The Scientific Journal of Cihan University – Sulaimaniya **PP: 85-97**
Volume (9), Issue (2), December 2025
ISSN 2520-7377 (Online), ISSN 2520-5102 (Print)

EXPERIMENTAL ANALYSIS OF RSRP AND RSRQ IN DENSE URBAN DEEP INDOOR SCENARIOS

Delman Ali Ahmed[1], Sara Azad Ahmed [2], Diyari Abdalkhaliq Hassan[3]

[1,2] Computer Engineering Department, Komar University of Science and Technology, Sulaimani, Iraq

[3] Faculty of Engineering & Computer Science, Qaiwan International University, Sulaimani, Iraq

Email: dilman.ali@gmail.com[1], sara.azad@komar.edu.iq[2], diyari.hassan@uniq.edu.iq[3]

Abstract:

This study experimentally investigates, Long-Term Evaluation (LTE) performance in a deep indoor dense urban environment, focusing on Reference Signal Received Power (RSRP) and Reference Signal Received Quality (RSRQ). Measurements were taken on a live LTE network operating on Band DCS1800 (EARFCN 1750) with a 20 MHz bandwidth. The main serving sites, Site-A and Site-B, significantly influenced basement signal reception. Site-A used a CNNPX303F antenna (gain 11.7 dBi, 68° horizontal and 23° vertical beamwidths, 46 dBm downlink, 23 dBm uplink, 25 m height). Before optimization, an azimuth of 350° and high RET (100°) produced weak RSRP (−115 dBm) and unstable RSRQ (−14 dB). After realigning Site-A to 30° and reducing Site-B's RET to 50°, RSRP improved by 6–10 dB over the 15 m path, while RSRQ showed limited gains due to interference. The findings reveal that azimuth and tilt optimization enhance RSRP but remain insufficient for RSRQ stability without effective interference-management strategies.

Keywords: Reference Signal Received Power, Reference Signal Received Quality, Long-Term Evaluation, indoor coverage, interference, optimization.

الملخص:

تتناول هذه الدراسة إجراء تحليل تجريبي لأداء نظام التطور طويل الأمد (LTE) في بيئة حضرية داخلية كثيفة، مع التركيز على مؤشري قوة الإشارة المرجعية المستقبَلة (RSRP) وجودة الإشارة المرجعية المستقبَلة (RSRQ). أُجريت القياسات على شبكة LTEحية تعمل ضمن نطاق DCS1800 (EARFCN 1750) وبعرض نطاق ترددي قدره 20 ميجاهرتز. وقد كان لمواقع الخدمة الرئيسة، الموقع (أ) والموقع (ب)، تأثيرٌ ملحوظ على جودة استقبال الإشارة في الطابق السفلي.

استُخدم في الموقع (أ) هوائي من نوع CNNPX303F بخصائص فنية تشمل كسبًا مقداره 11.7 ديسيبل، وعرض حزمة أفقيًا يبلغ 68 درجة وعموديًا 23 درجة، وقدرة استقبال قدرها 46 ديسيبل ميلي واط، وقدرة إرسال تبلغ 23 ديسيبل ميلي واط، وارتفاعًا مقداره 25 مترًا. قبل تنفيذ عملية التحسين، أدّى ضبط السمت عند 350 درجة مع قيمة ميل كهربائي (RET) مرتفعة بلغت 100 درجة إلى تسجيل مستويات منخفضة من RSRP بلغت ‎-115 ديسيبل ميلي واط، إلى جانب عدم استقرار في قيم RSRQ وصلت إلى ‎-14 ديسيبل.

وبعد إعادة ضبط سمت الموقع (أ) إلى 30 درجة، وخفض زاوية الميل الكهربائي (RET) للموقع (ب) إلى 50 درجة، لوحظ تحسّن في مستوى قوة الإشارة المرجعية المستقبَلة (RSRP) تراوح بين 6 و10 ديسيبل على امتداد مسار قياس بطول 15 مترًا. في المقابل، أظهرت قيم جودة الإشارة المرجعية المستقبَلة (RSRQ) تحسنًا محدودًا، يُعزى ذلك إلى تأثيرات التداخل. وتشير النتائج إلى

DOI: http://dx.doi.org/10.25098/9.2.30

The Scientific Journal of Cihan University – Sulaimaniya **PP: 85-97**
Volume (9), Issue (2), December 2025
ISSN 2520-7377 (Online), ISSN 2520-5102 (Print)

أن تحسين عوامل السمت والميل يسهم بفاعلية في تعزيز مستوى RSRP ، إلا أنه يظل غير كافٍ لتحقيق استقرار ملحوظ في RSRQ ما لم تُعتمد استراتيجيات متقدمة وفعّالة لإدارة التداخل.

