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INMARSAT-C TRACKING AT HIGH LATITUDES

THREE CASE STUDIES

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Authors
Ove A. Davidsen
Svein E. Maubach

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Abstract

The tracking of three Norwegian fishing vessels at high latitudes in the Svalbard area have been studied to examine the functioning of Inmarsat-C units with a stored position capability.

The period covered spans three winter months during 2003/04.

The overall results show a high degree of tracking regularity where the vessels have operated throughout the area of theoretical coverage.

Distribution

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THREE CASE STUDIES

INTRODUCTION

Whereas polar orbiting satellites such as the Argos ® system are inherently well suited for certain uses at high latitudes, it is well known that at latitudes above about 75° communication via the Inmarsat-C system will deteriorate [1], to become virtually impossible to achieve at latitudes above 81.3° N or S. The reason for this is that the elevation angle towards such geostationary satellites should be in the region of about 5° or higher above the horizon as seen from a point on earth for best performance [2]. The maximum elevation angle from a given latitude is generally achieved when both the point of observation and the satellite are on the same longitude.

Further, due to the fact that the orbit of even a geostationary satellite normally has a certain angle of inclination with the equatorial plane, the satellite as seen from a certain point at a high latitude will have an angle of elevation that is not fixed, but varies somewhat over a 24 hour time period. Under marginal conditions this variation may be significant.

Early field trials indicated that Inmarsat-C availability in areas with an elevation angle in the region of 0–5° did on the average fall between 80–85 % using one antenna only [3].

All the same, experience has shown that it is possible to achieve a sufficient degree of regularity so as to allow Inmarsat-C equipment to be used for tracking purposes in fisheries surveillance and control also at high latitudes.

NORWEGIAN REGULATIONS

Norwegian authorities have laid down regulations to the effect that, for Inmarsat-C equipment to be used for mandatory satellite tracking purposes onboard Norwegian fishing vessels exceeding 24m l.length, such equipment must be able to record and store vessel GPS positions and timestamps on an hourly basis also when contact can not be established between the Inmarsat unit and an Inmarsat-C satellite. When contact is again achieved, such stored positions will be automatically downloaded to the Fisheries Monitoring Centre (FMC).

All Inmarsat-C position reports are assigned a Macro Encoded Message (MEM) type number.

In addition to stored *Normal* position reports (MEM 70), also a number of exception conditions must be reported by an approved unit. We would here like to draw special attention to two such conditions, e.g. *PowerUp* (MEM 64), *PowerDown* (MEM 66) and *Antenna Blocked* (MEM 69). A report of the latter type is automatically generated the very moment the Inmarsat-C unit registers a loss of communication, irrespective of whether or not an ordinary scheduled position report was due at the time. It goes without saying that such a report must also be stored, and can only be forwarded to the FMC when communication is again possible.

This means that when a vessel equipped with an approved Inmarsat-C unit moves deeper into an area where satellite coverage is increasingly getting worse, the number of position reports per time period will at first actually increase, as the unit will now generate automatic MEM 69 reports to the FMC momentarily in between and in addition to the ordinary hourly scheduled (MEM 11) position reports.

The further the vessel moves, say north, the more frequent will become the stored MEM 70 reports, recorded at the scheduled intervals and forwarded to the FMC as circumstances allow, each couple of MEM 70 reports also accompanied by a MEM 69 report. All the reports mentioned give the vessel GPS position and timestamp, together with platform speed and course.

An approved Inmarsat-C unit must be able to store at least 24 reports in a ring-buffer before overflowing, loosing the oldest rercords. Some of the units have a much higher capacity

There are at present three types of Inmarsat-C units that have been approved for tracking by Norwegian fisheries authorities:

Trane & Trane	TT 3020 C
Furuno	Felcom-12/15
Sailor	H 2095 C

The Sailor unit is an OEM version of TT 3020 C

THE PLATFORMS

In order to be able to study tracking at high latitudes in some detail from a practical point of view, we decided to take a closer look at this on a vessel- by-vessel basis. As a point of departure, we decided to concentrate if possible on activities during a recent time period, i.e. November – December 2003 and January 2004. Our aim has been to study in some detail the activities of three vessels, one with each of the abovementioned Inmarsat-C stations.

