2nd URSI AT-RASC, Gran Canaria, 28 May – 1 June 2018

High Bandwidth Maritime Communication Systems – Review of Existing Solutions and New Proposals

Luke Robinson*[1,2], Thomas Newe[1], John Burke[2], Gerard Dooly[1], Joseph Coleman[1] and Daniel Toal[1]
(1) CRIS – Centre for Robotics and Intelligent Systems, University of Limerick, Limerick, Ireland.
(2) CIL – Commissioner of Irish Lights, Dun Laoghaire, Co. Dublin
*Contact Email: luke.robinson@ul.ie

Abstract

This paper presents a review of high bandwidth maritime communication technologies. High bandwidth maritime communication technologies can broadly be divided into two main areas – commercially available systems and research based systems. A detailed review of the current technology in each area is undertaken. Several commercially available systems use satellite communications technologies. A number of these systems are reviewed and bandwidth, latency and cost comparisons are made. Point to point links, another commercially available technology, is also discussed and similar criteria are used for their comparison, including range and bandwidth.

As well as commercially available technologies, several novel methods of maritime communications are reviewed that are current research topics in the marine communications field. Many of these show interesting possibilities, such as evaporation ducting and tropospheric scatter. The main mode of operation of each technology is discussed, and the possible performance for each in terms of range and bandwidth is compared. Issues and challenges that need to be overcome for the technologies to be viable in the marine environment are also discussed.

The aim of this paper is to provide the reader with a deeper knowledge of what technologies are currently available to facilitate high bandwidth maritime communications, and how they compare under a number of key performance metrics. In addition, an overview of new technologies that are currently under research is provided, and the potential benefits these technologies could bring to maritime communications and the technological issues in doing this is discussed.

1. Introduction

With a fleet of over 50,000 merchant ships manned by more than one million sailors, around 90% of the world's trade is transported at sea. [1] Despite this large volume of ships in the world's oceans, each ship remains relatively isolated once it is out of sight of land. This is partly due to the lack of high bandwidth communications available on board. For the purpose of this paper, high bandwidth communication systems are considered to be systems that are capable of transmitting a video signal. This typically requires a bandwidth of at least 1 Mbit/s.

2. Satellite Communications

At present, one of the most common ways of achieving long distance high bandwidth communications at sea is with one or more communications satellites placed in orbit above the earth. The signal is sent from the ship to the satellite, which then retransmits the signal to a ground station on land. From the ground station there is typically access to the internet. The advantage to using this system is that it makes high bandwidth communications available from most points at sea, but there are a number of disadvantages to it also. One problem is the high latencies due to the distance the signals must travel. [2] Another problem is the relatively high cost associated with purchasing the equipment and ongoing data charges.

Satellite communication systems can be classified according to their orbits, low earth (LEO), medium earth (MEO) and geostationary (GEO). Low earth orbit systems typically require a large number of satellites to provide global coverage. One example is the Iridium system, which uses a constellation of 66 satellites. [3] Medium earth orbit systems use satellites in a higher orbit than LEO, and require fewer satellites. An example is the O3b network, designed to provide backhaul links between mobile phone towers. [4] The most common orbit for communications satellites is the geostationary orbit. This orbit, where the satellite is exactly 35,786 km above the equator, means that the satellite orbits the earth at exactly the same speed as it rotates. This allows the satellite to remain in a fixed position above the earth's surface, meaning that earth based antennas can be fixed to point in the one direction. [5] Inmarsat currently operate 13 geostationary satellites, which cover the whole globe except for extreme polar regions. The satellites offer varying levels of service. [6] It can be seen in Table 1 that geostationary satellites typically have a much higher latency than satellites in lower orbits. This high latency can be a problem in some applications.

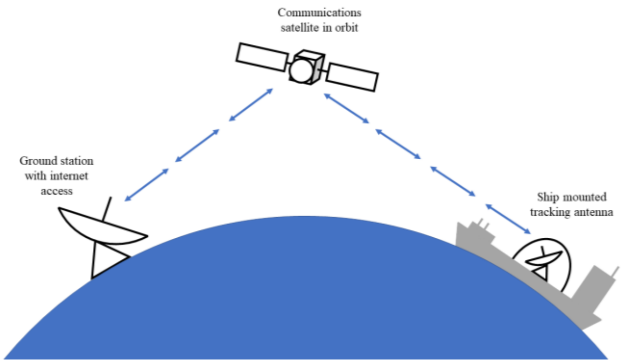

Figure 1. A simplified diagram showing how satellites enable communications over the horizon.

3. Point to Point Links

Point to point links, similar to the kind used in terrestrial communications, are also used in the maritime environment. A simple point to point communication setup consists of two directional antennas, pointed at each other. Such links are often used on land as mobile backhaul, and in home and business uses such as extending a local area network. As the signals only travel in line of sight, the distance between the two points is limited by the curve of the earth. Greater distances can be achieved by raising the height of the antenna.

The main advantage of using this method is the cost savings – the equipment setup is less expensive than with satellite communications and there are no ongoing costs involved. The disadvantage is that the range is much shorter, as the antennae must be in line of sight of each other. The range can be extended by mounting the antennae as high as possible on both sides, but it is ultimately limited by the horizon.

