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AN EXPERIMENT IN ARTIC VLF NAVIGATION
(Final Report)

by

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ABSTRACT

The passage of ice island ARLIS II into the East Greenland Sea early in 1965 and the resulting higher drift rate made necessary a more continuous type of navigation than was possible with celestial navigation. An experimental VLF system was available which could theoretically provide navigational accuracies of ±2 miles. Three VLF stations (GBR, NSS, and NPG) were received on the island. The VLF phase tracking data was in error, however, due to defective preset counters in the frequency synthesizers. Operational problems and potentials of the system in Arctic use are discussed.

The passage of ice island ARLIS II into the East Greenland Sea early in 1965 presented special navigation problems not normally associated with ice island navigation. Celestial navigation is adequate when the island is in the Arctic Basin and total drift is on the order of 2 miles per day. Currents in the East Greenland Sea, however, move the island at speeds up to 2 knots making a more continuous type of navigation desirable.

Until early February there was still considerable uncertainty whether ARLIS II would remain within the circulation system of the Pacific gyral or come within the influence of the Greenland Current and be swept out of the Arctic Basin. When it became certain that the island was caught in the Greenland Current, little time remained to provide a suitable navigation system. The urgency of the situation was magnified by 1) the prevailing overcast weather in this region during the spring, and 2) the greatly increased number of flights to the island necessary to accommodate the accelerated scientific program.

ARLIS II was clearly beyond the range of existing electronic aids to navigation. The only other navigation system that was applicable under the existing limitations of time, logistics, and availability was an experimental VLF system which Woods Hole Oceanographic Institution was willing to loan to the project.

The VLF system consisted of:

2 - Textran Corporation Model 599-CS phase tracking receivers
1 - Sulzer Model 2.5 crystal frequency standard
1 - Texas Instrument Recti-Riter dual channel recorder
1 - Textran Model 599-601C VLF loop antenna

Navigation by use of VLF signals is accomplished by comparing the phase of the received VLF signal with that of a locally generated reference signal (Fig. 1). If the two signals are not in phase, an error signal is produced by the phase comparator which drives the phase shifter servo. This servo shifts the phase of the 100 kc input signal to the frequency synthesizer until its output signal is in phase with the VLF signal. The phase shifted reference signal is then locked in phase null condition relative to the VLF carrier. Change in travel time from the transmitting station to the VLF receiver, which is indicated by a front panel digital readout, was also recorded in analog form on the dual channel recorder. A radial displacement of one mile corresponds to a travel time change of 6.18 micro sec.

VLF stations transmitting stabilized carrier frequencies which could be received in the East Greenland Sea area are as follows:

GBR	RUGBY, ENGLAND	16.0 kc/s	30 kw	52°22'N	01°11'W
NPG	JIM CREEK, WASH.	18.6 kc/s	250 kw	48°12'N	121°55'W
NSS	ANNAPOLIS, MD	21.4 kc/s	100 kw	38°59'N	76°27'W

The coordinates of the range circles which surround the above transmitters were computer calculated for the East Greenland Sea area and provided by Woods Hole Oceanographic Institution. These coordinates were given for the range from the transmitter in micro seconds which allowed navigation to be accomplished without converting from phase shift in micro seconds to range change in miles. After a brief training period on the use of the equipment at Tracor in Rockville, Maryland, the operator and equipment went to Barrow, Alaska where records of the diurnal shifts of GBR and NPG were made. Representative records for the period of 15 February 1965 to 5 March 1965 are shown in Figure 2.

The VLF system was put into operation at ARLIS II on 8 March 1965. It was found that the two receivers would not track properly when connected to a common antenna. This problem, which is caused by stray radiation from one receiver being picked up by the other receiver, can be eliminated by the use of a common mode rejection antenna coupling transformer. Since one was not available the two receivers were placed on separate antennas--one on the loop antenna, and the other on a long wire antenna approximately 200 feet long.

The system appeared to be functioning properly, however, the first comparison between radio and celestial fixes showed the radio data to be grossly in error.

