TWENTYFIRST WEEK. G.B.Todd, RMlc.
MASTER HETERODYNE FREQUENCY METER.

QUESTION #1. What circuit is used in the Master Heterodyne Frequency Meter?

ANSWER #1. The Master Heterodyne Frequency Meter uses an inductively coupled method of regeneration in a tuned grid oscillator circuit, which is an adaption of the circuit used in a TV transmitter. Two condensers (A and B in circuit) are in series with the tuned grid circuit. These condensers are varied simultaneously so that the larger one (A) always has about three times the capacity of the smaller (B). Since they are in series, the combined capacity of the two is always less than the capacity of the smaller (b). The capacity between the grid and filament is quite small compared to the capacity of the condenser which is in parallel (A), since the grid and filament are connected only across the larger condenser. So, a large change in the tube element capacity will produce only a small change in capacity of the condenser (A) in parallel and a very much smaller change in the combined capacity of the two condensers in series in the tuned grid circuit (A and B). This the advantage of this circuit is: constancy of frequency and freedom from variations of frequency on account of the small variations in tube interelement capacities. The two condensers (A and B) are on the same shaft and are thus varied at a constant ratio to each other, therefore the grid voltage is the same for all condenser settings with a certain coil. This gives the circuit another advantage; that of being independent of plate and filament voltage variations thruout the condenser range. No means are used to vary the tickler, the circuit being in the oscillating condition at all times. Any kind of phones may be used or the meter can be used without any phones and still the frequency will not vary, since the phones are not connected directly into the plate circuit, but are coupled inductively through a telephone transformer.

QUESTION #2. Explain the coil system used in the meter.

ANSWER #2. Eight inductance coils together with tickler are mounted inside the aluminum case of the Master Heterodyne Frequency Meter, to cover the entire frequency range (125 to 4000 KCS). Any one of these coils can be connected into the circuit by depressing and locking, by turning, the proper switch, upon which is printed the frequency range of that particular coil. Each coil is set at an angle to the adjacent coil and consists of two inductances, with the common tickler between them, wound on a Pyrex glass form. Pyrex was used because of its low coefficient of expansion and its mechanical strength.

QUESTION #3. What type of switching system is used in this meter?

ANSWER #3. A unique system of connecting and locking the desired coil into the circuit. The system consists of eight switches, each of which has four contacts; two connect to the inductance coil terminals and two connect to the tickler coil terminals. The switches are so arranged that when one is pushed down about a quarter of an inch and turned to the right about 30°, in which position it locks, none of the other coils are connected in the circuit, and none of them can be connected as long as this one is locked. In order to connect another coil in the circuit, it is necessary to depress this particular coil again, and turn it back to the left, at which point it releases from the catch and is sprung back into position by a spring, which is a part of each switch.

QUESTION #4. Explain the type of variable condenser used in this meter.

ANSWER #4. When this meter was built, the main object was to obtain a constancy of frequency and a uniform oscillation over the entire range. To obtain this, the variation of plate and filament voltage must have no effect on the frequency. This was accomplished by means of two condensers in series in the tuned grid circuit. These two condensers are variable and are mounted on the same shaft, the movable plates being connected to the shaft and are varied by a handle on the upper right hand side of the aluminum case. This simultaneous variation of the two condensers keeps the ratio between them constant, thus causing uniform oscillation thruout the entire range and helping to maintain a constant frequency even tho the plate and filament voltages varied. The condenser plates were constructed with such a shape that the change at the lower end of the condenser scale was very gradual, thus producing what is known as a straight line frequency curve. In order to obtain extreme accuracy with the meter, some method was needed to obtain precise readings. This is accomplished by means of a worm and gear, such that 25 rotations of the condenser knob are necessary to obtain 180° rotation of the condenser. These numbers 1 to 25 are read thru the left hand window near the condenser knob. Each rotation of the condenser knob is divided into 100 more divisions, read thru the right hand window. This gives a total of 2500 divisions in the semi-circle of condenser rotation. The number in the left hand window is hundreds of divisions and the number read in the right hand window is tens and units. So that, if the number 3 is read in the left hand window and the number 78 is read in the right hand window, the reading would be 378 condenser divisions. The frequency corresponding to this reading is obtained from the frequency curves, provided on charts furnished with each meter, and which will be discussed later.

