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Technical Report

**Satellite Earth Stations and Systems (SES);
Satellite Digital Radio (SDR) service;
Functionalities, architecture and technologies**

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Satellite Earth Stations and Systems (SES).

1 Scope

The present document concerns the functionalities, reference architecture and technologies for Satellite Digital Radio (SDR) systems. In particular, the radio interface of SDR broadcast receivers is addressed. It provides a summary of technologies that can be used to address the functionalities in a manner compatible with the reference architecture. The various technologies have been submitted during an internal call for proposals of the ETSI TC SES/SDR working group. Within the scope of the present document, the various technology choices and interfaces/layers are not intended to be completely definitive, and other choices might be considered. It should also be noted that various architectures described in the present document are not intended to be interoperable with each other. The material in the present document should be useful for the creation of an SDR radio interface standard or standards for particular parts of the SDR system.

2 References

For the purposes of this Technical Report (TR), the following references apply:

[1]   ETSI EN 300 744: "Digital Video Broadcasting (DVB); Framing structure, channel coding and modulation for digital terrestrial television".

[2]   ETSI EN 300 401: "Radio Broadcasting Systems; Digital Audio Broadcasting (DAB) to mobile, portable and fixed receivers".

[3]   ETSI EN 301 192: "Digital Video Broadcasting (DVB); DVB specification for data broadcasting", clause 7 "Multiprotocol Encapsulation".

[4]   ITU-R Recommendation BO.1130-4: "Systems for digital satellite broadcasting to vehicular, portable and fixed receivers in the bands allocated to BSS (sound) in the frequency range 1400-2700 MHz".

NOTE: System A is DAB, D_S is WorldSpace, D_H is an enhanced WorldSpace, and E is MBCO (Japan) / S-DMB (Korea).

[5]   ISO/IEC 13818-1: "Information technology -- Generic coding of moving pictures and associated audio information: Systems".

[6]   CEPT ECC/DEC/(03)02: "ECC Decision of 17 October 2003 on the designation of the frequency band 1479.5-1492 MHz for use by Satellite Digital Audio Broadcasting systems".

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[12]   Chuberre N.: "An Innovative Mobile Satellite System Concept", International Workshop for B3G/4G satellite Communications, Korea, 18 November 2004.

[13]   Terzani et.al.: "Results of the WARC 92 Conference", EBU Technical Review - Summer 1992, pp 27-35.

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[18] Puetz J.: "Satellite Radio" The Journal of The Council of Advisors, May 2001.

[19] "Special Arrangement of the European Conference of Postal and Telecommunications Administrations (CEPT) relating to the use of the band 1452 - 1479.5 MHz for Terrestrial Digital Audio Broadcasting (T-DAB)", Final Acts of CEPT T-DAB Planning Meeting (4) Maastricht, 2002 (available from ERO web site).

[20] ITU Resolution 528 (WARC 92).

[21] Faller C. et. al.: "Technical Advances in Digital Audio Radio", Proc. IEEE August 2002, pp 1303-1333.

[22] Michalski Richard A.: "An Overview Of The XM Satellite Radio System", AIAA 2002.

[23] Briskman Robert D.: "DARS Satellite Constellation Performance", AIAA 2002.

[24] Briskman Robert D.: "Evolution of Satellite Digital Audio Radio Services", 23rd AIAA (ICSSC 2005), Rome September 2005.

3 Definitions and abbreviations

3.1 Definitions

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

channel: RF resource

NOTE: Inline with the terminology used for DVB.

channel coding: adding redundancy to cope with transmission errors

complementary terrestrial segment: the primary function of the Complementary Terrestrial Segment is the transmission or re-transmission of SDR content

NOTE: Additionally, it may also select, multiplex, modulate and transmit SDR content depending on the particular SDR system implementation.

Channel Transport Stream (C-TS): data stream (bit stream) representing the input to the modulator = data stream including all redundancy added by the FEC encoder

modulation: process of varying the characteristic of a carrier according to an information bearing signal

NOTE: The input are the data bits at the output of the FEC coding and multiplexing. The output are the signals transmitted of the air.

MPEG-TS: transport stream compliant to MPEG standard ISO/IEC 13818-1 [5]

program: collection of program elements

NOTE 1: A program element may be an audio video or data component.

NOTE 2: In line with the definition used for MPEG.

service: set of programs and related auxiliary information

spot: geographical area under beam coverage

Service Transport Stream (S-TS): generalized term for transport stream

NOTE: MPEG-TS is one example for a service transport stream.

terrestrial transmitter: functional part of the Complementary Terrestrial Segment

NOTE: Might also be described as terrestrial repeater or gap-filler.

time diversity: application of time delayed signal processing, incorporating the use of redundant bits or symbols

NOTE: Used to improve the robustness of the signal.

time interleaving: reordering bits or symbols without adding redundancy

NOTE: Used to improve the robustness of the signal to short term impairments, in conjunction with FEC coding.

Word Error Rate (WER) or Block Error Rate (BLER): ratio of blocks containing at least one error to number of transmitted blocks

NOTE: Word length may depend on system. In case of MPEG-TS the word length is 188 Bytes.

3.2 Abbreviations

For the purposes of the present document, the following abbreviations apply:

BER   Bit Error Rate
BLER   BLock Error Rate
BSS   Broadcasting Satellite Service
C-TS   Channel-transport stream
EER   Event Error Rate
FEC   Forward Error Correction
FFR   File Failure Rate
FSS   Fixed Satellite Service
GEO   Geostationary Earth Orbit
HEO   Highly Elliptical Orbit
MCS   Management and Control Segment
MPEG   Motion Picture Expert Group
Msym   Modulation symbols
OFDM   Orthogonal Frequency Division Multiplex
PER   Packet Error Rate
PHY   Physical layer
QoS   Quality of Service
RF   Radio Frequency
Sat   Satellite
SC   Service Component
SC   Service Component

NOTE: MPEG uses the term "Packetized Elementary Stream" (PES).

SCC   Satellite Control Centre
SC-TS   Service Component Transport Stream
S-DAB   Satellite-Digital Audio Broadcasting
SDR   Satellite Digital Radio
S-TS   Service-Transport Stream
TCR   Telemetry, Command and Ranging
T-DAB   Terrestrial-Digital Audio Broadcasting
Terr   Terrestrial
WER   Word Error Rate

NOTE: A modulation symbol may carry several bits. Beside symbols carrying data the signal may also include pilot symbols or preambles useful for synchronization and/or channel estimation.