Figure 3 shows the ensuing deviation between radio and celestial fixes. The chart covers ten days--from the 8th to the 18th of March, 1965. Coordinates are shown both in latitude-longitude and in micro seconds from the two stations NSS-21.4 kc and GBR-16 kc. The true path of the island follows the solid line going from A to G. The path from any one celestial fix as determined by the VLF system is shown in dotted lines. Had the radio system been operating properly the line AB' would coincide with line AB and similarly C' would coincide with C, D' with D etc. The angles between the true drift path and radio fix lines ranges from 16°E to 17°W. A comparison of the length of the radio determined lines and the celestial lines shows that the radio determined lines are always longer by at least 20%. There is no consistent relationship between the difference obtained with the two methods. The line AB' taken over a period of 4 days is 34% longer than AB. Line BC' taken over a one day period is 100% longer than line BC.

Charts made for the rest of March and for May 2 through 5 show similar erratic behavior.

The first indication of trouble actually occurred on 11 March 1965 when both receivers were tuned to NPG for one hour. The receiver on the loop antenna showed a signal strength of -7 db and indicated that the islands drift was away from NPG at a rate of .3 knots (Fig. 4). The receiver on the long wire antenna had a signal strength of +20 db, tracked poorly by comparison, and showed a drift rate of approximately 1.5 knots away from NPG. Dr. Baltzer of Tracor recently pointed out that since

