OPERATIONAL RESULTS USING LOW POWER GOES TRANSMITTERS IN MOORED BUOY APPLICATIONS – 300 BAUD UPDATE

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THE CHALLENGE

Canada's current moored buoy program will need to adapt to several upcoming changes in satellite communications. The current 100 baud GOES data communication channels will be upgraded to 300 baud in order to accommodate more users. In the past we have been operating moored buoys that utilize relatively high power transmitters (40 watt) at the 100 baud transmission rate using omni directional antennas. The challenge is to move to the higher data transmission rate, using the new generation of lower power transmitters (10-16 watt), without deterioration of data reception reliability.

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 RF 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. In presenting the results of our original testing at 100 baud transmission rates, we were unable to test at the higher baud rate because the 300 baud GOES demodulators were not ready for operational use. We have now been able to operate a buoy on a 300 baud assignment and the results are presented as an update to the original paper.

Eventually, all new assignments allocated by the National Environmental Satellite, Data and Information Service(NESDIS), for data transmission through the GOES system, will be 300 baud or higher. It is important to resolve the power requirement issues while there is still time to develop signal amplification systems, if required, before the 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 X 10^{-6})
  - F (Fair, error rate between 1 X 10^{-4} and 1 X 10^{-6})
  - P (Poor, error rate worse than 1 X 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 the 100 baud portion of 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. For the 300 baud tests, comparisons between baud rates could not be made on the same GOES channel, since the 100 baud and 300 baud channels are different. 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 at 100 baud 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 transmitters. 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 2002 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.

The 300 baud tests were conducted during August 2003. The signal strength and data quality was compared to transmissions from the same buoy and transmitter configured to operate at 100 baud during August of 2002 as a reference.

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 of British Columbia, Canada (WMO 46183) contained the higher power Synergetics transmitters. See Figure 1.