xPSK   any Phase Shit Keying

4　Satellite Digital Radio (SDR) service - overview

4.1　Typical system architecture

A typical SDR system (see figure 4.1) is based on an architecture combining satellite broadcast and, where necessary, complementary terrestrial transmitters to ensure seamless reception for vehicles when satellite is not in line of sight, especially in urban zones.
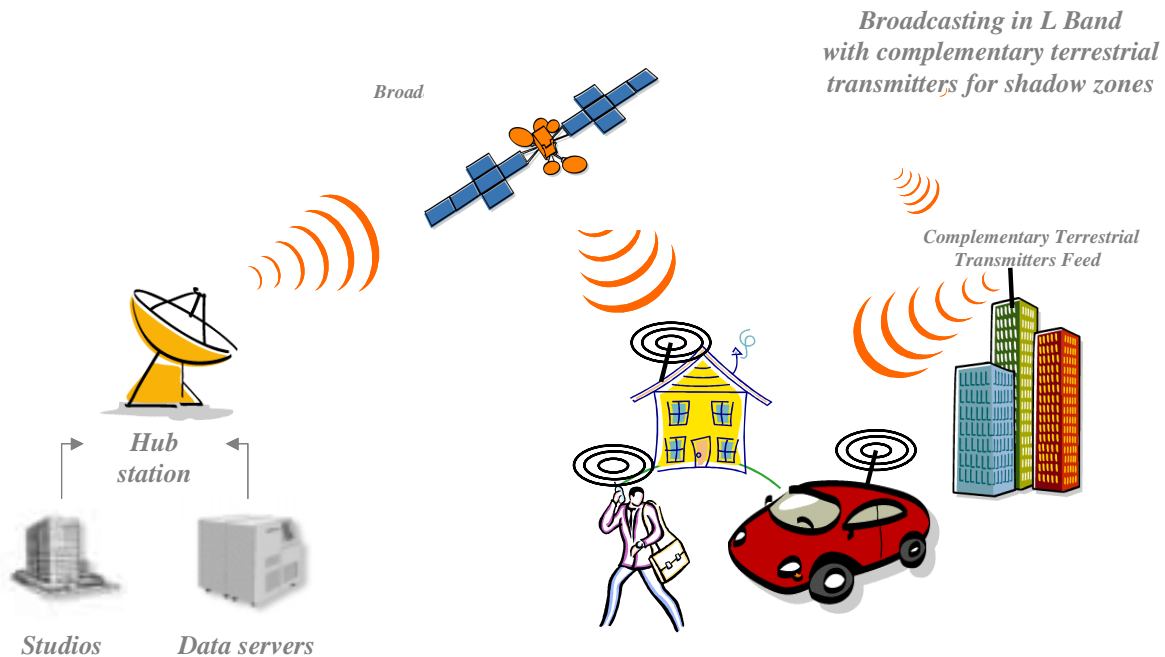
Figure 4.1: Typical SDR system architecture

The satellite signal would employ FEC and time diversity techniques, which enhance robustness of signal reception in mobile environment. This technique alleviates signal drop when obstacles are momentarily blocking line of sight to the satellite and allows providing consistent quality signals in shadowed areas not covered by terrestrial transmitters.

The radio and data programs provided by the content providers are gathered by one or more "hub stations" before being multiplexed and transmitted toward Radio Receivers through satellite.

The Complementary Terrestrial Segment receives and retransmits the satellite signal in urban areas. The signal received by this segment may be for example the satellite signal (e.g. around L-band), or a signal transmitted from a geostationary FSS satellite (e.g. in C or Ku band). Terrestrial transmission could use a different carrier frequency and modulation scheme than the satellite transmission.

4.2　Typical system performance

The performance objectives for SDR systems are to efficiently provide high quality and high availability digital radio and associated services for mobile reception.

The overall system performance is achieved using state of the art transmission schemes. If, as an example, one would take a transmission scheme similar to existing "SDR" systems in the USA, the architecture of a typical SDR system would include the following features:

- Satellite transmission using a TDM/nPSK waveform, with FEC (such as Turbo Coding) and time interleaving. This waveform provides the best satellite power efficiency, as it uses single carrier and nearly constant amplitude modulation. Coding rate FEC, together with time interleaving, are optimized in order to provide very high signal availability.

- Terrestrial transmission using OFDM waveform with nQAM modulation, with FEC Turbo coding and time interleaving. OFDM allows propagation in heavy urban environment (multipath impairment).

However, alternative solutions are possible and are considered in the present document.

Latest and ongoing advances in digital signal processing and content compression technology allow for high efficiency SDR systems. For example, MPEG 4 AAC+ codec delivering digital quality with 20 kbps to 24 kbps mono and 32 kbps to 48 kbps stereo.

4.3   Typical SDR Segments Overview

The SDR system is typically composed of the following segments shown on figure 4.2:

- Space Segment (Satellite(s), with associated Ground Control Segment).
- Management and Control Segment (MCS).
- Hub Segment.
- Complementary Terrestrial Segment.
- Radio Segment (receivers).
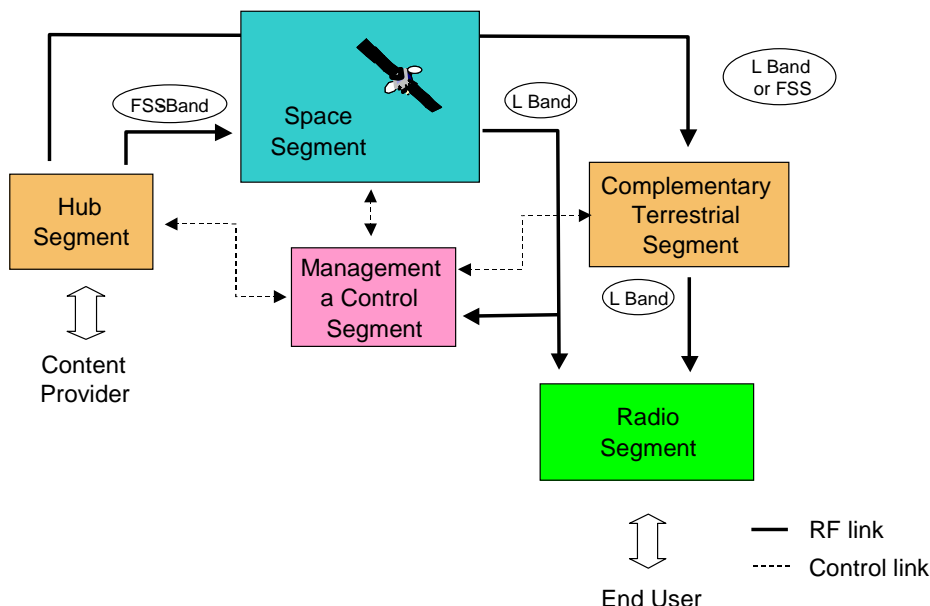
Figure 4.2: Typical SDR System Segments

4.3.1   Hub Segment

The Hub Segment includes one or more Hub Stations which will access the SDR satellites, and/or the FSS satellite feeding the complementary terrestrial transmitters (if any). It has the following main functions:

- Assembly and coding of the contents coming from the various content providers.
- Multiplex of the contents and modulation.
- Radio uplink to different satellites (FSS bands).
- Possible interconnection to terrestrial transmitters.
- When the SDR satellite includes only bent pipe transponders, the digital formatting of the satellite waveform is performed in the Hub Segment.

4.3.2   Space Segment

The Space Segment is used for providing wide area SDR broadcast services. It is composed of satellites, which may have any type of orbit - geostationary orbit (GEO) or highly elliptical orbit (HEO) for example.

Feed of the Complementary Terrestrial Segment can be done by the Space Segment.

The Space Segment also includes the Ground Control Segment for Satellite command and control. It consists of a Satellite Control Centre (SCC), plus redundant Telemetry, Command and Ranging (TCR) Stations.

Several satellite coverage architectures are envisaged depending on service area and throughput requirements. The examples below assume European coverage. Single beam coverage means there is a unique spot covering the entire Europe area. Multi-beam coverage means a satellite serves several spots, for instance 1 spot per linguistic area (7 multi-beam configuration) or 1 spot per regional area (extended multi-beam configuration).

