LS-26 (6/20/85)

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38.9 MHz Capacitively-Loaded Coaxial Cavity Design for the Booster

I. Introduction

The accelerator cycle for the synchrotron booster of the 6-GeV light source is divided into two parts; the first part of the cycle between 0.35 and 2.25 GeV is on the 52nd harmonic at 38.974 MHz and the second part of the cycle between 2.25 and 6.0 GeV is on the 468th harmonic at 350.76 MHz. A peak voltage of 200 kV is required for the low frequency cavity.

One option for the design of the 38.9 MHz cavity is a capacitive-loaded coaxial cavity shown in Figure 1. The design parameters for this type of cavity are presented here. Frequency tuning is accomplished with a circular matching plate across from the capacitive-loading plate at the high voltage end of the cavity. Several choices of material for the cavity are possible, but copper-plated stainless steel is probably best from the point of view of ease and quality of construction and ability to withstand bakeout.

II. Cavity Design

The dimensions of the capacitively-loaded coaxial cavity are given in Table I and a list of relevant parameters are given in Table II. The $E(\phi = 0)$ and r^*H_ϕ field patterns for the fundamental accelerating mode are shown in Figure 2.

The range in operating frequency of the cavity is 38.49 to 39.03 MHz, accomplished by moving the tuning plate by $\pm$ 0.2 cm. The corresponding gap varies between 7.5 and 7.1 cm.

The cavity is excited by a coupling loop at the shorted end of the cavity. It is proposed to keep the loop out of the vacuum by providing a vacuum sealed ceramic penetration. This is shown in Figure 1. The ceramic must be coated with a microscopic layer of titanium to avoid multipactoring.

The effective peak voltage including transit time is 200 kV, while the actual peak voltage is 205.1 kV. The cavity power required for 200 kV is 15412 W. The power distribution in the cavity is shown in Figure 3.

