BEHAVIOR OF A MOBILE COMMUNICATION LINK IN AN URBAN ENVIRONMENT: A TEST CASE

João Paulo Pereira do Carmo
Instituto Politécnico de Bragança - Escola Superior de Tecnologia e Gestão
Campus de Santa Apolónia, 5300 Bragança, PORTUGAL
Fax : +351-273-313051, e-mail: jcarmo@ipb.pt

Abstract – This paper presents practical and theoretical results. The practical were obtained during one test-drive made at Porto downtown (CBD), named Baixa. Practical results are compared with application of theoretical models. The urban parametrs was assumed to be position-independent. These results will be of importance for mobile cellular communication systems in macro and microcells scenarios at urban dense areas. Two models to downtown are presented: Regression Line Fit (RLF) and Okumura Baseline Fit (OBF). Generated results confirm the good agreement to the zone under study, due lowest absolute mean errors and standard deviations generated.

I. Introduction

In the last years we had assisted cellular mobile traffic increasing due to increased solicitation from users. This leads to a saturation of the systems if no ways are taken to deal with it. Consequently we assist to the degradation of the QoS. To maintain normal QoS, the operators are in the necessity to increase theirs capacity. The increasing of capacity is achieved by two ways [1][2]: *i)* increasing the service area, and *ii)* increasing the capacity, maintaining fixed the service area. For both types of expansion considered, the propagation characteristics are aspects that more and more demand specialised studies. The mobility of the users difficult the channel characterisation due to resultant dynamic behaviour. For these reasons, the theme propagation (of signs) will be more and more pertinent. Phenomenon, whose analysis there is still little time had a value purely academic, they became in the concern of operators.

In this paper we present the results from applying Linear Regression Fit (RLF) and Okumura Baseline Fit (OBF) models; the results confrontation with measurements and final conclusions.

II. Theory

The most suitable models are based on path loss

$$PL(d)=A+B\log_{10}(d) \quad \text{(dB)} \qquad (1)$$

and power of the signal received on mobile station

$$p_R(d)=\alpha p_T d^{n} f_a(\phi,\theta) g_{max} \quad \text{(W)} \qquad (2)$$

where

d: distance from transmitting antenna (m);
p_R: power of the signal received (W);
p_T: power injected on the transmitter antenna feed system (W);
α: loss in feed system;
n: propagation factor, with negative value;
$f_a(\phi,\theta)$: normalised gain of transmitter antenna, in the direction of azimute ϕ and elevation θ;
g_{max}: gain of transmitter antenna in maximum gain direction.

The ratio p_R/p_T in terms of equation (2) in dB is

$$PL(d)=10\log_{10}[\alpha p_T f_a(\phi,\theta) g_{max}]-10n\log_{10}(d) \qquad (3)$$

The constant values A and B in equation (1) are

$$A=10\log_{10}[\alpha p_T f_a(\phi,\theta) g_{max}] \qquad (4)$$

and

$$B=-10n \;\Rightarrow\; n=-B/10 \qquad (5)$$

Path loss given by equation (1) [2] due to Log-Normal slow fading is the median value not exceeding 50% of time or 50% of locations in the place under study. We can account with an additional term X_0 due to Rayleigh fast-fading. That term is the standard deviation with typical value around ±4dB [3].

A useful relation is the behaviour with frequency, given by $C\log_{10}(f_{MHZ})$, where f_{MHZ} is the frequency in MHz. Most prediction tools used by GSM-DCS operators in Portugal (like *VODAFONE*) use one additional correction factor $K_{clutter}$ related to the clutter of the terrain.

