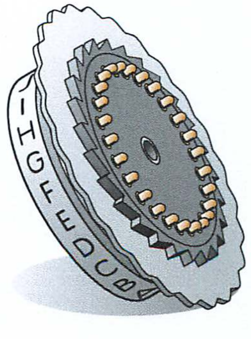
EC Mark III

Easy Chair P.E. Mark IIIA
Final Report

30 June 1959

Project Easy Chair



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Project Easy Chair Mk III A

30th June 1959

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Final Report

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Introduction

As requested in the Memorandum of November 24th 1958 and in accordance with the existing research contract a study was made of the various subjects, as agreed upon; the results of these studies will be discussed in some detail in this Final Report. One item has been given priority, as requested by the Contracting Group; a report on this work has been produced on 15th March 1959 as Report No.1.

1.1. A study of the desirability of having the carrier frequency of a system such as EC - Mk III adjustable over a limited frequency range of minus or plus 50 Mc/s of the center frequency 378 Mc/s.

When experimenting with Mk III equipment under simulated operational conditions one is troubled often by the poor results obtainable from some of the tested P.E. positions in the target area. In fact, as the field strength meter shows at once, these "blind spots" fit into the standing wave pattern set up in a target area when walls and pieces of furniture are in the vicinity. These objects each reflect part of the r.f. power and this reflected power interferes with the incident power field.

This reflection may increase the field strength at some points whilst on other points the field strength is reduced. These points tend to repeat themselves with a spatial periodicity of about one half wavelength of the transmitter frequency used, but in many cases marked discrepancies occur. On some points the direction of polarization of the r.f. field changes by as much as 90°. This is caused by the mutual interference between the individual interference patterns of many reflecting objects in the vicinity.

The dead spots thus found often shift to another position in the target area when the antenna at the base station is moved. This result could also often be reached by changing the transmitter frequency.

In order to evaluate the relative merits of this system for dead spot removal it was intended to set up a simulated target area being as typical for actual conditions as possible. As a test target area a house near the laboratory at a distance of about 40 meters looked very attractive for more than one reason, but unfortunately this house could not be acquired. Other houses in the neighbourhood of the laboratory could not be acquired either, thereby upsetting the intended program. The effort put into the items 1.2 and 1.3 further limited the time left for the item under discussion so that only a few very limited tests could be made. The number of observations is however too small to allow a firm statement to be made.

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In connection with this subject some considerations have to be put forward however.
The possibility of varying the operating frequency of a Mark III system will require the use of a broadband base station antenna, having a relative bandwidth of nearly 27%, when all the figures suggested in the heading of this section are taken as a basis for discussion. The use of a greater number of antennas to cover the frequency band, or the use of a tunable version of an antenna of the yagi type as used with EC - Mk III is for the moment not considered practical.
The average gain of such a broadband antenna, having outside dimensions not exceeding those of the Mk III antennas used now, will be substantially lower than the 17 and 19 dB found for present Mk III antennas. No figures are available to the laboratory but a guess might be that the loss of gain is 6 or 7 dB.
At the other end of the r.f. path the P.E. antenna will also cause a loss due to its selectivity. The single dipole is however better in bandwidth than the multi-element yagi antennas and may therefore be used unchanged. The loss in gain at the edges of the frequency band may for discussions sake be assumed to be 5 dB. The average loss over the frequency band may be assumed to be half that figure, or about 2,5 dB.
The resulting overall transmission loss from transmitter-receiver terminals at the base station to the r.f. input terminals of the P.E. may thus be assumed to be about 9 dB higher than in a comparative fixed-frequency case.
Furthermore it is assumed that the variable frequency transmitter and receiver possess the same power output and sensitivity as the present fixed-frequency equipment. This will probably result in an equipment occupying more packaging space and having a greater weight.
Under these assumptions it will be clear that in order to give equal performance as the present equipment the variable frequency equipment should provide a 9 dB profit by virtue of the frequency choice. To improve existing results this profit should be considerably higher than 9 dB. An improvement of 1 or 2 dB over existing equipment may not be seen as a profit justifying the additional effort.
A profit of at least 15 dB by virtue of frequency choice alone might be the value which would justify the adoption of this technique. This would render the variable frequency equipment 6 dB better with respect to allowable path attenuation than the existing equipment.
The nature of the actual conditions in a built-up area are however such that for a general review of the problem only statistical data are of any significance. This will be clear from the results of propagation tests reported in section 1.6.
The statement above should in our opinion therefore be altered such that a statistical profit of at least 15 dB is to be obtained from the possibility of frequency choice alone before the extra effort would be justified.

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It should be realized also that some parts of the frequency spectrum covered by the variable frequency equipment, although on some occasions optimal for propagation, might be of no use due to the presence of other services operating there such as e.g. aircraft navigational aids.
A profit of less than 15 dB would make it doubtful whether with the same effort the existing fixed-frequency system could be altered to provide higher performance. In this connection the possibilities of higher transmitter power and the use of a more sensitive receiver are conceivable, although the increase in r.f. field-strength in the target area might be objectionable from a secrecy point of view. Furthermore the duplexer balance adjustments, necessary to prevent receiver overloading, would become highly critical, which is undesirable from an operational point of view.

On three single spots of the program reported upon in section 1.6 a limited variable frequency test was made, which failed however to indicate a substantial profit. The impression was obtained that a similar profit or something coming close to it could be obtained by shifting the base station antenna and by using other directions of polarisation for the base station antenna alone.
Not too much weight should however be attached to these results regarding the effects of variable frequency because three single spots are by no means sufficient for a statistical analysis. More conclusive results can only be obtained from an elaborate series of tests carried out under carefully selected conditions which could be regarded as representative for practical circumstances.

1.2. <u>A study of improvements of the secrecy of the system</u>.

During acceptance tests performed by the Contracting Group and the laboratory of the first Mk III equipment it became apparent that under circumstances the P.E. modulation could be picked up by a communication receiver in the area of operation. The pick-up frequency range extended to a few megacycles on either side of the 378 Mc/s transmitter carrier.
This result came more or less as a surprise at that moment and led to a further investigation into the causes and possible remedies of this undesirable characteristic.
The situation was simulated in a test bench set-up, containing all the elements used before in actual experiments, with the exception of the radio path's which were substituted by suitable attenuations and coupling members.
The communication receiver available was an EDDYSTONE model 770 U, continuously tuning from 150 to 500 Mc/s and providing both a.m. and f.m. detection facilities.
It was found that intelligible P.E. modulation could be detected both on a.m. and f.m. on a number of tuning points of the communication receiver, separated by mutual frequency intervals of about 100 kc/s, i.e. the P.E. subcarrier frequency.

