Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

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In the Matter of	)	
	)	
Cable Television Technical and Operational Requirements	)	MB Docket No. 12-217
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	)	
	)	

COMMENTS OF ARCOM DIGITAL, LLC

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I. INTRODUCTION

ARCOM DIGITAL, LLC ("Arcom") respectfully submits these comments in response to the Federal Communications Commission's ("FCC") above-captioned Notice of Proposed Rulemaking ("NPRM"). Among other things, the FCC seeks comment on appropriate measurement techniques for detection of leakage from digital signals.[1] Additionally, the FCC seeks comment on any alternative standards that could be used instead of SCTE 40 2011.[2] Arcom is a manufacturer of specialized test equipment. Over the past several years Arcom has developed and commercialized a system specifically designed for measuring leakage of digital signals from cable television networks. Arcom has also developed and commercialized measurement equipment this is placed throughout the cable network with the function of remotely measuring the quality of the transmitted signal.

[1] 77 Fed. Reg. 61363, ¶36 ("[W]e seek comment on an appropriate measurement technique for digital signals.")

[2] 77 Fed. Reg. 61357, ¶10 ("We also seek comment on any alternative standards that could be used to ensure a good quality digital signal.")

II. DESCRIPTION OF ARCOM DIGITAL'S QAM SNARE SYSTEM

The digital leakage detection system is marketed under the name and registered trademark, QAM Snare. QAM Snare operates by capturing samples of an existing QAM channel signal at the headend. These samples are time stamped using the reference clock from the GPS system, and are subsequently transmitted over a wireless network to a field location. At the field location there is an antenna and a sensitive detector used to record samples of the QAM channel signal leaking from the cable plant. Similar to the processing at the headend, the GPS timing information is used to time stamp the moment the samples are recorded. Additionally, for leak location purposes, information on current GPS coordinates of the detector is also retained. A cross correlation process is then employed where the two sets of samples are compared – the samples of the QAM channel signal at the headend and the samples of the QAM channel signal leaking from the cable plant. When there is correlation between the two sets of samples, with certainty a QAM leak has been detected at its specific frequency. The correlation process will output the magnitude of detected leaks as well as the time delay from the headend to the detector. From this information the exact GPS coordinates of the leak can be calculated.

QAM Snare is frequency agile and the current implementation can be used for digital leak detection on any QAM channel from 133MHz-860MHz.[3] QAM Snare additionally has the built in capability to simultaneously detect up to three QAM channels anywhere within the tuning band. As such, for example, it could simultaneously detect one channel in the aeronautic band and one channel at or near the LTE band, and one channel at some other desired frequency.

The next section will discuss the sensitivity of QAM Snare.

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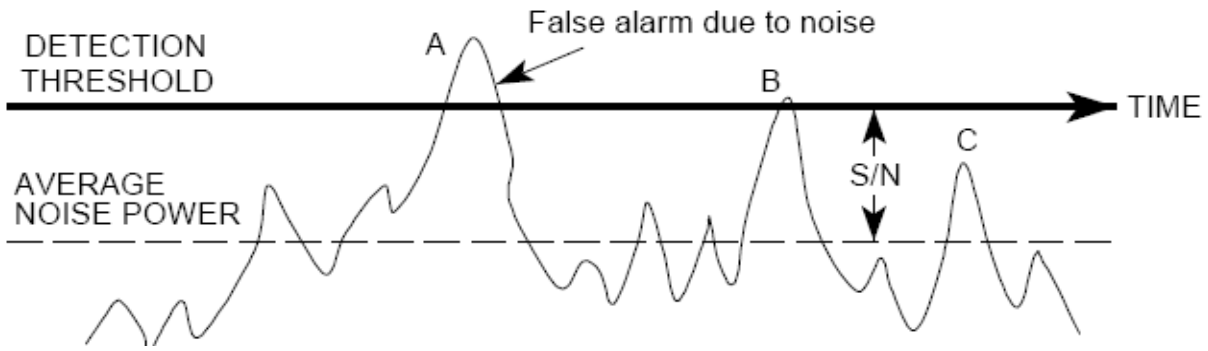
[3] Thus, QAM Snare can meet any new requirements that expand the frequencies protected or allow the test frequency to be outside the 108-137 MHz band, should such requirements be adopted. *See* 77 Fed. Reg. 61363-64, ¶38 ("We seek comment on … whether or not we need to expand the frequencies protected, and whether to maintain the requirement that the test frequency be located within the 108–137 MHz band.")