Single Beam
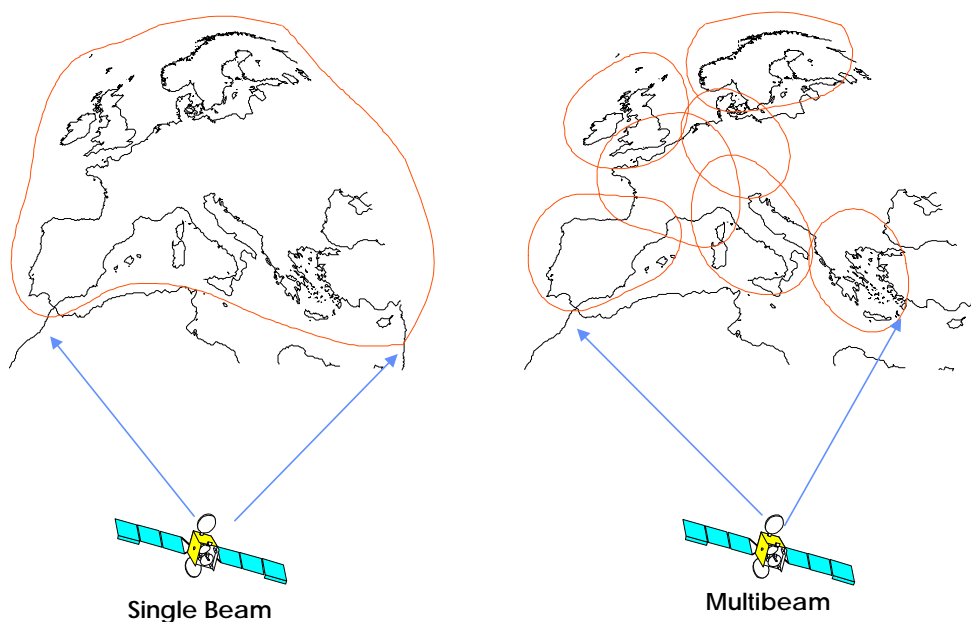
Multibeam

Figure 4.3: Single beam coverage and Multi-beam coverage

4.3.3   Management and Control Segment (MCS)

This segment performs the overall system management and controls. It has the following functions:

- Management of the other segments.

- Ground Network management.

- Broadcast Signal Monitoring.

- Resource Management.

- Subscriber's Access Keys Management.

4.3.4   Complementary Terrestrial Segment

The Complementary Terrestrial Segment is composed of Terrestrial Transmitters. There can be different networks in each country. Each network is managed by an entity interfaced with the MCS. The main function of terrestrial transmitters is the transmission or re-transmission of SDR content. It may also select, multiplex, modulate and transmit SDR content depending on the particular SDR system implementation.

4.3.5 Radio Segment

The satellite radio receiver typically has the following topology, shown on figure 4.4:

- An active antenna at e.g. L-band with low noise figure amplifier allows signal acquisition at very low signal level.

- The RF signal is down-converted through an RF tuner that may have two arms, one for the satellite component(s) and the other for the terrestrial component(s).

- After analogue to digital conversion, baseband signal processing performs all the physical layer functions (digital demodulation, bit and phase synchronization) and transport layer functions (FEC decoding, time de-interleaving, frame synchronization, combining of the satellite and terrestrial paths, etc.).

- Then, the contents are decoded, according to their type.

- The data components are passed through a data port for storage in a cache memory or forwarded to a higher level end application.

- The receiver also includes a Conditional Access processor for the control of subscription based services.
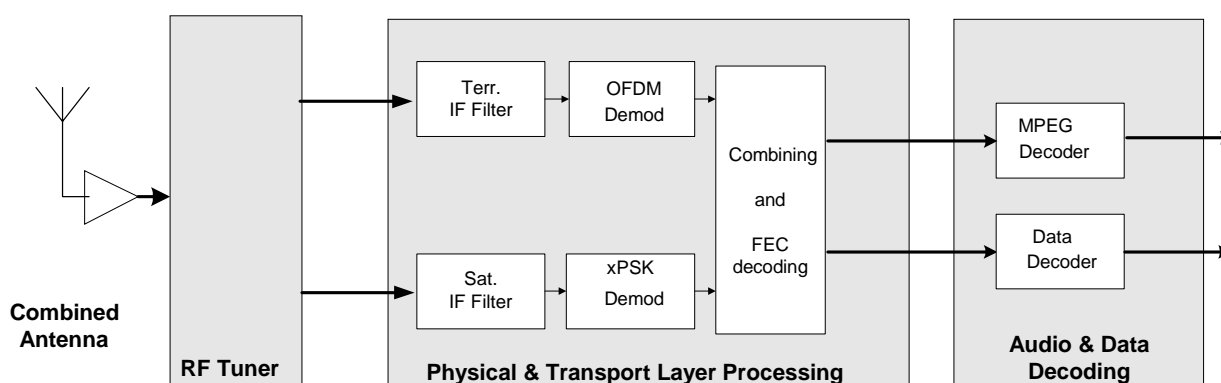
Figure 4.4: SDR Receiver Architecture (example)

5 Sdr functionalities

5.1 Services

5.1.1 Market

SDR systems will primarily provide radio broadcasting services to mobile terminals (e.g. car radios). It will also address fixed and portable wireless receivers. Wireless in-door reception of SDR services is also targeted, possibly in a seamless way with respect to the other modes of reception (mobile, or portable).

Two types of markets may be considered:

- Country/Language Markets, focusing a territory such as France, Italy, UK, Germany and Spain. These markets are similar to current Radio markets.

- Pan-European market, focusing on a set of several countries. Multilingual content may be considered in that case.

5.1.2   Broadcasting Services

Services to be provided by SDR systems are primarily broadcasting services. Multicasting, that is broadcasting to an identified set of terminals, is considered as a sub-set of Broadcasting Services.

Primarily, SDR systems will provide digital compressed audio contents. Enhanced Multimedia content, potentially associated with audio, will be possible for services such as weather and traffic information, news. Services may include text, image, video and data content.

As far as possible, existing and standardized coding schemes may be used.

5.1.3   Interactive Services

The SDR systems, considered as a broadcast layer, may have the capability to provide interactive services at application layer level. This is enabled by integration with point to point communication systems (e.g. GSM, GPRS, UMTS, or satellite). The system may then be able to have the adequate interface with these external systems.

It is not anticipated that the complementary terrestrial segment is used as a return channel in an interactive service.

5.1.4   Flexibility

The system will offer a wide range of content formats, and should be able to allocate system capacity based on each format's quality (audio fidelity for example) requirements, e.g. more capacity dedicated for music formats than for talk or variety formats, or allocation varying with time in a day. As an example, the system could have the flexibility to "divide" a high quality channel (i.e. music) into 2 or more lower quality channels (i.e. talk): this could be used for example for "international" programs addressing end users speaking different languages.

5.1.5   Business model

The system may be capable of supporting the following business models, depending on the content: free to air, subscription, or Pay Per Listen/View/Download. The service operator may select a combination of these models for the bouquet of services provided.

It may be possible to have several Service Operators sharing the system capacity.

5.1.6   Channel and Program Guides:

The capability to have a Channel Guide and a Program Guide may be possible.

5.1.7   Real-time and non-real-time services:

For all broadcast services a combination of near real-time and non-real-time programs may be possible. In particular, data storage capabilities linked to non real time applications will offer users the opportunity to "create" their own radio programs.

5.2   Quality of Service

5.2.1   Generalities

Services offered by SDR systems are of two types:

- Streaming services, providing a flow of continuous and synchronized media stream(s) to the end-user.

- File download services, for store-and-play type of applications.

For both services, the application's requirement on delays is expressed through the transfer delay and the access time attributes:

The transfer delay characterizes the time difference between the time when the information is fed from the source and the time when this information is made available to the user.

The access time is the time between the moment a service is selected by the user and the moment when it is available to the user.

The service availability is defined as the probability that at a specified set of locations and period of time the service can be received within a specified access time.

5.2.2   Streaming Applications

Streaming applications are similar to conventional broadcasting services. Streaming applications may have transmission delay constraints, if it is for example news or sport event. Generally, high service availability is required.

For streaming applications, objective criteria such as Word Error Rate (WER), Block Error Rate (BLER), Packet Error Rate (PER) or Event Error Rate (EER) are typically used.

For audio and video applications subjective quality may also be used.

5.2.3   File Applications

File applications may include:

- Internet-like radio, including a set of files downloaded in the receiver, and played at the listener convenience;

- Data download for non-specific radio applications (car maintenance, traffic info, weather forecast, security announcement, etc.);

- Two-way applications based on third parties (e.g. GSM/GPRS/UMTS) return link.

