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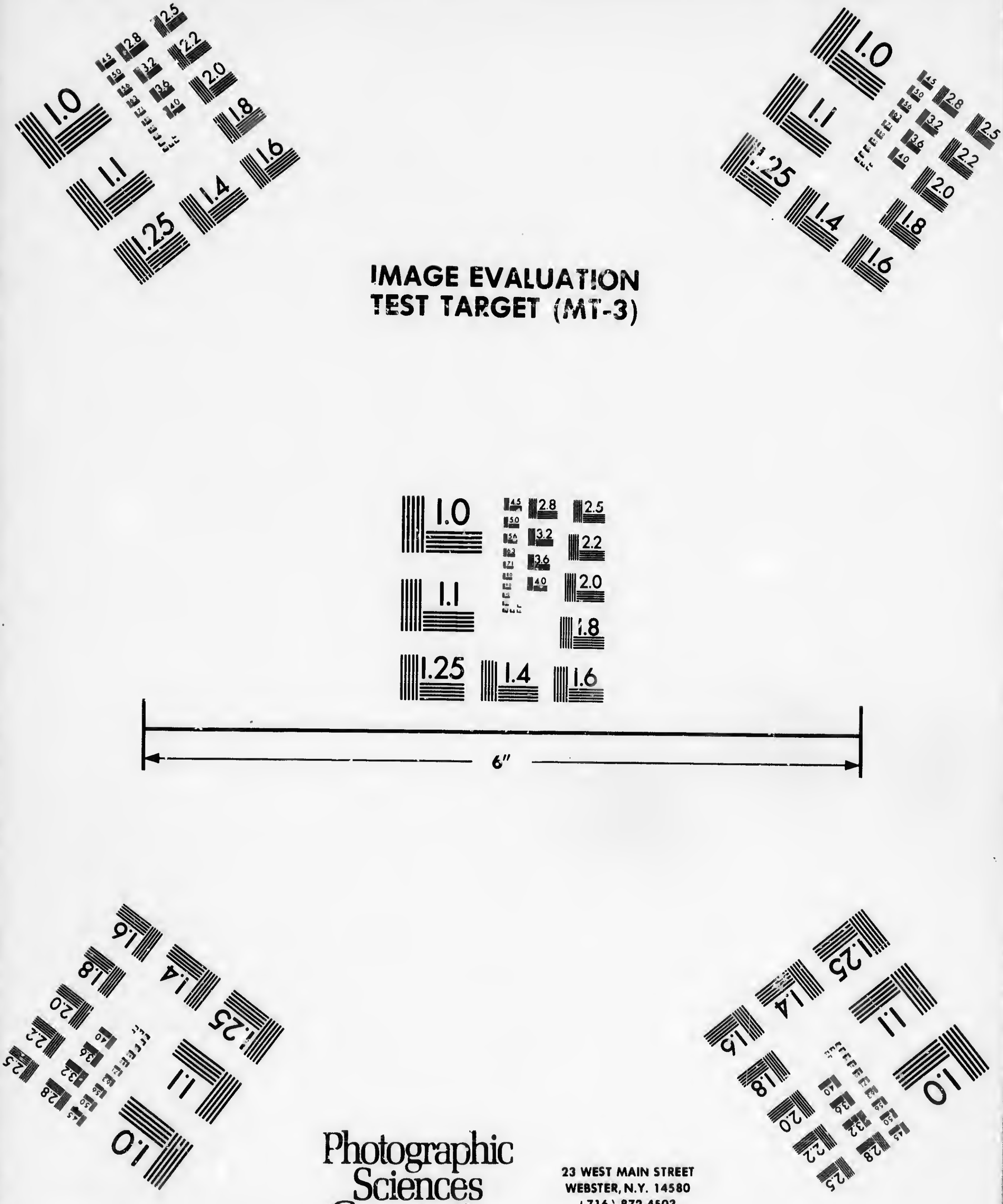

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THE SIMPLIFICATION OF THE QUADRUPLEX, AND THE IMPORTANCE OF ITS ACHIEVEMENT.

By D. H. Keeley, A.M. Can. Soc. C. E.

To be read Friday, 11th November, 1892.

