QAM Testing Requirements

In this last quarterly technical report for 2011, I'm going to deviate again from my planned report subject to address the area of QAM carrier testing, as I've had many questions on this subject over the past several months. There appears to be some level of confusion as to whether QAM testing is required under present FCC rules, and if so, which tests are required and methods by which to conduct them.

Introduction.
Although the following are technically analog carriers; QAM, OFDM and 8-VSB carriers are modulated with different digital formats, and are now routinely carried in the modern HFC network. All are 'analog' signals, with information encoded in the amplitude and typically phase domains (except for 8-VSB which is amplitude modulated only). Some knowledge regarding the 'makeup' of these signals is necessary for proper level setting and troubleshooting; and the ability to test 64 & 256-QAM carriers is now mandatory for all cable systems with an operational bandwidth of 750 MHz or greater. This report will address QAM testing requirements only. 8-VSB and OFDM signals were investigated in previous quarterly technical reports; see the download list to obtain them.

Several years ago, the FCC appended their rules in the technical testing section, such that the following is now included. Note the areas with emphasis {red/red underline} added.

§ 76.640 Support for unidirectional digital cable products on digital cable systems.

(a) The requirements of this section shall apply to digital cable systems. For purposes of this section, digital cable systems shall be defined as a cable system with one or more channels utilizing QAM modulation for transporting programs and services from its headend to receiving devices. Cable systems that only pass through 8 VSB broadcast signals shall not be considered digital cable systems.

(b) No later than July 1, 2004, cable operators shall support unidirectional digital cable products, as defined in §15.123 of this chapter, through the provisioning of Point of Deployment modules (PODs) and services, as follows:

(1) Digital cable systems with an activated channel capacity of 750 MHz or greater shall comply with the following technical standards and requirements:

(i) SCTE 40 2004 (formerly DVS 313): "Digital Cable Network Interface Standard" (incorporated by reference, see §76.602), provided however that with respect to Table B.11, the Phase Noise requirement shall be −86 dB/Hz, and also provided that the "transit delay for most distant customer" requirement in Table B.3 is not mandatory.

(ii) ANSI/SCTE 65 2002 (formerly DVS 234): "Service Information Delivered Out-of-Band for Digital Cable Television" (incorporated by reference, see §76.602), provided however that the referenced Source Name Subtable shall be provided for Profiles 1, 2, and 3.

(iii) ANSI/SCTE 54 2003 (formerly DVS 241): "Digital Video Service Multiplex and Transport System Standard for Cable Television" (incorporated by reference, see §76.602).

(iv) For each digital transport stream that includes one or more services carried in-the-clear, such transport stream shall include virtual channel data in-band in the form of ATSC A/65B: "ATSC Standard: Program and System Information Protocol for Terrestrial Broadcast and Cable (Revision
B)" (incorporated by reference, see §76.602), when available from the content provider. With respect to in-band transport:

(A) The data shall, at minimum, describe services carried within the transport stream carrying the PSIP data itself;
http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&sid=a0b1c7045abd9e3f08f6d3233a640e58&rg... 5/6/2011
Electronic Code of Federal Regulations:

(B) PSIP data describing a twelve-hour time period shall be carried for each service in the transport stream. This twelve-hour period corresponds to delivery of the following event information tables: EIT–0, –1, –2 and –3;

(C) The format of event information data format shall conform to ATSC A/65B: "ATSC Standard: Program and System Information Protocol for Terrestrial Broadcast and Cable (Revision
B)" (incorporated by reference, see §76.602);

(D) Each channel shall be identified by a one- or two-part channel number and a textual channel name; and

(E) The total bandwidth for PSIP data may be limited by the cable system to 80 kbps for a 27 Mbits multiplex and 115 kbps for a 38.8 Mbits multiplex.

