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The Italian Cross Radiotelescope.

I – Design of the antenna.

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Introduction.

The telescope, which is primarily intended for identification and high resolution studies of weak radiosources, is designed to work around the frequency of 408 MHz. It will be constituted by two antennas about 1.2 km long and 30 meter wide forming a «Mills' cross» (1). This shape, or the equivalent ones are, nowadays, the best compromise between resolution, sensitivity and cost for work at wave-lengths around one meter.

In the following pages a general description of the instrument and the essential electromagnetic and mechanic details are given. It should be however remembered that the final *minute* performance of various parts of the instrument cannot be reliably computed or measured on models, so that quite a considerable part of the design will follow the operation of components at full scale.

(1) B. MILLS, A. LITTLE, K. SHERIDAN and O. S. LEE: *Proc. Inst. Radio Engrs.* **46**, 67 (1958).

1. – General design.

In a cross radiotelescope the motion of the earth provides the scanning in right ascension. In addition the beam can be tilted in declination by properly adjusting the phase of the antenna elements in the North-South arm.

The elements of this arm can be either closely spaced, as in the original Mills' cross or, alternatively, located at a certain distance from each other. In the first case the N-S arm is illuminated with continuity and hence no grating fringes are expected. On the other hand a large array of closely spaced elements requires a very large number of phase shifters thus complicating enormously its maintenance and operation.

If alternatively the N-S arm is made of elements several wavelenghts wide, as for instance parabolic reflectors, a phase adjustment is needed for a much smaller number of elements. In this case however the antenna pattern contains also maxima of higher order than zero.

These can be eliminated in either of two ways:

i) by displacing the center of the two arms of the cross so as to bring the signal corresponding to the first order maximum of the N-S arm 90 de-

