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A NEW 290-310 GHz MIXER

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A new 290-310 GHz mixer block has been designed as part of a general upgrade of the Schottky receivers at the 12-meter telescope. Over the past few years we have investigated extending the frequency range of existing NRAO 200-240 GHz, 240-290 GHz, and 330-360 GHz mixers to cover the whole 200-360 GHz band. It seems difficult to get good performance over this whole band with only three fixed-tuned mixers. Our goal was to obtain a receiver noise temperature of about 800 K from 290-310 GHz, so a new design was needed.[1] As there was insufficient time to begin a completely new design, the new mixer was scaled from a successful design. The mixer block itself was to be an exact scale of the Archer 200-290 GHz block [1], [2], and the feed was to be an exact scale of the Ulich horn and lens [3].

The Archer 200-290 GHz mixer block is a proven design, with mixer noise temperatures varying from the record low 330 K (using UVA 2P9-300 diodes) to today's more typical 500 K (using UVA 2I1, 1I2, 2P19 and 1H6 diodes). It is used on the 12-meter telescope today, not only on the main 200-290 GHz Schottky receiver, but also on the new 8-feed, 230 GHz focal plane array receiver [4]. The waveguide circuitry and the quartz substrate of the new 290-310 GHz mixer were scaled by 0.7667 (the ratio of 230 GHz/300 GHz) from the Archer 200-290 GHz design. The outer dimensions of the mixer block and the horn were kept the same as those of the Archer mixer to ensure that the new blocks would fit the dewar, test jigs and standard bias tees.

The Ulich feed is a corrugated horn and lens combination that has become a standard on the 12-meter. As the original Ulich horn and lens were designed for a center frequency of 93.5 GHz, the new horn and lens were scaled by 0.3177, the ratio of 93.5 GHz/300 GHz.

As is often the case in frequency scaling millimeter wave equipment, it was not possible to scale all dimensions exactly. The width of the corrugations in the feed horn had to be increased slightly, as electroformed copper would not throw well into the comparatively deep, narrow grooves of the strictly scaled Ulich horn. The distance between the feed horn and the circular-to-rectangular waveguide transition had to be increased in the new design in order to maintain the thickness of the mixer block. The whisker post had to be made slightly smaller than scale in order to use the 14.5 mil diameter posts that were on hand. About 16 mils of 50 ohm line had to be added to the choke substrate between the filter and the bellows contact so that the substrate would be long enough to reach the bellows. One last difference between the Archer prototype and the new scaled block was the use of a 5-mil, gold wire gasket instead of a choke groove to seal the mixer block to its backshort plate, ensuring a low loss connection at both signal and harmonic frequencies.

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[1] All noise temperatures quoted in this note are single sideband numbers, measured with the mixer cooled to about 20 K. All frequencies are local oscillator frequencies.

Five mixer blocks were made. Figures 1, 2, and 3 show the assembly of the Archer prototype mixer, diode, and bias tee [5]. Figures 4-17 are the complete machining drawings for the scaled 290-310 GHz mixer and its feed horn. 2I1-150 diodes, which had given good results in the 230 GHz mixers, were used exclusively in the new 300 GHz blocks. Fabricated by Prof. R. Mattauch at the University of Virginia Semiconductor Device Lab, these diodes have 2.3 micron diameter anodes, a zero bias capacitance of 4.5 fF and a room temperature series resistance of 13.5 ohms. (They were designed to be similar to the old 2P9-300 diodes.) The 2 x 4 mil diode chips were mounted in the mixer block with the face of the chip flush with the edge of the waveguide. The diode was contacted by a pointed, 0.5-mil diameter, gold-plated, phosphor bronze whisker. The whisker wires were typically 5.5 mils long before bending and, as the post was usually flush with the waveguide wall, the whisker tip was typically 3.8 mils from the post face. Figures 18 and 19 are actual scanning electron microscope (SEM) photographs of a 290-310 GHz mixer, showing the substrate, diode chip and contact area.

The noise temperature of this new design averaged about 1100-1200 K at 300 GHz, but tended to increase sharply at the high frequency band edge (see Figure 20). There is no rolloff at the low frequency band edge. The new design is an improvement over the old 270-290 GHz design, but not as much an improvement as was hoped. So far, time has prevented more than an initial optimization of the chip position, post position and whisker length. Figure 21 compares the noise temperature of the new mixer with the mixer used the previous year on the telescope. The performance of the new mixer does compare well with the performance of other mixers using the same diode, as can be seen in Figure 22. (The 2I1-150 diodes are now used at every frequency range except for 240-290 GHz, where the old 2P9-300 diodes are still used.)

REFERENCES

[1] J. W. Archer, "All Solid-State, Low-Noise Receivers for 210-240 GHz," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-30, pp. 1247-1252, Aug. 1982.

[2] J. W. Archer, "A Multiple Mixer, Cryogenic Receiver for 200-300 GHz," *Rev. Sci. Instr.*, vol. 54, no. 10, pp. 1371-1376, Oct. 1983.

[3] B. L. Ulich, "Optimized Cassegrain Feed System," Tucson Operations Internal Report No. 6, March 1980.

[4] J. Payne, "A Multi-Beam Receiver for Millimeter-Wave Radio Astronomy," submitted to *Rev. Sci. Instr.*, to appear in the September 1988 issue.

[5] J. W. Archer, "Low-Noise Receiver Technology for Near-Millimeter Wavelengths," in *Infrared and Millimeter Waves: vol. 15, Millimeter Components and Tech., Part IV*, K. Button, ed., New York: Academic Press, Inc., 1986, pp. 1-86.

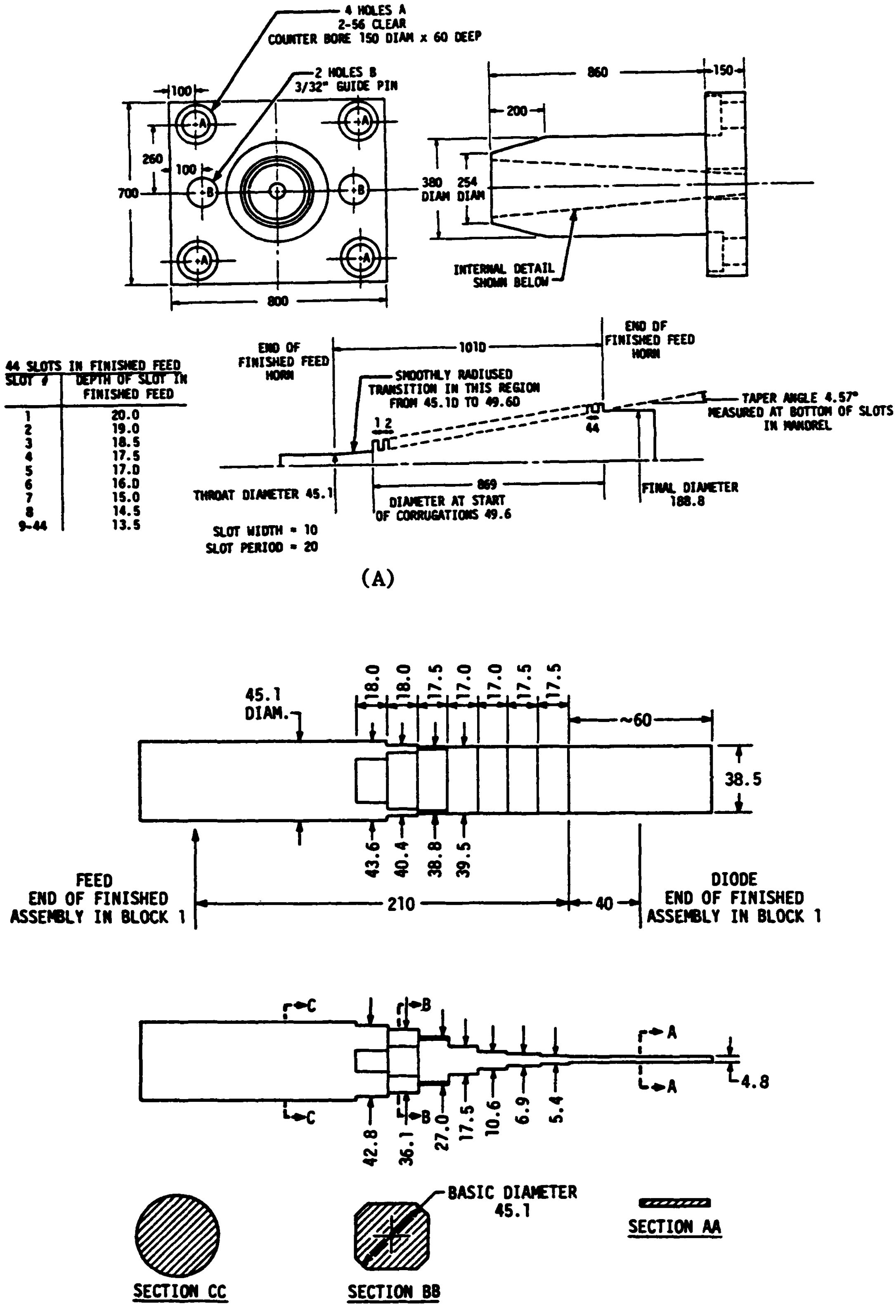


Fig. 1. Diagrams of the waveguide circuitry in the Archer prototype mixer. All dimensions are in mils. From [5].
(A) Details of corrugated horn.
(B) Details of aluminum mandrel used to electroform the circular-to-rectangular transition, as well as the waveguide step transition in the 200-290 GHz prototype mixer.

