# Mode Transformer between TEM Mode to $1^{st}$ Higher Mode in Tri-plate Strip Transmission Line

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Printed transmission lines, such as a microstrip transmission line and a coplanar waveguide, are preferable for applications in centimeter-frequencies. They are commonly used in millimeter-wave regions to realize cost-effective front-ends due to good mass-productivity. The printed transmission lines, however, suffer from considerable transmission loss. To reduce such transmission loss, a higher order mode of microstrip transmission line has been studied, but unfortunately, such a mode easily emits unwanted radiation at curved sections and discontinuities.

To realize a low-loss printed transmission line at millimeter-wave frequencies, we developed the first higher mode in a tri-plate strip transmission line. This transmission line, termed higher mode tri-plate strip transmission line (HS line) in this paper, consists of metal strips inserted in a below cutoff parallel plate waveguide as shown in Fig. 1. A basic reactance component such as a slot was investigated to apply to a matching circuit and a suppressor of the lowest mode, which is the TEM mode in the tri-plate strip transmission line. To apply the HS line to some printed strip transmission lines, a mode transformer between the HS line and the tri-plate strip transmission line with only TEM mode propagation was developed. The field distribution of the HS mode in the cross-sectional plane resembles that of the $TE_{10}$ mode in the hollow rectangular metal waveguide, while that of the tri-plate strip transmission line is similar to the coaxial line mode, that is the TEM mode. With this in mind, a mode transformer between the HS line and the tri-plate strip transmission line could be constructed by making a right-angle corner as shown in Fig. 2. To reduce the reflection from the mode transformer, the corner edge was trimmed off. No TEM mode propagation in the HS line is guaranteed by using the TEM mode suppressor consisting of three slots. Fig. 3 shows the measured VSWR from the mode transformer as circles. A flat VSWR performance measured to be 1.6 on average was obtained. To perform perfect matching at 32 GHz, a matching slot was sited behind the TEM mode suppressor as shown in Fig. 2. The VSWR of the mode transformer with the matching slot is plotted in Fig. 3 as dots. It is obvious that there is no reflection, though the center frequency was shifted to 100 MHz. Fig. 4 shows the measured transmission loss versus frequency in the back-to-back structure of two mode transformers, where, to obtain a flat frequency response, the matching slots were not installed. The transmission loss was measured to be less than 0.6 dB in the frequency range from 31 GHz to 33 GHz.

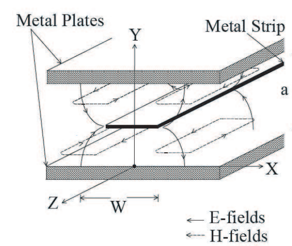


Figure 1: Rough sketch of field distribution of the first higher in tri-plate strip transmission line.

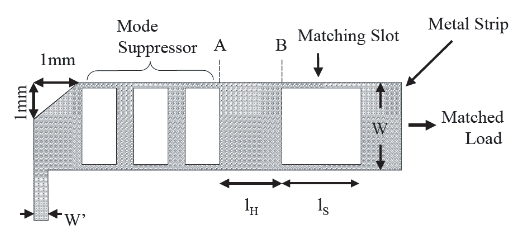


Figure 2: Mode transformer between HS mode and TEM mode.

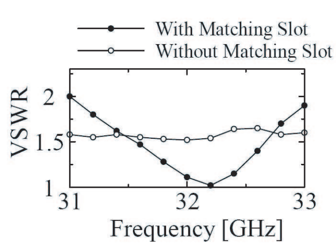


Figure 3: Measured VSWR of mode transformer between HS mode and TEM mode.

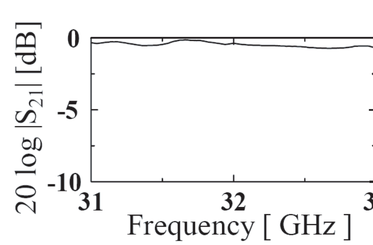


Figure 4: Measured transmission loss versus frequency in back-to-back structure.