A SURVEY ON DIRECT CONVERSION RECEIVERS

By Luiz Amaral
PY1LL/PY1LL

Much is said on direct conversion receivers, but many details are still unknown by great part of the hamradio community. Let's consider an audio transmission.

A direct conversion receiver is nothing more than a super heterodyne one, but with the IF on 0Hz, that is, the IF band is the audio itself and, therefore, the image of an LSB is a USB and vice-versa, as the image frequency is the desired one summed or subtracted of the doubled IF frequency.

In the diagram of Figure 1, we see the simplest system for such a receiver and we will present its advantages and disadvantages. Later on, we will join other elements to improve the performance of the receiver, presenting yet the new diagram and corresponding commentaries.

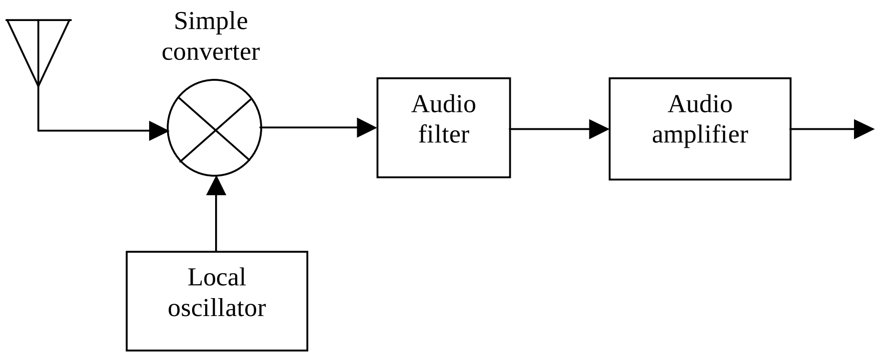

Figure 1

In this simple model, the signal from the antenna is wideband, that is, with no filtering, and excites the converter that has, as local oscillator, the frequency F itself. At the converter output that is a simple one, not balanced, we have the local oscillator, the wideband input RF signal, their harmonics and the audio, besides other signals with no importance here. The following audio filter, that only permits to pass, say, from 300 to 3,000Hz, filters out all signals. The amplified audio goes to the output.

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We can verify the following:

A – The total receiver gain (in dB) is given by the audio amplifier gain plus the converter gain minus the eventual audio filter losses. As the amplifier gain has to be very great, undesirable oscillations of difficult removal can occur. This amplifier has to be a low noise one due the small signal at its input.

It is important to remember that diode ring converters, although with excellent IP3, have negative conversion gain, demanding yet more gain for the audio amplifier.

B – In a correctly tuned common AM signal with carrier, its beat with the local oscillator, besides the sum, produces the frequency difference that is zero, that is, a DC voltage. If the converter is a type with diode(s) and directly coupled, for example, this DC will modify the diode(s) polarization(s), altering the gain and the response of the converter (this is valid for any DC sensitive converter)

C – A clean SSB signal will be demodulated, but no undesirable band will be rejected. Indeed, the undesirable band is the image of the desirable one, and, as this receiver has no image rejection device, both bands are received.

D – As the input is wideband, all signals of that band contributes to the intermodulation products, deteriorating, in practice, the receiver quality

E – Normally, for good conversion efficiency, the signal from the local oscillator has great amplitude, square or squared at the converter itself and, thus, rich in odd harmonics.

Those harmonics also detect signals, as does the fundamental frequency, producing, in the audio, a mixture of the signals resulting from the frequencies F, 3F, 5F, etc. In a square wave, the amplitude of the **2n-1** (with **n = 1, 2, 3...**) order harmonic (only odd harmonics are present) is inversely proportional to **2n-1**, in such a way that the contribution of the **2n-1** harmonic in the audio is proportional to the RF signal amplitude. But it is also attenuated by a factor equal to **20 log (2n-1)** in dB. Thus, for example, a signal relative to the third harmonic (n=2) is attenuated by 9,5 dB. Even so, it hinders much the reception in special if the RF signal at the harmonic frequency is strong.

