Optimization

and

Log File Analysis

in

GSM

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Contents

1. INTRODUCTION

Every alive Network needs to be under continues control to maintain/improve the performance. Optimization is basically the only way to keep track of the network by looking deep into statistics and collecting/analyzing drive test data. It is keeping an eye on its growth and modifying it for the future capacity enhancements. It also helps operation and maintenance for troubleshooting purposes.

Successful Optimization requires:

• Recognition and understanding of common reasons for call failure

• Capture of RF and digital parameters of the call prior to drop

• Analysis of call flow, checking messages on both forward and reverse links to establish "what happened", where, and why.

Optimization will be more effective and successful if you are aware of what you are doing. The point is that you should now where to start, what to do and how to do.

1.1. Purpose and Scope of Optimization

The optimization is to intend providing the best network quality using available spectrum as efficiently as possible. The scope will consist all below;

- Finding and correcting any existing problems after site implementation and integration.
- Meeting the network quality criteria agreed in the contract.
- Optimization will be continuous and iterative process of improving overall network quality.
- Optimization can not reduce the performance of the rest of the network.
- Area of interest is divided in smaller areas called clusters to make optimization and follow up processes easier to handle.

1.2. Optimization Process

Optimization process can be explained by below step by step description:

1.2.1. Problem Analysis

Analyzing performance retrieve tool reports and statistics for the worst performing BSCs and/or Sites

Viewing ARQ Reports for BSC/Site performance trends

Examining Planning tool Coverage predictions

Analyzing previous drive test data

Discussions with local engineers to prioritize problems

Checking Customer Complaints reported to local engineers

1.2.2. Checks Prior to Action

Cluster definitions by investigating BSC borders, main cities, freeways, major roads

Investigating customer distribution, customer habits (voice/data usage)

Running specific traces on Network to categorize problems

Checking trouble ticket history for previous problems

Checking any fault reports to limit possible hardware problems prior to test

1.2.3. Drive Testing

Preparing Action Plan

Defining drive test routes

Collecting RSSI Log files

Scanning frequency spectrum for possible interference sources

Re–driving questionable data

1.2.4. Subjects to Investigate

Non–working sites/sectors or TRXs

In–active Radio network features like frequency hopping

Disabled GPRS

Overshooting sites – coverage overlaps

Coverage holes

C/I, C/A analysis

High Interference Spots

Drop Calls

Capacity Problems

Other Interference Sources

Missing Neighbors

One–way neighbors

Ping–Pong Handovers

Not happening handovers

Accessibility and Retainability of the Network

Equipment Performance

Faulty Installations

1.2.5. After the Test

Post processing of data

Plotting RX Level and Quality Information for overall picture of the driven area

Initial Discussions on drive test with Local engineers

Reporting urgent problems for immediate action

Analyzing Network feature performance after new implementations

Transferring comments on parameter implementations after new changes

1.2.6. Recommendations

Defining missing neighbor relations

Proposing new sites or sector additions with Before & After coverage plots

Proposing antenna azimuth changes

Proposing antenna tilt changes

Proposing antenna type changes

BTS Equipment/Filter change

Re–tuning of interfered frequencies

BSIC changes

Adjusting Handover margins (Power Budget, Level, Quality, Umbrella HOs)

Adjusting accessibility parameters (RX Lev Acc Min, etc..)

Changing power parameters

Attenuation Adds/Removals

MHA/TMA adds

1.2.7. Tracking

Re–driving areas after implementing recommendations

Create a tracking file to follow–up implementation of recommendations

1.2.8. Other Optimization Topics

Verifying performance of new sites

Verifying handovers

Verifying data after Re–Homes

Investigating GPRS performance

Verifying Sectorizations

Collecting DTI Scan files

Verifying coverage

Verifying propagation model by importing DTI scan files to Planet

Periodic Consistency Checks

Frequency Planning Check

Analyzing cell access parameters

Analyzing Handover parameters

Analyzing Power control parameters

Analyzing Frequency Hopping parameters (HSN, MAIO)

Implementing/analyzing optional features

Keep helping local engineers with emergency cases

Benchmarking

1.3. Before Starting

This document was prepared with TEMS screen shots from live examples of previous experiences to guide RF Engineers on how to define/analyze problems or cases and optimize network. After each case/problem demonstration, specific step to be taken will be defined and appropriate recommendation will be given.

The document will be focusing on Drive Testing part of the Optimization Process and give definitions on basic GSM principals, features and parameters when needed.

The readers of this document are considered to have basic knowledge of cell planning and TEMS Investigation usage. Only little information will be given just to remember TEMS interface.

2. DRIVE TESTING

Drive testing is the most common and maybe the best way to analyze Network performance by means of coverage evaluation, system availability, network capacity, network retainibility and call quality. Although it gives idea only on downlink side of the process, it provides huge perspective to the service provider about what's happening with a subscriber point of view.

The drive testing is basically collecting measurement data with a TEMS phone, but the main concern is the analysis and evaluation part that is done after completition of the test. Remember that you are always asked to perform a drive test for not only showing the problems, but also explaining them and providing useful recommendations to correct them. Please note that a successful analysis should be supported by handling of network statistics from a statistics tool (Metrica/NetDoc–NMS/SRP–OSS, etc..) and careful evaluation of coverage predictions from a cell planning tool (Planet, DB–Planner, TEMs Cell Planner, etc..). Please see *Figure 1* for a usual view from TEMS.

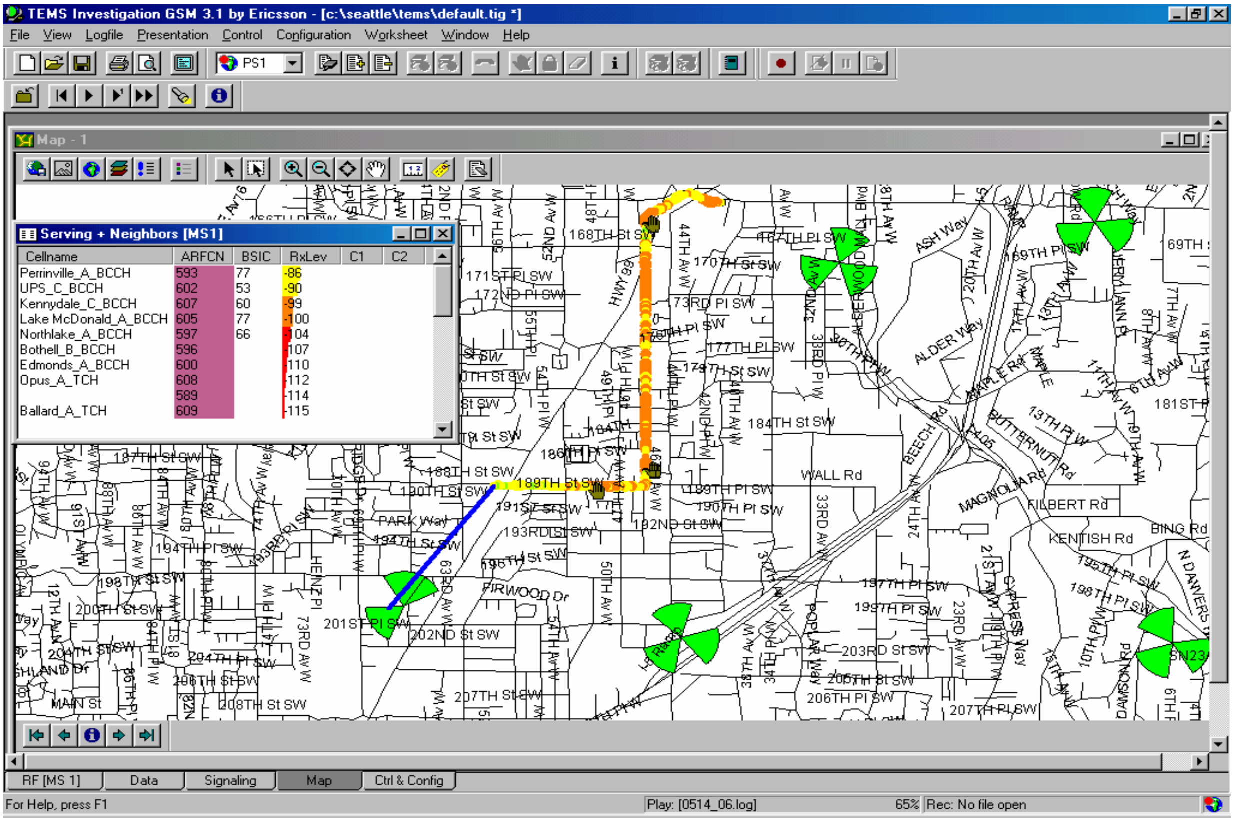


Figure 1– TEMs Screen: *TEMs gives great presentation options to the user like displaying multiple windows of different indicators on the map. Theme properties will make you understand easier by showing the serving cell on the map.*

2.1. TEMS Information

The information provided by TEMS is displayed in status windows. This information includes cell identity, base station identity code, BCCH carrier ARFCN, mobile country code, mobile network code and the location area code of the serving cell.

There is also information about RxLev, BSIC and ARFCN for up to six neighboring cells; channel number(s), timeslot number, channel type and TDMA offset; channel mode, sub channel number, hopping channel indication, mobile allocation index offset and hopping sequence number of the dedicated channel; and RxLev, RxQual, FER, DTX down link, TEMS Speech Quality Index (SQI), timing advance (TA), TX Power, radio link timeout counter and C/A parameters for the radio environment.

The signal strength, RxQual, C/A, TA, TX Power, TEMS SQI and FER of the serving cell and signal strength for two of the neighboring cells can also be displayed graphically in a window.

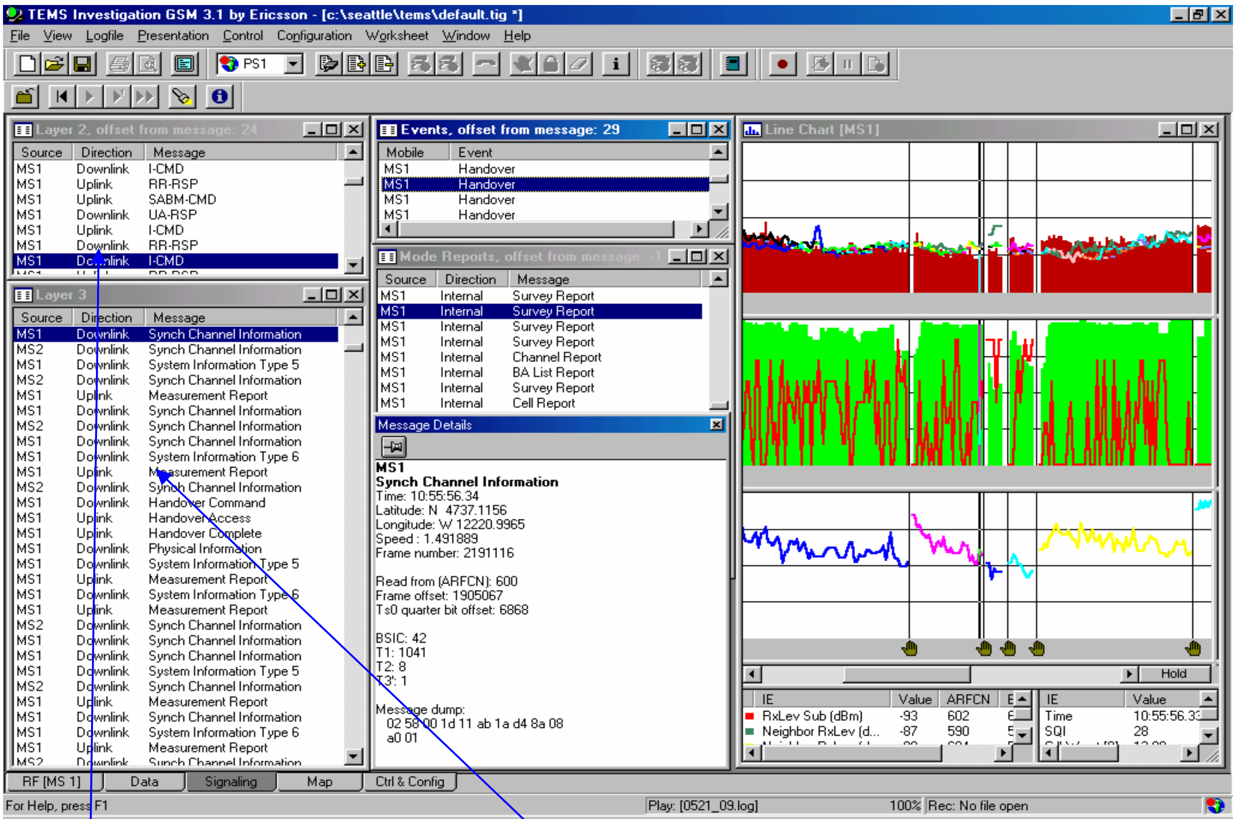


Figure 2– Layer 2 and Layer 3 Messages

Layer 2 Messages

Layer 3 Messages

Layer 2 and 3 messages and SMS cell broadcast messages are displayed in separate scrollable windows as can be seen in *Figure 2*. If desired, specific Layer 3 messages can be displayed.

By connecting an additional TEMS phone to a vacant serial port of the PC, data from two networks can be monitored and logged at the same time. In this case, the data from the second mobile phone is serving cell and neighboring cell data and radio environment parameters.

TEMS Investigation also can perform frequency scanning of all significant carrier frequencies. The information presented is ARFCN, RxLev and, if successfully decoded, BSIC.

2.2. Basic Counters of Network Performance

2.2.1. Accessibility

Accessibility counter is one of the most important statistics and it is the performance expression of the network at the first glance. Accessibility is calculated by multiplying SDDCH serviceability by TCH accessibility.

Accessibility = SDCCH Serviceability * TCH Accessibility

For accessibility performance of the network, repeated short call set–ups must be performed by drive tests.

2.2.2. Retainability

Retainability is the clue to network continuity and targets TCH Call Success rate of the network. It takes all type of drops into consideration.

Retainability = TCH Call Access Rate = 1 – TCH Call Drop Rate

TCH Call Drop rate is calculated by dividing total number of drop calls to number of total TCH seizures and attempts. Total number of drop calls contains all types of TCH drops including any radio related, user activated, network activated, ABIS fail, A interface, LAPD, BTS failure or BSCU reset drops. Please note that any TCH re–establishment should be subtracted from TCH call drop rate as call is somehow able to continue. Total number of TCH attempts and seizures will include any TCH seizures for new calls and TCH to TCH attempts during Handover and number of intracell handovers as well.

Retainability is wanted to be as near as to 100 percent. For measuring retainability and integrity of a network, long continuous calls must be performed by drive tests.

2.2.3. Access Fails

Access failures are the total number of unsuccessful TCH attempts which is calculated by subtracting number of assigned TCH seizures from number of TCH attempts – including the ones during handovers.

2.3. Idle Mode Behavior

A powered on mobile station (MS) that does not have a dedicated channel allocated is defined as being in idle mode (*see Figure 3*). While in idle mode it is important that the mobile is both able to access and be reached by the system. The idle mode behavior is managed by the MS. It can be controlled by parameters which the MS receives from the base station on the Broadcast Control Channel (BCCH). All of the main controlling parameters for idle mode behavior are transmitted on the BCCH carrier in each cell. These parameters can be controlled on a per cell basis. Moreover, to be able to access the system from anywhere in the network, regardless of where the MS was powered on/off, it has to be able to select a specific GSM base station, tune to its frequency and listen to the system information messages transmitted in that cell. It must also be able to register its current location to the network so that the network knows where to route incoming calls.

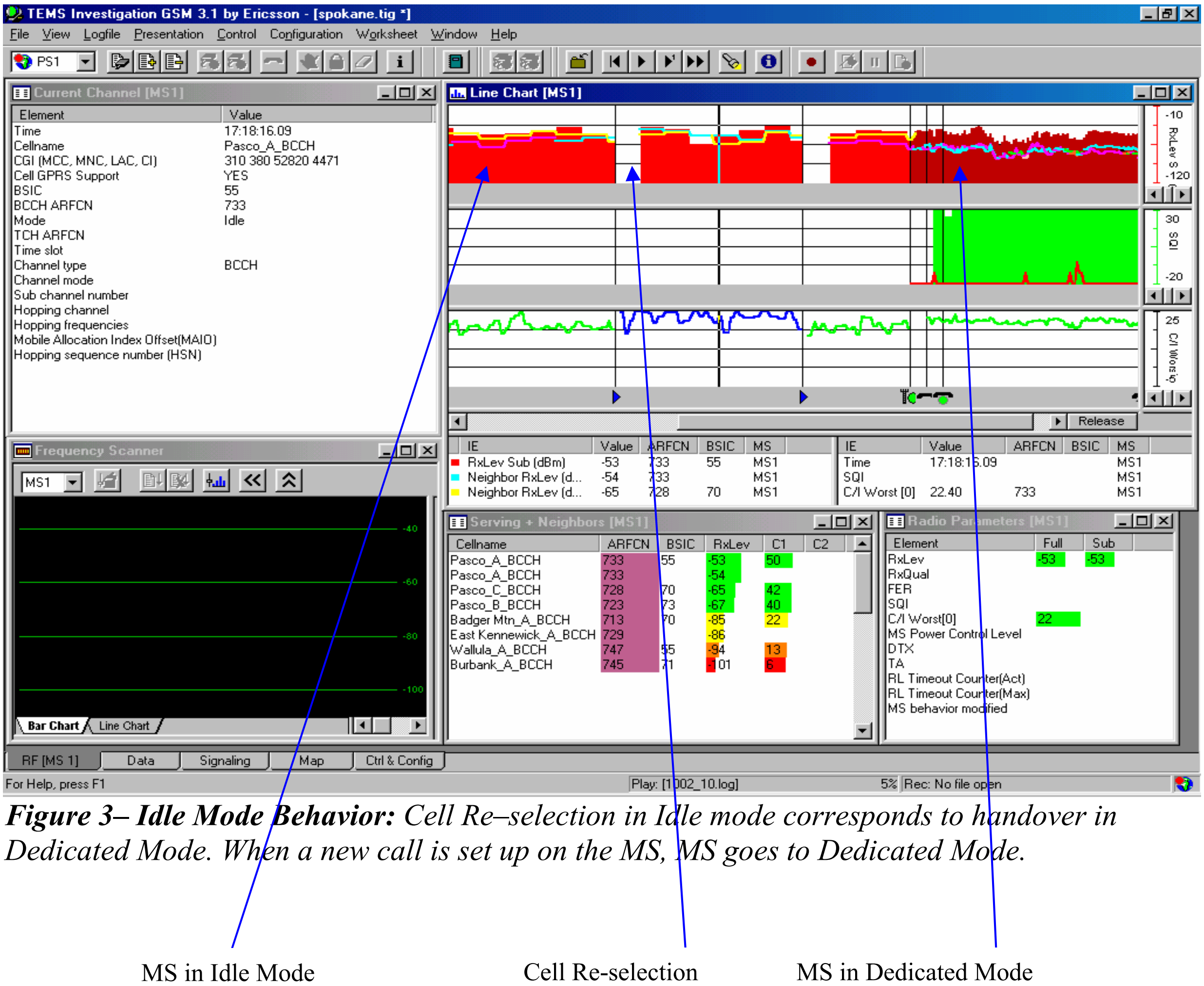


Figure 3– Idle Mode Behavior: *Cell Re–selection in Idle mode corresponds to handover in Dedicated Mode. When a new call is set up on the MS, MS goes to Dedicated Mode.*

The PLMN selection mechanism, the cell selection and reselection algorithms in addition to the location updating procedure are the core of the idle mode behavior. The purpose is to always ensure that the mobile is camped on the cell where it has the highest probability of successful communication. In idle mode the MS will notify the network when it changes location area by the location updating procedure. Thus, the network will be kept updated concerning which location area the MS is presently in. When the system receives an incoming call it knows in which location area it should page the MS, and does not need to page the MS throughout the whole MSC service area. This reduces the load on the system. If the MS does not respond to the first paging message, then the network can send a second paging message.

Sometimes MS does not camp on the best cell and needs to perform a cell re–selection process before initializing the call *(see Figure 4)*. This could be related to wrong Cell Reselection parameters like CRO – Cell Reselect Offset, Cell Reselect Hysteresis, Temporary Offset or Penalty Time used in C1–C2 criteria calculation.

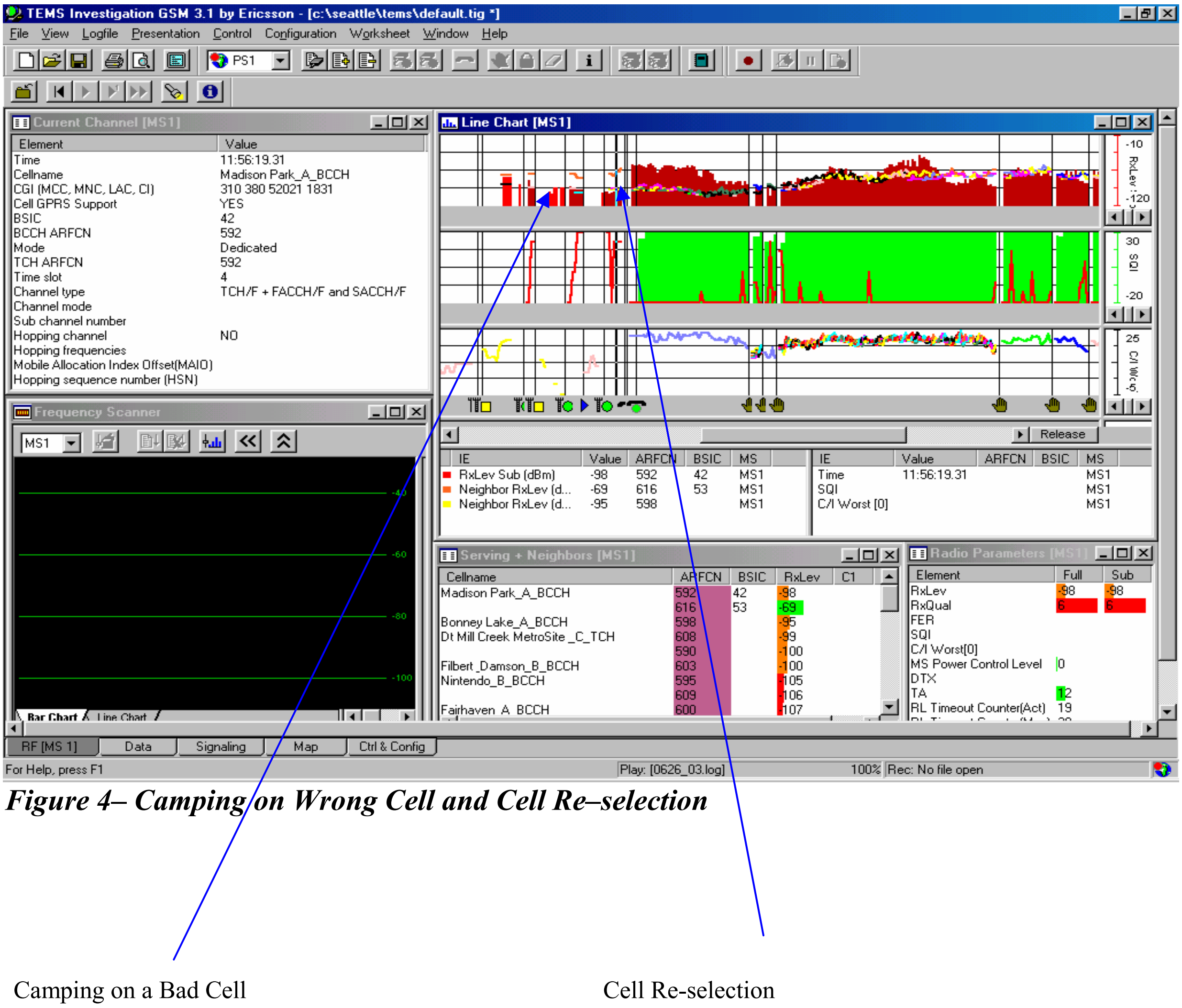


Figure 4– Camping on Wrong Cell and Cell Re–selection

2.4. Location Update

The MS listens to the system information, compares the Location Area Identity (LAI) to the one stored in the MS and detects whether it has entered a new location area or is still in the same location area. If the broadcast LAI differs from the one stored in the MS, the MS must perform a location update, type normal. The MS sends a channel request message including the reason for the access. Reasons other than location updating can be for example, answering a page or emergency call.

The message received by the BTS is forwarded to the BSC. The BSC allocates a signaling channel (SDCCH), if there is one idle, and tells the BTS to activate it. The MS is now told to tune to the SDCCH. The outcome of the procedure is that a radio resource connection is dedicated to the MS. The procedure is therefore called RR connection establishment.

The MS sends a location updating request message which contains the identity of the MS, the identity of the old location area and the type of updating. The authentication parameter is sent to MS. In this case the MS is already registered in this MSC/VLR and the authentication parameter used is stored in the VLR. If the MS is not already registered in this MSC/VLR the appropriate HLR or the previously used MSC/VLR must be contacted to retrieve MS subscriber data and authentication parameters. MS sends an answer calculated using the received authentication parameter.

If the authentication is successful, the VLR is updated. If needed, the old HLR and old VLR are also updated. The MS receives an acceptance of the location updating. The BTS is told to release the SDCCH. The MS is told to release the SDCCH and switches to idle mode.

If the MS is moving in a border area between location areas, it might repeatedly change between cells of different location areas. Each change of location area would require a location updating to be performed, which would cause a heavy signaling load and thereby also increasing the risk of paging messages being lost.

Cells bordering a different location area may have lots of location updating, and cells on a highway probably have many handovers. In order to calculate the need for SDCCHs the number of attempts for every procedure that uses the SDCCH as well as the time that each procedure holds the SDCCH must be taken into account. The procedures are; location updating, periodic registrations, IMSI attach/detach, call setup, SMS, facsimile and supplementary services.

Next step will be analyzing Call Set–up process. Being the start point and direct factor to accessibility of the network, call set–up has great importance in GSM performance. Some basic information on the procedure will be given. As Layer 3 messages will be our reference point when defining problems during log files analysis, they will also be explained with their appearance order during and after call set–up.

2.5. Call Setup

The cell selection algorithm tries to find the most suitable cell of the selected PLMN according to various requirements. If no suitable cell is found and all available and permitted PLMNs have been tried, the MS will try to camp on a cell irrespective of PLMN identity and enter a limited service state. In this state the MS will be able to make emergency calls only. If the MS loses coverage it will return to the PLMN selection state and select another PLMN.

After a cell has been successfully selected, the MS will start the cell reselection tasks. It will continuously make measurements on its neighboring cells to initiate cell reselection if necessary. For multiband MSs the strongest non–serving carriers may belong to different frequency bands. The MS continuously monitors all neighboring BCCH carriers, as indicated by the BA list, in addition to the BCCH carrier of the serving cell, to detect if it is more suitable to camp on another cell. At least five received signal level measurement samples are required for each defined neighboring cell. A running average of the received signal level will be maintained for each carrier in the BA list. Provided that the MS is listening to the system information in the cell and that it is registered in the MSC/VLR handling this cell, the MS can attempt to make a call.

First, radio connection between MS and network is established. Then MS indicates that it wants to set up a call. The identity of the MS, IMSI, is analyzed and the MS is marked as busy in the VLR. Authentication is performed as described for location updating. Then ciphering is initiated. MSC receives a setup message from the MS. This information includes what kind of service the MS wants and the number (called the B number) dialed by the mobile subscriber. MSC checks that the MS does not have services like barring of outgoing calls activated. Barring can be activated either by the subscriber or by the operator. If the MS is not barred, the setup of the call proceeds. Between the MSC and the BSC a link is established and a PCM TS is seized. The MSC sends a request to the BSC to assign a traffic channel (TCH). The BSC checks if there is an idle TCH, assigns it to the call and tells the BTS to activate the channel. The BTS sends an acknowledgment when the activation is complete and then the BSC orders the MS to transfer to the TCH. The BSC informs the MSC when the assignment is complete. The traffic control subsystem analyzes the digits and sets up the connection to the called subscriber. The call is connected through in the group switch. An alert message is sent to the MS indicating that a ringing tone has been generated on the other side. The ringing tone generated in the exchange on the B subscriber side is sent to the MS via the group switch in MSC. The ringing tone is sent over the air on the traffic channel.

When the B subscriber answers, the network sends a connect message to the MS indicating that the call is accepted. The MS returns a connect acknowledgment, which completes the call set–up.

Please see *Figure 5* for the Call Set–up process.

