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MICROWAVE LINK BETWEEN CERN, MEYRIN AND CERN, PREVESSIN

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ABSTRACT

A microwave link operating at 64 GHz between Meyrin and Prévessin has been established to measure attenuation caused by rain, snow, etc. This report describes the set-up of the link and some preliminary experimental data on attenuation.

Prévessin - July 1979

1. INTRODUCTION

The purpose of the link[1] is to synchronize the RF acceleration system of the CERN SPS with that of the CERN PS, in order to improve the injection efficiency at high intensity. Before any such microwave link is set up, reliability of such a system has to be tested against meteorological conditions[2,3].

In order to measure the atmospheric attenuation due to fog, rain and snow, the present link has been installed between the Meyrin Site (Water Tower) and Prévessin Site (BA3), between which the distance is 2.6 km. Although it was proposed to operate in the range of 71 to 84 GHz, the French PTT has authorized the use of 59-64 GHz for measurement purposes.

2. THE LINK

The transmitter, which is situated on the Water Tower, consists of a levelled sweep generator, using Impatt diode, with a 1 KHz on-off modulation capacity. The receiver at BA3 consists of a 10 GHz bandwidth flat detector with a narrow-band video (≃ 15 Hz) amplifier with a 1 KHz centre frequency (e.g. H.P. SWR meter 415E). The output of the amplifier can either be connected to an x-y plotter or to a thermal printer. Both the transmitting and the receiving antennae are 4 feet (1.2. metre) Cassegrain dish. The layout is shown in Figure. 1

2.1 Theory

The received power P_r by an antenna of gain G_r when the transmitted power P_t is radiated by an antenna of gain G_t is given by

$$P_r = P_t \cdot G_r \cdot G_t \cdot \lambda^2/(4\pi\tau)^2 \quad (1)$$

where

λ = wavelength
τ = range, i.e. the distance between the two antennae
G_r and G_t are the gains over an isotropic radiator.

The effective area of an antenna of gain G is

$$A = G\lambda^2/4\pi \quad (2)$$

From (1) and (2),

$$\frac{P_r}{P_t} = \frac{A_r \cdot A_t}{\lambda^2 \tau^2} \tag{3}$$

where A_r and A_t are the effective areas of the receiving and the transmitting antennae respectively.

For a parabolic antenna of diameter D(= 2R);

$$A = 0.54 \frac{\pi}{4} D^2 \ . \tag{4}$$

Since both the antennae have equal diameters

$$\frac{P_r}{P_t} = \frac{0.54\pi \ R^2}{\lambda\tau} \quad \ldots\ldots \tag{5}$$

The 3 dB power bandwidth of the transmitting antenna

$$\theta = 1.241 \frac{\lambda}{D} \tag{6}$$

where θ, λ and D are in radians, mm and mm respectively.

Referring to Fig. 2, if the angle covered by the receiving antenna to the transmitting antenna over the range τ is α, then

$$\alpha = \frac{D}{\tau} \quad \text{for} \quad D \ll \tau \ . \tag{7}$$

From (5), (6) and (7), we obtain

$$\boxed{\frac{P_r}{P_t} = \left(0.526 \frac{\alpha}{\theta}\right)^2} \tag{8}$$

[4)]

This formula is valid for far-field region.

To obtain the actual power received, the loss due to the atmospheric absorption (namely oxygen resonance in the frequency band of interest) and other path attenuations should be taken into account.

2.2 Experiment and result

The experiment with the microwave link can be divided into two categories, namely:

i) Measurement in dry atmospheric conditions;

ii) Measurement in wet (rain/snow) conditions.

2.2.1 Measurement under dry conditions

Measurements under dry conditions were carried out over a few months so as to find the correlation between the measured and the computed values of the received power. Initial adjustments of the antennae were done by the Survey Group, but the final alignment of the antennae was made under signal condition with a klystron source (170 MW output power). Further measurements were carried out using a Hughes Impatt source, the characteristic of which is shown in Figure 3 and Table 1. Following computation at 64.77 GHz, illustrates the signal strength at the receiving antenna. The atmospheric absorption due to oxygen resonance is rather significant in the frequency band of interest (see Fig. 4) and this has been taken into account.

