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حساب الضياع في الهوائيات الخليوية مائلة الاستقطاب والهوائيات الذكية

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(قبل للنشر في 2000/10/26)

□ الملخّص □

إن استخدام الهوائيات المتصالبة والمائلة الاستقطاب بزاوية +45 أو −45 ,أدى إلى نشوء منهج جديد في حسابات القدرة المستخدمة في وصلات الاتصال الخليوي الحديثة .

أما الضياع في الطاقة المحمولة على الموجة عند استخدام الهوائيات المائلة الاستقطاب ,فهو أعلى بقليل منه في حال استخدام الهوائيات ذات الاستقطاب الشاقولي ,وهذا الاختلاف في الضياع يدعى ضياع الاستقطاب المائل ,وهذا يخص فقط وصلة الاتصال الهابطة، أما بالنسبة لوصلة الاتصال الصاعدة فإن الضياع يعوض عن طريق زيادة الربح في نظام تباين الهوائيات .

و بالنتيجة نقترح لشبكات الاتصال المستقبلية العالية السعة استخدام مزيج من الهوائيات ذات الاستقطاب المتصالب والهوائيات الذكية ,وهذه الطريقة سوف تساهم في تخفيض التشويش الكلي الناتج عن التداخل بين الإشارات الواردة إلى المحطة الثابتة ,وبالتالي زيادة في السعة الكلية للشبكة .

و تكمن أهمية هذا البحث في دراسة ربح نظام تباين الهوائيات المختلفة وتحليلها ،و اقتراح استخدام الشبكة الخليوية لمزيج من الهوائيات المائلة الاستقطاب ,والهوائيات الذكية ,وذلك للاستفادة من خصائص هذين النوعين مقارنة بالهوائيات التقليدية المستخدمة حاليا ,وتأثير ذلك في الطاقة المحمولة وفي الأداء العام للنظام الخليوي . مع العلم بأن كل قيم الربح في نظام تباين الهوائيات ذات الاستقطاب المائل المستخدمة في هذا البحث منسوبة إلى الهاتف الخليوي المحمول يدوياً.

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Cellular Antenna Slant Loss Calculation and Smart Antennas

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ABSTRACT

The use of ±45 polarized antennas introduced new concepts in the calculation of link budgets. The propagation loss from an X-polarised antenna will be slightly higher than that for a vertically polarised antenna. This difference is referred to as the so-called 'slant polarisation loss' or simply 'slant loss'. The issue is complicated by the fact that the slightly worse propagation, compared to vertically polarised antennas, is compensated on the uplink by a better diversity gain. Therefore slant loss should be used in link budgets for downlink but not for uplink, while the diversity gain remains unchanged despite the introduction of X-polarised antennas. The value of this research is link budget calculation correction and suggesting for future high capacity networks to deploy a mix of X-polarised and smart antennas which will decrease the overall interference and increase the network capacity. The values in this research of diversity gain and slant polarisation loss apply to hand held MSs.

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1. BACKGROUND AND THEORY

One way of reducing the influence of multipath fading in the uplink is to use antenna diversity. This means that the signals from two Rx branches are decoded and the most probable bit values are chosen on a bit per bit basis. The result of the method is equivalent to maximum likelihood estimation. The antenna diversity gain will depend on the correlation between the fading of two antenna signals as well as the efficiency in power reception of the two separate antennas. There are two different types of antenna diversity used in the mobile networks:

· space diversity and polarisation diversity.

Space diversity means that two Rx antennas positioned at a certain minimum distance from each other are used. Typically, space diversity improves the uplink by 3.5 dB.

Polarisation diversity offers relief by allowing two space diversity antennas separated by several meters to be replaced by one dual polarised antenna. This antenna has normal size but contains two antenna arrays with different polarisation.

A dual polarised antenna replaces two standard (directional) antennas used for space diversity. The most suitable type for BTS configurations is the X-polarised or ±45° antenna. This can advantageously be used in the following way:

· Easier site acquisition in dense urban areas since fewer antennas are needed

· Simpler tower constructions can be built since there will be less weight and wind load with fewer antennas, thus saving installation and hardware costs.

· Higher tower can be built for the same cost as a tower dimensioned for space diversity (higher wind load), thus increasing the coverage.

· Save combiner loss in configurations with more than 2 transceivers per cell. With X-polarised antennas and coupling distribution unit it is possible to have 4 transceivers per cell using only two antennas (combining in the air) or 6 transceivers per cell with the smart range configuration.

