DuSLIC –

Infineons High Modem Performance Codec

Introduction

Modems that use the regular telephone network are and will be the dominant technology for the internet access and other data applications. The reasons among others are inexpensive technology, high volume and access possibilities from anywhere a phone is located. Over the years, modems continuously used newer and better signal processing capabilities to achieve higher data rates and fulfil the demands of internet users. Especially the design of internet pages with graphics and animated pictures made it necessary to provide high data transmission rates.
Since the V.90 modem standard was introduced Infineon Technologies has performed detailed investigations to enhance the modem performance of its Codecs.

Traditional modem technology

Former modem technologies, up to V.34, used tone signals within the voice band to transmit information over the PSTN[1]. Those algorithms reproduced the appropriate signal forms and tried to compensate the impairments caused by the network. During the start-up phase of a data connection modems sample the telephone network to determine the characteristics of the connection. Based on this information they decide what the best parameters are for a data transmission under these conditions.
Figure 1 shows a traditional telephone network with an analog client modem communicating to an analog ISP[2] modem. Because both sides, client and ISP, are analog, two line cards are present in the network which means that the impairments from two line cards are added to the original signal. Under ideal conditions, the limit for V.34 modems is 33.6 kbit/s over such a network.

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[1] PSTN: **P**ublic **S**witched **T**elephone **N**etwork

[2] ISP: **I**nternet **S**ervice **P**rovider

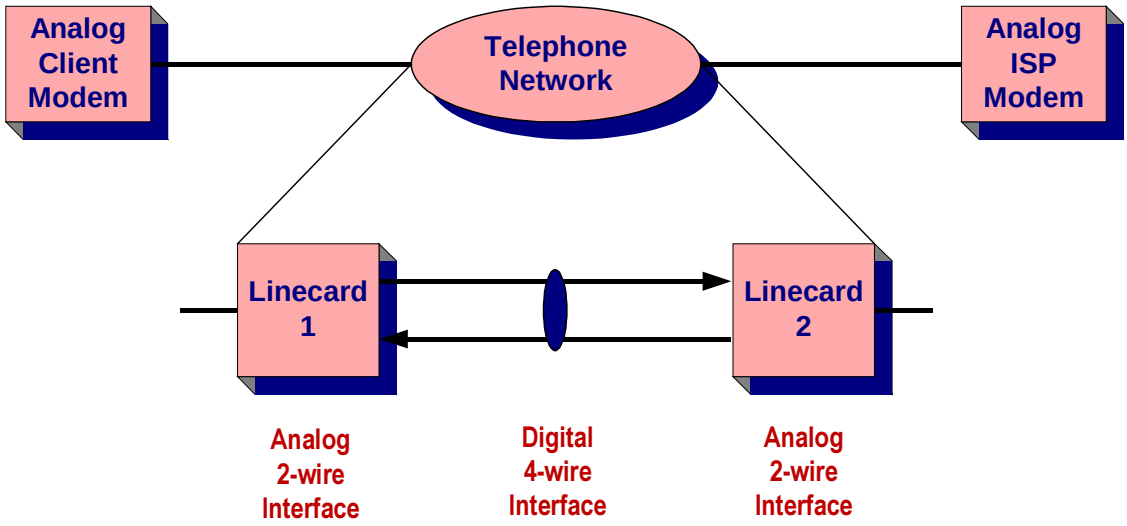

Figure 1: *Traditional Telephone Network*

Over the time, the telephone network became digital between the central office switches and only the connection to the consumer remained analog. A result from this transition was, that Codecs where introduced at the central office line card and the line card on the ISP became digital (see Figure 2). The V.90 standard takes advantage of this situation and uses a digital connection to the remote modem which is located at the point-of-presents or ISP. With the current technologies (PCM[3] coding and 8kHz sample rate) only one digital to analog conversion is allowed in the data path to achieve V.90 connections. In cases where line multiplexing equipment, which connects analog into the central office, is used, a V.90 connection is just possible with improved data processing algorithms. Under normal conditions V.34 is the best what can be achieved.

