



# Lowering the Cost of Fiber Deep Networks with Motorola Gallium Nitride (GaN) Technology



## Introduction

Hybrid gain blocks have been the engine of Node and RF access distribution actives since the very early 1970's. As the mainstay of almost every CATV active product for nearly 30 years, hybrid gain blocks were comprised of silicon (Si) transistor cascode push-pull discrete device amplifier circuits laid out on ceramic substrates attached to an aluminum block. In the late 1990's the forward march of ever increasing bandwidth needs and subsequent distortion requirements to support analog plus 256 QAM loading drove the move to Gallium Arsenide (GaAs) mesfet technology. The advantages of GaAs hybrids and MMICs quickly overtook silicon in cable applications just as it did many years before in satellite receivers, cell phones, and many other commercial amplifier products. Higher gain bandwidth, lower noise figure, and improved distortion performance allowed the BW extension to 1GHz without re-spacing every active in the network.

Now, after a successful run of more than 10 years, CATV GaAs gain blocks are about to be succeeded by a new generation of semiconductor device technology that has already proven its capabilities in numerous military, aerospace, and commercial applications. This new technology improves node and amplifier performance, extends fiber deep network reach, and lowers capital and operational expenses of fiber deep networks for cable operators.

## Introducing Gallium Nitride Semiconductors

Like Gallium Arsenide, Gallium Nitride (GaN) is a III –V group direct band gap semiconductor, but with unique properties that have allowed the development of daylight LED's, Blu-ray lasers, and high power / high frequency RF amplifier devices.

GaN is a very hard material and fabricating bulk pure crystalline wafers proved to be so difficult that applications for GaN were limited to small area devices such as LED's or specialized lasers and military applications which could absorb the higher costs of small area wafer processing. Advances in chemical vapor deposition and vapor phase epitaxy growth during the 1990's allowed GaN thin films to be deposited on silicon (Si) and silicon carbide (SiC) wafers, providing the possibility of large-scale fabrication. GaN devices processed on Si or SiC wafer substrates have the added advantage of significantly improved thermal performance compared to devices built on GaAs wafers.

Gallium Nitride has a wider band gap (3.4 eV) than Si (1.2 eV) or GaAs (1.4 eV). This allows GaN devices to operate at much higher temperatures without degradation and also to be designed for higher operating voltages than GaAs field-effect transistors (FETs) can tolerate. These properties of Gallium Nitride result in devices with roughly 10 times higher power density - while maintaining wide bandwidths at frequencies up to 4 GHz - than other competitive technologies. These advantages of Gallium Nitride

along with high ionization resistance (radiation hardness), increased ESD and surge voltage tolerance have made GaN based devices an obvious choice for high power military RF applications. More recently, GaN RF devices have begun to challenge Si LDMOS in the 2 GHz WiMAX power amplifier base station market.

While GaAs mesfet devices are optimized for operation at low voltages, the unique properties of GaN devices were initially targeted for military applications operating at 50 volts. Wafer fab processing has now optimized these devices for use at 24V which is in line with typical CATV node and RF amplifier working voltages. The thermal conductivity of Gallium Nitride is 2X higher than Gallium Arsenide. Fabrication on SiC wafer substrates ( $T_c = 4.9 \text{ W/cm}^2\text{K}$ ) allows GaN devices to operate at higher output power levels while maintaining safe junction temperatures.

Motorola's patented hybrid circuit technology in conjunction with the robust GaN semiconductor properties described above creates a new generation of hybrid gain block amplifiers that have demonstrated superior performance in both node and amplifier applications.

