ON THE ORIGIN OF THE SUPER-HETERODYNE METHOD*

By

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Mr. E. H. Armstrong recently explained in this Journal[1] that the idea of the receiving method named by him "Super-Heterodyne Reception" first occurred to him as a solution of the requirements of a war problem, and that in the course of further investigations, and due to various suggestions for improvements, this idea resulted in the excellent broadcasting receiving set that we admire so much to-day. As interchange of views and, consequently, uniformity of scientific and technical development have now apparently been re-established to a large extent between the enemy countries, you will no doubt allow me to give a short outline of how and when the corresponding idea took shape in Germany.

It was a special and relatively unimportant war problem, namely wireless remote control, which claimed the collaboration of the Siemens Laboratory—whose experiments were in part managed by me—in the course of 1917[2].

As in the case of the problem mentioned by Mr. Armstrong, discrimination against waves of other frequencies and atmospheric disturbances was the dominant aim, and thus led to theoretical investigations relating to the selectivity problem of radio reception in general. The most obvious suggestion of improvement consisted in modulating the transmitted high frequency by means of a lower one, and in providing a correspondingly double-tuned receiving set,—a suggestion which, as we now know, was the chief claim of Lucien Lévy's patent application, filed in the summer of 1917[3]. An exhaustive investigation which I made in December 1917, of the advantages that

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[1] The Super-Heterodyne, Its Origin, Development and Some Recent Improvements, October, 1924.

[2] The Zentrallaboratorium of the Wernerwerk, known at that time as "Schwachstromkabel (K—) Laboratorium."

[3] English Pat. 143583 dated August 4, 1917. See also B. F. Meissner, Radio Dynamics 145-149, New York, 1916.

might be gained by this method as applied to transmitting and receiving sets showed, however, that these would not altogether fulfil our immediate expectations. Under the most varying conditions possible, I compared the effects which an impulse (*i.e.* a sudden alteration of the electric field intensity) or a non-modulated radio frequency signal would produce in the terminal set, with the effect of the signal to which the receiving set was intended to respond; and I established the fact that insensibility to impulse disturbances is, to a large extent, *only dependent on the ratio of the period*[4] *required for the terminal signal, to the period inherent to the (most rapid) radio frequency cycle employed.* Only in the case of interference due to non-modulated radio frequency signals lasting longer than about one-third of the mean frequency cycle, did a correspondingly reduced sensitivity result, compared with a simple receiving *circuit* tuned to this interfering frequency. Furthermore, the ratio of interference sensitivity to signal sensitivity was chosen to be dependent on whether the rectification of the mean frequency followed a linear law or, (as in the case of weak signals in ordinary detectors and rectifiers) a square law; it was shown that the square law rectifying action prejudicially affected the ratio of interference sensitivity to signal sensitivity. For this reason, and on account of the well-known loss in amplification which cannot be avoided with weak signals under square-law rectification, I considered the possibility of amplifying, by means of a non-selective radio frequency amplifier, the two adjacent frequencies γ_1 and γ_2 contained in the modulated carrier wave, to such an extent before their passage through the first rectifier, that the rectifying action would become approximately linear. But here I encountered a problem, the general importance and difficulties of which were already familiar to me, and which I had at first hoped to solve by the construction of special amplifying valves having large electronic currents and small internal resistance[5]. My acquaintance with the idea of inaudibly-modulated carrier frequency presented me (at the end of February and beginning of March) with a new solution, viz: that the incoming high frequency (at frequencies γ_1 and γ_2 or, in case of non-modulated high frequency transmission, at frequency γ) could be converted linearly like ordinary heterodyne reception—into a lower fre-

[4] Where mechanical relays are operated, the period of the terminal signal may be the natural oscillation of the armature; in the case of telephonic signals —the cycle of the highest frequency that can be transmitted.

