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APPLICATION OF GROUND PLANE IN OPTIMIZATION OF MOBILE MEASUREMENT TEST FOR LTE NETWORK COVERAGE

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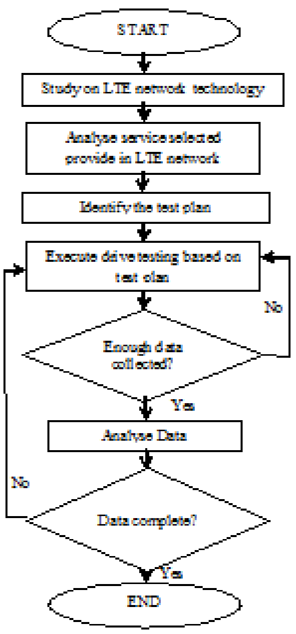
Graphical abstract



Abstract

Nowadays, the cellular communication evolution had shown that the demand for two-way voice communication had decreased against data rate demand after the globalization of Internet usage. This is where the cellular systems took another phase of evolution with Long Term Evolution (LTE) known as the fourth generation of cellular systems. LTE network is a system of packet switched network where the architecture had been simplified from the previous Universal Mobile Telecommunication System (UMTS) which is known as the third generation of cellular system. By having a simpler architecture than previous generation technology, the LTE standard has high data performance in wireless mobility. In measuring the performance of the LTE coverage, a lot of cost had been spent for the radio frequency optimization where the activity had been for the unwanted location where the poor coverage area is not applicable. This study is expected to optimize the data collection methodologies in mobile measurement in which could also be the turnkey of the current Telecommunications industry in benchmarking, new site implementation, solving customer complaints, and other related data collection services. The aim of this study is to develop an advanced measurement of LTE coverage by applying a sheet of electrical conductive material with two different sizes under the measurement device, and to determine the effectiveness of the proposed method. To determine the effective method in mobile measurement, the measured value of the conventional measurement will be compared with the proposed method together with the theoretical value of the measurement.

Keywords: LTE, drive test, ground plane

1.0 INTRODUCTION

Wireless mobile communications is undoubtedly by any measure had become the fastest growing sector of the communications industry. Through the technology evolution of LTE, high data rate can be achieved as the need of fast, smooth, and reliable mobility data solution would ensure the connectivity of people around the world.

In this study, section II would explain more on the literature review of the architecture, measurement equipment, proposed solution, and theoretical equation. Section III would explain more on how the methodology of the study would take place with the equipment settings, ground plane implementation, measurement process, and calibration procedure. While section IV would discuss on the results of the measurement, analysis and discussion that would justify the effectiveness of the measurement method.

Finally, this study would be concluded and recommendations are highlighted for future development through section V.

2.0 LITERATURE REVIEW

2.1 LTE Network Architecture

LTE standard of System Architecture Evolution (SAE) where the network architecture had been compressed described as Evolved Packet System (EPS). The terminal as an User Equipment (UE) with LTE capability connected to Evolved - UMTS Terrestrial Radio Access Network (E-UTRAN) which is also known as Evolved Node B (E-Node B) where the signalling of layer 3 messages took place with the UE. E-UTRAN would enable a direct connection and synchronize with the Evolved packet Core (EPC) for Packet Switch (PS) services in other words such as data transfer (uplink and downlink), browsing, streaming, and others. In this research, the performance of LTE would be optimized by utilizing the application of the ground plane to the mobile measurement test. Figure 1 shows the illustration of EPS where there are 2 types of network elements that signalling from the E-UTRAN terminal need to pass through before reaching the network gateway of the system.

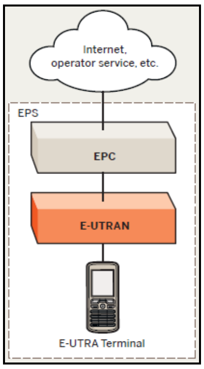


Figure 1 Evolved Packet System (EPS)