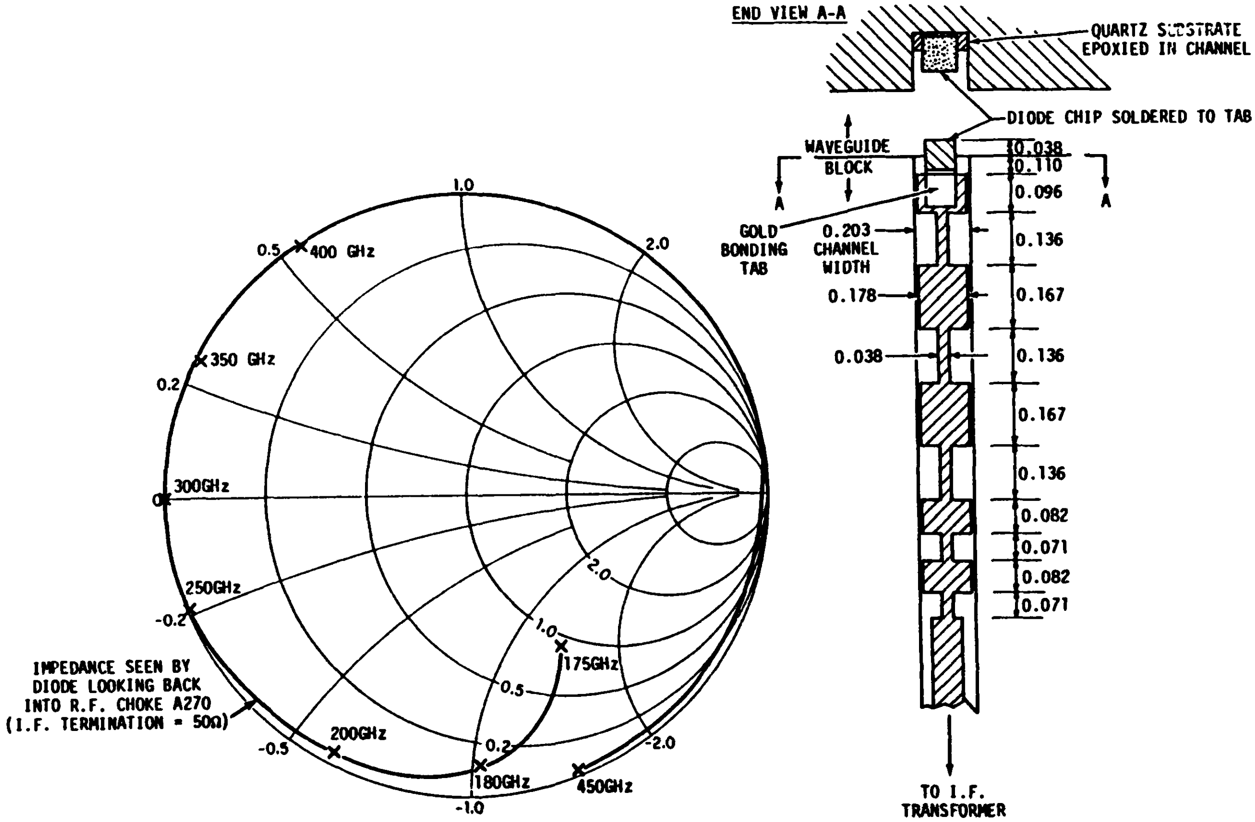


Fig. 2. A diagram showing the substrate in the Archer prototype mixer and the attachment of the diode chip to the substrate. (N.B. The substrate shown is not the substrate that was scaled for the present work, compare this diagram to Fig. 16.) From [5].

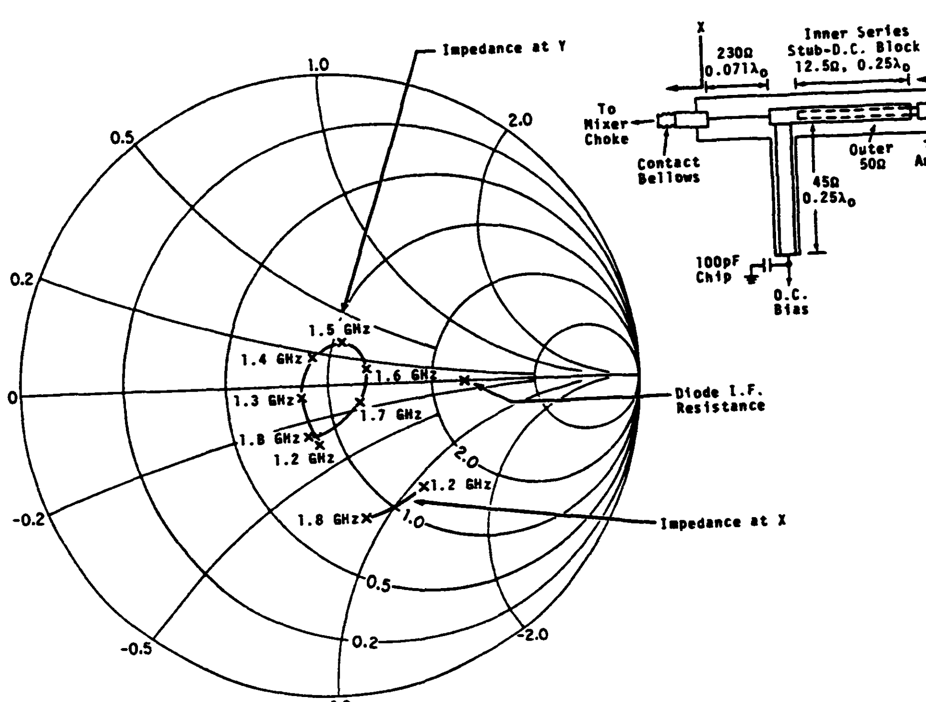
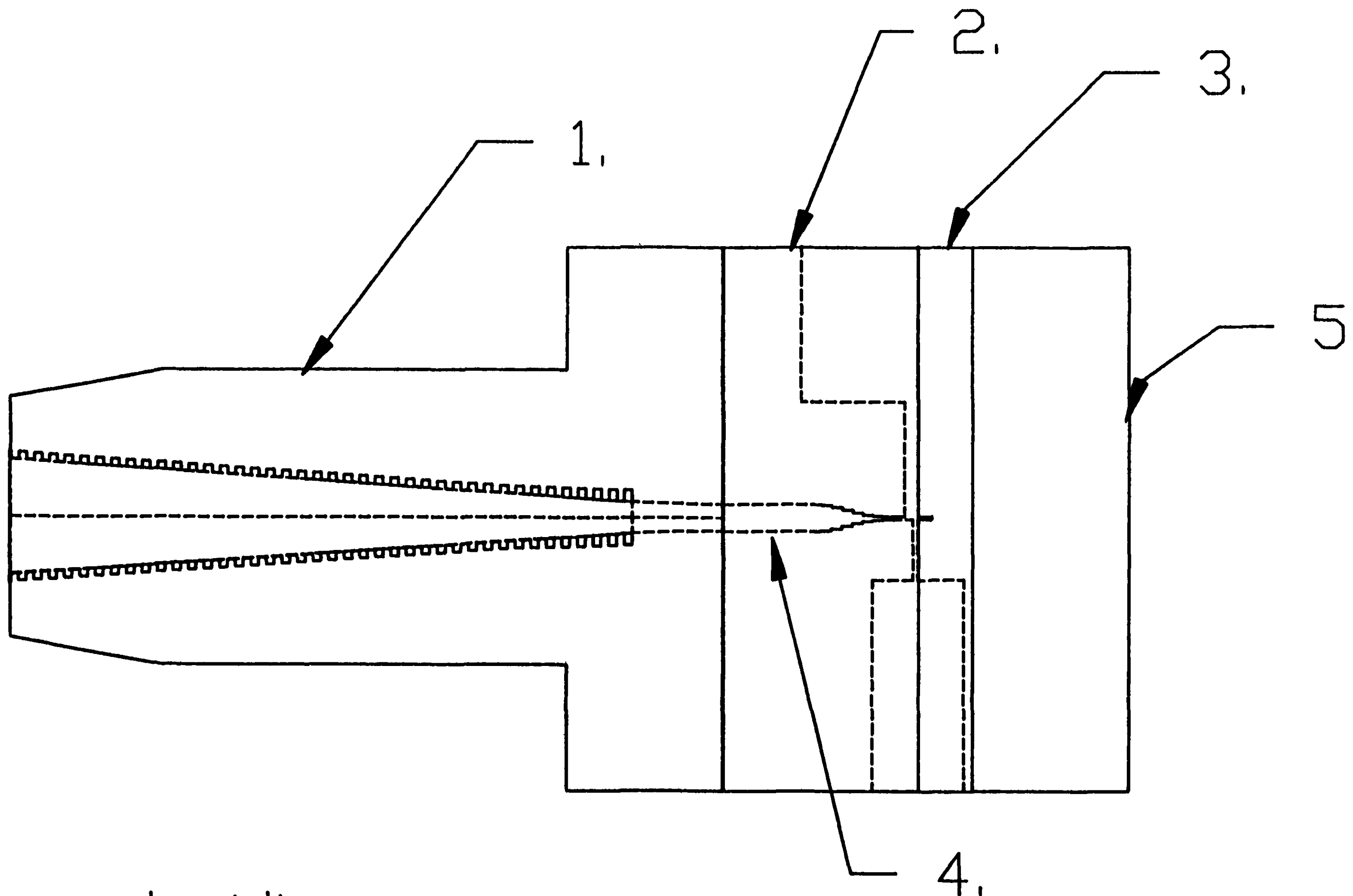


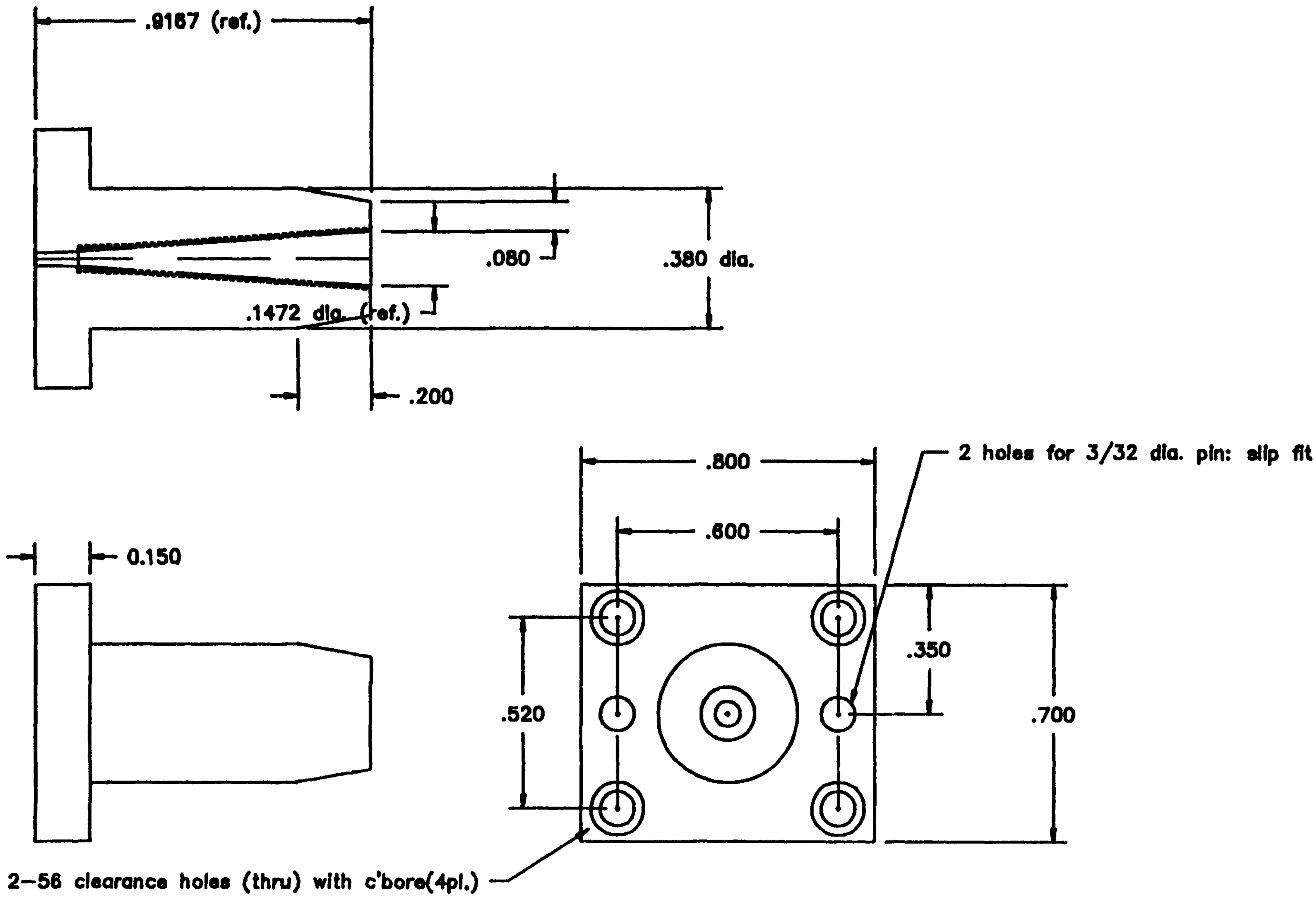
Fig. 3. Diagram showing details of bias tee. The Smith chart gives the impedance measured in the Archer prototype mixer when the diode is biased to an IF incremental resistance of 300 Ω. From [5].