File applications may have several grades of transmission delay constraints, depending on the content criticality (e.g. high availability for Alert message, low availability for Juke box update).

For file based applications, criteria such as File Failure Rate (FFR) are typically used.

For some applications the FFR should be very low. In this case the conditions may be defined which has to be fulfilled that a guaranteed delivery (FFR= 0) is achieved.

5.2.4   Service availability

Because of the wide variety of services to be provided, it may be possible to define a service availability per type of service.

For in-door reception, several grades of reception conditions should be possible, ranging from somewhere and sometime, to anywhere and anytime, depending on extent of user cooperation and use of augmentation systems (example: micro repeater).

5.3   Capacity

The system capacity is based on a trade-off between spectrum availability, the market to be addressed, the system performance and regulatory considerations (e.g. competition issues).

Thus flexible capacity allocation may be possible.

Typically, capacity equivalent to 50 radio programs per Country/Language market should be made available to the end user per SDR system, subject to regulatory considerations.

Because of regulatory constraints and system architecture optimization, the terrestrial component of the signal may not necessarily be similar to the satellite content.

5.4 End users terminals

Terminals will be either externally power supplied (vehicles, or fixed home reception) or battery power supplied (portable device).

SDR system reception functionalities may be able to be embedded in other end user terminals, such as car radio, multimedia players, mobile phones.

User receivers may be able to have a storage capability for:

- Audio recording capability.

- Downloading of data for multimedia multicast applications such as traffic info, weather forecast, video applications.

The targeted price of the end user receiver may be compatible with mass market for electronic products.

5.5 Regulatory considerations

5.5.1 Broadcasting frequency resource

At ITU level, the 1452 MHz to 1492 MHz band is allocated on a co-primary basis to the Broadcasting Satellite Service (BSS) worldwide except for the USA, and through footnote RR 5.345, the use of this band is limited to digital audio broadcasting. The use of the above band by BSS systems is restricted to the 1467 MHz to 1492 MHz band pursuant to ITU Resolution 528.

In Europe, pursuant to the Maastricht Special Arrangement (2002), CEPT has planned the band 1 452 MHz to 1 479,5 MHz for T-DAB.

According to ECC Decision ECC/DEC/(03)02 [6], CEPT has designated the band 1 479,5 MHz to 1 492 MHz on a harmonized basis to S-DAB in Europe.

In principle, certain Mobile Satellite Service Space-to-Earth frequency allocations (around 1,5 GHz, or around 2,1 GHz) and Broadcasting Satellite Services frequency allocations around 700 MHz could also be used to accommodate SDR.

5.5.2 Satellite component frequency resource

The main candidate band is the 1479.5 MHz to 1492 MHz band.

Other candidate bands are 1518 MHz to 1525 MHz (available from April 1, 2007), 1 525 MHz to 1 559 MHz, 2 170 MHz to 2 200MHz, 2 483,5 MHz to 2 500 MHz, and 620 MHz to 790 MHz.

5.5.3 Terrestrial component frequency resource

The main candidate band is the 1 452 MHz to 1492 MHz band.

Other candidate bands are the 174 MHz to 230 MHz band, as well as satellite component frequency resource through appropriate reuse.

5.5.4 Satellite feeder link frequency resource

The satellite feeder link frequency band may be any existing satellite FSS frequency band.

5.5.5 Terrestrial transmitters spectrum mask

Complementary Terrestrial Segment transmitters operating within the 1 452 MHz to 1 479,5 MHz band associated with an L band satellite component may be able to meet the EN 300 401 [2] RF spectrum mask. If the Terrestrial segment carrier frequency is located below 1 479,5 MHz in the L band, the carrier should be able to use the spectrum slot center frequencies described in the T-DAB allotment plan adopted in 2002 in Maastricht by the CEPT planning conference.

5.5.6 Standardization issues

In application of the recommendation included in article 17 of the EU Framework Directive (2002/21) [7], several administrations require that digital signals, for the delivery of which they grant authorizations, be described in open standards.

5.5.7 Terrestrial Retransmission of Satellite Content

For some countries, the terrestrial retransmission will not necessarily be possible for the whole satellite content. In this case, there would be a need to control the content being retransmitted.

5.6 High Level System Functionalities

This clause defines the high level system functionalities needed to meet the service characteristics identified in clauses 5.1 and 5.2.

5.6.1 Satellite

The SDR system may include at least a satellite.

The satellite system may include several satellites, with any orbit (GEO, HEO, etc.). Selection and use of satellite orbits, together with associated frequencies, will be subject inter-alia to applicable ITU filling and coordination processes.

5.6.2 Terrestrial transmission

If needed by the system's required quality of service, Terrestrial Transmitters will be used.

For specific reception areas (such as wireless in-door reception), authorized type of transmission means may be used (such as WIFI).

5.6.3 Radio Spectrum

See clause 5.5.

5.6.4 Signal bandwidth and Capacity

From capacity considerations in clause 5.3, the bandwidth of the signals to be broadcast by SDR systems should be:

- For the satellite component:

    - Any subset of the available frequency band assigned to an SDR system.

- For the terrestrial component:

    - For frequency below 1 479,5 MHz, it should comply with requirement of clause 5.5.

Capacity allocation within that bandwidth will be compliant with the system capacity and flexibility defined in clause 5.3.

5.6.5 Service and content format and interface

Services will consist in the aggregation of several contents. This aggregation, together with the format of these contents, should be compatible with existing state of the art standards (such as MPEG 4). This will ease the integration of SDR systems and other systems, and simplify the interface.

5.6.6   Digital Right Management

SDR systems will also support Digital Right Management.

5.6.7   Encryption and Conditional Access

SDR systems will implement encryption and conditional access capability to cope with possible business models.

5.6.8   Layers

A layered approach should be defined, in order to ease the integration of SDR systems and other systems, and simplify the interface.

5.6.9   Quality of Service

The SDR systems may be able to cope with the various QoS level and grades defined in 5.2. This setting should be able to be set for each service, and to be changed with time.

The overall system Quality of Service involves all layers. Thus any feature improving the QoS at any layer will be considered (for example FEC at application layer level). The share of the processes in each layer improving QoS should be settable according to the type of service to be broadcasted.

5.7   System Reference Architecture

The SDR system reference architecture is presented in Figure 5.1. It only relates to the SDR specific processing of content at the Application Layer. Possible merger of this SDR processing within global processing of this content involving other platforms (DVB, 3GPP, etc.) is not included. That integration capability will be function of the selected interface to the SDR system.
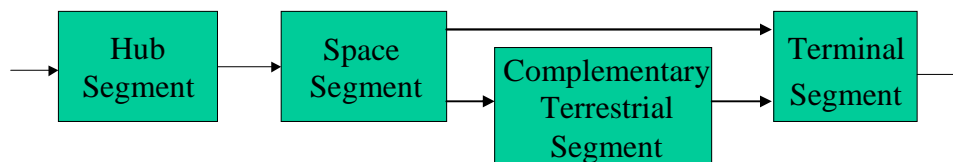
Figure 5.1: SDR system reference architecture

It consists of 4 Segments, described hereafter.

5.7.1   Hub Segment

The Hub Segment gathers all functionalities required to assemble content and to format them for provision to the Space and Complementary Terrestrial Segments. It may not be physically located in a single place.

The hub segment is composed of two parts:

- Components assigned to the SDR system operator.

- Functionality implemented by the content service provider.

5.7.2   Satellite Segment

The SDR system Space Segment is composed of one or more satellites with any type of orbit. Several satellites may be used in case of HEO orbits, or to provide spatial diversity, or enlarged system capacity, or redundancy.

