L-Band Class-F High Efficiency Power Amplifier based on GaN-HEMT Technology

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Content
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L-Band Class-F High Efficiency Power Amplifier based on GaN-HEMT Technology

- Introduction.
- Envelope Elimination and Restoration (EER) technique.
- Class-F amplifier.
- GaN-HEMT Transistor and load planes.
- Prototype Class-F amplifier.
- Conclusion.

Introduction

<table>
<thead>
<tr>
<th>Linear amplifier</th>
<th>No linear amplifier</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class A</td>
<td>Good linearity</td>
</tr>
<tr>
<td>Class B</td>
<td>Simple circuits</td>
</tr>
<tr>
<td>Class AB</td>
<td>Low efficiency</td>
</tr>
<tr>
<td>Class AB</td>
<td>High efficiency</td>
</tr>
<tr>
<td>Complex modulations</td>
<td>Good linearity</td>
</tr>
<tr>
<td>High spectral density</td>
<td>Complex circuits</td>
</tr>
<tr>
<td>High peak to average ratio</td>
<td></td>
</tr>
</tbody>
</table>

Linearized HEPAs: EER / ET Doherty LINC

- High efficiency
- Good linearity
- Complex circuits
**Envelope Elimination and Restoration**

- Invented by Kahn in 1952.
- Used to efficiently amplify non constant envelope RF signals:
  - The RF signal is divided into its envelope and phase components. The Envelope amplifier, usually a DC-DC converter, amplifies the envelope component of the RF signal, the high efficiency power amplifier (HEPA) amplifies the phase modulated RF component of the RF signal (envelope removed).
  - The amplified envelope is used to feed the HEPA.

**Class-F amplifier**

- High efficiency amplification class (100% ideal).
- Load impedances at fundamental and harmonics:
  - $Z @ f_0 = R + 0^\ast j$ (resistive)
  - $Z @ 2nf_0 = 0$ (short-circuit)
  - $Z @ (2n+1)f_0 = \infty$ (open-circuit)
- Bi-harmonic class-F:
  - Only load at fundamental, $2f_0$ and $3f_0$ harmonic are controlled
  - Maximum drain efficiency = 88.36%
**GaN-HEMT Transistor**

- **RF3931 – RFMD:**
  - 0.5µm GaN HEMT technology
  - Maximum power: 45 W
  - Breakdown voltage: 175 V
  - Packaged (ceramic package)
  - No built in matching networks.

- **Load impedance planes:**
  - The parasitics introduced by the package of the transistor limit the harmonic control of the load provided to transistor.

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**GaN-HEMT Transistor**

- **Effect of the package of the transistor at 1640 MHz:**

The package restricts the class of operation.
Prototype class-F amplifier

AWR simulation results:

- 48 V drain voltage
- 40 W output power
- 80 \% drain efficiency
- 250 MHz bandwidth

Experimental results:

- 48 V drain feed
- 40 W output power
- 70 \% drain efficiency
- 280 MHz bandwidth
Conclusion

- A high efficiency high power class-F amplifier has been designed and built at 1640 MHz using GaN HEMT technology.
- Harmonic load control has been used to satisfy load conditions required for class-F operation.
- Simulations and measurements on a circuit prototype have been presented showing good agreement. The main performances of the amplifier are:
  - Output power: > 45W
  - Drain efficiency: up to 70% (recently measured up to 78%)
  - Bandwidth: 280 MHz (17% fractional bandwidth).
  - Easy to implement and replicate.
- Main applications: Mobile satellite communications in L-Band.
- Ongoing research work:
  - Optimization of the load network of the amplifier to improve the efficiency.
  - Design for other frequency bands: UMTS, Wi-Fi...