Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**Seaport Path Loss Model for Fixed Wireless Applications**
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Re:	Call for Contributions IEEE 802.16 Relay Task Group, dated April 06, 2006 (IEEE 802.16j-06/001) This contribution responded to the second sub-item of the third item: Channel model
Abstract	This document provides a submission that describes a seaport radio path loss model suitable for fixed wireless applications.
Purpose	This is for use by the Relay Task Group to evaluate air interface performance
Notice	
Release	
Patent Policy and Procedures	

Seaport Path Loss Model for Fixed Wireless Applications

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Introduction

Due to the rapid development of the Internet, more and more users in anchored or moving ships in seaports hope to access broadband IP services. Although the users may access the Internet services via the GPRS or satellite links, the access is normally limited due to the small bandwidth or the limited channels available. WiMAX can be a good candidate to provide broadband services to the ship users since the Fixed Wireless Applications has potential data rate of several Mbps or several tens Mbps and a relatively long cell radius of tens kilometers [1]. In order to build an IEEE802.16 network to provide broadband services to the seaport users, a wireless channel model in seaport environments is necessary for evaluation of the air interface performance of the Fixed Wireless Applications. However, to the knowledge of the authors so far, the channel models for Fixed Wireless Applications previously proposed to the IEEE 802.16 Task Group just include models in urban and suburban environments [2]; a path loss model for Fixed Wireless Application in seaport environments cannot be fund in current available IEEE802.16 documents. In this document, we propose an empirical seaport path loss model for the Fixed Wireless Applications. This document is to fill the above mentioned blank and to serve as a supplement to the path loss models in urban and suburban land environments proposed in [2].

The Proposed Seaport Path Loss Model

The seaport path loss model proposed in this document is given by

$$PL = A + 10\gamma \log 10\left(d/d_0\right) + s + \Delta PL_f \quad \text{[dB] for } d>d_0, \qquad (1)$$

where

- $A = 20\log 10\left(4\pi d_0/\lambda\right)$ (λ is the wavelength in m), d_0=100 m, d is the Tx-Rx distance in m
- $\gamma = a - b\times h_b + c/h_b$, a=2.358, b=0.00145, and c=0.45, h_b is the base antenna height between 4 m to 185 m
- s is a zero mean Gaussian variable with standard deviation $\sigma = l - m\times\sqrt{h_b} + n/\sqrt{h_b}$ [dB], l=7.6, m=0.35, and n=6.4, h_b is between 4 m to 185 m
- ΔPL_f =6log10(f /5800), f is frequency in MHz

The path loss above means, $PL = P_t+G-P_r$ [dB], where P_t is the transmitter power in dBm, G (dB) includes the effect of antenna gain and the cable loss, and P_r is the mean received power in dBm.

Testing Environment and Data Collection Method

The path loss measurement is carried out in Singapore Port, which is one of the busiest ports in the world. It has a typical seaport environment with many ships anchored or moving in the port as shown in Fig. 1 [3]. The sea wave height in good weather condition is about 1 m. Due to the sea environment, the radio channel properties of the seaport are different from the urban and the suburban environments and it is necessary to be studied for evaluation of the performance of the Fixed Wireless Applications specially.

The testing configuration diagram is schematically shown in Fig. 2. The transmitter was fixed on the shore or on the top of a tall building. The receiver is amounted on a ship. During the measurements, the receiver ship stops on different locations to change the transmitter-receiver distance. GPS is used to keep track of the separation distance between the transmitter and receiver. As the transmitter is at a fixed location in one measurement scenario, only the receiver is required to read the GPS position. In the test, the GPS is read every second by a laptop and time-stamped automatically. In the measurement, the separation between the transmitter and the receiver can be far as 18 km.

Three experiment scenarios were implemented: two in east side of the Singapore Port and one in the West Coast of the Singapore Port. In the three experiments, the base station antenna heights are 4 m, 76 m and 185 m (to the mean sea surface), respectively. The receiver antenna height is about 8 m (to the mean sea surface). The base station antenna and the receiver antenna are both omni directional. The radio-frequency of the continue wave (CW) in measurements is 5.8 GHz.

The receiver antenna is connected to a spectrum analyzer. For continuous data acquisition, the spectrum is connected through Ethernet cable to a laptop. The laptop will record peak power reading from the spectrum analyzer with the laptop's timestamp. The measured data are averaged every 30 seconds to average the fast local fading due to multipath. In addition the roll of the receiver ship can provide spatial averaging of the fast local fading in some degree.

