RADIO ARCHITECTURE OF A WIDEBAND DS-CDMA TESTBED FOR FUTURE CELLULAR SYSTEMS

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Abstract

The radio implementation of a wideband test system which has been developed by Ericsson is described. With the testbed wireless multimedia service investigations for UMTS/FPLMTS can be done under field conditions. The system architecture provides a flexible air interface where new services can easily be introduced. Already implemented services are high quality speech with fixed or variable data rates as well as high data rate transmissions for video, internet or other TCP/IP data applications. The high data rates and the flexibility of applications result in new demands for the radio architecture and for key components, like digital-to-analog and analog-to-digital converters and power amplifiers.

This paper provides a system overview describing some applications and a more detailed description of the radio architecture of the wideband testbed. Finally measurements of the data throughput and of the radio channel are shown.

Introduction

Future cellular systems require high flexibility for new services and the possibility to transmit much higher data rates than with present systems. Several investigations are ongoing to enhance present systems e.g. multi slot techniques for TDMA systems and/or multicarrier techniques for TDMA and FDMA systems. A possible access technique for UMTS/FPLMTS [1], which could provide applications at high flexibility, is wideband CDMA [2]. Ericsson has developed and implemented a testbed to investigate wideband DS-CDMA techniques which is based on the results from the CODIT project [3]. CODIT was an international research project within the European RACE program in which Ericsson was a prime contractor.

When implementing wideband DS-CDMA systems new demands arise for RF engineers to design wideband transceivers. Full advantage and full flexibility for applications of this access technique can only be obtained if the frequency band is wide. This means a bandwidth of 5 MHz or wider. A 15 MHz wide frequency band which contains two 5 MHz wide channels with guard bands can be handled within the developed testbed.

Services

Several applications are implemented to investigate and demonstrate the flexibility of the system. For speech applications different speech codecs are using fixed or variable data rates. The rate depends on the speech activity and ranges from 0.4 kbps up to 16 kbps [4]. The speech service requires short delay. For data services a longer delay can be allowed which makes longer interleaving possible. Symmetrical data transmission, used e.g. for video applications, with data rates up to 128 kbps is available. The data rates can vary with each frame to adjust to the required need for data transmission [2]. Asymmetrical variable data transmissions which appear e.g. with Internet applications are also supported.

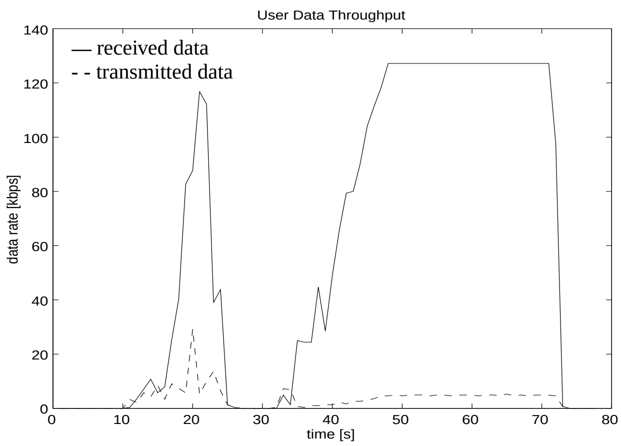

Figure 1. Data throughput at mobile station when using a WWW browser.

In figure 1 the measured asymmetrical data throughput over time during browsing the WWW at the mobile station can be seen. The first impulse represents the data transmis-

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sion during login to the browser and the second impulse is due to a download of a picture of Stockholm. The commands in the uplink do not need the full capacity of the radio channel. On the uplink only a few commands need to be transmitted and the usage of the radio capacity is kept small. On the downlink, full capacity is only used during the time of high data transmission. Efficient usage of the radio resource will be of key importance for future mobile systems which are to provide multimedia services.

System Architecture

Figure 2 shows the block diagram of the system with a mobile station (MS), a base station (BS) and a radio network controller (RNC).

