where c_m is the velocity of propagation for the mth eigenmode. It can be shown that $1/c_m^2$ is an eigenvalue of **LC**. The actual conductor voltages can be obtained from the modal intensities using equation (12).

The concept of scattering matrix can be extended to junctions of coupled lines. In this case the scattering matrix **S** relating $\mathbf{V}^{out}$ to $\mathbf{V}^{in}$ at a junction for coupled lines consists of submatrices $\mathbf{S}_{jk}$'s. The submatrices $\mathbf{S}_{jk}$'s are computed using relations similar to (7) and (8) except that the quantities involved are matrices. For example,

$$\mathbf{S}_{kk} = (\mathbf{Z}_{LK} + \mathbf{Z}_k)^{-1} (\mathbf{Z}_{Lk} + \mathbf{Z}_k) \quad (16)$$

where $\mathbf{Z}_K$ is the characteristic impedance matrix for kth coupled system and the matrix $\mathbf{Z}_{LK}$ is to be computed in a manner similar to that of uncoupled case.

The scattering matrix relating $\mathbf{g}^{out}$ to $\mathbf{g}^{in}$ in all the lines coming to a junction is given by

$$\mathbf{S}' = \mathbf{M}^{-1} \mathbf{S} \mathbf{M} \quad (17)$$

where **M** is a block-diagonal matrix composed of the matrices $\mathbf{S}_V$'s for the sets of coupled lines forming the junction.

4 LOSSY LINES

For a single lossy line of length ℓ between nodes "a" and "b," the signal coming in at node "b" from node "a" is

$$V_b^{in}(t) = \exp(-\gamma_1 \ell) V_a^{out}(t - \delta) + \gamma_2 \ell \int_{\delta}^{t} V_b^{out}(t - \tau) \exp(-\beta_1 \tau) A(\tau) d\tau \quad (18)$$

where $A(\tau) = \dfrac{I_1(\beta_2\sqrt{\tau^2 - \delta^2})}{\sqrt{\tau^2 - \delta^2}}$,

$\gamma_1 = 0.5(G\sqrt{\frac{L}{C}} + R\sqrt{\frac{C}{L}})$, $\gamma_2 = 0.5(G\sqrt{\frac{L}{C}} - R\sqrt{\frac{C}{L}})$,

$\beta_1 = 0.5(\frac{G}{C} + \frac{R}{L})$, $\beta_2 = 0.5(\frac{G}{C} - \frac{R}{L})$ and $I_1(z)$ is the modified Bessel function of the first kind [2]. The first term in (18) corresponds to the attenuated wavefront arriving from the other end at instant t, while the second term represents the trailing effects from the voltage waves whose wavefronts arrived at node "b" previously. Similar equation can be written for the signal coming into node "a."

Computing the second term in the above equation demands extensive run time and storage capacity. In order to be computationally feasible for a large number of interconnects, simpler models are needed.

TLSIM ignores the effect of loss on transmission lines. Fig. 3 shows the voltage at the load end for a matched line excited with a step function. The top curve in this Fig. shows the voltage at the load under lossless condition. Other three curves (from top to bottom) correspond to three values of R: 50Ω/cm 100Ω/cm and 200Ω/cm respectively (G is assumed to be zero for simplicity). The effect of loss is small for small R and short interconnects.

The method of decoupling coupled lines as presented in section 4 is not applicable, in general, in the presence of loss. This is because the transmformation matrix used to diagonalize the **LC** matrix, in general, transforms the diagonal **R** and **G** matrices to nondiagonal matrices. Thus the resulting system becomes coupled again. However, if coupling is considered among neighboring conductors only, then there exists a transformation matrix which does not change the diagonal nature of **R** and **G** matrices [2]. In that case the above technique for loss computation can be applied [2].

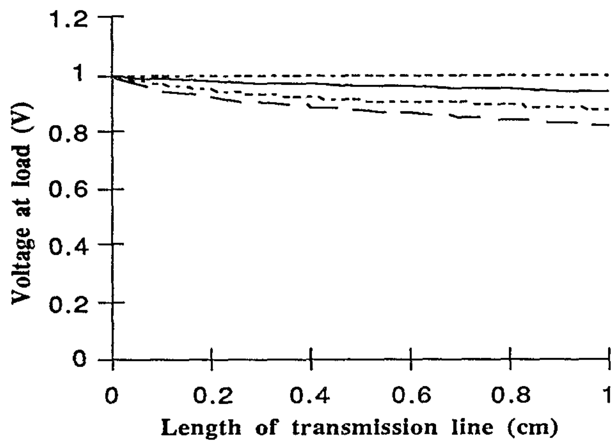

Fig. 3. Loss of accuracy as a function of R and transmission-line length.

5 SIMULATION RESULTS

Some results of investigations with direct coupled GaAs FET logic (DCFL) circuits and transmission lines are now presented.

During initial power up of logic circuits, there may exist considerable amount of transients in the power supply voltage and currents. As an example, Fig. 4 shows the power up transient in the power supply line of a DCFL inverter chain. The values used for V_{dd} and V_{SS} are 1.6 V and 0 V respectively. Each transmission line between two adjacent inverters is assumed to be 0.1 mm long.

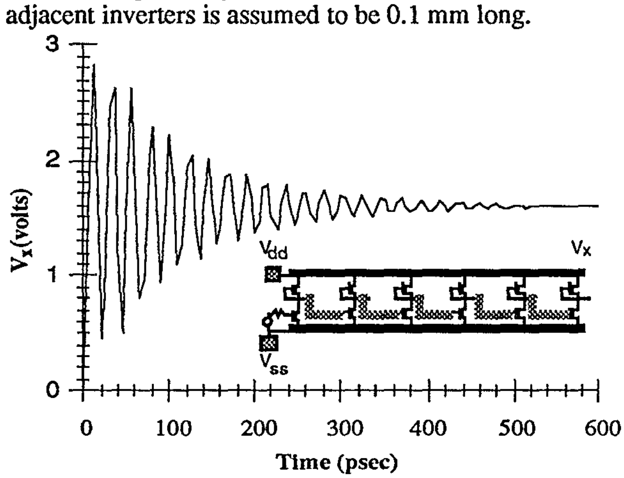

Fig. 4. The power up transients at the far end of the power transmission line.