300 Ghz mixer machining assembly drawing. (rev. A, fixed short)

part number	description
1.	300 Ghz mixer feed horn block
2.	300 Ghz mixer diode block
3.	300 Ghz mixer fixed backshort plate.
4.	300 Ghz mixer mandrel
5.	backshort pressure plate

Fig. 4. Partial assembly drawing for the scaled mixer block and corrugated horn.



Notes:

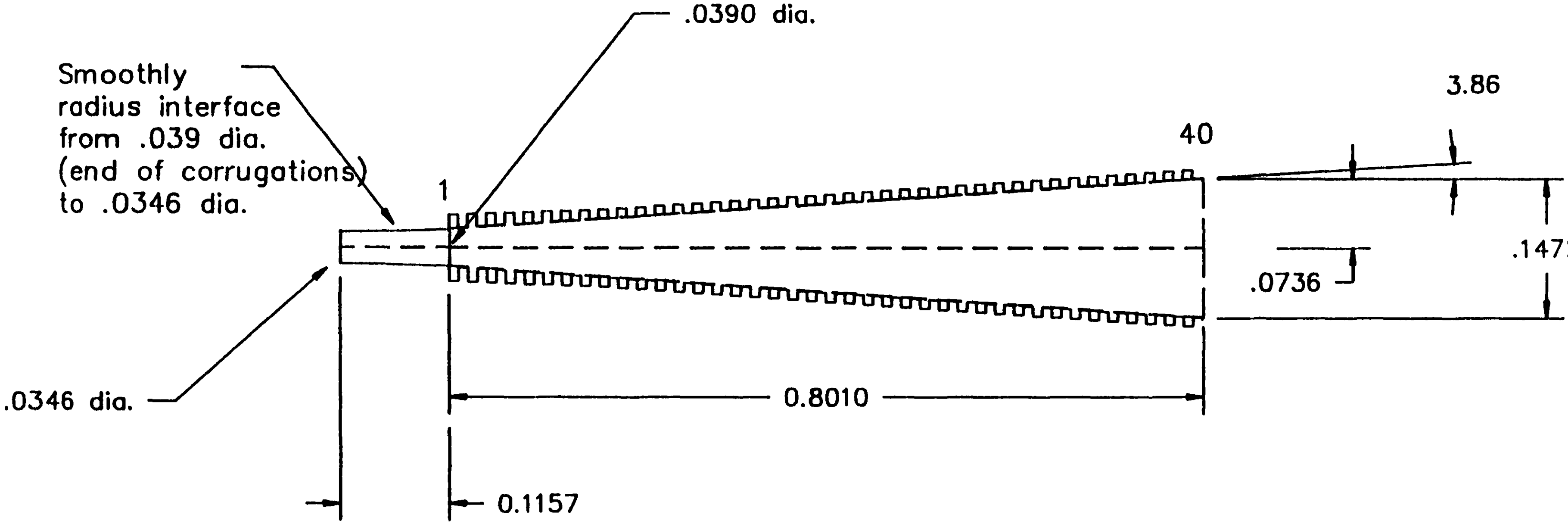
1. mandrel detail for horn angle, corrugations &c. on seperate page.
2. 3/32 pin holes to be drilled such that circular hole at end of mandrel lines up with the hole in the mating diode block.
3. Gold plate.

300 Ghz. mixer feed horn block.

(pg. 1 of 2, mandrel detail on page 2)

rev A. aug. 6, 1987 njb

Figs. 5-6. Mixer feed horn block drawings.



slot number	slot depth d"
1	.0156
2	.0150
3	.0143
4	.0137
5	.0131
6	.0122
7	.0115
8	.0109
9 – 40	.0103

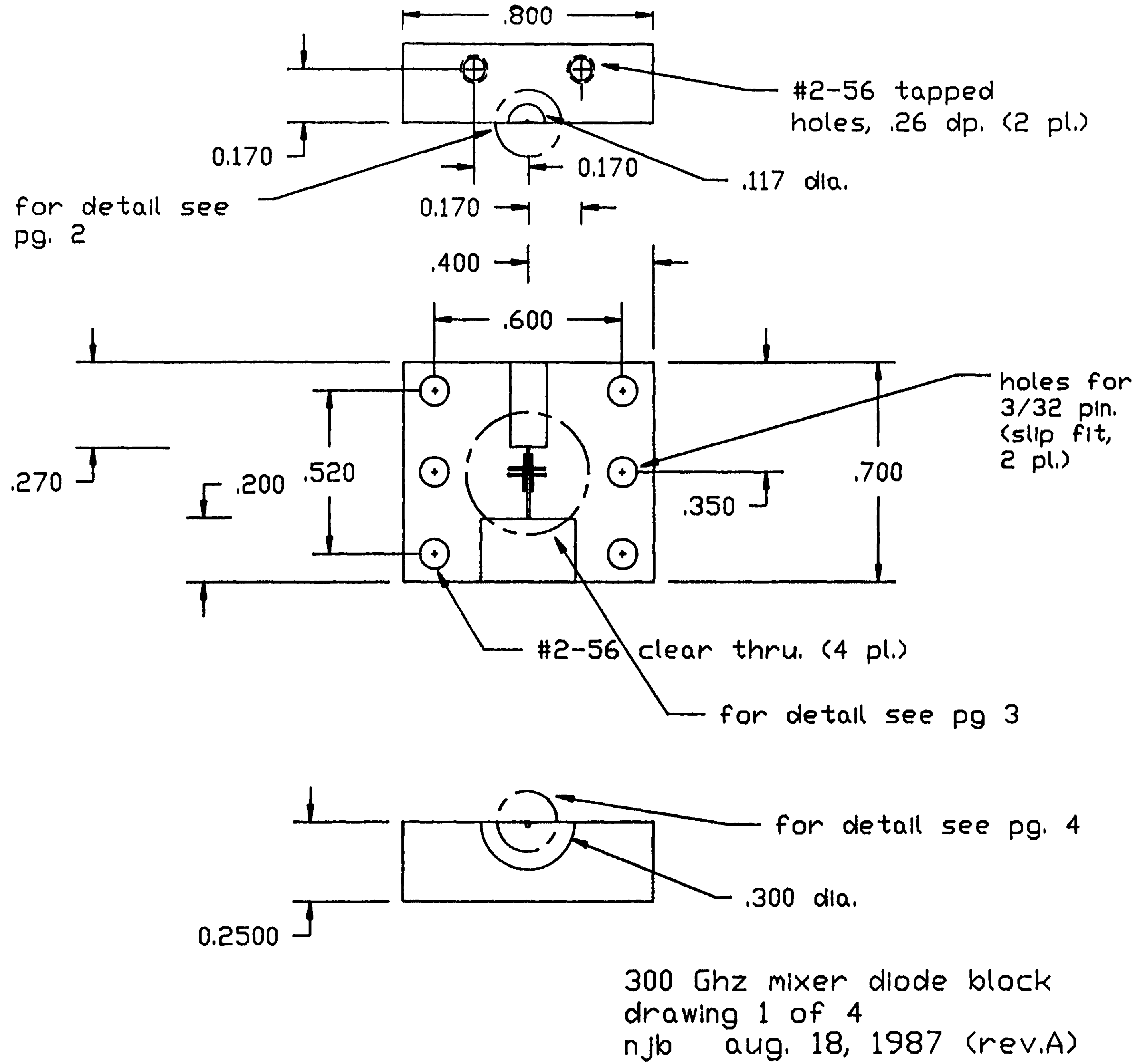
slot width: .0100"
slot period: .0200"

Mandrel detail for 300 Ghz feed horn. Almost scale of Ulich, save for period of the corrugations.

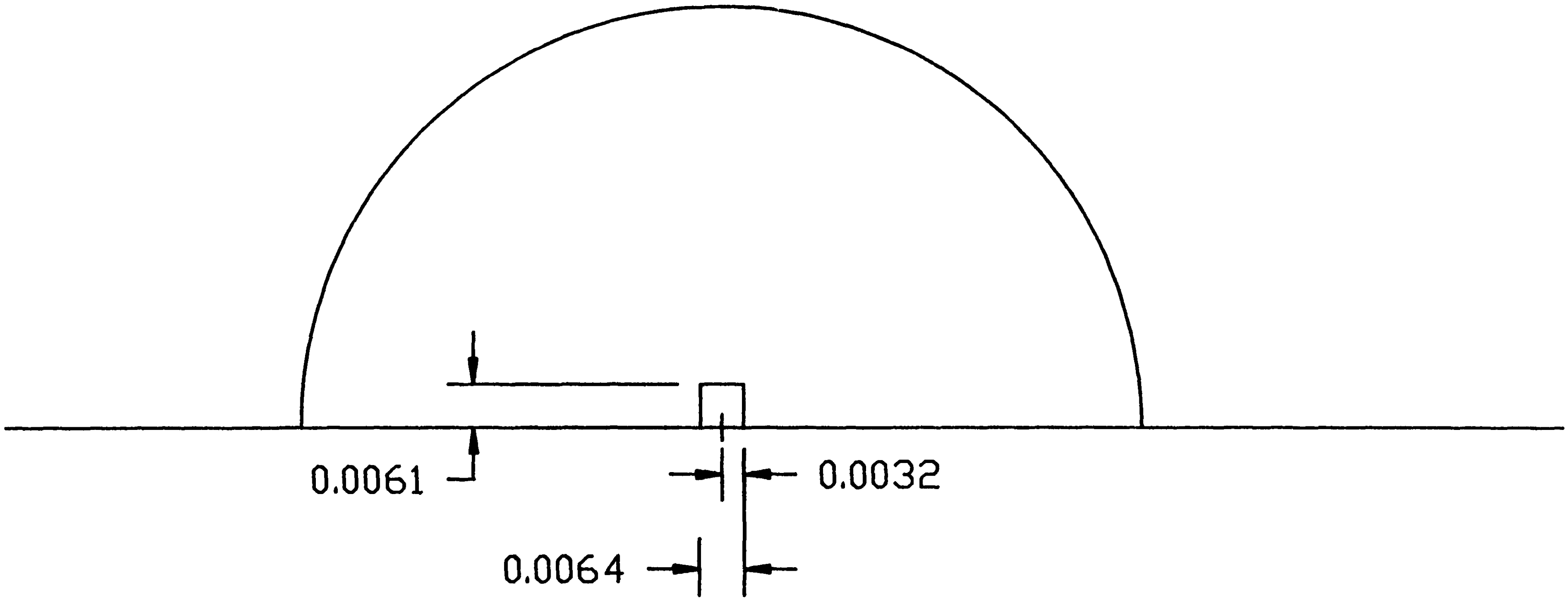
rev. A, Aug 18, 1987 njb

(page 2 of 2, 300 Ghz feed horn block)

