Physiology. — "*The string galvanometer in wireless telegraphy*". By W. F. EINTHOVEN. (Communicated by Prof. W. EINTHOVEN).

(Communicated at the meeting of March 24, 1923).

The string galvanometer, as is well known, consists of a conducting fibre stretched like a string in a strong magnetic field. A current passing through the fibre induces a displacement of it in a plane perpendicular to the lines of magnetic force. The deflection can be observed with a microscope and the magnified image can be photographed.

Many attempts have been made to use this instrument for the reception of wireless signals, but only ordinary models, with a relatively long, not very much stretched string have been tried, and these show great sensitiveness towards disturbing direct currents. The wireless signals were received in such a way that the high frequency oscillations were rectified by means of some device, and the rectified current impulses were passed through the string; this was affected in the same way as when conveying a true direct current.

But, used in this way, the string galvanometer has only brought disappointment in wireless telegraphy, for it reacts to every current of some duration with the same sensitiveness, and even the smallest atmospherics are sufficient to give trouble. Some large Companies, who have tried to use the string galvanometer at their transatlantic stations, have abandoned work with it.

The application here to be described of the instrument is based on a quite different method [1]). The incoming high frequency oscillations are not rectified but are sent through the string immediately. The string is short and stretched so much, that its own period corresponds to the period of the ether waves used in wireless signalling. Choosing the lenght of the string conveniently and adjusting its tension, we can bring it in tune with practically all continuous waves available in radio-telegraphy. If for instance these have a length of 1 kilometer corresponding to 300.000 periods per sec., the string is adjusted so that the proper frequency of its vibrations is also 300.000 per sec.

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[1]) Patented.

The length of the string, being about 10 millim. for waves of (for instance) 10 kilom., is only 1 millim. for waves of 1 kilom. We have also experimented with shorter strings showing a still higher frequency of their proper vibrations. Heretofore as far as we know it has not been possible to induce these frequencies in any mechanism.

The string, for which we take a fine quartz fibre, is rendered able to conduct by cathode bombardment, and stretched between two microscopes; one of these serves to concentrate the light, the other to project the image, whilst both microscopes, in order to obtain a sharp definition of the string, must be very near to one another. The objectives, having a numerical aperture of 0,95, are no more than 0,2 millim. away from the string. Since the front lens of such an objective has a diameter larger than the length of the string, a special device is necessary to fix the string; this is done in such a manner that the rays of light are not intercepted, and the full angle of aperture of the objectives is made use of efficiently.

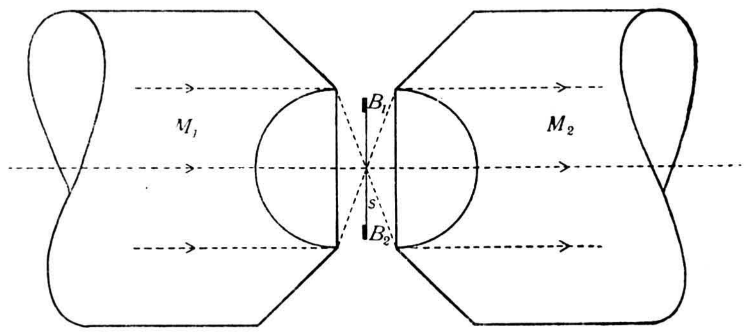

Fig. 1.

Diagram of the string s between both of the microscopes M_1 and M_2. B_1 and B_2, fine metal strips to which the string is soldered. The direction of the rays of light is indicated by the dotted lines and arrows.

The difficulty was overcome by soldering both ends of the string to fine metal strips placed in the optical plane perpendicular to the string, and rigidly attached to the apparatus in order to tighten and slacken the string.

