DIGITAL TELEVISION SWITCHOVER IN JAMAICA

ATSC 3.0 Transmission Operating Guidelines

Prepared by the

BROADCASTING COMMISSION

In consultation with

The Spectrum Management Authority,

The DSO Network & ASO Planning Work Stream

and

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D-2 Signal Transmission

1 Overview

This document describes Transmission Operating Guidelines for carrying ATSC 3.0 RF transmissions in Jamaica. These Guidelines are intended to provide guidance in the provision of digital transmission services in Jamaica using the ATSC 3.0 standards.

Signal coverage analysis is being conducted by broadcasters for each analogue channel to be replicated by digital service at the initial site. There are twenty-two (22) analogue transmitters currently deployed across the island, by two of the three licensed/incumbent free-to-air broadcasters.

The broadcasters will provide information on the existing analogue and planned digital transmitters, such as location, antenna patterns, antenna height, transmitter power and other related information not in the possession of the regulators.

A separate document will review and confirm that broadcasters' designs meet the requirements in the Transmission Operating Guidelines.

Broadcasters should note that several technical recommendations made herein go beyond those made by FCC regulators and ITU Recommendations, including the following:

- Planning Factors for establishing reliable coverage
- Transmitter operating power
- Interference mitigation, including that on adjacent channels
- Considerations regarding the use of multiple PLPs
- Coverage prediction using different models

It should be noted additionally that the document also provides guidance as to what features broadcasters should <u>not</u> implement, which will enable a more expeditious DSO implementation.

2 References

- ATSC A/300 and ATSC documents referenced therein
- ITU P.1812-6
- CRC-Predict, Communications Research Centre (CRC) service coverage prediction model
- NAB Engineering Handbook, 11th Edition
    - Chapter 6.5 - DTV Single-Frequency Networks and Distributed Transmission, S. Merrill Weiss
- NAB Next Generation Television (ATSC 3.0) Station Transition Guide

- Pearl NextGen-TV Host Station Manual, V12
- CEA-766-D, U.S. and Canadian Rating Region Tables (RRT) and Content Advisory Descriptors for Transport of Content Advisory Information Using ATSC Program and System Information Protocol (PSIP)
- CTA CEB-32.2-A, Recommended Practice for ATSC 3.0 Television Sets, Physical Layer
- Broadcaster-supplied information per BCJ Request for Information
- U.S. Code of Federal Regulations, Title 47[1]
    - §73.625 - DTV coverage of principal community and antenna system
    - §73.699 - TV engineering charts

ITU-R Recommendations, Reports, and Handbook

- REC-BT.1877-3, Error-correction, data framing, modulation and emission methods and selection guidance for second generation digital terrestrial television broadcasting systems, Annex 2
- REC-BT.2033-2, Planning criteria, including protection ratios, for second generation of digital terrestrial television broadcasting systems in the VHF/UHF bands, Annex 7
- REC-BT.2036-4, Characteristics of a reference receiving system for frequency planning of digital terrestrial television systems, Annex 3
- REP-BT.2299-3, Broadcasting for public warning, disaster mitigation and relief
- REP-BT.2383-4, Typical frequency sharing characteristics for digital terrestrial television broadcasting systems in the frequency band 470-862 MHz
- REP-BT.2468-1, Guidance for selection of system parameters and implementation of second generation DTTB systems
- REP-BT.2485-1, Advanced network planning and transmission methods for enhancements of digital terrestrial television broadcasting
- REP-BT.2495-2021, Methods for the evaluation of the quality of service of the ATSC 3.0 system
- R-HDB-63, ITU Handbook on Digital Terrestrial Television Broadcasting networks and systems implementation

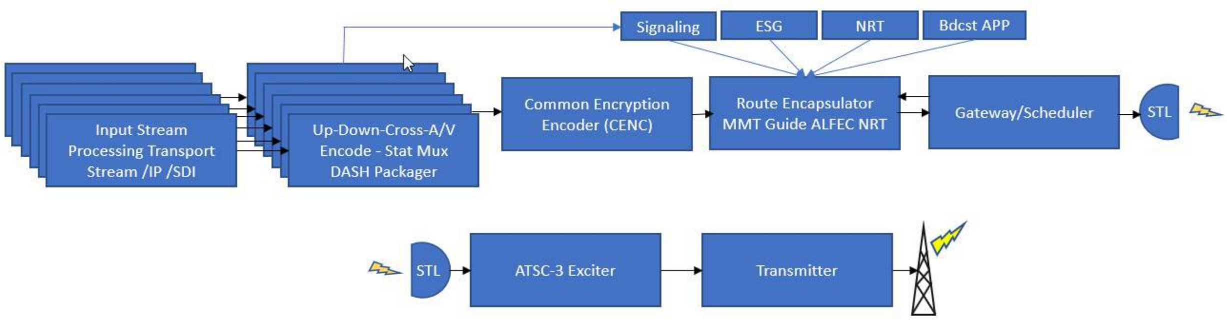
[1] The CFR references are given for historical perspective and should not be used without attention to the specific guidelines provided in this document.

