Nov. 22, 1949 H. TUNICK 2,488,612

FREQUENCY MODULATION RECEPTION

Filed March 9, 1940 4 Sheets-Sheet 1

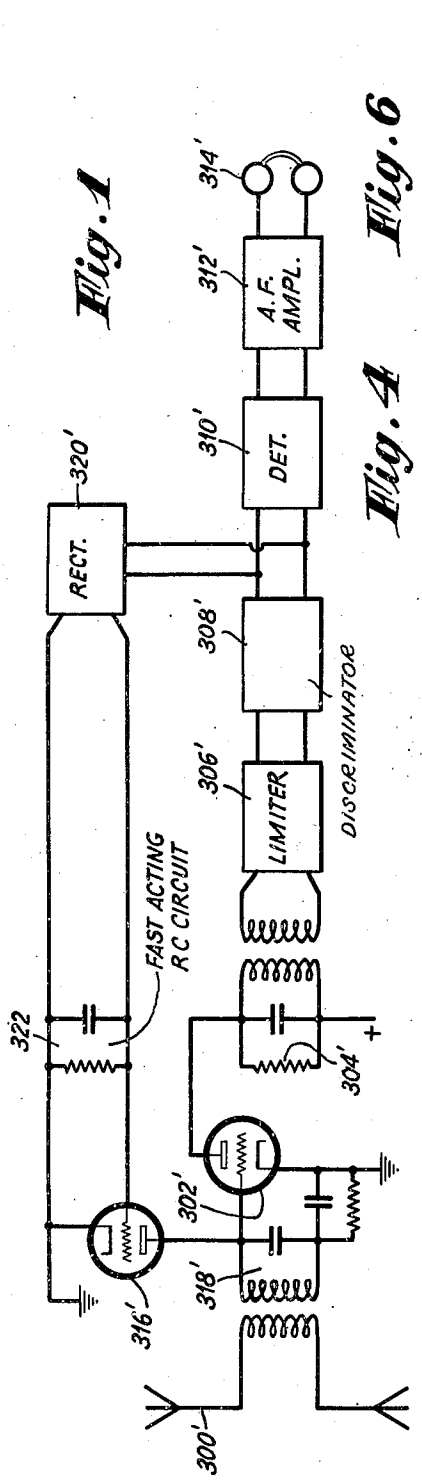


Fig. 1

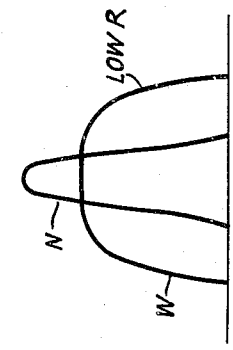


Fig. 6

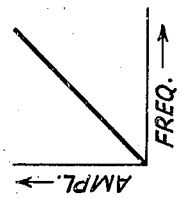


Fig. 4

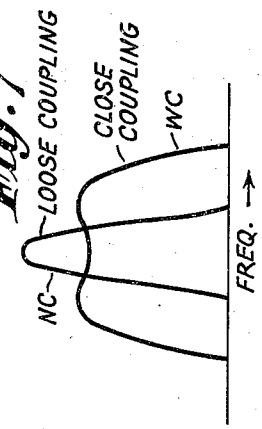


Fig. 7

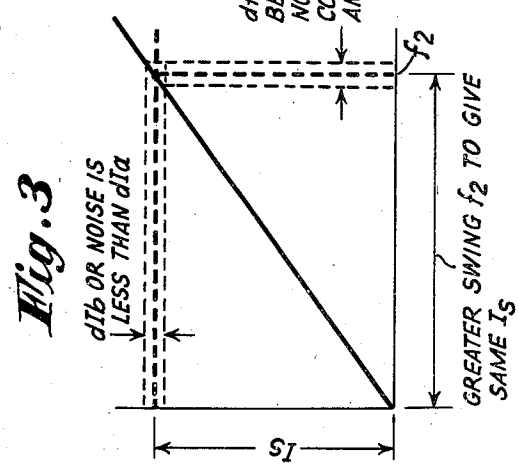


Fig. 3

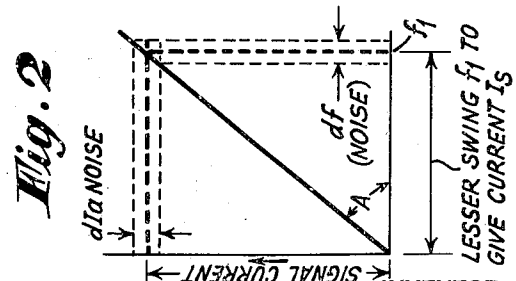


Fig. 2

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FREQUENCY MODULATION RECEPTION

