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Implementation of Transmitter and Receiver of v.34 High Speed Modem in Half Duplex Mode.

K. Satish Kumar, M.Tech student,P. S. Chakravarthi, M.Tech student,T. Naveen M.Tech Student,P.Satyanarayana, Asst.Proffesor, VRSEC,G.Chakravarthy, Asst.Proffesor, VRSEC.

Abstract— **Communication plays a vital role in development of society. For data communication, modem is a key component. Modem is a combination of transmitter and receiver. Transmitter transfer the information to the destination i.e., receiver and receiver will receive it. This paper deals with implementation of ITU-T V.34 communication protocol on the TMS320 DSP Processor. In this modem QAM modulation technique is used for modulation, trellis encoder is used to get the coding gain. The modem implemented in C code and then dumped in the processor, the outputs of the modem shown in results.Here it is an asynchronous digital subscriber line (ADSL) modem, which is used for both data and voice communication.**

Index Terms—**transmitter, receiver, ADSL modem, QAM modulation.**

I. INTRODUCTION

MODEM is a device which is primarily intended for performing modulation and demodulation operation. Modulation is meant for making transmission of data over large distance possible. Demodulation helps in assimilating the original data from transmitted modulated signal. Modulation is the process of sending the data signal using a carrier signal and demodulating is removing the carrier and getting the message signal.

International Telecommunications Union (ITU) recommendation V.34 is used as the reference for designing the modem. This modem standard is intended for using on General-switching telephone networks(GSTNs) and on leased point-to-point 2-wire telephone type circuits. Modem can operate upto data signaling rate of 9,600bit/s [1]. It is the first standard which can adapt to varying channel characteristics.

Modems that are being used at present are built around imported processors. The intension behind this project is to develop a half-duplex modem using DSP processor and make communication possible.

II.MOTIVATION AND BACKGROUND

The main idea of V.34 recommendation is to attain high data signaling rate by using the same old GSTNs. This up gradation in communication is due to the advancement in coding techniques. Modem that can transmit data quickly and reliable over telephone lines is preferred [2].

In this paper, a soft modem is being implemented using a DSP processor. It is important to adapt international standards to local designed processor so as to get the processor accepted on international platforms. In this paper the simulation results of V.34 recommendation conferred.

A. Fundamentals of Communication Systems

Communication systems are used to transfer data between two devices via some transmission medium such as cables. A basic communication system consists of three basic components which are transmitter, receiver and communication channel as shown in fig 1.

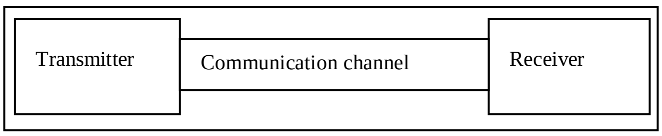

Fig 1: Communication system

In a communication system the transmitter will convert the data from the sending system into communication channel compatible form. Receiver will accept the signals from channel and convert them back to data that has been transmitted. Data can be transmitted in two forms in the channel i.e., analog or digital form. Communication channel can be anything like air, twisted pair, optical fiber etc..

B. Fundamentals of Modem

Modem is a device which converts binary signals into analog signals that propagate through channel and reach the destination. At the destination these analog signals are converted back to binary form by the receiver modem.

The modem which sends request for data is known as calling modem. The modem which sends the required information to the calling modem is called answering modem. For this communication between calling modem and answering modem to occur there should be proper establishment of channel. The procedure by which suchchannel is established is known as channel start-up.

Modems are of three types which are controller based modem, controller less modem and soft modem. In a soft modem all the components of the computer are used by modem for its operation [3].

C. ITU-T Recommendations

ITU-T V.8 recommendation gives procedures for starting sessions of data transmission over the public switched telephone network [4]. This standard gives various signals for startup for establishing connection between call modem and answer modem. Signals like call indicator (CI), ANSam, call menu (CM), joint menu (JM) and CM terminator (CJ). All these signals are modulated according to ITU-T V.21 standard.

ITU-T V.21 recommendation according to this binary data is modulated using frequency shift resulting in modulation rate being equal to data signaling rate [5]. The circuit for a data transmission is duplex circuit whereby transmission of a data is possible in both directions simultaneously at a rate of 300 bit/s or less.

