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Mismatch Caused by Waveguide Tolerances, Corner Radii, and Flange Misalignment

A. R. Kerr

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The results given below were obtained using the EM simulator QuickWave. Approximate analytical formulas for the reflection coefficients of junctions of waveguides with slightly different dimensions are given by Banister *et al.* [1]. A formula for the effect of finite corner radii on cutoff frequency is given by Brady [2].

Effect of *a*- and *b*-dimension tolerances

Figs. 1 and 2 show the reflection coefficient of a mated pair of waveguides with 2:1 nominal aspect ratio whose *a* and *b* dimensions include the maximum allowed tolerances. As in the MIL-DTL-85/3C standard, it is assumed that *a* and *b* are specified with the same tolerance, ± *t*. In Fig. 1, one waveguide has the maximum possible width (*a* + *t*) and minimum height (*b* - *t*), and the other has minimum width (*a* - *t*) and maximum height (*b* + *t*). In Fig. 2, one waveguide has the maximum possible width (*a* + *t*) and height (*b* + *t*), and the other minimum width (*a* - *t*) and height (*b* - *t*). It is clear that the configuration in Fig. 1 produces a larger reflection than that in Fig. 2, and Fig. 1 should therefore be used as a basis for setting the tolerance on waveguide dimensions.

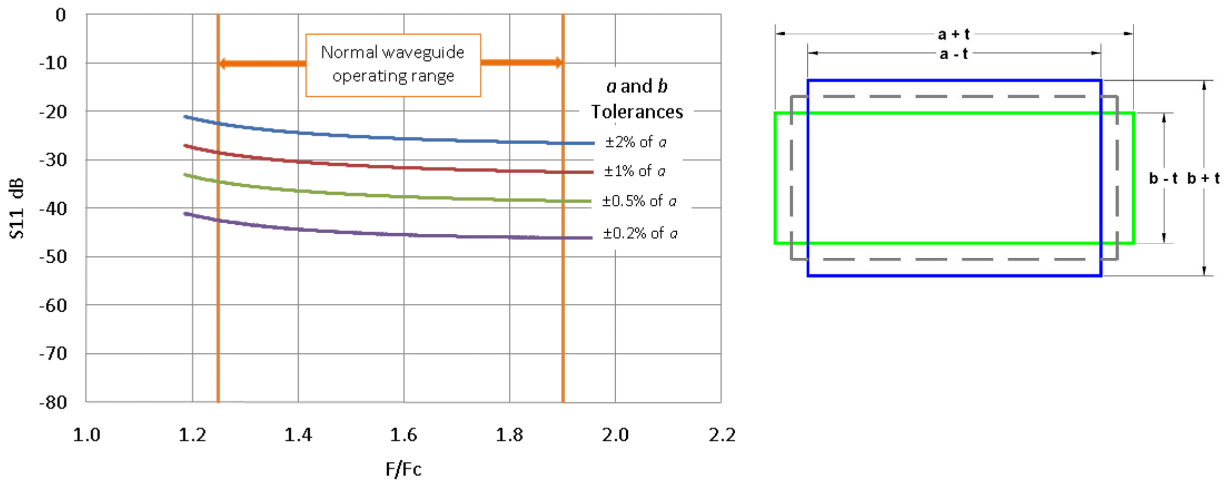

Fig. 1. Reflection coefficient of a junction of two rectangular waveguides with 2:1 nominal aspect ratio. Waveguide 1: *(a - t)* × *(b + t)*. Waveguide 2: *(a + t)* × *(b - t)*. *t* is the tolerance on both *a* and *b*.

