Heliyon 5 (2019) e01656

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.heliyon.com

Performance investigation of different pathloss models for a wireless communication system in Nigeria

O.G. Igbinosa [a], U.K. Okpeki [b,*]

[a] Department of Electrical/Electronic Engineering, University of Benin, P.M.B 1154, Benin City, Edo State, Nigeria
[b] Department of Electrical/Electronic Engineering, Faculty of Engineering, Delta State University, Oleh Campus, Oleh, Nigeria

ARTICLE INFO

Keyword:
Electrical engineering

ABSTRACT

Television is an electronic communication system that is capable of transmitting, processing and receiving information by wireless medium. This work is aimed at investigating the performance of selected pathloss models for wireless communication. In this work, two TV stations were considered for investigation. The work presents a field measurement conducted at 645.00 MHz (station 1) and 698.00 MHz (station 2) in Abuja. The measurement were taken for each TV station with a handheld RF field strength spectrum analyzer and a Garmin 72H GPS receiver. In this work, we assessed the performance of ten selected pathloss models and in comparison with pathloss model based on propagation measurements taken from selected TV stations. These pathloss model were subjected to performance metrics: Mean Prediction Error (MPE) and Root Average Squared Prediction Error (RASPE) to ascertain their suitability and applicability in the environment under consideration. The RASPE is the most apparent metric for analyzing error of predictive models. The results of the prediction provide detailed error analysis of the existing pathloss models. The acceptable radio prediction value for TV is 10 dB. The lower the value, the better the performance. Besides, the ten existing prediction models gave RASPE values in excess of 10 dB. Therefore, this translates to the fact that these models do not fully predict the pathloss for TV broadcasting in Abuja.

1. Introduction

The television system is an electronic communication system that is capable of transmitting, processing and receiving of information by wireless means. Television broadcasting is an instrument used by social, political, economic, business, religious and educational organizations to disseminate information to their viewers. Television system is also used for surveillance, industrial process control and guiding of weapons, in places where direct observation is difficult or dangerous [1]. The far-reaching demand for wireless communication technologies is ever increasing in all the human-life activities and this has boosted the development of wireless networks [2, 3, 4, 5, 6]. Television signal, like radio waves are electromagnetic in nature, which when radiated from transmitting antennas travel through space to distant places and are picked up by receiving antennas. The difference of signal strength from transmitter to receiver antenna is termed pathloss. In communication systems, pathloss is a very important issue for quite a while now, with new prediction models with extended frequencies, we need to know which model is suitable for different application and different environment [7, 8, 9, 10, 11]. Pathloss at destination is generally determined by the use of different models [12, 13, 14, 15].

In this work, existing empirical models such as Free space, Extended COST-231 Hata, Okumura, Plain-Earth model, Egli, Ericsson, Davidson, Hata, COST-231 Hata and Walfish-Ikegami were considered for this study. Estimating propagation pathloss is important in order to predict the performance of wireless system in its working environment.

2. Materials and methods

The materials and methodologies adopted for the realization of this work are as follows:

i. **Field Strength Measurement:** The essence of this research work is to investigate the performance of different pathloss models for wireless communication. To achieve this, two Television stations were considered for investigation. The field strength from these TV broadcasting stations were measured along five different routes, starting from each of the broadcasting stations. The

* Corresponding author.
E-mail address: ufuomakazeem@gmail.com (U.K. Okpeki).

https://doi.org/10.1016/j.heliyon.2019.e01656
Received 4 December 2018; Received in revised form 20 March 2019; Accepted 1 May 2019

Table 1
Comparison of measured pathloss with selected models for station 1 (route 1).

Distance (km)	Measured Mean Pathloss (dB)	Model Pathloss (dB)									
		FSPLM	OKPLM	HPLM	PEPLM	C231H	WI	EGLI	E-C231H	ERICSSON	DAVIDSON
1.10	146.85	89.52	121.29	119.37	81.88	120.86	99.87	120.11	117.89	105.31	12278
2.13	148.77	95.26	129.53	128.85	93.36	130.34	107.33	131.63	127.37	114. 03	131.69
5.22	150.46	103.04	140.81	141.71	108.93	140.20	117.45	142.23	140.22	125.85	138.71
8.85	151.51	107.63	147.40	149.28	118.10	146.77	123.41	145.43	147.80	132.82	142.71
9.23	153.87	107.99	148.26	149.88	118.83	150.37	123.89	148.17	148.40	133.37	147.26
10.33	157.79	108.97	150.34	151.50	120.78	151.99	125.16	149.11	150.02	134.86	152.74
11.29	161.29	109.74	151.21	152.77	122.33	153.26	126.16	151.66	151.29	136. 03	153.90
11.44	161.47	109.86	151.33	152.96	122.56	153.45	126.31	151.91	151.48	136.21	154. 08
12.22	163.33	110.43	152.00	153.91	123.70	155.40	127.05	154.2	152.43	137. 08	154.94
12.60	163.56	110.70	152.27	154.35	124.24	155.84	127.40	154.51	152.87	137.48	155.34
15.37	164.72	112.42	154.19	157.20	127.69	158.69	129.64	158.01	155.72	140.10	157.92
17.22	164.76	113.41	156.18	158.83	129.66	160.32	130.93	160.99	157.35	141.60	159.38

FSPLM = Free Space Pathloss Model; HPLM = Hata Pathloss Model; OKPLM = Okumura Pathloss Model; PEPLM = Plain-earth Pathloss Model; C231H = COST_231 Hata; WI = Walfish-Ikegami Model; Egli = Egli Model; E-C231H = Extended COST-231 Hata Model; Ericsson = Ericsson Model; Davidson = Davidson Model.