QUESTION #5. Describe in detail the oscillation indicator.

ANSWER #5. A direct-current milliammeter is inserted in the circuit in series with the grid-leak and is used to indicate oscillations. The meter is placed on the panel just above the condenser knob. The circuit is oscillating when there is a deflection on this meter. Some men have the mistaken idea that a dip in the reading of this meter indicates resonance, but this is not the case. The meter's sole purpose is to indicate oscillation. A variation of plate current will cause a deflection downward in the meter reading. The amount of deflection is insignificant since it varies on the several coils from about half scale down to zero.

QUESTION #6. Give an explanation of the heterodyne principle.

ANSWER #6. The heterodyne, or "beat" method of reception utilizes a local oscillator to partly cancel the incoming frequency, leaving just enough to be within the audible range. Most incoming frequencies are so high that they cannot be detected by the human ear. If local oscillations are superimposed the frequency of the incoming oscillation can be completely cancelled out. This explains the silence band or zero beat of continuous wave reception. If the incoming frequency is 500 KCS and the local receiver is oscillating at 500 KCS, no signal will be heard, but if the local oscillations are 501 KCS, the audible signal is the difference between the two, in this case 1000 cycles. This occurs on either side of the zero beat. If the local oscillations are 499 KCS, the audible signal is still 1000 cycles. The Master Heterodyne Frequency Meter makes use of this principle. On the lower freqencies this silence band is quite broad, therefore, to determine the exact point of zero beat, it is necessary to tune the meter to zero beat, then vary the condenser up the scale until a low note is heard; note this condenser setting; then vary the condenser down the scale until another low note is heard, and note this setting; the correct reading is the mean of the two, or half way between the two. Once the correct reading is obtained, the frequency can be determined from the charts.

QUESTION #7. Explain how you would use the meter to tune a receiver to pick C.W. transmitter of known frequency.

ANSWER #7. The meter must be put into operation by the following methods, before it can be used: The filament is lighted by pressing the filament switch to "on" position and turning the rheostat until the voltmeter reads 7 volts. The proper coil is connected in the circuit, by depressing and turning to right to lock, the switch corresponding to the frequency range desired. An inspection of the "range in kilocycles" seen through the celluloid window on panel just above the line of switches. With the switch locked down and the filament lighted, the oscillation indicator shoul

ANSWER #7. Continued.

show a deflection. The meter is adjusted to the desired frequency by obtaining the condenser setting from the calibration curves, furnished with each meter. An, example; if the meter is to be set to 315 KCS: The coil which includes this frequency, is depressed and locked. The condensers setting for this frequency is determined from the calibration curve. In this case it is 1250 divisions. The condenser knob is turned until the left hand window indicates between 12 and 13, then the knob is turned until the right hand window indicates 50. The meter is now set and oscillating (if the milliammeter shows a deflection) on 315 KCS. The coils overlap each other a little and it will be found from operation that the overlap is at the upper end of the higher frequency coils and the lower end of the lower frequency coils. In order to tune a receiver to pick up a C.W. transmitter of known frequency, the meter is set in operation and adjusted to assigned transmitter frequency as explained above. The coupling wire must be in place, unless none is needed. The receiver is adjusted to approximate frequency, then the receiver is varied until a high pitched note is heard in the receiver phones (The frequency meter phones should never be used, except to pick up a near-by transmitter). Then, the frequency meter is shut off and the transmitter should be heard, if it is on the proper frequency and in operation.

QUESTION #8. How would you use the meter in tuning a local transmitter on a ship having a separate transmitting and receiving room?