III. SENSITIVITY OF ARCOM'S QAM SNARE® SYSTEM

Prior to a discussion on QAM Snare sensitivity, it is necessary to first establish some terms and definitions.

A. Terms and Definitions

The sensitivity of the receiver in the QAM Snare leakage detector is defined as the minimum QAM input signal level (in dBm or dBmV) required to detect peaks of the cross-correlation function at the output of the correlation processor, with some fixed minimum signal-to-noise ratio (typically +5 to +15 dB) added such that false alarms are not recorded. The diagram below illustrates the minimum required S/N ratio; however, a detector threshold needs to be selected higher than that shown below in order to avoid false alarms.



The level of the QAM signal is defined as the level of the CW carrier at the output of a QAM modulator, when the QAM modulation is OFF (a similar technique as is employed for measuring QAM signal levels in the cable industry). This also means that the sensitivity of the QAM Snare receiver is defined over the full frequency band of the QAM signal (6 MHz for NTSC).

The signal-to-noise ratio at the output of the QAM Snare receiver depends upon:

a) Cumulative noise level at the input of the receiver (Gaussian noise plus all interference noise in the QAM signal frequency band);

b) The processing gain of the cross-correlation processor.

The processing gain of the cross-correlation processor depends upon the accumulation time for the coherent accumulator (integrator). Therefore, the sensitivity of QAM Snare also depends upon this accumulation time. The typical value of accumulation time can be selected from a few to a hundred milliseconds, depending upon the leakage sampling rate (typical sampling rate is 2 times per second).

B. Theoretical Calculation of Sensitivity for Correlation Processor Receiver

The sensitivity S_{in} (dBm) of the QAM Snare receiver is defined as follows:

S_{in} (dBm) = NF (dB) + KTB (dBm) + E_b/N_o (dB) - G (dB)

where:

NF = total noise factor of the receiver before the cross-correlation processor, in dB;

KTB = input thermal noise power, dBm;

where:

K = Boltzmann's constant = 1.381×10^{-23} W/Hz/K,

T = 290° K at room temperature and

B is the bandwidth of the receiver in Hz (B = 6 MHz for QAM Snare);

E_b/N_o is the signal-to-noise ratio at the output of the cross-correlation processor, in dB;

G is the processing gain of the cross-correlation processor, in dB.

The processing gain of the cross-correlation processor is defined as G = 10 Log (B x T_o), where T_o is the accumulation time (the duration of the QAM signal used for calculation of the cross-correlation function). For an accumulation time of T_o = 10 ms (10 x 10^{-3} seconds), the

processing gain is:

$$G = 10 \text{ Log } (6 \times 10^{6} \text{ Hz} \times 10^{-3} \text{sec}) = 47.78 \text{ dB}.$$

Assume that the noise factor of the receiver is NF = 6 dB (a typical value), the thermal noise power for room temperature (T = 290° K) is KTB = –106.2 dBm, the accumulation time T_o = 10 ms (10 x 10^{-3} seconds), and the signal-to-noise ratio (SNR) E_b/N_o = 15 dB, then the sensitivity of the QAM Snare receiver is calculated as follows:

$$S_{in} \text{ (dBm)} = 6 \text{ dB} - 106.2 \text{ dBm} + 15 \text{ dB} - 47.78 \text{ dB} = -132.98 \text{ dBm } (-86 \text{ dBmV}).$$