ITU-T V.25 recommendation gives the procedure for sequence of events that occur between automatic calling station and automatic answering station [6]. It also gives the procedure for disabling echo canceller and echo suppressor.

II. V.34 MODEM TRANSMITTER

The transmitter has four logical units. The block diagram of the basic V.34 transmitter is shown in Figure 2. The first of these units is parse which accepts a group of binary input data (32 bits), scrambler scrambles it, and then divide these scrambled bits into various groups to be passed to the next unit. The second logical unit is point-select which uses the parsed bits to select signal points from a constellation of two dimensional (2D) points that has been used in V.34. The third logical unit is precode unit. This unit contains the trellis encoder, connected in a feedback configuration which ensures that the transmitted points correspond to a proper trellis sequence. The final unit is modulation unit. It performs quadrature amplitude modulation (QAM) of the signal points to construct the final output waveform.

The parser logical unit serves two major purposes in the transmitter. First, the scrambler scrambles the input data to eliminate long, repetitive sequences of bits. Such sequences could cause a periodic output signal, loss of symbol clock tracking or unstable behavior in the adaptive filters of the receiver. Second, it groups the scrambled bits into discrete packets for further processing by the point-select stage of the transmitter.

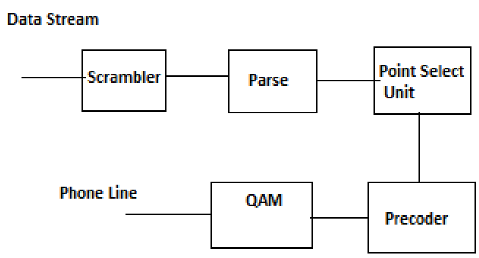

Fig 2: Block diagram of v.34 transmitter

A. Scrambler

The scrambleris a device. It encodes a message at the transmitter to make the message unintelligible at a receiver. At the receiver we do descrambling to get back the data. For that we use descrambling device. The other name for scrambler is randomizer.Here we are using multiplicative scrambler.

Call mode modem generating polynomial

$$GPC = 1 + X^{-18} + X^{-23}$$

Answer mode modem generating polynomial

$$GPA = 1 + X^{-5} + X^{-23}$$

B. Parse data

The parser partitions the block of binary data for one mapping frame into different groups of bits for processing by subsequent stages of the transmitter. One groupof bits (20 bits)goes to the

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shell mapper and four groups of bits (Each group contains 3 bits. Total 12 bits) go to the differential encoder into the point-select stage.

C. Point-select unit

V.34 uses a unique method of selecting points from a two-dimensional constellation. The V.34 super-constellation consists of L points.L value is 28 shown in TABLE I. A signal constellation with L points consists of the L/4 (28/4=7 points) points from the quarter-constellation with labels 0 through 6, and the 3L/4 (3*7=21 points) points which are obtained by rotating the signal points by 90, 180 and 270 degrees. The point select unit block diagram is as shown in fig3.

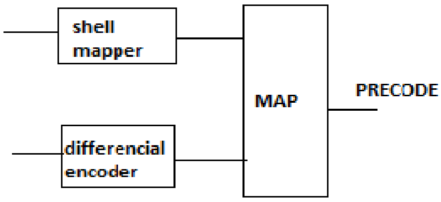

Fig 3:point select unit

The point with the smallest magnitude is 0 and it is closer to the origin of the constellation. The point with the next higher magnitude is labelled as 1, and so on. The point selection unit contains three sub units. They are shell mapper, differential encoder, and mapper.

D. Shell mapper

It is a technique used to achieve shaping gain to minimize the power of the transmitted signal. The shell mapper algorithm selects an order of eight rings for the eight 2D points in a single mapping frame. Shell mapping reduces the average signal energy and improves the modem performance with the signal-to-noise ratio (SNR).

Shell mapping is an algorithmic method of achieving the spherical constellation shaping in a high number of dimensions with bounded QAM constellation expansion.

E. MAP

The mapping algorithm supports any integer number of bits per 16 dimensions (8 QAM symbols) up to a certain maximum. This is combination of appropriate framing and switching, which supports all the combinations of symbol rates and bit rates specified in V.34 [1].

