National Radio Astronomy Observatory

EDTN 211

Effects of Misalignment of Square Waveguide Joints

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Abstract: **The effects of misalignment between two square waveguides are examined using the QuickWave FDTD EM simulator. The levels of cross-polarization and TE11 and TM11 modes generated at the discontinuity are determined for a number of lateral and rotational misalignments.**

Misaligned joints between square waveguides can generate cross polarization and excite the TE11 and TM11 modes. To examine the magnitude of these effects waveguide joints were simulated with several degrees of misalignment. Motivating this work was the possibility that misalignment between the feedhorn and OMT might account for the unexpectedly high cross-polarization measured on the ALMA Band 6 (211-275 GHz) receivers, and the simulations were done in that frequency range; however the results apply to any misaligned square waveguides with appropriate scaling of dimensions inversely with frequency.

The ALMA Band 6 horn and OMT have 0.0370" square waveguides for which the cutoff frequency of the fundamental TE10 and TE01 modes is 159.5 GHz. Above 225.6 GHz the TE11 and TM11 modes can also propagate. The simulations were done using the QuickWave [1] finite difference time-domain EM solver and included all four of these modes. The maximum mesh size was $\lambda_0/30$. A typical misaligned waveguide assembly is shown in Fig. 1. Each of the modes was assigned a 'port' at each end of the waveguide, a total of eight ports, as indicated in the tables above Figs. 2 and 3.

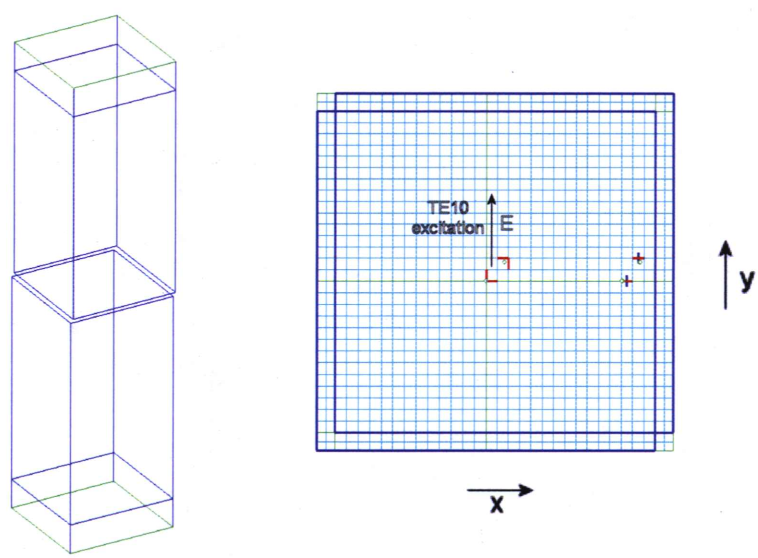

Fig. 1. 0.037" square waveguides with misalignment Δx = Δy = 2 mils, as analyzed by QuickWave, showing the mesh and the mode excitation points.

Fig. 2 shows the TE10 mode transmission and reflection (S21 and S11) and the coupling to the cross-polarized TE01 mode for several misalignments. Fig. 3 shows same information and also the coupling to the TE11 and TM11 modes at each end of the waveguide. (Note the different vertical scales in Figs. 2 and 3.)

Port Numbering

Mode	Source End	Load End	Fc GHz
TE10	1	2	159.5
TE01	4	3	159.5
TM11	5	6	225.6
TE11	7	8	225.6

