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FREQUENCY CONVERSION SYSTEM

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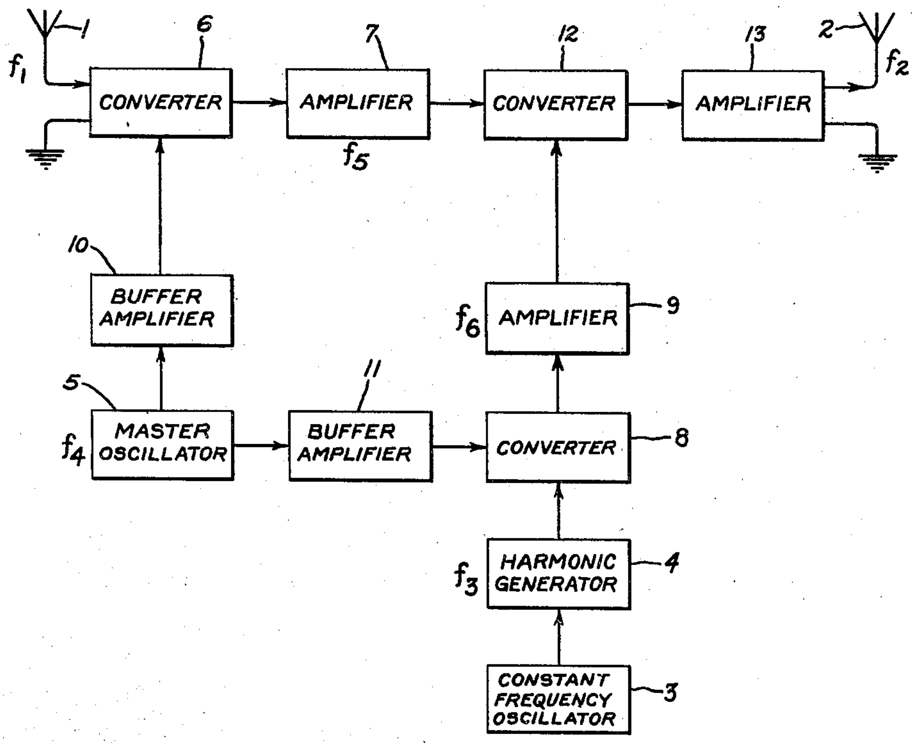

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FREQUENCY CONVERSION SYSTEM

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My invention relates to a frequency conversion system of the double heterodyne conversion type, particularly adapted for converting signal-modulated waves from one high frequency to another high frequency.

The advantages of the double heterodyne conversion system, which comprises a first heterodyne conversion to an intermediate frequency at which the signal-modulated wave is readily amplified, followed by a second heterodyne conversion to the desired resultant frequency, are well known. Such a system requires two locally generated waves of different frequencies for effecting the consecutive conversions. Two independent oscillators may be employed or the two waves may comprise different harmonics of a particular frequency derived from a single oscillator. The former case permits greater flexibility in the choice of frequencies than the latter, but ordinarily the frequency of the resultant output wave is affected by any fluctuations in the frequencies of the two locally generated waves in a random manner. Consequently, the advantages of greater flexibility may be offset either by decreased frequency stability of the output wave or by the expense of providing oscillators of closely controlled frequency.

It is an object of my invention to provide an improved double heterodyne conversion system which employs two separate oscillators and which has both flexibility and desirable characteristics.

Another object of my invention is the provision of such a frequency conversion system adapted for stable operation at very high frequencies.

Another object of my invention is to provide an economical and highly stable double heterodyne conversion system in which the waves generated by one oscillator can be utilized directly in one of the conversions, thereby eliminating the need for intervening frequency multipliers or like devices which may introduce undesirable interfering frequencies.

It is a further object of my invention to provide a double frequency conversion system in which the waves employed for effecting the consecutive conversions are interdependent though derived from independent sources.

