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Implementation of Power Line MODEM for TDC Pulse Detection of SEPA

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Abstract : Recently, there are many cases to use a ship's engine performance analyzer(SEPA) to measure pressure in cylinder and top dead center(TDC) of piston of engine, and analyze its performance such as fuel injection time and horsepower as well as wear of piston ring. But, SEPA needs TDC pulses(T(1)~T(n)) generated when pistons of engine are located to the TDC position(TDC(1)~TDC(n)), these pulses are gathered from sensors connected to gear wheel of the propeller shaft in the remote distance from the measurement point. Therefore, operators need a long wire cable(WRC) to TDC detecting sensor to get these pulses, but this method is a very uncomfortable and expensive in case of installation, and it might decrease user's purchase desire. In this paper, we design and fabricate a small and inexpensive MODEM cable(M0C) so that it may be available to transmit TDC pulse generated from sensor in propeller shaft through existing power line. We also verify the facts that this MOC can be applied to SEPA and the effectiveness of the system through the experiments.

Key words : SEPA(Ship's engine performance analyzer), TDC(Top dead center)

1. Introduction

Ship's engineers must analyze wear of cylinder liner and piston ring through measuring of cylinder pressure to prevent main engine's breakdown, and also, must inspect control circuit and fuel injection system at regular intervals.

Ship's operators regularly measure cylinder pressure and *pt* diagram which shows the relation between pressure and time.

They can get information of effective pressure and indicated horsepower, opening and closing time of fuel injection valve, magnitude of cylinder compression pressure(P_{comp}), and relation of P_{comp} and maximum pressure($P_{\max}$), ignition time, opening and closing time of suction and exhaust valve from those diagrams, and from which calculate main engine's efficiency.

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This pressure indicator amplifies and indicates the change of pressure in cylinder that is delivered through indicator's piston and water pressure film, there are various kinds of indicators such as mechanical, electrical, digital, pressure equilibrium and optical type etc.

There are analog and digital type in this electrical pressure indicators, the former shows changed voltage signal using analog circuit, and the latter shows the signal using digital display device.

Recently, there are many ships where mechanical and digital pressure indicators are used.

Some of the ships use digital pressure indicators(DPI) developed by Pentatech company, which measures the pressure of engine cylinder and analyze its performance.

To analyze the performance of engine and the peripheral device by using pressure indicator, we must know *pv* diagram in cylinder and TDC, mechanical maximum position of piston.

Because DPI marks TDC point on the existing pressure indicator that indicate *pv* relationship in cylinder, it has advantages that can be used to analyze fuel injection timing and engine horsepower as well as wear of piston ring.

But, DPI needs TDC pulse T(1)(number in parenthesis means firing order) generated at TDC(1), the timing when the fastest piston of firing order of engine is located to top position, and also continuously needs pulses(T(2)~T(n)) that is occurred in each TDC(2)~TDC(n)), the TDC timing of the rest of pistons.

To get these pulses, operators connect long wire cable(WRC) to TDC detecting sensor which is attached to the main engine propeller shaft.

And also, to improve this uncomfortable problems of carrying these wires by hand whenever operators use DPI, operators should fix wires on the wall or floor, but these works cost too much, and it could decrease the user's purchase desire.

In this paper, we fabricate a small and inexpensive MODEM cable(MOC) which transmit propeller shaft TDC pulses through existing power line.

We also verify the facts that this MOC can be applied to SEPA and the effectiveness of the system through the experiments.

2. MODEM configuration

2.1 System outline

Fig. 1 shows SEPA's application example that consists of propeller shaft, PSGB (proximity sensor and gear box) that have 2 round type gears and 2 proximity sensors assembled with pair on the shaft. And also MOC system consists of transmitting modem cable M1 which sends pulses through power line and receiving modem cable M2 of SEPA side.

PSGB has 2 proximity sensor P1 and P2, P1 sensor generates one pulse(T(1)) per revolution of propeller shaft.

Unlike gear teeth number of P1 sensor, when the number of piston is N, the gear teeth number of P2 sensor to detect TDC (n) of each piston are determined by the multiple of N.

Therefore, only if controller counts pulses of P2 sensor(T(n)) whenever it passes the tooth, it can find TDC(n) of corresponding piston that is stored in computer memory beforehand. At the end of this process, SEPA marks the point of pressure and TDC(n) on the LCD screen for the corresponding cylinder.

P2 sensor measures T(1)~T(n) point and pressure in cylinder as well as the speed of engine shaft.

In industrial field, SEPA is essential equipment that can analyze various parameters of engine performance such as delay and fastness of fuel injection time, horsepower calculation and wear of piston ring and cylinder liner. SEPA can protect fatal troubles of engine using these functions and so, in advance.

