INTERACTION OF ELECTROMAGNETIC PULSES WITH MOVING AND STATIONARY MEDIA

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Propagation of plane electromagnetic waves in moving/stationary media constitutes a fundamental and exciting field of electrodynamics. Whereas, the study of electromagnetic wave propagation in stationary media covers a wide variety of problems[1-4], the studies for moving media are largely confined to isotropic/anisotropic absorptionless steady state homogeneous cases[5-11]. Fewer studies appear to have been made in the field of electromagnetic wave propagation through inhomogeneous moving media[12-14]. Electromagnetic wave interaction with moving media has been a topic of current and wide interest because of its many possible applications. Thus it was considered worthwhile to devote the major portion of the thesis to the interaction of an electromagnetic pulse with moving isotropic homogeneous and inhomogeneous media.

Some interesting problems in the field propagation of electromagnetic pulses in stationary media have also been analysed; probably the most interesting one in this class is the distortion of a laser pulse after propagation through a cladded fiber.Laser radiations are very efficient carriers of information because of high information capacity of the optical spectrum. Glass fibers are being proposed as transmitting media for such beams[18-20]. Time bounded electromagnetic pulses are incident on the entrance aperture of the fiber, and on propagation through the fiber suffer delay and distortion. A realistic theory for the propagation of electromagnetic pulses through cladded fibers has been presented and found to be in reasonable agreement with experiment.

The thesis has been divided in three chapters: chapter I deals with electromagnetic pulse interaction with moving media, chapter II deals with the propagation of laser pulses through fibers and chapter III deals with modification of modulated pulses propagating through a waveguide. A chapterwise summary of the thesis follows:-

Chapter - I

Interaction of Electromagnetic Pulses with Moving Isotropic Media

Using the covariance of Maxwell's equations, the phase invariance principle of plane waves and the Fourier techniques, we have investigated the interaction of electromagnetic pulses with moving isotropic homogeneous/inhomogeneous media. This chapter has been divided into six sections as follows:-

1. Total reflection of electromagnetic pulses from moving plasmas.
2. Total reflection of FM electromagnetic pulse from a moving plasma.

3. Interaction of bounded EM beams with homogeneous isotropic media.
4. Reflection of Gaussian AM pulse from a moving inhomogeneous medium.
5. Reflection of electromagnetic pulses from a moving inhomogeneous plasma.
6. Electromagnetic pulse reflection from jet streams.

Section 1:

A theoretical investigation of the reflection of Gaussian pulses from an absorptionless plasma half-space or slab moving perpendicular to the interface has been carried out. It is seen that the nature of the reflected pulse depends strongly on the characteristics of the moving medium.

Section 2:

Reflection of a frequency modulated electromagnetic pulse from a moving homogeneous and lossless plasma half-space or slab has been investigated theoretically. Dependence of the reflected pulse on various moving plasma parameters and the modulation of the incident pulse is discussed.

Section 3:

The interaction of bounded electromagnetic beams with moving homogeneous dielectric half-space or slab have been analytically investigated. It is seen that the beam gets displaced at the boundary and the skipping is a complicated function of the velocity, direction of motion of the moving medium and the angle of incidence. Some numerical results have been presented to exhibit this dependence.

Section 4:

We have analyzed the reflection of an amplitude modulated Gaussian pulse at the plane of discontinuity in refractive index gradient in a uniformly moving, isotropic, inhomogeneous dielectric half-space. On the basis of covariance of Maxwell's equations and the principle of phase invariance, analytical expressions for the amplitude reflection coefficient for plane electromagnetic waves and the electric vector of the reflected pulse have been obtained. It is found that the reflection coefficient and the nature of the reflected pulse depends strongly on the velocity of the moving medium.

Section 5:

We have analyzed the problem of reflection of plane waves and Gaussian envelope amplitude modulated pulses from an inhomogeneous plasma, moving uniformly in a direction parallel to the plane of incidence and to the interface. The electron density is assumed to vary linearly in the plasma such that the moving plasma is described by a linearly decreasing dielectric constant profile. Some numerical illustrations have been presented which show the dependence of amplitude reflection coefficient, reflection point and the nature of the reflected pulse on the velocity of the moving inhomogeneous plasma, inhomogeneity parameter and the angle of incidence.

