Remote Diagnosis of Adjacent Channel Interference in a High-Split System

A Technical Paper Prepared for SCTE by

Lei Zhou
Principal Architect
Charter Communications
14810 Grasslands Drive, Englewood, CO USA
lei.zhou@charter.com

Table of Contents

Title **Page Number**

List of Figures

Title **Page Number**

List of Tables

1. Introduction

As the demand for network bandwidth continues to grow, the stress on the upstream direction of transmission becomes more pressing. This trend calls for more spectral resources for the upstream channels in a traditionally asymmetric coax-based access network. The DOCSIS® specification has defined mid-split and high-split spectrum allocation schemes to expand the upstream capacity. The work of this technical paper is to facilitate the deployment of mid-split and high-split DOCSIS networks with a proposed solution of managing potential radio frequency interferences among customer premises devices operating on the new spectral chart.

1.1. Mid-Split and High-Split DOCSIS Networks

Most Hybrid Fiber Coax (HFC) networks on which DOCSIS technology is operating allocates frequencies between 5 and 42 MHz for the upstream channels and above 54 MHz for the downstream. In the 42 – 5 = 37-MHz wide frequency band, typically four bonded 6.4-MHz Single-Carrier Quadrature Amplitude Modulation (SC-QAM) channels are configured to offer up to 140 Mbps of upstream bandwidth.

A *mid-split* spectrum allocation scheme was introduced in the DOCSIS 3.0 specification [1]. It moves the upper edge of the upstream band to 85 MHz, practically doubling the upstream spectral bandwidth. The DOCSIS 3.1 specification [4] pushed the upper edge further to 204 MHz and is referred to as the *high-split* scheme. Retrospectively, the legacy scheme with the 42 MHz upstream edge is called *sub-split*. The spectrum allocations between the DOCSIS upstream and downstream in sub-split, mid-split and high-split schemes are illustrated in Figure 1.

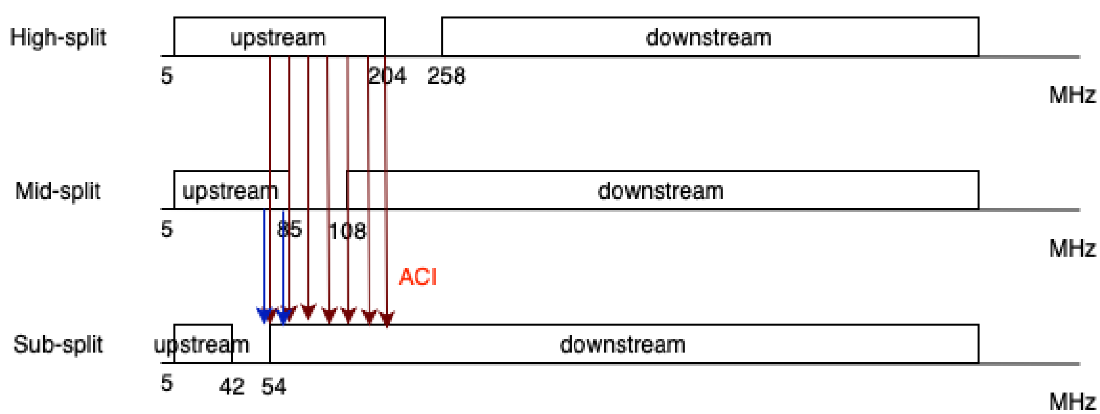

Figure 1: High-Split, Mid-Split and Sub-Split Spectra and ACI

The mid-split and high-split schemes ease the deployment of more efficient modulation and multiple access control technology, OFDMA, as they supply extra spectral bandwidth to accommodate the new signaling while keeping the legacy SC-QAM channels occupying the band below 42 MHz intact to support the large number of non-OFDMA-capable devices. When OFDMA is used in a high-split system, up to 2.5 Gbps upstream capacity can be achieved in DOCSIS 3.1 networks.

1.2. Adjacent Channel Interference in Mid-Split and High-Split Systems

A challenge to the deployment of a mid-split or high-split scheme is spectral compatibility. In a mid-split or high-split HFC network, the upstream radio frequency (RF) signal can go up to 85 or 204 MHz, respectively. However, the receiver of a sub-split customer premises equipment (SS-CPE) such as a video set-top box (STB) accepts RF signals starting from 54 MHz. The overlap of the upstream and downstream transmission bands, as shown in Figure 1, means that the SS-CPE may "see" RF power transmitted from mid-split or high-split cable modems (MS-CMs or HS-CMs) in the 54 – 85 or 54 – 204 MHz range.

Although downstream services will have been excluded from the frequencies below 108 or 258 MHz, the downstream lower edge of the mid-split or high-split system, a SS-CPE may still be susceptible to such interfering RF energy if it comes into and impairs the RF font-end of the SS-CPE receiver. This effect is referred to as *Adjacent Channel Interference* (ACI). Strong enough ACI can cause service impairment. For example, a sub-split set-top box may show video tiling when a neighboring MS-CM or HS-CM is transmitting in the upper part of the upstream band of a mid-split or high-split system. While an uncommon scenario, ACI can also exist from a HS-CM to a MS-CPE, because the upstream band of the high-split system partially overlaps the downstream band of the mid-split system.

Preventing ACI from causing service impairments is critical to the deployment of mid-split and high-split networks on which SS-CPE will be co-existing with MS-CMs and HS-CMs. Calibrating the downstream power for the worst case, ACI may not be practical as the output RF power at a node may have already been maximized for other reasons, such as to achieve maximum household-per-node efficiencies. ACI can be rejected or attenuated by installing a band-stop filter at the input of the SS-CPE to eliminate signals between 54 – 85 or 54 – 204 MHz. Then identification of the ACI-prone devices is highly desired because installing a band-stop filter on all SS-CPE devices in a network is prohibitively expensive.

1.3. Diagnosis of ACI

Many studies of mid-split and high-split ACI have been conducted to establish baselines and thresholds of ACI power in relation to margins when service impairments are observed. The metrics used by those studies may not be easily obtainable in a production network due to the lack of readily available telemetry data from the SS-CPE, MS-CMs, HS-CMs and other RF components. Consequently, the methods in those studies may not be suitable for the task of identifying SS-CPE devices that may be impacted by ACI, and subsequently should be targeted for proactive ACI mitigation.

This paper investigates an alternative method for remote diagnosis of ACI on a per SS-CPE basis using existing telemetry data from online devices. The method helps identify the devices suffering from ACI. Then ACI mitigation can target those problematic sites or devices so that high-split or mid-split can be enabled for them. The proposed method is generally applicable to both mid-split and high-split scenarios. The paper will focus on the high-split case.

2. Characteristics of High-Split ACI

2.1. Scenarios of High-Split ACI

High-split ACI is the 54 – 204-MHz RF signal emitted from a HS-CM and sinking into a SS-CPE. There are primarily two scenarios where ACI may manifest itself and both are illustrated in Figure 2.