It is important to have the string vibrating as freely as possible. Therefore it has not only to be fine but also strongly stretched like a string of a piano or a violin. Its minute mass per unity of length causes it to suffer a strong damping effect from the air, and this must be avoided. Therefore the space around it is evacuated, and in order to make the vacuum efficient it has to be made high. We attained vacua of 1 μ Hg and even higher and were able to show, that under such conditions the air damping has practically no more influence on the movement of the string. The vibrations do not die away more slowly when the vacuum is made higher than 1 μ, since the internal friction of the string itself, i. e. the fact that the material of the string has no perfect elasticity is another cause of damping.

It is not to be expected, that the vibrations of a coated quartz fibre stretched like a string would die away as slowly as those of a pure quartz rod which has been fixed at only one end. Experiments of HABER and KERSCHBAUM [1]) have shown that it took more than 12 minutes, before the amplitude of a quartz rod vibrating in vacuo was diminished to one half of the original size. LANGMUIR [2]) succeeded in lowering the pressure in an incandescent bulb lamp so much that the time of halving the amplitude was lengthened to nearly two hours.

But if we cannot make the vibrations of our string die away equally slowly, nevertheless for the purpose aimed at the result is satisfactory. We could for instance show, that a string performing 40.000 vibrations per sec., without the intentional application of a damping factor needed a time $\tau = 0{,}65$ sec. to diminish its amplitude in the proportion of $1 : \frac{1}{e}$, wherefrom it may be inferred, that the logarithmic decrement of the movement amounted to 4×10^{-5}, conf. fig. 2.

Fig. 2.
A string the vibrations of which are dying away freely.
$\lambda = 7{,}5$ km, $\tau = 0{,}65$ sec., $\delta = 4 \times 10{-}5$.

This decrement is of the greatest value for our purpose, for the smaller it is so much the better is the selectivity of the instrument. If the string has been put in tune with a definite wave, it will react to atmospheric disturbances and to currents of different wave lengths coming in from other stations so much the less, the smaller the decrement is. Generally speaking we may say that the efficiency of a receiving apparatus is determined by the amount of its decrement.

For purposes of comparison it may be recalled, that the smallest

1) Zeitschr. f. Elektrochemie. Bd. 20, 1914, p. 296.

2) Journal of the American Chem. Soc. 35, 107 (1913) cited from HABER u. KERSCHBAUM.

available decrement of an electric circuit is about 0,01 and that in most cases this value is higher. The decrements of all the receiving apparatus known to us, which mechanically register the signals are larger than that of the string galvanometer.

However it is only possible to profit fully by a small decrement,

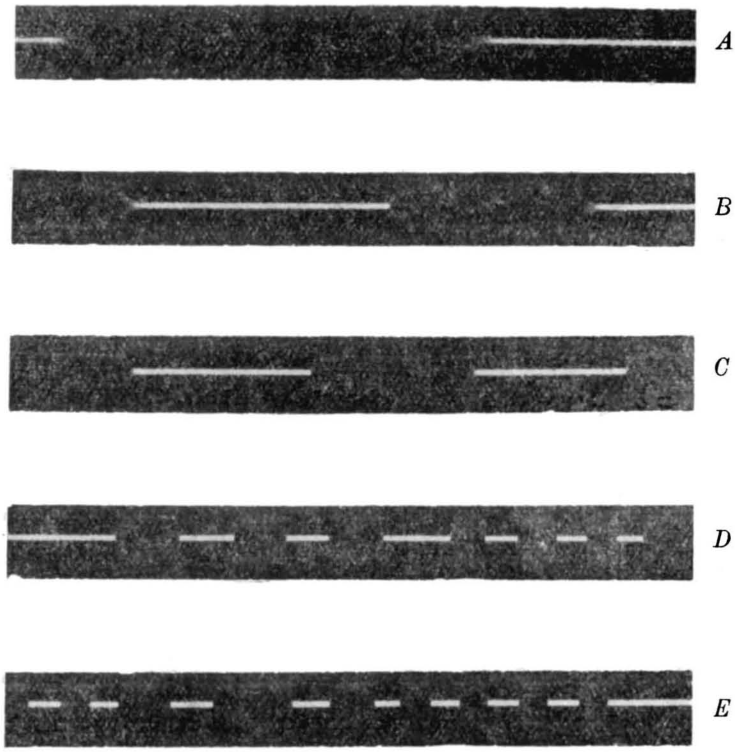

Fig. 3.

