Computational Methods for Differential Equations
http://cmde.tabrizu.ac.ir
Vol. 7, No. 4 (Special Issue), 2019, pp. 535-544

Mapping a new system for outdoor GSM signal strength

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Abstract The Analysis of radio wave propagation is a crucial part in designing an efficient wireless communication system. The Geographic information system (GIS) can be incorporated into this procedure because most of the factors in radio wave propagation are geographic features. For reliable cellular mobile communication received signal level must be above the receiver sensitivity. Determining of network zone in which this requirement is satisfied is done in the phase of planning of the mobile network by using various methods of field strength prediction. In this Paper, a system for automatic measurement of signal level in Global System for Mobile Communication (GSM) 900/1800 MHz channel with Global Position System (GPS) localization is tested in a field driving test carried out in Suaimania City, Kurdistan Region, Iraq. The result indicates that through the use of GSM, GPS and GIS (G3) technologies a map could be developed and used to study the signal strength of a particular location. In addition, the multipath fading phenomena effect of the mobile radio coverage could be also analyzed based on the wireless communication principles.

Keywords. GSM, Mobile networks, GIS, Signal strength.
2010 Mathematics Subject Classification. 65L05, 34K06, 34K28.

1. Introduction

Wireless communication has developed into one of the most exciting technologies of the last century since its birth in 1897 as the radio telegram see [1]. Wireless communication in the past several decades is better known as cellular network communication. Currently, requirements for providing wireless communication services can be simply described as the 5Ws. That means, not only the availability, but also the quality of the network has become a key parameter of wireless communication service. In this case, cellular network design is becoming more and more important since the network quality is highly dependent on the distribution of base stations [2]. To design a cellular network for a particular region efficiently and accurately, the analysis of radio wave propagation is an important determination. This process is

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also called wireless planning. Hence to meet the mobile network planning efficiency in Sulaimanyia City Center, a useful map that illustrates the Global System for Mobile Communication (GSM) signal strength and shows the coverage of the GSM operators within the Sulaimanyia City is necessary [3, 4, 5]. The important of obtaining a satisfactory coverage of locations is of great interest, however, random previous studies and incomplete data on GSM coverage have hindered the progress in obtaining GSM signal strength coverage map. Furthermore unreliable data of GSM coverage regarding Sulaimanyia cause a delay in information on GSM radio coverage in Sulaimanyia. Mapping the GSM level is a great of interest in which plotting the mobile radio coverage in a particular area by visualizing in a digital map gives better mobile network planning and standard level in radio maintenance quality control [2, 6, 7, 8]. Most people would like to have very good GSM signal coverage around the day regardless the mobile propagation problems such as multipath fading. This paper is carried out to solve this type of problem [9]. Geographic Information System (GIS) technology is critical to the success of the planning process in a cellular network operation, hence demographic and customer problems analyses are needed. Plotting the mobile radio coverage by visualizing it in the map provides better level in quality control by developing the predictive aspects of the implementation process [10, 11, 12]. Customer care locates coverage or quality-specific customer claims by placing reported signal problems for example on an Intranet Web page. Transmission engineers analyze the incident reports and produce terrain profiles for transmission planning. Therefore due to that maintaining up-to-date coverage map of the network is must and very useful. Accordingly this paper first objective is to use economical developed system for automatic measurement of signal level in GSM 900/1800 MHz channel with GPS localization [13]. Then, to carry out empirical data collection needed for the map development and to analyze the empirical data for radio propagation of coverage area in GSM cellular system.

2. GIS in Wireless Signal Propagation

In this paper, GIS-aided data analysis was implemented in an experimental derive test to study the influence of geographic features on the predicted wireless signal strength along roadways in 5 km radius of Sulaimaniya City center, Iraq. Data were collected by the G3 Integration system that recorded the strength of the GSM 900/1800 MHz signal received from the Mobile operator towers (Asiacell, Zain Iraq, Korek Telecom) while driving [14]. GIS mapping also performed a significant role in the analysis of driving test data. Terrain, land cover types and radio wave propagation path were hypothesized among the factors affecting the signal strength at each spot in the study area. Propagation mechanisms are very complex and diverse. Because of the separation between the receiver and the transmitter, attenuation (reduction or loss) of the signal strength occurs. It is important to understand radio propagation for land mobile radio for a number of reasons. Multipath propagation between a vehicle and a base station prevents %100 reliable communications throughout a service area. Free-space propagation takes place between a transmitting and a receiving antenna in empty space with no interfering bodies between. There are no ground reflection or diffraction losses. Free-space attenuation occurs during the first few miles of path.

