

Technical Guide



ANNEX D

SKYPLEX

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1. Introduction

This module contains a description of the Skyplex system to be used on HOT BIRD™ 4 and HOT BIRD™ 5 for the first time. System operation will be demonstrated on HOT BIRD™ 4 using Channel 110 and the capability to initiate commercial operation will be available on HOT BIRD™ 5 using Channels 90, 91 and 92.

The Skyplex general architecture illustrating the principles of operation has been shown in Module 1 in Figure 4.8-1. Namely, Skyplex enables the uplinking of television, multimedia or Internet programming formatted as MPEG - 2 transport streams from independent, geographically dispersed locations; multiplexing them on-board the satellite; and transmitting them as a single signal in DVB (digital video broadcast) format to consumer receivers connected to a television set or personal computer. Thus, the received Skyplex signal is of an identical format to a DVB multiplexed on the ground and transmitted by HOT BIRD™ in a transparent mode.

As implied above, transmission schemes for the uplink and downlink are different, namely:

- On the uplink, stations access either in a continuous mode, referred to for convenience as SCPC, or in a TDMA mode. Both types of access are at a maximum transmission rate of the order of 6 Mbits/s.
- On the downlink, the single output stream transmitted by the satellite is a continuous TDM digital stream at 27.5 Msymbols/s (55 Mbits/s).

The following sections cover the system concept and architecture, the transmission rates and access modes, network control and monitoring (including a description of the ground station) and service data handling.

2. System Concept and Architecture

As mentioned above, the processing carried out by the Skyplex system (ground and satellite) is such that the satellite transmitted Skyplex DVB downlink signal is indistinguishable from any DVB TDM stream multiplexed on the ground and transmitted (transparently) on a single carrier through a full satellite transponder.

The processing for a transparent DVB satellite transmission is shown in *Figure 1*. Thus, as shown, the different uplink signals in MPEG-2 transport stream format are multiplexed, scrambled, undergo outer encoding, interleaving and inner encoding, are QPSK modulated and uplinked to the designated RF satellite channel.

To achieve the same DVB result, the Skyplex multiplexing structure has been adapted with some functions performed on the ground by the uplink earth stations and the complementary functions performed on-board the satellite. The Skyplex architecture showing the functional split between ground and satellite processing is shown in *Figure 2*.

The salient features of the Skyplex architecture include:

- The on-ground functions include transport packet generation and multiplexing, Reed-Solomon outer encoding, Short Energy Dispersal (SED) scrambling and QPSK modulation. The on-board functions include demodulation of each Skyplex channel, SED descrambling, multiplexing, Modified Energy Dispersal (MED) scrambling, Viterbi inner encoding and QPSK modulation.
- An MPEG - 2 transport stream is composed of transport packets, each packet containing 184 bytes of payload data and 4 bytes of header data. The MPEG-2 transport stream structure is shown in *Figure 3*. (Note that the 204 byte DVB packet, referred to below, includes the additional 16 bytes for Reed-Solomon encoding.)

In the case of Skyplex, the generation of transport packets is performed independently on the ground for each uplink transport stream. As shown in *Figure 4*, Packet Elementary Streams (PES) of video, audio and data are multiplexed on the ground in a transport multiplexer for uplink transmission. A limited number of fixed transmission rates is available for each uplink stream. Thus, a simple on-board packet multiplexer, as shown in *Figure 4*, creates the high rate downlink transport stream.

For Skyplex, there are either 6 (HOT BIRD™ 4) or 8 (HOT BIRD™ 5) channels within the 33 MHz transponder bandwidth, each accommodating a continuous transport stream transmitted by a single uplink station (SCPC access) or a number of transport streams operating in burst mode (TDMA access) from a set of uplink stations. An example of the HOT BIRD™ 5 Skyplex channelization is shown in *Figure 5*.

For each uplink transport stream, the Reed-Solomon encoding is performed (on-ground) on an MPEG - 2 packet basis to protect against both uplink and downlink generated errors. In order to enhance system availability assuming simultaneous fades on the different uplinks and downlinks, a relatively low target worst case BER of 10^{-5} has been chosen since there is no error correction on the uplink.

The integrity (or availability) of the individual programme streams in the downlink multi-programme stream is maintained irrespective of the (availability or unavailability) of other uplink programme streams.

The SED scrambling function (performed on the ground) has a scrambling sequence with a length of 203 bytes, (one DVB packet excluding the clear sync byte), for robust uplink synchronisation. After on-board demodulation, the energy dispersal produced by the SED scrambler is removed on-board using an appropriate descrambler, as shown in *Figure 2*.

As shown in *Figure 2*, the Energy Dispersal Scrambling is performed on-board and hence follows Reed-Solomon encoding, while in the transparent DVB transport scheme it is performed prior to Reed-Solomon encoding (*Figure 1*). Hence, a Modified Energy Dispersal (MED) scrambling algorithm has been developed which provides a fully DVB compliant result.

Programme Specific Information, Service Information and Conditional Access related data are passed transparently through the Skyplex on-board payload. This facilitates independent encryption using different encryption systems or clear programming from the various uplink sites.

