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"The Big Hunt"

De-TVIing a 600-Watt, 14-Mc Transmitter

By

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After considering the great deal of time and effort which must be spent on the solution of TVI problems, the amateur is justified in taking time out to consider such activities objectively, especially with respect to the definition of the word "hobby." Indeed, TVI problems offer an interesting challenge to the ham who has an above-average technical background—but then the effort spent on study, experiments, and redesign can be greater than that which he expends on his vocation. With the basic purpose of a hobby in mind, i.e. relaxation, this TVI story by W2IYG departs from the style generally followed for technical articles.

THE de-TVIing of an amateur transmitter can be likened to a hunting trip. However, unlike the average sportsman, I cannot truthfully admit that I looked forward to the hunt. Frankly, the pursuit and capture of certain game ("game" being represented by spurious TVI-producing radiations) was motivated only by the generous bounty offered—carefree operation without TVI complaints.

For obvious reasons I refer to these interfering radiations as "beasties," and identify them by numbers (until they can be classified, according to species, and given scientific names). Those most numerous in the New York TV service area are beasties 2, 4, 5, 7, 9, 11, and 13.

It would be unfair to liken these obnoxious critters to any member of the animal kingdom. Actually, no man has ever seen a TVI beastie with the unaided eye; they can only be observed by means of a kinescope!

Although their natural habitat is the rf, if, and video stages of TV receivers, some beasties have been encountered in the audio stages.

History tells us that some of the early pioneers managed to capture beasties by means of traps (circuits, that is). Mechanical traps (shielded cabinets) have been found effective; however, Bring-'em-Back-Attenuated Seybold, W2RYI, has conducted many experiments to show that the elusive beastie can, among other things, escape from a metal cabinet—right through the cracks between panels!*

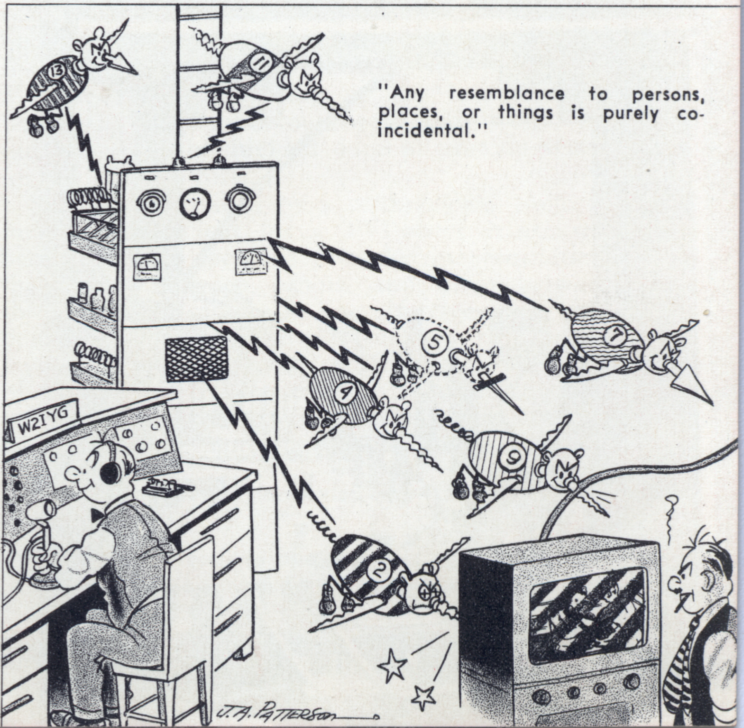
Description of the Pre-TV Transmitter

The 600-watt, 14-Mc transmitter at W2IYG, mounted in a conventional, unshielded, open-type rack, did not employ any anti-TVI devices. The line-up included a converted BC-696 as a 3.5-Mc, VFO-exciter with a 1626 oscillator, and a 1625 keyed amplifier stage. This unit was connected by coaxial cable to the main transmitter which employed a 6L6 operating as a 7-Mc, 8-watt, grounded-grid doubler, and an 828 operating as a 14-Mc, 100-watt buffer-doubler driving an 833-A final amplifier.

Before this hunt began, I used various evasive tactics to avoid the beasties—live and let live. Many hams are no doubt using such tactics as "quiet-hour" operation, operation during the wee hours of the morning while the kinescopes are

*"Shielding Experiments and TVI," by A.M.Seybold, W2RYI CQ, June 1949.

†RCA Tube Dept., Harrison, N. J.



"Any resemblance to persons, places, or things is purely coincidental."

de-energized, etc. As the months rolled by, new TV antennas appeared nearer and nearer my humble abode. The beasties seemed to love the gadgets which people were having mounted on their roof tops, chimneys, window sills, and even within their homes. I realized that I must either hunt these beasties or else find myself being hunted by the neighbors!

TVI Checks

To bring the beasties within range so that I could study their characteristics, I employed a receptor device (a commercial TV receiver). Interference on my unfiltered TV receiver was very severe on channels 2 and 4, diminishing in severity through channels 5, 7, and 9. My TV set is located in a room directly under the shack. The TV antenna is situated in the attic about six feet below my 600-ohm transmission line for the 3-element, 14-Mc rotary beam, mounted on the roof of the house.

