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ENERGY MANAGEMENT

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**From the Editors**

Within this first 2019 Journal of Energy Management we will evaluate some strategies and technologies including Grid over the Internet of Things (GoIoT) where Robert Cruickshank demonstrates two distinct use cases for cable's participation in GoIoT. First, how GoIoT increases energy efficiency within cable operations. Second, how cable's participation in GoIoT unveils compelling new business opportunities.

Next, Lamar West presents research regarding the reduction of RF signal loading of a cable network in times of low traffic. This might enable the reduction of 50 Hz / 60 Hz input power usage at those times by the active devices in the network. A number of novel approaches have been proposed for power reduction in the next generation of access network electronics, but one popular suggestion is to reduce the downstream occupied RF bandwidth on the network during times of low traffic.

Another Outside Plant (OSP) energy cost reduction strategy presented by Richard Kirsche includes utilizing assets such as battery storage that traditionally were only used for back-up power purposes when the utility grid failed. This approach relies on load shedding by employing a percentage of the charge in the batteries to assist the power grid during times when that grid is under stress from peak loads, energy costs highest, or from the sudden loss of generating capacity.

And finally, Dave Smargon describes how to "right-size" HVAC units by utilizing standards and various ratios to evaluate both heat load and comfort.

SCTE•ISBE Journal of Energy Management Senior Editors,

David Mendo
Senior Director, NDCIS East and Central
Comcast

Derek DiGiacomo
Senior Director, Energy Management Programs and Business Continuity
SCTE•ISBE

 

# Grid Over The Internet Of Things™

## Jointly Optimizing Electric Power Generation and Use

A Technical Paper prepared for SCTE/ISBE by

Robert F Cruickshank III, PhD Candidate, University of Colorado Boulder, SCTE/ISBE Member,
Visiting Researcher, National Renewable Energy Laboratory
1880 Denver West Drive, Apt 1834
Golden, CO 80401
rfciii@cruickshank.org
+1-703-568-8379

Laurie Asperas Valayer, Strategy Consultant, SCTE/ISBE Member
MBA Energy Management, **ΔμΔ**
1880 Denver West Drive, Apt 1834
Golden, Colorado 80401
asperasvalayer@gmail.com
+1-631-335-9197

 

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## 1. Abstract

This paper introduces Grid over the Internet of Things (GoIoT$^{TM}$) as an innovative way for the cable broadband industry to better manage energy, such as electricity and natural gas. In this paper we demonstrate two distinct use cases for cable's participation in GoIoT. First, how GoIoT increases energy efficiency within cable operations. Second, how cable's participation in GoIoT unveils compelling new business opportunities. These opportunities lead to partnering with energy utilities and distributed energy entities, thereby providing solutions to growing concerns and issues for all stakeholders.

Demonstrated is how GoIoT optimizes energy supply and demand by favoring the least-cost forms of generation. Using broadband connectivity to influence energy use in cable operations, commercial and residential markets serves to favor low-cost conventional generation and renewable energy sources (RES). Methodologies are presented that prove GoIoT's value in increasing operational efficiency of the energy supply chain allowing for higher RES penetration and a reduction in energy costs.

## 2. Introduction

The evolution of global energy landscapes and the aging of power systems continues to result in the need for countless upgrades in energy markets and infrastructure. Indeed, trends for increasing low-cost RES penetration in cable operations, commercial, and residential buildings are on the rise causing economic imbalances between utilities and consumers. These trends are influencing energy generation to become decentralized, creating the need for time- and location-based retail pricing. Concerns over how to modernize the metering and accounting of electricity and gas are mounting.

In GoIoT, forecast pricing introduces a customer-friendly distributed control signal called adaptive demand-side management (A-DSM), which allows cable operators and all users to manage the timing and cost of their consumption of energy. Further, A-DSM provides opportunities for the cable industry to optimize its operational energy efficiency and leverage customer connectivity to capitalize on the modernization of the energy supply chain.

## 3. What is Grid over IoT?

GoIoT is a telecommunications solution that provides critical support for the development, modernization, efficiency, and security of the power grid. GoIoT allows the best of energy and broadband networks to be leveraged for a greater and improved result. Using the superior speed and connectivity of the broadband network enables the existing electrical grid to deliver and manage power in a more effective and efficient way than has ever been possible. Further, GoIoT provides unique business opportunities for cable operators to leverage existing assets to effectively optimize the efficiency of the grid while simultaneously addressing environmental concerns. Potential customers of the GoIoT system are all stakeholders in the energy value chain. These include energy utilities, companies in the energy ecosystem who service or interconnect with utilities, investors in and developers of renewable energy projects, and industrial, commercial & residential consumers, all of whom rely on electric power. The end-to-end scope of GoIoT is shown in Figure 1.

 

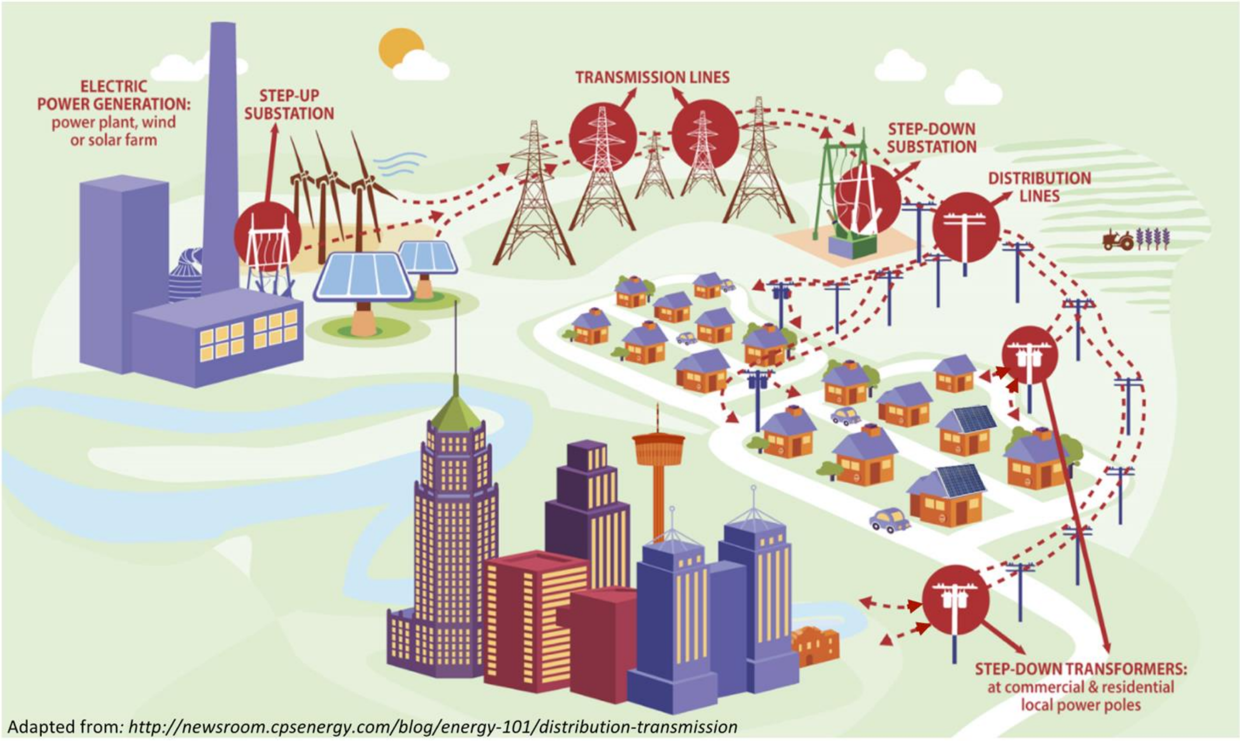


**Figure 1 - Grid over IoT end-to-end system**

In short, GoIoT is an architected solution that jointly optimizes electricity generation and use. Specifically, GoIoT is software that 1) analyzes weather and forecasts energy needs over large geographic areas, and 2) specifies future energy prices that favor the lowest-cost generators like hydro, wind, and solar — and delay the startup of power plants until they can run most efficiently. The Internet carries forecast weather and future costs directly to smart appliances, connected thermostats (CT) electric vehicle chargers — so each can always plan to use the cheapest energy.

## 3.1. How GoIoT Raises Efficiency

GoIoT raises efficiency in generation by continuously orchestrating energy supply and demand throughout the grid. GoIoT inverts the traditional energy supply and demand relationship, with supply no longer relegated to following demand, rather, demand following the lowest cost forms of supply. To do so, GoIoT accommodates the variable and uncertain nature of RES, enabling more low-cost wind and solar power on the grid, thus reducing electricity production costs. GoIoT also improves the efficiency of conventional thermal generation including nuclear, natural gas, coal, oil, and biomass-fired power plants. GoIoT accomplishes this by minimizing the part-load operation of thermal generators as shown in Figure 2, which depicts the heat rate, a measure of electrical generation efficiency, as a function of thermal generator output power.

