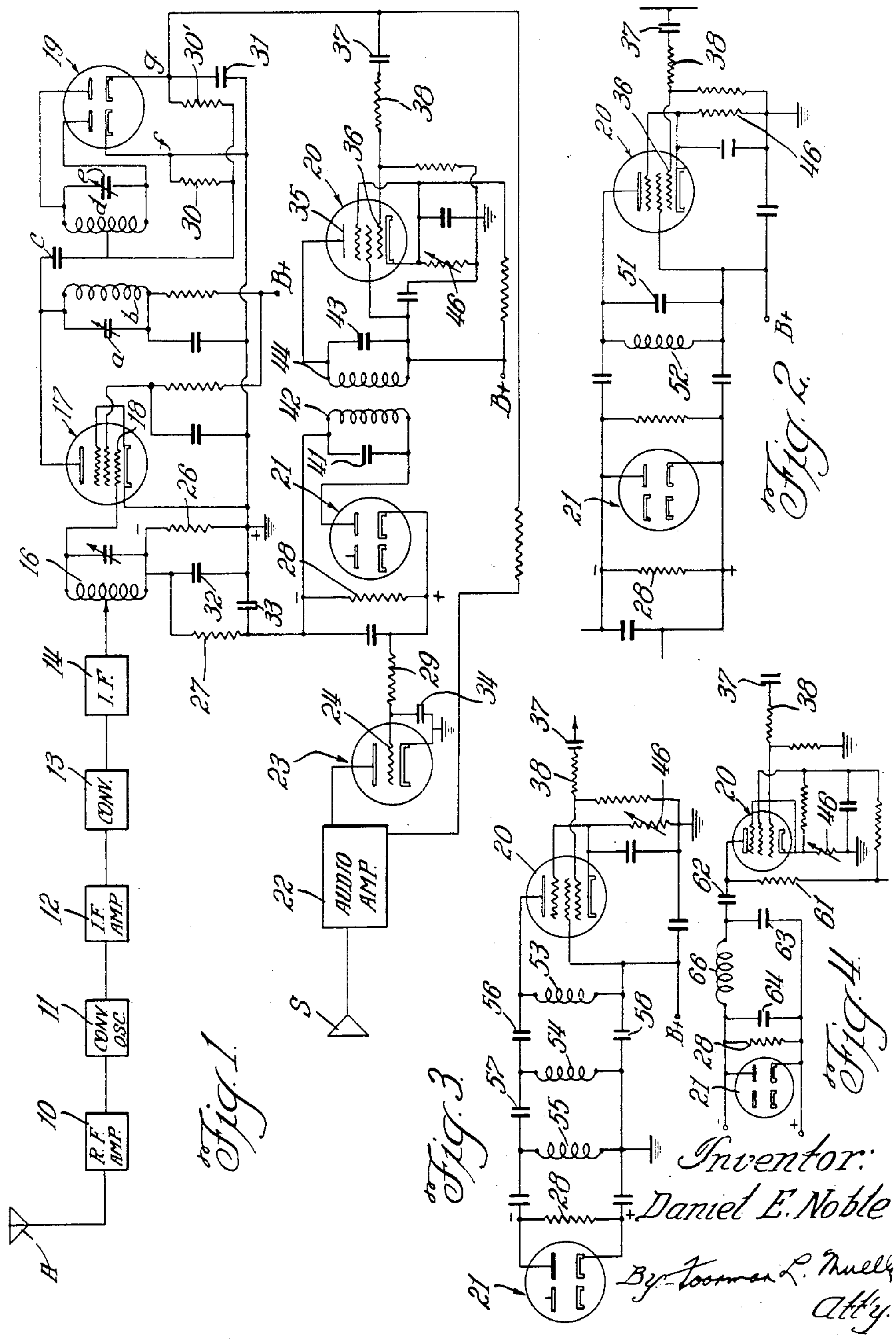
Jan. 18, 1949. D. E. NOBLE 2,459,675

INTERFERENCE REDUCING RADIO RECEIVER

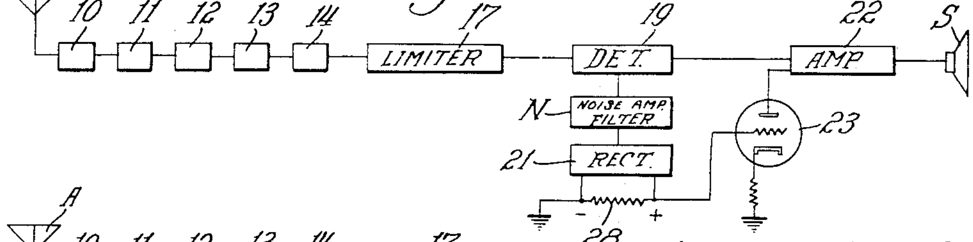
Original Filed April 5, 1941 2 Sheets-Sheet 1



INTERFERENCE REDUCING RADIO RECEIVER

Original Filed April 5, 1941 2 Sheets-Sheet 2

Fig. 5.



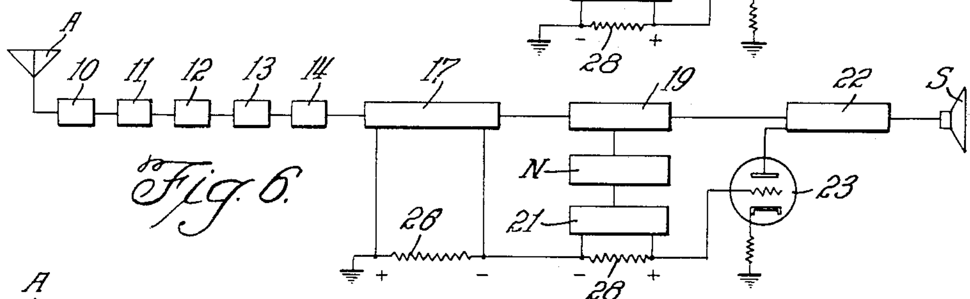


Fig. 6.

