

SCTE • ISBE[®]

S T A N D A R D S

Digital Video Subcommittee

AMERICAN NATIONAL STANDARD

ANSI/SCTE 55-1 2019

**Digital Broadband Delivery System:
Out of Band Transport Part 1: Mode A**

NOTICE

The Society of Cable Telecommunications Engineers (SCTE) / International Society of Broadband Experts (ISBE) Standards and Operational Practices (hereafter called “documents”) are intended to serve the public interest by providing specifications, test methods and procedures that promote uniformity of product, interchangeability, best practices and ultimately the long-term reliability of broadband communications facilities. These documents shall not in any way preclude any member or non-member of SCTE•ISBE from manufacturing or selling products not conforming to such documents, nor shall the existence of such standards preclude their voluntary use by those other than SCTE•ISBE members.

SCTE•ISBE assumes no obligations or liability whatsoever to any party who may adopt the documents. Such adopting party assumes all risks associated with adoption of these documents, and accepts full responsibility for any damage and/or claims arising from the adoption of such documents.

Attention is called to the possibility that implementation of this document may require the use of subject matter covered by patent rights. By publication of this document, no position is taken with respect to the existence or validity of any patent rights in connection therewith. SCTE•ISBE shall not be responsible for identifying patents for which a license may be required or for conducting inquiries into the legal validity or scope of those patents that are brought to its attention.

Patent holders who believe that they hold patents which are essential to the implementation of this document have been requested to provide information about those patents and any related licensing terms and conditions. Any such declarations made before or after publication of this document are available on the SCTE•ISBE web site at <http://www.scte.org>.

All Rights Reserved

© Society of Cable Telecommunications Engineers, Inc. 2019

140 Philips Road

Exton, PA 19341

TABLE OF CONTENTS

1. INTRODUCTION	1
2. ACRONYMS	3
3. REFERENCES	5
4. COMPLIANCE NOTATION.....	6
5. OUT-OF-BAND SYSTEM SPECIFICATIONS.....	7
6. PHYSICAL LAYER SPECIFICATION.....	8
6.1. PHYSICAL LAYER FOR OOB TRANSMISSION	8
6.1.1. OOB Transmission Format	8
6.1.2. OOB Coding Scheme.....	8
6.1.3. OOB QPSK Mapping	12
6.1.4. OOB Modulator RF Output.....	13
6.1.5. OOB Carrier Input Power at Receiver.....	13
6.2. PHYSICAL LAYER FOR RETURN-PATH TRANSMISSION	14
6.2.1. Return-Path Modem Description.....	14
6.2.2. RF Return Path Packet Format.....	14
6.2.3. RF Return-Path Forward Error Correction.....	14
6.2.4. RF Return-Path Randomizer	14
6.2.5. RF Return Path Modulator.....	15
6.2.6. RF Return-Path Demodulator Specification	16
6.3. EXTENDED PRACTICE FOR RETURN-PATH TRANSMISSION	17
7. DATA LINK LAYER	19
7.1. APPLICATION PDU PROCESSING	19
7.2. LINK LAYER HEADERS/TRAILERS	22
7.2.1. Upstream Link Layer Header.....	22
7.2.2. Padding	23
7.2.3. Downstream Link Layer Header	23
7.2.4. Upstream CRC Function	23
7.2.5. Downstream CRC Function.....	24
7.2.6. Acknowledgment protocol	24
7.3. SEGMENTATION AND RE-ASSEMBLY	25
7.3.1. Upstream	25
7.3.2. Downstream.....	25
7.3.3. Maximum PDU Sizes.....	25
7.4. MAC INFORMATION TRANSPORT	26
7.4.1. Downstream MAC Message Format	26
7.4.2. Upstream Packet Format	28
7.5. MAC SIGNALING MESSAGES	31
7.5.1. MAC Signaling Message Encapsulation	31
7.5.2. MAC Signaling Message Format	32
7.5.3. ALOHA MAC Messages	33

1.INTRODUCTION

This document is identical to SCTE 55-1 2009 except for informative components which may have been updated such as the title page, NOTICE text, headers and footers. No normative changes have been made to this document.

This contribution is a derivative work created from DVS/110. The intention of this document is to provide a contribution whose scope is limited to the physical layer specification for Out-Of-Band cable system. Specifications of MAC Layer and Link Layer are also provided for the Aloha implementation. The latter should be updated in the future, recognizing the potential adaptation of DOCSIS MAC Layer Specification [3].