3. Transmission Rates and Access Modes

The Skyplex system provides DVB compatible broadcasting services delivered to the end user by means of a high rate digital multiprogramme stream of 27.5 Msymbols/s. The available user access rates can cater for the different services envisaged including TV, multimedia services, Internet applications, sound broadcasting, etc. Thus, these rates vary from around 6 Mbits/s to a few hundred kilobits/s in TDMA mode.

The Skyplex transmission parameters are shown in Table 1 for both HOT BIRD™ 4 and HOT BIRD™ 5. As mentioned above, access is both in continuous mode (SCPC) and in burst mode (TDMA). The TDMA mode offers the flexibility such that a full Skyplex channel may be shared by up to 6 uplink stations and in unequal proportions.

As shown in *Figure 5*, the Skyplex units on HOT BIRD™ 4 and HOT BIRD™ 5 operate over a 33 MHz bandwidth with a maximum (for HOT BIRD™ 5) of 8 carriers per 33 MHz channel, as shown. The Skyplex carrier spacing is defined in *Table 1* including only high rate carriers (RH) for HOT BIRD™ 4 and high rate plus low rate (RL) carriers for HOT BIRD™ 5.

3.1. SCPC Mode

Based upon the Skyplex scheme for DVB compatible transmission, the uplink information bit rates are adjustable within the limit of the downlink transport stream symbol rate (R_{dw}) of 27.5 Msymbols/s, the number of active uplink channels and the selection of the convolutional coding rate (FEC).

For HOT BIRD™ 5, two classes of information rate are defined in the SCPC mode. These include ‘high data rates’ (RH) at approximately 6 Mbits/s and ‘low data rates’ (RL) at approximately 2 Mbits/s. For HOT BIRD™ 4, only the high data rates are available.

The exact RH and RL rate values may be deduced from the following equation:

$$R_{dw} = (N_H * R_H + N_L * R_L) * (204/188) * (1/2r)$$

where RL is fixed at 2.112 Mbits/s

r = the FEC rate

NH = the number of ‘high data rate’ active channels

NL = the number of ‘low data rate’ active channels

204/188 = the Reed-Solomon expansion ratio

Note that $N_L = 0$ for HOT BIRD™ 4.

Table 2 provides the total number of permissible configurations of high and low information data rate channels for HOT BIRD™ 5. These rates apply for both SCPC and TDMA access modes. As noted in *Table 2*, for HOT BIRD™ 4, only the 4 configurations without the low data rates are available.

Note that the corresponding Skyplex uplink transmitted rates are equal to those in *Table 2* multiplied by the Reed-Solomon encoding ratio of (204/188). Thus, for example, the 6.336 Mbits/s information rate becomes a 6.875 Mbits/s uplink transmitted rate. As a symbol rate, it is 3.438 Msymbols/s (at the on-board demodulator input).

3.2. TDMA Mode

Each HOT BIRD™ 5 Skyplex carrier may be independently shared by 1, 2, 3, 4 or 6 uplink stations, referred to in *Table 3* as TDMA modes. For HOT BIRD™ 4, Mode 1 is not available, as noted.

The Skyplex TDMA uplink frame organisation is shown in *Figure 6*. The uplink TDMA frame is constant for all modes and is uniquely defined as the equivalent time for the on-board multiplexer to transmit 48 consecutive DVB packets from a given Skyplex channel. (Note that, as mentioned above, a DVB packet is 204 bytes in length.) As shown, the equivalent time of 4 DVB packets is allocated for guard time and a carrier and clock recovery (CCR) plus unique word (UW) sequence for demodulator synchronisation purposes.

The uplink transmitted TDMA bit rates (RTDMA) are equal to those in *Table 2* multiplied by the Reed-Solomon ratio of 204/188 and the TDMA overhead ratio given as:

$$\text{RTDMA} = \text{RSCPC} * 52/48 .$$

This relationship is independent of the TDMA mode since the frame length is constant. Hence, the overhead ratio of 52/48 (or 8% of overhead) is constant. The burst length depends on the number of active TDMA stations. *Table 3* provides the number of useful DVB packets per burst and the TDMA overhead times as a function of TDMA mode.

4. Network Control and Monitoring

The Skyplex overall system management and operational integrity is enabled by a number of different control and monitoring functions. These involve the participation of the Skyplex ground stations and the Skyplex on-board units. In addition, certain service information required by the eventual user is managed by a Service Information Management Server (SIMS) and this is described in *section 5*. below.

The Skyplex system defines three levels of control and monitoring of network operations. These include:

- Level 1 - This concerns the Skyplex unit as an equipment and its interfaces (RF, power, thermal, etc.) with the HOT BIRD™ spacecraft.
- Level 2 - This concerns the implementation and monitoring of the Skyplex unit configuration for the service in use (code rate selection, TDMA operational mode, etc.)
- Level 3 - This is a subset of Level 2 parameters of direct interest to the uplinking earth stations.

A review of the control and monitoring functions will be given below. Initially, the Skyplex ground station will be described.

4.1. Skyplex Ground Station

Although the principal use of the Skyplex ground station is to uplink the program material for diffusion by the HOT BIRD™ satellite, it must also receive the downlink stream in order to access, synchronise, update, etc. and generally monitor its transmissions in order to assure its correct operation within the Skyplex system. This includes the functions reviewed above including transport stream multiplexing, Reed-Solomon encoding, scrambling, TDMA processing (if used), QPSK modulation and RF transmission.

