Modified Monte Carlo scheme for high-efficiency simulation of the impulse response on diffuse IR wireless indoor channels

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These were used with our simulation results for estimating overheads. For instance, our simulations with an 8 × 8bit multiplier revealed that, using the conventional and the new multiplication algorithms, the average switched capacitance per multiplication is 14.88 and 5.23pF, respectively. Hence, the switched capacitance of the shifter was calculated to be 14.88 – 14.88 × 97.67/100 = 0.34pF. This is added to 5.23 to account for the shifter overhead. For this reason the net reduction for the above multiplier with our algorithm is 62.56%. The above procedure was repeated for both 16 × 16 and 24 × 24bit multipliers. The results show that overheads are between 1 and 3%, as can be deduced from Table 2.

Conclusions: This Letter presents a power saving algorithm for the implementation of digital filters on CMOS DSP systems. The algorithm aims to reduce the amount of switched capacitance within the multiplier section of the filter, this being the most computationally intensive part of the DSP, through fragmentation of the coefficients into two primitive parts, which can be processed with a significant reduction in the amount of switched capacitance. Results have been presented which indicate significant power savings. Although the algorithm has been demonstrated with FIR filter examples and two's complement representation, it can be generalised to most types of digital filter implementation using different data representations.

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Modified Monte Carlo scheme for high-efficiency simulation of the impulse response on diffuse IR wireless indoor channels

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A modified Monte Carlo method to calculate multipath dispersion due to wall reflections on indoor wireless diffuse optical channels is presented. As with other Monte Carlo methods, it allows evaluation of not only the Lambertian but also specular reflections and can be used to validate previous simulation schemes. The main difference is that for each ray traced and for each rebound, a contribution to the receiver is calculated. This leads to a faster and more accurate simulation.

Introduction: A modified Monte Carlo algorithm for the calculation of the impulse response on infrared wireless indoor channels is presented. This work follows guidelines for studies of infrared (IR) wireless diffuse data communications systems. As is well-known, the characteristics of the room where the IR diffuse channel is implemented determine some communication problems, such as multipath penalty over the maximum baud rate or 'hidden station' situations. Classical algorithms [1, 2] require a high computational effort to calculate the impulse response in a regular sized room. The Monte Carlo method [3] makes it possible to validate the assumptions made for these classic algorithms (basically, the Lambertian nature of all reflections) with a computational complexity determined by the accuracy desired by the user. It is also a structure that can easily be assumed by a parallel computer architecture. Conversely, its main drawback is that, for a regular sized room, we need to send many more rays than the number of components that we will receive. This is because rays are not usually intercepted by the receiver. We have developed a mixed Monte Carlo deterministic algorithm which assures that each ray contributes to the final channel response function each time it rebounds against an obstacle. It dramatically increases the number of contributions and reduces the time required for an accurate simulation.

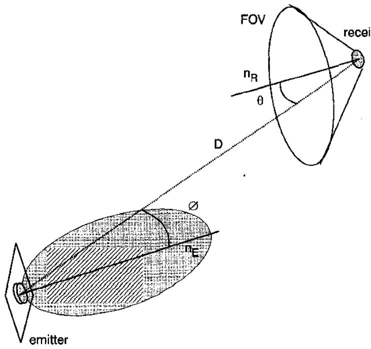

Fig. 1 *Angles used to calculate received power for LOS component*

Description of algorithm: The Monte Carlo diffuse IR channel response estimation procedure is split into three stages: ray generation, wall processing and calculation of the channel response. The walls (including the ceiling and floor) are defined by their reflection coefficient ρ at each point. We also define a diffuse-to-mirror ratio (DMR) depending on the incidence angle, which determines the amount of the incoming power that is specularly reflected or scattered. The DMR is a function of the roughness of the material [3]. The emitter is considered to follow a generalised-Lambertian profile [4], with a modal number *m* that defines the directivity of the emitted beam and is given by its position and its pointing direction. Monte Carlo modelling allows us to easily transfer this assumption to other radiation profiles, such as Gaussian or user-defined. The receiver is considered to be a semiconductor photodiode, defined also by its position and its pointing direction, and by two other characteristics: active area and the field of vision (FOV) [4]. It is also easily included that the effect of lenses in the emitter, receiver or both, is usually considered aspheric and is defined by its diameter (*d*) and focal distance (*f*).

The ray generation step depends on both the radiation profile and (for extended Lambertian sources) on the modal number *m*, as a measure of beam directivity. Rays are generated using the method proposed in [3]. In the wall processing stage, the first issue to be considered is the *impact* point of the ray, and whether it is on the receiver (line-of-sight (LOS) contribution) or in a wall (and in which wall). This is done through the use of a rotation matrix which relates the emitter position and the ray direction with the absolute coordinates of the room. Once the impact point is calculated, we can separate two components: the *LOS* (if it exists) and the *diffuse* components. The LOS component from the reflector to the receiver is calculated by

$$P_{LOS} = \frac{1}{\pi \cdot R^2} \cdot \cos(\theta) \cdot \cos(\varphi) \cdot A_r \cdot K(FOV) \qquad (1)$$

where we consider $m = 1$ (as it is a pure Lambertian scattering). A_r is the active area of the receiver and $K(FOV)$ is a retine function that indicates whether or not the incoming ray is seen by the receiver (depending on its FOV). R is the distance between the emitter and the receiver and will decide to which position of the received power vector this power should be added (as is detailed in the following). The angles indicate the ratio as a function of deviation from the centre of the radiation profile (Fig. 1). Note that, most of the time, all rays produce as many components as they suffer reflections. This makes this algorithm far more efficient than the classic Monte Carlo method, as only a fraction of the rays are required to produce sufficient power contributions.

