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Software tool for optimising indoor/outdoor coverage in a construction site

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A system architecture, an empirical propagation model, and a software combined with a CAD tool, have been designed to offer mobile communication services to construction sites. Results have been validated by measurements.

Introduction: Mobile communications technology is today robust and portable enough to be introduced into the construction sector as a way to improve the overall product quality and the work force safety. Base stations (BSs) linked by cable are typically used for indoor mobile systems, but in buildings under construction the installation of fixed cables should be avoided [1] and therefore other ways to offer coverage have to be employed. We propose the use of conventional BS installed outdoors, but in the building vicinity. In particular a DECT system is retained because of its suitability in such scenarios, so that the BSs and their controller can be in a communications container (hub). The increase in attenuation due to both a higher distance between terminals and external wall losses can be overridden by the use of directive antennas, the number of required antennas being dependent on building topology and distance to the hub. Instead of ray tracing or ray launching techniques, which are much more time consuming, we use a distance and partition dependent path loss empirical model [2, 3]. A measurement campaign was carried out to obtain wall loss factors at DECT frequencies, and also to validate the propagation model.

Propagation model: The model considers free space propagation and the additional path loss, caused by the incidence angle and the physical obstacles that lie between transmitter and receiver, is added. The model should account for: the difference between the floor plan that is at the same height level than the BS and the rest of floors, and the effects of the angle of illumination (angle between the BS antenna and the surface of the external wall). Received power is calculated by

$$P_R[\text{dBm}] = P_T[\text{dBm}] + G_T + G_R - L_{desc} - t(\varphi) - L \quad (1)$$

where P_T, G_T, G_R and P_R the transmitted and received power and antenna gain, respectively, L_{desc} the lack of adaptation in the antenna (2.2dB is considered), $t(\varphi)$ the transmitter antenna radiation diagram and L the path loss. Total path loss is given by the following expression [3] (Fig. 1):

$$L[\text{dB}] = L_0 + 20\log(S + d) + Le + LGe\left(1 - \frac{D}{S}\right)^2 + \max(\Gamma_1, \Gamma_2) \quad (2)$$

with

$$\Gamma_1 = \sum_{i=1}^{I} k_i L_{wi} \qquad \Gamma_2 = \alpha(d-2)\left(1 - \frac{D}{S}\right)^2$$

where L_0 is the 1m free space propagation loss, D and d are the perpendicular distances from the external wall to the BS and mobile, respectively, and S is the physical distance between the BS antenna and the external wall at the actual floor. The grazing angle θ is calculated as $\sin\theta = D/S$ and changes considerably with floor height at short distances D. Le is the attenuation of the external wall at perpendicular illumination and LGe is the additional loss when $\theta = 0°$ (20dB is considered). $\Gamma 1$ is the attenuation due to internal walls, where Lwi is the attenuation due to a wall of type i and ki the number of walls of type i in the line between the transmitter and receiver. If there are no internal walls, the additional loss is given by $\Gamma 2$ with α the extra attenuation in dB/m (~0.6dB/m is considered). Four different types of wall are considered: light walls (non-supporting wall such as plasterboard, wood, L_{w1}: 1.5–3dB), medium walls (thin concrete or brick walls, L_{w2}: 4–6dB), heavy wall (concrete wall, L_{w3}: 7–10dB) and external walls (loss changes from 7 to 12dB). It is important to note that the loss factors are not physical losses but model coefficients which are optimised by multiple linear regression to the measured path loss. So the values include the effect of furniture, diffraction and scattering as well as the signal path guided through corridors.

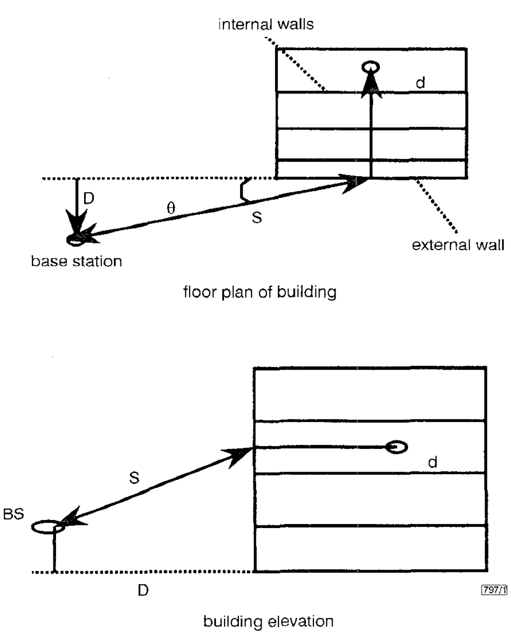

Fig. 1 *Parameters used in propagation model*

System architecture: All the required BSs are placed outdoors and can be connected to the BS controller via cable inside the hub container. Moreover, this network layout allows the container to be moved from one construction site to another as needed, avoiding costly network deployment with indoor BS layout. Owing to the low transmitted power specified in the DECT system and to cope with building penetration losses, directive antennas will be used. This allows us to illuminate only the building to be covered reducing interference with other systems. The antenna gain, the radiation beamwidth and the distance between the antenna and the building determine the number of floors to be covered by one single antenna and then if more antennas are required.