The reception path involves the demodulation, decoding, de-interleaving and descrambling necessary to provide the required information to the control and monitoring unit and the Service Information Processing and Control Unit.

The control and monitoring unit performs the following functions:

- The reception and processing of network control information such as the selection of the transmission frequency channel, the selection of the information bit rate on command from the network operator, etc.
- The reception and processing of programme provider information based on the data in the downlink transport stream. This includes telemetry packet extraction, interrogation packet generation and dummy packet extraction. The use of these elements is explained below.
- TDMA frame acquisition and synchronisation is applicable.
- Measurement and diagnostic functions (i.e. BER measurement).

The Service Information Processing and Control Unit generates PSI/SI data both internally and also sends requests to the SIMS for PSI/SI updates based on the reception of the downlink transport stream.

Note also that the Short Energy Dispersal (SED) scrambler consists of a Pseudo Random Binary Sequence (PRBS) generator whose scrambling sequence length is 203 bytes (i.e. the Reed-Solomon 204 code block less the sync byte). The MPEG-2 sync byte (unscrambled) initialises the PRBS generator. As mentioned earlier, the short length is selected for robust synchronisation in the presence of a high BER (10^{-5}).

4.2. Skyplex Control, Monitoring and Coordination Functions

EUTELSAT, as the satellite operator, configures, controls and monitors the Skyplex on-board units and its interfaces with the rest of the HOT BIRD™ satellite using the satellite telemetry and command functions. This is the Level 1 function mentioned earlier.

In addition, the system configuration for the targeted service constitutes the Level 2 function. This also involves the telemetry and command data.

Finally, the Level 3 functions provide operational type coordination and monitoring and are implemented by the insertion of dummy/telemetry packets into the downlink transport stream by the on-board units, by the insertion of interrogation packets into the uplink stream by the ground stations and by the insertion of service related information into the upstream by the SIMS.

The Level 1 telecommand functions include for each unit such items as Skyplex switch selection (operational or bypassed), Skyplex unit on/off and Skyplex unit redundancy selection. The Level 1 telemetry functions include the switch status and payload/bus parameters such as temperature, power, etc.

The Level 2 telecommand functions include the selection of the FEC coding rate, the selection of the active Skyplex channels and their redundant demodulators and the selection of the operational mode of each active channel (i.e. SCPC or TDMA and TDMA mode). The Level 2 telemetry includes the status of the various telecommands; the input amplifier gain, input power measure, carrier and clock recovery loop status and input buffer status for each Skyplex channel.

The Level 3 functions include enhanced Coordination and Monitoring Functions (CMF) which are implemented both on-board and on-ground. On-board, they permit the monitoring of each uplink chain independently through a set of measured parameters such as power, frequency offset, burst arrival time (for TDMA) and synchronisation byte control. These functions are provided by the use of specific CMF packets within the uplink and downlink streams which are identifiable by their PID (packet identification descriptor) values or numbers within the packet header (*Figure 3*).

These include:

- Dummy Packets- These have a PID value specific to each uplink Skyplex channel and are inserted at unit start-up and recovery of any individual uplink. The dummy packets always contain the latest telemetry data.

In the case of the absence of a valid sync byte or signal loss on one or more channels operating in SCPC or TDMA mode, dummy packets are inserted to replace the invalid packets.

When a Skyplex channel is configured in TDMA mode, the on-board unit (multiplexer) immediately inserts dummy packets defining a virtual TDMA frame in the downlink stream. The earth stations monitor the frame reference to accomplish frame acquisition and control frame synchronisation.

- Interrogation Packets- These have a unique Packet Identification Descriptors (PID) and are inserted by each requesting station within its own uplink transport stream for the monitoring of its uplink transmissions. The Skyplex multiplexer responds to these packets and generates telemetry packets with appropriate telemetry /status (alarm) data which are therefore available on the downlink transport stream.

4.3. Skyplex Network Synchronisation

The Skyplex system is designed so that the on-board master clock defines system timing and synchronisation. Each uplink station slaves its data transmission clock to the downlink transport stream data rate. Thus, no reference earth station is required and no timing and phase coordination between uplink stations is needed either in SCPC or TDMA modes during the acquisition of synchronisation states. The on-board processor coherently demodulates and independently buffers the received transport streams. The on-board demodulators tolerance to frequency variations is adequate to cover earth station overall Doppler shifts.

4.3.1. SCPC Synchronisation

Once the Skyplex system is configured, the number of operating Skyplex channels is fixed.

At system start-up, or following a reconfiguration, and/or during recovery of any individual uplink, the on-board unit inserts dummy packets in order to provide continuity in the transmitted downlink stream. Each new earth station accessing in SCPC mode, may start transmitting by replacing the dummy packets (identified by the PID assigned to the specific Skyplex channel) with the uplink program packets.

The on-board received packets are checked for the correct sync byte and once 5 consecutive correct packets are detected, the uplinked packets are normally multiplexed and transmitted. A sequence of 5 invalid packets triggers the generation of dummy packets.