Process Building the Seaport Path Loss

A general path loss model is used in building the seaport path loss model similarly to the method used in [4]. The general path loss model is given by

$$PL = A + 10\log10\left(d/d_0\right) + s \quad \text{for } d > d_0, \qquad (2)$$

where d_0 is the close-in reference distance [2], [4], $A = 20\log10\left(4\pi d_0/\lambda\right)$ (λ is the wavelength in m) is the path loss at the reference distance d_0, and s is a zero-mean Gaussian variable with standard deviation σ describing the shadowing effect [4].

By setting a typical reference distance for macrocell d_0=100 m [2], the scatter plot for the cases with base station antenna heights 4 m, 76 m and 185 m are shown in Fig. 3, Fig. 4 and Fig. 5, respectively. The blue points in the three figures are the averaged path loss, and the read lines are the linear regression results with Minimum Mean Square Error (MMSE) constraint for the measured data. In Table I, the analyzed path loss exponent γ and the standard deviation σ are listed.

Table I. Results of the linear regression with MMSE constraint for seaport path loss measurements.

Base antenna height (m)	4	76	185
γ	2.462	2.259	2.090
σ	10.084	5.111	3.362

By curve fitting as shown in Fig. 6, the change of the path loss exponent measured with the antenna height h_b is given by

$$\gamma = a - b \times h_b + c/h_b , \qquad (3)$$

where a=2.358, b=0.00145, and c=0.45, and the h_b is between 4 m to 185 m. Similarly, the curve fitting of the standard deviation of s to the antenna height is shown in Fig. 7, and is given by

$$\sigma = l - m \times \sqrt{h_b} + n/\sqrt{h_b} \text{ [dB]}, \qquad (4)$$

where l=7.6, m=0.35, and n=6.4, h_b is between 4 m to 185 m.

Since our measurements were carried out at 5.8 GHz, the path loss in seaport environment is needed to be corrected if applied to other close frequencies [5]. When a typical value of α=0.6 is used, where α is the parameter describing the path loss changes with frequency by $f^{2+\alpha}$ [5], the frequency correction term is given by

$$\Delta PL_f = 6\log10(f/5800) \text{ [dB]}, \qquad (5)$$

where f is the frequency in MHz. The parameter α may deviates from 0.6 depending on the detailed environment [5].

References

[1] IEEE Standard for Local and Metropolitan area networks, Part 16: Air Interference for Fixed Broadband Wireless Access Systems, IEEE 802.16™-2004

[2] V. Erceg, et.al, “Channel Models for Fixed Wireless Applications,” IEEE 802.16a-03/01

[3] http://www.geog.umontreal.ca/Geotrans/fr/ch5fr/conc5fr/singportfr.html

[4] V. Erceg., et.al, “An empirically based path loss model for wireless channels in suburban environments,” IEEE JSAC, vol. 17, no. 7, July 1999, pp. 1205-1211.

[5] T.-S. Chu and L.J. Greenstein, “A quantification of link budget differences between the cellular and PCS bands,” IEEE Trans. Veh. Technol., vol. 48, no. 1, Jan. 1999, pp. 60-65.

Fig. 1. A view of the Singapore Port [3].

