New Interesting Leakage Behavior on Microstrip Lines with a Slot on a Ground Plane

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Abstract **— We have proposed here a new structure of a microstrip line in which the dominant-mode leaks above some critical frequency or all frequencies. This structure has a slot on the ground plane and also has dielectric multilayers under it. The appropriate combination between dielectric layers produces the leakage into the multi-layers. This means that the leaky field does not leak into the substrate of the microstrip line and so we can get the lossy uniform microstrip line above the critical frequency without affecting the surrounding circuit. We present here the dependence of the structural parameters of the proposed guide on the leakage properties.**

I. INTRODUCTION

We now know that the dominant mode on printed-circuit transmission lines is purely bound at lower frequencies and leaky at higher frequencies except for microstrip lines[1]-[3]. The leaky mode carries power in the forms of the surface wave propagating on substrate and then leakage effects can produce serious performance difficulties in circuits, such as crosstalk between neighboring portions. But, if the leakage effect can be produced without such propagation on substrate, we can have a low-pass property of the dominant mode on the uniform line by using power loss due to leakage.

In this paper, we propose here a new structure of a microstrip line with a low-pass property due to leakage effect. The proposed guide has a slot on the ground plane and also has dielectric layers under it. When we take the appropriate combination between dielectric layers, the leakage occurs through the multilayer separated from a substrate above some critical frequencies or all frequencies. As a result, the transmitted power along the guide decays, but the leaky field does not propagate on the substrate. We investigate here the leakage properties of the proposed guide by varying the structural parameters.

II. LEAKAGE MECHANISM

Figure 1 show a proposed structure of a microstrip line. The conventional microstrip line with the strip width w and the dielectric constant ε_r is modified by introducing a slot with width d on the ground plane and also under it,

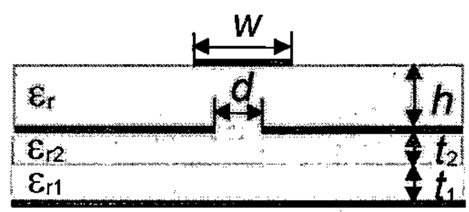

Fig. 1. New structure of a microstrip line.

setting two dielectric layers with thickness t_1, t_2 and dielectric constants ε_{r1}, ε_{r2}, respectively. We assume here the relation between the dielectric constants to be $\varepsilon_{r2} < \varepsilon_r < \varepsilon_{r1}$. The leakage of the dominant mode occurs when its phase constant becomes lower than that of the surface wave propagating on the surrounding dielectric layers. In the present guide, we have two surrounding layers; one of them is the conductor-backed slab waveguide with the dielectric thickness h, and the other is the parallel-plate guide with two dielectric layers. Figure 2 shows typical dispersion behaviors of the dominant mode on the conventional microstrip line (slot width d = 0) and two lowest TM_0 surface-wave modes on surrounding guides. In this figure, the dielectric constants are chosen to be ε_r =

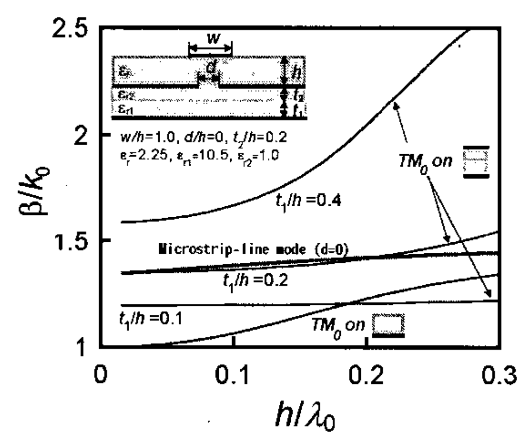

Fig. 2. Dispersion behaviors of the dominant mode on the conventional microstrip line and the TM_0 surface-wave mode on the surrounding dielectric waveguides.