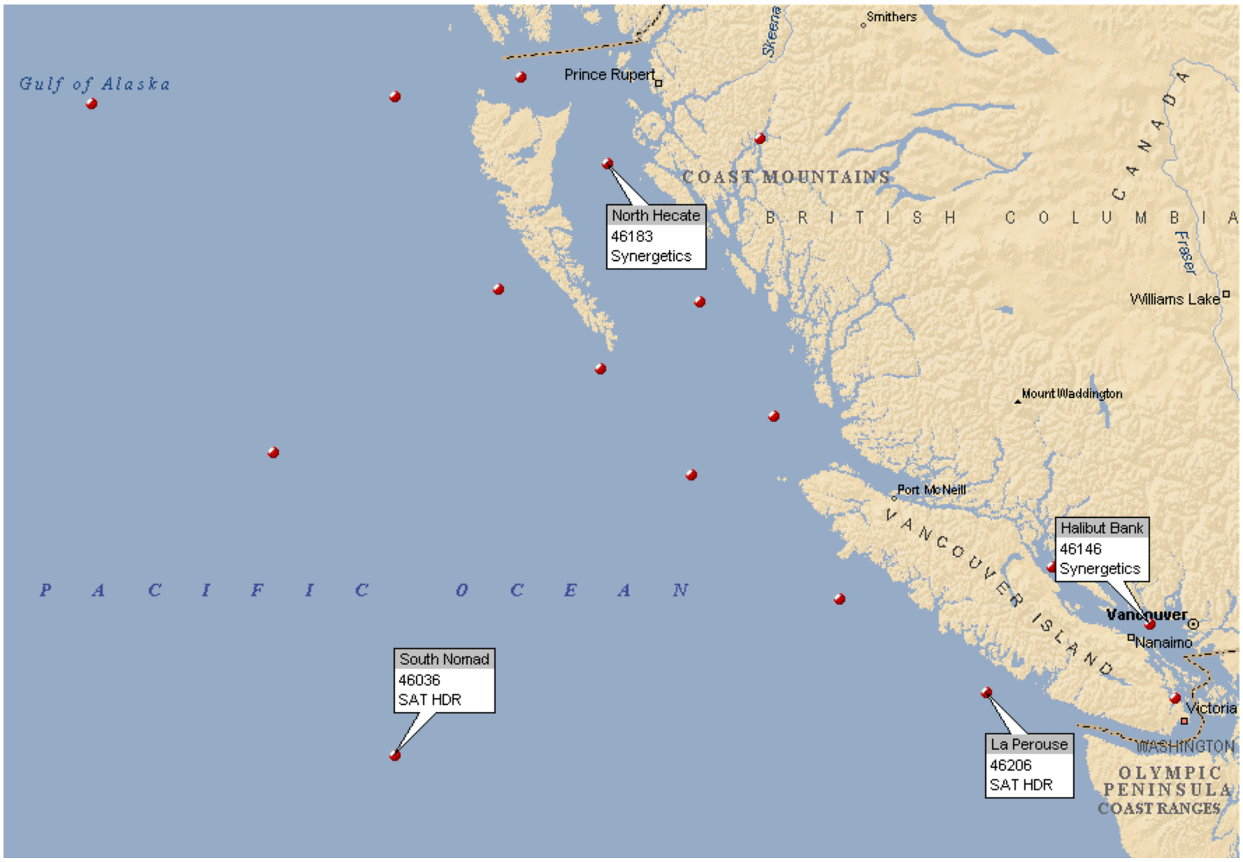

Figure 1. Location of MSC moored buoys (red dots). The four buoys used for the channel 008 W comparisons are shown by the labels.

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.

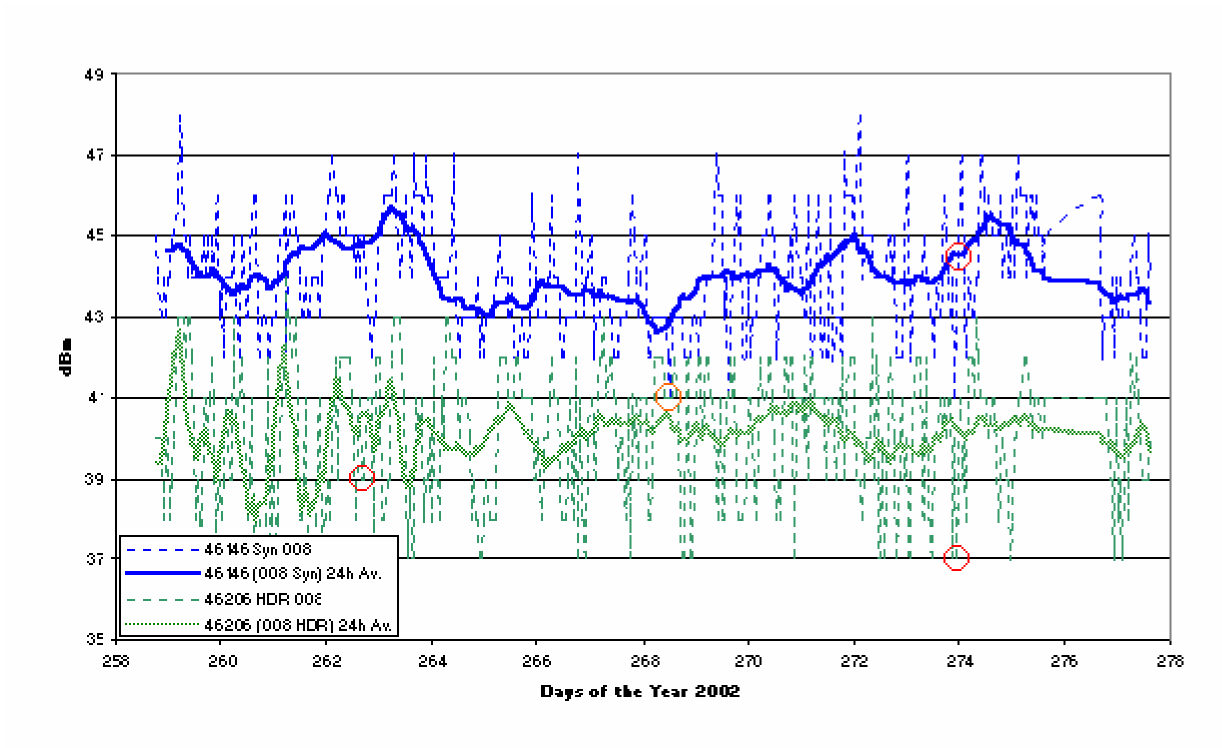

Figure 2. Average twenty-four hour and hourly DAMS signal strength (dBm) comparison between buoy 46146 using a high powered transmitter (upper), and buoy 46206 using a low powered transmitter (lower) on GOES channel 008W. Red circles denote missing messages.

