# EGT HEMi™ Application Note

## Inserting MDU, Community and Enterprise Channels in the Digital Tier

June, 2007

Encode | Groom | Transport

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## Executive Summary

As more Americans chose to live in apartments, condominiums and close-knit communities, they continue to grow as a percentage of the total cable subscriber base; now reaching almost 35%, and making up the majority of subscribers in large urban centers such as Chicago and New York. As information-based business and economies continue to thrive, video has becomes a standard component of many enterprise communication packages.

For these reason, new and emerging competitors in the video services arena are actively targeting MDU and commercial services contracts to convert large numbers of subscribers en masse. Further, the FCC has recently moved to open up the MDU market by disallowing continued bulk-contract exclusion of competitive service providers. The ability to offer a fully integrated video service that includes the highly localized community or enterprise channels is a competitive differentiator that cable operators should continue to exploit in order to maintain and grow their residential and commercial subscriber bases.

Localized video services for the MDU and Commercial Services segments have been an important component of the full service offering. Historically, these services were delivered in analog format and notched in at the MDU or business. With the advent of digital quality and bandwidth efficiency, operators are aggressively converting their video networks to digital and the local MDU and commercial services channels are now included in this transformation.

As with any new application, there are a number of important factors to be considered. Technical challenges related to QAM deletion filters and grooming within encrypted multiplexes must be overcome. Operational concerns for ease of installation, management, monitoring, reliability and safety must be addressed. And like any video service, picture quality is always of paramount importance.

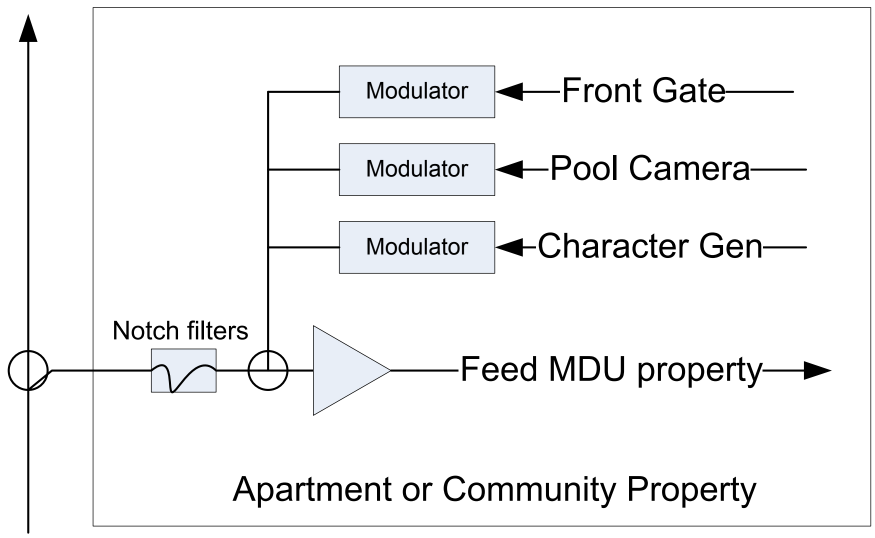
This paper examines the insertion of local community or enterprise channels in the digital tier and answers both the technical and operational questions raised by this new application of digital video technology.

## Community Channels Today

The value of our cable networks and services are increasingly judged by the degree to which they are localized and personalized. Subsequently, local channels are a critical component of any full scale video service. Although cable operators have known this for some time, satellite providers have only recently realized the importance of local channels and have moved to offer them as a part of their total package.

But localization does not stop at the city or town. More and more subscribers are interested in access to video services that are specific to the community in which they live. In many cases, these channels provide additional security measures; the most obvious and widely deployed is the front-gate or front-door camera. But in many locations, these security channels are augmented with localized convenience or service channels, such as community events calendars or message boards.

Historically, the method for enabling these local channels was to switch in the analog community channel(s) in the place of alternate analog services. In some locations, operators have pre-designated which analog services will be replaced while in others it is based on a negotiation with the community for which the program is being substituted. But in nearly all cases, the inserted community-channels are analog.




Although this implementation provides the required community-specific services, the analog nature of the channels presents specific challenges. Chief among the challenges is the amount of required bandwidth. In the above example, an operator would have to devote three full 6 MHz channels to the community services. By simply converting these community channels to digital, the operator gains back enough bandwidth inside of the building to offer eight new HDTV channels.

The other limitation of this analog programming is that it is incompatible with the all-digital network and all-digital set top box. As operators look to unlock bandwidth and control CPE costs, the continued use of analog programming becomes a bottleneck to significant cost savings and service expansion. Lastly, the all-digital network gives the operator more flexibility to either add additional channels within the community without adding bandwidth, or deploy advanced bandwidth management tools such as Switched Digital Video.

## EGT HEMi™ – HeadEnd Micro for digital community channels

The EGT HEMi™ is a fully integrated solution designed specifically to relieve the bottleneck associated with the analog community services. The EGT HEMi™ is capable of:

- Tuning to a digital QAM frequency.
- Demodulating the input multiplex.
- Digitally encoding the local (analog) community service.
- Either adding the local channel to the input multiplex or replacing one or more of the incoming digital programs. This is possible for both encrypted and "in-the-clear" QAMs.
- Remultiplexing the programs.
- Re-modulating and up converting the newly modified QAM channel.

The deployment of a digital solution for community-based services is critical to realizing the bandwidth and cost efficiencies of the all-digital network. However, the application has its own set of challenges that must be understood for the effort to be successful.