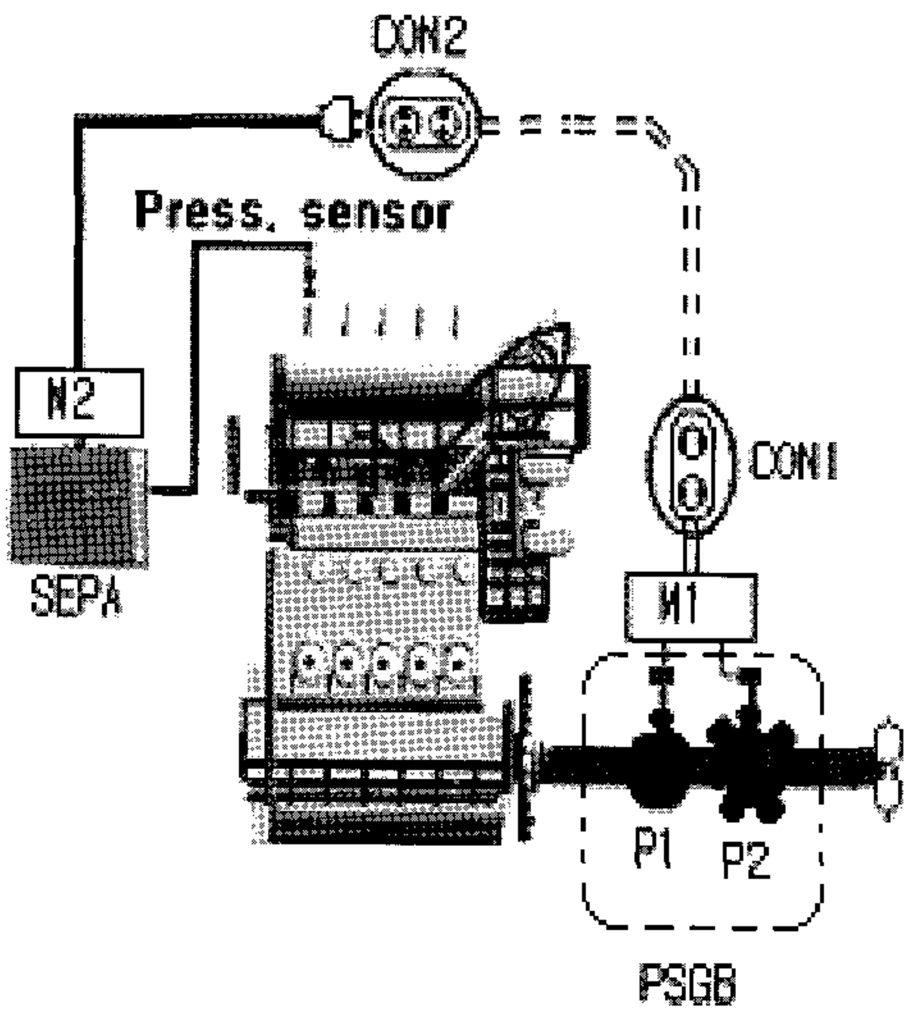


Fig. 1 SEPA diagram using power line MODEM

Fig. 2 shows a control block diagram. As shown in this figure, pulses of two different frequencies(P1_P, P2_P) generated from P1, P2 are changed to one pulse string(T(1)→T(2)~T(n)→T(1)→T(2)~T(n)···) in the logic circuit and transmitted through transistor, coupler and power line.

These pulse strings are decoupled by two signals in the two resonant circuits that are designed with each different frequencies, and then those are demodulated through the demodulator composed of amplifier and comparator and those signal are read in the SEPA[1][2].

Because transmission part consists of two low-power and small-size transformer, one transistor, two capacitor, one low-power rectifier, two pulse generator and single NOR element, it can be manufactured on low cost.

Receiving part is almost the same cost as the transmission part, and also it might be simpler than conventional WRC method when installed inside SEPA at its manufacturing process.

