CT's EDGE QAM TECH GUIDE

October 2008

INSIDE THIS ISSUE

Let There Be More QAM

The loud buzz surrounding edge quadrature amplitude modulation (QAM) devices at Cable-Tec Expo 2007 turned quiet over the following year.

That lower decibel level largely derived not only from the closing of Comcast's request for proposals and apparent selections (of ARRIS and Harmonic) but also from a lengthening of timetables on switched digital video (SDV) rollouts.

Edge QAM products have been linked primarily to the deployment of video on demand (VOD). (See "History" sidebar, on page 4.) Dubbed "VOD on steroids," SDV not only calls for edge QAM modulators, but lots of them. Analog reclamation having risen as a top priority at Comcast, then there was going to be less immediate need to deploy these devices.

CRITERIA

The buzz departed, but in its place came a sort of quiet hum, emanating from integration labs, from isolated vendor launches, from progress on DOCSIS 3.0 (and to a lesser extent, modular CMTS) and from continued SDV rollouts from Time Warner Cable, the industry SDV pioneer.

"It's more relevant now than in 2007," said Time Warner Cable Senior Director, Video Systems, when we asked about his paper on narrowcast services from May 2007. Thus, the excerpt from that paper, along with a follow-up Q&A that touches upon the under-reported issue of combining networks. (See page 4.)

Not to say that Comcast has been neglecting the overall topic. Two of Philadelphia's brightest minds, Distinguished Engineer Philip Gabler and Comcast Fellow Weidong Mao, presented a paper at Cable-Tex Expo this year on SDV challenges and design considerations. The section excerpted here serves as a reminder that the edge QAM stands not alone, but within a framework of network elements. (See page 8.)

A key challenge for vendors has been to accommodate the separate sets of interfaces that have emerged from these two leading North American MSOs. Only this September has Camiant, for instance, one innovator in the universal edge resource management (UERM) category, stated that it support both Comcast's next-generation on-demand (NGOD) and Time Warner Cable's Interactive Services Architecture (ISA).

That point of universality is one of several technical hurdles facing the edge QAM vendors. What makes an edge QAM universal is its current or upgradable ability to accommodate specifications related to DOCSIS 3.0 and the modular cable modem termination system (M-CMTS) architecture.

Not surprisingly, upgrade paths and continuing software support were two issues raised by several of the MSO engineers who talked with us about edge QAM devices. Add those to the standard questions of density, rack real estate, power consumption and addressable frequency ranges. (See Table 1, page 3.)

Signal integrity, crosstalk avoidance, encryption capabilities and redundancy were additional topics that ranked high.

It's difficult to peg any one of these as determinative. Overall, the demands that the industry has placed upon the UEQAM are nearly staggering. That said, the relationship between RF performance and density, elaborated in Hardin's Q&A, may get to the heart of one of the most crucial tradeoffs.

QAM BASICS

A final point about technology dealing with the modulation

Glossary

BIT ERROR RATE (BER)

Number of bits in error, as a portion of transmitted bits. A measurement of transmission accuracy. A ratio of bits received in error vs. bits sent.

CARRIER

An RF or optical wave used to transport (carry) video, audio or data signals over various media such as coaxial cable, microwave, broadcast TV, radio, or optical fiber employing various modulation techniques.

EDGE QAM

A multi-purpose QAM modulator, as opposed to one dedicated to a particular purpose, such as digital broadcast video. They are distinguished by Gigabit Ethernet interfaces (1 and 10). Flexibility is key—many edge QAMs can accommodate switched digital video (SDV) and video on demand (VOD) in addition to broadcast digital video. Universal edge QAMs are designed to add data to that mix. The term "edge" refers to the somewhat amorphous logical edge of the network, as opposed to a physical location.

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Cisco RF Gateway 1 Edge QAM

Your solution for powerful, scalable advanced services

The Cisco® RF Gateway Series Edge QAMs offer industry-leading density, modularity, and flexibility – providing an ideal solution for rolling out advanced digital services such as VoD, Switched Digital Video (SDV), and DOCSIS® Data Services.