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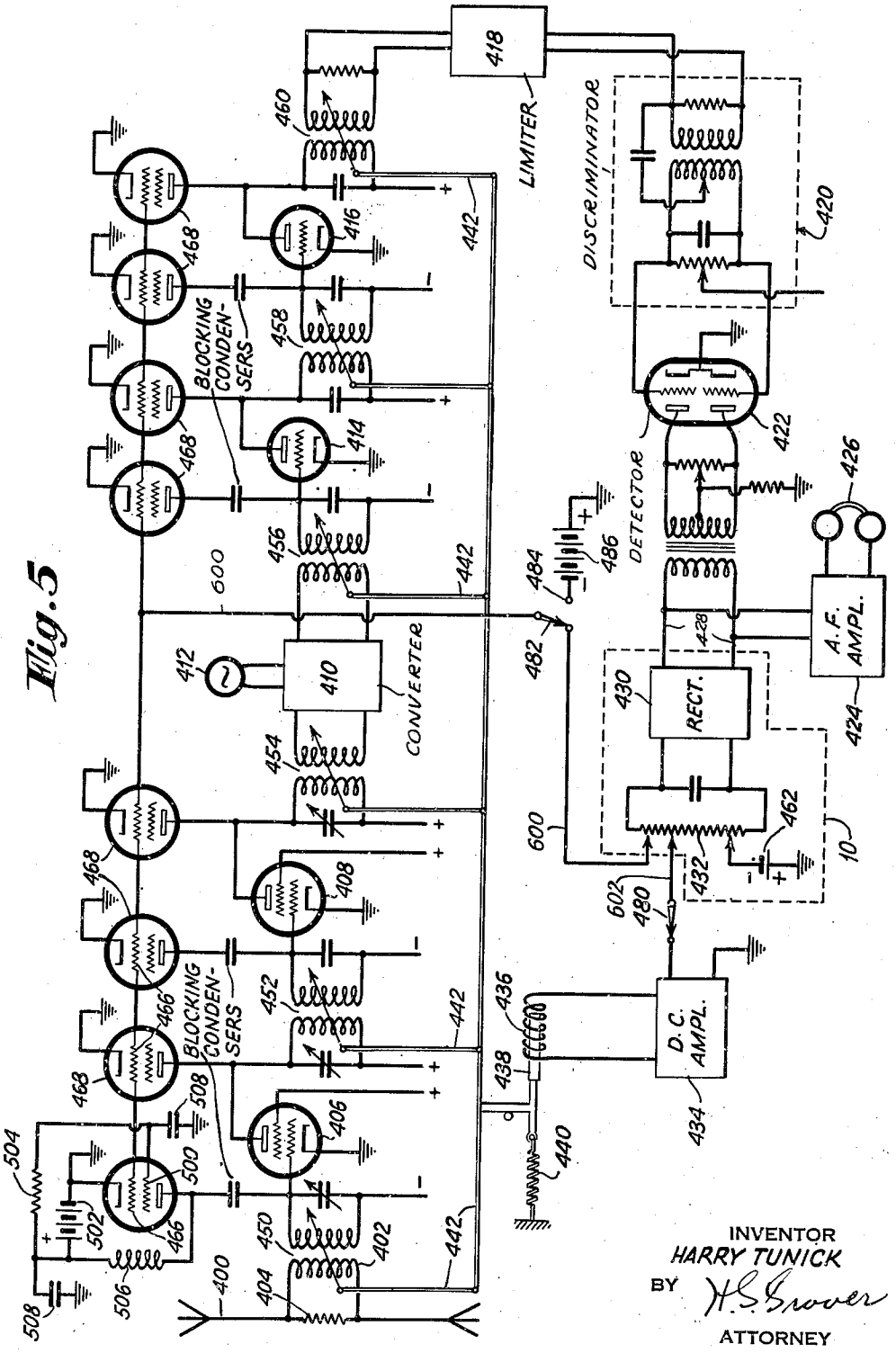