The pictures, and sound on channels 2 and 4 were completely gone. Channels 5, 7, and 9 fared a little better in that sound was available. The picture for channel 5 was almost washed out, the picture for channel 7 was somewhat better, and channel 9 displayed even further improvement; channels 11 and 13 were unaffected. The addition of a commercial high-pass filter had little effect in clearing up the interference. Telephone calls indicated that my transmitter was interfering with reception on TV receivers located up to ¼ mile from the transmitter. A test with a ham located at this distance confirmed these reports. He reported that interference was severe on channels 2, 4, and 5.

To become familiar with the beasties, I laboriously studied the extensive and detailed reports of others who had sought out the beasties and had captured them.* These successful hunters used many methods and various devices with great success.

The first step in this anti-TVI campaign was the sifting of this wealth of information on TVI elimination to determine the basic methods for preventing and eliminating TVI. Simple tests were made to determine the nature and sources of the spurious radiations from the transmitter; and finally, a study was made to determine the simplest method of obtaining TVI-free operation of the transmitter.

*See "TVI Bibliography" in the Winter 1950-'51, and Spring 1951 issues of HAM TIPS.

Checking for Spurious Radiations

The existence of harmonics in the output of the average oscillator, frequency multiplier, or class C amplifier, can be easily verified because their frequencies are known, i.e., they are integral multiples of the fundamental frequency. Interfering signals from the transmitter, that fall within a TV channel, but whose frequencies are not harmonically related to the fundamental, are usually generated by parasitic oscillations.

Very-high-frequency parasitics can be as troublesome as very-high-frequency harmonics. Actually, the damaging results are the same in either case. Very-high-frequency parasitics can occur in any rf stage due to feedback within the tube (at some frequency other than the fundamental), when lead inductances and stray capacitances in the grid and plate circuits resonate at the same or nearly the same frequency. Many of the rules which apply to the reduction of harmonics apply here also.*

In spite of careful design and construction, very-high-frequency parasitic oscillations may occur. The following simple method was used to check each stage to determine whether parasitic oscillations were present: With the rf excitation removed from the stage being checked, and with all normal voltages applied, the grid bias for this stage was adjusted to the value where static plate current began to flow (without exceeding the plate-dissipation rating of the tube).

Plate current was then observed while the tank capacitor was varied through its range. The absence of sharp changes in plate current during this check indicated that parasitic oscillations were absent. A grid-dip oscillator is recommended for determining the frequency of the parasitic oscillation.** (When a grid-dip oscillator is used, be sure that all voltages are removed from the circuit.)

To determine whether fundamental oscillation was occurring in the stage being checked, a receiver was tuned through the frequency of the fundamental. The presence of a signal would indicate that this stage required further neutralization.

Inasmuch as the output of the transmitter did

*"The Pursuit and Elimination of Parasitics," by W.I.Orr, W6SAI, CQ, Dec. 1950.

**The elimination of parasitics has been treated very thoroughly in various publications. The amateur handbooks are excellent references.

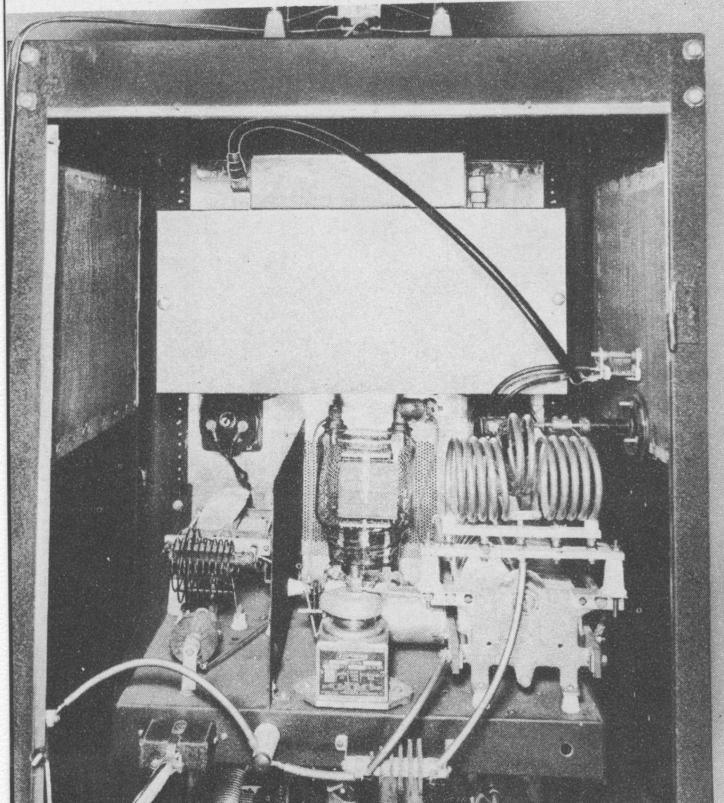


Fig. 1. Rear view of the shielded transmitter. Note the 56-Mc series trap on the plate cap of the 833-A, the louver shielding, and the paint-free edges of the cabinet for contact with the rear door (removed). The high-voltage capacitor on the left-hand side of the cabinet bypasses a B+ lead from an external modulator. The shielded box directly above the final amplifier contains the antenna coupler which is connected by means of a right-angle, coaxial fitting to the low-pass filter (mounted on top of the coupler).

