Radio Receiver Specifications: Dynamic Performance

The dynamic performance specifications of a radio receiver deal with the performance in the presence of very strong signals. It is important to understand and apply these specifications because of the extremely dense radio spectrum in existence today.

1.0 1 dB compression point

Please refer to the FIGURE 1 below which shows the input/output of an RF amplifier in terms of power in dBm.

![FIGURE 1](image)

The job of an amplifier is to produce an output signal that is equal to or greater than the input signal. A linear amplifier must do this without saturation. However, in reality all amplifiers gradually saturate i.e. the output no longer increases with an increase in the input as shown in FIGURE 1.

The dotted line which follows the amplifier characteristic in its linear region is the ideal case amplifier characteristic. The difference between the real characteristic and the ideal characteristic shows that the amplifier starts saturating. As the amplifier saturates, the actual gain starts departing from the ideal gain at some level of input signal.

The 1 dB compression point is that output level at which actual gain departs from the ideal gain.

The 1 dB compression point is an important measure of dynamic performance, for it is at this point that the amplifier starts producing inter-modulation products described below.
2.0 Inter-modulation products: (IP)

It is important to understand the impact of inter-modulation products on receivers. IM products are generated whenever two or more signals are mixed together in a non-linear circuit. When this happens the output of the circuit has signals that are generated according to:

\[ mF_1 + nF_2 \]

where \( m \) and \( n \) are either integers or zero.

Mixing can occur purposely (as in a mixer) or in an over-driven RF amplifier which has been driven beyond its linear range. Mixing can even occur on corroded antenna connections, or parasitic PN junctions. Wherever there is a non-linear circuit element, whatever the cause.

Not all IM products are assumed of equal importance. The main ones are:

- **Second order:** \( F_1 \pm F_2 \)
- **Third order:** \( 2F_1 \pm F_2 \), \( 2F_2 \pm F_1 \)
- **Fifth order:** \( 3F_1 \pm 2F_2 \), \( 3F_2 \pm 2F_1 \)

When an amplifier is overdriven the second order content of the output signal increases as the square of the input signal level.

The third order responses increase as the cube of the input signal level.

For example: Let us assume two RF signals. One at 10 Mhz and the other at 15 Mhz. For these frequencies, the various IM products are at:

- **IP2:** 5Mhz and 25Mhz
- **IP3:** 5 Mhz, 20 Mhz, 35 Mhz and 40 Mhz
- **IP5:** 0 Mhz, 25 Mhz, 60 Mhz, 65 Mhz.

If any of these frequencies fall within the pass-band of the receiver then they will cause untold problems. An example is the phantom signal at IP frequencies. Another problem could be adjacent channel signals and their IP products.

**The third – order intercept point:**

Please refer to FIGURE 2. We assume that the third order IPs are the most important in the receiver’s dynamic performance because they predict performance as regards inter-modulation, cross modulation and blocking de-sensitization.

See also FIGURE 3 and the accompanying description for a further understanding of IP3.
Increasing input levels can drive the amplifier out of its linear range, causing IP spurious responses (SPURS) to rise above the receiver noise levels causing interference and other problems. Since these products grow in an exponential fashion they can increase very fast indeed.
FIGURE 3 shows a plot of the output signal against the fundamental input. The theoretical output is shown as usual by the dotted line. The third order IM products rise above the noise level as shown at some input level and increase as the cube of the input signal. The slope of the third order products increases as 3 dB for every 1 dB increase in the response to the fundamental. The third order product line also saturates. A very important parameter can be defined if the third order line is also continued (theoretically) upwards and made to intersect with the fundamental (theoretical) gain line.

This point of intersection is the third order intercept point. Receivers have specified third order intercept points. A TIP of 5 to 20 dBm is considered very good to excellent performance. They are still regarded as fairly good up to 0 to 5 dBm TIP’s. Anything less than -10dBm is not so good!! If strong interferers are anticipated then acquire/design receivers with the highest TIPs possible for good performance.
3.0 **Receiver dynamic range:**

The receiver dynamic range may be defined as the range from the minimum discernable signal to the maximum allowable signal in dBs.

The above description is simple and easy to understand. However many other definitions are also used.

Another definition of dynamic range states that it is the difference in the input signal between the sensitivity figure (e.g. 0.7uV for 20 dB S+N/N) and the level that drives the receiver far enough into saturation to create defined amount of distortion in the output signal.

Another definition of dynamic range defines the difference in dB from the sensitivity level to the 1 dB compression point.

Yet another definition defines dynamic range as the range of signals from the sensitivity to the blocking level.

All of these are single signal definitions, so they do not account for the receiver’s dynamic parameters. If dynamic effects are taken into account another definition of dynamic range is the range of signals over which the dynamic effects do not exceed the noise floor of the receiver.

A recommendation is that the dynamic range should be 2/3 of the difference between the noise floor and the TIP in a 3 kHz bandwidth.

The dynamic range specification difference using single signal and multi-signal can sometimes be 40dB. Therefore it is important to specify the dynamic range carefully to avoid problems.

4.0 **Blocking:**

Blocking specifications refer to the capability of the receiver to withstand extremely powerful signals that are a minimum of 20kHz away from the required signal. If the input of the receiver has these strong unwanted signals in close proximity to the desired signal, they cause the receiver to lose sensitivity to the desired signal. Please see FIGURE 4 below.
**Cross modulation:**

Cross modulation occurs when the amplitude modulation from a strong signal is transferred to a weaker signal. Testing is done with a 20kHz separation between the two signals and the desired signal is set to a level of 1000μV EMF (which is -53 dBm). The undesired signal is amplitude modulated to 30%. This signal is increased in power level until an unwanted AM output appears on the desired signal 20 dB below the desired signal is produced.
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