THE DESIGN AND CONSTRUCTION OF A UNIVERSAL-WAVE DOUBLE SUPERHETERODYNE RADIO RECEIVER

THESIS FOR THE DEGREE OF M. S.

Harold Joseph McGarvey

1933

Radio

Physics

DESIGN AND CONSTRUCTION OF A UNIVERSAL-WAVE DOUBLE SUPERHETERODYNE RADIO RECEIVER

Thesis for Degree of M.S.

Harold J.McGarvey

1933

Acknowledg ments

I am greatly indebted to Mr. Harold Higgs for the suggestion of the problem, to Professor O.L.Snow and Professor C.W.Chapman for helpful suggestions and the securing of parts and materials, and to the whole Physics Department for advice and help whenever it was needed.

Harold J.McGarvey

Contents

Introduction

The object of this work has been an attempt to design and build a universal wave radio receiver which would be simple both in construction and operation.

This report gives the complete results of the design and experimental work upon such a receiver, which can cover a range of 15,000 K.C. to about 150 K.C. without the changing of a single circuit therein.

There are several limitations which must be recognized. These are covered in the report, and suggestions are given as to the solution of some of them.

The receiver was built with the idea of using commercial parts and tubes as much as possible, and all these are operated within their correct limits of current and voltage. Since the completion of the receiver, several new tubes have been made available, making it possible to substitute one tube in place of two in a number of cases; therefore in any future study of this project, it may be seen that changes may be made in the types of tubes used.

Reasons For Choosing This Project

The design of any universal wave radio receiver brings up problems that are not involved in the design of a receiver for the reception of broadcast programs only. In the design of a receiver for the broadcast band, it is only necessary to provide tuned circuits that can cover a range of 540 K.C. to 1500 K.C., which is a frequency range of about 1 to 3. This range is not large, but when any attempt is made to increase it to any extent serious difficulties are encountered.

The problem is that radio receivers are tuned by varying the capacity of a tuned circuit in which the frequency varies inversely as the square root of the capacity. This means that to have a frequency range of 1 to 3 it is necessary to have a capacity ratio of 1 to 9. When the distributed fixed capacity of the circuit is considered it will be seen that a greater range of frequency is quite impossible without also altering the inductance of the circuit.

If the extending of the frequency of any receiver is considered, the most obvious solution, therefore, is the changing of the inductances or the tuning coils. This practice gives good results; but if the range is to be made very large, it becomes necessary to have complicated switches and coil combinations. Commercial receivers upon the market at the present time give all wave reception, but it is necessary to have at least four combinations of coils and sometimes five to cover from 540 K.C. to about 15,000 K.C.

The commercial receivers that are called all wave do not cover all the waves, because in most cases there is no consideration of the long waves. The long waves are those longer than the broadcast band. These waves do not ordinarily have any of the broadcast programs, but they include almost all the shipping and most of the commercial news as it is given from one station to another. The weather reports can always be picked up every few minutes on the longer waves as they are given to airplanes. It might be stated that the longer waves do not have very much use in this country to the ordinary person who does not know the code, but still there is enough phone work to interest many in this type of reception.

There is some chance that in the years to come commercial programs may be broadcast over the longer waves on account of their greater range of direct covering without fading. At the present time the radio receivers that are shipped to Europe must cover a range of 20 to 2,000 meters. This type of receiver calls for very complicated coils and switches.

It can now be seen why some thought has been given to the problem of designing a receiver which can cover all the wave lengths and still be as simple to operate as one built for broadcast reception.

General Theory of Operation

Since in this receiver we propose to avoid the changing of coils or condensers, a different method is required.

If a range of from 20 meters to about 2,000 meters is desired, the necessary range of frequency is from 15,000 K.C. to 150 K.C. For purposes of design such a range as this might be considered to be from 15,000 K.C. to zero.

Having decided upon such a frequency range, we must think next of how to cover it with commercial coils and condensers. Accordingly, we are forced to adopt some form of high frequency circuit in which it will be possible to get a wide range of frequency. A high frequency oscillator, built to tune from 15,000 K.C. to 30,000 K.C. will give the required range. The problem then is one of making proper use of such a high frequency oscillator and its wide range of coverage.

The only way to make use of such an oscillator in a radio receiver is to make it a superheterodyne, thus making possible the use of the full range of the oscillator.

The superheterodyne receiver is very different from other types of receivers. The ordinary set is tuned to the frequency to be received, but in the superheterodyne, the frequency we want is in effect changed to some other frequency by means of an oscillator. The method by which this frequency change is effected is as follows. If two different frequencies are mixed together under the right conditions, the sum of the two frequencies, the difference of the two frequencies, and also the two original frequencies will be present in the resultant. If the receiver is designed to amplify at one frequency only, it is possible to have an oscillator that can form combinations of frequency such that almost any frequency can be received. It must be remembered furthermore that oscillators do not always give out pure sine waves of energy. They may radiate large number of harmonics. These harmonics are also radio frequencies, and they too can mix with the signal frequency and therefore it is desirable that the oscillator fundamental and its harmonics be controlled to such an extent as to avoid undesirable combinations of frequency.

It is the presence of the second harmonic that makes it impossible to have a range of oscillator frequency greater than 1 to 2, because when the oscillator is at the lower frequency, the second harmonic is giving the same result at some higher frequency as the oscillator tuned to the higher frequency. This would cause double tuning on some stations.

Accordingly, an oscillator is chosen that will tune from 15,000 K.C. to 30,000 K.C. with which to cover the desired range of frequency and yet not have a ratio of frequency greater than 1 to 2. This range is the lowest frequency possible which would meet all the requirements.

Now let us consider an illustration of just how such an oscillator may work in the reception of a station at 1000 K.C. If we assume 15,000 K.C. as our fixed intermediate frequency and if the oscillator is adjusted to 16,000 K.C. we find that the difference between the signal and our local oscillator is 15,000 K.C.

If we wish to receive a signal of 10,000 K.C. it is only necessary to tune the local oscillator to 25,000 K.C. and again the difference is 15,000 K.C.

This shows how such a receiver might work, but actually it is not so simple; because most stations are only 10 K.C. apart and when a station is tuned in on 1000 K.C. the intermediate frequency is 15,000 K.C., but if some powerful station is at 1010 K.C. its signal will be changed to 15,000 K.C. by the oscillator. This means that the intermediate amplifier must receive 15,000 K.C. and reject 15,010 K.C. This is impossible with coils and condensers.