Revision History

Revision	Date	Editor	DESCRIPTION
Initial Release	August 26, 1998		General Instrument's Implementation Specification of the Digital Broadband Delivery System: Out-of-Band Transport
0	August 26, 1999	N. N. Y. Chu	1. Removal of Upstream CNR for both QPSK and 16-QAM definition for AWGN in Table 10, 2. Labeled Data Link Layer Section as informative, 3. Updated Reference to the latest DOCSIS version, 4. Added Acronyms and References Sections, 5. Unified format presentations for Data Link Layer messages, 6. Overall editorial improvements for ease-of-reading.
1	September 10, 1999	N. N. Y. Chu	1. Added Revision History in Section 1, 2. Incorporated comments from Reviewing Conference Call conducted on September 9, 1999, 3. Re-ordered Physical Layer to Section 5 and Data Link Layer to Section 6.
2	February 25, 2000	N. N. Y. Chu	1. Appended title with Mode A, removing specific reference to General Instrument, 2. Updated Data Link Layer based on Aloha Implementation, 3. Incorporated comments from DVS ballot

			results.
3	March 11, 2008	Chris Stone	1. Updated OOB randomizer in section 6.1.2.1. 2. Corrected CRC polynomial in sections 7.2.4 and 7.2.5. 3. Updated references in section 3.0.

2.ACRONYMS

AAL	ATM Adaptation Layer
AWGN	Additive White Gaussian Noise
ATM	Asynchronous Transfer Mode
BW	BandWidth
CBD	Connection Block Descriptor
CRC	Cyclic Redundancy Check
CW	ClockWise
DAVIC	Digital Audio Video Council
DCM	Default Configuration Message
DLL	Data Link Layer
DOCSIS	Data Over Cable System Interface Specification
FEC	Forward Error Correction
GF	Galois Field
IB	In-Band
IBTM	In-Band Timebase Message
ID	IDentification
IE	Information Element
IP	Internet Protocol
LFSR	linear Feedback Shift Register
MAC	Media Access Control
MAP	Map of Bandwidth Allocation
Mbps	Mega bits per second
Msp	Mega symbols per second
MCNS	Multimedia Cable Network System
MPEG	Motion Picture Expert Group
NRC	Network Related Control
OBTM	Out-of-Band Timebase Message
OOB	Out-Of-Band

PDU	Protocol Data Unit
PER	Packet Error Rate
PN	Pseudo-random Number
PT	Payload Type
QAM	Quadrature Amplitude Modulation
QPSK	Quaternary Phase Shift Keying
R-S	Reed-Solomon Coding
SDU	Service Data Unit
SER	Symbol Error Rate
TDMA	Time Division Multiple Access
TS	Transport Stream
UPM	UPstream MAC

3. REFERENCES

1. IEEE Std 802-1990, Local and Metropolitan Area Networks: Overview and Architecture, and ISO/IEC 10039:1991 Information Technology, Open Systems Interconnection, Local Area Networks, Medium Access Control (MAC) Service Definition.
2. ITU-T Recommendation H.222.0 | ISO/IEC 13818-1: 2007, Information Technology – Generic Coding of Moving Pictures and Associated Audio Information Systems.
3. CableLabs, Data-Over-Cable-Service Interface Specifications (DOCSIS): Radio Frequency Interface Specification, SP-RF1v1.1.I01-990311 (1999).
4. Digital Audio Visual Council 1.4 Specification Part 8, “Lower Layer Protocols and Physical Interfaces” (<http://www.davic.org>).
5. Clark, G. C. and Cain, J. B. (1981): Error-Correction Coding for Digital Communications, Plenum Press.

4. COMPLIANCE NOTATION

“SHALL”	This word or the adjective “REQUIRED” means that the item is an absolute requirement of this specification.
“SHALL NOT”	This phrase means that the item is an absolute prohibition of this specification.
“SHOULD”	This word or the adjective “RECOMMENDED” means that there may exist valid reasons in particular circumstances to ignore this item, but the full implications should be understood and the case carefully weighted before choosing a different course.
“SHOULD NOT”	This phrase means that there may exist valid reasons in particular circumstances when the listed behavior is acceptable or even useful, but the full implications should be understood and the case carefully weighed before implementing any behavior described with this label.
“MAY”	This word or the adjective “OPTIONAL” means that this item is truly optional. One vendor may choose to include the item because a particular marketplace requires it or because it enhances the product, for example; another vendor may omit the same item.

