modelling elements depicted in the following class diagram:

![Class Diagram](image)

Figure 16: Transmit Channel main composition

END_FEAT_TX_CHAN_MOD_030
FEAT_TX_CHAN_MOD_040 [   Transmit Channel modelling elements 2

Transceiver Subsystem model involving feature Transmit Channel shall use the modelling elements depicted in the following class diagram:

![Class Diagram](image)

**Figure 17: Transmit Channel and Cycle Profile**

END_FEAT_TX_CHAN_MOD_040

### 3.2.5 Implementation Languages Requirements

#### 3.2.5.1 C++ Requirements

Interfaces between the Waveform Application and the Transceiver Subsystem for the Transmit Channel core feature are:

- **Transmit Control**
- **Transmit Data Push**

Both are seen in a modeling analysis as abstract classes defining abstract operations. In C++ language, this leads to consider these operations as pure virtual methods of its respective classes. These methods can not be implemented by these abstract classes, but shall be overridden and implemented by derived classes.
TransmitControl interface

FEAT_TX_CHAN_CPP_010 [ TransmitControl C++ definition ]
Implementations in C++ using the feature Transmit Channel shall use the interface TransmitControl as declared in the following C++ reference source code extract:

```cpp
class I_TransmitControl {
    public:
        virtual void createTransmitCycleProfile(
            Time requestedTransmitStartTime,
            Time requestedTransmitStopTime,
            UShort requestedPresetId,
            Frequency requestedCarrierFrequency,
            AnaloguePower requestedNominalRFPower) = 0;

        virtual void configureTransmitCycle(
            ULong targetCycleId,
            Time requestedTransmitStartTime,
            Time requestedTransmitStopTime,
            Frequency requestedCarrierFrequency,
            AnaloguePower requestedNominalRFPower) = 0;

        virtual void setTransmitStopTime(
            ULong targetCycleId,
            Time requestedTransmitStopTime) = 0;
};
```

] END_FEAT_TX_CHAN_CPP_010

FEAT_TX_CHAN_CPP_020 [ TransmitControl C++ header file ]
Implementations in C++ using the feature Transmit Channel shall include the header file entitled TransmitControl.h, corresponding to the header file of the TransmitControl definition.

] END_FEAT_TX_CHAN_CPP_020

TransmitDataPush interface

FEAT_TX_CHAN_CPP_030 [ TransmitDataPush C++ definition ]
Implementations in C++ using the feature Transmit Channel shall use the interface TransmitDataPush as declared in the following C++ reference source code extract:

```cpp
class I_TransmitDataPush {
    public:
        virtual void pushBBSamplesTx(
            BBPacket * thePushedPacket,
            Boolean endOfBurst) = 0;
};
```

] END_FEAT_TX_CHAN_CPP_030

FEAT_TX_CHAN_CPP_040 [ TransmitDataPush C++ header file ]
Implementations in C++ using the feature Transmit Channel shall include the header file entitled TransmitDataPush.h, corresponding to the header file of the TransmitDataPush definition.

] END_FEAT_TX_CHAN_CPP_040
3.2.5.2 VHDL Requirements

The `pushBBSamplesTx` operation of the Transmit feature is described in VHDL as:

```vhdl
library IEEE;
use IEEE.std_logic_1164.ALL;

entity Transmit is
  generic(
  G_CODING_BITS : natural := 16 -- for instance
  );
  port (
    -- Common Signals
    clk : in std_logic;  -- Clock signal
    rst_n : in std_logic;  -- Reset signal
    -- pushBBSamplesTx
    BBSample_I : in std_logic_vector(G_CODING_BITS-1 downto 0);
    BBSample_Q : in std_logic_vector(G_CODING_BITS-1 downto 0);
    BBSample_write : in std_logic;
    BBSamplesPacket_start : in std_logic;
    BBSamplesPacket_end : in std_logic;
    BBSample_ready : out std_logic
    -- Other signals
  );
end entity Transmit;
```

The Transmit entity signals are summarized in the following table:

<table>
<thead>
<tr>
<th>Signal Name</th>
<th>Direction</th>
<th>Signal Format</th>
<th>Signal Units</th>
<th>Signal Min Value</th>
<th>Signal Max Value</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clk</td>
<td>in</td>
<td>1-bit Discrete</td>
<td>Clock</td>
<td>0&gt;1 = Active Edge</td>
<td>1&gt;0 = Passive Edge</td>
<td>XX MHz Transmit Clock</td>
</tr>
<tr>
<td>rst_n</td>
<td>in</td>
<td>1-bit Discrete</td>
<td>Level</td>
<td>0</td>
<td>1</td>
<td>Active-low, asynchronous reset</td>
</tr>
<tr>
<td>BBSample_I</td>
<td>in</td>
<td>CodingBits-1 bit Signed</td>
<td>N/A</td>
<td>-32,768</td>
<td>32,767</td>
<td>Imaginary Sample value</td>
</tr>
<tr>
<td>BBSample_Q</td>
<td>in</td>
<td>CodingBits-1 bit Signed</td>
<td>N/A</td>
<td>-32,768</td>
<td>32,767</td>
<td>Quadrature Sample value</td>
</tr>
<tr>
<td>BBSample_write</td>
<td>in</td>
<td>1-bit Discrete</td>
<td>Level</td>
<td>0</td>
<td>1</td>
<td>Data valid flag to request sample transmission</td>
</tr>
<tr>
<td>BBSamplesPacket_start</td>
<td>in</td>
<td>1-bit Discrete</td>
<td>Level</td>
<td>0</td>
<td>1</td>
<td>Packet start flag</td>
</tr>
<tr>
<td>BBSamplesPacket_end</td>
<td>in</td>
<td>1-bit Discrete</td>
<td>Level</td>
<td>0</td>
<td>1</td>
<td>Packet end flag</td>
</tr>
<tr>
<td>BBSample_ready</td>
<td>out</td>
<td>1-bit Discrete</td>
<td>Level</td>
<td>0</td>
<td>1</td>
<td>Accept/ready flag to activate sample transmission</td>
</tr>
</tbody>
</table>

*Table 15: VHDL Transmit Entity signals*

A `BBSample` is transmitted only if both ‘write’ and ‘ready’ signals are asserted.

The `BBSamplePacket` concept is described in VHDL using additional signals to indicate the start and the end of a sample packet:

Every feature using `BBSamplePacket` concept has to implement the following protocol:

- the `BBSamplesPacket_start` signal is asserted with the first sample of a packet
- the `BBSamplesPacket_end` signal is asserted with the last sample of a package
- In any other case, `BBSamplesPacket_start` and `BBSamplesPacket_end` signals are deasserted
This behaviour is shown in the next timing diagram:

![Timing Diagram](image_url)

*Figure 18: BBSamplePacket Transmit Timing diagram for VHDL*
3.3 - Core Feature “Receive Channel”

3.3.1 Principle

For radio reception, a Receive Channel within a Transceiver Subsystem is down-converting and most probably down sampling and filtering bursts of input RF signal into bursts of output Baseband Signal. A Receive Cycle denotes the phase corresponding to the down-conversion of a particular RF signal burst.

A Receive Channel implementation is namely composed of the following specific sub-items:
- A Baseband FIFO
- A Down-conversion Chain

The Down-conversion Chain is the signal processing chain which performs the down-conversion of the burst of RF Signal, outputting it as a burst of Baseband Signal to be contained in Baseband FIFO.

The programming interface ReceiveDataPush enables the samples packets to be retrieved by the Waveform Application from the Receive Channel. The ReceiveChannel takes in charge the packets produced by Down-Conversion Chain, stores them into Baseband FIFO, where Waveform Application retrieves them in real-time and generates the Baseband Signal. The samples need to be available in Baseband FIFO before the retrieving process starts, and need to be continuously stored in Baseband FIFO in a timely manner that prevents signal corruption from occurring.

The programming interface ReceiveControl enables the Waveform Application to manage when and how Receive Cycles shall occur. For each Receive Cycle, this control is based on specification of when the concerned RF burst reception shall start and stop, and through characterization of the applicable Tuning Profile, which characterizes the exact signal processing transformation to be applied to RF Signal by Down-conversion Chain on the concerned burst in order to generate the Baseband Signal.

The following figure summarizes the previous concepts:

![Figure 19: Overview of a Receive Channel](image-url)
3.3.2 Overview

3.3.2.1 Programming interfaces overview

The following table provides an overview of the programming interface ReceiveControl:

<table>
<thead>
<tr>
<th>Signature (in pseudo-code)</th>
<th>Used by</th>
<th>Realized by</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>createReceiveCycleProfile (Time requestedReceiveStartTime, Time requestedReceiveStopTime, Ulong requestedPacketSize, UShort requestedPresetId, Frequency requestedCarrierFrequency);</td>
<td>Waveform Application</td>
<td>Transceiver Sub-system</td>
<td>Creation and configuration of a Receive Cycle.</td>
</tr>
<tr>
<td>configureReceiveCycle (Ulong targetCycleId, Time requestedReceiveStartTime, Time requestedReceiveStopTime, Ulong RequestedPacketSize, Frequency requestedCarrierFrequency);</td>
<td>Waveform Application</td>
<td>Transceiver Sub-system</td>
<td>Configuration of an existing Receive Cycle.</td>
</tr>
<tr>
<td>setReceiveStopTime (Ulong targetCycleId, Time requestedReceiveStopTime);</td>
<td>Waveform Application</td>
<td>Transceiver Sub-system</td>
<td>Configuration or reconfiguration of the end of a Receive Cycle.</td>
</tr>
</tbody>
</table>

Table 16: Overview of programming interface ReceiveControl

The following table provides an overview of the programming interface ReceiveDataPush:

<table>
<thead>
<tr>
<th>Signature (in pseudo-code)</th>
<th>Used by</th>
<th>Realized by</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>pushBBSamplesRx (BBPacket thePushedPacket, Boolean endOfBurst);</td>
<td>Transceiver Sub-system</td>
<td>Waveform Application</td>
<td>Enable the Waveform Application to retrieve a baseband samples packet from the Receive Channel.</td>
</tr>
</tbody>
</table>

Table 17: Overview of programming interface ReceiveDataPush
3.3.2.2 Characteristics overview

Explicit Notions

Explicit Notions as defined in §2.3 are observable, implementation in-dependent and exchanged characteristics of the Transceiver Subsystem. The following table summarizes the Explicit Notions related to Receive Channel:

<table>
<thead>
<tr>
<th>Explicit Notion Name</th>
<th>Defined in</th>
<th>Nature</th>
<th>Exchange Mechanism</th>
<th>Associated Argument</th>
<th>Associated Property</th>
</tr>
</thead>
<tbody>
<tr>
<td>ReceiveCycle</td>
<td>Core Feature</td>
<td>Logical</td>
<td>Programmable</td>
<td>targetCycleId</td>
<td>n.a.</td>
</tr>
<tr>
<td>ReceiveStartTime</td>
<td>Core Feature</td>
<td>Real-Time</td>
<td>Programmable</td>
<td>requestedReceiveStartTime</td>
<td>n.a.</td>
</tr>
<tr>
<td>ReceiveStopTime</td>
<td>Core Feature</td>
<td>Real-Time</td>
<td>Programmable</td>
<td>requestedReceiveStopTime</td>
<td>n.a.</td>
</tr>
<tr>
<td>TuningPreset</td>
<td>Core Feature</td>
<td>Logical</td>
<td>Programmable</td>
<td>requestedPresetId</td>
<td>n.a.</td>
</tr>
<tr>
<td>CarrierFrequency</td>
<td>Common Concept</td>
<td>Signal</td>
<td>Programmable &amp; Configurable</td>
<td>requestedCarrierFrequency</td>
<td>CarrierFrequency</td>
</tr>
<tr>
<td>PacketSize</td>
<td>Common Concept</td>
<td>Signal</td>
<td>Programmable &amp; Configurable</td>
<td>requestedPacketSize</td>
<td>PacketSize</td>
</tr>
</tbody>
</table>

Table 18: Explicit Notions related to Receive Channel

Implicit Notions

Implicit Notions as defined in §2.3 are observable, implementation in-dependent and not exchanged characteristics of the Transceiver Subsystem. The following table summarizes the Implicit Notions related to Receive Channel:

<table>
<thead>
<tr>
<th>Implicit Notion Name</th>
<th>Defined in</th>
<th>Nature</th>
</tr>
</thead>
<tbody>
<tr>
<td>BasebandFIFOSize</td>
<td>Core Feature</td>
<td>Logical</td>
</tr>
<tr>
<td>MaxPushedPacketSize</td>
<td>Core Feature</td>
<td>Logical</td>
</tr>
<tr>
<td>OverflowMitigation</td>
<td>Core Feature</td>
<td>Logical</td>
</tr>
<tr>
<td>BasebandSignal:...</td>
<td>Core Feature</td>
<td>Logical</td>
</tr>
<tr>
<td>BasebandSamplingFrequency</td>
<td>Common Concept</td>
<td>Signal Processing</td>
</tr>
<tr>
<td>BasebandCodingBits</td>
<td>Common Concept</td>
<td>Signal Processing</td>
</tr>
<tr>
<td>BasebandNominalPower</td>
<td>Common Concept</td>
<td>Signal Processing</td>
</tr>
</tbody>
</table>

Table 19: Implicit Notions related to Receive Channel
### Internal Notions

*Internal Notions* as defined in §2.3 are *observable* and *implementation dependent* characteristics of the *Transceiver Subsystem*. The following table summarizes the *Internal Notions* related to *Receive Channel*:

<table>
<thead>
<tr>
<th>Name</th>
<th>Defined in</th>
<th>Nature</th>
<th>Transceiver Design Formulas</th>
</tr>
</thead>
<tbody>
<tr>
<td>TuningDuration</td>
<td>Core Feature</td>
<td>Real-time</td>
<td>$\leq \text{MaxTuningDuration}$</td>
</tr>
<tr>
<td>TuningStartTime</td>
<td>Core Feature</td>
<td>Real-time</td>
<td>$= \text{ReceiveStartTime} - \text{TuningDuration} \in [\text{ReceiveStartTime} - \text{MaxTuningDuration}; \text{ReceiveStartTime}]$</td>
</tr>
<tr>
<td>DownconversionLatency</td>
<td>Core Feature</td>
<td>Real-time</td>
<td>$\leq \text{MaxDownConversionLatency}$</td>
</tr>
<tr>
<td>ProductionStartTime</td>
<td>Core Feature</td>
<td>Real-time</td>
<td>$= \text{ReceiveStartTime} + \text{DownConversionLatency} \in [\text{ReceiveStartTime}; \text{ReceiveStartTime} + \text{DownConversionLatency}]$</td>
</tr>
<tr>
<td>ProductionStopTime</td>
<td>Core Feature</td>
<td>Real-time</td>
<td>$= \text{ReceiveStopTime} + \text{DownConversionLatency} \in [\text{ReceiveStopTime}; \text{ReceiveStopTime} + \text{DownConversionLatency}]$</td>
</tr>
<tr>
<td>ReactivationTime</td>
<td>Core Feature</td>
<td>Real-Time</td>
<td>$&gt; \text{MinReactivationTime}$</td>
</tr>
<tr>
<td>RxChannelTransferFunction</td>
<td>Common Concept</td>
<td>Signal</td>
<td>Fits in mask defined by ChannelMask</td>
</tr>
</tbody>
</table>

*Table 20: Internal Notions related to Receive Channel*
### Constraints

*Explicit Notions* as defined in §2.3 are *non-observable* characteristics which are constraining the *Transceiver Subsystem* and/or *Waveform Application* implementation. The following table summarizes the *Constraints* related to *Receive Channel*:

<table>
<thead>
<tr>
<th>Name of the Constraint</th>
<th>Nature</th>
</tr>
</thead>
<tbody>
<tr>
<td>MaxTuningDuration</td>
<td>Real-time</td>
</tr>
<tr>
<td>MaxDownconversionLatency</td>
<td>Real-time</td>
</tr>
<tr>
<td>MinReceiveStartProximity</td>
<td>Real-time</td>
</tr>
<tr>
<td>MinReceiveStartAnticipation</td>
<td>Real-time</td>
</tr>
<tr>
<td>ReceiveTimeProfileAccuracy</td>
<td>Real-time</td>
</tr>
<tr>
<td>MinReceiveStopAnticipation</td>
<td>Real-time</td>
</tr>
<tr>
<td>MaxReceiveControlInvocationDuration</td>
<td>Real-time</td>
</tr>
<tr>
<td>MaxReceiveDataPushInvocationDuration</td>
<td>Real-time</td>
</tr>
<tr>
<td>MinPacketPreparationTime</td>
<td>Real-time</td>
</tr>
<tr>
<td>MinReactivationTime</td>
<td>Real-time</td>
</tr>
<tr>
<td>ChannelMask:…</td>
<td>Signal Processing</td>
</tr>
<tr>
<td>SpectrumMask:…</td>
<td>Signal Processing</td>
</tr>
<tr>
<td>GroupDelayMask:…</td>
<td>Signal Processing</td>
</tr>
<tr>
<td>MaxCycleId</td>
<td>Logical</td>
</tr>
<tr>
<td>MaxRxCycleProfiles</td>
<td>Logical</td>
</tr>
</tbody>
</table>

*Table 21: Constraints related to Receive Channel*
3.3.3 Analysis Requirements

The mnemonic used for identification of requirements of Transmit Channel feature is: “RX_CHAN”.

3.3.3.1 Receive Channel

FEAT_RX_CHAN_ANA_010 [ Definition of a “Receive Channel“

The core feature Receive Channel shall be used to refer to the capabilities provided by the Transceiver Sub-system component that performs down-conversion of a succession of input analogue RF Signal bursts into Baseband Signal bursts.

] END_FEAT_RX_CHAN_ANA_010

FEAT_RX_CHAN_ANA_020 [ Creation of a “Receive Channel”

The deployment of a Receive Channel and all its constituents shall be undertaken by the Transceiver Sub-system implementation, following implementation specific choices.

The state of a Receive Channel just after its creation and any of its constituent shall be state Deployed.

The initialization of the Receive Channel shall be conducted by deployment.

] END_FEAT_RX_CHAN_ANA_020

The steps setting one Down-conversion Chain into state Deployed are realized by (re)configuration mechanisms proper to the Transceiver implementation, which are out of the scope of this specification.

FEAT_RX_CHAN_ANA_030 [ Composition of a “Receive Channel“

The following concepts shall be integrated as constituents of a given Receive Channel:

- Concept Down-conversion Chain,
- Concept Receive Baseband Signal FIFO.

] END_FEAT_RX_CHAN_ANA_030

They are defined in their respective definition requirements as specified in the following paragraphs.

3.3.3.2 Receive Baseband Signal

The Receive Baseband Signal is the signal provided by the Receive Channel to the Waveform Application in order to be processed.

Terms and definitions used in this section are based on those presented within Common Concepts §4.2.4 Baseband Signal.

FEAT_RX_CHAN_ANA_040 [ Definition of “Receive Baseband Signal”

The concept Receive Baseband Signal shall describe the useful baseband signal sent by the Receive Channel to the Waveform Application for baseband signal processing and further treatments.

] END_FEAT_RX_CHAN_ANA_040
Useful baseband signals can include the following possible information:
- Power rising pattern
- Power falling pattern
- ALC and/or AGC patterns
- Data and eventually WF specifics pattern (sequences for synchronization)

**FEAT_RX_CHAN_ANA_050** [ Implicit Notions of “Receive Baseband Signal”

A Receive Baseband Signal shall be characterized using the following notions, defined by Common Concept Baseband Signal.
- Implicit notion Baseband Coding Bits
- Implicit notion Baseband Nominal Power

] END_FEAT_RX_CHAN_ANA_050

**FEAT_RX_CHAN_ANA_060** [ Receive Baseband Signal configuration

The properties of Receive Baseband Signal shall be set to values appropriate for the considered waveform during Receive Channel deployment.

] END_FEAT_RX_CHAN_ANA_060

### 3.3.3 Receive Baseband FIFO

The Receive Baseband FIFO contains baseband signal samples provided by the Down-conversion Chain in order for them to be consumed by the Waveform Application.

Consumption of baseband samples in the Receive Baseband FIFO is realized in a packet mode.

The FIFO monitors samples availability in order to raise error notification in case the samples needed by the Waveform Application are not consumed properly (overflow situation).

**FEAT_RX_CHAN_ANA_070** [ Definition of “Receive Baseband FIFO”

The terminology Receive Baseband FIFO shall be associated with the part of the sub-part of the Receive Channel storing the baseband samples pushed by the Down-conversion Chain and consumed by the Waveform Application.

] END_FEAT_RX_CHAN_ANA_070

**FEAT_RX_CHAN_ANA_080** [ Implicit Notion “BasebandFIFOSize”

The implicit notion BasebandFIFOSize shall be the Ulong value which captures the size of the Receive Baseband FIFO, capturing the maximum number of baseband samples possibly stored inside the Baseband FIFO.

] END_FEAT_RX_CHAN_ANA_080

**FEAT_RX_CHAN_ANA_090** [ Configuration of “Receive Baseband FIFO”

The properties of Receive Baseband FIFO shall be set to the values required by the considered Waveform Application during the Receive Channel deployment.

] END_FEAT_RX_CHAN_ANA_090

**Availability deadline and Overflow situations**

Any sample of the burst shall be present within baseband FIFO when the Waveform Application is going to consume them. An availability deadline is therefore attached to each sample to be consumed.
In case any received sample to be consumed would not be retrieved effectively by the Waveform Application, the Receive Channel goes into a *SignalOverflow* situation. This is an error situation.

**FEAT_RX_CHAN_ANA_100** [ Error “FIFOOverflow”
During the *Active* state of a *Receive Cycle*, an error *ERR_FIFOOverflow* shall be generated if the FIFO runs into an overflow situation.
]

**FEAT_TX_CHAN_ANA_110** [ FIFO Overflow ReceiveStop
During the *active* state of a *Receive Cycle*, if *Baseband FIFO* runs into an overflow situation, the reception shall be stopped by initiating a *ReceiveStop* transition, immediately after the last sample pushed into *baseband FIFO* has been retrieved by *Waveform Application*.
]

It is worth noting that during reception there is only the overflow scenario that deserves consideration as an error, because this means that the waveform application is not consuming samples fast enough to ensure continuous operation. Underflow scenario would signify only that the waveform is faster than the down-conversion chain.

### 3.3.3.4 Down-conversion Chain

**FEAT_RX_CHAN_ANA_120** [ Definition of the “Down-conversion Chain”
Concept *Down-conversion Chain* shall denote the signal processing chain in the Receive Channel which undertakes, during periods of time denoted as *Active Receive Cycles*, continuous transformation of one input *RF signal* burst into the corresponding output *Baseband signal* burst.
]

**FEAT_RX_CHAN_ANA_130** [ Constraint “MaxDownconversionLatency”
The constraint *MaxDownconversionLatency* of type *Latency* shall be used to characterize the allowable time boundary between the instant an *RF signal* is consumed by the *Down-conversion Chain* and the instant the first corresponding sample is produced for the *Baseband FIFO*.
]

This value has to be taken into consideration by the waveform application engineering process. The term *DownconversionLatency* is used in the following sections as an Internal Notion which is implementation related and does not exceed the above constraint.
States and Transitions of Down-conversion Chain

The following figure summarizes the concepts addressed in this section:

![State diagram]

**Figure 20: States and transitions of the Down-conversion Chain**

**FEAT_RX_CHAN_ANA_140 [ States of Down-conversion Chain**

The following states shall be implemented by a Down-conversion Chain:

- **Deployed**: Initial state of the chain once deployed according to considered Waveform requirements.
- **Unactive**: The state during which the Down-conversion Chain is not consuming RF signal, and is not outputing any baseband signal in the Baseband FIFO. Automatically reached once Down-conversion Chain is Deployed.
- **Activation**: The transient state during which the Down-conversion Chain has started to consume RF signal, while it is not yet outputting the corresponding baseband signal in the Baseband FIFO. Arrival of the useful baseband signal in the Baseband FIFO corresponds to the end of the state.
- **Active**: The state during which the input RF signal is continuously consumed by the Down-conversion Chain, and transformed into the associated baseband signal which is produced by the chain at its output.
- **Deactivation**: The transient state during which the RF signal is not consumed anymore by the Down-conversion Chain, while the previously consumed signal is still being processed by the Down-conversion with associated baseband signal produced. End of useful signal processing corresponds to the end of the state.

] END_FEAT_RX_CHAN_ANA_140
Activation and Deactivation are transient states which have a duration equal to the DownconversionLatency, which is the time elapsed between (i) the instant when consumption of the RF signal occurs at the RF connector and (ii) the instant when the corresponding baseband signal is output in the Baseband FIFO.

A Tuning activity, not depicted in the preceding figure, is the step during which the Waveform Application shall configure a Receive Cycle for the reception of the next burst.

**FEAT_RX_CHAN_ANA_150 [ Transitions between “Down-conversion Chain” states**

The instantaneous transitions between states of a Down-conversion Chain shall respect the following list:

- **RFReceiveStart**: transition between states Unactive and Activation
- **BBProductionStart**: transition between states Activation and Active
- **RFReceiveStop**: transition between states Active and Deactivation
- **BBProductionStop**: transition between states Deactivation and Unactive

} END_FEAT_RX_CHAN_ANA_150

**FEAT_RX_CHAN_ANA_160 [ Timings associated to Down-conversion Chain transitions**

The following timings shall be associated to instants when instantaneous transitions of Down-conversion Chain are happening:

- **ReceiveStartTime**: associated with transition RFReceiveStart
- **ProductionStartTime**: associated with transition BBProductionStart
- **ReceiveStopTime**: associated with transition RFReceiveStop
- **ProductionStopTime**: associated with transition BBProductionStop

} END_FEAT_RX_CHAN_ANA_160

**FEAT_RX_CHAN_ANA_170 [ Tuning activity**

The Tuning activity shall be used to configure the signal processing requirements captured in Tuning Profile. This activity is characterized by the time it starts, TuningStartTime, and its duration, TuningDuration.

} FEAT_RX_CHAN_ANA_170

**FEAT_RX_CHAN_ANA_180 [ Constraint “MaxTuningDuration”**

The Constraint MaxTuningDuration of type Latency shall be used to characterize the maximum allowable constant duration of the Tuning activity.

} END_FEAT_RX_CHAN_ANA_180

This value has to be taken into consideration by the waveform application engineering process. The term TuningDuration is used in the following sections as an Internal notion which is implementation related and does not exceed the above constraint.

**FEAT_RX_CHAN_ANA_190 [ Internal notion “TuningStartTime”**

The internal notion TuningStartTime shall be used to specify the beginning of the Tuning activity. Nominal use of TuningStartTime is described by the relationships below:

\[
\text{TuningStartTime}[n+1] = \text{RFReceiveStart}[n+1] - \text{TuningDuration} \\
\text{TuningStartTime}[n+1] \geq \text{ProductionStopTime}[n]
\]

Although rarely used, the TuningStartTime[n+1] may start before the ProductionStopTime[n], for example in case of duplicated channels for very fast frequency hopping applications.