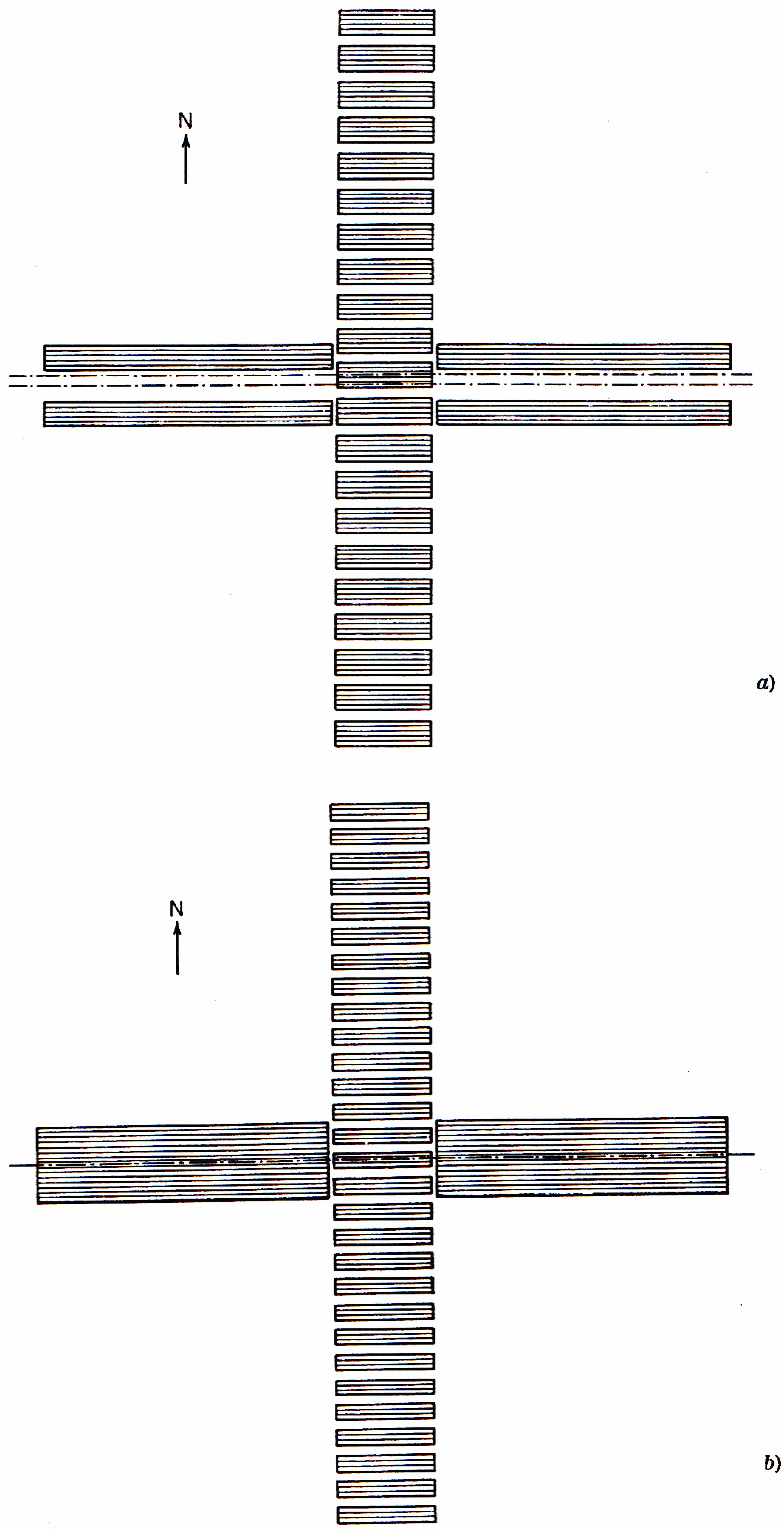

Fig. 1.

grees out of phase from that of the E-W arm, thus eliminating the correlated response (see Fig. 1*a*) ([2]), and

ii) by multipliyng the fringed N-S pattern by one which is narrower than the distance between two fringes. This can be obtained by making the width of the E-W arm considerably larger than the distance between the elements of the N-S arm (Fig. 1*b*).

The first solution, although very elegant, requires for an efficient suppression (20 db) of the secondary fringes to achieve tolerances of less than 1% in field amplitude and about 1 mm in electric lenghts, while the suppression of fringes in solution ii) depends on an inherently less critical parameter, *i.e.* the low sidelobes level of the E-W arm. This consideration has led us to prefer the second solution, which has in addition the attractive feature of allowing the independent use of the E-W fan beam.

2. – The E-W and N-S arms.

The East-West arm will be made by a cylinder of conducting wires supported by rotating parabolic sections as in the Cambridge ([3]) and the Medicina ([4]) instruments. The sections are 50 and are spaced 23.5 meter, except for the central part where a 47 meter gap is left, across which passes the N-S arm. The width of the reflecting surface is 30 meters; the total length, including two extension of the reflector at the edges is 1190 meter. A top view of the cross center is shown in Fig. 2; Fig. 3 is a drawing of a parabolic section.

