

[72]	Inventor	Anthony G. Muzzi 6703 Marsh Ave., Huntsville, Ala. 35806
[21]	Appl. No.	788,821
[22]	Filed	Jan. 3, 1969
[45]	Patented	Dec. 14, 1971

**[54] AMPLITUDE MODULATION INTENSIFIER
METHOD AND APPARATUS
7 Claims, 9 Drawing Figs.**

[52] U.S. Cl. 325/438,
325/305, 325/329, 325/431
[51] Int. Cl. H04b 1/26
[50] Field of Search. 325/301,
307, 430, 435, 439, 432, 442, 473, 474, 476, 487,
305, 431, 438, 329; 343/206, 205, 176, 180;
329/50, 163, 164, 166, 146

[56] **References Cited**

UNITED STATES PATENTS

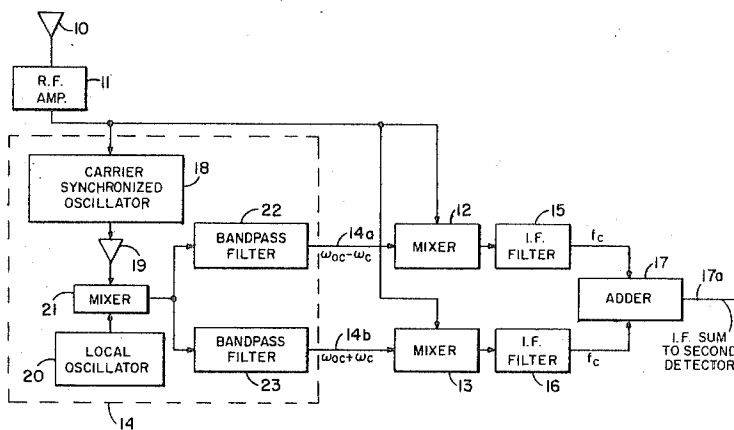
2,493,093	1/1950	Sussman.....	325/329 X
2,924,706	2/1960	Sassler.....	325/329
2,955,199	10/1960	Mindes.....	343/206 X

Primary Examiner—Robert L. Griffin

Assistant Examiner—R. S. Bell

Attorneys—Harry M. Saragovitz, Edward J. Kelly, Herbert Berl and Aubrey J. Dunn

ABSTRACT: An amplitude-modulated RF carrier wave is separately mixed with two phase-locked frequency waves, one lower than the carrier by an amount equal to a desired intermediate frequency, and the other higher by the same amount. The two resulting IF's are added to give an IF output with an improved signal-to-noise ratio over the RF wave. The inventive apparatus includes the necessary means for generating the two waves, for mixing, etc.



