Doc. CS/TSG-696r1
20 July 2006

Candidate Standard:
ATSC Automatic Transmitter Power Control (ATPC) Data Return Link (DRL) Standard

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The Advanced Television Systems Committee, Inc., is an international, non-profit organization developing voluntary standards for digital television. The ATSC member organizations represent the broadcast, broadcast equipment, motion picture, consumer electronics, computer, cable, satellite, and semiconductor industries.

Specifically, ATSC is working to coordinate television standards among different communications media focusing on digital television, interactive systems, and broadband multimedia communications. ATSC is also developing digital television implementation strategies and presenting educational seminars on the ATSC standards.

ATSC was formed in 1982 by the member organizations of the Joint Committee on InterSociety Coordination (JCIC): the Electronic Industries Association (EIA), the Institute of Electrical and Electronic Engineers (IEEE), the National Association of Broadcasters (NAB), the National Cable Television Association (NCTA), and the Society of Motion Picture and Television Engineers (SMPTE). Currently, there are approximately 140 members representing the broadcast, broadcast equipment, motion picture, consumer electronics, computer, cable, satellite, and semiconductor industries.

ATSC Digital TV Standards include digital high definition television (HDTV), standard definition television (SDTV), data broadcasting, multichannel surround-sound audio, and satellite direct-to-home broadcasting.

About the Candidate Standard

This specification is being put forth as a Candidate Standard by the TSG/S3 Specialist Group on Digital ENG. ATSC members and non-members are encouraged to review and implement this specification and return comments to cs_amend_editor@atsc.org. ATSC Members can also send comments directly to the TSG/S3 Specialist Group. The ATSC believes this specification is stable. It is expected to progress to Proposed Standard within a period of time ending 20 May 2007.

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Candidate Standard:
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1. INTRODUCTION

This Candidate Standard was prepared by the Advanced Television Systems Committee (ATSC) Technology and Standards Group (TSG) Specialist Group on Digital ENG (TSG/S3). The document was approved by TSG on 9 May 2006 as a Candidate Standard for a period of time ending 15 December 2006.

1.1 Data Return Link Background

In the 10 November 2003 ET Docket 95-18 *Third Report and Order*, the United States Federal Communications Commission (FCC) adopted a suggestion of the Society of Broadcast Engineers (SBE) to create two 500-kHz wide data return[1] link (DRL) bands [4] at the lower and upper edges of the re-farmed 2,025–2,110 MHz TV Broadcast Auxiliary Service band [5]. A total of forty 25-kHz wide DRL channels were created, twenty in the lower DRL band, and twenty in the upper DRL band. These channels may be used to support important new applications relating to remote station operations.

The DRL channels permit a "feedback" or "return" link to be established from an ENG receive only (ENG-RO) site to an originating TV pickup station (commonly referred to as an ENG truck). This link allows automatic transmitter power control (ATPC) by ENG trucks, and more efficient usage of the seven 2 GHz TV BAS channels. ATPC is the application addressed by this standard.

Complimentary applications relating to remote production, such as camera control and operator communications, are also envisioned but are not included in this standard[2]. It is important to note that "return" as used above is not limited to signals going from the receive site to the remote location. The data might also go the other way. As such, the channels could also be used for two-way data communications, camera intercom, control functions, and so on.

1.1.1 The ATPC Application

Because the ET 95-18 *Report and Order* did not adopt technical or operating rules for DRL channels, there was, accordingly, a need for the appropriate technical specifications to be developed. Elements addressed by this standard relating to ATPC include:

- Basic system parameters; e.g., modulation type, occupied bandwidth, radiated power, emission mask, and frequency stability.
- Protocols and signaling. Established communications protocols are used where possible.
- Operational issues; e.g., data transmitted, priority of messages, and station identification.

