Broadcasting Technical Quality of Service Standards: Subscription and Free-to-Air Television Broadcasting Services in Trinidad and Tobago

April 2019

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Abbreviations

64 QAM	Quadrature amplitude modulation with 64 constellation points
256 QAM	Quadrature amplitude modulation with 256 constellation points
AM	Amplitude modulation
ATSC	Advanced Television Systems Committee
BER	Bit error rate
Cable	Cable television systems
CIR	Carrier-to-interference ratio
C/N	Carrier-to-noise ratio
CSO	Composite second order
CTB	Composite triple beat
dB	Decibel (a logarithmic value of a ratio)
dBc	Decibels relative to carrier amplitude
dBm	Decibels relative to one milliwatt
dBmV	Decibels relative to one millivolt across a given impedance (75 ohms in North American cable systems)
DOCSIS	Data over cable service interface specification
DSG	DOCSIS Set-top gateway
DSL	Digital subscriber line
DTV	Digital television
FAT	Forward application transport
FDC	Forward data channel
FTA	Free-to-air
HDTV	High-definition television
IF	Intermediate frequency
HRC	Harmonically related carrier
IP	Internet Protocol
IPTV	Internet Protocol television
IRC	Incrementally related carrier
IRE	Institute of Radio Engineers

kbps	Kilobits per second (bits per second in thousands)
kHz	Kilohertz (cycles per second, in thousands)
Mbps	Megabits per second (bits per second in millions)
MER	Modulation error ratio
MHz	Megahertz (cycles per second in millions)
MPEG	Moving Picture Experts Group
mV	Millivolt (thousandths of a volt)
NTSC	National Television System Committee
OTT	Over-the-top
p-p	Peak-to-peak
QPSK	Quadrature phase shift keying
RF	Radio frequency
RMS	Root mean square
SCTE	Society of Cable Telecommunications Engineers
SDTV	Standard-definition television
SMPTE	Society of Motion Picture and Television Engineers
SNR or S/N	Signal-to-noise ratio
STB	Set-top box
SI	Service/system information

1 Introduction

1.1 Rationale

The rationale for the establishment of standards is derived mainly from the objectives of the Telecommunications Act, Chap. 47.31 (the Act) and the functions and powers given therein to the Telecommunications Authority of Trinidad and Tobago (the Authority). Section 45 (2) Part V empowers the Authority to "identify, adopt or establish technical standards".

The Authority has created this document, *Broadcasting Technical Quality of Service Standards: Subscription and Free-to-Air Television Broadcasting Services in Trinidad and Tobago,* (Broadcasting Technical QoS), as a complement to its *Consumer Rights and Obligations Policy — Consumer and Customer Quality of Service Standards for the Telecommunications and Broadcasting Sectors of Trinidad and Tobago* (CROP) (2014). CROP defines the technical standards for customer service and consumer-related quality of service (QoS) for the telecommunications sector but does not include QoS technical standards for the broadcasting sector.

This Broadcasting Technical QoS document also provides a much needed update to the broadcasting technical QoS indicators referenced in Schedule F of a Type 5 concession, under which subscription broadcasters are authorised. The technical quality indicators specified in the current concession do not facilitate the verification of consumer complaints about the quality of broadcasting services or accurately measure the QoS delivered to consumers. Additionally, as both subscription television and non-subscription, i.e., free-to-air (FTA) television are transitioning from analogue to digital broadcasting, QoS indicators are needed for digital services.

1.2 Purpose

This document specifies technical QoS standards for subscription television and non-subscription (FTA) television broadcasting services in Trinidad and Tobago. These standards are to be used in measuring and gathering data to address consumer complaints and ensure compliance with QoS obligations by subscription and FTA television providers. Standards for digital cable signal leakage are also specified, to mitigate interference to other radiocommunications services.

1.3 Background

Since its establishment in 2004, the Authority, in accordance with its mandate, has sought to guarantee consumers good quality services through policy and industry guidelines, while at the same time imposing on concessionaires the lightest possible burden in relation to testing and compliance.

After the publication of CROP in 2014, work began on the first draft of this document to provide technical QoS standards for the television broadcasting sector which, as stated in the rationale, are not provided in CROP. In proposing these technical QoS standards, the Authority sought guidance from international organisations such as regulators and standardisation bodies involved in the development, testing and monitoring of QoS parameters for subscription and FTA networks and services. The recommended technical standards in this document are based on the current technical environment of subscription and FTA television broadcasting services in Trinidad and Tobago. Additionally, in light of the technological advances and best practices in the television industry worldwide, the QoS standards put forth by the Authority in this document cater for the implementation of digital television services.

1.4 Objective

This document establishes the technical QoS standards for:

a) Subscription television services
    i. Analogue cable systems

ii. Digital cable systems
    1. QAM-based
    2. Non QAM-based
    3. IPTV
iii. Analogue and digital cable systems signal leakage

b) Non-subscription (FTA) television services
    i. Analogue systems
    ii. Digital systems

1.5 Scope

This document does not deal with the resilience and robustness of subscription and FTA television broadcasting networks. It focuses on the provision of regular subscriber services under normal conditions and not the provision of services under extraordinary conditions, which will be treated in a subsequent document.

Additionally, this document does not deal with the establishment of broadcasting technical QoS standards for over-the-top (OTT) services.

1.6 Relevant Legislation

The salient sections of the Act that inform this document are set out below. (The clauses in bold are the specific parts of the extracted sections that are pertinent to the purpose of this document.)

