

ADDITIONAL EXPERIMENTS WITH IMPULSE EXCITATION * †

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In the June, 1916 issue of the PROCEEDINGS, the writer published a paper dealing with the design and operation of an impulse excitation transmitter. It is the purpose of this paper to set forth the results of some further experiments with this type of apparatus.

In the original paper, a hydrogen atmosphere gap of the modified Eastham-Peukert type, worked at considerably above atmospheric pressure, was described; and the various effects of gap speed, gap surface, and tone and antenna circuit absorption were set forth. In this paper, as in the last one, the term "impulse excitation" will be used to designate that form of shock excitation in which the antenna circuit is set into oscillation by a blow delivered from a rush of current in an adjacent aperiodic, or practically aperiodic, circuit as distinguished from the "beat" excitation of those quenched gap transmitters which make use of several current oscillations in the gap circuit before the antenna circuit is excited to free oscillation.

The writer has found it of assistance in the contemplation of impulse excitation to consider shock excitation in general to be divided into two regions of action, the one—impulse excitation, the other—"beat" excitation, using the definitions of these two terms given in the preceding paragraph. A transmitter which ordinarily might come in the one class, may, by the mere alteration of its spark gap, be placed in the other. That is to say, a gap circuit of high capacitance and low inductance, the action of which ordinarily places it in the "beat" excitation region, may be placed in the impulse region by the employment of one or more of a variety of artifices, and the reverse action may take place by the omission of the same.

* Received by the Editor, September 1, 1916.

† See "PROCEEDINGS OF THE INSTITUTE OF RADIO ENGINEERS," volume 4, number 3, page 233.

For instance, in the original paper, it was shown that when using the rotary quenched gap, with sectored surfaces, in air, impulse excitation could not be obtained. However, by the use of alcohol vapor at a pressure above atmospheric, this gap action could be brought well within the impulse region. The use of smooth gap surfaces brought it still further within this region and the use of a tone circuit shunted across the gap acted even more favorably. While the omission of any one of these aids to rapid damping of the current in the impulse circuit will still keep the action of the gap well within the impulse region, the use of all of them is desired.

HYDROGEN FIELD

With reference to the employment of the hydrogen atmosphere under pressure in the transmitter described in the original paper, the criticism has been made that too much time would elapse before the proper pressure could be built up, but this may be easily answered. In the first place, the use of the alcohol vapor is not essential to bring the gap action into the impulse region if smooth disks are used in the gap or if the tone circuit is used with either set of disks. But even when the sectored disks are used without the tone circuit, the pressure is built up within the gap just as rapidly as it is needed. Conductivity of the gaseous medium between the electrodes of any gap "is due mainly to the ions of the metallic vapor formed by the heating of the electrodes."¹ So long as the gap electrodes remain cool, and hence the surrounding medium, a high resistance, and therefore good quenching, will be maintained. Thus, at the start, when the gap is cold, the alcohol vapor under pressure is not needed to secure a high resistance. However, as soon as the enclosed gases begin to heat, the very heat which ordinarily would lower the resistance of the gap causes the increased pressure of the alcohol vapor, which raises the resistance.

That "the one action automatically compensates for the other," as stated in the original paper, has been repeatedly demonstrated. Using the sectored disks, the gap has been operated without the hydrogen vapor, causing the initial antenna current to drop rapidly 45 per cent. and more. The current drop is due to the fact that as the enclosed air heats, impulse excitation no longer takes place and the transmitter becomes merely a

¹ From "Wireless Telegraphy," Zenneck-Seelig, page 98.

"beat" excitation, quenched spark transmitter, the gap and antenna circuits of which have widely different time periods. Upon admitting alcohol to the spark chamber, vaporization immediately takes place and sufficient pressure is made to cause the antenna current to return instantly to its normal value, indicating that impulse excitation is once more taking place.

COUPLING

The criticism was also made that the coupling between the impulse and antenna circuits in the transmitter previously described was not sufficiently close. Figure 5 of the original paper is herein reproduced as Figure 1. This illustration shows the

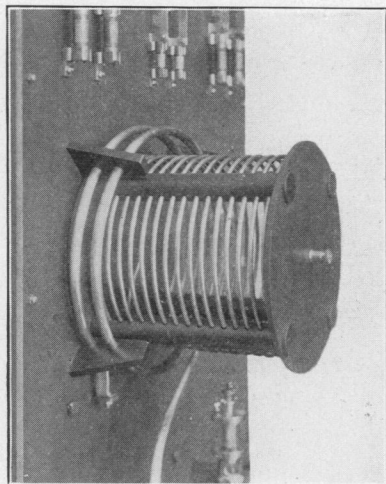


FIGURE 1

inductive coupler. While the coupling between the two windings is close when considering the usual coupled circuits, it is in reality fairly loose for impulse operation, and the writer is grateful for this fact being called to his attention.