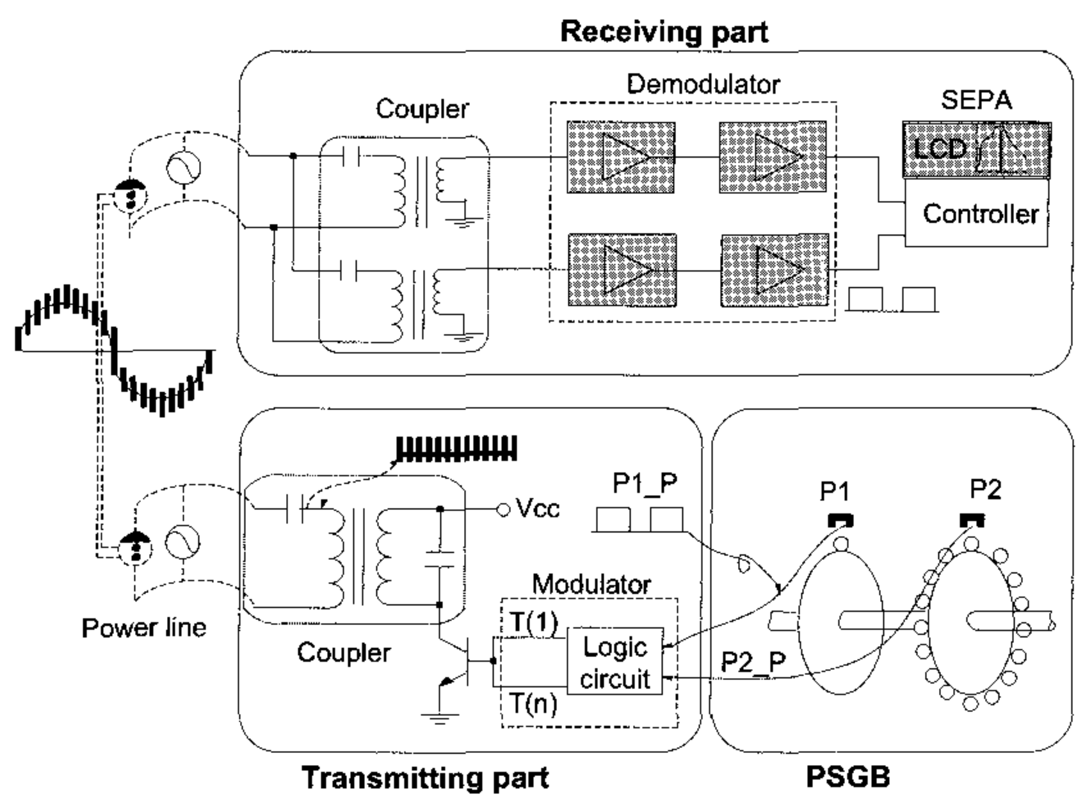


Fig. 2 Overall control diagram of MODEM cable

2.2 Configuration of transmission MODEM

Fig. 3 is transmission part composed of power source and carrier wave generating circuit, coupler(Coup1) and modulator using digital logic elements[3]-[6].

NOR1 and NOR2 have three input elements, if one among these three input has high signal(+5V), output signal does not appear.