5. OUT-OF-BAND SYSTEM SPECIFICATIONS

This document specifies the Physical Layer and the Data Link Layer (including the MAC Layer) of the Out-Of-Band cable system transport. Section 5 describes the Physical Layer protocol. Section 6 describes the Data Link Layer protocol.

The MAC Layer specification refers to the DOCSIS [3]. However, not all DOCSIS specifications for the MAC Layer are required. The minimum set is specified. Future enhancements toward full DOCSIS compliance are expected based on customers' input.

This specification assumes that the reader has some:

1. fundamental understanding of the conventional cable frequency plan, and
2. familiarity with the Ethernet specification and the Reed-Solomon Coding of Error Correction Schemes.

Also use of the references denoted in Section 3 are highly recommended for a full understanding of this specification.

6. PHYSICAL LAYER SPECIFICATION

This section describes the physical layer of the Out-Of-Band downstream and upstream channels.

6.1. PHYSICAL LAYER FOR OOB TRANSMISSION

The aggregate information rate of the Out-Of-Band (OOB) channel is 2.048 Mbps. Up to 1.544 Mbps may be utilized for access control and other control information as well as application data, application program downloads, program guides, etc. The OOB data channel provides continuous communication from a headend to the Digital Terminals. The Digital Terminal typically remains powered-up even when it is in the “off” state. The OOB channel remains active independent of the tuned video channel, whether the received TV channel is analog or digital, and whether the Digital Terminal box is turned “on” or “off”. Thus, whenever the Digital Terminal connected to the coaxial cable and AC power, the OOB channel is active for downstream communication.

6.1.1. OOB TRANSMISSION FORMAT

The following table summarizes the physical attributes of the OOB channel.

Parameter Name	Specifications
Modulation:	QPSK, differential coding for 90° phase invariance
Symbol Rate:	1.024 Msps
Symbol Size:	2-bits per symbol
Channel Spacing (BW):	1.8 MHz
Transmission Frequency Band:	70 to 130 MHz
Carrier Center Frequency (default):	75.25 ¹ MHz $\pm$ 0.01%
Data Rate:	2.048 Mbps $\pm$ 0.01%
Forward Error Correction:	96,94 Reed-Solomon block code, T=1, 8bit symbols
FEC Framing	Locked to MPEG-TS, two FEC blocks per MPEG packet
Interleaving	Convolutional, (96,8)
Nominal Information Rate:	2.005 Mbps (132.8 b/s margin)
Frequency Response:	Raised Cosine filter, $\alpha = 0.5$ (receiver only)

1. Other possible OOB carrier center frequencies are 72.75 MHz and 104.2 MHz.

Table 1: Out-Of-Band Transmission Specifications

The OOB channel spacing is 1.8 MHz with frequency step size of 50 kHz. The center frequency for the downstream cable frequency plan can be between 70 to 130 MHz, with 75.25 MHz as the default value.

6.1.2. OOB CODING SCHEME

The forward-error-correction scheme for the OOB channel is composed of the randomization, Reed-Solomon (R-S) coding, and interleaving layers as shown in Figure 1.