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.

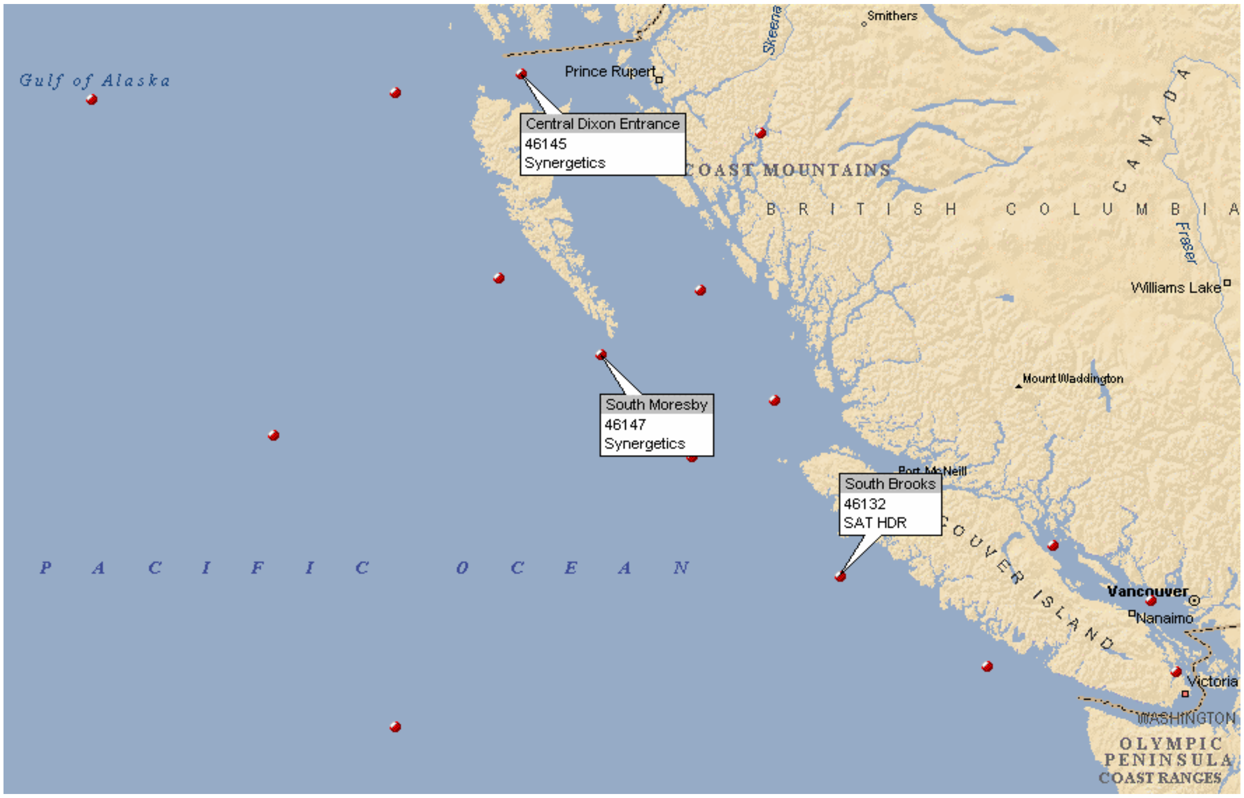

Figure 4. Location of MSC moored buoys (red dots). The three buoys used for the channel 010W comparisons are shown by the labels.

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.