Obtaining Selectivity

The problem of selectivity of a receiver built for general purpose work is not an easy one. Selectivity is wanted, but a receiver must not tune so sharply that the side band frequencies are cut off to any extent. With some receivers the cutting of the side bands is very possible, but receivers for broadcast programs should not cut any of the side bands because quality is thereby impared.

The selectivity of our receiver must be such as will give good results on all the broadcasting stations, and for this reason an attempt must be made to obtain what may be called average selectivity, thus retaining most of the side band frequencies which in turn makes average good selectivity and quality possible. Selectivity to within 10 K.C. cannot be obtained when we are working with 15,000 K.C. unless a Quartz crystal is used as a tuned circuit in a band pass filter, which would cost too much, hence we are forced to use another method.

The method adopted is to effect a second change in frequency and this time to a much lower, then our 10 K.C. becomes a much greater percent of the total frequency. In the application of this scheme of lowering the frequency we are limited only by the appearance of so called image effect.

This image effect may best be explained by an illustration as follows. If we want a signal of 1000 K.C. and the intermediate frequency is 100 K.C. it is only necessary to have a local oscillator of 1100 K.C. and the difference between the oscillator and the signal is the correct frequency, but if for some reason a station should be on 1200 K.C. it can be seen that the difference in this case also is the intermediate frequency of 100 K.C. The problem is to provide circuits ahead of the oscillator and mixer to prevent such signals from coming through. This is a problem in any superheterodyne design.

If we are considering a 100 K.C. second intermediate frequency it will be seen at once that a second local oscillator of 14,900 K.C. must be used. The difference in the frequencies of the first intermediate and the second oscillator will give the 100 K.C. for the second intermediate, but if the first intermediate is not selective enough to keep out signals of 14,800 K.C. they too can come through and combine with the oscillator frequency and form the last intermediate frequency, which is the image effect.

It will be seen that a low frequency last intermediate would give very good results, for selectivity, but it is necessary to prevent signals from coming in on the image frequency. In the case considered above it can be seen that the high frequency intermediate stage must be very selective to prevent image. In fact it would have to be better than we can build.

The solution of this problem is to use a higher frequency last intermediate and use good coils and a larger number of circuits to obtain selectivity.

If the limit of tuned circuits is three or four and ordinary coils are used we cannot allow this last intermediate to go much above 1000 K.C. because it will be impossible to obtain the desired selectivity.

Let us now consider the selectivity at 1000 K.C. It is the same frequency as the broadcast stations. This means that we can obtain the same degree of selectivity as is obtained in tuned radio frequency radio receivers of two or three stages of gain, or the use of three or four tuned circuits.

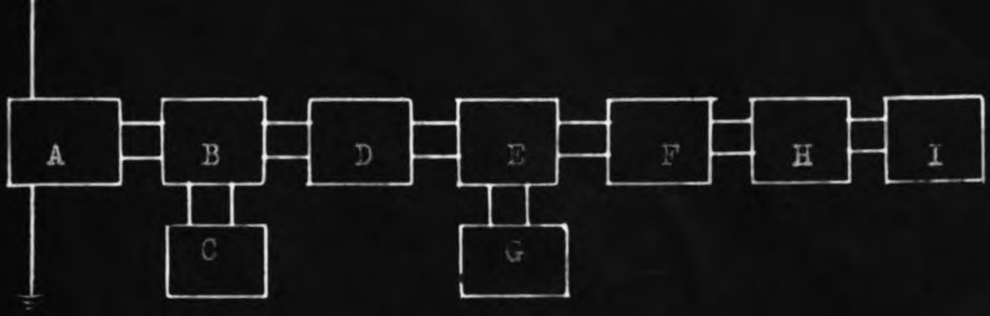
If we consider the probability of image trouble at the last intermediate frequency of 1000 K.C. we find that if the same high frequency first intermediate is used the oscillator must be tuned to 14,000 K.C. This means that the image frequency to cause trouble would be 13,000 K.C. The difference between the 15,000 K.C. and the 13,000 K.C. signal is a rather small percent, but from the experimental standpoint it has been found to be very satisfactory.

The 1000 K.C. last intermediate may not be the best frequency to use, but if the frequency is much less the image effect would be bad and if the frequency is much higher selectivity would be poor.

The picking of the frequencies for this receiver is the same problem as in any other receiver. It is a problem of cut and try. When something is gained in one way there is almost always a loss in some other.

Another problem which must be solved is the rejection of any signals of the same frequency as the first intermediate, because they would be coming in all the time through the untuned grid circuit of the first tube. This rejection is done by the use of a series tuned circuit between the grid of the first tube and ground.

It has been found that automobile ignition systems are the greatest source of trouble at this high frequency. The spark discharge in the spark plug of the automobiles is a damped oscillation and thus it is a rather effective in causing trouble.



A - Filter used to keep out the signals of the same frequency as the first intermediate.

B - First mixer.

C - First oscillator (Variable).

D - High frequency intermediate.

E - Second mixer.

G - Second oscillator (fixed).

F - Low frequency intermediate (for selectivity and Gai)

H - Last detector.

I - Audio section.

The chart shown the parts of the receiver and gives a good idea of the working of each part. It also shows where the frequency is changed and what happens to the signal as it goes through the receiver.

Oscillators and Harmonics

Since the receiver is a double superheterodyne with two oscillators both of which are at rather high frequencies there are problems in their design that are not ordinarily encountered. One of these problems requiring careful consideration is the effect of harmonic frequencies, or multiples of the fundamental frequencies of the oscillator. These harmonics can cause combinations of frequency which, if in the first or second intermediate stages, would act the same as a station except they produce only noise, much like the noise of a carrier frequency, hence all harmonics are to be kept out if possible. In this discussion there is to be no reference made to the first harmonic because the fundamental is considered to be the first harmonic.

The first oscillator is variable and the second is fixed. The one fixed oscillator helps some in eliminating harmonics because then tube voltages can be adjusted for best results and then left at that setting.

The first oscillator must tune from 15,000 K.C. to 30,000 K.C. This is rather a high frequency and a high voltage output at such a frequency is hard to obtain. The total number of tubes being limited, only one can be used for each oscillator. Since the standard screen grid tube is good at the high frequencies it is used for the first oscillator. The voltage output of the oscillator should, for best results be about 10 volts.* This may be regarded

* This is given as the correct voltage upon a mixer tube in a superheterodyne by the R-10 Technical handbook of The Radio Corporation of America.

as a rather high voltage for such a high frequency, and the only way to obtain it is to use a very good quality tuned circuit, one having a relatively small amount of resistance, and operating the tube at its highest safe value of current and voltage. The plate current is usually the limiting factor in the output of small tubes such as are used in this receiver.

