

Functional receiver specification of satellite digital interactive television with a low data rate return channel via satellite — Modem layer specification

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**Functional receiver specification
of satellite digital interactive television
with a low data rate return channel via satellite -
Modem layer specification**

Spécification pour le fonctionnement
du récepteur pour la télévision interactive
par satellite avec une voie de retour
à bas débit par satellite -
Spécification du modem de la couche

Funktionale Empfängerspezifikation
für digitales interaktives
Satellitenfernsehen mit Rückkanal
niedriger Datenrate über Satellit -
Festlegungen Modemschicht

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CENELEC

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Foreword

This European Standard was prepared by the Technical Committee CENELEC TC 206, Consumer equipment for entertainment and information and related sub-systems.

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Introduction

This European Standard has been produced by CENELEC Committee TC 206 with the support of the research and development activities carried out within the SATMODE Project. The SATMODE project is part of the ARTES program of the European Space Agency (Contract No 16905/02/NL/US). More information on SATMODE project is available in Annex D.

This document provides the specification containing the essential elements necessary to facilitate the implementation of the interaction channel for interactive television networks using Geostationary Satellites with fixed return channel satellite terminals via low data rate dedicated return link.

The system is called SATMODE and consists of many terminals installed at the user-customer premises, one or several HUB stations, possibly co-located with the broadcaster or interactive service provider uplink stations, and a satellite which is transparent for uplink and downlink signals. The main application for SATMODE system is the implementation of suitable networks for interactive digital television systems requiring a return channel of low data rate.

The document facilitates the use of SATMODE system for individual or collective installation (e.g. SMATV) in a domestic environment applied to interactive digital television (iTV). It also supports the connection of such terminals with in-house data networks. The document may be applied to all frequency bands allocated to GEO satellite services. The solutions provided for interaction channel for satellite interactive networks are a part of a wide set of alternatives to implement interactive services associated to digital television systems following the DVB reference model for interactive services.

The modem layer specification included in this document (physical air interface layer and data link layer components) describes the requirements needed to establish radio communication links between the user earth stations (terminals) and the HUB earth station and between the HUB station and the user terminals.

The Satmode System

The SATMODE design having led to the present specification was optimized for the iTV case.

The choice of constant envelope modulations was made to minimize the terminal cost. Thanks to this property, very low cost ODU's operating at full saturation and in non-linear mode can be used.

The moderate bit rates of SATMODE allow to use very low power transmitters (typically 100 mW), keeping the cost compatible with the mass-market.

The selected access scheme -slotted ALOHA- is efficient on iTV traffic and very easy to scale up to a very high number of terminals only sending a few packets from time to time.

The SATMODE modem specification aims at fully specifying the behavior SATMODE modem function used in a terminal.

To increase the applicability and the probability of commercial success of SATMODE, it was decided to design SATMODE as a system usable with existing space segments and ready for future satellites improved for point-to-point applications.

Considering this objective, it was considered as mandatory to have built-in flexibility in terminals deployed today and ready for the future.

This flexibility allows SATMODE to be used in extreme scenarios by adjusting the modem parameters:

- very power limited scenarios (it's the case for most VSAT Ku-band satellites);
- aggressive multi-beam space segment, targeting high spectral efficiency.

To reach that goal and nevertheless keep full interoperability of terminals, SATMODE uses a fully specified waveform toolbox.

Each building block has a well-defined space of operation and can be used without limitation in this space.

The building blocks of the SATMODE toolbox are

- symbol Rate: 2 kHz to 128 kHz,
- binary or quaternary CPM,
- programmable phase filter for CPM modulations (GMSK being a specific case),
- flexible Turbo or Turbo-like,
- programmable interleavers (3),
- programmable constituent codes with bypass possibilities (2),
- programmable Unique Word structure,
- tables extraction from a DVB TS (DVB-S or DVB-S2 broadcast).

All the parameters are sent by the HUB through tables, even allowing changes during operation:

- FCT: Spectrum organisation in Carrier Groups;
- FAT: Spectrum Allocation to services.

Signalisation information sent to specific terminals is embedded in the SMT tables.

The terminal is fully defined: it must be able to play the complete waveform space.

The HUB usually only implements one scheme and send the tables to the terminals to instruct them to play that scheme.

Modem Layer providers can thus compete on the modem performances, although using fully interoperable terminals.

1 Scope

This standard applies for the interaction channel for interactive television networks using Geostationary Satellites with fixed return channel satellite terminals via low data rate dedicated return link. It specifies the essential elements for the implementation of the interaction channel.

2 Normative references

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

ETSI EN 300 421, *Digital Video Broadcasting (DVB); Framing structure, channel coding and modulation for 11/12 GHz satellite services*

ETSI EN 300 468, *Digital Video Broadcasting (DVB); Specification for Service Information (SI) in DVB systems*

ETSI EN 300 802, *Digital Video Broadcasting (DVB); Network-independent protocols for DVB interactive services*

ETSI EN 301 192, *Digital Video Broadcasting (DVB); DVB specification for data broadcasting*

ETSI EN 301 459, *Satellite Earth Stations and Systems (SES); Harmonized EN for Satellite Interactive Terminals (SIT) and Satellite User Terminals (SUT) transmitting towards satellites in geostationary orbit in the 29,5 GHz to 30,0 GHz frequency bands covering essential requirements under Article 32 of the R&TTE Directive*

ETSI EN 302 307, *Digital Video Broadcasting (DVB); Second generation framing structure, channel coding and modulation systems for Broadcasting, Interactive Services, News Gathering and other broadband satellite applications*

ETSI ETR 154, *Digital Video Broadcasting (DVB); Implementation guidelines for the use of MPEG-2 Systems, Video and Audio in satellite, cable and terrestrial broadcasting applications*

EN ISO/IEC 13818-1, *Information technology - Generic coding of moving pictures and associated audio information; Part 1: Systems (ISO/IEC 13818-1)*

ETSI TR 101 202, *Digital Video Broadcasting (DVB); Implementation guidelines for Data Broadcasting*

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of this document, the following terms and definitions apply:

3.1.1

forward link

satellite link carrying traffic towards the user terminals

3.1.2**return link**

satellite link carrying traffic originating from the user terminals

3.1.3**interactive Digital Television**

service based on the reception of digital television and interaction between the end user and the broadcaster or interactive service provider through a return channel

3.1.4**network**

collection of resources and services providing the SATMODE return channel, which is under the control of a single organisation (the network operator)

3.1.5**beam**

satellite network associated to a return link transponder with its associated bandwidth and geographical coverage

3.1.6**carrier group**

set of return link carriers sharing the same SATMODE physical link parameters (modulation type, symbol rate, coding rate). Different carrier groups are provided in the SATMODE network in order to cope with variable link conditions (fades)

3.1.7**class of service**

set of return link carriers that is shared by return traffic requiring the same Quality of Service

3.2 Symbols

For the purpose of this document, the following symbols apply:

- × multiplication;
- ≠ different than, unequal to;
- ≤ lower than or equal to;
- ≥ higher than or equal to;
- Σ sum;
- Π interleaver.

3.3 Abbreviations

The following acronyms are used in this document:

ACRONYM	MEANING
ACPR	Adjacent Channel Power Ratio
ACK	Acknowledgment
ARQ	Automatic Repeat Request
B	Byte
BAT	Bouquet Association Table
bd	baud
BER	Bit Error Rate
BSS	Broadcast Satellite Service
CC	Convolutional Encoding
CENELEC	European Committee for Electrotechnical Standardization
CG	Carrier Group
COS	Class of Service
CPM	Continuous Phase Modulation
CRC	Cyclic Redundancy Check
DL	Downlink
DMT	Download Messaging Table
DSM-CC	Digital Storage Media - Command and Control
DTH	Direct-To-Home
DVB	Digital Video Broadcast
DVB-S	Digital Video Broadcast by Satellite
EIRP	Effective isotropic radiated power
EIT	Event Information Table
EN	European Norm
EOM	End Of Message
ESA	European Space Agency
ETS	European Telecommunications Standard
ETSI	European Telecommunications Standards Institute
FAT	Frequency Allocation Table
FCT	Frequency Composition Table
FSS	Fixed Services by Satellite
GEO	Geostationary Earth Orbit
GMSK	Gaussian Minimum Shift Keying.
GT	Guard Time
G/T	Gain to Temperature
HUB	SATMODE modem hub

IEC	International Electrotechnical Commission
IF	Intermediate Frequency
IIM	Interactive Interface Module
iLNB	Interactive LNB
IPR	Intellectual Property Rights
iSTB	Interactive set top box
ITT	Invitation to Tender
ITU	International Telecommunication Union
iTV	Interactive Digital Television
LFSR	Linear Feedback Shift Register
LLC	Link Layer Control
LNB	Low Noise Block Converter
LSB	Less Significant Bit
MAC	Medium Access Control
MF-TDMA	Multiple Frequency-Time Division Multiple Access
MPEG	Moving Pictures Expert Group
MSB	Most Significant bit
MTU	Maximum Transmissible Unit
NCR	Network Clock Reference
NIM	Network Interface Module
NIT	Network Information Table
NIU	Network Interface Unit
OSI	Open Systems Interconnection
PAT	Program Association Table
pc	Per cent
PCCC	Parallel Concatenated Convolutional Coding
PDU	Protocol Data Unit
PID	Packet IDentifier
PISO	Parallel in serial out block
PMT	Program Mapping Table
PRBS	Pseudo Random Binary Sequence
PSI	Program Specific Information
QPSK	Quaternary Phase Shift Keying
QRCC	Quaternary Ring Convolutional Coding
RTF	Reply To Field
S-ALOHA	Slotted-ALOHA
SAR	Segmentation and Reassembly
SCCC	Serial Concatenated Convolutional Coding
SDT	Service Description Table

The present document addresses the satellite interactive network dependent aspects only, which are addressed here as the modem layer specification made up by physical air interface layer and data link layer.

