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A NEW WALL CURRENT MONITOR FOR THE PS

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1. INTRODUCTION

For the future $e^{\pm}$ operations in the PS a pick-up with extended bandwidth and dynamic range is required for observation and measurement of beam characteristics.

A new wall current monitor has been designed containing only passive components which will replace the present wideband electrostatic pick-ups.

Wall current monitors (or resistive pick-ups) are well known for their good behaviour with respect to :

- wide bandwidth (KHz to GHz),
- wide dynamic range (between noise and signal handling capability,
- reliability, radiation resistance (reduced maintenance).

As this kind of beam monitor is quite well documented for its theoretical aspects[2]), this note concentrates mainly on the technical side of the design, and on measurement results.

2. *THE MONITOR DESIGN*

2.1 General description (Figure 1)

The wall current monitor is based on the fact that as a particle beam travels at near light velocity, the charge image onto the vacuum chamber contains the same information as the beam itself.

a) The Gap

It is quite easy to cut the vacuum chamber and to extract the beam signal for observation. The gap length has to remain shorter than the bunch, but a shorter gap has a higher capacitance which gives a loss of high frequency bandwidth.

b) The shielding box

Some shielding must be provided for vacuum purposes, and for electro-magnetic interference protection. As this shielding length is not infinite (in fact a short circuit at DC), some inductive components may be added to achieve a low frequency cut-off (≃ 100 KHz) compatible with reference 1.

c) How to extract the signal

The beam signal is picked-up by eight 50 Ω transmission lines distributed around the gap, combined to give a position independent monitor.

The simplified step response of the monitor is shown in Figure 2. This picture, purposely, does not take care of microwave ringing in the shielding box and around the gap.

This design is a synthesis, applied to the elliptic PS vacuum chamber, of the SPS[3] (microstrip tansmission lines, microwave absorbing tiles) and Booster[4] (high μ ferrite rings) wall current monitors, with some specific parts such as a long shielding box, and SMA reduced size vacuum feedthroughs.

2.2 Shielding box and ferro-magnetic materials

As shown in Figure 3, the shielding box is 936 mm long with internal diameter equal to 185 mm. In the last quarter, this diameter increases to 255 mm as it needs to house 6 Philips 240 mm diameter Ferrocube 8C11 rings for improving the low frequency response[5]. This shielding length is selected to provide a rather long flat amplitude response (Figure 2) for a distortion free reproduction of the $e^{\pm}$ bunch shape. Because of possible microwave modes in the shielding box, a set of 96 absorbing material tiles (Emerson & Cuming - Eccosorb - NZ 31) is screwed uniformly along the chamber. This type of tile is selected according to shielding box length and attenuation characteristic (Figure 4).

Finally, ferrite rings and tiles quoted above are accepted in high vacuum. Nevertheless, a vacuum pump connection is foreseen, shielded by a perforated screen.

2.3 Vacuum feedthrough and microstrips

As previously pointed out, the beam signal is coupled to the outside world by means of eight microstrip 50 Ω transmission lines, as in the SPS design[3]. Each microstrip is calculated using Wheeler's equation[6], and finally trimmed one by one, due to their particular geometry. The shielding box is circular, the vacuum chamber elliptic so the microstrip bending and length are unequal. Moreover, two microstrips are close to microwave absorbing ferrite tiles. Also, some "cut and try" method is needed for the transition between the microstrip lines and the SMA coaxial vacuum feedthroughs[7,8].

2.4 Coaxial connections (phase compensation) and power combiner

Because of microstrip length differences, a precise phase compensation is provided, outside the monitor, by means of semi-rigid coaxial cables RG402/U. These lines are matched to ± 5 pS typically, using RF phase measurement at 1.2 GHz.

The power combiner is certainly the simplest form to be found (Figure 5). In the ideal case, all of the eight outputs give equal phase and amplitude signals, so one needs only to provide a $(\frac{50\ \Omega}{8})$ load at the junction point. For power dissipation and signal distribution reasons, a <u>16 way direct connected junction</u> is built from semi-rigid coaxial cable and SMA connectors.

We did not use a reactive hybrid combiner since we could not find a component with enough bandwidth and power handling capability.

3. *MEASUREMENTS*

3.1 <u>Test bench description</u>

The beam is simulated by a voltage step on a 171 Ω transmission line, parallel matched to the 50 Ω impedance of the instrumentation set-up (sampling 7S11-7T11 + S6 Tr ≈ 30 pS). Conical vacuum chamber transitions, subnanosecond pulse generator and S52 (Tektronix) are as previously used[9]).

Very fast signals are difficult to handle on such a high impedance line, but minimum loading effect on the monitor gap as well as on microwave modes in the vacuum chamber give this choice a better approach to reality. Nevertheless, there is already a high frequency bandwidth loss in beam simulation due to the poor skin effect characteristic of such a high impedance line.

The matching of this coaxial system, referred to 50 Ω, is better than 5% (voltage reflection coefficient). The rise time of the measurement set up is 35 pS (Figure 6). One should be careful for the interpretation of results because the first microwave mode (TE_{11}) appears at roughly 1300 MHz in the PS elliptic vacuum chamber[10]). Figure 7a shows the set-up used for this measurement. It consists of two available lengths of PS vacuum chamber, each 40 cm long, with conical sections at the end fitted with 50 Ω coaxial connectors. Each coaxial connector is loaded with a capacitive probe which launches or captures microwave modes in the vacuum chamber. Figure 7b shows the measurement result using the hp 8754a Network Analyser on the transmit and receiving side of the bench. The same result occurs using hp 8754a on the transmit side (manual scan) and 7L14 Spectrum analyser on the receiving side (figure 7c).

3.2 Monitor response

Figure 8 shows the 100 pS rise time at the output of the combiner, which indicates an upper frequency limit in excess of 3GHZ for the pick-up. Figures 9, 10, 11 demonstrate, under the same test conditions a fairly clean response of the monitor, even for wide proton bunches. Figure 12 shows, one by one, each 50 Ω output and the combiner one for a beam simulation slightly under the chamber center position.

Figure 13 is the combiner output for beam simulations at 15 mm up, down, left and right from the chamber center position; this demonstrates the fairly independent behaviour of the monitor with respect to beam position. Figure 14 : The marker indicates the -3dB low frequency cut-off at 105 KHz.

By these measurements, one calculates a transfer impedance of 5.407 Ω @ 50 MHz (or a sensitivity of $\frac{5.407\ V}{A(I_b)}$).

As for an operational evaluation period, this wall current monitor will be linked to MCR and CB by two $\frac{7}{8}$" transmission lines, whose losses are shown in figure 15.

ACKNOWLEDGEMENTS

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10. F. Caspers, E. Schulte, Private Communication.