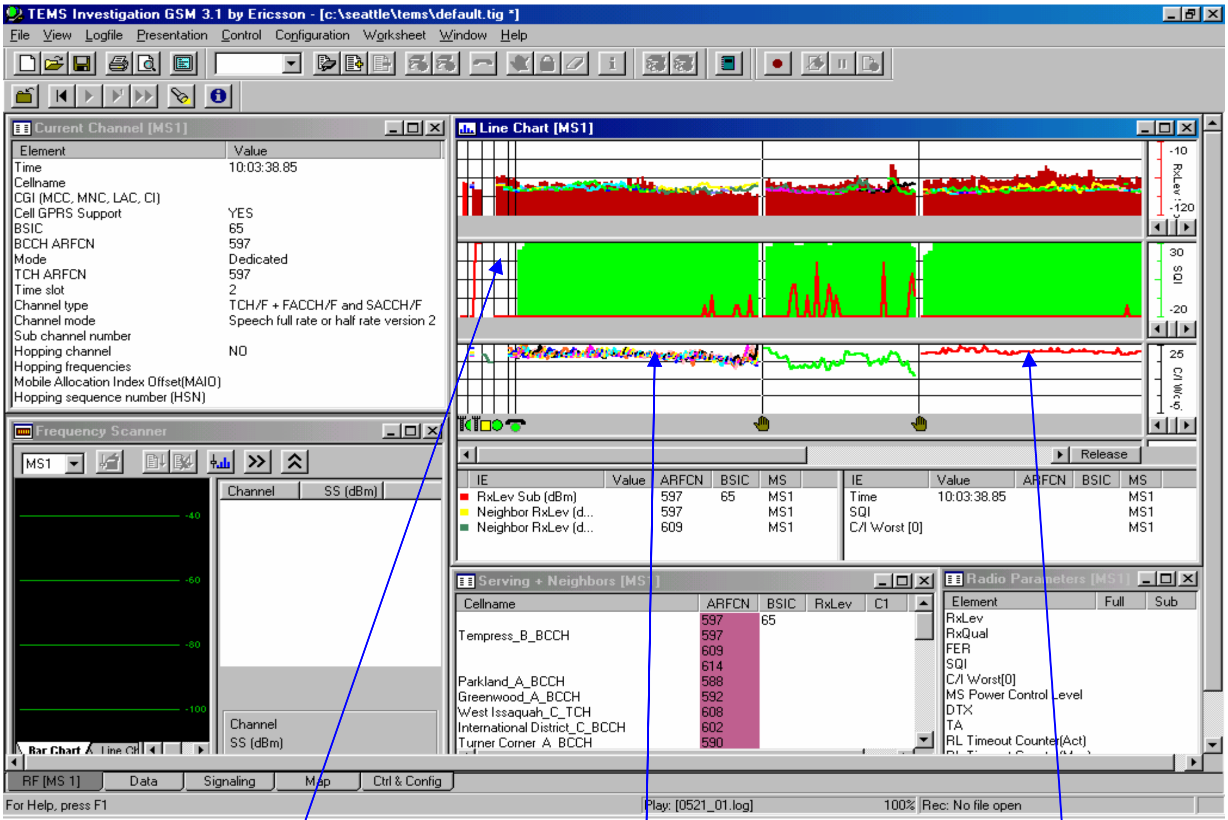


Figure 5– Call Set–up process*: Please pay attention to the C/I appearances of hopping and non–hopping cells on the chart. C/I for every hopping channel are displayed separately. This explains how hopping deals better with interference, every other frequency in hopping list has different effects from the interferer and this optimizes the overall speech quality minimizing fading dips and reduces interference effect.*

Signaling and Synchronization for call set-up

C/I Appearance of a Hopping Cell

C/I Appearance of a Non-Hopping Cell

2.6. Call Set–up Process in Layer 3 Messages

Call Set–up procedure starts with Channel Request Command and MS passes to Dedicated Mode with this command. This channel request message is sent in random mode on the RACH (Random access channel –Uplink only, used to request allocation of a SDCCH) and the most important part of the message is Establishment cause. The cause for channel request could be;

–Answer to paging
–Emergency call
–Call re–establishment
–Other services requested by the mobile user (originating call, supplementary service short message)
–All Other cases

Below window dump in *Figure 6* showing a channel request from TEMS is an example to an originating call.

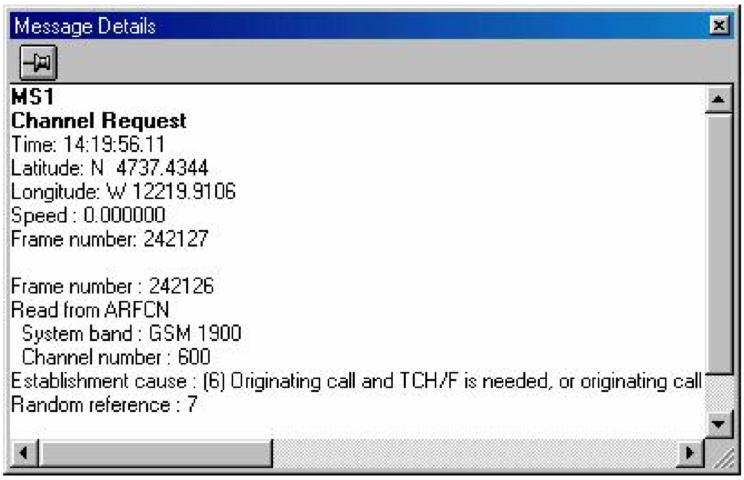


Figure6– Channel Request

The Channel request command is followed by Paging request message (*Figure 7*) which is sent on the CCCH (Common Control Channel) by the network to up to two mobile stations to trigger channel access by these.

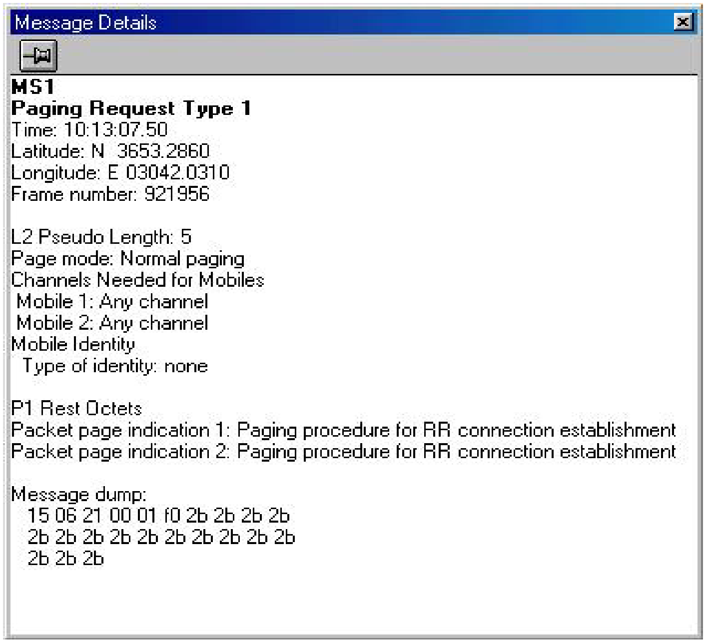


Figure7– Paging Request Type 1

System Information Type 13 (*Figure 8*) message is sent to determine GPRS options of the cell with the given ARFCN.

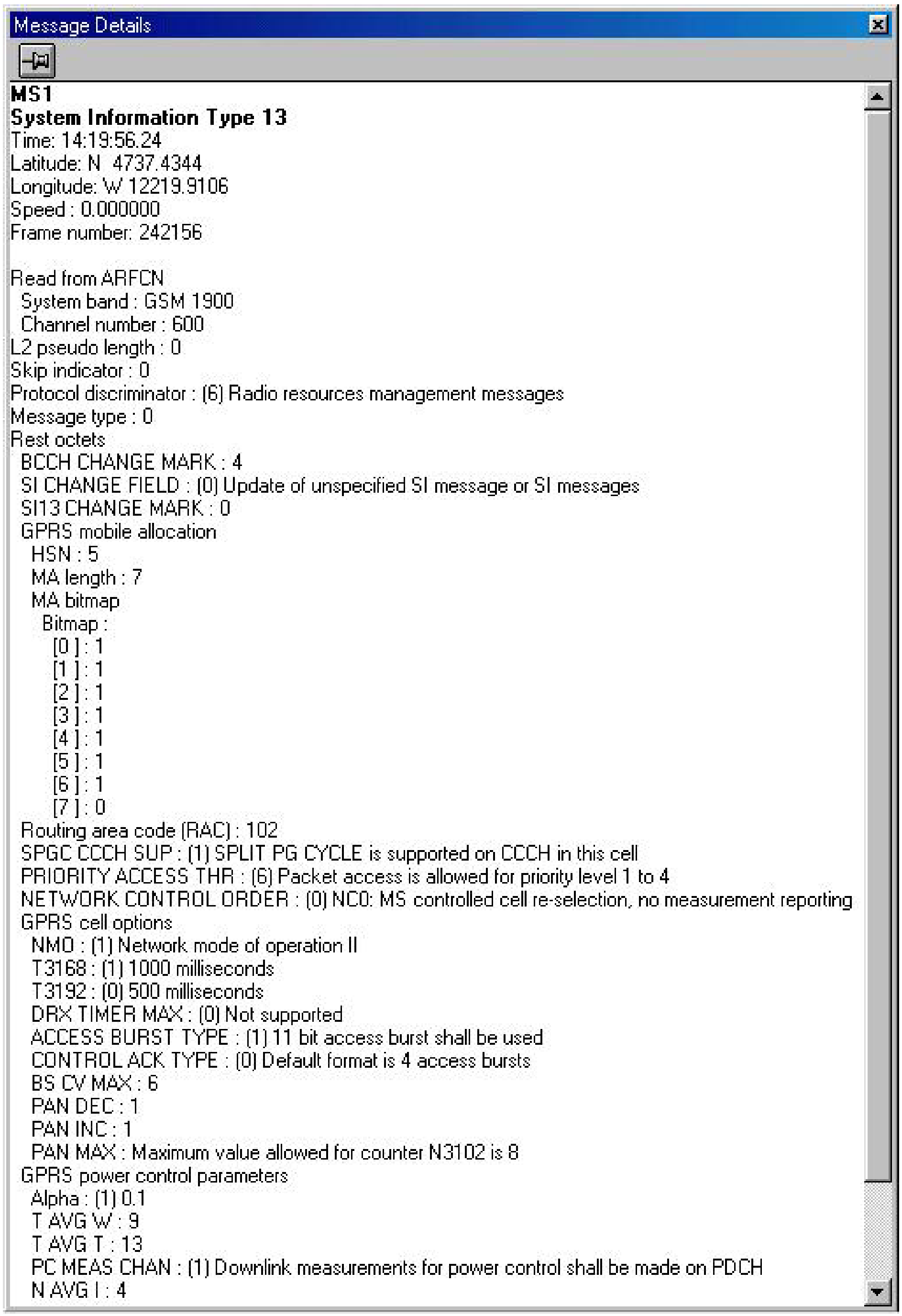


Figure 8– System Information Type 13

Immediate Assignment message in *Figure 9* is sent on the CCCH by the network to the mobile station in idle mode to change the channel configuration to a dedicated configuration while staying in the same cell.

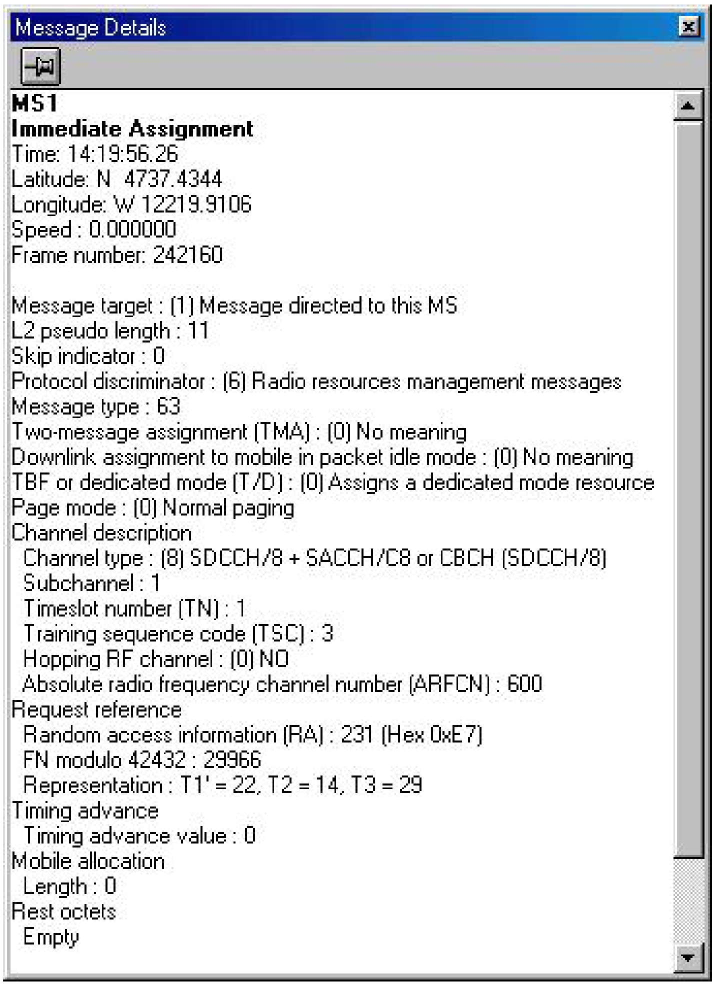
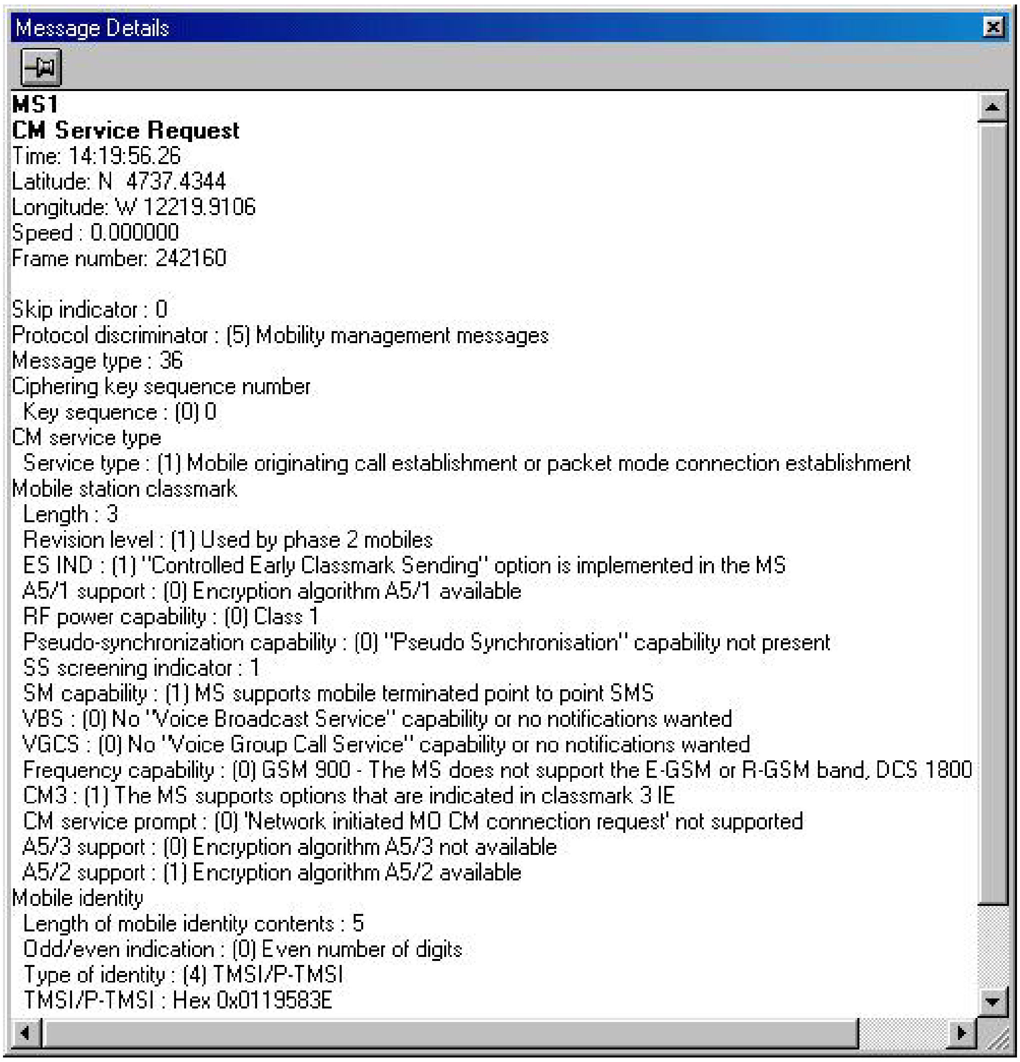


Figure 9– Immediate Assignment

CM Service Request message in *Figure 10* is sent by the mobile station to the network to request a service for the connection management sub layer entities, e.g. circuit switched connection establishment, supplementary services activation, short message transfer.


Message Details

MS1
CM Service Request
Time: 14:19:56.26
Latitude: N 4737.4344
Longitude: W 12219.9106
Speed : 0.000000
Frame number: 242160

Skip indicator : 0
Protocol discriminator : (5) Mobility management messages
Message type : 36
Ciphering key sequence number
  Key sequence : (0) 0
CM service type
  Service type : (1) Mobile originating call establishment or packet mode connection establishment
Mobile station classmark
  Length : 3
  Revision level : (1) Used by phase 2 mobiles
  ES IND : (1) "Controlled Early Classmark Sending" option is implemented in the MS
  A5/1 support : (0) Encryption algorithm A5/1 available
  RF power capability : (0) Class 1
  Pseudo-synchronization capability : (0) "Pseudo Synchronisation" capability not present
  SS screening indicator : 1
  SM capability : (1) MS supports mobile terminated point to point SMS
  VBS : (0) No "Voice Broadcast Service" capability or no notifications wanted
  VGCS : (0) No "Voice Group Call Service" capability or no notifications wanted
  Frequency capability : (0) GSM 900 - The MS does not support the E-GSM or R-GSM band, DCS 1800
  CM3 : (1) The MS supports options that are indicated in classmark 3 IE
  CM service prompt : (0) 'Network initiated MO CM connection request' not supported
  A5/3 support : (0) Encryption algorithm A5/3 not available
  A5/2 support : (1) Encryption algorithm A5/2 available
Mobile identity
  Length of mobile identity contents : 5
  Odd/even indication : (0) Even number of digits
  Type of identity : (4) TMSI/P-TMSI
  TMSI/P-TMSI : Hex 0x0119583E

Figure10– CM Service Request

System Information Type 5 (*Figure 11*) is sent by the network to mobile stations within the cell giving information on the BCCH allocation in the neighbor cells. When received, this information must be used as the list of neighboring cells to be reported on. Any change in the neighbor cells description must overwrite any old data held by the MS. The MS must analyze all correctly received system information type 5 messages.

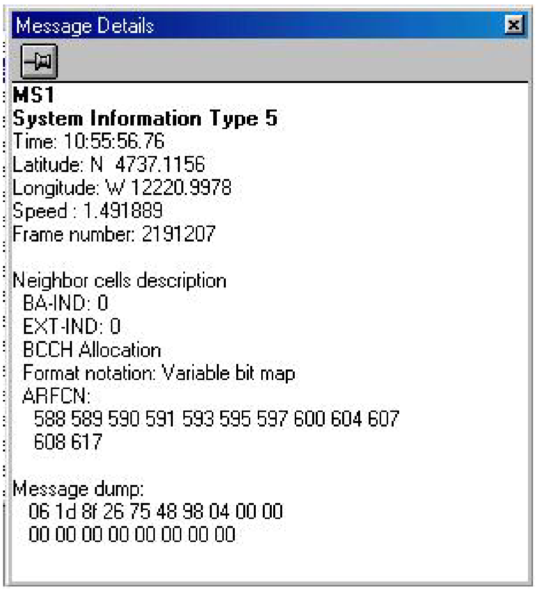


Figure 11– System Information Type5

Class mark Change message in *Figure 12* is sent on the main DCCH by the mobile station to the network to indicate a class mark change.

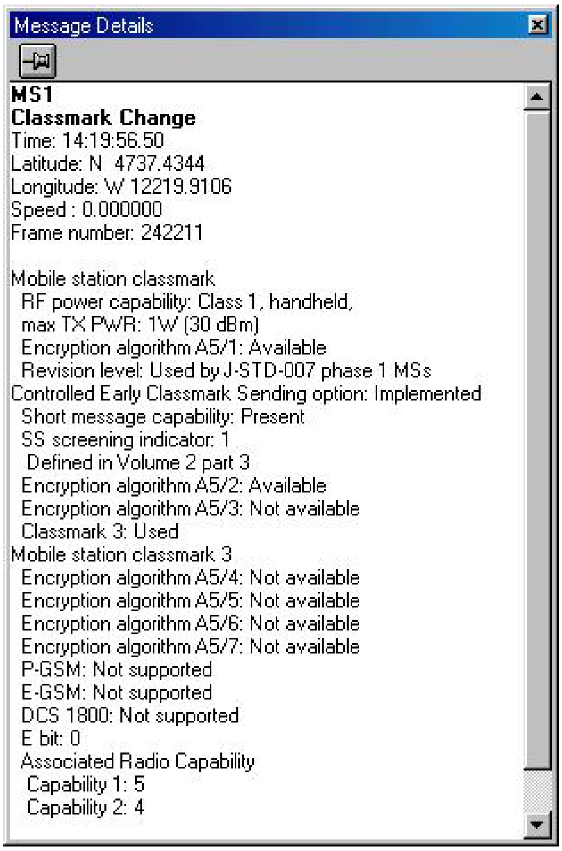


Figure12– Class mark Change

GPRS Suspension Request in *Figure 13* asks system to suspend GPRS.

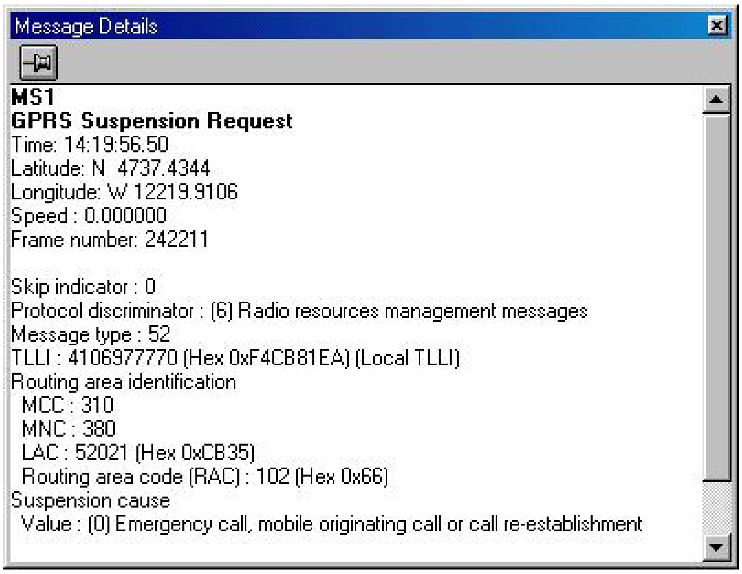


Figure13– GPRS Suspension Request

Ciphering Mode Command message (*Figure 14*) is sent on the main DCCH from the network to the mobile station to indicate that the network has started deciphering and that enciphering and deciphering shall be started in the mobile station, or to indicate that ciphering will not be performed. This message is followed by a Ciphering Mode complete message (*Figure 15*).

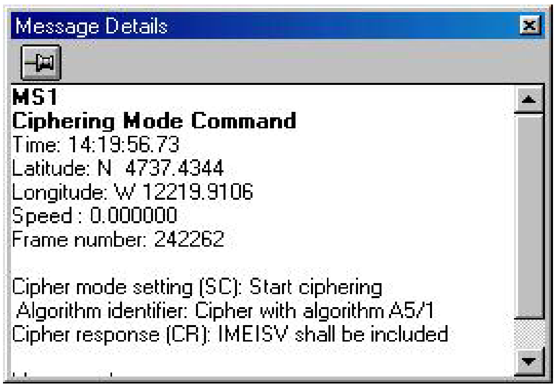


Figure14– Ciphering Mode Command

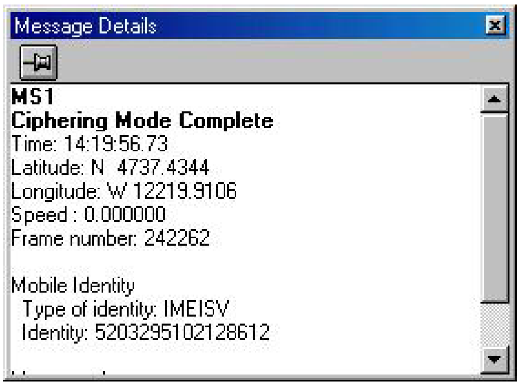


Figure 15– Ciphering Mode Complete

Call Set–up message (*Figure 16*) is sent, from either the mobile station or the network, to initiate call establishment. It consists of below information elements;

–Protocol discriminator

–Transaction identifier

–Message type

–Repeat indicator: The repeat indicator information element is included immediately before the first bearer capability information element when the in–call modification procedure is used.

–Bearer capabilities: In the mobile station to network direction, at least one bearer capability information element must always be present. In the network to mobile station direction, the bearer capability information element may be omitted in the case where the mobile subscriber is allocated only one directory number for all services.

–Mobile identity: May be included by the calling mobile station to identify the calling mobile station.

–Facility: May be included for functional operation of supplementary services.

–Progress indicator: Included in the event of interworking or in connection with the provision of in–band information/patterns.

–Signal: Included if the network optionally provides additional information describing tones.

–Calling party BCD number: May be included by the network to identify the calling user.

–Calling party sub–address: Included in the Mobile Station–to–network direction when the calling user wants to indicate its sub address to the called user. Included in the network–to–Mobile Station direction if the calling user includes a calling party sub–address information element in the SETUP message.

–Called party BCD number: The called party BCD number information element is included by the network when called party number information is conveyed to the mobile station. The called party BCD number shall always be included in the mobile station to network direction.

–Called party sub– address: Included in the Mobile Station–to–Network direction when the calling user wants to indicate the called party sub address. Included in the Network–to Mobile Station direction if the calling user includes a called party sub address information element in the SETUP message.

–Repeat indicator: The repeat indicator information element is included when the in–call modification procedure is used and two low layer compatibility information elements are included in the message.

–Low layer compatibility: Included in the MS–to–network direction when the calling MS wants to pass low layer compatibility information to the called user. Included in the network–to–mobile station direction if the calling user included a low layer compatibility information element in the SETUP message.

–Repeat indicator: The repeat indicator information element is included when the in–call modification procedure is used and two high layer compatibility information elements are included in the message. The repeat indicator information element is not included when the optional high layer compatibility information elements are omitted.

–High layer compatibility: Included in the MS–to–network direction when the calling MS wants to pass high layer compatibility information to the called user. Included in the network–to–mobile station direction if the calling user included a high layer compatibility information element in the SETUP message. This information element may be repeated if the in–call modification procedure is used. Bearer capability, low layer compatibility, and high layer compatibility information elements may be used to describe a CCITT telecommunication service, if appropriate.

–User–user: Included in the calling mobile station to network direction when the calling mobile station wants to pass user information to the called remote user. Included in the network to called mobile station direction when the calling remote user included a user–user information element in the SETUP message.

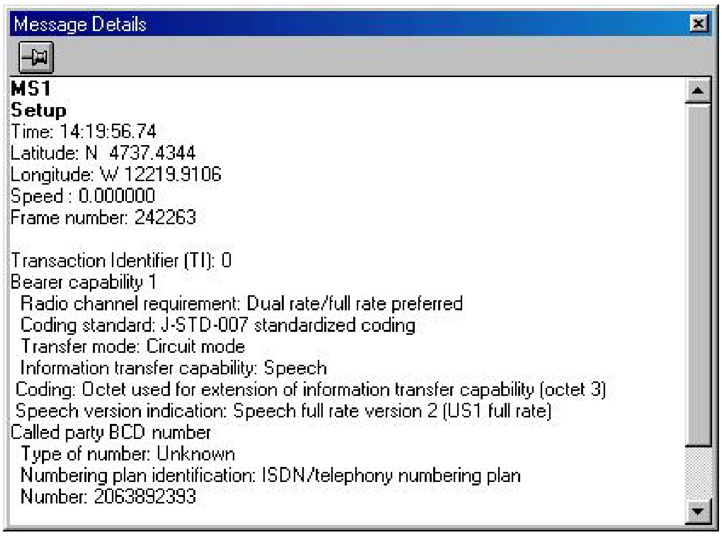


Figure16– Set Up

System Information Type 6 (*Figure 17*) is sent on the SACCH by the network to mobile stations within the cell giving information of location area identification, of cell identity and various other information.

SACCH –Slow Associated Control Channel is used to transmit system information or measurement reports. One SACCH period corresponds to 0.48 second. The free time slots on TCH are used as SACCH when needed.

SACCH DL transmits system information messages to MS during calls. SACCH UL is used to transmit measurement reports from MS to BTS. SACCH is also used for Mobile originated (Connection initiated by the MS) or Mobile terminated (Connection initiated by the network towards MS) SMS when a call is simultaneously on.

FACCH –Fast Associated Control Channel is used to transmit Handover commands, last messages of call setup and call clearing messages. These messages are sent on TCH by using the TCH in signaling mode. No speech or data is transmitted while the TCH is used as FACCH.