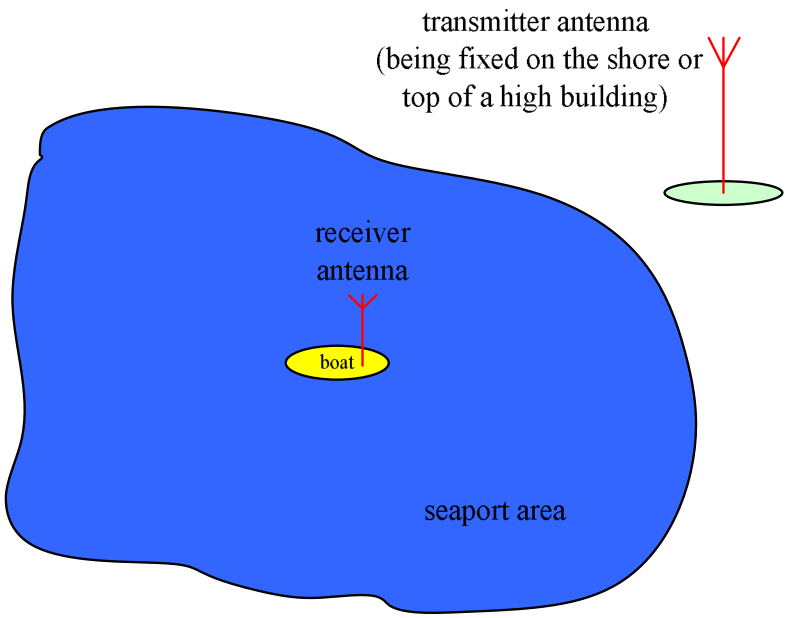

Fig. 2 Schematic diagram of radio path loss measurement in seaport environments.

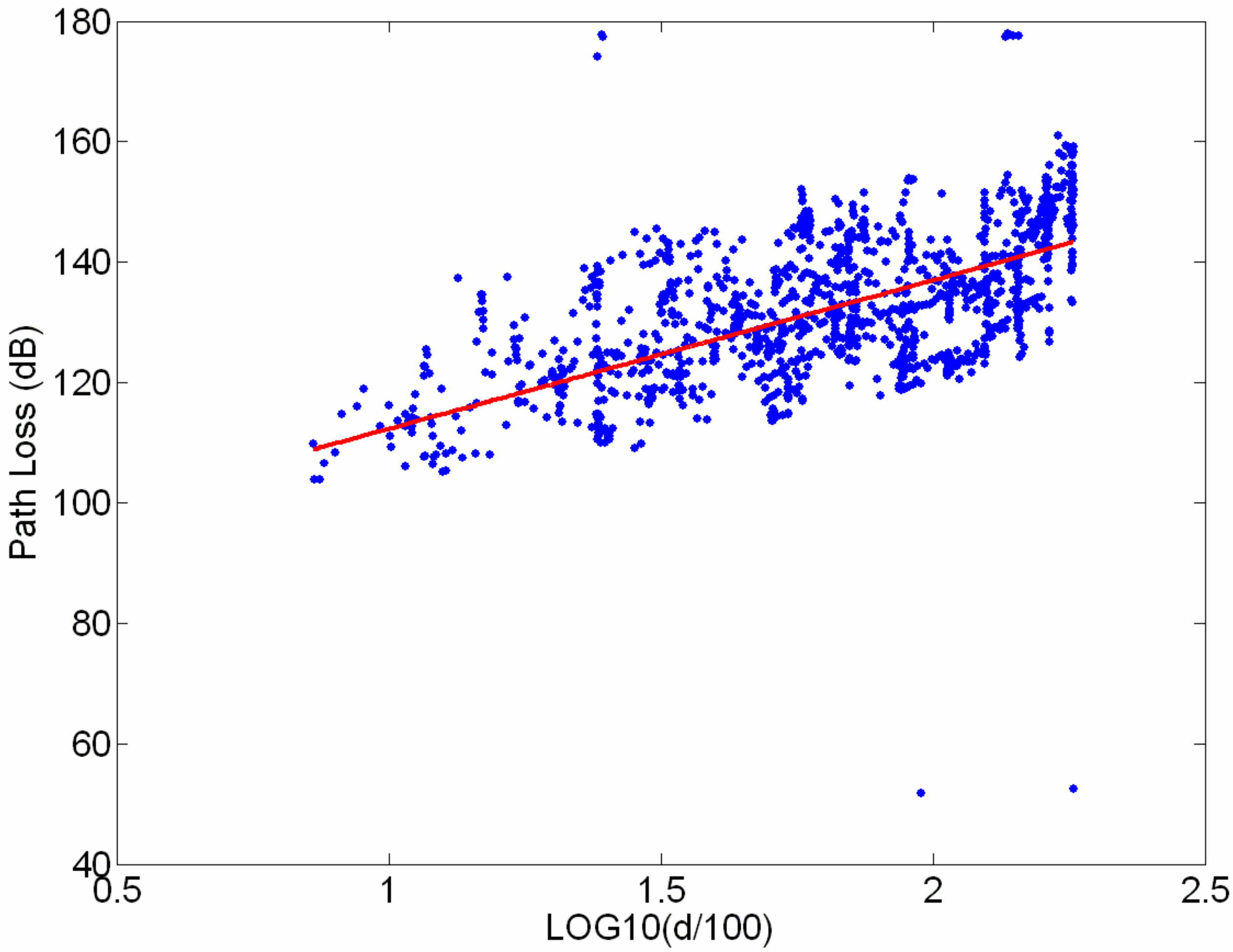

Fig. 3 Scatter plot for path loss measurement at frequency 5.8 GHz in the Singapore Port with base station antenna height of 4 m. The path loss exponent is analyzed to be γ=2.462, and the standard deviation of s is σ=10.084 [dB].

