GCSCH/iw

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN/MPS/AE 74-1
14.8.1974

THE WIDE BAND RESTITUTION PICK-UP SYSTEM OF THE CLOSED ORBIT DIGITAL DISPLAY AND THE CPS BEAM CONTROL

G.C. Schneider

1. Introduction

The Wide Band Restitution (WBR) Pick-Up (PU) signal transmission was proposed in ref 1) and then constructed. It is now in operation since several years at 43 compact PU stations (ref. 2) and 3)) of the PS ring. 40 serve for the Closed Orbit Digital Display (CODD, ref. 4) and 3 for the radial beam control loop.

The transmission system has no active electronic elements in the proximity of the vacuum chamber. Drifting due to radiation was considerably reduced as only metal and ceramic was used near the PU station.

The WBR system was described, mathematically investigated and optimized in ref 1) and 3). The transmission principle will be shortly repeated in the following:

2. Principle of the WBR Transmission

The signals influenced by the beam on the 4 capacitive electrodes are directly transmitted to the amplifier via 4 coaxial cables.

The amplifier restitutes the necessary frequency band and forms the position and intensity signals. Fig. A shows the equivalent circuit for 2 opposite electrodes.

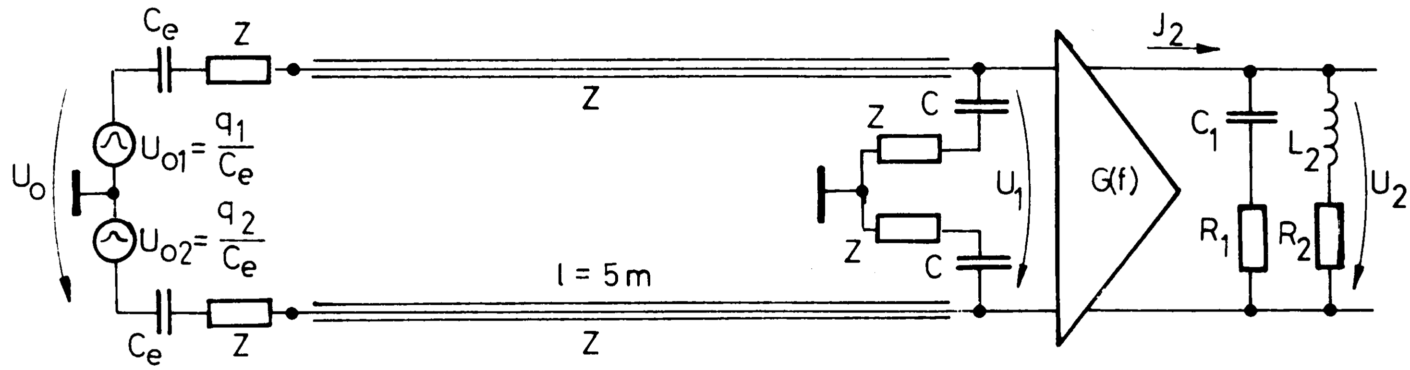

Fig. A

U_{01} and U_{02} are the voltages influenced by the beam on the electrodes of capacity C_e. These electrodes are connected via resistor Z to 5 m coaxial cables of impedance Z. The cables are terminated with a condensor C in series with a resistor Z.

For low frequencies, where the cables do not yet transform, the input voltage U_1 is determined by the capacitive voltage divider. For high frequencies the cable is matched and U_1 is half of the source voltage U_{01} (Ohmic divider). The approximated frequency response of U_1 is shown in Fig. B.

