OPERATIONAL RESULTS USING LOW POWER GOES TRANSMITTERS IN MOORED BUOY APPLICATIONS

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THE CHALLENGE

Canada's current moored buoy program will need to adapt to several upcoming changes in satellite communications. In the past we have been operating moored buoys that utilize relatively high power transmitters at the 100 baud transmission rate using omni directional antennas. The challenge is for us to move to a higher data transmission rate, using the new generation of lower power transmitters, without increasing data loss.

This report describes the background of satellite communications, signal quality measurements, and describes testing of two transmitter technologies.

Geostationary Operational Environmental Satellites (GOES) each circle the Earth in orbits whose speed exactly matches that of the Earth's rotation. This makes them appear to "hover" continuously over one position on the surface above the Earth's equator. This then allows the GOES data collection system to schedule hourly transmissions, providing an "ideal" communications path for routine weather observations from moored buoys. However, the geosynchronous plane is approximately 35,800 km (22,245 miles) above the Earth. Unlike the polar satellites orbiting at 870 kms (540 miles) that will receive data reliably from transmitters radiating at 1 watt or less, geostationary satellites require higher output transmitters due to the greater distances involved.

Directional antennae cannot be used on buoys, so the radiated power is further reduced by the use of omni-directional antennae. This issue has been solved in the past by the use of higher power 40-watt transmitters, or lower powered transmitters with external RF amplifiers. The latest generation of High Data Rate (HDR) transmitters now on the market are 16 watts or less in output power, and suitable external amplifiers are currently not available.

Since it is becoming increasingly difficult to obtain parts and service for the old GOES transmitters, which have been in service since the mid 1980's, new High Data Rate (HDR) compatible transmitters are now being installed in Canadian moored buoys. Due to initial problems experienced by the National Environmental Satellite Data and Information Service (NESDIS) in the implementation of the new 300-baud demodulators, we are operating these new transmitters at 100 baud. Once the 300-baud system is operational, further evaluation will be completed at the higher baud rates to determine if additional signal amplification will be required.

Eventually, all new assignments assigned by NESDIS for data transmission through the GOES system will be 300 baud or higher, therefore, it is important to resolve the power requirement issues while there is still time to develop signal amplification systems, if required, before use of the higher data rate channels becomes mandatory.

BRIEF DESCRIPTION OF THE GOES DATA COLLECTION SYSTEM AUTOMATIC PROCESSING SUBSYSTEM (DAPS)

The GOES West and GOES East geostationary satellites provide imagery as well as a Data Collection System (DCS). The satellites provide coverage of North and South America, which also extends into a significant portion of the Atlantic and Pacific Oceans. The GOES DCS system is used by the

Meteorological Service of Canada to obtain weather data from remote automated weather stations and moored weather buoys.

In order to determine the performance of transmitters using the GOES DCS system, the received quality and signal strength from each Data Collection Platform (DCP) message is measured at the Wallops Command and Data Acquisition station in Virginia. By using calibrated pilot carrier levels the DCP carriers are compared in amplitude against the calibrated pilot level to determine the Effective Isotropic Radiated Power, (EIRP) of each DCP transmitter. The Data Acquisition & Monitoring System (DAMS) performs additional signal quality measurements as described below and appends the DAMS quality information to the end of each DCP message.

The DAMS units provide four signal quality measurements on each message received from a DCP. These are the DCP transmit EIRP, DCP transmit frequency offset, DCP modulation index and the received data quality. Normal values for the parameters measured are as follows:

- *Transmit EIRP* - between 32 - 57 dBm with the normal range usually between 44 - 49 dBm. The absolute accuracy of the signal strength reading is plus or minus 2 dB.
- *Frequency Offset* - $\pm$5 50 Hz increments ($\pm$ 250 Hz)
- *Modulation index* - the nominal operating character for modulation index is N and is expressed by one of the three characters:
    - N (Normal, 60^o)
    - L (Low, $<50^o$)
    - H (High, $>70^o$)

- *Data Quality* - The nominal operating character for data quality is N and is expressed as
    - N (Normal, error rate better than 1×10^{-6})
    - F (Fair, error rate between 1×10^{-4} and 1×10^{-6})
    - P (Poor, error rate worse than 1×10^{-4})

To eliminate any potential errors introduced by differences in the calibration of the DAMS quality measurement equipment on different GOES DCS channels, only transmitters operating on the same GOES channel were compared for this evaluation. Any remaining differences in signal quality should therefore be due to the individual transmitter performance (including cable and antenna), with perhaps some influence introduced by the geographical location of the buoy, local environmental conditions, or atmospheric conditions. In addition to the signal quality measurements listed above, messages containing parity errors are flagged by the DCS system. Parity errors were counted and included in the data quality comparisons.

