OBSERVATION OF CONSOL SIGNALS AT GREAT DISTANCES WITH SPECIAL EMPHASIS ON THE SO-CALLED « PEILTAKT » PHENOMENON [1]

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By Walter STANNER

INTRODUCTION

It seems to me that the radio navigation systems « Radio Mailles » and « Navaglobe » which have just been explained to us in the course of this session are very ingenious, but still rather complicated. Since, up to now, they have not yet gone beyond the experimental stage, no proof can be offered that the figures communicated on range and accuracy may ever be reached by ship and airborne receivers. On the other hand, the Consol system of which I am going to speak is not at all complicated and yet could theoretically be of very high operational accuracy if there were not certain unfavourable ionospheric influences. There exist two main types of errors, the usual random polarisation errors, and a systematic error due to the fact that when reflected rays are being used, the path lengths from the Consol aerials to the receiver aerial do not bear the ideal ratios assumed with respect to the ground rays with the result that there is a phasing error. Under favourable conditions Consol signals can be received at great distances, but the useful range is usually limited by interference, for which atmospherics and other transmitting stations are responsible. Numerous trials to determine the operational accuracy of the Consol system have been conducted by many observers under various conditions and at various times, but a direct comparison of the results obtained is not possible. Convincing results may therefore only be expected if at a selected site a few experienced observers can monitor the five European Consol stations at the same time using the same equipment.

OPERATION « BERGDOHLE »

With this end in mind, we initiated « Operation Bergdohle » at our station at Garmisch-Partenkirchen, located in the southernmost part of Germany at the foot of the Bavarian Alps. In view of the fact that this town is famous for the beauty of its mountains and as a centre for winter sports, it may be considered surprising that trials which usually take place in airplanes, aboard ship or in coastal regions could be successful in this area. Several of my colleagues were extremely sceptical, believing that results worthy of evaluation could never be obtained at such a place, an objection which had already been raised in connection with our short-wave station operated at the same location about 20 years ago (call-sign : D 4 UAO). Disregarding all this talk, we waited for a night with low atmospherics

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(1) « Peiltakt » : bearing rhythm.

in order to listen to whatever happened, and I confess that I myself was much astonished when at once and without difficulty we heard the familiar Consol signals of Stavanger, Bushmills and Ploneis. This was the beginning of the « Bergdohle » tests.

AURAL OBSERVATIONS

From this time on we monitored these stations. A survey regarding favourable receiving conditions for the five European Consol stations is contained in Table I. I should like to mention that during the summer atmospherics are very troublesome. The counting of the dots and or dashes emitted by the two Spanish stations becomes practically impossible when listening through ear-phones owing to interference by other transmitters on the same frequencies. Later on, however, we succeeded in measuring the equi-signal time by a visual method.

Table II shows characteristic data such as the calculated true bearings, the corresponding dots or dashes, the number of the sector, range, etc. The first period of our observations revealed that at our station the deviation of the equi-signal zone in day time amounts to $\mp$ 1 - 2 signs. During the night deviations are caused by night effect which, however, can easily be recognized as such. Counting the signs emitted by Lugo — destined to be received only on winter nights (see Table I) — we always found a deviation of about 10°, whose cause has so far not been established, although there is some hope that further investigations during the winter period of 1955/1956 may lead to the explanation of this error. We are especially pleased to point out that the bearing of the Stavanger beacon is fairly constant, since the angle between the line from Stavanger to « Bergdohle » and the line of aerials at Stavanger amounts to only 4.3°. This means that the bearing takes place in the most unfavourable part of the so-called « unreliable sector ». The observations made, however, over a one-year period have not revealed any special facts which might justify the application of the term « unreliable sector ».

To avoid any mistakes we expressly state that the results published in this paper are not to be regarded as general inasmuch as they depend upon a coincidence of several favourable conditions. An interesting example as to results obtained at another monitoring station (weather ship), communicated to us by courtesy of the Director of Telecommunications, London, is given in Table III. These may be considered as additional proof that in a favourable geographical position, accurate bearings on Consol beacons at great distances can be obtained without any special equipment.

