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AFCRL-408

ISTITUTO DI FISICA TECNICA

of the

UNIVERSITY OF NAPLES

SOME CONSIDERATIONS ON IONOSPHERIC SELFMODULATION AT OBLIQUE INCIDENCE

by

M. Cutolo

Scientific Report No. 2

Contract No.A.F.61(514)-1299 Supplemental Agreement.No.3

December 1960

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by

M. Cutolo

With collaboration of
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University of Naples - Italy

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The research reported in this document has been sponsored by the GEOPHYSICS RESEARCH DIRECTORATE, AIR FORCE CAMBRIDGE, RESEARCH CENTER of the AIR RESEARCH and DEVELOPMENT COMMAND, UNITED STATES AIR FORCE, through its European Office.

Contents

ABSTRACT

During the years 1957-1958 and 1959 some thirty experiments were made on the phenomenon of ionospheric selfmodulation at oblique incidence.

In the Report No. 1 of 1959 the theoretical and experimental methods used in the experiments were described and the results given of the experiments made in the year 1958.

In the Report No. 2 the results of the experiments made in the years 1957 and 1959 are given.

In all three years the phenomenon showed the behaviours a) b) and c) as detailed on page 7 of this report.

The values of the product $G\nu$, ν_0 (collision frequency) and α (mean coefficient of total absorption) for the carrier frequency of AFN Frankfurt (872 kc/s) have been calculated from the measures made and from the theoretical method applied.

These values are given in the Tables Nos. 2 and 3 of page 36.

The value of ν_0 is given as the order of magnitude 10^4 and α is included between 1,4000 and 2,0048 Neper.

The Appendix (page 29) explains the method used by us to calculate $G\nu$, ν_0 and α .

Some experimental observations on the study of fading are given on page 22.

1. - PURPOSE AND DESCRIPTION OF THE EXPERIMENTS

A long series of experiments on the phenomenon of selfmodulation at oblique incidence was made between 1st July 1957 and 30th November 1959.

The Report No. 1 spoke of the experiments made from January to December 1958. The Report No. 2 deals with the experiments made in the second semester of 1957 and during the whole year 1959.

The phenomenon of ionospheric selfmodulation (as said in Report No. 1) consists in the increase and decrease of the percentage of modulation of a radiowave when the wave passes across the ionosphere. In other words, when a radiowave is emitted from the transmitter with a percentage of, for e.g., 60%, it is received, by way of the ionosphere, at the receiver with a greater, or smaller, percentage (by several percent) than the emitted percentage.

The band of frequencies studied to date by authors concerned with the phenomenon (M. Cutolo, S.N. Mitra, G.J. Aitchison and G.L. Goodwin) is from 863 to 1500 Kc/s. J.W. King, however, used frequencies of 200 Kc/s and 647 Kc/s frequencies far removed from the gyrofrequency.

In the experiments discussed in the Report No. 1 and in those described in this report we used a frequency of 872 Kc/s emitted by the American Radio station AFN Frankfurt (872 Kc/s, 150 kW) kindly put at our disposal by the ARDC Brussels. Experiments were carried out in several cycles, one cycle for each season of the year.

The cycles performed are listed in the Table No. 1. Experiments were always performed during the night, from $01^h15'$ a.m. to $03^h25'$ a.m. Mean Time Central Europe. Reception was always made in Naples, at the Laboratory of the Technical Physics Institute of the University.

Table N° 1

N°	Experiments			Radio transmitting station AFN Frankfurt				
	Date	Hour		carrier Kc/s	% of modul.	POWER	Modulat. freq.	
		from	to			kW	from c/s	to c/s
1	16/ 7/1957	0120	0251	872	90	150-50-150	20	2000
2	19/ 7/1957	0120	0220	"	80-90	150-50	80	4000
3	23/ 7/1957	0120	0209	"	80	150-50	1200	4000
4	26/ 7/1957	0120	0251	"	90	150-50-150	20	2000
5	30/ 7/1957	0120	0220	"	80-90	150-50	80	4000
6	2/ 8/1957	0120	0209	"	80	150-50	1200	4000
7	9/ 8/1957	0120	0223	"	60	150-50	40	4000
8	16/ 1/1958	0115	0252	"	60	150-50-150	30	2000
9	21/ 1/1958	0115	0222	"	60	150-50-150	30	2000
10	24/ 1/1958	0115	0252	"	60	150-50-150	30	2000
11	25/ 3/1958	0115	0248	"	60	150-100-50 100-150	30	2000
12	28/ 3/1958	0115	0248	"	60	150-100-50 100-150	30	2000
13	1/ 4/1958	0115	0248	"	60	150-100-50 100-150	30	2000
14	13/ 5/1958	0115	0236	"	60	150-50-150	30	4000
15	17/ 5/1958	0115	0236	"	60	150-50-150	30	4000
16	22/ 5/1958	0115	0236	"	60	150-50-150	30	4000
17	23/ 7/1958	0115	0236	"	60	150-50-150	30	4000
18	26/ 7/1958	0115	0236	"	60	150-50-150	30	4000
19	12/ 2/1959	0115	0313	"	60	150-50	50	5000
20	19/ 2/1959	0115	0313	"	60	150-50	50	5000
21	27/ 2/1959	0115	0313	"	60	150-50	50	5000
22	25/ 6/1959	0115	0313	"	60	150-50	50	5000
23	27/ 6/1959	0115	0236	"	60	150-50-150	30	4000
24	1/ 7/1959	0115	0313	"	60	150-50	50	5000
25	30/10/1959	0115	0236	"	60	150-50-150	30	4000
26	4/11/1959	0115	0236	"	90	150-50-150	30	4000
27	7/11/1959	0115	0325	"	60	150	300	2500
28	17/11/1959	0115	0236	"	60	150-50-150	30	4000
29	21/11/1959	0115	0236	"	90	150-50-150	30	4000
30	25/11/1959	0115	0325	"	60	150	300	2500

In November 1959 reception was made not only in Naples but also at the following laboratories :

1) Research Laboratory of Electronics, Chalmers Institute of Technology Göthenburg (Sweden)
2) Kiruna Geophysical Observatory Kiruna C. (Sweden)
3) École Nationale Supérieure d'Électrotechnique d'Électronique et d'Hydraulique Toulouse (France)

The Naples receiving station consisted of a good antenna and a superheterodyne receiver. The output of 2nd I.F. (intermediate frequency) was connected to an oscillograph so as to have the envelope of the modulated wave. A movie-camera recorded the line enveloping the instantaneous percentage of modulation M".

$$M'' = \frac{V\ max - V\ min}{V\ max + V\ min} \times 100$$

where V max and V min are the maximum and the minimum voltage of modulation.

The receiver was calibrated by a signal generator whose carrier frequency was modulated by a generator at audiofrequency. The answering curve of the receiver was obtained in this way and it was possible to keep count of the demodulation provoked by the receiver at the high frequencies of modulation for 60%, 80% and 90% of modulation.

The receiving stations operating in Göthenburg, Kiruna and Toulouse will be described elsewhere. The method of the envelope was used by these stations, as was by us, for the measurements of M".

The AFN Frankfurt radio station emitted its carrier frequency (872 Kc/s) at 150 kW (full power), 100 and 50 kW at 60%, 80% and 90% of modulation.

The modulation frequencies emitted by the AFN Frankfurt were as follows :

1) 20-30-40-80-100-150-200-300-400-600-800-1000-1200-1400-1600-1800-2000 c/s.
2) 80-200-400-1000-2000-2500-3000-3500-4000 c/s.
3) 40-80-200-500-1000-1500-2000-3000-4000 c/s.
4) 30-70-150-300-500-800-1000-1500-2000-2500-3000-3500-4000 c/s.
5) 30-70-150-400-800-1000-1500-2000 c/s.
6) 50-200-400-500-700-900-950-1000-1050-1100-1150-1300-1500-1600-1750-1850-1900-2000-2200-2400-2600-3000-3300-3600-3800-4000-4500-5000 c/s.

Each one of these frequencies was emitted during one minute for each power in progressive order according to previously agreed on plans. Variations of emitted power by the AFN Frankfurt were made for each frequency going from 150 to 100 kW, 100 to 50 kW, 50 to 100 kW, 100 to 150 kW ; each variation took place in one minute. Sometimes a whole band of frequencies was emitted with power of 150 kW and at other times the same band was emitted with power of 50 kW.

During the experiments 60 or more oscillograph pictures were taken for each frequency of modulation. Each point of the curves shown in the diagrams represents the average measurement of M" of the 60 pictures taken.

While in the Report No. 1 the point was shown together with a vertical segment that represented the error of reading, in the Report No. 2 the vertical segment represents the fluctuation of the percentage of modulation during the minute of transmission. To avoid any effect of selective fading we considered only sinoidal oscillograms, as judged by the naked eye, and when the percentage of these (85%) was much greater than the distorted ones.

2. - PRESENTATION OF THE RESULTS

In the Report No. 1 the series of experiments made on selfmodulation during the year 1958 was described.

As stated in that paper the behaviours of the phenomenon obtained from 1950 (first appearance of the selfmodulation) to 1955 (a percentage of demodulation increasing up to 1000 c/s with the frequency of modulation, or a percentage of demodulation almost constant from 30 c/s to 4000 c/s) were never observed during the year 1958.

The behaviours noted in 1958 instead were the following :

a) Percentages of modulation greater than those transmitted by the station were observed at the lowest frequencies of modulation (fig. 26)

b) Appreciable demodulation was observed at the lowest frequencies of modulation with a slow asymptotic return to the emitted modulation at the higher frequencies (fig. 27)

c) Demodulation at the low frequencies and overmodulation were observed at the highest frequencies of modulation with a tendency to return asymptotically to the emitted modulation (Report No. 1)

It was pointed out that in the case of these behaviours the phenomenon, in particular for a) and b) depended distinctly (at the lowest frequencies of modulation) on the power emitted from AFN Frankfurt.

In the Report No. 2 the results are given of the experiments made in 1957 (July onwards) and in 1959 while the figs. 1-11 report some observations made in 1958 not published in the Report No. 1.

From the diagrams it is seen that th. behaviour of the phenomenon during the year 1958 (figs. 1-11) is similar to that of the year 1959 (figs. 15-19) and only slightly different from that of the year 1957 (figs. 12-14).

As already stated, the behaviours found in 1958 are the three indicated above with a) b) and c) with exception of the figs. 1, 2 and 4 where, on average, the percentage of modulation remained practically constant for all the frequencies of modulation and much the same as that emitted by the station.

During the year 1958 only the three mentioned behaviours were observed but in the year 1957 (July and August) the behaviours of 1955 were also observed (see figs. 10, 12a, 12b, 12c and 13; that is, the demodulation increased with the frequency of modulation ; in fig. 12a there is a slight overmodulation at the low frequencies of modulation). Figs. 15a, 16, 17, 18 and 19 represent the observations made instead in February, June and November 1959. As can be seen, the behaviours are identical to those a) b) and c) observed in 1958 save for the fig. 19b where a slight, almost constant, demodulation is seen at the increase of the frequency of modulation.

Outwith this exception, verified the night of 21st November 1959, the behaviours are always similar to those of 1958.

As already stated, and as can be seen from the figures, the phenomenon is studied in dependence of the power emitted ; for each frequency of modulation the power was varied from 150 to 50 and back to 150 kW. This was done for every frequency for period of five minutes.

In fig. 8 a variation of the percentage of modulation received with the variation of the power is seen (from 150 to 50 to 150 kW) mainly at 300, 500, 800 and 2000 c/s; that is, at these frequencies the demodulation is greater at 150 kW than at 50 kW. In the figs. 9a and 9b it is seen that at the lowest frequencies of modulation the dependence of the phenomenon on the power is clear up to 500 c/s.

In fig. 11 it is seen that the demodulation is greater at 150 kW than at 50 kW at frequencies of 500, 800, 1000 and 1500 c/s.

In fig. 12 a variation of power is not seen outwith those instants in which change was made from 50 to 150 kW but not from 150 to 50 kW.

In fig. 14 a variation of power is not seen but in fig. 15 it is noted that in passing only from 150 to 50 kW the dependence on the power is evident for all frequencies with exception of frequencies 50, 1900, 2200, 4000 and 5000 c/s.

In fig. 17 the variation of the power in passing from 150 to 50 kW and from 50 to 150 is clear, at least up to 100 c/s, even although it was not considered worth while tracing a curve for the fig. 17b because of the dispersion of the points.

In fig. 18 the dependence on the power is not clear and in fig. 19 it is even less so.

In figs. 8b, 8c, 12b, 12c, 17b, 18a and 18b the experimental curve is only partly traced owing to the dispersion of the points due to causes not fully understood.

In several of the figures some points are shown encircled. These points were thought to represent the measurements whose percentages of modulation were altered by mechanical interference and so these points were not taken into account when tracing the curve.

In fact, if the difference of path d between two rays that have travelled different paths in the ionosphere (one ray reflected in E layer other in F layer) is given by the formula $d < \frac{1}{8} \frac{c}{f}$ where c is the speed of light and f is the frequency of modulation, it is found that in the case Frankfurt-Naples (1216 km) the frequencies affected by possible mechanical interference may be those higher than, roughly, 850 c/s.