 

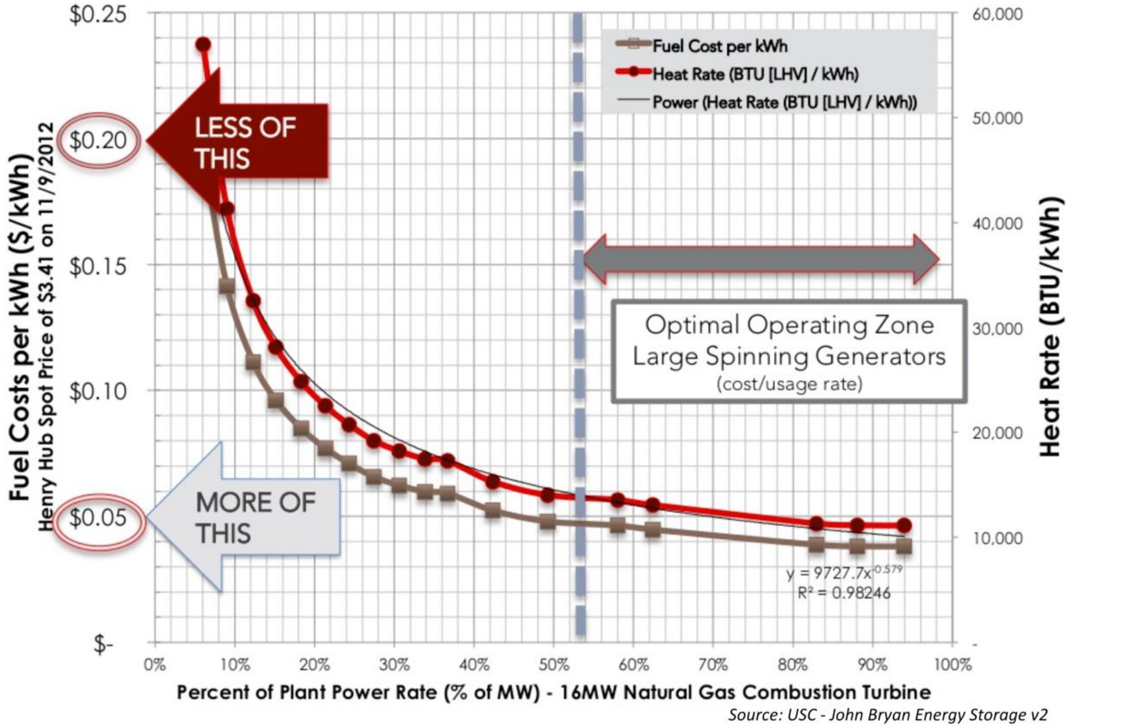


**Figure 2 - Conventional Thermal Generation Heat Rate Efficiency**

Note the high generation cost per kWh of electricity at upper left when the generator is running at a low percentage of output power, and the dramatically lower generation cost as the generator approaches 100 percent of output power. Not shown on this graph, but of equal or greater importance are the similar declines in the associated thermal and greenhouse emissions per unit of generated electricity.

### 3.2. Criticality of Grid over IoT

GoIoT's application of A-DSM to continuously modulate demand throughout the day will be increasingly critical in efficiently managing the smart grid to reliably deliver clean, low-cost energy. This increasing criticality is due to environmental concerns as well as the steady decline in the cost of new RES generation, resulting in an exponential rise in RES projects. Simply put, in current and upcoming world markets, it is cheaper to build new RES than to operate existing thermal generators. These economics are a major driving force for the successful implementation of GoIoT. Indeed, of the cities receiving at least 70 percent of their power from RES, 57 percent are in Latin America, 20 percent are in Europe, 9 percent are in Africa and 9 percent are in North America [Inside Climate News 2018]. Make no mistake, the timing of business opportunities for cable operators to assist utilities and municipalities is now. Domestic opportunities include the city of Los Angeles achieving a 100 percent renewable energy grid by 2030 and the States of Hawaii and California achieving 100 percent renewable energy generation by 2045. Many other cities and states have new and pending renewable energy portfolio standards that are opportunities for GoIoT. In addition, there are countless more projects in adding load flexibility that need cable's help worldwide.

 

### 3.3. Adding Flexibility in the Grid and Increasing Renewables Penetration

Using the generation and distribution of electricity as an example, the aforementioned increased penetration of RES generation presents significant operational challenges as the grid has traditionally been controlled using dispatchable generation that provides electricity to meet demand along with standby (spinning and non-spinning) reserves to meet contingencies. New controls are urgently needed as the generation mix evolves and large-scale, high-inertia thermal generators are replaced by low-inertia RES generation, particularly end-of-line and last-mile distributed generation—for example, rooftop solar photovoltaic panels. This creates opportunities for GoIoT cable operators to assist energy utilities in deploying advanced supervisory grid control algorithms, such as voltage optimization, volt-var optimization (VVO), conservation voltage reduction (CVR), distribution system optimal power flow, and the provision of bulk power system ancillary services from distributed energy resources (DERs).

## 4. Methodology

GoIoT lowers the cost of electric service and achieves a host of electric grid benefits by applying production cost modeling and model predictive control (MPC). The production cost modeling and MPC joint optimization technology is based on recent advances in supercomputing, weather and electric load forecasting, and bulk power system planning and operations software. In GoIoT, a multistage algorithm follows a cascaded sequence of mathematical models and forecasts as follows:

1. First, a physics-based model of residential buildings and appliances uses forecast weather in order to forecast electric loads on the grid.
2. Next, a production cost model of the bulk power system uses the forecast electric loads in order to forecast the marginal price of electricity in 5-minute intervals. Marginal prices, from a consumer perspective, are those prices consumers pay for their last units of energy used.
3. Then, the day-ahead forecast of 5-minute marginal pricing is continuously broadcast to energy end uses via broadband DOCSIS cable modems and in-home networks.
4. Finally, the MPC application in CTs, home energy management systems, smart appliances, and battery chargers determines the least cost operating strategy throughout the day by subtly adjusting set points for energy uses such as air conditioning, heating domestic hot water, and charging battery walls and electric vehicles. Setpoint adjustment enables electric load shaping opportunities, for example, where additional cooling energy is stored in a building's thermal mass when lowered and is released when raised.

During preliminary research, the production cost reductions attributable to the use of A-DSM were estimated by coupling an electricity production cost model with the pricing-based MPC of the ON and OFF setpoints of air conditioners. For a typical hot summer day in Houston Texas, electric load was simulated on a prototypical electrical distribution feeder [Chassin et al. 2008, Chassin et al. 2014] using the method of Corbin and Henze [Corbin & Henze 2016]. The electricity production costs to meet the load were estimated for the serving area of the residential distribution feeder.

In software-based simulation, an energy utility created load flexibility by broadcasting forecast pricing of electricity that varied over time to favor the lower cost generators. Through reception and processing of the variable price of electricity along with forecast weather, air conditioning thermostats automatically optimized setpoint adjustments to minimize customers' cost of electricity while maintaining customer comfort.

 

## 5. Results

Figure 3 shows the preliminary simulation results for a single electrical distribution feeder with 2,146 homes on a typical summer day in Houston, Texas. Simulation results are based on 5-minute forecast pricing using a reduced order model of 3 generators, each providing 3 MW of capacity, with production costs of $100, $200, and $300 per MWh respectively. As expected, the A-DSM system maximizes the use of the lowest cost generators, providing an overall reduction in daily generation costs. Without A-DSM, the simulated production cost is $16,222 per day. The simulated production cost with A-DSM is $15,904 per day, representing a 2 percent reduction. Scaling across all of Houston's electrical distribution feeders, savings approach $500,000 on a typical summer day, representing an annual savings opportunity of $2 billion in the U.S and a $10 billion worldwide.

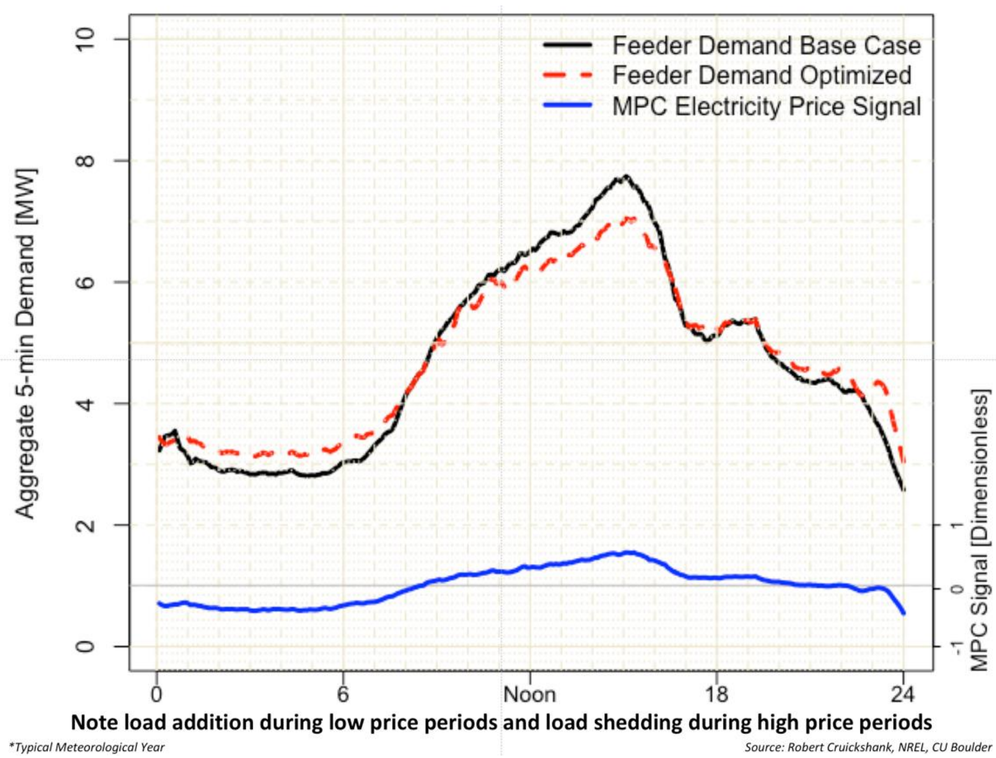


**Figure 3 - Simulation results of A-DSM on 20 July TMY* for 2,146 houses on Houston, Texas, Distribution Feeder 22**

While preliminary research has produced early proof of concept results, continued research is being done to further prove the effectiveness and value of GoIoT in the energy value chain across large grids such as the Electric Reliability Council of Texas.

Using algorithms that programmatically value solar, other renewable energy sources and conventional generation at every simulation interval, GoIoT reduces the production cost of electricity which is on the order of $100 billion/year in the U.S. and $500 billion/year worldwide [Enerdata 2018].

# 6. Cable Operations Efficiency Opportunities

The size of efficiency opportunities in using GoIoT to reduce electricity and gas costs is related to the proportional mix of conventional and RES generation technologies in use. In the near- and long-term, as the generation mix evolves, optimizing output from conventional thermal power plants along with new RES additions will continue to provide financial returns for efficient cable operations. Figure 4 depicts the Society for Cable and Telecom Engineers (SCTE) Access Network Efficiency (ANE) group's Road Map of Technologies and Energy Conservation Measures (ECM's) [Howard et al., 2018]. Energy efficiency within cable operations can be increased by adding GoIoT alongside the APSIS™ function [APSIS 2018]. In doing so, the GoIoT pricing signal becomes available to various uses within cable operations, most notably in air conditioning of critical infrastructure such as data centers and hub sites.