[1] In this context, the "return" path is from an ENG receive only (ENG-RO) site to a TV pickup station (ENG truck) originating an incoming ENG feed. Thus, the "return" path is not from an ENG truck in the field to an ENG-RO site or TV station studio, but from an ENG-RO site back to the ENG truck. The purpose is to let the ENG truck operator know that a successful link has been established with a particular ENG-RO site, and to let the ENG truck operator know the strength of that incoming digital ENG signal. This allows (but does not require) automatic transmitter power control (ATPC) by the originating ENG truck.

[2] Such applications may be addressed in future extensions of this standard or through development of new standards.

With proper implementation of a DRL ATPC system, only the necessary amount of ENG output power is utilized to achieve reliable transmission. This facilitates more efficient use of the current ENG spectrum by minimizing the likelihood of interference among users in a given market or geographic location. It should be noted that any location may become frequency-congested in response to a major news or sporting event.

> Note: Throughout this document the term "ENG" is used. It is important to emphasize that the applications for DRL systems extend beyond strictly news events. Related and complimentary applications include coverage of sporting events (e.g., golf tournaments and motor races) and remote field production (e.g., parades and political conventions).

1.2 Scope

This document provides the necessary specifications to construct a Data Return Link (DRL) system for automatic transmitter control (ATPC) applications. The emitted signals of transmitters operated in accordance with this document comply fully with the specifications outlined in Section 5. This document further specifies the mechanisms necessary for basic identification and power control of TV Broadcast Auxiliary Service (BAS) transmitters, in either an automatic or manual mode. The initial, and default, operating mode is known as the "Beacon Mode." An optional, lower-power operating mode, known as the "Transport Mode," may be used if the RF environment permits. Both modes include the necessary mechanisms to permit the carriage of specialized private data (e.g., camera control information and operator communications) that is applicable to remote field production.

This document defines transmission parameters only. Receiver implementations are beyond the scope of this specification.

1.3 Document Structure

The document is organized as follows:

- Section 1 – Provides this general introduction.
- Section 2 – Lists references and applicable documents.
- Section 3 – Provides a definition of terms, acronyms, and abbreviations for this document.
- Section 4 – Provides detailed information on the background and use of DRL systems. (*Informative*)
- Section 5 – Specifies the transmitter transmission parameters for a DRL system. (*Normative*)
- Section 6 – Provides receiver implementation information for a DRL system. (*Informative*)
- Section 7 – Provides implementation guidance for construction of a DRL system (*Informative*)

The sections listed above fully specify the Beacon Mode of the DRL system and provide the necessary links to the optional Transport Mode, which may be developed as a future extension of this specification.

2. REFERENCES

At the time of publication, the editions indicated below were valid. All standards are subject to revision, and parties to agreement based on this standard are encouraged to investigate the possibility of applying the most recent editions of the documents listed below.

2.1 Normative References

The following documents contain provisions which, through reference in this text, constitute provisions of this standard.

[1] IEEE/ASTM SI 10-2002, "Use of the International Systems of Units (SI): The Modern Metric System", Institute of Electrical and Electronics Engineers, New York, N.Y.

[2] TIA-422-B: "Electrical Characteristics of Balanced Voltage Digital Interface Circuits," Telecommunications Industries Association, Arlington, VA, 1 May 1994.

[3] ATSC A/110A: "Synchronization Standard for Distributed Transmission," Advanced Television Systems Committee, Washington, D.C., 19 July 2005.

2.2 Informative References

[4] FCC ET Docket 95-18, Third Report and Order, Federal Communications Commission, Washington, D.C., November 2003.

[5] Title 47 Code of Federal Regulations, Part 74, "Experimental Radio, Auxiliary, Special Broadcast and Other Program Distribution Services," Subpart F (Television Broadcast Auxiliary Stations).

[6] ATSC A/111: "Design Of Synchronized Multiple Transmitter Networks," Advanced Television Systems Committee, Washington, D.C., 3 September 2004.

[7] IEEE 802.3, "LAN/MAN CSMA/CD Access Method," Institute of Electrical and Electronics Engineers, New York, NY.