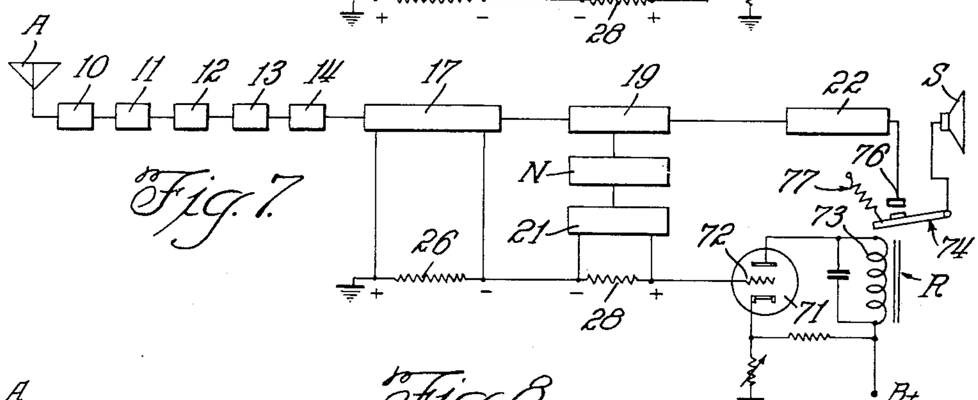


Fig. 7.

Fig. 8.

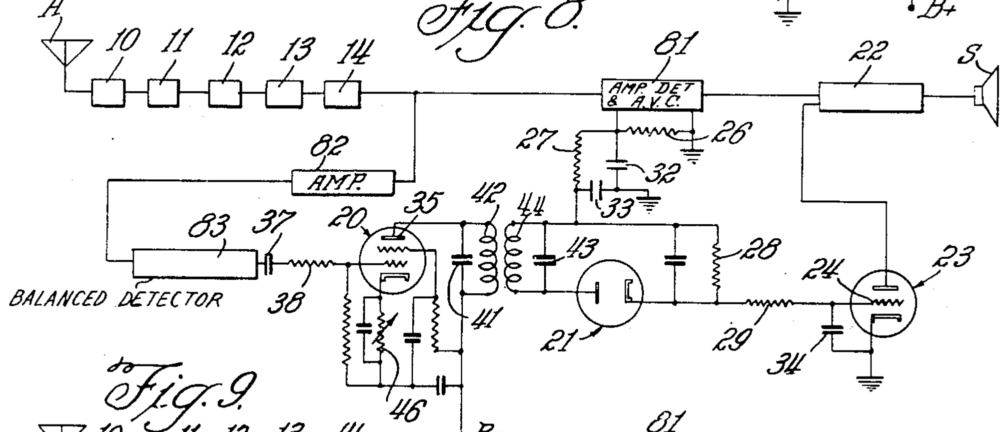
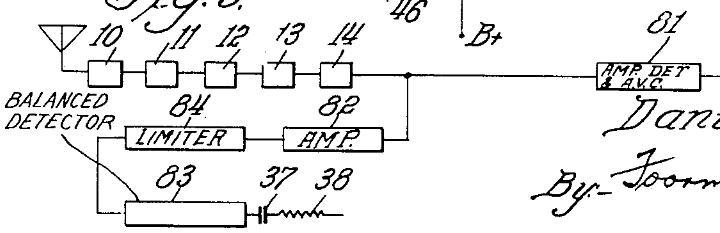


Fig. 9.



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UNITED STATES PATENT OFFICE

2,459,675

INTERFERENCE REDUCING RADIO RECEIVER

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Original application April 5, 1941, Serial No. 386,989, now Patent No. 2,343,115, dated February 29, 1944. Divided and this application April 5, 1943, Serial No. 481,821

10 Claims. (Cl. 250—20)

1

The present invention relates in general to a radio receiver system having means for producing a voltage which is preferably employed to operate a muting circuit in the system but which may also be used for other purposes within the capabilities of the magnitude of such voltage. This application is a division of copending application Serial No. 386,989, filed April 5, 1941, now Patent No. 2,343,115 granted February 29, 1944. The invention relates more in particular to an amplitude modulated radio receiver circuit, and a muting or squelch system therefor, particularly adapted for use in communication equipment for emergency and military service, to substantially maintain silence at the loud speaker or similar reproducer of a receiver in such equipment while the receiver is retained in continuously operating condition ready for immediate reception of a signal at any time it is transmitted to the receiver.

As is well known, receivers in communication equipment for emergency and military service particularly, are normally maintained tuned to a single frequency and in an operating condition, so that the receiver will always pick up and reproduce at any time signals of the desired frequency which might be put on the air continuously or intermittently. With the receiver maintained in an operating condition, in the absence of a carrier the receiver will reproduce noise unless some system is employed to mute the audio circuit or other appropriate portion of the receiver system. This noise is extremely annoying at best, and becomes unbearable in many instances.

When such muting means, or squelch system, as it is generally called, is applied to a receiver, the reproducing means and normally the audio system is rendered inoperative until it is automatically rendered operative by the reception of a carrier wave at the input of the receiver. Thus, the muting or squelch system permits the operation of the receiver in a normal condition ready for the reception of a desired signal, but without reproducing undesirable noise in the meantime.

For the purpose of this disclosure, the process of rendering the radio receiver output quiet will be described as "muting," or "closing the squelch," while the process of making the radio receiver operative for the purpose of reproducing desired communications, will be described as "opening the squelch."

Muting or squelch systems for the above noted purpose are old in both amplitude modulated

2

receivers, and in frequency modulated receivers. However, in the prior art muting or squelch systems, noises such as electrical interference from ignition and other man-made sources, will open the squelch system when it is adjusted for the most sensitive and hence desirable operation even though no carrier is present. This undesirable result is due to the fact that the prior systems have as their controlling function, an average increase in the average signal and the noise passing through the radio receiver. This undesirale result is particularly noticeable in areas of high noise level such as areas of heavy traffic, or where there are other sources of electrical interference. It is particularly disturbing to an operator and interferes with the efficient use of the receiver apparatus. In these prior devices when the squelch system is adjusted so that man-made noises will not open the squelch system and hence render the audio-system operative, then the receiver is not sensitive to the reception of carrier waves of low level and oftentimes messages are inaudible to the listener. The seriousness of this condition in the use of communication equipment for emergency and military service is obvious.

