A TECHNICAL DEEP DIVE FOR THE AMATEUR RADIO COMMUNITY

AURORA & POLAR MODULATION

How FlexRadio reengineered the RF power amplifier using Envelope Elimination & Restoration – the basis of Polar Modulation

EER · DSP · CLASS D · ~95% EFFICIENCY

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TONIGHT'S ROADMAP

Tonight's Agenda

1

EER Fundamentals

Leonard Kahn's original 1952 concept, broken into its four building blocks.

2

Aurora's DSP Approach

How the Aurora replaces Kahn's analog stages with real-time digital signal processing.

3

Benefits & Differentiation

Why polar modulation matters for efficiency, weight, and spectral purity in your shack.

PART 1

Envelope Elimination & Restoration

The 1952 idea behind every high-efficiency polar transmitter

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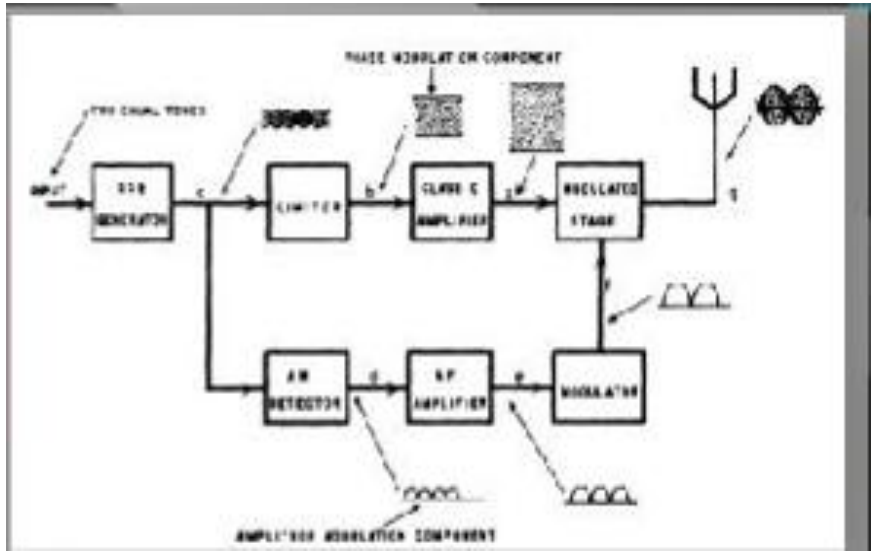
What Is Envelope Elimination & Restoration?

- Traditional linear amplifiers (Class AB) waste power dissipating the unwanted envelope as heat.
- Leonard Kahn proposed splitting a signal into its envelope (amplitude) and its phase (a constant-amplitude carrier).
- The phase-only carrier can be pushed through a highly efficient saturated amplifier (Class C, D, or E).
- The envelope is restored onto that carrier afterward, reconstructing the original waveform.



Kahn's original EER concept, 1952

Leonard R. Kahn — proposed this technique in 1952; it remains the foundation of nearly every modern high-efficiency RF transmitter.

L. R. Kahn, "Single-Sideband Transmission by Envelope Elimination and Restoration," Proc. IRE, vol. 40, no. 7, pp. 803–806, July 1952.

The Four Stages of EER

Input SSB signal

Reconstructed RF output

1

Signal Splitting

Input signal is separated into an envelope (amplitude) component and a phase (carrier) component.

2

Efficient Amplification

The constant-amplitude phase carrier is driven into saturation by a high-efficiency PA.

3

Restoration

The envelope signal is reapplied to the amplified carrier, restoring the original amplitude.

4

Recombination

Envelope and phase merge back into a single, faithfully reproduced RF output signal.

This four-stage architecture is the essence of EER — Aurora keeps the concept but reimplements every stage in the digital domain.

