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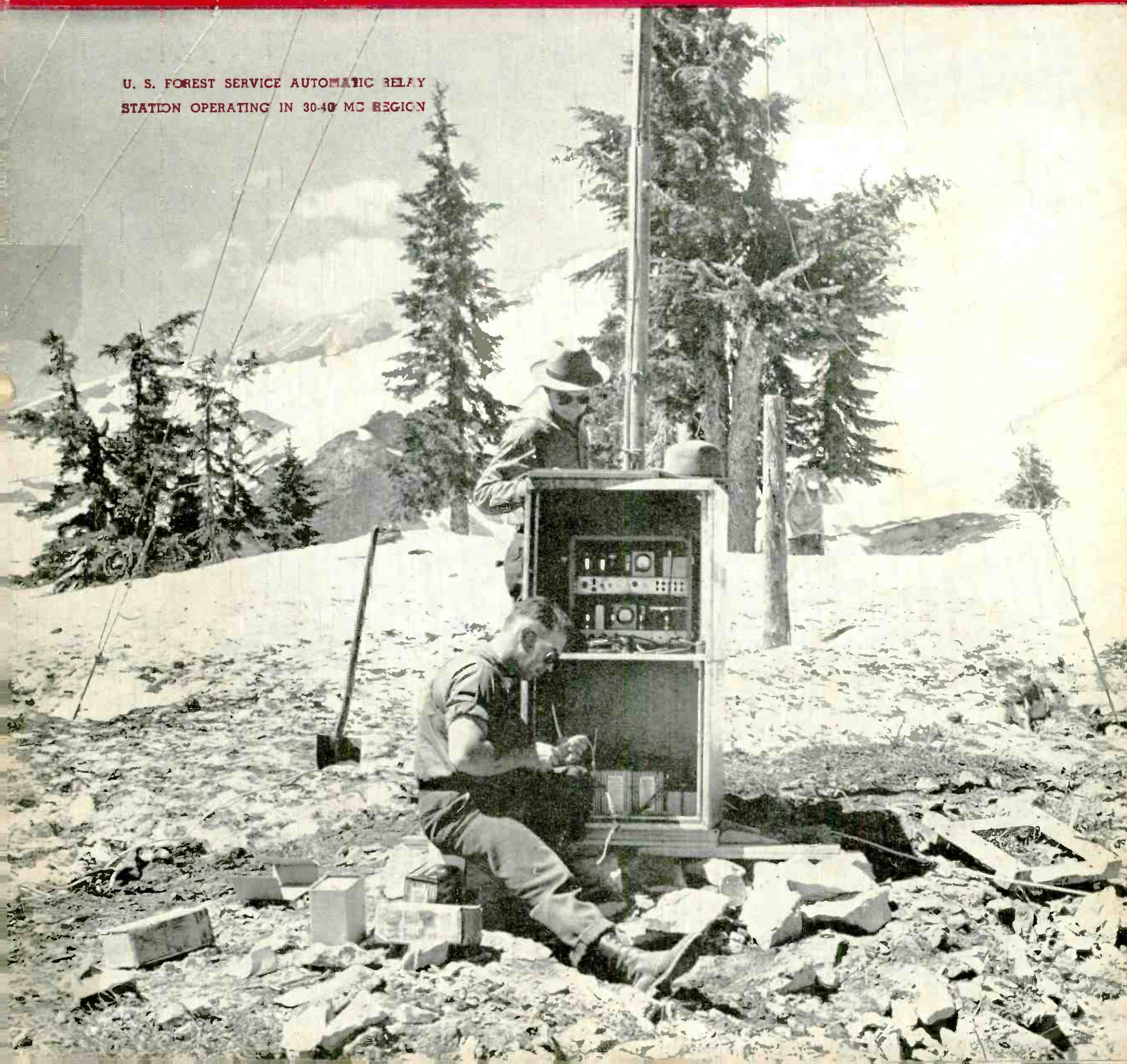

U. S. FOREST SERVICE AUTOMATIC RELAY STATION OPERATING IN 30-40 MC REGION

# electronics

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### DEPARTMENTS



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# Mobile 30-40 Mc Receiver

**A receiver, for mobile use, and receiving amplitude-modulated signals, designed to compete with frequency modulated systems from standpoint of immunity to pulse-type noises. May be manually tuned, or spot-frequency tuned**