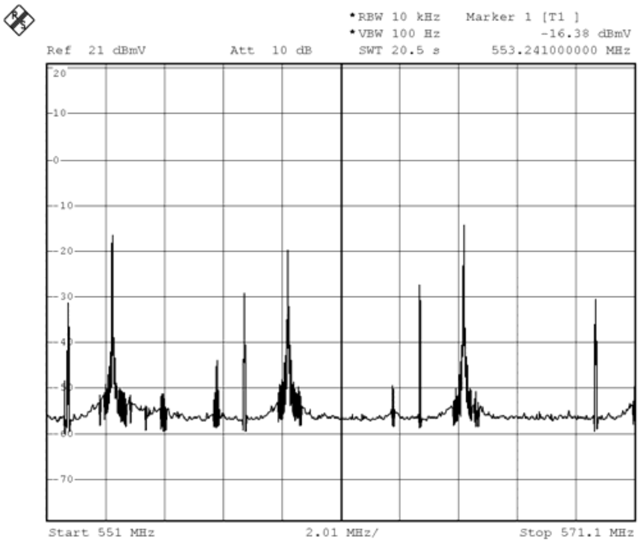
Operators do not need to deploy splitters/combiners to split off the HFC service and recombine the community QAM channel with the rest of the line-up. This technology is provided as in integrated function of the HEMi RF Bypass module. However, to make full use of digital channel efficiency, a solution for QAM channel deletion filters is required.

QAM channel filters are required in order to isolate a 6 MHz channel in the digital tier and then insert the local community/MDU/enterprise channels as programs within a multi-program transport stream (MPTS). The local channels can be in addition to the digital programs already within that MPTS, or in place of them. But in either case, the isolation and rejection of the incoming QAM channel is required in order to replace that QAM channel with a QAM channel generated by the HEMi.

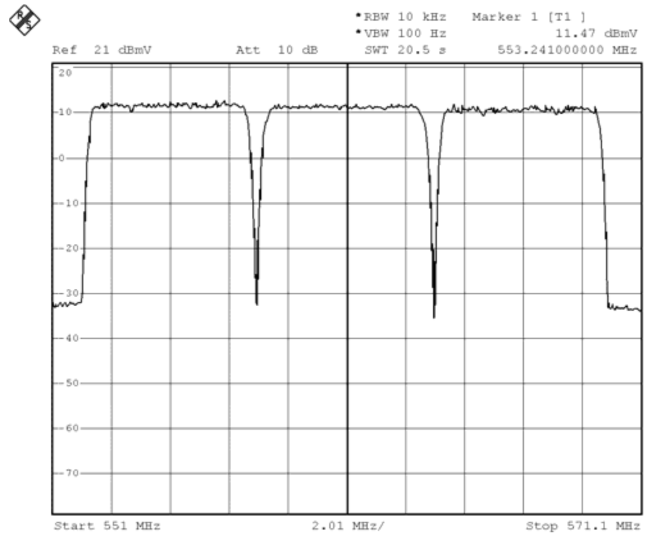
As QAM channel deletion is a relatively new application in cable, there are technical issues and considerations that must be understood.

## Digital QAM Deletion Filters

Digital QAM enables operators to pack more services per 6 MHz channel and in comparison to the analog channel are quite dense.



