INSTRUMENT EQUIPMENT OF DRIFTING BUOYS FOR TRANSMISSION OF METEOROLOGICAL AND OCEANOGRAPHICAL DATA VIA SATELLITES

A Preliminary Study

Magne Eggestad

Teknisk notat E-188, Norwegian Defense Res. Estab., 31 Oct., 1968

POSTBOKS 25 - KJELLER, NORWAY

Translated by Techtran Corp.
Glen Burnie, Md.
under Contract NAS 5-14826
Item No. 44

Instrument Equipment of Drifting Buoys for Transmission of Meteorological and Oceanographical Data Via Satellites
A Preliminary Study

Magne Eggestad

Table of Contents

1 Introduction

At an informal meeting between the Meteorological Institute and the Defense Research Establishment, Division E, in the summer of 1968 possibilities for transmission of meteorological data from drifting buoys via satellites were discussed. The upshot of the meeting was that FFIE was disposed to work out a proposal for equipping buoys with instruments.

In this preliminary study, which has been worked out in consultation with CMI, Bergen, we have first undertaken a calculation of the necessary radiated effect from the buoy based upon synchronous satellites. We have further discussed the way of handling the system, and we have attached a possible technical solution sketched in the form of block diagrams.

The study proposes to draw up directional lines in broad terms. We have deliberately left out details, since these are not regarded as appropriate to our purpose the first time round.

2 Available Satellites

Today no available satellite exists which is directly suited for conveying data to the telemetry station at Tromso. The only possibility seems to be ATS-3, which is placed in a synchronous orbit at a position 47° west longitude. But in this position the elevation angle from Tromso will be under +5° and it is to be expected that at VHF frequencies of 135 to 150 MHz scintillation will intervene heavily, with resultant marginal noise, compensated signal.

Among satellites currently planned for a period within one year the ATS-4 and a Nimbus satellite may be mentioned. Like ATS-3, ATS-4 will be a synchronous satellite, while the Nimbus will be of the low orbit type. Further data regarding the position and orbits for these satellites are not known.

We shall take as our point of departure for further calculation the data furnished for ATS-3.

3 Calculation of Initial Effect

Premising ideal transmission conditions, the necessary effectively radiated effect from the buoy is defined as the product of the sender effect P_T and the antenna gain G_T, given by the following formula:

$$ERP = P_T G_T = \left(\frac{4\pi r}{\lambda}\right)^2 \cdot \frac{1}{G_R} \cdot F \cdot (KT_e B) \cdot (S/N)_o \qquad (3.1)$$

In this formula:

r - Distance to satellite (m)

λ - Wave length (m)

F - Noise factor of satellite's receiver

K - Boltzmanns Constant = $1.37 \cdot 10^{-23}$ joule/°Kelvin

T_e - Effective noise temperature of satellite's receiver system (°Kelvin)

B - Noise band width of satellite's receiver

$(S/N)_0$ - Necessary noise-compensated signal at exit of satellite's receiver.

The following data are given for the ATS-3 satellite:

P_{TS} = 17 db W

G_{TS} = 10.5 db

G_{RS} = 7.5 db

F = 4.0 db

Receiver Frequency = 149.22 MHz

Sender Frequency = 135.60 MHz

Band Width = 100 kHz

With the exception of the effective noise temperature T_e and the noise-compensated signal $(S/N)_0$, all parameters are given direct.

In annexes I and II we undertake a calculation of T_e and $(S/N)_0$, with the following results:

$T_e \simeq 2000$ °K

$(S/N)_0 \simeq 10$ db

On the basis of equation (3.1), we show in Figure 3.1 the relationship between the necessary radiated effect from the buoy as a function of distance, to the antenna gain as a parameter. With a non-directional dipole antenna the requirement for radiated effect will be in the range of 400 W. With today's technology a transistor in these frequencies will be able to deliver 40 to 50 W. An initial stage of 400 W will therefore call for about 10 transistors in parallel configuration, which must necessarily result in an extremely complicated and critical circuitry. For this effect level and frequency range the tube technique continues to be the only one possible. But the use of tubes is in this case not well adapted to the purpose, by reason of the high electrode voltages, which call for transformers and effect losses in heating.

It therefore appears clear that here one must use a directional antenna in the buoy. An appropriate type of antenna is a four-element yagi with antenna gain of about 7 db and a ray width of 80 - 90°. In this way the requirement for initial effect is reduced to about 100 W, which can be achieved with transistors and without excessively great technical difficulties.

4 Proposal for System

From the meteorological standpoint it is important that data transmission shall be able to occur at set times and intervals. An interval of three hours has been indicated as desirable. This possibility will not be available in the cases of low orbit satellites, which will be beyond the horizon for about 10 hours during the course of 24. This means that one will have to rely upon synchronous satellites.

