Class-E Power Amplifiers for Radar for Deep-Space Missions

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Abstract: Class-E amplifiers provide high efficiency, low parts-count solutions for RF and microwave power amplifier applications. These amplifiers utilize an output network which allows voltage across or current through the single switching transistor, but not both simultaneously. By avoiding the overlap of voltage and current in the transistor, device dissipation is reduced. Lower dissipation means higher efficiency, lower heat load, and substantially more output power from a given device. Because the output network can absorb the capacitance of the active device, it is possible to extend the upper frequency limit of a particular transistor. Class-E amplifiers have been built and tested for use at HF, VHF, and UHF. A 50 MHz amplifier for the Europa Orbiter Radar Sounder produces 30 watts with 90% drain efficiency. A schematic for the Radar Sounder Class-E amplifier with driver stages is shown, along with a system block diagram including a simple transmit-receive switch, and possible telemetry. Where the non-linear nature of a switched-mode amplifier is acceptable, the Class-E amplifier's savings in power, weight, and heat make it attractive for spacecraft use.

The authors gratefully acknowledge the support of the Advanced Radar Technology Program, Jet Propulsion Laboratory, NASA.

A 30-W 50-MHz Class-E Solid-State Amplifier

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September 15, 1999

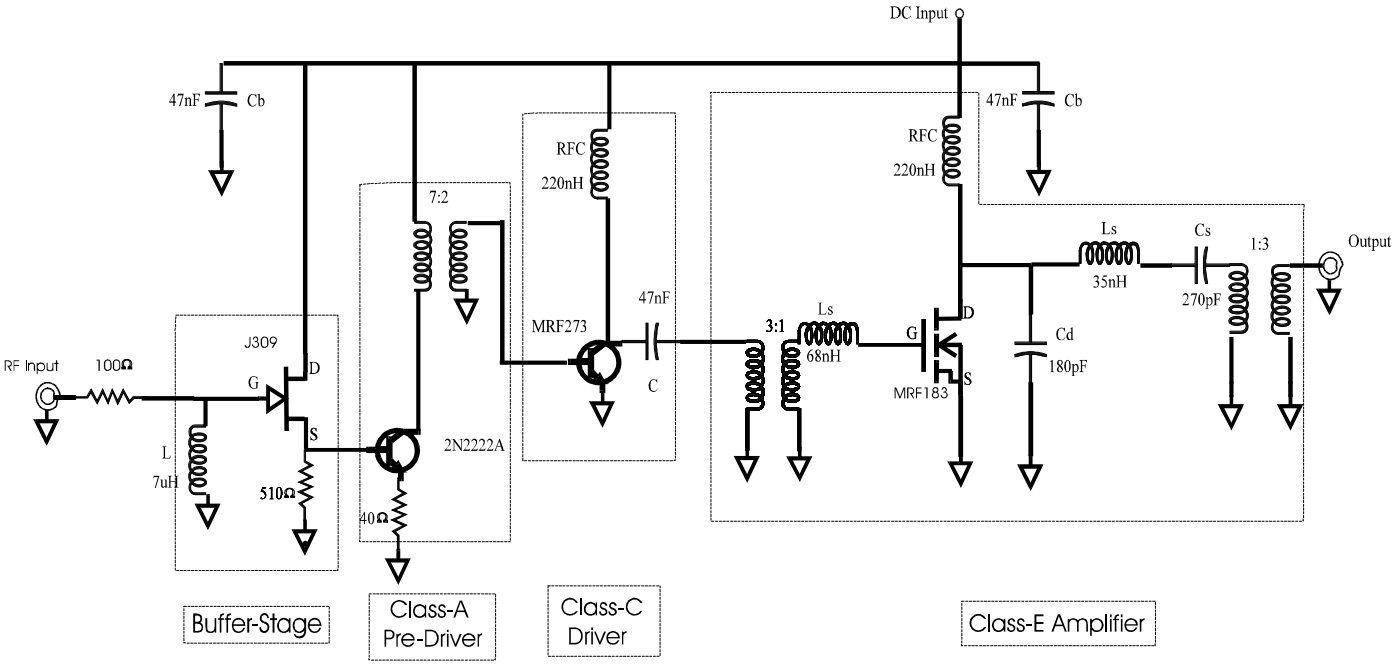
Class-E Operation

- First investigated by Dr. Gerald Ewing
- Developed and patented by Nathan and Alan Sokal in 1975
- Transistor functions in switch mode
  - voltage is low with the transistor on
  - current is low with the transistor off
  - resonant output network returns voltage to zero before transistor turn-on
  - ideal efficiency is 100%; practical efficiencies of 90%+ are attainable

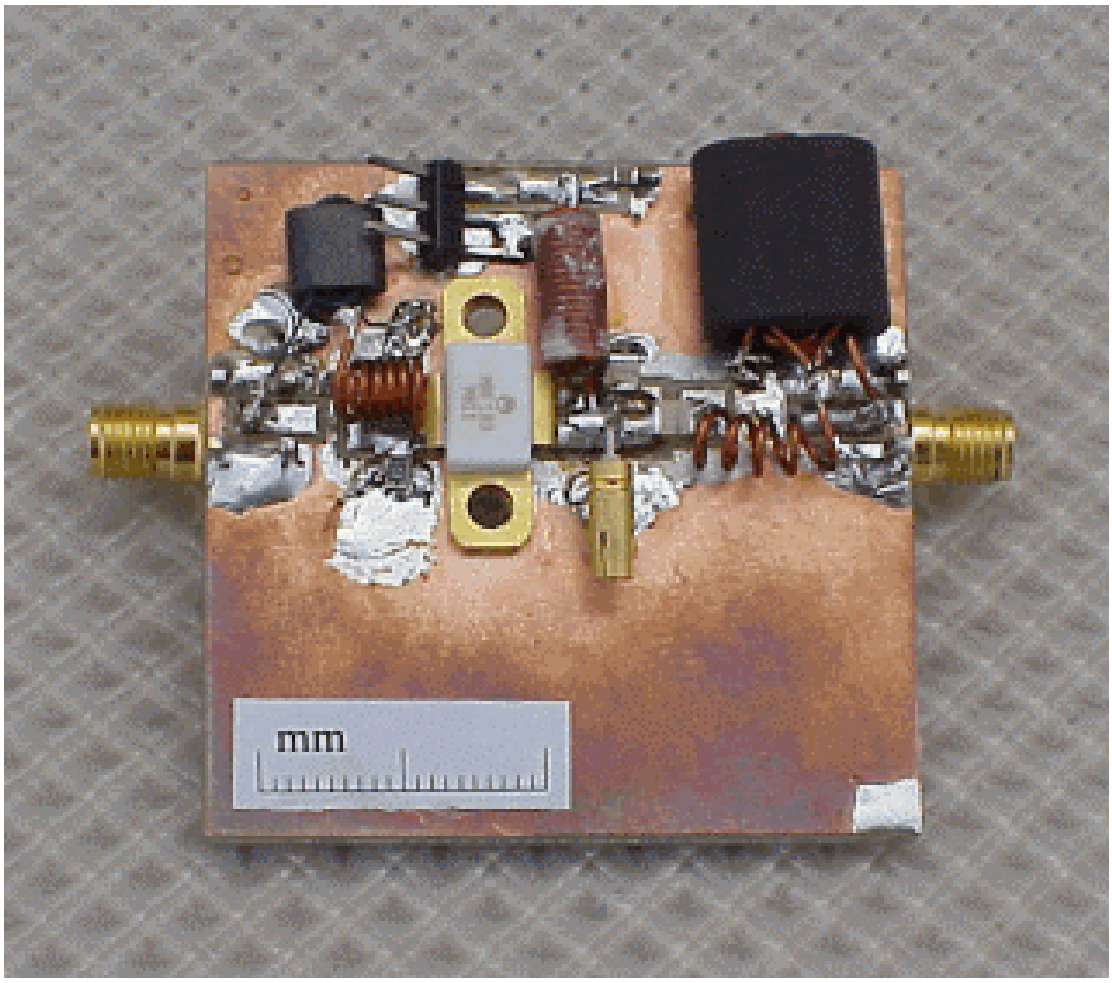
Class-E amplifiers are efficient amplifiers