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- **Efficiency** – Complements the Cisco Universal Session and Resource Manager (USRM) for dynamic QAM sharing to maximize bandwidth efficiency across services
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The Cisco RF Gateway 1 is a highly dense, highly available U-EQAM device. A hot-swappable modular design allows operators to scale services as subscriber demand increases.

With this winning Cisco architecture, cable operators can deploy a robust and dependable U-EQAM solution that enables a converged next-generation cable network.

Learn more at www.cisco.com

Edge QAM Modulator Lineup

Name:	Product:	#QAM	RU	Power	Freq Range	Freq Step
Arris Group 678.473.2000	D5	48	2	320	57-867MHz	13.3kHz
Bigband Networks 650.995.5000	BEQ6000	48	1.5	265		
	BME50	24	1.5	265		
Casa Systems 978.688.6706	C2100	64	1	400	50-860MHz	12.5kHz
	C2150	64	1	400	91-867MHz	5kHz
Cisco Systems 408.526.4000	RF Gateway 1	48	1	410	45-1000MHz	1kHz
	XDQA24	24	1	230	45-1000MHz	25kHz
GoBackTV 650.473.1285	GigaQAM 1000	24	1	280	51-858MHz	62.5kHz
	GigaQAM 2000	24	1	280	51-858MHz	62.5kHz
	GigaQAM 3000	24	1	280	51-858MHz	62.5kHz
Harmonic 408.542.2500	NSG9000	72	2	220	53-867MHz	3kHz
LiquidxStream Systems 514.352.0770	LxS-3216	512	3	1000	55-1000MHz	"not applicable"
Motorola 514.352.0770 (?)	Apex 1000	48	1	240	57-999MHz	250kHz
RGB Networks 408.701.2700	USM100	128	1	500	54-870MHz	30kHz
Tandberg Television 678.812.6300	EQ8096	96	2	350	57-867MHz	10kHz
Teleste Corporation +358-2-2605 6110 (Finland)	Virtuoso Edge QAM	48	2	320	57-867MHz	13.8kHz
Vecima Networks, Inc. 888.292.8266	HyperQAM	128	2	600	54-1000MHz	

Publicly available specifications on the latest crop of edge QAM devices

continued from page 1

scheme that is so crucial to all of cable's digital transmission. Engineers on the vendor and operator side agreed that what is happening in these edge devices should redound to the benefit of the industry's overall handling QAM channels, which his happening on several fronts.

The reclamation of analog spectrum, for instance, does not spontaneously correspond with the dropping of analog channels. Rather, it requires QAM modulators–as with SDV, lots of them.

That bodes well for anyone in the QAM device business, and calls for no slackening in the education and training of the industry's technical teams in the basics (see Glossary and Hranac Q&A, pages 1 and 6) surrounding the care and feeding of QAM signals.

— Jonathan Tombes and Bruce Bahlmann

Access Intelligence

Communications TECHNOLOGY

editorial
editor **Jonathan Tombes**
(301) 354-1795, jtombes@accessintel.com
managing editor **Ron Hendrickson**
(303) 422-3373, rhendrickson@accessintel.com
contributing analyst, **Bruce Bahlmann,** scifilivalways@yahoo.com

design/production
sr. graphic designer **Vince Lim** (301) 354-1680
sr. production manager **John Blaylock-Cooke** (212) 621-4655

Access Intelligence
4 Choke Cherry Road, 2nd Floor, Rockville, Maryland 20850

Unified and Combined Narrowcast

Excerpted from "Narrowcast Services--Unifying the Architecture," by Glen Hardin, Time Warner Cable. Reprinted with permission of NCTA, from the *2007 NCTA Technical Papers*.

UNIFYING THE ARCHITECTURE

A couple of questions need to be asked when architecting a unified narrowcast architecture.

Does it make sense to have one narrowcast for all services sharing the same downstream infrastructure physical layer or are there many?

