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ABNORMAL REGION - E IONISATION.

Abnormal E ionisation, as it is generally called, introduces the main uncertainties in propagation. Skip distances and the pattern of pulses produced by the F layer are quite well defined when there is no abnormal E, but long distance propagation, and the pattern produced by impulses, may be entirely modified or altered by the presence of patches of abnormal E. It may even, if it stretches far enough, produce abnormal long distance transmissions. Its cause is unknown, although it appears to be associated with the same mechanism as produces scatter clouds. At least, there appears to be a perfectly continuous gradation between such scatter clouds and abnormal E. This abnormal E has been studied by Appleton in a paper before the Physical Society "Normal and Abnormal Region-E Ionisation" by E.V. Appleton, F.R.S. and R. Naismith, M.I.E.E. in which a good many of the facts concerning this ionospheric phenomenon are given. The nature and characteristics of the layer produced by abnormal E are now fairly well known, and there can be no doubt that it is a sharply defined region of ionisation within the E layer. It appears to be sometimes very irregular, and sometimes so continuous that it prevents any penetration.

A preliminary analysis of an ionised layer produced by particles suggests that it is very sharply defined. It is also likely to be embedded in the E layer where there are many molecules in an excited state which can be easily ionised by particles.

It is shown here that abnormal E cannot be more than a few wave lengths thick and that all the characteristics observed can be attributed to the thinness of the layer.

ABNORMAL REGION-E IONISATION.

During the past few years this abnormal-E ionisation has been investigated. The cause of it has proved a problem of great difficulty. The investigation described here was carried out in 1941 with a view to understanding something of its mechanism rather than its cause. The investigations were made rather at the end of what may be called "the abnormal-E season", and only recently has the opportunity occurred to observe it again. It is mostly a summer effect. Some of the facts concerning this transmission may be recapitulated. Thus, reflections from abnormal-E occur at frequencies greater than the E critical frequency, which is usually marked by a cusp in the curve of reflection height against frequency. On these frequencies, greater than normal E critical frequency, it is usual to receive both an E reflection and an F reflection simultaneously. At sufficiently high frequency, reflections from the abnormal E cease, but the curves of abnormal E reflection heights do not turn up at the end in the way that is usually associated with the critical frequency. The curves just carry on as straight lines, which peter out at sufficiently high frequency. It may be that the use of a higher power transmitter would make them carry on further, but the evidence that we have suggests that this is not entirely the case. The simultaneous observations of abnormal E reflections and F reflections has sometimes been attributed to partial reflection at this lower layer; but this seems to me to be unlikely. As many as nine reflections from the abnormal E layer have been seen, suggesting that it is a nearly perfect reflection; yet at the same time, F reflections have been observed at good strength. If E had been a nearly perfect partial reflector, very little would have reached the F layer, and there would have been no appreciable F reflections. Again, the reflection from the tops of the abnormal E layer should be as good as from below when there is no attenuation, and if there had been F reflections, there should equally well have been M reflections. These were not observed. It seems to me that the abnormal E layer is patchy. The F is observed through the holes, while the high reflections from abnormal E take place at the denser and thicker patches. Sometimes these holes are filled up. Then the F reflections are no longer observed. The reflections from the E layer are similar to those from a thin reflecting region, and differ from those of a thick region in having no apparent critical frequency. This is such that perfect reflections, or nearly perfect reflections, are received on frequencies which are less than this critical frequency, and no reflections are received on frequencies greater than the critical frequency. It is an all or nothing effect. For a thin layer, the transition is not so sharply defined, and we have to pass through quite a range of frequencies before the signal is lost. In the experiments referred to, measurements were made to disclose this gradual transition. This transition, when it is sharp, is also usually disclosed by the turning up of the height curve. When it does not turn up, it usually implies a thin layer without a very definite critical frequency. Measurements of the field intensity reflected from the abnormal E layer were made with a Type T.M.E. Marconi field strength measuring set. Measurements of the first, second and third echoes were made, so that the average reflection coefficient could be found. The transmitter was situated at Ongar, and was of the order of $\frac{1}{2}$kW radiation power. This was at a distance of 19 km from the receiver. Typical individual curves of the field reflected from the abnormal E are shown in curve Fig.I. Difficulty in obtaining repeatable results was produced by the fact that abnormal E never remained constant. The highest observable frequency - a critical frequency, if you may call it so - often varied quite rapidly; but this was usually, (in the experiments carried out) in the neighbourhood of 6 mc/s. A composite curve has been drawn, which gives the field strength of the reflected signal reduced to a six megacycle maximum frequency. It is the shape of this curve that matters, not the actual critical frequency. It will be seen that on three mc/s, it is considerably less than it would be if perfectly reflected. The signal increases nearer to nearly perfect reflection on 6 mc/s, and then drops off suddenly, so that it drops off 20 dB's in about 0.6 mc/s. It is not quite so sharply defined a reduction as occurs with a thick layer, and by the way that it falls off, an estimate of the thickness of tge layer can be obtained.