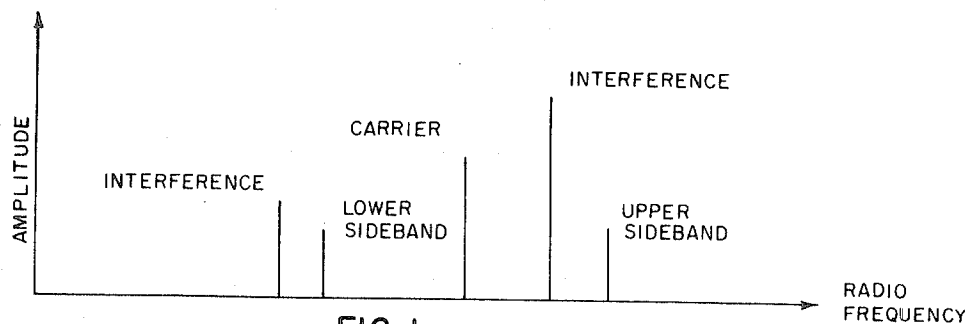


FIG. 1

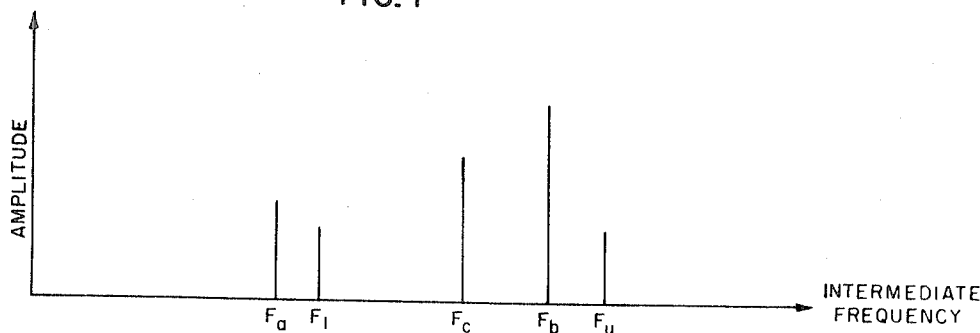


FIG. 2

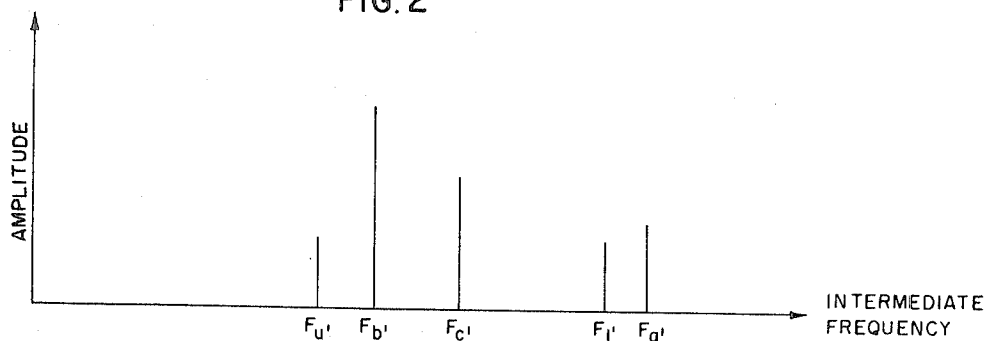


FIG. 3

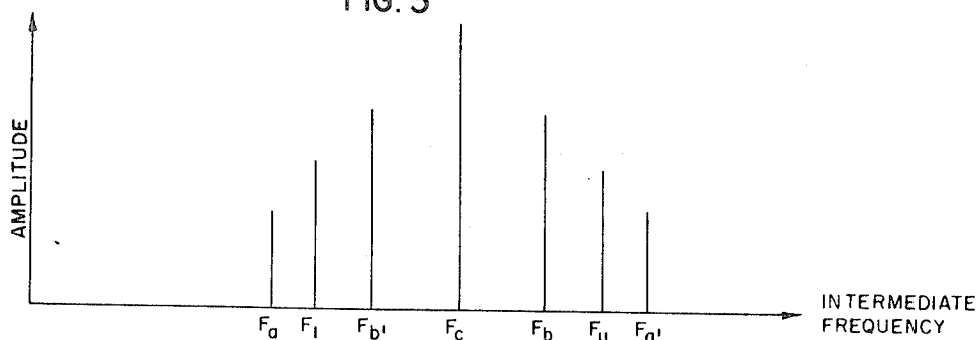


FIG. 4

Anthony G. Muzzi
INVENTOR.