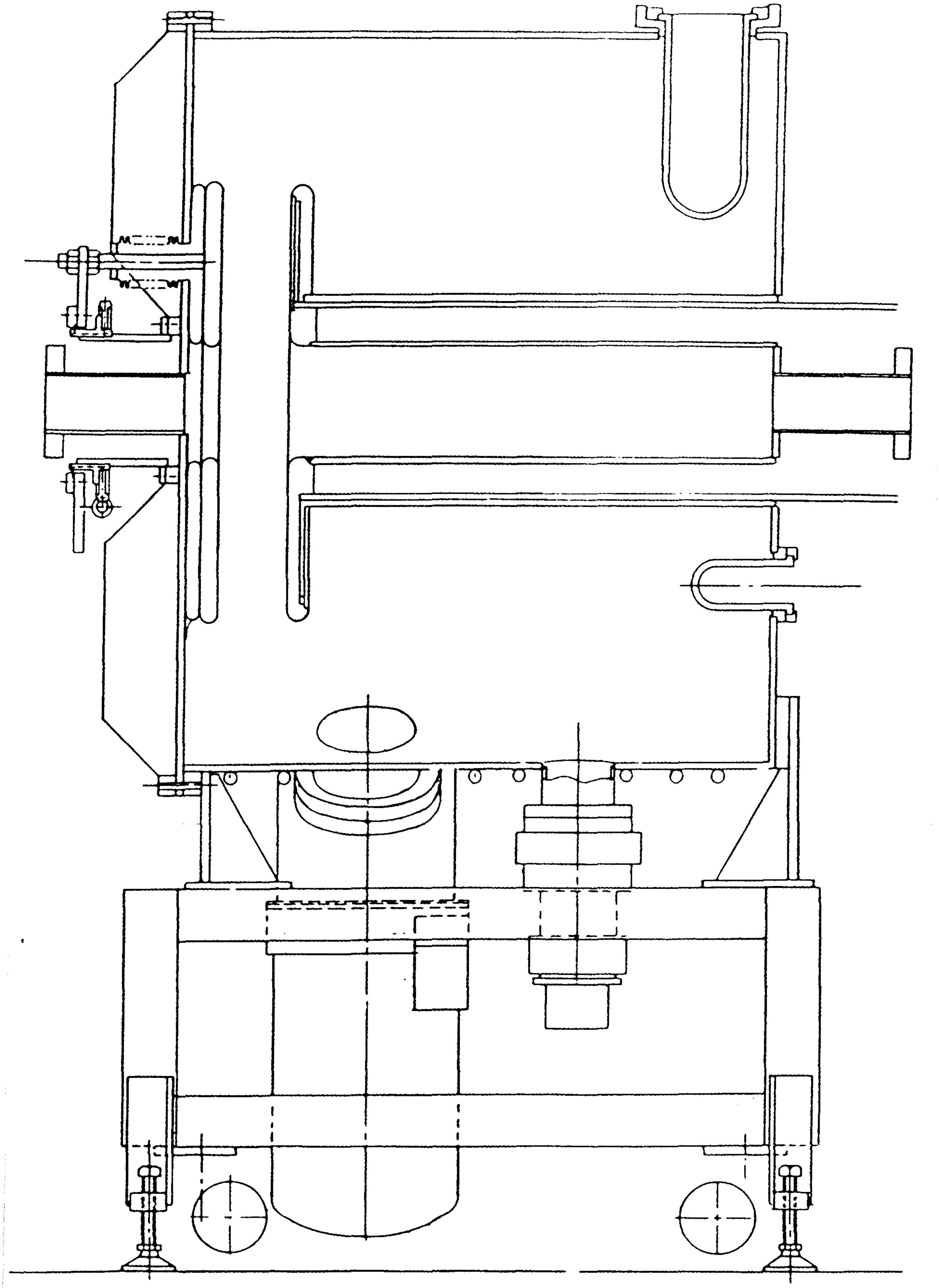

Fig. 1. Capacitive-Loaded Coaxial Cavity

Table I
Dimensions of the Capacitively-Loaded Coaxial Cavity

Length of outer shell	1.103 m
Radius of outer shell	0.500 m
Length of inner conductor (shorted end of cavity to front face of capacitive-loading plate)	1.003 m
Outer radius of inner conductor	0.145 m
Inner radius of inner conductor	0.077 m
Thickness of capacitive-loading plate	0.030 m
Outer radius of capacitive-loading plate	0.300 m
Outer radius of tuning plate	0.300 m
Inner radius of tuning plate	0.077 m
Gap between capacitive-loading plate and tuning plate, variable	0.071 - 0.075 m
Skin depth of EM fields	10.6 microns
Thickness of copper plating	30-50 microns

Table II
Parameters for the Capacitively-Loaded Coaxial Cavity

Operating Frequency	38.49 - 39.03 MHz
$\int E_z \cos(k*z/\beta)dz$	200 kV
Cavity Power @ 200 kV	15412 W
Cavity Z	21730
Shunt Impedance	2.6 MΩ
Tuning Plate Movement	±0.2 cm
Peak Electric Field on Surface @ 200 kV gap voltage (38.49 MHz)	3.80 MV

