

Simulation of the Wireless Communications Channel in Marine Buoys Applications

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Abstract — The performance of a radio-communication link between nodes of a network of wireless sensors in marine drift buoys, is presented for applications in the measurement of physical and chemical parameters of sea conditions in waters near the coast. The behavior for various values of irregular sea conditions is assessed. From the carried out simulations, it can be seen that the performance deteriorates in the case of swell conditions.

Keywords — Drift Buoys, Wireless Sensor Networks, Sea States, Radio Signal Propagation, Sea Waves Spatial Spectrum Sea Waves Temporary Spectrum.

I. INTRODUCTION

A large part of the earth is covered by the sea. Which provides us with valuable resources and is a vital means of communication. Therefore we need a better knowledge of radio-communication at the sea. The current use of wireless technology, specifically sensor networks, has arisen in importance and each time, more scenarios are considered. The above due to its processing capabilities, communication, networking, low cost and to be able to operate once configured autonomously for the acquisition of measurements in environments or conditions that would be difficult for people or simply inexpensive from the economic approach. This work analyzes the behavior of a network of drift buoys that are elements of a wireless sensors network considering the different propagation conditions that affect the wireless communication channel [1]. Specifically, the performance of the link between two nodes in conditions Typical found in marine environments. Such buoys allow real-time measurement of different conditions and physical variables such as temperature, direction of sea currents, and other quantities of interest for the study of sea behavior in coastal areas [2]. It is known that the marine wireless communication channel has a different behavior than the one corresponding to the urban or interior environments, which are the typical scenarios of this class of networks, in addition to the energy limitations of the devices of these networks [2],[3].

The network structure to analyze is based on nodes with short distances between them (10-70 meters), which drift into groups or "clusters" and that maintain to some extent this distance despite drifting. These nodes communicate with each other for the purpose of sending the information to a fixed central node on land.

Several works have been published for network nodes with short-distance links between them in outdoor environments and on marine environments. Personal

area wireless networks have been studied and characterized for certain conditions and scenarios [4],[5], and in the case of marine environments it has been found that permittivity and conductivity of sea water modify the conditions of propagation on trajectories on the Sea or freshwater bodies.

This work analyzes the behavior of the link between nearby nodes in terms of the bit error rate of a wireless sensor network (WSN) considering the IEEE 802.15.4 standard in drift buoy applications, considering the different conditions in the scenario Marine, specifically the conditions of propagation due to the waves of the sea.

II. PROPAGATION IN MARINE ENVIRONMENT

In a wireless communications environment, the free space propagation model is that the power received is [6]:

$$P_r = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d^2 L^2} \quad (1)$$

Where P_t is the transmitted power, G_t is the gain of the transmitting antenna, G_r is the gain of the receiving antenna, λ is the wavelength of the carrier signal, d is the distance between the transmitter and receiver and L are the system losses unrelated to the above parameters. The basic mechanisms that affect the propagation of radio-electrical signals in wireless systems are diffraction, reflection and scattering [4]-[8].

III. BEHAVIOR OF RADIO SIGNALS ON THE SEA SURFACE

The incidence of a radio-electric signal from a dielectric surface causes part of the signal to be reflected, and if the surface is perfectly flat, it can produce fading effects of the received signal by reducing the performance of the link at certain propagation distances [6]. On the other hand, for applications where the transmitting and receiving antennas are low, the attenuation effect caused by sea water reflection is higher [2]. Due to different phenomena, such as wind, sea currents and other effects on the surface. It can be considered for the sea to have some roughness. If we consider a flat and reflecting surface, as it could be a scenario of short-distance application between the transmitter and receiver, the equation describing this condition is [7] :

$$P_r = 4P_t \left(\frac{\lambda}{4\pi d} \right)^2 G_t G_r \sin^2 \left(\frac{2\pi h_t h_r}{\lambda d} \right) \quad (2)$$

Where h_t and h_r are the transmitter and receiver antenna heights respectively. The variation of the strength of the received signal is obtained from the graph of the above equation for values of interest (Figure 1), [6]. In addition to the above condition, the surface of the sea is not perfectly flat and can be considered as a rough surface, in which roughness is a function of different environmental conditions. This surface produces diffuse reflection of the signal (dispersion) and it is considered that only a fraction of the energy incident on this surface is directed towards the receiving antenna and its contribution could be considered negligible [7].

