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Comparative Analysis and Simulation of Television White Space in Lagos State, Western Nigeria

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Abstract- Television White Space (TVWS) is the practically unused portion of the television broadcast spectrum that can be assigned to secondary communication systems under interference-protection constraints. This paper presents an expanded empirical assessment of TVWS availability and path-loss behaviour in Lagos, Nigeria. Spectrum measurements were reported for the 470–870 MHz UHF range at Ajah, Ikorodu, and Epe, representing urban, suburban, and rural environments, respectively. The source measurements identified 50 analysed channels, 11 occupied channels, and 39 white-space channels, corresponding to 312 MHz and 78% white-space availability. A drive-test

I. INTRODUCTION

Broadband deployment in Nigeria is constrained by uneven infrastructure, high deployment costs, and the difficult economics of serving remote communities [1]. TVWS can complement fibre, microwave, and cellular networks because UHF signals generally provide useful coverage over relatively long distances and can penetrate common obstructions better than higher-frequency unlicensed systems. The practical value of TVWS, however, depends on knowing which channels are vacant at a location and on predicting the received signal level accurately enough to protect incumbent broadcasters [2].

The supplied study addresses these requirements through spectrum sensing in Lagos and propagation measurements along three representative routes. This expanded paper reorganizes the work as a publication-style technical article, preserves the reported numerical results, and adds analytical tables and plots derived from the document's data.

II. STATEMENT OF PROBLEMS

The first problem is the lack of reliable local information on UHF channel occupancy. A channel that appears vacant in one location may be occupied in another because of transmitter coverage, terrain, antenna height, and local clutter. The second problem is model transferability: propagation equations calibrated in other countries or frequency ranges may produce significant errors when applied directly to Lagos. These errors can cause under-provisioning, excessive infrastructure cost, coverage gaps, or unsafe secondary transmission near incumbent receivers [3].

III. LITERATURE REVIEW

TVWS measurement is commonly performed using a detector method or a geolocation-database method [4]. Detector systems observe the received energy directly, whereas databases estimate channel availability from transmitter parameters, propagation calculations, and regulatory protection margins [5]. A robust operational system can combine both approaches: a database provides a prior occupancy map, while sensing validates local and time-varying conditions [6].

Propagation models used in TVWS planning include theoretical free-space and Plane Earth formulations and empirical Hata, COST 231, and Egli formulations. Theoretical models are useful for baseline analysis but do not fully represent clutter, reflections, foliage, and irregular terrain [2][7]. Empirical models incorporate environmental behaviour, yet their coefficients remain location-dependent. The source study therefore compares established models with Lagos measurements and derives an adjusted OressuffTV model.

IV. METHODOLOGY

Measurements were performed at Ajah (urban; 6.4646° N, 3.5725° E), Ikorodu (suburban; 6.6194° N, 3.5105° E), and Epe (rural; 6.6055° N, 3.9470° E).

Spectrum sensing covered 470–870 MHz. A 100 m antenna arrangement and an auto-tuned television receiver were used to identify occupied television channels [3]. The propagation drive test used TEMS tools at 615.25 MHz, corresponding to UHF channel 39, with a 114.5 m base-station antenna and 1.5 m mobile antenna. The source document reports a 3.5 kW transmitting rating and a noise threshold of −110 dBm [8].

For each route, received signal strength was recorded at 0.1 km intervals up to 2.0 km. Path loss was compared using mean error, standard-deviation error, and root-mean-square error (RMSE): RMSE = sqrt[(1/n) $\Sigma(P_{measured} - P_{model})^2$]. The OressuffTV equations were obtained by adjusting the COST 231 structure to the measured Lagos specific data [9].

Table 1Measurement configuration

Parameter	Value
Frequency	615.25 MHz
Base-station antenna height	114.50 m
Mobile antenna height	1.50 m
Transmitting rating	3.50 kW
TV channel	39
Noise threshold	−110 dBm
Measurement distance	0.10 – 2.00 km
Measurement duration	Approximately four weeks

V. RESULTS AND PRESENTATION OF RESULTS

Fig. 1. Map of the areas investigated

A. Spectrum occupancy

The band-level results show a clear increase in white-space availability toward the upper part of the analysed range. The 770–870 MHz segment was reported as entirely unused in the measured locations, whereas the 470–570 MHz segment contained the highest reported occupancy. Across the complete analysed set, 39 of 50 channels were classified as white space illustrated in table 2.

