RTT TECHNOLOGY TOPIC
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# 3 G Receiver noise budget

This month's hot topic is the first part of a series examining the many factors comprising the link budget performance (both through the propagation medium and the hardware) of a 3G mobile air interface utilising Wideband CDMA technology.

The first article works through the post despreading process of a typical wideband receiver implementation.

The objective is to consider and hence dimension some of the prime parameters that influence the output quality of the receiver and to provide a methodology that can be adapted to individual requirements.

Arguably the prime destructive energy in any communication system is noise and the less than ideal nature of components that we use to control it.

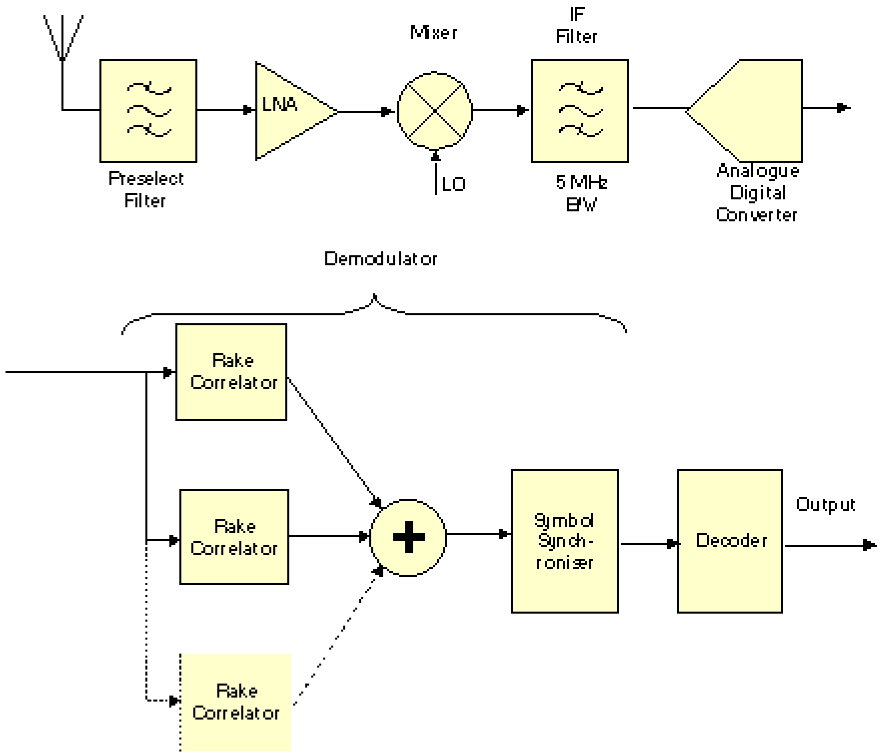


**Fig 1 - A Typical W-CDMA Superhet Receiver**

The preselect filter bandwidth ensures that only inband signals are presented to the LNA. This is to minimise the risk of intermodulation products being generated in the LNA, the mixer or subsequent stages. The LNA amplifies the incoming RF signal, raising it above the noise floor of subsequent stages.

The amplified RF is then passed to the mixer where it is mixed with the Local Oscillator (LO) to produce the Intermediate Frequency (IF). The IF output by the mixer is passed through an IF filter(s) which is centred on the IF and has bandwidth of approximately 5 MHz (WCDMA). The band limited IF is digitised in a Sampling Analogue-to-Digital converter and output as digital samples to the RAKE receiver.

The RAKE receiver consists of correlators, each receiving a multipath signal. After despreading by correlators, the signals are combined to accumulate multipath energies.

The raw correlated signal is further processed, i.e. de-interleaving, decoding, symbol synchronisation to obtain an optimum base band bit stream.

Part of this processing is the detection and/or repair of bit errors. This improvement of BER is referred to as Coding Gain.

An analysis can now be made of the above process to derive the sensitivity of an ‘ideal’ receiver.

