

The Low-Area of New arc-tangent Look-up Table and A Low-Overhead for CATV Modem Systems

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Abstract

It is made possible a removal of the preamble for carrier recovery and symbol-timing recovery by storing a burst in memory with low overhead QPSK demodulation and this demodulation method also effects frame efficiency improved by processed synchronization performance.

In this paper, we have proposed that new algorithm for arc-tangent look-up table which transform the input I, Q data by phase. This I, Q data plays an important role in demodulation and makes demodulator with low-overhead by storing a burst in memory.

To evaluate proposed new algorithm and symbol-timing recovery method, function simulation and timing verification have been done by using synopsys VHDL tool.

I. Introduction

To transmit a burst information in wireless system, a preamble technique is indispensable for frame efficiency[1]-[4]. This effect reduce a frame efficiency when it transmit a short burst, in

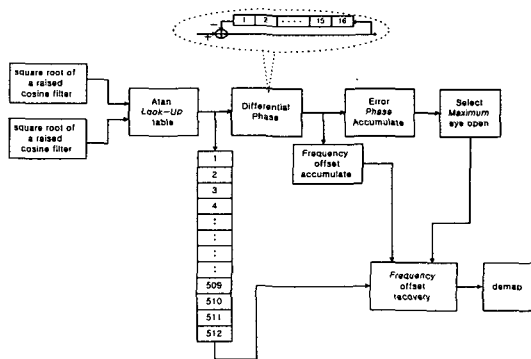
particular, overhead for synchronization will reduce the frame efficiency[5].

This issue can be fixed with store and demodulation. Store and demodulation is convert the received signal as A/D converter and then store in memory symbol-timing recovery and carrier recovery are possible by using all received signals.

The frame efficiency will be improved by removal of a preamble configuration. The whole burst signals can be used to synchronize, moreover, function of carrier recovery and symbol-timing recovery can be improved[7]. The contents of this paper are as follows. Chapter II shows total receiver configuration and chapter III indicates new algorithm for arc-tangent look-up table which has low-area memory in demodulaion.

II. Total receiver configuration

This paper proposed the low-area of new arc-tangent look-up table and a low-overhead digital coherent burst demodulator for 40MHz QPSK modem systems.



< Figure 1 > demodulation block diagram

Receive signal is made possible by storing a burst delay in memory after digitization of a low-frequency bandpass signal. In the first pass, symbol-timing carrier frequency-offset estimations are performed as block processes using the error signal resulting from differential demodulation in a feed-forward structure. In the second pass, two digital phase-locked loops, opening in forward and backward directions on the received signal phase, recover the carrier. These techniques allow demodulation of isolated bursts with no overhead penalty for symbol-timing, frequency estimation or coherent carrier recovery, and introduce a delay of only two bursts in the demodulator.

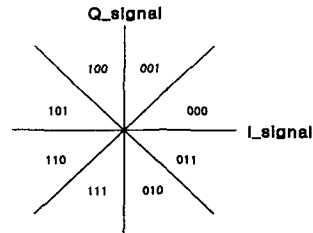
III. New arc-tangent look-up table

The new arc-tangent look-up table embodies with memory and it varies the input data as phase. To reduce quantization error, using input data bit would be a variable thereby the area in larged as $2^{2n} * k$ Times(n is passed signal of raised cosine filter, k is its phase expressed bit number). The direct embodiment often carry to failure because of the problem of area. But, phase can be stored in memory by using the symmetry of recieved signal from 0 to $\pi/4$ and same amount of efficiency can be implemented by the proposed arc-tangent look-up table. Therefore, we have showed the proposed system have designed whith new arc-tangent look-up table.

The output of new arc-tangent look-up table is 9bit. A higher 2 bits are I-channel and Q-channel

which show the information data.

- (0, 0) - first quadrant,
- (1, 0) - second quadrant,
- (1, 1) - third quadrant,
- (0, 1) - forth quadrant



<Figure 2> MSB 3bits mapping diagram

The higher third bit indicate selected input signal and phase from a quadrature. The bit indicate 1 when I-channel's value is more bigger than Q-channel. And the bit represents 0 is when Q-channel's value is more bigger than I-channel. Arc-tangent look-up table's data is 9 bits, the higher third bits is not stored in memory but is the value by manipulated bits. So, it doesn't matter with memory capacity for phase value. Now, the important matter is abs(i-q) information because absolute value for quadrant data are same.

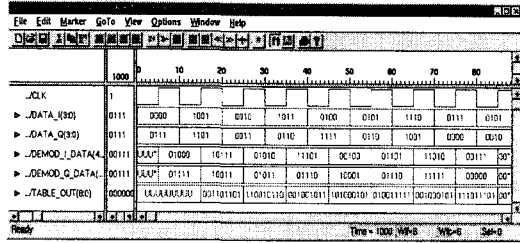
<Table 1> I data or Q data is 7

I data	Q data	abs(i-q)	θ	위상차
7	0	7-0 =7	0	45- 0=45
7	1	7-1 =6	8	45- 8=37
7	2	7-2 =5	16	45-16=29
7	3	7-3 =4	23	45-23=22
7	4	7-4 =3	30	45-30=15
7	5	7-5 =2	36	45-36= 9
7	6	7-6 =1	41	45-41= 4
7	7	7-7 =0	45	45-45= 0

