Team Workshop Problem 19

Microwave Field in a Loaded Cavity

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Abstract. Proposed problem for the TEAM workshop: microwave field in a loaded cavity.

The benchmark

A standard 86.36 x 43.18 mm waveguide abuts on a cylindrical cavity, closed except for a rectangular iris. (Cf. Figs. 1 and 2. All dimensions are as measured *inside* the cavity. The metal sheets are 3 mm thick, and made of electrolytic copper, σ =4.7.10^7 S/m.) There are two symmetry planes, one horizontal and one vertical. The iris height is 43.18 mm, and its width is variable. The electric field at the entrance of the waveguide is as shown in Fig. 1 (TE_{10} mode). Measurements give the standing-wave ratio (actually, the entry S_{11} of the S-matrix), as a function of the frequency. Fig. 3 is typical in this respect. The resonant frequency is immediately read off these figures.

The cavity may be empty, or loaded as shown on Fig. 1, by inserting a vertical rod of either Plexiglas or PVC, whose diameter is either 7 or 9 mm. Best estimates for the $\varepsilon_r = \varepsilon/\varepsilon_0$ of these materials are: $\varepsilon_r = 2.7 - 0.01$ i (Plexiglas) and $\varepsilon_r = 4.0 - 0.1$ i (PVC). There is some uncertainty about these values, and this is the weak point of the benchmark. On the other hand, the monitoring of the frequency and of the SWR is quite accurate.

The resonant frequency has been determined for a series of increasing values of the iris width, and for five different loading conditions: empty cavity, PVC and Plexiglas rods of diameters 7 and 9 mm. Results are displayed on Fig. 4. The parameter in abscissa is the width *l* of the iris. This width was steadily increased, day by day, over a period of a few weeks in June and July 1992, by careful, hand-made and eye-controlled, machining. Each time, measurements were taken for all loading conditions.

The cavity must be disassembled between two experiments, and because of the unavoidable play, its dimensions are never quite exactly the same. Fig. 5 shows the irregularity in the frequency response due to this factor. There is an erratic error on the resonant frequency. We believe the absolute error to be less than 1 MHz.[1]

Some impedance values are also available (Cf. Fig. 6, and the zoom in Fig. 7). Upon comparison between Figs. 6 and 5, we believe the measurement-points marked '?' to be spurious.

Suggested computations

1° Assume the iris-width l = 15 mm and the 9 mm plexi rod. For a series of values of the frequency in the range 2400-2600 MHz, compute the electric field in the cavity, as excited with the TE_{10} mode of Fig. 1, and determine the highest magnitude. Plot this against the frequency. Locate the resonance peak. Do the necessary complementary computations to plot the frequency in a 10-MHz wide range around the resonance frequency thus determined. (Increments of 1 MHz or less are recommended.)

2° Give visualizations for both fields e and h at the resonance value (e in the vertical symmetry-plane and h in the horizontal one), at phase 0. (Optional: give plots of both fields in the plane of the iris. We plan to make infrared thermography measurements there in a not too distant future.)

3° Still with l = 15 mm, and for all five loading cases, try and locate the resonant frequency, by the above method or any other method.

4° If computing resources are sufficient, do this for other iris-widths as well.

5° Suggested themes for discussion: What is the dependence of the results on ε' and ε"? How sensitive are they to the shape of the aperture? How critical is the modeling of this part of the cavity, especially as regards the width of the iris wall (d in Fig. 1)? How important is it to refine the mesh in the load and near it? How beneficial are mesh-refinement procedures?

1. In a few cases, we have two measurements on the same configuration, before and after a full disassembly, to confirm this estimate: at l = 15 mm, no load, 2.54538 the first time, then 2.54454, i.e., Δf = .84 MHz; at l = 15.5 mm, with the PVC9 load, Δf =.6 MHz.

