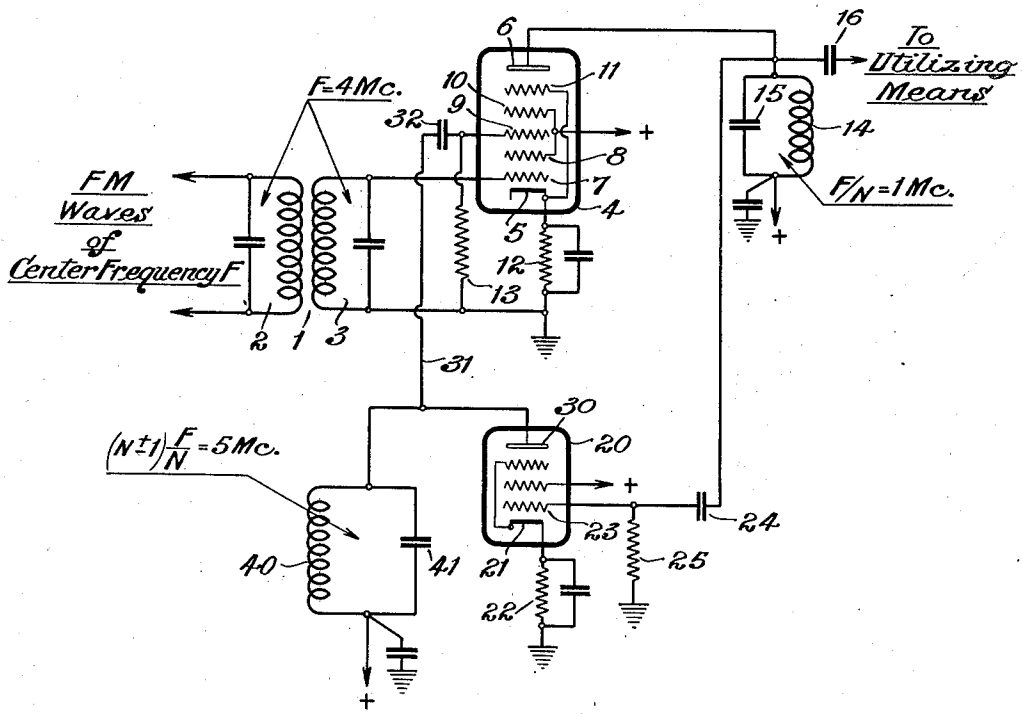
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FREQUENCY DIVIDER NETWORK

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INVENTOR
Murray G. Crosby
BY H. S. Grover
ATTORNEY

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FREQUENCY DIVIDER NETWORK

Murray G. Crosby, Riverhead, N. Y., assignor to Radio Corporation of America, a corporation of Delaware

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My present invention relates to frequency division networks, and more particularly to a method of, and means for, frequency division in which no output voltage is produced in the absence of the high frequency voltage whose frequency is to be divided.

The usual frequency divider circuit consists of a multi-vibrator, or relaxation, oscillator which is normally so unstable that it may be easily held in step at a sub-harmonic of the frequency to be divided. This type of frequency divider network has the disadvantage for some purposes that oscillations are produced even in the absence of the controlling input waves.

Accordingly, it may be stated that it is one of the important objects of the present invention to provide a frequency division network which is provided with means to prevent output oscillations at the divided frequency in the absence of the alternating input voltage whose frequency is to be divided.

Another important object of the invention may be stated to reside in the provision of a frequency dividing circuit system of a superheterodyne converter network and a frequency multiplier network, the multiplier functioning to provide for the converter network oscillations whose frequency differ from the converter input wave frequency by the frequency of the converter output circuit.

Frequency division networks are desirable for use in receivers of angular velocity modulated carrier waves, such as phase, or frequency, modulated carrier waves, and such frequency division networks have been disclosed in my U. S. Patent No. 2,064,106, granted December 15, 1936, as well as in my U. S. Patent No. 2,230,231, granted February 4, 1941. In the circuits of these patents, prior to demodulation of the modulated carrier waves the latter are subjected to the frequency division in such a manner that the band width of the modulated carrier wave is reduced in the same proportion as the center frequency of the modulated carrier wave. As pointed out in the said patents, such frequency division is particularly advantageous in the reception of phase, or frequency, modulated carrier waves because the signal to noise ratio at the input of the demodulator is greatly improved the narrower the band width of the demodulation network input circuit.

It may be stated, therefore, that it is another object of my invention to provide a frequency division network prior to the demodulator of a receiver of angular velocity modulated waves, the division network comprising a converter whose output circuit is resonant to a predetermined fractional frequency of the center frequency of the converter input circuit, and a frequency multiplier being operatively associated with the converter network in such a manner that output voltage will not be developed at the aforesaid converter output circuit unless the center frequency of the applied modulated carrier waves is very close in frequency to the converter input circuit frequency and unless the amplitude of the converter input voltage is above a predetermined amplitude level which corresponds to a level above an undesired noise level.

