Electromagnetic Modeling of Distributed-Source-Excitation of Coplanar Waveguides: Applications to Traveling-Wave Photomixers

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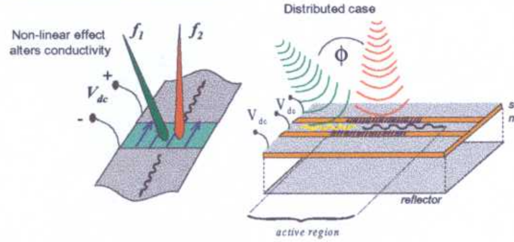
1. Abstract

An electromagnetic model is presented for the characterization of a distributed source excitation in coplanar waveguides (CPW). The solution to this problem is directly applicable to the understanding and optimization of membrane traveling-wave photomixers. This local oscillator technology is capable of generating radiation above 1 THz and may make the implementation of future wide-band electronically tunable heterodyne receivers possible. The methodology we present allows the determination of the intrinsic dynamic propagation constant along the CPW, the optimal lengths of the active area needed to generate the maximum RF power, and an evaluation of the amount of radiated power when matching to a slot antenna.

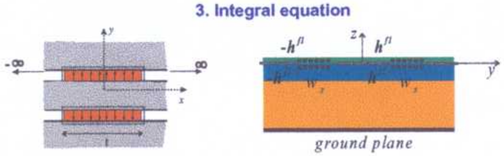
The analysis is performed in two steps: First, the magnetic current distribution is evaluated in the two gaps of an infinitely extended CPW excited by a distributed impressed electric current. We achieve this by assuming that the dependence of the magnetic currents are separable in the transverse and longitudinal dimensions. The transverse dependence is well represented by one edge-singular basis functions. These basis functions have opposite signs in the two slots to represent the propagating asymmetric mode. The longitudinal magnetic current distribution is obtained by superposing the solutions of the plane wave scattering problem. Each of these plane waves arises from the longitudinal expansion of the impressed magnetic field, which is distributed over a finite area. In the second step, a slot antenna that is matched to the CPW line is introduced to launch the maximum possible power into free-space. We validated the procedure described in step one and the behavior of the entire structure, CPW and slot antenna, with a custom-developed Galerkin Method-of-Moments code.

2. Distributed Photomixer

Traveling-wave photomixer devices have shown capable of generating radiation well into the THz frequency regime. In this paper we seek to optimize the design of this source with the goal of improving the optical-to-heterodyne conversion efficiency. The approach we are taking is to locate the photomixer material on a thin membrane in order to eliminate substrate losses. A back reflector serves to ensure upward coupling of generated radiation.



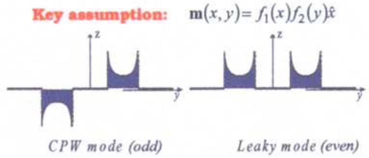
3. Integral equation



A Continuity of the Magnetic Field Integral Equation (C.M.F.I.E.) is formulated

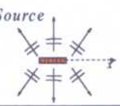
$$\iint_{CPW} g_{xx} m dS = -h^f \quad \text{where} \quad g_{xx} = g_{xx}^{up} + g_{xx}^{down}$$

Key assumption: $\mathbf{m}(x,y) = f_1(x) f_2(y) \hat{x}$

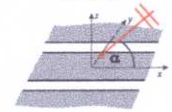


Spectral Solution

The impressed magnetic field is expanded in terms of plane waves, $k_x = k_0 \cos\alpha$



For each of these plane waves a **Scattering** problem



$$f_1(x) = \frac{1}{2\pi} \int_{-\infty}^{+\infty} F_1(k_x) e^{-jk_x x} dk_x$$

We obtain the following spectral solution:

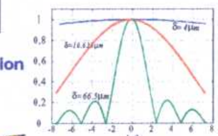
$$F_1(k_x) = \frac{-2H^f(k_x)}{\underbrace{\int_{-\infty}^{+\infty} J_0(k_y W_s/2)(-2j\sin(k_y a))^2 G(k_x, k_y) dk_y}_{D(k_x)}}$$

valid for any kind of G (layered media)

4. Zero-Pole Cancellation

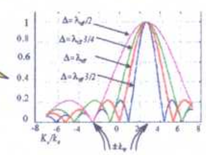
The spectrum of the source corresponding to the poles of $D(k_x)$ dominates the solution.