Fig. 6

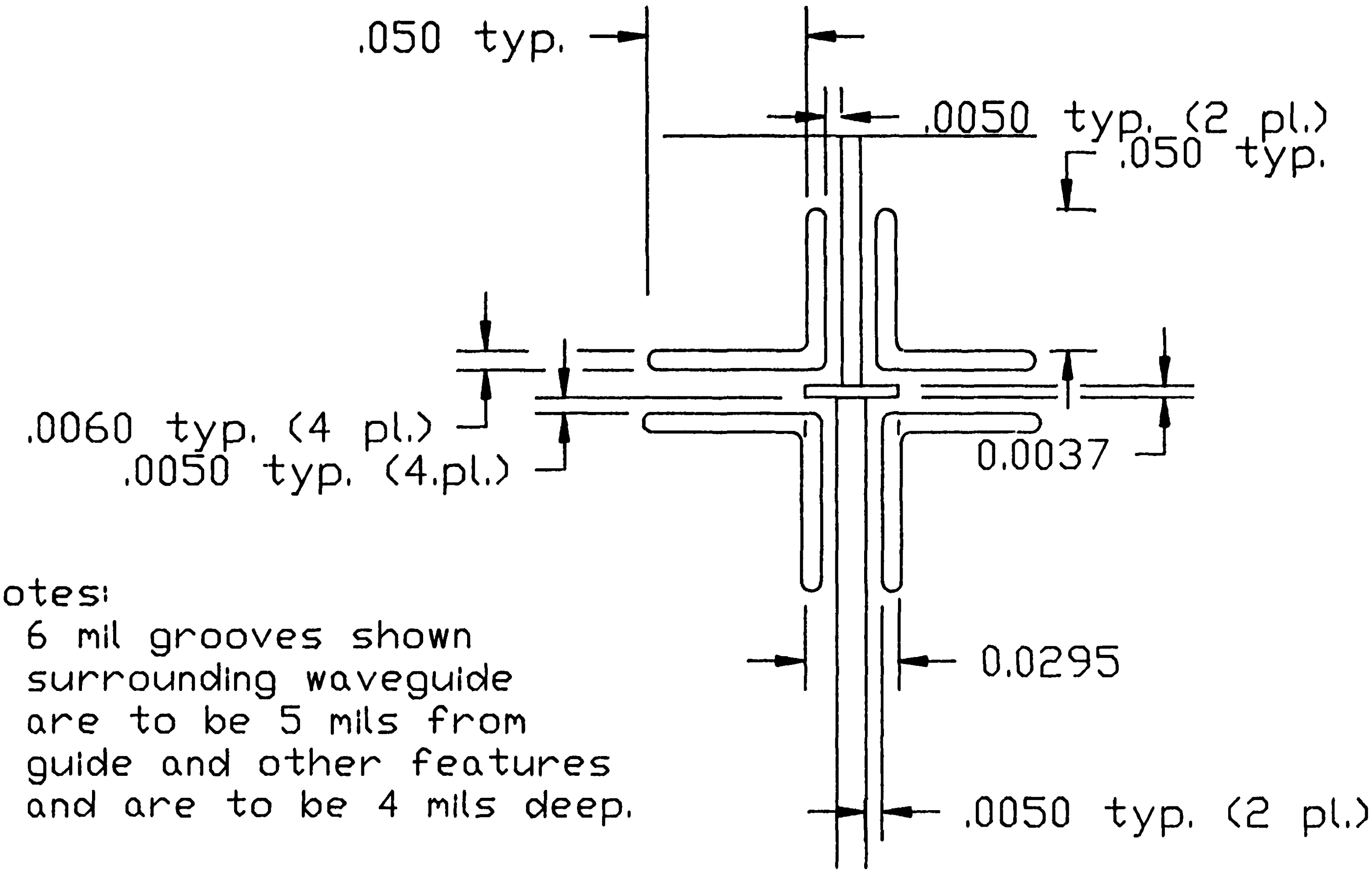


Figs. 7-10. Mixer diode block drawings.



300 Ghz mixer diode block
drawing 2 of 4:
detail of substrate groove.
njb   july 9, 1987

Fig. 8

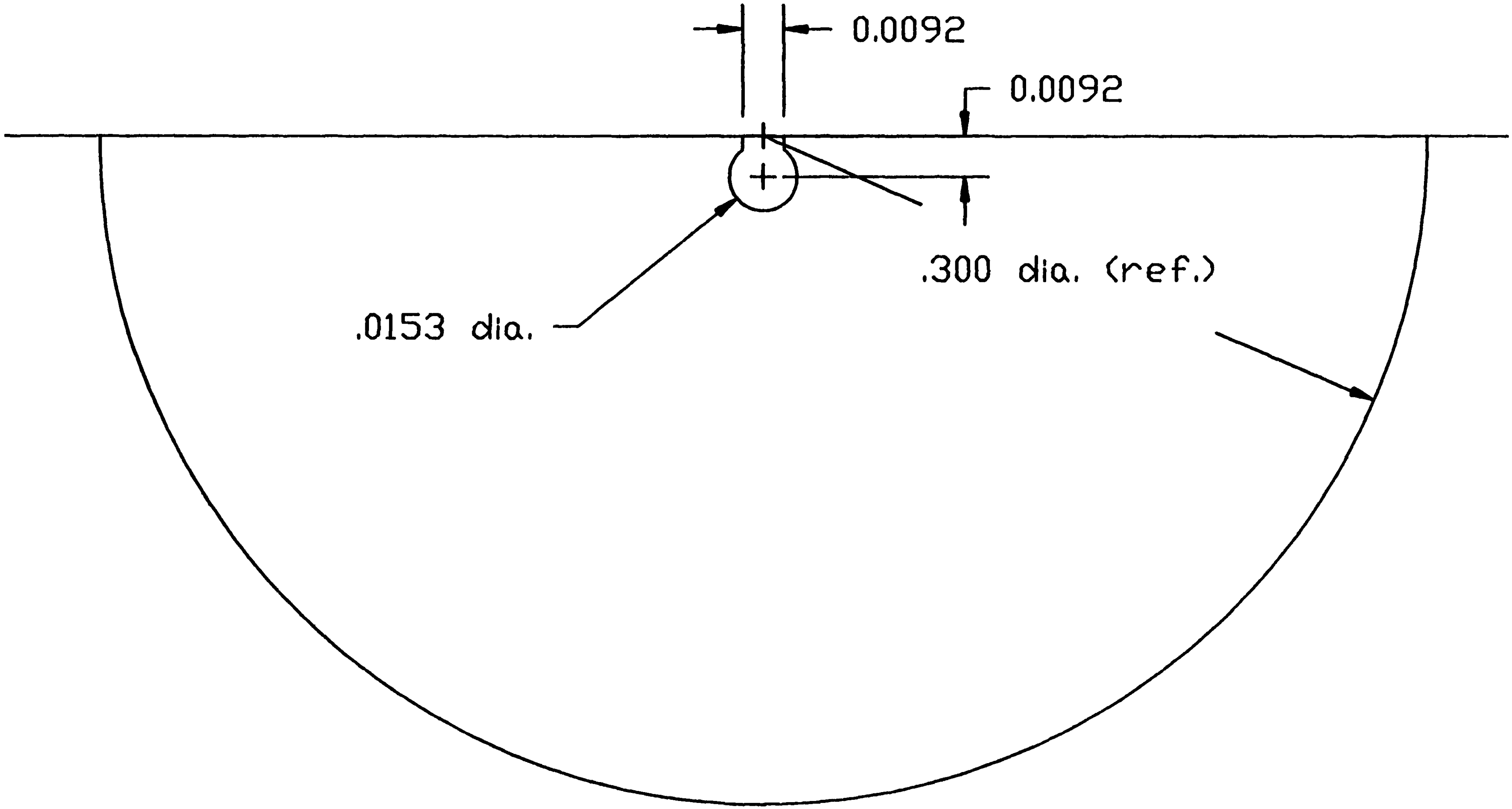


Notes:
1. 6 mil grooves shown surrounding waveguide are to be 5 mils from guide and other features and are to be 4 mils deep.

2. The waveguide is in the center of the block.

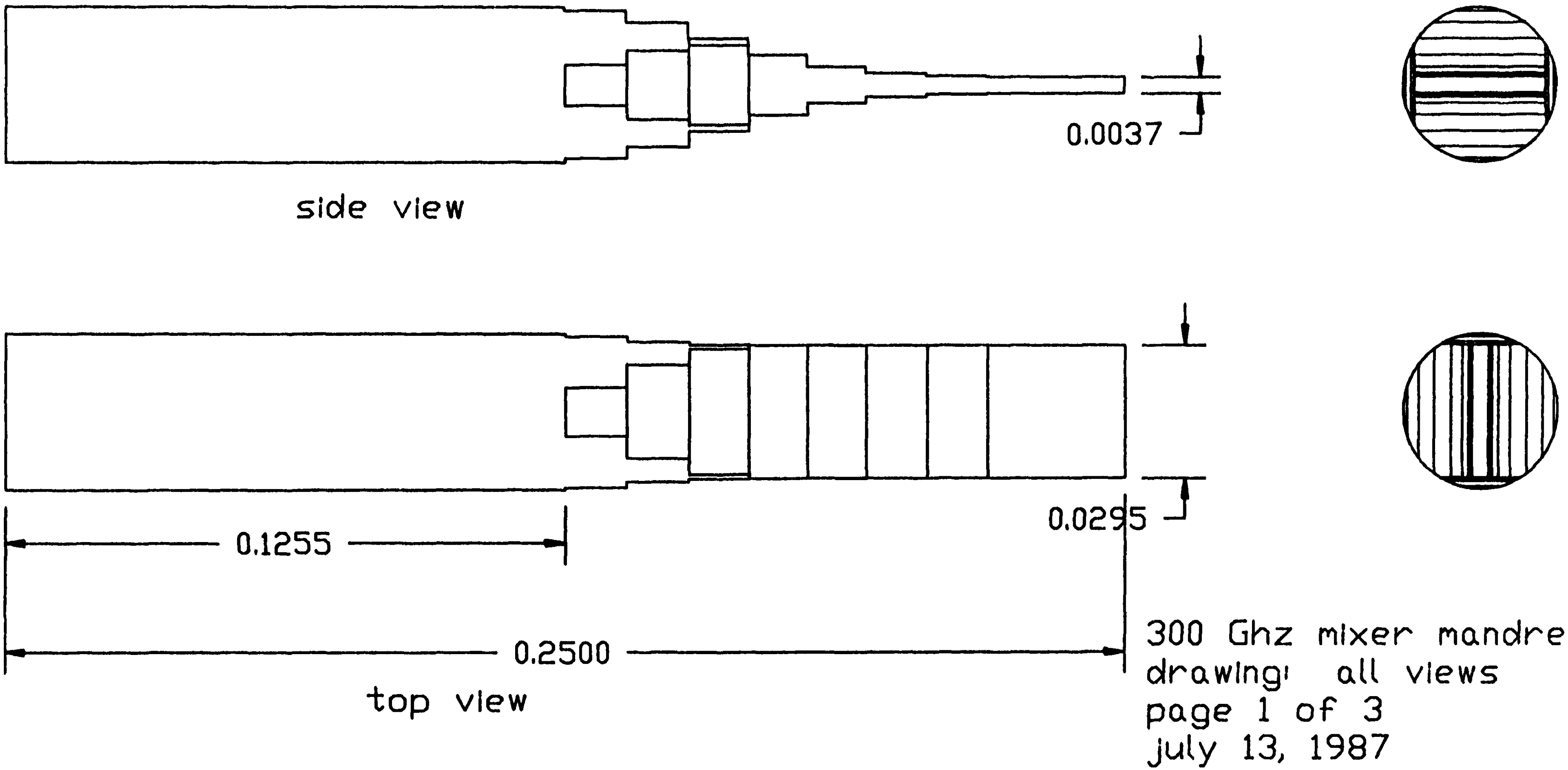
300 Ghz mixer diode block
page 3 of 4.
detail of waveguide and
surrounding area
njb july 8, 1987

Fig. 9



300 Ghz. mixer diode block
page 4 of 4
detail of post hole
july 8, 1987

Fig. 10



Figs. 11-13. Mixer mandrel drawing.