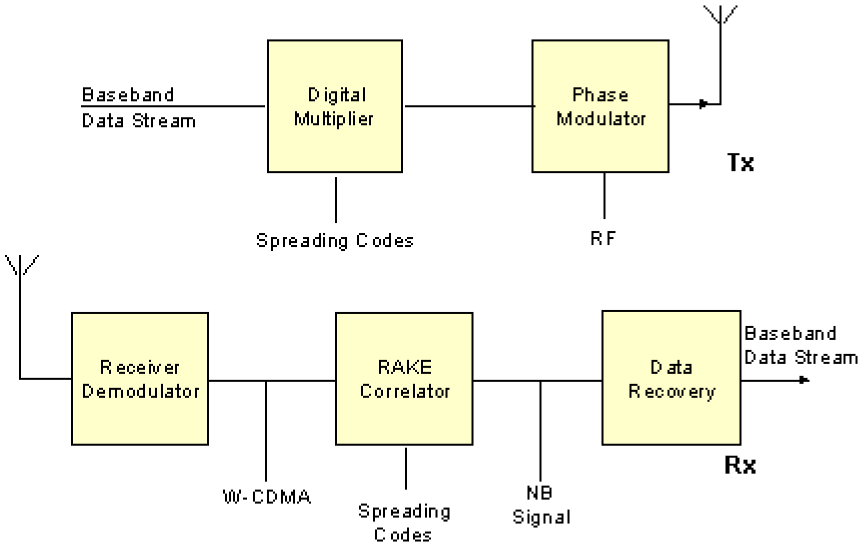


**Fig 2 - The WCDMA Channel**

## Performance Benchmarks

- Initial Conditions:
- Spreading Rate 3.84 Mchips/sec
- RF/IF Filter response ($\propto$) 1.30
- IF Bandwidth 5.0 MHz
- Data rate examples to be evaluated:
  - 32 kb/s
  - 64 kb/s
  - 1024 kb/s - uplink proposal
  - 2048 kb/s - downlink proposal
- Target Quality (BER) $1 \times 10^{-3}$
  $1 \times 10^{-6}$

**Receiver Noise Floor**

Thermal (Gaussian) noise at the receiver input must be considered. All conductive mechanisms, for example metals and semiconductors in a state of ‘thermal agitation’ generate electrical noise. The available noise power in a resistance (impedance) is independent of the resistance value, is proportional to temperature and fills the measurement (or channel) bandwidth available to it.

The noise power is dimensioned by Boltzman’s Constant ($k = 1.38 \times 10^{-23}$ J/K) and standardised to a temperature (T) of 290K. (17°C).

In order to make the value applicable to any calculation it is normalised to a 1 Hz bandwidth. The value (k x T) is then multiplied up by the bandwidth (B).

The reference noise power value from the above is –174dBm/Hz and is used as the ‘floor reference’ in sensitivity/noise calculations.

**Bandwidths**

Given the modulation format (QPSK) the modulation bandwidth must be considered.

Bandwidth required for digital data modulation is a trade off of occupied bandwidth against signal (carrier) distortion or truncation. Bandwidth truncation infers a spectrum limiting of the power spectral density (PSD) which is evidenced by Intersymbol Interference (ISI).

The most popular measure of bandwidth for digital communications is the width of the main spectral lobe, where most of the signal power is contained. This is the null-to-null bandwidth.

**Table 1 Null-to-Null Bandwidth**

| Modulation Method | Typical Bandwidth (Null-to-Null) |
|---|---|
| QPSK, DQPSK | 1.0 x Bit Rate |
| MSK | 1.5 x Bit Rate |
| BPSK, DBPSK, OFSK | 2.0 x Bit Rate |

Although suitable as a definition for BPSK, QPSK, OQPSK and MSK it must be used with care as some modulation formats lack well defined side lobes.

Table 2 lists relevant example data rates, their modulation format and the null-to-null bandwidth.

The bandwidth is determined by the filter(s) in the receive system and this in turn allows calculation of the noise power bandwidth from Noise Power = 10 $\log_{10}$ BW dB, this parameter is also listed in Table 2.

**Table 2 Data Rate Samples to be Evaluated**

| Signal Number | Data Rate kb/s | Modulation Format | Theoretical N-to-N B/W kHz | Noise Pwr (in N-to-N B/W) dB |
|---|---|---|---|---|
| 1 | 32 | QPSK | 32 | 45 |
| 2 | 64 | QPSK | 64 | 48 |
| 3 | 1024 | QPSK | 1024 | 60.1 |
| 4 | 2048 | QPSK | 2048 | 63.1 |

**Theoretical Receiver Noise Floor**

The theoretical noise floor through the receiver to the demodulator, ie through the bandwidth defining filters is expressed as –174dBm/Hz + Bandwidth noise contribution.

Table 3 gives this figure by signal number (see Table 1) using the allocated bandwidth noise power (see Table 1, column 3).

**Table 3 Theoretical Receiver Noise Floor**

| Signal Number (Data Rate kb/s) | Noise Power (in QPSK B/W) dBm | Receiver Noise Floor (theory) dBm |
|---|---|---|
| 1 (32) | 45 | -129 |
| 2 (64) | 48 | -126 |
| 3 (1024) | 60.1 | -113.9 |
| 4 (2048) | 63.1 | -110.9 |

The real noise floor for a practical receiver is always higher due to filter losses, LNA and mixer noise, synthesiser noise etc.

In a well-designed Wideband CDMA receiver 5 dB would be a reasonable figure.

**Table 4 Practical Receiver Noise Floor**

| Signal Number (Data Rate kb/s) | Noise Power (in QPSK B/W) dBm | Receiver Noise Floor (practical) dBm |
|---|---|---|
| 1 (32) | 45 | -124 |
| 2 (64) | 48 | -121 |
| 3 (1024) | 60.1 | -108.9 |
| 4 (2048) | 63.1 | -105.9 |

The next stage in the process is to consider the required output quality and assess how this is influenced by the data rate, modulation type, demodulator characteristics and any other subsequent processing gains, eg coding.

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