5.7.3   Complementary Terrestrial Segment

SDR systems may require terrestrial transmitters to extend satellite reception to match QoS requirements, especially in urban areas and for in-door reception. The system may permit insertion of local content at the terrestrial level.

Thus, two types of Terrestrial Transmitters may be possible:

- Type A: No change of the multiplex content provided by the satellite signal.

- Type B: Change of the multiplex content provided by the satellite signal, with the possibility to remove or insert content locally.

Depending on the system concept, the Terrestrial Transmitters may use on-channel configuration.

5.7.4   Terminal Segment

The SDR Terminal Segment performs the reception of the various broadcast components and processes them in order to retrieve the basic content sent by the Hub Segment. In addition to the low layers processing, it will include adequate application layer decoders.

6   SDR REFERENCE ARCHITECTURE

6.1   Introduction

After careful analysis of applicable existing standards (3GPP/MBMS, DAB/T-DMB, DVB-H/S2, ITU-R Recommendation BO.1130-4 [4] system D_H and system E), it has been determined that none of them fulfil the functionalities listed above on satellite digital radio services and that a new standard is needed. Therefore, a new architecture allowing the introduction of new technologies has been conceived to meet these functionalities. This clause gives a description of a typical reference architecture of the SDR system. The architecture defines the scope of the layers, the general functionality of the related building blocks and the scope of the interfaces.

6.2   Functional Overview of the Broadcast Chain

Figure 6.1 and 6.2 give an overview of the building blocks of a generalized broadcast system. The block diagram defines the following layers

- Service layer:
  The service layer includes the generation and source encoding of the payload data. Different types of service components can be distinguished:

  - Main service components (e.g. audio signal, video signal, data stream or data file). A service component can be a stream or a file.

  - Program content (synchronized to the content) related auxiliary information. Examples are song title or advanced program guides. Two types of program guides are considered:

    - Common program guide for a set of programs.

    - Program guide for one program.

  - Other auxiliary information (e.g. static information like list of available programs).

  - Generalized data stream ("transparent data").

- Transport layer:
The transport layer converts the input data (service components) to transport streams. If necessary the transport layer generates also the side information required for de-multiplexing of the transport streams. One or several transport streams may be issued by the transport layer. Typically the FEC encoding is done at the lower layers. The transport layer may also include some FEC encoding. Examples are:

  - In case of file transmission some redundancy may be added at file level.

  - If the lower layer does not provide a link with very low BER or WER additional redundancy for error correction may be added.
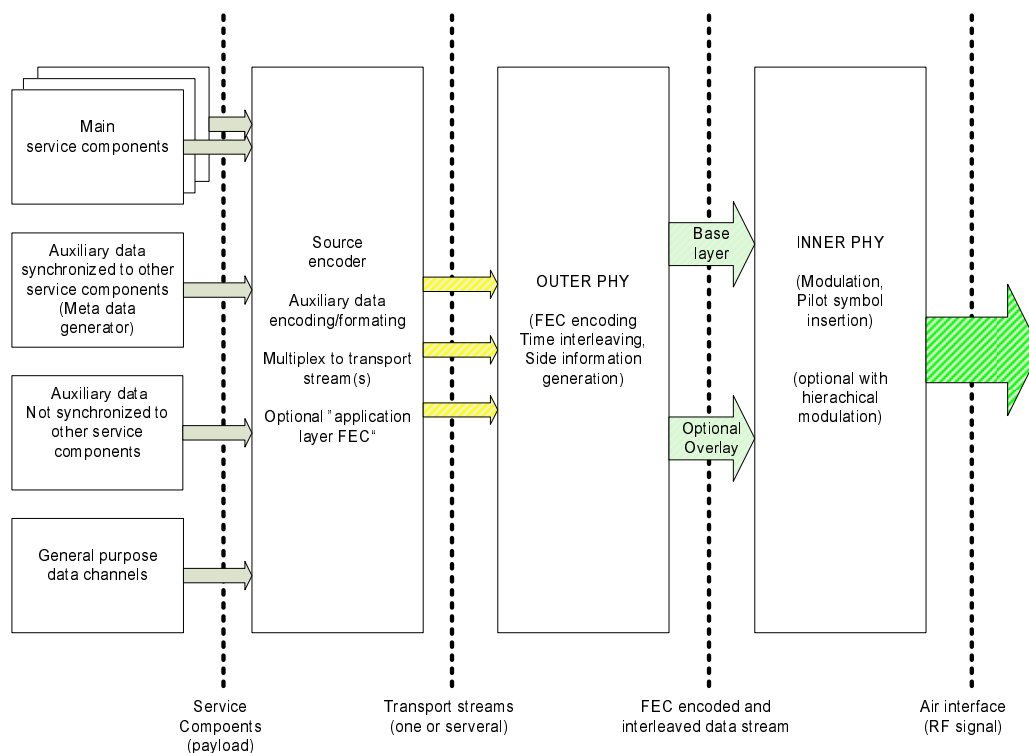
Figure 6.1: Functional overview of the transmit part (generalized block diagram)
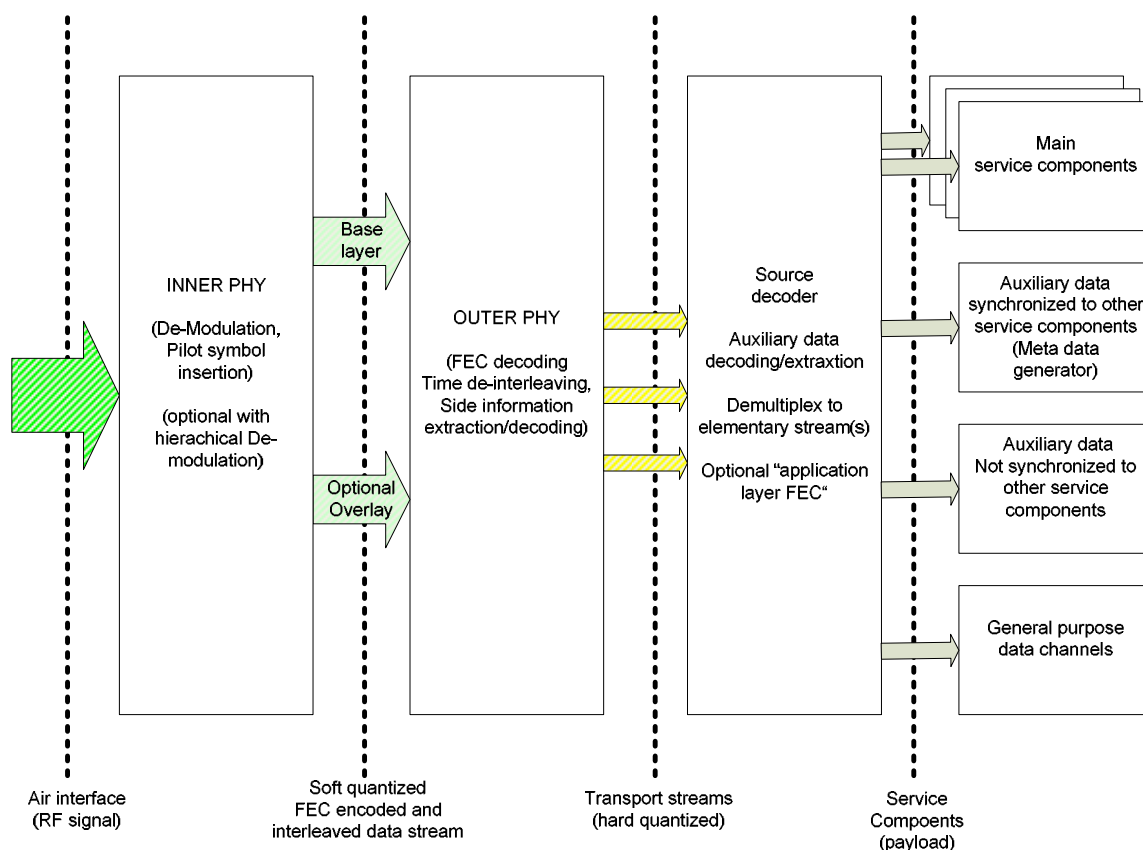
Figure 6.2: Functional overview of the receive part (generalized block diagram)

Building blocks related to the conditional access scheme are not shown in the block diagrams. Encryption can be done at different layers. The SDR system may support encryption at service component level (the input is already encrypted) or at transport stream. In this case the encryption module can be inserted between the service layer and the physical layers.