As can be understood from the above discussion, this difficulty can, and did arise in mobile receivers as well as in fixed receivers, where the noise level in the surrounding locality might vary from time to time. In these prior systems as the noise level decreased the receiver was adjusted for more sensitive signal operation. This would permit noise, if it increased in intensity, to open the squelch in the absence of a carrier, and be reproduced. Another adjustment of the squelch system in the receiver would then become necessary, and this continued changing was not only troublesome and time consuming, but interfered with efficient operation of the equipment.

It is an object of my invention to provide an improved muting or squelch system for radio apparatus.

It is also an object of my invention to provide an amplitude modulated radio receiver having improved muting or squelch means therein.

Another object of my invention is to provide a muting or squelch system for an amplitude modulated radio receiver so that the receiver may be maintained at all desired times in the most sensitive operating condition and ready for signal reception, and yet remain silent in the absence of a signal in areas of noise due to electrical disturbances, which noise may vary widely in intensity and frequency.

A still further object of my invention is to provide a squelch system for an amplitude modulated radio receiver which will open on a carrier of low signal level as well as high signal level, so that reproduction of all desired signals is possible, and yet the receiver will be muted and the squelch system retained closed in the absence of a carrier at all levels of ignition noises or other man-made noises.

It is also an object of my invention to provide a sensitive squelch system for an amplitude modulated radio receiver, which system will remain closed at high noise levels and will open at low carrier levels; and to accomplish these desirable operating conditions in a simple and effective circuit.

A feature of my invention is the provision of an amplitude modulated radio receiver system which produces a source of voltage therein that may be used to operate an electronic muting or squelch system, to operate a relay for accomplishing muting, or to operate other electronic or electrical devices for other purposes in the receiver system.

Another feature of my invention is the provision of an amplitude modulated radio receiver circuit in which a particular voltage is developed in an improved manner as a result of a change of potential within the circuit and this may be used to control any muting device such as a squelch or audio-muting system, or to control a mechanical relay connected into the loud speaker circuit of the receiver circuit, or it may be used for other special purposes in such receiver circuit.

Another feature of my invention is the provision of a squelch or muting system for an amplitude modulated radio receiver, which system is unusually sensitive to a desired carrier or signal, and yet at the same time is substantially entirely insensitive to undesired signals or noise at high as well as low power levels.

Other objects, advantages, and features of my invention will be apparent from the following description taken with the drawings, in which:

Fig. 1 is a schematic illustration of a frequency modulation receiver circuit;

Fig. 2 is a modification of the selective circuit portion of the complete circuit of Fig. 1, and is adapted to be substituted for the corresponding portion in Fig. 1;

Fig. 3 is a circuit diagram of another modification of the selective circuit portion of the receiver circuit of Fig. 1 and may likewise be substituted for the corresponding portion in the circuit of Fig. 1;

Fig. 4 illustrates diagrammatically a band pass circuit for selecting a band of noise frequencies below the communication frequencies, and this circuit can be substituted for the corresponding frequency band selecting portion of Fig. 1;

Fig. 5 is a simplified and abbreviated block diagram introduced purely for purposes of clarity to show a portion of the squelch control system in Fig. 1 in a different manner from that in which it is illustrated in Fig. 1;

Fig. 6 is a circuit diagram after the fashion of the diagram of Fig. 5, showing the complete preferred squelch system of Fig. 1 in a simplified manner;

Fig. 7 illustrates in a manner similar to that of the diagram of Fig. 6, the control system of Fig. 1 for operating a relay rather than a squelch tube;

Fig. 8 illustrates diagrammatically a complete radio receiver system operating with amplitude modulation and employing a squelch control system in accordance with my invention; and

Fig. 9 illustrates a fragmentary portion of a modification of Fig. 8, which can be substituted for the corresponding portion in the complete system of Fig. 8.

Referring now to Fig. 1, a frequency modulated radio receiver system is illustrated including an antenna A, a speaker S, and a receiver circuit for translating the frequency modulated waves received at the antenna A into reproductions at the speaker S, or a similar device. The receiver circuit includes an RF amplifier **10**, a converter and oscillator **11**, an IF amplifier **12**, a second converter **13**, and an IF amplifier **14**, all connected in cascade and in turn connected to an inductance coil **16**. The portion of the circuit just described is conventional and no detailed diagram has been illustrated. The remainder of the circuit as illustrated includes a limiter tube **17**, with a grid **18**, and a balanced frequency detector, or discriminator portion including the tube **19**. The remainder of the circuit also includes an audio-tube or noise amplifier **20** in a selective system, as will be hereinafter described, a rectifier tube **21**, and an audio amplifier **22**. The amplifier **22** is preceded in the circuit by a squelch tube **23** with a grid **24** which tube controls the operation of the audio-amplifier and hence determines reproduction at the speaker S, or similar device.

As to the balanced frequency detector, or discriminator portion of the receiver circuit, this includes a primary circuit condenser *a*, and coil *b*, condenser *c*, secondary coil *d*, and condenser *e*. The primary circuit is coupled inductively to the secondary circuit through the mutual inductance between the coils *b* and *d*, and they are coupled capacitively through condenser *c*. The terminals of the secondary coil circuit connect to the plates of the twin diode, or frequency detector tube **19**, and the rectified current flowing through the twin diode passes through resistors **30** and **30'**. The action of this circuit portion is to translate a frequency modulated wave into a hybrid wave which includes both frequency modulated and amplitude modulated components. After that, the amplitude modulated audio-signal component is recovered in the well known manner.

When a pure amplitude modulated wave appears at the primary circuit including condenser *a* and coil *b*, equal and opposite voltages will appear at the secondary terminals. The rectified currents through resistors **30** and **30'** will vary at the modulating signal frequency in phase opposition and in such a manner that the potential from point *f* to point *g* in the circuit portion will remain zero in a perfectly balanced system. Hence the audio response at the output will be zero for a pure amplitude modulated wave input. In other words, the balanced frequency detector will detect variations in frequency of the wave, but will not detect or recover amplitude variations of an amplitude modulated wave.

