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Novel Anti-coincidence Method for Superheated Liquid Neutron Sensor

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ABSTRACT

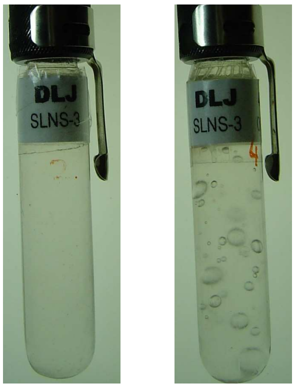
Superheated liquid neutron sensor (SLNS) has vast applications in nuclear emergency disaster management. In the SLNS the bubbles are formed due to neutron exposure. The authors have made effort to improve the performance of the developed bubble counter with focus on minimizing its sensitivity to the ambient acoustic noise signal effect of shock/vibrations using new anti-coincidence circuit. The paper presents the new universal anti-coincidence method and its experimental verification by considering the 3-D time estimation delay model. The results show that the developed anti-coincidence method eliminates the environmental acoustic noise effectively.

Key word: Superheated liquid neutron sensor, anti-coincidence, delay time.

INTRODUCTION

The Superheated Drop Detector (SDD) [1] is a homogenous suspension of super heated Freon droplets inside a viscous elastic gel, which may undergo transitions to the gas phase upon energy deposition by incident radiation. Each droplet behaves as a micrometric bubble chamber. SDD have been widely used in neutron dosimetry [2-3] and spectrometry [4-6]. SDD have shown to comply with ICRP 60 recommendation of measurement, real time response, low minimum detection threshold and most importantly, a nearly dose equivalent response.

The bubble formation in SDD is always accompanied with acoustic pulse. In the early stages of development of superheated drop detector (SDDs), active electronics instrumentation was designed on acoustic registration of bubble nucleation [7]. The front end electronics is consist of a piezo-electric transducer, an amplifier , a high- pass filter accepting the frequency range of the pulses, a differentiator separating fast initial oscillations from showers after effects and a comparator establishing a threshold. In the late 1980s, a second transducer was added for anti-coincidence discrimination of spurious noise and this led to first commercial device used by various groups to investigate the properties of SDDs [8-10].The manufacture, Apfel Enterprises, marketed the device only for short period as it became clear that noise and vibration could paralyses the counting electronics and that the temperature sensitivity of the detector had to accounted for. In 1990s, the advent of digital signal processing led to development of new survey meters in which a micro processor discriminated between bubble signals and spurious signal via pulse shaping analysis [11-13].



Unexposed exposed

Figure1 Superheated liquid neutron sensor (SLNS)

Fig.1 shows the indigenously developed superheated liquid neutron sensor (SLNS). Defence laboratory, Jodhpur is working on development of superheated emulsion drop detector since last 15 years [14-15]. Superheated emulsion detector based bubble reader system is developed indigenously [16]. The bubble reader system is very useful in case of nuclear emergency disaster management. The instrumentation has a limitation of acoustic noise registration along with the actual bubble count. The acoustic noise increases the possibility of incorrect neutron dose and dose rate estimation. To resolve the above limitation novel time delay estimation model is developed and experimentally verified [17]. The delay model estimates the maximum time delay for fixed spatial separation between the two transducers. The time duration of the delay is used to decide the pulse width of the mono-stable multivibrator. The pulse decides the disable time of the counter in the presence of acoustic noise. The paper describes the universal anti-coincidence circuit based on delay time model. This method will be used to improve the performance of existing bubble reader system.

MATERIALS AND METHODS

Time delay estimation model developed and experimentally verified for evaluating the time difference of arrival between the transducers/microphones [17].

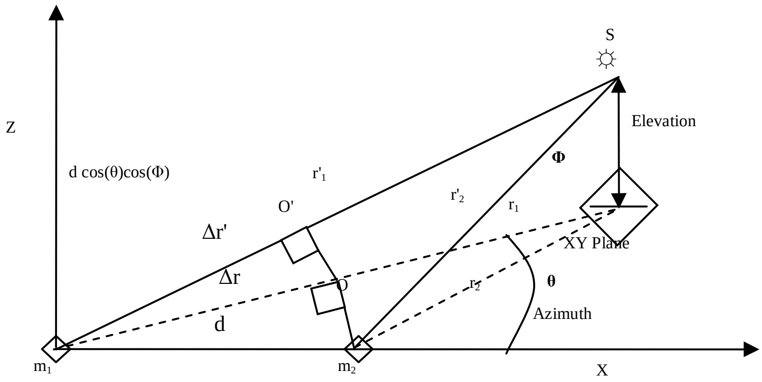


Figure 2 Delay estimation model

The time difference of arrival of acoustic signal at two microphones (m_1 & m_2) is given by equation 1. The time delay depends upon the spatial separation and cosine of the both azimuth and the elevation angle from the x-axis (the axis passing through the micro-phones) as shown in fig.2**.** All the values were calculated considering velocity of the acoustic in air 330m/s.