6.3   Layer Definition

Together with the definitions above the following layers and interfaces are proposed for the SDR standard.

Transmit Part   **Receive Part**

```
    Service Component Layer                      Service Component Layer
         (SC Layer)                                   (SC Layer)

             SC-TS                                        SC-TS

      Service Layer                                 Service Layer
      (Multiplex, etc.)                             (Multiplex, etc.)

             S-TS                                         S-TS

        OUTER-PHY                                     OUTER-PHY

             C-TS                                         C-TS

        INNER--PHY                                    INNER--PHY


        RF signal                                     RF Signal
```
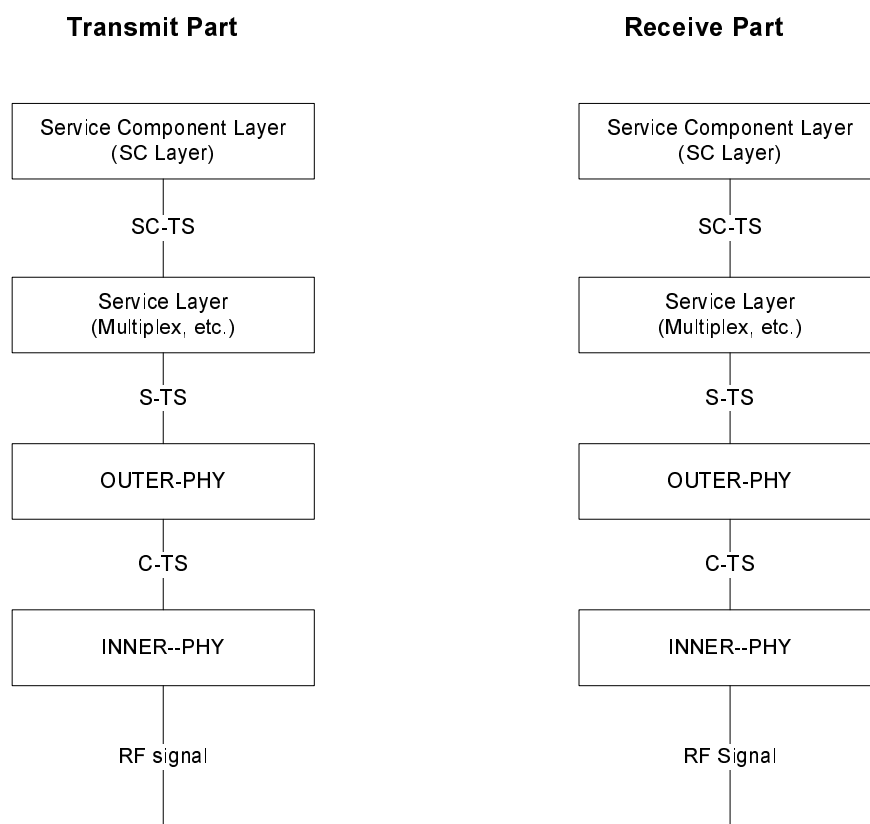
Figure 6.3: Layer definition proposed for SDR standard

6.4   Interface definitions

The SDR system can be basically split into two parts.

- The higher layers defining the aggregation of the content to a transport stream.

- The lower layers defining the transport mechanism of the satellite and the terrestrial transmitter.

It is assumed that especially for the higher layers many existing standards will be reused or adapted to the SDR functionalities. The interface between the higher layers and the lower layer should be a transport stream containing source encoded data (e.g. audio data encoded according to the MPEG4 standard) and related auxiliary information. The system should also include hooks for transparent data channels.

According to figure 6.3, the following interfaces should be referenced by the SDR standard.

S-TS: This is the interface between the higher layers and the transport related layers.

C-TS: This interface defines the content of the air-interface before modulation. At this point all redundancy for error correction has already been added. According to the initial SDR concept it may be worthwhile to use different modulations for the satellite and terrestrial signals. To also allow advanced diversity combining strategies between terrestrial and satellite signals it may be worthwhile to use a common concept at least up to this point.

RF-Signal: Defines the signals as transmitted from the antenna.

According to this definition the modulator converts a C-TS to a RF-Signal. The modulator may provide only one input for one C-TS. Optional configurations with hierarchical modulation may be useful. In this case the modulator should provide two inputs for two C-TS.

The SDR system may provide interfaces to other systems. The SDR standard should cover all layers. For some layers other standards may be included by reference. The layer concept is similar to the DVB standards. The channel adapter as defined by the DVB standards, for example EN 300 744 [1], covers the OUTER_PHY and INNER_PHY. One possible implementation of the S-TS interfaces may be MPEG2-System layer (part 1 of the MPEG2 standards, called MPEG-TS) based protocols.

6.5   Possible System Configurations

Based on the functionality previously defined, different configurations for a system can be considered.

Examples for possible configurations are:

- The satellite and terrestrial signals use the same air interface, the interface is identical for satellite and terrestrial (see figure 6.3);

- Different modulations are used for the satellite and terrestrial signals. The C-TS is identical. This implies that the content and the FEC parameters are identical (see figure 6.4);

- Different parameters are used for the FEC scheme and related time interleaver. The content (S-TS data) is identical for the satellite and terrestrial signals (see figure 6.5);