Still other objects of the invention are to improve generally the efficiency and reliability of frequency division networks in receivers of frequency modulated carrier waves, and more particularly to provide dependable frequency division networks having limiting action, and which are economically manufactured and assembled in frequency modulation receivers.

The novel features which I believe to be characteristic of my invention are set forth in particularity in the appended claims; the invention itself, however, as to both its organization and method of operation will best be understood by reference to the following description taken in connection with the drawing in which I have indicated diagrammatically a circuit organization whereby my invention may be carried into effect.

Referring now to the drawing there is shown the frequency division network of my present invention, and it will be understood that it may be considered, for a specific utilization, as being located between the intermediate frequency amplifier network and the demodulation network of a frequency modulation receiver of the superheterodyne type. For example, let it be assumed that the superheterodyne receiver is one employed in the presently assigned frequency modulation band of 42 to 50 megacycles (mc.), and that the first detector reduces the center frequency of the modulated carrier waves to an intermediate frequency chosen from a range of 2 to 5 mc. In such case many advantages are secured if a frequency division network is utilized to reduce the center frequency, say 4 mc., by a desired factor which is an integer. As explained in my aforementioned patents, the band width is simultaneously decreased by the same factor. In other words, if the center frequency is reduced by a factor of 4, then the band width would be reduced by the same factor of 4. Since the maximum permissible center frequency deviation in use at present in broadcast FM reception is 100 kilocycles (kc.) to either side of the center frequency, it will be seen that reducing the center frequency by a factor of 4 will result in a reduction of the band width from 200 kc. to 50 kc. By such frequency division and simultaneous band width reduction the input circuit of the frequency modulation detector may be adjusted for the reduced band width with a consequent improvement in signal to noise ratio at the detector input circuit.

Specifically considering the circuit shown on

the drawing, let it be assumed that numeral 1 designates the usual intermediate frequency transformer coupled to the plate circuit of the last intermediate frequency amplifier tube. In that case each of the primary and secondary resonant circuits 2 and 3 would be tuned to the center frequency F. As stated before, and merely by way of specific illustration, F is assumed to have a value of 4 mc. As is well known the center or carrier frequency is deviated at the transmitter in dependence upon the amplitude of the modulation signal, and the rate of frequency deviation is dependent upon the modulating frequencies themselves. In the assumed case the permissible band width of transformer 1 would be 200 kc.

The numeral 4 designates the converter tube which may be of the 6SA7 type, although the invention is not restricted to this type of tube nor to a tube of the pentagrid type. Generally, the tube may comprise a cathode 5 and an output electrode, or plate, 6. Between the cathode 5 and plate 6 are arranged in sequential relation a signal input grid 7, a positive screen grid 8, and a second signal, or oscillation, input electrode 9, a positive screen grid 10 and the usual suppressor grid 11. The cathode 5 is connected to ground through the customary biasing resistor 12 shunted by an intermediate frequency by-pass condenser. The low potential side of secondary circuit 3 is established at ground potential, while the opposite side is connected to the signal grid 7. The electrode 9 is connected through resistor 13 to the grounded end of biasing resistor 12.

The plate 6 is connected to the positive terminal of a direct current source through a resonant output circuit comprising a coil 14 shunted by condenser 15. The circuit 14—15 is tuned to a frequency

$$\frac{F}{N}$$

It will be understood that N may be any factor which is an integer. The signal modulated carrier voltage developed across circuit 15—14 may be transmitted to any utilizing means through the condenser 16 which has a low impedance to the carrier voltage. As explained before, it is desired to divide the center frequency of the modulated carrier waves and secure simultaneously proportional reduction of the band width or frequency deviation. Hence, the effective band width of the energy in circuit 14—15 would be reduced N times. If the effective band pass width at transformer 1 was 200 kc., and N equalled 4, then the pass band width at tuned circuit 15—14 would be 50 kc. The utilizing means can be any well known type of frequency modulation detector which functions to derive the modulating signal from the modulated carrier wave. Reference is had to my aforesaid patents for disclosure of networks which may be used following circuit 15—14.

The frequency multiplier tube is designated by numeral 20, and it may be a tube of the pentode type such as one of the 6SK7 type. The cathode 21 of this tube includes a self-biasing resistor 22 connected to ground and shunted by an appropriate by-pass condenser. The input grid 23 is connected by the coupling condenser 24 to the high potential side of circuit 14—15, the grid being connected to ground through the leak resistor 25. The plate 30 of tube 20 is connected by lead 31 and coupling condenser 32 to the grid 9. The plate 30 is also connected to the high potential side of a resonant circuit comprising a coil 40 and a shunt condenser 41, the low potential side of this circuit being connected to a positive terminal of an appropriate direct current source.