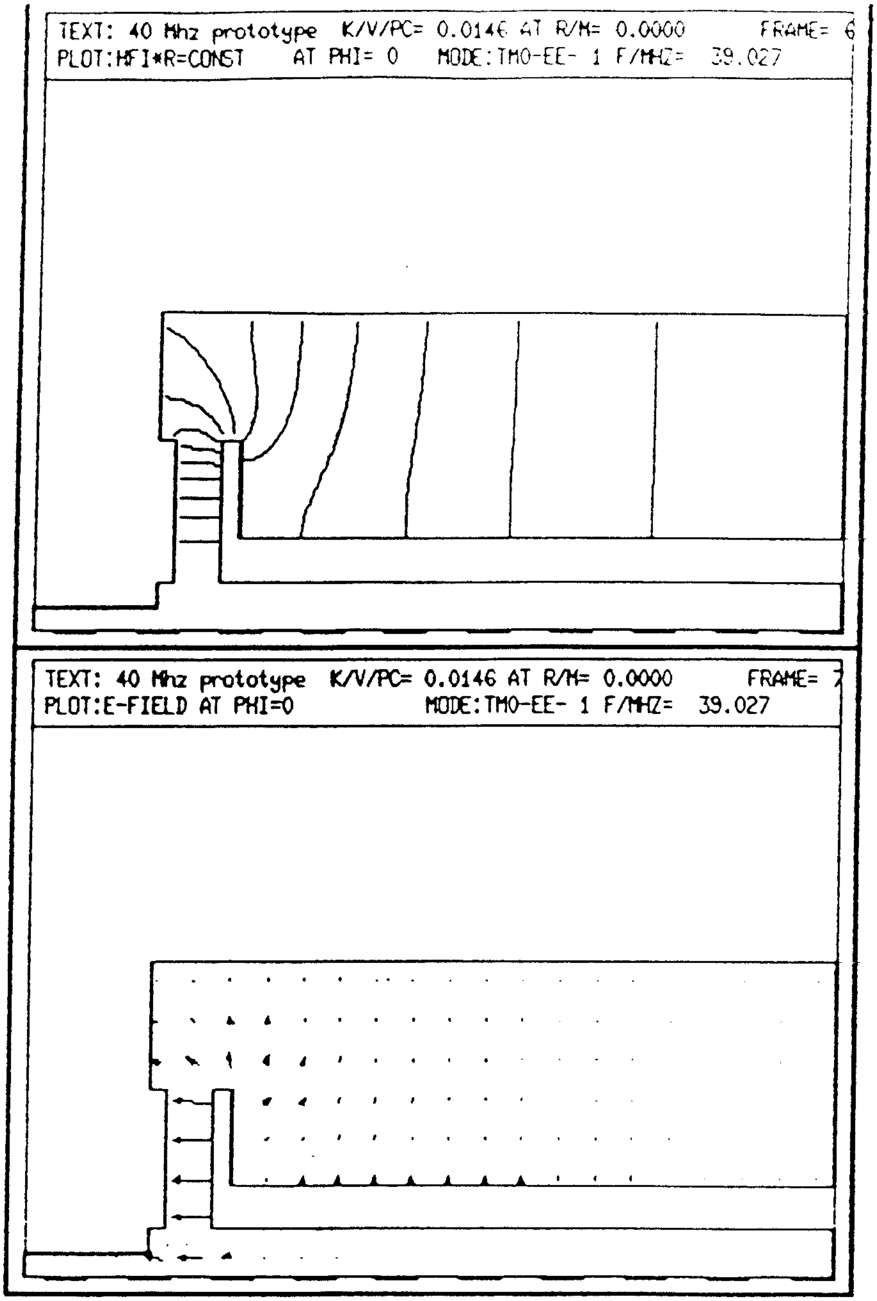

Fig. 2. E and $r*H_\phi$ Field Patterns for the Fundamental Accelerating Mode

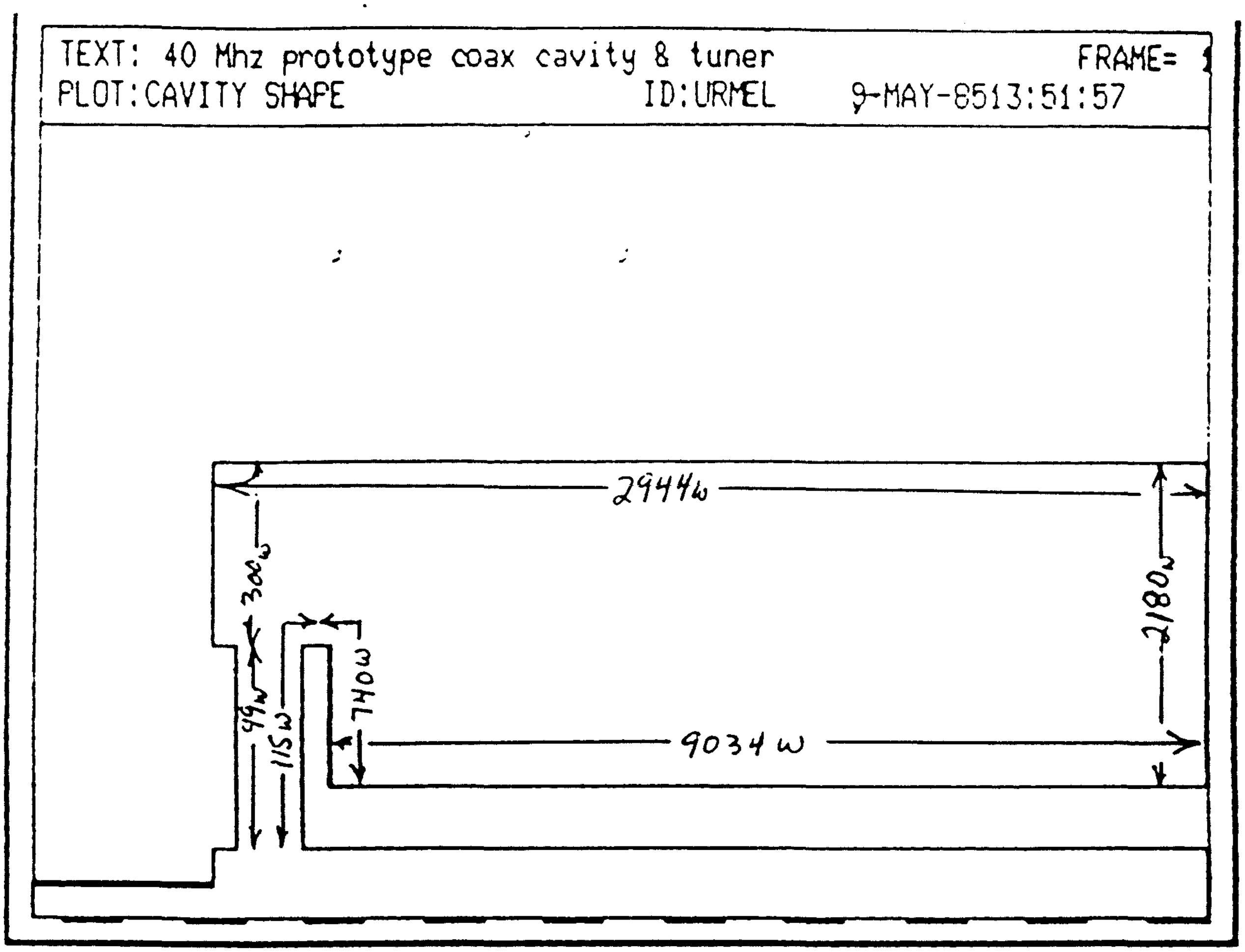

Fig. 3. Cavity Power Distribution

III. Higher Order Modes

A list of the nine lowest-frequency higher-order longitudinal modes is given in Table III. If the ratio of the higher-order mode frequency to the fundamental frequency is near an integer, mode damping will be necessary. This can be accomplished by placing a $\lambda/4$ wavelength antenna in or near the region of high electric field for that mode.

For instance, the frequency of first higher-order mode occurs at 4.073 times the fundamental frequency. The field patterns for this mode are shown in Figure 4. As can be seen from the E field, the antenna must be located in the outer shell and must be radially directed. Unfortunately, an antenna in this location will also strongly couple to the E field of the fundamental mode; thus, a $\lambda/2$ trap for the fundamental mode has to be added in parallel to the damping resistor to prevent excessive energy loss. The antenna location for this mode is indicated as OS in Table III. Other modes, for instance the 9th, have E fields perpendicular to the shorted end of the cavity. The field patterns for the 9th higher-order mode are shown in Figure 5. The antenna for these modes are located in the end flange and are axially directed. They do not couple to the fundamental mode since the E field of the fundamental mode is zero in this region. Also, these antenna can be placed inside a vacuum-tight ceramic penetration, since the E fields for the fundamental mode are zero in this region and will be damped for the higher-order modes. The ceramic penetrations for the antenna are indicated in Figure 1.

Transverse modes are listed in Table IV. Mode damping is accomplished using $\lambda/4$ antenna in either the outer shell (modes 1 through 4) or the end flange (modes 5 and 6). As indicated for the longitudinal modes, when the antenna is located in the outer shell, a $\lambda/2$ trap is needed to prevent coupling to the fundamental mode, and ceramic vacuum penetrations can be used for antenna on the end flange. The field patterns for the third higher order transverse mode are shown in Figure 6. The field patterns are typical of those requiring a radially-directed antenna in the outer shell. The field patterns for the fifth higher-order transverse mode are shown in Figure 7. These are typical of modes that require an axially-directed antenna in the end flange.

