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Calibrating the Standard Path Loss Model for Urban Environments using Field Measurements and Geospatial Data

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The susceptibility of the wireless channel to both signal fading and interference has made ***efficient radio network planning*** a vital part of the pre-deployment process in cellular systems [1].

The reliability of the radio network planning, toward optimal coverage, largely depends on the ***accuracy of the path loss prediction models*** that are employed [2].

Introduction

Introduction (*Cont'd*)

Findings from previous research [3-7] showed that the prediction results of widely used empirical path loss models do not match, in general, the field measurement data collected on the *local terrains* in Nigeria.

Hence, the need for ***model calibration*** that will improve the accuracy of the models so as to truly represent the actual signal propagation behavior of the target local environments of Nigeria.

Research Aim

- This research work is aimed at improving the prediction accuracy of the Standard Propagation Model (SPM) to the specific case of Lagos, Nigeria, by adequately ***accounting for the effect of local geographic features*** within the urban propagation environments.

Materials and Method

- Extensive measurement campaigns were conducted in the ***dense suburban*** *(Locations A and B)* and ***dense urban*** (*Locations C and D*) areas of Lagos to collect Received Signal Strength (RSS) data over GSM networks operating at 1800 MHz.

Materials and Method (*Cont'd*)

- In order to reduce the prediction error, automatic model calibration was performed in ATOLL radio network planning tool based on the geospatial data:
    - *Clutter height;*
    - *Clutter classes;*
    - *Altitude*; and
    - *Elevation* of the area under study.

Materials and Method (*Cont'd*)

- Field measurements data collected at Locations *A* and *C* were used for ***model calibration*** while Locations *B* and *D* served as the ***model verification*** sites.
- The performance of the SPM and the calibrated SPM were compared using the following statistical performance metrics:
  - *Mean Absolute Error (MAE);*
  - *Root Mean Square Error (RMSE);*
  - *Standard Deviation (SD).*

Generally, the RSS decreased as the distance between the Base station and the mobile station increased, as expected.

The RSSL varies randomly between -43 dBm and -100 dBm.

The calibration process significantly changed the model parameters, as shown in Table 1.

- *In fact, the calibrated SPM accounted for **additional path losses of 25 dB** in the urban environments.*

Results and Discussion

Table 1: Calibration Result of SPM for Urban Environments

Parameter	Description	Before	After
H_t Method	-	Abs Spot H_t	Slope at receiver
Diffraction Method	-	Deygout	Deygout
K_1	-	22	51.4
K_2	log (d)	44.9	20
K_3	log (h_t)	5.83	20
K_4	Diffraction	1	0
K_5	log (d) .log (h_t)	-6.55	-4.97
Additional Losses	Clutter Losses	0	25

Results & Discussion (Cont'd)

Results and Discussion (Cont'd)