If there is any one thing more than another in the domain of practical telegraphy that hangs on the consideration of fine points, it is the successful operation of a quadruplex system, and to those who have had opportunity for enquiring into the philosophy of the thing, this fact is more than patent, inasmuch as it is found that a very serious difficulty exists where at the outset none whatever is apprehended.

As a matter of fact, when the quadruplex was a novelty and not yet in extensive use the text books were silent on the one vital but seemingly unimportant point to which the delay in developing the system was referable, and it was sometime before the really difficult part of the problem was appreciated and understood by any excepting those immediately concerned in its conception. However, that time is past, and the student of to-day in consulting his text book will find the whole anatomy of the quadruplex laid bare, and the devices introduced to obviate the difficulty that is due to an *inherent defect* are taken into account as an essential part of the whole. That at any rate is the point of view from which this paper is written; and its object is to show in the first place, that in the established system of quadruplex telegraphy there is an inherent defect whose obviation has encumbered the fundamental principle with complex apparatus—thereby, from a theoretical standpoint at least, demonstrating its inadequacy; and, in the second place, to show how by building upon a different but equally simple principle, the same practical results can be secured with much less machinery.

With this end in view, a little consideration can now be given to a comparison of the different principles involved, and incidentally the whereabouts and character of the inherent defect to which allusion has been made, will be perceived, and the method proposed for its elimination understood.

For convenience of elucidation it will be well to start with the conception that a quadruplex is a combination of two duplexes. A duplex is a system in which the recorder at each end of the line is so arranged as to be unaffected by currents outgoing, while free to respond to currents incoming. In the quadruplex, therefore, the distant recorders respond to the home keys or transmitters, and the home recorders respond to the manipulation of the distant transmitters; the result of which is that a single conductor is made to afford four distinctive circuits. These circuits, however, are not precisely similar, because the constitution of a quadruplex is such that the duplex element cannot be lost sight of, and a system of this kind is therefore necessarily always regarded as having *two sides*. The apparatus on one side (one of the two duplexes) being operated by currents differing in polarity or in degree from those operating on the other side. The trouble has been to obviate not only the liability but the *possibility* of an interference of one side with the other.

The several methods of quadruplex telegraphy that have been invented are comprised in two general classes. (1.) The *Polar systems*, or those in which the receivers on the one side are actuated by increase and decrease of a normal current, and on the other side by reversals of that current, and (2.) the *straight current systems*, or those in which the receivers are actuated by three different strengths of current of a given and unchanging polarity.

We can best consider them separately under distinctive headings, and assume a practicable type as embracing the whole in each instance.

THE POLAR QUADRUPLEX.

It is the polar quadruplex that has found favor in practice, but it presents several undesirable features, and, excepting where dynamic currents are available, is expensive to maintain in consequence of large batteries being required for its exclusive use.

According to this method, the signalling battery is arranged in two sections. One of the transmitters operates to put one or both of the sections to line; and the other transmitter operates to reverse the direction of the current. The receiving apparatus consists of polarized and neutral electro magnets. The armature lever of the polarized instrument is normally held against its limiting stop by the — current of the smaller section of the battery, that traverses the line when both of the transmitting keys are at rest (upraised), and it remains in the same position when the key that puts the second section of the battery in circuit, is depressed; but it passes freely over to its front stop or signalling contact when the + current, from one or both sections of the battery, traverse the circuit, hence the polarized instrument responds to the manipulation of the reversing key. The armature of the neutral instrument is responsive to both — and + currents, but it is held back by a retractile spring exerting a greater force than the magnetic attraction due to the current from the smaller section of the battery. This latter can therefore be reversed repeatedly and continuously, thereby producing signals on the polarized receiver, without in any way affecting the neutral instrument. Whenever the increment key is depressed, however, the current from both sections of the battery traverses the circuit, the retractile force is insufficient to withstand the magnetic attraction imparted to the neutral receiver, and its armature passes over to its front stop or signalling contact; the neutral relay is thus responsive to the manipulation of the increment key.

So far the action appears to be smooth and satisfactory, and one might think he could go to work and set up his quadruplex; but he will discover, as did many an early investigator, that his knowledge is as yet incomplete. It will be found that while no effect is produced on the neutral relay by the changes of polarity of the small section of the battery, there is a marked interference when the current of both sections together is traversing the circuit. When the increment key is depressed the neutral receiver responds; if now the reversing key is depressed, a short false signal will be produced on the neutral receiver. The reversal of the battery by the reversing key momentarily withdraws the current from the circuit, and in that brief interval the magnetic attraction of the neutral receiver drops sufficiently to allow its armature to fall back from its signalling contact.