For a better understanding of the complete system of Fig. 1, particularly as to the operation of the squench or muting portion of the system, one possible means for operation of the squelch portion will be explained preliminary to the description of the complete system. A noise voltage received at the input to the radio receiver or developed in the initial stages of the receiver system is amplified and introduced at the grid **18** of the limiter tube **17** which produces a rectified current flowing through resistor 26. This will develop a potential across the resistor 26 varying in magnitude with the variation of the amplitude of the noise voltage arriving at the grid 18. The potential across resistor 26 is negative with respect to ground and will pass through the circuit including the resistors 27, 28 and 29, to the grid 24 of the squelch tube 23. The negative potential on the grid 24 will open the squelch tube and cause the audio amplifier to amplify the noise originally applied to the squelch tube for reproduction in the speaker S. The tube 23 is so arranged in a well known manner that with a proper change in potential on its grid circuit, the gain of the amplifier 22 will be changed so that such amplifier will not function, and hence the speaker S will fail to operate. The amplifier 22 can be controlled in this manner by applying an abnormally high negative potential at the grid of one or more tubes in the amplifier 22, or by greatly reducing the potential at the plate of such tube or tubes.

From the above explanation, it is clear that with this type of operation, noise voltages will open the squelch if they attain a necessary voltage level, and voltages of the same magnitude generated by a carrier in the receiver system will operate the squelch in the same manner.

Noise voltages of alternating current character, different, of course, from the voltages produced by the rectified current or integrated D. C. in resistor 26, may be prevented from reaching the tube 23 by the use of a suitable filter or time delay network including capacitances 32 and 33, resistors 27 and 29, and capacitance 34. These elements will serve as a de-coupling filter to prevent audio-frequencies of an A. C. character from passing to the grid 24. The rectified current producing a corresponding noise voltage will pass to the grid 24 of the squelch tube 23 in the absence of a carrier in the receiver system when sufficient integrated voltage accumulates across resistor 26, and this voltage at the grid 24 will open the squelch. It is undesirable to open the squelch with noise, and hence reproduce noise at the speaker, and this difficulty becomes particlarly serious, as can be understood, in an area where a great deal of noise abounds. Under such circumstances an operator will be forced to listen to noise continuously or intermittently reproduced at the speaker in the absence of a carrier int he system. This noise reproduction can be reduced or eliminated by varying the value of the resistor 26 so as to reduce the sensitivity of the response of the squelch tube 23 to integrated noise voltages. When the sensitivity is reduced, however, to prevent the opening of the squelch by noise, the squelch is also less sensitive to carrier signals. Under such circumstances it is possible that a carrier signal of relatively low level, but a level which normally should be audible at the speaker, is not of sufficient strength to open the squelch and permit the operation of the amplifier 24 and the speaker.

In a receiver system such as illustrated in Fig. 1, however, this difficulty with reference to noise, and lack of sensitivity to carrier signals, can be overcome by utilizing a potential developed across the resistor 28 to oppose the potential developed across the resistor 26. To simplify the explanation of the development of this potential across the resistor 28, an FM circuit is illustrated diagrammatically in Fig. 5, in which merely the principal elements employed to accomplish this operation are shown diagrammatically. The operation will be more clear by a reference to both Figs. 1 and 5. The block diagram indicated by the reference character N in Fig. 5 corresponds generally to the amplifier tube 20 whose grid 36 is coupled to the output of the frequency detector 19 and the selective system or filter as will be described.

In the absence of a carrier at the input to the receiver, noise voltage generally made up of thermal agitation potentials and shot noise introduced at the input to the receiver or developed in the RF amplifier and converter stages, is amplified through the successive stages of the receiver and appears at the output of the detector 19 to be coupled to the grid 36 of the noise amplifier tube 20, through the condenser 37, and the resistor 38. The noise voltages are amplified in the tube 20 to increase the intensity of the voltage at the plate 35 of such tube, and desired frequencies are selected in the tuned circuit consisting of condenser 41, inductance 42, condenser 43, and inductance 44. This circuit is tuned to select a band of frequencies in the noise spectrum above the range of audio-frequencies used in the complete receiver system for communication purposes. The circuit including the tube 20 and the selective system described acts as the combination noise amplifier and filter N as mentioned above. For instance, in one embodiment of the system described, voice communication is used with a maximum frequency for voice reproduction of 3,000 cycles. The noise band selected by the selective system described may be anywhere above 3,000 cycles, and this noise band should be selected in a manner such that the tuned circuit described will not pass the audio-frequencies or voice frequencies below 3,000 cycles. In practice, the tuned selective circuit has been tuned to 8,000 cycles, to 12,000 cycles, or to 20,000 cycles when the voice reproduction is 3,000 cycles.

After amplifying and selecting the band of noise voltages, such noise voltage is rectified by rectifier tube 21, and the rectified current flows in resistance, or resistor 28 to produce a voltage with a polarity as shown in Figs. 1 and 5. With no carrier voltage at the input to the receiver, this rectified noise voltage appearing across resistance 28 will be large in magnitude, and may be made to reach any desired value by means of suitable amplification. With ordinary amplification voltages ranging from 10 to 60 volts have been developed in various embodiments of the invention. Where additional voltages have been required without the use of further amplification in the circuit, the tube 21, which can be a standard 6H6 tube, consisting of a double rectifier element construction can be connected into a conventional voltage doubling circuit so as to produce the increased potential across resistor 28, without otherwise changing the illustrated circuit. As illustrated, only one of the diode portions of the tube 21 is being utilized. The potential developed across the resistor 28 as a result of noise voltages in the receiver system acts on the squelch 23 to maintain it closed.