Free-space loss is 6 dB per octave of distance (doubling the distance) [15]. The formula for free-space attenuation using a dipole antenna for both antenna and receiver is:

$$Attenuation(dB) = 32.6 + 20logf + 20logd\,. \tag{2.1}$$

Where; F = frequency in megahertz, d = distance in miles between the transmitting and receiving antennas. Diffraction losses as the radio wave passes over an obstacle is one limitation to free-space propagation. Plane-earth propagation is the multipath propagation due to the reflection from a smooth earth. Plane-earth attenuation is twice that of free space attenuation with distance. That is, plane-earth propagation is attenuated 12 dB per octave of distance compared to the 6 dB per octave of distance for free space. The formula for plane earth attenuation is decibels is:

$$Attenuation(db) = 144.6 + 40logD - 20log(HTHR)\,. \tag{2.2}$$

Where; D= distance between transmitting and receiver dipole antennas, miles, HT= height of the transmitting antenna, ft, HR= height of the receiving antenna, ft [16, 17, 18]. To achieve the proposed objectives, there are some steps were followed as follows: Collection of GSM signal level coupled with the GPS localization around City Center. Collection of data in the form of map for City Center and build its data base. Collection the GPS coordinates of the GSM operator towers in the City Center Locations. Analysis of the signal strength level in City Center based on the multipath fading.

3. Data Collection and Analysis

Several data collection were done in which all of them were conducted inside the study area, the data collection are as follows: A derive test was done around Sulaimanyia City Center campus for collecting the signal strength data. Basic data was collected in the form of AutoCAD drawing format. This data includes the map of the study area which contains the details of the buildings and the road network. GPS survey data collection for obtaining the contour lines was needed. Asiacell, Zain Iraq, Korek Telecom mobile towers GPS coordinate determined within City Center for obtaining the coverage map for each. After the collection of the data sets , each data set will be managed separately based on the available software tools in order to set up an integration of the all the data sets layers to come with the G3 map. Regarding the City Center map, it will be manipulated by applying some changes on it. The changes may include the cleaning of drawing and development of building and network topology. After these changes the data base will be developed by defining the buildings which are collected from the master plan map. Regarding the GSM signal strength, each signal reading will be processed along with its GPS coordinates. Signal level measurement along with the GPS localization would be saved as text document in notepad file which contains signal strength, cell ID, latitude, longitude, date and time respectively. After that the next step to convert the text file document into a shape file so that it can be processed by the GIS ArcView software. Moreover, Contour lines will be subjected for processing by using Skypro software, since the contour line plays an active role in effecting the signal strength. For this data collection purpose a GPS survey will be conducted. After processing the above mentioned data collection an

integration of these sets will take place in ArcView software as overlaid themes. Once the G3 map is obtained it will be shown in Graphical and text formats. Graphical format will show the signal strength in Sulaimaniya City Center based on gradual color classes, while the text format will show the map data base [19]. The analysis part can be done based on the cellular network communication and multipath fading problem.

