system of flow lines of current through the sea, and these might be detected by any other ships furnished with two plates dipping into the sea at stem and stern, and connected by a wire having a telephone in its circuit, provided that the two plates were not placed on the same equipotential surface of the original current flow lines. Experiments of this kind were actually tried by Graham Bell in 1882, with boats on the Potomac river, and signals were detected at a distance of a mile and a half.

At a later date, 189r, Trowbridge discussed another method of effecting communication at a distance, viz., by means of magnetic induction between two separate and completely insulated circuits. If a primary circuit, consisting of a large coil of wire P (fig. 36), has in circuit a battery B and an in­terrupter I, and at some distance and parallel to this primary circuit is placed a secondary circuit S, having a telephone T included in it, the interruptions or reversals of the current in the primary circuit will give rise to a varying magnetic field round that circuit which will induce secondary currents in the other circuit and affect the telephone receiver. Willoughby Smith found that it was not necessary even to connect the telephone to a secondary circuit, but that it would be affected and give out sounds merely by being held in the variable magnetic field of a primary circuit. By. the use of a key in the battery circuit as well as an interrupter or current reverser, signals can be given by breaking up the continuous hum in the telephone into long and short periods. This method of communication by *magnetic induction* through space establishes, therefore, a second method of wireless telegraphy which is quite independent of and different from that due to *conduction* through earth or water.

Sir W. H. Preece, who took up the subject about the same time as Prof. Trowbridge, obtained improved practical results by combining together methods of induction and con­duction. His first publication of results was in 1882 *(Brit. Assoc. Report),* when he drew attention to the considerable distance over which inductive effects occurred between parallel wires forming portions of telephonic and telegraphic circuits. Following on this he made an interesting experiment, using Morse’s method, to connect the Isle of Wight telegraphically with the mainland, by conduction across the Solent in two places, during a temporary failure of the submarine cable in 1882 in that channel. In subsequent years numerous experi­ments were carried out by him in various parts of Great Britain, in some cases with circuits earthed at both ends, and in other cases with completely insulated circuits, which showed that conductive effects could be detected at distances of many miles, and also that inductive effects could take place even between circuits separated by solid earth and by considerable distances. A. W. Heaviside in 1887 succeeded in communicating by tele­phonic speech between the surface of the earth and the sub­terranean galleries of the Broomhill collieries, 350 feet deep, by laying above and below ground two complete metallic circuits, each about 2¼ m. in length and parallel to each other. At a later date other experimentalists found, however, that an equal thickness of sea-water interposed between a primary and secondary circuit completely prevented similar inductive inter­communication. In 1885 Preece and Heaviside proved by experiments made at Newcastle that if two completely insulated circuits of square form, each side being 440 yds., were placed a quarter of a mile apart, telephonic speech was conveyed from one to the other by induction, and signals could be perceived even when they were separated by 1000 yds. The method of induction between insulated primary and secondary circuits laid out flat on the surface of the earth proves to be of limited application, and in his later experiments Preece returned to a method which unites both conduction and induction as the means of affecting one circuit by a current in another. In 1892, on the Bristol Channel, he established communication between Lavernock Point and an island called Flat Holme in that channel by placing at these positions insulated single-wire circuits, earthed at both ends and laid as far as possible parallel to each other, the distance between them being 3∙3 m. The shore wire was 1267 yds. long, and that on the island 600 yds. An interrupted current having a frequency of about 400 was used in the primary circuit, and a telephone was employed as a receiver in the secondary circuit. Other experiments in in­ductive telegraphy were made by Preece, aided by the officials of the British Postal Telegraph Service, in Glamorganshire in 1887; at Loch Ness in Scotland in 1892; on Conway Sands in 1893; and at Frodsham, on the Dee, in 1894. (See *Jour. Inst. Elec. Eng.,* 27, p. 869.) In 1899 experiments were made at Menai Straits to put the lighthouse at the Skerries into communication with the coastguard station at Cemlyn. A wire 750 yds. in length was erected along the Skerries, and on the mainland one of 3½ m. long, starting from a point opposite the Skerries, to Cemlyn. Each line terminated in an earth plate placed in the sea. The average perpendicular distance between the two lines, which are roughly parallel, is 2∙8 m. Telephonic speech between these two circuits was found possible and good, the communication between the circuits taking place partly by induction, and no doubt partly by conduction. On the ques­tion of how far the effects are due to conduction between the earth plates, and how far to true electromagnetic induction, authorities differ, some being of opinion that the two effects are in operation together. A similar installation of inductive telephony, in which telephone currents in one line were made to create others in a nearly parallel and distant line, was estab­lished in 1899 between Rathlin Island on the north coast of Ireland and the mainland. The shortest distance between the two places is 4 m. By stretching on the island and mainland parallel wire circuits earthed at each end, good tele­phonic communication over an average distance of 6½ m. was established between these independent circuits.

The difficulty of connecting lightships and isolated lighthouses to the mainland by submarine cables, owing to the destructive action of the tides and waves on rocky coasts on the shore ends, led many inventors to look for a way out of the difficulty by the adoption of some form of inductive or conductive telegraphy not necessitating a continuous cable. Willoughby S. Smith and W. P. Granville put into practice between Alum Bay in the Isle of Wight and the Needles light­house a method which depends upon conduction through sea water. (See *Jour. Inst. Elec. Eng.,* 27, p. 938.) It may be ex­plained as follows:—Suppose a battery on shore to have one pole earthed and the other connected to an insulated submarine cable, the distant end of which was also earthed; if now a galvanometer is inserted anywhere in the cable, a current will be found flowing through the cable and returning by various paths through the sea. If we suppose the cable interrupted at any place, and both sides of the gap earthed by connexion to plates, then the same conditions will still hold. Communication was established by this method in the year 1895 with the light­house on the Fastnet.@@1 A cable is carried out from the mainland at Crookhaven for 7 m., and the outer end earthed by connexion with a copper mushroom anchor. Another earthed cable starts from a similar anchor about 100 ft. away near the shore line of the Fastnet rock, crosses the rock, and is again earthed in the sea at the distant end. If a battery on the main­land is connected through a key with the shore end of the main cable, and a speaking galvanometer is in circuit with the short cable crossing the Fastnet rock, then closing or opening the battery connexion will create a deflection of the galvanometer. A very ingenious call-bell arrangement was devised, capable of responding only to regularly reversed battery currents, but not

@@@1See Fahie, *History of Wireless Telegraphy,* p. 170; also 5th Report (1897) of the Royal Commission on Electrical Communication with Lightships and Lighthouses.