Sea Turtles Geolocalization in the Indian Ocean: An Over Sea Radio Channel framework integrating a trilateration technique

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Sea Turtles Geolocalization in the Indian Ocean: An Over Sea Radio Channel framework integrating a trilateration technique

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Abstract. This paper deals with the modeling of the over sea radio channel and aims to establish sea turtles localization off the coast of Reunion Island, and also on Europa Island in the Mozambique Channel. In order to model this radio channel, a framework measurement protocol is proposed. The over sea measured channel is integrated to the localization algorithm to estimate the turtle trajectory based on Power of Arrival (PoA) technique compared to GPS localization. Moreover, cross correlation tool is used to characterize the over sea propagation channel. First measurement of the radio channel on the Reunion Island coast combine to the POA algorithm show an error of 18 m for 45% of the approximated points.

1. Introduction

Assessing functional habitats for marine species is critical for conservation and management purposes. Since the 1990s, the development of tags that records the positions of marine species has enabled scientist to better determine these habitats. Sea turtles track are currently on the list of endangered species by the International Union for Conservation of Nature (IUCN). Hence, a better scientific knowledge about these species ecology is a critical need. French Research Institute for Exploitation of the Sea [1] wants to set up a localization system of sea turtles. There are different devices for the marine animal localization available on the market, but they are most often expensive and researchers have no access to the algorithms used to estimate animal positions. To overcome these disadvantages, we have chosen to use several radio modules, associated with different localization algorithms [2] that involve gateways to be placed on the coast. The distances between sea turtles and gateways will be in the order of kilometers, which is acceptable for this type of localization. Juvenile turtles that we focus the study on are generally foraging in coastal areas. Sea turtles can reach peak speeds of the order of 35 $km.h^{-1}$ and can have very short times spent at the surface to breathe between $[100\ ms; 500\ ms]$ and more longer times in $[2\ mins; 3\ mins]$ [3]. In addition, we take into account the radio conditions of the over sea environment, which may be extreme in some cases [4, 5] as waves, wind and sea spray. These elements alter the signal drastically. This is why we decide to model the over sea radio channel conditions, in order to adapt the Radio Frequency (RF) technologies and the algorithms used to attain the best possible accuracy on turtle localization.

Table 1: Channel profile of scenario 1 and scenario 2.

	Scenario 1		**Scenario 2**	
Paths	Delay (μs)	Mean gain (dB_m)	Delay (μs)	Mean gain (dB_m)
1	0	-0.38	0	-3.39
2	18.38	-5.00	11.73	-5.36
3	27.19	-4.73	26.89	-5.14

2. Benchmark and radio channel measurement

To model the over sea radio channel, we made a terrestrial measurement framework composed of a Turtle Transmitter (TT) and Gateway Receiver (GR). Software Define Radio technology is used to perform an easy and fast post-processing on the computer. Thus, the TT and GR devices are configured at a carrier frequency $f_c = 868\ MHz$ like the LoRa European Band with a transmit power $T_x = 9\ dBm$ with a sensitivity of $-148\ dB_m$. To realize a radio channel power profile we use a specific sequence called Seq of length $N = 456\ bits$ and processed with a sample rate $f_r = 10\ MHz$. Thanks to this, we are able to have a path resolution channel in the order of 100 ns. The Seq sequence is not encoded to protect itself and it's known by TT and GRs. Moreover, Seq is transmitted directly to consume the least amount of energy as possible and preserve the battery life on the TT. Also, for the same reason the transmit power T_x can not increased and is fixed. On the receiver side, a cross correlation algorithm is implemented along an observation window W to extract some channel profiles using a specific modulation like GFSK. Different experimental scenarios are done with the strong hypothesis that the TT is quite static for the moment and always on the ground. Also, multiple initial conditions are varied to analyze their influence on the RF signal propagation. First of all, the height h of the GR is varied in order to study its influence on the reception quality: multi-path, delay path, path loss. Then, we changed the distance d between the TT and the GR to highlight the signal attenuation.