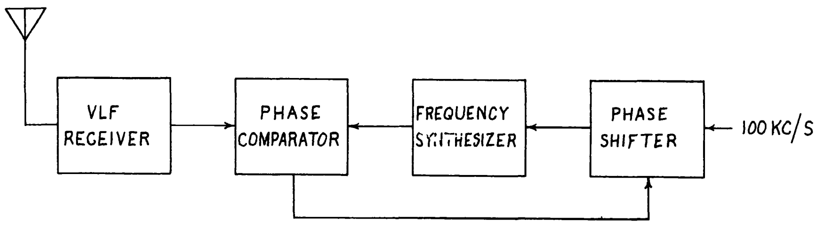

Fig. 1 VLF PHASE TRACKING RECEIVER

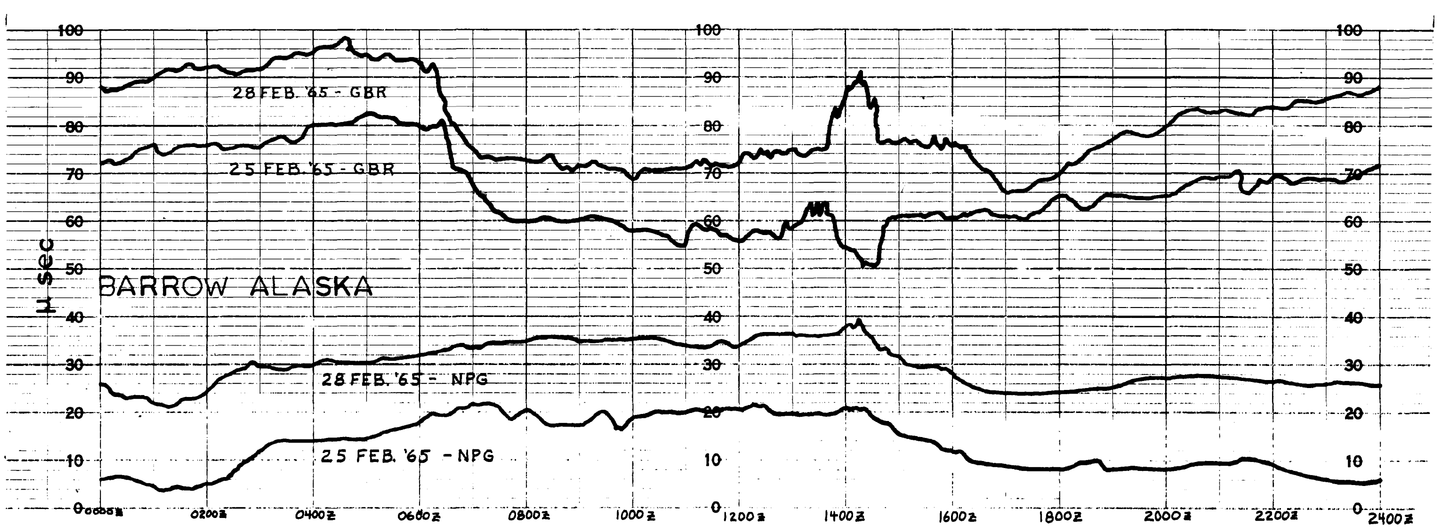

Fig. 2 DIURNAL SHIFTS OBTAINED AT BARROW, ALASKA FROM RADIO STATIONS GBR AND NPG

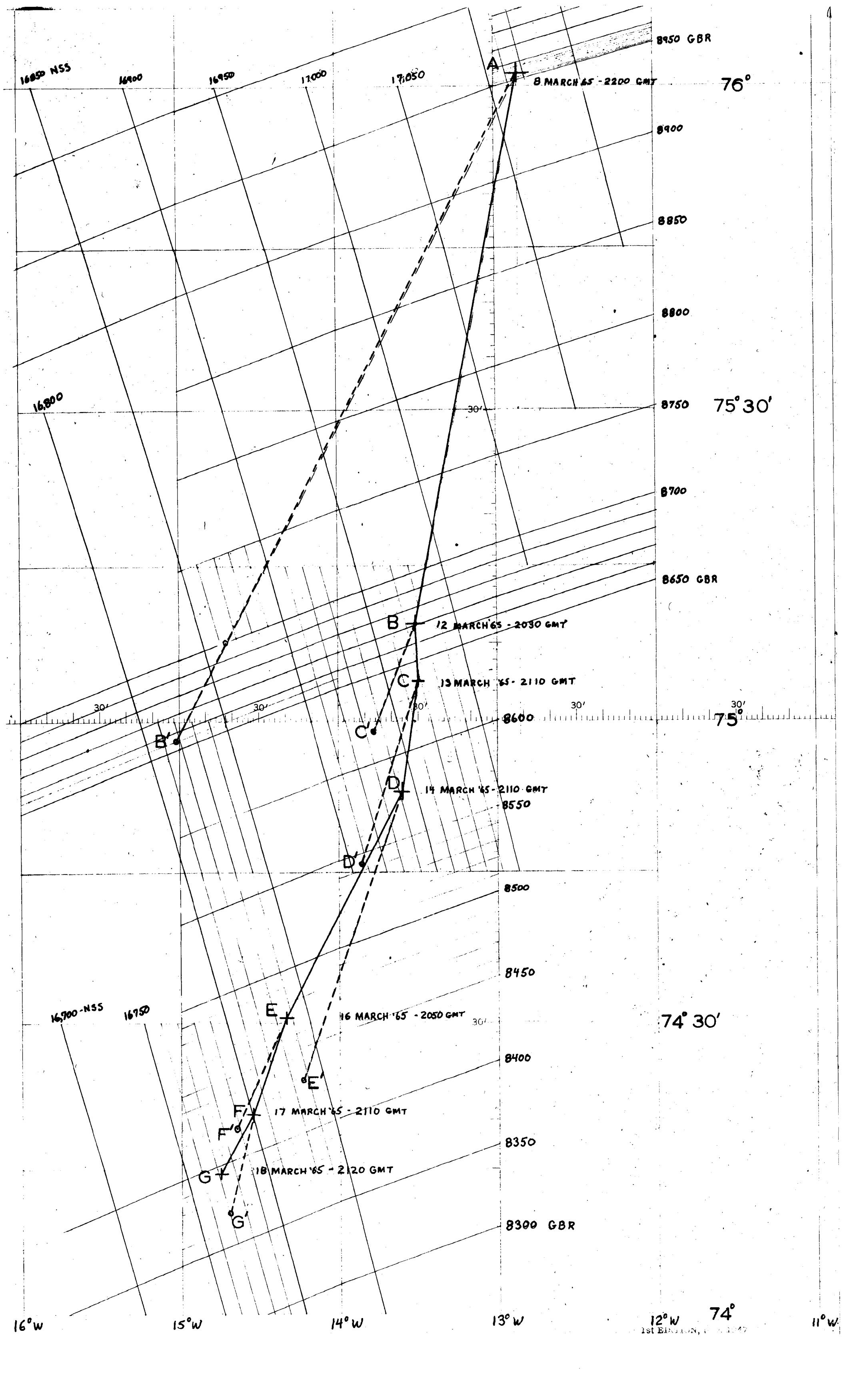

Fig. 3 A COMPARISON OF VLF NAVIGATION DATA AND TRUE PATH OF ARLIS-II

both receivers were on different antennas they may have been receiving different modes of the transmission. Over a short time, therefore, the plots may well be different; however, over a longer period of time they should agree. Dr. Baltzer did not know if one hour was long enough for this agreement to take place.