One noteworthy objective relates to the protection of customers, as outlined in section 3 of the Act, which provides for the establishment of the conditions for:

"… (c) promoting and protecting interests of the public by –

(i) promoting access to telecommunications services;

(ii) ensuring that services are provided to persons able to meet the financial and technical obligations in relation to those services;

(iii) providing for the protection of customers;

(iv) promoting the interests of customers, purchasers and other users in respect of the quality and variety of telecommunications services and equipment supplied;"

Furthermore, section 18 provides that:

"... (1) the Authority may exercise such functions and powers as are imposed on it by this Act and in particular—

…

(d) establish national telecommunications industry standards and technical standards;

…

(f) advise the Minister on technical standards;

(g) ensure compliance with the Convention;

…

(o) test and certify telecommunications equipment, subject to section 48(3), to ensure compliance with—

(i) international standards; and

(ii) environmental health and safety standards, including electromagnetic radiation and emissions;"

…"(3) In the performance of its functions; the Authority shall have regard to the interests of consumers, and in particular -

(a) **to the quality and reliability of the service** provided at the lowest possible cost;

(b) to fair treatment of consumers and service providers similarly situated;

(c) **in respect of consumers similarly placed, to non-discrimination in relation to access, pricing and quality of service**; and

(d) current national environmental policy."

Additionally, section 45 provides for the establishment of appropriate technical standards, as follows:

"45. (1) Subject to the other provisions of this Act, concessionaires and licensees may implement such technical standards as they deem appropriate and which are in conformity with accepted international standards.

(2) Notwithstanding subsection (1), **the Authority may identify, adopt or establish preferred technical standards.**"

1.7 Review Cycle

This document will be revised periodically to meet changing needs. The Authority will review the standards, as necessary, and in consultation with stakeholders, ensure that it is guided by relevant international standards.

Questions or concerns regarding the maintenance of this document may be directed to the Authority via e-mail to consultation@tatt.org.tt.

1.8 Consultation Process

In accordance with its *Procedures for Consultation in the Telecommunications Sector of Trinidad and Tobago* (ver. 2.0, 2010), the Authority sought the views of the general public and industry stakeholders on the first draft of this document, published on September 26, 2017, with an initial closing date of October 25, 2017. The closing date was extended to November 8, 2017, following requests from stakeholders.

The comments and recommendations received from the first round of consultation, and the Authority's decisions on these comments and recommendations, have been compiled in the decisions on recommendations (DoRs) in Appendix II.

The following revisions to the first consultative document were made:

i. Clarification on the minimum and maximum parameters in section 3.1
ii. Clarification on the minimum and maximum parameters in section 3.2
iii. Change to part c) of the permissible variation of visual carrier level in Table 6
iv. Change to the line amplifier voltage value in Table 6
v. Minor editorial changes to enhance the clarity of the document

The Authority sought the views of the general public and industry stakeholders on the second draft of this document, published on July 15, 2018, with an initial closing date of August 13, 2018. The consultation period was re-opened for an additional two weeks from August 27, 2018 to September 10, 2018, to allow stakeholders to comment on information added to the DoRs from the first round of consultation.

The comments and recommendations received from that round of consultation, and the Authority's decisions on these comments and recommendations, have been compiled in the DoRs in Appendix III.

This document includes the following changes, based on the second consultative round:

i. Structural changes to section 1 to enhance the flow of the document and to conform with the new style rules of the Authority
ii. Minor editorial changes to enhance the clarity of the document
iii. Modifications (technical information) to section 1.9
iv. The inclusion of the phrase, "The Authority intends to incorporate the standards into Schedule F of a Type 5 concession for the quality requirements of ……" in sections: 2.2.1, 2.3, 3.1 and 3.2 of the document

1.9 Other Relevant Documents

In addition to the information received from Trinidad and Tobago broadcasting industry stakeholders, the following documents make provisions which were helpful in finalising the proposed QoS standards for subscription and FTA television services:

i. *Consumer Rights and Obligations Policy – Consumer and Customer Quality of Service Standards for the Telecommunications and Broadcasting Sectors of Trinidad and Tobago* (ver. 1.0, 2014)
ii. *Authorisation Framework for the Telecommunications and Broadcasting Sectors of Trinidad and Tobago* (ver. 0.5, 2005)

iii. *Concession for the Operation of a Public Telecommunications Network and/or Provision of Public Telecommunications and/or Broadcasting Services*
iv. *Equipment Standardisation and Certification Framework for the Telecommunications and Broadcasting Sectors of Trinidad and Tobago* (ver. 1.0, 2008)

1.10 Definitions

Amplitude modulation-vestigial sideband (AM-VSB) — a modulation technique that varies the amplitude of the carrier signal. It is used to broadcast analogue NTSC video signals.

Audio-visual service — a service that possesses both a sound and a visual component, and includes analogue and digital broadcast, on-demand services and premium, tiered and other video services

Bit error rate (BER) — the percentage of bits with errors divided by the total number of bits that have been transmitted, received or processed over a given time period

Carrier — an RF signal used to carry information (video, audio and data) by some modulation scheme (SCTE 40, 2011)

Carrier-to-interference ratio (CIR) — the ratio of the power in the RF carrier to the power of the interference signal

Composite triple beat (CTB) — a third-order distortion, caused by mixing three carriers (A+B-C), that falls on the fundamental of a carrier (SCTE 40, 2011)

Composite second order (CSO) — the sum effect of all second-order distortion products (SCTE 40, 2011)

Demarcation point — a point at (or about) 12 inches outside of where the cable wire enters the subscriber's premises (FCC Rules 47 CFR Section 76.5)

Digital television (DTV) — a general term for the digital coding and transmission of an audio /video programme (SCTE 40, 2011)

Downstream — transmission from the headend to the terminal device (SCTE 40, 2011)

Forward application transport channel (FAT) — a cable network communication channel. The forward application transport channels are QAM channels that comply with ITU J83.B/ ANSI/SCTE 07[2]. The information is carried from the headend to the terminal device at a rate of 26.97 or 38.81 Mbps (SCTE 40, 2011).