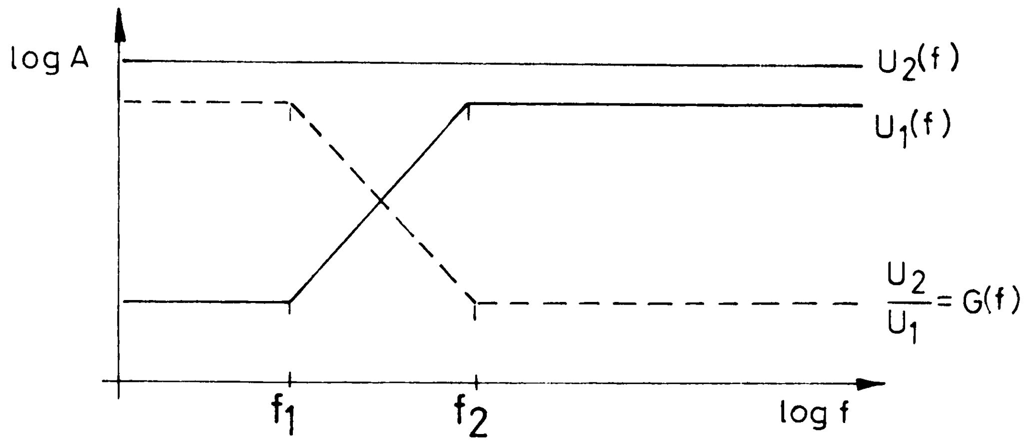

Fig.B

With an amplifier gain U_2/U_1, as indicated by dotted line, the output voltage U_2 is frequency independent. The superimposed distortions, due to incorrect cable matching for medium frequencies ($f_1 < f < f_2$), are compensated by a filter of special characteristics. The filter amplifier which compensates for constant frequency - and constant propagation time response - is shown on the right hand side of Fig. A (R1, C1, R2 and L2).

3. Description of the Realized PU System

Fig. 1 gives a schematic diagram of the PU station and the combined WBR amplifier. The signals influenced by the beam on the PU electrodes (left hand side) travel via 22 Ohm resistors, 15 cm coaxial cables (Z_1 = 22 Ω), 100 Ω resistors and 5 m coaxial cables (Z = 125 Ω) to the 4 inputs of 2 differential amplifiers (one for radial and the other for vertical beam position measurement. The equally denoted contacts R1, R2, V1 and V2 are connected together.)

The differential collector current of the first transistor stage (T1, T2) passes through the discussed filter (R1, C1, R2 and L2). The second differential stage (T3, T4) amplifies this restituted signal with adjustable gain. The variable emitter - emitter resistance of the double emitter transistor T5 (3N87) allows a gain control of 40 db with sufficient band width corresponding to a control voltage of between 0 and 15V. The gain of the connected IC amplifier μA 733 is 30 db. The output emitter follower T6 allows an output load of 75 Ω. The bandwidth of the total system is limited to 30 MHz by means of the RC filter at the base of the emitter follower T6. (The bandwidth limitation was introduced in order to reduce the dynamic range of the output signal. Without band limitation and appropriate transistors a bandwidth of 200 MHz can be obtained with the WBR method (ref. 5)).

A further RC filter between the emitters of the second differential stage (T3, T4) compensates for the cable losses of the 150 m coaxial transmission cable (3/8" Flexwell 75 Ω) between the amplifier output and the observation point.

The radial and vertical differential amplifiers are identical except for the values indicated in the vertical amplifier. The differences in the feedback of the second stage are due to the different sensitivities of the horizontal and vertical PU electrodes (elliptical shape). The overall sensitivities or the calibration factors for the radial and vertical position measurement are equal.

The sum signal of the 4 input signals is derived at the symmetry points between the 2 emitters of the first differential stages. It appears at the collectors of the transistors T7 and T8. This signal passes through the WBR filter, the amplifier stage with gain control (T9, T10, T11), the IC amplifier μA 733 and the output emitter follower T12.

The current feedback resistors of the first differential and sum stages (T1, T2 and T7, T8) can be switched by the relay contacts a,b,c,d,e and f from 100 Ω to 790 Ω to avoid input overload at beam intensities higher than about 2 Tp/p. The corresponding attenuation is 18 db.

The differential input stages are balanced for a common mode rejection better than 55 db between 6 kHz and 30 MHz bandwidth by means of the potentiometers P2, P3, P4, P6 and the trimmer capacitor C2 (at the basis of T1 and T2). Potentiometer P5 allows to find the symmetry point for a sum signal independent of the beam position.

The potentiometers R1 and R2 of the WBR filter serve to optimally adjust the step transient response. The potentiometer P11 of the gain control stage allows to compensate for differences between the double emitter transistors T5 resp. T11. (The same hyperbolic gain characteristic of 120 amplifiers (of 40 PU's) would be desirable as all have to be switched simultaneously in steps to different gains with the same control voltage. Small differences are compensated by the automatic calibration of the CODD.)