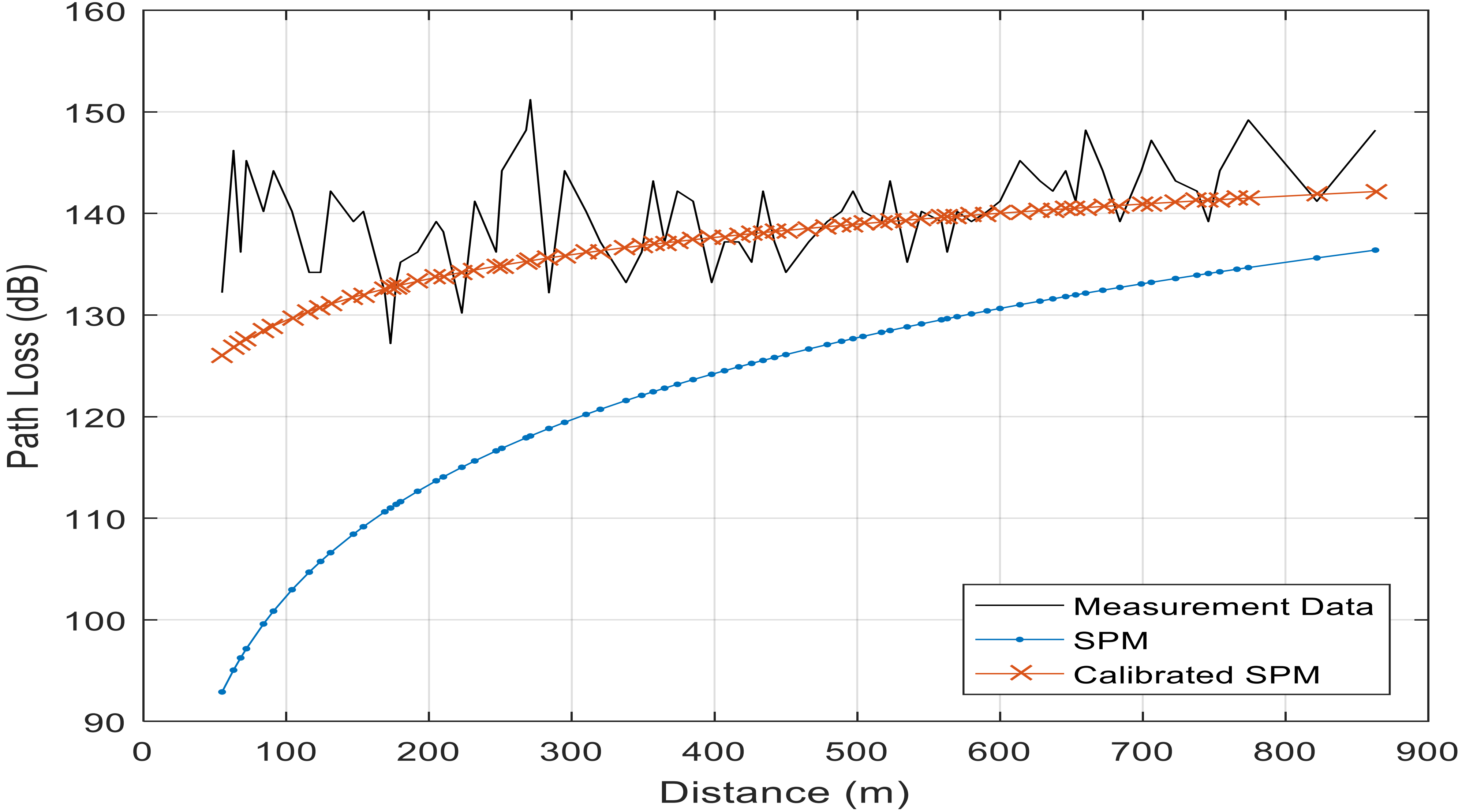

Figure 1: Path Loss Predictions in Location A (Dense Suburban)

Results and Discussion (Cont'd)