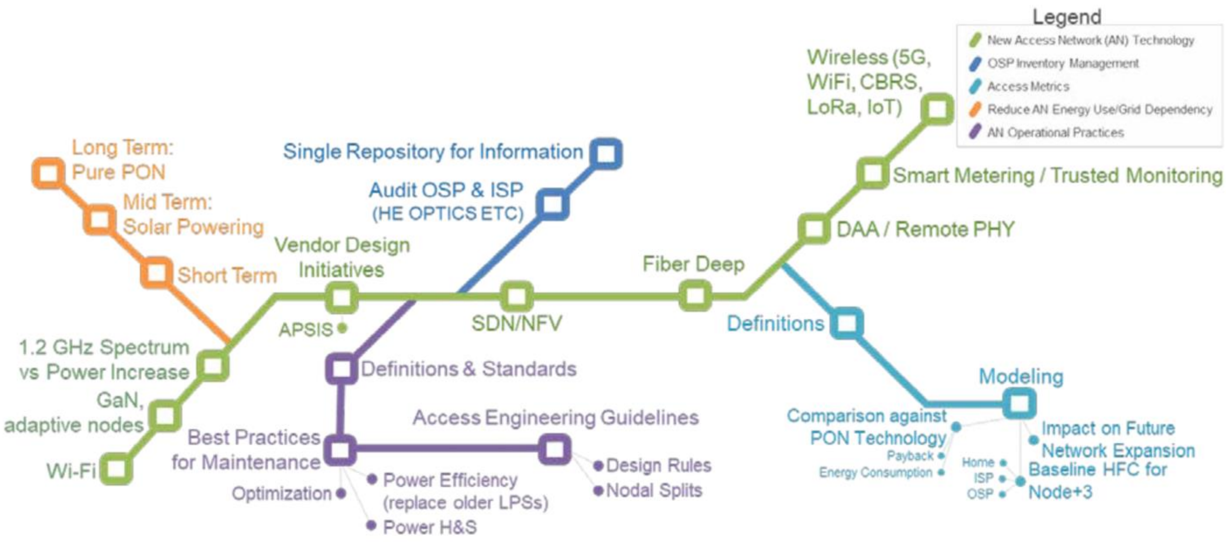


**Figure 4 - Cable access network efficiency roadmap of technologies and energy conservation measures**

## 6.1. A Growing Market

As noted, concerns over energy consumption have spurred cable operators and many other industries to seek sustainable methods in energy management and efficiency. There is evidence that all stakeholders in the energy value chain are developing or piloting some of these methods, including relaying pricing signals using connected home technologies. These technologies are on the brink of leveraging GoIoT. Moreover, a recent report from the U.S. Department of Energy Office of Scientific and Technical Information (OSTI), shows multi-industrial acceptance of energy management through GoIoT. This includes utilities, Internet providers, and connected home product manufacturers. According to OSTI, Wi-Fi and modern-connected products such as connected thermostats (CT's), are "forecasted to grow to 24.6 million by 2019. By this same year, the global CT market is forecasted to exceed $1 billion." [OSTI 2017]

# 7. Conclusions

In aggregate, across all homes on an electrical distribution feeder, broadband-enabled setpoint adjustments provided megawatts of A-DSM electric load shaping that improved both the customer experience and the efficiency of the grid. Key performance indicators were developed, and the impacts of A-DSM were evaluated across generation, transmission, and distribution. Preliminary results indicated load shaping increased system efficiency and supported the case for further research and development in grid optimization using GoIoT.

With GoIoT devices, information can be gathered, shared and monetized across both the grid and cable plants. If GoIoT is embraced, the industry stands to develop the technologies and financial justification necessary to provide A-DSM orchestration systems for advanced grid operations through existing broadband networks. This disruptive innovation will accelerate smart grid technology adoption and ensure Cable's ability to increase energy efficiency within its own operations. Additionally, cable broadband stands to become a valuable and proactive contributor in energy management businesses.

# 8. Ongoing Research

The benefits of GoIoT's jointly optimizing energy use with conventional and renewable generation are being evaluated at a scale that matters. An ongoing case study reveals the system-wide financial savings in the highly-cable-populated wholesale electric markets managed by the Electric Reliability Council of Texas (ERCOT) followed by the California Independent System Operator (CAISO), the Midcontinent Independent System Operator (MISO), and the PJM Regional Transmission Operator, which collectively supply half of all U.S. electricity.

# 9. Abbreviations and Definitions

## 9.1. Abbreviations

| | |
|---|---|
| A-DSM | adaptive demand side management |
| DOCSIS | data over cable service interface specifications |
| GoIoT | grid over the internet of things |
| ISBE | International Society of Broadband Experts |
| MPC | model predictive control |
| RES | renewable energy sources, e.g., wind, solar and hydropower |
| SCTE | Society of Cable Telecommunications Engineers |

## 9.2. Definitions

| | |
|---|---|
| Ancillary Services | The United States Federal Energy Regulatory Commission (FERC) defines ancillary services as: "those services necessary to support the transmission of electric power from seller to purchaser given the obligations of control areas and transmitting utilities within those control areas to maintain reliable operations of the interconnected transmission system." Ancillary services are the specialty services and functions provided by the electric grid that facilitate and support the continuous flow of electricity so that supply will continually meet demand. The term ancillary services is used to refer to a variety of |

 

| | |
|---|---|
| | operations beyond generation and transmission that are required to maintain grid stability and security. These services generally include, frequency control, spinning reserves and operating reserves. Traditionally ancillary services have been provided by generators, however, the integration of intermittent generation and the development of smart grid technologies have prompted a shift in the equipment that can be used to provide ancillary services [Wikipedia] |
| APSIS - Adaptive Power Systems Interface Specification (APSIS™) | ANSI/SCTE 216 2015 enables cable operators to measure and control energy consumption associated with delivery of services. SCTE 216 defines software interfaces that allow energy measurement and optimization applications to command and control devices within a service delivery pipeline. |
| conservation voltage reduction (CVR) | Conservation Voltage Reduction is a technology for reducing energy and peak demand. It is a measure implemented upstream of end service points in the distribution system, so the efficiency benefits are realized by consumers and the distributor. This is done without any intervention on the part of consumers. CVR is implemented by controlling the voltage on a distribution circuit to the lower end of a tolerance band, either defined by ANSI C84.1 (114–126 volts) or another target range. Conservation then occurs on the circuit when certain end-use loads draw less power when voltage is lowered. |
| distribution system optimal power flow (OPF) | Optimal Power Flow represents the problem of determining the best operating levels for electric power plants in order to meet demands given throughout a network, usually with the objective of minimizing operating cost. |
| SCTE Energy Management Operational Practices for Cable Facilities | SCTE 184 provides guidelines for design and management of mission-critical hub site facilities supporting the cable industry. SCTE 184 focuses on information, methods, metrics, and processes that balance operational energy efficiency and management with essential business availability requirements and infrastructure investment. This guideline leverages existing industry best practices for smart energy use in vital cable edge facilities and applies these to the specific characteristics and requirements of cable systems hub sites. |
| voltage optimization | Voltage optimization is an electrical energy saving technique which is mainly installed in series with the mains electricity supply to provide a reduced supply voltage for the site's equipment. |
| volt-var optimization (VVO) | Volt/VAR optimization (VVO) is a process of optimally managing voltage levels and reactive power to achieve more efficient gird operation by reducing system losses, peak demand or energy consumption or a combination of the three. |

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# A Proposed Optimized Frequency Loading to Obtain Maximal Energy Savings in Launch Amplifier Low-Power Mode

Letter to the Editor prepared for SCTE•ISBE by

Lamar West, Ph.D., Principal, LEW Consulting, LLC, SCTE•ISBE Member
7848 Holly Springs Road
Maysville, GA 30558
Lamar@lamarwest.com
(770) 536-2853

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## 1. Introduction

Considerations are being given to the reduction of RF signal loading of a cable network in times of low traffic. This might enable the reduction of 50 Hz / 60 Hz input power usage at those times by the active devices in the network. Specifically, a reduction of the input bias current or voltage of the downstream output amplifier stages may be possible at times of low RF signal loading while maintaining acceptable levels of intermodulation distortion performance. A cursory examination of the frequency distribution of the intermodulation distortion products at several different frequency allocations during times of low traffic indicates that there may be an optimum frequency loading. A judicious choice of frequencies will eliminate the effects of second order intermodulation distortion thereby permitting a maximum reduction of bias current or voltage in the downstream output stages. It could also facilitate and simplify digital predistortion if this predistortion is used in the low traffic case. Additional study is advised.

## 2. Discussion

A number of novel approaches have been proposed for power reduction in the next generation of access network electronics. One popular suggestion is to reduce the downstream occupied RF bandwidth on the network during times of low traffic. For example, a reduction of the downstream RF occupied bandwidth might permit the reduction of DC bias current or DC operating voltage in the output amplifier stages of a node launch amplifier while maintaining adequate amplifier carrier-to-distortion performance. Most work on this subject has been based solely on the reduction of composite RF power.

In a system with downstream RF loading from 54 to 1200 MHz, one typical suggestion is to reduce the downstream RF loading to 54 to 600 MHz at times of low traffic. However, it may be worthwhile to look at alternative downstream loading frequency plans during times of low traffic. The correct choice of downstream frequency loading might further reduce the distortion performance requirements of an output amplifier when operating with reduced current or voltage.

Today most access networks are loaded exclusively with RF carriers modulated with digital data, typically using single carrier QAM or OFDM. Consequently, the distortion products no longer fall at discrete frequencies as in the case of the previous networks that were loaded with multiple analog video carriers. Previously we could measure the amplitude of distortion based on the distortion order, such as composite second order (CSO) and composite third order or as it was more commonly known as composite triple beat (CTB). We generally characterized CSO and CTB as a function of frequency across the entire occupied RF spectrum.

Today, in networks loaded with RF carriers modulated with digital data, the distortion products tend to spread out rather than falling at discrete frequencies. This distortion is usually referred to as composite intermodulation noise or CIN. However, CIN is still composed of the various distortion orders, dominated by second order and third order. It may also be characterized as a function of frequency across the entire occupied RF spectrum. Today, newer amplifier technologies are typically characterized by the composite power (sum of all RF carriers) that load the amplifier at a particular RF occupied bandwidth and RF tilt across that band.

