The Harmoniker is a harmonic attenuating filter, designed to work on any one amateur band, and designed to attenuate greatly all harmonics of any signal transmitted in that particular band. It is placed between the final output circuit and the antenna feed line. The Harmoniker is sufficiently effective that, properly constructed and intelligently installed, it should enable the average amateur effectively to eliminate all TVI caused by harmonic radiation from the antenna and antenna feed lines.

Attenuating all harmonics in a filter of this sort means that individual harmonic traps normally installed in the plate leads of the final are unnecessary. Elimination of separate plate traps is extremely desirable because normally a set of them is required for each TV channel. If harmonic radiation from the feeder and the antenna proper is minimized, by use of the Harmoniker, to the point where it will not cause TVI it is then only necessary to ensure that radiation directly from an unshielded transmitter is not causing trouble. This aspect of TVI will not be covered, since the Harmoniker acts only to attenuate harmonics which might otherwise be radiated from the antenna system. However, in most cases the major source of TVI is harmonic radiation from the antenna system.

Whether or not you are troubled with TVI, the use of such a filter in your antenna system will reduce the harmonic output of your station (transmitter and antenna) to a marked degree and may save you the worry of a warning ticket from the FCC for excessive harmonics.

GENERAL FEATURES

The Harmoniker is a half-wave filter with special properties that make it an ideal harmonic attenuator for amateur transmitters. For example, it is effective over the entire width of any one amateur band. This means that it is not necessary to stay on one particular frequency—you can use your VFO to its full extent.

Note that the Harmoniker is not the type of low-pass filter which will pass any frequency up to some given point, for example, 30 megacycles, and attenuate only higher frequencies. With a filter of this sort no low order harmonic attenuation is achieved when operating in the lower frequency bands.

No appreciable amount of power is lost in the Harmoniker. Generally speaking, inserting this filter between the final output tank and the antenna feeders will occasion a loss of only 0.5 dB—that is, only 1/60 of an S unit.
Probably the most important feature of this filter is that the harmonic attenuation is obtained over a wide range of impedances. That is the Harmonizer will work with a wide variety of transmission lines almost without regard to their impedances—be they 50 ohms, 300 ohms, etc. Further, the Harmonizer can be installed between transmitter and transmission line without changing any coupling adjustments or tuning. It's as though the filter weren't there as far as your fundamental frequency is concerned, but it does keep the harmonics out of the antenna system.

The attenuation afforded to harmonics is as follows: second harmonic—31 db (1200 to one in power); third harmonic—48 db (50,000 to one in power); fourth harmonic—97 db (almost one million to one in power); fifth harmonic—67 db; sixth harmonic—75 db; seventh harmonic—79 db; eighth harmonic—84 db. For each additional harmonic, the attenuation becomes greater and greater, increasing at the rate of approximately 30 db per octave.

**DESIGN DETAILS**

It is hoped that the Harmonizer will be used by the beginning amateur as well as the old timer. Harmonics can and do emanate from practically any type of transmitter, whether it be a ton watt or a thousand watt job. In order that the beginning amateur may take advantage of the Harmonizer's properties without wading through a technical dissertation, this section will be treated in simple terms. The more technical-minded are referred to "Design Theory" at the end of this module.

Acting as a half-wave filter, the Harmonizer has many of the properties of a half-wave transmission line. For example, any half-wave filter can be used at any impedance, since the input impedance of the filter...
with load is the same as that of the load itself. The same is true of a half-wave transmission line. For example, the Hammaraker attenuates harmonics while the half-wave transmission line will not.

In a general manner of speaking, then, the Ham- maraker may be placed between the transmitter and the load. However, if any amateur installation, regardless of the impedances of the transmission line itself. While this is true, there are several points to be noted. If the transmission line had not been matched, standing waves would have been created. Consider the Hammaraker inserted in this line, these standing waves would still be present and the power dissipated as heat. If the Hammaraker were then placed between the transmission line and the load, the power dissipation would be equal, but now the Hammaraker would absorb this power and only the power line and load would be dissipated.