Means have been described above including a noise amplifier for amplifying the noise voltages at the output of a detector system, and a selective circuit for selecting a band of noise voltages which are rectified by a rectifier tube and applied to a resistance to produce a voltage thereacross. When a carrier is applied to a frequency modulated receiver system, a limiter such as the limiter 17 acts to reduce the level of noise appearing at the output of a detector tube as the detector 19. Inasmuch as the noise voltage appearing across the resistor 28 was developed in the receiver circuit and appeared as a noise voltage at the output of the detector 19, as previously described, the rectified noise voltage just described as appearing across the resistor 28 will be reduced as a result of the application of a carrier voltage to the input of the FM receiver. In fact, in a properly designed receiver with a limiter, or with balanced detection, or both, a small carrier voltage applied at the input, as the antenna A, can be made to produce a large reduction in noise voltage within the receiver, and hence can likewise be made to produce a large reduction in the rectified noise voltage across the resistor 28. In one particular embodiment of the invention, a reduction of 20 decibels of noise voltage at the output of the receiver was accomplished, as a result of injecting a carrier voltage of 0.4 microvolt into the input of the receiver.

In an FM receiver, or in fact, an AM receiver, as will be described, noise reduction or silencing may be achieved in the presence of a carrier, when all RF and IF circuits are tuned to exact resonance with the carrier, and the balanced discriminator or frequency detector circuit portion is tuned to precise balance with the carrier. Under such a condition the limiter may have little additional effect in reducing the noise in the presence of a carrier. This action all results from the lack of response of such detector system to amplitude modulation so that the noise side bands produced by the beating of noises with the incoming carrier will be balanced out at the output of the detector system. However, in communication equipment of the type particularly described herein, precise tuning at least with present equipment cannot be maintained in a practical manner in the rugged hard usage to which it is put. However, the limiter will act to eliminate the amplitude variations over reasonably wide limits of detuning from the carrier frequency, and it therefore becomes a more practicable means for all operating conditions to accomplish noise reduction.

It is apparent, therefore, from the above description, that the present invention provides a system in which the noise voltage across the resistance 28 may be made large in the absence of a carrier input to the receiver and with this voltage applied to the grid 24 of the squelch tube 23, the squelch is retained closed. This voltage, however, may be reduced by the application of a small carrier voltage to the input to the receiver, and the squelch system could be so designed that this change from a high potential across resistor 28 to a low potential, in the presence of a carrier, will open the squelch and permit the operation of the amplifier 22 in the speaker S.

A more desirable, and in fact the preferred means for operating the squelch system of my invention in the complete receiver system of Fig. 1, is to effect a differential action of two voltages to open and close the squelch. The complete system illustrated in Fig. 1 is illustrated in an abbreviated manner in Fig. 6 to show more clearly the more essential elements of the system. Fig. 6 is presented merely in the interest of clarity of understanding of the invention, the same as for Fig. 5, as previously explained.

The differential action involves voltages developed across the resistor 26, and also the resistor 28. The production of the voltage across

the resistor 28 has been discussed in detail, and some mention was originally made of the production of a voltage across the resistor 26. Briefly, as to the latter, a carrier voltage, or noise voltage, appearing in the receiver circuit at the inductance 16, and rectified at the grid 18 of the limiter tube 17, will produce a voltage across the resistor 26 which is negative in respect to ground.

In the case of the application of a carrier at the input to the receiver, there will be an increase in the voltage across the resistance 26 that will normally tend to open the squelch. Inasmuch as a noise voltage will normally always appear across the resistance 26, whether there is a carrier, or is not a carrier at the input of the receiver, this voltage at resistance 26, regardless of its nature, will tend to open the squelch unless it is kept at a low magnitude, or opposed by a voltage of opposite polarity.

In the present system, the voltage across the resistance 26 is opposed by a voltage across the resistance 28 of opposite polarity, as is shown in Fig. 1, but possibly more clearly in the abbreviated diagram of Fig. 6. In order to close the squelch 23 by opposing the voltage across the resistance 26 with the voltage across the resistance 28, the latter must be adjusted to a suitable value. This adjustment may be made by changing the amplification produced by the amplifier tube 20, and in the circuit of Fig. 1 this is accomplished by varying the magnitude of the resistor 46. The voltage across the resistor 28 may also be changed by varying the voltage of the noises introduced to the grid of the noise amplifier tube 20 from the detector tube 19. This adjustment is made until the differential between the two voltages is such that the squelch just closes with a noise voltage across each resistor.

With the receiver system energized but the audio-amplifier 22 and loud speaker S muted by the closed squelch, as described, there will be silence until a carrier is introduced to the receiver through the antenna A. A carrier, or a modulated signal, will produce an increase in the negative voltage across the resistance 26 as previously described. Simultaneously, with the action of the frequency modulated system upon the introduction of a carrier, there will be a reduction in the noise voltage appearing at the output of the frequency detector 19 and this will be translated into a reduction in the voltage appearing across the resistance 28, as previously described. In other words, the carrier, or modulated signal, increases the negative potential tending to open the squelch 23 while at the same time it decreases the potential across the resistor 28 tending to keep the squelch closed. This differential action produces a very positive and sensitive control for the squelch 23, which in turn controls the output from the receiver.

The amplifier 20 input from the detector 19 can be controlled by an adjustment of the elements of the intervening circuit, or the amplification of the tube 20 may be varied by the variation of the resistor 46, so that in all the voltage appearing across the resistor 28 can be made to be substantially greater than that necessary to just maintain the squelch in a closed condition in the absence of a carrier. In this condition, noise voltages in the receiver system, although they may produce substantial noise voltages across resistor 26, tending to open the squelch, such voltages will always be opposed by a voltage across resistor 28 which is increased to a point that it will definitely prevent the opening of the squelch by opposing the voltage at the resistor **26**. Inasmuch as a carrier in the receiver will immediately substantially reduce the voltage appearing across the resistor **28**, however, the differential action will accomplish an unbalanced condition between the voltages across resistors **26** and **28**, and will permit the predominant negative voltage from the carrier at the resistor **26** to open the squelch. The squelch system as described will operate in a very sensitive manner.

