Chemical agent monitor simulator (CAMSIM): prototype

C Torasa\textsuperscript{1}, K Won-in\textsuperscript{2,*} and P Dararutana\textsuperscript{3}

\textsuperscript{1}Suan Sunandha Rajabhat University, Bangkok, 10300, Thailand
\textsuperscript{2}Department of Earth Science, Faculty of Science, Kasetsart University, Bangkok, 10900, Thailand
\textsuperscript{3}Royal Thai Army, Bangkok, 10900, Thailand

*E-mail: kritwonin@gmail.com

Abstract. Chemical Agent Monitor Simulator or CAMSIM is used for training the trainees of the Royal Thai Army Chemical School in the Chemical Warfare Detection Course to familiarize, and to expert for using detection and identification. This research is aimed to design and produce a prototype of the CAMSIM which uses in the military training. The designed system is operated using ultrasound with the difference intensity for training to detect chemical residues in the field and on the body or clothing. The product is composed with the Chemical Agent Monitor Simulator (CAMSIM) which can be detected 4 different ultrasonic signals simultaneously and 4 different ultrasonic sources. The CAMSIM can present both in type (ultrasonic frequencies) and intensity of the chemicals (ultrasonic intensities). It can be concluded that this is real, safe and amenable to deliver and validate the high quality training. It is simultaneously signal detection. And the trainees are also familiar with the operations.

1. Introduction
Presently, hazardous chemicals which cause death or harm to living things, are used as a weapon in the war to attack soldiers or harm people in terrorism that called chemical weapons. Attacking with them has less expense while using a lot of budget to eliminate or destroy the remained chemical weapons. The chemical warfare agents are chemical compounds whose toxic properties are used to kill, injure or incapacitate, human body, such as blood agents, blister agents, nerve agents, and toxic industrial chemicals. Whether water and/or sand are used to decontaminate, the chemicals are still bad effect in the long term and ruined soldier and people’s condition of mind. The Royal Thai Army gives priority to the usability and prevention of chemical weapon by establishing the Royal Thai Army Chemical Department to take responsibilities for planning, direction, coordination, control, research and development about production, dispensation, maintenance, training and studying about the operation and prevention in chemical, biology, radiation and nuclear (CBRN) activities, including the science activities of the Royal Thai Army. The Royal Thai Army Chemical Department allocates budget to purchase instruments to use in the department. For example, a Chemical agent monitor (CAM) for examining toxic chemical which is used to detect in a chemical war, and a Chemical agent monitor simulator (CAMSIM) for personnel training of the department, which is used to train the Royal Thai Army Chemical School’s students to practice the instrument correctly and increased a skill for using the instrument. However, due to limited budget, high price and necessary to purchase from abroad, a quantity of CAMSIM is insufficient for personnel training and teaching students. Moreover, when a
CAMSIM is out of order, the department cannot repair it. Finally, the Royal Thai Army Chemical Department has decided to develop the CAMSIM for internal use.

CAMSIM is realistic, safe and environmental chemical warfare simulator devices that are enabling a military to deliver and validate the high quality training the CBRN responder community requires to ensure effective operational response in a real emergency [1-3].

The previous work was studied by the analysis of the imported CAMSIM system and the development ultrasonic training system [4].

2. Experimental
The concept of the chemical agent monitor simulator used an ultrasound signal to simulate as a distribution of the toxic chemicals, which were used as the toxic chemicals in the chemical warfare agent, as shown in figure 1. The received transmitted signal depended on the ultrasonic transmitters and the ultrasonic receivers. The ultrasonic transmitters signaled with differences in frequency, which each simulated as a group of toxic chemical. While the measured signal strength was simulated as a concentration of toxic chemical distribution. The feasibility study was also done [4]. The research procedure of CAMSIM prototype was shown in figure 2.

\begin{figure}[h]
\centering
\includegraphics[width=0.8\textwidth]{figure1.png}
\caption{The concept of chemical agent monitor simulator}
\end{figure}