	Silicon (Si)	SiC	GaAs	GaN
Band Gap	1.12 eV (300K)	3.05 eV (300 K)	1.424 eV (300 K)	3.2 eV (300 K)
Electron Mobility	1500 $\text{cm}^2/(\text{V}\cdot\text{s})$ (300K)	900 $\text{cm}^2/(\text{V}\cdot\text{s})$ (300 K)	8500 $\text{cm}^2/(\text{V}\cdot\text{s})$ (300K)	1670 $\text{cm}^2/(\text{V}\cdot\text{s})$ (300 K)
Thermal Conductivity	1.49 $\text{W}/(\text{cm}\cdot\text{K})$ (300K)	4.9 $\text{W}/(\text{cm}\cdot\text{K})$ (300 K)	0.55 $\text{W}/(\text{cm}\cdot\text{K})$ (300 K)	1.3 $\text{W}/(\text{cm}\cdot\text{K})$ (300 K)

**Table 1 - Electrical / Thermal Properties of Common CATV Semiconductor Devices**

## Motorola GaN Technology Improves Node and Amplifier Performance

The most significant performance limitation in access networks today is composite carrier to noise (CCN). Ever increasing digital loading up to 1 GHz creates carrier to intermodulation noise (CIN) which, along with thermal noise, generated in the various active components combine to produce CCN. While the other analog distortions (CSO, CTB) are still very important to the performance of the network, CCN is the dominant distortion that determines the maximum output level that nodes and amplifiers can achieve.

Figure 1 shows comparative data for composite CCN performance of a Motorola BLE100 1GHz Line Extender tested with existing GaAs hybrid gain blocks and with Motorola's new GaN technology hybrid gain blocks. Although this is single station data the plots illustrate the improved distortion performance of GaN. This enhanced performance allows the BLE output to be increased by 2 – 3 dB from typical operating levels without degrading end of line distortion.

Figure 2 demonstrates N+0 link performance testing using the Motorola SG4 segmentable node. With existing GaAs hybrid gain blocks the SG4 is capable of +58 dBmV (1 GHz virtual) output at 18 dB tilt. The same link utilizing Motorola GaN technology hybrid gain blocks provides 3 – 4 dB of additional output level for the same distortion performance.

The improvement in output level that is achievable with Motorola GaN technology is key to lowering the cost of fiber deep network deployments.

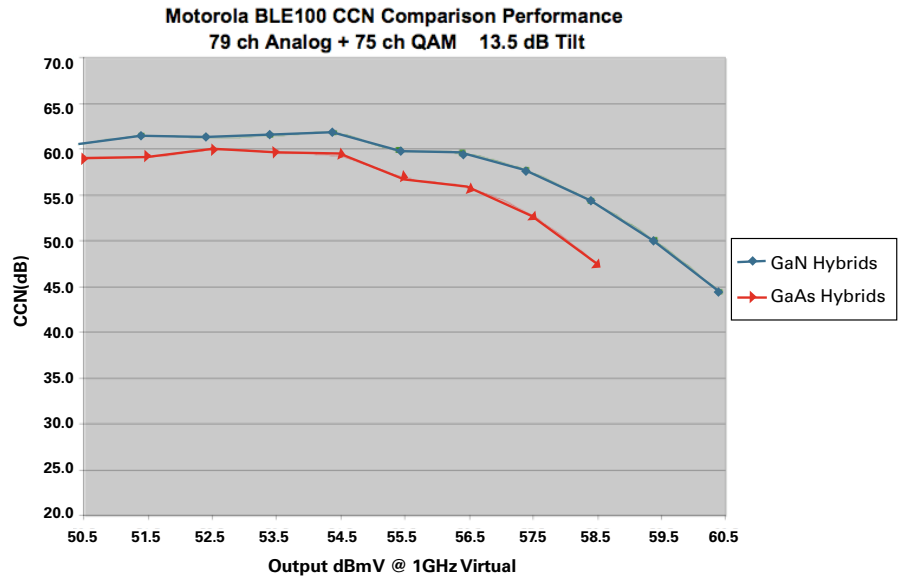


Figure 1 - BLE Single Station CCN Test Results (25C Data)

