

# TRANSMITTER ARCHITECTURES FOR HIGH EFFICIENCY AMPLIFICATION

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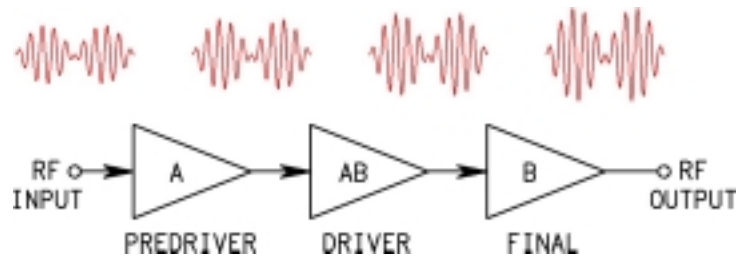
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1. INTRODUCTION
2. AVERAGE EFFICIENCY
3. ARCHITECTURES FOR MODULATION
4. ARCHITECTURES FOR DYNAMIC RANGE

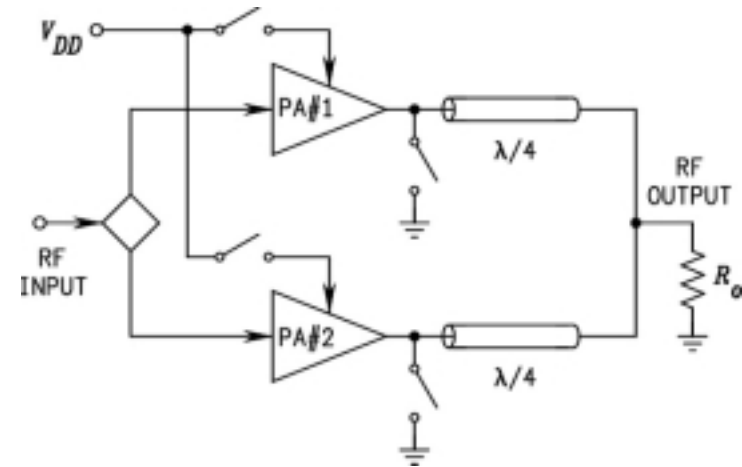


# TRANSMITTER ARCHITECTURES

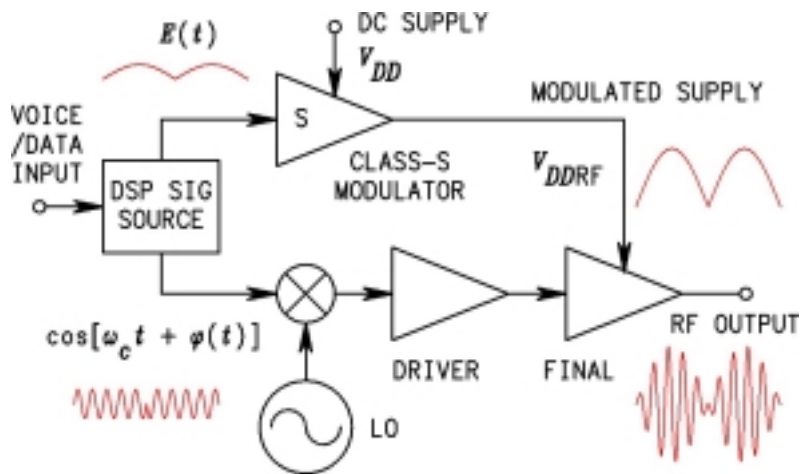
## LINEAR



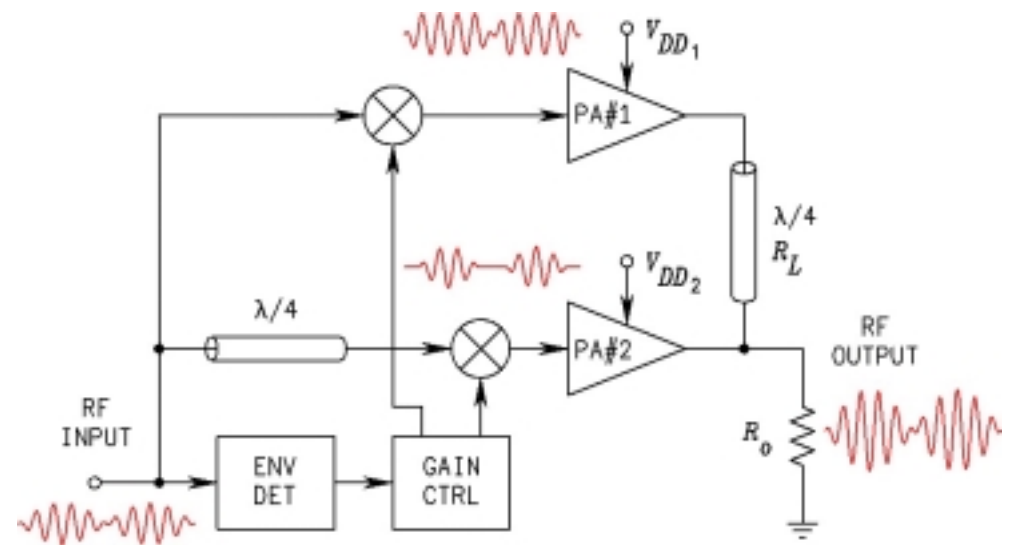
## LOAD SWITCHING



## KAHN

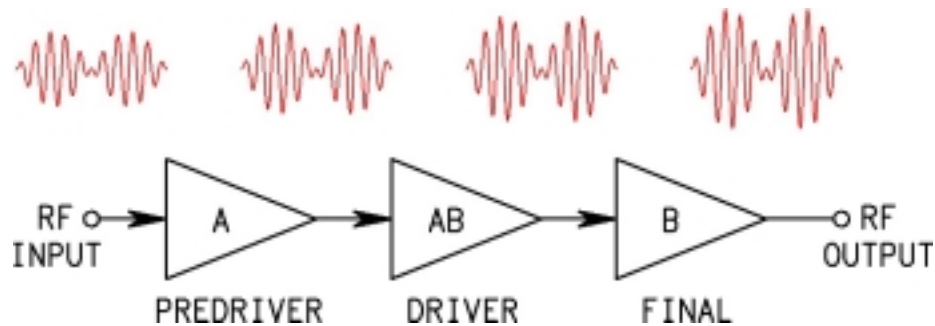


