Impedance-Matched Magic Tee

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The magic tee is an important microwave-circuit element. While symmetry is crucial for combining and separating signals, it is not the only factor. For certain applications it is also important that certain reflections at the junction be small to maximize power throughput. This implies that appropriate impedance matching be applied.

The subject of magic tees (a special kind of hybrid junction or network) has an extensive literature. There are many variations on this theme, but they all have a common feature: symmetry. It is symmetry which divides the electromagnetic waves into two kinds with respect to a symmetry plane: symmetric and antisymmetric. This allows signals to be fed into (or out of) two ports on the symmetry plane (Δ port and Σ port) into the remaining two ports, without the Δ and Σ ports coupling to each other.

One of the uses of a magic tee is as part of a microwave-pulse-compression scheme. When switching out the power by breaking the symmetry (such as by switch firing), it is important to switch out the energy as fast as possible so as to have the highest possible power into the load. (e.g., antenna). For this purpose one needs to minimize reflections at the magic tee. This can be accomplished by appropriate impedance matching.

Such magic tees can be constructed in coaxial cables and (standard rectangular) waveguides. Retaining symmetry (as usual) we next need to consider the impedances of the various guides to minimize reflections, or (equivalently) to obtain the maximum power transmission out of and into the appropriate guides. This is accomplished by appropriately changing the waveguide heights.

The nonstandard heights can be transitioned to standard height ($\alpha/2$) by means of transformers. One can smoothly vary the height over several wavelengths to achieve a broadband match (low reflection). One can accomplish this by a quarterwave transformer in a much shorter, but more narrow-band, device. In this a waveguide of length $\lambda/4$ with height as the geometric mean of the two heights (to be matched) is used. In the present case this gives a factor of $\sqrt{2}$ times the smaller height for the transformer height.

Taking one end of the quarter-wave transformer as right at the magic-tee junction, one can perhaps avoid some extreme cases of guide height by increasing or decreasing the extreme values by a factor of $\sqrt{2}$. This still leaves the question of design details in the junction itself, still maintaining the symmetry plane.