We can get a fairly good idea of the shape of abnormal E by studying its composite curve. It is quite clear that the reflection coefficient is fairly low for frequencies of the order of 2 or 3 mc/s, comes up to a maximum near what may be called "penetration frequency", and then, in half a megacycle or more, drops 20 dB's, or so, and finally peters out. This apparent or pseudo critical frequency varies very much from time to time, and we can only get a representative composite curve by referring to an abscissa which is six times the ratio of the actual frequency to this frequency. The type of curve is rather similar to the type of reflection from, say, the E or the F layer, but in these cases there is a very sharply defined critical frequency, beyond which there is no reflection. In the case of abnormal E, this pseudo critical frequency is not very sharply defined, and there are reflections even beyond it. By a knowledge of the behaviour of the curve in this region, the thickness of the layer can be accurately determined. With a thick layer, this critical frequency is very charply defined; with a thin layer, it is not; and it is possible to find out what thickness of the layer will produce a 20 dB. drop in $\frac{1}{2}$ mc. when the average frequency is of the order of 6 mc/s. This calculation has been made, neglecting the earth's magnetic field, but this is not likely to produce major effects at this frequency.

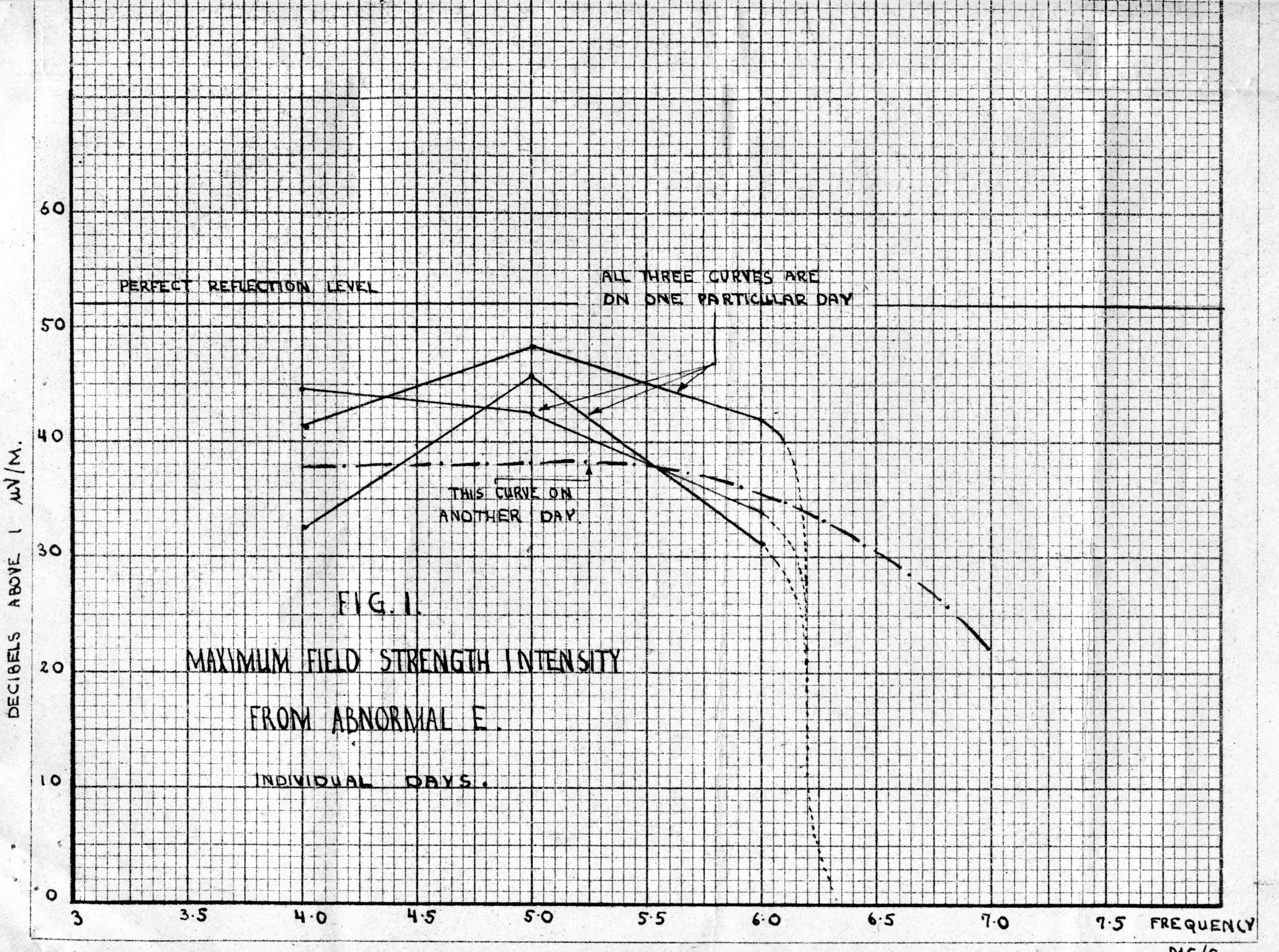
The method used to determine the reflection coefficient of a layer is related to a non-linear solution of the differential equation of propagation. This non-linear equation can be solved arithmetically, and it tells us that a layer of the mathematical form $\sin^2 Z/Z_0$ will produce the observed effect only if it is about three wavelengths thick. Exact thicknesses cannot be given, as they probably vary from time to time, but the composite curve gives a composite thickness of the order of 150 m., and this is the probable order of thickness of the abnormal E layer.

