Morse Micro

MM8108 Transmitter Efficiency

A Morse Micro White Paper

January 2025

Overview

01

Introduction

Modern wireless systems, including Wi-Fi HaLow (IEEE 802.11ah), must deliver higher data rates, broad coverage, and long device lifetimes under increasingly constrained power budgets.

Achieving these objectives is particularly challenging in transmitters for OFDM-based standards due to the inherently high peak-to-average power ratio (PAPR) of the signals. The PAPR requirement necessitates linear operation over a wide dynamic range, which can reduce efficiency and increase power consumption.

Traditional linear transmitter architectures, while meeting spectral mask and linearity requirements, often exhibit low efficiency under realistic operating conditions. This results in reduced battery life, thermal management challenges, and higher operational costs for large-scale deployments.

To address these limitations, Morse Micro integrates multiple techniques in a single CMOS SoC.

By combining a digital power amplifier (DPA), multi-way Doherty configuration, supply voltage scaling, polar modulation, and robust digital pre-distortion (DPD), the solution achieves efficiency levels not previously observed in commercial Wi-Fi transmitters.

02

The Core Challenge: High-PAPR Signals and Efficiency Trade-offs

OFDM waveforms introduce large amplitude variations. PAs must accommodate these variations linearly, operating many decibels below their peak power levels for the vast majority of the transmission.

Conventional linear amplifiers experience substantial efficiency degradation at these back-off levels. Overcoming this degradation while maintaining stringent EVM and spectral mask compliance is the central design challenge in high-efficiency Wi-Fi transmitters.

03

Key Architectural Innovations

Morse Micro’s integrated CMOS SoC employs several strategies to address the efficiency-linearity trade-off:

Digital Power Amplifier (DPA)

A DPA leverages digital circuitry and high-speed switching rather than continuous-mode biasing. This approach simplifies integration and reduces intrinsic power losses.

Polar Modulation

Decomposing the signal into amplitude and phase components allows more efficient operation. This improves overall efficiency and linearity.

Multi-Way Doherty Configuration

Rather than employing a conventional two-way Doherty architecture, the PA is divided into multiple sub-arrays. Each sub-array provides an efficiency optimum at different back-off points, resulting in higher average efficiency when transmitting high-PAPR signals.

Supply Voltage Scaling

Adjusting the supply voltage, rather than relying solely on code-based back-off, preserves efficiency at reduced output powers. For example, dropping the supply from 1.8 V to 0.45 V achieves a 12 dB reduction in peak power with less efficiency penalty than conventional methods.

Robust Digital Pre-Distortion (DPD)

DPD compensates for nonlinearities introduced by the DPA, multi-way Doherty approach and power supply. By correcting AM-AM and AM-PM distortions, DPD ensures that the transmitter maintains low EVM and meets spectral mask requirements. DPD has proven to be robust over a large range of antenna impedances as this DPA is fairly insensitive to antenna impedance.

04 Measurement Technique

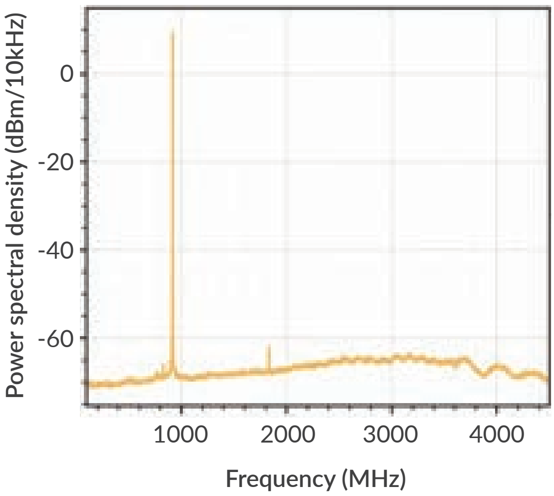
Efficiency figures are measured at the system level, with the entire SoC powered from a single 3.3V supply. This includes the RF front-end, digital baseband, MAC/PHY, packet generation, and integrated power management.

