B.E. 4/4 ECE 422

RADAR ENGINEERING AND NAVIGATIONAL AIDS

Unit-4
Types Of Mixers In Radar Receivers

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Out line

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   b. Balanced Mixer
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   d. Image-rejection Mixer
   e. Image-recovery Mixer

Mixer

- Converts the incoming Radio Frequency to Intermediate Frequency (RF to IF).
- Output is proportional to Product of RF Echo signal and LO signal.
- Two output frequencies are produced, sum and difference of the input Frequencies $f_{RF} \pm f_{LO}$ (Assuming $f_{RF} > f_{LO}$)

  But $f_{RF} - f_{LO}$ is the desired output frequency, $f_{RF} + f_{LO}$ component is filtered out.

Mixer

- There are two possible difference frequency signals :

  $f_{RF} - f_{LO}$ and f_{LO} - f_{RF} *(When* $f_{RF} < f_{LO}$*)*.

  only one of these two is desired frequency, the other is called *image frequency*.

- This image frequency is to be rejected using RF filter or a special type of mixer called *Image-reject mixer*.

Noise figure

Noise figure is dependent on conversion loss and noise-temperature ratio.

1. Conversion Loss
2. Noise-Temperature ratio

   1. Conversion Loss L_c

      Available RF Power / Available IF Power

   2. Noise-Temperature ratio t_r

      Actual available IF noise power / Available noise power from an equivalent resistance

Noise Figure

Noise Temperature Ratio

$$t_r = F_m G_c = F_m / L_c$$

F_m is the noise figure due to mixer

Where L_c = *Conversion Loss* = $1/G_c$

T_r varies inversely with IF frequency

Lower the conversion rate larger is the t_r.

Receiver Noise Figure includes the IF amplifier noise figure too which becomes more dominant.

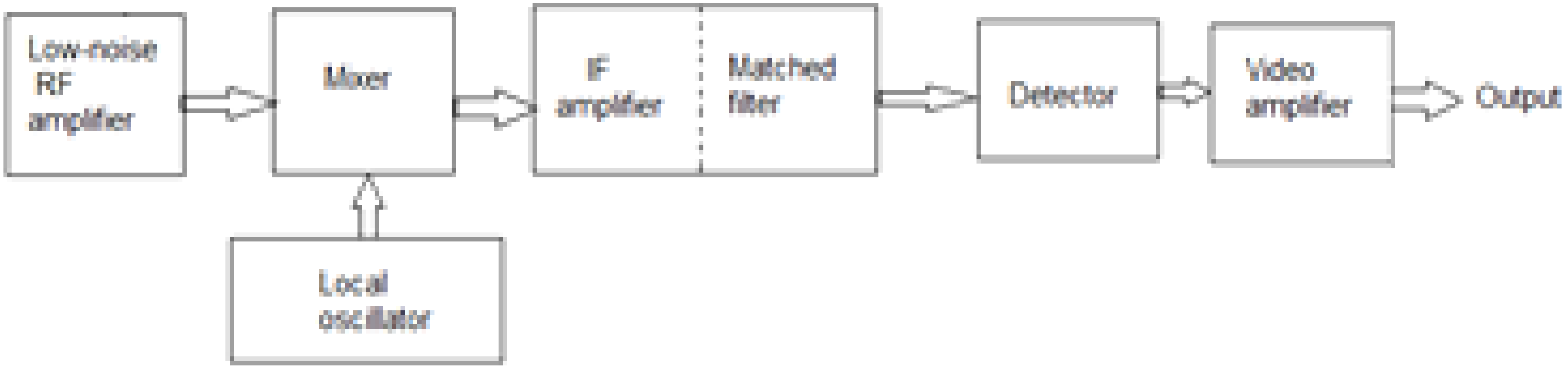
Receiver Noise Figure

- Receiver noise Figure

$$F_r = F_m + (F_{IF} - 1)\, L_c = L_c (t_r + F_{IF} - 1)$$

F_{IF} *is the noise Figure due to IF amplifier.*

Radar Receiver



Ideal Mixer

An ideal mixer must possess the following characters

1. Low conversion loss
2. Minimized spurious responses
3. Should not be susceptible to burnout
4. Large noise-temperature ratio.