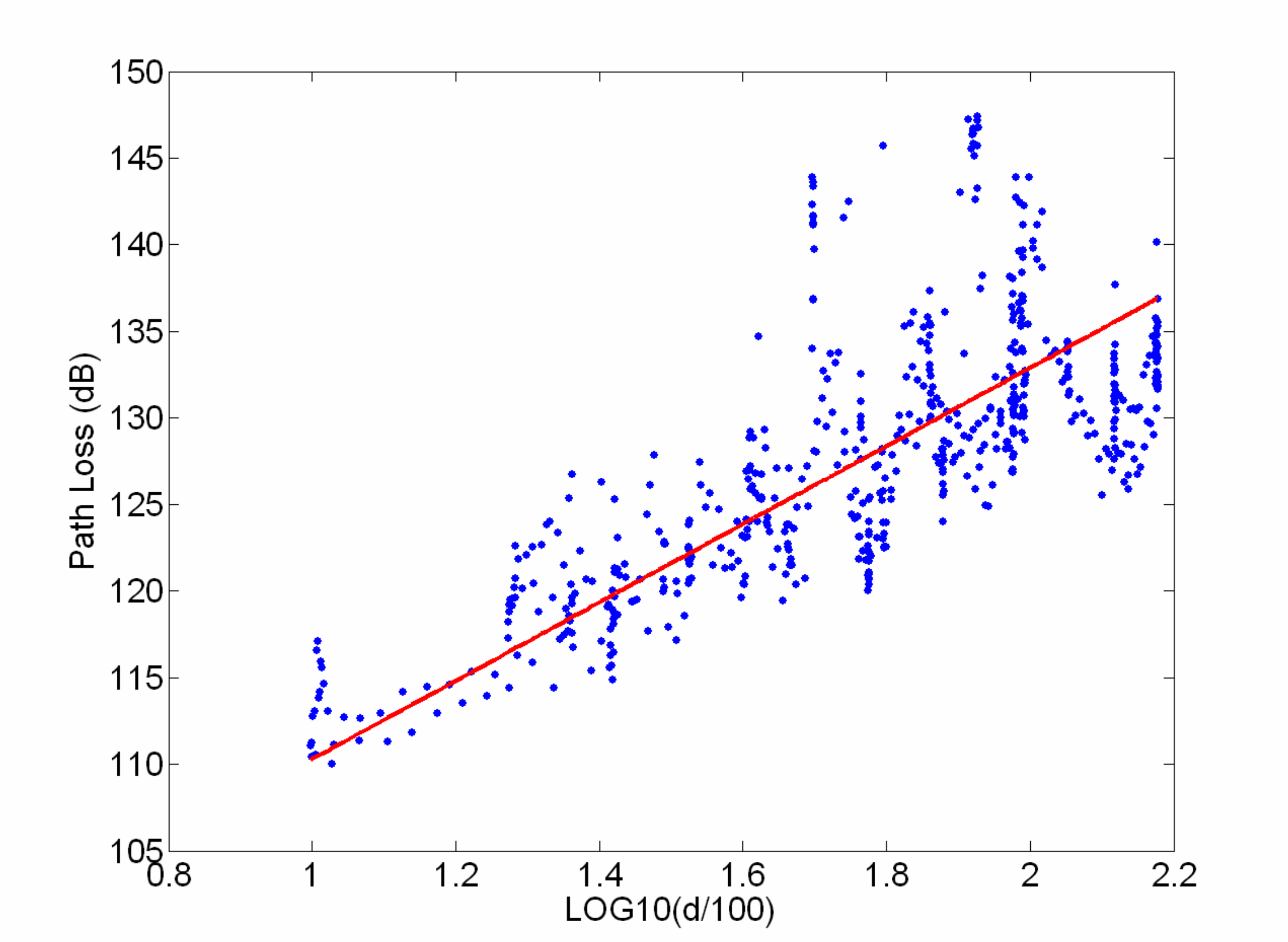

Fig. 4 Scatter plot for path loss measurement at frequency 5.8 GHz in the Singapore Port with base station antenna height of 76 m. The path loss exponent is analyzed to be γ=2.259, and the standard deviation of *s* is σ=5.111 [dB].