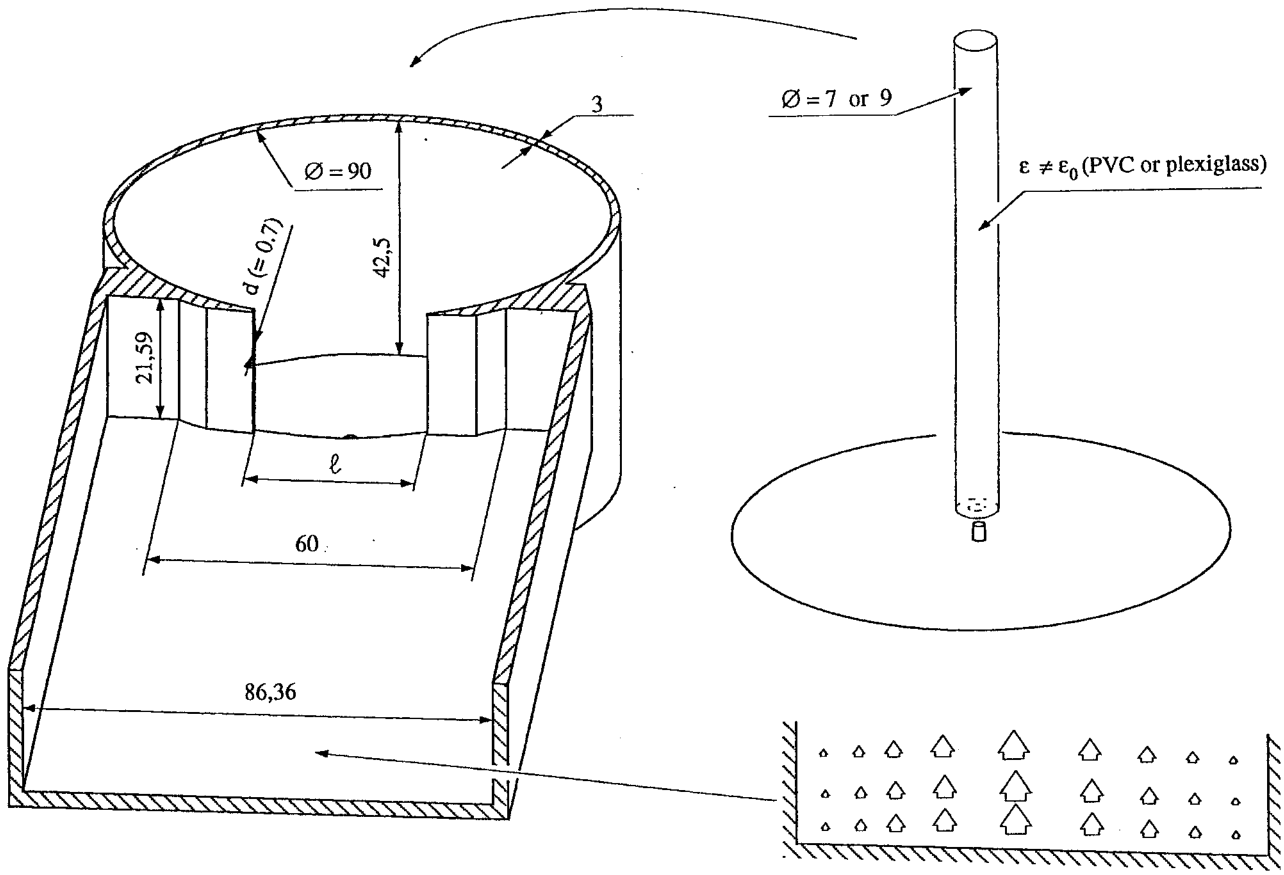

Figure 1. Left: the lower half of the cavity. Above right: how the dielectric rod is placed (small pegs at the bottom and at the ceiling of the cavity help center it. Bottom right: shape of the electric field in the front cross-section of the wave-guide.