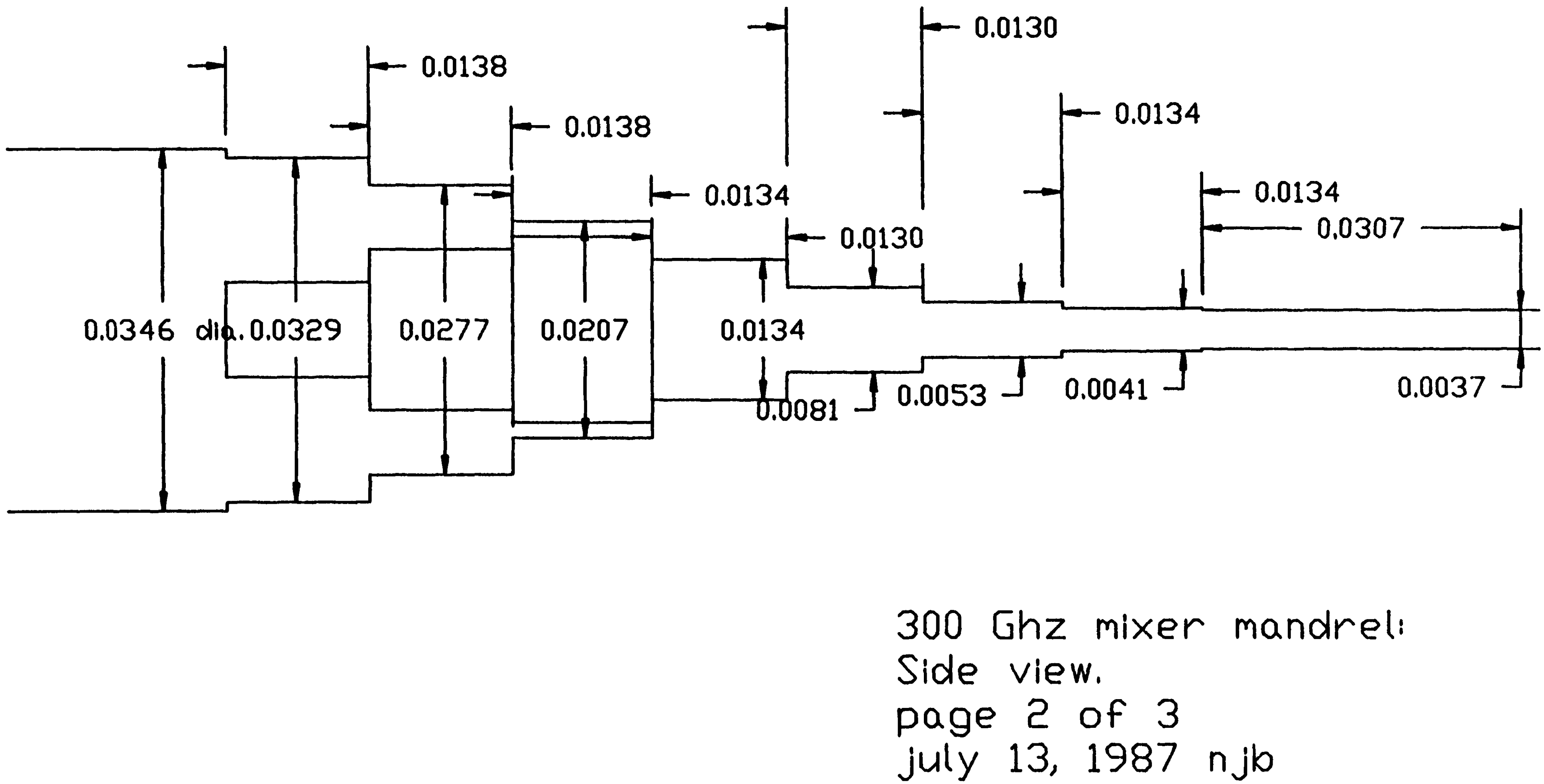
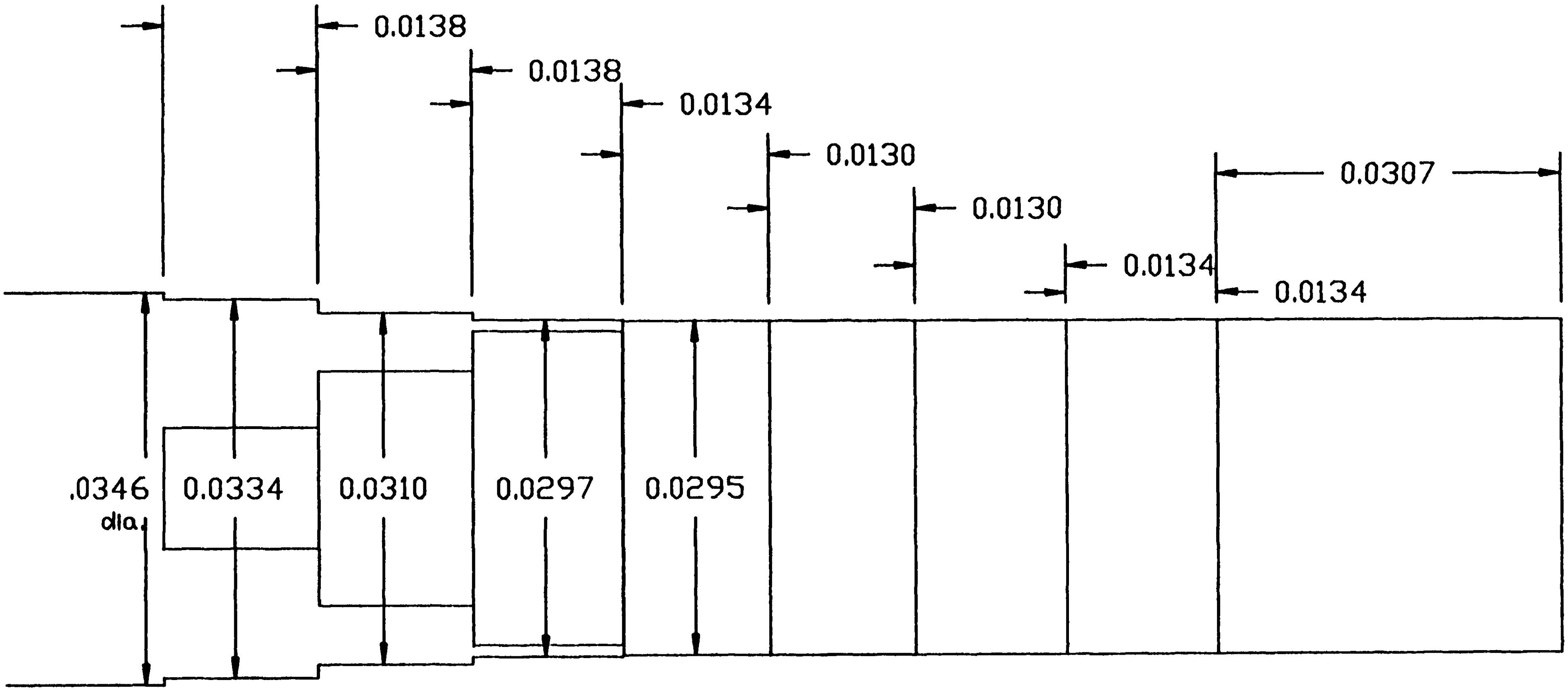

0.0138
0.0138
0.0134
0.0130
0.0130
0.0134
0.0134
0.0307
0.0346 dia.
0.0329
0.0277
0.0207
0.0134
0.0081
0.0053
0.0041
0.0037
300 Ghz mixer mandrel:
Side view.
page 2 of 3
july 13, 1987 njb