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FIG.1 Wall current monitor:
A general description

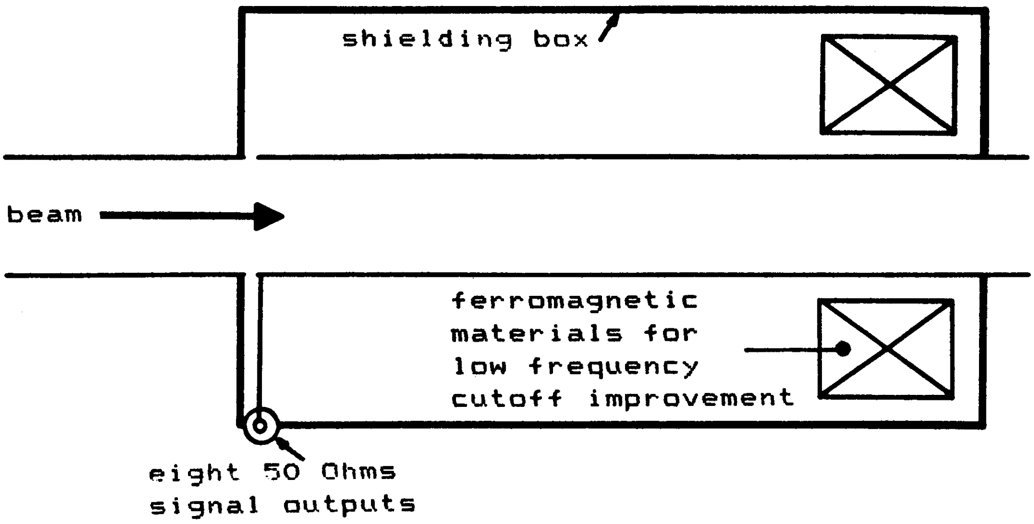
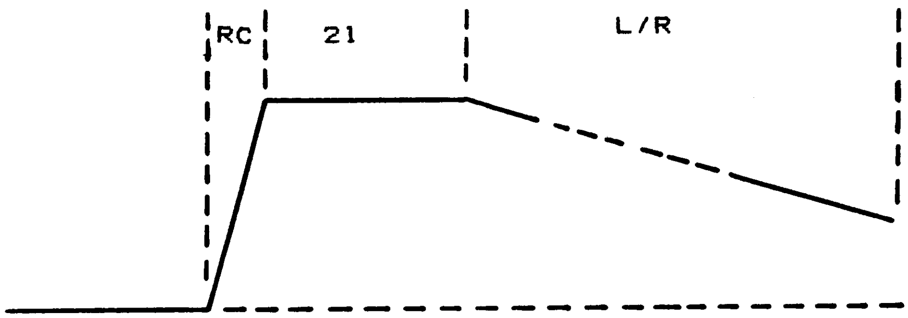


FIG.2 Simplified step response.



Where:
R=eight 50 Ohms loads // Z0 shielding box
C=capacitance at the gap
l=electrical length of the shielding box
L=inductance of the shielding box

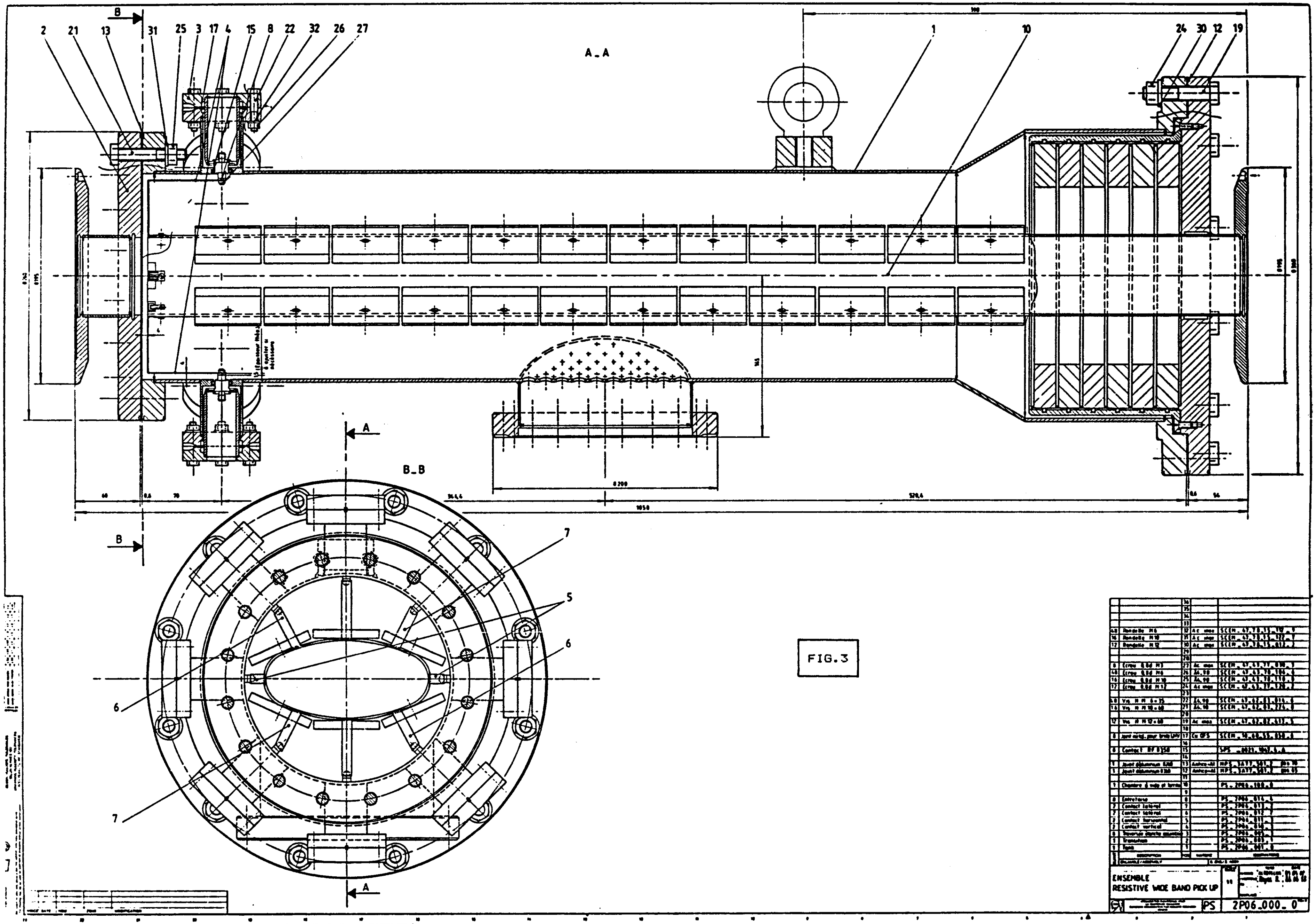
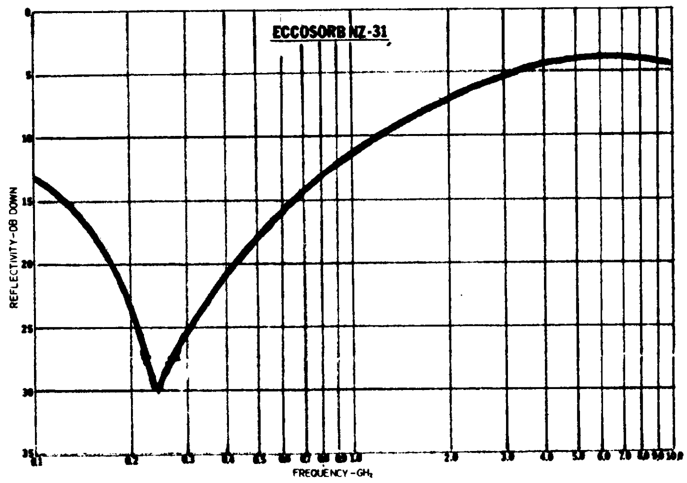