The only criteria apart from that have been:

1. that each of the vessels should have covered an area of interest from about 75° N and towards the highest reaches of satellite coverage
2. that the vessels should have stayed for some time within the area of interest so as to counter the effect of varying environmental parameters to some extent

Please note that under marginal circumstances things like weather conditions (wind, temperature, humidity etc.) will have a bearing on the results. Orbital parameters for the satellites at the time will also need to be considered to enable a comprehensive analysis. We have made no effort whatsoever to try to establish to which extent such conditions have had an impact on the results. Generally, however, weather conditions in the area chosen tend not to be favourable for tracking purposes during the winter months, so any influence may well on the balance have been negative.

THE SVALBARD AREA

An area quite suitable for such studies is the Fisheries Protection Zone around Svalbard. This area, which is approximately diamond-shaped, reaches from close to 72° up to well above 84° N, and from nearly 4° W to beyond 42° E. A large part of the zone falls in the interesting area above 75°N where one would expect to see the first signs of reduced tracking regularity.

One reason why this area is of special interest, is that it partly falls within the coverage of two of the Inmarsat satellites, i.e. the East Atlantic Satellite (AOR-E) at 15.5° W, and the Indian Ocean Satellite (IOR) at 64.5° E [4].

Fig.1 shows the zone with superimposed average coverage lines calculated for both the AOR-E and IOR satellites for satellite elevation angles 5° and 0° respectively, corrected for atmospheric refractivity [5].

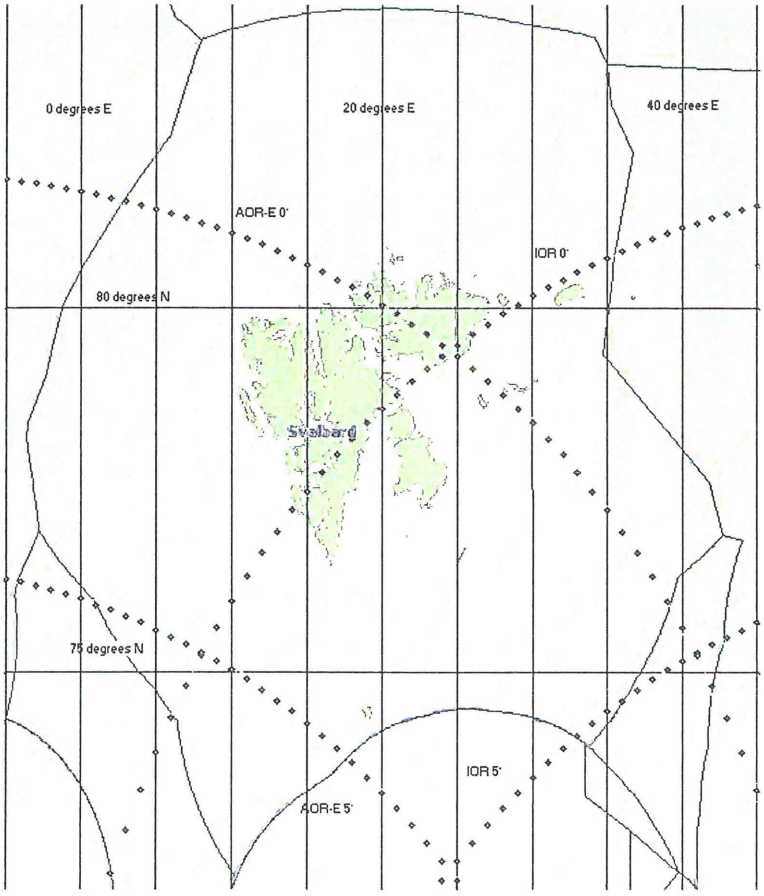

Fig.1 Svalbard Zone with Inmarsat-C coverage

Before we study the actual tracking data in more detail, two special circumstances must be recalled. First, although geometry alone may point to a latitude (81.3°) above which a geostationary satellite can not be seen, the direction of travel of radio waves is somewhat deflected as they pass through the atmosphere due to the atmospheric refractivity. At low elevation angels this bending becomes significant, adding an apparent 0.6° to the otherwise observed satellite elevation. This effect varies, however, depending on atmospheric conditions.