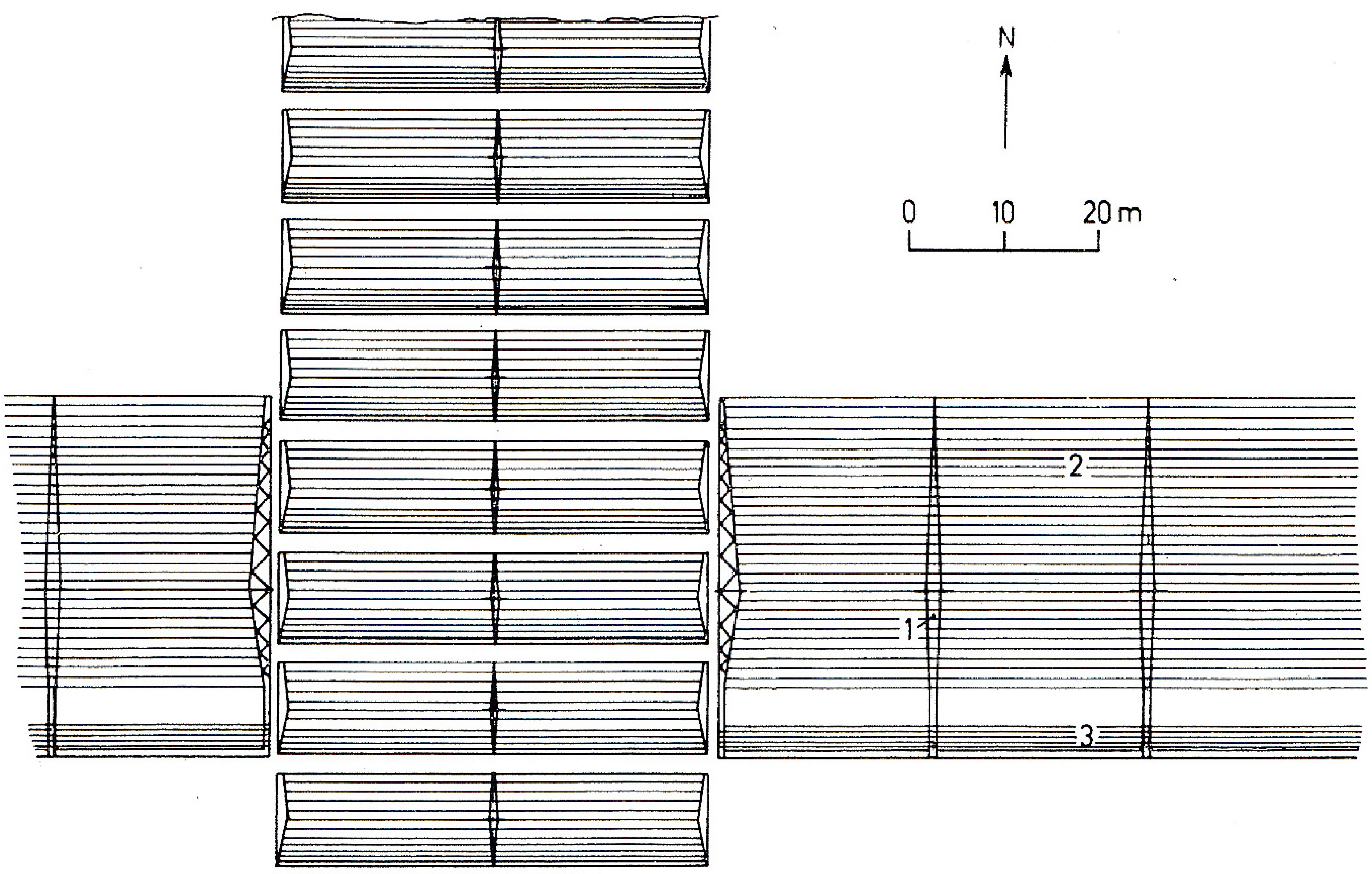

Fig. 2. – 1) parabolic section; 2) reflecting surface; 3) corner reflector and antenna frame.

([2]) W. CHRISTIANSEN and J HÖGBOM: *A Design for the Benelux Cross Antenna*, private circulation (1960).

([3]) M. RYLE: *Nature*, **180**, 110 (1957).

([4]) A. BRACCESI, M. CECCARELLI, G. MANNINO, G. SETTI and G. SINIGAGLIA: *Nuovo Cimento*, **17**, 614 (1960).