In all, at least five antenna penetrations are required in the outer shell and four in the end flange. In addition, since the tuning plate is symmetrical, it will help prevent excitation of the transverse modes as will locating the cavities in low β regions of the accelerator.

Table III
Higher-Order Longitudinal Modes

HOM Number	Frequency MHz	HOM Freq./ Fund. Freq.	Mode Damping*
0	39.027	1	-
1	158.970	4.073	OS
2	290.778	7.451	NN
3	372.417	9.543	NN
4	421.616	10.803	NN
5	454.346	11.642	NN
6	491.376	12.591	NN
7	536.855	13.756	NN
8	587.248	15.047	EF
9	619.821	15.882	EF

* Mode damping is accomplished with λ/4 antennas located either on the outer shell (OS) or the end flange (EF). If the ratio of the frequency of the higher-order mode to the fundamental is far enough away from an integer value, mode damping is probably not necessary (NN).

Table IV
Higher-Order Transverse Modes

Mode Number	Frequency MHz	HOM Freq/ Fund. Freq.	Mode Damping*
1	193.738	4.964	OS
2	248.438	6.366	OS
3	341.658	8.754	OS
4	417.140	10.688	OS
5	451.071	11.558	EF
6	480.093	12.302	EF

* Mode damping is accomplished with λ/4 antennas located either on the outer shell (OS) or the end flange (EF).

