Standing Wave Measurements of First Structure

The structure was set up to measure the reflection coefficient with the output shorted with a variable length short. The first set of measurements was that of the resonant mode frequencies at different lengths of the short. Based on these results, measurements were made with different length shorts, each one putting an effective short circuit at the output coupling iris. The results are reported in this note.

Measurement of the Length of the Adjustable Short. (5/30/97) The adjustable short is manufactured by Aerowave. Changes in the location of the shorting element are measured on a micrometer barrel (with readout units of 0.001"). The absolute position of the shorting element was determined by approximately measuring its position, and then measuring the phase and comparing that with the phase of a short circuit connected directly to the waveguide. The approximate length measurement was used to determine the multiples of 180^o that must be added to account for the measured phase shift. The result is that the short is 18.750 mm behind its waveguide flange when the micrometer reading is zero.

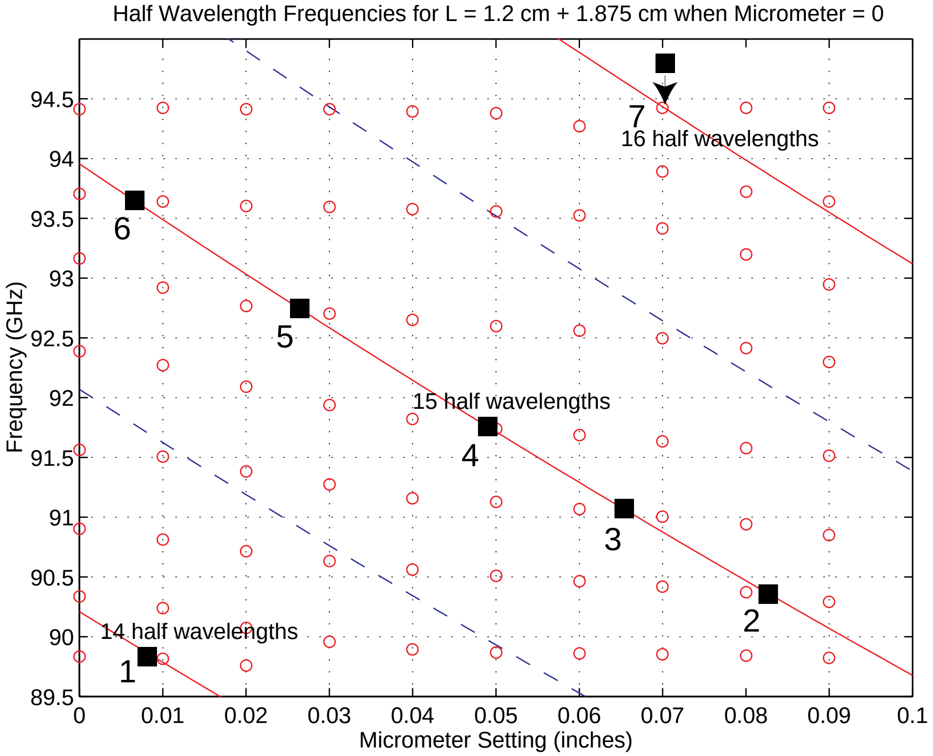

Figure 1: Solid lines indicate the adjustable short equal to a multiple of one-half wavelength in length. Dashed lines indicate multiples on one-quarter wavelength. The circles are the resonant frequencies determined from scans at different lengths of the adjustable short. Squares indicate settings for scans on 6/2/97 (discussed below)

Frequency Scans with Different Lengths of the Adjustable Short. (5/24/97) Frequency scans from 89.5 - 95 GHz were taken for different lengths of the adjustable short 0.000", 0.010",...,0.080", 0.090". The results are summarized in the plot above which shows the resonant frequencies together with lines corresponding to different half-wavelength multiples of the termination. (The total termination length is 18.75 mm plus 12 mm, the length of the waveguide transition that is part of the structure plus the difference of the micrometer from zero setting.)

The frequency of an individual mode decreases as the length of the short is increased. Depending on the length of the short there can be either seven or eight modes observed. Modes disappear when the frequency falls below ~ 89.6 GHz, and new modes appear near 94 GHz as the length of the short is increased.

Frequency Scans on a λ/2 Line. (6/2/97) Frequency scans were performed over limited frequency ranges at the points indicated in figure 1. The lengths were selected by having the mode cross a λ/2 line at that value of the length; this corresponds to the iris being shorted. Points are numbered as indicated in the figure.* The amplitude versus frequency is shown below.

