*Sky*WAN® with a C2Sat antenna for a maritime VSAT bundle

Introduction

*Sky*WAN® is a pure MF-TDMA, hub less VSAT system with multiple frequency channels for transmit and reception. It provides bandwidth on demand capability based on a DAMA (Dynamic Access Multiple Access) scheme and offers a number of unique features to differentiate itself from other products in the market. Next to mainly land-based networks, *Sky*WAN® was also used for maritime applications in the past already, integrated mainly by partners. The usage of the *Sky*WAN® modem for maritime remote stations gives a very good feedback. This is mainly based on the general feature set as meshed capabilities (single hop), possible single carrier operation (outbound and inbound together in one carrier), QoS features – especially for voice, automatic transmission power control for each remote (important for ships because of fast changing weather conditions), load balancing, different redundancy concepts etc. One main aspect is also the fast re-acquisition time in case of short losses of direct sight to the satellite (because of ship deck structures or other shadowing effects) or short term positioning problems of the antenna system.

With the new modems series *Sky*WAN® 7000 and used Turbo-Phi coding scheme as well as 8PSK support and embedded link-encryption (hardware option), available performance data offers further enhancements for efficient usage of transponder capacity and needed uplink power (amplifier size) as well as embedded security. Uplink rates between 2-4Mbps even for remote station in maritime or mobile environment with 1.2m antenna size and limited amplifier power is possible quite often. The *Sky*WAN® 1070 unit with 1RU size can drive ODU equipment up to 60W (24DCV) total power consumption (around 6W Tx power class), and works optional with AC (230V) or DC (24V).

Very often, there are questions about the complexity to connect a *Sky*WAN® modem to a maritime antenna system, since each modem in the market may have special requirements, limitations or need changes in the outdoor equipment like amplifier, LNB etc. This paper shall give an overview how a *Sky*WAN® modem work together with the C2Sat maritime antenna system, a relative new, high performance antenna in the maritime market for VSAT

Maritime Antenna System from C2Sat

C2Sat says about itself to be “is a world leader in the development of innovative VSAT stabilized antenna systems for the global market. C2SATs business objective is to reduce costs for maritime VSAT satellite services making it possible to get availability to the bandwidth actually paid for during dynamic conditions.” The company exists since 2000, and with end of 2006, C2SAT’s four-axis antenna platform was successfully completed and production started. The original design for the real 4-axes stabilized antenna systems was for mainly military and commercial usage with high performance needs and to be “Always On – Not Almost Always On”. Until mid of 2009, based on C2Sats own information, around 90 units of their four-axis antenna platform were sold and in operative status. The basic system is the same for Ku-and C-Band, only reflector and feed horn are replaced in case. A revised version standard system for smaller amplifiers and reduced weight was developed, the 4M model (~30kg less), therefore less than 100kg, but with reduced space and max weight for amplifier enabling shorter geometric path and less rotation torque for each axis. Both systems have the same electronic and controller. In the test, the standard 1.2m Ku-band antenna was used.

The antenna system itself is often presented in marketing material as a whole polished system as depicted below, but the working system is most time painted blue for the mechanical part. The reflector is a hydromechanical deep drawing metal dish, working as a prime focus system.

Marketing photo

Photo of a real working system

C2Sat does it own feed horn - as well as the reflector – which also contains the OMT. The LNB is not mountable at the feed horn directly but fixed on the rear side of the reflector, connected by a flex waveguide. Based on C2Sats information, this setup was done to reduce possible interference/side lobe effects using a prime focus antenna and minimized diameter for the Radom. As a disadvantage, additional losses of 0.8-1dB need to be taken into account for link budget calculations. C2Sat provides a Tx reject filter directly connected in front of the LNB, which is fixed by normal wire straps. This may be an unconventional fixing, but also allows a flexible handling of different LNBs as well as positioning. The *Sky*WAN® modem works normally with PLL LNBs with external reference provided by the modem itself for high accuracy and low phase noise reasons, especially in case lower symbol rates for the carriers are used. The used standard LNBs are working in a range of 15-24V. However, C2Sat is using its own DC supply for the LNB to get a proper working condition for its pointing system with a DC block in the incoming Rx path (given by historical reasons: many other VSAT modems are not providing the DC stability as needed for C2Sats own pointing system). Since the maximum voltage provided by C2Sat in max 14V, a different approach for *Sky*WAN® is needed (as explained later on).