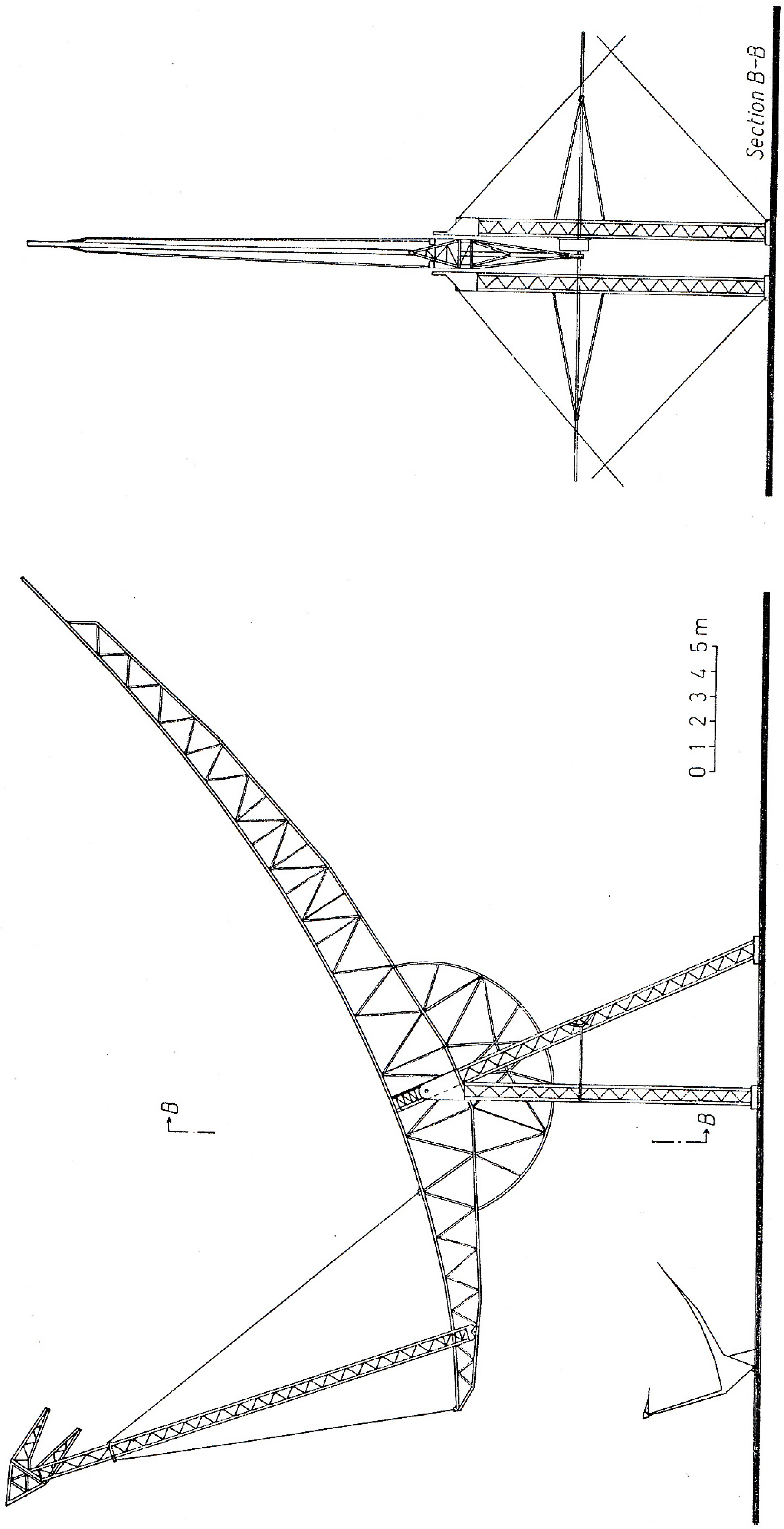

Fig. 3.

It can be seen that the feed is displaced from the center so to avoid blocking of the aperture and hence reduce spillover. This feature is essential for the suppression of N-S fringes. In addition this design of the parabolic section allows to bring the feed down to ground level for maintenance.