3.4.2 System Model

Figure 2 shows the system model which is used by the DVB for the definition of interactive services. The same generic model is valid for SATMODE system and it is thus adopted.

In the system model, two channels are established between the service provider and the user.

- **Broadcast Channel:** a unidirectional broadband Broadcast Channel including video, audio and data is established from the broadcast and/or interactive service provider to the users. In the case of the SATMODE system, it includes the Forward Interaction Path.
- **Interaction Channel:** a bi-directional Interaction Channel is established between the service provider/user and the user for interaction purposes. It is formed by
 - **Return Interaction Path (Return Channel):** from the user to the service provider. It is used to make requests to the service provider/user, to answer questions or to transfer data,
 - **Forward Interaction Path:** from the service provider to the user. It is used to provide information from the service provider to the user(s) and any other required communication for the interactive service provision. In the SATMODE system, the forward interaction path is embedded into the Broadcast channel.

The SATMODE terminal is formed by the Network Interface Unit (consisting of the Broadcast Interface Module and the Interactive Interface Module) and the Interactive media player. The SATMODE modem layer provides interface for both Broadcast and Interaction Channels. The interface between the SATMODE and the interaction network is via the Interactive Interface Module.

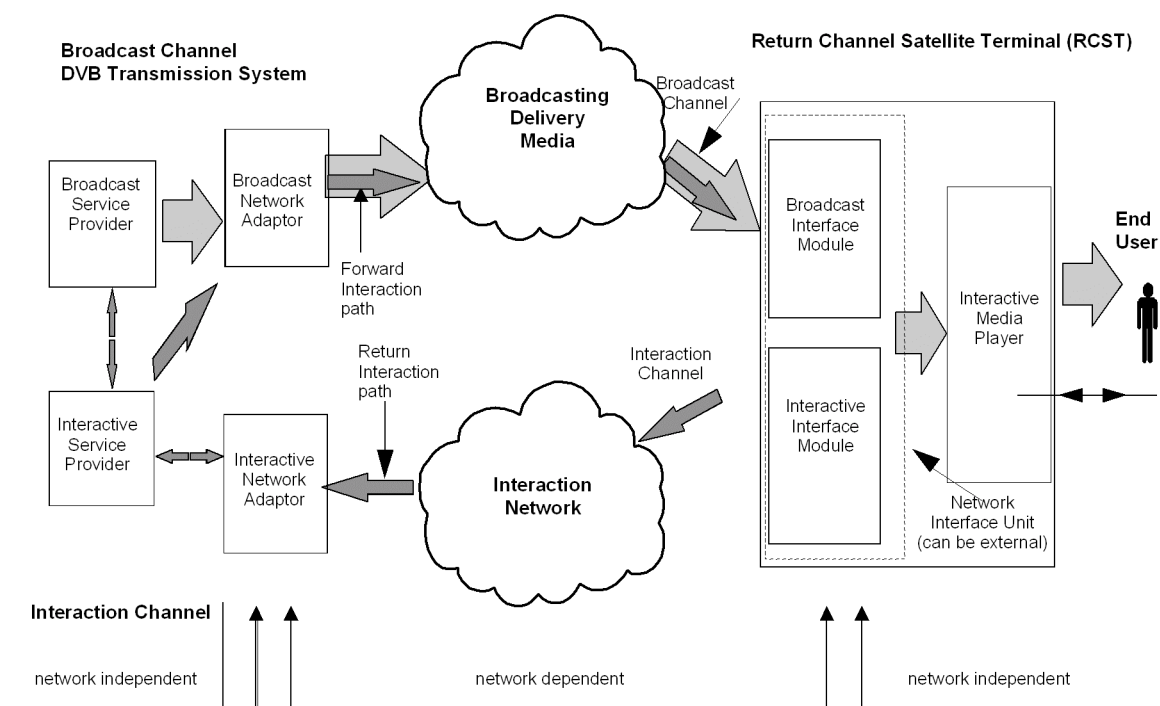


Figure 2 – A generic system Reference Model for Interactive Systems

The generic model represented in the Figure above does assume the Network Interface Unit or the Interactive Interface Module is embedded into the Set-Top-Box. Externally implemented NIU/IIM can also be used.

3.4.3 Reference System Architecture for SATMODE

SATMODE is an interactive satellite communication system, in which GEO satellites are used to carry forward and return traffic between a central HUB station (or one of a relatively small number of remote HUB stations) and a very large number of end-user terminals. Figure 3 shows the overall concept of the SATMODE interactive service with a low data rate return channel over satellite.

The SATMODE terminal consists of

- antenna,
- interactive LNB, that is an integrated LNB and low power transmitter,
- interactive Set-Top-Box, consisting of
 - STB function, equipped with any necessary software for interactive digital television (iTV) applications, capable to receive the DVB-S signals (and optionally the DVB-S2 Broadcast mode signals),
 - SATMODE modem function, providing an interactive return channel over satellite. The SATMODE modem can be external to the STB.

The SATMODE modem generates a modulated IF signal that is upconverted by the iLNB and sent over the satellite to the HUB. Data are forwarded from the HUB to the Broadcaster and/or Interactive service provider.

NOTE The SATMODE modem function is represented in the generic DVB reference model as the NIU (Network Interface Unit), as Figure 2 shows.

The forward channel is provided by a DVB-S compatible broadcast link, usually based on the Ku band frequency range 10,7 GHz to 12,75 GHz. It uses ETSI EN 300 421 (DVB-S). The system also allows the optional use of the new DVB-S2 (ETSI EN 302 307) framing coding and modulation scheme for the satellite broadcast DVB channels (DVB-S2 Broadcast mode). Forward link interactive data is multiplexed on the interactive service providers' streams in the regular DVB-S streams.

The SATMODE return channel can work in any typical fixed satellite service frequency band, although the system has been conceived originally for the use of the Ka band frequency range 29,5 GHz to 30 GHz. The SATMODE system does not restrict implementations which can make use of other broadcast bands in combination with other return channel FSS bands. The forward and return channel may be on the same satellite station.

In addition there can be remote HUB stations providing a forward link capability and a capability to receive return channels. Remote HUB stations can be used in cases where it is not convenient or economic to use the main HUB station. Remote HUB stations will offer service providers the possibility of receiving the return channel signals from SATMODE terminals directly as well as the possibility of uplinking forward traffic data directly instead of via the main satellite operator's HUB. Remote HUB stations can either manage a range of system resources (bandwidth and power) allocated by the main HUB independently or they can simply receive and transmit traffic data leaving signalling and control processing to be performed by the main HUB.

At the user side the SATMODE terminals shall be used to receive and process the interactive forward traffic coming from the HUBs via standard FSS/BSS transponders carrying not only SATMODE traffic but also other video/audio services within DVB compatible streams.

For the return link all messages generated by the end user shall be processed in the SATMODE return link part of the SATMODE modem or the interactive STB. Together with the iLNB (interactive LNB: SATMODE transmitter), this shall include all data encapsulation, modulation, up-conversion, amplification and transmission of the return channel to the satellite. The appropriate HUB shall receive this user return link data. A time and frequency slotted ALOHA multiple access system is used operating over a number of carrier frequencies (TF S-ALOHA) in order to govern the transmissions from the end user terminals to the HUB.

Control and signalling data will be used during the installation phase providing a feedback for measurement results to the SATMODE terminal. During installation, a SATMODE terminal sends specific bursts, which are measured in power, time, and frequency. These measurements allow antenna-pointing refinement assistance after proper pointing through the receiving signal, delay compensations and synchronization verification.

The HUB consists of the equipment to

- insert the payload and network control information in the Forward Link,
- allocate and manage the capacity of the Return Link,
- receive the information sent by the SATMODE terminals in the Return Link,
- synchronize and Control the SATMODE terminals accessing the Return Link,
- connect the interactive service provider(s) to the satellite network.