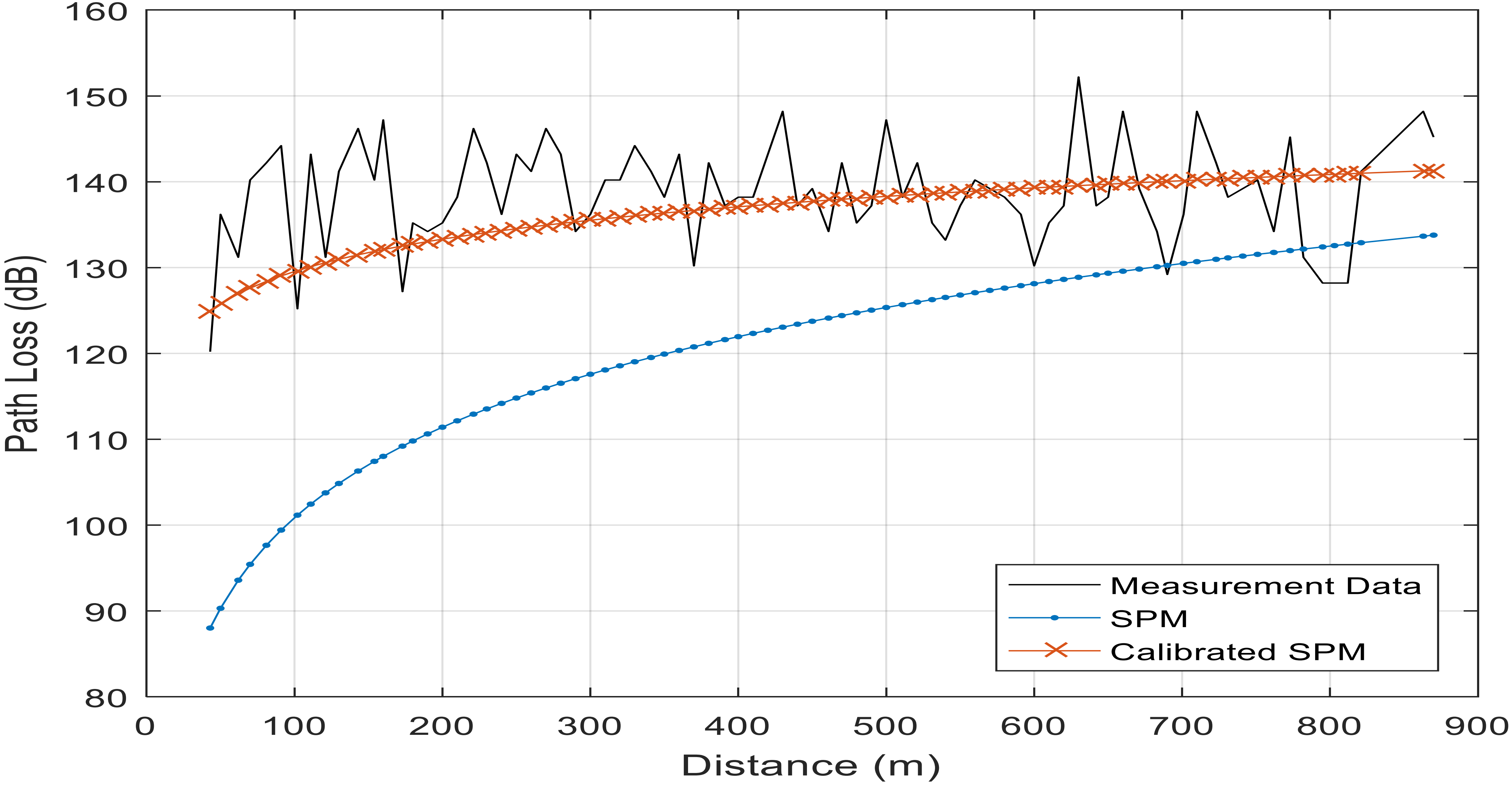

Figure 2: Path Loss Predictions in Location B (Dense Suburban)

Results and Discussion (Cont'd)