FIG.3

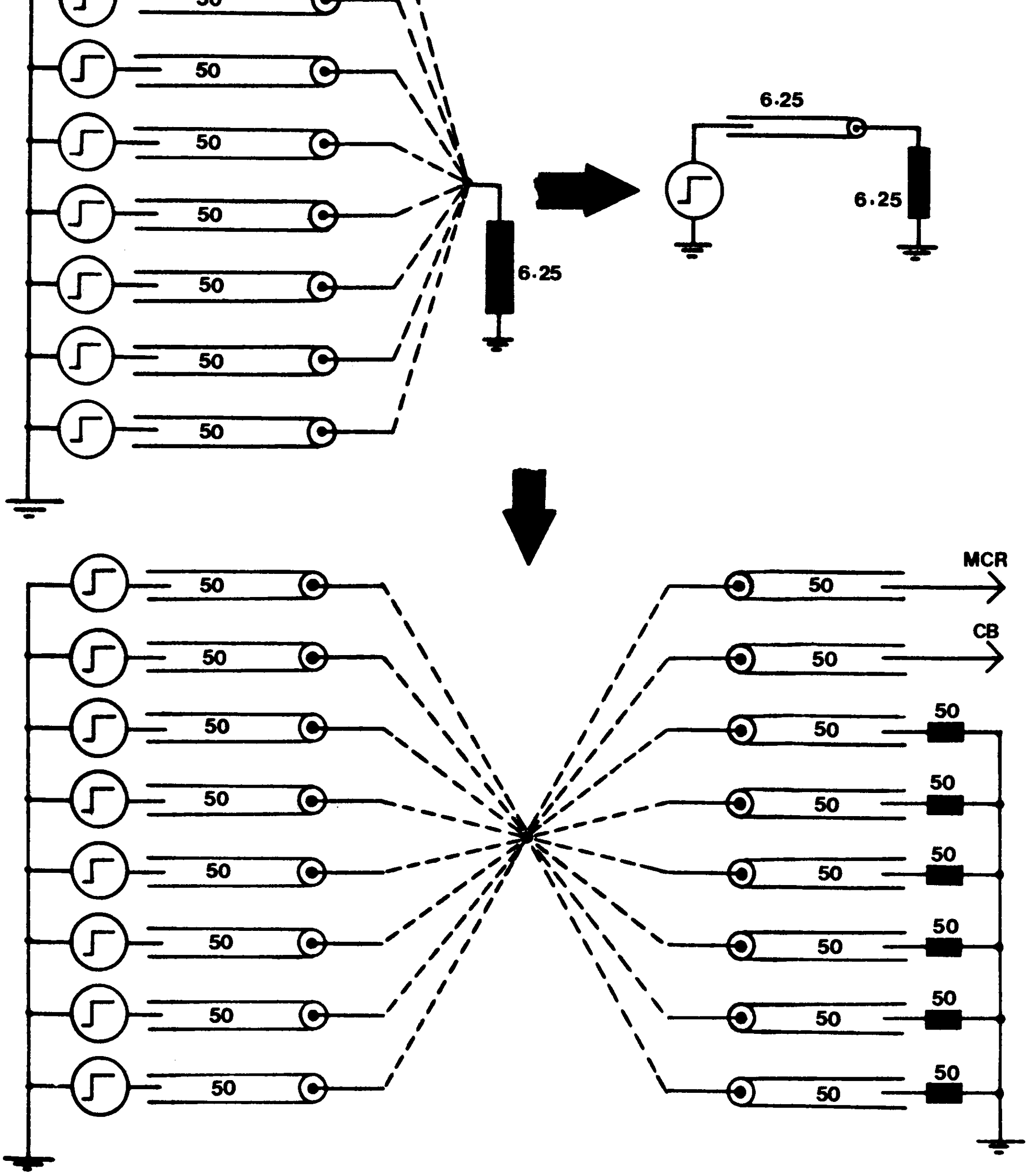
FIG.4 Attenuation characteristic of Eccosorb NZ-31 tiles.



NZ-31

25 - 3,000
Flat Tile
2.35 x 2.35
6.0 x 6.0
0.31 (0.8)
7.7 (37)
Sintered Ferrite
Black
-65 to 500
-54 to 260
20
(3.1)

FIG.5 From the 8 pick up outputs to the 16 way direct connected junction.



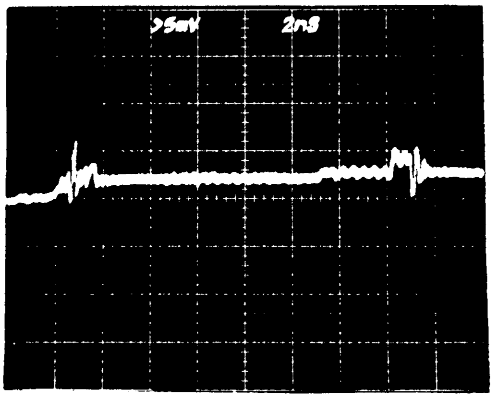


FIG.6 Voltage reflection coefficient of the 171 Ohms line used for beam simulation.
Sampling 7S11-7T11-S6
S52 step generator
r=5% /division
2 nS /division

