

Multi standard Transceiver IC enabling low cost Femtocell deployment

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The concept of femtocells and the advantages they offer in terms of in building coverage and operator value proposition to the end customers has been the subject of debate within the industry. Extensive trials and assessments by suppliers and operators have provided encouraging results to the point that deployment is now imminent.

The future of femtocells depends in resolving a number of key challenges such as functionality and cost. Issues such as timing/synchronisation, radio interference and handover into the femtocell from a traditional macro cell have impacted the design and implementation of the radio part of femtocells. The multiple frequency bands and standards adds further complications to the relatively long supply chain, resulting in the high overall cost.

The above challenges have resulted in adding more features to the Femtocell transceiver IC s such as listening mode on a nearby macro BTS cell broadcast channels for receiving information such as location and timing information. These broadcast channels maybe from any of the popular modulation standards and not necessarily the same as one used by the Femtocell transceiver. In order to minimise cost and part count in the Femtocell radio it is preferable if the radio resource from the main transceiver can be borrowed for this listening function. This requires a number of considerations in ensuring that the transceiver can be operated not only over a number of different frequency bands but also modulation standards without the need for excessive additional circuitry to meet the aggressive price points.

The concept presented in this article is based on a a fully reconfigurable receiver which can be used for the dominant modulation standards and has multiple wideband LNA inputs to allow direct connectivity to up to 3 Receive band filters enabling a seamless transition to 'listen' mode without the need for the addition of yet another receiver chain. The design also allows the downlink to continue transmitting its own broadcast channel while the receiver is being used independently.

Femtocells have the unique characteristic that they are a piece of radio infrastructure equipment which must work seamlessly with the existing

infrastructure but they are installed by and located with the end user in their home. Once powered up, the Femtocell must therefore be able to self set up based on its macro environment. Hence, it must be capable of listening to both its own macro network and possibly those on other frequencies and modulation standards.

This network listen mode feature requires the femtocell to utilize multiple receive paths/ICs based on the existing single frequency and standard transceiver implementations. The problem gets even more complicated by the release of new frequency bands with no device availability.

Listening to your own downlink

Interference management is key to the successful deployment of Femtocells and the need to listen to its own downlink raises the following transceiver requirements:

- A receiver chain capable of working in the downlink band
- Switching of a downlink filter to the receiver input when in 'Listen' mode.

Flexibility is an inherent requirement in the listen mode, covering all the bands. It is also prudent to use the existing antenna filter used for the transmitter when listening to the same band. Low power levels in femtocell make the addition of a low cost RF switch possible so that when required the Tx filter can be used as a receive path.

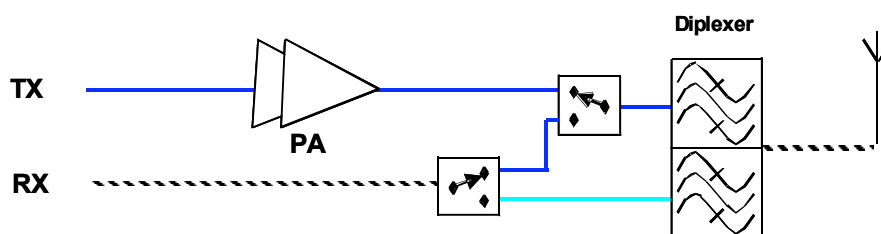


Fig1

If the system is limited to using a single receive path to implement then it is also necessary to also add a switch to the main receive path, Fig 1, this can have a number of negative effects on receiver performance

- The switches insertion loss will reduce Rx sensitivity ($\approx 0.5\text{dB}$)
- Tx to Rx isolation of the diplexer requirement is $>45\text{dB}$, hence switch isolation is dominates the Tx to Rx isolation ($\approx 2 \times 20\text{dB} = 40\text{dB}$)

Whilst these issues are insurmountable, any additional components required adds to the cost and complexity. By utilising an additional receiver input at the transceiver IC, the downlink listen path can be kept separate from the main receiver removing all the identified risks and reducing part count.