[8] TIA-568-B.2.5: "Commercial Building Telecommunications Cabling Standard – Part 2: Balanced Twisted-Pair Cabling Components," Telecommunications Industry Association, January 2003.

[9] ISO/IEC IS 13818-1:2000 (E), International Standard, Information technology – Generic coding of moving pictures and associated audio information: systems.

[10] TIA-102.CAAA-B, "Digital C4FM/CQPSK Transceiver Measurement Methods," Telecommunications Industries Association, Arlington, VA.

[11] FCC Rules: Part 74, Subpart F, Section 74.637, "Emissions and Emission Limitations," Federal Communications Commission, Washington, D.C.

3. DEFINITION OF TERMS

With respect to definition of terms, abbreviations, and units, the practice of the Institute of Electrical and Electronics Engineers (IEEE) as outlined in the Institute's published standards [1] shall be used. Where an abbreviation is not covered by IEEE practice, or industry practice differs from IEEE practice, then the abbreviation in question will be described in Sections 3.3 and 3.4 of this document.

3.1 Compliance Notation

As used in this document, "shall" or "will" denotes a mandatory provision of the standard. "Should" denotes a provision that is recommended but not mandatory. "May" denotes a feature whose presence does not preclude compliance, which may or may not be present at the option of the implementer.

3.2 Treatment of Syntactic Elements

This document contains symbolic references to syntactic elements used in the audio, video, and transport coding subsystems. These references are typographically distinguished by the use of a different font (e.g., restricted), may contain the underscore character (e.g., sequence_end_code) and may consist of character strings that are not English words (e.g., dynrng).

3.3 Acronyms and Abbreviation

The following acronyms and abbreviations are used within this specification.

ACRR	adjacent channel rejection ratio
ACIR	adjacent channel interference ratio
ACLR	adjacent channel leakage ratio
ATC	ancillary terrestrial component (MSS terrestrial base stations)
ATPC	automatic transmitter power controls
ATSC	Advanced Television Systems Committee
BAS	Broadcast Auxiliary Services (Part 74 of the FCC Rules)
BER	bit error rate
BFO	brute force overload
BPSK	binary phase-shift keying
BSS	buried spread spectrum
C/N	carrier to noise
CMRS	commercial mobile radio services (cellular, SMR and PCS)
COFDM	coded orthogonal frequency division multiplexing
CRC	cyclic redundancy check
DENG	digital electronic news gathering
DRL	data return link
EIRP	equivalent isotropic radiated power
ENG	electronic news gathering (in the context of this document, “ENG” includes electronic field production
ENG-RO	ENG receive-only site (also known as "central" receive site)
FEC	forward error correction
FSPL	free-space power loss
FSK	frequency-shift keying
GMSK	Guassian minimum shift keying
LOS	line of sight
LQ	link quality
MER	modulation error ratio
MSK	minimum shift keying
MSS	mobile satellite service
MWCS	Miscellaneous Wireless Communications Services
OOBE	out of band emissions (spurious signals)
OQPSK	offset quadrature phase-shift keying
PCS	personal communications services
PPM	parts per million
PSK	phase-shift keying
QPSK	quadrature phase-shift keying
RCL	receive carrier level
rpchof	remainder polynomial coefficients, highest order first
RF	radio frequency
SCM	single carrier modulation)
simsbf	signed integer, most significant bit first
S/N	signal to noise ratio
SMR	specialized mobile radio
TPO	transmitter power output

TV BAS	Television Broadcast Auxiliary Service rules (Part 74, subpart f, of the FCC Rules)
TxID	transmitter identification signal
uimsbf	unsigned integer, most significant bit first

3.4 Terms

Beacon Mode – The initial (default) operating mode of the DRL system in which the communication link is established and the general operating parameters are set.

buried spread spectrum – A technique permitting carriage of data in the same spectrum with, but without interference to, another signal by transmitting that data at a much reduced level relative to the primary signal and using coding techniques to permit its recovery with adequate signal-to-noise ratio.

modulation error ratio – A measure of the constellation cluster variance due to any impairment imperfections measured relative to the ideal constellation point locations.

packet – A collection of data sent as a unit, including a header to identify and indicate other properties of the data, and a payload comprising the data actually to be sent, either having a fixed, known length or having means to indicate either its length or its end.

