Summary

This thesis "A Theoretical Investigation into Steel Surface Emissivity", arose out of a need from industry to more fully comprehend how the surface emissivity, an important parameter in the non-contact measurement of steel surface temperature, varied with the steel object's surface structure and its electrical properties. As well, the variation of emissivity with temperature and wavelength are required.

The surface emissivity of an object is directly related to its reflectivity. The industrial problem becomes an investigation of the reflective properties of a surface covered by iron-oxide layers of irregular configuration. It is thus an optics problem in the interference and scattering of electromagnetic waves.

The thesis is divided into three parts : Part 1, deals with an introduction to the thesis problem, see chapter 1; Part 2, considers the analysis of the optical problem from a multilayer interference viewpoint, see chapters 2, 3 and 4; Part 3 considers the scattering of electromagnetic radiation from layered surfaces, refer to chapters 5, 6, 7, 8 and 9.

Chapter 1 is an introduction to the area of non-contact temperature measurement (thermometry). Optical Pyrometry and millimetre wave Radiometry, the current method of temperature measurement, is discussed as well as the concept of emissivity. It discusses the formation of oxide layers on steel at high temperatures, their structure and electrical properties, the growth of layers and the structures possible in an industrial environment. Chapter 2, 3 and 4 analyse the Optical problem of the reflection characteristics of the combined steel/oxide structure. The theoretical aspects of reflection and refraction from these plane surfaces is discussed, as well as a review of current research in this topic.

Chapters 5 and 6 deal with the theoretical aspects of surface roughness and the scattering of radiation from such surfaces. Chapter 6 outlines the scattering approach used in this thesis. The theory of Beckmann (a modified version of Kirchhoff theory) used in the thesis problem is given, leading to a scattering integral and the determination of rough surface emissivity.

Chapters 7 and 8 are devoted to analytical solutions of the scattering integral for both unoxidised (ch 7) and oxidised (ch 8) surfaces. The fundamental work of this thesis is then outlined : the solution of the Beckmann scattering integral for dielectric periodic surfaces. The solution includes the influence of surface edges. It gives a simple formulation of both oxidised and unoxidised scattering coefficients in terms of the smooth reflectivity and a multiplier making up the roughness contribution. This simple expression gives rise to the complete scattering behaviour of the rough surface.

General conclusions for the entire thesis are then made in section 9.3, with a discussion of further possible research covered in section 9.4. Most of this thesis contains original work which contributes as follows :

1. Previous research on scattering of radiation assumed a single non-absorbing layer of oxide of constant low conductivity, when in fact :
   - Oxides are highly absorbing, section 1.4.
   - The oxides are semiconductors at high temperatures, section 1.4.
   - More than one layer of oxide exists, they are wustite, mgnetite and haematite, section 1.3.

2. Previous work concentrated on rough perfectly conducting surfaces and complex numerical models. The solution of this problem is made as follows :
   - A simple analytic solution is found with a straightforward physical interpretation for both oxidised and unoxidised surfaces, sections 7.8, 7.9, 8.3.
   - The solution specifically treats dielectric surfaces having finite conductivity, sections 7.8, 8.3.
   - The solution is easily extended to surfaces of infinite dimensions, section 7.2

For both the flat surface interference case and the rough surface case numerical simulation confirm the theoretical solutions, chapter 4 and 9.