Receiving Naples; Transmitter AFN Frankfurt (872 Kc/s. ,60%, 150 kW).

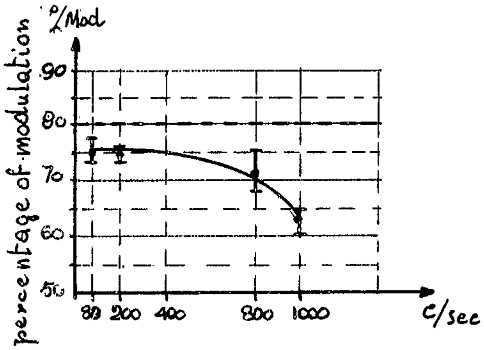


Fig. 13 30-7-1957 (Trans. AFN Frankfurt, 80%, 150 kW)

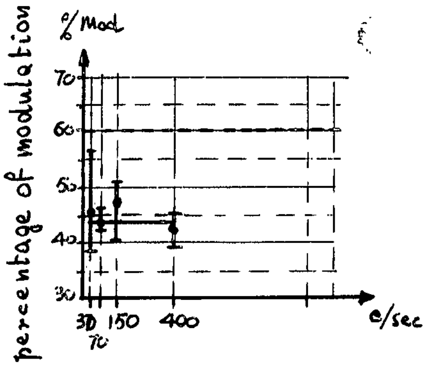


Fig. 1 16-1-1958

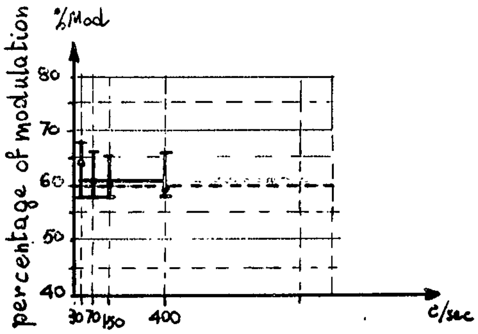


Fig. 2 21-1-1958

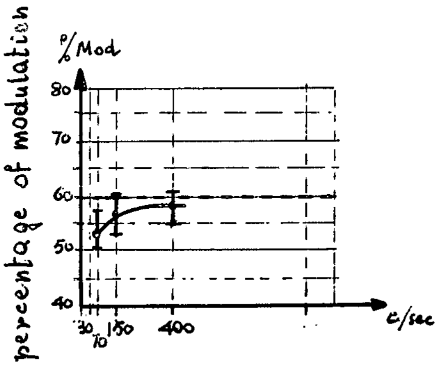


Fig. 3 24-1-1958

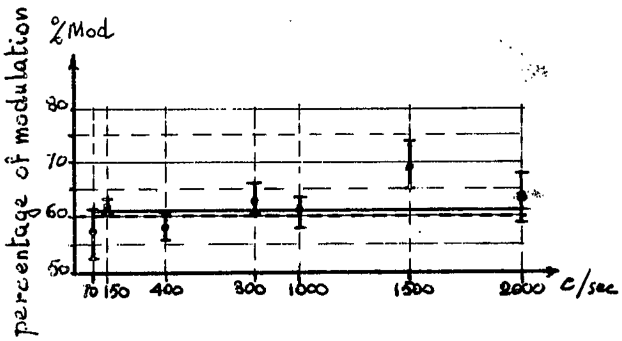


Fig. 4 24-1-1958

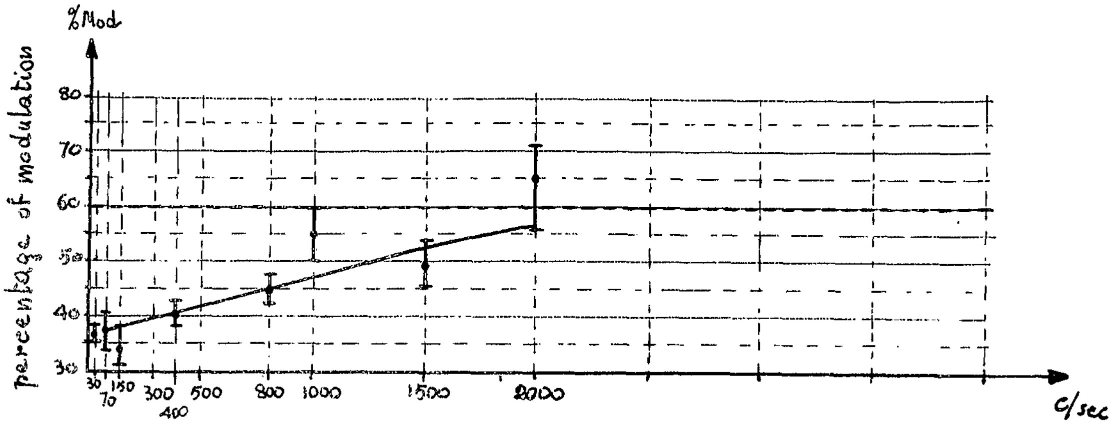


Fig. 5 28-3-1958 (AFN Frankfurt, 60%, 100 kW)

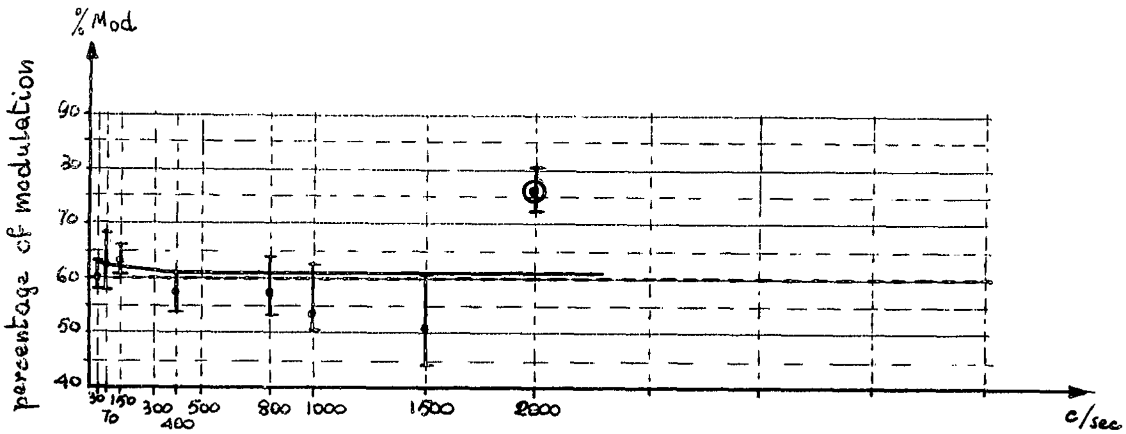


Fig. 6 1-4-1958 (AFN Frankfurt, 60%, 100 kW)

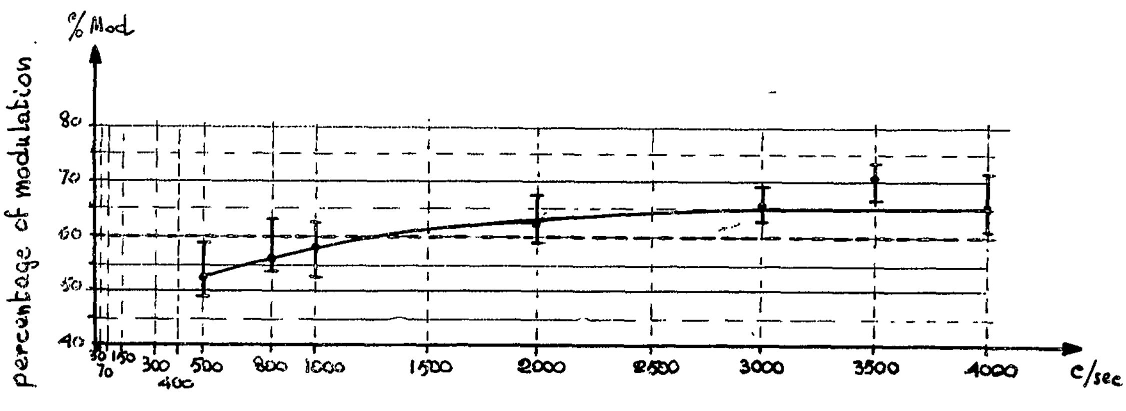


Fig. 7 13-5-1958 (AFN Frankfurt, 60%, 50 kW)

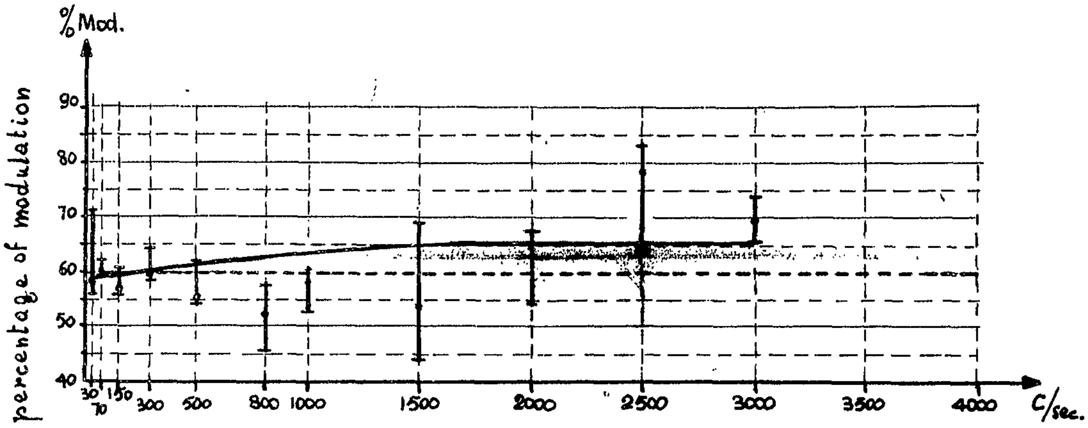


Fig. 8a 22-5-1958 (AFN Frankfurt 60%, 150 kW)

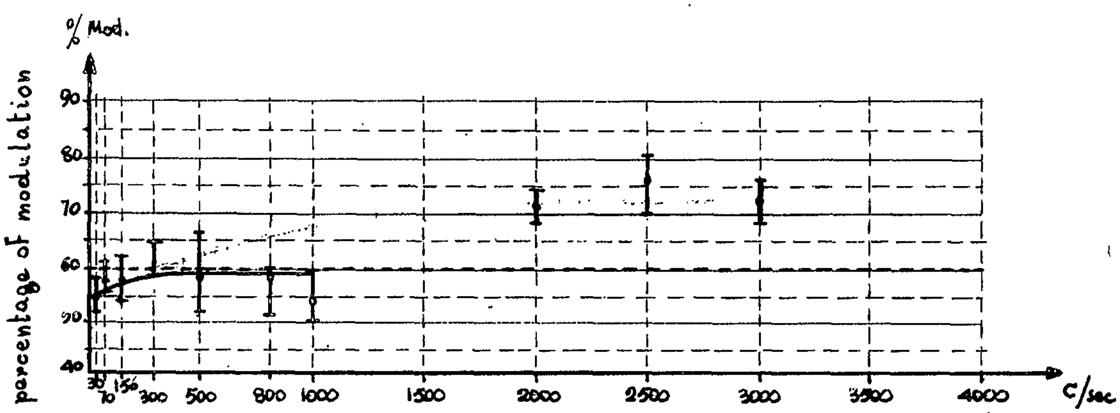


Fig. 8b 22-5-1958 (AFN Frankfurt, 60%, 50 kW)

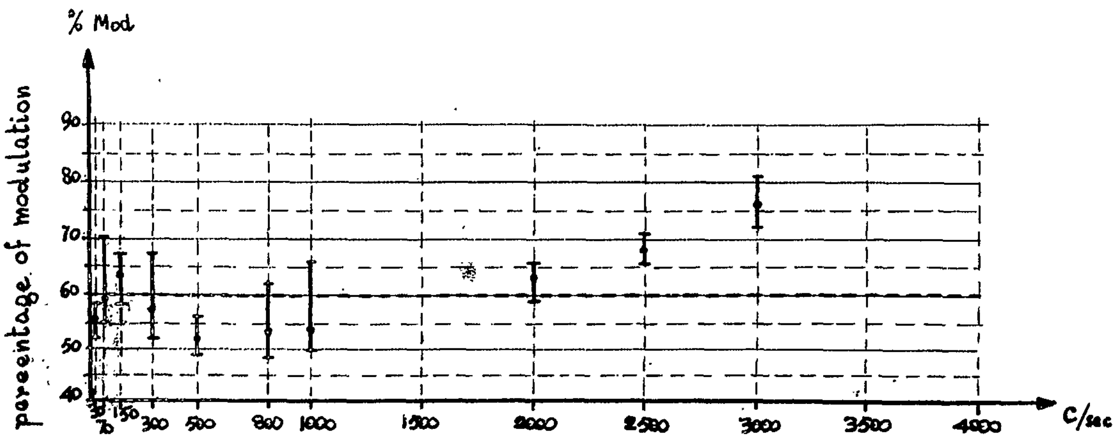


Fig. 8c 22-5-1958 (AFN Frankfurt, 60%, 150 kW)