For the purposes of this discussion, let’s take a look at the distribution of conventional second and third order distortion products as produced by CW carriers located at the picture carrier frequencies of conventional analog video carriers. As mentioned before, it is recognized that when the network is loaded with RF carriers modulated with digital data (such as single carrier QAM or OFDM) the distortion will be spread around the locations of the narrowband distortion products created by loading with CW carriers.

Consider a network loaded in the downstream from 54 MHz to 1200 MHz. In order to examine the distribution of the distortion products we will consider loading with CW carriers at the picture carrier frequencies of analog video carriers following the CEA-542-C channel assignments. A very simple algorithm may be written to count the number of second order ($2F_1$ or $F_1 \pm F_2$) and third order ($3F_1$, $F_1 \pm 2F_2$ or $F_1 \pm F_2 \pm F_3$) distortion products falling on any given channel. The frequency distribution of these distortion products, or beats as they are typically called, can be graphed. The graph will show the frequency distribution for both beats created by analog video channels or RF carriers modulated with digital data, as long as it is kept in mind that the distortion products from the carriers modulated with digital data will be spread in frequency with respect to the analog video case. What is also not clear at this time is how broadly the distortion products will be spread in frequency, particularly when dealing with OFDM signals.

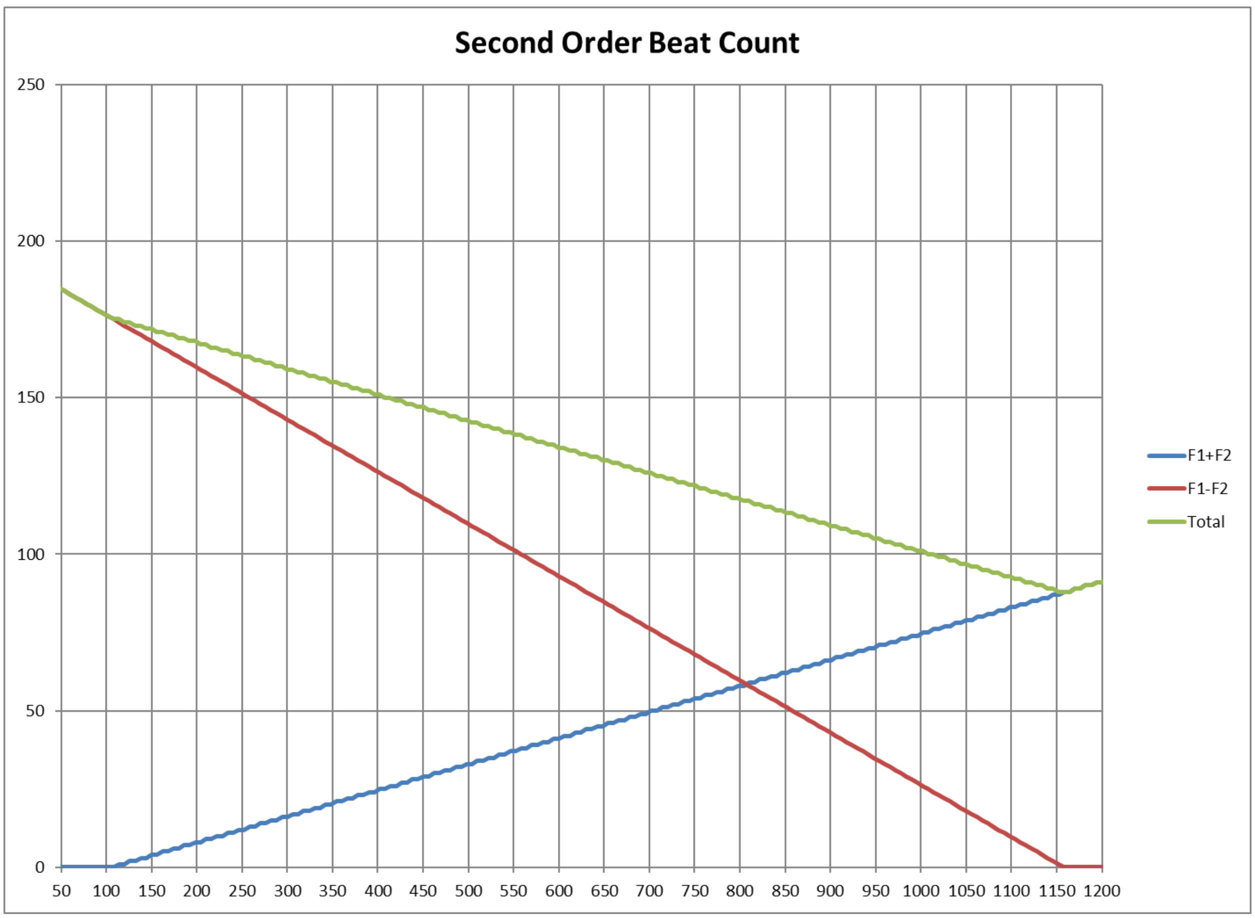



**Figure 1 - Second Order Beat Count Loaded 54 to 1200 MHz**

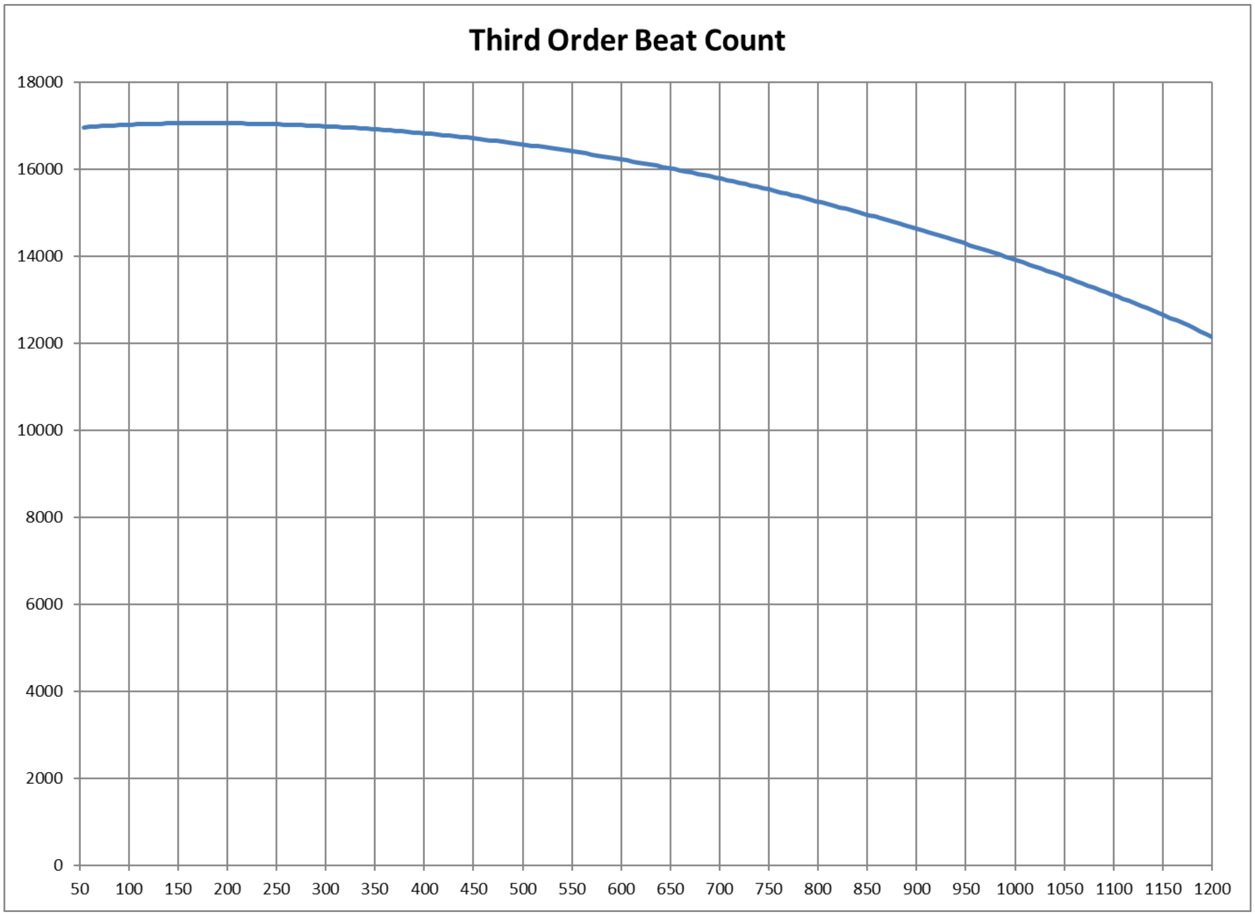



**Figure 2 - Third Order Beat Count Loaded 54 to 1200 MHz**

Note that the beat count must be weighted by the coefficients of the transfer characteristic of a particular device (amplifier) in order to estimate the actual distortion levels, and those coefficients may vary as a function of frequency. It must also be weighted by the tilt of the RF signals across the occupied band. However, beat count is a useful tool to see a rough frequency distribution of the distortion. We are also assuming that the device under test is sufficiently well below hard compression that the distortion is dominated by second order and third order products and higher order products may be considered negligible.

Now consider what will happen to this beat count if the system is now loaded from 54 to 600 MHz.