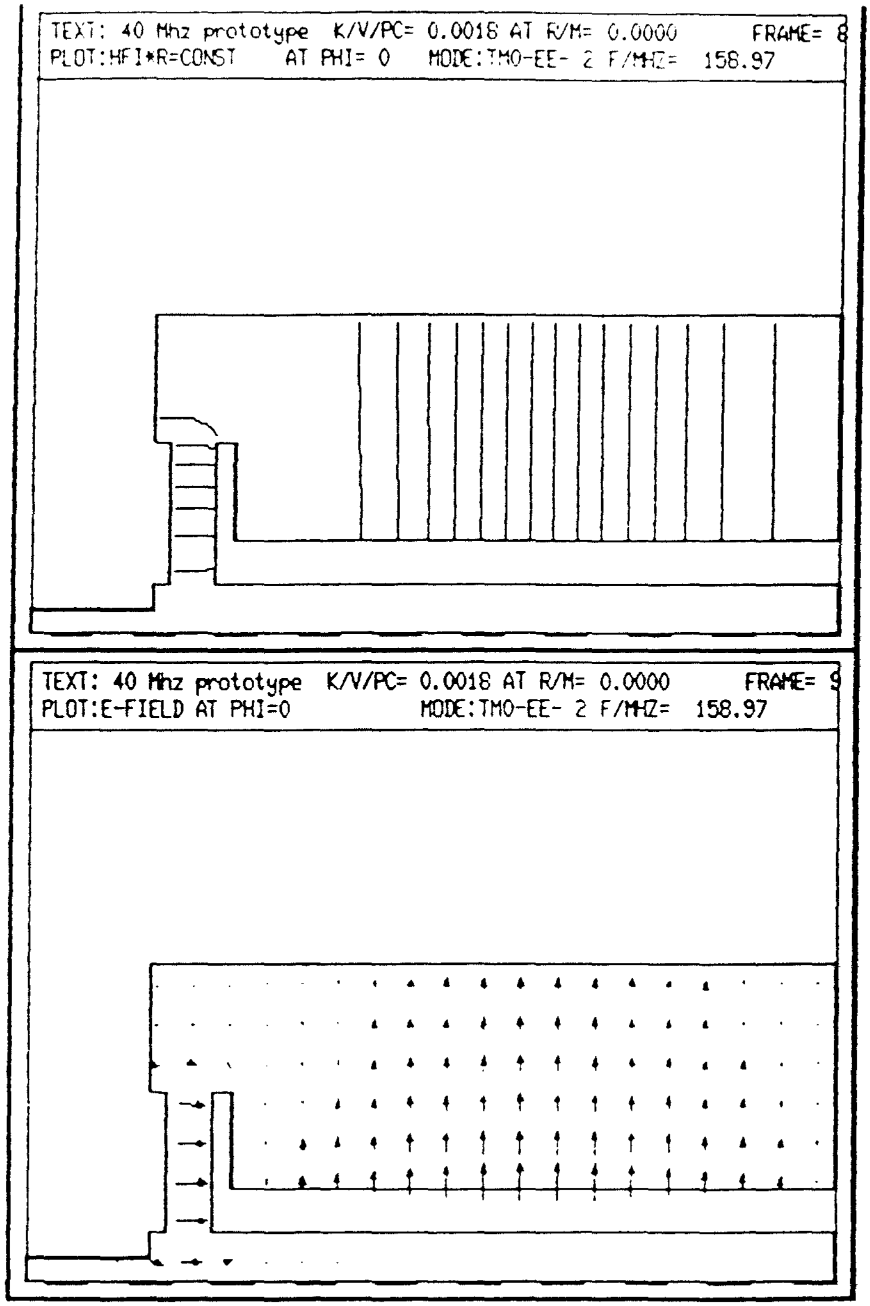

Fig. 4. Field Patterns for the First Higher-Order Longitudinal Mode.