الكلمات المفتاحية: الإشارة، الجوال، التغطية الداخلية، الشبكة، قوة الإشارة، تجريبي، التداخل، التوهين، السمت.

پوختە:

ئەم توێژینەوەیە بە شێوەی تاقیکردنەوەیی، لێکۆڵینەوە دەکات لەسەر کارایی سیستەمی نەوەی چوارەم (LTE) لە ناوچەی نیشتەجێبونی زۆر چڕ، بە تایبەتی سەرنج دەدات بە هێزی ئاماژەی پێوانەیی وەرگیراو (RSRP) و جۆری ئاماژەی پێوانەیی وەرگیراو (RSRQ). پێوانەکان لەسەر تۆڕێکی کارا ی LTE ئەنجام دران کە لە سەر شەپۆلی DCS1800 (EARFCN 1750) کار دەکرد، بە پانایی باندی ٢٠ میگاهێرتز.

دوو خاڵی سەرەکی لە نهۆمی ژێرزەمینی ناوچەیەکی چڕدا دیاری کراون، خاڵی A و خاڵی B، کە هەریەکەیان بەهۆی زۆری کاریگەری شەپۆلە شکاوەکان پێوەری توەندی شەپۆلی سەرەکی زۆر لاواز بوو کە لە خوار پێوەری دیاریکرو بوون. ئەمەش هۆکاری پەك کەوتنی پەیوەندیکردن بوو لەو ناوچەیە. پێوەرەکانی هەریەك لە سایتەکان لەو ناوچەیە بەم جۆرە دەستنیشان کران (بەرزکەرەوەی ئەنتێناکان dBi ١١.٧ ، گۆشەی ستوونی °٦٨ ، گۆشەی ئاسۆی °٢٣، وە بەرزی هەریەك لە تاوەرەکان ٢٥ م) پێش ئەنجامدانی چاکسازی، ئاراستەی ئاسۆی (Azimuth) بە گۆشەی °٣٥٠ دیاری کرابوو، وە بەرزی خودکاری ئاسۆی (RET) بە گۆشەی °١٠٠ جێگیر کرابوو، لەم دۆخەدا هەردوو پێوانەی (RSRP و RSRQ) لە خوار ئاستی گونجاو بوون کە (dBm - ١١٥ و dBm - ١٤).

لە پاش ئەنجامدانی چاکسازی لە ئاراستەی ئاسۆی و ستونی ئەنتێناکانی تاوەری A و B بە گۆشەی °٣٠ و °٥٠ ، بەرزبوونەوەی بەرچاو لە پێوەری RSRP تۆمارکرا بە نزیکەی (dB ٦-١٠) لە دووری ١٥م لە تاورەکەوە، بەڵام RSRQ گۆڕانکاری بەرچاوی تۆمار نەکرد، لەبەر زۆری سەریەك چونی شەپۆلەکان، لە دەرئەنجامی ئەمەوە دەتوانین بڵێن کە چاکسازی لە ئاراستەی ئاسۆی و ستونی ئەنتێناکانی تاوەرەکان دەکرێت پێوەری RSRP بەرە دۆخێکی باشتر بگۆڕێت بەڵام هیچ کاریگەرێکی ئەوتۆ ناکاتە سەر پێوەری RSRQ.

کلیلە وشە: گۆشەی ستونی ، گۆشەی ئاسۆی، پێوەری توندی شەپۆلی وەرگیراو ، جۆری شەپۆلی وەرگیراو، سەریەکچونی شەپۆلەکان.

DOI: http://dx.doi.org/10.25098/9.2.30

Introduction

The topic of indoor wireless coverage has become a primary research focus in the last 20 years, particularly as LTE becomes more widespread and 5G is on the verge of being adopted (Dudhat, A., & Mariyanti, T., 2022). Much literature has highlighted challenges that have been faced with respect to signal penetration and subsequent reduction of the quality of signal in the indoor setting.

The use of mobile communication networks in densely populated cities has brought about a special issue of coverage, capacity and quality of service. The ubiquitous development of mobile communication infrastructures in modern metropolitan environments has spawned a set of issues related to coverage, capacity and the quality of service (Imoize, A., et al., 2023). As more people begin to use indoor mobile connectivity in business, entertainment and day-to-day activities, the performance of wireless network in indoor environment has become a decisive factor on the level of user satisfaction. The penetration loss, multi path fading, and interference of multiple neighbouring sites make deep indoor conditions especially difficult, as it occurs in basements and underground shopping centres (Holma, H., & Toskala, A. 2011).