not contain any parasitics, it was evident that harmonics were being generated in the transmitter. The strongest harmonic was causing severe interference on channel 2. The sources of the harmonics were located by noting the changes in interference on a nearby TV receiver as the final, buffer, and each of the exciter stages were disconnected, in turn. This check disclosed that the 833-A final was generating the strong channel-2 harmonic which interfered with reception on my neighbor's set, and that all stages were causing some interference.

How to de-TVI? (Modification vs Rebuilding)

After reading the literature on TVI, I was tempted to completely rebuild the transmitter; however, I gave serious thought to avoiding this drastic step because it meant tearing down an efficient transmitter. Nevertheless, the TVI problem had to be solved. With an open mind, I studied the constructional details of the transmitter and then carefully weighed the merits of rebuilding against those for modification.

Rebuilding. A new design for a TVI-free rf section would have to be based on the following factors:

1. Selection of a single-ended class C amplifier, instead of a push-pull stage, for lower second-harmonic output.[1]
2. The use of a final-amplifier tube of the tetrode or pentode type—an easy-to-drive tube eliminates the necessity for numerous exciter stages.
3. The utilization of a pi-type tank circuit for additional attenuation of harmonics.[2]
4. The use of low-capacitance, high-voltage capacitors connected between the plate and cathode (or filament) in rf stages (especially the high-power stage) to provide an effective and relatively simple means of reducing very-high-frequency harmonics generated in these stages.[3]
5. Minimum number of frequency multipliers.
6. Restriction of frequency multiplication to very-low-power stages if several frequency multipliers are required because of low-frequency VFO control.

Modification. To be made TVI-proof, it is necessary that the transmitter modifications:

1. Provide the necessary shielding to prevent direct radiation from the circuits.
2. Prevent the generation of harmonics.
3. Attenuate all very-high-frequency components (lying within the portion of the spectrum allocated to TV) in the output.
4. Prevent cables and leads, located outside the cabinet, from radiating interfering signals.

An appraisal of the transmitter in the light of these modern design requirements revealed that this pre-TV transmitter lacked all of these essentials for TVI-free operation. For example, the open-type rack did not provide the necessary shielding, and the meters required shielding to prevent them from radiating.

Because channel-2 interference was the strongest, much improvement could be effected by means of a 56-Mc trap in the tank circuit of the final amplifier. (Quite possibly, one of the other beasties may be causing you as much or more trouble. If this is the case, the parallel-tuned, series plate trap should be tuned to the beastie's frequency.) Harmonics which occur in each rf stage, and fall within the TV channels, should be suppressed as much as possible at their source.*

Planning the Hunt

Being an active DX man, I wanted to complete the TVI-elimination project in the shortest possible time. The object of this project was to solve the TVI problem without employing any cut-and-try methods. Because this requirement ruled out any time-consuming experimenting, a thorough job of TVI elimination could be assured only by the application of *all* of the basic methods for de-TVIing a transmitter.

Careful evaluation of the various TVI-elimination techniques revealed that I must use the following weapons: (1) shielding, (2) lead filtering, (3) output filtering by means of a low-pass filter, and (4) modification of rf circuits.

The Hunt

Girding my hunting gear, I set forth with confidence and determination. The details of the hunt are as follows:

A parallel-tuned, 56-Mc series plate trap in the final amplifier, and a six-section, M-derived, low-pass filter (together with an antenna coupler) were employed to obtain an attenuation of approximately 150 db. This attenuation was sufficient for beastie No. 2, the most troublesome of all, and more than adequate for the other beasties.

It cannot be emphasized too strongly that, to obtain this very desirable attenuation, it is extremely important that shielding and lead filtering be as near to perfection as possible. The following procedures describe the simple and straightforward steps which were followed to completely de-TVI the transmitter:

Shielding

The use of the open-type relay rack, having individual shielding of each rf unit, was seriously considered. However, this idea was discarded because many filter circuits would be required for the various leads connecting the individual rf units. Also, shielding of the individual rf units was avoided because each unit would require a specially shielded door to provide access to the plug-in coils.