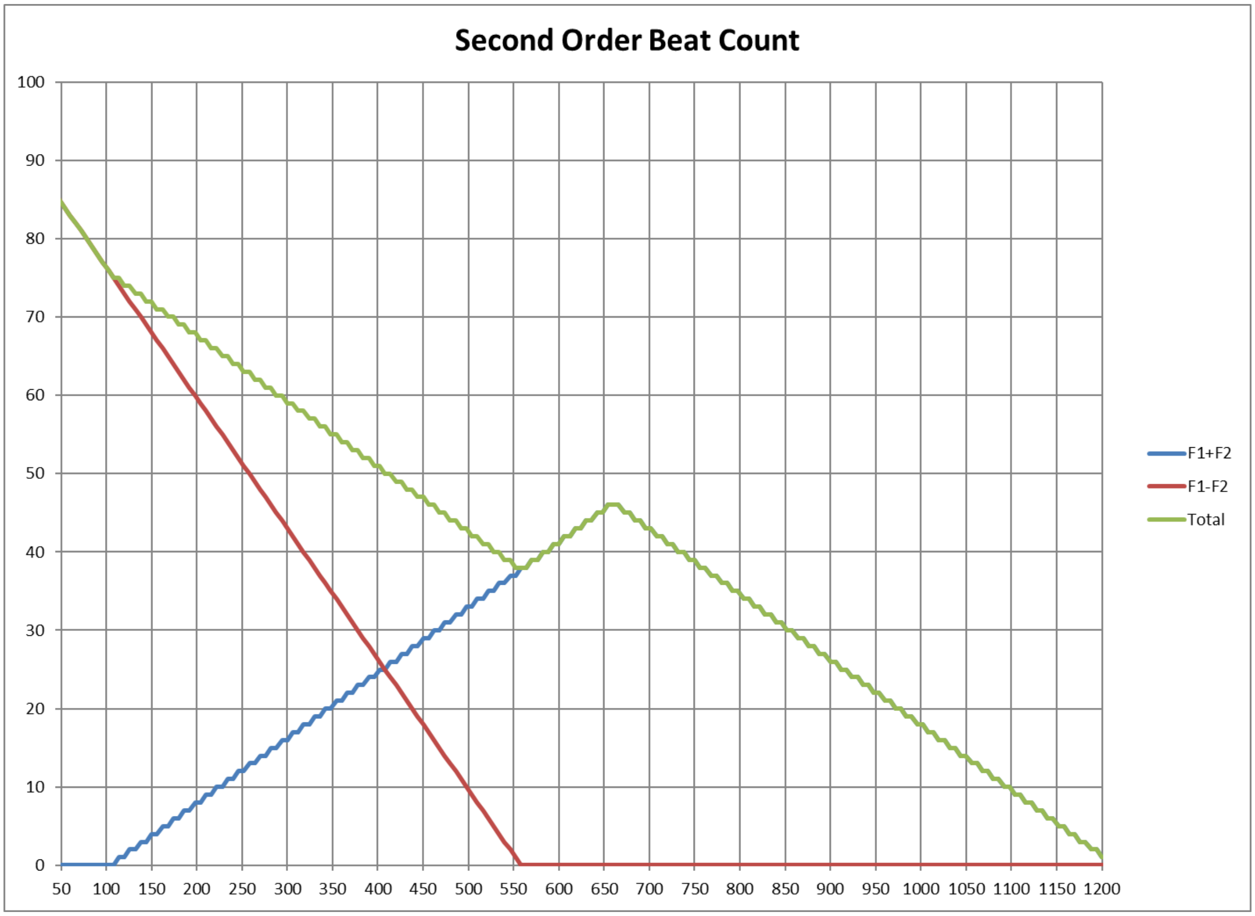



**Figure 3 - Second Order Beat Count When Loaded 54 MHz to 600 MHz**

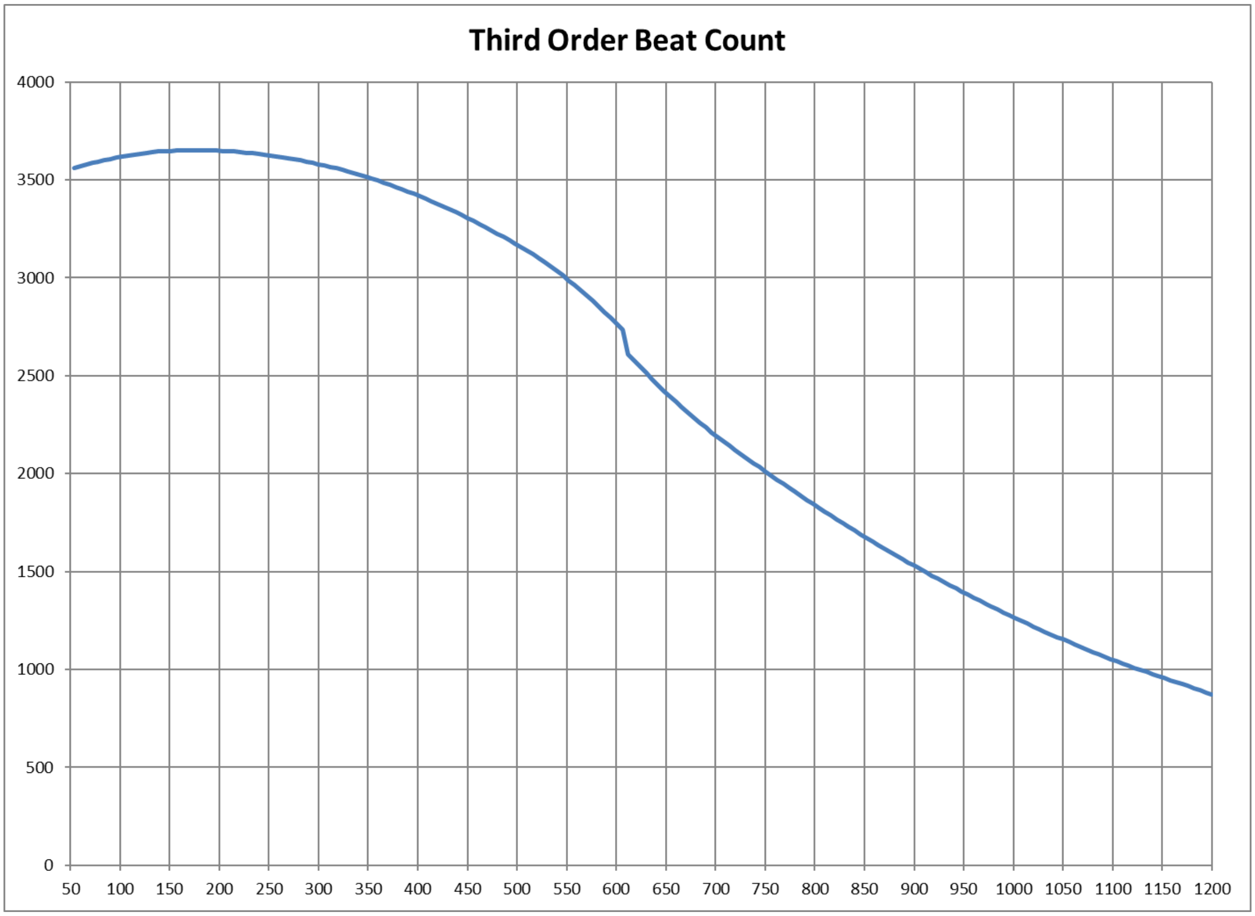



**Figure 4 - Third Order Beat Count When Loaded 54 MHz to 600 MHz**

Note that there are still a significant number of second order products that fall in the 54 MHz to 600 MHz band. This scenario represents a reduction in composite power of approximately 6.6 dB with respect to the 54 to 1200 MHz case (assuming 12 dB of up-tilt).

Now consider the case of loading from 600 to 1150 MHz. This is the same RF occupied bandwidth as the previous example.