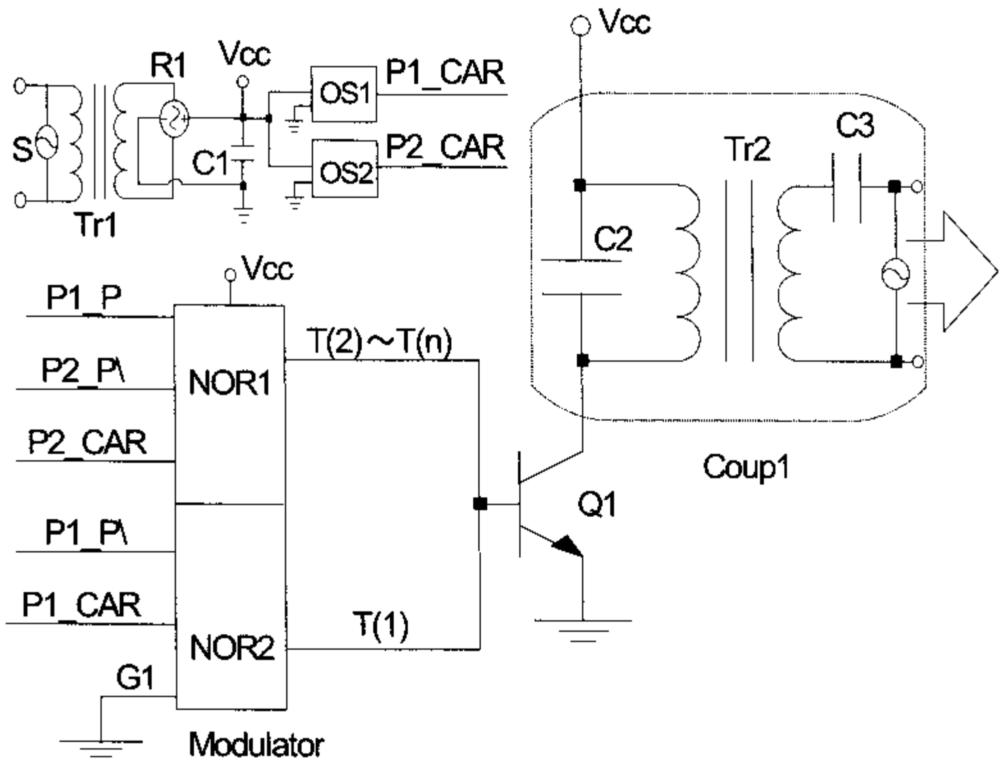


Fig. 3 Transmitting circuit

Therefore, as shown in Fig. 4, NOR1 sends carrier wave(P2_CAR, 260kHz) of TDC(n) to T(2)~T(n) signal source when P1_P and P2_P are Low(0V), NOR2 sends carrier wave(P1_CAR, 450kHz) of TDC(n) to T(1) signal source when P1_P\, inverted signal of P1_P is Low(0V). Transmission coupler should be designed to send pulse to power line in the smallest diminution condition, here, inductance and capacitance of primary side coil is L = 9.65μH, C = 0.01μF respectively, and turns ratio is 1:16.

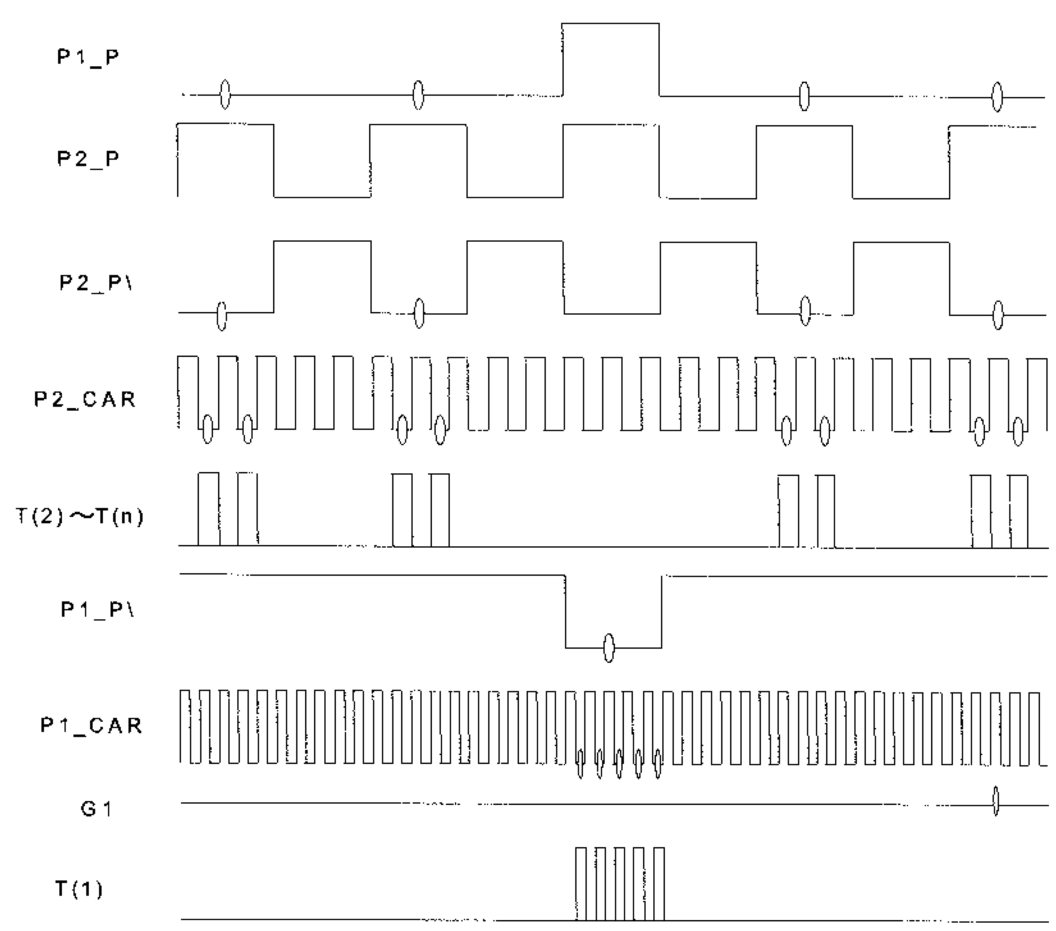


Fig. 4 Modulator waveforms

2.3 Configuration of Receiving MODEM

Fig. 5 shows a receiving circuit, is consisted of two coupler(Coup2, Coup3), connected with C4, Tr3, C5 and Tr4, and small signal amplifier(Amp1, Amp2), comparator(com1, com2). Modulation wave T(1) and T(2)~T(n) are separated in two couplers, and being demodulated by P1_P, P2_P in the amplifier and comparator, is used to calculate of TDC of each piston and speed in SEPA's controller[3]~[5].

Coup2 has capacitance C4(0.001μF) and primary inductance of transformer L (149.07uH), turns ratio 1:18, and Coup3 has capacitance C5(0.0033μF), primary inductance of transformer L(36uH), turns ratio 1:5.