All support circuitry such as power management, LO buffers and frequency synthesis are included in the efficiency calculation. Reporting efficiency from a single supply voltage source provides a realistic metric that reflects total system performance in practical deployment scenarios.

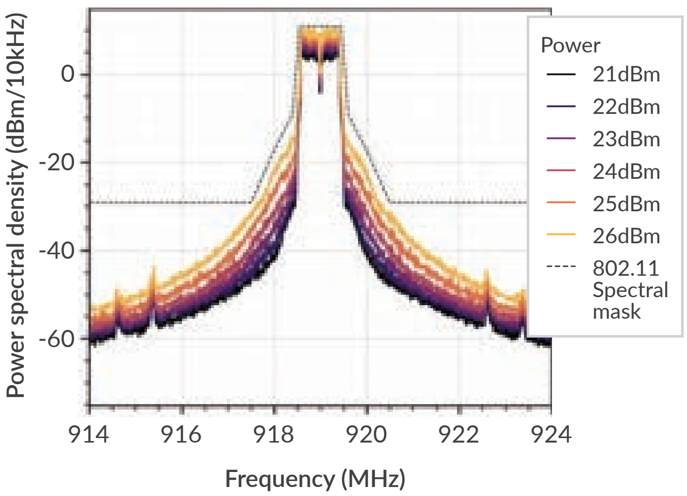
The MM8108 requires a low cost harmonic filter consisting of four small passive components in order to meet FCC regulatory requirements for spectral emissions. The measurements reported are taken at the output of the harmonic filter. Furthermore, all results presented are compliant to the 802.11 spectral mask specification, with margin. Thus the reported performance can be achieved in a mass produced, regulatory and 802.11 spec compliant product.

The following figures shows measurement results for wide band emissions at 26dBm output power and the close in emissions for output powers from 21dBm to 26dBm, with the 802.11 spectral mask shown (dotted line).