Table 2
Comparison of measured pathloss with selected models for station 1 (route 2).

Distance (km)	Measured Mean Pathloss (dB)	Model Pathloss (dB)									
		FSPLM	OKPLM	HPLM	PEPLM	C231H	WI	EGLI	E-C231H	ERICSSON	DAVIDSON
1.10	147.77	89.52	121.29	119.37	81.88	120.86	99.87	120.11	117.89	105.31	122.78
2.13	149.87	95.26	129.53	128.85	93.36	130.34	107.33	131.63	127.37	114.03	131.69
2.20	153.39	95.54	129.81	129.31	93.92	130.80	107.69	132.28	127.83	114.45	132.12
4.18	155.21	101.11	137.88	138.52	105. 07	140. 01	114.94	143.41	137.04	122.92	140.74
7.46	161.59	106.15	144.91	146.83	115.13	148.32	121.48	153.47	145.35	130.56	148.45
12.08	163.59	110.33	151.10	153.74	123.50	155.22	126.92	161.84	152.26	136.74	154.79
15.18	163.67	112.32	154.09	157.02	127.47	158.50	129.50	165.79	155.54	139.94	157.76
18.87	163.81	114.21	157.08	160.14	131.25	161.62	131.96	169.58	158.66	142.81	160.55

Table 3
Comparison of measured pathloss with selected models for station 1 (route 3).

Distance (km)	Measured Mean Pathloss (dB)	Model Pathloss (dB)									
		FSPLM	OKPLM	HPLM	PEPLM	C231H	WI	EGLI	E-C231H	ERICSSON	DAVIDSON
1.10	149.37	89.52	121.29	119.37	81.88	120.86	99.87	120.11	117.89	105.31	122.78
2.13	153.25	95.26	129.53	128.85	93.36	130.34	107.33	131.63	127.37	114.03	131.69
5.22	158.59	103.04	140.81	141.71	108.93	143.19	117.45	147.23	140.22	125.85	143.71
9.23	163.83	107.99	148.26	149.88	118.83	151.37	123.88	157.17	148.40	133.37	151.26
12.41	165.07	110.57	151.44	154.13	123.97	155.62	127.23	162.29	152.65	137.28	155.14
13.06	165.25	111.01	152.08	154.86	124.86	156.35	127.81	163.19	153.38	137.95	155.80
14.21	165.41	111.74	152.91	156.07	126.32	157.56	128.76	164.65	154.59	139.07	156.90
14.87	165.75	112.14	153.31	156.72	127.11	158.21	129.27	165.44	155.24	139.67	157.49

Table 4
Comparison of measured pathloss with selected models for station 1 (route 4).

Distance (km)	Measured Mean Pathloss (dB)	Model Pathloss (dB)									
		FSPLM	OKPLM	HPLM	PEPLM	C231H	WI	EGLI	E-C231H	ERICSSON	DAVIDSON
1.10	149.37	89.52	121.29	119.85	81.88	120.86	99.87	120.11	117.89	105.31	122.78
2.13	153.25	95.26	129.53	128.85	93.36	130.34	107.33	131.63	127.37	114.03	131.69
4.06	153.55	100.86	137.63	138.10	104.56	139.59	114.61	142.87	136.62	122.54	140.35
4.51	153.89	101.77	138.64	139.61	106.39	141.10	115.80	144.70	138.13	123.92	141.75
5.11	155.13	102.86	140.63	141.15	108.56	142.89	117.21	146.91	139.92	125.57	143.17
5.18	155.29	102.98	140.75	141.59	108.79	143.08	117.36	147.12	140.11	125.75	143.60
5.22	158.59	103.04	140.81	141.71	108.93	143.19	117.45	147.23	140.22	125.85	143.71
6.19	157.21	104.52	142.79	144.15	111.89	145.64	119.37	150.23	142.67	128.10	145.97
6.81	157.75	105.35	144.12	145.52	113.55	147.01	12045	151.86	144.04	129.36	147.24
7.40	158.39	106.08	144.84	146.71	114.99	148.20	121.39	153.32	145.23	130.46	148.34
7.84	158.63	106.58	145.45	147.54	115.99	149.03	122.04	154.31	146.06	131.22	149.11
8.08	159.09	106.84	146.61	147.97	116.52	149.46	122.38	154.84	146.49	131.62	149.50
8.49	159.41	107.27	147.04	148.68	117.38	150.17	122.94	155.72	147.20	132.27	150.15
8.85	159.79	107.63	147.40	149.28	118.10	150.77	123.41	156.42	147.80	132.82	150.71
9.23	163.83	107.99	148.26	149.88	118.83	151.37	123.89	157.17	148.40	133.37	151.26

Table 5
Comparison of measured Pathloss with selected models for station 1 (route 5).

