RECOMMENDATION ITU-R F.750-3*

ARCHITECTURES AND FUNCTIONAL ASPECTS OF RADIO-RELAY SYSTEMS FOR SYNCHRONOUS DIGITAL HIERARCHY (SDH)-BASED NETWORKS

(Question ITU-R 160/9)

(1992-1994-1995-1997)

The ITU Radiocommunication Assembly,

considering

a) that ITU-T Recommendations G.707, G.708 and G.709 specify the bit rates, the multiplexing structure and the detailed mappings associated with the synchronous digital hierarchy (SDH);

b) that ITU-T Recommendations G.781, G.782 and G.783 specify the general characteristics and functions of synchronous multiplexing equipment and ITU-T Recommendation G.784 specifies the management of SDH equipment and networks;

c) that ITU-T Recommendations G.703 and G.957 specify the physical parameters of the electrical and optical interfaces of SDH equipment;

d) that ITU-T Recommendations G.803 and G.831 specify the architectures and management capabilities of transport networks based on the SDH;

e) that among the family of SDH equipment there will be synchronous radio-relay systems (SDH-DRRs);

f) that there is a need to ensure a complete operational integration of the SDH-DRRs in a synchronous network;

g) that Recommendation ITU-R F.751 specifies transmission characteristics and performance requirements of SDH digital radio-relay systems,

recommends

1 that digital radio-relay systems for the synchronous digital hierarchy comply with the requirements described in Annex 1.

ANNEX 1

Contents

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* This Recommendation should be brought to the attention of Radiocommunication Study Group 4 (Working Party 4B) and Telecommunication Standardization Study Groups 13 and 15.

1 Introduction

1.1 Scope

This Annex defines the architectures and functional aspects of the SDH-DRRS aiming at their complete operational integration in a SDH-based network.

The architectures are defined in terms of functional blocks without any constraint on physical implementation.

1.2 Abbreviations

ADM	Add/drop multiplexer
ATM	Asynchronous transfer mode
ATPC	Automatic transmitter power control
AU	Administrative unit
AUG	Administrative unit group
BIP	Bit interleaved parity
C	Container
DCC	Data communication channel
DRRS	Digital radio-relay system
DXC	Digital cross-connect
ECC	Embedded communication channel
FEC	Forward error correction
EW	Early warning
FOTS	Fibre optics transmission system
HO	Higher order path
HOVC	Higher order virtual container

HPA	Higher order path adaptation
HPC	Higher order path connection
HPT	Higher order path termination
IOS	Intra-office section
IOST	Intra-office section termination
ISI	Intra-system interface
LOF	Loss of frame
LOP	Loss of pointer
LOS	Loss of signal
LOVC	Lower order virtual container
LPA	Lower order path adaptation
LPC	Lower order path connection
LPT	Lower order path termination
MAF	Management application function
MCF	Message communications function
MS	Multiplex section
MSA	Multiplex section adaptation
MSOH	Multiplex section overhead
MSP	Multiplex section protection
MST	Multiplex section termination
MUX	Multiplexer
NE	Network element
NEF	Network element function
NNI	Network node interface
OAM	Operation, administration and maintenance
OH	Overhead
OHA	Overhead access
OLI	Optical line interface
OLT	Optical line termination
OR	Optical repeater
OSF/MF	Operation system function/Mediation function
PDH	Plesiochronous digital hierarchy
POH	Path overhead
PPI	Plesiochronous physical interface
RCSOH	Radio complementary section overhead
RF	Radio frequency
RFCOH	Radio frame complementary overhead
ROHA	Radio overhead access
RPI	Radio physical interface (generic)
RPPI	Radio plesiochronous physical interface
RPS	Radio protection switching
RR-EI	Radio-relay equipment interface

RR-MSA	Multiplex section adaptation for sub-STM-1 radio-relay
RR-MST	Multiplex section termination for sub-STM-1 radio-relay
RRR	Radio-relay regenerator
RR-RP	Radio-relay reference point for sub-STM-1 radio-relay
RR-RSPI	Radio sub-STM-1 synchronous physical interface
RR-RST	Regenerator section termination for sub-STM-1 radio-relay
RR-SPI	Synchronous physical interface for sub-STM-1 radio-relay
RR-STM	Synchronous transport module for sub-STM-1 radio-relay (STM-0 as defined by ITU-T Recommendation G.861)
RRT	Radio-relay terminal
RS	Regenerator section
RSOH	Regenerator section overhead
RSPI	Radio synchronous physical interface
RST	Regenerator section termination
SDH	Synchronous digital hierarchy
SEMF	Synchronous equipment management function
SETPI	Synchronous equipment timing interface
SETS	Synchronous equipment timing source
SMN	Synchronous management network
SMS	SDH management sub-network
SOH	Section overhead
SPI	SDH physical interface
STM-*N*	Synchronous transport module of order *N*
TMN	Telecommunications management network
T, T′	Baseband access points
TU	Tributary unit
TUG	Tributary unit group
VC	Virtual container

1.3 Definitions

The following definitions are relevant in the context of SDH-related Recommendations.

Add/drop multiplexer (ADM)

These are Type III multiplexers as defined in ITU-T Recommendation G.782.

They provide the ability to access any of the constituent signals within a STM-*N* signal without demultiplexing and terminating the complete signal. The interface provided for the accessed signal could be either according to ITU-T Recommendation G.703 or an STM-*m* ($m < n$).

Asynchronous transfer mode (ATM)

See ITU-T Recommendations I.150, I.311, I.321 and I.327.

Administrative unit (AU)

An AU is the information structure which provides adaptation between the higher order path layer and the multiplex section layer (see ITU-T Recommendation G.708 for details).

Administrative unit group (AUG)

An AUG consists of a homogeneous, byte interleaved assembly of AU-3s or AU-4s.

Bit interleaved parity (BIP)

BIP-X is a code defined as a method of error monitoring (see ITU-T Recommendation G.708 for details).

Container (C)

A container is the information structure which forms the network synchronous information payload for a VC (see ITU-T Recommendation G.708 for details).

Data communication channel (DCC)

See ITU-T Recommendation G.782.

Digital cross-connect (DXC)

See ITU-T Recommendation G.782.

Embedded communication channel (ECC)

See ITU-T Recommendation G.782.

Higher order path (HO)

In a SDH network, the higher order path layers provide a server network from the lower order path layers (see ITU-T Recommendations G.782 and G.783).

Higher order virtual container (HOVC): VC-n (n = 3,4)

This element comprises either a single C-n (n = 3,4) or an assembly of TUGs (TUG-2s or TUG-3s), together with the VC POH appropriate to that level.

Higher order path adaptation (HPA)

The HPA function adapts a lower order VC (VC-1/2/3) to a higher order VC (VC-3/4) by processing the TU pointer which indicates the phase of the VC-1/2/3 POH relative to the VC-3/4 POH and assembling/disassembling the complete VC-3/4 (see ITU-T Recommendation G.783).

Higher order path connection (HPC)

The HPC function provides for flexible assignment of higher order VCs (VC-3/4) within an STM-N signal (see ITU-T Recommendation G.783).

Higher order path termination (HPT)

The HPT function terminates a higher order path by generating and adding the appropriate VC POH to the relevant container at the path source and removing the VC POH and reading it at the path sink (see ITU-T Recommendation G.783).

Hitless switch

A switch event between a working and a protection channel which does not add any errors to those already produced by the propagation medium during the switching procedure.

Inter-office section

See ITU-T Recommendation G.958.

Intra-office section (IOS)

See ITU-T Recommendations G.957 and G.958 and § 3.1.

Intra-office section termination (IOST)

See ITU-T Recommendation G.958 and § 3.1.

Intra-system interface (ISI)

Interface with reduced SOH functionality. See ITU-T Recommendation G.708.

Lower order virtual container (LOVC): VC-*n* (*n* = 1, 2)

This element comprises a single C-*n* (*n* = 1, 2) plus the lower order VC POH appropriate to that level.

Lower order path adaptation (LPA)

The LPA function adapts a PDH signal to an SDH network by mapping/de-mapping the signal into/out of a synchronous container. If the signal is asynchronous, the mapping process will include bit level justification.

Lower order path connection (LPC)

The LPC function provides for flexible assignment of lower order VCs in a higher order VC.

Lower order path termination (LPT)

The LPT function terminates a lower order path by generating and adding the appropriate VC POH to the relevant container at the path source and removing the VC POH and reading it at the path sink.

Management application function (MAF)

This is the origination and termination of TMN messages. See ITU-T Recommendation G.784.

Message communications function (MCF)

See ITU-T Recommendations G.782 and G.783.

Multiplex section adaptation (MSA)

The MSA function processes the AU-3/4 pointer to indicate the phase of the VC-3/4 POH relative to the STM-*N* SOH and byte multiplexes the AU groups to construct the complete STM-*N* frame (see ITU-T Recommendation G.783).

Multiplex section overhead (MSOH)

MSOH comprises rows 5 to 9 of the SOH of the STM-*N* signal.

Multiplex section protection (MSP)

The MSP function provides the capability of branching the signal onto another line system for protection purposes (see ITU-T Recommendations G.782 and G.783).

Multiplex section termination (MST)

The MST function generates and adds rows 5 to 9 of the SOH (see ITU-T Recommendation G.783).

Network element (NE)

This is an element of the SMS. See ITU-T Recommendation G.784.

Network element function (NEF)

See ITU-T Recommendation G.784.

Network node interface (NNI)

See ITU-T Recommendation G.708 and § 2.3.

Operation, administration and maintenance (OAM)

See ITU-T Recommendation G.784.

Overhead access (OHA)

The OHA function gives external interfaces to standardized SOH signals (see ITU-T Recommendation G.783).

Optical line interface (OLI)

See ITU-T Recommendation G.957.

Optical line termination (OLT)

See ITU-T Recommendation G.958.

Operation system function/Mediation function (OSF/MF)

See ITU-T Recommendation G.784.

Path overhead (POH)

The VC POH provides for integrity of communication between the points of assembly of a VC and its point of disassembly.

Plesiochronous digital hierarchy (PDH)

See ITU-T Recommendations G.702 and G.703.

Radio complementary section overhead (RCSOH)

The transmission, in sub-STM-1 DRRS, as a well identified case of RFCOH, of a capacity equivalent to the six missed columns of a full STM-1 SOH format (see § 6.6 and 6.7 and Recommendation ITU-R F.751).

Radio frame complementary overhead (RFCOH)

The transmission capacity contained in the radio frame (see § 4.4 and 6.7 and Recommendation ITU-R F.751).

Radio overhead access (ROHA)

The ROHA function gives external interfaces to radio specific SOH or RFCOH signals and gives suitable handling for the radio specific internal communication channels (see § 3.3.3 and 7.2.3).

Radio physical interface (RPI)

Generic terminology for the typical radio-relay functions, including modulator, demodulator, transmitter, receiver, possible radio-framer, etc. (see § 6.4).

Radio plesiochronous physical interface (RPPI)

A common description for the typical plesiochronous radio-relay functions, including modulator, demodulator, transmitter, receiver, possible radio-framer, etc. (see § 6.4).

Radio protection switching (RPS)

See § 3.4.

Radio-relay equipment interface (RR-EI) for sub-STM-1 radio-relay

See Appendix 1.

Multiplex section adaptation for sub-STM-1 radio-relay (RR-MSA)

See § 6.4.

Multiplex section termination for sub-STM-1 radio-relay (RR-MST)

See § 6.

Radio-relay physical interface (RR-SPI) for sub-STM-1 radio-relay

See § 6.5.

Radio-relay regenerator (RRR)

See § 3.1 and 3.4.

Radio-relay reference point for sub-STM-1 radio-relay (RR-RP)

See § 6.2.

Radio-relay terminal (RRT)

See § 3.1 and 3.4.

Regenerator section (RS)

A regenerator section is part of a line system between two regenerator section terminations.

Regenerator section overhead (RSOH)

The RSOH comprises rows 1 to 3 of the SOH of the STM-*N* signal.

Radio synchronous physical interface (RSPI)

A common description for the typical synchronous radio-relay functions, including modulator, demodulator, transmitter, receiver, possible radio-framer, etc. (see § 6.4).

Radio sub-STM-1 synchronous physical interface (RR-RSPI)

A common description for the typical sub-STM-1 synchronous radio-relay functions, including modulator, demodulator, transmitter, receiver, possible radio-framer, etc. (see § 6).

Regenerator section termination (RST)

The RST function generates and adds rows 1 to 3 of the SOH; the STM-*N* signal is then scrambled except for row 1 of the SOH (see ITU-T Recommendation G.783).

Regenerator section termination for sub-STM-1 radio-relay (RR-RST)

See § 6.4.

Synchronous equipment timing physical interface (SETPI)

The SETPI function provides the interface between an external synchronization signal and the multiplex timing source (see ITU-T Recommendations G.783 and G.813).

Synchronous equipment timing source (SETS)

The SETS function provides timing reference to the relevant component parts of multiplexing equipment and represents the SDH network element clock (see ITU-T Recommendation G.783).

Section overhead (SOH)

SOH information is added to the information payload to create an STM-*N*. It includes block framing information and information for maintenance, performance monitoring and other operational functions.

SDH physical interface (SPI)

The SPI function converts an internal logic level STM-*N* signal into an STM-*N* line interface signal (see ITU-T Recommendation G.783).

Synchronous equipment management function (SEMF)

The SEMF converts performance data and implementation specific hardware alarms into object-oriented messages for transmission over DCCs and/or a Q interface (see ITU-T Recommendations G.782 and G.783).

Synchronous digital hierarchy management network (SMN)

This is a subset of the TMN. See ITU-T Recommendation G.784.

Synchronous digital hierarchy management subnetwork (SMS)

This is a subset of the SMN. See ITU-T Recommendation G.784.

Synchronous transport module (STM)

A STM is the information structure used to support section layer connections in SDH. See ITU-T Recommendation G.708 for more details.

Synchronous transport module for sub-STM-1 radio-relay (RR-STM)

Medium capacity synchronous transport module defined as STM-0 by ITU-R Recommendation G.861. See § 6.2.

Telecommunications management network (TMN)

The purpose of a TMN is to support administrations in the management of their telecommunications network. See ITU-T Recommendation M.30 for details.

Tributary unit (TU)

A TU is an information structure which provides adaptation between the lower-order path layer and higher-order path layer. See ITU-T Recommendation G.708 for details.

Tributary unit group (TUG)

One or more TUs, occupying fixed, defined positions in a higher-order VC payload is termed as a tributary unit group.

T, T′

Access points of telecommunications equipment as defined in Recommendation ITU-R F.596.

Virtual container (VC)

A VC is the information structure used to support path layer connections in the SDH. See ITU-T Recommendation G.708 for details.

Type I/IA multiplexer:

– ***Type I*** (see ITU-T Recommendation G.782)

  This provides a simple G.703 to STM-*N* multiplex function. For example, $63 \times 2\,048$ kbit/s signals could be multiplexed to form an STM-1 output or, $12 \times 44\,736$ kbit/s signals could be multiplexed to form an STM-4. The location of each of the tributary signals in the aggregate signal is fixed and dependent on the multiplex structure chosen.

– ***Type IA*** (see ITU-T Recommendation G.782)

  The ability to provide flexible assignment of an input to any position in the STM-*N* frame can be provided by including a VC-1/2 and/or VC-3/4 path connection function.

2 Features and layering of the SDH-based networks

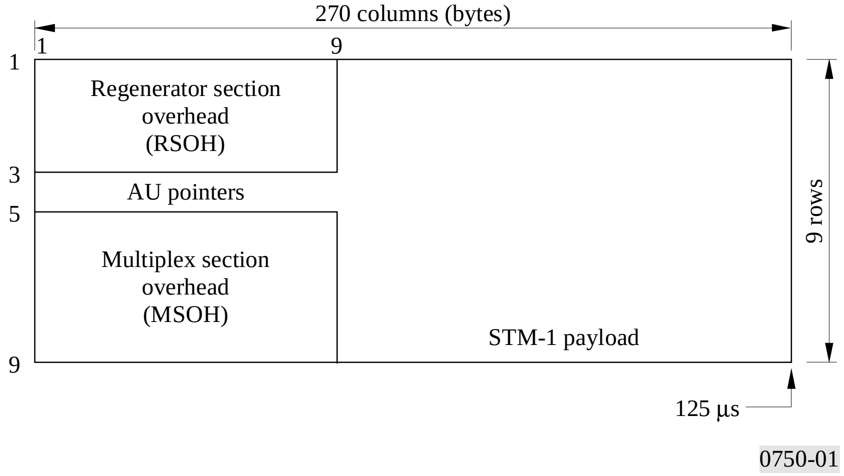
2.1 SDH description

The synchronous digital hierarchy (SDH) is described in ITU-T Recommendations G.707 (Synchronous Digital Hierarchy Bit Rates), G.708 (Network node interface for the synchronous digital hierarchy), and G.709 (Synchronous multiplexing structure). These Recommendations embrace a new multiplexing method and frame structure which result in a basic rate of 155 520 kbit/s, known as STM-1. The next higher level bit rates are 622 080 kbit/s or STM-4, 2 488 320 kbit/s or STM-16 and 9 953 280 kbit/s or STM-64.

The frame structure of the STM-1 provides a payload area and a section overhead (SOH) as shown in Fig. 1. The multiplexing method is such that a variety of signals may be combined to form the payload by building up tributaries into packages within the STM frame. The section overhead is divided into a number of bytes of RSOH and MSOH for transmission media management and network operator functions.

FIGURE 1

STM-1 frame structure



Details of the SOH are given in § 4. The higher order signals (STM-*N*) are formed by byte interleaving lower order STM-1 signals (see ITU-T Recommendation G.708).

2.2 SDH layering

2.2.1 Layering

One of the basic principles which is described in ITU-T Recommendation G.803 is the concept of layering of transport networks.