Another important object of my invention is the provision of a double heterodyne conversion system in which fluctuations in the frequency of one of the locally generated waves may be compensated so as to have no effect on the frequency of the resultant waves.

The features of my invention which I believe to be novel are set forth with particularity in the appended claims. My invention itself, however, both as to its organization and method of operation, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the accompanying drawing, in which the single figure diagrammatically illustrates one embodiment of my invention.

Referring now to the drawing, the invention is shown embodied in a radio relay station for receiving signal-modulated waves of one frequency and retransmitting or rebroadcasting similarly modulated waves of a different frequency. Since the component elements of the system are all conventional and well known to those skilled in the art, the circuit connections and elements have not been shown in detail but are represented in conventionalized form by a one line diagram.

High frequency waves, which may be modulated in any desired manner, as by audio signals or television video signals, are received by a suitable energy reception device such as the antenna 1 at the left-hand side of the drawing. Waves of a different high frequency, similarly modulated, are to be retransmitted or rebroadcasted by a suitable energy propagation device, such as the antenna 2 at the right-hand side of the drawing. It is of course obvious that the waves may be received and retransmitted by wire lines rather than by the wireless system shown. A local oscillator 3 generates a substantially constant frequency wave utilized in one of the frequency conversions, to be described presently. This oscillator is of conventional design, and frequency stability may be insured in any well-known manner, as by crystal or resonant line control. For the particular embodiment shown, representing a high frequency relay station, the frequency of the oscillator 3 will ordinarily be too low to be used directly, and hence a synchronized harmonic generator 4 is employed, operating at some fixed multiple of the frequency of oscillator 3.

The oscillator employed in this system for producing the second wave utilized in the frequency conversions is the master oscillator 5. As will be explained in detail later, the frequency of this oscillator ordinarily will not be highly constant but may fluctuate, either purposely or through inherent instability. Waves generated by the master oscillator 5 are heterodyned with the received signal-modulated wave in the converter 6 and a selected modulation product resulting from this conversion is supplied to the amplifier 7. The converter 6, often called a detector or mixer, may comprise any one of a number of conventional circuits well known in the art, and it is thought unnecessary to describe it in detail. Briefly, the converter performs the two functions of heterodyning the two waves to produce a group of modulation products and of selecting one desired product as the converter output wave. Waves generated by the oscillator 5 are also heterodyned with waves supplied by the harmonic generator 4 by means of a converter 8, which functions in the same manner as the converter 6, and a selected modulation product is supplied to the amplifier 9. Buffer amplifiers 10 and 11 are preferably interposed between the master oscillator 5 and the converters 6 and 8 to amplify the oscillations and prevent undesirable reactions between the various circuit elements, according to known practice.

The signal-modulated waves supplied to the amplifier 7, as a result of the first conversion, are next subjected to a second conversion in the converter 12 in which they are heterodyned with the waves from the amplifier 9. The selected modulation product of this conversion comprises the signal-modulated output wave which is supplied to the antenna 2. Optionally, it is first further amplified by the amplifier 13 prior to retransmission.

It will be understood, of course, that one or more of the various amplifiers shown may be omitted, or that additional amplifiers may be employed where desirable as, for example, between the antenna 1 and the converter 6.

Since frequency stability of the waves generated by master oscillator 5 is not a primary consideration, the waves may be generated directly at the desired frequency. No frequency multiplying device, such as a harmonic generator similar to the harmonic generator 4 employed with constant frequency oscillator 3, will generally be required even at higher frequencies. This is a distinct advantage in that it reduces the cost and complexity of the apparatus and also minimizes the possibility that undesired parasitic frequencies will be introduced into the circuit, as will be apparent to those skilled in the art.

An important feature of my invention is the manner in which the frequencies of the waves are related. Referring to the drawing, the wave received at the antenna 1 is designated by f_1, indicative of its frequency. Similarly the output wave at antenna 2 is denoted by f_2, the constant frequency wave supplied by the harmonic generator 4 by f_3, the wave supplied by the master oscillator 5 by f_4, the selected modulation product supplied to amplifier 7 by f_5 and the selected modulation product supplied to amplifier 9 by f_6.