The harmonic output of the second oscillator is kept down as much as possible by the use of high capacity tuned circuits. Low capacity in the first oscillator however is not required, because the harmonics of one oscillator cannot cause trouble unless they can combine with harmonics of another.

In building these oscillators the values of the inductances were kept very low, in fact for the fixed oscillator the inductance of the coil is about .4 microhenry and the capacity about 250 micro microfarads. Such a combination of inductance and capacity is not common, but in our work the limit of capacity is the point where the voltage output of the oscillator is just enough to properly excite the mixer tube.

Another way to prevent the harmonics of an oscillator from causing trouble is to use a pick-up coil in the tuned circuit of the oscillator, then any voltage in this coil will have less harmonic content.* The voltage induced in this pick-up coil is used to excite the mixer tube.

The frequency stability of the two oscillators is another problem to be considered, if the frequency of either

* Prevention of Harmonics Radio News. April 1, 1933.

oscillator varies much the set will not be stable in operation, and because these frequencies are so high a very small percentage change would cover quite a range of radio stations on a basis of a 10 K.C. separation of stations.

The adding of capacity to the tuning circuit helps to stabilize the frequency, because a small change in capacity in the tube will not make much change in frequency.* The use of a high quality circuit with a small amount of resistance also helps the frequency stability, because the circuit has larger circulating currents and is therefore not effective as much by outside changes and influences.

* Frequency Stability, from Principles of Radio by Henney.

Selection of Parts

The selection of parts for this receiver involves mostly the selection of tubes only, because most of the parts are standard or else are so special that they must be made up particularly for this receiver.

The selection of tubes is made according to the purpose for which they are to be used. The oscillators which we will consider first, must operate at rather high frequencies. This means that to get good operation, it is almost necessary to use screen grid tunes on account of their greater stability in high frequency circuits. There are several types to choose from and several different tubes were actually tried out as oscillators. The 224A tube worked very well as also did the 257 tube. The 224A tube being an older tube and easily obtainable at every store, was chosen for these tubes V_2 and V_4.

The selection of the mixer tubes V_1 and V_3 was a different problem, because practically any tube will work in this position. Screen grid pentode tubes type 258 were however selected for this position, because they function equally well under a great many different conditions.

The next part of the set consisting of the second intermediate frequency amplifier tubes V_5 and V_6, and the last detector tube V_7 can also use almost any type of tube, but here again some work better than others. A screen grid tube is better in the amplifier so the choice was between several, but again an older type was used. The final choice being between the 224A and the 235A. The

224A was used because of its lower plate current and much less shot effect.

The last detector tube V_7 is a triode because there are times when headphones might be used in a receiver of this type and a triode is a good tube to use with headphones, although its gain as a detector is less than a screen grid tube operating under the same conditions.

The last tube in this receiver is a 247 pentode power tube. This tube does away with the audio stages and gives very high output. Its quality may not be as good as a triode, but by using it less tubes are required, which is a big consideration.

Since the building of this receiver several new radio tubes have been brought out, some of which could be used. There is a frequency changer that could replace our present system of oscillators and mixers. This would reduce the total number of tubes by two. The tube is known as number 2A7.

There are a few other parts that should have special mention. Condensers are one of the most important items. The one tuning condenser must be of solid construction and the spacing of the plates must be large so they will not cause trouble by vibrations, which would cause the set to drift from one station to another.

All the fixed condensers must have low temperature coefficients or they will cause drifting of the set. All the condensers used in the tuning of the high frequency circuits are air or mica and all the mica condensers are sealed in tight containers so moisture will have less effect.

The coils used in the last intermediate are commercial tuning coils, tuned with a trimming condenser. The coils L_3 and L_4 in the first intermediate are made up of four turns of No. 14 copper wire on an inch form and are not commercially obtainable.

The power transformer and filter chokes and filter condensers are all standard. The shields, bypass condensers, sockets, resistances, and all small parts are standard quality parts obtained from radio supply houses.

Experimental Work and Construction.

The experimental work on this receiver was the most interesting, because much of it was new and if trouble was experienced it was an interesting problem to overcome it. The first experiments were upon the oscillators. The real work with them was to increase their voltage output to a point where they would sufficiently excite the mixer tubes. The tubes tried were the 27, 67, 224A, 235A, and the 57. The 27 worked very well up to about 10 meters, but it would fail to go much beyond this value. The operation on longer wave lengths was very good.

The operation of the 67 was much the same as the 27 except that its operation was some better, but it too, was limited at the high frequencies. The 224A worked very well to about 4 or 5 meters. The operation of the 235A was poor in the same way. Its current drain was high and its operation at the higher frequencies was much like the 27, not very good. The operation of the 57 was very good, but little different than the 224A, so the 224A was taken as the best tube to use, then further experiments were carried on to increase the output of the oscillator tube.

The tubes were operated all the time during this experimental work with meters in the plate circuits so the safe current would not be exceeded. The final operating voltages for the 224A as an oscillator was 300 volts plate, 100 volts screen grid, 50,000 ohm grid leak, plate current of 3.5 milliamperes, and screen grid current of 1.5 milliamperes.

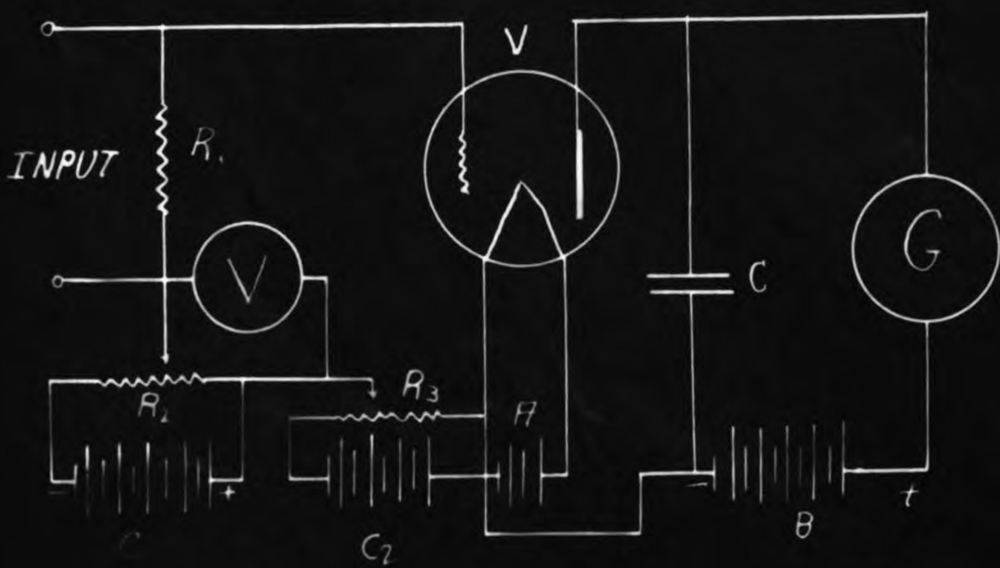
The output of the oscillator was checked at every change in its operating conditions by a vacuum tube voltmeter. This voltmeter was of standard construction and its diagram is given here to indicate its operation. The voltmeter as used in this work measured the peak voltages, because it is usually the peak voltage that is the most important in radio work.