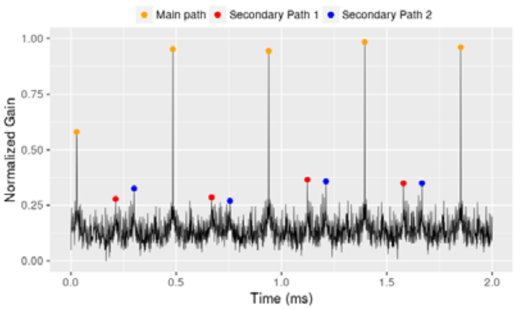

Figure 1: Scenario 1 normalized channel profile at $d = 20\ m$, $h = 1\ m$ and $W = 2\ ms$.

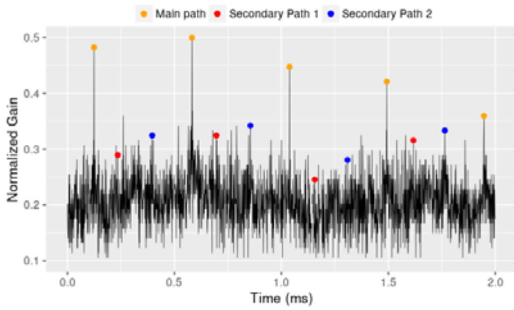

Figure 2: Scenario 2 normalized channel profile at $d = 20\ m$, $h = 0\ m$ and $W = 2\ ms$.

The results obtained by these two scenarios show the importance of the GR height. A more precise analysis of scenario 1 and 2 results shows that different secondary paths occurred and disturbed the main signal path. Table 1 summarizes the channel profiles for two scenarios.

Figure 3 presents the localization results realized on Omnet++ simulator combined with Matlab to simulate the propagation channel. On the left side of the figure 3 the localization is done by using an ideal channel called FreePathLoss and on the right side with the realistic channel model from the scenario 2. The algorithm used here is the Power Of Arrival (POA). The scenario 2 channel implementation gives more realistic results and this is why we integrate the over sea channel model. Actually, we did terrestrial experiments on radio beacon localization using POA algorithm. So, in a first time we introduce the POA algorithm used for the experiments then we present the first results for the terrestrial experiments.

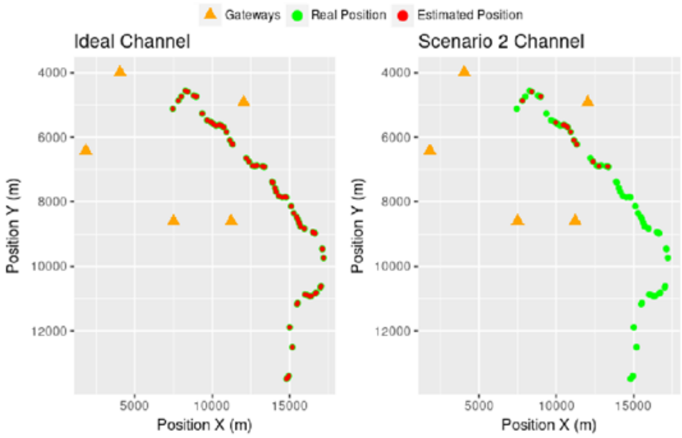

Figure 3: Localization of a turtle by trilateration using POA on ideal channel model and scenario 2 channel model.