Circuit Configuration

Buffer + Class-A Pre-driver + Class-C Driver + Class-E Amplifier



50 MHz Amplifier
Class-E Final Stage



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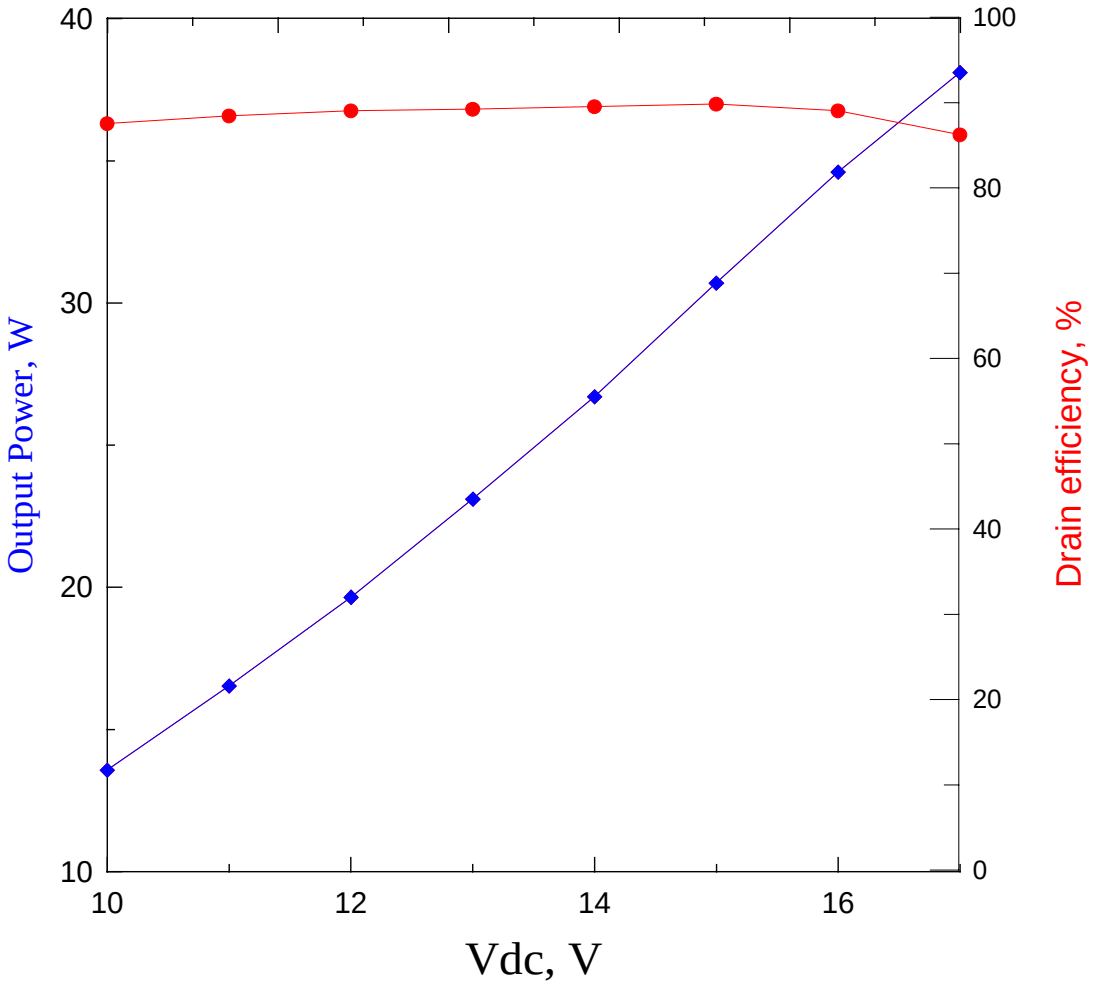
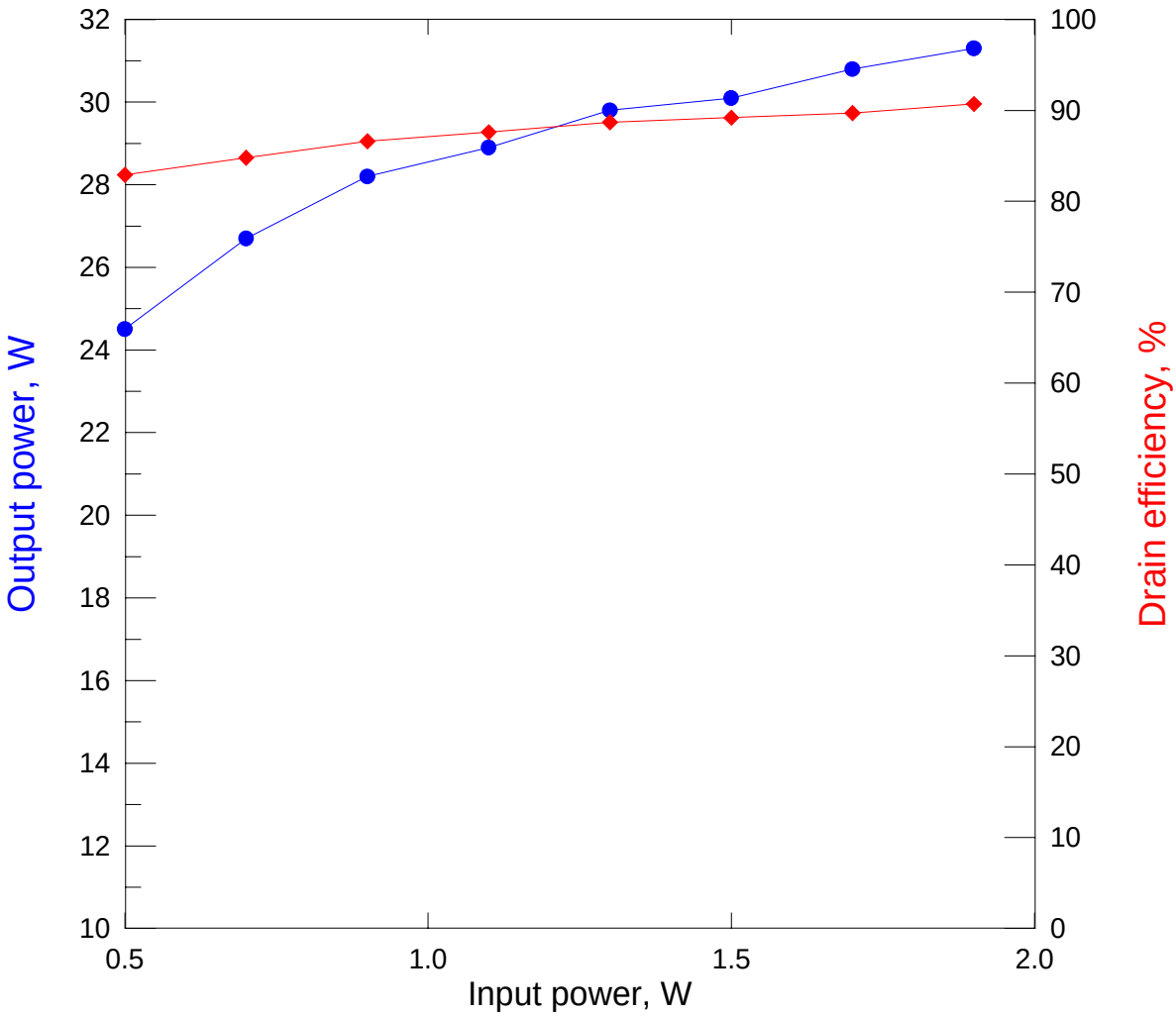
Output Power and Drain Efficiency
vs.
DC Voltage Supply