$$\text{Time delay (D)} = 3\text{x}10^{-3} d\cos\theta\cos\Phi \text{ --------- (1)}$$

Where d= spatial separation between the micro phones

θ = Azimuth angle between X axis and path line of acoustic source at microphone1

Φ = Elevation angle between X-Y plane and path line of acoustic source at microphone1

S= Acoustic source i.e. Buzzer

The delay model theory will be helpful in estimating the maximum and minimum time delay. Maximum delay condition has been considered for worst case design of the anti coincidence circuit.

Case I

If both θ and Φ angles are set at 0°. Then the time delay will be directly proportional to d (cos0°=1) as per the equation 1. This is the condition for maximum delay. Arrangement scheme of microphones and acoustic source for maximum delay is shown in the fig.3. Maximum delay is considered as a worst case design. Maximum delay was calculated for optimized spatial separation (5 cm).i.e. 150 micro-second as per equation 1.

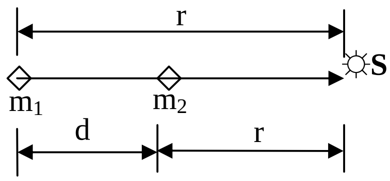


Fig.3 Arrangement of microphones and acoustic source for maximum delay

Case II

If both θ and Φ angles are set at 180° degree, then the time delay will be negative (cos180°= -1) as per equation 1. This is the condition of maximum negative delay. It is concluded that the microphone1 received the acoustic signal earlier than microphone 2. Arrangement scheme of microphones and acoustic source for negative delay is shown in the fig.4. This delay will be used for optimisation of streching period of pulse.

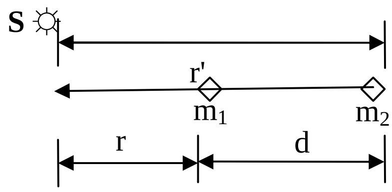


Fig.4 Arrangement of microphones and acoustic source for negative delay

Case III

If both θ and Φ angles are set at 90° degree, then the time delay will be zero (cos90°=0) as per equation 1.This is the condition of minimum delay. It is concluded that both the microphones received the signal at a same time. Arrangement scheme of microphones and acoustic source for minimum delay is shown in the fig.5.

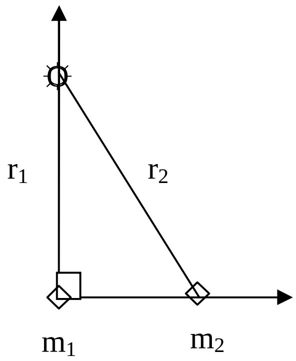


Fig.5 Arrangement of microphones and acoustic source for zero delay

A. Anti-coincidence method

The conventionally used anti- coincidence (ANC) circuit is designed and developed to cancel acoustic noise pulses as shown in fig.6. Two microphones are placed in the reader system. One transducer attached with the neutron sensor for counting of bubble formation due to neutron exposure. Second one is placed for monitoring of the environment acoustic noise. If there is environmental noise present then both the transducers will be affected. The block schematic is consisting of transducer (mic), signal processing and mono-stable multivibrator. The signal conditioner consists of the amplifier, band pass filter and comparator. The output of the band pass filter is applied to comparator unit. For each acoustic detected by micro-phone, the mono-shot produces a fixed duration pulse. Two such units were designed and outputs of the both units are applied to exclusive – OR gate. The out put of the exclusive gate is applied to counter. The circuit is conditionally true when the azimuth or elevation angle of the acoustic arrival should be

90° as shown in case III. The circuit is valid only when arrivals of both the signals are in coincidence. The circuit has limitation that it will not work for case I and II