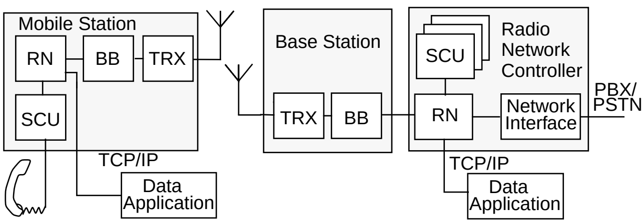

Figure 2. System overview.

The MS comprises the radio network (RN), the baseband (BB) and the transceiver (TRX) processing units and the speech codec unit (SCU). The RN contains the radio protocol and the system management and combines the applications with the physical layers in the BB and the TRX units. Man-machine interface (MMI) functions are also implemented in the RN unit.

The architecture of the BS is almost similar to that of the MS. The functionality of the BB and TRX units in the BS corresponds to the functionality in the MS. The RN together with the SCU is located in the RNC which is geographically separated from the BS. The RNC can be connected to several BS in order to handle hand over or macro diversity. A network interface connects the testsystem with the PBX/PSTN.

As applications in the testbed different speech codecs [4] are implemented and a standard TCP/IP connection makes it possible to implement any kind of data application.

Testbed Transceiver Architecture

A transceiver architecture that can handle two 5 MHz channels and that achieves the transmultiplexing of channels and the channelization in the digital domain was chosen. The benefits of this are that minimum duplication of hardware is necessary when transmitting or receiving more than one frequency simultaneously and that the channel selection can be made faster and easier synchronized with the frame clock.

Figure 3 and 4 show more in detail the block diagram of the transceiver and the functionality is described below. In the transmitter the incoming 20 Msps digital I and Q signals are first pulse shape filtered (PSF) in a 52-tap FIR filter implementation. Following this is an interpolation and filtering stage which increases the sample rate to 40 Msps before the signals enter the complex multiplier. The signal is then multiplied with the complex signal which is generated by the numerically controlled oscillator (NCO). The chosen frequency and phase of the NCO determines the selected 5 MHz transmit channel within the 15 MHz frequency band. Next the signal is yet again interpolated by a factor of two and converted into a real signal in the IQ modulator resulting in a sample rate of 80 Msps. This IQ modulator also frequency converts the signal by 10 MHz. The last stage in the digital chain is the 12-bit digital-to-analog converter (DAC) which operates at a sampling frequency (f_s) of 80 MHz and converts the digital representation of the channel to an analog intermediate frequency (IF) signal centered around 20 MHz. The spurious free dynamic range (SFDR) for the DAC measured in the system is in access of 60 dB.

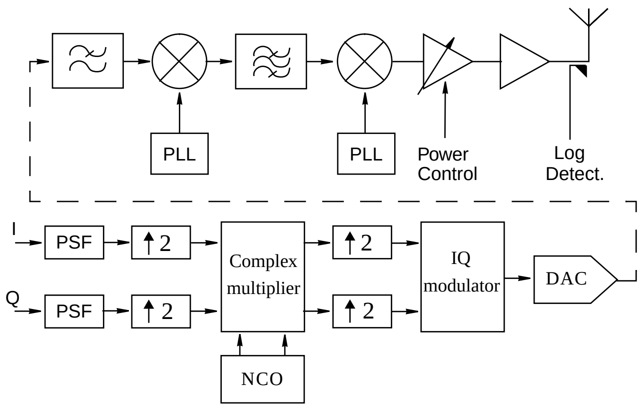

Figure 3. Transmitter implementation.

The analog IF signal is then upconverted to 2.2 and 2.3 GHz for the uplink and downlink respectively via an IF of 140 MHz and passed through a variable gain amplifier, which implements the required power control. Finally a power amplifier with +36 dBm output power amplifies the spectrum, see figure 5. An open loop power control is included for logging the transmitted power. The bandwidth of the analog part of the transmitter is 15 MHz handling two 5 MHz channels with guard bands.