Pin = 1.57W , SWR = 1.1



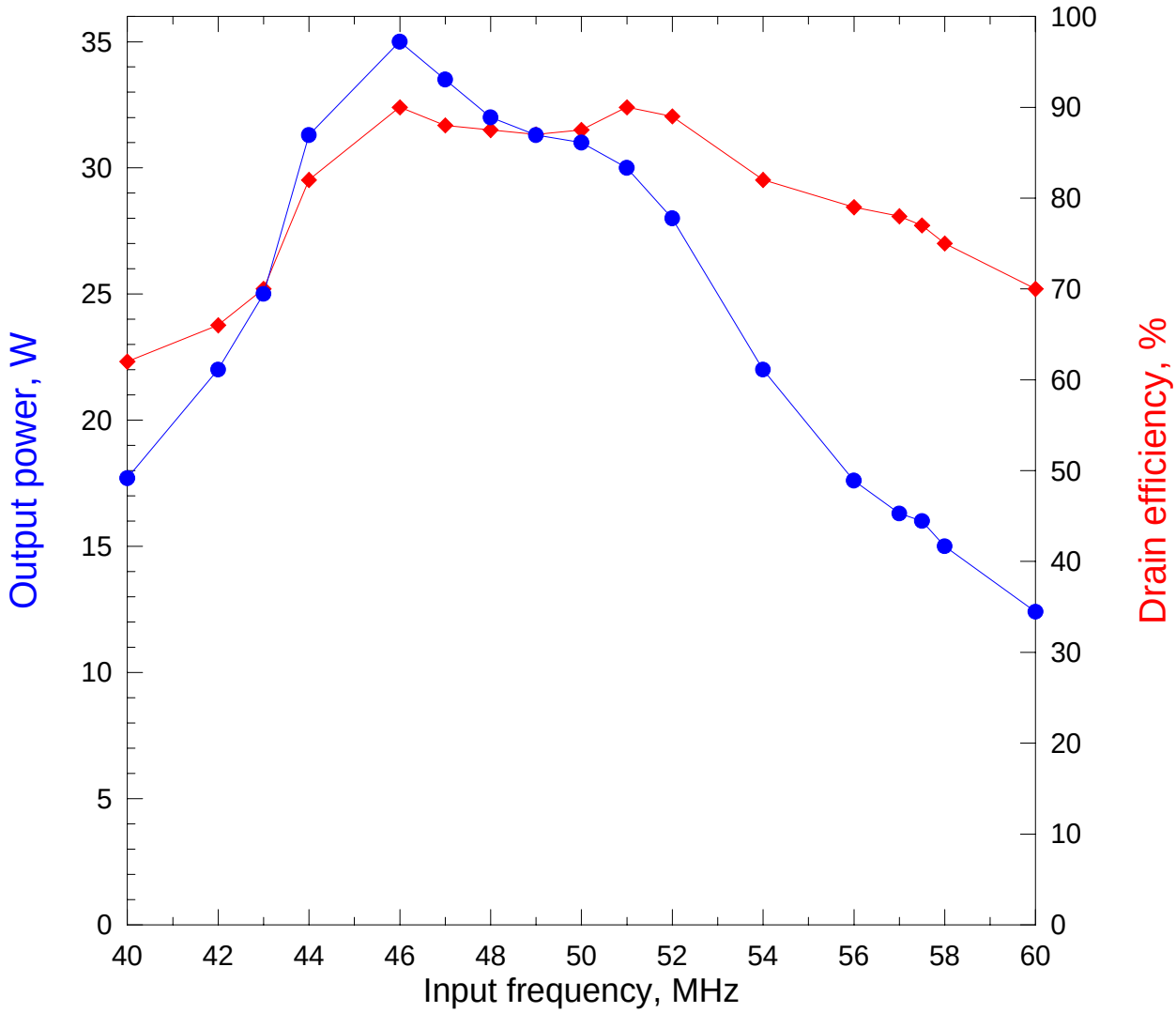
Output Power and Drain Efficiency vs. RF Input Power

