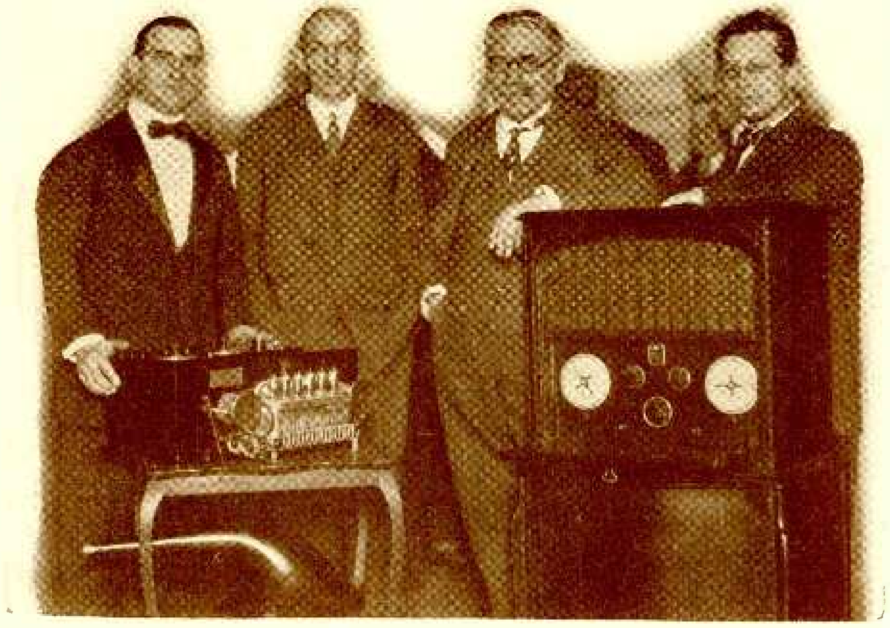


This interesting picture might well be entitled

## RADIO PINNACLES

The group shown here includes the leaders of radio design, (from left to right) Dr. Alfred N. Goldsmith, B.S., Ph.D., Fellow I.R.E., Director of Research, Radio Corporation of America; Major Edwin H. Armstrong, radio inventor and designer; Professor Michael I. Pupin, Ph.D., Sc.D., LL.D Professor of Electro-Mechanics, Columbia University and Professor John H. Morecroft, E.E., President of the Institute of Radio Engineers. In the foreground are to be seen the Armstrong super-heterodyne (second harmonic) and the new Radiola Super-VIII, premier of radio receivers

# The Super-Heterodyne

### Major Armstrong, Its Inventor, Traces Development and Explains Principle—Full Report of Major Armstrong's Address Before the Institute of Radio Engineers Written Expressly for The Wireless Age

By Abraham Ringel
Member Institute of Radio Engineers

ON the evening of March 5th, in the Auditorium of the Engineering Societies Building in New York City, Major Edwin H. Armstrong presented a paper entitled: "The Super-Heterodyne, Its Origin, Development, and Some Recent Improvements," before a meeting of the Institute of Radio Engineers. The Auditorium was barely sufficient to hold the enthusiastic throng of radio engineers and their guests. On the platform, in addition to Major Armstrong and Professor Morecroft, President of the Institute, who presided, were Professors Pupin and Goldsmith, names to conjure with in radio. In the audience was practically every important engineer in the country. The gathering was also considerably augmented by the presence of many radio amateurs from all over the country, who were simultaneously attending the Second District Amateur Radio Convention at the Hotel Pennsylvania.

Professor Morecroft opened the meeting with a few brief remarks and then introduced Professor Pupin, who has been Major Armstrong's mentor and counsellor in all his work. Professor Pupin dwelt on the fact that it was now up to the professor to seek knowledge from his former pupils, and enumerated them, all prominent in the radio fraternity: Armstrong, Morecroft, Goldsmith, Vreeland and many others. It was indeed a proud moment for the dean of American electrical engineers when he introduced Edwin H. Armstrong, one of the most outstanding of his flock of students.