Each station monitors its transmission by regularly transmitting interrogation packets (as mentioned above). The on-board unit substitutes telemetry packets for the interrogation packets, the ground station monitors the relevant system performance and can initiate corrective action if necessary.

4.3.2. TDMA Synchronisation

Uplink stations accessing the Skyplex system in TDMA mode have to be synchronised since there may be up to 6 stations sharing each TDMA frame of 48 useful packets (*Figure 6*). The TDMA acquisition and synchronisation is performed using a telemetry assisted loopback process. The process includes an initial earth station TDMA frame and assigned position acquisition (using dummy packets), an uplink short burst terminating in an interrogation packet, an on-board unit measurement of the burst position relative to the virtual TDMA frame, the earth station reception of the looped back burst and its determination of the burst arrival time at the satellite and a correction of its position accordingly.

During synchronisation, earth stations track frame variation by periodically sending interrogation packets to measure burst arrival time. An interrogation packet sent every 10 seconds is sufficient to assure that the probability of burst collision due to satellite motion is negligible.

5. Service Data Handling

Service Information (SI) and Program Specific Information (PSI) are service related data necessary for the user (consumer) to perform automatic tuning and to present user-friendly information such as program name, program duration and facilitate conditional access. These data require continuous transmission (for random access) and thus necessitate centralised management.

For each Skyplex unit, a unique Skyplex ground station, the SI Management Server (SIMS) is responsible for the on-ground compilation, storage and playback of PSI/SI data as specified by the MPEG-2/DVB standards. As shown in *Figure 7*, the concerned uplink stations send their requests to the SIMS to update the PSI/SI data pertaining to their service. The requests are sent within the uplink transport streams in private packets with special PID designations.

The SIMS processes the requests from different clients to compile the SI/PSI structures. These include Program Association Tables, Conditional Access Tables, Service Description Tables, Event Information Tables, etc. The SIMS informs the client, via the downlink transport stream, that an update has taken place (i.e. that the above mentioned tables contain his updated information).

Parameter	HOT BIRD™ 4	HOT BIRD™ 5	
Satellite Channels (33 MHz)	110 (18.11918 GHz)	90 (14.15344 GHz), 91 (14.17262 GHz), 92 (14.19180 GHz)	
Access Scheme	SCPC or TDMA	SCPC or TDMA	
Max No. of Skyplex Channels	6	8	
Centre Frequencies wrt Transponder Centre Frequencies	$\pm 2.75, \pm 8.25, \pm 13.75$ MHz	RH $\pm 2.75, \pm 8.25, \pm 13.75$ MHz	RL as for RH and at -4.583 MHz and -0.917 MHz
Nominal Input Signal Flux Density per Ch.	- (95.7 + G/T) dBW/m ²	- (91 + G/T) dBW/m ²	- (95 + G/T) dBW/m ²
Input Flux Density Dynamic Range per Ch.	- (105.7 + G/T) to - (94.7 + G/T) dBW/m ²	- (106 + G/T) to - (86 + G/T) dBW/m ²	
Downlink Transmission Rate	27.5 Msymbols/s	27.5 Msymbols/s	
Information Bit Rate per Uplink Channel	See Table 2	See Table 2	
No. of Uplink Stations Sharing TDMA Mode	2, 3, 4 or 6	1, 2, 3, 4 or 6	
TDMA Frame Organization	See Table 3	See Table 3	

Table 1: Skyplex Transmission Parameters

FEC	NH * RH	NL * RL
r = 3/4	6 * 6.336	0
	5 * 6.336	3 * 2.112
r = 2/3	6 * 5.632	0
	5 * 6.758	0
	4 * 6.336	4 * 2.112
r=1/2	4 * 6.336	0
	3 * 6.336	3 * 2.112
	2 * 6.336	6 * 2.112

Table 2: HOT BIRD™ 5 Information Bit Rates per Uplink Skyplex TS Channel (Mbits/s)

Note: Only the 4 configurations without low data rates (RL) are available on HOT BIRD™ 4.

TDMA Mode	Number of Stations (bursts) per Frame	Number of Useful DVB Packets per Burst (K)	Burst Overhead in Number of DVB Packets (λ)
1	1	48	4
2	2	24	2
3	3	16	1.33
4	4	12	1
6	6	8	0.667

Table 3: HOT BIRD™ 5 TDMA Frame Organisation

Note: Mode 1 is not available on HOT BIRD™ 4.