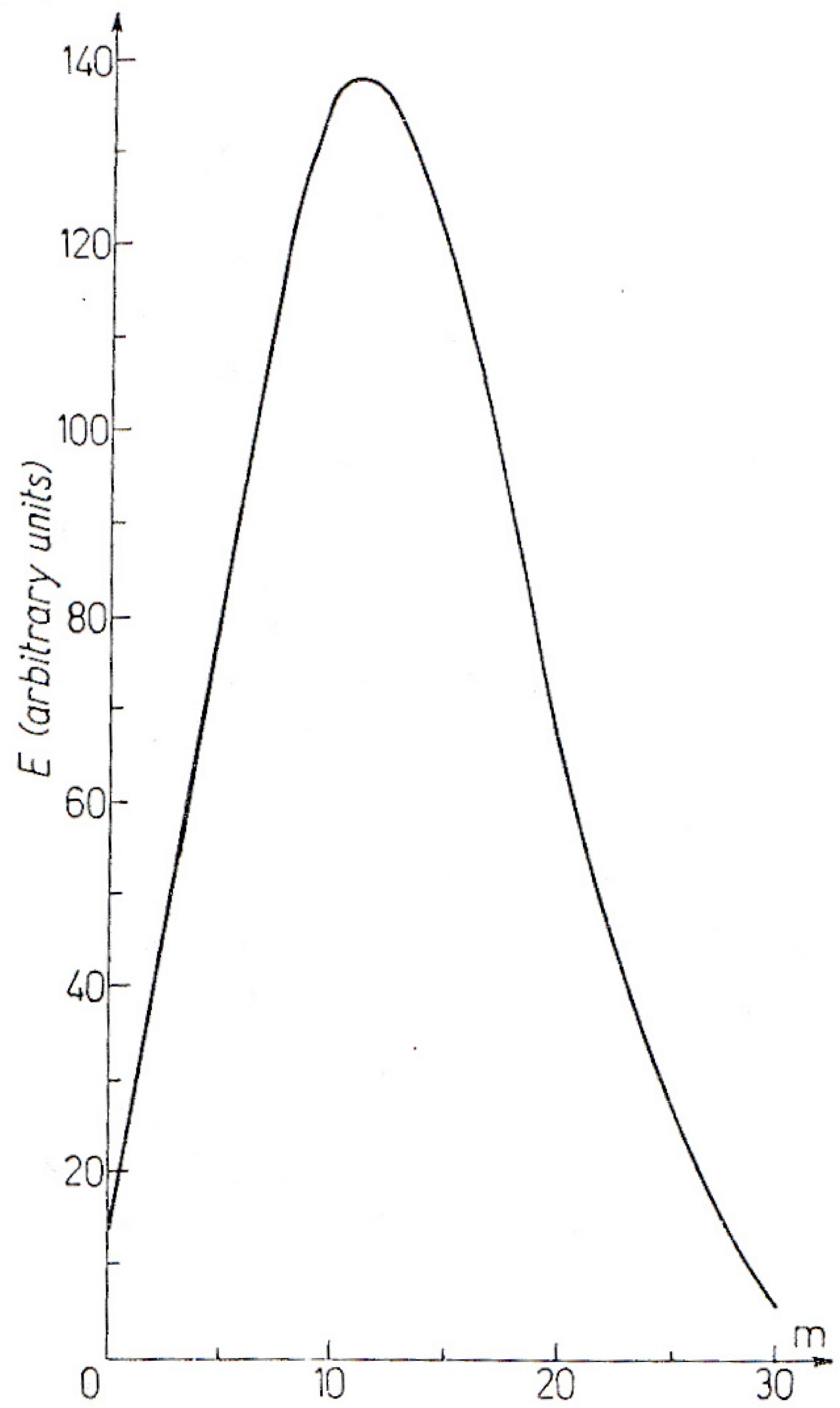

Fig. 4.

Each parabolic section will be driven by a properly demultiplied motor and a shaft will connect all motor boxes at an intermediate step of demoltiplication so as to ensure their synchronism as well as motion of a section in case of failure of its motor. Additional devices are also planned to avoid damages in case of non synchronous movement.

The E-W cylinder will be illuminated by a conveniently shaped corner reflector energized by a total of 3072 half-wave dipoles. The resulting illumination and the corresponding antenna pattern in the H plane are shown in Fig. 4 and 5.

The North-South arm will be formed by a total of 96 parabolic cylinder reflectors, each having a width of 8 meter and a lenght of 42.0 meters, placed parallel with a spacing of 11.5 meter.