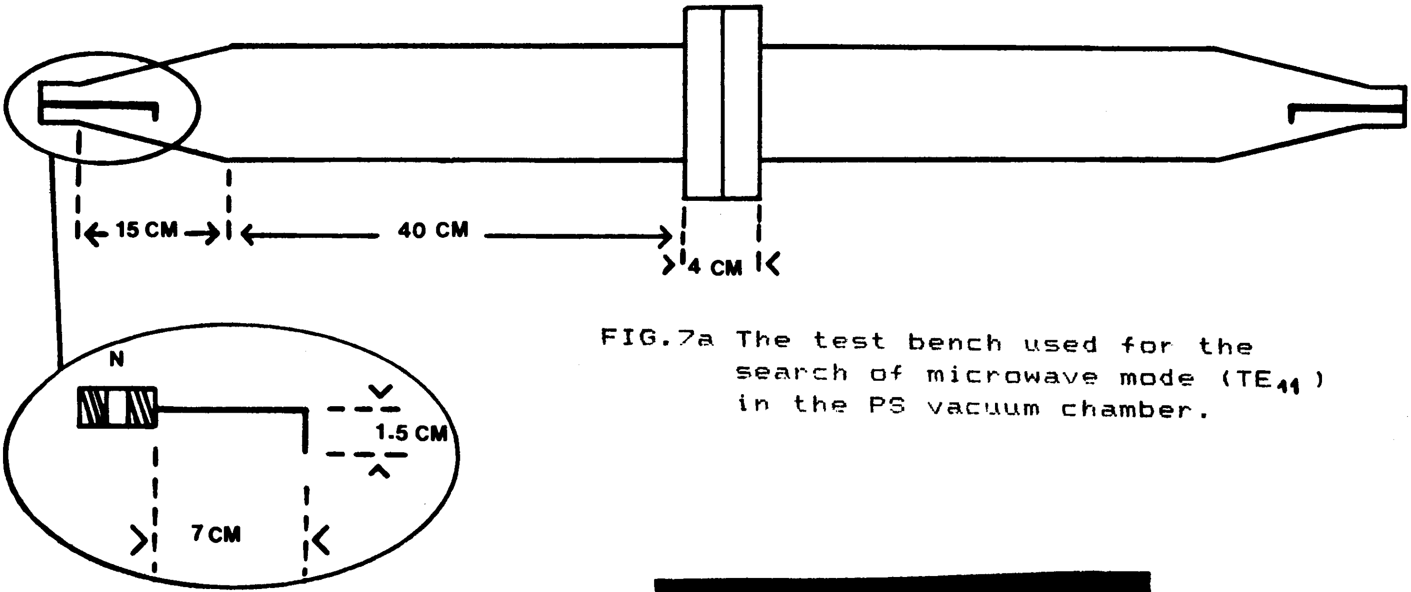


FIG.7a The test bench used for the search of microwave mode (TE_{11}) in the PS vacuum chamber.

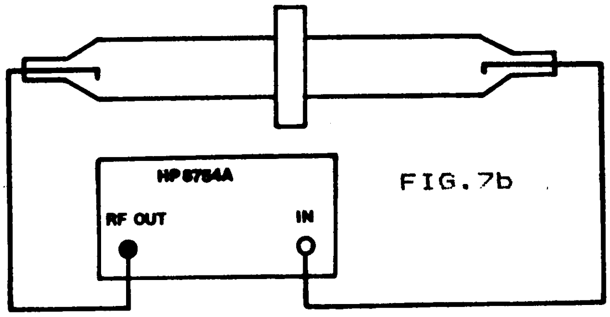
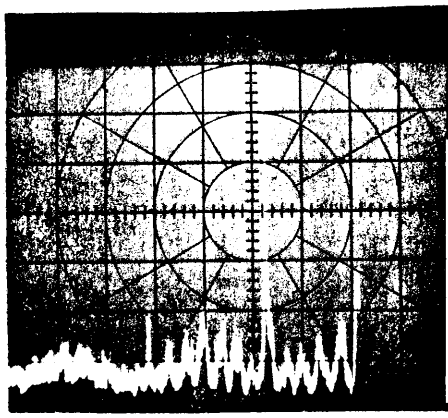


FIG.7b



HP8754a
center f:1308 MHz
ref:-78 dBm
2.5 dB/div
1 MHz/div
sweep:10 MHz
slow scan
video filter

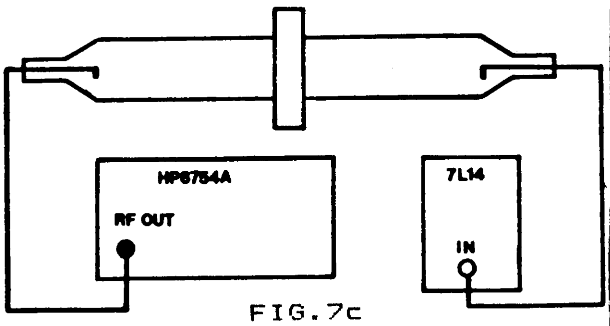
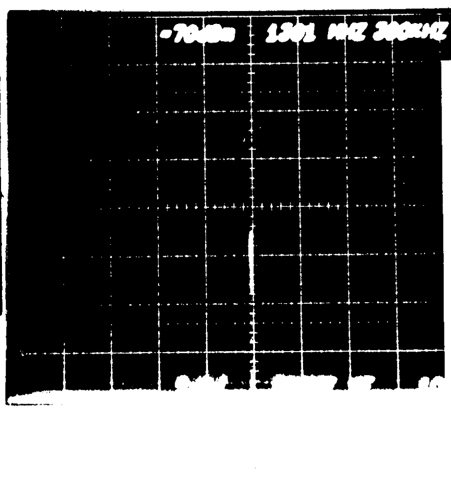


FIG.7c



HP8754a
manual scan

7L14
center f:1301 MHz
ref:-70 dBm
10 MHz/div
2 dB/div
IF bw:300 KHz
video f:30 KHz

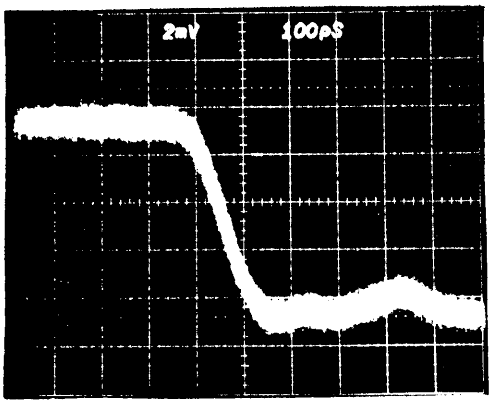


FIG.8
Wall current monitor rise time
S52 step generator
Sampling 7S11-7T11-S6
2mV/div
100pS/div

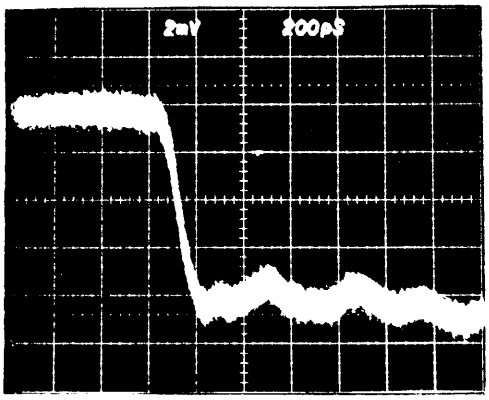


FIG.9
Wall current monitor rise time
S52 step generator
Sampling 7S11-7T11-S6
2mV/div
200pS/div