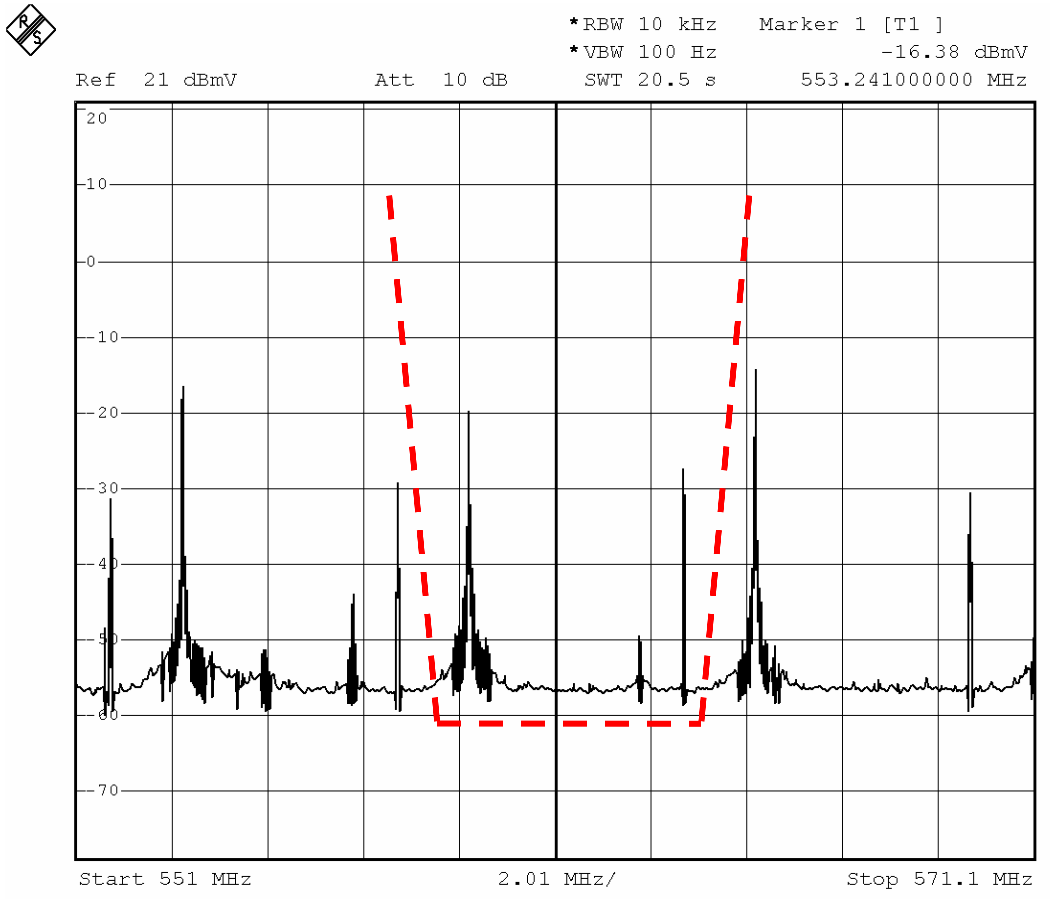

*3 adjacent analog channels*




*3 adjacent digital QAM channels*

Filters come in all types but the two parameters that they all have in common is amplitude distortion and group delay. Amplitude distortion typically consists of two types: in-band ripple and roll off at the band edges. Group delay is the change in phase per a unit change in frequency.

When filtering an analog channel the amplitude distortion and group delay is such that adjacent channels are not significantly impacted. The effectiveness of the analog notch filter is in large part responsible for their wide application.




*Analog Notch filter applied to middle analog channel*

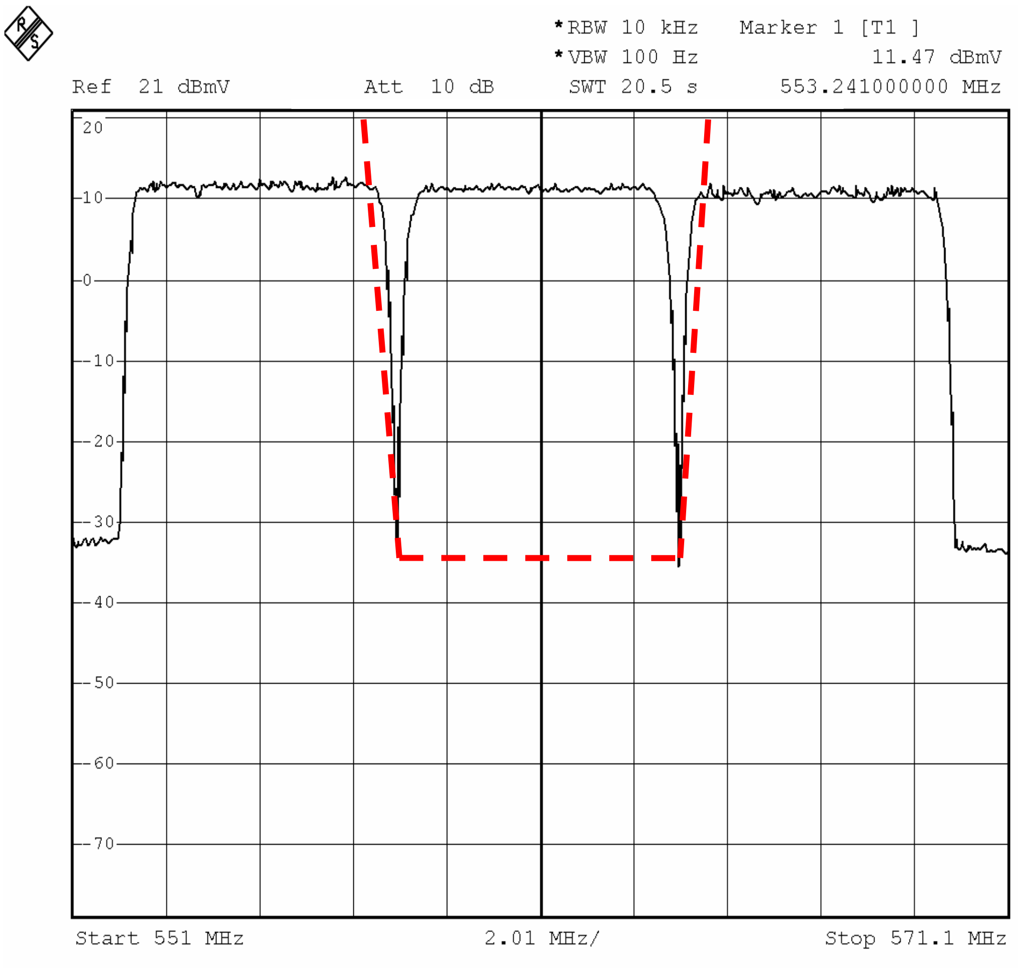
The integrity of a QAM signal depends upon the amplitude and phase of the medium through which it is being transmitted to be constant. Any variation in these two parameters causes a data point to "lie" in the wrong position on the decoding map thus causing an error. The error caused by the variations is measured either by the bit error ratio, BER, or more common for QAM signals, the Modulation Error Ratio, MER. MER is closely related to signal-to-noise ratio and includes all imperfections including deterministic amplitude imbalance, quadrature error and distortion.

Filters are characterized by the "Order" of the filter. Each additional section of an inductive and capacitive element, or its equivalent, increases the order by one. A filter whose order is 8 will have 8 tuned sections. As the order of the filter is increased, the sharpness of the amplitude characteristic of the filter increases. In general, the higher the order is, the better the performance of the filter is in rejecting the undesired band of frequencies. The disadvantage with higher order filters is the group delay also increases.

To use a digital QAM deletion filter for the typical community-channel insertion (256 QAM) we need at least 40 dB of rejection in the desired channel to keep it from distorting the new or modified (post-HEMi) signal being applied to this same channel. In addition the filter has to provide at least 35 dB of rejection at the signal's Nyquist frequency.