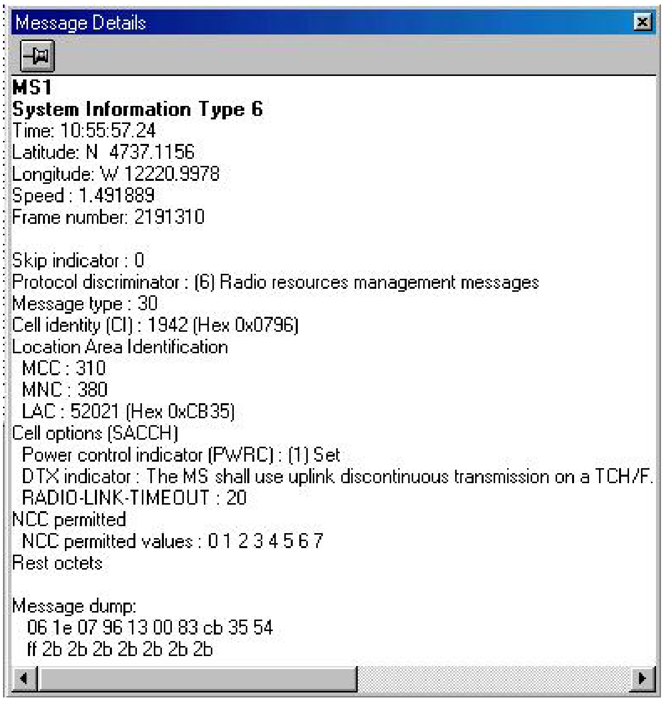


Figure 17– System Information Type 6

Measurement Report message (*Figure 18*) is sent on the SACCH by the mobile station to the network to report measurement results about the dedicated channel and about neighbor cells. This message is repeated for every new measurement report to generate neighbor lists and is the basis for handover command.

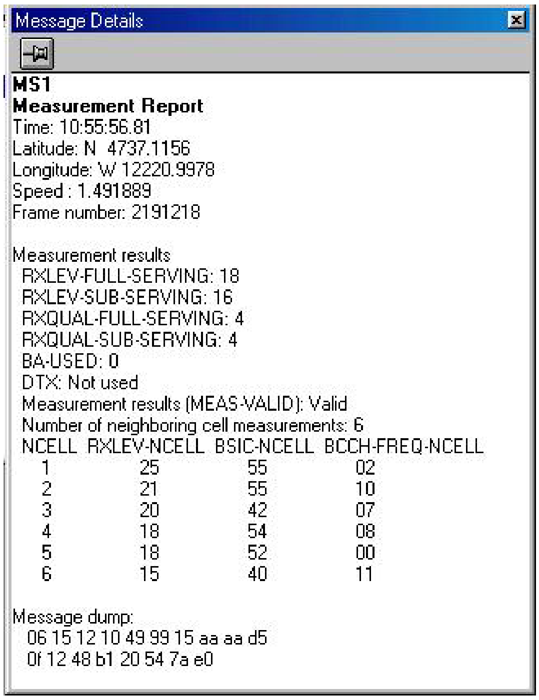


Figure 18– Measurement Report

Call Proceeding message (*Figure 19*) is sent by the network to the calling mobile station to indicate that the requested call establishment information has been received, and no more call establishment information will be accepted.

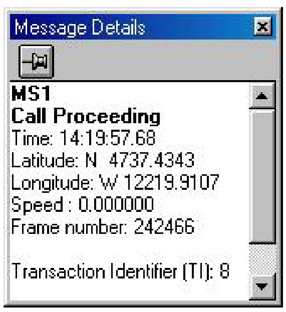


Figure 19– Call Proceeding

Assignment Command message (*Figure 20*) is sent on the main DCCH by the network to the mobile station to change the channel configuration to another independent dedicated channel configuration. Below are some definitions of information given in this message.

–Channel mode information element appears if the channel mode is changed for the channel defined in the mandatory part of the message.

–Channel description information element appears in the case of a so–called intracell handover or an assignment occurring after a call reestablishment if the MS carries two connections (on two dedicated channels).The connection using the channel previously defined in the mandatory part of an ASSIGNMENT COMMAND or HANDOVER COMMAND message shall use the channel defined in the mandatory part of the ASSIGNMENT COMMAND message defining the new configuration.The first indicated channel carries the main DCCH. The SACCH used is the one associated with that channel.

–Channel mode 2 information element appears if the channel mode is changed for the channel defined in the optional channel description information element.

–Mobile allocation information element appears in the case of frequency hopping. It applies to all assigned channels.

–Starting time information element appears in particular if a frequency change is in progress.

After this command comes Assignment Complete (*Figure 21*) message.

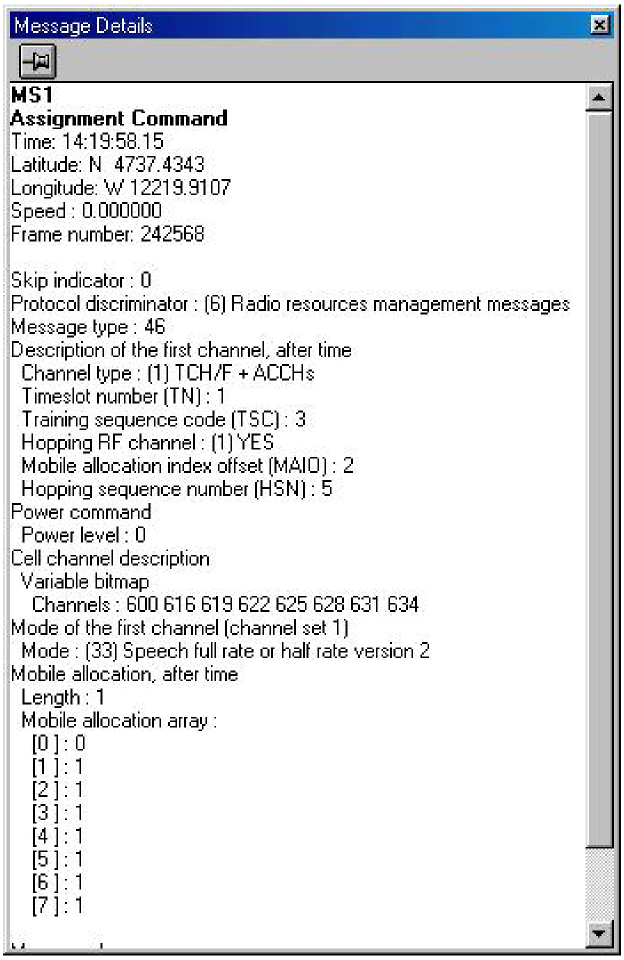


Figure 20– Assignment Command

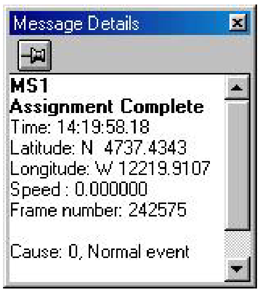


Figure 21– Assignment Complete

3. ANALYSIS of LOG FILES

3.1. Coverage Problems

Low signal level is one of the biggest problems in a Network. The coverage that a network operator can offer to customers mostly depends on efficiency of network design and investment plans. This problem usually pops up when building a new Network or as the number of subscribers increases by the time resulting in new coverage demands.

Low signal level can result in unwanted situations that could directly lower the network performance. Poor coverage problems are such problems that are really hard to solve, because it is impossible to increase coverage by optimizing network parameters. Any hardware configuration changes might improve the coverage a little.

Let’s have a look at some different cases to poor coverage related problems.

3.1.1. Low Signal Level *(Figure 22)*

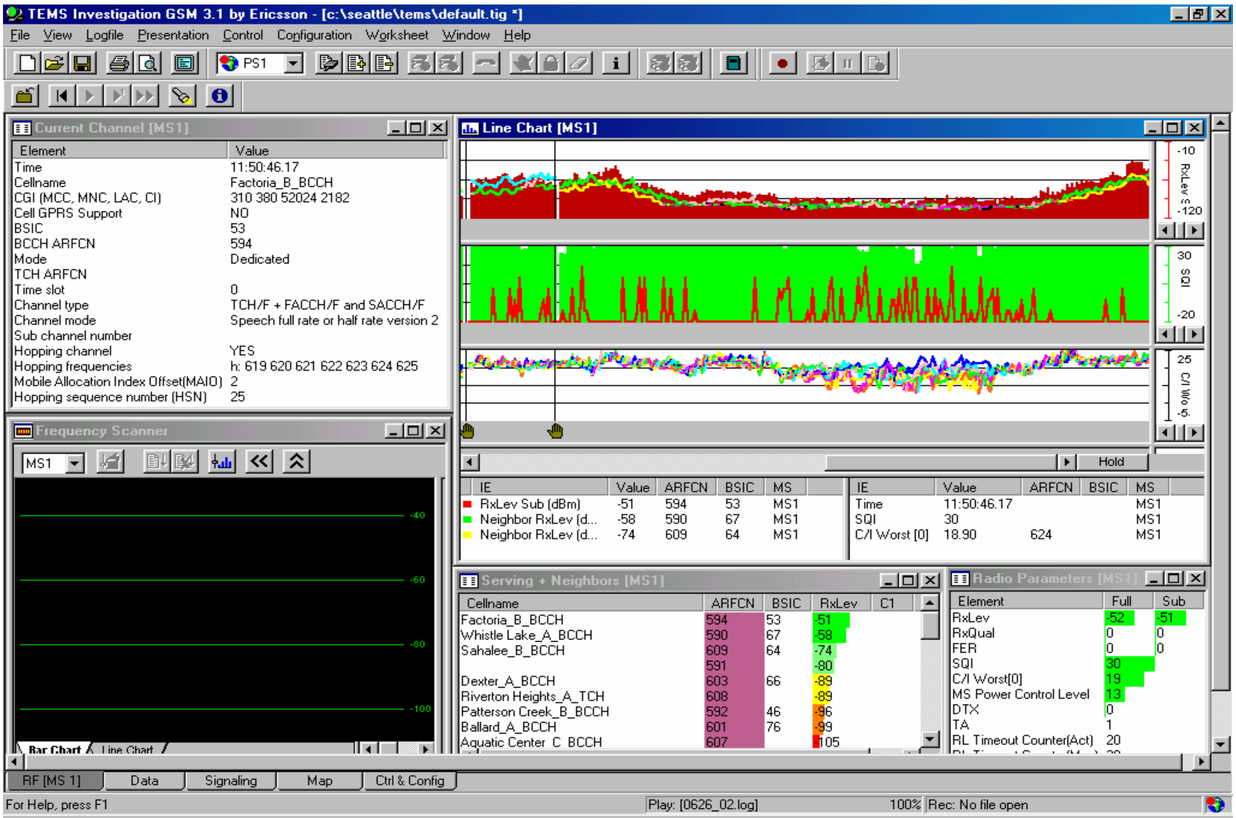


Figure 22– Low Signal Level: *In areas where there are few sites and too many different types of terrain structures like hills or obstacles those stopping the line of sight to the broadcasting signal, there might be a lot of coverage holes or places with insufficient signal level. Pay attention to the significant oscillation on the C/I affected by the drop of signal level.*

3.1.2. Lack of Dominant Server *(Figure 23)*

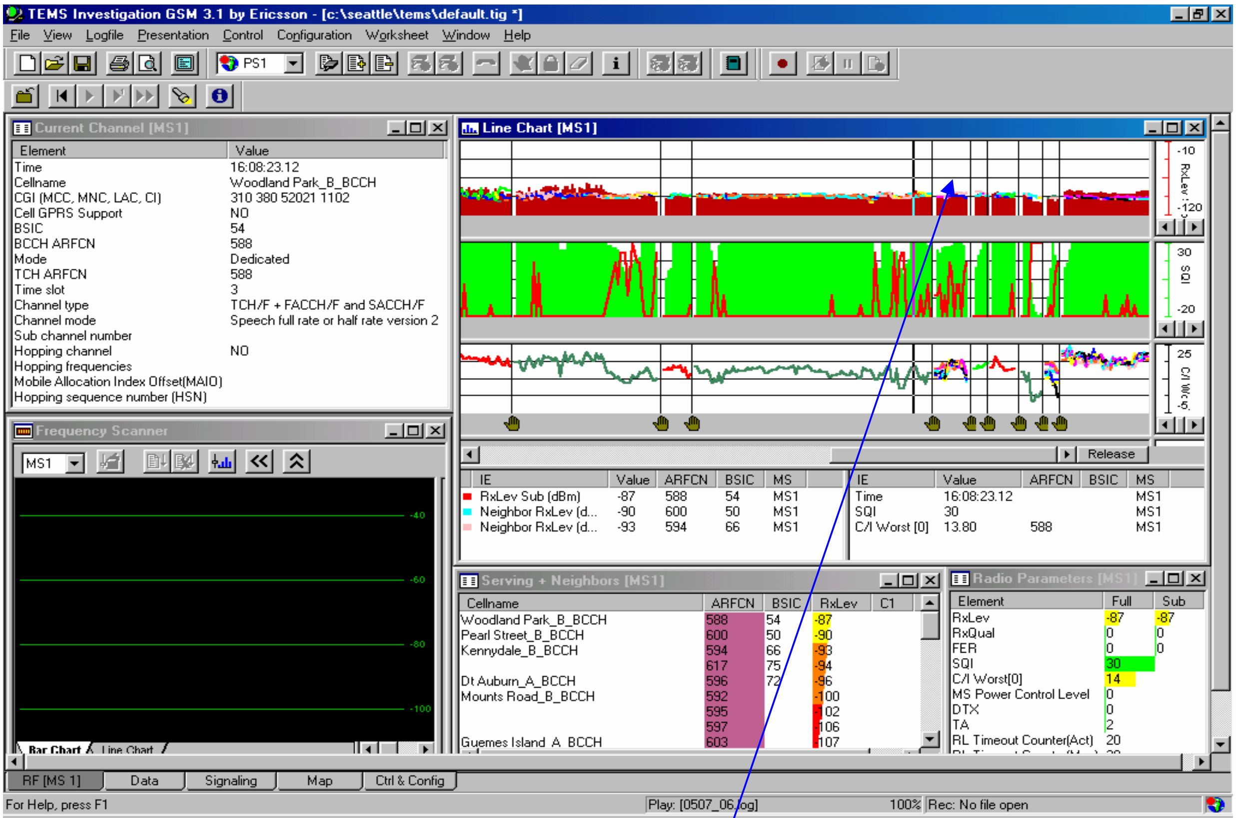


Figure 23– Lack of Dominant Server: *Signals of more than one cell can be reaching a spot with low level causing ping pong handovers. This might happen because the MS is located on the cell borders and there is no any best server to keep the call.*

Lack of Dominant Server Causes
Too many Handovers Between
the same Cells

3.1.3. Sudden Appearance and Disappearance of Neighbors *(Figure 24)*

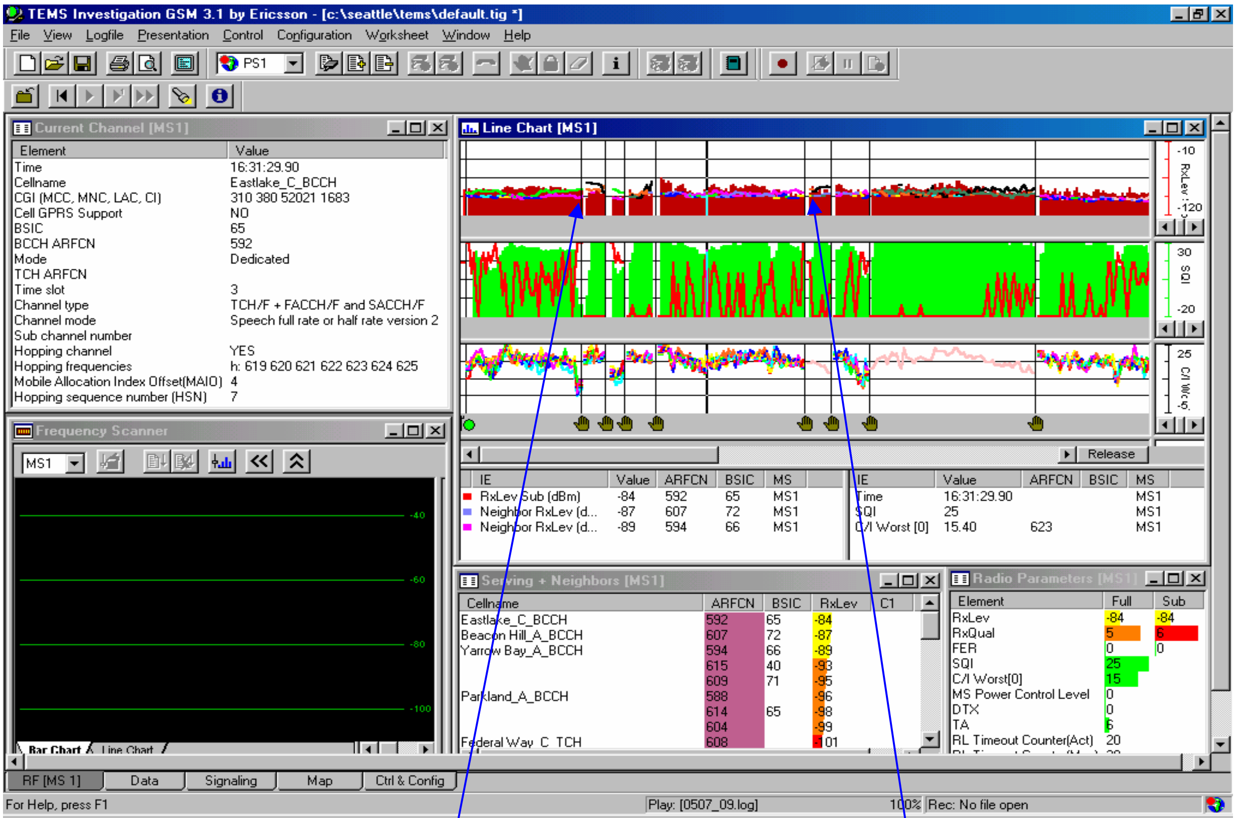


Figure 24– Sudden Appearance of Neighbors – Terrain Effect: *Due to terrain or obstacles, neighbors may pop up with high levels causing the BSC to give wrong handover decisions. In this case, there won't be a stable server, but the call will be handed to the neighbors for very short period.*

3.1.4. Fast Moving Mobile *(Figure 25)*

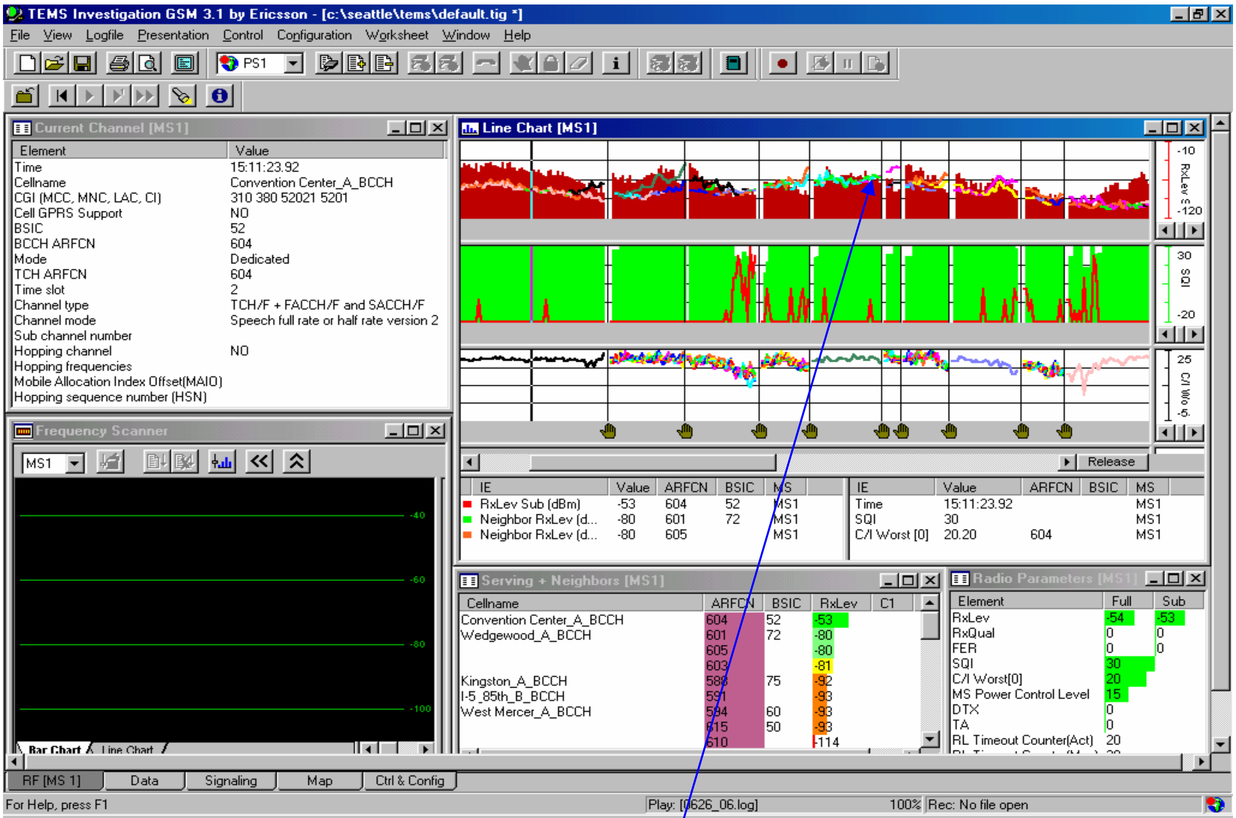


Figure 25– Sudden Appearance of Neighbors – Fast Moving Mobile Effect: *When MS moves very fast, the tester will see a lot of handovers and sudden changes on signal levels. This case might happen when the MS user is driving fast on the highway. The serving time of the cell will depend on the cell size and vary with hierarchical cell structure of the network. There seem to happen too many handovers but this is due to fast moving mobile.*

Sudden appearance of Neighbors
due to Fast Moving Mobile

3.1.5. Sudden Decrease on Signal Level *(Figure 26)*

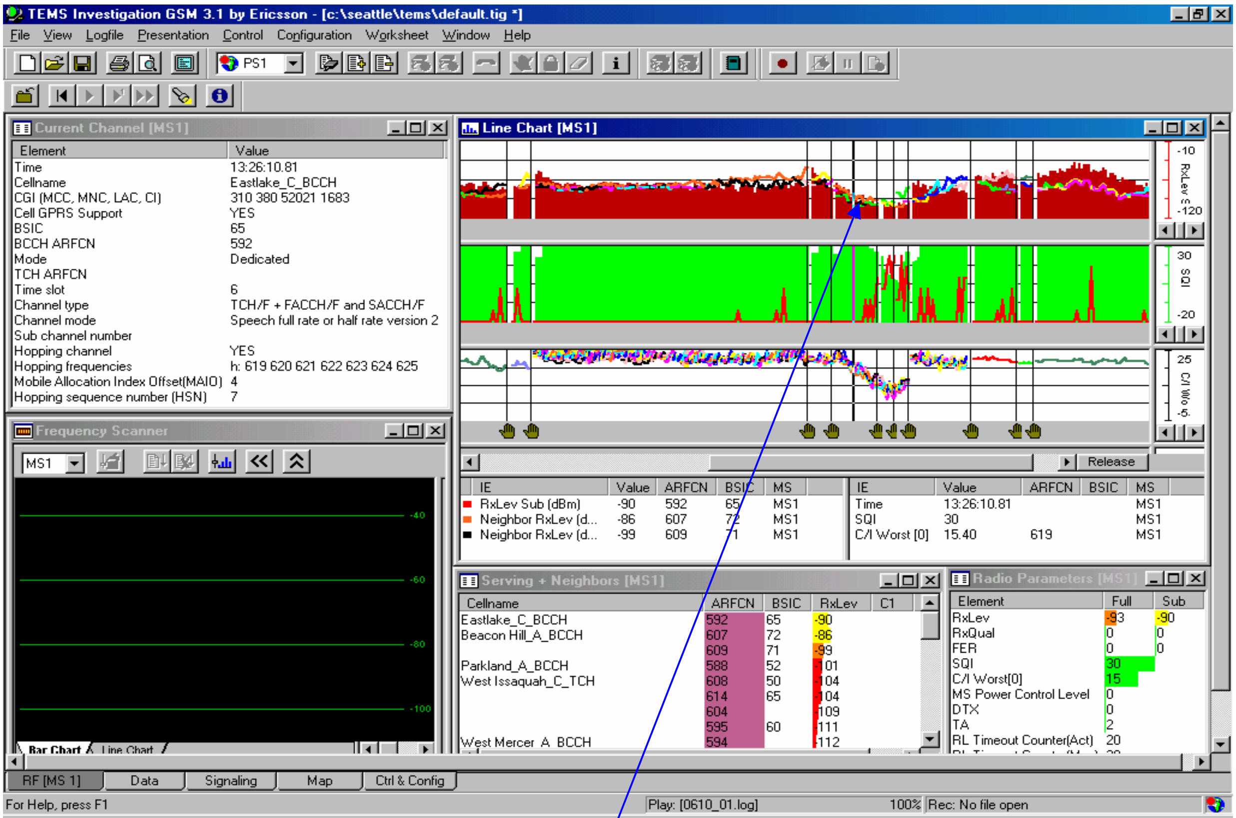


Figure 26– Sudden Decrease on Signal Level – Tunnel Effect: *Tester may notice sudden decrease on signal level when analyzing the log files. This will result in excessive number of handovers. Before suspecting anything else, check if the test was performed on a highway and that particular area was a tunnel or not. Signal level on the chart will make a curve rather than unstable changes. Tunnel effect will most likely result in ping pong handovers.*

Curve Formation due to Tunnel Effect Causing Sudden Level Decrease and Ping Pong Handovers

3.1.6. Stable Behavior *(Figure 27)*

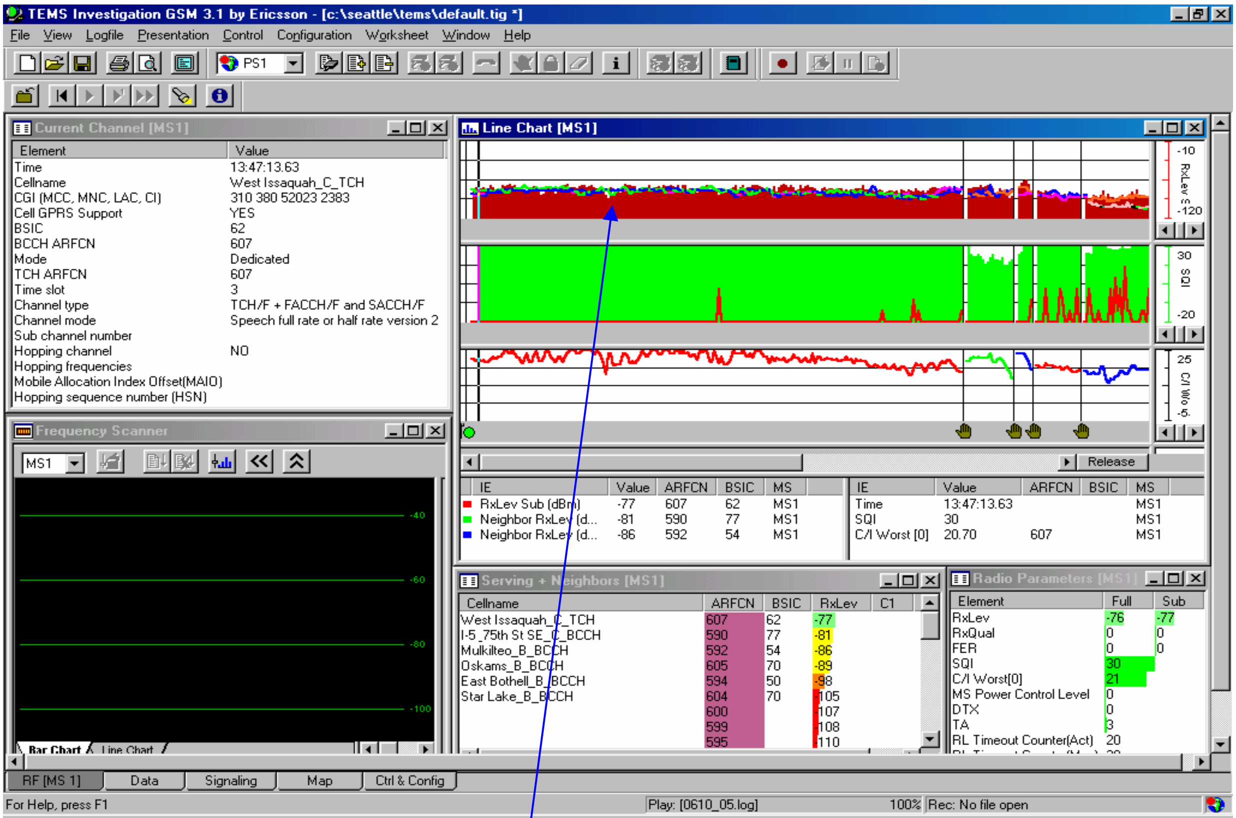


Figure 27– Stable Behavior – The same Cell serving for a long Time: *Looking to above view, tester may think the serving cell's coverage is very good and it's serving through a long period. Sometimes this may not be correct and this stable look may result in misunderstanding. Check if the drive test vehicle was waiting for a red light or any traffic jam causing the vehicle to wait at the same spot for a long time.*