There are two methods by which the coupling between two circuits may be increased, one—purely mechanical, the other—electrical. The first is to increase the proximity of the two windings of the inductive coupler, the other is to make, as nearly as possible, all of the inductance in each circuit common to both. The latter limit would result in maximum coupling, but it is of

course impossible to attain. The nearest approximation is to combine the usual antenna loading inductance with the antenna circuit winding of the inductive coupler, thus bringing all of the lumped inductance of the antenna circuit into the field of the impulse circuit. In addition, as much of the inductance in the impulse circuit as practicable should be designed so as to be effective in inducing energy in the antenna circuit winding of the coupler.

A reference to Figure 2, which shows the new coupler, will show how these two methods have been utilized. The impulse circuit winding of the coupler has been reduced to but one turn,

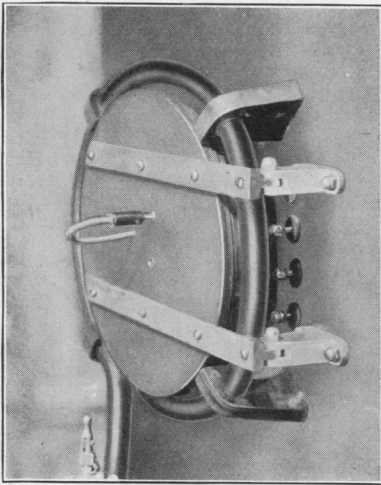


FIGURE 2

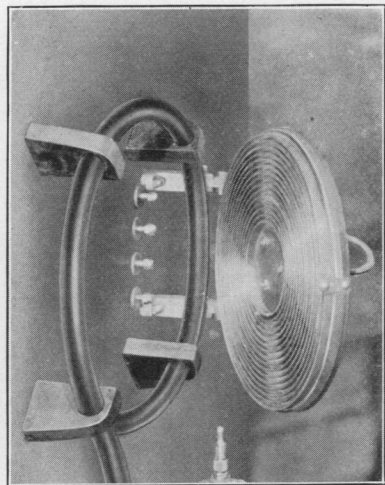


FIGURE 3

and the condenser capacitance increased. In order to handle the momentarily high current amplitude, a special form of litzendraht has been made up, which is enclosed in a vulcanite tube for protection. The antenna circuit winding is wound spiral fashion on an insulating base and is arranged to swing directly into the single loop of the impulse circuit inductance.

Figure 3 shows the antenna circuit winding swung back from its normal position in order to show the construction.

Due to the low potentials generated in the antenna circuit, the turns of the antenna circuit winding may be very closely spaced, thus securing enough inductance to obviate the necessity of loading inductance.

A plug with two sockets is shown, one for 600 meters, the other for 300 meters. The connections are such as to cut in a series condenser in the antenna circuit when the plug is inserted in the 300 meter socket.

The adoption of the new coupler resulted in a two-fold advantage, i. e., increased antenna current together with a lower antenna current decrement.

Figure 4 shows three resonance curves for various wave length settings of the antenna circuit with a fixed time period of the impulse circuit. Expressing this time period in terms of wave length, this was about 700 meters.

GAP LENGTH

The effect of gap length is of more than slight importance in the attainment of impulse excitation. Figures 5, 6, 7, 8 and 9 show resonance curves of the current in the antenna circuit for various gap separations, using the smooth disks. It should be borne in mind that, because of the construction of this particular type of gap, the actual spark length is twice the gap separation. The stationary disk is divided into two parts to which the terminals from the secondary of the step-up transformer are connected. The spark passes from one stationary electrode to the revolving disk and back from the disk to the other stationary electrode, thus making the total spark length twice the separation distance.

In each of these resonance curves, the logarithmic decrement given is the antenna current decrement; that is to say, the decrement as computed from the resonance curve minus the decrement of the measuring instrument.