INABILITY to obtain adequate coverage with mobile equipment employing amplitude modulation, as opposed to frequency modulation, is in practically all cases the result of inferior receiver performance in the presence of heavy ignition interference. The U. S. Forest Service Type KU-R receiver herein described relieves this condition to such an extent that many amplitude modulation communications systems now being discarded with heavy investment loss can be made to serve adequately. This receiver will not provide completely noise-free reception nor is it directly comparable to fm in this respect. Its performance is, however, so outstanding as compared to mobile a-m receivers with conventional noise limiter circuits that it will undoubtedly assist in solving many of the problems arising from limitations imposed by ignition and other sharp pulse type noise. The Type KU-R receiver permits actual use of absolute signal values below 1 μv when used on cars without spark plug suppressors or other forms of ignition noise treatment. An occasional noisy generator requires correction by electrical filtering and cleaning, but beyond this no special preparation is required to make a workable installation. A convenient and simple measure of useful sensitivity is the signal input value required to produce a 4 to 1 change in the audio power output when modulation is increased from 0 to 30 percent. Measured by this method the average sensitivity of a group of 25 receivers was 1.4 μv. (See editor's note at end of article.)

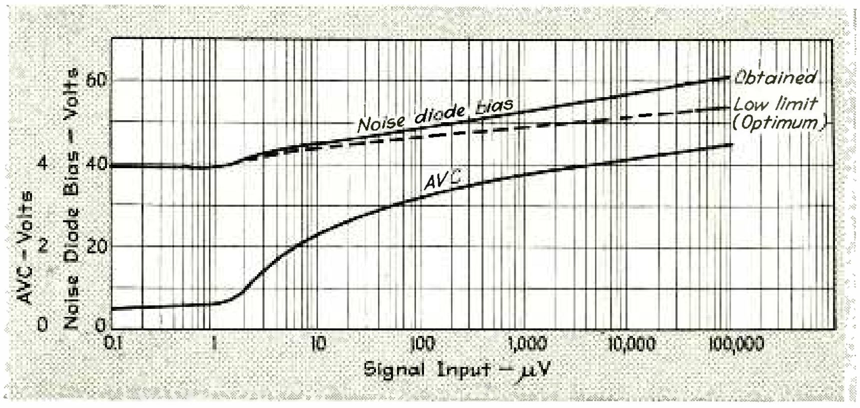
Before entering upon a discussion of this receiver it is of interest to review briefly the general trend of forestry radio equipment to provide a background for the requirements of this unit. Of the 4000 radio telephone units in use by the U. S. Forest Service over 90 percent are of the strictly portable type falling in a weight class of from 6 to 21 pounds complete with all accessories and power. During the past five years the trend of forestry radio has been toward a more intensive use of those frequencies lying between 30,000 and 40,000 kc. Of the 2,000 u-h-f radiophone transmitters in use, only 1 percent have a power output in excess of two watts. The maximum power of this group is 20 watts. Quite naturally there is an urgent need for communication with mobile units, such as fire tank trucks, forest highway patrolmen, and supervisory personnel on large project fires. The limiting factor in the successful application of mobile ultrahigh frequency equipment to this job has, up until this time, been the lack of a satisfactory receiver.

With the normally low signal fields provided by the portable units, it is essential that the mobile receiver provide usable sensitivity in the vicinity of 1 μv absolute. Usable sensitivity in this case is not considered as being realized under ideal laboratory conditions, but rather under actual road test conditions and through electrical noise encountered in heavy traffic.

### Primary Design Considerations

The requirements of such a receiver are:

1. Provision for manual tuning over the range of 30 to 40 Mc as well as crystal controlled spot frequency operation.
2. Compact structure to permit installation in space restricted by special fire fighting tools and devices in all types of motor vehicles.
3. Low primary power consumption to permit prolonged use without constant battery charging while the car may be temporarily immobile in fire service.
4. High sensitivity to fit into the general scheme of low power transmitter operation.
5. Broad acceptance band to minimize criticalness of manual tuning and loss of signals due to all sources of drifting.




**Ideal and realized characteristics of the noise silencer circuit**

# for the U.S. Forest Service

By H. K. LAWSON and L. M. BELLEVILLE
*U. S. Forest Service Radio Laboratory*
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6. Freedom from pulse type interference, particularly ignition noise, originating in both the forest car and in other traffic.