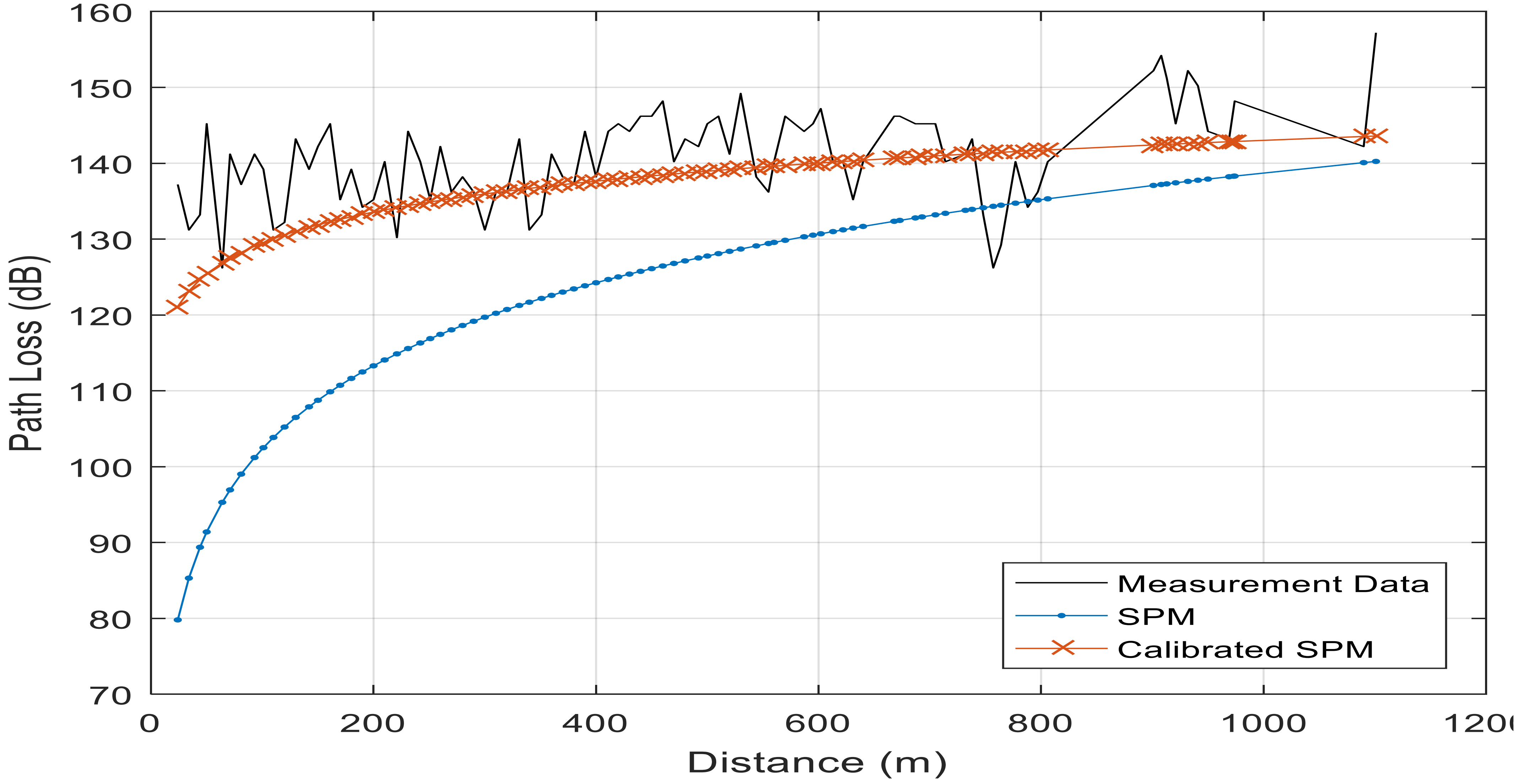

Figure 3: Path Loss Predictions in Location C (Dense Urban)

Results and Discussion (Cont'd)

