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### Original Citation

Charitopoulos, Romanos and Sibley, Martin J.N. (2009) Experimental coder/decoder of dicode pulse position modulation. In: Proceedings of Computing and Engineering Annual Researchers' Conference 2009: CEARC'09. University of Huddersfield, Huddersfield, pp. 124-129. ISBN 9781862180857

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# EXPERIMENTAL CODER/DECODER OF DICODE PULSE POSITION MODULATION

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## ABSTRACT

*Dicode Pulse Position Modulation has been proposed as an alternative coding scheme which has many advantages over previous Pulse Position Modulation formats. As it is a new coding scheme, few analyses and less experimental results have been published. For the first time, the original design of an experimental Dicode Pulse Position Modulation coder and decoder and experimental results are presented in this paper. These circuits are the basic tools needed for any further investigation of this format.*

**Keywords:** Coder, Decoder, Dicode Pulse Position Modulation (DiPPM)

## INTRODUCTION

Many Pulse Position Modulation (PPM) formats have been investigated in the past such as Multiple Pulse Position Modulation (MPPM) [1-2], Differential Pulse Position Modulation (DPPM) [3-4] and many related modulation coding schemes such as Pulse Interval Modulation (PIM) [5], Digital Pulse Interval Modulation (DPIM) [6] and Dual Header Pulse Interval Modulation (DH-PIM) [7]. Analysis has shown that although each code has many advantages compared to Pulse Code Modulation (PCM), it does so at the expense of bandwidth. This makes them attractive for use in glass fibre or directed line of sight networks where bandwidth is not at a premium. Unfortunately glass optical fibre cable is expensive and is not suitable for everyday use such as networks. On the other hand, Plastic Optical Fibre (POF) is inexpensive but suffers with a low bandwidth making it unattractive for use with PPM schemes.

Digital PPM (DigPPM) had been proposed in the past [8-11] as the best coding scheme for optical communication, compared to the other PPM formats. Unfortunately the format of digital PPM means that although the scheme offers a sensitivity advantage over standard PCM, it does so at the expense of a large bandwidth expansion factor resulting in a final data rate that can be prohibitively high. This led to the investigation of various other PPM schemes. One of those was Dicode PPM – ISI guards, which was proposed by M.J.N. Sibley [12] as a more advantageous format than DigPPM. More theoretical analysis has been followed on Dicode PPM scheme by the same author [12-15].

In 2006, R.A. Cryan and M.J.N. Sibley [16] presented Dicode PPM (DiPPM) in a different form. They considered reducing the impact of intersymbol interference on dicode PPM by proposing an alternative detection strategy to the slope detection technique normally employed in PCM systems. By moving from slope detection to central decision detection, they showed that the DiPPM receiver can be significantly simplified with equivalent sensitivity performance in the higher fibre bandwidths and considerably enhanced performance at the lower bandwidths. Hence, DiPPM at its final version, is very easy to implement as it uses two slots to transmit one bit of PCM and, unlike DigPPM, the DiPPM system achieves a better sensitivity than PCM at a slot rate of twice the original PCM data rate [12-16]. The data is coded as follows: a PCM transition from zero to one produces a pulse in slot S and a one to zero transition generates a pulse in slot R (fig. 1.1). No pulses are transmitted when the PCM data is constant at either 1 or 0.

Table 1 shows the dicode PPM symbol alphabet. As the symbols are four, each symbol has a probability of  $\frac{1}{4}$ . However, the probability of a no pulse sequence (N) is  $\frac{1}{2}$  as it occurs with both 00 and 11 PCM sequence. The S symbol has the same probability as the no pulse (N), because there are only two possible PCM sequences (00 or 01) after an R pulse has been transmitted. A typical dicode PPM sequence would be S, xN, R with probability of  $\frac{1}{4}$ ,  $(\frac{1}{2})^x$  and  $\frac{1}{2}$  respectively.

