COMPUTER-AIDED DESIGN OF MACHINABLE RECTANGULAR WAVEGUIDE TWISTS

Jens Bornemann

Laboratory for Lightwave Electronics, Microwaves and Communications (LLiMiC)
Department of Electrical and Computer Engineering
University of Victoria, Victoria, B.C. Canada V8W 3P6

SUMMARY

Twists in rectangular waveguides can be realized either from straight guides for a prescribed degree of rotation or as twisted waveguide components, where several slices of rectangular waveguides are individually rotated on a common axis. Theories on the propagation characteristics of continuously twisted rectangular waveguides have been published in the early eighties, and twisted waveguide components have been investigated since the fifties for applications as filters and field rotators.

However, modern integrated waveguide technology places two restrictions on the realization of twisted waveguide sections. The components must be, first, designed and fabricated without post-assembly tuning possibilities and, secondly and more important, machinable by CNC machines. Only one structure addressing these problems has been proposed so far. It involves a continuously varying L-shaped guide for 90-degree rotation. The design is not only several wavelengths long but is also inconvenient for computer-aided design strategies.

Therefore, this paper presents short and machinable rectangular waveguide twists which are formed exclusively by rectangular cross-sections and, therefore, can be efficiently analyzed by mode-matching techniques. The mode of operation is based on cascading a number of rectangular waveguide sections where each discontinuity contributes to a conversion from the TE_{10} to the TE_{01} mode, the latter of which is the fundamental mode of the output guide in a 90-degree rotation. The advantage of this design is that the overall length is less than an eighth of a wavelength for a 90-degree twist. Due to its compactness, the bandwidth of this structure is limited to about three to five percent for 20 dB input return loss. This is sufficient for many applications. For a more broadband design, three 90-degree components are cascaded to form a 270-degree twist section. By this measure, the bandwidth can be increased to up to twenty percent. The additional space requirements compared to a single 90-degree section are not extensive so that the component's overall length lies between 0.4 and 1.3 guide wavelengths at midband frequency.

The analysis procedure is based on a rigorous full-wave mode-matching technique. Intermediate regions are introduced in the model to calculate cross-section overlapping discontinuities, i.e., where the smaller waveguide's cross-section is not a subset of that of the larger one's. Between 25 and 35 TE_{mn} modes plus their respective TM_{mn} parts are sufficient for convergence within 1 dB of input return loss. Measurements at the basic discontinuity formed by two offset-connected waveguides support the theoretical model.

The design of 90-degree twists is carried out by selecting the individual waveguide cross-sections according to a given contour which specifies the corner-to-corner connections of the input and output guide. The individual section lengths are approximately one sixteenth of a guide wavelength devided by the number of sections between input and output. Such a design requires approximately 10 minutes of CPU time on a 66 MHz personal computer. Three of these designs are cascaded for the broadband component. However, the section lengths need to be reoptimized in order to balance reflections from the individual designs. This might take several hours of CPU time.