EQUIPMENT FOR VISUAL OBSERVATION

Due to the fact that the values of bearings calculated almost perfectly correspond with the results actually obtained, we decided not to go on with aural observations, primarily intended for the calculation of exact figures of the standard deviation and the mean error, but to devote our time to investigations of certain short-time fluctuations observed some years ago by ships equipped with new cathode ray tube direction finders. These fluctuations, which you cannot hear but only see on the screen, are in perfect synchronism with the dot dash keying of the aerials of the Consol stations. It was our intention to take up this matter more intensively, and for this reason we set up a combination of two crossed loops with two receivers and a cathode ray tube as shown in Figure 1.

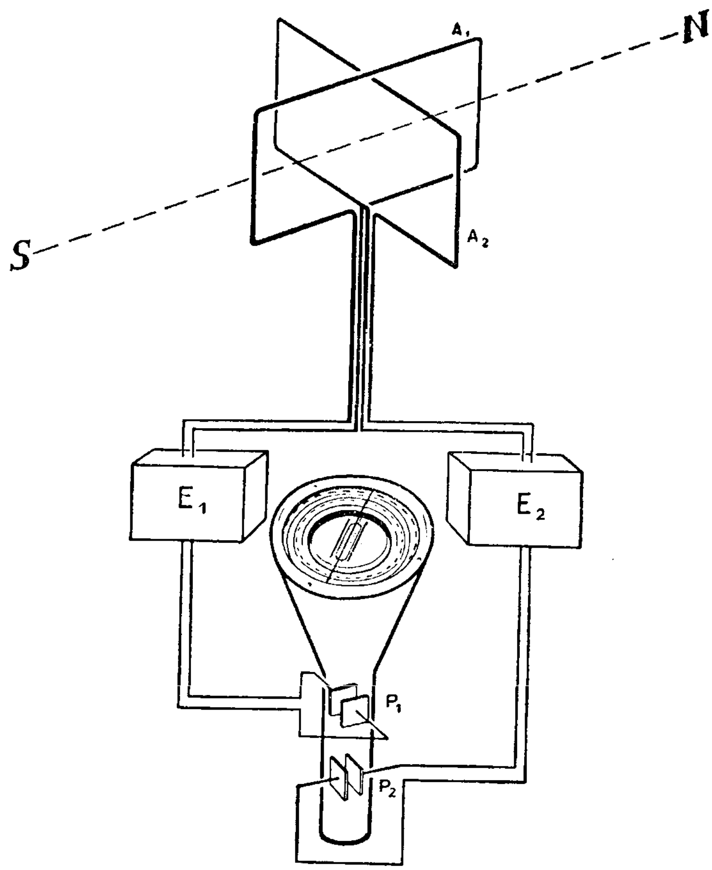

Fig. 1.
Block Diagram of the Direction Finder.
(C. Plath GmbH, Hamburg.)

The aerial A_1 is connected with the receiver E_1 and the output is applied to one pair (P_1) of plates of a cathode ray tube. In a similar manner the aerial A_2 is connected with the receiver E_2 the output of which is applied to the other pair of plates (P_2) of the cathode ray tube.

The two receivers are of high sensitivity and selectivity and must be tuned for symmetrical amplification by means of a special circuit.

A normally polarized wave is indicated as a straight line on the screen of the tube, the direction of which corresponds with the direction of the incoming wave, which means that the bearing from the receiving station to the transmitter can be read direct from a scale when the direction of North is determined. When receiving signals from two stations in different directions on the same frequency, the above-mentioned straight line spreads and takes the form of a parallelogram.

The direction of its sides indicate the bearings to these two stations. Night effect gives a variety of types of ellipticity in the trace, which at times is circular, and at times forms an ellipse in directions widely divergent from the main direction.