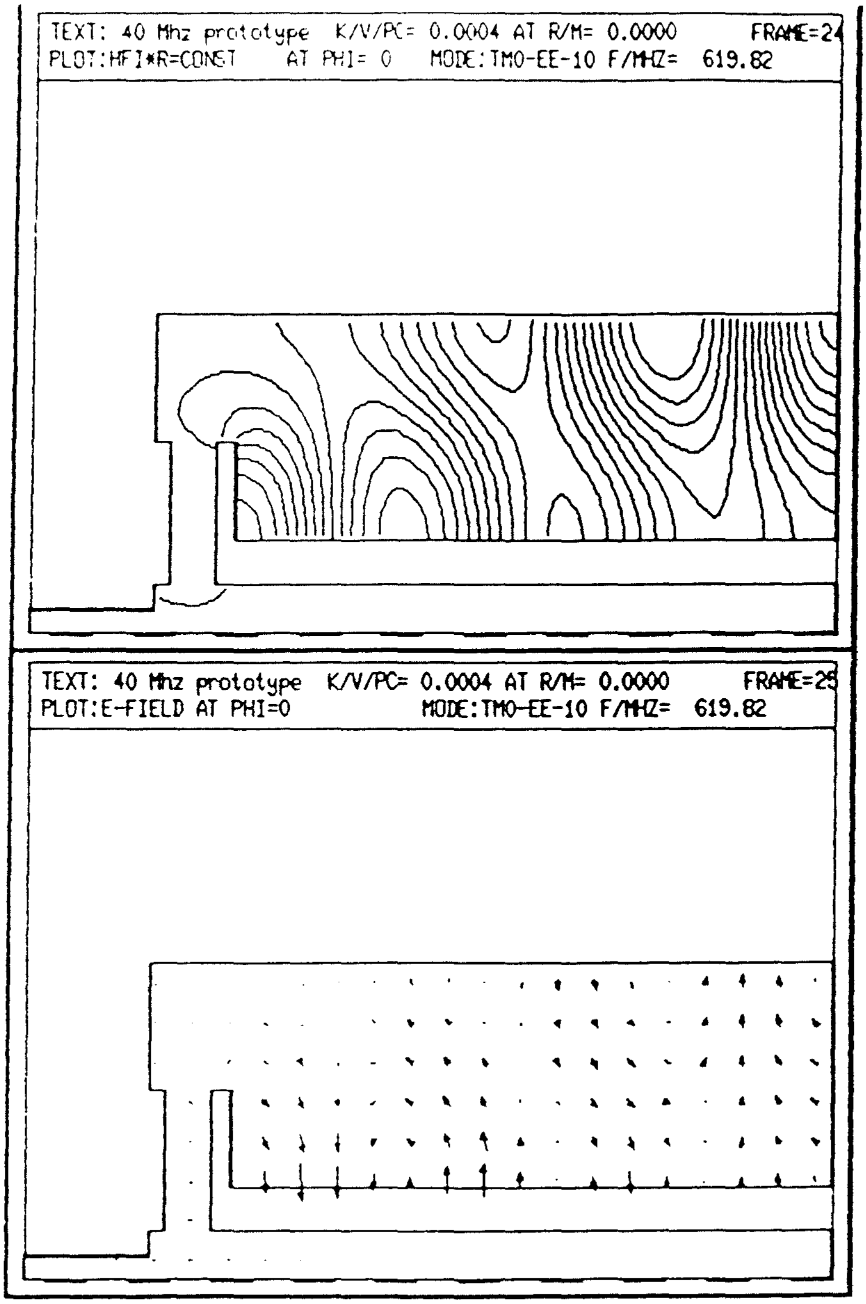

Fig. 5. Field Patterns for the Ninth Higher-Order Longitudinal Mode.

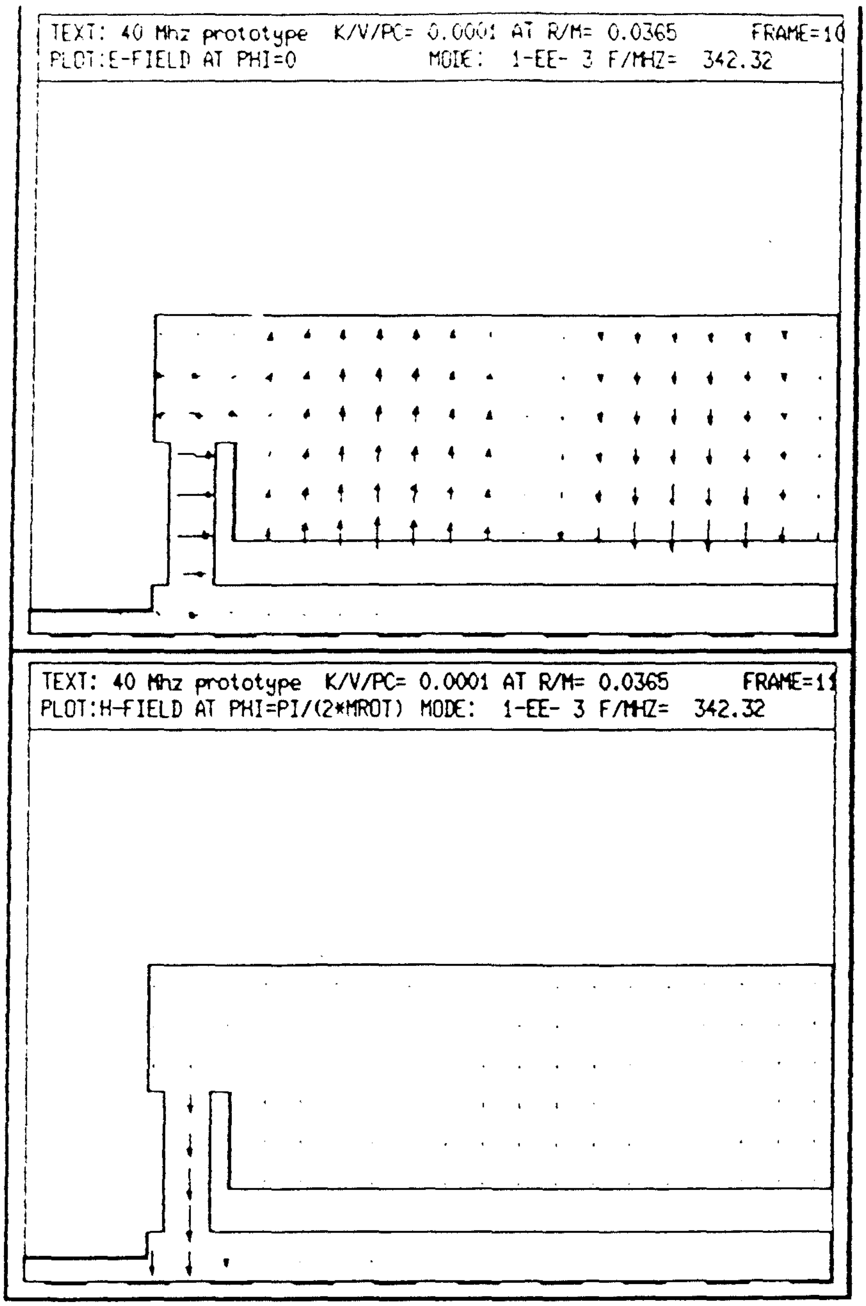

Fig. 6. Field Patterns for the Third Higher-Order Transverse Mode.

