

j) that the World Administrative Radio Conference (Malaga-Torremolinos, 1992) (WARC-92) allocated the band 1 452-1 492 MHz to the BSS (sound) and complementary terrestrial broadcasting service for the provision of DSB. Also, additional footnote allocations were included for specific countries in the band 2 310-2 360 MHz and in the band 2 535-2 655 MHz in Radio Regulations (RR) Nos. 5.393 and 5.418,

noting

- a) that a summary of the digital systems that allow hybrid operation is presented in Annex 1;
- b) that condensed system descriptions for Digital System D_H and E are given in Annexes 2 and 3;
- c) that complete systems descriptions of Digital System D_H and E are contained in the DSB Handbook,

recommends

1 that administrations that wish to implement hybrid satellite/terrestrial DSB services meeting most or all of the requirements as stated in Recommendation ITU-R BS.774 should consider either of the two Digital Systems, D_H or E, using Table 1 to evaluate their respective merits. (see Note 1). This should be done in conjunction with the consideration of Recommendation ITU-R BO.1130 for the satellite portion in view of the selection of an overall hybrid BSS (sound) system.

NOTE 1 – Technology in this area is developing rapidly. Accordingly, if additional systems meeting the requirements given in Recommendation ITU-R BS.774 are developed, they may also be recommended for use when brought to the attention of the ITU-R. Administrations engaged in the development of DSB systems should make efforts to bring about, as much as possible, harmonization with other systems already developed or currently under development.

TABLE 1

Performance of Digital Systems D_H and E evaluated on the basis of the recommended technical and operating characteristics listed in Recommendation ITU-R BS.774

Characteristics from Recommendation ITU-R BS.774 (condensed wording)	Digital System D _H	Digital System E
1. Range of audio quality and types of reception	Range is from 16 kbit/s to 128 kbit/s per audio channel in increments of 16 kbit/s. Each 16 kbit/s increment can be split into two 8 kbit/s services. MPEG-2 and MPEG-2.5 Layer III audio coding are used. The system is intended for vehicular, portable and fixed reception	Range is from 16 kbit/s to 320 kbit/s per audio channel in any increment size. MPEG-2 AAC audio coding is used. The system is intended for vehicular, portable and fixed reception

TABLE 1 (*continued*)

Characteristics from Recommendation ITU-R BS.774 (condensed wording)	Digital System D _H	Digital System E
2. Spectrum efficiency better than FM	FM stereo quality achievable in less than 200 kHz bandwidth; co-channel and adjacent channel protection requirements much less than that for FM. (QPSK modulation with concatenated block and convolution error correcting coding)	FM stereo quality achievable in less than 200 kHz bandwidth; co-channel and adjacent channel protection requirements much less than that for FM. (CDM based on QPSK modulation with concatenated block and convolutional error correcting coding)
3. Performance in multipath and shadowing environments	The system is a hybrid satellite/terrestrial system designed for diversity reception of a TDM signal via satellite complemented by a terrestrially retransmitted MCM signal. MCM is especially designed for multipath operation. It works by power summing the echoes falling within a given time interval	System is especially designed for multipath environment. It works on the basis of receiving power summation of multipath using a RAKE receiver. This feature allows the use of on-channel repeaters to cover shadowed areas. Also, more than 1 s blackout will be recovered using segmented convolutional bit wise interleaver
4. Common receiver signal processing for satellite and terrestrial broadcasting	Receivers are being developed for TDM-MCM reception in urban environments, including mobile applications. A TDM-MCM signal is radiated from terrestrial transmitters that repeat the satellite TDM. Circular polarization is used for satellite reception, vertical for terrestrial. External antennas are used for mobile	This system is based on the simultaneous reception from both satellite and complementary on-channel repeaters. Allows the use of the same receiver, from the RF front end to the audio and data output Adoption of MPEG-2 systems achieves maximum interoperability among the same kind of digital broadcasting receivers, e.g. ISDB-S, ISDB-T, and DVB-T, DVB-S through using future interconnection mechanism, i.e. IEEE1394

TABLE 1 (continued)