	Field magnet current	τ	δ
A	0,5 Amp.	0,27 sec.	$9{,}25 \times 10^{-5}$
B	1,— "	0,1 "	$0{,}25 \times 10^{-3}$
C	2,— "	0,03 "	$0{,}83 \times 10^{-3}$
D	4,— "		$3{,}- \times 10^{-3}$
E	6,— "		$6{,}2 \times 10^{-3}$

when signalling is excessively slow. Signals coming in at the usual speed would be intermingled if the vibrations of the string died away so slowly. Therefore it is necessary to increase the decrement of the receiver purposely. This is not performed by admitting air around the string. On the contrary the vacuum is kept as high as possible in all experiments, but the strength of the magnetic field is changed. By varying this value from zero to a maximum the amount of the decrement can be adjusted in a simple and at the same time very precise manner.

In the above fig. 3 the photos are reproduced of the same string as that of fig. 2 the strip of paper moving with the same velocity, i. e. 10,75 millim. per sec. Continuous waves the length of which was 7,5 kilom. were coupled inductively with the circuit of the string, and switched on and off repeatedly, whilst in the successive photos the current exciting the field-magnet was increased from 0,5 to 6 Amp. The photos show, that the time in which the vibrations of the string die away is shorter as the exciting current increases. The decrements can only be measured in the photos *A, B* and *C* because of the low speed of the paper strip. For *D* and *E* they have been calculated from the intensity of the magnetic field, which amounted tot 7600 and 10.900 Gauss respectively.

In the calculations of all useful decrements in radio-telegraphy, the proper decrement of the string itself caused by its internal friction is to be neglected, whilst in a high vacuum also the air damping is not to be taken into account. Under these circumstances the relation between the decrement and the field intensity is given by the formula

$$\delta = \frac{4}{\pi_2} \cdot \frac{H^2 \times 10^{-9}}{m\,w\,N} \quad \ldots \ldots \ldots \quad (1)$$

where δ represents the logarithmic decrement,

H the intensity of the magnetic field in Gauss,

m the mass of the string in grams per centim.,

w The resistance of the galvanometer circuit in Ohms per centim.,

N the number of periods per sec. of the string when vibrating in resonance with the continuous waves induced.

When receiving a signal the decrement must be adjusted so that the dots and dashes of a signal only just begin to blend, as may

Fig. 4.
Record of signals from an Italian station, made in Leyden. The decrement of the string has been adjusted so that the dots and dashes of a signal only just begin to blend.

be illustrated in the next fig. 4. The greater the speed of the signals so much the greater the intensity of the magnetic field, i. e. so much the larger the decrement has to be made. The maximum speed of still readable signals being about 600 words per minute is obtained when the intensity of the field is maximum, being 22.600 GAUSS in one of our instruments.

If sufficiently strong signals be available, the allowable speed could still be increased by admitting air around the string.

One of the difficulties that had to be overcome on designing the instrument was the adjustment of the tension of the string. This must be secured in an exceedingly precise and punctilious manner.

We stretch the string by extending it. In the figures reproduced above a string has been used of a length of 6 millim., stretched so that it was in tune with a wave of 7,5 kilom. Suppose that it then be extended to an amount of 1 °/₀ and thus be lengthened by 60μ. If the current exciting the electromagnet is 1 Amp. the decrement of the string is 0.25×10^{-3}. From this it can be calculated that an increase of the elongation to an amount of $4,8\,\mu\mu$, suffices to bring the string so much out of tune that the amplitude of its vibrations will decrease in the proportion of $1 : \frac{1}{\sqrt{2}}$ i.e. 30 °/₀. The same effect is produced by changing the wave-length of the signal to an amount of 30 centim. on 7,5 kilom.