When the system was first put into operation on ARLIS II it was found that only two stations GBR and NSS could be received. The two other stations NPG-18.6 and WWVL-20 kc which should also have been received, were effectively masked by a very strong, unexpected signal at 19 kc. This station could be received with the receiver gain turned fully down. The code transmitted by this 19 kc station could be heard when tuned to 20 kc even though a 20 kc filter was being used. Changing the receiver's local oscillator to above or below 20 kc did nothing to improve the situation. A similar problem existed with NPG. As soon as this problem was discovered a narrowband filter for NPG was ordered. The filter, which arrived on 29 March 1965, eliminated the 19 kc interference problem.

On 24 March, the sync alarm light on one receiver came on indicating that it was no longer tracking. The defective circuit board was found to be a preset counter in the frequency synthesizer. A new board was not ordered at this time since it is possible to navigate with one receiver by switching from station to station.

On 28 March, the entire VLF system was moved from the base camp to the University of Wisconsin hut approximately 0.6 mile distant. This move was necessary to make room for the influx of personnel occurring at this time. When the system was reconnected at its new location it was found that the remaining receiver was now defective. The fault was characterized by a staircasing curve on the track plotter (Fig. 5).

The defective circuit board was again found to be the preset counter in the frequency synthesizer. Two new boards were immediately ordered from Tracor in Maryland. Unfortunately these boards did not arrive before the ice island was abandoned.

Resistance measurements were made on the defective boards, but nothing abnormal was found. The boards could not be tested while in operation as extension cards were not available.

During the month of April 1965 celestial navigation was stepped up to include two fixes per day. Sun shots and star shots were made whenever cloud cover permitted.

On 2 May 1965 the VLF system was repaired and some additional data was recorded. The celestial navigation data, however, showed the same erratic behavior as was evidenced in March. The diurnal shifts obtained at this time (Figs. 6 and 7) are only as good as the linearity of the drift which occurred during the measurement period. As was noted previously, this drift can be anywhere from 20% to 100% per day.

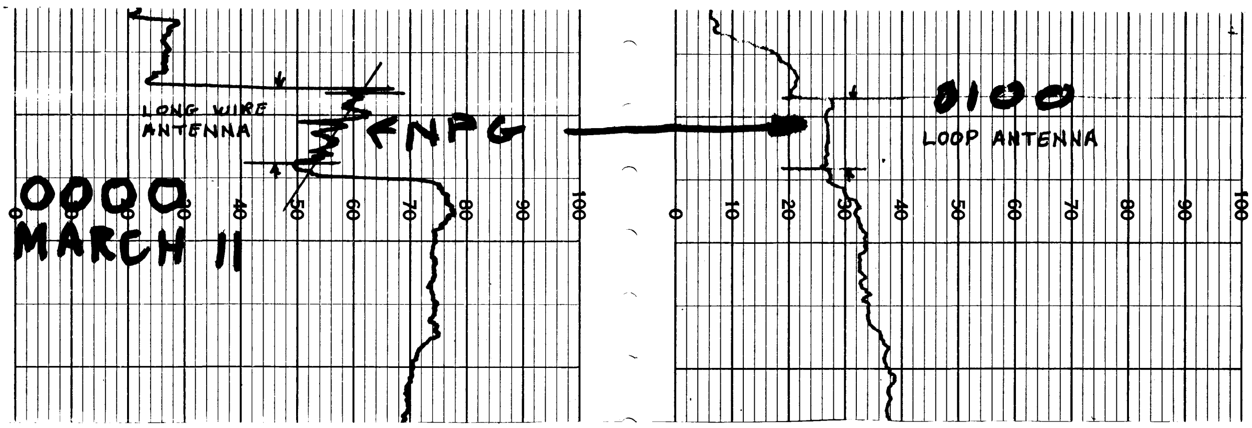

Fig. 4 DUAL CHANNEL RECORD SHOWING APPARENT UNEQUAL VELOCITIES FROM STATION NPG.