Of course, actually, with a definite decrease in the voltage appearing across the resistor **28** upon the introduction of a carrier, the voltage across the resistor **26** could remain at the same value and the differential action would weigh in favor of the voltage opening the squelch. By the same token, inasmuch as there is this reduction of voltage at the resistor **28** upon the introduction of a carrier, it is not necessary under any circumstances for the voltage across the resistor **26**, in the absence of a carrier, to overcome the opposing action of the voltage across resistor **28**. There is a further action of this complete system which tends to make it insensitive to undesirable operation by noise voltages in the receiver system. Although the application of additional noise from within the receiver itself, or man-made noise introduced to the input of the receiver, will tend to increase the voltage across resistor **26** and hence tend to open the squelch **23**, this same noise voltage will pass through the receiver system to increase the noise output at the detector **19**, and increase the magnitude of the opposite voltage across resistor **28**. Therefore, with an increase in noise level in a particular locality, and hence an increase in the noise voltage across resistor **26**, there is a simultaneous increase of opposing voltage across the resistor **28** and the squelch is prevented from opening.

Although the operation of the present system to close the squelch after the carrier has gone off the air can be understood from the above description, it is mentioned briefly that the squelch **23** is closed to prevent reproduction of noise at the speaker in the continuously energized radio receiver system, either by the application of a predominantly positive voltage to the grid **24** of the tube **23**, or by the reduction of the negative voltage applied thereto. The presence of noise voltages will produce a negative potential across the resistor **26**, but likewise will simultaneously produce an opposing voltage across the resistor **28** adjusted so that the latter voltage is great enough to oppose the potential across the resistor **26**.

It is therefore apparent, from the above description, that with the differential action of voltages across the resistors **26** and **28** when they are in opposing relation, and the voltage across the resistor **28** is predominant, the squelch is closed. However, when the voltage across the resistor **26** increases as a result of the application of a carrier to the receiver system, or at least remains the same, the voltage across the resistor **28** is at that same time being reduced, until the negative potential at the resistor **26** predominates and the squelch is opened. Stated another way, the voltage at the squelch tube **23** equals the differences between the voltages across the two resistors or resistances **26** and **28**. When the difference represents a voltage of sufficient negative polarity, the tube is open or ineffective, but when the voltage has a positive polarity the squelch is closed and remains closed.

Fig. 2 illustrates diagrammatically a modified means for selecting the desired noise band to produce a potential across resistor **28**. The elements corresponding to those in the selective system of Fig. 1 are numbered the same as in Fig. 1. Fig. 2 illustrates a simple well known parallel resonant circuit including a condenser or capacitance **51**, and an inductance **52**. The system is resonant above the audio-frequencies desired to be reproduced in the receiver system just as was the selective system of Fig. 1.

Fig. 3 illustrates diagrammatically a high pass filter which may also be used to select frequencies above the audio frequencies used for communication transmission in the complete receiver system. This circuit includes the conventional inductances **53**, **54**, and **55**, together with capacitances **56**, **57** and **58** acting as the high pass filter. The operation of this circuit is readily understood from the preceding description. The selected band of noise voltages is, of course, rectified and applied across the resistor **28** to provide a squelch closing potential for application to the grid **24** of the squelch tube **23**.

Although high pass filters and selective systems to select a noise band above the band of frequencies for communication, have been previously described, it is also understood that the selected band of frequencies can be below the audio-transmission limits. A low pass filter to accomplish this purpose is illustrated diagrammatically in Fig. 4. In addition to elements in the selective circuit of Fig. 4 corresponding to those in Fig. 1, there is also provided a tuning and filter circuit including resistance **61**, condenser **62**, and capacitances or condensers **63** and **64** together with the inductance **66**.

While the squelch control system of the present invention has been described as used for squelching or muting the audio system in receiver systems where a maximum frequency of 3,000 cycles have been used in the audio system, it is likewise obvious that the operation of this squelch control system is not limited to audio-frequencies. The same principle, with a differential action between the voltages developed across different resistances may be applied to the control of a squelch, a relay, or other device, where radio frequencies are used for the modulating signal. Since the noise spectrum in the presence of a carrier in the output of an FM receiver is triangular in character, that is, the magnitude of the noise increases with increase in frequency, it is obvious that the system of this present invention may be used where the communication signal is a high frequency, and the noise used for developing the operating voltage for a squelch or other device, is a low frequency. A low pass filter may be used to select a noise band, and prevent the signal or communication from passing through a filter, while the operating circuit is designed to make use of a high frequency signal. In general, such a system may work with improved effectiveness, because a greater change in the level of the low frequency noises will be produced by the application of a carrier to the input of the receiver, than occurred by the application of a carrier to the input of a receiver when high frequency noises were passed or selected by the selective portion of the complete system.

Although the preceding description has been concerned with the use of the differential action for the two voltages to operate a squelch tube, this differential action is equally applicable to the control, or operation of a relay instead of a tube to accomplish the control of the reproduction of the speaker. Such an application is illustrated in Fig. 7 shown in a manner similar to a diagram of Fig 6. The elements or portions of the circuit corresponding to that of Figs. 1 and 6 have the same reference characters in Fig. 7. A relay control circuit is substituted for the squelch tube of Fig. 6, and this circuit includes a D. C. amplifier tube **71** with a grid **72** connected to the resistor **28**. A relay R includes an energizable coil **73** connected to the tube **71**, and a movable armature **74**, as a switch arm for the contact **76** to open and close the circuit of the speaker S, or audio channel, in the same manner as the squelch tube of the circuit of Fig. 1. With the differential action of the voltages at the resistors **26** and **28**, as previously described, when noise predominates, the positive potential on resistor **28** acting through the tube **71** energizes the relay and breaks the speaker circuit through the armature **74** and contact **76**. Upon the introduction of a carrier at the input to the receiver, the noise voltage is reduced, as previously described, the relay is deenergized, and the spring **77** pulls the armature into contact with **76** to close the speaker circuit. More particularly in the latter case, a signal applied to the input of the receiver causes an increase in voltage across resistance **26**, while that across **28** decreases, resulting in a substantial increase in voltage between grid **72** and ground. The resulting decrease in plate current in the tube **71** will cause coil **73** to be deenergized and the armature **74** to be released.

