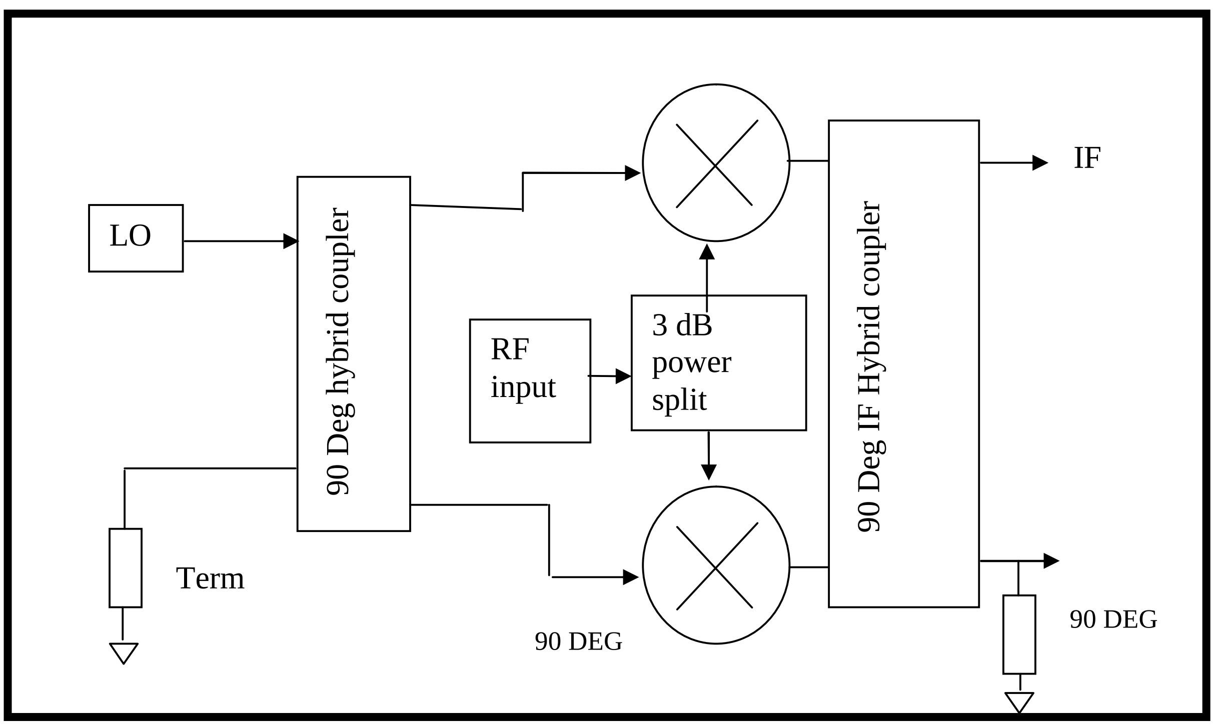
An image reject (suppression) mixer

An image reject or suppression mixer is a device or circuit that is used in receivers to suppress “image“ frequencies* from causing faulty reception of signals. (For a definition of image frequencies see the Signal Processing Group Inc.’s website and the article in Engineer’s corner.)

The block diagram shown below is one possible implementation of an image suppression mixer.

In comparison to conventional Double Balanced mixers, Image Reject Mixers achieve image-rejection through phase cancellation, not filtering, so the frequency spacing between the image and desired inputs can be negligible. This means that down conversion can be accomplished without preselection, and in fewer stages, saving the cost of extra mixers, amplifiers, local oscillators, and filters. For similar reasons, upconversion can also be simplified by using single sideband mixers.



A functional block diagram of an image reject mixer.

Signal Processing Group Inc., technical memorandum. Website: http://www.signalpro.biz
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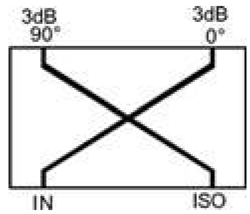
A 90 degree hybrid coupler

A 3 dB, 90° hybrid coupler is a four-port device that is used either to equally split an input signal with a resultant 90° phase shift between output ports or to combine two signals while maintaining high isolation between the ports.