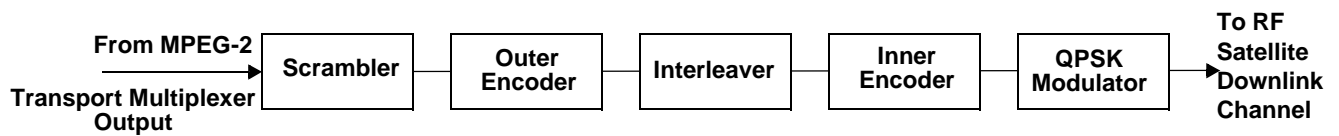


Figure 1 : DVB Satellite Channel Adaptation

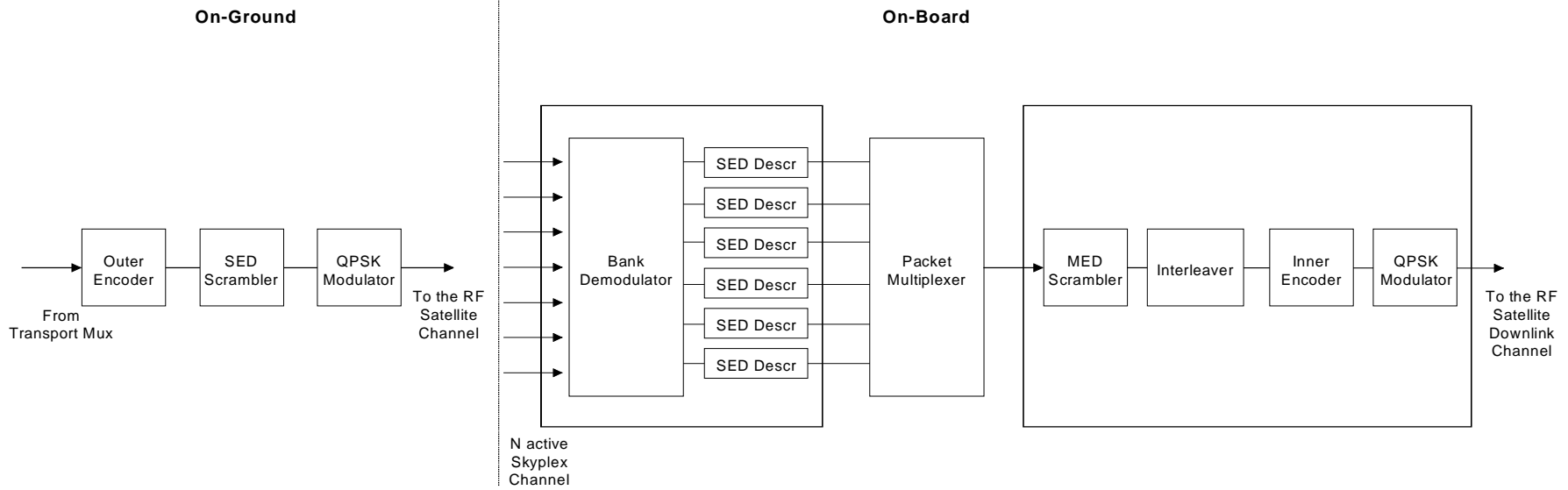


Figure 2 : DVB Satellite Channel Adaptation for Skyplex