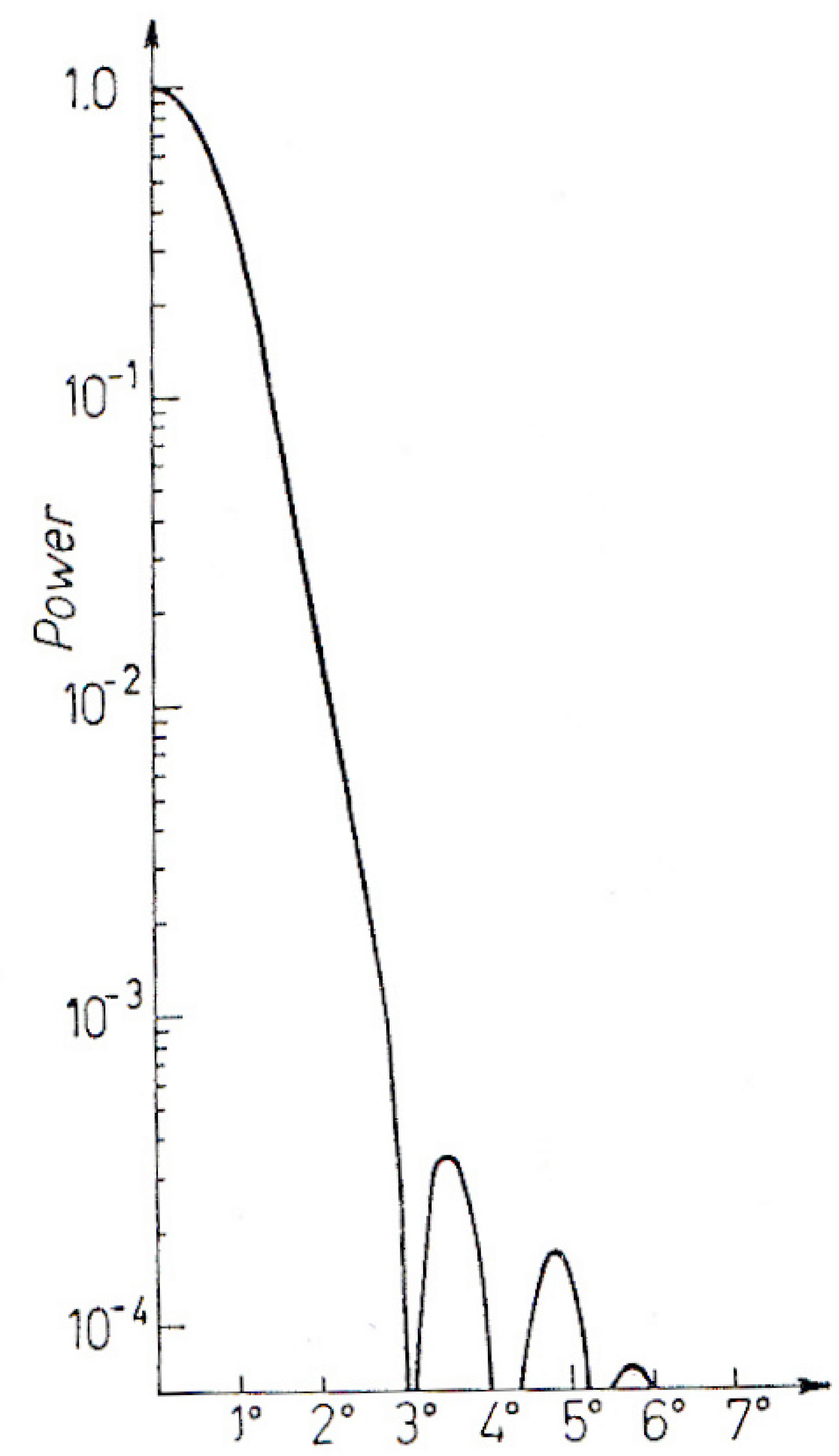

Fig. 5.

With these dimensions the beam can be tilted by ±45 degrees without shadowing and the first order fringe is well outside the main beam of the E-W arm.

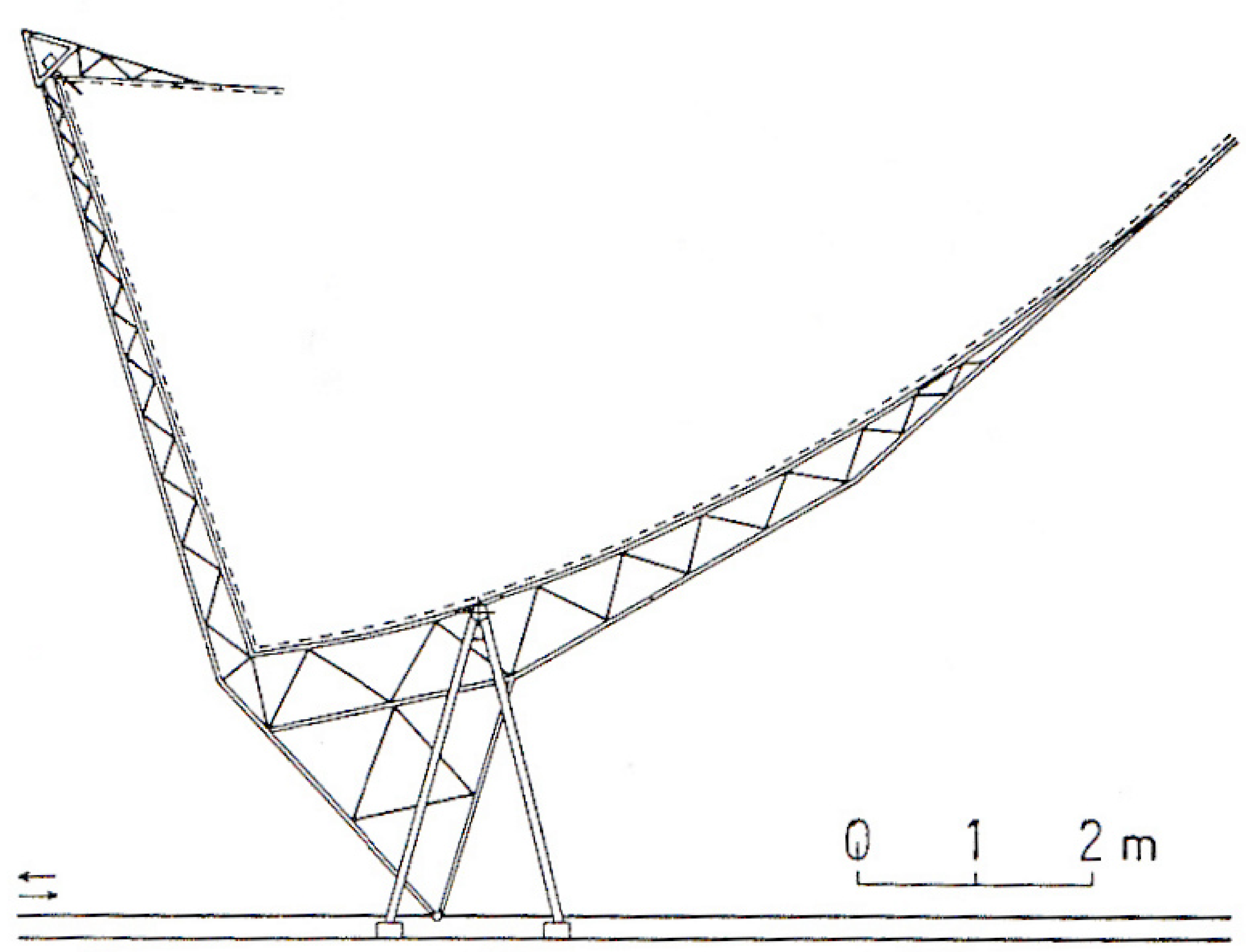

Fig. 6.