RF watermark – A buried spread spectrum (BSS) signal carrying codes used for the purpose of identification of the host signal with which it is associated and for carrying a small amount of low speed data.

Transport Mode – An optional, lower-power operating mode of the DRL system that may be used if the RF environment permits. Note that the initial, and default, operating mode of the DRL system is the *Beacon Mode*.

4. DRL SYSTEM OVERVIEW (INFORMATIVE)

The DRL system is intended to serve as a 2 GHz microwave return link from the ENG central receive site to the ENG truck in the field. The link is used to supply return *power control* metrics and other applicable information vital for remote ENG communications. The DRL system is also intended to facilitate various applications useful for remote field production, which may be specified in a future revision of this document or left to individual users and/or vendors to develop.

The return power control metrics are used to control the 2 GHz ENG transmitter output power for a digital ENG application. The power control capabilities are used to improve the spectrum efficiency with which ENG transmissions take place. The DRL return link regulates the amount of output power with which ENG transmissions can occur; only the necessary amount of ENG output power is utilized to achieve reliable transmission. This facilitates more efficient utilization of the current ENG spectrum by minimizing the likelihood of interference among users in a given market or geographic location.

For the ATPC application, the DRL system consists of a 2 GHz DRL microwave transmitter and antenna situated high atop the central receive site or any other microwave-friendly environment. The microwave transmitter is supplied DC and control information via a specified cable interface. A 2 GHz DRL receiver is utilized at the ENG truck, which interfaces with the ENG transmitter.

4.1 Operating Environment

The DRL channels provide forty 25-kHz wide channels in the same frequency band as the seven 12-MHz wide 2 GHz TV BAS channels. The intended use is to provide a communications path from an ENG-RO site to an ENG truck (or other ENG platform). It should be noted that the incoming ENG feed already provides a communications path from an ENG truck to an ENG central receive site.

A secondary purpose is to provide 0.5 MHz wide guard bands, at the lower and upper edges of the 2,025–2,110 MHz TV BAS band to minimize the interference threat from adjacent-band Commercial Mobile Wireless Services (CMRS) and Miscellaneous Wireless Communications Services (MWCS) base stations with an equivalent isotropic radiated power (EIRP) of up to 1,600 watts.

4.1.1 General Operation

The DRL system conveys two basic signals: the *RF watermark* and the *Beacon*/*Transport Mode* data. The RF watermark signal is used to uniquely identify the DRL transmitter and to serve as a homing beacon. It is transmitted continuously as a buried spread spectrum signal. The Beacon Mode is the initial (default) operating mode of the system, providing data on the received carrier level (RCL) of the incoming feed and other parameters. Once the DRL link has been established, the Transport Mode, a lower-power optional mode, may be used if the RF environment permits.

Auxiliary private data may be conveyed in the Beacon/Transport Mode to accommodate the case where an ENG truck has line-of-sight to an ENG-RO site, but not to the station's main DTV transmitting antenna. For this situation, the ancillary data portion of the 8-VSB broadcast signal might not be available for communication from the DTV station to an ENG truck. However, a DRL channel, originating from an ENG-RO site that does have line-of-sight to the ENG truck could then be used for data transfer purposes, albeit with a much smaller data throughput than that available using the station's DTV signal.

4.2 DRL Band Plan Definition and Channel Assignments

Figure 4.1 shows the DRL channel frequencies across the 1 MHz of available DRL spectrum, 500 kHz in the DRL lower band and 500 kHz in the DRL upper band. Channels 1 – 20 are within the DRL lower band and channels 21 – 40 are within the DRL upper band.