## DOHERTY

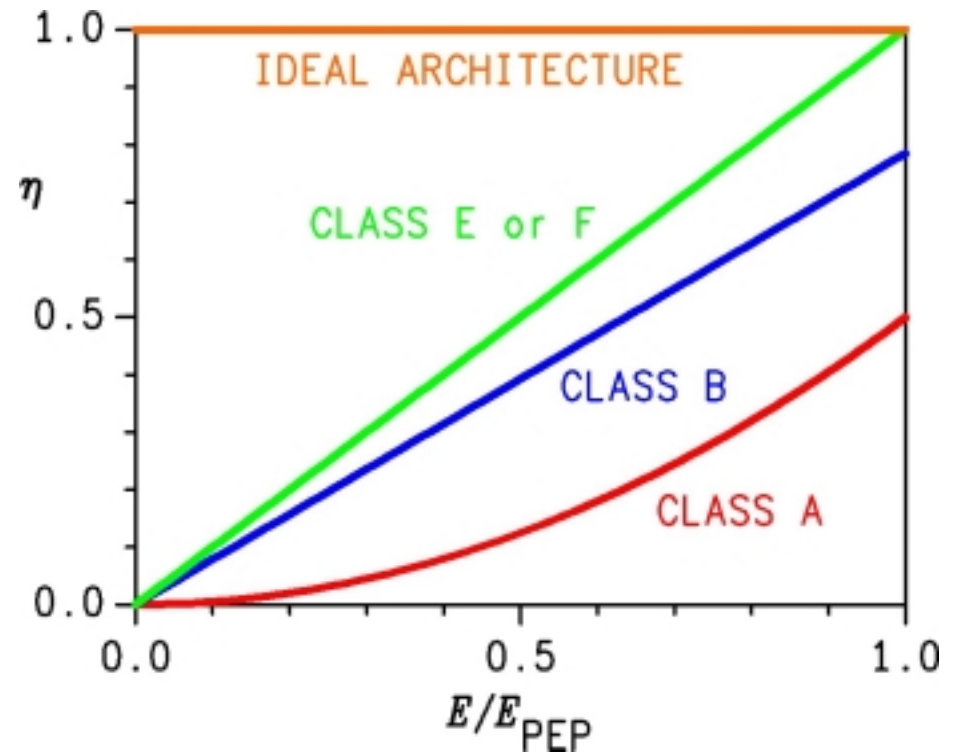


# LINEAR RF-POWER AMPLIFIERS

## LINEAR-AMPLIFIER CHAIN

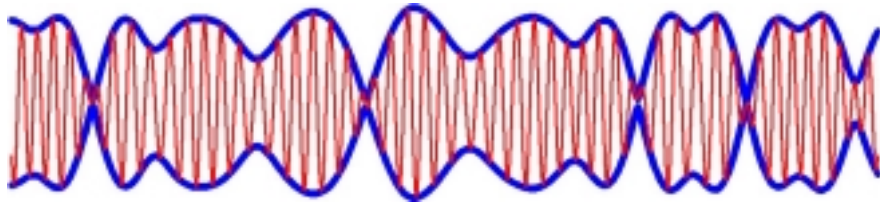


## INSTANTANEOUS EFFICIENCY

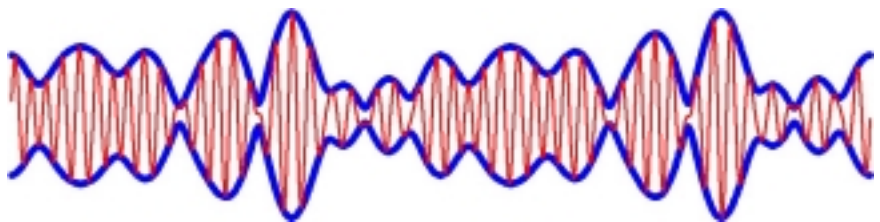


# MODERN COMMUNICATION SIGNALS

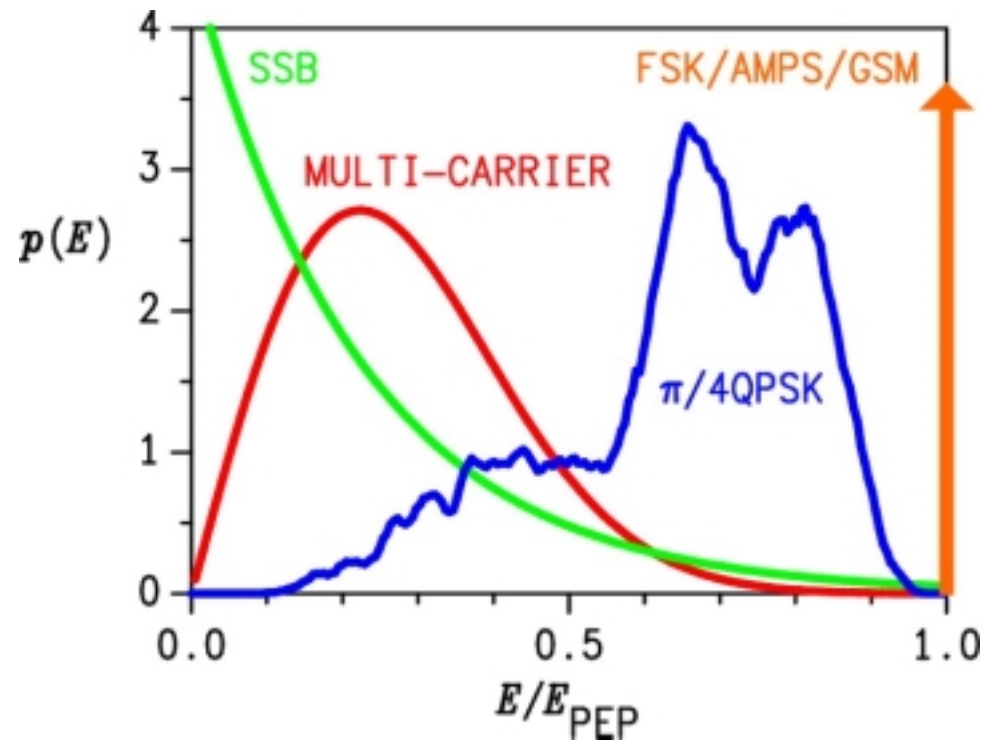
## SRRC



## OFDM



## ENVELOPE PDF

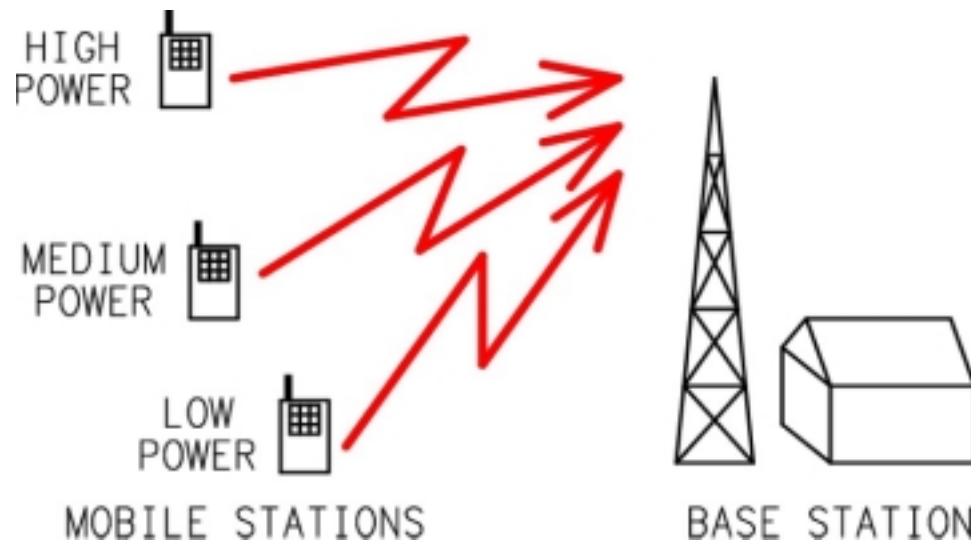


- Low amplitudes more likely

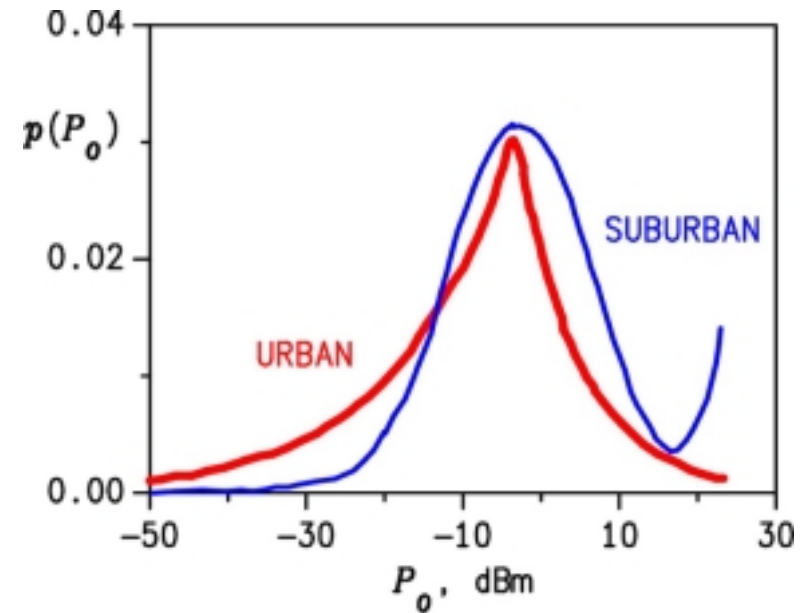
- Low average efficiency