One of the biggest providers of point to point networking equipment is Ubiqiti. The Ubiquiti PowerBeam is widely used as a point to point link between buildings, businesses etc. [7]

4. Current Research Topics

Evaporation ducts are a phenomenon that have been known about for many years, but only recently have been exploited to aid maritime communications. An evaporation duct is formed in the first few metres above the ocean's surface, due to the rapid change in humidity and refractive index. This change in refractive index acts as a waveguide and allows for electromagnetic waves to travel around the curve of the earth. Evaporation ducts are present over all the earth's oceans, but to varying heights. The amount the signal is refracted depends on the height of the duct. [8]

Some research has been done on evaporation ducts by a group in Australia, where a 78 km link from the Great Barrier Reef to the mainland was developed. [9] Research has also been completed in Malaysia on a similar project, showing that a 64 km non-line-of-sight link was possible. [10]

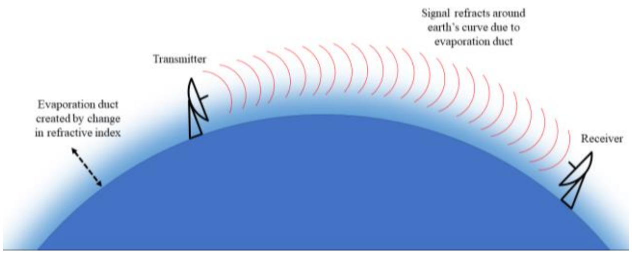

Figure 2. The basic operating principle of evaporation duct communications

Troposcatter is a radio propagation technique where radio signals are scattered as they pass through the troposphere. Some of the signals are reflected back to earth, where they can be picked up by a sufficiently high gain antenna. Several commercial systems have been developed over the years, for military and civil applications. [11] Recently, the focus has been on developing smaller and more efficient antennas for troposcatter systems. [12]

5. Comparison of Systems

To compare the performance of the various systems available, a number of metrics were decided on. These include range, bandwidth, latency and cost. Range is compared for each of the systems as it varies widely. Bandwidth and latency are important metrics, as they are the main factors that determine whether a system is usable for a certain application. Finally, cost was included to show how accessible each system is. The metrics for each system are shown in the table below.

Table 1. A comparison of various high bandwidth marine communication systems.

System	Range	Band width	Latency	Cost
LEO satellite	Global	Low	~ 120 ms	Med-ium
MEO satellite	Between 45° N/S	High	~ 150 ms	High
GEO satellite	Between 80° N/S	Med-ium	~ 600 ms	High
Point to point link	Line of sight	High	Low	Low
Evaporation duct link	~80 km	High	Low	Low
Troposcatter link	~250 km	High	Low	High

6. Acknowledgements

The authors would like to thank the Commissioner of Irish Lights (CIL) and the SFI Centre for Marine and Renewable Energy Ireland (MaREI), Grant References: 12/RC/2302 and 14/SP/2740 for facilitating this work.

7. References

[1] International Chamber of Shipping, "Shipping and World Trade," [Online]. Available: http://www.ics-shipping.org/shipping-facts/shipping-and-world-trade. [Accessed 08 December 2017].

[2] Y. Zhang, D. De Lucia, B. Ryu and S. K. Dao, "Satellite Communications in the Global Internet: Issues, Pitfalls, and Potential," in *Seventh Annual Conference of the Internet Society*, Kuala Lumpur, 1997.

[3] C. E. Fossa, R. A. Raines, G. H. Gunsch and M. A. Temple, "An overview of the IRIDIUM (R) low earth orbit (LEO) satellite system," in *Proceedings of the IEEE 1998 National Aerospace and Electronics Conference*, 1998.

[4] M. Williamson, "Connecting the other three billion," *Engineering Technology*, vol. 4, pp. 70-73, 2009.

[5] G. Maral and M. Bousquet, Satellite Communications Systems, Wiley, 2009.

[6] Inmarsat plc, "Our satellites," [Online]. Available: https://www.inmarsat.com/about-us/our-satellites/. [Accessed 22 February 2018].

[7] Ubiquiti Networks, "PowerBeam 2AC Datasheet," [Online]. Available: https://dl.ubnt.com/datasheets/PowerBeam_ac/PowerBeam_PBE-2AC-400_DS.pdf. [Accessed 28 February 2018].

[8] K. D. Anderson, "Radar Measurements at 16.5 GHz in the Oceanic Evaporation Duct," *IEEE Transactions on Antennas and Propagation*, 1989.

[9] G. S. Woods, A. Ruxton, C. Huddlestone-Holmes and G. Gigan, "High-Capacity, Long Range, Over Ocean Microwave Link Using the Evaporation Duct," *IEEE Journal of Oceanic Engineering*, vol. 34, 2009.

[10] K. S. Zaidi, V. Jeoti, A. Iqbal and A. Awang, "Feasibility of Trans-Horizon, High-Capacity Maritime Wireless Backhaul Communication Link," in *International Conference on Intelligent and Advanced Systems*, Kuala Lumpur, 2014.

[11] Comtech Systems Inc., "Introduction to Troposcatter Communications," 2009.

[12] S. Kravchuk and K. Mykola, "Features of creation of modem equipment for the new generation compact troposcatter stations," in *2016 International Conference Radio Electronics Info Communications (UkrMiCo)*, Kiev, 2016.