HiPAP frequency planning

Purpose

The HiPAP system uses 24 frequencies. Eight of these are used by the transceivers to interrogate transponders, and 16 are used by the transponders when replying. There are 56 different channel settings, so there is not a unique frequency allocated to each channel. As a result, when multiple transponders are deployed it is very likely that some of them will share interrogation or reply frequencies or both.

Channel planning is therefore necessary to avoid interference between interrogations from different HiPAP systems. This can occur in two different, but equivalent, situations:

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

Note: *On a dual pole system you cannot interrogate the same transponder from both poles, except in the full dual-HiPAP mode which works OK by design (dual-pole mode uses a single pole to transmit the interrogation, and then triangulates the reply with both poles to give improved accuracy). The APOS software should prevent you from selecting channels that cause interference between the poles (but I'm not sure what algorithm Kongsberg uses to do this). It can help to treat the two poles as independent and make a channel plan using the information below.*

Principles of operation

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

After transmitting an interrogation, the 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. It follows therefore that two vessels should never attempt to interrogate the same transponder.

How interference can happen

Two different forms of frequency clash can occur:

- On interrogation, the transmissions from two different poles can arrive at a transponder at the same instant; if either pulse frequency from the interfering interrogation matches a digit of the transponder's channel number then it could cause 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 using any of the same digits in their channel plans. For every channel, there are thirteen others that share at least one digit, so this can be challenging.
- For a subset of the above, there is a second mode of interference that can happen in addition. This is when two or more transponders share the same reply frequency. If these transponders are interrogated simultaneously by different systems, then the replies are indistinguishable and position errors can result. For each channel, there are either two or three other channels that use 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

Strategies

The way to avoid both modes of interference completely is to avoid sharing channel ID digits - this means that both interrogation and reply frequencies will be different. This is often impossible in a practical situation, so the most important factor is to avoid sharing reply frequencies. Four scenarios are illustrated below.

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 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.*

Scenario 1 - Single vessel (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 - Vessels working together, no sharing of channel digits, non-interfering

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 easiest to 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 full separation can not be achieved with more than four vessels.

There are only six ways of sharing out the eight available digits. 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.

	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 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 - Vessels working together, no sharing of second digit, partial interference

When vessels need to work closely without sharing, 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 its exclusive use. 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 the second 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 can be interference of the interrogations which might result in mis-triggering. The risk of this increases with the number of channels in use, but it is better than a free-for-all.

4 – Shared seabed installations – partial interference

When several beacons are installed in the water and must be interrogated at different times by different vessels in the area, it is best to use the reply frequency table to select channels. Up to sixteen channels are thus available. If sixteen beacons are in the water, planned using this table, then any combination of them may be interrogated without any clashing of reply frequencies.

Note of course that it is *never* possible for more than one vessel to interrogate the same beacon at the same time without risk of interference.

Using the table below, enter each chosen channel number in the appropriate box for each 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								