Forward data channel (FDC) — a cable network communication channel carried from the headend to the terminal device in a modulated channel at a rate of 1.544 to 3.088 Mbps (SCTE 40, 2011)

Headend — the control centre of a cable television system, where incoming signals are amplified, converted, processed and combined into a common cable, along with any locally originated programming, for transmission to subscribers (SCTE 40, 2011)

Hum modulation of carrier — the peak-to-peak magnitude of the amplitude distortion relative to the radio frequency (RF) carrier signal level due to the fundamental and low-order harmonics of the power-supply frequency

Intermediate frequency (IF) — a signal processing stage between RF and baseband (SCTE 40, 2011)

Moving Picture Experts Group (MPEG) — indicates a suite of digital media standards developed by this working group

Noise — an undesired or unintended element of a signal (SCTE 40, 2011)

Out-of-band (OOB) — outside of the programming channels band. The OOB channels provide communication channels between the network and the terminal (SCTE 40, 2011).

Quadrature amplitude modulation (QAM) — a radio frequency modulation scheme that combines phase and amplitude modulation (ANSI/SCTE, 2007)

Quadrature phase shift keying (QPSK) — a form of modulation in which two bits are modulated, resulting in one of four possible carrier phase shifts

Radio frequency (RF) — the part of the electromagnetic frequency spectrum that is used to transmit video, audio and data over the air or via coaxial cable

Reed-Solomon — a coding method that adds parity symbols to a data packet, thereby providing a forward error correction capability (SCTE 40, 2011)

Signal quality margin test — a fast and simple pass/fail measurement that can give an indication of the digital service quality at various nodes in the cable distribution network

Signal-to-noise ratio (SNR or S/N) — the ratio of the strength of a signal carrying information to that of unwanted noise

Society of Cable Telecommunications Engineers (SCTE) — an organisation that develops standards for cable telecommunications systems (Portal 2018)

Society of Motion Picture and Television Engineers (SMPTE) — a standards organisation devoted to advancing theory and application in motion imaging, including film, television, video, computer imaging and telecommunications (SCTE 40, 2011)

Transport stream (TS) — MPEG-2 transport stream is a format used for transmission and storage of audio, video and metadata.

Terminal device — a television interface device, such as a cable set-top box (STB), that serves, as its primary function, to connect a cable system to a television broadcast receiver or other subscriber premise equipment

Upstream — transmission from the terminal device to the headend (SCTE 40, 2011)

1.11 Compliance Notation

"SHALL"	The concessionaire is required to fully comply with the standard as specified.
"SHALL NOT"	The item is an absolute prohibition of this standard as specified.
"SHOULD"	There may exist valid reasons in particular circumstances to ignore this standard, but the full implications are to be understood and the case carefully considered before choosing.
"SHOULD NOT"	There may exist valid reasons in particular circumstances when the stated condition is acceptable or even useful, but the full implications are to be understood and the case carefully considered before implementing any conditions described in this standard.
"MAY"	This item is optional. A concessionaire is at liberty to choose to include the item because a particular marketplace requires it or because it enhances a product; another vendor may omit the same item.

2 Quality Requirements for Subscription Service

In keeping with its statutory mandate to identify, adopt or establish preferred technical standards that take account of changes in technology, the Authority is adopting new and improved technical standards for subscription broadcasting service. Subsection 2.1 defines the technical QoS standards for analogue cable systems. Subsection 2.2, comprising of subsections 2.2.1, 2.2.2 and 2.2.3, defines the technical QoS standards for digital cables systems, such as quadrature amplitude modulation (QAM)-based digital cable systems, non-QAM digital cable systems and Internet Protocol television (IPTV) cable systems, respectively. These standards shall be used to ensure that subscription broadcasters in Trinidad and Tobago satisfy their quality requirements as defined in Schedule F of a Type 5 concession.

2.1 Analogue Cable Systems Technical Standards

The Authority shall adopt the latest version of the Federal Communications Commission (FCC) Cable Rules Part 76.605 Technical Standards (2014) for analogue NTSC or similar video downstream cable television service. The Authority shall incorporate these standards into Schedule F of a Type 5 concession for the quality requirements of an analogue cable television system. This standard requires that analogue cable television systems transmit signals to subscriber equipment on frequencies in accordance with the Cable Television Channel Identification Plan, CEA-542-D (SCTE 204 2014).

2.1.1 Purpose

The purpose is to update existing technical standards and ensure that analogue cable television providers are delivering a good quality signal to subscribers.

2.1.2 Measurement Method

The Trilithic 860 DSPi instrument or other suitable test instruments capable of measuring the parameters outlined in Tables 1 and 7 shall be used to take all measurements.

2.1.3 Threshold and Standards

The requirements in Table 1 apply to the performance of a cable television system, as measured at any subscriber terminal with a matched impedance at the termination point or at the output of the modulation or processing equipment (generally the headend) of the cable television, and are applicable to each NTSC or similar video downstream subscriber television channel in the system.

The technical standards for an analogue NTSC or similar video downstream cable television channel in the system shall not exceed the ranges prescribed in Tables 1 and 7.

Table 1. Analogue cable systems technical standards (FCC 2014)

Technical Standards	
Television standard	NTSC
Channel bandwidth	6.0 MHz per channel
Channel configuration	Standard 4.5 MHz video/audio: audio 15-17 dB below carrier
Minimum signal level at TV	2 dBmV across 75-ohm termination at the channel input
Minimum carrier/noise	30 dBc (below carrier)
Permissible variation of visual carrier level	a) Over 24 hours 12 dB max b) Between two adjacent channels 3 dB max c) Between low and high visual carrier 12 dB max
Frequency response (each channel)	+ 2 dB from 0.75 kHz to 4 kHz above visual carrier level
Aural frequency deviation	25 kHz
Signal to intermodulation ratio	45 dB min
Radiation level	< 15 uV/m at 30 metres
Line amplifier voltage	89 Vac max
Prohibited frequencies	No cable television system may utilise a frequency at power levels equal to or exceeding 10 microwatts within 100 kHz plus tolerance of the emergency aircraft locator frequency, 121.5 MHz, or within 50 kHz plus tolerance of the distress signal frequencies, 156.8 MHz and 243.0 MHz.

