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Verifying 3G License Coverage Requirements

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1. Introduction

In the beginning of the 21'st century, the 3rd generation mobile phone systems, 3G, were introduced all around the world. In most countries, spectrum for this technology was allocated through some kind of licensing procedure. In Europe, the prevailing approach was to allocate spectrum through auctions, a process which led to a situation where the European operators found themselves committed to pay a staggering 130Bilion Euros for their 3G licenses.
However, in most European countries, the fee was not the only obligation put on the licensee: A coverage, "roll-out" requirement was in many cases also connected to the license (Northstream, 2002). Typically, these coverage requirements required that the licensees cover a certain area at a certain point in time after that the licenses had been awarded.
In order for the regulators to verify that the licensees had met the coverage requirement and, hence, complied with the regulation, a method for coverage verification was needed. Such methods have therefore since then been developed by several European regulators (e.g. PTS 2004; ECC 2007). In this book chapter we describe some general underlying consideration for the verification of radio coverage in UMTS systems and in particular we describe the Swedish methodology developed by the Swedish Telecom regulator Post & Telestyrelsen (PTS).

2. Licensing of 3G in Sweden

In 2001, the Swedish Telecom regulator Post & Telestyrelsen (PTS) granted four licenses for the operation of third generation mobile phone systems (PTS 2001). In contrast to most other European countries, the Swedish licenses were granted through a beauty contest. When acquiring the licenses, the licensees committed themselves to build networks that covered a population of 8.860.000 inhabitants. This requirement implied that each operator would cover some 99.98% of the Swedish population (as counted for in 1996). However, in order to support the roll out, the regulator allowed the operators to build their networks in a combination of self owned sites in the major cities (30% of population) and shared sites in the countryside (70%) (Beckman and Smith, 2005). The roll-out of these 3G networks was delayed several times and the coverage requirements somewhat modified, but in 2007 all Swedish operators reported that they complied with the license requirements. Today Sweden is unique in that more than 98% of the population and 48% of the of the national territory (170.000 km²) has 3G service coverage (PTS 2008).
In contrast to many other European countries, the original Swedish 3G license defined coverage by specifying a field strength requirement to be measured outdoors on the primary

common pilot channel, CPICH. The assumption was that depending on the environment and the average building penetration pathloss, the pilot signal strength can be related to a particular data service (rate) indoors.
In the original Swedish license requirement the operators where obliged to provide an out-door signal strength that in the 3GPP release 99 standard of the UMTS system (3GPP 2000) corresponded to an in-door packet switched data services, of 384 kbps in downlink and 144kbps in uplink. These requirements were then translated into a field strength for the signal received from the base station. In the original license agreement coverage requirement was that when measured outdoors at a height of 1.7m above ground over 5MHz, the field strength on the CPICH should be at least 58 dBμV/m with an area probability of 95% (PTS 2001).
The design of the Swedish measurement method is previously described in a number of papers, e.g. PTS 2004; PTS 2004 II; Beckman et al 2006; Beckman et al 2008.

3. General considerations

To verify coverage one needs to develop a practical test procedure for measuring field strength. The verification can then easily be performed e.g. in a drive test (PTS 2004; ECC 2007). However, designing such test presents a number of challenges:

- A requirement can be given for a particular field strength measured on the common pilot channel. However, in the UMTS systems the power to be allocated to the CPICH is not given by the standard or by the regulator
- There is no given relation between pilot power and service. In the Swedish license requirements it was assumed that an outdoor signal strength of 58dBμV/m on the CPICH in practise relates to a downlink service indoors of 384 kbps and an uplink service of 144kbps (PTS 2001). However, building penetration path loss varies in different environment. Hence, field strength requirement must vary accordingly.
- A license is typically given for area and population coverage while a drive test only measures along a linear route. In order to convert measurement data from drive testing to a probability of coverage for a given area with a certain population, one needs a statistical model based on population density and geography.

4. The primary Common Pilot Channel

The Universal Mobile Telephony System (UMTS) is a 3G systems specified by the Third Generation Partnership Project organization (3GPP 2002). It has a radio interface based on a code division multiple access scheme, cdma, and 5MHz wide radio channels. Since the radio channel is somewhat wider than previous cdma systems it is referred to as: "wideband" cdma or WCDMA.
The primary Common Pilot Channel, CPICH, is one of many codes in the WCDMA common downlink pilot channel (Holma and Toskala 2002). It is a control channel mainly used for handovers. It does not have a fixed power allocated to it so it is principle not related to any service in either the up- or down-link.