- In case of limited bandwidth for the terrestrial signal it may be useful to transmit only parts of the satellite content over the terrestrial signal or to replace parts of the satellite (global) content by local or regional content. In this case the S-TS data may be different for the satellite and terrestrial signals (see figure 6.6).
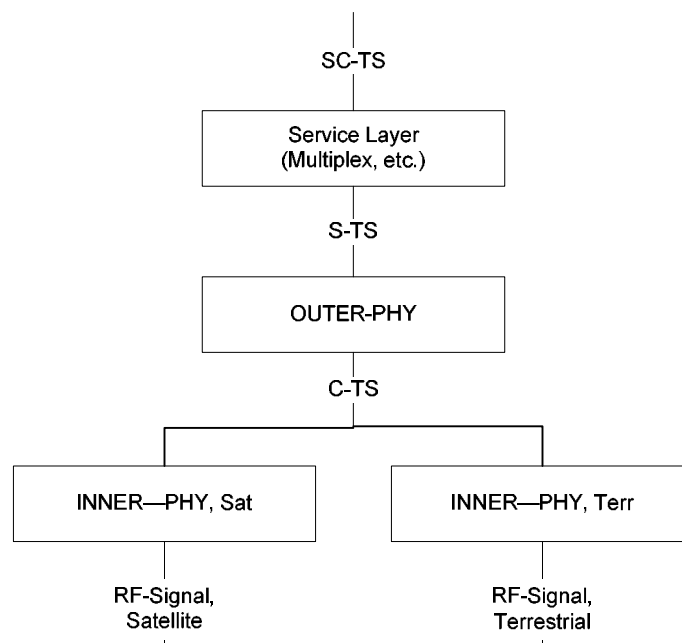
Figure 6.4: Configuration "Only modulation is different for satellite and terrestrial"
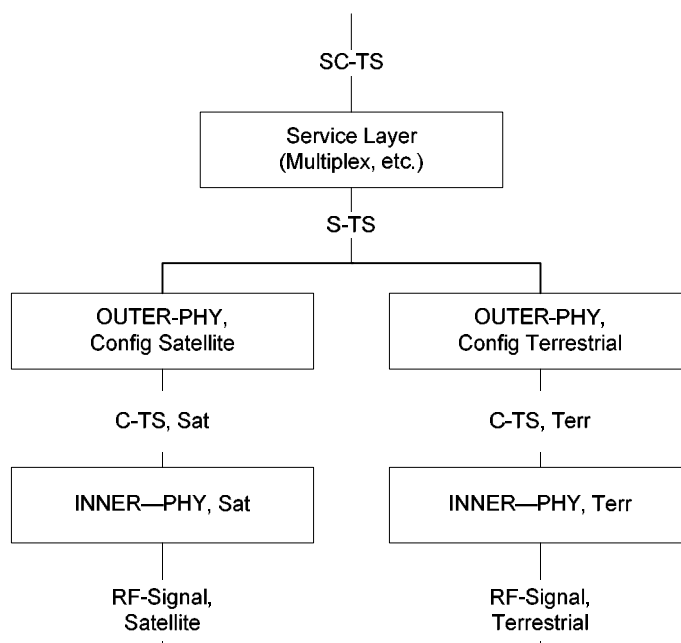
Figure 6.5: Configuration "Same content, but different FEC/Interleaver parameters are used for satellite and terrestrial
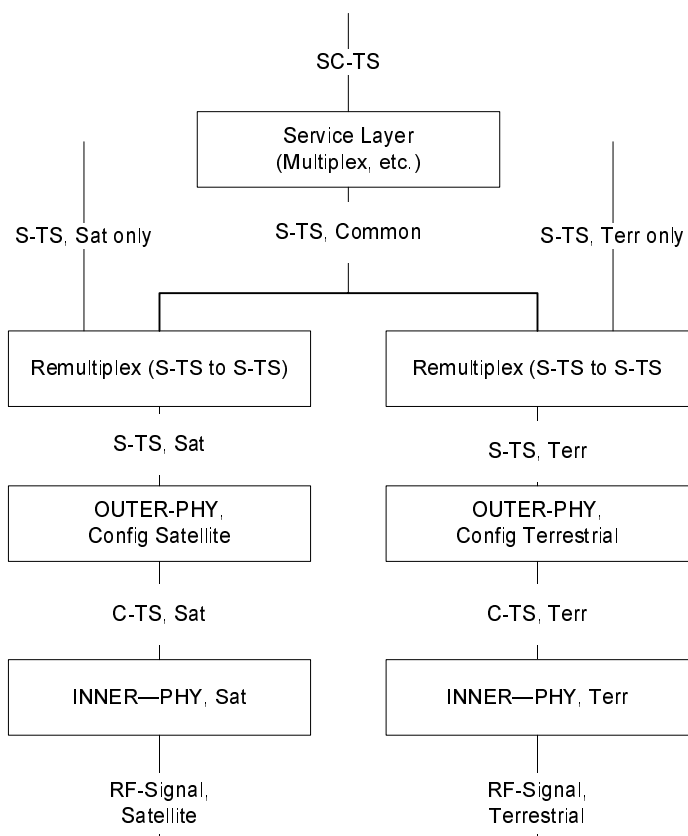
Figure 6.6: Configuration different content on satellite and terrestrial signal

6.6   Interfaces for Conditional Access

The layered structure allows encryption at different layers. The encryption/decryption module may be located between two layers and may use only one interface. The encryption module can use the SC-TS (as shown in figure 6.7) or S-TS interface (as shown in figure 6.8). It may be useful that the encryption system allows that free-to-air services and services with conditional access can be multiplexed to one transport stream.