Secondly, the Inmarsat-C antenna is normally placed high up in the mast or vessel superstructure. In one previous study [3] it was calculated that situating the antenna 13.5 metres above sea level added an additional 0.11° to the lowest angle of elevation.

THE FELCOM 12 PLATFORM

The vessel concerned twice came into the area during the November through January period. She first appeared on 29 November, going for high latitudes, and stayed above 80° during two four-day excursions, reaching 80.5° north before leaving for home on 20 December.
On 04 January the vessel reappeared, staying in the area until 20 January. On this second occasion she stayed mostly above 80° from 09 until 12 January, coming down to about 79.9° for two five-hour periods only.

Tracking results are listed in **Table 1**. Column 2 gives the total number of positions received by latitude, followed in col. 3-6 by a breakdown also by MEM-code. The calculated average interval between positions in minutes will be found in col. 7.

As can be seen from the table, the tracking showed an extremely high degree of regularity. The slight deviation found in the table at 73° is due to the loss of one single position.

Table 1: Felcom 12 - 1 111 position reports

		MEM Codes				
Latitude	Positions	64/66	69	70	11	Min Interval
81-82°	0	0	0	0	0	0
80-81°	304	0	63	83	158	41
79-80°	295	0	50	61	184	46
78-79°	382	2	35	21	324	53
77-78°	69	0	3	4	62	55
76-77°	21	0	0	0	21	60
75-76°	17	0	0	0	17	60
74-75°	15	2	0	0	13	52
73-74°	8	0	0	0	8	67