Wide band emissions at 26dBm output power



Close in emissions for output powers from 21dBm to 26dBm

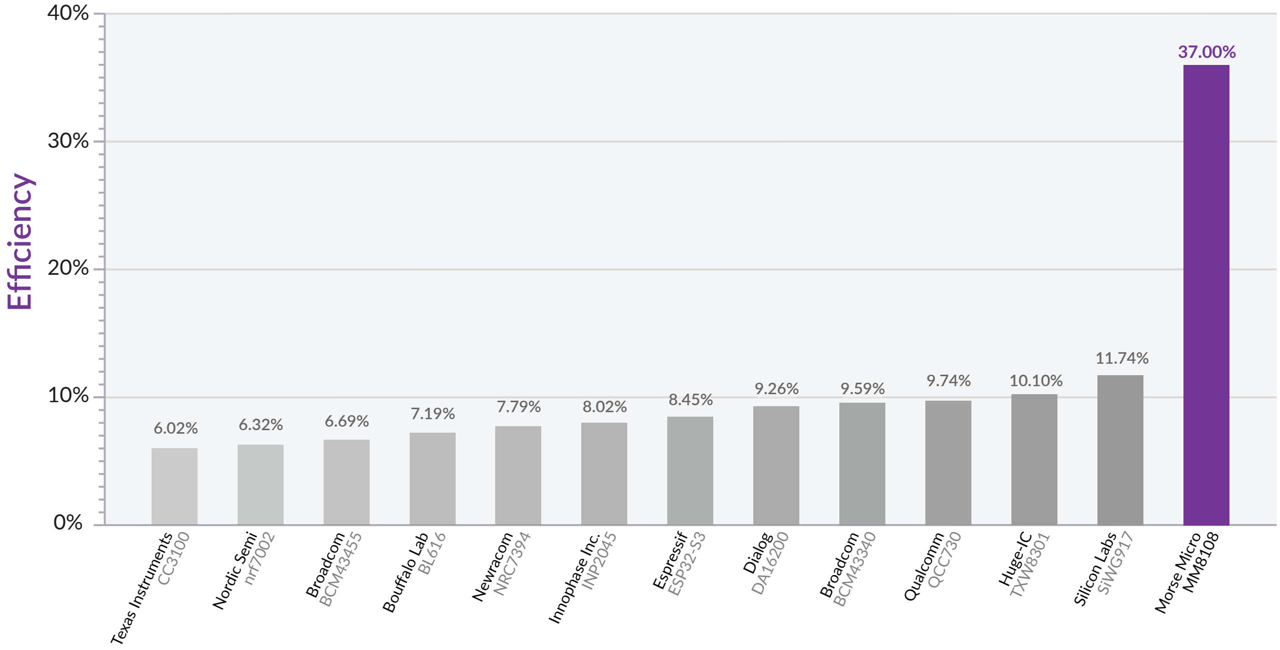


05 Performance Data and Benchmarking

Morse Micro’s transmitter achieves efficiency levels that exceed, by a significant margin, the typical range for OFDM devices.

The following chart shows the system level efficiency of Wi-Fi CMOS SoCs in transmit mode. Efficiencies in the 7% to 10% range are typical with the Silicon Labs SiWx917 datasheet reporting 11.74% as the best available in the market. By comparison, the MM8108 achieves substantially higher efficiency of 37%.

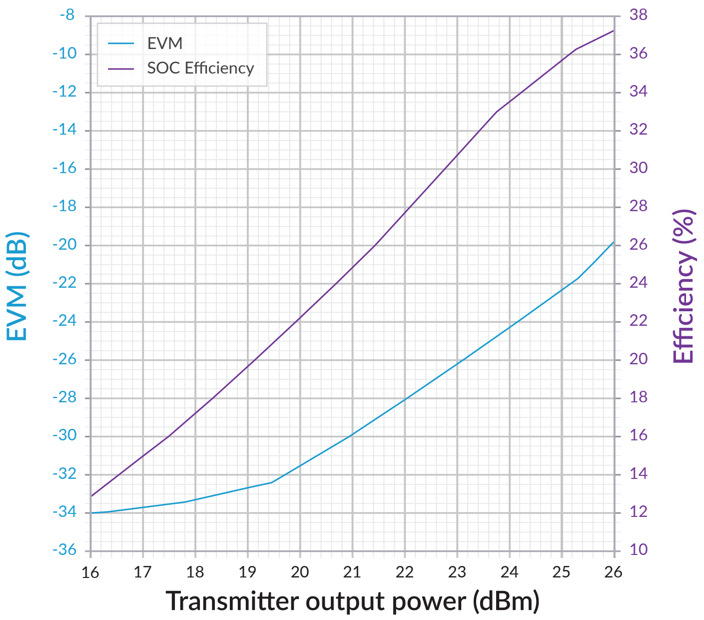
Transmit Efficiency vs Part



Not only does the MM8108 provide higher efficiency than competitive integrated CMOS SoC solutions, but its 37% efficiency is comparable, or even superior, to expensive multi-chip envelope tracking solutions that require the complexity and added expense of separate RF modulators, power management, and power amplifiers.

The chart below shows the measured efficiency and EVM performance vs output power in 2MHz mode of operation.