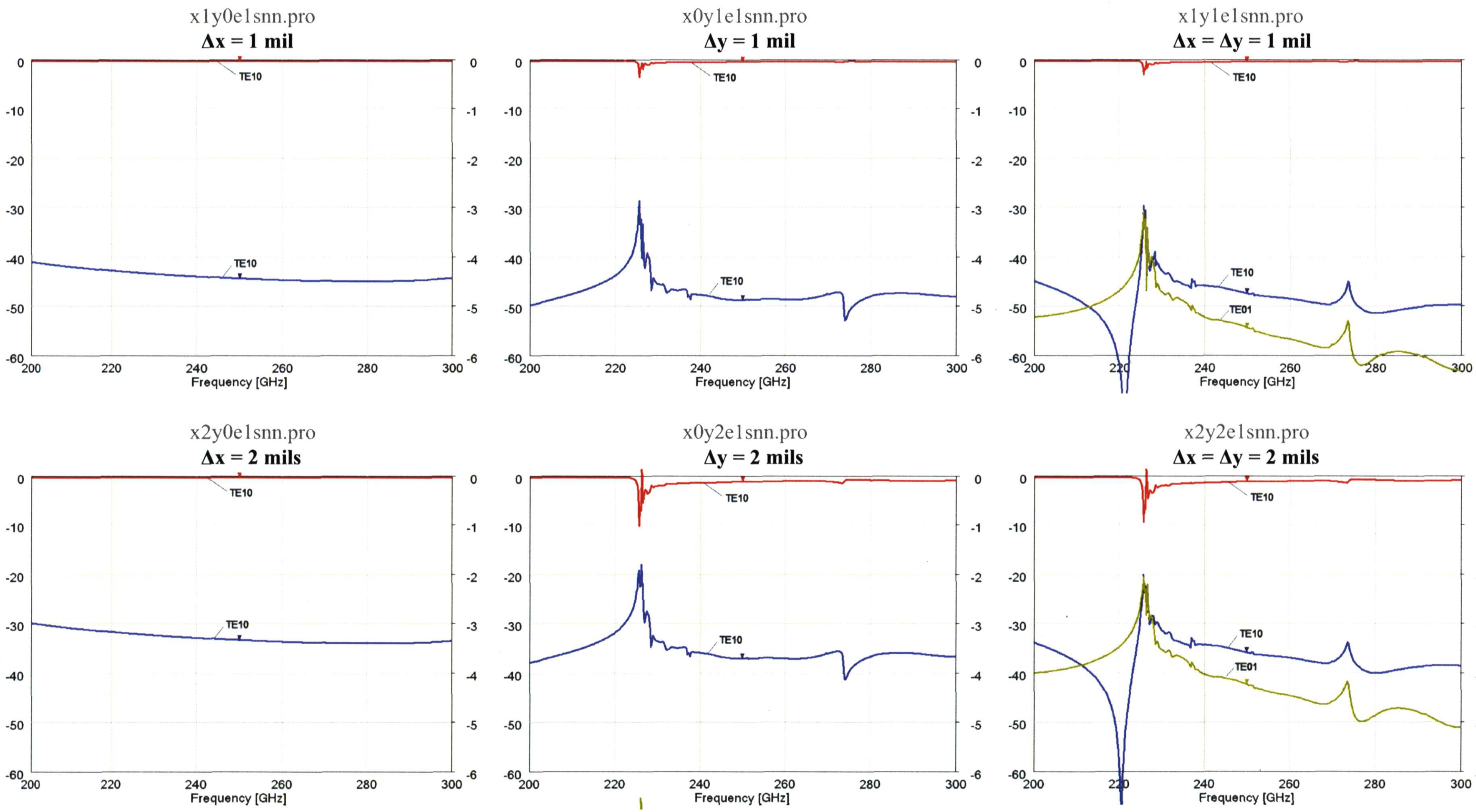

Fig. 2. TE10 mode transmission (red, right scale) and reflection (blue, left scale), and coupling to orthogonal TE01 mode (green, left scale) for several flange misalignments.

