A UNIVERSAL ALGORITHM OF MODULATION AND DEMODULATION

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Abstract A new universal algorithm of modulation and demodulation is presented to process most signals of digital phase-related modulation schemes such as M-DPSK, MSK and even some M-FSK with low modulation level. It can easily deal with modulation and demodulation of the signals with different modulation schemes and data rates by only setting a few input arguments of the versatile software modules. The computational complexity of the algorithm is far less than that of conventional methods. The average processing capacity of the algorithm is about 15 instructions per symbol when processing DQPSK signals. It can be applied to software radios.

Key words Software radio; Modulation; Demodulation; M-DPSK; FSK

I. Introduction

Software radios[1] is a new conception that means a communication terminal is constructed by a universal programmable hardware platform which can accomplish as much radio functionality as possible by means of downloading software programs. The Joint Tactical Radio System (JTRS) developed by US DOD is the typical system for US army. In the current development of software radios, many particular processing algorithms have been presented to process different signals. It costs a huge amount of memory and is complex to construct the soft terminals. These methods can not meet the requirements of software radios.

A universal algorithm of modulation and demodulation is presented to process most phase-related signals such as M-DPSK, MSK and even some of M-FSK with low modulation level. The algorithm processes different signals by means of selecting some input arguments or tables with the main software modules unchanged. In the following contents, the universal modulation and demodulation algorithms are introduced respectively in Section II and Section III. Section IV discusses the performance of the algorithm. Finally, conclusions are drawn.

II. Universal Algorithm of Modulation

M-DPSK signals can be expressed as[2]

\[ s(t) = \cos[\omega_c t + \theta_0 + h(t) * \sum_i \Delta \Phi_i u(t - iT)] = \cos[\omega_c t + \Phi_{n-1} + \varphi(t)], \quad nT \leq t < (n + 1)T \]  

where the symbol "*" represents convolution operation; \( \omega_c \) is the carrier frequency; \( \theta_0 \) is the initial phase; \( \Delta \Phi_i \) is the phase offset of the i-th symbol according to input data; \( h(t) \) is

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the impulse response of the smoothing filter; \( u(t) \) represents the unit step function; \( T \) is the period of a symbol; \( \Phi_{n-1} = \theta_0 + h(t) \ast \sum_i \Delta \Phi_i u(t - iT) \bigg|_{t=nT} \) is the signal phase at the end of the \((n-1)\)-th symbol; \( \varphi(t) = \theta_0 + h(t) \ast \sum_i \Delta \Phi_i u(t - iT) - \Phi_{n-1}, \; nT \leq t < (n+1)T \).

For M-DPSK, \( \Delta \Phi_i \) is determined by the input data. Obviously the number of its possible values is finite. Assumed that \( h(t) \) is truncated into a finite segment in \([0, KT)\) \((K \) is a positive integer), then the number of possible values of function \( \varphi_n(t) = \varphi(t - nT) \) is also finite during \([nT, nT + T)\), where \( \varphi_n(0) = 0 \). If one symbol is made up of \( m \) bit (we define \( 2^{m} \) as modulation level of the signal), \( \varphi_n(t) \) has at most \( 2^{m+2\lceil \frac{K-1}{2} \rceil} \) kinds of possible values, where \( \lceil x \rceil \) is the minimum integer greater than or equal to \( x \).

For DQPSK signal, \( \Delta \Phi_i \in \{0, \pm \pi/2, \pi\} \). Given \( K=1 \), which means that each symbol is only affected by the adjacent two symbols, the possible values of \( \varphi_n(t) \) are shown as Fig.1.

![Fig.1 Possible values of \( \varphi_n(t) \) for DQPSK](image)

There are only four kinds of states for \( \varphi_n(t) \). The state number will greatly grow with the increase of \( K \) and \( m \). Here \( \varphi(t) \) is defined as the possible values of \( \varphi_n(t) \).

In the development of software radios, the mapping method of looking-up tables is often utilized to improve the speed of signal processing as long as the input and output states of a system are finite and have corresponding relationships. The modulation of M-DPSK including \( \pi/4 \)-DQPSK signals can use the method of looking-up tables.

Establishment of mapping tables is the most important part of this method. To achieve modulation of M-DPSK, we should establish the phase difference tables of \( \varphi(t) \) in advance. The tables can be obtained by

\[
 f(l) = \varphi(lT_s) - \varphi(lT_s - T_s)
\]

where \( l \) denotes the offset address in the tables; \( T_s \) represents the sampling interval. To simplify problems, we let \( M = T/T_s \) be an integer, which is the sampling numbers of one symbol, and \( \varphi(t) = 0(t \leq 0) \).

Some of these tables have the same values and can be combined into one. If normalized data are adopted in the tables, the number of the tables will be reduced greatly. Generally the final number of the tables for one kind of signal is no more than \( 2^m \) when \( K=1 \).

For each kind of signals to be processed, the corresponding tables should be made and are managed by some pointers. For example, a pointer is assigned to represent one type of modulation scheme and some sub-pointers to delegate the corresponding phase difference tables. All of these pointers and sub-pointers are organized to form a database shown as Fig.2.

When the modulation scheme is selected, the software module can utilize the pointer database to find the correct tables to process the signals. So it is easy to modify modulation