'Possibilities and Limitations in Software Defined Radio Design.

or

‘Die Eierlegende Wollmilchsau‘

Peter E. Chadwick

Chairman, ETSI ERM_TG30

, co-ordinated by ETSI ERM_RM

Software Defined Radio
or
the answer to life, the universe and everything

- The ideal SDR will cover all frequencies from 9kHz to 300GHz.
- It will receive/transmit and modulate/demodulate all modulation modes and bandwidths
- It will configure itself automatically.
- Thus it is ‘ein eierlegende Wollmilchsau’

Limitations in SDR

- There are technology limits on achievable RF performances
- The choice of architecture depends on the available technology e.g ADC performance, semiconductor technology
- Software reliability (or the lack thereof) may define overall radio reliability, rather than hardware limitations

Power requirements in SDR

- Even medium performance SDR tends to require more power for a given function than equipment designed specifically for purpose with optimum analogue/digital architectural partitioning

- Ultra Low Power equipments not requiring large frequency ranges or modulation types are currently still better implemented in conventional architectures

Technology implications

- The optimum RF technology will vary with frequency
- The complexity of the DSP will be dependent upon parameters such as bandwidths and demodulation requirements
- DSP complexity can be limited by power requirements

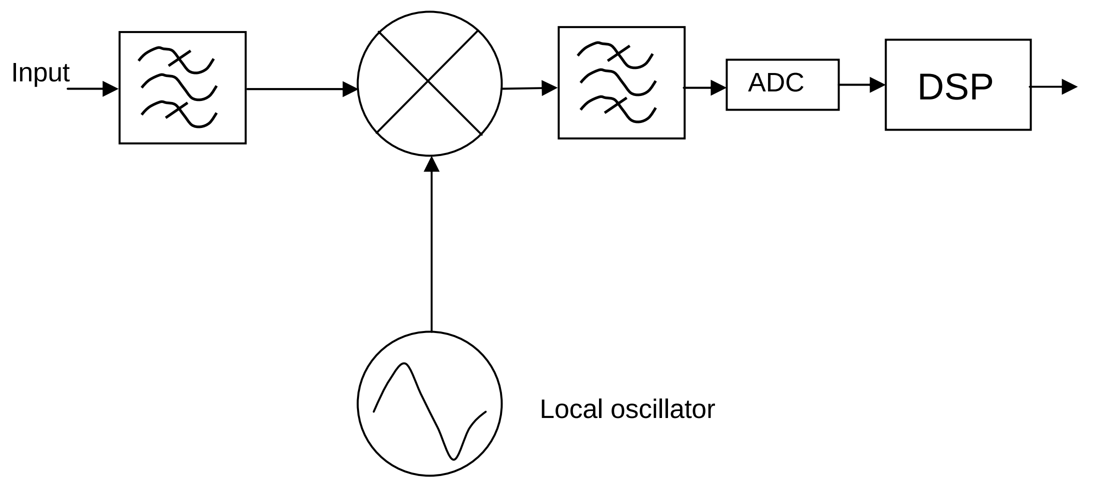
Basic SDR Receiver Limitations

- The Analogue – Digital Conversion can limit the simultaneous dynamic range (DR)
- It is usual to consider that there will be 6dB of dynamic range for each bit of AD conversion.
- At least the LSB (and preferably the least 2 bits) should ‘toggle’ on the receiver noise
- Receiver instantaneous DR requirements can range from 80 to 140+ dB

Receiver Architectures

- Conventional superhet, with digitisation at IF
- Low IF superhet, using DSP to eliminate the image
- Direct conversion (‘zero IF’)