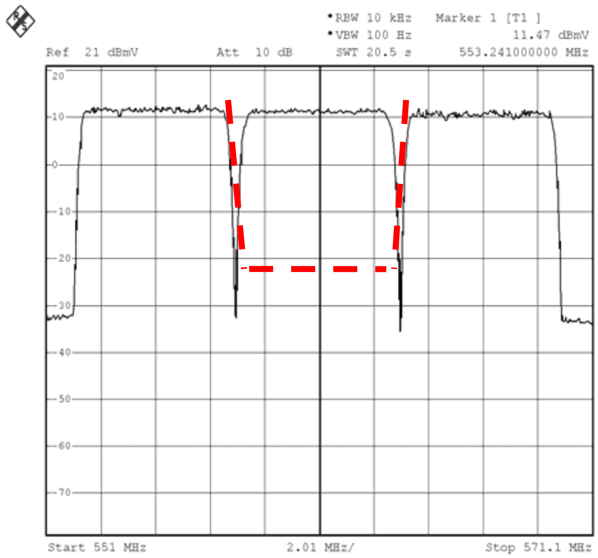
This comes at a price – the adjacent channels will have amplitude distortion and group delay distortion imposed upon them. The reason for this is that the filter's amplitude performance has to start rejecting the signal in the adjacent channel in order to get enough rejection in the desired channel.

As shown in the diagram given below, applying a standard analog notch filter to a digital QAM channel can successfully notch out the channel, but not without severely impacting the performance of the two adjacent channels.

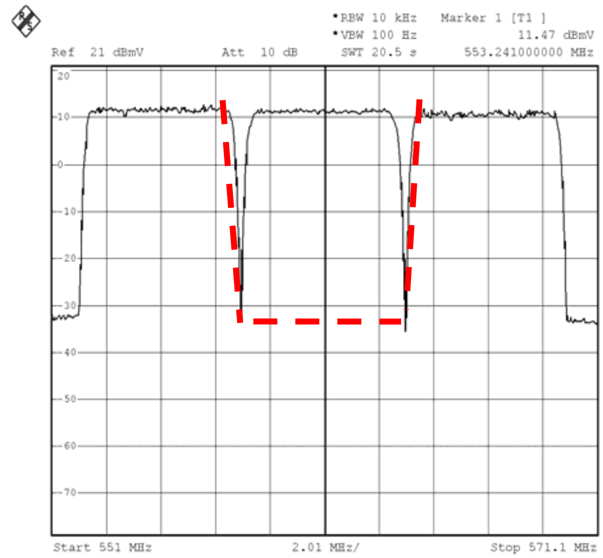



*Analog Notch filter applied to middle digital QAM channel*

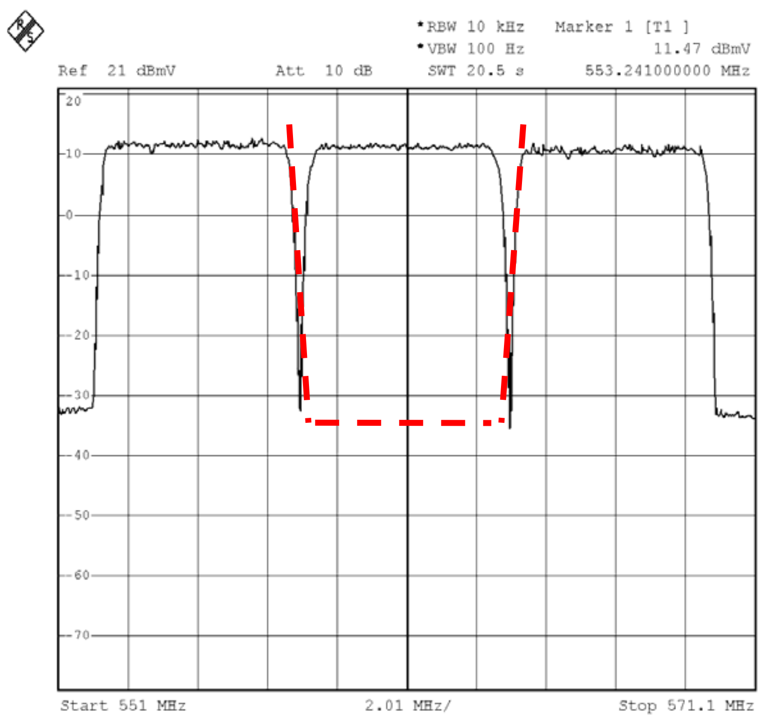
The trick to a successful QAM deletion is a careful balancing of the frequency, the MER, the order and the group delay. For our 256 QAM signal application, EGT laboratory tests show the filter order needs to be 10. An 8$^{th}$ order filter caused less degradation to the adjacent channel performance but did not sufficiently reject the incoming signal: The MER was degraded by less than 2 dB. A 12$^{th}$ order filter shows no degradation to the modified (HEMi) channel. It did however result in up to 2.5 dB degradation in the adjacent channels MER performances.