The distance $2D^2/\lambda$, where D is the diameter of the antenna, is considered to be the beginning of the far field region. For the antenna under consideration D = 1.219 m and λ = 4.632 mm (f = 64.77 GHz), the far-field region beginning 640 m from the transmitting antenna. The distance between the transmitting and the receiving antennae is τ = 2.6 km; hence using Equation (8)

$$\frac{P_r}{P_t} = \left(0.526 \frac{\alpha}{\theta} \right)^2$$

$$= -\ 25.63 \text{ dB.}$$

dB calculation

Power in the transmitting antenna	= 10.0 dbm
P_r (as computed above)	= -25.63 dB
Attenuation due to oxygen absorption (≃ 5 dB/km)	= -13.00 dB
Computed incident power on the receiving detector	= -28.63 dbm
Measured power with detector calibrated	= -39.1 dbm
|Error|	= 10.47 dB

Approximately 10 dB error in received signal strength may be due to the fact that the antennae are not perfectly aligned. Also the surface finish of the antennae not being very smooth, reduces the respective gains of the antennae. Reflections from the roof of BA3 and nearby trees also reduce the signal strength. No allowance has been made for water vapour absorption. Although the attenuation due to oxygen absorption at 64.77 GHz has been assumed to be approximately 5 dB/km, a more accurate value can only be obtained by elaborate computation[5,6].

2.2.2 Measurements under wet conditions (rain)

Measurements of attenuation caused by rain were made during the second week of March 1979. Data of rainfall, temperature, and dew point for every thirty minutes were obtained from the Centre Météorologique at Geneva Airport. Table 2 shows the measured attenuation, rainfall and absolute humidity for a 72 hour period at the airport. Figure 5 shows the variation of attenuation against varying average rainfall. It has been observed that the attenuation due to light and medium snowfall is not very significant.

3. DISCUSSION

In dry atmospheric conditions, the dynamic range of the transmitter-receiver system is 20 dB maximum. This limited dynamic range is due to the fact that the incident power to the detector is only 10 dB (approximately) above the noise margin (see typical flat detector characteristic in Figure 6). The selective HP amplifier (15 Hz bandwidth) however improves the signal-to-noise ratio and hence the 20 dB dynamic range has been obtained. Use of the external crystal-controlled 1 KHz modulator improves the measurement accuracy and stability against modulation frequency drift.

In the receiving antenna, a few layers of mylar have been attached to the horn to prevent insects from entering (incidently, a few insects in the waveguide can attenuate a signal 20 dB or more). The mylar also helps to improve the gain of the receiving antenna. To protect the flat detector against a transient occurring from long cables, a buffer amplifier is introduced between the detector and the HP amplifier.

4. CONCLUSION

The attenuation due to rainfall of 10 mm/hr is 10 dB over the path length of 2.6 km (ref. Fig. 5). Heavy uniform rain or fog over the total path would cause total loss of signal. Hence, for around-the-year measurement of path attenuation, the dynamic range of 20 dB is inadequate. Since it is desired to evaluate the path losses during rain it will be necessary to provide some kind of shelter to stop the antennae from becoming wet. A wet antenna (inner surface) degrades the gain considerably[7)]. Adequate rainfall and raindrop size measuring equipment are to be installed to give meaningful results. Also a proper protection device (namely switch off of both transmitter and receiver solid-state circuits) has to be incorporated in case of thunderstorms and lightening.

An improved receiving system[8)] with higher dynamic range could be installed with commercially-available components. The system is shown in Fig. 7.

Assuming a conversion loss of the mixer of 7 dB and the spectrum analyser having minimum sensitivity of -70 dbm, the dynamic range of the system will be 45 dB which should be adequate for the measurements. A tunable detector (more sensitive than a flat detector) along with an HP narrow-band amplifier can be used instead of the spectrum analyser. If necessary a double drift Impatt oscillator which delivers excess of 500 mW (27 dbm) output power in the 64 GHz range can be installed in the transmitting station. A typical calculation of signal-to-noise ratio at the output of the mixer is shown below

$$SNR = P_r/(FKTB)$$

where

SNR	=	signal-to-noise ratio at the output of the mixer
P_r	=	power into the mixer
F	=	mixer noise figure
K	=	Boltzman's constant = 1.38×10^{-23} joules per degree Kelvin
B	=	noise bandwidth of receiver = information bandwidth
P_r(dbm)	=	$P_t + G_t + G_r$ - free space attenuation - oxygen absorption - unaccounted error of 10 dB.