} FEAT_RX_CHAN_ANA_190
The following figure summarizes the definitions introduced in this section:

![Diagram](image-url)

Figure 21: Time Profile of a Receive Cycle

FEAT_RX_CHAN_ANA_200 [ Constraint “MinReactivationTime”]

The constraint MinReactivationTime of type Latency shall be used to quantify the minimum time elapsed between the ReceiveStopTime of one given Receive Cycle and the ReceiveStartTime of the next one.

} END_FEAT_RX_CHAN_ANA_200

Remark: Transmit Channel has its own “MinReactivationTime” constraint, but not equally defined.

Identification of Current Cycle

Default event-based time requests are to be based on the notion of “Current” Transmit Cycle.

FEAT_RX_CHAN_ANA_210 [ Definition of the “Current” Receive Cycle]

The notion of current Receive Cycle shall be applied, for operations invoked by the Waveform Application making event-based time requests, as a function of the instant when the considered operation is invoked by Waveform Application.

} END_FEAT_RX_CHAN_ANA_210

FEAT_RX_CHAN_ANA_220 [ Rule for “Current” Receive Cycle identification]

The current Receive Cycle shall be the Active Receive Cycle, if the operation is invoked when a Receive Cycle is active, or the last Receive Cycle that finished before invocation.

} END_FEAT_RX_CHAN_ANA_220

Uncertainty of identification of the current Receive Cycle thus exists when invocation of createReceiveCycle() happens close to the ReceiveStartTime of a certain cycle. It is up to Waveform Application design to make appropriate assumptions to avoid calls happening within this time zone.
3.3.3.5 Receive Cycle

A compliant execution by the Down-conversion Chain of a given Receive Cycle relies on availability of two sorts of information:

- Control data, captured into the Receive Cycle Profile
- Output data, denoted as the Receive Cycle Output Burst

The Receive Cycle Output Burst is the slice of baseband signal, provided by the Down-conversion Chain after application of signal processing requirements captured in Tuning Profile and real-time requirements captured in Time Profile.

Receive Cycle Output Burst

FEAT_RX_CHAN_ANA_230 [ Definition of “Receive Cycle Output Burst”

The Receive Cycle Output Burst shall denote the un-interrupted slice of Baseband signal provided by the Down-conversion Chain for being transferred and processed by the Waveform Application during the considered Receive Cycle.

] END_FEAT_RX_CHAN_ANA_230

FEAT_RX_CHAN_ANA_240 [ Definition of “Receive Cycle First Sample”

The Receive Cycle First Sample shall denote the first sample of the considered output burst.

] END_FEAT_RX_CHAN_ANA_240

FEAT_RX_CHAN_ANA_250 [ Definition of “Receive Cycle Last Sample”

The Receive Cycle Last Sample shall denote the last sample of the considered output burst.

] END_FEAT_RX_CHAN_ANA_250

Receive Cycle Profile

FEAT_RX_CHAN_ANA_260 [ Definition of “Receive Cycle Profile”

The concept of Receive Cycle Profile shall be used to control the Receive Cycles implemented during the life-time of one Down-conversion Chain, one specific Receive Cycle Profile instance being created for each specific Receive Cycle occurrence.

] END_FEAT_RX_CHAN_ANA_260

FEAT_RX_CHAN_ANA_270 [ Composition of “Receive Cycle Profile”

A Receive Cycle Profile shall be composed of a Cycle Identifier, a Time Profile and a Tuning Profile.

] END_FEAT_RX_CHAN_ANA_270

Cycle identifier

FEAT_RX_CHAN_ANA_280 [ Explicit notion “ReceiveCycle”

Each created cycle has a unique integer identifier ReceiveCycle which shall be an explicit notion set up during creation to a value incremented by one for each newly created Receive Cycle, starting at 0 (ZERO) for the first created cycle and reaching the value of constraint MaxCycleId before restarting counter to 0.

] END_FEAT_RX_CHAN_ANA_280
The constraint $MaxRxCycleProfiles$ shall refer to the maximum number of $Receive Cycles$ simultaneously existing at any time within the Receive Channel.

**Time Profile**

The $Time Profile$ is set by the $Waveform Application$ to define time positioning of the $Receive Cycle$. It is composed of Explicit Notions $ReceiveStartTime$ and $ReceiveStopTime$.

They correspond to the only externally observable instants attached to a $Receive Cycle$ which are not dependent on the $Down-conversion Chain$ implementation.

A $Time Profile$ shall be composed of a $ReceiveStartTime$ explicit notion and a $ReceiveStopTime$ explicit notion.

The constraint $ReceiveTimeProfileAccuracy$ shall refer to the $Event Accuracy$ associated to the $Time Profile$ explicit notions, namely $ReceiveStartTime$ and $ReceiveStopTime$.

The implementation-independent explicit notion $ReceiveStartTime$ shall be used within $Time Profile$ to contain the $Receive Start Time$ of the corresponding $Receive Cycle$.

The “ReceiveStart” event, associated to the $Receive Start Time$ explicit notion, shall be the unique $Referenced Event Source$ of the Receive Channel.

The implementation-independent explicit notion $ReceiveStopTime$ shall be used within $Time Profile$ to contain the $Receive Stop Time$ of the corresponding $Receive Cycle$.

Explicit notions $ReceiveStartTime$ and $ReceiveStopTime$ obey accuracy assumptions directly imposed by radio link interoperability conventions between transmitting and receiving radio nodes. Low accuracy on those values is requested for waveforms such as fixed frequency AM/FM speech waveforms, while high accuracy is needed for frequency hopping digitally modulated waveforms. $ReceiveStartTime$ and $ReceiveStopTime$ may be explicitly set by the $Waveform Application$ by means of operations arguments. They belong to the Programmable subtype.
Implementation-dependent internal notions

Implementation-dependent time internal notions may be derived from implementation-independent explicit notions introduced beforehand, using implementation-dependent durations or latencies:

- ProductionStartTime equal to ReceiveStartTime plus DownconversionLatency
- TuningStartTime equal to ReceiveStartTime less TuningDuration
- ProductionStopTime equal to ReceiveStopTime plus DownconversionLatency

Refer to Figure 21: Time Profile of a Receive Cycle for a graphical representation of above concepts

Tuning Profile

FEAT_RX_CHAN_ANA_350 [ Definition of “Receive Tuning Profile”

A Tuning Profile shall be used to characterize which signal processing explicit notions values shall be applied by the Down-conversion Chain when the Receive Cycle is activated.

] END_FEAT_RX_CHAN_ANA_350

FEAT_RX_CHAN_ANA_360 [ Contents of “Tuning Profile”

The following explicit notions are contained within the Tuning Profile:

- PacketSize
- Tuning Preset
- CarrierFrequency

] END_FEAT_RX_CHAN_ANA_360

From one Receive Cycle to the next one, depending on the deployed waveform needs, Tuning Profile explicit notions may be totally different, partially different, or identical.

Examples

| In fixed frequency TDD mode with unique channelization, the Tuning Profile is identical from one Receive Cycle to the next. |
| In advanced frequency hopping waveforms, the CarrierFrequency, the Channelization and even the Sampling Rate can be changed from one Receive Cycle to the next, incurring different Tuning Profiles. |
States and Transitions of Receive Cycle Profile

The following figure shows how, for Active Receive Cycle number $n$ of a given Down-conversion Chain, active states of the corresponding Receive Cycle Profile are defined:

![Diagram of Receive Cycle Profile States and Transitions](image)

**Figure 22: States and Transitions of a Receive Cycle Profile**

**FEAT_RX_CHAN_ANA_370** States of a “Receive Cycle Profile”

The following states shall be implemented by a Receive Cycle Profile:
- **Creation**: The Receive Cycle Profile is created by Receive Channel.
- **Pre-Activation**: The Receive Cycle Profile is kept dormant with possibility for the Waveform Application to update profiles’ explicit notions (Time Profile or Tuning Profile).
- **Active Phase**: The profile values are taken into account by the Down-conversion Chain to launch the Receive Cycle of interest, with undefined explicit notions completed according to Tuning, and updated to reflect what is effectively implemented during the Receive Cycle.
- **Post-Activation**: The Receive Cycle specified by the Receive Cycle Profile is over, but the profile is kept available to let the Tuning of the next Receive Cycle re-use previous values.
- **Destruction**: The Receive Cycle Profile is destroyed by the Receive Channel.

**Remark**: Receive Cycle Profile states are identical to Transmit Cycle Profile state, but not their transitions.
FEAT_RX_CHAN_ANA_380 [ Transitions of “Receive Cycle Profile”

The instantaneous transitions between states of a *Receive Cycle Profile* shall respect the following list:

- **Created**: transition between states *Creation* and *Pre-Activation*
- **ActivePhaseStart**: transition between states *Pre-Activation* and *Active Phase*
- **ActivePhaseStop**: transition between states *Active Phase* and *Post-Activation*
- **DestructionStart**: transition between states *Post-Activation* and *Desctruction*

] END_FEAT_RX_CHAN_ANA_380

FEAT_RX_CHAN_ANA_390 [ Transitions correspondance

The transitions of the *Down-conversion Chain* for the *Active Receive Cycle # N* shall comply with the following relationships with the transitions of the corresponding instance of *Receive Cycle Profile*:

- **ActivePhaseStart** and **TuningStart(n)** simultaneous
- **ActivePhaseStop** and **BBProductionStop(n)** simultaneous
- **DestructionStart** after than **TransmitStartTime(n+1)**

] END_FEAT_RX_CHAN_ANA_390

### 3.3.3.6 Active Phase

**Triggering conditions**

The process leading to the activation of the *Receive Channel Profile* is starting when the *Down-conversion Chain* starts the *Tuning* activity, shortly before state *Activation* starts.

The triggering condition to start *Tuning* activity is based on the definition status of *ReceiveStartTime*:

- If *ReceiveStartTime* is defined, **TuningStart** will be realized so as to have the resulting **RFReceiveStart** happen at **ReceiveStartTi**me.
- Another triggering condition can be envisaged. The principle is to trigger the reception at the input of the Down-conversion Chain as soon as the power of the RF signal reaches a threshold power.

If explicit notion *ReceiveStopTime* is set to a defined value when **TuningStart** is happening, the *Receive Cycle* is activated for a pre-defined duration. Otherwise, the cycle ending conditions remain to be defined after the cycle has started.

FEAT_RX_CHAN_ANA_400 [ Time-defined transition “StartTuning”

If the explicit notion *ReceiveStartTime* of the *TimeProfile* is defined, the *Receive Channel* shall initiate a **TuningStart** transition so as to have the **RFReceiveStart** happen at the instant specified by value of explicit notion **ReceiveStartTime**.

] END_FEAT_RX_CHAN_ANA_400

FEAT_RX_CHAN_ANA_410 [ Error “ERR_TooLateRequest”

In case the cycle specified by argument *targetCycleId* has already reached the state *Tuning*, or went further in the life sequence of the *Receive Cycle Profile*, the operation can not be taken into account and an error **ERR_TooLateRequest** shall be generated.

] END_FEAT_RX_CHAN_ANA_410
Setting applicable profile

**Feat_RX_CHAN_ANA_420 [ Precedence rules for Tuning explicit notions definition**

For each Down-conversion processing explicit notion of any given Receive Cycle, except the first one, the values applicable by the Down-conversion shall be determined during state Tuning in compliance with the following precedence rules, sorted in decreasing order:

- Last value set by a call during the state Idle
- Value set during the call to createReceiveCycle()
- Value applied for the considered explicit notion on the previous Receive Cycle, if defined

] END_FEAT_RX_CHAN_ANA_420

### 3.3.3.7 Post-Activation

#### Triggering conditions

State Post-Activation of the Receive Channel Profile corresponds to when the Down-conversion Chain has finished its state Deactivation and is back to state Unactive.

Entering into state Post-Activation is entirely based on the triggering condition ReceiveStopTime which causes the Down-conversion Chain to enter into state Deactivation.

- ReceiveStopTime shall be defined and RF Signal reception will be stopped at the instant provided by the ReceiveStopTime explicit notion value. Baseband samples production will continue until RF Signal will be exhausted at instant BBproductionStop.
- If ReceiveStopTime value is not defined RF Signal receptions will be stopped immediately.

**Feat_RX_CHAN_ANA_430 [ Destruction start time**

The destruction of a given Receive Cycle Profile shall not be realized by the Receive Channel until the next Receive Cycle has reached its transition RFRReceiveStart.

] END_FEAT_RX_CHAN_ANA_430

This requirement allows the Tuning of the next cycle to be able to re-use the previous Tuning Profile for undefined properties.

### 3.3.3.8 Receive Control

**createReceiveCycleProfile()**

#### Purpose

The operation createReceiveCycleProfile() enables to request the creation by the Down-conversion chain of a specific Receive Cycle Profile. It aims at performing a systematic call for any necessary Receive Cycle.

#### Syntax

**Feat_RX_CHAN_ANA_440 [ Operation “createReceiveCycleProfile()”**

The operation createReceiveCycleProfile() shall be implemented by the Receive Channel and be used by the Waveform Application in order to request the creation of a particular Receive Cycle Profile.