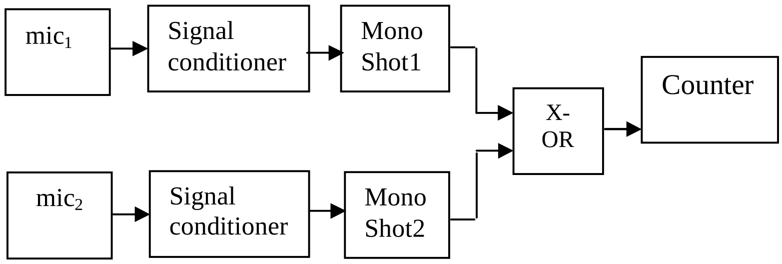


Fig.6 Block diagram of general anticoincidence circuit

B. Universal Anti-coincidence method

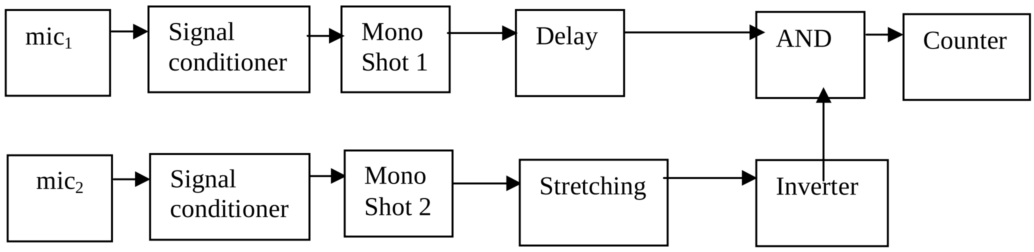


Fig.7 Block diagram of universal anticoincidence circuit

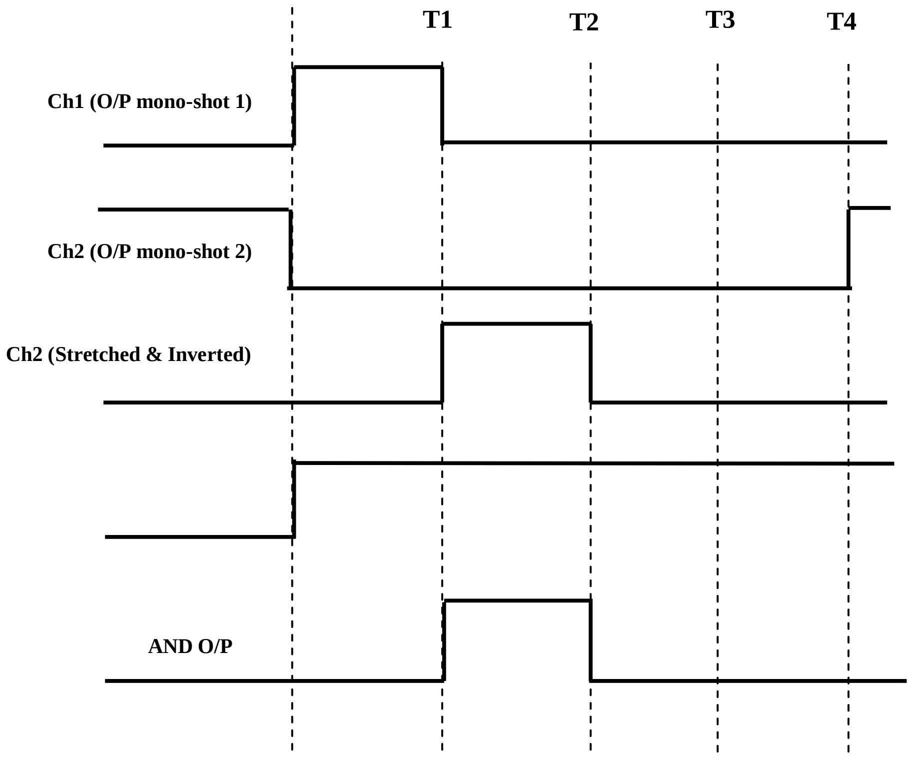


Fig.8 State diagram for the condition no noise signal only bubble signal at mic1

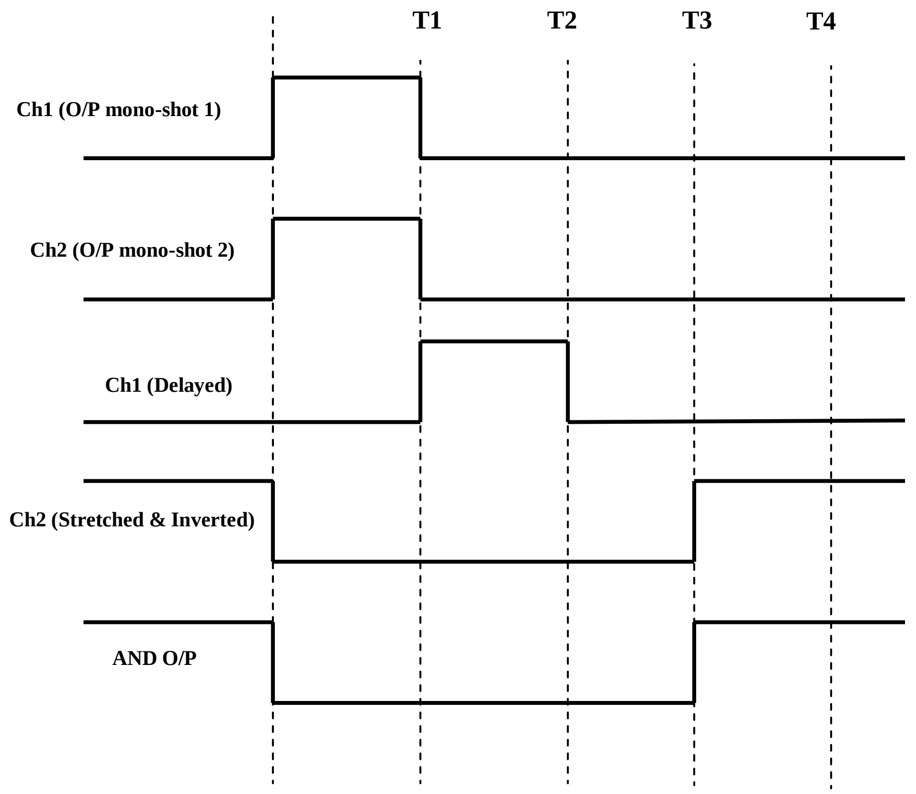


Fig.9 State diagram for the condition (a) both mics pick up noise signal at a time