4. Classification of collected data

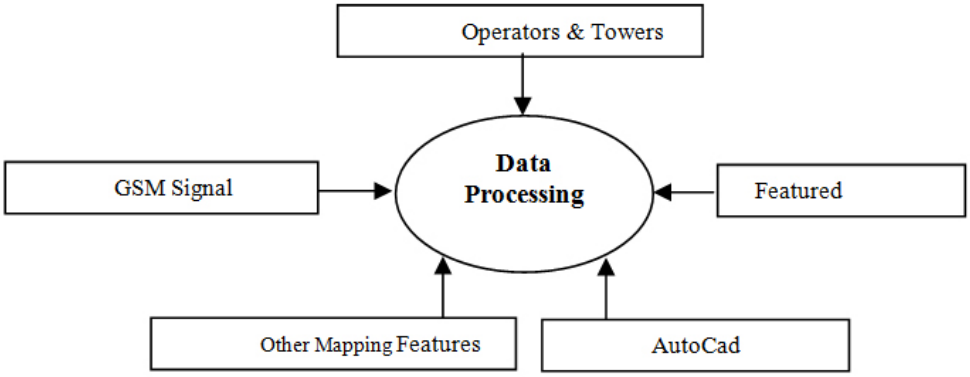
The data collected can be classified in few classes depending on its necessity as below:

- Measurement of the signal strength level.
- Graphical data about the study area.
- Featured data about the study area.
- Attribute data about the buildings in the study area.
- Attribute data about the Mobile towers.
- Other features required for analysis.

The measurement of signal strength in the study area was carried out by the developed system for measurement of signal level. Its a system in which an integration of GSM mobile is done with the GPS localization as shown in Figure 1. This integration is done in steps as shown below: Step 1: Development of GSM module to collect the received signal strength. Netmonitor menu in the Nokia hand phone will be activated. This menu contains various network parameters which are sent by base station via the air interface. Only received signal strength will be extracted. Step2: Development of GPS module to acquire position of measured data. NMEA0183 protocol is utilized to transmit the data from GPS to the PC. The data will then be processed in order to get the latitude and longitude of the desired locations. Step3: Integration of the GSM and GPS along with the Visual Basic program in order to obtain the required GSM signal level along with their GPS coordinates. Step 4: Conduct field measurement of signal strength of network provider, by carrying out test derive in Sulaimaniya City Centre. Figure 1 Shows the GSM 900/1800 Signal strength measurement system. A derive test in the study area was conducted using developed system. The system had been taken into a personal car, with a non-stop constant speed for better measurement reading by the system. The deriving test took place on City center main road including the hills areas and valleys. Furthermore, roaming in the blockages area was done respectively. Signal level measurement along with the GPS localization would be saved as text document in notepad file. Graphical data of the study area was collected in the form of the plan map, which was in the AutoCAD drawing format (*.dwg). Nevertheless, that (*.dwg) file was obtained by digitizing the ordinary map showing the plan printed on the paper. The AutoCAD drawing file had certain layers about the study area like road network, academic buildings, river, residential buildings, parking spaces and other places showing their detailed information and graphic location [7]. GPS data collection was carried out for every BTS inside the Sulaimaniya City Center. The GPS format was in World Geodetic System (WGS84) and due to that the final map is in Cassini coordinates Towers attributes

FIGURE 1. The GSM 900/1800 Signal strength measurement system.

FIGURE 2. Flow of data collection to its processing.



has to be in Cassini as well. Only one way is convert the initial GPS format in WGS84 to Rectified Skewed Orthomophic (RSO) using the stand alone GPS then converting to the Cassini coordinates using Coordinates Transformation Software (CTS) [8]. To execute such type of analysis, computer hardware and software are needed. In the hardware it may contain a computer which can support the softwares like AutoCAD, Autodesk Map, and some GIS software easily. And for the software side, there are few types of software which were used to manipulate and analyze the data. The software used were AutoCAD to view the drawing, Autodesk Map to build the topology, MapInfo to convert the projections of map and data, Microsoft Excel to develop the database and many more. The main software for the creating the Signal strength map ArcView 3.1. Data collection can be organized as shown in Figure 2. After collection of whole data it was started to manipulate through several software. To achieve the aim of this study, it was necessary to manipulate the data to get the right format

of the respective GIS software for analysis. Data Manipulation was consisted of few processes which are listed below:

- Editing of drawing file in Autodesk Map.
- Cleaning and Building of topology of the drawing.
- Application of drawing interchange file format (*.dxf) to ArcView.
- Conversion of the (*.dxf) file to the ArcView format.
- Inserting attribute data of buildings and the mobile towers in the database.