Experimental work was also done on the inductance of the oscillator. The first tests were run with coils made of No. 14 copper wire. The results were just fair. The size of the wire was increased and the voltage output was increased, but when the wire was increased above 1/8 inch the voltage did not increase to any extent. Good quality soft copper tubing of 1/8 inch outside diameter was finally used and the results were good.

The only type of circuit tried for the oscillator was the electron coupled Hartley. In this circuit there is a grid leak in the grid circuit which connects to one end of the inductance; the other end of the inductance is grounded. A tap is made on the inductance to form the cathode portion of the coil. The best position for the tap was found to be 1/4 the coil length distance from the ground end. The portion of the coil between the tap and the ground acts just the same as a plate coil would in any other method of connection.

A very interesting point was brought out in this work by the use of mica condensers. The first oscillator is tuned by an air condenser, but the second being at one fixed frequency all the time, is tuned by a mica condenser. The output voltage of the circuit that had the mica condenser was about 75% of the output voltage of the circuit tuned with a very good quality air condenser.

The greatest output obtained with an air condenser and tubing inductance was 15 volts peak measured across the inductance. When the mica condenser was used the output was decreased to about 12 volts peak, and at the same time there was a slight increase in the current drain of the oscillator tube. This check was made at the same frequency and with the same tube and inductance.



VACUUM TUBE VOLTMETER

The operation is rather simple. When the voltmeter reads zero the resistance R_3 is adjusted until the galvanometer just reads sero. Then any unknown voltage can be measured direcly, by adjusting R_2 until the galvanometer again shows sero current. The voltmeter will then read the peak volts direcly.

Constants of the Meter

R_1	1,000,000 Ohms
R_2	10,000 Ohms
R_3	10,000 Ohms
C	1.0 Mf.
C_1	must equal the peak voltage to be measured.
C_2	6 to 8 Volts
A	2 volts
B	25 volts
V	130 type radio tube
G	Galvanometer.

The High Frequency Intermediate

The problem of the first intermediate which must operate at about 20 meters was a hard one,because it is new and data as to the value of any parts could not be obtained. The first work was done with a single coil tuned with a variable mica condenser. It was found that a circuit could be made quite selective,if the inductance was low and the capacity high. All the tests were made with a plate tuned circuit and the grid of the next tube connected through a small condenser and a high resistance to ground.

The capacity used in the circuit was about 175 Micro-microfarads, the inductance was made up of four turns of No. 14 copper wire,self supported,and wound so the diameter of the coil was one inch. The inductance was about .35 microhenry. This arrangement gave very good results,but when the whole receiver was tested it was found that the single tuned circuit would pass enough signals in the broadcast band to cause whistles in the operation of the receiver.

The amount of energy going through the circuit at broadcast frequency was too much,so the only solution was to change to a double tuned circuit. This was tried with a coil in the plate circuit of one tube and a coil in the grid circuit of the next tube. The values of inductance and capacity were kept at about the same values as were used in the first arrangement.

The experimental work necessary to arrange the coils so they would not tune double was considerable,and the only method was to cut and try. The solution was found placed at right angles to each other and one coil offset so that it overlapped the other only to the extent of 1/4 inch. The coupling with this arrangement was found to be about correct. Even with this arrangement a certain amount of energy would feed thorough, but by changing the last intermediate frequency a little, pratically all of this trouble was eliminated.

Second Intermediate Frequency Amplifier

Since the second intermediate frequency amplifier operates in the broadcast band at 1000 K.C., the selection of coils for it was not hard. The coils used have 145 turns of Litz wire equal to number 26 and the form is 7/8 inch diameter. The coils are placed in the plate circuit of the tube and coupled to the next tube through a condenser and a high resistance to ground. Each coil was tuned with a trimming condenser which had a capacity of 80 micro microfarads. The full capacity of the condenser in each case was used. The inductance of each coil was about 240 microhenry.

Tests were made at first with simple transformer coupling, but the total gain was not enough to give satisfactory results. The plate tuned circuit gives very good results for gain, and in this instance the added capacity of the plate does not cause any trouble, because we are not trying to cover a band of frequencies.

When the set was completed it was tested with three coils in the second intermediate amplifier, but the gain and selectivity was not good enough, so an extra tube was added. The results were good, but there were too many tubes, so an attempt was made to use only two tubes for gain. This study of reducing the number of tubes led into some rather interesting details. When the number of tubes was reduced, and these pushed harder to get the necessary gain it was found that the noise was increased in the output even though the total number of tunes was reduced. After considerable experimenting it was found that the total noise was not increased if the number of tubes was increased even more. This discovery let to much thought as to why an increase in the number of tubes should decrease the total noise in the output when each tube added ordinarily adds a certain amount of noise to the total. After much experimenting, and study this noise was attributed to shot effect, which is discussed in the next part of this report.

The selectivity of this last intermediate was found to be inadiquate, but the adding of coils or more stages could not be considered. The lowering of the frequency would solve the problem, but again this would not be possible because the first intermediate was already at the limit of image separation. One of the possible methods left to effect an improvement was some form of regeneration and accordingly it was tried.

The introduction of regeneration has the effect of decreasing the resistance of the circuit to which it is added. This decreasing of the resistance of the circuit increases the selectivity. This process can be carried on however until all the advantage is lost. In this receiver regeneration was added by putting a small capacity C_{23} between the plates of the last amplifier tubes V_6 and V_7.

Shot Effect

The shot effect is known as noise that is generated in the tube itself. It is caused by the unevenflow of electrons from the cathode to the plate. The plate current is quite regular in flow,but it is made up of electrons and the number released from the cathode one instant,may not be the same as the number the next instant. This irregular flow of current is what causes the noise called shot effect.

when the flow of current from a cathode is space charge limited,it means that there is always an over supply of electrons at the cathode,but that they cannot get away. When the flow of current is temperature limited,it means that all the electrons being released at any one instant are being drawn away and that the only way to increase the number is to drive more out which usually means increasing the temperature.