Types of Mixers

1. Single-ended Mixer
2. Balanced Mixer
3. Double- balanced Mixer
4. Image-rejection Mixer
5. Image-recovery Mixer

1. Single-ended Mixer

- Also called as an unbalanced or crystal mixer.
- Uses a single diode that terminates a transmission line, LO is inserted via a directional coupler.
- An LPF after the diode filters out RF and LO signals allowing only IF.
- The unwanted Image frequency is short circuited or Open circuited.

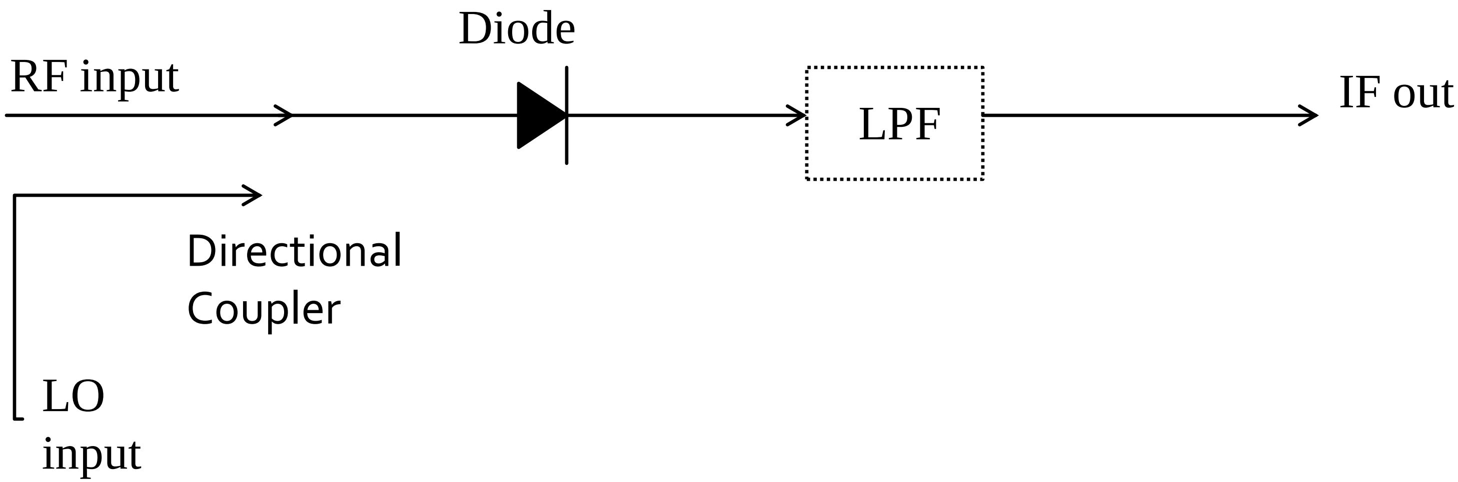
Single-ended Mixer

- Diode being a non-linear device produces inter-modulation products, called *Spurious responses*. (When $mf_{RF} + nf_{LO} = f_{IF}$)
- Taylor proposed a mixer chart to determine the RF and LO frequencies that are free from spurious responses.
- A Mixer chart is a graphical representation of wanted and unwanted (spurious) mixing products in-band and out-of-band.

Single-Ended Mixer

- Presence of two or more RF signals also results in spurious responses.
- LO noise is to be removed by an RF filter between LO and Mixer.
- Single conversion receivers suppress these spurious responses.