Fig. 5

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Fig. 8

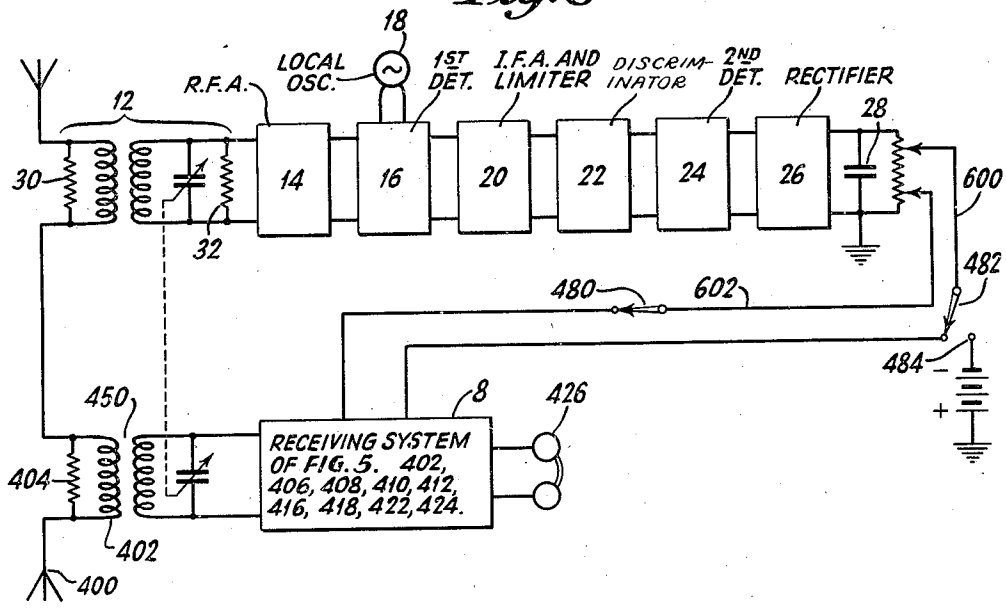
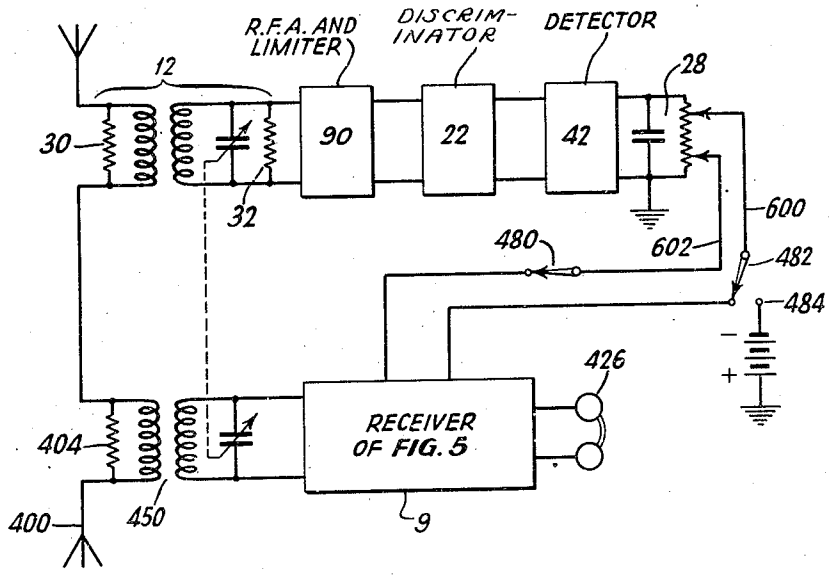