3 ATSC 3.0 Transmission Operating Guidelines (PHY layer)

a. Delivering legacy services to new digital stations

A typical DTV system architecture is shown here in Figure 1.

Figure 1



b. Maximizing digital service

Historically, television broadcasting has been engineered with two key considerations: service availability (coverage) and interference protection. For analog service, this resulted in frequency allocations and transmitter separations that would accommodate broadcasters in designated market areas that were defined by geographical and business considerations. In order to generate these solutions, planning factors were developed based on the technical characteristics of the available analog receiver designs.

When digital service was introduced, the planning factors were adjusted to replicate analog service based on expectations of digital receiver designs. DTV transmitter locations, effective radiated power (ERP) and antenna height above average terrain (HAAT) were chosen based on these adjusted planning factors.

Those planning factors, while considering highly-complex multi-broadcaster spectrum allocations and co-assignment of analog simulcast channels, could not as well take into account previous digital deployment history.

In a new deployment scenario, such as that in Jamaica, where simulcast broadcasting will be in different bands, it is therefore reasonable to use a new set of planning factors based on local geographic and logistical considerations, as well as the deployment experience in the U.S. and other regions.

c. Planning factors for quasi-error-free reception

ITU-R Recommendation BT.2033-2 and U.S. FCC Bulletin OET-69 describe planning factors that characterize the equipment, including antenna systems, used for home reception.

The planning factors are related as follows:[2]

$$C/N = F_s + K_d + K_a + G - L_D - N_t - N_s - L_M - L_S - L_R$$

These terms are defined in the following Tables and associated text.

Table 1: Typical UHF Planning Factors for DTV Reception

Planning Factor	Unit	Symbol	Value
Geometric mean frequency of band	MHz	F_m	560
Channel	#	ch	21, 22, … 36
Channel mid-frequency	MHz	F_{ch}	$515 + 6 \cdot (ch - 21)$
Channel occupied bandwidth	MHz	---	5.83
Dipole factor	dB	K_d	-130.8
Dipole factor adjustment	dB	K_a	$20 \log (F_m/F_{ch})$
Antenna Gain over dipole	dBd	G	10
Downlead line loss	dB	L_D	4.0
Thermal noise	dBm	N_t	-106.3

Based on these revised planning factors, we can develop the Reception Threshold for various receiving scenarios. These are given in the following Table 2.

[2] Three new factors have been added here: L_M, L_S, and L_R, which represent Downlead mismatch loss, Splitter loss and Receive Margin, respectively. The latter accounts for a revised understanding of field strength variability.

Table 2: Revised Planning Factors, Outdoor Antenna[3]

Scenario		**#1**	**#2**	**#3**	**#4***	**#5**	**#6**
Carrier-to-noise ratio	dB	0	5	10	15	15	20
Channel	#	28	28	28	38	28	28
Receive Margin (L_R)	dB	5	5	5	0	5	5
Downlead mismatch loss (L_M)	dB	2.8	2.8	2.8	0	2.8	2.8
Splitter loss (L_S)	dB	4.5	4.5	4.5	0	4.5	4.5
System noise figure (N_S)	dB	4	4	4	7	4	4
Field strength at limit of coverage	dBu	36.0	41.0	46.0	40.7	51.0	56.0

*** The initial *Ns* proposed for first-generation DTV (ATSC 1.0) was 10 dB; this was modified in practice to 7 dB to support lowering maximum transmitter power in the N.A. Region from 2 MW to 1 MW, and also relaxed interference susceptibility. This number resulted in a limiting field strength of 41 dBu for a *C/N* of 15 dB for first-generation DTV service.