Software tool: An interactive software tool for assisting in BS placement, which is intended to be easy to use, has been designed. After the user has selected a possible BS location within a graphical building plan, the system interprets the building plan and uses the proposed path loss model to estimate coverage regions. The software tool allows arbitrary antenna radiation patterns and orientations (and includes a database of commercial antennas). It can also deal with arbitrary building topology and construction materials. The predicted signal level is represented in different colours and in 3D as the building is in progress, therefore offering the possibility of designing the DECT network in an active way, choosing the best configuration at each construction stage the software is programmed in AutoLisp and in C language and runs combined with AutoCAD (at least the 13th version). A database is generated with information about different construction materials at the frequency band of the DECT system allowing the association of building walls, windows, etc. to building materials from the database and therefore to attenuation.

The software is structured by menus and submenus. Interactivity is also possible as system parameters can be changed through the program. There are functions to help in choosing automatically the best antenna type and position accounting for the possibility of having more than one antenna. In this case, the coverage area is represented with an indication of which antenna is the best server at each floor plan and also giving the coverage percentage obtained with each antenna. The possibility that at the final construction stage perhaps it will be difficult to reach some locations of the building due to obstacle shadowing (walls and ceilings already constructed can introduce considerable attenuation) has been also considered. In this case, there is the possibility of locating a repeater (directive antenna pointing towards the BS and omnidirectional antenna for the coverage of the floor(s) to obtain a global coverage of the building). Repeater coverage could also be represented. As an example in Fig. 2 the received power for a given area inside the building is represented in different colours.

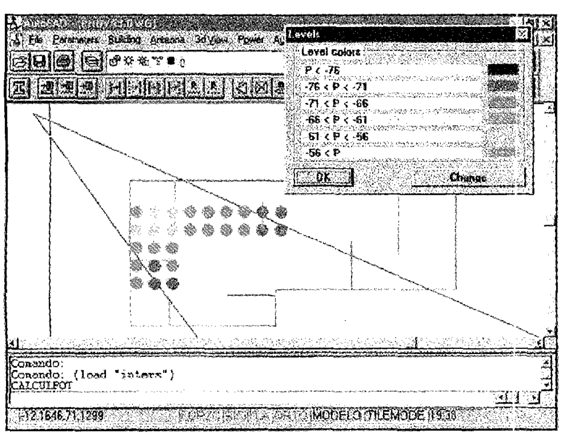

Fig. 2 *Received signal level in area inside building*

Measurement campaign: A signal generator (HP8644A) was used as the transmitter. Both a $\lambda/4$ monopole and a directive antenna were used as transmitters, the receiver being a $\lambda/4$ monopole connected to a spectrum analyser (HP8561A). The video output of the spectrum analyser was connected through an acquisition card to a personal computer. Fading due to movement was removed by averaging. Some of the wall loss factors obtained are given in Table 1. To validate the model more measurements were made for different BS antennas and illumination angles, comparing predicted and measured received power through the calculation of the RMS error. We found that the mean error is very low (0.7dB) with a deviation of ~ 6.4dB, which is of the same order as most mobile power prediction models.

Table 1: Empirical wall loss factors

Type of wall	Attenuation
	dB
External wall (first floor)	7.7
External wall+windows+balcony	12.4
Internal brick walls	5.2
Staircase	6.9
Concrete internal walls	10.5
Lift	29.1

Conclusions: Existing simulation tools do not take into account the fourth dimension on a construction site: time. They also seldom support specific systems such as DECT, devices such as directional antennas, and environments such as, for instance, those required to operate in a mixture of indoor and outdoor scenarios. Our work enables construction companies to plan the DECT network in advance for the full duration of the construction project.

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Carry-select adder using single ripple-carry adder

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Instead of using dual carry-ripple adders, a carry select adder scheme using an add-one circuit to replace one carry-ripple adder requires 29.2% fewer transistors with a speed penalty of 5.9% for bit length $n = 64$. If speed is crucial for this 64bit adder, then two of the original carry-select adder blocks can be substituted by the proposed scheme with a 6.3% area saving and the same speed.

Introduction: The carry-select adder (CSA) [1] provides a compromise between a small area but longer delay carry-ripple adder (CRA) and a larger area with shorter delay carry look-ahead