Fig. 12



300 Ghz mixer mandrel:
Top view
page 3 of 3
july 13, 1987 njb

Fig. 13

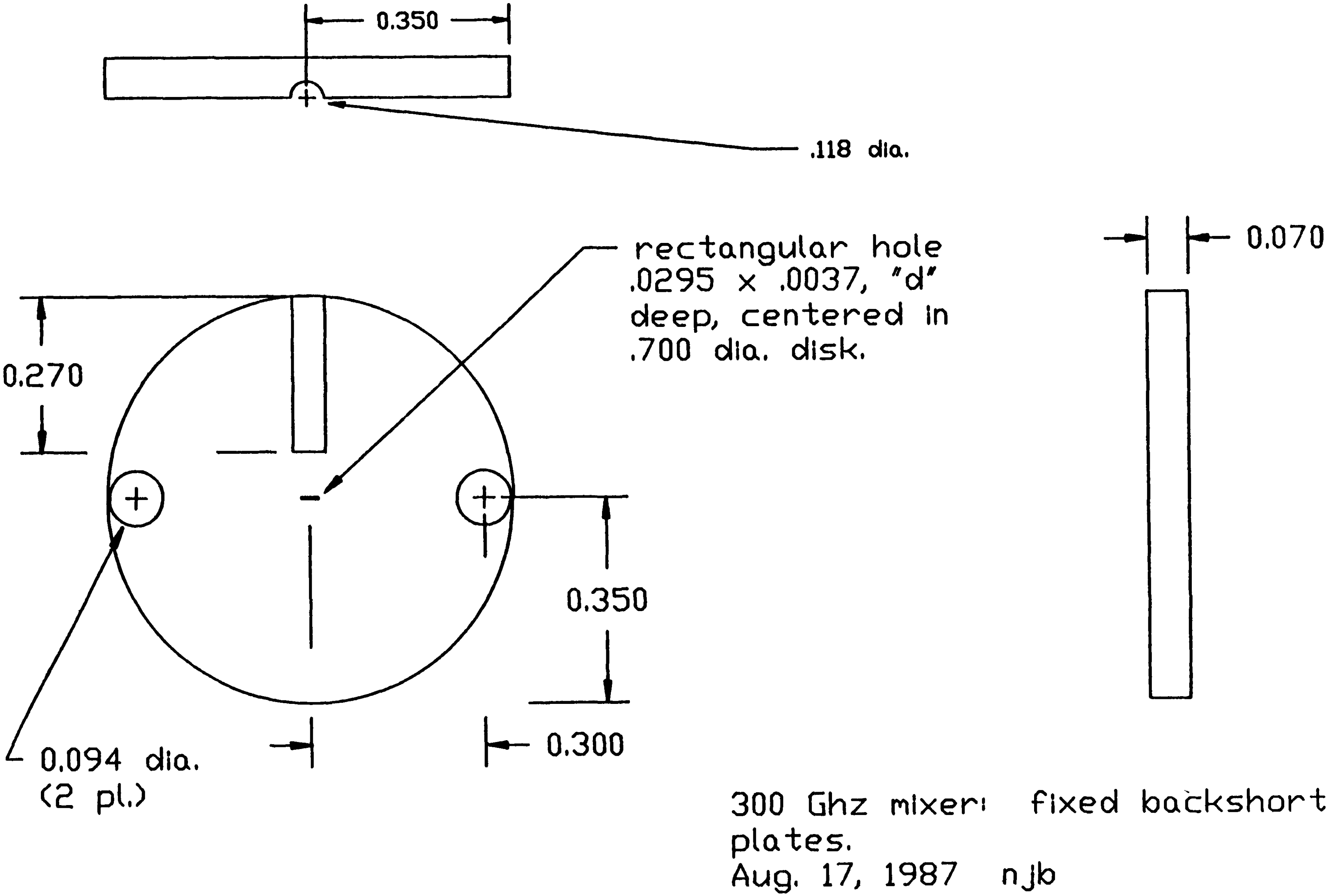
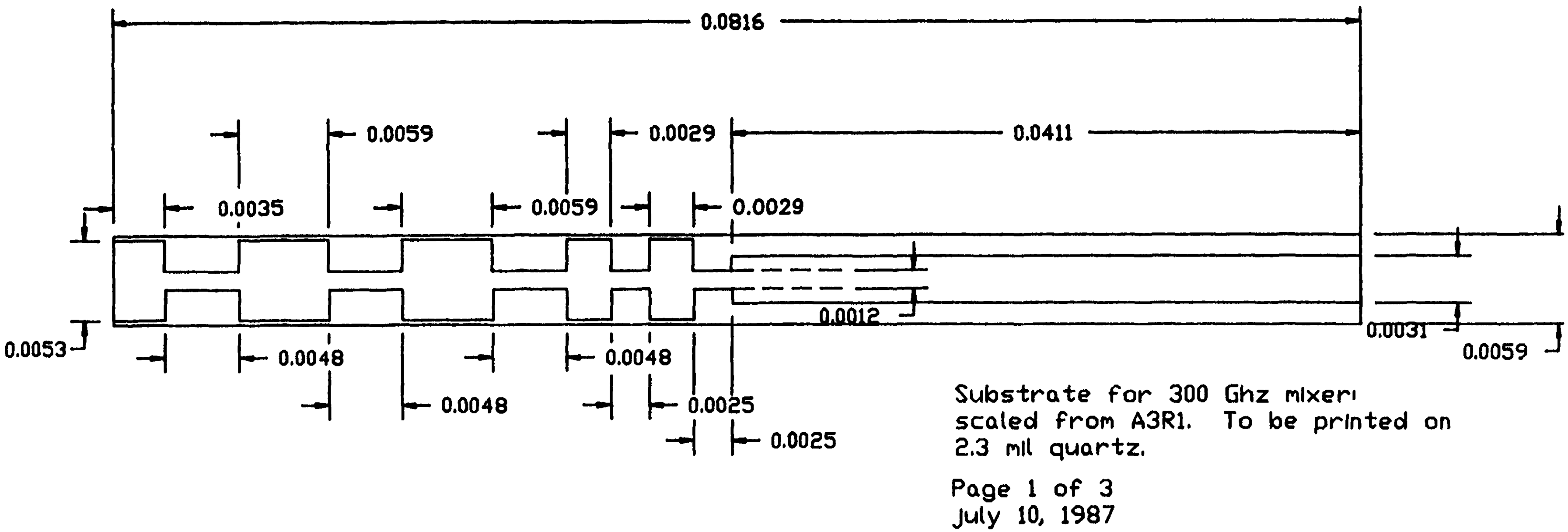


Fig. 14. Fixed backshort plate. Several plates with differing backshort depths ("d" in the drawing) were made. The distance "d" varies from 15 to 18 mils in 1-mil increments.



Figs. 15-17. Mixer substrate drawing.

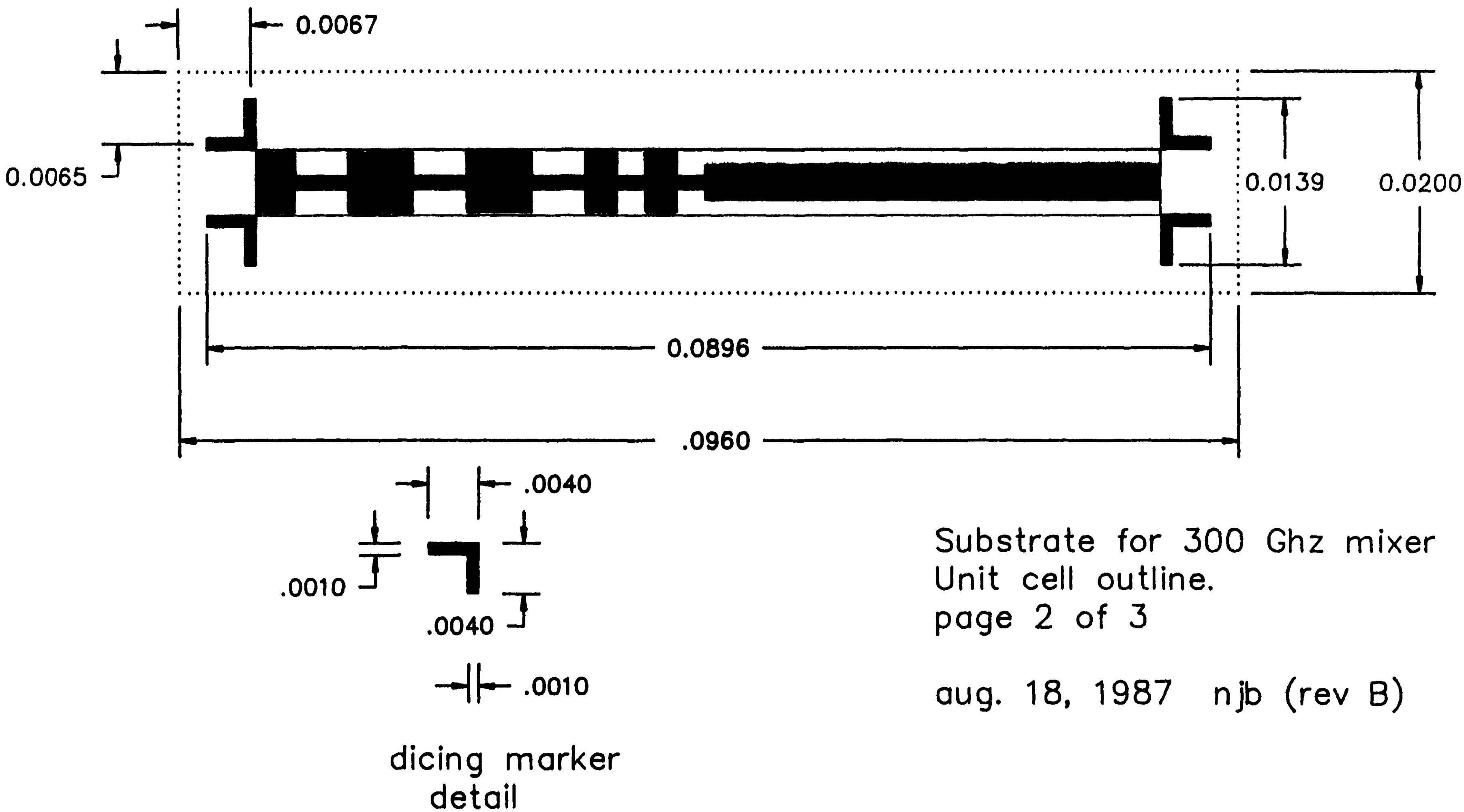

0.0067
0.0065
0.0139
0.0200
0.0896
.0960
.0040
.0010
.0040
.0010
dicing marker
detail
Substrate for 300 Ghz mixer
Unit cell outline.
page 2 of 3
aug. 18, 1987 njb (rev B)

Fig. 16

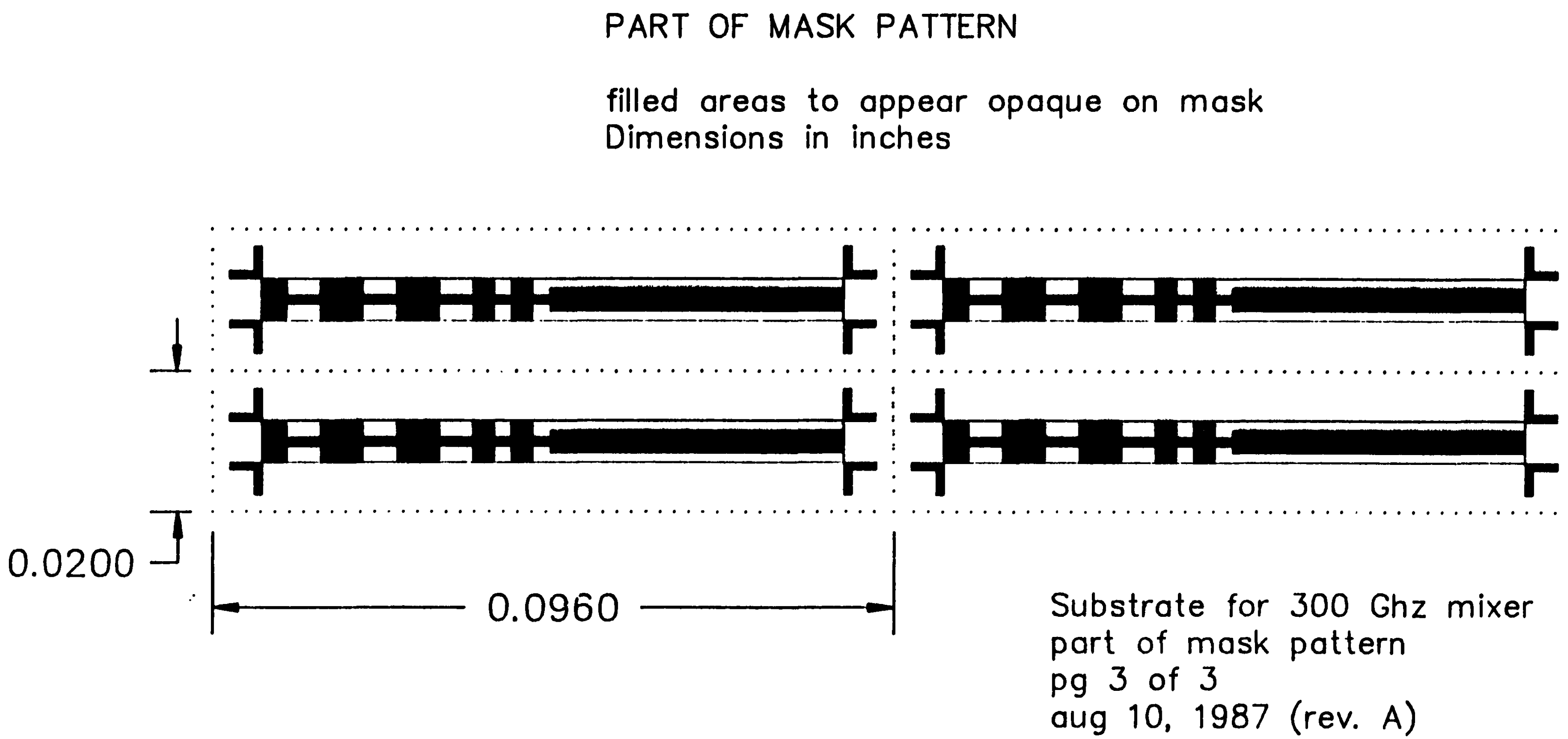

PART OF MASK PATTERN
filled areas to appear opaque on mask
Dimensions in inches
0.0200
0.0960
Substrate for 300 Ghz mixer
part of mask pattern
pg 3 of 3
aug 10, 1987 (rev. A)