For the above calculations formula (2) has been used :

$$\frac{\lambda_r - \lambda_1}{\lambda_r} = \frac{\delta}{2\pi} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \quad (2)$$

where λ_r represents the wave-length of continuous waves inductively coupled with a circuit and being in tune with its proper period, and λ_1 the wave-length that is so much smaller or larger than the former one, that the electric power of the circuit is reduced to one half. Here the movement of the string is substituted for the coupled current, and the amplitude of its vibrations for the square root of the electric power.

It need not be emphasized, that much smaller changes of the amplitude are measurable than the value which is mentioned above for convenience' sake. The apparatus for stretching the string must enable elongation to be effected within certain limits with absolute regularity, and by degrees smaller than $1\,\mu\mu$. Both of our present models comply with this requirement.

The experiments performed with the galvanometer have brought to light some phenomena concerned with the movement of string in general, which could not be observed heretofore, since no vibrating string with so small a decrement has ever been available. Suppose, that the vibrations of a string of a piano or a violin die away as slowly as they do in the galvanometer, e.g. within about 2 or 3 sec. and that the frequency is a hundred times less, then accordingly the decrement is 100-times greater; for we have

$$\delta = \frac{1}{N\tau} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

where δ and N have the same meaning as in form. (1) whereas τ represents the time in seconds necessary for the amplitude to diminish in the proportion of $1 : \frac{1}{e}$. For the time of dying away we may allow 3 to 5-times the value of τ.

The musical string therefore vibrates much less freely, and we cannot tune it as sharply. However this is really unnecessary for the purpose it is used for, since the human ear is unable to discriminate so minute variations of pitch. The increase of tension experienced by the musical string, when moving from the position of equilibrium to that of the maximum displacement, may be left out of account at least when the amplitude is moderate. Every theory of the movement of strings is based on the supposition that in the different phases of a period of the vibration the tension of the string remains constant. [1])

However the conditions of the string of the galvanometer are different. A small amplitude, for instance to an amount of 1 per thousand of the length of the string, may be sufficient under definite conditions to display the influence exerted by the increase of the tension which the string is subjected to by its displacement.

We hope later on to revert to these phenomena, which may be referred to as those of the "jumping point". But it should be noticed here, that the difficulties caused by it are diminished to a large extent and practically overcome when the string which is to be in tune with a certain wave, is made as long as possible and extended to a maximum.

In fig. 5 a record made in Leyden is reproduced, which is of special interest for us in Holland; it represents the signals received from the alternator on the Malabar at Bandoeng. In order not to disclose the secret of the telegram only a few separate words and figures are given, so that the meaning will be understood by none.

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[1]) Conf. RAYLEIGH. The theory of sound, London 1877. Vol. 1, p. 36 and 128.

Although our only receiver was a small, not very favourable aerial, we were able repeatedly to take long telegrams, the signals of which came in absolutely clear.

