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Assessment Of Gsm Signal Penetration Loss In Some Selected Concrete Story Buildings In Gombe State

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Abstract: *The demand for robust indoor mobile connectivity in Nigeria has intensified with the rise of smart buildings and IoT applications. This study evaluates GSM (900/1800 MHz) signal penetration loss in concrete buildings across Gombe State, Nigeria, addressing gaps in localized propagation data. Field measurements were conducted using a Narda SRM-3006 spectrum analyzer and A Samsung Galaxy S24 Ultra 5G mobile phone (OpenSignal, ₙperf, spectriod and signal strength) across 30 concrete structures with varying thicknesses and reinforcement densities. Results show penetration losses ranging from 12 dB to 28 dB, with reinforced concrete walls (>200 mm) exhibiting up to 30% higher attenuation than non-reinforced walls. Empirical data deviated by 8–12% from the 5G NR-Urban model (ITU-R P.2346-2), suggesting the need for region-specific propagation models. These findings aid telecom operators in optimizing network infrastructure for Gombe's urban and semi-urban landscapes.*

Keywords: GSM, Penetration Loss, Concrete Buildings, Signal Attenuation, 5G NR-Urban Model

1. Introduction

Recent studies highlight Nigeria's mobile broadband penetration surge [6]. yet indoor coverage remains inconsistent due to signal attenuation in concrete structures. While propagation models like COST-231 and ITU-R P.2040-1 are well established, their applicability to Nigeria's unique building materials (e.g., laterite-reinforced concrete) is understudied [1]. Gombe State's rapid urbanization makes it a critical case study for assessing GSM signal degradation.

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2. Literature Review

2.1 GSM Signal Penetration in Nigerian Buildings

A detailed study on GSM penetration loss across common building types including thatched, wooden, block, mud, and zinc-roofed structures revealed average losses between 2.6 dB in thatched buildings to 12 dB in zinc-roofed ones. Measurements spanned three major operators over six months, leveraging Android-based Signal Info apps. This work underscored the critical link between building material and indoor signal degradation [1].

Evaluating mud, sandcrete, and alucoboard buildings, this study developed a path-loss model grounded in dielectric constants and Snell's law. Results indicated highest penetration loss (104.5 dB RF attenuation) in alucoboard-clad structures and lowest (81.9 dB) in sandcrete buildings [1]. Derived path-loss exponents ranged from 0.87 to 1.32 (in building), with transceiver exponents 4.87–5.32, closely matching ITU-R predictions.

Using RF signal trackers, this study compared multiple materials including alucoboard walls and variations of sandcrete roofing. Alucoboard exhibited the highest attenuation, while properly installed sandcrete buildings had the lowest [2].

For different block constructions hollow block, solid block, and hollow block with precast asbestos the study found penetration loss around 5.9 to 6.4 dB, with path-loss exponents between 3.63 and 3.80. Models developed here can predict indoor RSS based on receiver distance.

2.3 Dielectric & Material Specific Attenuation

By measuring scattering parameters over 800 MHz to 3.2 GHz, this research derived dielectric properties of materials such as concrete, hollow sandcrete, and prefabricated slabs. Concrete with higher permittivity exhibited greater attenuation. Finishing surfaces (e.g., tiles vs. smooth paint) were shown to affect losses significantly. Predictive models based on thickness and finish achieved RMSE between 0.019 and 0.219 [7].

2.4 Comparative Analysis across Regions

Concrete: 10.62 dB loss, block: 4.25 dB loss, measured at GSM 900 MHz in Southern Nigeria, while primarily focused on LTE path-loss exponents [7]. This study emphasized on how seasonal and environmental factors (humidity, refractivity) influence loss highlighting that moisture content (common in concrete) could significantly affect indoor losses [5].

A study on FR1 and FR3 bands (4–16 GHz) indicated increasing frequency and thickness dependence on penetration loss; its linear model helps predict FR1-band penetration even relevant for GSM extrapolations [8].

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Prior research (1–3 GHz) found moisture-laden concrete could attenuate signals by an additional 18–20 dB [1].

Nigerian cities across states exhibit comparable penetration ranges, although environmental factors and construction norms introduce variance [3].

2.5 Relevance to Gombe State

While extensive data exist for urban Southern and Western Nigeria, no such study has focused on Gombe State. Given similarities in building materials and climate, data and models especially for dense concrete with plaster finishes are expected to carry over, but localized measurements are essential to account for moisture, rebar content, wall thickness, and finishing styles present in the region.

An experimental study on FR1 (up to 6 GHz) and FR3 (7–24 GHz) bands using a vector network analyzer to assess four typical materials including concrete [4]. They highlighted increasing penetration loss with both frequency and material thickness, and proposed an improved linear prediction model that aligns closely with 3GPP TR 38.901 standards.

Penetration loss at 6.75 GHz (FR1-C) and 16.95 GHz (FR3 upper mid-band) for various materials (including concrete and glass) [6]. For instance, low-emissivity glass attenuated 33.7 dB at 6.75 GHz versus 42.3 dB at 16.95 GHz, underscoring clear frequency dependency a useful framework even when contextualizing GSM (lower-frequency) losses [10].