Figure 2 describes the layer model of the transport network. Features of the layered model are as follows:

– a circuit layer network, a path layer network and a transmission media layer network;

– the relationship between any adjacent two layers is a server/client relationship;

– each layer has its own OAM capability;

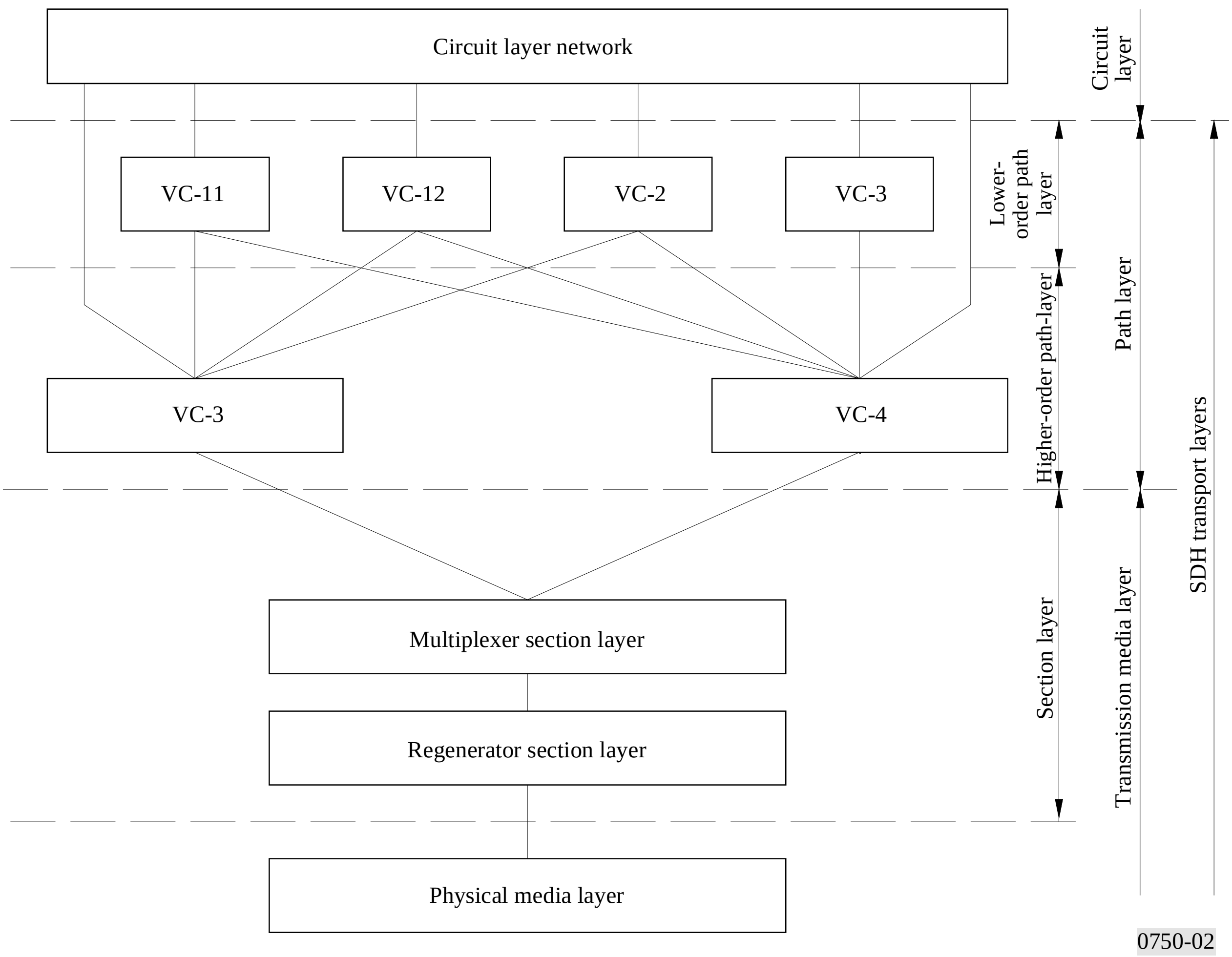
– a circuit layer network provides telecommunications services to users. The circuit layer network is independent of the path layer network;

– a path layer network is commonly used by the circuit layer networks for different services. The path layer network is independent of the transmission media layer network;

– a transmission media layer network is dependent on the transmission medium such as optical fibre and radio. The transmission media layer is divided into a section layer and a physical media layer. A section layer can be further divided into a multiplex section layer and a regenerator section layer.

FIGURE 2

SDH-based transport network layered model



2.2.2 Layering and the SDH frame structure

The SDH frame structure implies an organization of the network in logical layers, namely path and section layers.

The path layer consists of:

– the lower-order VC layer (LOVC) based on the tributary unit,

– the higher-order VC layer (HOVC) based on the administrative unit.

The section layer consists of:

– the multiplexer section layer (MS), and

– the regenerator section layer (RS).

The RS is media dependent, the MS may be media dependent with a restricted point-to-point topology, while the LOVC and HOVC are designed to be media independent with a wide, complex meshed topology.

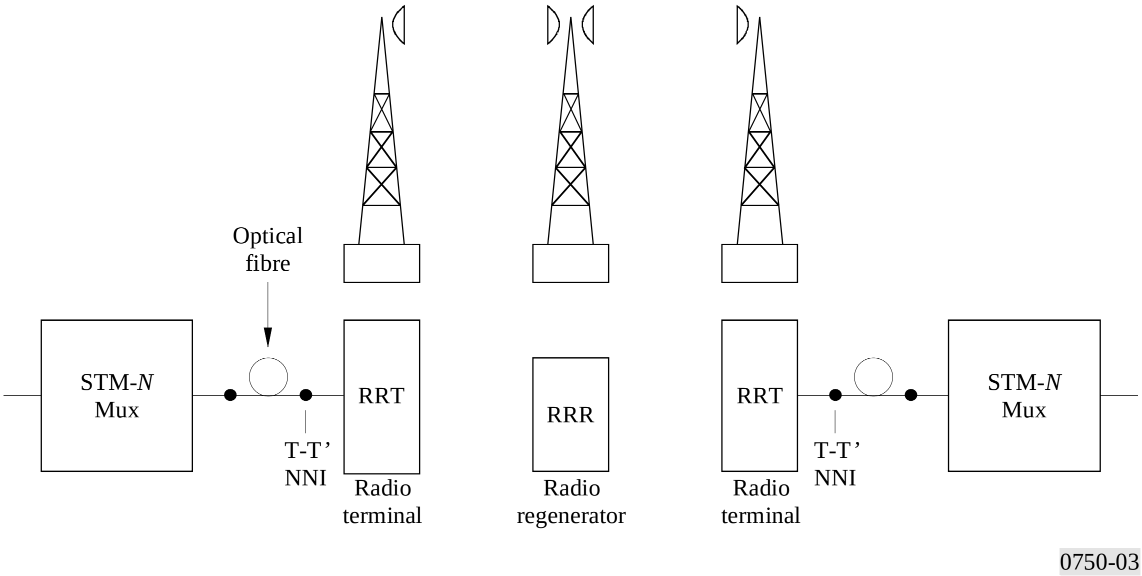
2.3 Network node interfaces (NNI)

The connection between radio systems and other SDH network elements shall be at standardized interface points. The recommended connection is to make T, T′ points (as defined in Recommendation ITU-R F.596) coincide with the network node interface (NNI) points identified in ITU-T Recommendation G.708.

An example of the positions of the T, T′ points and the NNIs is shown in Fig. 3, where optical connections are used; electrical interfaces, as foreseen in ITU-T Recommendation G.703, may be used too.

FIGURE 3

SDH radio system NNI interface points



2.4 Functional blocks of SDH equipment

The use of functional blocks has been adopted by ITU-T Recommendations G.782 and G.783 to simplify the specification of SDH equipment. Decomposition of SDH DRRS into functional blocks complying with these Recommendations is discussed in § 3.3 and 6.4.

3 Application of radio-relay systems to SDH-based networks

3.1 General considerations

The scope of this section is to underline the possible applications and topologies foreseen for SDH-DRRS.

The inter-operability of equipment from different media and sources is maintained as long as the functional requirements of SDH are properly adhered to.

The following main applications for SDH-DRRS are foreseen:

– use of radio-relays to close an optical fibre ring (see an example in Fig. 4);

– connection in tandem with fibre optic systems (see an example in Fig. 5);

– multimedia protection (see an example in Fig. 6);

– point-to-multipoint systems with integral multiplex functions.

Media independent multiplex sections are possible only if all different media use the MSOH for the same overhead functions (with no media-dependent functions).

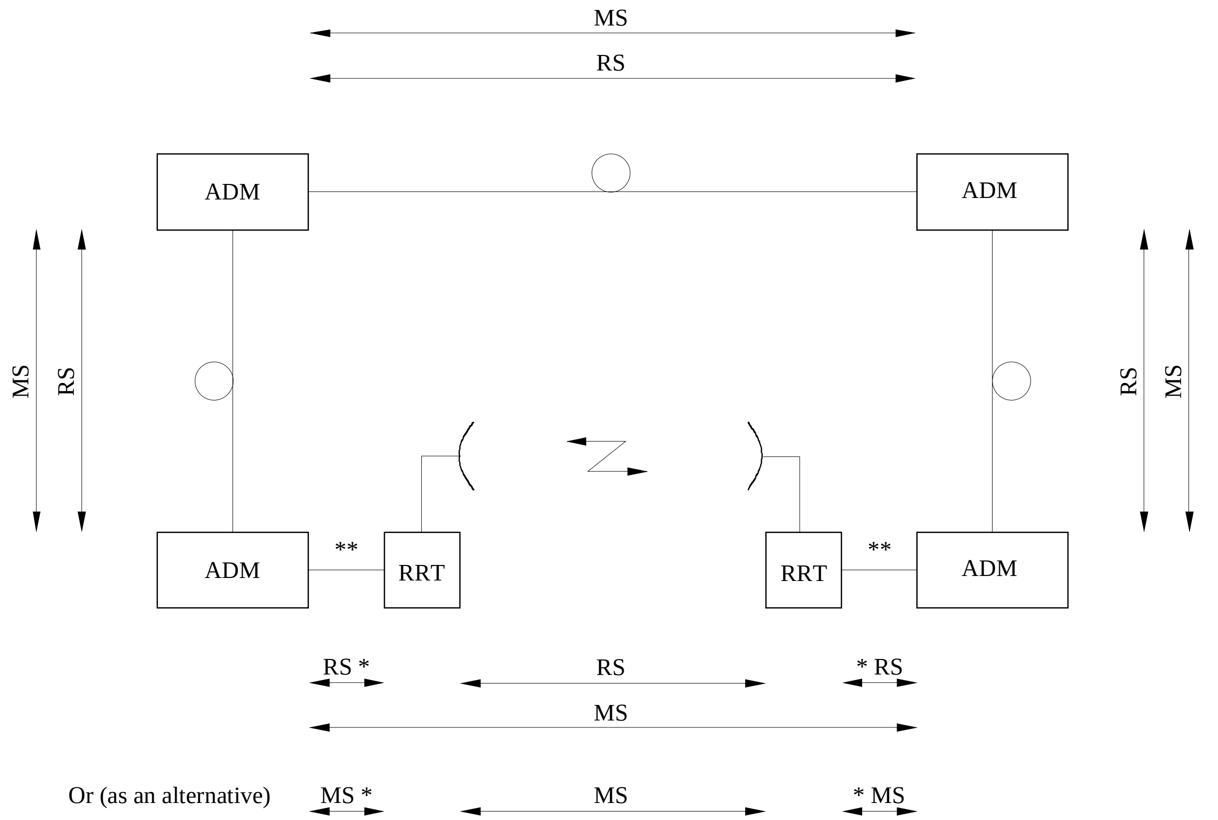
When using multi-line protection switching ($n + m$), the protected radio section may, in some cases, be coincident with a multiplex section (see § 3.3, 3.4 and Appendix 3).

It should be noted that if SDH radio-relay systems include facilities for radio-protection switching then they may need to access and recalculate the embedded block error monitoring present with the SOH in the B1 and B2 bytes. In this case, if the B2 bytes are recalculated, the radio-switching section should be regarded as a multiplex section.

The sections before a radio multiplex section can be either an intra-office section (IOS) or an inter-office connection.

FIGURE 4

Use of radio-relay to close a ring



* With possible reduced functionality of an intra-office section (see ITU-T Recommendation G.958) or with the functionality of an intra-station interface (see ITU-T Recommendation G.708).

** Optical, electrical or internal (proprietary) interface; in the last case the connection is not considered a section.

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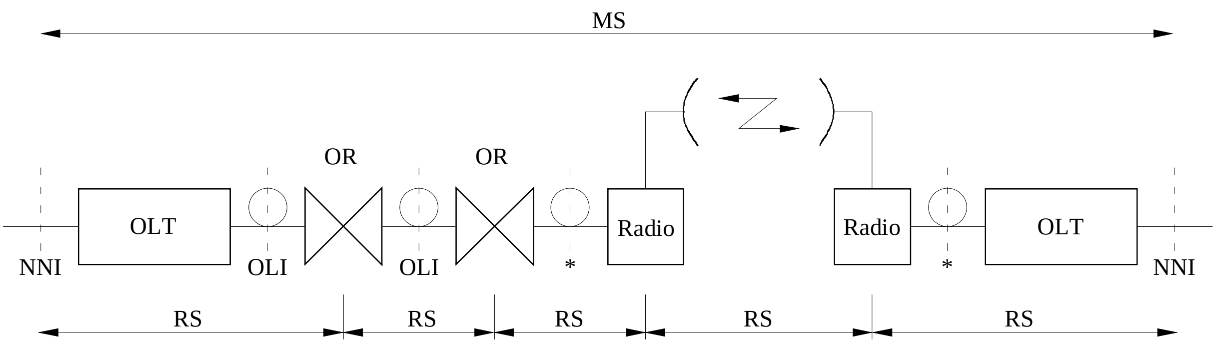
FIGURE 5

Tandem connection type



* Optical, electrical or internal (proprietary) interface; in the last case the connection is not considered a section.

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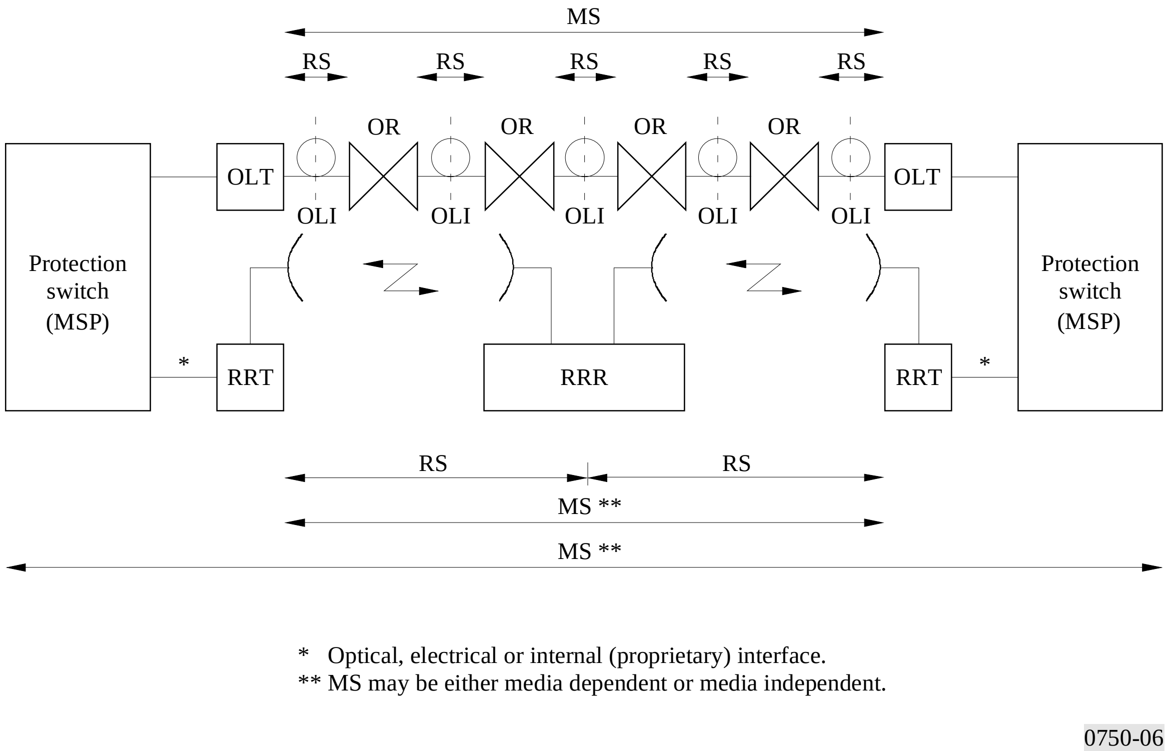
FIGURE 6

Multi-media protection



3.1.1 Interfaces

Unless a radio-relay system is integrated with another SDH equipment, it shall interface to the SDH network at the NNI.

Radio-relay systems can provide either an electrical or an optical interface. The electrical interface is defined in ITU-T Recommendation G.703 while the optical interface is defined in ITU-T Recommendation G.957 (see Table 1/G.957).

3.1.2 Mid-air interconnectivity

It is not practicable for radio systems to provide a radio-frequency interface for mid-air interconnectivity. Mid-air compatibility would require standardization of many additional parameters such as the modulation and coding method, filtering arrangements, diversity combining and protection switching methods and associated control algorithms, adaptive equalizers, overhead bit patterns, FEC, adaptive transmitter power control, etc. Such detailed specifications and standardization would stifle future innovation and would not leave the freedom for different modulation schemes to be used for different applications. Therefore, standardization of a mid-air interface is not required.