Additional network listen modes

As well as the requirement to listen to the downlink of a Macrocell at the same frequency and modulation type as itself, the Femtocell may also be placed in a location where such option may not be available. Therefore, it is desirable to be able to obtain network information from other standards and bands. Hence, further requirements are placed on the listen mode path, primarily that it must be able to cope with different modulation standards (most commonly GSM) and frequencies that are possibly an octave or more separated from the primary transceiver band.

Broadband operation

Multi band transceivers often use multiple LNAs each tuned to deal with different RF frequency bands, however in the Femtocell market the frequency of the required listen mode needs to remain flexible to the geographical location of the deployment. A minimum set of receive frequencies to cover the popular European and US bands would be:

- Main Receive
 - WCDMA (band I ,US band class 6), Uplink – 1920 to 1980 MHz
 - WCDMA (band V, US band class 0), Uplink – 824 to 849 MHz
- Listen modes
 - WCDMA (band I, US band class 6), downlink - 2110 to 2170 MHz
 - WCDMA/GSM850 (band V, US band class 0), downlink – 869 to 894 MHz
 - GSM900 (band VII, US band class 9), downlink – 925 to 960 MHz
 - GSM1800 (band III, US band class 8), downlink – 1805 to 1880 MHz
 - GSM1900 (band II, US band class 1), downlink – 1930 to 1990 MHz

Clearly, to provide a fully flexible system it becomes unfeasible to keep adding receiver inputs for every band, since other bands will become available in the future. The cost due to additional silicon and pin count (hence package size) of the transceiver IC will start to dominate.

The improved performance obtained by tuning the LNA is desirable for the main receive path, however for the listen modes (which in general are listening to the broadcast channels of the local Macro network) there are a number of factors which can allow a slightly relaxed noise figure:

- Listen mode receivers are required to meet mobile sensitivity levels.
- When in listen mode the transmitter is off, so there is no degradation due to transmit noise.
- Additional filtering is not required in receive path to deal with transmitter signal rejection (hence lower front end loss).

The optimum solution therefore is to offer high performance receiver inputs for the main receive paths which can be dedicated to this task and a wideband LNA input for listen mode which accepts all bands.

Modulation, GSM receive

The narrowband nature of GSM signals requiring low noise receivers and offering little coding gain make them very susceptible to IP2 distortion in a zero IF receiver. More modern wideband modulations schemes such as WCDMA , LTE and WiMAX are not as susceptible to this form of distortion and make zero IF receivers a simpler proposition.

By retuning the LO in the zero IF receiver to provide an offset at some low IF and by using the I and Q branches to form an image reject receiver it is possible to turn the zero IF WCDMA receive chain into a low IF chain suitable for GSM.

The selection of IF and the choice of IF filter BW is important as blockers are specified on the high and low side of the wanted signal. Hence making the IF higher in frequency keeps it away from the DC IP2 product, which also allows the RF-offset blocker to get through the IF stage low pass filter.

The IF frequency can be set somewhere between 400kHz to 600kHz IF. A low pass filter (LPF) bandwidth of around 600-800kHz is optimum to ensure that ADCs following the LPF are not compressed.