EVM Performance vs Output Power

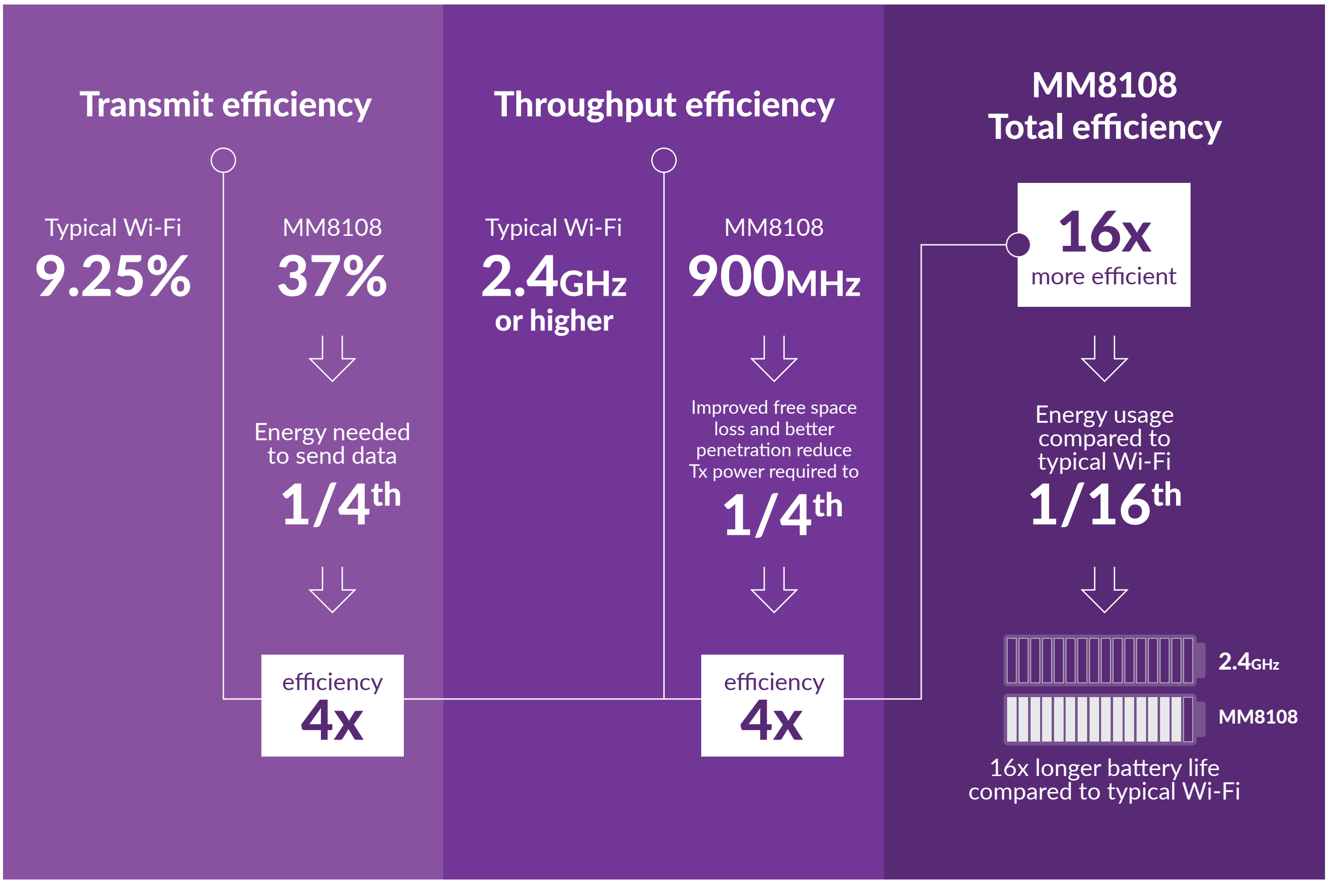


It can be seen that not only does the transmitter give very good efficiency at high output power, but that it can maintain reasonable output power at excellent efficiency even when low EVM is required. This ensures that high MCS (Modulation and Coding Scheme) rates, and thus high throughput, can be achieved at excellent output power and thus range.

06 System-Level Implications

Higher efficiency under back-off conditions directly translates into extended battery life in IoT and other power-constrained devices.

By increasing efficiency by approximately four times, energy usage from the battery is reduced by about 75%. Additionally, when operating in the sub-GHz bands defined by Wi-Fi HaLow, improved free-space propagation and enhanced penetration through walls and building materials results in a better link budget than 2.4GHz Wi-Fi. This improved link budget allows higher MCS rates and thus higher data throughput. As a result the transmitter can spend more time off and the energy required to achieve a given data rate is reduced by a factor of four compared to conventional 2.4GHz Wi-Fi operation. Overall the MM8108 required about 1/16th the energy of conventional 2.4GHz in order to sustain the same transmit throughput.