From the curves, it will be seen that the best results are obtained when the gap length is as short as it is possible to make it. In actual practice, the revolving electrode is screwed up to the stationary one by means of the bearing shaft, which is threaded into the casing of the spark chamber, until the two touch. The bearing is then turned backward just enough to separate them from contact.

This is illustrative of one advantage of the revolving impulse discharger over the stationary one. To preserve such an exceedingly short distance with a stationary gap is somewhat difficult. The theory of the plane surface, short gap is that by providing large parallel surfaces, "wandering" of the spark may be effected, since as fast as the electrode is pitted, thus increasing

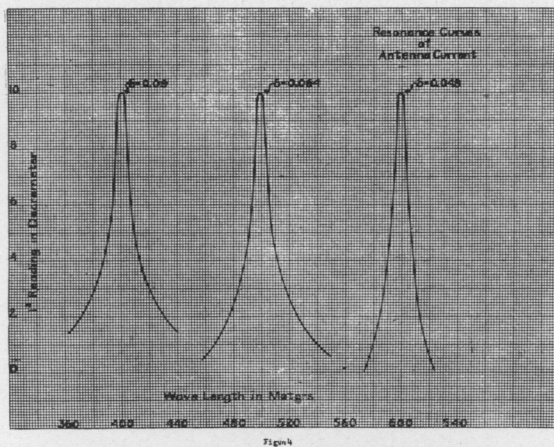


Figure 4

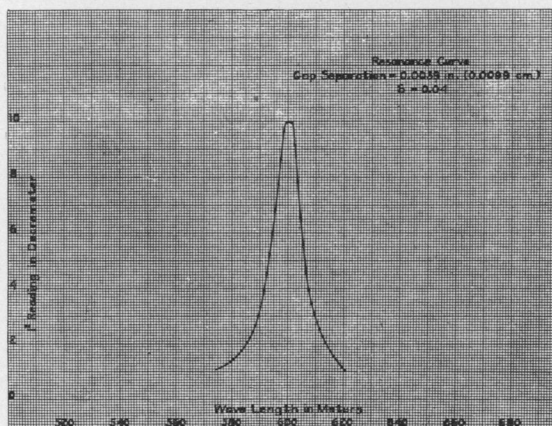


Figure 5

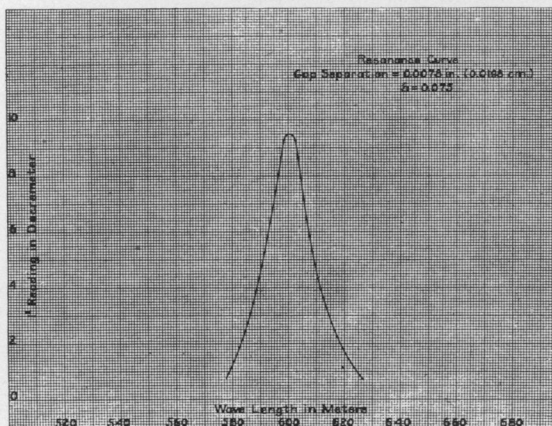


Figure 6

the gap length, the spark moves to a new and cooler position. This may work quite satisfactorily in ordinary quenched gap operation where the current amplitude in the gap circuit is not extremely high, but with impulse excitation and the consequent momentarily high current value encountered, burrs are very often formed on the gap surface. This prevents spark "wandering," and the action being cumulative, the gap soon becomes short-circuited.

With a revolving discharger, on the other hand, such effective "wandering" of the spark is obtained as to eliminate the formation of burrs and extremely low gap lengths may be employed without danger of fusion.

However, the use of a revolving discharger with a separation of the order of 0.004 inches (0.01 centimeter) necessarily entails extremely accurate lathe work. Roller bearings at each end of the bearing shaft and a system of facing up all surfaces have made the realization of such a short gap possible.

As set forth in the original paper, one of the chief requisites for high damping of the current in the impulse circuit is that the gap must rapidly regain its initial high resistance. That is to say, de-ionization of the gases between the gap electrodes must be effected as speedily as possible.

Zenneck discusses the various factors tending to bring about the de-ionization of spark gaps,² and concludes that such de-ionization is caused chiefly by the electric field between the gap surfaces and by absorption of the ions by the electrodes. It will be seen that the shorter the gap length, the more intense the electric field, and the more opportunities for absorption of ions by the gap disks.