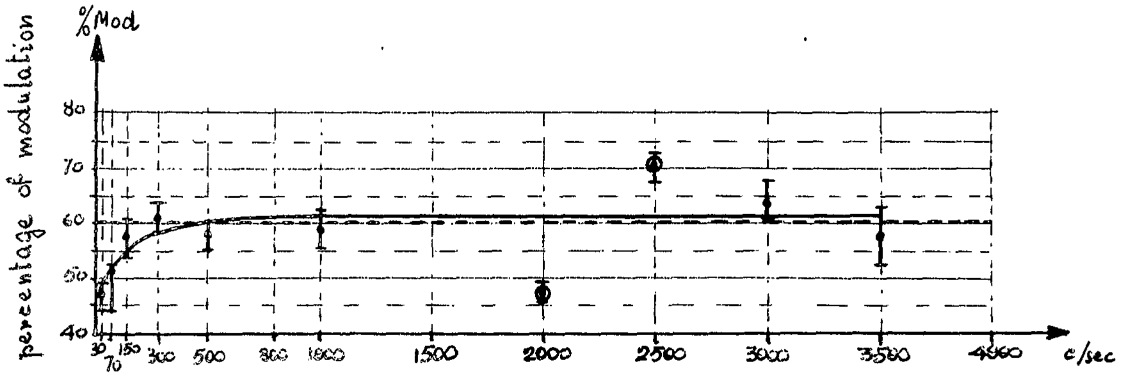


Fig. 9a 23-7-1958 (AFN Frankfurt, 60%, 150 kW)

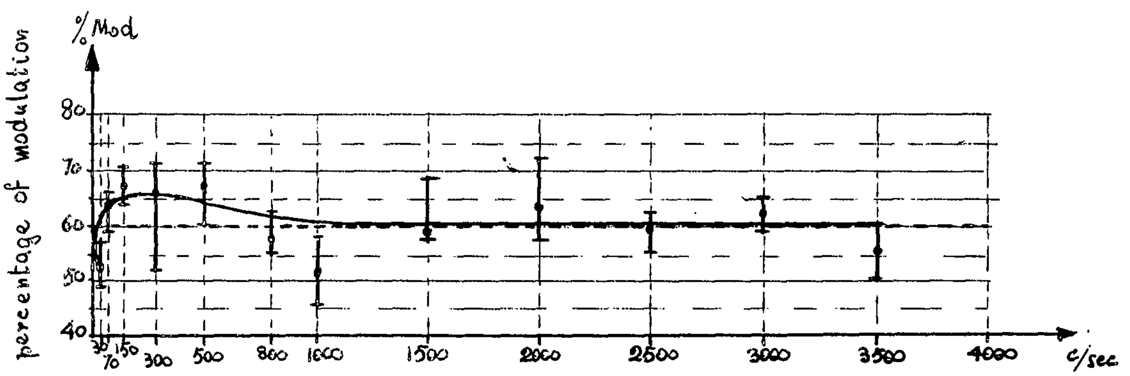


Fig. 9b 23-7-1958 (AFN Frankfurt, 60%, 50 kW)

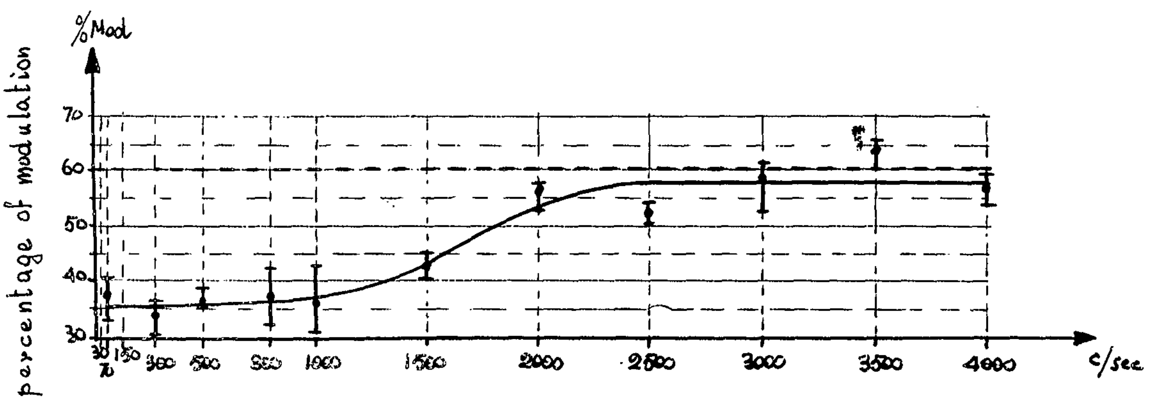


Fig. 10 17-5-1958 (AFN Frankfurt, 60%, 150 kW)

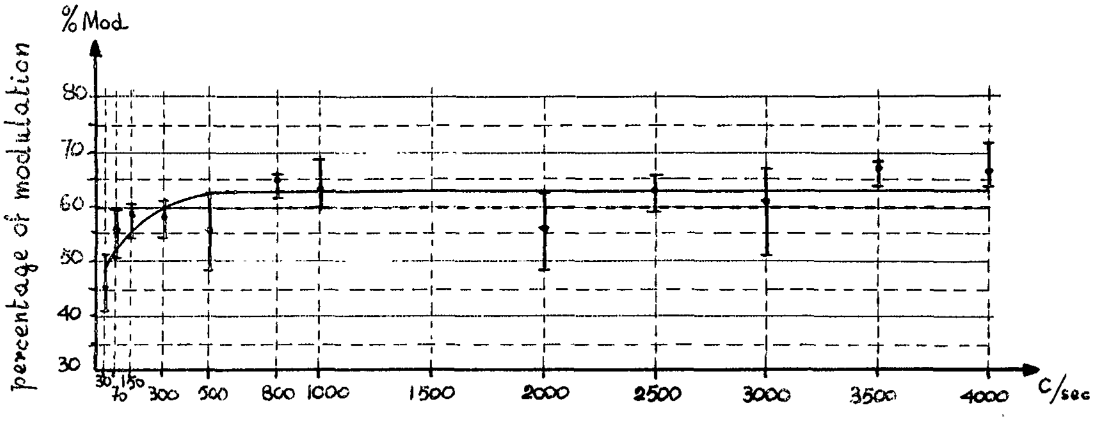


Fig. 11a 26-7-1958 (AFN Frankfurt, 60%, 150 kW)

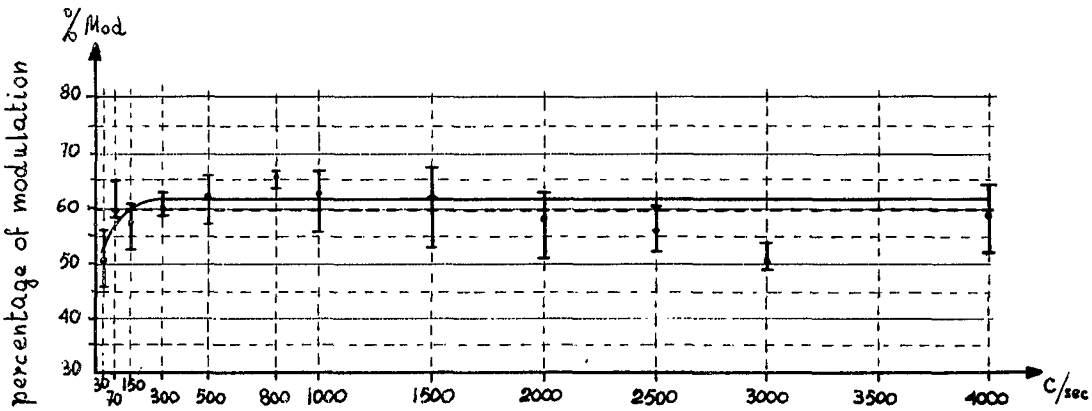


Fig. 11b 26-7-1958 (AFN Frankfurt, 60%, 50 kW)

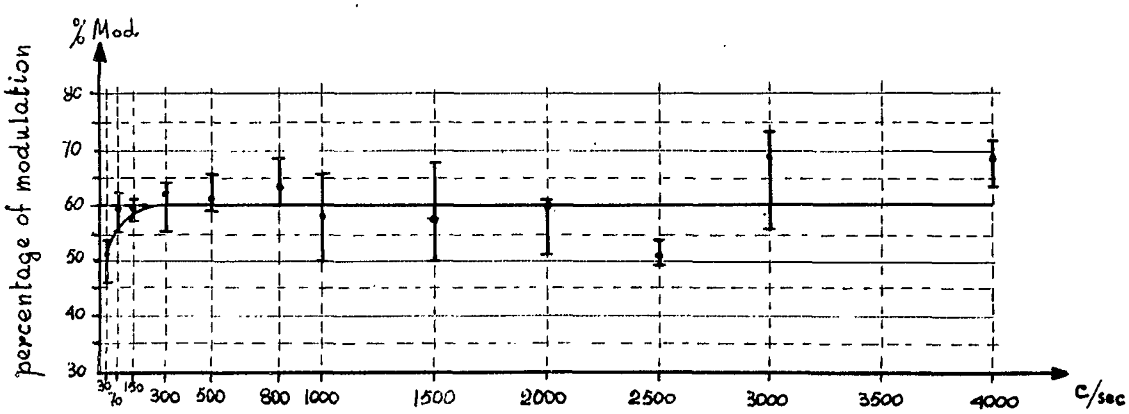


Fig. 11c 26-7-1958 (AFN Frankfurt, 60%, 150 kW)

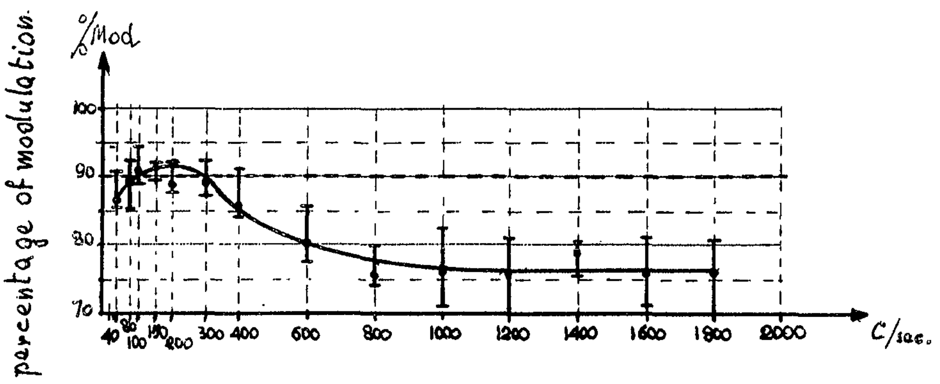


Fig. 12a 26-7-1957 (AFN Frankfurt, 90%, 150 kW)

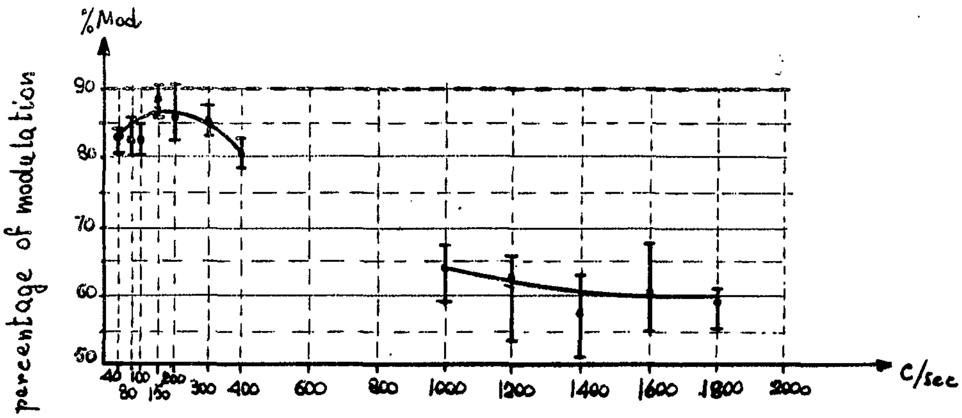


Fig. 12b 26-7-1957 (AFN Frankfurt, 90%, 50 kW)