Vdc = 15V , SWR = 1.1



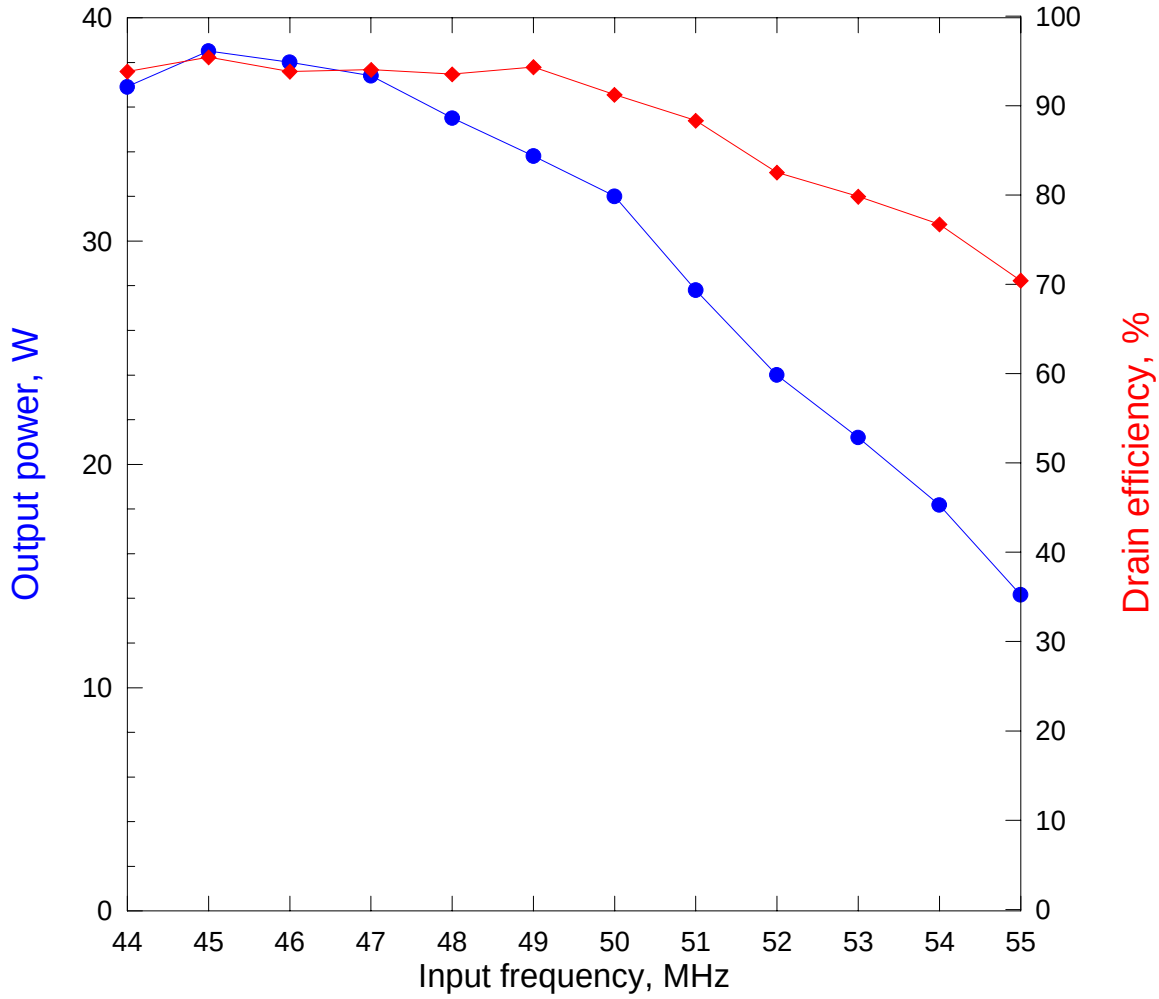
Output Power and Drain Efficiency vs. Input Signal Frequency