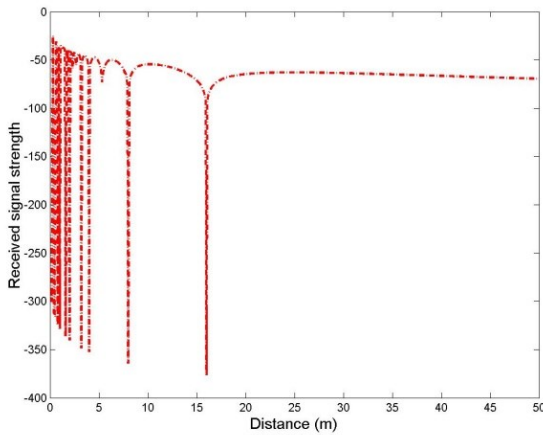


Fig. 1. Signal Strength variation due to Effect of de specular reflection as function of distance.

IV. MODEL OF BUOYS AFFECTED BY IRREGULAR SEA

In a scenario where communication is between buoys, which transmit / receive, antennas are at low altitude above sea level, waves may have a block effect, especially in severe meteorological conditions [2]. Under normal conditions, the fluctuation of the buoy or floating object due to the waves may be reflected as a change in the height of the antenna position [9]. This change of height is due to the dynamics of the swell and the buoy or floating object. Waves have different origin and shape, depending on many physical, geological and meteorological factors, having many theories developed on this important subject [3], [10]. A widely used model is the trochoidal waveform is given by the equations:

$$x = x_0 + a \sin(kx_0 - \omega t) \quad (3a)$$

$$y = a \cos(kx_0 - \omega t) \quad (3b)$$

Where (x_0, z_0) is a point on the surface at rest on the water surface, $a = H/2$ is the height of the wave, $k = 2\pi/\lambda$, is the wave number and $\omega = 2\pi/T$ is the frequency and T is the period of the same. However, in nature, the waves are far from being sinusoidal or trochoidal due to the interaction of themselves and the various mechanisms that generate them. More closer to reality is the generalization of the last expressions, so that we can consider that the

wave as the sum of several frequency components in form of the Fourier series [3]:

$$x = x_m - \sum_m^N a \sin(k_n x_n - \omega_n t + \delta_n) \quad (4a)$$

$$y = \sum_n^N a \cos(k_n x_n - \omega t + \delta_n) \quad (4b)$$

Where δ_n is an arbitrary phase angle.

Taking into account the above, and applying theories on the random nature of ocean waves, this can be obtained, as well as their different variables, such as height, wavelength, energy, etc., of their respective spatial of temporary spectrum [3],[10]. In the case of wave height, the spectrum S_h can be considered [3]:

$$S_h(k) = \frac{\beta}{k^2} \exp\left(-1/(k^2 L^2)\right) \left| \hat{k} \cdot \hat{\omega} \right| \quad (5)$$

To obtain waves with random height, the following equation can be used:

$$h_0 = \frac{1}{\sqrt{2}} (\gamma_a + \gamma_b) \sqrt{S_n(k)} \quad (6)$$

Where γ_a, γ_b are independent Gaussian random variables with mean equal zero and variance 1. The angle of arrival to the antenna is obtained from the relative position between transmitter and receiver, considering that the antennas are located at the center of the buoys and without loss of generality and for the sake of simplification, neither the pitch angle nor the yaw were considered.

V. SIMULATION AND ANALYSIS

The simulations carried out to analyze propagation behavior in marine environments, considered the effect of waves between two nodes of the WSN (IEEE 802.15.4) affected for the perturbation of the signals due to the ocean waves. For this it was considered that the elements of the wireless sensor network are installed inside buoys with an antenna height above sea level of 1.5 meters using a dipole antenna.