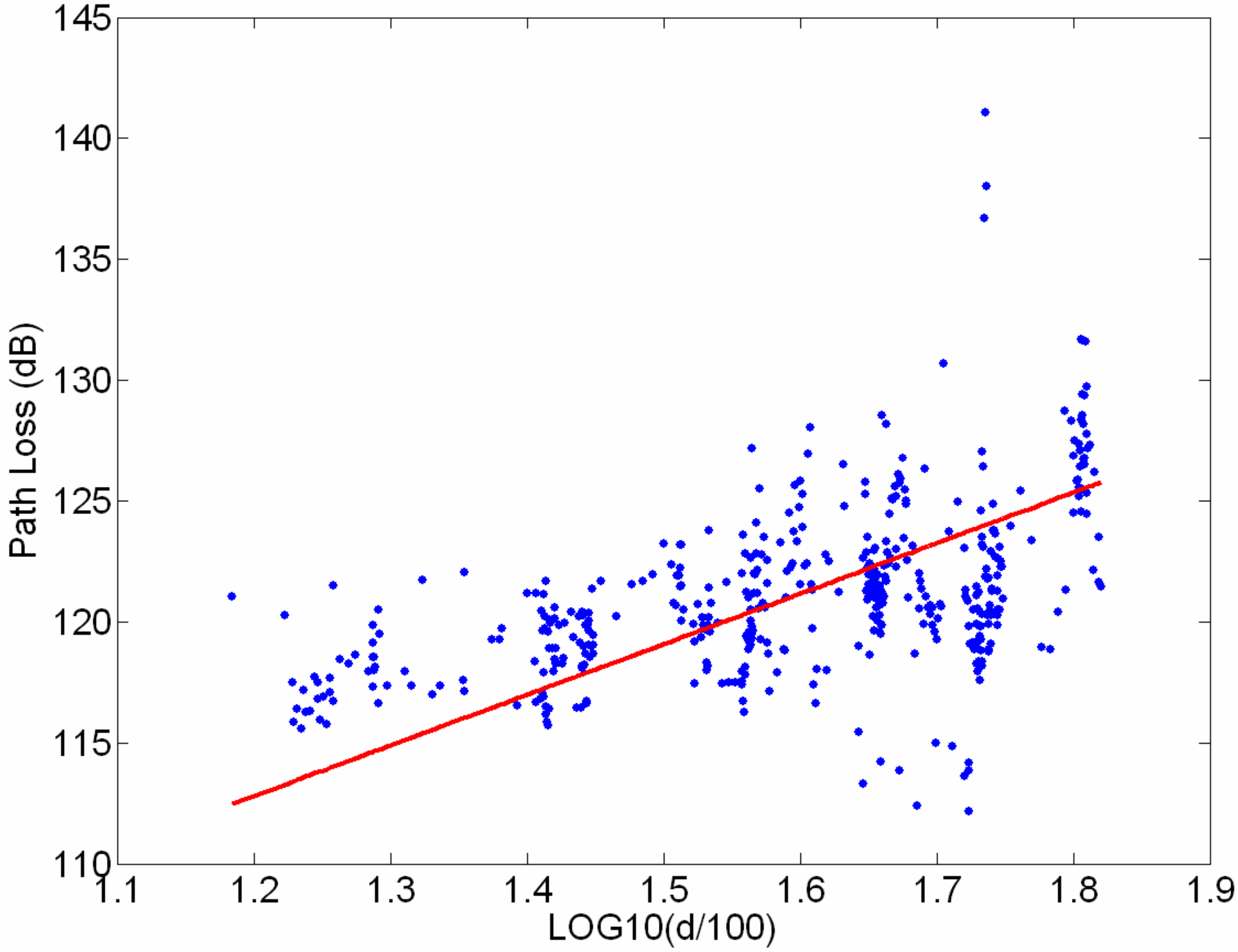

Fig. 5 Scatter plot for path loss measurement at frequency 5.8 GHz in the Singapore Port with base station antenna height of 185 m. The path loss exponent is analyzed to be γ=2.090, and the standard deviation of s is σ=3.362 [dB].