Using the transmitter scheme of Fig. 1 and assuming absolute temperature of receiver to be 290°K (= 17°C), for an information bandwidth of 500 MHz,

P_r	=	$-$ 39.0 dbm
F	=	7.0 dB
K_T	=	$-$ 174 dbm
B	=	87 dB
SNR	=	+ 41.0 dB

ACKNOWLEDGEMENTS

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Table 1

Impatt Source Characteristic (unlevelled)

Impatt Source : Model 44154H s/n: 022

Plug in : Model 44420H s/n: 069

Scale : Model 44096H s/n: 046

s/n	Bias current	Frequency	Output power	
	mA	GHz	mW	dbm
1	293.2	66.18	13.18	11.2
2	280.4	64.9	10.54	10.23
3	250.0	64.23	9.22	9.65
4	237.6	63.84	7.90	8.98
5	221.6	63.61	6.59	8.19
6	208.4	63.26	5.27	7.22
7	191.2	62.64	3.95	5.97
8	168.8	60.91	2.63	4.21
9	152.4	60.39	1.26	1.0
10	136.0	58.93	0.70	-1.55
11	128.4	58.12	0.255	-5.93
12	119.6	57.27	0.252	-5.98
13	106.0	55.18	0.252	-5.98
14	96.8	54.12	0.063	-12.0

Table 2

Meteorological Data and Attenuation

Date March 1979	Time GMT Hrs.	Temperature ^{o}C	Dew-point ^{o}C	Relative humidity %	Absolute humidity grs/m^3	Rainfall mm/hr.	Received power (relative) dB
8	16.50	9	-4	41	3.8	-	-1.0
8	17.50	7	-6	42	3.3	-	-3.0
8	21.50	0	-5	75	3.5	-	-3.7
8	23.50	1	-5	80	3.5	-	-1.5
9	01.50	-2	-5	85	3.5	-	-1.5
9	04.50	-3	-5	90	3.5	-	-1.6
9	08.50	5	-3	60	4.0	-	-3.0
9	11.20	9	-2	50	4.2		-1.6
9	12.50	11	-3	40	4.0		-0.8
9	17.50	11	-4	32	3.8	-	-2.4
9	22.20	6	5	93	6.9	5.0	-8.25
10	00.50	6	4	90	6.4	11.4	-10
10	02.50	6	5	95	6.9	11.4	-6.1
10	06.50	8	1	62	5.2	0.5	-0.5
10	08.50	6	1	72	5.2	0.5	-0.5
10	12.50	7	1	68	5.2	1.1	-2.5
10	14.20	7	1	68	5.2	1.1	-0.85
10	18.20	5	2	82	5.6	1.1	-3.0
10	22.50	5	4	95	6.5	3.3	-2.75
10	23.50	6	4	85	6.5	3.3	-2.75
11	02.50	6	5	95	6.9	11.0	-6.1
11	04.20	7	6	94	7.3	11.0	-4.0
11	07.20	7	6	94	7.3	6.4	-4.9
11	09.50	8	7	94	7.8	6.4	-6.1
11	13.20	10	8	90	8.4	2.0	-6.1
11	16.50	10	7	82	7.9	1.5	-6.1
11	18.50	10	8	90	8.4	1.5	-1.4
11	21.50	9	8	95	8.4	1.5	-3.3
11	23.50	9	8	95	8.4	1.5	-4.75