] END_FEAT_RX_CHAN_ANA_440
FEAT_RX_CHAN_ANA_450 [ Argument “requestedReceiveStartTime”]
The argument requestedReceiveStartTime of type Time shall be used to request an initial value for the explicit notion ReceiveStartTime.
] END_FEAT_RX_CHAN_ANA_450

FEAT_RX_CHAN_ANA_460 [ Constraint “MinReceiveStartProximity”]
If the argument requestedReceiveStartTime is an Event-based Time, it shall respect the Min Event Proximity constraint specified by “MinReceiveStartProximity”.
] END_FEAT_RX_CHAN_ANA_460

FEAT_RX_CHAN_ANA_470 [ Constraint “MinReceiveStartAnticipation”]
The constraint MinReceiveStartAnticipation of type Latency shall be used to characterize the minimum allowed elapsed time between the instant the createReceiveCycleProfile() operation is invoked and the target Receive start time.
] END_FEAT_RX_CHAN_ANA_470

FEAT_RX_CHAN_ANA_480 [ Argument “requestedReceiveStopTime”]
The argument requestedReceiveStopTime of type Time shall be used to request an initial value for the explicit notion ReceiveStopTime.
] END_FEAT_RX_CHAN_ANA_480

FEAT_RX_CHAN_ANA_490 [ Argument “RequestedPacketSize”]
The argument RequestedPacketSize of type ULong shall be used in order to request initial values for the PacketSize explicit notion.
] END_FEAT_RX_CHAN_ANA_490

FEAT_RX_CHAN_ANA_500 [ Argument “requestedPresetId”]
The argument requestedPresetId of type UShort shall be used in order to indicate the PresetId value of the Tuning Preset to be applied on the considered burst.
] END_FEAT_RX_CHAN_ANA_500

The requirements associated to Tuning Presets are provided in Common Concepts.

FEAT_RX_CHAN_ANA_510 [ Argument “requestedCarrierFrequency”]
The argument requestedCarrierFrequency of type Frequency shall be used in order to request initial values for the CarrierFrequency explicit notion.
] END_FEAT_RX_CHAN_ANA_510

Semantics

FEAT_RX_CHAN_ANA_520 [ ReceiveCycleProfile initialization]
The Receive Channel shall set the initial values of the corresponding explicit notions in ReceiveCycleProfile to the values specified by passed arguments.
] END_FEAT_RX_CHAN_ANA_520

If argument requestedReceiveStartTime is defined by the Waveform Application, the Receive Channel will start the Active Phase according to the specified time. If the initial value of ReceiveStartTime was left undefined, the Active Phase may not start until the value is further set or signal-based conditions are met.
FEAT_RX_CHAN_ANA_530 [ Constraint “MinReceiveStartAnticipation”]

If argument *requestedRecieveStartTime* is set to a defined value by the Waveform Application, the operation invocation which corresponds with internal notion *ReceiveStartAnticipation* shall happen before the corresponding *TuningStartTime* respecting the *MinReceiveStartAnticipation* real-time constraint

] END_FEAT_RX_CHAN_ANA_530

FEAT_RX_CHAN_ANA_540 [ Error “ERR_TooManyCreatedRxProfiles”]

The Receive Channel shall generate an error *ERR_TooManyCreatedRxProfiles* if creation of the *Receive Cycle Profile* would cause a number of created profiles exceeding the value of constraint *MaxRxCycleProfiles*.

] END_FEAT_RX_CHAN_ANA_540

FEAT_RX_CHAN_ANA_550 [ “requestedReceiveStartTime” using Absolute Time Request format]

Usage of domain type *Absolute Time Request format* shall be available as a type possibility for argument *requestedReceiveStartTime*.

] END_FEAT_RX_CHAN_ANA_550

FEAT_RX_CHAN_ANA_560 [ “requestedReceiveStartTime” using event-based format]

Usage of domain type *Event-based Time Request* shall be available as a type possibility for argument *requestedReceiveStartTime*.

] END_FEAT_RX_CHAN_ANA_560

FEAT_RX_CHAN_ANA_570 [ Default event source for event-based time requests]

The default *Event Source* for event-derived expression of *requestedReceiveStartTime* shall be the *ReceiveStartTime* of the current *Receive Cycle*.

] END_FEAT_RX_CHAN_ANA_570

For the first *Receive Cycle* of the *Receive Channel* lifetime, since no previous *Receive Cycle* exists, the current *Receive Cycle* is not defined and an event-based approach can not be used.

FEAT_RX_CHAN_ANA_580 [ Default event occurrence for event-derived time requests]

The default *event occurrence* for event-derived expression of *requestedReceiveStartTime* shall be the current occurrence.

] END_FEAT_RX_CHAN_ANA_580

```
configureReceiveCycle()
```

**Purpose**

This operation is the way a Waveform Application can set the *Down-conversion* profile during its state Pre-activation.

**Syntax**

FEAT_RX_CHAN_ANA_590 [ Operation “configureReceiveCycle()”]

The operation *configureReceiveCycle()* shall be implemented by the Receive Channel and be used by the Waveform Application in order to set all explicit notions values of a previously created *Receive Cycle*.

] END_FEAT_RX_CHAN_ANA_590
FEAT_RX_CHAN_ANA_600 [ Target cycle identification in “configureReceiveCycle()”

The Receive Cycle for which the requested explicit notions values are applicable shall be identified by the argument targetCycleId of type ULong, which specifies the Cycle Identifier of the target Receive Cycle.

] END_FEAT_RX_CHAN_ANA_600

FEAT_RX_CHAN_ANA_610 [ Argument “requestedReceiveStartTime”

The argument requestedReceiveStartTime of type Time shall be used to request an initial value for the explicit notion ReceiveStartTime.

] END_FEAT_RX_CHAN_ANA_610

FEAT_RX_CHAN_ANA_620 [ Constraint “MinReceiveStartAnticipation”

The constraint MinReceiveStartAnticipation of type Latency shall be used to characterize the minimum allowed elapsed time between the instant the configureReceiveCycle() operation is invoked and the target Receive start time.

] END_FEAT_RX_CHAN_ANA_620

FEAT_RX_CHAN_ANA_630 [ Argument “requestedReceiveStopTime”

The argument requestedReceiveStopTime of type Time shall be used to request an initial value for the explicit notion ReceiveStopTime.

] END_FEAT_RX_CHAN_ANA_630

FEAT_RX_CHAN_ANA_640 [ Argument “RequestedPacketSize”

The argument RequestedPacketSize of type ULong shall be used to request an initial value for the explicit notion PacketSize.

] END_FEAT_RX_CHAN_ANA_640

FEAT_RX_CHAN_ANA_650 [ Argument “requestedCarrierFrequency”

The argument requestedCarrierFrequency of type Frequency shall be used to request an initial value for the explicit notion CarrierFrequency.

] END_FEAT_RX_CHAN_ANA_650

Errors

FEAT_RX_CHAN_ANA_660 [ Error “Unknown Target Cycle”

In case the cycle specified by argument targetCycleId is not created, the operation can not be taken into account and an error Unknown Target Cycle shall be generated.

] END_FEAT_RX_CHAN_ANA_660
setReceiveStopTime()

Purpose

The operation setReceiveStopTime() is intended to allow setting the explicit notion ReceiveStopTime value for a Receive Cycle.

FEAT_RX_CHAN_ANA_670 [ Operation “setReceiveStopTime()”

The operation setReceiveStopTime() shall be implemented by the Receive Channel and be used by the Waveform Application in order to set the ReceiveStopTime of the considered Receive Cycle.

END_FEAT_RX_CHAN_ANA_670

FEAT_RX_CHAN_ANA_680 [ Argument “requestedReceiveStopTime”

The argument requestedReceiveStopTime shall be available in operation setReceiveStopTime() in order to enable the Waveform Application to specify when the transition RFReceiveStop shall happen.

END_FEAT_RX_CHAN_ANA_680

FEAT_RX_CHAN_ANA_690 [ Constraint “MinReceiveStopAnticipation”

The constraint MinReceiveStopAnticipation of type Latency shall be used to characterize the minimum allowed elapsed time between the instant the setReceiveStopTime() operation is invoked and the target Receive stop time.

END_FEAT_RX_CHAN_ANA_690

FEAT_RX_CHAN_ANA_700 [ Defined “requestedReceiveStopTime”

If argument requestedReceiveStartTime is set to a defined value by Waveform Application, the Receive Channel shall deactivate the Receive Cycle in respect of the specified value.

END_FEAT_RX_CHAN_ANA_700

FEAT_RX_CHAN_ANA_710 [ Undefined “requestedReceiveStopTime” (instant Deactivation)

If argument requestedReceiveStartTime is set to undefined by Waveform Application, the Receive Channel shall immediately turn the current Transmit Cycle into Deactivation state.

END_FEAT_RX_CHAN_ANA_710

FEAT_RX_CHAN_ANA_720 [ Constraint “MinReceiveStopAnticipation”

The operation setReceiveStopTime() shall be called with an anticipation relative to the requestedReceiveStopTime at least equal to the value of the constraint “MinReceiveStopAnticipation, of type Latency.

END_FEAT_RX_CHAN_ANA_720

The operation setReceiveStopTime() may be used to modify as often as necessary the ReceiveStopTime of a Transmit Cycle, provided it always respects the ReceiveStopAnticipation invocation margin.
Errors

FEAT_RX_CHAN_ANA_730 [ Error “ERR_TooLateRequest”]

If the operation setReceiveStopTime() is invoked after ReceiveStopTime – MinReceiveStopAnticipation, the Receive Channel is not able to guarantee correct application, and an error ERR_TooLateRequest shall be generated.

] END_FEAT_RX_CHAN_ANA_730

Interface real-time constraints

FEAT_RX_CHAN_ANA_740 [ Constraint “MaxReceiveControlInvocationDuration”]

Operations of the ReceiveControl interface shall respect the MaxInvocationDuration constraint specified by MaxReceiveControlInvocationDuration.

] END_FEAT_RX_CHAN_ANA_740

3.3.3.9 Receive Data Push

Overview

The programming interface Receive Data Push enables the Waveform Application to retrieve packets of baseband samples from the Receive Channel.

The programming interface relies on: (i) a single operation, pushBBSamplesRx(), (ii) the data retrieved by the Waveform Application, denoted as The Pushed Packet.

pushBBSamplesRx() is used by the Transceiver Subsystem to: notify the Waveform Application of the availability of a new packet in the Baseband FIFO of size Packet size.

The Pushed Packet structure is defined by common concept Baseband Packet. It must be prepared by the Down-Conversion Chain prior to the pushBBSamplesRx() notification. The samples are retrieved by the Waveform Application in conformance with specific packets contents requirements.

Prior to pushBBSamplesRx() notification, the Receive Channel undertakes packets handling activities:

- First, it takes in charge the pushed packet, copying its content into an internal memory zone.
- Second, it stores the corresponding data into the Baseband FIFO.

The way a Receive Channel implementation takes in charge the pushed packet and stores it into the Baseband FIFO is implementation dependent. Most reactive implementations will take in charge and store in baseband FIFO the pushed packet in one single data copy. More complex designs may exist, especially when the digital part of the Transceiver Subsystem is distributed over different digital signal processing units.

Under notification by the pushBBSamplesRx(), the Waveform Application launches a packet copy of the pushed packet into its own memory. The packet copy is an implementation-dependent mechanism, which may involve several elementary copies (for instance pushed samples to be distributed at both ends of a circular buffer).

### The Pushed Packet

#### Structural requirements

FEAT_RX_CHAN_ANA_750 [ Definition of “The Pushed Packet”]

A data construct denoted The Pushed Packet, of type Baseband Packet, shall be used to contain the Baseband Signal samples to be retrieved.
FEAT_RX_CHAN_ANA_750 [ Creation of “The Pushed Packet”

The Pushed Packet shall be created by the Receive Channel.

] END_FEAT_RX_CHAN_ANA_750

FEAT_RX_CHAN_ANA_760 [ Visibility on “The Pushed Packet”

The Pushed Packet shall be visible by the Waveform Application with read rights and be visible by the Receive Channel with write rights.

] END_FEAT_RX_CHAN_ANA_760

FEAT_RX_CHAN_ANA_770 [ Destruction of “The Pushed Packet”

The Pushed Packet shall be destroyed by the Receive Channel.

] END_FEAT_RX_CHAN_ANA_770

Packets ordering requirements

This section specifies a certain number of requirements applicable to packets content.

FEAT_RX_CHAN_ANA_790 [ Packets burst alignment

The pushed baseband samples shall be aligned with the Receive Cycles Input Bursts, which means no packet contains samples belonging to two different input bursts.

] END_FEAT_RX_CHAN_ANA_790

FEAT_RX_CHAN_ANA_800 [ Sequential bursts transmission

The pushed baseband samples packets shall be transmitted one burst after the other.

] END_FEAT_RX_CHAN_ANA_800

FEAT_RX_CHAN_ANA_810 [ Ordered packets pushes

The pushed baseband samples packets shall not be interverted within a given burst.

] END_FEAT_RX_CHAN_ANA_810

Packets identification

The first packet of a burst is defined as the packet where the first sample is the first received sample of the burst.

The last packet of a burst is defined as the packet where the last sample is the last received sample of the burst.

A packet containing all the samples of a given burst is at the same time the first and last packet of the burst.

The last packet of a burst is therefore systematically followed by the first packet of the next burst.
pushBBSamplesRx()

Syntax

FEAT_RX_CHAN_ANA_820 [ Operation “pushBBSamplesRx()”

Operation pushBBSamplesRx() shall be used by the Transceiver Subsystem and realized by the Waveform Application, in order to: (i) notify the Waveform Application of the availability of a new packet of samples, and (ii) indicate if the pushed packet is the last packet of the received burst.

] END_FEAT_RX_CHAN_ANA_820

FEAT_RX_CHAN_ANA_830 [ Argument “thePushedPacket”

The argument thePushedPacket, of type BBPacket, shall contain information enabling access to the pushed packet.