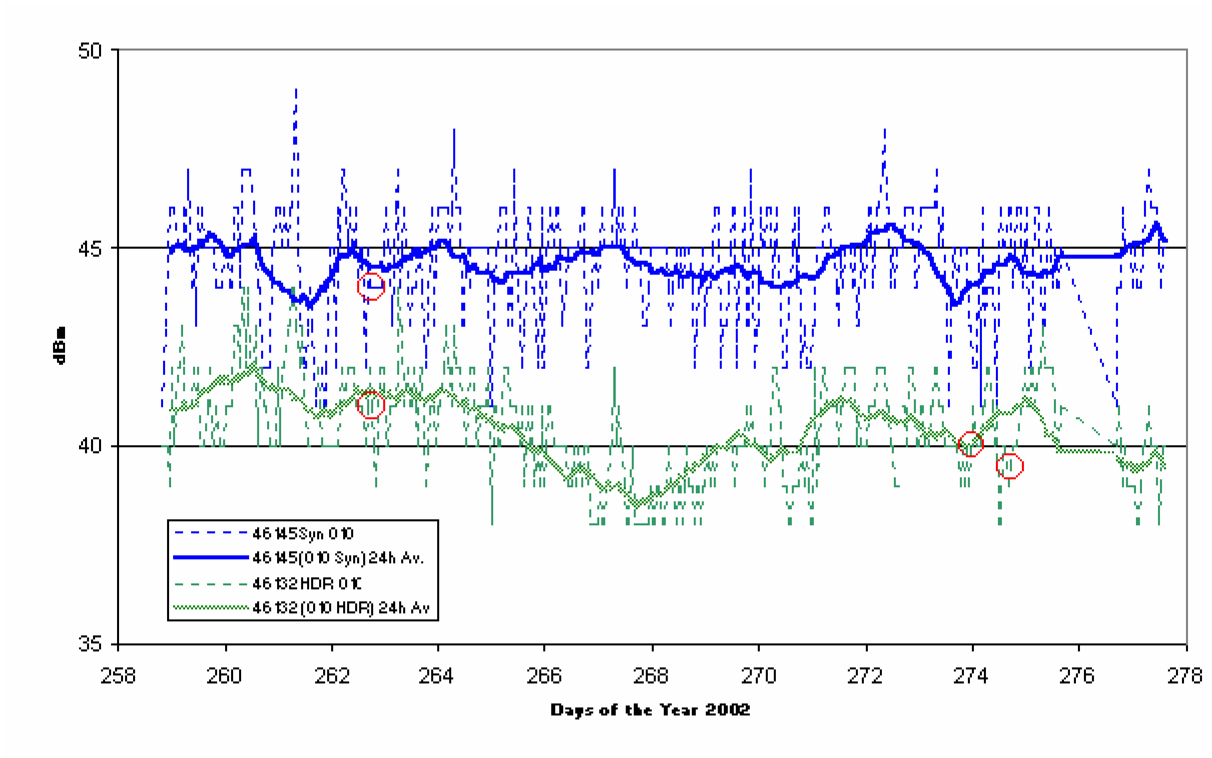

Figure 5. Average twenty-four hour and hourly DAMS signal strength (dBm) comparison between buoy 46145 using a high powered transmitter (upper), and buoy 46132 using a low powered transmitter (lower) on GOES channel 010W. Red circles denote missing messages

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, no data quality errors, no 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	427	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

As mentioned previously, due to problems experienced at NESDIS with operational implementation of the 300-baud demodulators during our original 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.

However, once the 300 baud system stabilized, we converted a 3 metre buoy to transmit at the 300 baud data rate. The only modification required was by software and the buoy was otherwise unchanged from the previous 100 baud configuration.

To provide a basis of comparison, an identical period of time was selected during August, 2002, when the buoy was transmitting at 100 baud and August, 2003, when the buoy was programmed to transmit at 300 baud. The DAMS signal strengths are compared in figure 7.

The average DAMS signal strength when transmitting at 100 baud on GOES channel 002 west was 40.7 dBm. When the transmitter was switched to 300 baud operation on channel 196 west, the average DAMS signal strength was 41.3 dBm. While it is understood that the individual calibration values for the DAMS calculations on the two channels will vary, it does appear that the observed signal strengths at 300 baud are as good as, or better than the strengths measured at 100 baud.