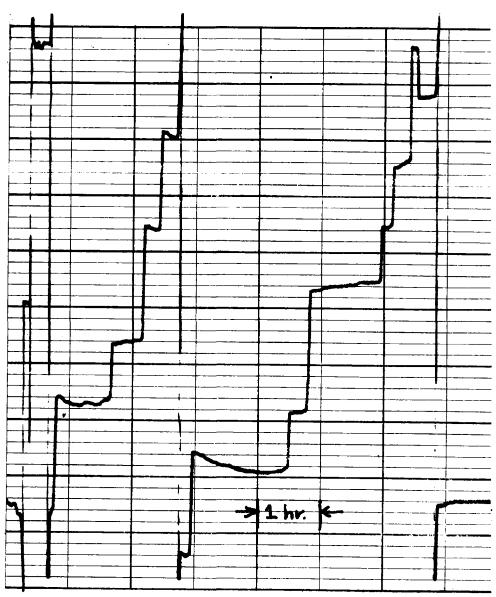

Fig. 5 STAIRCASING FAULT CAUSED BY DEFECTIVE PRESET COUNTER.

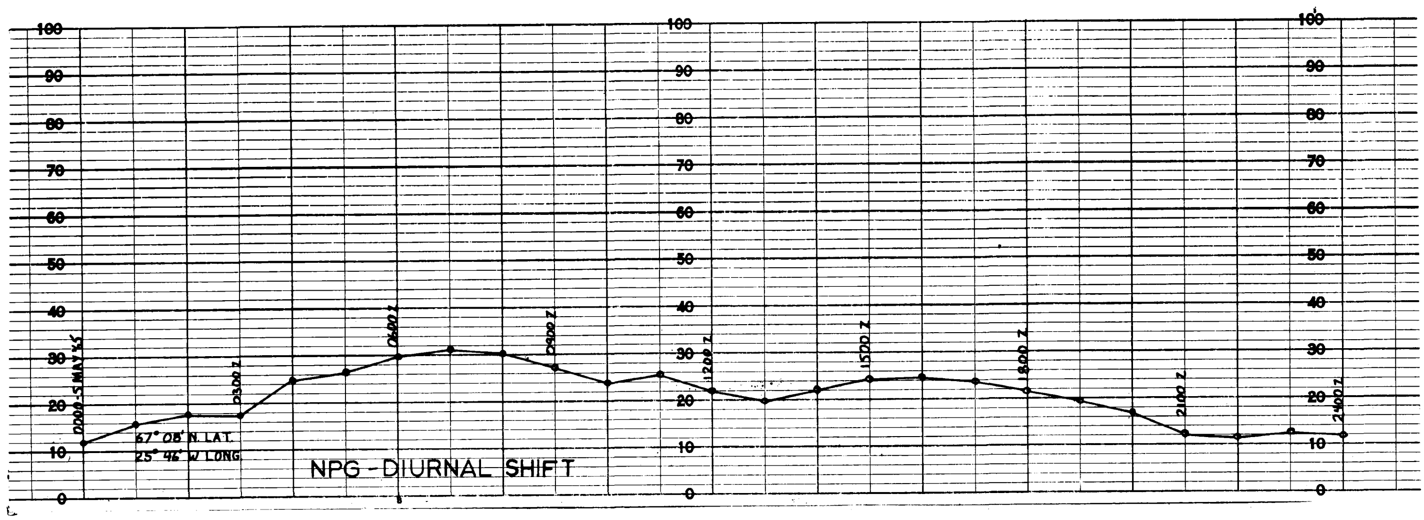

Fig. 6 DIURNAL SHIFT FROM STATION NPG ON 5 MAY, 1965.