Experiments carried on in the past have shown that when the plate current is temperature limited the noise of shot effect is the greatest and the least when the cirrent is space charge limited. *

The problem then in this receiver is,to always make the current space charge limited. This means a high grid biasing voltage on the tubes so that the plate current will not be great. This shows why noise was not so bad with more stages,because each tube was not pushed as hard,thus the plate current was not great.

The problem then is to get gain without large plate

* Noise generation within radio Receivers,By R.DeCola Presented before I.R.E. From Radio ENG. Aug. 1931.

currents.,Here the literature on the subject was consulted and it was found that the noise level of different tubes is very different. During the first work on the receiver the type 245 tube was used in the first stages and according to Rinaldo DeCola the noise level of this tube is much greater then the 224A. *

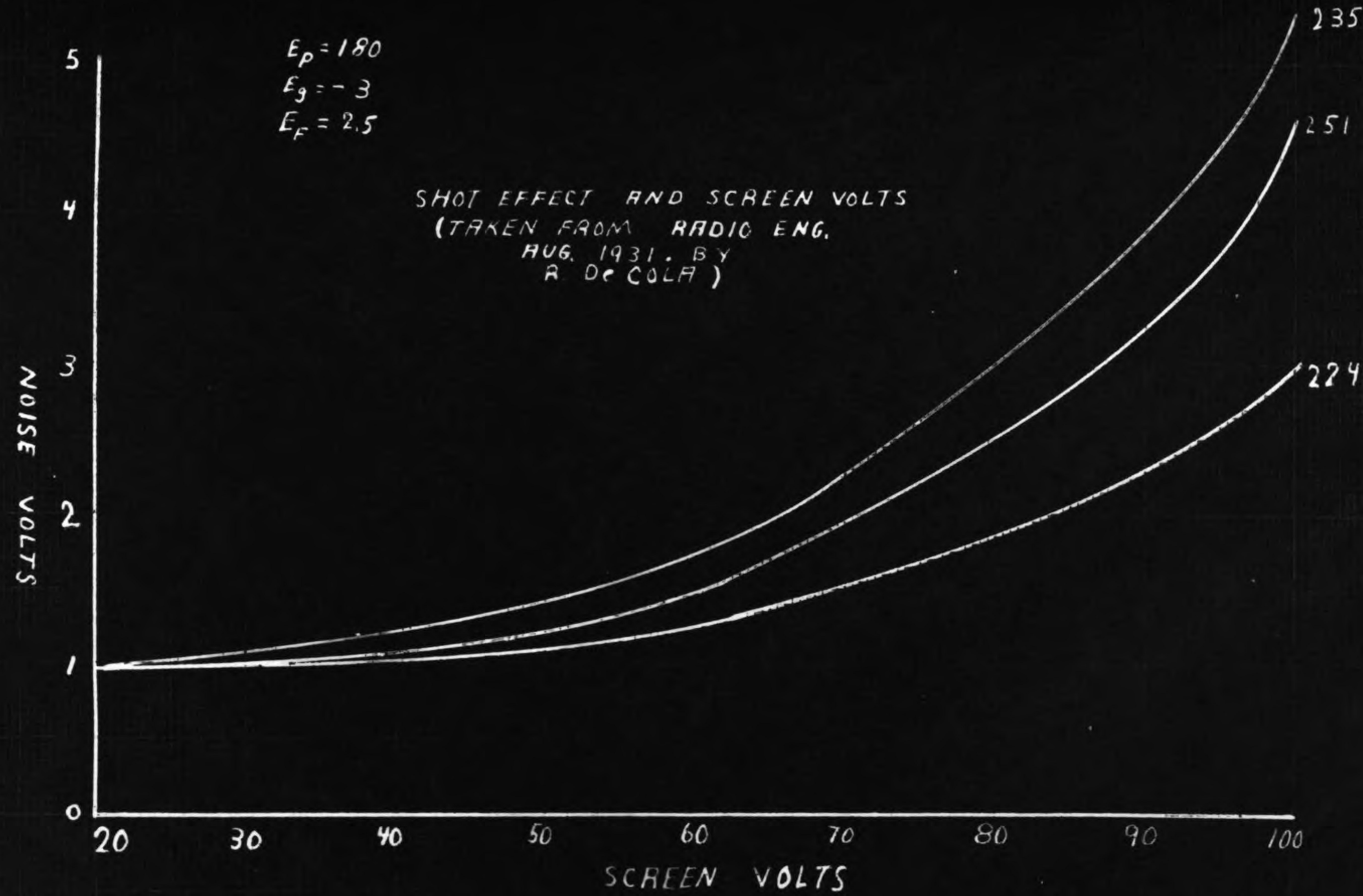
The 224A tube was then used in place of the 235 and the results were better,but still not good enough.

Then after considerable study and experimenting the volume control was taken off the last amplifier tube and it was connected up for full gain all the time. The first amplifier tube was the only one used for the control of the gain.mThis method worked out very well. The total noise was reduced,because the first tube was operating most of the time with rather low plate current as the the volume control was usually not advanced to the full extent. We might expect the shot effect in the last tube to be high,but the signal reaching the last tube would be strong,so the noise would not be increased to any extent.

The manner in which this works out can be shown by a little illustration. If the total gain necessary for a certain station is 1000 and the last tube gives a gain of 100,the first tube must give a gain of 10,but if the two tubes are controlled together the gain of each would be only about 31.5. This means that the first tube must give three times the gain with the standard method as when only one tube is controlled. This reasoning applies very well except when the maximum gain of both

* Noise generation Within Radio Receivers, R.DeCola.

tubes must be used. The curve taken from an article on shot effect shows what shot effect amounts to in volts for different tubes under different conditions. The reduction of noise level in a radio receiver is a problem in itself and was found so to be in this receiver.



$E_p = 180$
$E_g = -3$
$E_F = 2.5$
SHOT EFFECT AND SCREEN VOLTS
(TAKEN FROM RADIO ENG.
AUG. 1931. BY
R DeCOLA)
235
251
224
NOISE VOLTS
0
1
2
3
4
5
SCREEN VOLTS
20
30
40
50
60
70
80
90
100

Final Adjustments and Changes

The final adjustments of a receiver of this type is a most important and exacting operation. The range of the receiver was considered to be from zero frequency to 15,000 K.C. This range should be extended to include stations below 20 meters,and so in the final adjustment the range was extended down to 18 meters.