The output frequency f_2 is determined by the values of f_1 and either f_3 or f_4, depending on the particular combination of modulation products selected in the three conversions. First assume, as is usually the case, that f_1 and f_2 are arbitrarily selected, and that f_3 is to remain substantially constant. Frequency f_3 is then selected so that f_2 is equal either to the sum or to the difference of f_1 and f_3. If it is selected equal to the sum, obviously f_2 must be greater than f_1, whereas if it is selected equal to the difference, f_2 may be either greater or less than f_1.

Now under the above-assumed conditions, for any chosen value of f_4 a particular combination of the sum or difference frequency modulation products will produce the desired value of f_2. There are a number of combinations which will give f_2, determined by the relative magnitudes of f_1, f_3 and f_4 and on the choice of modulation products.

Under these conditions it is desired to investigate the effect of variations in master oscillator frequency f_4 upon the output frequency f_2. This effect will depend upon the relative magnitudes of f_1, f_3 and f_4 and upon the particular modulation products f_5 and f_6 selected. However, for any possible combination a variation in f_4 will produce one of two results: either the frequency variation in f_4 will not vary f_2 at all, or it will produce twice this frequency variation in f_2. Thus the frequency variation in f_4 will either be compensated completely or multiplied as far as its effect upon f_2 is concerned.

In some situations it may be desirable to utilize the frequency multiplication effect just described, but in the particular embodiment illustrated it is desired to utilize the frequency compensation effect. As stated, there are a number of different combinations of the sum or difference frequency modulation products f_5 and f_6 which will produce this compensation effect. In general, there are two possible combinations of these principal modulation products for any selected values of f_1, f_3 and f_4. It can also be stated as a general rule that if the selected modulation products f_5 and f_6 vary in the same sense as variations in f_4, then f_2 must be their difference frequency product; whereas, if the selected modulation products f_5 and f_6 vary in the opposite sense with variation in f_4, then f_2 must be their sum frequency product. If it is desired to utilize the frequency multiplication effect, obviously the converse is true.

To illustrate these rules more clearly tables are presented below of some possible combinations of frequencies which will eliminate the effect of variations in master oscillator frequency f_4 upon the output frequency f_2. Table I immediately below illustrates various frequency relationships which will maintain f_2 independent of variations in f_4 for the case where f_2 has been selected equal to the difference between f_1 and f_3.

Table I

Relative magnitudes of f_1, f_3 and f_4	Select f_5 as the sum or difference product of f_1 and f_4, as indicated below	Select f_6 as the sum or difference product of f_3 and f_4, as indicated below	Select f_2 as the sum or difference product of f_5 and f_6, as indicated below
$f_4 \gtreqless$ both f_1 and f_3	Sum	Sum	Difference.
	Difference	Difference	Difference.
$f_1<f_4<f_3$ or $f_3<f_4<f_1$*	Sum*	Sum*	Difference.*
	Difference	Difference	Sum.

Thus in the first case above, when f_4 is either greater than or less than both f_1 and f_3, f_5 may be selected as the sum frequency product of f_1 and f_4, f_6 as the sum frequency product of f_3 and f_4, and f_2 as the difference frequency product of f_5 and f_6; or f_5 may be selected as the difference frequency product of f_1 and f_4, f_6 as the difference frequency product of f_3 and f_4, and f_2 as the difference frequency product of f_5 and f_6.

Table II below illustrates various frequency relationships which will maintain f_2 independent of variations in f_4 for the case where f_2 has been selected equal to the sum of f_1 and f_3.