The final expression to path loss is

$$PL(d)=A+B\log_{10}(d)+C\log_{10}(f_{MHZ})+X_0 \text{ [dB]} \qquad (6)$$

$K_{clutter}$ is included in A parameter like following

$$A=10\log_{10}[\alpha p_T f_a(\phi,\theta) g_{max}]+K_{clutter} \qquad (7)$$

Having a general form to our propagation model in terms of path loss, we now list the three models applied in our study and propagation characterisation of Baixa.

a) Linear Regression Fit (RLF) $H(\text{d})=A_{reg}+B_{reg}\log_{10}(d)$ [2];

b) Okumura Baseline Fit (OBF) model [4].

c) In linear regression (in a logarithmic fashion) we got the parameters A_{reg} and B_{reg}. These parameters define straight lines $PL(\text{d})=A_{reg}+B_{reg}\log_{10}(d)$ that reasonably describe the propagation behaviour of the zone under study. These models are very attractive due to easiest to obtain, compute and integration in prevision software packages.

d) Okumura Baseline model was obtained from curves in Figure 41c) and Figure 41d) to 900 MHz and 1500 MHz, respectively in [5]. Value of 1500 MHz is the most close of the 1800 MHz found on Figure 41. The goal was to get the general expression

$$PL=A(f_{MHZ},h_{te})+B(f_{MHZ},h_{te})\log_{10}(d_{km})+\Delta G(h_{re}) \qquad (8)$$

where $\Delta G(h_{re})$ is the gain due to effective height of receiver antenna relatively to reference h_{te}=1.5 m

$$\Delta G(h_{re})=20\log_{10}[h_{re}/1.5] \qquad (9)$$

Equation (8) was interpolated with frequency f_{MHz} and antenna height h_{te} from the following expressions

$$PL_{900\text{ MHZ}}=A_1(h_{te})+B_1(h_{te})\log_{10}(d_{km}) \qquad (10)$$

$$PL_{1500\text{ MHZ}}=A_2(h_{te})+B_2(h_{te})\log_{10}(d_{km}) \qquad (11)$$

The functions A_1, A_2, B_1 and B_2 are obtained from Figure 41 in [5] taking in account that in Porto the heights of transmitting antennas not exceed 70 m and

2002 12th Int. Crimean Conference "Microwave & Telecommunication Technology" (CriMiCo'2002). 9-13 September, Sevastopol, Crimea, Ukraine
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distances with interest to this study also not exceed 20 km. Those functions were obtained from Tables 1 and 2, to 900 MHz and 1500 MHz. $A(f_{MHZ},h_{te})$ and $B(f_{MHZ},h_{te})$ were obtained after interpolating the two pairs of functions $[A_1(h_{te}), B_1(h_{te})]$ and $[A_2(h_{te}), B_2(h_{te})]$, respectively, giving

$$A(f_{MHZ},h_{te})=-116.6-0.0117f_{MHZ}+0.1h_{te} \tag{12}$$

$$B(f_{MHZ},h_{te})=B_a(f_{MHZ},h_{te})+B_b(f_{MHZ},h_{te}) \tag{13}$$

$$B_a(f_{MHz},h_{te})=-\left(37.525+0.441\frac{f_{MHz}-900}{600}\right) \tag{14}$$

$$B_b(f_{MHz},h_{te})=\left(0.0625-0.0025\frac{f_{MHz}-900}{600}\right)\times h_{te} \tag{15}$$

On Tables 1 and 2, path loss values were obtained from equation (4) in Hata [6].

Table 1. Values extracted from Figure 41c) in [5] for 900 MHz

H_{te} (m)	d_{km} (km)	Electric field strength dBμVm^{-1}	Path loss (dB)
30	1	74	-124
	10	38	-160
	20	28	-170
50	1	76	-122
	10	42	-157
	20	32	-167
70	1	79	-120
	10	46	-153
	20	36	-163

Table 2. Values extracted from Figure 41d) in [5] for 1500 MHz

h_{te} (m)	d_{km} (km)	Electric field strength dBμVm^{-1}	Path loss (dB)
30	1	71	-131
	10	35	-168
	20	25	-178
50	1	74	-129
	10	39	-164
	20	29	-174
70	1	76	-127
	10	42	-161
	20	32	-171

III. Experiment

Our work is based on measurements taken in Porto, more specifically in Baixa, due to great importance of this zone in terms of traffic. The measurements were made in collaboration with one Portuguese cellular mobile operator *VODAFONE* using one mobile station (MS) coupled to one laptop with TEMS from ERICSON integrated with one GPS receiver. Figure 1 shows the entire path of test-drive rendered with MAPINFO tool. Figure 2 shows Porto in detail.