2.2 User Equipment

Handheld measurement device for LTE performance in physical and application layer measuring on the LTE throughput which would be the main concern in this research and would influence the performance of overall LTE services [2]. In accessing the LTE performance for benchmarking, measurement data is taken by using certain software which is able to collect the measurement data of the LTE signalling. The usage of certain software in data collection is due to the limitation of device performance which is used as the UE such as LTE modem or LTE compatible phone where the specifications are not the same within different UE as used in different software. In 4G mobile application, a Multiple in Multiple out (MIMO) antenna is used for transmitting the signal to create an LTE coverage area. The antenna is using the resonance of double ground planes located on upper and lower in the mobile terminal are excited as the radiator [3]. The performance of an antenna is evaluated by a key parameter of Envelope Correlation Coefficient (ECC) for a MIMO system. This method of measurement had proved that the effectiveness of utilizing ground plane could improve the performance of small antennas. Mobile measurement using a LTE capable mobile phone would require a MIMO antenna pre-installed upon manufactured. In maintaining a good isolation between antenna elements where multiple antennas are closely placed into a slim mobile phone, the challenge is to find new techniques for isolation improvement inside mobile phone between the antenna elements [4]. Improving the isolation between antenna elements and ground slits which is also known as ground plane had been introduced in order to improve the isolation characteristic. At a specific frequency band, ground slits are utilized to disperse the surface currents. However, the application of the ground plane only proposed to be merged with the antenna system. But if the application of the ground plane is applied to a measurement equipment which would also having antenna system, the utilization of the ground plane could also improve on the antenna isolation thus help to optimize the mobile measurement test.

2.3 Ground Plane

The application of ground plane is the element to reflect the emission from equipment under test to the receiving antenna in Open Area Test Site (OATS). OATS is widely used for radiated emission measurement for national or international standards [5]. The concept of ground plane application in the OATS could be applied in optimizing the mobile measurement test by assuming only two waves propagation which are direct wave and reflected wave. By applying the concept of direct wave and reflected wave, the OATS only happen to measure the radiated emission instead of mobile signalling by ground plane utilization. High impedance ground plane offers planar solution with electromagnetic characteristics allows reducing the interaction between the antenna and its backward environment [6]. These advantages yield better isolation of the antenna thus improving the efficiency in term of bit rate or distance range. It is proved that the application of the ground plane to antenna had significantly improved the antenna isolation and overall efficiency of the antenna. However, the study would only offer the electromagnetic characteristics to the antenna instead of a mobile measurement. By offering the planar solution to the antenna, the application of ground plane in mobile measurement test could be optimized in data collection for LTE coverage. The surface wave is suppressed by applying the high impedance ground plane to an antenna which is used in a phased array application [7]. The resonance result in a suppression of surface waves benefit in a variety of antenna applications by creating less interference from neighbouring elements. But this method could only improve on the band gap of the antenna, thus applying this technique of suppressing the surface wave could be applied externally to the antenna of a UE for mobile measurement test in LTE. The ground plane of the mobile phones plays important role in the antenna system behaviour instead of optimizing the antenna geometry which is a common way in designing an antenna to have required performance [8]. The planar antenna with the application of ground plane discussed in this research would only be available for a custom mobile handset. However, the ground plane is not utilized externally which would make an improvement of the mobile signalling. In the research of an antenna using slots of a ground plane forces the antenna to resonate at a certain frequency which improves the bandwidth.

2.4 Radio Condition Measurement

The measurable radio condition of LTE network had been specified through the 3rd Generation Partnership Project (3GPP) where the measurement of LTE coverage area refers to the Reference Signal Received Power (RSRP) which is correlated with Reference Signal Strength Indicator (RSSI) throughout the coverage area. The theoretical RSRP under 100% Physical Resource Block (PRB) utilization with high SNR [9] is calculated in dBm according to equation (1).

$$\text{RSRP (dBm)} = \text{RSSI (dBm)} - 10\log(12N) \qquad (1)$$

Where N is the number of PRB across the measured RSSI and the value depends on the bandwidth of the transmission as shown in Table I.

Table 1 LTE bandwidth and prb scaling

Bandwidth	1.4 MHz	3 MHz	5 MHz	10 MHz	15 MHz	20 MHz
Number of PRB	6	15	25	50	75	100
Scaling: -10log(12N)	-18.57	-22.55	-24.77	-27.78	-29.54	-30.79

In order to determine the effectiveness of each method, a deviation of RSRP is calculated in dBm between the measurements of the conventional (normal), with application of 10cm x 10cm ground plane, and 20cm x 20cm ground plane according to equation (2) and (3).

$$\Delta\text{RSRP (dBm)}_{20\text{-}n} = \text{RSRP(dBm)}_{20x20} - \text{RSRP(dBm)}_{normal} \qquad (2)$$

$$\Delta\text{RSRP (dBm)}_{20\text{-}10} = \text{RSRP(dBm)}_{20x20} - \text{RSRP(dBm)}_{10x10} \qquad (3)$$

Where the deviations are referred to the measurement of 10cm x 10cm and 20cm x 20cm ground plane application as the improvement is expected to be on the value of RSRP compared to the conventional measurement.