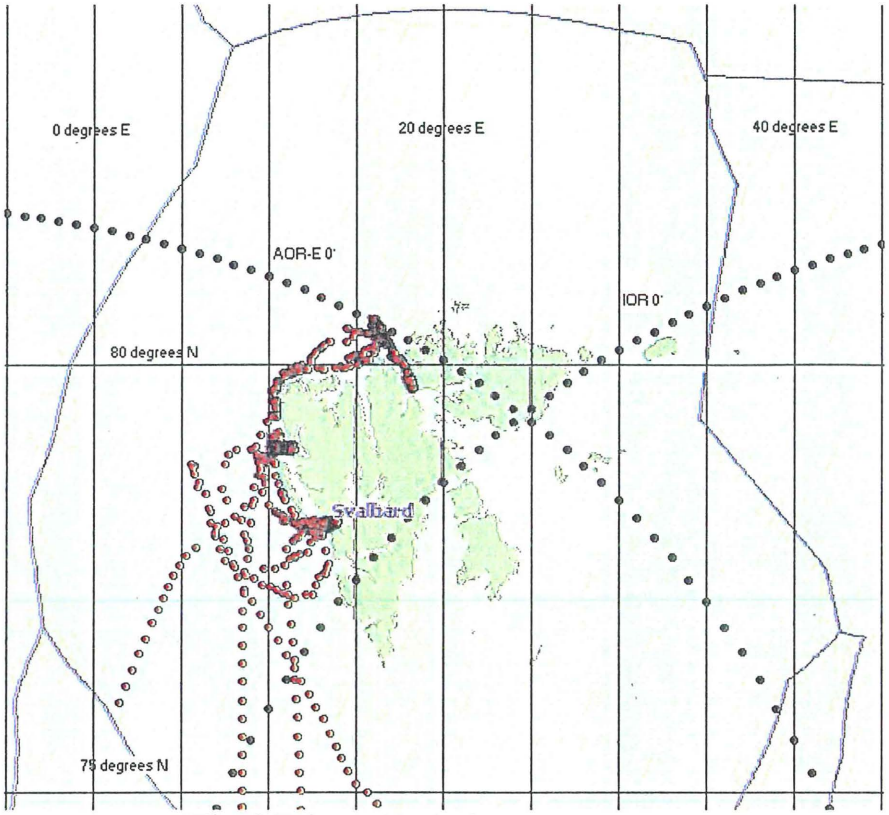

Fig. 2 Felcom 12 platform - all MEM-codes

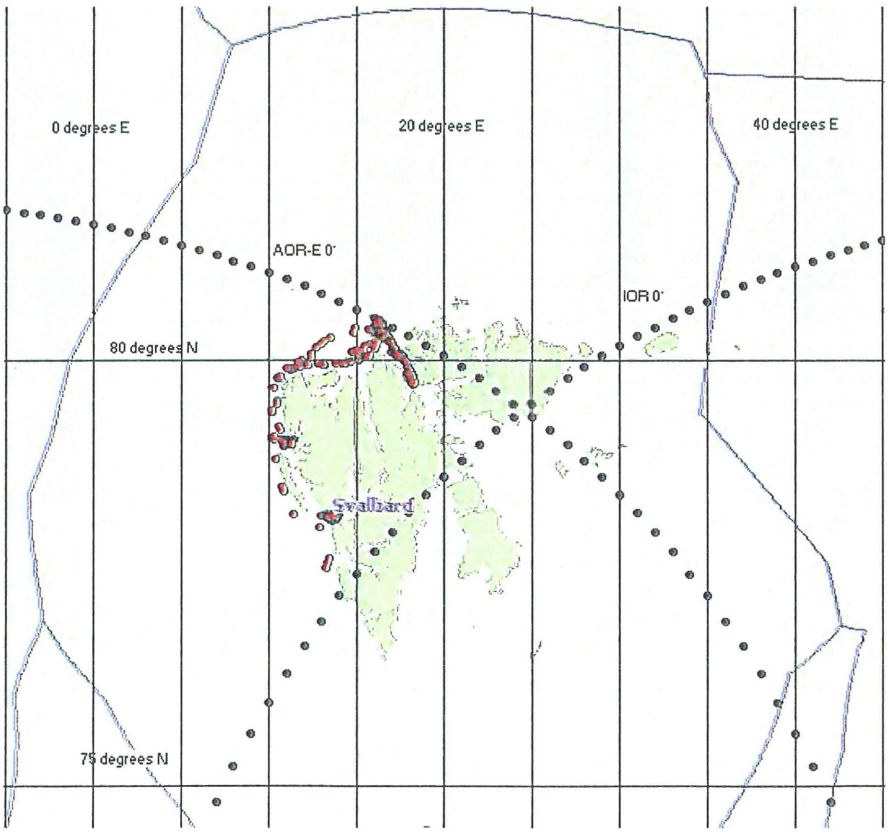

Fig. 3 Felcom 12 platform - positions without MEM-code 11

THE TT3020C PLATFORM

This vessel also visited the area twice. Appearing first on 01 November heading north, she reached 80° on the afternoon the following day, coming as far north as 80.15° at about 19.6° east on 03 November before reverting to the area around 78-79° on the 05th.
On 09 November she again reached above 80°, where she mostly lingered, coming as far north as 81.2° at 20.5° east on 11 November. Note that the absolute cut-off point at this longitude is 79.85° (AOR-E , **Fig 4-5**), even benefiting from the atmospheric refractivity. Going 1.35° better is not bad at all !

She remained at very high latitudes until 24 November. The tracking was six times interrupted, however, possibly due to the storage capacity of the unit being exhausted. She left the area heading south on 27 November.

On 30 November the vessel again appeared heading north, passing above 80° on 12 December. She stayed mostly in the area at about 78-79° north and more or less 13° east, before leaving the area on 15 January.

