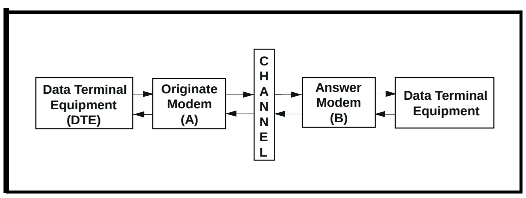
Modem Software Component Products

Introduction

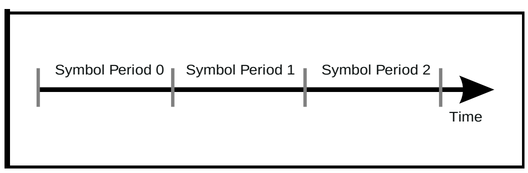
DSPSE has developed a line of software modems for the TMS320C3x and TMS320C5x family of DSPs. This information sheet provides an introduction to wireline modems and discusses the benefits of a software modem implementation.

Overview

Voice band modems are used to transform a binary data stream into a signal suitable for transmission over the Public Switched Telephone Network (PSTN). The word **modem** is a concatenation of **mo**dulator and **dem**odulator. A modulator accepts a binary data stream and modulates an analog signal (tone) in some combination of frequency, phase, and amplitude. Since the transmission media is typically the standard telephone network, which was designed for transmission of speech signals, the characteristics of the modulated signal must conform to voice-like signal requirements. The telephone channel bandwidth is 4 KHz with the band centered from 300 Hz to 3300 KHz. A demodulator is a complementary device that accepts a modulated analog signal and produces a binary data stream.



A sinusoidal carrier at a frequency f_c is modulated to transmit digital information. The modulation process converts a **baseband** (digital) signal into a **passband** (analog) signal. Continuous time is segmented into discrete intervals known as symbol periods. It is important to note that symbols are the actual transmitted elements. Therefore, the sinusoidal carrier is modulated as a function of a symbol (or as a function of the difference between adjacent symbols). The discrete symbol periods, also referred to as **baud** periods, have a duration of T seconds. The symbol rate, or **baud rate,** is the inverse of the symbol period (1/T). Each symbol represents from 1 to N bits of data. The **data rate** (bits per second, bps) is equal to the baud rate times the number of bits per symbol. Higher data rates are achieved by increasing the baud rate. This does not come without a cost, as the baud rate is directly related to the signal **bandwidth.** As the baud rate increases, the bandwidth necessary to transmit the signal also increases. The maximum baud rate employed by ITU QAM modems is 2400 baud (corresponds to a bandwidth of approximately 2400 Hz).



The International Telecommunication Union (ITU) publishes specifications for voice band wireline modems. These modems utilize frequency shift keying (**FSK**), phase shift keying (**PSK**), and quadrature amplitude modulation (**QAM**) schemes for modulating the carrier sinusoid. FSK represents each symbol by a unique frequency. Specifically, ITU FSK modems utilize two unique frequencies and map a single bit to each frequency (i.e., a 0 or “space” is one frequency and a 1 or “mark” is a different frequency). For this example, each symbol represents 1 bit and thus the baud rate is equal to the bit rate. PSK maps symbols as phase changes from one symbol to the next. This scheme is known as differential phase shift keying (DPSK). ITU PSK modems typically use symbol sizes from 2 to 4 bits (therefore the baud rate does not equal the bit rate). QAM maps symbols as quadrature phase changes (0, 90, 180, or 270) and discrete amplitudes. This scheme modulates phase and amplitude for providing higher data rates.