These requirements appear generally conventional and relatively universal with the possible exception of the combination of tunable and spot frequency operation.

The two requisites for maximum sensitivity in a receiver are; the highest possible signal-to-noise ratio and adequate gain to deliver full audio output with no input other than the first circuit noise. A triode first detector is used in this receiver to keep the conversion noise at the lowest possible value. One stage of r-f amplification adds further gain in signal-to-noise ratio and assists in suppressing image interference.

It should be noted that the r-f and first and second i-f tubes are of the sharp cutoff type. Among several considerations dictating this choice, the $g_m/I_k$* noise factor of merit was of major importance, a higher ratio of $g_m/I_k$ being available in tubes of the sharp cutoff type. Further, where power consumption is a consideration the variable-mu tube is at a disadvantage. The saving in plate current by the use of sharp cut-off tubes in this receiver amounts to approximately two watts. Better a-v-c characteristics are also realized with tubes which do not require a high bias for cutoff.

Careful investigation of the field of commercially available receivers failed to disclose a unit with all essential features combined. The most generally available types were of fixed tuned design intended for police service. In this field there appeared to be a lack of high usable sensitivity and good pulse noise suppression. Some of the better receivers indicated high sensitivity as measured in the laboratory and at the same time developed acceptable noise suppression at relatively high signal levels, but all failed to permit use of their maximum sensitivity in the presence of heavy ignition interference.

**U. S. Forest Service type KU-R Mobile Receiver. Top to bottom, speaker, r-f tuning head, amplifier unit. Note universal mounting clamp which permits steering-column or under-dash mounting of r-f tuning head. Bottom cover of amplifier unit serves as mounting plate and entire unit may be removed for service by releasing trunk hasps**

Although fm may be considered to be the ultimate answer to this problem there are two outstanding reasons that immediately rule out this system for U. S. Forest Service application. First; the Forest Service now has on hand some 2,000 u-h-f radiophones, all amplitude modulated and all serving a useful purpose in forestry communication. Any one of these may be called upon to communicate with a mobile unit, yet such communication is relatively incidental to their entire field of usefulness. Consequently it would not be economically sound to attempt a replacement of all equipment merely to provide a more ideal mobile system. Second; frequency modulation technique has not advanced sufficiently far to date to permit design of a reliable portable unit that can compete in size, weight, cost and over-all low power consumption with the portable units now in service.

A thorough investigation of available mounting space in various types of cars and trucks, resulted in a decision to break down the receiver into two small units, plus an externally mounted speaker. To avoid mechanical complications arising

* Ratio of transconductance to cathode current. See *RCA Review*, April 1941, page 518.

from an attempt to eliminate rubbery backlash from remote mechanical tuning, a complete r-f tuning head was designed to be mounted in the same manner as the conventional remote tuning mechanism. The common flexible shaft method of mechanical tuning becomes satisfactory over the relatively wide range of 30 to 40 Mc only when extremely high gear ratios are employed. Such an arrangement results in slow and tiresome manipulation to tune over the entire band.

#### Radio-Frequency Tuning Head

The r-f tuning head of this receiver contains the signal r-f amplifier, detector, tunable heterodyne oscillator, crystal oscillator, and frequency multiplier.

An eight-conductor cable and separate i-f transmission line connect the tuning head with the larger unit. The eight-wire cable carries primary power from a switch on the head unit to tube heaters and plate supply, plate voltage for tubes in the tuning head, squelch control and audio level control. The intermediate frequency of 1600 kc is fed to the i-f unit through a length of 64-ohm flexible concentric transmission line. Careful design of the 1600-kc inter-unit line coupling transformers eliminates line resonances and permits the use of any length of high quality line found necessary.

Transfer from manual tuning to crystal controlled spot frequency operation is accomplished by a relatively rough setting of the tuning dial to a pre-marked point and throwing the "manual tune — spot frequency" toggle switch on the tuning head to the spot frequency position. The panel switch serves merely to transfer plate voltage from the tunable oscillator to the crystal controlled oscillator and tripler. It is evident that the tunable oscillator and the fixed frequency tripler are in a measure interlocked through their common coupling to the detector grid. Special attention to mechanical layout and simple but adequate shielding have minimized the interlocking between the tripler and tunable oscillator to a point where it is not apparent at any position of the manual tune dial. The use of an entirely independent spot frequency heterodyne source eliminates the necessity of switching in high frequency circuits where it is usually desired to avoid using such devices.