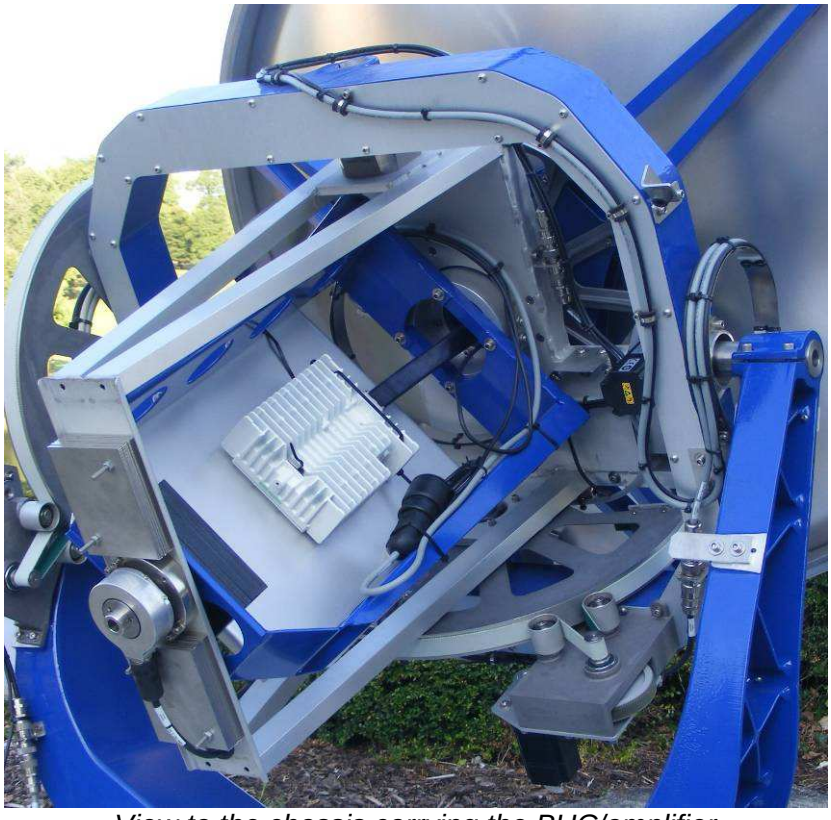
Feed Horn with OMT

TX Reject Filter and LNB

Fixing LNB with wire straps

In the middle of the prime reflector, a small absorber blanket is fixed to protect the LNB for too high direct transmit reflections. Despite this attenuation, C2Sat is sure to keep the given parameter for Tx and Rx gain for the antenna as depicted in their data sheet (Rx : 40.7 dBi min, Tx : 42.9 dBi min). In projection of the polarization axis behind the reflector, there is the chassis for the used amplifier. This is to keep best balancing conditions while moving the antenna. The whole chassis moves with the antenna during pointing. For the test a NJR BUC with 6W was taken (small white box in the chassis depicted below), allowing in the given link budget environment burst rates up to 2,3Mbps with QPSK FEC 5/6 (exact configuration data see below), still with enough power reserve in case of worse conditions on site. Connection to the feed horn is again given by flexible waveguide (keep in mind the loss for link budget conditions). The rotary joint in the antenna system provides Tx and Rx connectivity to BUC and LNB (see picture left below). Therefore, in case, the connected modem can drive the BUC directly with DC power via the TX cable, but there is a limitation in maximum power by the rotary joint. C2Sat lists max 1,3A/24VDC (there is some reserve but permanent power is limited). Most time sufficient for a 4W Ku BUC or 5W C BUC, but already limited for the NJR 6W, consuming 63W max. Therefore, the BUC was connected directly to the modem for the test. Anyhow, an AC plug is available at the chassis, allowing to connect directly BUCs with an higher transmit power with integrated power supply like offered by Codan (16W or 25W AC powered) or others (but unfortunately not NDSatcoms own RFT 3000). The choice for usable amplifiers for the C2Sat 4M system (smaller amplifier space and less weight) is limited, but also new 20W or 25W BUC versions as offered by Actox with downsized dimensions and reduced weight or others might be used in the 4M system.

