A NEW FIELD OF APPLICATION FOR
ULTRA-SHORT WAVES*

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Summary—In a previous issue of the Proceedings, A. Eissau and W. M. Hahnemann referred to the applications of ultra-short waves and to their being suitable for a precise bundling of radiation. In the meantime, other authors have discussed the same subject. The present paper describes the use of this kind of waves in connection with radio beacons. A new method of forming a guide ray by keeping the reflectors is stated. The dependence of the guide ray upon size, spacing, and number of reflectors is measured. There is no distortion due to reflections. A description is given of the use of the radio range beacon for blind landing of airplanes in thick weather. Simultaneous visual and aural reception in the airplane is possible without changing the method of keeping the transmitter.

The extremely rapid oscillations (10⁸ cycles per second and over) corresponding to wavelengths below ten meters in their very nature are similar to the oscillations of the visible light spectrum. Exactly as in the case of these their range is limited to the straight visibility between transmitter and receiver when the influence of diffraction, etc., is disregarded. Their penetration qualities, however, are considerably stronger than those of the visible rays, for they penetrate fogs or clouds unweakened. Due to their limited range, these waves can be used for telegraph communication only in exceptional cases. They may be used, however, to great advantage wherever the known optical signaling means, such as lighthouses and normal beacons, fail due to poor visibility.

One requirement is imposed on all such optical signals, viz., to cover only a strictly limited angle of the compass card, for example, in order to indicate harbor entrances or to warn of dangerous zones. This necessity, so easily to be complied with in the case of optical lights with the help of reflectors and lens systems, can be met with difficulty only—at least as far as waves longer than one meter are concerned—because of the large dimensions of the required mirrors or reflectors.

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† Numbers refer to bibliography.
until the advent of the so-called radio beacons has it been possible to transmit sufficiently concentrated beams of electric wave energy—especially in times of bad visibility—to make possible a welcome supplement to purely optical signaling systems. It is the object of this paper to show that these radio beacons for short and ultra-short waves can be very simply and efficiently designed, so that an extensive use of this approved system can be foreseen.

The idea of using a comparison of field strengths for the indication of a guiding line was first expressed by Scheller in 1907, and a patent was granted. It is probably due to the stage then arrived at in the radio art that this new method of direction finding was not adopted for general use. Only individual trials, carried out with more or less success, showed that engineers became interested now and then in this sort of equipment. The experiments of Kiebitz are especially worth mentioning. It was not until aviation with its long straight routes became a common means of traffic that the simplicity and usefulness of the guide ray system was again recognized, and credit is due to the U. S. Department of Commerce, the U. S. Army, and the Bureau of Standards that the radio beacon for long waves has been developed to its present state in the art.

Although this system is well known, a short description will be given here. If two directional radiators are arranged in vertical direction with respect to each other and transmit complementary signals (for instance $a = \cdot \cdot -$ and $n = \cdot \cdot -\cdot$) in such a way that these signals are combined into a uniform permanent signal, they will produce the so-called guide ray or equal-signal zone defined by the line connecting the places where both signals are received with equal intensity. An airplane or boat moving on such a line will receive a permanent signal in its radio receiver, but when deviating from that line, it will receive the signal (either $a$ or $n$) with the greater intensity which is assigned to that side by the directional ray system. A variation of this idea is the modulation of the two directional transmitters with different tone frequencies, and the comparison of the intensities of these two sounds by means of a reed frequency meter or of a rectifier with milliammeter, respectively.

At first sight, it seems natural to use crossed horizontal dipoles as directive antennas when applying this idea to the short-wave field. Such an arrangement will, however, be liable to cause considerable misdirections because then a horizontal dipole is also necessary for the receiving station, and because such a receiving antenna will have its own directional characteristics. Consequently, and in conformity with the relative position of the receiving with respect to the transmitting
aerial one or the other of the two complementary signals will be preferred in the equal-signal zone.

It results therefore that only vertical polarization is admissible. On this basis it has been found possible to develop a simple method of keying antenna reflectors which is especially adapted to the principle of radio beacons.

![Diagram](image_url)

Fig. 1—(a) Propagation of transmitting dipole $S$ and reflector $R$. (b) Propagation diagram of transmitting dipole $S$ with two reflectors.

