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Impact on Quality of Service (QoS) of Third-Generation Networks (WCDMA) with Pilot Signal Pollution

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Abstract

This paper shows an experimental development to identify the phenomenon called pilot pollution and observe its impact on Quality of Service (QoS) of 3G networks. The analysis is based on coverage maps, created from spot measurements obtained with specialized measuring equipment, able to obtain information based on the Key Performance Indicator (KPI) of the WCDMA system, called Common Pilot Channel (CPICH). Consequently, we analyze various performance indicators that allow us to identify the signal problems. Then, using a Geographic Information System (GIS), identify the problem areas, overlapping coverage and trend in signal propagation.

Keywords: 3G; CPICH; Ec/Io; GIS; KPI; Krige; QoS; RSCP; WCDMA.

1. Development of Research Paper

The mobile communication networks have been developed over time. This because constant demand for services that has led to growth and thus an improvement in cellular mobile communications systems. With Third Generation systems, we have an increase on speed and data transfer, all thanks to medium access technique called WCDMA (Wideband Code Division Multiple Access) that providing us a compromise between coverage and capacity of systems. WCDMA provides several advantages such as the use of a single frequency for all users and immunity to noise. The use of spread spectrum technique allows the data integrity

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is preserved even in hostile scenarios. However, the most common problem for these systems is related to frequency reuse scheme that in 2G networks are the access control parameter. This means that WCDMA networks require a control based on another parameter, in this case a power control for deciding the base station (Node B) that will provide service to mobile terminals, this control must be widely controlled and avoid problems that may affect systems performance.

UMTS Terrestrial Radio Access Network (UTRAN) is the system of UMTS radio access. The components of the UTRAN are the base stations, which are also called Node B and control nodes (RNC, Radio Network Controller). The analysis on the characteristics of the signal is performed over the Uu interface or on the downlink between the user equipment and Node B as shown in Fig 1.

![Image](https://example.com/image1)

Fig. 1 Access Plane Architecture

In WCDMA systems each base station transmits a pilot code; this code makes possible the coherent demodulation, reducing the level of Ec/Io and improves system performance. The pilot code is transmitted over the Common Pilot Channel (CPICH) that is a physical reference for other channels. It is used for power control, transmission and coherent detection, channel estimation, measurement of adjacent cells, process of soft-handover and obtaining the Scrambling Code (SC) [1] [2].

The CPICH power level allows us to determine that base station will serve to the mobile terminal, even this does not guarantee that the signal that is received is acceptable due to interference [3]. Although the received signal has a power level suitable for that the receiver can recognize the signal, communication can be degraded due to interference and the transmission rates could be reduced.

In 3G networks using WCDMA, mobile terminals receive signals from multiple nodes B. Therefore, it is possible that the mobile terminal cannot start logging network because several pilot signals are received with high reception, but none of them is sufficiently dominant so that the mobile can choose. Within the network planning there are efforts to prevent this type of problem, ensuring that only a pilot signal is dominant.

1.1. Research Case

The pilot channel pollution represents a problematic for operators that work on WCDMA. Basically, the pilot pollution is a type of interference, this occurs when there is not pilot dominance this means that there are several pilots with high power levels, but the mobile terminal cannot choose between them.

In areas of high pilot pollution, soft-handover algorithm is unable to do decisions because there are pilots with high power in the same coverage area, preventing that terminal chooses any of them [3].
In this paper, we developed an experimental analysis on CPICH power values, Key Performance Indicator that lets us know the performance and WCDMA network coverage. Furthermore, this analysis allows us to look problems on the network in a specific area.

1.2. Measurement Methodology

The measurements were performed by a spectrum analyzer capable of working in the frequency range of 100 kHz to 7.1 GHz [4]. The equipment is able to demodulate and decode the WCDMA signal for mixing the corresponding code, so it is possible to obtain information from different performance factors such as: the power of the CPICH channel, Ec/Io that it is the difference between the signal strength and the noise floor, Ec and Pilot Dominance.

The measurements were performed by measuring “On the Air” (OTA, Over the Air). It was using an antenna in the appropriate frequency band. The Table 1 shows us the settings of equipment and antenna characteristics, values that allow us to work on the characteristics of the analyzed service provider.

| Parameter                  | Value / Features                                      |
|----------------------------|-------------------------------------------------------|
| Carrier Frequency          | 887.5 MHz                                             |
| Channel                    | 1087                                                  |
| Working Band               | Band V - Additional Channel Systems for UMTS Downlink   |
| Working Frequency Antenna  | 870-960 MHz                                           |
| Antenna Type               | Omnidirectional                                       |

The measuring area delimited shown in Fig 2. In the area of analysis, we present a variety of constructions with representative characteristics, given by its height and building materials. It also shows us the distribution of Nodes B in the area.

