of R1 moves into contact with the auxiliary lever *l* and closes the circuit of the sounder S1. When K2 only is depressed a current + 4 is sent to the line. This acts on both relays, but is powerful enough to overcome the pull of the spring T1, and so to move the lever *l* and break the cir­cuit of the

sounder S1 be­fore it has time to act. Thus K2 acts on the sounder S2 but not on the

sounder S1. When both keys are depressed a current +1 is sent into the line. This is sufficient to move the lever of R1 into con­tact with *l* but not to overcome the pull of T1, and hence the circuit of sounder S1 is closed ; it is also sufficient to move the lever of R2 and close the circuit of S2. When therefore both keys are down the sounders S1 and S2 at the other end of the line are both set in action ; the first responds to K1 and the second to K2. Thus all the conditions for the simultaneous transmission of two messages are provided for. It is not necessary to enter again into the ques­tion of continuity at the different positions of the keys. The figure illustrates how this diplex system may be duplexed, and hence how quadruplex working can be obtained. It is only necessary to wind the coils of the relay magnets differentially, when, by means of a precisely similar arrangement to that used for simple duplex, the instruments at the sending station are left unaffected by the out­going currents, but are affected by the incoming currents. The method here indicated is on the differential principle ; but it is scarcely necessary to say that the bridge method is equally appli­cable. A combination of the bridge and the differential methods has been used by Prescott and Smith, and possesses some advan­tages in certain cases. It is impossible in this article to go into the great variety of detail in arrangement and method with which it is possible to obtain good results.

The several methods that have been proposed for the transmission of a number of messages in one direction on the same wire are reducible to two classes. In one the time which a revolving con­tact slider takes to make one revolution is divided into as many intervals as there are sets of sending and receiving instruments on the line, and by means of it the current is closed through the different sets of apparatus in succession. This implies the syn­chronous movement of the revolving sliders at the two ends of the line. In a sense this may be said to be simultaneous transmission : all the messages are being sent at the same time, but the progress of any one message is slower than it would be if it alone was occupy­ing the whole line in the ordinary way. The method possesses some advantages when the line is capable of being worked at a higher speed than a single operator can attain, or when one of the stations can advantageously be used as a distributing station, for in that case one set of apparatus may be used as an automatic distributor. Multiple telegraphy on this plan was proposed by Thomson in 1858.@@1 A very complete set of apparatus for the purpose was shown by Meyer at the Vienna exhibition of 1873.@@2 Delaunay’s multiple telegraph is the most recent development of the system, and has been lately adopted on some circuits in Great Britain.@@3

In the other class there are joined to the two ends of the line of wire a number of branch circuits, in each of which a set of trans­mitting and receiving apparatus is included. In the circuit, between the line and each of the sending keys, an electromagnetic vibrator is placed so as to open and close the circuit a great number of times during each signal. The vibrators in the key circuits at one end of the line have all different and, if possible, relatively incommen­surable periods. The receivers at the other end of the line consist of a corresponding set of electromagnetic vibrators, mounted on resonators and having exactly the same vibrational periods as those in the key circuits at the sending end. When any one of the keys is manipulated the currents sent into the line have such a pulsatory character that they only affect the receiver, which is capable of vibrating freely in unison with these pulsations. When a number of keys are manipulated at the same time the receivers analyse the resultant wave, each picking out its own component, thus separ­ating the different messages. The “harmonic telegraph” of Mr Elisha Gray of America is a good example of this class.

