During the last class we considered amplifiers which are generally used as the first stage (RF input) for radio receivers. For frequencies of about 100MHz and below other designs which involve feedback and multiple transistor stages may be used. These are generally used as IF
amplifiers.

Recall, for the first stage, low noise is often the major consideration. Gain does not need to exceed 10-15 dB and the IP2 and IP3 specifications do not need to be high. On the other hand, for IF amplifiers, high intercept points and high
gain are of more interest.
For amplifier design in the 1 - 100 MHz range it is the common practice to use y-parameters. Chpt. 5 describes some aspects of using these parameters. There are many more design techniques and available devices for amplifier designs in these
frequencies than are available for \(\sim 10\text{ GHz}\) and above. Here we make some rather general comments that may provide guidance in amplifier selection.

1) For cases where a mixer occurs before the first amplifier, low noise is probably an important concern. A single-stage (transistor)
amplifier may be the best choice in this case. (See Table 5.11 (pg. 231) of text.)
The primary choices here are common emitter (source) and common base (gate) circuits. CE and CS circuits have the advantage that their input impedances are more reasonable (50Ω and up) and they can achieve
somewhat higher power gain. (The CE stage has some advantage over the CS stage due to the very high, and primarily capacitive, input impedance of the FET. However, the effect of capacitance can be reduced with a suitable matching circuit.) On the other hand, CB and CG stages
are generally capable of somewhat higher frequencies because the CE and CS stages are affected by the Miller capacitance. Also, CE and CS stages are less stable than their counterparts at higher gains, again due to the Miller capacitance. (See Fig.5.8, pg. 229, for performance comparison.)
2) For cases where low noise is not a major consideration a common choice is the cascode circuit. Also, with RF ICs another type of choice is a differential amplifier (See Fig. 5.10, pg. 230, for an example) which uses a differential cascode input.
3) Feedback is commonly used in IF amplifiers. Feedback is used to reduce distortion, control input and output impedances to obtain gain flatness over frequency, and to improve stability. Nonlinearity in FETs and BJTs is largely a result of nonlinearities in the
transconductance and voltage dependence of the depletion capacitances. These effects can be reduced with feedback. Recall from EE3304 that the feedback types are:

a) voltage-shunt
b) voltage-series
c) current-shunt
d) current-series

Some hybrid of these may be used.
These circuits are reviewed in Fig. 5.15 (pg. 240). High-frequency transformers may also be used to increase the flexibility in controlling input and output impedances with feedback. (See figures 5.16, 5.17 and 5.18 of text.)

Amplifier Gain Control

Automatic gain control (AGC) is often used to
increase the dynamic range of a receiver. (Figs. 5.19, 5.20 and 5.22 illustrate basic ideas of AGC.)

Important considerations in AGC circuits include:

d) response time
b) dwell time
c) stability
d) affects on overall intermodulation (for large gain variations).
Notice that this list is not all-inclusive.

For some receivers, such as simple FM broadcast receivers, a limiting amplifier is used in place of an AGC circuit. This type of amplifier provides a high gain to all signals such that a constant $A(saturated)$
signal is produced at the output. This approach is possible because information is not contained in the envelope of the signal. The AGC approach has been found to lead to better receiver performance even for cases where the signal has a constant envelope.
Mixers

The basic function of a mixer is to intentionally distort the superposition of the intended signal and a known local oscillator (LO) signal in such a way as to generate a replica of the information-bearing signal at a predetermined...
fixed frequency, i.e., intermediate frequency. An ideal mixer is able to do that without generating other undesired responses.

A variety of different types of mixing circuits have been developed. The advantages and disadvantages of several of these will be considered.
Begin with passive mixers, which generally make use of diodes. The simplest type is probably a single-ended mixer circuit.

Recall the I-V characteristic for a conventional diode takes the
form \( i = I_0 \left( e^{\frac{\nu}{\sqrt{2}\gamma}} - 1 \right) \). As

the voltage \( v = A_L \cos(\omega_L t) + A_{RF} \cos(\omega_{RF} t) \)

is applied, the diode responds by varying the current such that

\[
    i = K \left( a + bv + cu^2 + \cdots \right)
\]

\[
    \uparrow
\]

Taylor series expansion of the exponential.
The term $bu$ contains frequency components $\omega_{LO}$ and $\omega_{RF}$. $c_{u^2}$ contains $2\omega_{LO}, 2\omega_{RF}$ and $\omega_{LO} \pm \omega_{RF}$. We have already discussed the form of $mf_{LO} \pm (n-m)f_{RF}$ where $n$ is the order of $u$ being considered. In the most common case
only the frequency component \( \omega_{\text{LO}} + \omega_{\text{RF}} \) or \( \omega_{\text{LO}} - \omega_{\text{RF}} \) is desired. Generation of the additional components leads to conversion inefficiency and a substantial number of spurious responses. In addition, the VSWR into the various ports of the mixer will generally be rather high. These
drawbacks can be somewhat overcome by appropriate design of the matching network and the filter. However, this is not a very practical approach due to the large number of spurious responses being generated. This approach is most suited for millimeter-wave frequencies and higher, where more
complex circuitry leads to unsatisfactory conversion losses.

**Balanced Mixer**

One of the major spurious responses generated by the single-ended mixer includes who and harmonics of this. These are easily coupled back to the RF port where they may radiate through the antenna.

To improve port-to-port
isolation and to reduce the numbers and levels of spurious responses, diodes are often connected in a balanced arrangement.

For a single-balanced mixer the circuit may be drawn as:

![Circuit Diagram]

This circuit provides isolation at RF port.
In addition it suppresses even harmonics of the LO from reaching the IF port.

To obtain better isolation between the various ports a double balanced mixer is generally used. Also, instead of square-law mixing, a switching-type of mixing is more commonly used.