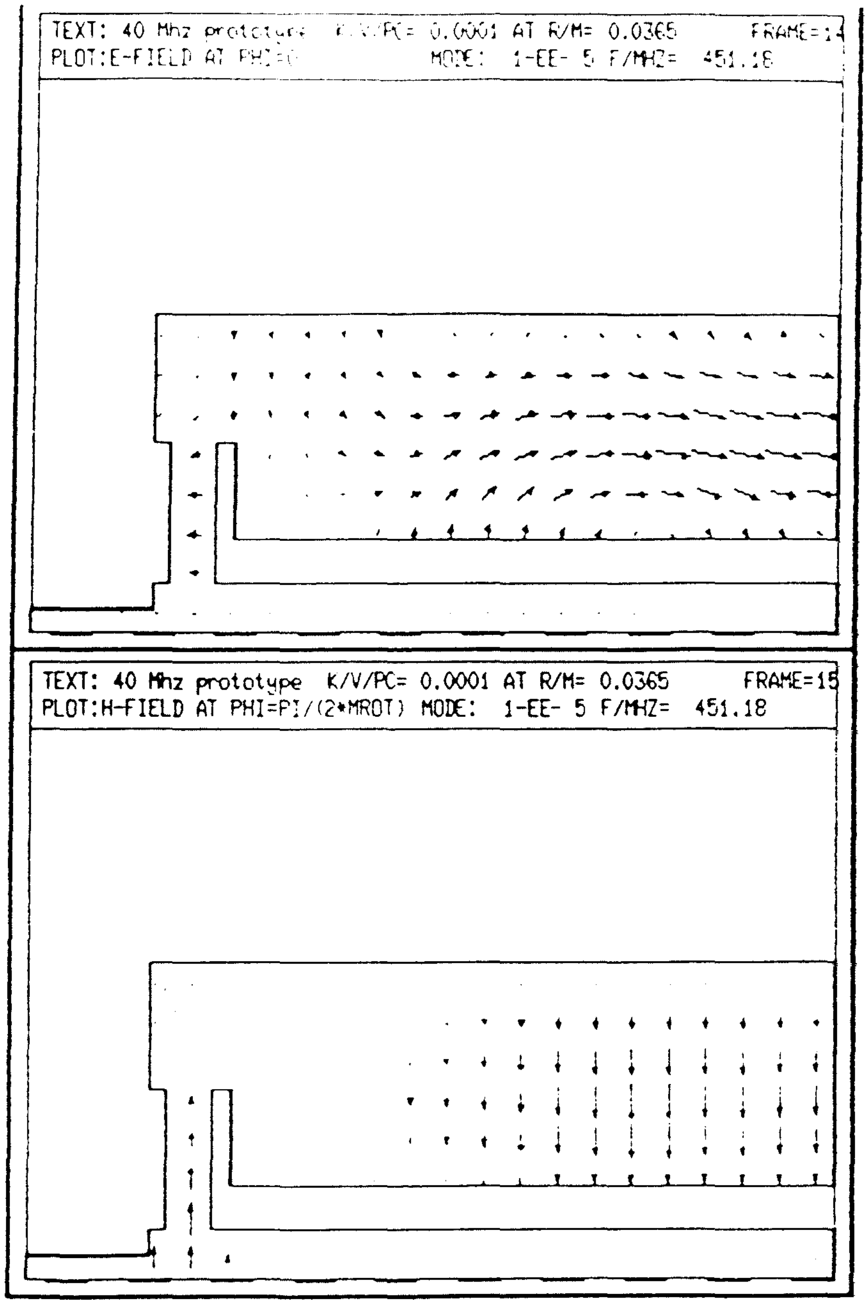

Fig. 7. Field Patterns for the Fifth Higher-Order Transverse Mode.