3. Sea turtle localization algorithm based on PoA

To geolocalizate the sea turtles, we decide to use the multilateration [7] in order to approximate their relative positions to a given gateway called *master*. To be able to compute the distance between the sea turtles and the gateways, we do the strong hypothesis that we are in a line-of-sight situation in a classical free space path loss channel. Thanks to this hypothesis, we can approximate the distances between the sea turtles and the gateways. Thus, to do it we use a metric called the Receive Signal Strength (RSS). This metric corresponds to the receive signal power of each gateway. By knowing the signal power during the transmission and the RSS, it's possible to compute the distance between a given sea turtle and a given gateway using the following Friiz equation :

$$d = \frac{\lambda}{4\pi} \times \frac{1}{\sqrt{\frac{1}{P_t G_t G_r} \times 10^{\frac{P_r - 30}{10}}}} \tag{1}$$

With d is the distance between the transmitter and the receiver in meters; p_r is the Received Signal Strength in dB_m; p_t the Transmit power in Watt; G_t and G_r are respectively the linear gain of the transmitter antenna and the receiver antenna; λ is the signal wave length in meters. By knowing a minimum of three distances from a given turtle and the gateways, it is possible to estimate the sea turtle position by computing circle intersections. Each circle should be centered on a gateway with a radius that corresponding to the distance from this gateway to the sea turtle unknowing position. This is how the POA algorithm works. For validating the sea turtle approximated position, we decided to use the Global Position System (GPS) that provides the real sea turtle position at each transmission time with an error range between one and two meters. These values are based on real experiments. To be able to compare the position estimated by the POA algorithm and the GPS position, a projection of the geographic coordinates need to be done on a two dimensional plan. This projection should be relative to the master gateways for the comparison. The figure 4 presents the results obtained by a coastal experimentation. We use three gateways and one radio transmitter representing the sea turtle.

This figure shows also the paths followed by the turtle and its position at each transmission time. The purple points represent the differents approximated positions. So, the the algorithm is able to approximate 31 positions over 68. This represent 45% of the positions. For these approximated positions, we have mean error of 18 meters.

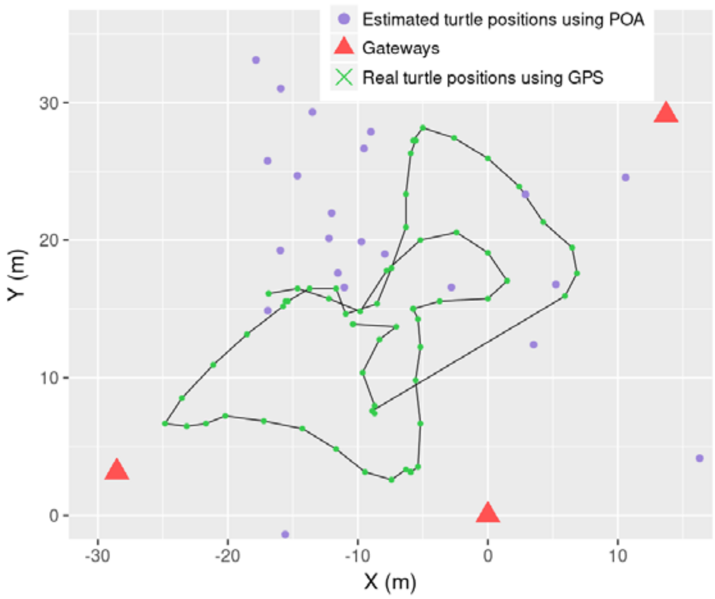

Figure 4: Results from POA experimentation.

4. Conclusion

In this article we show how to model an RF channel in real conditions using a correlation technique with a resolution of 100 ns. This approach has been validated for coastal purpose based on parameters such as the height or the distance. The height of the different gateways on the coast will be very important for the localization accuracy. Moreover our coastal experiment shows that localization in the over sea radio channel will not be easy. In fact, with line of sight communication channel we are able to approximate 48% of the total positions with 18 meters mean error. The results confirm that it is possible to geolocalize radio beacons using our technique for terrestrial purposes. The next step is to integrate the over sea radio channel to be able to do geolocalization experiments on sea turtles. To achieve this goal, we are planning to carry out measurement campaigns to be able to characterize the over sea radio channel. In this way, we will take into account the effects of the radio channel on the localization accuracy.

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