Harry M. Saragovitz
Edward J. Kelly
Herbert Bail
Aubrey J. Dunn

BY

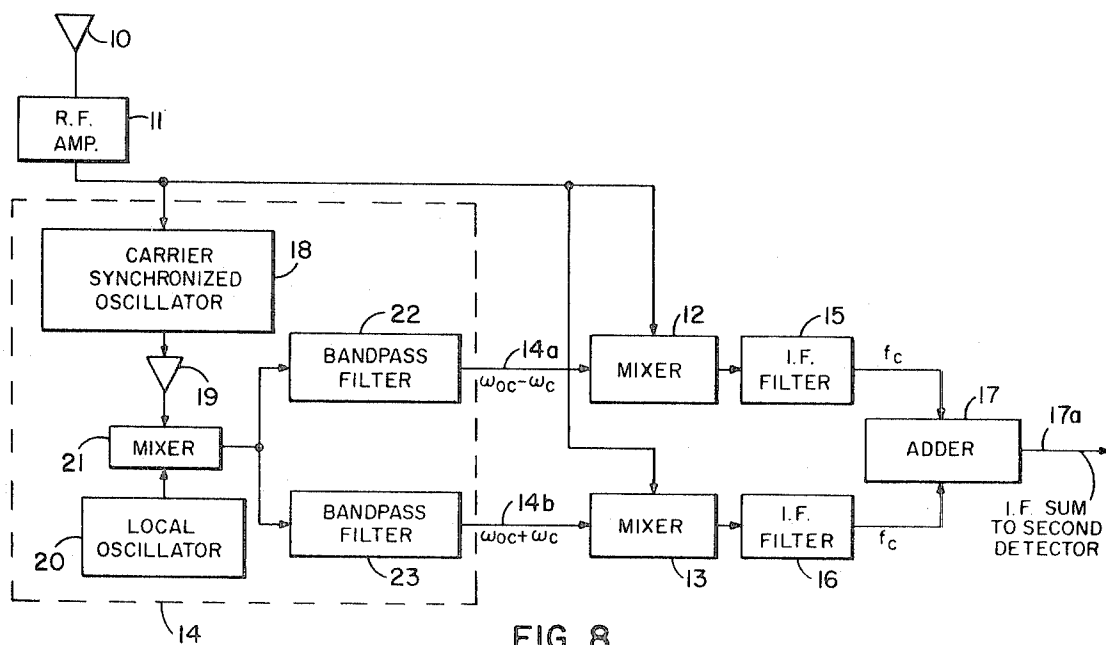


FIG. 8

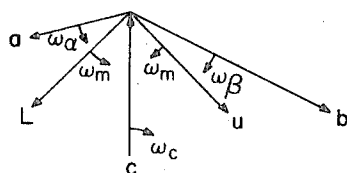


FIG. 5

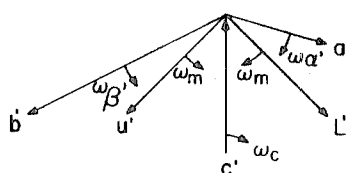


FIG. 6

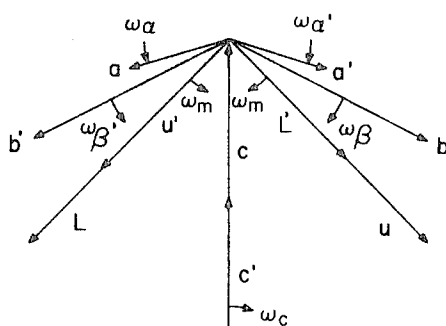


FIG. 7

Anthony G. Muzzi

INVENTOR

Harry M. Saragovitz
Edward J. Kelly
Harbert Hall
Aubrey J. Dunn

BY

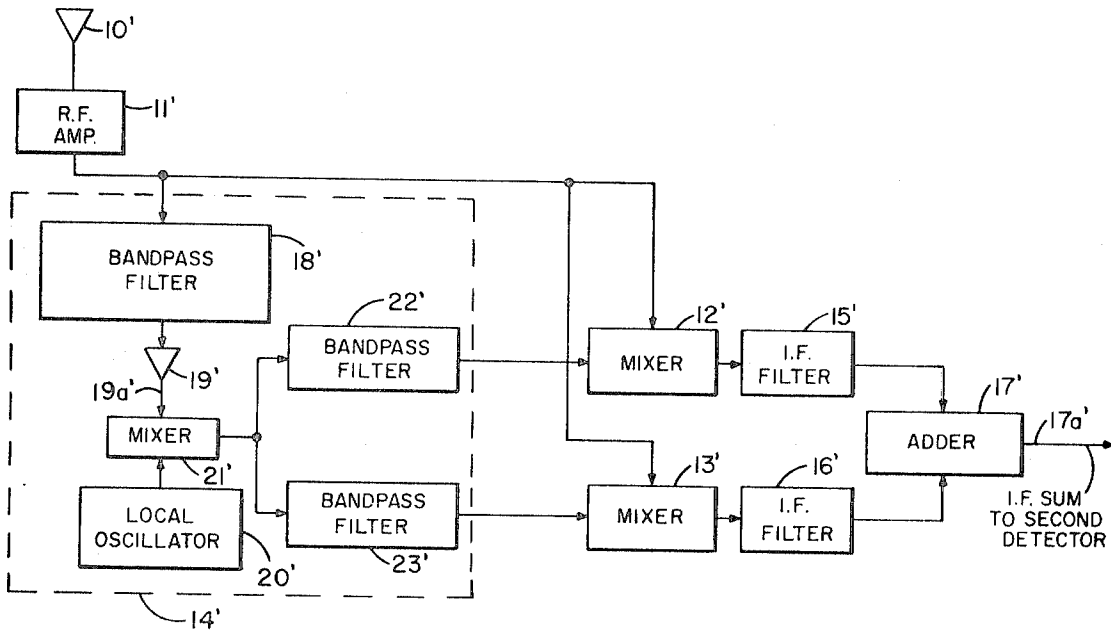


FIG. 9

Anthony G. Muzzi

INVENTOR

Harry M. Saragovitz
Edward J. Kelly
Herbert Beil
Aubrey J. Dunn

BY

AMPLITUDE MODULATION INTENSIFIER METHOD AND APPARATUS

BACKGROUND OF THE INVENTION

In recent years there has been a steady decrease of interest in pure amplitude modulation for use in propagated audio communication. Interest has shifted to modulation methods such as single sideband-suppressed carrier, double sideband, etc. The dominant reason for this shifting interest in pure amplitude modulation is due to the inefficiency of converting source power into radiated information power. There are of course other reasons for the shifting interest, such as bandwidth conservation. However, all of the added complexities required to generate special modulated signals were motivated predominantly by the desire to propagate the most information power from the transmitting antenna.