The amplifier gains are adjusted so that the beam position can be found with the following formula

$$\Delta X = 2 \frac{U_d}{U_s} [cm]$$

(U_d = vertical or radial difference voltage (ΔV or ΔR)
U_s = sum voltage (5))

The gain adjustment (calibration) is accomplished by exciting relay G or H with a test signal at the test input. The coupling condensors C_{kv} and C_{kr} are preadjusted so that a beam with a radial position of

$$\Delta r = 3,2 \text{ cm}$$

and a vertical position of

$$\Delta v = 3{,}6 \text{ cm}$$

is simulated. This means, the voltage ratio

$$\frac{\Delta R}{U_s} = 1{,}6$$

respectively

$$\frac{\Delta V}{U_s} = 1{,}8$$

must be adjusted for the calibration factor of 2.

The excitation of both relays G and H simultaneously allows to check the balance or to measure the offset errors.

4. Characteristics

The following list gives a summary of the essential parameters of the WBR amplifier :

- high frequency input impedance	125 Ω
- max. input signal (with 18 db input attenuation)	7 V
- output impedance	3 Ω
- nominal output load	75 Ω
- max. output swing	3,2 Vpp
- linearity	1 %
- output noise (R_{3N87} = 50 Ω)	2 mVpp
- lower frequency limit	6 kHz
- upper frequency limit (with 150 m 3/8" Flexwell cable included)	30 MHz
- cross-over frequency of WBR system	1,9 MHz
- common mode rejection (CMR) (6 kHz ÷ 30 MHz)	56 db
- max. signal to noise ratio (S/N)	60 db
- dynamic range of gain control	40 db
- gain ratio G_{LF}/G_{HF} of input stage with filter	21 db

- input attenuation switched — 18 db
- calibration factor for position measurement $(\Delta X \frac{U_s}{U_d})$ — 2 cm
- simulated beam position for calibration — Δr 3,2 cm and Δv 3,6 cm

Power Supply Requirements

+ 6 V ± 1%, 150 mA
- 6 V ± 1%, 150 mA
- 150 V ± 1%, 150 mA

- gain control 0 ÷ 15 V, 5 mA
- 18 db attenuation 38 mA, 12 V
- calibration relays 38 mA, 2 V

5. Results

The manner how the WBR circuit works is demonstrated in the time domain on photo 1. A clean rectancular pulse from the EH 122 pulse generator was coupled via a 2 pF condensor (current source) to a radial PU electrode. The output pulse shows, apart from the droop (due to the lower band limitation), a small ringing after the steps. This error of about 1,5 % remains after optimum adjustment of the WBR filter elements. It corresponds to the computer plotted figures in ref. 1). Photo 2 gives the output pulses of the WBR system with 150 m transmission cable for gaussian input pulses of 20 ns width and 10 MHz repetition frequency. There can also be observed a small ripple at the base line.

Signals from the beam are shown on photos 3 and 4. Photo 3 displays the sum signal of the PU station 90 at injection (beam intensity 1,5 Tp/p). Due to the 3 turn injection the signal goes up in steps at the beginning. Then it drops due to the lower cut off frequency. The following behaviour shows the synchrotron oscillations after injection. Photo 4 gives the radial and sum signals of the PU station 80. It was taken at the most critical case of acceleration at transition (B 270) where the short pulses ($\simeq$ 6 ns) excite very high frequencies. Due to the band limitation at 30 MHz, which was introduced to avoid saturation, the signals have about 25 ns pulse width.

The radiation stability of the common mode rejection factor was considerably increased with respect to the earlier cathode follower transmission. As the drifting cathode followers could be suppressed, also the remote balancing could be abandoned.

A measurement of the stability during 1 month (end 1972) showed that the mean square offset error of 25 WBR PU stations was 0,3 mm. Photo 5 shows the WBR amplifier card (schematic diagram, see Fig. 1). The WBR chain is displayed on photo 6. It contains the PU electrodes, the cable plug-in, the amplifier plug-in, the control chassis (not shown). The four 125 Ω cables are mounted fix at both ends due to the high common mode rejection requirements.

The power supply chassis which house the electronic parts are fixed to special lifts in the PS ring. In the lower position of the lift the semiconductors of the amplifiers are hidden against radiation behind more than 1,5 m concrete.

Acknowledgements

I should like to thank D. Boussard for stimulating discussions during the development, P. Pelletier, J. Bernard and R. Wiencek for the help during the series production and calibration of 50 WBR amplifiers.

Furthermore I am thanking R. Bourgeois for the maintenance of the beam position measurement system and E. Schulte for reading this draft and his comments.

