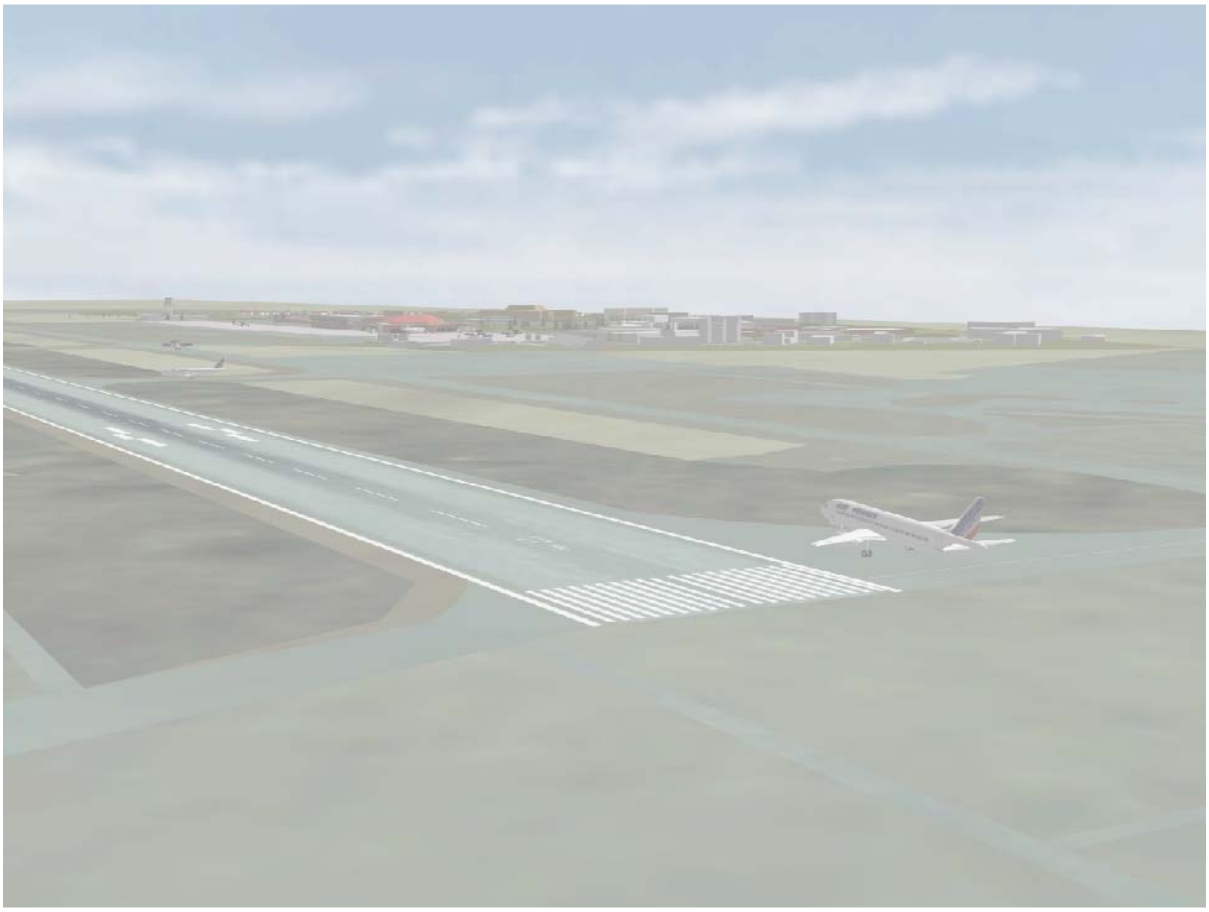
Contract N°: AST3-CT-2003-502817

Dissemination report: Technical requirements



CONTENTS

0. Introduction

0.1 General presentation

This report will focus on the level of detail, which is required for the modelling of the different features that will be represented.

0.2 General approach

The goal: to split the technical requirement into different exhaustive under categories:

- Static modelling of the synthetic environment.
- EM exploitation and rendering: dynamic computation at reception points.

0.3 Context

0.3.1 General definition of a 3D model for EM simulation

A virtual mock-up, as modelled in SIRENA, is made of:

- A geometrical representation of the scene
- Visual textures that are mapped on the polygons
- Physical information for EM simulation, associated with the scene and the objects
- Physical information for EM simulation, associated with sources and receivers

0.3.2 Level of detail

The notion of level of detail (LOD) has been created, in order to manage several representations for the same object and so optimise real time performances.

It is important to distinguish two different concepts:

- The object polymorphism
- The way to manage these representations in the targeted application

0.3.3 Use of texture for database enrichment

The use of texture has two essential functions:

- To improve the rendering of a database
- To minimise the amount of polygons in the database

0.3.4 Texture classification

The classification process is used in order to create textures for physical simulations, from visible textures. The classification process is a photo based interpretation that provides raster information characterizing the physical material distribution.