The squelch system of the present invention as above described is not limited to use in an FM receiver system but may also be applied to an amplitude modulated receiver. Such a system is illustrated in Fig. 8, in which all elements on the diagram corresponding to elements in Figs. 1, 2 and 3 with similar functions are numbered the same. In Fig. 8, the squelch opening voltage is produced across resistor **26** in a manner similar to that described in the description of the action of the FM receiver. In the present embodiment the rectified current produced at the amplitude detector or AVC rectifier **81** passes through resistance **26** to produce the desired controlling voltage. In order to provide a controlling voltage in opposition to that produced at resistance **26**, a portion of the radio frequency voltage available at the output of amplifier **14**, is coupled to the input of amplifier **82**, and the amplifier **82** output is coupled to the balanced detector **83**. Balanced detector **83** is so designed that it will provide random noise voltages similar to those at the output of the FM detector **19** in Fig. 1. The noise voltages coupled through condenser **37** and resistance **38** will be amplified by tube **20**, selected by the band pass filter including the elements **43**, **44**, **42** and **41**, and rectified by rectifier **21**, so that the rectified currents flowing through resistance **28** will produce a voltage across such resistance or resistor. This voltage appearing across resistor **28** is connected in series with the voltage appearing across resistance **26** in such a way that the differences between the voltages across resistors **28** and **26** will appear between ground and grid of squelch tube **23**.

This system of Fig. 8 will now work in a manner similar to that described for the action of the system shown in Fig. 1. The application of a carrier at the input to the receiver will increase the squelch opening voltage across resistor **26** and decrease the squelch opposing or a squelch closing voltage across resistor **28**. This differential change in voltages across resistors **26** and **28** will result in an increase in the negative potential between grid **24** and ground of tube **23**, and that change in potential will be equal to the sum of the change in potential produced across resistor **28** and the change in potential across resistor **26**. The absolute value of voltage between grid **24** and ground will be equal to the difference between the voltage across resistor **28** and the voltage across resistor **26**.

Fig. 9 is a modification of the circuit of Fig. 8, merely as to the addition of a limiter **84** after the amplifier **82** and ahead of the detector **83**. The diagram of Fig. 9 is fragmentary but it is believed to be unnecessary to duplicate the similar portions of Fig. 8. The purpose of the limiter **84** is to reduce or eliminate amplitude variations of the signal fed to the detector **83**. Where a balanced RF and detector system is used the noise reduction produced by the carrier input to the receiver will follow without the use of a limiter, but such noise reduction may not take place in the event that all circuits are not balanced and the detector is not in a perfectly balanced condition. The limiter serves to remove amplitude variations and so make the noise reduction less dependent upon the balance of the circuits and therefore to make the system less critical.

The fundamental operation of the complete system illustrated fragmentarily in Fig. 9 is essentially the same as that disclosed for Fig. 1. The essential factor in the systems of Fig. 8 and Fig. 9 necessary to produce the squelch action described for Fig. 1 is the noise reduction at the output of detector **83** when a carrier is fed into the input of the receiver. In Fig. 9, this noise reduction is achieved by the use of limiter **84** which removes the hiss or noise voltages whenever the carrier signal input at antenna A is approximately twice as great as the poise peaks or voltages produced by thermal agitation, fluctuation noise, or interference at the input of amplifier **10**. This same effect may be achieved by the use of a balanced detector associated with a properly balanced amplifier. However, it may also be desirable to use both the limiter and the balanced detector system for best results.

In the present invention, therefore, I provide a radio receiver circuit including means for developing a voltage for operating control means within the receiver circuit, and particularly for operating a squelch or muting means. The invention may be practiced in either a frequency modulated receiver or an amplitude modulated system. The preferred embodiment, particularly, in which a differential action between two voltages developed within the receiver circuit is utilized to in turn provide a single operating potential for operating a squelch, has proven especially effective for sensitive, positive operation under a wide range of conditions as to noise and carrier levels. Because it is equally effective at high as well as low noise levels the communication equipment utilizing my invention has a much more widespread and efficient use than similar equipment of the prior art. Furthermore, because of its extreme sensitivity and its response to low carrier levels the service range for the equipment has been materially increased. In addition, under all of these circumstances the operator has the most pleasant as well as effective receiving conditions for his equipment.

Although the invention has been described merely in its preferred embodiments, it is understood that it is not limited thereto, but is limited only by the scope of the appended claims.

I claim:

1. In combination with an amplitude modulation wave signal receiving system which includes a signal transmission channel and a signal responsive device, a control channel coupled to said signal transmission channel and including means responsive to noise signals appearing in said signal transmission channel in the total absence of a received amplitude modulated carrier for developing a control voltage which is utilized to control said signal transmission channel in the correct sense to prevent said device from responding to the noise signals, means comprising an amplitude limiter included in said control channel for decreasing, without any tuning of the system, said control voltage when an amplitude modulated carrier is received in the presence of noise signals, and means for controlling said signal transmission channel to render said device responsive to the modulation components of the received carrier when said control voltage is decreased by said last-named means.

2. In combination with an amplitude modulation wave signal receiving system which includes a signal transmission channel and a signal responsive device, a control channel coupled to said signal transmission channel and including means responsive to noise signals appearing in said signal transmission channel in the total absence of a received amplitude modulated carried for developing a control voltage which is utilized to control said signal transmission channel in the correct sense to prevent said device from responding to the noise signals, means comprising an amplitude limiter and a balanced detector connected in tandem in the order named and included in said control channel for decreasing, without any tuning of the system, said control voltage when an amplitude modulated carrier is received in the presence of noise signals, and means for controlling said signal transmission channel to render said device responsive to the modulation components of the received carrier when said control voltage is decreased by said last-named means.