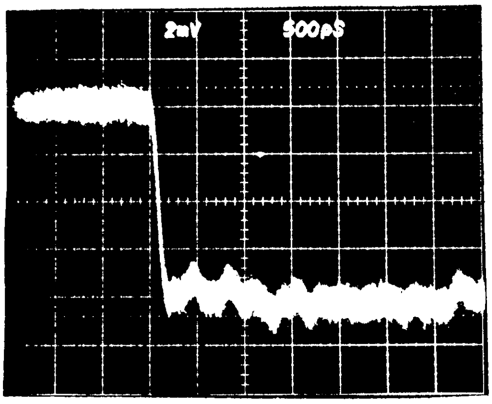


FIG.10
Wall current monitor rise time
S52 step generator
Sampling 7S11-7T11-S6
2mV/div
500pS/div

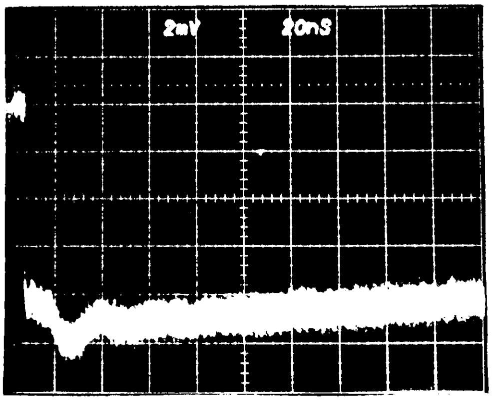


FIG.11
Wall current monitor rise time
S52 step generator
Sampling 7S11-7T11-S6
2mV/div
20nS/div

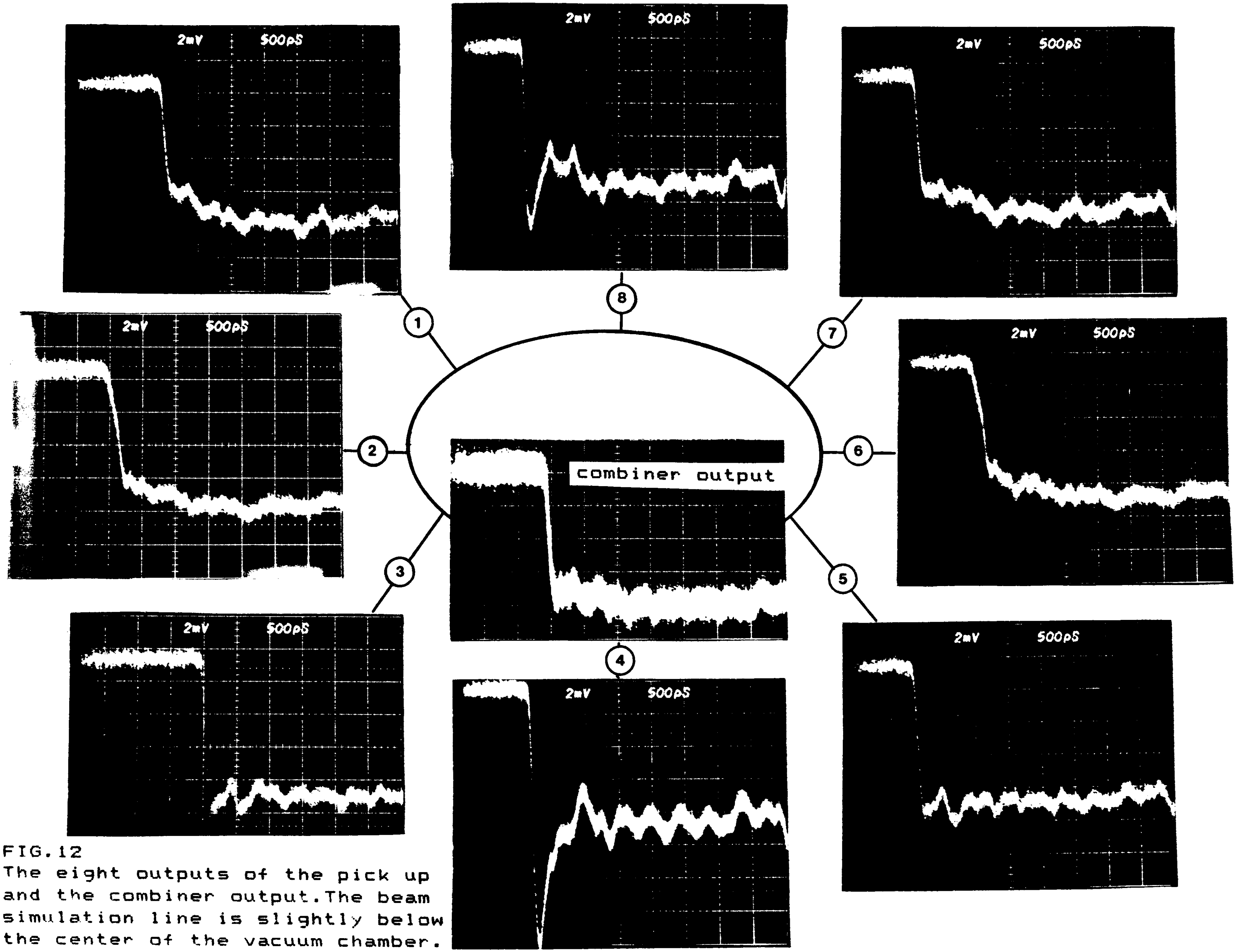


FIG.12
The eight outputs of the pick up and the combiner output.The beam simulation line is slightly below the center of the vacuum chamber.