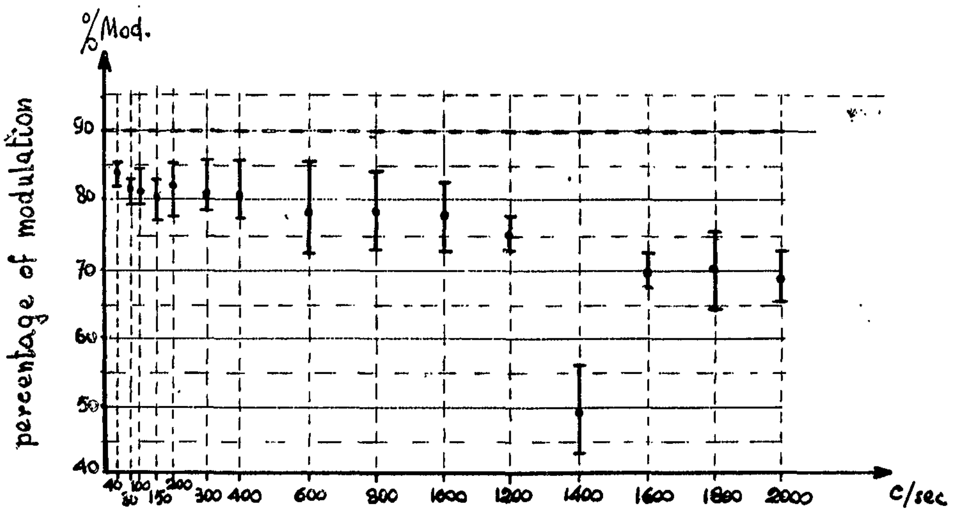


Fig. 12c 26-7-1957 (AFN Frankfurt, 90%, 150 kW)

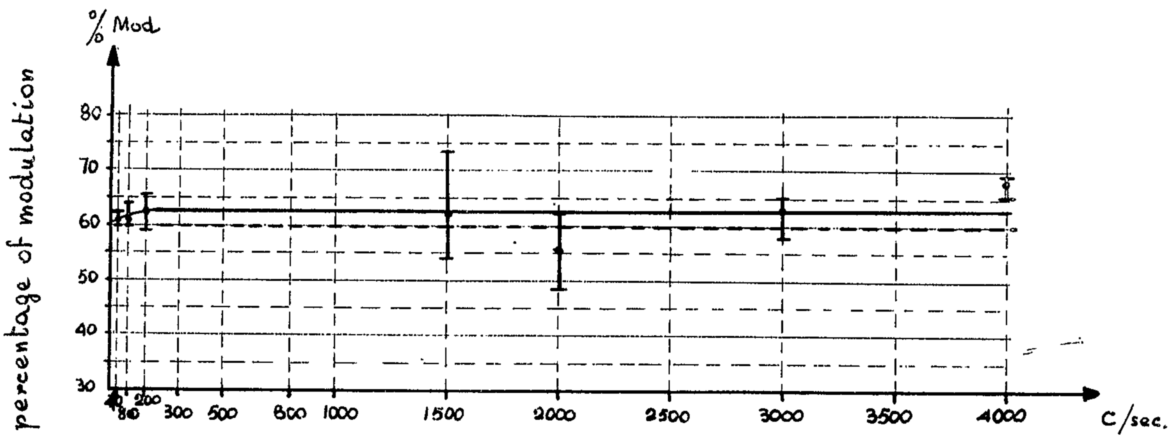


Fig. 14a 9-8-1957 (AFN Frankfurt, 60%, 150 kW)

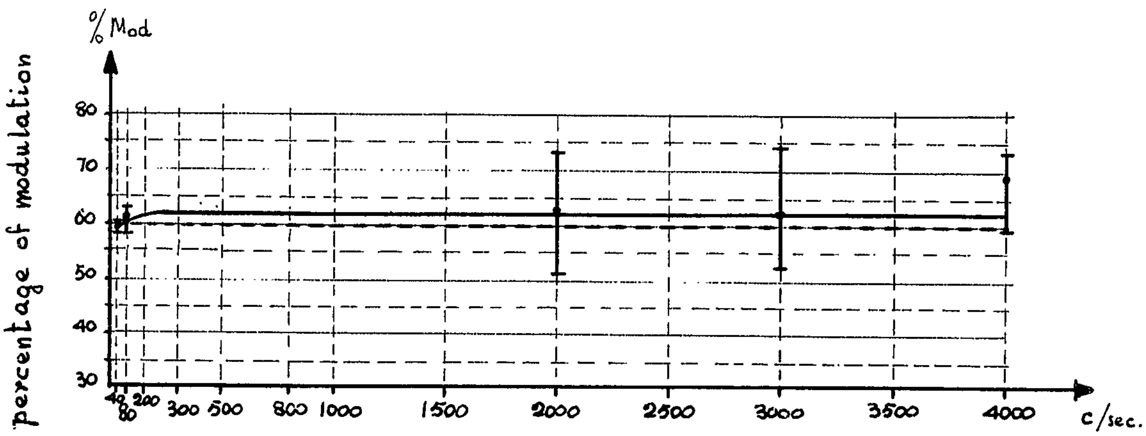


Fig. 14b 9-8-1957 (AFN Frankfurt, 60%, 50 kW)

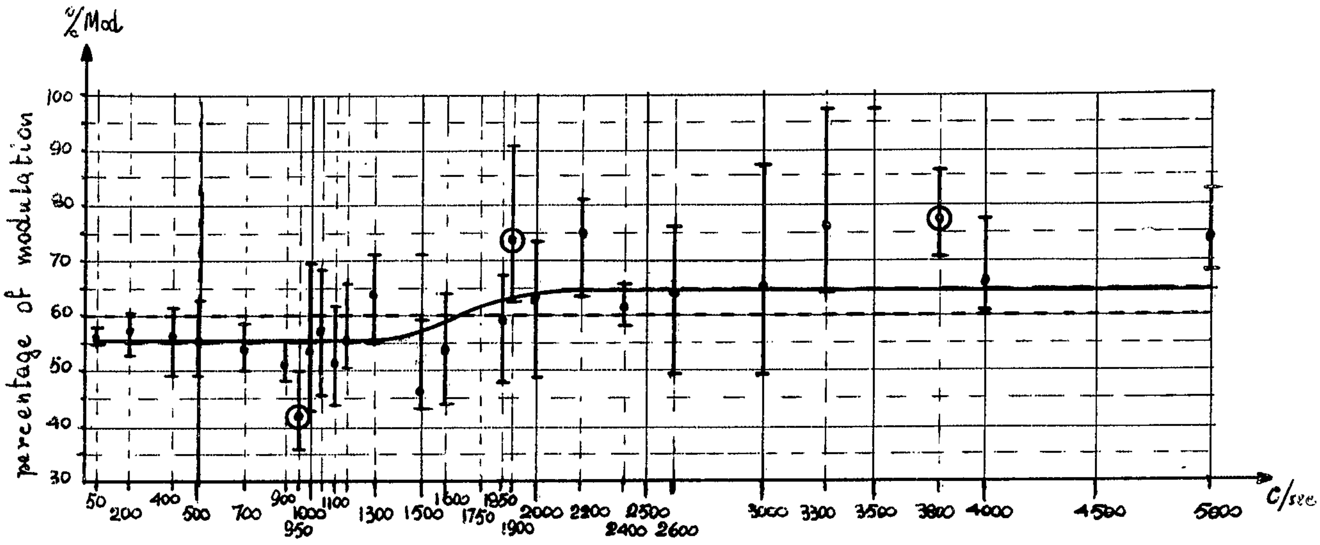


Fig. 15a 12-2-1959 (AFN Frankfurt, 60%, 150 kW)

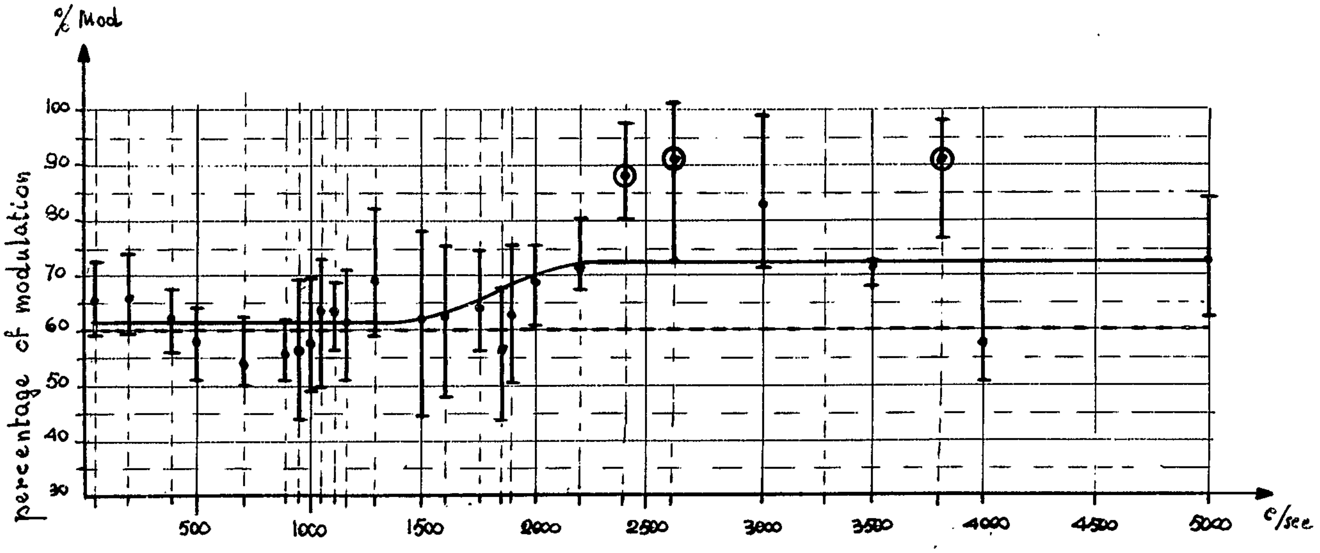


Fig. 15b 12-2-1959 (AFN Frankfurt, 60%, 50 kW)

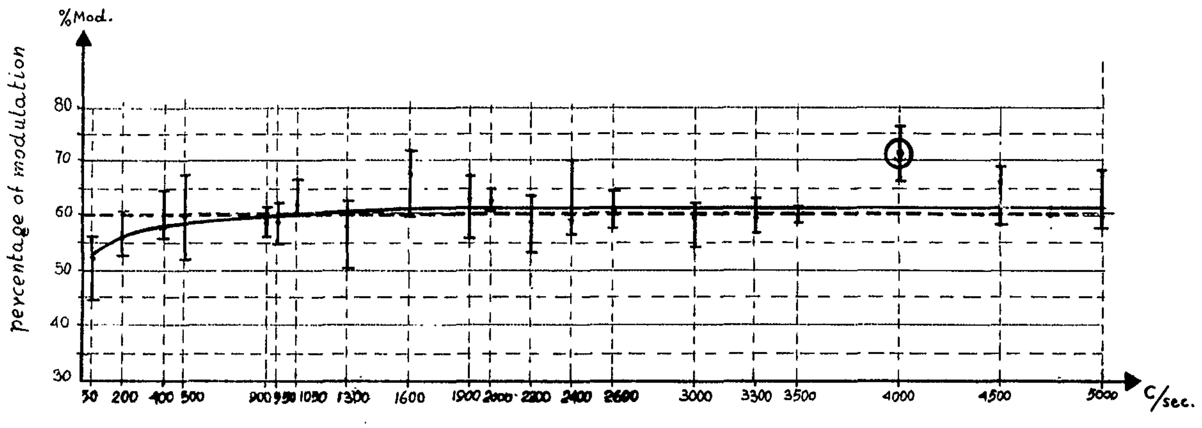


Fig. 16a 25-6-1959 (AFN Frankfurt, 60%, 150 kW)

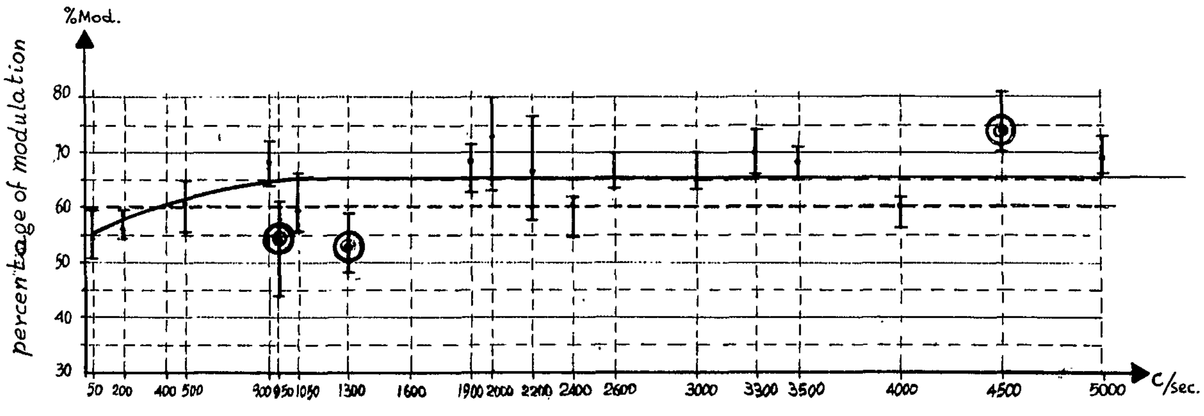


Fig. 16b 25-6-1959 (AFN Frankfurt, 60%, 50 kW)