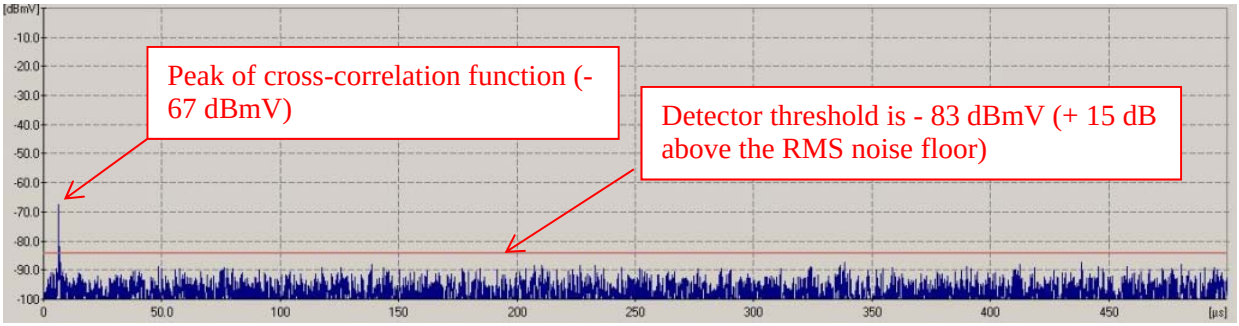
The sensitivity data for different combination of SNR and accumulation times are shown in the table below.

QAM Snare Sensitivity, dBm / dBmV

SNR, dB	Accumulation time, ms			
	1	10	50	100
3	- 135/- 88	- 145/- 98	- 152/- 105	- 155/- 108
5	-133/- 86	- 143/- 96	- 150/- 103	- 153/- 106
10	- 128/- 81	- 138/ - 91	- 145/ - 98	- 148/- 101
15	- 123/ - 76	-133/- 86	- 140/ - 93	- 143/- 96

C. Comparison of Realized Sensitivity to Theoretical

The plot below is an actual output response of QAM Snare taken during field testing. The accumulation time was established at 10 ms during this test.



As illustrated above, the measured sensitivity of QAM Snare is –83 dBmV for a selected SNR = 15 dB. This closely correlates to the theoretical value of –86 dBmV.

D. Conversion of Measured QAM Snare Signal Level to Field Strength

To recalculate the measured signal level at the input of the QAM Snare receiver into field strength, the antenna conversion factor should be used. Field strength is defined as:

$$E\ (\text{dBmV/m}) = K\ \text{dB/m} + U\ \text{dBmV},$$

where K is the antenna factor and U is the signal level measured at the receiver 50 Ohm input (output of antenna). The equation for the antenna factor is as follows:

$$K\ \text{dB/m} = 20\ \text{Log}(f) - 29.7707\ \text{dB} - G\ \text{dBi},$$

where f is the frequency in MHz, G is antenna gain in dBi (referenced to isotropic receiver). Below is the antenna factor for a half-wave dipole and monopole for selected frequencies:

	Antenna Factor, (dB/m)	
	1/2 wave dipole	monopole
Frequency, MHz	G = 2.15 dBi	G = 5.15 dBi
100	8.08	5.08
200	14.10	11.10
300	17.62	14.62
400	20.12	17.12
500	22.06	19.06
600	23.64	20.64
700	24.98	21.98
800	26.14	23.14

Taking the measured threshold sensitivity of -83 dBmV described above and converting to field strength at 100 MHz and 700 MHz, for example, yields the following results:

E (dBmV/m) = K dB/m + U dBmV,

$E_{\text{min QAM Snare detectable @ 100MHz}}$ (dBmV/m) = 5.08- 83 dBmV = -77.92dBmV/m

$E_{\text{min QAM Snare detectable @ 700MHz}}$ (dBmV/m) = 21.98- 83 dBmV = -61.02dBmV/m

Converting to µV/m

$E_{\text{min QAM Snare detectable @ 100MHz}}$ (µV/m) = 10^(-77.92dBmV/m /20)*1000= 0.13µV/m

$E_{\text{min QAM Snare detectable @ 700MHz}}$ (µV/m) = 10^(-61.02dBmV/m /20)*1000= 0.89µV/m

Thus, the QAM Snare receiver, when implemented with SNR = 15 and an accumulation time of 10ms, can measure field strengths of QAM channel leakage signals that are as low as 0.13µV/m at 100 MHz and as low as 0.89µV/m at 700 MHz.[4]

E. Signal Level Detection Range

As described previously, the minimum signal level (sensitivity) as shown above depends upon selected accumulation time of the correlation processor and SNR.