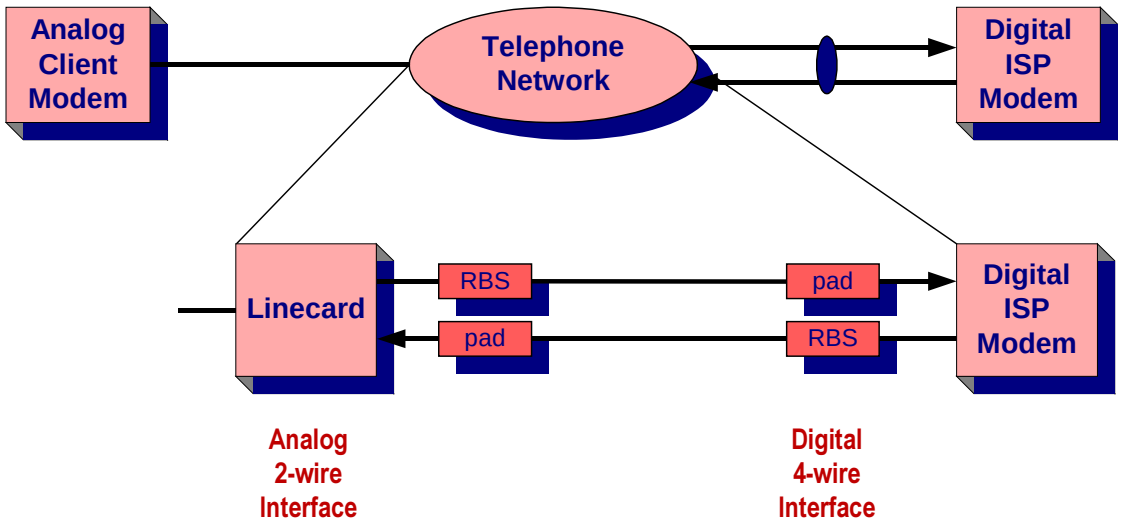

Figure 2: *Current Telephone Network*

[3] PCM: **P**ulse **C**ode **M**odulation

Compared to the traditional network (Figure 1) the current network (Figure 2) has only one analog part left, from the analog client modem to the line card. The remaining portions are all digital. Pads[4] and RBS[5] links can occur in the digital data path to either change the signal level or perform in-band signaling.

Samples of 8 bits with a frequency of 8kHz are transferred over the telephone network and a bandwidth from 300 Hz up to 3.4 kHz is available. A quantization algorithm, that decreases the dynamic range of large amplitude signals, is used to convert analog levels into 8 bit code words. This is commonly know as PCM coding which is specified in ITU recommendation G.711.

