RADIO MANUFACTURERS SERVICE

Lesson Number Six

OPERATION AND ADJUSTMENT OF COMPENSATING CONDENSERS

W. M. Cook

Prepared by

Philco Parts and Service Division

Especially for Members of

Radio Manufacturers Service

HONEST, COMPETENT — RADIO MANUFACTURERS SERVICE — Your Guarantee of Best Radio Service — A PHILCO SERVICE PLAN — RADIO SERVICE

FOREWORD

This is the sixth in a series of Radio Lessons prepared for the members of Radio Manufacturers Service. These lessons will be prepared and available for your use as rapidly as possible.

Philco engineers have written into this book a thorough explanation of the design, the adjustment, the replacement and the operation of I. F. circuits.

Each subject of radio will be discussed in these lessons. You, as a serviceman, cannot afford to miss the detailed, technical information each R. M. S. lesson contains.

Radio Manufacturers Service Lessons will help you become a better serviceman.

Any question concerning the text or material contained in this lesson should be taken up with the Philco distributor's service manager, the local chairman of Radio Manufacturers Service in your community.

Radio Manufacturers Service brings you Radio Training—Service Jobs—more Service Profits.

RADIO MANUFACTURERS SERVICE

PHILADELPHIA

OPERATION and ADJUSTMENT of COMPENSATING CONDENSERS

R. M. S. LESSON NO. 6

Prepared by Philco Service Department for Members of RADIO MANUFACTURERS SERVICE

An extremely important part of the modern superheterodyne receiver is the small compensating condenser which is used to make adjustments of the various tuned circuits. The serviceman should understand thoroughly the construction, purpose, and method of adjusting these condensers, because the operation of the receiver is largely dependent upon the correct setting of the compensating condensers.

In R. M. S. Lesson No. 1, a complete description was given of the procedure for adjusting all Philco receivers. The purpose of the present lesson is to explain in detail just what takes place when these adjustments are made by means of the compensating condensers.

These small, adjustable condensers, which are sometimes referred to as padders or trimmers, are constructed in several different ways, but essentially they consist of two or more plates, one of which is of spring material so that it will hold the adjustment which is made by turning a screw or a nut. One type of compensating condenser, which is most generally used, employs mica dielectric between the plates. Some manufacturers employ air dielectric condensers but these are usually much too large in size to be practical under most conditions. Usually the condenser is constructed on a bakelite or other insulating base and is arranged in such a way that it can be conveniently mounted near the associated coil.

The purpose of compensating condensers in a radio set is to permit fine adjustments of the various tuned circuits so that these circuits can be completely in resonance and thus function at their maximum efficiency. It is commercially impossible to construct a coil or a tuning condenser which will be absolutely accurate at every point on the broadcast dial. Perhaps this could be done in the laboratory, but certainly not in production. By placing the compensating condensers across the coils, it is possible to obtain precision adjustments which will be far more accurate than precision winding of the coil. The compensating condenser merely tunes the coil to the correct frequency and, because the condenser has a relatively small capacity, it is possible to make this adjustment with extreme ease and at the same time to obtain the greatest possible accuracy of tuning.

There is nothing complicated or nothing mysterious about making the adjustments of these condensers on any radio set. Some servicemen are a bit afraid to make the adjustments because they do not understand what they are doing. If the serviceman appreciates the simple fact that the compensating condenser is merely a tuning device for the associated coil, there is no reason why he should ever have any trouble or why he should ever be worried in any way as to the accuracy and precision with which he can make the adjustments.