Reference Signal Received Power (RSRP) and Reference Signal Received Quality (RSRQ) are two key performance indicators of LTE networks. RSRP quantifies the mean power of reference signal received, and RSRQ quantifies the ratio of RSRP to the total reaches of Received Signal Strength Indicator (RSSI) including interference and noise. Though a general belief that raising the RSRP will thereby raise the RSRQ, the experimental results show that this cannot be a linear relationship particularly in an environment with high interference (Lin, Y., Choi, J., & Kim, J. 2013, and Lee, D., et al. 2012).

LTE performance measurement studies, as noted by Holma and Toskala (2009), highlight that RSRQ is more sensitive to interference than RSRP, while 3GPP (2018) provides measurement methods that do not fully reflect real-world indoor interactions. Propagation models such as COST 231 (1999) and WINNER II (Kyösti et al., 2007) attempt to account for signal attenuation due to walls and materials but often underestimate interference effects in dense environments. Earlier indoor propagation research (Saleh et al., 1985) predates modern small-cell LTE deployments. More recent studies emphasize RF optimization techniques—such as antenna tilt and azimuth reorientation—to enhance coverage, with Sesia et al. (2011) noting that tilt adjustments can expand coverage but require interference control, and Lin et al. (2013) and Zhang et al. (2013) showing that while azimuth optimization strengthens signals, it may not improve quality under co-channel interference.

This work aims at giving empirical information on the practical interference of the RSRP and RSRQ at deep indoor dense urban conditions. In this paper we attempt to provide empirical data that explains the interdependence of RSRP and RSRQ below the ground surface of the earth. In particular, we consider the performance of LTE Band DCS1800 in a basement market in Sulaimaniyah City, Iraq. The article gives an in-depth experimental finding before and after introducing RF optimisation methods such as altering antenna azimuth and remote electrical tilt (RET) adjustments. We show the variation of RSRQ with RSRP through step-by-step measurements because of intra-band interference.

DOI: http://dx.doi.org/10.25098/9.2.30

The Scientific Journal of Cihan University – Sulaimaniya **PP: 85-97**
Volume (9), Issue (2), December 2025
ISSN 2520-7377 (Online), ISSN 2520-5102 (Print)

The aims of this study are three-fold to:

1- give comprehensive experimental measurements were conducted in the downtown Sulaimaniyah city market basement in Iraq and this permitted realistic consideration of signal propagation within the complex multi-layered indoor environment.
2- compare the effect of RF optimisation activities on RSRP and RSRQ.
3- comment on the wider impact on network planning and optimisation strategies in LTE and wider.

Methodology

2.1 Experimental Environment

The test campaign was carried out in the market basement of a market located in downtown Sulaimaniyah City. It is a high-density urban hot spot with many macro-cell locations. The basement is built with 15 cm thick walls and is some 2.5m under the surface as shown in Fig.1. These structural parameters are the major hurdles to radio wave propagation, thus making the location ideally convenient to explore the performance of deep indoor signals.

2.2 Network Configuration

The LTE network discussed in the current research works on Band DCS1800 (EARFCN 1750), which is a frequency range that is widely implemented in high-density urban areas due to its appropriate balance between the coverage area and the capacity offering. The identified two base stations, which are referred to as Site-A and Site-B, have been recognized as the major contributors of the indoor coverage performance that has been realized in a basement test site. Antenna orientation as well as mechanical tilt of the antennas have a preponderant effect on the effectiveness of signal penetration in such an environment.

Figure 1: Study site of the experimental campaign in downtown Sulaymaniyah City

DOI: http://dx.doi.org/10.25098/9.2.30

First, it was discovered that the azimuth of Site-A had been disturbed and was pointing at 350 o C and this was sending the larger portion of its radiated energy out of the basement door. Therefore, the signal quality was poor because the signal obtained depended heavily on off-axis inferior reflections. Site-B with high-tilt (RET 100%), gave minimal horizontal penetration and hence low deep-indoor coverage, which was reflected in the RSRP values of up to -115 -1/m and RSRQ values of -14 -1/m.

To eliminate these shortcomings, Site-A was re-aligned to an azimuth of 30 o, and the entrance to the basement was therefore directly aimed at. At the same time, site B was mechanically tilted by 50, hence allowing the radiated energy to travel better in the interior spaces. The antenna (Site-A CNNPX303F) has a high amount of transmit power, 46dBm in the downlink and 23dBm in the uplink, and a gain of 11.7dbi, but this power cannot be fully utilized without accurate alignment.

Post-optimization tests indicated a significant improvement of RSRP of 6 to 10 dB along the 15 m indoor route, whereas RSRQ had rather modest improvements, as it was typically less than 1 dB, due to still remaining interference effects. These results highlight the fact that, despite the fact that azimuth and tilt optimization significantly increase signal strength and spatial coverage, these measures are not enough to stabilize RSRQ in deep-indoor conditions. In this regard, to ensure a complete signal quality improvement in dense LTE deployments, a combination of RF optimization methods with interference -management solutions that directly address the factors that cause signal degradation are required.