The analysis of the tracking of this vessel is very interesting, in that she stayed at high latitudes at the extreme reaches of satellite coverage for so long. The tracking even at the high latitudes shows a surprising degree of regularity, the performance above 80° depending mostly on the stored position capability.

To give just two examples, from 11 till 22 November 19 consecutive stored positions are reported, and from 23-24 November a record number of 26. On both occasions however, there has ultimately been a manual reset of the unit (MEM-64). This could indicate some kind of an interlock, leading one to speculate whether a problem can appear when the transmitter buffer is filled up that makes a reset necessary.

One has to bear in mind that when an Inmarsat-C unit looses contact with the satellite, an alarm is sounded on the bridge. This is something of a nuisance when sustained for hours and hours, and a temptation to switch off or reset the unit when it looks like having ceased to operate properly can be understood.

A main problem at such extreme latitudes is that the Inmarsat satellite can only be seen for a short time each day, interfering with the necessary downloading of the stored positions.

Note that just 76 out of altogether 173 positions reported from the vessel above 80° are of the instantaneous type (MEM-11), and that 4 power interrupts were observed there.

If we look at the six instances where losses of positions occurred, an interesting pattern emerges. We take note that on all six occasions, the vessel stayed well east of the AOR-E satellite longitude (15.5°W), so that the maximum northern reach of the satellite was significantly reduced. And all fell within the two periods mentioned above, when we have stored positions only.

TT 3020C Losses listed in tabular form:

Date	Minutes	Latitude	Longitude
13 Nov	1400	80.19°N	17.01°E
13 Nov	836	80.06°N	17.57°E
16 Nov	3896	79.77°N	18.26°E
17 Nov	1067	80.13°N	17.27°E
22 Nov	6856	80.14°N	17.19°E
24 Nov	1534	79.89°N	17.73°E

We can calculate that, benefiting from the atmospheric refraction, the maximum northern reach of the AOR-E satellite will be 80.39° at 17.0°E and 80.28° at 18.0°E, subtracting 0.6° if we want to consider a geometric calculation only. Noting the overflow problem previously mentioned (remember that the antenna blocked positions are also stored), the system has performed surprisingly well up to the very limit of theoretical coverage (**Table 2**)

Table 2: TT3020C - 2 202 position reports

		-------- MEM Codes -------				Min
Latitude	Positions	64/66	69	70	11	Interval
81-82°	12	0	0	12	0	60
80-81°	161	4	28	53	76	121
79-80°	835	8	196	26	605	39
78-79°	1065	18	179	10	858	40
77-78°	59	2	6	0	51	44
76-77°	24	2	0	0	22	55
75-76°	21	0	0	0	21	60
74-75°	18	0	0	0	18	53
73-74°	7	0	0	0	7	60