Shielding provided by a conventional enclosed rack is insufficient for a TVI-proof transmitter because of the openings provided for ventilation, the cracks between panels, and those between the door and cabinet. Also, effective slots exist between overlapping metal surfaces wherever a layer of paint causes a separation of the parts of the cabinet.** Consequently, the entire transmitter (including power supplies), the low-pass filter, and the antenna coupler were mounted

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[1] *"Down With Harmonics," by J.H.Owens, W2FTW, CQ, Feb. 1948.*

[2] *"Pi-Network Tank Circuits," by E.W.Pappenfus, WØSYF, and K.L.Kilppel, WØSQD, CQ, Sept. 1950.*

[3] *"More on TVI Elimination," by P. S. Rand, W1DBM, QST, Dec. 1948. "TVI Tips," QST, Oct. 1949.*

* *"Don't Pamper Your Harmonics," by P.S.Rand,W1DBM, QST, Feb. 1950.*

** *Each slot can radiate because it is equivalent to an antenna whose length is equal to the length of the slot.*

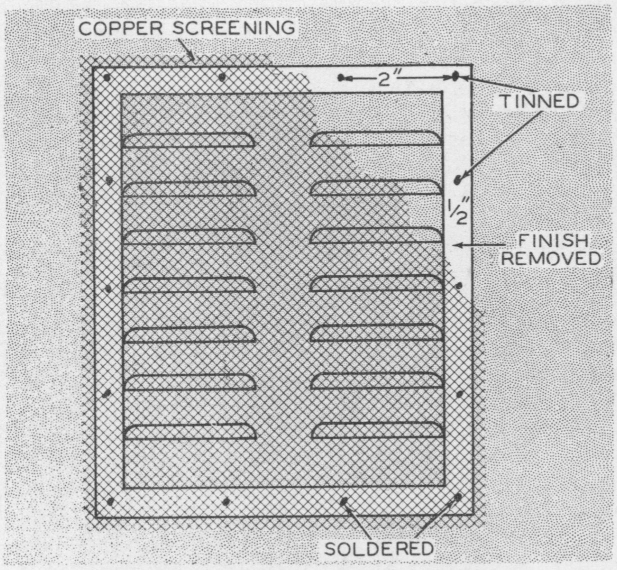


Fig. 2. Louver shielding details.

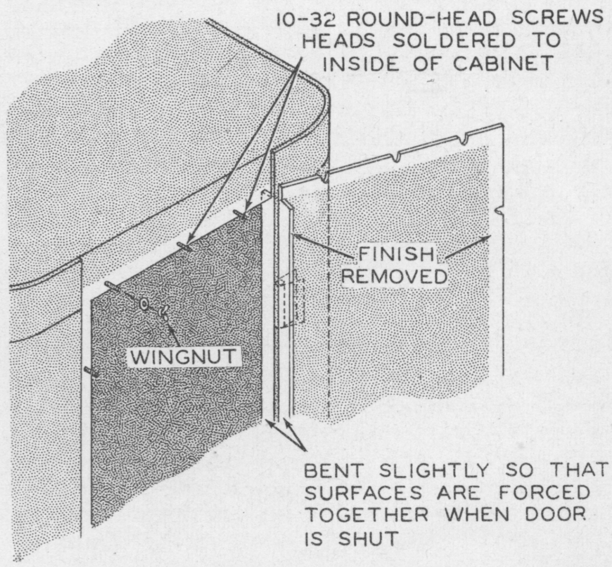


Fig. 3. Scheme employed to insure metal-to-metal contact between the door and rear edges of the enclosed rack.

within a modified enclosed rack.

In my particular case, I believe that shielding was the most important factor in reducing TVI because:

1. Thorough shielding provided by the modified enclosed cabinet prevents direct radiation from rf stages.
2. Shielding permits the external line filters and low-pass filters to function without interference from rf fields.
3. Complete shielding permits the use of unshielded and unfiltered leads within the cabinet.
4. Conventional circuits can be used in the exciter stages without resorting to critical constructional details and circuit arrangements.

Cabinet Alterations

The areas of overlap of the various parts of the cabinet were defined with the aid of a china-marker crayon. The cabinet was disassembled and paint remover applied with a small brush to those marked areas which were in contact when the cabinet was assembled. The softened crackle finish was then removed with a wire brush and the marked area was wiped dry with a clean cloth.

Shielding of the louvers was accomplished as follows: A frame-shaped area was marked around the louvers as shown in *Fig. 2,* and the paint was removed from the area. After the metal surface was thoroughly cleaned, a 500-watt soldering iron was employed to tin small areas located every two inches along the frame-shaped area.

Copper shielding, slightly larger than the outer dimensions of this frame-shaped area, was soldered to the previously tinned areas. For a smooth neat job, the screening was pulled up tightly before each point was soldered.

The cabinet was then reassembled with the paint-free areas making contact; the problem of providing metal-to-metal contact between the door and the cabinet was solved as follows: The paint was removed from the inside edges of the door and from the rear edges of the cabinet, along the entire area where the door overlapped the edges of the cabinet. (See *Fig. 3.*)

Since the door was not rigid enough to fit flush against the rear edges of the cabinet, a reasonably tight joint between the door and the cabinet was obtained by employing the scheme illustrated in *Fig. 3.*

The holes for the bolts are spaced about 10 inches apart along the rear edges of the cabinet. Roundhead 10-32 screws, a half-inch long, were inserted from the inside of the cabinet and the heads soldered in place on the inner surfaces. Holes were then drilled in the door to allow these screws to pass through when the door was closed. Wing-nuts were used to pull the door up tightly against the rear edges of the cabinet. Shielding at the hinge edge of the door was accomplished as shown in *Fig. 3.*