Distance (km)	Measured Mean Pathloss (dB)	Model Pathloss (dB)									
		FSPLM	OKPLM	HPLM	PEPLM	C231H	WI	EGLI	E-C231H	ERICSSON	DAVIDSON
1.10	146.85	89.52	121.29	119.37	81.88	120.86	99.87	120.11	117.89	105.31	12278
2.13	148.77	95.26	129.53	128.85	93.36	130.34	107.33	131.63	127.37	114. 03	131.69
5.22	150.46	103.04	140.81	141.71	108.93	140.20	117.45	142.23	140.22	125.85	138.71
8.85	151.51	107.63	147.40	149.28	118.10	146.77	123.41	145.43	147.80	132.82	142.71
9.23	153.87	107.99	148.26	149.88	118.83	150.37	123.89	148.17	148.40	133.37	147.26
10.33	157.79	108.97	150.34	151.50	120.78	151.99	125.16	149.11	150.02	134.86	152.74
11.29	161.29	109.74	151.21	152.77	122.33	153.26	126.16	151.66	151.29	136. 03	153.90
11.44	161.47	109.86	151.33	152.96	122.56	153.45	126.31	151.91	151.48	136.21	154. 08
12.22	163.33	110.43	152.00	153.91	123.70	155.40	127.05	154.2	152.43	137. 08	154.94
12.60	163.56	110.70	152.27	154.35	124.24	155.84	127.40	154.51	152.87	137.48	155.34
15.37	164.72	112.42	154.19	157.20	127.69	158.69	129.64	158.01	155.72	140.10	157.92
17.22	164.76	113.41	156.18	158.83	129.66	160.32	130.93	160.99	157.35	141.60	159.38

Table 6
Comparison of measured pathloss with selected models for station 2 (route 1).

Distance (km)	Measured Mean Pathloss (dB)	Model Pathloss (dB)									
		FSPLM	OKPLM	HPLM	PEPLM	C231H	WI	EGLI	E-C231H	ERICSSON	DAVIDSON
1.10	146.20	90.21	122.32	120.36	82.01	122.12	100.56	120.94	119.15	105.82	123.55
1.82	146.53	94.58	127.59	127.59	90.75	129.35	106.24	129.76	126.38	112.46	130.34
1.85	149.72	94.72	128.13	127.83	91.04	129.59	106.43	130.07	126.62	112.68	130.57
3.25	152.88	99.62	134.83	135.92	100.83	137.68	112.79	139.85	134.71	120.11	138.16
4.06	155.36	101.55	137.46	139.11	104.69	140.87	115.30	143.70	137.90	123.05	141.14
4.07	155.32	101.57	137.58	139.15	104.73	140.91	115.33	143.76	137.94	123.08	141.17
4.26	156.36	101.97	138.48	139.81	105.53	141.56	115.84	144.57	138.59	123.68	141.79
4.82	156.59	103.04	140.75	141.58	107.67	143.34	117.24	146.67	140.37	125.31	143.44
4.85	156.69	103.09	140.90	141.67	107.78	143.34	117.31	146.78	140.46	125.39	143.52
4.99	157.11	103.34	141.25	142.08	108.27	143.84	117.63	147.29	140.87	125.77	143.91
5.81	161.90	104.66	142.67	144.26	110.92	146.02	119.35	149.94	143.05	127.78	145.93
6.60	165.48	105.77	144.68	146.09	113.13	147.85	120.79	152.15	144.88	129.46	147.63
9.58	166.52	109.00	149.92	151.44	119.60	153.20	124.99	155.62	150.23	134.37	152.57
11.72	167.70	110.76	152.17	154.34	123.11	156.10	127.27	158.13	153.13	137.04	155.23
15.03	167.79	112.92	155.03	157.91	127.43	159.67	130.08	161.45	156.7	140.32	158.48
17.62	167.68	114.30	157.21	160.20	130.19	161.96	131.88	163.22	158.99	142.41	160.55
19.52	167.76	115.19	159.10	161.67	131.27	163.43	133.03	165.39	160.46	143.47	161.46

Table 7
Comparison of measured pathloss with selected models for station 2 (route 2).