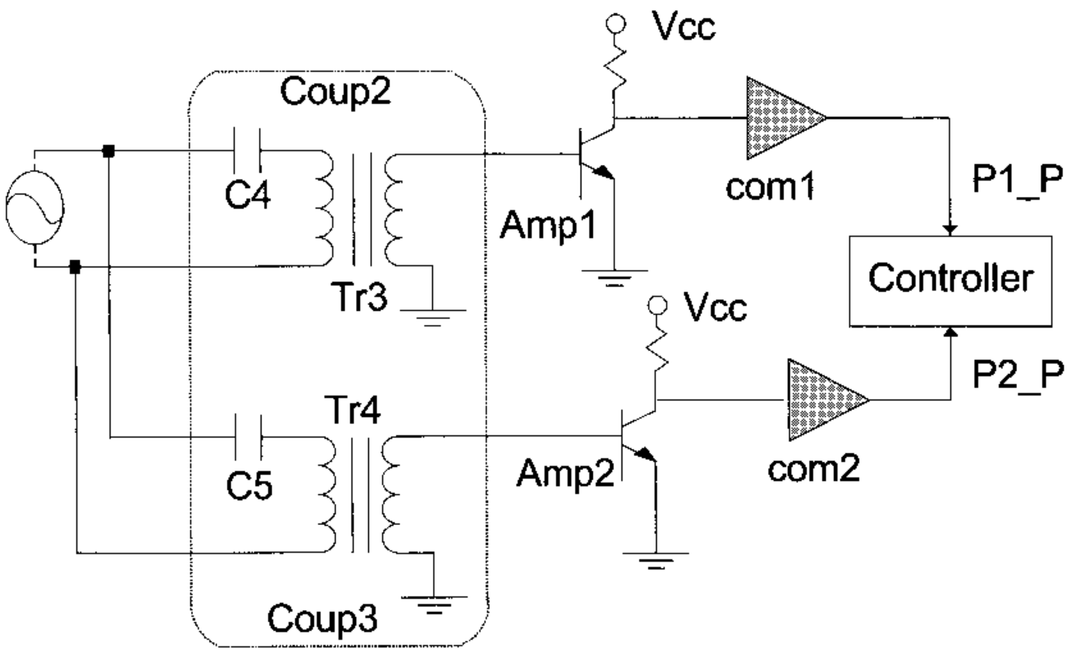


Fig. 5 Receiving circuit

3. Experimental investigation

3.1 Experimental device

Experimental works were carried out in Korea Maritime University training ship "HANNARA" to using SEPA for test with graphic LCD, MODEM and oscilloscope to confirm TDC pulse waveform as shown in Fig. 6.