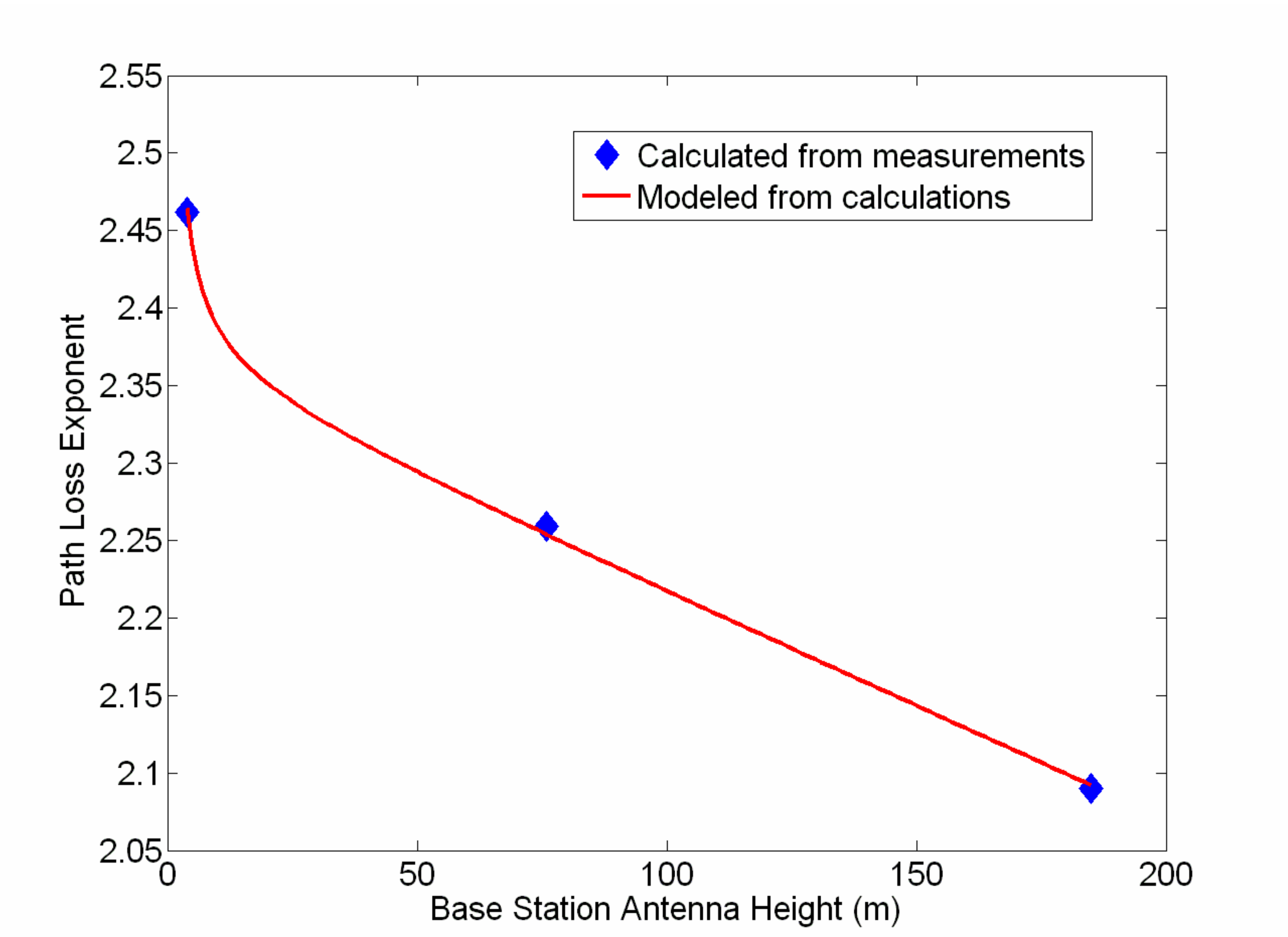

Fig. 6 Curve-fitting of the seaport path loss exponent to the base station antenna height. The curve fitted can be described by: $\gamma(h_b) = a\text{-}b\times h_b+c/h_b$, where a= 2.358, b= 0.00145, and c= 0.45, and the h_b is between 4 m to 185 m.