*8th order filter*
*Does not introduce group delay*
*but does not provide enough channel rejection*

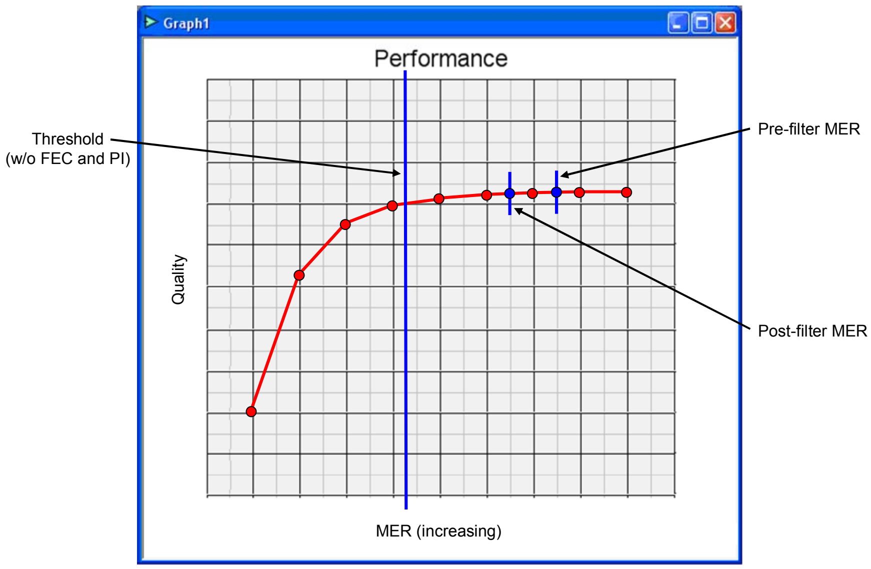



*12th order filter*
*Provides enough channel rejection, but introduces*
*group delay, degrading adjacent channel MER*




*10th order filter*
*Provides the right balance between group delay, adjacent*
*channel MER and channel rejection*

While all channel deletion filters will have some impact on MER, the 10th order filter will provide acceptable signal rejection while not degrading MER beyond the threshold of perceptibility. If a filter introduces too much group delay, or MER, the signal will fall below the threshold and the signal can no longer be recreated with 100% accuracy, resulting in video quality degradation or ultimately in an inability for a tuner/decoder to lock to the signal. Although sufficient margin exists for the implementation of 10th order filters, advanced modulation technologies for error handling (packet interleaving and forward error correction) have now been employed to allow for even greater threshold variability.




## Operational Considerations

As the installation locations are distributed outside the headend or hub, the HEMi platforms must not only be designed for a higher level of usability and system robustness but must be easily monitored and managed via standard network management tools and protocols.

### Installation and Management

First, the HEMi devices must be simple to install. They must come equipped with default configurations that work "out-of-box" and are easily adaptable for community or enterprise-specific requirements. The user interfaces need to be intuitive and easy to access. By providing default configurations that work and remote management capability, the installation and initial bring-up of the HEMi systems can be streamlined, saving time and expense. Once the systems are installed and operational, there must be standards-based support for remote monitoring and management, namely SNMP 'get' and 'set' support. As subscriber demand for more security cameras and other community-based video grows, cable operators will want to leverage the deployed base of HEMi solutions. The HEMi devices should be scalable; they must be able to add additional channels without adding significant complexity or space to the community installation.

**RF Bypass**

Exception handling and fault tolerance are critical to overall service reliability. The community/enterprise channel application should recognize and account for an inherent stream prioritization. Those channels provided by the cable operator, watched by the subscriber, and purchased by the advertiser have a justifiably higher level of priority than the local events calendar or front-gate camera. This accounting for priority levels is especially relevant when replacing digital network channels with local channels. When the HEMi is 'working' within a digital QAM, the other network services within that QAM must be protected at all costs. For this reason, EGT has added RF Bypass capability to the EGT HEMi™, so that any disruption to the HEMi service or device is transparent to the consumers of the network content. If an EGT HEMi™ were to lose power, the input QAM channel is passed directly and passively through the HEMi, honoring the inherent priority of the network streams.

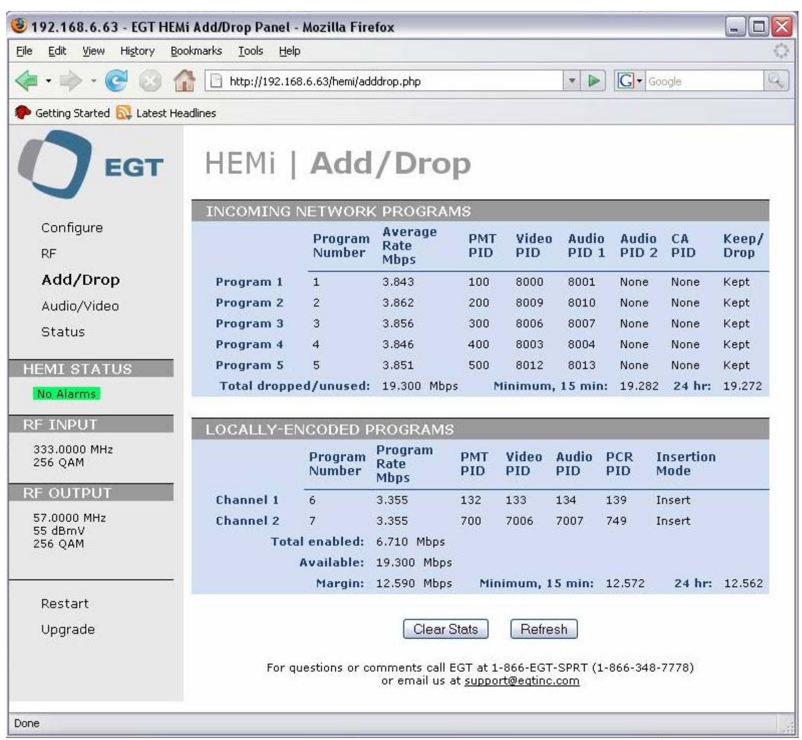
As mentioned above, the RF Bypass function includes signal acquisition (splitting) as well as re-combining of the modified QAM channel back into the digital spectrum. If no digital QAM deletion filter is installed in the network, the EGT HEMi™ will output only the single QAM channel it is processing. The capability is not only critical in terms of system resiliency, but also vastly simplifies the installation, management and operation of the device. RF Bypass is unique to the EGT HEMi™.