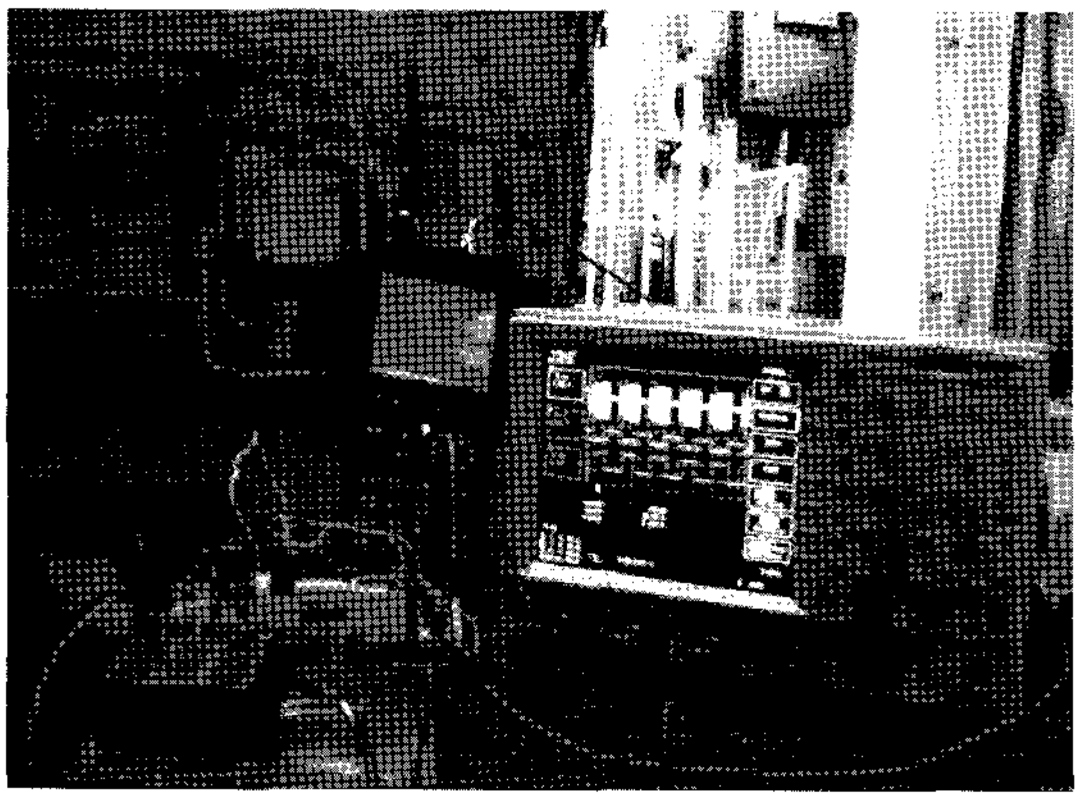


Fig. 6 Experimental device

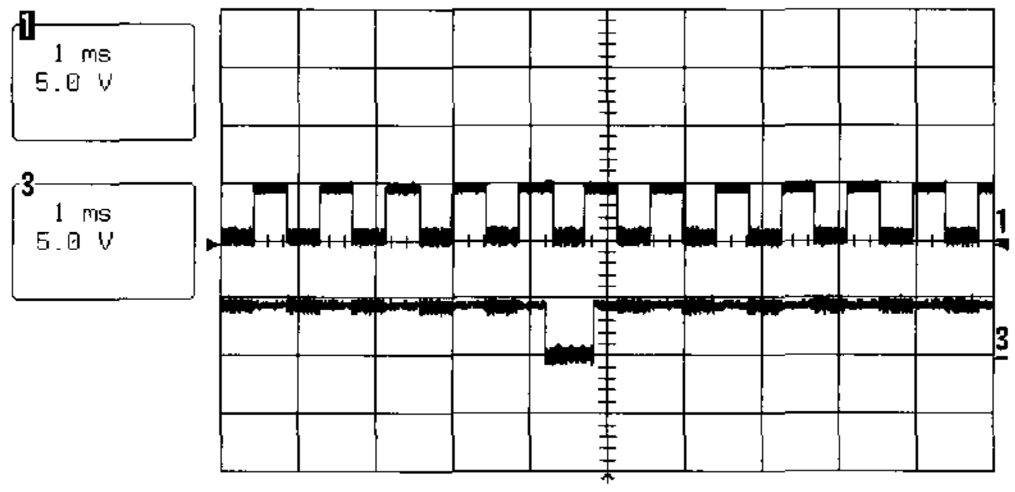
In SEPA system, two pulse chains generated from proximity sensor are introduced to modulator, modulation wave, T(1) and T(n) is transferred to SEPA for test via power line and demodulator.

3.2 Experimental waveforms

Fig. 7 shows P1_P, P2_P pulse waveforms generated from P1, P2 pulse sensor, P1_P pulse is displayed whenever propeller shaft rotates one revolution, and all cylinder of ship's engine complete one cycle(stroke) between this pulse.

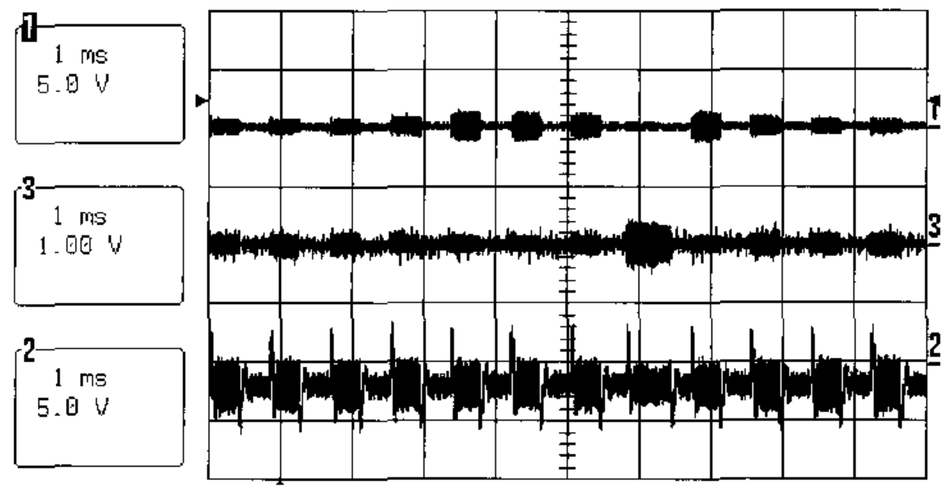
Fig. 8 shows the waveform(Ch1) of primary side of coupler Coup2, waveform(Ch3) of primary side of Coup3, waveform(Ch2) of the secondary side of transmission coupler Coup1.