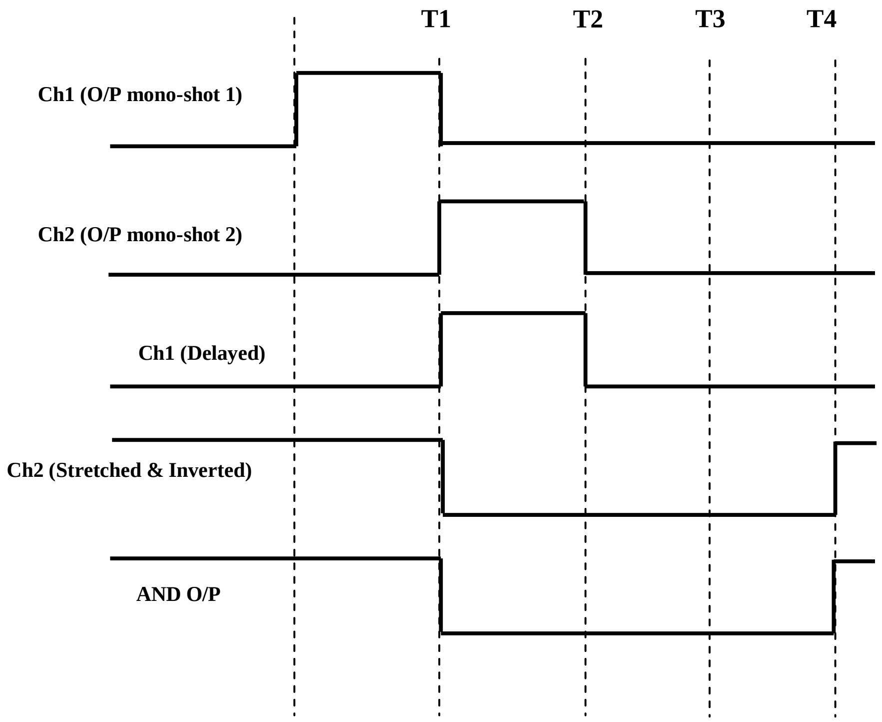


Fig.10 State diagram for the condition (b) mic1signal leads mic2 signal

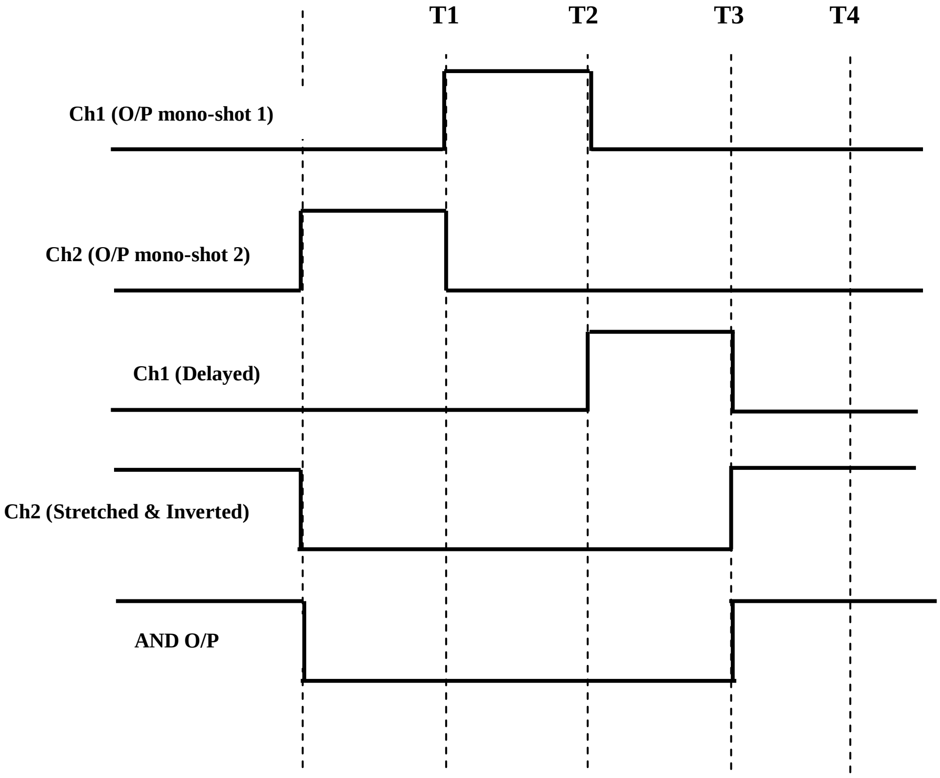


Fig. 11 State diagram for the condition (c) mic1signal lags mic2 signal

Case-A

When acoustic noise is not present. The AND gate is enabled and the bubble acoustic signal detected by mic1 passes through AND gate and is counted. The state diagram for condition as shown in fig.8. The output was only due to bubble event.

Case-B

When acoustic noise is sensed by both mics their exist three conditions:

(A) IF both mics senses noise at same time means the acoustic noise arrived at both microphones at same time. In this condition output of the Microphones identical and same in timing. The switch stops the signal for time T1 to T3 as shown in the fig.9.

(B) IF Mic1 signal leads Mic2 signal. In this case the acoustic noise signal arrived at microphone1 is earlier than microphone2. The switch stops the signal for time T2 to T4 as shown in the fig.10.

(B) IF Mic1 signal lags Mic2 signal. In this case the acoustic noise signal arrived at microphone1 is later than microphone2. The switch stops the signal for time T1 to T3 as shown in the fig.11.

The trailing edge of noise signal in channel 2 is stretched so that it disables the AND gate for duration twice of the delay time and ensures that noise signal picked by mic1 is always stopped by the AND gate. In the case of acoustic noise registration, the bubble counter will be stopped for the period and thus avoiding the external noise with the bubble count.

Experimentation

Experiments were carried out for performance evaluation of anti-coincidence circuits having two microphones/transducers and one acoustic source. Both the transducers are mounted on the same base plate such as spatial separation between the transducer was adjustable. Buzzer was used as acoustic source and energized by sharp electric pulse (duration 500 ms). Microphone mic_1 was placed at the center of circle with radius of 1m and the source (buzzer) was placed on the periphery of circle from 0° to 360° at steps of 30°. During the experiment spatial separation of two mics was kept 5 cm and elevation angle 30°. In the performance evaluation of ANCs with elevation angle the experiment repeated by keeping fixed azimuth angle 30° and varying the elevation angle from 0° to 360° at steps of 30°. The performance of the both ANCs was tested by generating the acoustic signal (500ms duration) at different locations. All the experimentations were carried out by following assumptions