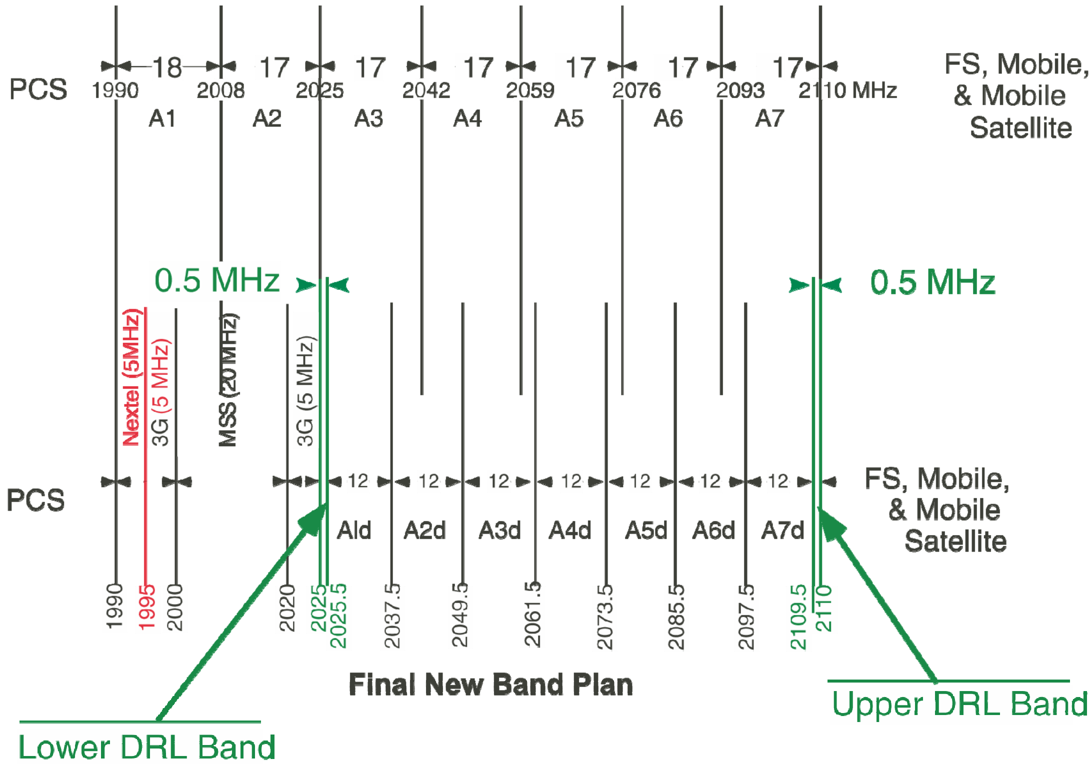

Figure 4.1 BAS channel plan (frequencies shown in MHz).

The DRL channel assignment is dependent upon and varies with each individual market segment. A DRL "home channel" plan may be developed for individual markets. A scanning system may also be used that automatically selects the next available cross-band[3] second-adjacent DRL channel in response to an incoming ENG feed.

4.3 DRL System Control Metrics

If an ENG truck (or other ENG platform) is equipped with a DRL receiving system, the DRL receiver will typically interface to the ENG transmitter to allow for ATPC by the ENG truck transmitter. Such ATPC is especially important in congested ENG markets, where split-channel operation using COFDM signals with 6-MHz wide pedestals are most likely to be used, in order to increase the effective channel capacity from seven to fourteen channels.

For split-channel operation, it is particularly important that the desired-to-undesired (D/U) signal ratio between the two incoming signals be close to zero dB. If one originating ENG truck is close to an ENG-RO site, but the other truck is not, the DRL signal can be used to reduce the transmitter power of the close-in truck so as to match the RCL of the COFDM signal from the distant ENG truck.