The disadvantage to the pure AM signal is that the signal power is divided among carrier and upper and lower sidebands while the information is contained in one sideband. It does seem to be a rather wasteful distribution. Suppose, however, that the upper and lower sidebands at the receiver are combined in such a way as to add the voltage amplitudes in phase. Since the sideband amplitudes for a theoretical AM signal are equal, the result would be to double the sideband voltage levels. This provides a 6 db. gain in signal strength or the equivalent of quadrupling the received information power. If this operation is performed on the desired signal and not on the noise, a substantial increase in signal to noise ratio will be realized.

SUMMARY OF THE INVENTION

A method and apparatus whereby the signal-to-noise ratio of an AM signal may be enhanced. The invention apparatus compares the frequency spectrum on either side of the signal carrier for frequency and phase symmetry. For a theoretical AM signal, the beat frequencies between the sidebands and the carrier are equal and in phase. The apparatus described herein properly conditions and vectorially adds the sideband signals.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows the RF frequency spectrum of an AM signal, with interference (noise) present.

FIG. 2 shows a frequency spectrum of a normal IF signal derived from the FIG. 1 signal.

FIG. 3 shows a frequency spectrum of an inverted IF signal derived from the FIG. 1 signal.

FIG. 4 shows a frequency spectrum of a sum IF signal derived from the FIGS. 2 and 3 signals.

FIGS. 5, 6, and 7 show various signal vector presentation.

FIG. 8 shows one embodiment of the inventive apparatus.

FIG. 9 shows another embodiment of the invention apparatus.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

As stated earlier, the inventive apparatus operates on the principle of comparing the frequency spectrum above and below the carrier for symmetry to the carrier. The first function that must be performed by the AM discriminator, therefore, is to prepare the AM signal so that this comparison can be performed.

Consider the signal whose frequency spectrum is shown in FIG. 1. This represents the original AM signal which it is desired to discriminate, plus two arbitrarily chosen interference signals (one in the upper sideband frequency spectrum and one in the lower sideband frequency spectrum). For the sake of this disclosure, it is assumed that the carrier is modulated by a single modulating sine wave. The resulting modulated wave will show the carrier with equal height, equally spaced sidebands, if displayed on a spectrum analyzer.

If this signal is heterodyned to a lower intermediate frequency with a local oscillator whose frequency is less than the

original carrier, the frequency spectrum of the intermediate frequency signal will appear the same as the original AM signal in FIG. 1. The only difference will be that all of the signal frequencies will be reduced by an amount equal to the local oscillator frequency. This frequency spectrum will be referred to as the *normal* frequency spectrum (see FIG. 2).

If the original signal is heterodyned with a local oscillator whose frequency is higher than the original AM carrier, the frequency spectrum of the intermediate frequency will be as shown in FIG. 3. Here the frequency spectrum is inverted; i.e., those signals which were higher than the original carrier will be lower than the intermediate frequency carrier. This frequency spectrum will be referred to as the *inverted* frequency spectrum.

The IF carrier frequency in both of the above cases is determined by the difference in frequency between the original carrier and the local oscillator. If both local oscillators are chosen such that the IF carriers produced are at exactly the same frequency and in phase, a comparison can be performed on the sideband symmetry. The lower sideband of the normal frequency spectrum is at the same frequency and in phase with the upper sideband of the inverted frequency spectrum and vice versa. The two local oscillator frequencies may be provided in several ways, two of which will be shown hereinafter.

If the two IF signals of the FIGS. 2 and 3 are added, the frequency spectrum for the resulting signal is as shown in FIG. 4.

Observation of the frequency spectrum of the FIG. 4 IF sum signal indicates that the sideband signals are added while the unwanted signals remain unchanged in amplitude.

In the above-stated description of the the phasing of the AM intensifier the addition has been illustrated in the frequency domain for the purpose of simplicity. In this type of description, there is a complete disregard for the phase angle of the signals being added. This is obviously a fallacy since two signals being added to produce another signal of the same frequency with peak amplitude ranging from zero to the sum of the peaks depending upon the phasing. It is, therefore, necessary to analyze the phasing of the signals to be added. This will now be performed with the aid of vector presentation.