Rotary Joint for Tx/Rx cable



View to the chassis carrying the BUC/amplifier

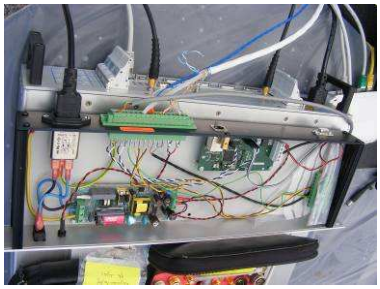
Pointing

"C2SAT gradient tracking system identifies and finds any selected satellite within 6 seconds." This statement from C2Sat might be not valid for all possible conditions, but for some. Nevertheless, in our test case (~170° movement required) the pointing works quite fast (~10s to get in first contact to the satellite and carrier, and ~20s in total with fine pointing and SkyWAN IDU online). The working of the intelligent pointing algorithm is working as following:

a) antenna system is getting GPS and compass data from the system of the ship. These data are already very accurate. With the configured data for the used satellite and the own IMU (inertial measurement unit), the system (ACU) calculates the required position (azimuth, elevation and polarization) for the system and moves to its calculated position. This initial step is most time already good enough to get a locked SkyWAN signal.
b) afterwards the antenna system starts a maximum signal fine pointing. For this step the controller measures at a defined frequency (pre-defined in configuration file) the integral signal strength in a 2.6MHz window range. Using the integral sum of the signal the system starts a tracking sequence in a ± 2° range in azimuth to find exact satellite position, respectively signal maximum. The elevation angle stays fixed, since this never seems to be a problem during pointing and tracking accuracy. During operation, this sequence may be repeated, respectively is always active to keep fine pointing routine (system will always return to exact position even exact view to satellite might be disturbed by heavy movement or shadowing effects). Since the C2Sat system uses its own carrier tracking in an independent way (no connected modem required , the antenna systems needs control of the used LNB. Therefore, the system provided the DC for LNB and not the modem (DC-Block in Rx path to modem). The maximum DC voltage is 13-14V, therefore too low for several LNBs. The board with signal processing is directly placed at the antenna itself, using a tuner & receive chip known from standard STB boxes. Because of this setup, a careful check for usable LNBs is required.
c) for *Sky*WAN® an extension in the ACU of the C2Sat system was implemented. In case the ACU detects a SkyWAN unit via SNMP, a third cycle routine will start. The ACU will poll the Rx lock status to get a feedback of a locked signal. After locked Rx status is active, fine pointing in azimuth will be done based on the Es/No signal strength of the *Sky*WAN® modem itself. The extension has several benefits: improved signal in case of adjacent satellites and possible mismatches in frequency coordination and control of availability of network carrier and therefore correct tracking. In case the *Sky*WAN® IDU is on and no SkyWAN carrier can be detected, the search/scanning range will be increased for additional 2°. If no carrier can be found, the master and/or carrier will be seen as not available, but the antenna system is continuing the tracking sequence to be ready for operation as soon as the receive signal is active again.

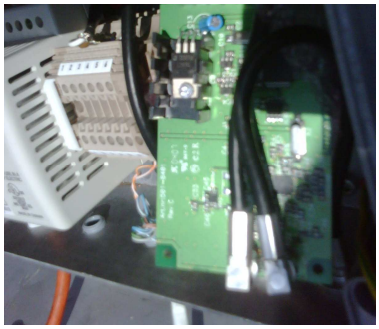
With the implemented pointing routine, the system supports a very stable, exact and reliable pointing as well as always keeps pointed. In operational use, we never got more than ~22s to run through the whole startup routine after initialization from the zero point.

It is planned to increase the functionality of the ACU to support beam switching (different footprint areas) during operation, based on a small database and available GPS data (automatic replacement of parameter for antenna as well as FTP upload of new configuration file inside IDU), but this is requiring a modified ACU with some more memory and storage capability.



External simple ACU component: Microcontroller board (early version)

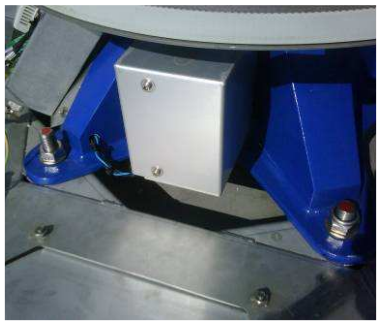
a) Tx and Rx connector board with LNB DC control …



b) … and logic to measure RX signal power.