*Working of Submarine Cables.—*The arrangement of the apparatus for working some of the most recent cables is shown in fig. 29. The cable is supposed to be worked duplex ; but, if S, C1, C2, and AC are removed and the key connected directly with C3, the arrange­ment for simplex working is obtained. The apparatus consists of a sending battery B, a reversing transmitting key K, a slide of small

resistance S, three condensers C1, C2, C3, an artificial cable AC, the receiving instruments I and G, and one or more resistances R for adjusting the leakage current. The peculiar construction of AC has been already referred to. The conductor of the cable is practi­cally insulated, as the condensers in the bridge have a very high resistance ; hence no appreciable current ever flows into or out of the line. Two receiving in­struments, a siphon re­corder and a mirror galva­nometer, are shown ; one only is abso­lutely neces­sary, but itis convenient to have the

galvanometer ready, so that in case of accident to the recorder it may be at once switched into circuit by the switch *s.* When one of the levers of K is depressed, the condenser C1 and the cable, and the condenser C2 and the artificial cable, are simultaneously charged in series ; but, if the capacity of C1 bears the same pro­portion to the capacity of the cable as the capacity of C2 bears to the capacity of the artificial cable, and if the other adjustments are properly made, no charge will be communicated to C3. After a very short interval of time, the length of which depends on the inductive retardation of the cable, the condensers corresponding to C1 and C3 at the other end begin to be charged from the cable, and since the charge of C3 passes through the receiving instrument I or G the signal is recorded. The charging of C3 at the receiving end will take place, no matter what is the absolute potential of the condensers, consequently the incoming signals are not affected by those which are being transmitted from that end. In actual prac­tice the receiving instrument is so sensitive that the difference of potential between the two coatings of the condenser C3 produced by the incoming signal is only a very small fraction of the potential of the battery B. When the key is relieved the condensers and cables at once begin to return to zero potential, and if the key is depressed and relieved several times in rapid succession the cable is divided into sections of varying potential, which travel rapidly towards the receiving end, and indicate their arrival there by pro­ducing corresponding fluctuations in the charge of the condenser C3. All cables of any great length are worked by reverse currents, the single needle alphabet being used : that is to say, currents in one direction indicate dots and in the other direction dashes.

The following descriptions of the mirror galvanometer and the siphon recorder are, with some slight alteration, taken from a lecture delivered by Sir W. Thomson before the Institution of Engineers and Shipbuilders in Scotland.@@4

1. The instrument first used for receiving signals through a long submarine cable (the short-lived 1858 Atlantic cable) was the mirror galvanometer,@@5 which consisted of a small mirror with four light magnets attached to its back (weighing in all less than half a grain), suspended by means of a single silk fibre within the hollow of a bobbin of fine wire,—a suitable controlling magnet being placed adjacent to the apparatus. The action of the instrument is as follows. On the passage of a current of electricity through the fine wire coil the suspended magnets with the mirror attached tend to take up a position at right angles to the plane of the coil, and are deflected to one side or the other according as the current is in one direction or the other. Deflexions to one side are interpreted as dots and to the other side as dashes, and the messages are trans­mitted in accordance with the international Morse code of signals.
2. The spark recorder in some respects foreshadowed the more perfect instrument—the siphon recorder—which was introduced some years later. Its action was as follows. To an indicator, suitably supported, a to-and-fro motion was given by the electro­magnetic actions due to the electric currents constituting the signals. The indicator was connected with a Ruhmkorff coil or other equivalent apparatus, designed to cause a continual succession of sparks to pass between the indicator and a metal plate situated beneath it and having a plane surface parallel to its line of motion. Over the surface of the plate and between it and the indicator there was passed, at a regularly uniform speed, in a direction per­pendicular to the line of motion of the indicator, a material capable of being acted on physically by the sparks, either through their chemical action, their heat, or their perforating force. The record of the signals given by this instrument was an undulating line of fine perforations or spots, and the character and succession of the undulations were used to interpret the signals desired to be sent.
3. The latest form of receiving instrument for long submarine cables is the siphon recorder, for which Sir W. Thomson obtained

@@@1 *Tel. Journ.,* September 1886.

@@@2 For a description, see Prescott’s *Electric Telegraph,* p. 862.

@@@3 Preece, *Journ. Soc. Tel. Eng.,* vol. xv. p. 231.

@@@4 See his *Mathematical and Physical Papers,* vol. ii. p. 168.

@@@5 For a description of the mirror galvanometer, see art. Galvanometer, vol. X. p. 50 *sq.*