[4] *Compare* 77 Fed. Reg. 61362-63, ¶34 ("[W]e propose … to require analog and digital detectors to have sufficient sensitivity to detect the 1.2 dB decrease in the maximum signal leakage level we propose above, or 17.4 µV/m, in those systems which operate digital signals in the aeronautical bands.")

The maximum signal level at the input of QAM Snare is 0 dBmV. This level depends upon the dynamic range of the down-converter and the AGC. QAM Snare will still indicate the presence of leaks under conditions of signals more powerful than 0 dBmV, but measured results of the signal level and direction will not be correct due to overloading of the receiver.

This signal level range should be completely adequate for the types of leaks expected from digital channels in a cable network. For example, accounting for the antenna factor, to overload the receiver the field strength would need to be +23dBmV or 14,125 µV/m at 550MHz – an unlikely scenario.

F. Rationale Behind the Selected SNR and Accumulation Time

As described earlier, the sensitivity of the QAM Snare receiver of the QAM Snare detector ("Navigator") is dependent upon SNR threshold and accumulation time. The table below[5] illustrates reasonable values of SNR for different types of detectors. As shown, for an auto-detection algorithm realized within a leak detector that measures amplitude, time delay and coordinates - the minimum SNR threshold should be selected within the 14 to 18 dB range.

The acceptable minimum Signal-to-Noise ratio (or think of it as Signal **above** Noise) for a receiver depends on the intended use of the receiver. For instance, a receiver that had to detect a single radar pulse would probably need a higher minimum S/N than a receiver that could integrate a large number of radar pulses (increasing the total signal energy) for detection with the same probability of false alarms. Receivers with human operators using a video display may function satisfactorily with low minimum S/N because a skilled operator can be very proficient at picking signals out of a noise background. As shown in Table 1, the setting of an acceptable minimum S/N is highly dependant on the required characteristics of the receiver and of the signal.

Table 1. Typical Minimum S/N Required

Skilled Operator	Auto-Detection	Auto-detection with Amplitude, TOA, and Frequency Measurements	AOA Phase Interferometer	AOA Amplitude Comparison
3 to 8 dB	10 to 14 dB	14 to 18 dB	14 to 18 dB	16 to 24 dB

Accumulation time directly influences the volume of wireless data traffic from the headend signal processor and server to the QAM Snare detector. As such, in order to reduce data

[5] Source: Naval Air Warfare Center "ELECTRONIC WARFARE AND RADAR SYSTEMS ENGINEERING HANDBOOOK", 1 April 1999. Pg 5-2.2

traffic, it makes good engineering sense to select the minimally sufficient accumulation time required for effective leak detection. As an example, for an accumulation time of 10 ms, the monthly data traffic is approximately 10-15 GB; while for 1 ms accumulation time it is an order of magnitude less, 1 – 1.5 GB.

Additionally, increasing accumulation time will impact the immunity of the cross-correlation processor to Doppler frequency shift due to a moving truck or aircraft (flyover test) relative to the leak. For example, for an accumulation time of 10 ms, the critical frequency offset equals 1/(2 x10ms) = 50 Hz. Thus, if the Doppler frequency offset is more than 50 Hz, then the amplitude of the peak cross-correlation function will be reduced by more than 3 dB. A Doppler frequency shift at 700 MHz for a truck speed of 60 mph equals 64 Hz and 160 Hz for an aircraft traveling at 150 mph in a flyover test. Accounting for the specified vehicle speed, the maximum accumulation time is limited to 7.8 ms for surface vehicles and 4 ms for aircraft.