Another view to BUC chassis

View to controller boxed for the drive engines (four axes)



View to used IMU

Mechanical Adaption for SkyWAN usage

As described above the a usage of the normal approved and released LNB model as listed below is not possible, since DC on incoming Rx cable is blocked at the C2Sat antenna, and the maximum DC power provided by the system is only 14V. The NJR PLL LNB with external reference work only between 15-24VDC and therefore not stable working conditions are given.

LNB External PLL Reference

Power Requirement	+24 VDC (+15 to +24 VDC)
Current Drain	380 mA typ., 400 mA max.
Dimension & Housing (without Interface Connectors)	130 mm (L) x 65 mm (W) x 40 mm (H) [5.12" (L) x 2.56" (W) x 1.57" (H)]
Weight	450 g [0.99 lbs]

NJR it self is providing a series of new PLL LNBs with internal reference and good local stability of ± 3ppm (even with ± 1ppm). An extract of the data sheet is depicted below. This type of LNB is working in a DC range of 12-24Volt and therefore capable to work with the C2Sat system. Caused by the used symbol rate of ~1.4MBaud a more precise LNB is not required and works with the SkyWAN modem in a stable way.

No measurements were done with smaller symbol rates to gain more information up to which symbol rate the new type of LNB is working in a proper way with the SkyWAN system, although at this time no real limiting factor under normal network conditions can be seen. Further advantage of the used LNB could be seen in the smaller dimension as well as weight if directly fixed at the rear side of the reflector.

NJR LNB: Internal Reference

Model No.	RF Frequency	Local Frequency	IF Connector	Local Stability	IF Connector	Power Supply
NJR2837S	10.95 to 11.70GHz	10.00 GHz	950 to 1,700 MHz	+/- 3 ppm	F-type	+24 VDC (+12 to +24 VDC)
NJR2837SN					N-type	
NJR2839S	11.20 to 11.70 GHz	10.25 GHz	950 to 1,450 MHz		F-type	
NJR2839SN					N-type	
NJR2835S	11.70 to 12.20 GHz	10.75 GHz			F-type	
NJR2835SN					N-type	
NJR2836S	12.25 to 12.75 GHz	11.30 GHz	950 to 1,450 MHz		F-type	
NJR2836SN					N-type	

Noise Figure (Ta.: +25 C)	0.8 dB typ., 1.0 dB max.
Linear Gain (Ta.: +25 C)	60 dB typ., 55 dB min.
Local Stability	+/-2.5 ppm (Ta.: -30 to +60 C)
	+/-3.0 ppm (Ta.: -40 to +60 C)
L.O. Phase Noise	-70 dBc/Hz typ. @ 100 Hz
	-80 dBc/Hz typ. @ 1 kHz
L.O. Leakage Level	-25 dBm max. at the IF Output Connector
	-60 dBm max. at the RF Input Flange
Spurious	a) -140 dBm max. at input, Fixed frequency spur, unrelated to test CW signal (Measured at specified IF band).
	b) -55 dBc max. with test CW signal -10 dBm IF output (Measured at specified IF band).
Input V.S.W.R.	2.5 : 1 typ.
Output V.S.W.R.	2.5 : 1 max.
Power Requirement	+24 VDC (+12 to +24 VDC)
Current Drain	200 mA max.
Temperature Range (ambient)	-40 to +60 C (operating), -40 to +80 C (storage)
Dimension & Housing (without Interface Connectors)	100.5 mm (L) x 40 mm (W) x 40 mm (H) [3.96" (L) x 1.57" (W) x 1.57" (H)]
Weight	260 g [0.57 lbs]

Although the C2Sat system supports amplifier with much bigger dimensions and power, for the test a 6W from NJR was used and mechanical mounted inside the chassis.

Despite the fact of the limiting rotary joint in maximal current, the BUC was directly connected to the modem via Tx cable. In an operative environment with closed Radom, a 4W BUC must be used, or a BUC with direct VAC support.