Of the 768 expected messages during the test period, there were no modulation errors, 2 parity errors and 1 missing message at the 100 baud rate and no modulation errors, 2 parity errors and 2 missing messages at the 300 baud rate. However, the 100 baud test data (August 2002) revealed a continuous DAMS quality error. In examining the data it became apparent that the error was most likely due to a NESDIS channel calibration problem, since the quality error also showed up with the previous Synergetics transmitter. This transmitter, cable and antenna was replaced with the SAT HDR transmitter and a new cable and antenna, operating on the same time and channel assignment at 100 baud, but the error persisted. However, the error disappeared when the transmitter was moved to the high data rate GOES channel operating at 300 baud. See figure 8.

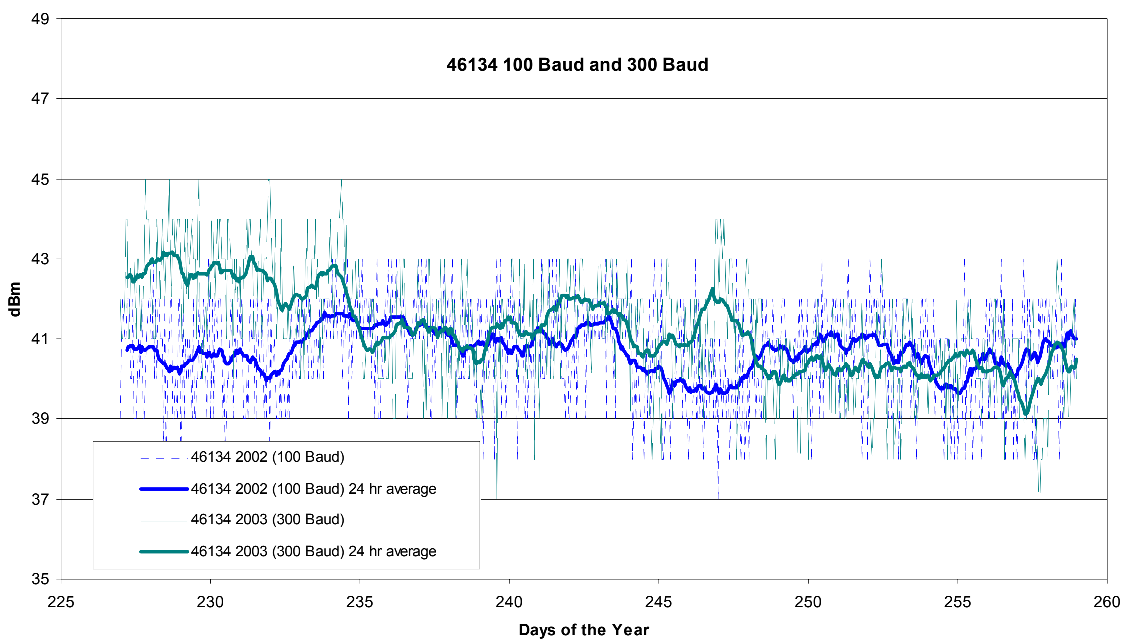

Figure 7. Average twenty-four hour and hourly DAMS signal strength (dBm) comparison between buoy 46134 transmitting at 300 baud on GOES ch 196W in August 2003 (upper green line), and transmitting at 100 baud on GOES ch 002W in August 2002 (lower blue line).

Baud Rate	Total Msg	Mod Errors	Q Errors	Parity Errors	Missing Msg	Avg Sig Str
100	768	0	767	2	1	40.69
300	768	0	0	2	2	41.25

Figure 8. Error summary by type for 100 baud and 300 baud operation using the same SAT HDR low power transmitter on GOES channel 002W (100 baud) and channel 196W (300 baud).

EFFECT OF HIGH WAVES ON SIGNAL QUALITY

As mentioned earlier in this paper, we examined high wave events and could not find a clear relationship between wave height and signal strength in the events which were available to us at the time. Subsequently, a storm generating significant wave heights in excess of 9 metres was experienced in the first week of January 2003 at 3 metre buoy (WMO 46207), located off the west coast of Vancouver Island.

This buoy is equipped with a SAT HDR low power transmitter operating at 100 baud. DAMS signal strength values from this event were examined and are shown in figure 9. In this event, there does appear to be an inverse relationship between the DAMS signal strengths and the significant wave height, with the DAMS values being in the high 30's during the period of highest waves and increasing to 41 as the waves subsided. However, DAMS signal strengths do have temporal variations and due to the conflicting results from several high wave events, we can not say conclusively that wave heights affect the signal in any appreciable way.