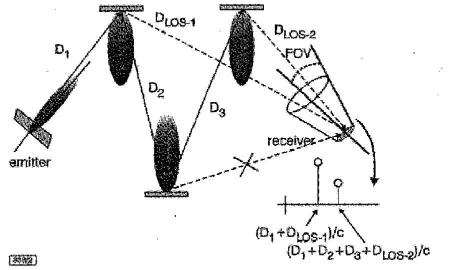

Fig. 2 *Ray is scattered (or reflected) until path length exceeds a given value*

Each time it arrives at a reflector (and LOS component lies inside FOV), a power contribution is added to $h(t)$. Delay spread is equal to path length divided by light speed

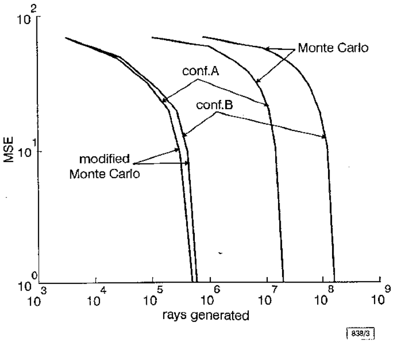

Fig. 3 *Comparison of required computational complexity for both Monte Carlo and modified Monte Carlo models*

Conf. B: diffuse system with emitter and receiver near corner

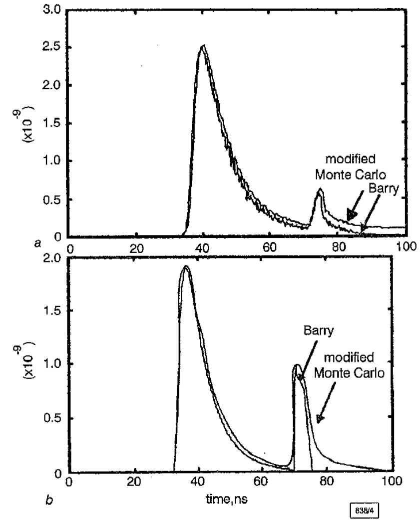

Fig. 4 *Comparison of simulated h(t) functions for Barry and modified Monte Carlo algorithm*

a Configuration A
b Configuration B

The remaining power is reflected or scattered (as is determined by the DMR expression). For the scattering component, the output power is obtained by multiplying the incoming power with the reflection coefficient ρ at the impact point (Fig. 2). The output ray direction is calculated as for the emitter [3]. In this case, the radiation profile will have $m = 1$ in the ray-generation routine in all cases. For the specular contributions, the output direction of the ray is then strictly determined and no further calculation other than the output power is needed. In both schemes, we have to keep the path length described by the ray, so as to have the time dispersion on the receiver. Once the output direction and power have been calculated, the procedure is repeated in the next wall. In this case, as the number of contributions per ray is much longer than in the classic Monte Carlo method, we can make a more accurate simulation, using receiver areas closer to commercial equipment (~ 1mm²). Incoming power is added to a vector(s) representing the temporal evolution of the power in the detector(s), which is the objective of the simulation. We continue processing it until the path length (divided by light speed) exceeds the desired simulation time of the impulse response.

Table 1: Data used in simulations

Parameter		Conf. A	Conf. B
Room	Length (x)	10	10
	Width (y)	10	10
	Height (z)	3	3
	ρ_{North}	0.8	0.8
	ρ_{South}	0.8	0.8
	ρ_{East}	0.8	0.8
	ρ_{West}	0.8	0.8
	$\rho_{Ceiling}$	0.8	0.8
	ρ_{Floor}	0.3	0.3
Source	Mode	224′46	45′27
	Position (x)	0.1	0.1
	Position (y)	0.1	0.1
	Position (z)	1.5	1.5
	Elevation	45°	45°
Receiver	Area	1cm²	1cm²
	FOV	40°	40°
	Position (x)	9.0m	1.0m
	Position (y)	1.0m	9.0m
	Position (z)	1.5m	1.5m
	Elevation	45°	45°

Results and discussion: The algorithm was implemented in a Pentium II based PC, using the MICROSOFT® Visual Basic compiler. The room sizes for the test, and the data of the simulation are given in Table 1. Fig. 3 shows the time responses for the receivers (compared with other methods [1]), while Fig. 4 compares the number of rays needed with the classical Monte Carlo [3] simulation as a function of the medium-square error (compared with iterative methods). It can be seen that these complexity values are even more different when a pure diffuse channel, with emitter and receiver near obstacles, is considered.

Conclusions: The method presented here is much faster than Monte Carlo classical simulation schemes. It can be used as a method of simulation itself or as a validation algorithm for other comparative studies of pulse broadening.

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