Stable Behavior – Probably Long Stop
for a Traffic Light or Traffic Jam

3.1.7. Oscillation on Hopping Channels *(Figure 28)*

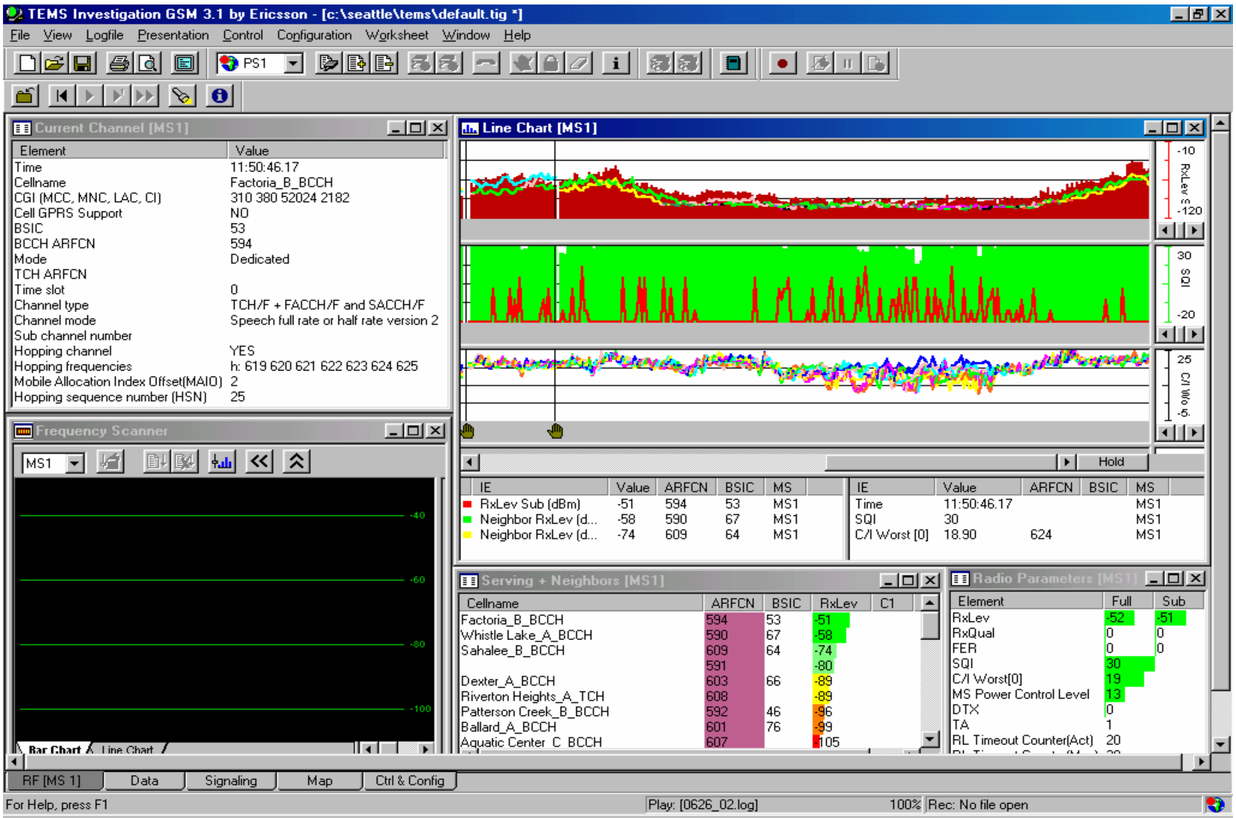


Figure 28– Oscillation on Hopping Channels Become more Significant with Low Level: *Poor coverage brings low quality and is a very significant sign of future drop calls. Low level on down link signal strength can mostly occur because of low number of sites in the network, high attenuation from the obstacles like buildings or hills, or high path loss caused by Rayleigh Fading.*

3.1.8. Same Cell in the Neighbor List *(Figure 29)*

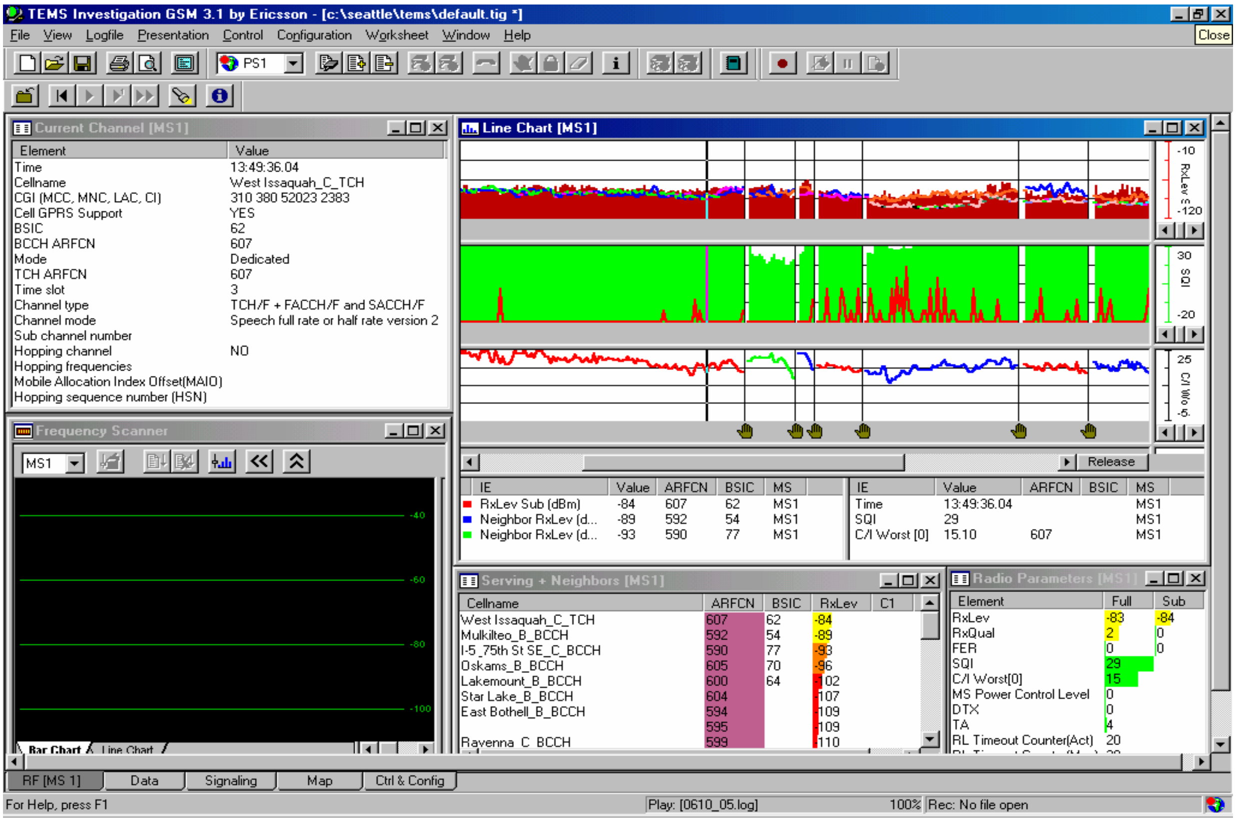


Figure 29– The same cell always popping up as the second strongest neighbor in the list through a large area might show an overshooting cell. This kind of situations will

3.1.9. RX Levels too Closed to Each Other *(Figure 30)*

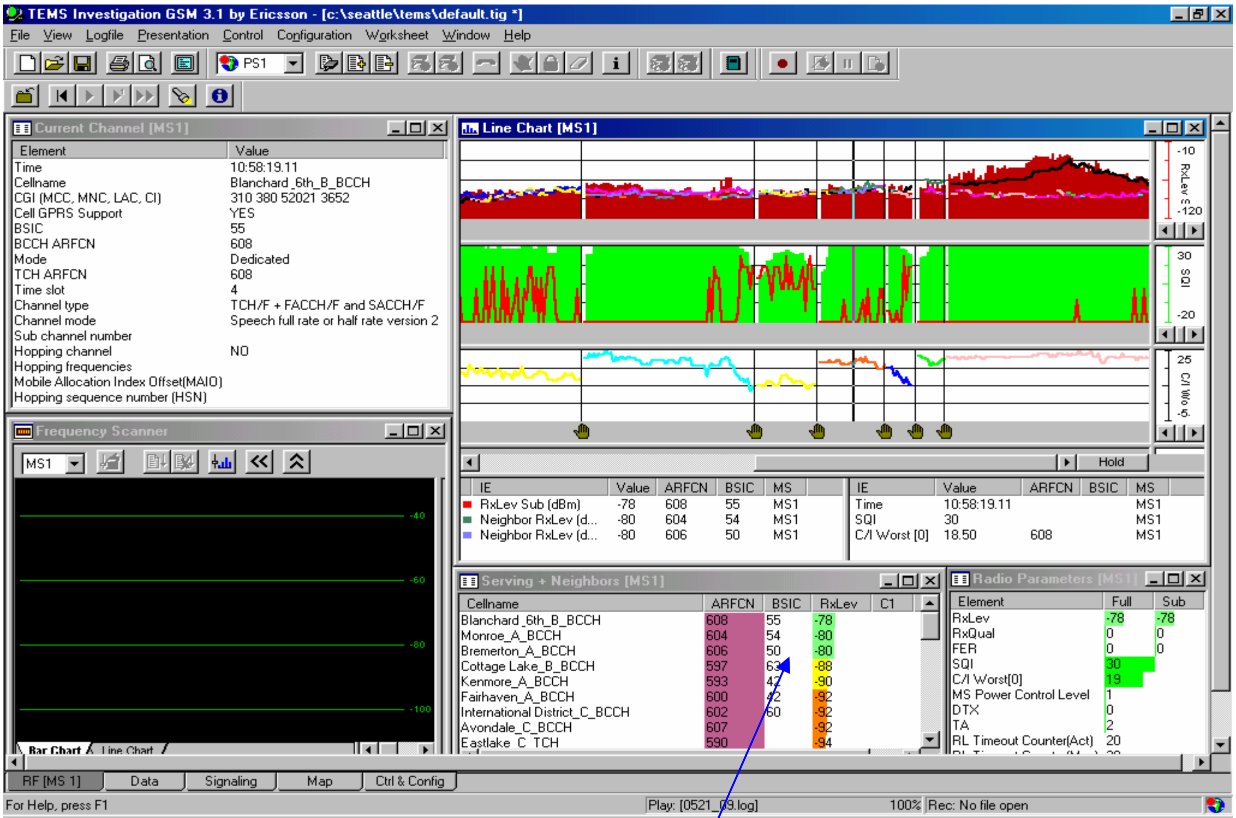


Figure 30– Ss levels of 3–4 cells are too closed to each other – This might point overlapping cells: *Other cells else than the one that suppose to serve at that particular area should be coverage reduced by power reductions, downtilts or other configuration changes.*

Signal Levels of the serving cell
and its 3-4 Neighbors are too
closed to each other

3.1.10. RX Levels of Many Cells are Almost the Same *(Figure 31)*

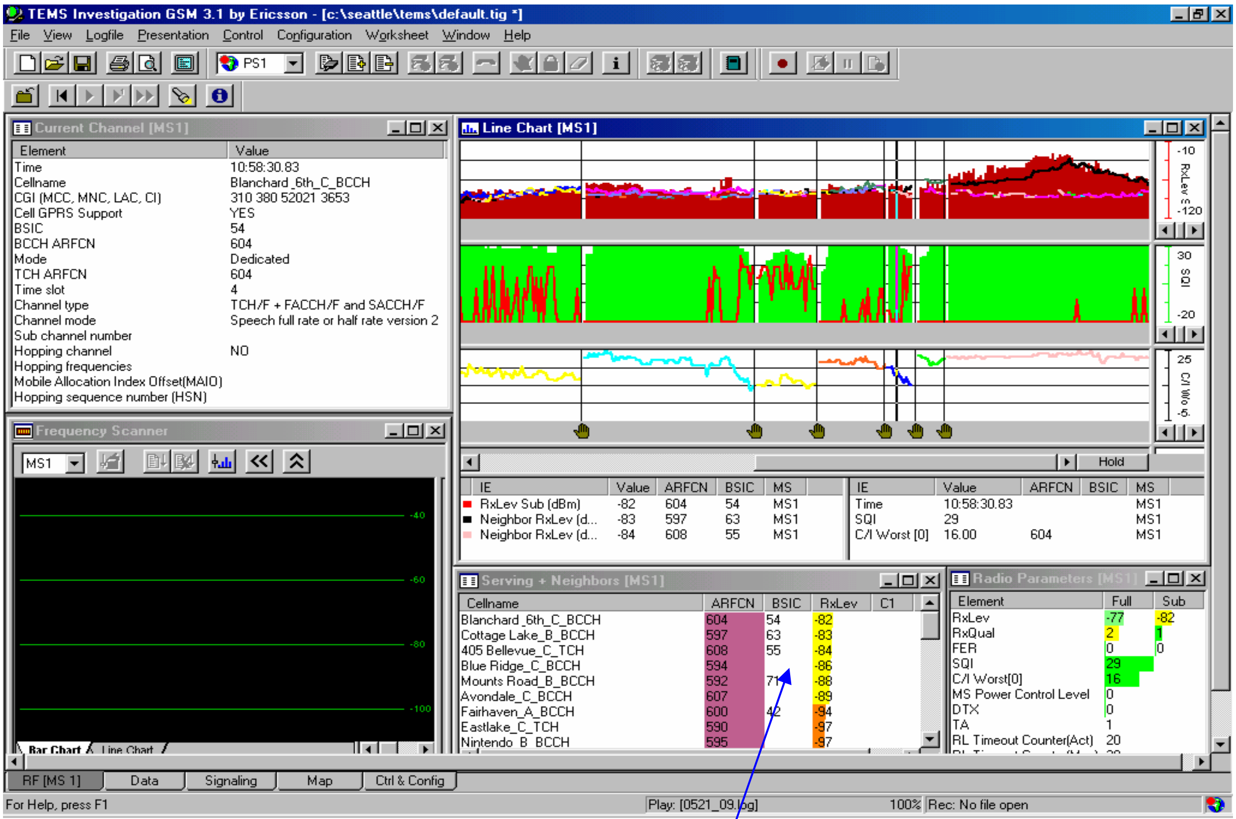


Figure 31– Signal Strength of All the neighbors are almost the same with each other. *This shows the network needs big optimization work because there are too many cells having overlapping coverage. This will cause quality problems because of frequency reuse and immediate action to optimize cell coverage should be taken.*

Too many Overlapping Cells

3.1.11. Line of Sight Lost *(Figure 32)*

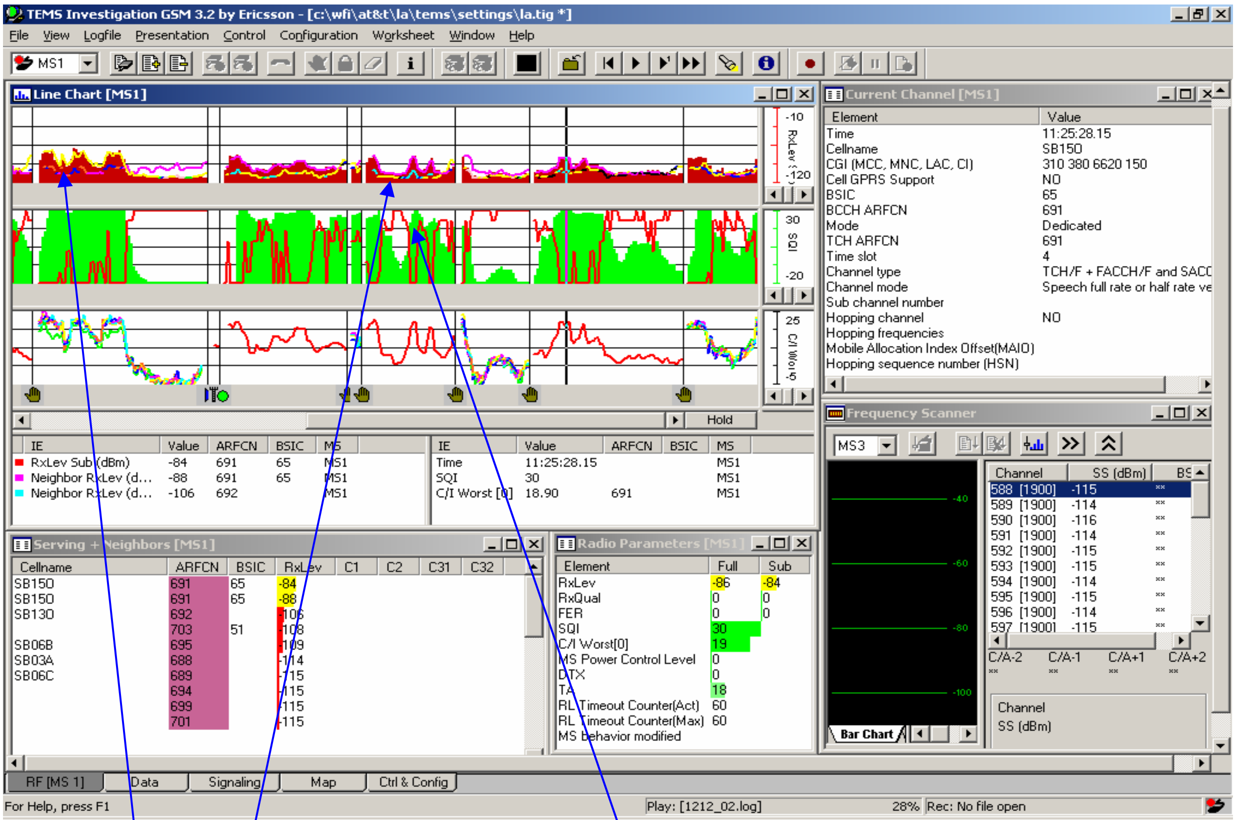


Figure 32– Both Signal Strength and SQI are changing fast due to far away server being blocked by obstacles from the terrain. The other way, signal from the server looses line of site to the mobile because of a hill or something.

Signal Strength of the server cell makes fast up and downs due to lost Line of Sight

Quality goes worst when the level drops down fast.

3.1.12. Log File Recording on Resume *(Figure 33)*

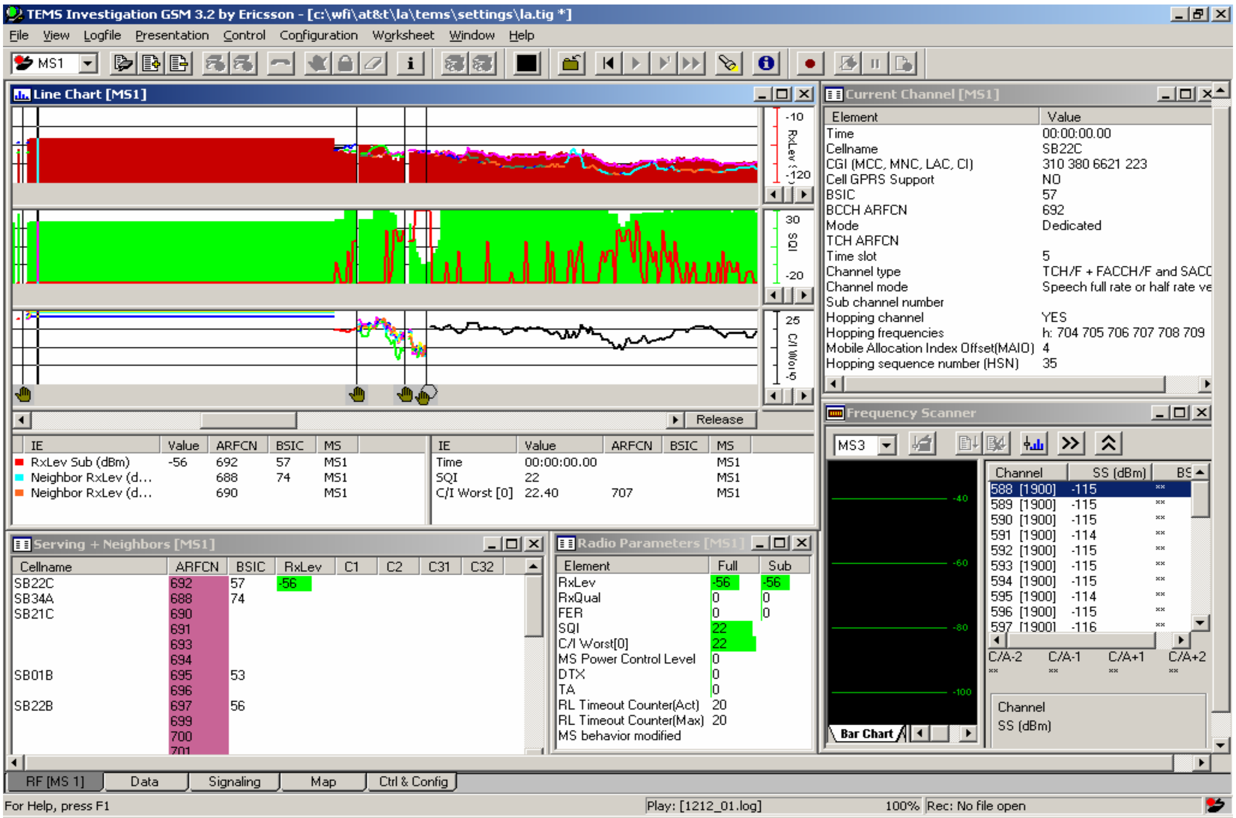


Figure 33– TEMS on Resume. Don't worry, everything is fin: *Although this looks weird, the straight look in the chart is just because tester resumed recording log file to take a break during the test. You will see a straight line for the period of time test was resumed.*

3.1.13. Drop Call due to Bad Coverage *(Figure 34)*

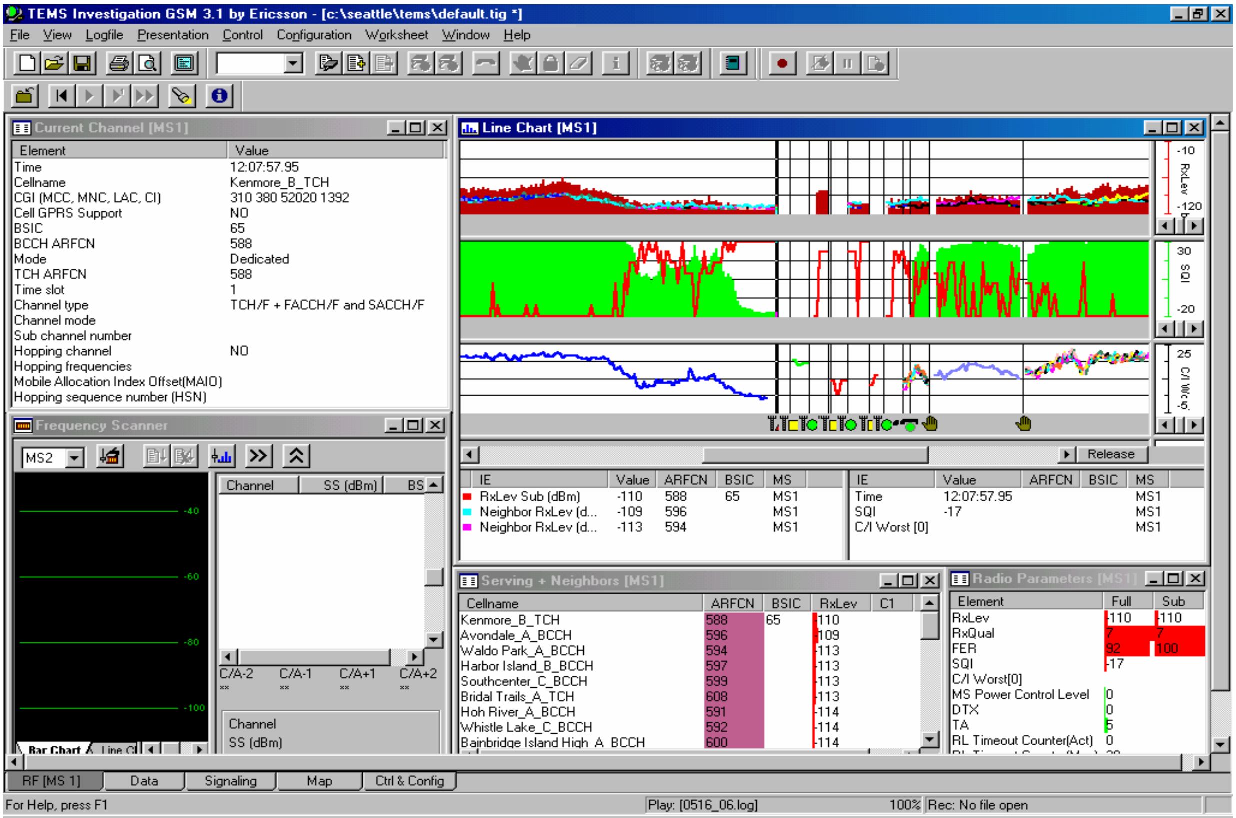


Figure 34– Drop Call due to Bad Coverage: *Call is dropped because of poor coverage. The signal level goes down below the minimum signal level that system could carry on. Remember this minimum level is much lower than RX Access Minimum Level to prevent on–going call from dropping.*

3.1.14. Access Failures After a Drop Call *(Figure 35)*

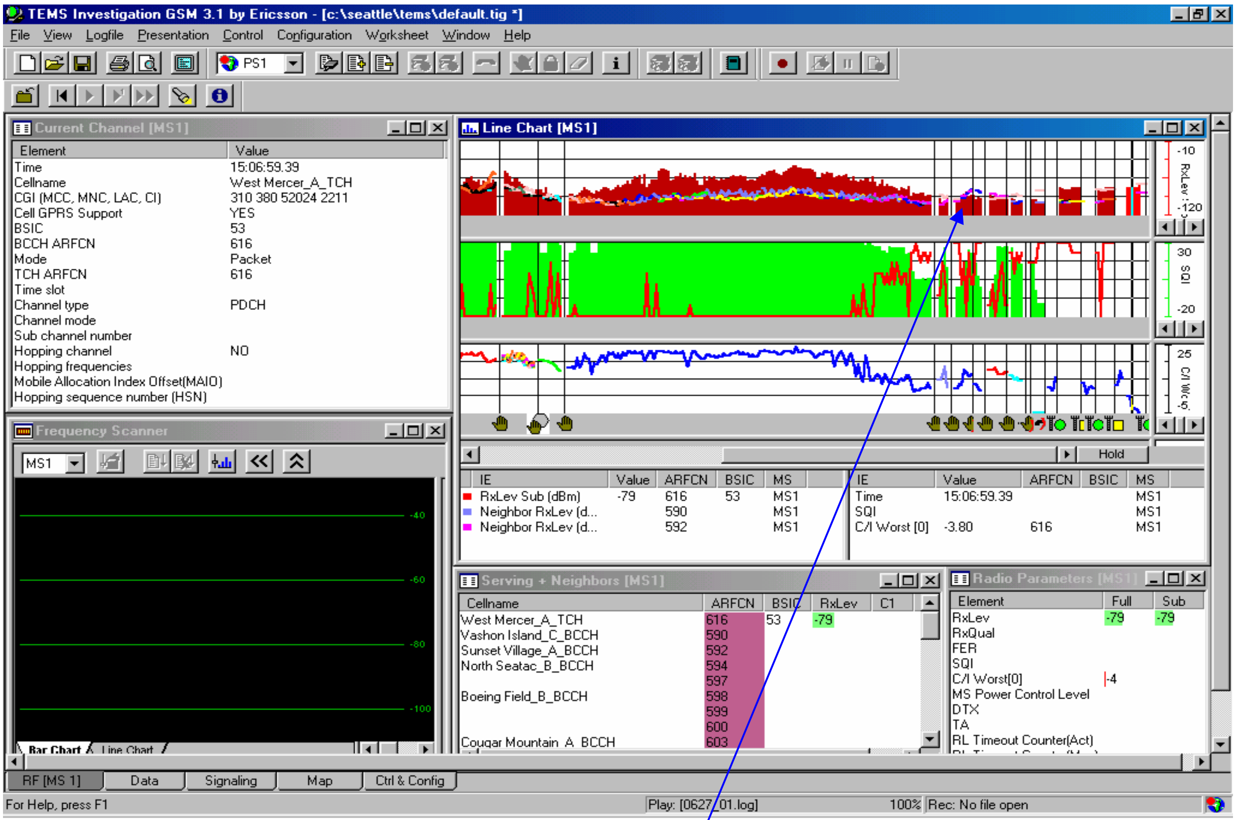


Figure 35– Access Failures After a Drop Call: *Access failures can happen because of low level below ACCMIN, bad quality or blocking in the target cell, or hardware failures. If you get a blocked call message during call set–up, it is because the signal leveling the cell you are trying to make call set–up is below ACCMIN which prevents MS to access the cell. ACCMIN is generally set to –104dBm depending on sensitivity level of equipments and is referred during call set–up. A low value of ACCMIN means that the coverage in idle mode is improved at the expense of the risk of having an increased number of call set–up failures.*

Access Failures in a Cell during
Call Set-Up

3.1.15. Solutions to Low Level Problems

Possible solution ways can be listed as below:

–New Site Proposal
–Sector Addition
–Repeater
–Site Configuration Change (Antenna Type, height, azimuth, tilt changes)
–Loss or Attenuation Check (Feeders, Connectors, Jumpers, etc..)

The best thing to do in case of low signal strength could be recommending new site additions. A prediction tool with correct and detailed height and clutter data supported with a reasonable propagation model could be used to identify the best locations to put new sites. If client is not eager to put new sites because of high costs to the budget or finds it unnecessary because of low demand on traffic, then appropriate repeaters could be used to repeat signals and improve the coverage. Adding repeaters always needs extra attention because they can bring extra interference load to the network. The received level in the repeater should be above –80dBm (or desired limits) so that it can be amplified and transmitted again. The mobile should not receive both the original and the repeated signals at the same area, cause signal from the repeater is always delayed and it will interfere with the original signal. A repeater should not amplify frequencies outside the wanted band.