TRANSMITTER AND TEST DESCRIPTION

The DAMS signal quality measurements for two transmitter types operating on GOES channels 008 West and 010 West were compared during a twenty-day period in September 2002. The transmitters compared were the Synergetics 3426A and the Campbell Scientific SAT HDR. The average transmit RF power measured prior to deployment using a Bird wattmeter (at the transmitter output) was 37.5 watts for the Synergetics transmitters and 8.7 watts for the Campbell Scientific SAT HDR's. The antenna used was the omni directional Synergetics model 14A.

Although the lower power SAT HDR transmitters under test were first deployed in May 2002, the period in September was selected because it was the first period in which a weather event occurred which presented an opportunity to make some measurements during more adverse weather conditions.

As noted earlier, it is important to remember that all comparisons were made at 100 baud using operational GOES channels. Problems experienced at NESDIS with the implementation of the 300-baud demodulators made it impossible to conduct operational deployments and comparisons using the high data rate channel assignments.

CHANNEL 008 COMPARISONS

Four transmitters were compared on GOES Channel 008W. The SAT HDR transmitters were installed in a NOMAD buoy (WMO 46036), located approximately 400 nautical miles west of Vancouver Island, and a 3 Metre Discus buoy (WMO 46206), located approximately 20 nautical miles west of the southern portion of Vancouver Island. Two 3 Metre Discus buoys, located in Southern Georgia Strait between Vancouver and Vancouver Island (WMO 46146) and northern Hecate Strait between the Queen Charlotte Islands and the mainland (WMO 46183) contained the higher power Synergetics transmitters. See Figure 1.