3.2 Multiplex and regenerator sections

Within a network based on the synchronous digital hierarchy, connections made by radio-relay systems shall form either a multiplex section or a regenerator section. In the former case both RSOH and MSOH within the STM-*N* signal are accessible. In the latter case the RSOH is accessible (see also § 3.3 and Figs. 8 and 10).

3.3 Functional block diagrams of STM-*N* digital radio-relay systems

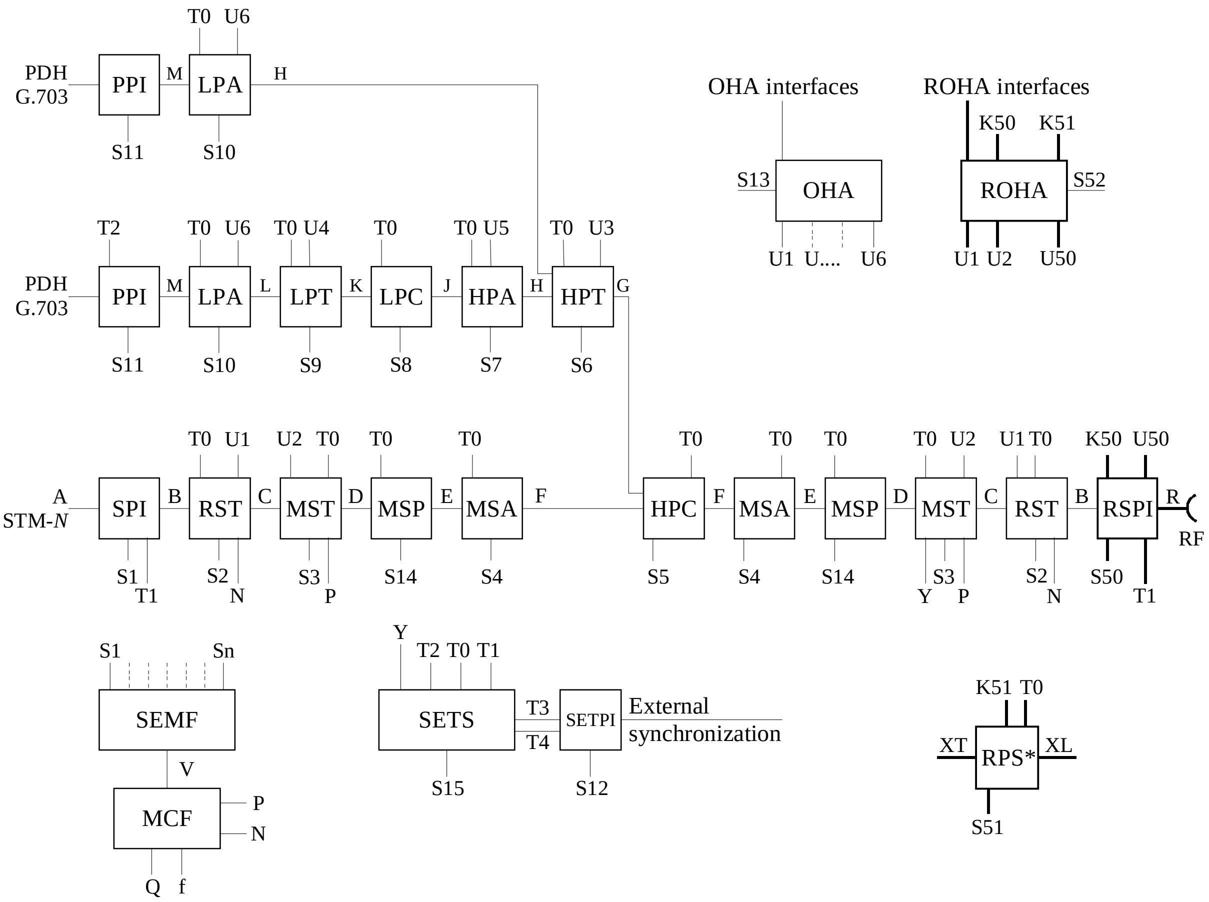
The partitioning into functional blocks is used to simplify and generalize the description and it does not imply any physical partitioning and/or implementation.

The functional block diagram is intended to be used, in conjunction with ITU-T Recommendation G.783, for a “formal” description of the main functionality of an SDH radio equipment.

Figure 7 is taken as a generalized block diagram for STM-*N* systems. In Fig. 7, for clear distinction from ITU-T Recommendation G.783 definitions, U*x*, K*x* and S*x* interfaces numbering, for radio specific blocks, has been taken starting from 50 onward.

FIGURE 7

Generalized SDH-DRRS logical and functional block diagram



* The RPS functional block is composed of a connection type function which, for implementation purposes, can be inserted in between any other functional block to perform specific ($n + m$) line protection for the radio section. XL and XT are functionally the same interface and always fit any interface where the RPS may be inserted (see Appendix 3 for examples).

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In Fig. 7 only the most common ITU-T Recommendation G.783 defined functional blocks are reported, together with the radio specific ones. Nevertheless other actual or future ITU-T Recommendation G.783 defined functional blocks may be implemented, if applicable, into SDH DRRS.

In Fig. 7, where other references are taken from ITU-T Recommendations G.782 and G.783, it may be noted that the following additional radio specific functional blocks, reference points and interfaces, with respect to those defined by ITU-T, are included:

– RSPI: radio synchronous physical interface (functional block)

– RPS: radio protection switch (functional block)

– ROHA: radio overhead access (functional block)

– R: reference point at RSPI radio-frequency interface

– XT: reference point at RPS input/output interfaces (tributary side)

– XL: reference point at RPS input/output interfaces (line side)

– U50: reference point for RFCOH (if used) at RSPI/ROHA interconnection

– S50: reference point of RSPI management and supervisory information, accessed by SEMF function for equipment internal functionality and TMN

– S51: reference point of RPS management and supervisory information, accessed by SEMF function for equipment internal functionality and TMN

– K50: interface point of communication byte(s) for radio specific functions (e.g. ATPC) between RSPI and ROHA to be addressed on U1 (media bytes) or U50 (RFCOH) for far end transmission

– K51: interface point of communication byte for multiline $n + m$ RPS switching protocols between RPS and ROHA to be addressed on U1 (media bytes) or U50 (RFCOH) for far end transmission.

The main functionality of each of the three newly introduced radio specific functional blocks follows:

– RSPI is the radio equivalent of optical SPI defined in ITU-T Recommendations G.783 and G.958; it takes care of translating the fully formatted STM-*N* signal at reference point B, into a radio-frequency modulated signal at reference point R and *vice versa*. Reference point R differs from ITU-T Recommendation G.783 reference point A by the non-standardized use of media specific RSOH bytes and, if used, by an arbitrary added RFCOH.

– RPS performs the radio protection functions which may not be accommodated by the MSP function; as a matter of fact K1 and K2 protocols are not suitable for hitless functionality, to counteract multipath phenomena; consequently RPS will use a non-standardized, high efficiency, communication protocol on dedicated interface K51.

  Moreover, when mixed media MS may be foreseen, RPS function may be used also in regenerator sections which coincide with a radio switching section terminal.

  The RPS functional block is composed of a connection type function (see Note 1) which input/output interfaces, XL and XT, are functionally the same, and fit to any interface where the RPS function may be inserted (namely B, C, D, E and F reference points). For implementation dependent reasons, RPS may be inserted between any other functional blocks to perform specific $n + m$ line protection for the radio section.

  NOTE 1 – A connection function does not operate on the content of the signal, but acts as a matrix function (e.g. HPC functional block in ITU-T Recommendation G.783).

– ROHA is a functional block which is introduced to "formally" take care of the transmission and interconnection of the media specific information flow between RSPI and RPS at radio terminals and repeaters.

  It manages the media specific functions required by RPS and RSPI, at interfaces K50 and K51 respectively, and the related transmission data channels in media-specific bytes or RFCOH, at reference points U1 and U50 respectively.

The formal descriptions in the following § 3.3.1, 3.3.2 and 3.3.3 will correspond to the methodology used by ITU-T Recommendation G.783 for those aspects in regard to definitions relating to these three radio-specific functional blocks.

Refer to Appendix 2 for a migration strategy from PDH to SDH-based networks.

3.3.1 SDH radio synchronous physical interface function (RSPI)

The RSPI function provides the interface between the radio physical medium at reference point R and the RST function at reference point B.

Data at R is a radio-frequency signal containing an STM-*N* signal with no media-dependent bytes and (if used) an additional arbitrary RFCOH (radio frame complementary overhead). Therefore mid-air interconnectivity between transmitters and receivers from different vendors is not required.

The information flows associated with the RSPI function are described with reference to Fig. 8a. This functional block is expanded in Fig. 8b.

FIGURE 8a

RSPI functional block

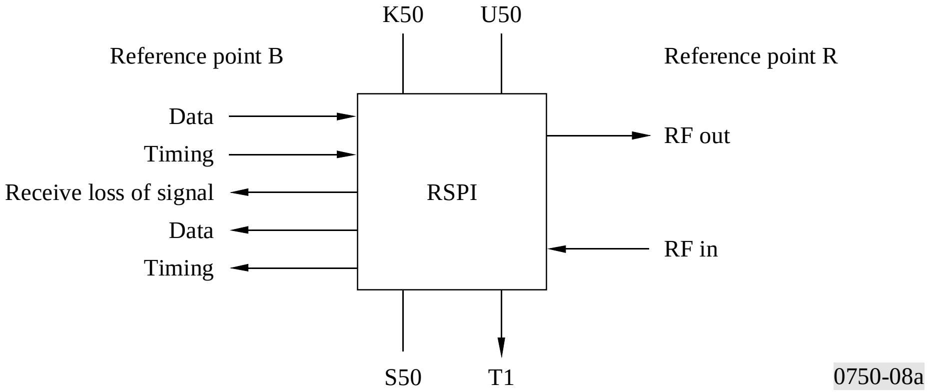
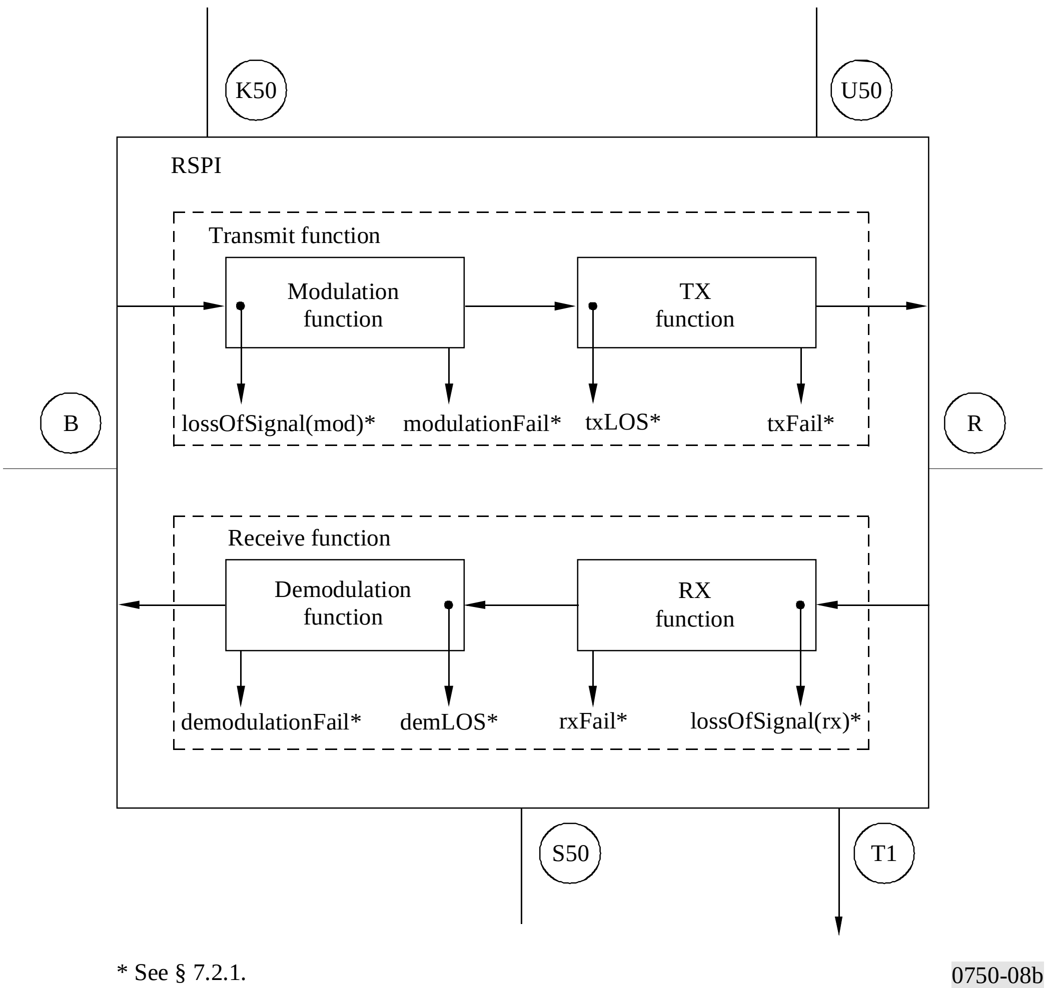


FIGURE 8b

RSPI functional block (detail)



* See § 7.2.1.

K50 is an interface for any radio-specific control and monitoring use (e.g. ATPC) making use of the media specific bytes of RSOH or of RFCOH extracted through reference points U1 or U50 respectively and made available by the ROHA functional block.

The RSPI function is subdivided into transmit and receive functions; these may be subdivided into two smaller sub-blocks, as shown in Fig. 8b, namely:

– transmit function → modulation function
TX function

– receive function → demodulation function
RX function

These functions may be described as follows:

– The modulation function may include all the processing to transfer the STM-*N* data signal at reference point B into a suitable IF or RF signal (whichever is applicable), including any digital processing (e.g. scrambling, channel-coding and RFCOH insertion).

– The TX function represents the process of power amplifying the signal, filtering and optionally up-converting the signal coming from the modulation function for presentation at reference point R.

– The RX function represents any signal processing (including propagation countermeasures, e.g. space diversity reception) between the receiver input, at reference point R, and the demodulation function input.

– The demodulation function represents the process of converting the IF or RF signal (whichever is applicable), into a STM-*N* data signal for presentation at reference point B. The demodulation function may include any analogue and digital processing (e.g. filtering, carrier and timing recovery, descrambling, RFCOH extraction and propagation countermeasures like equalizer, cross-polar interference canceller, error correction).

In multicarrier STM-*N* system applications (where the STM-*N* signal is split to more than one modem set) the overall sets of modulation and demodulation "functions" will be regarded as a single one.

Figure 8b also shows a minimum set of indications for maintenance purpose, descriptions of which are given in § 7.2.1.

Indications relating to the physical status of the interface shall be reported at S50 to the SEMF functional block (see § 7.2.1 and Appendix 5).

3.3.1.1 Signal flow from B to R

Data flow at B is the fully formatted STM-*N* data as specified in ITU-T Recommendations G.707, G.708 and G.709. Data is presented together with associated timing at B by the RST function. The RSPI function multiplexes these data together with the RFCOH (if used) and adapts them for transmission over the radio-frequency medium (by means of a suitable modulation format, carrier frequency and output power) and presents it at R.

Data for inclusion in RFCOH (if used) are inserted at reference point U50.

Radio-specific management data (e.g. ATPC increase/decrease power request from the far end receiver function to control the local transmitter function) will be shown at K50 from ROHA functional block, which provides proper extraction from the media-specific byte of RSOH or from RFCOH through reference point U1 or U50 respectively (see ROHA functional block description in § 3.3.3).

3.3.1.2 Signal flow from R to B

The RF signal received at R may be either a single signal or a doubled (or multiplied) signal for a space and/or angle diversity protection against adverse propagation phenomena.

The RF signal at R contains STM-*N* signal together with an arbitrary RFCOH (if used). The RSPI function recovers at B data and associated timing from the RF signal. The recovered timing is also made available at reference point T1 to the SETS for the purpose of synchronizing the synchronous equipment reference clock if selected. The RFCOH, if present, is made available at reference point U50.

When the relevant receiver thresholds are exceeded (e.g. by receiver power level or by error correction activity), radio-specific management data (e.g. ATPC increase/decrease power request from the local receiver function to be sent to the far end transmitter function or early warning (EW) switching request to the local RPS or to be forwarded from a regenerative repeater to the next one) will be shown at K50 to ROHA functional block, which will provide for proper insertion in the media-specific byte of RSOH or in RFCOH through reference point U1 or U50 respectively.

Fast detection time of EW thresholds is of high importance for hitless operation of the RPS.

If the signal fails at R, or the input signal to the demodulation function fails (see § 7.2.1), then the receive loss of signal (LOS) condition is generated and passed to the reference point S50 and to the RST function at B. The signal at R is considered to be failing when the receive function (whatever its redundant physical implementation) cannot provide a signal to enable the demodulation function to distinguish and recover the transmitted symbols.

3.3.1.3 Application to the transmission of *N* times STM-*N*

The case of systems carrying more than one STM-*N* either by a multicarrier technique or by a single carrier with a bit rate *N* times STM-*N*, will be represented, from the functional point of view, by duplicating up to *N* times the RSPI functional block. It has to be noted however that this does not imply any relationship with physical hardware implementation.

3.3.2 Radio protection switching (RPS)

The RPS function provides "*m*" protection channels for "*n*" STM-*N* signals against channel-associated failures for both hardware failures and temporary signal degradations or losses due to propagation effects (e.g. rain or multipath phenomena) within a radio section composed of a number of regenerative repeater sections (see Note 1).

NOTE 1 – The status information coming from S2, S3, S4, S50 and S52 of RST, MST, MSA, RSPI and ROHA respectively are shared through the SEMF function. This switching information has, in general, dedicated hardware interfaces for real time operation, but for a logical description they are here considered as supervisory primitives at the S51 interface. Information from S2, S3 and S4 may not be applicable due to the logical blocks sequence of some practical implementations (see Appendix 3).