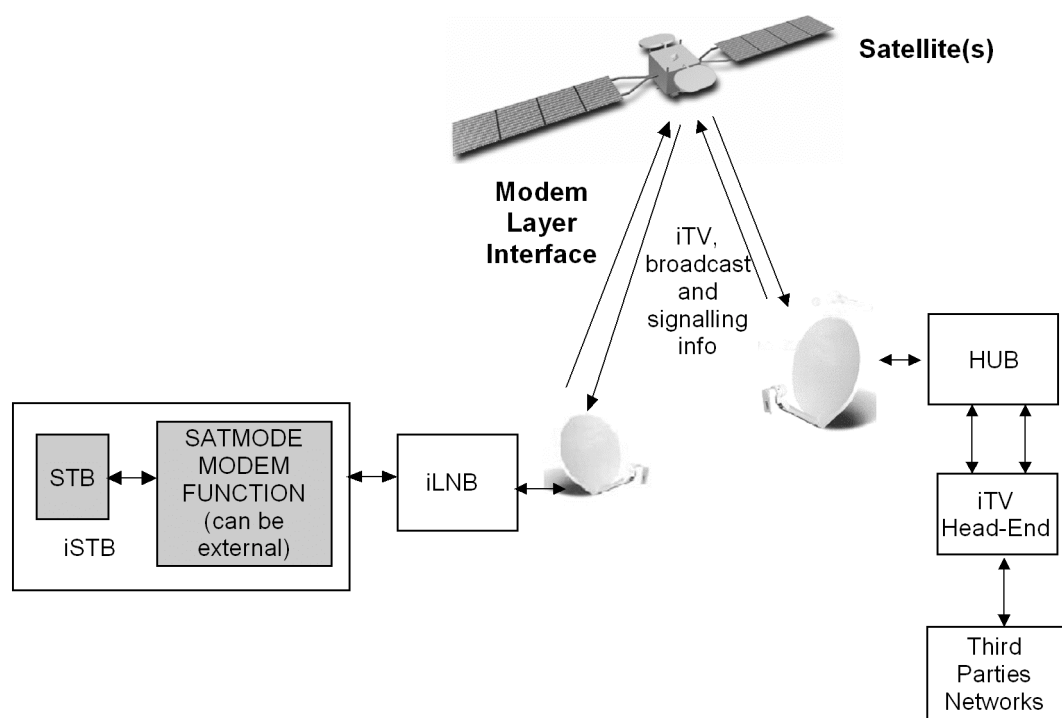


Figure 3 – Overall system description of SATMODE

Although the system does include additional interfaces between blocks and components of the overall architecture, it is understood that they are specific to industrial implementation and therefore are not defined at this stage. This specification covers the Interfaces necessary for unambiguous definition of the air interface (modem layer: physical air interface layer and data link layer components). In Figure 3, this interface is defined at point MODEM LAYER INTERFACE, aiming at compatibility and interoperability of the SATMODE terminals. In Figure 3, the combination of the blocks STB and SATMODE modem does represent a generic case of the integrated Interactive STB (iSTB), which embeds the functionalities of the SATMODE modem.

Figure 4 illustrates the dataflow in the SATMODE concept.

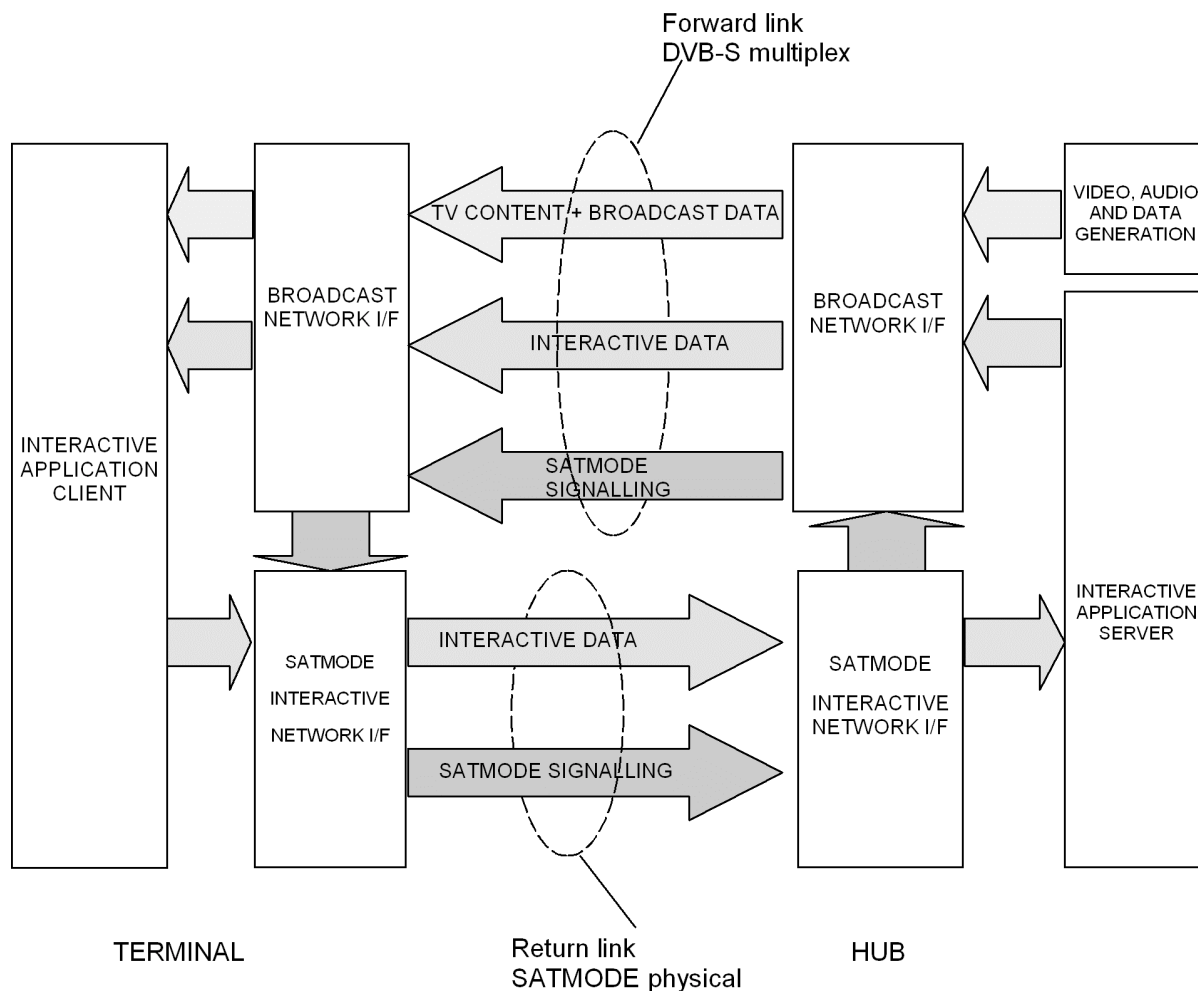


Figure 4 – Interactive traffic data

The terminal provides two network interfaces:

- the broadcast network interface (Broadcast Interface Module), used for receiving data through the existing (DVB-S and optionally DVB-S2 Broadcast mode compliant) broadcast network (**forward link**);
- the SATMODE network interface (SATMODE interactive interface module), used for sending data over the SATMODE network (**return link**).

The forward link data consists of 3 components:

- TV content (video, data, text) and broadcast data;
- Interactive traffic data;
- **Signalling** required by the SATMODE function in the terminal.

In this context **interactive traffic data** is defined as data associated with an individual SATMODE terminal.

The return link data consists of 2 components:

- Interactive traffic data;
- **Signalling** required by the SATMODE function in the HUB.

As the broadcast network may provide a bouquet of several multiplexes (several transponders) in the forward link, and a typical terminal is only capable of receiving from one transponder at a time, there is a requirement for the SATMODE terminal to signal to the HUB which transponder has to be used to send interactive traffic data to that terminal (this avoids the need of copying the interactive traffic data in all transponders). This signalling information is contained in a 'Reply to Field' (RTF) parameter.

The return link signalling of the SATMODE function is carried 'in band'. In the return link, this means signalling information is carried inside one packet together with the data. In the forward link, the signalling data is embedded into the overall DVB-S multiplexed broadcast data.

4 Terminal forward link interface

4.1 Broadcast Interface

The SATMODE end user terminal shall be able to receive digital signals conforming to ETSI EN 300 421, ETSI TR 101 202, ETSI EN 300 802, ETSI EN 300 468, ETSI EN 301 192, ETSI ETR 154, and optionally DVB-S2 Broadcast Mode in ETSI EN 302 307.

4.1.1 Frequency

The SATMODE system is not dependant on any specific frequency range and it can work in any of the BSS and FSS available frequency bands, in the range 10,7 GHz to 12,75 GHz. The system could also be deployed in other frequency ranges.

