Electromagnetic coupling to nearby conducting strip through narrow and wide slits in parallel plate waveguide.

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ABSTRACT

The problem of electromagnetic coupling to a conducting strip through narrow and wide slits in a parallel-plate waveguide (PPW) is considered for the purpose of understanding more about the coupling mechanisms of aperture-coupled and proximity-coupled microstrip antennas. The problem for consideration is "Under what conditions can most of the incident power $P_m$ be radiated into the upper-half free space", i.e., can perfect matching occur?"

The first geometry under consideration is given in Fig. 1, where $z_s$ is the short stub length from the narrow slit center, the TEM field is assumed
to be incident upon the slitted region, and the height \( h \) and inside dielectric constant \( \varepsilon \) of PPW are chosen to be comparable to those of a typical microstrip structure.

A pair of coupled integral equations is formulated whose unknowns are the induced electric current density on the conducting strip and the equivalent magnetic current density over the shorted slit and which is solved using the Method of Moment (MoM).

For a narrow slit case, where the slit width \( 2a \) is much smaller than the wavelength \( \lambda \) in the PPW and the PPW height \( h \), similar to a typical aperture-coupled microstrip antenna, almost perfect matching can be achieved by introducing the short stub scheme, as shown in Fig. 1. The location \( Z_s \) of the shorting wall in the PPW is chosen to be about \( \lambda/2 \) away from the slit center such that the length \( Z_S \) of the short stub plays the same role as that of the quarter wavelength open stub of the microstrip line used in typical aperture-coupled microstrip antennas. Two types of coupling mechanisms can facilitate such perfect matching, cavity-type and parasitic-type. Cavity-type coupling uses a smaller separation \( h_0 \) than the parasitic-type, as such, a strong mode field (\( TM_{01} \) mode to \( x \)-direction) is excited in the cavity between the strip and the upper plate of the PPW, so the magnitude of the induced electric current density on the strip is much larger than that for the parasitic-type. Because of the half cycle variation of the \( TM_{01} \) mode (x-component electric field) along the z-direction, the strip offset \( Z_C \) which produces the perfect matching is then observed at two offset positions symmetrical about the zero offset position.

In contrast, the parasitic-type coupling uses a relatively larger separation \( h_0 \), therefore, a strong mode field is not excited. However, the radiation beam is more directive than that for the cavity-type, and maximum coupling occurs when the offset \( Z_C \) is zero. In this sense, the strip behaves more as the driver of the 2-element Yagi-Uda array instead of forming a cavity along with the upper plate of the PPW. Although the two types are quite different from each other, as described above, the roles of the strip are the same in both types. That is, at perfect matching, the presence of the strip increases the very small load conductance from the value the load admittance \( \frac{1}{Y_L} \) would have without the presence
of a strip to almost the same value as the characteristic admittance of the PPW. Furthermore, the strip also provides the required inductive susceptance for resonance with a large capacitive susceptance, which the load admittance would have without the presence of a strip. This also occurs in the case of a wide slit.

In the case of a wide slit where the location $Z_s$ of the shorting wall is moved to positive infinity, i.e., $Z_s \to \infty$ and the slit width $2a$ becomes comparable to or larger than the wavelength $\lambda$ in the PPW, the power transmitted to the guide beyond the slit becomes negligible, therefore, the problem in the wide slit case can be reduced to the structure as shown in Fig. 2. This second geometry under consideration can be thought of as a simplified structure of a proximity-coupled microstrip antenna. Similarly, in the case of a wide slit, there are also two types of radiative coupling, cavity-type and parasitic-type. In the case of cavity-type coupling, when the offset position $Z_C$ is, for example, $-0.18 \lambda_d$ (here $\lambda_d$ : wavelength in dielectric slab), maximum coupling (perfect matching) is achieved when $h_d$ is so small that a cavity can be formed between the strip and the upper plate of the PPW. In contrast, in parasitic-type coupling, as the relative dielectric constant $\varepsilon_{er}$ of the dielectric slab is decreased and its thickness $h_d$ is increased gradually, the offset position which produces the maximum coupling is moved to the point where $Z_C = 0$. As in the case of a narrow slit, the induced current distribution on the strip with cavity-type coupling is significantly larger than that for the parasitic-type. In addition, perfect matching can also be achieved when $h_d + h$ in Fig. 2 is so small that a cavity can be formed between the strip and the lower (ground) plate of the PPW, plus the inserted length $l_s$ of the upper plate of the PPW is so small that the inserted part does not result in any significant perturbation to the cavity.

It is believed that the above observations will help in designing various feeding structures for aperture-coupled and proximity-coupled antennas as well as microstrip leaky wave antennas.

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**References**


