THE FURTHER APPLICATION OF SCIENCE TO HYDROGRAPHY AND NAVIGATION

by

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"Science is Nature's deciphered messages" and every fresh one that is decoded is immediately examined as to its adaptability for practical use.

In the past, human sight and hearing and the feeling of a hand lead touching the bottom were necessary to safe navigation. In rare cases the sense of smell might also have aided the navigator, while many humorous stories are told of the claims of pilots of various nationalities to being able to fix the position of the ship by the taste of the bottom sample brought up by the hand lead.

The human senses are no less important than ever, but the requirements of human intelligence are considerably greater in order to utilise all of the modern aids to navigation with which science is periodically providing it. Fortunately most of the improvements in the art of navigation have almost equal application to the art of hydrography. The special application of electro-magnetic waves, or impulses, has proved particularly useful, not only in radio-communication, in echo sounding and in radio-beam and radio-compass bearings, but also in sound ranging, while the hydrophone, submarine bell, leader cable, gyro-compass, "the iron quarter-master" and the gyro-course tracer have solved many other difficulties, but, at the same time, have required higher standards in ship personnel. Mathematical tabulations and advanced methods of astronomical observations at sea have also contributed their aid to modern navigation, not to mention physics and chemistry in improvements in communications, in lights, and in sound signals. It is the purpose of this article, however, to consider principally the present status of the application of electro-magnetic and kindred waves or impulses to hydrography and navigation, in order to speculate as to what may seem to be the direction from which further scientific developments may be expected or may seem possible. We know of the development of radio-transmission in the utilisation of long, or low frequency, waves and the more amazing developments in the use of short waves, or high frequency transmission, for long distances, by means of radio-telephone, by beam and by ordinary radio-transmission, using lower power.

The Washington Radio-Telegraph Conference, in 1927, drew up a resolution with regard to the use of long wave transmission by radio which, when approved by the various Governments, will have the effect of shortening the wave lengths used in very many high powered stations in Europe and North America. This is not important from our point of view, at the moment, except that it will eliminate much interference in radio communication as affecting broadcasting of time signals, weather reports, storm warnings, and important notices to mariners.

Table I, appended to this article, shows the frequency periods, and wave lengths, in both water and air, corresponding to audible sounds in the air to which the human ear responds. In the region "under investigation" under "*audible sounds or acoustic waves*" between musical waves and the upper limit of audible sounds there may be discovered something of practical value as a further aid to navigation.

It is well known that the lower animals have a much wider range of audibility than human beings both in infra and super sounds, and give evidence of it in many ways without our realising the significance of it, when we actually witness their perturbation. It is said, for instance, that in Berlin the police have whistles for police dogs which, when blown, make no sound to the human ear but to which the dogs respond immediately. This suggests the possibility of signalling from ship to ship, or from shore to ship, by means of inaudible whistles which may be converted into audible sounds by some receiving device not yet invented, just as is done in echo sounding, using super-sonic electro-magnetic waves. If such an invention were forthcoming, it might have practical application in navigation at sea, and might lead to the discovery of numerous sounds of shorter wave length. There are, for instance, invisible lights, emitted by infra-red rays, which may be made visible by wearing a special kind of goggles or eye-glasses. We know, also, that infra-red beams, projected from a shore station or from a ship, may be received, by means of thermo-electric cells, and converted into a signal to act as a range of lights by which to enter a harbour or steer a course in a channel.

Also, in Table I, the corresponding wave length of sounds in the air and in water gives us an idea of how much farther sounds are heard under the water than in the air, until we realise the differences in their velocities in the respective mediums. Submarine bells are often heard many miles at sea quite out of sight of the light-ship emitting them, whereas, in the air, one would have to be rather close aboard to hear the same bell if sounded in the air, especially if atmospheric conditions were unfavourable.