The i-f amplifier is substantially flat over a band of 50 kc centered at 1600 kc. This choice of bandwidth was influenced by the necessity of receiving some of the older type modulated oscillator transceivers which are still in service. A relatively wide acceptance band also serves to minimize the effect of normal drift of various crystal controlled transmitters. Although all current transmitting equipment of the U. S. Forest Service employs crystals having a temperature coefficient of four parts per Mc per degree C or better, none of these units are temperature controlled, and when operated on a mountain peak, may encounter temperatures varying from near freezing in the morning to over 100 degrees by mid-afternoon.

### The Cover Picture

**A battery-operated automatic relay or repeater station is shown in operation. It utilizes the 30 to 40 Mc region and ties 5 forests into a central fire and weather forecasting office in the State of California. It also serves as a repeater for mobile equipment in the forest in which it is located. The longest circuit covered is 200 miles. For reasons which our readers will understand, the location of these installations cannot be published now**

The requirement of a 50-kc band necessitates three i-f stages for adequate gain. It can be shown that for a given bandwidth and stage gain the intermediate frequency can be varied between fairly wide limits. With available i-f transformer Q's a 50-kc bandwidth can easily be had at an intermediate frequency of 5,000 kc. Such an amplifier would have excellent skirt selectivity. The same gain and bandwidth can also be obtained at a much lower frequency by proper adjustment of circuit Q. This shift will produce several results. First, the image response will be closer to the signal frequency; and second, skirt selectivity will be reduced. This latter factor may be either an advantage or a disadvantage depending upon the application of the receiver; third, stability with drift of trimmer condensers due to temperature change or vibration, will be improved at the low frequency. With consideration given to all of the above factors, the frequency of 1600 kc was selected primarily for the advantage of stability so necessary in mobile equipment.

By far the greater part of the work on this receiver went into the design of the noise silencer. A silencer of practically the same design as appears in the present model was incorporated in one of the test receivers at the beginning of this work. Due to what appeared to be excessive space requirements and circuit complications, the much simpler and more compact series diode limiter was employed in the next test receiver. Analysis of the series diode limiter indicated that this type of circuit could be expected to accomplish everything that might be expected from any form of limiter. A receiver employing this circuit gave excellent results under restricted conditions but the design would not stand the test of use in heavy traffic.

It was finally realized that the diode limiter could do an acceptable job of silencing only up to the point where interference became strong enough to actuate the avc. When this condition is reached, which is usual in the presence of heavy ignition noise, the signal will be reduced by action of the automatic volume control until it is lost in the residual noise. Resulting aural effects range from an increase in the staccato noise to a complete blanketing of the signals, depending upon intensity and rate of ignition. The noise silencer herein presented is based on variations in the type of silencer first proposed by J. J. Lamb (see *QST* Febuary 19, '36). To the best of our knowledge the most important of these variations first appeared in a receiver manufactured by the Pearson-Delane Company.

This form of limiter not only serves as a noise silencer but also protects the avc from the overloading produced by strong impulse interference. This silencer incorporates two major variations in the fundamental circuit proposed by Lamb. First, the output of the noise rectifier is impressed on the injector grid of the third i-f stage through a coupling condenser. This prevents the d-c component in the output of the noise rectifier from appearing on the controlled stage and thus eliminates the blocking normally encountered with this type of silencer.

The second circuit variation is made possible by the first, and consists of an automatic threshold control circuit which maintains the bias on the noise rectifier at the proper value for optimum silencing with variations in signal level.