Cracks between panels were covered with strips of ordinary household aluminum foil (cut to a width of one inch) held in place with adhesive tape as shown in *Fig. 4.*

It has been shown that it is equally important for all meters to be thoroughly shielded to prevent them from radiating. The meters were shielded quite effectively and simply as follows:

1. Each meter hole was enlarged to a diameter slightly greater than the diameter of the beaded edge around the front of the meter case.
2. Paint was removed from the back surface of the panel around the meter hole.
3. A piece of ordinary copper window screening was cut slightly larger than the maximum diameter of the meter hole, and the meter was fastened to the rear of the panel behind the screening as shown in *Fig. 4.* This screening did not obstruct vision of the meter face since it was bowed out slightly by the beading on the case, as the mounting screws were tightened. Some of the meters were flat faced (without the beading); the screens for these meters were bowed outward by pressing the end of a rounded screwdriver handle against the screens before the meters were fastened in place.

Lead Filtering

None of the leads within the cabinet were shielded. However, an L-type filter was connected to each lead leaving the shielded cabinet.*

**This lead filtering prevents rf feed-back, which may occur when rf is picked up by the 110-volt house wiring, through the various filament and power transformers to the VFO and high-gain audio circuits.*

Most of these leads are 110-volt power leads and 6.3-volt relay leads which were relatively simple to filter.

Filtering of these leads was accomplished as follows:

1. The 110-volt power leads were connected to simple L-type filters in a shielded compartment mounted on the outside of the transmitter cabinet as shown in *Fig. 6.* The coils have approximately 50 turns on 1½-inch diameter forms.* All inductors and capacitors were arranged to facilitate short wiring, and each capacitor was connected as close as possible to the point where the filtered lead passed through the shielded filter compartment.

2. For each low-current, low-voltage lead which supplies relay power, bias, or B+ voltage, where less than one ampere of current is flowing, an Ohmite Z-50 choke was employed together with a 0.1-μf capacitor. Voltage ratings for these capacitors are given in the Lead Filtering Data, *Table I.*

3. The L-type filter was used also for the high-voltage leads connected to the class B modulation transformer which was mounted in another relay rack. A 500-μμf, 10,000-volt television capacitor and an Ohmite Z-50 choke were employed in each of these filters.

Power for the VFO, located in the operating console, was obtained from a low-voltage power supply within the shielded transmitter cabinet. The outer shielding of the cables between these units were grounded directly to a point on the *inside* of the cabinet.*

Filtering of the Output

After shielding the transmitter and filtering

**The inductance values of these coils are not critical. Wire size should be selected on the basis of the current-carrying requirement.*

**To prevent radiation of any very-high-frequency harmonics which may be picked up by the outer conductors of the portions of these cables located inside the cabinet.*

Table I — Lead Filtering Data

Lead	Inductor, L		Capacitor, C	
	Inductance	Current Rating	Capacitance	Volt. Rating
Low-Voltage, Low-Current (Relays, etc.)	Ohmite Z-50	To I amp.	0.I μf	At least twice the voltage appearing between the lead and ground
Low-Voltage, High-Current (110-volt power leads)	See Text	See Text	0.I μf	
Med.-Voltage, Low-Current (B+, bias, etc.)	Ohmite Z-50	To I amp.	0.0005 to 0.I μf	
High-Voltage, Low-Current	Ohmite Z-50	To I amp.	0.0005 μf	

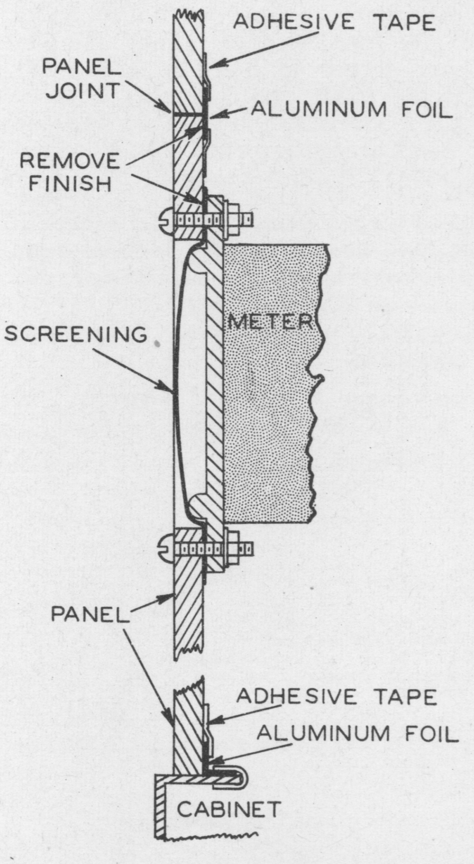


Fig. 4. Meter-shielding details and the simple method for sealing the cracks between panels.