The fundamental principle of such equipment, for the first time produced by the Radio Research Board (R.A. Watson-Watt and J. F. Herd), was published as early as 1926. The chief advantage of the visual type of indication of a bearing is in dealing with very short signals and in short-period fluctuations. On the other hand, generally speaking, operating the twin-channel direction finder in practice is not in every respect superior to the aural method, because the image appears rather complex, due to the fact that it is usually in a state of perpetual change and may be somewhat confused by noise. The complete lack of inertia of the beam is ideal for research work.

When receiving radiations from transmitters with non-directional aerials, the bearings as indicated by the trace on the screen should be constant and there is no reason why any fluctuations should occur whether or not the carrier is keyed, or whether or not it is modulated.

This statement has on large scale been proved by thorough observations of both non-directional beacons and several broadcasting stations located in various directions. Some non-directional aircraft beacons in particular, as shown in Table IV, can be received with very high field strength all day and all night long. The trace on the screen of the cathode ray tube in the twin channel direction finder with all these bearings extends throughout the length of the diameter. When the call of a non-directive beacon is keyed the carrier disappears during the intervals and the trace returns as a light spot in the centre of the screen. Afterwards it extends in the same direction. I am spending somewhat more time than you might think necessary for the explanation of these partly well-known facts, but this is in order to convince you that the equipment used by us is perfectly reliable and that the accuracy and constancy of the bearings on commercial and other transmitters of known location are quite satisfactory.

By that time we were of opinion that all preliminary steps required had been taken, and that we could go so far as to include the directional beacons in our investigation program, in other words : to turn from the aural observations of Consol stations to the visual method. Meanwhile we had also contacted the International Hydrographic Bureau asking this organization to let us know where and under what circumstances the European Consol stations were being monitored, and we received interesting information from Norway, Denmark, the Netherlands and France. May we at this point express our gratitude to the Directing Committee for all the assistance kindly granted us in order to facilitate our efforts.

OBSERVATION OF « RANGES »

It is a matter of common knowledge that in addition to Consol there exist also other directional beacons.

1. Navigational Beacon System (e.g. Consol).

2. Fixed Course or Course-Setting Beacons. The modulation of the radiated signal varies in the receiver according to whether a ship or aircraft is « Off Course Left », « On Course » or « Off Course Right » (e.g. US Radio Range Beacon System).

3. Rotating Directional Beacons which make it possible for the bearing of the ship from the beacon to be found using the ship's normal communication aerial and receiving equipment.

4. Aircraft Approach and Landing Beacons (e.g. ILS, SBA).

We shall restrict our considerations to types 1 and 2 and neglect the others. As just pointed out, these installations can be used without any direction-finding apparatus. But the question arises as to what happens if for the purpose of extending our research we receive directional beacons with crossed loops and observe the bearings on the screen of the twin channel direction finder. Now you might say that they probably behave similarly to the non-directional beacons. Certainly they ought to do so. We were very curious when we tuned in for the first time in order to receive a directional beacon. For this first experiment we had chosen the Four Course Beacon DHA (Type 2), the power of which amounts to 100 Watts, and the frequency to 310 kc/s. This station is located in the vicinity of Munich, approximately 100 km. away from us. We thus could expect to see a very bright and clear figure on the screen. It is difficult to describe our astonishment when instead of only one figure we dicovered two of them indicating two probable bearings. Each of these two figures was very sharp, corresponding to a well-defined bearing, unfortunately deviating about ten degrees clockwise from the calculated bearing or vice-versa. And these two figures overlapped each other in perfect synchronism with the keying of the aerials at the transmitter station. When we heard the dot and dash pertaining to the Morse letter A in the loudspeaker of a normal communication receiver we saw one figure while the other appeared in the intervals corresponding to the Morse letter N. Can we go so far as to believe in the existence of two propagation directions based upon the fact that the transmitter contains a relay to switch the coils of the radiogoniometer in the interlocked A/N rhythm ? We carefully checked to make sure whether or not we might have missed some essential points in our considerations. It was unfortunate that we could not discuss this problem with anybody, since there have been no previous publications on the subject of the reception of the radiation emitted by two crossed and switched loops by means of two other crossed loops connected with the two pairs of plates of a cathode ray tube. After observing this new phenomenon we were convinced that it was neither a hallucination nor a disturbance. Other ranges also showed the « Peiltakt » phenomenon, as we called it. It is not too difficult to devise a simple test in order to exclude even the slightest doubt as to the physical reality of the Peiltakt phenomenon. We see two alternating figures, and suppose that in the same moment in which the relay in the transmitter switches the aerials the trace jumps on the screen. If a skilled operator now holds the relay in one position, only one figure will paint on the screen. And when this man telephones to our station that he is changing the relay contact into the other position, the trace will indicate the other direction as soon as he does so, which fact has been proved.