Table 1. Network Configuration and Measurement Comparison Before and After Optimization

Parameter	Before Optimization	After Optimization	Observed Effect on Measurements
Site-A Antenna Azimuth	350° (not aligned with basement entrance)	30° (aligned with basement entrance)	Stronger direct beam penetration into basement; RSRP improved by ~6–10 dB.
Site-B RET	100 (high tilt, signal concentrated downward)	50 (reduced tilt, signal projects further)	Extended coverage footprint; improved RSRP penetration at mid distances.
RSRP (0m, deep indoor)	Very weak (≈ –115 dBm)	Improved (≈ –108 dBm)	~7 dB improvement, but RSRQ gain marginal (–15.0 → –14.2 dB).
RSRP (3m)	–111 dBm	–103 dBm	8 dB stronger signal; RSRQ improved only 0.4 dB (–14.5 → –14.06).
RSRP (6m)	–94.25 dBm	–88.31 dBm	~6 dB stronger signal; RSRQ improved slightly (–9.44 → –8.50).
RSRP (9m)	–90.69 dBm	–81.19 dBm	~9 dB stronger; RSRQ improved more significantly (–10.31 → –8.69).
RSRP (12m)	–78 dBm	–77 dBm	Minimal difference; RSRQ close in both cases (–8.38 → –8.06).
RSRP (15m, gate)	–65.81 dBm	–64.5 dBm	Both strong; RSRQ saturated near –7 dB.

DOI: http://dx.doi.org/10.25098/9.2.30

2.3 Measurement Tools

The main tool used in this study was the TEMS Investigation 18, an industry-accepted drive-testing and network-optimisation-tool that is experiencing a large-scale usage in the academic community as well as in the telecommunications industry. This software equips engineers with ability to record, query and visualise significant LTE performance indicators such as RSRP, RSRQ, and Signal-to-Interference-plus-Noise Ratio (SINR), and various handover incidents. TEMS Investigation was particularly beneficial in the current research since it includes real-time and fine-grained measurements that provide straightforward connect bridging physical-layer parameters and visible radio-network performance in deep indoor conditions.

These measurements were done in a predetermined path in the basement market starting at the most isolated inside location (0 m) and moving away to the main gate (15 m). To ensure the systematic data collection, data were observed in 3mb (0mb, 3mb, 6mb, 9mb, 12mb, and 15mb) successive intervals. At every point of measurement, data regarding the serving cell and the cells in the surrounding was recorded including the Physical Cell Identifier (PCI), the EARFCN, and the signal strengths involved. The methodology has enabled the identification of intra-band sources of interference that have direct effects on the RSRQ performance.

The testing set-up included lock settings to promote a methodological consistency. To avoid unintentional cell reselection or inter band transitions, the mobile test device was permanently connected to LTE Band DCS1800 (EARFCN 1750). In consequence, the total results were limited to the effect of optimisation of azimuth and tilt on the target serving cells.

Every data-collection session involved two different stages:

1. Measurements Pre-Optimisation: Measures obtained with the Site-A antenna azimuth fixed to 350° and Site-B RET value set to 100.
2. Post Optimisation Measures - These were done after changing the Site-A azimuth to 30° and decreasing the Site-B RET value to 50.

This combination of datasets will allow straightforward comparison at each discrete distance, allowing an accurate evaluation of the effects of RF optimisation actions on both RSRP and RSRQ.

DOI: http://dx.doi.org/10.25098/9.2.30

2.4 Mathematical Formulation

RSRQ is defined in (Sesia, S., et al. 2011):

$$RSRQ = \frac{N \times RSRP}{RSSI} \quad (1)$$

In dB:

$$RSRQ_{dB} = RSRP_{dBm} - RSSI_{dBm} + 10 * \log_{10}(N) \quad (2)$$

where N is the number of resource blocks, RSRP is the reference signal received power, and RSSI represents the total received signal strength including interference and noise. While RSRP is a direct measure of received power, RSRQ encapsulates the quality of that power relative to the interference environment.

Decompose total received power:

$$RSSI = S + I + N_o \quad (3)$$

where S is serving-cell power over the measured bandwidth, I is in-band interference from neighbors, and N_0 is thermal + receiver noise.