Superheterodyne Theory

In order to appreciate fully the importance of making these adjustments, let us review briefly some of the elementary theory of the superheterodyne circuit. In this circuit, we have an incoming R. F. signal which is impressed across the primary of the antenna coil. The secondary of this coil is tuned over the desired frequency range by means of a variable condenser, which in turn, is adjusted by means of a compensating condenser connected across the variable condenser. The signal is fed from the secondary of the coil into the grid of the first tube. In some cases, this tube is a detector oscillator and, in other cases, it is an R. F. amplifier. In some of the larger receivers which employ more circuits ahead of the first detector tube, the secondary of the antenna transformer feeds into another antenna coil which is likewise tuned by a variable condenser. The signal then goes to the first tube. In the circuits employing a combination detector-oscillator tube, a local signal is generated in the oscillator circuit and is mixed with the incoming R. F. signal so as to produce a beat note which is the difference in frequency between the local oscillator and the incoming R. F. signal. In some of the larger receivers, separate tubes are used as first detector and oscillator. In these cases, the oscillator signal is generated in the oscillator tube and is mixed with the incoming R. F. signal in the detector tube. In both cases, however, the two signals are brought together in the first detector tube so as to produce a beat note which amounts to the difference between the two frequencies. When the circuits are operating correctly, this frequency difference is equal to the intermediate frequency (I. F.) of the receiver. The oscillator circuit and the R. F. circuit are both tuned by means of variable condensers, and the circuits are so arranged that the difference between the local oscillator signal and the incoming R. F. signal will be equal to the I. F. of the set at all times. This frequency difference is maintained over the entire tuning range of the receiver, and for any frequency at which the set is tuned, there is always this constant frequency difference which produces the intermediate frequency.

In practice, the local oscillator is always designed to operate at a frequency which is higher than the incoming R. F. signal. This is done because it is much more economical to build a circuit with less capacity and inductance when the frequency is higher than it is when the frequency is lower than the incoming R. F. The values of capacity and inductance, when the higher frequencies are employed, are much lower than they would be if the oscillator were operated at a frequency lower than the incoming R. F.

The signal which results when the R. F. and oscillator signals are mixed in the first detector tube is fed into the intermediate frequency amplifier. The first I. F. transformer couples the output of the first detector to the input of the first I. F. tube. The signal is amplified through this tube and then passes through the second I. F. transformer where it may feed into the second detector tube or, in the case of the larger receivers, into a second I. F. amplifier tube. The intermediate frequency transformers are designed so that their natural frequency is approximately equal to that of the desired I. F. In order to obtain exact tuning of both the primary and the secondary of these transformers, a compensating condenser is connected across these windings to permit slight adjustments. In some receivers only the primary of the I. F. transformers is tuned by means of a compensating condenser. There is sufficient reaction between the primary and the secondary so that tuning of the primary will tune the secondary. In other cases, both the primary and the secondary are tuned by means of compensating condensers so as to obtain more accurate adjustment, which results in greater sensitivity and selectivity.

It is a known fact that higher amplification, and thus increased sensitivity, is obtained when we are dealing with low frequencies than with high frequencies. The lower frequencies are much easier to control and the capacity losses are a minimum. In the superheterodyne circuit we simply change a relatively high incoming R. F. signal to a low I. F. signal for the purpose of amplifying this signal more efficiently. Likewise with this change in frequency we can obtain far greater selectivity. Let us take the example of two stations 10 K. C. apart—one station operating on 1,000 K. C. and the other on 1,010 K. C. It will be seen that the difference in frequencies of these two stations is 1%, while the frequency separation is 10 K. C. Now, if we take an intermediate frequency of 175 K. C. and apply the 10 K. C. separation, it will be seen that the percentage separation now is approximately 5.6%, so that in comparison with the original 1,000 K. C. signal and the unwanted signal of 1% frequency separation we have an improvement of 5.6 times from a selectivity standpoint.