As two slots are used to transmit one bit of PCM and the line rate is two times that of the original PCM, the speed has been reduced compared to digital PPM. Hence DiPPM could be used in dense wavelength division multiplexing (DWDM) systems. Because DiPPM seems to be a promising PPM scheme, more authors are interested in it [17-23]. However, only the authors of this paper have presented experimental

results [20-23]. For the first time the hardware DiPPM coder and decoder will be presented and analysed in this paper, which are the basic investigation tools of the DiPPM scheme.

## DiPPM CODER/DECODER

As no version of the DiPPM coder and decoder construction has been reported in the past, these two parts had to be implemented to allow for further investigation of DiPPM scheme,. As the bit rate of the data to be coded was at a high frequency (100 -120 Mbit/s) [20-23], logic components from the F100K ECL family were used.

### 2.1 DiPPM Coder

The DiPPM coder is the part of a DiPPM system that formats any PCM sequences into sequences that contain the DiPPM alphabet symbols (Table 1). The logic components that have been used to complete this DiPPM coder are two Flip-Flops and five NOR gates (figure 2.1). Flip-Flop 1 and Flip-Flop 2 form a two bit store, the outputs of which are used to produce the *SET* and *RESET* sequences. Q0 and Q1 are passed through a NOR gate (1a) to produce the *SET* sequence and the pair Q0 and Q1 produce the *RESET* sequence through the NOR gate (1b). The use of the CLK and the NOT CLK signal is necessary to retime the DiPPM *SET* and *RESET* sequences. The DiPPM *SET* and *RESET* sequences are produced by the two NOR gates (2a and 2b). A NOR gate combines these two sequences and produces the final DiPPM sequence

### 2.2 DiPPM Decoder

The DiPPM decoder converts the DiPPM coded signal back to PCM format. The DiPPM decoder's parts are a NOR/OR gate, three NOR gates, a D Flip-Flop and a Direct Set/Clear component as figure 2.3 shows. In common with the DiPPM coder, the clock and NOT clock signal have to be used. These were generated by passing the clock signal through a NOR/OR gate. The DiPPM input signal to the decoder was inverted by a NOR gate prior to being gated with the clock and Not clock to produce the *SET* and the *RESET* sequence independent from the other one. The Direct *SET*/Clear component is the component that will produce the PCM signal by giving a high amplitude when the sequence *SET* is one, and zeros when the *RESET* sequence is 1. But even when the *SET* and *RESET* sequence are independent, it can be seen by figure 2.4 that they are not producing the correct decoding. Thus, a half clock period delay has to be introduced with the use of a D-type Flip-Flop. A synchronisation fault exists in the DiPPM decoder because the *SET* signal passes through one more component than the *RESET* signal, before both reach the Direct *Set*/Clear component. Thus, a delay has been added from the D Flip-Flop component at the *SET* sequence.

## DISCUSSION

### 3.1 Measurements from the DiPPM Coder

Running the system with a deterministic PCM input (1, 0, 1, 0, 1...) the output DiPPM sequence is shown at figure 3.1a in comparison with clock sequence. The DiPPM deterministic sequence has been perfectly synchronised with the clock. Figure 3.1a clearly shows that the DiPPM *SET* (10) gives a bit (1) at the beginning of a period clock and the DiPPM *RESET* (01) gives its bit (1) at the half of the clock period as expected (Table 1.A). Taking the same measurements as previous, but with Pseudo-random Binary Sequence (PRBS) PCM input signal to the DiPPM coder, the outcome sequence of the last is as shown in figure 3.1b.

### 3.2 Measurements and confirmation of DiPPM Decoder

The output of the DiPPM decoder, when its input signals are a deterministic DiPPM and the clock, is given in the figure 3.2a.

The PCM formatted output of the DiPPM decoder is perfectly synchronised with the clock. As was expected the start edge of every pulse starts when the clock period starts. Figure 3.2(b) shows the DiPPM PRBS input of the decoder compared with the DiPPM decoder's output. From the comparison of the waveforms it can be seen that the DiPPM sequence has been decoded correctly back to the PCM form. The delay that appears between those two sequences is a result of the delay in the decoder.