Characteristics from Recommendation ITU-R BS.774 (condensed wording)	Digital System D _H	Digital System E
5. Reconfiguration and quality vs. number of programme trade-offs	A flexible 16 kbit/s building block multiplex is employed. Up to 8 blocks can be assigned to each broadcast channel in order to trade off programme audio quality against number of services. Assignment to services is dynamically adjustable. FM-quality audio achieved at 64 kbit/s. All blocks are error protected. Data service transports streamed data and data packets	Multiplexing of payload data is based on MPEG-2 systems. Audio data rate can be selected in any step in order to trade off programme audio quality against the number of services. Higher-data rate service is possible using more than one CDM channel per programme audio stream
6. Extent of coverage vs. number of programme trade-offs	The system is optimized for diversity reception from satellite(s) and terrestrial repeaters. The trade off between extent of coverage and system throughput is fixed	Data rate of single CDM channel can be selected from 236 kbit/s to 413 kbit/s through using punctured convolutional coding. (Code rate can be selected from 1/2, 2/3, 3/4, 5/6 or 7/8)
7. Common receiver for different means of programme delivery:		
– Mixed/hybrid	– Allows hybrid use of satellite and complementary terrestrial transmissions in the bands allocated for BSS (sound) by WARC-92. A common receiver will receive the satellite TDM and the terrestrial MCM emissions that reinforce the satellite emissions.	– Allows the use of the same band as terrestrial sound broadcasting (mixed) as well as the use of terrestrial on-channel repeaters to reinforce the satellite coverage (hybrid) resulting in all these channels being received transparently by a common receiver.
– Terrestrial augmentations	– Allows local, subnational and national services with TDM-MCM modulation in terrestrial SFNs and TDM-QPSK in satellite line-of-sight via a common receiver.	– Allows local, subnational and national terrestrial services with the same modulation with a single transmitter or multiple transmitters operating in a SFN to take advantage of a common receiver.
– Cable distribution	– Signal can be carried transparently by cable	– Signal can be carried transparently by cable

TABLE 1 (*end*)

Characteristics from Recommendation ITU-R BS.774 (condensed wording)	Digital System D _H	Digital System E
8. PAD capability	PAD comprising text (dynamic labels) and graphics with conditional access control can be delivered	PAD multiplexing is based on MPEG-2 systems. Data services are available using any CDM channel and a part of CDM channel
9. Flexible assignment of services	The multiplex can be dynamically re-configured in a fashion transparent to the user	The multiplex can be dynamically re-configured in a fashion transparent to the user
10. Compatibility of multiplex structure with OSI	Multiplex structure is compatible with the OSI layered model	The system multiplex structure is fully compliant with MPEG-2 systems architecture
11. Value-added data capability	Capacity in increments of 8 kbit/s up to the full 1.536 Mbit/s capacity of the TDM can be assigned to independent data for the delivery of business data, paging, still pictures graphics etc. under conditional access control if desired. A data connector is provided on the receivers for interfacing to information networks	Capacity at any rate up to the full payload capacity (depends on the number of CDM channels multiplexed) can be assigned to independent data for the delivery of business data, paging, still pictures graphics etc. under conditional access control if desired
12. Receiver low-cost manufacturing	The satellite and MCM-TDM signal reception and digital processing will be embedded in microchips suitable for mass production	The system was specifically optimized to enable an initial low complexity vehicular receiver deployment. Standardization group has been established to achieve low cost receivers based on large scale integration mass production techniques

AAC: advanced audio coding
 CDM: code division multiplex
 DVB: digital video broadcasting
 FM: frequency modulation
 IEEE: Institute of Electrical and Electronics Engineers
 ISDB: integrated services digital broadcasting
 MCM: multi-carrier modulation
 MPEG: Moving Pictures Experts Group
 OSI: open system interconnection
 PAD: programme associated data
 QPSK: quadrature phase shift keying
 RF: radio frequency
 SFN: single frequency network
 TDM: time division multiplex

ANNEX 1

Summaries of digital systems**1 Summary of Digital System D_H**

Digital System D_H, also known as the hybrid satellite/terrestrial WorldSpace system, is designed to provide satellite digital audio and data broadcasting for vehicular, fixed and portable reception by inexpensive common receivers. The satellite delivery component of Digital System D_H is based on the same TDM broadcast channel transport used in Digital System D_S but with several significant enhancements designed to improve line-of-sight reception in areas partially shadowed by trees. These enhancements include fast QPSK phase ambiguity recovery, early/late time diversity and maximum likelihood combination of early/late time diversity signals.