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The tuning points adjacent to the transmitter frequency were masked by the strong carrier signal overloading the receiver. This masking effect extended to about 0,5 to 2,5 Mc/s on either side of the transmitter frequency, dependent on the attenuation ratio chosen for the signal paths from communication receiver to transmitter and to P.E.
When tuning points were chosen with larger frequency difference from the transmitter frequency, the amplitude of the detected signal dropped off gradually, not overriding receiver noise for frequency distances larger than about 3 to 8 Megacycles/second, dependent on the choice of the above mentioned attenuation ratios.
The P.E. subcarrier is fundamentally frequency modulated. Two factors can be mentioned which are responsible for the detectibility of subcarrier modulation with the receiver in the a.m. position, namely the residual amplitude modulation of the P.E. subcarrier, and the use of tuning positions of the receiver giving rise to slope detection. The residual amplitude modulation of the P.E. is small for average levels of frequency modulation but becomes progressively higher for modulation levels higher than average.
It was clear that the substantial square-wave modulation of the P.E. r.f. crystal was responsible for the wide frequency band filled with 100 kc/s separated sidebands. If these sidebands could be restricted to a pair of sidebands, one on each side of the transmitter frequency, the masking effect of the transmitter carrier would prevent the detectability of the P.E. modulation to such an extent that only a very specialised and adapted receiver could extract their information. The remedy at hand would be the sinusoïdal modulation by the subcarrier frequency of the reflected P.E. power.
For one thing the transistorized circuit of the P.E. was designed to supply a square-wave modulating voltage to the r.f. crystal with an eye on optimum efficiency in the modulating output transistor. If the requirement for a sinusoïdal modulating voltage exists, the efficiency of this part of the circuit would be impaired seriously. This is also true to a large extent when a filter circuit, only passing the fundamental 100 kc/s voltage, would be inserted between the r.f. crystal and a square-wave producing high-efficiency transistor output stage.
On the other hand the r.f. crystal has a substantially non-linear modulation characteristic. When a sinusoïdal modulating voltage is impressed on the crystal terminals at a level which provides relatively good modulating efficiency, the resulting r.f. modulation is flat-topped and far from sinusoïdal. When the modulating voltage level is reduced to such an extent that the resulting r.f. modulation is virtually sinusoïdal, the crystal modulating efficiency is down by several dB's. (See Report No. 1, section 2.7 and fig.1)
It follows that the desired linear modulation in a P.E. can be realized but at the cost of overall efficiency and system performance.
Research into this direction was not continued but it is up to the Contracting Group to indicate its preference in this respect.
Due to the restricted time available another approach was developped

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and tried out, which eventually could be used separately or in connection with the previous approach.
The idea was to apply a frequency modulation to the base station transmitter of e.g. 50 or 100 kc/s peak to peak frequency swing. This frequency swing would also be present at the P.E. sidebands. The base station would in first instance not be affected by this sweep because the 100 kc/s subcarrier is extracted there from the difference between instantaneous transmitter frequency and P.E. sidebands, both being swept in conjunction.
A third party listening in with a communication receiver on one of the sidebands generated by the P.E. would however be troubled very much by this modulation which in fact overrides the actual voice modulation several times.
One of the existing Mk III equipments was modified to this end and tests were carried out. The desired frequency modulation was obtained by means of a pair of voltage-variable capacitors type 6.8SC20, made by International Rectifier Corporation, El Segundo, California. These "Semicaps" were coupled inductively to the transmitter master oscillator tuning circuit and modulated by the application of audio voltage. Frequency sweeps of several hundreds of kc/s could be obtained, but peak to peak sweep widths during tests were always 50 to 100 kc/s.
These tests were disappointing in several respects. The different causes will be discussed here point by point:

a) Despite the jamming frequency modulation present on the P.E. sidebands, it was still possible to detect the presence of voice modulation at the same time.
Intelligibility of this voice modulation was of course very low, but this was regarded to be of little importance as a third party would not be especially interested in the actual words of the information going out of their area but more in the fact that anything at all was going out, the connection of which with their own area could be ascertained readily.
The jamming frequency was adjusted to three principal values, namely to 50 c/s, to 1000 c/s and to 15000 c/s.
The 50 c/s modulation was least objectionable in the output of the communication receiver, due to the dropping audio frequency curve of the receiver and headphone and also due to the relative insensibility of the ear for these frequencies.
The 15000 c/s modulation itself was not objectionable for the same reasons but had some nuisance value due to the production of intermodulation products between this frequency and the subcarrier frequency. The resulting sound was more or less hiss-like.
Optimum nuisance value was provided by the 1000 c/s modulation but, as mentioned before, this 1000 c/s sound was not enough to mask entirely the presence of voice modulation in the background.
A jamming modulation covering all or the major part of the audio spectrum might however be more effective for this purpose.

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b) A 1000 c/s frequency modulation of the base station transmitter proved to be difficult to achieve without the simultaneous production of amplitude modulation. This simultaneous amplitude modulation was caused by transmitter r.f. tuning circuits not exactly tuned to the top of their response curves. The tuning of these circuits became so critical that in practice no stability to this extent could be achieved over periods longer than perhaps 5 minutes. Duplexer balance controls suffered the same drawback. This Mk III equipment, up to now superior in performance reliability and ease of adjustment to optimum results, was degraded very seriously in these respects.

c) At longer distances between base station and P.E. the inevitable time delay (e.g. 1 microsecond for an actual distance of 150 meters) between outgoing transmitter signal and incoming P.E. signal causes, in conjunction with the frequency swept transmitter, a frequency discrepancy rendering the 100 kc/s sidebands on either side of the transmitter frequency to be no longer symmetrical in the frequency spectrum. The amount of asymmetry can be evaluated simply, but the net results in the receiver output is more difficult to predict. The interference in the receiver output will have a fundamental frequency equal to the original frequency modulation of the base station transmitter. Tests failed to indicate the actual magnitude of this effect because the interference mentioned under (b) did not allow a separation between them.
Critical adjustment of the duplexer balancing controls was able to remove almost all undesired by-products, but in this case we suspect that the interferences from different origins were balanced out to cancel each other.