# DYNAMIC POWER RANGE

## MOBILE-BASE GEOMETRY



## PDF OF PEP OUTPUT



- Use minimum power

- Wide range of PEP output

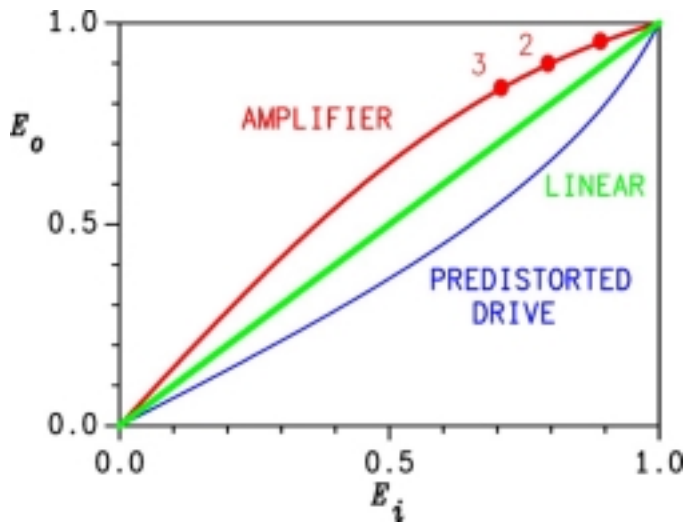
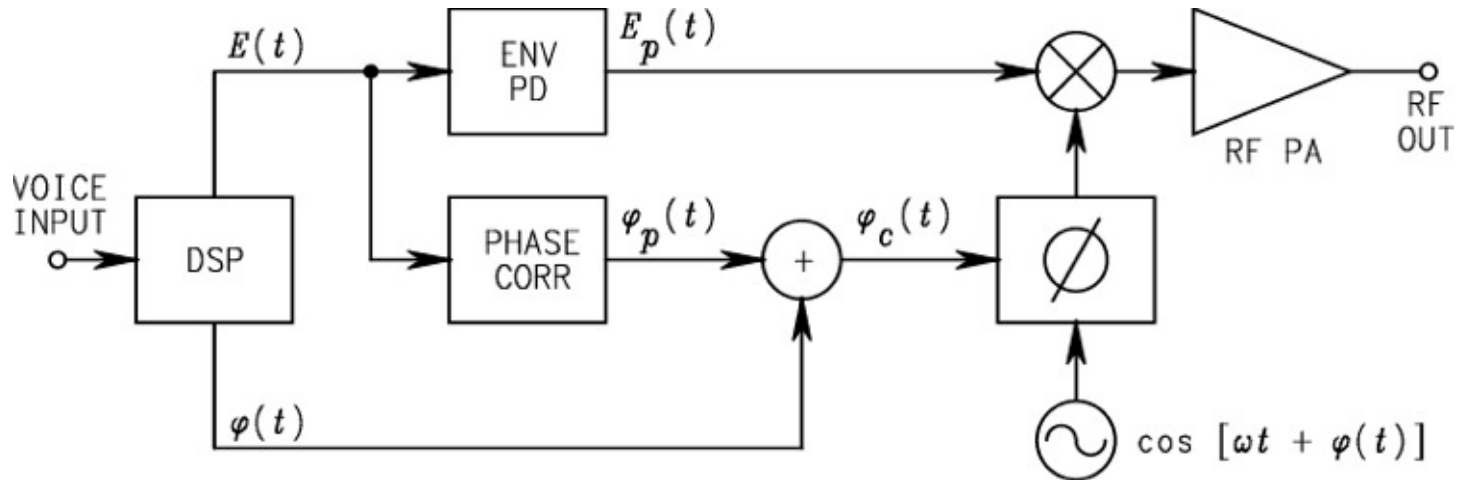
# ARCHITECTURES - TWO CATEGORIES

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1. HIGH EFFICIENCY OVER  
MODULATION ENVELOPE

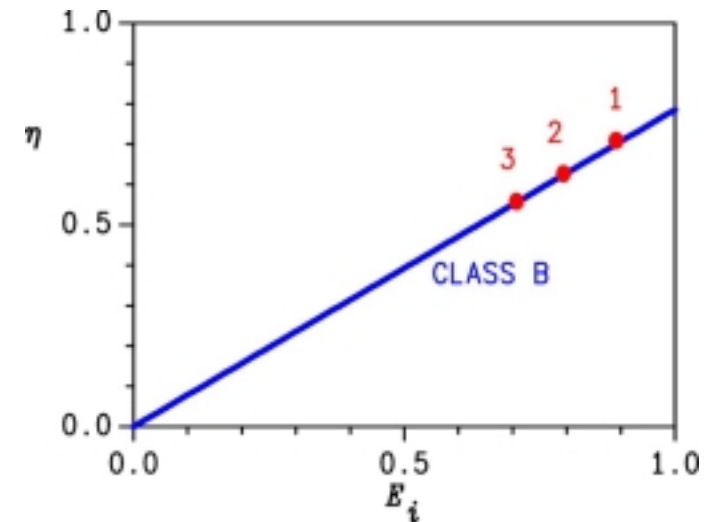
2. HIGH EFFICIENCY  
OVER DYNAMIC RANGE

# PREDISTORTION



Nonlinearity

- Backoff
- Reduced  $\eta$

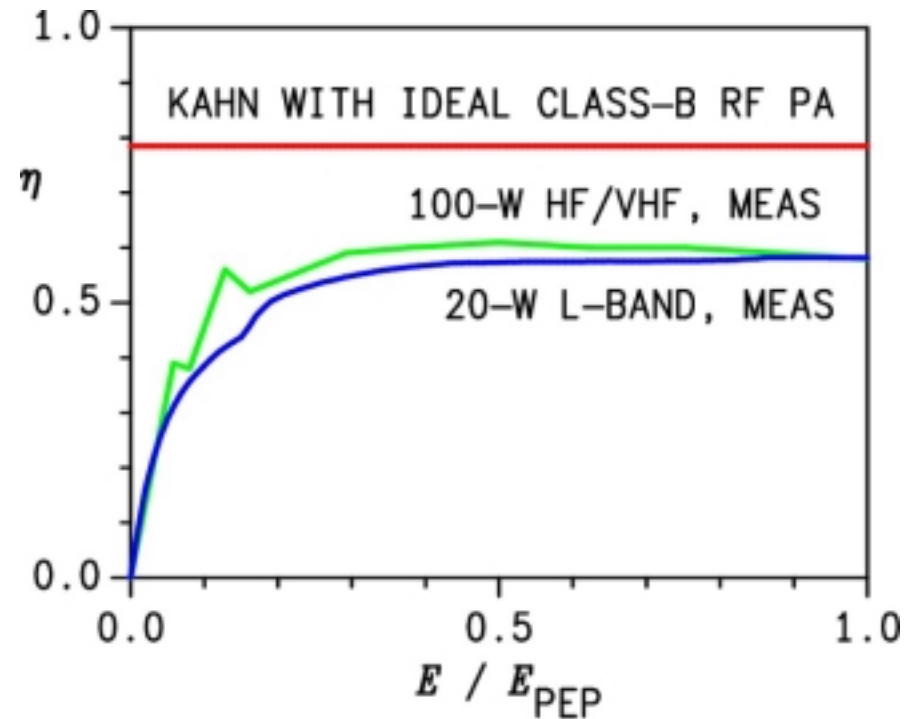
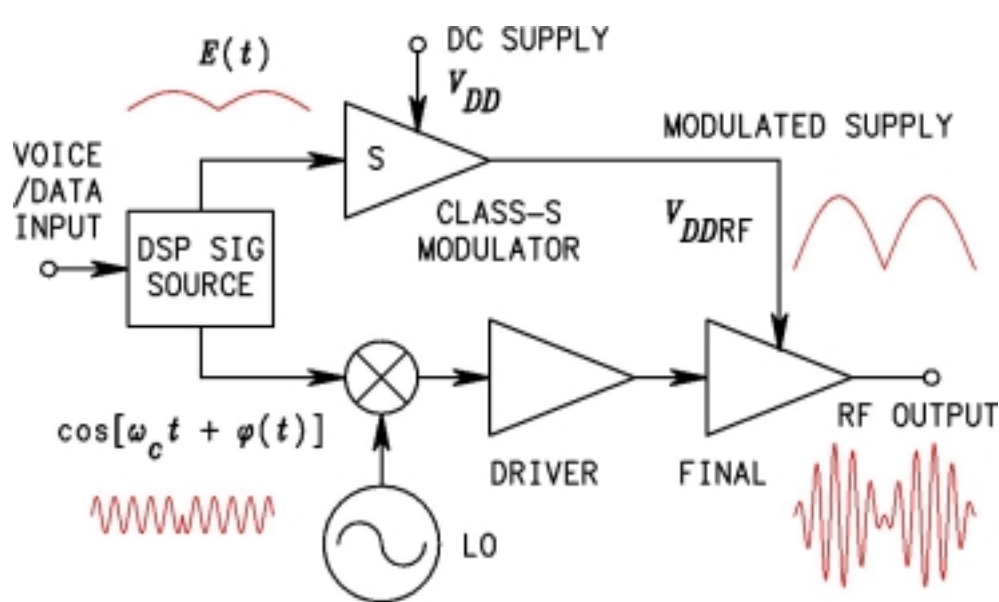