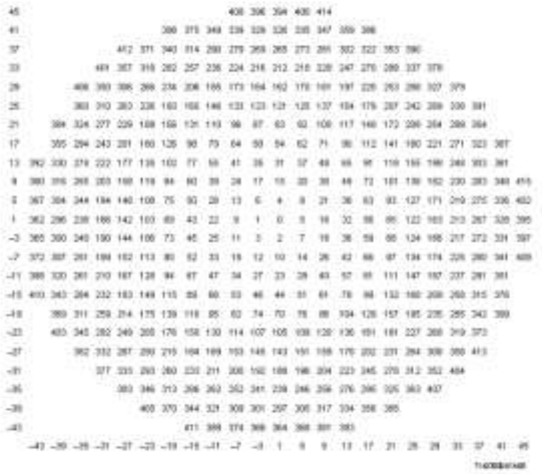

Fig 3: Constellation Diagram

F. Differential encoder

After the shell mapper and mapper portions of the point-select unit, they are differentially encoded to ensure that the transmitted sequence of symbols is 90^0 rotationally invariant. The purpose of the differential encoder is to make the sequence of symbols generated by the transmitter invariant to 90^o rotations. Since the receiver cannot detect a phase offset of 90^o the data to be transmitted is encoded according to differences in phase rather than absolute phases. Differential encoder operates on one 4D symbol at a time. For one mapping frame differential encoder is applied four times.

G. Precoder

The precode unit consists of the combined nonlinear precoder and trellis encoder as shown in fig4. The innovative combination of the two is another feature unique to the V.34 modem. By including the trellis encoder in a feedback loop, it is possible to compensate for the noise-whitening prediction-error filter of the V.34 receiver without destroying the shaping gain provided by the shell mapper. With flexible precoding, fractional data rates can be achieved without constellation switching.

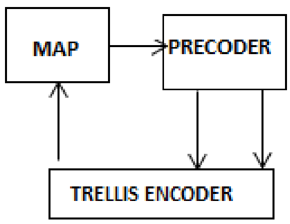

Fig4: Precoder unit

H. Trellis encoder

Trellis encoding is a method of achieving coding gain by increasing the density of the constellation while keeping the minimum distance between points the same. One important task of the trellis encoder is to ensure that the transmitted sequence of points conforms to a trellis sequence. A valid trellis sequence is essential for proper decoding by the receiver.

I. Modulate

Here we are using Quadrature amplitude modulation (QAM) modulation technic. It is a combination of both analog and digital modulation scheme. It combines two amplitude-modulated (AM) signals into a single channel, thereby doubling the effective bandwidth. It is widely used method for transmitting digital data over band pass channel. Bandwidth is used effectively by QAM. QAM fits nicely with Trellis coded modulation which is used in band limited channels.

TABLE I

V.34 PROTOCOL PARAMETERS [1]

Parameter	Value	
Symbol Rate (S)	2400 symbols/S	
Data Rate	9600 bits/S	
Carrier Frequency	1800 Hz	
Data Frames (J)	8	
Mapping Frames (P)	12	
No. of bits in mapping frame (b)	32	
No. of bits to shell mapper in each mapping frame (K)	20	
No. of rings (M)	Minimum	Expanded
	6	7
Constellation points (L)	24	28

III. Implementation Of Transmitter

The individual blocks in the transmitter are coded using C language and is compiled using GCC compiler in windows platform.

The input bits are first given to scrambler [1] which scrambles these bits using call modem generating polynomial (GPC).

$$GPC = 1 + X^{-18} + X^{-23}$$

The outputs from the scrambler are stored in a buffer of size thirty two. These bits are divided into various groups by the parser. Of these 32 bits first 20 bits are given to shell mapper (Si,1, Si,2, ..., Si,20). The remaining 12 bits are divided into four groups. From each group the first 3 bits are given to differential encoder (I1i,0, I2i,0, I3i,0), (I1i,1, I2i,1, I3i,1), (I1i,2, I2i,2, I3i,2) and (I1i,3, I2i,3, I3i,3). Where 'i' represents mapping frame number.