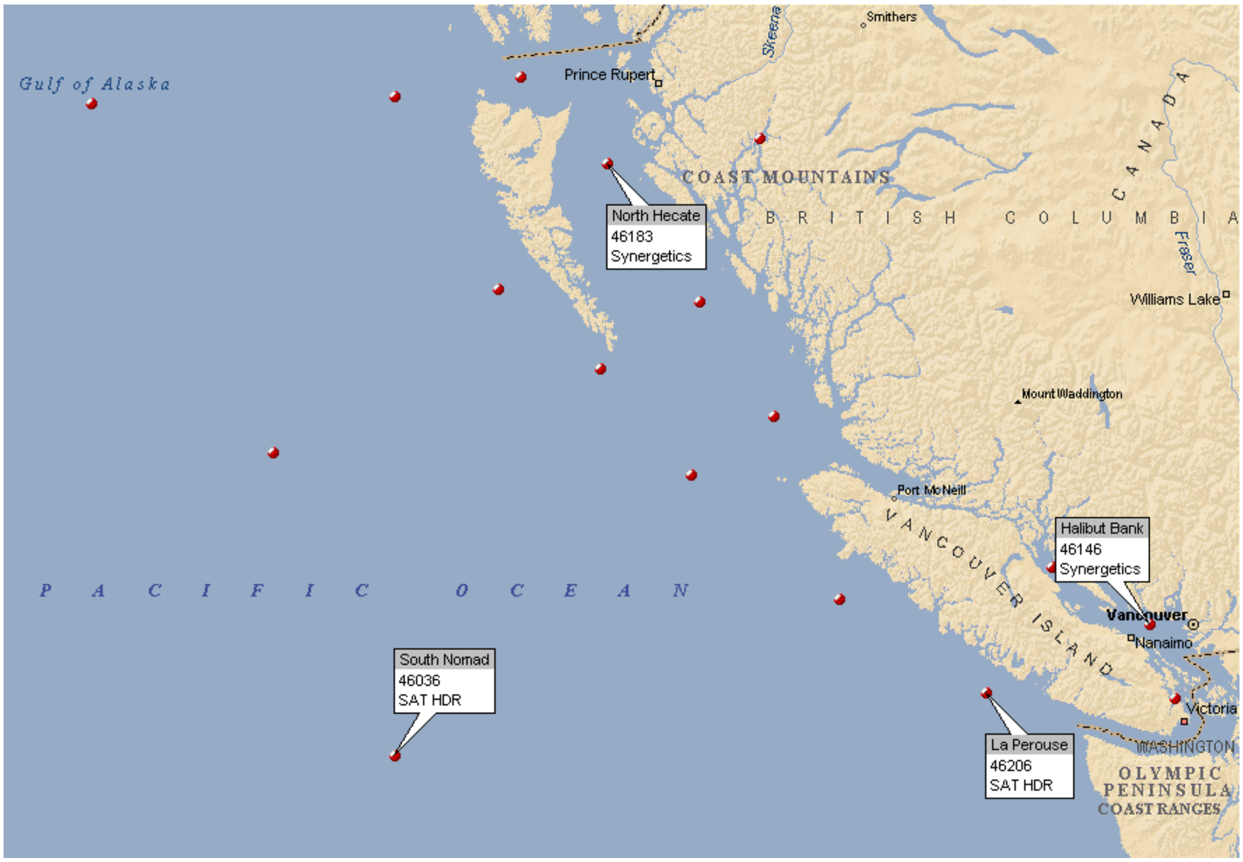

Figure 1. Location of MSC moored buoys (red dots). The four buoys used for the channel 008 W comparisons are shown by the labels.

Over the period of the comparison, the low power transmitters registered an average DAMS signal strength of 38-42 dBm while the higher powered transmitters averaged 43-45 dBm. A comparison of the 24 hour average and actual hourly DAMS signal strengths of one of the high powered transmitters and one of the low powered is shown in figure 2.

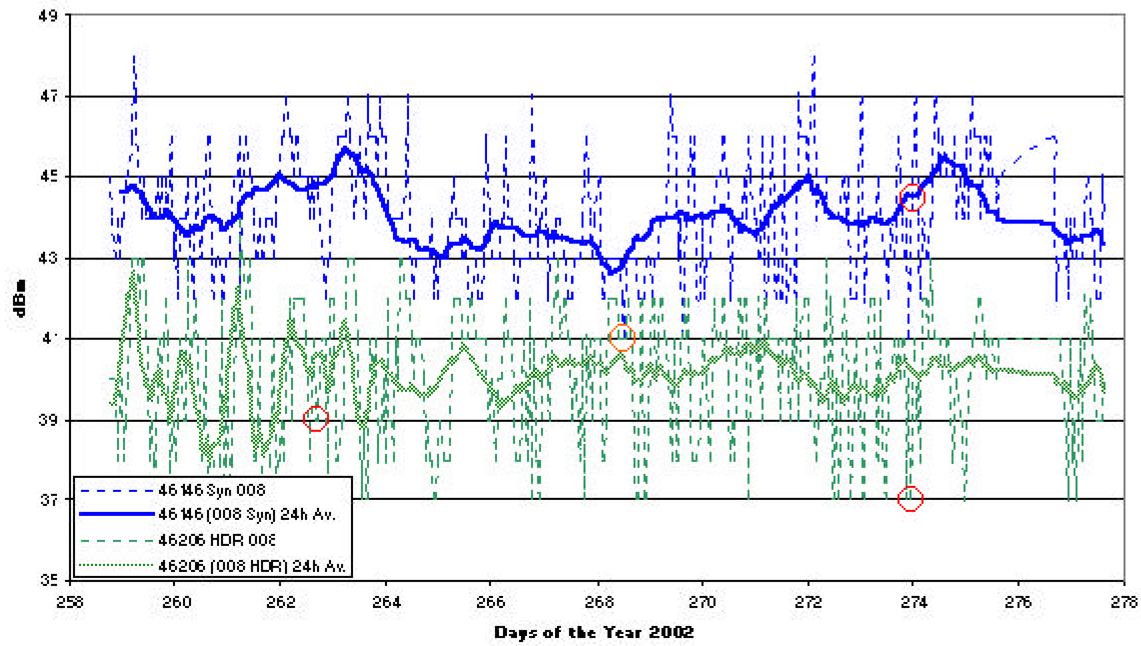

Figure 2. Average twenty four hour and hourly DAMS signal strength (dBm) comparison between buoy 46146 using a high powered transmitter (upper), and buoy 46206 using a low powered transmitter (lower) on GOES channel 008W. Red circles denote missing messages.