1. Single sound source i.e. buzzer.
2. Reflections from bottom of the plane and from the surrounding objects are negligible.
3. No disturbing noise source contributing to the sound field.
4. The noise source to be located, is assume to be stationary during the data acquisition period.
5. Microphones are assumed to be both phase and amplitude matched and without self noise.
6. The change in sound velocity due to change in pressure and temperature neglected. The velocity of sound in air is taken as 330 m/sec

RESULTS AND DISCUSSION

The figure 12 & 13 show the comparative performance of anti-coincidence methods with the azimuth angle and the elevation angle. The curves show the general coincidence method is conditionally valid for θ or Φ=90°. The newly developed method i.e. Universal ANC is applicable for all the locations of the noise source for both azimuth and elevation angle 0° to 360° (4π coverage).

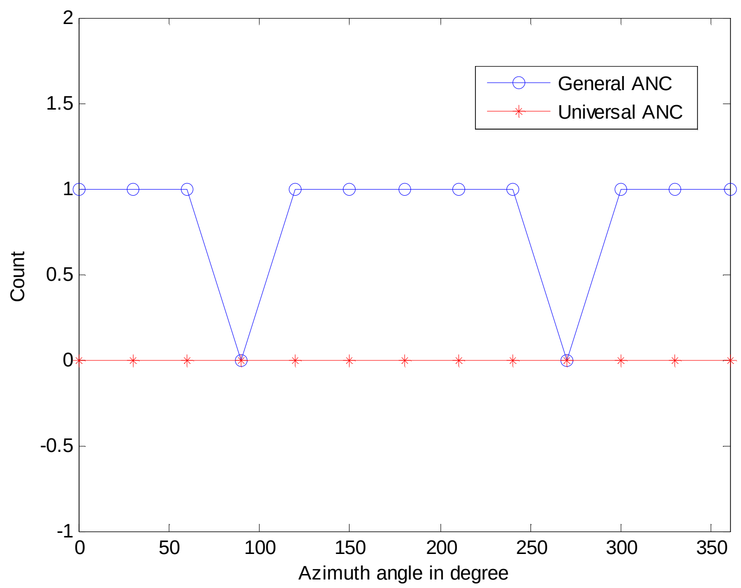


Fig.12 Performance of ANC circuits with azimuth angle

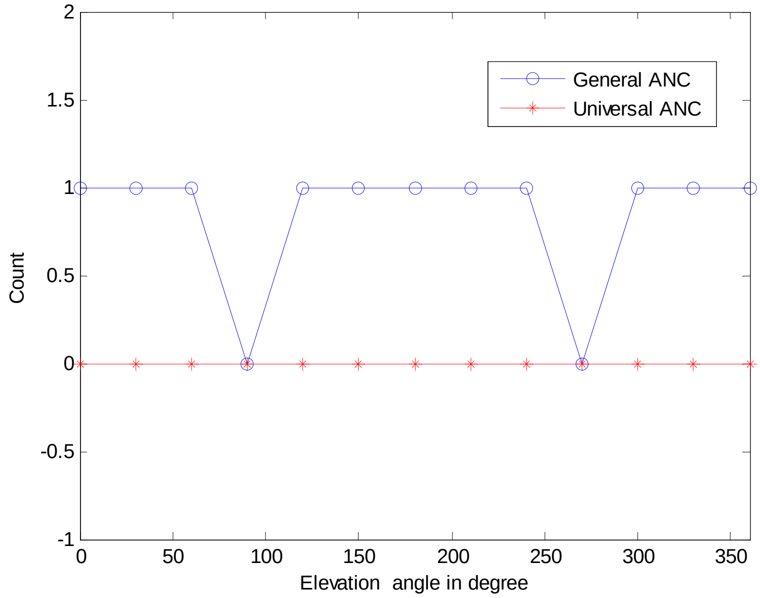


Fig.13 Performance of ANC circuits with elevation angle

CONCLUSION

The newly developed ANC method is very effective for acoustic noise elimination for superheated liquid neutron sensor. Effect of acoustic noise registration will be minimized which will improve the accuracy of the bubble counter. The Universal ANC method is worst case design. It is valid for airborne as well as surface borne acoustic noise. Thus we can estimate the accurate number of bubble, neutron dose and dose rate. Implementation of the universal anti-coincidence method in developed bubble reader system is under progress.

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