(v) When service information tables are transmitted out-of-band for scrambled services:

(A) The data shall, at minimum, describe services carried within the transport stream carrying the PSIP data itself;

(B) A virtual channel table shall be provided via the extended channel interface from the POD module. Tables to be included shall conform to ANSI/SCTE 65 2002 (formerly DVS 234): "Service Information Delivered Out-of-Band for Digital Cable Television" (incorporated by reference, see §76.602).
(C) Event information data when present shall conform to ANSI/SCTE 65 2002 (formerly DVS 234): "Service Information Delivered Out-of-Band for Digital Cable Television" (incorporated by reference, see §76.602) (profiles 4 or higher).
(D) Each channel shall be identified by a one-or two-part channel number and a textual channel name; and
(E) The channel number identified with out-of-band signaling information data should match the channel identified with in-band PSIP data for all unscrambled in-the-clear services.
(2) All digital cable systems shall comply with:
(i) SCTE 28 2003 (formerly DVS 295): "Host-POD Interface Standard" (incorporated by reference, see §76.602).
(ii) SCTE 41 2003 (formerly DVS 301): "POD Copy Protection System" (incorporated by reference, see §76.602).
(3) Cable operators shall ensure, as to all digital cable systems, an adequate supply of PODs that comply with the standards specified in paragraph (b)(2) of this section to ensure convenient access to such PODS by customers. Without limiting the foregoing, cable operators may provide more advanced PODs (i.e. , PODs that are based on successor standards to those specified in paragraph (b)(2) of this section) to customers whose unidirectional digital cable products are compatible with the more advanced PODs.
(4) Cable operators shall:
(i) Effective April 1, 2004, upon request of a customer, replace any leased high definition set-top box, which does not include a functional IEEE 1394 interface, with one that includes a functional IEEE 1394 interface or upgrade the customer's set-top box by download or other means to ensure that the IEEE 1394 interface is functional.
(ii) Effective July 1, 2005, include both a DVI or HDMI interface and an IEEE 1394 interface on all high definition set-top boxes acquired by a cable operator for distribution to customers.
(iii) Ensure that these cable operator-provided high definition set-top boxes shall comply with
http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&sid=a0b1c7045abd9e3f08f6d3233a640e58&rg... 5/6/2011
ANSI/SCTE 26 2001 (formerly DVS 194): "Home Digital Network Interface Specification with Copy Protection" (incorporated by reference, see §76.602), with transmission of bit-mapped graphics optional, and shall support the CEA–931–A: "Remote Control Command Pass-through Standard for Home Networking" (incorporated by reference, see §76.602), pass through control commands: tune function, mute function, and restore volume function. In addition these boxes shall support the power control commands (power on, power off, and status inquiry) defined in A/VC Digital Interface Command Set General Specification Version 4.0 (as referenced in ANSI/SCTE 26 2001 (formerly DVS 194): "Home Digital Network Interface Specification with Copy Protection" (incorporated by reference, see §76.602)).
[68 FR 66734, Nov. 28, 2003]

So, if your system has an activated bandwidth of 750 MHz or greater and you carry *any* downstream QAM signals, you are now required to test them to ANSI/SCTE 40 2004 specifications. A complete review of the ANSI/SCTE 40 2004 document is beyond the scope of this report, as are the complete FCC Part 76 rules; however, they are both available as separate downloads on the Cablesoft Engineering web site downloads page. What remains unclear for this author, even now, is exactly which tests are required, how to conduct those tests, and whether all QAM carriers must be tested at at field test point locations (it is assumed that all QAM carriers be fully tested at the headend). The NCTA Recommended Practices for Measurements on Cable Television Systems, 3rd Edition, has a digital testing section (Chapter 11); however, only MER, EVM and constellation patterns are addressed; which is very limited in terms of the testing defined under the ANSI/SCTE 40 2004 document.

CSEI Approach

Although QAM testing requirements were only recently added, CSEI (Cablesoft Engineering, Inc.) began including some QAM related measurements 5 to 6 years ago in our FCC Proof of Performance testing.

Basic QAM tests were initially added for two reasons:

- The systems we were testing often had no way to measure QAM carrier performance (in those early years), and QAM problems were disclosed found that the operator was completely unaware of.
- If the operator had QAM analysis equipment, they often did not understand how to interpret testing results.
- QAM testing tends to better identify existing HFC problems and their likely causes than required analog testing.

Early on, only MER (modulation error ratio), EVM (error vector magnitude) & BER (bit error rate or ratio) were measured; but as we implemented these tests we soon discovered that the QAM tests often disclosed HFC network problems not readily apparent during required analog carrier testing, and so additional QAM tests were added over time.