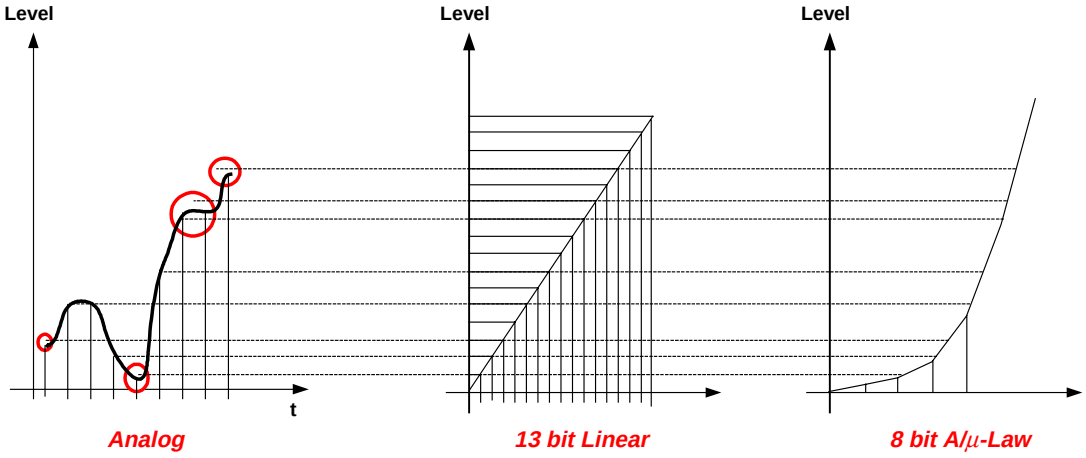

Figure 3: *PCM Coding/Distortion*

G.711 describes how a 13 bit digital value, representing an analog level, is converted into an 8 bit A/μ-law value (see Figure 3). It is done by providing a nonlinear transformation curve that consists of different groups, each group containing 16 different values. This procedure results in a different dynamic range over the available amplitude span, which utilizes less bits per converted analog value. The disadvantage is that it introduces quantization noise, when an analog level doesn't exactly match a possible PCM code (see Figure 3/Analog). Therefore, the PCM word finally transmitted deviates from the original analog value and the difference is called quantization error or quantization noise. All tone based modem algorithms suffer from this quantization noise, which is the main reason for V.34's limitation to 33.6 kbit/s.

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[4] Pad: Digital attenuator

[5] RBS: **R**obed **B**it **S**ignaling

V.90 Technology

V.90 or any other PCM modulation overcomes the problem of quantization noise by choosing exactly the PCM levels which are provided by the Codec. Those new technologies transmit the signal as a series of amplitude levels rather than tone signals. The D/A converters quantization noise is avoided, because the generated amplitude levels lie directly at the discrete voltage steps of the converter. The increased SNR[6] correlates directly to the possible data rate.

Figure 4 shows the difference between V.34 and V.90 transmission on the probing signal which is used to characterize the capabilities of the modem connection. This sequence is a series of tones that are spaced 150 Hz apart.
If this signal is generated by a V.34 modem, the quantization noise caused by the G.711 compander determines the SNR of the system. The modem recognizes additional impairments and the maximum connect rate is 33.6 kbit/s. A V.90 modem sends the same probing signal but considers it more as voltage levels than different tones. Due to this, it recognizes that as part of the generated sequence and therefore the SNR is improved dramatically which leads to connect rates of up to 56 kbit/s.