Table 2 White space channel variables

Band (MHz)	Channels analysed	Occupied	White-space	Occupied (%)	White-space (%)
470–570	12	5	7	42	58
570–670	13	5	8	38	62
670–770	12	2	10	17	83
770–870	13	0	13	0	100
Overall summary	50	11	39	22	78

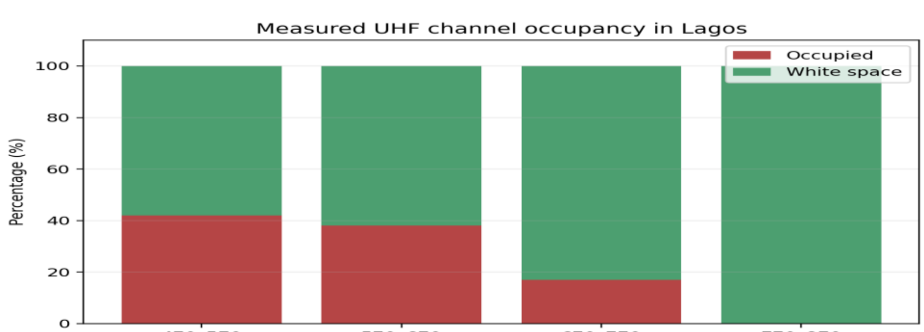

Fig. 2. Reported occupancy and white-space proportions in the four UHF segments.

Table 3 White space channel frequencies

Station	Channel	Centre frequency (MHz)
AIT	21	471.25
Silverbird	23	487.25
OGTV	25	503.25
Galaxy	27	519.25
LTV/LWT	35	583.25
Channels TV	39	615.25
ONTV	41	631.25
MITV	43	647.25
Superscreen	45	663.25
TV Continental	49	695.25
Wazobia Max	57	759.25

B. Measured received signal strength and path loss

The received signal becomes progressively weaker with distance, although local fluctuations occur because of multipath and route-specific clutter. The corresponding path loss generally increases with distance. Ikorodu shows several of the weakest received-signal values, while Epe and Ajah exhibit different local trends at intermediate distances. The map of the landscape of areas investigated are shown in Figure 3 above.

Table 4 White space channel distance and pathloss

Distance (km)	Ajah RSS (dBm)	Ikorodu RSS (dBm)	Epe RSS (dBm)	Ajah PL (dB)	Ikorodu PL (dB)	Epe PL (dB)
0.1	-43	-48	-47	91.14	92.41	93.20
0.2	-45	-51	-49	101.62	100.07	101.26
0.3	-49	-54	-53	106.42	104.24	107.14
0.4	-51	-56	-58	110.41	109.62	110.41
0.5	-55	-59	-55	113.41	111.74	113.79
0.6	-56	-64	-57	116.04	115.24	117.04
0.7	-58	-68	-62	118.18	117.25	119.81
0.8	-63	-74	-67	120.04	119.15	120.40
0.9	-66	-78	-69	121.14	120.70	121.64
1.0	-73	-88	-75	124.46	123.40	122.86
1.1	-77	-87	-79	125.64	126.20	124.41
1.2	-79	-85	-87	127.97	127.10	125.64
1.3	-80	-93	-90	127.28	128.15	126.76
1.4	-82	-92	-89	128.82	129.40	127.97
1.5	-84	-94	-91	129.11	128.15	128.28
1.6	-90	-95	-95	130.76	129.30	129.33
1.7	-89	-96	-97	131.15	130.25	130.76
1.8	-91	-98	-96	132.13	131.40	131.15
1.9	-97	-98	-97	133.60	132.50	132.13
2.0	-96	-99	-99	134.77	133.66	133.60