This balancing of RCLs applies to both a single ENG-RO site, where two split-channel COFDM signals are attempting to simultaneously feed a single site, and to separate but nearby ENG-RO sites of two different TV stations. In congested TV markets, it is to the mutual

[3] In this context, *cross-band* means that an incoming ENG feed on Channels A1 through A3 uses one of the twenty upper DRL channels, and an incoming ENG feed on Channels A5 through A7 uses one of the twenty lower DRL channels. An incoming feed on Channel A4 can use a DRL channel from either the lower or upper DRL bands.

advantage of even competing TV stations to cooperate on the technical operations of their respective ENG operations, especially when adjacent home-channel frequency assignments are involved. Figures 4.2 and 4.3 demonstrate this concept.

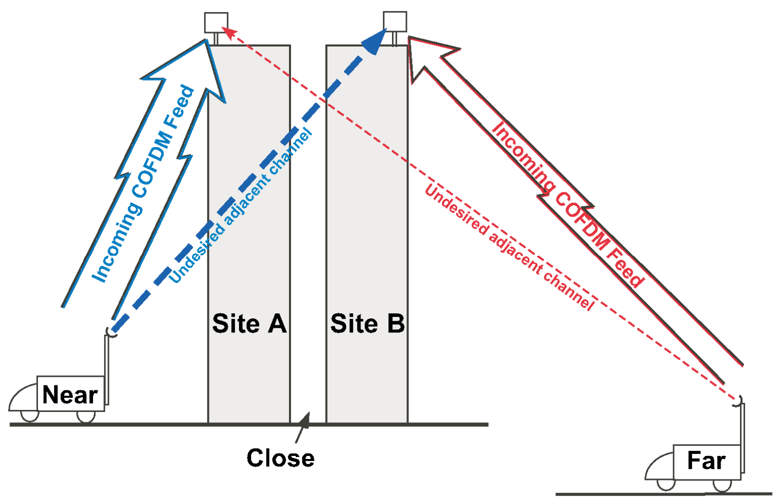

Figure 4.2 ENG-RO site without ATPC via DRL.

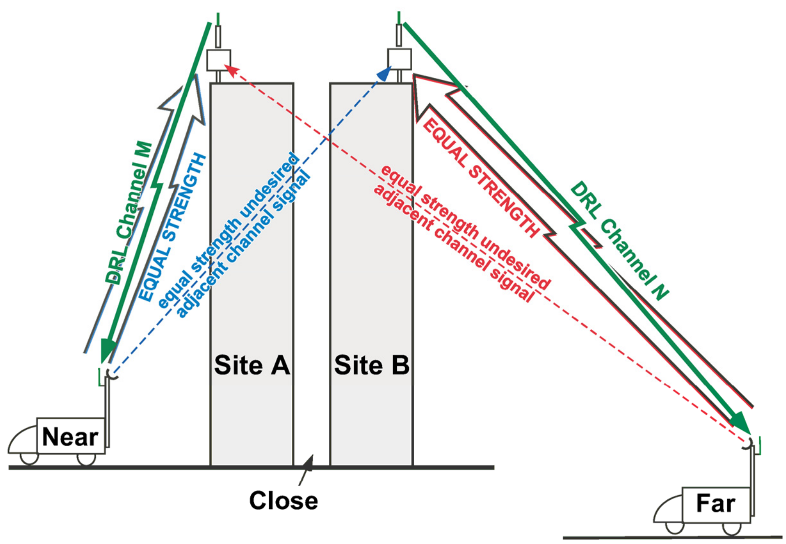

Figure 4.3 ENG-RO site using ATPC via DRL.

4.3.1 Reliability Predictions and Requirements

If ATPC is implemented, it should be fail-safe in nature; that is, if for any reason the DRL signal is lost, the default mode should be for the ENG transmitter to return to its full-power level, or to its manually-set power level. It is imperative that a DRL system never be the cause of a lost incoming COFDM feed.