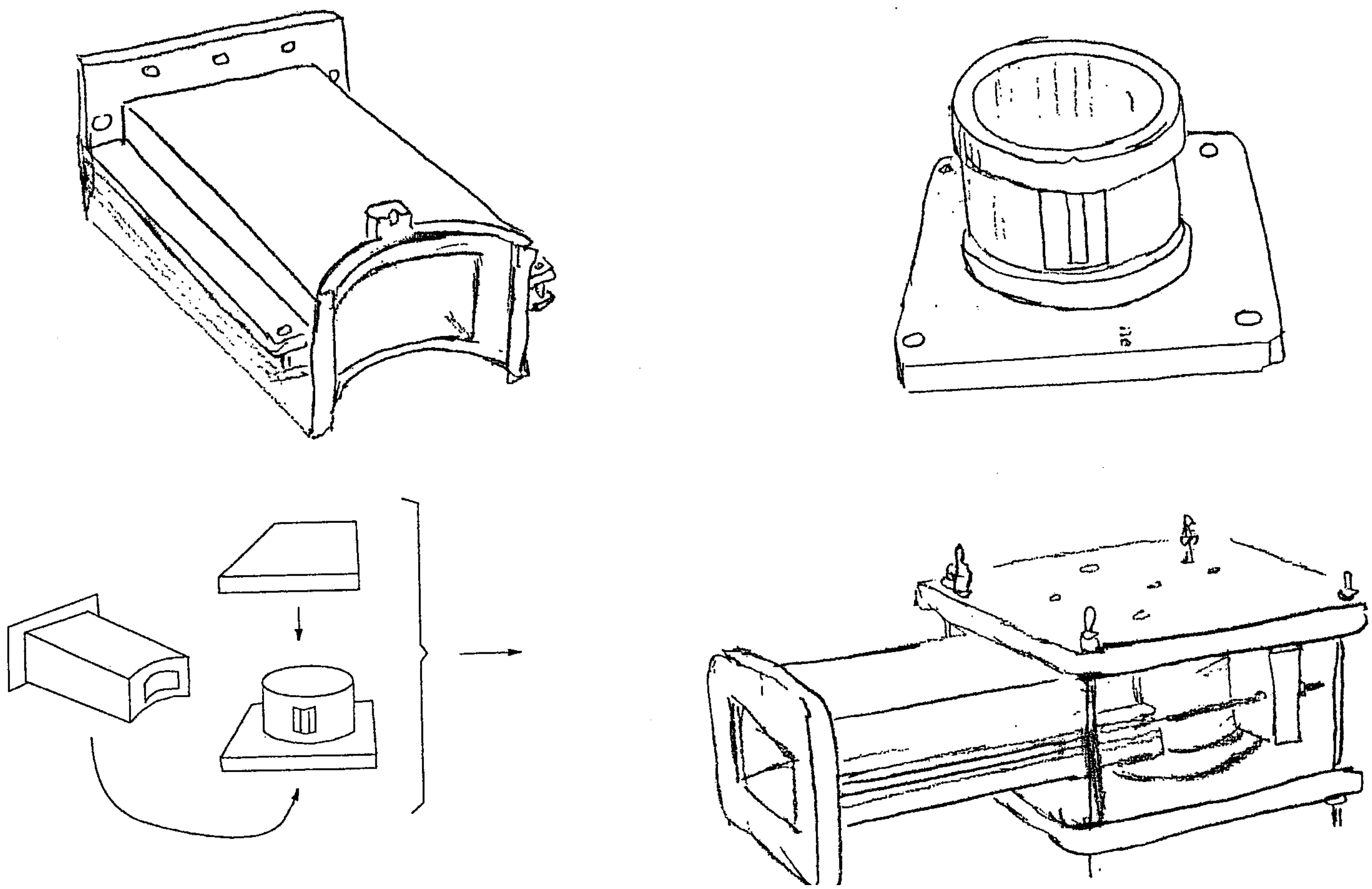

Figure 2. Assembly of the cavity from its main pieces: the slitted cylinder, the rectangular waveguide, the upper square flask. Bottom right, the whole apparatus.