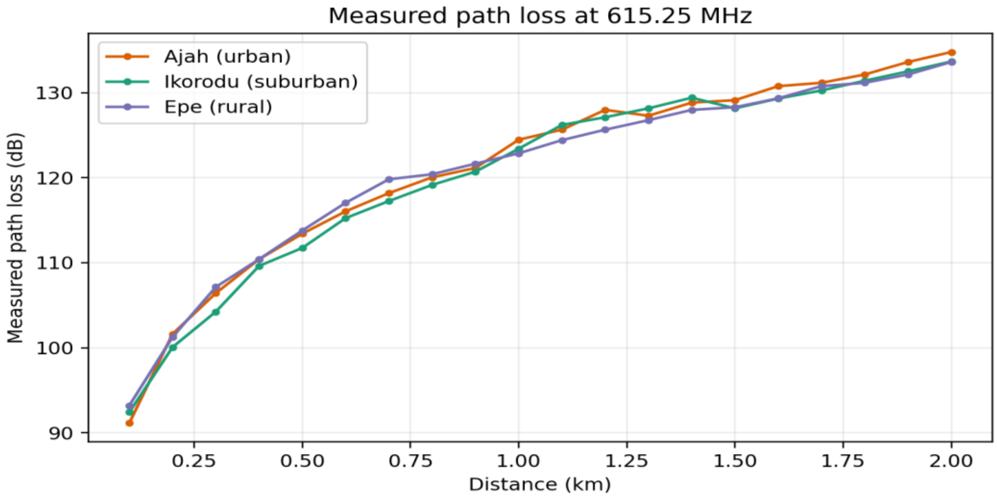

Fig. 3. Measured path loss for the three Lagos environments.

C. Propagation-model relationship

The model curves share a broadly increasing path-loss relationship with log-distance, but they differ substantially in intercept and slope. The Plane Earth values reproduced in the source table are physically inconsistent with the positive measured path-loss scale because the tabulated calculation produces negative values; this explains its very large reported RMSE. [10] Egli also departs from the measured trend. Hata and COST 231 track the observations more closely, with the preferred conventional model varying by environment.

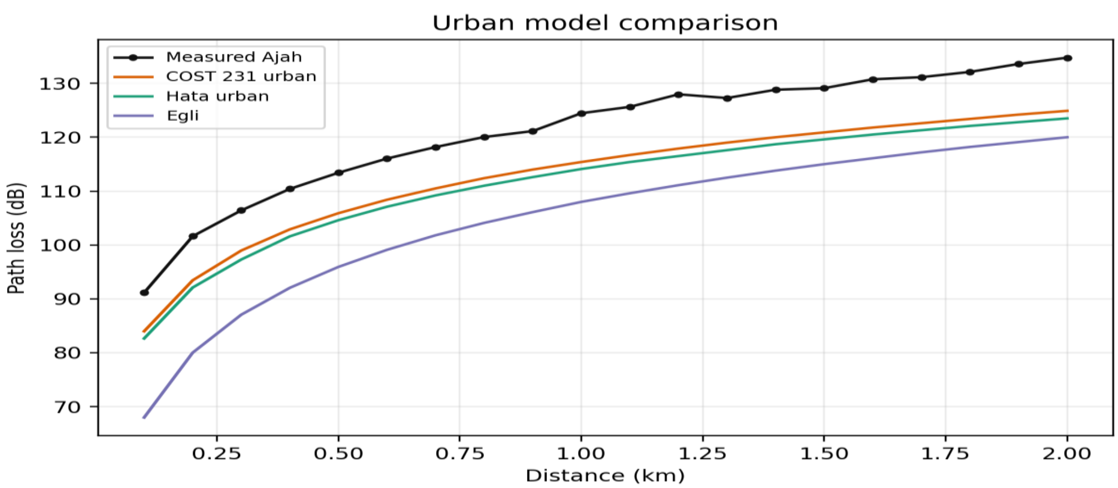

Fig. 4. Example urban comparison between measured path loss and selected models.

Table 5 results of various models

Model	Environment	RMSE (dB)	Std. deviation error (dB)	Mean error (dB)
Egli	Urban	16.65	2.41	16.4685
Egli	Suburban	15.98	2.43	15.8000
Egli	Rural	16.45	3.21	16.1035
Plane Earth	Urban	169.15	2.42	169.1300

Plane Earth	Suburban	168.44	2.43	168.4615
Plane Earth	Rural	168.83	3.22	168.8045
Hata	Urban	9.73	0.59	9.6925
Hata	Suburban	2.14	0.60	1.7745
Hata	Rural	28.22	0.19	28.2105
COST 231	Urban	8.38	0.61	8.3400
COST 231	Suburban	10.70	0.59	10.6325
COST 231	Rural	11.02	0.19	11.0150