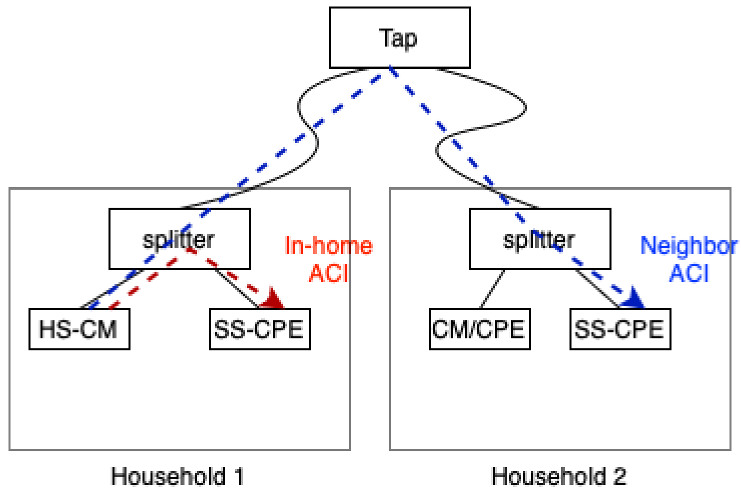

Figure 2: In-Home and Neighbor ACI Scenarios

2.1.1. In-Home ACI

The splitter in a customer home, which both the HS-CM and the SS-CPE are connected to, provides a signal path for the HS-CM's upstream to "leak" to the SS-CPE's receiver, when the port-to-port isolation of the splitter does not provide enough attenuation of the RF signals. The port-to-port isolation value of a typical consumer-grade splitter is about 25 dB. The cabling loss between the HS-CM and SS-CPE via the splitter also provides some attenuation of the ACI. Depending on the length of the coaxial cables, that loss is typically of 1-2 dB.

2.1.2. Neighbor ACI

Neighbor ACI happens between the HS-CM of one customer home and the SS-CPE of another through the tap shared by the two homes. The mechanism is like that of the in-home ACI, but the RF leakage happens between the ports of the tap.

The typical port-to-port isolation value of a tap is similarly 25 dB. There is much more cabling loss attributed to the two drop cables from the tap to the two homes, and the two in-home cables from the in-home splitters to the two devices. The insertion loss of the ground blocks and of the splitters in the two homes should also be accounted for when calculating the RF attenuation. The total attenuation is usually high enough to suppress the effect of ACI. ACI due to leakages of multiple hops of taps has less of an impact. Consequently, neighbor ACI is usually less of a concern than in-home in high-split systems.

2.2. Impact of ACI

The level and extent of the impact by ACI depend on the type of SS-CPE receiver and the pattern of ACI. There are several RF front-end architectures used in SS-CPE receivers, including the single-channel receiver, wide-band or block receiver and full-band receiver. The full-band receiver is prevalent in SS-CPE devices deployed in cable networks.

2.2.1. Automatic Gain Control Maladjustment

Figure 3 shows an example full-band RF receiver identifying the critical components of the RF front-end. The components include a Variable Gain Amplifier (VGA) to boost a weak input signal, an equalizer (EQ) to remove inter-symbol interference and an automatic gain control (AGC) logic to maintain the signal level to the QAM tuners. The AGC logic is a negative feedback loop: it calculates the difference between the output signal and a reference, integrates the error and uses the integral to tune the VGA and EQ. When in equilibrium, the AGC logic by design should get the optimal Signal to Noise ratio (SNR) and Modulation Error Ratio (MER) for QAM signals.

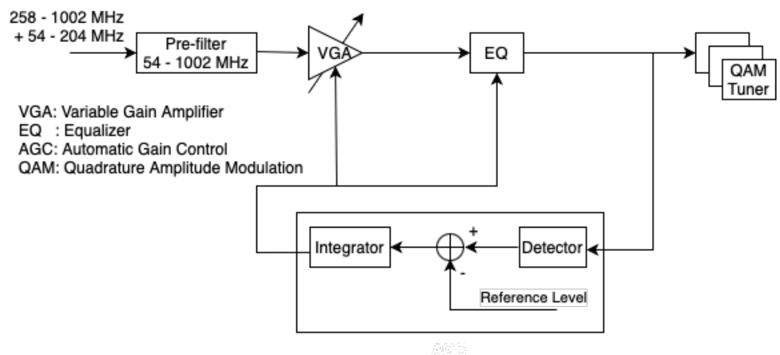

Figure 3: AGC in Full-Band Receiver

When ACI in 54 – 204 MHz frequencies enter the RF front-end of the SS-CPE receiver, the added energy will drive the AGC logic off the equilibrium. The AGC will then adjust to lower the gain of the VGA in response to the increased in-band power.

Several cases of the AGC adjustment due to ACI are illustrated in

Figure 4.

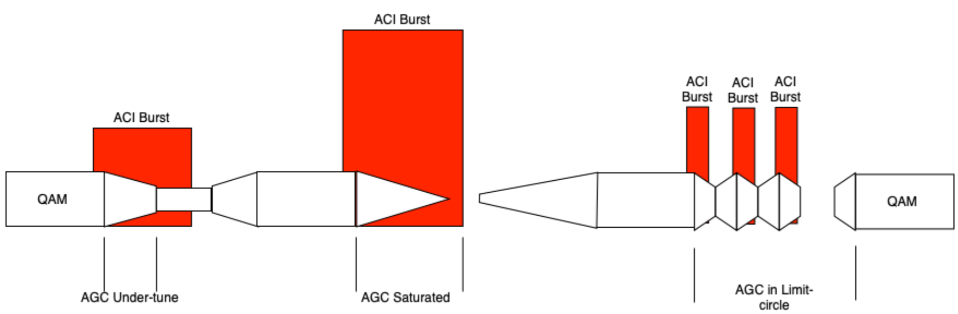

Figure 4: QAM Signal Level and AGC Changes Under Different ACI Patterns

Generally, the adjustment will result in reduced QAM signal levels to the input of the tuner. That also means reduced SNR and MER. In the case that the QAM signal level falls below a certain threshold, bit errors, packet loss and finally, service impairment will occur. When the ACI power is so high that it saturates the VGA completely, leaving no room for the AGC to maneuver, the QAM signal will be clipped. Signal clipping will result in excessive bit errors, packet loss and service interruption.

Another important case is when ACI comes in a sequence of short bursts. In this case, the AGC may step into a limit-circle and not converge to a steady state. The fluctuations in the QAM signal levels become added noise and significantly reduce the SNR at the QAM tuner.

2.3. Numerical Evaluations of High-Split ACI Impact to STB

The susceptibility of three models of sub-split STBs to high-split ACI from one HS-CM is evaluated in lab, with a focus on identifications of indices and value threshold that can be used for detections of service-impairing ACI situations. The test setup is depicted in Figure 5.