3. In an amplitude modulation wave signal receiving system which includes a signal transmission channel and a signal responsive device, the combination including means responsive to noise signals appearing in said signal transmission channel for developing a control voltage which is utilized to control said signal transmission channel in the correct sense to render said device responsive to the noise signals, a control channel coupled to said signal transmission channel, means included in said control channel and responsive to noise signals appearing in said channel in the absence of a received amplitude modulated carrier for developing a control voltage which opposes and exceeds said first-named control voltage, thereby to prevent said device from responding to the noise signals, and means included in said control channel for decreasing said second-named control voltage until said first named control voltage predominates thereover when an amplitude modulated carrier is received in the presence of noise signals, thereby to effect the response of said device to the modulation components of the received carrier.

4. In combination with an amplitude modulation signal receiving system which includes a signal transmission channel and a signal responsive device, a muting circuit operative to maintain said device non-responsive to noise voltages when a desired amplitude modulated carrier is not being received, means for controlling said circuit to render said device responsive to the modulation components of a received amplitude modulated carrier, a carrier amplitude limiter having its input side coupled to said channel, a balanced detector coupled to the output side of said limiter and operative to detect an undesired noise voltage transmitted to said limiter from said channel in the total absence of a received carrier, means responsive to the detected noise voltage for controlling said circuit to prevent said device from responding to the noise voltage, and means including said limiter operating in response to a received amplitude modulated carrier for decreasing the magnitude of the noise voltages transmitted to said detector, thereby to permit said device to respond to the modulaiton components of the received carrier.

5. In combination with an amplitude modulation signal receiving system which includes a signal transmission channel, a signal responsive device and automatic gain control means, a muting circuit having the function of maintaining said device non-responsive to noise voltages appearing in said system when a desired amplitude modulated signal carrier is not being received and including means controlled by said gain control means in the correct sense to render said device signal responsive when either a desired amplitude modulated signal carrier or undesired noise voltages are introduced into said channel, a balanced detector coupled to said channel at a point preceding said gain control means and operative to detect an undesired noise voltage introduced into said channel in the absence of a signal modulated carrier, and means controlled by the detected noise voltage for overriding the control exercised by said gain control means on said muting circuit, thereby to prevent said device from responding to noise voltage.

6. In combination with an amplitude modulation signal receiving system which includes a signal transmission channel, a signal responsive device and automatic gain control means, a muting circuit having the function of preventing said device from responding to noise voltage appearing in said system when a desired amplitude modulated signal carrier is not being received and including means controlled by said gain control means in the correct sense to render said device signal responsive when either a desired amplitude modulated signal carrier or undesired noise voltages appear in said channel, a carrier amplitude limiter having its input side coupled to said channel at a point preceding said gain control means, a balanced detector coupled to the output side of said limiter and operative to detect an undesired noise voltage impressed upon the input side of said limiter from said channel in the absence of an amplitude modulated carrier, and means controlled by the detected noise voltage for overriding the control exercised by said gain control means on said muting circuit, thereby to prevent said device from responding to said noise voltage.

7. In combination with an amplitude modulation signal receiving system which includes a signal transmission channel, a signal responsive device and automatic gain control means, a muting circuit having the function of preventing said device from responding to noise voltages appearing in said system when a desired amplitude

modulated signal carrier is not being received and including means controlled by said gain control means in the correct sense to render said device signal responsive when either a desired amplitude modulated signal carrier or undesired noise voltages appear in said channel, a carrier amplitude limiter having its input side coupled to said channel at a point preceding said gain control means, a balanced detector coupled to the output side of said limiter and operative to detect an undesired noise voltage impressed upon the input side of said limiter from said channel in the absence of an amplitude modulated carrier, means controlled by the detected noise voltage for overriding the control exercised by said gain control means on said muting circuit, thereby to prevent said device from responding to said noise voltage, and means including said limiter operating in response to a received amplitude modulated carrier for minimizing the detection of noise voltages by said detector.

8. In combination with an amplitude modulation wave signal receiving system which includes a signal transmission channel and a signal responsive device, a control channel coupled to said signal transmission channel and including apparatus operative to transmit noise signals appearing in said signal channel in the total absence of a received amplitude modulated carrier signal and also operative, without any tuning of the system, to reduce the noise transmitted thereby below a predetermined value when a desired amplitude modulated signal is received, means included in said control channel for selecting noise transmitted by said apparatus, and means coupled to said noise selecting means and responsive to the noise selected by said noise selecting means for preventing said device from responding to noise or signals appearing in the system so long as the noise transmitted by said apparatus exceeds said predetermined value.

9. In combination with an amplitude modulation wave signal receiving system which includes a signal transmission channel and a signal responsive device, a control channel coupled to said signal transmission channel and including a balanced detector operative to transmit noise signals appearing in said signal channel in the total absence of a received amplitude modulated carrier signal and also operative, without any tuning of the system, to reduce the noise transmitted thereby below a predetermined value when a desired amplitude modulated signal is received, means included in said control channel for selecting noise transmitted by said balanced detector, and means coupled to said noise selecting means and responsive to the noise selected by said noise selecting means for preventing said device from responding to noise or signals appearing in the system so long as the noise transmitted by said apparatus exceeds said predetermined value.

10. In combination with an amplitude modulation signal receiving system which includes a signal transmission channel, a signal responsive device and automatic gain control means, a muting circuit having the function of preventing said device from responding to noise voltages appearing in said system when a desired amplitude modulated signal carrier is not being received and including means controlled by said gain control means in the correct sense to render said device responsive either to a desired signal or undesired noise voltages appearing in said channel, means coupled to said channel at a point preceding said gain control means for detecting undesired noise voltages appearing in said channel in the absence of a signal modulated carrier, and means controlled by the detected noise voltage for overriding the control exercised by said gain control means on said muting circuit, thereby to prevent said device from responding to the noise voltage.

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Certificate of Correction

Patent No. 2,459,675. January 18, 1949

DANIEL E. NOBLE

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows:

Column 5, line 52, for "int he" read *in the*; column 6, line 10, for "protentials" read *potentials*; column 12, line 42, for "poise" read *noise*; column 13, line 33, for "carried" read *carrier*; column 14, line 19, for "modulaiton" read *modulation*;

and that the said Letters Patent should be read as corrected above, so that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 19th day of August, A. D. 1952.

[SEAL]

THOMAS F. MURPHY,
Assistant Commissioner of Patents.