If none of the above recommendations are accepted by the client, then cheaper and easier ways should be followed. First things to be checked would be possible attenuation on the cells. Faulty feeders–jumpers–connectors or other faulty equipment, high combiner loss, reduced EIRP, decreased output power, the orientations and types of antennas, unnecessary downtilts, existence of diversity and height of the site should be deeply investigated. Putting higher gain antennas, increasing output power, removing attenuations, changing antenna orientations towards desired area, reducing downtilts, replacing faulty equipment or usage of diversity gain could improve the coverage.

Please note, amplifiers (TMA or MHA) could be used to improve uplink or compensate the loss caused by long feeder. Be careful, because they will also amplify interfering signals and they will be received at higher level.

3.2. Quality Problems

Indicators collected from the network which give information about the speech quality are:

– Dropped calls due to bad quality
– Call releases due to bad quality
– Handover failures
– Handover, quality controlled
– Intra–cell handover, quality controlled
– RXQUAL distribution
– FER measurements/distributions

3.2.1. BER and FER

Let's remember **BER–** Bit error Rate and **FER–** Frame Erasure Rate expressions:

The speech quality is degraded by high BER for the air interface. The BER and frame erasure ratio (FER) are dependent on a number of factors such as fading and interference. Therefore a good cell planning is needed to avoid co–channel interference, adjacent–channel interference, time dispersion and other types of radio interference. The BER and FER caused by the radio network is the most important speech quality degradation factor. The degradation can be minimized by using the radio network features DTX, Power control and Frequency hopping. The handovers while moving from cell to cell will also introduce a speech quality disturbance.

3.2.2. Bad Quality due to Signal Strength – FER is Bad *(Figure 36)*

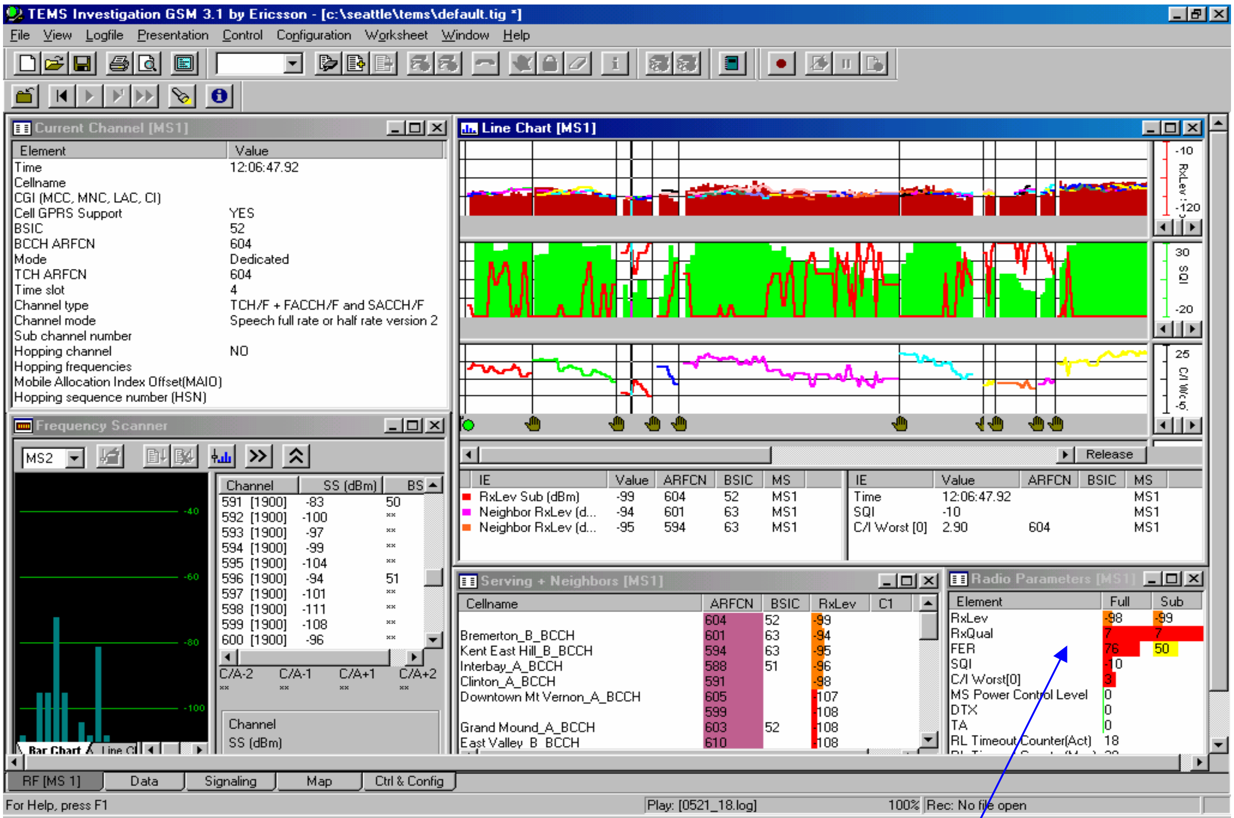


Figure 36– Bad Quality due to Signal Strength – Bad FER: *As the signal strength drops down, the quality of the call becomes worse being effected by interference and/ or fading. Consequently the system becomes weaker to handle the interference. Notice that not only Rx Quality is bad, but also FER is high. SQI is still within acceptable limits. That's why we check all RX Quality, FER and SQI when analyzing interference problems. System will face bad RX Quality, drop calls and ping pong handovers in such environments.*

Bad RxLev
Bad RXQual
Bad FER

3.2.3. Bad Quality due to Signal Strength – FER is OK *(Figure 37)*

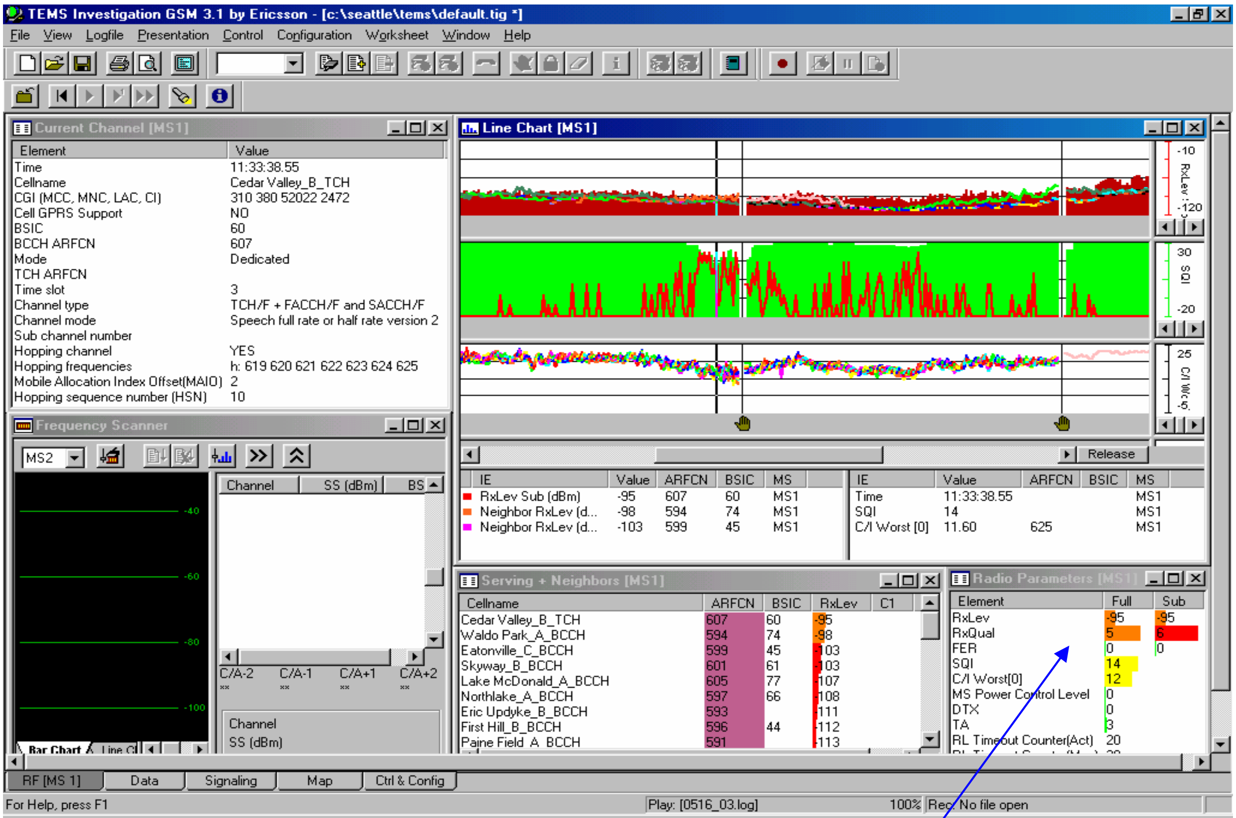


Figure 37– Bad Quality due to Signal Strength – FER is OK: *The difference of this case from the previous is only the difference in FER. Signal strength is also bad in this, but FER is still fine which means there is no obvious interference in the area. The area in this case should most probably be a flat area without any obstacles to create reflection and the site density should not be dense or re–use of frequencies is good to prevent any co–channel interference.*

RX Quality is bad
FER is fine

3.2.4. SQI

SQI, Speech Quality Index is another expression when Quality is concerned:

The need for speech quality estimates in cellular networks have been recognized already in the GSM standard, and the RxQual measure was designed to give an indication of the quality.

However, the RxQual measure is based on a simple transformation of the estimated average bit error rate, and two calls having the same RxQual ratings can be perceived as having quite different speech quality. One of the reasons for this is that there are other parameters than the bit error rate that affects the perceived speech quality. Another reason is that knowing the average bit error rate is not enough to make it possible to accurately estimate the speech quality. A short, very deep fading dip has a different effect on the speech than a constant low bit error level, even if the average rate is the same.

The TEMS Speech Quality Index, which is an estimate of the perceived speech quality as experienced by the mobile user, is based on handover events and on the bit error and frame erasure distributions. The quality of speech on the network is affected by several factors including what type of mobile the subscriber is using, background noise, echo problems, and radio channel disturbances. Extensive listening tests on real GSM networks have been made to identify what type of error situations cause poor speech quality. By using the results from the listening tests and the full information about the errors and their distributions, it is possible to produce the TEMS Speech Quality Index. The Speech Quality Index is available every 0.5 second in TEMS and predicts the instant speech quality in a phone call/radio–link in real–time.

3.2.5. Collusion of MA List Causing Low C/I *(Figure 38)*

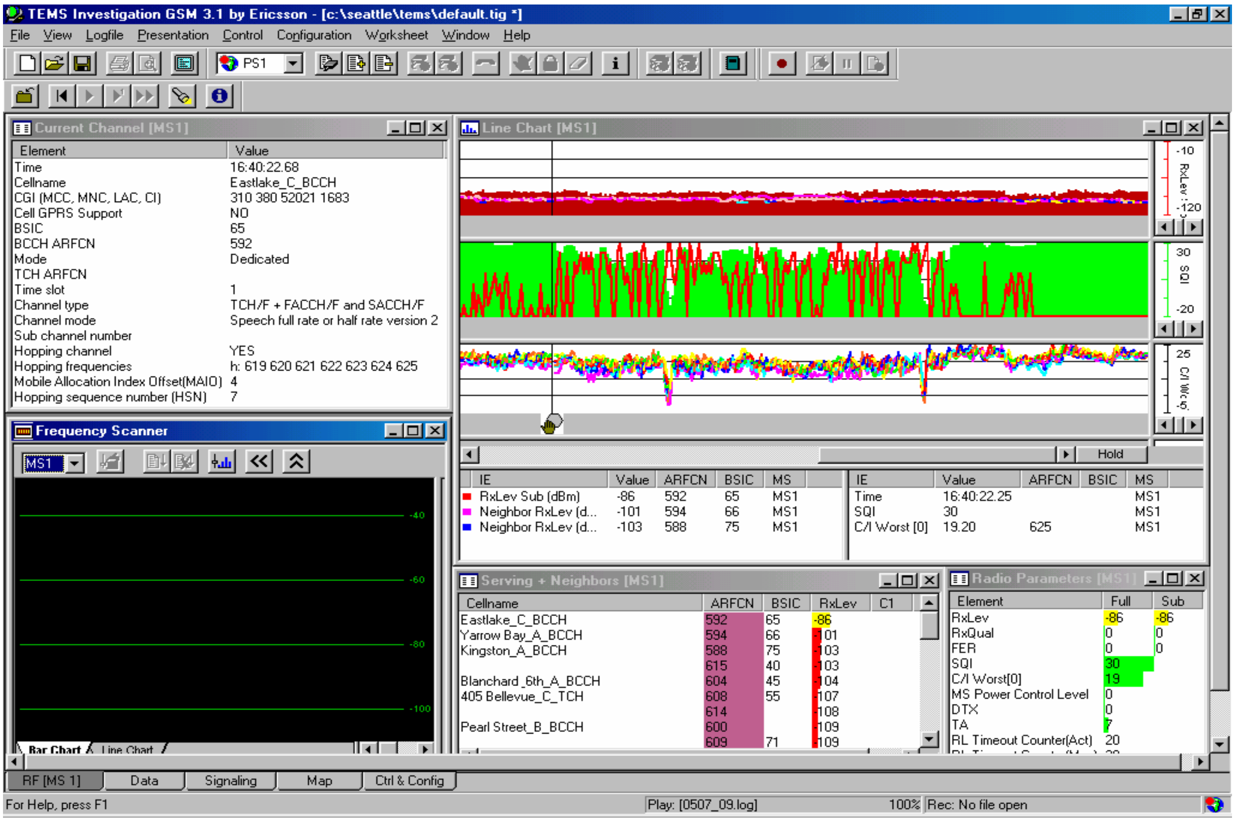


Figure 38– Collusion of MA list causing low C/I: *The collusion of frequencies with neighboring cells MAIO list frequencies become more significant with dropping signal level. To prevent this kind of interference, MAIO lists of neighboring cells should be properly planned or MAIO step could be used.*

3.2.6. C/I Aspect

Co–channel interference is the term used for interference in a cell caused by
carriers with the same frequency present in other cells.The GSM specification states that the signal strength ratio, C/I, between the carrier, C, and the interferer, I, must be larger than 9 dB. However it is generally recommended to use C/I >12 dB as a planning criterion. If frequency hopping is implemented, it adds extra diversity to the system corresponding to a margin of approximately 3 dB.

One must remember that interference does not only appear on the down–link, but also on the uplink. If interference on the downlink is experienced in one cell, there is a risk that you would have this problem on the uplink as well. Not in the same cell, but in the interfering cell. However, downlink interference is normally a larger problem than uplink interference.

C/I > 12 dB (without frequency hopping)

C/I > 9 dB (with frequency hopping)

3.2.7. C/A Aspect

The distance between adjacent frequencies on the uplink or the downlink is called channel separation. The channel separation is 200 kHz, regardless of the standard chosen from the ones mentioned above. This separation is needed to reduce interference from one carrier to another neighboring frequency.

Adjacent carrier frequencies (i.e., frequencies shifted ±200 kHz) with respect to the carrier cannot be allowed to have too strong a signal strength either. Even though they are at different frequencies, part of the signal can interfere with the wanted carrier's signal and cause quality problems. Adjacent frequencies must be avoided in the same cell and preferably in neighboring cells as well.

The GSM specification states that the signal strength ratio, C/A, between the carrier and the adjacent frequency interferer, A, must be larger than –9 dB. However, adjacent channel interference also degrades the sensitivity as well as the C/I performance. During cell planning the aim should be to have C/A higher than 3 dB.

C/A > 3 dB

3.2.8. C/A Interference *(Figure 39)*

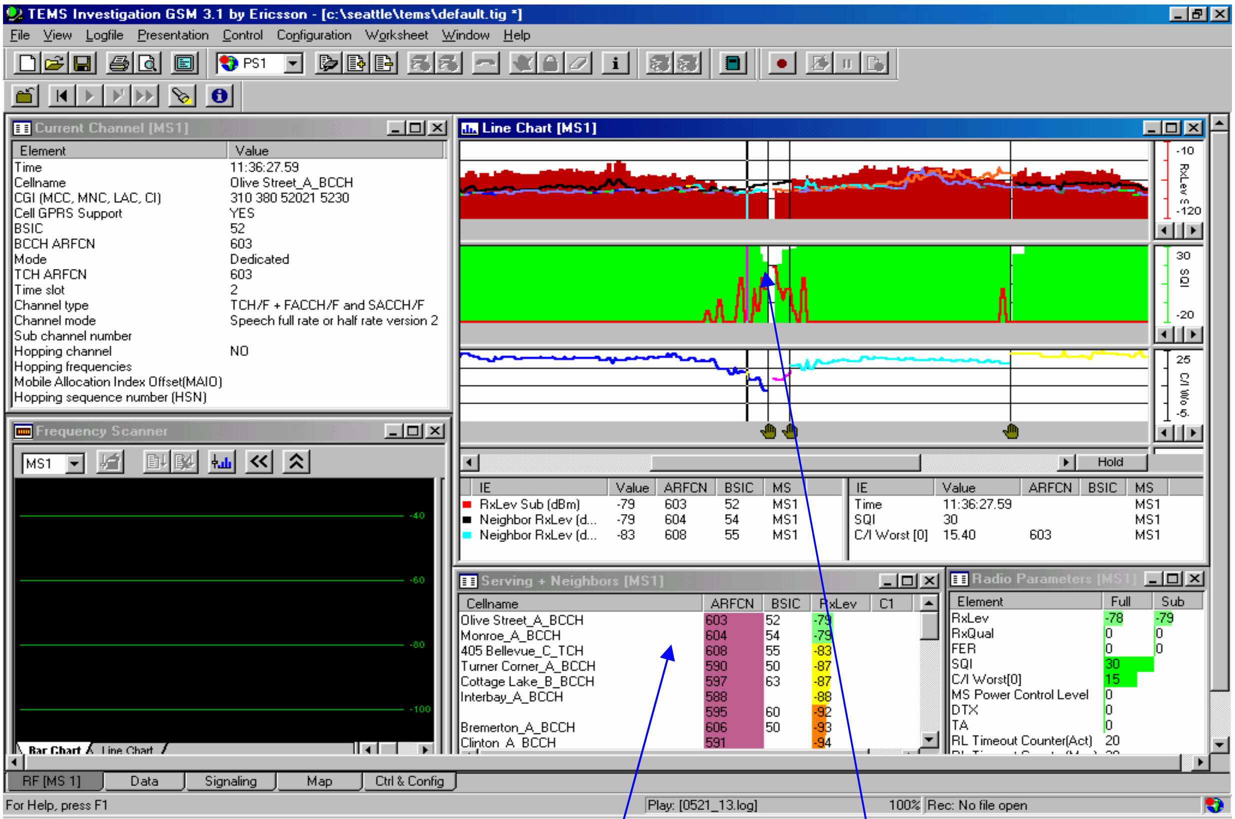


Figure 39– C/A Interference: *This is a good example of adjacent channel interference. Although our first and prioritized concern in frequency planning will be Co–Channel interference, some cases where you use adjacent channels in neighboring cells might bring you quality problems and even handover failures.*

Adjacent BCCH between best server and best neighbor

Bad Quality due to Adjacent Interference

3.2.9. Time Dispersion

Time dispersion may cause problems in environments with, e.g., mountains, lakes with steep or densely built shores, hilly cities, and high metal–covered buildings. The interferer, R, is a time delayed reflection of the wanted carrier. According to GSM specifications, the signal strength ratio C/R must be larger than 9 dB (compared to the C/I–criterion).

However, if the time delay is smaller than 15 ms (i.e., 4 bits or approximately 4.4 km), the equalizer can solve the problem. If there are quality problems, time dispersion measurements must be taken to verify that time dispersion is actually causing the poor quality.

By using all or most of the received power, instead of only the direct signal, there is a larger probability to decode the information. This may be considered as a type of time diversity.

There are couples of things to remember when dealing with time dispersion problems:

- Not all reflections are harmful, only low attenuated reflections that are delayed more than the equalizer can handle.

- The further away the objects are, the weaker the reflections are. Hence, objects just outside the ellipse are the ones most likely to cause the majority of problems.

- For problems to occur, there will, in most cases, be a line of sight from both mobile and base station to the reflector. Small cells in an urban environment are not likely to encounter any time dispersion problems. The distances (time delays) are short, and the buildings will shield from, and also scatter the reflections.

Reflections are a function of the location of the site and mobile. Therefore none of the radio network features are of much help in combating reflections. Frequency hopping does not improve on BER that is due to reflections (C/R).

The most radical solution is to move a site. A site could be placed near the reflecting object to prevent time dispersion. Easier and sometimes just as efficient is to modify the antenna arrangement, either in azimuth (horizontally) or by tilt (vertically). Those measures may also be used to improve C/I. For down–tilt to be efficient, antennas with narrow vertical lobes would be needed to avoid illuminating the reflector.

3.2.10. Bad Quality due to Time Dispersion *(Figure 40)*

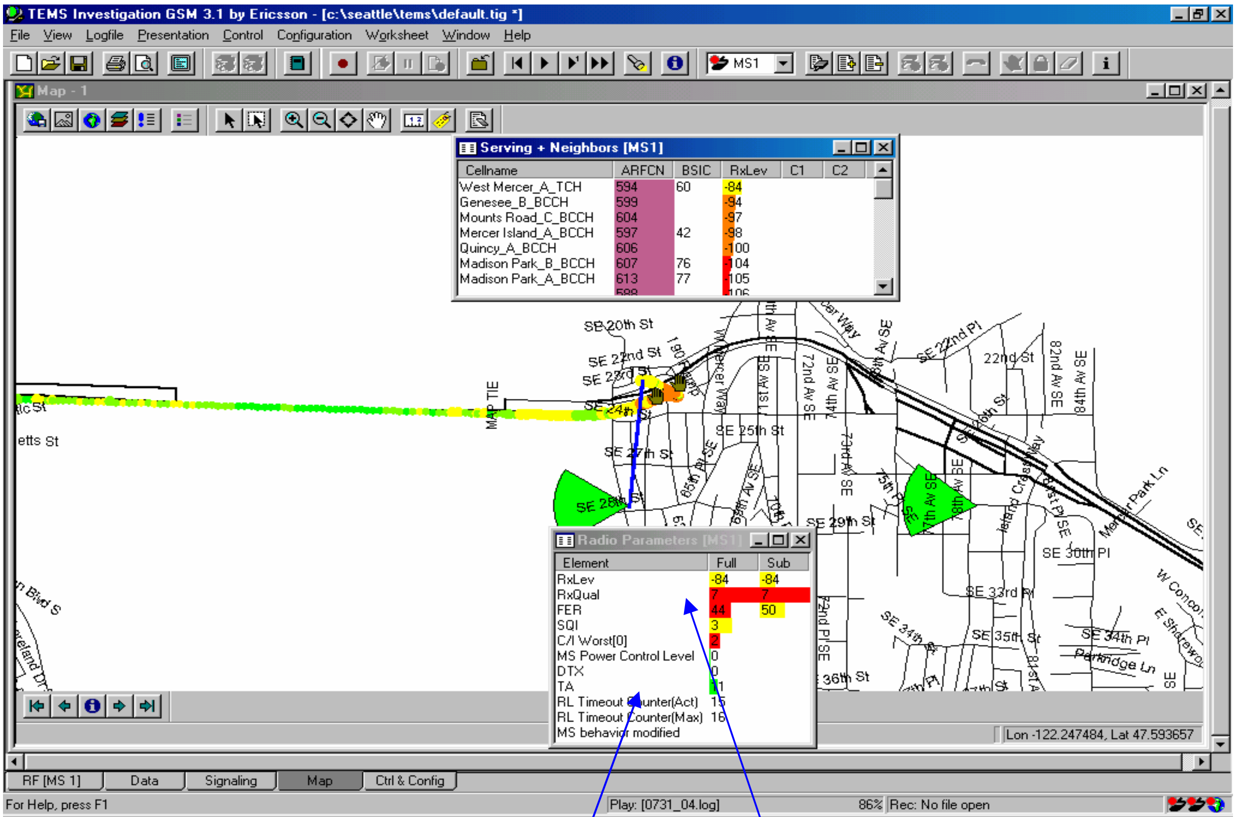


Figure 40– Bad Quality due to Time Dispersion: *This is a good example to reflection from a source of reflection whether a hill or a tall building. In this case, the reflected signal R is even stronger than the original signal C. Please pay attention to Time Advance value although MS is less than 1 Mile far to the cell.*

TA is too high even MS is too closed to the site. This is because TA stands for the reflected signal, but not the original signal.

Bad C/R resulting bad Quality

3.2.11. Inter–system Interference

Sometimes the planning is restricted by interference from external sources, such as other cellular systems in the same area operating on adjacent frequencies, or old microwave links or military equipment operating on certain frequencies within or close to the band.
This type of interference is often very difficult to control (avoid), and must thus be considered in the frequency planning. One possible countermeasure is to avoid disturbed frequencies on a certain site, or sites in a certain region.

If interference from external sources are anticipated or suspected, measurements are normally performed in order to get a clear picture of the situation. RFI measurements, utilizing a spectrum analyzer, is a common approach.

3.2.12. Propagation Behavior

Propagation properties are different across the frequency spectrum. Many factors including absorption, refraction, reflection, diffraction, and scattering affect the wave propagation.

The fast fading signal (peak–to–peak distance $\approx$ l/2) is usually present during radio communication due to the fact that the mobile antenna is lower than the surrounding structures such as trees and buildings. These act as reflectors. The resulting signal
consists of several waves with various amplitudes and phases. Sometimes these almost completely cancel out each other. This can lead to a signal level below the receiver sensitivity. In open fields where a direct wave is dominating, this type of fading is
less noticeable.

Short–term fading is Rayleigh distributed with respect to the signal voltage. Therefore, it is often called Rayleigh fading. This type of fading affects the signal quality, and as a result some measures must be taken to counter it.

The first and most simple solution is to use more power at the transmitter(s), thus providing a fading margin. Another way to reduce the harm done by Rayleigh fading is to use space diversity, which reduces the number of deep fading dips.

3.3. Handover

Mobiles in communication with the network will continuously perform measurements on serving and neighboring cells. The measurement results are sent to the BSC and used in the locating procedure to make decisions about handover. There are different types of handovers:

· Intra BSC handover: The new and old cells both belong to the same BSC. The BSC can handle the handover on its own.

· Inter BSC handover: The new and old cells belong to different BSC but the same MSC/VLR. In this case the MSC/VLR must help the BSC to carry out the handover.

· Inter MSC handover: The new and old cells belong to different MSC/VLR. The serving MSC/VLR must get help from the new MSC/VLR to carry out the handover.

· Intra cell handover: No change of cell but of connection within the cell.

During a call, the serving BSC decides that a handover is necessary. The handover procedure happens in this way:

- The serving BSC sends Handover Required, including the identity of the target cell, to the MSC.
- The old MSC asks the new MSC for help.
- The new MSC allocates a handover number (ordinary telephone number) in order to reroute the call. A handover request is sent to the new BSC.
- The new BSC, in cases where there is an idle TCH in the target cell, tells the new BTS to activate a TCH.
- The new MSC receives the information about the new TCH and handover reference.
- The TCH description and handover reference is passed on to the old MSC together with the handover number.
- A link is set up from the old MSC to the new MSC.
- A Handover Command message is sent on a signaling channel (FACCH) to the MS with information about which frequency and time slot to use in the new cell and what handover reference to use in the HO access burst.
- The MS tunes to the new frequency and sends HO access bursts on the FACCH. When the new BTS detects the HO access burst it sends physical information containing timing advance to the MS on the FACCH.

- The old MSC is informed (via, the new BSC and the new MSC) about the detection of HO bursts. The new path through the group switch in the old MSC is set–up.

- A handover complete message is sent from the MS. The new BSC and MSC inform the old MSC. The old MSC informs the old BSC and the old TCH is released.

The originating MSC retains the main control of the call until it is cleared. This MSC is called the anchor MSC. Because the call entered a new LA the MS is required to perform a location updating when the call is released. During the location updating, the HLR is updated and sends a Cancel Location message to the old VLR telling it to delete all stored information about the subscriber.