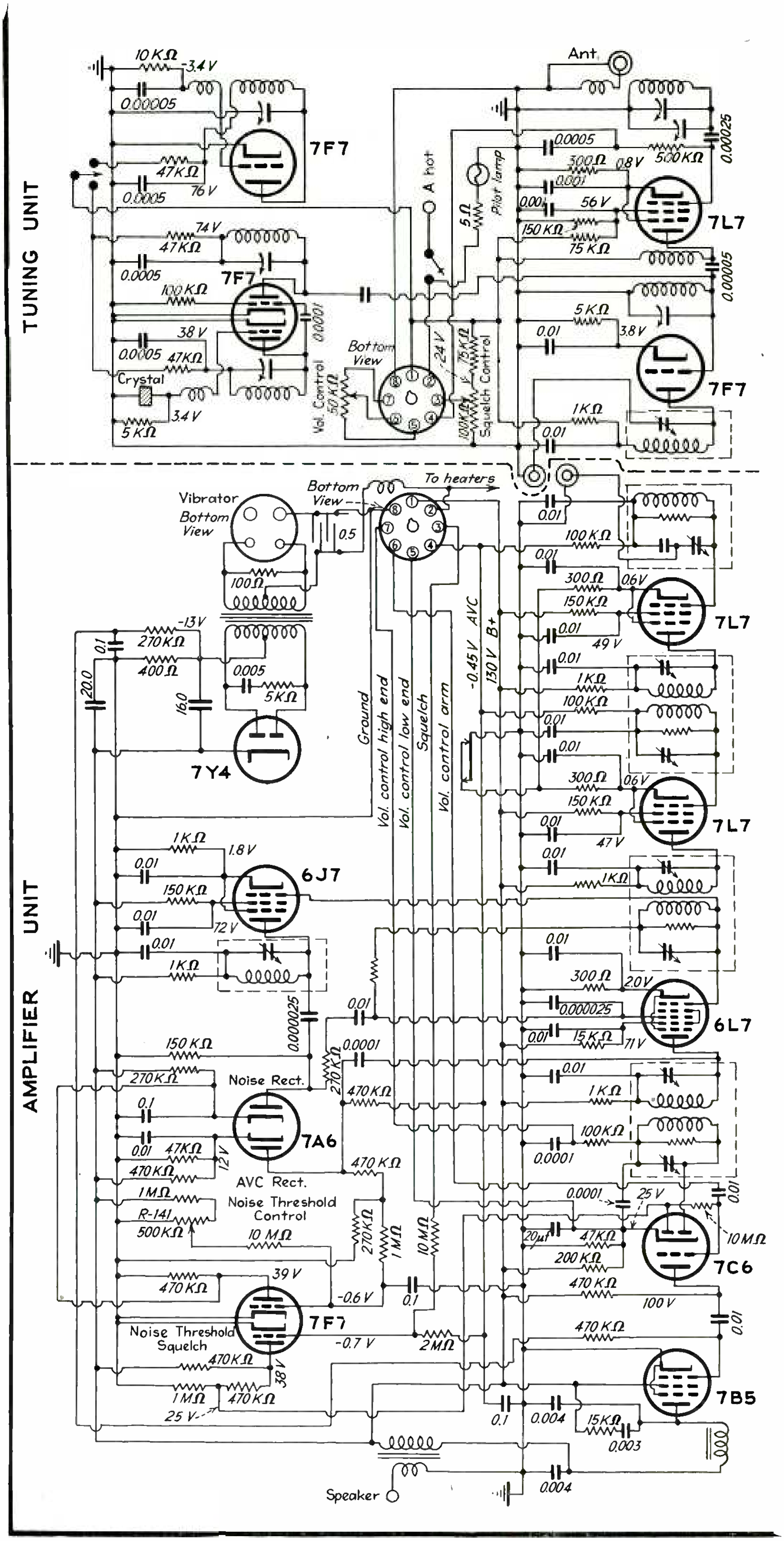
The fundamental operation of the silencer may be briefly described as follows: The output of the second i-f amplifier feeds both the noise controlled third i-f amplifier, and independent noise amplifier in parallel. The output of the 6J7 noise amplifier is rectified by one of the 7A6 diodes, and any pulses or irregularities in this rectified output are fed through the coupling condenser to the injector grid of the 6L7 third i-f stage. These pulses serve to block this tube for the duration of the rectified noise voltage and thus prevent the rise of the original noise impulse to full amplitude in its output circuit. The foregoing constitutes the fundamental actions of this circuit, but without additional devices and elaborations the system remains unworkable.