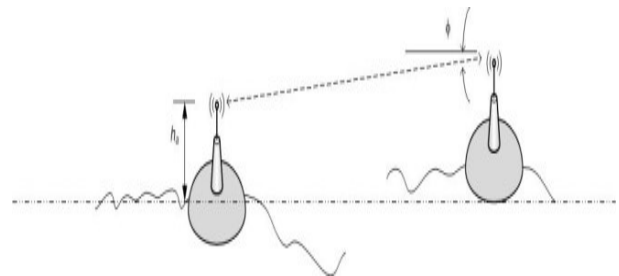


Fig. 2. Model of sea buoy communications link.

The scenario of the simulations is shown in figure 2 in which the link between the transmitter and the receiver installed in the buoys is shown, as would be the application of the wireless sensor network for monitoring physical marine variables or another application. In the figure, it can be seen that the height of the antennas is variable according to the variations of the swell in an irregular sea (tide). Also the figure shows the angle

between the transmitting antenna, which varies depending on the position and the effect of the wave. This will affect the power of the signal received because the maximum antenna gain will not always match the angle of arrival AOA. For the simulations, the ocean wave conditions shown in Table 1 were considered as well as the physical parameters used for the simulation, which are those established for the wireless sensor network technology standard (IEEE 802.15.4), as well as the previously described scenario.

On the other hand, both in calm and rough sea conditions the sea can be considered as a rough surface which affects the propagation of the reflected beams, which are mostly dispersed [3],[10] and those reaching the receiving antenna contribute with numerous signal components, generally small in magnitude compared to the direct signal or line of sight and being added this, it contributes to the incoherent component of the signal. The parameters for the performance evaluation of irregular sea channel model are summarized in Table I.

Table I. Simulations parameters

Simulation parameter	Value
Carrier frequency	2.4 Ghz
Transmit Power	18 dBm
Antenna	Dipole
Sea States	1, 2, 3 y 4
Data rate	250 kbps
antennas height	1.5 m

In the evaluation of the propagation scenarios established in the previous sections were carried out by means of the numerical calculation and visualization program Matlab™. Figure 3 shows the performance obtained in terms of the bit error probability considering the parameters of Table I given for different sea state conditions.

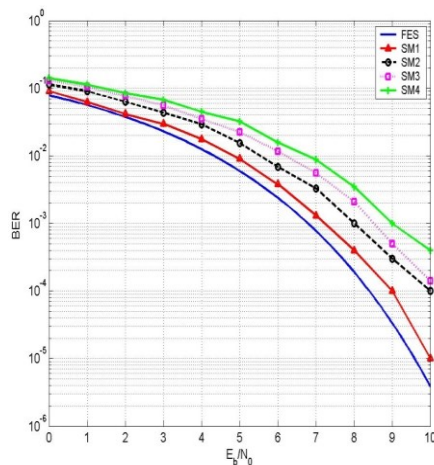


Fig. 3. Bit error rate vs. bit energy to noise level ratio,

for different values of sea state; SM1: sea state 1, SM2: sea state 2, SM3: sea state 3, SM4: sea state 4, FS: Free space.

In the graph we can observe the effect of the irregular sea considering only the variation of the height of the waves at the link for different sea states, compared with the graph of performance in which this disturbance is not considered. Buoys have been considered to be stabilized.

VI. CONCLUSION

In this work, the performance of a point-to-point (node-to-node) connection of a wireless sensor network based on the characteristics of the IEEE 802.15.4 standard for irregular sea conditions was analyzed by simulation. By means of simulations, we compare the performance of the radio link between two nodes for different sea states. For the generation or recreation of the waves, the method used was to obtain the different components using the Phillip spectrum [3], although other models can be used. The use of this method facilitates and makes the wave simulation efficient, allowing it to use few hardware resources.

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