It is important to note that there is no known method of making the wave lengths in ether which correspond to the audible ones in air and water. The maximum electro-magnetic wave length in ether so far generated is not much over 30,000 metres, and the present tendency is not to use much over 18,000 metres for practical purposes commercially. By the Washington Convention above alluded to, the wave lengths on long continuous waves is, for ships, limited to between 1875 and 1987 metres, and, for all special shore stations in Europe and North America, to between 2013 and 2703 metres. However, there is an amazing variety of wave lengths used by modulated and unmodulated continuous waves or (by using an alternator), by spark and by radio-beam transmission. The beam station at Grimsby, England, uses a beam service to Australia, for a distance of 9,000 miles to the Eastward, in the evening, and of 12,000 miles to the Westward, in the morning, using a wave length of slightly less than 26 metres. It also has a service to India, using a wave length of about 16 metres by day, and 34 metres by night.

In the matter of direction-finding stations, there are three systems used, *viz* :—

(1) Where each station is fitted with transmitting and receiving gear, and works independently.

(2) Where several stations are connected by special wires or cables controlled by one station, which is alone fitted with transmitting apparatus. The control station in such case is often an ordinary coastal radio station.

(3) Where a ship asks for only a single bearing from the station.

It should be noted that if bearings are very oblique to the coast line, errors of from 4^0 or 5^0 are frequent on account of the effect of the wave passing over the land. Also, from about one hour before sunset and from one hour after sunrise, the bearings are found to be unreliable on account of excessive error, unless the two stations are separated by a distance not exceeding 100 miles entirely over the sea, while in such cases, with the bearings over land, particularly if the country is hilly, the error is excessive. This error is probably due to cosmic and other radio active rays of high frequency, which are naturally more prevalent on the land than on the sea. With a single bearing, an error may be of approximately 180^0 because of the bearing coming from the wrong side of the vessel. On the other hand, stations are now being calibrated and, for the sector of the circle of which the compass coil at the station is in the centre, we find the bearings are generally true bearings. These direction-finding stations are sometimes special and sometimes are operated by regular radio-transmission stations in addition to other activities, but, in any case, its geographical position has to be accurately known to the ship receiving the message, but this is, of course, also true of any form of position fixing at sea by means of radio.

Great Britain has 8 direction-finding stations and charges 5 shillings; Norway has 4 stations, and makes no charge; Sweden has 4 stations, and charges frs. 3.50 (gold); Germany has 4 stations, and makes no charge; Denmark has no station; the Netherlands have 8 stations, and charge frs. 6 (gold); Belgium has no station; France has 14 stations on its own coasts, 3 in Marocco, 1 in Algeria, and 1 in Tunisia, and the charge is frs. 6 (gold); Portugal has 1 station and the charge is frs. 6.25 (gold); Spain has 3 stations and no charge is made. Italy with Italian Somaliland has 2 stations and the charge is frs. 6 (gold); India has 3 stations, and there is no charge. On the Pacific Coast of the U. S. of America there are 3 stations in Alaska, 19 on the mainland, and 1 in Panama and no charge is made. On the Atlantic and Gulf Coasts there are 27 stations, and on the Great Lakes there are 4, and no charge is made; Canada has 1 station in British Columbia; 1 in New Brunswick; 4 in Nova Scotia, and no charge is made. Newfoundland has 4 stations, no charge is made; and, finally, British Guiana has 1 station and the charge is 5 shillings.

Other types of radio apparatus used as aids to navigation and of more recent development are radio-fog signals or radio-beams which are one and the same thing. There are three types of radio-fog signals :— Beacon, Revolving Beam, and Rotating Beacon, the latter of which the British call Loop Stations. These are defined by the British Admiralty as follows. :—

(1) "The *Beacon* Station consists of an all-round wireless transmitter sending out a code signal in every direction, the bearing of which is obtained by means of a wireless direction finder or wireless compass fitted on board ship. When the wireless signal is combined and synchronised with a submarine sound signal, distance as well as bearing can be determined."