It extends the system structure of Digital System D_S by adding the terrestrial delivery system component based on MCM. MCM is a multipath-resistant orthogonal frequency division multiplex (OFDM) technique that has gained wide acceptance for pervasive mobile reception from terrestrial emitters. The MCM extension improves upon the techniques which are common in systems such as Eureka 147, which is one standard utilized for terrestrial microwave digital audio broadcast services. MCM utilizes multiple frequencies to avoid frequency selective fades to avoid deleterious effects of delay spread.

2 Summary of Digital System E

Digital System E, also known as the Association of Radio Industries and Businesses (ARIB) system, is designed to provide satellite and complementary terrestrial on-channel repeater (hybrid) services for high quality audio and multimedia data for vehicular, portable and fixed reception. It has been designed to optimize performance for both satellite and terrestrial on-channel repeater service delivery in the 2630-2655 MHz band. This is achieved through the use of CDM based on QPSK modulation with concatenated block and convolutional error correcting coding. The Digital System E receiver uses state-of-the-art microwave and digital large-scale integrated circuit technology with the primary objective of achieving low-cost production and high-quality performance.

ANNEX 2

Digital System D_H**1 Introduction**

Digital System D_H, also known as the hybrid satellite/terrestrial WorldSpace system, is designed to provide satellite digital audio and data broadcasting for vehicular, fixed and portable reception by inexpensive common receivers. It extends the system structure of Digital System D_S, described in Recommendation ITU-R BO.1130. Digital System D_S was designed to optimize performance

for satellite delivery using coherent QPSK modulation with block and convolutional coding, and non-linear amplification at travelling wave tube amplifier (TWTA) saturation. It is now operating over Africa using the WorldSpace AfriStar satellite at 21° East and over Asia using the AsiaStar satellite at 105° East. The system provides for a flexible TDM of digitized audio and data sources to be modulated onto a downlink TDM carrier, and uses a hierarchical multiplex structure of three layers (physical, service and transport) that conforms to the OSI Model as recommended in Recommendation ITU-R BT.807.

Since the launch of AfriStar in October 1998 Digital System D_S system has been delivering a satellite direct digital broadcast service over Africa. With the launch of AsiaStar in March 2000 the same service has started over Asia. Both satellites are delivering direct digital broadcast signal reception with very high margins of 4 to 13 dB within their outer beam coverage contour areas of 28 million km². Digital audio signals are being uplinked to transparent and processing payloads from diversely located uplink earth stations in the satellite global beams and broadcast via AfriStar over three 5.7° to 6° width beams covering Africa and the Middle East, and three more beams via AsiaStar from Indonesia and India to Korea and China. Four differently manufactured 1.5 GHz receivers receive these signals.

Digital System D_H extends the reception performance of Digital System D_S to deliver robust mobile reception performance to urban regions that suffer severe blockage by buildings and trees. A Digital System D_H architecture has now been specified. It provides terrestrial augmentation for DSB services in a mixed satellite/terrestrial configuration to mobile receivers as well as static and portable receivers. The development work has reached the stage where system validation testing has taken place using the AfriStar Satellite and a three-transmitter SFN in Erlangen, Germany. Further tests are planned in Pretoria, Republic of South Africa.

The satellite delivery component of Digital System D_H is based on the same TDM broadcast channel transport used in Digital System D_S but with several significant enhancements designed to improve line-of-sight reception in areas partially shadowed by trees. These enhancements include fast QPSK phase ambiguity recovery every 1.4375 ms, early/late time diversity and maximum likelihood combination of early/late time diversity signals.