4.3.2 Antenna Requirements

Because in the Beacon Mode the location of an ENG truck (or other ENG platform) relative to an ENG-RO site may not be well known in advance, it is recommended that DRL transmitting and receiving antennas be omni-directional in the azimuth plane. However, in the vertical plane the elevation pattern should be only as broad as necessary to cover the range of depression angles from the ENG-RO site to the operational area of the ENG trucks likely to communicate with the ENG-RO site. The use of an as-narrow-as-practical elevation pattern will minimize the brute force overload (BFO) threat to an ENG receiver on the same tower, while maximizing the link budget for the DRL system.

For operation in the optional Transport Mode, highly directional antennas may be practical and advisable.

4.4 DRL Coverage Area

Ideally, the path budget for DRL channels will be more robust than the path budget for an incoming ENG feed, so as to ensure that if an ENG-RO site is able to receive a useable incoming COFDM signal, an ENG platform equipped with a DRL receiver will always be able to receive a useable DRL signal (at least in the Beacon Mode).

4.4.1 Microwave Link Budget Analysis

The EIRP of a COFDM TV Pickup (ENG) station is typically 56 dBm, whereas the EIRP of a DRL transmitter will typically be limited to approximately 40 dBm so as to avoid causing BFO to a co-located ENG receiver (even after allowing for some vertical separation between the ENG receiving antenna and the DRL transmitting antenna). However, this possible 16 dB difference in EIRP is offset by the 27 dB difference in channel bandwidths (i.e., 25 kHz vs. 12 MHz), and the use of a highly robust, low-level digital modulation scheme for the DRL signal. Even if the effective range of the DRL signal is less than the effective range of an incoming COFDM signal, an ENG truck close enough to an ENG-RO site to be able to benefit from ATPC and match the RCL of a signal from a distant ENG truck should always be within the effective communications range of a DRL signal.

The overall system link budget values are listed in Table 4.1.

Table 4.1 DRL System Link Budget Values

Parameter	DRL	COFDM ENG
Transmitter power output (dBm)	+30	+37
Cable insertion loss (dB)	–1	–1
Transmitting antenna gain (dBi)	+9	+20
Transmitter EIRP	+38 dBm	+56 dBm
2 GHz free space loss at 10 miles (dB) [1]	–126	–126
Receiving antenna gain (dBi)	+5	+20
Received carrier level (RCL) [2]	–83 dBm	–50 dBm
Receiver thermal noise (dBm/Hz) [3]	–174	–174
Receiver noise figure (dB)	+4	+4
Receiver noise bandwidth (dB) [4]	+48	+70
Noise power (No) [5]	–122 dBm	–100 dBm
Eb/No (QPSK) 6 @ BER = 1E-6	+10.5 dB	
C/N (QPSK) with R = 1/2 coding, BER = 1E-6	+7.5 dB	
C/N (64QAM R=2/3, GI=1/32, 24.13bps)		+16.5 dB
DRL link margin (QPSK) dB	+30.6 dB	
COFDM link margin (QPSK) 1 dB		+33.5 dB

Notes:
[1] The system link budget numbers are under ideal transmitting/receiving conditions in a LOS environment; a non-LOS propagation model has not been factored into the free space line-of-sight (LOS) number.
[2] Assumes receiver cable loss is less than the NF of the receiver.
[3] At room temperature.
[4] 75 kHz for DRL receiver noise bandwidth; 10 MHz for ENG receiver noise bandwidth.
[5] Assumes an ideal receiver.
[6] These are theoretical values, the practical values are typically 1–2 dB worse.

4.5 RF Watermark Identification

The RF watermark transmitter identification system uses a digital binary sequence with a unique code assigned to each transmitter for transmitter identification (TxID). The TxID receiver can match and recognize each binary sequence to identify the associated transmitter.[4]

The RF watermark is injected at 10 to 20 dB below the desired signal noise threshold level. In this case, assuming the DRL system required S/N is 7 dB, the watermark signal injection level should –18 dB (1/8 the signal amplitude) below the DRL signal average power (See Figure 4.4) so that it will not impact the reception of the DRL signal.

[4] The RF watermark concept was introduced for DTV applications in ATSC A/110, "Synchronization Standard for Distributed Transmission." See [3] and [6] for more information.