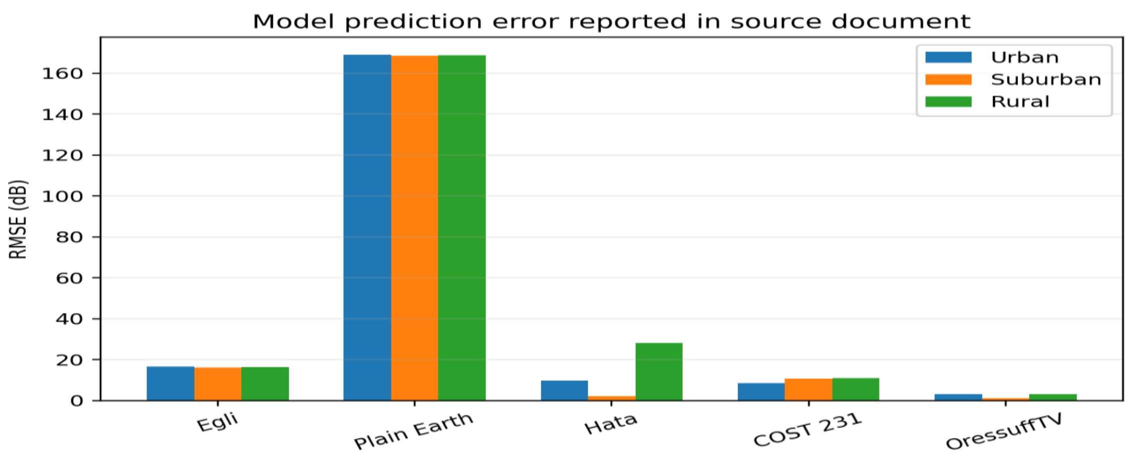

Fig. 4. Reported RMSE comparison. Lower values indicate closer agreement with measured path loss.

D. OressuffTV model

The source document selected COST 231 as the basis for optimization and reports the following Lagos-specific forms:

Urban: $\text{OressuffTV} = 54.68 + 33.9 \log10(fc) - 13.82 \log10(h1) - 3.2[\log10(11.75hm)]^2 - 4.97 + (44.9 - 6.55 \log10(h1))\log10(d) + 3$.

Suburban: $\text{OressuffTV} = 57 + 33.9 \log10(fc) - 13.82 \log10(h1) - (1.1 \log10(fc) - 0.7)hr - (1.56 \log10(fc) - 0.8) + (44.9 - 6.55 \log10(h1))\log10(d)$.

Rural: $\text{OressuffTV} = 57.328 + 33.9 \log10(fc) - 13.82 \log10(h1) - (1.1 \log10(fc) - 0.7)hr - (1.56 \log10(fc) - 0.8) + (44.9 - 6.55 \log10(h1))\log10(d)$.

Table 6 OresuffTV RMSE results

Model	Urban RMSE (dB)	Suburban RMSE (dB)	Rural RMSE (dB)
COST 231	8.38	10.70	11.02
OressuffTV	3.082	1.190	3.061

The reported OressuffTV RMSE values are below 6 dB in all three environments, indicating a substantial reduction in prediction error relative to the unmodified COST 231 values. The model should nevertheless be validated with independent routes and additional seasons before regulatory or commercial deployment.

VI. DISCUSSION

The occupancy results indicate that TVWS is not a single fixed quantity across Lagos; it depends on the analysed sub-band and local incumbent coverage. The aggregate 78% white-space result is therefore useful as a planning indicator, but it should not be interpreted as permission for unrestricted transmission. Channel-specific protection, sensing thresholds, guard bands, maximum power, antenna height, and incumbent-receiver protection remain necessary [10].

The model comparison demonstrates the relationship between propagation principles and engineering decisions. A theoretical model can provide a first-order reference, but the measured data reveal local losses that arise from the environment. COST 231 provides a useful baseline, while OressuffTV improves local fit. One limitation is that the source describes COST 231 as a 1500–2000 MHz model while applying it at 615.25 MHz; the reported optimization partly addresses this mismatch, but independent validation is essential.

VII. CONCLUSIONS AND RECOMMENDATIONS

This paper reproduced and expanded the uploaded empirical study of TVWS in Lagos. The reported measurements identified 39 white-space channels out of 50 analysed channels, equivalent to 312 MHz and 78% white-space availability. The path-loss data show increasing attenuation with distance and significant environmental variation among Ajah, Ikorodu, and Epe. Among the conventional models, COST 231 was the strongest overall baseline in the study, while OressuffTV produced the lowest reported RMSE in all three environments.

For implementation, spectrum regulators and network planners should: (1) combine sensing with a geolocation database; (2) conduct measurements at additional sites and times; (3) validate OressuffTV using independent data; (4) include seasonal, foliage, and weather effects; (5) define conservative protection margins and guard bands; and (6) evaluate TVWS for rural broadband, IoT, public-safety, and network-backhaul applications. The numerical results should be treated as empirical findings from the supplied document rather than as a substitute for a current regulatory channel-allocation decision.

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