Can the narrowcast services share the narrowcast bandwidth?

When all services are normalized to tuner math, either QAM tuners or DOCISIS tuners, the math and traffic analysis becomes an even more interesting exercise in And & Or (Boolean algebraic) Math and understand the peak trending of services.

A single QAM tuner can either be tuned to a broadcast stream or to a VOD stream or to a SDV stream or turned off. A QAM tuner cannot tune to multiple services at the same time. Therefore, it is easily conceived that for services targeted at QAM tuners the services can coexist and interoperate quite well within the same shared narrowcast. Or Math dictates that is just a series of tradeoffs. Therefore, when the bandwidth for QAM tuner narrowcast services are shared or pooled together there are economies of sharing.

Current DOCSIS tuners only tune to one frequency at time. With DOCSIS 3.0 and channel bonding the DOCSIS tuners can tune wideband frequencies, but as they are tuning discrete frequencies at any one point in time they can be considered bound by Or Math when operating in a shared bandwidth pool just like they are today. Typically a single 6 MHz narrowcast channel is allocated for HSD and VoIP phone service across the cable plant.

Today in the residential market, the coexistence complexity arises when looking at the peaks of QAM tuner services and DOCSIS tuner services. While each service type may be bound by Or Math when viewed together, the two services actually peak at or very close to the same time and are thus actually bound by And Math. Thus, the total load between a QAM tuner and a DOCSIS tuner is cumulative. There are not economies of scale to share the bandwidth between the two tuner service types.

In the near future, when cable has more greatly penetrated into the commercial market with its HSD offering there will be some advantages in sharing the bandwidth between video and HSD narrowcast services. This will be because video narrowcast services under-utilize narrowcast bandwidth during the daytime and that excess capacity could be switched over for commercial HSD use during the day and then back to residential video narrowcast services in the evening.

COMBINED NARROWCAST

There are two key technologies that are missing to truly unify the narrowcast services, the

BORN IN THE UNITED KINGDOM

The Edge QAM (EQAM) evolved out of a video on demand (VOD) project with Telewest in the United Kingdom (UK), back in 1999.

Harmonic's Nimrod Ben-Natan and Gil Katz assembled a team to address the technical aspects of the project. They discovered that although an existing Harmonic platform would fit the bill for Telewest, it was too expensive to meet the MSO's return on investment (ROI) targets.

The team decided to build something that was denser and cheaper, by a factor of 10. A year later, the narrowcast services gateway (NSG) 8108 arrived, featuring 8 QAM channels per 1RU and 2 QAM channels on 1 output port. A follow-up product packed even more QAM channels into the same chassis.

Harmonic then began looking for a VOD system architecture change that would address higher scalability and lower cost. Ben-Natan proposed a novel implementation of standard IP for video delivery (i.e. MPEG over IP) in 2002.

Harmonic persevered, and the industry has now renamed this MPEG over IP EQAM as a universal Edge QAM (uEQAM). It is a basis for advanced VOD, switched digital video (SDV), modular CMTS (M-CMTS) and linear broadcast delivery services.

— Bruce Bahlmann

"The physical layer of the narrowcast cannot just be thought of in an abstract way without really identifying with the physical infrastructure of the headend, hubsite, laser, node and customer's home."

global session resource manager (GSRM) and the business rules engine (BRE).

The Global Session Resource Manager (GSRM) is the unifying manager of all the source signal and bandwidth resources. The GSRM negotiates and arbitrates between all services and all requests. It is the key bandwidth allocation mechanism; employing bandwidth optimization algorithms to ensure that efficiencies are realized across the utilization of bandwidth across all narrowcast services.

The fact that the GSRM will be able to share the narrowcast bandwidth will allow for greater bandwidth usage efficiencies across the csombined services and is predicted to require less total bandwidth for the same blocking factor for any given service. Efficiency is the key to performance.