The price for reducing the number of antennas is that the propagation in the downlink is slightly degraded by so called slant loss when using X-polarised antenna. Figure 1. shows slant X-polarised cellular base station antenna.

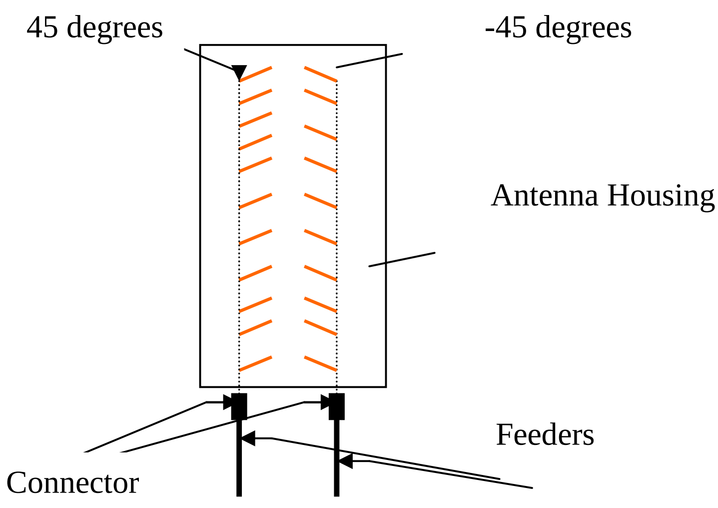
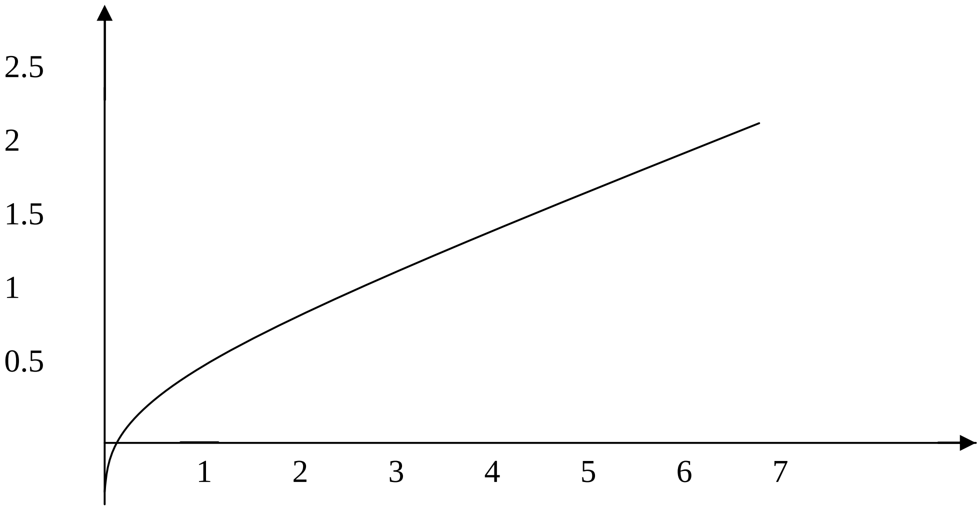


Figure 1. Slant x-polarised cellular base station antenna.

2. SLANT LOSS

Various tests have been made to compare uplink signal strengths for different macrocell antenna polarisation. Many of the tests indicate that there is a suppression of the horizontal component of the field caused by the propagation environment. This worse performance is assumed to be reciprocal, i.e. it affects both the uplink and the downlink. This effect is not caused by the MS antenna direction, although there is a small influence **of the MS angle.**
In the measurements mentioned in [1] and [2], the horizontally polarised antenna array caused mean losses of 1-7 dB, compared to the vertically polarised antenna array. These kinds of measurements have mainly been done with □ /90° and not X-polarised antennas. Therefore the behaviour of ±45° polarization is theoretically derived from □ °- 90° antenna measurements based on the fact that a 45° polarized field is made up by a horizontal component subjected to extra loss and a vertical component not influenced. The slant polarisation loss as a function of the horizontal polarisation loss is shown in Figure 2.

Slant polarisation loss [dB]



Horizontal polarisation loss [dB]

Figure 2. Expected slant polarisation loss derived as a function of mean vertical to horizontal power ratio.