4.1 Allocating power to the CPICH

In theory it is possible to allocate anything between 0% and 100% of the available power to the CPICH. In practice the allocated power has a lower bound which can be derived as follows (PTS 2004)

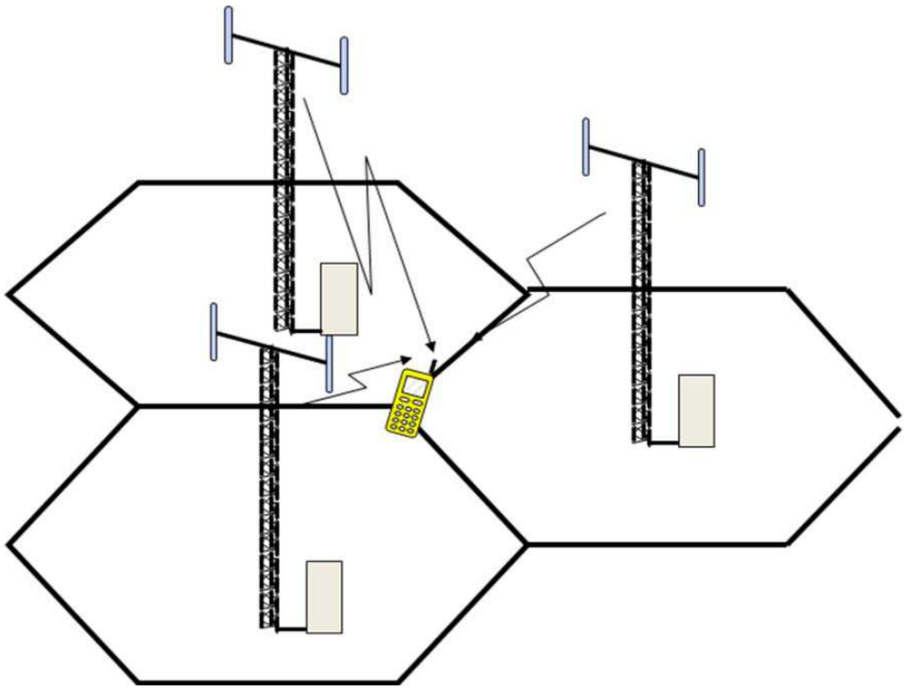


Fig. 1. Illustration of the downlink interference situation at the border between two cells

In order to initiate a soft handover at the border between two cells (Fig. 1.), a cell's pilot must be detected when an adjacent cell's pilot is 5 dB stronger. The required E_b/N_0 on the primary CPICH on the downlink is approximately 10 dB (3GPP 2002). The processing gain on the pilot is 10*log(3840/12.2) = 25 dB which means that the minimum output power for the pilot is approximately: 5 + 10 – 25= -10dB (10%) compared to the total output power from the base station. A worse case scenario is of course when the mobile is at the intersection of 3 cells. The interference level would then of course be doubled. Allocating between 10% and 20% of the available power in the radio channel is also often suggested in industry literature (PTS 2004 II). However, it is in the interest of the operators not to increase the pilot power unnecessarily since raising the pilot power will mean that less power is available for services.

4.2 Relationship between pilot power and services

As described above, there is no given relation between pilot power and services. Still, the regulator needs to have measurable criteria:

First of all one needs to consider what measure is most suitable. By tradition regulators uses prefers to measure the signal strength in e.g. dBμV/m. The main reason for this is that this parameter is easy to measure in a drive test and is independent on frequency and antenna gain. The relationship between signal strength E (as measured in dBμV/m) and signal power P (as measured in dBm) can we written as:

$$P = E - 20\log 10f - 77.219 + G, \tag{1}$$

where f is the frequency given in MHz and G the antenna gain given in dBi.

Assuming that 10% of the available power is allocated to the primary CPICH and that the building penetration path loss is known, it is now possible to estimate the pilot power

needed to provide the required services for different environments by calculating the link budgets (Holma and Toskala 2002).
The base station has typically 10-20 W (40-43 dBm) output power available, while the mobile unit has 0.125 W (21 dBm). The Noise Factor of the base station is typically ~4 dB compared to ~7 dB for the mobile receiver. Antenna diversity is implemented at the base station for the uplink and therefore approximately 4-5 dB lower Eb/N_0 than required in the downlink. Still the downlink has a 10-15 dB path loss advantage over the uplink in a symmetrical service. In case of asymmetrical load (higher bitrates in the downlink than in the uplink), the 10-15 dB advantage reduces to around 5-10 dB (assuming 384 kbits/s downlink and 144 kbit/s uplink).
Uplink coverage can be improved by introducing Tower Mounted Low Noise Amplifiers, i.e. an amplifier directly after the antenna. The gain of this is that the feeder losses in the uplink can be ignored (expect for a short jumper cable between the antenna and the amplifier), and that the TMA often has a better Noise Factor (NF) than the base station (1.5–2 dB compared to 4-5 dB). TMA is widely used by the operators to improve coverage in rural areas.
Mobile a terminals are used in a variety of environments, but to a large extent they are used indoors. The signal is thus being attenuated as it has to propagate through the walls or windows of the building where the user is located. Therefore, the link budget needs to include a margin for the penetration loss in case service is planned for indoor users.
It is evident that a single penetration loss value will not apply to all environments. In rural areas, people often live in small houses that have thin walls and windows in different directions, thus giving a lower penetration loss. In Sweden single family house are mainly constructed out of wood, while multi family and multistory buildings are normally made of concrete.
In the Swedish example, the following guidelines for building attenuation was suggested:

1. In rural areas, single family houses (11 dB attenuation)
2. In suburban areas, single family houses and semi detached homes (11dB)
3. In urban areas, concrete houses with large separation (16dB)
4. In dense urban areas, concrete houses with small separation (20dB)

The link budget calculations are summarized in Tables 1 and 2. Calculations are done for the four different scenarios mentioned above, with and without tower mounted low noise amplifiers, TMA, in rural, and for packet switched uplink and downlink data rates of 144kbps and 384kbps, respectively. The input data is in accordance with the 3GPP UMTS release 99 standard (3GPP 2001) and Holma and Toskala (2002).
In literature link budgets normally includes a margin for the “log normal fading”, which can be described statistically, to arrive at a maximum path loss that can be used for radio planning purposes. When comparing the above link budget with the license requirements, it is important to understand that the margin for the statistical variation of the measured signal in the outdoor environment is already

4.3 Coverage criteria

In Table 3 the main results of the link budget calculations are presented. As can be seen, in all cases it is the up-link that limits the service performance. However, the CPICH signal strength required in order to be able to provide the respective services varies in different environments. The pilot signal strength requirement of 58dBμV/m set out in the Swedish license seems to be ~ 7dB too low in dense urban and ~8dB too strict in rural environments.

Environment		Dense	Urban	Suburban	Rural	Rural TMA	Rural TMA
Service UL	kbit/s	144	144	144	144	144	64
Max mobile transmit power	dBm	21	21	21	21	21	21
Mobile Antenna Gain	dBi	0	0	0	0	0	0
Body loss	dB	0	0	0	0	0	0
EIRP	dBm	21	21	21	21	21	21
Thermal Noise	dBm/Hz	-174	-174	-174	-174	-174	-174
Noise Figure	dB	4	4	4	4	2	2
Noise Density	dBm/Hz	-170,0	-170,0	-170,0	-170,0	-172,0	-172,0
Noise Power	dBm	-104,2	-104,2	-104,2	-104,2	-106,2	-106,2
Interference Margin	dB	3	3	3	1	1	1
Receiver interference Power	dBm	-104,2	-104,2	-104,2	-110,0	-112,0	-112,0
noise + interference	dBm	-101,2	-101,2	-101,2	-103,2	-105,2	-105,2
Processing Gain	dB	14,3	14,3	14,3	14,3	14,3	17,8
Required Eb/No	dB	1,5	1,5	1,5	2	2	2
Receiver Sensitivity	dBm	-113,9	-113,9	-113,9	-115,4	-117,4	-120,9
Base station antenna gain	dBi	18	18	18	18	18	18
Cable loss	dB	4	4	4	4	1	1
Max Path Loss	dB	148,9	148,9	148,9	150,4	155,4	158,9
Fast fading margin	dB	4	4	4	4	4	4
Max Fading Path Loss	dB	144,9	144,9	144,9	146,4	151,4	154,9
Average Penetration Loss	dB	20	16	11	11	11	11
Max outdoor UL Path loss	dB	124,9	128,9	133,9	135,4	140,4	143,9

Table 1. Uplink link budgets for different services and environment used for the calculation of the Swedish license requieremnts

What is then a sufficient pilot strength criteria in order to determine whether an area is covered or not with 3G? What is evident from the above link budget calculations is that the signal strength requirements needs to be set differently for different environments. In Table 3, the modified Swedish CPICH requirements for different environments are summarized (PTS 2004 II).

Environment		Dense	Urban	Suburban	Rural	Rural TMA
Service DL	kbit/s	384	384	384	384	384
Total available Power	dBm	43	43	43	43	43
Cable Loss	dB	4	4	4	4	4
Antenna Gain	dBi	18	18	18	18	18
Transmitter total ERP	dBm	57	57	57	57	57
Max Service Power %		25%	25%	25%	50%	50%
Max Service ERP	dBm	51,0	51,0	51,0	54,0	54,0
Thermal Noise	dBm/Hz	-174	-174	-174	-174	-174
NF	dB	7	7	7	7	7
Noise Density	dBm/Hz	-167	-167	-167	-167	-167
Noise Power	dBm	-101,2	-101,2	-101,2	-101,2	-101,2
Processing Gain	dB	10,0	10,0	10,0	10,0	10,0
Required Eb/No	dB	6	6	6	6	6
Receiver Sensitivity	dBm	-105,2	-105,2	-105,2	-105,2	-105,2
Base station antenna gain	dBi	18	18	18	18	18
Cable loss	dB	4	4	4	4	4
Max Path Loss	dB	156,1	156,1	156,1	159,1	159,1
Fast fading margin	dB	4	4	4	4	4
Max Fading Path Loss	dB	152,1	152,1	152,1	155,1	155,1
Average Penetration Loss	dB	20	16	11	11	11
Max outdoor DL Path loss	dB	132,1	136,1	141,1	144,1	144,1

Table 2. Downlink link budgets for different services and environment used for the calculation of the Swedish license requieremnts

Environment	Limiting Link	Required CPICH [dBµV/m]	Modified Swedish Requirements[dBµV/m]
Dense Urban	UL	65.1	58
Urban	UL	61.1	58
Suburban	UL	56.1	52
Rural	UL	54.6	52
Rural TMA withTMA	UL	49.6	50

Table 3. Summary of the Swedish link budget calculations and modified CPICH requirements

5. Measurement set-up

The method used to verify the operators networks needs for obvious reasons to be accurate but also well accepted. The traditional way of performing radio coverage measurements is by conducting drive tests with a vehicle upon the roof of which antennas are mounted. The signal is then sampled, measured and stored on equipment carried inside.