The Business Rules Engine is the "uber" Policy Manger for all narrowcast services. It is the tool that determines how to "sell" the narrowcast bandwidth for how much, to whom and prioritizes services and customers. It "plugs" into the GSRM and is not so much an engineering tool as a business tool. It will allow the cable business to optimize its service, its services and its revenues.

Along with the adoption of the GSRM and BRE a holistic approach must be taken into account when architecting the narrowcast design. The physical layer of the narrowcast cannot just be thought of in an abstract way without really identifying with the physical infrastructure of the headend, hubsite, laser, node and customer's home.

This is purely a practical operational model concern. If the wiring of the various narrowcast services becomes too complicated to manage and the sheer number of service groups, types of service groups, QAMs combining and distribution networks, the field personnel will not be able to support it. Although not detailed in this paper, remember to not forget the complexity of the reverse path traffic modeling and its physical combining and splitting network which is almost equal to the forward path....

Q&A with TWC's Glen Hardin:

Have the GSRM and BRE technologies yet emerged?
Conversations around a GSRM are a lot more prevalent today than they had been historically. Additionally, I know of GSRM technology trials in the works.

What else has changed in since you wrote that paper?
Time Warner and the industry have reported strong growth in both high-speed data adoption and voice adoption. That increases the growth of the high-speed data narrowcast, bringing it more in parity with the VOD and switched narrowcast that are represented in the paper.

What's the implication for unified narrowcasting?
It increases the value statement. With concurrency rates driving in parity with each other, it makes sense to begin looking at a universal edge QAM/modular CMTS architecture that allows you to put out one edge device across all three services: high-speed data, voice and video on demand/switched.

How does that relate to your preference for more flattened combining?
In today's combining networks, we actually have a parent/child relationship within the RF combining network. A high-speed data service group may be a super-set of VOD and switched service groups, and then VOD be a superset of SDV. What ends up happening is a series of combining between the broadcast, the high-speed data network, video on demand and switched digital video network. This cascading combining network increases the inefficiencies of the network, because as you go through this cascading/combining network, you actually are throwing away a tremendous amount of RF energy.

How much RF?
You can easily lose some 25 to 30 some-odd dB in your cascading combining network. Typically, you want to hit the laser at about 17, plus-or-minus a few dBmV. So when you flatten the network, and you have one device with one spigot for DOCSIS 1.1 including voice, VOD and SDV, that get combined via a 4-way combiner with the DOCSIS 3.0 broadcast channels and RF two-way communications signals. And that will just go into the laser. So now you're only down 8dB with a 4-way combiner or 12 dB with an 8-way combiner, instead of down 20 or 30-plus dBmV through a cascading combining network. That means the RF power of these edge devices needs to be a lot less, and that plays into the density benefit, where my overall space, power and cooling requirements diminish.

Less power, more density?
Exactly. That way I don't have to worry about the overheating of the elements. Plus, with these new QAM architectures, reslience and redundancy can be natively designed into the platforms.

Is the vendor community responding to this math?
I think the vendor community is really looking at trying to address this by building out ultra -dense QAM devices that combine in the protocol awareness for VOD and switched, and the timing for the CMTS traffic.

QAM BASICS

QUICK QAM QUESTIONSQ&A WITH RON HRANAC

The move to more, switched or all-digital video typically means having to deal with more QAM channels and often more QAM modulators as well. What does that mean for system tech folks? Here are CT Senior Tech Editor Ron Hranac's answers to a few such questions.

As cable operators reclaim spectrum convert to digital modulation, the greater number of digital channels would appear to place additional stress on the QAM modulator. Is that the case? Not really any stress placed on a QAM modulator. They are typically designed to support from one to, say, four QAM channels ("haystacks") per connector. As the need for more channels arises, the operator can turn on additional QAM channels on each connector, up to the maximum number supported by that particular product. One caveat: As the number of QAM channels per connector increases, the per-channel signal level decreases in order to maintain the same approximate total power at the connector.

Does the channel spacing change? The spacing between channels does not change. Channels remain separated by 6 MHz.