The shell mapper [1] will take 20 input bits and gives 8 ring indices. By using these ring indices constellation points are mapped. Of the 3 bits given to differential encoder one bit is directly given to the mapper. The remaining 2 bits are processed to give I(m).

$$I(m) = I2_{ij} + 2 \cdot I3_{ij}$$

A differential encoder [1] shall generate an integer Z(m) as the modulo-4 sum of I(m) and the previously generated integer Z(m – 1).

The precoder [1] receives the complex-valued signal points u(n) from the mapper and generates the complex-valued signal x(n) according to

$$x(n) = u(n) + c(n) - p(n)$$

Compute the filter output using complex arithmetic according to

$$q(n) = \sum_{p=1}^{3} x(n-p)h(p)$$

Round the real and imaginary components of q(n) to obtain p(n). Quantize the real and imaginary components of p(n) to obtain c(n).

Calculate the channel output signal y(n) and the precoded signal x(n) according to below equations

$$y(n) = u(n) + c(n)$$
$$x(n) = y(n) - p(n)$$

The trellis encoder [1] consists of a convolutional encoder which generates an output bit $Y_0(m)$ and modulo encoder which generates an output bit $C_0(m)$. $U_0(m)$ is then determined as the modulo 2 sum

$$U_o(m) = Y_o(m) \oplus C_o(m)$$

Outputs from shell mapper, differential encoder and direct bits are given to mapper [1]. Trellis encoder is used in the feedback path. Mapper maps the given input bits to corresponding constellation points.

The output of the precoder is given to QAM which produces an analog signal and is transmitted through telephone line.

IV. Simulation Results Of Transmitter

The objective of V.34 transmitter is to take the binary data and convert it into analog signal and transmits this analog signal through the telephone lines. The binary data is first fed to the scrambler and the resultant scrambled output bits are divided among different blocks of the transmitter [1].

Here we are giving input to the transmitter as 'sample input transmitted'. The screen shot of the transmitter modem is shown in fig5. Since it is half duplex modem while transmitting the data, the receiver will receive until the transmission completes, then receiver will sends the data .The corresponding received data will be seen in section VII.

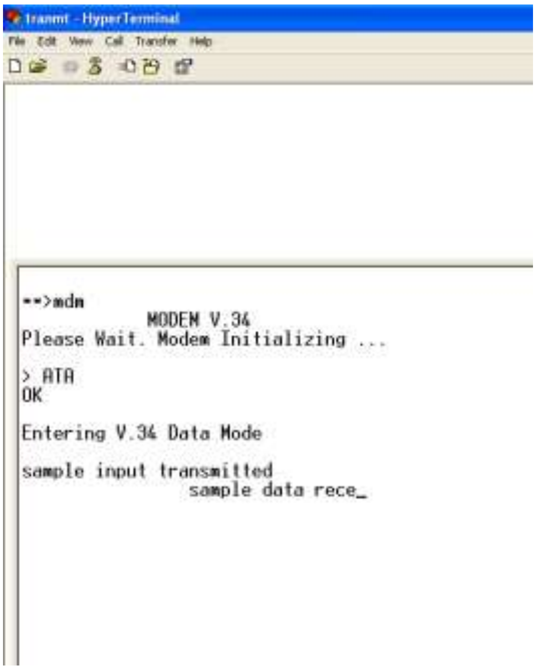

Fig. 5: TransmitterOutput of given message.

V. IMPLEMENTATION OF RECEIVER

The receiver has two logical units. Those two units are the main functional units of a modem receiver. The first unit is the demodulate unit. It accepts an analog waveform as input and demodulates it from QAM signal to a series of baseband signal points. The second unit is the decode unit. It takes the raw 2D points output by the demodulate unit, find out the most likely trellis sequence of constellation points, and decodes each mapping frame into the original sequence of bits. The receiver block diagram is shown in Fig 6 [2].

The aim of the V.34 receiver is to sample the sequence of 2D points which was transmitted by the V.34 transmitter and to perform the inverse of the transmitter's encoder operations on this sequence. The aim is simple in theory but difficult to achieve in practice because the transmitted QAM signal is distorted by a variety of nonlinearities during its journey to the receiver. But here we took the two BSNL connections and we tested the channel. In the channel there is no noise. So, here the channel is an ideal channel.