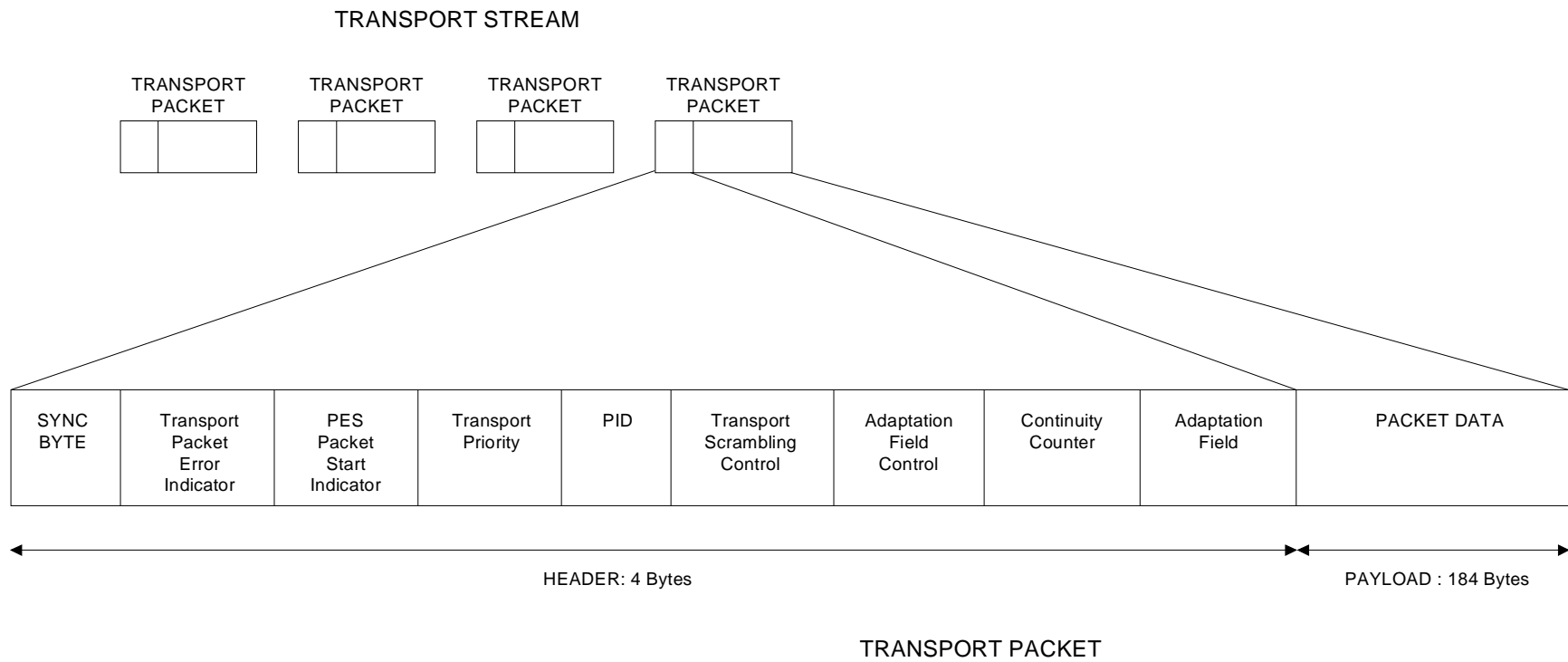


Figure 3 : MPEG-2 Transport Stream

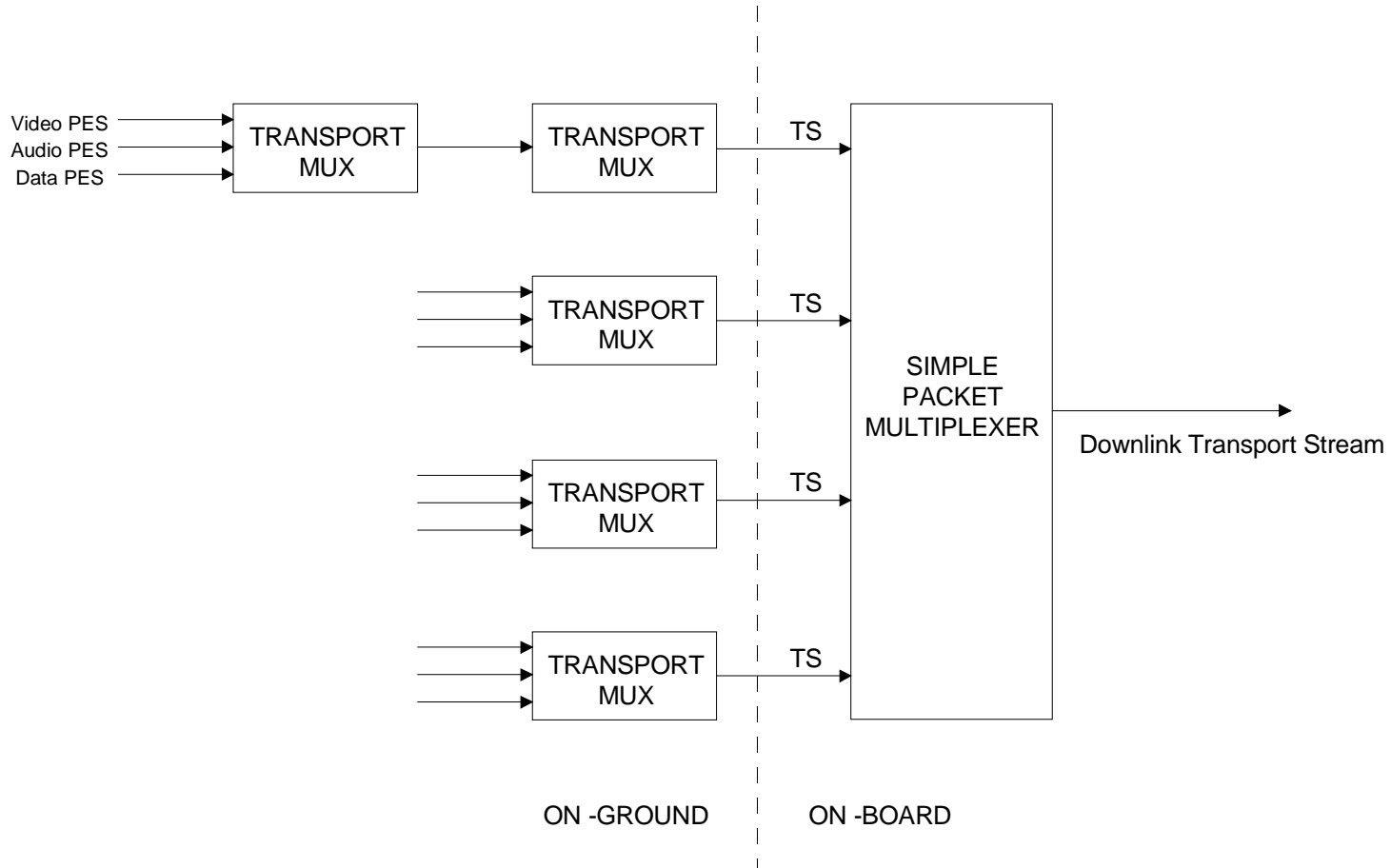


Figure 4 : Skyplex System: Multiplexing