PEILTAKT-PHENOMENON AND CONSOL

A similar switching apparatus is used with Consol stations. What happened when our receiver was tuned for Consol frequency ? At first nothing peculiar. On the frequency of Stavanger, for instance, we could see a satisfactory figure, the bearing of which approximately corresponded to the value calculated. The length of the trace followed the whole Consol sequence, but the direction indicated did not change. Nevertheless in the afternoon the trace suddenly started quivering, showing distinct signs of Peiltakt, which did not affect the maximum amplitude as much as it did the minimum amplitude. The deviation caused by Peiltakt as indicated on the screen amounted to as much as 20 degrees clockwise or counter-clockwise. This phenomenon, which is visible for about 5 minutes or more before it disappears, cannot be mistaken for any type of night effect.

The existence of the Peiltakt phenomenon seems to me clearly connected with the reception of directional beacons, such as Consol beacons, four-course beacons, or perhaps another type, that we have not yet had the opportunity to observe at our station.

After devoting so much time to the description of the apparatus and the phenomenon, I should not like to conclude my lecture without answering the two following questions :

(a) What is the explanation for Peiltakt ?

(b) Does Peiltakt affect the accuracy of Consol signals ?

As regards (a), let us consider a radiation pattern as shown in Figure 2. It is computed for two aerials, 6 wave-lengths apart and radiating in the same phase. There are many lobes of equal intensity. If the phases of the aerials are switched, the pattern can be rotated.

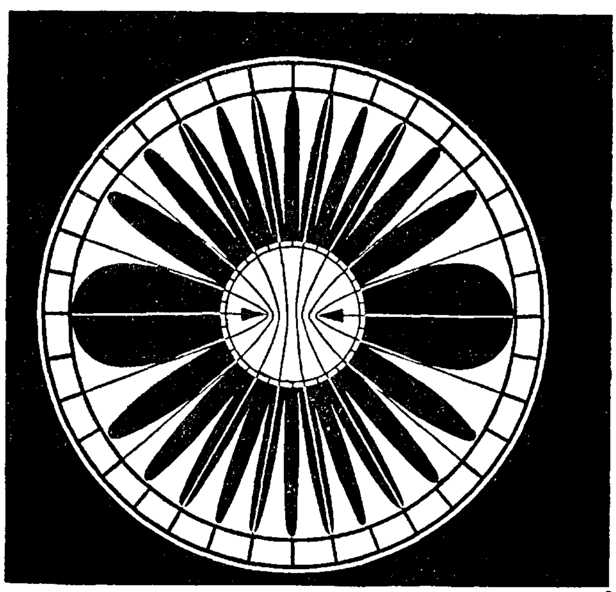

Fig. 2.
Radiation Pattern for Two Open Aerials with 6 λ Spacing.
(Deutsche RADAR. Verlagsgesellschaft.)