Fig. 2. Photo of the measurement car including the antenna solution with an extra disc as ground plane, used by the Swedish regulator, PTS

5.1 Instrumentation

The measurement system needs by necessity be able to simultaneously detect several control channels from several base station. The reason for that is that when the measurement is performed in urban environments the receiver will detect several base stations. In sub-urban or rural areas, it is of importance to be able to carefully measure at least two base staion control channels during (soft) handowver.

The standard way of doing this is to perform a so called Top N measurement. The measurement instrument then measures the scrambling codes transmitted on each detected CPICH. In a "Top N" measurement, the system scans for all 512 scrambling codes and returns the "N" strongest. In the Swedish measurement the top 6 scrambling codes were detected and measure but N can typically be any number between 1 and 32.

Since the receiver is often in a scattering environment, much of the power is not in the direct path but rather in the "echos" reflected from surrounding buildings and objects. The test instrument therefore needs to support "aggregate power" measurements where the receiver integrates over all reflected signals stronger than a certain level, (e.g. -17 below the maximum power, PTS 2004)
In addition to this it is o course of importance to keep track of the position of each sample, using a GPS, and store the all the acquired data. Table 4 below gives a list of the instrument chosen for the Swedish test. In Fig. 3, the test receivers and the operator display are shown.

Instrumentation	**Equipment**
Test receivers:	4 * Agilent E6455C (WCDMA)
GPS	Trimble
Computer	Shuttle XPC, P4 3.06GHz, 1GB ram, 160GB hd
Display	7" VGA
OS:	Windows XP
Application software	Nitro (Agilent)

Table 4. List of instrumentation used in the Swedish measurements



Fig. 3. Test receivers and the operator display are shown

5.2 Measurement antenna

For measurements of mobile radio coverage, it is important to have an omni-directional pattern, especially if different networks with different base station locations are to be compared.



Fig. 4. Photograph of the measurement antenna solution with an extra disc added on top of the car

Whereas a dipole provides an omni-directional pattern with maximum radiation in the horizontal plane, this is not the case for a monopole placed on a finite ground plane such as a car roof (Kronberger et al, 1997). To minimize antenna induced errors in the measurement one may consider an alternative ground plane.

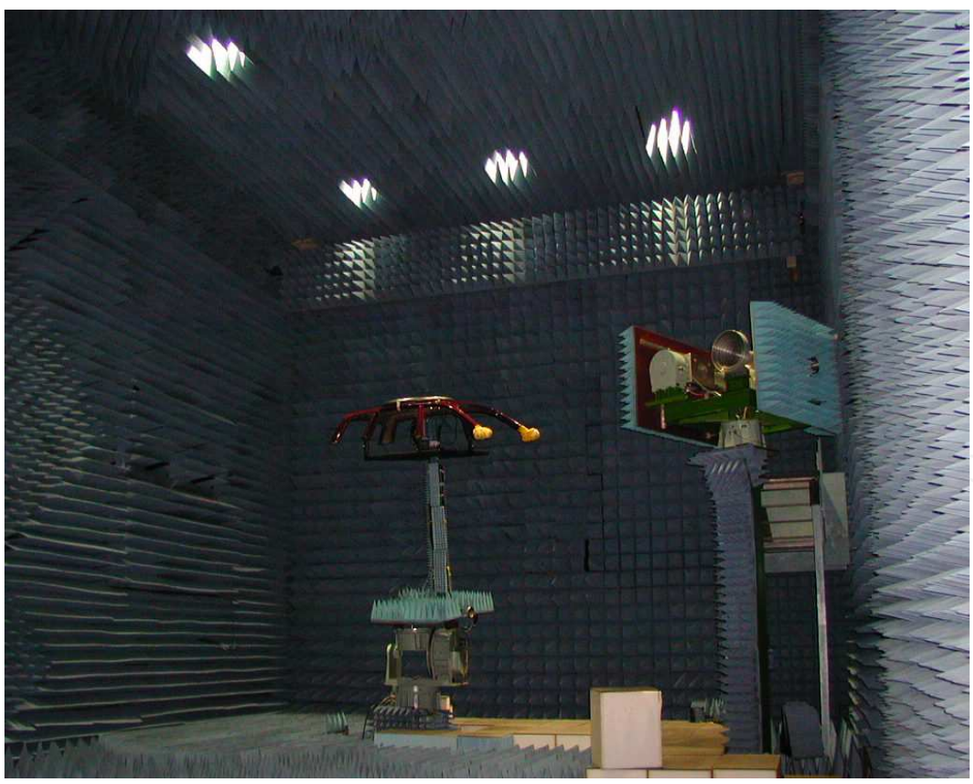


Fig. 5. The monopole antenna during verification measurements at Allgon's (today Powerwave) compact range in Stockholm Sweden. The monopole and the disc ground plane are mounted on the roof from a chassi of the same car as in the actualSwdish 3G verification measurements