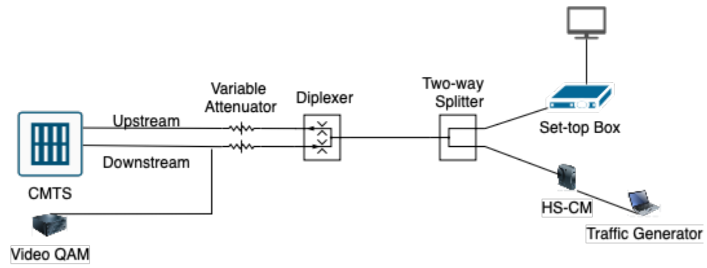

Figure 5: Test Setup for In-Home ACI Evaluation

Two variable attenuators are used to control the transmit and receive power of the two devices. A laptop is connected to the HS-CM and serves as a traffic generator to simulate upstream transmissions. The STB video output is monitored on a TV for subjective quality verification. The high-split upstream is configured with four SC-QAM channels and two OFDMA channels; the details of the channel parameters are shown in Table 1.

Table 1: Upstream Configurations of the Test Setup

SC-QAM 1	Center Frequency: 16.1 MHz Bandwidth: 6.4 MHz Type: ATDMA
SC-QAM 2	Center Frequency: 22.5 MHz Bandwidth: 6.4 MHz Type: ATDMA
SC-QAM 3	Center Frequency: 28.9 MHz Bandwidth: 6.4 MHz Type: ATDMA
SC-QAM 4	Center Frequency: 35.3 MHz Bandwidth: 6.4 MHz Type: ATDMA
OFDMA 1	Frequency: 39.6 – 88.0 MHz Subcarrier Spacing: 50 KHz Rolloff Period: 256 symbols Symbol Frame: 16 symbols Cyclic Prefix: 96 symbols
OFDMA 2	Frequency: 108.475 – 203.475 MHz Subcarrier Spacing: 50 KHz Rolloff Period: 96 symbols Symbol Frame: 16 symbols Cyclic Prefix: 256 symbols

The test procedure includes polling the HS-CM and the STB for metric data periodically for a specified duration. In the middle of polling, the traffic generator is triggered to send traffic upstream for a short period. The metric data polled includes STB receive SNR, AGC of the active QAM tuner, which is tunned at 321 MHz, and the QAM channel frequency closest to the upper edge of the upstream OFDMA channel of the system under test. The procedure is run under different HS-CM transmit power and STB receive power settings, which are set by the attenuators.

2.3.1. STB Model-A

Model-A STB supplies tuner SNR and AGC data through a diagnostic shell over SSH. The test procedure polls the tuner status by SSH logging in the device and running diagnostic command at 5-second intervals for 120 seconds. At the lapse of 20 seconds, the HS-CM upstream transmission is triggered and lasts for 70 seconds.

Figure 6 and Figure 7 show the sample series of the STB tuner SNR and AGC values under a fixed STB receive power level -5.0 dBmV and three HS-CM transmit power levels 41, 43 and 45 dBmV. The subjective video verification results under each parameter set are annotated in the legend labels. The data reveals the effect of increasing ACI levels to the tuner SNR and AGC at a fixed receive power. The STB tuner SNR drops and AGC increases nearly linearly as the ACI increases. Video tiling is the result when the SNR drops below a threshold (around 28 dBmV). The AGC value is a unitless quantity, but its decrement is clearly correlated to the ACI levels and consistent with the SNR decrement.

Figure 8 and Figure 9 show the sample series of the STB tuner SNR and AGC values under four STB receive power levels -2, -5, -6 and -7 dBmV and a fixed HS-CM transmit power level 45 dBmV. The data reveals that the STB tuner SNR is impacted by the same ACI more at a lower receive power. The tuner SNR values are rather close under different receive power levels when ACI is not present, but the decrements of the SNR are bigger for lower receive power levels.

This fact is further corroborated by Figure 10 and Figure 11, where the STB tuner SNR and AGC values under two sets of different STB receive power and HS-CM transmit power levels with the same power ratio (difference by the dB values). At lower receive power, the STB tuner experiences more SNR decrements and AGC increments even under lower ACI levels (translated from lower HS-CM transmit power). This observation may indicate that the Carrier to Interference Ratio (CIR) alone may not be enough to characterize the impact of ACI. The baseline receive power and SNR are needed for the diagnosis of an STB's susceptibility to ACI.

The STB tuner AGC increase almost linearly with the decrements of the receiver power, and it can be completely saturated by the ACI when the receive power is too low. An AGC saturation case is captured in Figure 9 when the receive power is -7 dBmV.

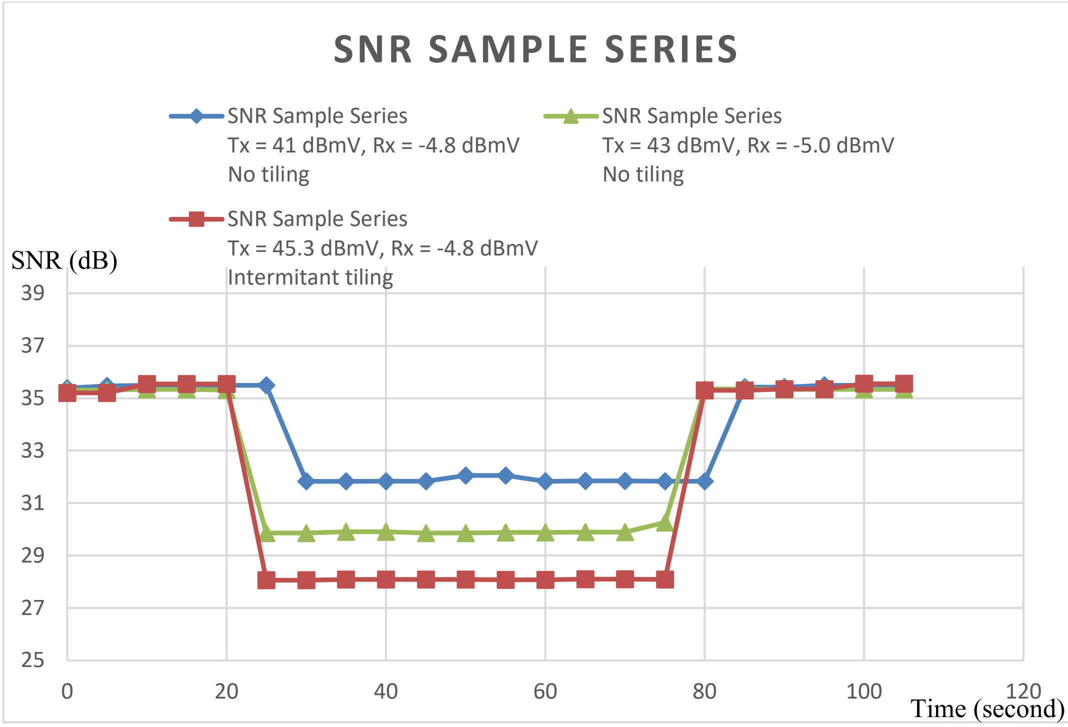

Figure 6: Model-A Tuner SNR Sample Series Under Fixed Rx Power and Variable HS-CM Tx Power (ACI level)