Port Numbering

Mode	Source End	Load End	Fc GHz
TE10	1	2	159.5
TE01	4	3	159.5
TM11	5	6	225.6
TE11	7	8	225.6

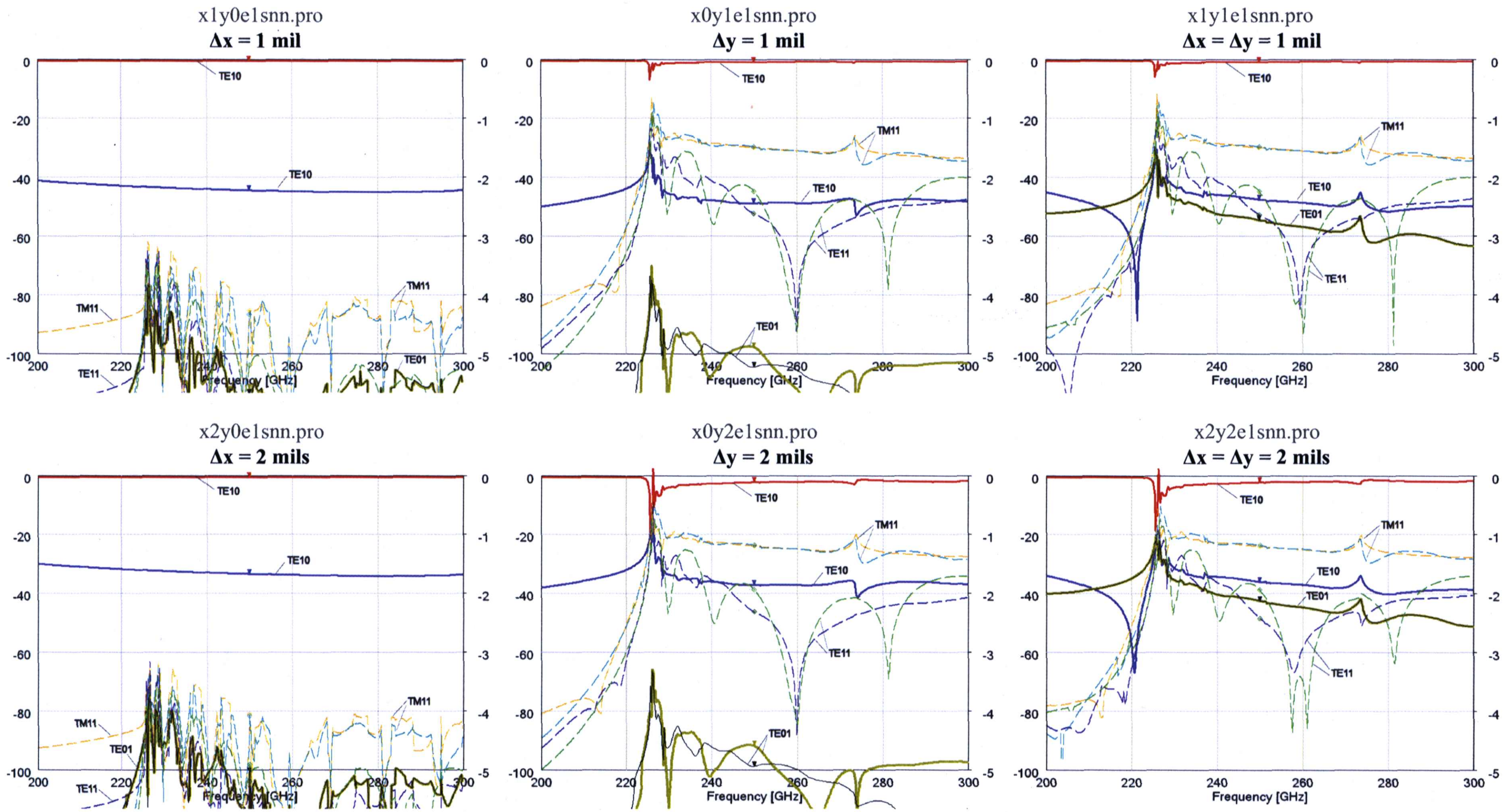

Fig. 3. Coupling (dB) from TE10 to other modes for several flange misalignments.