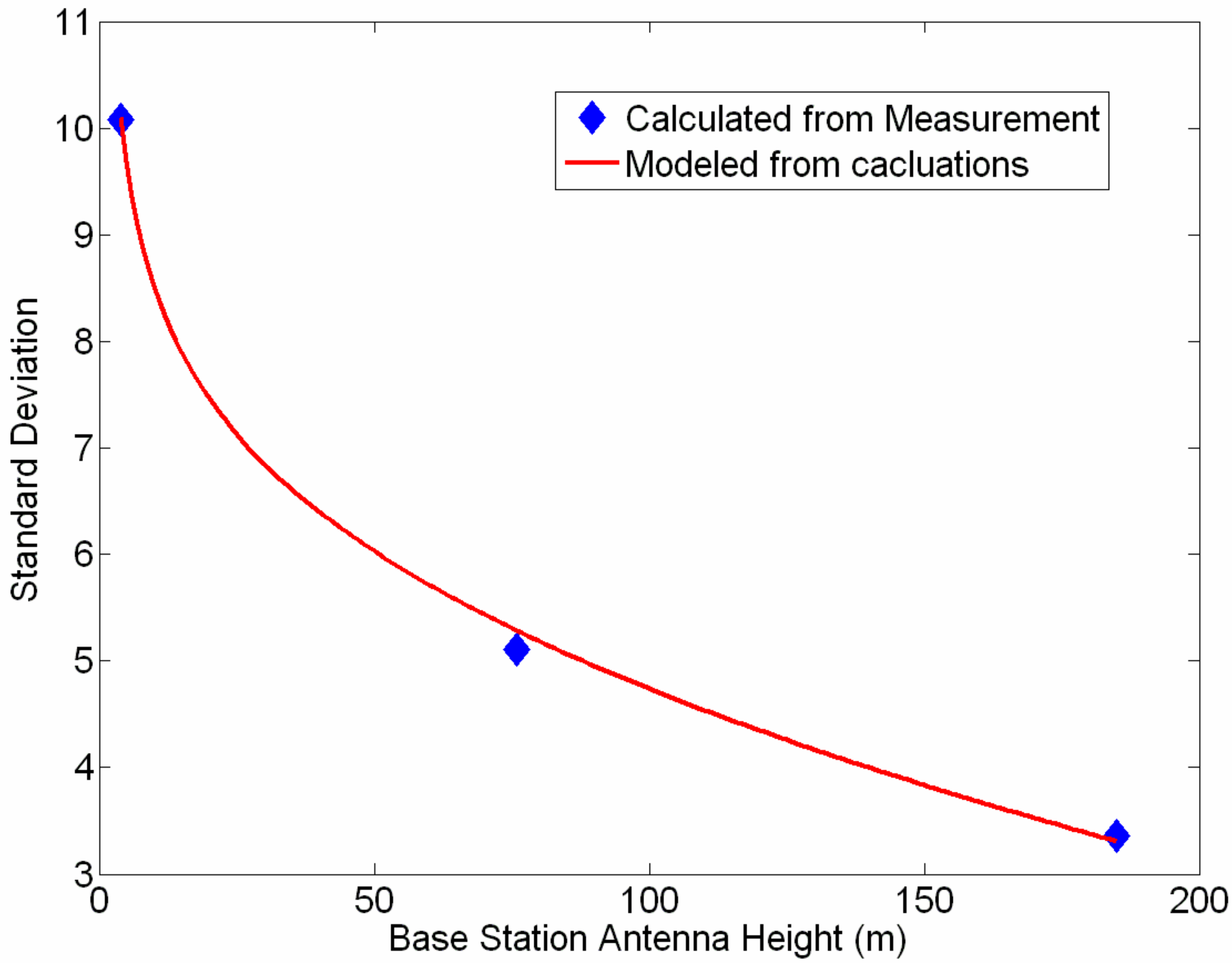

Fig. 7 Curve-fitting of the seaport *s* standard deviation to the base station antenna height. The curve fitted can be described by: $\sigma = l - m \times \sqrt{h_b} + n / \sqrt{h_b}$ [dB], where l=7.6, m=0.35, and n=6.4, h_b is between 4 m to 185 m.