The two RPS functions, to activate the switching procedures and to share information on the channels status at both ends of the connection, communicate with each other via a non-standardized protocol transmitted on a data communication channel at interface K51 made available by ROHA function, which provides proper insertion/extraction in one of the "media-specific bytes" or, as an alternative, in one of the RFCOH bytes available at reference points U1 or U50 respectively.

For a 1 + 1 architecture, when no occasional traffic facility is foreseen, communication between the two corresponding RPS functions is not required, being the working tributary permanently bridged to both working and protection lines.

In any case the RPS function may be considered as a specific connection matrix (somewhat like the HPC at VC-4 or STM-*N* level), whose "XT" (tributary side) and "XL" (line side) reference points on either side are the same and may match any other reference point along the functional block chain described in ITU-T Recommendation G.783 because its process does not affect the nature of the characteristic information of the signal.

The signal flow associated with the RPS function is described with reference to a generic description of the RPS functional block shown in Fig. 9.

Indications relating to the physical status of the interface shall be reported at S51 to the SEMF functional block (see § 7.2.1 and Appendix 5).

3.3.2.1 Signal flow

RPS provides a facility for re-addressing the "*n*" working signals, W, and the "*m*" occasional signals, O, at reference point XT to the "*n*" working signals, W, and the "*m*" protection signals, P, at reference point XL and *vice versa* without affecting the content of the signal concerned. The RPS connection matrix allows interconnectivity as given in Table 1.

FIGURE 9

RPS functional block

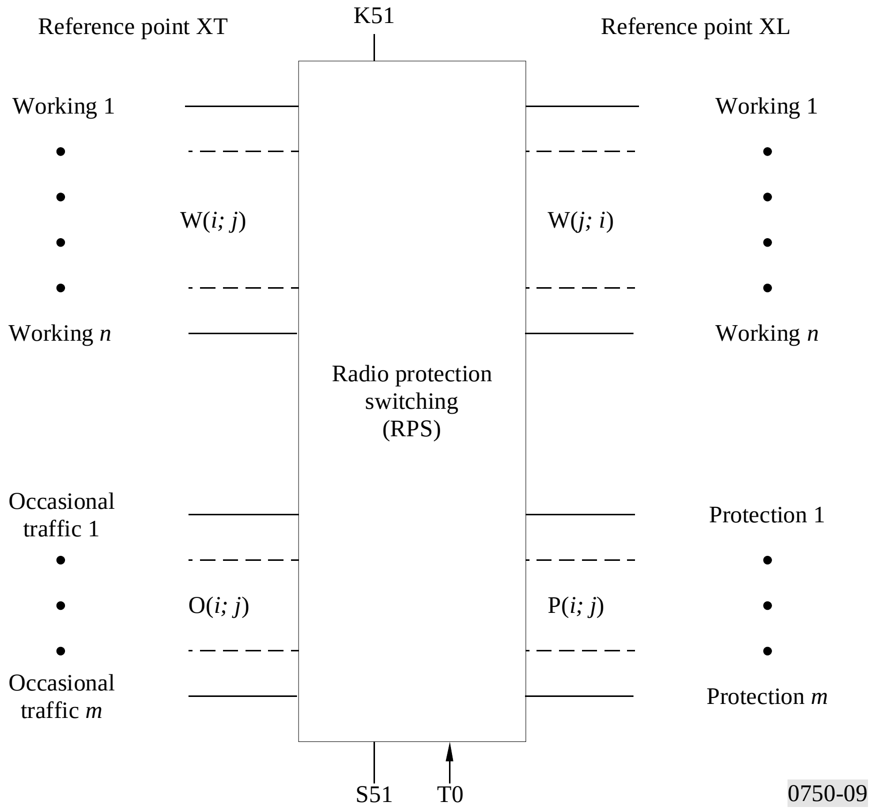


TABLE 1

Connection matrix interconnectivity for RPS

Output \ Input		W_i XL	W_i XT	P_i XL	O_j XT
W_j	XL	—	$i = j$	—	—
	XT	$i = j$	—	☒	—
P_j	XL	—	☒	—	$i = j$
O_j	XT	—	—	$i = j$	—

☒ : Connection is possible for any j and i

$i = j$: Connection is possible for the case that $j = i$ only

— : No connection is possible.

3.3.2.2 Additional functionality on the signal flow from XT (tributary side) to XL (line side)

The "*n*" tributary signals (W_i/XT) are doubled and sent to the corresponding working lines and to a distributor (TxD) respectively.

When protection is required on a specific working channel, the local RPS bridges it from the TxD to one of the "*m*" protection lines.

3.3.2.3 Additional functionality on the signal flow from XL (line side) to XT (tributary side)

When one of the working lines (W_i/XT) is degraded or fails, the local RPS detects this condition through the S51 reference point which shares the information of EW thresholds exceeded, signal degrade, signal fail and RSPI failure available for SEMF on the S2, S3, S50 and S52 reference points.

Consequently the local RPS sends the request, on a data channel at interface K51, to the far end corresponding RPS to activate the switching procedure.

3.3.2.4 Switching initiation criteria

Various levels of switching initiation may be foreseen. In any case they are described and prioritized according to proprietary schemes. Appendix 5 gives one example of a set of switching initiation criteria.

The switching criteria have, in general, dedicated hardware interfaces for real time operation, but for a logical description, they are considered as supervisory primitives at the S51 interface.

3.3.2.5 Switching performance

When used to improve the transmission performance in multipath fading conditions, RPS performance shall be such that from the detection of a propagation induced switching criteria a hitless switch shall be performed.

In any other case, the switching performance shall comply with ITU-T Recommendation G.783, § 2.4.4 (Switching time).

3.3.2.6 Switch restore

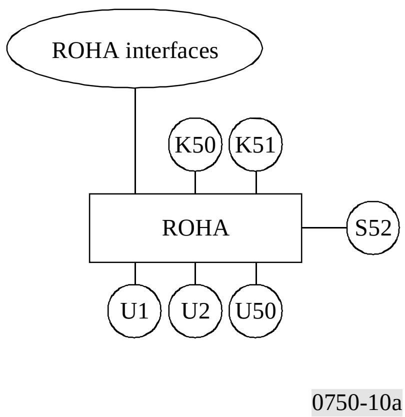
The switch restore procedure is performed by the RPS function on the basis of proprietary operation priority; an example of a set of switch restore requests is reported in Appendix 5.

3.3.3 ROHA (radio overhead access)

The description of this function makes reference to Fig. 10a.

FIGURE 10a

ROHA functional block



This function gives external access to RFCOH bytes (from reference point U50) and to the SOH unused bytes (i.e. bytes reserved for future international standardization, media-specific bytes and, in agreement with the National User, the National Use bytes available from reference points U1 and U2) in order to provide radio specific controls, monitoring interfaces and wayside traffic.

Moreover, it supplies transmission interfaces K50 and K51 to the RSPI and RPS functional blocks respectively, allowing the required information exchange between corresponding radio terminals or regenerators for managing specific functions (e.g. ATPC) and the unstandardized switching control protocol to operate the RPS in the $n + m$ configuration.

Data at the K50 and K51 interfaces will be inserted/extracted into/from the dedicated media-specific bytes of RSOH (available at reference point U1) or of RFCOH (available at reference point U50).

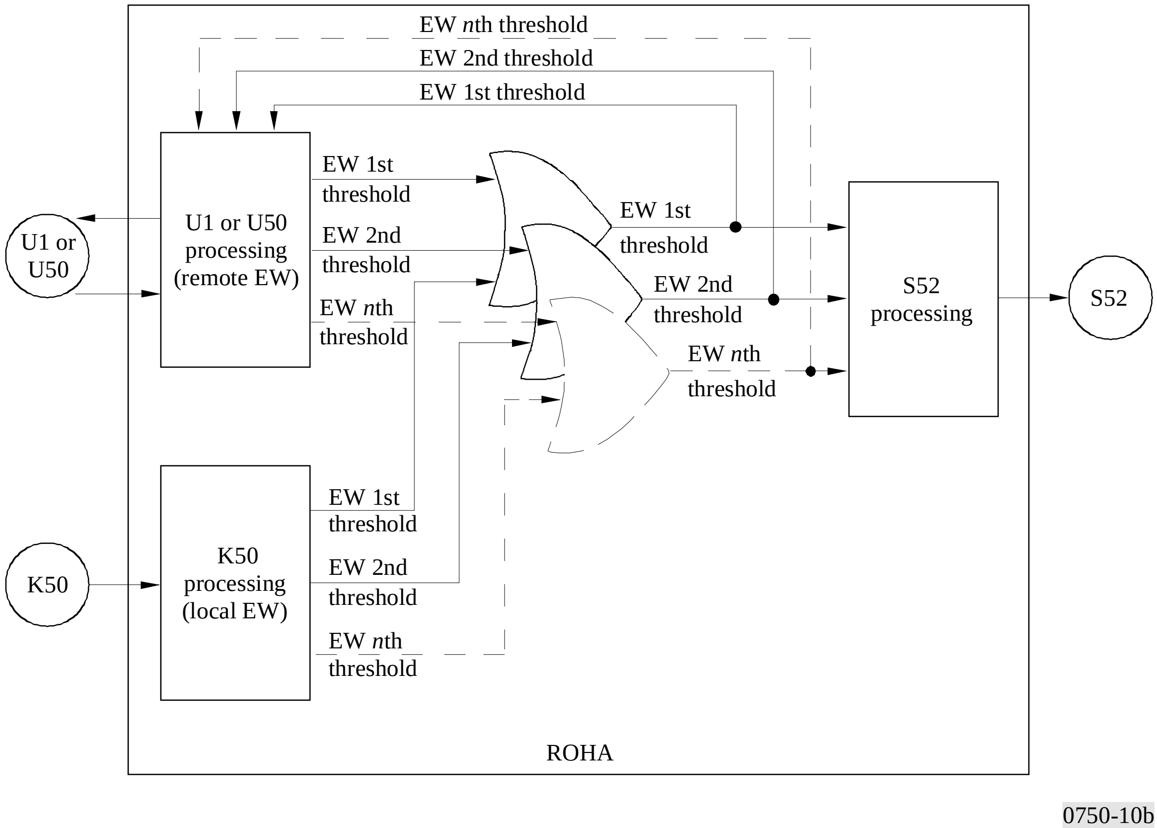
ROHA function can provide 1 + 1 protection for the above-mentioned signals.

The ROHA function recovers early warning (EW) switching requests of any foreseen threshold coming through the relevant bytes at U1 or U50 reference points, processes this information with the equivalent ones coming through K50 from the local receiver and makes the results available for further forwarding to the next repeater (through the relevant bytes at U1 or U50) in the regenerative repeaters or to RPS functional block (through reference point S52) in the radio terminals (see Fig. 10b).

Indications related to the physical status shall be reported at S52 to the SEMF functional block (see § 7.2.1 and Appendix 5).

FIGURE 10b

ROHA managing of early warning (EW) switching request



3.4 Radio terminals and repeaters arrangement of STM-*N* DRRS

3.4.1 Radio repeater arrangement

Two possibilities, from the point of view of the network management, can be envisaged.

3.4.1.1 radio repeaters may be configured as SDH optical regenerators are, provided that SPI would be substituted by RSPI;

3.4.1.2 radio repeaters may be configured as SDH optical repeaters. In this case RST is not provided and the RSPI cannot be seen as a manageable functional block unless it is included in the same network element with the radio terminals (case of NE made of a complete end-to-end radio connection described in § 7.1).

3.4.2 Radio protection switching (RPS) and radio terminals arrangement

A radio terminal may be configured either as a regenerator section (as part of a mixed-media multiplex section) or as a multiplex section.

The multiplex section protection (MSP) defined in ITU-T Recommendations G.782 and G.783 is not suitable for the improvement of transmission quality as required by radio-relay systems when multipath activity is present. Therefore three separate levels of protection are possible:

– radio protection switching (RPS) for radio section protection (either at RS or MS level);

– multiplex section protection (MSP) for multimedia MS protection;

– path protections (HPC or LPC).

Because K1 and K2 bytes are used for network protection and their protocol is not suitable for radio switching, a communication channel for the control signals of a multi-line ($n + m$) radio protection switching is needed (see § 4).

In the case of twin path (1 + 1) RPS the STM-1 signals on the operating and standby channels are synchronized both in frequency and in phase as the two channels are continuously fed in parallel by the same signal.

In multiline ($n + m$) RPS, if the STM-1 signals of the working and protection channels are not synchronized, both in frequency and in phase, the switching operation causes synchronization losses on the standby channel and consequently an increase of the switching time, when hitless functionality is required to counteract multipath activity, may impair the performance of RPS. To avoid this, radio terminals may incorporate MSA functions, becoming coincident with a multiplex section, otherwise proper non-G.783 standardized resynchronizing techniques have to be adopted, in any repeater, with respect to the dynamics of the fading to reduce the global switching operation time.

Mixed-media MS, with hitless RPS functionality in regenerator sections, may be possible in cases of § 3.4.1.1 and 3.4.1.2 with the following limitation: when 1 + 1 RPS is implemented or, in $n + m$ application, when the number of cascaded regenerative repeaters is so limited that the efficiency of the hitless RPS functionality will not be essentially degraded by the total time for A1/A2 frame recovery added up along the regenerator chain.

In some applications (e.g. when hitless operation is not required or when a fast unstandardized A1/A2 alignment recovery procedure is implemented) RPS function may also be used in regenerator sections without the restrictions mentioned above (see Appendix 3 for details).

As reported in the "formal" description of radio specific functional blocks of § 3.3 and 3.3.3, various radio terminal actual block diagrams may be derived from Fig. 7, pointing out the RPS position which may vary for implementation dependent reasons.

In Appendix 3 some of these are described. These are not part of the Recommendation and are reported for reference only. Other implementations are possible.

3.5 Synchronization

Synchronization requirements for SETS functional block of SDH digital radio networks are to follow the requirements of ITU-T Recommendations G.782 and G.783.

Primary reference and slave clocks are specified in ITU-T Recommendations G.811 and G.812 respectively. Slave clocks for SDH applications are specified in ITU-T Recommendation G.813.

Timing references may be derived from external synchronization interfaces (SETPI), tributary interfaces, or STM-N interfaces.

Requirements for jitter and wander performances for SDH radio-relay systems can be found in Recommendation ITU-R F.751.

4 Function and usage of section overhead (SOH) bytes

The frame structure of STM-1 signals provides a payload area and a SOH as shown in Fig. 1. The multiplexing method is such that a variety of signals may be combined to form the payload by building up tributaries into packages within the STM-1 frame. The SOH is divided into a number of bytes for various system and network operator functions.

4.1 Multiplex and regenerator section overheads (SOH)

The concepts of multiplex sections and regenerator sections are described in § 3. Associated with each of those sections is an overhead (MSOH and RSOH). Rules for access to specific rows are given in ITU-T Recommendation G.708 and in § 3.3.

Figure 11 shows the designation of these overhead bytes, as reported by ITU-T Recommendation G.708, which may be summarized as follows:

– 6 bytes (A1, A2) for frame alignment,

– 2 bytes (E1, E2) for order wire channels,

– 3 bytes (B2) for multiplex section bit error monitoring,

– 1 byte (C1) for STM identification,

– 1 byte (B1) for regenerator section bit error monitoring,

– 1 byte (F1) for user channel,

– 2 bytes (K1, K2) for automatic protection switching,

– 12 bytes (D1, . . . D3, D4, . . . D12) for data communication channels,

– 6 bytes reserved for national use,

– 4 bytes (Z1, Z2) not yet defined,

– 1 byte (S1) for synchronization,

– 1 byte (M1) for section far end block error reporting (FEBE),

– 6 bytes for media-specific usage,

– 26 bytes reserved for future international standardization.

SDH radio systems shall both transport and utilize the appropriate SOH functions in accordance with ITU-T Recommendation G.708, such that radio systems can be fully integrated into a managed transmission network.

4.2 Media-specific bytes

ITU-T Recommendation G.708 allows, in the STM-1 format, for a total of six bytes for media-specific usage in rows 1 to 3 of the SOH, designated S(2,2,1), S(2,3,1), S(2,5,1), S(3,2,1), S(3,3,1) and S(3,5,1). These bytes are shown in Fig. 11.

Equivalent bytes, for every STM-1 in STM-4 and STM-16 SOH formats, have been requested to ITU-T.

4.3 Reduced SOH functionality for intra-office sections

Intra-office sections offering reduced functionality are the subject of further study by the ITU-T and should be terminated by an intra-office section termination (see Fig. 4).

ITU-T Recommendation G.708 reports the required and the reduced SOH functionality of the intra-system interface (ISI).

5 Radio-relay specific functions

SDH-DRRS may provide auxiliary capacity necessary for radio-specific functions, e.g. supervisory functions, order wire, radio protection switching, etc.