As shown in Ch2, modulation wave T(1), T(2)~T(n) with different frequency in Coup1 is transmitted through single power line, but in receiving part, as shown in Ch1, Ch3, T(1) pulse does not appear when T(2)~T(n) pulse is received and T(2)~T(n) pulse does not appear when T(1) pulse is received.



Ch1 : P2_P inverse(P2_P) waveform
Ch3 : P1_P inverse(P1_P) waveform

Fig. 7 Output waveforms P1 and P2 sensor

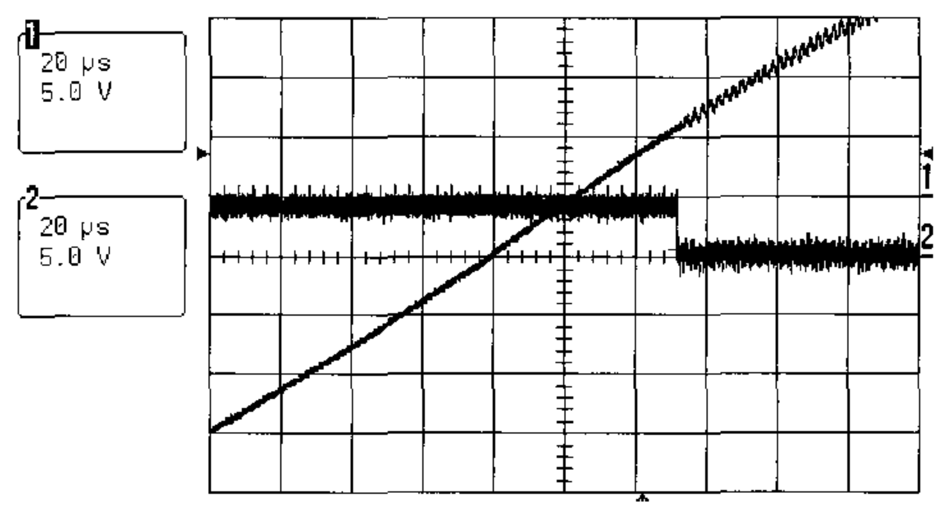


Ch1: Primary side T(n) waveform of Coup2
Ch3: Primary side T(1) waveform of Coup3
Ch2: Secondary side waveforms of Coup1

Fig 8. Waveforms of Coup1, Coup2 and Coup3

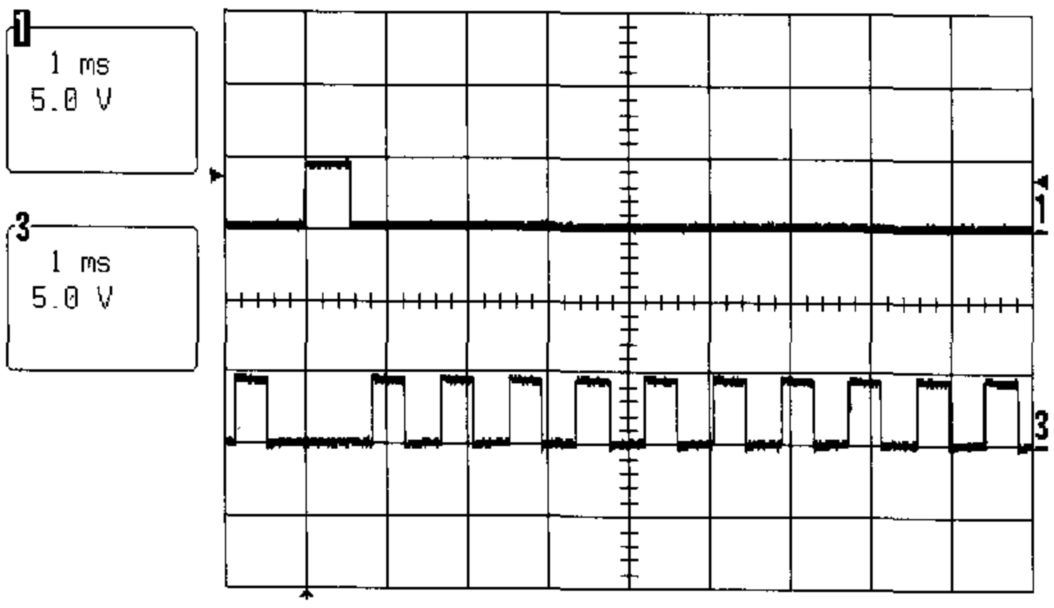
Fig. 9 shows waveform that measures modulation wave in power line, modulation wave is sent to power line in case T(1) pulse is low.

Fig. 10 shows P1_P and P2_P pulse that measure in com1 and com2 line, and amplified and modulated signal is demodulated by original pulse signal in comparator.