With the help of a reflector dipole coupled by radiation and arranged in parallel with the vertical transmitter dipole, it is possible to establish a great variety of field distortions depending on the lengths of the reflectors and their distance from each other. Length and spacing of the reflectors may be chosen in such a manner that the propagation diagram given in Fig. 1 (a) will result. If a second reflector of equal characteristics is mounted on the other side of the transmitting dipole.

![Diagram](image_url)

Fig. 2—Circuit of keying equipment for ultra-short-wave beacon. $S$ = transmitter dipole. $R_1$ and $R_2$ = reflector dipoles.

alternating in operation with the first reflector, as shown in Fig. 1 (b), the pilot ray is formed along the line connecting the points of equal field strength. The keying is simply effected by relays interrupting the reflector wires in their current antinodes (centers). This can be done with advantage by designing one of the relays with make contacts and the other with break contacts, so that only one kind of signal has to be keyed. The load on the transmitter itself remains uniform. Fig. 2 shows
the fundamental circuit of this equipment. The transmitter feeds the center dipole uniformly. Merely by keying the reflectors the radiation is directed once to the one side and again to the other side. Fig. 3 shows the construction of the antenna equipment for an 8-meter wavelength which has been in use since last year. Fig. 4 is a view of the 4-stage tourmaline controlled experimental transmitter for 70 watts modulated output, and of the keying motor for the relays.

Fig. 3—Ultra-short-wave beacon, Berlin-Tempelhof airport.

In conformity with the nature of the method of its production the pilot ray is independent of interference due to undesired reflections except very close to the beacon. In the case of short waves, simple direction finding by means of a loop antenna is disturbed by any incidentally existing reflector, even if this reflector may be tuned only approximately to the proper wavelength of the beacon. This leads to great deviations in practice. On the contrary, the pilot ray of this short-
wave radio beacon is absolutely rectilinear, as may be seen from Fig. 5. Here are shown measurements made on a beacon (2 watt output, 7 meters wavelength) over unsuitable ground. Neither the telephone line on the main road (see point 1 in Fig. 5), nor the railway line (point 3), nor the canal (points I and II), nor the forest (points III and IV) cause the least deviations.

An undesired reflector fed from the field of the beacon has no great influence at places far distant from the transmitter or from the zone of equal intensity. It cannot cause a disturbance unless its lateral distance from the pilot ray amounts to only a few wavelengths and is located in a place where the two field strengths are essentially different. This, however, is the case only in the close vicinity of the beacon. At all the other places the undesired reflector changes only the field strength in the equal-signal zone, but causes no distortion because it reflects only the desired signal and cannot reflect the signal from the other side of the course. The measurements given in the following table confirm these considerations.

For a discussion of the possibilities of using ultra-short-wave beacons, especially for harbor entrances and for similar safeguarding by means of pilot rays, it is necessary to know the precision of the guide
TABLE 1
\( \lambda = 7 \) meters

<table>
<thead>
<tr>
<th>Distance of Reflector from the Zone of Permanent Gain</th>
<th>( \lambda / 2 )</th>
<th>( \lambda )</th>
<th>( 3/2\lambda )</th>
<th>( 2\lambda )</th>
<th>( \lambda / 2 )</th>
<th>( \lambda )</th>
<th>( 2\lambda )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage of Energy Alteration by Reflector</td>
<td>+53</td>
<td>-35</td>
<td>-23</td>
<td>+50</td>
<td>-32</td>
<td>-20</td>
<td></td>
</tr>
<tr>
<td>Prevailing Signal</td>
<td>n</td>
<td>n</td>
<td>n</td>
<td>n</td>
<td>n</td>
<td>n</td>
<td></td>
</tr>
<tr>
<td>Corresponding Deviation of Guiding Line (in degrees)</td>
<td>1.5</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>0.5</td>
<td>0.75</td>
<td>1</td>
</tr>
<tr>
<td>Distance from the Transmitter</td>
<td>50 meters</td>
<td>200 meters</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

line actually obtainable. Assuming that a difference of 5 per cent between the two field strengths will suffice for securing distinctly perceptible indication, the width of the guiding beam will be about ±1 degree in the case of a long-wave four-ray beacon which originates two lemniscate diagrams normal to each other. If the directional diagrams are produced by reflectors coupled by radiation, as described above, the sectional angle of the curves of equal field strengths is subject to the influence of both the distance of the reflectors from each other and to