Table II

Relative magnitudes of f_1, f_3 and f_4	Select f_5 as the sum or difference product of f_1 and f_4, as indicated below	Select f_6 as the sum or difference product of f_3 and f_4, as indicated below	Select f_2 as the sum or difference product of f_5 and f_6, as indicated below
f_4<both f_1 and f_3	Sum	Difference	Sum.
	Difference	Sum	Sum.
$f_1<f_4<f_3$	Sum	Difference	Sum.
	Difference	Sum	Difference.
$f_3<f_4<f_1$	Sum	Difference	Difference.
	Difference	Sum	Sum.
f_4>both f_1 and f_3	Sum	Difference	Difference.
	Difference	Sum	Difference.

Summarizing the above rules, if f_1, f_2 and one oscillator frequency are selected, then for any value of the other oscillator frequency a combination of modulation products can be selected to give the desired result. For example, in an actual installation of the system shown in the drawing it was desired to convert a band of signal-modulated waves having a carrier frequency of 157.25 mc. to an identical band having a carrier frequency of 67.25 mc. The combination of frequencies indicated by asterisks (*) in Table I above was selected. The actual values of the various frequencies were as follows:

f_1=157.25 mc.
f_2=67.25 mc.
f_3=90 mc.
f_4=128.75 mc.
f_5=28.5 mc.
f_6=38.75 mc.

It will be seen that with the frequencies so chosen, f_4 increases due, for example, to instability of the master oscillator 5, f_1 and f_3 remaining constant, this increase in frequency produces a decrease in frequency f_5 and an increase in frequency f_6. The sum, f_2, of f_5 and f_6 is therefore unaffected by this change in frequency.

These particular values were chosen for practical reasons to permit conversion from one very high frequency to another high frequency with a much lower intermediate frequency at which the signal-modulated waves could be readily amplified.

It will be seen that I have provided a simple frequency conversion system having the flexibility of the double heterodyne system employing independent oscillators while retaining the frequency stability of the single oscillator system.

While I have shown one form of my invention embodied in a radio relay station, it will of course be understood that I do not wish to be limited thereto. As previously mentioned, there may be occasions when it is desirable to utilize the frequency multiplication effect which can be obtained by suitable combinations of selected modulation products. Thus, the frequency of the master oscillator 5 may be varied purposely in order to frequency modulate the output wave by twice that amount. Furthermore, by selecting modulation products in the three conversions which are higher harmonics of the combining frequencies, rather than the principal sum or difference frequency products, the frequency multiplication effect can be amplified to give a frequency variation of the output wave greater than twice the frequency variation in oscillator 5. The tables above illustrate only combinations of principal modulation products giving the frequency compensation effect. It is not thought necessary to enumerate combinations producing the converse effect since these are thought to be obvious from the above description. Since this and many other modifications may be made, both in the circuit arrangement and instrumentalities employed, I contemplate by the appended claims to cover any such modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. The method of converting electrical waves of a first frequency to waves of a second frequency which comprises the steps of producing waves of a third frequency, producing waves of a fourth frequency, combining the waves of said first and third frequencies to produce a resultant frequency, combining the waves of said third and fourth frequencies to produce a second resultant frequency, and combining said resultant frequencies to produce said second frequency waves.

2. The method of frequency conversion which comprises the steps of receiving signal-modulated waves of a first frequency, generating waves of a second, substantially constant frequency, generating independently waves of a third frequency subject to frequency variations, heterodyning the waves of said first and third frequencies to produce a first modulation product the frequency of which is affected by said variations, heterodyning the waves of said second and third frequencies to produce a second modulation product the frequency of which is also affected by said frequency variations and heterodyning said modulation products to produce a resultant wave the frequency of which is unaffected by said variations.

3. In a frequency conversion system for converting electrical waves of a first frequency to waves of a second frequency, the combination of an oscillator for generating waves of a third frequency, a second oscillator for generating independently waves of a fourth frequency, a converter for combining the waves of said first and fourth frequencies and for selecting a desired modulation product, a converter for combining the waves of said third and fourth frequencies and for selecting a second desired modulation product, and a converter for combining said selected modulation products and for selecting as a resultant modulation product waves of said second frequency.