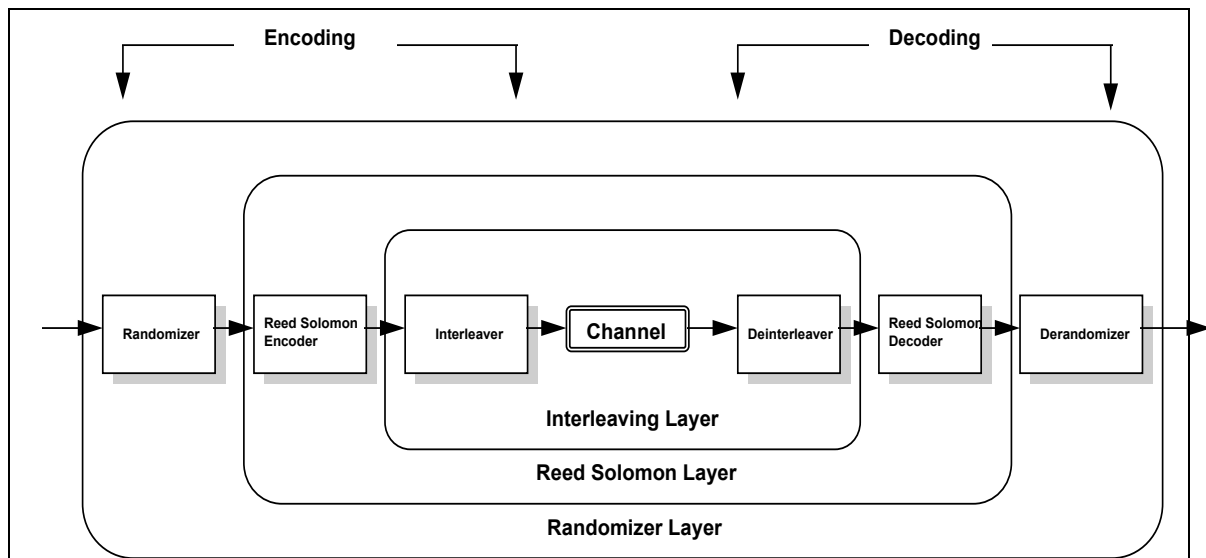


Figure 1: A Block Diagram for Layers of Coding in the OOB Channel

6.1.2.1. OOB RANDOMIZER

The MPEG-TS is randomized to ensure balanced modulation by removing unequal excitation of the QPSK modulation states. The randomizer circuit performs the exclusive OR function on the input MPEG transport sequence with the randomizer's Pseudo-random Number (PN) generator output sequence. The randomization frame consists of two MPEG packets with the randomizer PN generator pre-set at the start of every second MPEG-TS packet. Alternate MPEG-TS Sync bytes are converted from 0x47 to 0x64 by the randomizer. This improves receiver synchronization performance.

The randomizer PN generator is a 13-bit Linear Feedback Shift Register (LFSR) as shown in Figure 2. Binary arithmetic XOR gates and taps are placed at the output of stages 13, 11, 10, and 1. The shift register is preset with a seed value. The stages 10 and 1 are loaded with a seed value of "1" and all other stages, 2 through 9 and 11 through 13 are loaded with a seed value of "0". The seed corresponds to 0x0201. The corresponding generating polynomial is defined as:

$$f(X) = X^{13} + X^{12} + X^{10} + X^9 + 1$$

The randomizer PN generator is preset to the seed value on the 385th byte after clocking for a total of 384 bytes. The MPEG Sync byte 0x47 is converted to 0x64 on the 193rd byte by being exclusive OR'd with the 193rd PN generator output byte output which is 0x23. The randomizing action is gated out during bytes 95-96, 191-192, 287-288 and 383-384. The reason for these gaps in the randomization process is to permit the insertion of Reed Solomon parity bytes. The PN generator continues to run during these gaps but the output is not used. The RS bytes are inserted without being randomized.

The same circuit is used for de-randomizing the received MPEG-TS packets. The sync symbol of the first MPEG-TS packet in a frame remains 0x47 after randomization because the first randomizer output byte after reset is "0x00". The second MPEG-2 Sync byte is changed by the randomizer but will be returned to the MPEG-TS standard value 0x47 by the de-randomizer at the receive site.