The terrestrial delivery system component is based on MCM. MCM is a multipath-resistant OFDM technique that has gained wide acceptance for pervasive mobile reception from terrestrial emitters. The MCM extension improves upon the techniques that are common in systems such as Digital System A, which is one standard used for terrestrial digital audio broadcast services. MCM utilizes multiple frequencies to avoid frequency selective fades thereby avoiding deleterious effects of delay spread. The MCM modulation scheme is most suitable for reliable reception in urban mobile environments, and leads to spectrum efficient solutions when SFNs are used. A new Digital System D_H receiver design extends and improves upon the Digital System D_S design for satellite signal reception. It adds an MCM terrestrial reception branch to receive terrestrial signal single frequency network emissions. It uses two radio frequency tuner branches and demodulates the same TDM stream from both the satellite and terrestrial signal components. For its MCM extension, new terrestrial transport and physical layer specifications are added to the current service, transport and

physical layers of Digital System D_S. Because the terrestrial transport directly modulates the TDM baseband symbols recovered by receivers at each terrestrial station of a terrestrial re-radiation network onto MCM carriers, the terrestrial transport is referred to as TDM-MCM.

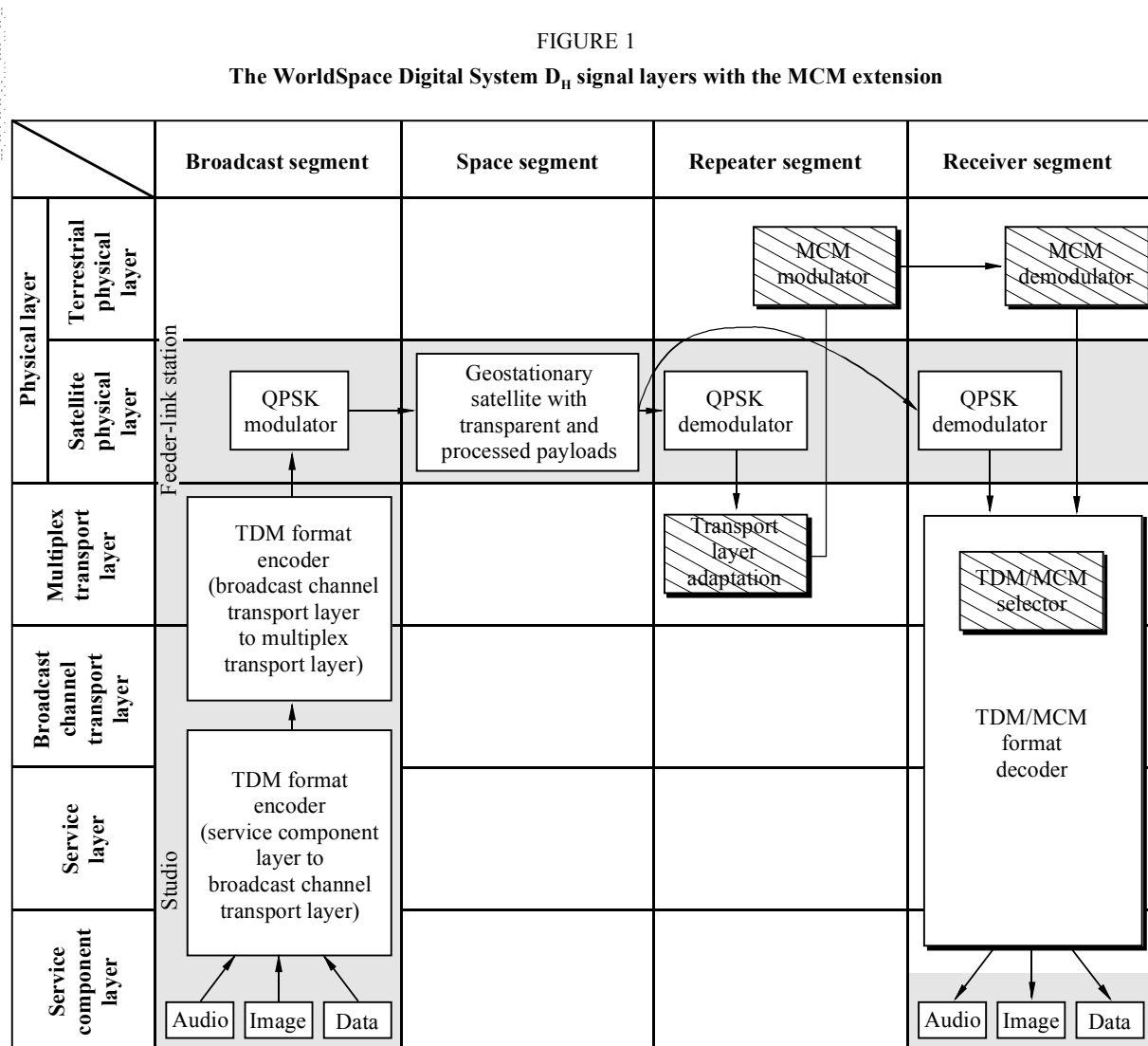
The following sections describe in more detail the satellite and terrestrial retransmission components of Digital System D_H.