Single-Ended Mixer

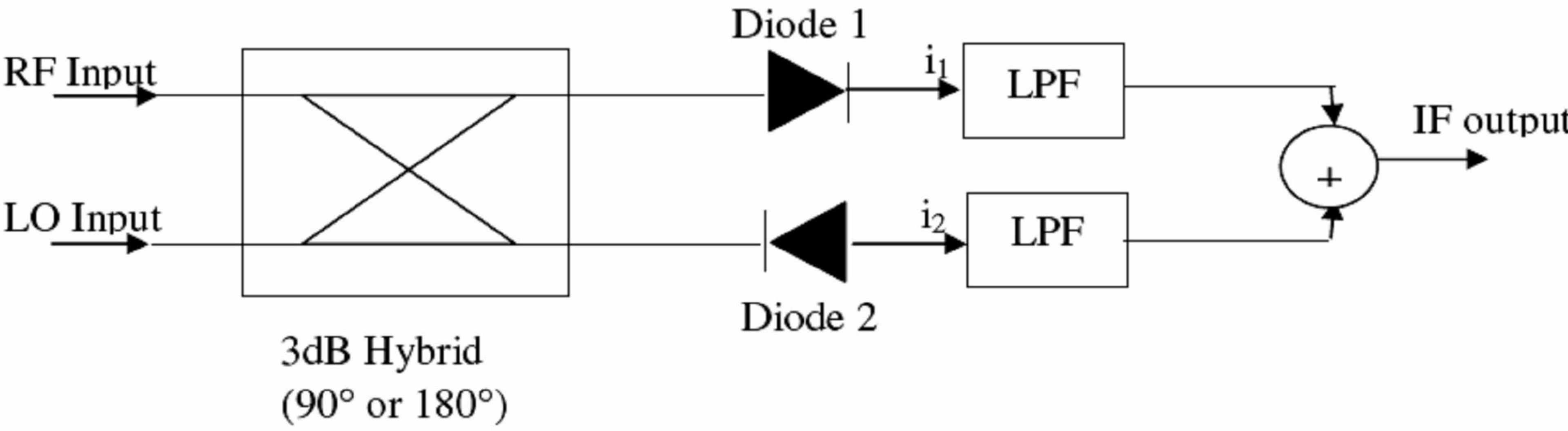


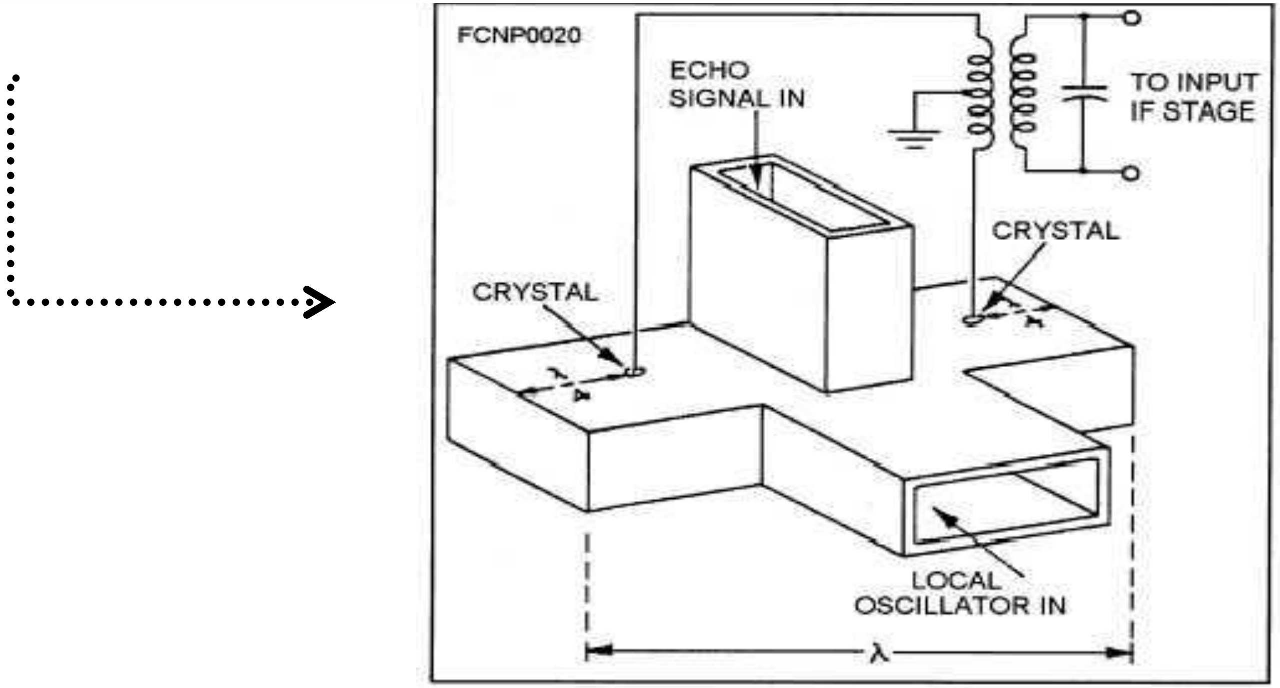
In some cases the RF and LO signals are subjected to a **Diplexer** in order to provide proper isolation between them.