1. Geometrical detail required for the 3D modelling of the scene

1.1 Definition of the required detail depending on the wavelength

1.1.1 General principle

Asymptotic formulations will be used to model the interactions between EM waves and the structures surrounding the airport.
The starting point in EM computation is the comparison between the size of the analysed object and the wavelength λ.

Moreover, this EM computation code requires the modelling of details and features as large as the wavelength (λ).

This leads to the following constraints for the modelling of the scene for the high frequencies and low ones:

- At the high frequencies the precision on the physical details of the scene can be limited

- At the low frequencies, X λ is the smallest size for objects which could be correctly modelled.

1.1.2 Physical assumptions

The greatest dimension of an interaction is the size of the longest segment that could be inscribed in the surface element that radiates or reflects the wave.

1.2 Detail required for the modelling of internal parts

For free space wavelengths greater than X m, the following assumptions can be made:

- Buildings are nearly transparent.
- Their effect is a slight attenuation of the incident field.

For free space wavelengths smaller than X m, it is assumed that the field only goes through apertures.

For metallic buildings such as hangars, it can be assumed that they are completely opaque to incident EM field.

1.3 Typology of buildings, terrain, vegetation and infrastructure

Depending on the wavelength, the geometrical detail required for a given object is quite different. It is clear that a detail inferior to X λ can be neglected.

Nevertheless, some specific parts of objects must be analysed cautiously:

- A long edge can be an important detail even if this detail profile is smaller than 3 λ.
- The suppression of some details must not create geometrical discontinuities susceptible to impact the EM field value
- For a building façade, the main question is the necessity or not to take into account the 3D details of the façade
- A simple metallic wire, constituting a dipole, isolated or surrounded by objects, can be important due to the EM re emission.

2. Required accuracy for the physical description of the scene

2.1 General description of the material properties

Specific features and textures related to infrared, optics and electromagnetism are provided for each polygon of the scene database and for each polygon of the objects.

Generally, for EM analysis, two classes of materials can be defined: the metallic and dielectric materials and the environmental clutter.

2.2 Definition of the required detail for terrain materials

Very sparse information is available concerning values and variations of usual man made and natural materials, versus frequency.

However, the following assumption is made, concerning the influence of an inaccurately defined material on the EM field values that will be computed: in such a complex environment, this influence is negligible for sparsely represented materials.

Backscattering coefficient average σ_0 characterises each category of clutter. Moreover, real simulation values for σ are obtained by including statistical fluctuations such as Rayleigh for speckle effects.

This leads to the conclusion that materials that have a great electric discontinuity with air should be all the more angularly sampled.

2.3 Classified texture methodology

The use of texture for the modelling of the terrain is a good means of optimisation.

Moreover, in the scope of a generic tool for airport simulation, this operation does not require a specific know-how, as opposed to computer graphics for geometrical modelling.

In the framework of SIRENA, we are dealing with electromagnetic (EM) waves from different sources at their own specific frequency. The same previously described classification process is used in order to create textures for EM simulations. In addition to the geometrical description, the database contains all the parameters required for the EM simulation.

3. Definition of the accuracy of 3D modelling of the target aircraft

3.1 Geometrical modelling of outer geometry

OKTAL SE Company is able to model virtual 3D geometrical databases composed of complex objects.

Concerning the aircraft modelling, the new requirements are due to the curved shapes of the objects that require specific EM formulation or very high density meshing before computation.

3.2 Geometrical modelling of inner parts (layers, inner objects) & associated methodology

Required level of modelling of the internal parts depends on:

1. The transparency (from an electromagnetic stand point) of the aircraft skin
2. The frequency range to be considered
3. The point of view i.e. if we are interested in the field inside or only outside the aircraft

The reason for the point 1 is that the field outside the aircraft may penetrate inside mainly by direct propagation through the windows and by diffusion through the skin of the aircraft.

The point 2 is linked to point 1 because the direct propagation through the apertures may become important for wavelength smaller than the aperture size.

4. Definition of the accuracy of physical material for the target aircraft

4.1 Introduction

In the scope of target aircrafts, only two kinds of materials are to be taken into account:

- the metallic materials
- the dielectric materials

Metallic or dielectric materials follow the Fresnel reflection coefficients

Dielectric materials are characterised by their dielectric permittivity and magnetic permeability.

4.2 Material modelling methodology

Most of the civilian aircrafts have their structure skin done with aluminium. This material can be considered as perfectly metallic.

Nevertheless, the SIRENA tool will enable to manage dielectric materials in the scope of future applications.

5. Definition of accuracy of EM emitting source modelling

5.1 Definition of the EM sources properties

The complete modelling of EM interaction between the incident wave and the scene implies the use of Geometrical Optics (GO), Physical Optics (PO), Uniform Theory of Diffraction (UTD) and Physical Theory of Diffraction (PTD) either in near or far field expressions.