The preferred design of section of the N-S arm is shown in Fig. 6. A final decision depends however on model tests. Because of their smaller weight a number of several sections will be connected together by a rope and driven by a single motor, as shown in Fig. 6·

For both arms the reflecting surface will be made of .5 mm diameter stainless steel wires with a 7 kg pull and a projected distance of 2 cm. The transparency of this screen at 408 MHz is of 2%; a value which is of the same order as the other sources of spillover, *i.e.* leads to sidelobes in the *H* plane about 30 db below the main beam.

As far as mechanical tolerances are concerned the factory building the steel sections has been asked to guarantee a maximum deformation of ± 1 cm in the feed and central part of the parabola. This maximum error, which should be achieved also in the positioning of the section and in the electric lenght of the R.F. cabling has been used for the computations of Sec. 4.

3. – Feed and radio frequency transmission.

The feed of the E-W arm will be an array of 64×48 half-wave dipoles placed in a corner reflector. Each group of 64 dipoles, forming a 23.5 meter sub-array, will be supported, through a frame, by the masts of two adjacent sections. A sub-array can then be easily changed in case of failure.

The dipoles will reach a strip transmission line designed in such a way to be protected against radiation and rain. This line runs at the dipole level and collects into a single descent line the signals from 256 dipoles; the signal is therefore brought down to ground level in 12 different locations and here preamplifiers and mixers are installed. After mixing, the signal is transmitted to the central post through a network of cables placed underground so as to minimize temperature effects.

In designing the R.F. transmission line of the arrays we had primarily in mind to ensure a very low and constant attenuation, a narrow phase tolerance and a comparatively broad band of operation.

We indeed foresee an attenuation of about 1 db and lenght tolerances within $\pm .5$ cm.

With the « X-mas tree » design of the transmission line (┌┴┐) the electric distances from each dipole to the preamplifiers are equal. This leads to a slightly greater complexity of the line but has the advantage of ensuring a strictly uniform longitudinal illumination over the whole band and a moderate variation of the SWR which might for instance allow a quite large frequency charge in case of otherwise unavoidable interferences.

The N-S array feeds and transmission lines will differ from those of E-W arm only in minor points obviously related to the different geometry of the two.

As far as grading of illumination along the arrays is concerned this will be obtained with properly matched **T** junctions along the transmission line. A final decision on the distribution function and its maximum admissible sidelobe level will however wait until experimental data on the actual sidelobes contribution due to unpredictable features of the whole electromagnetic and electronic system will be available.

4. – Antenna diagrams and evaluation of telescope sensitivity.

Fig. 7 shows the calculated radiation pattern of the antenna previously described, pointing at the zenith. The effect of the gap in the center of the cross was not included in the calculation. By splitting the signal of the central N-S elements between the two arrays the effect of the gap should be reduced to a comparatively flat lobe, about 1 degree wide, and with a power level of perhaps — 20 db. This pattern should generally be of little importance as far as « point » sources are concerned, being in this respect equivalent to the extended sources background.

About sidelobes a distinction has to be made between: *a*) sidelobes whose position and level remain stable and which can be determined either by calculation or measurements, and *b*) side-