2. Balanced Mixer

- Two single ended mixer in parallel and 180^o out of phase.
- A 4-port junction such as magic-T, hybrid junction or 3dB coupler is used.
- LO and RF signals are applied at ports 1 and 2, their sum and difference is obtained at ports 3 and 4.
- Diode mixers are present at ports output of ports 3 & 4.

Balanced Mixer





2. Balanced Mixer

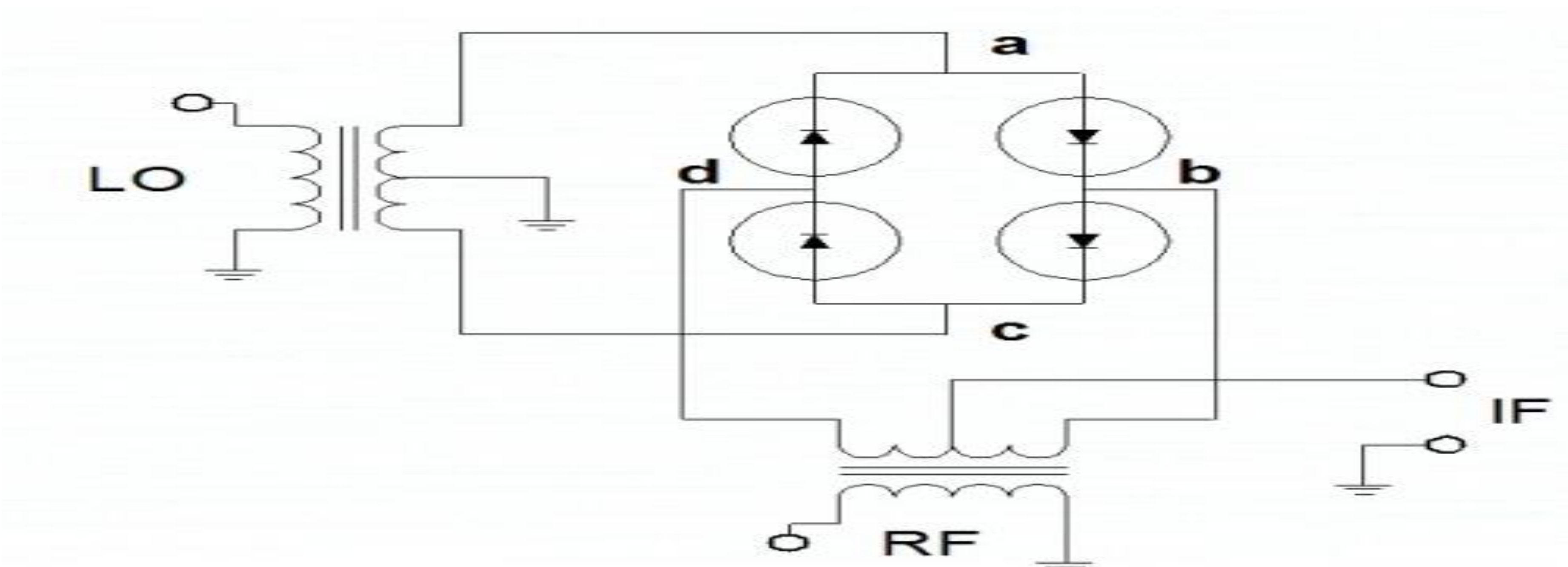
IF signal = Difference of the outputs of the two diode mixers.