ANSWER #8. The frequency meter is set in operation, as explained above, and the meter adjusted to the desired frequency. The phone connection is plugged into the control board so that the man in the transmitter room can hear the transmitter signal in the phones that he is wearing. The operator transmits on low power, while the man in the transmitter room varies the transmitter frequency until he hears the zero beat in the frequency meter phones. The transmitter is now on the correct frequency. After each operation the frequency meter should be shut down by pressing the filament switch and turning down the filament rheostat.

QUESTION #9. How would you measure the emitted frequency of a transmitter located on another ship?

ANSWER #9. The receiver is adjusted to zero beat with the transmetter and the frequency meter is then adjusted to zero beat with the receiver. The condenser setting is noted, care being taken that the exact center of the silence band is obtained. This condenser setting is found on the calibration chart and the corresponding frequency noted. This is the transmitter frequency. Much attention should be paid to tuning the receiver to zero beat with the transmitter as more error is made in this operation than in any other.

QUESTION #10. What precautions should be taken with master heterodyne frequency meter in general?

ANSWER #10. The general precautions which should be taken in the operation of the Master Heterodyne Frequency Meter are as follows:

Voltages:- The proper voltages are 120 volts on the plate and 7 volts on the filament. A filament battery of more than 10 volts should never be used. Although the circuit will oscillate below 100 volts it is desirable to keep the plate voltage always above 100 volts.

Switches:- Do not attempt to depress a coil switch when another coil is already engaged. If the switch will not depress and lock, inspect the other switches and see if one of them is about one quarter of an inch below the others, an indication that it is engaged. Depress and turn this switch to the left in order to disengage, before engaging the other.

Condenser Settings:- Extreme care should be taken in reading condenser settings. An error of 100 divisions is very easily made by reading one number too high in the left hand window. An example: If the true reading were 1599 it might easily be mistaken for 1699, since 16 is directly beneath the hairline, but a slight rotation of the condenser knob will turn the indicator to 1601 so it is obvious that the correct reading is 1599.

Tubes:- The tubes furnished with the meter are for this purpose only and should never be used for any other purpose.

Shield:- The negative filament and the negative plate terminals are connected to the metal shield and, if the ship's line is to be used for a plate supply, the shield will have a potential of the negative side of the ship's line.

Beats:- All settings should be made to zero beat (the exact center of the silence band) except when setting a receiver to pick up a signal, when it should be set off the zero beat by about 500 or 1000 cycles.

Coupling:- The coupling binding post at the back of the panel is simply a brass rod insulated from the panel and extending about 4 inches into the box. It furnishes capacity coupling from any coil to the external circuit if a wire is connected to the binding post and connected to the external circuit by means of a few turns around the antenna lead-in. Care should be taken NEVER to leave this wire connected to the meter when any high power transmitting is being done on the ship as the large transfer of power between antennae will be carried down to the coupling rod and the insulator which holds it will be charred.

DETAILS OF MASTER HETERODYNE FREQUENCY METER NOT COVERED BY QUESTIONS.

Plate Supply Filter:- An audio filter consisting of two chokes and two fixed condensers is connected in the plate circuit to permit the use of the 120-volt direct current ship line as plate supply. On the line available for test this filter has been found very effective. If, however, commutator sparking is found to cause a noticeable hum in the phones on the unit, batteries must be resorted to. While the unit is designed to oper ate on 120 volts, a drop in the line of 30 volts from this value will not stop oscillations, nor will the frequency be affected.

The tubes used are a 7½ watt, type DV 210, and only those equipped with the instrument should be used. These special tubes should be used for no other purpose.