Because RSRP is measured on reference-signal REs and RSSI on the full band, relate the two via an aggregation factor $\alpha > 0$:

$$S = \alpha \, RSSI \quad (4)$$

where α collects RE density, antenna ports, RS power boosting

RESULTS

3.1 Step-by-Step Measurements

Table 2 provides a detailed comparison of the obtained RSRP and RSRQ values at the following spatial points of 0m, 3m, 6m, 9m, 12m and 15m, starting at the most secluded point of the house and proceeding to the main entrance of the basement marketplace, before and after the application of RF-optimization measures. It is shown by empirical evidence beyond reasonable doubt that re-orientation of the antenna azimuth and recalibration of the RET parameters have had significant effect of increasing the received signal power at each sampling locus; however, the concomitant increase in RSRQ displayed a rather subdued, non-linear dynamism.

DOI: http://dx.doi.org/10.25098/9.2.30

Volume (9), Issue (2), December 2025
ISSN 2520-7377 (Online), ISSN 2520-5102 (Print)

Table 2. Measured RSRP and RSRQ Values Before and After Optimization

Distance (m)	RSRP Pre-Optimization (dBm)	RSRP Post-Optimization (dBm)	RSRQ Pre-Optimization (dB)	RSRQ Post-Optimization (dB)
0	Very Weak (~ -115)	Improved (~ -108)	-15.0	-14.2
3	-111	-103	-14.5	-14.06
6	-94.25	-88.31	-9.44	-8.50
9	-90.69	-81.19	-10.31	-8.69
12	-78	-77	-8.38	-8.06
15	-65.81	-64.5	-7.75	-6.94

3.2 Graphical Representation

To explain the relationship between RSRP and RSRQ, Fig. 2 and Fig. 3 portray the observed patterns in the entire distance band in the basement setting, prior to and after RF optimisation. These visualisations go hand in hand with the tabulated data and provide more transparent views into the dependence of coverage strength and signal quality on distance and network reconfiguration. A pre-optimisation plot of RSRP and RSRQ (see Fig. 2) shows the starting values of signal strength and quality throughout the basement. RSRP reaches middle values over the whole distance profile, and the well-covered areas are closer to the basement entrance (12 m to 15 m). RSRQ values do not show a great deal of variation and distance dependence, reflecting the impacts of interference and ambient noise.

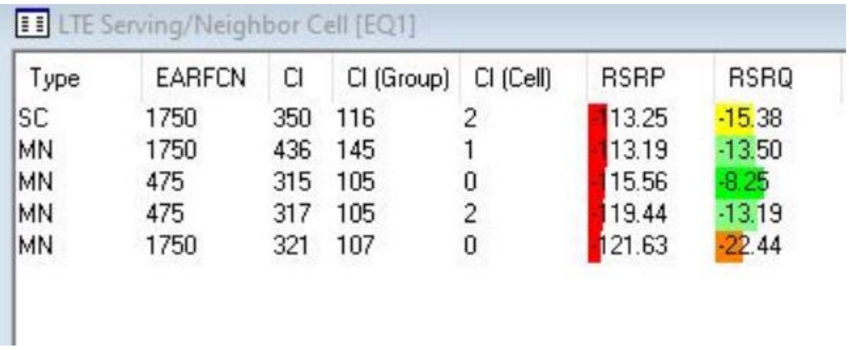
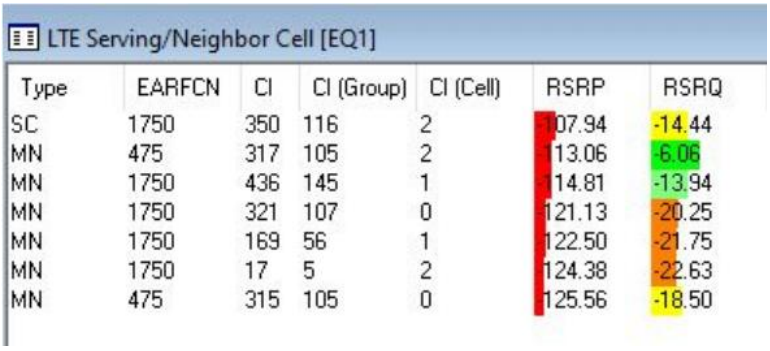


Figure 2: RSRP and RSRQ before optimization

Fig. 3, which illustrates RSRP and RSRQ following optimisation, shows the effect of RF optimisation, which is most evident between 3m and 9m where the gains are between 6-10 dB. The improvements are minimal with RSRQ and this indicates that it also depends not only on signal power but also on interference and noise. The synthesized point of view reveals that RF optimisation is a profitable approach to maximize the coverage power, although further interference-controlling techniques cannot be ignored to advance the quality of the signals in crowded indoor environments.