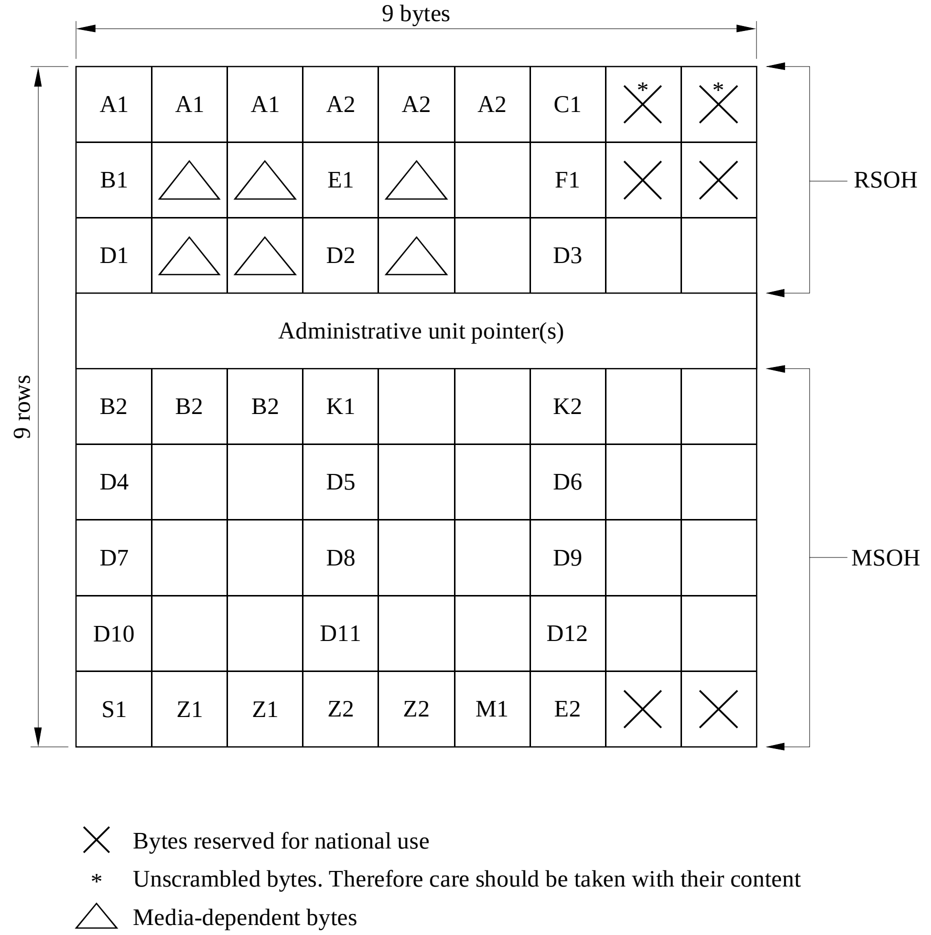
The radio-specific functions and the possible techniques used to transport the related data channels, e.g. using the SOH bytes of the STM-1 or the RR-STM frames or radio frame complementary overhead (RFCOH), are discussed in § 4 of Recommendation ITU-R F.751.

6 Sub-STM-1 transmission rate SDH radio-relay systems

This section proposes the integration of sub-STM-1 digital radio-relay systems (DRRS) to transport VC-3 payload with standard interfaces within a synchronous digital hierarchy (SDH) telecommunications network.

FIGURE 11

STM-1 SOH
(from ITU-T Recommendation G.708)



Note 1 – All unmarked bytes are reserved for future international standardization (for media-dependent, additional national use and other purposes).

0750-11

This area is of particular interest in cases where the required traffic payload is below that available within an STM-1 signal.

When the STM-1 signal is partly filled, there is the opportunity for the radio-relay to transport only a part of the STM-1 signal with the necessary SOH. This can provide savings in radio spectrum and/or reduced modulation complexity.

Radio-relay systems at sub-STM-1 bit rates to be integrated in an SDH network have to guarantee functional transparency of SDH networks between two STM-1 network node interfaces (see Note 1).

NOTE 1 – Functional transparency may be obtained if MSOH functions of STM-1 are passed through sub-STM-1 section without changing the informative content. B2 parity recalculation and VC-3/4 pointer adjustment will be performed anyway.

6.1 Network interfaces

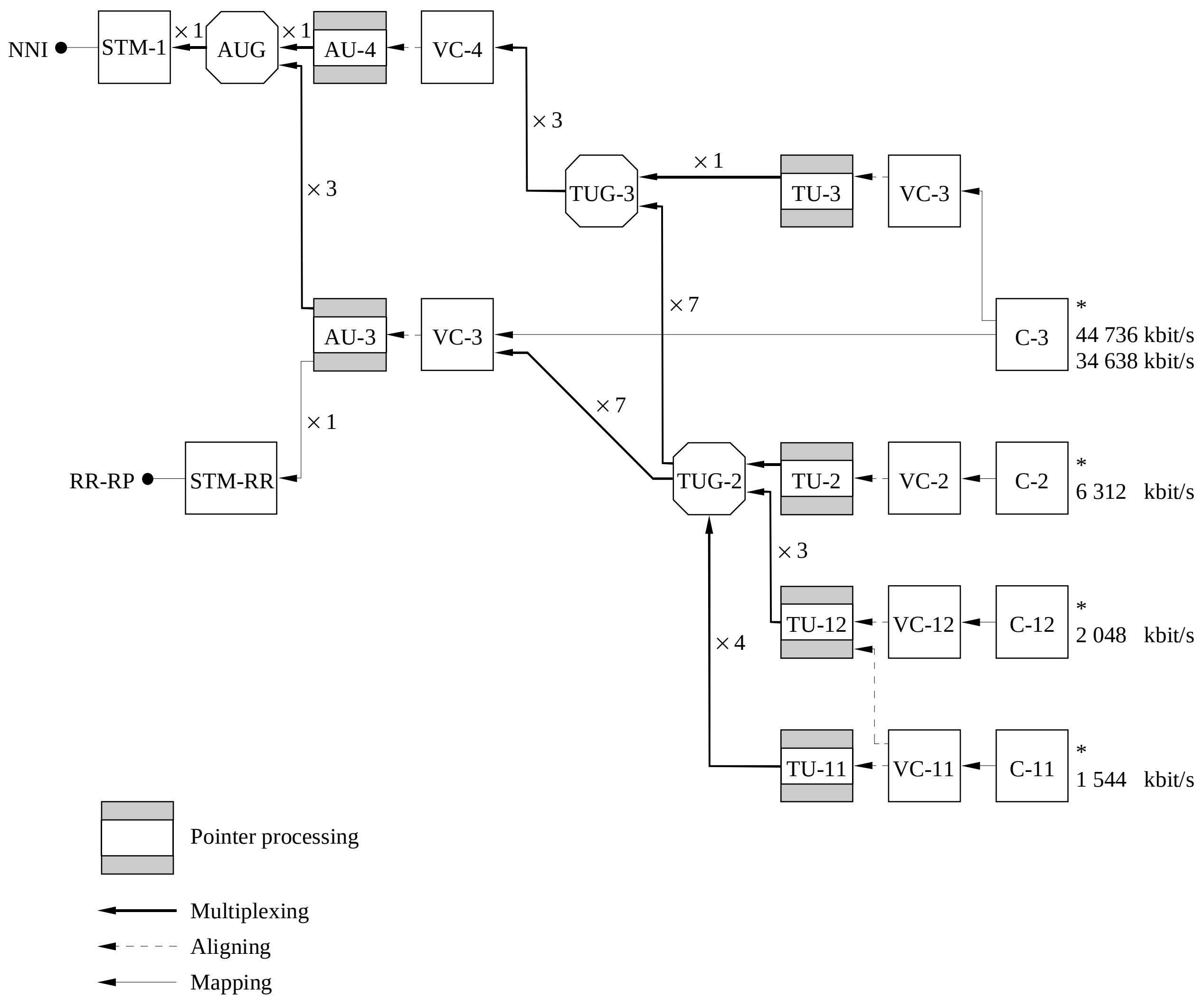
Sub-STM-1 SDH radio-relay systems shall employ network interfaces at the STM-1 level as described in ITU-T Recommendations G.707 and G.708 and at the tributary plesiochronous rates described in ITU-T Recommendations G.702 and G.703 and recognized by ITU-T Recommendation G.708.

6.2 Multiplexing schemes

The SDH multiplexing route to form the sub-STM-1 synchronous transport module for radio-relay (RR-STM) is deduced from the SDH multiplexing route. The sub-STM-1 signal can be derived from the STM-1 signal, or from tributary rates below the C-4 level as defined in ITU-T Recommendation G.703. These routes can be seen in Fig. 12.

FIGURE 12

Sub-STM-1 radio-relay system multiplexing scheme



RR-RP: radio-relay reference point for sub-STM-1 radio-relay

* ITU-T Recommendation G.703 tributaries associated with containers C-*x* recognized by ITU-T Recommendation G.708 are shown. Other signals, e.g. ATM, can also be accommodated.

0750-12

The following definitions apply to Fig. 12:

– *Radio-relay reference point for sub-STM-1 radio-relay (RR-RP):* a functional reference point within a sub-STM-1 radio system where the RR-STM is assembled.

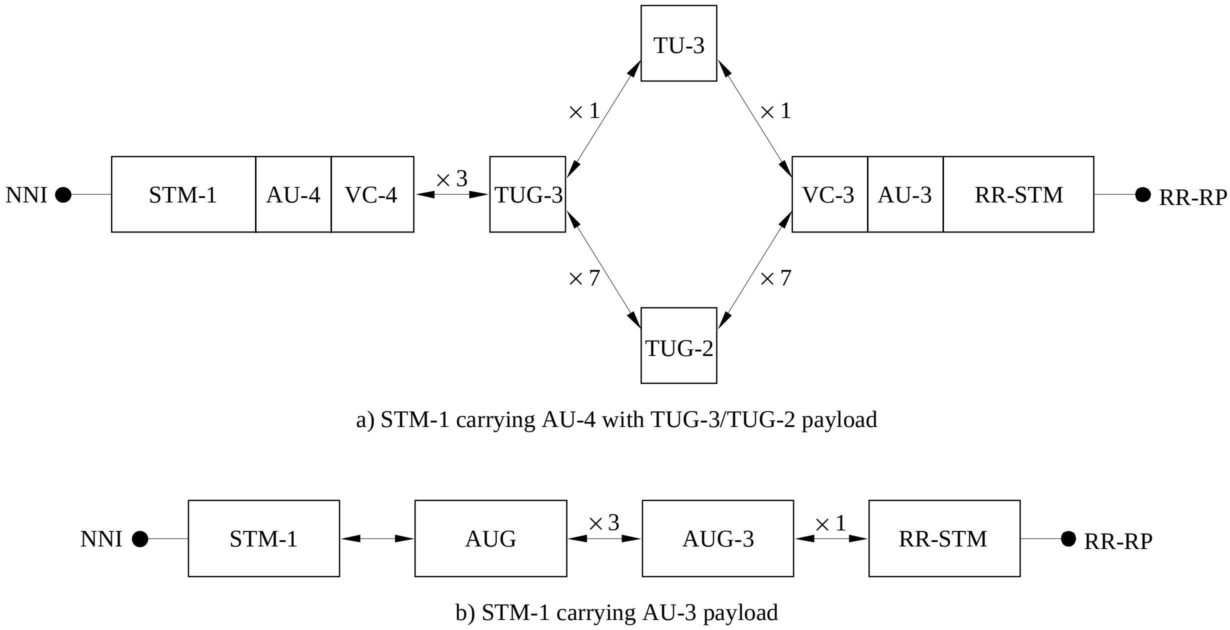
– *Synchronous transport module for sub-STM-1 radio-relay (RR-STM):* a frame structure at 51.84 Mbit/s rate with overhead and payload mapping as recommended in Annex A of ITU-T Recommendation G.708.

The interconnections of STM-1 and RR-STM are shown in Fig. 13a) and Fig. 13b) respectively for AU-4-based SDH networks and AU-3 based SDH networks.

In the case of AU-4-based SDH networks, the information structure AU-3 does not represent an administrative unit and is not managed as such at network interfaces.

FIGURE 13

Interconnection of STM-1 and RR-STM



0750-13

6.3 Multiplex and regenerator radio sections

This section identifies three configurations for sub-STM-1 SDH radio-relay systems as shown in Figs. 14, 15 and 16. In each case the allocations of the multiplex section and regenerator section are shown. These functions are analogous to the MST and RST functions of ITU-T Recommendations G.782 and G.783.

The configuration shown in Fig. 14 employs ITU-T Recommendation G.708 network node interfaces at each radio terminal, whilst providing an RR-STM transport capability.

The configuration shown in Fig. 15 employs a single ITU-T Recommendation G.708 NNI, a RR-STM transport capability, and integral multiplexing functionality to provide tributary payload access.

The configuration shown in Fig. 16 employs ITU-T Recommendation G.703 tributary payload access at each terminal with integral multiplexing with an RR-STM transport capability.

6.4 Functional block diagrams of sub-STM-1 digital radio-relay systems

This section contains functional block diagrams for the system configurations identified in § 6.3 for sub-STM-1 SDH radio-relay systems.

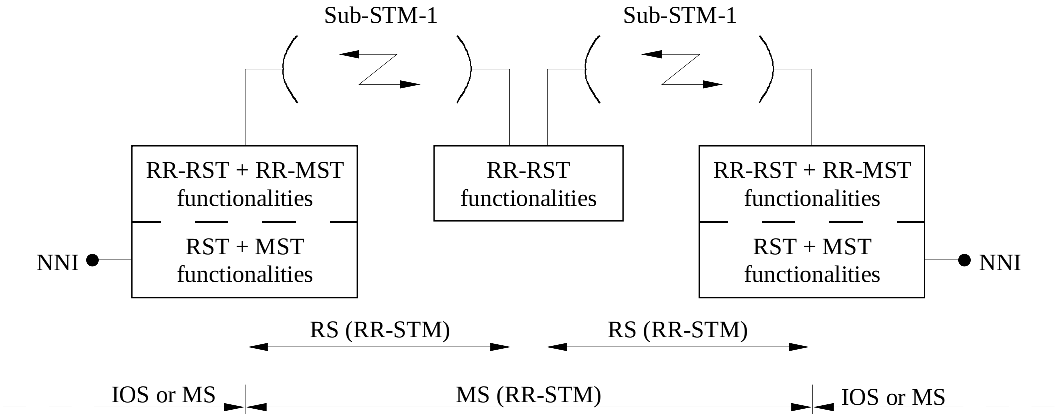
The partitioning into functional blocks is used to simplify and generalize the description and it does not imply any physical partitioning and/or implementation.

The functional block diagram is intended to be used, in conjunction with ITU-T Recommendation G.783, for a “formal” description of the main functionality of an SDH radio equipment.

Figure 17 is taken as a generalized block diagram for sub-STM-1 systems. As in previous Fig. 7 for STM-*N*, in Fig. 17, for clear distinction from ITU-T Recommendation G.783 definitions, U*x*, K*x* and S*x* interfaces numbering, for radio-specific blocks, has been taken starting from 50 onward.