Predistortion

- Eliminates nonlinearity
- PEP efficiency



# KAHN TECHNIQUE



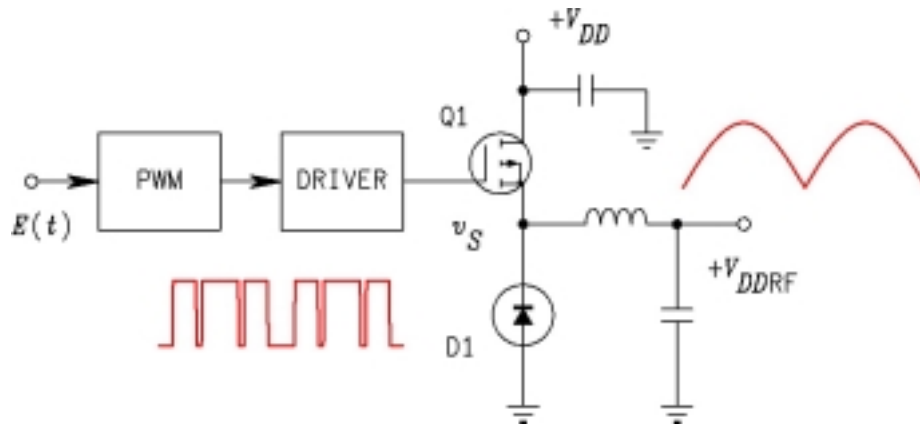
- High-efficiency linear transmitter
- RF signal: Simultaneous AM,  $\Phi$ M

- Saturated RF PA
- High-level AM
- Average efficiency 3 to 5 times class B



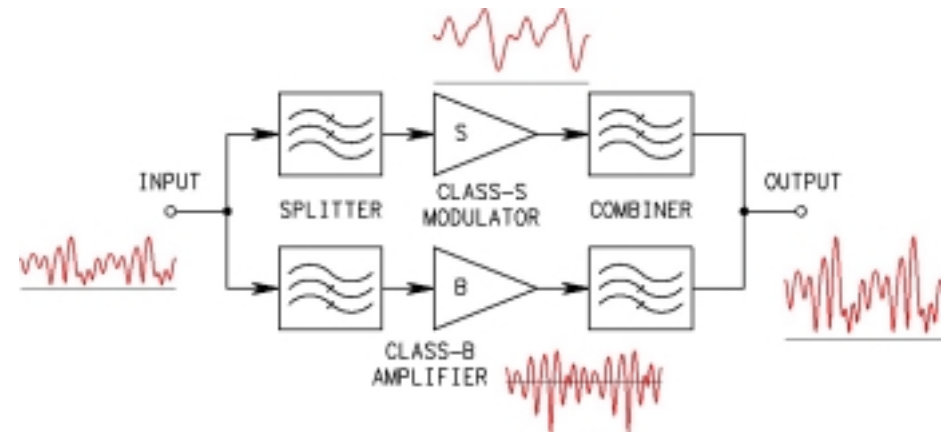
# MODULATORS FOR KAHN TECHNIQUE

## CLASS S



- Q1-D1 = SPDT switch
- Efficiency > 90%
- Wide dynamic range
- $f_s > 6-7 B_{RF}$

## SPLIT BAND



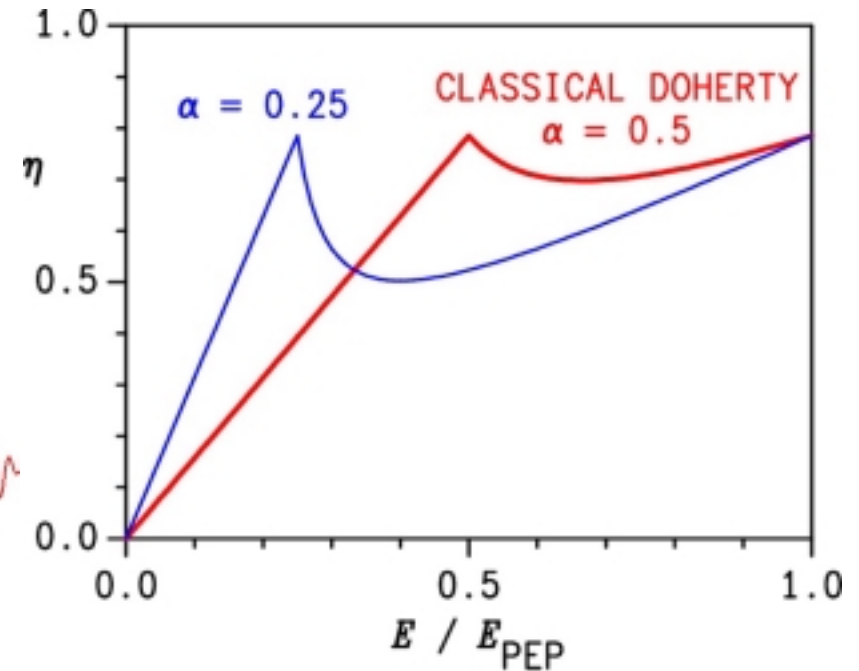
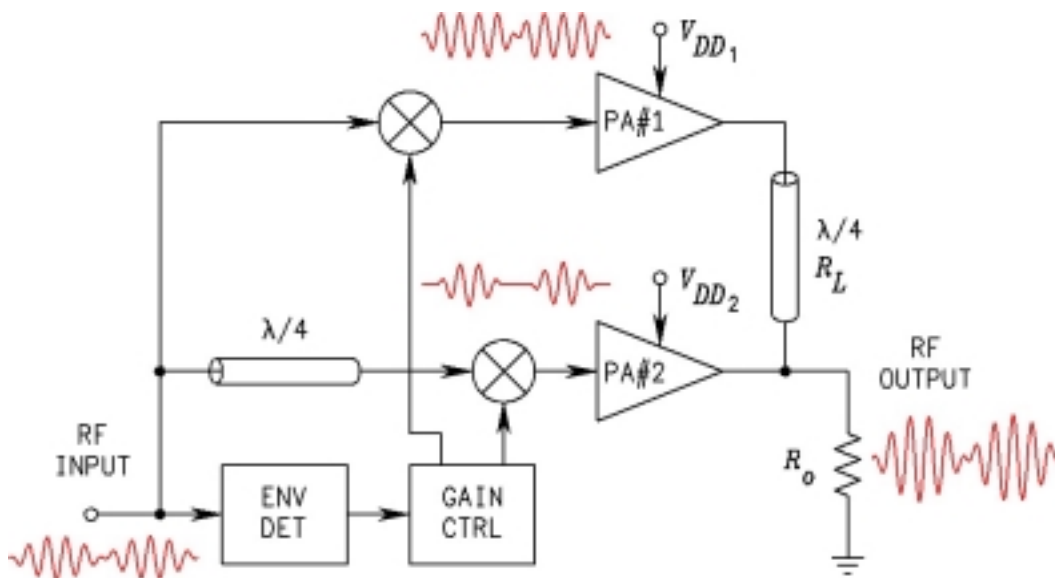
### LF COMPONENTS