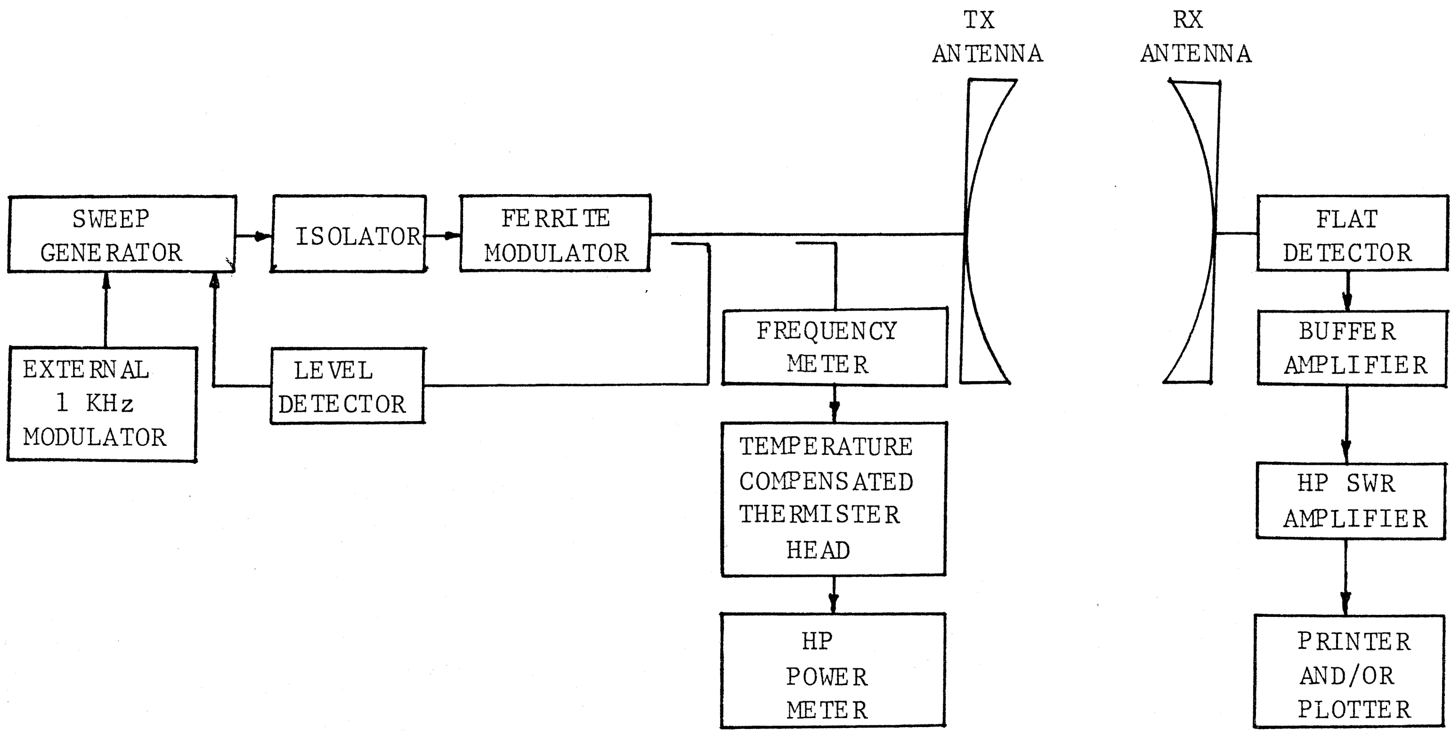

Figure 1 - Schematic of the 64 GHz link

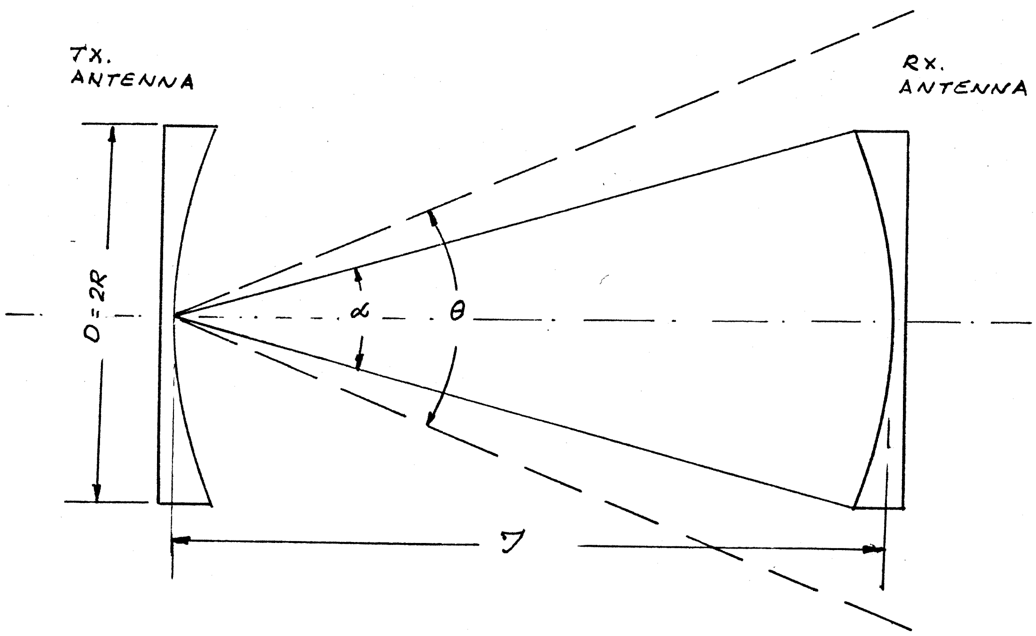