Handover decision is given following order of priority :

– RXQUAL
– RXLEV
– DISTANCE
– PBGT

3.3.1. Handover in Layer 3 Messages *(Figure 41)*

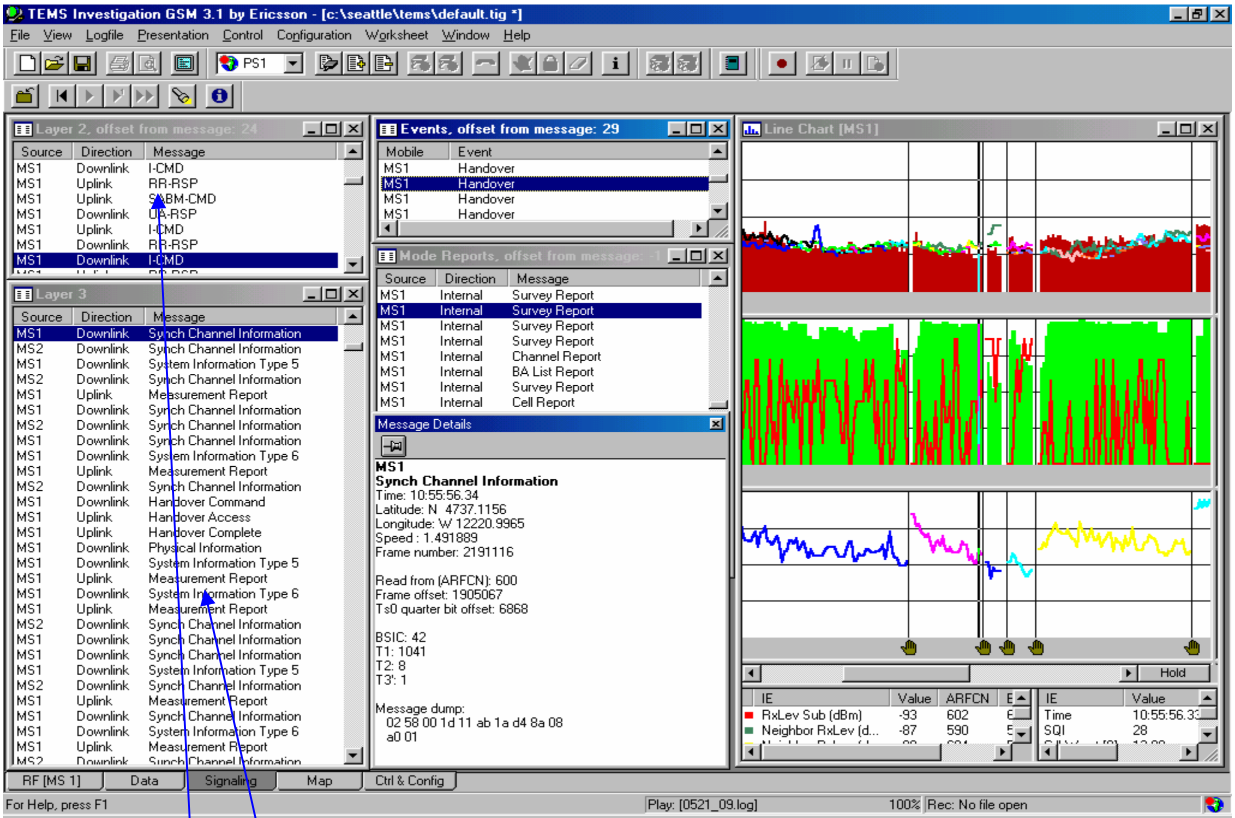


Figure 41– Handover in Layer 3 Messages: *Before ho takes place, system needs to decide the best candidate. First it repeats consecutive measurements to rank the cells according to HO algorithm. Please note that HO algorithm in different vendors systems or even in operators using the same equipment could be different. Some systems might rank the cells looking to their signal strength or some can rank them looking to their Path Loss or some can use both.*

Layer 2 and Layer 3
Messages during Handover
Process

Let’s have a look at Layer 3 messages to understand better about the Handover process. Synchronization Channel Information (*Figure 42*) message is sent on the SCH, which is one of the broadcast channels. Its purpose is to support the synchronization of a MS to a BSS and is repeated for many times during the call.

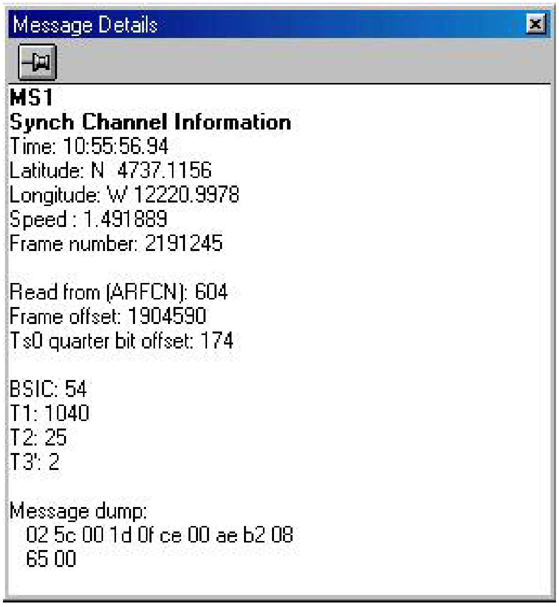


Figure 42– Synch Channel Information

Synchronization between BSS and MS is controlled by collecting Synchronization Channel Information for each channel. Synchronization Channel Information message continuously appears in Layer 3 messages display window. This message is sent on the SCH, which is one of the broadcasts. Its purpose is to support the synchronization of a MS to a BSS. This measurement is performed on downlink and contains carrier, BSIC and TDMA frame number information.

System Information Type 5 message (*Figure 43*) is sent on the SACCH by the network to mobile stations within the cell giving information on the BCCH allocation in the neighbor cells. This downlink information will later form neighbor lists. When received this information must be used as the list of neighboring cells to be reported on. Any change in the neighbor cells description must overwrite any old data held by the MS. The MS must analyze all correctly received system information type 5 messages.

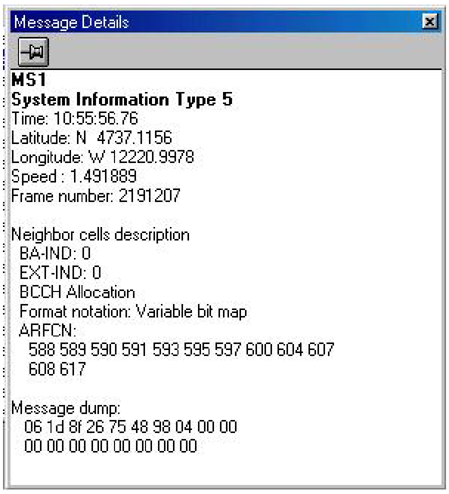


Figure 43– System Information Type 5

Meanwhile MS performs consecutive measurements to create neighbor lists. Measurement Report message (*Figure 44*) is sent on the SACCH by the mobile station to the network to report measurement results about the dedicated channel and about neighbor cells. It contains RXLEV and RXQUAL information of the serving carrier and list of best neighbors sorted by best RXLEV value. BCCH and BSIC information of the neighbor cell are also in this message. Consecutive neighbor measurement reports are performed during the process to update neighbor lists.

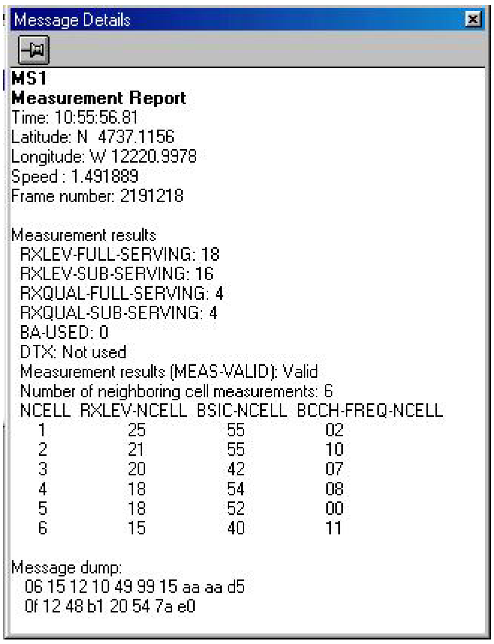


Figure 44– Measurement Report

Handover decision process continues with System Information Type 6 message (*Figure 45*) which is sent on the SACCH by the network to mobile stations within the cell giving information of location area identification, of cell identity and various other information.

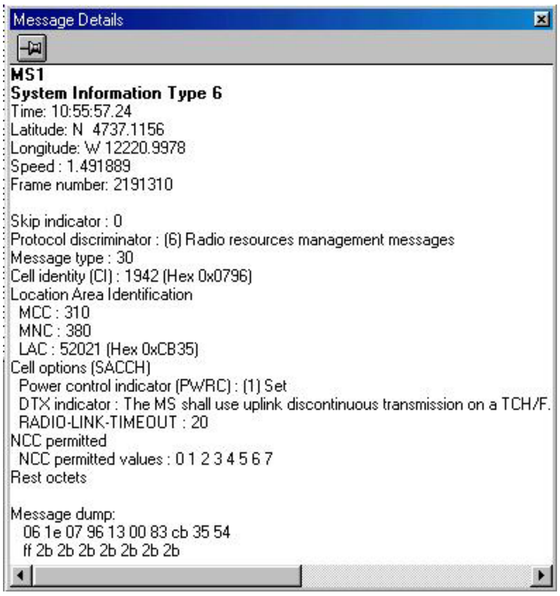
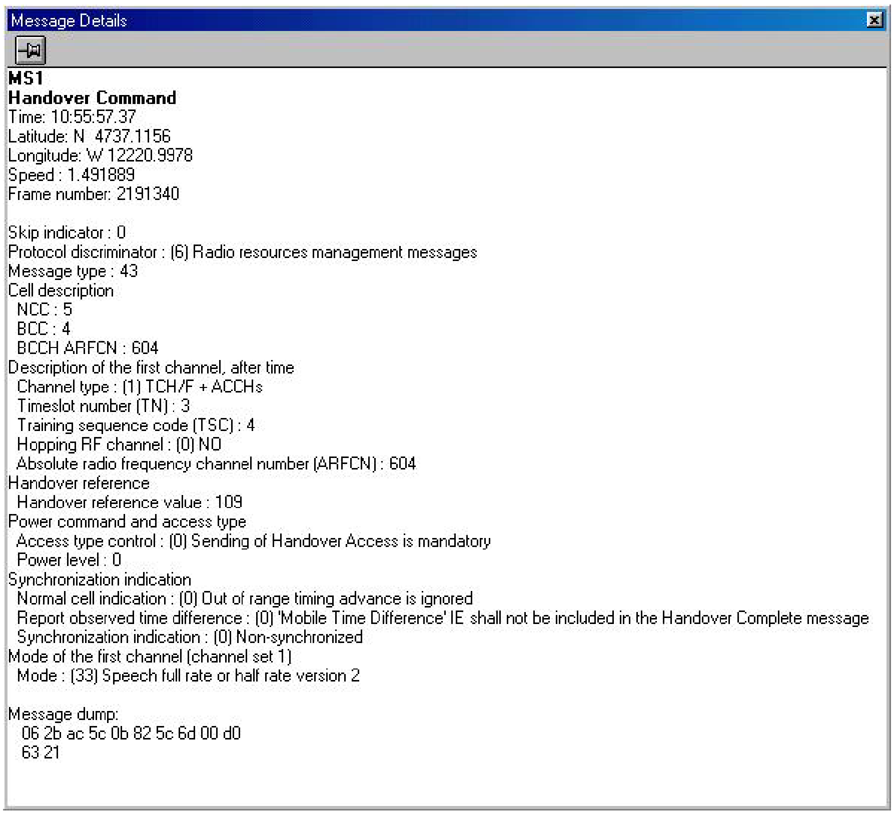


Figure 45– System Information Type 6

Handover command message (*Figure 46*) is sent on the main DCCH by the network to the mobile station to change the dedicated channel configuration. The message contains Cell description, Channel description, Handover reference, Power command, Synchronization indication, Cell channel description, Channel mode, Channel description, Channel mode 2, Frequency channel sequence, Mobile allocation and starting time information.

Cell channel description information element appears if frequency hopping is used on the new cell. Channel mode element appears if the channel mode is changed for the channel defined in the mandatory part of the message. Channel description information element appears if the MS carries two connections (on two dedicated channels). The connection using the channel previously defined in the mandatory part of an assignment command or handover command message shall use the channel defined in the mandatory part of the handover command message defining the new configuration.The first indicated channel (i.e. in the mandatory part) carries the main DCCH. The SACCH used is the one associated with that channel.

Channel mode 2 element appears if the channel mode is changed for the channel defined in the optional channel description information element. Frequency channel sequence element is a combination of mobile allocation element and cell channel description element. It is designed to allow the sending of the handover command in one signaling block for systems using frequency hopping. If this element is present, then the cell channel description and mobile allocation information elements are not required. Mobile allocation information element appears if frequency hopping is used on the new cell. If it appears, it applies to all assigned channels. This information element cannot appear if the cell channel description information element is not present. Starting time information element appears if a frequency change is in progress. It refers to the new cell time.


Message Details

MS1
Handover Command
Time: 10:55:57.37
Latitude: N 4737.1156
Longitude: W 12220.9978
Speed : 1.491889
Frame number: 2191340

Skip indicator : 0
Protocol discriminator : (6) Radio resources management messages
Message type : 43
Cell description
NCC : 5
BCC : 4
BCCH ARFCN : 604
Description of the first channel, after time
Channel type : (1) TCH/F + ACCHs
Timeslot number (TN) : 3
Training sequence code (TSC) : 4
Hopping RF channel : (0) NO
Absolute radio frequency channel number (ARFCN) : 604
Handover reference
Handover reference value : 109
Power command and access type
Access type control : (0) Sending of Handover Access is mandatory
Power level : 0
Synchronization indication
Normal cell indication : (0) Out of range timing advance is ignored
Report observed time difference : (0) 'Mobile Time Difference' IE shall not be included in the Handover Complete message
Synchronization indication : (0) Non-synchronized
Mode of the first channel (channel set 1)
Mode : (33) Speech full rate or half rate version 2

Message dump:
06 2b ac 5c 0b 82 5c 6d 00 d0
63 21

Figure 46– Handover Command

Handover Access message (*Figure 47*) is sent in random mode on the main DCCH during a handover procedure.


Message Details

MS1
Handover Access
Time: 10:55:57.39
Latitude: N 4737.1156
Longitude: W 12220.9978
Speed : 1.491889
Frame number: 1380285

Handover reference value: 109

Message dump:
6d

Figure 47– Handover Access

Handover Complete message (*Figure 48*) is sent on the main DCCH from the mobile station to the network to indicate that the mobile station has established the main signaling link successfully.

Figure 48– Handover Complete

If handover is not successful for some reason, then comes a Handover Failure message. This message is sent on the main DCCH on the old channel from the mobile station to the network to indicate that the mobile station has failed to seize the new channel.

3.3.2. Types of Handover

3.3.2.1. Power Budget Handover *(Figure 49)*

When signal strength difference between serving cell and neighbor cell exceeds Power Budget Handover margin which is set in Handover parameters, the call is handed over to the neighboring cell. This margin is usually set to 3 to 6 dB. Power Budget HO feature should be enabled for this type of Handover.

In case of ping–pong handovers between the same two cells, power budget handover margin between the two could be increased to reduce number of handovers. Margin should be decreased if faster handover decision is wanted.

Please keep in mind that adjusting power budget handover margin between two neighbors is something you have to pay extra attention. If it is not set correctly, there is high risk of interference. The strongest cell will not serve in the cell border area resulting C/I (Carrier to Interference ratio) to get bad.

Another risk will be stepping stone effect. Let's investigate this effect with an example:

Assume we have below power budget handover margins between three neighbors.

A to B HO Margin PBGT = 0
A to C HO Margin PBGT = +10
B to C HO Margin PBGT = 0

In an area where signal strength of cell A is the weakest and signal strength of cell C is strongest, the HO attempt might happen in such an order that cell A will first hand the call to B and cell B will immediately hand it to cell C. In this case, cell B will be used as a stepping stone to make a handover to the strong cell C. You will observe ping–pong or unnecessary handovers.

Ericsson uses KOFFSET and LOFFSET parameters to set this margin between the neighboring cells depending on the selected handover algorithm. KOFFSET stands for handover decision based on signal strength while LOFFSET does on path loss.

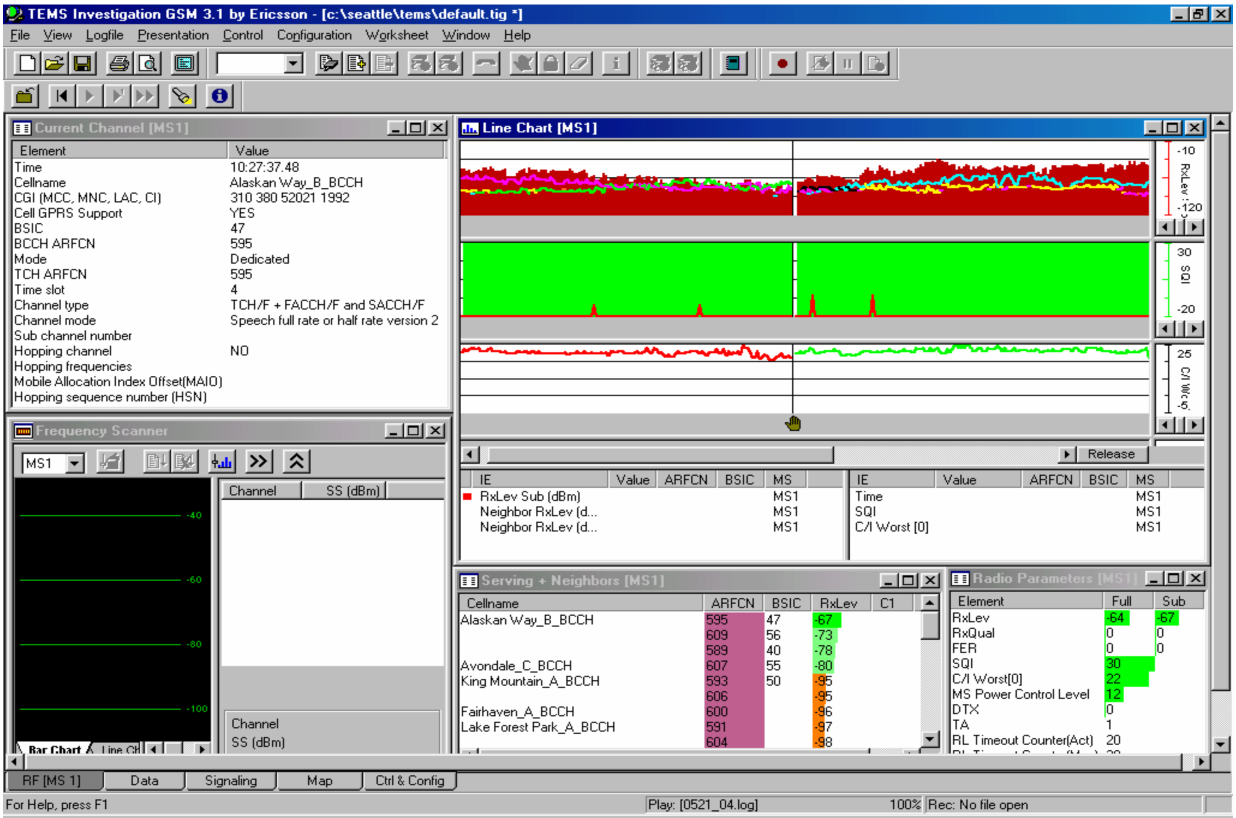


Figure 49–Power Budget Handover

3.3.2.2. Level Handover

If downlink level is worse then HO Thresholds Lev DL parameter, then an immediate level handover takes place. This parameter is set to –95dBm as default.

If uplink level is worse then HO Thresholds Lev UL parameter, then an immediate level handover takes place. This parameter is set to –105dBm as default.

3.3.2.3. Quality Handover *(Figure 50)*

If downlink quality is worse then HO Thresholds Qual DL parameter, then an immediate quality handover takes place. This parameter is generally set to 3.2%–6.4%. If uplink quality is worse then HO Thresholds Qual UL parameter, then an immediate quality handover takes place. This parameter is generally set to 3.2%–6.4%.

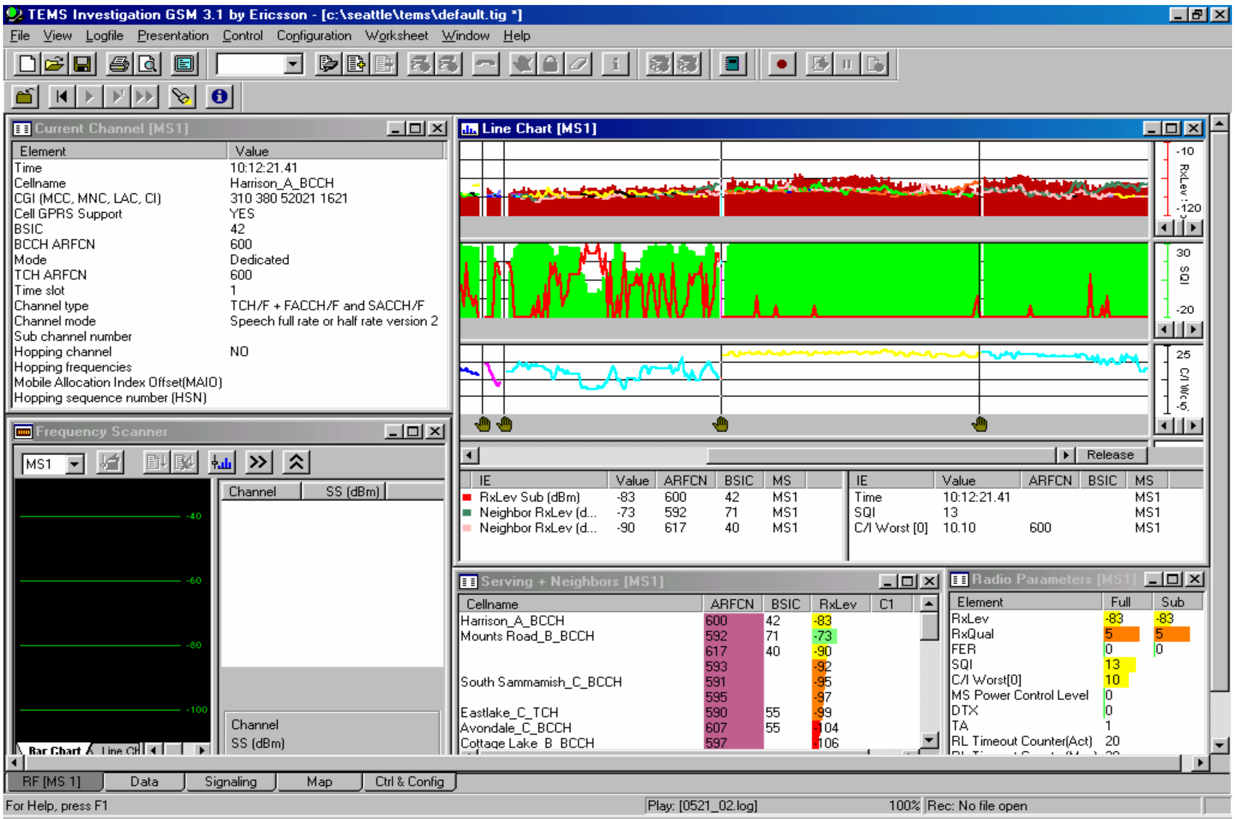


Figure 50– Quality Handover: *See a handover was performed to a better quality cell just after experiencing quality problems.*

3.3.2.4. Interference Handover

Any quality problem when downlink signal level is higher then HO Thr Interference DL causes a handover. This level is generally set to –80dBm.

Any quality problem when uplink signal level is higher then HO Thr Interference UL causes a handover. This level is usually set to –80dBm.

3.3.2.5. Umbrella Handover

Macro site which is defined as umbrella will shift all the TCH traffic to small sites until signal level of small site becomes worse then HO Level Umbrella RX Level parameter. This parameter could be set from –80 to –90dBm. HO Margin PBGT parameter should be set to 63 maximum to prevent any power budget handover.

Umbrella HO feature should be enabled for this type of Handover.

3.3.2.6. MS Distance Handover

MS Distance HO Threshold parameter MS Range Max should be set to desired value with the required Px–Nx Sampling values. This parameter is set to max 63 as default which corresponds to maximum Time advance value.

If an overshooting site is needed to hand its traffic after some distance from its origin, MS Range Max value could be adjusted to limit the serving area of the site.

MS Distance Process feature should be enabled for this type of Handover.

3.3.2.7. Intra–cell Handover (Full Rate to Half Rate) *(Figure 51)*

The Intra–cell Handover feature aims to maintain good quality of a connection by performing a handover to a new channel within the same cell when bad quality is detected. If the signal strength is very high, the interference is probably lower on another channel within the same cell. Intra–cell Handover aims at improving the carrier–to–interference ratio, C/I, for a connection when the bit error rate estimation, RXQUAL, has indicated poor quality, and the received signal strength at the same time is high. This is done by changing the channel within the cell, a so called intra–cell handover. The intra–cell handover can be triggered from bad quality in the uplink, as well as the downlink.

Intra–cell handover decision is given when serving cell is the best cell and quality is worse then 4 and signal strength is lower then –85dBm.

Intra–cell handover can solve temporary co– and adjacent channel interference as well as intermodulation problems, but permanent interference and time dispersion cannot be solved. Intracell Handover feature should be enabled for this type of Handover.

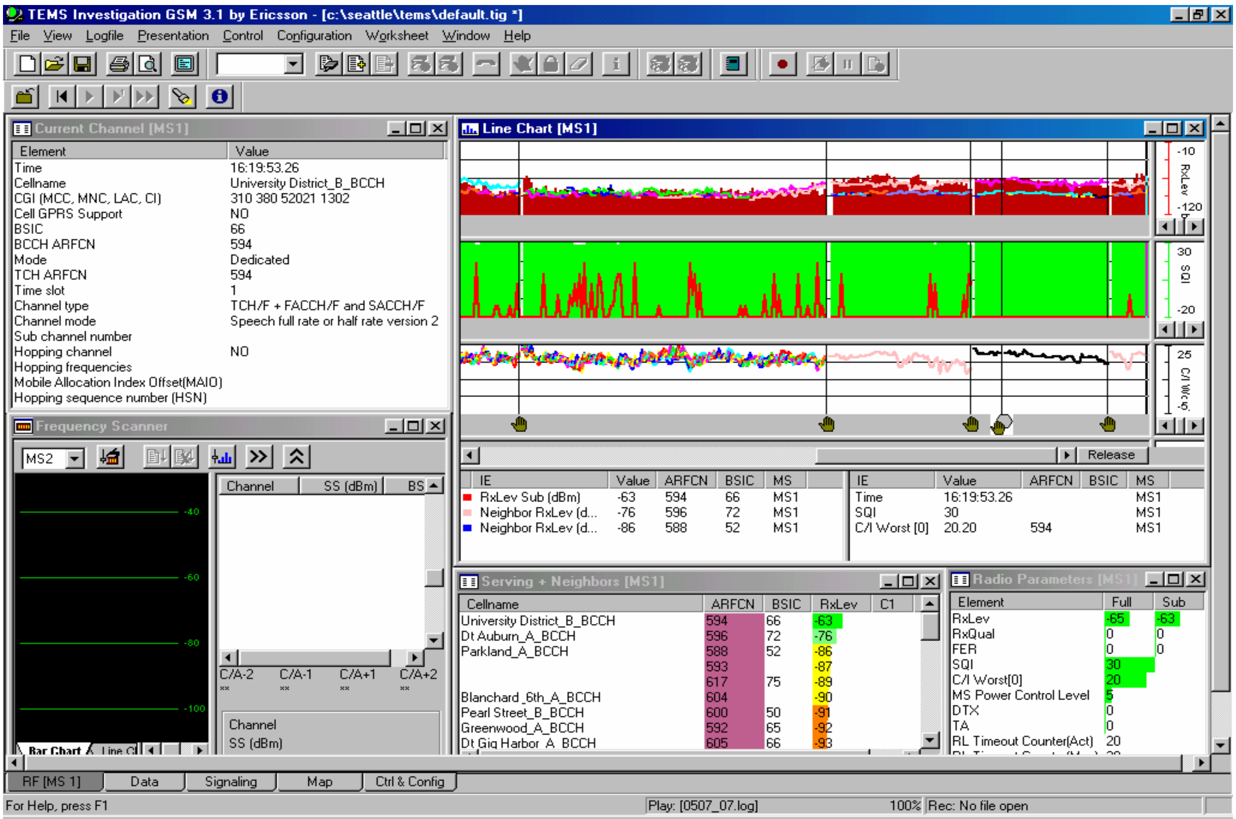


Figure 51– Intracell Handover, Changing Rate from Full Rate to Half Rate

3.3.2.8. Intracell Handover Based on Quality *(Figure 52)*

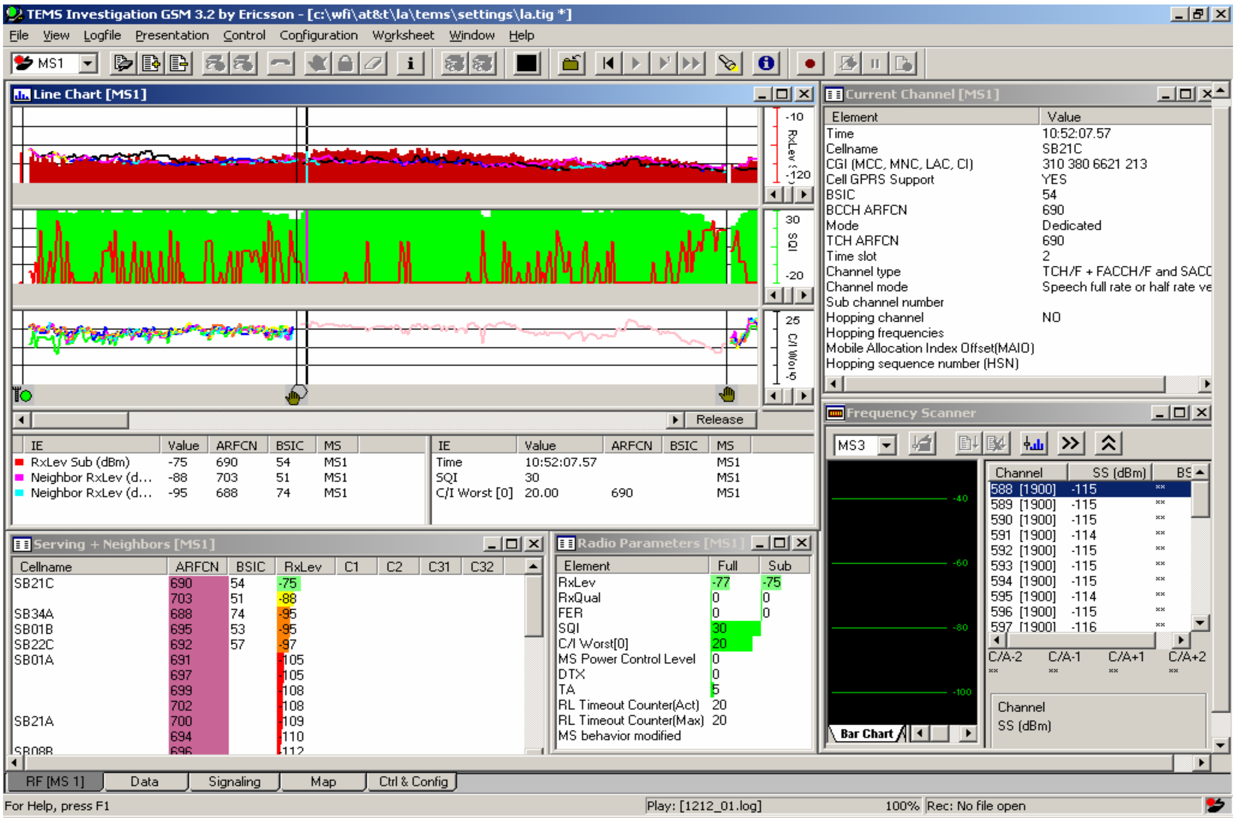


Figure 52– Intracell HO Based on Quality: *This is an example of intracell handover after experiencing quality problems.*

3.3.2.9. Rapid Field Handover

In some cases, UL RX Level suddenly decreases because of the terrain – generally in tunnels. This sudden level drop happens so fast that it is usually too late to give a handover decision for the BSC and call drops. This type of drop is called Rapid Field Drop.