Discussion

It is clear from Figs. 2 and 3 that cross polarization is not produced by a lateral waveguide misalignment in either the x-direction or the y-direction alone, but only by misalignment in both x- and y-directions simultaneously. This is as expected from symmetry. For the 0.037" square waveguides, a simultaneous x and y misalignment of 2 mils (about 5% of the a-dimension of the waveguide) generates a cross-polar component below -30 dB except for a narrow band near the 225.6 GHz cutoff of the TM11 and TE11 modes in which the cross-polar component is below -20 dB in the simulations.

The higher modes, TE11 and TM11, can propagate above 225.6 GHz and it is seen that they are excited by misalignment in the y-direction (*i.e.*, perpendicular to the E-field of the exciting TE10 mode), with the TM11 being the more strongly excited. In a practical circuit, in which there are complex waveguide elements either side of a misaligned square waveguide joint, there is the possibility that the adjoining elements will convert the TM11 or TM11 modes to TE01, thereby increasing the net cross-polar conversion.

Angular flange misalignment between square waveguides generates cross polarization in two ways: (i) directly, due to the rotation of the output waveguide relative to the input, the cross-polar power depending on the square of the sin of the rotation angle; and (ii) from the excitation of higher modes at the discontinuity produced by the rotation. Simulations show that for angles of a few degrees effect (ii) is substantially smaller than (i). Fig. 4 shows the dependence of cross-polarization on angular misalignment based on effect (i).

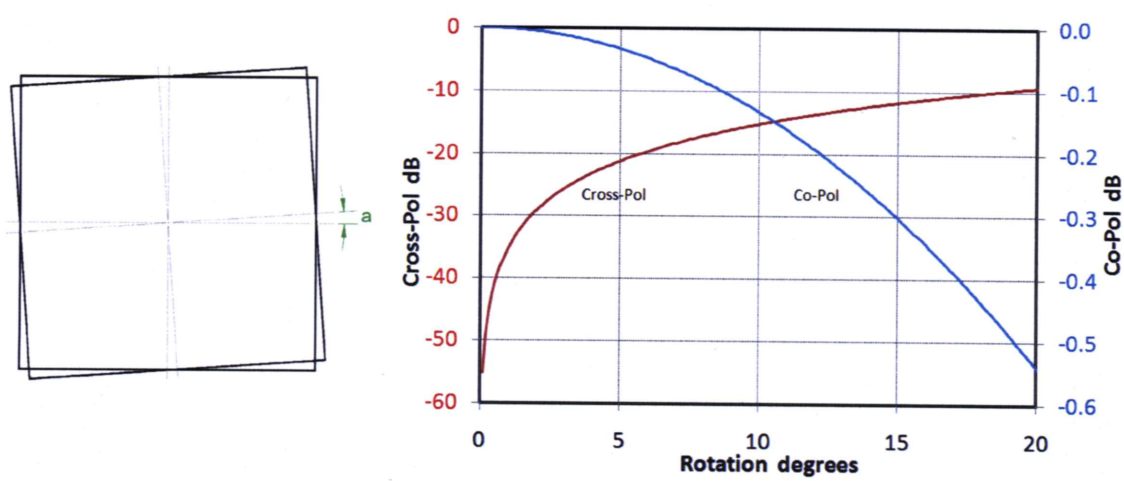

Fig. 4. Cross polarization caused by angular misalignment.

As an example, with the tight flange tolerances of the ALMA Band 6 components, the maximum possible angular misalignment is 2°, which would cause a -29 dB cross-polar component. With a 4° angular misalignment, the cross-polar component would be -23 dB.

