HIGHLY INTEGRATED RF - ICs FOR GSM AND DECT

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Abstract

TDMA based digital systems like GSM for cellular and DECT for cordless application have created an increasing market within Europe and gained widespread acceptance also outside Europe. This talk gives an overview of both systems. The system requirements and their influences on highly integrated RF ICs for GSM and DECT are discussed. The various trends of progresses in integration of both systems will be shown.

GSM - RF development progresses

The GSM system was established in the 900 MHz frequency band during 1992. First generation RF products were available from various suppliers in mid 1990 (see Figure 1). This designs were based on medium level integration (partly building blocks) and used a 5 V supply voltage [1, 2]. The RF board design of a complete handheld at that time consists of about 400 to 500 components (Cs, Ls, R, ICs etc.).
Figure 2 shows you a total view of all currently used transceiver architectures and their market share. At the beginning many different transceiver concepts were discussed. But currently four receiver and transmitter concepts are mixed up to eight combinations and are in volume production.

GSM - Receive signal path

In total four receiver concepts are in use in the application of the GSM-system.

1. Zero IF concept with additional baseband filtering and variabel gain baseband amplifier in front of the A/D converters.
2. Heterodyn receiver with an IF of 45 to 82 MHz [1, 5] and in new design up to 250 and 450 MHz [3, 8] and down conversion from IF to I/Q baseband, recently the IF gain control and conversion from 81.25 MHz is done in CMOS circuitry [5].
3. Heterodyn receiver with an IF of 72 MHz and a second down conversion with additional passive filtering at about 13 MHz and followed by IF sub-sampling.
4. Heterodyn receiver with an IF of 72 MHz and a second down conversion with additional filtering at about 6.5 MHz and followed by a phase-comparater and a slow A/D converter for radio signal strength measurement; this concept is similar used in all PDC 0.8 and 1.5 GHz applications in Japan.

The advantage of the zero-IF concept is, that it does not require the first IF-filter and the image filters.
The 2nd concept has a complete linear signal handling up to baseband and requires only a IF roofing filter. This allows to increase the IF-filter frequency from 70-80 MHz to values between 200 to 450 MHz.
The dual conversion to IF-sampling concept 3 is also a very interesting concept. Due to the limited range of A/D converter at this IF-frequency, it still needs a 2nd IF filter before subsampling to baseband. The phase and RSSI-sampling concept 4 has the highest requirement on the 2nd IF-filter because it uses a IF-limiter amplifier.

GSM - Transmit signal path

The transmitter part of the GSM related system concepts is also dominated by four concepts.

1. Low IF frequency I/Q-modulation (100-300 MHz) followed by a upconversion mixing and passive image filters. This concept is also in use at PDC 0.8 and 1.5 GHz and in CDMA applications.
2. Direct I/Q modulation with local oscillator running on transmit frequency.
3. Direct I/Q modulation with transmit LO signal generated by mixing via an IF LO and RF local oscillators. Using a frequency offset of both LOs results in less feedback leakage sensitivity. This is also very popular at PDC 0.8 and 1.5 GHz applications.
4. Low IF frequency I/Q-modulation (100-300 MHz) followed by a upconversion modulation loop.

Concept 1 has the advantage, that the interstage filter between modulator output and upconversion mixer input reduces the broadband noise at the RX band generated by the modulator. However it requires a very good image filter, to suppress the unwanted images.

Concept 2 is very straightforward and has no spurious problem, because only one LO signal is present during transmit mode. But it requires very good shielding of the unmodulated VCO, to prevent remodulation. It requires additional band filtering after the modulator to reduce the broadband noise of modulator in the receive band. Unfortunatly most power amplifiers have a very nonlinear transfer characteristic and TX broadband noise is mixed up to the receive band.

With concept 3 you can prevent the feedback problem by frequency offset of both local oscillators.

Finally the concept 4, when using a low noise TX-VCO with an output level of about +10 dBm offers lower broadband

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noise, so that the duplexer can be replaced by antenna switches and low pass filters.

Due to two active local oscillators during TX mode, concept 1, 3 and 4 are very sensitive to spurious emission and needs a good filtering and optimized frequency plans.
In the GSM related systems we find more and more tendency to Dual band handheld solutions and further increasing 1st IF frequency to the range up to 400-500 MHz. Also the total component count for the RF front end moved from 400-500 down to 200-300, with further potential to around 100 components or less. Since 1995 also complete handhelds using 2.7 V for the complete RF function without the power amplifier are available [3, 7, 8].