The shape of the composite curve can now be fairly well explained. The sharply defined abnormal E is embedded in the ordinary E layer at a height of 110/115 Km. With sufficiently low frequencies, the wave has to penetrate the ordinary before it is reflected at the abnormal E, and there is consequence attenuation at the bottom of E. As the frequency increases towards the pseudo critical frequency, the attenuation gets less, and the curve rises towards the perfect reflection level. On account of the thinness of the layer, there is no abrupt change at this pseudo critical frequency, and the reflection drops off fairly rapidly, but not absolutely abruptly. It is not an "all or nothing" effect. The behaviour at oblique incidence can be roughly gauged by the use of the equivalence theorem, which is, however, not very accurate for attenuation when the earth's magnetic field is present.

The behaviour at oblique incidence is only approximate, but because the variations of the abnormal E from time to time produce changes that are very large compared with the errors it is hardly worth while considering these errors in detail. There is a maximum usable frequency corresponding to the pseudo critical frequency at vertical incidence. This can be calculated by the usual methods, i.e. by fitting a transition curve onto the observed vertical reflection. The transmission at this maximum usable frequency does not usually carry on beyond about 1000 Km. This is because it is improbable that the abnormal E stretches for long distances. A measure of the probable size of the abnormal E clouds can be obtained by considering the probability that there is, for example, simultaneous abnormal E at Ottawa and Washington, which are 735 Km, apart. This has been obtained from vertical p'f results at both places. The probability that there is abnormal E at Ottawa at the same time as at Washington is very small - less than 10%, so that it is unlikely to have a continuous stretch of abnormal E more than 1000 Km. This accounts for the fact that ultra-short wave transmission by abnormal E at distances greater than 1600 Km or so is very rare. Nevertheless, if it were to extend the whole distance, say between here and New York, it would result in a transmission of very low attenuation. This attenuation can be roughly gauged by applying the equivalence theorem, and although this is not absolutely accurate, the frequencies are so high that the effect of the earth's magnetic field is small. The minimum attenuation occurs at or near the maximum usable frequency, and this is less than a dB or so for every 1000 km, so that if the ray could continue by reflection by abnormal E from, say, England to New York, it would only suffer a total attenuation of the order of 4 or 5 dB, which is small compared with the usual attenuation. But such an extreme spread of abnormal E is very improbable, and this type of transmission is only likely to occur very rarely.

The abnormal E does not seem to vary very much with the sunspot cycle; yet it is very marked when the sun is high in summer. It appears as if it were dependent upon both the radiation from the sun and some external agency which is not affected by the sunspot cycle. This is a suggestion made by E.V. Appleton, and it seems to me to be very probable. A mechanism by which this could be produced is as follows: The radiation from the sun might raise the electrons in the molecules to a high state of energy which can then be easily ionised by the external agency. Then the ionisation by the external agency would depend also upon the amount of solar radiation.

A mechanism by which this ionisation might be produced is by evaporated meteors. Small meteorites coming into the earth's atmosphere will be evaporated and produce streams of particles probably of very high molecular weight. These are very sharply absorbed at a definite height from the layer, and will produce a sharply defined abnormal E, for example. A similar mechanism is suggested for the scatter clouds. This, however, is only a speculation, and should be treated as such. The behaviour of abnormal E in producing irregular impulse patterns of echoes has been considered in another report. As suggested before, it produces the major difficulties in interpreting ionospheric results.