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For each NTSC or similar video downstream cable television channel in the system: 1. a) The cable television channels delivered to the subscriber's terminal shall be capable of being received and displayed by broadcast receivers used for the off-the-air reception of television broadcast signals. b) Cable television systems shall transmit signals to subscriber premises equipment on frequencies in accordance with the channel allocation plan set forth in CEA-542-C: Standard: Cable Television Channel Identification Plan. 2. The centre frequency of the aural carrier must be 4.5 MHz ± 5 kHz above the frequency of the visual carrier at the output of the modulating or processing equipment of a cable television system and at the subscriber terminal. 3. a) The visual signal level across a terminating impedance, which correctly matches the internal impedance of the cable system as viewed from the subscriber terminal, shall: i. not be less than 1 millivolt across an internal impedance at 75 ohms (0 dBmV). ii. not be less than 1.41 millivolts across an internal impedance of 75 ohms (+ 3 dBmV), as measured at the end of a 30-metre (100-foot) cable drop that is connected to the subscriber tap. b) At other impedance values, the minimum visual signal level, as viewed from the subscriber terminal, shall be the $\sqrt{0.0133\ (Z)}$ millivolts and, as measured at the end of a 30-metre cable drop that is connected to the subscriber tap, shall be twice the $\sqrt{0.00662\ (Z)}$ millivolts, where "Z" is the appropriate impedance value. 4. The visual signal level on each channel, as measured at the end of a 30-metre cable drop that is connected to the subscriber tap, shall not vary more than 8 dB within any six-month interval and shall be maintained within: i. dB of the visual signal level of any visual carrier within a 6 MHz nominal frequency separation. ii. 10 dB of the visual signal level on any other channel on a cable television system of up to 300 MHz of a cable distribution system upper frequency limit, with a 1 dB increase for each additional 100 MHz of cable distribution system upper frequency limit (for example, 11 dB for a system at 301 – 400MHz, 12 dB for a system at 401 – 500 MHz, etc). iii. a maximum level such that signal degradation due to overload in the subscriber's receiver or terminal does not occur. 5. The root mean square (RMS) voltage of the aural signal shall be maintained between 10 and 20 dB below the associated visual

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signal level and shall be met at the subscriber terminal and at the output of the modulating and processing equipment (generally the headend).

i. For subscriber terminals that use equipment that modulates and demodulates the signal (e.g., baseband converters), the RMS voltage of the aural signal shall be maintained between 6.5 and 17 dB below the associated visual level at the subscriber terminal.

6. The amplitude characteristic shall be within a range of ±2 dB from 0.75 MHz to 5.0 MHz above the lower boundary frequency of the cable television channel, referenced to the average of the highest and lowest amplitudes within these frequency boundaries. The amplitude characteristic shall be measured at the subscriber terminal.

7. The ratio of radio frequency (RF) visual signal level to the system noise shall not be less than 43 dB. However, good engineering practice targets end-of-line analogue television channel CNR in the 46 to 49 dB range.

8. The ratio of visual signal level to the RMS amplitude of any coherent disturbances, such as intermodulation products, second- and the third-order distortions, or discrete-frequency interfering signals not operating on proper offset assignments, shall be as follows:
   i. The ratio of the visual signal level to coherent disturbances shall not be less than 51 dB for non-coherent channel cable television systems, when measured with modulated carriers and time averaged.
   ii. The ratio of the visual signal level to coherent disturbances, which are frequency coincident with the visual carrier, shall not be less than 47 dB for coherent channel cable systems, when measured with modulated carriers and time averaged.

9. The terminal isolation provided to each subscriber terminal:
   i. shall not be less than 18 dB. In lieu of periodic testing, the cable operator may use specifications provided by the manufacturer for the terminal isolation equipment to meet this standard.
   ii. shall be sufficient to prevent reflections caused by open-circuited or short-circuited subscriber terminals from producing visible picture impairments at any other subscriber terminal.
10. The peak-to-peak variation in visual signal level caused by undesired low-frequency disturbances (hum or repetitive transients) generated within the system, or by inadequate low-frequency response, shall not exceed 3% of the visual signal level.

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Measurements made on a single channel using a single unmodulated carrier may be used to demonstrate compliance with this standard at each test location.

11. The following requirements apply to the performance of a cable television system, as measured at the output of the modulating or processing equipment (generally the headend) of the system:
    i. The chrominance-luminance delay inequality (or chrome delay), which is the change in delay time of the chrominance component of the signal relative to the luminance component, shall be within 170 nanoseconds.
    ii. The differential gain for the colour subcarrier of the television signal, which is measured as the difference in amplitude between the largest and smallest segments of the chrominance signal (divided by the largest and expressed as a percentage), shall not exceed ± 20%.
    iii. The differential phase for the colour subcarrier of the television signal, which is measured as the largest phase difference in degrees between each segment of the chrominance signal and reference segment (the segment at the blanking level of 0 IRE), shall not exceed ±10 degrees. Note: All measurements are taken at the headend.

12. Transit delay from headend to most distant customer shall be less than 0.800 ms (typically much less).

13. a) For operation in the frequency bands 108 – 137 and 225 – 400 MHz, the standards relating to signal leakage performance criteria and frequency separation standards are applicable to all subscriber television systems transmitting carriers or other signal components carried at an average power level equal to or greater than 10–4 W across a 25 kHz bandwidth in any 160 microsecond period, at any point in the cable distribution system and in the frequency bands 108 – 137 and 225 – 400 MHz, for any purpose.
    b) Before transmitting any carrier or other signal component with an average power level across a 25 Hz bandwidth in any 160 microsecond time period, equal to or greater than 10^{-4} W at any point in the subscriber television distribution system, and on any new frequency or frequencies in the aeronautical radio frequency bands, the licensee is required to notify the Authority.