DECT - RF development progresses

First cordless sets according DECT system were introduced in the market in mid 1994 see figure 3. They were already with a high level of integration in baseband, whereas the RF had a high content of discretes, resulting in nearly 400 components on the RF part of the board.

Three receiver and two transmitter concepts are mixed up to three combinations and are now in volume production see figure 4. We find solutions on the market with a one chip transceiver [6] and additional external discrete components. Also 2 ICs splitted horizontal into a receiver and transmitter [9] or splitted vertically into a front end RF part for up/down conversion and backend IF part for modulation/demodulation were published. Still solutions with a high level of discrete transistors and passive components are produced. Here RF-VCO modul don't have such a high market share than in the cellular application.

DECT - Receive signal path

1. Zero IF concept with additional baseband filtering and variabel gain baseband amplifier in front of the A/D converters. One company started now production with this concept.
2. Dual conversion receiver with an IF 110 MHz and a second IF of 5-6 MHz, with additional passive filtering followed by IF limiter amplifier and demodulator. The receiver part of first generation was dominated by dual conversion receiver design, now production is more and more replaced by a single conversion concept.
3. Heterodyn receiver with an IF of 110 MHz and a limiter amplifier and demodulator at this frequency. This concept gets more and more market share, because of its high sensitity [9].

If the zero-IF concept is used, additional analog baseband gain control, filtering and processing is required or two additional baseband A/D converters are needed. These increases cost and makes design more complicated compared to conventional IF-limiter amplifiers with FM demodulation.

The DECT GFSK modulation allows to use simple FM demodulator and a low cost 1st IF filter. Also the FM demodulation is very unsensitive to local oscillator frequency offsets and still has potential for further integration.

The dual conversion concept was easy to develop at the beginning, because all FM demodulator components from standard TACS, Amps and CT1 system were available. But the second down conversion incresaes component count.
The single conversion concept has brought down reasonable the component count in the application and has the same sensitivity of -95 dBm.

DECT - Transmit signal path

The transmitter part of the DECT system concepts is dominated also by two concepts (Figure 8).

1. Low IF frequency-modulation (100-300 MHz) followed by a upconversion mixing and passive image filters. This was only in the very beginning published, but is not in volume production now.
2. Open loop modulation with local oscillator running on half the transmit frequency, this concept has highest market share.

The low IF-modulation & upconversion mixing according concept 1 has the advantage, that there are no drift problems during TX time slot. If the loop filter frequency of the IF PLL is aligned to less than 1 kHz, then the modulation signal can be superimposed on the tuning voltage. But it requires a very good image filter, to suppress the unwanted image. A careful selection of both LO signals ios needed, to have a low enough spurious emission.

Concept 2 is very straightforward and has no spurious problem, becuase only one LO signal is present during transmit mode. But it requires very good shielding of the VCO, to prevent remodulation via the power amplifier output signal. When the local oscillator runs at half the transmit frequency the feedback pulling sensitivity is reduced. Also the PLL charge pump output must have a very low leakage current.

For the future, Dual-mode (GSM & DECT or PCN & DECT) applications may become available on the market. It depends on the cellular system providers and their monthly charges where the market finally will progress.

The ongoing RF-integration reduced the component count from about 400 parts to 150 in the meantime, with further potential to less than 100 components. Since 1996 also handhelds with 3 V supply voltage for the complete RF function without the power amplifier are available.

The future trend is to further reduce the supply voltage down to 2.7 V or less and decrease the current consumption and the peripheral component count. Bipolar power amplifiers may replace discrete transistor power amplifiers and GaAs power amplifiers.

Conclusion

The GSM and the DECT system have both created a strong new market within Europe and other areas of the world and by the way RF integration has become a very important fact to reduce component count and production cost. The new RF-ICs solutions enables the handset manufacturer to reduce voltage and power contributing in lower size and weight.

The development path to system-on-chip is still going on; limitations that we still have today can be solved step by step i.e. on-chip VCOs, on-chip filters, on-chip tuning, on chip demodulation and on chip alignement by 3 wire control lines etc. Also more and more low frequency and IF functions could be solved by CMOS- or BiCMOS-Technology.