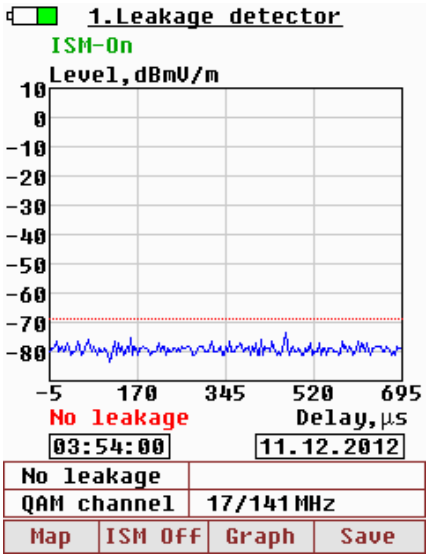
Based on the above reasons, the accumulation time for QAM Snare has been selected as 1.25 ms with an SNR threshold of 15 dB. With these parameters, the current QAM Snare equipment sold to the industry realizes an optimum sensitivity of < -76 dBmV (< -123 dBm), reasonable data traffic, minimal probability of false alarms and guaranteed immunity to Doppler frequency shift both for driving and flyover tests.

G. Sensitivity Test Results of Commercialized QAM Snare Implementation

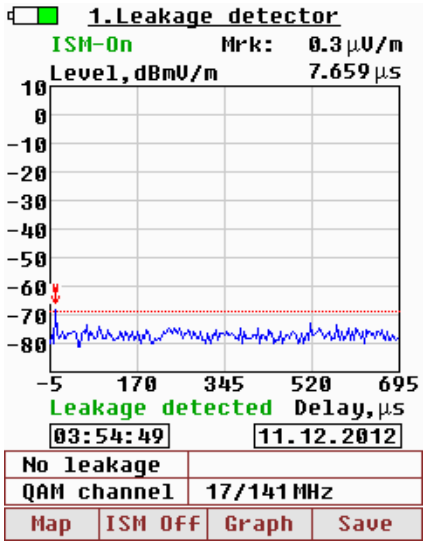
The test result below was performed in the aeronautic band at channel 17 (141MHz). Accumulation time is 1.25ms, SNR=15dB, with monopole antenna (G = 5.15 dBi). Minimum detected leak signal is 0.3µV/m at this frequency.[6]

[6] Unlike the field test results shown in Section C, in the commercial implementation of QAM Snare the antenna factor calculation is performed in software integrated within the calculation of the peak of the cross-correlation function.

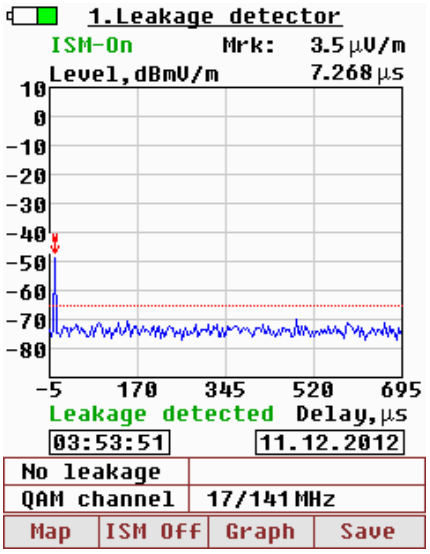
Terminated receiver input:



Minimal detected leak signal:

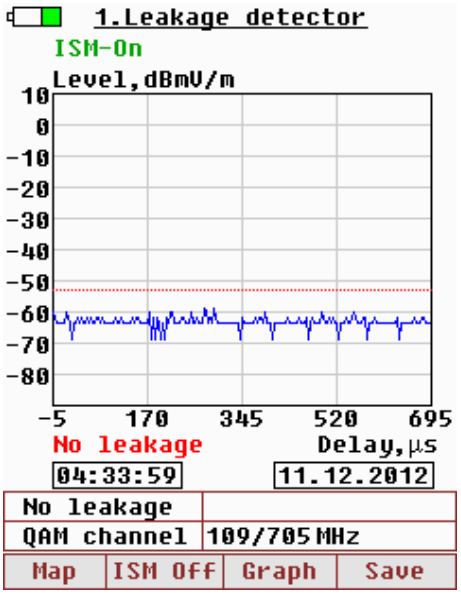


Typical leak signal:

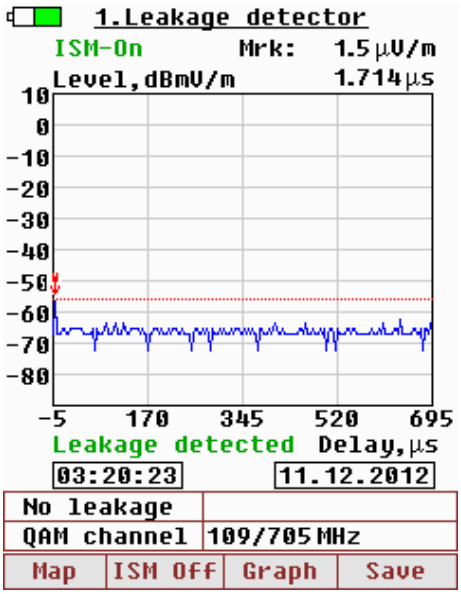


The test result below was performed at an LTE band frequency at channel 109 (705 MHz). Accumulation time is 1.25ms, SNR=15dB, with monopole antenna (G = 5.15 dBi). Minimum detected leak signal is 1.5µV/m at this frequency.

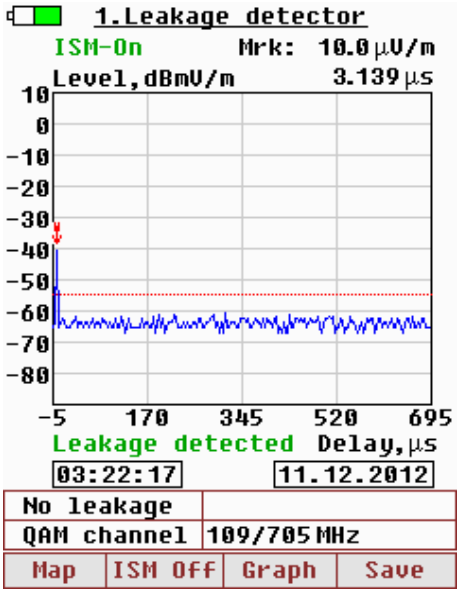
Terminated receiver input:



Minimal detected leak signal:



Typical leak signal:



H. Required Sensitivity to Meet the Detection Limits in the Proposed NPRM

Within the NPRM, the proposed signal leakage limits are as follows:

Frequencies	Signal leakage limit	Distance in meters (m)
Analog signals less than and including 54 MHz, and over 216 MHz	15 µV/m	30
Digital signals less than and including 54 MHz, and over 216 MHz	**13.1 µV/m**	**30**
Analog signals over 54 MHz up to and including 216 MHz	20 µV/m	3
Digital signals over 54 MHz up to and including 216 MHz	**17.4 µV/m**	**3**

As has been demonstrated and explained, the sensitivity of QAM Snare is such that it can detect field strengths significantly less than the signal leakage limits proposed in the NPRM.

IV. ALTERNATIVE METHOD TO DETERMINE WHETHER A GOOD QUALITY SIGNAL IS BEING DELIVERED TO SUBSCRIBERS

The Commission tentatively concludes that it should incorporate the SCTE 40 2011 Standard into the Rules as minimum signal quality standards for QAM digital cable service. (NPRM, Par. 10.) However, the Commission seeks comment on alternative standards to ensure a good quality signal. (Id.) Arcom and many others in the cable television industry are proposing another approach to ensuring signal quality, which Arcom respectfully submits should be incorporated into the Rules as an alternative to the SCTE 40 2011, for proof-of-performance. Just as the Commission is open to consider the role of set-top boxes to determine good signal quality (NPRM, Par. 24), it too should consider the role of downstream monitors or probes.