Major Armstrong, with his usual modesty of manner, disclaimed any unusual genius in his inventions, declaring that he believed he had been so fortunately placed by Divine Providence as to be just a little ahead of somebody else in making these discoveries. He then traced the gradual development of the Super-Heterodyne from the first crude model built while in the A. E. F. in France, with its multitudinous controls and at least nine or ten tubes to the present Radiola Super VIII, which is the last word in modern broadcast receivers.

Most of the wireless communication of the Signal Corps in the days of the Great War was on very short wave lengths. There was urgent need, therefore, for a radio frequency amplifier which would work efficiently for these frequencies. After exhaustive experiment with all the vacuum tubes then available, it was soon evident that, because of their high grid to plate capacity, their high filament to grid, and filament to plate capacities, not much amplification could be obtained for even moderately high frequencies such as 500,000 cycles (equivalent to a wave length of 600 meters). These capacities were of the order of 8 micro-microfarads and in general tended to act as short circuiting paths for currents of extremely high frequencies—in effect, short circuited the radio frequency amplifying transformers. The action of these capacities may be demonstrated by the reader to his own satisfaction at audio frequencies in the following manner: Connect a fairly large condenser, say .01 microfarad or more, across the secondary winding of an audio frequency transformer; the resulting volume of sound obtained from the amplifier will be very greatly reduced. The phenomenon is explained by the fact that the voltage in the windings, instead of passing to the grid of the amplifying tube, is short circuited by the large condenser.

Since it is impossible to greatly reduce these tube capacities, which are so harmful to radio frequency amplification (and which are also likely to set up oscillations in the amplifier), the problem resolves itself into working at some frequency at which these capacities will not act as short circuits. At a frequency of 1,000,00 cycles (300 meters wave length) a capacity of 8 micro-microfarads is equivalent to approximately 100,000 ohms reactance; at a frequency of 50,000 cycles (6,000 meters wave length) this capacity would give a reactance of about 2,000,000 ohms—which is very high. It is then quite apparent that an amplifier for 50,000 cycle frequency will not be affected by this capacity. This is borne out by actual practice. Amplifiers for such frequencies are quite efficient and stable—in fact they are as simple and easy to control as ordinary audio frequency amplifiers.

## Applying the Heterodyne Principle

Major Armstrong realized this. The problem of converting the very high radio frequency to some lower frequency was relatively simple. It consisted merely of applying another frequency at the receiver, which was slightly different from the received signal and detecting it. After the detector will be obtained a beat note, whose frequency is exactly equal to the difference in frequency between that of the incoming signal and the local oscillator. By varying the frequency of the local oscillator, this beat (or heterodyne) note may thus be varied at will—and then amplified in a suitable intermediate frequency amplifier. After it is amplified here, it is detected once more, which restores the original low frequency sound—and amplified at audio frequencies. [The beat or heterodyne phenomenon is only too familiar to present day radio fans—it is only too evident when some neighbor with a regenerative receiver has his set oscillating. The "birdies" that you hear is nothing but the beat note, produced by the broadcast station and oscillations from your neighbor's receivers. Whenever he changes his tuning slightly, you hear the note change in pitch—since he is changing the frequency of his oscillations.]

Whenever beats are produced, there is quite a deal of amplification obtained. The beat note may be several times as loud as the signal which is obtained with ordinary detection. In case the beat note is set at some frequency which is too high to be heard, say 50,000, the above may be stated in somewhat different wording: the voltage produced after the detector by this 50,000-cycle beat note may be many times greater than the voltage produced by the incoming signal alone after being detected. So that amplification results merely from heterodyning the incoming radio frequency. After detection the 50,000-cycle beat note is picked out and amplified in a suitable amplifier. This amplifier may be made of as many stages as is desired. Here lies the main advantage of the super-heterodyne. It is much easier to amplify at these intermediate frequencies, than at either radio frequencies or audio frequencies; three, four, five and even six stages of amplification have been employed successfully. Voltage amplifications of 10,000 times can readily be secured at intermediate frequencies, as compared with 400 times for the average audio frequency amplifier. This amplification can be made to give a uniform response over a sufficiently broad band of frequencies to give excellent quality of music or speech (something which cannot be said for the average audio frequency transformer-coupled amplifier).