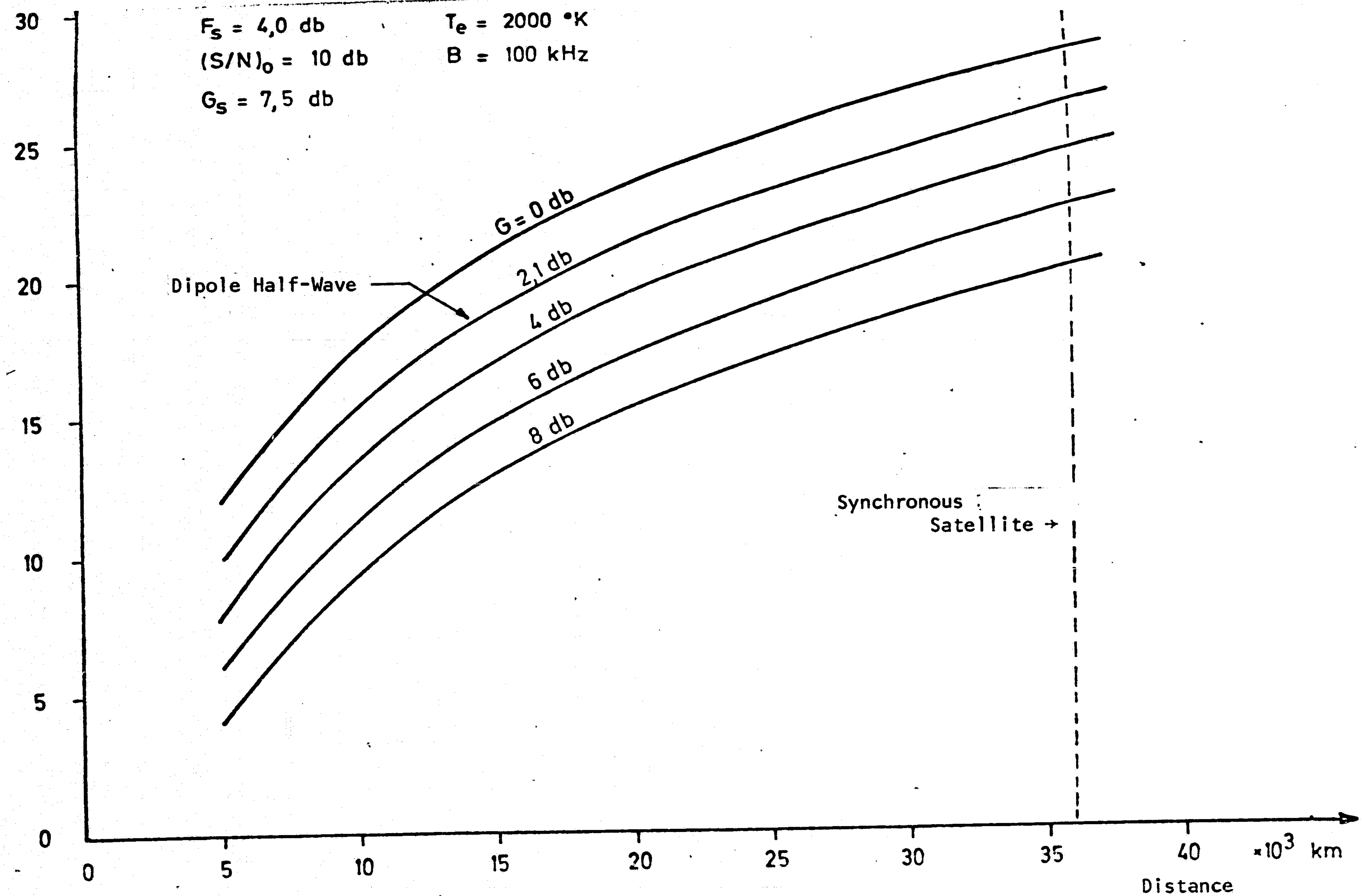


Figure 3.1. Initial Effect as Function of Distance, with Buoy's Antenna Gain as Parameter.

Insofar as concerns oceanographic data the situation is somewhat different. Here data registration should occur every half hour. On the other hand, the point in time for the transmission is not critical, and data can be gathered and can then be transmitted, for example, once every 24 hours.

Since the registry interval of 1/2 hour is a requirement, this implies that a data storage band must be included - since one can hardly count on it that the satellite will be accessible for direct transmission every half hour. But a data storage bank with accessory electronic equipment for identification of the various measurements will complicate the instrument equipment to a substantial degree, and should be avoided if possible. We count upon being able to transmit the meteorological data at their true time.

A coded command signal is sent from the telemetry station at Tromso via satellite to the buoy, and it sees to it that the buoy's sender apparatus is switched on. This implies that the buoy must be supplied with a command receiver which is operative at all times. Each buoy will in case of need have its own code, so that it can be turned on individually. After this data transmission to Tromso takes place over a period of one minute or less. The sending apparatus then automatically switches off by means of a clock mechanism and/or time-installed relays.

From the users standpoint it will also be desirable to be able to know the buoy's position at all times. Instrumentation of this character, however, has not been planned for the first round, and will not be evaluated here.

The use of a directional antenna calls for a simple servo-system which sees to it that the antenna always faces the direction of the satellite. The form the servo-system takes will in turn be dependent upon the buoy's properties in the sea. As a result of an investigation undertaken in CMI [1], the toroid buoy appears to be best adapted for the purpose, primarily by reason of better stability. This type of buoy rotates very slowly around its vertical axis. The servo-system must therefore be operative at all times; but must be so constituted that the antenna direction is corrected when deviation becomes greater than a maximum value to be specified more precisely. The servo-system is mounted together with the antenna in a plastic dome on top of the buoy.

5 Mechanical Structure and Circuitry

Figure 5.1 shows a sketch of a toroid buoy with possible placement of batteries, instrument containers, and antenna dome. The cable connections up to the antenna and the servo-system, and the various sensors for meteorological data, are not shown.