**QAM Auto-Protection**

When inserting a local channel into a VBR (Variable Bit Rate) multiplex, an additional measure of bandwidth management and service prioritization is required. In a closed-loop multiplex, the VBR programs are managed so that their aggregate bit rate is constant just at or below the QAM rate. However, as each individual service rate is variable, removing one or more individual streams from the multiplex will result in a aggregate total that is now variable. Therefore, the remaining bandwidth (into which the local services are being inserted) is also variable and without a minimum bit rate guarantee. This has two implications for the design of the HEMi.

<u>Historical Bit Rate Margin Analysis</u>

It is important to understand how much bandwidth is created by dropping one or more services from the incoming VBR multiplex. For this reason, the EGT HEMi™ provides a management screen showing each incoming stream and its associated bandwidth usage. When services are dropped from that multiplex, the EGT HEMi™ indicates the resultant bandwidth margin. It is in this bandwidth margin that new services are provisioned. Further, it is understood that the margin will change over time and that available margin at one minute will not be the same the next minute. For this reason, the EGT HEMi™ provides a



historical account of available margin over the last 15 minute and 24 hour periods. By examining available margin over a longer period of time, operators can be surer that the margin created by dropping services is indeed available.

QAM Auto-protection

Even after all precautions have been taken to create and assign an available margin, there is no guarantee that the network services won't at some time exceed their margin and cause the QAM to overflow. It is again imperative to understand the inherent priority of the services and to protect the network channels. For this reason, the EGT HEMi™ provides a mechanism to automatically drop the lowest priority local service in order to create bandwidth for the network services. Should it be necessary, the EGT HEMi™ will temporarily drop all local services in order to safeguard the other channels in the digital QAM. In the event of a margin over-run, the EGT HEMi™ will send an alarm and SNMP trap, mute as many local services as required and once sufficient margin has returned, reinstate the local channels.

**Cables and Connectors**

In an effort to better understand the new root causes of service disruption, Cox Communications has recently conducted a study on the core elements of network resiliency. The results of this study are both interesting and surprisingly obvious; the least resilient part of the network is the cables and connectors. What this means for the HEMi solution is that full system integration is vital to the overall fault resiliency of the application. A multitude of cables and connectors works against the desire for fault tolerance.

**Security and Safety**

Because the installation environments are not under the tight control of MSO management, there must be a way to secure the HEMi such that untrained, clumsy or even malicious action is not given the opportunity to modify or disrupt the community services. The EGT HEMi™ comes equipped with lockable front doors, password protection for the user interface and password protection for the front-panel control.

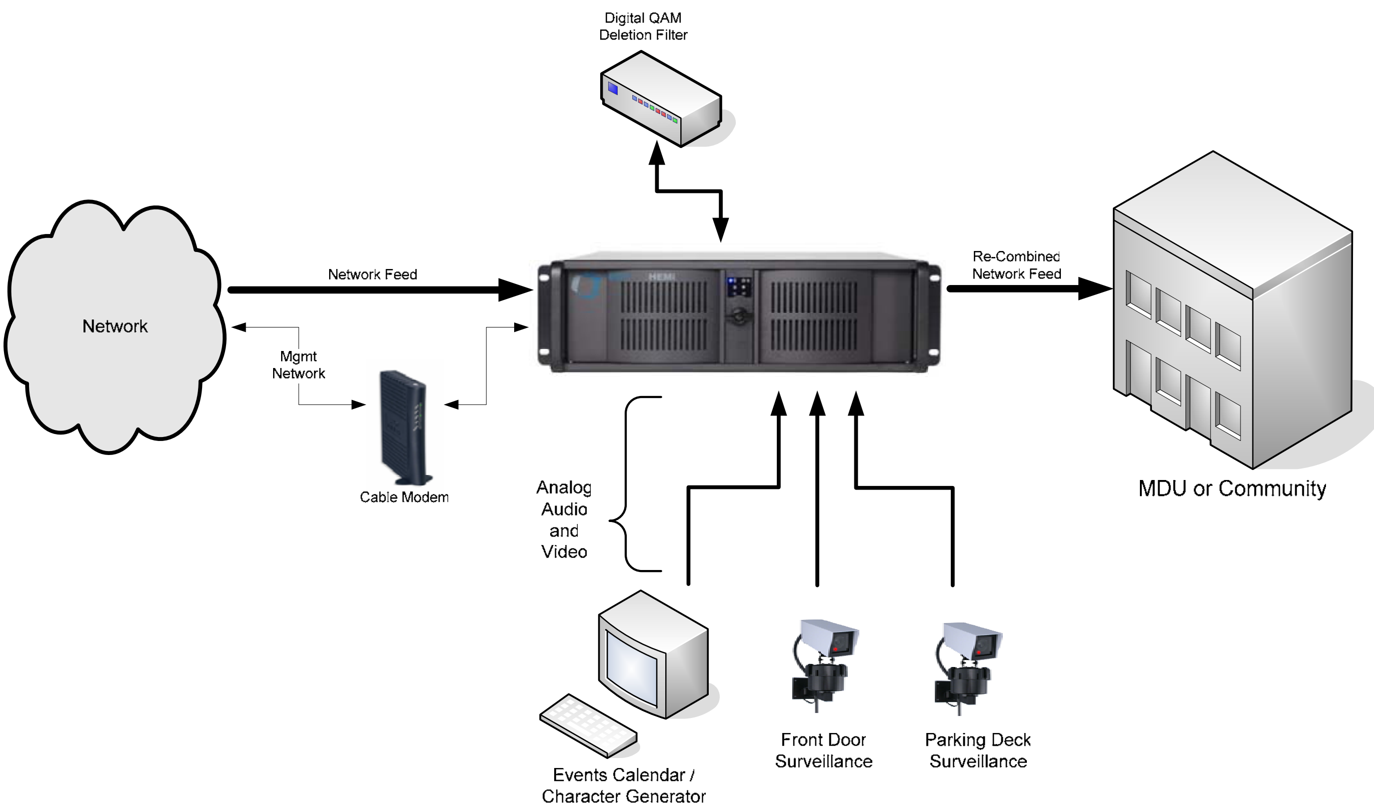
Because the installation environments may not be as clean or tidy as the average regional headend, the HEMi must be robust enough to tolerate temperature extremes and environmental hazards such as excessive dust. The EGT HEMi™ comes equipped with integrated, removable filters for these extreme environments, and replacement filter packs are also available.