Neither transmitters had modulation, data quality nor parity errors, however, one low power transmitter did miss 3 messages and the other one missed 2. Both high power transmitters missed 1 message. It was also noted during the test period that there was some commonality of missing messages on days 262/18 GMT and 274/00 GMT on both types of transmitters and on different GOES channels, therefore some of the missing messages could be attributed to a data problem at NESDIS. The missing messages are denoted by the red circle on the graph. A summary of the DAMS errors for all 4 transmitters is presented in figure 3.

Location	TX Type	Total msg	Mod Errors	Q Errors	Parity Errors	Missing msg
46206	HDR	428	0	0	0	3*
46036	HDR	428	0	0	0	2*
46146	Syn	428	0	0	0	1*
46183	Syn	428	0	0	0	1*
						* 1 message missing on all buoys

Figure 3. Error summary by type for high and low power transmitters on GOES channel 008W.

CHANNEL 010 BUOYS

Three transmitters were compared on GOES Channel 010W. The SAT HDR transmitter was installed in a 3 Metre Discus buoy (WMO 46132), located approximately 35 nautical miles west of the northern portion of Vancouver Island. The higher power Synergetics transmitters were installed in two 3 Metre Discus buoys, one located 10 nautical miles southwest of the southern tip of the Queen Charlotte Islands (WMO 46147), and the other in Central Dixon Entrance, (WMO 46145). See figure 4.