Model No.	RF Frequency	Local Frequency	IF Frequency	Output Power @ P1dB	IF Connector	Power Supply	LED Indicator
NJT5127	14.0 to 14.5 GHz (Ku-band)	13.05 GHz	950 to 1,450 MHz	6W Linear (+37.8 dBm min.)	N-type	+24 VDC (+15 to +24 VDC)	-
NJT5127F					F-type		
NJT5127L					N-type		Equipped
NJT5127FL					F-type		

Output Power @ 1 dB G.C.P.	+37.8 dBm min. over temperature	
Linear Gain	56 dB nom.	
ACPR Compliance with IESS308 / SSOG	-26 dBc max. @ Pout = +37.8 dBm	
Requirement for External Reference	[Frequency]	10 MHz (sine-wave)
	[Input Power]	-5 to +5 dBm @ Input port
	[Phase Noise]	-125 dBc/Hz max. @ 100 Hz
		-135 dBc/Hz max. @ 1 kHz
		-140 dBc/Hz max. @ 10 kHz
L.O. Phase Noise	-60 dBc/Hz max. @ 100 Hz	
	-70 dBc/Hz max. @ 1 kHz	
	-80 dBc/Hz max. @ 10 kHz	
	-90 dBc/Hz max. @ 100 kHz	
Receive Band Noise Density	-156 dBm/Hz max. @10.95 to 12.75 GHz	
Input V.S.W.R.	2.0 : 1 max.	
Output V.S.W.R.	2.0 : 1 max.	
Power Requirement	+24 VDC (+15 to +24 VDC)	
Power Consumption	63 W max.	
Mute	Shut off the HPA in case of L.O. unlocked or no 10 MHz reference signal.	
LED Indicator	GREEN: L.O. locked / RED: L.O. unlocked or no 10 MHz reference signal [Model No.: NJT5127L/27FL]	
Temperature Range (ambient)	-40 to +55 C (operating), -40 to +75 C (storage)	
Dimension & Housing (without Interface Connectors)	186.4 mm (L) x 167 mm (W) x 83 mm (H) [7.33" (L) x 6.57" (W) x 3.27" (H)]	
Weight	2.4 kg [5.3 lbs]	

*Sky*WAN® configuration

For the test with the C2Sat system following network configuration for the SkyWAN modem was used (2 carrier operation):

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Code rate:                              6/7
Required Eb/N0  [dB/10]:                56
Modem data rate [kbit/s]:               2300
User data rate  [kbit/s]:               2010
Symbol rate [kBaud]:                    1452
Frequency bandwidth [kHz]:              1742,4
Reference burst mode:                   MRB
Number of reference channels:           1
TDMA frame time  [µs]:                  101116
Length base gross container [byte]:     417
Time base slot [µs]:                    1487
Total efficiency [bit/symbol]:          1,427
Total efficiency [bit/s/Hz]:            1,189
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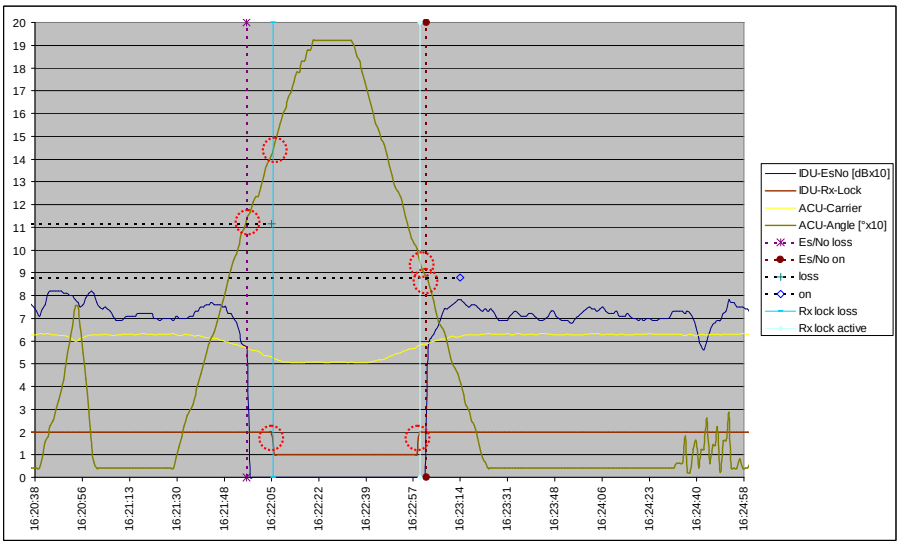
Re-Synchronization behavior with azimuth deviations