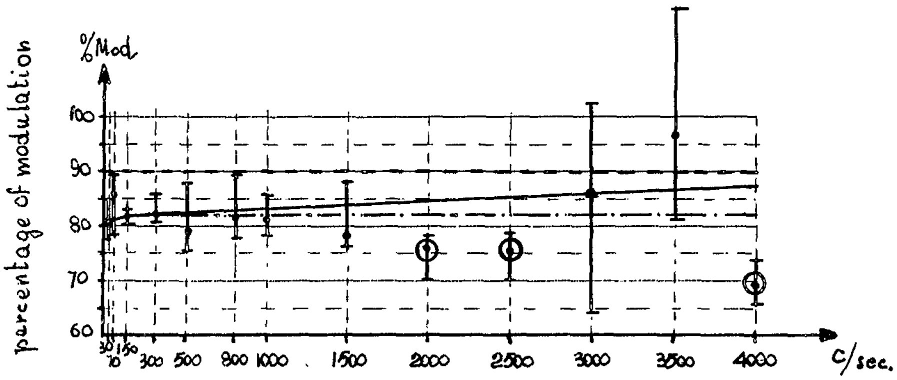


Fig. 17a 4-11-1959 (AFN Frankfurt, 90%, 150 kW)

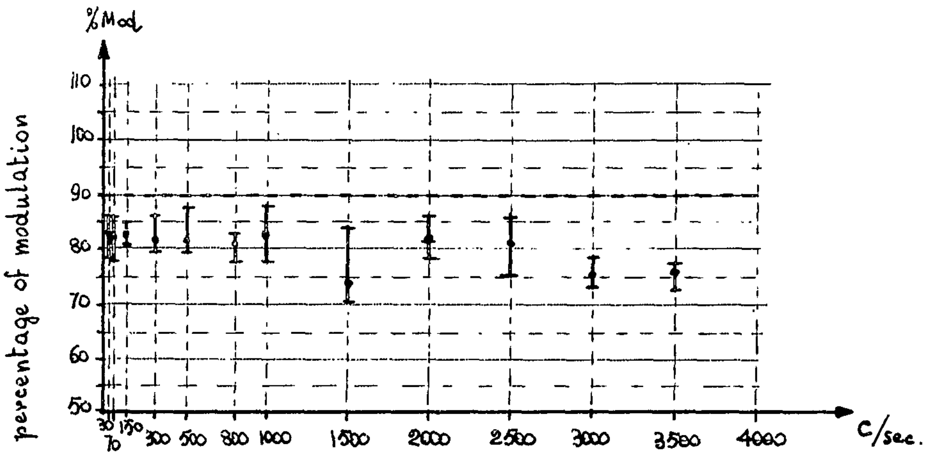


Fig. 17b 4-11-1959 (AFN Frankfurt, 90%, 50 kW)

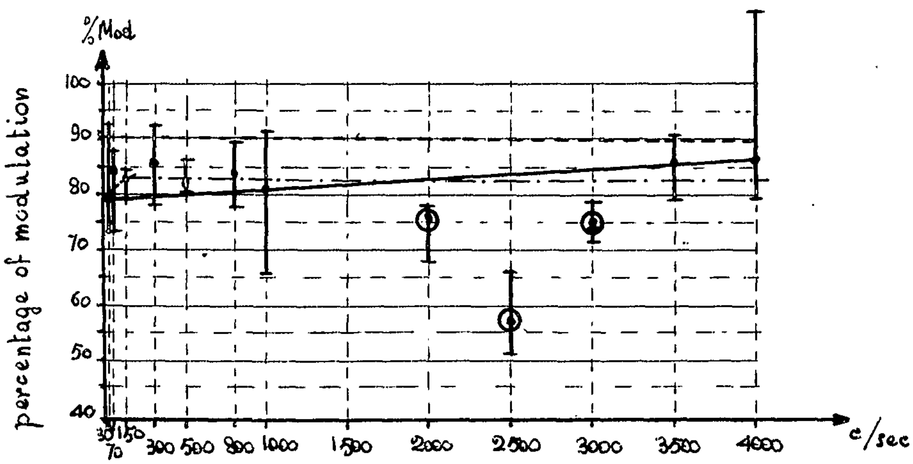


Fig. 17c 4-11-1959 (AFN Frankfurt, 90%, 150 kW)

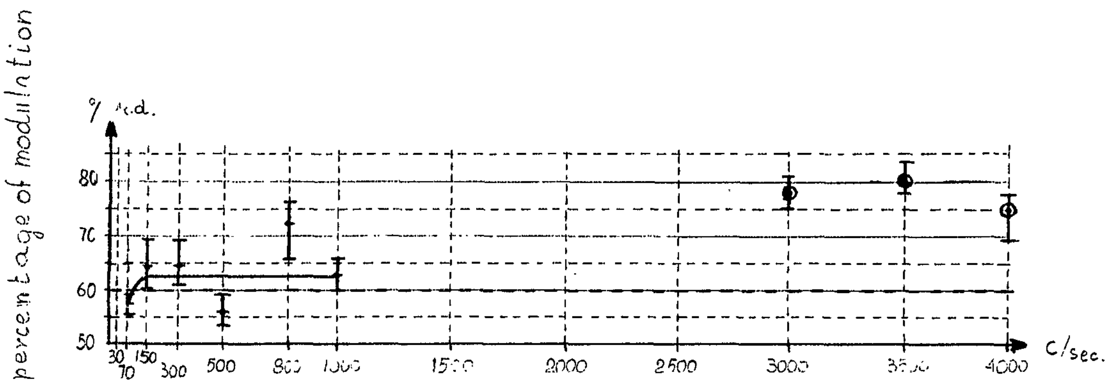


Fig. 18a 17-11-1959 (AFN Frankfurt, 60%, 150 kW)

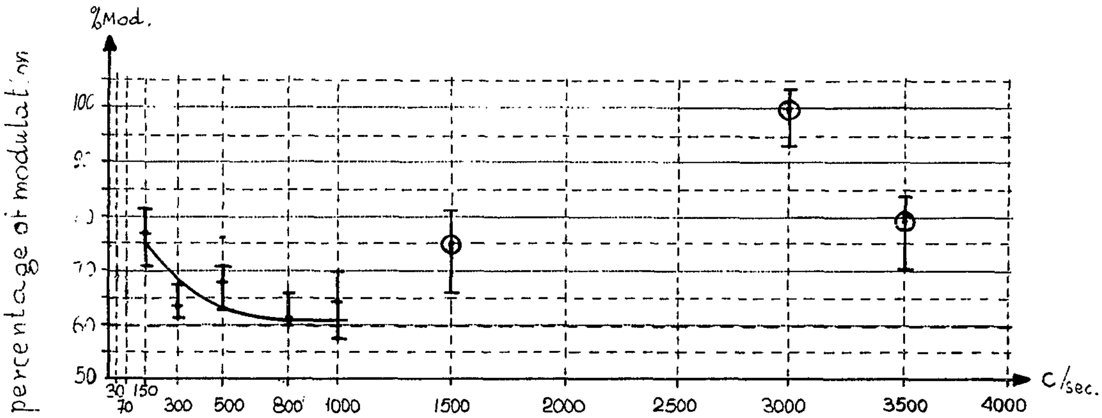


Fig. 18b 17-11-1959 (AFN Frankfurt, 60%, 50 kW)

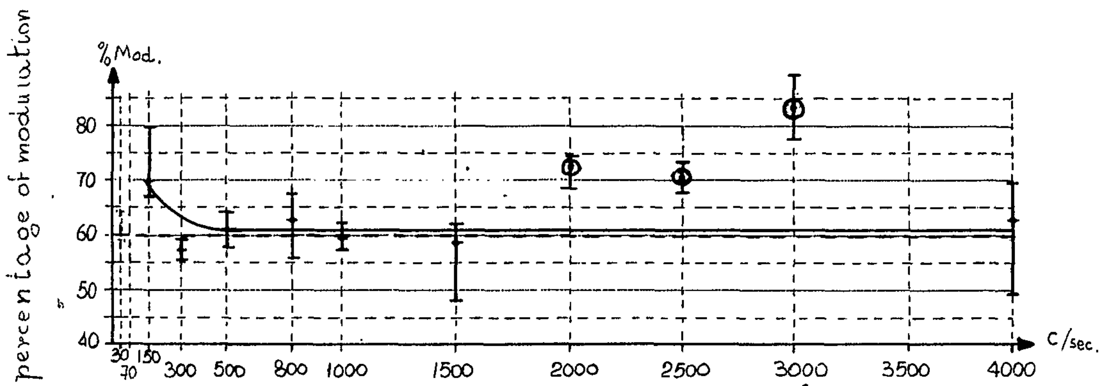


Fig. 18c 17-11-1959 (AFN Frankfurt, 60%, 150 kW)

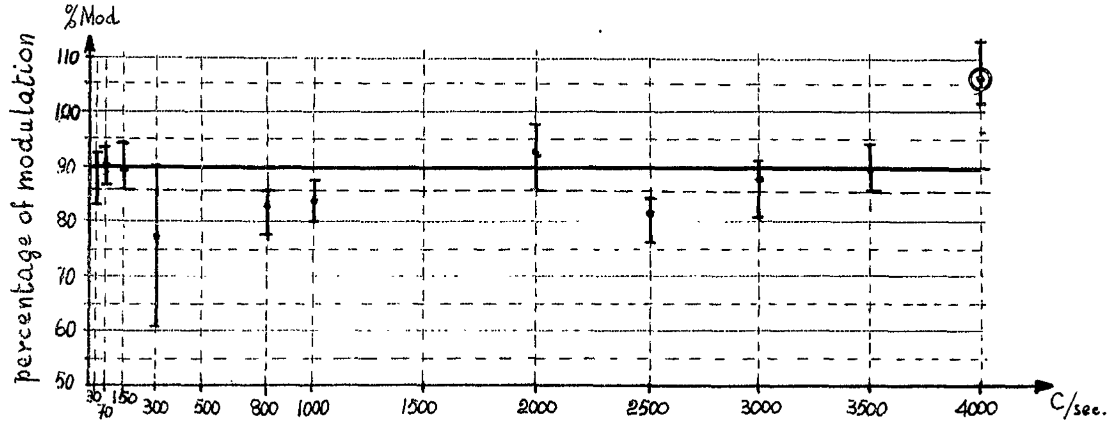


Fig. 19a 21-11-1959 (AFN Frankfurt, 90%,150 kW)

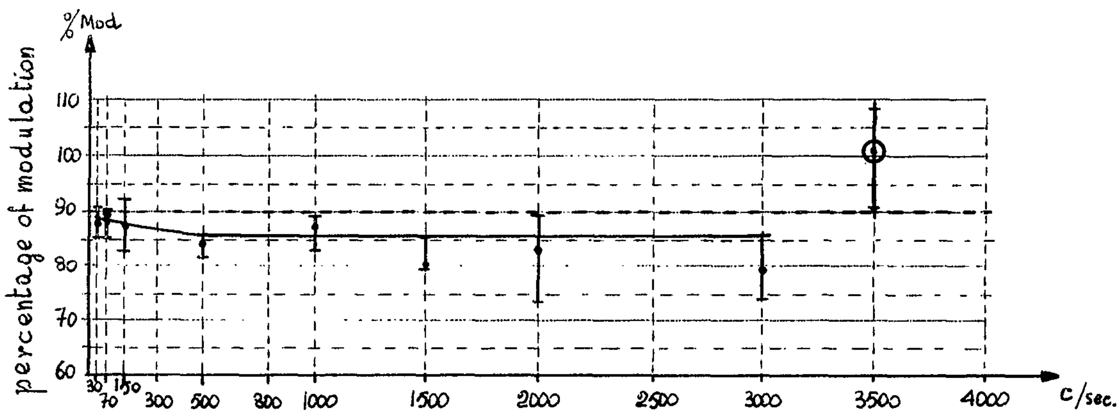


Fig. 19b 21-11-1959 (AFN Frankfurt, 90%, 50 kW)

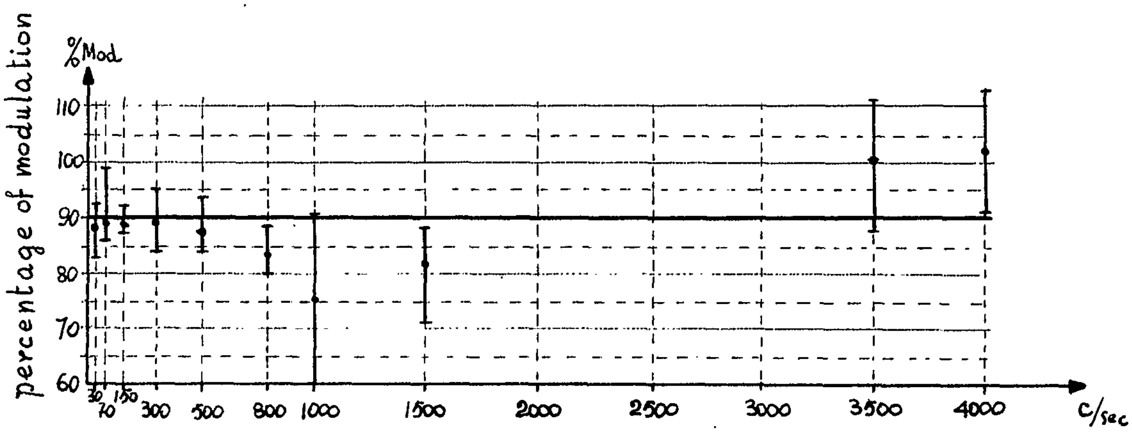


Fig. 19c 21-11-1959 (AFN Frankfurt, 90%, 150 kW)

If, for e.g. , the frequency 950 c/s is affected by selective fading evidently all the multiple frequencies of 950 might well be affected also.