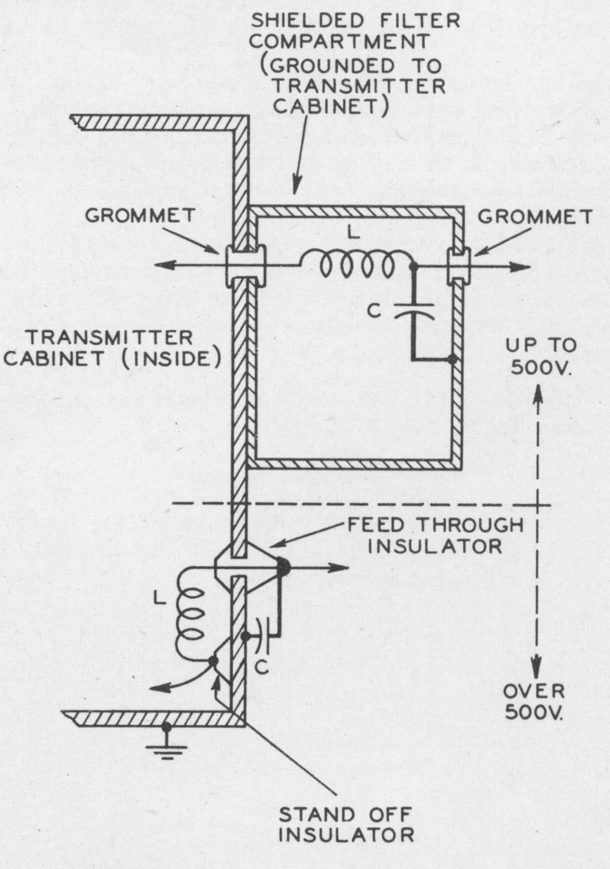


Fig. 5. Construction of lead filters for low- and high-voltage circuits.

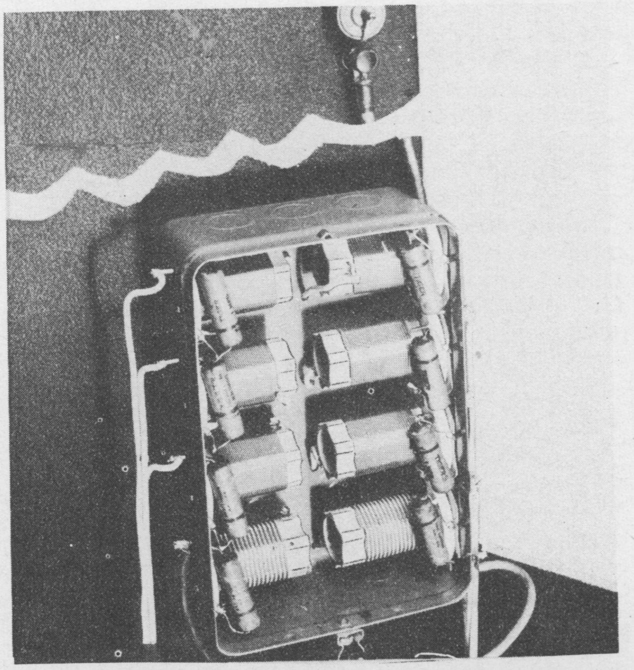


Fig. 6. A knock-out box serves as a convenient housing for eight lead filters. The high-voltage filter capacitor mounted on the side of the cabinet, several inches above the box, is the same capacitor that is shown in Fig. 1.

the leads, the only possible avenue of escape for the beasties is via the antenna terminals on the transmitter—if the output of the transmitter contains these spurious frequency components. A parallel-tuned, 56-Mc series trap was inserted into the plate circuit of the final amplifier as shown in *Fig. 7.* The purpose of this trap is to annihilate beastie No. 2 in his lair. However, TVI tests indicated that further attenuation of this frequency component was necessary. A low-pass filter in the antenna transmission line solved the problem by attenuating all frequencies above 35 Mc.

The original 600-ohm, open-wire line, to which the tank circuit had been link-coupled, was retained. However, construction and adjustment of a filter having a characteristic impedance of 600 ohms would require test equipment not available to the average ham.*

Instead, the antenna coupler shown in *Fig. 7* was connected into the 600-ohm trasmission line to transform the line impedance from 600 ohms to approximately 52 ohms (between links). Component values for a low-pass filter with a characteristic impedance of 52 ohms are not as critical as those required for a 600-ohm filter. The low-pass filter employed in my transmitter was purchased as a kit; it is a six-section, M-derived type, similar to the one described by M. Seybold in the December 1949 issue of *QST.*[1] In addition to functioning as an impedance-matching device, the antenna coupler provides approximately 18 db of attenuation of the harmonics.[2] The low-pass filter provides approximately 90 db of attenuation.

*"Eliminating TVI with Low-Pass Filters," by G.Grammer, W1DF, Feb. 1950, QST.

New Operating Conditions for RF Stages

For minimum TVI, rf amplifiers should be operated as close as possible to class B. Class B operation increases the operating angle, as compared with class C operation, thereby reducing the harmonic content in the output.[3] The operating angle may be increased by decreasing the grid-bias voltage. The bias was reduced on the 100-watt frequency multiplier, the 828 stage which preceeded the 833-A final amplifier.