Adjusting Compensating Condensers

Adjustment of the compensating condensers should be made when the set is lacking in sensitivity and selectivity and when other possible sources of trouble such as defective tubes or aerial have been checked. The condensers should be adjusted in all cases when replacement is made of coils or compensating condensers. When adjusting compensating condensers it is desirable to adjust the I. F. before the R. F. and oscillator circuits. A modulated signal generator is connected to the grid of the first detector tube. The signal generator frequency is adjusted to the intermediate frequency of the circuit, and the attenuator of the signal generator is regulated so as to obtain a reading on the output meter equal to approximately half scale. The output meter is connected between the plate and cathode of the output tube, or between the two plates in the case of push-pull output. It can also be connected across the primary of the output transformer if this is more convenient. With the signal generator in operation at the intermediate frequency, the I. F. compensating condensers are adjusted for maximum output meter reading. The order of adjustment of the I. F. transformers does not make any particular difference. The first transformer can be adjusted or the second transformer can be adjusted first, whichever is more desirable and convenient. Both the primary and secondary adjustment of a given transformer should follow one another. After these adjustments have been made, the I. F. amplifier circuit will then be responsive to a signal which is exactly equal to the frequency at which the circuit has been adjusted.

Some servicemen try to adjust the intermediate frequency of a receiver by ear rather than by using an output meter. This is not recommended in any case, because of the lack of accuracy. It is impossible to tell by ear when the maximum signal output is being obtained, and yet it is readily possible when using the output meter. An attempt is sometimes made to adjust the I. F. on a station rather than by the use of a signal generator. This practice is likewise undesirable because when the adjustment is first started one of the I. F. stages may be off slightly. The other stage is adjusted to the frequency of the off stage because an increased signal output will be heard. This results in detuning the intermediate frequency, and thus the amplification and the selectivity are greatly impaired.

In many superheterodyne receivers, particularly the modern short wave superheterodynes, a wave trap is employed to prevent the entrance of unwanted signals at the frequency of the I. F. For example, there are many commercial code stations which transmit at frequencies equal to or very near the frequencies employed for the I. F. in superheterodynes. If these commercial stations have a sufficiently strong signal, the I. F. portion of the amplifier will pick up the signal direct, and interference will result regardless of the setting of the tuning dial. By placing a wave trap in the antenna circuit and adjusting the trap so as to block out frequencies at the I. F., this interference can be overcome. The wave trap is usually connected in the antenna circuit between the antenna terminal of the receiver and the first coil. The trap is so constructed and adjusted that it will prevent the entrance of the unwanted signals, and yet will not have any influence upon signals of any other frequency. The proper adjustment for the trap is to turn the adjusting screw or nut until minimum interfering signal is heard. This is done by connecting the signal generator to the antenna terminal of the receiver and placing the signal generator in operation at a frequency equal to the I. F. of the circuit, and then adjusting the wave trap for minimum signal at that frequency.

R. F. compensating condensers are connected across the R. F. coils in a circuit in order to obtain accurate alignment of these different circuits. For example, we connect a R. F. compensating condenser across the antenna coil and another one across the detector coil. We connect the signal generator to the antenna and ground terminals of the radio set, and adjust the signal generator to 1,400 K. C. We then adjust the R. F. compensating condensers for maximum output meter reading when the dial is set at 1,400 K. C.

In the superheterodyne, there is also a compensating condenser in the oscillator circuit. The purpose of this condenser is to tune the oscillator circuit, so that it will track exactly with respect to the R. F. circuit. Since in any superheterodyne the local oscillator circuit operates at a frequency higher than the incoming signal, the amount of this difference is equal to the intermediate frequency of that particular set. For example, if we tune a station at 1,000 K. C., the local oscillator is operating at 1,260 K. C. in the case of a set with a 260 K. C. I. F. We must maintain this 260 K. C. difference at all frequencies over the entire dial. The high frequency oscillator condenser serves this function so far as the upper half of the tuning range is concerned. When making the adjustments at 1,400 K. C., the antenna, the R. F., and the oscillator compensating condensers are adjusted for maximum reading in the output meter.