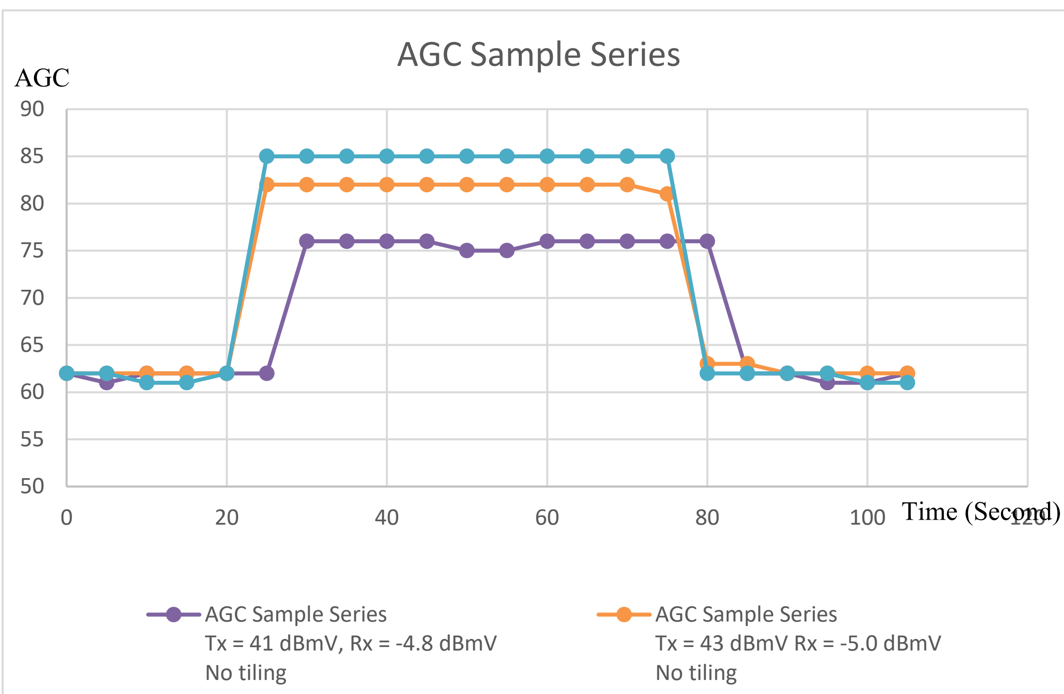

Figure 7: Model-A Tuner AGC Sample Series Under Fixed Rx Power and Variable HS-CM Tx (ACI level)

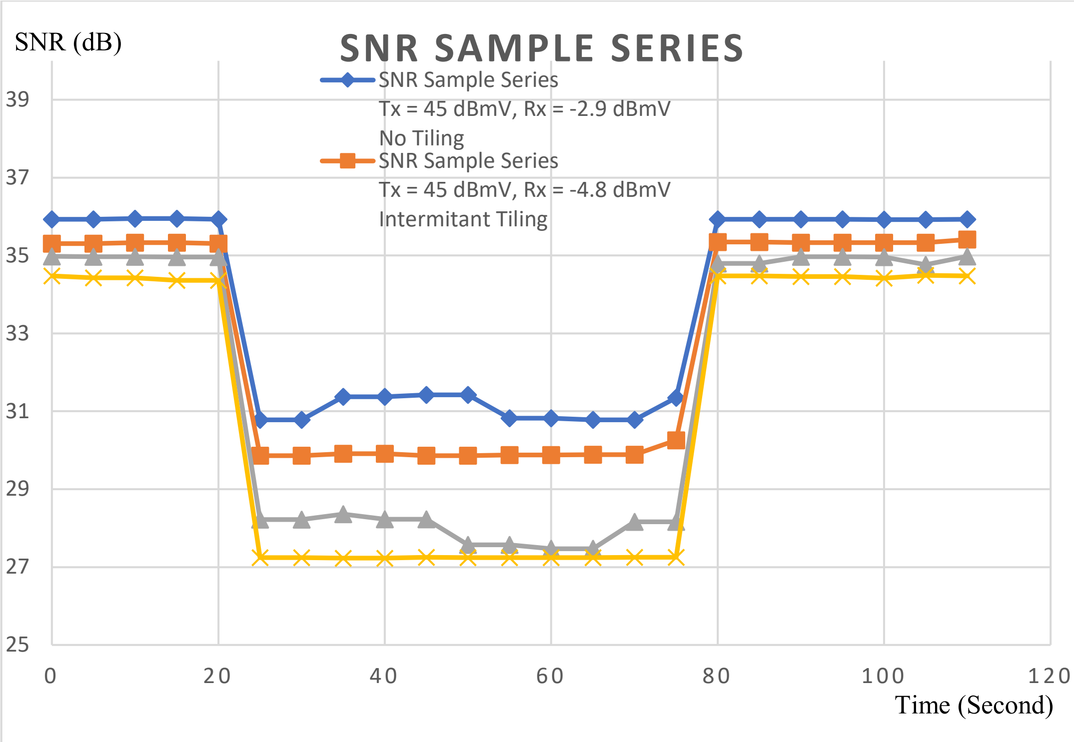

Figure 8: Model-A Tuner SNR Sample Series Under Variable Rx Power and Fixed HS-CM Tx Power (ACI level)

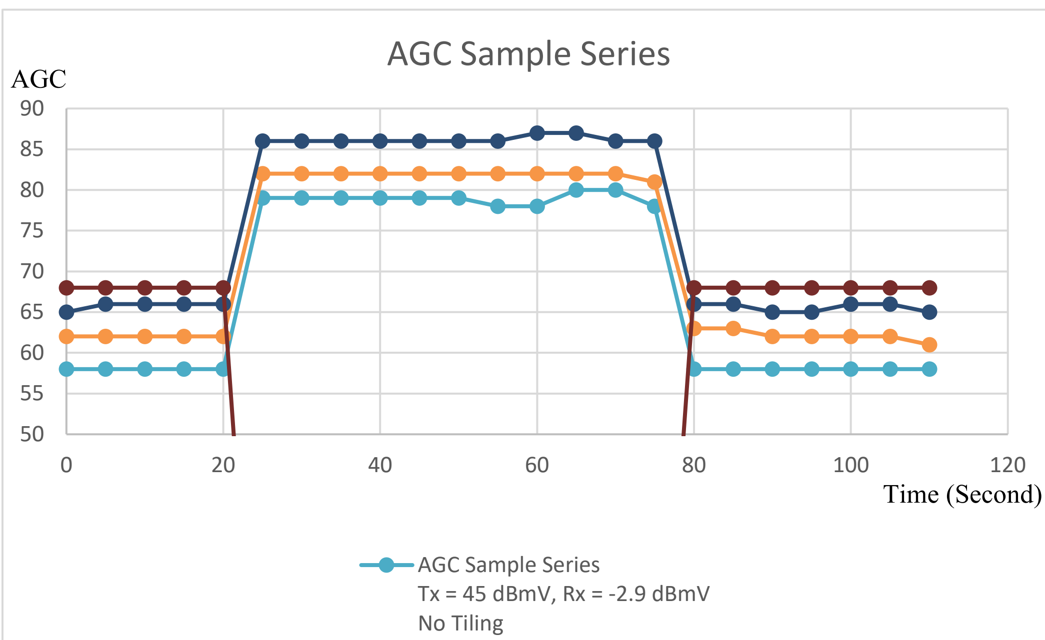

Figure 9: Model-A Tuner AGC Sample Series Under Variable Rx Power and Fixed HS-CM Tx Power (ACI level)