Section 6:

Reflection of plane Gaussian AM electromagnetic pulse from a laminar plane stratified jet stream has been investigated. Numerical results depicting the delay and distortion suffered by the pulse after reflection are presented.

Chapter-II

Propagation of optical pulses through cladded fibers: modified theory

Analysis of the propagation of laser pulses bounded in space and time, through a cladded fiber is presented. Following usual fourier technique, expressions for time delay difference and the broadening of the quasi monochromatic pulse are derived after the pulse has traversed certain length in the fiber. The skipping of the wave at the boundary upon reflection reduces the total path length, resulting in a smaller time delay difference. Results thus obtained show a marked improvement in agreement with experiment over the earlier theoretical results.

Chapter-III

Propagation of modulated electromagnetic pulses in waveguides

Waveform distortion when a transient pulse is propagating through a waveguide has been a topic of wide and current interest[21-27]. Most of the investigations are restricted to sinusoidal pulse, pulsed dc, rf signal and a short Gaussian envelope pulse; the studies are restricted to AM electromagnetic pulses. The FM pulse has an edge over the AM pulse because of two advantages viz., improvement in audioquality and reduction in noise. Using Fourier techniques the dispersion of an FM pulse after propagating through a waveguide has been studied and the optimum receiver bandwidth for such pulses is obtained.

The chapter has been divided into two sections. Section 1 deals with the propagation of FM pulses in waveguides and section 2 deals with the stretching and optimum receiver bandwidth for modulated pulses.

Section 1:

Transient propagation of an FM Gaussian envelope carrier pulse through a waveguide has been studied under realistic approximations. A qualitative comparison of the transmission characteristics of FM and AM electromagnetic pulse has been made in terms of the distortion of the pulse, pulse length etc. and the dispersion of the pulse is discussed by making use of Kelvin's principle of stationary phase.

Section 2:

Optimum receiver bandwidth for a modulated pulsed signal propagating through a dispersive medium is obtained by minimizing the stretching of the envelope. Bandwidth is shown to be strongly dependent on modulation and its dependence is discussed in detail.

The work reported in the thesis has resulted in the following publications:-

1. An investigation on the reflection of electromagnetic pulses from moving plasmas, J.Phys.D: Appl.Phys. 6, L87 (1973).
2. Propagation of optical pulses through cladded fibers: modified theory, Applied Optics, 12, 2482 (1973).
3. Propagation of frequency modulated pulses in waveguides, Int.J.Electronics (Accepted, 1973).
4. Total Reflection of FM electromagnetic pulse from a moving plasma, Int.J.Electronics (Accepted, 1973).
5. On stretching and optimum receiver bandwidth for modulated pulses, Int.J.Electronics (Accepted, 1973).
6. Electromagnetic pulse reflection from Jet streams, Applied Physics (Accepted, 1973).

7. On one problem of reflection of Gaussian AM pulse from moving inhomogeneous medium (Communicated 1973).

8. Reflection of Electromagnetic pulses from a moving inhomogeneous plasma (Communicated 1973).

9. Interaction of bounded electromagnetic beams with moving homogeneous dielectric media (Communicated 1973).

In addition to the work reported in the thesis, the author has the following publications in allied fields:

1. Distortion of electromagnetic pulses undergoing total internal reflection from a moving dielectric half-space, IEEE Trans. AP-21, 119 (1973).

2. Impulsive reflection from a moving homogeneous plasma, J.Phys.D: Appl.Phys., 6, L85 (1973).

3. A new method of focusing EM beams in elemental semiconductors: application of inhomogeneous magnetic fields, J.Phys.D: Appl.Phys., 6, L10 (1973).

4. Focusing of EM waves in plasmas by inhomogeneous magnetic fields, Appl.Phys. Letters, 22, 161 (1973).

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