With the inclusion of the terrestrial delivery component, Digital System D_H can meet the service requirements stipulated not just in Recommendation ITU-R BO.789, but also Recommendation ITU-R BS.774 for satellite and complementary terrestrial delivery of digital sound broadcasting.

2 System overview

2.1 Layer structure of Digital System D_H

Digital System D_H uses the system layer structure illustrated in Fig. 1. It comprises service, transport and physical layers for both the TDM satellite segment and the TDM-MCM terrestrial repeater segment.



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2.2 Satellite broadcast segment

2.2.1 Service layer

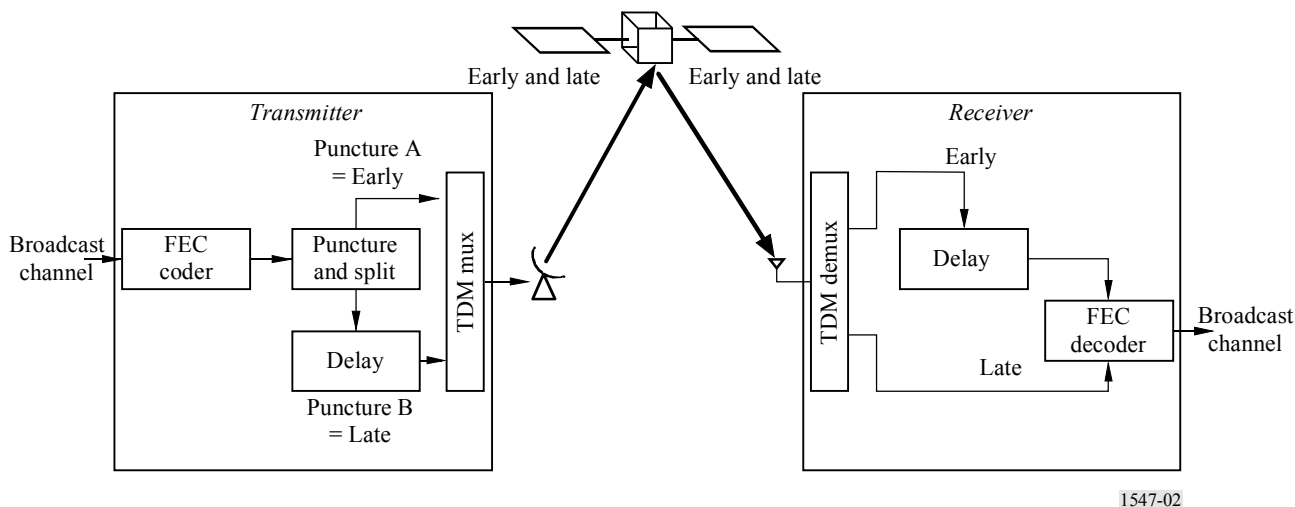
The service layer comprises audio, image and data source coders. WorldSpace uses a variation of International Organization for Standardization (ISO) MPEG 2 Layer III called MPEG 2.5 Layer III for audio and ISO Joint Photographic Experts Group (JPEG) for image. The source data is organized into 432 ms broadcast channel frames in prime rate increments of 16 kbit/s. Prime rate increments are the building bricks of the baseband multiplex architecture. A broadcast channel frame can support up to eight service components, each carrying a rate from 8 kbit/s to 128 kbit/s, that can be individually accessed at the receiver. Each prime rate increment can support two 8 kbit/s service components. The sum of service component rates in a broadcast channel must not exceed 128 kbit/s. A broadcast channel transports a mix of services such as music, talk in selectable multiple languages, images associated with the latter and data in the form of packets or streaming. Each broadcast channel frame carries a service control header (SCH) which at a receiver provides a broadcast channel frame synchronization preamble and the information needed to identify the type of information carried, the information rate, the identity of the various services carried, ancillary information related to the various services, alpha-numeric text display, narrow casting of services, selection of the accessed services and authorization to access restricted and subscription services to individual users.