At the end, the drawing file was saved as drawing interchange file format (*.dxf) to apply in ArcView. Step by step processes of editing, cleaning of drawing in Autodesk Map and building of network topology in Autodesk Map.

5. Results and Analysis

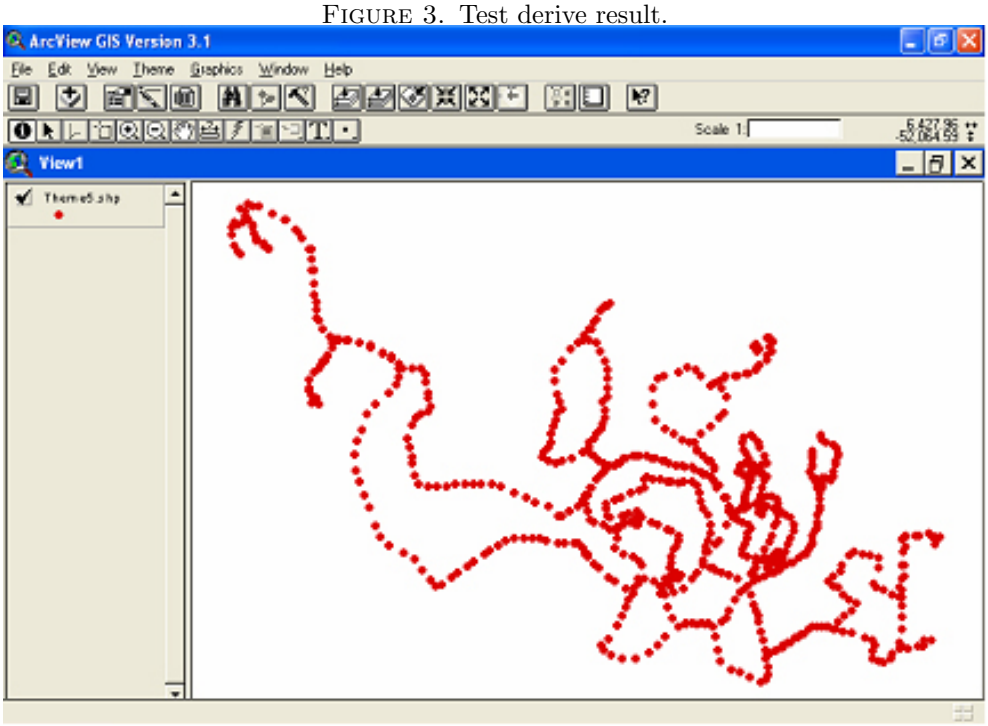
Consumers of mobile cellular telephone in Sulaimaniya City Center are placing ever higher demands on the quality of reception despite the hostile environment in which radio mobile receiver have to operate. Radio transmissions are expected to be clear and uninterrupted for all GSM900/1800 MHz users. This chapter illustrates the project results and analyze that various distortions that a signal may undergo during its propagation between the transmitter (BS) and the receiver (MS). The first measurement to be conducted in this project was the derive test around Sulaimaniya City Center using the signal level measurement system, Figure 3 shows the way points of the derive test in the study area.

Figure 4 shows the final result map in which it contains several themes in shape file format, themes which are listed below:

- Towers.
- Signal Level contours.
- Road network.
- Buildings.
- Sulaimaniya City Center signal strength level way points.
- Signal strength level