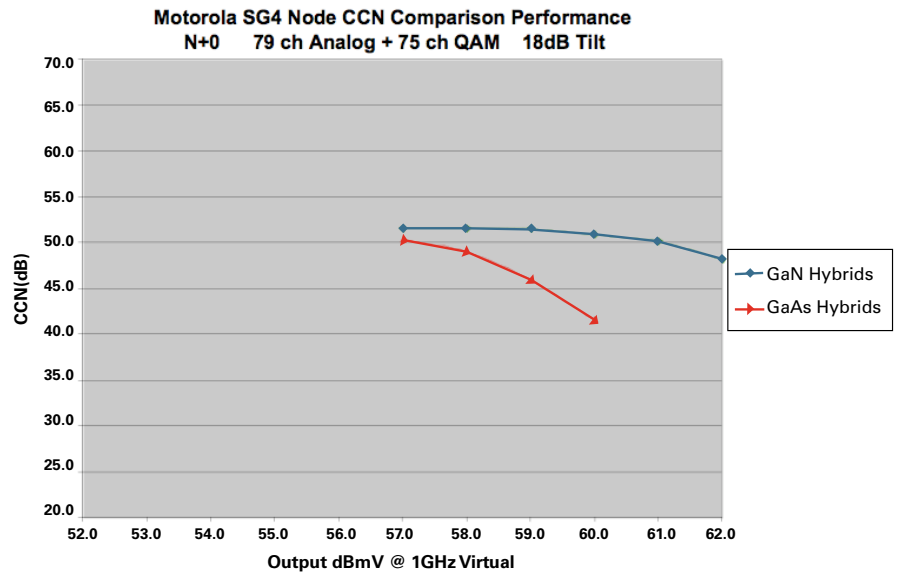


Figure 2 - SG4 Link Performance, 20km Fiber + Passive Loss (25C Data)

## Motorola GaN Technology Extends Fiber Deep Network Reach

The benefits of Fiber Deep architectures for expanding bandwidth and data rate capacity are well known. Unfortunately, the cost of deploying fiber deep systems can be prohibitive particularly as fiber is pulled deeper into the network and the number of nodes increases as serving area size decreases. Motorola GaN hybrid technology reduces the cost of Fiber Deep greenfield deployments by providing up to 3 dB of increased output level while maintaining the excellent distortion performance of current node and active products. This additional output level can have significant benefits including a reduction in the number of actives needed in new fiber deep designs and considerable improvements in maintaining amplifier locations during frequency expansion upgrades in older legacy networks.

## Motorola GaN Technology Lowers Network CapEx and OpEx

Using Motorola GaN technology in N+1 network designs has shown a 10 – 20% CapEx reduction resulting from the decrease in total number of actives required for the same service area compared to designs using existing GaAs amplifiers.

In one sample design, we were able to reduce the number of amplifiers per node from 12 amplifiers to 8 amplifiers. This reduced the maximum cascade from N+2 to N+1, while serving the same number of homes passed.

For N+0 system designs, Motorola GaN technology provides a true > 60 dBmV virtual level output capability at 1 GHz with full 79 channel analog plus 450 MHz of QAM loading (18 dB tilt). This allows operators to maximize reach and optimize the number of new node locations for a set number of homes passed per node.

Using extended reach technology in one N+0 design resulted in a 10% decrease in the number

of nodes required to feed the same number of homes passed. The lower number of actives in the GaN designs also enables additional CapEx and OpEx savings including:

### CapEx:

- Active Cost and Installation Cost
- Fiber and/or Cable Cost and Installation Cost
- RF and Optical Passives
- Connectors
- Accessories

### OpEx:

- Maintenance
- Repair
- Powering

For legacy brown field networks, system powering and HHP/actives are fixed by the previous design. Increased output level does not provide a meaningful advantage when upgrading to shorter cascades in this situation. In the case of a frequency expansion to 1 GHz, Motorola GaN technology can make a measureable difference in maintaining amplifier locations from a typical 95% for a 750 MHz / 1 GHz upgrade to ~98%. Older systems can also benefit from a much lower re-spacing of network actives in a frequency expansion upgrade than can be accomplished today.

## Summary

Gallium Nitride semiconductor devices are now entering the cable access market from multiple sources. These devices provide added ruggedness and improved thermal efficiency over existing GaAs hybrid and MMIC technology. By implementing GaN based gain blocks together with its patented hybrid circuit technology, Motorola has taken the lead in providing the highest available RF output levels for cable operators driving fiber deeper into their networks. Motorola's GaN technology makes fiber deep architectures more affordable by reducing the number of active components in a network and extending the available reach of each active.



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