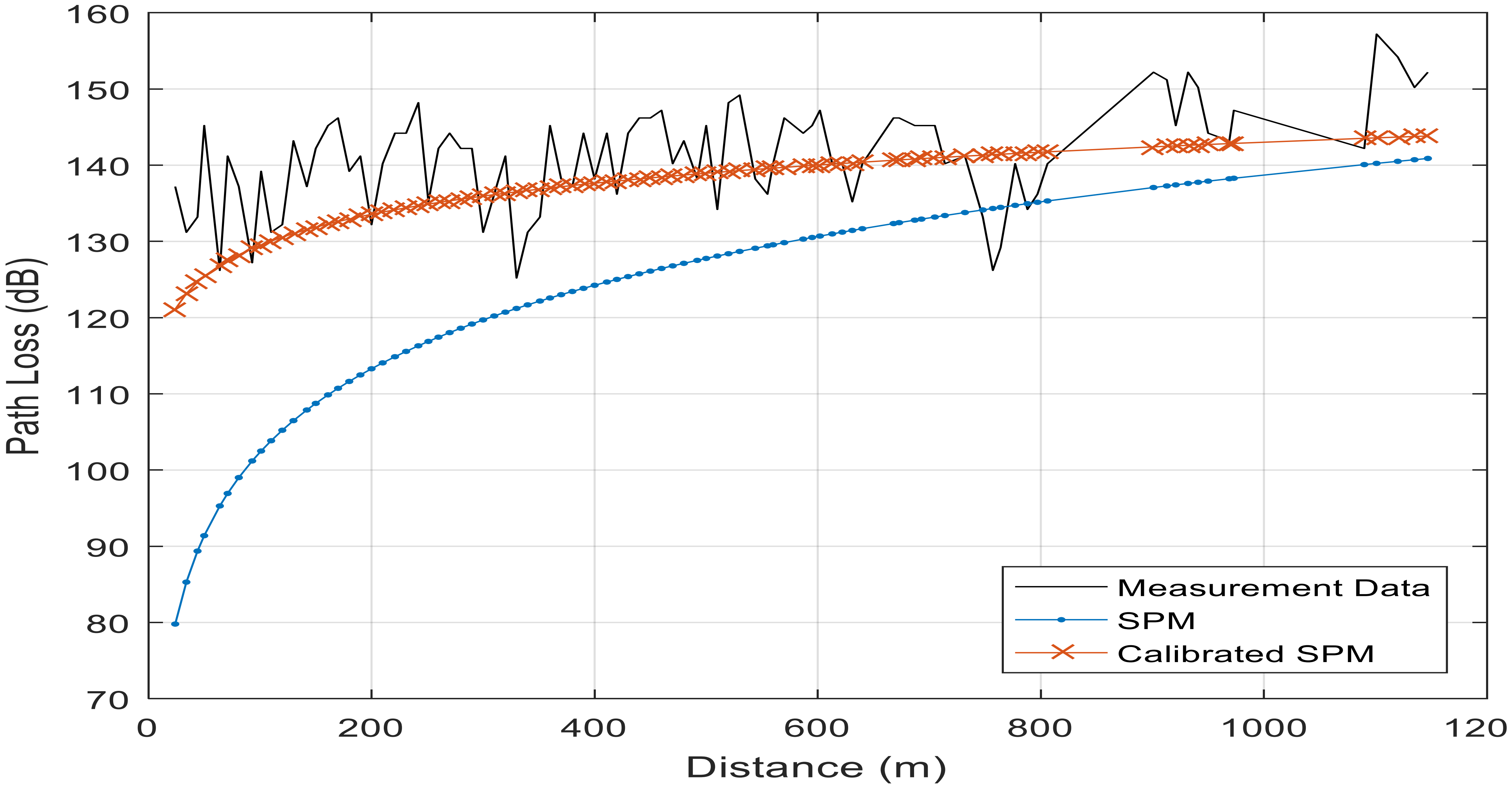

Figure 4: Path Loss Predictions in Location D (Dense Urban)

Results and Discussion (Cont'd)

Table 2: Performance Evaluation of the Model Calibration for Dense Suburban Areas.

	Location A (Calibration Site)		**Location B (Verification Site)**	
	SPM	**Calibrated SPM**	**SPM**	**Calibrated SPM**
MAE (dB)	18.28	**4.49**	18.60	**5.56**
RMSE (dB)	21.16	**6.17**	21.81	**7.03**
SD (dB)	10.65	**4.24**	11.40	**4.31**

Results and Discussion (Cont'd)

Table 3: Performance Evaluation of the Model Calibration for Dense Urban Areas.

	Location C (Calibration Site)		Location D (Verification Site)	
	SPM	**Calibrated SPM**	**SPM**	**Calibrated SPM**
MAE (dB)	18.15	**5.49**	18.26	**6.07**
RMSE (dB)	21.49	**6.96**	21.75	**7.46**
SD (dB)	11.51	**4.29**	11.83	**4.33**

Conclusion

- Our findings show that the calibrated SPM provides a significantly better fitness with the measured data collected.
- The average MAE, RMSE and SDE across all the routes are ***5.40, 6.90*** *and* ***4.29***, respectively.
- These values are much lower when compared with default values obtained with SPM (***18.32 dB, 21.55 dB*** *and* ***11.34 dB***, respectively) prediction results in the study area.

Conclusion

- In detail, we found that the calibrated SPM accounted for additional path losses of 25 dB in the urban environments.
- Thus, a generic and optimized model equation was provided for path loss as given by equation (1):

$$PL(dB) = 51.4 + 20log(d) + 20log(h_t) - [4.97log(d)\text{x}log(h_t)] \quad (1)$$

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