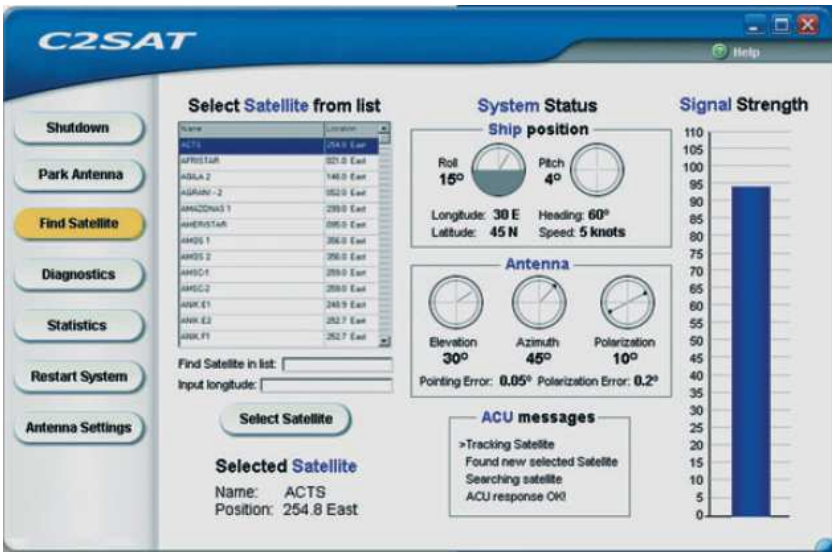
For completion of the tests, correlated measurements of azimuth deviation and locking behavior were done over time. The results are depicted below. The deviation in azimuth was ~2,23°/min. In case of an active connection Es/No will jump down if the deviation is larger than 1,12°, Rx locked status will be lost at ~ 1,43°. Driving back in the beam, Rx lock status will be detected as active 0,94° away from maximum peak, Es/No is increasing again 0,88° away from maximum peak detection. With an



azimuth deviation below 1° the system kept stable u nder the given conditions.

General monitoring and control of the C2Sat system

Finally, the M&C program of the antenna itself is depicted in a short way. The program is a MS Windows standalone software (executable). Web access to the ACU is not provided, although SNMP is supported for general requests. The configuration files for the antenna system is normally a fixed one with a list of pre-defined satellites, although this list may be adapted for special usage. At the moment, this adaptation must be done together with C2Sat in the pre/integration phase. The extension specially done in conjunction with a SkyWAN modem for the enhanced search and tracking was hard coded during the tests but a final version with configurable parameters will be finalized.



The standalone application supports the main command “Find (selected) Satellite”, “Park Antenna” and “Shutdown”. Nothing else is required. Additional “Diagnostic” and “Statistic“ information can be depicted, but the control GUI is a very small application. Next to the depiction of the signal strength (of the measured 2.6MHz window – not of the connected modem) the coordinated received by the ship system respectively ship position with roll and pitch status and therefore resulting antenna angles (elevation, azimuth and polarization) are presented in the GUI.

Conclusion

The C2Sat maritime antenna systems is a very good performing system, well usable for harsh and heavy moving ships (like smaller ships as well as for military or governmental usage), since it is a permanent tracking and re-positioning system – not given by every maritime antenna system. With the positioning extension working together with *Sky*WAN® the reliability to get and lock to the correct satellite and carrier can not beaten by every other system so far. Positioning time of the antenna system together with the very quick locking and synchronization time of the *Sky*WAN® provides a perfect bundle for highest availability, also in case of possible outage or blockages. Because of the design of the antenna, the support of high power amplifier together with the *Sky*WAN® 7000 modem performance provides best high VSAT data rates together with limited bandwidth usage, even for weaker Ku-Band satellites or C-Band usage. Disadvantage of the antenna system might be the higher weight and larger dimension compared to other available systems, but resulting in reduced vibration and self-oscillation and therefore faster tracking behavior and stability. For regions with higher average outside temperature, the available space for most time needed air condition simplifies the installation of the whole system. Finally, the combination of *Sky*WAN® and C2Sat is perfect in case of enhanced requirements to such a maritime VSAT system.