ADAPTIVE PINGER TECHNOLOGY FOR UNDERSEA LOCATION

Could adaptive pingers have aided search for MH370?

Although the number of aircraft lost at sea is not very high, over the past years a number of aircraft have suffered precisely that fate. With the recently renewed search for Malaysian Airlines flight 370 (MH370), one wonders about the technology in the underwater location of aircraft and other high-value objects. Underwater locator beacons (ULBs or ‘pingers’) are used for this, either on the airframe itself or on the black box. This article proposes making use of technological advancements to allow better detection.

Missing airliners

During the initial search for MH370 nearly 4 years ago, it became apparent that better aircraft location technology was necessary to avoid long searches. This started from the basic limitations of radar tracking, to the realisation that most aircraft do not automatically report location, culminating with the happenstance of limited position information derivable from the satellite data. This resulted in insufficient information to determine where the lost plane may have gone and, more specifically in cases such as MH370, where it entered the ocean when it disappeared.

Aircraft at the time that MH370 was lost, and largely today, carry simple, water activated acoustic transmitters to mark the location of the flight data recorder, the so-called ’black box’. The purpose of these ‘pingers’ was originally to help recovery teams home in on the black box for prompt recovery and analysis. In this case, there is an assumption that the crash site is well known. With an entry point known, a 30 day window to find the specific resting place of the data recorders is entirely adequate. As a result, conventional pinger technology is intended for a specific case, assuming that aircraft crashing into the ocean would be monitored from shore, providing a known starting point for undersea search operations. This held true in incidents such as TWA flight 800 (New York 1986) and Egypt Air flight 990 (Massachusetts 1999).

From MH370 to current technology

During the first weeks after the loss of MH370 significant media airtime was spent analysing the possibilities of ‘pings’ indicating the location of a sunken airliner. This coverage largely failed to note the original purpose of these pingers with a known point of entry. In cases such as that of MH370, the objective is first to find the airframe or debris field and then home in on key items such as flight data recorders. This is an entirely different requirement from that originally placed upon aviation pingers.

Aircraft lost at sea.

However, there are new technologies (and some old) being applied to better tracking of the aircraft throughout its journey and therefore allowing a better estimate of the location where the aircraft is lost. The new technologies include ‘nano’ satellite constellations, along with existing satellites (such as Inmarsat), which will receive the new International Civil Aviation Organization (ICAO) required reporting of the aircraft position every 15 minutes. This one change represents a very significant improvement over the status quo. Looking back to MH370, if this had been available it would have greatly improved the probability of detection by knowing where to search early on. But even with such an outcome, the undersea aspects of localising the aircraft, and its black boxes demands more technology.

Current aviation pingers

Among other global regulators, The Unites States Federal Aviation Administration (FAA) issues technical standard orders (TSO) which shape the current technologies used on commercial aircraft. As of 2014, when MH370 was lost, the primary guidance for pingers was TSO-C121 (Underwater Locating Devices (Acoustic) (Self-Powered)).

Pingers (Figure 1) simply transmit a simple signal, a ping, typically starting upon contact with water or loss of power. In black boxes the pingers are water activated. Because a pinger constantly issues a signal it also begins draining its battery immediately. The key parameters of a classic aviation pinger are shown in Table 1. These specifications are usually met with a compact (usually within 12cm long by 3.5cm diameter) and light (under 200g) device, even given the requirement to withstand pressures to 6,000 metres. These dimensions are desirable as airliners aim to minimise size and weight.

Frequency	37.5kHz (+/- 1 kHz)
Acoustic Output re 1μPa@1m	160.5dB
Pulse Length	10ms
Pulse Repetition	1 pulse/sec

Table 1: Typical ‘black box’ pinger specifications.

Pingers in deep water

To address challenges existing prior to MH370, regulatory guidance evolved. New black box pingers will slowly be required to provide 90 days of pinging. In addition, there is an upcoming guidance on ‘airframe locator’ specifications, which will increase the detection range as shown in Table 2. This will require 8.8kHz transmissions and an increase in source level to 180dB increasing the size of the pinger device to roughly 15cm long by 5cm diameter with weight increasing to just over 700 grams.