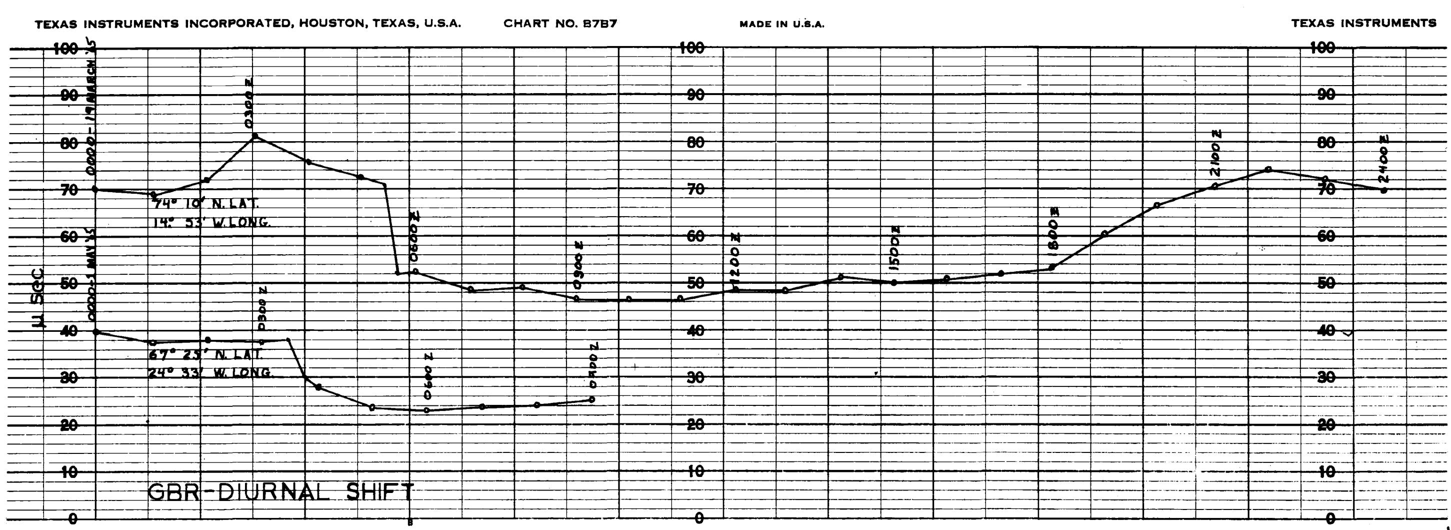

Fig. 7 COMPARISON OF DIURNAL SHIFTS FROM STATION GBR RECEIVED ON 19 MARCH, 1965 AND 1 MAY, 1965

On 8 May 1965 the unit was shut down in preparation for island evacuation.

Unfortunately, the press of time made this an unfair test of the equipment. The unit was not run long enough before being taken into the field, and the supply of spare parts was inadequate. Diurnal shift in the arctic should be better understood, however this is not a serious problem as the maximum error due to this at any time would amount to only about 3 miles. First order corrections can easily be made to reduce this error to less than one mile.

The computed range circle data supplied by Woods Hole Oceanographic Institution for the East Greenland Sea area would not be absolutely essential for normal ice island navigation as the slower speeds involved would allow ample time for doing the calculations by hand. Further simplification is possible by using straight line approximations for the range circles. It is only necessary then to calculate the bearing angle from the island to the transmitter and draw the range lines perpendicular to the bearing vector.

If power should be momentarily removed from the equipment either due to power failure or for repair purposes, the system, when turned back on, will not give a position identical to that before power loss. It is this that prevents exclusive use of this system for navigation purposes. Celestial navigation or some other system must be provided to give a new reference position once operation is resumed.

The VLF system is passive, inexpensive, and easy to operate. Total power consumption is less than 150 watts allowing operation from a transistorized 12 VDC to 110 VAC inverter. It occupies only 4 square feet of floor space, stands approximately 4 feet high, and weighs 375 pounds. An atomic frequency standard would eliminate corrections needed to compensate for frequency standard drift, but would add approximately $8000 to the total cost. Fortunately, these frequency drift corrections are easily made.

With adequate additional investigation such a VLF system should prove feasible for ice island navigation. A well trained operator devoting a reasonable amount of time to this system could expect navigational accuracies of at least ±3 miles and possibly ±1 mile over all daylight transmission paths. The accuracy, however, will never be better than the celestial fix which is used as the reference. Thus the present upper limit is better given as ±2 miles.

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