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

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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, \(\pm t\). 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.

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**Fig. 1.** Reflection coefficient of a junction of two rectangular waveguides with 2:1 nominal aspect ratio.

Waveguide 1: \((a - t) \times (b + t)\). Waveguide 2: \((a + t) \times (b - t)\). \(t\) 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: \((a + t) \times (b + t)\). Waveguide 2: \((a - t) \times (b - t)\). \(t\) 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.

![Diagram of waveguide with corner radii](image)

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.

![Diagram of waveguide with flange misalignment](image)

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 $S_{11}$ as a function of frequency for misalignments of $0.2a$ 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 $S_{11}$ 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 $1.4^\circ$. The angular alignment of the more precise variants of the UG-387 flange, and other more precise flange designs, is generally less than $1.4^\circ$. 
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


Revision Notes

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