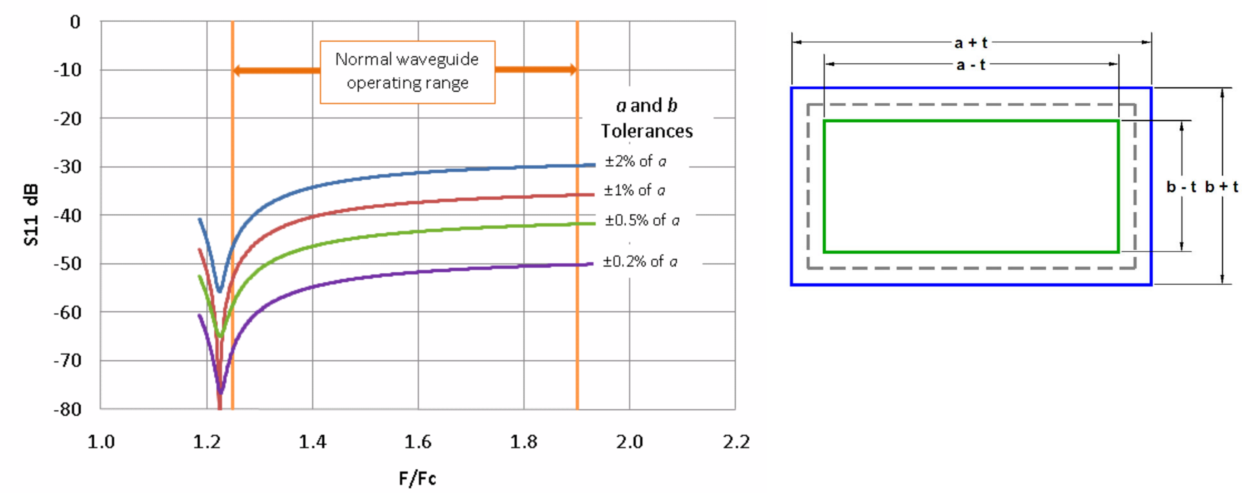

Fig. 2. Reflection coefficient of a junction of two rectangular waveguides with 2:1 nominal aspect ratio. Waveguide 1: *(a + t)* × *(b + t)*. Waveguide 2: *(a - t)* × *(b - t)*. *t* is the tolerance on both *a* and *b*.

Effect of corner radii

Fig. 3 shows the reflection coefficient of a waveguide with 2:1 aspect ratio and finite corner radii (*R*) connected to a perfectly rectangular waveguide with the same height (*b*) and width (*a*). The solid curves are the results of an EM simulation of this configuration. According to Brady [2], a rectangular waveguide with small corner radii is equivalent to a perfectly rectangular waveguide with the same height *b* and the width *a* adjusted to give the same aperture area. The dashed curves in Fig.3 (barely visible on top of the solid curves) are for a junction of two perfectly rectangular waveguides, one of whose width is adjusted using Brady's rule to correspond to the given corner radius.

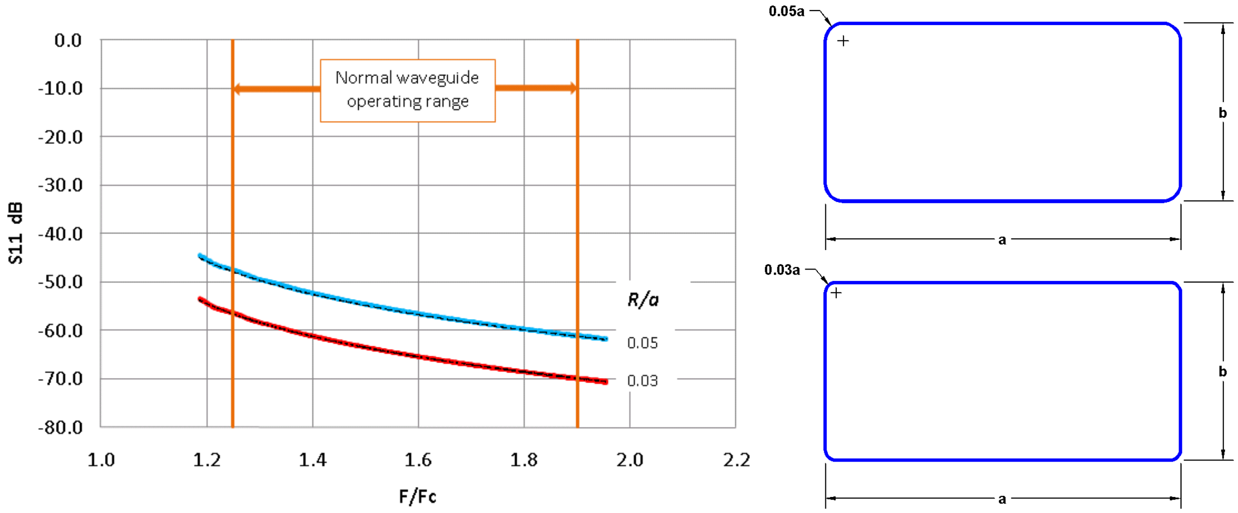

Fig. 3. Reflection coefficient of a perfectly rectangular waveguide of 2:1 aspect ratio connected to one of the same dimensions but with corner radii *R*.

Effect of linear flange misalignment

Figs. 4 and 5 show the reflection coefficient of a junction of two rectangular waveguides with 2:1 aspect ratio, misaligned in the *a*-direction and in the *b*-direction, respectively.