F **–** due the wide band, non-linearities corresponding to the RF input can mix strong signals with very close frequencies, generating an audio that cannot be separated from the desired one any more.

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PY1LL/PY1LL

G – The noise of this receiver scheme is given mainly by the converter and local oscillator, as any receiver with no RF amplifier, in spite of the noticeable contribution of the audio amplifier.

H – The converter non-linearity, under strong signals, detects them as a diode detector and, therefore, generates an audio at the converter output, *even with no local oscillator signal.* If it is a common AM, with carrier, the audio will be intelligible. This happens with the nightly broadcastings on 40m that disturb very much, as they appear even when one is tuning another frequency. This effect is sometimes called the 'Radio Moscow Effect'.

I – The DSB reception, for example, cannot be carried out in the correct manner, that is, in synchronous form.

- The item A effect can be mitigated by the use of an RF amplifier at the input, greater conversion gain and even an audio filter with gain, decreasing the need of too much great audio amplifier gain (in the case of a normal IF, its amplifier contributes much to the overall chain gain).

- The problem of item B may be solved with a not DC sensitive converter and little by the local oscillator input balancing.

- The problem pointed out in C may be much attenuated, if not solved, by the use of image frequency eliminator circuits. If they are of good quality type, just at the audio filter we get the SSB detection with rejection of the undesired band. We can use such circuits in a normal IF radios, increasing much the image attenuation, with an even possible elimination of a second conversion need.

- The indicated in D ocurrs in any wideband receiver, with direct conversion or not. We solve this with the use of a narrow band-pass filter at the receiver input, transforming it into a narrow-band input. The practical difficulty is that this filter has to be tuned to each desired frequency and the design of that tuning system is problematic, if it is to be automatic, that is, with no operator interventions.

The ideal receiver has just at its input (and with non-saturatable passive elements), all its selectivity. This is very difficult to achieve especially for great frequency covering receivers as those from 1 to 50MHz.

- The problem showed in E is also solved resolve with the band-pass filter referred above, in spite of the fact it can be with a simple low-pass filter at the input, with a cut-off frequency slightly above the reception frequency to eliminate the superior harmonics.

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PY1LL/PY1LL

- The problem of item F is solved with the use of a higher IP3 converter (or RF amplifier, if this is used.

- The G problem is solved obviously with a low noise converter and high quality local oscillator, that is, low phase noise. A good RF amplifier can improve the reception if the converter noise is high.

- The problem in H is solved by the use of a converter balanced as to the RF input, hindering the direct signals to generate audio.

- The problem of the item I is solved with the use of two converters, as those used in the image rejection systems.

The improved receiver diagram is showed in Figure 2.

The system uses two converters, two local oscillators signals 90° out-of-phase and two audio phase shifters of +45° and -45°, eliminating the lower or higher frequencies as to the desired one, that is, the image, in this case, the undesired band. The precision of those elements defines that rejection quality.

If we interchange, for example, the audio phase shifters, the rejected and desired band will be also interchanged (we change the reception from LSB to USB and vice-versa).

For wideband input receivers, the harmonics (odd of order **2n-1**) of the local oscillator also, and in an alternated manner, eliminate one band. The order **4n-3** (order = 1, 5, 9, 13, etc) harmonics eliminate one band and those of the order **4n-1** (order = 3, 7, 11, 15, etc) eliminate the other band. If, for instance, we tune 1 MHz in LSB, the signals detected by the harmonics 5, 9, 13, ... MHz will be also being detected in LSB and the signals of 3, 7, 11... MHz will be detected in USB.

That's why it is fundamental that, at least, a low-pass filter exists at the receiver input to eliminate all those referred harmonic detections.

The band-pass audio filter defines the receiver band, as the RF band-pass filter has poorer quality than the audio one concerning the off-band attenuation.