5.2 Definition of the emission diagram format

The diagram format takes into account:

- the spatial variation of the antenna gain
- its polarisation: linear, circular (or elliptic in general) and left or right

5.2.1 Near field condition

For a given antenna, in the near field condition, it is necessary to know the amplitude and phase values:

- For any direction in space.
- For any range, independently from E and H fields
- For each polarisation.

5.2.2 Far field condition

A possible implementation is to describe the spatial variation of a normalized field radiated by the antenna.

5.3 Antenna decomposition into unitary elements

The distance from which, this condition of far field is established is proportional to the square of the size of the antenna and inversely proportional to the wavelength.
If these requirements are not satisfied, one possibility consists in a specific subdivision of the whole antenna into “smaller” ones in order to reduce the far field distance

6. EM receiver modelling accuracy

The basic problem with receivers is that it is nearly impossible to make assumptions on the directions and more generally on any characteristic of incident EM field.

Moreover, it remains difficult to really characterise a receiver. As a matter of fact, the model really depends on the receiver geometry.

To accurately define a receiver modelling, more than previous features are required.
The phase centre definition is one of the most important.

7. Forecasted simulation issues

7.1 The fundamental technical approach in the scope of SIRENA

A typical airport scene area is about 3 x 5 kilometres. The critical required wavelength is about 3 millimetres, which implies a geometrical sampling of at least one millimetre.

SIRENA requires "asymptotic methods".

The first analysis clearly shows that several hundred thousand of polygons are needed for scene description.

The critical limitation relative to the amount of polygons leads to a **spatial subdivision based on a ray tracing approach**. A spatial subdivision method enables to get a perfect knowledge of the scene topology before the first computation.

The critical limitation relative to the rays leads to a **forward ray tracing method** and then to a **lazy ray tracing method based on antialiasing**.

The classical ray tracing method is called the "*backward*" approach. The possible ways of propagation between a source point and a reception point are explicitly computed using complex algorithms or analytic formulas.

The "*forward*" approach: the general idea is to cast rays "blindly", in all direction from the source point to the 3D environment, and to refine in the "good" direction, at each level of recursion.

The lazy ray tracing method consists in tracing rays only if necessary: the idea is to trace rays only in the relevant direction.

The associated algorithm for "sparing rays" is called antialiasing. The most important antialiasing criteria are the number of different polygons in the ray spot, the number of different materials, and the normal vector variation within the ray spot.

The critical points in the scope of SIRENA:

- Number of reception points
- Sources aperture
- Sources number
- Number of frequency
- Scene size

7.2 Computation time limitations

- **Reception points number:** the computation time is proportional to the number of reception points

- **Sources aperture:** the resolution and anti-aliasing mechanisms seem to be incomplete to insure good performances on large aperture sources

- **Number of sources**: computation time directly depends on the number of sources, large sources must be decomposed into several little sources.

- **Number of frequencies**: only one frequency per source will be used.

- **Scene size:** low power contributors, or contributors far from the reception point, have the same importance as the main contributors.

8. Definition of the level of sophistication of the physical EM models to be implemented

SPECRAY EM is the kernel ray tracing of the FERMAT workbench.

8.1 Methods of definition

FERMAT associates various techniques and tools. Currently, EM models related to surface and edge contributions have been investigated and implemented during the development of the FERMAT code.

8.2 Processing of dielectric transmission

A specific tool enables to create dielectric materials contribute to the EM scattering from surface computation. It could also be useful to compute EM transmission through these dielectric materials using GO or/and PO models.

8.3 Diffraction processing

Another FERMAT tool enables to specify the different edges to take into account.

9. Acceptable limitation of the physical model due to curvature and associated requirements

9.1 Processing of geometrical divergence in the scope of GO and UTD models

In FERMAT, GO and UTD models are used to evaluate the scattered near field from each interaction.

9.2 Associated physical model for non plane surface limitations and requirements

Through the definition of test cases, investigations are ongoing concerning new formulations using radii of curvature of incident wave. A trade-off must be found to avoid the burden in computing these parameters for each interaction of ray.

9.3 Impact on the meshing strategy and interest of NURBS

9.3.1 Physical Optics point of view

The chordal deviation function of wavelength is the good criterion to tessellate an object. Tessellation or ray-tracing sampling gives the same result. Even if we deal with analytic objects, using the current Physical Optic model, we will have to sample the object with this same criterion.

10. WP2 conclusion

10.1 Main WP2 issues

WP2 gives all the necessary rules in order to model the 3D objects and characterizes the physical materials of the airport scene with respect to physical constraints. These rules concern both airport terrain and targeted objects.

Goal: to check that the FERMAT workbench is compliant with SIRENA technical requirements, both in term of physical realism and time performances.

10.2 Main WP2 arisen problems

The main difficulty encountered concerns the EM kernel, based on ray tracing.
We can assume that the SIRENA technical effort will focus on ray tracing optimization.

Another problem has not been completely solved in WP2, concerns the necessity of improving the physical model due to curved surfaces and/or the necessity to introduce analytic geometrical models such as NURBS in addition to polygons.