Figure 2 - Transmitting and receiving antennae

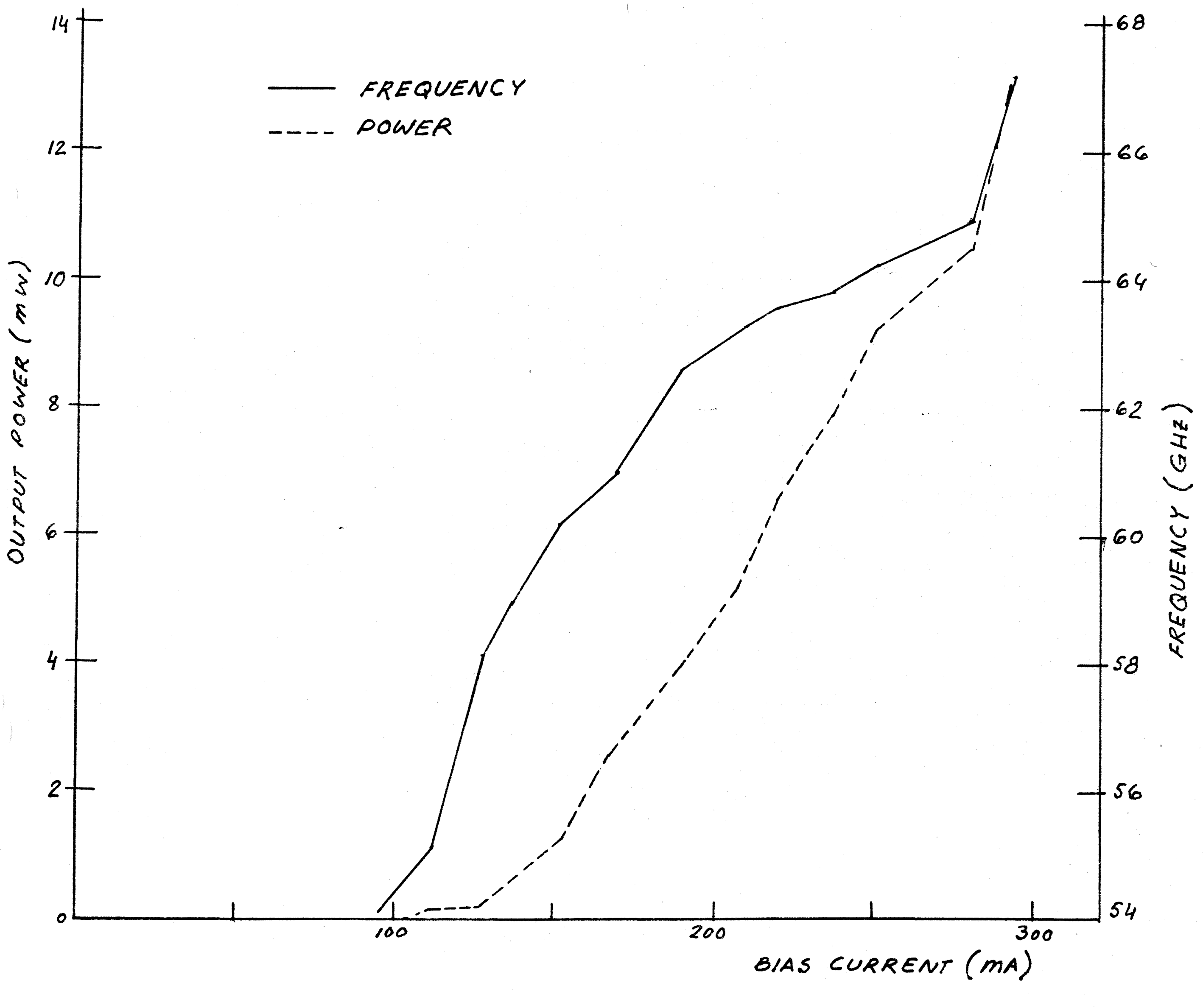

Figure 3 - Impatt source characteristic