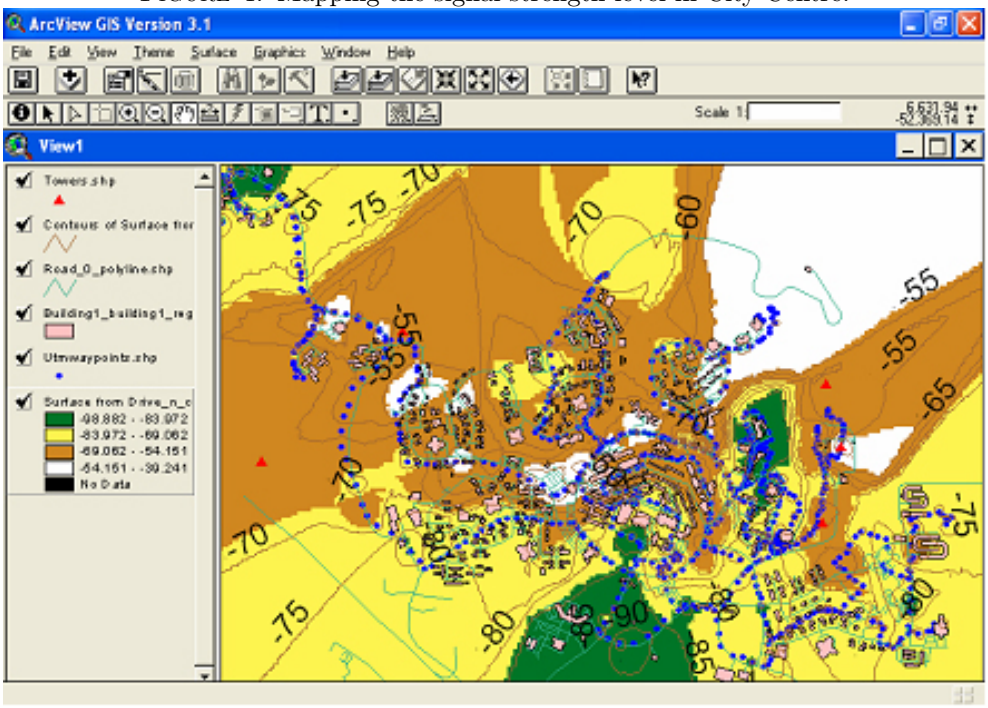
The problem of fading and multipath fading in Sulaimaniya City Center result from a number of different effects. However, as long as Sulaimaniya City Center is a concern they can been categorized as attenuation, slow fading, multipath delay spread, and Rayleigh and Racian fading. The received signal is usually a combination of direct and indirect paths, that is, those paths in a line of sights and those that involves diffraction, refraction and reflection off buildings or other objects. Each signal is influenced strongly by its distance from the transmitter. Electromagnetic radiation field strength varies in inverse proportion to the square of the distance, but when atmospheric attenuation effects and absorption of the terrain are taken into account the attenuation can be as high as the inverse sixth power of the distance. The map is very clear and understandable by everyone for instance mobile radio engineer, radio signal propagation analyzer, etc. The user easily can distinguish between the campus areas based on their signal strength, for example if the user wants to know which area in Sulaimaniya City Center got the strongest area then simply those areas with the white color are best areas that got very good GSM900/1800 radio coverage as

FIGURE 3. Test derive result.