] END_FEAT_RX_CHAN_ANA_830

The pushed packet content shall have been prepared by the Receive Cycle to contain the correct signal before invocation. The size of the pushed packet is determined by the value of argument requestedPacketSize set during the Receive Cycle creation or profile configuration.

FEAT_RX_CHAN_ANA_840 [ Argument “endOfBurst”

The argument endOfBurst, of type Boolean, shall be used to indicate that the pushed packet is the last packet of the current Receive Cycle Burst.

Value True if the packet is the last packet, False or undefined otherwise.

] END_FEAT_RX_CHAN_ANA_840

Semantics

FEAT_RX_CHAN_ANA_850 [ pushBBSamplesRx() Pre-Invocation

When invocation of pushBBSamplesRx() occurs, the samples values contained in the pushed packet shall be compliant with the packet contents requirements.

] END_FEAT_RX_CHAN_ANA_850

FEAT_RX_CHAN_ANA_860 [ pushBBSamplesRx() Post-Invocation

When return of pushBBSamplesRx() returns, the samples values contained in the pushed packet shall have been taken into account by the Waveform Application.

] END_FEAT_RX_CHAN_ANA_860

Real-time Constraints

FEAT_RX_CHAN_ANA_870 [ Constraint “MaxReceiveDataPushInvocationDuration”

The constraint MaxReceiveDataPushInvocationDuration, of type Latency, shall be used to identify the Max Invocation Duration to be met by pushBBSamplesRx implementations.

] END_FEAT_RX_CHAN_ANA_870

As noted in §2.3, the Max Invocation Duration of an operation corresponds to the time difference between:

- The instant when an operation invocation occurs,
- The instant when an operation return occurs.

The constraint may remain undefined if the real-time constraints of the radio capability do not justify it.
Max pushBBSamplesRx Invocation Duration is generally assigned a unique value, taking into consideration the maximum packet size used by the waveform application.

**FEAT_RX_CHAN_ANA_880** [Constraint “MaxPacketPreparationTime”]

The constraint MaxPacketPreparationTime, of type Latency, shall be used to identify the Maximum Time to be guaranteed in order to have a packet prepared in Baseband FIFO by the Transceiver Subsystem before a particular target time.

) END_FEAT_RX_CHAN_ANA_880

Transceiver Subsystem should be compliant with this constraint in order to avoid out of synchronization situations or scenarios where Transceiver Subsystem delays the signal leading to real-time violation.

**Overflow mitigation**

Two overflow mitigation options can be selected:

- PacketsTrashing: Transceiver Subsystem will trash the packets if the FIFO is completely filled and the waveform application does not retrieve them or does so at a slower pace.
- No Overflow: reaching overflow is corresponded to an error so the Transceiver Subsystem is requested to generate an error.

**FEAT_RX_CHAN_ANA_890** [Implicit notion “OverflowMitigation”]

The enumerated implicit notion Overflow Mitigation shall be used to set the applicable overflow mitigation option.

The possible values are: PacketsTrashing, and No Overflow. Undefined corresponds to Packets Trashing.

) END_FEAT_RX_CHAN_ANA_890

**FEAT_RX_CHAN_ANA_900** [PacketsTrashing Overflow Mitigation]

When implicit notion Overflow Mitigation is set to PacketsTrashing, the Transceiver Subsystem shall discard extra packets once the FIFO buffer reaches its maximum size.

) END_FEAT_RX_CHAN_ANA_900

This mode is kept as the default mode since it does not require any supplementary dependency between the Waveform Application and the platform. This occurs at the expense of handling trivial synchronization mechanisms.

**FEAT_RX_CHAN_ANA_910** [No Overflow Overflow Mitigation]

When implicit notion Overflow Mitigation is set to No Overflow, the Transceiver Subsystem shall raise an error if an overflow of the FIFO occurs.

) END_FEAT_RX_CHAN_ANA_910

This mode can be used in cases where the waveform design determines that overflow cases shall not occur.
### 3.3.3.10 Analysis Requirements Summary

The following table provides an overview of the Analysis requirements of Receive Channel:

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</tr>
<tr>
<td>FEAT_RX_CHAN_ANA_410</td>
<td>Error “ERR_TooLateRequest”</td>
<td>Active Phase</td>
</tr>
<tr>
<td>FEAT_RX_CHAN_ANA_420</td>
<td>Precedence rules for Tuning explicit notions definition</td>
<td>Active Phase</td>
</tr>
<tr>
<td>FEAT_RX_CHAN_ANA_430</td>
<td>Destruction start time</td>
<td>Post-Activation</td>
</tr>
<tr>
<td>FEAT_RX_CHAN_ANA_440</td>
<td>Operation “createReceiveCycleProfile()”</td>
<td>Receive Control</td>
</tr>
<tr>
<td>FEAT_RX_CHAN_ANA_450</td>
<td>Argument “requestedReceiveStartTime”</td>
<td>Receive Control</td>
</tr>
<tr>
<td>FEAT_RX_CHAN_ANA_460</td>
<td>Constraint “MinReceiveStartProximity”</td>
<td>Receive Control</td>
</tr>
<tr>
<td>FEAT_RX_CHAN_ANA_470</td>
<td>Constraint “MinReceiveStartAnticipation”</td>
<td>Receive Control</td>
</tr>
<tr>
<td>FEAT_RX_CHAN_ANA_480</td>
<td>Argument “requestedReceiveStopTime”</td>
<td>Receive Control</td>
</tr>
<tr>
<td>FEAT_RX_CHAN_ANA_490</td>
<td>Argument “requestedPacketSize”</td>
<td>Receive Control</td>
</tr>
<tr>
<td>FEAT_RX_CHAN_ANA_500</td>
<td>Argument “requestedPresetId”</td>
<td>Receive Control</td>
</tr>
<tr>
<td>FEAT_RX_CHAN_ANA_510</td>
<td>Argument “requestedCarrierFrequency”</td>
<td>Receive Control</td>
</tr>
<tr>
<td>FEAT_RX_CHAN_ANA_520</td>
<td>ReceiveCycleProfile initialization</td>
<td>Receive Control</td>
</tr>
</tbody>
</table>
Table 22: Overview of Receive Channel Analysis requirements
3.3.4 Modelling Requirements

3.3.4.1 Receive Channel interfaces

The following class diagram involves the interfaces realized and used by the Receive Channel, between the Waveform Application and the Transceiver Subsystem:

![Class Diagram](image)

**Figure 23: Receive Channel involved interfaces**

**FEAT_RX_CHAN_MOD_010 [ Receive Control interface**

Receive Control is the interface used to control the Receive Channel behaviors according to the Waveform needs. This interface shall include the following operations:

- `createReceiveCycleProfile()`
- `configureReceiveCycle()`
- `setReceiveStopTime()`

Definitions of operations and behaviors of their realizations by the Receive Channel core feature are specified in the baseline requirements of the Receive Channel.

} END_FEAT_RX_CHAN_MOD_010

**FEAT_RX_CHAN_MOD_020 [ Receive Data Push interface**

Receive Data Push is the interface used for transferring baseband samples from the Transceiver Subsystem to the Waveform Application. This interface shall include the following operation:

- `pushBBSamplesRx()`
Definition of this operation and associated behaviour of its realization by the Waveform Application are specified in the baseline requirements of the Receive Channel.

Note: Signatures of the operations are not provided for better visibility. Specification of the operations is depicted in paragraph Baseline Requirements of this chapter.

3.3.4.2 Receive Channel composition

FEAT_RX_CHAN_MOD_030 [Receive Channel modelling elements 1]

Transceiver Subsystem model involving feature Receive Channel shall use the modelling elements depicted in the following class diagram:

Figure 24: Receive Channel main composition

} END_FEAT_RX_CHAN_MOD_030
Transceiver Subsystem model involving feature Receive Channel shall use the modelling elements depicted in the following class diagram:

![Class Diagram](image)

Figure 25: Receive Channel and Cycle Profile

3.3.5 Implementation Languages Requirements

3.3.5.1 C++ Requirements

Interfaces between the Waveform Application and the Transceiver Subsystem for the Receive Channel core feature are:

- Receive Control,
- Receive Data Push.
Both are seen in a modeling analysis as abstract classes defining abstract operations. In C++ language, this leads to consider these operations as pure virtual methods of its respective classes. These methods can not be implemented by these abstract classes, but shall be overridden and implemented by derived classes.

**ReceiveControl interface**

**FEAT_RX_CHAN_CPP_010 [ ReceiveControl C++ definition**

Implementations in C++ using the feature *Receive Channel shall* use the interface *ReceiveControl* as declared in the following C++ reference source code extract:

```cpp
class I_ReceiveControl
{
public:
    virtual void createReceiveCycleProfile(
        Time requestedReceiveStartTime,
        Time requestedReceiveStopTime,
        ULong requestedPacketSize,
        UShort requestedPresetId,
        Frequency requestedCarrierFrequency) = 0;

    virtual void configureReceiveCycle(
        ULong targetCycleId,
        Time requestedReceiveStartTime,
        Time requestedReceiveStopTime,
        ULong requestedPacketSize,
        Frequency requestedCarrierFrequency) = 0;

    virtual void setReceiveStopTime(
        ULong targetCycleId,
        Time requestedTransmitStopTime) = 0;
};
```

**FEAT_RX_CHAN_CPP_020 [ ReceiveControl C++ header file**

Implementations in C++ using the feature *Receive Channel shall* include the header file entitled *ReceiveControl.h*, corresponding to the header file of the *ReceiveControl* definition.

**ReceiveDataPush interface**

**FEAT_RX_CHAN_CPP_010 [ ReceiveDataPush C++ definition**

Implementations in C++ using the feature *Receive Channel shall* use the interface *ReceiveDataPush* as declared in the following C++ reference source code extract:

```cpp
class I_ReceiveDataPush
{
public:
    virtual void pushBBSamplesRx(
        BBPacket * thePushedPacket,
        Boolean endOfBurst) = 0;
};
```

**FEAT_RX_CHAN_CPP_020 [ ReceiveDataPush C++ header file**

Implementations in C++ using the feature *Receive Channel shall* include the header file entitled *ReceiveDataPush.h*, corresponding to the header file of the *ReceiveDataPush* definition.
### 3.3.5.2 VHDL Requirements

The `pushBB SamplesRx` operation of the `Receive` feature is described in VHDL as:

```vhdl
library IEEE;
use IEEE.std_logic_1164.ALL;

entity Receive is
  generic(
    G_CODING_BITS : natural := 16 -- for instance
  );
  port (  
    -- Common Signals
    clk : in std_logic; -- Clock signal
    rst_n : in std_logic; -- Reset signal
    -- pushBB SamplesTx
    BBSample_I : out std_logic_vector(G_CODING_BITS-1 downto 0);
    BBSample_Q : out std_logic_vector(G_CODING_BITS-1 downto 0);
    BBSample_write : out std_logic;
    BBSamplesPacket_start : out std_logic;
    BBSamplesPacket_end : out std_logic;
    BBSample_ready : in std_logic  
  );
end entity Receive;
```

The Receive entity signals are summarized in the following table:

<table>
<thead>
<tr>
<th>Signal Name</th>
<th>Direction</th>
<th>Signal Format</th>
<th>Signal Units</th>
<th>Signal Min Value</th>
<th>Signal Max Value</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clk</td>
<td>in</td>
<td>1-bit Discrete</td>
<td>Clock</td>
<td>0-&gt;1 = Active Edge</td>
<td>1-&gt;0 = Passive Edge</td>
<td>XX MHz Transmit Clock</td>
</tr>
<tr>
<td>rst_n</td>
<td>in</td>
<td>1-bit Discrete</td>
<td>Level</td>
<td>0</td>
<td>1</td>
<td>Active-low, asynchronous reset.</td>
</tr>
<tr>
<td>BBSample_I</td>
<td>out</td>
<td>CodingBits-1-bit Signed</td>
<td>N/A</td>
<td>-32,768</td>
<td>32,768</td>
<td>Imaginary Sample value</td>
</tr>
<tr>
<td>BBSample_Q</td>
<td>out</td>
<td>CodingBits-1-bit Signed</td>
<td>N/A</td>
<td>-32,768</td>
<td>32,768</td>
<td>Quadrature Sample value</td>
</tr>
<tr>
<td>BBSample_write</td>
<td>out</td>
<td>1-bit Discrete</td>
<td>Level</td>
<td>0</td>
<td>1</td>
<td>Data valid flag to request sample transmission</td>
</tr>
<tr>
<td>BBSamplesPacket_start</td>
<td>out</td>
<td>1-bit Discrete</td>
<td>Level</td>
<td>0</td>
<td>1</td>
<td>Packet start flag</td>
</tr>
<tr>
<td>BBSamplesPacket_end</td>
<td>out</td>
<td>1-bit Discrete</td>
<td>Level</td>
<td>0</td>
<td>1</td>
<td>Packet end flag</td>
</tr>
<tr>
<td>BBSample_ready</td>
<td>in</td>
<td>1-bit Discrete</td>
<td>Level</td>
<td>0</td>
<td>1</td>
<td>Accept/ready flag to activate sample transmission</td>
</tr>
</tbody>
</table>

*Table 23: VHDL Receive Entity signals*

A `BBSample` is transmitted only if both ‘write’ and ‘ready’ signals are asserted.

The `BBSamplePacket` concept is described in VHDL using additional signals to indicate the start and the end of a sample packet.