Figure 5.2 shows a sketch of the principle for an antenna arrangement. The antenna's polarization direction must be in harmony with the radiated electromagnetic wave from the satellite. Circular polarization calls for two antennas in cross configuration. One may conceive of the compass sensor as placed in a gimbal mounting which is set up on the vertical antenna stay. This, in turn, is set up to the rotor in a servo-motor. The coaxial downward connection is taken via a coaxial rotary joint.

A block diagram for a simple servo-system is shown in Figure 5.3. No special demands are made upon the system's exactitude or rigidity. An installation exactitude of the antenna of ±20° is regarded as sufficient. The whole servo-apparatus is mounted upon a bottom plate within the antenna dome.

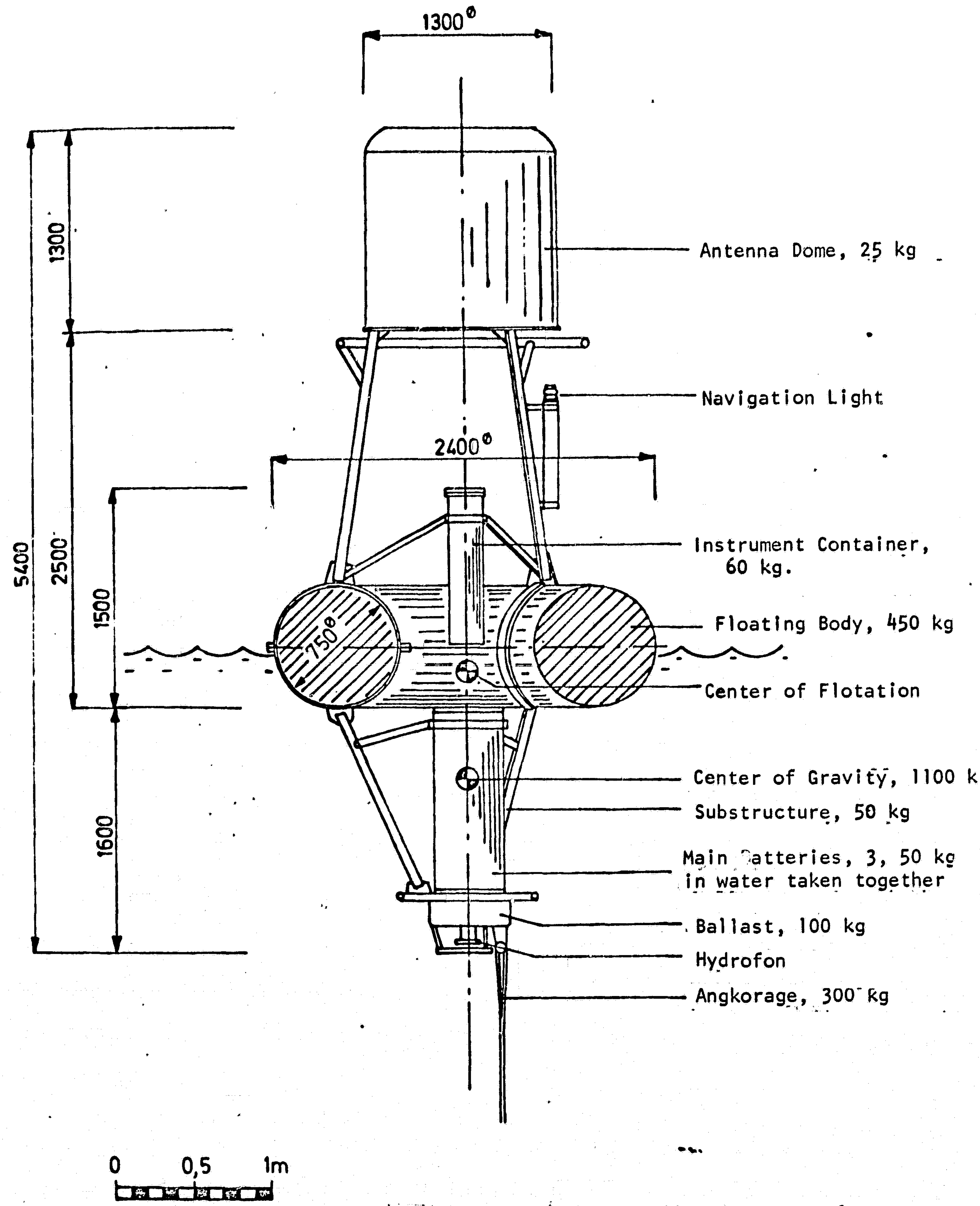
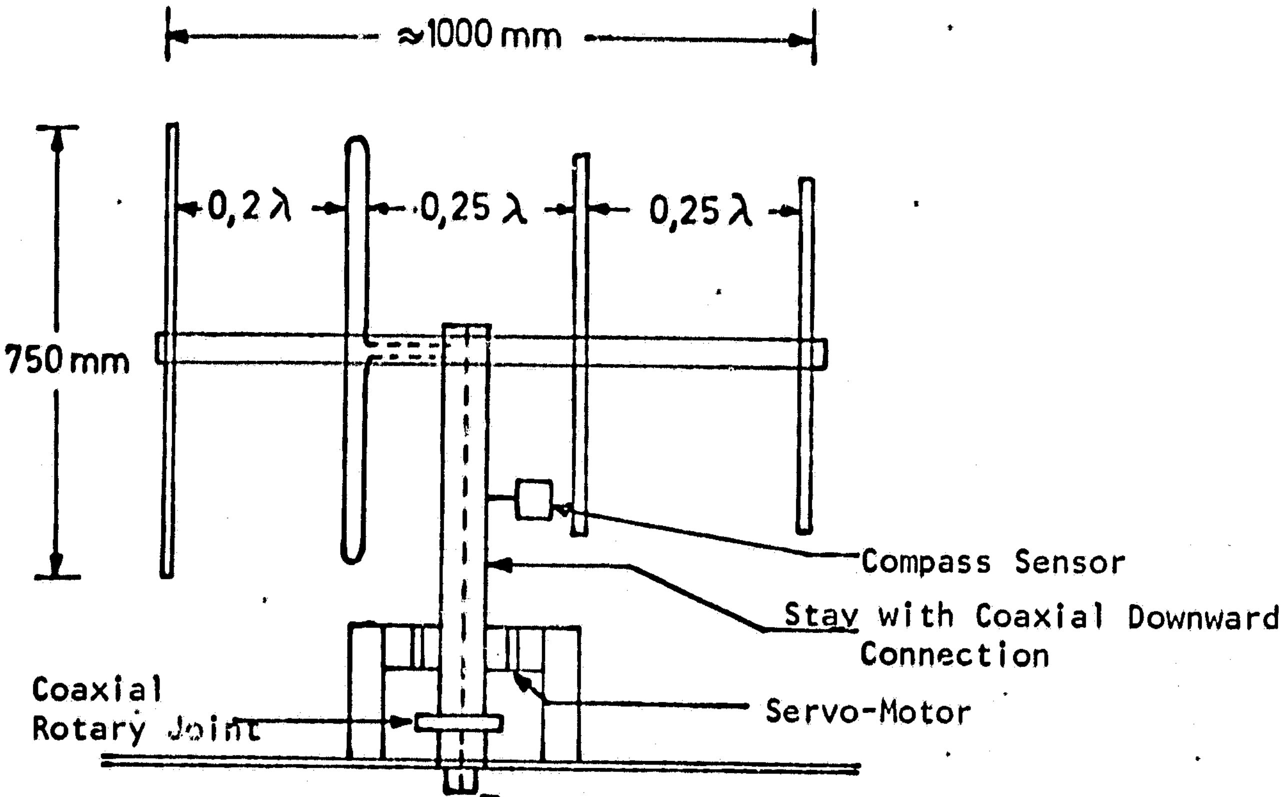