14. All subscriber television systems that operate in the frequency bands 108 – 137 and 225 – 400 MHz shall comply with the following frequency separation standards:
    a) In the aeronautical radiocommunications bands 108 – 137, 225 – 328.6 and 335.4 – 400 MHz, the frequency of all carrier

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signals or signal components carried at an average power level equal to or greater than 10^{-4} W in a 25 kHz bandwidth in any 160 microsecond period must operate at frequencies offset from certain frequencies that may be used by aeronautical radio services operated by licensees or by government agencies. The aeronautical frequencies from which offsets must be maintained are those frequencies that are within one of the aforementioned aeronautical bands and, when expressed in MHz and divided by 0.025, yield an integer. The offset must meet one of the following two criteria: i. All such cable carriers or signal components shall be offset by 12.5 kHz, with a frequency tolerance of ± 5 kHz. ii. The fundamental frequency from which the visual carrier frequencies are derived by multiplication by an integer number shall be 6.0003 MHz with a tolerance of ± 1Hz (harmonically related carrier (HRC) comb generators only). b) In the aeronautical radionavigation bands 108 – 118 and 328.6 – 335.4 MHz, the frequencies of all carrier signals or signal component carriers at an average power level equal to or greater than 10^{-4} W in a 25 kHz bandwidth in any 160 microsecond period shall be offset by 25 Hz with a tolerance of ±5 kHz. The aeronautical radionavigation frequencies from which offsets must be maintained are as follows: i. Within the aeronautical band 108 – 118 MHz, when expressed in MHz and divided by 0.025 yield an even integer ii. Within the band 328.6 – 335.4MHz, the radionavigation glide path channels are listed in Section 87.501 of the FCC Cable Rules. Note: The HRC system, as described above, will meet this requirement in the 328.5 – 335.4 MHz navigation glide path band. Those incrementally related carrier (IRC) systems, with comb generator reference frequencies set at certain odd multiples equal to or greater than three times the 0.0125 MHz aeronautical communications band offset, e.g., (6n ± 1.250 ± 0.0375) MHz (where n = an integer value to deduce an interval frequency), may also meet the 25 kHz offset requirement in the navigation glide path band.

2.2 Digital Cable Systems Technical Standards

Digital cable systems transmit encrypted cable television signals over QAM-based hybrid fiber-coax (HFC) networks, IP networks or other non QAM-based types of networks.

2.2.1 QAM-Based Digital Cable Systems Technical Standard

An HFC network provides digital subscription television service, broadband Internet access service and fixed telephony service utilizing a fiber optic cable transport network and a coaxial cable access network. This subscription television service is delivered via STBs and other devices to television sets or other displays, in standard and high-definition formats, at a quality that is discernible from FTA broadcast television.

The majority of digital signals transmitted by HFC cable plants are delivered via QAM (FCC NPRM 2012). The Authority is adopting the Society of Cable Telecommunications Engineers' (SCTE) digital cable network interface standard (SCTE 40 2011) for QAM-based digital cable systems and shall conduct tests that assess compliance with this standard.

The SCTE 40 2011 standard is also adopted by other Region 2 administrations, such as the Federal Communications Commission (FCC), and provides the current means of ensuring that consumers are receiving a good quality signal from digital cable systems. The Authority shall incorporate this standard into Schedule F of a Type 5 concession for the quality requirements of a QAM-based digital cable system.

By selecting an existing industry-developed standard that is already followed by QAM-based digital cable operators, the Authority is placing little to no additional burden on cable operators. The SCTE 40 2011 standard provides the metrics for compliance. However, only those quality indicators treating with the delivery of digital video signals shall be tested by the Authority for compliance. Quality indicators for the upstream or downstream of data shall not be tested for compliance.

2.2.1.1 Purpose

This standard defines the characteristics and normative specifications for the digital network interface between a cable television system and commercially available digital cable products that are used to access multi-channel television programming.

2.2.1.2 Measurement Method

The Trilithic 860 DSPi instrument, or other suitable test instruments capable of measuring the technical characteristics of a QAM-based digital cable system, shall be used to take all field measurements. The forward application transport (FAT) digital signal power shall be measured as the average signal power in a 6 MHz channel.

2.2.1.3 Threshold and Standard

The minimum signal quality for QAM-based digital cable system shall comply with the SCTE 40 2011 standard, which has received American National Standards Institute (ANSI) approval (ANSI/SCTE 2011). This standard describes the basic technical operational characteristics of digital cable systems using QAM, including such characteristics as relative channel power, carrier-to-noise ratios, and adjacent-channel characteristics. (See Appendix I for the technical standard for QAM-based digital cable systems.)

Compliance with this technical standard shall be tested as follows:

1. A subset of channels shall be utilised for checking compliance with the channel-specific standard for normal video channels contained in the FAT table. (See Appendix I, Table 10.)
2. The nominal power levels (see Appendix I, Table 11) and the adjacent channel levels (see Appendix I, Table 12) shall be tested across every QAM channel on the system.

2.2.2 Non-QAM Cable Systems and Qualitative Signal Quality

Apart from QAM/HFC and IPTV systems, there are few non-QAM cable systems used in Trinidad and Tobago for the transmission of digital subscription television. It should be noted that the largest operator that utilises fixed twisted pair copper wire technology for delivering services in Trinidad and Tobago has stated that this technology will be phased out in favour of wireless technology in two to three years.

The Authority recognises that there are no established industry QoS standards or guidance for the testing and measurement of each particular new technology in the subscription television industry.