(2.) "The *Revolving-Beam* Station consists of the emission on short wave lengths of wireless signals projected in a narrow beam, a different Morse letter signal being transmitted for each point and half-point of the compass. The navigator listens by means of a special type of wireless receiver (independent of the ordinary W/T installation) and hears a series of five or more Morse letters, transmitted at a uniform speed, as the revolving-beam intersects the ship's course. The middle letter of the series indicates the exact bearing of the ship (derived from a special chart giving the lettered sectors) in relation to her course. By repeating the observations at short intervals and co-ordinating the results with the ship's course and speed, the exact position of the ship can be determined."

(3.) "The *Rotating Beacon* or *Loop* Station consists of a medium-wave wireless beam transmitter rotating at a uniform speed. A continuous signal is transmitted with special code signals as the beam passes certain points of the compass. These signals are received on a standard wireless receiver and as the beam rotates the signal strength rises and falls being at a minimum as the beam passes the ship. As the speed of the rotation of the beam is known, the bearing of the station can be calculated by measuring the time interval between the beam passing a known point of the compass (indicated by the transmission of the code signal referred to above) and passing the ship (indicated by the minimum strength of signal.)"

These signals are established at some of the more important lighthouses and lightships, in various parts of the world. The ordinary radio and direction-finding stations can be used as radio-beams stations. A distinctive radio-signal is, as stated above, emitted automatically and, for the reception of these signals it is necessary that the ships should be equipped with their own direction-finding installation, or radio-compass, or radio-goniometre, by means of which the bearing of the transmitting station is obtained, in relation to the ship's true course. When these signals are transmitted in conjunction with a submarine bell or other automatic sound it enables the mariner not only to obtain a radio-bearing, but also to determine, within limits, the distance of the ship by synchronising the radio and sound signals. For instance, suppose a submarine bell, or oscillator, sounds special Morse letters, and at the end of the last dash or dot sends at that exact instant a radio-signal consisting of a number of dots spaced at an interval of time apart and commencing with the last emission of the submarine bell. All ships receiving would count the number of dots received until the sound of the submarine bell expires on the instant of the starting of the radio dots. The number of dots indicates the distance of the ship in miles and the bearing is taken from the sound of the instrument. The ship thus fixes her position accurately There are many variations of this method and each one is explained in the *"Radio Code Book"*. Some types require computation, using 4875 feet (1486 metres) for each second; but different values are given by different stations, according to the accepted velocity of sound in sea-water.

While the word "fog" is used in designating these signals, certain stations send out signals, at fixed times daily, irrespective of atmospheric conditions, thus providing a navigator with an opportunity of calibrating his direction-finding instrument and, when the transmitting station is visible, as well as checking the ship's position. The great advantage of radio-fog signals, or the beacon system, in general, is that any number of vessels may obtain bearings from these signals simultaneously. A further advantage of a ship having its own direction-finding apparatus is that it may locate the bearings of other ships during thick and foggy weather; it is able to locate a vessel in distress sending out an S. O. S. or message of any kind, and it does not involve charges for service.

Of radio-fog signals and beacons, Great Britain has 10; Norway, 1; Sweden, 2; Denmark, 7; Germany, 7; Netherlands, 1; France, 9; Spain, 5; New Zealand, 1; Hawaii, 1; Alaska, 2; Pacific Coast of U. S. A., 11; Gulf Coast, 3; Atlantic Coast, 21; Great Lakes, 20; British Columbia, 1; Nova Scotia, 3; Canada, 3; Newfoundland, 2; and Iceland, 2.

In the above list all of the German, Swedish, Danish and the Netherlands stations emit distance signals, but in Great Britain only 4, and in Canada 1 station is so equipped, while no other of the beacon stations, mentioned above, do so.

Radio-stations which send out weather bulletins, storm-warning signals, navigational warnings, time signals, distress signals all over the world are too numerous to mention. A limited number of radio-stations broadcast signals of the International Union of Scientific Radio-Telegraphy (U.I.R.S.) for the study of wave transmission phenomena. There are also many radio-telephonic stations available all over the world for transmitting messages from ship to shore, or vice versa, and from shore to shore, and which use a relatively short wave length.