The laboratory's impression is that the reduction of frequency spectrum occupied by the application of truly sinusoïdal modulation is a possible approach ad hoc at the price of several dB's in performance, but the laboratory regards the masking solution by frequency modulating the base station transmitter as a relatively ineffective and operationally objectionable solution.
The laboratory would like to draw the attention to the arguments used before in connection with the eventual truly sinusoïdal modulation to be obtained from the P.E. subcarrier at the price of several dB's in performance. This sacrifice could be less unattractive when the arguments for the particular requirement reported in section 1.5 of this report are of prime importance. This is for the Contracting Group to decide upon.

1.3. <u>A study of the possible merits of including batteries in the P.E.</u>

This part of the research program has been given priority, as requested in the "Memorandum for the Record" of 24th November 1958, topic 2, as received from the Contracting Group.
This research has been reported extensively in our research report no. 1, dated 15-3-1959. A P.E.-unit taking full advantage of this development was delivered to the Contracting Group along with the report.

In the period after 15-3-1959 a number of similar P.E.'s was made for various purposes and proved to be reproducible quite well.
The bench of batteries under test for life expectancy has since then produced more evidence over a longer period. A new graph including the results will be found in this report, fig. 1.
These results give more ground to the expectation, mentioned in report no. 1, for an actual operating life of these batteries of well over 6 months.
No other battery types were tested since then. A small number of mercury cells and Burgess chrome-protected dry cells have been handed over by the Contracting Group, but the laboratory would like to have some additional information regarding the time elapsed since they were newly supplied or since they were recharged last, as well as data concerning the recharging of these units.
The laboratory advises that in eventual future life tests the actual operating conditions with very low current loading are carried out fully along with accelerated life tests. The final result will take more time to get, but may be more representative and reliable. Such tests would require a larger number of batteries of each type to be supplied, e.g. 12.

In this connection the laboratory draws the attention to the March 1959 issue of "Signal" (Journal of the Armed Forces Communications and Electronics Association), Volume XIII no. 7, page 14 up to and inclusive page 17.
This article deals with new developments in the power source field and mentions on page 17 a magnesium cell, having a capacity of more than three times as much as a regular flashlight cell and retaining as much as 95% of its capacity after two years' storage.

1.4. <u>A study of the performance of the P.E. with regard to improving sensitivity, repackaging and the use of improved antennas for the P.E.</u>

As mentioned in report no. 1 dated 15-3-1959 the existing passive element can have improved sensitivity by using a better r.f. crystal than the type CS2A of British Thomson Houston used up to now. The use of BOMAC crystals types IN21C or 416C is recommended. The overall increase in sensitivity is of the order of 2,5 dB, which allows an extra attenuation on the actual r.f. propagation path of 1,25 dB.

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No substantial improvement can be expected in the Mk III P.E. by the use of different circuitry or different components and transistors. Several new types of transistors have been tried for the Philips type OC44 used now, but no better substitute was found.

Another effort was directed to the reshaping of the P.E.-units. This reshaping was undertaken, bearing in mind the wishes on this subject of the The Hague section of the Contracting Group.
The existing unit was subdivided into three items, namely a center-fed antenna and r.f. crystal, a microphone and a unit containing the transistorized circuitry. A number of situations might be envisualized in which this separation and wired interconnection is quite feasible, but on the other hand a great many instances exist where these units cannot be installed at all, or only with a substantial sacrifice in performance. These cases relate to installation possibilities e.g. a table leg, where only a relatively thin and long space is available. The existing model of P.E. required in this instance that the connecting wires from antenna center box to transistorized circuit unit and microphone would run parallel and relatively close to one of the dipole legs, thus reducing antenna efficiency substantially. Moreover the necessity to drill a hole with a diameter of about 25 mm can be regarded as a requirement which is very difficult to be satisfied under actual circumstances.

The new packaging consists also of a dipole antenna. The halves of these dipole antennas are dissimilar in diameter, one half having an outside diameter of 4 mm and the other half having an outside diameter of about 12 mm. The dipole part having the 12 mm diameter contains the r.f. crystal and the transistorized circuit. Only the microphone is a separate unit.
In order to install this new unit (without the microphone) in e.g. a wooden member, it is necessary to drill a hole of slightly more than 4 mm in diameter for about 360 mm depth and thereafter to increase the diameter of the first 140 mm to slightly more than 12 mm.
From the point of view of installing this can be regarded as an important simplification, whilst full performance is still available. The decreased overall size might also increase the number of installation possibilities.
The Mk IIIA type of P.E. (battery-aided) has also been constructed in this way, but this one has a slightly larger diameter for the thicker half of the dipole, namely 16 mm. This diameter is also in agreement with the diameter of a flashlight dry cell with a coating to prevent the battery contents from damaging its surroundings after the zinc container has corroded through.
For a particular application as asked for by the The Hague section of the Contracting Group a thin type of Mk IIIA P.E. was constructed.

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The outside dimensions of the unit, containing the transistorized circuit and the r.f. crystal unit, were 8 x 22 x 107 mm.
The antenna was attached to this unit by a small screw and consisted of a thin strip of copper foil about 10 mm. wide and about 200 mm. long. The unit and the antenna strip formed a T-configuration.
The electrical tuning of the antenna for this unit in the prpper surrounding was obtained by cutting the strip each time by about 10 mm and measuring the resulting subcarrier at the base station in a short-range laboratory set-up.
The tuning of the antenna of the cylindrical units described before was performed similarly with the exception that the thin half of the dipole had a telecoping rod which allowed easy length adjustments to be carried out.
The length of the adjustable dipole half depends on the nature of the surrounding material. This adjustment under actual or simulated conditions is recommended for optimum performance.
An improvement in performance could be expected by the use of more complicated and sophisticated antenna constructions. A multitude of designs and configurations can be adapted for this purpose.
The possibilities in this respect have been studied and discussed with the The Hague section of the Contracting Group.
Besides the possible improvement in performance only disadvantages are to be expected, however. For one thing the multi-element antennas will require a considerably larger space, which in a great many instances will prohibit their application entirely. Another drawback may be the almost inevitable increase in directional properties of the P.E. This will rule out many installation possibilities in movable objects such as furniture.
Installation in fixed objects requires the correct orientation of the P.E,-antenna and an advance knowledge of the place where the base station will be located.
The installation of a multi-element antenna will certeinly require more time and skill and occasions may exist in which the time to be spent in the target area must be limited to the bare minimum.
In connection with these considerations the laboratory advises to adopt one P.E. model as a general purpose item possessing reasonable performance and maximum installational possibilities. For this general purpose unit the repackaged cylindrical unit is recommended.
When special occasions arise, providing the above-mentioned desirable factors such as time available, space available and the advance knowledge of favourable location and orientation possibilities, the laboratory will gladly go to work on a "tailor-made" P.E. from which improved and optimum performance can be expected under specific circumstances.