4.1.2 Modulation/Coding

The modulation and coding in the forward link follow the DVB-S specification in ETSI EN 300 421 and optionally the DVB-S2 specification (ETSI EN 302 307, Broadcast mode). All the other DVB specifications mentioned in section 2 shall be supported by the SATMODE system.

4.1.3 Symbol rate

The SATMODE system shall operate under the same conditions set up for the DVB-S channel, therefore not adding any restriction to the inherent flexibility of the DVB-S specification in ETSI EN 300 421.

4.1.4 Polarization

There are no restrictions due to SATMODE specification on possible usage of linear (vertical or horizontal) or circular polarization (left handed or right handed).

The terminal shall be capable to select and align the right polarization as per information provided by the DVB-SI system or manually driven.

4.2 Forward Interaction Path

4.2.1 Forward Interactive Traffic Data

The HUB shall encapsulate the interactive traffic data into one or more Transport Streams. These streams shall be multiplexed in the multiplexer to form one or more composite Transport Streams as required. SATMODE does not impose restrictions on the chosen encapsulation scheme; however it should be based on established DVB means (incl. "data piping", MPE, data carousel, etc.).

4.2.2 Forward Link signalling

4.2.2.1 SATMODE tables

The SATMODE service descriptors and configuration tables are made up of existing DVB tables and new SATMODE specific tables. MPEG-2 PSI tables such as PAT, PMT and DVB-SI tables such as NIT, BAT, SDT, EIT and others will be used (as defined in ETSI EN 300 468) in conjunction with these new tables.

The SATMODE function provides 3 new data link layer signalling tables, detailed in Annex A:

- frame composition table (FCT);
- frequency allocation table (FAT);
- signalling message table (SMT).

4.2.2.2 Table definitions

A brief description of the purpose of these tables is explained below.

- **Frame Composition Table (FCT)**

This table shall provide the terminal information about programmable parameters, to support different air interface 'profiles' in terms of transmitting frequencies, transmit timing, modulation and coding, and rates. Main programmable parameters are: SATMODE specific network, return link beams, number of carrier groups, symbol rate, frequency, frequency spacing, number of carriers within a carrier group, modulation index, modulation type, polynomial description of encoders, description of interleavers, UW configuration.

- **Frequency Allocation Table (FAT)**

This table provides the terminal information about bandwidth allocation (assigned frequency carriers) to each COS, within each beam and within each carrier group. For each COS the table also provides information about the COS type, the weight to be applied in priority scheduling and about parameters used for congestion control (backoff).

- **Signalling Message Table (SMT)**

This table supports a mechanism for sending messages to terminals. Messages can be broadcast (to all terminals in the network), multicast (addressing a group of terminals), or unicast (addressing an individual terminal). One type of messages provides aloha protocol acknowledgments (ACK's), including a power level feedback indication by the HUB. Other message types are used to provide ranging information, enable/disable transmission and assign multicast addresses.

4.2.2.3 Repetition rates

The repetition rates for transmission of these tables are defined in Table 1:

Table 1 – Repetition rates

Table	Repetition rate		
	Minimum	Typical	Maximum
FCT	Each 15 s	~ Each 10 s	Each 5 s
FAT	1 per frame	According to operational needs	1 s ⁻¹
SMT	0 s ⁻¹	According to operational needs	500 s ⁻¹

4.2.2.4 Descriptor identification and location

Table 2 – Descriptor identification and location

Descriptor	Descriptor_tag	SDT	PMT
Service_descriptor	0x48	x	–
SATMODE_Service_descriptor	0xF2	x	–
SATMODE_content_descriptor	0xF1	–	x
x = present; – = not present			

4.2.2.5 Service descriptor

This descriptor shall be placed in the loop of the SDT and associated to a service_id, as defined in ETSI EN 300 468. The presence of the descriptor indicates that SATMODE signalling is present in the transport stream. The corresponding service_id is the same as the prg_nr of the PMT that defines the PID's for the FCT, FAT and SMT. The descriptor provides the names of the SATMODE operator and SATMODE service (see Table 3).

Table 3 – (DVB-SI) service descriptor

Syntax	No. of bits		Information Mnemonic	Value
	Reserved (see note)	Information		
service_descriptor() {				
descriptor_tag		8	uimsbf	0x48
descriptor_length		8	uimsbf	
Service_type		8	uimsbf	0xC1 (NOTE)
service_provider_name_length		8	uimsbf	
for (i=0;i<N;i++){				
char		8	uimsbf	
}				
service_name_length		8	uimsbf	
for (i=0;i<N;i++){				
char		8	uimsbf	
}				
}				

4.2.2.6 SATMODE service descriptor

This descriptor shall be placed in the loop of the SDT and associated to a service_id is used for the SATMODE signalling. The descriptor provides the Reply To Field value (RTF) linked with the transportstream that contains the SDT (see Table 4).

Table 4 – SATMODE service descriptor

Syntax	No. of bits		Information Mnemonic	Value
	Reserved (see note)	Information		
SATMODE_service_descriptor() {				
descriptor_tag		8	uimsbf	0xF2 (NOTE)
descriptor_length		8	uimsbf	
RTF		8	uimsbf	
}				

4.2.2.7 SATMODE content descriptor

The SATMODE content descriptor (see Table 5) shall be placed in the second loop of the PMT. Each descriptor defines the SATMODE table associated with one elementary PID.

Table 5 – SATMODE content descriptor

Syntax	No. of bits		Information Mnemonic	Value
	Reserved (see note)	Information		
SATMODE_content_descriptor() {				
descriptor_tag		8	uimsbf	0xF1 (NOTE)
descriptor_length		8	uimsbf	
Table_id		8	uimsbf	0x81 (for FCT), 0x82 (for FAT), 0x83 (for SMT), 0x84 (for DMT) (NOTE)
}				

NOTE With the aim of facilitating interoperability between different SATMODE terminals, these table_id and descriptor_tag values indicated in the Tables 3, 4 and 5 are recommended values. These values are within the private range allowed by the MPEG (EN ISO/IEC 13818-1) and DVB-SI (ETSI EN 300 468) standards.

4.2.2.8 Acquisition of forward link signalling

The PID's under which the various forward link signalling tables are carried, are retrieved from a corresponding PMT, as illustrated in the following Figure 5.