FIGURE 14

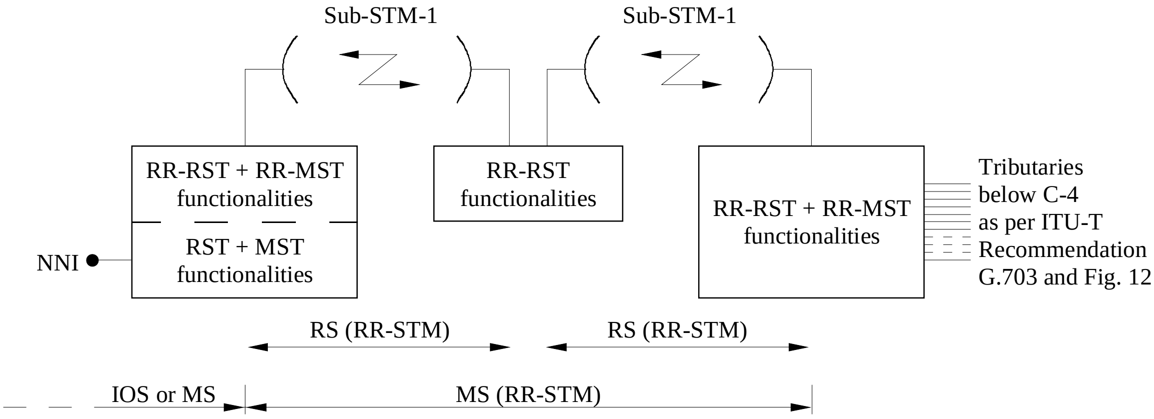
NNI/NNI configuration



0750-14

FIGURE 15

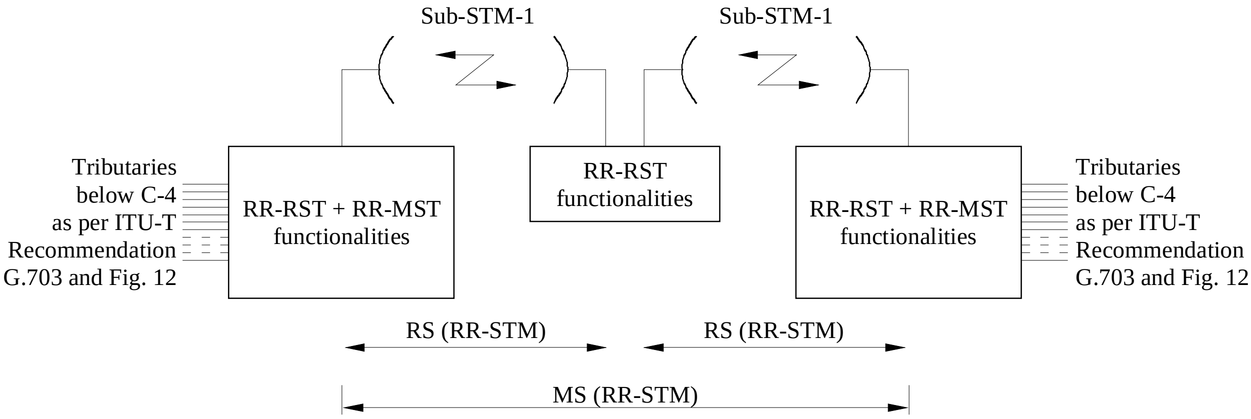
NNI/tributary rate configuration



0750-15

FIGURE 16

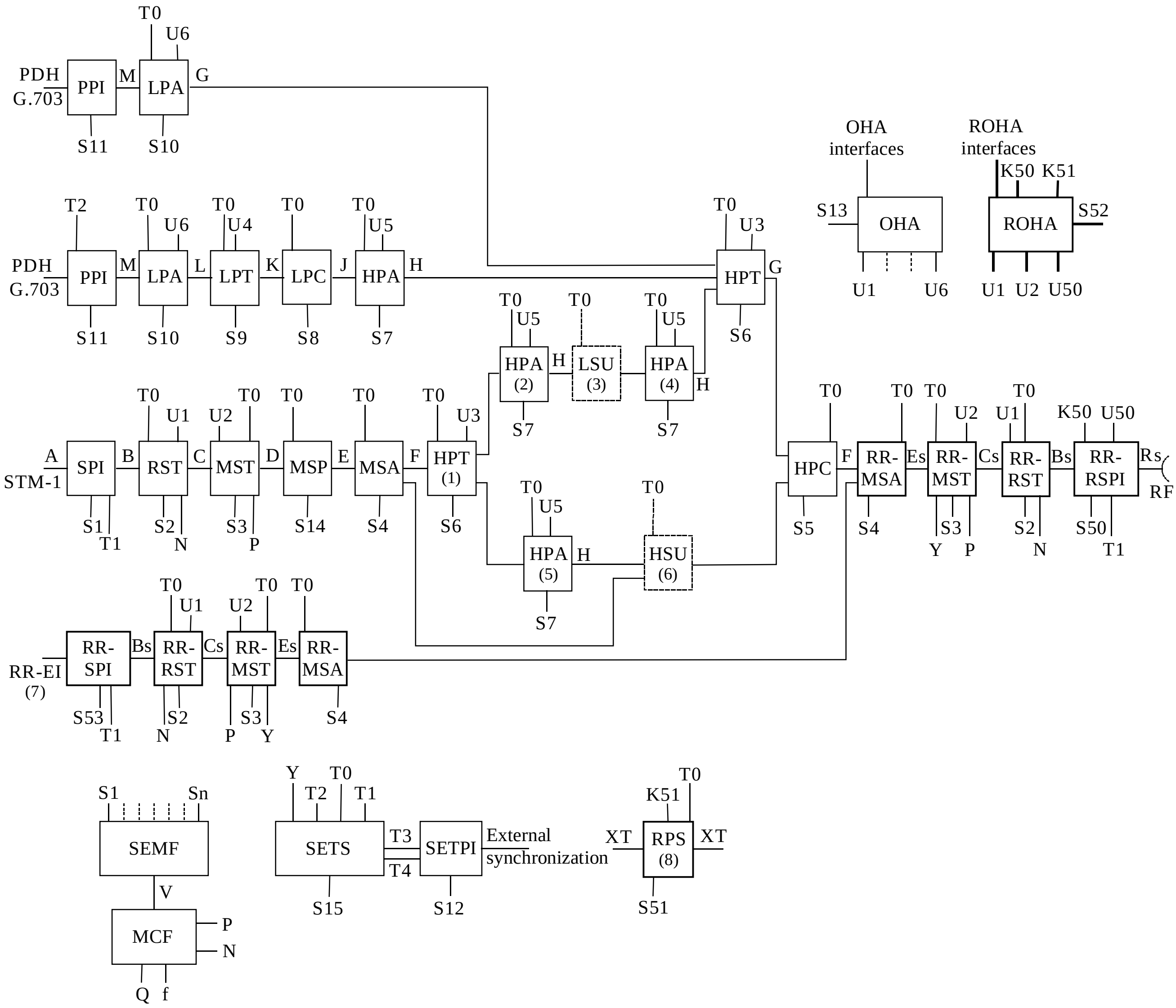
Tributary rate/tributary rate configuration



0750-16

FIGURE 17

Generalized SDH-sub-STM-1 DRRS logical and functional block diagram



[(1)] VC-4 termination.

[(2)] TUG-3/TUG-2 adaptation.

[(3)] Unequipped VC-3 or VC-2 or VC-11 or VC-12 generation (reduced functionality, these unequipped VC being permanently unused, their monitoring is not required).

[(4)] TUG-2/VC-3 adaptation.

[(5)] TUG-3/TU-3/VC-3 adaptation.

[(6)] Unequipped VC-3 generation (reduced functionality, these unequipped VC being permanently unused, their monitoring is not required).

[(7)] This is not an NNI, see § 6.4.5.

[(8)] The RPS functional block is composed by a connection type function which, for implementation purposes, can be inserted in between any other functional block to perform specific ($n + m$) line protection for the radio section. XL and XT are functionally the same interface and always fit any interface where it may be inserted.

0750-17

In Fig. 17, where other references are taken from ITU-T Recommendations G.782 and G.783, it may be noted that the following additional radio-specific functional blocks, reference points and interfaces, with respect to those defined by ITU-T or already introduced in Fig. 7 and § 3.3, are included:

– RR-RSPI: radio sub-STM-1 synchronous physical interface (functional block)

– RR-RST: regenerator section termination for sub-STM-1 radio-relay (functional block) (see Note 1)

– RR-MST: multiplex section termination for sub-STM-1 radio-relay (functional block) (see Note 1)

– RR-MSA: multiplex section adaptation for sub-STM-1 radio-relay (functional block) (see Note 1)

– RR-SPI: synchronous physical interface sub-STM-1 radio-relay (functional block)

– RR-EI: reference point at radio-relay equipment interface

– Rs: reference point at RR-RSPI radio-frequency interface

– Bs: reference point between RR-RSPI and RR-RST (see Note 1)

– Cs: reference point between RR-RST and RR-MST (see Note 1)

– Es: reference point between RR-MST and RR-MSA or RR-SPI (see Note 1)

NOTE 1 – ITU-T Recommendation G.708 specifies the frame structure for sub-STM-1 rate. The required functional blocks, like RR-RST, RR-MST and RR-MSA (together with their related interfaces B, C and D), are similar to the RST, MST and MSA functional blocks defined by ITU-T Recommendation G.783, but not identical. Hence their differences are described in § 6.4.2 to 6.4.4.

6.4.1 Radio-relay sub-STM-1 synchronous physical interface (RR-RSPI) function

The RR-RSPI function provides the interface between the radio physical medium at reference point Rs and the RR-RST function at reference point Bs.

Data at Rs is a radio-frequency signal containing an RR-STM signal with an unstandardized use of SOH media-dependent bytes and (if used) an additional arbitrary radio frame complementary overhead (RFCOH). Therefore mid-air interconnectivity between transmitters and receivers from different vendors is not required.

The function description of this block is identical to the RSPI of § 3.3.1 apart from the different input/output reference points.

6.4.2 Radio-relay sub-STM-1 regenerator section termination (RR-RST)

The description of this block is identical to the RST described in ITU-T Recommendation G.783 apart from the input/output reference points Bs and Cs which are analogous to B and C of ITU-T Recommendation G.783 but at a bit rate of RR-STM; RSOH processed at U1 reference point is limited only to RR-RSOH relevant columns.

6.4.3 Radio-relay sub-STM-1 multiplex section termination (RR-MST)

The description of this block is identical to the MST described in ITU-T Recommendation G.783 apart from the input/output reference points Cs and Es which are analogous to C and E of ITU-T Recommendation G.783 but at a bit rate of RR-STM; MSOH processed at U2 reference point is limited only to RR-MSOH relevant columns.

6.4.4 Radio-relay sub-STM-1 multiplex section adaptation (RR-MSA)

The description of this block is identical to the MSA described in ITU-T Recommendation G.783 apart from the input/output reference points Es which is analogous to E of ITU-T Recommendation G.783 but at a bit rate of RR-STM; moreover AU grouping functionality is not performed.

6.4.5 Sub-STM-1 radio-relay synchronous physical and equipment interface (RR-SPI and RR-EI)

In some cases, it may be desirable to connect radio-relay equipment at a sub-STM-1 interface rate of 51.84 Mbit/s. This interface applies at the RR-RP and is not an NNI; rather it is intended as an optional interface between sub-STM-1 radio-relay equipment.

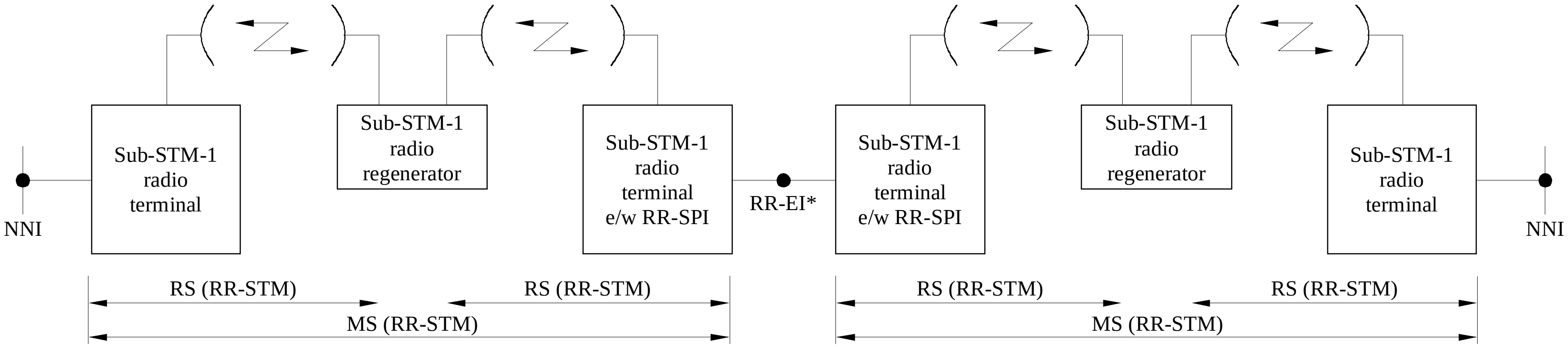
The electrical characteristics of the sub-STM-1 RR-EI are found in Appendix 1.

An application of the RR-EI is shown in Fig. 18, where inter-operability of equipment from different suppliers within MS can be pursued.

The functional block diagram of a sub-STM-1 regenerator is shown in Fig. 19. The RR-SPI function converts the internal logical level RR-STM into an RR-EI line interface signal.

FIGURE 18

NNI/NNI connection with RR-EI



* Optional sub-STM-1 radio-relay equipment interface.

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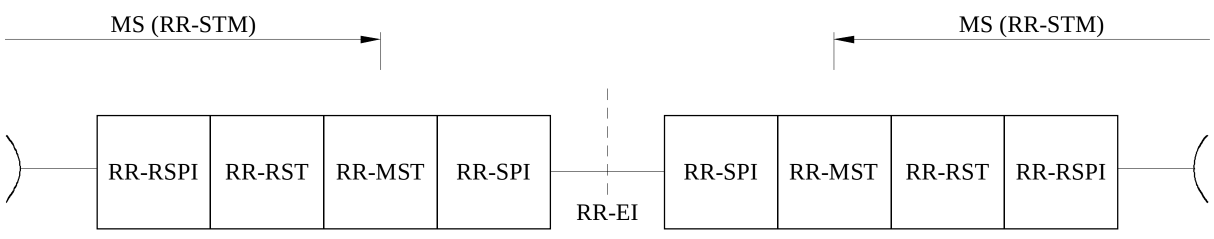
FIGURE 19

Functional block diagram of sub-STM-1 regenerator using RR-EI



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6.5 Radio protection switching

Sub-STM-1 radio-relay systems may have radio protection switching (RPS). If the RR-STM multiplex section contains radio-relay equipment connected through the RR-EI, then RPS may be implemented independently on either side of the RR-EI.

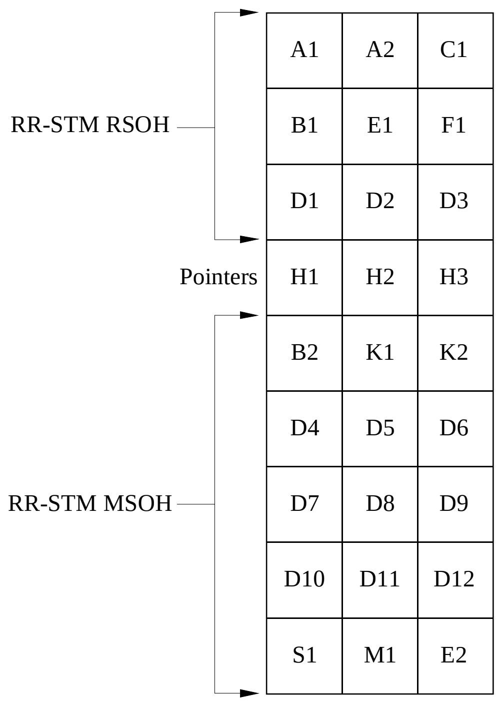
A communication channel, if required, for the sub-STM-1 radio protection switching should be implemented using RFCOH, or depending on implementations, bytes C1, F1 and/or one of the data communication channels may be used. The K1 and K2 bytes are reserved for network protection switching.

6.6 Section overhead (SOH) for sub-STM-1 DRRS

Figure 20 shows the section overhead (SOH) bytes in the RR-STM. The RR-STM SOH information is classified into regenerator section overhead (RSOH) which is terminated at regenerator functions and multiplexer section overhead (MSOH) which passes transparently through regenerators and is terminated where RR-STM is assembled and disassembled (see Note 1).

FIGURE 20

RR-STM SOH



0750-20

NOTE 1– There may be a requirement of functional transparency of MSOH information contents even through radio terminals (see § 6).

The description and the function of the RR-STM bytes are analogous to the corresponding bytes of the STM-1 SOH.

The need for radio-specific SOH bytes for sub-STM-1 radio-relay applications has been identified.

The MS-FEBE (far end block error, renamed as REI) function provided by the M1 byte which has been introduced in the 51.84 Mbit/s frame by ITU-T Recommendation G.707 (version 1995) and in a different position with respect to STM-1 SOH. As a consequence sub-STM-1 DRRS may have provided this functionality within RFCOH.

Media-specific SOH bytes have not been assigned. However, depending on the sub-STM-1 radio-relay applications, some of the SOH bytes may be available because their standard function as in ITU-T Recommendation G.708 may not be necessary or may be achieved by other means, e.g. use of FEC indications for radio performance monitoring. Depending on the implementations, bytes C1, F1 and/or one of the data communication channels may be used. However, RFCOH could also be used to perform media-specific functions.

6.7 Techniques for transport of media-specific functions

A description of possible radio-relay specific functions is found in § 4 of Recommendation ITU-R F.751. The technique adopted to provide these functions may be implementation dependent; examples of possibilities are:

– use of RR-STM SOH as in § 6.6;

– the transmission of an unstandardized arbitrary radio frame complementary overhead (RFCOH); this may be used for the transmission of other functions which ITU-T provides into the missed 6 columns of STM-1 SOH;

– the transmission, as a well identified case of RFCOH, of the missed 6 columns of a full STM-1 SOH as a radio complementary section overhead (RCSOH). An example of this application is shown in Appendix 4.

7 Operation and maintenance aspects

The operation, administration and maintenance features of SDH radio systems should be designed in accordance with ITU-T Recommendations M.20 (Maintenance philosophy for telecommunications networks), M.30 (Principles for a telecommunications management network) and G.784 (SDH management).

7.1 Management functions

SDH radio-relay systems will be part of an overall managed telecommunications network. In particular, these radio systems will be part of a managed synchronous network.

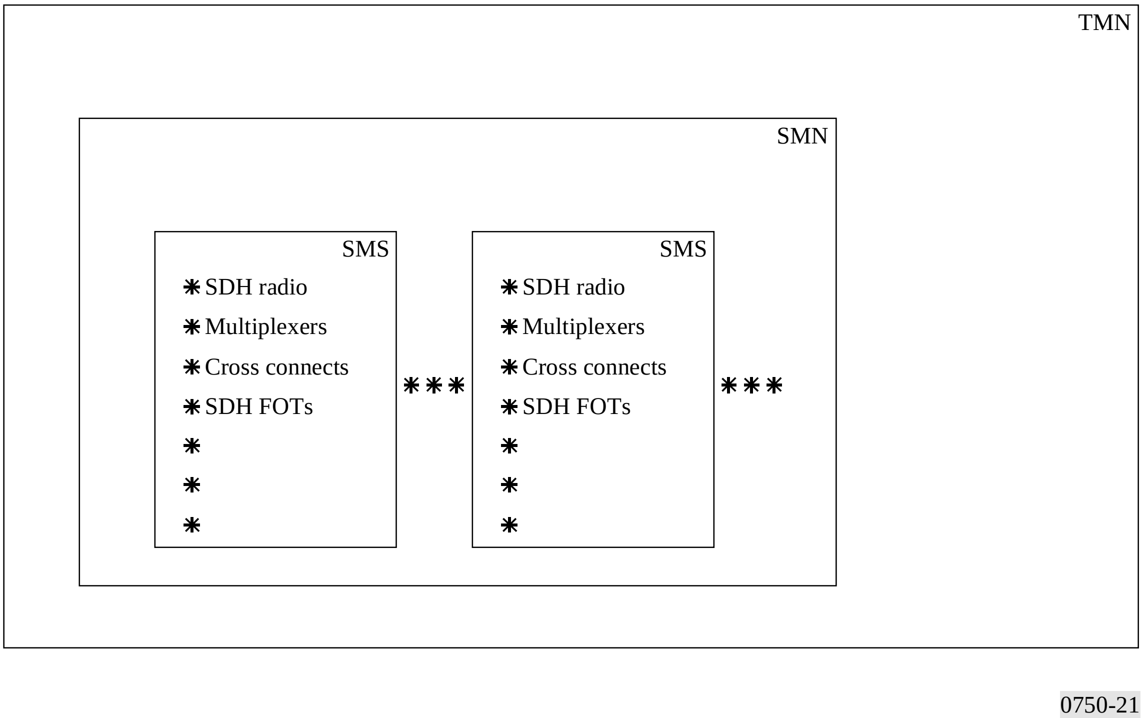
ITU-T Recommendation G.784 allows the SDH management network (SMN) to consist of various managed SDH sub-networks. SDH radio-relay systems will be managed within an SDH management sub-network (SMS) as shown in Fig. 21.