[5] D. R. P. 366829, filed November 11, 1917.

quency wave which could be easily amplified, by causing the first receiver valve to oscillate at a frequency which would give inaudible beats when receiving the incoming high frequency. In order to obtain the linear conversion of the wave, the amplitude of this auxiliary oscillation should be dimensioned in such a manner that it entirely *controlled the super-heterodyne valve over about one-half its characteristic.*

It was by no means difficult to recognise the importance of this method, which actually represents the super-heterodyne principle, for all purposes of radio reception. In fact, the following entry was made by me in the journal of the K = Laboratorium for the period February 25 to March 16, 1918:

> "*A Frequency Transformation for Radio Reception*
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> "As the amplification of very short waves in many "cases involves a large consumption of energy in the "amplifier valves employed, it is of advantage to be able "to convert short waves at their reception, without any "loss of energy, into longer, similarly inaudible waves and "then to amplify these only. This is accomplished by "heterodyning another frequency differing by about "10 % so that the beat-wave again becomes high frequen-"cy, but longer. Of special importance for radio telephony "in which ordinary heterodyning is not possible."

The German patent for this method was filed on the 18th June, 1918[6]; since I could not myself draw it up nor pursue the matter further, it did not, unfortunately, assume the form I should have wished. Nevertheless, it emphasizes the essential features of the super-heterodyne method and, thanks to the Nolan Act, patents have been granted in America and England, so that according to the present state of patent law in these countries as well as in Germany, the manufacture of at least such heterodyne sets as permit the *amplification* of the transformed (inaudible) high frequency, is involved in the possession or right of utilization of this patent.

I should like to conclude this little historical note by referring to some still earlier publications and patent applications in our field[7], which are of historical importance in relation to the super-heterodyne idea, but were, probably, as unknown to Mr. Armstrong as to me. The idea of employing the advantages of heterodyne reception for radio telephony also, by selecting an

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[6] D. R. P. 368937; English Pat. 135177, appl. 1502063. The first patent E. H. Armstrong is dated 30th December, 1918.

[7] See also the report of J. H. More, Electrician, 1925, p. 121.

inaudibly high beat frequency, was probably published originally in 1913 by Mr. Hogan in the course of a discussion[8]. The idea of producing a beat frequency by means of a local source of oscillation, which was not intended to make the signals audible, but expressly to provide for another tuning and thereby increased selectivity, has been patented by Graf Arco and A. Meissner[9], and by H. J. Round[10]; Round's application also lays stress on providing inaudible beat frequencies, but actually offers no good selectivity against interference owing to the inherent necessary detuning of the aerial. Finally, the aforementioned patent of Lucien Lévy[11] is of fundamental importance to the whole field; he must be considered, at least from the point of view of patent law, as the true originator of the super-heterodyne method, since the super-imposition of an adjacent frequency, an intermediate circuit tuned to inaudible frequencies, and a further rectification in order to convert into the desired signal, are described explicitly in his application (as one of several constructions). In regard to earlier existent publication, there may be a doubt as to whether the information would have brought about the desired technical progress we owe to the super-heterodyne method, as conceived by Mr. Armstrong and also described in the German application. After all, the actual aim of the high-frequency transformation or super-heterodyning principle consists in providing a suitable and relatively convenient radio frequency amplifier for short waves, whereas the selectivity effects that Lévy solely had in view are less important, according to the above considerations, and might be obtained as well by the use of a slightly attenuated or reaction-coupled radio frequency syntonizing circuit. The drawings of this application also leave it doubtful whether the elimination of the square-law rectifying action, which is so essential for the commercial use of the apparatus, would have been obtained by means of experimental sets constructed on the principle indicated in the application.

The "word" seems, at any rate, to have been far less important in this field than the "deed," and there appears to be no doubt that it is Mr. Armstrong and his collaborators to whom we owe the deed, which has made the super-heterodyne method such as invaluable instrumentality in radio engineering.

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[8] Hogan, PROCEEDINGS OF THEINSITUTE OF RADIO ENGINEERS, 1,97 (1913).

[9] English Pat. 252, 1914, filed January 5, 1914 and D. R. P. 300896, January, 15, 1917.

[10] English Pat. 27480, 1913, filed November 11, 1913.

[11] English Pat. 143583, date of appl. April 8, 1917.