Any suggestion on what engineers and technicians should be looking for to help ensure signal integrity in a world of more QAM modulators at the headend and at the edge? Use appropriate test equipment to ensure that the QAM modulator is properly set up: center frequencies, power (level) per channel, and so forth.

Any other QAM signal-related bugaboos or potential ankle-biters worth mentioning in this transitional period? In general, QAM modulators are more or less plug-and-play. One issue to consider is the headend combining and cabling. Beyond that, cable ops need to make certain that levels are managed, especially at the input to downstream lasers.

Elements of SDV

From "Challenges and Design Considerations for Deploying Switched Digital Video," by Phillip A. Gabler, Distinguished Engineer, National Engineering & Technical Operations, Comcast Cable; and Weidong Mao, Ph.D., Comcast Fellow, Office of the CTO, Comcast Cable. Presented at SCTE Cable-Tec Expo 2008. This section covers a high-level architectural view of several SDV elements, including:

SDV SESSION MANAGER

The switched digital video session manager (SDVSM) is configured with a list of switched channels, including the source ID, multicast address and port, encoding format and bandwidth information.

The SDVSM sends configuration data to the SDV clients using the mini-carousel protocol (MCP). This configuration information includes the address of the SDVSM and the list of switched channel source IDs....

EDGE RESOURCE MANAGER

The edge resource manager (ERM) managed bandwidth and program resources for the Edge QAMs. For multicast-based switched digital video (SDV), the ERM is responsible for directing the Edge QAMs to join and leave IP multicast groups.

The ERM supports session requests from multiple session managers; the VOD session manager and the SDV session manager will both be requesting edge resources from it.

If the Edge QAMs announce a failure to the ERM, the ERM does not make any session-related decisions. Instead, the ERM forwards the notification to the SDVSM to allow the SDVSM to determine how to resolve the issue.

EDGEQAMS

The Edge QAMs use the registration interface to send its QAM and input resource information to the ERM. The ERM uses this information to discover the QAMs available to the set-top boxes. The Edge QAMs also use the registration interface to announce QAM failures and service state information.

The ERM sends a setup request to the Edge QAMs to direct the Edge QAMs to deliver a multicast to a particular QAM and program number. The Edge QAMs send an IGMP (Internet group management protocol) v3 Join to the switch in order to receive the multicast. The Edge QAMs should validate whether the multicast Join is successful. The results of the Join are returned to the ERM.

The universal Edge QAMs allow QAM resource sharing among various services, such as VOD, SDV and DOCSIS using the modular CMTS architecture.

SDV CLIENT

The SDV client is responsible for translating channel requests into tuning information so that the subscriber can watch the selected program. The set-top box native guide or middleware invokes the SDV client. The SDV client communicates with the SDVSM and uses the information from the SDV channel change protocol to resolve channel requests into tuning data....

GLOSSARY

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MODULATION ERROR RATIO (MER)

A ratio (expressed in dB) of average power in error vectors compared to the average power in ideal vectors of a QAM constellation, with the error vector being the resultant between the ideal and actual power vectors.

MODULATOR

A device that places video, audio or data signals onto a carrier.

QUADRATURE AMPLITUDE MODULATION (QAM)

A technique that uses two amplitude-modulated carriers with a 90-degree phase angle between them to produce a signal with an amplitude and phase angle that can vary continuously. A digital frequency modulation technique that is combination of both amplitude modulation (AM) and phase modulation (PM). By combining phase and amplitude modulation, it is possible to transmit significantly more bits per symbol, increasing spectral efficiency. Despite their high susceptibility to interfering signals, QAM carriers are increasingly being used in the return path.

QUADRATURE COMPONENT

The vertical axis (amplitude) that is shifted 90 degrees from the horizontal axis (or in-phase component) of QAM.

QAM CONSTELLATION

A graphic representation of the phase and polarity of individual digital signal components plotted as coordinate points on an x and y axis.

QAMMUNISM

The theory and practice of constantly moving to ever higher orders of modulation. Its advocates are, of course, QAMmies.