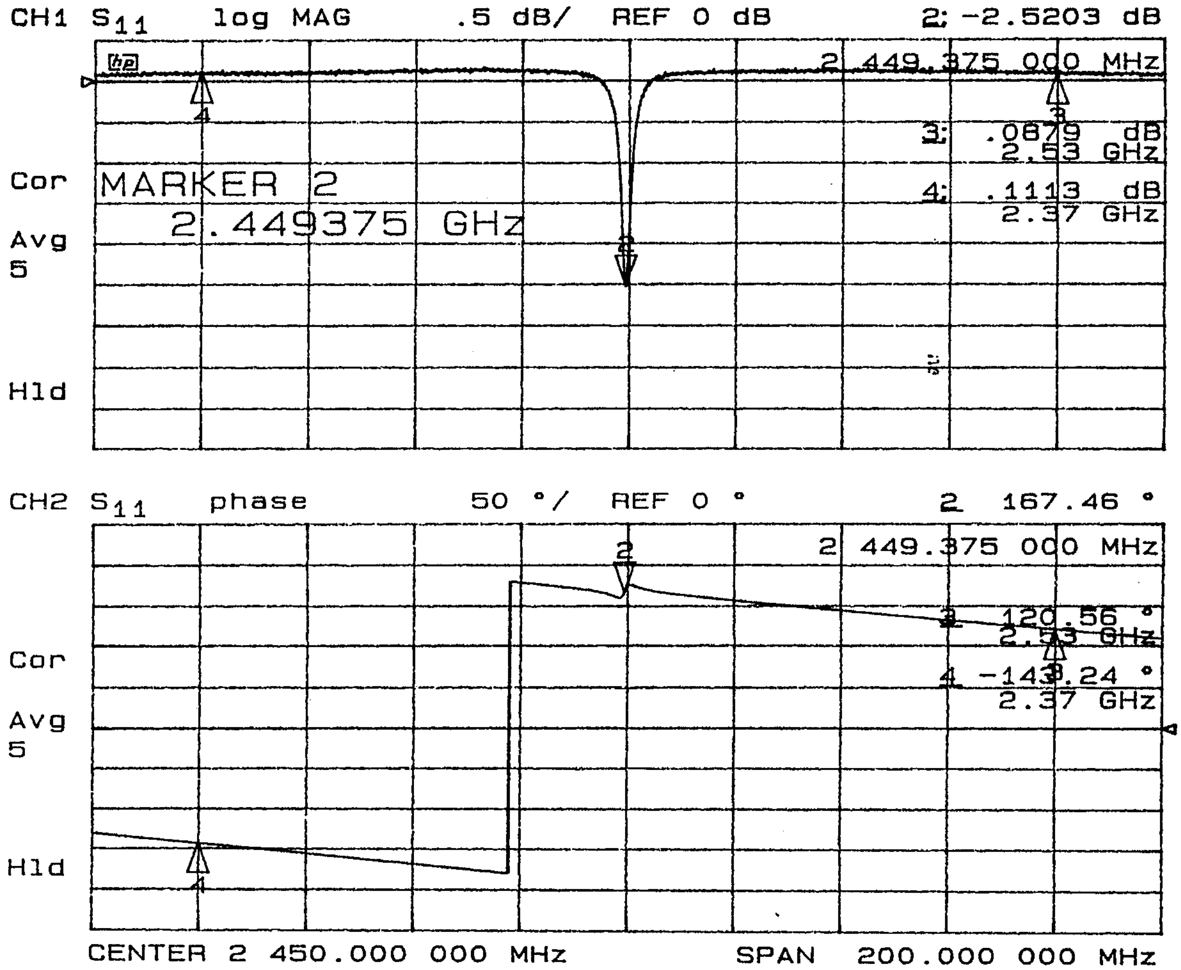

Figure 3. Results of a typical run (here *l*=15mm and the PVC9 load).