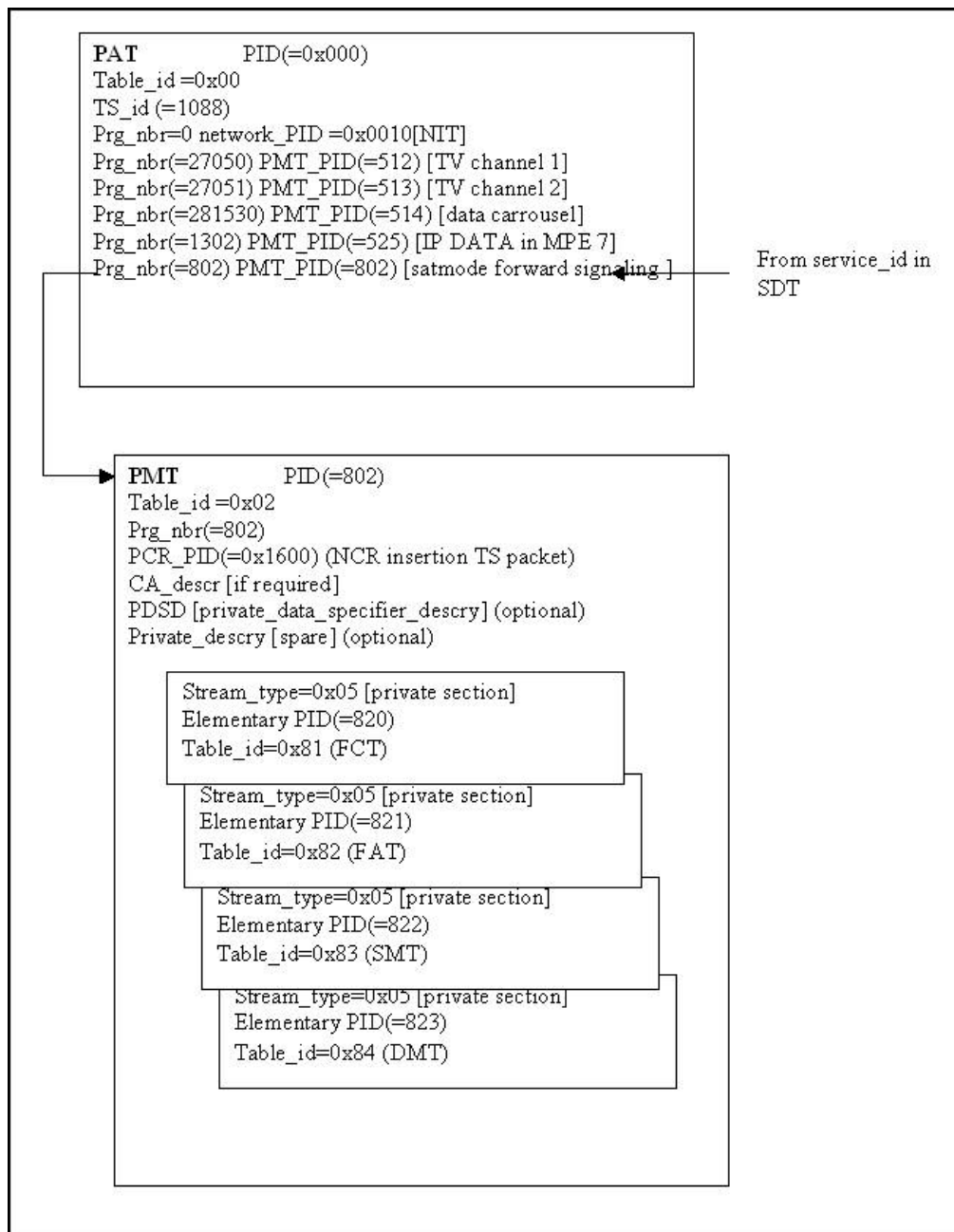


Figure 5 – Tables of PAT, PMT descriptors

5 Terminal return link interface

5.1 General

5.1.1 Access Method

Multi frequency time division multiple access (MF-TDMA) is used in the return link to govern the access from the end user terminals to the HUB. MF-TDMA allows a group of SATMODE terminals to communicate with a HUB, where the terminals share a set of carrier frequencies, each of which is divided into time-slots. Contention can occur between bursts transmitted by different SATMODE terminals working under the same service definition. This is illustrated in Figure 6.

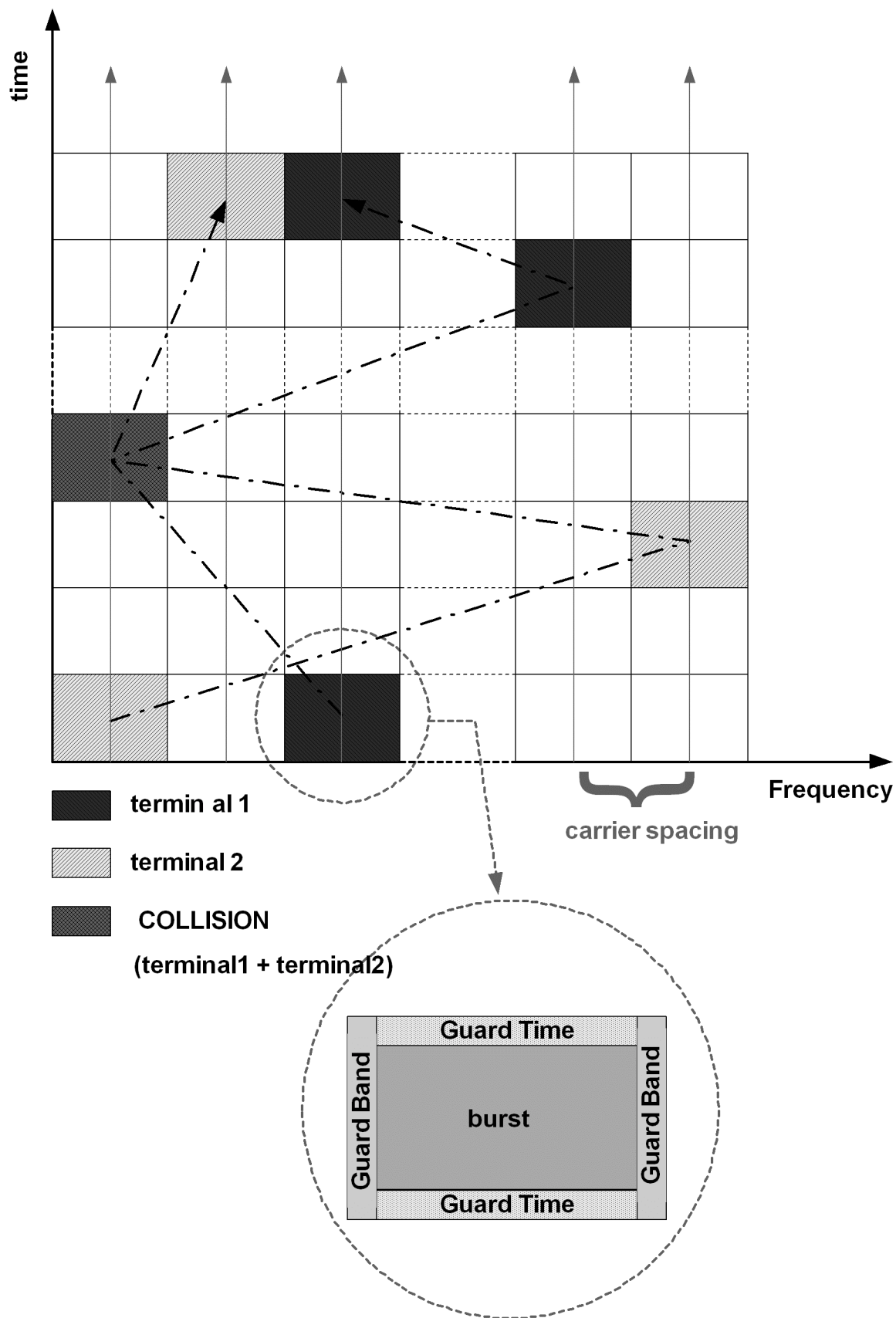


Figure 6 – Time and frequency Slotted Aloha

5.1.2 Network

The SATMODE network is the collection of resources and services providing the SATMODE return channel, and which is under the control of a single organisation (the network operator).

Each network operational on a satellite will be assigned a unique identifier by the satellite operator, which is a number in the range 0 – 255 (SATMODE_network_id).

A unique FCT shall be provided within the network.

5.1.3 Beams

Beam refers to a return link transponder with its associated bandwidth and geographical coverage. The network may operate by means of several beams.

Within a network, beams shall be identified using a number in the range 0 – 255 (beam_id).

A unique beam shall be assigned by the network operator to each terminal.

5.1.4 Carrier groups

The SATMODE system is based on the concept of carrier groups. A carrier group is a group of return link carriers sharing the same SATMODE physical link parameters such as modulation type, symbol rate and coding rate. Different carrier groups are provided in the SATMODE network in order to cope with variable link conditions (fades). The available bandwidth in each beam is divided between the various carrier groups. Each carrier group consists of a set of adjacent frequency carriers.

The physical layer parameters, uniquely defined within each carrier group, are

- the encoder parameters,
- the modulation parameters,
- the UW parameters,
- the symbol rate,
- the number of carriers,
- the frequency of the first (lowest) carrier in the group,
- the carrier spacing in the group,
- timeslot duration,
- the offset of the burst start with respect to the slot start.

These parameters are signalled in the forward link in the Frame composition table (FCT) and the Frequency Allocation Table (FAT), according to the syntax specified in Annex A.

The maximum number of carrier groups that can be defined is 6. Carrier groups are uniquely identified by their carrier_group_ID, which is a number between 0 and 5.

For each next carrier group, in ascending order of carrier_group_ID, the physical layer parameters will be defined in such a way that the clear sky link budget margin is 3 dB less than that for the previous carrier group. The carrier group with ID = 0 corresponds to the highest clear sky link margin; this carrier group is also used for installation purposes. The carrier group selection changes dynamically according to the fading conditions. This process is described in 5.2.3.

5.1.5 Services

The SATMODE network can provide several '**services**'. Each service can be characterised by its own branding (trade name), sales organisation, tariffs and billing rules, distribution organisation, service organisation, geographical service area, bandwidth or Quality of Service requirements.

There is no requirement that every service shall be available within every beam.

Within a network, services shall be identified using a number in the range 0 – 255 (SATMODE_service_id). A unique service shall be assigned by the network operator to each terminal within the network. A unique FAT will be provided for each service, providing information about the beams where the service is available.

5.1.6 Classes of service and priority

Each service is divided in a number of classes of service (COS). Each COS corresponds to a quality of service level and has a unique identifier (COS_ID), which is a number in the range 0 to 6.

For installation purposes, each service will at least support the COS with COS_ID = 0 and with COS_ID = 1.

For data traffic, each service will support at least one of the 5 possible COS, which are defined in Table 6, which gives an overview of all possible COS.

Table 6 – Possible COS types

Possible COS types		
COS_ID = 0	antenna pointing bursts	
COS_ID = 1	login (ranging) bursts	
COS_ID = 2	Assured forwarding data traffic	Critical priority
COS_ID = 3		High priority
COS_ID = 4		Medium priority
COS_ID = 5		Low priority
COS_ID = 6	Best Effort data traffic	

COS_ID'S for data traffic shall have values in the range 2 – 6. When sending a packet with ACK (assured forward), it must be sent in the COS corresponding to its priority (COS 2 to 5). If the packet is sent without ACK (best effort), it must be sent in a separate COS (COS 6) used for that purpose only (i.e. no acknowledgment, anonymous and login packets).