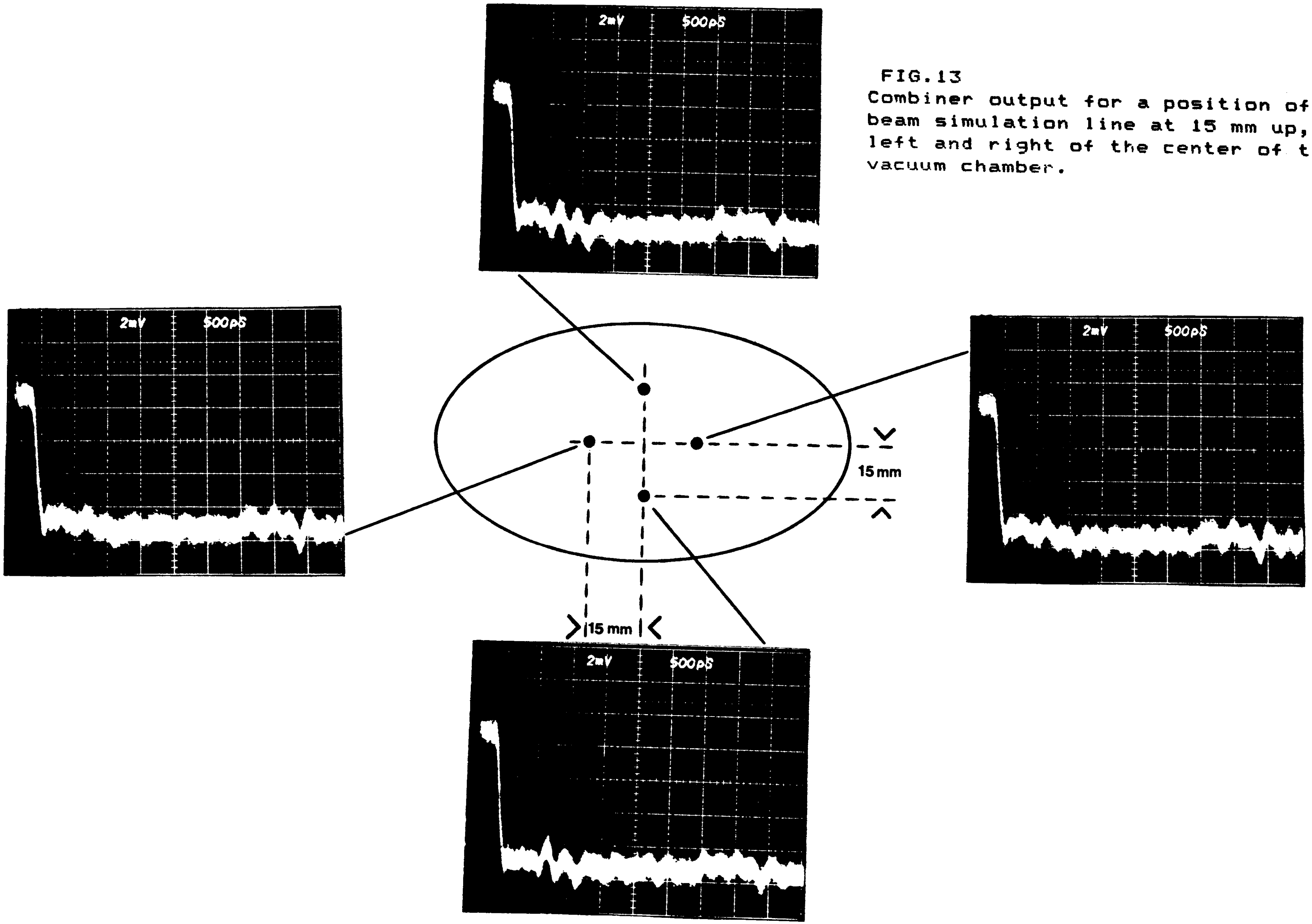


FIG.13
Combiner output for a position of the beam simulation line at 15 mm up,down, left and right of the center of the vacuum chamber.

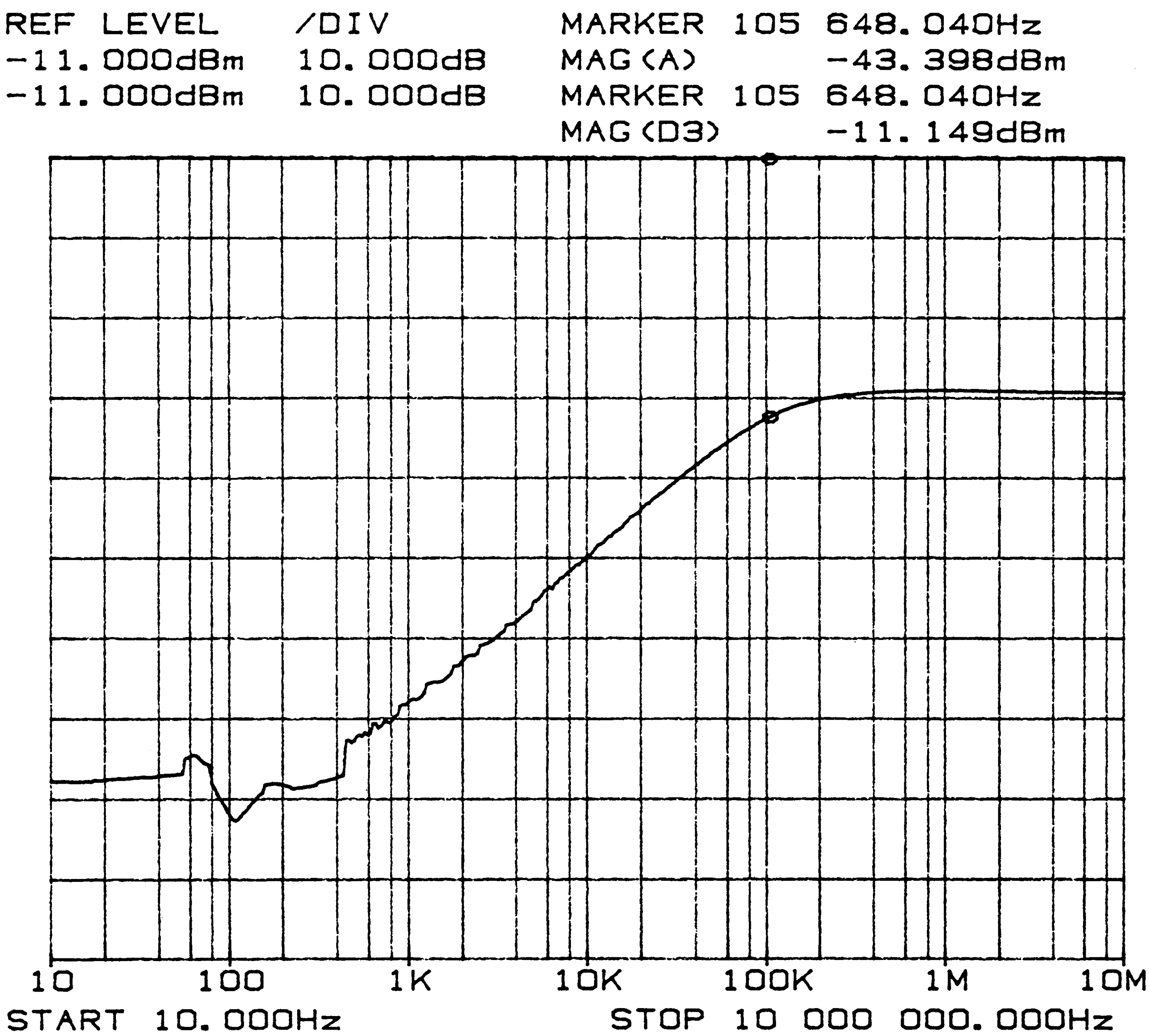


FIG.14
The low frequency cutoff of the wall current monitor.
The marker indicates the -3 dB point.
Ref. is the level on the beam simulation line.