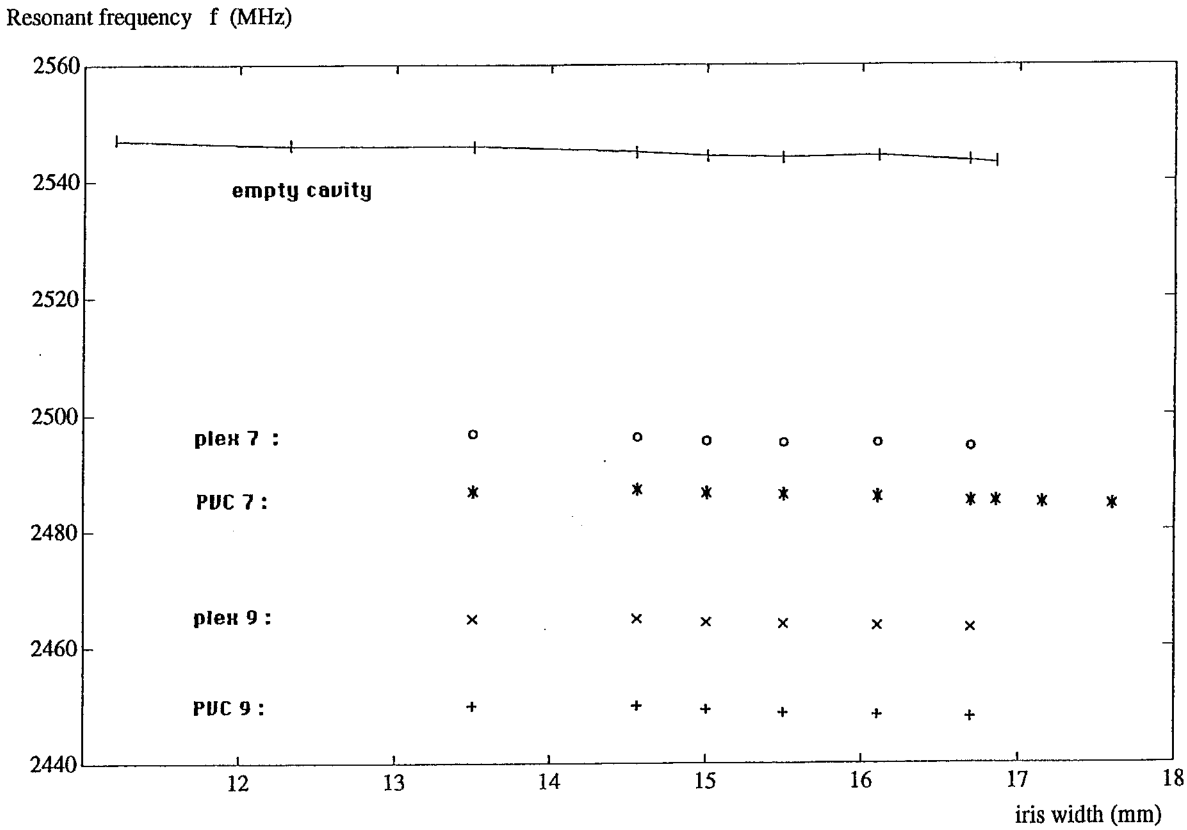

Figure 4. Experimentally determined resonant frequencies.