4. A system for the conversion of signal-modulated waves of a first high frequency to similarly modulated waves of a second high frequency comprising means for receiving the waves of said first frequency, a source of waves of a third high frequency subject to frequency variations, means for heterodyning the waves of said first and third frequencies to produce waves of a resultant frequency, means for utilizing said resultant frequency waves to produce the waves of said second frequency, and means for preventing said frequency variations from having any effect upon the frequency of said second frequency waves.

5. In a double heterodyne conversion system, means for receiving waves of a first frequency, an oscillator for generating waves of a second, substantially constant frequency, a second oscillator for generating independently waves of a third

frequency subject to frequency fluctuations, a converter for heterodyning the waves of said first and third frequencies to produce a modulation product the frequency of which is affected by said fluctuations, a second converter for heterodyning the waves of said second and third frequencies to produce a second modulation product the frequency of which is also affected by said fluctuations, and a third converter for heterodyning said modulation products to produce a resultant wave the frequency of which is unaffected by said fluctuations.

6. In a system for converting electrical waves of a first frequency to waves of a second frequency, the combination of a source of waves of a third frequency, a source of waves of a fourth frequency, means for combining the waves of said first and fourth frequencies to produce a resultant frequency, means for combining the waves of said third and fourth frequencies to produce a second resultant frequency, and means for combining said resultant frequencies to produce said second frequency waves.

7. The combination in a frequency conversion system, of means for receiving waves of a first frequency, means for generating waves of a second, substantially constant frequency, means for generating independently waves of a third frequency subject to frequency variations, means for combining the waves of said first and third frequencies to produce a pair of sum and difference frequency products the frequencies of which are affected by said variations and for selecting one product from said pair, means for combining the waves of said second and third frequencies to produce a second pair of sum and difference frequency products the frequencies of which are also affected by said variations and for selecting one product from said second pair, means for combining said selected products to produce a third pair of sum and difference frequency products and for selecting as a resultant wave one product of said third pair the frequency of which is unaffected by said variations.

8. In a frequency conversion system for converting received, signal-modulated waves of a first high frequency to similarly modulated waves of a second high frequency, the combination of an oscillator for generating waves of a third, substantially constant high frequency, a second oscillator for generating waves of a fourth high frequency subject to frequency variations, a first converter for combining the waves of said first and fourth frequencies to produce sum and difference frequency products and for selecting one product affected by said variations in one sense, a second converter for combining the waves of said third and fourth frequencies to produce sum and difference frequency products and for selecting one product affected by said variations in the opposite sense, and a third converter for combining said selected products to produce sum and difference frequency products and for selecting their sum frequency product as said second high frequency waves.

9. In a frequency conversion system for converting received, signal-modulated waves of a first high frequency to similarly modulated waves of a second high frequency, the combination of an oscillator for generating waves of a third, substantially constant high frequency, a second oscillator for generating waves of a fourth high frequency subject to frequency variations, a first converter for combining the waves of said first and fourth frequencies to poduce sum and difference frequency products and for selecting one product affected by said variations in one sense, a second converter for combining the waves of said third and fourth frequencies to produce sum and difference frequency products and for selecting one product affected by said variations in the same sense, and a third converter for combining said selected products to produce sum and difference frequency products and for selecting their difference frequency product as said second high frequency waves.

10. A radio relay station for receiving signal-modulated waves of a first high frequency and for retransmitting similarly modulated waves of a second high frequency, comprising, in combination, a first oscillator for generating waves of a third substantially constant high frequency equal to the difference between said first and second frequencies, a second oscillator for generating waves of a fourth high frequency intermediate said first and third frequencies and subject to frequency fluctuations, a first converter for heterodyning together the waves of said first and fourth frequencies and for selecting their difference frequency product, a second converter for heterodyning together the waves of said third and fourth frequencies and for selecting their difference frequency product, a third converter for heterodyning together said selected products and for selecting their sum frequency product as said second high frequency waves and means for retransmitting said second high frequency waves.

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