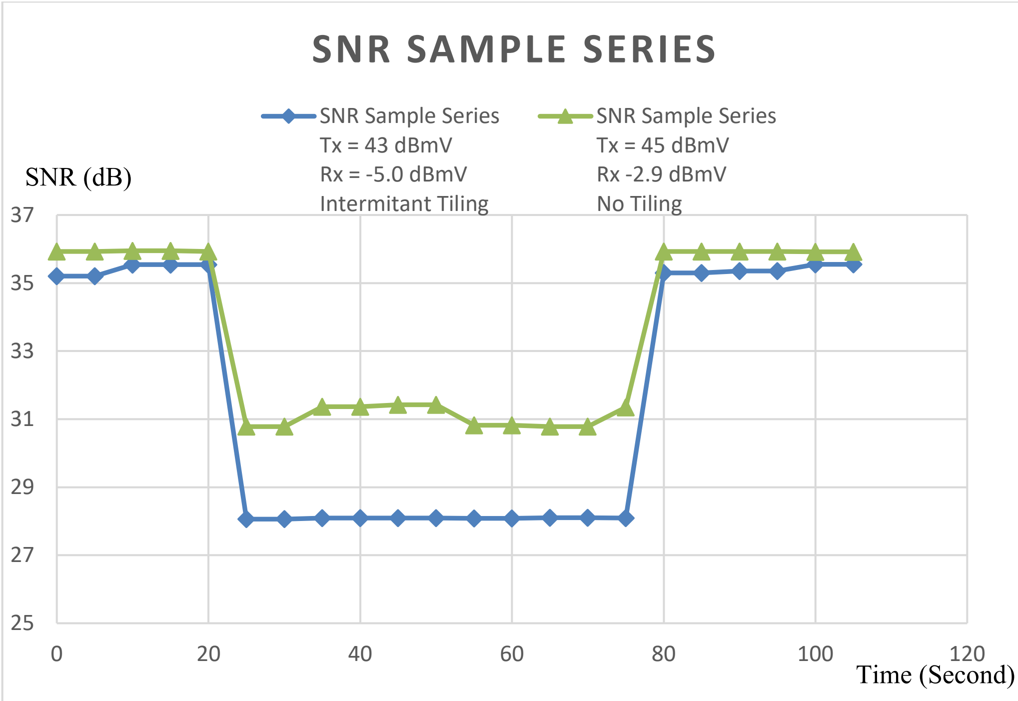

Figure 10: Model-A Tuner SNR Sample Series Under Different Rx and HS-CM Tx Power but Fixed Power Ratio

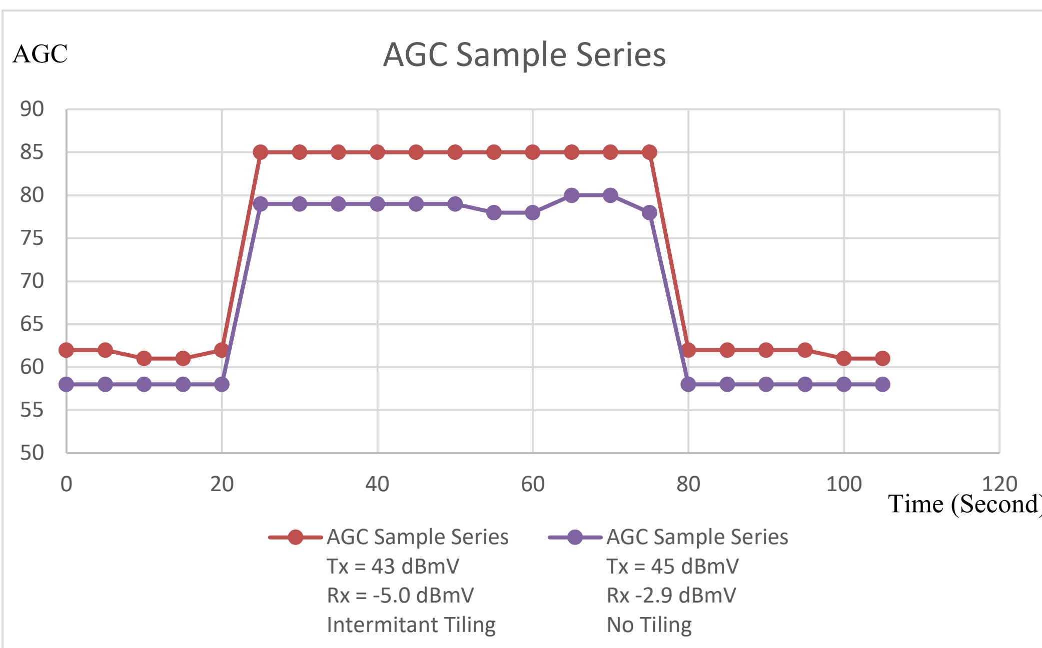

Figure 11: Model-A Tuner AGC Sample Series Under Different Rx and HS-CM Tx Power but Fixed Power Ratio

2.3.2. STB Model-B

Model-B STB has similar hardware and software architecture as Model-A. The tuner SNR and AGC data are also obtainable through a diagnostic shell over SSH. The STB is tested with the same sets of receive and SS-CM transmit power levels and same data polling procedure. The results are summarized in Figure 12 and Figure 13.