3.0 RESEARCH METHODOLOGY

In beginning of the project, a suitable location should be determined in order to fulfil the criteria of the mobile measurement that is going to be tested in LTE network. Then a calculation should be made in order to get the theoretical value of the RSRP which then would be measured through the mobile measurement method of drive test where the usage of car with a power inverter is needed to perform the measurement. In this study, the area of Universiti Teknologi MARA, Shah Alam, Selangor, Malaysia had been determined as the proposed area with Celcom LTE network coverage area. The measurement has been done simultaneously by using conventional method, with 10cm x 10cm ground plane, and with 20cm x 20cm ground plane which would be the proposed method in replacing the conventional measurement. As for the movement speed of the vehicle throughout the drive test method would be around 30 to 50 km per hour where the Doppler's effect could be reduced in this measurement.

3.1 Measurement Equipment

The following equipment is used when performing a radiated emission measurement. All equipment used in this project is declared complies with the International Telecommunication Union (ITU) standard regulatory in order to get a valid result of mobile measurement of LTE network. Figure 2 shows the equipment used for the mobile measurement and Table II is the list of equipment with type and specification that would be used in the drive test.

Figure 2 LTE measurement equipment

Table 2 LTE measurement equipments

Equipment	Type/Specification
LTE Scanner	R&S TSMW
Modem Data Card	Huawei E392
Laptop	Lenovo Intel i7 processor
USB cable	Extension for modem
Nemo Outdoor	Version 7.0
Nemo Analyze	Version 6.5
Ground Plane I	10cm x 10cm
Ground Plane II	20cm x 20cm

3.1 Ground Plane Implementation

A conducting ground plane is required during the implementation of the mobile measurement for

10cm x 10cm and 20cm x 20cm as proposed. It is proven that antenna with ground plane can cover a complete frequency range as it is known as a wideband antenna [10]. The ground plane is made from aluminium with the thickness ±2 mm^2 and is shaped into a square shaped plane. Then, the edge of the ground plane is earthed to the grounding of the car with cable clip. The ground plane is placed on the dashboard under a modem data card inside the vehicle which is used for the purpose of drive test. Figure 3 shows that the ground plane is implemented with the modem data card which is defined as the UE.

Figure 3 Implementation of ground plane with UE

3.2 Conventional Measurement

The measurement of LTE network performance that had been applied today had never been optimized in measuring the peak performance. This is where the cost of optimization had increased due to the reporting of non-peak performance of the LTE network. The conventional measurement had been implemented in this study in order to determine the effectiveness of using two different size of ground plane instead of conventional measurement alone. The method of the conventional measurement is applied by placing the UE on the dashboard of the vehicle using the USB cable extension connected to the laptop.

3.3 LTE Scanner Measurement

Before initiating the process of mobile measurement, the UE need to be calibrated in order to determine that it is measuring the acceptable value throughout the coverage area of LTE. This practice is done to avoid any faulty that might affect the UE from recording unreliable data during the drive test process. This is due to performance of the UE which is running on downlink throughput test case does not vary within the cell where a single user in the cell is taking all of the available bandwidth while the scanner only tracks the reference channel in each band [11]. The measured value would keep fluctuating between the LTE scanner and the UE which would be hard to be calibrated by just referring to the recorded data. To calibrate the performance of the UE with the scanner would need an analysis through the map plotting which is done by using Nemo Analyze. Since the scanner reading could only be plotted according to the bandwidth of the LTE network measurement, this calibration need to consider for both bandwidth of 10 MHz and 20 MHz which is defined in carrier number of 1650 and 3150 for Celcom LTE network. Figure 4 shows the calibration of the UE by referring to the scanner reading.