Figure 5.1. Placement of Instruments - Toroid Buoy.



Principle Data:

Antenna Gain:	≈ 7.5 db
Ray Widths:	80-90°
Weight:	≈ 3 kg

Figure 5.2. Sketch of Principle for Antenna Arrangement.

A block diagram of the VHF instrumentation is shown in Figure 5.4. It is assumed here that the PCM encoder which has been developed for the F-9 project can be used in its entirety. It is built for far more channels than there is need for here. The main technical data are as follows:

Clock frequency	: 10240 Hz
Bit speed	: 1280 bits per second

Word length	:	8 bits
Frame length	:	32 words
Number of Frames	:	16
Input level	:	0 - 0.5 V
Commulation Relationship	:	2:1, 1:1, 1:2, 1:4, 1:8, 1:16
Channel Distribution	:	2, 9, 10, 12, 32, 64
Sampling Frequencies	:	10, 5, 2.5, 1.25, 0.625, 0.3125 samples per second
Mechanical Dimensions	:	
Botton plate with Flanges	:	190 × 182 mm
Height	:	129.5 mm

Since by reason of space consideration it will not be practicable to implement the PCM unit directly, it will be appropriate for our purposes to make use of the same card type in a new simplified version of, for example, 28 channels.

In the modulator a subcarrier at 10240 Hz is used, which is phase modulated at ± 90° of the PCM signal. This frequency is identical with the clock frequency and is eight times the bit speed. This makes possible synchronous detection at the receiver end in Tromso and under most favorable circumstances will result in an improvement of the noise-compensated signal by + 3 db.

This phase modulated signal frequency modulates a VHF directional sender with a maximum deviation of ± 50 kHz.

Accordingly the modulation system is PCM/PM/FM.

The directional sender is followed by a transistorized drive stage at 100 W initial effect.