DOI: http://dx.doi.org/10.25098/9.2.30

The Scientific Journal of Cihan University – Sulaimaniya PP: 85-97
Volume (9), Issue (2), December 2025
ISSN 2520-7377 (Online), ISSN 2520-5102 (Print)


LTE Serving/Neighbor Cell [EQ1]

Type	EARFCN	CI	CI (Group)	CI (Cell)	RSRP	RSRQ
SC	1750	350	116	2	-107.94	-14.44
MN	475	317	105	2	-113.06	-6.06
MN	1750	436	145	1	-114.81	-13.94
MN	1750	321	107	0	-121.13	-20.25
MN	1750	169	56	1	-122.50	-21.75
MN	1750	17	5	2	-124.38	-22.63
MN	475	315	105	0	-125.56	-18.50

Figure 3: RSRP and RSRQ after optimization

3.3 Prediction via Geolocation Tool

The measurement patterns during the experimental campaign are supported by the geolocation model used herein. Using the Geolocation Tool, forecasts were made in the basement-market micro-environment, including the deepest indoors loci and the main entry point under two different operating regimes before and after applying radio frequency (RF) optimisation processes to the main serving cells. The simulated results showed that, without optimisation, the average Reference Signal Received Power (RSRP) in deep indoor locations had reached the value of -81.62 dBm with the RSRQ being -11.10 dB. The latter are reflective of the attenuation caused by architectural barriers, i.e., 15-centimetre thick walls that surround the basement, which in addition to weakening signal, also increases intra-band interference, as shown in Figs 4 and 5. Progressive increases in RSRP at progressive distances to the main gate were correlated with concomitant increases in signal strength and its quality, though the dependence between RSRQ and RSRP was non-linear, hence indicative of the dual dependence of RSRQ on received power and ambient interference RSSI.

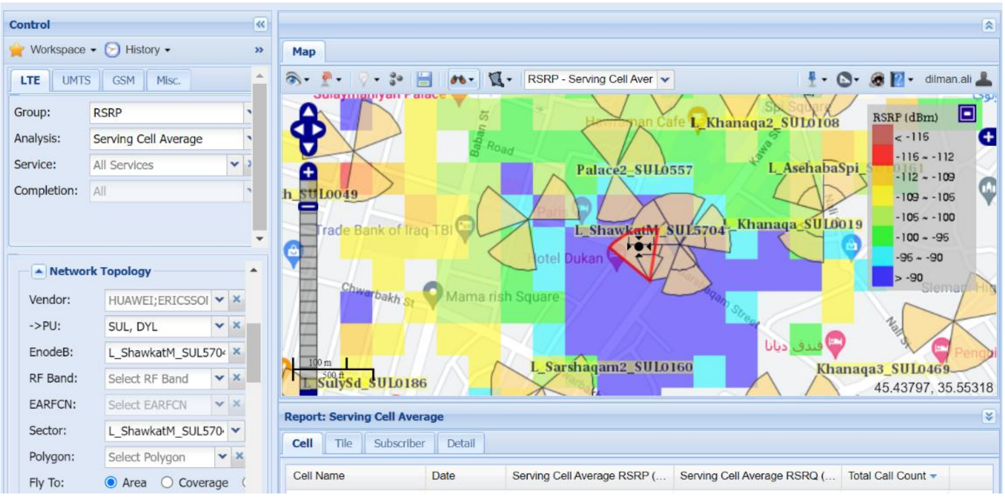


Figure 4: Geolocation simulation of RSRP in the basement market before RF optimization

DOI: http://dx.doi.org/10.25098/9.2.30

Figure 5: Geolocation simulation of RSRQ in the basement market before RF optimization.

The post-optimisation predictions show that there is a significant increase in the RSRP to -74.58 -1 dBm, which is to attest to a significant improvement in coverage capacity. On the other hand, the measured RSRQ enhancement was small as it increased to -10.79 dB. These measurements capture the additional effect of RF optimisation: although signal strength RSRP can be easily enhanced by corrective measures, signal quality RSRQ is mainly limited by existing levels of interference and not the actual power transmission.

Interestingly, the simulations also indicate that, under the settings where the indoor and outdoor RSRP values are comparable, RSRQ can be marginally higher at the areas within the hotspots indoors. The reason of such phenomenon is that outside environments normally have more cells on the same frequency band and therefore the attenuation of the signal in the basement settings reduces the interference; however, the attenuated signal of the basement setting allows RSRQ to sustain a slightly higher level at a given RSRP as seen in Figs. 6 and 7.