The values acquired are temporal means in windows of 6 to 7 seconds. Due to the motion of mobile station at speeds about 60 km.h^{-1}, in one second at 900 MHz, we have distances between 300 to 350 wavelength λ.

During complete test-drive the mobile station made systematically handovers inter-cell and intra-cell to kept the power of the signal received above –85 dBm. According *VODAFONE* this is the minimum value to maintain one call with acceptable subjective quality. Figure 3 shows the power at mobile station during the complete test-drive. On that figure the changes on trace occurred when the mobile station made an handover.

Results comparison was made taking in account the power of the received signal, the power predicted by our three models as well as the positions and sectors related to fixed stations (FS) in the zone under study. This rectangular area is defined by co-ordinates in the two opposed vertexes, the upper left corner at (41º09´50´´N,08º06´47´´W) and the inferior right corner at (41º08´34´´N,08º06´15´´W).

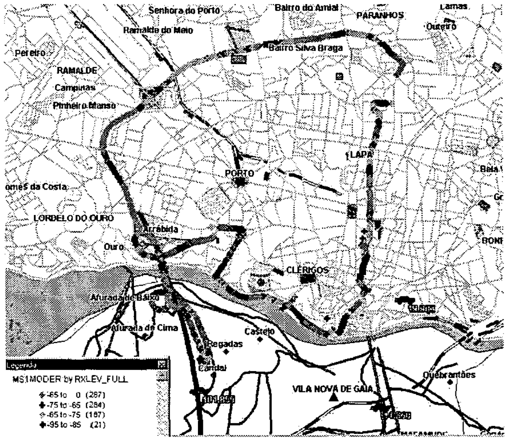

Figure 1. Full path of test-drive rendered with MAPINFO

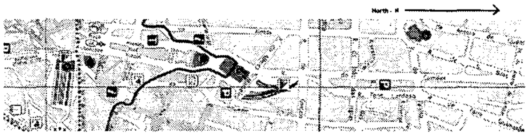

Figure 2. Baixa in detail

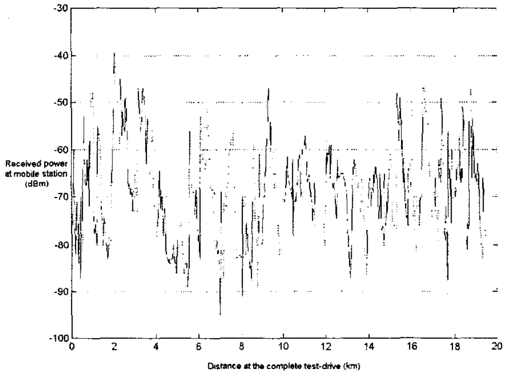

Figure 3. Power (dBm) during the complete test-drive.

The well knowledge of pattern radiation of the antennas at fixed stations was a mandatory requirement. The fixed stations are:

a) FS 2828 at (41º09´39´´N,08º06´36´´W), with only one antenna (omni-direcional) down-tilted mechanically 3º to North, in our study is "Hospital Santa Maria";

b) FS H271 at (41º09´26´´N,08º06´32´´W), with three symmetric sectors, in our study is "Faria Guimarães";

c) FS H2026 at (41º08´45´´N,08º36´26´´W), with three sector symmetric sectors, in our study is "Batalha".

Test-drive path at Baixa followed started at point (41º09´40´´N,08º36´36´´W) and finished at point with coordinates (41º08´43´´N,08º36´39´´W).