Due to the expansion of digital services and the continued increase in the number of QAM channels being deployed, the cable television industry (e.g., Comcast, CableLabs, Time Warner, Cox, etc.) have collaborated in developing specifications for a new cable system architecture that integrates digital and IP services and provides increased capacity for multiple

services.[7] As part of this effort, automated downstream monitors or probes are specified.[8] These devices can be deployed throughout the HFC network as outside plant components, either as a stand-alone device or as a probe attached to an existing device. A central management server at a hub or headend communicates with the probes. The probes automatically and continuously measure parameters or metrics that are indicative of signal quality. The probes measure the parameters on all NTSC and QAM channels according to a pre-programmed schedule. The probes can measure the parameters of different QAM modulations, such 16, 32, 64, 128, and 256 QAM. Each probe establishes a permanent proof-of-performance test point and, due to the low cost of the probe and the present state of technology, many test points (e.g., 10-20) can be installed in each node.

Arcom has demonstrated that such probes can be manufactured at relative low cost due, in part, to the present state of tuner and QAM demodulator chipset technology. Thus, the use of these probes can provide a cost effective means to monitor and report on signal quality delivered to subscribers.

While such probes are not able to measure all metrics associated with the SCTE 40 2011 Standard, they do measure: RF or carrier signal level; MER; pre & post FEC BER; and uncorrected code word errors.[9] These metrics are sensitive to all RF impairments within the

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[7] J. Salinger and J. Leddy, Comcast Update: What is a CMAP?, Shelving (packet and access) Figures in this Key NGAA Element, Communications Technology Magazine, Feb. 1, 2010; Comcast's CMAP Gains as Cable TV-to-IP Migration Path, Screenplaysmag.com, May 25. 2010; and M. Robuck, CED Person of the Year: Jorge Salinger, A One-Man Dynamo for the Cable Industry's CCAP Initiative, CED Magazine, Jan. 1, 2012.

[8] Salinger and Leddy, Comcast Update: What is a CMAP?, Communications Technology Magazine, Feb. 1, 2010.

[9] Most, if not all, modern day tuner and demodulator silicon chipsets, utilized by the cable television industry, contain built-in measurement tools that provide such video transmission quality metrics, a reason the Commission is open to consider the role of set-top boxes.

transmission network and reflect the actual quality of the transmitted digital signals. As such, these modern metrics are what is utilized every day by cable television technicians throughout the world to measure and monitor the quality of digital signals transmitted on the network. In addition to the metrics, and in accordance with proposed Rule § 76.605(c)(2), Adjacent Channel Characteristics (Table 6) and Nominal Relative Carrier Power Levels (Table 5) can be obtained by the probes. To reiterate, the downstream monitor/probe system provides measurements of these metrics as appropriate on *all* NTSC and QAM channels, on a continuous basis, documenting the measurements (and compiling hourly or daily averages), and doing this at many test points (many more than currently specified in the proposed rules). Thus, Arcom and many in the industry believe the downstream monitor/probe approach can achieve the goals of ensuring digital cable subscribers receive good quality signals and of reducing the burden on cable operators to demonstrate compliance with proof-of-performance.

Should the Commission choose to adopt the downstream monitor/probe approach as an alternative to the SCTE 40 2011, it would allow for new inexpensive test equipment to be permanently deployed at end of the line locations such that video quality could essentially be monitored 24/7. Proof-of-performance measurements could be automated and performed remotely, thereby enabling a very efficient compliance methodology for the operator.

V. CONCLUSION

Arcom has described its QAM Snare® System, which is designed to measure leakage of digital signals from the cable television plant. The QAM Snare System is able to perform detection and measurement of digital signal leakage in accordance with the FCC's proposed rule changes. The QAM Snare System has the sensitivity to measure such values and much lower values, over a broad range of frequencies. QAM Snare can utilize (as a test signal) any existing QAM channel signal in the frequency band of 133 MHz to 860 MHz, and has the capability to measure leakage at three QAM channel frequencies simultaneously.

Arcom has additionally proposed the use of monitoring probes with capability to measure and automatically report on the modern and widely used metrics indicative of the quality of the transmission of digital video signal, as an alternative to SCTE 40 2011.

Respectfully submitted,

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