There is still a way to save the call and hand it to one definite neighbor that is known to be the best handover candidate in such cases. This is done by handing the call to a chained cell whenever a threshold is reached in Uplink direction. The handover candidate has to be defined as Chained Adjacent Cell to the target cell to take the call regardless of any other neighbors in the area. This threshold is set with the parameter HO Thr Rapid Lev UL. Its value is –110dBm by default.

Rapid Field handover decision could be given faster by adjusting Px sampling speed value if needed.

3.3.2.10 Directed Retry Handover

When no TCH is available in the serving cell, TCH can be allocated in an adjacent cell regardless of mobile originated or mobile terminated call. It is basically handover from SDCCH to TCH. Handover candidates are ranked based on radio properties.

SDCCH handover should be enabled to have use of this type of handover.

3.3.2.11. Short Neighbor List *(Figure 53)*

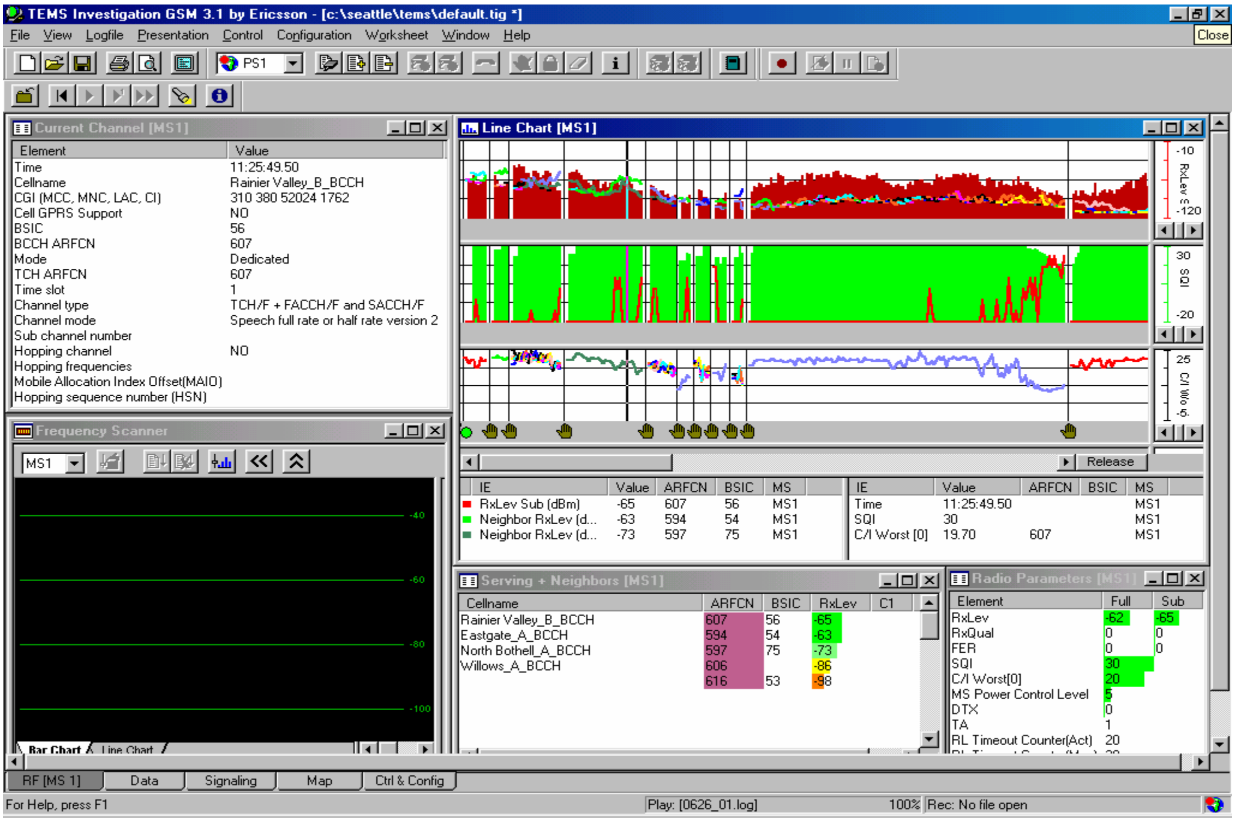


Figure 53– Short Neighbor List: *Sometimes TEMs will help you notice possible problems like a short neighbor list. If you see a couple of cell is the neighbor list of a cell when analyzing your log files, check if that cell really does not need.*

3.3.3. Handover Problems

Always keep in mind that all power related parameters need to be correctly set. Otherwise the handover (HO) attempts will be done in a wrong place.

There will always be risk of a handover loop if handover parameters between two neighbors are not correctly set.

3.3.3.1. Late Handover *(Figure 54)*

There will be such cases that you will notice handover process taking place a little late. There could be couple of reasons to that. First thing to check will be handover margins between the neighbors. If margins for level, quality or power budget handovers are not set correctly, handover will not take place at the right time. If margins are too much, handover will happen late, vice versa.

If umbrella handover is enabled between two neighbors, you will notice that the small site will still keep the traffic although the level of umbrella cell id too much higher. This is due to HO Level Umbrella RX Level which is set to some definite level.

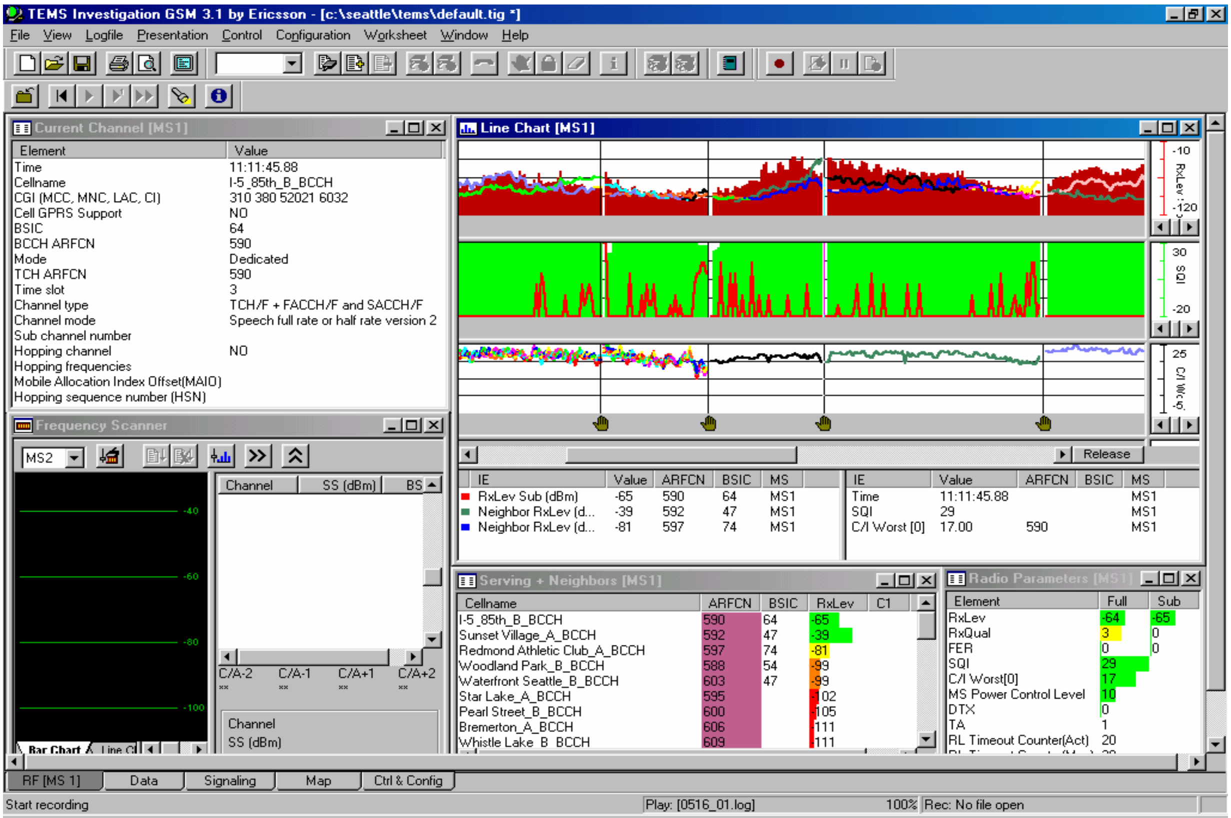


Figure 54– Late Handover: *Could be because of incorrect setting of handover margins or hierarchy between the cells or fast moving mobile.*

3.3.3.2. Power Control Effect *(Figure 55)*

Power Control feature also misleads planners sometimes. Looking to their RX Levels on TEMs Line charts, you might think that handover is happening too late between two neighbors. HO margins look fine and umbrella HO is disabled. Remember that power balance is possible only on traffic channels, but not in broadcasting channels. You will sometimes notice that the call you are continuing is on a timeslot that belongs to TCH TRX. In this case, power control feature will try to reduce output power as much as possible until a quality problem occurs. That's why you will see your serving cell signal level is less than neighbor's level. It looks less but in reality, the signal level on BCCH TRX is still higher than neighbors broadcasting level.

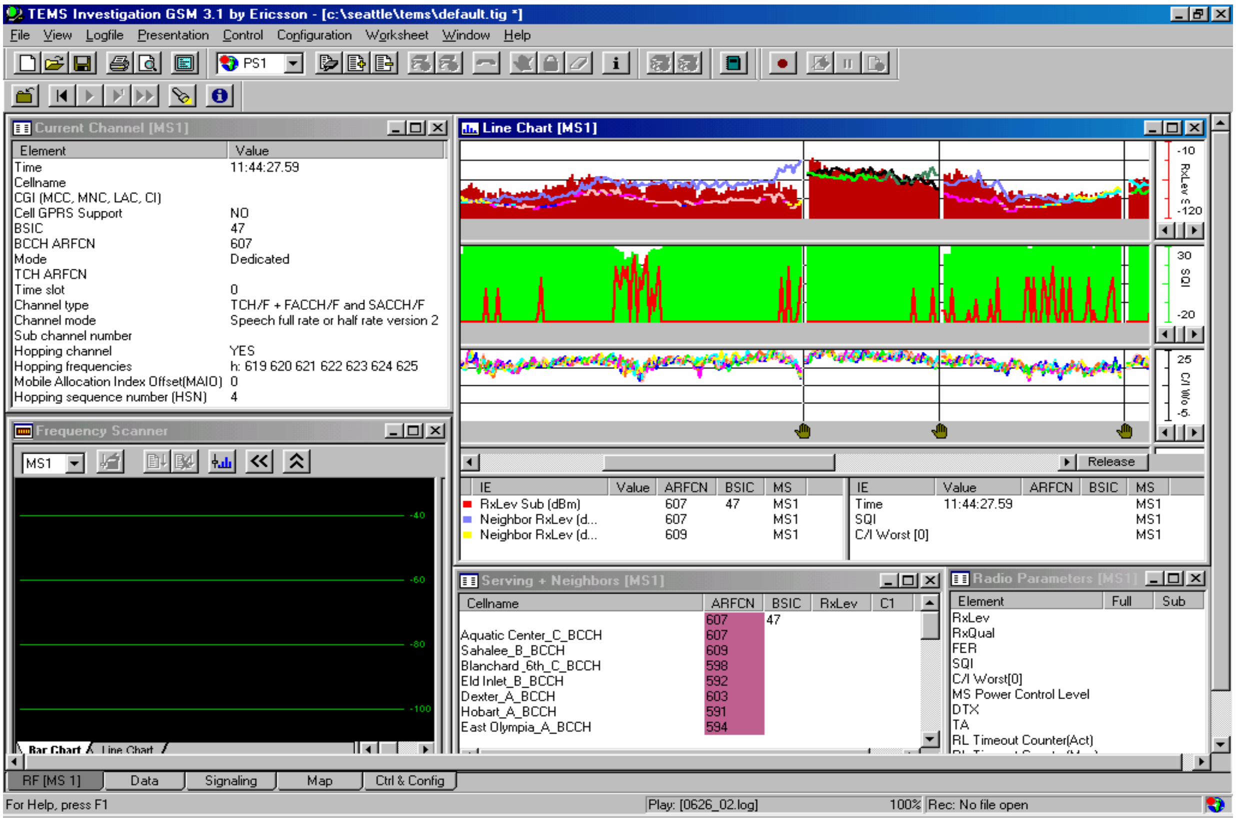


Figure 55– Power Control Effect on Handover

3.3.3.3. Ping–Pong Handover *(Figure 56)*

If measurement analysis shows an inconsistency in the parameter setting, hysteresis and offset parameters can be tuned to improve network quality.

A hysteresis is used to prevent the ping–pong effect i.e., several consecutive handovers between two cells. The ping–pong effect can be caused by fading, the MS moving in a zigzag pattern between the cells, or by non–linearities in the receiver.

Incorrect handover margins will cause ping–pong handovers. You will have to adjust these margins in such a way that handover will happen at the right time, not earlier or late.

Remember, lack of dominant server in an area or too many overlapping coverage can also cause ping–pong effect.

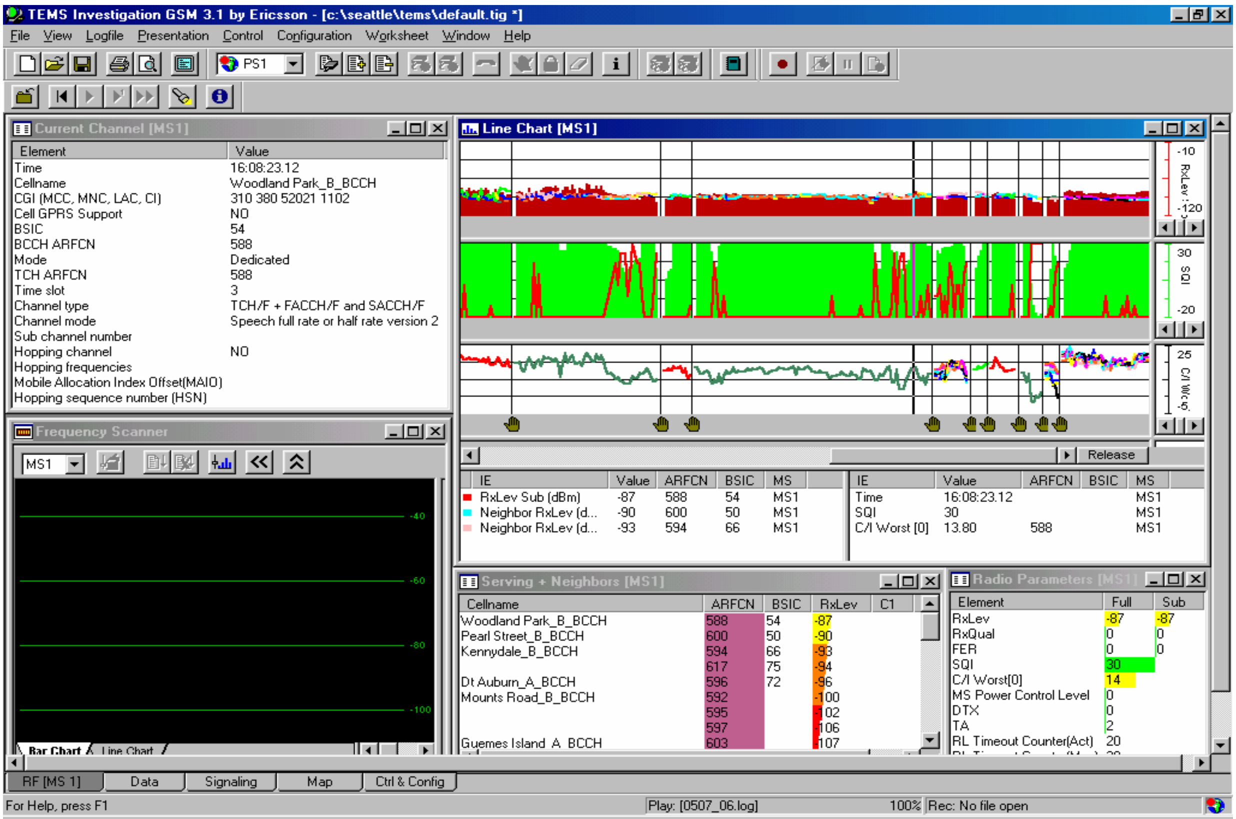


Figure 56– Ping–Pong Handover due to Lack of Dominant Server

3.3.3.4. Unnecessary Handover *(Figure 57)*

Just like ping–pong handover effect, incorrect margins can cause unnecessary handovers that will directly affect network performance. The more number of handovers, higher the risk of facing quality problems or even drop calls.

Unnecessary handovers or ping–pong handovers will decrease the efficiency of data networks.

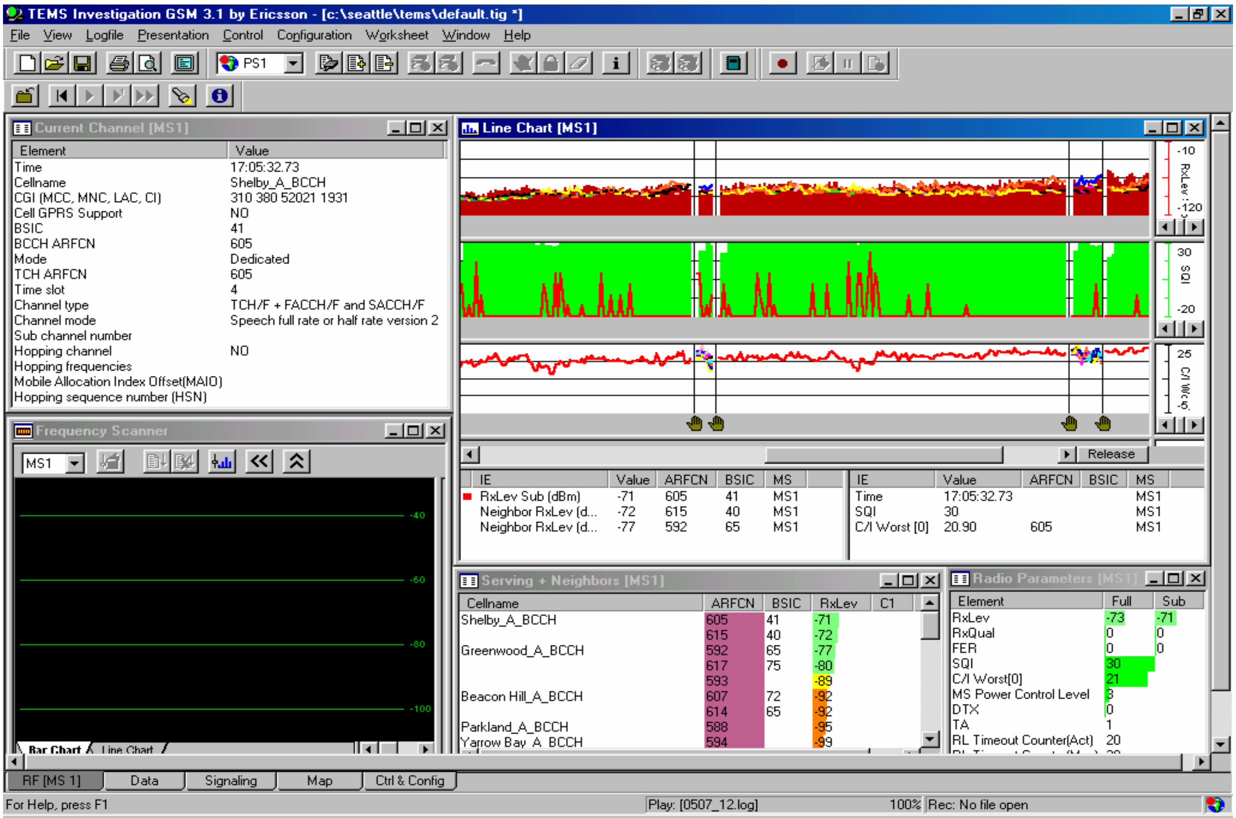


Figure 57– Unnecessary Handover – Adjust Power Budget Handover

3.3.3.5. Missing Neighbor Relation *(Figure 58)*

If a handoff is not performed to a neighbor cell that seems to be best server, there is a possibility of a missing neighbor relation. This will happen with sudden appearance of strong cell in the neighbor list just after a handover.

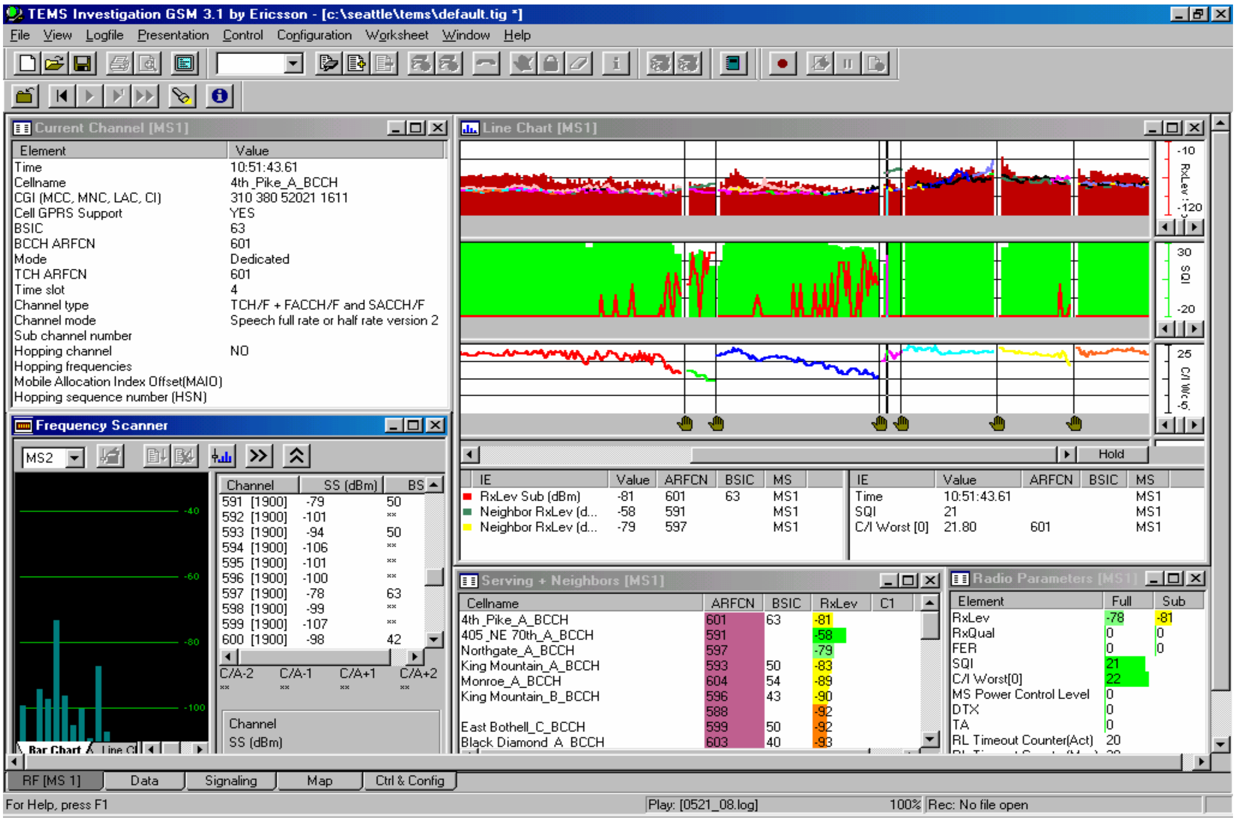


Figure 58– Missing Neighbor

3.3.3.6. Fake Neighbor *(Figure 59)*

Sometimes you will see a good handover candidate in the neighbor list but handover will not take place and call will drop. Although that neighboring cell with a very good signal level appears to be a neighbor, in reality it is not. Just because the serving cell has another neighbor with the same BCCH, this cell appears in the list.

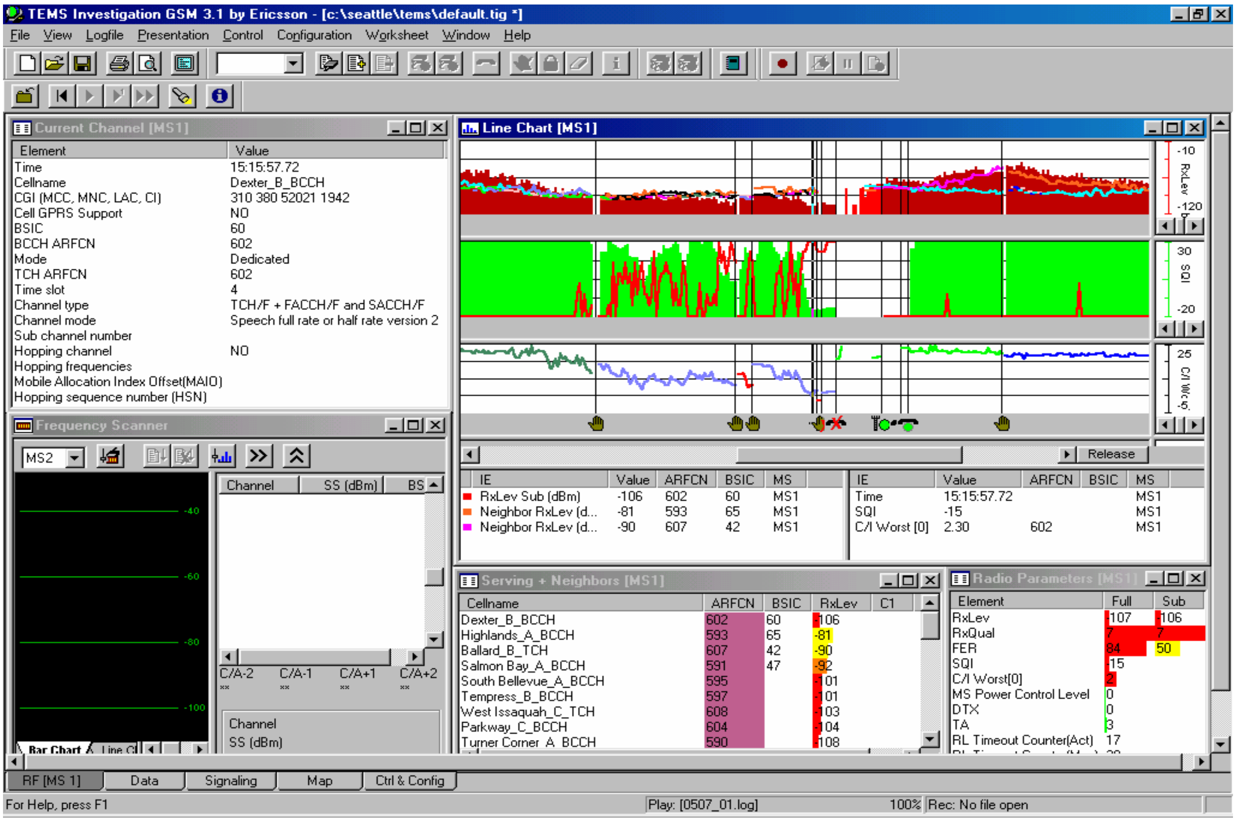


Figure 59– Fake Neighbor

3.3.3.7. BCCH Missing from Serving Cells MBCCH list

There will be cases you will notice handover is not taking place although two cells are defined as neighbors to each other. If neighbors BCCHNO is missing from serving cells MBCCHNO list, MS will not monitor or report the neighbors BCCH frequency. This will prevent HO attempt to the neighbor.

3.3.3.8. NCC Missing from Serving Cells NCCPERM List

If neighbors NCC (Network Color Code – first number in BSIC) is missing from serving cells NCCPERM list, then MS will not be allowed to include the neighbor in the measurement report, because its NCC is not permitted. This will result HO attempt not to happen.