Our most recent change now moves us to the testing of all *available* SCTE 40 tests on all downstream QAM carriers. The required tests that must be conducted are, according to my read of ANSI/SCTE 40, average carrier power (or DCP, digital channel power), MER (modulation error ratio), EVM (error vector magnitude), pre and post FEC BER (forward error correction bit error rate or ratio), frequency response (in channel response of QAM carrier), adaptive equalizer stress, and group delay. Several other measurements that we include but not specifically required are ENM (estimated noise margin) and constellation pattern quality.

The following chart illustrates the results of QAM tests of the above parameters conducted on 40 QAM carriers. Our proof testing form highlights failing test results in red, and ‘close to failing’ in yellow. In the case of this particular system (these are actual measurements from a nearby HFC plant *field TP*), all parameters passed and therefore all results are in black.

Field Testing Form - Digital Channels

12/16/2011

Company: Sample USA
Headend: Primary
TP Location: 123 Anywhere Street, Generic USA

Cascade: Node plus 3 actives

Channel Description	Lock	DigChlPwr (dBmV)	MER	PreBER	PostBER	Frequency Response	EQ Stress	Group Delay	EVM	ENM	Type	Comments
66 [477 MHz]	Locked	16.5	39.9	1E-11	1E-11	1.26	-25	53.1	0.6	11.7	256-QAM	
67 [483 MHz]	Locked	16.6	38.3	1E-11	1E-11	0.99	-25	31.7	0.7	10.1	256-QAM	
68 [489 MHz]	Locked	17.0	38.6	1E-11	1E-11	0.80	-24	30.0	0.7	10.4	256-QAM	
69 [495 MHz]	Locked	17.0	39.3	1E-11	1E-11	0.99	-25	36.0	0.6	11.1	256-QAM	
70 [501 MHz]	Locked	17.1	38.8	1E-11	1E-11	1.04	-22	55.0	0.7	10.6	256-QAM	
71 [507 MHz]	Locked	17.3	38.3	1E-11	1E-11	0.65	-27	39.5	0.7	10.1	256-QAM	
72 [513 MHz]	Locked	17.7	37.4	1E-11	1E-11	1.06	-23	53.6	0.8	9.2	256-QAM	
73 [519 MHz]	Locked	18.2	38.2	1E-11	1E-11	1.08	-24	60.2	0.7	10.0	256-QAM	
74 [525 MHz]	Locked	18.6	39.8	1E-11	1E-11	0.94	-27	52.6	0.6	11.6	256-QAM	
75 [531 MHz]	Locked	18.4	38.8	1E-11	1E-11	1.49	-21	47.0	0.7	10.6	256-QAM	
76 [537 MHz]	Locked	18.1	38.3	1E-11	1E-11	1.18	-19	57.7	0.7	10.1	256-QAM	
77 [543 MHz]	Locked	17.5	>40	1E-11	1E-11	1.05	-27	38.4	0.6	11.8	256-QAM	
78 [549 MHz]	Locked	16.8	39.5	1E-11	1E-11	1.38	-19	68.4	0.6	11.3	256-QAM	
79 [555 MHz]	Locked	16.8	38.1	1E-11	1E-11	1.03	-21	63.9	0.7	9.9	256-QAM	
80 [561 MHz]	Locked	17.7	39.0	1E-11	1E-11	0.75	-27	36.7	0.6	10.8	256-QAM	
81 [567 MHz]	Locked	17.3	38.2	1E-11	1E-11	1.19	-24	48.9	0.7	10.0	256-QAM	
82 [573 MHz]	Locked	17.6	38.9	1E-11	1E-11	0.95	-26	34.7	0.6	10.7	256-QAM	
83 [579 MHz]	Locked	17.5	39.4	1E-11	1E-11	0.86	-26	40.4	0.6	11.2	256-QAM	
84 [585 MHz]	Locked	17.2	>40	1E-11	1E-11	0.84	-27	34.0	0.6	11.8	256-QAM	
85 [591 MHz]	Locked	16.9	38.9	1E-11	1E-11	0.70	-27	33.2	0.6	10.7	256-QAM	
86 [597 MHz]	Locked	17.7	>40	1E-11	1E-11	1.27	-22	49.9	0.6	11.8	256-QAM	
87 [603 MHz]	Locked	17.0	39.4	1E-11	1E-11	0.93	-23	53.0	0.6	11.2	256-QAM	
88 [609 MHz]	Locked	17.3	39.9	1E-11	1E-11	0.80	-23	49.8	0.6	11.7	256-QAM	
89 [615 MHz]	Locked	17.0	>40	1E-11	1E-11	1.74	-21	59.1	0.6	11.8	256-QAM	
90 [621 MHz]	Locked	17.2	39.8	1E-11	1E-11	0.75	-25	48.0	0.6	11.6	256-QAM	