It should be noted that these and other limitations were "grandfathered" into NextGenTV service in the U.S., and broadcasters did not seek to revise this or the other "analog" planning factors for a number of reasons:

(1) coverage reliability was now capable of modification by transmission factors other than power increase, such as modcods, etc.;

(2) any proposed power increase would require a new Rulemaking by the FCC, since it affects interference to competing stations;

(3) changes to the established planning factors could affect advertising revenue; and

[3] We have not considered a low-noise antenna amplifier in this tables – which would typically add about 10 dB of gain with a noise figure of about 4.5 dB (what CTA has allowed in their standards for antenna amplifiers) – but this, of course, would add cost to the consumer.

(4) the FCC did not mandate a transition to NextGenTV service in the United States – it remains a *voluntary* broadcaster option.

Jamaican broadcasters, however, are not constrained by the limitations practiced in the U.S. and elsewhere. For this reason, we have developed a set of Revised Planning Factors for NextGenTV service that seek to maximize service reliability. As shown in "Scenario 5," a DTV broadcaster in Jamaica planning for operation at a C/N of 15 dB would observe the following:

the minimum F(50,90) field strength in dBu (dB above 1 μV/m) provided over the entire principal community to be served should be no less than 51 dBu.

For historical reference, we include here the planning factors used by the U.S. FCC as "Scenario 4," which used a Geometric mean frequency of 615 MHz. Note that the FCC did not consider receive margin, downlead mismatch loss or splitter loss, and used a noise figure of 7 dB. The updated figures presented here represent industry estimates for state-of-the-art hardware solutions.

In predicting the distance to the field strength contours, the F(50,90) field strength charts and the F(50,10) field strength charts of U.S. CFR 47§73.699 can be used for the interfering contour. Field Strength in dBu has been predicted using:

F(50,50) F_S = 64 - 20 log[615/(channel mid-frequency in MHz)][4]

F(50,90) F_S = 41 - 20 log[615/(channel mid-frequency in MHz)][5]

When planning for indoor reception using small inexpensive antennas, building penetration loss, negative antenna gain, and antenna height loss must be considered, so that a higher receiving field strength (or equivalent *C/N* selection) may be needed for satisfactory reception.

Table 3 shows Planning Factors for indoor reception.

[4] These figures are based on analog coverage.

[5] These figures are based on ATSC-1 coverage; broadcasters may want to consider (50,95) or even (50,98).

Table 3: Planning Factors, Indoor Antenna[6]

Scenario		#1	#2	#3	#4	#5	#6
Carrier-to-noise ratio	dB	0	5	10	n/a	15	20
Channel	#	28	28	28	n/a	28	28
Receive Margin	dB	5	5	5	n/a	5	5
LNA gain	dB	10	10	10	n/a	10	10
LNA noise figure	dB	4.5	4.5	4.5	n/a	4.5	4.5
Antenna gain	dB	-8	-8	-8	n/a	-8	-8
Bldg Penetration Loss	dB	16	16	16	n/a	16	16
Rcvg Antenna Hgt	dB	1.5	1.5	1.5	n/a	1.5	1.5
Height Gain/Loss	dB	-20	-20	-20	n/a	-20	-20
Receiver noise figure	dB	4	4	4	n/a	4	4
Field strength at limit of coverage	dBu	77.2	82.2	87.2	n/a	92.2	97.2

Where practical conditions limit the feasibility of operating at the transmission powers and antenna heights necessary to achieve the recommended minimum field strength, broadcasters may elect to provide comparable service coverage through a combination of alternate modulation/coding parameters, multiple PLPs, Single-Frequency Networks, or On-channel Repeaters (gap fillers). As many users may not have outside antennas, broadcasters should take into account indoor coverage predictions, so that all consumers will get "acceptable" coverage. See Sections f , h, and 1 below.

[6] The FCC did not describe planning factors for indoor reception of DTV transmissions. Building penetration loss has been documented as high as 20 dB. We use an intermediate figure here to estimate

d. Co-channel operation

There could be overlapping regions where a receiver would receive a signal from each of two (2) transmitter locations operating on the same broadcast channel. In that case, the two co-channel transmission signals would have to be identical at the physical layer to ensure that there was no undesirable interference from one site into the receiving area of the other.

For co-channel transmitters to work as a SFN where a receiver can receive both signals desirably, both transmitters must transmit identical signals and guard intervals should be set in such a way that the delay in receipt of signals does not exceed the guard interval. There must be identical programming, modulation, and coding on both channels.