Distance (km)	Measured Mean Pathloss (dB)	Model Pathloss (dB)									
		FSPLM	OKPLM	HPLM	PEPLM	C231H	WI	EGLI	E-C231H	ERICSSON	DAVIDSON
1.10	146.10	90.21	122.32	120.36	82.01	122.12	100.56	120..94	119.15	105.82	123.55
1.82	146.66	94.58	127.59	127.59	90.75	129.35	106.24	129.76	126.38	112.46	130.34
1.85	152.70	94.72	128.13	127.83	91.04	129.59	106.43	130. 07	126.62	112.68	130.57
3.25	154.64	99.62	134.83	135.92	100.83	137.68	112.79	139.85	134.71	120.11	138.16
3.46	154.88	100.16	135.57	136.82	101.91	138.58	113.50	140.94	135.61	120.94	138.99
4.07	158.20	101.57	137.58	139.15	104.73	140.91	115.33	143.76	137.94	123. 08	141.17
4.33	158.38	102.11	139.22	140.04	105.81	141.8	116.03	144.83	138.83	123.90	142.00
4.41	158.68	102.27	139.88	140.30	106.13	142.6	116.24	145.15	139. 09	124.14	142.25
4.85	158.80	103.10	140.90	141.67	107.78	143.34	117.31	146.78	140.46	125.39	143.52
6.41	164.22	105.52	144.23	145.67	112.62	14743	120.46	151.64	144.46	129. 07	147.24
8.59	167.14	108.06	148.77	149.88	117.71	151.64	123.76	156.74	148.67	132.94	151.14
12.72	167.55	111.47	153.08	155.52	124.53	157.28	128.20	163.55	154.31	138.12	156.31
16.14	167.80	113.54	156.25	158.94	128.67	160.70	130.89	167.69	157.73	141.26	159.41
19.68	168.28	115.26	159.37	161.78	132.11	163.54	133.12	171.14	160.57	143.87	161.96

measurement were taken for each TV station with a handheld RF field strength spectrum analyzer and a Garmin 72H GPS receiver. Pathloss was computed from measured values of field strength obtained.

ii. **Evaluation and Comparison of Existing Pathloss Models with Measured Data:** The far-reaching demand for wireless communication technologies is ever increasing in all human-life activities and this has boosted the development of wireless systems. To estimate the performance of wireless channels, propagation models are used [16]. Pathloss models are used extensively in signal prediction, coverage analysis [17]. In order to find out the suitable propagation models applicable for propagation prediction in Abuja, the ten selected empirical models deployed were evaluated using available data of the TV broadcasting stations under investigation. Computations were made and compared with measured data as depicted in Tables 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10. The computations were done for the first 20km.

iii. **Model Evaluation**: In order to ascertain the suitability and applicability of these prediction models for prediction for Abuja, they were subjected to two novel metrics to gauge their

Table 8
Comparison of measured pathloss with selected models for station 2 (route 3).

Distance (km)	Measured Mean Pathloss (dB)	Model Pathloss (dB)									
		FSPLM	OKPLM	HPLM	PEPLM	C231H	WI	EGLI	E-C231H	ERICSSON	DAVIDSON
1.10	146.40	90.21	122.32	120.36	82. 01	122.12	100.56	120.94	119.15	105.82	123.55
1.82	146.78	94.58	127.59	127.59	90.75	129.35	106.24	129.76	126.38	112.46	130.34
1.85	150.56	94.72	128.13	127.83	91. 04	129.59	106..43	130.07	126.62	112.68	130.57
3.25	154.32	99.62	134.83	135.92	100.83	137.68	112.79	139.85	134.71	120.11	138.16
4.07	158.20	101.57	137.58	139.15	104.73	140.91	115.33	143.76	137.94	123. 08	141.17
4.85	160.80	103.10	140.90	141.67	107.78	143.43	117.31	146.78	140.46	125.39	143.52
8.13	163.50	107.58	147.59	149.09	116.75	150.85	123.14	155.77	147..88	132.21	150.51
9.13	165.60	108.59	149.30	150.75	11877	152.51	124.45	157..78	149.54	133.74	151.94
10.61	166.32	109.89	151.00	152.91	121.38	154.67	126.15	160.40	151.70	135.72	153.92
12.01	166.72	110.97	152.48	154.69	123.53	156.45	127..55	162.55	153.48	137.36	155.55

Table 9
Comparison of measured pathloss with selected models for station 2 (route 4).

Distance (km)	Measured Mean Pathloss (dB)	Model Pathloss (dB)									
		FSPLM	OKPLM	HPLM	PEPLM	C231H	WI	EGLI	E-C231H	ERICSSON	DAVIDSON
1.07	146.10	89.97	121.38	119.96	81.53	121.72	100.24	120.42	118.75	105.45	123.17
1.10	146.40	90.21	122.32	120.36	82. 01	122.12	100.56	120.94	119.15	105.82	123.55
1.75	146.72	94.24	127.15	127.03	90. 07	128.79	105.80	129.14	125.82	111.94	129.82
1.82	146.78	94.58	127.59	127.59	90.75	129.35	106.24	129.76	126.38	112.46	130.34
2.04	152.50	95.57	129.48	129.23	92.74	130.99	107.53	131.79	128. 02	113.97	131.88
2.90	153.16	98.63	133.04	134.28	98.85	136. 04	111.50	137.85	133. 07	118.61	136.62
2.98	153.38	98.86	133.27	134.67	99.32	136.43	111.81	138.33	133.46	118.97	136.98
3.51	158.36	100.29	135.80	137.02	102.16	138.78	113.66	141.18	135.81	121.13	139.18
3.90	158.74	101.20	136.91	138.54	103.99	140.30	114.85	142.99	137.33	122.52	140.60

Table 10
Comparison of measured pathloss with selected models for station 2 (route 5).