- Most of power
- Amplify efficiently – class S

### HF COMPONENTS

- Amplify linearly – class B

# DOHERTY TRANSMITTER



## LOW AMPLITUDES

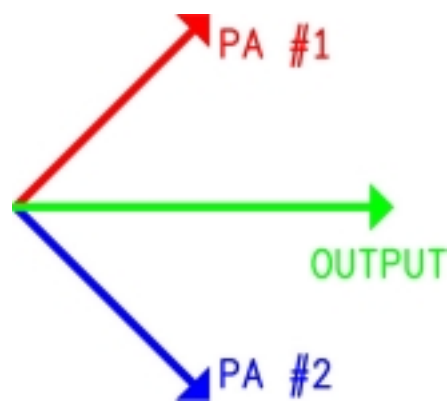
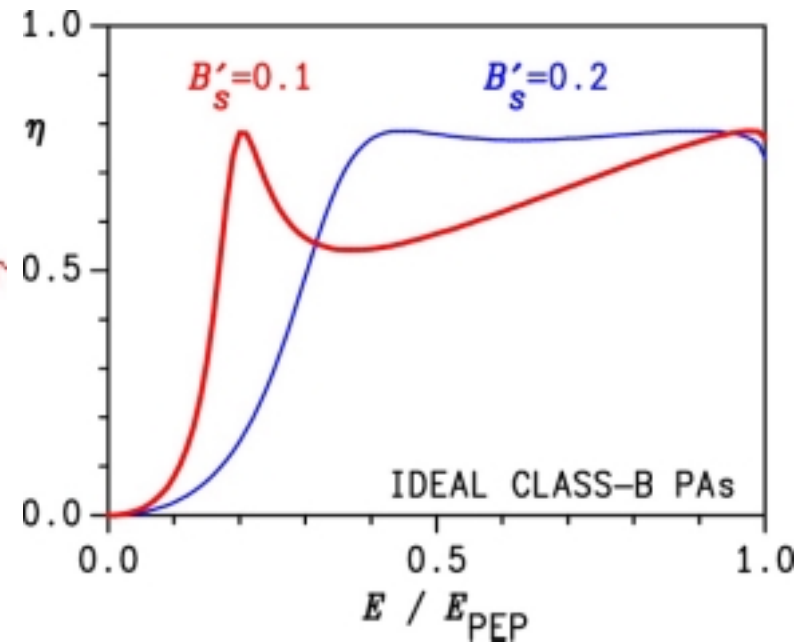
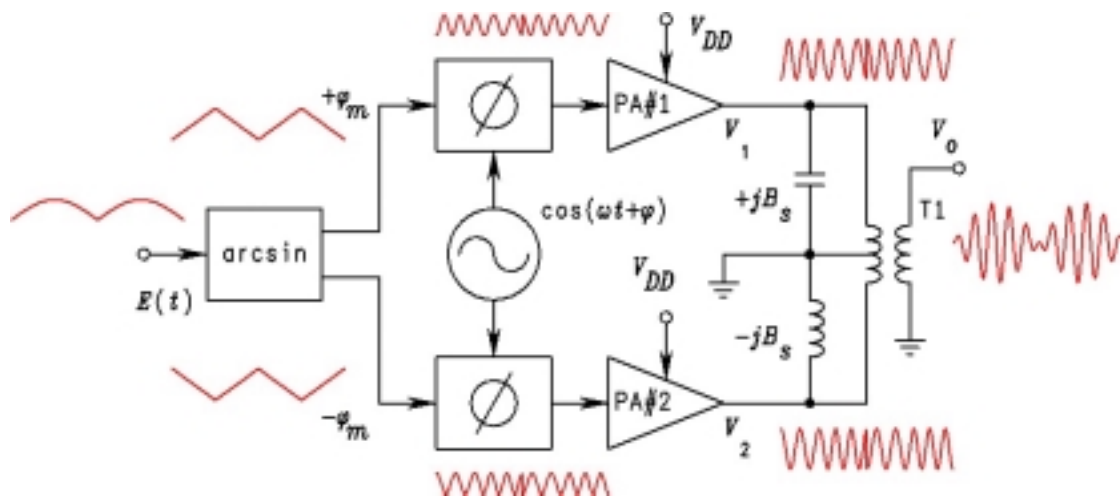
- PA #1 linear
- PA #2 off

## HIGH AMPLITUDES

- PA #2 active
- PA #1 saturated  
variable load

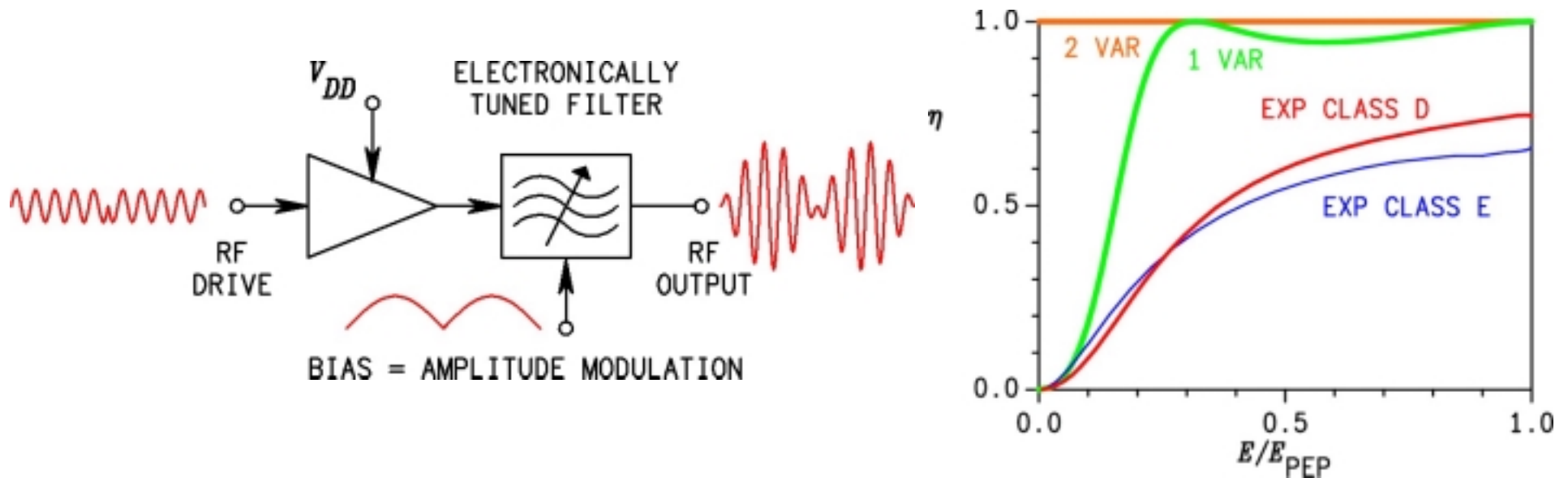


# CHIREIX OUTPHASING TRANSMITTER



- Vary phases in opposite directions
- PAs saturated
- Sum -> desired amplitude
- Tune-out load reactance mid range
- Wide bandwidth - limited by phase modulator

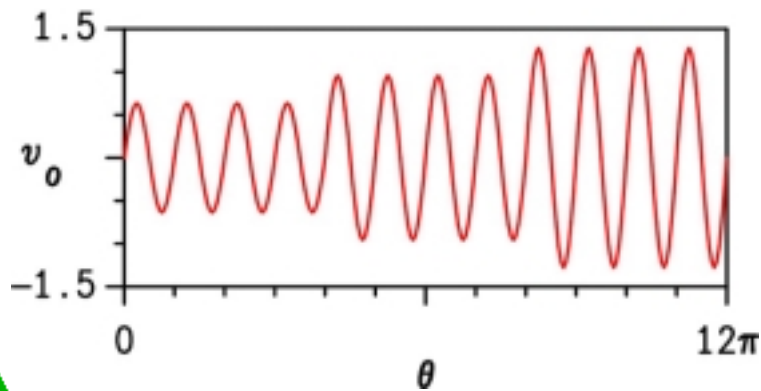
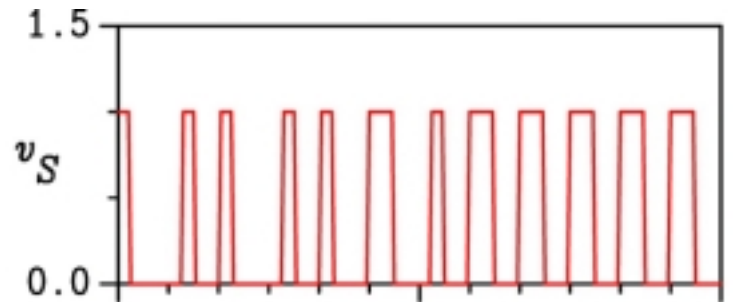
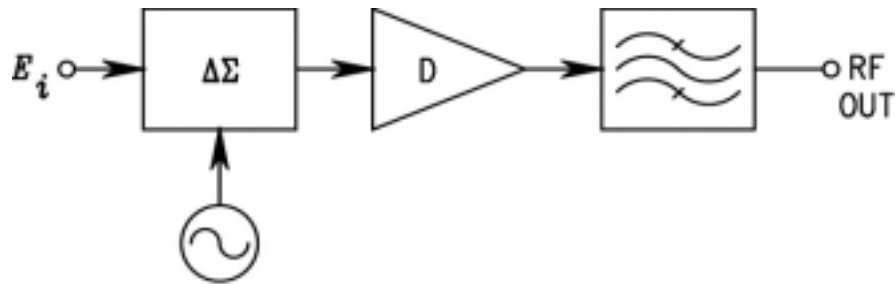
# LOAD MODULATION