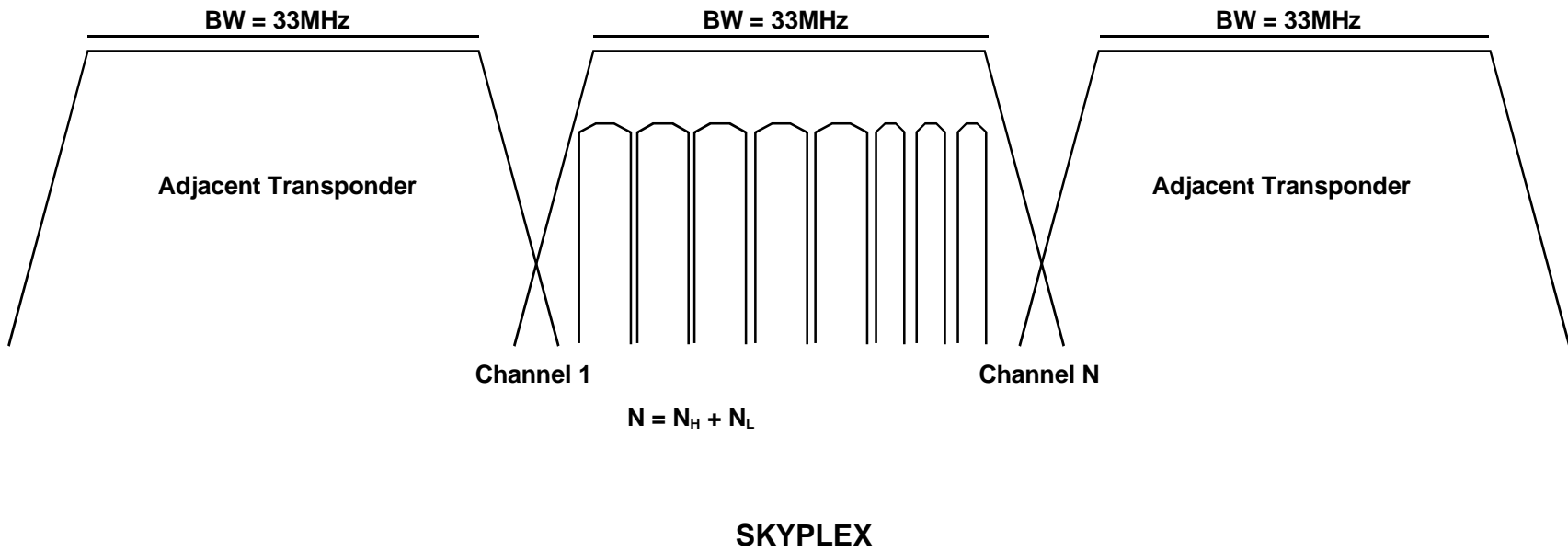


Figure 5 : Example of Skyplex Uplink Channelisation per Transponder

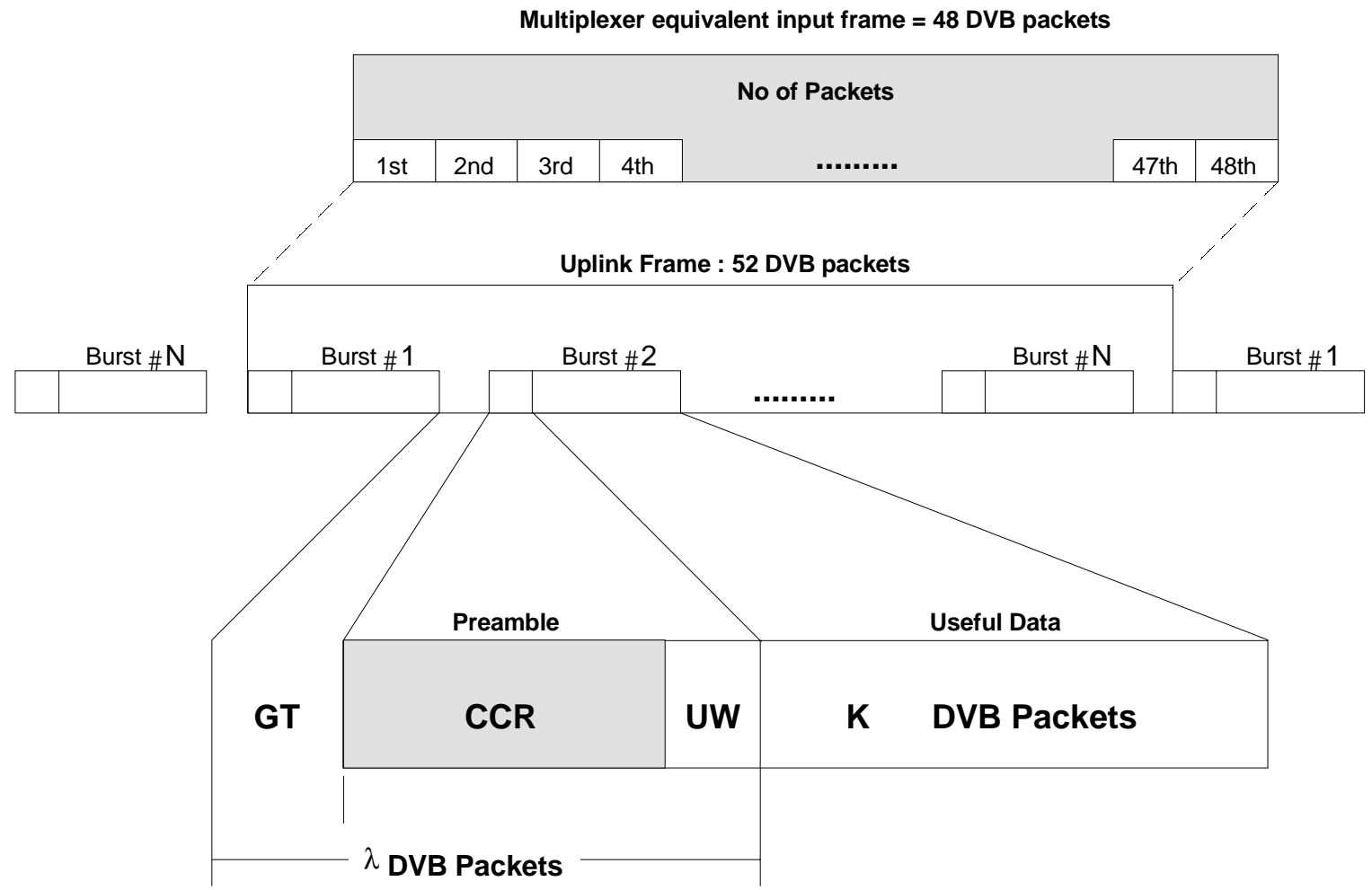


Figure 6 : Skyplex TDMA Uplink Frame Organisation