Fig. 17

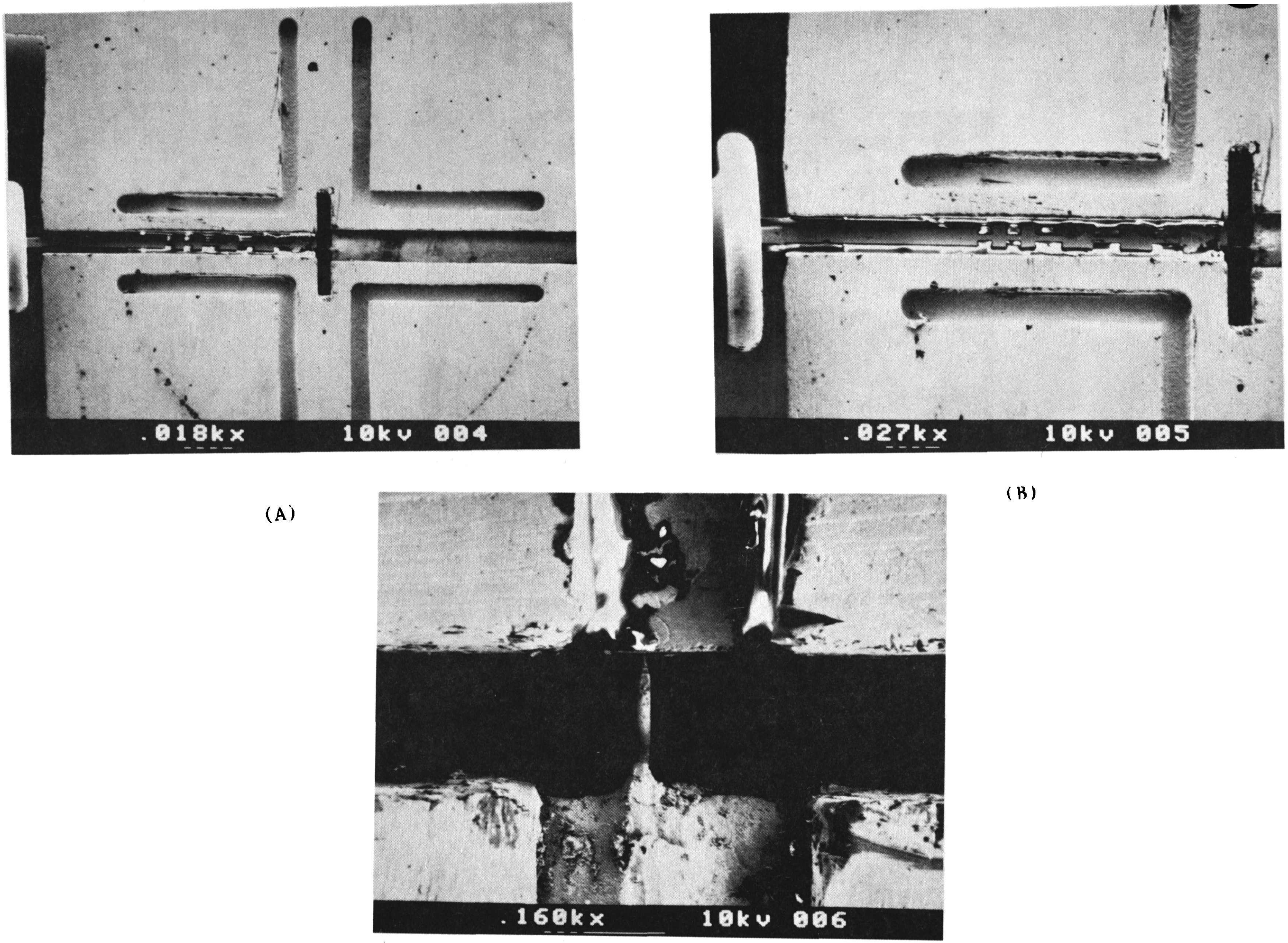
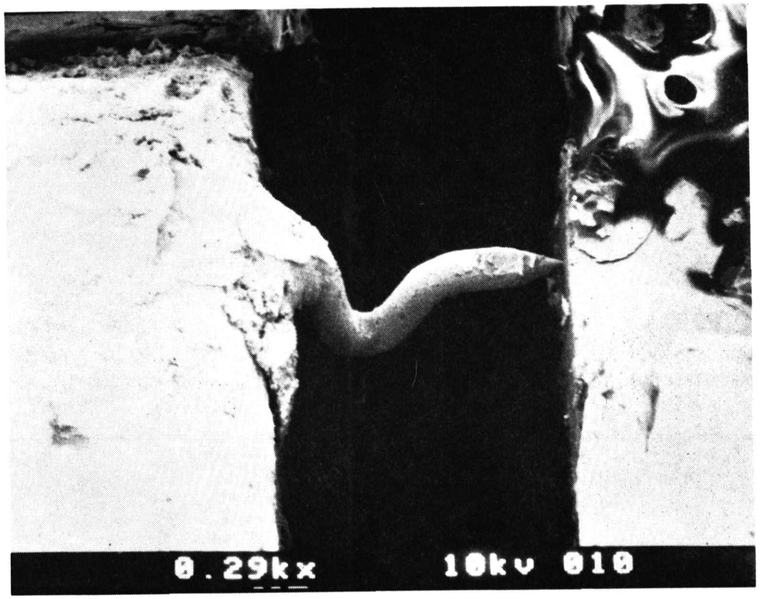
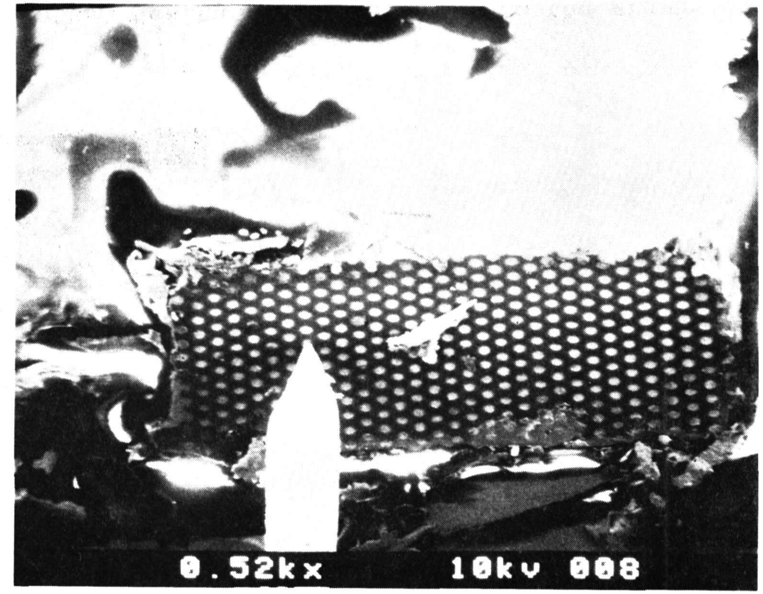


Fig. 18. SEM photographs of mixer #4. These are photographs of the contact designated 2I1-150-H-: in the graphs.
(A) Photograph showing entire substrate, contact, and grooves for the gold-wire gaskets.
(B) Close-up of the substrate, showing bellows contact.
(C) Photograph showing chip and post position in the waveguide.



(A)



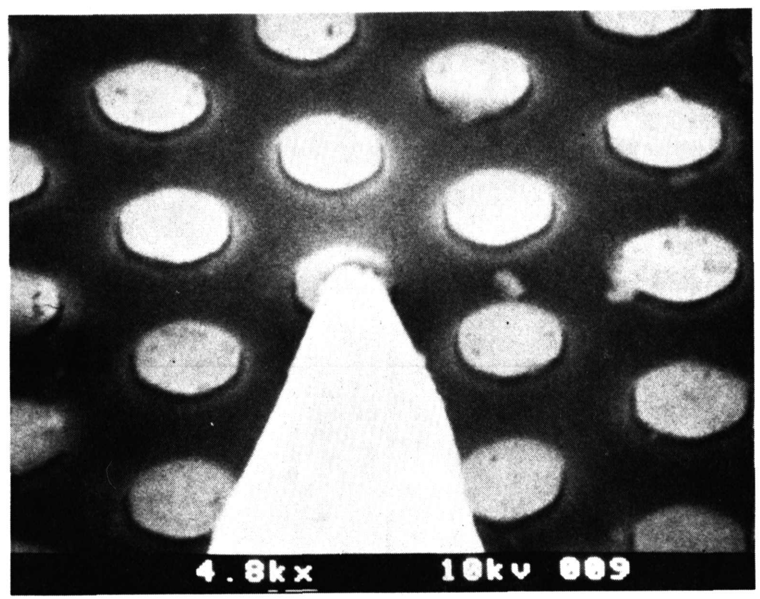


Fig. 19. SEM photographs of the mixer shown in Fig. 19, focusing on the contact area.
(A) Photograph showing the sha[illegible]f the bent whisker.
(B) A good picture of the face[illegible]the diode chip.
(C) Close-up of the contact.