We start from the assumption that there are two kinds of orientation possible which we are going to mark (I) and (II). Under position (I) any of the maximum lobes should be directly pointed toward us so that we thus receive the maximum field strength available. Under orientation (II), the pattern should be rotated in such a manner that we are lying on a line of minimum field strength. If there were ideal propagation conditions, the bearing indicated on the screen ought to be the same for both positions of the pattern, i.e., they ought to be equal for the maximum and the minimum amplitude received. Under this assumption there would never be any solution of this problem, and the Peiltakt would always remain enigmatic. Ideal conditions, however, only exist theoretically, and never in practice. In fact reflected or scattered rays from surface obstructions or returning from the ionospheric layers are responsible for ray interference effects. If we rotate a radiation pattern, the lobes of which are small enough, we have a wonderful instrument for testing whether or not there is the slightest amount of multipath effect. When the location of the scattering source is such that under orientation (I) it will radiate only with weak intensity, the direct ray pointing toward us is hardly affected thereby. When under orientation (II), however, the scattering source will radiate with high intensity, and its influence upon our receiving station is so great as to cause the electronic beam to jump in synchronism with the keying sequence. On the basis of the foregoing statements, not only are we able to explain the Peiltakt phenomenon, but we maintain that any suitable apparatus of this kind must show this phenomenon if the receiver is tuned to a directional beacon.

With reference to (b), while observing we counted the signals of Consol beacons by listening through the earphones, and by watching the trace on the screen at the same time. Inasmuch as the number of counts remained unchanged during Peiltakt periods, we see no connection between the number counted and the Peiltakt observed. In spite of the fact that the material compiled cannot yet be considered sufficient to uphold with certainty that the Peiltakt does not adversely affect the Consol system, we are convinced that this phenomenon constitutes no new source of inconvenience to navigation. We have the impression that the brief fluctuations which we call the Peiltakt cannot be identified by a navigator using normal equipment, and we shall be extremely pleased if our further investigations result in the irrefutable proof of our statements.

TABLE I

RECEIVING CONDITIONS FOR CONSOL STATIONS AT GARMISCH-PARTENKIRCHEN

	SUMMER		WINTER	
	Day	Night	Day	Night
Bushmills	—	good	good	good
Ploneis	—	good	good	good
Lugo	—	—	—	good
Sevilla	—	—	—	good
Stavanger	—	good	good	good

TABLE II

	Bushmills MWN	Ploneis TRQ	Lugo LG	Sevilla SL	Stavanger LEC
Frequency	266	257	285	315	319
Aerial spacing	4.4	5.2	5.3	5.7	5.7
Direction of normal to aerial line	130°.2	106°.3	88°.5	83°.0	247°.0
Bearing from Consol Station to Garmisch-Partenkirchen	118°.0	87°.2	65°.5	46°.2	161°.3
Angle between direction of normal to aerial line and bearing from Consol Station to Receiving Station	12°.2	19°.1	23°.0	36°.8	85°.7
Bearing from Garmisch-Partenkirchen to Consol Station	298°.0	267°.2	245°.5	266°.2	341°.3
Distance (km.)	1,500	1,000	1,500	1,800	1,300
Number of Sector	A 4	B 3	A 2	B 2	A 7
Calculated value of dots or dashes	57	42	6	28	16

Table III

WEATHER SHIP 59° N 19° W (1)

	Bushmills MWN	Ploneis TRQ	Stavanger LEC
Angle between direction of normal to aerial line and bearing from Consol Station to Receiving Station	5°	40°	35°
Distance (km.)	870	1,600	1,400
Number of sector	B 9	B 11	B 11
Observations by day (10.00-14.00 hrs.) :			
Reception probability (%)	100	71.1	97.5
Mean error	—1.52	+2.00	+1.30
Standard deviation	1.35	1.73	1.18
Observations by night (22.00-02.00 hrs.) :			
Reception probability (%)	100	100	80.0
Mean error	—1.27	+1.29	+1.03
Standard deviation	1.98	1.79	2.85

Table IV

Beacon	Call	Frequency	True Bearing
Fürstenfeldbruck	FF	345	2°
Kalundborg	—	245	360°
Augsburg	DIJ	315	346°
Nördlingen	DIN	377	344°
Illertissen	FI	478	322°
Kempten	DHK	298	296°
Strasbourg	FOS	389	293°
Trassadingen	HEZ	395	275°
Innsbruck	OEJ	278	142°
Reichertsheim	DHR	294	43°
München NDB	DLM	364	26°
Neudiberg	NU	419	24°

(1) Information by courtesy of the Director of Telecommunications, London.