Distance (km)	Measured Mean Pathloss (dB)	Model Pathloss (dB)									
		FSPLM	OKPLM	HPLM	PEPLM	C231H	WI	EGLI	E-C231H	ERICSSON	DAVIDSON
1.10	146.20	90.21	122.32	120.36	82.01	122.12	100.56	120.94	119.15	105.82	123.55
1.82	146.53	94.58	127.59	127.59	90.75	129.35	106.24	129.76	126.38	112.46	130.34
1.85	149.72	94.72	128.13	127.83	91.04	129.59	106.43	130.07	126.62	112.68	130.57
3.25	152.88	99.62	134.83	135.92	100.83	137.68	112.79	139.85	134.71	120.11	138.16
4.06	155.36	101.55	137.46	139.11	104.69	140.87	115.30	143.70	137.90	123.05	141.14
4.07	155.32	101.57	137.58	139.15	104.73	140.91	115.33	143.76	137.94	123.08	141.17
4.26	156.36	101.97	138.48	139.81	105.53	141.56	115.84	144.57	138.59	123.68	141.79
4.82	156.59	103.04	140.75	141.58	107.67	143.34	117.24	146.67	140.37	125.31	143.44
4.85	156.69	103.09	140.90	141.67	107.78	143.34	117.31	146.78	140.46	125.39	143.52
4.99	157.11	103.34	141.25	142.08	108.27	143.84	117.63	147.29	140.87	125.77	143.91
5.81	161.90	104.66	142.67	144.26	110.92	146.02	119.35	149.94	143.05	127.78	145.93
6.60	165.48	105.77	144.68	146.09	113.13	147.85	120.79	152.15	144.88	129.46	147.63
9.58	166.52	109.00	149.92	151.44	119.60	153.20	124.99	155.62	150.23	134.37	152.57
11.72	167.70	110.76	152.17	154.34	123.11	156.10	127.27	158.13	153.13	137.04	155.23
15.03	167.79	112.92	155.03	157.91	127.43	159.67	130.08	161.45	156.7	140.32	158.48
17.62	167.68	114.30	157.21	160.20	130.19	161.96	131.88	163.22	158.99	142.41	160.55
19.52	167.76	115.19	159.10	161.67	131.27	163.43	133.03	165.39	160.46	143.47	161.46

performance: Mean Prediction Error (MPE) and Root Average Squared Prediction Error (RASPE). Besides, the RASPE is the most apparent metric for analyzing error of predictive model. It is a measure of the difference between values predicted by a model and the values actually observed from the environment that is being modelled [18].

$$RASPE = \sqrt{\frac{\sum_{j=1}^{n}\left(X_{obs,j} - X_{model,j}\right)^2}{n}} \tag{1}$$

$$MPE = \frac{\sum X_{obs,j} - X_{model}}{n} \tag{2}$$

Table 11
Computed Mean Prediction Error values from Models for station 1 data.

ROUTES	MEAN PREDICTION ERROR (dB)									
	FSPLM	OKPLM	HPLM	PEPLM	C231H	WI	EGLI	E-C231H	ERICSSON	DAVIDSON
Route 1	50.78	11.13	9.81	41.36	9.24	35.32	10.05	11.30	26.14	9.74
Route 2	54.31	16.65	15.64	48.42	14.15	39.90	10.10	17.12	31.52	13.75
Route 3	55.66	17.11	15.62	47.62	14.09	40.58	9.31	17.06	31.71	13.93
Route 4	53.64	15.83	14.85	47.56	13.37	39.18	9.25	16.34	30.73	12.92
Route 5	50.78	11.13	9.81	41.36	9.24	35.32	10.05	11.30	26.14	9.74

Table 12
Computed RASPE values from Models for station 1 data.

ROUTES	ROOT AVERAGE SQUARED PREDICTION ERROR (dB)									
	FSPLM	OKPLM	HPLM	PEPLM	C231H	WI	EGLI	E-C231H	ERICSSON	DAVIDSON
Route 1	50.91	12.47	11.90	42.31	11.17	35.63	11.66	13.15	26.80	11.10
Route 2	54.38	17.83	17.61	49.65	16.30	40.23	14.96	18.93	32.28	15.46
Route 3	55.70	17.96	17.22	48.66	15.84	40.82	13.71	18.53	32.31	15.29
Route 4	53.70	16.39	15.75	48.06	14.36	39.35	11.55	17.16	31.08	13.76
Route 5	50.91	12.47	11.90	42.31	11.17	35.63	11.66	13.15	26.80	11.10

Table 13
Computed Mean Prediction Error values from Models for station 2 data.