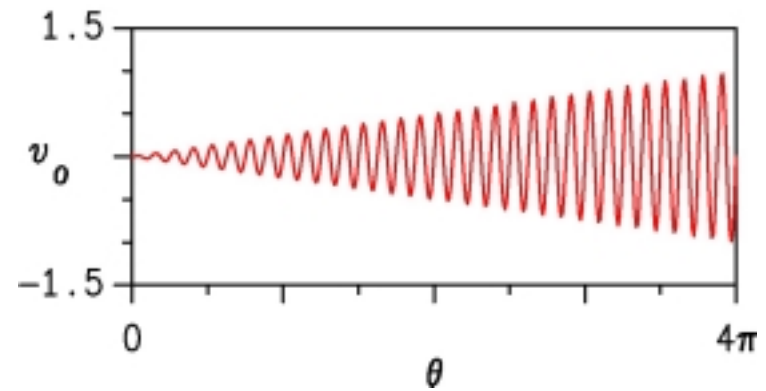
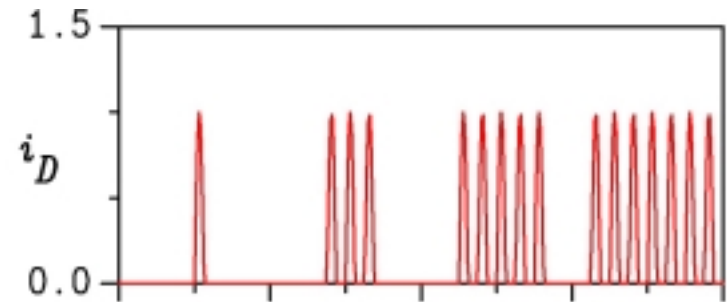
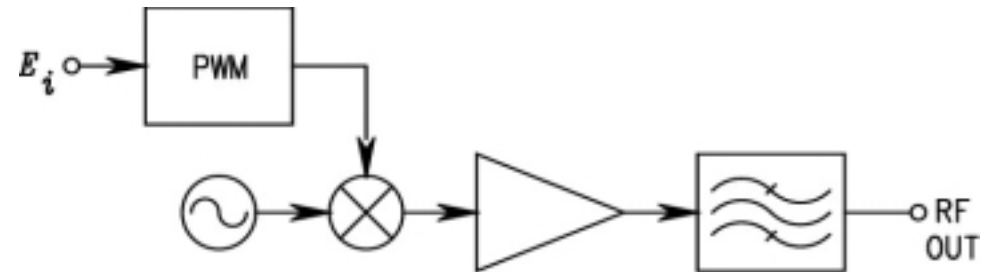
- Vary bias(es) of electronically tuned filter
- Variable load impedance to power amplifier
- Variable output power and amplitude
- Phase information in drive signal
- Wide bandwidth – limited only by bias feed/modulator

# RF PULSE-WIDTH MODULATION

## DELTA-SIGMA RF PWM



## CARRIER PWM



# ARCHITECTURES - TWO CATEGORIES

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MODULATION ENVELOPE

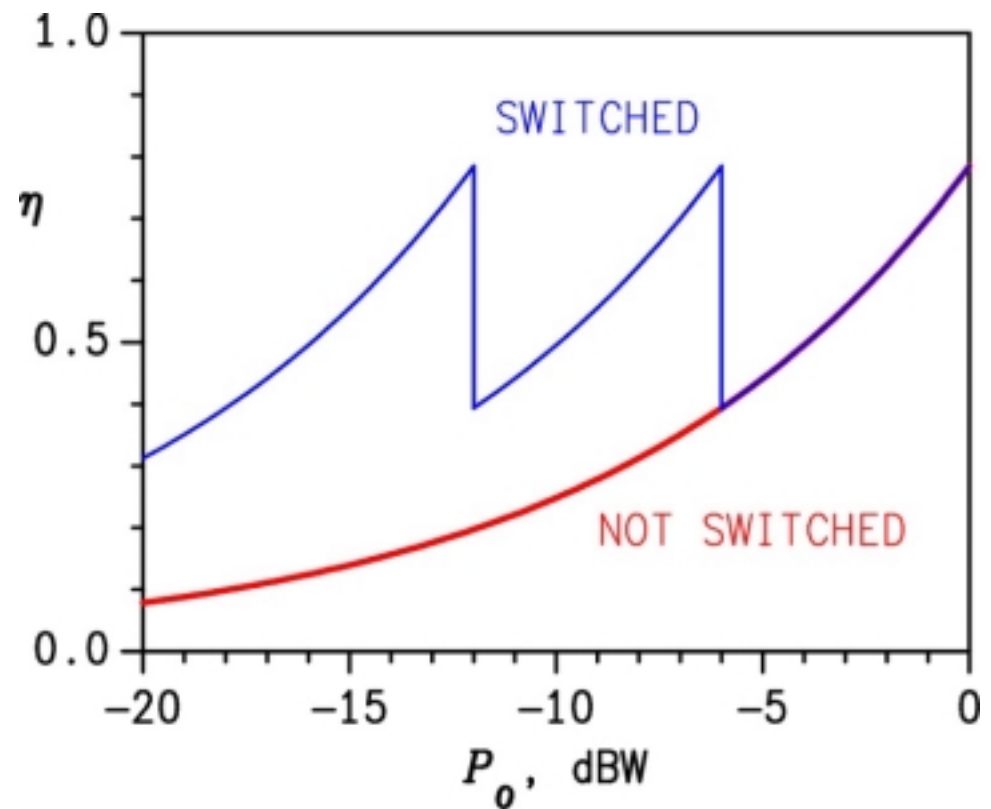
2. HIGH EFFICIENCY  
OVER DYNAMIC RANGE

# EFFICIENCY OVER DYNAMIC RANGE

## CHARACTERISTICS

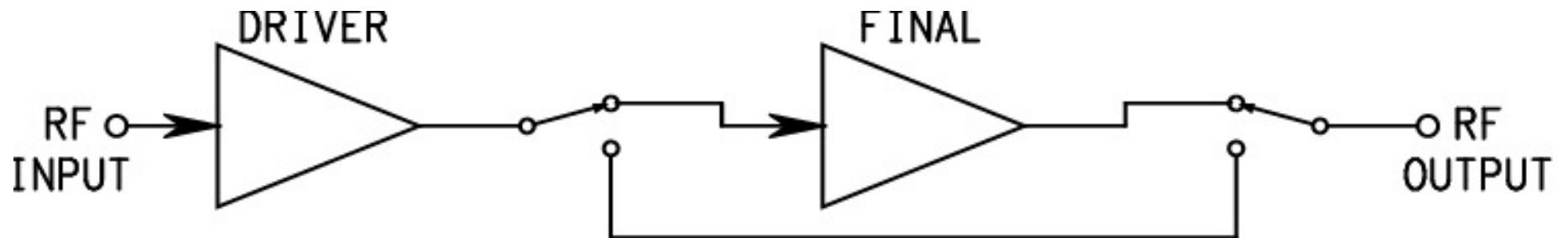
- Mobile transmitters
- Wide range of power
- Mostly switched
- Follows PEP, not envelope