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2.25, $\varepsilon_{r1} = 10.5$, and $\varepsilon_{r2} = 1.0$, and also the strip width w and dielectric thickness t_2 are fixed to be $w/h = 1.0$ and $t_2/h = 0.2$, respectively. Only the dielectric thickness t_1 is varied from $t_1/h = 0.1$ to 0.4. The dispersion curve of the dominant mode on the conventional microstrip line indicated by the red line always lies above that of the TM_0 surface-wave mode on the conductor-backed slab waveguide indicated by the black curve, so that the dominant mode does not leak in all frequencies. However, if the slot width d is not equal to zero, whether the dominant mode leaks or not depends on the dispersion curve of the parallel-plate guide indicated by the blue lines. This reason is the following. The phase constant of the dominant mode maintains almost the same value without being affected by the slot, because the dielectric constant ε_{r2} of the dielectric layer faced on the slot is lower than ε_r of the substrate. As a result, the leakage of the dominant mode is approximately decided by the relation between the dispersion curves of the conventional microstrip line and the parallel-plate guide. Therefore you can find from Fig. 2 that the dominant mode does not leak for $t_1/h = 0.1$ in the given frequency range. But in the high frequency, it leaks above some critical frequency because the phase constant of the parallel-plate guide approaches to the square root of $\varepsilon_{r1} = 10.5$. As a result, the guide has a low-pass property. While the dominant mode for $t_1/h = 0.4$ always leaks. Furthermore, for $t_1/h = 0.2$, its dispersion behavior is expected to become complicate. In the following section, we calculate the dispersion behavior for the various structural parameters by using the spectral domain method.

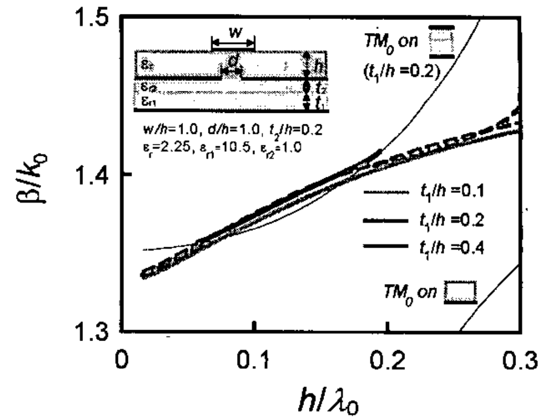
III. Dispersion Behavior

A. Dependence of dielectric thickness t_1

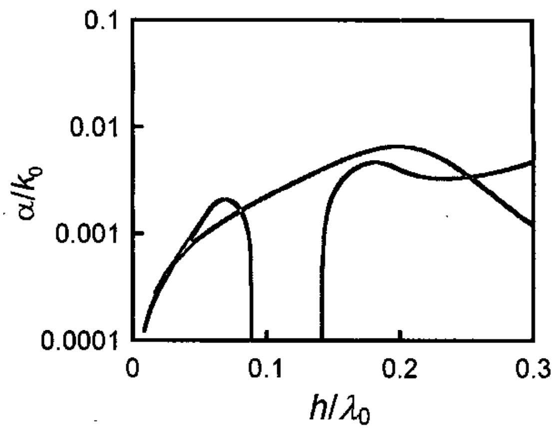
Figure 3(a) and (b) shows the normalized phase constant β/k_0 and leakage constant α/k_0 of the dominant mode on the proposed microstrip line. The structural parameters are the same with those given in Fig. 2 and the slot width is assumed to be $d/h = 1.0$. The bold solid lines indicate the bound dominant mode of the guide, while the bold dashed lines indicate the leaky dominant mode. The fine solid lines are the TM_0 surface-wave mode of each surrounding dielectric guide. As expected from the discussion in the previous section, the dominant mode for $t_1/h = 0.1$ indicated by the green line does not leak in the given frequency range, while that for $t_1/h = 0.4$ indicated by the red line always leaks as shown in Fig. 3(b). The dispersion behavior for $t_1/h = 0.2$ indicated by the blue line is very interesting. In this case, the dominant mode is purely bound in some frequency range, so that the guide has a band-pass property as shown by the blue curve in Fig. 3(b). This dispersion actually shows more complicate behavior, so such a behavior will be investigated deeply by changing the dielectric thickness t_2 in the next section.

B. Dependence of dielectric thickness t_2

Figure 4(a)-(c) shows the normalized phase constant β/k_0 for the dielectric thickness $t_2/h = 0.2$, 0.24 and 0.4, respectively, keeping $t_1/h = 0.2$. In these figures, the bold blue line indicates the bound mode, the red one is the leaky mode, and the green one is the improper real mode. The fine black lines are the TM_0 surface-wave modes and the fine blue line is the dominant mode of the conventional microstrip line. Figure 4(d) also summarizes the leakage constant α/k_0 for the various dielectric thickness t_2. Figure 4(a) depicts in detail the behavior of the phase constant for $t_2/h = 0.2$ shown in Fig. 3(a) on the expanded scale. It is obvious from this figure that the mode