Digital cable systems distributing signals on conventional coaxial or hybrid fiber-coaxial cable which, because of their basic design, cannot comply with one or more of the technical standards set forth in sections 2.2.1 and 2.2.3, may be permitted to operate, upon the Authority's approval, on a case-by-case basis. To obtain the Authority's approval, cable operators must submit to the Authority, at a minimum, their own proof-of-performance plans for ensuring subscribers receive good quality signals.

2.2.3 Internet Protocol Television (IPTV) Systems Technical Standards

Internet Protocol television (IPTV) refers to the delivery of digital subscription television service over an IP-based network that is managed to support the required level of QoS, quality of experience (QoE), security, interactivity and reliability. IPTV is delivered via STBs and other devices to television sets or other displays, in standard and high-definition formats, at a quality that is discernible from FTA broadcast television.

QoE is applicable to IPTV systems. Using IP instead of traditional RF technologies to carry video over a network comes with its own set of unique challenges. Consumers have high expectations and are quick to point out any glitches present on a system. Therefore, ensuring that the subscriber is completely satisfied with an IPTV service is a priority for service providers. One of the core requirements of achieving high satisfaction levels is to implement a QoE

measurement system that would closely monitor and benchmark the perception that an IPTV end user has of the service. This contrasts with QoS where the measurements are purely based on networking parameters. (O'Driscoll 2008). QoE is not applied to QAM-based systems as there are QoS standards that are more appropriate.

QoE is defined in ITU-T Recommendation G.1080 as the overall acceptability of an application or service, as perceived subjectively by the end user. Good QoE is reliant upon error-free delivery of packet data without retransmission and is built on the foundation of good QoS. QoE testing on an IPTV network must encompass both service and transmission layers for the most accurate result.

In the design of an IPTV network, QoS and QoE are key performance metrics that determine whether subscribers will receive an end product of acceptable quality. QoS involves the totality of a telecommunications service that bears on its ability to satisfy the stated and implied needs of the user of the service. Good QoS standards increase the likelihood that high QoE expectations will be met.

The quality parameters of an IPTV network are defined at different layers of the network. There are a number of objective parameters of service performance, such as encoding bit rate, packet loss, delay and bandwidth availability, that affect the overall QoE of customers. The relationship between QoE and QoS performance metrics is estimated empirically.

Once identified, the QoE/QoS relationship can be used in two ways:

1. Given a QoS measurement, in principle, the expected QoE for a user can, with appropriate assumptions, be predicted.

2. Given a target QoE for a user, in principle, the net required service layer performance can, with appropriate assumptions, be deduced.

In keeping with the QoE/QoS relationship, the Authority shall adopt the International Telecommunication Union – Telecommunication (ITU-T) Recommendation G.1080 for testing and monitoring the QoE of an IPTV video service. The Authority shall incorporate the standards from the Recommendation G.1080 into Schedule F of a Type 5 concession for the quality requirements of an IP-based television service. Recommendation ITU-T G.1080 defines the QoE requirements from an end-user perspective and is agnostic to network deployment architectures and transport protocols. The recommended minimum transport layer standards for satisfactory QoS and QoE for MPEG-2 and MPEG-4 encoded standard definition television (SDTV) and high-definition television (HDTV) IPTV video services are listed in Tables 2, 3, 4, 5 and 6. Standards are for the IP flows containing video streams only. The requirements for network performance of broadcast SDTV applications listed in Tables 3 and 4 also apply to video on demand (VoD) and premium content services.

2.2.3.1 Purpose

The recommended technical standards for digital video signals transmitted over an IPTV network are designed to ensure the appropriate service quality is delivered. This recommendation addresses the QoE targets and expresses QoE requirements in the context of parameters such as bit rate or packet loss rate.

2.2.3.2 Measurement Method

The Agilent IPTV testing instrumentation or other suitable test instruments capable of measuring the parameters outlined in Tables 2, 3, 4, 5 and 6 shall be used to conduct all quality tests. Compliance testing of these standards shall be carried out from time to time at both the headend and at a customer's STB.

2.2.3.3 Thresholds and Standards

The process of determining the QoE and/or QoS performance targets depends on a number of issues, such as the compression coding scheme to be used for the service, content characteristics,

content provider requirements and customer satisfaction. The following assumptions were made when establishing technical standards for IPTV:

i. MPEG transport stream for generic coding of moving picture
ii. H.262 and H.264 codec for SDTV and HDTV, respectively
iii. No or minimal loss concealment (tolerable loss rates may be higher depending on degree and quality of STB loss concealment)
iv. Standards are end-to-end, from headend encoder output to any application-layer protection mechanisms at the customer's premises.
v. Standards are for the IP flows containing video streams only. IP streams for other applications may have different performance requirements.

The technical standards for testing and monitoring the video signal quality transported across an IP network shall not exceed the ranges specified in Tables 2, 3, 4, 5 and 6. These values are all based on assumptions made above (e.g., MPEG compression coding) and are not applicable to all possible IPTV systems.

Table 2. Video service control plane technical standards (DSL Forum, Architecture & Transport Working Group; 2006)

User Action	Description	Maximum Recommended Delay
User interface actions	Electronic program guide (EPG) scrolling: VoD remote control button push to onscreen indication that command was received	200 ms
Channel zapping	Zapping delay is defined as the time between pushing the remote control button and the first stable channel displayed on the TV.	≤ 2 seconds
System start-up time	Time from STB power on to channel availability	10 seconds

Table 3. Minimum level of transport layer performance for satisfactory QoE for H.262/MPEG-2 encoded SDTV services (ITU 2008)

Transport stream bit rate (Mbps)	Latency (delay)	Jitter	Maximum duration of a single error	Corresponding loss period in IP packets	Loss distance	Corresponding average IP video stream packet loss rate
3.0	<200 ms	<50 ms	≤ 16 ms	<6 IP packets	≤1 error event per hour	≤ 5.85×10^{-06}
3.75				<7 IP packets		
5.0				<9 IP packets		

