BULL. AUSTRAL. MATH. SOC. 68A50, 78A45
VOL. 18 (1978), 307-309.

Radiation losses in dielectric optical waveguides

Ian Arthur White

The effect of irregularities and deviations from the perfect structure of the ideal waveguide is to scatter some of the guided power carried by the modes of the ideal waveguide incident on the irregularity. This scattered power is redistributed over the (non-attenuating) bound modes of the structure and into the radiation modes of the waveguide. The study of this redistribution of the power over the discrete (bound) mode spectrum can be adequately analysed by conventional electromagnetic Coupled Mode Theory. However, the application of this technique for the analysis of the radiative losses, that is, the coupling into the radiation modes of the waveguide proves to be extremely tedious due to the difficulty of normalisation and orthogonalisation of these "improper" modes. The aim of this thesis is to present alternative techniques to the Coupled Mode Theory analysis, which provide simple treatments of these radiation loss processes in weakly guiding dielectric optical fibres. The philosophy of the presentation is to present the technique and choose the least number of practical examples that elucidate the strengths and deficiencies of each approach, rather than list *ad nauseum* a wide range of practical examples.

In Chapter 1, a general background to the theoretical analysis of propagation in dielectric optical waveguides is presented, together with a qualitative introduction to the effects of irregularities and their relative importance in the design of a practical fibre optic communications network.

In Chapter 2, the bound electromagnetic modes of the weakly guiding

Received 9 March 1978. Thesis submitted to the Australian National University, August 1977. Degree approved, March 1978. Supervisors: Professor Allan W. Snyder, Dr Colin Pask.

https://doi.org/10.1017/S0004972700008157 Published online by Cambridge University Press

dielectric optical fibre of circular cross section with an arbitrary dielectric profile in the core and an infinite uniform cladding are presented in the azimuthal travelling wave form, namely, $\exp\{-il\phi\}$ variation. These results are derived within the approximation of ignoring all terms in the gradient of the dielectric permittivity. These modal fields are used as the basis of all the analysis of the remaining chapters.

In Chapter 3, the philosophy of the Volume Current Method for the calculation of the radiation loss due to slight imperfections in the ideal straight optical waveguide is presented. In particular, the radiation induced by small weak isolated dielectric irregularities and fluctuations in the core radius are analysed by this technique. Comparisons are made with the exact treatment (to first order in the perturbation) of Coupled Mode Theory, to display the validity of the method.

In Chapter 4, the breakdown of the Volume Current Method for paraxially directed radiation is discussed and a correction to the Volume Current Method is formulated, so that the simplicity of the analysis via the Volume Current Method is retained but the validity of the results extended. The correction based upon the harmonic time equivalent of the "method of images" in statics is applied to both planar and circular cylindrical structures.

In Chapter 5, the philosophy of the Surface Current Method which is derived from the Stratton-Chu Integral, is presented and applied to determine the tunnelling leaky mode power attenuation coefficient for the tunnelling leaky modes of arbitrary dielectric profile. In this chapter, we demonstrate the relative simplicity of the Stratton-Chu Integral for the radiation fields of the weakly guiding dielectric optical fibre when the azimuthal travelling wave modes are used.

In Chapter 6, this Surface Current Method is applied to the study of radiation losses due to slow bends in dielectric optical waveguides. The modal power attenuation coefficient of a mode incident on a planar bend of constant curvature is derived for slabs and fibres and compared with previously reported results. Ray optical analyses are used to elucidate the physical nature of the approximations utilised in the analysis and from those arguments, restrictions on the radius of curvature for which no significant field deformation and mode coupling occurs, are presented.

In Chapter 7, we summarise the major conclusions of this thesis and suggest directions for further research in this field.