All transmitters that are part of a Single-Frequency Network (SFN) should be operated under the following conditions:

i. when the transmitters in the SFN carry identical payloads, the transmissions are considered to be non-interfering, and the Guard Interval of each transmission signal should be set to exceed the highest expected delay between the received signals for all areas of significant signal overlap;

ii. when transmitters carry non-identical payloads,[7] the transmissions are considered to be interfering, and the co-channel interference desired-to-undesired protection ratio in the significant region should not be less than the following, which is based on the threshold listed in Table 33 of ITU-R Recommendation BT.2033-2:

   1. 32.8 dB D/U, when operating at 256 QAM, 13/15 code rate, 32K FFT and 64,800-bit codelength[8]

iii. Consider channel frequency offset to improve interference protection. The ATSC 3.0 Scheduler allows a carrier frequency offset in order to avoid co-channel interference among neighboring transmitters. The allowed carrier frequency offsets are ±1 OFDM carriers in the 8K FFT size. See Section 9.3 of A/324:2018 for more details.

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[7] Strictly speaking this not an SFN.

[8] These transmission parameters would result in a C/N of about 22.4 dB. The use of other transmission modes will change the D/U threshold; as the interfering signal can be considered to be noise, the improvement will be related to the C/N improvement.

e. Adjacent channel operation

The SMA has allocated UHF spectrum in a manner that supports co-located operation on adjacent channels. The DTV into DTV protection ratio values provided in Recommendation ITU-R BT.1368-13 are −28 and −26 dB, for lower and upper adjacent channel interferences respectively. These protection ratios were based on asymmetric transmitter splatter in the first adjacent channel. Recommendation ITU-R BT.2036-4 describes an intermediate figure of −27 dB for weak signals, and -20 dB for strong signals.

To the extent that adjacent-channel installations will be co-located, the service areas will exhibit an improved tolerance to adjacent-channel interference over that of non-co-located transmitters.

In order to afford the highest protection for adjacent-channel operation, broadcasters should use an 8-pole mask filter at the output of their transmitter power amplifier. While the use of such a filter will lower interference, broadcasters should verify reliable reception in the interference areas. In addition, ATSC 3.0 transmission parameters can be modified to offer additional protection in a particular scenario.

f. Use of multiple PLPs for video/audio and signaling

The ATSC 3.0 standard supports the simultaneous receiver processing of up to four PLPs.[9] In situations where it may be difficult to provide adequate coverage by other means, broadcasters may consider operating related audio and video services in separate PLPs with different coverage extents. In this manner, audio services could continue to be delivered reliably even when the C/N is insufficient to provide error-free video service. A similar approach can be applied to video, using Scalable HEVC coding (SHVC) to present related Standard Definition and High-Definition video in separate PLPs. This type of transmission could be used to emulate a "graceful degradation" of the signal at the most distant points of coverage.

As an example, at a C/N of 15.0 dB (as given in Scenario 5 in Table 2), changing the modulation parameters to operate at the equivalent C/N of about 9.6 dB would result in a Data Rate of about 13.3 Mb/s. See Section 1 below, *Reference transmission conditions*.

[9] From ATSC A/322, §5.1.1: "The maximum number of PLPs in a frame carrying content requiring simultaneous recovery to assemble a single delivered product shall be four…" From CTA-CEB-32.2-A: "Reception of an ATSC 3.0 RF channel may require processing of up to four ALP streams. Since each ALP stream is carried in a separate PLP, it is recommended that ATSC 3.0 Television Sets include at least four PLP processors."

g. Layered Division Multiplexing

Field tests have demonstrated that the LDM mode can provide a more efficient method than multiple-PLP TDM to deliver a variety of services (e.g. mobile, indoor and stationary services) with different robustness and payload within a single RF channel. It has also been demonstrated that, in the case of indoor and mobile reception, since there exist large penetration and antenna losses which weaken signal field strength considerably, LDM can provide a gain over TDM.

If LDM is used, broadcasters must plan their facilities to operate at the power level required by the sum of the two layers. Broadcasters should also be sensitive to the fact that, depending on the relative layer injection levels, not all locations in the base layer coverage area will be able to receive the enhancement layer.

h. DTV transmitter parameters

DTV transmitters should be set up using parameters selected from the following Table 4, so as to achieve the target C/N throughout the coverage area:

Table 4, Typical Setup Parameters

PHY-Layer Feature	**Parameters**
Modulation and Coding	Per CTA-CEB-32.2-A
FEC length	16200, 64800
FEC code	BCH, CRC+LDPC
Code Rate	[2…13]/15
Guard Interval	1024, 1536 typical; others available, e.g., for dense SFNs
Scattered Pilot Patterns	16 patterns available per A/322 Table 8.3; constrained by Guard Intervals, FFT choices
Constellation	QPSK, 16QAM, 64QAM, 256QAM, 1024QAM
Transmission mode	SISO (MISO, MIMO more complex)
Interleaving	Convolutional Time Interleaver, Hybrid Time Interleaver
FFT size	8K, 16K, 32K