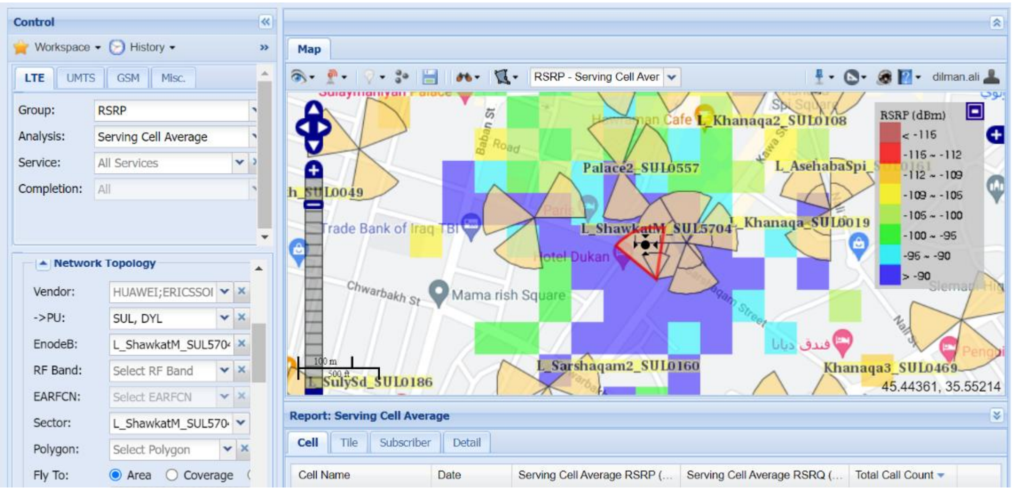


Figure 6: Geolocation simulation of RSRP in the basement market after RF optimization.

DOI: http://dx.doi.org/10.25098/9.2.30

The Scientific Journal of Cihan University – Sulaimaniya PP: 85-97
Volume (9), Issue (2), December 2025
ISSN 2520-7377 (Online), ISSN 2520-5102 (Print)

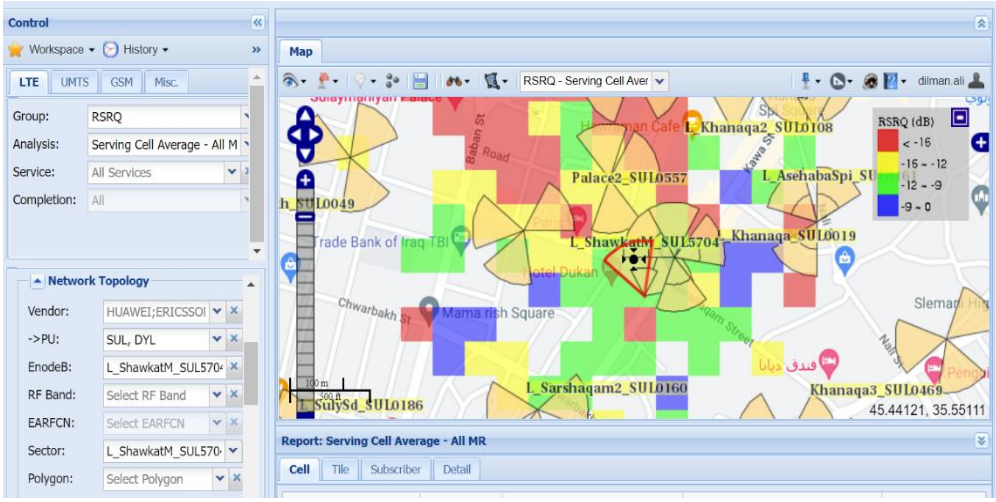


Figure 7: Geolocation simulation of RSRQ in the basement market after RF optimization.

Overall, the predictions of the Geolocation Tool provide strong theoretical evidence of the empirical findings: attenuation of RSRP leads to an improved coverage, and stabilisation of RSRQ requires the use of elaborate interference-management techniques, which reminds that the need to adopt advanced mitigation methods in dense indoor deployments is urgent.

3.4 Analysis of Intra-Band Interference

The empirical results emphasize that intra-band interference is the dominant limitation toward improvements in RSRQ in dense cellular networks. Although RSRP is significantly boosted through RF optimizations, e.g. azimuthal steering of antennas, Reduction in the RET or a fine-adjusted transmit power, the gain in RSRQ is limited by the growth of neighbouring cells within the same frequency band. The limitation is since RSRQ is a composite measure not only based on received signal strength but on aggregate interference and noise as the RSSI. Accordingly, RSRP among superior systems, although ensuring greater coverage, and perhaps signal penetration, is not inherently associated with proportional increases in signal fidelity.

RSRQ tends to plateau or experience only marginal increases in intra-band interference scenarios with a strong intra-band interference. This observation underlines the urgency of the interference-management schemes, e.g., dynamic spectrum-allocation, coordinated-multipoint (CoMP) transmission, or advanced interference-cancellation techniques, to ensure that the possible enhancements in network quality measures are fully utilized.