Fig. 9



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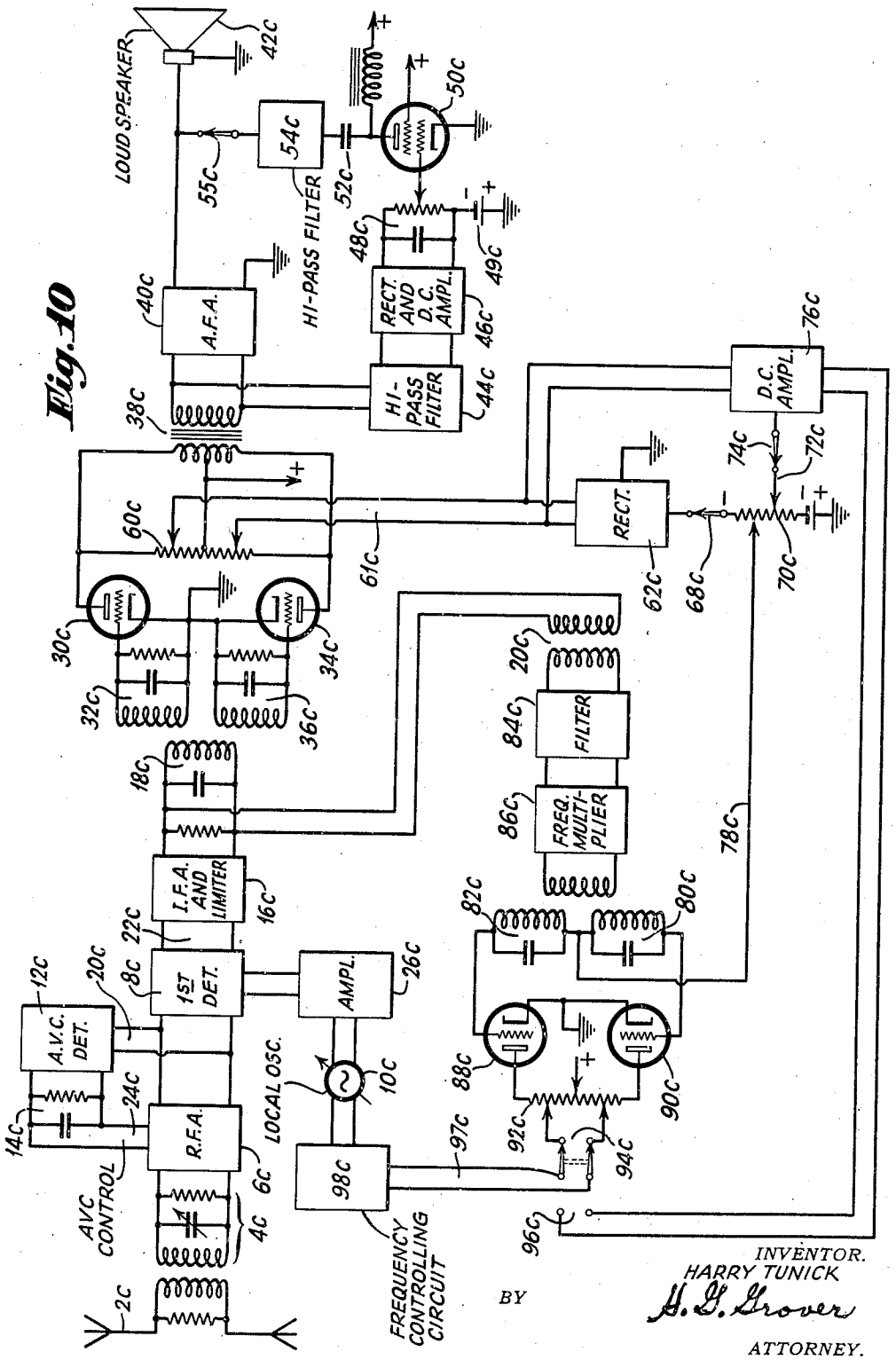
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FREQUENCY MODULATION RECEPTION

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Fig. 10



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2,488,612

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2,488,612

FREQUENCY MODULATION RECEPTION

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Application March 9, 1940, Serial No. 323,089

2 Claims. (Cl. 250—20)

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My present invention relates to receivers for receiving and translating frequency modulated waves. The principal object of my present invention is to provide an improved frequency modulation receiver in which the pass band is automatically varied in accordance with the frequency swing of the received waves. In this manner, as will be described more fully later, I provide a receiver having an improved signal to noise ratio.

Further objects, as well as features and advantages of my present invention, will be self-evident as the description thereof proceeds.

In the drawings:

Figure 1 is a schematic diagram of a variable pass band frequency modulation receiver;

Figures 2, 3 and 4 are graphs used in the explanation of my invention;

Figure 5 is a modified form of the receiver of Figure 1;

Figures 6 and 7 are curves partially explanatory of the operation of the receiver of Figure 5; and

Figures 8 and 9 are modifications of the receiver of Figure 5.

Fig. 10 shows another modification of the invention.

Figures 1 to 7 inclusive are, respectively, Figures 3, 3*a*, 3*b*, 3*c*, 4, 4*a* and 4*b* of my application Serial No. 310,495, filed December 22, 1939, now Patent No. 2,296,962, granted September 29, 1942.