It is fascinating to see how system specifications and progresses in SAW filter technology had an influence on the RF-concepts and the forward integration. This leaded to the RF-product families available on the market. The common development in the last years are the power of RF-analog design and implementation technique, as well as the further evolution in silicon processing technology.

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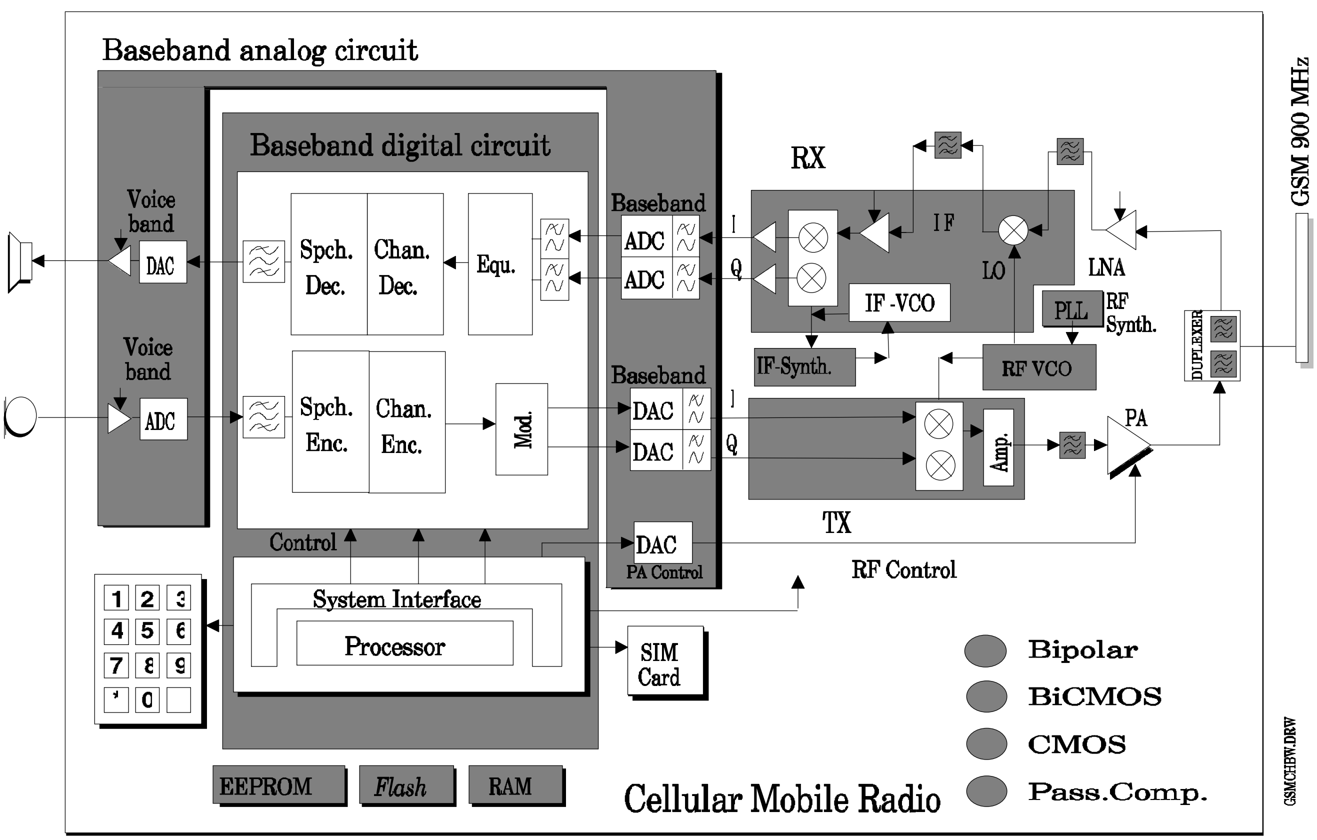

Figure 1: Block diagram of a typical RF and Baseband 5 V chipset for cellular GSM telephones