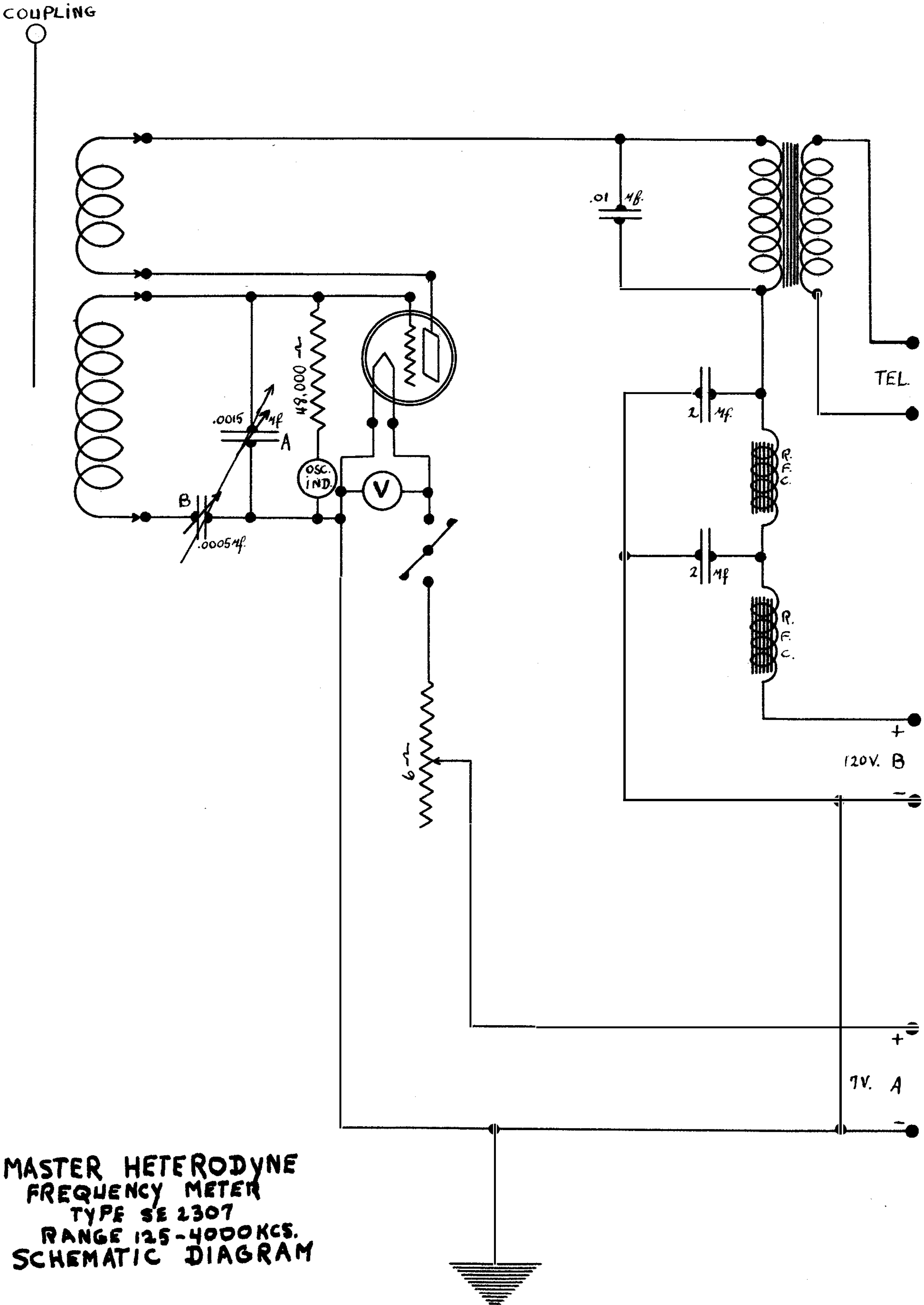
To tune a local transmitter where transmitter and receiver are in same room:- First, determine if the signal of the different transmitters can be heard distinctly on the frequency-meter phones where it is installed. If not, run an insulated wire from the coupling binding post on the frequency meter up near the receiving-antenna lead-in or some other part of the circuit carry ing radio-frequency currents. The wire may terminate in a coil of several turns but should not touch any part of the transmitter circuits. The amount of coupling required will depend on how well the transmitter is shielded and when this is determined it should be recorded for reference. If, in tuning a low-power transmitter such as the CW-938A, by listening on the heterodyne frequency meter phones, a louder note is desired, due to excessive local noises, the following method is employed: 1. Instead of listening on frequency meter phones, tune the SE-1420 or other receiver to zero beat with frequency meter set on the transmitter frequency. Then, with receiver phones still on, tube the CW-938A transmitter to zero beat with the receiver. With coupling to give a signal in frequency meter phones, tune the transmitter to zero beat.