DECIBELS ABOVE 1 µV/M.
0
10
20
30
40
50
60
3
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
FREQUENCY
MC/S
PERFECT REFLECTION LEVEL
ALL THREE CURVES ARE
ON ONE PARTICULAR DAY
THIS CURVE ON
ANOTHER DAY
FIG. 1.
MAXIMUM FIELD STRENGTH INTENSITY
FROM ABNORMAL E.
INDIVIDUAL DAYS.

RD/SK 4171

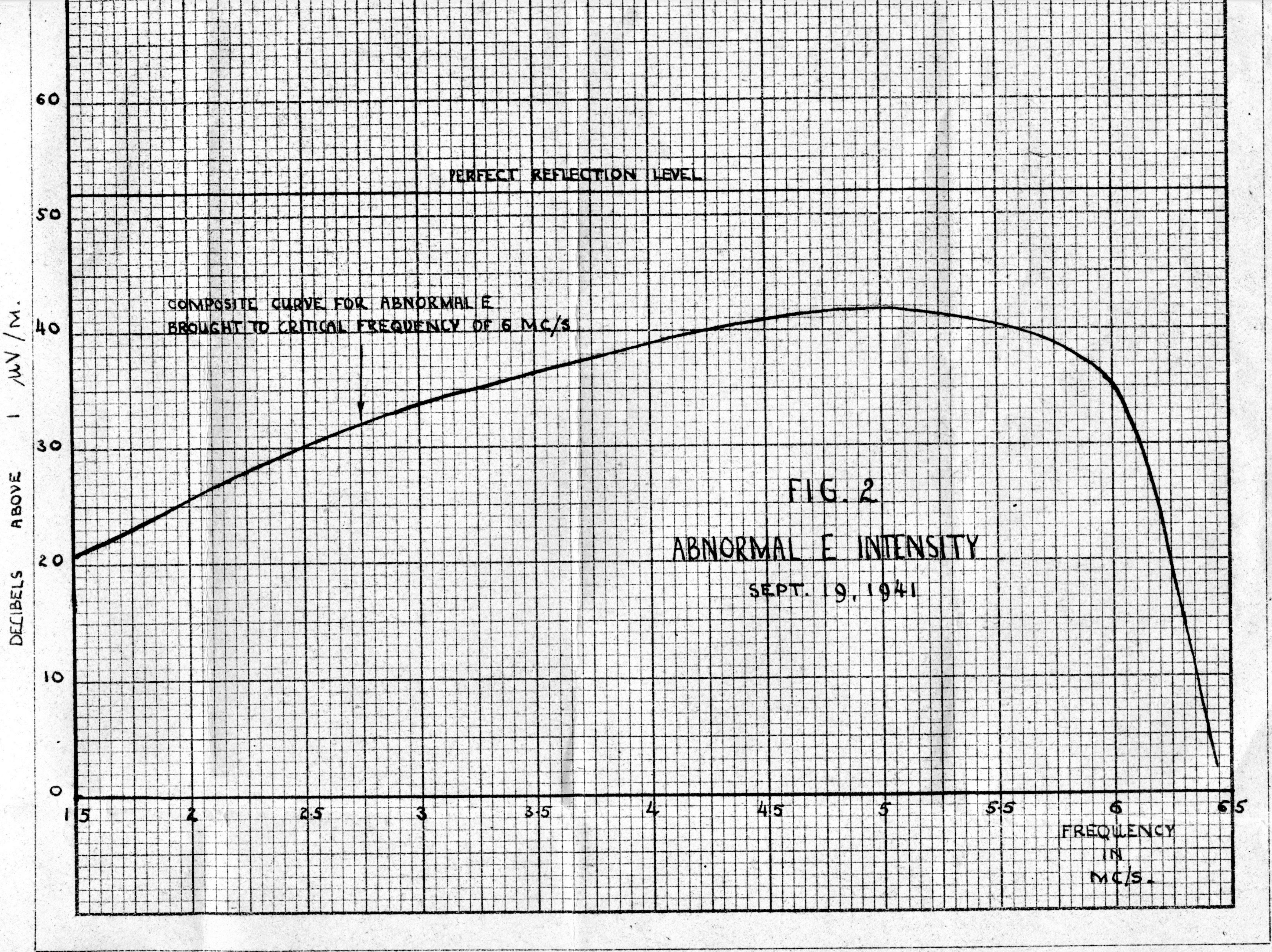


FIG. 2
ABNORMAL E INTENSITY
SEPT. 19, 1941

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