Every Feature using BBSamplePacket concept has to implement the following protocol:

- the `BBSamplesPacket_start` signal is asserted with the first sample of a packet,
- the `BBSamplesPacket_end` signal is asserted with the last sample of a package,
- In any other case, `BBSamplesPacket_start` and `BBSamplesPacket_end` signals are deasserted.
This behaviour is shown in the next timing diagram:

![Timing Diagram](image)

*Figure 26: BBSamplePacket Transmit Timing diagram for VHDL*
4 - Common Concepts Specification

4.1 - Introduction

The following chapters specify Common Concepts:

- Time handling Domain Types
- Tuning Characteristics Definition
- Tuning Characteristics Setting
- Baseband Packets

Overview of specified Characteristics

The following table identifies the notions specified by Common Concepts:

<table>
<thead>
<tr>
<th>Name of the Notion</th>
<th>Category</th>
<th>Sub-category (if applicable)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseband Signal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BasebandSamplingFrequency</td>
<td>Implicit</td>
<td></td>
</tr>
<tr>
<td>BasebandCodingBits</td>
<td>Implicit</td>
<td></td>
</tr>
<tr>
<td>BasebandNominalPower</td>
<td>Implicit</td>
<td></td>
</tr>
<tr>
<td>RF Signal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CarrierFrequency</td>
<td>Explicit</td>
<td>Programmable &amp; Configurable</td>
</tr>
<tr>
<td>NominalRFPower</td>
<td>Explicit</td>
<td>Programmable &amp; Configurable</td>
</tr>
<tr>
<td>ChannelTransferFunction</td>
<td>Internal</td>
<td></td>
</tr>
<tr>
<td>PresetId</td>
<td>Explicit</td>
<td>Programmable</td>
</tr>
</tbody>
</table>

*Table 24: Overview of Common Concepts notions*

PresetId is a programmable argument, and takes its values from a requested argument through interfaces defined in core features. In Transmit Channel and Receive Channel features, PresetId is requested through argument requestedTuningPreset, respectively in operations createTransmitCycleProfile() and createReceiveCycleProfile().
The following tables identify the *constraints* specified by *Common Concepts*:

<table>
<thead>
<tr>
<th>Name of the Constraint</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Channel Mask</strong></td>
<td></td>
</tr>
<tr>
<td>ChannelBandwidth</td>
<td>Signal Processing</td>
</tr>
<tr>
<td>CarrierFrequencyAccuracy</td>
<td>Signal Processing</td>
</tr>
<tr>
<td><strong>Spectrum Mask</strong></td>
<td></td>
</tr>
<tr>
<td>Ripple</td>
<td>Signal Processing</td>
</tr>
<tr>
<td>HighBoundTransitionBand</td>
<td>Signal Processing</td>
</tr>
<tr>
<td>HighBoundRejectionGain</td>
<td>Signal Processing</td>
</tr>
<tr>
<td>HighBoundRejectionSlope</td>
<td>Signal Processing</td>
</tr>
<tr>
<td>LowBoundTransitionBand</td>
<td>Signal Processing</td>
</tr>
<tr>
<td>LowBoundRejectionGain</td>
<td>Signal Processing</td>
</tr>
<tr>
<td>LowBoundRejectionSlope</td>
<td>Signal Processing</td>
</tr>
<tr>
<td><strong>Group Delay Mask</strong></td>
<td></td>
</tr>
<tr>
<td>MaxGroupDelayDispersion</td>
<td>Signal Processing</td>
</tr>
</tbody>
</table>

*Table 25: Overview of Common Concepts constraints*

Refer to Figure 27: Characteristics of Spectrum Mask and Figure 28: Characteristics of Group Delay Mask in the following paragraphs for an schematic representation of the above Constraints.
4.2 - Time handling Domain Types

This chapter specifies requirements applicable to domain times used to specify time values.

CC_TIME_000 [ Generic Domain Type “Time”]

The generic domain type Time shall be used for arguments of control operations used to specify a time request, specifying the Event Time of a particular event. The associated physical unit is the second.

The generic type can be derived into type Absolute Time or Event-based Time.

MinAnticipation and Accuracy are constraints attached by the Facility core specification to each control operation. Each Waveform Capability is subject to define specific values for those properties, else they remain undefined.

4.2.1 Absolute Time

Principle

Absolute Time uses a time representation convention which counts the duration between an Absolute Time Reference and the Event Time. The Absolute Time Reference is equal to the beginning of year 2000, i.e. January 1st 2000, 00:00:00.

This count is realized using an Absolute Time, composed of an unsigned 32 bit value, complemented by an unsigned 32 bit value, counting the nanoseconds.

Absolute Time values handle a notion of time which corresponds to the time accessible to the Transceiver Sub-system.

Handling of the corresponding time source (by the Waveform Application or by Radio Set specific mechanisms), namely to set it to the right time with the required accuracy, is not in the scope of the current specification.

Specification

CC_TIME_010 [ Domain type “Absolute Time”]

The domain type Absolute Time shall be used to express time requests defined as the time elapsed from January 1st 2000, 00:00:00 (24h) to the Event Time.

It is derived from generic domain type Time.

END_CC_TIME_010

CC_TIME_020 [ Default setting for “Time Specification”]

The default setting for the domain type Time Specification shall be expressed using a couple of unsigned 32 bit values, respectively representing the number Second Count of seconds (s) elapsed since the reference time, and the number Nanosecond Count of supplementary nano-seconds (ns) within the referenced second.

The maximal accessible date approximately equals to 4.10^9 seconds after 1-jan-00, i.e. slightly more than 136 years. The default setting provides a resolution of 1 ns.
4.2.2 Event-based Time

Principle

*Event-based Time* uses a time representation convention which identifies the requested *Event Time* using a reference event available within the platform, from which a time shift enables accurate identification of the desired *Event Time*.

The reference event is identified using a particular event source, which is identified using its public identifier, in conformance with the principles exposed in § Event Sources. The occurrence count value and the notion of last and previous events, introduced in this chapter, are used as well.

Event-based time presents the advantage of avoiding (i) the Waveform Application part realizing control operations on the Transceiver Sub-system and (ii) the Transceiver Sub-system itself having knowledge of the absolute date.

It requires, as a counterpart, to carry on a generally more difficult real-time engineering effort, and may not be applicable to the radio interoperability protocols of most demanding waveforms.

Requirements

**CC_TIME_030** [ Domain type “Event-based Time”]

The domain type *Event-based Time* shall be used to express a *Time Request* defined through (i) identification of a *Reference Event*, a specific past or coming event generated by the *Platform Support*, (ii) provision of a *Time Shift* to apply from this *Reference Event* to compute the *Event Time*.

It is derived from generic domain type *Time*.

} END_CC_TIME_030

**CC_TIME_040** [ Composition of an “Event-based Time”]

The domain type *Event-based Time* shall be a structure composed of the four following fields:

- Event Source Id,
- Event Count Origin,
- Event Count,
- Time Shift.

} END_CC_TIME_040

Fields *Event Source Id*, *Event Count Origin* and *Event Count* together define the *Reference Event*.

**CC_TIME_050** [ Field “Event Source Id”]

The field *Event Source Id* of the domain type *Event-based Time* shall be an unsigned 16 bit value, identifying the *Event Source from the Platform Support* used to define the *Reference Event*.

} END_CC_TIME_050

**CC_TIME_060** [ Undefined “Event Source Id” value]

An *Undefined* value for field *Event Source Id* shall correspond to the *Default Event Source* attached to the control operation.

} END_CC_TIME_060
CC_TIME_070 [ Defined field “Event Source Id”]
A Defined value for field Event Source Id shall refer to the Event Source Identifier of the event source used to identify the Reference Event.
} END_CC_TIME_070

CC_TIME_080[ Field “Event Count Origin”
The field Event Count Origin of the domain type Event-based Time shall be an enumerated field, taking values between {Beginning, Previous, Next}, identifying the origin from which the events of the event source are counted in order to identify the Reference Event.
} END_CC_TIME_080

CC_TIME_090 [ Enumerated value “Beginning”
The enumerated value Beginning of the enumerated field Event Count Origin shall be used to indicate that the Reference Event shall be counted from first occurrence of the Event Source.
} END_CC_TIME_090

CC_TIME_100 [ Enumerated value “Previous”
The enumerated value Previous of the enumerated field Event Count Origin shall be used to indicate that the Reference Event shall be counted from the previous occurrence of the Event Source, relative to the instant when the operation is invoked.
} END_CC_TIME_100

CC_TIME_110 [ Enumerated value “Next”
The enumerated value Next of the enumerated field Event Count Origin shall be used to indicate that the Reference Event shall be counted from the next occurrence of the Event Source, relative to the instant when the operation is invoked.
} END_CC_TIME_110

CC_TIME_120 [ Field “Event Count”
The field Event Count of the domain type Event-based Time shall be a signed 32 bit value which identifies the number of Event Source occurrences separating the Reference Event from the Event Count Origin.
} END_CC_TIME_120

A value of 0 for Event Count Value means that the Reference Event is equal to the Event Count Origin.

CC_TIME_130 [ Undefined “Event Count” value
An Undefined value for field Event Count shall not be used by the Waveform Application.
} END_CC_TIME_130

CC_TIME_140 [ Field “Time Shift”
The field Time Shift of the domain type Event-based Time shall be a domain type Latency value which gives the positive or negative amount of time separating the Requested Time from the Reference Event.
} END_CC_TIME_140
4.3 - Tuning Characteristics Definition

4.3.1 Introduction

The Tuning Characteristics Definition exhaustively identifies the set of notions and constraints which need to be assigned a value in order for the Up-/Down-conversion Chains to be tuned before activation.

This chapter explains the question of definition of the Tuning Characteristics.

4.3.2 Domain definitions

Baseband Power

The Baseband Power of Baseband Signal is measured over a time period consistent with the stationarity of the measured signal.

$dB_{FS}$

A Baseband Power value is expressed in “dB relative to full scale”, abbreviated as “$dB_{FS}$”, capturing the power ratio between the measured signal and a reference harmonic signal. The reference full scale signal is defined as a complex harmonic signal with an envelope magnitude equal to the maximum envelope possible coded using the full scale of the stream defined by the number of coding bits.

Nominal reception conditions

In reception, nominal conditions are defined as conditions when a reference signal with a constant level is applied at Low Power RF level, while a baseband signal is generated towards the Waveform Application, using nominal reception gain settings.

Nominal transmission conditions

In transmission, nominal conditions are defined as conditions when a reference signal with a constant level is applied at baseband signal level by the Waveform Application, while a Low Power RF Level is generated at Transceiver Subsystem output, using nominal transmission gain settings.

Absolute uncertainty

The Absolute Uncertainty, denoted $dx$, attached to a specified property value $x$, shall be such that the Transceiver Subsystem implementation guarantees a measurable implementation value comprised in the interval $[x-dx,x+dx]$.

4.3.3 Domain types

This chapter introduces domain types applicable to characteristics of (i) the common concept and (ii) features specifications.

The requirement attached to the domain type definition indicates the signification of the type with the associated physical unit, while the default setting is attached to a default numerical representation.

The default setting is not useful in the context of the characteristic remaining virtually defined with no representation in the Transceiver Subsystem implementation. Any design value can then be taken into consideration.

If the considered characteristic is represented, in any respect, in the Transceiver Subsystem implementation, the default setting is then applicable to characterize how the associated characteristic shall be numerically represented. This is realized using a base type and identifying the chosen sub-unit for this representation.

Floating point representation is voluntarily ignored to achieve generic radio configuration designs.
When accessing implemented characteristics, a read operation will retrieve values compliant with the setting chosen for the characteristic. This value will represent the true value with an accuracy eventually documented in the Transceiver Sub-system implementation release notes.

**Frequency**

**CC_DOMAIN_TYPE_000** [ ] Domain type “Frequency”

The domain type *Frequency* shall be used to refer to any frequency expressions within the specification, using *hertz (Hz)* as the default associated physical unit.

} END_CC_DOMAIN_TYPE_000

**CC_DOMAIN_TYPE_020** [ ] Default setting for “Frequency”

The default setting for the domain type *Frequency* shall be expression of values represented using *ULong* values, representing positive values in steps of 1 hertz.

} END_CC_BB_DOMAIN_TYPE_020

The default setting provides a resolution of 1 Hz, a minimal value of 0 Hz, and a maximal value of 4,294,967,295 Hz.

Note that for some applications, i.e satellite communications, the frequency range is not large enough. Further improvements are thus needed, such as a so-called “type of range” setting, which would set the appropriate frequency range (application dependent) during the deployment.

**Baseband Power**

**CC_DOMAIN_TYPE_030** [ ] Domain type “Baseband Power”

The domain type *Baseband Power* shall be used to refer any baseband signal power expression, using *decibels-relative-to-full-scale (dBFS)* as the associated unit.

} END_CC_DOMAIN_TYPE_030

**CC_DOMAIN_TYPE_040** [ ] Default setting for “Baseband Power”

The default setting for the domain type *Baseband Power* shall be an expression of values represented using *Short* values, representing signed values in steps of 0.1 dBFS.

} END_CC_BB_DOMAIN_TYPE_040

The default setting provides a resolution of 0.1 dBFS, a minimum value of -3276.8 dBFS, and a maximum value of +3276.7 dBFS. Such values largely exceed meaningful physical values, towards low or high values. In particular, exceeding by more than a few dB the full scale signal is not physically possible.

**Analogue Power**

**CC_DOMAIN_TYPE_050** [ ] Domain type “Analogue Power”

The domain type *Analogue Power* shall be used to refer any analogue signal power expression, using *decibels-relative-to-1-milliwatt (dBm)* as the associated physical unit.

} END_CC_DOMAIN_TYPE_050

**CC_DOMAIN_TYPE_060** [ ] Default setting for “Analogue Power”

The default setting for the domain type *Analogue Power* shall be an expression of values represented using *Short* values, representing signed values in steps of 0.1 dBm.