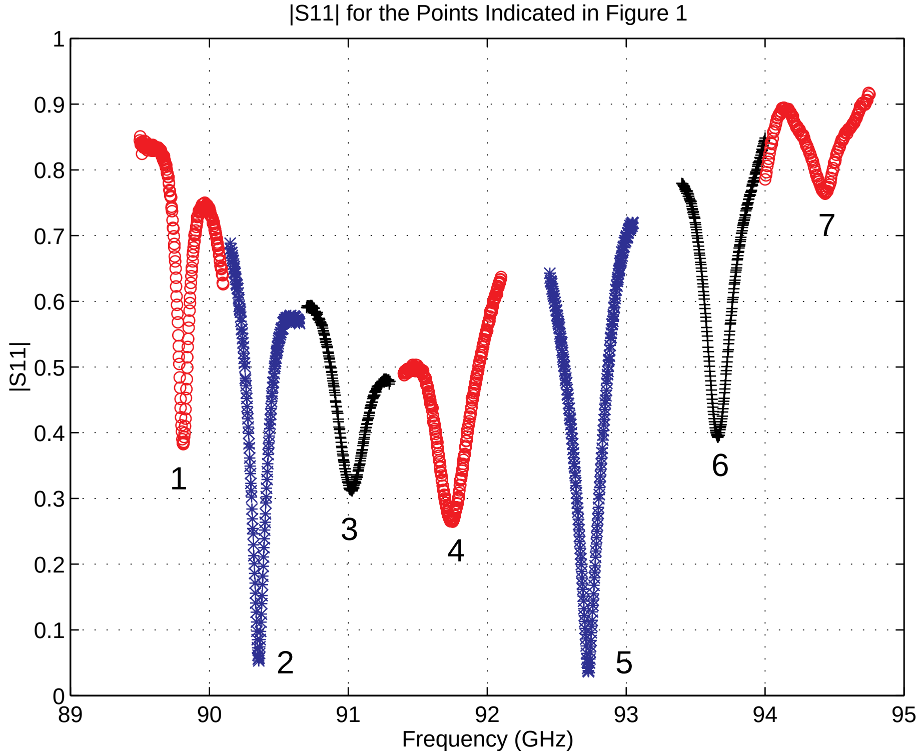

Figure 2: $|S_{11}|$ for the seven point in Figure 1.

The frequency scans were fit with the following model: 1) a factor that accounts for the attenuation in the 12 mm long wave guide transition; 2) reflection from a reactance in series with an LCR circuit. An explanation follows. S_{11} as recorded by the LabView program includes a correction for the length of the waveguide transition but not for the losses in it. The measured S_{11} in terms of ρ, the reflection coefficient at the entrance to the structure is

$$S_{11} = \rho\frac{1+\alpha L}{1-\alpha L} = \rho F$$

in terms of α, the loss per unit length. The factor F in the tables below is given by this equation. The reflection coefficient ρ is given by

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[*] This is not the same nomenclature used when recording data. See log book for details when using raw data files.

$$\rho = \frac{Z/Z_0 - 1}{Z/Z_0 + 1}$$

For the circuit model of a reactance in series with a resonant circuit (Ginzton, eq 9.19)

$$\frac{Z}{Z_0} = j\frac{X}{Z_0} + \frac{\beta_1}{1 + 2jQ_0\delta}; \quad \delta = \frac{f - f_0}{f}$$

The real and imaginary parts of S_{11} for the scans shown above in figure 2 were fit with this model. The free parameters were a phase offset, ϕ_0; the loss factor, F; the reactance, X/Z_0; the coupling, β_1; the unloaded Q, Q_0; and the resonant frequency f_0. The fits were good except for point 7. Two typical fits are on the next page. Note that they are an approximately critically coupled and an undercoupled case. In the former case the phase of S_{11} decreases as the resonance is crossed, and in the latter case it increases.

The results form the fits are below

Point	**Micro-meter**	**ϕ_0 (degrees)**	**F**	**X/Z_0**	**β_1**	**Q_0**	**f_0 (GHz)**
1	0.009"	0	1.28	-0.167	0.35	1310	89.814
2	0.083"	-215	1.42	-0.151	1.21	920	90.366
3	0.066"	-271	1.32	-0.049	2.45	630	91.038
4	0.049"	-62	1.51	-0.026	2.44	740	91.745
5	0.026"	-235	1.52	-0.071	1.13	680	92.729
5'	0.0215"	-235	1.49	-0.093	1.03	690	92.760
6	0.006"	-315	1.34	0.042	0.31	670	93.657
7	0.070"	60	1.10	22.9	61.1	2500	94.051

For the six points that are reasonably fit, <F> = 1.40 which implies $\alpha L = 0.20$ or the loss is 160 db/m which is to be compared with ~ 4 db/m for Aerowave WR10 waveguides. We need the test cut waveguides from RWI to see if the losses are really this bad. In all but one case the reactance is negative indicating that the iris is capacitive rather than inductive as assumed in the equation above.