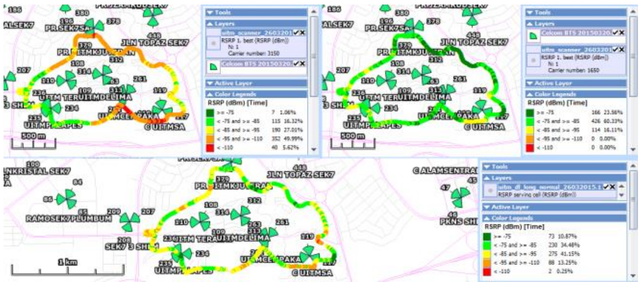


Figure 4 Calibration analyses by measurement plotting

4.0 RESULTS, ANALYSIS, AND DISCUSSION

The measurement process took three weeks for the data to be gathered. This measurement had been done on 26th March, 2nd, and 9th April 2015 with the same timeline to ensure the recorded data would be able to be combined once the data had been analysed. From the data also would be able to interpret the application of the theoretical RSRP with the measured value from the drive test. The combination of data would be done in term of every procedure which had been proposed for the mobile measurement procedure.

4.1 Conventional RSRP Measurement

The result from the first method of conventional measurement of RSRP will be averaged throughout three different dates which happen to be on the same day and same time. The same concept would also be used for the other proposed method of the mobile measurement which is for the application of the ground plane of 10cm x 10cm and 20cm x 20cm. The graph from Figure 5 shows the result of the average of conventional measured RSRP versus theoretical RSRP which had been calculated based on the measured RSSI value limited to the bandwidth of 20 MHz LTE sites only. The measured and theoretical value is bound by the acceptability criterion of ±5dBm which is defined as Sum of Max and Sum of Min.

The measurement of the conventional mobile measurement fulfilled the RSRP acceptability criterion of ±5dBm with value of depicted theoretical RSRP value. The conventional mobile measurement method would be the benchmark for the proposed application of the ground plane.

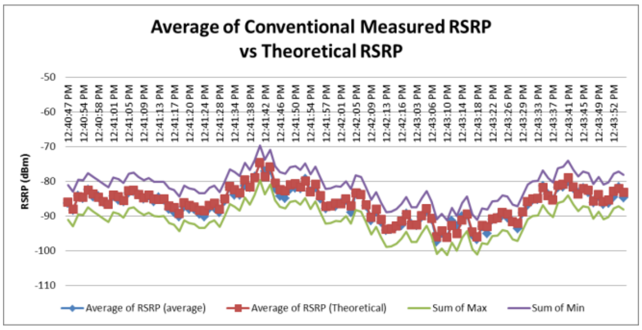


Figure 5 Conventional measurement result

4.2 10cm x 10cm Ground Plane RSRP Measurement

The mobile measurement continues with a different timeline by implementing the ground plane size of 10cm x 10cm. The implementation of the ground plane is proved to optimize the transmitting and receiving electromagnetic wave by considering the concept of direct wave and reflected wave [5]. Figure 6 shows the average of the mobile measurement which applied the concept of ground plane with 10cm x 10cm size of the square-shaped plane compared with the theoretical value of RSRP. The measurement shows the measured value is within the minimum and maximum which fulfilled the acceptability criterion of the measurement.

With the measured value depicted theoretical RSRP value, an analysis had been done by using the concept of deviation between 10cm x 10cm measurement and the conventional measured value. This method of analysis is shown in Figure 7 where the positive value from the Sum of Difference shows 10cm x 10cm ground plane measurement is having a better RSRP value than the conventional measurement. This has been proven that the antenna geometry had been optimized through the application of the ground plane [8] when it is utilized externally from the UE instead of the planar antenna which is designed for a custom mobile handset to have required performance. As an LTE capable mobile phone which is pre-installed with a MIMO antenna would only suppress the isolation between the antenna elements [4], application of the ground plane would be able to disperse the surface current thus improving the isolation characteristics.