2.1. Ultrasonic transmitter and receiver circuit design
2.1.1. Ultrasonic transmitter circuits. It was designed for 4 different frequencies of ultrasonic transmitter used to simulate as 4 types of toxic chemicals. H and G assigned normally for blister agents and nerve agents, respectively. B and A labelled up to the training procedures, such as blood agents, toxic industrial chemicals, and explosives. Each the ultrasonic transmitter signaled a different frequency, which is calculated from the frequency of the crystal divided by 256, as show in Table 1.

\begin{table}[h]
\centering
\caption{Ultrasonic frequency}
\begin{tabular}{ccc}
\hline
Crystal frequency (MHz) & Ultrasonic frequency (kHz) & Toxic chemical types \\
\hline
6.4000 & 25.0000 & H \\
8.0000 & 31.2500 & G \\
10.0000 & 39.0625 & B \\
12.0000 & 46.8750 & A \\
\hline
\end{tabular}
\end{table}
Start

Ultrasonic receiver and transmitter circuit design

Microcontroller code writing

HW and SW tested

HW and SW modified

CAMSIM case design

CAMSIM field test

Stop

Figure 2. Research procedure diagram

The ultrasonic transmitter circuit was shown in figure 3. The ultrasonic frequency output of a divider circuit was sent to a BC549 transistor for increasing the ultrasonic signal level, and then to a transistor-to-transistor logic (TTL) level. The TTL level converted it to a sine wave by a MAX 232 and a LC resonant circuit. The inductance value was calculated by the equation (1). Table 2 showed the inductance of coils for the ultrasonic transmitters.

\[ 2\pi f = \frac{1}{\sqrt{LC}} \]  

\( f \) is frequency (Hz)
\( L \) is inductance (H)
\( C \) is capacitance (F), The capacitance of ultrasonic transducer is 1.77 nF

Table 2. Inductance of coil

| Ultrasonic frequency (kHz) | Inductance (mH) | Used (mH) |
|---------------------------|----------------|-----------|
| 25.0000                   | 23.2           | 27.0      |
| 31.2500                   | 14.8           | 15.0      |
| 39.0625                   | 9.5            | 10.0      |
| 46.8750                   | 6.6            | 6.4       |
2.1.2. **Ultrasonic receiver circuits.** Ultrasonic receiver circuit was composed of 8 parts, such as a transducer, a preamplifier state 1, a band pass filter, an amplifier, a rectifier & filter, a preamplifier state 2, a micro controller and a LCD display, as showed in figure 4.

2.1.2.1. **Transducer and preamplifier parts.** This part used a piezoelectric substance ultrasonic transducer for receiving the ultrasonic signals from an ultrasonic transmitter. The ultrasonic signal amplified by 2 states of inverting amplifier, the first state was a voltage gain approximately 47 and the second one was 100. A low noise op-amp integrated circuit, TL074 designed to invert an amplifier circuit, as shown in figure 5. The ultrasonic output signal was sent to a filter part.

2.1.2.2. **Band pass filter and amplifier parts.** It was designed for 4 passive LC band pass filters for each ultrasonic frequency. The LC band pass filters were shown in Table 3. The amplifier was used to amplify the signal from a band pass filter to higher value by using an Op-amp number TL074, connected to an amplifier circuit by inverting an amplifier circuit, as shown in figure 6.

2.1.2.3. **Rectifier and amplifier part.** This part converted a sine wave signal to a square wave signal using a diode number 1N4148, and sent to a non-inverting amplifier circuit using an Op-amp number LM324, as shown in figure 7.

2.1.2.4. **Microcontroller part.** This part used a microcontroller number PIC18F2525, which is microcontroller 8 bits, to control a received ultrasonic analyzing, and showed a type of toxic chemical and distribution of simulated toxic chemical for 1 transmitter for using as CAMSIM, as shown in figure 8.