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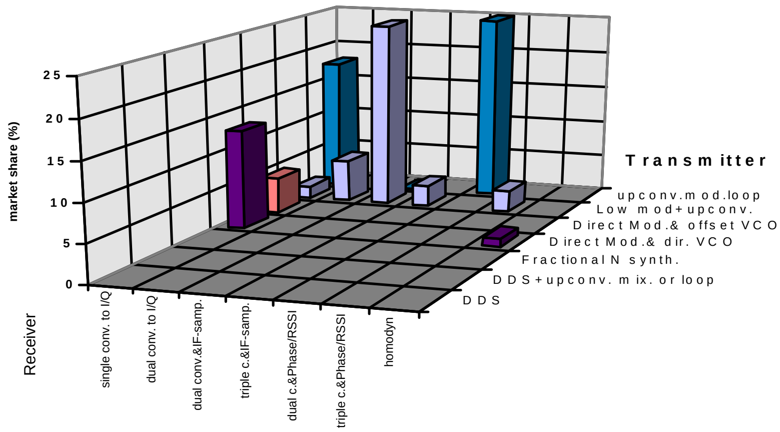

Figure 2: Transceiver concepts used at the moment within the digital GSM handheld market

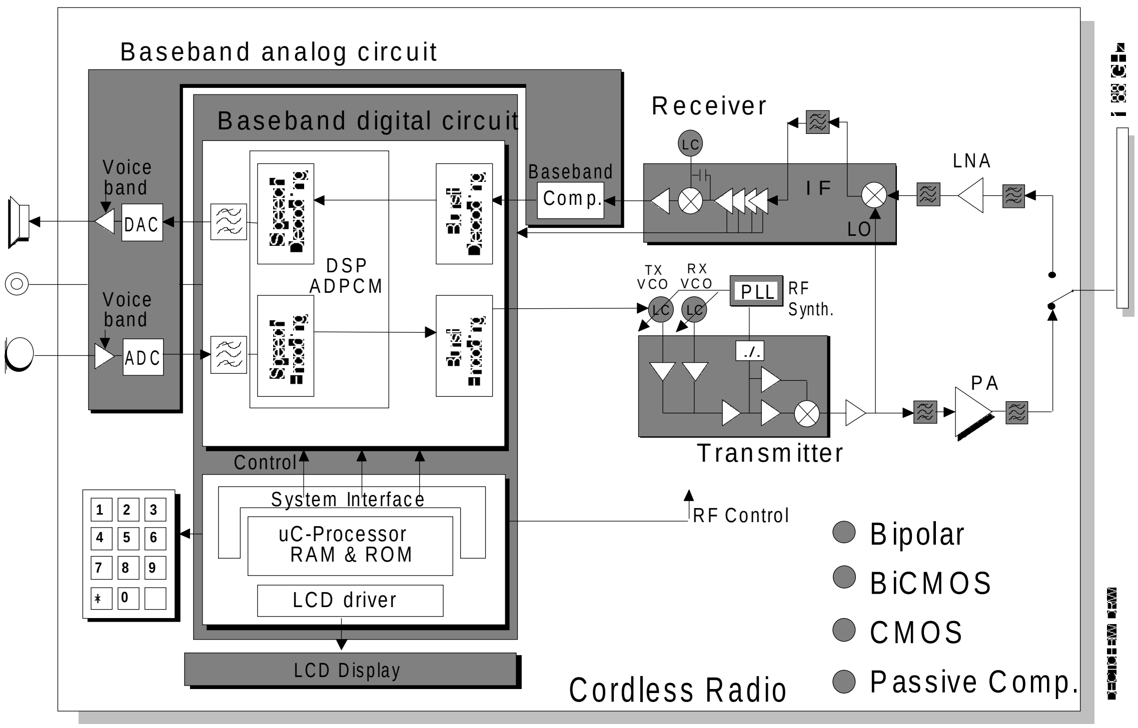

Figure 3: Block diagram of a typical RF and Baseband 3 V chipset for cordless DECT telephones

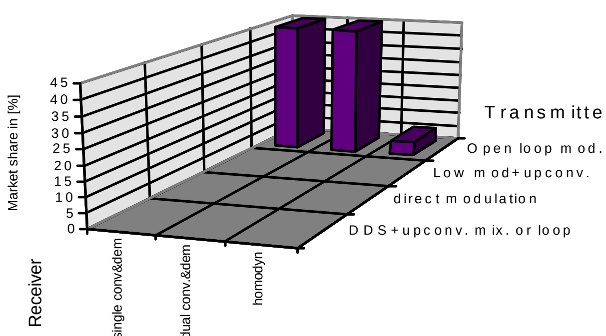

Figure 4: Transceiver concepts used at moment within the digital DECT handheld market