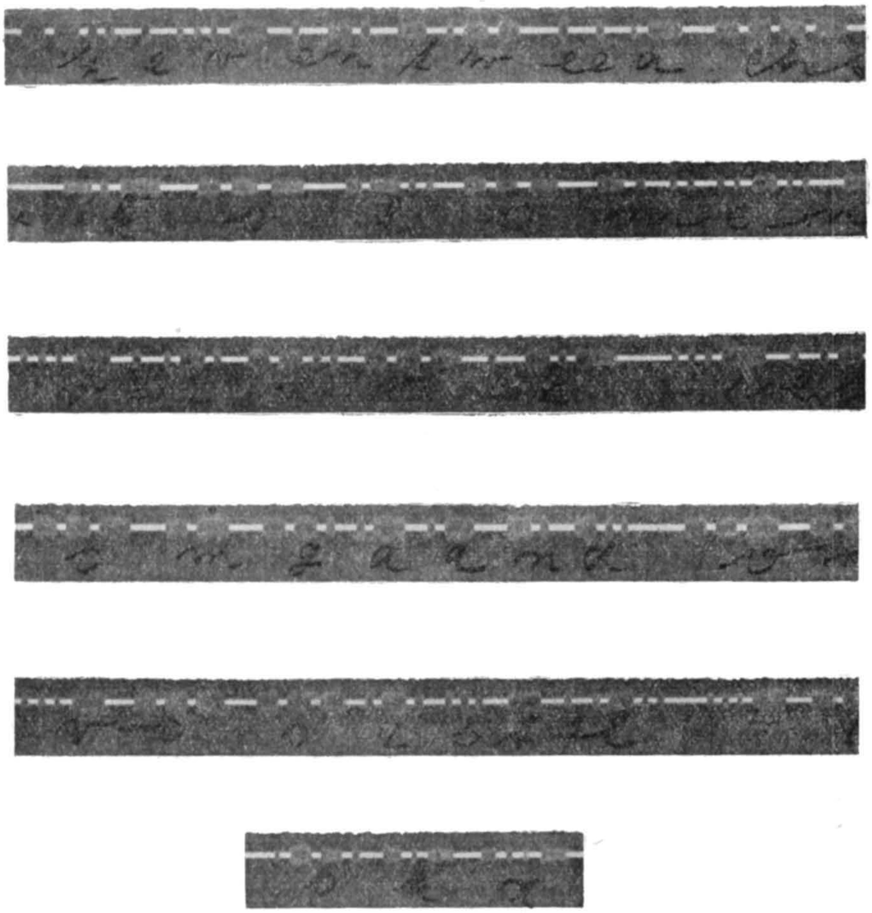

Fig. 5.

Record of signals from the alternator on the Malabar at Bandoeng, made in Leyden January 13th, 1923.

To what extent can the reception by means of the galvanometer stand comparison with the ordinary telephone reception?

In order to answer this question we shall first compare the sensitiveness of the two instruments. The human ear is a very sensitive organ. According to MAX WIEN [1]) it is sufficient to apply to the tympanic membrane an energy amounting to 0.83×10^{-12} ergs

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[1]) MAX WIEN. Ueber die Empfindlichkeit des menschlichen Ohres für Töne verschiedener Höhe. PLÜGER's Arch. f. d. ges. Physiol. Bd. 97, S. 1.

per sec. that is a power of $0{,}83 \times 10^{-19}$ watts, in order to produce a sensation of sound; the necessary amplitude of the air waves being a thousand times smaller than the diameter of a molecule. In accordance with this the telephone is capable of responding audibly to very weak currents. The modern telephones, now much in use in wireless telegraphy, which are put in tune with the most favourable note for perception by the human ear, are to be considered among the most sensitive of all existing instruments.

MAX WIEN [1]) states that for the most sensitive telephone under most favourable conditions a power of $3{,}03 \times 10^{-14}$ watts is wanted to produce a just barely audible sound. AUSTIN [2]) indicates a 60 times smaller value viz. $0{,}5 \times 10^{-15}$ watts.

To evaluate the sensitiveness of the galvanometer we suppose that during the reception of a signal a uniform effective electromotive force E be applied to the terminals of the string. At the first moment when the string is still in rest, it will be traversed by a maximum current $I = \frac{E}{W}$, where W represents the ohmic resistance of the string, but gradually the current will decrease by the back-electromotive force which is set up in the string by its movement. If we neglect the internal friction in the string itself and make the vacuum so high, that it may be considered as absolute, the back-electromotive force produced will be equal to E as soon as the end- amplitude is attained. The current flowing through the string then $= 0$. As long as the signal lasts the string goes on oscillating in tune with it without consuming energy.

