HiPAP channel planning

As of the date of this update, the analogue channels of the HiPAP system are still in wide use, but it seems likely that Kongsberg's Cymbal transponders will become dominant over the next couple of years. Meanwhile, there is still a need for planning when HiPAP analogue systems are used by ships in simultaneous operations.

Requirement

The HiPAP analogue system uses 24 frequencies. Eight of these are used exclusively by the transceivers to interrogate transponders, and 16 are used by the transponders when replying. With 56 selectable channels, there cannot be a unique frequency allocated to each channel. As a result, when multiple transponders are deployed it is normal that some of them will share interrogation or reply frequencies, or both.

Channel planning is necessary to avoid interference between interrogations when *more than one* HiPAP system operates in the same area. This can occur in two different, but equivalent, ways:

- Interference between HiPAP systems on two or more different vessels operating in proximity
- Interference between two HiPAP poles on the same vessel (only if the systems are independent of each other).

Note: *A proper dual pole system will not interrogate the same transponder from both poles, except in the full dual-HiPAP mode which works OK by design (dual-pole mode chooses a single pole to transmit the interrogation, and then triangulates the reply using both poles to give improved accuracy). The APOS software should prevent you from selecting channels that cause interference between the poles (I don't know what algorithm APOS uses to do this).*

Principle of operation

A HiPAP transceiver interrogates a transponder by transmitting two pings, representing the first and second digits of the channel number. The addressed transponder replies with a single ping whose frequency is selected according to the odd or even status of the first digit, together with the second digit of the channel number. This is how 16 frequencies are needed for replies.

After transmitting an interrogation, a transceiver must wait for the reply (or a timeout in the event of no reply heard) before interrogating another transponder. In other words a single transceiver/pole can be interrogating one, and only one, transponder at any moment. (Because of this there can never be any interference when a single system operates in isolation – one HiPAP pole can operate any or all of the 56 available channels because each is interrogated in turn).

Since ranging depends on measurement of the time period between transmission of the interrogation and reception of the reply, it can be rendered inaccurate if a transponder is spuriously triggered by another interrogating system. This would only happen if both systems interrogated at about the same moment, but common sense dictates that two vessels ought never to interrogate the same transponder (although setting ping rates that are slightly different, e.g. 2s and 2.1s can reduce interference to a minimum if sharing a transponder is really necessary).

How interference can happen

Even if two systems never attempt to interrogate the same channel, two different modes of interference can still occur:

- On interrogation, transmitted pings from two different poles might arrive at a transponder at the same instant; if either ping frequency from the interfering interrogation happens to match one digit of the transponder's channel number then the interleaved pings could combine to form a “valid” but unintended interrogation, causing mis-triggering (unintentional triggering or a failure to trigger at all, or at the right time). To avoid this possibility completely, vessels operating together would have to avoid sharing any of the same interrogation ping frequencies (channel digits) in their channel plans. Since only eight frequencies are used, this can be challenging.
- A second mode of interference can occur when two or more transponders used by different vessels share the same reply frequency. If these different transponders are interrogated simultaneously by different systems, then the replies are indistinguishable and position errors can result. For every channel, there are either two or three other channels that share the same reply frequency, so this clash is more easily avoided.

So your channel plan should always be designed to avoid the second form of interference, and as much as possible of the first.

Frequency matrix

There are eight interrogation frequencies:

1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
21000	21500	22000	22500	23000	23500	24000	24500

There are sixteen reply frequencies:

First digit	*Second digit* 1	2	3	4	5	6	7	8
Odd	28750	29250	29750	30250	30750	27250	27750	28250
Even	28500	29000	29500	30000	30500	27000	27500	28000

Complete non-interference

Both modes of interference can be avoided completely by not sharing channel ID digits between vessels, so that neither interrogation or reply frequencies will ever clash. This is the gold solution, but is often impossible in a practical situation where more than two vessels are present. In that situation the important factor is to avoid sharing reply frequencies.

The following numbers of channels are available when using a restricted choice of digits:

Used digits	*Available channels*
2	2
3	6
4	12
5	20
6	30

For example: using only the three digits 1-3, six channels (12, 13, 21, 23, 31 and 32) are available. *HiPAP does not use the repeated digit (11, 22...) channels, which is why there are only 56 available channels and not 64.*

Strategies

Which strategy you use will depend upon circumstances. Your situation might match one of those below.