2.2.2 Transport layer

2.2.2.1 Time diversity only

For time diversity only using one satellite, the transport layer uses the architecture shown in Fig. 2. It accepts the bits of the broadcast channels from the service layer and first organizes them into symbols, each carrying two bits. Forward error correction (FEC), using the concatenation of a Reed-Solomon (RS) block coder and a convolution coder, next codes the symbols. Puncturing of the latter coder output creates two complementary companion error correction protected broadcast channels. One of the punctured broadcast channels is designated as the early channel. It is interleaved over a 432 ms frame to combat short term reception fades. Its companion punctured broadcast channel, designated as the late channel, is delayed for approximately 4.32 s. This channel is intended for reception by the current standard WorldSpace receivers as well as by the new mobile radios. Also, it is not interleaved because doing so would render it incompatible for reception by a conventional WorldSpace receiver. The 4.32 s delay between the early and late broadcast channels provides long delay protection to combat blockages of satellite signal reception by bridges, short tunnels and trees as a vehicle travels along highways at typical speeds. The two companion punctured broadcast channels are then division multiplexed into the TDM stream along with other mobile and non-mobile conventional broadcast channels. The system is intended to carry a mix of conventional broadcast channels for reception by the ordinary WorldSpace satellite broadcast receivers and complementary pairs of punctured broadcast channels, one early and one late, for reception by mobile receivers.

FIGURE 2
Time diversity with a single satellite

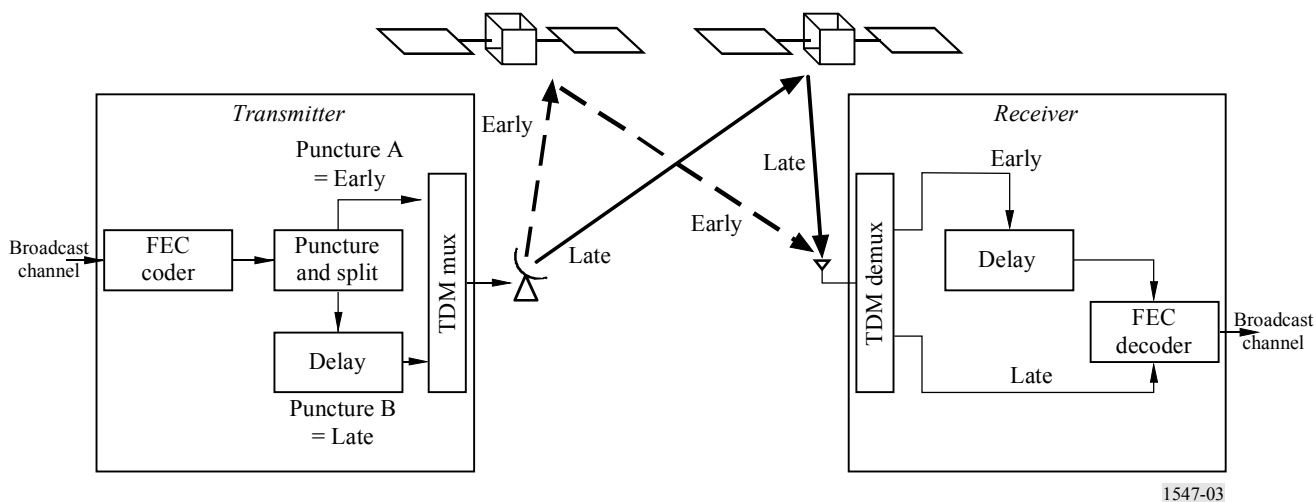


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2.2.2.2 Time and space diversity