For most samples in [1] and [2], the horizontal polarisation loss was around 4 dB or less. According to Figure 1 a slant polarisation loss of 1.5 dB should be recommended for cell planning.
In [3] the horizontal polarisation loss was measured for three different cases: an urban environment, a suburban environment and a country area environment with a 50 m mast. The values were found to be 3.0 dB, 2.0 dB and 6.6 dB respectively for a 50 % level of the cumulative distribution. Corresponding slant polarisation loss values should then be 1.2 dB, 0.8 dB and 2.1 dB in accordance with Figure 1. In [4] and [5] the slant polarisation loss for a ±45° polarized antenna has been measured for a mobile as well placed on the vehicle roof as placed inside a car for two different routes. A comparison with a □ /90°antenna has then been done. The slant polarisation loss is here defined as,

$$L_s \text{ (dB)} = -10 \log\{[\frac{P45}{P0}]\}$$

where P0 and P45 are the signal levels for the vertical and slanted branches. The result of the measurement in [4] is given in Table 1.

Table 1. Slant polarisation loss according to the measurement in [4].

Route	Mobile	L(dB)
A	Outside	2.6-2.7
A	Inside	0.4
B	Outside	2.5-2.6
B	Inside	0.8

As seen, the slant loss is much lower when the mobile is placed inside the car. As the path loss is generally higher due to the vehicle penetration loss, the limiting case is when the mobile is inside the car, i.e. the slant loss is this case less than 0.8 dB.
In [5], the +45 (S1) as the -45 (S2) branches have been measured too for two different antenna heights and the result is given in Table 2.

Table 2. Slant polarisation loss according to the measurement in [5].

		BS height = 20 m		BS height = 30 m	
		L S1 (dB)	L S2(dB)	L S1 (dB)	L S2 (dB)
Route 1	Outside	2.7	2.8	2.8	2.7
	inside	2.5	1.8	1.0	2.5
Route 2	outside	2.9	2.4	3.4	2.1
	inside	2.1	1.2	2.4	1

The measurements have been performed for the case where the mobile antenna is mounted on the vehicle roof and for the case where the mobile is inside the car. As seen, the difference of the slant loss between these two cases is not remarkable as that in [4].
Besides, there is an imbalance between the S1 and S2 branches. Still there is however a tendency that the slant loss is a bit lower for the case where the mobile is placed inside the car but here the slant loss is closer to 2 dB. Similar results regarding the imbalance have been found in [6], but in this case the slant loss is found to be 0.5 dB.

Table 3. Summary of slant loss results.

Measurement	L S (dB)
[1]&[2]	1.5
[3] Suburban	0.8
[4]	0.8
[5]	2
[6]	0.5

If we take an average of these results, we obtain a slant loss value of 1.1 dB that can be rounded to 1 dB.