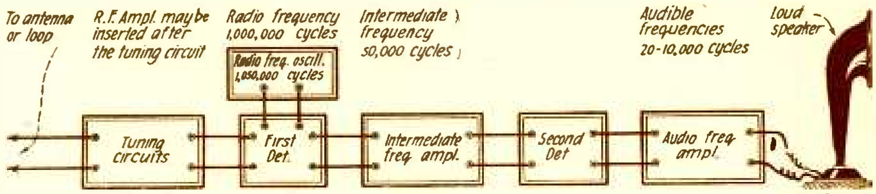
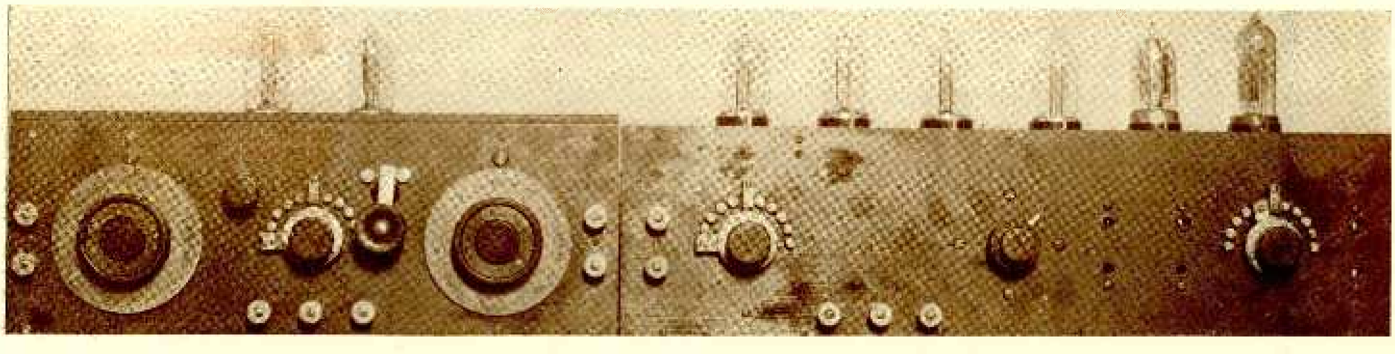



**Figure 1—Principal elements in the Super-Heterodyne Receiver showing the tuning unit, first detector, intermediate frequency amplifier, second detector and finally the audio frequency amplifier.**

## Wonderful Results From Super-Heterodyne

After suitably amplifying this intermediate frequency, a second detector is required for obtaining the original sound. An audio frequency amplifier may be added to this. The general principles involved are illustrated schematically in figure 1. The super-heterodyne receiver is far superior to any other type of radio receiver in every respect. Its sensitivity is unequaled, for we have here not only actual amplification at an intermediate frequency, but also amplification due to the heterodyne or beat phenomenon, as explained above. Its simplicity of operation is unrivaled. Only two controls are required, neither of which is dependent on the other; one controls the frequency of the local oscillator, the other tunes the loop, which is all that is necessary for reception. It cannot be approached in selectivity. In order to emphasize these points, Major Armstrong gave a few specific examples of actual reception of station 2LO in London by an old lady in Massachusetts who had had no previous experience with radio receivers whatever—and of reception at the same time of Los Angeles, with himself at the tuning controls. Near-by locals were broadcasting at the time too. Later Dr. Alfred M. Goldsmith, in a New York apartment, had no difficulty in receiving KGO, of Oakland, California, while four powerful local stations, all well within a radius of 5 miles, were operating—and one of them was only about a meter off in wave length from KGO.

The super-heterodyne as originally build by Major Armstrong, with the capable assistance of Sergeants Houck and Lewis, was not exactly practicable. It used nine storage battery tubes—and required at least a 200 or 300 ampere-hour storage battery. The wire required to safely carry the filament current was as thick as a man's thumb. Several similar sets were built later in the United States on his return here. One of these, it is rumored, was built for Mr. John D. Rockefeller, the oil magnate; this is quite probable, as Major Armstrong pointed at one containing nine tubes which he had built



**The original super-heterodyne set constructed in France during the war**