To calibrate an ordinary service frequency meter:- (con sisting of a coil, a condenser, and a current-indicating device):- This must be done through the medium of some vacuum tube oscillator such as the L.A. driver. L. Set the condenser of the ordinary service meter at a point desired and adjust the driver to resonance with it, as indicated on the current-indicating instrument, or, in the case of the L.A. driver, by a "dip" on the meter. Detune the service frequency meter. 2. Tune the Master Heterodyne Frequency Meter to zero beat with the driver. With the two only a foot or two apart, the beat note should be heard in the frequency meter phones. 3. Read the frequency from the calibration curves Repeat the procedure for any number of points desired.

Harmonics:- Besides the energy emitted on the fundamenta frequency, all vacuum tube oscillators radiate, a relatively small amount of energy on exactly twice this frequency, on three times this frequency, and so on. These are called harmonics of the fund amental frequency. A transmitter, a receiver, and the master heterodyne frequency meter, when set at 150 KCS radiate also at 300 KCS, at 450 KCS, and so on, each succeeding harmonic growing a little weaker than the proceeding one. Harmonics are undesirable as they represent a power loss and because they are an interfering note on frequencies which are an integral multiple of the fundamental frequency. But they may be used for certain practical purposes. By their use the range of the Master Heterodyne Frequency Meter may be, in effect, extended below 125 KCS.

How to use harmonics to determine frequencies below 125 KCS (assume that it is desired to tune a receiver to "stand-by" for a 76-KC station):- 1. Set the master heterodyne frequency meter at exactly twice this frequency - 152 KCS. 2. Tune receiver circuits roughly to 76 KCS by dial calibration. If primary circuit is uncalibrated, increase inductance coupling and vary primary circuit to secure "resonance click" in phones. Now tune receiver slowly to pick up a high-pitched note with frequency meter. This is the oscillating receiver harmonic at double its fundamental frequency, beating with the fundamental of the frequency meter. 3. Shut off the frequency meter. The receiver is now set to hear the 76 KC station. The explanation is as follows: The harmonic of the receiver, at twice the fundamental frequency is tuned to give an audible beat frequency with the fundamental of the heterodyne frequency meter. The frequency meter is set at 152 kilocycles. Therefore, if a kilocycle beat note is heard in the receiver phones, this harmonic of the receiver is 1 kilocycle above or below 152 kilocycles. Assume it is 151 KCS. Then the receiver fundamental is one-half this frequency, or 75.5 KCS. This would give a 500 cycle beat note with a transmitter (or tube) on 76 KCS. When a loud note can be heard with the receiver fundamental tuned to the frequency meter fundamental, then this harmonic should give an audible note. If the receiver were set at around 300 KCS, another harmonic might be heard, but this would be the harmonic of the heterodyne frequency at twice the fundamental (152 x 2) beating with the receiver fundamental.

How to tell the fundamental from harmonics:- 1. The note between fundamentals is louder than that heard on a harmonic. 2. The beat notes due to harmonics fall at twice, three times, etc., or one-half, one-third, etc., the fundamental of the frequency meter. With any rough calibration of a transmitter or receiver as a guide, no harmonic should ever be taken for the fundamental. If harmonics are heard on a receiver, determine if the fundamental of the heterodyne frequency meter can be picked up without the coupling wire.



MASTER HETERODYNE
FREQUENCY METER
TYPE SE 2307
RANGE 125-4000 KCS.
SCHEMATIC DIAGRAM