91 [627 MHz]	Locked	17.2	>40	1E-11	1E-11	1.00	-24	59.0	0.6	11.8	256-QAM	
92 [633 MHz]	Locked	15.3	39.1	1E-11	1E-11	1.53	-23	40.9	0.6	10.9	256-QAM	
93 [639 MHz]	Locked	15.1	39.5	1E-11	1E-11	1.88	-19	86.6	0.6	11.3	256-QAM	
94 [645 MHz]	Locked	15.5	38.2	1E-11	1E-11	0.93	-24	57.0	0.7	10.0	256-QAM	
100 [651 MHz]	Locked	15.2	>40	1E-11	1E-11	1.60	-23	48.4	0.6	11.8	256-QAM	
101 [657 MHz]	Locked	15.3	39.6	1E-11	1E-11	1.04	-23	64.4	0.6	11.4	256-QAM	
102 [663 MHz]	Locked	15.7	>40	1E-11	1E-11	0.97	-21	53.1	0.6	11.8	256-QAM	
103 [669 MHz]	Locked	14.3	39.9	1E-11	1E-11	1.11	-22	43.2	0.6	11.7	256-QAM	
104 [675 MHz]	Locked	14.7	38.3	1E-11	1E-11	0.89	-21	47.5	0.7	10.1	256-QAM	
105 [681 MHz]	Locked	15.1	38.2	1E-11	1E-11	1.36	-21	54.8	0.7	10.0	256-QAM	
106 [687 MHz]	Locked	15.2	38.2	0.0	0.0	1.39	-24	51.3	0.7	10.0	256-QAM	
107 [693 MHz]	Locked	15.8	37.4	0.0	0.0	1.68	-23	70.6	0.8	9.2	256-QAM	
108 [699 MHz]	Locked	16.9	39.3	1E-11	1E-11	1.10	-21	50.3	0.6	11.1	256-QAM	
109 [705 MHz]	Locked	16.7	>40	1E-11	1E-11	1.21	-23	57.7	0.6	11.8	256-QAM	
110 [711 MHz]	Locked	16.6	>40	1E-11	1E-11	1.37	-20	58.7	0.6	11.8	256-QAM	

The above tests were conducted by an automated testing routine; more on this later.

Pass/Fail Parameters
The following comments refer to the previous QAM grading worksheet. First, note that other digital carriers such as 8-VSB, OFDM, COFDM can be included, but when these type signals are carried in an HFC network, CSEI normally measures average power level only. Separate 8-VSB and OFDM analyzers are available in the test equipment market, and CSEI has this equipment and the ability to measure most of the below parameters in the other carrier formats, but we typically do so only at the operators request; since they are not covered by the ANSI/SCTE 40 document and not required under present FCC Part 76 rules. The following test limits therefore apply to downstream QAM carriers only.

TEST	**CSEI Test Limit**	**SCTE/FCC Limit (3)**	
DCP	>= -5 dBmV	>= -15 dBmV	
MER	>= 31 dB	>= 27 dB	
PreBER	1 X 10^{-5}	No spec	
PostBER	1 X 10^{-8}	No spec	
FrqResponse	<= 2 dB	<= 5 dB	
EQ Stress	<= -30 dB	Reflec ------------->	- 10 dB @ <= .5 microsec
Group Delay	<= 150 ns/MHz	<= 250 ns/MHz	- 15 dB @ <= 1 microsec
EVM	<= 1.25 %	No spec	- 20 dB @ <= 1.5 microsec
ENM	>= 6 dB	No spec	- 30 dB @ <= 4.5 microsec

Comments

- Pre and post FEC BER limits are not defined by the ANSI/SCTE 40 document. While we do suggest limits in the above CSEI Test Limit column, I generally expect to see zero BER in the headend and at field test points; and we typically conduct further testing when any BER is present in the headend or system. Stated differently, in a properly functioning downstream HFC headend or plant, no BER should be present.
- The EQ stress limit is dependent upon the {time} delay between the reflected and incident signal, so care must be taken in interpreting results of this test if conducted as part of an automated routine. More on this in the next section.