There is also another compensating condenser in the oscillator circuit for the purpose of making adjustments at the low frequency end of the dial. This is usually a larger capacity condenser, because increased capacity is required to tune the lower frequencies. This adjustment is usually made with the dial set at 600 K. C. The purpose of this low frequency oscillator condenser is to keep the oscillator circuit tracking with respect to the R. F. circuit at the lower frequencies.

Accurate Signal Generator Necessary

It is evident from the foregoing discussion of the superheterodyne circuit that the adjustments of the I. F., the R. F. and oscillator circuits must be made with extreme accuracy and with signal generator equipment which is accurately calibrated. If, for example, the signal generator were off frequency by say 10 K. C., the dial of the signal generator would be set to the desired intermediate frequency, but the actual signal would be something different. The I. F. of the set would be aligned in accordance with the signal from the signal generator, and this alignment would not then correspond to the frequency of the I. F. signal which was coming out of the first detector tube when the set was placed in operation. The result would be feeding a signal at one frequency into a circuit which was tuned to another frequency. It is evident that the amplification would be greatly reduced, and thus the efficiency of the receiver would be down. On the other hand, if the signal generator is accurate then the I. F. circuit will be tuned exactly to the frequency of the signal which is fed into this circuit, with the result that maximum efficiency is obtained. The ordinary service signal generator which is being carried around at all times is subject to changes in frequency and calibration, and this fact must be guarded against carefully. Changes in tubes and tube characteristics, as well as in the batteries and the battery voltages, will have a decided effect upon the calibration of the signal generator.

Most signal generators used by servicemen are of the intermediate frequency type. That is, the variable fundamental range of the signal generator is within the intermediate frequency range of tuning. Harmonics of these I. F. fundamental notes are used to produce signals in the broadcast band, and for making adjustments of the R. F. and oscillator compensating condensers. If the signal generator is off calibration in the intermediate frequency band, it will likewise be off in the broadcast band. A small percentage of inaccuracy in the calibration of the intermediate frequency signal generator will be reflected as the same percentage in the R. F. end, but the number of kilocycles will be greatly increased. It is important, therefore, that the signal generator which employs the I. F. fundamental range be adjusted with extreme accuracy and then checked on broadcast signals of known frequency in order to obtain the desired accuracy of calibration.

The most pronounced effect of incorrect R. F. and oscillator adjustments due to off calibration of the signal generator are lack of sensitivity and selectivity, particularly at the high frequency end of the band. It is necessary that the R. F. circuits be aligned exactly with respect to each other and also that the oscillator circuit be aligned in such a way that a constant frequency difference will be maintained between the oscillator signal and the incoming R. F. signal. If any of these factors are disturbed, the oscillator will not track properly and the dial calibration will accordingly be off frequency.

Changing the I. F.

In many parts of the country, interference from commercial code stations is experienced as described above. In extreme cases, the wave trap, which is tuned in such a manner as to block the incoming signals at the frequency of the I. F., is not sufficient to prevent the entrance of these signals to the intermediate frequency circuit. In such cases, it then becomes necessary to alter the intermediate frequency to some other value at which point there will not be interference from code stations. For example, suppose that in a certain location excessive code interference is being heard from a station operating on 462 K. C. The superheterodyne is tuned to 460 K. C., but there is sufficient overlap in the adjustment so that the 462 K. C. note will be clearly heard. The signal generator should be connected to the grid of the first detector tube and placed in operation at some other frequency, such as 450 K. C. All of the I. F. compensating condensers are then readjusted at this frequency for maximum output meter reading. The signal generator is next transferred to the antenna and ground terminals and is set at 1,400 K. C. for making the R. F. and oscillator adjustments. When the I. F. is tuned to 450 K. C. it is obviously necessary to retune the oscillator circuit so that a beat note of 450 K. C. will be produced. This is done simply by readjusting the oscillator with the high frequency oscillator and the antenna condensers for maximum output meter reading. Next, the low frequency oscillator compensating condenser is readjusted for maximum output meter reading, and any necessary fine touch-up adjustments are again made on the high frequency oscillator compensating condensers. In this way, the intermediate frequency circuit is retuned to a frequency which is not responsive to the frequency of the interfering code station. The oscillator circuits are readjusted so that the constant frequency difference between the incoming R. F. signal and the local oscillator circuit remains the same and is equal to the frequency at which the I. F. compensating condensers are adjusted. When selecting the other frequency from the standard at which the set has been adjusted in the factory, we must bear in mind the possibility of there being another code station at, or near, the other frequency which might be selected. Some point will be found where these interfering stations will not be heard. As long as this frequency remains within 20 K. C. above or below the original intermediate frequency, satisfactory results will be obtained and comparatively accurate dial tracking will be maintained at all times.