The fact that a very short gap insures more rapid damping of the current in the impulse circuit than a longer one explains why better results were obtained with smooth instead of sectored gap disks as set forth in the original paper. The sectored gap, having projecting surfaces as in any rotary gap, causes the spark discharge to be drawn out, or the electrodes separated, as the projections pass each other, which is equivalent to using a gap of wider separation.

In taking the data for the curves in Figures 5, 6, 7, 8, and 9, the tone circuit was omitted for fear of puncturing the paper condenser in that circuit, due to raising the potential across the gap by the abnormal separation of the disks.

Figure 10 shows a curve of antenna current for the various

²"Wireless Telegraphy," Zenneck-Seelig, page 97, *et seq.*

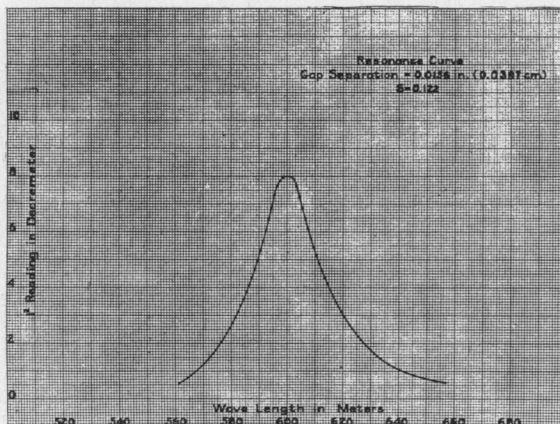


Figure 7

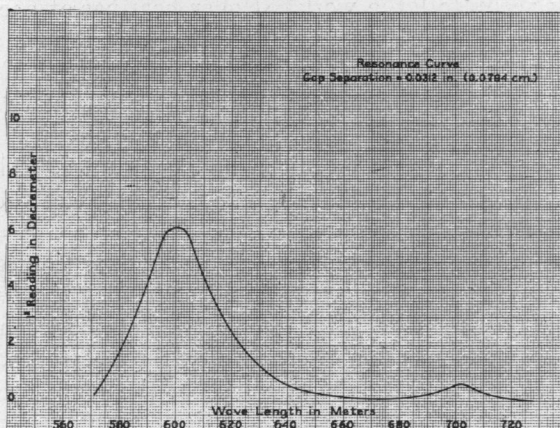


Figure 8

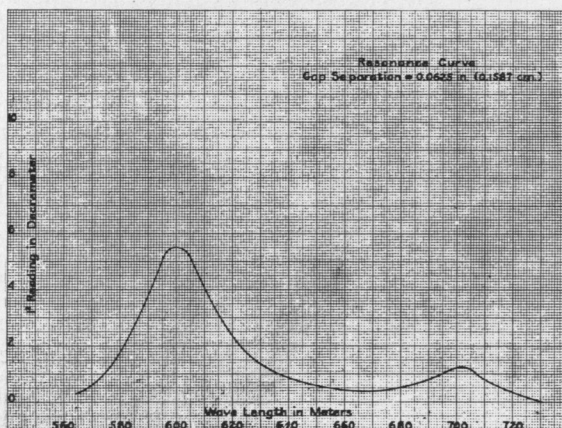


Figure 9

gap separations used in the preceding curves. It will be noted that while this current curve is a rising one with increased gap separation, the resonance curves in Figures 5, 6, 7, 8 and 9 successively decrease in amplitude. This is an excellent demonstration of the unreliability of aerial ammeter readings in damped wave transmission, at least, so far as the determination of effective energy for signalling purposes is concerned. Contrary to