} END_CC_DOMAIN_TYPE_060
The default setting provides a resolution of 0.1 dBm, a minimum value of -3276.8 dBm, and a maximum value of +3276.7 dBm. The step value chosen, 0.1 dBm, satisfy most of the current Transceiver architectures.

**Latency**

**CC_DOMAIN_TYPE_070 [ Domain type “Latency”**

The domain type *Latency shall* be used to refer to any analogue signal power expression, using *seconds (s)* as the associated physical unit.

} END_CC_DOMAIN_TYPE_070

**CC_DOMAIN_TYPE_080 [ Default setting for “Latency”**

The default setting for the domain type *Latency shall* be an expression of values represented using *Ulong* values, representing signed values in steps of 1 ns.

} END_CC_DOMAIN_TYPE_080

The default setting provides a resolution of 1 ns, a minimum value of 0 ns, and a maximum value of +4,294,967,295 ns.

**Gain**

**CC_DOMAIN_TYPE_090 [ Domain type “Gain”**

The domain type *Gain shall* be used to refer to any gain expression, using *decibel (dB)* as the associated physical unit.

} END_CC_DOMAIN_TYPE_090

**CC_DOMAIN_TYPE_100 [ Default setting for “Gain”**

The default setting for the domain type *Gain shall* be an expression of values represented using *Short* values, representing signed values in steps of 0.1 dB.

} END_CC_DOMAIN_TYPE_100

The default setting provides a resolution of 0.1 dB, a minimum value of -3276.8 dB, and a maximum value of +3276.7 dB.

**Gain Slope**

**CC_DOMAIN_TYPE_110 [ Domain type “Gain Slope”**

The domain type *Gain Slope shall* be used to refer to any gain slope expression, using *decibels per kilohertz (dB/kHz)* as the associated physical unit.

} END_CC_DOMAIN_TYPE_110

**CC_DOMAIN_TYPE_120 [ Default setting for “Gain Slope”**

The default setting for the domain type *Gain Slope shall* be expression of values represented using *Short* values, representing signed values in steps of 0.1 dB/kHz.

} END_CC_DOMAIN_TYPE_120

The default setting provides a resolution of 0.1 dB/kHz, a minimum value of -3276.8 dB/kHz, and a maximum value of +3276.7 dB/kHz.
4.3.4 Baseband Signal

This chapter identifies the burst tuning characteristics attached to the Baseband Signal.

**Definition of “Baseband Signal”**

The concept of Baseband Signal shall be used to refer to the baseband analytic signal exchanged between Waveform Application and (i) Transmit Channels for transmission, (ii) Receive Channels for reception.

The implicit notions attached to Baseband Signal are:

- Baseband Sampling Frequency
- Baseband Coding Bits
- Baseband Nominal Power

**Notion “Baseband Sampling Frequency”**

The implicit notion Baseband Sampling Frequency, of type Frequency, shall be used for the sampling rate of the complex analytic baseband signal exchanged at the Baseband Signal.

Usage of default settings provide a range of values going from 0 to 4.2 GHz by steps of 1 Hz.

**Notion “Baseband Coding Bits”**

The implicit notion Baseband Coding Bits, expressed using UShort values, shall be used for the number of bits used for quantification of each of the InPhase and InQuadrature (I,Q) components of the Baseband Signal it is referring to.

Any signal in the stream with (I,Q) components instant values exceeding the maximum possible dynamic range shall be cut off in order to respect the value of Baseband Coding Bits.

The typical values for Baseband Coding Bits are from 12 to 20, depending on the dynamic range of the radio signal represented. Lower values can be encountered for radio environments with low co-channel interference, thus reducing the desired dynamic range.

Denoting \( n \) as a certain Baseband Coding Bits value, the possible expressed signal values range from \(-2^{n-1}\) to \(+2^{n-1}\).

**Notion “Baseband Nominal Power”**

The implicit notion Baseband Nominal Power, of type Baseband Power, shall be used as a representation of the power of the Baseband Signal measured under nominal conditions.

The Baseband Signal measured under nominal conditions is defined differently in receive and transmit cases. The dynamic range of a Baseband Signal is defined as the ratio between the maximum instantaneous Baseband Power and the smallest positive instantaneous Baseband Power. Denoting \( n \) as a certain Signal...
Coding Bits value, the dynamic range of a given digital representation is then equal to $20 \times \log(2^n) = 6.02 \times n$ dB.

With a typical value for $n$ 20 this results in a theoretical maximum dynamic range of 120 dB, if the analogue RF Signal is scaled appropriately.

### 4.3.5 RF Signal

This chapter identifies the tuning characteristics attached to RF Signal.

**CC_RF_SIGNAL_000 [ Definition of “RF Signal”**

The concept of RF Signal shall be used to refer to the RF analogue signal on the antenna either in transmission or reception.

] END_CC_BB_RF_SIGNAL_000

The characteristics attached to RF Signal are:

- **Carrier Frequency**
- **Nominal RF Power**

**Notion “Carrier Frequency”**

**CC_RF_SIGNAL_010 [ Notion “Carrier Frequency”**

The explicit notion Carrier Frequency, of type Frequency, shall be used for the carrier frequency around which the RF Signal is centered.

] END_CC_RF_SIGNAL_010

Since the default setting for domain type Frequency has a maximum value around 4.2 GHz, addressing “beyond 4 GHz” radio capabilities would require introduction of supplementary settings.

Since the default setting for domain type Frequency has a resolution of 1 Hz, addressing “VLF” radio capabilities would require introduction of supplementary settings.

**Notion “Nominal RF Power”**

**CC_RF_SIGNAL_020 [ Notion “Nominal RF Power”**

The explicit notion Nominal RF Power, of type Analogue Power, shall be used for the nominal power attached to the RF Signal.

] END_CC_RF_SIGNAL_020

The notion Nominal RF Power will be attached to different nature of signals dependent on the receive or transmit case.
4.3.6 Channelization

This chapter identifies the tuning characteristics attached to Channelization. Channelization denotes signal processing characterization of the treatments performed by Up-/Down-conversion chains.

CC_CHAN_000 [Definition of “Channel Transfer Function”]

The internal notion of Channel Transfer Function shall designate the transfer function response of the transformation operated, by Up-conversion Chain between the Baseband Signal and RF Signal, and by Down-conversion Chain between the RF Signal and the Baseband Signal.

It shall not operate spectrum inversion.

END_CC_CHAN_000

Note that Channel Transfer Function is an internal notion and not a constraint. The constraints applicable to the Channel Transfer Function are defined below.

Channel Mask

CC_CHAN_010 [Definition of “Channel Mask”]

The concept Channel Mask shall be used to define the requirements which shall be met by the Channel Transfer Function of a given Conversion Chain.

END_CC_CHAN_010

The characteristics directly attached to a Channel Mask are:

- Channel Bandwidth
- Carrier Frequency Accuracy

CC_CHAN_020 [Constraint “Channel Bandwidth”]

The signal processing constraint Channel Bandwidth, of type Frequency, shall determine the bandwidth of the channel.

END_CC_CHAN_020

CC_CHAN_030 [Constraint “Carrier Frequency Accuracy”]

The signal processing constraint Carrier Frequency Accuracy, of type Frequency, shall be used to characterize the absolute uncertainty attached to the Carrier Frequency.

END_CC_CHAN_030

Additional characteristics attached to Channel Mask are regrouped under the following concepts:

- SpectrumMask
- GroupDelayMask

Spectrum Mask characteristics

CC_CHAN_040 [Concept “Spectrum Mask”]

The concept Spectrum Mask shall be used to characterize the spectrum mask to be satisfied by the modulus of the Channel Transfer Function.

END_CC_CHAN_040
The characteristics attached to Spectrum Mask are:

- Ripple,
- High Bound Transition Band,
- High Bound Rejection Gain,
- High Bound Rejection Slope,
- Low Bound Transition Band,
- Low Bound Rejection Gain,
- Low Bound Rejection Slope.

The following figure illustrates those characteristics signification:

![Figure 27: Characteristics of Spectrum Mask](image)

The Carrier Frequency appearing on the figure corresponds to the null frequency of the baseband signal.

**CC_CHAN_050 [Constraint “Ripple”]**

The signal processing constraint Ripple, of type Gain, shall be used to characterize the absolute uncertainty to be met by the Channel Transfer Function relative to the gain at Carrier Frequency.

) END_CC_CHAN_050

**CC_CHAN_060 [Constraint “High Bound Transition Band”]**

The signal processing constraint High Bound Transition Band, of type Frequency, shall be used to characterize the frequency span from Carrier Frequency, equal to Carrier Frequency + (Signal Bandwidth)/2 + High Bound Transition Band, after which a certain rejection level shall be met by Channel Transfer Function.

) END_CC_CHAN_060

**CC_CHAN_070 [Constraint “High Bound Rejection Gain”]**

The signal processing constraint High Bound Rejection Gain, of type Gain, shall be used to characterize the minimum attenuation met by the Channel Transfer Function at the frequency span specified using High Bound Transition Bound.

) END_CC_CHAN_070
CC_CHAN_080 [ Constraint “High Bound Rejection Slope”

The signal processing constraint *High Bound Rejection Slope*, of type GainSlope, shall be used to characterize the attenuation progression to be followed by the Channel Transfer Function at frequency spans higher than the point specified using *High Bound Transition Band*.

] END_CC_CHAN_080

CC_CHAN_090 [ Constraint “Low Bound Transition Band”

The signal processing constraint *Low Bound Transition Band*, of type Frequency, shall be used to characterize the frequency span from Carrier Frequency, equal to Carrier Frequency - (Signal Bandwidth)/2 - Low Bound Transition Band, before which a certain rejection level shall be met by Channel Transfer Function.

] END_CC_CHAN_090

CC_CHAN_100 [ Constraint “Low Bound Rejection Gain”

The signal processing constraint *Low Bound Rejection Gain*, of type Gain, shall be used to characterize the minimum attenuation met by the Channel Transfer Function at the frequency span specified using *Low Bound Transition Band*.

] END_CC_CHAN_100

CC_CHAN_110 [ Constraint “Low Bound Rejection Slope”

The signal processing constraint *Low Bound Rejection Slope*, of type GainSlope, shall be used to characterize the attenuation progression to be followed by the Channel Transfer Function at frequency spans lower than the point specified using *Low Bound Transition Band*.

] END_CC_CHAN_110

Group Delay Mask Properties

CC_CHAN_120 [ Concept “Group Delay Mask”

The concept *Group Delay Mask* shall be used to characterize the group delay response to be satisfied by the Channel Transfer Function.

] END_CC_CHAN_120

The characteristic attached to *Group Delay Mask* is the Max Group Delay Dispersion.

The following figure illustrates this characteristic signification:

![Figure 28: Characteristics of Group Delay Mask](image-url)

-1/2π.d(Arg(H(f))/df

Max GroupDelay Dispersion

Channel Bandwidth

Up/Down Conversion Latency

frequency

min latency

max latency

Carrier Frequency

---

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CC_CHAN_130 [ Constraint “Max Group Delay Dispersion”

The signal processing constraint *Max Group Delay Dispersion*, of type *Latency*, **shall** be used to characterize absolute uncertainty possible tolerated from *Carrier Latency* for values of group delay of frequencies comprised within *Channel Bandwidth*.

] END_CC_BB_CHAN_130

4.3.7 Implementation Language Requirements

4.3.7.1 C++ Implementation

Base Types

Base Types are platform dependent and can be set as follows:

```cpp
typedef bool Boolean
typedef short Short
typedef long Long
typedef unsigned short UShort
typedef unsigned long ULong
```

```cpp
typedef unsigned long ULong CC_CPP_010 [ BaseTypes C++ header file

Base types **shall** be defined in the header file untitled *BaseTypes.h*.

] END_CC_CPP_010
```

```cpp
CC_CPP_020 [ BaseTypes.h edition

*BaseTypes.h* header file **shall** be edited in consideration with the target processor, as base types depend on the processor.

] END_CC_CPP_020
```

Domain Types

Requirements on domain types are relative to the default setting. Use of the domain types with settings different from the default ones is not in the scope of this specification.

The default settings can be defined as follows:

```cpp
typedef ULong typeFrequency
typedef Short typeBasebandPower
typedef Short typeAnaloguePower
typedef ULong typeLatency
typedef Short typeGain
typedef Short typeGainSlope
typedef Short typeIQ
```

```cpp
CC_CPP_030 [ DefaultSetting.h C++ header file

Implementation using default settings for domain types **shall** include the *DefaultSetting.h* header file.

] END_CC_CPP_030
```
The domain types are set as follow, in case of using default settings:

```c
typedef typeFrequency Frequency;
typedef typeGain Gain;
typedef struct EventBasedTimeStruct {
    UShort eventSourceId;
    enum { Beginning, Previous, Next } eventCountOrigin;
    ULong eventCount;
    Latency timeShift;
} EventBasedTime;
```

etc...

Note that other definitions of domain types can be used, for example in order to use different settings for different variables.