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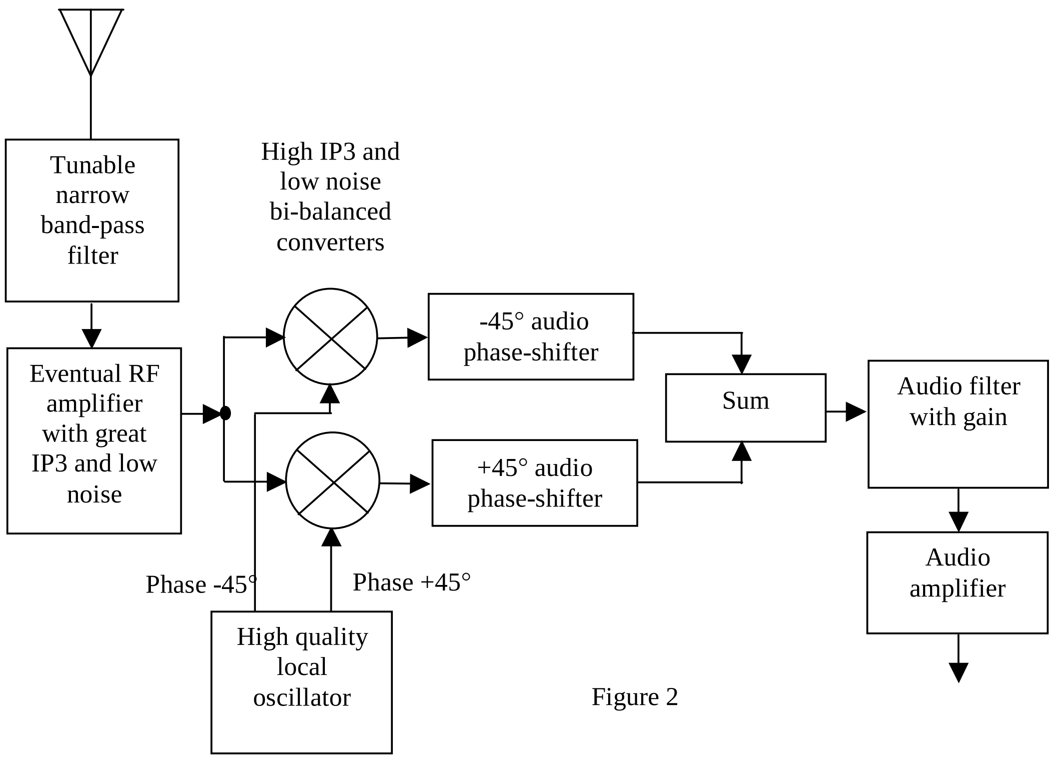

Figure 2

As those difficulties discourages commercial manufacturers to produce direct conversion receivers.

But really, with enough building care, it is possible to design very interesting direct conversion receivers.

For example, one of those precautions is on the audio phase-shifters. They are exigent circuits as to the components precision that are very numerous. Capacitors are difficult to get with much precision, but one can associate some to get the sought value.

Homemade precision resistors are easier to get: we choose a resistor (carbon type) with a value slight smaller than de desired. While measuring its value with a precision ohmmeter, we grind out some material of the resistor with a razor blade with care and slowly till we get the sought value. After, we cover the resistor with a thin layer of slow hardening polymer rosin for protecting the component and stabilize its value. To mark the component after ready is advisable.

Audio phase-shifters can be passive or active.

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PY1LL/PY1LL

Another very important factor for the elimination of the correct band is the equality of the amplitudes of both signals at the suming circuit input.

A low value (comparing with the suming circuit resistor ones) potentiometer) can produce this very important amplitude balance.

This amplitude differences exist due the fact that the conversion gains of both converters are not equal and the different attenuations of the audio phase-shifters themselves. The phases and amplitudes must be as close to their theoretical value as possible. Little differences produce great loss of attenuation of the undesired band. In the literature there are tens of articles showing that need.

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PY1LL/PY1LL