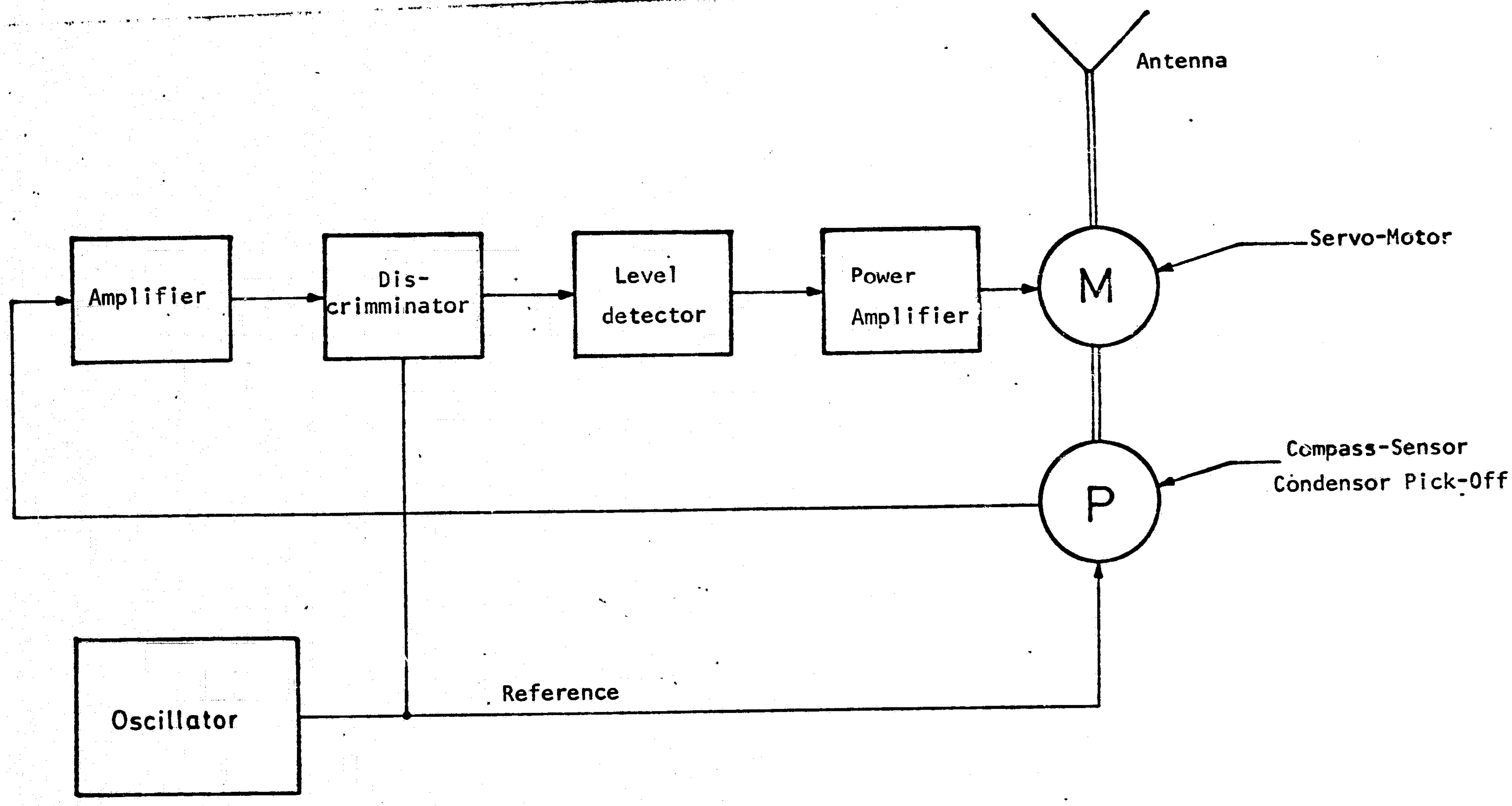


Figure 5.3. Block Diagram of Servo-System.