Vdc=15V



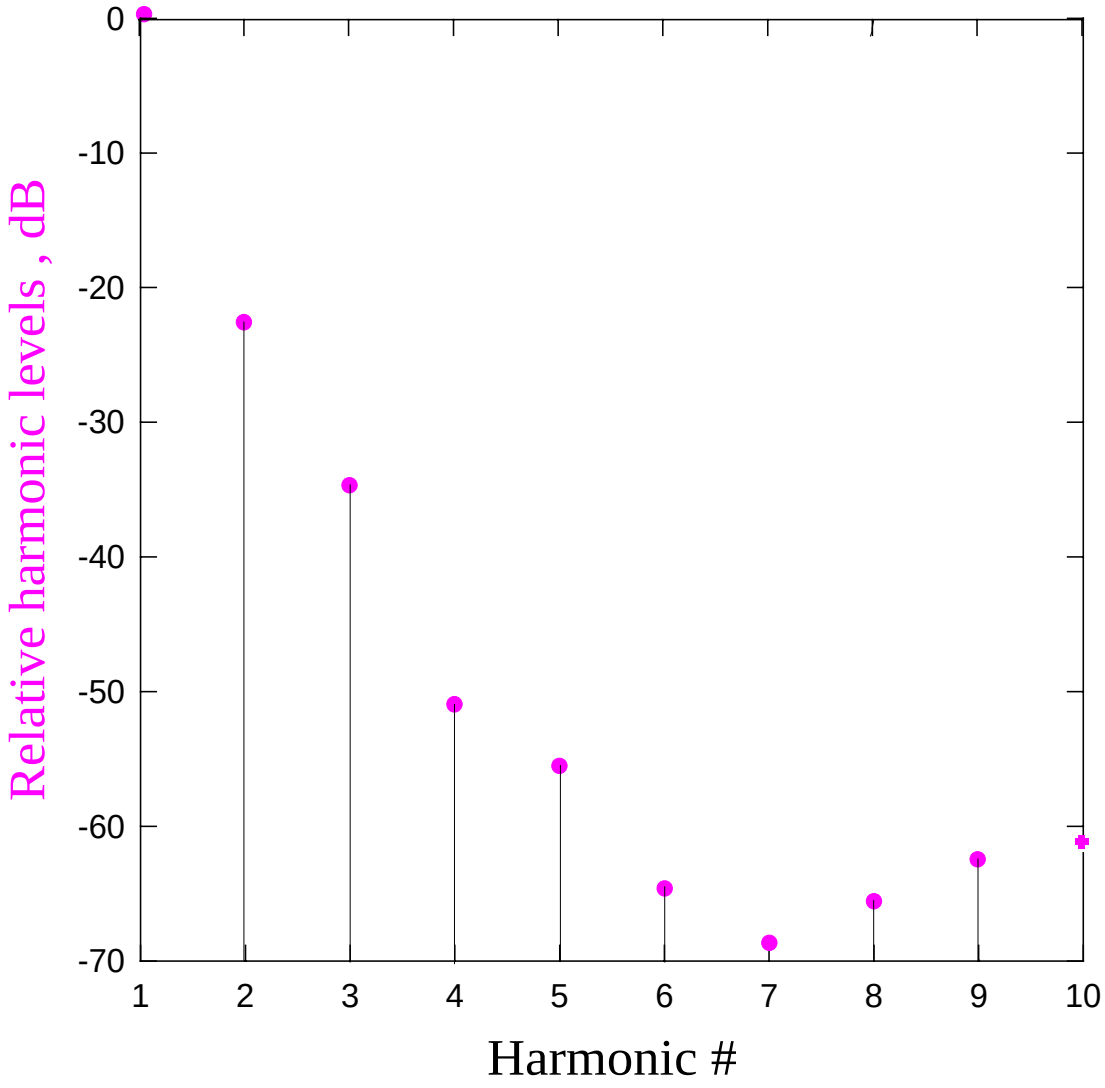
Output Power and Drain Efficiency vs. Input Signal Frequency for Entire Chain