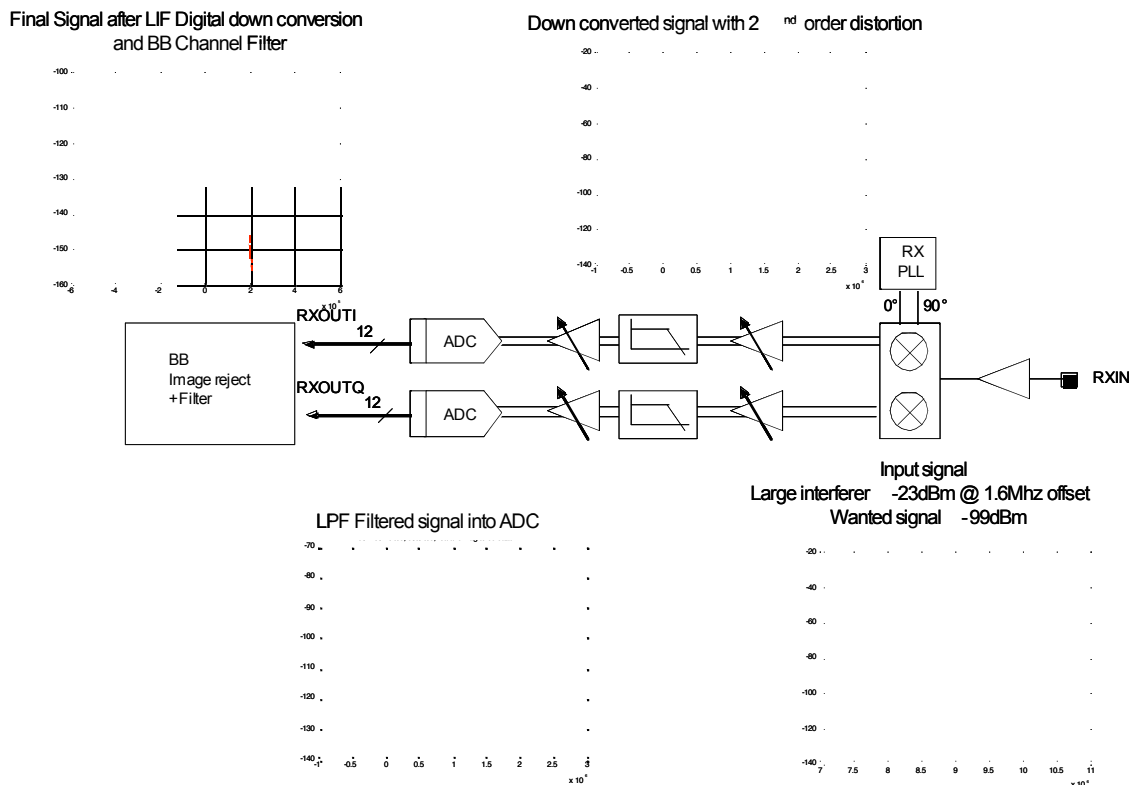


Figure 2

The example in Figure 2 uses the largest blocker from the GSM900 Mobile Station requirement using the following parameters:

Blocker Level = -23dBm @1.6MHz
 Wanted signal = -99dBm
 Rx Input Referred IP2 = 35dBm
 Low IF = 500kHz
 Rx IF BW = 750kHz

It can be seen that the wanted signal is recoverable after BB down conversion and filtering with an SNR > 10dB which is sufficient to reliably demodulate in baseband.

Hence with a small overhead in the baseband processing to carry out the single sideband low IF down conversion, it is possible to share the same receiver HW resource for both WCDMA and GSM receive modes. In order to enable this reuse of resource, the receiver must have sufficient linearity, and compression to avoid distortion in the presence of the blocking signal, together with RF frequency agility and IF filter BW selectability as indicated above.

Implementation

A transceiver IC developed at Lime Microsystems with an operational range between 375MHz to 4GHz covers all of the frequency bands specified in 3GPP. It also provides 2 transmitter outputs, 2 main receiver inputs and a broadband receiver input optimized for the listen mode discussed in the previous section. The Lime transceiver is shown in figures 3 and 4.

As the transceiver has not gained flexibility by adding additional circuitry but by providing reuse of existing design blocks then it offers a cost effective solution for both a single frequency system targeted at a single market (e.g. WCDMA band I in Europe) or a multi-band, multi-standard system capable of dynamically reconfiguring to any cellular band.