## PEP EFFICIENCY (TYPICAL)



# STAGE BYPASSING

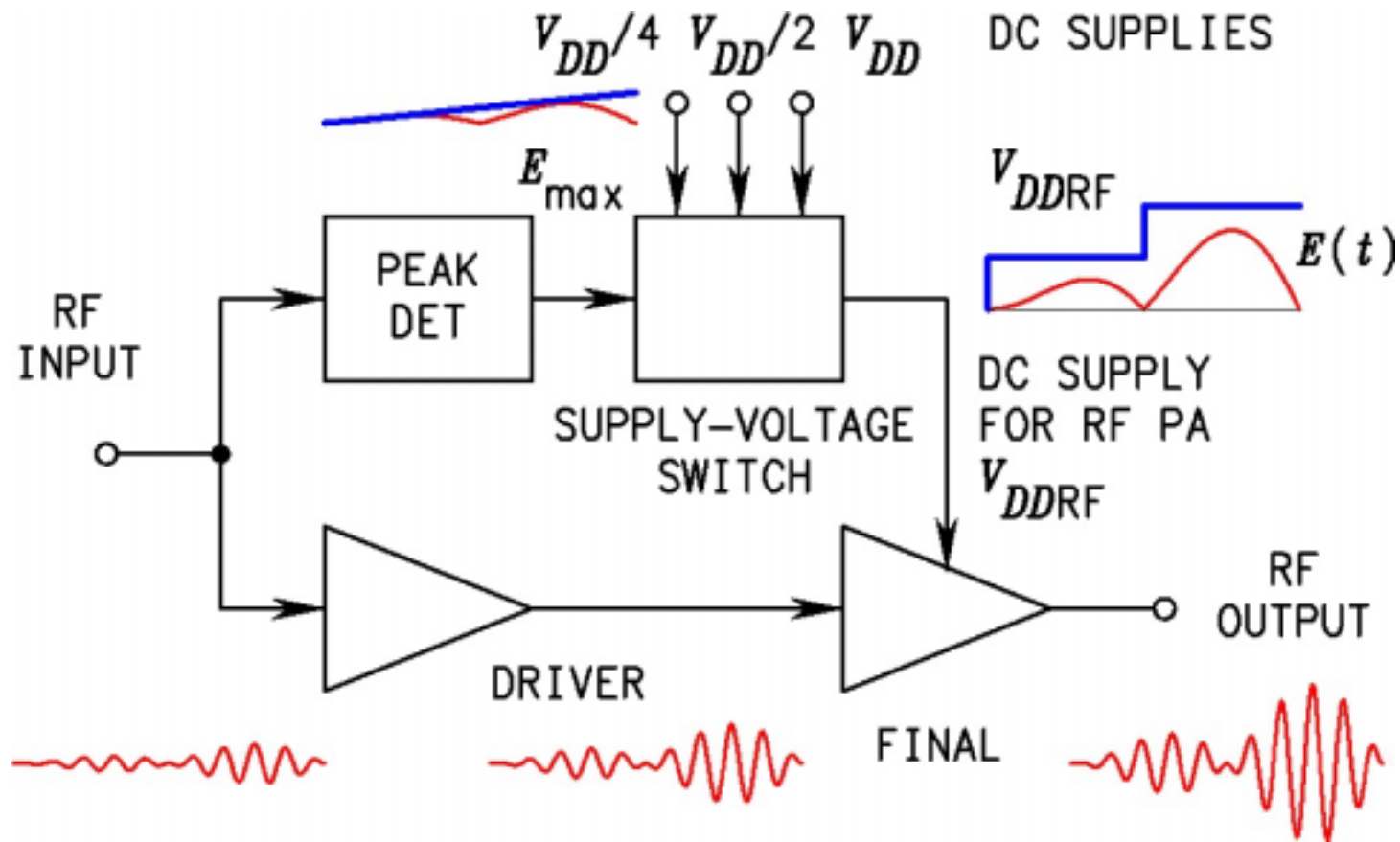
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- LOW OUTPUT: Use driver
- HIGH OUTPUT: Use final