In Hansell Patent No. 1,819,508 there is described a frequency modulation signaling system in which the frequency deviation at the transmitter or the frequency channel employed is made greater or smaller and the receiver is similarly adjusted so as to accommodate the transmitter swing. As shown in Figure 2 when the Hansell system is adjusted for the narrower swing in frequency, a swing in frequency *f1* will produce a signaling current in the detector Is. When the Hansell system is adjusted to a wider swing a deviation at the transmitter of *f2*, as shown in Figure 3, will be required to produce the same current Is in the radio receiver. The background noise in both cases is the same and may be represented by a change in frequency of the carrier equal to *df*. That is, as the carrier is swung in frequency with the modulating signal, the background noise gives the carrier a supplemental vibration or quiver equal to *df* which is productive of the noise in the receiver. In Figure 2 when the system is adjusted for narrow swings the noise current produced in the receiver is equal to *dIa*. In this case then the signal to noise ratio is given by the ratio of Is to *dIa*.

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As shown in the Hansell patent, when the wider swings are employed, and as illustrated in Figure 3, the wiggle in carrier frequency *df* produced by the noise produces a noise current in the receiver equal to *dIb* for the same receiver or detector output Is. The signal to noise ratio in this case, shown by Figure 3, is, therefore, Is divided by *dIb*.

Since the noise current *dIa* in the case of Figure 2 operation is equal to *df*·tan A and since in the case of Figure 3 *dIb* is equal to *df* tan B, it follows that *dIa* is to *dIb* as *f2* is to *f1*.

In other words, the constant background noise is reduced in direct proportion to the swing in frequency employed in the system.

In either system it should also be clear that the signal to noise ratio improves with louder signals; that is to say, in either system the current produced in the receiver is directly proportional to the frequency *f* and since the noise current represented by background noise is substantially constant, there is a better signal to noise ratio at the louder signals than at the weaker or softer signals. Also, when the frequency swing is small, representative of, for example, soft music, the entire pass band of the receiver is not usefully employed and the pass band of the receiver in excess of that necessary to instantaneously pass the signaling frequencies may permit passage of impulse noises or atmospheric static during soft or weak signal reception. In this way in ordinary frequency modulation systems, where adjusted for narrower or wider swings, the signal to noise ratio is at its worst during soft music when it should be at its best. To improve this situation and provide a receiving system which has a better signal to noise ratio during softer or weaker signals is an object of my present invention. This object is effected by providing means for automatically adjusting the pass band of the receiver in accordance with the frequency swing or loudness of the signals. Thus, when the frequency swing is small and the signal transmitted may be represented by soft music, the pass band of the receiver is made smaller.

As shown in Figure 1 the antenna **300'** feeds a first tuned radio frequency amplifier stage **302'**. For simplicity, polarizing and biasing sources have been omitted from Figure 1. The output circuit of stage **302'** is broadened by resistance **304'** and feeds into a limiter **306'** whose output level is of constant value. The output of limiter **306'** is fed into the analyzing circuit **308'** which has the characteristic shown in Figure 4. That is, analyzer **308'** may be a single off-tuned cir-

cuit converting frequency modulating currents into currents of varying amplitude. The rectangle 308' is designated as "Discriminator" to indicate the latter function. These currents of varying amplitude are fed into a detector 310' whose audio output in turn is fed to an audio frequency amplifier 312'. Connected to the audio frequency amplifier are the earphones or loudspeaker 314'. Tube 316' acts as a variable resistance shunting the input circuit 318' of the first radio frequency stage 302'. Part of the output of the discriminator circuit is fed to a rectifier 320' provided with a suitable time constant circuit 322' which may be adjusted to be fast or slow as found satisfactory. The output of rectifier 320' thereby varies the conductivity of tube 316' making it more conductive in the case of louder signals and thereby widening the pass band of the first stage 302'. When soft signals come through in which there is only a small frequency swing, tube 316' becomes less conductive and acts as a higher resistance in shunt to circuit 318'. Hence, the pass band of the receiver during weaker signals or softer passages becomes sharper, thereby reducing noise passed by the first stage of the receiver.

This action is illustrated in Figure 6 where the curve marked N illustrates the narrow frequency band passed by the tuned circuit 318' of Figure 1 when soft music is being received and when tube 316' is cut off or practically cut off. With louder signals, tube 316' becomes conductive and hence broadens the pass band of circuit 318' as shown by curve W of Figure 6. The changes in amplitude produced by changing the pass band of circuit 318' have no effect on the ultimate receiver output in loudspeaker 314' because of the fact that limiter 306' serves to eliminate these undesirable amplitude changes.