The fig. 15a could confirm this hypothesis. In fact, if it is supposed that the frequency 950 is affected by mechanical interference, it is found that also frequencies 1900 and 3800 (multiples of 950) are altered by the interference. These frequencies are therefore shown in fig. 15 by encircled points.

3. - <u>STUDY OF THE FADING</u>

With the aim of studying the influence of the fading on the selfmodulation some experiments were organized on two nights as follows :

During the nights of 7th and 25th November 1959 the AFN Frankfurt Radio emitted its carrier at full power modulated at 50% for a period of forty minutes for each of the frequencies of modulation 300, 1000 and 2500 c/s. The frequency 300 c/s was transmitted from 0115 to 0155; the frequency 1000 c/s from 0200 to 0240; the frequency 2500 c/s from 0245 to 0325.

The results of the observations are given in figs. 20, 21, 22, 23, 24 and 25. The percentages of modulation received are shown in the ordinates while the times, in minutes, are given in the abscissae. The point corresponding to each minute represents the average of roughly 60 observations made during that minute.

From these figures it is seen that the behaviour is regular for frequency 300 c/s (figs. 20 and 23) while the dispersion increases for frequencies 1000 and 2500 c/s and especially so for the last frequency.

For frequency 300 c/s it is found that on the night of 7th November the percentage of modulation received remained below that emitted while on the night of 25th

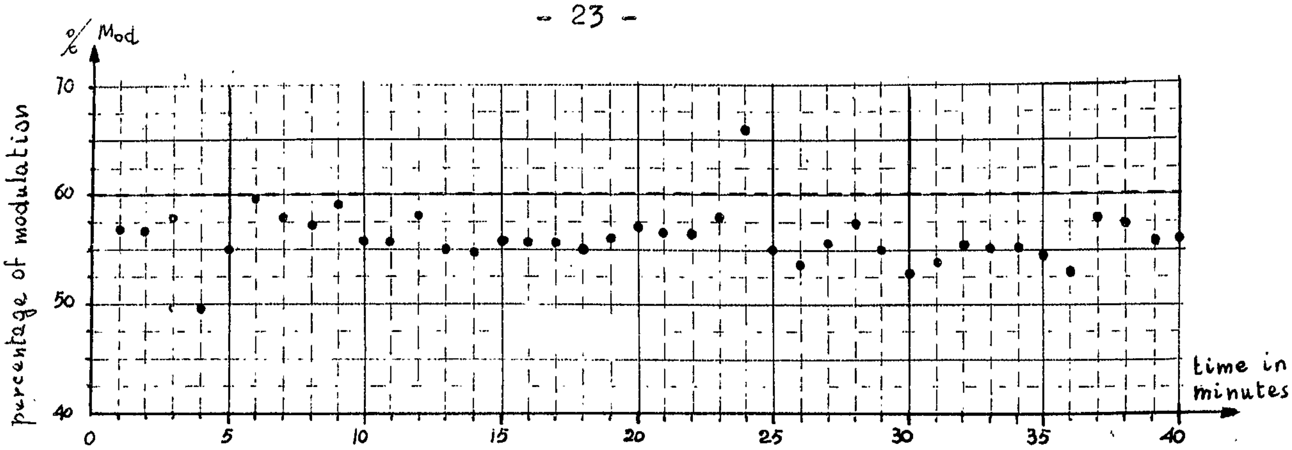


Fig. 20 7-11-1959 from hours 0115 to 0155 (AFN Frankfurt, 300 c/s. 60%, 150 kW)

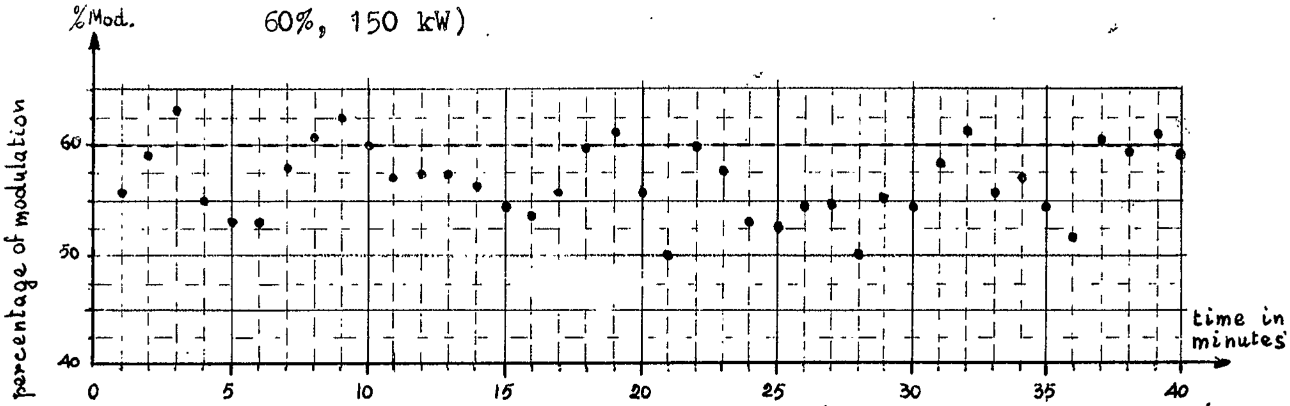


Fig. 21 7-11-1959 from hours 0200 to 0240 (AFN Frankfurt, 1000 c/s. 60%, 150 kW)

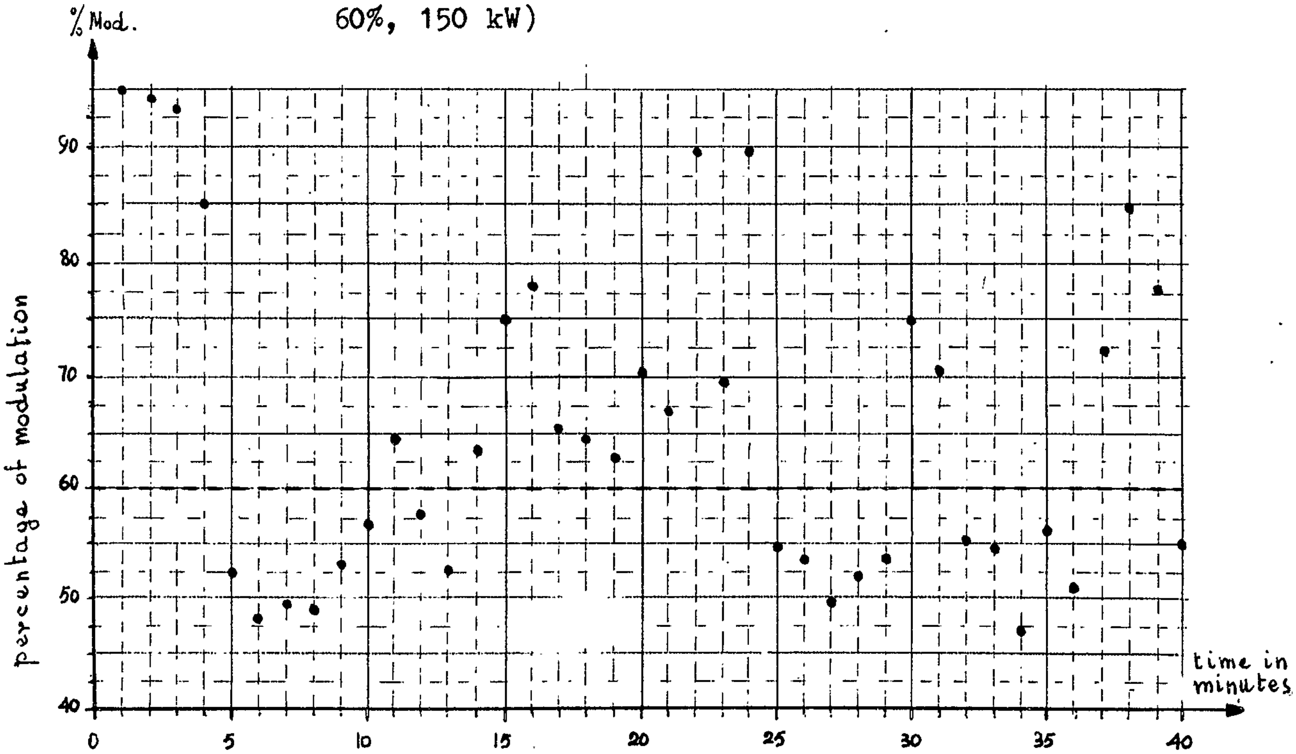


Fig. 22 7-11-1959 from hours 0245 to 0325 (AFN Frankfurt, 2,500 c/s. 60%, 150 kW)

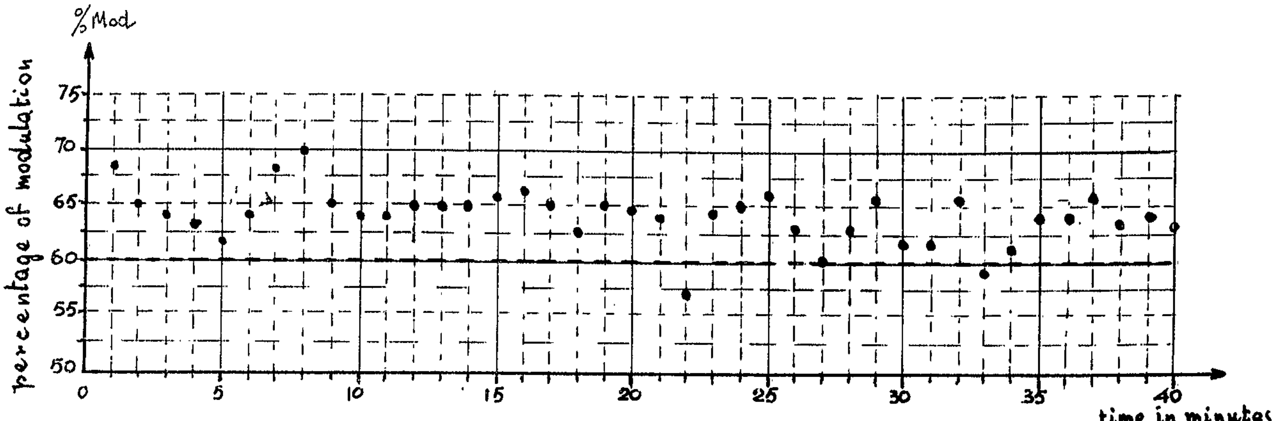


Fig. 23 25-11-1959 from hours 0115 to 0155 (AFN Frankfurt, 300 c/s. 60%, 150 kW)

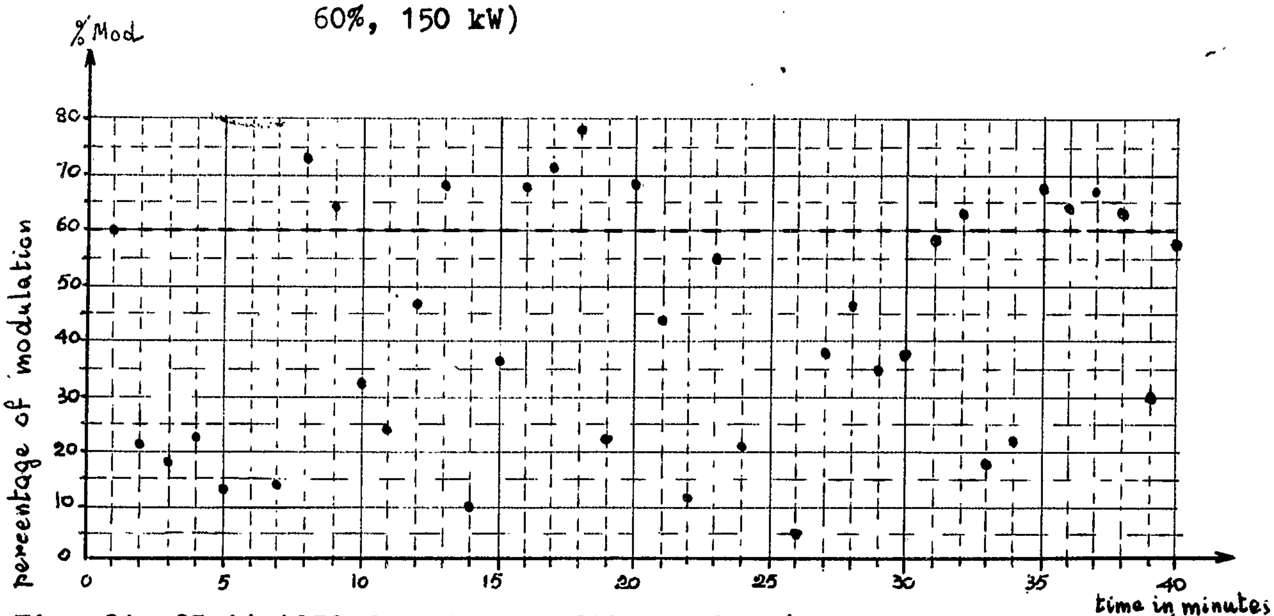


Fig. 24 25-11-1959 from hours 0200 to 0240 (AFN Frankfurt, 1000 c/s 60%, 150 kW)