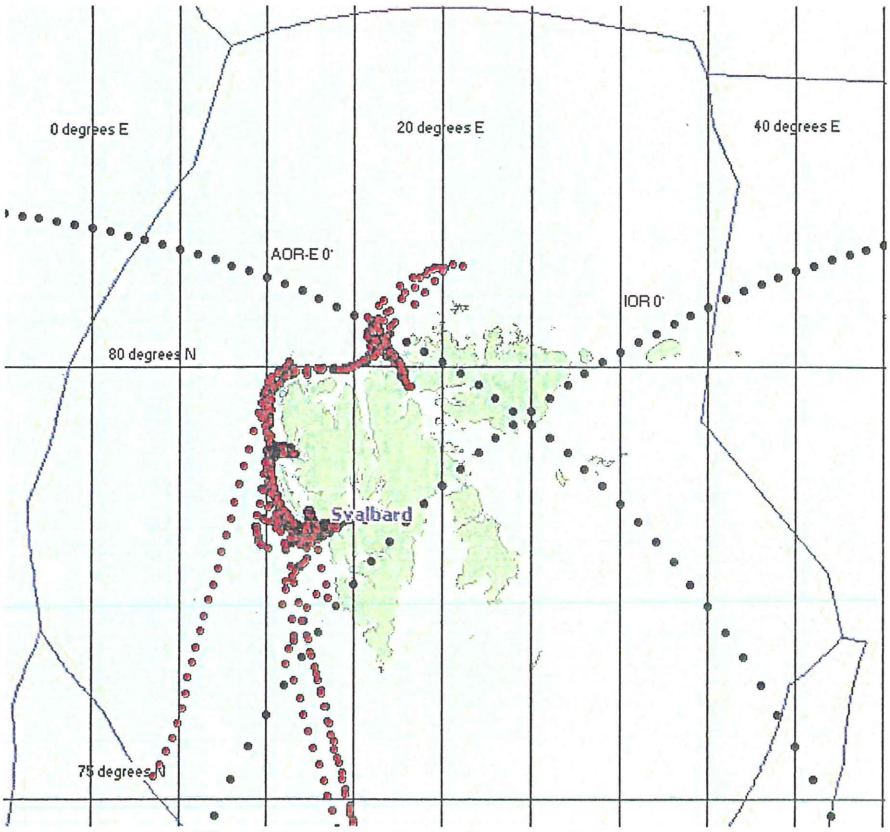

Fig. 4 TT 3020C platform – all MEM-codes

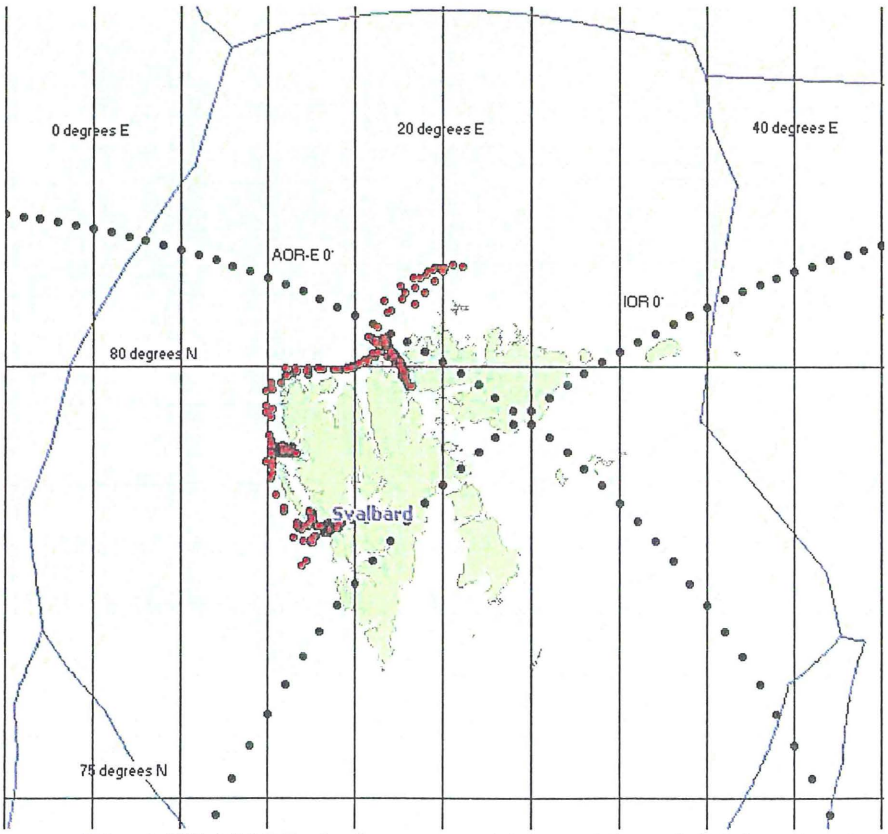

Fig. 5 TT 3020C platform – positions without MEM-code 11

THE H2095C PLATFORM

This vessel only entered the area on 01 January, and stayed for 3 weeks until 20 January. Mostly she stayed clear of the northern reaches, but during the period 07-13 January she operated above 79°, even venturing above 80° briefly at 11° east on the 10th.