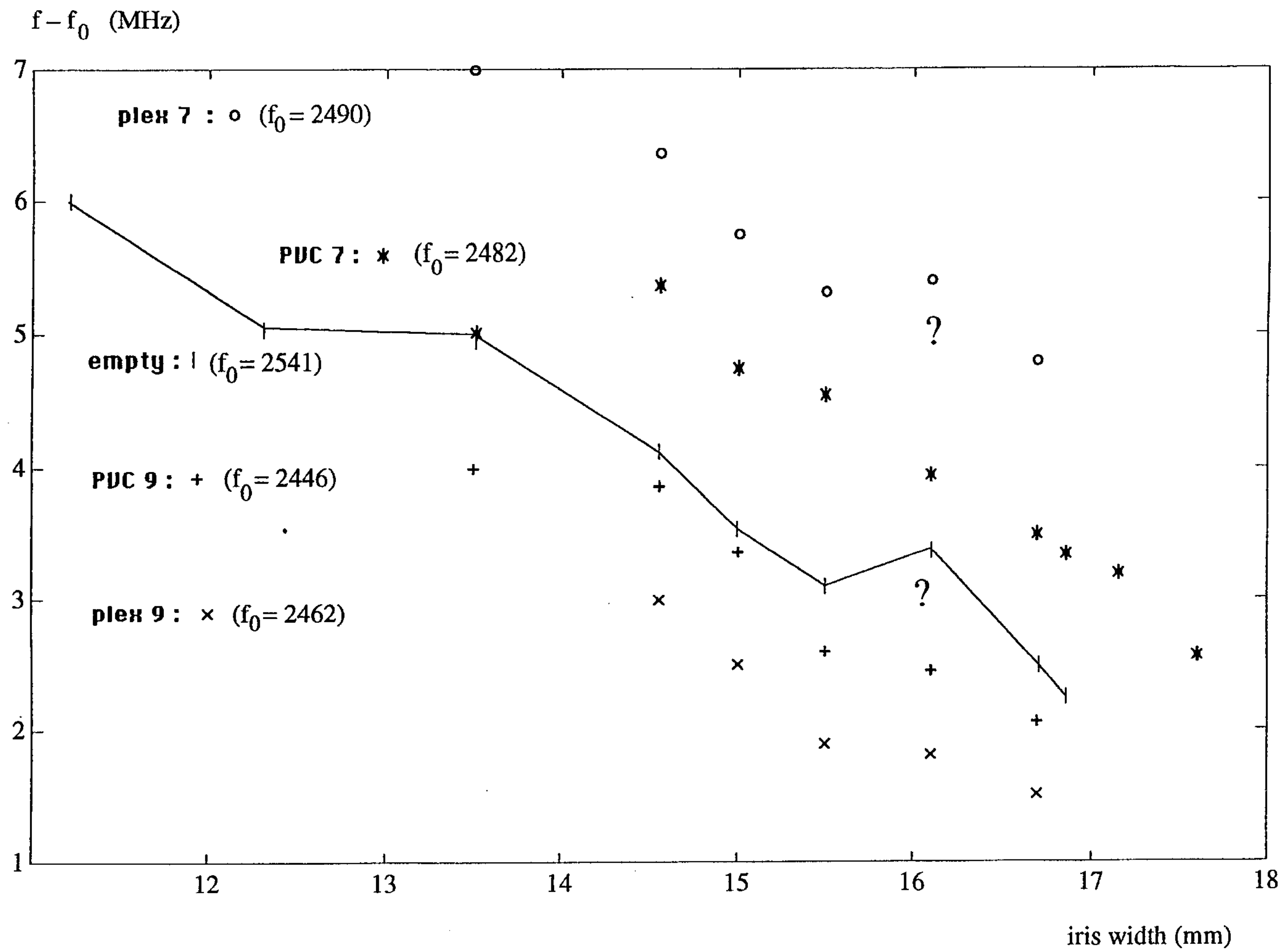

Figure 5. Blow-up of Fig. 4, with shifted origins (shift = f), suggesting the magnitude of experimental error, and some possibly spurious points.

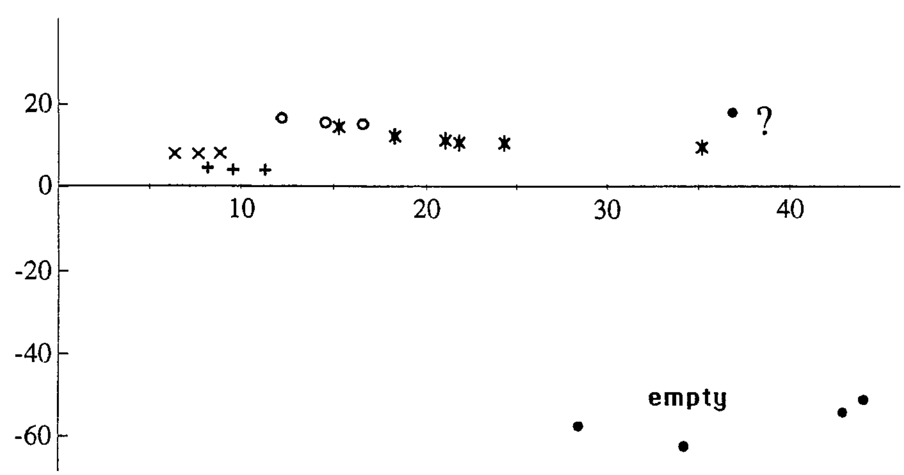

Figure 6. Impedance

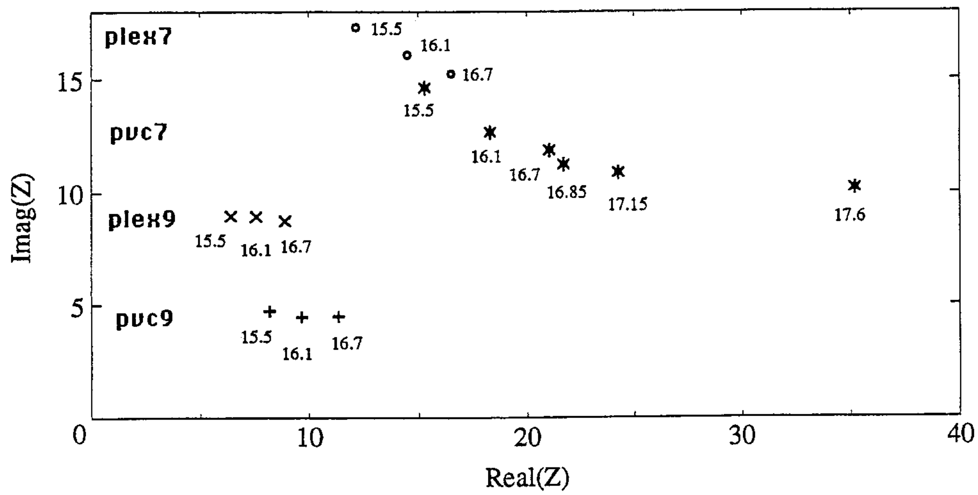

Figure 7. Impedance, for all loaded cases.