All stages, after the keyed 1625 stage, were biased to allow for a key-up plate current of about five per cent. This practice aids in the reduction of key clicks. Under key-down conditions, the grid bias for the 833-A stage is obtained from a grid resistor, a fixed-bias supply being used only under key-up conditions. This grid resistor was adjusted for minimum biasing just sufficient for proper amplitude modulation.

Success!

After placing the de-TVIed transmitter in operation, I immediately checked for interference on my TV receiver and found all channels clear, except channel 2. The picture was barely discernible, although the sound was unaffected.

Since I was chiefly interested in satisfying my neighbors, I called one located two houses away (125 feet) to give him the glad tidings. He was cooperative, and agreed to help in testing for TVI. I turned the rotary beam so that it faced my neighbor's TV antenna, and after getting one of the local hams to operate my rig, I started off to my neighbor's house.

[1] *Numerous articles on the design and construction of low-pass filters have been published in recent years (see TVI Bibliography in the Winter, 1950-51 and Spring 1951 issue of RCA HAM TIPS.)*

[2] *"Tailor-Made Antenna Couplers," by G.Grammer, W1DF, QST, May 1950.*

[3] *"Harmonic Suppression in Class C Amplifier," by F.Q.Gemmill, W2VLQ, QST, Feb. 1949.*

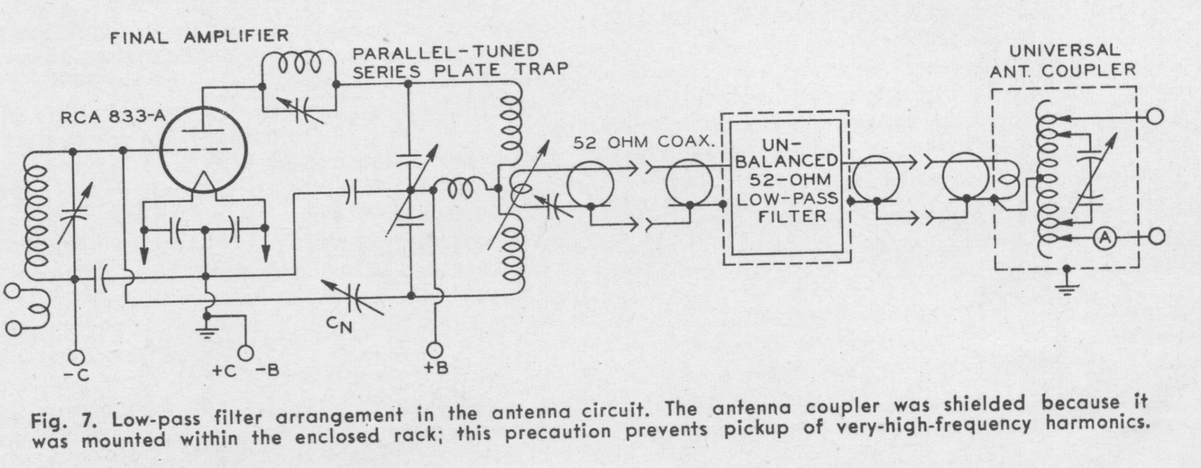


Fig. 7. Low-pass filter arrangement in the antenna circuit. The antenna coupler was shielded because it was mounted within the enclosed rack; this precaution prevents pickup of very-high-frequency harmonics.

I guess the trip to his TV receiver could be compared to the "last mile." You can imagine the suspense! As I walked down the street to his house, I began to recall the past few weeks of removing paint, scraping, filing, drilling, and soldering. Would all this be worth the effort? Would it be worth all the rare DX I had missed during the time I was off the air? I would soon have the answer.

I checked all channels on his TV set and found absolutely no interference on any channel. In a way, this was hard to believe, since a high-pass filter which I brought along was still in my pocket! Needless to say, my neighbor was just about as happy as I about the whole thing. My closest neighbor, about 50 feet away, reported he had no objectionable interference on his set.

Being interested in eliminating the channel-2 interference on my TV receiver, located in the room below the transmitter, I conducted further tests to determine which stage (or stages) of the transmitter was causing the trouble. The 600-watt 833-A stage was turned off without any noticeable interference reduction. Next the 14-Mc, 100-watt buffer-doubler was turned off, but the interference remained unchanged. Finally, the 7-Mc, 8-watt 6L6 frequency multiplier was turned off and no reduction in interference was noted. By the process of elimination, I knew that the 3.5-Mc, 8-watt VFO-exciter was the offender.

This unit is a converted BC-696 with a 1626 oscillator and single 1625 keyed-amplifier. With the key in the up position and the oscillator running, all traces of interference disappeared. The 3.5-Mc amplifier was causing the interference in spite of the fact that I had thoroughly shielded this unit. Feeling that there would probably be no interference from this VFO-exciter unit operating in the 3.5-Mc band with only 8 watts input, I had not observed the precaution of filtering the power leads as was done on the transmitter proper.

I traced the interference to the unfiltered power-supply leads for the VFO; these leads were radiating harmonics. This example illustrates the importance of lead-filtering when one wishes to reduce harmonic radiation to practically zero in close proximity of the transmitter, regardless of the power input or the frequency of operation.