Transmit Part   **Receive Part**

| Service Component Layer (SC Layer) | | Service Component Layer (SC Layer) |

Not encrypted SC data   Not encrypted SC data

| Encryption | | Decryption |

Encrypted SC data   Encrypted SC data

| Service Layer (Multiplex, etc.) | | Service Layer (Multiplex, etc.) |

S-TS   S-TS

| OUTER-PHY | | OUTER-PHY |

C-TS   C-TS

| INNER--PHY | | INNER--PHY |

RF signal   RF Signal

Figure 6.7: Encryption at SC-TS

Transmit Part   **Receive Part**

```
┌─────────────────────────┐        ┌─────────────────────────┐
│  Service Component Layer │        │  Service Component Layer │
│        (SC Layer)        │        │        (SC Layer)        │
└─────────────────────────┘        └─────────────────────────┘
              │                                  │
           SC data                            SC data
              │                                  │
┌─────────────────────────┐        ┌─────────────────────────┐
│      Service Layer       │        │      Service Layer       │
│     (Multiplex, etc.)    │        │     (Multiplex, etc.)    │
└─────────────────────────┘        └─────────────────────────┘
              │                                  │
     Not encrypted S-TS                 Not encrypted S-TS
              │                                  │
┌─────────────────────────┐        ┌─────────────────────────┐
│        Encryption        │        │        Decryption        │
└─────────────────────────┘        └─────────────────────────┘
              │                                  │
    (partly) encrypted S-TS             (partly) encrypted S-TS
              │                                  │
┌─────────────────────────┐        ┌─────────────────────────┐
│        OUTER-PHY         │        │        OUTER-PHY         │
└─────────────────────────┘        └─────────────────────────┘
              │                                  │
            C-TS                               C-TS
              │                                  │
┌─────────────────────────┐        ┌─────────────────────────┐
│        INNER--PHY        │        │        INNER--PHY        │
└─────────────────────────┘        └─────────────────────────┘
              │                                  │
          RF signal                         RF Signal
              └──────────────────────────────────┘
```
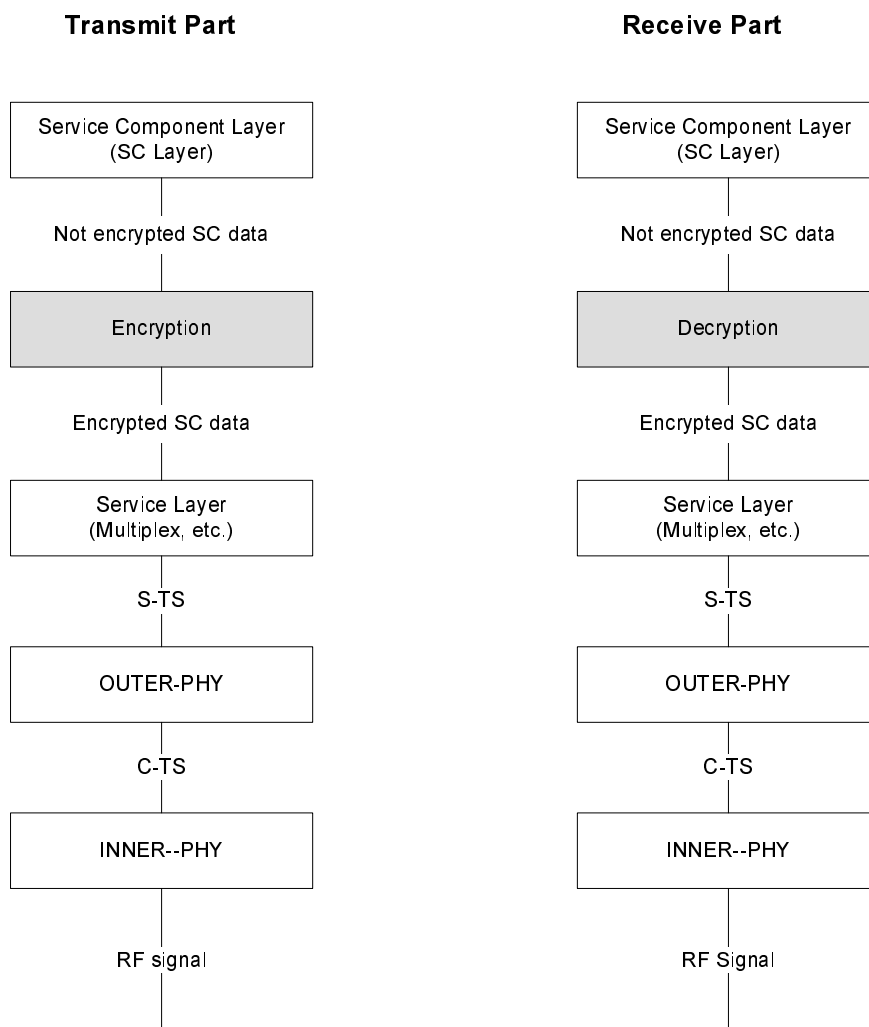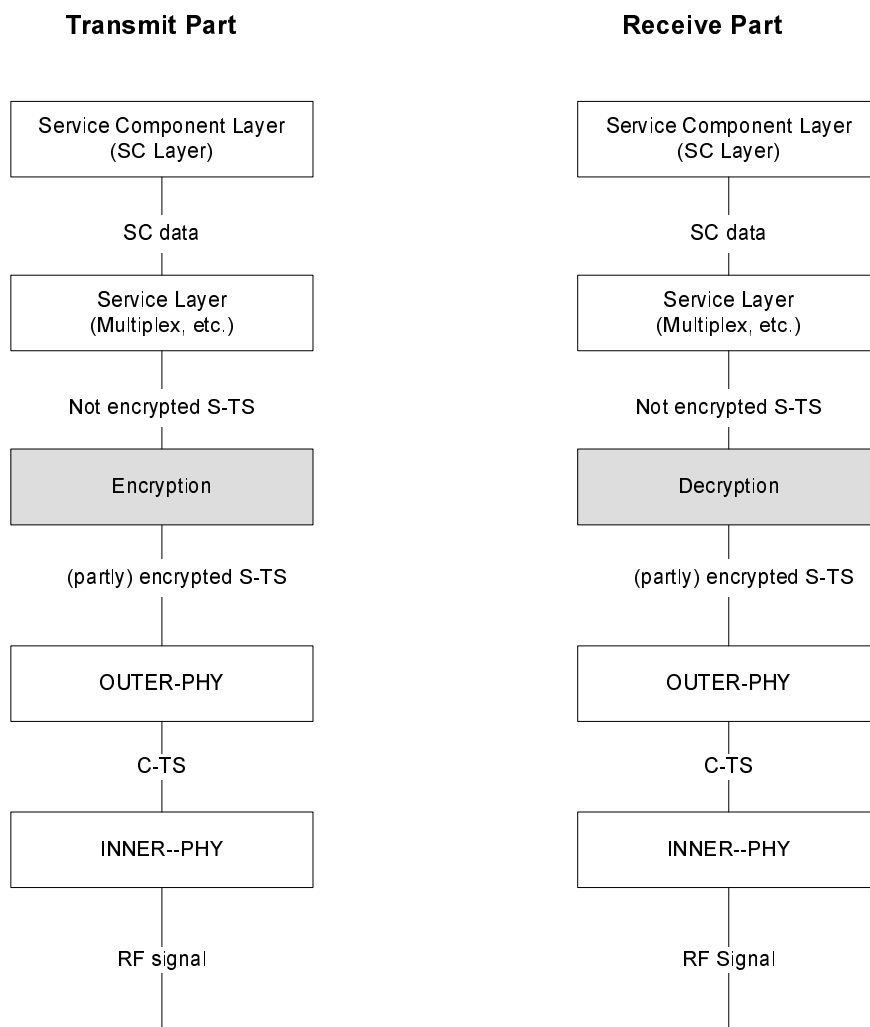
Figure 6.8: Encryption at S-TS level

7   Matrix of technologies for sdr functional layers and example implementation choices

This clause gives a description of SDR technologies which will be considered for each of the SDR Functional Layers consistent with the general SDR architecture and layers defined in clause 6. These technologies are based on inputs provided by various companies in response to the internal call for proposal within TC SES/SDR working group of September 2005 for candidate SDR technologies. This clause also provides some example implementation choices for various scenarios considered of practical interest to the development of SDR services in Europe.

In the following tables the Technical Choices are chosen to match known arrangements and are presented in tabular form but not in any priority order.

Where items are enclosed in parentheses ( ) they represent examples for such an element.

7.1   Matrix of available / proposed technologies for each functional layer

It should be noted that technology choices are related to a specific row, and are independent between rows.

Layer	Technology Choice 1	Technology Choice 2	Technology Choice 3	Technology Choice 4	Technology Choice 5
SC TS Interface	MPEG 4 Tool Box (e.g. HE-AAC)	IP datagram	MPEG /DVB (e.g. Associated data ((EPG))		
S-TS Interface	MPEG TS (e.g. DVB-MPE [3])	Packet Stream (e.g. IP Data Stream)	Continuous bit stream	EN 300 401 [2]	
OUTER-PHY	Encapsulation (e.g. Coating) Configurable bit rate Turbo code, variable coding rate, low CR capability (e.g. 3GPP2) Time interleaving, variable length Multiplexing Time diversity, tunable Time slicing capability Spatial diversity capability Multi C-TS capability for Diversity	Encapsulation (e.g. Coating) Configurable bit rate LDPC code, variable coding rate Time interleaving, variable length Multiplexing Time diversity, tunable Time slicing capability Spatial diversity capability Multi C-TS capability for Diversity			
INNER-PHY	n-PSK Configurable symbol rate Configurable bandwidth (e.g. 0,5 MHz multiple)	QPSK 1,84 Msps, Framing compatible with ITU-R Recommendation BO.1130-4 [4] system Ds	Wide band OFDM QPSK, 16QAM (e.g. derivative from existing OFDM waveform) Hierarchical modulation capability Configurable symbol rate (e.g. 0,5 MHz multiple)	Segmented OFDM QPSK, 16QAM (e.g. derivative from existing OFDM waveform) Hierarchical modulation capability Configurable symbol rate Configurable bandwidth (e.g. 0,2 MHz multiple)	OFDM QPSK, n-PSK, 16QAM (e.g. derivative from existing OFDM waveform) Hierarchical modulation capability Configurable symbol rate Configurable bandwidth Coherent or Differential

7.2 Possible SDR System Implementations Paths

The following table provides some possible implementations, using the Technology Choices (TC) defined in clause 7.1.

Layer	GEO A	GEO B	GEO C	HEO A	HEO B
SC TS Interface	TC 1	TC 1/TC 2	TC 1	TC 1	TC 1 / TC 3
S-TS Interface	TC 3	TC 1 /TC 2	TC 2 /TC 3	TC 1/TC 3	TC 1/TC 2
OUTER-PHY	TC 1	TC 1	TC 1 / TC 2	TC 1 / TC 2	TC 1 / TC 2
INNER-PHY	Sat: TC 1/2 Terr: TC3	Sat : TC 1 / TC 3 Terr : TC 3	Sat+Terr: TC 4	Sat: TC 1 / TC 3-4 Terr: TC3	Sat: TC 1 Terr: TC 5

8 Conclusion

A review of Satellite Digital Radio (SDR) systems has been conducted and the inputs received from a first call for proposals for candidate SDR systems analysed and the results included in the present document.

The analysis covered the functionalities, reference architectures and technologies for SDR systems. In particular, the radio interface of SDR broadcast receivers was addressed.

Thus, the present document has been produced by the ETSI Technical Committee Satellite Earth stations and Systems (TC SES) based upon known implementations and concepts for SDR which provide a solid platform to facilitate the creation of appropriate standards and specifications in the field of SDR systems.

History

Document history		
V1.1.1	September 2006	Publication