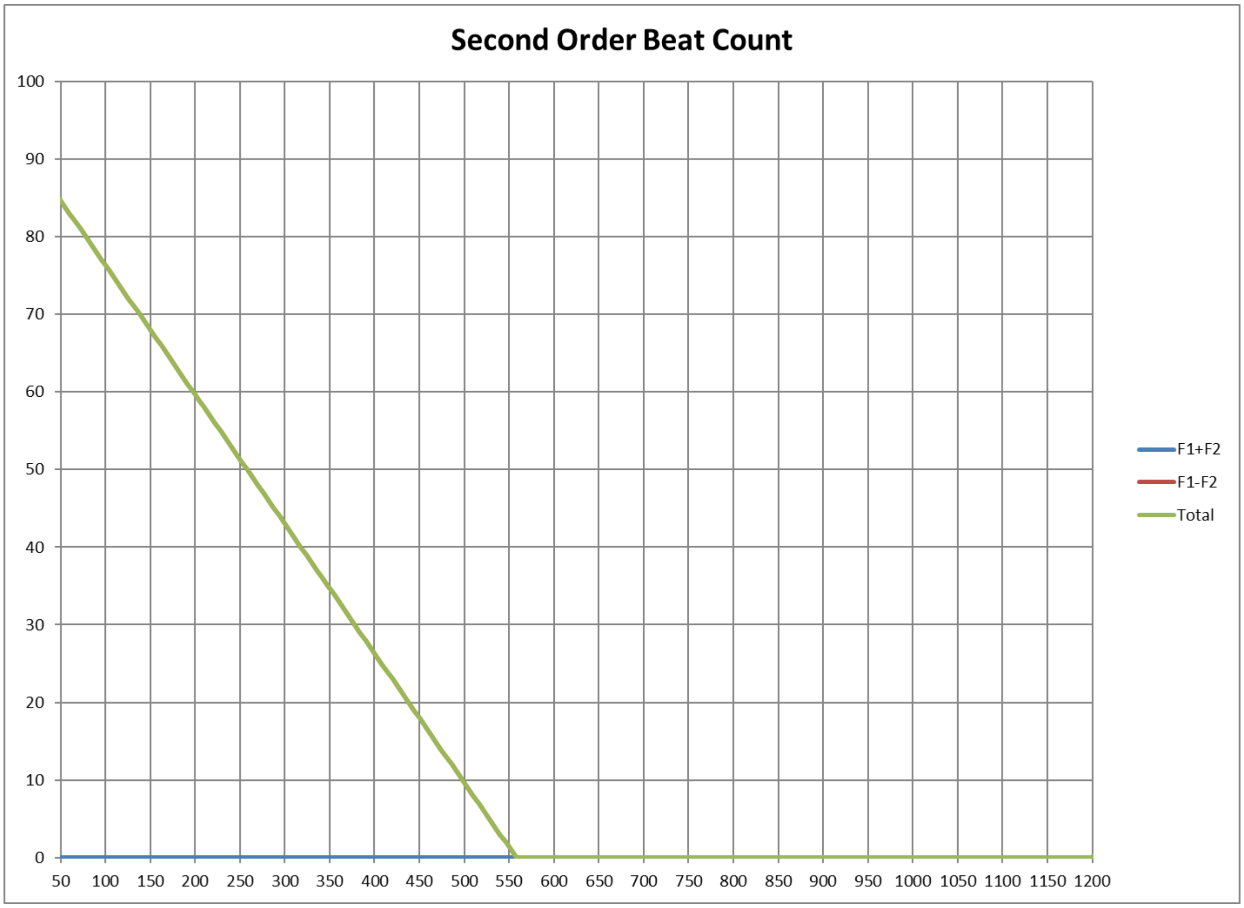



**Figure 5 - Second Order Beat Count When Loaded 600 MHz to 1150 MHz**

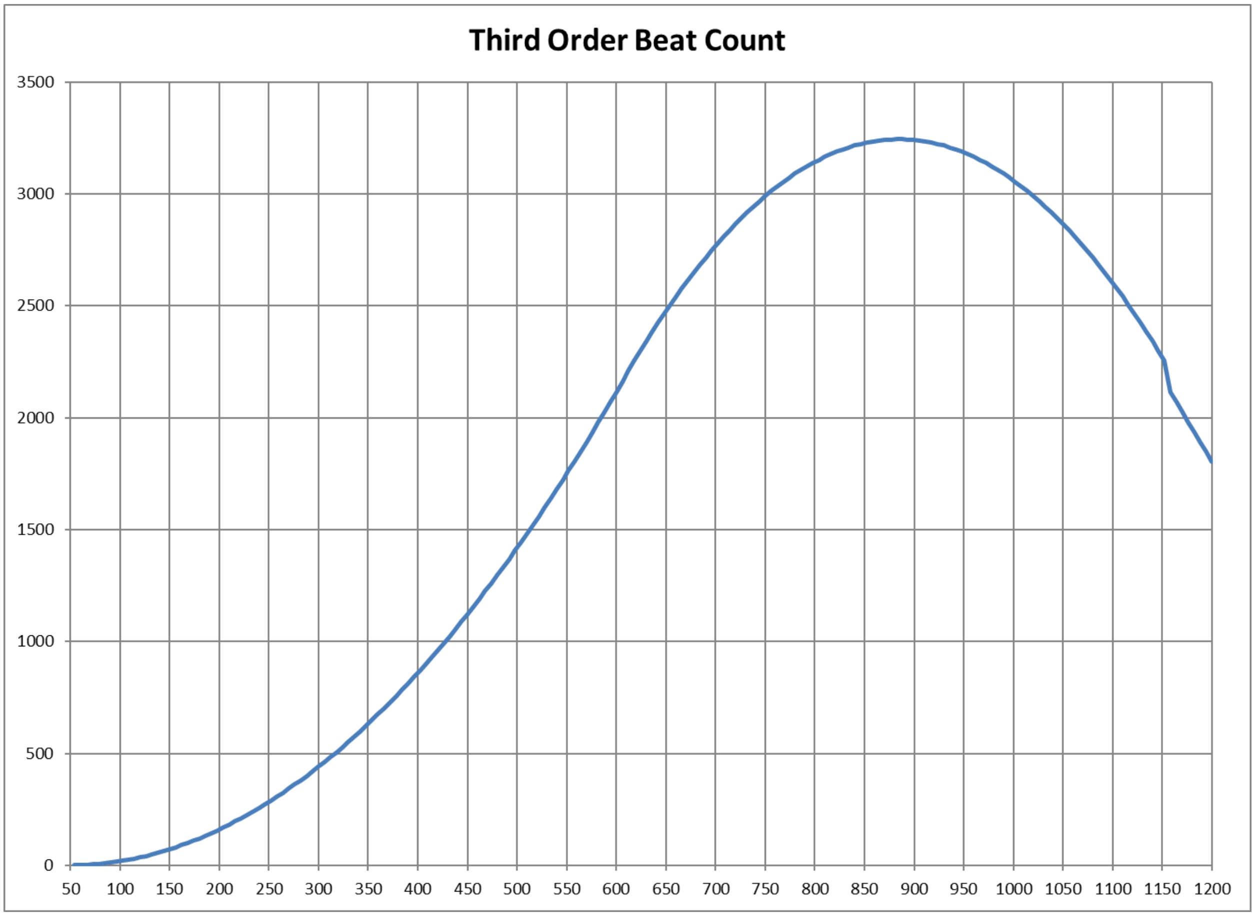



**Figure 6 - Third Order Beat Count When Loaded 600 MHz to 1150 MHz**

Note that since the system is loaded with RF over only one octave, no second order products fall in the 600 to 1150 MHz band. Even if we weight these results for tilt and a particular transfer characteristic, we still have zero second order beats in the occupied band (600 MHz to 1150 MHz). Note also that the third order beat count is also slightly reduced in the occupied band.

This scenario represents a reduction in composite power of approximately 1.6 dB with respect to the 54 to 1200 MHz case assuming 12 dB of up-tilt, as opposed to 6.6 dB in the 54 to 600 MHz case. Therefore, it is desirable to look for a case that minimizes second order distortion while also minimizing composite RF power.

What if we assume that in the low traffic case we can operate with only 400 MHz of downstream RF occupied bandwidth (as opposed to 550 MHz) and we load from 400 to 800 MHz?