For evaluating the sensitiveness we have to take the maximum number of watts wanted i.e. $\frac{E^2}{W}$. If the string have a mass of M grams, being in tune with N cycles per sec., and its electromagnetic decrement being δ_{em}, the number of watts wanted to induce an end-amplitude of U cetim. is

$$B = \frac{\pi^2}{2} \times 10^{-7} \times M\, U^2\, N^3\, \delta_{em} \quad . \quad . \quad . \quad . \quad . \quad (4)$$

or also

$$B = \frac{4500\, \pi^2\, M U^2}{\lambda^3\, \tau}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

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1) WIEDEMANN's Annalen 4. IV, 1901, p. 450.

2) Jahrbuch der drahtl. Telegr. 11 and 12, 1916. „Conf. also H. O. TAYLOR. Telephone receivers and radio telegraphy. Proceedings of the institute of Radio engineers, 1918, Vol. 6, p. 37.

where λ represents the wave-length in kilometers, and τ the time in seconds necessary to raise the amplitude of the oscillations of the string from 0 to a value $\left(1-\frac{1}{e}\right)$ of the end amplitude. The speed of transmission admissible is inversely proportional to τ.

The minute amount of energy sufficient to keep the string oscillating with its end-amplitude can easely be evaluated. For the sum of the values neglected previously, can be determined by measuring the decrement of the vibrations when dying away freely.

Denote this decrement with δ_{l+s} then the value to be found is

$$B_1 = \frac{\pi^2}{2} \times 10^{-7} \times MU^2N^2\,\delta_{l+s} \quad . \quad . \quad . \quad . \quad . \quad (6)$$

or also

$$B_1 = B \times \frac{\delta_{l+s}}{\delta_{em}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

where δ_{l+s} is again supposed to be small in comparison with δ_{em}. This is always the case with a good string, a moderate field and an attainable vacuum. Under the conditions of the figures 2 and 3 we have $\delta_{l+s} = 4 \times 10^{-5}$, whilst δ_{em} with a magnetizing current of 4 amp. attains a value which is 75-times larger viz. 3×10^{-3} and therefore $B_1 = 0{,}0133\,B$.

What value is to be computed for B when use is made of formula (4)? The result depends on the dimensions, especially on the diameter of the string inserted in the galvanometer.

If we take a fine string[1]) with a diameter of $0{,}2\,\mu$, a vibration amplitude of the same dimension will already be visible and suitable to be recorded. We have then $U = 2 \times 10^{-5}$ centim. The mass of a string of the above mentioned diameter and of 1 centim. length may be taken as $M = 2 \times 10^{-9}$ grams. Suppose, moreover, $N = 20.000$, and $\delta_{em} = 0{,}001$, then we find, for the number of watts wanted, that $B = 3{,}2 \times 10^{-15}$. From this we infer, that the sensitiveness of the galvanometer is to be evaluated to an amount of the same order of magnitude as that of the telephone.

The use of such fine strings is attended with certain practical difficulties, so that we prefer to work with strings 5 to 6 times thicker and therefore considerably less sensitive. Moreover the sensitiveness decreases, when the wave-length is shorter and the speed of transmission higher, as may be seen from formula (5).

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[1]) Conf. W. EINTHOVEN, Ueber die Beobachtung und Abbildung dünner Fäden. PFLÜGER's Archiv. f. d. ges. Physiol. Bd. 191, S. 60.

However, in view of the comparison between string and telephone it may be pointed out, that the maximum sensitivity of the latter named instrument is by no means available in radio practice, for there is a great difference between the intensity of a signal just barely audible and one which is readable.

It will be noticed that we only have compared the power sensitiveness of the galvanometer and of the telephone as such, and that the application of these instruments in combination with the oscillating audion and with low and high frequency amplifiers has been left out of consideration. For the sensitiveness of reception by telephone in combination with the oscillating audion we may refer to the paper of AUSTIN [1]). He mentions that for a just audible signal the absolute sensitiveness of the oscillating audion is $1,2 \times 10^{-15}$ watts, that is to say a power, which is about 2,5 times greater than that needed by the telephone as such.