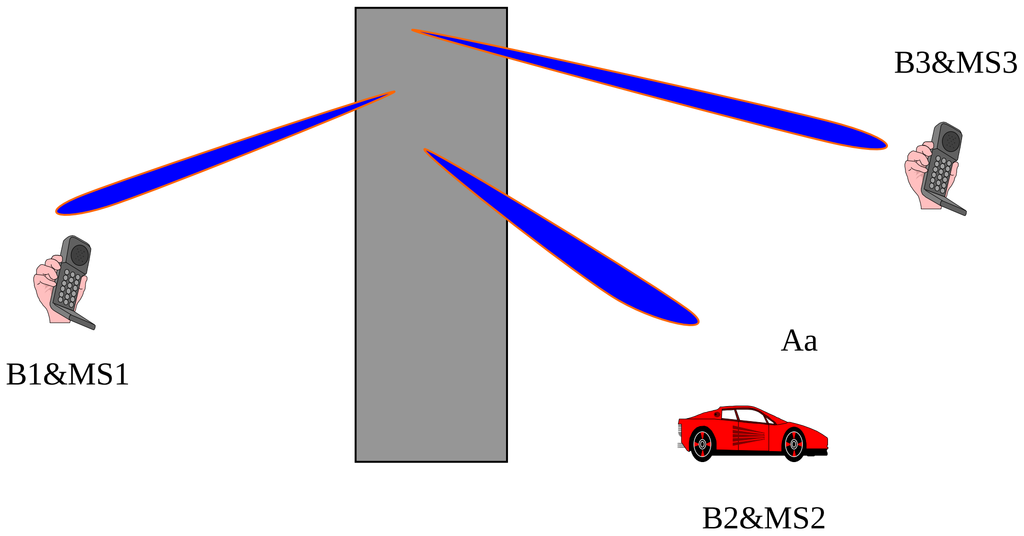
3. DIVERSITY GAIN

Measurements show that the diversity gain for X-polarised antennas is comparable to space diversity, when it comes to outdoor environments. In [8], the diversity gain has been measured for a ±4□ □polarized antenna and a space diversity system in a pure indoor environment. The diversity gain has there been obtained from cumulative probability curves for the measured signal levels as the difference between the no diversity branch and the diversity branch at the 0.1 probability level. The result is that the diversity gain is 2 dB better for the ±4□ □polarized antenna.
The worse propagation characteristics of slant polarisation is thus a hidden negative effect that has to be subtracted from a diversity gain defined this way.
It is in environments like indoor and in-car that the coverage is critical and therefore it is adequate to use this indoor and in-car diversity gain in link budgets. Other measurements, [9], have shown that the effective polarisation diversity gain is 1-2 dB worse than space diversity except in these coverage critical environments where the gains are almost equal. This result is in accordance to [8].
It is the lower cross-correlation of polarisation diversity that causes the higher gain, especially in highly scattering environments such as indoor, in-car or at long distances. Therefore the effective diversity gain used for cell planning is the same for space and polarisation diversity despite the slant polarisation loss:

Effective diversity gain =diversity gain –slant loss

4. NEW TECHNOLOGIES AND RECOMMENDATIONS

It is recommended for future communication networks to use a mix of cross-polarized antennas which has many advantages as mentioned above, and adaptive antennas (smart antenna) which can markedly reduce radio interference in both uplink and downlink, improving performance in both directions resulting in substantial capacity gains. Significant service quality improvements are also obtained. By putting the technology to use in the network "hot spots", an operator can also achieve significant improvements in overall network performance with the upgrade of only a few of the base stations see figure 3. The benefits of adaptive antenna technology are great for mobile communications industry, adaptive antenna technology uses beam



B : **Beam**
MS: **Mobile Station**
Figure 3. Adaptive smart base station antenna.

Forming to direct an antenna's energy in a narrow beam toward the location of a mobile phone (terminal), limiting the amount of energy needed. As the mobile phone moves, the base station tracks its location and changes the beam direction accordingly (DOA). Figure 4 shows schematic drawing of antenna system architecture with multi-beam (switched beam) adaptive antenna solution.

Smart antenna technology is wide topic by it self, and is currently under intensive research, and practical investigation. There are many different ways for implementation, which could be found in IEEE research papers. As we know the mobile communication systems are interference limited so cell antenna parameters have to be designed, so it can cope with max number of subscribers which is dependent on the frequency channels assigned to the cell. Signal amplitude as well as the phase are dependent on the mobile location inside the cell.

A conventional antenna system transmits and receives signals to and from all parts of a cell. The use of beam-forming technology significantly reduces interference with other cells in the network by minimising the amount of energy used during communication subsequently increases the capacity and network efficiency.

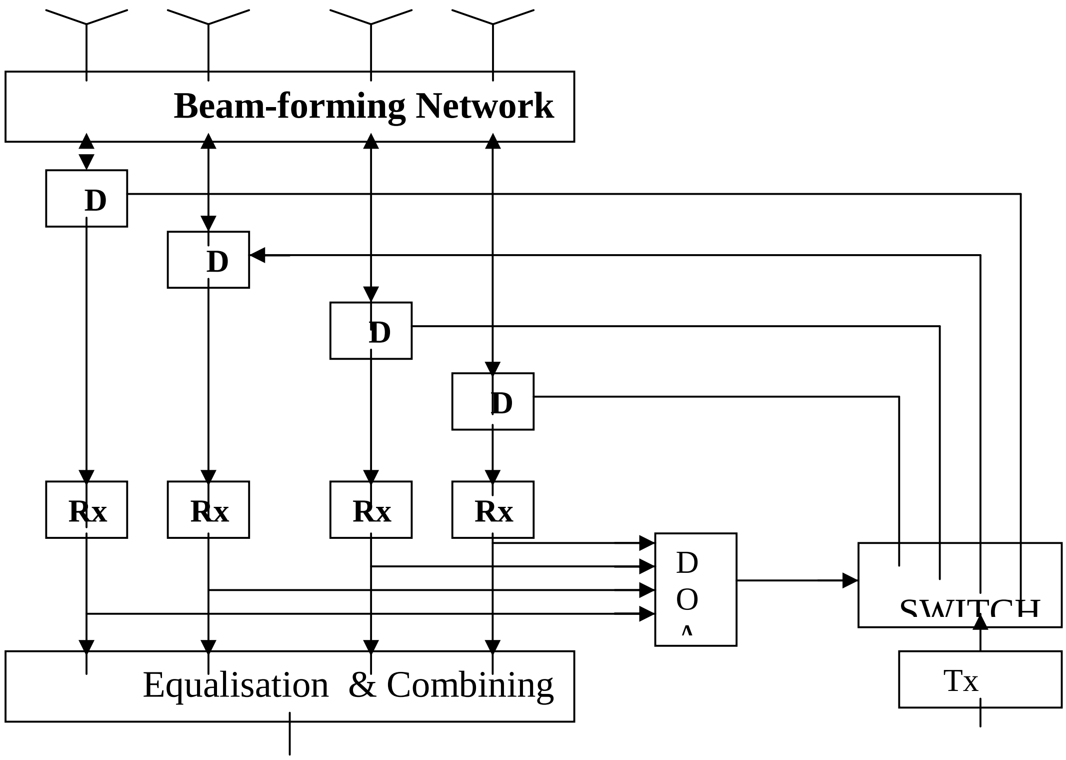
At the conclusion of this research we recommend:

1. Deployment of slant cross-polarised and smart antennas with:

- Better economics, less antennas and less coasts
- More environmental friendly, less antennas and better shape
- Better diversity gain for the uplink
- □ □1 dB slant loss in the downlink is recommended for link budgets.
- Slant loss should only be used in link budgets for downlink but not for uplink. A better diversity gain in the uplink will compensate for the slant loss in this case.

2. Deployment of smart antennas which will:

- Reduce the overall interference
- Increase network capacity and efficiency.



DX : **Duplexer filter** **DOA:** **Direction of arrival**
Tx: **Transmitter** **Rx:** **Receiver**

Figure 4. Schematic architecture of adaptive antenna system.

5.TERMINOLOGY

BTS	Base transceiver station
B	Antenna radiation beam
DOA	Direction of arrival
DX	Duplexer filter
Ls	Slant loss
MS	Mobile station
P0	Signal strength for vertical branch
P45	Signal strength for slant branch
Rx	Receiver
Tx	Transmitter
X	Cross polarised

REFERENCES

……………………………….

[1] F. Lotse, J.-E. Berg, U. Forssen, P. Idahl, "Base Station Polarization Diversity Reception in Macrocellular Systems at 1800 MHz", T/U-96: 015, Rev. A, Jan 96.

[2] F. Lotse, "Macrocell Measurements of Received Power Levels in a Dual Polarized Base Station Antenna", T/B-94:526, Rev. A, Nov 94.

[3] F. Lotse, "Cross-Correlation and Relative Signal Levels between Polarisation Diversity Branches Measured Using a Vertically and Horizontally Polarized Base Station Antenna in Macrocells at 1800 MHz", T/U-96:321, Rev. A, July 96.

[4] H. Asplund, "Simultaneous Narrowband Measurements on Two Polarizations in an Urban Macrocell", T/U-98:357, July 98.

[5] H. Asplund, "Slant Loss in a Small Urban Macrocell" T/U-99:368, Aug 99.

[6] T. B. Sorensen, A. O. Nielsen, P. E. Mogensen, M. Tolstrup, L. Steffensen, "Performance of Two-Branch Polarisation Antenna Diversity in an Operational GSM Network", Conference Proceeding, VTC May 98.

[7] J. Lempaeinen, J. Laiho-Steffens, "The Performance of Polarization Diversity Schemes at a Base Station in Small/Micro Cells at 1800 MHz", IEEE Trans. On Vehicular Technology, Vol. 47, No. 3, Aug 98.

[8] A. Alayon, "Indoor Radio Measurements with Polarization Diversity at 870.3 MHz", T/U-97:028, Jan 97.

[9] K. Isaksson, "DCS 1800 Measurements Comparing Polarization Diversity With Space Diversity", LT/SR-94:3058, Rev. A, Nov 94.

[10] "Interference Rejection Combining for GSM", J. Karlsson and J. Heinegård. In proceedings of ICUPCConference, 1996

[11] "Adaptive Antennas in GSM Systems with Non-Synchronized Base Stations", J. Karlsson. Licentiate's Thesis, Department of Signals, Sensors and Systems, Royal Institute of Technology, Sweden, 1997.