The first adjustment was for the purpose of getting the correct range for the first oscillator. The final range was 8 to 16 meters or 37,500 K.C. to 18,750 K.C. The next adjustment was the tuning of the high frequency intermediate to 18,750 K.C. The last intermediate frequency is 1000 K.C. so the last oscillaor was adjusted to 17,750 K.C. This then means that the highest frequency that the receiver can receive is 17,750 K.C.,because when this frequency is reached it will pick up its own oscillator. The reason the second oscillator is at a lower frequency than the first intermediate is that if it was higher the first oscillator would tune at one time to the same frequency as the second oscillator and there would be trouble as the shielding is not good enough to permit two oscillators to tune to the same frequency and not make beats which would be picked up. The two oscillators would also tend to fall into step when their frequencies were close.

The design and construction of these high frequency circuits is rather critical and cannot be made very accurately so when the set is put into service it is necessary to make several adjustments to get good operation. The fact that the last intermediate frequency is in the broadcast frequency band was also a source of trouble. It was necessary to make some rather close adjustments in this part of the receiver so that it would not tune to some powerful station and be picking up signals from it all the time. Even with the best of shielding it was found that the set would pick up enough voltage from some stations to cause trouble part of the time.

The adjustment of the first intermediate for the correct amount of coupling was an experimental problem. The only way found was to adjust the circuits and coupling so as to make each coil $L_3$and L_4 have a single point of resonance, then increase the coupling until this condition was lost, and finally decrease the coupling a little until the tuning was best.

The adjustments of the filter condenser C_1at the input was rather simple. Some station was tuned in, then some local noise or frequency was noticed and then the condenser was adjusted until this local disturbance was decreased to a minimum. When the correct setting has been reached the filter acts as a low resistance path to ground for any noise that was of the same frequency as the first intermediate.

Some changes were made in the receiver after it was completed. The 235 tubes were replacedby 224A tubes. This reduced the noise. The number of turns on the oscillator pick up coils were reduced to provide a good output voltage at all frequencies. Mixing of the signals was tried on the suppressor grids of the 258 tubes, but this failed. There were several little changes made in the voltages to different parts that were not recorded, but the final values of all voltages are given in the table of constants for the receiver.

Limitations of The Receiver

In the building of something a little different there are always new limitations that may be placed upon it. The building of this receiver has brought up limitations that are very new to commercial receivers. A different kind of trouble in this receiver has been encountered, caused by the heat of the set changing the temperature of the condensers and their dielectrics so that their capacity is altered. When the receiver has been in operation for an hour or more this trouble disapears, but it is quite serious during the first 30 minutes or more. A drift of 40 K.C. has been observed between the time the receiver was first turned on and when it became stable. The solution to this problem is a study of the condensers to find out where changes might be made to overcome the trouble. It is a difficulty that has been avoided commercially, where the best of construction has been followed, and such high frequency circuits are not attempted.

The receiver has been found to be about average in selectivity. It could be improved by the use of a lower frequency last intermediate. This would mean that the selectivity of the first intermediate would have to be increased. This however could be done by the addition of another stage at the high frequency.

The harmonics of the two oscillators have been a source of trouble even though an effort was made to eliminate them. However harmonics cause trouble only on four or five points over the whole range, so they are not very serious.

The receiver is rather noisy in operation. This noise could be reduced by the addition of another high frequency stage. More work on the oscillators with the idea of increasing the voltage output would also help in the reduction of noise.

One undesirable feature of this receiver, but one which does not mean so much now days is the large number of tubes necessary for its operation. The parts that go with the tubes are however simple and inexpensive.

A study of the receiver by an unbiased person would of course bring out different points of advantage and disadvantage and limitations and operating characteristics. The above list would doubtless be enlarged, if a complete study was made by such a person.

The work so far has shown very well that such a receiver will operate and that the coverage of all the wavelengths is possible. Whether improvements can be made so the receiver will be thoroughly satisfactory for home operation can only be told as more experimental work is done upon it, incorporating the suggestions indicated.