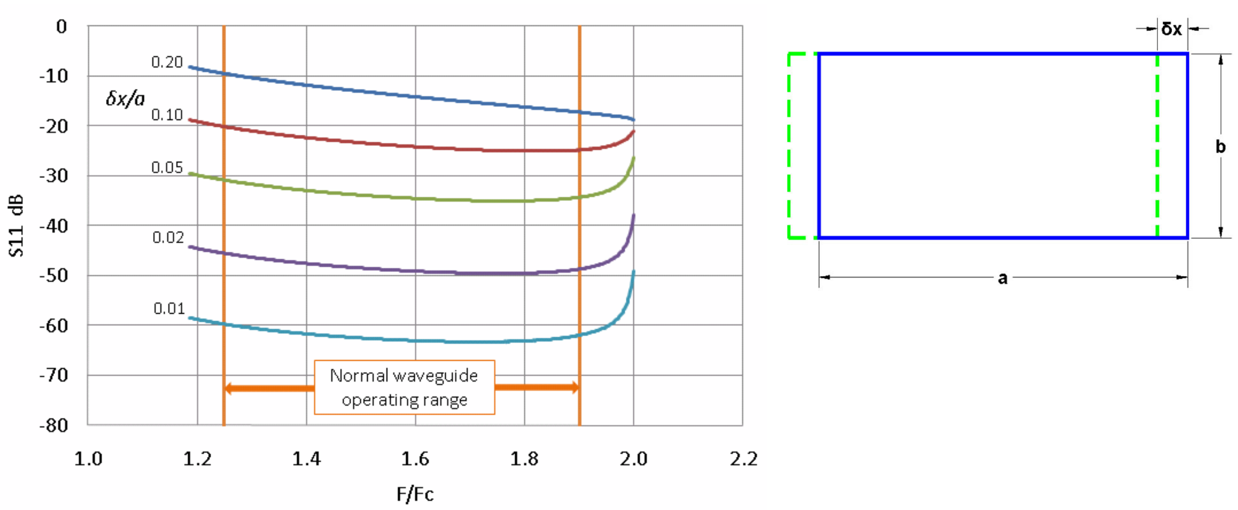

Fig. 4. Effect of flange misalignment parallel to the *a*-direction, for rectangular waveguides with 2:1 aspect ratio.

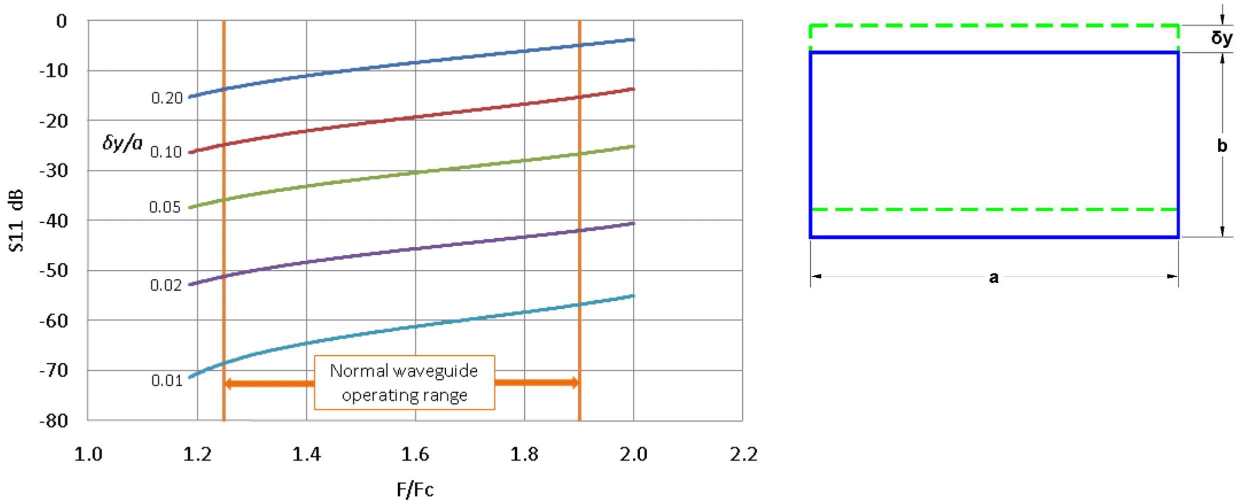

Fig. 5. Effect of flange misalignment parallel to the *b*-direction, for rectangular waveguides with 2:1 aspect ratio.

To first order, a misalignment in the *a*- or *b*-direction is equivalent to a frequency dependent shunt susceptance at the plane of the waveguide junction. For a misalignment in the *x*-direction the susceptance is negative (inductive), and for a misalignment in the *y*-direction the susceptance is positive (capacitive). This is evident in Fig. 6 which shows S11 as a function of frequency for misalignments of 0.2*a* in the *a*- and *b*-directions.