1.5. A study of the possibility of the use of multiple P.E. installations in a single target area.

The application of this technique might be desirable for two conceivable purposes:

a) The installation of more than one P.E. in a single room in order to increase the chances of communication by having other possibilities when one of the P.E.'s happens to be in a particular unfavourable spot with respect to r.f. fieldstrength.
It could be envisualized that, when for a given target area a statistical chance would exist of 80% that a P.E. could be picked up, the statistical chances for two P.E.'s at different positions would be that at least one of the P.E.'s could be picked up in 96% of the occasions.
b) The installation of more than one P.E., one in each room, these rooms being close to each other or adjacent, with the intention to overhear conversation at will in either of these rooms.

To begin with, some general remarks can be made about the operation of e.g. two P.E.'s in the same area.
When both P.E.'s are exposed to the same field strength from a single base station the r.f. attenuation between base station and both P.E.'s is equal. In this case both subcarriers will arrive at the base station receiver with equal amplitude. Their subcarrier frequencies will certainly be unequal, thereby producing beat notes in the receiver output which will render the usefulness of either P.E. next to zero.
The choice of widely different subcarrier frequencies for the P.E.'s might be considered, thereby opening the possibility that the receiver i.f. channel by frequency-selective means could choose amongst them. In this connection it should be realized however that the subcarrier modulation characteristic of the P.E, is seriously non-linear, producing multiple sidebands which are harmonically related and spread over some Mc/s on either side of the transmitter carrier frequency. This increases the chances of subcarrier modulation products of each of the P.E.'s coming within a few kc/s of each other, providing possibilities for beat note generation.
Further it must be remembered that the absolute value of the subcarrier frequency in each case is dependent to a large extent on prevailing conditions such as r.f. field strength powering the P.E. and the ambient temperature.
On the other hand it might be considered that, due to the choice of frequency modulation for the subcarrier, interference effects will be less serious due to the inherent qualities of frequency modulation. This is certainly true to some extent. It would be fully valid when the receiver front end would operate linearly, which is not entirely the case because of the relatively large amounts of r.f. carrier power fed to the input. Redesign of the input circuit with consequent change of the system constants would reduce this effect, but would also make the duplexer balance adjustments highly critical.

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An improvement in separation under conditions of almost equal field strength can be expected when a truly sinusoïdal modulation of the subcarrier in the P.E. is ascertained. This could be done, as already outlined in sec. 1.2, by supplying the r.f. crystal with a sinusoïdal subcarrier voltage at a level which causes the crystal to operate linearly. This will cost several dB's of performance however.
Under actual conditions and according to experience gained so far, it is however unlikely, although always possible, that two P.E.'s in a single target area are exposed to the same field strength. In order to prevent the generation of the beat notes mentioned before, it would be desirable to have a field strength difference on the two P.E. positions of at least 5 to 10 dB. This might be realized in the majority of actual conditions by choosing the base station antenna position and direction properly. No guarantee can be given however.
These considerations render the purpose mentioned under (a) partly realizable. In this case it is sufficient that one out of two or more P.E.'s is operative.
The purpose suggested under (b) requires a different operating possibility. In that case each installed P.E. in the same target area must be reached from the base station position, but only one at a time may produce a signal in the receiver output. A favourably mounted P.E. cannot make up for another unfavourably located P.E. Separation of individual P.E.'s is the major problem, to which end some suggestions can be made. Use of truly sinusoïdal modulation at the P.E. will be helpful to a certain extent, but cannot cope with the highest expected difference in path conditions, leading to the presence of a strong unwanted subcarrier along with a weak wanted subcarrier at a different frequency in the receiver. The selectivity requirements for the receiver would have to be very high under these conditions as well as the purity of the sinusoïdal subcarrier modulation.
Another way of separation would be the use of different transmitter carrier frequencies for each of the P.E.'s used. This would call for the possibility at the base station to switch or detune frequency and on the other side for the P.E. to possess a certain degree of r.f. selectivity. This r.f. selectivity should be such that a P.E. tuned to one of the r.f. frequencies would provide e.g. at least 20 dB of attenuation for the nearest other r.f. frequency used. Some degree of r.f. selectivity is present in the form of the half-wave dipole, but this selectivity is not very high. This would call for a relatively large r.f. frequency difference between adjacent channels, or the addition of a high-Q tuned circuit to the P.E.
In addition the transmitter antenna is likely to have insufficient bandwidth for more than one r.f. working channel. Either an extra transmitter antenna for each extra P.E. should be used or one wide-band antenna which will surely result in less gain for a given size.
The extra complexity of the tunable or switchable transmitter and base station receiver, in connection with the above mentioned

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arguments, leads to the question whether the adoption of an entirely different transmitter carrier frequency for the additional channel would be a better solution.
In this case separation can be quite good and if necessary both channels can operate simultaneously.
Moreover the existance of an equipment on an entirely different frequency might prove useful in situations where the propagation of the regular 378 Mc/s, used up to now, is from experience known to be not too good.
It is conceivable also that P.E.'s can be made responsive to both frequencies, so that the installation of such a P.E. provides two chances for missing a blind spot in the field strength pattern.
The availability of equipment on an entirely different r.f. frequency may in addition contain some element of surprise for a third party.
A suitable extra frequency for this purpose could be something of the order of 140 Mc/s. Different propagation properties can be expected in built-up areas for this frequency, but no definite indications as to the general trend are available.
Many more hopes, doubts, suggestions and improbabilities could be added, but these may not help to clear up the picture at present and may well fall outside the scope of this section.

1.6. Testing out of the EC - Mk III equipment under simulated operational conditions.

The objective of these tests was to obtain a sounder judgement of the practical usefulness of the Mk III equipment and to arrive possibly to a set of conclusions as to the recommended ways of installing P.E.'s and siting base stations when some margin in this respect is possible. Furthermore a better approximation of the useful operating range under actual conditions was desired.