The Hammaraker should normally be used only with transmission lines that are relatively free from standing waves.

Aside from the transmitter power, another thing can affect the voltage across the circuit elements of the Hammaraker. Refer to the circuit diagram, Fig. 2. It will be seen that there are four end condensers, (two on the input side, two on the output side) and four center condensers. Assume that a Hammaraker was designed for a 300 ohm load. If this filter were used with a 300 ohm matched transmission line, the voltages on the center condensers would be equal. However, if this same unit were used with a 600 ohm load, the voltage on the end condensers would be greater than the voltage on the center condensers. If the unit was used on a 150 ohm load, the reverse would be true.

Three voltage relationships (caused by standing waves in the filter itself) will be treated in subsequent letters; but are mentioned here to show why it was found desirable to design two different Hammarakers— a low and a high impedance unit—for each band. Having two designs available, you can select the one which most closely matches your load and avoid the necessity of using condensers with a high voltage rating.

If the impedance of your transmission line is between 50 and 150 ohms, you would use the low impedance Hammaraker which is designed for 100 ohm work. Similarly, you would use the high-impedance Hammaraker, which is designed for 300 ohm work, if your transmission line impedance is between 150 and 600 ohms.

The circuit diagram also shows three input terminals and three output terminals. The input and output connections are A—B and A—B', respectively, for balanced lines (such as twin-lead and open-wire lines). The connections to be used for unbalanced lines are A—G and A—G', respectively, when unbalanced lines such as coaxial cable are used.

Because only half of the Hammaraker is being used when an unbalanced line is employed, the 150 ohm unit automatically becomes a 50 ohm unit for coaxial cable use. Thus an exact design is available for the popular 50 ohm coaxial line. If the Hammaraker is to be used directly for unbalanced feeder use, then only one-half of the unit need be constructed. Everything that was said above may be repeated. However, if the complete unit is built, it may be used for unbalanced feeder work if a shorting connection is made between terminals G and B (or G' and B') and center connection untapped and A—B' or A—G' and end one shorting connection.

SELECTION OF PROPER UNIT

For 50, 72 or 85 ohm coaxial cable, use the design data for the 100 ohm Hammaraker. Make only half the design as given, that is, use two coils, C1, and four condensers, C2.

For 85 ohm twin conductor cable, 72 ohm twin-lead, twisted pair, or any other balanced line whose imped- ance is not over 150 ohms, use the design data for the 100 ohm Hammaraker and build the entire unit as shown. Make connections to A—B and A—B' and run a short ground connection to either terminal G or G'.

For 300 ohm twin-lead or open-wire transmission lines with impedances up to 600 ohms; use the 300 ohm Hammaraker and connect to A—B and A—B', again grounding either G or G'.

The more advanced amateur may design his Hammaraker to the exact impedance of his transmission line if he so desires. Full information on how this may be done will be given under "Design Theory."

POWER CAPABILITY

The data given under "Circuit Constants" is for a Hammaraker which is rated nominally for one kilowatt peak level. When only one-half of the unit is used, as in the case when coaxial cable is employed, the unit will operate at 500 watt peak level.

Therefore, if a higher peak level is required, it will be necessary to use condensers with a higher voltage rating. It is also possible that the coils may overheat, but this may be experienced in only a few high-power amateur installations.

The voltage rating for condensers C4 specified under "Circuit Constants" will be adequate for a one kilowatt (output) CW, NB, FM, SSB, etc. transmitter, or for a 500 watt AM transmitter, assuming that both sections of the filter are used, as in the case with a balanced feed line. If coaxial cable is employed and only one-half of the unit is in use, the power rating is 500 watts for CW, etc., and 375 watts for AM phone.
The Harmonizer may be used with a one-kilowatt AM rig (balanced line feed) if condensers with twice the specified voltage rating are substituted. Similarly, twice the voltage rating is required if a one-kilowatt CW rig feeds an unbalanced line (half the unit in use). It will be necessary to use condensers with four times the voltage rating if a one-kilowatt AM rig is used with unbalanced feeders.

