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Frederick Bloom

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
University of South Carolina
Dept of Mathema tics & Statistics
Columbia SC 29208

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The investigator focused on and produced papers in the following areas of research "Systems of nonlinear hyperbolic equations associated with problems of classical electromagnetic theory," "Shock formation in inhomogeneous quasilinear systems associated with nonlinear electromagnetic models," and "Shock wave formation for inhomogeneous hyperbolic systems associated with nonlinear transmission line problems." Details on this research are contained in the report.

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TO: AFOSR
Bolling, AFD, DC 20332

FROM: Frederick Bloom, Professor
Department of Mathematical Sciences, NIU

RE: Final Scientific Report, AFOSR-81-0171, 15 May 1982 - 14 May 1983

During the period 15 May 1981 - 14 May 1982 the principal investigator was on leave at the University of Connecticut (Fall 1981) and the University of Maryland (Spring and Summer 1982); work completed during that period is summarized in the enclosed interium report covering that period. During the period 15 May 1982 - 14 May 1983 our efforts were centered on studying shock formation for plane waves propagating in nonlinear dielectric media and on the possible dissipative effects of anisotrophy, nonlinear conduction currents, and nonlinear dielectric relaxation. We also considered problems of singularity formation for electromagnetic wave propagation in nonlinear distributed parameter transmission lines. Appropriate summaries of our work in this area, some of which was completed after the principal investigator had accepted his present position at Northern Illinois University, may be found in the attached abstracts #4, 5, and 6.

:sec

Frank Bloom

#4

Systems of Nonlinear Hyperbolic Equations Associated with Problems of Classical Electromagnetic Theory

Frederick Bloom
Department of Mathematical Sciences
Northern Illinois University
DeKalb, Illinois 60115

Abstract

The manifestation of a variety of nonlinear phenomena in electromagnetic theory is considered with specific emphasis on shock formation for plane waves propagating in nonlinear dielectric media and the possible dissipative effects of anisotrophy, nonlinear conduction currents, and nonlinear dielectric relaxation. Also considered are problems of singularity formation for electromagnetic wave propagation in nonlinear distributed parameter transmission lines.

#5

Shock Formation in Inhomogeneous Quasilinear Systems Associated with Nonlinear Electromagnetic Models

Frederick Bloom

Department of Mathematical Sciences
Northern Illinois University
DeKalb, Illinois 60115

ABSTRACT

We consider the problem of the existence of smooth globally defined solutions to a quasilinear system of inhomogeneous hyperbolic equations; these equations are shown to model both the behavior of a distributed parameter nonlinear transmission line, with voltage dependent capacitance and non-zero resistance and leakage conductance, and the interaction of a plane electromagnetic wave with a nonlinear dielectric half-space in the presence of a nonlinear conduction current. Specific conditions are exhibited, for both models, under which shocks form if the gradients of the initial data in each respective problem are, pointwise, sufficiently large. The analysis is based upon a study of the behavior of appropriate sets of Riemann invariants along their respective characteristic curves.

#2

SHOCK WAVE FORMATION FOR INHOMOGENEOUS HYPERBOLIC SYSTEMS ASSOCIATED WITH NONLINEAR TRANSMISSION LINE PROBLEMS

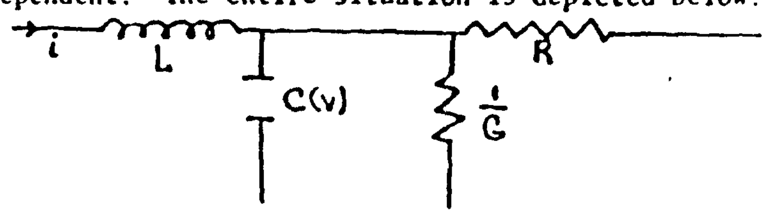
Frederick Bloom
Department of Mathematical Sciences
Northern Illinois University
DeKalb, Illinois 60115

Abstract

The problem of the existence of smooth globally defined solutions to a quasilinear system of inhomogenous hyperbolic equations modelling the behavior of a distributed parameter nonlinear transmission line is considered; the model assumes constant self-inductance, voltage dependent capacitance, and non-zero resistance and leakage conductance. Specific conditions are exhibited under which shocks form in solutions of the transmission line equations if at some point in the line the initial gradients of charge and current are sufficiently large.

Introduction

We consider a distributed parameter nonlinear transmission line with constant self-inductance L, current i, resistance R, and leakage conductance $\frac{1}{G}$ per unit length of the line; it is assumed that $Q = Q(v)$ where $v = v(x,t)$ is the voltage at a point in the line x units distance from an origin $\underset{\sim}{0}$ chosen in the line. The capacitance C is then given by $C \equiv C(v) = dQ(v)/dV$ and is, thus, also voltage dependent. The entire situation is depicted below:



$$\frac{\partial u_i}{\partial t} + \frac{\partial f_i}{\partial x}(\underset{\sim}{u}) = g_i(\underset{\sim}{u}) \tag{3}$$

$$\underset{\sim}{u} = \begin{pmatrix} i \\ Q \end{pmatrix}, \quad \underset{\sim}{f}(\underset{\sim}{u}) = \begin{pmatrix} \frac{1}{L} V(Q) \\ i \end{pmatrix}, \quad \underset{\sim}{g}(\underset{\sim}{u}) = -\begin{pmatrix} \frac{R}{L} i \\ GV(Q) \end{pmatrix} \tag{4}$$

and associated with (2) are the real characteristics in the x,t plane defined by $\frac{dx}{dt} = \pm \frac{1}{\sqrt{L}} \sqrt{V'(Q)}$.

Remarks.

(1) If $G \equiv 0$ then the system (2) reduces to

$$\begin{cases} Q_{,t} + i_{,x} = 0 \\ i_{,t} + 1/L(V(Q))_{,x} = -(R/L)\, i \end{cases} \tag{5}$$

which is a special case of the damped quasilinear system

$$\begin{cases} \frac{\partial w}{\partial t} - \frac{\partial v}{\partial t} = 0 \\ \frac{\partial v}{\partial t} - \Gamma'(w) \frac{\partial w}{\partial x} = -\alpha v \end{cases} \tag{6}$$

considered by Nishida [1] and Slemrod [2] for the care of associated periodic initial data $w(x,0) = w_0(x)$ $v(x,0) = v_0(x)$. It was shown in [1] that if $\Gamma'(0) > 0$, $\Gamma''(0) > 0$, and $\|w_0\|_{L^\infty}$, $\|v_0\|_{L^\infty}$, $\|w_0'\|_{L^\infty}$, $\|v_0'\|_{L^\infty}$ are all sufficiently ...