Automated QAM Testing
Many if not most modern QAM analyzers will allow for the operator to manually conduct the tests described thus far; however, as analog carrier numbers continue to drop & QAM carrier counts continue to rise in most systems, the problem for the operator is the time required to manually conduct required QAM tests, record the results to paper (or take screenshots, which is even more time intensive), and to then key those results into some sort of ‘grading spreadsheet’. During our most recent round of testing, I found that it was taking an estimated 10 to 20% longer to conduct each system FCC POP test because of the shift in the number of analog vs QAM carriers, and because of the increase in the number of required tests on each QAM carrier to meet ANSI/SCTE 40 specifications.

I therefore felt compelled to attempt to locate an ‘automated’ QAM testing solution to resolve this issue. There may be other solutions available (I checked with all major manufactures last fall); however after much research the solution chosen by CSEI is from Sunrise Telecom Broadband (SRT BB). I normally refrain from recommending any specific equipment or test equipment manufacturer; however in this case and at present, there is really only one viable solution in my opinion *at this time*.

A version 3 or 4 SRT AT2500RQv spectrum analyzer, with up-to-date firmware, can utilize their AT-WEB software. This software package is resident in the analyzer firmware and is controlled via a standard web browser interface and a channel plan built by their System Editor software. The QAM channel testing plan is loaded by the AT-WEB software and used to control the analyzer during testing. The AT2500RQv analyzer is therefore ‘mated’ with a notebook computer during testing, and after testing is complete the results can be stored back to the notebook computer.

The results from our sample tests run in several systems were very encouraging. I’ll now provide some honest feedback on this system that includes both advantages and a few potential concerns.