Fig. 6—Width of equal-signal zone, (field strengths differing 5 per cent or less), as a function of reflector distance and reflector length.

the length of the reflectors. The separation controls the phase of the exciting field relative to the oscillator itself; the length of the reflectors controls phase and amplitude of the counteracting field. Fig. 6 shows two curves which have been found experimentally for the field strength ratio (5 per cent) mentioned above using the 7-meter wave. The diagrams, however, can be essentially altered according to the method by which they are produced. It is possible to obtain different characteristics all having the same sectional angles. Fig. 7 shows a variety of curves for constant distance between the reflectors and variable lengths of reflectors. Fig. 8 illustrates the influence of reflector distance for constant length of the reflectors.
The latter two figures show that there exist a great variety of possibilities. By adding a third reflector for example the reverse part of the guide beam can be nearly completely eliminated so that only one pilot ray (Fig. 9) results. With this arrangement a certain section can be marked also simply by simultaneously connecting and disconnecting two of the three reflectors (see \( R_1 \) and \( R_2 \) in Fig. 10). The desired combination may be chosen in accordance with the special conditions to be met with.

In the following an especially important application of the radio range beacon principle is described, viz., its use in connection with thick weather flying and blind landing of airplanes. Experience has shown that, when clouds are about 40-50 meters above ground, it is
sufficient if the pilot receives the direction of the airport approaches and a signal at the spot where he can safely penetrate the clouds in order to arrange for his landing ("thick weather landing"). The arrangement described before is especially suited for this purpose. The direction is indicated by the beacon; the signal for penetrating the

![Diagram](image1)

**Fig. 9**—Pilot ray in one direction obtained with three reflectors. \( R_1 \) and \( R_2 \) are keyed alternately. \( l_a \) refers to reflector length, \( d \) to reflector distance.

![Diagram](image2)

**Fig. 10**—Same beacon as in Fig. 9. Reflectors \( R_1 \) and \( R_2 \) keyed simultaneously for marking a sector.

clouds is given when the plane is just vertically above the beacon by an interruption of the reception, since in the case of vertical polarization no radiation takes place within a cone of a certain angle above the transmitting dipole.\(^9\) It is therefore useful to erect the beacon a few hundred meters before the airport's boundary in the direction of the approach.

A wavelength below 10 meters proves to be extremely useful for this particular purpose. The range of these waves being limited, all airports can work with the same landing wave, without causing any mutual
interference. This simplifies further the apparatus necessary in the airplane as well as its maintenance. Inasmuch as radiation into the open atmosphere is concerned, the range, on the other hand, is so large as to allow a sufficient field strength for reliable reception at 23-30 kilometers if the airplanes are flying at a height of 300-400 meters. Moreover, as experience shows, these waves are not subject to fading and the receivers operate uninfluenced by atmospheric noises. Finally, the antennas have rather small dimensions even with a most favorable radiation efficiency and, therefore, the whole transmitter including the antenna can be established as a truck station, in order to be located in accordance with the actual wind conditions.

Last winter such an equipment was tested at the instigation of the Deutsches Reichsamt für Flugsicherung (German Board for the Protection of Aircraft) and in close cooperation with the Deutsche Luft Hansa and the Deutsche Versuchsanstalt für Luftfahrt (German Research Institute for Aviation) at the airport of Berlin-Tempelhof. The apparatus was supplied by C. Lorenz Aktiengesellschaft (see Figs. 3 and 4). The receiver used was a 4-valve audion detector set, and the receiving antenna in the airplane was a vertical rod about 60 centimeters in length.

The flight tests proved that the equipment complied with the requirements set forth. The direction transmitted by the beacon was distinctly noticeable when approaching the airport. It was found advantageous to work with a relatively great width of the course indicating ray (3 degrees). Smaller width can be easily established as shown in Fig. 6. The increasing volume of sound, when approaching, permits rough estimation of the distance from the airport. The cone within which no reception above the transmitter is possible, had an angle of about 60 degrees; i.e., when passing the transmitter equipment at a height of about 200 meters there is no reception for a duration of about 4-5 seconds. This zero zone is also perceptible when the airplane passes the transmitter laterally outside of the pilot ray, and it is of such a characteristic nature that it is easily distinguished from temporary or casual failure of the receiver.