ROUTES	MEAN PREDICTION ERROR (dB)									
	FSPLM	OKPLM	HPLM	PEPLM	C231H	WI	EGLI	E-C231H	ERICSSON	DAVIDSON
Route 1	54.78	16.91	15.68	49.29	13.92	40.33	11.63	16.89	32.06	13.99
Route 2	55.85	18.31	17.33	51.24	15.57	41.66	12.37	18.54	33.59	15.53
Route 3	55.83	18.75	17.92	52.16	16.16	41.93	13.15	19.13	34.06	16.01
Route 4	55.40	21.69	21.50	53.56	19.74	43.33	18.86	22.71	36.81	18.89
Route 5	54.78	16.91	15.68	49.29	13.92	40.33	11.63	16.89	32.06	13.99

Table 14
Computed RASPE values from Models for station 2 data.

ROUTES	ROOT AVERAGE SQUARED PREDICTION ERROR (dB)									
	FSPLM	OKPLM	HPLM	PEPLM	C231H	WI	EGLI	E-C231H	ERICSSON	DAVIDSON
Route 1	54.82	17.31	16.37	49.77	14.69	40.42	12.77	17.53	32.30	14.53
Route 2	55.88	18.75	18.05	51.77	16.36	41.76	14.46	19.21	33.85	16.11
Route 3	55.85	19.00	18.39	52.56	16.68	41.97	14.65	19.53	34.22	16.37
Route 4	55.44	21.77	21.68	53.90	19.93	43.38	19.26	22.88	36.89	19.06
Route 5	54.82	17.31	16.37	49.77	14.69	40.42	12.77	17.53	32.30	14.53

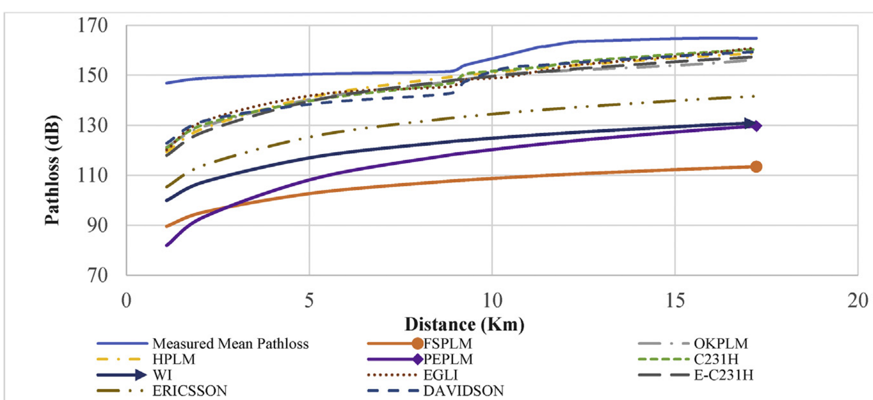

Fig. 1. Plot of measured pathloss and pathloss obtained from models for station1 (route 1).

Where, X_{obs} is the observed values and X_{model} is the modeled value at time/place, *j*

From the prediction error obtained, the mean prediction error and RASPE values were determined for each of the model used as shown in Tables 11, 12, 13, and 14. From Tables 12 and 14, the RASPE values from these existing models were in excess of 10dB.

2.1. Data presentation

The computations obtained from existing propagation models evaluation with data from station having frequency of 535.25MHz (station 1) are presented in Tables 1, 2, 3, 4, and 5 and that of the station with frequency of 590MHz (station 2) in Tables 6, 7, 8, 9, and 10. Besides, the computed MPE values and RASPE values from models for station 1 data are presented in Tables 11 and 12 and that of station 2 in Tables 13 and 14.

2.2. Data analysis

The computations obtained from models were compared with that of measured data and analyzed graphically. The graphical plots showing the comparison of the measured pathloss and the pathloss obtained from existing models are presented in Figs. 1, 2, 3, 4, and 5, for the different routes and stations under investigations. This is to enhance easy interpretation of the effect of pathloss variation with distance. From Tables 12, 13, and 14 the computed RASPE and MPE values for the ten models deployed in the investigation are high above the accepted performance standard of 10dB. To get relatively close to the acceptable performance value, the EGLI and DAVIDSON models have RASPE and