The satellite broadcast transport layer architecture for time and space diversity, illustrated in Fig. 3, uses two satellites spaced apart from one another by 15° to 35° along the geostationary orbit. It is best if the bisector between the satellites is centred over the intended earth coverage area. It uses the same early and late broadcast channel architecture described above for the time only diversity case. However, two TDM carriers are used, one transported by each satellite. Each may carry a mix of early and late broadcast channels or one can be designated to carry only early and the other only late. Also conventional broadcast channels not intended for mobile reception can be mixed with those for mobile. This is possible because every broadcast channel has its own broadcast channel identifier (BCID) that is used at the receiver to select specific broadcast channels from one or either of two received TDM stream(s).

FIGURE 3
Space and time diversity with two satellites

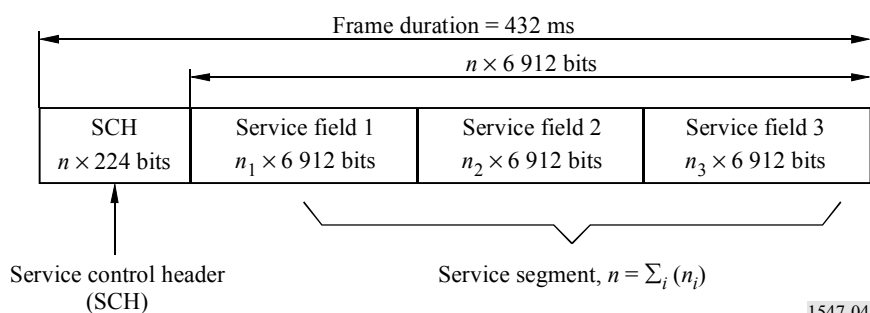


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2.2.2.3 Broadcast channel frame and FEC

Figure 4 shows a broadcast channel frame containing three service fields. Each service field carries a rate that is an integer multiple n_i of the 16 kbit/s prime rate increment. Thus within each 432 ms frame, a service field i carrying a rate $n_i \times 16$ kbit/s has assigned to it $n_i \times 6\,912$ bits. The bit rate of a service field has a range from 16 kbit/s to 128 kbit/s. Also the bit rate of a broadcast channel has a range from 16 kbit/s to 128 kbit/s. A broadcast channel can carry a maximum of eight service components that have rates ranging from 8 kbit/s to 128 kbit/s. Note that service components are in multiples of 8 kbit/s. Hence, whenever a service component's rate is an odd multiple of 8 kbit/s, a dummy 8 kbit/s must be appended to produce an integer multiple of 16 kbit/s for the service fields in a broadcast channel. The total number of service fields in a broadcast channel is $n = \sum_i (n_i)$. To prepare for transport, each 6 912-bit service field prime rate increment of a broadcast channel is assigned 224 bits in a SCH bringing the number of bits per broadcast channel frame to $n \times 7\,136$. The broadcast channel frame is next FEC coded by a 223,255 RS block coder to yield an output of $n \times 8\,160$ bits per frame. To prepare for mobile service, the output of the RS coder is next supplied to a R 1/4 convolution coder whose output is split into two R 1/2 convolution coded broadcast channels, one destined to be the early broadcast channel and the other the late broadcast channel. At this point there are $n \times 16\,320$ bits assigned to the n service fields in each broadcast channel. The n service fields are next demultiplexed into n prime rate channels (PRCs). Adding a 96-bit preamble to each PRC brings the total to 16 416 bits per PRC.

FIGURE 4
Broadcast channel frame



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2.2.2.4 Terrestrial transport

If an originating studio is remote from an uplink station, the PRCs of a broadcast channel are transported to the station over terrestrial digital telephony links. This is typically done via ITU-T Recommendation G.736 digital telephony multiplexes. If the originating studio is collocated at or near the originating studio, the signals are simply transported over a local cable. The signal transported is that generated at the output of the RS block coded level. At this point the broadcast channels are said to be carried in a protected form. At the uplink stations the PRCs of the protected broadcast channels arriving from a multiplicity of origins are synchronously aligned by means of a plesiochronous buffer to prepare them for uplinking to the satellite. Next the PRCs of the protected