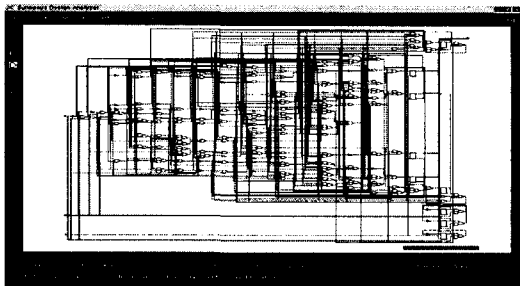
<Table 2> I data or Q data is 6

I data	Q data	abs(i-q)	θ	위상차
6	0	6-0 =6	0	45- 0=45
6	1	6-1 =5	7	45- 7=36
6	2	6-2 =4	18	45-18=27
6	3	6-3 =3	27	45-27=18
6	4	6-4 =2	34	45-34=11
6	5	6-5 =1	40	45-40= 5
6	6	6-6 =0	45	45-45= 0

For example, if Q-channel data is "0110", and I-channel is "0111" then the absolute value is not different. Therefore, the phase error is same: table 1, 2. In other words, $(0 \sim 2\pi)$ can be represented phase of with 8 different types of 3 bits. There will be a way to reduce the number of bits with only representing $(0 \sim 2\pi)$ phase by $(0 \sim \pi/4)$. It needs 9 bits to show 2π but 6bits is enough to do for $\pi/4$. $2^{2^n} * k$ shows that k diminished from 9 to 6 so does π to $1/8$.



<Figure 3> Result of arc-tangent look-up table



<Figure 4> Logic of arc-tangent look-up table

IV. Symbol Timing And Carrier Frequency Offset Estimates

Using the new arc-tangent look-up table, we translate I and Q signals into phase angle. All further processing is done using phase angles. Received signal can be expressed by the following equation:

$$S(n) = I(n) \cos\left(\frac{\pi}{2} n\right) + Q(n) \sin\left(\frac{\pi}{2} n\right) \quad (1)$$

Where

$S(n)$ is modulated of IF signal and $I(n)$, $Q(n)$ is

passed signal of raised cosine filter. Phase angles can be expressed by the following equation;

$$\theta(n, k) = \tan^{-1} \left(\frac{Q(n, k) + y(n, k)}{I(n, k) + x(n, k)} \right) \quad (2)$$

n is symbol and k is sampling rate for symbol.

We can denote k th sample ($k=1, 2, 3, \dots, 16$) of baseband I and Q signals within the n th symbol ($n=1, 2, 3, \dots, M$) as $I(n) + x(n, k)$ and $Q(n) + y(n, k)$, respectively where $I(n)$ and $Q(n)$ are signal components and are contributed by various kinds of impairments such as noise and the intersymbol interference (ISI) caused by filtering. Since $x(n, k)$ and $y(n, k)$ represent the combined effects of various impairments, they are random variables in general with a non-Gaussian distribution. For ISI, noise, and noise-like interference, it is reasonable to assume that they have zero cross-correlation and are uncorrelated between symbols. At the ideal sampling points, ISI vanishes so that both $x(n, k)$ and $y(n, k)$ are minimized on average. Noise and interference other than ISI may introduce random errors at the ideal sampling instant: therefore, M symbols are averaged to suppress these errors. With a sufficiently large M , the "signal-to-impairment ratio" is maximized at the ideal sampling timing. We will show that the cumulative magnitude of the phase deviation from the constellation points used in the symbol-timing estimation can indicate the "signal-to-impairment ratio" and is thus suitable for determining the sampling timing.

Differential demodulation is performed at the sampling rate using the calculated phase angles, which is 16 times the symbol rate. The differentially demodulated signal is used to calculate an error signal to perform estimation of the frequency-offset and the symbol-timing. These estimates are then used to perform coherent demodulation. Using a one-symbol delay, the differential phase between two consecutive symbols is obtained by subtraction.

Differential demodulation is

$$\theta_{diff}(n, k) = \theta(n, k) - \theta(n-1, k) \quad (3)$$

Error signal estimated

$$\varepsilon(n, k) = \theta_{di}(n, k) - \theta_{ref}(n, k) \quad (4)$$

where θ_{ref} is reference constellation.

The symbol-timing estimator selects one of the 16 samples per symbol for detection based on differential phase error magnitude from the differential constellation points (constellation error) accumulated over the burst in 16 registers. Differential phase is used in the estimation because the differential phase is clustered around one of 4 possible constellation points, while the received phase is not locked until carrier recovery is achieved. As the received phase stored in a RAM, these 16 registers are accessed in circular order to accumulate the differential phase error magnitudes. At the end of a burst, the index of the accumulator containing the minimum value determines the sampling point. The carrier frequency-offset estimator similarly averages differential phase error per symbol including sign values. This averaging suppresses noise and interference terms while integrating differential phase errors due to frequency-offset.

Sampling point can be expressed by the following equation:

$$k_{sampling\ point} = select(k) \left[\sum_{n=1}^M |\varepsilon(n, k)| \right] \quad (5)$$

After symbol-timing and carrier frequency-offset are estimated, the stored received phase at the desired sampling instant is gated out of the RAM and fed to the input of the carrier recovery circuitry. By correcting the phase error within the loop by an amount equal to the estimated phase rotation per symbol produced by carrier frequency-offset, the loop becomes robust against such frequency-offset.

V. Conclusion

In this paper, we have proposed the method of reduction for arc-tangent look-up table memory address. As a result, We can obtain various advantages derived from the condition of $(0 \sim 2\pi)$

phase. It needs 9bits to show 2π but 6bits are enough for $\pi/4$. And in the process of restoring the symbol-timing and frequency-offset, the higher rank 3bits use as a operation condition. Actually, operation is possible with 6bits thus we can save system capacity. We have designed the proposed algorithm with I-channel input and Q-channel input bit and have about 430 gates. We have showed the simulation result obtained by using synopsys tool in figure 4. Also, from the process of symbol-timing and frequency-offset restoring, we can conclude that symbol-timing and frequency-offset recovery system area is as half size except memory area for burst.

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