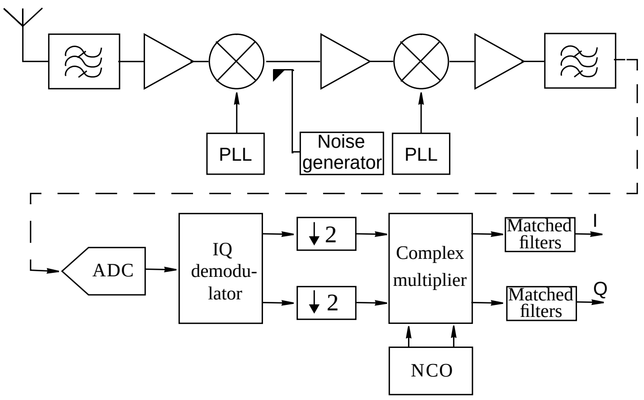

Figure 4. Receiver implementation.

The analog part of the receiver also uses two frequency conversions before analog-to-digital conversion. On the first IF, which is at 150 MHz, a broad band noise source is implemented to simulate other mobiles in the uplink. This is possible since all other users appear as broad band noise because of the chosen code properties. The analog-to-digital converter (ADC), running at a sampling frequency of 40 MHz, converts the signal to its digital representation. Since the IF, centered around 30 MHz, is in the second nyquist band, between $f_s/2$ and f_s, the signal will be mirrored around $f_s/2$ and the spectrum will be inverted. The ADC, also a 12-bit architecture, achieves when used in a subsampling mode an SFDR of approximately 70 dB.

Following the ADC is the IQ demodulation which also performs a frequency conversion of the signal by 10 MHz and a low pass filtering. A decimation by two precedes the complex multiplication where an upconversion is performed. This reason for the upconversion is to centre the negative (complex represented) frequency band around zero, thus compensating for the mirroring that occurred due to the subsampling process. Last in the receiver chain is the pulse shape matched filters.

The fundamental property of the implemented receiver chain is that the NCO together with the digital filters do the channelization, i.e. channel selection and channel filtering while the phase locked loops (PLLs) select the 15 MHz band.

The controlling and setting of the output power together with the upconversion from IF to RF is done with an Ericsson designed RF IC. After upconversion and prior to the power amplification, filtering and preamplification is performed. The power amplifier is characterized by a 1 dB compression point of +36 dBm. More details of the power amplifier will be described in the next chapter.

On the transceiver board an open loop power control and a closed loop power control with a dynamic range of 65 dB are implemented. The closed loop power control is updated 20 times per 10 ms frame [2].

Measurements

It is sufficient for a test system to have coverage of a few kilometers around the BS antenna. Therefore an output power of +36 dBm is appropriate for BS and MS. This output power can be handled by already matched power modules. The power amplifier is designed for a very wide bandwidth of about 600 MHz and is not optimized for the specific used bandwidth and RF frequency. The intermodulation levels and the adjacent channel powers are therefore determined by the power amplifier.

The output spectrum of the BS is shown in figure 5 for an average output power of +36 dBm and is compared with an average output power of +30 dBm. The spectral regrowth can be seen for an average power in the order of the 1 dB compression point of the power amplifier.

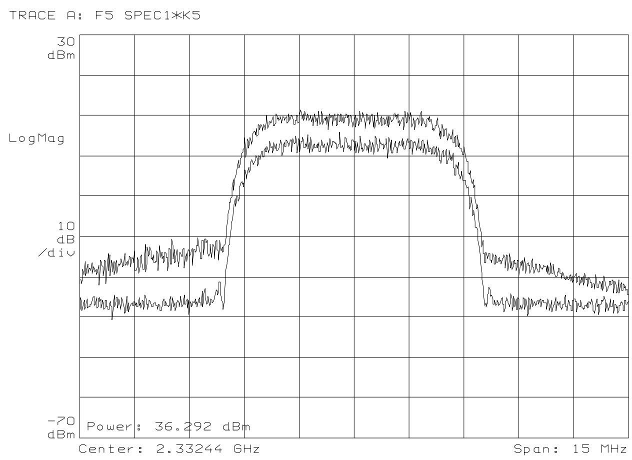

Figure 5. Output power spectrum.