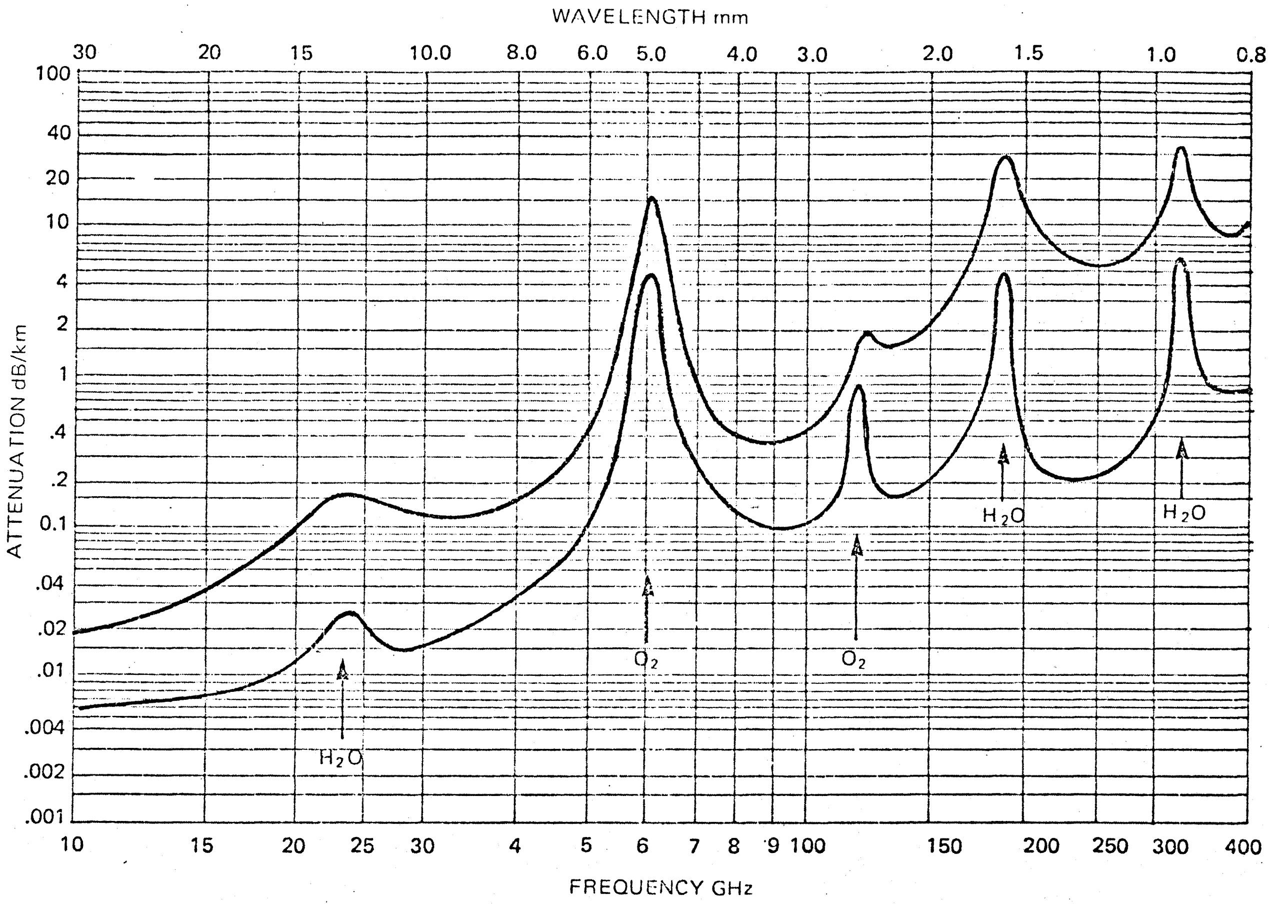

Figure 4 - Average atmospheric absorption of millimetre waves