For the practical use of the string galvanometer in radio-telegraphy it is superfluous to try to obtain the greatest possible sensitiveness of the instrument. It is not the sensitiveness which determines its usefulness, since weak signals may be strengthened by means of amplifying vacuumtubes without limit. The efficiency of a receiver is much more determined by its selectivity i.e. its freedom from disturbances.

If we wish to compare the reception by the galvanometer to that by the telephone from the point of view of their selectivities, we must discuss once more the properties of the human ear. As is well known we are able to distinguish by means of hearing many sounds produced simultaneously. If we pay special attention to one of the numerous musical instruments of a complete orchestra, we are able to follow its performance separately. So also the Marconist can distinguish the tone of a signal, although many other sounds or noises of, for instance, extraneous stations or atmospheric disturbances reach him at the same time. This secures for reception by telephone an important advantage over every form of reception which has the object of recording the signal graphically. In the graphical image of a concert of sounds it is extremely difficult to follow the tone which we wish to analyse and often it will be even quite impossible to do so.

But against this disadvantage of the galvanometer there is the

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1) LOUIS W. AUSTIN. The measurement of radio-telegraphic signals with the oscillating audion. Proceedings of the Institute of Radio engineers, 1917, Vol. 5, p. 239.

advantage of a much smaller decrement, and we may ask how far in practice advantage and disadvantage are counterbalanced.

The answer depends on the possibility of deriving the full profit from the small decrement of the receiver. Let us for instance try to receive in Leyden the signals of the present high frequency alternator at Bandoeng. It does not keep its wave of 7,5 kilom. absolutely constant, but according to our measurements the wave varies by amounts of 1 to 2 per thousand. If, by diminishing the field intensity, we decrease the string decrement so much as would be desirable when receiving a constant wave, a signal would only be received now and then, that is to say only at those moments, when the varying wave of the transmitter coincides exactly with the wave to which the string is put in tune. To different wave-lengths the string does not respond, so that the dots and dashes transmitted are not received regularly and the telegram becomes unreadable. We are obliged to increase the string decrement and so to enable the reception of a greater range of variation of the wave-length of the transmitter.

On experimenting we obtained the impression that the reception by telephone of the high frequency alternator of Bandoeng is disturbed by extraneous noises about as much as the reception by the galvanometer. In both cases practically as many signals become unreadable by atmospherics. But we have not yet had the opportunity to carry out exact measurements on this point and it may be noticed, that the difference in skill of the various Marconists, who are carrying on the comparative experiments must also be allowed for.

If the wave transmitted oscillates still more than is mentioned above, the Marconist will obtain the better result, but if it is being kept steady, such as actually is the case with many modern transmitters, then the advantage will pass to the side of the galvanometer. The dots and dashes on the strip of paper will then be like those of fig. 4 and of the upper part of fig. 6.

The slower the rate of transmission so much the smaller the string decrement may be made; the freedom from disturbances becomes improved proportionately and thus the possibility of receiving with the galvanometer increases. On the other hand the Marconist is not able to take advantage of a more constant transmission wave; it is impossible for the human ear [1]) to perceive the minute variations in pitch, to which a string vibrating with a small decrement is capable of responding noticeably.

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[1]) Practically also when the Marconist is applying beat reception.

But it is not only with a slow transmission that the string is superior. If, in relation to the disturbances, the signals are strong enough to make a record of them with a moderate or even a large string decrement, then high speeds of transmission will become possible and soon the Marconist will no more be able to read the signals, while the galvanometer is recording easily a few hundreds of words per minute.