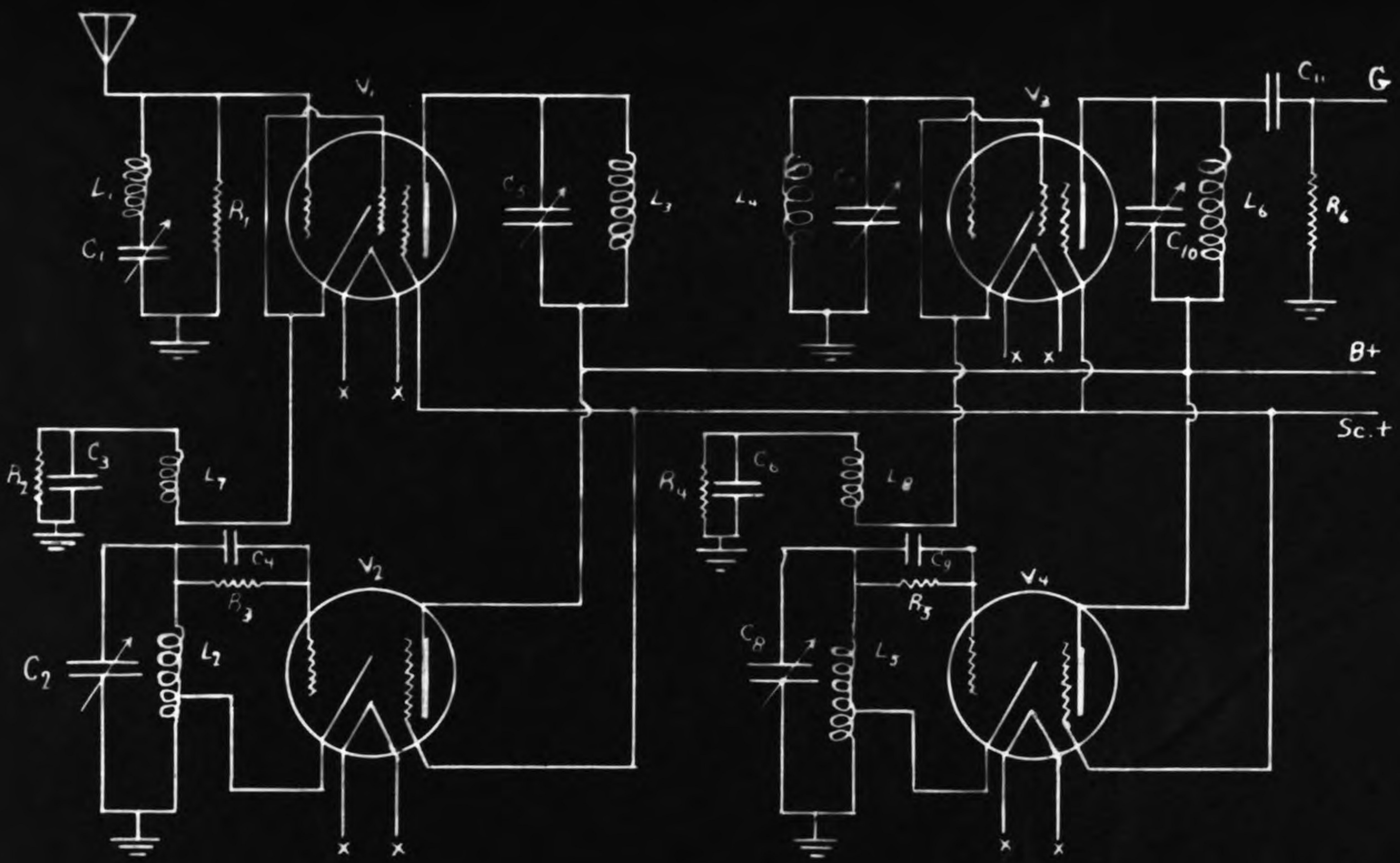
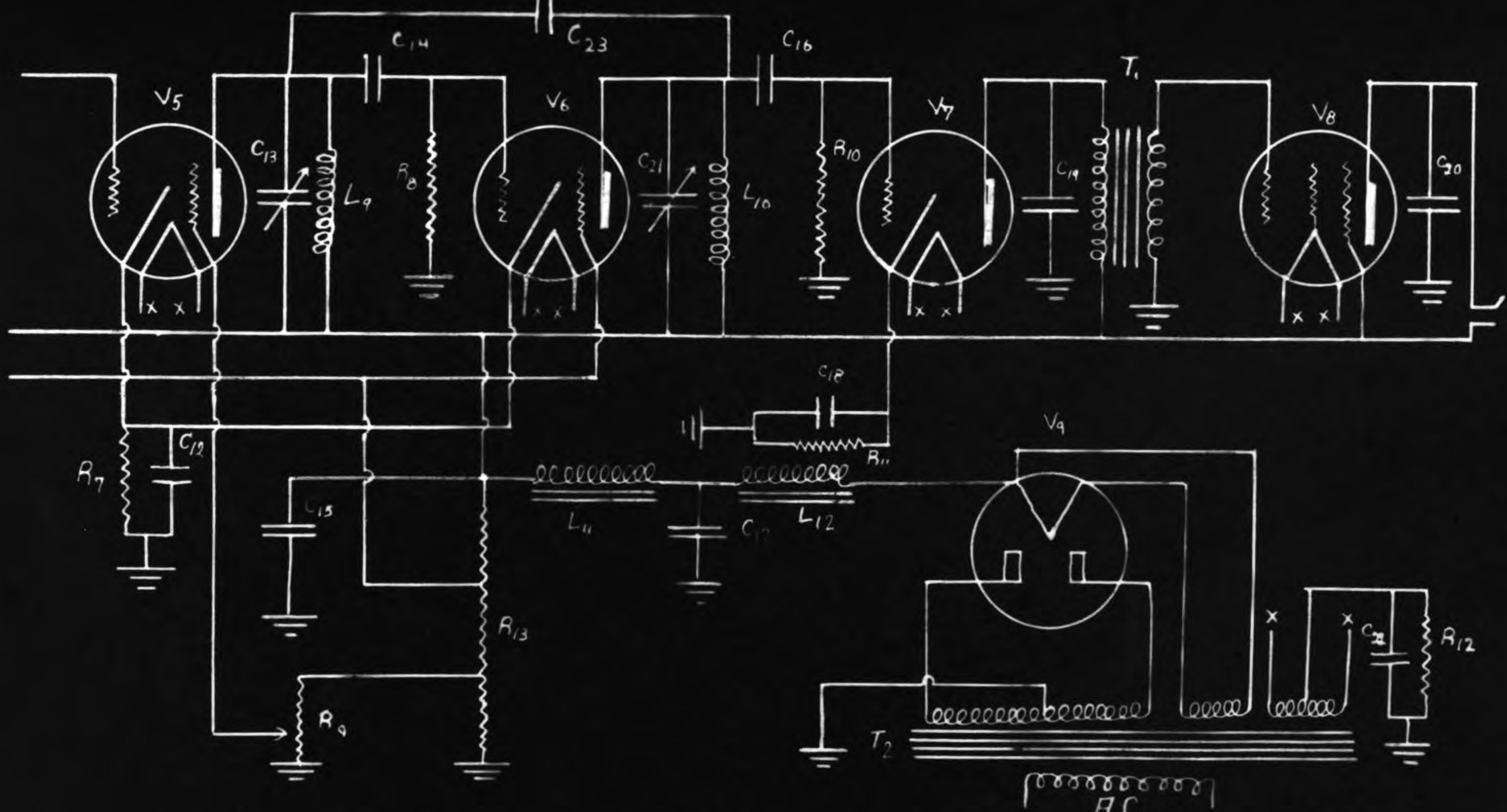


DIAGRAM OF TUNER



AMPLIFIER AND POWER SUPPLY

Parts and Constants

C_1 .000025 microfarad condenser used to tune the tune the filter circuit. A standard trimmer.

C_2 .000125 microfarad condenser. A General Radio double spaced transmitting condenser.

C_3, C_6 1/10 microfarad by pass condenser.

C_4, C_6 .000 25 microfarad mica grid condenser.

C_5, C_7 .000175 microfarad mica condenser, constructed so its value can be cahnged. A DeJur Amsco Corp. product.

C_8 .0003 microfarad mica condenser with a small pilot air condenser in parallel.

C_{10}, C_{13}, C_{21}. .00008 microfarad mica trimmer.

C_{11}, C_{14}, C_{16} .0002 microfarad bypass condenser.

C_{12}, C_{18} 1/10 microfarad by pass condensers.

C_{15} 8 microfarad filter condenser, with a .25microfarad by pass condenser in parallel.

C_{17} 16 microfarad filter condenser.

C_{19}, C_{20} .0006 microfarad mica condenser use for tone tone correction and radio frequency bypass.

C_{22} 25 microfarad by pass condenser.

C_{23} A loop of wire between the two platewire to produce feed back.

L_1 12 turns of No.26 wire on a 1 and 1/8 inch form.

L_2 5 turns of 1/8 inch copper tubing on a 1 andl/4 inch diameter. Self supported, and a tap one turn from the ground end.