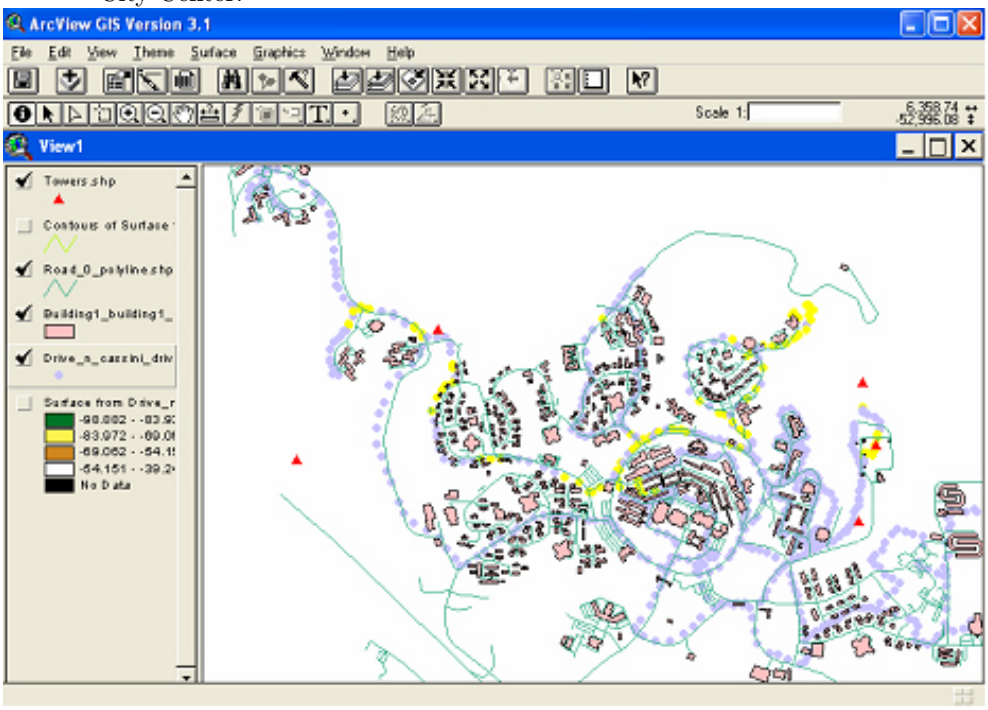
illustrated in the legend. Most of the Sulaimaniya City Center area got medium signal level that ranges between -54.151 to -69.260, its deemed to be a good coverage, nevertheless, its effected by the multipath problem. In Figure 4 the yellow legend indicates the signal level that ranges from -62.069 to - 83.972 which can be classified as low medium range. These above mentioned areas are located in very congested zone where lots of buildings are available and heavy traffic motion exists. In such urban-up multipath occurs due many factors in which the most important is due reflection from the ground and surrounding structures. Hence the signal received by the mobile at any point in space may consist of a large number of plane waves having randomly distributed amplitudes, phases, and angles of a large number of arrivals. Finally the last legend in Figure 4 indicates the poorest signal strength level in Sulaimaniya City Center, from -83.972 to -98.882 with green color. In other words the GSM signal in such area in a deep fade due to many reasons like movement of the receiver at high speed can pass through several fades in a small period of time, movement of the surrounding objects at high speed and the combination of the arrival signals in constructively manner which cause cancellation of the signals. These factors along with others don't cause the receiver to go in deep feed merely, but may stop in a particular location (within the green colored area) at which the receiver cannot functioning any more. Multipath creates difficult reception problems. The three significant in the mobile network of the study area are delay spreading, Ray fading

FIGURE 4. Mapping the signal strength level in City Centre.



and random Doppler shifts. Multipath propagation occurs when signals arrive at the receiver both directly from the transmitter and via reflections from, or transmission through, an obstacle. Large reflectors, and hence long path difference, cause multipath or frequency-selective fading. The amount of signal reflected depends on a number of factors, including the polarization of the incident wave, the angle of arrival, the carrier frequency and the relative permittivity of the surfaces. ArcView Query Builder lets the user by text input to query for specific signal strength data and shows the relevant information. In this query, a feature named as query builder is used to input text. To start the query, the user has to click the Theme properties icon on the tool bar displayed on the top. Query Builder button is available in the theme properties dialog in which the user by clicking on it can build a query expression to specify which signal strength level is needed to be highlighted. By default, the query is contained within parentheses, but the parentheses may not be required, depending on the complexity of the query. The Query Builder dialog in which can be utilized in finding the strongest signal strength level waypoints, to do so the surface signal strength level legend has to be ticked off and the Sulaimaniya City Center waypoints.shp has to be activated. By following the above method, the result looks like as shown in Figure 5.

FIGURE 5. Signal strength level of -54 dBm around the Sulaimaniya City Center.



6. Conclusion

The success and rapid growth of cellular system has been foremost in establishing a critical need for maintaining a standard quality of GSM signal strength level that will greatly increase mobile communication coverage. Moreover wireless design, also known as wireless planning, is a very complicated task for engineers and most results do not inspire a high level of confidence since there has never been a general theory that can be used in every geographic location because of the diversity of circumstances. This project made an attempt to map the GSM900/1800 signal strength in Sulaimanyia City Center and to analyze the effecting factors of the multipath fading on the signal strength. The integration of the GIS,GPS and GSM (G3) forming a powerful system that helps in managing the wireless design platform by boosting and marinating an excellent radio coverage between the operator base station and the mobile Receiver, taking into account the geographic land factors and their relevant problems.

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