In some locations, it is desirable to make the same changes of the intermediate frequency in order to overcome interference between two broadcasting stations. For example, suppose that in a certain set there are two stations of fairly strong signal, one of which operates at 1,000 K. C. and the other at 1,460 K. C. If we have a superheterodyne with a 460 K. C. I. F., there will be squeals and howls reproduced on the receiver when both of these stations are operating simultaneously. At some times, one station will be heard, and at other times, the other station will be heard; and it does not make any particular difference to which part of the dial the set is tuned. By altering the intermediate frequency 10 or 15 K. C., this interference or heterodyning between two stations is overcome and satisfactory performance will be obtained. The same condition can apply on superheterodynes with other intermediate frequencies if the frequency difference between the two local broadcasting stations is equal to the intermediate frequency of the receiver. A complete understanding of the operation of the superheterodyne and the method of adjusting the compensating condensers will enable the serviceman to correct difficulties of this kind.

Adjusting the Signal Generator

It is highly important that a portable oscillator or signal generator used in radio service work be checked at frequent intervals for correct dial calibration. The constant moving and shocks to which a portable instrument are subjected can easily throw out the calibration sufficiently to cause serious errors in the adjustment of a radio set.

Most signal generators have compensating condensers which can be adjusted from time to time to correct any calibration discrepancies. The adjustment is simple, for it only involves

(1) Tuning in a reliable broadcasting station of known frequency

(2) Removing the antenna and substituting a connection from the signal generator

(3) Tuning the signal generator until its dial calibration corresponds to the frequency of the station

(4) Adjusting the compensating condenser or condensers of the signal generator until the signal is heard in the radio with maximum volume.

In practice, it is desirable to use an output meter to indicate maximum volume rather than to rely upon the ear. It is also necessary to check the adjustment on several other frequencies, making any necessary small readjustments to obtain correct calibration at all points.

Before concluding at any time that the signal generator is in need of recalibration, it is advisable to test the batteries. Run-down batteries, particularly a weak "A" battery, will cause a variation in calibration.

In the PHILCO Models 048 and 024 Signal Generators the adjustment is made by tuning in a station at or near 1,000 K. C.

The compensating condenser for adjustment of the B scale is located on the side of the tuning condenser. In many instruments, both Model 048 and 024, it will be found that the movable plate of this compensating condenser has been bent almost at right angles to the stationary plate, and that the adjusting screw has been removed. In such cases, no adjustment for this scale will ordinarily be found necessary. In some extreme cases, however, it may be necessary to bend the plate slightly until the correct setting is found.

The A scale is adjusted by placing the switch in the A position and adjusting the compensating condenser on the signal generator base (reached through the hole in the back) for maximum output meter reading. Here again the adjustment is made by tuning in a station at or near 1,000 K. C., and then substituting the signal from the signal generator for that from the broadcast station. In the Model 024, the adjustments can be reached by removing the metal plugs in the housing of the signal generator.