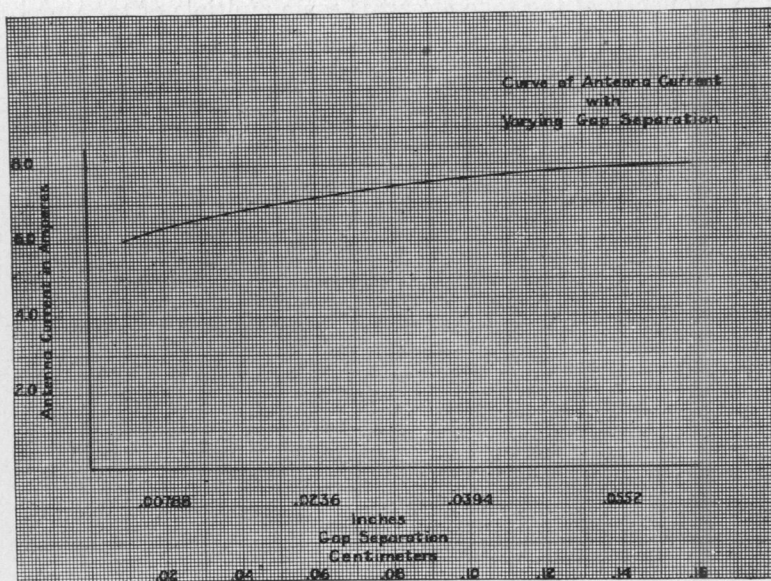


Figure 10

the action of the current indicating device in a decimeter, the aerial ammeter indicates the average integral effect of a large number of oscillations instead of the current amplitude at the oscillation frequency of the antenna circuit. Other things being equal, the higher the decrement of the antenna current, the greater the aerial ammeter reading—hardly a reliable method of measurement.³

TONE CIRCUIT

Figure 11 shows the schematic diagram of connections, the tone circuit being shunted across the impulse discharger. The condenser in the tone circuit is a paper one with fairly high

³Cf. Discussion by J. Zenneck, "PROCEEDINGS OF THE INSTITUTE OF RADIO ENGINEERS," volume 4, number 4, page 337.

capacitance. With this particular transmitter, signals are louder when received on crystal or audion (non-oscillating) detector when the tone circuit is used. However, because of the irregular impulse frequency and possible train interference in the antenna circuit, the note is not musical, altho possessing definite pitch. Mr. Eldridge Buckingham has found from experimentation with a Cutting and Washington gap on alternating current that, when using the tone circuit, the purest notes are obtained when the frequency of the tone circuit is some multiple of the supply frequency, or the group impulse frequency. This is in confirmation of one of the experiments described in the original paper in which the action of the tone circuit was noted when shunted

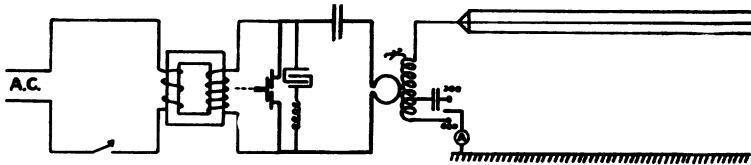


FIGURE 11

across the sectored gap. "Certain speeds of the gap were found which tended to improve the tones greatly (These critical gap speeds were probably those which placed the impulse group frequency in resonance with the oscillation frequency, or a multiple thereof, of the tone circuit.)"

The use of a higher supply frequency would not tend greatly to improve the situation since it would not insure any more regularity of the impulse discharges. However, with a tone circuit adjusted to the same audio frequency as that of the supply current, say 500 cycles, favorable results should be obtained. Such an arrangement might seem unnecessary if it were not for the fact that the addition of the tone circuit secures greater telephonic response, altho with no actual increase of received energy, at the receiving end.

This is because, when omitting the tone circuit, the great number of partial discharges or impulses and their irregular spacing "tend to weaken rather than strengthen the effect upon the telephone diafram, as it may often not have time to return to its position of equilibrium and in any case is forced into extremely complex movements."⁴ This is evidenced by the very

⁴"Wireless Telegraphy," Zenneck-Seelig, page 198.

definite click heard in the receivers when the transmitter key is depressed and again when it is released.

This same lack of auditory response with crystal detector is encountered in arc operation. Here, the frequency is so high as to prevent the diafram from vibrating in its normal fashion, and it is simply pulled over toward the magnets and held there until the current flow ceases.

With the alternating current impulse excitation transmitter, the addition of the tone circuit, by the superimposition of its regular, audio frequency oscillations on the hissing impulse note, secures a more pronounced auditory effect.

The use of a sectored gap, properly milled, connected synchronously to the shaft of a 500 cycle generator, and with the voltage so adjusted as to give but one impulse per half cycle, has been suggested. This would undoubtedly produce a clear note without the use of a tone circuit. Whether the energy transfer between the impulse and antenna circuits would be as efficient with such a low impulse frequency might be questioned.

SUMMARY: After drawing a definite distinction between "impulse excitation" and "beat excitation," the writer considers broadly the conditions under which each of these is brought about.

In connection with a type of impulse excitation transmitter, there are considered the effect of a hydrogen atmosphere in the gap, the construction of the necessarily closely inductive coupler between spark gap circuit and antenna circuit, the effect of gap separation and "wandering" of the spark, and the effect of the tone circuit shunted around the gap.

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