Advantages

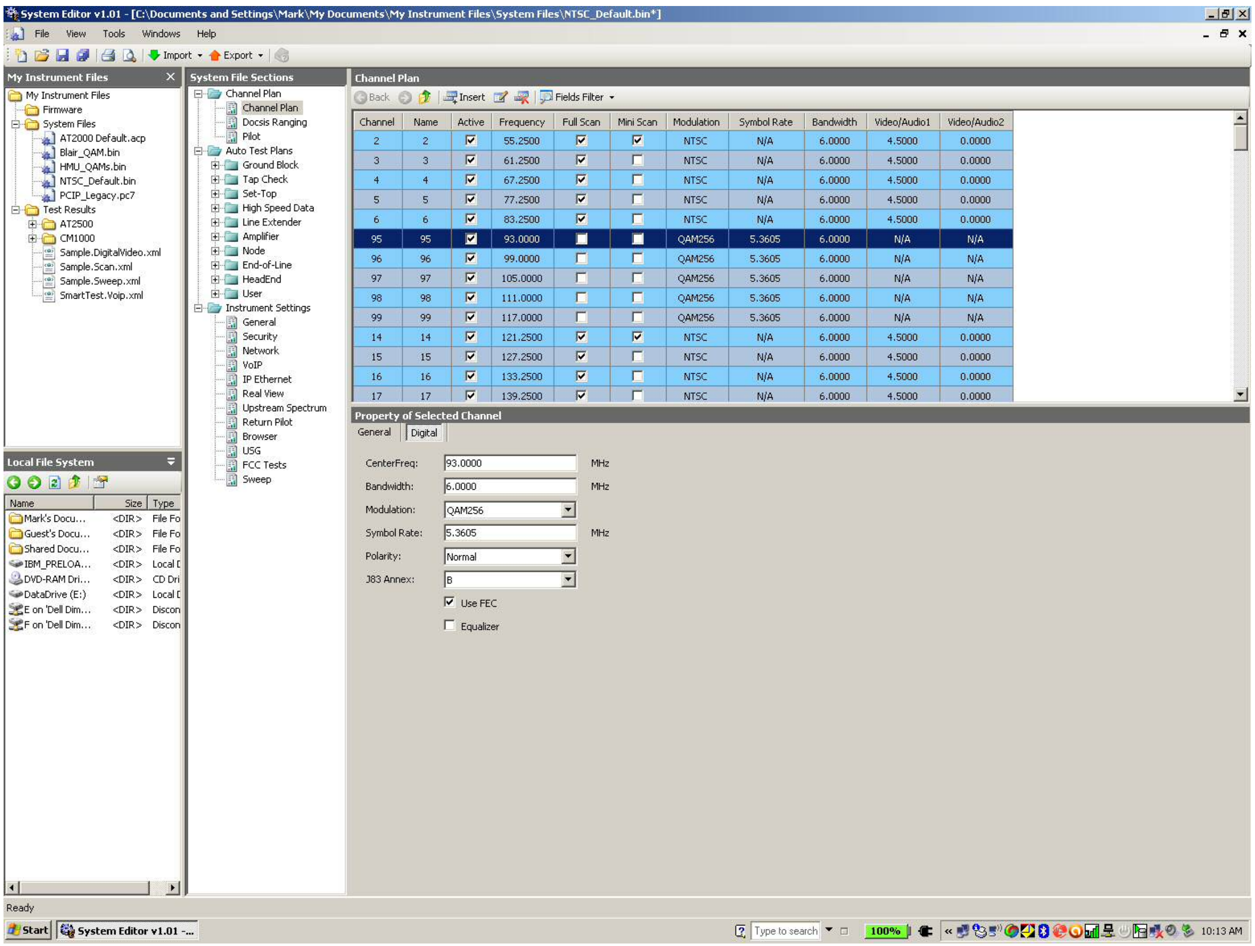
1. QAM testing takes approximately 1/3rd the time that is required to manually run the same tests. The full test run on the 40 QAM carriers shown earlier in this technical letter took approx. 12 minutes to run, with the results stored to a .csv file that can be easily imported into a grading spreadsheet. This significant reduction in testing time will now allow us to test all QAM carriers in the field as well as the headend (previously, in order to conserve time, we were testing only ½ of the QAM carriers at each field location). And since the results can be imported into a grading sheet, time required to grade and assemble the final report should also be significantly reduced, along with possible data entry errors.
2. QAM testing results appear to be very accurate, and in some cases are more accurate than manual testing where results sometimes have to be 'guestimated' from on-screen graphical representations, such as group delay and carrier frequency response.
3. The AT-WEB software can be used to remotely control the AT2500RQv series analyzer (complete functionality); thus effectively replacing their separate WinRemote software.

Disadvantages

1. The cost of the AT-WEB software, possible costs to upgrade your analyzer to v3 or v4, and the cost to return your analyzer to SRT BB to have the AT-WEB software installed. This cost, however, as compared to the time savings realized during testing, was well worth it in my opinion.
2. A notebook must be linked with the spectrum analyzer during testing; however, this again is considered to be a manageable issue.
3. Regarding the measurement of adaptive equalizer stress, results of these tests and ANSI/SCTE parameters (whether pass or fail) have to do with the time delay between incident and reflected signals. At present, the SRT automated run lists the worst case (-dBc) reflection within each carrier, but without regard to the time delay of that reflection. So, it's not possible to know for sure in reviewing automated testing results whether a given test passes -- without reverting back to a manual measurement where time delays are indicated. My approach, for now, is to scan the results of this particular test after the .csv file is stored, and to manually retest any carriers where it appears 'adaptive equalizer stress' may be higher than expected.
4. For now, the QAM HUM test is inaccurate. This issue is independent of the automated testing process and will hopefully be resolved in the next firmware update for v3 and v4 AT2500 series analyzers.