3.3.3.9. The Same BCCH&BSIC Combination

During calls the MS reports the BCCH, BSIC and Signal strength of the six strongest neighbors to the BSC. BSC has to map the neighbors BCCHNO&BSIC combination to neighbors CGI (Cell Global Identity – combination of MCC–MNC–LAC and CI). Therefore all neighbors of same cell shall have a unique BCCHNO&BSIC combination.

Let’s remember what **BSIC** is;

The MS attempts to decode the **BSIC –** base station identity code, parameter for each of the six strongest surrounding cells at least every 30 seconds, to confirm that it is still monitoring the same cells. The **BSIC** parameter consists of two parts; NCC, Network Color Code and BCC, Base Station Color Code. If another **BSIC** is detected, it will be treated as a new carrier and the BCCH data for this carrier will be determined.

Otherwise the BSC will start a HO attempt always to the first neighbor will matching BCCHNO&BSIC combination even though the MS may have reported another neighbor having the same combination.

3.3.3.10. Unexpected Coverage Lake

If cell B has a lake of strong coverage inside cell A and cell B is not a neighbor and cell C is a neighbor and the BCCHNO&BSIC combination is the same in cells B and C, then BSC will start a HO attempt to cell C, when the Ms has monitored/reported the cell B.

3.3.3.11. One–Way Neighbor Relation

A neighbor relation needs to be defined as mutual. When defining cell A and Cell B as neighbors to each other, neighbor relation from A to B and from B to A have to be defined. Otherwise the HO attempt is not possible in both directions.

Please remember there will be rare cases where planner will need one–way neighbor relations.

3.3.3.12. Neighbor Cell in an other BSC

You will always observe handover problems in BSC borders, because neighbor relations in these cases need extra attention. When the neighbor is in another BSC, the neighbor needs to be defined as an external cell in neighboring BSC with correct CGI, BCCHNO, BSIC and power related parameters. This must also be like this on the other way to have a mutual neighbor relation.

If the neighboring cell belongs to a different MSC, the cell needs to be defined as an outer cell in neighboring MSC with correct CGI and MSC name/address. This must also be like this on the other way to have a mutual neighbor relation.

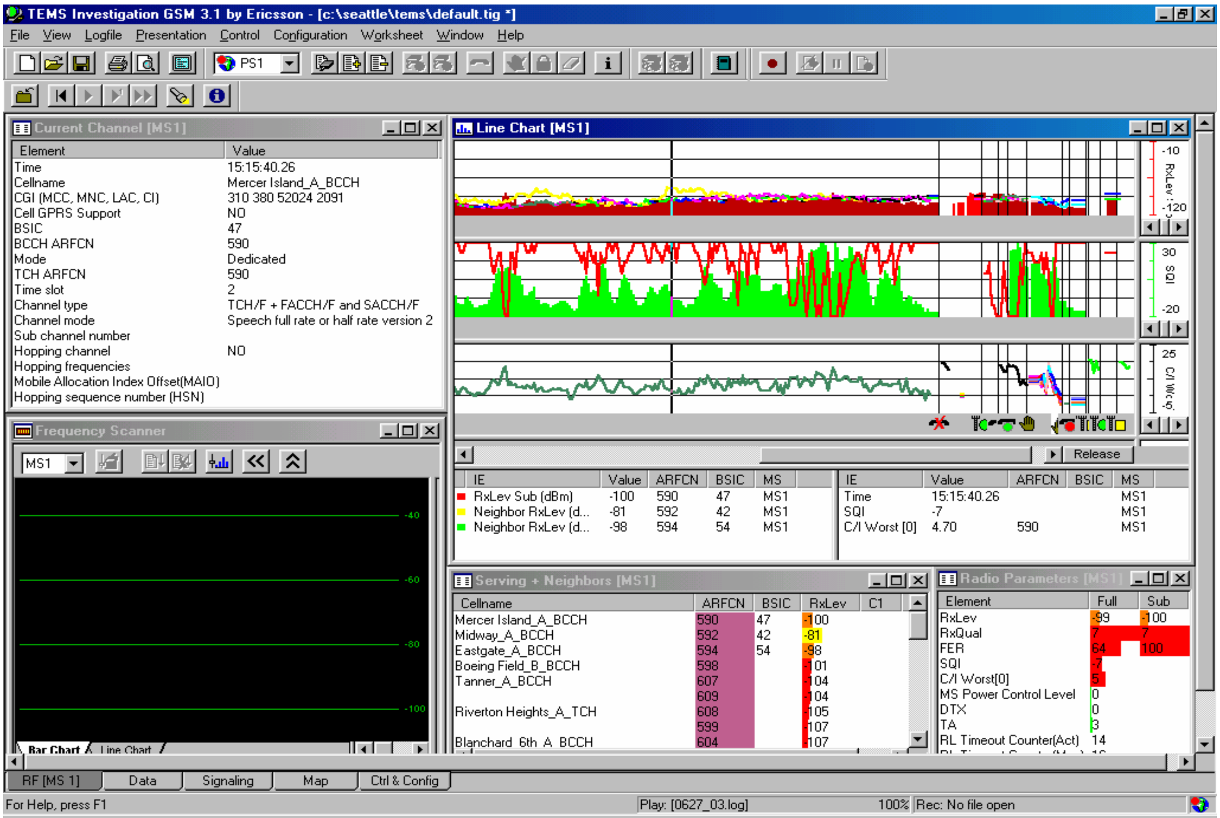


Figure 60– Handover not Happening and Dropped Call: *The call is not handed to the other cell although the level of the neighboring cell seems to be good enough. This example looks like fake neighbor case. After making sure all handover parameters between these two cells are correctly set, you should look for a neighboring cell to the serving cell with the same BSIC and BCCH combination. The cell that appears in the neighbor list is not a neighbor to the serving cell in reality. Just because there is another neighboring cell with the same BCCH, TEMs measures this BCCH and lists as a neighbor. Handover will not happen because those two are not neighbors in reality.*

3.3.3.13. Handover Failure

Reasons for handover failure could be unavailable time slots because of high traffic, congestion, low signal strength or bad quality *(Figure 61)* on target cell. Handover can be failed because of hardware problems *(Figure 62)* in target cells –more likely TRX or time slot problems.

If handover attempt fails, MS tries to return to old channel. If it can not, call drops. Handover attempt is repeated after a penalty time.

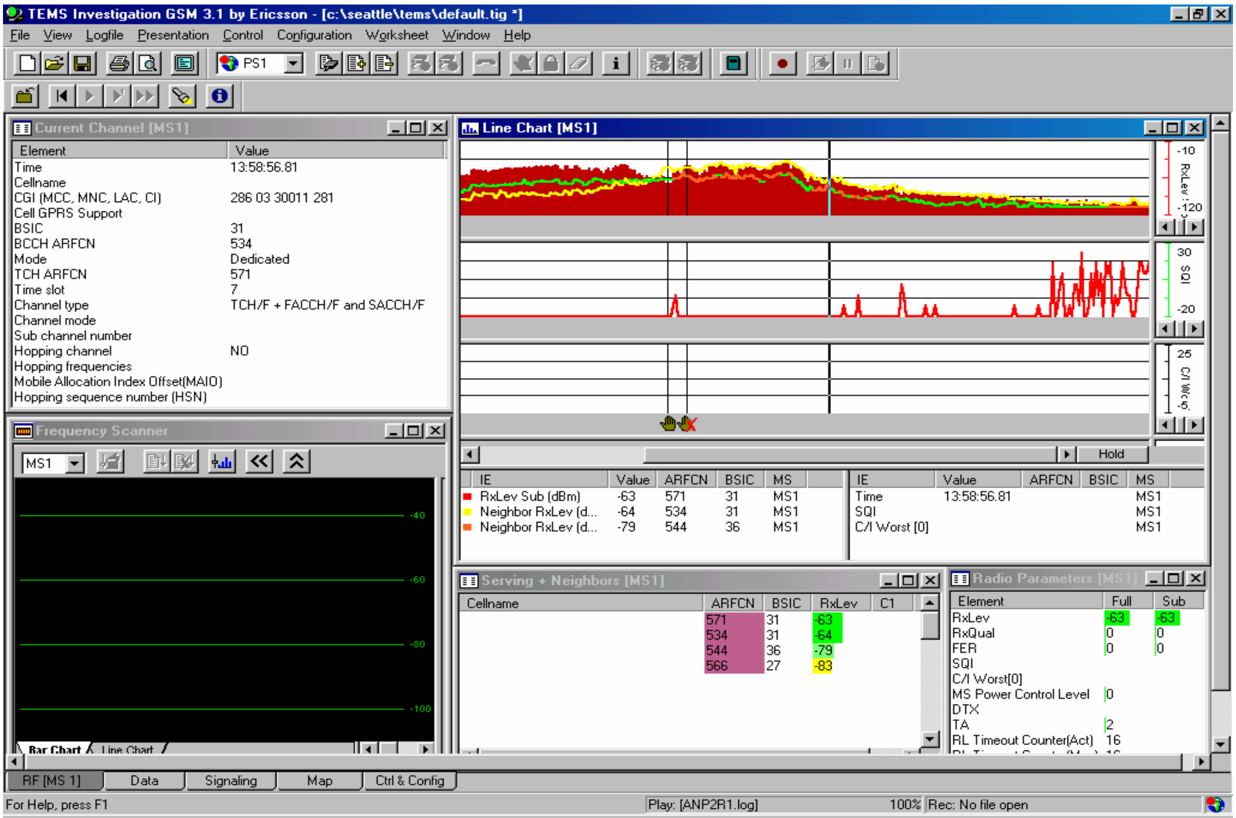


Figure 61– Handover Failure: *Handover attempt was failed and the call returned back to its all channel.*

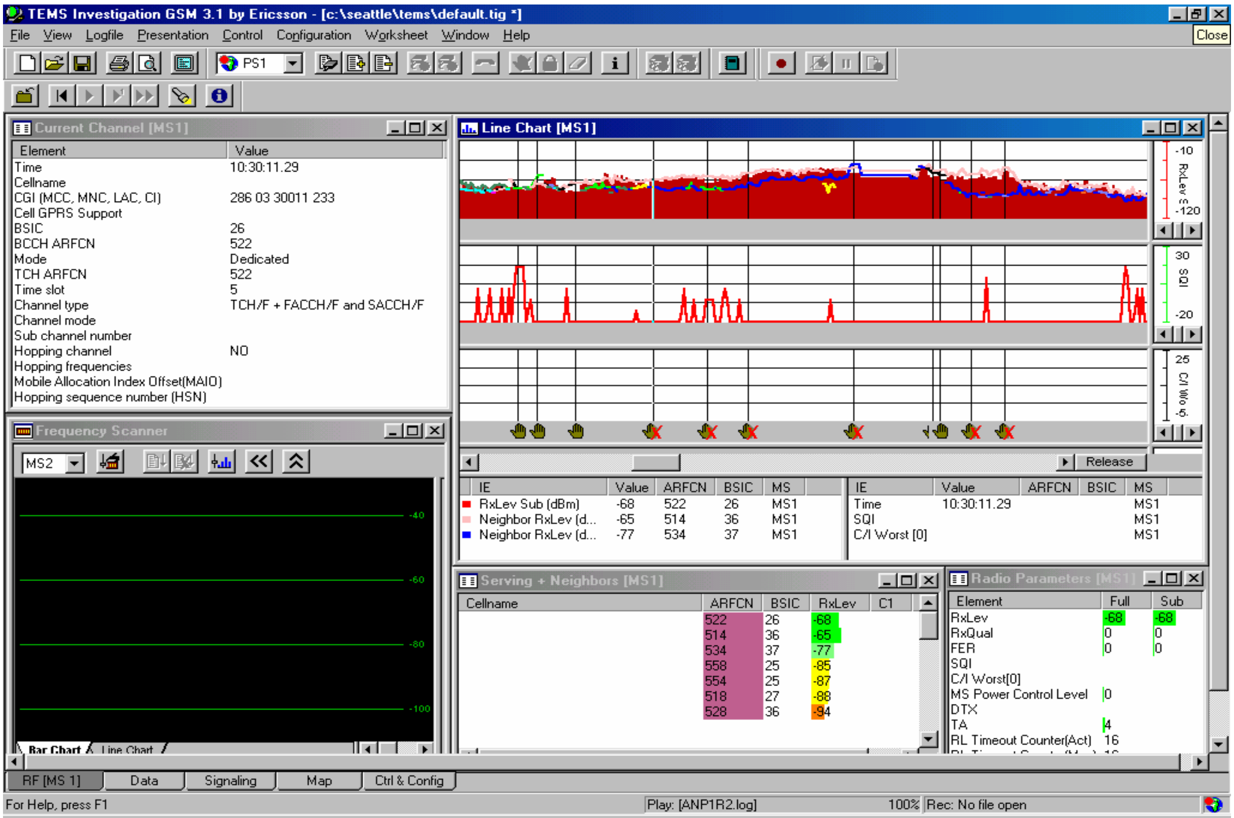


Figure 62– Excessive Number of Handover Failure due to Hardware Problem

3.4. Drop Calls

If the radio link fails after the mobile sends the Service Connect Complete Message then it is considered a dropped call. Dropped call analysis can consume a considerable amount of time. Using good post–processing analysis tools, the root cause of some of the drops can be determined from mobile data alone. However, there will be cases where the cause cannot be reliably confirmed unless system data is also used.

Calls often drop when strong neighbors suddenly appear. When the mobile is suddenly confronted with a strong new signal, or when the signal it is using takes a sudden deep fade, it will have poor C /I o and high forward FER. The call will drop unless it gets help quickly**.**

Using a post– processing tool, display a map of the locations of dropped calls that exhibit symptoms of poor coverage. Verify this type of drop is not occurring in good– coverage areas. If so, suspect and investigate hardware at the serving site.

Use the prediction tool to help identify other strong signals reaching the drop areas.

Another technique is to examine the dropped call message files and identify the BTS from which the sync channel message is received immediately after each drop (this will be the cleanest pilot the handset sees at that time). This could be achieved by analyzing Layer 3 messages in log files or running traces from NMS/OSS.

Drop calls can be classified by looking to their orientations:

- TCH radio drops are the drops that occurred due to summation of radio and ABIS reasons.

- TCH non–radio drops are the drops that occurred due to summation of network management, BSCU reset, BTS fail, LAPD failure, user and A interface.

- TCH handover drops are the drops that occurred in handover phase while the call tries back to old serving channel but fails and drops. These drops may occur due to RF, ABIS and A interface reasons.

3.4.1. General Reasons for Drop Calls are as follows:

Drop Call due to Low Signal Strength

Drop Call due to Missing Neighbor

Drop Call due to Bad RX Quality

Drop Call due to Not–happening Handover

Drop Call due to Interference

Radio Failures

Radio Failures on old Channel in HO

Transcoder Failures.

Transcoder Failures of old Channel in HO

Abis Failures on old Channel in HO

Lapd Failures

BTS failures

Failures due to User Actions

Failures due to BCSU Reset

Failures due to Radio Network Configuration Action

Channel Activation Failures During Call

3.4.2. Drop Call due to Locked Call *(Figure 63)*

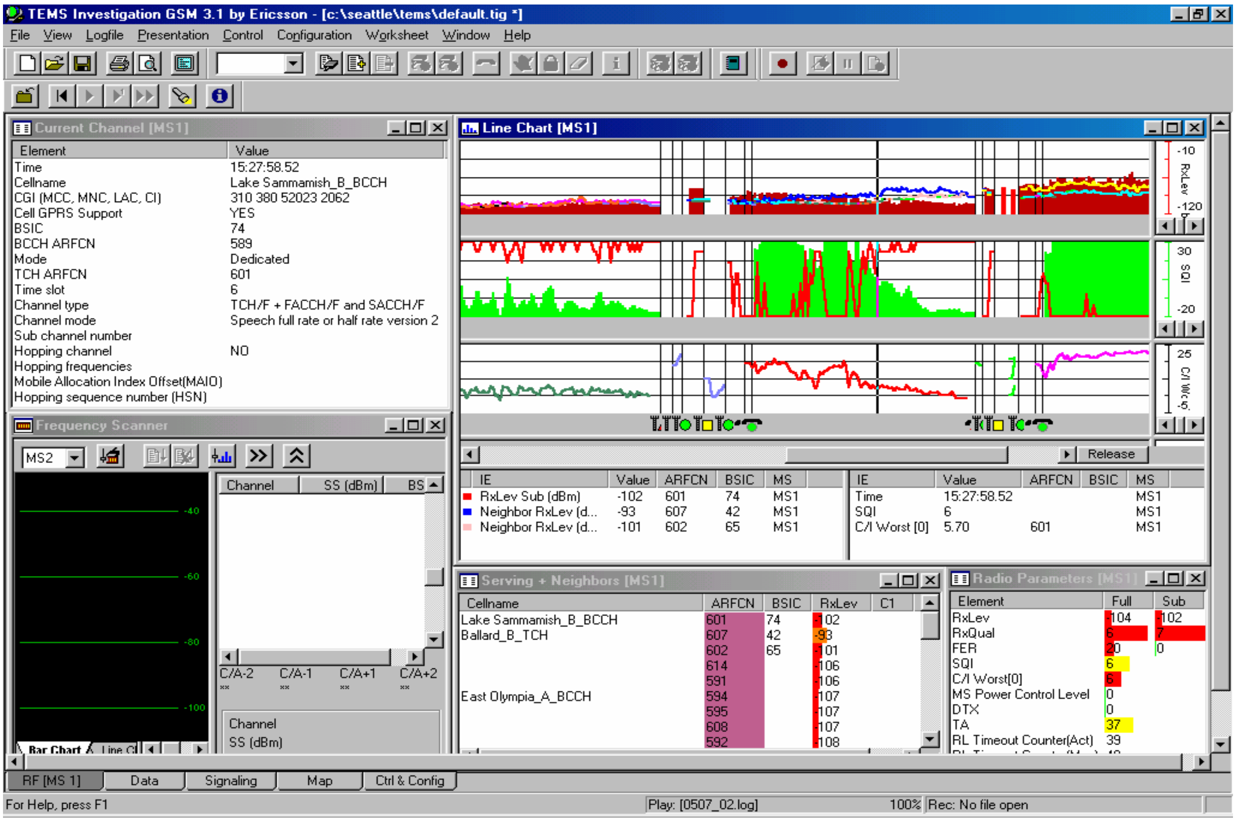


Figure 63– Dropping Call due to MS Stuck on Overshooting Cell: *In this example, MS is stuck on an overshooting cell which is far away. You may check Time advance value in the Radio Parameters window. MS can not handover to another cell because this overshooting cell was not defined as neighbor to the cells nearby as expected. The only way to leave that cell and restart call on a nearby cell will be possible after the call is dropped.*

4. REPORTS of ANALYSIS

Below are some example recommendation reports those were provided to the clients during previous optimization projects.

4.1. Downtown Seattle Network Performance Recommendations

A Drive Test was performed in Downtown Seattle on 05/21/02 by WFI team. The selected route starts with AT&T Eastlake Office, includes most of the major and primary roads in the downtown area and ends with China town in the south. Two MSs were used during the test. One was acting like an ordinary Mobile phone on dedicated mode and the other was scanning the 1900MHz frequency band. RXQual & RXLev Plots are attached for your reference. The following recommendations are being given after analyzing the drive test data:

1– Below missing neighbor relations were observed:

Eastlake 179A – DennyWay216B
Olive Street 209A – Blanchard 6th 374C
Olive Street 209A – Waterfront Seattle 186B
Blanchard 6th 374C – Battery Street 191A
Lenora 3rd 426A&B – Waterfront Seattle 186B
Convention Center 185A – Dennyway and Steward 216B
Lenora 3rd 426A – Pike Street 208A
Alaskan Way 211B – Pike Street 208A

2– Below Co–Channels were observed:

Waterfront Seattle 186B – Safeco Field SW 212A (CH589)
Lenora 3rd 426A – Safeco Field NE213A (CH606)
Key Tower 195B – Capitol Hill 180C (CH596)
Blanchard 6th 374C – Convention Center 185A (CH604)
International District 375C – Key Tower 195C (CH599)
Battery Street 191A – Union#2 210A (CH593)
Dexter 206A – Lenora & 3rd 426B (CH597)
Olive Street 209A – First Hill 214B (CH603)
Harrison 173A – Interbay 188A (CH600)
Safeco Field NE213A – Spokane Street 178B (CH606)

3– Below adjacencies were observed:

Olive Street 209A – Blanchard 6th 374C (603–604)
International District 375C – Safeco Field NE 213B (599–600)
Convention Center 185A – Capitol Hill 180B (604–605)

4– Northlake 122B is overshooting and causing interference on Blanchard 6th 374B. They have the same BCCH (608). Increasing the downtilt on Northlake is recommended.

Woodlandpark 116A is overshooting in the northern downtown as well. It has the same BCCH (595) with Alaskan Way 211B and causing low speech quality. Decreasing EIRP on Woodlandpark 116A by 3dB will prevent it overshooting. Alaskan Way 211B is also interfered by Spokane Street 178C.

University District 137B is overshooting near Dennyway and interfering with Blanchard 6th 374A (594). Retune recommended.

5– 4th & Pike 172B is being interfered by Harbor Island 175A (591). Uptilt on Harbor Island 175A is recommended.

Blanchard 374C is being interfered by Woodinville 145A (604).

Union#2 210A is being interfered by White Center 184A (593). White Center should be sectorized and the antenna facing to downtown should have reduced power.

6– Proposed site Spring&3rd will bring a best server to 3rd & Marion Street and prevent Waterfront 186B serving there.

7– Other proposal First&Columbia will serve on 2nd Ave and prevent Safeco Field serving out there. It will as well prevent Ping–Pong handovers between International District 375C / Safeco Field NE 213A and Key Tower 195B.

8– Increasing EIRP for Pier70 204A by 6dB is recommended. This will pop it up on the area where 2nd & 3rd Ave starts. It will also prevent Ping–Pong handovers between Harrison 173A and Pier70 204A. Harrison 173A is interfered by Interbay 188A (600). Retune recommended.

9– Safeco Field and International District are causing many interBSC handovers in the area. If BSC border could be shifted to south by moving these two sites from BSC5 to BSC2, HO performance will be improved.

4.2. LAKE SAMMAMISH AREA NETWORK PERFORMANCE RECOMMENDATIONS

A Drive Test was performed on 06/10/02 by WFI team. The selected route covers all around Lake Sammamish and some part of Bellevue on the west specifically near site Crossroads. Also a trouble ticket of a customer complaint was taken with and that problematic area was driven. Two MSs were used during the test. One was on dedicated mode and the other was scanning the 1900MHz frequency band. RXQual & RXLev Plots are attached for your reference. The following recommendations including site configuration changes proved by before and after plots are being given after analyzing the drive test data:

1– Sunset Village should be sectorized to have better sector gain and improve coverage. The proposed sectorization is attached in a plot.

2– Site Issaquah is overshooting and overlapping with West Issaquah and South Sammamish mostly. Rotating sector A from 50 degrees to 30 degrees with keeping the downtilt but exchanging antenna type with 7250_05_6deg_1900 that has 6 degrees electrical downtilt. The possible coverage loss after this modification on southeast cost of Lake Sammamish will be compensated after appropriate modifications to West Issaquah and South Sammamish sectors described below.

3– Rotating the antennas in South Sammamish Sector C from 340 to 310 degrees and changing antenna type with 7250_02_1900 for higher gain is recommended. This will help the coverage on Southwest coast of Lake Sammamish.
Rotating Sector A antennas from 115 to 80 degrees and exchanging the antenna type to a higher gain antenna is recommended. This will reduce Ping–Pong handovers between South Sammamish, Issaquah and West Issaquah and improve the coverage in the area.

4– Rotating West Issaquah Sector C from 355 to 10 degrees will help to have a better coverage on southeast of the lake.

5– Eastgate should be sectorized to have better coverage on East Side of the Lake Sammamish where a customer complaint has been reported. In this area drop calls due to poor coverage was observed. The proposal for the sectorization is given in a plot with the following site data:

*Sector A facing to 20 degrees with 0 degrees downtilt on a 7250_05_6deg_1900 type of antenna having 50 feet's height and 50dBm EIRP.

*Sector B facing to 100 degrees with 3 degrees downtilt on a 7250_02_1900 type of antenna having 54.5 feet's height and 55dBm EIRP.

*Sector C facing to 210 degrees with 0 degrees downtilt on a 7250_05_6deg_1900 type of antenna having 50 feet's height and 50dBm EIRP.

6– We were told not to make any changes on Site Gene Beal, because it is a VIP site. If we could only be able to increase EIRP on both of the sectors, than we could have a better coverage in the area. If it could be done with the appropriate hardware configuration, adjacencies of this site should be rechecked. Currently the level is so poor in the area and even Downtown Redmond is serving there.

7– Overlake Sector A does not handover to Sector B even with level difference of 7 to 10dB. This is the same case with Factoria Sector B and C.

8– Lack of coverage and poor quality with Ping–Pong handovers on North–Up Way on East of 156th Ave were observed. Changing the antenna type to type 3 for Overlake Sector A and reduce its downtilt from 5 to 2 degrees is recommended. Also attenuation reduction to 0 is recommended on Crossroads (All Sectors).

9– Below missing neighbor relations were observed:

405/520 244A – Crossroads 483A
Crossroads 483A – Bridal Trails 139A

10– Drop call on NE 8th street near 156th Ave was observed. South Sammamish 428C is serving here and its heavily interfered by Crossroads 483B (BCCH 602). It is strongly recommended to add Crossroads 483A as neighbor to South Sammamish 428C.

11– Drop call on NE 4th Street on west of 156th Ave NE is observed. It is recommended to add Crossroads 483B as neighbor to West Issaquah 251C.

12– Lack of coverage and poor quality with Ping–Pong handovers near intersection of 148th Ave NE and NE 8th Street is observed. It is recommended that Lake Hills which is an Omni site to be sectorized with the high gain antennas facing this intersection.

5. CONCLUSION

Optimization is a process that never ends. You can always try improving the quality of the Network by making site configuration changes or changing parameters or try to understand what is happening in the network by looking into stats. Everybody knows that there is a lot that could be done by means of optimization but it is always hard to start. People sometimes get lost in stats, sometimes struggle with parameters or log files.

Below is a chart *(Figure 64)* that shows how you could start doing optimization and the steps to be followed. I am sure you will find vital information on the total process. Hope this works..

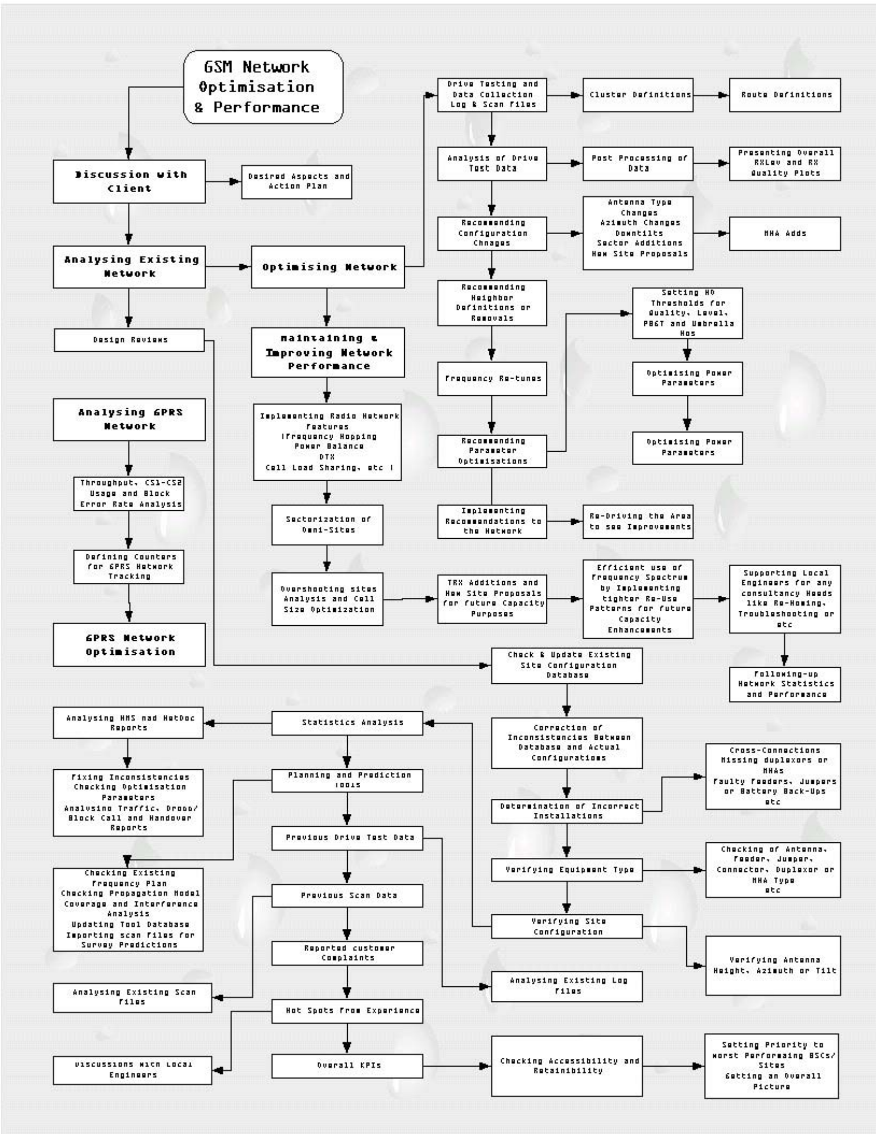


Figure 64– Optimization Diagram