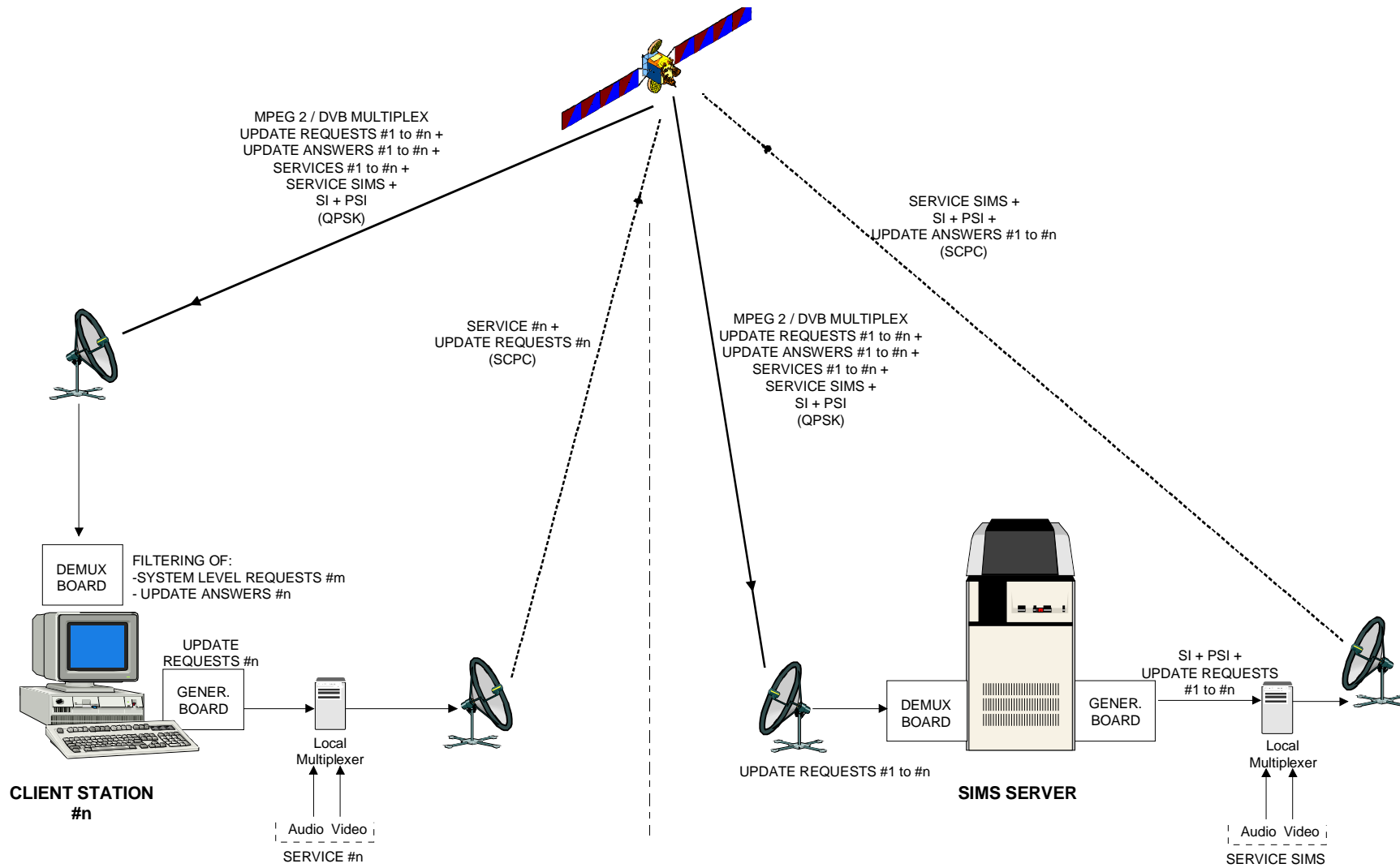


Figure 7 : Skyplex Network Management

6. Contact Details

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