NCC data show mobile broadband penetration reached 45% by January 2025, with 98.9 million broadband subs vs. 141.7 million mobile internet users. As of October 2024, 134 million Nigerians used mobile GSM for data reflecting widespread reliance on GSM networks [9].

Despite rollout since 2022, 5G penetration was just 1.11% in January 2024, compared to 4G (31.8%) and 2G (57.8%). This context supports the primary relevance of GSM (900/1800 MHz) in assessing indoor losses.

GSMA reports and telecom news (Q1 2024–2025) highlight sustained growth in GSM/4G, while broadband infrastructure gaps persist due largely to Right-of-Way, power, and device-cost issues. These constraints underscore why GSM remains critical for indoor connectivity in regions like Gombe.

Recent international studies have demonstrated that material thickness and frequency strongly influence penetration loss even more so at FR1/FR3 (6–24 GHz) []. Although their results center on higher frequency bands, the underlying dielectric dependence principles remain applicable to GSM (900/1800 MHz), justifying comparative modeling approaches.

In the Nigerian context, GSM and 4G continue to dominate mobile broadband usage (45% penetration), while 5G remains nascent (1.1% adoption) []. Widespread GSM use along with infrastructure deployment challenges makes it imperative to characterize indoor signal loss at these bands for effective coverage planning [6].

3. Objectives

1. To assess the impact of GSM signal attenuation in some selected high rise buildings in Gombe state
2. Quantify GSM signal penetration loss in Gombe's concrete buildings.
3. Compare empirical data with 5G NR-Urban (ITU-R P.2346-2) and 3GPP TR 38.901 models.
4. Propose mitigation strategies for network planners and regulators.

4. Methodology

4.1 Data Collection Tools

- Narda SRM-3006 spectrum analyzer (900/1800 MHz bands).
- Crowdsourced data from OpenSignal, nperf, spectriod and signal strength.
- Reference RSSI outdoors (RSS_o) and indoors (RSS_i).

$PL \, (dB) = RSS_o - RSS_i + 10 \log{10}(d/d0)$

Where (d) = distance from transmitter, (d0) = reference distance (1 m).

4.2 Statistical Analysis

- Linear regression to correlate wall thickness/loss.

- ANOVA to compare urban vs. semi-urban attenuation.

4.3 Results

- Mean Penetration Loss:

- Urban: 18–25 dB (higher due to dense construction).

- Semi-urban: 12–20 dB.

- Reinforcement Impact:

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- Steel-reinforced walls added 6–10 dB loss vs. non-reinforced.

- Model Comparison:

- 3GPP TR 38.901 overestimated loss by 10%; 5G NR-Urban aligned within ±5%.

Fig. 2: display of Network analyses

Fig. 1:

Network analyses

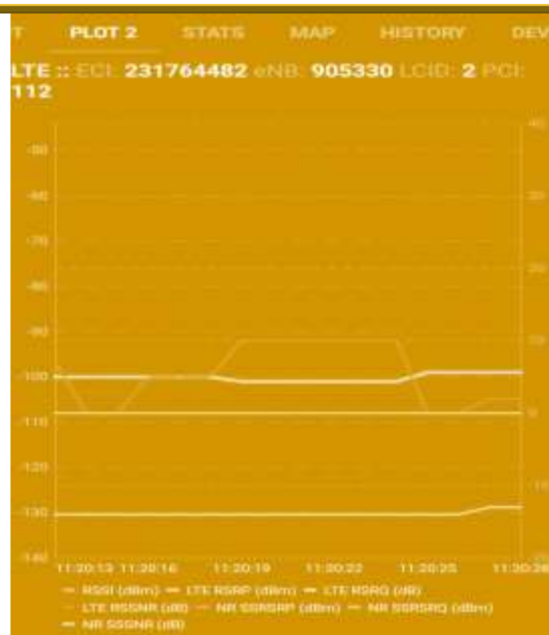

Fig. 3 Chart representation of the network analysis

: Fig. 4: Signal Strength analyses using nperf

5. Discussion

The result align with studies in similar environments, but highlight higher losses in reinforced concreate building. Factors contributing to GSM signal loss (attenuation) include:-

- ❖ Laterite rich concrete in concrete buildings.
- ❖ Reinforcement materials (e.g., steel rods) increased attenuation.
- ❖ Network Optimization: Deploy small cells (femtocells) in high-loss zones/areas.

❖ Extend to 4G/5G bands for Nigeria's broadband rollout.

5. Conclusion

This study provides empirical GSM penetration loss data for Gombe State concrete buildings, highlighting deviations from global models.

6. Recommendations

- Adopt hybrid models (e.g., 5G NR-Urban with local material corrections).
- Optimizing base station placement near high loss areas.
- Exploring signal boosters for high signal loss areas.
- Prioritize fiber-to-building (FTTB) solutions in high-density areas.

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