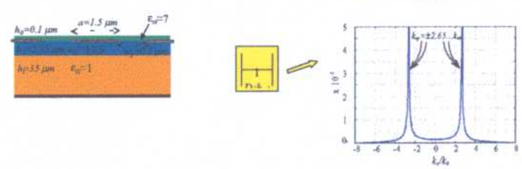
$h^f(x) = rect[0, \delta/2]$



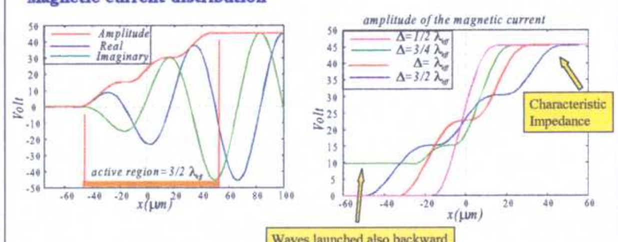
No backward traveling wave is launched when the spectrum of the source is zero for $k_x = -k_{xo}$

$h^f(x) = rect[0, \Delta/2] e^{-jk_{xp}x}$

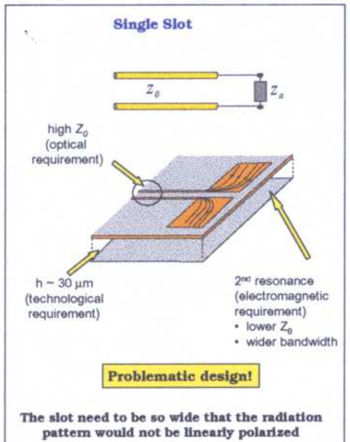


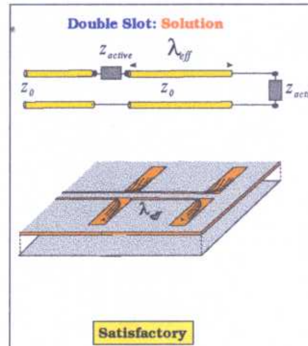


Magnetic current distribution



5. Antenna Design



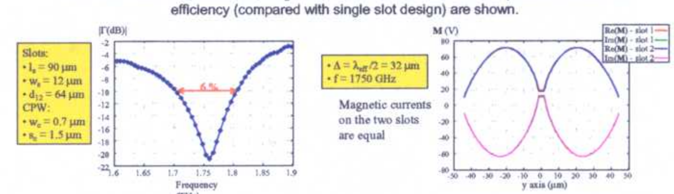


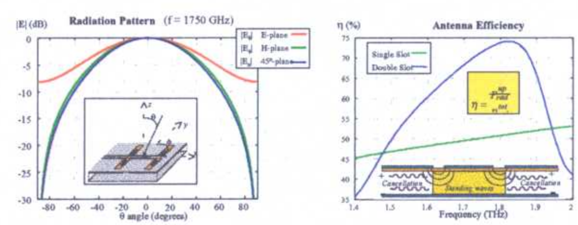
Two narrow slots (l/w ≈ 8):

- Impedance match
- Clean polarization of the currents
- Almost symmetric radiation pattern
- Good radiation efficiency

MoM Analysis

Plots of the reflection coefficient, magnetic current distribution, radiation pattern and antenna efficiency (compared with single slot design) are shown.





6. Summary

- An original model has been developed for distributed sources in CPW's
- Design guidelines to optimize the coupling from the sources to the CPW have been obtained
- Design of a double slot antenna matched to a CPW with good performance has been accomplished
- Entire procedure was verified with Method-of-Moments

D. Pasqualini, et al., 12th Int. Symp. of Space THz Technology, San Diego, CA, February 14-16, 2001.