PART 2

Aurora's DSP Innovation

Trading analog envelope detectors and PLLs for real-time math in an FPGA

Lead Engineer: Tony Brock-Fisher, K1KP

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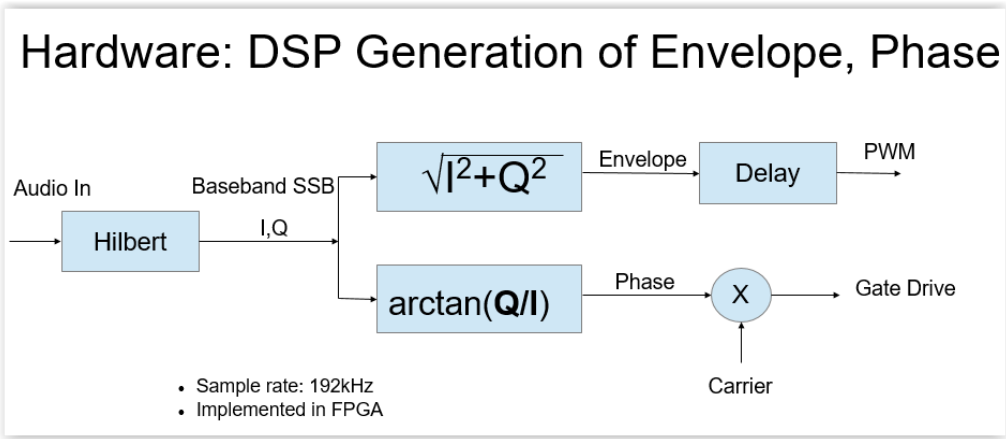
From Analog to Digital

- Transforms conventional I/Q DSP signals into envelope and phase components that directly drive switching RF power stages
- Classic EER needs analog envelope detectors and phase-locked loops — sources of noise, drift, and complexity across 1.8–54 MHz.

- Aurora computes everything mathematically: a Hilbert transform converts audio into baseband I/Q data.
- Envelope = √(I² + Q²) · Phase = arctan(Q / I) — both derived entirely in the digital domain.
- Implemented in an FPGA running at a 192 kHz sample rate, with no analog restoration components at all.



DSP-generated envelope and phase paths, implemented in FPGA

Same idea, new hardware: Kahn's splitter and restoration circuits become a few lines of FPGA math.

PART 2 · AURORA'S DSP APPROACH

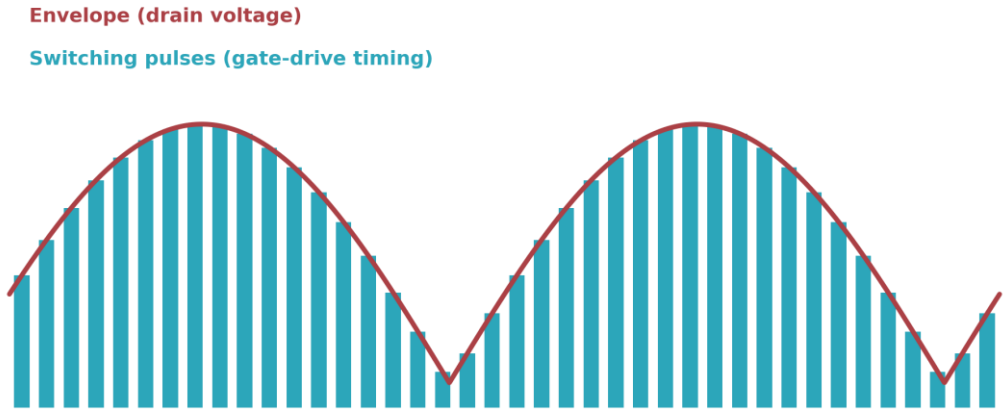
The High-Efficiency Class D Audio Modulator

A basic half-bridge Class D design switches at high sample rates to reconstruct the envelope with minimal loss — entirely replacing Kahn's analog restoration stage.