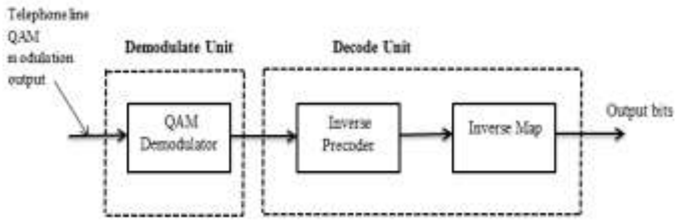

Fig 6: V.34 Receiver Block Diagram

A. QAM Demodulator

The operation of QAM demodulator is the reverse of the QAM modulator.

Whenever the signal enters at the system, it is divided and each side is applied to a mixer. One half has the in-phase local oscillator signal is applied and the other half has the quadrature oscillator signal is applied. We can get the QAM modulator input as the output of the QAM demodulator.

B. Inverse Precoder

The output of the QAM demodulator is given to inverse precoder. Inverse precoder operation is the reverse of precoder operation at the transmitter [2].

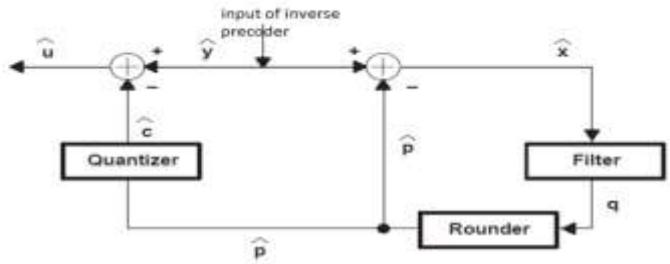

Fig7: Inverse Precoder

Algorithm:

1. Calculate the filter output q^(n).
   q^(n)=f(1)x^(n-1)+f(2)x^(n-2)+f(3)x^(n-3)
   Where x^ is the previous symbols.
2. Round q^(n) to get p^(n).
3. Calculate x^(n)=y^(n)-p^(n).
4. Quantize p^(n) to obtain c^(n) .
5. Calculate u^(n)=y^(n)-c^(n).

C. Inverse Map

The goal of the inverse mapper is to recover the input bits (the S and I bit groups) from one entire mapping frame. Ideally, the input to the inverse mapper is the exact sequence of points that was output from the point select stage of the transmitter. To get the original sequence of bits from these points, it is necessary to invert the operation of differential encoder, shell mapper, parser and scrambler [2].

From the inverse shell-mapper we can get S bits. It is the complex task in the inverse mapper. It is the reverse process of shell mapper. We can get the first 20 bits from the 8 ring indices values.

From the differential decoder we can get I bits. The rotation factor of the received point within its ring is easy to obtain. By solving below equations we can get I bits.

$$(I_3, I_2) = [Z_{m-1} - Z_m] \bmod 4$$
$$(I_1, I_0) = [Z_m - W_m] \bmod 4$$

From differential decoder we can get 12 bits (in 32 bits these 12 bits are from 21 to 32 bits). Here we are not taking I0 bit. From each rotation we can get 4 values from that we can take 3 bits. Here we have 4 rotation values from that we can get 12 bits (4*3=12).

From the inverse parser we can combine the 20 bits which are coming out from the inverse shell-mapper and the 12 bits which are coming out from the differential decoder. Like that we can get total 32 bits. After getting the 32 bits we can send them to descrambler.

From the descrambler we can apply inverse scrambler algorithm and get the input data which is given to the transmitter side.

VI. SIMULATION RESULTS OF RECEIVER

The objective of V.34 receiver is to take the analog signal from the telephone line and convert it into binary data. The binary data is fed to the descrambler and the resultant descrambled output bits are divided in 4 groups. Each group contains 8 bits. From 8 bits we can get the one ASCII character. Like this we can get 4 ASCII characters which is given at the input side shown

Fig 8: Receiver outputs

VII. CONCLUSION

The high speed modem was implemented on DSP processor according to ITU-T V.34 modem protocol with data rate 9600 bits/sec. Quadrature Amplitude Modulation (QAM) is used for modulation and trellis encoder is used for attaining coding gain. We can also implement ITU-T V.90 modem on the DSP processor.

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