Table 4. Minimum level of transport layer performance for satisfactory QoE for H.264/MPEG-4 encoded SDTV services (ITU 2008)

Transport stream bit rate (Mbps)	Latency (delay)	Jitter	Maximum duration of a single error	Corresponding loss period in IP packets	Loss distance	Corresponding average IP video stream packet loss rate
1.75	<200 ms	<50 ms	≤ 16 ms	<4 IP packets	≤1 error event per hour	≤ 6.68×10^{-06}
2.0				<5 IP packets		≤ 7.31×10^{-06}
2.5				<5 IP packets		≤ 5.85×10^{-06}
3.0				<6 IP packets		≤ 5.85×10^{-06}

Table 5. Minimum level of transport layer performance for satisfactory QoE for H.262/MPEG-2 encoded HDTV services (ITU 2008)

Transport stream bit rate (Mbps)	Latency (delay)	Jitter	Maximum duration of a single error	Corresponding loss period in IP packets	Loss distance	Corresponding average IP video stream packet loss rate
15.0	<200 ms	<50 ms	≤ 16 ms	<24 IP packets	≤1 error event per 4 hours	≤ $1.17x10^{-06}$
17.0				<27 IP packets		≤ $1.16x10^{-06}$
18.1				<29 IP packets		≤ $1.17x10^{-06}$

Table 6. Minimum level of transport layer performance for satisfactory QoE for H.264/MPEG-4 encoded HDTV services (ITU 2008)

Transport stream bit rate (Mbps)	Latency (delay)	Jitter	Maximum duration of a single error	Corresponding loss period in IP packets	Loss distance	Corresponding average IP video stream packet loss rate
8.0	<200 ms	<50 ms	≤ 16 ms	<14 IP packets	≤1 error event per 4 hours	≤ $1.28x10^{-06}$
10.0				<17 IP packets		≤ $1.24x10^{-06}$
12.0				<20 IP packets		≤ $1.22x10^{-06}$

2.3 Standards relative to Analogue and Digital Cable Systems Signal Leakage

Under certain circumstances, a coaxial cable plant can "leak" and interfere with over-the-air users of spectrum. Except for the general provision requiring measurements to be made at subscriber terminals, and without regard to the type of signal carried by the cable television systems, signal leakage from a cable television system shall be limited, as specified in Table 7.

Table 7. Cable systems signal leakage standards (FCC 2014)

Frequencies	Signal Leakage Limit	Distance in Meters (m)
Analogue signals less than and including 54 MHz, and over 216 MHz	15 µV/M	30
Analogue signals over 54 MHz, up to and including 216 MHz	20 µV/M	3
Digital signals less than and including 54 MHz, and over 216 MHz	13.1 µV/M	30
Digital signals over 54 MHz, up to and including 216 MHz	2.4 µV/M	3

3 Free-to-Air (FTA) Television Technical Standards

Over-the-air tuners allow users to watch live, analogue or digital FTA television channels. The signal is captured by an antenna, transmitted via coaxial cable and then received by an over-the-air tuner that converts the signal to USB output. This section outlines the technical quality standards associated with digital and analogue FTA television networks.

3.1 Analogue Free-to-Air (FTA) Technical Standards

The Authority recognises that there are various quality standards, quoted in product specifications and the literature, to measure the quality of an analogue FTA video signal after its transmission. However, the essential technical standards for testing the quality of an analogue FTA video signal are specified in Table 8. This table is derived from FCC part 76.605 and manufacturers' technical specifications. The Authority intends to incorporate these standards into Schedule F of a Type 5 concession for the quality requirements of an analogue FTA television system.

3.1.1 Purpose

These standards shall be used for the testing, monitoring and enforcement of quality of an analogue FTA television service.

3.1.2 Measurement Method

The Trilithic 860 DSPi instrument or other suitable test instruments capable of measuring the parameters outlined in Table 8 shall be used to conduct all QoS tests.

3.1.3 Threshold and Standards

The QoS indicators for an analogue FTA television service are specified in Table 8.

Table 8. Analogue FTA QoS threshold and standards

Quality Indicators	Description	Standards
RF signal power (RxLev)	Level measurement of the currently tuned carrier within the service area of an FTA broadcaster	≥ 60 dBµV at 30ft above ground level within the service area
Aural frequency deviation	The amount of variation of a carrier frequency or centre frequency from its assigned value	± 25 kHz
Carrier-to-noise (C/N) ratio	Ratio between the modulated signal power and the equivalent noise power for the same bandwidth (according to television standard)	≥ 43 dB
FM deviation	Measurement of the frequency peak deviation for any modulated analogue carrier in FM	± 75 kHz
AM hum modulation	The peak-to-peak variation in visual signal level caused by undesired low-frequency disturbances (hum or repetitive transients) generated within the system, or by an inadequate low-frequency response	≤ 3% of the visual signal level
Chroma/luma delay	Change in delay time of the chrominance component of the signal relative to the luminance component	Shall be within 170 ns
Differential phase	Nonlinear chroma phase as a function of luminance level. A change in the colour saturation results.	≤ ±10 degrees
Differential gain	Nonlinear chroma gain as a function of luminance level. A change in hue results.	≤ ± 20%

3.2 Digital Free-to-Air (FTA) Technical Standards

Digital FTA television is an advanced broadcasting technology that enables superior audio-visual quality and more interactive services. Two broadcasting formats are supported by this technology, namely, SDTV and HDTV. The Authority shall adopt Advanced Television Systems Committee (ATSC) broadcasting standards for digital FTA television service in Trinidad and

Tobago. The Authority shall incorporate these standards into Schedule F of a Type 5 concession for the quality requirements of a digital FTA television system. These quality standards are outlined in Table 9 and shall be used for testing ATSC networks for QoS.

3.2.1 Purpose

These standards shall be used for monitoring and enforcement of the quality of a digital FTA television service.