Circuit 40—41 is tuned to a frequency which is equal to

$$(N\pm 1)\frac{F}{N}$$

In the specific illustration given, the resonant frequency of circuit 40—41 would be 5 mc. The biasing resistor 22 is given a value such that, in the absence of input voltage to grid 23, direct current voltage developed across resistor 22 is sufficient preferably to bias grid 23 so as to adjust the grid close to plate current cut-off. It will now be realized that the resonant frequency voltage developed across the circuit 40—41 is impressed upon the electrode 9 simultaneously with the impression of the frequency modulated carried wave energy of center frequency F upon grid 7.

The frequency modulated carrier wave voltages impressed on respective grids 7 and 9 are heterodyned by virtue of electron coupling, and produce the beat frequency voltage whose center frequency is

$$\frac{F}{N}$$

in circuit 15—14. Hence, it will be seen that the output of the converter tube is tuned to the desired subharmonic frequency, and that this converter output voltage is fed to the input electrode of a frequency multiplier tube. In the latter circuit the sub-harmonic frequency receives a multiplication of $N\pm 1$ times, and this multiplied output is then fed to the electrode 9 of the converter tube 4 so that the output of the converter consists of the heterodyne beat between the center frequency F and the frequency of the voltage developed across circuit 40—41. It will be seen under these circumstances an oscillation will exist in circuit 15—14 when the converter gain and the multiplier gain exceed unity. The converter gain depends upon the strength of the signal applied from the input transformer 1 so that in the absence of signal energy at the input transformer 1 there will be no output voltage at circuit 15—14 since there will be no oscillations produced through the multiplier tube. Tubes 4 and 20 cooperate with the associated tuned circuits to provide a re-entrant circuit i. e., a regenerative modulation circuit. The constants of the tubes 4 and 20 are chosen so that when the signal input level exceeds a predetermined amplitude then the re-entrant action becomes sufficient to sustain oscillation.

Additionally, the network of this invention may have its constants adjusted so as to provide the characteristics of a limiter stage. With such adjustment, when the signal input voltage is raised above the level required to start oscillations the output voltage does not appreciably increase. Accordingly, when used to divide the frequency, or phase, deviation in a frequency, or phase, modulation receiver, the division network also performs the function of a limiter network. Therefore, the usual limiter stage employed prior to the detector may be dispensed with.

A further advantage of this type of frequency divider, when employed in a frequency, or phase, modulation receiver, is in the selective action thereof. Due to the resonant frequencies of the

circuits employed in the regeneration circuit, there is a limited range of frequency F which will cause the system to oscillate and produce an output voltage. Thus, the receiver may be tuned to the proper center frequency F so as to produce oscillations in the divider, and interfering signals which do not have the frequency F, but which come through the usual selective circuits, will be rejected.

A still further advantage which this division circuit has for use in frequency, or phase, modulation receivers is its threshold action which can be utilized to eliminate noise from the receiver in the absence of signals. The usual frequency modulation receiver produces a roar of noise when there is no signal present. This is due to the fact that the limiter increases the gain of the receiver so as to amplify the noise to full volume. However, with the present type of frequency divider-limiter network, the gain of the receiver may be adjusted so that the threshold of the divider is just above the noise level. Hence, there will be no output voltage unless a signal is present which is stronger than, and over-rides, the noise level. It will, therefore, be appreciated that the present frequency division network improves the signal to noise ratio at the demodulator input circuit by virtue of a conjoint action of the division of the band width of the frequency modulated carrier waves and the threshold action of the network itself. Furthermore, by virtue of the improved selectivity and the limiting action distortion is greatly minimized.

While I have indicated and described a system for carrying my invention into effect, it will be apparent to one skilled in the art that my invention is by no means limited to the particular organization shown and described, but that many modifications may be made without departing from the scope of my invention, as set forth in the appended claims.

What I claim is:

1. In a frequency division network, a tube provided with at least an electron emission element, an output electrode and at least two cold electrodes located in the electron stream to said output electrode, a source of frequency modulated oscillations of a predetermined mean frequency and predetermined frequency deviation connected to one of said cold electrodes, an output circuit connected to said output electrode, said output circuit being tuned to a subharmonic frequency

$$\frac{F}{N}$$

where F equals said predetermined frequency and N is an integer, a second tube provided with at least an electron emission element, an output electrode and an input electrode, means for impressing from said output circuit upon said second tube input electrode frequency modulated oscillations of said subharmonic frequency and whose deviation is reduced by N, a second output circuit connected to said second tube output electrode, said second output circuit being tuned to a frequency

$$(N\pm 1)\frac{F}{N}$$

and means for applying to said second cold electrode of said first tube frequency modulated oscillations developed across said second output circuit, the gain at said source being chosen sufficiently high so that said first tube threshold is above the noise level whereby oscillations of mean frequency

$$\frac{F}{N}$$

are not developed in said first tube output circuit in the absence of frequency modulated oscillations at said source whose amplitude overrides said noise level, and said first tube additionally functioning as an amplitude limiter in response to said oscillations of mean frequency

$$\frac{F}{N}$$

being produced.

