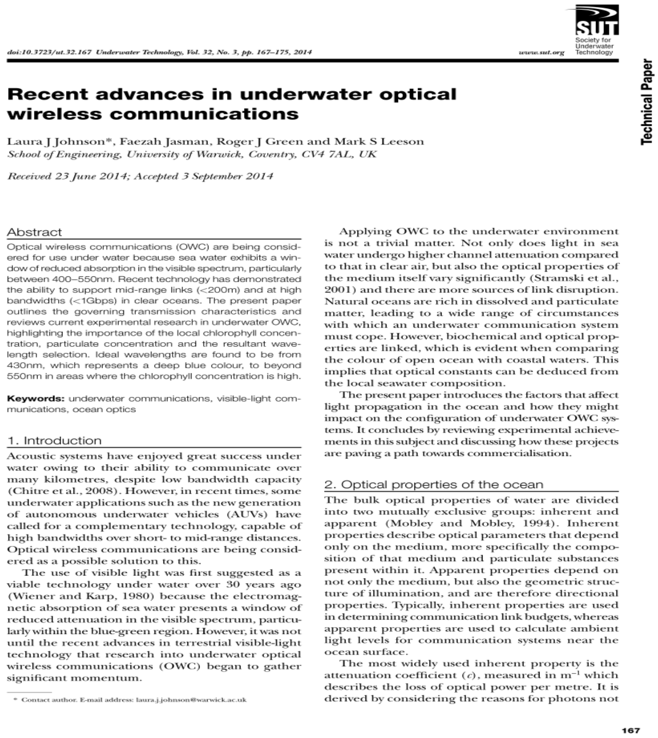
Communications And Networks: A Survey Of Recent Advances



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Technical Paper

Recent advances in underwater optical wireless communications

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Abstract

Optical wireless communications (OWC) are being considered for use under water because sea water exhibits a window of reduced absorption in the visible spectrum, particularly between 400–550nm. Recent technology has demonstrated the ability to support mid-range links (<200m) and at high bandwidths (<1Gbps) in clear oceans. The present paper outlines the governing transmission characteristics and reviews current experimental research in underwater OWC, highlighting the importance of the local chlorophyll concentration, particulate concentration and the resultant wavelength selection. Ideal wavelengths are found to be from 430nm, which represents a deep blue colour, to beyond 550nm in areas where the chlorophyll concentration is high.

Keywords: underwater communications, visible-light communications, ocean optics

1. Introduction

Acoustic systems have enjoyed great success under water owing to their ability to communicate over many kilometres, despite low bandwidth capacity (Chitre et al., 2008). However, in recent times, some underwater applications such as the new generation of autonomous underwater vehicles (AUVs) have called for a complementary technology, capable of high bandwidths over short- to mid-range distances. Optical wireless communications are being considered as a possible solution to this.

The use of visible light was first suggested as a viable technology under water over 30 years ago (Wiener and Karp, 1980) because the electromagnetic absorption of sea water presents a window of reduced attenuation in the visible spectrum, particularly within the blue-green region. However, it was not until the recent advances in terrestrial visible-light technology that research into underwater optical wireless communications (OWC) began to gather significant momentum.

Applying OWC to the underwater environment is not a trivial matter. Not only does light in sea water undergo higher channel attenuation compared to that in clear air, but also the optical properties of the medium itself vary significantly (Stramski et al., 2001) and there are more sources of link disruption. Natural oceans are rich in dissolved and particulate matter, leading to a wide range of circumstances with which an underwater communication system must cope. However, biochemical and optical properties are linked, which is evident when comparing the colour of open ocean with coastal waters. This implies that optical constants can be deduced from the local seawater composition.

The present paper introduces the factors that affect light propagation in the ocean and how they might impact on the configuration of underwater OWC systems. It concludes by reviewing experimental achievements in this subject and discussing how these projects are paving a path towards commercialisation.

2. Optical properties of the ocean

The bulk optical properties of water are divided into two mutually exclusive groups: inherent and apparent (Mobley and Mobley, 1994). Inherent properties describe optical parameters that depend only on the medium, more specifically the composition of that medium and particulate substances present within it. Apparent properties depend on not only the medium, but also the geometric structure of illumination, and are therefore directional properties. Typically, inherent properties are used in determining communication link budgets, whereas apparent properties are used to calculate ambient light levels for communication systems near the ocean surface.

The most widely used inherent property is the attenuation coefficient (c), measured in m^{-1} which describes the loss of optical power per metre. It is derived by considering the reasons for photons not

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