In order to improve the pattern for the Swedish test, Ribbenfjärd et al (2004) presented a solution with a monopole on a circular dish placed on the car roof. The design was made using simulations in CST Microwave Studio. A photograph of the antenna is seen in Fig. 4. It is very difficult to make accurate measurement or simulation of an antenna mounted on a complete vehicle, and the validation of the design was therefore made on the part of the roof seen in Fig. 5. The result is shown in Fig. 6 where it is compared to the pattern of a monopole mounted directly on the car roof.

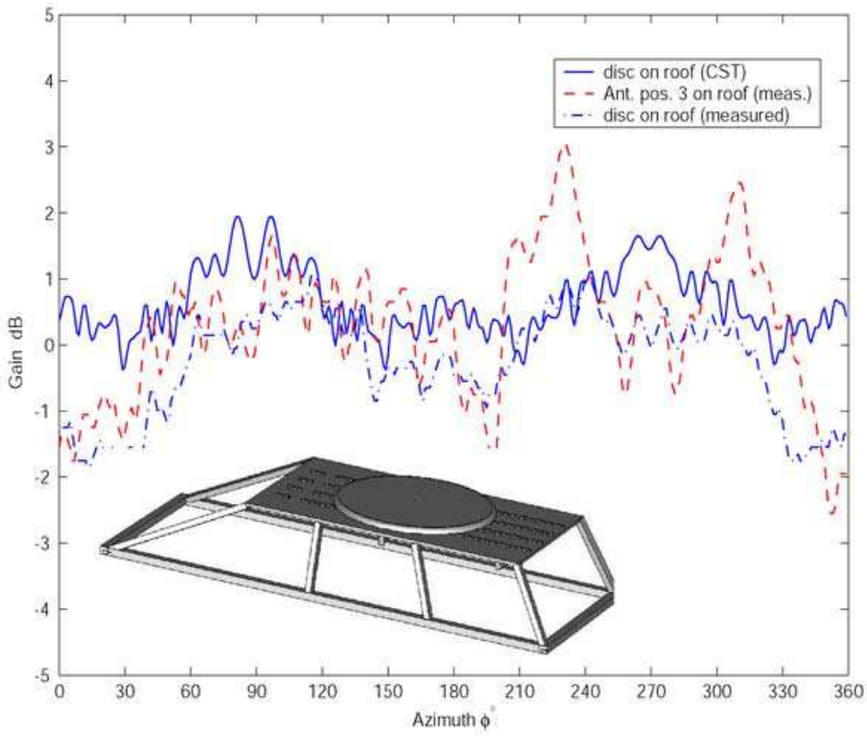


Fig. 6. Simulated and measured azimuth pattern of a monopole antenna with a ground plane disc on the roof at 2GHz The co-polar pattern of a monopole antenna directly on the roof is also shown. The inserted drawing shows the CST-model of the antenna with disc on the car roof. (from Ribbenfjärd et al 2004)

The results show that a substantial improvement in both azimuth and elevation is possible if an additional ground plane in the form of a disc or a cone with corrugated edge is added. The peak-to-peak gain variation in the horizontal plane is reduced from ~5 dB to ~2.5 dB.

6. Compensation for polarization mismatch

For practical reasons, regulators want to measure the vertical field component only, i.e. using a vertically polarized antenna. However, the operators may very well use polarization diversity on reception at the base station. In this case, the base station typically transmits on a 45 degrees slant linear polarization. Therefore, we can expect that the field at the measurement location will have a non-zero horizontally polarized component.

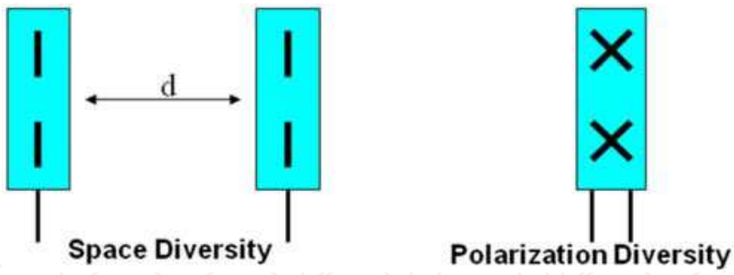


Fig. 7. Illustration of antenna systems for space (left) and polarization (right) diversity reception. In order to receive uncorrelated signals with a space diversity system the distance between the antennas (d) must typically be in the order of 10 wavelength

6.1 Cross polar discrimination

An important parameter related to polarization diversity is the cross polar discrimination or XPD of the radio channel caused by the environment. With this we mean the power ratio of vertically and horizontally polarized wave components incident on our receive base station antenna when a mobile is transmitting.