During this seven day event, there were no parity, modulation or quality errors. There was one missing message, however, examination of data for other buoys in relatively calm conditions revealed the same hour missing, indicating that the missing message was most likely due to a NESDIS problem.

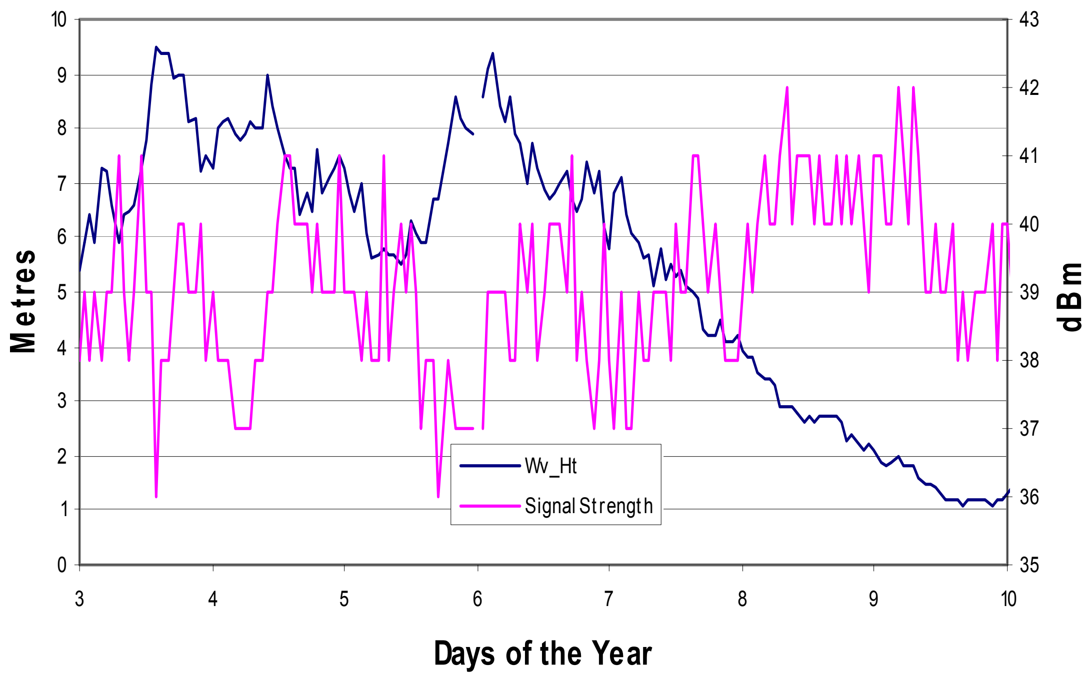

Figure 9. Hourly DAMS signal strength (dBm), lower pink line, and Significant Wave Height (metres), upper dark blue line, for buoy 46207 during January 3-10, 2003.

OBSERVATIONS

- As expected, lower powered transmitters have a lower DAMS signal strength (approx. -3dBm) 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.

- Due to conflicting results comparing DAMS signal strengths during high wave events, we can not say conclusively that wave height affects the signal strengths.

- 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 that most of the data losses could be attributed to a problem at NESDIS.

- 300-baud transmissions had signal strengths as good as, or better than, the same transmitter operating at 100 baud (40.7 dBm at 100 baud vs. 41.3 dBm at 300 baud) with no increase in DAMS errors. Of a possible 768 messages, at 100 baud, 1 message was unavailable, while 2 messages were unavailable at 300 baud. Based on testing to date, our results would indicate that additional RF amplification in order to operate at the 300 baud data rate is not essential.

FUTURE FOLLOW UP

In the spring of 2004 an operational buoy in a more exposed West Coast location will be converted to operate at 300 baud using the SAT HDR transmitter. The results will be evaluated to determine the validity of our original conclusion that additional signal amplification is not required.

REFERENCES

NOAA/NESDIS DAPS User Interface Manual Ver. 1.1

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