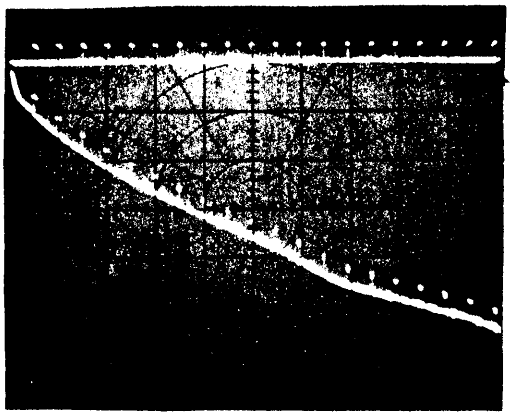


FIG.15a
Transmission line loss:
cable number 11900(ring-CB)
1.25 dB/div
100 MHz/div
sweep 4-1000 MHz
marker:50 MHz

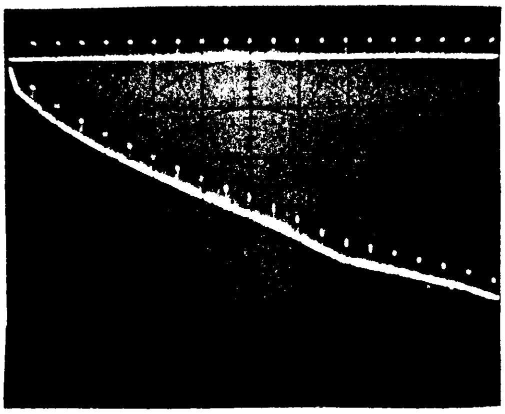
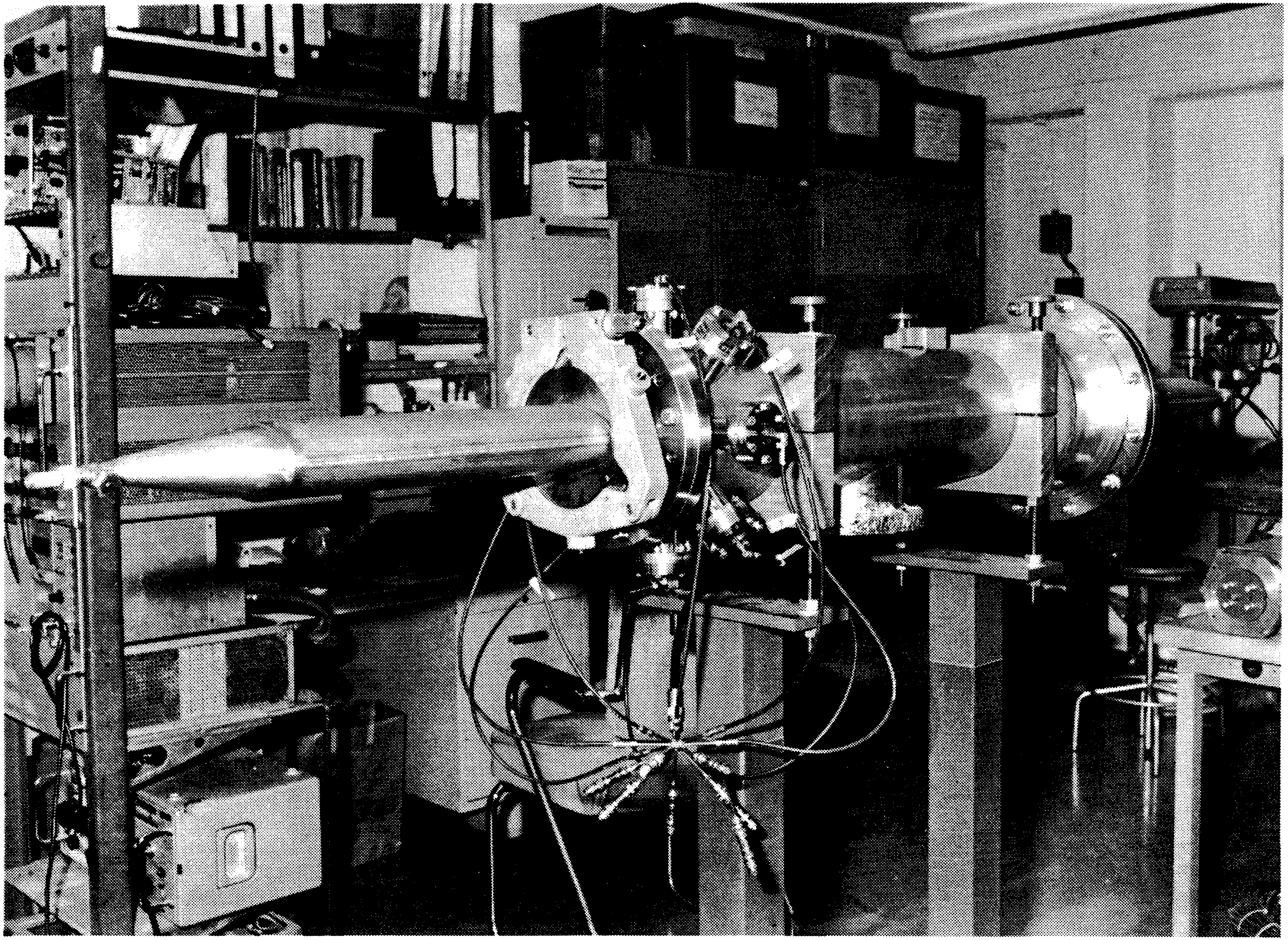
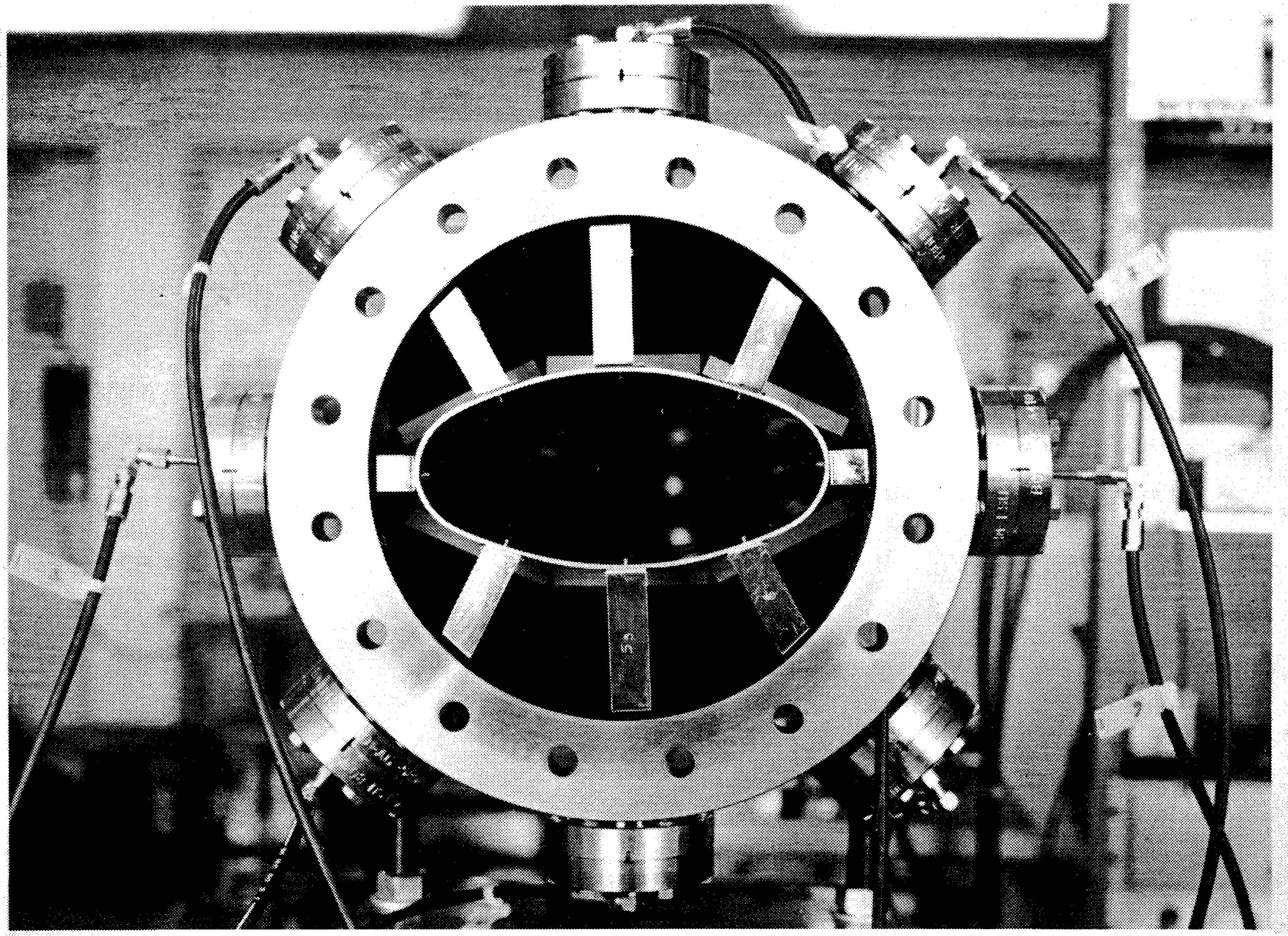