ITU-T Recommendation G.784 defines the NE as: “A stand-alone physical entity that supports at least NEFs and may also support OSF/MFs. It contains managed objects, a MCF and a MAF.”; this means that NE definition is not intended for standardization but is related to the practical implementation of the SDH equipments.

SDH NEs may be formed by a suitable interconnection of the various functional blocks as described in ITU-T Recommendation G.783 or, for radio-specific equipment, in § 3.3 or 6.4; therefore, according to implementation, radio NEs may be formed by a single radio or switching equipment, or by a set of these equipment forming more complex functions (up to a full $n + m$ radio terminal or repeater or to a complete end-to-end radio connection).

FIGURE 21

Relationship between SMS, SMN and TMN



A generic example of an SMS consisting of a radio system connected to multiplex equipment is shown in Fig. 22. Examples of the network elements (NEs) to be managed are also shown.

As an SDH-NE, the radio-relay terminal or repeater may have a work-station interface F and/or a Q interface. It may be linked to other NEs according to the architecture of Fig. 3.4 of ITU-T Recommendation G.784. One NE in the SMS should be a gateway NE to facilitate communication with a mediation device or the operations system.

7.2 Maintenance functions

Radio-specific alarms and a standardized message set have to be defined within Q protocols (ITU-T Recommendations G.783, G.784 and G.831).

This section describes parameters which should be monitored in SDH digital radio systems (see Note 1).

NOTE 1 – The parameters reported in this Recommendation are related to network operation and maintenance only, they are not intended to cover specific hardware units decomposition which, in any case, are equipment oriented and, in consequence, may not be standardized.

The radio-specific functional blocks, namely RSPI, RR-RSPI, RPS and ROHA, will give to the SEMF functional block, through S50, S51 and S52 reference points respectively, the anomalies and defects indications that are reported in § 7.2.1, 7.2.2, and 7.2.3 and resumed in Tables 2, 3 and 4 together with the consequent actions.

7.2.1 RSPI and RR-RSPI maintenance functions

The set of indications of RSPI and RR-RSPI functional block (see Fig. 8b) may be described as follows:

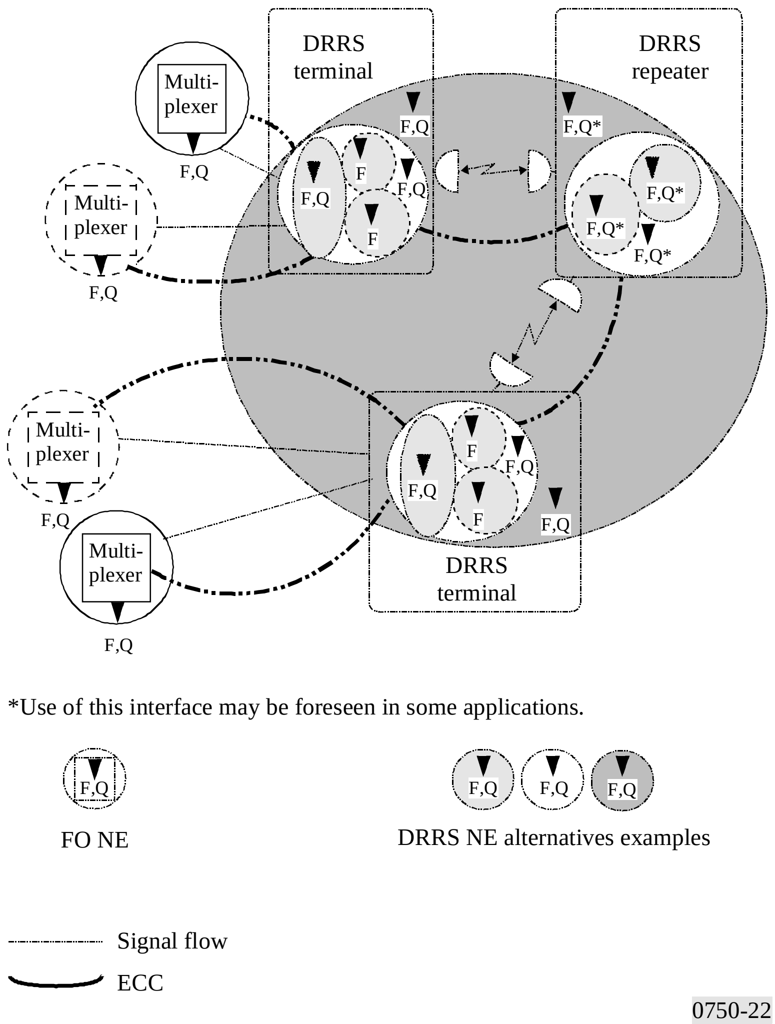
– lossOfSignal(mod) This indication shall indicate a loss of the incoming data for the modulation function. This indication is used in case of split indoor/outdoor functions of RSPI and RR-RSPI, therefore this indication is optional.

– modulationFail This indication shall report the internal failures of the modulation function affecting the modulated signal, and the loss of incoming data to the modulation function.

- txFail — This indication shall indicate a failed transmitted signal caused by internal failures of the transmitting function (TX).
- txLOS — This indication shall indicate a loss of the incoming signal for the transmitting function (TX). When the distinction between txFail and txLOS cannot be carried out with a sufficient degree of confidence, the use of txFail indication should be preferred, therefore this indication is optional.
- lossOfSignal(rx) — This indication shall report a loss of the incoming signal at reference point R for the RX function. When the distinction between rxFail and lossOfSignal(rx) cannot be carried out with a sufficient degree of confidence, the use of rxFail indication should be preferred, therefore this indication is optional.
- rxFail — This indication should report the internal failures of the RX-function affecting the received signal.
- demLOS — This indication shall indicate a loss of the incoming data for the demodulation function. When the distinction between demodulationFail and demLOS cannot be carried out with a sufficient degree of confidence, the use of demodulationFail indication shall be preferred, therefore this indication is optional.
- demodulationFail — This indication should report the internal failures of the demodulation function affecting the demodulated signal.

FIGURE 22

Examples of a mixed radio/FO SMS



In Table 2 the related SEMF filtering and consequent actions are reported.

TABLE 2

RSPI and RR-RSPI maintenance function

Signal flow	Anomalies and defects	Report across	SEMF filtering		Consequent actions
		S50	Alarm	Performance	All Ones (AIS) inserted at reference point C
From R to B and from Rs to Bs	lossOfSignal(rx)[(1)]	Yes	Yes		Yes
	rxFail	Yes	Yes		Yes
	demLOS[(1)]	Yes	Yes		Yes
	demodulationFail	Yes	Yes		Yes
From B to R and from Bs to Rs	lossOfSignal(mod)[(1)]	Yes	Yes		
	modulationFail	Yes	Yes		
	txFail	Yes	Yes		
	txLOS[(1)]	Yes	Yes		

(1) These indications are optional, see description above.

In addition to the above defined set of "formal" indications other primitives may also be envisaged to be accessed via reference point S50 for maintenance and RPS operation purposes; in Appendix 5 an example is reported.

7.2.2 RPS maintenance functions

The set of indications of RPS functional block may be described as follows:

– RPSFail (Failure of RPS)

  RPSFail should be declared when RPS function is no more able to supply protection to one or more of the protected channels.

Primitives may also be envisaged to be accessed via reference point S51 for maintenance and operation purposes; in Appendix 5 an example is reported.

In Table 3 the related SEMF filtering and consequent actions are reported.

TABLE 3

Radio protection switch anomalies and defects

Signal flow	Anomalies and defects	Report across	SEMF filtering		Consequent actions
		S51	Alarm	Performance	
From XT to XL and from XL to XT	RPSFail	Yes	Yes		

7.2.3 ROHA maintenance functions

In Appendix 5 an example of possible operation and maintenance indication is reported.

7.3 TMN interfaces

SDH radio systems should provide at least one interface at each network element conforming to ITU-T Recommendation G.773.

Full implementation of the TMN interface is the subject of further study.

APPENDIX 1

TO ANNEX 1

RR-EI electrical characteristics

Nominal bit rate: 51.840 Mbit/s

Bit rate tolerance

During synchronized operation, the bit rate tolerance shall be that of the network clock. In a mode without any synchronization to a network clock (e.g. self-timed, free running), the bit rate tolerance shall not exceed 1 037 bit/s (20 ppm).

Line code: B3ZS

Termination

One coaxial line shall be used for each direction of transmission.

Impedance

A resistive test load of 75 Ω ± 5% shall be used at the interface for the evaluation of pulse shape and the electrical parameters specified below.

Power level

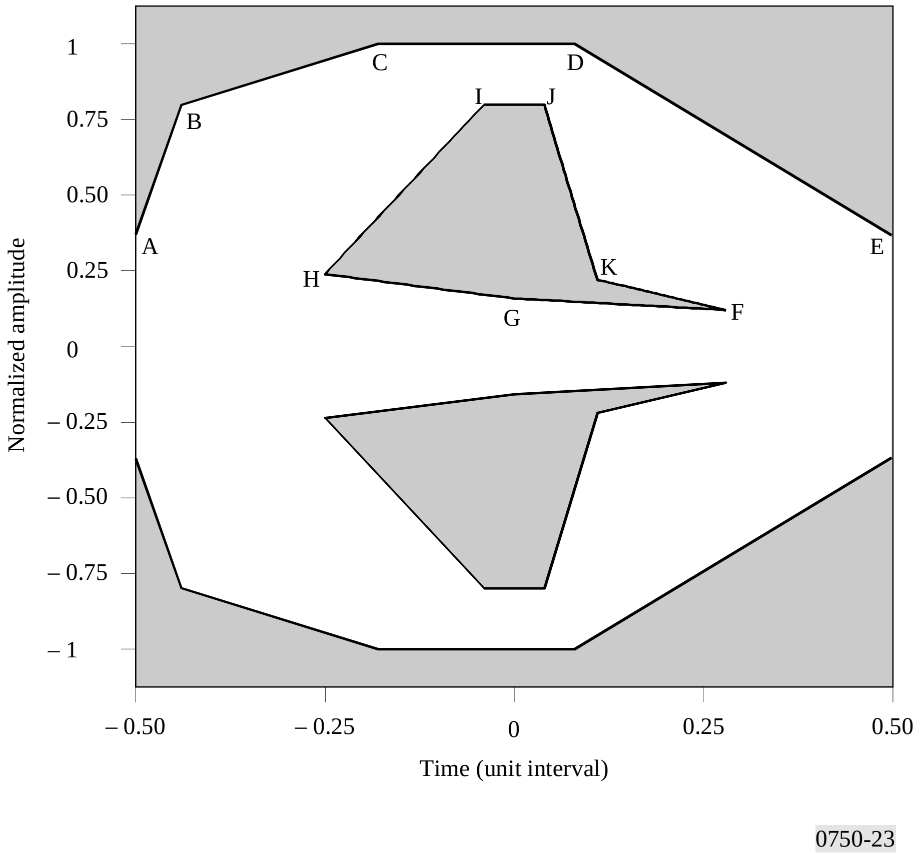
A wideband power measurement using a power level sensor with a working frequency range of at least four times the bit rate frequency shall be between –2.7 dBm and +4.7 dBm, accounting for both transmitter variations and a range of connecting cable lengths between 68.6 m and 137 m. A filter with a characteristic equivalent to a Butterworth low pass filter with a cut-off frequency of 207.360 MHz shall be used.

Eye diagram

An eye diagram mask based on the maximum and minimum power levels and cable lengths given above is shown in Fig. 23 where the voltage amplitude has been normalized to one, and the time scale is specified in terms of the unit interval T. Exclusionary regions are shown as shaded areas on the figure. The corner points of these regions are listed below the figure.

FIGURE 23

RR-EI eye diagram



Outer region corner points			Inner region corner points		
Point	Time	Amplitude	Point	Time	Amplitude
A	–0.50	0.37	F	0.28	0.12
B	–0.44	0.80	G	0.00	0.16
C	–0.18	1.00	H	–0.25	0.24
D	0.08	1.00	I	–0.04	0.80
E	0.50	0.37	J	0.04	0.80
			K	0.11	0.22

NOTE 1 – Both inner and outer regions are symmetric about the zero amplitude axis.

DC offset

There shall be no DC power flow across the interface.

Frame structure

The signal shall have the frame structure and scrambling as defined in ITU-T Recommendations G.708 and G.709.

Jitter

This requires further study.

APPENDIX 2

TO ANNEX 1

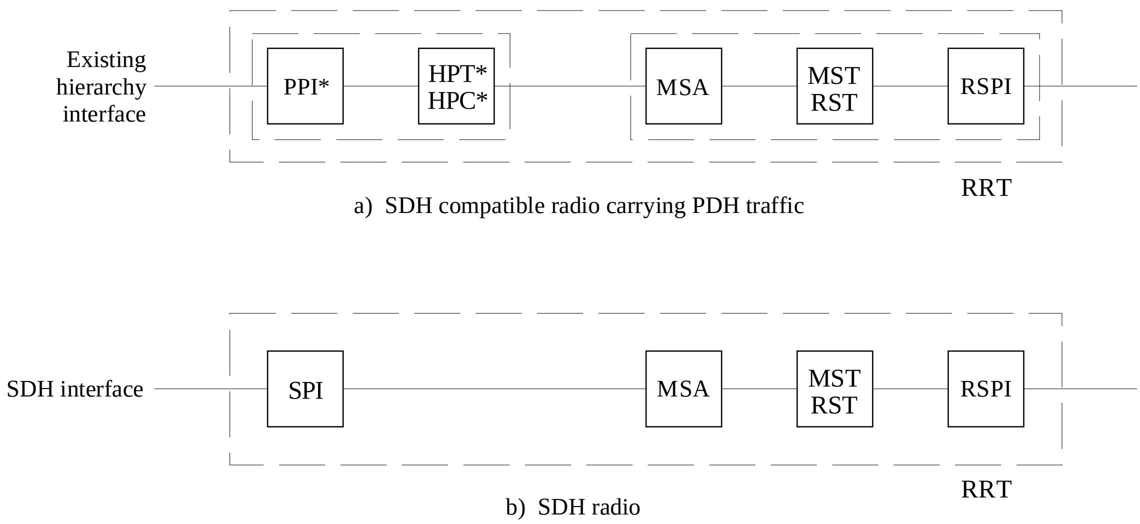
Migration strategy from an existing PDH to SDH-based networks

In the case of migration from an existing PDH (e.g. 140 Mbit/s) to SDH, one possibility is to have SDH-compatible radio systems during the transition period, which have the ability to transport SDH bit rates, although carrying PDH traffic. This can be done by providing special hardware marked by * in Fig. 24a), which will convert the PDH signal to an SDH signal according to the mapping rules of ITU-T Recommendation G.709. When the need to transport real SDH signals arises, the extra hardware will be discarded as shown in Fig. 24b) and replaced by a synchronous physical interface module.

The radio equipment would result in a radio system with full SDH functionality.

FIGURE 24

Simplified block diagram



HPC: higher order path connection
HPT: higher order path termination
MSA: multiplex section adaptation
MST: multiplex section termination
PPI: plesiochronous physical interface
RRT: radio-relay terminal
RSPI: radio synchronous physical interface
RST: regenerator section termination
SPI: SDH physical interface

Note 1 – Only functions are shown. Radio protection switching is not shown.

*These modules will be discarded after migration to SDH.

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APPENDIX 3

TO ANNEX 1

Examples of practical implementations of the RPS function

In this Appendix some possible implementations of RPS with hitless functionality are described together with some comments about its functionality and characteristics.

The more common types of RPS may be observed in the four block diagrams reported in Fig. 25. These may be more detailed as reported in the following Fig. 26.