The first 2 COS's are used for installation, pointing, synchronization and ranging.

The FAT provides a list of the available COS together with their characteristics.

5.1.7 Usage of return link physical resources

The organisation of the network and the associated spectral resources are illustrated in Figure 7. Within each beam the available bandwidth is divided between the carrier groups.

The bandwidth allocated to a carrier group, within a beam, is divided between the services available in that beam (each service is allocated a subset of the carriers in the group).

Within each carrier group, the bandwidth allocated to a service is further divided between the Classes of Services (COS) available for that service (each COS is allocated a subset of the carriers allocated to the service). The organization of time slots is provided in 5.2.3.2.

COS with COS_ID = 0 and 1 are only available in CG 0.

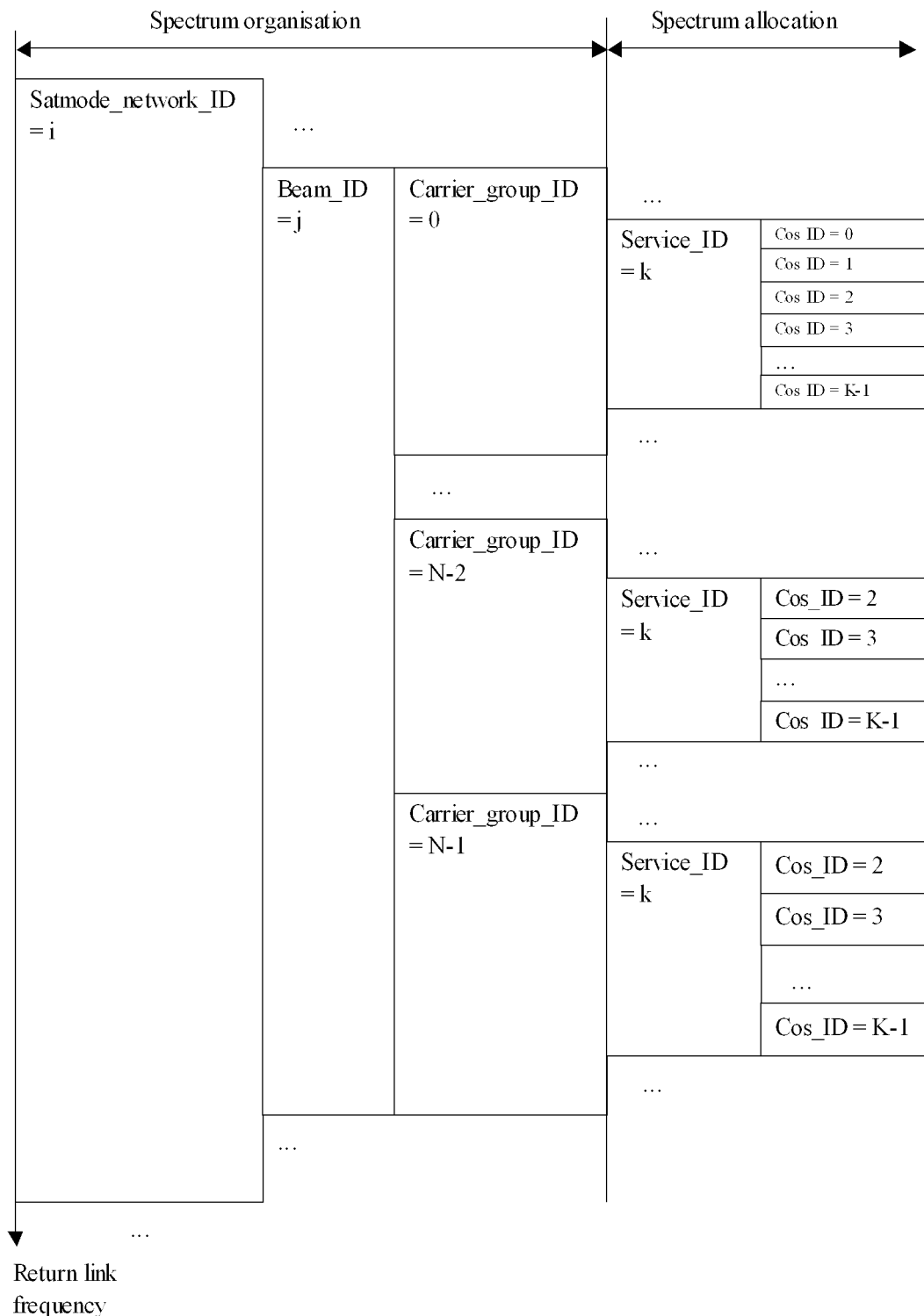


Figure 7 – Organisation of the network and spectral resources

The contention between SATMODE terminals on the return link is managed using a slotted aloha protocol. If a terminal has a MAC packet of a given COS to transmit, the terminal will do the following.

- The terminal will define its fade condition according to the mechanism defined in 5.2.3.2, and accordingly will select a carrier group.
- The terminal will then select randomly one of the TX carrier frequencies reserved for the required COS and the selected carrier group. The reserved carrier frequencies for each carrier group and for each COS are signalled in the FAT.
- The terminal will select a timeslot, according to the Aloha protocol, to transmit a burst containing that MAC packet. The timeslots are aligned on the NCR clock. The NCR clock is defined in 5.2.1.1. The parameters defining the alignment structure are signalled in the FCT.
- If necessary the terminal will retransmit the packet, according the protocol definition.

5.2 Physical Layer Interface

5.2.1 Return link synchronisation

Synchronisation of the terminals must be achieved both in frequency and time.

5.2.1.1 Acquisition of clock reference

The synchronization scheme is based on information contained within the NCR (Network Clock Reference).

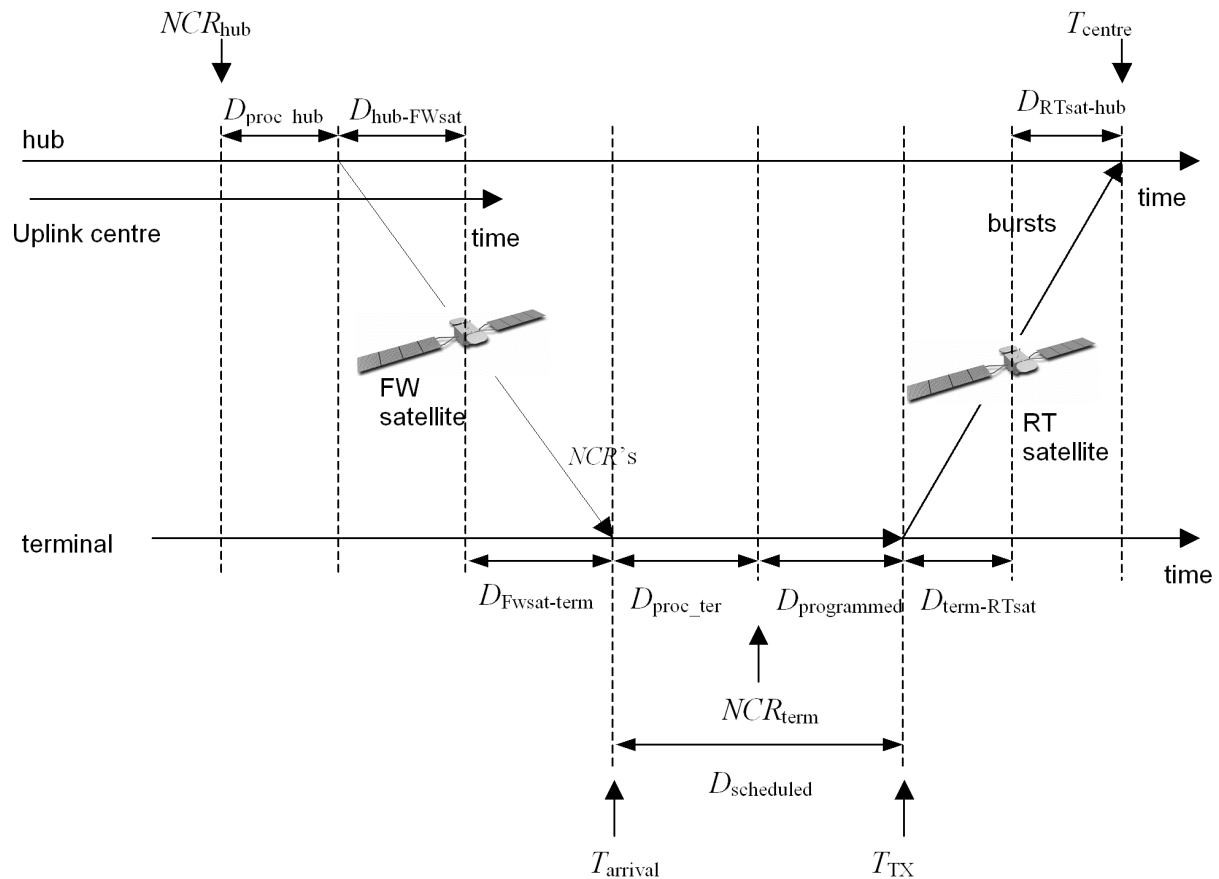
The NCR is distributed with a specific PID within the MPEG2 Transport Stream that carries the Forward Link Signalling. The NCR distribution follows the PCR distribution mechanism as defined in EN ISO/IEC 13818-1, which is usually derived from an MPEG video encoder, whereas in the SATMODE system the NCR is derived from the HUB reference clock. The NCR is expressed as number of periods of a 27 MHz clock, slaved to the HUB reference clock. The HUB reference clock will have a relative accuracy of 10^{-8} or better. The NCR signalling interval will be 40 ms +/- 5 %.

