Third Order Intercept Point

Third order intercept point (IP3) is a term sometimes heard when amateur radio operators are discussing the qualities, or lack thereof, of a receiver. Third order intercept point is just one of several specifications that can be used to judge the quality of a receiver. Some of the other specifications such as signal to noise ratio and selectivity are relatively easy to understand and interpret. It should be pointed out that in many instances complete specifications are not provided in manufacturing literature and must be obtained from independent testing sources or through other means. The term is somewhat involved and many people don't actually know what it really means. Most who us it do know that the higher the number the better the receiver. Numbers may range from something like –10db to something in the range of +30 to 40 db.

In very simple terms IP3 is a way of expressing how well a receiver separates two closely spaced signals. However, there is a second part that creates confusion. This second part will be the basis for our discussion. It is based one the two closely spaced signals just mentioned.

Lets be clear that IP3 is a theoretical point that is calculated and is not measured as is specifications such as selectivity.

All modern receivers have at least one intermediate frequency (IF) between their antenna input and their audio amplification stages which drive the speaker. Most have at least two and in some models three mixers. When a single signal is received and processed it of course can be easily heard and understood. However, if two adjacent signals say 3 to 5 khz apart are received we can readily see that the receiver is going to have a difficult time separating them for us. The IP3 of the receiver is it's ability separate these two signals. However, it calculates a theoretical value rather than actually measuring the ability two separate signals.

IP3 is calculated by injecting two signals into the antenna port of a receiver. These two signals are typically 20 to 30 khz apart with a known amplitude. These are mixed together in the mixer of our receiver along with a local oscillator signal. They produce several major signals or products. Some of which are at a frequency that will pass thru the IF amplifier that follows the mixer. Along with the two signals mentioned will be intermodulation products which is the difference and sum of the two signals. The intermodulation products that are the most worry some are the third harmonics. They are also know as third order tones. Thus the term applied to the number calculated is third order intercept point. We will discuss the intercept point in just a moment.

As signal strength is increased by 1 db the intermodulation products increase by 3 db. The IP3 point is the hypothetical output signal level at which the third-order tones would reach the same amplitude level as the desired input tones. When this point is reached the mixer theoretically becomes saturated and a further increase in

input signal will not cause a further increase in output volume. Thus the signal nearby the signal we want to hear has caused our receiver to saturate or block preventing us from receiving the signal we want to hear. This saturation or blocking is actually caused by the intermodulation products between the two nearby signals and not directly from either signal being too high in amplitude. On a practical basis before complete blocking occurs we will notice distortion in the received signal. We may also hear additional sounds that are shrill. The IP3 point is a calculation of the gain of the signal verses that of the intermodulation products.

The following formula can be used to determine IP3 from measured values.

$$IP3 = \frac{3xPa - Pim3}{3 - 1}$$

where:

IP3 is the third-order intercept point

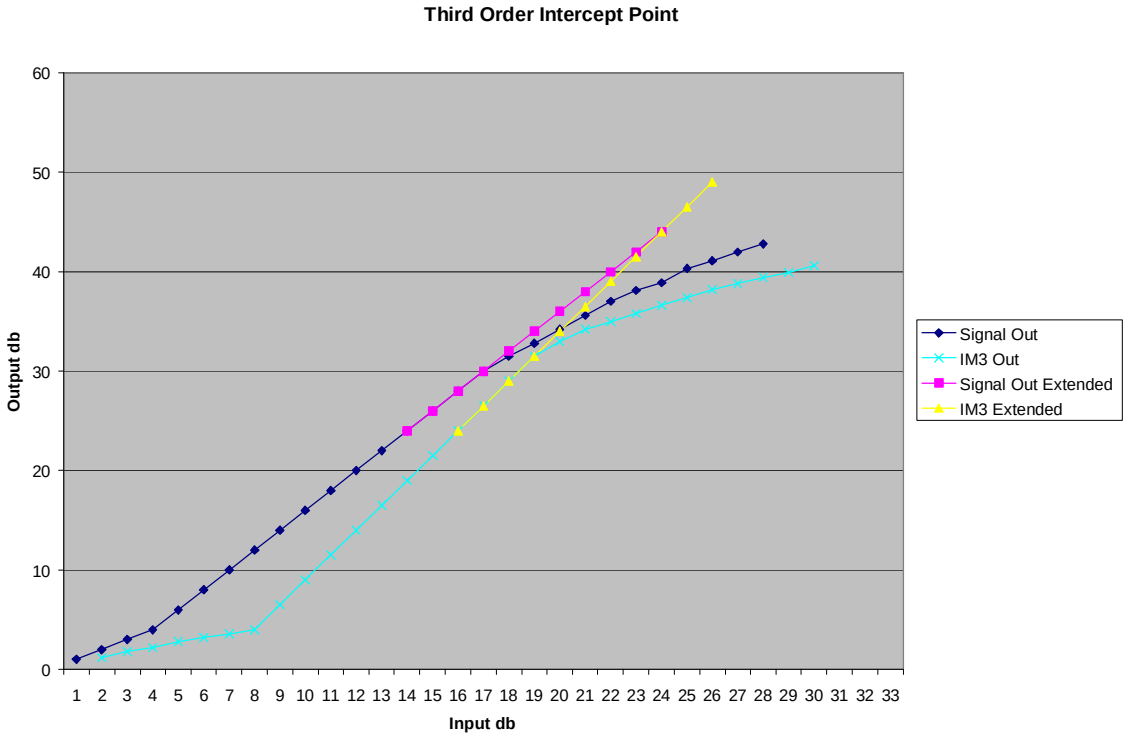
PA is the input power of one of the signals on the receiver input

PIM is the power of the intermodulation distortion (IMD) products

As an example of finding the third-order intercept point, suppose that we use two tones with a strength of –30 dBm each to test our receiver again. This time we measure the third-order IMD products to be –70 dBm. We want to find the third-order intercept point for this receiver. By solving the equation we find the IP3 of this receiver is –10dbm. Not very good actually.

The attached figure illustrates the IP3 point. It is the intercept point of the magenta (Signal extended out) and the yellow line (IM3 extended).

We hope that this short technical note has helped you understand IP3. Without a grasp of mixers it can be difficult to understand. If you are still having trouble with IP3 carefully review this article several times. Additionally reading about mixers will also help.


Third Order Intercept Point
Output db
Input db
0
10
20
30
40
50
60
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33
Signal Out
IM3 Out
Signal Out Extended
IM3 Extended