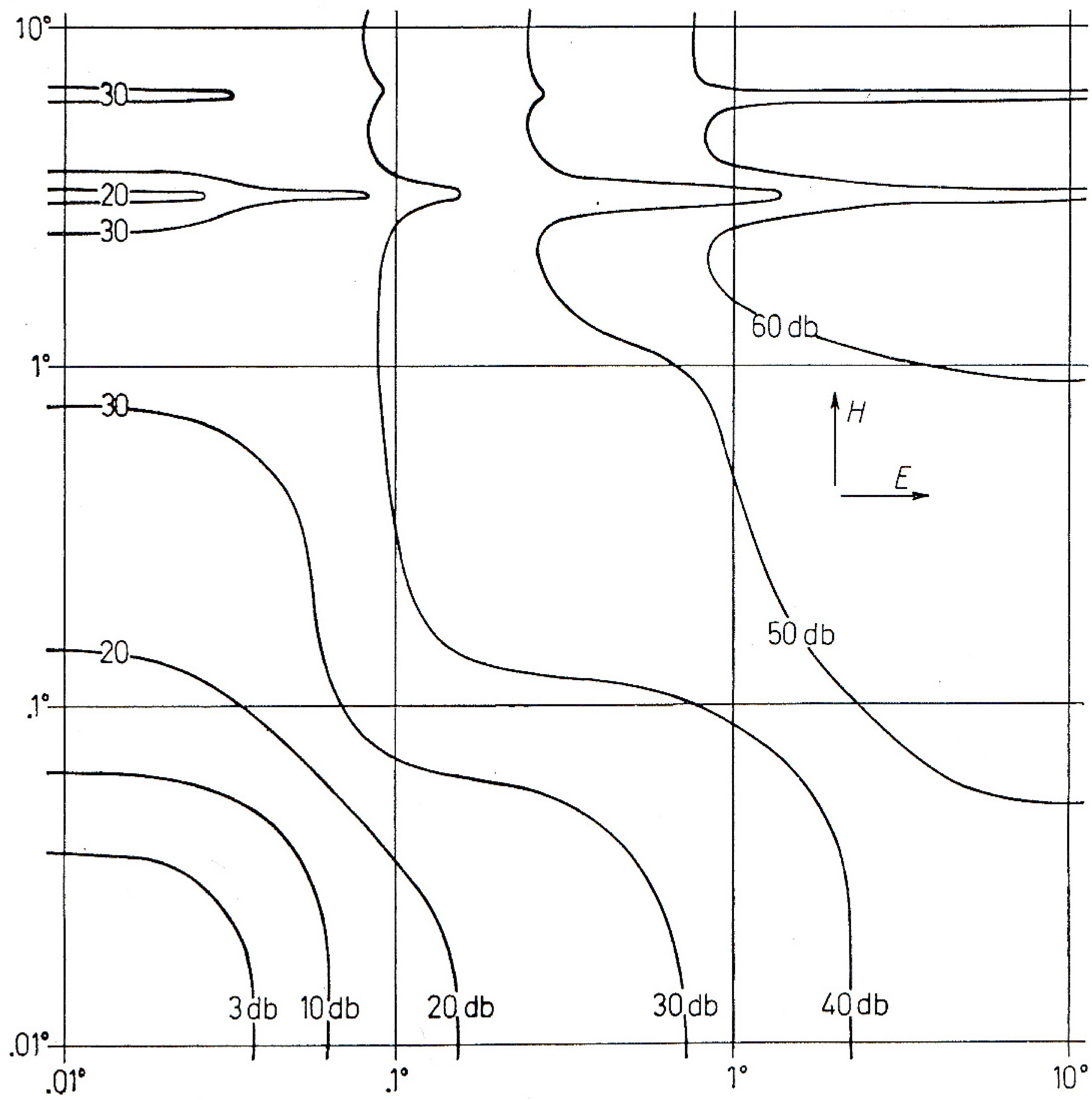

Fig. 7.

The sensitivity of a radiotelescope, *i.e.* the minimum source flux which can be measured with given accuracy, is ultimately related only to the antenna pattern (beamwidth and sidelobes level) and not to the noise factor of the receiving system. Flux errors, and hence confidence levels of source identification, derive either from superposition of weak sources in the primary beam, or from superposition to the source to be measured of sidelobe images of stronger sources. Errors of the first type depend only from the linear dimensions of the telescope; of the second one from the design of the antenna and the accuracy of its construction.

lobes of approximately known maximum level but unknown direction, which are due for instance to adjustment errors, thermal dilatations, reflections from the ground etc., and which might change from day to day. Sidelobes *a*) might be comparatively strong but extended only over a small angular region; the others, on the contrary, are generally much weaker but can interest the whole sky.

The effect of these lobes is to establish, for a given flux distribution of sources, the maximum absolute error in a flux measurement for each direction.

The various contributions to errors were computed from the data used for Fig. 7 and from known and extrapolated data on the source distribution in the sky. As a significant index of sensitivity was taken the minimum flux of a «point» source which can be measured with a 10% accuracy.

This minimum flux turns out to be of $1.5 \cdot 10^{-27}$ as an effect of superposition of weak sources in the primary beam and of $5 \cdot 10^{-28}$ W/m² Hz as an effect of sidelobes. The sensitivity of the antenna seems therefore limited by its dimensions rather than by the sidelobe level. Since the second evaluation is by far less reliable than the first, due to the much larger number of parameters coming into play, it is agreable to have a safety limit of a factor three.

In order to obtain *by a single scan* of the antenna described here a response with 10% error from a $1.5 \cdot 10^{-27}$ W/m² Hz a receiver is needed with a noise temperature of about 500°, for a band width of 2 MHz. The major problem in the receiving system is not therefore to achieve an extremely low noise figure but to guarantee, by its phase and gain stability, a highly controlled antenna field. The preferred design for this system will be described in a next paper.

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