PLP mapping	Single-PLP; TDM, FDM, TFDM, LDM (up to 4) for a single or separate service
Layered Division Multiplexing (LDM)	Supports additional multiple services with different robustness and throughputs in one TV channel. Support in all receiver devices must be verified.
Channel Bonding	Can be used to distribute PLPs across two RF channels. May require more complex receiver. Not recommended for initial deployment, due to receiver complexity.

i. Reference transmission parameters

Selected transmission parameters are shown in Table 5 below. The QEF condition in Simulation AR-222 below achieves a Data Rate of 24.6 Mbps with a C/N of 15.9 dB in an AWGN channel.

Table 5: Example Transmission Conditions

PHY-Layer Feature			
Simulation[10]	AR-222	AR-223	AR-2060
FEC length	64800	64800	16200
FEC code	BCH	BCH	BCH
Code Rate	9/15	10/15	5/15
Guard Interval	1536	1024	1536
Scattered Pilot Patterns	8_2	16_2	8_2
Constellation	256QAM	256QAM	256QAM
Transmission mode	SISO	SISO	SISO
Interleaving	Convolutional Time Interleaver	Convolutional Time Interleaver	Convolutional Time Interleaver
FFT size	32K	32K	32K
PLP mapping	Single-PLP	Single-PLP	Single-PLP
Layered Division Multiplexing (LDM)	n/a	n/a	n/a
Channel Bonding	n/a	n/a	n/a
Data Rate	24.6	28.0	13.3
C/N	15.9	17.3	9.6

[10] BCJ (internal) project designations

4 Signal coverage analysis

Broadcasters have already been asked to submit information on the existing analogue and planned digital transmitters, such as location, antenna patterns, antenna height, transmitter power, signal coverage prediction and other related information.

Broadcasters should note that, although models such as Longley Rice, ITU-P.1812, and CRC-Predict have been historically used to predict signal coverage, each has strengths and weaknesses, such as the consideration of ground clutter, and so forth. Broadcasters are expected to conduct field testing to verify that their signal coverage meets the expectations implied by predictions.

The Broadcasting Commission will review and confirm that the analyses submitted by broadcasters meet the requirements in the Transmission operating guidelines.

5 Transmission plant requirements.

The Broadcasting Commission and Jamaican regulators will review and confirm that broadcasters' designs meet the requirements in the Transmission Operating Guidelines.

Broadcasters should note that this section is intended for use by regulators in the review process and is provided here only as background information for broadcasters.

Broadcasters should particularly note that the provision of particular services could be specific to different viewers, and this could mean a segmentation of the viewer market.

Technical

1. Requirement to utilize the ATSC Standard
    a. A/321, A/322, A/324, A/330, A/331, A/332, A/337, A/341, A/360, A/200
    b. A/342 Part 1 defines a common framework that shall be used for all audio systems in ATSC 3.0 broadcasts. Subsequent Parts of the Standard define the audio systems and associated constraints on coding to be used within the framework defined in Part 1.
    c. Broadcasters in the U.S. have selected the audio system defined in A/342 Part 2 as the audio system for use in U.S.; it is currently in use in the U.S., and all ATSC-3.0 receivers deployed there support A/342, Part 2.[11]

[11] This system is commonly known as "AC-4." A/342-2 establishes a set of constraints on ETSI TS 103 190-2 for use within ATSC 3.0 broadcast emissions.

d. Broadcasters in Korea have selected the audio system defined in A/342 Part 3 as the audio system for use in Korea; it is currently in use in Korea, and all ATSC-3.0 receivers deployed there support A/342, Part 3.[12]

e. It cannot be assured that receivers deployed in the U.S. and Korea are cross-compatible when only an opposite audio system is transmitted.

f. [system to be used in Jamaica TBD]

2. ATSC-3 equipment:

   a. Transmitter

      i. Confirm all technical requirements, including transmitter emission parameters, 8-pole mask filter, Microwave STL Bandwidth, etc.