**HARMONIZER CONSTRUCTION**

The Harmonizer shown in the photographs is a 100 ohm, 3.3 to 4.6 mc. unit. It is built into a 2 by 4 by 5 inch metal box. This size box is adequate for all Harmonizer designs with the possible exception of the 300 ohm unit for 80 and 40 meters. The coils for these two units are rather large, and might require a larger box.

Fig. 1 indicates 'where the components are mounted on one removable piece of the box. Four feed-through nuts are used for terminals A, A’, B and B’. These are mounted on, or the 4 by 5 inch plate one inch each side of center and one inch in from the ends of the plate. Two metal binding posts are used for terminals G and G’. A heavy bus wire is run between terminals G and G’.

The inter-section shield is 2 by 3 by 5 inches. It may be made from almost any material, although brass was used in the unit pictured, for easy soldering. The shield is not an integral part of the mounting plate. Note that the point has been wrapped from the entire edge of the bus and the point of the mouse is connected to the mounting plate. Similarly, the point must be removed at the point where terminals G and G’ are attached, and where the inter-section shield is fastened to the mounting plate.

Fig. 2 shows the correct way to wire the Harmonizer circuit. It is necessary to make connections to the condensers as close to their molded case as possible. The objective is minimum lead inductance. Toward this end use large diameter wire—No. 12 is suitable. Note that the leads from each end of the coil are brought separately to the condensers, as at points P and Q. Do not use a common lead, such as WY or X. Also, connect the other end of the coil directly to the condenser at point B, and do not connect it back to point Z. It is not advisable to wind your own coils unless equipment is available to check the inductance accurately. The use of Barlow and Williamsohn Inductors, as specified, will ensure correct inductance. Mount the coils as shown in the photographs. The number of turns specified refers to the actual number of turns on the coils, but leave enough extra wire on each end to make connections. This extra lead length has been taken into account. The actual inductance specified, which may be used if you wind your own coils, refers to the total inductance of the coil and its leads. It is important that the coil specifications be followed closely, since the unit will not be "tuned" for the proper frequency.

The condensers used should be mica condensers. It will be worthwhile to go to a little trouble to get condensers used as close to new as possible. Insulation as the capacitance specified can not be obtained, in most cases, with one mica condenser; it will probably be necessary to parallel condensers in order to get the required capacitance.

Probably the easiest way to obtain the proper condensers is to purchase mica condensers with a plus or minus 5 percent tolerance. As a double check, these could be compared with each other on an inexpensive capacitance bridge, and any condenser returned which was found to be of a substantially different capacitance discarded.

It would also be possible to use mica trimming condensers of the same voltage rating. These should be set to the proper capacitance on a capacitance bridge which could be purchased for the purpose. The advantage here is that the Harmonizer would probably not fit in a 3 by 1 by 5 inch box if adjustable condensers were used.

The care that is taken to ensure that the specified value of capacitance is obtained, the better the results.

The two center condensers in each half of the circuit may be replaced by a single condenser if so desired. This single condenser, having a capacitance twice the value of C2, may be placed on either side of the inter-section shield. Caution should be exercised to maintain a low lead inductance. Because this is difficult with some of the smaller size condensers, two identical condensers were used in the original unit.

**INSTALLATION AND OPERATION**

Inasmuch as harmonics are not attenuated until they encounter the Harmonizer, mount the unit as near the antenna as possible. The TVI (the Harmonizer could be mounted on the outside of the television set, if one were available) is, as a general rule, preplugged. Care must be taken with the leads to the main screen, or to the transmitter of the television set, because these leads can radiate harmfully. Harmonizer, as the case may be, in the case of television sets.

In general it will be unnecessary to change your present output coupling system. However, if you are using line coupling with the center of the line grounded, remove this ground connection. The Harmonizer (used as a balanced filter) does this job for you automatically, and will give better results than any arrangement on the pickup coil.

It is advisable to use the Harmonizer only with a reasonably "flat" line, that is, one which has a low standing-wave ratio. This is particularly necessary when operating at power levels which may produce standing waves across the condenser circuits or when the proper voltage ratings. If the unit is placed in a line with a high SWR, the result will undoubtedly be a few blown condensers in the Harmonizer.