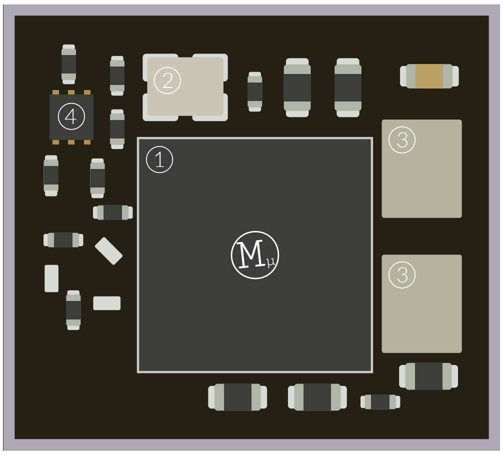


The reduction in power dissipation lowers thermal stress and simplifies thermal management. Furthermore, improved efficiency and power density can enable enhanced coverage ranges or higher data rates for a given energy budget.

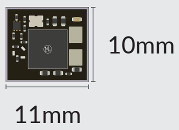
A modest bill of materials (BOM) supports worldwide regulatory environments. This fully integrated approach, combined with stable DPD calibration, simplifies the design-in process and improves device-to-device consistency in mass production. The figure below shows the design and BOM for Morse Micro's reference module.

MM8108 RBOM

1. MM8108 chip
2. a 32MHz crystal
3. 2x PMU inductors
4. a TR switch
5. ~19 very small low cost passives



Actual size



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Adaptability to Evolving Standards

As Wi-Fi standards evolve to higher-order modulation schemes, wider bandwidth and higher frequency bands, the architectural principles demonstrated here remain applicable.

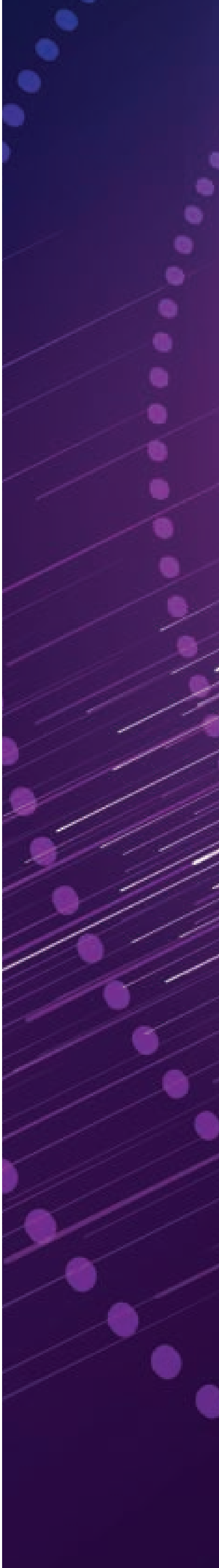
While the MM8108 transmitter is designed for sub-GHz 1/2/4/8MHz bandwidth with up to 256QAM modulation, the transmitter architecture is suitable for wider channel bandwidths, higher RF frequencies and modulation schemes with more stringent EVM requirements.

08

Conclusion

Achieving high efficiency in OFDM-based Wi-Fi transmitters requires addressing the interplay between linearity and back-off performance. By integrating digital power amplification, multi-way Doherty, supply voltage scaling, polar modulation, and effective DPD into a single CMOS SoC, Morse Micro demonstrates efficiency levels not previously demonstrated in mass-production Wi-Fi HaLow products.

The system-level measurement approach indicates that these gains are realized in realistic operating conditions, including power management and baseband processing overheads. As a result, product designers can leverage this approach to enhance battery life, reduce operating costs, and extend coverage, while maintaining compliance with spectral and regulatory specifications. This capability contributes to more robust and efficient wireless systems, better suited to the evolving demands of modern connectivity.



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