Perks:

- LO noise at the two diode mixers are in phase and gets cancelled out
- Suppresses the even harmonics of either LO signal or the RF signals.

3. Double-balanced Mixer

- Uses four switching devices (diodes) arranged in form of a ring network
- Wire wound transformer is used as BALUN



3. Double-balanced Mixer

Advantages:

- Better isolation between RF and LO ports.
- Permits wide bandwidth.
- Suppresses even harmonics of both LO and RF ports.

Drawbacks:

- High LO drive required.
- Increased cost and complexity.

4. Image-Rejection Mixer

- The RF signal is split into two and fed into two individual mixers.
- LO signal is split into two using a 90^o Hybrid junction.
- A second hybrid junction (IF) imparts another 90^o phase shift to separate the image frequency.
- The port with the image frequency is match terminated.

Image Rejection Mixer

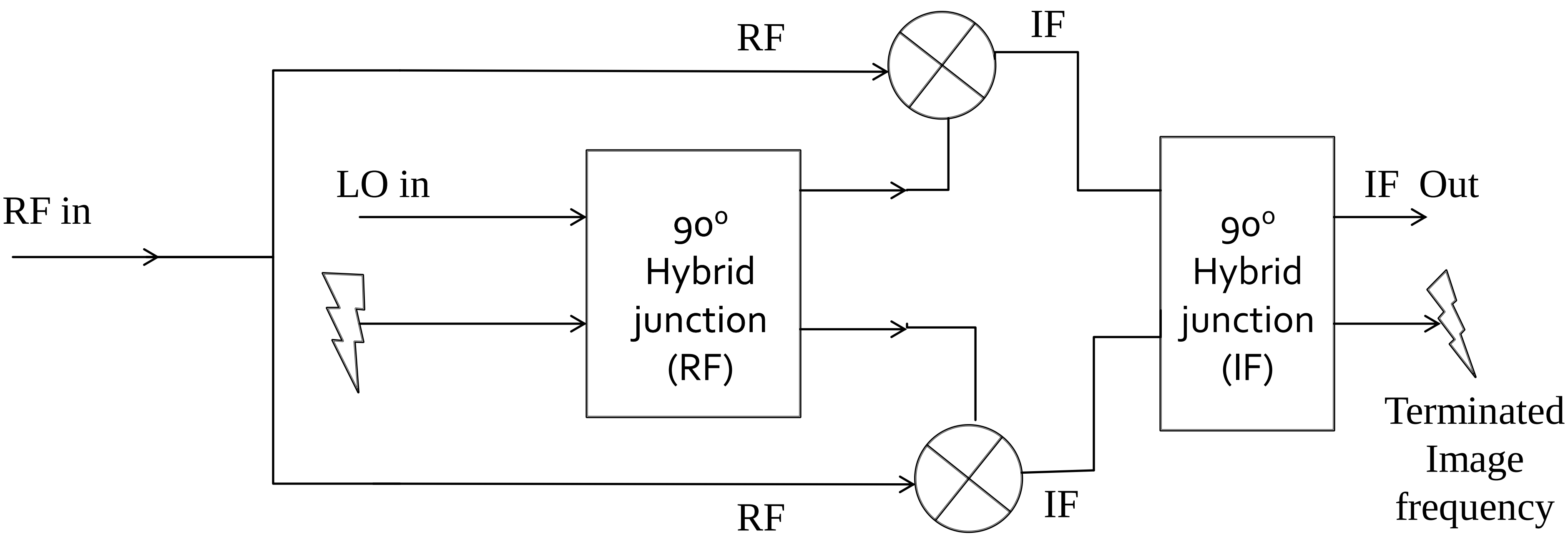


Image-rejection Mixer

Advantages

- High **Dynamic range**
- Good **VSWR**.
- Low **Inter-modulation Products**.
- Less susceptibility to **Burn out**.

Drawback:

- Provides only 30dB image rejection, which may not be suitable for some applications.
- High **noise figure**.

4. Image Rejection Mixer

- Dynamic Range of a radar receiver is the Ratio of max input signal power to minimum input signal power without degradation in performance.
- Third order modulation product affects the dynamic range of radar.
- Third-order distortion products are produced by a nonlinear device when two tones closely spaced in frequency are fed into its input

5. Image-recovery Mixer / Image-Enhanced

- It is a modified version of Image-rejection mixer.
- Mixer conversion loss is reduced by terminating a diode in a reactance at the image frequency.
- The improvement using this image enhancement is as low as 1 or 2 dB.
- Band pass filtering around the input source prevents the image frequency from entering into the mixer again.

Requirements for Radar receivers

- The ideal radar receiver is required to:
- amplify the received signals without adding noise or introducing any form of distortion;
- optimise the probability of detection of the signal by its bandwidth characteristics;
- provide a large dynamic range to accommodate large clutter signals;
- reject interfering signals so that the required information can be optimally detected.

Minimum Detectable Signal (MDS)