Here, then, we have the inherent defect of the system clearly defined. It resides in this lack of continuity of current.

Divers devices—perhaps multitudinous is a better word to describe their number—have been worked out with a view to obviating this ill effect of the current reversals. Out of them all, the clever arrangements due to the ingenuity of Messrs. Gerritt Smith and F. L. Jones have been sifted and adopted in the standard quadruplex of the telegraph companies. There is not much to choose between these two devices; they are distinctive types, and have gone a long way to make the quadruplex what it is. Smith puts an extra coil on the neutral receiver core and connects it in circuit with a condenser shunting a considerable resistance. The current from both sections of the signalling battery charges the condenser, and the instant the current is withdrawn the condener discharges through the shunted resistance and the extra coil on the neutral receiver, the magnetic attraction of which latter is thereby maintained. Jones substitutes an induction coil for the condenser; the secondary wire is in circuit with the extra coil on the receiver, and the primary is traversed by the current from both sections of the signalling battery; the instant the current is interrupted an induced current traverses the extra coil, and, as in the other case, retains the armature attracted.

Either of these devices necessitates the use of heavier currents than would be required for the mere production of signals on the receivers, because the condenser discharge and the induced wave have to impart nearly the same degree of magnetism as the transmitted current, so it is found that the coils traversed by the transmitted current in the standard quadruplex of to-day are not designed to produce a maximum magnetic effect, whereas the coils traversed by the secondary currents are designed to that end and wound to suit the high potential of the condenser and induction coil discharges.

It is seen now that the feature of heavy currents has been dragged into and made a necessary part of the standard quadruplex, in consequence of a defect that seemingly could not in any other way be surmounted.

Let us see whether this feature of heavy currents is attended with any considerable drawback.

In consequence of electricity being as a general thing now so plentiful and cheap, it might at first sight be considered immaterial, from an economical standpoint, whether heavy or light currents were used in the operation of the quadruplex; but we have to bear in mind that only a small percentage of the telegraph wires of this continent are supplied by dynamos, and that, as regards the vast majority of cases, the customary galvanic battery is in use the world over, and its cost is just as great now as it was 15 or 20 years ago. This fact, dealing with the quadruplex alone, is in itself worth looking at; but when we go further and consider the circumstance that in the course of operation of a polar quadruplex, the positions of the transmitting keys are at times such as to throw the entire current + from one end and — from the other into the line, whence it follows that the line becomes inordinately charged and by induction would interfere with every other circuit running parallel with it were they not also supplied with otherwise unnecessarily large currents in order to obviate the ill effects occasioned in them: we can appreciate the very great importance of this question.

A few years ago, before the days of the quadruplex, our telegraph circuits were equipped with receivers designed to afford a maximum of magnetic attraction, and the necessity for anything like large currents did not exist. The ordinary run of the old relays measured in the neighborhood of 300 ohms, and we could get good work out of them over long distances. To-day the ordinary run measures 150 ohms; and without going into calculations we can see that on a given line the latter instrument will be less efficient than the former, and to make it answer our purpose an increased current must be supplied. So we have perforce reduced the sensitiveness of our apparatus and increased our currents; and this it appears is the only way we could keep pace with the quadruplex, for had the more sensitive instruments with comparatively weak currents been retained, the induction from the quadruplex circuits would have rendered the ordinary single circuits well nigh inoperative.

We see in all this then that the advances made in telegraphy while admittedly very great from a practical standpoint, have been at the sacrifice of an economic and a scientific principle.

Is it now too late to rectify this error and to return to the old and economical practice that was departed from? Perhaps if an improvement in quadruplex apparatus, recently devised with a view to dispensing with the necessity of heavy currents, had been hit upon some twelve or fifteen years ago, this regrettable departure from the old practice might have been averted; and even now it might suggest the practicability of going back to first principles, if the advantages to be gained thereby were considered of sufficient importance to warrant the reversion.