Of course, the Harmonizer may be used in a line with a high standing-wave ratio (tuned line) if the impedance at that particular point is known. So that the Harmonizer may be designed accordingly. A low voltage should be allowed to appear across the condensers in the Harmonizer. Be certain to connect terminal G and G’ by means of
a short heavy conductor directly to the chassis or frame of the transmitter.

Never try to use a Harmonizer on a band for which it is not intended. For example, if one kilowatt of power on ten meters was fed into a twenty meter Harmonizer, the result would be 999 watts dissipated in the Harmonizer and one watt fed through to the antenna for perhaps a fraction of a second. A further result would be that you would no longer have that twenty meter Harmonizer.

TVI ELIMINATION

Interference to television reception caused by amateur transmitters is generally due to one or more of four effects: radiation of harmonics from the transmitter itself; radiation of harmonics from the antenna system; overload of the TV receiver by the fundamental; and overload of the video circuit in the TV receiver by the harmonics. The first two effects come from radiation on the 160 and 80 meter bands.

The last two effects, overload of the TV receiver by your fundamental frequency or signals getting into the video amplifier, are most easily eliminated by placing suitable filters, traps or shields directly on the receiver. At any rate, these effects will be noted only when the TV receiver is very close to the transmitting location.

Radiation of harmonics from the transmitter (facili-
tator stage, buffer stages, power supply leads, final stage, etc.) is another cause of TVI. The approach to cure this effect is complete shielding of the transmitter and bypassing of power supply leads, etc.

The third, and probably the most prevalent cause of TVI is radiation of harmonics from the antenna system. It should be possible to eliminate this con-
dition by use of the Harmonizer. In especially severe TVI cases, and of course when you are certain of the cause, two Harmonizers may be used in series if one proves to be insufficient.

When attempting to close up TVI for the first time, here is a suggested approach.

If you are operating on 3, 14, or 26 megacycles, determine whether the TVI is caused by fundamental or harmonic radiation. To do this, transmit carrier and examine the TV tube screen when the TV receiver is tuned to a TV signal. If the screen becomes blank, or the picture "washes out," then harmonics are the cause. The procedure is undoubtedly causing your trouble. If a herring- bone pattern appears, the trouble is most likely due to harmonic radiation. With modulation, horizontal bars will appear on the screen and may obscure the picture. You can, however, still detect the modulated carriers for this preliminary test. Of course, if you have a 500 line monitor, it will be necessary to transmit a single frequency (carrier or a sidereal tone) to get adequate ground level signal.

When operating on the 160 and 80 meter bands the checker method above will not be effective, because 1.75 to 4 megacycle energy may get into the video amplifier of the receiver. Therefore, to deter-
mine what causes the TVI in this case, another method is suggested. Change the frequency of the trans-
mitter and watch the herringbone pattern on the screen. A change of frequency from one end of the band to the other will not change the spacing of the pattern appreciably if the interference is from the fundamental but the pattern will change substantially if the interference is caused by harmonic radiation.

Once you have determined the cause of TVI, the method of attack is obvious. The radio receiver, namely overloaded the receiver; are best cured at the receiving point before.

Radiation direct from the transmitter require shielding of the transmitter and proper bypassing of power supply and other leads. Interference caused by harmonic radiation from the antenna system is a job to cure. Merely install a Harmonizer and relax to enjoy your future QSO's. 

DESIGN THEORY

As is well known, an integral number of half wave-
length sections of lossless transmission line of any impedance may be placed between a source of power and a load and the operation of the system will be the same as though the load were connected directly at the source. The half-wave filter is similar to one half-
wave section of transmission line in this respect. The important point of dissimilarity is that a half-wave line will not attenuate harmonics, while the half-wave filter, on the other hand, attenuates all harmonics, the attenuation increasing with the order of the harmonic.