Environment and source	Mobile orientation	XPD (dB)	Frequency	Correlation between vertical and horizontal field ρ_{env}
Urban (Kozono et al 1984)	Vertical car antenna	4-7	920 MHz	0.02 median
Urban (Vaughan 1990) Sub-urban	30° on large groundplane	7 12	463 MHz	-0.003 0.019
Urban & Sub-urban (Turkmani 1995)	0° 45°	10 4.6-6.3	1790 MHz	<0.7 for 95% <0.7 for 95%
Urban (Lotse et al 1996) Sub-urban	70 ±15 deg in- an outdoor	1-4 2-7	1821 MHz	<0.2 for 90% <0.1 for 90%
Urban & Sub-urban (Eggers et al 1983)	0° 45°	4-7 0	1848 MHz	<0.5 for 93% <0.5 for 93%
Urban (Eggers et al, 1998)	Car mounted monopole	7.6±2.1	970 MHz	0.09±0.09
Urban & Sub-urban (Lempiainen and Laiho-Steffens, 1998)	Random, in- and outdoor	<5	1739 MHz	-0.25 to 0.24
Sub-urban (Wahlberg et al, 1997)	Vertical mobile LOS & NLOS	7	1800 MHz	< 0.2 average
Urban & Sub-urban (Joyce et al, 1999)	Vertical dipole	8-11	900 & 1800 MHz	< 0.7 all values
Urban (Wahlberg et al, 1997) Sub-urban	Vertical monopole	5 10	1800 MHz	-

Table 5. References from measurements of cross polar discrimination in different environments

In Table 5, a number of known references from measurements of cross polar discrimination in different environments are summarized. For example, we find that for an sub-urban environment we typically have XPD = 6dB, between 2 and 5dB in urban environments, and about 5 to 10dB in sub-urban.

6.2 Polarization mismatch

For 3G network verification purposes, we are interested in the amount of power lost if we transmit on slant 45degrees antenna and receive using a vertically polarized antenna only, i.e. the polarization mismatch loss. By virtue of reciprocity, we can use the results for a vertically polarized mobile station transmitting to determine this power. A relevant measurement is then Turkmani et al (1995) where a value of XPD=10dB is reported for a vertically polarized monopole in a suburban environment.

Since this environment discriminates the horizontal polarization a concern in using a 45 degrees slanted polarized antenna for transmission is the increased path loss compared to a vertically polarized. Due to reciprocity the transmission analysis is the same as for the reception, and the maximum average path loss using a slanted 45 degrees antenna vs. a vertically polarized antenna is limited to 3 dB if XPD is infinite.

What is then the difference between transmitting on slanted 45 degrees (P_{45°) antenna compared to vertical (P_{vp}) in a typical sub-urban environment? This can be calculated if one knows the XPD as:

$$P_{45^\circ} = \frac{P_{vp}}{2}(1 + 1/\mathrm{XPD}) \tag{2}$$

If we use the example mentioned in Turkmani et al (1995) where a value of XPD = 10dB is reported, we find that the mean power difference between transmitting on 45 degrees slant compared antenna compared to a vertical is: ~2.60dB

6.3 Compensation for the polarization mismatch

So, how large should this compensation be? The theory above only shows the expected differences in measured field strength when transmitting on 45 degrees slant polarization compared to vertical in a radio channel which discriminates the horizontal polarization. However, it could also be argued that in some environments the propagation of the horizontal polarization is more favourable than vertical [10]. When that is true then no compensation should really be applied at all.

In conclusion we then find that the polarization mismatch adds an error to the measurement spanning from 0 to 3dB depending on environment. Hence, a general compensation factor of 3dB would be most fair to the operators.

7. Statistical model

The purpose of the test method is to establish whether or not an operator has fulfilled the coverage requirements set out in the license [3]. The method must ensure that the license requirement is fulfilled with sufficient statistical significance and that the sampled data is uncorrelated.

The way to ensure that the data is uncorrelated is to make sure it is received over a large enough geographical area. This is done by dividing the geographical area to be verified

for 3G coverage into ”test squares”. If 95% of the tested squares have a sampled field strength exceeding the one set out in the license requirement, the area is considered to be covered.

7.1 Test squares

The size of the test squares is dependent on the environment and population (Table 6 and Figure 1). The denser the population the smaller the size. In the evaluation only one sample for each test square is used.