Low-level spurious effects in the simulations

To check for low level effects due to the finite mesh size and numerical roundoff errors, the simulation was run with no misalignment. The result is shown in Fig. 5. The fundamental (TE10) mode return loss is greater than 110 dB across the band. The only spurious responses above the -100 dB level are the TM11 mode, with a peak of -70 dB near the 225.6 GHz cutoff frequency of the 11 modes. It is not surprising to find a spurious response close to a mode cutoff frequency as the guide wavelength becomes infinite there.

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TE11	7	8	225.6

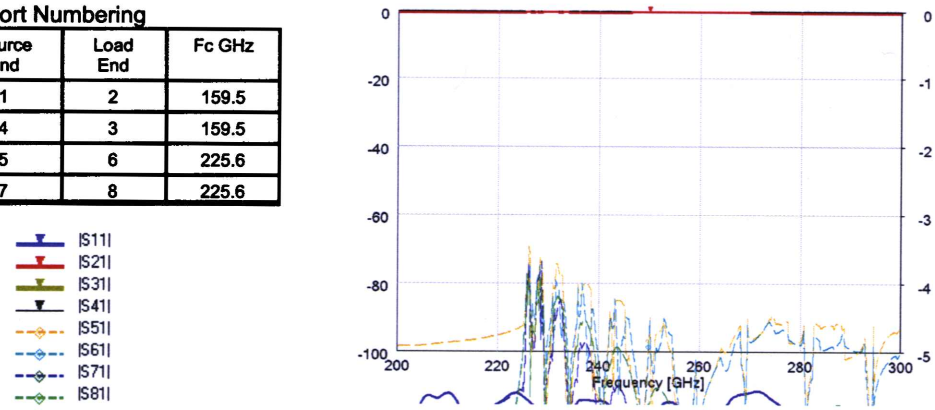

Fig. 5. Simulation with no misalignment.

When the square waveguides are misaligned, as in Fig. 3, the TE11 mode is excited at frequencies above its cutoff at a small but significant level. The quasi-periodic ripples in the TE11 curves in Fig. 3 appear to be an artefact of the simulator as their spacing depends on the length of waveguide used in the simulation; in a perfect simulator with an infinitely fine mesh and perfect absorbers the length of the waveguides would not influence the result as long as the discontinuities were a few waveguide widths from the reference planes and loads. Fig. 6 shows the results for $\Delta x = \Delta y = 2$ mils, as in Fig. 3 but with waveguides twice as long.

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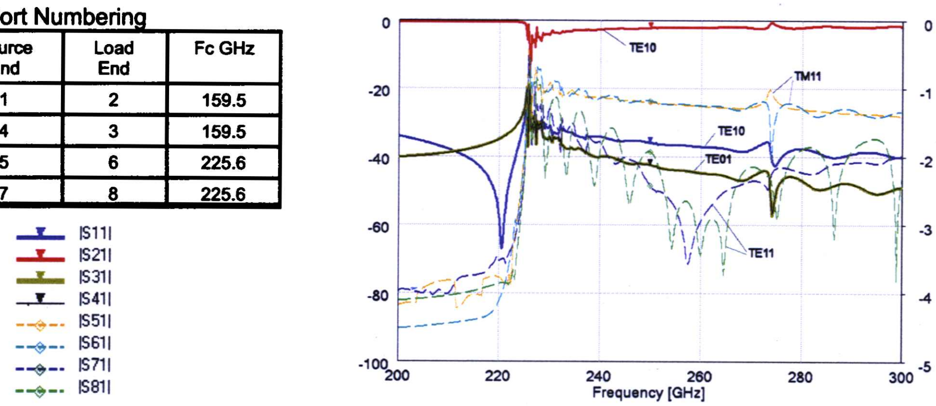

Fig. 6. As in Fig. 3 with $\Delta x = \Delta y = 2$ mils but waveguides twice as long.

Reference

[1] QuickWave 3-D v. 7.0: QWED Sp. z o.o., Warsaw, Poland. http://www.qwed.com.pl/.