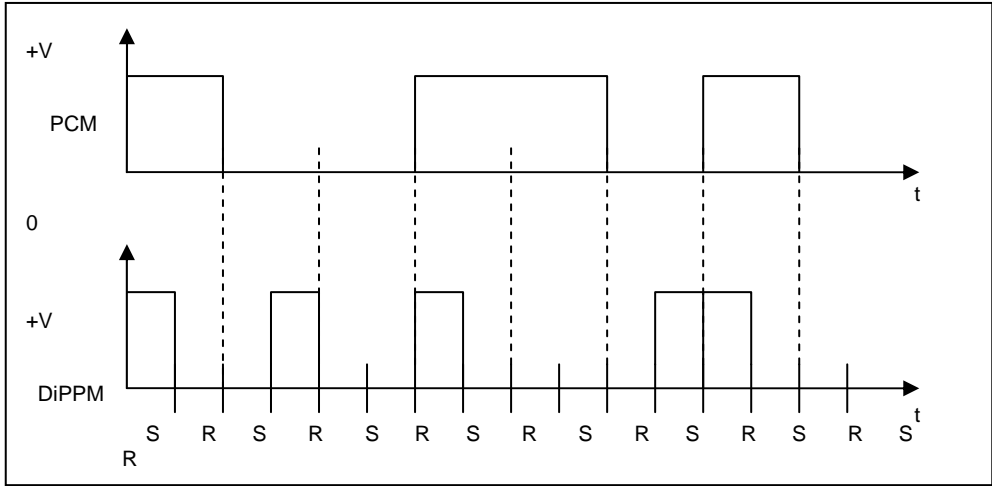
Comparison of the input signal from the PRBS generator, with that which comes out of the DiPPM decoder is shown in figure 3.3a-b for both deterministic and PRBS signals. Even if the presented outputs prove that the DiPPM coder and decoder work correctly, measurement with the error detector had to be taken to ensure correct functioning. When connected to a Bit Error Rate Test set, no errors were registered ( $0 \times 10^{-6}$ ).

## CONCLUSIONS

In this paper, the construction of a DiPPM coder and decoder has been presented for the first time. Theoretical representations of DiPPM coder and decoder waveforms and practical outputs have been given. The two most basic parts of the DiPPM system, coder and decoder, have been developed and further investigation on DiPPM scheme can be achieved with the use of them.

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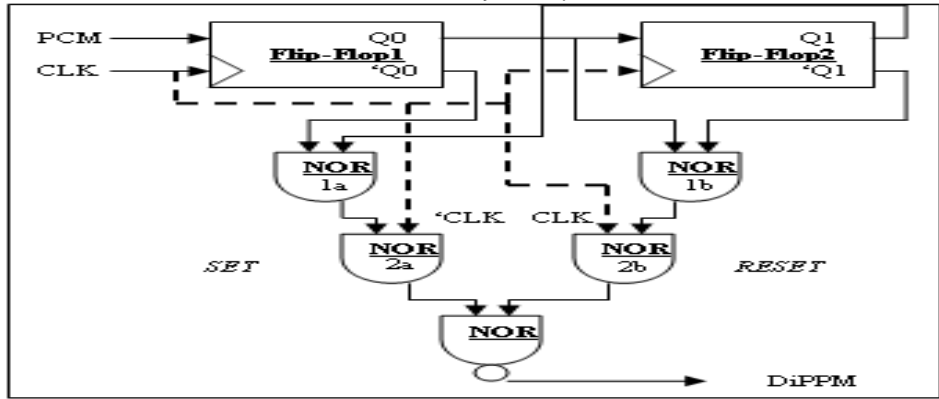
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**Fig. 1.1:** Conversion of PCM data (top trace) to dicode PPM (bottom trace).