Environment	Population (per square)	Size (m)
Rural	0 <= x < 20	500
Suburban	20<= x < 80	250
Urban	80 <= x < 200	125
Dense Urban	x >= 200	50

Table 6. Size and population of test squares

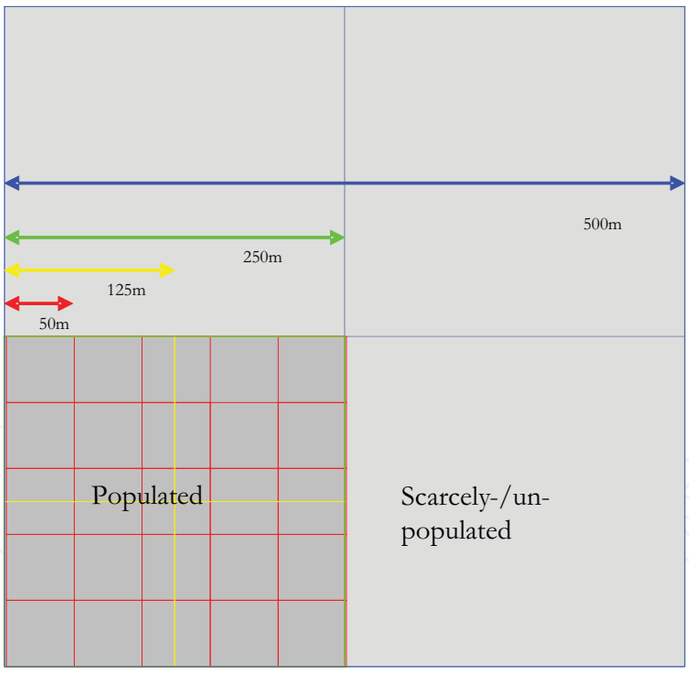


Fig. 8. Size relation between test squares

For practical reasons the measurements are conducted in a drive test using a car. Hence the sampling rate is dependent on the speed of the car and the size of the test squares. Each tested square is allocated the value of “1” if the license requirement is fulfilled and “0” if not. At least 500 test squares are measured in order to assume that the number of “1” are binomially distributed (n; p) where p >= 0.95 in the event that the license requirements are fulfilled.

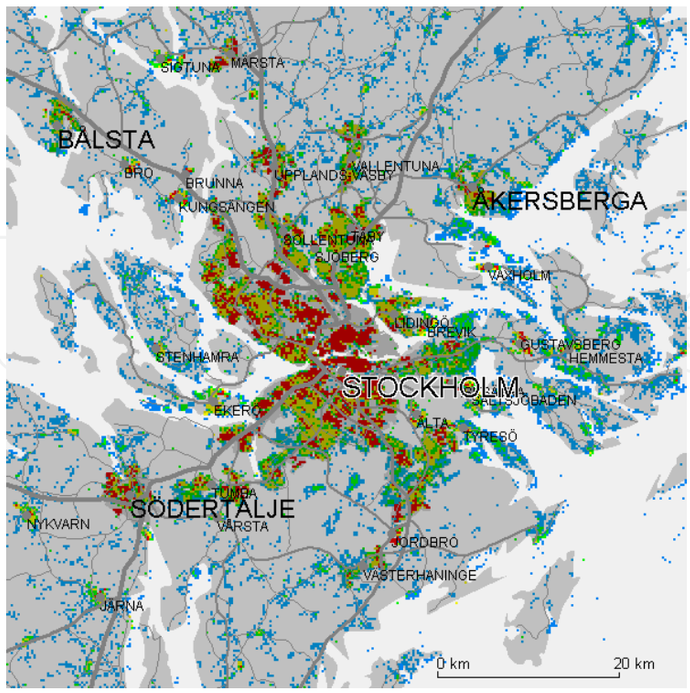


Fig. 9. Graphic illustration of the population density in the Stockholm area

8. Results from the Swedish measurement campaign

In 2007 all Swedish 3G licensees reported that they had fulfilled the modified (see Table 3) coverage requirements. In order to verify these claims the Swedish regulator PTS subsequently conducted some initial and preliminary tests.

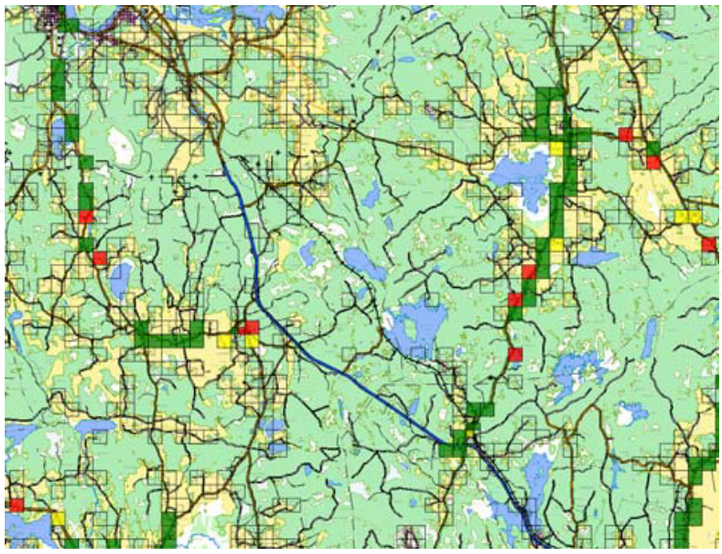


Fig. 10. Graphic illustration of coverage in the Fagersta region at the 52dBµV/m CPICH level. Green Squares indicate Test squares passed, yellow are at the boarder line, and red square are failed

8.1 Suburban environment: test case Fagersta

The first test case was conducted in a typical Swedish suburban environment in an area of and around the city of Fagersta. The field strength requirement was set to 52dBµV/m. In total 535 test squares were measured and in order to pass the test not more than 39 were allowed to fail for the operator to comply with the license requirement.