The question of where to install the radio beacon on the line of approach is determined by the size of the landing field and by the angle in which the airplane glides when landing. This is due to the fact that the nonreception of the guide signal indicates to the pilot that he is to start landing. The use of the radio beacon for blind landing solely with the aid of measuring instruments will be dealt with in a special paper as soon as certain experiments undertaken in cooperation with the Deutsche Versuchsanstalt für Luftfahrt have been completed.
According to experience gathered by numerous flight tests, it can be assumed that in certain cases visual indication is an advantage for the control of the course deviation and of the guide signal. While a number of pilots were of the opinion that the eye of the pilot, especially at blind flight, is already overloaded by the number of instruments to be watched, and that an audible signal should indicate the direction, there were others who expressed the idea that it is impossible to see and hear, to watch and listen with full attention because the ear ought to be free for controlling the motor. Therefore, a method has been developed which with the same keying of the transmitter allowed simultaneous visual and aural operation.

The keying signals employed for this simultaneous indication are short dots and long dashes, respectively, transmitted in the time ratio of 1:8 or 1:10. This method of signaling has been found especially clear also from the acoustic and physiological point of view, because these signals can be distinguished more easily than a or n even by an unexperienced ear. The simultaneous visual indication is obtained by the deflection of an instrument pointer in accordance with the course deviation. In order to have the two kinds of signals cause a deflection of the pointer to two different sides, the following solution was arrived at: If the rectified signals are transmitted via a transformer (Tr2 in Fig. 11), only the beginning and the end of the signals will become effec-
tive at the secondary side of the transformer. Therefore, the impulse starting a dot, for instance, will deflect the pointer of a direct-current instrument to the left and at the end of the dot will deflect it to the right, whereas at the end of a dash the pointer is deflected in the reverse, i.e., first to the right and then to the left. If the instrument is of a suitable slow-acting type and provided with means to minimize its sensitivity with increasing deflection (see Fig. 12), the pointer will respond only to the first impulse deflecting it from the zero position. The instrument will, however, not be sensitive enough to react on the immediately succeeding reverse impulse as this impulse finds the instrument still in a position of reduced sensitivity. The pointer then reaches the zero position in the long interval between the dots or in the interval

![Diagram](image)

Fig. 13.—Method of visual indication.
I = signal in dot zone. II = signal in dash zone.
(a) = low-frequency currents in headphones at receiver output for acoustic indication.
(b) = anode current of rectifier.
(c) = secondary voltage of transformer Tr 2.
(d) = movement of instrument pointer.

indicated by the dashes. Fig. 13 (a-d) explains this method by which the pointer of the instrument is deflected in one direction by any dot radiated from the transmitter, and after having slowly returned to zero is deflected in the opposite sense by any dash. The required sensitivity characteristic of the instrument can easily be attained by suitably shaping the pole pieces of the magnet.

By biasing the rectifier (Fig. 11) and increasing the transformation ratio (of Tr1) it is possible to obtain a considerable sensitivity so that the width of the ray found by comparison of the acoustic signals may forthwith also be measured by visual signals.

A second instrument which is connected to a copper-oxide rectifier and to the output terminals of the receiving set indicates the distance from the transmitter of the beacon and the cessation of reception above the beacon. In the case of an approach on the proper course the pointer
of the direction finding instrument will maintain its center position, while the deflection of the instrument measuring the intensity will increase more and more as the airplane approaches the beacon.

Tests with a radio beacon of a similar type were made last summer on the beach of the Baltic near Swinemünde for harbor approaches. Also in this case the results obtained are very satisfactory although the precision of the ray has to be increased for some purposes. These tests will be continued this summer.

Summarizing, one can conclude that for ranges of about 30 kilometers ultra-short-wave beacons form a simple and consequently safe means for securing guide lines by pilot rays. Their special advantages are their limited range, their freedom from atmospheric interference, the absence of fading phenomena, and the small dimensions of the necessary antennas.

† H. A. Chinn observed ranges greatly in excess of this distance. The author regrets very much that his report in these PROCEEDINGS, June, (1933), was not published before the present paper was completed.

Bibliography*

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* Further literature references may be found in the papers mentioned and in an essay of H. Fassbinder, Hochfrequenztechnik in der Luftfahrt, page 492, (1932).