References

1) G.C. Schneider : Proposed Beam Observation Signal Transmission for Increased PS Beam Intensity; MPS/SR/Note 70-5.

2) G.C. Schneider : The New Pick Up Electrodes for the CPS; MPS/Int. RF 65-9.

3) G.C. Schneider : Messwerterfassung und -übertragung zur Strahllagebestimmung beim 28 GeV Protonen Synchrotron von CERN; Dissertation 16.12.71

4) J. Boucheron, D. Boussard, F. Ollenhauer, G.C. Schneider : The CERN Proton Synchrotron Orbit Display; Particle Accelerators 1971, Vol 2 pp 315-324.

5) G.C. Schneider : The 200 MHz Position Pick Up Station with the WBR Method (in preparation).

Distribution : open

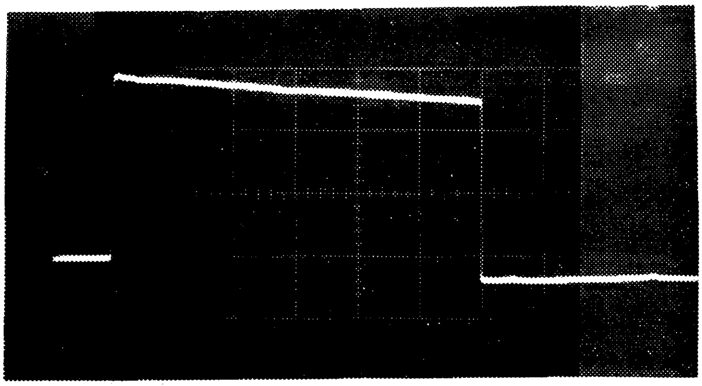

PHOTO 1

ΔR
0,5 μs/div
20 mV/div

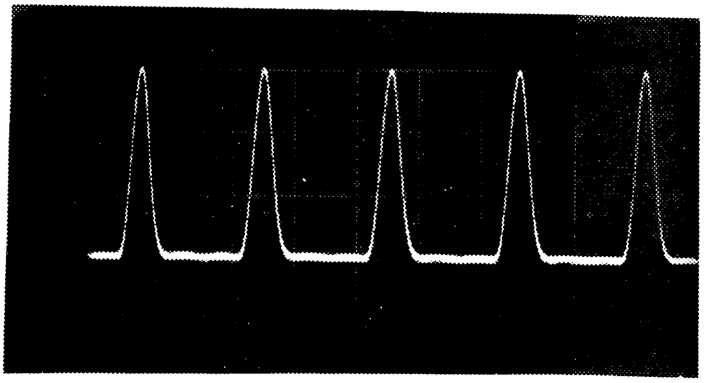

PHOTO 2

ΔR
50 ns/div
100 mV/div

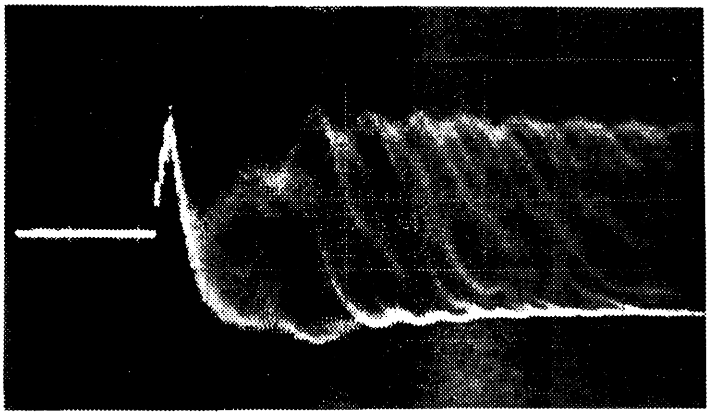

PHOTO 3

S
500 μs/div
40 mV/div
injection

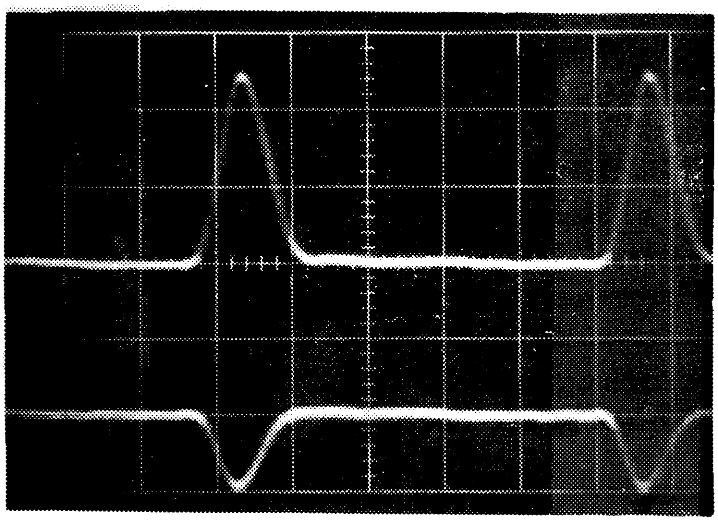

PHOTO 4

S 400 mV/div
20 ns/div
ΔR 200 mV/div
transition
(B270)