**CC_CPP_050 [ Domain type “Frequency” C++ definition**

The domain type `Frequency` with the associated default setting `shall` be defined as follows:

```c
typedef typeFrequency Frequency;
```

**END_CC_CPP_050**

**CC_CPP_060 [ Domain type “Baseband Power” C++ definition**

The domain type `Baseband Power` with the associated default setting `shall` be defined as follows:

```c
typedef typeBasebandPower BasebandPower;
```

**END_CC_CPP_060**

**CC_CPP_070 [ Domain type “Analogue Power” C++ definition**

The domain type `Analogue Power` with the associated default setting `shall` be defined as follows:

```c
typedef typeAnaloguePower AnaloguePower;
```

**END_CC_CPP_070**

**CC_CPP_080 [ Domain type “Latency” C++ definition**

The domain type `Latency` with the associated default setting `shall` be defined as follows:

```c
typedef typeLatency Latency;
```

**END_CC_CPP_080**

**CC_CPP_090 [ Domain type “Gain” C++ definition**

The domain type `Gain` with the associated default setting `shall` be defined as follows:

```c
typedef typeGain Gain;
```

**END_CC_CPP_090**
CC_CPP_100 [ Domain type “Gain Slope” C++ definition

The domain type Gain Slope with the associated default setting shall be defined as follows:

```cpp
typedef typeGainSlope GainSlope;
```

] END_CC_CPP_100

CC_CPP_110 [ Domain type “Event-based Time” C++ definition

The domain type Event-based Time with the associated default setting shall be defined as follows:

```cpp
typedef struct EventBasedTimeStruct
{
    UShort eventSourceId;
    enum { Beginning, Previous, Next } eventCountOrigin;
    ULONG eventCount;
    Latency timeShift;
}EventBasedTime;
```

] END_CC_CPP_110

CC_CPP_120 [ Domain type “Absolute Time” C++ definition

The domain type Absolute Time with the associated default setting shall be defined as follows:

```cpp
typedef struct AbsoluteTimeStruct
{
    ULONG secondCount;
    ULONG nanosecondCount;
}AbsoluteTime;
```

] END_CC_CPP_120

CC_CPP_130 [ Domain type “Time” C++ definition

The domain type Time with the associated default setting shall be defined as follows:

```cpp
class C_Time
{
    public:
    AbsoluteTime       absolute;
    EventBasedTime     eventBased;
    // Instances of this class will be either AbsoluteTime, or EventBasedTime, depending on the type of time provided
    // in the constructor
    Time(AbsoluteTime);
    Time(EventBasedTime);
    ~Time();
};
```

] END_CC_CPP_130

CC_CPP_140 [ DomainTypes.h C++ header file

Implementations in C++ using domain types shall include the header file untitled DomainTypes.h, corresponding to the header file of the domain types definitions.

] END_CC_CPP_140
4.4 - Tuning Characteristics Setting

4.4.1 Introduction

The Tuning Characteristics Setting specifies mechanisms that enable access to tuning characteristics.

Tuning actors

Dependent on the nature of characteristics, Tuning characteristics can be set by the Deployment, the Configuration or the Waveform Application.

Deployment setting of a characteristic consists of initializing the Transceiver Subsystem so as to support the considered characteristic initial value. This initial value may be explicitly described to Deployment thanks to meta-data, or be hard coded with no explicit implementation.

Waveform Configuration setting of a characteristic consists in the setting the Transceiver Subsystem so as to support the desired characteristic value.

The Waveform Application can only set programmable characteristics (explicit notions), thanks to programming interface operations introducing a forward relationship between the Waveform Application and the Transceiver Subsystem.

Any implementation-level representation of a characteristic shall use the format specified for the considered characteristic.

Access mechanisms

Two sorts of access mechanisms are identified as access characteristics:

- Elementary access
- Preset usage

A given notion may exclusively be subject to one of the possibilities, and this choice is mandated by the specification.

These access mechanisms are not applicable on internal notions. They pertain to characteristics which are implicit and explicit notions.

Elementary access

Elementary access corresponds to individual access to a notion. It is used for notions taking values independently from others, with possible values among a presumably large range of values.

Elementary access can be realized using:

- Programming interface operations access, when the Waveform Application is using a Programming interface,
- Direct access, when Configuration is accessing the characteristic, through an explicit notion.

Preset usage

Preset usage corresponds to simultaneous access to a collection of tuning characteristics. A unique preset is defined in the specification, which characterizes a possible signal processing performance tuning for the Conversion Chains.

The Deployment initializes all the presets applicable for a given radio configuration, each of them being given a unique identifier eventually known by the Waveform Application.

At run-time, the Waveform Application or the Configuration is subject to modification by applicable preset.
4.4.2 Preset characteristics

CC_PRESET_010 [ Definition of “Tuning Preset”

A concept Tuning Preset shall be used to identify a set of tuning characteristics values, and provides the corresponding requested values.

] END_CC_PRESET_010

CC_PRESET_020 [ Composition of a “Tuning Preset”

A Tuning Preset shall be composed of a unique identifier PresetId, of type UShort, followed by a list of requested characteristics values attached to the preset.

] END_CC_PRESET_020

CC_PRESET_030 [ List of characteristics in a “Tuning Preset”

A Tuning Preset shall be composed of the following characteristics:

From Baseband Signal:
- Baseband Sampling Frequency
- Baseband Coding Bits
- Baseband Nominal Power

From Channel Mask:
- Channel Bandwidth
- Carrier Frequency Accuracy

From Spectrum Mask:
- Ripple
- High Bound Transition Band
- High Bound Rejection Gain
- High Bound Rejection Slope
- Low Bound Transition Band
- Low Bound Rejection Gain
- Low Bound Rejection Slope

From Group Delay Mask:
- Max Group Delay Dispersion

] END_CC_PRESET_030

Refer to Figure 27: Characteristics of Spectrum Mask and Figure 28: Characteristics of Group Delay Mask for a graphical representation of above constraints.

In the current version of the Facility the Preset characteristics are only accessible via the “Tuning Preset” or “Configuration”.

4.4.3 Modelling Support Requirements

**CC_PRESET_040** Tuning Preset modelling elements

The **Transceiver Subsystem** model involving concept Tuning Preset shall use the modelling elements depicted in the following class diagram:

![Tuning Preset class diagram](image)

**Figure 29: Tuning Preset class diagram**

END_CC_PRESET_040

4.5 - Baseband Packets

4.5.1 Introduction

Overview

The concept of **Baseband Packets** addresses the transmit or receive baseband samples interface, which are the main data interfaces exchanged between the **Waveform Application** and the **Transceiver Subsystem**.

The following concepts are defined by **Baseband Packets**:

- **Baseband Packet**
- **Baseband Sample**

**Baseband Packets** are the data structures used for signal exchange between the **Waveform Application** and the **Transceiver Subsystem**.

**Baseband Samples** are the elementary information items contained in **Baseband Packets**.
4.5.2 Specification

Baseband packet

Baseband Packets are the elementary pieces of information involved during effective real-time exchanges between the Waveform Application and the Transceiver Subsystem. Usage of Baseband Packets is specified with operations using them.

CC_BB_PACKET_010 [ Concept “Baseband Packet”

The concept of Baseband Packet shall be used to refer to the packet of samples exchanged between the Waveform Application and Transceiver Sub-system.

A Baseband packet is a finite number of sequenced baseband samples.

The private attribute Samples Number, of type ULong, contains the number of samples contained in the Baseband Packet.

The packet is composed of a quantity of Baseband Samples equal to Samples Number.

] END_CC_BB_PACKET_010

Baseband sample

CC_BB_PACKET_020 [ Concept “Baseband Sample”

The concept Baseband Sample shall represent an elementary complex sample of the Baseband Signal. It is composed of a valueI and valueQ, represented on an implementation language-dependent type.

] END_CC_BB_PACKET_020

The type chosen for implementation to represent the Baseband Samples components shall be capable of representing values coded on a number of bits equal to the implicit notion BasebandCodingBits.

4.5.3 Implementation Language Requirements

4.5.3.1 C++ Implementation

BBSample

CC_CPP_150 [ BBSample C++ definition

Implementations in C++ using the Common Concept BasebandPackets shall use the class BBSample as declared in the following C++ reference source code extract:

```c
typedef struct BBSampleStruct
{
    typeIQ valueI;
    typeIQ valueQ;
}BBSample;
```

] END_CC XXX_CPP_150

CC_CPP_160 [ BBSample.h C++ header file

Implementations in C++ using the Common Concept BasebandPackets shall include the header file untitled BBSample.h, corresponding to the header file of the BBSample definition.

] END_CC_CPP_160
BBPacket

CC_CPP_170 [ BBPacket C++ definition

Implementations in C++ using the Common Concept BasebandPackets shall use the class BBPacket as declared in the following C++ reference source code extract:

```cpp
class C_BBPacket
{
private:
    ULong SamplesNumber;
    BBSample * packet;

public:
    BBPacket(ULong, BBSample *);
    ~BBPacket();
};
} END_CC_CPP_170

CC_CPP_180 [ BBPacket.h C++ header file

Implementations in C++ using the Common Concept BasebandPackets shall include the header file untitled BBPacket.h, corresponding to the header file of the BBPacket definition.
} END_CC_CPP_180
### 4.5.4 List of requirements

For convenience, the following table provides an overview of the requirements specified in the chapter Common Concepts:

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Table 26: Overview of Common Concepts requirements
5 - Annexes

5.1 - Using implementation standards

5.1.1 JTRS radios with MHAL RF Chain Coordinator

This figure illustrates a typical case of the defense radio industry:

![Figure 30: JTRS radios with MHAL RF Chain Coordinator]

5.1.2 OBSAI/CPRI compliant Base-stations

This figure illustrates a typical case of the cellular base-stations industry:

![Figure 31: Transceiver Subsystem in OBSAI / CPRI compliant Base stations]
5.1.3 DigRF-compliant Handsets

This figure illustrates a typical case of the cellular phones industry:

![Diagram of RF components](image)

*Figure 32: Transceiver Subsystem in DigRF-compliant Handsets

5.2 - Implementation Language Reference Source Code

5.2.1 C++ Implementation

**Inclusion rules**

The following sources are organized in header files, and correspond to the content of these header files. Note that for a C++ implementation, it is required to include header files in the following strict order:

```cpp
#include "BaseTypes.h"
#include "DefaultSetting.h"
#include "DomainTypes.h"

#include "BBSample.h"
#include "BBPacket.h"
```

Next, use of interfaces specified in core features requires the Common Concepts header files to be included. The extract below shows the right order of inclusion:

```cpp
#include "BBSample.h"
#include "BBPacket.h"
```

**BaseTypes.h**

```cpp
typedef bool Boolean
typedef short Short
typedef long Long
typedef unsigned short UShort
typedef unsigned long ULong
```

**DefaultSetting.h**

```cpp
typedef ULong typeFrequency
typedef Short typeBasebandPower
typedef Short typeAnaloguePower
typedef ULong typeLatency
typedef Short typeGain
typedef Short typeGainSlope
```
typedef Short typeIQ

DomainTypes.h

// Domain type Frequency
typedef typeFrequency Frequency;

// Domain type BasebandPower
typedef typeBasebandPower BasebandPower;

// Domain type AnaloguePower
typedef typeAnaloguePower AnaloguePower;

// Domain type Latency
typedef typeLatency Latency;

// Domain type Gain
typedef typeGain Gain;

// Domain type Gain Slope
typedef typeGainSlope GainSlope;

// Domain type AbsoluteTime
typedef struct AbsoluteTimeStruct
{
    ULong secondCount;
    ULong nanosecondCount;
}AbsoluteTime;

// Domain type EventBasedTime
typedef struct EventBasedTimeStruct
{
    UShort eventSourceId;
    enum { Beginning, Previous, Next } eventCountOrigin;
    ULong eventCount;
    Latency timeShift;
}EventBasedTime;

// Domain type Time
class C_Time
{
    public:
        AbsoluteTime absolute;
EventBasedTime eventBased;

// Instances of this class will be either AbsoluteTime, or
// EventBasedTime, depending on the kind of time provided
// in the constructor
Time(AbsoluteTime);
Time(EventBasedTime);
~Time();

BBSample.h

typedef struct BBSampleStruct
{
    typeIQ valueI;
    typeIQ valueQ;
}BBSample;

BBPacket.h

class C_BBPacket
{
private:
    ULong SamplesNumber;
    BBSample * packet;

public:
    BBPacket(ULong, BBSample *);
    ~BBPacket();
};

TransmitControl.h

class I_TransmitControl
{
public:
    virtual void createTransmitCycleProfile(
        Time requestedTransmitStartTime,
        Time requestedTransmitStopTime,
        UShort requestedPresetId,
        Frequency requestedCarrierFrequency,
        AnaloguePower requestedNominalRFPower) = 0;

    virtual void configureTransmitCycle(
        ULong targetCycleId,
        Time requestedTransmitStartTime,
        Time requestedTransmitStopTime,
        Frequency requestedCarrierFrequency,
        AnaloguePower requestedNominalRFPower) = 0;

    virtual void setTransmitStopTime(
        ULong targetCycleId,
        Time requestedTransmitStopTime) = 0;
};
TransmitDataPush.h

class I_TransmitDataPush
{
    public : 
        virtual void pushBBSamplesTx(
            BBPacket * thePushedPacket,
            Boolean endOfBurst) = 0;
};

ReceiveControl.h

class I_ReceiveControl
{
    public :
        virtual void createReceiveCycleProfile(
            Time requestedReceiveStartTime,
            Time requestedReceiveStopTime,
            ULong requestedPacketSize,
            UShort requestedPresetId,
            Frequency requestedCarrierFrequency) = 0;

        virtual void configureReceiveCycle(
            ULong targetCycleId,
            Time requestedReceiveStartTime,
            Time requestedReceiveStopTime,
            ULong requestedPacketSize,
            Frequency requestedCarrierFrequency) = 0;

        virtual void setReceiveStopTime(
            ULong targetCycleId,
            Time requestedTransmitStopTime) = 0;
};

ReceiveDataPush.h

class I_ReceiveDataPush
{
    public :
        virtual void pushBBSamplesRx(
            BBPacket * thePushedPacket,
            Boolean endOfBurst) = 0;
};