As shown in Table IV, the result from the measurements show that the operator passes the test easily. Even if the CPICH field strength requirement would be increased to 53dBµV/m would the operator still pass the test indicating that the planning is fairly robust against fading.

Field strength (dBµV/m)	No. Failed Squares
53	31
52	23
51	19
50	17
49	16
48	9
47	6

Table 7. Test results from Fagersta

8.2 Urban environment: test case Sundbyberg

The second test was conducted in a typical Swedish urban environment in the city of Sundbyberg some 10km north of Stockholm. In total 602 test squares were measured and in order to pass the test not more than 43 could fail for the operator to comply with the license requirement. In this environment the required field strength on the CPICH is 58dBµV/m.

Field strength requirement (dBµV/m)	No. Failed Squares
64	11
63	9
62	5
61	3
60	1
59	0
58	0
57	0

Table 8. Test results from Sundbyberg

As is evident from Table 8, the coverage planning is even more robust and the field strength on the CPICH higher in urban areas. Even if the requirement is increased with 6dB the result for the examined operator is still clearly above the limit of 95% area coverage.

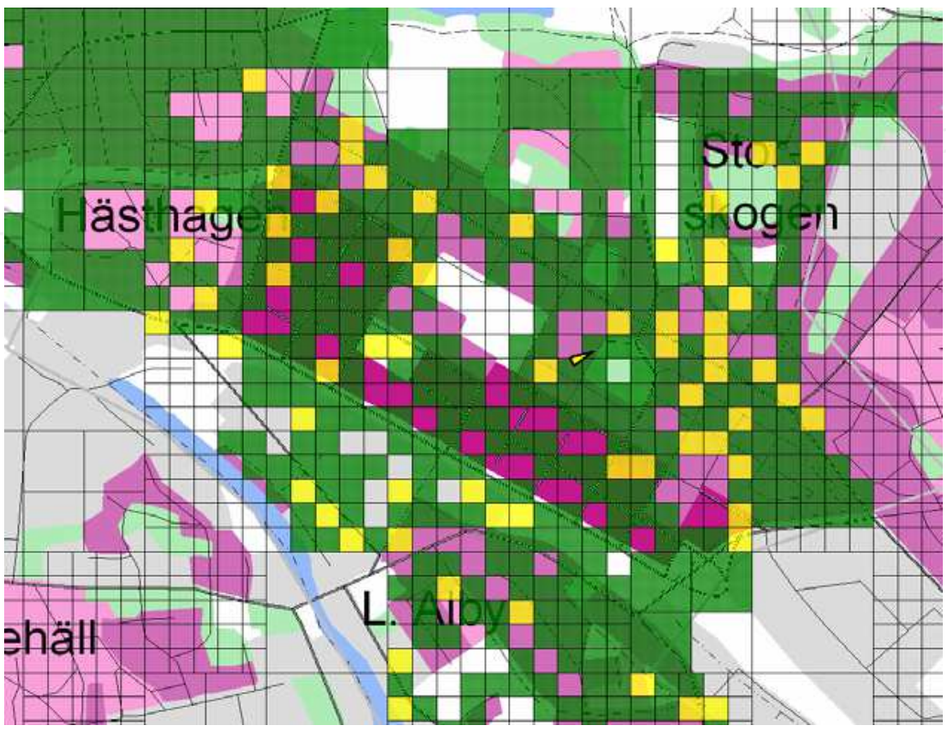


Fig. 11. Graphic illustration of coverage in the Sundyberg region at the 58dBµV/m CPICH level. Green Squares indicate Test squares passed, yellow are at the boarder line, and red square are failed

9. Conclusions

In the beginning of the 21st century, 3G was introduced and most countries in the western world allocated spectrum for this technology. In Europe, the prevailing approach was to allocate spectrum through auctions. However, in Sweden the 3G licenses were awarded after a beauty contest, in which the winners committed themselves to cover a population of 8.886.000 which at the time corresponded to 99.98% of the country's population. The coverage requirements were concrete and measurable and in 2007 it was verified that all Swedish operators complied with the requirements The development of an accepted test method was an important part of this succesfull licensing.

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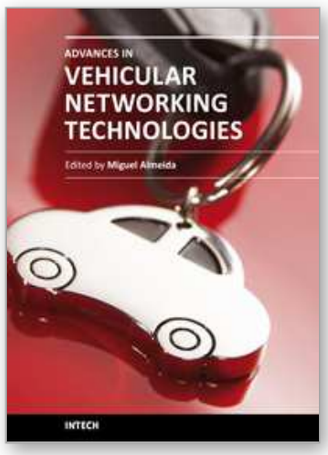
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