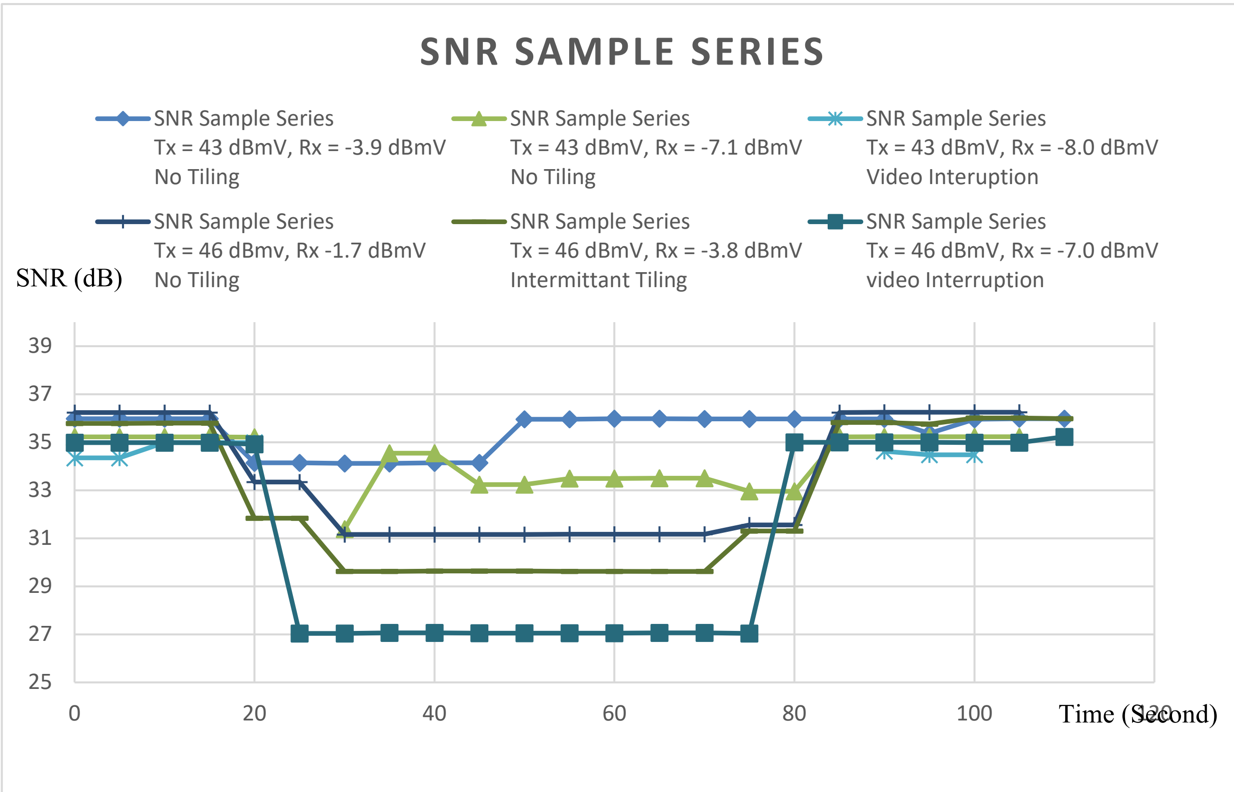

Figure 12: Model-B Tuner SNR Sample Series Under Different Rx and HS-CM Tx Power Levels

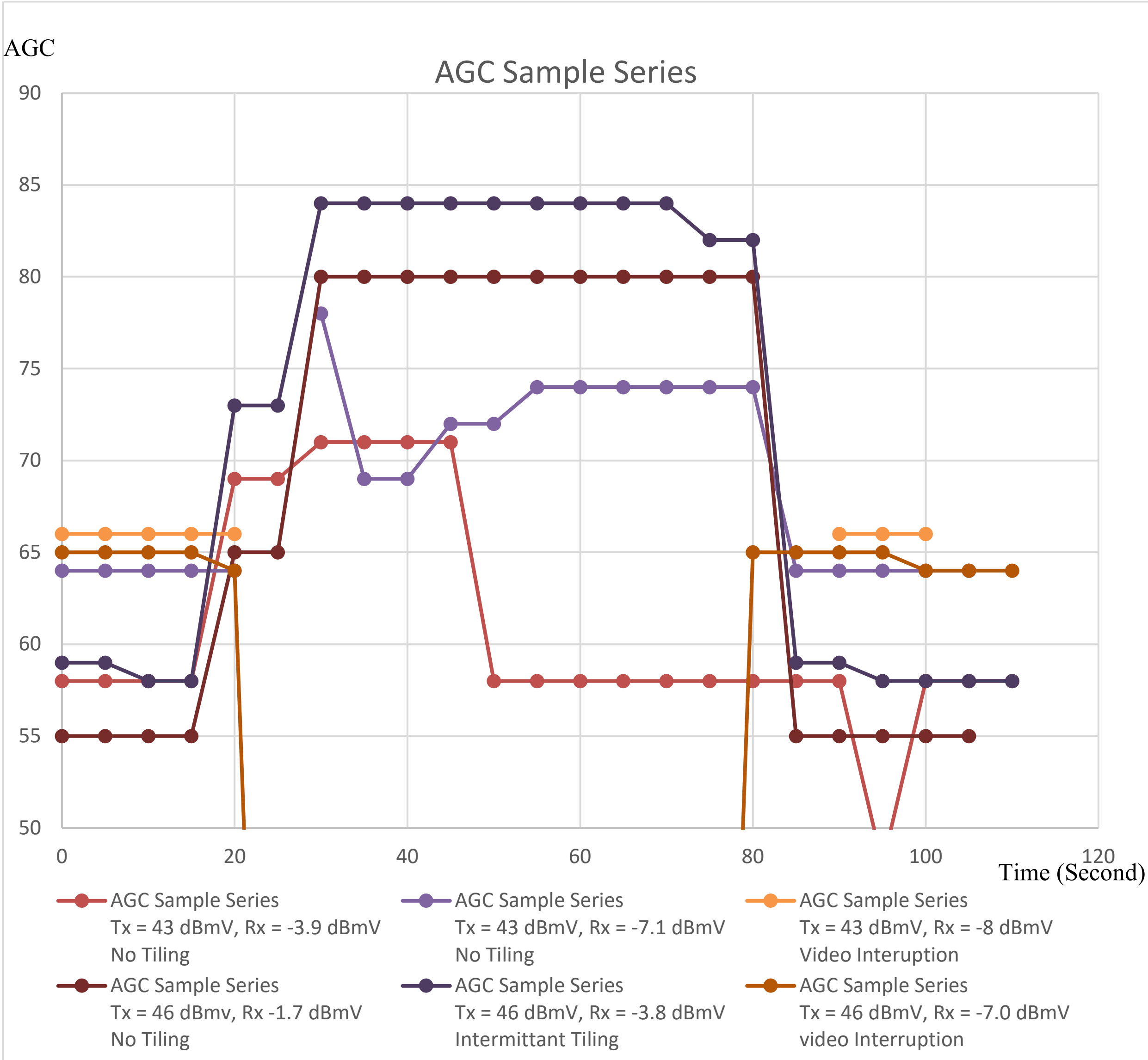

Figure 13: Model-B Tuner AGC Sample Series Under Different Rx and HS-CM Tx Power Levels

Model-B STB shows more dynamics in SNR and AGC values under ACI. Though most of the conclusions for Model-A apply to it, Model-B is slightly more tolerant to SNR drops in the low receiver power region.

2.3.3. STB Model-C

The obtained SNR series are plotted in Figure 14, with the subjective video verification results annotated in the labels.