DOI: http://dx.doi.org/10.25098/9.2.30

The Scientific Journal of Cihan University – Sulaimaniya **PP: 85-97**
Volume (9), Issue (2), December 2025
ISSN 2520-7377 (Online), ISSN 2520-5102 (Print)

Conclusion

The paper presents a strict experimental investigation of the dynamics of RSRP and RSRQ in deep indoor, dense urban situations. The empirical results show that, although RSRP can be significantly improved by making specific RF optimization efforts, RSRQ improvements will always be inherently limited by ubiquitous interference. A strong RSRP is essential in stabilizing RSRQ but alone, it is impractical under the circumstances of extremely interfering ones.

The obtained data reveal a strong nonlinear relationship between RSRP and RSRQ present in the real-life indoor environment. RSRP alone is a poor proxy of network performance because it only measures signal strength but not the complexity of the interference patterns that are present in an indoor network. This means that successful network planning should simultaneously consider the RSRP as well as RSRQ and in doing so obtain a comprehensive analysis of the quality of links. In highly populated urban areas, intra-band interference caused by neighbouring cell significantly impairs RSRQ, which is why the importance of interference-reduction techniques is in addition to more traditional RF optimization. Furthermore, strategic changes in the azimuth and tilt of the antenna can provide improvements in the RSRP but the subsequent enhancement of the RSRQ is insignificant unless the interference is addressed directly.

These findings are not only applicable to the case of LTE systems but also to the areas of 5G and future 6G systems where the spread of a small-cell infrastructure stresses out the issues of managing interference. Further investigation should be given to advanced technologies, such as Coordinated Multi-Point (CoMP), interference-cancellation algorithms, and dynamic spectrum allocation, as the complementary solutions. Also, there is potential of predictive modelling with the integration of geolocation-based network planning tools; however, the accuracy of predictive models remains to be empirically tested, as predictive frameworks can often predict and model RSRP with high precision but are often less able to model the variability in RSRQ.

DOI: http://dx.doi.org/10.25098/9.2.30

References

COST Action 231. (1999). *Urban transmission loss models for mobile radio*. COST.

Dudhat, A., & Mariyanti, T. (2022). Indoor Wireless Network Coverage Area Optimization. *International Journal of Cyber and IT Service Management*, *2*(1), 55-69.

Holma, H., & Toskala, A. (2009). *LTE for UMTS – OFDMA and SC-FDMA based radio access*. Wiley.

Holma, H., & Toskala, A. (2011). *LTE for UMTS: Evolution to LTE-Advanced*. Wiley.

Kyösti, P., et al. (2007). *WINNER II channel models* (IST-4-027756 WINNER II D1.1.2 V1.2).

Imoize, A. L., Udeji, F., Isabona, J., & Lee, C. C. (2023). Optimizing the quality of service of mobile broadband networks for a dense urban environment. *Future Internet*, *15*(5), 181.

Lee, D., et al. (2012). Coordinated multipoint transmission and reception in LTE-Advanced: Deployment scenarios and operational challenges. *IEEE Communications Magazine, 50*(2), 148–155. https://doi.org/10.1109/MCOM.2012.6146493

Lin, Y., Choi, J., & Kim, J. (2013). Impact of antenna tilt on LTE performance in urban environments. *IEEE Wireless Communications, 20*(2), 80–87. https://doi.org/10.1109/MWC.2013.6507390

Saleh, A., Valenzuela, R. A., & Liberti, J. C. (1985). Propagation models for indoor radio communications. *IEEE Transactions on Vehicular Technology, 34*(2), 27–31. https://doi.org/10.1109/T-VT.1985.24076

Sesia, S., Toufik, I., & Baker, M. (2011). *LTE – The UMTS Long Term Evolution: From theory to practice*. Wiley.

Shirvanimoghaddam, M., Johnson, S. J., & Vucetic, B. (2020). Dynamic spectrum sharing for 5G and beyond: Challenges and opportunities. *IEEE Access, 8*, 81640–81658. https://doi.org/10.1109/ACCESS.2020.2991144

Zhang, H., et al. (2013). Interference management for heterogeneous networks in LTE-Advanced: A survey. *IEEE Communications Surveys & Tutorials, 15*(3), 1238–1257. https://doi.org/10.1109/SURV.2013.010413.00280

Zhang, J., et al. (2014). On the effects of antenna azimuth optimization in LTE networks. In *2014 IEEE International Conference on Communications (ICC)* (pp. 555–560). IEEE. https://doi.org/10.1109/ICC.2014.6883357

3GPP. (2018). *Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer measurements* (3GPP TS 36.214).

DOI: http://dx.doi.org/10.25098/9.2.30