PCM	Probability	DiPPM	Symbol
00	1/4	no pulse	N
01	1/4	SET	S
10	1/4	RESET	R
11	1/4	no pulse	N

**Table 1:** DiPPM symbol alphabet.



**Fig. 2.1:** DiPPM coder's circuit.

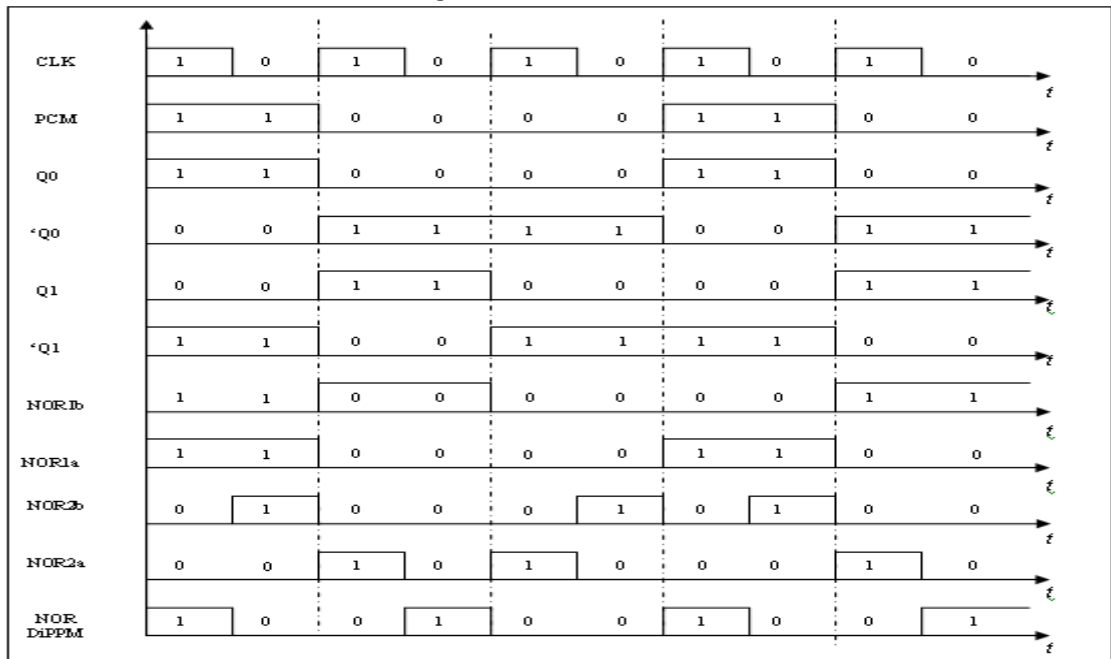


Fig. 2.2: DiPPM coder's waveforms.

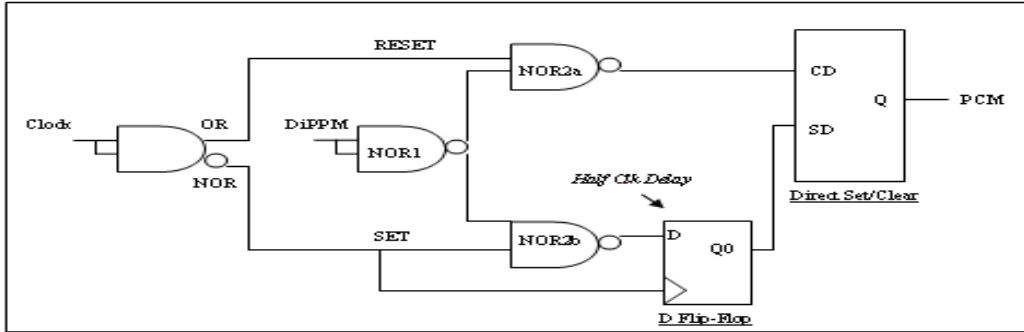


Fig. 2.3: DiPPM decoder circuit.