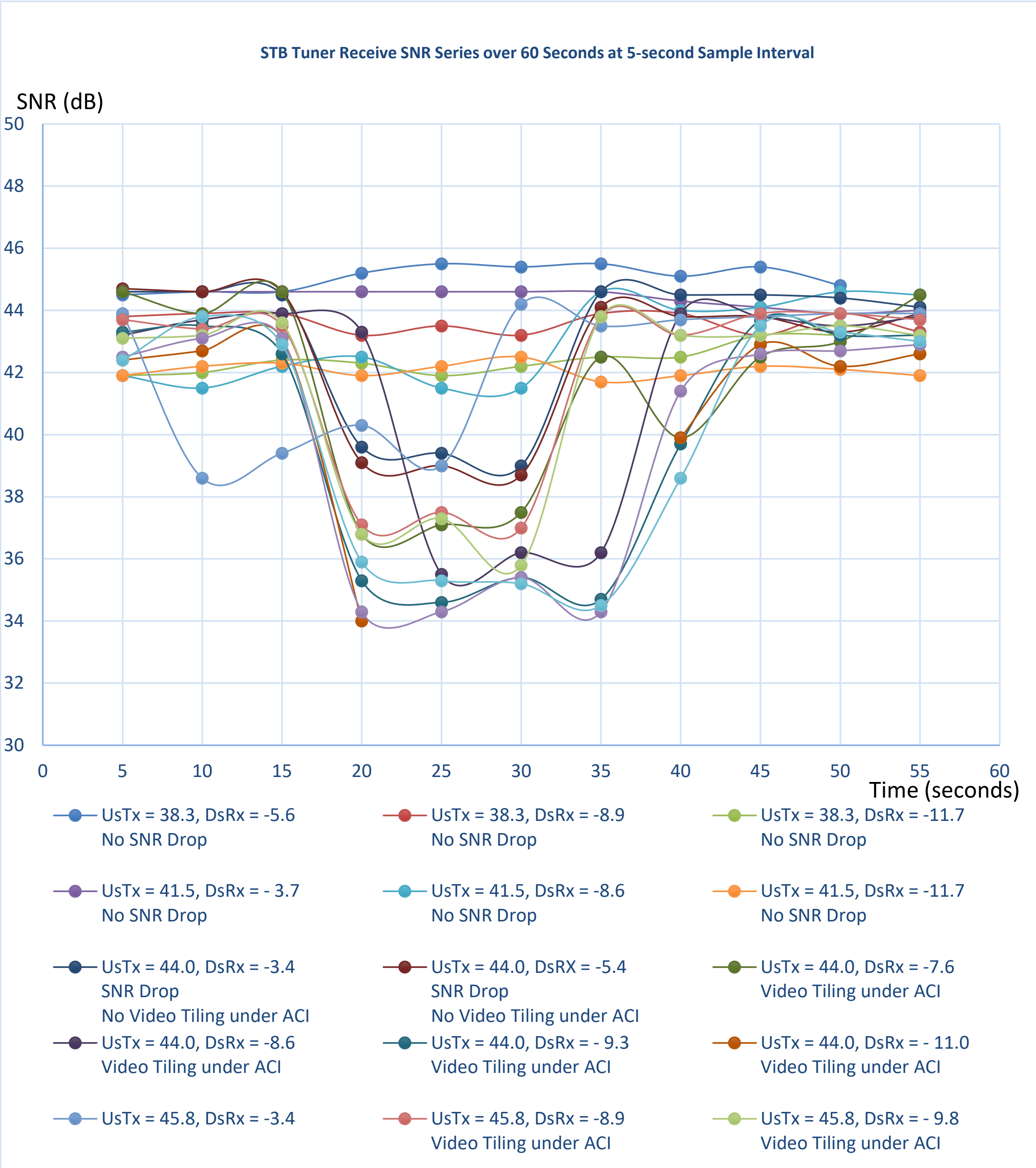

Figure 14: Model-C Tuner SNR Sample Series Under Different Rx and HS-CM Tx Power Levels

Model-C STB is of different hardware and software architecture from the previous two under tests. It supports Simple Network Management Protocol (SNMP) and provides Management Information Base (MIB) objects for tuner SNR. The tuner AGC MIB is defined but only gives a fixed value that does not reflect the changed input to the RF front-end. The STB is tested with the same sets of receive and SS-CM transmit power levels as those for Model-A and Model-B. The data collection procedure is somehow different in that MIB polling is performed at 5-seconds for only 60 seconds and HS-CM upstream transmission is triggered at 10-seconds lapse for only 20 seconds.

The data reveals the following observations:

1) SNR drops happen when the HS-CM is transmitting, thus generating ACI. The SNR drops only occur when the HS-CM transmit power is above a certain threshold (44 dBmV in the test results) and the STB receive power is below a certain threshold (-3.4 dBmV in the test results). It is noteworthy that high transmit power or low receive power alone does not necessarily translate to SNR deterioration. This fact may be due to the nonlinearity of the AGC.
2) SNR drops do not necessarily translate to uncorrectable FEC errors. Only when the STB receive power is at the low-value region (below -7.6 dBmV in the test results) do uncorrectable FEC errors occur with SNR drops. It has been confirmed with subjective verification that video tiling happens when uncorrectable FEC errors occur.

The test data is also processed for characterizations of the magnitude of the SNR drop due to ACI, as summarized in Table 2.

Table 2: Model-C STB Tuner SNR drop due to ACI under different HS-CM transmit power and STB receive power; Data corresponding to video tiling are highlighted with colors.

STB Rx Power (dBmV) → **SNR (dB) Drop at ACI** ↓CM Tx Power(dBmV)	-4	-5	-8	-9	-10	-11	-12
38	**0**	**x**	**x**	**0**	**x**	**x**	**0**
42	**0**	**x**	**x**	**0**	**x**	**x**	**0**
44	**5.2**	**5.7**	**7.2**	**5.2**	**8**	**8.7**	**x**
46	**0**	**x**	**x**	**6.3**	**6.6**	**8.2**	**7.5**

The SNR drops are calculated as the difference between the average SNR when no traffic is generated and the average SNR when traffic is sent. All averages are taken for the lowest three values.

3. Detection of ACI Using Telemetry

Generally, the ACI of coexisting HS-CMs and SS-CPE is not easily resolvable. An efficient solution should be individualistic, which means that the high-split mode should be turned on or off for customer premises equipment individually, based on each site's unique RF and network conditions. A procedure should be developed that can remotely evaluate each customer home for ACI vulnerability so that interference mitigation measure, such as using a band-drop filter, can be targeted only to the vulnerable homes.

In Section 2.3, the key metric indices used to evaluate the impact of ACI, which include STB receive power, HS-CM transmit power, STB Tuner SNR and AGC, can be used in a production environment for targeted interference mitigations and proactive network managements. To implement the diagnostic procedure of that in Section 2.3, a telemetry to monitor the metric indices and a method to exert upstream RF signals are needed.

As described in Section 2.3, two STB models, Model-A and Model-B, support remote access to the status of their tuners through SSH. The format of the data obtained through the diagnostic shell is not standardized, so a data parsing script shall be developed to make the data available for analytics purposes. STB Model-C supports SNMP and provides MIBs for the STB tuner status. The standard communication protocol and data model are already employed by many operation support systems so they offer easier data collection and analytics.

The following subsection will summarize some standard and proprietary MIB objects for STB receive power, HS-CM transmit power, STB Tuner SNR and AGC.

3.1. Useful MIBs

3.1.1. HS-CM Transmit Power MIBs

The transmit power of the HS-CM can be obtained through two MIB objects for OFDMA and SC-QAM channels.