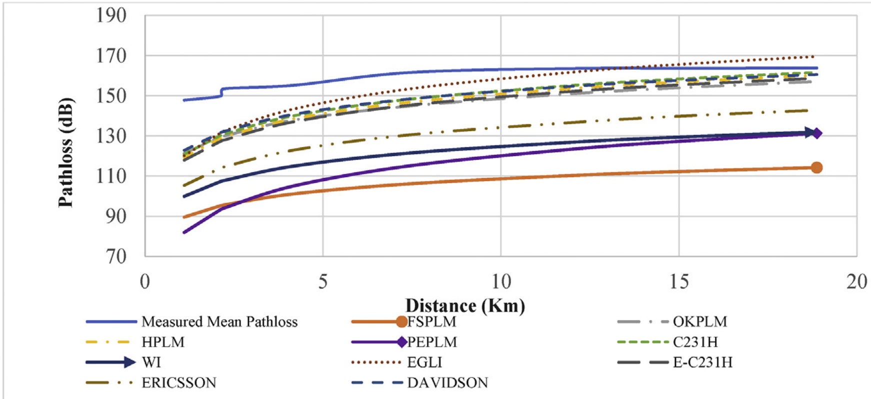

Fig. 2. Plot of measured pathloss and pathloss obtained from models for station1 (route 2).

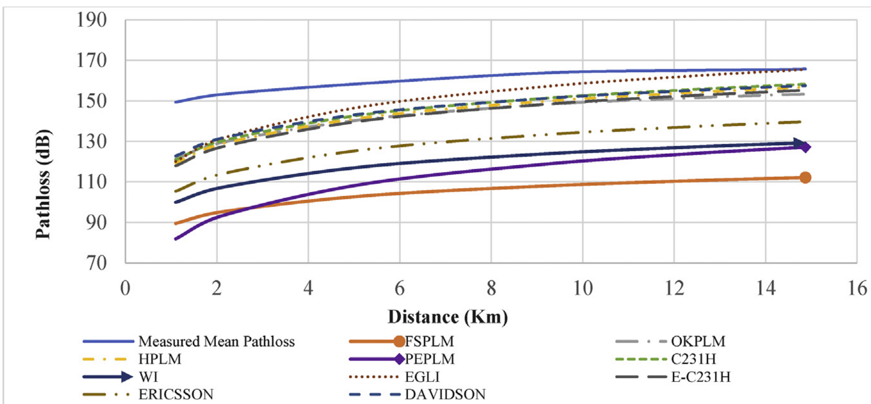

Fig. 3. Plot of measured pathloss and pathloss obtained from models for station1 (route 3).

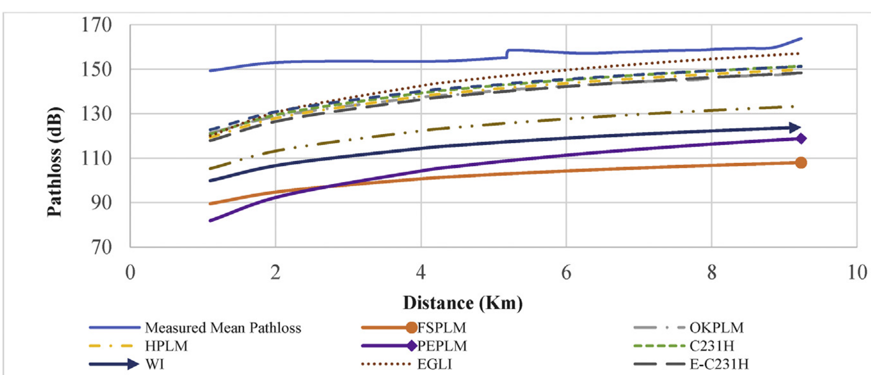

Fig. 4. Plot of measured pathloss and pathloss obtained from models for station1 (route 4).

MPE slightly close to the acceptable performance values and that is clearly shown in Figs. 1, 2, 3, 4, and 5.

3. Discussion

This research work is aimed at carrying out investigation on the performance of selected pathloss models for wireless communication. To achieve this, two TV stations were considered for investigation. The field strength from these TV broadcasting stations were measured with a handheld RF field strength spectrum analyzer and a Garmin 72H GPS receiver. Pathloss was computed from measured values of field strength obtained.

In this paper, we assessed the performance of ten selected pathloss models and in comparison with pathloss based on propagation measurements taken from these selected TV stations. These existing propagation models were evaluated using available data of the TV broadcasting stations under investigation. Computations were made and compared with measured data as shown in Tables 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10. In order to find out the suitability and applicability of these models, they were subjected to performance metrics: Mean Prediction Error (MPE) and Root Averaged Squared Prediction Error (RASPE) as presented in Tables 11, 12, 13, and 14. The pathloss obtained from models were compared with that from measurement and analyzed graphically. This is to enhance easy interpretation of the effect of pathloss

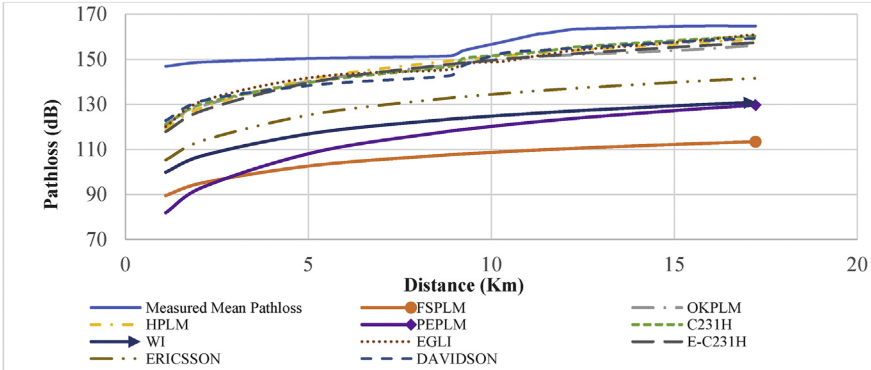

Fig. 5. Plot of measured pathloss and pathloss obtained from models for station1 (route 5).

variation with distance.