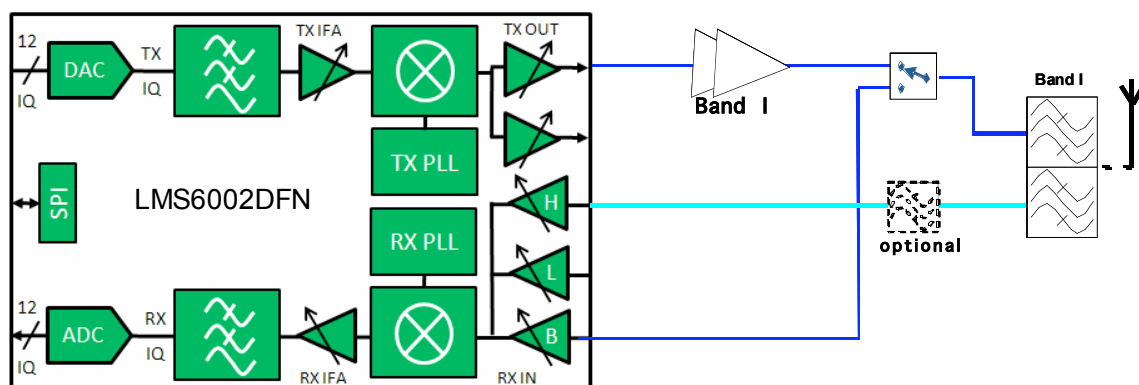


Figure 3

Figure 3: Minimum system implantation for targeted band and minimum BOM cost.

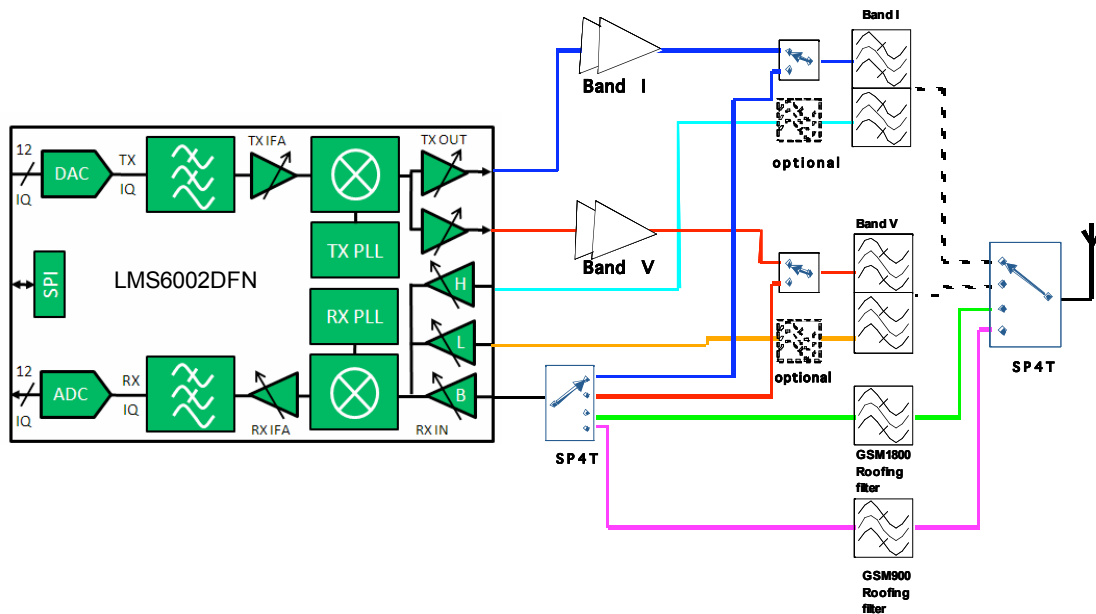


Figure 4

Figure 4: Lime transceiver set up for multi-band, multi-standard operation covering WCDMA bands I&V with downlink listen mode and GSM900/1800 listen mode offering single BOM covering dominant European bands.

Summary

A single low cost receive path with a sufficient frequency range, BW flexibility and linearity can be shared for both WCDMA and GSM receive paths. Having enabled the possibility of sharing the same hardware for multiple bands and standards, an optimum solution for transceiver connectivity has been identified.

Using a single low cost receive path for multiple receive modes reduces the need for multiple receiver devices (whether separate devices or on chip), the LO, filters and ADC are reused offering significant saving on part count and/or silicon cost.

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About Lime Microsystems

Founded in March 2005, Lime Microsystems is a fabless semiconductor company specializing in digitally configurable transceivers for the next generation of wireless broadband systems. Lime has developed broadband transceiver ICs that significantly reduce the bill of materials for small cell (femtocell and picocell) wireless networks. Working in partnership with leading baseband technology companies, the company has also produced a reference design in industry-standard MicroTCA format. Lime has development teams in the UK and Lithuania and is backed by ACT Venture Capital and DFJ Esprit. Further information is available at www.limemicro.com.