1.6.1. This program could only partially be carried out. For one thing time ran out on us and the The Hague Group was unable to secure some suitable dummy target areas surrounding the laboratory.
The following test situations were used:

a) Considerable effort was spent in one target area, which however was inaccessable after the installation of a P.E.-unit. The results and details of these tests are however considered to be of a nature which renders them for the present not suitable for discussion in this report.
b) Another series of tests was conducted from an outside room of the laboratory to a neighbouring house. No access into this house was possible, so only propagation through that house was available. Due to the fact that these tests therefore had to be carried out on the public road, no elaborate investigations were feasible and no numerical data can be given. The indications supplied however a useful knowledge about the way in which subsequent tests would have to be carried out in order to become meaningful and conclusive.

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c) and d) For these tests regular livinghouses of the working-group members were used. These tests used a garage as the location for the base station, whilst the attenuation to a large number of arbitrarily chosen points inside the house was measured.
The points were always chosen with an eye on possible concealment of a P.E., e.g. against walls, in corners of rooms, against table or chair legs or inside cupboards. In each case the P.E.-antenna was set up for vertical polarization.
The houses were built with brick walls about 20 to 25 cm in thickness, had relatively large windows and were furnished in the usual way.
The garages were also brick buildings and had relatively small windows.
For each chosen P.E.-position in the house the base station antenna was aimed, moved and adjusted for the direction of polarization until maximum response was obtained from the P.E.-antenna. This maximum response was considered to be typical for a particular P.E. position in that building.
The transmitter consisted of a test oscillator, modulated with a frequency of 1000 c/s, providing about 0,25 W of r.f. power.
The antenna at this end was a dipole with reflector.
The P.E. antenna was a single half-wave dipole feeding a crystal detector and a high-gain transistorized audio amplifier with audio output metering.
The meter readings were compared with those obtained by the insertion of calibrated attenuation pads, eventually through a process of interpolation. Direct coupling between the transmitter and the measuring receiving set up via calibrated attenuators was also used for reference purposes. These checks were carried out before and after each series of measurements.
The power gain of the antennas was estimated and, by addition to the attenuation figures measured, this led to the figure expressing the propagation loss between a pair of isotropic dipoles under the same conditions.
The actual range in meters was measured, from which the theoretical free space attenuation between isotropic dipoles could be deduced.
Finally, by comparing this last figure with the actual attenuation between supposed isotropic dipoles, a figure indicating the difference between free space propagation [and actual propagation] on the site could be arrived at.
This figure may be called: "building loss".
For each specific chosen position of the P.E. antenna a value for this building loss was obtained. The whole lot of figures was finally elaborated statistically.
For the actual numerical data we refer to section 1.6.2.

The laboratory draws the attention to an article published in "The Bell System Technical Journal", volume XXXVIII no.1, page 197. The article is entitled: "Radio Transmission into Buildings at 35 and 150 Mc/s". The author is L.P. Rice.

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Although the operating frequency is entirely different from the transmitter frequency of Mk III equipment, the data obtained are nevertheless very interesting in connection with the problem under study in our case.
The figures for building loss given in this article are at first sight alarmingly high and would, if applicable to our case, make the entire operation of an E.C.-system under actual conditions very doubtful.
It should be realized however that some of the assumptions in the article do not apply to the E.C.-system.
The article deals with the problem of attenuation between a fixed transmitting antenna, mounted on a roof, and arbitrarily chosen positions anywhere in a building.
The system described in the article is used to provide personal signalling facilities from a central position to a person, carrying around a portable receiver, and being on any conceivable place in a group of buildings. The high values for building loss found in a relatively large number of spots merely indicate the dead spots only too well known from E.C. practice.
The article's assumption leaves out the possibility of moving around one of the antennas in order to avoid propagation between transmitter and receiver to be spoilt by an accidental unfavourable combination of reflections from surrounding objects.
The only figures being of some interest in the scope of this report are the figures for minimum attenuation in every building. These figures indicate a favourable positioning of both antennas in a given built-up and furnished area.

1.6.2. The tests mentioned under (c) and (d) of section 1.6.1 will now be discussed in some detail.
In house nr. 1 tests were carried out in the livingroom and in a spare bedroom on the first floor. In both instances the base station was located in the garage, the distance to the nearest wall of the main house being 15,5 meters. (Fig. 2)
The lay-out of the livingroom, occupying the full depth of the house can be seen in Fig. 3. The various positions of the antenna of the measuring set-up are indicated by numbered dots, corresponding with the numbered positions in Table nr. 1.
The situation in the spare bedroom on the first floor is shown in Fig. 4. The distance of the nearest wall of this room to the base station was in this case 20 meters. Here also the numbered dots indicate the various positions of the antenna of the measuring set-up, corresponding with the numbered positions in Table nr. 1. Between the last mentioned room and the outer wall facing the garage was another bedroom, separated from the spare bedroom by an innerwall with built-in cupboards, containing mainly clothing. The transmitting and receiving antennas had gains of respectively 6.8 and 2.2 dB over an isotropic radiator, making a total difference of 9 dB.
In house nr. 2 (Fig. 5) the same sort of tests were carried out.

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Here also the livingroom (ground floor) and a bedroom (first floor) were examined. The lay-out of these rooms is shown in figures 6 and 7, the numbered measuring positions corresponding with the position numbers in Table nr. 1. In this instant the distance between the base station, situated in the garage, and the nearest outer-wall of the house was 20 meters.
The results of the tests are laid down in Table nr. 1. Although the total number of measurements is too small for a rigid statistical analysis, a 50% figure of the building loss has been calculated. As far as building loss is concerned the following conclusion can be drawn:

Minimum value of building loss	4 dB
Maximum " " " "	21 dB
50% " " " "	11 dB

Generally spoken, this means that for E.C. equipment the working range between houses is shortened in comparison with the free space range with a factor of at least 1,58. The maximum value of this factor might be 10,8, its' average (50%) value being 3,55. This applies of course to houses of the type as used in the tests, but the chances of major deviations of these figures is remote.
If it is assumed that the E.C. equipment has a free space range of 300 meters under optimal conditions, an average house-to-house range of $\frac{300}{3.55}$ = 85 meters can be expected in 50% of the cases.
The predictable minimum and maximum ranges would be respectively

$\frac{300}{10,8}$ = 28 meters and $\frac{300}{1,58}$ = 190 meters.