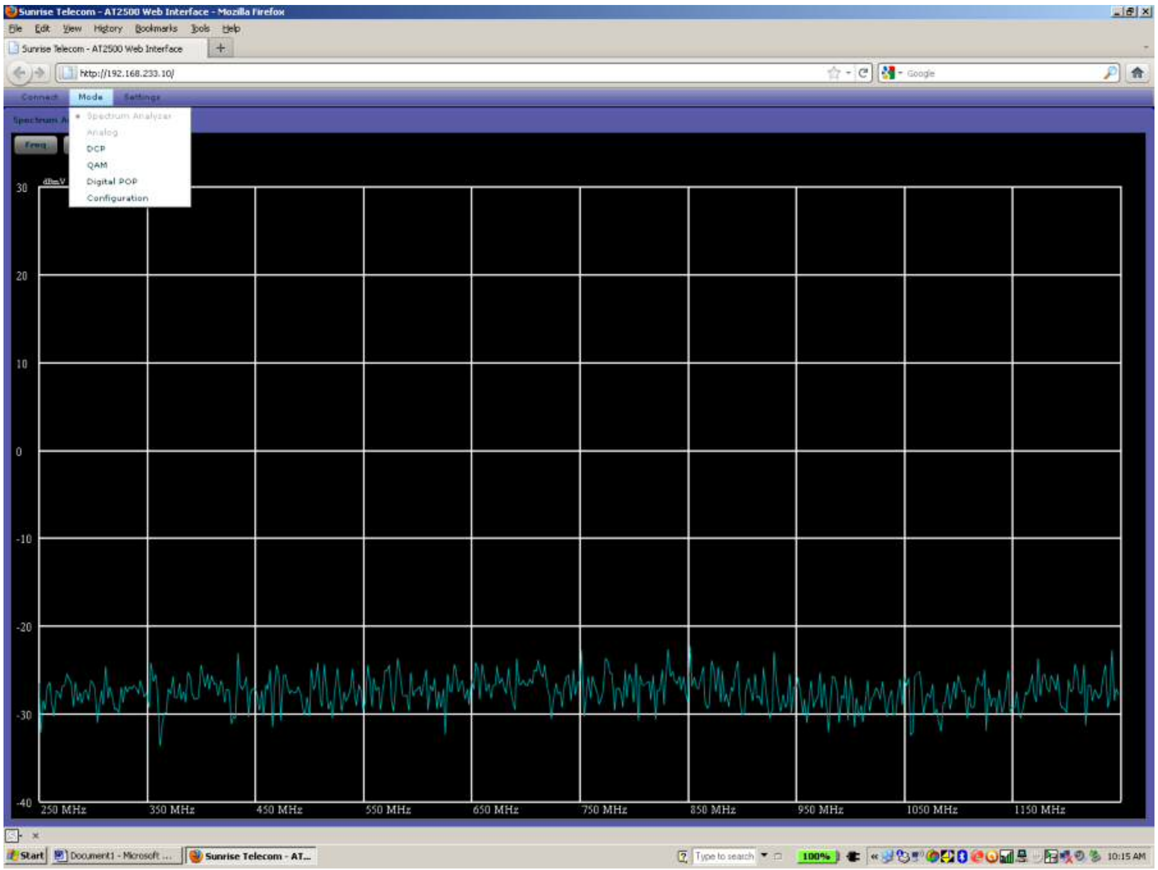
In fairness, I should note that other test equipment manufacturers are working on automated QAM testing solutions, and one promising solution from a different manufacturer was reviewed last fall; however I was disappointed with the results along several fronts including accuracy of the tests, ease of use of both hardware and software components, and the variety of QAM tests available and whether they met present ANSI/SCTE 40 requirements.

The following screen shots were captured during use of the SRT BB System Editor, AT-WEB software, and automated testing routine.