Frequency	Source level	Approximate detection range
37.5kHz	162dB	1km typical 2-3km depending on sea conditions
8.8kHz	180dB	2km typical 3-4km depending on sea conditions

Table 2: Approximate aviation pinger detection ranges.

Recognising that ocean depths can exceed 6km and average ocean depth is over 4km it becomes clear that these improvements are modest. When detection ranges are approximately the same as the local water depth this requires the search system to effectively pass right over the pinger to detect it. In the case of MH370 the estimated search zone was originally estimated at some 60,000 square km, a huge area to cover even with 90 days of pinging. Simple pingers might not be the answer for this type of aircraft loss.

Advanced, adaptive pinger technologies

There are many advanced technologies that can provide significant improvements for undersea localization. Unfortunately, these concepts exceed the cost or size/weight constraints of the modern aviation industry. Fortunately, new concepts for adaptive pingers have been introduced that enable new approaches to energy conservation and acoustic waveform adaptation.

Map of the flight path of Malaysia Airlines Flight 370. (Courtesy: Andrew Heneen)

One aspect of the energy conservation methods is delaying the start of the acoustic emissions from the pinger. This simple change allows time to identify the search area, and deploy search vessels on station. If this approach is applied to an airframe locating pinger, presuming conventional pingers remain on black boxes, it provides a significant extension of the search window. An adaptive pinger could be designed to have a ’delayed start’ of 30 days, for example, allowing the maximum use of the existing black box pinger battery while also allowing time for searchers to deploy with the proper hydrophone equipment. Alternatively, airframe pingers could start immediately and black box pingers could be delayed. This simple delayed start can easily be applied to existing pingers with minimal impact on cost or size and weight.

An adaptive pinger also has the ability to change its acoustic waveform for purposes of maximizing battery power. Algorithms for this feature can be predefined and contained within the adaptive pingers circuitry taking input from an integral depth sensor which tells whether it is in shallow or very deep water. The depth of the water will influence the time it takes to be located, so deep water will call for more robust battery conservation than shallow water, thereby extending battery life for the more complex location task and increasing the probability of detection. The depth can also be transmitted as part of the coded pulse to search vessels.

Figure 1: A flight data recorder with pinger attached.

Current pingers emit a high power acoustic pulse, generally every second. This pulse is typically 5-10ms in length and repeats continuously until the battery is depleted. The pulse frequency is 37.5khz for the majority of the pingers in use on black boxes which is most suitable for shallow waters, whereas very deep waters are better served by low frequency pulses of 8-10khz. The lower frequency beacon has become an ICAO requirement for airlines to carry as an airframe locator, and it is likely to become an FAA requirement as well. An adaptive pinger can emit signals on one of two frequencies or on both frequencies and as it can understand, algorithmically, whether it is in deep water, it can then shift its acoustic output frequency to optimize for deep water.

Additionally, the adaptive pinger can follow pre-set algorithms to adapt the waveform by reducing the pulse repetition rate, modulate the pulse power, or both, all in relation to the depth sensor inputs.

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The depth value is transmitted by either of two methods: one is an acoustic pulse frequency shift (frequency shift key in proportion to the depth), and the other is in a coded pulse sequence similar to the aviation Mode C reporting format for altitude. Once the depth code is received and understood by the search vessel, then by comparison to the available local bathometry data, these search vessels can more quickly narrow the search to areas that match the reported depth.

Conclusion

The techniques described in this article are all available and the adaptive pingers have also been patented. Current technology is not a limiting factor; some of the new adaptive pinger technologies can easily be added to existing products. Others might require additional development. All might require modest new engineering to survive airframe crashes. The primary challenges are the ‘social engineering’ issues of the business case and regulatory processes. When the users and end customers of undersea locating systems ask for it, improved technology will be readily available.