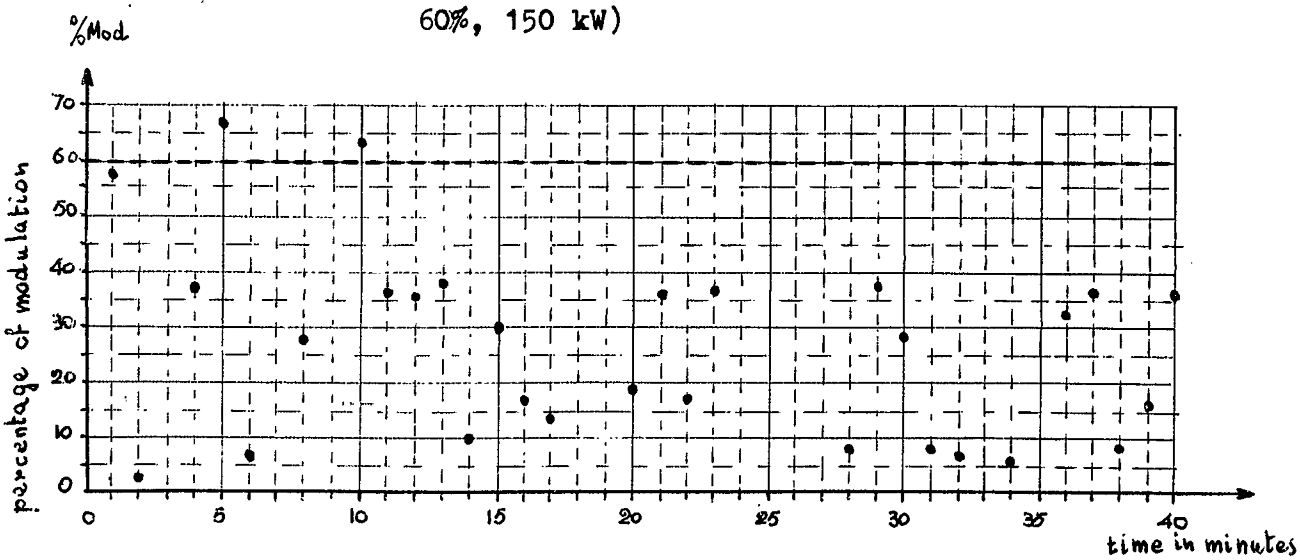


Fig. 25 25-11-1959 from hours 0245 to 0325 (AFN Frankfurt, 2500 c/s. 60%, 150 kW)

November the percentage was higher than 60%. For frequency 1000 c/s it is found that, in general, the percentage is smaller than 60% for both nights even although the behaviour of the phenomenon is not so clear for the night of 25th November. For frequency 2500 c/s the percentage is alternatively greater and smaller than 60% (on average greater) for night of 7th November and clearly smaller for night of 25th November. It is very interesting to note that the behaviour of the phenomenon for both nights and for all three frequencies becomes slowly sinoidal specially for frequency 300 c/s.

4.- COOPERATION OF THE IONOSPHERIC LABORATORIES OF GÖTHENBURG, KIRUNA AND TOULOUSE

In the experiments made October and November 1959 the following laboratories cooperated, as they did in the cycle made May 1958 (reported briefly in the Report No. 1).
The Research Laboratory of Electronics, Chalmers Institute of Technology, Göthenburg (Sweden) Director, Prof. O. Rydbeck.
The Kiruna Geophysical Observatory, Kiruna c. (Sweden) Director, Dr. D. Hultqvist.
The École Nationale Supérieure d'Électrotechnique, d'Électronique et d'Hydraulique, Toulouse (France) Director, Prof. P. Dupin.

The results obtained by the above laboratories are very good and coincide among themselves.

We are at present holding, together with our collaborators at Göthenburg, Kiruna and Toulouse, an extensive examination of all the measurements made at each of the laboratories. The results of the examination will be given in a separate publication.

5. - CONCLUSION

As stated in the Reports Nos. 1 and 2 the cycles of experiments on ionospheric selfmodulation at oblique incidence begun 16th July 1957 and completed 25th November 1959 were 8 in number with a total of 30 nights of experiments and with about 75 hours of observations. Measurements made totalled 101,273 of which, however, unfortunately, only 70,581 were of use. Various disturbances (interference from radiotelegraphic stations, defects of the camera) affected 22,504 and the remaining 8188 could not be used because of distortions due to the ionosphere. A careful examination shows that the results are very good as they give a better clarification of the general behaviour of the phenomenon.

For the first time it was ascertained that it is possible to have overmodulation as well as demodulation and for this reason it was decided to call the phenomenon "ionospheric selfmodulation" instead of "ionospheric selfdemodulation" as it was called in the past years.

In the cycles made between July 1957 and November 1959 it is seen that we had at almost all times the three behaviours a) b) and c) indicated in Paragraph 1 as well as demodulation increasing with the frequency of modulation or almost constant demodulation from 30 to 4000 c/s. As the cycles were made in three different years (1957, 1958 and 1959) and as they were spread over the various seasons of the year it would appear that the phenomenon depends markedly on the conditions of the ionosphere. In fact, in the years 1958 and 1959 only the behaviours a) b) and c) were observed at Naples and never those behaviours reported in the previous works (demodulation increasing or almost constant with the frequency of modulation). In the year 1957, however, over and above the noting of the behaviours a) and c) the behaviours of the previous years were observed.

During the year 1958 a probable seasonal effect was also noted (see the Report No. 1). The Laboratories of Göthenburg, Kiruna and Toulouse took part in the cycles of May 1958 and October-November 1959 and, as the results obtained in these laboratories coincide with the behaviours of 1956, it seems to us that the behaviour of the phenomenon depends on the direction of propagation of the radiowaves as regards the direction of the lines of force of the earth's magnetic field (see the Report No. 1 page 22).

From examination of the diagrams published in the Reports Nos. 1 and 2 it would seem that a dependence on the power does exist but that it is not always evident as the percentage of modulation decreases from 150 to 50 kW to return to the primitive value when the power returns from 50 to 150 kW. On the contrary, it is seen, at times, that the percentage of demodulation is greater at 50 kW than at 150 kW. This strange evidence of the dependence of the phenomenon on the power hinders the affirmation that the self-modulation is explainable with the theory of interaction. Only in the cases a) and b) is there a possibility of explaining the selfmodulation with the theory of interaction, as is shown in the Report No. 1, and as is briefly repeated in the Appendix to this report.

When modulation and overmodulation are obtained contemporaneously or when the demodulation is almost constant from 30 c/s to 4000 c/s or increases with the increase of the frequency of modulation, the mechanism of the phenomenon is very obscure. Perhaps only in the case of fig. 13 would it be possible to explain it with the hypothesis of Tiberio and with the theory of Possenti.

The determining, time by time, of the height of reflection of the radiowaves used and the number of the paths traversed in the ionosphere by the radiowaves in going from the transmitter to the receiver could be useful for the construction of a general theory.

A transmitter working alternatively in CW and pulses has already been set up to determine the number of multiple paths.

There is also in course a series of experiments on selfmodulation at vertical incidence with pulses to study the phenomenon by day, to find the height of reflection of the radiowaves and to eliminate any influence whatsoever of mechanical interference.

In conclusion it is shown how the method used by us, that is, transmission in CW of modulated waves with different frequencies of modulation with rapid leaps of power and measure by the envelope method of the percentage of modulation received allowed us to observe demodulation and overmodulation, to discard those measurements affected by selective fading and to note that at the changing of the power there can be a passing from one behaviour to another.

In the case of the behaviours a) and b) the frequency of collision and the mean coefficient of total absorption can be determined as shown in the Appendix.

APPENDIX

1. - MEASUREMENT OF $G\nu$

As stated in the Report No. 1, page 11, the behaviours a) and b) can be explained by the ~~theory~~ of M. Carlevaro.

However, as the English of the Report No. 1 was not at all clear, we are taking the opportunity to repeat here the manner in which the product $G\nu$ and the mean coefficient of total absorption α are calculated for the behaviours a) and b).

In the Report No. 2 the figs. 26 and 27 represent respectively the behaviours a) and b). In the fig. 28 the theoretical curve only is traced as it coincides with the experimental one. In the fig. 27, however, the theoretical and experimental curves are both drawn.

The theory of M. Carlevaro, reported briefly in the Report No. 1 has been published in the Supplement No. 4 to "IL NUOVO CIMENTO" 1956, pages 1422-1429. Carlevaro develops his theory beginning from the equation of V.A. Bailey Phil. Magazine S7 - 23 No. 157, 929 (1937) relative to the movement of an electron in a gas under an alternating electric field.

He arrives at the conclusion that if M is the percentage of modulation in the transmitting station (in our case AFN Frankfurt) and the percentage of modulation received is M" there is obtained :

$$\left(\frac{M''}{M}\right)^2 = \frac{1-4\varrho(1-\varrho)\cos^2\psi}{(1-\varrho M^2\cos^2\psi)^2} = \frac{1-A\cos^2\psi}{(1-B\cos^2\psi)^2} \quad [1]$$

$$A \leq 1 \;;\; B > 0$$

Calling Wo the mean value of the work done by the electric field on an electron between two consecutive collisions, G is a constant, that is, the mean relative loss in a collision, T the thermal equilibrium of the electron,

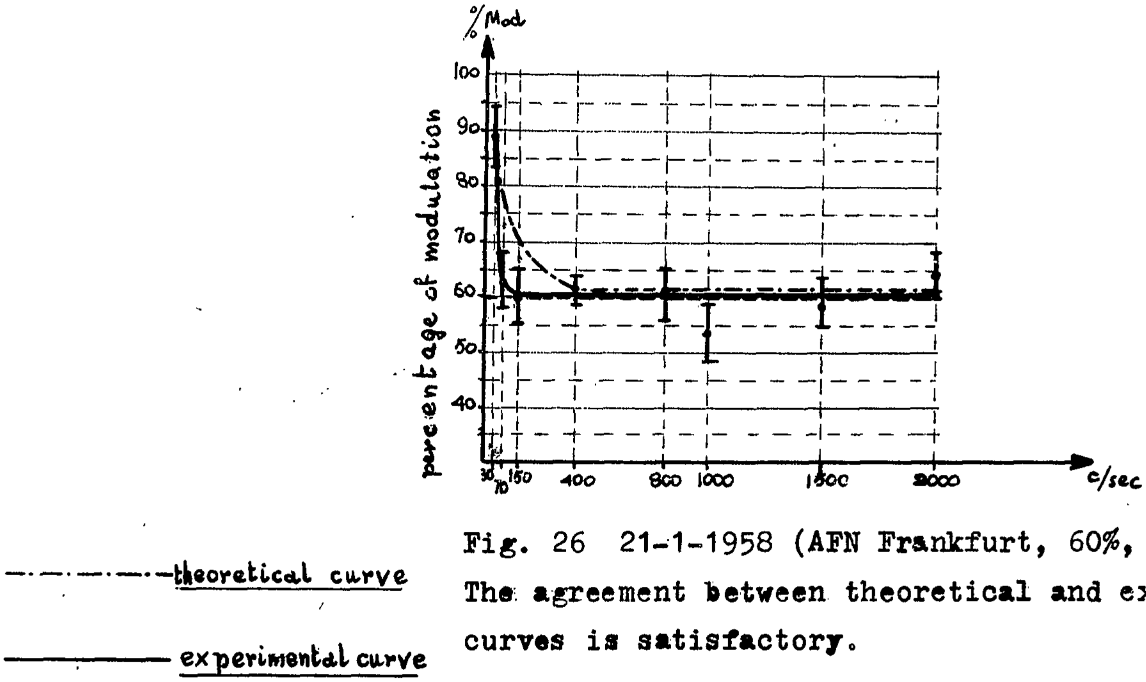


Fig. 26 21-1-1958 (AFN Frankfurt, 60%, 50 kW)
The agreement between theoretical and experimental curves is satisfactory.