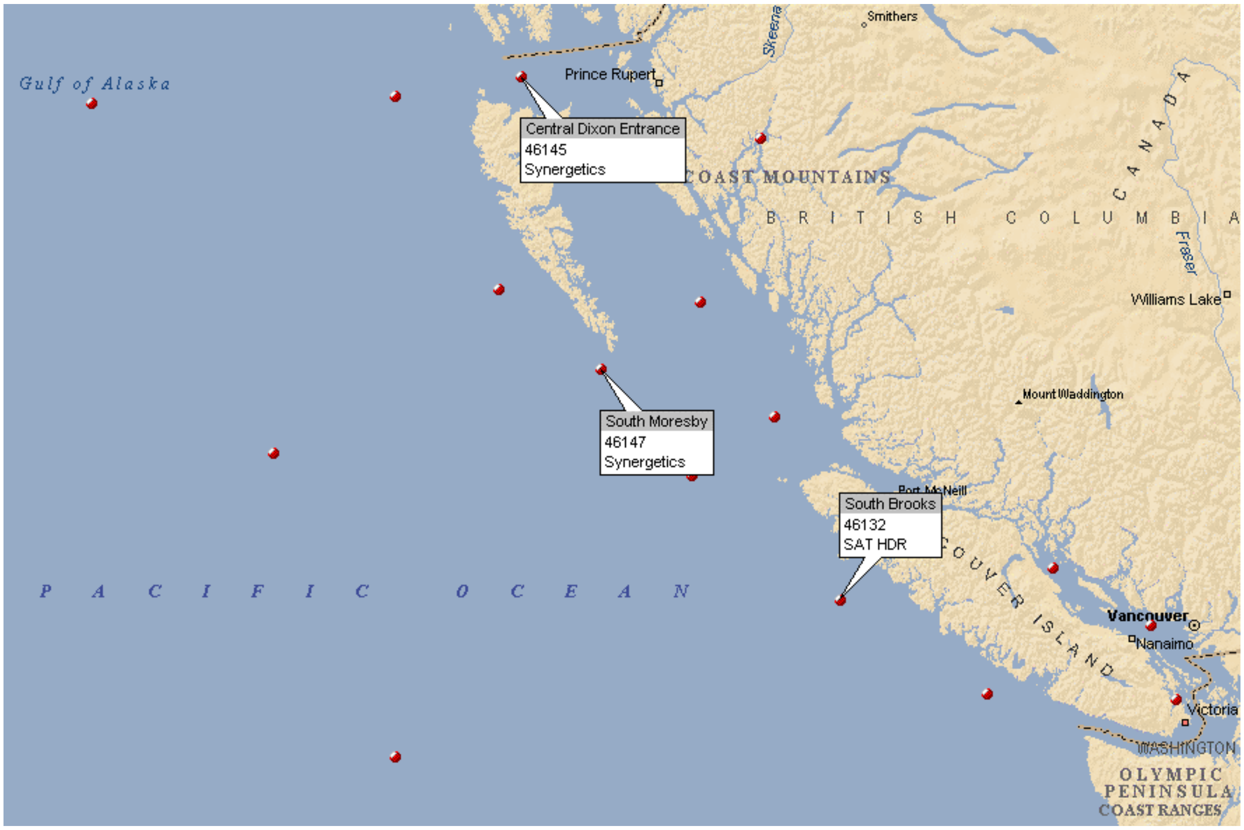

Figure 4. Location of MSC moored buoys (red dots). The three buoys used for the channel 010W comparisons are shown by the labels.

Over the period of the comparison, the low power transmitter registered an average DAMS signal strength of 38-42 dBm while the higher powered transmitters averaged 44-45 dBm. A comparison of the 24 hour average and actual hourly DAMS signal strengths of one of the high powered transmitters and the low powered transmitter is shown in figure 5.

The dip between day 267 and 268 to a DAMS value of 38 dBm for the low power transmitter was at first attributed to an increase in significant wave height to 3 metres, however, later data during a much more severe storm event on Nov 12th, 2002 did not show a strong linkage between wave height and DAMS signal strength. During the later event the significant wave heights reached 8.8 metres and the DAMS signal strengths were between 42-44 dBm. It is important to note that no missing messages occurred during the period of reduced received signal strength. Again, atmospheric conditions affecting signal propagation could be a more significant variable than wave height during the period in question.