Straight logarithmic lines shown in Table 3 were obtained from regression of power of received signal at mobile station during test-drive. Path loss formulas on Table 3 and on Figures 4 and 5 that show for each model the power prevision of the signal received, were obtained for each position *i* of MS on the test-drive [5].

$$PL_{observed}(d_i)=P_{observed}-EIRP_{jk}-F_a(\theta_{jk},\varphi_{jk}) \qquad (16)$$

$$P_{predicted}(d_i)=EIRP_{jk}+F_a(\theta_{jk},\varphi_{jk})+PL_{predicted}(d_i) \qquad (17)$$

where

$PL_{observed}(d_i)$: real path loss (dB);

$PL_{predicted}(d_i)$: predicted path loss (dB);

d_i: distance between antennas with MS at point *i* (m);

$P_{observed}(d_i)$: power of the received signal (dBm);

$P_{predicted}(d_i)$: predicted value for power of the received signal (dBm);

$EIRP_{jk}$: power *EIRP* (dBm) radiated on antenna *k* from the FS *j*, already includes the value of the directive gain in the direction of maximum gain g_{max};

$F_a(\theta_{jk},\varphi_{jk})$: effect of normalised radiation pattern of antenna *k* on FS *j*;

θ_{jk} and φ_{jk}: vertical and horizontal angles from the antenna *k* in FS *j* with respect to the antenna axis of the MS.

Table 3. Path loss lines obtained by regression

Fixed Station	Logarithmic straight lines (dB)
Hospital Santa Maria	$PL(d)=-34.92-34.06\log_{10}(d)$
Faria Guimarães	$PL(d)=33.00-58.27\log_{10}(d)$
Batalha	$PL(d)=389.97-194.11\log_{10}(d)$
Combination of three FS	$PL(d)=-33.41-29.09\log_{10}(d)$

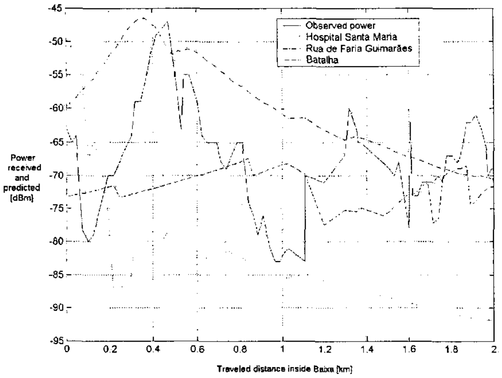

Figure 4. Behaviour of predicted power with RLF model versus observed power (dBm)

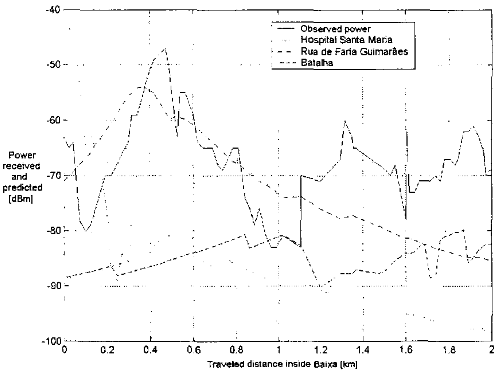

Figure 5. Behaviour of predicted power with OBF model versus observed power (dBm)

In Figures 6 and 7 are ilustrated individual and combined prevision at Porto downtown, obtained from selection of maximum value (of three previsions due each FS), to RLF and OBF models, as well as test-drive path inside downtown.

Figure 8 ilustrates received and obsered power (dBm) inside downtown during test-drive.