As the installation environment will in many cases not be equipped with robust or redundant cooling systems, the HEMi must be capable of not only alerting an administrator to internal temperature status, but of taking protective action to ensure the safety of the location. The EGT HEMi™ indicates core processor temperature as well as ambient internal temperature and sends alarms via SNMP should temperatures reach unsafe levels. Should out-of specification temperatures persist, the EGT HEMi™ will initiate an RF Bypass switch to pass-through the network services, send a final alarm trigger and shut down until temperature conditions can be investigated.

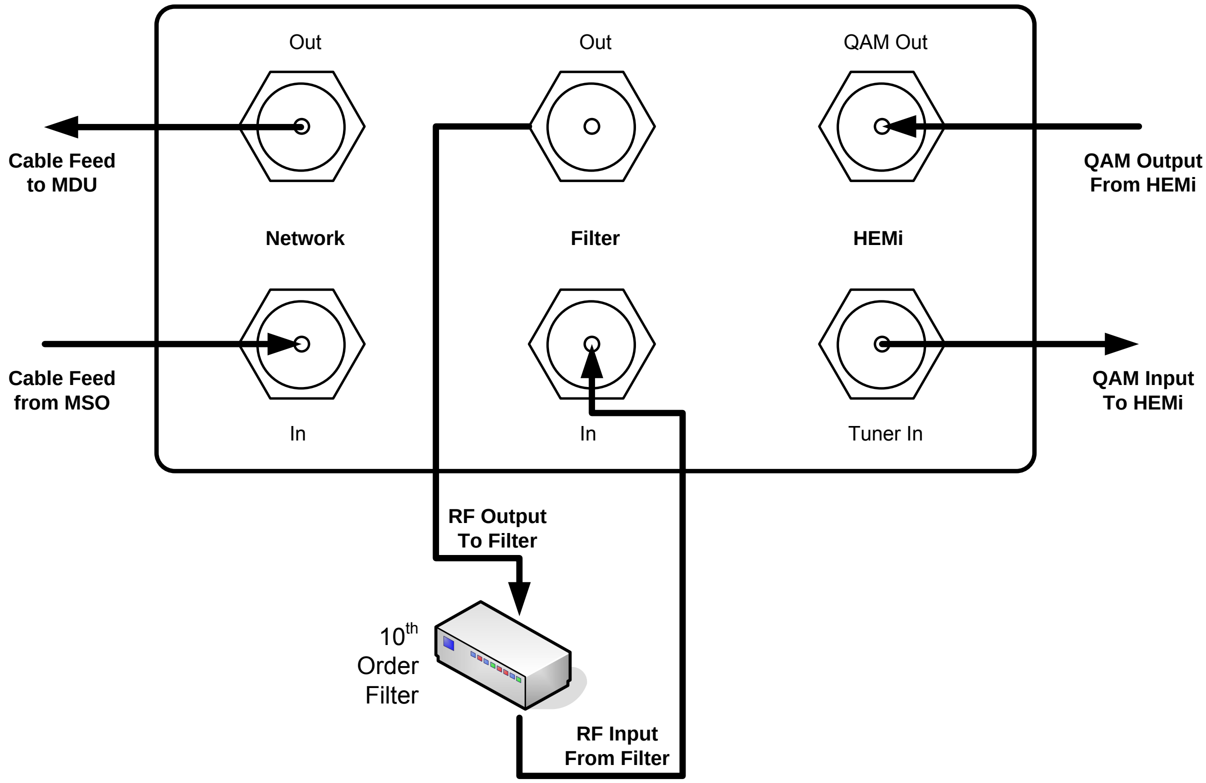
## Conclusion

By applying digital video efficiencies and quality to the new "edge" of the digital video network, video service providers have a unique opportunity to meet the demand for more localized and personalized video services, while winning a larger share of valuable MDU and Commercial service contracts. Cable has taken the lead in providing localized services and is better positioned to capitalize on this new opportunity, even as federal regulations are moving towards breaking open the MDU bulk contract market. The EGT HEMi™ provides not only the right technical solution, but the right total solution, ensuring high levels of reliability and enabling the move towards the all-digital network and to new levels of network capacity, flexibility and cost-effectiveness.

## Appendix A: Network Architecture



## Appendix B: RF Bypass Cabling



## Appendix C: Digital QAM Deletion (Notch) Filter Technical Data

An **error vector** is a vector defined as the Euclidean distance in the I-Q plane between the ideal constellation point and the point received by the receiver.

The modulation error ratio is equal to the ratio of the RMS power of the reference to the power of the error vector. It is defined in dB as:

$$\mathrm{MER(dB)} = 10\log_{10}\left(\frac{P_{\mathrm{signal}}}{P_{\mathrm{error}}}\right)$$

where $P_{error}$ is the root mean square power of the error vector, and $P_{signal}$ is the root mean square power of ideal transmitted signal.