L_3, L_4 4 turns of No.14 copper wire self supported diameter land 1/8 inches.

L_5 4 turns of 1/8 inch copper tubing self supported tap one turn from ground end, and 1 and 1/8 inch diameter.

L_6, L_9, L_{10} 150 turns of Lits on 7/8 inch form.

L_7 1 and1/2 turns of No.30 wire on a land 1/8 inch form. Placed very close to the main coil.

L_8 2 and 1/2 turns of No.30 wire on a 1 inch form placed vary close to the main coil.

L_{11}, L_{12} Filter chokes.

T_1 Audio transformer.

T_2 Jefferson power transformer.

R_1 50,000 Ohms.

R_2, R_4 2,000 Ohms.

R_3, R_5 50,000 Ohms.

R_6, R_8, R_{10} 1,000,000 Ohms

R_7 500 Ohms.

R_9 0-7,500 Ohms.

R_{11} 30,000 Ohms.

R_{12} 500 Ohms.

R_{13} 18,000 Ohms tapped voltage divider.

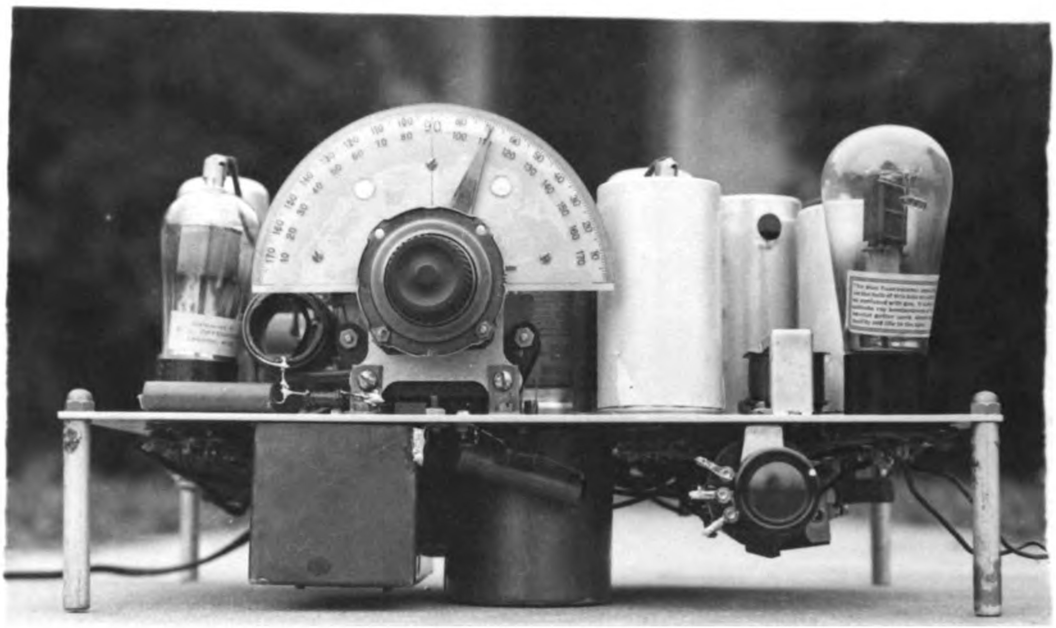
V_1, V_3 258 tubes.

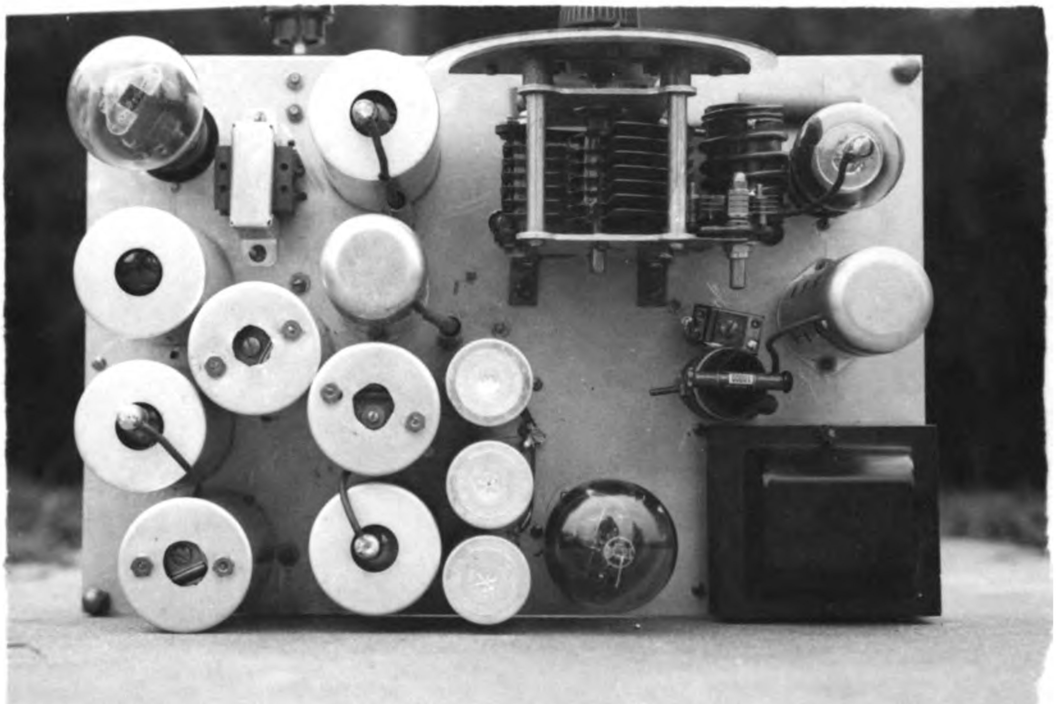
V_2, V_4, V_5, V_6 224A tubes.

V_7 27 tube.

V_8 247 tubes.

V_9 280 tube.





Bibliography

Henney, Keith	Radio Engineering Handbook.
Henney, Keith	Principles of Radio.
Ramsey, R.R.	Fundamentals of Radio.
De Cola, Rinaldo	Noise generation Within Radio Receivers Presented before I.R.E. From August, Radio Engineering, 1931.
Dow, J.B.	Temperature Effects on Oscillators. Q.S.T. May, 1933.
Smith, A.W.	Electrical Measurements in Theory and application.
R.C.A.	Technical Handbook R-10.
Messing, Edgar	Acoustic feedback in Superheterodyne Receivers. From March, 1932 Radio Engineering.
Hirsch, Charles	Design of R.F. Band pass filters. From, Radio Engineering, Sept. 1929.