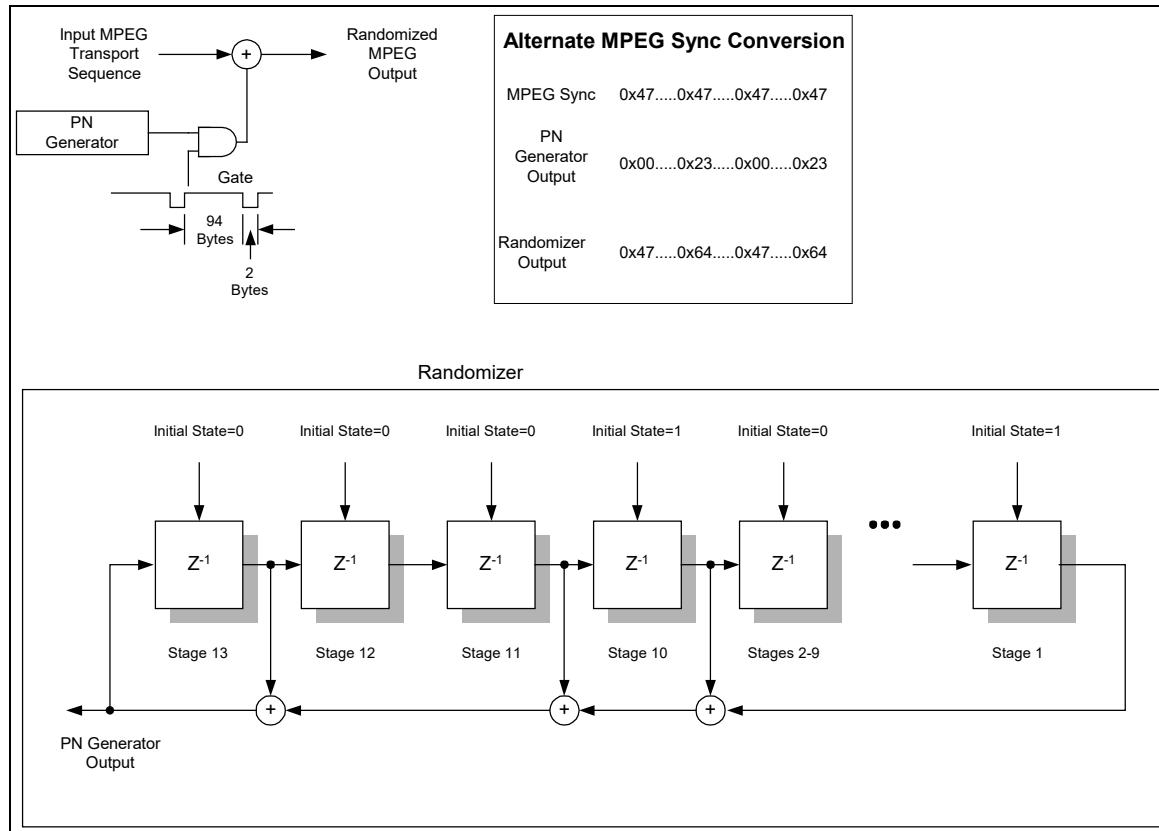


Figure 2: The Out-Of-Band Randomizer

6.1.2.2. FORWARD ERROR CORRECTION CODE

The forward-error-correction (FEC) code in the OOB transmission system is a Reed-Solomon (R-S) block code [5]. No codeword shortening and padding is used with the R-S coding. No convolutional coding is required for the relatively robust QPSK transmission on cable-TV transmission networks. The FEC scheme uses (94,96) Reed-Solomon code defined over Galois Field $GF(2^8)$. The R-S code is $T=1$ (96, 94) over Galois Field $GF(256)$, which is capable of performing 1 symbol error-correction every R-S block of 96 symbols. The (94,96) code is equivalent to a (253, 255) R-S code with 159 leading zero symbols followed by 96 non-zero symbols.

The $GF(256)$ is constructed based on the following primitive polynomial over $GF(2)$, namely,

$$p(X) = X^8 + X^4 + X^3 + X^2 + 1$$

The generating polynomial for the R-S code is defined as:

$$g(X) = (X - \alpha)(X - \alpha^2)$$

where α is a primitive element in $GF(256)$. The OOB FEC frame consists of two Reed-Solomon blocks. This OOB FEC frame equals one MPEG transport packet as illustrated in Figure 3.