Measurements were performed with the measuring equipment placed at an average height of 1.00 to 1.40 meters above ground level. This value was considered as the average value in which users carry and use their mobile equipment. The distance between measurements was approximately 4 to 5 meters, covering the area of analysis. For a correct analysis of experimental results was necessary to have georeference information. To obtain this information, the equipment has a GPS and generates position information of (Latitude, Longitude,
Altitude and Time) these GPS information requires at least 4 satellites.

It should be noted that weather conditions affect the values obtained in measurements, so it was necessary that the measurements be made under similar climatic conditions.

1.3. Information Processing

The measurements are stored in the internal memory of the computer. All these measurements are downloaded to a computer, to be interpreted by software called Master Software Tools (MST). This tool allows us to view and export the measurement to a format file *.cvs for further processing [5]. Fig. 3 shows the working environment and displaying the measurements.

![Master Software Tools and Working Environment](image)

Using a program developed in C++, we are able to obtain the parameters of interest for each file *.cvs. Fig. 4 shows in final file format each parameters of interest.

![File Format Post-Processing](image)

Once the information is into a single file, we can obtain 1667 measurements of each Scrambling Code and its parameters, with this file it is possible to determine the occurrence of each SC. Finally, we can identifying 50 different Scrambling Codes in the measurement area. We found the existence of Scrambling Codes with a high occurrence within the measurement area. The SC with an occurrence greater than 100 were: SC 85, SC 93 and SC 229 with 113, 118 and 109 respectively.

1.4. Building Coverage Maps

Information obtained through spot measurements, helps us generate continuous coverage maps of each of the key performance indicators, such as the power of CPICH and value Ec/Lo.

With the points measured, it was possible to generate coverage maps. The data were processed using software called Easy Kriging to implement the kriging geostatistical method, that was initially developed by Daniel G. Krige based on interpolation algorithms by least squares regression. The method takes the point values and generates continuous graphic, performing an interpolation of them. Krige

The process of generating coverage maps consists mainly of four steps:
1. Data reading. Longitude, Latitude and the performance indicator.
2. Generate a theoretical variogram based on one experimental. Predicting the behavior of the signal transmitted by node B.
3. Running the Kriging process.
4. Validation and map display. Ensure the effectiveness of the prediction is needed validation process; included in the application of “EasyKrig” in which the approximation error is within the acceptance region determined by the variability of the measurement power.

The Fig. 5 illustrates each of the steps, allowing visualize the process of creating the maps.

Fig. 5 Procedure for Creating Coverage Maps

1.5. Distribution CPICH Power Level

The CPICH is a network element that enables mobile devices estimate the radio channel and the signal sent by this channel is used as input in the selection mechanisms of cell/sector and the process of transferring calls [6].

We obtained 1667 measurements by Scrambling Code, 804 which belong to the dominant pilots within the analysis area. Table 2 presents the main dominant pilots and their incidence within the study area.

Table 2. Incidence of Pilot Dominance

| Scrambling Code | Incidence | Pilot Dominance (PD) |
|-----------------|-----------|----------------------|
| 93              | 118       | 64                   |
| 85              | 113       | 75                   |
| 229             | 109       | 56                   |
| 268             | 94        | 58                   |
| 77              | 83        | 22                   |
| 125             | 75        | 38                   |
| 21              | 74        | 39                   |
| 69              | 63        | 33                   |
| 284             | 63        | 24                   |
| 372             | 62        | 42                   |
| 364             | 61        | 26                   |
| 468             | 60        | 42                   |
Fig. 6 presents an overview of the distribution of the CPICH power levels. Considering that the sensitivity of most mobile devices available on the market is -80 dBm [8], one can see that the power levels are within this range. This result indicates that the test area has a good coverage in the CPICH power levels. However, this does not mean that mobile teams can establish a session with the Nodes B. Besides considering the power levels, we need to analyze each of the SCs and verify that they are not interfering with each other.

Performing the analysis for each SC into the measurement area, we found one area within the test area with a total of seven SC with CPICH power levels very close together. This means that there are over 3 SCs that defined in the communication standard [7]. Fig. 7 shows this phenomenon with an overlap of maps involved, SC 69, SC 77, SC 125, SC141, SC 205, SC 460 and SC 468.