In Figure 5, I have illustrated a receiver employing the features explained in connection with Figures 1 and 6. In addition, supplementary control is provided by change in coupling as shown in Figure 7. Thus, when the coupling between stages or circuits is loosened, the pass band may vary from one extreme, as illustrated by curve WC of Figure 7, to a pass band illustrated by curve NC of Figure 7.

Turning to Figure 5, the antenna 400 feeds through coupling coil 402 shunted by resistance 404 the first R. F. amplifying stage 406. Stage 406 successively feeds amplifying stage 408, the latter in turn feeding a converter 410 also fed with local oscillations from a local source 412. The resultant beat frequency energy is fed through beat frequency amplifier stages 414, 416 to a limiter 418. The network 420 is a discriminator, and may be constructed as described in Seeley Patent 2,121,103. The variable amplitude currents derived from circuits 420 are fed to the push-pull detector tubes 422, the latter in turn feeding an audio frequency amplifier 424 and earphones or loudspeaker 426.

Part of the audio frequency energy, or video frequency energy in case television signals have been transmitted, is fed through leads 428 to rectifier 430 and thence to time constant circuit 432 which may be slow or fast as found desirable and is preferably made fast. Part of the voltage developed across the resistor of circuit 432 is fed to the D. C. amplifier 434 energizing solenoid 436, the latter pulling the core 438 against the action of spring 440. Hence, as the audio output from rectifiers 422 becomes larger, solenoid 436 sucks the core 438 to the right, thereby moving the uni-control system 442 in such a way as to increase coupling between the primary and secondary coils of transformers 450, 452 and 454 in the radio frequency stages of the receiver and also increasing the coupling 456, 458 and 460 in the intermediate frequency stages of the receiver.

The louder signal also overcomes the negative voltage source 462 to impress with louder signals voltages through leads 600 upon the grids 466 of resistance tubes 468 so as to make them more conductive and, hence, of lesser resistance. In this way, the pass band of the receiver is increased by not only broadening the circuits with resistance by the action of tubes 468, but also by increasing the coupling between stages. If desired, of course, the increased coupling feature may be removed by opening switch 480. Alternatively, the receiver system may be set for narrow band operation by moving switch 482 from its position shown so as to contact with point 484 of blocking voltage source 486, which is of sufficiently high value to block and prevent all current flow through the resistance tubes 468.

All of the resistance tubes 468 are identical. Hence, only the complete connections for the first tube to the far left are illustrated. The connections for the remaining tubes are identical and hence need not be illustrated or further explained. Tubes 468 may be provided with screen grids 500, a source of plate potential 502, voltage dropping resistors 504, choke coils 506 and bypassing condensers 508.

All of the frequency modulation receivers described herein may be used to receive phase modulated waves, it being understood that, preferably, an additional correction circuit is added to the signal or audio frequency amplifier stages of the receiver. This additional correction should have a characteristic such that the amplifier output falls off with increase in frequency. The preferred correction circuit for the receivers described herein when used to receive phase modulated waves is described in Crosby Patent No. 2,060,611.

In connection with the described receivers, as explained in connection with Figures 2 and 3, it is preferred that the narrowest adjustment or narrowest pass band of the receiver be equal to and no less than twice the highest audio or modulating frequency. This follows from the fact that in frequency modulation the band width necessary is the higher of two factors, namely, the highest modulating frequency or the highest swing in frequency of the radiated or carrier frequency.

In the receiving systems of Figures 8 and 9, the reeciving apparatus within rectangles 8 and 9 and between antenna 400 and loudspeaker or earphones 426 is identical to that shown in Figure 5 with the exception that the apparatus within the dotted rectangle 10 of Figure 5 is omitted and the controlling voltages are applied to leads 602, 600 in different ways.