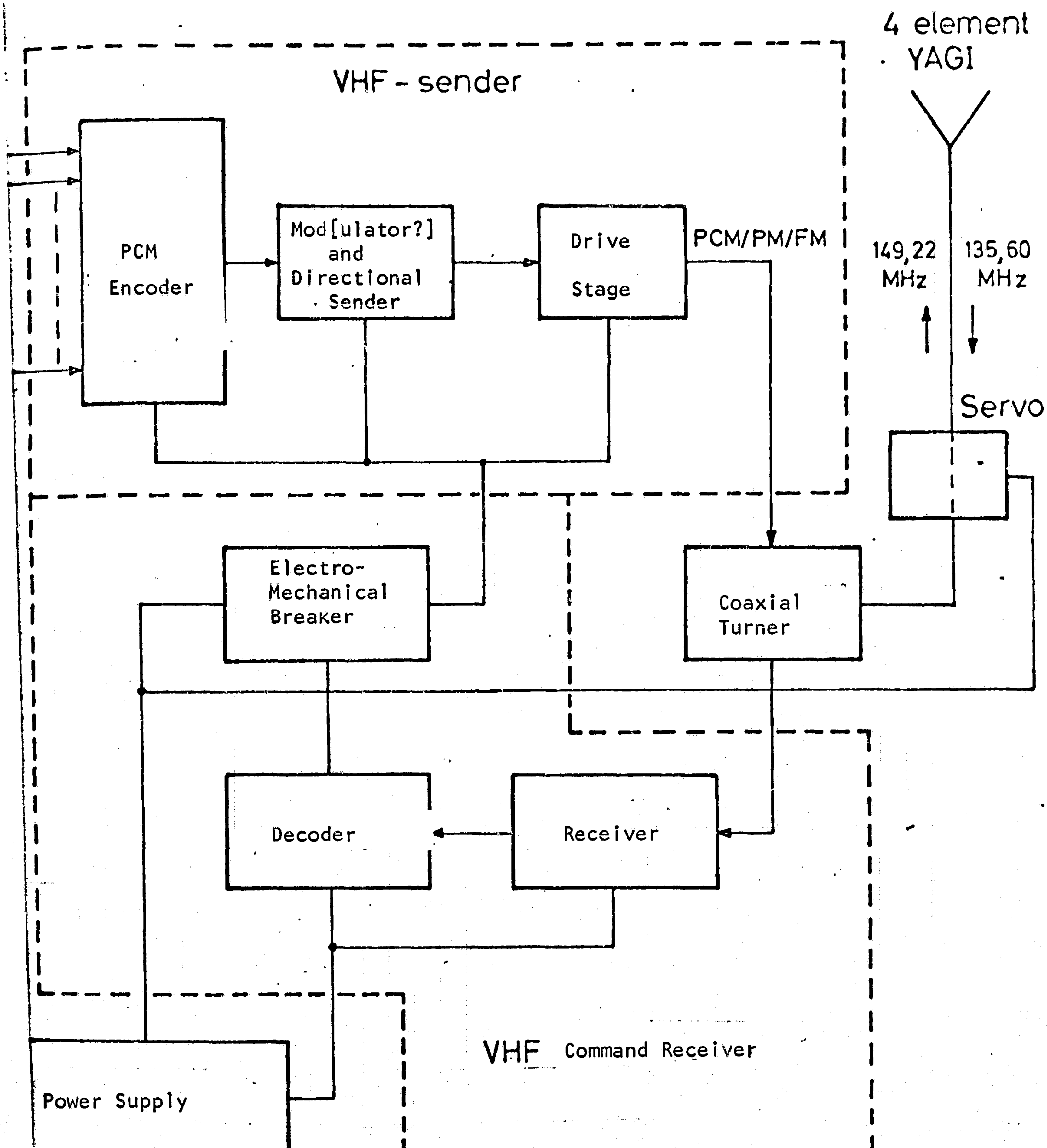


Figure 5.4. Block Diagram of VHF Sender and Command Receiver.

The command receiver can be a relatively simple type tuned fixedly to a receiver frequency of 135.60 MHz. Its sensitivity may be in the range of - 105 dbm and the noise factor may be + 4 db or better.

The receiver is followed by a decoder which sees to it that an electronic or electromechanical breaker is activated and switches on the power supply to the sender unit.

When data transmission has concluded, the sender apparatus can in principle again be switched off by a coded signal from Tromso. But this solution would require a complete diplex unit which is complicated, expensive, and bulky, and which should be avoided. The problem of sending and receiving over the same antenna installation can here most simply be solved with the help of a coaxial turner which normally stands in the receiver position. When the sender apparatus is switched on, the turner moves into a hold engagement for sending, and it automatically switches back again when the transmission is at an end.

The sender switches off automatically by means of a time relay which cuts the current off after a set period of time. The cut-off arrangement must have a high degree of reliability in order to prevent the sender's continuing permanently in on position. A double safety device will presumably be necessary here.

6 Power Consumption

The following figures are proposed ones:

1) Sender part with modulator and PCM encoder — 220 W

   With a sending time of 1/2 minute per 3 hours this comes to about — 15 W per 24 hours

2) VHF receiver with decoder: — 0.5 W

   This comes to — 12 W per 24 hours

3) Servo-system 1 W average

This comes to 24 W per 24 hours

4) Relays, coaxial turner, etc. 0.5 W average

This comes to 12 W per 24 hours

Thus the total power consumption ought to be in the range of 63 W per 24 hours.

The toroid buoy would appear to afford space for a total battery capacity of about 5.5 kWt, which gives an active life of about 3 months.

7 Concluding Remarks

In this preliminary study we have placed emphasis on the simplest technical solution possible without reducing the requirement for a full-value data system, reliability, and up to date circuitry technique. Instrument supply must be arranged in such fashion that it falls within an economical framework that will make possible a production-scale output of a number of units at a later stage

Bibliography

1. Strömme, J., Reading off from Satellites, Preliminary Project between FFI and CMI, CMI No. 66, 31-8/JS.

Annex I

Calculation of Effective Noise Temperature T_e

According to I.1 a frequency of 150 MHz makes a significant contribution to space noise at about 0.3 μV/m with a band width B_f = 10 kHz. Provided that this curve also holds good at a distance of 36,000 km from the earth, the effect density of the noise at the satellite's receiver antennae is given by:

$$p = \frac{E^2}{2\eta} \ W/m^2 \qquad (I.1)$$

where

E - the noise supplement in μV/m

η - the wave impedance in free space = 120 π.

The antenna's effective aperature is given by

$$A = \frac{G_R \lambda^2}{4\pi} \ m^2 \qquad (I.2)$$

where

G_R - the receiver antenna's gain

λ - the wave length in m.

Thus the noise effect at the receiver's input over the band width B = 100 kHz is given by

$$P_k = \frac{E^2 \cdot G_R \cdot \lambda^2 \cdot B}{8\,\eta\pi B_f} = k\,T_k\,B \qquad (I.3)$$

where

k - Boltzmans Constant = $1.37 \cdot 10^{-23}$ joules/°Kelvin

T_k - the effective noise temperature by reason of cosmic noise.