The SCs detected have similar power levels, effect which causes that mobile equipment not be capable of establishing a session with the Node B. Although the analysis CPICH power level allows us to identify such problems, it is necessary to analyze the relationship based on Ec/Io.
1.6. Analysis of Interference based on Ec/Io and RSCP

The interference of a given area is determined by the indicator Ec/Io. This value is defined within the CPICH which is measured before the despreading of the received signal. And, RSCP (Received Signal Code Power) denotes the power measured by a receiver in a physical communications channel after the despreading of signal.

The value of Ec/Io must be greater of -9dB in the 95% of area coverage [7], so that there are association of sectors and we can establish a voice call. According to Table 3, each SC presents few instances in which the level of Ec / Io has good power levels, these levels are barely acceptable level within the measurement zone. In laboratory tests [9] were found that the values of Ec/Io and RSCP can be considered:

| Good: Ec/Io ≥-9dB. | Acceptable: -14dB ≤ Ec/Io ≤ -9dB | Poor: Ec/Io ≤-14dB |
|--------------------|----------------------------------|---------------------|
| Good: RSCP ≥-88 dBm| Acceptable: -95 dBm ≤ RSCP < -88 dBm | Poor: RSCP < -95 dBm |

Table 3. Values Ec/Io in the Area with Problem

| Scrambling | Ec/Io ≥-9dB | -14dB ≤ Ec/Io ≤-9dB | Ec/Io ≤-9dB |
|------------|-------------|---------------------|-------------|
| 69         | 0           | 23                  | 69          |
| 77         | 2           | 29                  | 81          |
| 125        | 9           | 18                  | 66          |
| 141        | 9           | 16                  | 51          |
| 205        | 6           | 7                   | 41          |
| 460        | 8           | 8                   | 38          |
| 468        | 5           | 33                  | 55          |

Figure 8 presents a comparison of the levels of Ec / Io and RSCP in the problem area, where occurs pilot signals pollution or when there are more than three SC below of a reference called Best Server and values of these signal no exceed 3 dB in the power level Ec/Io and the value of RSCP >-90dBm.
In Fig. 8 shows the Scrambling Codes arriving at a certain area. The SC 125 acts of Best Server, and together with the SC 141 and SC 205 is the "Active Set" of pilots who serve the mobile. However, the SC 460 has a power within 3 dB comprising the Active Set, thus introducing contamination of pilot signals to the mobile terminal. Fig. 9 shows us an overview on the levels of Ec / Io and RSCP in the measurement area.

Fig. 9 Power Level Distribution of a) Ec/Io and b) RSCP

Conclusions

We found 50 different SC. This is a warning signal in WCDMA networks, due to that the higher number of different SCs within the coverage area increases the chances of finding pilot pollution. It was observed that although the CPICH power level is at appropriate levels, the set of obstacles and losses signal path, cause that the coverage is decreased within the study area. Problems caused by the overlap of SC or pilot pollution causing a continuous transfer of calls, records failed, low transmission rates, low capacity of the system, in general, problems that affect the quality of service.

References

[1] P. H. D. John S. Sheybold, “Introduction to RF Propagation”, John Wiley & Sons, 2005, New Jersey.
[2] Tachikawa, Keji, “W-CDMA Mobile Communication System”, John Wiley & Sons, LTD, 2002, England, P. 102-103.
[3] Korhonen, Juha, “Introduction to 3G Mobile Communications”, Artech House, 2nd Edition, 2003, Norwood MA, P. 53, 80, 93-95, 109, 263.
[4] Spectrum Master™ MS2721A, Benchtop Performance in a Handheld Spectrum Analyzer, User Guide, p. 1-1.
[5] Master Software Tools, User Guide.
[6] http://www2.rohde-schwarz.com/file_5150/OP_RE_UMTS.pdf.
[7] QUALCOMM, “WCDMA Network Planning and Optimization, Revision B, May 2006, San Diego, C.A., ’p. 7-8.
[8] M. Licea, S. Vidal, C. Barroeta, “Characterization of the Performance Parameters of Data Transmission in Mobile Communication Terminals of Broadband”, B.S Dissertation Department of Communications, National Polytechnic Institute, Mexico, 2010,p. 95-98.
[9] Isaac Josue Guachilema Valencia, Iván Andrés León Drouet, “Calidad de Servicio (QoS) de la Red UMTS en la Ciudad de Durán”. P. 1-2.