In Figure 8 part of the waves picked up on antenna 400 are fed through the broadly tuned coupling system 12 to a radio frequency amplifier 14. The output of amplifier 14 is beat down in the first detector 16 with waves from the local oscillator 18. The beat frequency waves are fed through an intermediate frequency amplifier and limiter 20. The output of unit 20 is fed into a second unit 22 which converts the frequency modulated waves into waves of varying amplitude. This unit 22 may be of the type shown in rectangle 420 of Figure 5 or it may be the off-

tuned circuit system shown in either Conrad Patent No. 2,057,640 or Crosby Patent No. 2,071,-113. Or, it may be of the type shown in Seeley Patent No. 2,121,103. The converted waves of varying amplitude are fed to a second detector 24 and, if desired, further rectified in a rectifier 26 and then fed into a suitable time constant condenser-resistor circuit 28 to which leads 600, 602 are tapped as shown. As illustrated, the coupling circuit 12 is unicontrolled with the tuning of the receiving system 8. Resistors 30, 32 are provided, as illustrated, so that for all tunings of the receiver radio frequency amplifier 14 is enabled to receive the largest changes in frequency transmitted. Similarly, the circuits within units 16, 20, 22 and 24 are broadened with resistance so as to accommodate the largest frequency changes received.

The system of Figure 9 is a simplified arrangement of the receiver of Figure 8. In the system of Figure 9 unit 90 is a radio frequency amplifier and limiter whose output is fed into a discriminator circuit 22 already described in connection with Figure 8. Unit 22 of Figure 9 is followed by a rectifier or detector 42 whose output is fed into the time constant circuit 28 supplying voltages to the controlling leads 600, 602. If desired, of course, another rectifier following 42 and ahead of circuit 28 may be provided.

All of the remarks made in connection with Figure 5 are, of course, equally applicable to Figures 8 and 9. For example, switch 480 of Figures 8 and 9 may be opened or switch 480 may be closed and switches 482 moved over to contacts 484.

In the receiver of Figure 10, frequency modulated waves are picked up by antenna 2c and fed through tunable broad pass coupling 4c to radio frequency amplifier 6c. The output of radio frequency amplifier 6c is fed to the first detector 8c which is also supplied with oscillations from local oscillator 10c. Beat frequency energy is fed into the intermediate frequency amplifier and limiter stages 16c. Radio frequency amplifier 6c is provided with a detector or rectifier 12c, operating as an automatic volume controlling rectifier whose output, through a suitable time constant circuit 14c, controls the gain of radio frequency amplifier 6c. If desired, the input leads 20c may be connected to the output leads of the first detector 8c. In either event, the automatic volume control leads 24c may be connected as shown or they may be connected to amplifier 26c to vary the energy fed from oscillator 10c to the first detector. If desired, leads 24c may be connected to both radio frequency amplifier 6c and to amplifier 26c to simultaneously control the gain or output thereof. The purpose of having the energy fed to the limiters of the I. F. stages volume controlled is to prevent the limiters from being subjected to wide variations whereby the output of the I. F. limiter stages to the input side of detectors 30c and 34c is substantially constant and devoid of drooping levels following from under or over excitation of limiters.

Circuits 32c and 36c are tuned to opposite sides of the mean intermediate frequency and have overlapping resonance curves. The outputs of detectors 30c and 34c are connected in phase opposition and fed through transformer 38c to audio frequency amplifier 40c connected to a loudspeaker 42c.

For high fidelity reception, audio frequency amplifier 40c and loudspeaker 42c are made substantially flat from about 20 to 15,000 cycles.

Since the higher notes above 8,000 or 9,000 cycles to 15,000 cycles are present only in infrequent high character programs such as presented by philharmonic orchestras, etc., I provide an arrangement to keep high frequency noise background out of the loudspeaker when ordinary run of the mill programs are received.

To do this I connect a high pass filter which passes solely 8,000 to 15,000 cycles across the input side of the audio amplifier 40c. The output of filter 44c is fed to rectifier 46c feeding the time constant circuit 48c. Bias voltage source 49c is chosen so that in the presence of only high frequency back ground noise which is of low level, tube 50c is substantially conductive. Filter 54c is arranged to freely pass energy from 8,000 to 15,000 cycles and, hence, effectively grounds the loudspeaker 42c for these noise frequencies through by-passing condenser 52c and normally conducting tube 50c. However, in the presence of musical frequencies strong enough to override the back ground noise, filter 44c passes enough of such energy to rectifier 46c to bias the grid of tube 50c negatively to a higher degree and thus cause tube 50c to become non-conductive. Hence, filter 54c is effectively open circuited and the higher frequencies are no longer shunted away from, but are permitted to flow into, loudspeaker 42c.

If desired a switch 55c may be provided to render inoperative this feature of Figure 10.