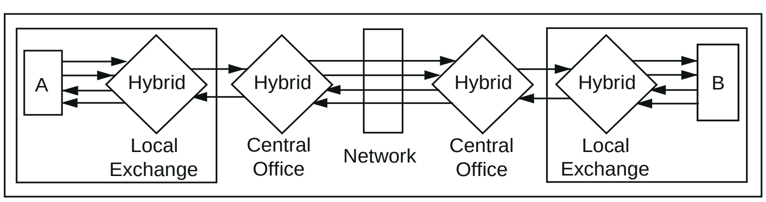
Modem Standard	Type	Bit Rate(s) (Kbps)	Modulation
V.27ter	H/D	4.8, 2.4	QAM
V.29	H/D	9.6, 7.2	QAM
V.17	H/D	14.4, 12.0, 9.6, 7.2	QAM
V.21	F/D FDM	300	FSK
V.22	F/D FDM	1.2	DPSK
V.22bis	F/D FDM	2.4, 1.2	QAM
V.32	F/D EC	9.6, 4.8	TCM/QAM
V.32bis	F/D EC	14.4, 12.0, 9.6, 7.2, 4.8	TCM/QAM
V.32terbo	F/D EC	19.2, 16.8	TCM/QAM

The telephone channel can be used for data transmission in a number of ways. **Simplex** operation refers to the ability to transmit signals in only one direction. **Half-duplex** operation refers to the ability to transmit signals in both directions, but not both simultaneously. **Full-duplex** operation refers to the ability to transmit signals in both directions simultaneously.

In addition to these transmission channel utilization schemes, it is important to understand the physical implementation of the telephone channel. The telephone network is comprised of a collection of two-wire and four-wire lines connected together. A four-wire line consists of two two-wire lines, with one pair of wires dedicated for transmitting and the other pair dedicated for receiving. The two paths are physically separate thus providing isolation between the transmit and receive signals. A two-wire line must support the transmit and receive signal on the same pair of wires. Two-wire lines are connected to four-wire lines using a **hybrid.** A hybrid is a source of impedance mismatches in an end-to-end communication path which, in turn, cause reflections and interference between transmit and receive signals. This type of interference is known as **echo.**

A connection is established from a local user to a remote user through a local loop to the local central office (CO) and through many central offices to the remote central office and finally through the remote users local loop to the final destination. The local loops are two-wire lines and the CO-to-CO connections are via four-wire lines. The quality of any connection is typically limited by the two-wire lines and the hybrids that are present. Two-wire lines do not pose a problem for simplex or half-duplex communication, but do cause complications for full-duplex communication.

Full-duplex communication over a two-wire line requires the ability to separate the transmit signal from the receive signal. This can be accomplished via frequency division multiplexing (FDM) or by echo canceling. FDM is a technique whereby the transmit



signal and the receive signal occupy separate frequency bands within the voice-grade channel. Since the transmit and receive channels do not share the same frequency space, they can be separated by filtering. Modems employing FDM techniques to achieve full-duplex communication are commonly referred to as "split-band" modems. V.22bis is an example of an ITU split-band modem.

Split-band modems are inefficient since the transmit and receive signals are allotted only half of the available signal bandwidth. Another technique for full-duplex communication allows the transmit and receive signals to share the same full bandwidth channel. In this case, the burden of signal separation is shared by the hybrids and by the receiver. Echo cancellation is a technique whereby the local receiver subtracts a delayed estimate of the reflected local transmit signal from the incoming signal. In this fashion, the desired receive signal can be separated from the composite signal. V.32bis is an example of an ITU modem that achieves channel separation using echo cancellation techniques.

Software Modem Implementation

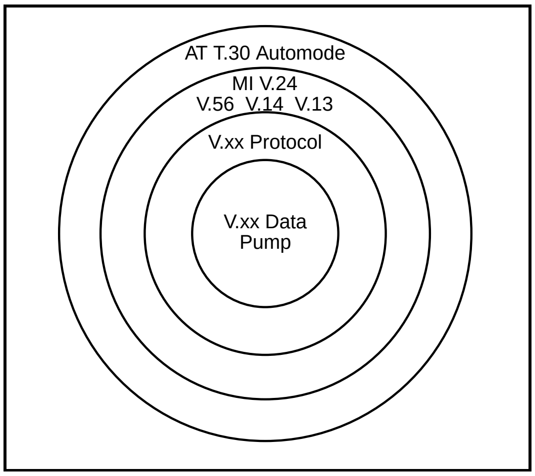
Traditionally, modems have been implemented using analog designs and more recently using dedicated modem chipsets (Rockwell, AT&T, etc.). With the availability of low-cost general-purpose digital signal processors (DSPs), the interest in software implementations of modem applications has grown substantially. The advent of the information superhighway has provided the impetus for desktop multimedia. This desire for multimedia capable platforms can be met with powerful general-purpose DSPs capable of executing many different applications. This soft approach provides for easy enhancement and maintenance while also allowing for the optimal use of the DSP resources for other applications. Conversely, fixed-function DSPs cannot share powerful resources with other applications.