These figures are based upon the assumption that at the base station an antenna with a gain of 19 dB is used and a path attenuation of 54,5 dB between base station and P.E, is allowable.
If in the path between the two houses bushes or trees are situated, the extra attenuation by these obstacles has to be taken into account. Representative figures of this effect are however not yet at hand, although, according to results obtained so far, it is not supposed that this effect will be too serious.
It will be clear that a non-optimum siting of a P.E. involving a loss of performance of a few dB's can lead directly to a decrease of the probable working range. Therefore it is felt that the use of the repackaged type of P.E., guaranteeing a larger percentage of optimum performance chances under actual operational conditions, must be strongly advised.

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TABLE No. 1

Position	Distance in meters	Free space attenuation in dB, isotropic	Measured attenuation between antennas in dB	Measured and deduced attenuation in dB, isotropic	Building loss in dB	Remarks	
1	21	51.5	51	60	8.5		Positions 1 - 10: house nr. 1, living room
2	22.5	52	55.5	64.5	12.5		
3	22.5	52	57	66	14		
4	19.5	51	51.5	60.5	9.5		
5	20	51	48.5	57.5	6.5		
6	18.5	50	48	57	7		
7	18	50	47.5	56.5	6.5	low position	
8	17	49.5	47	56	7		
9	18.5	50	45.5	54.5	4.5		
10	21	51.5	54	63	11.5	Low position behind fire stove	
11	22	52	54.5	63.5	11.5	low position	Positions 11 - 20: house nr. 1, spare bedroom
12	22.5	52	60	69	17	low position, partly behind chest with iron mounting	
13	23.5	52.5	56	65	12.5		
14	23.5	52.5	58	67	14.5		
15	22.5	52	58.5	67.5	15.5		
16	22.5	52	49	58	6		
17	21.5	51.5	60	69	17.5		
18	20.5	51	52.5	61.5	10.5		
19	20.5	51	54.5	63.5	12.5		
20	23.5	52.5	51.5	60.5	8	behind back of chair with springs	

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TABLE Nr. 1 (continued)

21	18	50	44.5	53.5	3.5	1 m	Positions 21 - 40: house nr. 2, livingroom
22	20	51	50	59	8	1 m	
23	21.5	51.5	50	59	7.5	1.3 m	
24	22	52	50	59	7	1.3 m	
25	22.5	52	62.5	71.5	19.5	transm.antenna horizontal 1.3 m	
26	23.5	52.5	53.5	62.5	10	0.5 m	
27	24	52.5	57.5	66.5	14	0.2 m	
28	25	53	60	69	16	0.7 m	
29	25	53	51.5	60.5	7.5	0.7 m	
30	24	52.5	62	71	18.5	0.8 m	
31	23	52	63.5	72.5	20.5	1.3 m transm.antenna horizontal	
32	21	51.5	52.5	61.5	10	ca. 1.5 m	
33	21	51.5	59.5	68.5	17	ca. 0.2 m	
34	20	51	47.5	56.5	5.5	0.8 m	
35	18	50	53.5	62.5	12.5	1 m	
36	18.5	50	50.5	59.5	9.5	0.2 m transm.antenna horizontal	
37	19	50.5	48.5	57.5	7	0.8 m	
38	21	51.5	53.5	62.5	9	0.2 m (on floor)	
39	23	52	52	61	9	0.5 m	
40	24	52.5	52.5	61.5	9	0.5 m	
41	22	52	49	58	6	0.2 m (on floor)	Positions 41 - 50: house nr.2, bedroom
42	23	52	50.5	59.5	7.5	0.5 m	
43	25	53	56.5	65.5	12.5	0.5 m, transm.antenna hor.	
44	26.5	53.2	61.5	70.5	17	0.2 m (on floor)	
45	26.5	53.2	59	68	14.5	2 m	
46	23.5	52.2	52.5	61.5	9	0.5 m	
47	24	52.5	51	60	7.5	0.5 m, at foot end of bed	
48	22.5	52	58.5	67.5	15.5	0.2 m (on floor), transm. ant.hor.	
49	26.5	53.5	55.5	64.5	11	0.2 m (on floor)	
50	25.5	53	55.5	64.5	11.5	0.2 m (on floor)	

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FIG.1

FIG.1.

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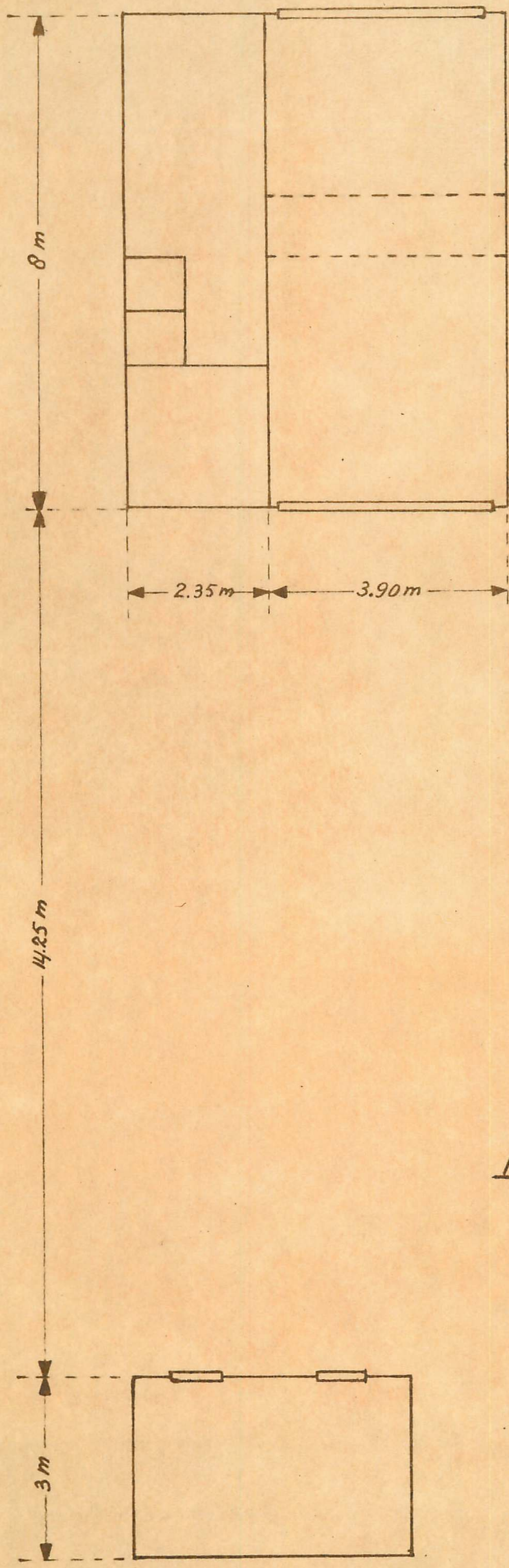

FIG. 2 HOUSE № 1.