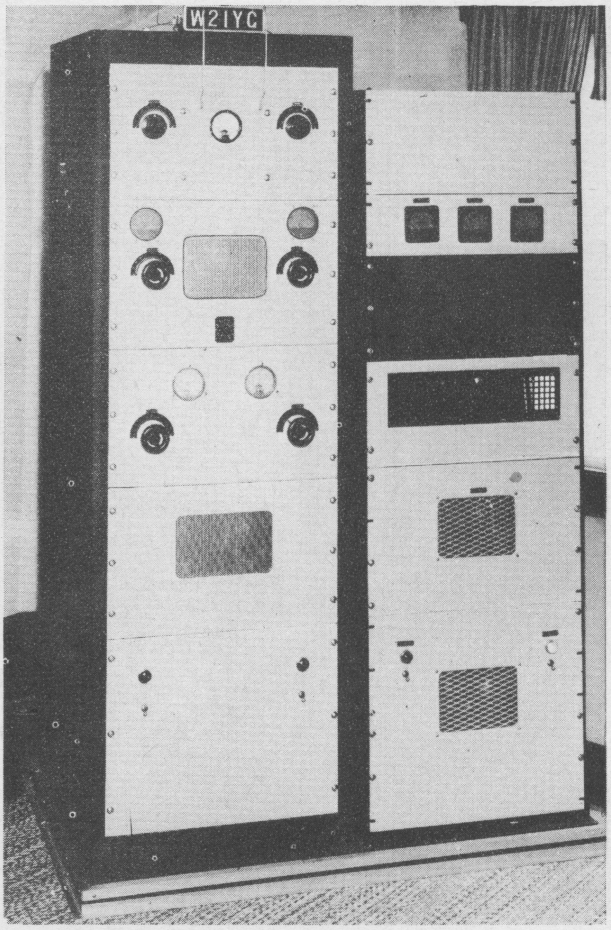
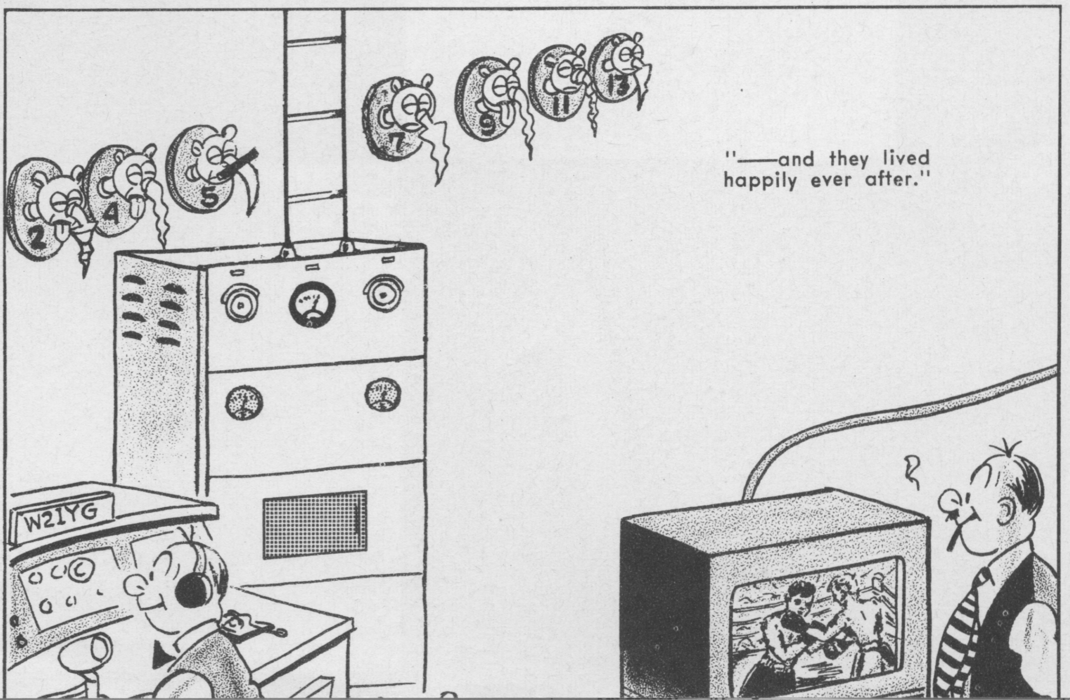


Fig. 8. Completely TVI-proofed and ready for operation. Before the transmitter was modified, the rf section (in the left-hand cabinet) was mounted in an open-type relay rack identical to the unshielded right-hand rack which contains the modulator. Observe the small-hole screen used in the panel-viewing windows in the rf rack. These windows were originally backed with the type of screening employed in the modulator rack. (The antenna meter did not require shielding because it was mounted in a shielded box enclosing the antenna coupler.)

The importance of shielding can be further emphasized by the following incident: One evening while I was working on the transmitter, with the rear door removed, my phone rang. It was a neighbor, five houses away, reporting interference on channel 2—and with the door on, he never knew when I was on the air!



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