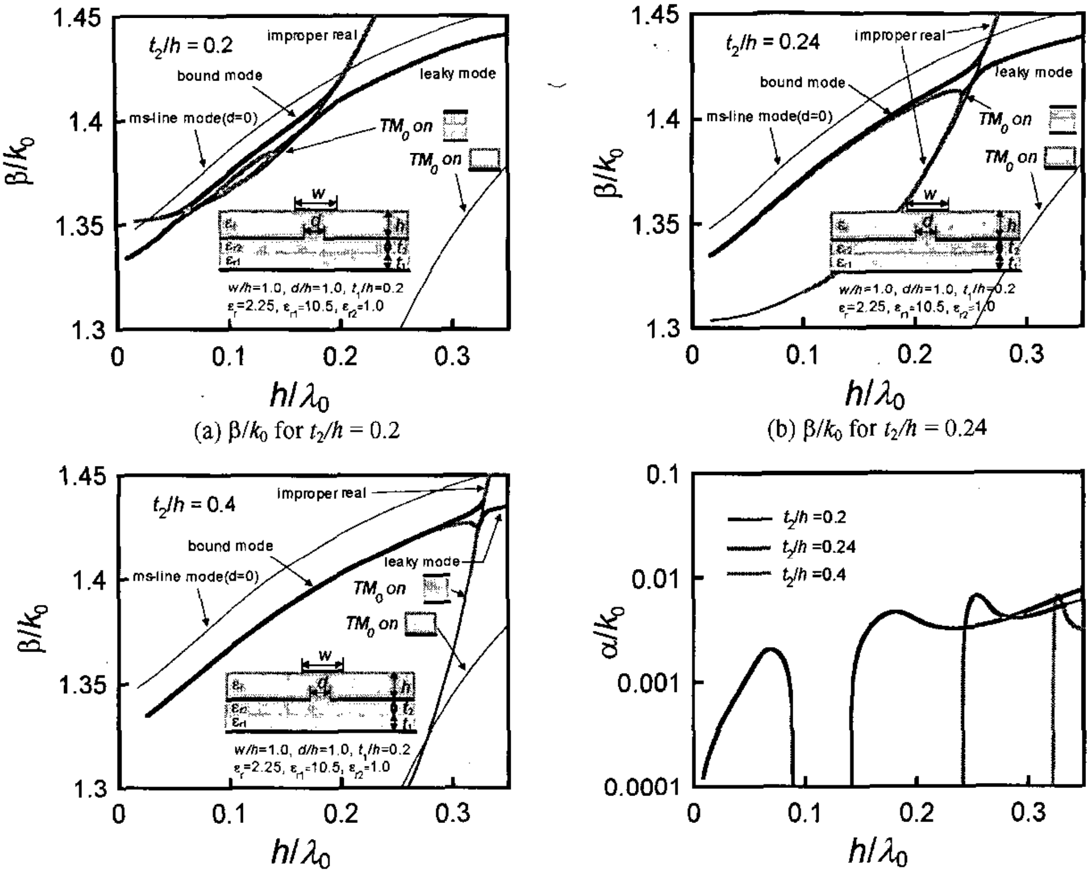


(a) β/k_0



(b) α/k_0

Fig. 3. Normalized phase constant (a) and leakage constant (b) of the dominant mode for various dielectric thickness t_1.



(a) β/k_0 for $t_2/h = 0.2$

(b) β/k_0 for $t_2/h = 0.24$

(c) β/k_0 for $t_2/h = 0.4$

(d) α/k_0 for different values of t_2/h

Fig. 4. Dependence of the dielectric thickness t_2 on the dispersion behavior.

coupling occurs in the transient region from the bound mode to the leaky one around two frequency regions. These couplings are similar to the leakage phenomenon of a coplanar waveguide[4] and are caused by the interaction between the dominant mode of the microstrip line and the surface-wave-like (SWL) mode lying along the TM_0 surface-wave mode on the parallel-plate guide. Then, in the coupling region, the leakage constant also moves between both modes, so that its behavior becomes complicatedly as seen at around h/λ_0=0.2 in Fig. 4(d). The dispersion curves of the dominant mode for t_2/h = 0.24 and 0.4 shown in Fig. 4(b) and (c) intersect with that of the TM_0 mode on the parallel guide only in the higher frequency region, so that the guide has a low-pass property although the coupling between the dominant mode and the SWL mode still occurs. The property of the leakage constant for the different values of t_2/h in the higher frequency shows the almost same behavior except for the shift of the critical frequency.