4. Conclusion

The results of the prediction provide detailed error analysis of the existing propagation pathloss models. The acceptable radio prediction value for Television is 10dB. The lower the value, the better the performance. From Tables 12 and 14, it is clearly evident that the RASPE values from the ten existing prediction models were in excess of 10dB. These implies that the models do not adequately predict the pathloss for Television broadcasting in Abuja.

Conclusively, suitability of these models in terms of usage vary due to environmental factors and the terrain profile. Besides, peculiarities of these models gives rise to high prediction errors when deployed in a different environment other than the one initially built for.

Declarations

Author contribution statement

Igbninosa O.G: Conceived and designed the experiments; Performed the experiments.

Okpekia U.K: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Funding statement

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

References

[1] K.S. Ajay, Radio and Television Broadcasting, Random Publishers, New Delhi, India, 2012, pp. 226–227.
[2] J.B. Anderson, T.S. Rappaport, S. Yoshida, Propagation Measurements and Models for Wireless Communication Channels, IEEE Communication Magazine, 1995, pp. 42–49.
[3] k. Pahlavan, A.H. Levesque, Wireless Information Networks, Wiley-Interscience, New York, 1995, pp. 73–112.
[4] P. Bernardin, M. Yee, T. Ellis, Estimating the cell radius from signal strength measurements, in: 6th WINLAB Workshop, March 20 -21, 1997.
[5] D. Tipper, Wireless Communication Fundamentals, University of Pittsburgh Lecture, 2005, pp. 40–42.
[6] M.A.S. Ahmed, A.R. Tharek, H.Z. Marwan, S. Ibraham, Pathloss model and channel capacity for UWB- MIMO channel in outdoor environment, Wireless Pers. Commun. (2019). https://link.Springer.com/article/10.1007/s/1277-019-06253-W.
[7] Z. Aymen, D. Milian, Performance analysis of pathloss prediction models in wireless networks in different propagation environments, in: 3rd Congress on Electrical Engineering and Computer Systems and Sciences (EECSS'17), 2017. https://www.researchgate.net/publication/317286827.
[8] S. Shu, S.R. Theodore, A.T. Timothy, G. Amitava, C.N. Huan, Investigation of prediction accuracy, sensitivity and parameter stability of large scale propagation pathloss models for 5G wireless communications, IEEE Trans. Veh. Technol. 65 (5) (2016).
[9] K. Haneda, 5G 3GPP- like channel models for outdoor urban microcellular and macrocellular environments, in: Proc. IEEE 83rd VTC Spring, Nanjing, China, 2016.
[10] G.R. MacCartney, T.S. Rapport, M.K. Samimi, S. Sun, Millimeter- wave omnidirectional pathloss data foir small cell 5G channel modeling, IEEE Access 3 (2015) 1573–1580.
[11] M.K. Samimi, Probalistic omnidirectional pathloss models for millimeter-wave outdoor communications, IEEE Wireless Commun. Lett 4 (4) (2015) 357–360.
[12] ECC, The Analysis of the Co-existence of FWA Cells in the 3.4 – 3.8GHz Band." European Conference of Postal and Telecommunication Administration (CEPT), technical Report, 2003, p. 33.
[13] T.S. Rappaport, Wireless Communications: Principles and Practice, Prentice Hall, New Delhi, 2005.
[14] M.G. Wacek, The Path of the Ultimate Loss Ratio Estimate, Casualty Actuarial Society Forum, 2007.
[15] P.K. Sharma, R.K. Singh, Comparative analysis of propagation pathloss models with field measured data, Int. J. Eng. Sci. Technol. 2 (6) (2010) 2008–2013.
[16] D. Chhaya, Propagation pathloss modelling for deployed WIMAX network, Int. J. Emerg. Technol. Adv. Eng. 2 (8) (2012) 172–175.
[17] N. Faruk, A.A. Ayeni, Y.A. Adediran, Characterization of propagation pathloss at VHF/UHF bands for Ilorin city, Nigeria, Niger. J. Technol. 32 (2) (2013) 253–265.
[18] J.A. Slawomir, J.K. Ryszard, The selected propagation models analysis of usefulness in container terminal environment, ICWMC 2, in: 7th International Conference on Wireless and Mobile Communication, 2011.