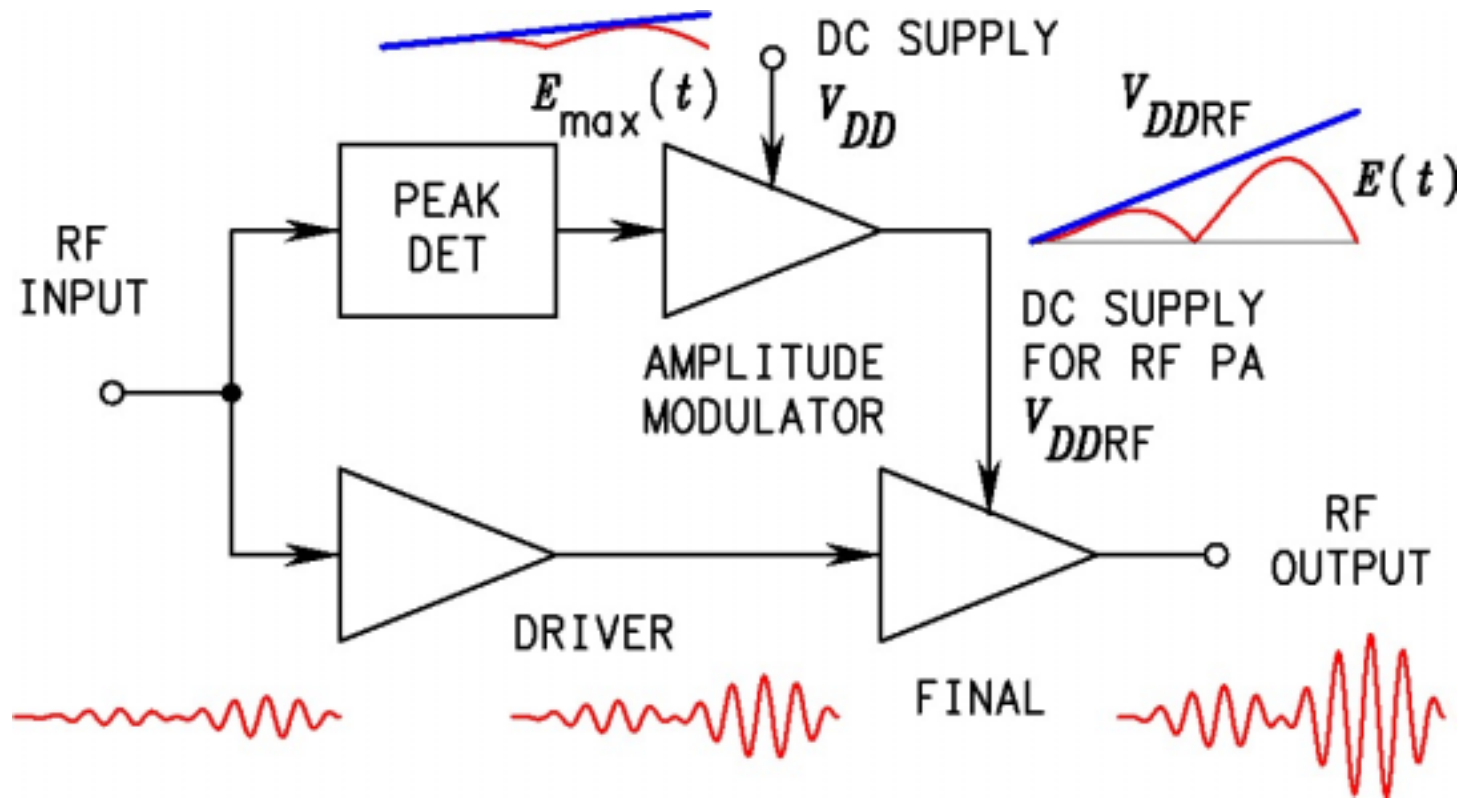


# ENVELOPE TRACKING - DISCRETE



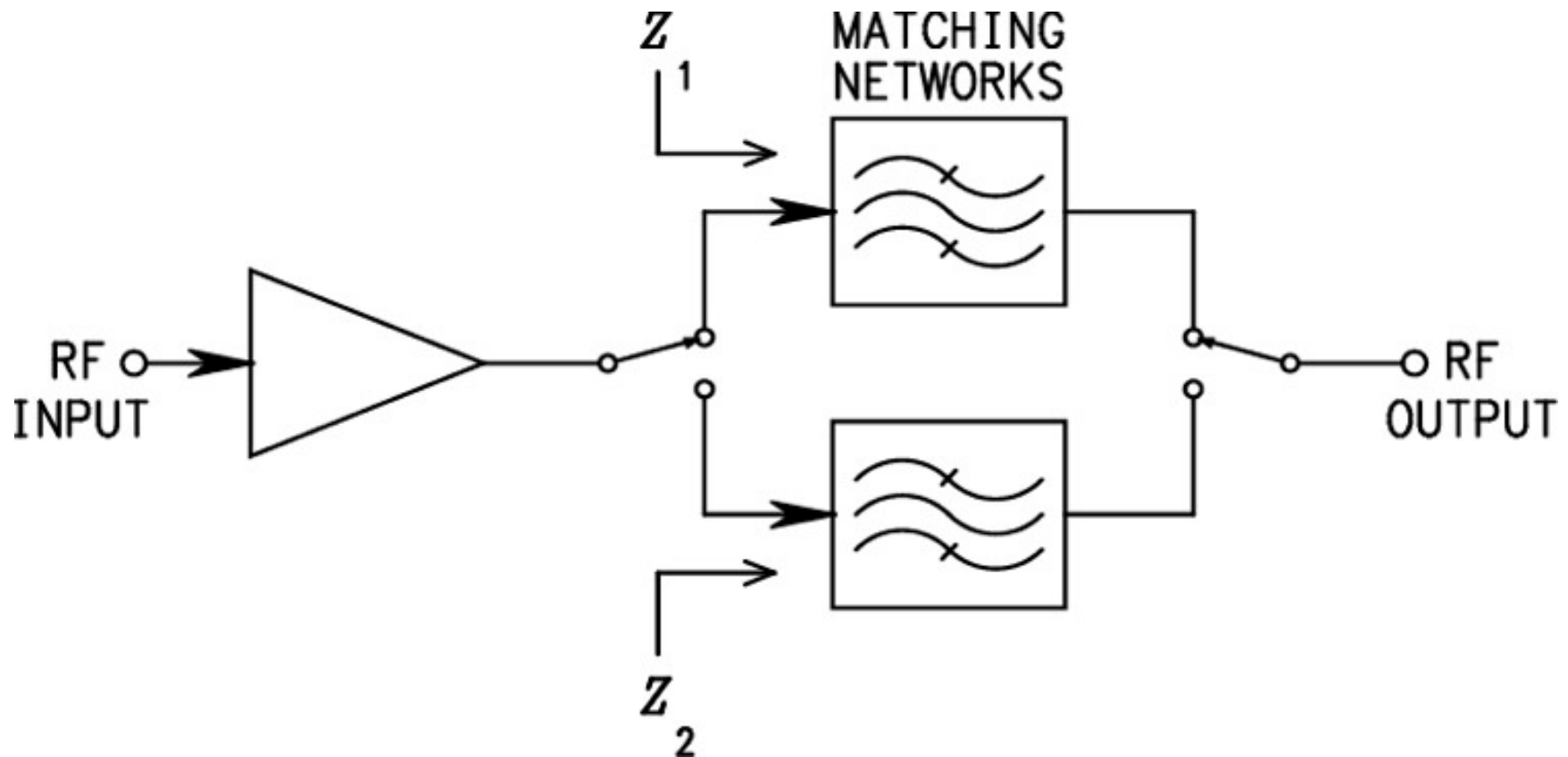
- RF PA: Linear
- Select minimum supply voltage for linear operation
- May cause detuning (mismatch)

# ENVELOPE TRACKING - CONTINUOUS



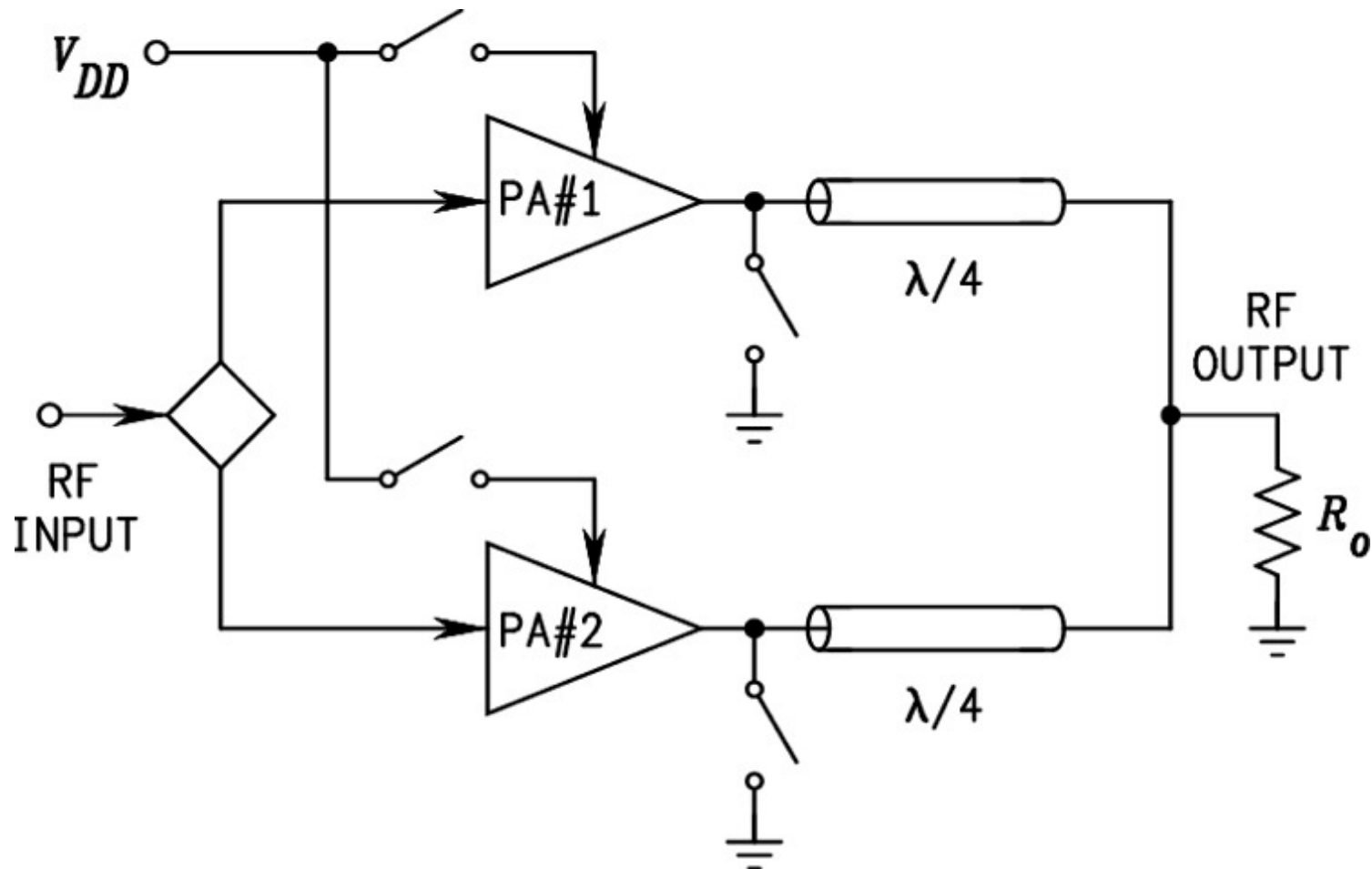
- RF PA: Linear
- Supply voltage = minimum + headroom
- May cause detuning (mismatch)
- Often minimum voltage (boost converter)

# LOAD-IMPEDANCE SWITCHING



- High impedance  $\rightarrow$  low power
- Low impedance  $\rightarrow$  high power
- Matched both cases

# MULTIPLE SWITCHED PAs



- Number of PAs active  $\sim P_{oPEP}$
- Short PA output  $\rightarrow$  Decouple from output

# CONCLUSIONS

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Variety of techniques available.

Significant improvements in average efficiency.

Each has advantages and disadvantages.

Combinations possible.

Interesting research to be done.

What is old is sometimes new again.