C. Dependence of slot width d

Figures 5 and 6 show the dispersion behaviors for the slot width d/h=0.5 and 0.25, respectively, keeping t_1/h = t_2/h = 0.2. Comparing these figures with Fig. 4(a) and (d) for d/h=1.0, the phase constant of the dominant mode approaches to that of the conventional microstrip line indicated by the fine blue curve as the slot width is decreased. The value of the leakage constant becomes small with decreasing the slot width, because the microstrip field does not penetrate so much into the parallel-plate guide through the slot.

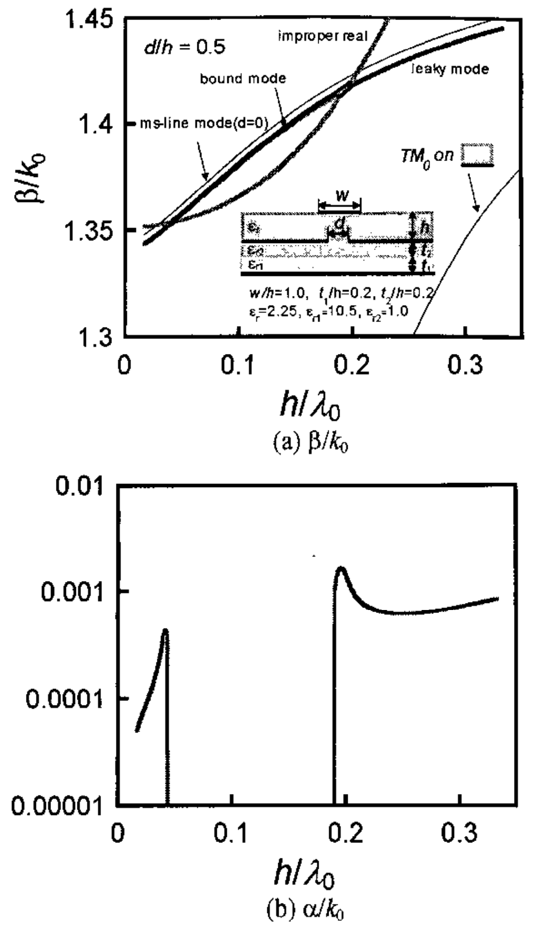


Fig. 5. Dispersion behavior for the slot width $d/h = 0.5$.

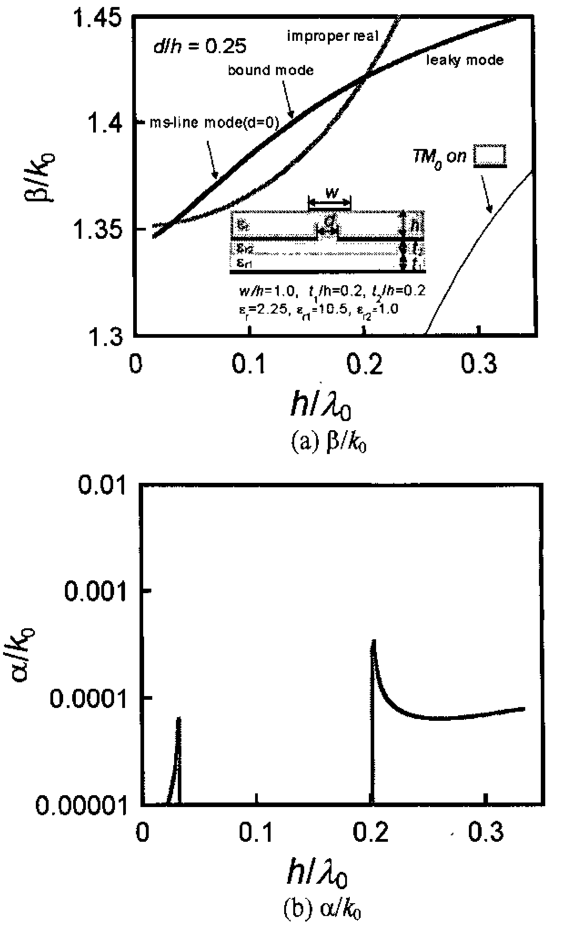


Fig. 6. Dispersion behavior for the slot width $d/h = 0.25$.

IV. Conclusion

We have proposed a new structure of a microstrip line in which the dominant mode becomes leaky without the surface-wave propagation on the substrate. The dispersion behavior has been investigated for various structural parameters and then the proposed guide has a low-pass or a band-pass property has been confirmed. At the talk, we will present the experimental results for the proposed guide.

Acknowledgement

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