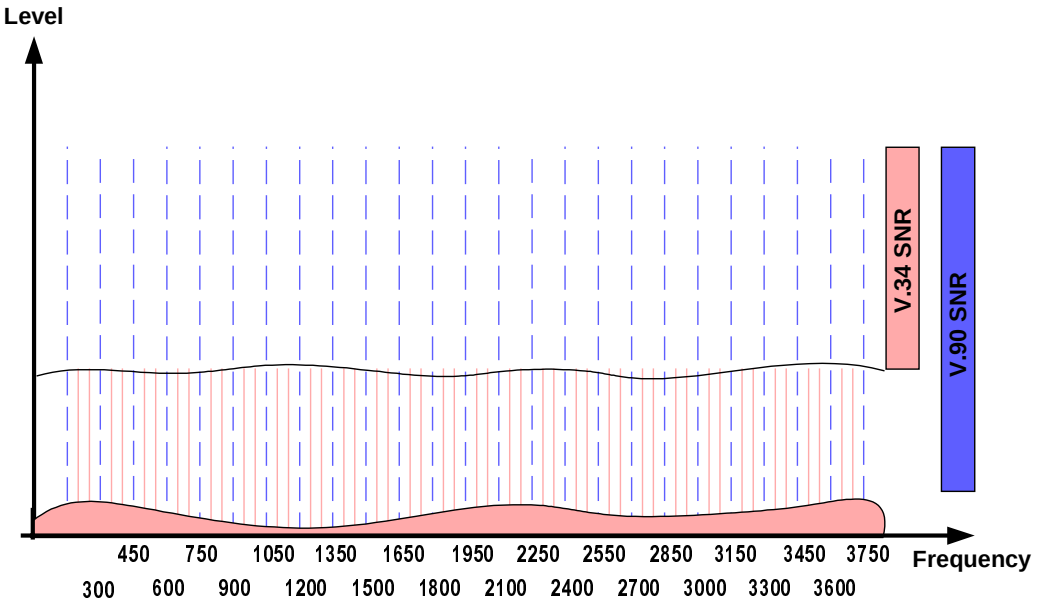

Figure 4: *Probing Signal*

[6] SNR: **S**ignal to **N**oise **R**atio

Which impairments affect V.90 performance

There are impairments on the analog line as well as digital impairments caused by the telephone network.
Digital impairments are originated by pads or RBS links. These impairments reduce the number of available PCM codes and hence decrease the data rate. If the digital impairments are detected correctly, the influence on the data rate is low. If they are detected incorrectly, the expectation of the modem will not match with the analog signal generated from the received PCM levels. The DIL[7] sequence, that comes at the end of the V.90 start up procedure, is known by both modems and they can check if their expectations match with the received analog signal. Due to this procedure it is possible for the modems to determine the digital impairments on the line. A V.90 optimized Codec simplifies the correct detection of Pads and RBS links and ensures a secure adaptation.

Analog impairments also have decisive influences on a V.90 connection. They reduce the SNR, the bandwidth and they effect the accuracy of reproducing the transmitted PCM codes. Unfortunately, analog impairments are random and can't be really detected or even corrected. Some of these impairments are caused through the CODEC and SLIC and therefore Infineon improved the data transmission quality of its Codec/SLIC chip sets.

V.90 optimized Codecs

V.90 optimized Codecs have to have a very high SNR performance. Since the power level of the digital modem is limited by FCC regulations it is necessary to reduce the noise generated by the Codec in order to improve the signal to noise ratio. This is done by providing an ICN[8] performance which has to be significantly better than the requirements for voice applications.
For optimizing the signal to noise ratio it is not enough to look at the ICN performance of the Codec. The SLIC idle channel noise performance and the optimal adaptation of Codec and SLIC influences the modem performance, too. Therefore, a V.90 optimized solution consists of a well balanced kit including the Codec and SLIC. An optimized line card solution has to provide at least an ICN of –77dB on system level.

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[7] DIL: **D**igital **I**mpairment **L**earning

[8] ICN: **I**dle **C**hannel **N**oise

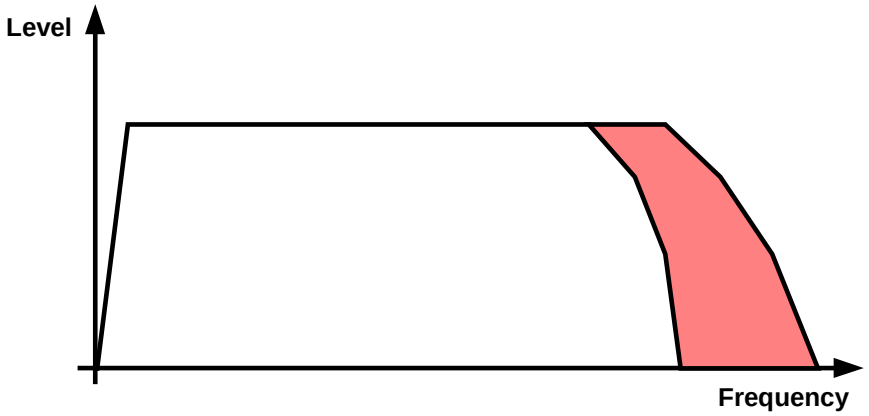

Figure 5: *Increased Bandwidth*

Another impairment is the available bandwidth. Usually, the characteristic of a Codec is fixed by a certain design of a low pass filter. This filter starts to cut off at a frequency of 3.4 kHz. To increase V.90 performance it is necessary to modify the low pass filter and provide more bandwidth in the range between 3.4 and 4 kHz (see Figure 5). Infineon optimized its Codecs for V.90 performance and allows the user to program the low pass filter characteristic. Together with the integrated modem tone detector it is possible to detect a modem call and change the low pass filter characteristic on the fly to a modem optimized one.