Scenario 1 – Single vessel (or single transceiver) – no problem

There is never any possibility of interference when only one vessel/pole is in the area. In this situation any selection of channels may be used. *"A single pole cannot interfere with itself"*.

Scenario 2 – Systems working together, no sharing of channel digits – no problem

If vessels must work together but do not need to share the use of any transponders, then a restricted choice of channel digits is best, and is also easiest to plan and understand. *If two vessels do not use the same digits then they do not use the same frequencies – either for interrogation or replies – so no interference.* This form of complete non-interference can not be achieved with more than four vessels, and is unlikely to be practical with more than two. It can be seen from the table below that if it is used with three vessels, at least one of them will have only two channels available.

There are only six ways of sharing out the eight available digits so that each is only used by one vessel. These combinations can be designated 2-6, 3-5, 4-4, 2-2-4, 2-3-3 and 2-2-2-2, according to the number of digits allocated to each vessel. The most restrictive fully non-interfering plan is 2-2-2-2 – four vessels each using two digits so having only two channels each for a total of eight assets in the water with zero possibility of interference.

	Number of assets				
Plan	**Vessel 1**	**Vessel 2**	**Vessel 3**	**Vessel 4**	**Total**
2-6	2	30			32
3-5	6	20			26
4-4	12	12			24
2-2-4	2	2	12		16
2-3-3	2	6	6		14
2-2-2-2	2	2	2	2	8

Fully non-interfering plans

Example: Plan 4-4

Two vessels work together. Each uses four available digits. 1 – 4 are allocated to vessel A, and 5 – 8 are allocated to vessel B. Each vessel then has twelve channels available for a total of 24 assets in the water, and they will be completely non-interfering.

Example: Plan 3-5

Two vessels work together. One uses three digits, and the other uses five. 1 – 3 are allocated to vessel A giving 6 channels, and 4 – 8 are allocated to vessel B giving 20 channels. There can be a total of 26 assets in the water, and they will be completely non-interfering.

Scenario 3 – Systems working together, no sharing of second digit – interrogations can partially interfere

When vessels need to work closely, but the plans above do not provide enough available channels, a relaxation of the fully non-interfering model can be used. In the relaxed plan, each vessel is allocated one or more second digits for her exclusive use (for example a vessel might be allocated the channels 14, 24, 34, 54, 64, 74, 84). Because the second digit of the channel ID determines the reply frequency, this is the same as allocating unique reply frequencies to the vessel. *If two vessels do not use the same second digits then they do not use the same reply frequencies, so that form of interference is avoided.*

For each second digit allocated there will be seven available channels so, for example, allocating two second digits to each of four vessels will allow each of them to choose from 14 available channels.

Remember that interrogation frequencies are determined by both the first and second digit, and so in this model there remains the possibility of interference of the interrogations which might result in occasional mis-triggering. The risk of this increases with the number of channels in use, but it is better than a free-for-all and it is unlikely to cause noticeable problems in practise.

Scenario 4 – Shared seabed installations – partial interference

When several transponders are left installed in the water and might need to be interrogated at different times by different vessels in the area, it can be helpful to refer to the reply frequency table to select channels. By selecting one channel for each of the boxes in the table below, up to sixteen channels are available, each with its own unique reply frequency. If sixteen transponders are in the water, planned in this way, then any combination of them may be interrogated without any clashing of reply frequencies.

Note of course that although it is *possible* for more than one vessel to interrogate the same transponder at the same time, it cannot be done without a strong risk of interference. If this has to be done, then the ping rate should be adjusted so that clashes are rare – for example set the ping rate to 2s on one vessel and 2.1s on the other, and you can hope that no more than one in twenty interrogations clash.

Using the table below, write each chosen channel number in the appropriate box for the channel. If you find that you have already have a number in the box, then that is an interfering channel.

First digit	***Second digit***							
	1	***2***	***3***	***4***	***5***	***6***	***7***	***8***
Odd 1, 3, 5, 7								
Even 2, 4, 6, 8								