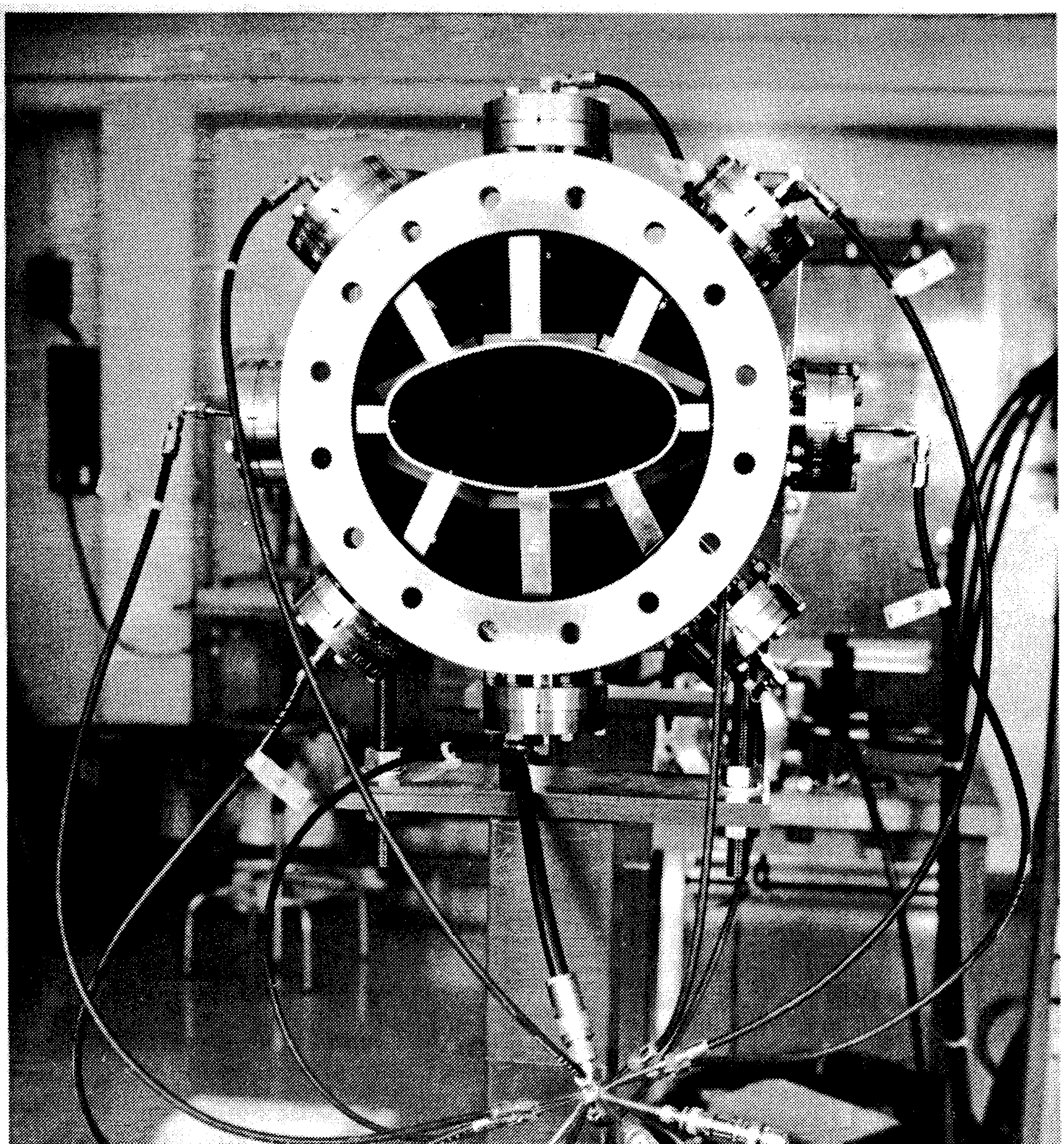
FIG.15b
Transmission line loss:
cable number 11899(ring-MCR)
1.25 dB/div
100 MHz/div
sweep 4-1000 MHz
marker:50 MHz



The wall current monitor on the test bench. At each end of the pick up are two lengths of PS vacuum chamber with conical sections for 50 Ohms matching of the beam simulation line.



A look at the gap (end plate removed):eight 50 Ohms microstrip transmission lines,microwave absorbing tiles,phase compensation with semi rigid coaxial cable.



The 16 way direct connected junction linked to the eight outputs of the wall current monitor.