The improvement referred to is in connection with and might now be taken into consideration under the head of

THE STRAIGHT CURRENT QUADRUPLEX.

In this system the signals are produced, as has already been stated, by three different strengths of current of a given polarity. This method of transmission was for a long time the favorite hunting ground of inventors seeking a solution of the problem of sextuplex telegraphy. It appeared to be an easy matter to form a quadruplex on this plan, and add thereto the reversing key of the polar system and thus obtain as many as six circuits in a single conductor. It, however, came about in the long run that the formation of the quadruplex itself, according to this method, was extremely problamatical. As a matter of fact, there never was a straight current quadruplex in practical operation. The difficulties that were presented in the way of its successful adoption have, however, been investigated in many quarters, and the invention as a whole has in the course of time been improved to an extent that warrants its now being characterized *the simplified and perfected system.*

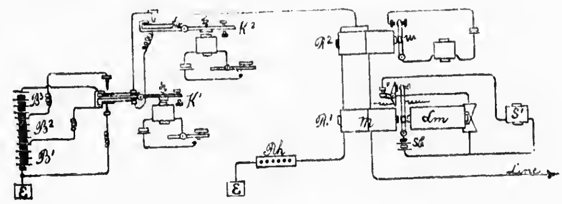
That this simplified quadruplex is fairly calculated to fill the bill already outlined for the practicable operation of the general telegraphs on currents of much less power than are at present employed, will be recognized in view of the fact that the straight current quadruplex, as a system, presents none of the objectionable features of the polar system already pointed out. There are no reversals of the current to occasion disturbance in one of the receivers, so the necessity for extraordinarily large batteries for the operation of devices such as those described is done away with; and there is no need to charge the line beyond the voltage of the maximum current emanating from one end alone, because a system of this description is operative with either like or unlike poles to line, so there are no ill effects due to induction communicated to circuits adjacent to the line upon which this quadruplex may be in operation. The importance and value of the invention need not perhaps, in view of these facts be further emphasized.

The straight current quadruplex in its simplest and perfected form is shown in the accompanying diagram. It will be noticed that the signalling battery is in one unbroken series, with its — pole to earth. The terminal and two top wires are connected with the transmitters, which operate to put the main line in connection with the battery at some one of the three points tapped according to the position of the transmitter levers, and in this way the requisite three strengths of current are presentable for the transmission of signals. The battery being in one unbroken series with one pole constantly to earth, is rendered available for the supply of current to other wires or circuits independent of the quadruplex; just as in the case where several Morse circuits are supplied from a single battery commen to them all in one of the regular main offices. This is a feature of great advantage, as it obviates the necessity for separate and exclusive batteries for the operation of the quadruplex circuits. This arrangement of the battery and transmitters was supposed to have originated quite recently, along with a further improvement of the writer's to be described further on. But an examination of the fyles of the United States Patent Office disclosed the fact that its invention was anticipated, as far back as January, 1877, by Benjamin Thompson, of Toledo, to whom it was patented (No. 195,055) in September of that year; and it is perhaps due to the unfortunate circumstance of its being covered in conjunction with an unwieldy and inadequate mass of receiving apparatus, that it never worked its way forward to the recognition that its merit deserves. As will be seen by an examination of the diagram, the transmitters are so connected that when both of the levers are upraised the line is to earth; when K^1 alone is depressed, the line connects with B^1; when K^2 alone is depressed, the line connects with B^3; and when both K^1 and K^2 are depressed, the line connects with B^2. It follows, therefore, that K^1 sends the minimum current to line; K^2 sends the maximum current to line; and when both keys together are in action, an intermediate strength of current goes to line. At the distant end there are two receivers. One of them is an ordinary duplex relay R^2 connected in the usual way; a retractile spring holds its armature with a force superior to the magnetic effect of the minimum current, but it is responsive to the intermediate and maximum currents; R^2 therefore, freely and readily responds to the manipulation of the transmitter K^2. The other receiver comprises the distinctly unique feature that has raised the straight current quadruplex to its present perfection. Its contrivance is such that the sounder or recording instrument operating in its local circuit responds promptly and accurately to the manipulation of K^1, under the action of the minimum and intermediate currents, while the maximum current produces upon it absolutely no effect whatever. In this arrangement the sounder is operated directly by the armature lever contacts, and there is consequently no enfeeblement of the signals and no uncertainty whatever about its action. In consequence, the transmissions on both sides are equally rapid and reliable. For the information of those interested in the solution of the problem involved, a detailed explanation of the receiver R^1 is given in the accompanying note.