Practically all of the radio-stations of the world use a wave length somewhere between 18,280 metres and 13 metres, so as not to interfere with international reservations of the Radio Conference wave lengths, for, according to the agreements of the Radio-Telegraph Conference at Washington, the wave lengths for certain commercial stations in Europe and North America are to be from 2,703 to 2,013 m; for ships commercial radio from 1,987 to 1,875 m; and for radio beacons, for navigational purposes, from 1,050 to 950 m.

In Europe, direction-finding stations for air craft use 900 m. and, for ships, from 800 to 400 m; whereas in North America, the direction-finding stations use 800 m. for both air craft and for ships. The short-wave radio stations of the world use from 146 to 13 m., and the long-distance short-wave beam stations in Europe use from 24 to 35 metres, the minimum wave length so far obtained scientifically being 2 m/m.

Referring to Table I, we see that in what is called 1st Zone, "Under Investigation", there is some chance for future inventions to convert inaudible sounds into audible ones. Referring to Table II, 2nd Zone, "Under Investigation", we have in the Mercury-Vapour Light, the present upper limit of calorific rays which are able to penetrate a fog apparently better than any other form of light, but it is hoped that a calorific ray of longer frequency may be discovered which may make visual signalling in a fog penetrable for short enough distances at sea to be useful in preventing collisions. It is not thought that, in the 3rd and 4th Zones, there is much promise of future discoveries of value to hydrography or navigation.

TABLE I

AUDIBLE VIBRATIONS IN SPACE, AIR AND WATER

$V = 300.000$ k.m. — 186.700 miles.

	SCALES FOR ETHER		UNDULATIONS IN WATER AND AIR.					
			WATER	AIR				
	FREQUENCY $N = \frac{1}{T}$ PER SECOND.	PERIOD T.	$V = \begin{cases} 1500 \text{ met. sec.} \\ 4920 \text{ feet sec.} \end{cases}$ $\gamma = VT.$	$V = \begin{cases} 340 \text{ met. sec.} \\ 1115 \text{ feet. sec.} \end{cases}$ $\gamma = VT.$	.... Infra Sounds.			
THEORETICAL.	10	0.1 sec.	150 met.	34 met.	Audible Sounds lower limit.			Audible sounds or Acoustic waves
	16	0.063	94	21	Do_2 or C.		Musical waves.	
	27	0.037	56	13	Piano lowest note.			
	64	0.0156	23	5.3	Bass.			
	435	0.0023	3.45	0.78	La_3 or A'.	Human voice.		
	500	0.0020	3.00	0.68	Spoken Tones.			
	800	0.0016	2.36	0.54				
	1024	0.00098	1.47	0.33	Soprano............			
	2048	0.00049	0.76	0.17	Highest Soprano. (*Lucrezia Agujari*)			
	4700	0.00021	0.32	0.07	Fife.			
UNDER INVESTIGATION - 1st ZONE - PROMISING FIELD FOR NEW INVENTIONS								
RADIO, AUDIBLE ONLY WHEN INTERRUPTED.	10000	0.000100	Maximum obtained.					
	12500	0.000080						
	20000	0.000050	Maximum used practically					
	38000	0.000026	0.04	0.009	Audible Sound upper limit.			Ultra Sound or ultra-Sonic wave.
	40000	0.000025	0.038	0.0085	Practical ultra Sound (not audible).			
INAUDIBLE FREQUENCIES, AUDIBLE ONLY WHEN INTERRUPTED.	....	....	....	....				
	....	....	0.015	0.0034				
	....	....	....	....	....			
	....	....	....	....	....			