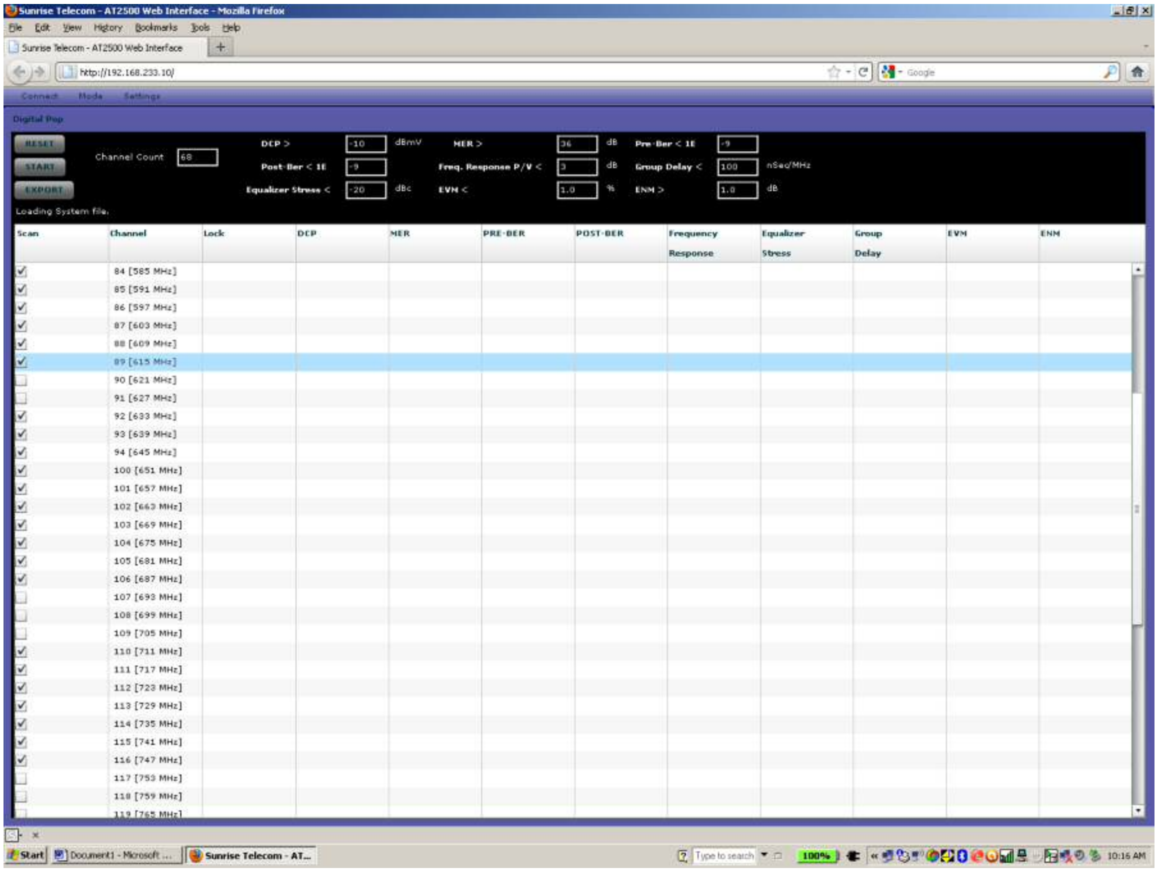


System Editor software, while building a channel plan for automated QAM testing.

Initial view of the AT-WEB software using a Firefox web browser.



The AT-WEB software defaults into spectrum analyzer mode. The open menu above shows other testing options, including Digital POP, which contains the automated QAM testing routines.



This final screen shot shows the AT-WEB software in Digital POP mode and an appropriate channel testing plan loaded. All that remains is to click on the 'start' button and settle back and watch the testing of each channel. Once complete, results can be exported to the notebook in .csv format. Screen results at the end of the testing routine are graded according to the parameters set at the top of the screen.

Final Thoughts

1. This report takes a broad overview regarding each QAM test, as an in-depth examination would require a document much larger than is intended for these quarterly technical reports.
2. I believe 'automated QAM testing' will rapidly transition from an optional feature to a mandatory one over the next several years, as the HFC plant a few years from now will likely contain very few analog carriers and a large quantity of QAMs. Manual measurements of perhaps 60 to 80 QAM carriers to full ANSI/SCTE 40 specifications will prove to be far too time consuming for most operators. My hope is that acceptable solutions will appear from other test equipment manufacturers, but as of the time of my equipment reviews this last September through October, the SRT BB AT-WEB solution was the only available and accurate solution in my opinion.

My 'planned' 1st Quarter 2012 Technical Report will provide an examination of wireless links, how they are designed and implemented, along with some actual measurements an operational 2 mile 2.4 GHz wireless link.

Take care, and my best regards during this Holiday Season!

Mark Bowers
VP of Engineering
Cablesoft Engineering, Inc.

Bibliography

ANSI/SCTE 40 – 2004 Rules (available as a separate .pdf document download on the CSEI website)
FCC Part 76 Rules (available as a separate .pdf document download on the CSEI website)