![Figure 3. Ultrasonic transmitter schematic](image)

| Band pass filter (kHz) | Inductance (mH) | Capacitance (μF) | Toxic chemical types |
|------------------------|----------------|-----------------|---------------------|
| 25.0000                | 9.2            | 0.005           | H                   |
| 31.2500                | 5.18           | 0.005           | G                   |
| 39.0625                | 5.03           | 0.0033          | B                   |
| 46.8750                | 5.24           | 0.0022          | A                   |

2.2. **Microcontroller code writing**
The C language was a writing code for controlling an ultrasonic receiver circuit to operate for each a designed function. The receiver circuit started to work by checking the readiness of an ultrasonic frequency. When the parts were already at work, the controller checked and analyzed the ultrasonic
signals. The final results were shown as a type of simulated toxic chemicals and a distribution level of simulated toxic chemicals on the LCD, as shown in figure 9.

![Ultrasonic receiver block diagram](image)

**Figure 4.** Ultrasonic receiver block diagram

![Transducer and preamplifier schematic](image)

**Figure 5.** Transducer and preamplifier schematic

### 2.3. Prototype
The prototype of Chemical Agent Monitor Simulator: CAMSIM consist with 1 set of ultrasonic receiver; simulates as the Chemical Agent Monitor (CAM), 4 sets of ultrasonic transmitter; simulates as toxic chemicals, 1 set of 12 volts external battery for CAMSIM and 1 set of battery charger, as shown in figure 10.

### 3. Results and discussions
From testing ultrasonic receiver and transmitter circuit, they can use as per design functions. Ultrasonic receiver can receive an ultrasound, which is sent from the transmitter within 1 meter and can show the type of toxic chemical correctly. They are able to show the concentration of simulated toxic which depends on the distance of the receiver circuit and can transmit an ultrasound within approximately 1 meter. The receiver circuit shows the decreasing in the concentration of simulated toxic chemical with the longer distance. However, the receiver circuit moves closer to the transmitter circuit, the receiver circuit respectively shows the increasing in the concentration of simulated toxic chemical.

All of 4 ultrasonic transmitters, which simulates 4 types of toxic chemical, can work well with ultrasonic receiver circuit that simulates the chemical agent monitor. It is able to simulate more toxic chemical than a chemical agent monitor simulator, which the Royal Thai Army Chemical Department bought from abroad that simulates only 2 types of toxic chemical.
Figure 6. Filter and amplifier schematic

Figure 7. Rectifier and amplifier schematic
Figure 8. Microcontroller and LCD display schematic

Figure 9. LCD display
4. Conclusion
Nowadays, toxic chemicals are used as weapons in the war to attack soldiers or harm people in terrorism. To prepare for checking and preventing a chemical war, the Royal Thai Army by Royal Thai Army Chemical Department allocated budget to purchase instruments to station in the department. The Royal Thai Army Chemical Department has developed the prototype of the CAMSIM to design and invented by designing an ultrasonic transmitter circuit for 4 sets to simulate as the toxic chemicals and an ultrasonic receiver circuit for 1 set to simulate as the CAM. From the field testing, this system can measure signal within 1 meter and the receiver can precisely show type of simulated toxic chemicals.

Acknowledgments
The research funding is partly supported by the Office of the Higher Education Commission under the Collaboration Project between the Office of the Higher Education Commission and the Royal Thai Army in the year of 2015. The Suan Sunanadha Rajabhat University jointly supported the experimental laboratory. The Royal Thai Army also kindly supported the officers and military testing.

References
[1] Department of the U.S. Army 1985 *Field Manual 3-100 NBC Operations* (Washington DC: Headquarters Department of the Army Commandant)
[2] www.argonelectronic.com 2015 *Real experience training for CBRN & Hazmat response*
[3] Sharma M 2010 *J Pharm Bioallied Sci.* **2** 275
[4] Torasa C and Dararatana P 2016 *Proceeding of the Second Asian Conference on Defence Technology* (Chiang Mai) January 21-23, 2016 (Chiang Mai: Thailand) 199