Vdc=15V, P_{in}=0dBm

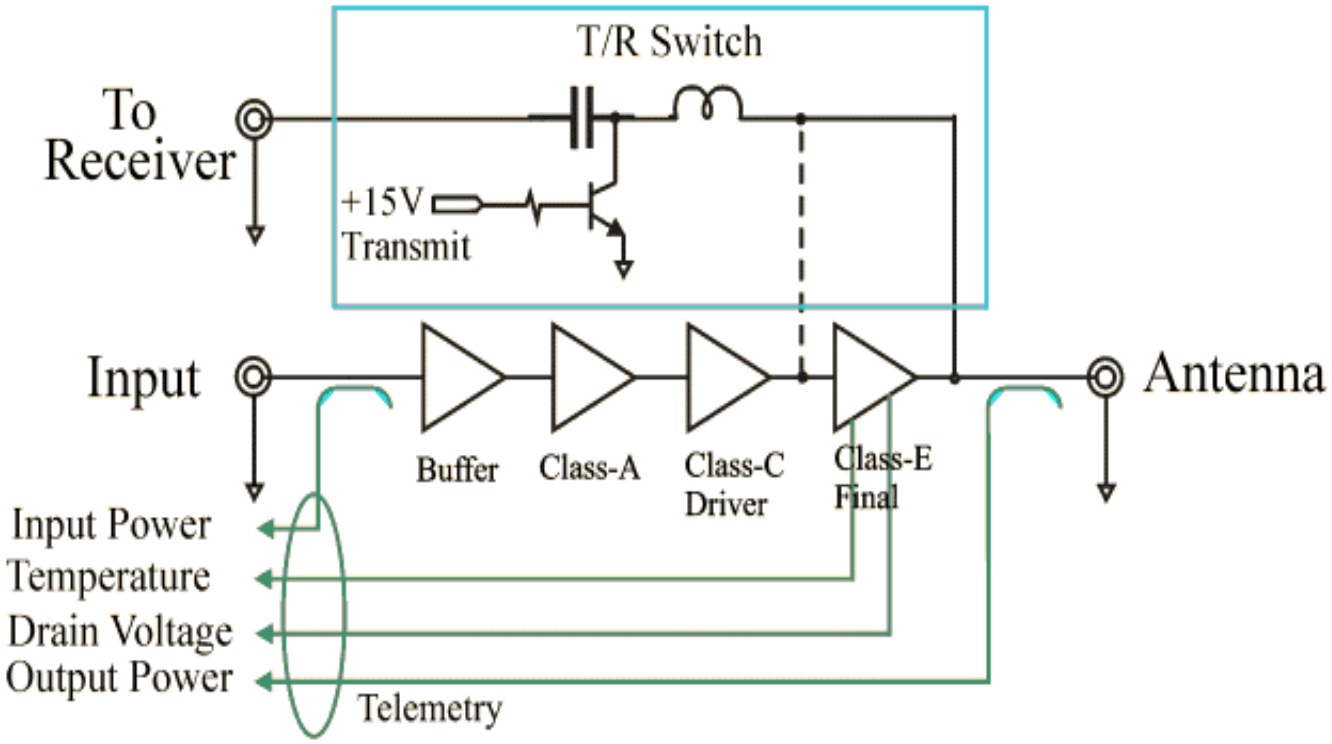


Harmonic Levels
for Entire Chain

Pin= 0dBm



Class-E Amplifier Block Diagram



Amplifier Chain Performance Summary

- **DC input**

Vdc	15 V
Idc	2.2 A

- **Power Data**

Pin	0dBm
Pout	30W
Power Gain	45dB
Drain Efficiency	90 %

- **Frequency Range**

Center frequency	50MHz
3dB bandwidth	10MHz