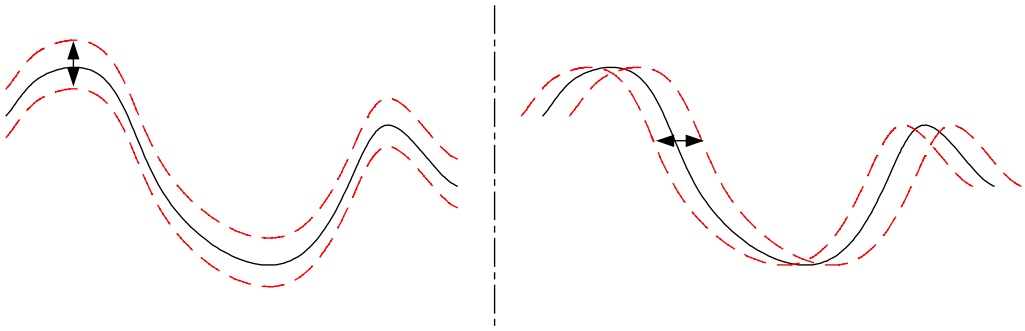

Figure 6: Accuracy

Accuracy is a further problem and influences the reproduction of an analog level out of a PCM code word. Inaccuracy affects the signal like shown in Figure 6 and different analog levels might be reproduced out of the same PCM word. These wrong generated analog levels lead to transmission errors and therefore decrease the connect and data transmission rate.
Infineon has a long experience in programmable Codecs which use digital filters instead of analog ones. This is the key for ensuring accuracy and making sure that one and the same PCM word results always in one and the same analog level. The advantages of digital filters are stability regarding temperature, manufacturing process or age. Furthermore, they are programmable and even allow to change the low pass filter characteristic to increase the available bandwidth.

Results of the improvements

The above mentioned improvements result in very stable and reliable V.90 modem connections at data rates of up to 56 kbit/s. Figure 7 shows test results done with Infineons new DuSLIC chipset.

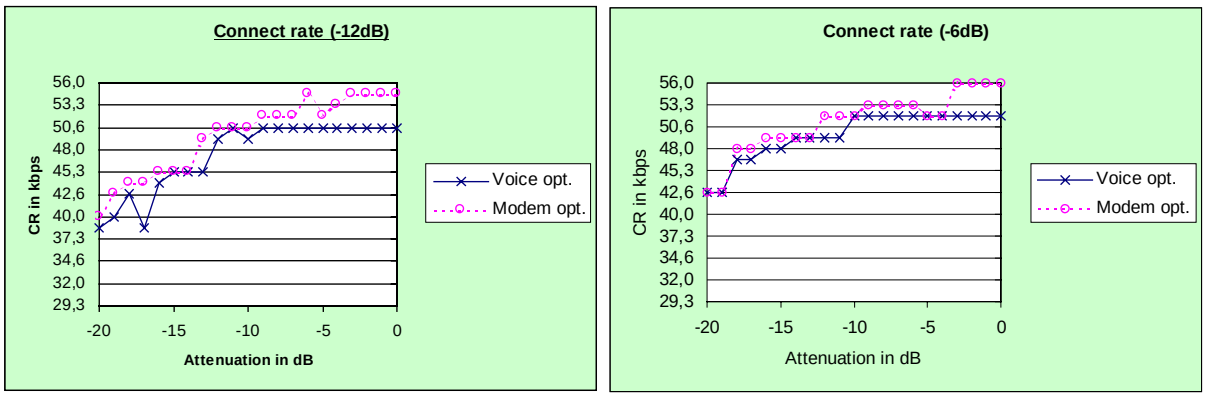

Figure 7: *Connect Rates*

The charts show the influence of analog gain versus connect rate at a maximum power level of –12 dB or –6dB. The solid line (x) shows the connect rates achieved with the normal voice optimized filter set. The maximum rate which is possible is 52 kbit/s. The dotted line (O) represents the rates achieved with the modem optimized filter set which provides rates of up to 56 kbit/s.
With the DuSLIC it is possible to detect a modem and switch dynamically to the modem optimized filter set. If the connection is over the system switches back to the voice filter set. DuSLIC therefore provides always the optimal voice and modem transmission performance.

Conclusion

The capabilities of Infineons new V.90 optimized Codecs, e.g. DuSLIC or MuSLIC, allow constant high data rates of up to 56kbit/s with current modem standards and technologies.