The tracking (**Table 3**) was very close to perfect, with little need for stored positions and no power interrupts. But as expected, a number of antenna blocked (MEM-69) instances were recorded.

Table 3: H2095C - 482 position reports

Latitude	Positions	MEM Codes 64/66	69	70	11	Min Interval
81-82°	0	0	0	0	0	0
80-81°	2	0	0	0	2	56
79-80°	159	0	51	8	100	53
78-79°	236	0	43	2	191	56
77-78°	53	0	7	0	46	67
76-77°	11	0	0	0	11	60
75-76°	13	0	0	0	13	60
74-75°	7	0	0	0	7	68
73-74°	1	0	0	0	1	60

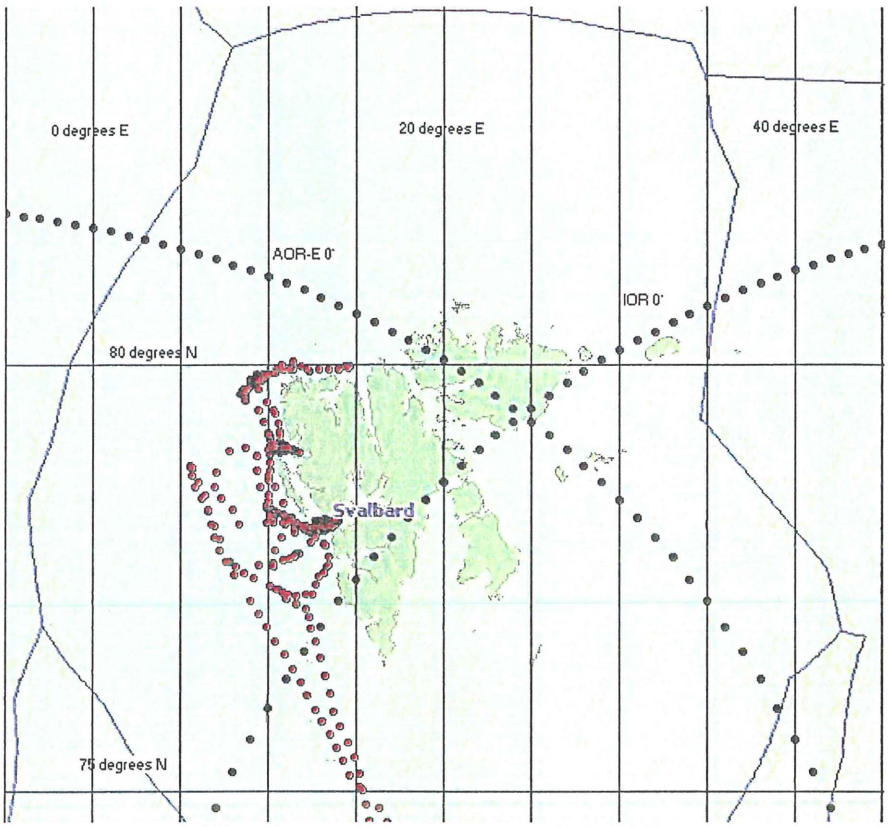

Fig. 6 H2095C platform – all MEM-codes

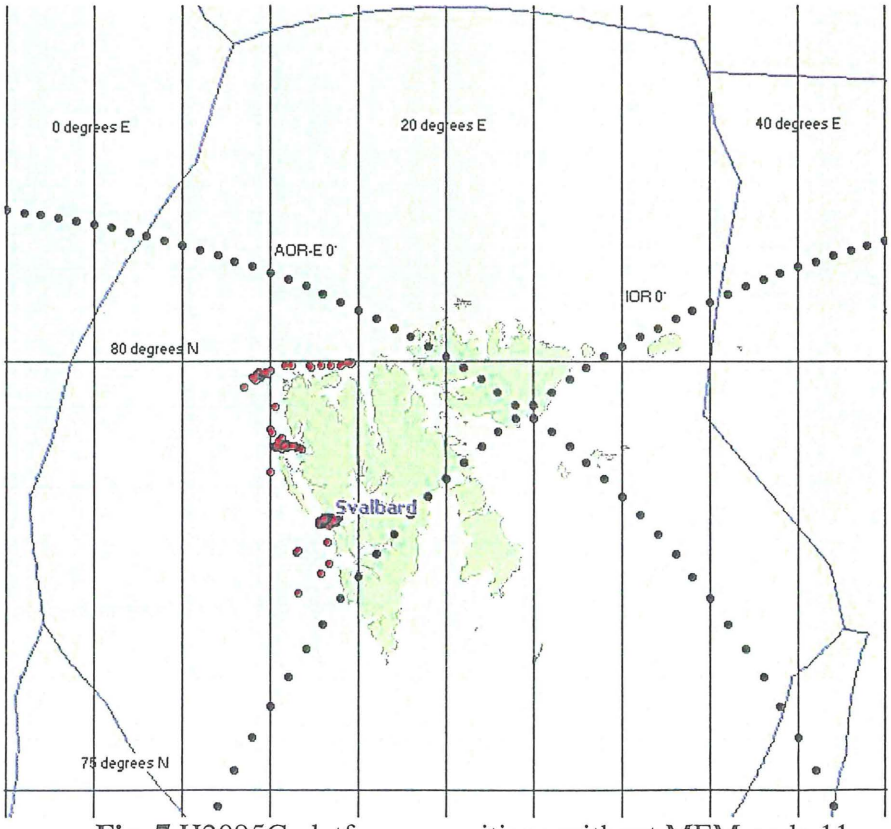

Fig. 7 H2095C platform – positions without MEM-code 11

CONCLUSIONS

Tracking results for all three vessels have been consolidated in Table 4. We believe that the ratio of stored positions (MEM 70) to the sum of all scheduled position reports (MEM 11 + MEM 70) can be read as an indication of the overall feasibility of a stored position capability. This ratio has been calculated and entered in the column headed *Ratio*.

Noting that in our sample virtually all of the positions have come from longitudes 20° or more to the east of the AOR-E satellite, we see that below about 79°N just about 2.5% of the positions have been stored, but none so below 77°. In the 79-80° region, however, the ratio is significant at close to 10%, increasing to a good 1/3 (36.6%) between 80° and 81°N.

The main reason why this tracking of three fishing vessels has been analysed in some detail, has been that the approval by Norwegian fisheries authorities for the various types of Inmarsat-C equipment used for fisheries tracking purposes are now coming up for periodic renewal. A routine pilot study was therefore mandated, to look into the performance of such units at high latitudes, and if necessary identify aspects that might have to be considered further.