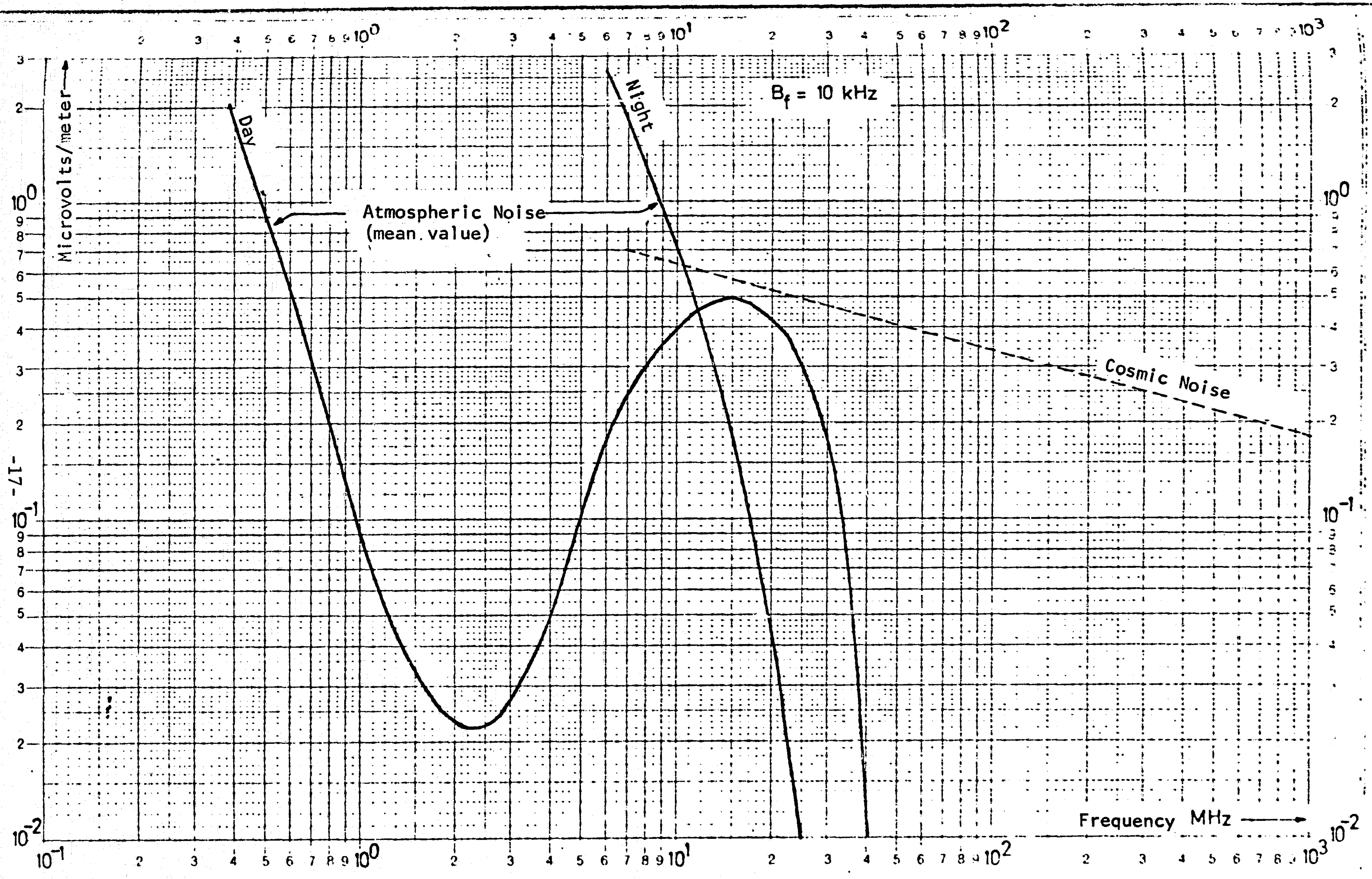
If one takes the temperature of the surroundings in the satellite as being T_s = 300 °K, the effective noise temperature is given by

$$T_e = T_k + T_s = \left(\frac{E^2 G_R \lambda^2}{8 \eta \pi \cdot B_f \cdot k} + T_s\right) {}^{\circ}K \qquad (I.4)$$

Insertion of figure values gives

T_e = 1870°K.

Taking into account the fact that one has other lesser noise supplements, it appears reasonable to set T_e as being equal to 2,000°K.



Logarithmic Division 1-300 and
1-10,000 unit 62.5 mm.

Figure 1.1. Typical Noise Level As Function of Frequency
band width 10 kHz.

Annex II

Calculation of Necessary Noise-Compensated Signal $(S/N)_0$ at Receivers Outlet (Satellite)

The parameter which is decisive here is the noise-compensated signal which can be required at the receiver end in Tromso. This depends to some extent upon the modulation system which is used.

Given ideal transmission conditions, the signal effect at input into the satellite's receiver is given by

$$P_i = \frac{P\, G_{TB}\, G_{RS}\, \lambda_u^2}{(4\pi r)^2} \qquad \text{(II.1)}$$

where

P - output effect from the buoy (W)

G_{TB} - the sender antenna's gain (bouy)

G_{RS} - the receiver antenna's gain (satellite)

λ_u - the sender frequency from the buoy (m)

r - the distance from the buoy to the satellite (m).

According to Annex I, the noise supplement referred to the receiver's input is

$$N = \frac{E^2\, G_{RS}\, \lambda_u^2\, B}{8\, \pi\, \eta\, B_f} + k\, T_s\, B \qquad \text{(II.2)}$$

The noise-compensated signal at the receiver's output is therefore

$$S = (S/N)_o = \frac{P_i}{N F_s} \qquad (II.3)$$

where F_s is the noise factor of the satellite receiver.

We shall assume that the satellite's transponder is of a hard limiter type and that the signal pressure from the buoy is sufficient to put the sender in motion.

The signal effect outward from the satellite is then

$$P_s = P_o \frac{S}{1+S} \qquad (II.4)$$

and the noise effect is

$$P_N = P_o \frac{1}{1+S} \qquad (II.5)$$

where P_o is the sender's output effect.

The signal effect at intake into the receiver at Tromso is then

$$P_M = \frac{S}{1+S} \cdot \frac{P_o G_{TS} G_{RM} \lambda_d^2}{(4 \pi r)^2} = \frac{S}{1+S} \cdot P_1 \qquad (II.6)$$

where

λ_d - the wave length of the satellite's sender frequency = 2.21 m

G_{RM} - the receiver antenna's gain (Tromso) which equals 18 db

G_{TS} - the sender antenna's gain (Satellite) which equals 10.5 db.