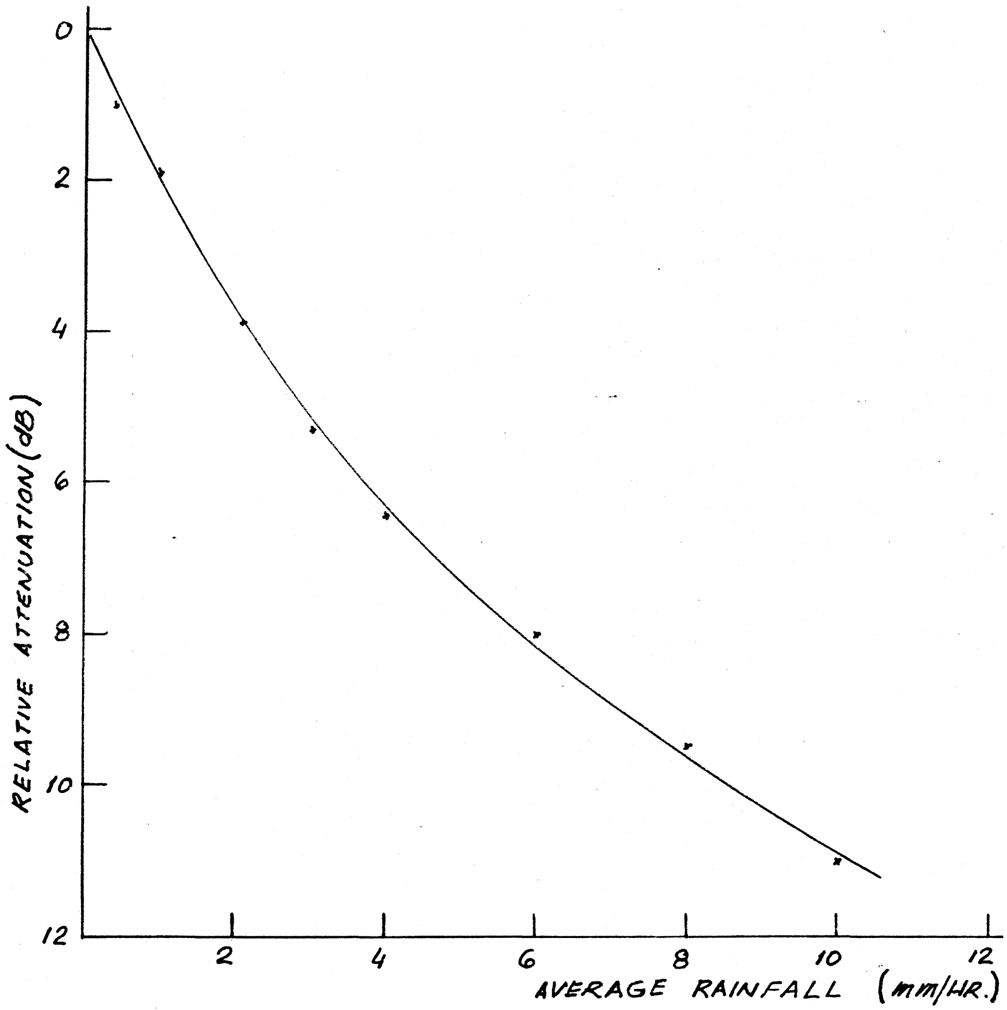

Figure 5 - Attenuation due to rain

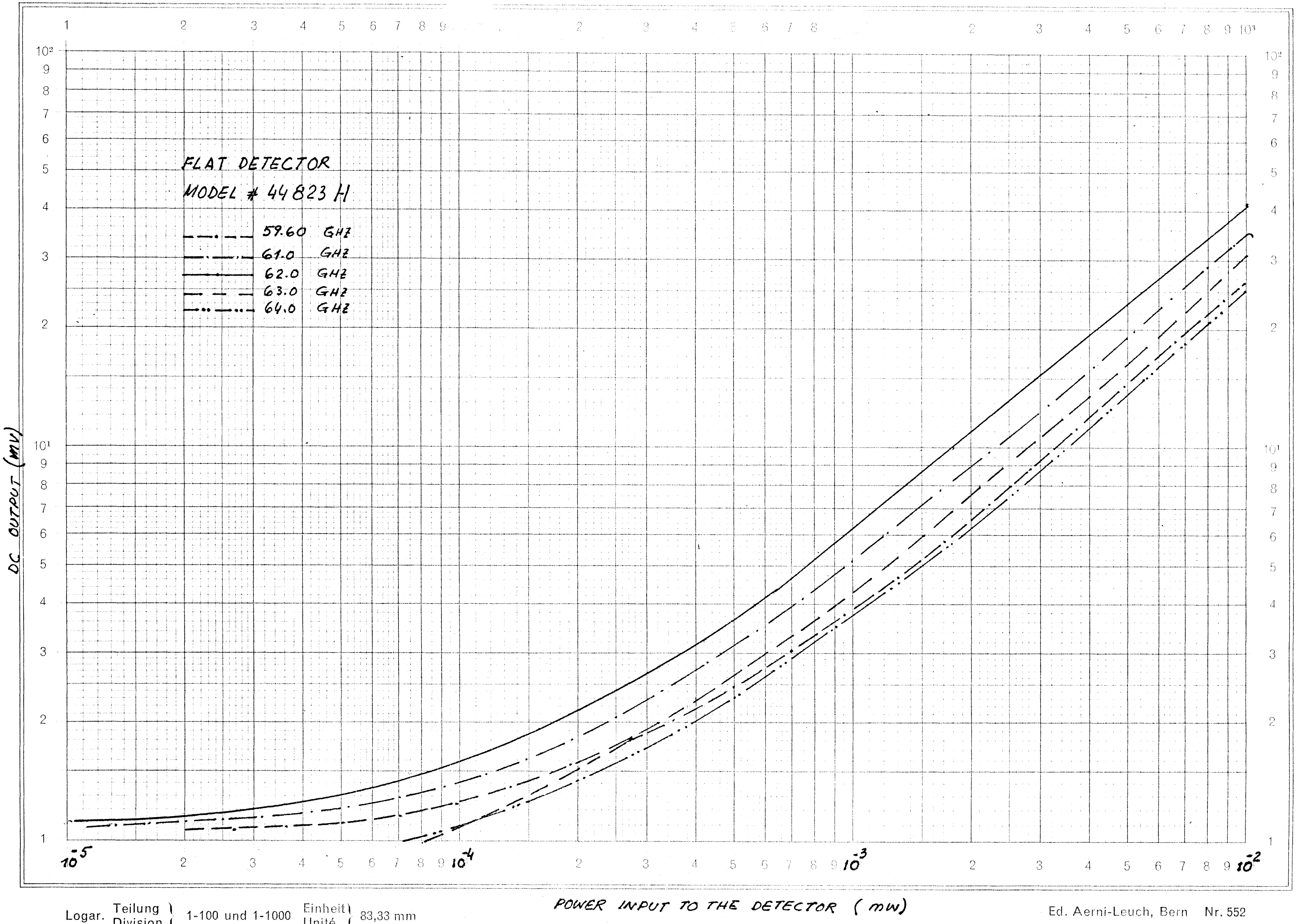