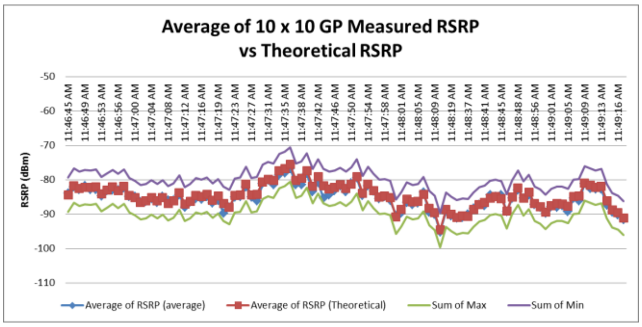


Figure 6 Ground plane application 10cm x 10cm measurement result

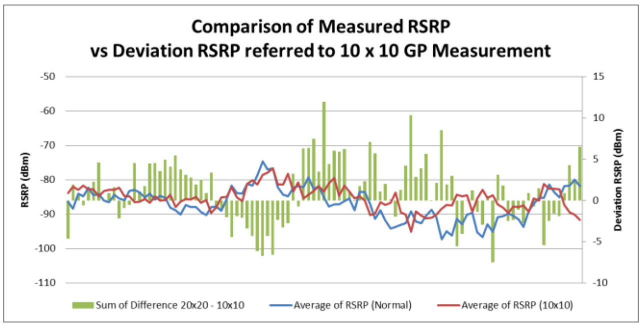


Figure 7 RSRP measurement deviation referred to 10cm x 10cm ground plane application

4.3 20cm x 20cm Ground Plane RSRP Measurement

By referring from the previous measurement analysis result with the application of 10cm x 10cm ground plane, another proposed size of the ground plane should be taken into consideration which is 20cm x 20cm. Initial analysis of the size for the ground plane where two sizes of ground plane are proposed, the size had been double from 10cm x 10cm to 20cm x 20cm. This is to ensure by applying the concept of ground plane can be correlated with two different sizes. From Figure 8, it observed that there is a deep slope during the initial measurement and rises drastically after that. This condition could be assumed as the backward environment where high impedance ground plane offers planar solution with electromagnetic characteristics [6]. However, the measurement shows the measured value of RSRP is still within the acceptability criterion.

With the measured value depicted theoretical RSRP value, an analysis had been done by using the concept of deviation referred to 20cm x 20cm measurement against conventional measured value and 10cm x 10cm ground plane measured RSRP value. This method of analysis is shown in Figure 9 where the positive value from the Sum of Difference shows 20cm x 20cm ground plane measurement is having a better RSRP value than the conventional measurement and the application of smaller size ground plane. By increasing the size of the ground plane, this would introduce higher impedance than the smaller ground plane and would suppress the surface wave and create less interference [7].

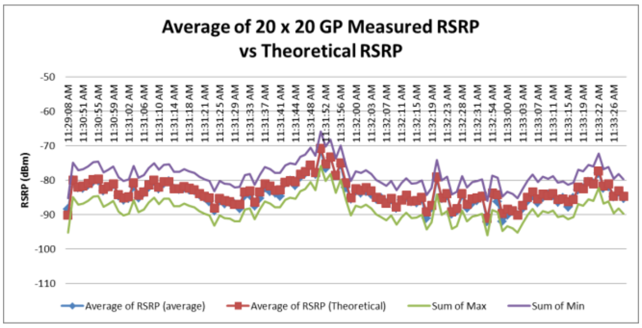


Figure 8 Ground plane application 20cm x 20cm measurement result

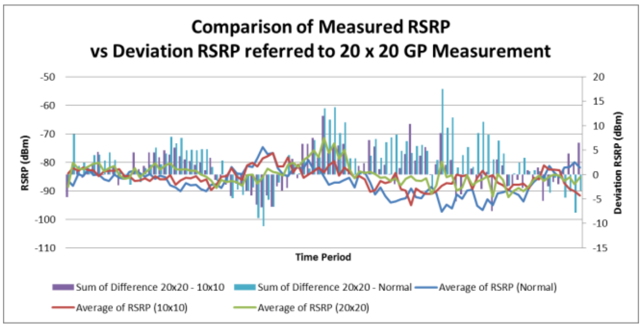


Figure 9 RSRP measurement deviation referred to 20cm x 20cm ground plane application

5.0 CONCLUSION

It has been shown in this paper that the application of the ground plane could optimize the mobile measurement test in the LTE network. In conclusion of this study, the proposed 20cm x 20cm ground plane had significantly optimized the measurement value compared to the conventional measurement which is being practiced in the daily LTE network performance measurement and could reduce the cost of optimization need following the acceptable peak performance by using the ground plane. By comparing the proposed size of the ground plane, 20cm x 20cm ground plane able to apply the concept of higher impedance than 10cm x 10cm ground plane where there is more positive value of RSRP deviation when referring to the Sum of Difference 20x20 - 10x10. Therefore, the ground plane is applicable in the mobile measurement test and proven to optimize the LTE network coverage.

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