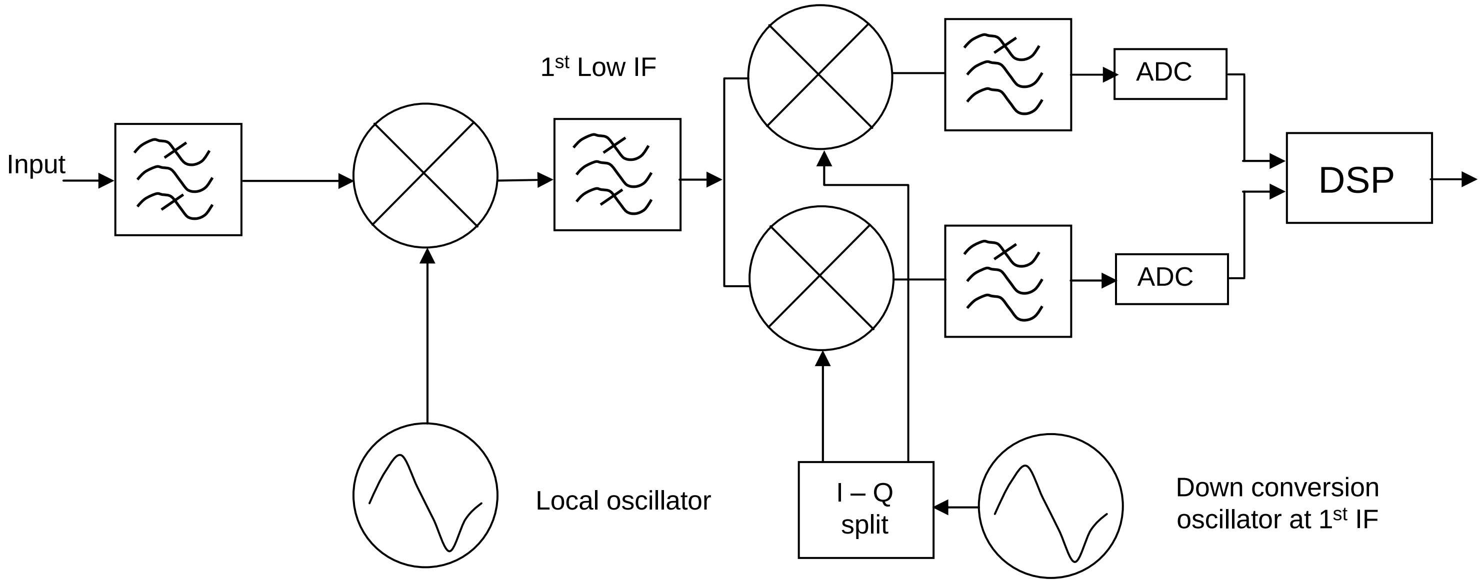
Superhet receiver



The Superhet Receiver

- The incoming signal is converted to an intermediate frequency at which signal processing is done
- An analogue ‘roofing’ filter is required to remove unwanted mixer products prior to the ADC.
- This filter can also potentially reduce the required dynamic range of the ADC
- Analogue pre-mixer filtering is required to remove image responses