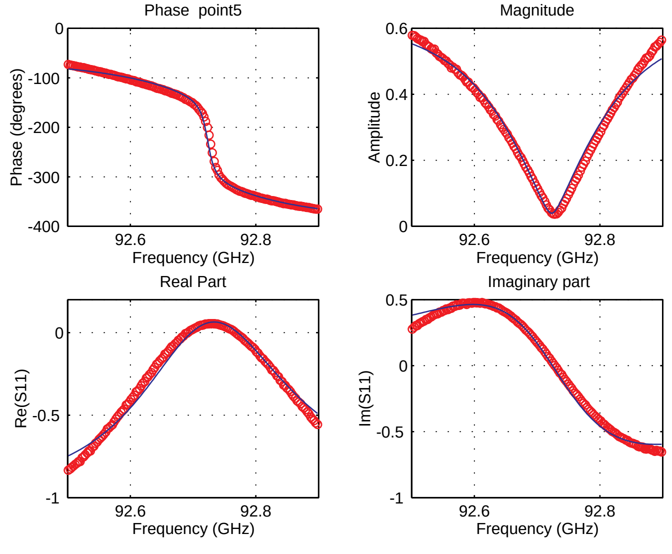

Figure 3: Fit to the real and imaginary parts of S_{11} for point 5.

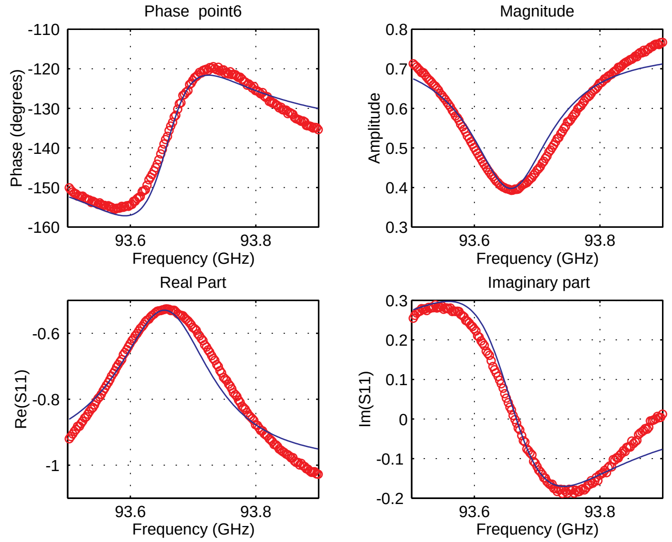

Figure 4: Fit to the real and imaginary parts of S_{11} for point 6.

Points 2 and 5 are close to being critically coupled. The coupling can be tuned with small changes in the length of the short. The figure below shows this for the region near point 5. Moving the micrometer from 0.026" to 0.0215" makes the coupling close to critical.[*]

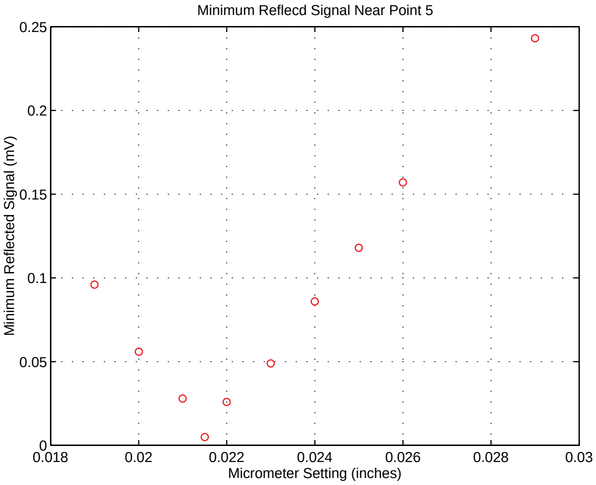

Figure 5: Value of minimum signal in the region of point 5.

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[*] This point is in the table above as point 5'.