Dr. DE GROOT of Bandoeng, to whom we are much indebted, has suggested a valuable idea. For his enthusiastic collaboration in the difficult experiments carried on at Bandoeng with the galvanometer some time ago, we thank him heartily here.

Dr. DE GROOT has suggested the application of two galvanometers simultaneously when an arc generator be used for transmission; one string may be put in tune with the active wave, the other with the wave of rest. An atmospheric appearing at a given moment may be easily recognized as such, if it influences the registration of only one of the two waves. Thus the possibility of making the signal readable throughout the atmospheric disturbances will become greater.

In fig. 6 a record is reproduced which has been made at Leyden according to the suggestion of Dr. DE GROOT. The string of one

Fig. 6.

Record of the arc generator FL, Paris with 2 galvanometers in parallel. The signalling wave is registered by one, the non signalling wave by the other galvanometer.

galvanometer is seen vibrating every time the other is standing still and vice versa. How great the practical value of this method will be has yet to be determined, but the first impressions which we have obtained from the result of a few experiments are favourable.

The idea of using 2 galvanometers simultaneously may find another application when signals are to be received, the wave-length of which is not very constant. Either string may be put in tune with a different wave; one with a wave which is a little longer, the other with a wave, which is a little shorter than the mean length around which the transmission wave is fluctuating. So the admissible range of fluctuation is increased, while the decrement of the vibrations of either string may remain small.

However, rather than applying this, after all, somewhat defective means, it is better to try to improve the transmitter. As a matter of fact present technique is actually capable of producing transmitters which keep their wave practically constant.

The advantages of the reception by galvanometer in distinction from the reception by telephone are worth mentioning. On transmitting slowly it will be possible to receive signals with the galvanometer, which are not readable by telephone. Every improvement in this direction of the receiving apparatus, which always remains relatively simple, saves, as AUSTIN[1]) observes rightly, large sums needed both for the erection of high power sending stations and for their working expenses. And that, as matters stand at present, improvements are still wanted, is obvious from the many difficulties experienced even with the best installations. To quote an example it may be noticed, that during the whole of July 1921 the communication between two of the Trans-Atlantic stations, which are considered among the most reliable, was so poor that only 23 per cent of the words sent were successfully received[2]).

The high speed reception with the galvanometer makes it possible to take full advantage of the installation at those hours of the day and the night, which are the most favourable for the transmitting of the signals, and to transmit many more words than could be received by telephone. Moreover the secrecy of the telegrams can be better secured since the numerous telephone-receivers will not be able to read the quick signals.

In time of war the interference by a second station will be hindered, when the signalling wave and the non signalling wave of an arc transmitter are received simultaneously with two galvanometers.

Finally we may mention another advantage which bears upon the general use of wireless telegraphy in the world. It is Dr. DE GROOT, who has placed it on the fore-ground. During night and day numerous signals are sent from many hundreds of transmitters. The installations interfere with one another, if they use waves the lengths of which do not greatly differ. The difference in wave-lengths which are applicable for transmitting signals is limited; only these waves are useful, which range neither below nor above a certain length; in other words: the spectrum of the useful waves is comparatively small. Everyone using a part of it takes it away from another man.

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[1]) Conf. L. W. AUSTIN, Long distance radio communication. Journal of the Franklin Institute, Vol. 193, Apr. 1922, p. 437 (458).

[2]) Conf. L. W. AUSTIN l.c. p. 443.

The smaller the part of the spectrum he uses, the larger the part which remains for others.

Owing to the small decrement of the galvanometer a wireless installation may be restricted to using a smaller part of the spectrum than heretofore, with the result that it will be possible to increase the number of simultaneously working installations. This increase is badly needed, so we may expect on good grounds, that the galvanometer will be capable of rendering a service to radio communication in general.

We do not finish this paper without rendering our tanks to the many persons who have been ready to help us with our work. Especially we wish to express our gratitude for the interest and the support, which we have received from Mr. Th. B. PLEYTE wo was at that time our Colonial Minister.