2. In a frequency modulated carrier wave reception system, an input circuit tuned to the center frequency F of said modulated carrier waves, said input circuit having a pass band sufficiently wide to pass a relatively wide range of frequency deviation of the modulated waves, an electron discharge tube provided with at least two signal input electrodes, said input circuit being connected to one of said signal input electrodes, a modulated carrier voltage output circuit for said tube which is tuned to a subharmonic

$$\frac{F}{N}$$

of said center frequency, means for multiplying modulated carrier oscillations produced across said output circuit so as to produce further modulated carrier oscillations whose center frequency is equal to

$$(N\pm 1)\frac{F}{N}$$

and means for applying said last named oscillations to the second signal input electrode of said tube thereby to produce in said output circuit frequency modulated carrier oscillations of a mean frequency

$$\frac{F}{N}$$

and whose frequency deviation is reduced from said wide deviation by N; the gain of the system at said input circuit being chosen to provide a threshold for said tube above the noise level thereby to prevent production of oscillations in said output circuit for input waves below said noise level.

3. In a frequency division network for a frequency modulated carrier wave receiver of the superheterodyne type, a tube provided with at least an electron emission element, an output electrode and at least two cold electrodes located in the electron stream to said output electrode, an intermediate frequency-tuned input circuit connected to one of said cold electrodes, an output circuit connected to said output electrode, said output circuit being tuned to a sub-harmonic frequency

$$\frac{F}{N}$$

where F equals said intermediate frequency and N is an integer, said output circuit having a pass band width which is N times narrower than the pass band width of the said input circuit, a second tube provided with at least an electron emission element, an output electrode and an input electrode, said second tube being connected as a non-oscillating multiplier, means for impressing upon said second tube input electrode voltage of said sub-harmonic frequency, a second output

circuit connected to said second tube output electrode, said second output circuit being tuned to a frequency

$$(N\pm 1)\frac{F}{N}$$

and means for applying to said second cold electrode of said first tube voltage developed across said second output circuit and the gain of the receiver at said tuned input circuit being so chosen that the threshold of the first tube is just above the noise level, the output circuit voltage remaining substantially constant in response to the intermediate frequency energy increasing above said threshold level thereby to provide an amplitude limiting function.

4. In a frequency modulated carrier wave reception system, an input circuit tuned to the center frequency F of said modulated carrier waves, an electron discharge tube provided with at least two signal input electrodes, said input circuit being connected to one of said signal input electrodes, a modulated carrier voltage output circuit for said tube which is tuned to a subharmonic

$$\frac{F}{N}$$

of said center frequency and whose pass band width is reduced N times relative to the input circuit pass band width, the gain of the system at said input circuit being sufficiently high to permit said tube to have a threshold above the noise level, means for multiplying modulated carrier oscillations produced across said output circuit so as to produce frequency modulated carrier voltage whose center frequency is equal to

$$(N\pm 1)\frac{F}{N}$$

and means for applying said last named voltage to the second signal input electrode of said tube and said tube additionally having an amplitude limiting characteristic whereby said oscillations produced in said output circuit remain substantially constant in amplitude in response to said oscillations of means frequency

$$\frac{F}{N}$$

being produced.

5. In a frequency modulated carrier wave reception system, an input circuit tuned to the center frequency F of said modulated carrier waves and having a wide pass band, an electron discharge tube provided with at least two signal input electrodes, said input circuit being connected to one of said signal input electrodes, a modulated carrier voltage output circuit for said tube which is tuned to a subharmonic.

$$\frac{F}{N}$$

of said center frequency and having a pass band reduced N times in width from the input pass band, means for multiplying modulated carrier oscillations produced across said output circuit so as to produce frequency modulated carrier voltage whose center frequency is equal to

$$(N\pm 1)\frac{F}{N}$$

means for applying said last named voltage to the second signal input electrode of said tube, and the gain of said system at said input circuit being so chosen that no modulating carrier voltage is developed across said output circuit until a modulated carrier wave amplitude at said input circuit exceeds a predetermined noise level and said tube having an amplitude limiting characteristic such that voltage at said output circuit remains substantially constant after the wave amplitude at the input circuit exceeds the noise level.

MURRAY G. CROSBY.