For a misalignment with components in both the *a*- and *b*-directions, the opposite susceptances tend to cancel one another; this is shown in Fig. 6 for a diagonal misalignment with $\delta x = \delta y = 0.2a$.

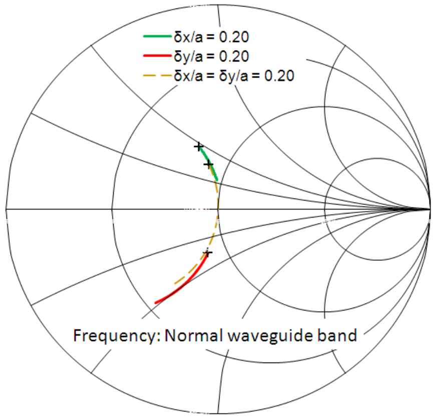

Fig. 6. Smith chart plot of S11 for misalignments $\delta x = 0.2a$ (green), $\delta y = 0.2a$ (red), and $\delta x = \delta y = 0.2a$ (orange). Markers (+) indicate the low-frequency end of each curve.

Effect of angular flange misalignment

It was shown in [3] that rectangular waveguides are quite tolerant to angular misalignment. Fig. 7 shows the reflection coefficient of a pair of waveguides for several angular misalignments. For a pair of UG-387 flanges with the standard pin and pin-hole sizes and location tolerances, the maximum angular misalignment is 1.4°. The angular alignment of the more precise variants of the UG-387 flange, and other more precise flange designs, is generally less than 1.4°.

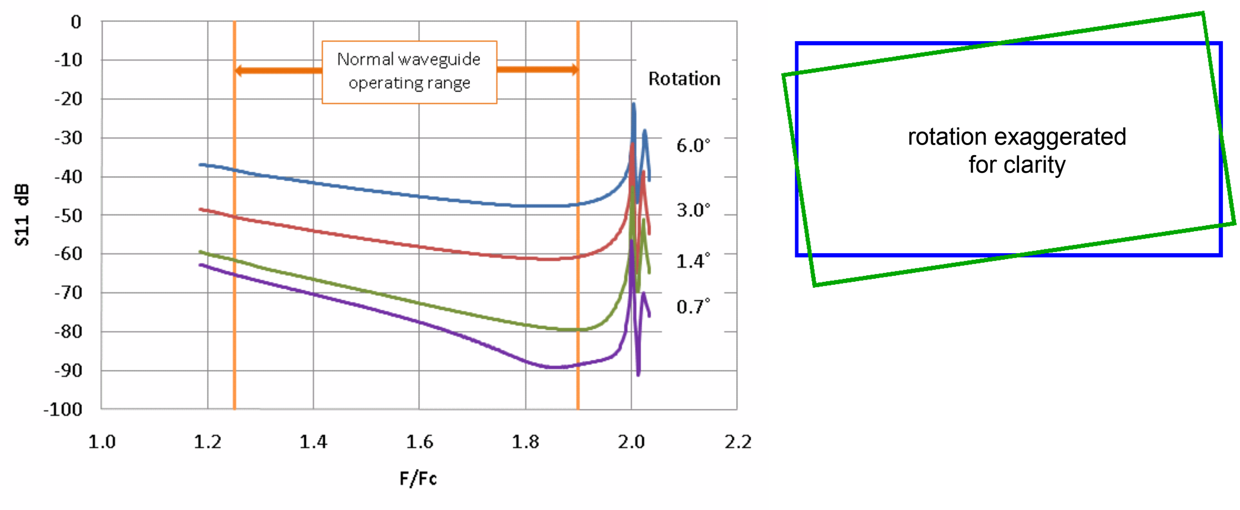

Fig. 7. Effect of an angular misalignment of rectangular waveguides with 2:1 nominal aspect ratio. The original UG-387 specification allows a maximum angular misalignment of 1.4°.

References

[1] D. J. Bannister, E. J. Griffin, and T. E. Hodgetts, "On the Dimensional Tolerances of Rectangular Waveguide for Reflectometry at Millimetric Wavelengths, NPL Report DES 95, September 1989.

[2] M. M. Brady, "Cutoff wavelengths and frequencies of standard rectangular waveguides," Electronics Letters, vol. 5, no. 17, pp. 410-412, 21 Aug 1969.

[3] A.R. Kerr, E. Wollack, and N. Horner, "Waveguide Flanges for ALMA Instrumentation," ALMA Memorandum 278, 9 Nov. 1999. http://www.alma.nrao.edu/memos/html-memos/alma278/memo278.pdf.

Revision Notes

Original EDTN 215, 7 December 2009.
Revised 11 January 2010: Added Figs. 5 and 6 and related discussion.