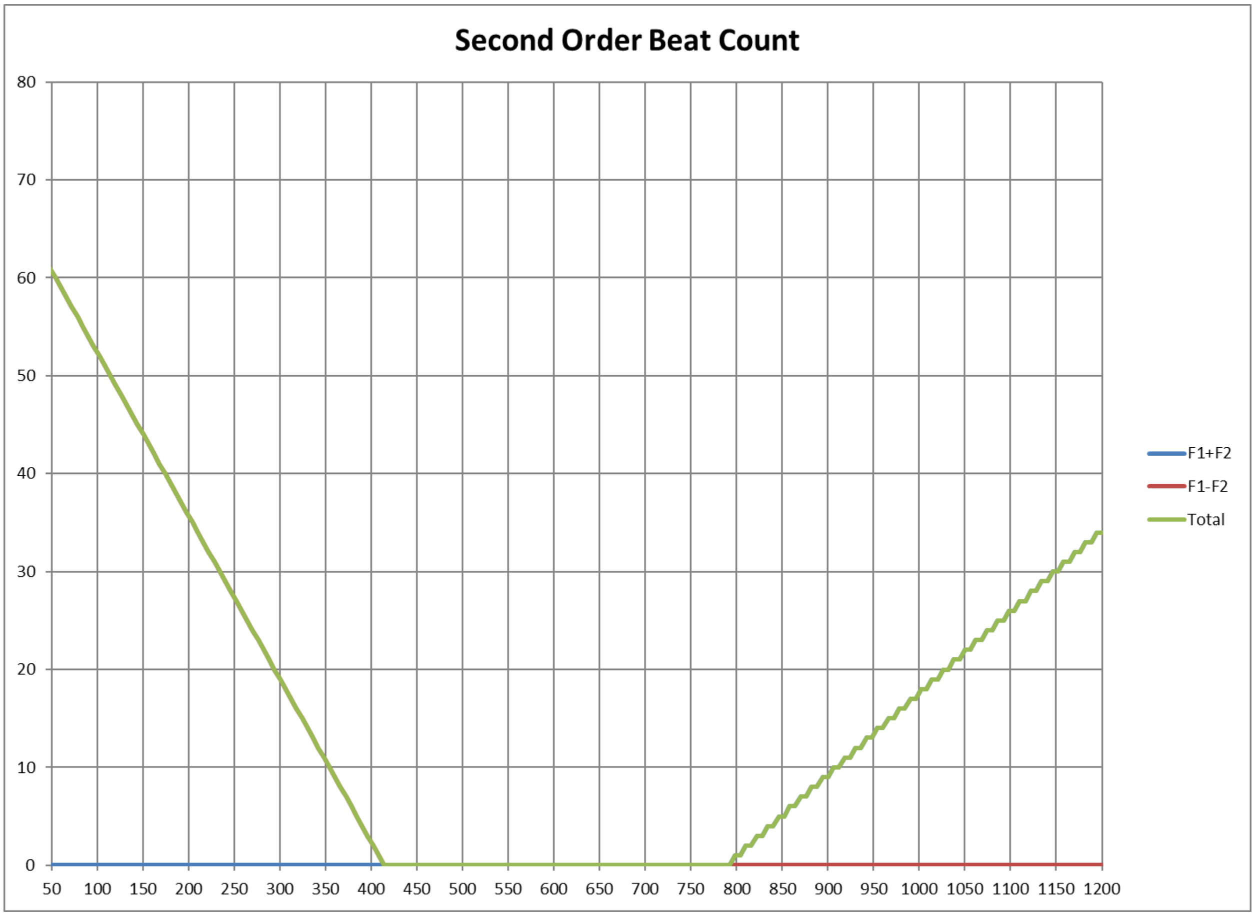



**Figure 7 - Second Order Beat Count When Loaded 400 MHz to 800 MHz**

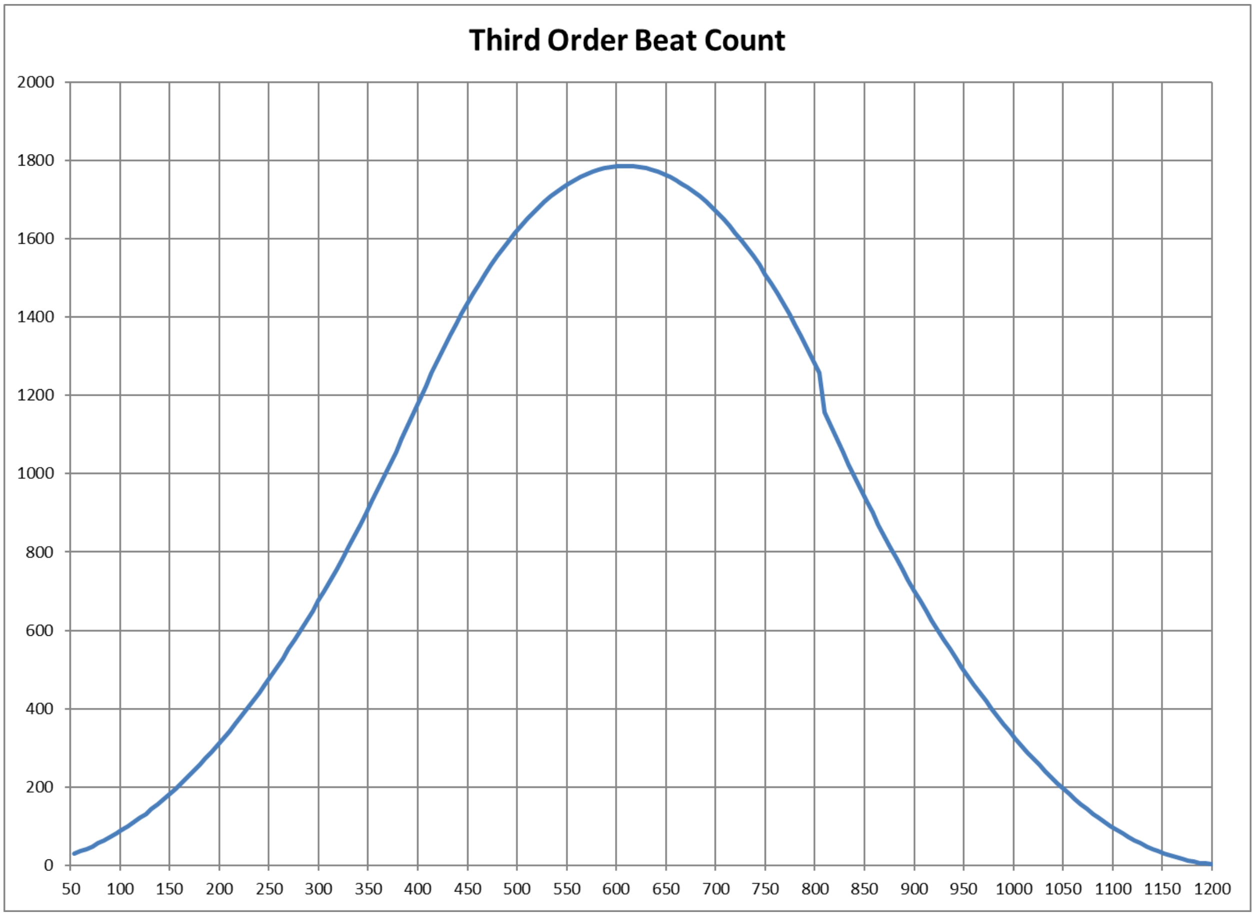



**Figure 8 - Third Order Beat Count When Loaded 400 MHz to 800 MHz**

As before, no second order beats fall in the RF band of interest (400 to 800 MHz). The number of third order beats in-band is also reduced with respect to the previous examples. This scenario represents a reduction in composite power of approximately 5.96 dB with respect to the 54 to 1200 MHz case assuming 12 dB of up-tilt. This is only 0.7 dB greater composite power than the 54 MHz to 600 MHz case.

As stated earlier, what is not clear is how much the second order distortion products will spread and tend to fill in the edges of the areas where the beat count is low or zero, particularly in the case of OFDM loading. Intuitively, from a frequency convolution standpoint, I would expect to see a very broad dip in second order distortion in areas where the beat count is zero. However, the results seem so significant and counterintuitive that they should justify additional study by those persons that have access to the latest amplifier technologies and can measure the performance (CIN level or MER) under various RF loading scenarios.

One must also consider how this approach will affect full-duplex DOCSIS (FDX). In the normal, full traffic case, a 1.2 GHz FDX system would potentially have a duplex return in the 108 MHz to 684 MHz range. In such a case the bandwidth of the upstream full duplex RF spectrum bandwidth would be approximately 50% of the width of the downstream RF spectrum bandwidth.

Consider the low traffic case with downstream loading from 400 to 800 MHz as described in the last example. In such a case the duplex return could be limited to 400 MHz to 684 MHz. This would allow operation of the duplex upstream at frequencies where it would avoid any second order distortion products created by the downstream output amplifier stages (or upstream output stages, for that matter). In this case the RF bandwidth of the duplex upstream spectrum would be 284 MHz wide or approximately 71% of the width of the downstream RF spectrum bandwidth. Assuming the upstream traffic scales with the downstream traffic at times of low traffic, there should be more relative upstream capacity than in the full bandwidth, high traffic case.

# 3. Conclusions

A cursory review of the frequency distribution of intermodulation distortion products RF loading on a cable network indicates that there may be an optimal frequency distribution of RF signals during times of low traffic. Use of that optimal RF frequency distribution would enable a maximum reduction of power usage by the active devices in the network while still meeting adequate intermodulation distortion performance. It could also simplify the implementation of digital predistortion, if used. As indicated previously, additional study is recommended.

# 4. Abbreviations

## 4.1. Abbreviations

| | |
|---|---|
| CEA | Consumer Electronics Association |
| CIN | Composite Intermodulation Noise |
| CSO | Composite Second Order |
| CTB | Composite Triple Beat |
| CW | Continuous Wave |
| DC | Direct Current |
| FDX | Full Duplex DOCSIS |
| Hz | hertz |
| OFDM | Orthogonal Frequency Division Multiplexing |
| QAM | Quadrature Amplitude Modulation |
| RF | Radio Frequency |

## 4.2. Definitions

| | |
|---|---|
| Downstream | Information flowing from the hub to the user |
| Upstream | Information flowing from the user to the hub |

# 5. Bibliography and References

CEA-542-C: Cable Television Channel Identification plan

# An Active Role for Outside Plant Standby Power Supplies

Letter to the Editor prepared for SCTE•ISBE by

Richard Kirsche
Kirsche Consulting LLC
SCTE•ISBE Member

Cable Television distribution systems (Outside Plant) have relied on amplifiers to compensate for the attenuation of the radio frequency (RF) television signals for many decades. Early in cable service history, the industry settled on utility-pole mounted ferro-resonant transformers to supply a quasi-square wave, 60 Hz, voltage multiplexed with the Cable television RF channels over the trunk and feeder cables to supply power to those amplifiers. Ferro-resonant supplies have proven to be rugged and reliable in the harsh environment of the outside cable plant. As the distance between amplifiers increased, outside plant power supplies have been modified by increasing the AC output voltage. Recently, those power supplies have been improved to include the capability of providing power when the commercial power grid failed.

As Cable Operator's service offerings broadened to include communications services (Internet and Telephony) and the Video Service offerings expanded to include a broad range of valuable content the reliability of the Cable Service became increasingly important. Cable Service providers responded with network improvements to meet the requirements of those broadband communications services. Outside plant power supplies have been a key part of those improvements.

The shift to Hybrid Fiber-Coaxial Cable (HFC) signal transport represents one major change. That shift to HFC is a major enhancement in network reliability. Extending fiber transmission lines deeper into the network greatly reduces the power consumption of the cable plant and the number of outside plant power supplies. It is possible to project a continuing shift to fiber optic transmission and outside plant efficiency improvements with a corresponding reduction in the requirement for power supplies. However, it seems unlikely that outside plant power supplies will disappear in the immediate future because the existing HFC plant represents a significant investment that is working well and Cable's increasing success supporting Wi-Fi services creates a continuing requirement to support active electronics on the outside plant.

Cable plant reliability is reliant on the quality of the commercial power grid supporting those plant power supplies. Loss of power to a supply take cable line amplifier off line. Loss of an amplifier in the transmission path prevents signals from continuing to parts of the network that might otherwise have electrical service. Many power outages are of relatively short duration (a few hours or less) Power supplies that go out of service when commercial power is interrupted which would interrupt signals flowing past that point to provide service to areas unaffected by the loss of power. Cable service providers have addressed those commercial power grid interruptions by adding a standby power inverter, powered by storage batteries, to maintain power on the cable plant during those interruptions. The standby power duration varies depending on the number of batteries attached to that standby power supply and the electrical load of the cable plant. Those power supplies help raise the reliability of modern cable distribution systems to a level suitable for communications services.

Historically, the US commercial power distribution system supplied power from large generating stations that relied on nuclear energy, coal, natural gas, or water power to meet the energy demand of the connected power grid. Operators adjusted the output of those generating plants to meet the power grid load and maintain the alternating current frequency at 60Hz. This system operated reliably with minor localized power interruptions and very rare major grid failures caused by large widespread weather events. (Hurricanes, ice storms, floods, tornados, etc.)

At this time power grid is in the process of transitioning to, what some call, Power Grid 3.0. This new power grid is designed to maximize the production of electricity from renewable sources (Wind, Solar, and hydroelectric) while electricity generated from non-renewable fossil fuels is minimized. Distributed Energy Resources (DER) is a distinguishing characteristic of Grid 3.0. Generation from numerous sources, primarily Solar and Wind, is aggregated by the power delivery service provider to replace much of the energy sourced from legacy fossil fuel generating stations. Much of the Grid 3.0 generating resources are small to moderate facilities. A significant portion of that energy comes from "the other side of the meter". That power is not directly controlled by the power distributer because it comes from sources such as residential rooftop solar panels that are on the producer's side of the utility meter. In some cases, energy providers or consumers combine a group of sources together into smaller microgrids to have a manageable group of power generators.

Power delivery companies are challenged by the intermittent character of renewable energy sources and a poor ability to manage many small sources. The output of Windmill farms varies with the wind. Even though it is rare the wind actually stops occasionally. Solar generation relies on the Sun. Output ceases at night. Output also varies with cloud cover. Clouds can occlude part of a solar array. Sudden storms and weather fronts can also affect solar generation over a wider area. Power providers must be ready to bring alternate sources of generation on line as the intensity of solar radiation varies over large areas. Those sources such as gas turbine generators provide costly backup electricity and it is difficult to maintain a pure 60Hz frequency.

California is the nation's leading producer of clean energy. They are so successful at promoting solar energy that they are finding themselves with an "over-generation" problem. Their energy demand curve frequently has excess energy production and lower demand during the middle of the day followed by a steep ramp up of demand in the evening hours (6 P to 9 PM) when consumers return home and turn up their air conditioning or heat, begin cooking meals, turn on area lighting and entertainment, and, more recently, plug in electric vehicles to recharge them. California electric utilities are beginning to explore large and expensive energy storage facilities to smooth out the demand curve.

Hawaii is moving toward 100% renewable electricity. Their most recent regulations encourage residential installations of solar generation to also include energy storage to provide energy for non-daylight hours. Storage is becoming key component of renewable energy systems as that technology becomes a basic part of the electric grid.

The Cable Industry has opportunities to provide load shedding value from its interface with the commercial power grid. The following discussion will address two solutions that are well within the current state of the art. Both of them will require discussion with local power providers to coordinate their implementation and to attain a recognition of the value they provide. It will not make great sense to implement those measures without some recognition of their value by the local power providers because implementing them can come with a small reduction in cable network reliability.