SCALE 1:100

SECRET

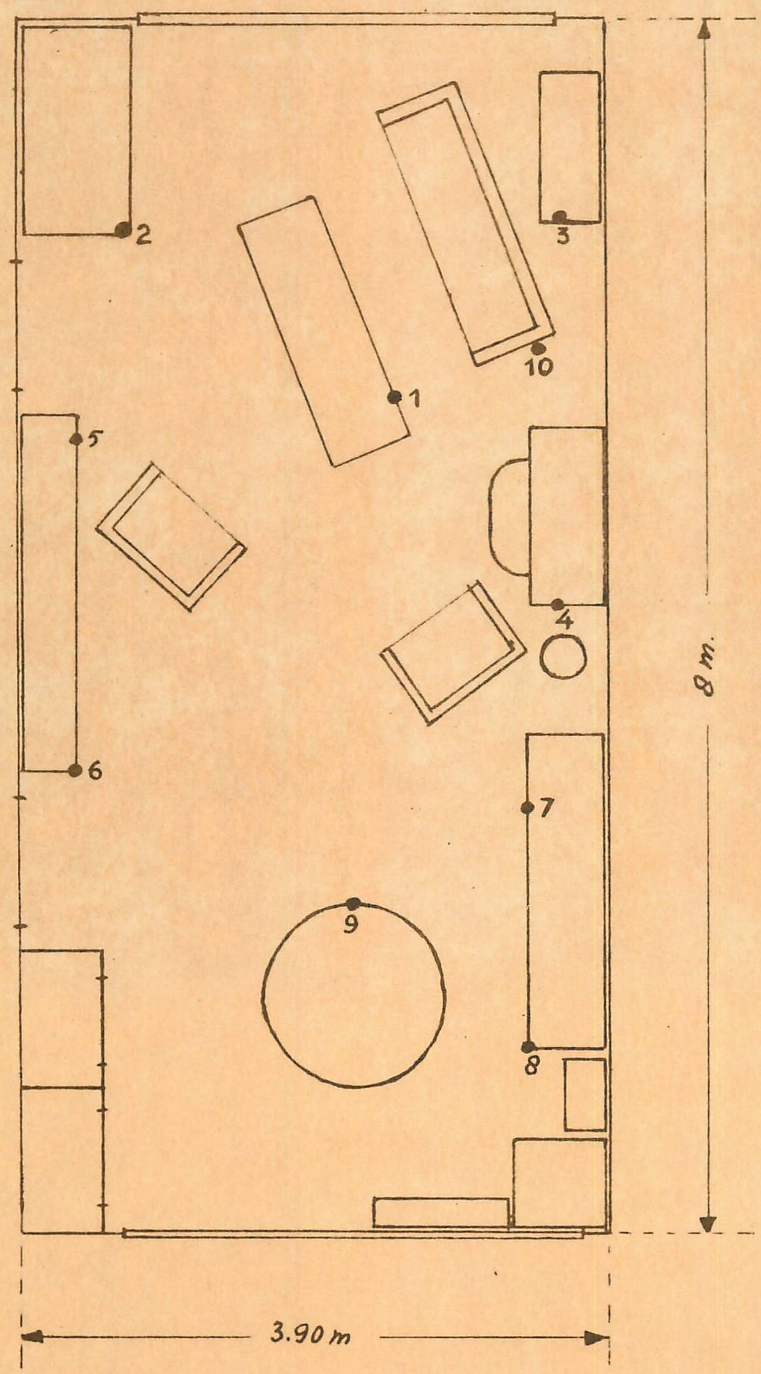

FIG. 3 HOUSE №1

LIVING ROOM

SECRET

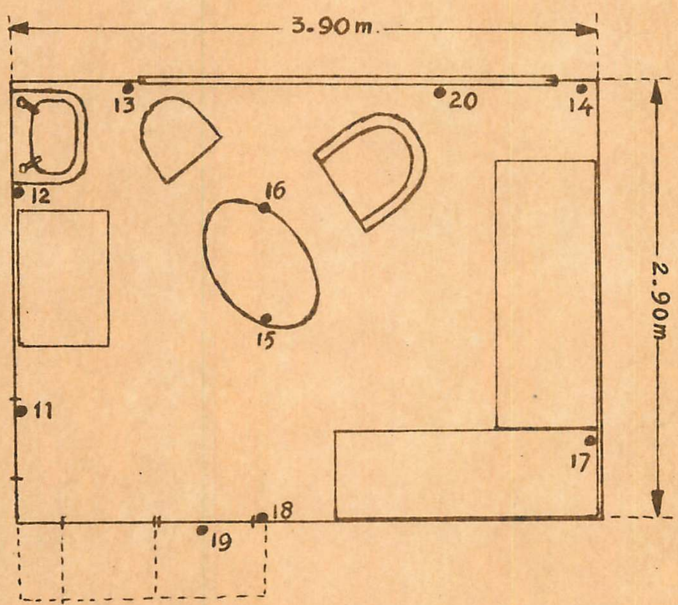

FIG. 4 HOUSE Nº1

SPARE BEDROOM - FIRST FLOOR

SECRET

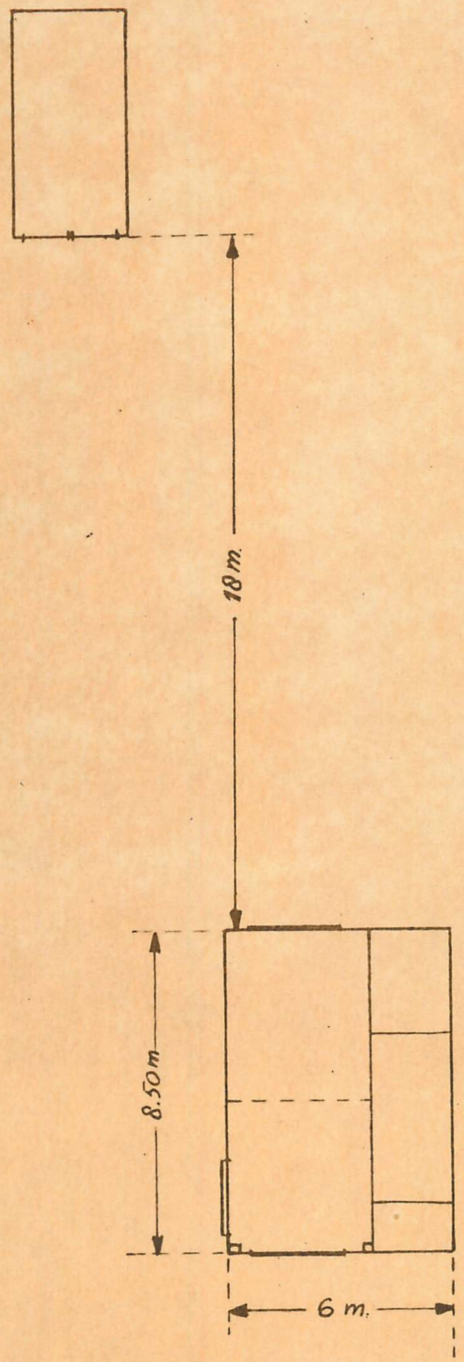