Even though three types of units have been included in the study and individually identified, we must emphasize that this pilot study has neither been designed to compare the level of performance between the units, nor can any such conclusions be based on such a small sample.

As the main criteria for including the individual vessels in the pilot study was a presence at high and possibly marginal latitudes for some time, the test results have confirmed the general impression that with a stored positions capability, Inmarsat-C tracking on an hourly basis also in the area where the satellite angle of elevation falls below 5° is fully feasible and can be conducted with a high degree of regularity.

Only at the very limit of possible reach clues have come to light that can warrant further research to try to establish whether the firmware release of that unit can be improved, or whether the observed phenomena must be otherwise explained. This is currently being looked into.

Table 4: All three vessels - 3 795 position reports

		MEM Codes				Min	
Latitude	Positions	64/66	69	70	11	Interval	Ratio
81-82°	12	0	0	12	0	60	100.0
80-81°	467	4	91	136	236	69	36.6
79-80°	1289	8	297	95	889	42	9.7
78-79°	1683	20	257	33	1373	45	2.3
77-78°	181	2	16	4	159	55	2.5
76-77°	56	2	0	0	54	58	-
75-76°	51	0	0	0	51	60	-
74-75°	40	2	0	0	38	55	-
73-74°	16	0	0	0	16	64	-

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