.iso.org.dod.internet.private.enterprises.cableLabs.clabProject.clabProjDocsis.docsIf31Mib.docsIf31MibObjects.docsIf31CmUsOfdmaChanTable.docsIf31CmUsOfdmaChanEntry.docsIf31CmUsOfdmaChanTxPower

.iso.org.dod.internet.mgmt.mib-2.transmission.docsIfMib.docsIfMibObjects.docsIfCmObjects.docsIfCmStatusTable.docsIfCmStatusEntry.docsIfCmStatusTxPower

There is one (maybe of less interest) which gives the 1.6MHz power spectral density (PSD) associated with SC-QAM channels.

.iso.org.dod.internet.private.enterprises.cableLabs.clabProject.clabProjDocsis.docsIf31Mib.docsIf31MibObjects.docsIf31CmUsOfdmaChanTable.docsIf31CmUsOfdmaChanEntry.docsIf31CmUsOfdmaChanTxPower

3.1.2. SS-CPE Receive Power and Tuner Status MIBs

Depending on the type of the SS-CPE, the tuner information is reported in different MIB trees. For cable modems, DOCSIS has two MIBs for receive power on OFDM and SC-QAM channels.

.iso.org.dod.internet.private.enterprises.cableLabs.clabProject.clabProjDocsis.docsIf31Mib.docsIf31MibObjects.docsIf31CmDsOfdmChannelPowerTable.docsIf31CmDsOfdmChannelPowerEntry.docsIf31CmDsOfdmChannelPowerRxPower

.iso.org.dod.internet.mgmt.mib-2.transmission.docsIfMib.docsIfMibObjects.docsIfBaseObjects.docsIfDownstreamChannelTable.docsIfDownstreamChannelEntry.docsIfDownChannelPower

For the STB, the receive power of the QAM tuner is usually vendor proprietary. Though Open Cable Application Platform (OCAP) has defined the following MIB table:

.iso.org.dod.internet.private.enterprises.cableLabs.clabProject.clabProjOpenCable.ocStbHostMibModule.ocStbHostMibObjects.ocStbHostSystem.ocStbHostInterfaces.ocStbHostServiceProgramInfo.ocStbHostInBandTunerTable

it is not widely supported by STB vendors.

The STB Model-C provides the following MIBs on status of the QAM tuner. Noted that the MIBs, eSTBInBandTunerAGCValue and eSTBInBandTunerAGCState, do not reflect the true AGC status of the STB tuner.

1.3.6.1.4.1.1166.1.300.12.9.5 eSTBInBandTunerTable

1.3.6.1.4.1.1166.1.300.12.9.5.1 eSTBInBandTunerEntry

1.3.6.1.4.1.1166.1.300.12.9.5.1.1 eSTBTunerIndex

1.3.6.1.4.1.1166.1.300.12.9.5.1.2 eSTBInBandTunerModulationMode

1.3.6.1.4.1.1166.1.300.12.9.5.1.3 eSTBInBandTunerCarrierLock

1.3.6.1.4.1.1166.1.300.12.9.5.1.4 eSTBInBandTunerPCRLock

1.3.6.1.4.1.1166.1.300.12.9.5.1.5 eSTBInBandTunerDataLock

1.3.6.1.4.1.1166.1.300.12.9.5.1.6 eSTBInBandTunerEMMDataPresent

1.3.6.1.4.1.1166.1.300.12.9.5.1.7 eSTBInBandTunerFrequency

1.3.6.1.4.1.1166.1.300.12.9.5.1.8 eSTBInBandTunerAGCValue

1.3.6.1.4.1.1166.1.300.12.9.5.1.9 eSTBInBandTunerAGCState

1.3.6.1.4.1.1166.1.300.12.9.5.1.10 eSTBInBandTunerSNRValue

1.3.6.1.4.1.1166.1.300.12.9.5.1.11 eSTBInBandTunerSNRState

1.3.6.1.4.1.1166.1.300.12.9.5.1.12 eSTBInBandTunerCorrectedErrors

1.3.6.1.4.1.1166.1.300.12.9.5.1.13 eSTBInBandTunerUncorrectedErrors

1.3.6.1.4.1.1166.1.300.12.9.5.1.14 eSTBInBandTunerLongTermErrors

3.2. Availability of Upstream Traffic Generator

To diagnose ACI, controlled transmissions in the upstream direction from the HS-CM must be performed. In the test described in Section 2.3, a customer client device is used as a traffic generator. This method may not be practical in production, as accessing a customer client or installing a test client in the customer home is not generally allowed. On the other hand, the HS-CM usually implement some speed test applications for device and network monitoring purposes. These applications offer good tools to generate controlled upstream traffic.

Besides the Layer-3 or -4 packet generator internal or external to the cable modem, a DOCSIS technology, OFDMA Upstream Data Profile (OUDP), can readily serve the purpose. The OFDMA protocol needs to be aware of the frequency and time-fading conditions of the channel to perform many tasks such as channel equalization and data profile calculation. That means that periodic upstream transmissions of “training signals” are required. There are two forms of training signals: the upstream probe and the OUDP test. The upstream probe is a carrier-only burst, which is primarily for ranging-related functions. The OUDP test is in the form of user data and is transmitted using the assigned upstream data profiles and interval usage codes (IUCs) so it can be used to mimic user traffic to sound the upstream channel at both the physical and the medium access control layers. The OUDP test can be controlled by the Cable Modem Termination System (CMTS) via the MAP messages with mini-slot assignments, just like any upstream user data transmissions.

The advantages of the OUDP test signal include: 1) As part of the DOCSIS built-in messaging it does not require external devices or additional software functions for packet generation, 2) the bandwidth and duty cycle can be controlled from the CMTS and 3) it behaves the same as customer traffic.

4. Conclusion

This paper investigated an alternative scheme for remote diagnosis of in-home ACI in high-split DOCSIS networks. It is found that the tuple of STB receive power, HS-CM transmit power and STB tuner SNR and AGC forms metric indices to evaluate the impact of ACI to a QAM tuner. Collecting this metric data using telemetry, coupled with data analytics, support remote diagnoses of ACI in production for targeted interference mitigation and proactive network management.

Abbreviations

ACI	Adjacent Channel Interference
AGC	automatic gain control
CM	Cable Modem
CLI	command-line-interface
CMTS	Cable Modem Termination System
DOCSIS	Data Over Cable Service Interface Specification
EQ	equalizer
FEC	Forward-Error-Correction
HS-CM	high-split cable modem
HFC	Hybrid Fiber Coax
IUC	interval usage code
MER	Modulation Error Ratio
MS-CM	mid-split cable modem
MIB	Management Information Base
OFDMA	orthogonal frequency division multiple access
OUDP	OFDMA Upstream Data Profile
PSD	power spectral density
QAM	Quadrature Amplitude Modulation
SNR	Signal to Noise ratio
SS-CPE	sub-split customer premises equipment
SNMP	Simple Network Management Protocol
SC-QAM	Single-Carrier Quadrature Amplitude Modulation
STB	set-top box
VGA	Variable Gain Amplifier

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