5.2.1.2 Burst transmission timing

The NCR's are received by the terminal through the Forward Link. The terminal reconstructs (recovers) the received NCR clock. The recovered NCR clock (terminal NCR clock), together with parameters signalled in the forward link, is used by the terminal for timing burst transmissions (5.2.1.6). The original HUB NCR clock is used by the HUB for timing the acquisition process of bursts.

If a remote uplink centre is used that is not geographically collocated with the HUB, the NCR values will be adjusted to compensate for the difference between the propagation delay from the remote uplink centre to the satellite and the propagation delay from HUB to satellite.

The SATMODE terminal NCR clocks lags behind the HUB NCR clock. The various delays involved are outlined in Figure 8, which also shows how the Forward Link signalling parameters are used by the terminal for determining the start of burst transmission.



Key

D_{proc_hub}	=	processing delay in modulation and encoding functions at HUB
$D_{hub-FWsat}$	=	propagation delay forward link HUB-to-satellite
$D_{FWsat-term}$	=	propagation delay forward link satellite-to-terminal
D_{proc_term}	=	processing delay in demodulation and decoding functions at terminal
$D_{programmed}$	=	programmed delay in terminal
$D_{scheduled}$	=	scheduled delay in terminal (this delay can be different for every terminal and also serves to compensate for the terminal's geographical position)
$D_{term-RTsat}$	=	propagation delay return link from terminal-to-satellite
$D_{RTsat-hub}$	=	propagation delay return link from satellite-to-HUB
NCR_{hub}	=	NCR clock value in HUB
NCR_{term}	=	recovered NCR clock value in terminal
T_{centre}	=	centre of search window for burst start, referred to HUB NCR clock
$T_{arrival}$	=	time of arrival in terminal of NCR packet
T_{TX}	=	start of burst transmission, referred to terminal NCR clock

Figure 8 – Description of delays between SATMODE terminal and HUB

Assuming that all delays are expressed in periods of a 27 MHz clock, the following relations are applicable:

$$NCR_{hub} = NCR_{term} + D_{proc_hub} + D_{hub-FWsat} + D_{FWsat-term} + D_{proc_term}$$

$$T_{centre} = NCR_{hub} + D_{proc_hub} + D_{hub-FWsat} + D_{FWsat-term} + D_{proc_term} + D_{programmed} + D_{term-RTsat} + D_{RTsat-hub}$$

The HUB will compensate for the delays $D_{\text{proc_hub}}$, $D_{\text{hub-FWsat}}$, $D_{\text{FWsat-term}}$, $D_{\text{scheduled}}$, $D_{\text{term-RTsat}}$, $D_{\text{RTsat-hub}}$ by adjusting the centre of the search window for the burst start, according to this last formula.

The terminal will select a slot for transmission according to the frame structure defined in the FCT and FAT as defined in Figure 9.

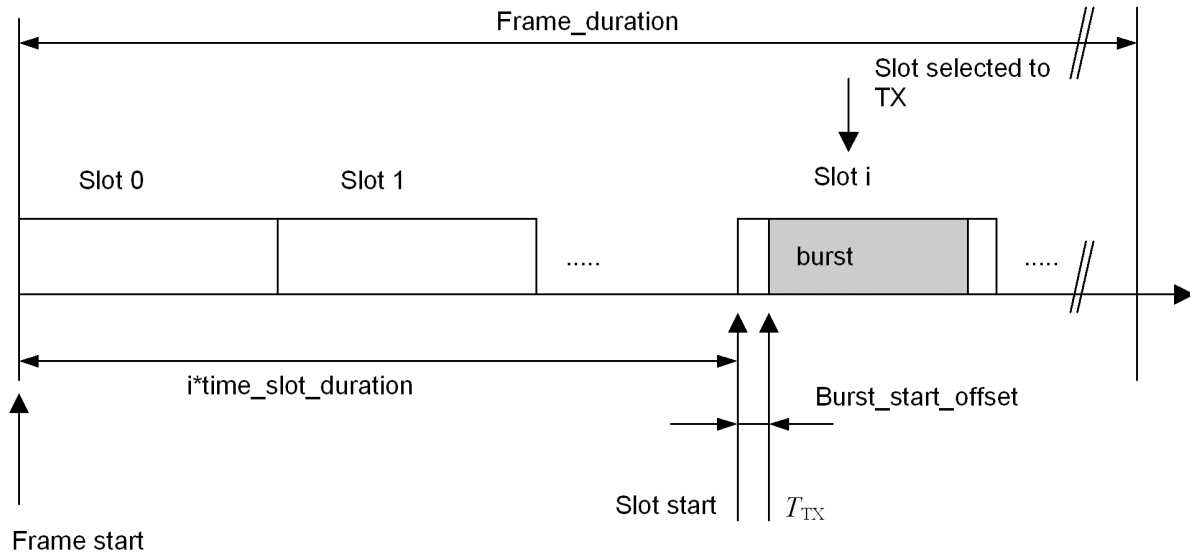


Figure 9 – Forward link signalling parameters

The frame structure is defined in the FCT and FAT using the following parameters:

- Time_slot_duration (expressed in periods of 90 kHz clock, as a partition of 27 MHz / 300));
- Burst_Start_Offset (expressed in periods of 27 MHz clock);
- Frame_duration (expressed in periods of 27 MHz clock).

The burst start T_{TX} is then defined with respect to the frame start by the following expression:

$$T_{\text{TX}} = \text{frame start} + i \times \text{time_slot_duration} \times 300 + \text{Burst_Start_Offset}$$

The start of the current frame shall be derived from the current value of the recovered NCR clock (NCR_{term}) and a frame_start_origin in the past (that is referred to the NCR clock) following the method defined in Figure 10.

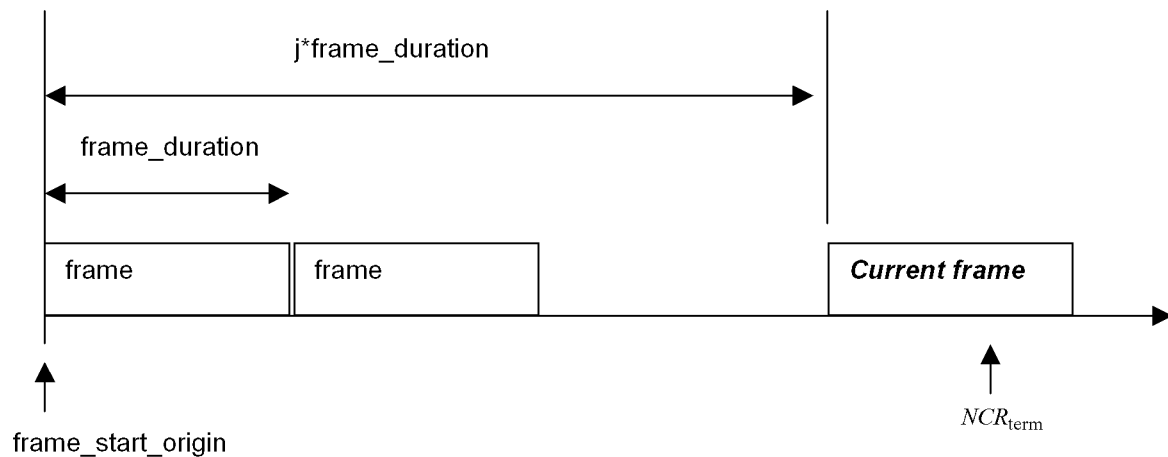


Figure 10 – Frame start origin

The $\text{frame_start_origin}$ is given by the following expression:

$$\text{frame_start_origin} = \text{frame_start_FAT} \times 300 + D_{\text{programmed}}$$

whereas

frame_start_FAT is the parameter defined in the corresponding field of the currently applicable FAT (expressed in periods of 90 kHz clock);

the programmed delay $D_{\text{programmed}}$ is also expressed in periods of a 27 MHz clock.

