Radio Frequency Amplifiers

an overview
Amplifiers – basic specifications

• Gain, bandwidth, noise figure, output power
• Power efficiency
Class A

Excellent Linearity
Low Distortion
Broad Bandwidth
Good Noise Figure
Medium Output Power Capability

Class A Disadvantages:

Poor Efficiency (Heat Dissipated)
Larger Size than Class C

Applications:

IF and Low Noise Amplifiers
(and plenty of specialised applications)

Class A amplifiers have a fixed forward bias.

Base current, \( I_b \), and collector current, \( I_c \), flow over the full RF cycle.
In addition, when operated below compression, the RF signal swing is uniformly above and below the quiescent DC bias set point and well within the linear region of the transistor.
Class AB

Very high output power available
Compact size
Good linearity
Low distortion

Class AB Disadvantages:

Limited dynamic range (15-30dB)

Applications:

Transmitter output stages

Apply a small DC bias, Ib. The collector current with no RF drive is 1%-10% of the maximum design value.

As the input RF power is increased, the Ib is increased
Class C

Excellent Efficiency
Compact Size
Multikilowatt Pulse Output Power
Cool Operation
CW, FM, Phase and Pulse Amplification

Class C Disadvantages:

Poor Dynamic Range
Cannot Support AM Signals

Applications:
FM Amplifiers
Digital constant-envelope signals (FSK and variants)

Apply a zero DC bias, $I_b$. The collector current with no RF drive is 0% of the maximum design value.

The full RF carrier waveform is recovered through filtering in the matching network.
Class summary
Amplifier Efficiency

• The primary consideration is to produce an amplifier that does the job well. An important secondary condition is to do the job efficiently, which keeps the temperature down, and therefore, increases reliability.

• Efficiency = RF Forward Power Output / DC Power Input

• **Class AB & C CW (continuous wave) Amplifiers**
  – DC input power is at the maximum level when rated RF drive is applied and at an idle level when RF drive is removed.

• **Class A Amplifiers**
  – Power added efficiency is usually specified at the 1 dB compression point. DC input power is continuous at all input levels (except saturation).
Amplifier Cooling

- Cooling can be accomplished in a number of ways:
  
  - **Conduction** - The amplifier baseplate is mounted to the heatsink. The heatsink must be designed such that the maximum specified baseplate temperature is not exceeded, normally about 70°C.

  - **Convection** - The amplifier contains a very large finned heatsink. The surface area is large enough to dissipate the heat in a still air environment.

  - **Forced Air** - Cooling air is directed through a finned heatsink in the amplifier.

  - **Liquid** - The cooling fluid is pumped through a chill plate in the amplifier. The cooling heat exchanger is external to the amplifier.
Amplifier Cooling
Big Power Amplifiers

- 150 kW linear amplifier
- Combines 128 650W amplifiers
- Water cooled
Amplifier Linearity – the third order intercept point (IP)

- 3\textsuperscript{rd} order intermodulation is caused by non-linearity
  - E.g. two tones $f_1$ and $f_2$ will create 3\textsuperscript{rd} order IPs at frequencies $2f_1-f_2$ and $2f_2-f_1$
- The intercept point (IP) is an imaginary point where the slopes of the fundamental, 2nd order IMD and 3rd order intermodulation distortion (IMD) meet
- IP is approximately 10 dB above 1 dB compression point
- IP is defined for Class A amplifiers only
Amplifier Harmonics

- **HARMONICS** are (usually unwanted) signals which are exact multiples of the operating frequency, $F_0$.

- **SPURIOUS** are other unwanted signals. Amplifiers do not generate signals (other than IMD) unless they are unstable.
Amplifiers vs Modulation Types

• Constant-envelope modulation
  – FSK, GFSK, CDMA
  – Class C amplifiers are often used, best efficiency

• Some modulation schemes have an amplitude component
  – QAM
  – Raised-cosine filtered QPSK etc.
  Class AB amplifiers are normally used for these

• Complex modulation such as OFDM (orthogonal frequency division multiplexing) is noise-like with a high peak-mean ratio
  Trouble with class AB and class C – too much distortion
  Use class A (large, expensive, inefficient) or ...
Amplifier Linearisation

• Nujira- currently leading the technology
  – ET – envelope tracking
• Other techniques also
Envelope tracking PAs in a mobile phone
References

Diagrams in these notes are taken from the following sources, which are also recommended for further reading:

http://www.rf-amplifiers.com/
http://mwrf.com/components/linearize-power-amps-rf-predistortion
http://www.solar-uk-conference.co.uk/article/90457-power-amplifiers-nujira-cmos-could-spell-the-end-for-gaas.html
http://www.embedded.com/print/4233749 (Understand and characterize envelope-tracking power amplifiers)