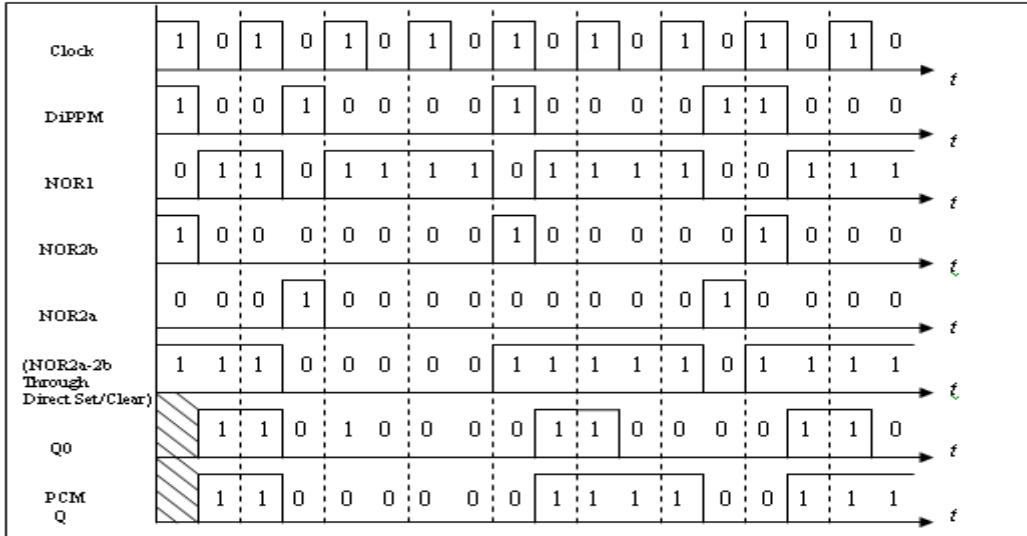


Fig. 2.4: DiPPM decoder's waveforms.



Fig. 3.1: (a) DiPPM coder's deterministic outcome (top trace), clock sequence (bottom trace).  
(b) DiPPM coder's PRBS outcome (top trace), clock sequence (bottom trace).

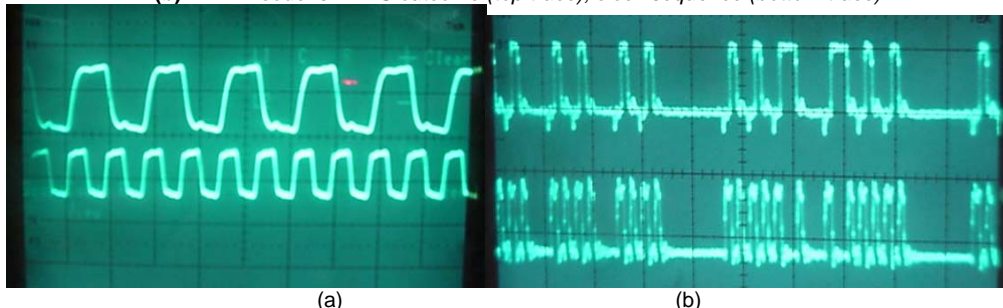
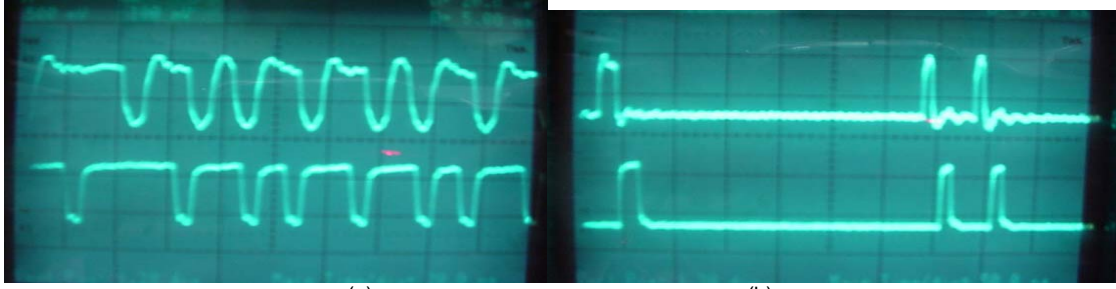


Fig. 3.2: (a) DiPPM decoder's deterministic outcome (top trace), clock sequence (bottom trace).  
(b) DiPPM decoder's output (top trace), DiPPM PRBS (bottom trace).



(a) (b)  
**Fig. 3.3:** (a) PCM deterministic input (top trace), PCM deterministic output (bottom trace),  
(b) PCM PRBS input (top trace), PCM PRBS output (bottom trace),