FIGURE 25

Possible logical allocation of the RPS functional block

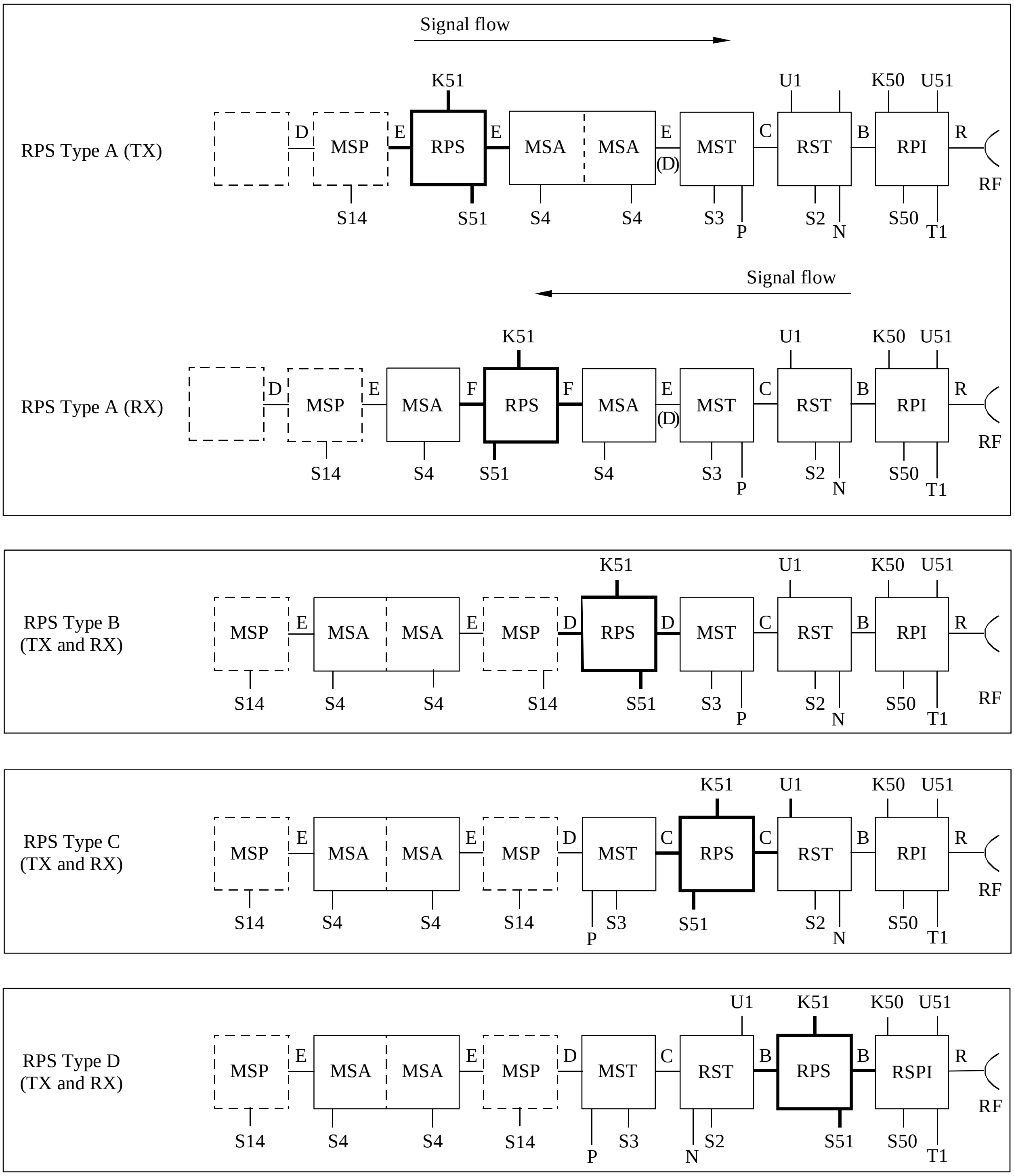

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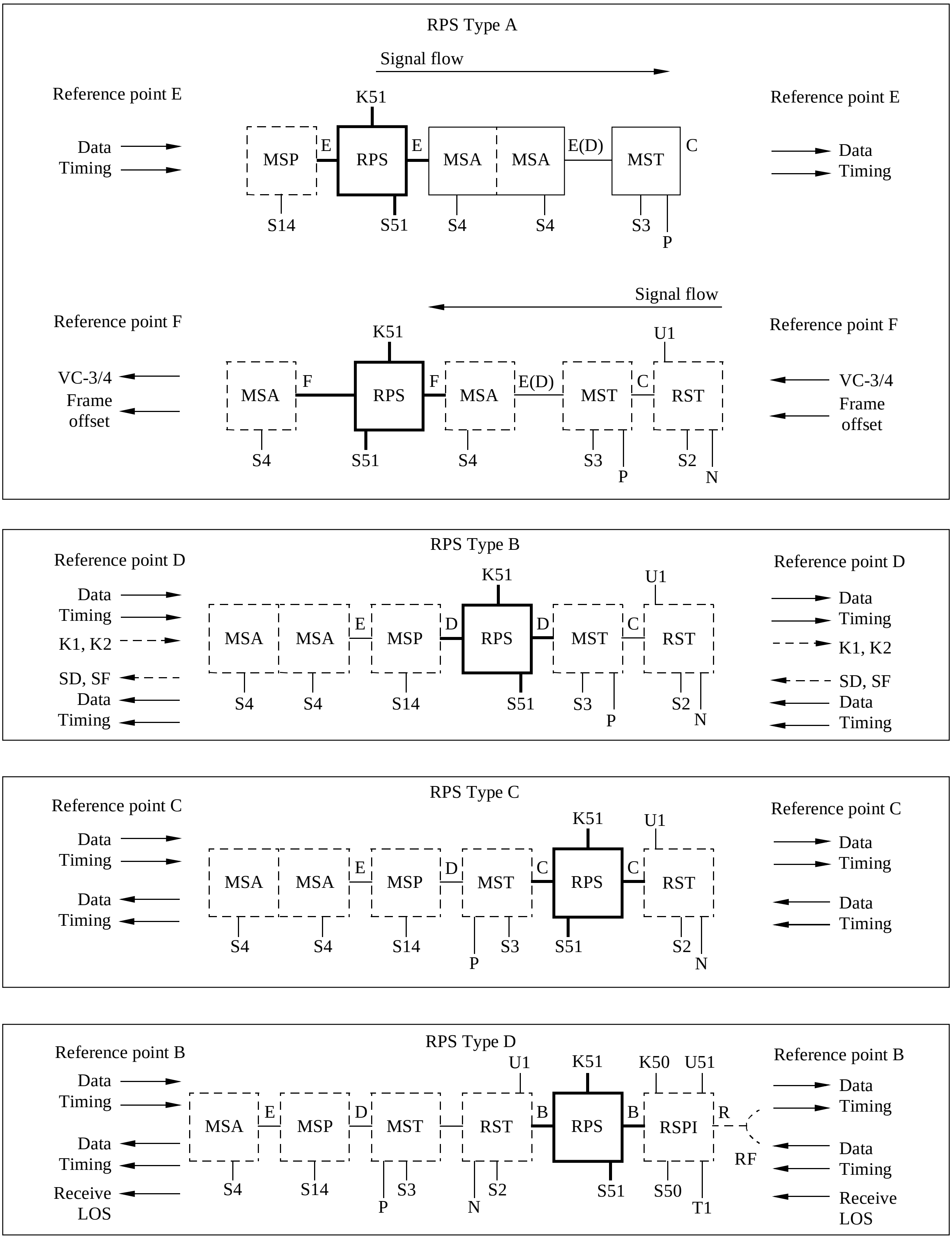
FIGURE 26

Possible reference points of the RPS functional block



0750-26

1 Signal flow and main functionality

1.1 RPS type A

The signal splitting and distribution in the TX side is performed before the MSA function so that, when the protection channel is required, the change of payload on the protection channel is recovered by the pointer adjustment mechanism without affecting the SOH location.

As a consequence, with the content of the working and standby signal different to the STM level, the receiver side alignment and switching of working and standby channels is performed at VC level, in a similar way to that performed by the HPC function.

Due to the logical allocation of the RPS function this type A is not suitable for use in conjunction with the MSP function, but network protection, if required, will be performed at VC-*n* level by HPC or LPC functions.

1.2 RPS type B

The TX-side MSA functions are all synchronized, both in frequency and frame phase, so that the standby channel frame alignment is never affected when different signals are sent on it.

As an alternative special, not G.782 standardized, frame alignment/disalignment procedures have to be implemented in every radio terminal or regenerator.

The receiver side alignment and switching between working and standby channels is performed at STM level taking suitable cautions against the possible difference in the content of SOH (e.g. skipping the bit-to-bit comparison during the time-frame of SOH location).

1.3 RPS type C

When the radio switching section coincides with the multiplex section, the TX-side MSA functions are all synchronized, both in frequency and frame phase, so that the standby channel frame alignment is never affected when different signals are sent on it.

The receiver-side alignment and switching between working and standby channels is performed at STM level taking suitable cautions against the possible difference in the content of SOH (e.g. skipping the bit-to-bit comparison during the time-frame of SOH location).

This type of RPS may not use switching initiation extracted from BIP-24 evaluation criterion so that no SDH path quality criteria may be used for switching initiation, unless RPS performs B2 parity evaluation monitoring as its internal functionality.

Provided that the number of regenerators between the two corresponding RPS is kept to a reduced amount, this type C RPS is suitable for $n + m$ protection with hitless functionality also in SDH regenerator sections (without MSA and MST functions; in this case the multiplex section may not be terminated in the radio terminals allowing mixed media MS).

1.4 RPS type D

This RPS type refers to the radio repeater structure described in case b) of § 3.4.1.

When RPS is inserted at reference point B, all switching initiation criteria are derived from the RSPI.

When it is required that radio repeaters are equivalent to SDH optical regenerators (see § 3.4.1), the link connection made up of several radio hops is considered a single regenerator section. The cumulative performance monitoring information is made available from the ROHA function.

APPENDIX 4

TO ANNEX 1

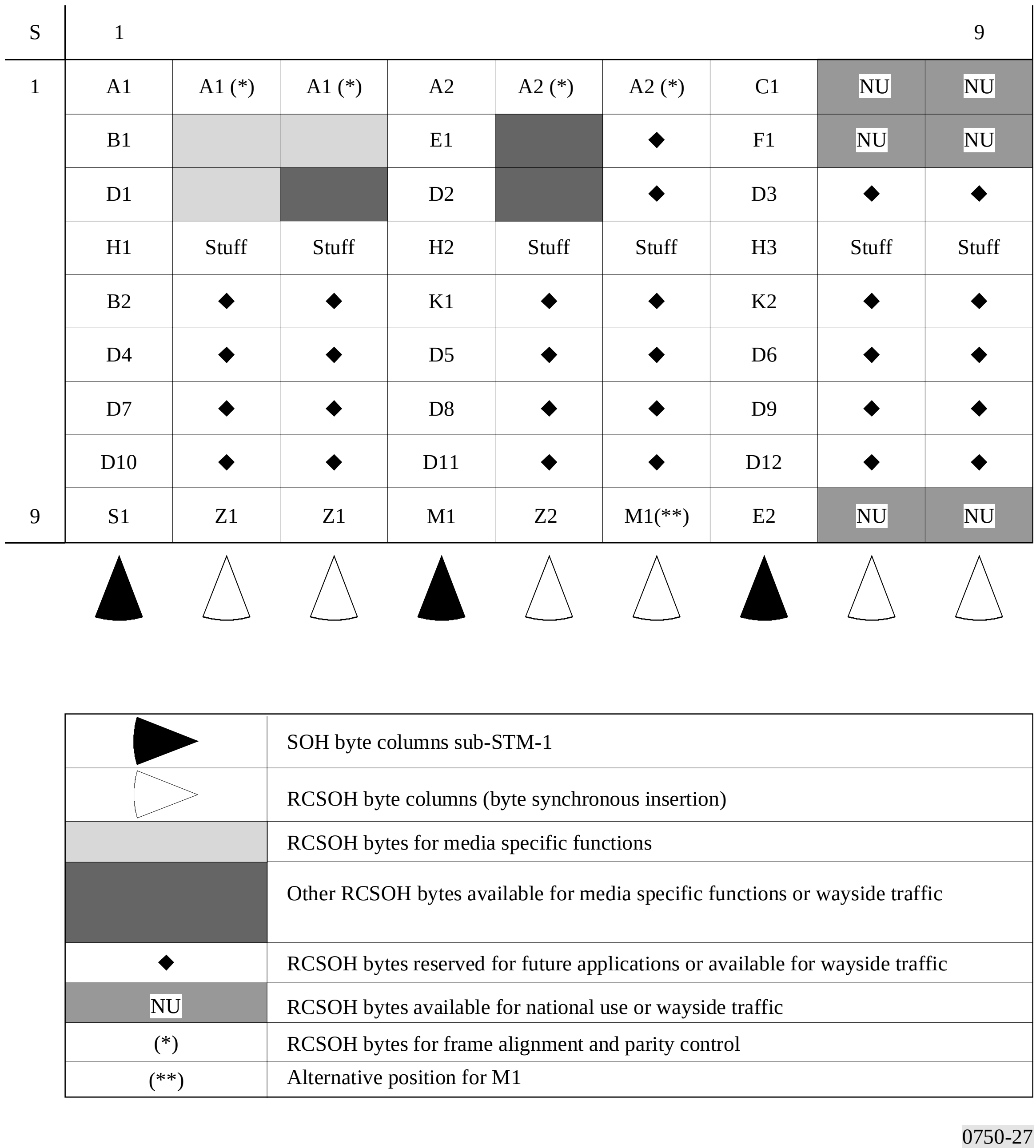
Transmission of media-specific functions of sub-STM-1 DRRS through radio complementary section overhead (RCSOH)

The transmission of media-specific functions in sub-STM-1 DRRS may be accomplished by the transmission as a well identified case of RFCOH of a full STM-1-like SOH format, in which six columns may be regarded as a byte synchronous radio complementary section overhead (RCSOH); also in this way other STM-1 standardized functions (e.g. national use bytes or M1 byte) may be transported.

For this solution Fig. 27 shows an example of possible usage of the bytes.

FIGURE 27

Mixed SOH and RCSOH for sub-STM-1 (full STM-1 compatibility)



APPENDIX 5

TO ANNEX 1

Examples of additional primitives for operation and maintenance purpose of RSPI/RR-RSPI, RPS and ROHA functional blocks

This Appendix reports an example of additional primitives which are possibly reported through interfaces S50, S51 and S52 for RPS operation or maintenance purpose.

1 RSPI additional primitives

When applicable the following optional command, configuration and provisioning on a "GET" or "SET" basis as reported in Table 4 may be provided.

TABLE 4

Command, configuration and provisioning information flow over S reference points

S reference point	GET	SET
S50 (RSPI)	ATPC status	ATPC enable
	Transmitted level	
	Received level	

1.1 Received level request

Returns the received power level at reference point R detected by the RX-function. When a single receive-function comprises more than one RX-function for diversity redundancy, the received level request will address each RX-function for return of its detected received power level.

1.2 ATPC status

Returns the ATPC status of the TX-function as "ATPC implemented/not implemented" and "ATPC enabled/disabled".

1.3 ATPC enable

Command to enable/disable ATPC for the TX-function, provided when ATPC is implemented.

1.4 Transmitted level request

Returns the monitored transmitter output power at reference point R for the TX-function.

2 Supervisory switching initiation primitives

The following switching initiation criteria (see Table 5) may represent a complete set of practical cases.

TABLE 5

Example of switching initiation criteria

Priority	RPS request
1 (higher)	Lockout
2	Forced switch
3	Autoswitch signalfail (SF)
4	Autoswitch highBER (HBER)
5	Autoswitch lowBER (LBER)
6	Autoswitch earlywarning (EW)
7	Manual switch
8	Exercise

The use of some of the autoswitch requests is conditioned by the logical allocation of the RPS function. Depending on implementation, switching initiations coming from functional blocks (e.g. MSA and/or MST) logically allocated outside the RPS section are not applicable.

For RPS without hitless capability autoswitch LBER and EW requests are optional.

Lockout

Lockout RPS request is applicable to a working and to a protection channel. In the first case it prevents a working channel from being protected and in the second case it prevents a protection channel from being used for protection. Lockout RPS request is generated by command from the local F interface (local lockout) or from the Q interface by TMN/OS (remote lockout) and is consequently forwarded to the RPS function by the MCF and SEMF functions via management reference point S51.

Forced switch

Forced switch RPS request is generated by command from the local F interface (local forced switch) or from the Q interface by TMN/OS (remote forced switch) and is consequently forwarded to the RPS function by the MCF and SEMF functions via management reference point S51.

Autoswitch signalfail

An autoswitch signalfail request may be generated by detection of a logical OR of the following defects: RSPI lossOfSignal and fails, A1/A2 LOF, MS-AIS, AU-AIS and LOP. Depending on the application a subset of these criteria could be used. Other proprietary indications that have an equivalent weight could also be used.

Autoswitch HBER and LBER

Autoswitch HBER and LBER RPS requests may be generated by excessive error and SD information respectively as derived from local MST. For RPS purposes equivalent HBER and LBER indications (as for example derived from the RSPI along the radio switching section with EW methodology) may alternatively be used as switch initiation criteria. The detection thresholds for HBER and LBER should, in this case, not be worse than the excessive error and SD thresholds respectively.

Autoswitch EW

An Autoswitch EW RPS request is generated by proprietary early warning threshold crossing detected by local or remote RSPI along the radio switching section. EW requests may be also generated by detection of a logical OR of different EW types.

Manual switch

Manual switch RPS request is generated by command from the local F interface (local manual switch) or from the Q interface by TMN/OS (remote manual switch) and is consequently forwarded to the RPS function by the MCF and SEMF functions via management reference point S51.

Exercise

Exercise is an optional RPS request which may be used to test the RPS function by initiating an RPS process without actual switching. Exercise may be initiated either by the local control terminal at the F interface or by TMN/OS at the Q interface and is consequently forwarded to the RPS function by MCF and SEMF functions via management reference point S51.

3 Supervisory switch restore primitives

The following switch restore criteria may represent a complete set of practical cases.

Priority	RPS switch restore request
1	Forced restore of a channel in protection
2	Automatic forced restore of a channel in protection
3	Automatic switch restore request from a channel in protection

Forced restore

Forced restore RPS request is generated by command from the local F interface (local forced restore) or from the Q interface by TMN/OS (remote forced restore), which is consequently forwarded to the RPS function by the MCF and SEMF functions via management reference point S51.

Automatic forced restore

Automatic forced restore of a channel in protection occurs when all protection channels are occupied and another working channel, with an RPS request priority higher than one of the currently protected working channels, requires access to protection channel. In this case the protected channel with the lowest RPS request priority will be restored to its normal working channel.

Automatic switch restore

The RPS automatic switch restore request occurs, for the channel in protection, as soon as none of the RPS requests are active in its corresponding regular working channel. Upon this request, the RPS functional block performs the switch restore.

4 RPS additional primitives

As for the MSP functional block the following maintenance primitives may be provided.

4.1 SWITCH STATUS

This indication reports the situation of alarm and commands active on RPS.

4.2 CHANNEL STATUS

This indication reports RPS request/failure (see § 3.3.2 switching initiation criteria) condition active in channel #.

Where the symbol # refers to the channel number identifier (# = 1....*n* or 1....*m*).

Table 6 reports the "GET" and "SET" command and configuration provisioning.

TABLE 6

Command, configuration and provisioning information flow over S reference points

S reference point	GET	SET
S51 (RPS)	SWITCH STATUS	
	CHANNEL STATUS	
		Lockout
		Forced switch
		Manual switch
		Exercise

5 ROHA primitives

The following primitives may be reported to interface S52, to SEMF alarm filtering, for service/wayside channel network maintenance:

– lossOfSignal#(in).

This indication reports the loss of input signal (TX side) for service/wayside channel number #.