3.2.2 Measurement Method

The Promax TV Explorer HD ATSC instrument or other suitable test instruments capable of measuring the parameters outlined in Table 9 shall be used to conduct all quality tests.

3.2.3 Threshold and Standards

The technical standards for a digital FTA television service are specified in Table 9. The information in the table was sourced from standards publications, papers presented at meetings and test equipment manufacturers specifications.

Table 9. Digital FTA QoS threshold and standards for ATSC networks

Quality Indicators	Description	Standards
Outlet signal level (RxLev)	Signal level is measured assuming that power spectral density is uniform throughout the channel bandwidth.	60 – 70 dBµV
Carrier-to-noise (C/N) ratio	Out-channel measurement. Noise level is measured at $f_{noise} = f_{tuning} \pm ½ *$ Channel BW. To measure it correctly, the digital channel must be tuned to its centre frequency.	≥ 26 dB
Modulation error rate (MER)	Modulation error ratio with noise margin indication	≥ 25 dB
VBER	BER (bit error rate) measurement for the digital signal after error correction (BER after Viterbi)	$< 2x10^{-7}$
SER	Measuring the number of erroneous segments divided by the total segments received	≥ 20 dB

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5 Appendix I: Digital QAM-Based Technical Standards

The following tables are reprinted from ANSI/SCTE 40 2011 for convenience. The original versions of these tables can be found in the SCTE 40 2011 standard for digital cable systems at http://www.scte.org/documents/pdf/standards/SCTE_40_2011.pdf.

Table 10. Analogue and FAT channel: RF transmission characteristics (Cable Telecommunications 2011)

1.	RF channel spacing	6 MHz
2.	RF frequency range	54 MHz to 1002 MHz, IRC/HRC/Standard Channel Plans
3.	Transit delay from headend to most distant customer	≤ 0.800 ms (typically much less)
4.	Carrier-to-noise-plus-interference ratio, C/(N+I), in a 6-MHz band, where C/(N+I) includes the simultaneous presence of all additive impairments in the 6-MHz channel bandwidth including CTB, CSO and other forms of discrete interference. The carrier, noise and interference are all subject to any linear channel distortions (micro-reflections) present in the transmission path. C/N (analogue channel)	Not less than: 27 dB for 64 QAM 33 dB for 256 QAM 43 dB for AM-VSB analogue
5.	CTB	Not greater than -53 dBc referenced to inband carrier levels for analogue channels
6.	CSO	Not greater than -53 dBc referenced to inband carrier levels for analogue channels
7.	Carrier-to-any other discrete interference	Not greater than -53 dBc

	(ingress)	
8.	AM hum modulation	No greater than 3% p-p
9.	Group delay variation	≤ 0.37 μs/MHz across the 6-MHz channel
10.	Chroma/luma delay	≤ 170 ns (AM-VSB analogue)
11.	Phase noise	≤ -86 dBc/Hz @ 10 kHz offset (relative to the center of QAM signal spectrum)
12.	Maximum amplitude variation across the 6 MHz channel (digital channels) Maximum amplitude variation across the 6 MHz channel (analogue channels)	≤ 6 dB p-p ≤ 4 dB p-p
13.	Bound for a single dominant micro-reflection	-10 dB at ≤ 0.5 μs -15 dB at ≤ 1.0 μs -20 dB at ≤ 1.5 μs -30 dB at ≤ 4.5 μs Micro-reflections longer than 4.5 microseconds are included under item 4 (of this table) as a contributor to the interference I in C/(N+I). Micro-reflections, if present, shall not cause the channel group delay variation and maximum amplitude variation in 4.9 and 4.12, respectively, to be exceeded.
14.	Carrier level at the terminal input	64 QAM: -15 dBmV to +15 dBmV 256 QAM: -12 dBmV to +15 dBmV Analogue visual carrier (c): 0 dBmV to +15 dBmV Analogue aural carrier: -10 dBc to -17 dBc

Table 11. Nominal relative carrier power levels (Cable Telecommunications 2011)

Analogue NTSC	0 dB (reference level)
256 QAM FAT	-5 ± 2 dB
QPSK FDC	-8 ± 5 dB
64 QAM FAT	-10 ± 2 dB

Table 12. Adjacent channel characteristics (Cable Telecommunications 2011)

	Desired (D) Channel Modulation	*Undesired (U) Adjacent Channel Modulation*	*Worst Case D/U Ratio*
1	Analogue NTSC	64 QAM	+2 dB
2	Analogue NTSC	256 QAM	-3 dB
3	Analogue NTSC	QPSK FDC	-3 dB
4	64 QAM FAT	Analogue NTSC	-18 dB
5	64 QAM FAT	256 QAM	-15 dB
6	64 QAM FAT	QPSK FDC	-15 dB
7	256 QAM FAT	Analogue NTSC	-13 dB
8	256 QAM FAT	64 QAM	-5 dB
9	256 QAM FAT	QPSK FDC	-10 dB
10	QPSK FDC	Analogue NTSC	-19 dB
11	QPSK FDC	64 QAM	-11 dB

12	QPSK FDC	256 QAM	-16 dB
13	Analogue NTSC	Analogue NTSC	-3 dB
14	64 QAM FAT	64 QAM	-6 dB
15	256 QAM FAT	256 QAM	-6 dB
16	QPSK FDC	QPSK FDC	-6 dB

i. Independent of the D/U ratios, the C/(N+I) and the absolute signal levels shall meet the requirements for those parameters as described elsewhere in the specification.

ii. Good engineering practice normally requires that only a single FDC channel be adjacent to a FAT channel.

6 Appendix II: Decisions on Recommendations (DoRs) Matrix for First Consultation Round

Matrix is attached separately.

7 Appendix III: Decisions on Recommendations (DoRs) Matrix for Second Consultation Round

Matrix is attached separately.