FIG. 5 HOUSE No 2

SCALE 1:200

SECRET

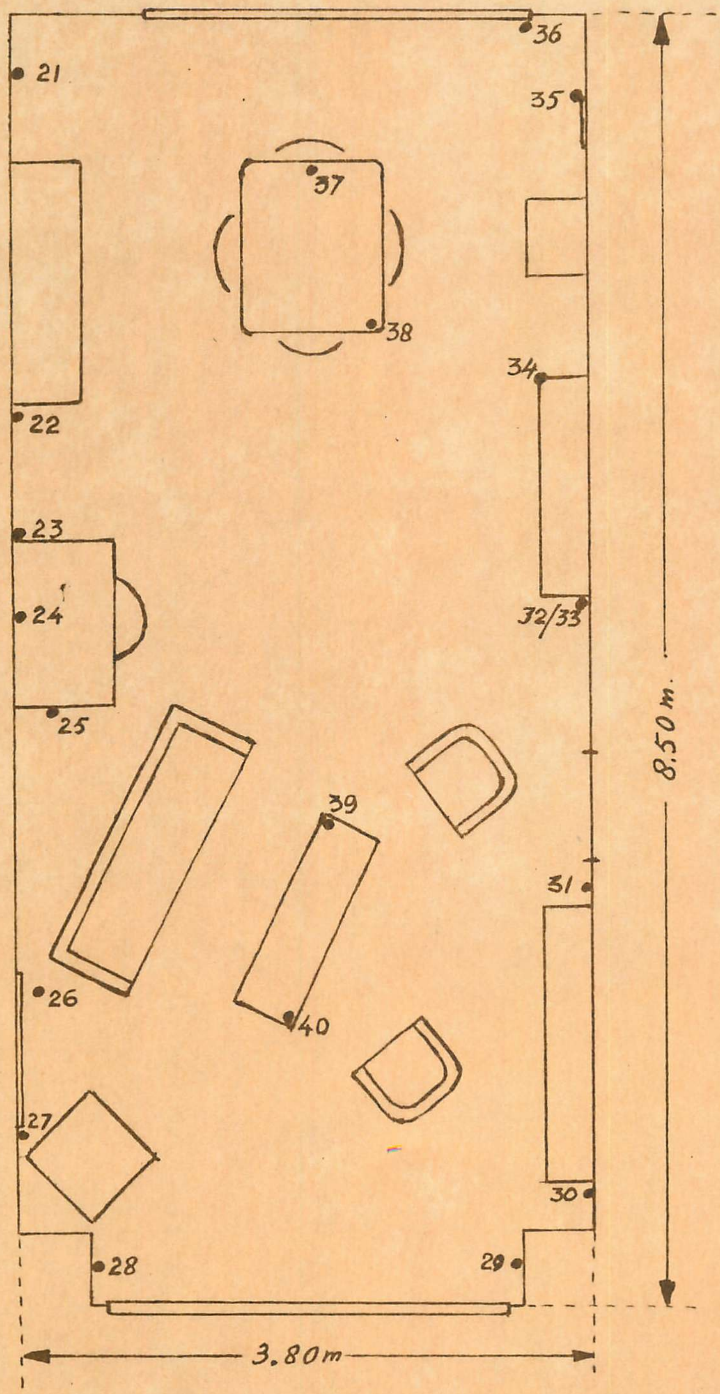

FIG. 6 HOUSE No 2

LIVING ROOM

SECRET

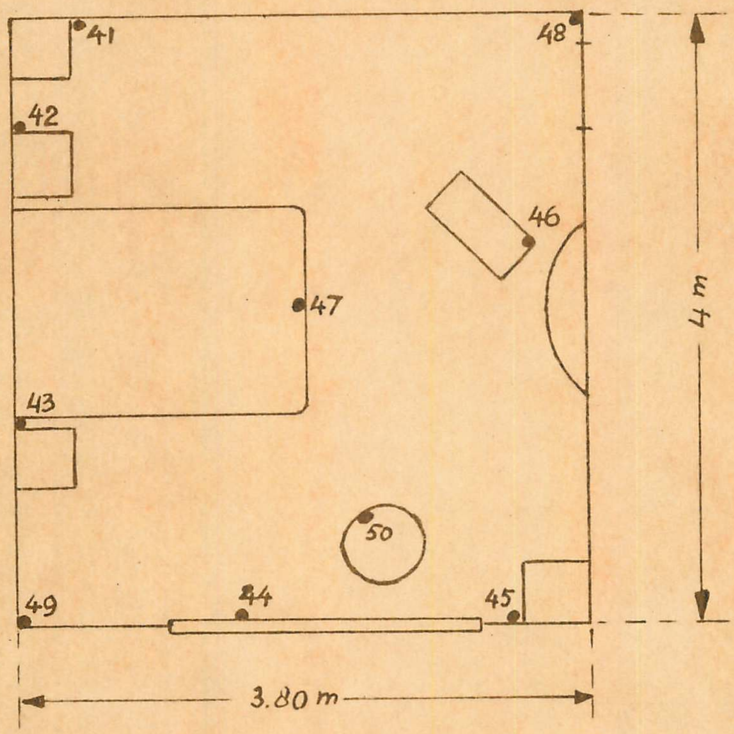

FIG. 7, HOUSE No 2

BEDROOM - FIRST FLOOR