- The minimum receivable power (P_{emin}) for a given receiver is important because the minimum receivable power is one of the factors which determine the maximum range performance of the radar.
- The sensitivity level MDS has got a value of 10^{-13} Watts (-100 dBm) for a typical radar receiver.
- All receivers are designed for a certain sensitivity level based on requirements.

  One would not design a receiver with more sensitivity than required because it limits the receiver bandwidth and will require the receiver to process signals it is not interested in.

  In general, while processing signals, the higher the power level at which the sensitivity is set, the fewer the number of false alarms which will be processed. Simultaneously, the probability of detection of a "good" (low-noise) signal will be decreased.

Bandwith

- One of the most important factor is receiver noise.

  Every receiver adds a certain amount of noise to its input signal, and a radar receiver is no exception.

  Even with very careful design, noise due to thermal motion of electrons in resistive components is unavoidable.

  The amount of such thermal noise is proportional to **receiver bandwidth**.

- Therefore, bandwidth reduction is a possible solution to the problem of receiver noise.

  However**, if the bandwidth is made too small the receiver does not amplify and process signal echoes properly**.

  A compromise is required. In practice, the receiver bandwidth of a pulse radar is normally close to the reciprocal of the pulse duration. For example, a radar using 1 μs pulses may be expected to have a bandwidth of about 1 Mhz.

Dynamic Range

- The receiver system must amplify the received signal without distortion.
- If a large clutter signal sends the system into saturation, the result is a modification to the spectrum of the signal.
- This change in spectral content reduces the ability of the signal processor to carry out Doppler processing and degrades the MTI improvement factor. Furthermore, if the receiver enters saturation, then there can be a delay before target detection is restored.
- In principle, the dynamic range of the receiver must exceed the total range of signal strength from noise level up to the largest clutter signal.
- In practice dynamic ranges of 80 dB's or so meets system requirements. The clutter power confirms this requirement as it averages:
  - Rain clutter up to 55 dB
  - Angels to 70 dB
  - Sea clutter to 75 dB
  - Ground clutter to 90 dB.

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