These spectra are measured during downlink data transmission at 128 kbps for one user. On the downlink a pilot channel, a synchronization channel, a physical control channel and a physical data channel are transmitted simultaneously and a peak-to-average value of about 4.5 dB is

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calculated. No significant spectral regrowth can be seen for the spectrum at an average power of +30 dBm.

Performance evaluation of the testbed by comparing simulations and measurements done in the field and in the lab are shown in [6]. For lab measurements a channel emulator is used to generate different profiles of the radio channel. Performance of different services in different environments has been evaluated.

In figure 6 a typical received spectrum after the channel emulator using the JTC9a channel [5] without additional attenuation is depicted. According to these measurements fading dips occur which can be up to 1 MHz wide. These fading effects can be handled in a wideband system.

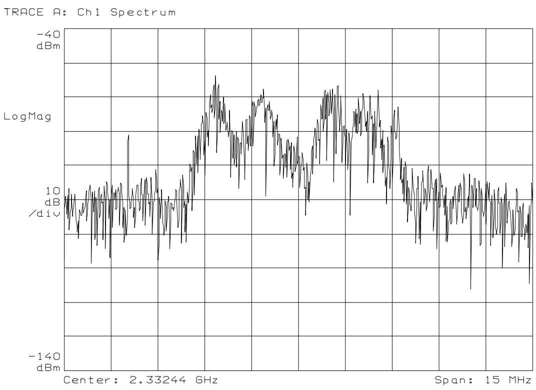

Figure 6. Received power spectrum after channel emulator.

The impulse response of the radio channel is characterized by the delay power spectrum. Figure 7 shows the delay power spectrum after applying the JTC9a channel model. This channel model includes several propagation paths within a delay spread of 1.7 µs. In a wideband system it is possible to resolve these rays and combine them in a RAKE receiver [2]. In a narrowband system these rays cannot be resolved, i.e. the frequency diversity gain will be less in such a system under these channel conditions.

Conclusion

A mobile radio test system which is based on wideband DS-CDMA techniques is presented. Services at data rates which are about ten times higher than the data rates available in present systems can be investigated with laboratory and field measurements. Implemented services are speech with variable data rates up to 16 kbps as well as symmetrical and asymmetrical data transmission with data rates up to 128 kbps.

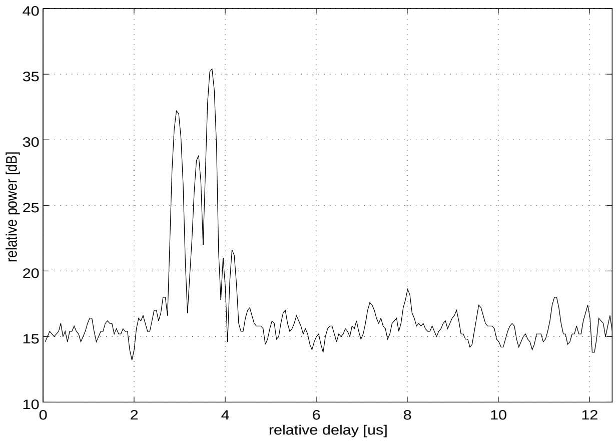

Figure 7. Delay power spectrum.

The testbed transceiver architecture, which is presented in detail, handles two 5 MHz channels with guard bands and supports the flexibility of the overall test system. The channel filtering is done in the digital domain which enables faster and easier channel selections and the possibility to apply and investigate different air interface concepts. Measurements of 5 MHz output spectra and delay power spectrum, which characterize the radio channel, are depicted.

References

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