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Round-Ended Waveguide Short-Circuits

A. R. Kerr

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At millimeter and submillimeter wavelengths, it is easier to machine waveguide short-circuits with a round end than with the usual square end. This note answers the question: where is the effective short-circuit plane of a round-ended waveguide short-circuit, and how much does its location vary with frequency? Fig. 1 shows square and round-ended waveguide shorts. When split-block construction is used, the waveguide is split along the indicated center-line.

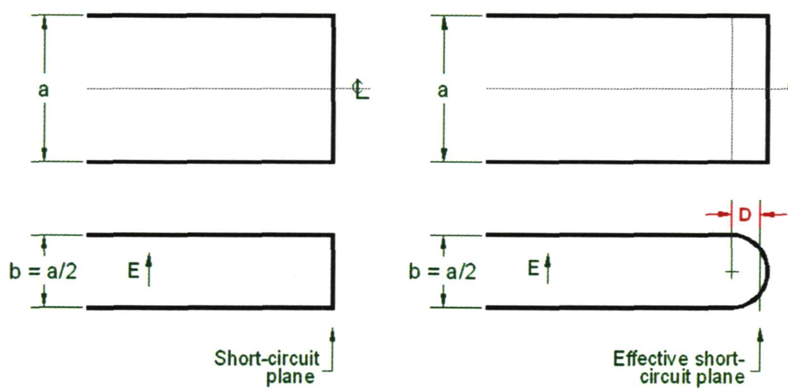

Fig. 1. (Left) Square-ended WR-10 short-circuit. (Right) Round-ended WR-10 short-circuit. Dimensions in inches.

The red curve in Fig. 2 shows the reflection coefficient of a WR-10 round-ended short-circuit as simulated using the FDTD EM simulator QuickWave. The reflection coefficient is referred to the center of the semicircular end of the waveguide (D = 0) . When the reference plane is moved

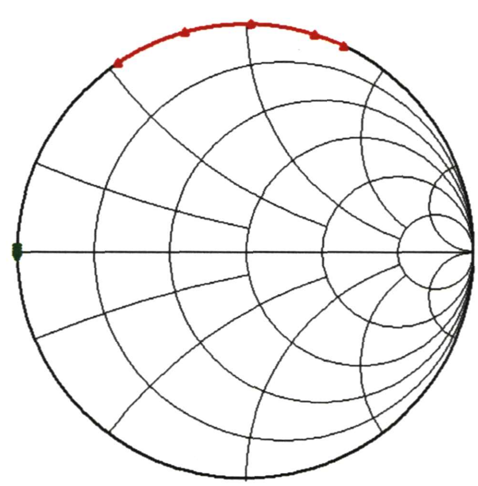

Fig. 2. WR-10 simulation. S11 with reference planes: D = 0 (red), D = 0.0202" (green).

to D = 0.0202" (= 0.202 a), the reflection coefficient (green curve) is within ± 1° of a perfect short circuit over the full waveguide band. Fig. 3 shows the variation of the phase of the reflection coefficient at the plane D = 0.202a as a function of frequency.

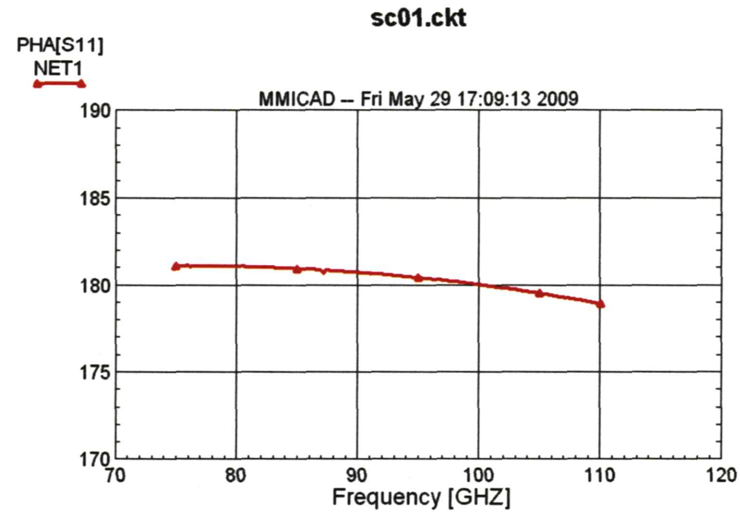

Fig. 3. Phase of S11 at plane D = 0.202*a* (red).

Although the simulations were done for WR-10 waveguide (75-110 GHz), the results apply to any waveguide with a 2:1 aspect ratio.

Circuit models

For use in microwave circuit simulators, it is useful to have a circuit model of the round-ended waveguide short-circuit. While the simple extended waveguide model above will be

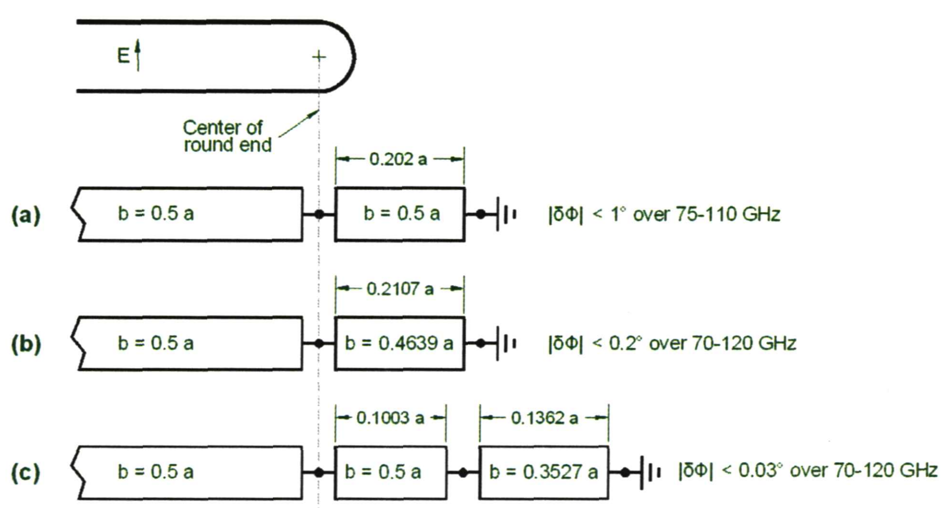

Fig. 4. Equivalent circuit models of the round-ended short-circuit. δφ is the error in the phase of the reflection coefficient of the model relative to that of the QuickWave EM simulation.

sufficiently accurate for most practical applications, two other models give better accuracy. The three models are shown in Fig. 4. Fig. 4(a) shows the simple extended waveguide model in which the extended waveguide is the same size as the main waveguide. Fig. 4(b) also uses a single waveguide extension, but with smaller height than the main waveguide. In fig. 4(c), two waveguide extensions are used, one with the same size as the main waveguide and the other with reduced height. As indicated in the figure, the accuracy of the models improves from (a) to (c).

Discussion

It is clear that the round-ended waveguide short-circuit is very close in behavior to the standard square-ended short. In WR-10 waveguide (75-110 GHz), the $\pm 1°$ variation in the phase of S11 corresponds to a variation in the effective short-circuit plane from + 0.00035"(9 μm) at the low end of the band to −0.00018" (5 μm) at the high end of the band. This is close to the precision achievable with many CNC milling machines.

It should be noted that these results apply to waveguides with the usual 2:1 aspect ratio. Similar results should apply to waveguides with other aspect ratios.