MER is defined as a percentage in a compatible way:

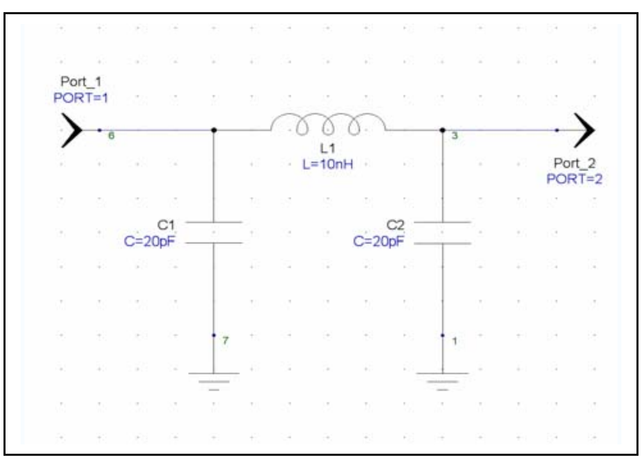
$$\mathrm{MER}(\%) = \sqrt{\frac{P_{\mathrm{error}}}{P_{\mathrm{signal}}}} * 100\%$$

with the same definitions.

MER is closely related to EVM, error vector magnitude, but MER is calculated from the average power of the signal. MER is also closely related to signal-to-noise ratio. MER includes all imperfections including deterministic amplitude imbalance, quadrature error and distortion, while noise is random by nature.

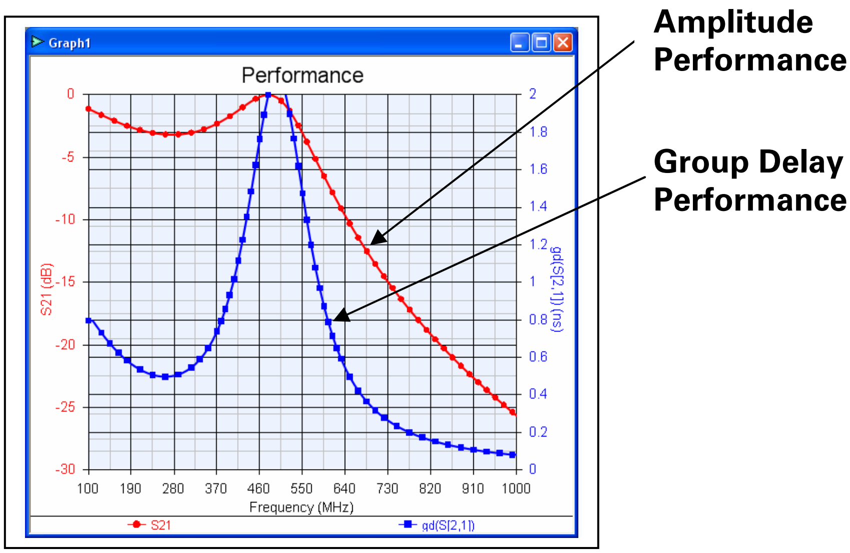
Filters are made from capacitors and inductors (or their mechanical equivalents such as a cavity or transmission line). Capacitors and inductors have a property called impedance that depends upon the frequency at which it is measured. Given this fact, the phase shift to the signal of interest depends upon the frequency of interest. Capacitors have less impedance as the frequency is raised higher while inductors have more impedance.

At a particular frequency called the resonant frequency the capacitive impedance will cancel the inductive impedance. Below the resonant frequency the impedance will be capacitive and above inductive. The signal will experience a phase shift as it passes through its resonant frequency. It is this phase shift that causes the group delay.




Simple Schematic of a low pass filter using 2 inductors and a capacitor.

Performance of circuit shown above:




The performance of this simple 3rd order low-pass filter shows the inherent group delay associated with the use of inductors and capacitors. Also, it can be seen that a 3rd order filter does not roll off fast enough with frequency to reject the next 6 MHz channel. It is for this reason that a 10th order filter is required.

$\tau_g$ and $\tau_\phi$ are the **group delay** and **phase delay** respectively and both are potentially functions of ω. In a phase linear system (with non-inverting gain), both $\tau_g$ and $\tau_\phi$ are equal to the same constant delay of the system and the phase shift of the system increases linearly with frequency ω.
It can be shown that for an LTI system with transfer function *H*(*s*) that if such is driven by a complex sinusoid of unit amplitude,

$$x(t) = e^{i\omega t}$$

the output is

$$y(t) = |H(i\omega)| e^{i(\omega t + \phi(\omega))}$$

where the phase shift $\phi$ is

$$\phi(\omega) \stackrel{\text{def}}{=} \arg\{H(i\omega)\}.$$

Additionally, it can be shown that the group delay, $\tau_g$, and phase delay, $\tau_\phi$, are related to the phase shift $\phi$ as

$$\tau_g = -\frac{d\phi(\omega)}{d\omega}$$

$$\tau_\phi = -\frac{\phi(\omega)}{\omega}.$$

In physics, and in particular in optics, the study of waves, the term **group delay** has the following meanings:

1. The rate of change of the total phase shift with respect to angular frequency,

$$\tau_g = -\frac{d\phi}{d\omega}$$

   through a device or transmission medium, where $\phi$ is the total phase shift in radians, and $\omega$ is the angular frequency in radians per unit time, equal to $2\pi f$, where $f$ is the frequency (hertz if group delay is measured in seconds).

2. In an optical fiber, the transit time required for optical power, traveling at a given mode's group velocity, to travel a given distance.