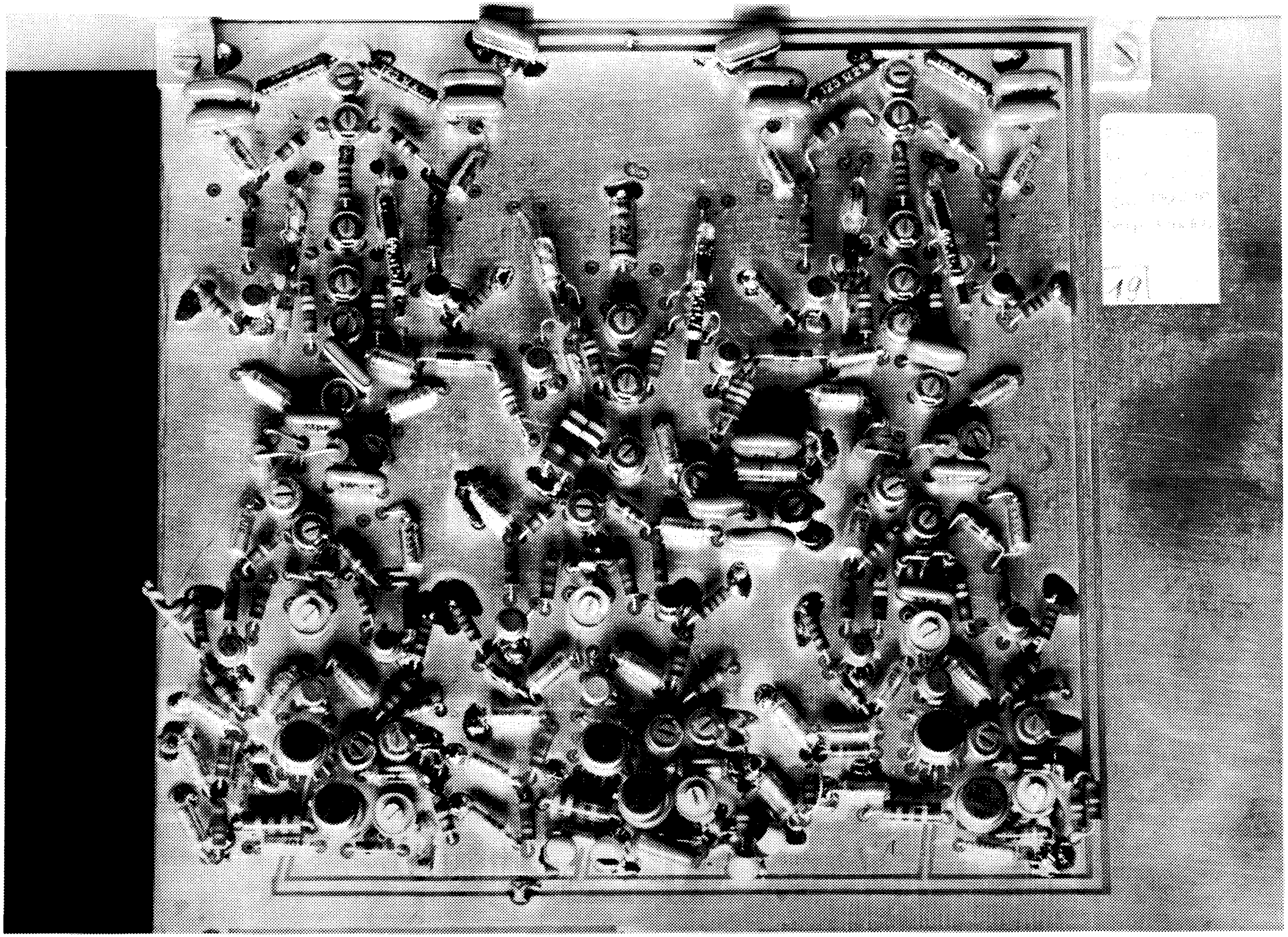

PHOTO 5: WBR Amplifier Card

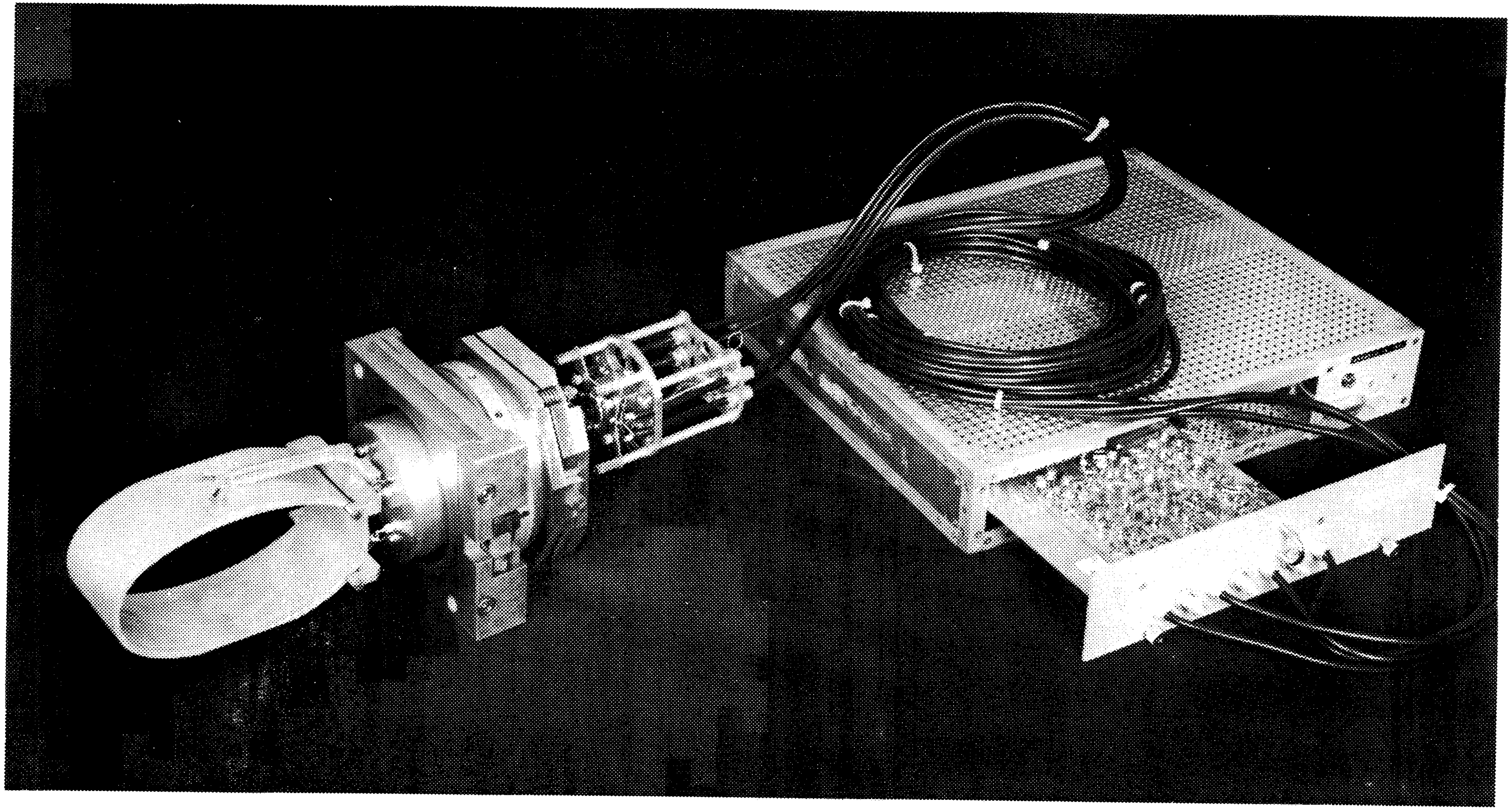

PHOTO 6 :   PU WBR Chain

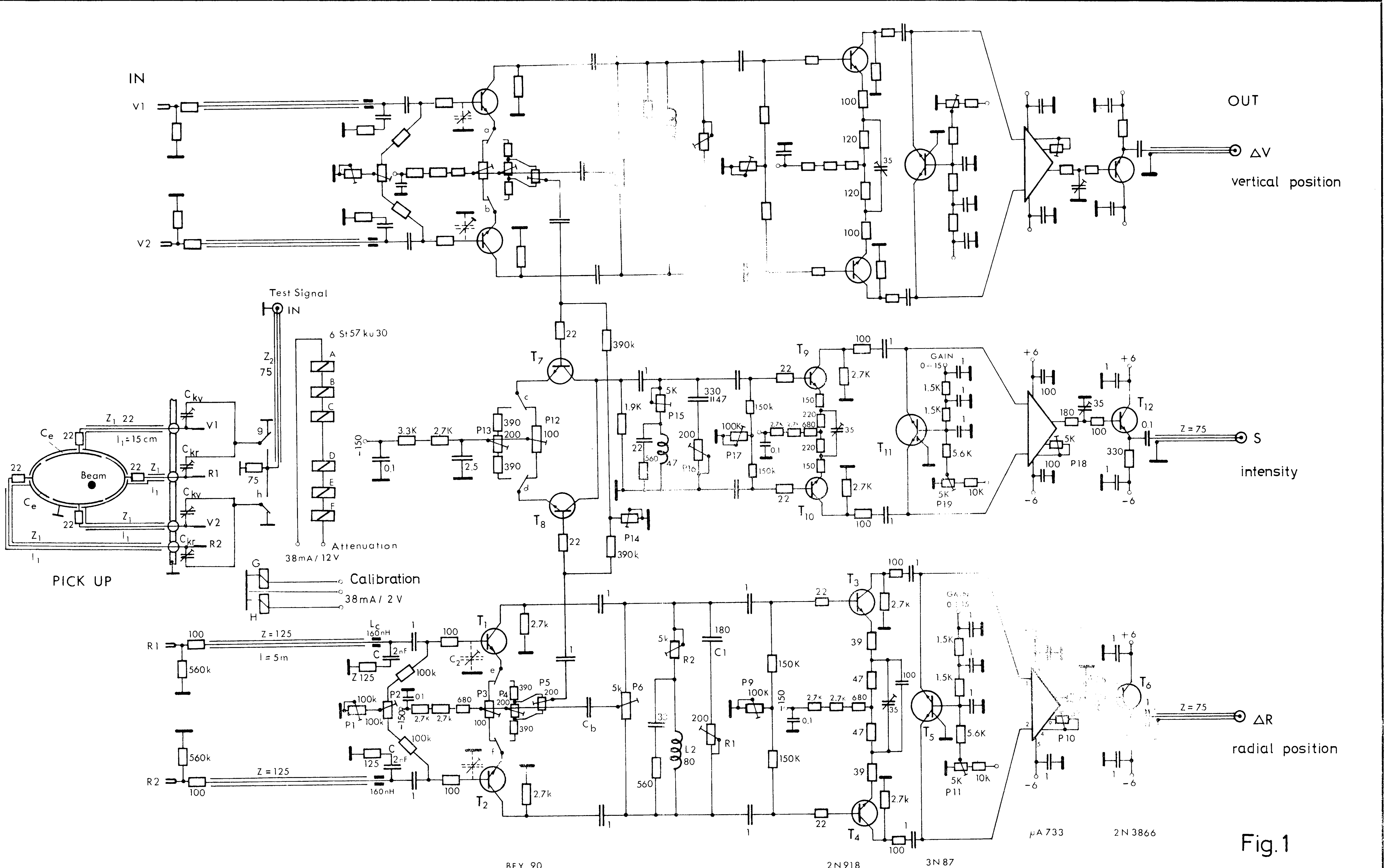

Fig. 1

Ensemble / Assembly	S/ensemble / S/assembly		Nom-Name	Date	Issue
PU-Compact		Echelle / Scale	Dessiné: J. Schn.	23.3.73	
WBR - PU - AMPLIFIER			Contrôle		

ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE
EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH
CERN LAB 1 CH-1211 GENÈVE 23

MPS/SR 7371-EL1-2

First angle projection
Projection européenne