The basic configuration of a hybrid coupler is shown in the figure above which illustrates two cross-over transmission lines over a length of one-quarter wavelength, corresponding with the center frequency of operation. When power is introduced at the **IN** port, half the power (3dB) flows to the **0**° port and the other half is coupled (in the opposite direction) to the 90° port. Reflections from mismatches sent back to the output ports will flow directly to the **ISO** port or cancel at the input. This is why hybrids are so widely used to split high power signals in applications where unwanted reflections could easily damage the driver device.

Operating principles of the image reject mixer

As can be seen from the figure above, an image reject mixer consists of two balanced mixers. A 90 degree hybrid at the input and another at the output.

The LO is applied to the input coupler where it is split into a in phase and quadrature signal and applied to the two mixers as shown.

The input RF is applied to the mixers through a 3 dB attenuator as shown to keep the power levels of the LO applied signal consistent with the RF signal.

Suppose then that the input RF signal is of the form of:

$Cos(\omega s)t$ and the LO signal has the form of $Cos(\omega LO)t$ and $Cos[(\omega LO)t-90]$. Then considering phase differences only, the output signal from the top mixer is of the form $Cos(\omega s - \omega LO)t$ and the that from the bottom mixer is $Cos[(\omega s - \omega LO)t + 90]$.

If the mixer utilizes low side mixing i.e the frequency of the input signal is higher than the LO signal, then the input to the output coupler from the top mixer is $Cos(\omega_{IF} t)$ and that from the bottom mixer is $Cos[(\omega_{IF} t)+90]$.

The output coupler takes the top signal and converts it to two quadrature signals: $Cos(\omega_{IF} t)$ at the top and $Cos[(\omega_{IF} t)-90]$ at the bottom.

The output from the bottom mixer also goes through the output coupler and couples as $Cos(\omega_{IF} t)$ to the top (because there is a 90 Deg phase lag) and $Cos[(\omega_{IF} t)+90]$ to the bottom of the coupler (0 Deg phase shift). The two signals at the bottom port of the coupler cancel and the two signals at the top of the coupler add giving the IF frequency at the top of the coupler.

The image signal also transitions the mixer as follows: The output from the top mixer is $Cos(\omega i - \omega LO)t$ (where ωi is the image frequency.) From the bottom mixer the output is $Cos[(\omega i - \omega LO)t + 90]$.

In this case the frequency $\omega i - \omega LO$ is a negative number, since ωi is < ωLO. However, Cos(-x) = Cos(x). Thus the two outputs can be written in terms of positive frequencies as $Cos(\omega_{IF} t)$ and $Cos[(\omega_{IF} t)-90]$.

Note how the $Cos[(\omega i - \omega LO)t + 90]$ changes to $Cos[(\omega_{IF} t)-90]$ as a result of the negative frequency.

If we look at the paths of the image frequency we find that the output of the bottom mixer for the image is $Cos[(\omega_{IF} t)-90]$ (for the reasons shown in the box above)

The top mixer generates $Cos(\omega_{IF} t)$. The hybrid takes the $Cos(\omega_{IF} t)$ and sends a portion of it to the lower side of the hybrid i.e $Cos[(\omega_{IF} t)-90]$.

The output of the bottom mixer is $Cos[(\omega_{IF} t)-90$ from the contribution of the lower mixer. However there is also the same contribution from the upper end of the hybrid. So we have an additive signal here which is the image signal. The situation at the upper end of the hybrid is different. Here there is the $Cos(\omega_{IF} t)$ and also a $Cos[(\omega_{IF} t)-180)$ from the bottom side (an additive phase of -90 because of the action of the hybrid. The two signals are equal in amplitude but 180 degrees in phase so they cancel. i.e there is no image signal at the top. The only signal at the top is the IF frequency and the only signal at the bottom is the image frequency. The image frequency can be absorbed by an appropriate load at the bottom leaving only the IF frequency at the top.

This whole operation is not too easy to understand but a few iterations through the textual description should ultimately yield intuitive understanding of the action of this type of mixer.