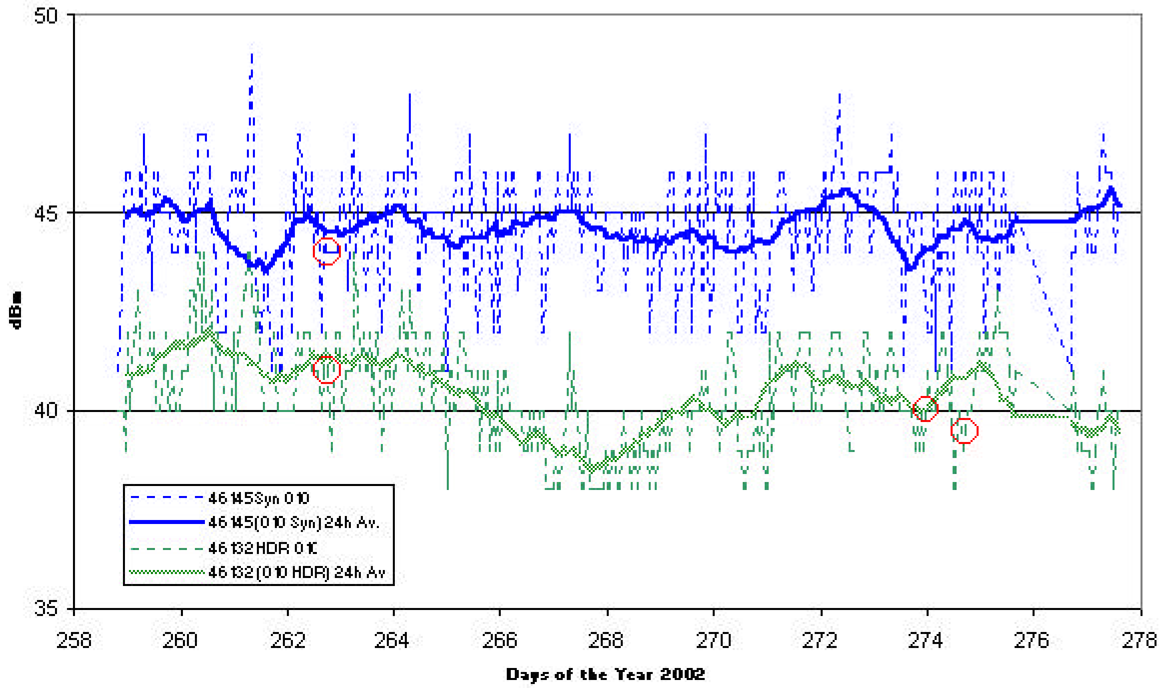

Figure 5. Average twenty four hour and hourly DAMS signal strength (dBm) comparison between buoy 46145 using a high powered transmitter (upper), and buoy 46132 using a low powered transmitter (lower) on GOES channel 010W. Red circles denote missing messages

During the 20 day test period, the channel 010 buoy using the low power transmitter had 0 modulation or quality errors, but did have 7 parity errors and 3 missing messages. The causes of the parity errors for the low power transmitter are unknown at this time, but could be related to antenna or cable problems and not necessarily due to a fault with the transmitter. One of the high power transmitters had 0 modulation, data quality or parity errors, but had 1 missing message. The other high power transmitter obviously had a problem, showing 428 modulation errors, 0 data quality errors, 0 parity errors and 1 missing message. Similar to the problems on channel 008, there was some commonality of missing messages on days 262/18 GMT and 274/00 GMT on both types of transmitters and on different GOES channels, therefore some of the missing messages could be attributed to a data problem at NESDIS. The missing messages are denoted by the red circle on the graph. A summary of the DAMS errors is presented in figure 6.

Location	TX Type	Total msg	Mod Errors	Q Errors	Parity Errors	Missing msg
46132	HDR	428	0	0	7	3*
46145	Syn	428	0	0	0	1*
46147	Syn	428	428	0	0	1*
						* 1 message missing on all buoys

Figure 6. Error summary by type for high and low power transmitters on GOES channel 010W.

300 BAUD TESTING

Due to ongoing problems experienced at NESDIS with operational implementation of the 300-baud demodulators during our test period, we were unable to conduct any meaningful performance testing at the higher data rates using an HDR transmitter installed in an operational buoy.

We were able to do some transmissions in a lab environment with an external omni-directional antenna at various power levels to evaluate the resultant DAMS signal strength values. At a measured output power of 6 W, an average DAMS value of 35 dBm was reported by NESDIS. At output powers of 7 and 12.5 W, the reported DAMS values were 39 dBm and 43 dBm respectively. During the 4-day period of the 300-baud testing, 0 modulation, data quality, parity errors or missing messages were reported in the DAMS messages.

OBSERVATIONS

- As expected, lower powered transmitters have a lower DAMS signal strength than high powered transmitters, however, there does not seem to be any statistically significant relationship between the lower power and an increase in missing data or a reduction of data quality. Parity errors and data quality errors all remained in the normal range.

- At first there seemed to be relationship between wave height and DAMS signal strength, although the worst wave case (during the test period) did not result in any errors or missing data. (Later data evaluated after the study period during a much more severe weather and wave event did not show a significant relationship between wave height and signal strength).

- One low power transmitter (46132) did show some parity errors: Transmitter or antenna related?

- One high power transmitters (46147) had modulation anomalies: Transmitter or antenna related?

- The low powered transmitters missed 2-3 observations during the 428 message test while the higher powered transmitters missed 1 message. However, there was a commonality of missing messages at 262/18 GMT and 274/00 GMT which would indicate the problem could be attributed to a data problem at NESDIS.

- 300-baud transmissions had good signal strengths even with reduced (6W) output, with slightly more missing messages. NESDIS was not fully operational for 300 baud service so reliable conclusions cannot yet be made for the higher data rate performance.

FUTURE FOLLOW UP

When the high data rate 300-baud demodulators and processing system reach operational status, selected buoys equipped with SAT HDR transmitters will be programmed to transmit at the higher data rate and similar comparisons will be made to determine if reliable 300 baud operation can be achieved via an omni-directional antenna. It will then be possible to determine if data quality and reliability will be satisfactory, or if additional RF amplification will be required.

REFERENCES

NOAA/NESDIS DAPS User Interface Manual Ver. 1.1

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