Figure 6 - Flat detector characteristic

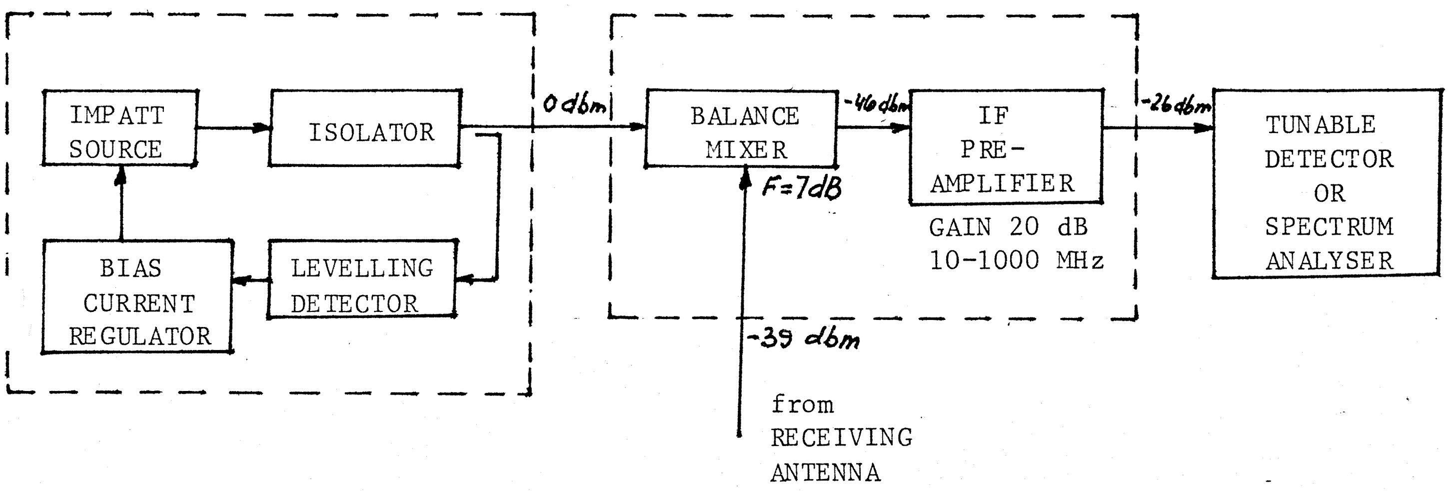

Figure 7 - Scheme of new receiving system