INTERACTION OF ELECTROMAGNETIC PULSES WITH MOVING AND STATIONARY MEDIA

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PREFACE

Propagation of plane electromagnetic waves in moving/stationary media constitutes a fundamental and interesting field of electrodynamics. While the study of electromagnetic wave propagation in stationary media covers a wide variety of problems[1-3], the studies for moving media are largely restricted to isotropic/anisotropic absorptionless steady state homogeneous cases[4-10]; along with a few attempts at Doppler effect studies for moving inhomogeneous media[11-13]. The studies for moving media have important bearing on problems in astrophysics (e.g. radio emission from sun), electrodynamics (e.g. amplification of electromagnetic waves and transformation of their spectra), plasma physics (plasmoid diagnostics), space communications, and the motion of domains in semiconductor oscillators and ferrites etc.[14-16].

Thus it is worthwhile to investigate the interaction of electromagnetic pulses with moving media. The major portion of the thesis is concerned with the electromagnetic pulse interaction with moving isotropic dispersive/non-dispersive homogeneous and inhomogeneous media.

Another important aspect of electromagnetic wave interaction with stationary media which has acquired lot of interest in recent years is the self-focusing of electromagnetic waves in media with intensity dependent index of refraction[17-19]. However, the extremely high intensities ($\sim 10^{13}$ W/cm^2) required for self-focusing may give rise to a host of other effects that may mask the phenomenon of self-focusing. This motivated us to propose a method for the focusing of low intensity electromagnetic waves by applying an inhomogeneous magnetic field.

The thesis has been divided in three chapters: Chapter I deals with electromagnetic pulse interaction with moving media, Chapter II deals with electromagnetic pulse interaction with stationary media (ionosphere and waveguides) and Chapter III deals with focusing of electromagnetic waves in plasmas by inhomogeneous magnetic fields. 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 of plane waves and with the help of Fourier techniques, we have investigated the interaction of electromagnetic pulses with moving isotropic homogeneous/inhomogeneous media. The chapter has been divided into four sections. Section 1 deals with transient signal propagation in unbounded lossless moving dispersive homogeneous media. Section 2 deals with distortion of electromagnetic pulses undergoing total internal reflection from a moving dielectric half-space. Section 3 deals with the problem of impulsive reflection from a moving homogeneous plasma, and section 4 deals with the problem of reflection of a Gaussian amplitude modulated (AM) electromagnetic pulse from a moving isotropic inhomogeneous media.

<u>Section 1</u>: Transient signal propagation in unbounded lossless dispersive moving media is discussed at length for two kinds of input carrier pulses viz., Gaussian and rectangular envelope carrier pulses. The results show explicit dependence of various pulse parameters on the velocity of the medium.

<u>Section 2</u>: The distortion of electromagnetic pulses undergoing total internal reflection from a moving dielectric half-space has been studied. It is shown that the distortion of the reflected pulse depends strongly on the velocity, direction of motion and the angle of incidence.

<u>Section 3</u>: Using the known steady state solution for a moving homogeneous plasma half-space, the reflected field of an impulsive plane electromagnetic wave normally incident on vacuum-moving plasma interface is derived. It is concluded that the reflected field $E_r(\tau)$ is explicit function of the velocity and the plasma frequency of the moving plasma.

<u>Section 4</u>: We have analyzed the reflection of an AM Gaussian pulse at the plane of discontinuity in refractive index in a uniformly moving isotropic

inhomogeneous dielectric half-space. The analytical expressions of the amplitude reflection coefficient for plane electromagnetic wave and the reflected pulse have been obtained. It is found that the reflection coefficient and nature of the reflected pulse depend strongly on velocity and direction of the moving medium.

Chapter-II

Propagation of FM Electromagnetic Pulses in Ionosphere and Waveguides

Wave form distortion when a transient signal is propagating in the ionosphere and when it is propagating through a waveguide has been a topic of recent interest, theoretically as well as experimentally[20-26]. Most of the studies todate are restricted to truncated sinusoidal pulse, sinusoidal unmodulated carrier with Gaussian envelope, pulsed d.c., r.f. signal and a short Gaussian envelope pulse; which are all basically AM electromagnetic pulses. However, the propagation of frequency modulated (FM) electromagnetic pulses has not been investigated. The FM pulse has an edge over an AM pulse because of two advantages, viz., the improvement of audioquality and reduction of noise. Using Fourier techniques, we have investigated the degradation of a FM pulse after propagation in the ionosphere and a waveguide.

The chapter has been divided into two sections. Section 1, deals with the reflection of FM electromagnetic pulses from the ionosphere and section 2, deals with the problem of propagation of FM electromagnetic pulses in waveguides.

Section 1: We have derived tractable analytical results to appreciate explicitly the distortion of the amplitude, pulse length and rate of frequency shift of a FM Gaussian shape pulse, after undergoing reflection from an ionospheric model with a linear electron density profile and constant collision frequency.

Section 2: Transient propagation of a FM Gaussian envelope carrier through a waveguide has been studied under workable approximations. A qualitative comparison of the transmission characteristics of FM and AM electromagnetic pulses has been mad in terms of distortion of the pulse and pulse length etc. and the dispersion of the pulse is discussed by using Kelvin's principle of stationary phase.

Chapter-III

Focusing of Electromagnetic Waves in Plasmas by Inhomogeneous Magnetic Fields

The focusing of electromagnetic radiation in media with intensity dependent index of refraction has lately assumed great importance in the field of understanding and exploiting nonlinear interaction phenomena. In plasmas the laser beam intensity needed to produce self-focusing in a typical laboratory plasma, is estimated to be $\sim 10^{13}$ W/cm^2.

However, at such enormous power, in addition to its being difficult to obtain, it will be precluded by other plasma phenomena[19], thus complicating the observation of specific mechanism of interest. Hence we have proposed a new method for focusing low intensity electromagnetic waves in a plasma by applying an external inhomogeneous magnetic field having an appropriate spatial configuration.

It is seen that the electromagnetic beam gets periodically focused in the plasma; for typical parameters, a focusing length of $\sim$ 1.05 cm has been predicted.

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

1. Transient Signal Propagation in Unbounded Lossless Dispersive Moving Media.
   Indian J.Pure and Appl.Phys.10, 645 (1972).

2. Distortion of Electromagnetic Pulses Undergoing Total Internal Reflection From a Moving Dielectric Half-space.
   IEEE Trans. AP-21, 119 (1973).

3. On the Reflection of FM Electromagnetic Pulses From the Ionosphere,
   Radio Sci.7, 1113 (1972).

4. Propagation of Frequency Modulated Pulses in Waveguides
   Int.J.Electronics (Accepted 1972).

5. Focusing of EM Waves in Plasmas by Inhomogeneous Magnetic Fields,
   Appl.Phys.Letters 22, 161 (1973).

6. Impulsive Reflection from a Moving Homogeneous Plasma.
   J.Phys.D.(Accepted, 1973).

7. Reflection of a Gaussian AM Pulse From a Moving Inhomogeneous Medium.
   (Communicated 1973).

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