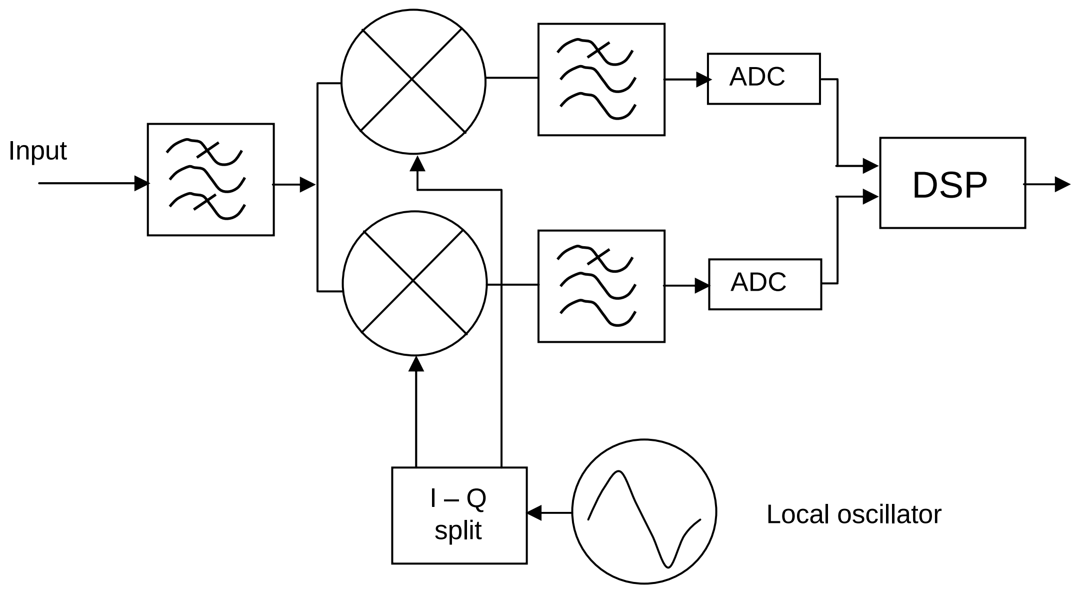
Low IF Superhet



The Low IF Superhet

- The low IF superhet accepts that there is an image response: it may use DSP as shown to reduce this, or it may be able to accept it when a suitable channel plan is in use.
- It simplifies the pre-mixer RF filtering
- Because signal processing is at low frequency, there is a potential for implementing the IF filter in active analogue circuitry and reducing the power consumption, which is a reason for its popularity.
- Because the LO frequency is somewhat removed from the signal frequency, both close-in phase noise and mixer DC offset produced by LO radiation are less of a problem

Direct Conversion Receiver



The Direct Conversion Receiver

- The DC receiver has been the ‘Holy Grail’ of receiver design for over 30 years
- It has the potential of providing maximum integration of the radio onto one silicon chip
- It has several fundamental problems
- Despite these difficulties, it has had a significant number of successful applications over the last 30 years

DC Receiver Limitations - 1

- Close in LO phase noise is demodulated to baseband, limiting ultimate sensitivity
- LO leakage to the mixer input will cause a DC offset at the mixer output, which gives problems with low frequency signal components
- Second order transfer characteristic effects can lead to demodulation of the AM components of unwanted signals, leading to an effective higher baseband noise levels
- Because there are I and Q channels, the power consumption is generally higher than for other architectures.
- Analogue FM reception requires AGC, DC coupling, and close gain matching between I and Q channels.

DC Receiver Limitations - 2

- DC offset problems mean that modulation schemes that have very low frequency components have problems
- This means either AC coupling (which may not be practical because of chip area in a fully integrated receiver) or a feedback loop, adding complexity.
- Especially with CMOS or Gallium Arsenide technologies, 1/f noise can be problematical. This can lead to the ‘front end’ gain having to be higher than is desirable from a dynamic range standpoint.

Transmitter limitations

- There are fewer limitations on the transmitter in an SDR radio

- Modulation can be accomplished by I and Q modulators, possibly operating at final frequency.

- The use of linear amplification may be necessary: this can have negative implications in terms of DC-RF conversion efficiency

Overall Complexity

- The SDR radio may be more or less complex than the classical approach it replaces – depending upon the frequency range and modulation types it has to handle.
- For very wide frequency coverage, the RF hardware may need to be built in separate portions of circuitry dedicated to particular frequency ranges

SDR Reliability

- There are two areas of reliability to consider:
  - Hardware reliability
  - Software reliability
- Hardware reliability follows classic patterns
- Software reliability (or the lack thereof!) may lead to lower overall reliability, depending on the implementation mechanisms

Measuring the SDR Radio

- Basic radio performance requirements do not change

  - receivers still operate in a non-benign RF environment

  - Transmitters still have limitations on occupied bandwidths, Out-of-Band and spurious emissions

- Measurement of receiver instantaneous dynamic range cannot be extrapolated in the same way as in analogue receivers – integral and differential non linearities have effects that vary with input level

Standards requirements for SDR -1

- Because classical radio measurement techniques are not necessarily applicable to SDR implementations, the new measurement methods that are required must be reflected in applicable standards, especially where such standards are intended to be Harmonized.

- This may well lead to a requirement to re-evaluate the approach to the determination of measurement uncertainties

Standards requirements for SDR -2

- One standard for an SDR to cover all possible applications would be unwieldy

- Standards for specific SDR/CR applications, such as WAPECS in defined frequency bands e.g. those allocated for UTRA/3GPP etc are a practical possibility

- When all the users of a particular service in a given frequency range have fully capable SDRs meeting the same standards, spectrum ’re-farming’ becomes practical at very short notice, offering major benefits for spectrum management

- By using a cognitive radio approach, high level modulations can be used where the carrier to noise (c/n) ratio is high, offering higher data throughputs, and changing to lower throughputs with a lower level modulation when the c/n is low – if built into the standard

Summary

- The advent of SDR presents new challenges in design, power consumption, measurement and standards production
- The current technologies do not provide all the necessary requirements for universal application of the technique
- There may well be applications where the complexity of SDR will never offer advantages, because of such factors as complexity, price and/or power consumption - even if it is ‘Die Eierlegende Wollmilchsau’