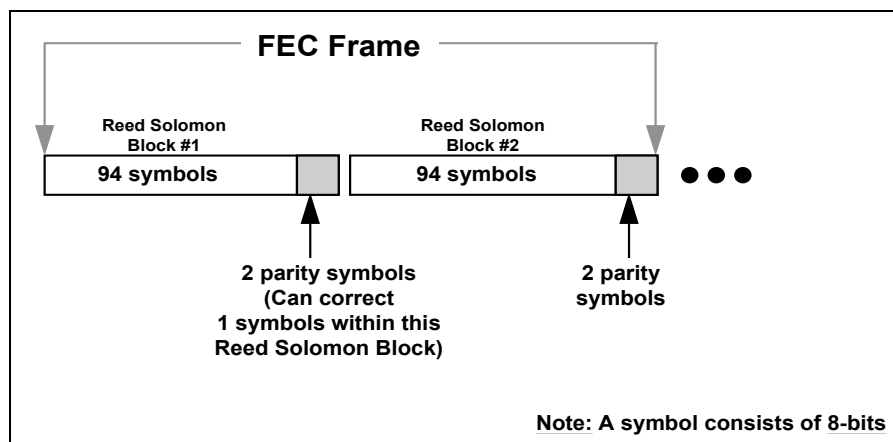


Figure 3: The OOB FEC Frame Packet Format

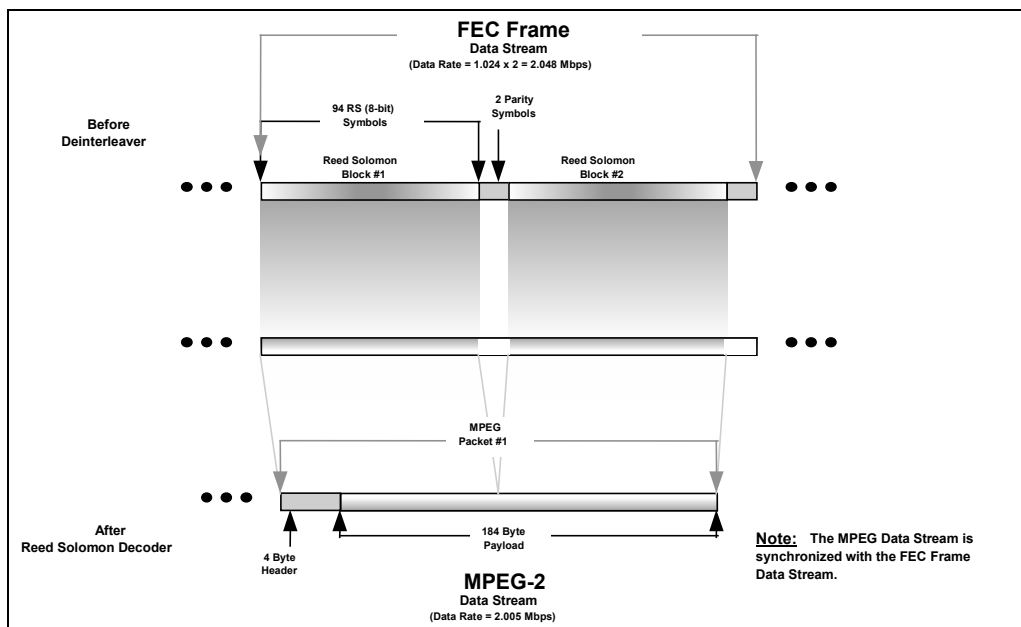


Figure 4: The Out-Of-Band FEC Frame to MPEG-TS Framing

Mapping from an FEC Frame to an MPEG-TS packet is illustrated in Figure 4. The first 94 bytes are unaltered and used directly as received. The next 2 bytes are the parity bytes obtained from the Reed-Solomon polynomial calculation. Two blocks of 96 bytes are sent for every 188 byte MPEG packet received. The FEC frame is reset at the start of each MPEG-TS packet.

6.1.2.3. OOB INTERLEAVER

Interleaving the coded R-S symbols before transmission and de-interleaving after the reception may cause multiple burst errors during transmission to be spread out in time. Thus, the receiver has to handle them as if they were random errors. Separating the R-S symbols in time enables the random-error-correcting R-S code to be useful in a bursty-noisy environment. Using a convolutional interleaver with a depth of $I = 8$ symbols, the R-S T=1 (96,94) decoder can correct an error burst of 8 symbols, which corresponds to a burst noise protection of 32 μsec .

Interleaving is synchronized to the R-S blocks and hence to MPEG-TS packets. MPEG-TS Sync bytes always pass through commutator branch 1 of the interleaver and hence are not delayed through the interleaver. The convolutional interleave algorithm delays various blocks of bytes in a systematic way, as illustrated in Figure 5.