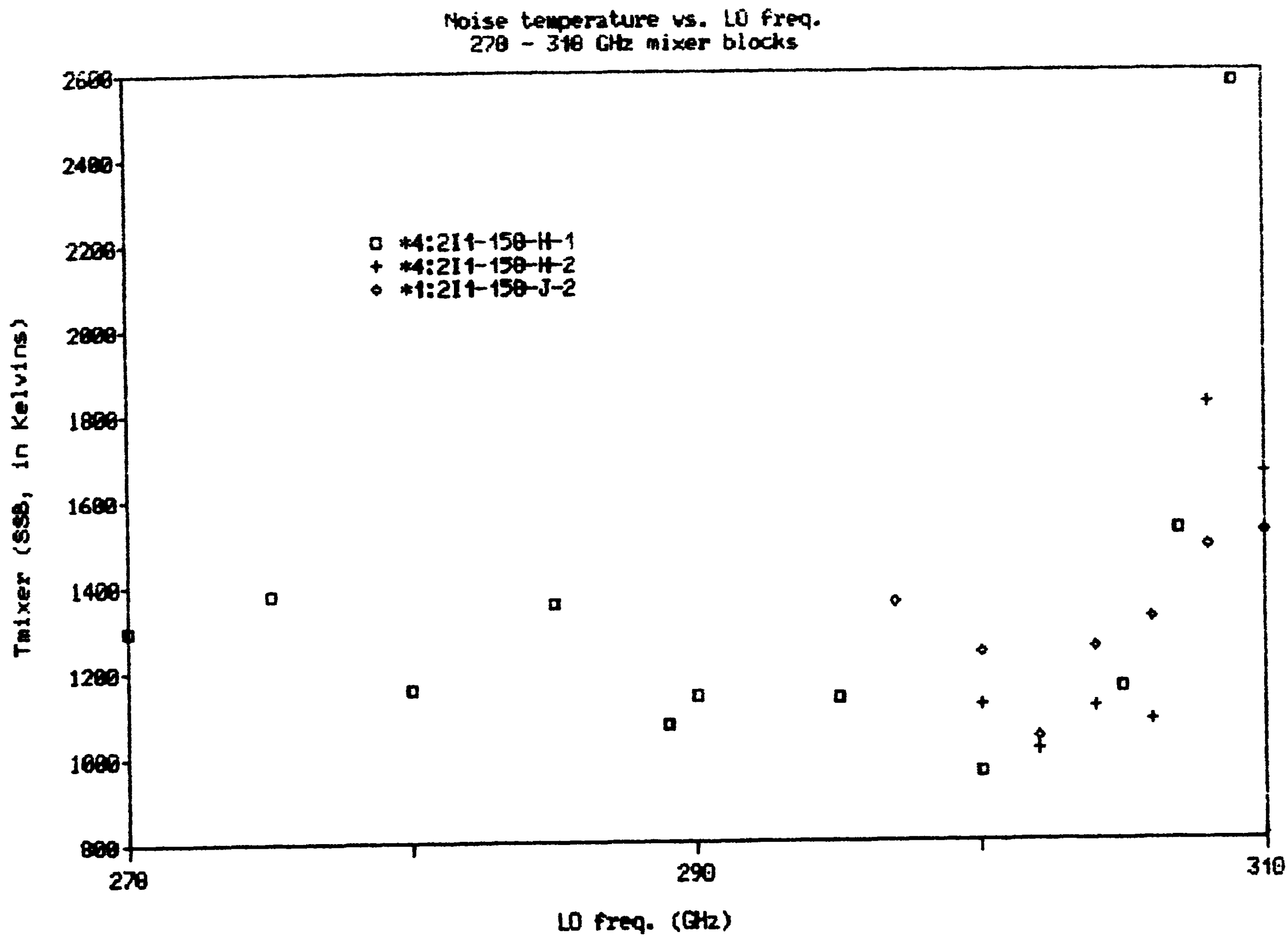


Fig. 20. Mixer noise temperature vs. LO frequency of scaled mixer. These measurements were made at 20 K.

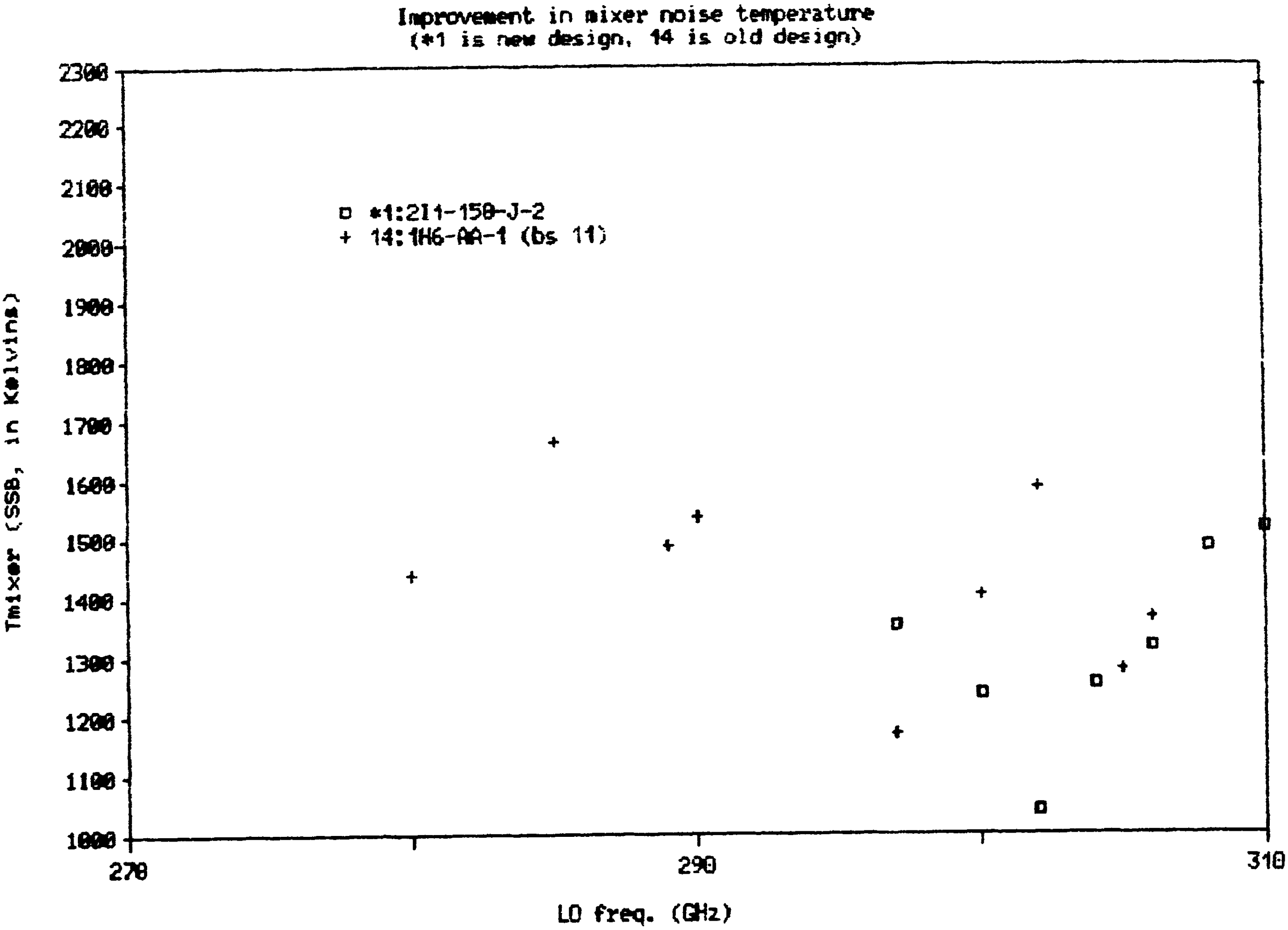


Fig. 21. Improvement in mixer noise temperature. Mixer 14 was used on the 12 meter telescope for the 1986-1987 observing season.

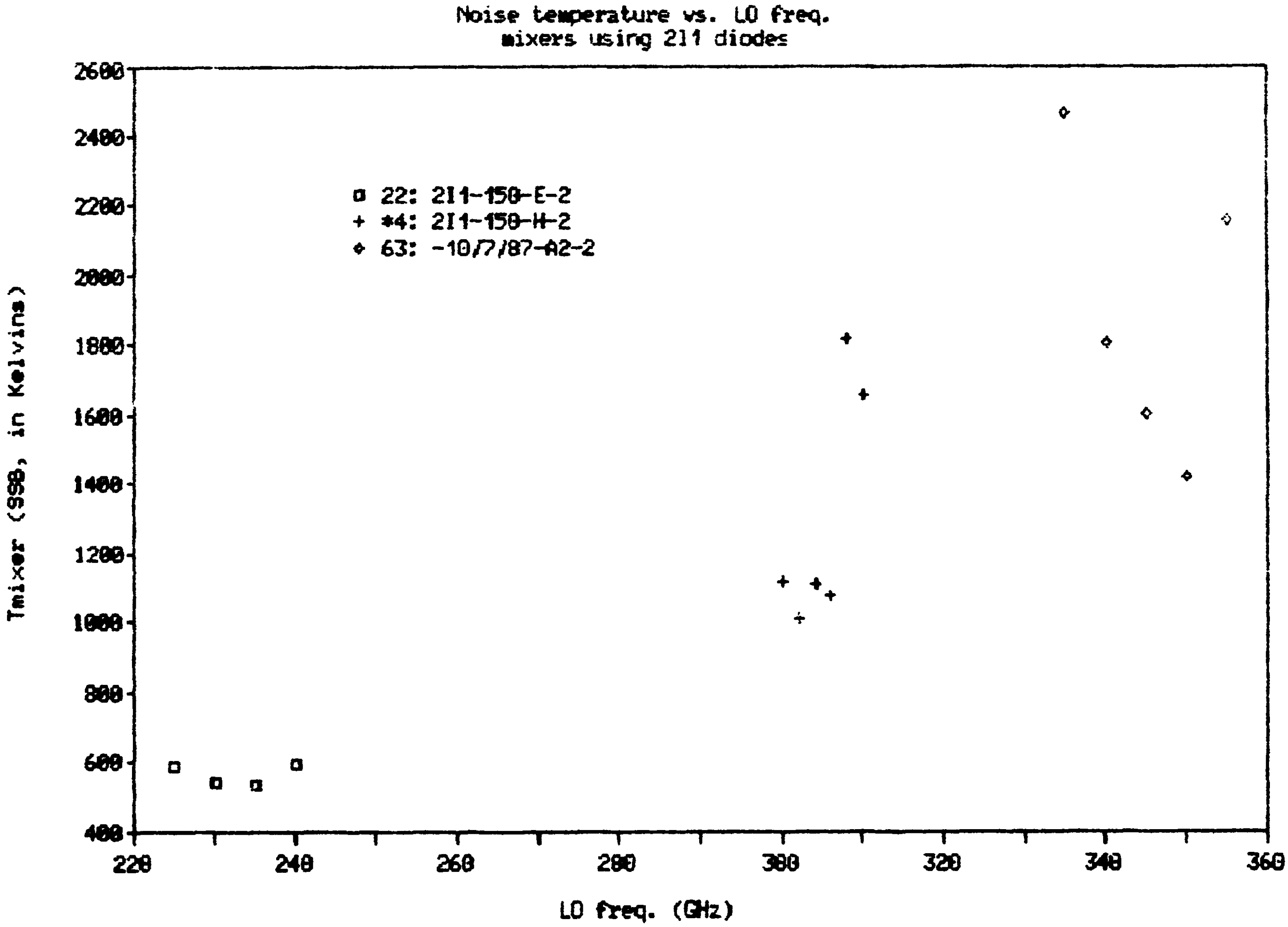


Fig. 22. Noise temperature vs. LO frequency for three different mixers in three different frequency ranges. All three of these mixers use 2I1-150 diodes.