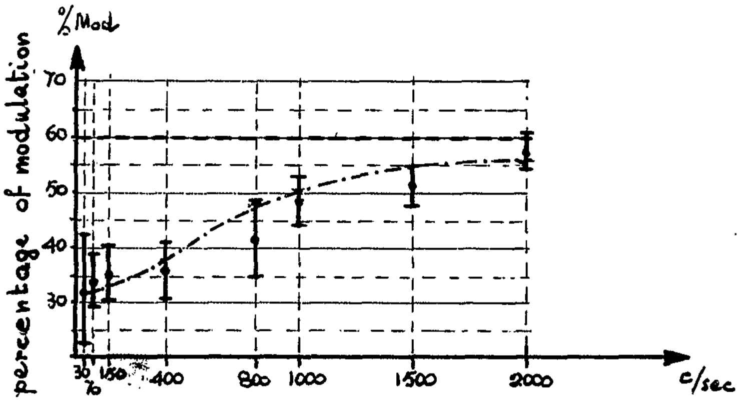


Fig. 27 28-3-1958 (AFN Frankfurt, 60%, 150 kW)
The experimental curve is not drawn because it is coincident with the theoretical curve.

α the mean coefficient of total absorption,

$$\rho = \frac{\alpha}{2} \quad \frac{W_0}{W_0 + GT} \qquad [2]$$

$$tg\psi = \frac{n}{G\nu} \quad [3] \quad ; \quad \nu = \nu_0\sqrt{1 + \frac{W_0}{GT}} \qquad [4]$$

where n is the frequency of modulation, ν is the collision frequency of the electron and ν_0 is the thermal equilibrium value of ν.

The derivative of $(\frac{M''}{M})^2$ with respect to ψ, and the dependence of M on ρ can be expressed by the relation

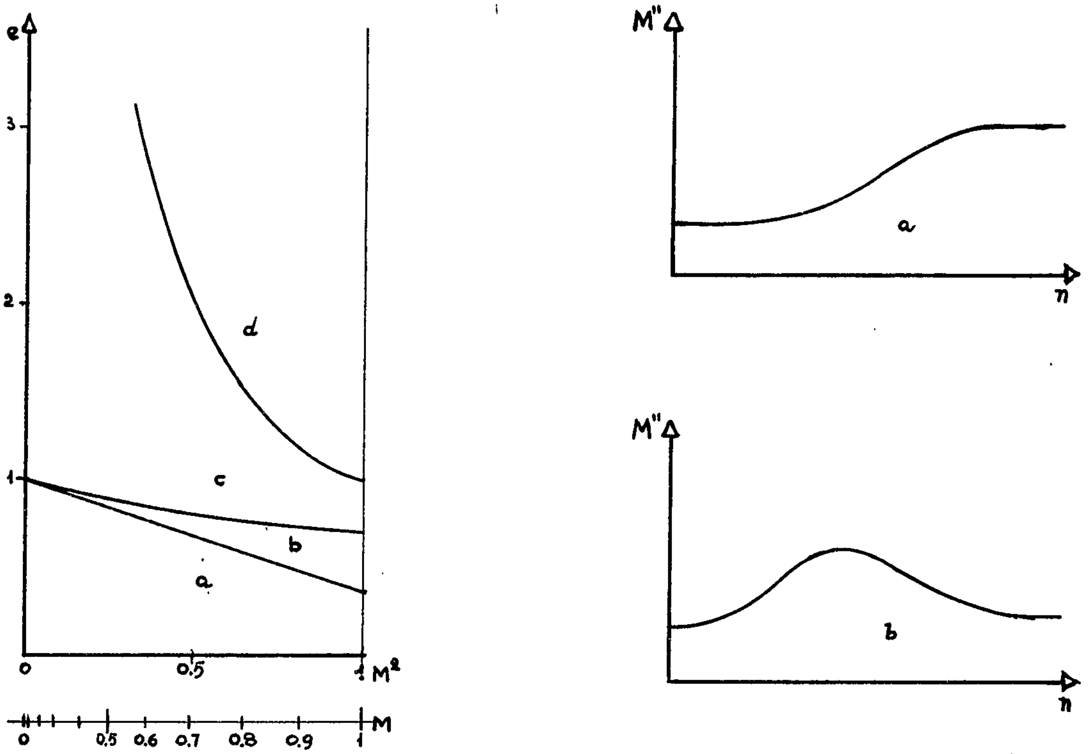
$$\frac{d}{d\psi}\left(\frac{M''}{M}\right)^2 = \frac{A - 2B + AB\cos^2\psi}{(1-B\cos^2\psi)^3} \sin 2\psi$$

In doing so, Carlevaro finds that ρ depends on M and that its range of variation is from 0 to values greater than one. That is, from Carlevaro's theory it follows that for a given value of M there are four small intervals of the value of ρ for each of which there is one of the behaviours a, b, c and d of fig. 28. If M = 0,6 (as in our experiments) we have the behaviour a) for $0 < \rho \leq 0{,}82$; the behaviour b) for $0{,}82 \leq \rho \leq 0{,}90$; the behaviour c) for $0{,}90 \leq \rho \leq 3{,}00$. The behaviour d) of fig. 28 has not yet been found experimentally and so has not been considered by us here.

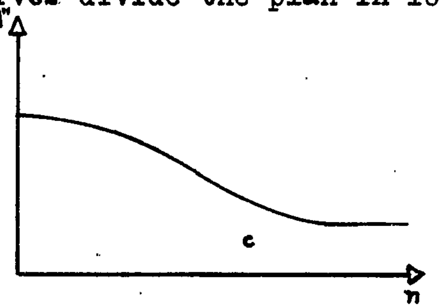
From the experimental results of the figs. 26 and 27 it is seen that the behaviour of fig. 27 is similar to that a) of fig. 28, and the behaviour of fig. 26 is similar to that c) of fig. 28. Therefore, for fig. 26 the value of ρ must be between $0{,}90 \leq \rho \leq 3{,}00$ and for fig. 27 the value of ρ must be between $0 < \rho \leq 0{,}82$.

To find the theoretical curve capable of explaining the behaviour of each of our experimental curves it is necessary only to put in the equation [1] , one at a time, the values of ρ included in one of the three intervals indicated above, corresponding to each of the three behaviours a) b) and c)

Fig. 28



The figure 28 represents the plane M, ρ, limited to the interval of physical significance of M. Three curves divide the plan in four regions.

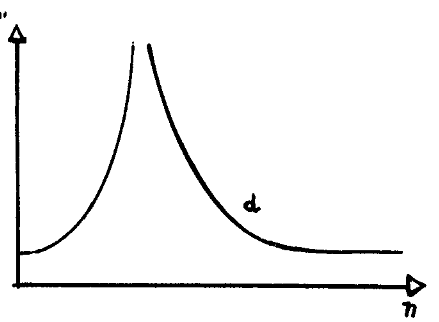


The equation of each curve is respectively :

$$M^2 = 1/\rho$$

$$M^2 = 2(1 - \rho)/\left[1 - 2\rho(1 - \rho)\right]$$

$$M^2 = 2(1 - \rho)$$



so as to obtain the value of ρ needed to build a theoretical curve closest to the experimental one.

Having found in this way the most suitable value of ρ it is easy to find ψ by equation [1] since M and M" are known. Having found ψ we find the product $G\nu$.

For instance, for the fig. 26 the theoretical curve closest to the experimental one is obtained for ρ = 1,0.

Using this value of ρ we choose any point of the fig. 26, for instance, the point corresponding to n = 800 c/s. For n = 800 c/s M" = 60,60 and as M = 0,6 (the depth of modulation transmitted by AFN Frankfurt) we find from equation [3] that $tg\psi$ = 8,0 for which $G\nu$ = 100 . In this way we can draw the theoretical curve of the fig. 26. The theoretical curve of fig. 27 is obtained in the same manner.

Studying the theoretical and experimental curves it is seen that agreement between theory and experience is very satisfactory. The relative values of ρ and $G\nu$ for every diagram are found in the Table No. 2 of the Report No. 1. Some of those values are repeated in the Table No. 2 of this report.

2. - MEASUREMENT OF α

We can also determine directly, by means of [2], the value of ρ because all the parameters are known. As $\alpha = \frac{3}{2}$ (according to Bailey 1937); (Huxley and Ratcliffe 1949) $T = 4.10^{-14}$ erg and $G = 0,9.\ 10^{-3}$, it is only necessary to calculate the value of Wo to find ρ .

To find Wo we use the following equation by Bailey(1937)

$$W_0 = \frac{e^2 \nu E_0^2}{2 m \omega^2} \qquad [5]$$

where $\frac{e^2}{m}$ is the ratio of the square of the charge to the mass of the electron, ω is the angular velocity of the carrier of AFN Frankfurt, and E_o is the peak of the electric field in the ionosphere. The equation [5] neglects the influence of the earth's magnetic field, but this influence is small because $\omega/2\pi$ for Frankfurt differs from the gyrofrequency (1200 kc/s) by 27,34%.

To find the value of Eo we have supposed that the region of selfmodulation is between 80 and 90 km high, that is, in the lower border of the E layer and that the propagation from Frankfurt to Naples is along only one path. So the region of selfmodulation would be located 80-90 km above the earth at latitude 45°30' N and longitude 12°0' E.

As the distance between Frankfurt and Naples is 1116 km the middle point (representing the projection on the earth of the sky zone where the phenomenon occurs) lies at 558 km, and so the peak value Eo of the field, at the end of the radius vector of length r which makes an angle θ with the vertical, is given by :

$$E_o = \frac{14,04\sqrt{W}\cos(\pi/2\cos\theta)}{r\sin\theta} \quad \text{(M.K.S. Units)} \; [6]$$

where W is the emitted power by AFN Frankfurt.

Since $a \cong 90$ km, $r = 558$ km, $\theta = 80°50'$, we have for the power of 50 kW

$$E_o = 0.524 \times 10^{-2} \quad \text{volt/metres}$$

Substituting this value in the equation [5] and keeping $\nu = 1,1.10^5$

$$\frac{e^2}{m} = 2,54.10^8 \quad \text{(U.E.S.)} \; ; \; \omega/2\pi = 872.10^3 \quad \text{c/s}$$

we have $W_o = 1,43 \times 10^{-14}$ erg/second

Substituting in [2] the actual value of Wo and the respective values of G, T and α (α = 3) we find that ρ = 1,49 so that it is greater than the value assumed by us, that is, ρ = 1,0 . The difference between the exact value of ρ , statistically calculated, and that calculated by us using [2] depends on supposing α = 3 as suggested by the authors mentioned above, while we did not use the real value of α , since we could not find it experimentally.

In fact, if we go in the opposite direction, that is, if we substitute the values of ρ (ρ = 1,0) W, G and T calculated in the [2] we find α = 2,005 and not α = 3 as we had supposed.

Since it is possible to determine ρ with accuracy, and also Wo is calculated with sufficient approximation, the equation [2] offers a method of sufficient precision to determine the mean coefficient of total absorption. Naturally we suppose that the values of G and T are correct at the region of the ionosphere where the phenomenon occurs.

It would be possible to determine the height at which the phenomenon occurs if we could transmit alternately on CW and pulses. A transmitter for this purpose is now in operation at the ionospheric station of Nola (Naples) and with this station we will be able to calculate α from the experimental determinations of ρ and also the true height for which α has the value obtained by us.

The Table No. 3 gives some values of α calculated by [2] according to the method indicated above.

For a height of reflection between 75 and 95 Km the value of Eo changes by a small quantity because θ in equation [6] varies and consequently the variation of α would be of the order of magnitude of 10^{-4} .

Table N° 2

N°	Experiment							Values of			
	Date	Hour		% of mod. transmitted	Power kW	Freq. of modulat.				(G=0,9x x10^{-3})	(*)
		from	to			fr. c/s	to c/s	ρ	Gv	v	vo
1	16/1/1958	0115	0252	60	50	30	2000	1,00	300	3,30. 10^5	1,00. 10^4
2	28/3/1958	0115	0248	"	100	30	2000	0,90	1000	1,1. 10^6	1 . 10^4
3	28/3/1958	0115	0248	"	150	30	2000	0,70	1000	1,1. 10^6	1 . 10^4
4	1/4/1958	0115	0248	"	150	30	2000	0,90	45	0,5 . 10^5	0,2. 10^4
5	17/5/1958	0115	0236	"	150	30	4000	0,75	4000	4,4 . 10^6	2 . 10^4
6	21/1/1958	0115	0222	"	50	30	2000	1,00	100	1,1 . 10^5	0,5 . 10^4
7	24/1/1958	0115	0252	"	50	30	2000	0,87	144	1,6. 10^5	0,65. 10^4
8	28/3/1958	0115	0248	"	150	30	2000	0,70	1000	1,1. 10^6	1 . 10^4

(*) v_o is obtained from [4]

Table N° 3

Experiment					Experimental value	Mean coeffic. of total absorption
N°	Date	Hour		Power		
		from	to	kW	ρ	α
1	16/1/1958	0115	0252	50	1,00	2,0048
2	28/3/1958	0115	0248	100	0,90	1,5501
3	28/3/1958	0115	0248	150	0,70	1,4000
4	1/4/1958	0115	0248	150	0,90	1,8032
5	17/5/1958	0115	0236	150	0,75	1,5000
6	21/1/1958	0115	0222	50	1,00	2,0048
7	24/1/1958	0115	0252	50	0,87	1,7427
8	28/3/1958	0115	0248	150	0,70	1,4000

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