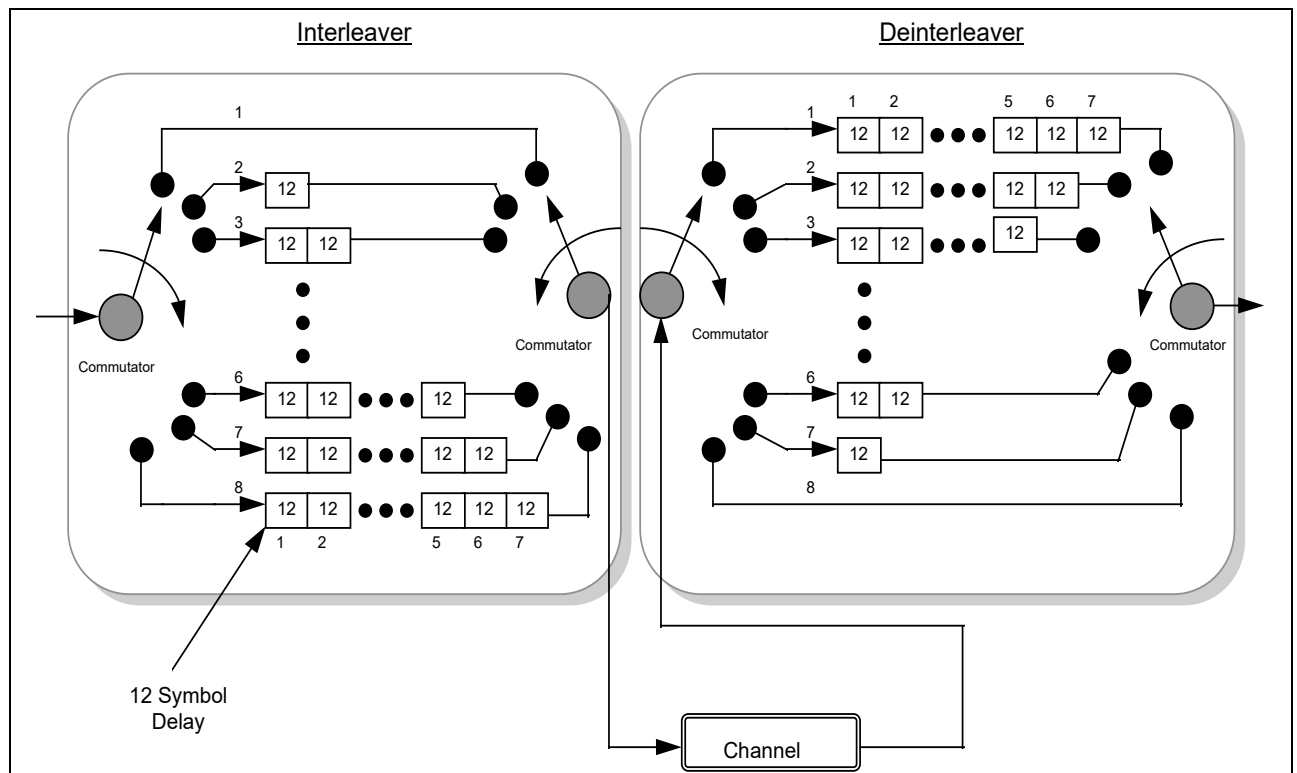


Figure 5: Out-of-Band Interleaving Functional Block Diagram

6.1.3. OOB QPSK MAPPING

The OOB modulator uses differential encoding scheme to resolve the 90° ambiguity in the detection of the QPSK signal at the demodulator. The OOB QPSK demodulator should be capable of handling both forms of differential coding as listed in Table 2. Also, a means of selecting the appropriate form of decoding for the user's system must be present in the QPSK demodulator.

I Data	Q Data	Default Carrier Phase Changes	Alternate Carrier Phase Changes
0	0	No Change	No Change
0	1	-90 degrees CW	+90 degrees CW
1	0	+90 degrees CW	-90 degrees CW
1	1	180 degrees	180 degrees

Table 2: The Differential Coding Scheme for OOB QPSK Signal**6.1.4. OOB MODULATOR RF OUTPUT**

The OOB QPSK modulator RF output specifications are shown in Table 3.

Parameter Name	Specification
Center Frequency RF Output	75.25 ¹ MHz carrier frequency
Step Size for RF Output	50 kHz
RF Output Power range	+30 to +50 dBmV
Output level stability vs. time & temperature	±2 dB
Output level stability vs. frequency changes	±2 dB
RF Center frequency accuracy	±0.01%
I/Q Amplitude Imbalance	0.5 dB typical
I/Q Phase Imbalance	1.0 degree typical

1. Other OOB carrier frequencies in the 70 to 130 MHz are possible.

Table 3. The OOB Modulator RF Output**6.1.5. OOB CARRIER INPUT POWER AT RECEIVER**

The received power level of the OOB carrier at the subscriber's decoder is from +5 dBmV to -10 dBmV at 75 Ω cable impedance.