Drifting in I. F. and R. F. Circuits

Frequency "drift" necessitating small changes in compensating condenser adjustments is a relatively common occurrence in superheterodyne receivers. It may be found in some cases that the sensitivity will be reduced noticeably over a period of time, and by readjusting the I. F. compensating condensers, normal sensitivity is restored. After a period of a few weeks, the set may again require readjustment. This condition is usually caused by excessive moisture absorption in the compensating condensers or in the I. F. coils, in which case replacement of the questionable parts should be made. It may also be caused by the compensating condensers having faulty elastic or spring qualities in the movable plates. After any replacements are made, all of the I. F., R. F. and oscillator compensating condensers should be readjusted.

Frequency drifting may also occur in the oscillator circuit and will be noticeable by low sensitivity, selectivity and incorrect dial calibration. Drift of this type is often noticeable during the time the set is in operation; that is, when the set is first turned on, the dial calibration will be correct, but after the set has been playing for a short time, better signals will be heard by readjusting the station selector slightly. This condition is usually noticeable on short wave receivers because very slight capacity changes when the set is tuned to the short wave ranges produce comparatively large frequency changes in tuning. In many receivers, the normal heat of operation is sufficient to cause expansion of condensers and coils which in turn causes the slight frequency changes in the circuit. Moving the radio set to a cooler part of the room, or providing better cabinet ventilation will usually correct excessive trouble of this nature. Faulty compensating condensers in the oscillator circuit, or a faulty oscillator coil will also produce such drifting.

Poor sensitivity at the high frequency end of the dial can be caused by drifting of the R. F. compensating condensers. Replacement of the faulty compensator will correct this type of trouble.

Recent Design Improvements

A number of improvements have been made recently in the design and construction of compensating condensers. The earlier type condenser which was generally used by most manufacturers consisted of a base of bakelite which had been punched from a large sheet of this material. The edges were rough and would, in many cases, absorb moisture. This small amount of moisture absorption was sufficient in some cases to permit expansion which resulted in slight changes of compensating condenser capacities. The later compensating condensers are mounted on a special molded material which is entirely free from porous edges. This eliminates the possibility of moisture absorption, and thus the condenser can maintain a constant capacity under all weather conditions. Another type of condenser is known as the Isolantite material. This is similar to a high-grade porcelain and is not affected by any possible moisture absorption. The small washers which are placed between the movable plate of the compensating condenser and the adjusting screw are now made of molded bakelite instead of being punched from a large sheet of bakelite. Likewise the change in the base material prevents moisture absorption with resulting capacity change.

Improving Radio Performance

The average radio receiver, after it is installed in the home, may be improved by readjusting the compensating condensers. In some cases, this improvement is extremely slight, but in other cases it is very noticeable and is sufficient to make the performance of the receiver far better after the adjustment is made. Slight changes in the setting of the compensating condensers occur during transit of the receiver from the factory to its ultimate destination. Weather conditions in some cases affect the adjustment of these condensers and in other cases the heat of operation of the chassis may have a small effect. It is reasonable to assume that the great majority of receivers can be definitely improved by adjusting of the compensating condensers. When this is done, the customer will feel that his radio is performing far better than it ever did. As a matter of fact, the set will perform better than it has at any time since it was in the possession of the owner, because it will then have been given a factory adjustment—something which the owner did not have at the time the set was first installed.

It is highly important that every serviceman be in a position to do a complete radio service job every time he works on a receiver. A serviceman can restore operation of a set without much difficulty, but with slightly more effort it is possible for him to restore original factory performance, and this is just exactly the thing to which the customer is entitled. The word-of-mouth advertising which results from the serviceman making a complete adjustment of all compensating condensers at the time he works on a receiver can only react in the man's favor and gain for him the reputation of being a first-class serviceman.

It is evident that the serviceman must have good test equipment to do a complete service job. He must have the necessary radio set testers, and he must also have a signal generator and output meter for making the various adjustments. It is further important that the serviceman understand the method of adjusting his signal generator and that he make it a practice to check the calibration of the signal generator at least once a week.