A half-wave filter looks like a lossless filter of two sections. These sections may be identical, but only the pi type of filter will be discussed. Fig. 4A shows an unbypassed pi filter and Fig. 4B shows a bal-
anced pi filter. These filters become half-wave filters when the load voltage is 180 degrees out of phase with the input source voltage. The formulae for the in-
ductances and capacitances required to make half-wave pi-section filters (see Figs. 4A and 4B) are:

$$L = \frac{4}{\pi} \frac{1}{f_0^2} \quad \text{and} \quad C = \frac{1}{\pi f_0}$$

where $L$ is the load impedance (resistance) which gives a standing wave ratio of one-to-one in the filter at the frequency $f_0$. The units are henrys, ohms and cycles per second.

The formulae on these figures the reader is referred to Communication Engineering, by W. L. Hurst, in Edition, 1932, pages 115-181, McGraw-

Hill Publishing Co., New York. In other words, this information has been obtained for some time. The Harmonizer now is it reality because WIRKO realized how important the practical application of this in-
formation could be in an attack on all harmonic radiation.

The half-wave filter is quite forgiving of impedance mismatch. The attenuation of harmonics is virtually unaffected by mismatch, and the very low insertion loss makes this filter the most attractive for most modern transmitters but very links with mismatch ratio. It is only when the filter is used with high power sources that it becomes con-
cerned about serious mismatch since the circuit elements of the filter have maximum current and voltage ratings.

The curve of Fig. 5 illustrates what happens when the resistive load into which the filter operates departs from the design impedance of the filter when operated at a given output power. The vector zero indicates the conditions at the design impedance. The symbol
Fig. 6. Detailed View of Eighty-Meter, 300 Ohm Harmonizer Showing Placement of Parts and Wiring Details

\[ R/Z \] is the ratio of the load resistance (into which the filter actually works) to the design \( Z \) of the filter. The voltage ratio is the ratio of the voltage on either the center or end condensers to their voltage \( (E) \) when working in a filter where \( R/Z \) is equal to unity.

In all cases \( E = \sqrt{P/E} \) where \( P \) is the output power in watts. Note that when \( R \) is greater than \( Z \), the voltage ratio increases for the end condensers. In general, the voltage across the 3rd condenser is

\[ E_3 = E_2 \sqrt{Z/R} \]

and the voltage across the center condenser is

\[ E_2 = E_2 \sqrt[4]{R/Z} \]

These formulas hold only for the unbalanced filter. For the balanced filter, the voltage across any one condenser will be one-half that given by these formulas. The curve of Fig. 5 holds for either the balanced or unbalanced case.

When designing your own Harmonizer, care should be taken to use condensers with a sufficiently high voltage rating. To ensure this, make calculations as follows. First determine the \( R \), voltage from the formula involving power and the design impedance of the filter impedance. This impedance should be the same as the load impedance for most economical design. (For a balanced filter, divide this value of voltage by two.) Next, refer to Fig. 5 to find the multiplying factor for mismatch (unless you choose a \( Z \) equal to \( R \)). The value you now have is the RMS voltage across any condenser in the filter, unless you intend to use the filter in an AM phone rig, in which case multiply the voltage by two. The peak voltage will now be 1.414 times the RMS value. Choose condensers having at least this voltage rating—or higher.

The power lost in the filter increases when\( R \) and \( Z \) are not equal. In general this increase is small. For example, the power lost is 25 per cent greater when \( R/Z \) is equal to 0.5 (or 2) than it is when \( R \) is equal to \( Z \).

If you use CW, NBFM or SSB the peak output power is the value you should use for \( P \) in calculations. It is safe to use a value for \( P \) that is 0.8 times the DC peak input. In any case, the objective is to prevent damage to the condensers because of overvoltage.

Fig. 7. View of Completed Harmonizer Showing Input and Output Terminals

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CQ . . . CQ . . . When you send in questions to me, please indicate whether your question is an entry for Questions and Answers or whether you desire an immediate answer.

—Lighthouse Larry

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**Schenectady, N.Y.**

(In Canada, Canadian General Electric Company, Ltd., Toronto, Ont.)

Printed in U.S.A.