Ch1: T(1) waveform in power line
Ch2: P1_P waveform

Fig. 9 Modulation waveform in power line



Ch1: Demodulated waveform(P1_P) of com1
Ch3: Demodulated waveform(P2_P) of com2

Fig. 10 Demodulated waveforms

Fig. 11 shows waveforms of P1_P, P2_P pulse on the LCD screen, and indicates engine speed by calculation of the pulse.

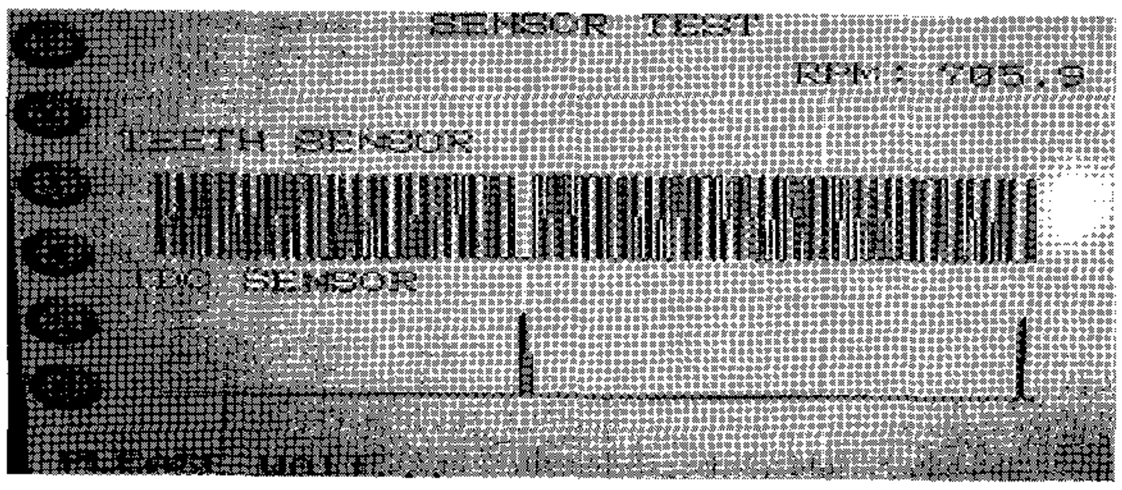


Fig. 11 LCD screen

4. Conclusions

Conclusions obtained by experimental works using a developed MODEM are summarized as follows.

1) This modem is manufactured with very small and inexpensive logic devices and programmed pulses were changed to modulation waves of different frequency (T(1), T(2)~T(n)) through simple logic circuit, and these pulses is sent through single power line.

2) Conventional product has uncomfortable problems of carrying these long cable by hand whenever operators use DPI, operators should fix wires on the wall or floor, these works cost too much, and it could decrease the user's purchase desire.

But proposed method does not require installation cost, not need to pull around wire cable, so we expect to maximizes financial growth for company with the increase of customer's interest.

3) In particular environment such as narrow engine room space of ship, this modem technology of communications that does not have any extra transmission line is expected to be widely applied in near future.

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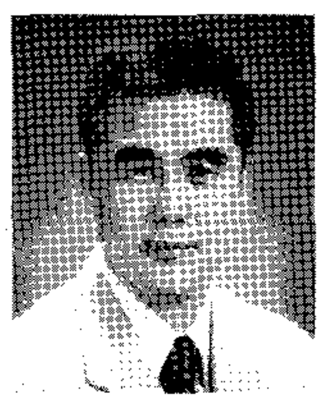

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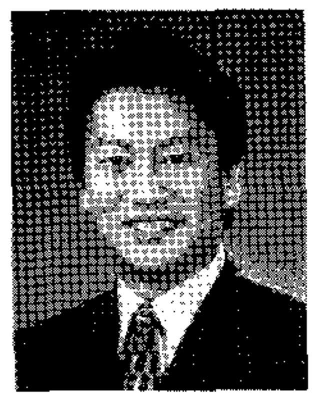

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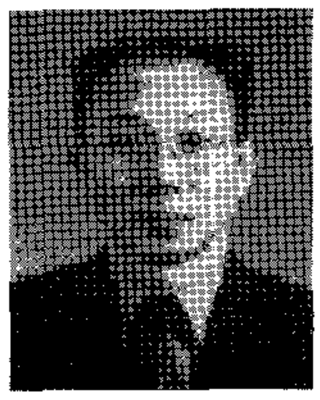

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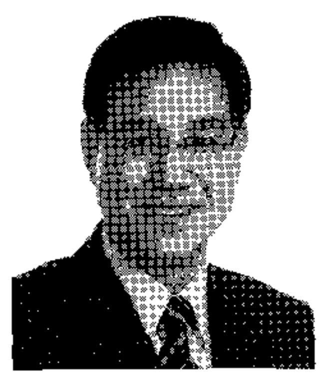

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