To implement **Automatic Gain Control (AGC)** we need to make the gain of the IF amplifier **adjustable**:

![AGC Diagram]

**Q:** Are there such things as **adjustable gain amplifiers**?

**A:** Yes and no.

Typically, voltage controlled amplifiers work **poorly**, have **limited** gain adjustment, or both.

Instead, receiver designers implement an adjustable gain amplifier using one or more **fixed gain amplifiers** and one or more **variable attenuators** (e.g., digital attenuators).
Two amplifiers are used in the design above, although one, two, three, or even four amplifiers are sometimes used.

The adjustable attenuator can likewise be implemented in a number of ways. Recall the attenuator can be either digital or voltage controlled. Likewise, the attenuator can be implemented using either one attenuator, or with multiple cascaded attenuator components.

However it is implemented, the gain of the overall IF amplifier is simply the product of the fixed amplifier gains, divided the total attenuation \( A \). Thus, for the example above:

\[
G_{IF} = \frac{G_1 G_2}{A}
\]

Now, the key point here is that this gain is adjustable, since the attenuation can be varied from:
Thus, the IF amplifier gain can vary from:

\[ G_{L}^{IF} < G < G_{H}^{IF} \]

Where \( G_{L}^{IF} \) is the lowest possible IF amplifier gain:

\[ G_{L}^{IF} = \frac{G_{1} G_{2}}{A_{H}} \]

And \( G_{H}^{IF} \) is the highest possible IF amplifier gain:

\[ G_{H}^{IF} = \frac{G_{1} G_{2}}{A_{L}} \]

Note the gain is the highest when the attenuation is the lowest, and vice versa (this should make perfect sense to you!).

However, recall that the value of the lowest attenuation value is not equal to one (i.e., \( A_{L} > 1 \)). Instead \( A_{L} \) represents the insertion loss of the attenuators when in their minimum attenuation state.

Recall also that the total receiver gain is the product of the gains of all the components in the receiver chain. For example:

\[ G = G_{LNA} G_{preselector} G_{mixer} G_{IF} G_{IF\text{filter}} \]
Note, however, that the only adjustable gain in this chain is the **IF amplifier** gain $G^{IF}$, thus the remainder of the receiver gain is fixed, and we can thus define this fixed gain $G_{fixed}$ as:

$$G_{fixed} = \frac{G}{G^{IF}}$$

Thus, $G_{fixed}$ is simply the gain of the entire receiver, with the exception of the IF amplifier.

Since the gain of the **IF amplifier** is adjustable, the gain of the **entire receiver** is likewise adjustable, varying over:

$$G_L < G < G_H$$

where:

$$G_L = G_{fixed} G_L^{IF}$$

and:

$$G_H = G_{fixed} G_H^{IF}$$

Thus, a receiver designer must design the “IF Amplifier” such that the **largest possible** receiver gain $G_H$ exceeds the minimum gain requirement (i.e., $G_H > G_{min}$)—a requirement that is applicable when the receiver input signal is at its **smallest** (i.e., when $P_{in} = MDS$).
To accomplish this, we find that:

\[ G_H > G_{\text{min}} \]
\[ G_{\text{fixed}} G^IF_H > G_{\text{min}} \]
\[ G^IF_H > \frac{G_{\text{min}}}{G_{\text{fixed}}} \]

Thus, since \( G_{\text{min}} = \frac{P^\text{min}_D}{MDS} \) we can conclude that the highest possible gain \( G^IF_H \) of our "IF amplifier" must exceed:

\[ G^IF_H > \frac{P^\text{min}_D}{G_{\text{fixed}} MDS} \]

or

\[ G^IF_H (dB) > P^\text{min}_D (dBm) - G^\text{fixed} (dB) - MDS (dBm) \]

Additionally, a receiver designer must design the "IF Amplifier" such that the smallest possible receiver gain \( G_L \) is less that the maximum gain requirement (i.e., \( G_L < G_{\text{max}} \))—a requirement that is applicable when the receiver input signal is at its largest (i.e., when \( P_{\text{in}} = P_{\text{in}}^{\text{sat}} \)).

To accomplish this, we find that:
Thus, since $G_{\text{max}} = \frac{P_D^{\text{max}}}{P_{\text{in}}^{\text{sat}}}$ we can conclude that the lowest possible gain $G_L^{\text{IF}}$ of our "IF amplifier" must be lower than:

$$G_L^{\text{IF}} < \frac{P_D^{\text{max}}}{G_{\text{fixed}} P_{\text{in}}^{\text{sat}}}$$

or

$$G_L^{\text{IF}} (dB) < P_D^{\text{max}} (dBm) - G_{\text{fixed}} (dB) - P_{\text{in}}^{\text{sat}} (dBm)$$

**Q:** I'm still a bit confused. Now what is the difference between $G_{\text{min}}$, $G_{\text{max}}$ and $G_L$, $G_H$?

**A:** The values $G_{\text{min}}$ and $G_{\text{max}}$ are in fact requirements that are placed on the receiver designer. There must be some IF gain setting that will result in a receiver gain greater than $G_{\text{min}}$, and there must be some IF gain setting that will result in a receiver gain less than $G_{\text{max}}$. 
In contrast, the values $G_L$ and $G_H$ are the actual minimum and maximum values of the receiver gain. They state the performance of a specific receiver design.

Properly designed, we will find that $G_H > G_{\text{min}}$, and $G_L < G_{\text{max}}$. However, this is true only if we have properly design our “IF Amplifier”!