The programmed delay $D_{\text{programmed}}$ that the terminal will apply is obtained from the scheduled delay $D_{\text{scheduled}}$ as follows:

$$D_{\text{programmed}} = D_{\text{scheduled}} - D_{\text{proc_term}}$$

whereas the scheduled delay is obtained from the **time_correction** and **min_delay** parameters that are signalled in the forward link:

$$D_{\text{scheduled}} = (\text{min_delay} + \text{time_correction}) \times 300$$

The **min_delay** parameter (expressed in 90 kHz clock periods) is signalled in the FCT.

The **time_correction** parameter (also expressed in 90 kHz clock periods) is signalled in the SMT and is obtained during the installation procedure (ranging procedure). The default value of the **time_correction** parameter is 0.

The exact definition for the time of arrival T_{arrival} which serves to determine the processing delay $D_{\text{proc_term}}$ is provided in detail in Annex B.

5.2.1.3 Transmit frequency accuracy

The transmit frequency (TX_freq) shall satisfy the following inequality:

$$\left| \frac{TX_freq}{nom_TX_freq} \cdot \frac{27\text{ MHz}}{ideal_rec_NCR_freq} - 1 \right| \leq 0,85E-8$$

whereas

nom_TX_freq is the nominal TX frequency defined in the forward link signalling;

ideal_rec_NCR_freq is the ideal recovered NCR clock frequency, defined as the HUB NCR clock frequency plus the frequency shift caused by the Doppler effect in the forward link.

5.2.1.4 Burst transmission timing accuracy

Burst transmission timing accuracy shall be within 1 NCR base unit (11 µs).

5.2.1.5 Symbol clock synchronisation

The transmission symbol clock of the terminal shall be referred to the recovered NCR clock. Symbol clock accuracy shall be within 20 ppm from the nominal symbol_rate value in the FCT (see Annex A). The symbol clock rate shall have a short-term stability that limits the time error of any symbol within a burst to 1/20 symbol duration.

5.2.1.6 Login and TX-pointing procedure

5.2.1.6.1 Terminal operation

The state chart defining the required terminal behaviour is presented in Figure 11.

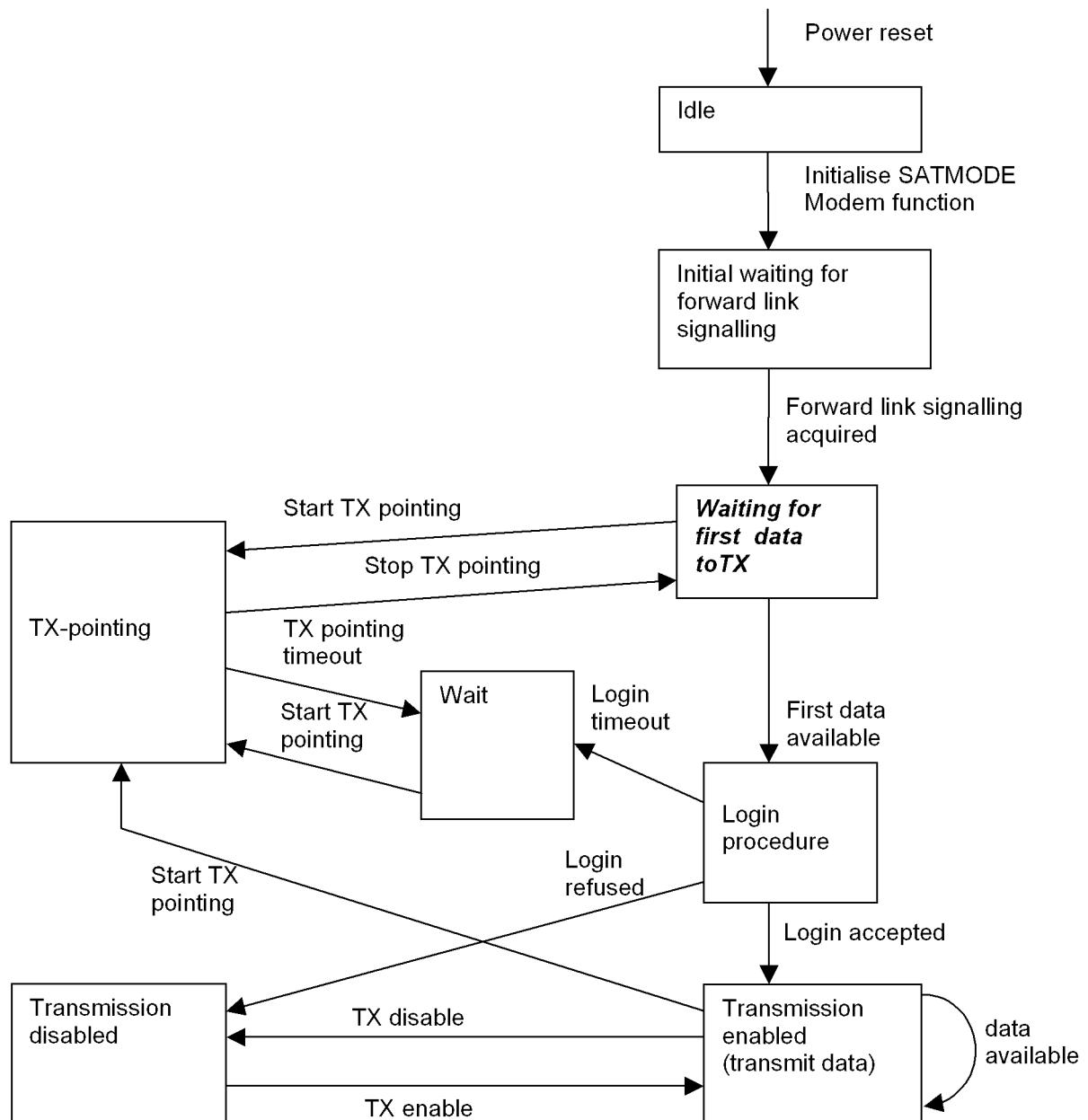


Figure 11 – Terminal Operation

The states are defined in Table 7:

Table 7 – Definition of login and TX-pointing procedure states

State	Definition
Idle	The terminal is ready to receive commands from the control plane. The terminal is not allowed to transmit.
Initial waiting for forward link signalling	The terminal is initialised to acquire the forward link signalling. This acquisition is ongoing and the terminal is not allowed to transmit.
Waiting for first data to transmit	The terminal has acquired the forward link signalling, no data for transmission are available. The terminal will not transmit.
Login procedure	The terminal sends login bursts until login has been accepted or refused by the HUB. In absence of reply from the HUB this transmission will be stopped, after a timeout has been reached.
TX pointing	The terminal sends bursts for antenna pointing.
wait	The terminal is not controlled by the network management and is not allowed to transmit.
Transmission disabled	The terminal is controlled by the network management and is not allowed to transmit.
Transmission enabled	This is the state of normal operation). The terminal transmits data when available.

The following transitions are not shown for clarity, but shall be implemented:

- from every state the terminal shall transit to the 'idle' state following a software reset command;
- every state (commands see Table 8), except the 'idle' state and 'initial waiting for forward link signalling' state, has an associated 'waiting for forward link state' in which the terminal shall not transmit. The terminal shall transit to this associated 'waiting for forward link state' when signalling is lost and return to the original state when signalling is recovered.

Table 8 – Commands

Command	Channel
Start TX pointing	Control channel between application layer and SATMODE modem layer
Stop TX pointing	Control channel between application layer and SATMODE modem layer
Software reset	Control channel between application layer and SATMODE modem layer, SMT
Login acceptance	SMT
Login refusal	SMT
Transmit enable	SMT
Transmit disable	SMT

5.2.1.6.2 Login procedure

The login_procedure will be started when the first data for transmission are available after a power reset of the terminal or after TX pointing. During the login procedure the terminal will perform a synchronisation procedure to compensate for the variation in propagation delay due to its geographical position. This login procedure is defined in Figure 12.

The carrier group offering the best possible link condition (carrier_group_ID = 0) will be used for login bursts. This carrier group will be defined in such a way to provide at least 4 ms of guard time. The COS with COS_ID = 1 will be dedicated for login.

The terminal will start to transmit installation bursts with the time_correction parameter defined in 5.2.1.2 set to 0. The HUB will answer with a login_response message in the SMT containing the correct time_correction parameter value that should be applied for traffic bursts. After reception of the SMT the terminal will store time_correction value and go to the standby state. The terminal continues to transmit installation bursts until a SMT is received with a time_correction message. If the terminal doesn't receive the SMT after a specified number of attempts it will go to the off state.

There is no specific burst format for installation; the format of the bursts is the same for installation and traffic. The burst used for login will contain the login MAC packet.