To produce a workable circuit, it is necessary to adjust automatically the threshold of rectification so that modulation peaks are not rectified and thus cause to clip and distort, and to maintain this threshold of rectification as closely as possible to these peaks to prevent the rise of unwanted noise. An ideal curve for this condition was plotted by applying manual control to the rectifier for various signal levels from 1 $\mu$v to 1 volt. The nearest possible duplication of this curve was then obtained with one section of the dual triode 7F7. The slope of the plotted curve produced by this tube can be controlled largely by selection of the proper proportion of a-v-c voltage. The starting point or height of the curve can be further controlled by means of the variable positive potential available at $R_{141}$. By careful selection of the values of the components in these circuits, it is possible to obtain almost ideal control of the noise rectifier, and accordingly to realize optimum silencing at all signal levels.

#### Squelch Circuit

The audio output of the receiver is effectively silenced by the operation of a d-c amplifier between the a-v-c bus and the grid return of the

(*Continued on page* 98)




Complete circuit diagram of the Forest Service receiver

## 30-40 Mc Receiver

(*Continued from page 25*)

first a-f tube. Operating under a no-carrier condition the grid of the first audio tube is biased beyond cut-off, thus effectively silencing the audio output of the receiver. A small negative shift in a-v-c voltage produces approximately a 40 times shift at the plate of the d-c squelch amplifier in the positive direction. A portion of this shift is applied to the grid return of the 7C6 audio tube. The shift is limited by the diode to a value which permits only a very small grid current to flow and the first audio tube operates as if the 10 megohm grid-leak were returned to the cathode. The sensitivity of the squelch circuit is such that the audio channel may be held inoperative with no signal, and be entirely opened by a signal of less than 1 $\mu$v, or if set to reject signals below three microvolts the circuit may be entirely opened with an input of 3.5 $\mu$v. Due to the protection afforded the a-v-c circuit by the noise silencer, the squelch circuit remains relatively insensitive to ignition noise.

#### Low-pass Output Filter

The inclusion of a simple low-pass output filter, having a cutoff frequency of 5,000 cps, increased the usable sensitivity of this receiver by a factor of two to one. This result is reasonable when it is considered that the random noise output of a wide band receiver does not cut off at 3 to 5 kc as in the case of the more conventional narrow band unit, but extends to possibly 25 kc before being appreciably attenuated by the selectivity of the i-f amplifier. The importance of this high frequency noise output is greatly increased by the rising impedence characteristics of the usual output transformer-speaker combination. Inclusion of this type of filter serves to minimize one of the principle disadvantages inherent in broad band i-f amplifier receivers.

#### Power Requirements

It is usually desirable to hold the power consumption of a mobile receiver to a minimum without sacrificing performance. The type KU-R receiver draws 5 amps. from a 6-volt battery, which is moderate when it is considered that twelve tubes are employed. Power savings not common in usual practice were effected by the following points.

1. The power consumed by the B supply will be roughly proportional to the square of the B supply voltage. The item which usually dictates the required B voltage is the required audio output. By mounting the loud speaker separately, at approximately ear level, intelligibility is greatly increased and much less audio output is required. An output of 500 mw used in this manner appears to be adequate and is readily obtained with a plate voltage of 150.

2. The use of sharp cutoff r-f and i-f amplifier tubes as previously discussed accounts for further saving.

3. Tubes having 0.15 amp. heaters in place of 0.3 amp. heaters are used wherever suitable tubes of this type are available.

A slight sacrifice in primary power consumption was made in the selection of a tube type rectifier in place of a self rectifying vibrator. It was felt that this was more than offset by elimination of an occasional complication arising from the variety of battery polarities encountered.

Space for power components was reduced and added simplicity effected by the use of a resistor-capacitor filter in place of the usual iron core choke arrangement. The drop in the filter resistor is used as bias for the audio power-output tube. Since the compact arrangement of all circuits in this receiver necessitates complete isolation filtering these added filters are, where necessary, designed to augment the simple basic power filter.

It should be noted that even though the vibrator power supply is an integral part of the receiver unit, only the most conventional r-f filtering is required for noise-free power supply operation. The noise silencer serves to remove the vibrator interference which, by radiation or otherwise, may escape suppression in the power supply r-f filter. This reliance on the noise silencing circuit to cover an additional function results in a saving in space and greater freedom in mechanical layout.

Editor's note.—Regarding this method of indicating sensitivity, the authors state, "an unmodulated 1 $\mu$v signal is fed into the receiver and the noise output measured. Then the input is modulated 30 percent and a second reading taken. This reading will be approximately 3 times the first. Now the input is increased to 1.4 $\mu$v and the two readings taken again. These readings will be 4 times the first set."