When receiving on shorter wave lengths, the swing of the carrier may be quite large, numerically. Thus, for transmitting an audio signal on a frequency modulated carrier of mean wave length of 65 centimeters, the loudest sound transmitted may cause a swing of the carrier of plus and minus 400 k. c. The frequency characteristic or slope of circuits 32c and 36c will not be great and, hence, the voltage drop across 60c due to small changes in frequency caused by frequency drift will be small and generally ineffectual to frequency control the local oscillator 10c.

This situation may be remedied in either of two ways. First, a part of the intermediate frequency energy is fed through transformer 20c and then through filter 84c which has a pass band greater than the permissible drift range of oscillator 10c. The energy passed by filter 84c is fed to frequency multiplier 86c which has a multiplying factor such as desired, for example, the factor may be any number from 2 to 50. The output of multiplier 86c is fed to relatively sharply tuned circuits 80c and 82c having overlapping resonance curves and tuned symmetrically to opposite sides of a mean frequency corresponding to the desired correct mean frequency of I. F. amplifier 16c multiplied by the multiplying factor of multiplier 86c. As a result small changes in frequency cause relatively large correcting voltages across resistor 92c, which through switch 94c and leads 97c are fed to the frequency controlling circuit 98c for oscillator 10c. In this way, oscillator 10c is quickly brought to its correct operating frequency or to a frequency producing a correct intermediate frequency should the transmitter mean frequency vary.

In the alternative, a direct current amplifier 76c may be provided which amplifies small changes in voltage appearing across the taps for leads 61c. By throwing switch 94c to contacts 96c, the amplified output of 76c is fed to leads 97c and thence to the frequency controlling circuit 98c for oscillator 10c.

In either frequency controlling case, it may

be found desirable to automatically suppress frequency control when the signal is on and to have it operate only during silent passages in a received program. This is accomplished by rectifying part of the signal fed through leads 61c to rectifier 62c. The rectified output of rectifier 62c impressed through resistor 70c and through leads 78c and 74c on the grids of tubes 88c, 90c and rectifier 76c block the amplifier and tubes. In the absence of audio signal or when the audio signal drops to a low value, automatic frequency control of oscillator 10c again takes place. If it is desired to remove the suppressing action referred to, switch 68c may be opened.

It is to be clearly understood that all of the features, such as the audio stage noise suppression and automatic frequency control features, disclosed in Figure 10 may be combined with and included in the receiving systems described in Figures 5, 8 and 9. Because such combined wiring diagrams cannot be placed upon a single sheet of drawings, I have not illustrated the combined system in a single figure. Moreover, it should be understood in connection with Figure 10 that the pass band 8,000 to 15,000 cycles is merely given by way of example. Other limiting values may be chosen. For example, the overall pass band for the audio frequency stages may be from 10 to 10,000 cycles. High frequency noise elimination in the absence of signal over-tones may be made to take place in the band from 7,000 to 10,000 cycles, for example.

Having thus described my invention, what I claim is:

1. In a frequency modulated carrier wave receiver of the type comprising a plurality of cascaded carrier wave amplifiers, a carrier-tuned selector network coupling each pair of cascaded amplifiers, and at least one of the selector networks consisting of a pair of coupled tuned circuits resonated to the center frequency of a modulated carrier wave, means for deriving modulation voltage from the amplified received carrier wave, the improvement which includes a device connected with at least one of said tuned circuits for controlling the damping thereof, a second device for controlling the degree of coupling between said pair of tuned circuits, and further means for deriving from said modulation voltage a unidirectional voltage representative of the extent of carrier frequency deviation of the received modulated carrier waves, said further deriving means controlling said devices in a sense directly to synchronize the pass band width of said pair of tuned circuits with said carrier frequency deviation.

2. In a frequency modulation receiver of the superheterodyne type including a signal collector, a converter, an intermediate frequency amplifier including at least one pair of coupled resonant circuits tuned to the intermediate frequency, an amplitude modulation limiter, means for deriving modulation voltage from the amplified frequency-modulated, intermediate frequency voltage; the improvement which comprises means operatively associated with said intermediate frequency amplifier tuned circuits for adjusting the coupling therebetween and thereby the effective pass band width of said amplifier, means for deriving from the said modulation voltage a unidirectional control voltage whose magnitude is directly proportional to the modulation voltage amplitude, and means utilizing said control voltage for regulating said coupling adjusting means.

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