A test which the writer was enabled to make, in conjunction with Mr. H. Bott of Ottawa, on a line between this place and Toronto, nearly 300 miles long, showed that the apparatus would respond properly to currents (= ·038 amp. max.) derived from batteries of 150 cells at each end of the line. On the self same line wire the standard polar quadruplex is regularly operated with currents (= ·070 amp.) derived from batteries of 275 cells at each end of the line; which, under certain positions of the transmitting keys, produces in the circuit a current of (·070 × 2 =) ·140 amp. max. from the combination of the (275 × 2 =) 550 cells.

The comparison speaks for itself.

We have now arrived at the conclusion of this paper. Its purpose has been to show that the practice of telegraphy to-day, despite the many advances that have been made in the service in one way and another, is not so scientific as we find it to have been so long as twenty years ago. An endeavor has been made to show that the development of the polar quadruplex, now so extensively used, has occasioned this departure from first principles, and how the now perfected straight-current quadruplex would admit of a return thereto. And the question submitted for consideration is, Would it be worth while now to return to the original practice and continue in that good old way?



NOTE.

In the straight-current quadruplex the receiver on one side responds to the stronger currents and the receiver on the other side responds to the weaker currents. It is obviously an easy matter to prevent the former being interfered with by the currents intended for the latter side, as it is only a matter of adjustment of the retractile force on the armature lever. On the other hand, it is equally obvious that an electro magnet cannot be constructed to respond to weak currents and at the same time be unaffected by strong ones. As, however, the signals are, in practice, always taken from a second instrument, operating on a local circuit of the receiver or relay, it is possible to so arrange the intervening mechanism that the local circuit shall be closed only when the currents designed therefor are traversing the magnet coils. In the construction of the instrument, therefore, a supplementary lever is hung in such a way as to hold the armature lever in an intermediate position, between its limiting stops, when attracted by the weaker currents. A strong current will attract the armature with sufficient force to carry it beyond the intermediate position, and when there is no current the armature lever falls back to its rear limiting stop. It then becomes only necessary to connect the local circuit in such a way that it shall be closed in the intermediate position of the lever, and open when the lever is in either of its extreme positions, in order to meet the requirements of the case. That at least was the assumption; but the idea proved impracticable, in consequence of a brief contact, completing the sounder circuit, that was found to obtain in the passage of the armature lever between its extreme limiting stops every time the strong current was applied or withdrawn. This difficulty has never been successfully dealt with until now. In the receiver R^1 an auxiliary electro magnet Lm, wound to produce a considerable counter e. m. f., is placed directly behind the relay armature so as to act thereupon in opposition to the main circuit coils m. In the normal condition, with no current traversing m, the armature lever is held against its back stop by a light retractile spring in the usual way. When a weak current, say the minimum, traverses m, the armature lever is attracted to the intermediate position, this closes the circuits of both Lm and S^1; the retractile power (that is, what the magnetic attraction in this case becomes) of Lm is delayed by its own counter e. m. f. until the attraction of m has grown sufficient to retain the armature in the position to which it was drawn, so the closed circuit of S^1 remains undisturbed. The same action attends the intermediate current; so S^1 responds to the minimum and intermediate currents. When the maximum current traverses m, the armature lever is carried from its intermediate position, and S^1 opens, but the circuit through Lm remains uninterrupted. If the current again decreases, the lever returns to its intermediate position, and S^1 closes; but if the maximum current is entirely withdrawn, the armature lever will, in consequence of the steady pull exerted on it by Lm, be drawn sharply back to its rear limiting stop. And if, when the armature is resting in the latter position, the maximum current is applied to m, the armature lever will pass directly over to the front limiting stop, in consequence of the counter e. m. f. of Lm robbing it of any retractile power during its passage across the contacts in the intermediate position. There is, therefore, no hindrance to the forward movement of the armature, and there is an acceleration of its movement rearward; hence the maximum current can be applied and withdrawn at pleasure, without in any way affecting the local circuit by which the sounder S^1 is operated.