TABLE OF EXPLORED UNDULATIONS OF THE ETHER

INCLUDING VISIBLE AND INVISIBLE RAYS

SCALES FOR ETHER		UNDULATIONS OF THE ETHER			
FREQUENCY $N = \frac{1}{T}$ PER SECOND	PERIOD T. IN SECONDS	V = 300,000 km. sec. 186,700 miles $\lambda = VT$. Wave Length			
10000	0.000100	30000 metres	Maximum obtained.		Electro magnetic waves.
12500	0.000080	23500	18000 – 14 m. Radio stations of the world.	Radio	
20000	0.000050	15000			
38000	0.000026	....	6650 – 217 m. Radio telephones of the world.		
40000	0.000025	7500			
....	....	....			
....	....	....			
....	....	....	2703 – 2013 m. Certain special commercial stations in Europe and North America.		
100000	0.000010	2500			
120000	0.000008	2000	1987 – 1875 m. Ships commercial radio.		
150000	0.000006	1000	1050 – 950 m. Radio beacons.		
300000	0.000003	800	900 - Aircraft direction finding (Europe).		
375000	0.0000027	600	800 – 400 m. Direction finding stations in N. America for both ships and air craft.		
500000	0.000002	300	146 – 14 m. Short wave radio stations of the world.		
1000000	1.0×10^{-6}	100	34 – 25m. Radio beam stations.		
3 millions	0.35×10^{-6}	30			
10 »	1.0×10^{-7}	1 metre.			
300 »	0.33×10^{-8}	200 m/m			
1500 »	0.06×10^{-8}		Short Waves (Righi).		
50 milliards or billions	0.02×10^{-9}	6 m/m	(Van Bayer).		
150 »	0.0066×10^{-9}	2 m/m	Minimum obtained.		

UNDER INVESTIGATION - 2nd ZONE - PROMISING FIELD

900 milliards	0.001×10^{-9}		314 Microns	Mercury arc emission.		Infra-Red or calorific waves.
2700 »	0.00033×10^{-9}		96.7	Incandescent mantle.		
57 trillions.	0.18×10^{-12}	Feeling	5.3	Solar spectrum observed Limit (Bolometer).		
215 »						
300 »	0.046		1.4	Spectrum limit photographed.		
375 »	0.033		1.			
450 »	0.027		0.8	Visible solar spectrum limit.		Light or visible spectrum luminous waves.
500 »	0.022		0.65	Mean Red	Rainbow.	
550 »	0.020		0.60	» Orange.		
600 »	0.018		0.58	» Yellow.		
650 »	0.017	Visible	0.52	» Green.		
700 »	0.015		0.47	» Blue.		
750 »	0.014		0.43	» Indigo.		
780 »	0.013		0.41	» Violet.		
860 »	0.0128		0.39	Visible spectrum limit.		
1035 »	0.0116		0.36	Limit for flint-glass.		Ultra-violet or chemical.
	0.00097		0.292	» » quartz & atmosphere.		
1500 »	0.00067		0.200	» » gelatine phot.		
1640 »	0.00061		0.183	» » rarefied air.		
3 quatrillions.	0.33×10^{-15}		100 millimicrons.	» » fluorine.(SCHUMANN'S RAYS).		
15 »	0.067		20 »	Ultra-violet obtained limit. (Nickel-spark).		

UNDER INVESTIGATION - 3rd ZONE - PROBABLY THERAPEUTIC

250 quatrillions.	0.004×10^{-15}	1.2 millimicrons.	X Rays.	Radio-active. waves.
60 quintillions.	0.017×10^{-18}	0.05 angstrom.		
150 »	0.0067	0.02	Radiography.	
300 »	0.0033	0.01	γ Rays (Mean).	
600 »	0.0017	0.005	γ Rays (very penetrating) (RUTHERFORD).	
750 »	0.0013	0.004	Cosmic Rays (MILLIKAN).	
1500 »	0.00067	0.002		

UNDER INVESTIGATION - 4th ZONE - NOT SO PROMISING

American, French and Italian million, trillion, quadrillion and quintillion are, in English and German, Thousand million, billion, Thousand bilion and trillion.