650W	192kHz	~95%	Half-Bridge
OUTPUT POWER	SAMPLE RATE	EFFICIENCY	BASIC TOPOLOGY

Driving a Switching Class D Power Amplifier

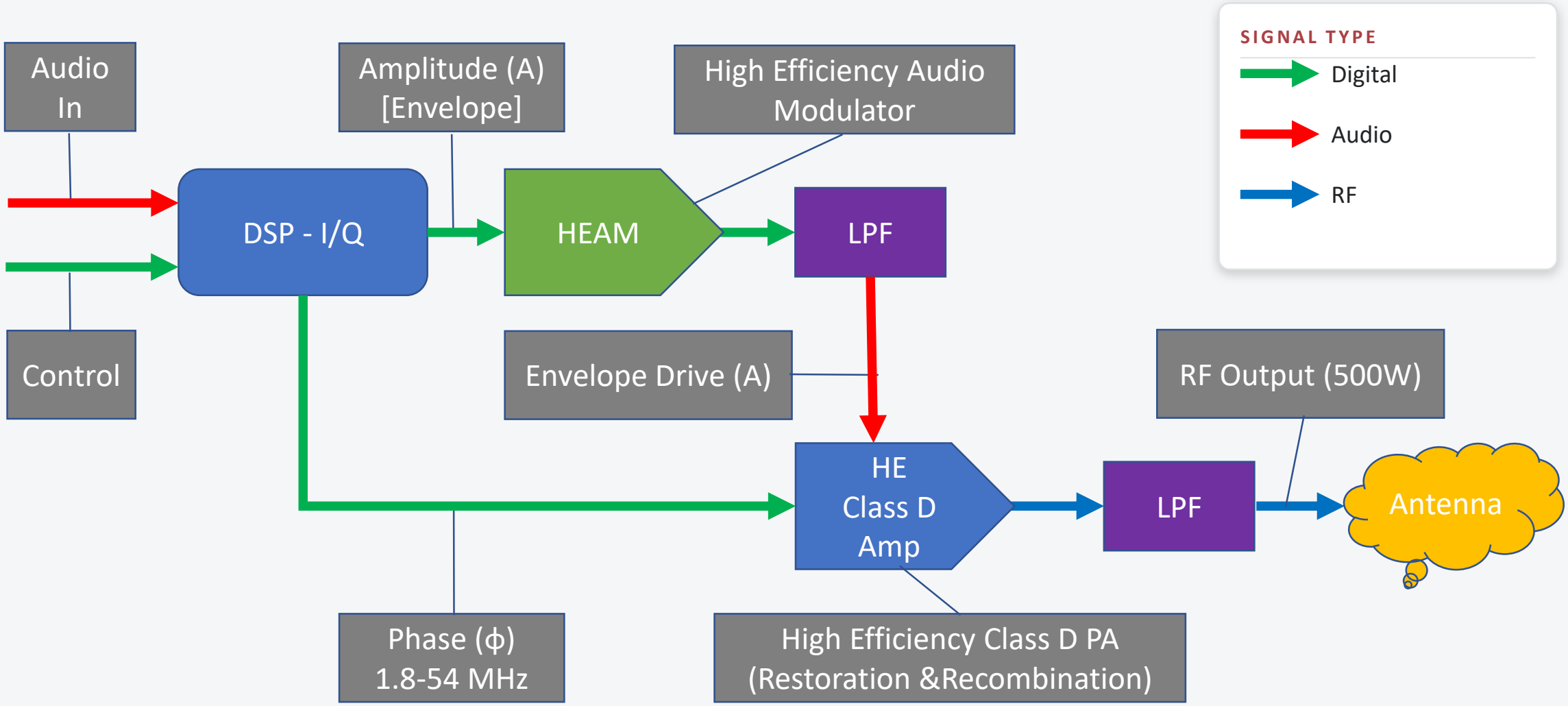
- Switching PAs (Class D and up) are highly efficient but sacrifice amplitude control.
- By converting I/Q samples to Polar Modulation, the signals needed to drive a high-speed switching PA are generated directly:
  - Amplitude is applied as drain voltage
  - Phase modulation is applied to gate drive



Switching pulses (teal) tracking the amplitude envelope (red) at the PA drain

Direct polar drive: No linear stage needed — I/Q becomes drain voltage and gate-drive timing directly.

Putting It Together: The Aurora Signal Path



PART 3

Benefits & Differentiation

Why polar modulation matters for the way you operate

Lighter, cooler, quieter — the difference you'll notice at the operating position.

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Traditional Linear PA vs. Aurora Polar Modulation

Attribute	Traditional Linear PA (Class AB)	Aurora Polar Modulation (EER + DSP)
Efficiency	~50–60%, most loss as heat	**~95%, switching losses only**
Cooling needs	Large heatsinks, forced-air fans	**Minimal cooling required**
Weight	Heavy transformers & heatsinks	**Lightweight by comparison**
Power consumption	High idle bias current	**Efficient only when transmitting**
Spectral purity	Linearity/efficiency trade-off	**Clean digitally recombined output**

Key Benefits at a Glance

A

Efficiency

~95% efficient switching vs. ~50–60% for linear amplifiers.

B

Weight Reduction

No large linear-stage heatsinks or transformers to carry.

C

Power Consumption

Draws power only when actively transmitting.

D

Long-Term Reliability

Fewer analog components means fewer things to drift or fail. Lower temperatures puts less thermal stress on the components

E

Spectral Purity

Digitally recombined signal path minimizes distortion products.

F

Quieter Operation

Minimal amplifier forced-air cooling means a quieter operating position.

RECAP

The Big Picture

1

EER Fundamentals

Kahn's 1952 insight still holds: split amplitude from phase, amplify the phase efficiently, then restore the amplitude.

2

Aurora's DSP Approach

Aurora reimplements every EER stage as FPGA math — Hilbert transform, envelope, phase, and a direct polar-driven Class D output — trading analog drift for digital precision.

3

Benefits & Differentiation

~95% efficiency, less weight, less heat, and quieter operation — a fundamentally better way to key up.

THANK YOU

Aurora: EER Reimagined for the Digital Age

Questions & Discussion

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