The total noise supplement at the receiver's intake is made up of the transmitted noise from the satellite, the receiver's own noise, and cosmic noise, and is given by

$$P_{Nt} = \frac{P_1}{1+S} + k\,T_s\,B + k\,T_c'\,B \qquad \text{(II.7)}$$

where

$T_s = 300°K$

$$T_c' = \frac{E^2\,G_{RM}\,\lambda_d^2}{8\,\pi\,\eta\,B_f\,k}\ °K$$

B = band width = 100 kHz.

The noise-compensated signal at the receiver's output is thus

$$S_{OM} = \frac{\frac{P_1 S}{1+S}}{\left[\frac{P_1}{1+S} + k\,B(T_s + T_c')\right]F_M} \qquad \text{(II.8)}$$

where

F_M - the receiver's noise factor which equals + 4 db.

Upon the insertion of figure values in equation (II.8) there is shown in Figure II.1 the relationship between S and S_{OM}.

With the proposed PCM/PM/FM modulation system one counts upon it that a noise-compensated signal of 4 ÷ 5 db at the receiver's video output will be sufficient, which corresponds to a noise-compensated signal S = + 10 db at the satellite receiver's output.

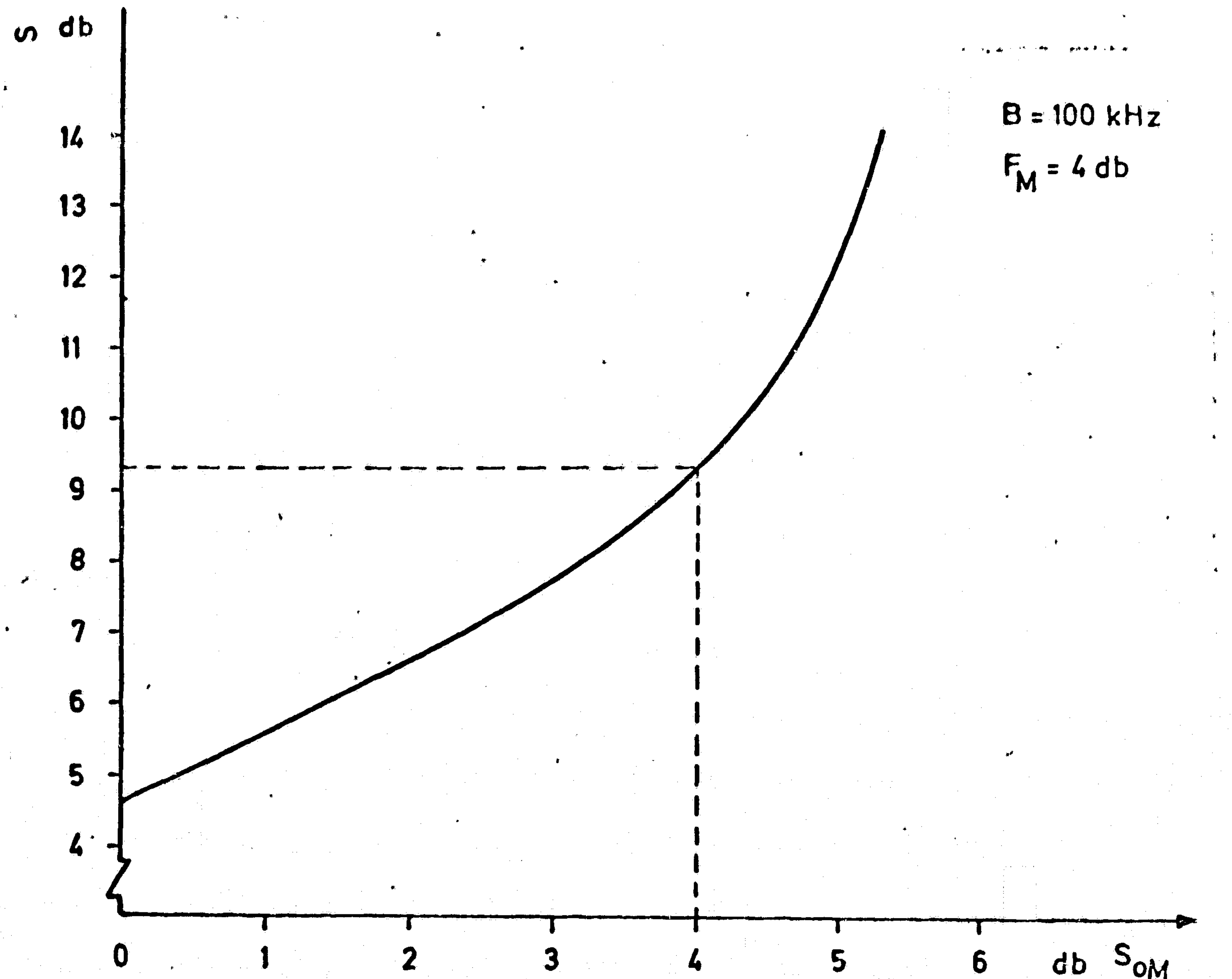


Figure II.1. Noise-Compensated Signal $S = (S/N)_o$ at the Satellite Receiver's Output as Function of the Noise-Compensated Signal S_{OM} at the Terminal's Receiver Output (Tromso).