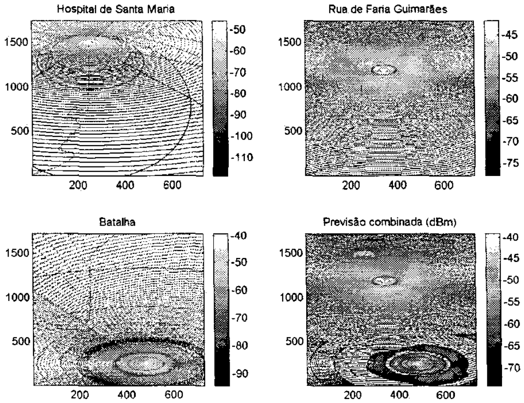

Figure 6. Individual and combined prevision (dBm) with RLF model

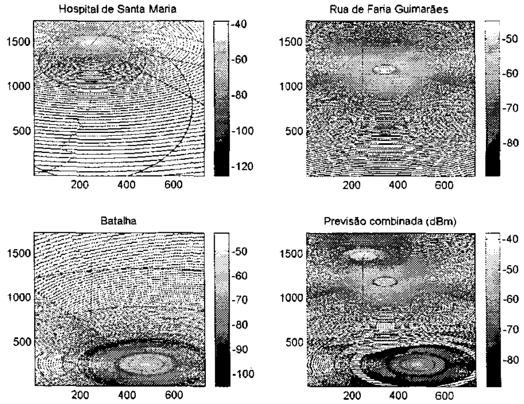

Figure 7. Individual and combined prevision (dBm) with OBF model

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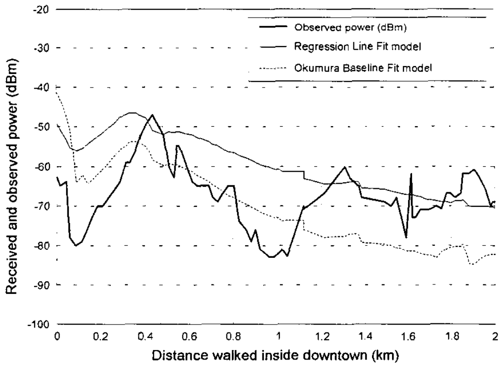

Figure 8. Received and obsered power (dBm) inside downtown during test-drive

Table 4 was constructed taking in account that for each position i of the MS in the test-drive had one absolute error ε_i given by

$$\varepsilon_i = |P_{predicted}(i) - P_{observed}(i)| \quad \text{(dB)} \qquad (18)$$

where

$P_{observed}(i)$: power of the signal received (dBm);

$P_{predicted}(i)$: prevision to the power of the received signal (dBm).

The mean of the absolute error and the standard deviation are, respectively,

$$\bar{\mu} = \frac{\sum_{i=1}^{N} |\varepsilon_i|}{N} \quad \text{(dB)} \qquad (19)$$

and

$$\sigma = \left[\frac{\sum_{i=1}^{N} \left(|\varepsilon_i| - \bar{\mu} \right)}{N} \right]^{\frac{1}{2}} \quad \text{(dB)} \qquad (20)$$

where N is the number of total samples acquired during the test-drive.

Table 4. Mean of the absolute error and respective tandard deviations

Fixed Station	Model	$\bar{\mu}$ (dB)	σ (dB)
2828	RLF	17.69	0.99
	OBF	21.68	1.04
H271	RLF	10.24	0.89
	OBF	9.44	0.75
H2026	RLF	7.56	0.72
	OBF	16.80	1.11
Combination of three FS	RLF	0.16	1.56
	OBF	0.15	1.42

IV. Conclusions

The first three straight in RLF model are in accordance with local propagation conditions near its FS. However the fourth straight line due to combination of all FS is more appropriated to caracterization of all downtown due to low absolute error of 0.16 dBm with a standard deviation of 1.56 dB. The propagation factor n=2.91 is well suited.

Like in RLF model, OBF model is very suited due to low absolute error of 0.15 dB and a low standard deviations of 1.42 dB.

To conclude, RLF and OBF models agree very well with real propagation conditions in Porto, as had been confirmed with prediction tools of *VODAFONE* applying our parameters, due to be obtained with terrain caracteristics.

V. References

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Acknowledgement

The author is indebted to vodafone who made possible the test-drive in Porto, as well as all support given in terms of means and access to the facilities.