Power provider's need to balance out daily variations in renewable power production and demand peaks has resulted in wide variations in time-of-day demand charges. A cable power supply might be programmed to shift to internal power during those times with the most costly electricity pricing without requiring a new special pricing tariff from the power provider.

Modern Cable standby line power supplies are usually attached to utility poles at locations throughout the community that are optimum for injecting power into the cable system's signal distribution coaxial cables. Their standby powering capability can vary by design (2 or 4 hours are typical) and the load placed by the electronic equipment in the part of the network supported by that unit. In normal operation those power supplies furnish power from their utility grid connection and maintain the charge on the batteries that will be needed if that utility grid fails.

Both approaches discussed here rely on employing a percentage of the charge in those batteries to assist the power grid during times when that grid is under stress from peak loads or the sudden loss of generating capacity. Availability of that percentage (possibly 25%) will have to be tightly managed by the Cable Operator. That management can be provided via an IP communication link transmitted over the cable plant. That link will monitor the outside plant power supply status and enable the features discussed below based on the cable operator's assessment of the potential requirement for that capacity. The Cable Service provider will also need to receive status information from the electric utility that they interface with.

During normal operation the operator may draw on the standby capacity of the power supply for unexpected failures of the commercial grid. Events like a vehicle striking a pole, short duration storms, and a power grid component failure are difficult to predict but normally of short duration (less than 4 hours). On days when electrical storms are forecast the operator may elect to forego the normal grid support. It will be important to manage support for the electrical grid so that our network reliability is not diminished. If enough value accrues to the operator from this power grid support, it may be possible to dedicate additional batteries to this action. Dual purpose devices are not uncommon on the cable plant. Some service providers are presently fielding dual purpose residential modems that serve subscriber and also have the capability to act as a wireless access point

The least sophisticated of the two approaches I am outlining, involves the simple action of disconnecting the input power to the standby supply for a period of time when the power provider indicates the grid is under stress. Coordination with the power provider will be essential. The operator should develop a predetermined plan of action for various situations. Some operators are already monitoring their line power supplies. Adding this capability should not be too challenging

A second approach is more complex but will provide greater value to the electric grid. This action is similar to a system that has been floated in a number of papers referencing electric vehicles. Those papers propose to draw on the energy stored in garaged electric vehicles to support load peaks on the electric grid. This approach can be accomplished based on the same limitations on the power available to share from the power supply. In this instance when support for the grid is indicated, the power supply load will be disconnected from the grid and a microinverter (similar to those employed in solar arrays) would be activated to feed extra power directly to the grid. This action would also have to follow safety constraints to prevent supplying power to a deactivated power grid.

In both of these cases the aggregated value of a number of power supplies acting to support the electric grid could help the operator negotiate deals favorable to both parties. While one supply presents a small benefit, hundreds of supplies, acting in concert represent a significant amount of energy that can support the local electric grid.

Looking forward; improvements in our power supplies with more modern battery technology can increase our storage capacity and provide a bigger reliability margin for the cable operator while increasing the magnitude of our backup ability. Perhaps a financial arrangement with the power provider will be the factor that makes the cost of deploying better batteries for standby service cost effective.

# What Standard Should You Use For Choosing An HVAC System To Cool An Electronic Equipment Room?

Letter to the Editor prepared for SCTE•ISBE by

Dave Smargon, Chief Operating Officer, AIRSYS North America, SCTE•ISBE Member
dave.smargon@air-sys.com
805.312.7549

EER or Energy Efficiency Ratio has long been an energy efficiency standard for HVAC systems. This standard was originally established to provide an "apples to apples" comparison of HVAC systems designed to deliver human comfort. This standard is not very useful and somewhat misleading for HVAC systems that are tasked with managing the heat load generated by powering electronic equipment.

The following article will describe in detail why EER is not correct and will examine other standards used in the HVAC industry to represent relative efficiency. It will conclude by making a recommendation for an efficiency metric that can be readily ascertained by pulling published performance specifications.

Why is EER OK for human comfort and NOT electronic cooling?

Quite simply EER reflects the energy efficiency related to TOTAL capacity of an HVAC system.

**Total Capacity** is the sum of **Sensible Capacity** and **Latent Capacity.**

The heat generated by powering electronic equipment is 100% sensible. Therefore, the Latent capacity is (mostly) not relevant and can steer the MSO Engineer looking to find the right size, energy efficient system in the wrong direction.

**Latent Capacity:** The amount of capacity (in Tons, BTUh or in kW) that is dedicated to the removal of moisture from the air. This is the capacity that is at work when running the air conditioner in your car results in a puddle of water underneath. That is the latent capacity forcing the water vapor out of the air. This very important in human comfort applications but not so important in handling the heat load of electronic equipment.

**Sensible Capacity:** The amount of capacity that is dedicated to the removal of dry bulb heat. This is the portion of the heat load that is completely absent of moisture. This is precisely what the heat load of electronics is: 100% dry bulb heat. Therefore, this is the primary concern for judging the efficiency of one HVAC system compared to another in any electronic cooling application.

| | | | | |
|---|---|---|---|---|
| **Total Cooling Capacity** | = | **Latent Capacity**<br><br>(H2O removal) | + | **Sensible Capacity**<br><br>(Dry Bulb Heat Removal) |

EER= Total Capacity/Total Power at standard test conditions*

*Standard test condition for EER, applicable for commercial and industrial packaged and split air conditioner (AHRI 340/360/390): Outdoor Temp = 95°F, Indoor Temp = 80°F Dry Bulb/67°F Wet Bulb (~50% RH)

So, if EER is not the right metric for judging the relative efficiency of HVAC systems used for electronic cooling applications then what is?

In January of 2016 the United States Department of Energy (DOE) adopted the SCOP metric as the only metric applicable to computer room air conditioners. This was codified in CFR Title 10, Volume 3, Chapter II, Subchapter D, Part 431, and Subpart F for 2016. Per federal law the SCOP is the only efficiency metric that is to be applied to computer room air conditioners. The DOE has mandated that the conditions at which computer room air conditioners must be tested for rating are those found in ASHRAE 127-2007. The current rating conditions for the entering air are 75° dry bulb temperature and a dew point of 52.2°F. The SCOP requirements found in this federal regulation are identical to the one found in ASHRAE 90.1-2010/2013.

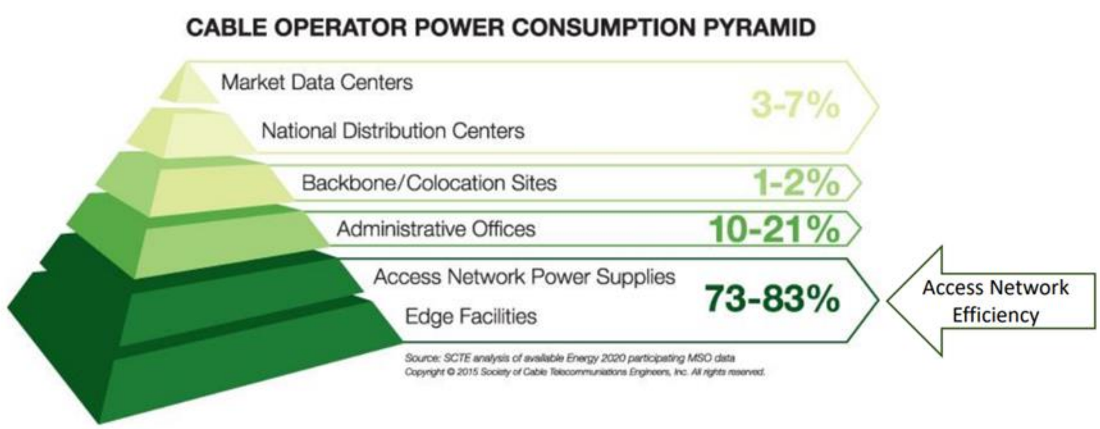
Per federal directive, EER, SEER, COP, IPLV or other HVAC efficiency metrics are not legally applicable to computer room air conditioners. The supremacy clause in article VI of the constitution tells us that when there is a conflict between federal law and state or municipal regulations, the federal law must be followed. The only federally recognized efficiency metric for this type of equipment is the SCOP.

The efficiency metric that is mandated in ASHRAE 90.1 is the Sensible Coefficient of Performance (SCOP). The SCOP is defined in ASHRAE 127 (Method of Testing for Rating Computer and Data Processing Room Unitary Air Conditioners) as the quotient of the total net sensible cooling divided by the total power required to produce that cooling with all values in like terms. (October 11, 2016 by Dave Meadows, Director of Industry Standards and Technology, STULTZ USA)

This was a major correction by the industry to separate the efficiency standards for HVAC's used in electronic cooling applications from those utilized in human comfort applications.

While this clarifies the standard for CRACs there are many HVAC systems in use in MSO facilities that do not utilize CRACs

## The Problem:



73 – 83% of the electricity consumed by MSOs is in the Hub/edge sites in the network. This is where WPUs (Wall Packaged Units) are commonly deployed. These are a good fit for the Hub and Edge sites because:

- Relatively inexpensive upfront cost: Equipment and installation.
- Takes up ZERO indoor space allowing more room for equipment
- Can deliver air side economization with supply air temperature control. Air side economization is one of the MOST efficient methods for cooling

WPUs still utilize EER or IPLV as their primary efficiency metric. WPUs are far more commonly deployed in human comfort application such as portable/modular classrooms and offices. Therefore, they are still encumbered with the human comfort efficiency standards. You will not find SCOP on the cut sheet for a WPU nor will you find the data to calculate this value. So, what do we do?

**RECOMMENDATION**: Use **Sensible** Energy Efficiency Ratio or “SnsEER

If you understand how EER is arrived at then from a common WPU cut sheet you can translate that into SnsEER.

**Key**: From AHRI 390, EER is always measured under the following conditions:

**Outdoor Temperature** = 95°F/35°C

**Indoor Temperature** = 80°F/27°C Dry Bulb Temperature and 67°F/19°C Wet Bulb Temperature

You can commonly find both total capacity and sensible capacity listed at AHRI 390 conditions. Then it becomes a simple multiplier.

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140 Philips Road | Exton, PA 19341-1318 | T: 800.542.5040 | F: 610.884.7237 | scte.org • isbe.org