      ii. Proof Transmitter for ATSC 3.0

      iii. Conduct field test to confirm signal coverage at selected fringe sites

      iv. Develop an ATSC 3 Disaster Recovery Model

   b. Local and OTA monitoring

   c. Video Encoders with Variable Bit Rate and statistical multiplexing

   d. Scheduler/Broadcast Gateway, with ROUTE Encapsulation/Signaling Server/ Guide Insertion

   e. ATSC-3 watermark embedder for each service for the broadcaster's use of the audio watermark as described in ATSC A/344:2016

   f. Content Advisory signaling. ATSC A/322 Service Announcement provides descriptions of content offerings, which can be used in a receiver to provide a filtering capability based on user preferences and content properties, such as content advisory ratings.[13]

      Content advisory rating information corresponds to a rating system defined by a Rating Region Table (RRT) that is transmitted by broadcasters, which is further defined in CEA-766-D. Current receiving devices targeted for North America are capable of responding to RRTs developed for the U.S. and Canada rating regions.

[12] This system is commonly known as "MPEG-H." A/342-3 establishes a set of constraints on ISO/IEC 23008-3 for use within ATSC 3.0 broadcast emissions.

[13] A/322 can also signal the presence or absence of captioning, interactive enhancements, video formats (3D, SD, HD, UD), audio formats (stereo, 5.1, immersive), caption formats (IMSC1 text or image), content genre, accessible audio tracks, alternate languages, etc.

As elaborated in CEA-766-D, the RRT for the U.S. contains the following dimensions:

(0) Entire Audience, (1) Dialogue, (2) Language, (3) Sex,
(4) Violence, (5) Children, (6) Fantasy Violence, and (7) MPAA.

As customization of a local RRT for Jamaica would involve added expense and development time for consumer electronics (CE) manufacturers (because of the new elements required in a user interface), we conclude that it is prudent to adopt the existing RRT deployed in the U.S.

The decision as to how to label and tag content is left up to broadcasters, in compliance with any imposed regulations on content in Jamaica, e.g., the Children's Code for Programming/Content Code.

g. CENC encoder (for DRM) and required licensing for A3SA Packager. Starting as soon as 2023, ATSC 3.0 devices from major brands sold in the U.S. market can be expected to start to reject unsigned services and apps. Certificates for signing ATSC 3.0 services and apps are believed to be only available via the A3SA.

   In regions where distributors are highly likely to source devices sold in U.S. stores, broadcasters need to be aware of this and take steps to either (a) sign their applications and services with certificates from A3SA or (b) set up their own "security authority" and root-of-trust and arrange for appropriate certificates to be installed on consumer devices,[14] or (c) only support specific devices to be sold in the region's closed market and ensure CE makers don't turn off the ability to accept unsigned services/apps in their market. This third option, however, is not encouraged, as it precludes the future implementation of conditional access services.

h. Decoding and or interface equipment to import legacy services to feed up/down/cross and encoding equipment.
i. Fiber, Microwave, OTA demodulators, required transmitter interfaces
j. STL capable of > 50Mb/sec in IP UDP/RTP Multicast
k. Internet stream feeds, optionally using hybrid capability of A/300

[14] There are, for example, 3rd-party certificate management systems under development. The GoJ, for example, has established a Public Key Infrastructure with eGov Jamaica Ltd. being the GoJ's Certificate Authority.

General

a. Required number of HD / SD streams to carry
b. Agreement and interface w/ EPG source
    i. MVPD providers
    ii. TV set manufacturers
    iii. Device manufacturers
c. Possibility of support for the "return path" for fully-interactive content, which could be either wired (e.g., internet) or by out-of-band wireless means. There is a return channel specification that is defined by ATSC that was designed to use Out-of-Band spectrum for a return path/channel. Broadcasters may want to consider partnership(s) with mobile operators to provide data plans to facilitate the provision of a return path as part of their package, for those customers desiring that feature.

Content

- NextGen TV Service in ATSC 3.0:
    - Confirm primary service
        - While the highest quality experience is strongly encouraged, SD can be used as needed to address coverage issues and bandwidth constraints. Nonetheless, at least one HD service should be provided.
        - Evaluate video quality for key scenarios, e.g., @25Mbps, including reserve for audio, datacasting and possible future higher content resolutions (SD/HD, 540p/1080p, HD/UHD/4K)
            - Support for 4K, High Dynamic Range, Wide Color Gamut content
    - Specification of multicast services
    - Specification of pay services
    - Specification of ancillary services
        - services that may be provided include, but are not limited to computer software distribution, data transmissions, teletext, interactive materials, aural messages, paging services, audio signals, subscription video, and any other services that do not derogate primary obligations

- Specification of arrangements entered into with outside parties affecting service operation

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