The soft modem approach is uniquely suited to problems requiring "integrated" modem solutions. The fixed-function processor approach is targeted for the "stand-alone" modem solution. Examples of "integrated" modem products where our soft modem solution has been successfully employed include: ISDN systems providing backward compatibility with traditional analog modems and facsimile machines, digital multiplexers requiring demodulation / remodulation capability, and host-downloadable multifunction applications.

Layered Architecture

At DSPSE, we have drawn on our expertise in the area of digital signal processing and utilized strong software engineering concepts to develop an architecture for developing soft modems. Our approach combines the requirements of low-cost, real-time, limited-resource, high-complexity DSP with structured software methodology to develop high-performance soft modems. Our soft modems are designed to make optimal use of system memory and to provide a clean, structured interface for building re-entrant modem components.

The modular, object-based approach produces software that is re-entrant and can execute under an operating system task model. The software is structured to allow ease of integration for each user's application requirements. To achieve this goal, a



four-layer hierarchy is employed.

This layered software architecture allows the user to customize high-level functions at the outer layers without impacting the performance of the low-level data pump functions at the inner layers. The Control / Host Interface layer contains the highest level user interface functions. This layer provides the user with the necessary functionality to allow proper utilization and management of the modem system. The V series modem interface (VMI) layer provides the common interface to all of DSPSE's V-series data pumps. This layer provides data handling and routing functionality. The V.xx protocol layer contains data pump-dependent interconnection software. The V.xx data pump layer contains DSPSE's proprietary algorithms for implementing the V-series data pumps. This layer consists of highly-optimized and tested, real-time signal processing software for implementing V-series data pumps on a TMS320 DSP. Modification of the V.xx data pump layer is not recommended, thus the source code containing these proprietary algorithms is not provided.

The *Control/Host Interface Layer* is the interface between the host and the modem. It has control of both data pump and protocol initiation. This layer contains elements such as the AT Command Handler, the Group 3 Fax Control State Machine (T.30) along with other high-level modem control state machines. These state machines do not require specific knowledge of the underlying signaling schemes that are represented by the protocol and data pump layers.

The *V Series Modem Interface* is a standard software front-end to all DSPSE modem products. VMI is an intermediate layer between the modem and the user, which hides the implementation details of the modem and allows a transparent data path between multiple modem standards. VMI simplifies the task of integrating multiple modem standards by providing a single entry and exit point to all modem functions. VMI also contains a number of complex data conversion, data framing, and modem interconnect algorithms. Included are: simple data packing, asynchronous-to-synchronous conversions, HDLC link-layer protocols, and DTE-to-DCE circuit emulation.

The VMI software package consists of several independent, C-callable functions that perform the full-duplex modem function as well as status, control, and messaging operations. It also includes functions that reflect the implementation's object-based interface. The encoder and decoder interface with linear arrays of XX-bit linear PCM samples and X-bit code words.

The *modem protocol* is a state machine whose main task is to perform the initial hand shaking that establishes the appropriate rate and goes through training of the remote and local modems. The separation of the protocol from the data pump makes it possible for different modems to share the common data pump modules. It also results in more readable and better maintainable code. Since DSPSE's software modem is a block-based processing, in contrast with the conventional sample-based processing, the overhead of the protocol is minimized. Therefore, the protocol can be written using high-level language, e.g., C, as long as the target DSP has a C compiler. Users who wish to modify the protocol will benefit from the fact that the protocol is separated from the data pump and is written in C.

The core of the software modem is the *modem data pump* containing the signal-processing algorithms of the modem. The modem data pump transforms binary bit streams into a signal which conforms to the telephone voice bandwidth. This is the most computationally-intensive part of the modem and is optimized for the target DSP processors.

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