Consider the vector presentation of the signal shown in FIG. 5. This represents the normal IF signal. The vertical vector C represents the carrier. The rotational direction of the carrier vector is clockwise as shown. The angular velocity is ω_c . The upper sideband vector, U, is shown with a clockwise rotational direction, the same as the carrier. Its angular velocity with reference to the carrier is ω_m (2π times the modulating frequency). Its total angular velocity is therefore $\omega_c + \omega_m$. It should be noted that all vectors with a clockwise rotational direction will have total angular velocities greater than the carrier; i.e., they will be at a higher frequency than the carrier. The interference signal represented by vector B is rotating clockwise with an angular velocity relative to the carrier of ω_i . Its total angular velocity is $\omega_c + \omega_i$. The lower sideband vector, L, is rotating counterclockwise with angular velocity ω_m relative to the carrier.

The total angular velocity of the lower sideband signal is therefore $\omega_c - \omega_m$. It should be noted that both the upper and lower sideband vectors have the same angular velocity of ω_m with respect to carrier. The only difference being the direction of rotation. The interference vector A is rotating counterclockwise with angular velocity relative to the carrier of ω_i . The total angular velocity of the signal is $\omega_c - \omega_i$. Thus far, the normal IF signal vector presentation has been analyzed and the groundwork has been laid as to the technique that is employed to understand the vector presentation.

FIG. 6 is a vector presentation of the inverted IF signal. The rotational direction of the carrier was chosen to remain as in FIG. 5 and will remain the same for any instant. All vectors are now denoted with a prime to indicate they resulted from the inverter IF signal.

FIG. 7 is a vector presentation of the IF sum signal. It is the result of vectorially adding FIG. 6 and FIG. 7. It can be seen that only signals symmetric to the carrier in both phase and angular velocity will add directly. The unwanted signals now appear as sidebands modulated on the carrier, but not added in magnitude.

Since the interference now appears as sidebands to the carrier, any attempt to repeat the AM intensifier on the IF Sum signal would prove fruitless. The total signal would be increased by 6 db. with no improvement in signal-to-noise ratio.

The key to the Amplitude Modulation intensifier is to produce two local oscillator signals such that when they heterodyne with the original signal, the IF carriers will be at the same frequency and in phase with each other.

FIG. 8 shows a system including the usual antenna 10 for receiving AM signals, and may include an RF amplifier 11, if desired. The output of 11 is fed to mixers 12 and 13. Numeral 14 designates a device for providing two local oscillator signals symmetrical in frequency to the RF carrier. This system includes a local oscillator 20 feeding one input of mixer 21. Said mixer 21 has another input fed from a carrier synchronized oscillator 18, by way of amplifier 19. Obviously, amplifier 19 may be omitted, if the signal (ω_{oc}) from 18 is of sufficient strength. Oscillator 18 is synchronized in frequency and phase with the RF carrier output of amplifier 11. The output of local oscillator 20 is at the desired IF center frequency (f_c) of IF filters 15 and 16, wherein $f_c = \omega_c/2\pi$. The output of mixer 21 is the modulation products of the RF carrier and the local oscillator. Band-pass filters 22 and 23 provide outputs on lines 14a and 14b, which are respectively the difference and sum modulation products. The signal on line 14a is $\omega_{oc} - \omega_c$, and the signal on the line 14b is $\omega_{oc} + \omega_c$. The signals on lines 14a and 14b are respectively mixed with the RF signals in mixers 12 and 13, which mixers provide outputs including the IF signal f_c . IF filters 15 and 16 each pass said f_c , and AM sidebands of f_c . Adder 17 has two inputs connected respectively to the outputs of filters 15 and 16, vectorially adds these two outputs. The sum output of 17 appears on line 17a, and may pass to the usual second detector, etc. It should be noted that the output on 14a is at a frequency lower than the carrier of the AM signals by the desired IF, and the 14b output is at a frequency higher than the said carrier by the same IF. The output of mixer 12 is thus a normal IF spectrum as shown in FIGS. 2 or 5, and the output of mixer 13 is an inverted IF spectrum as shown in FIGS. 3 or 6. The output on line 17a is a signal similar to the original, except that it is at an IF and the amplitude of the sidebands, relative to the noise, has been increased, giving an obvious signal-to-noise improvement. With sidebands of equal amplitude, the information power is effectively quadrupled, without affecting the noise level to any large degree.

FIG. 9 is similar to FIG. 8, with primed numerals used to show corresponding elements. FIG. 9 differs in the manner in which the local frequencies for the mixers are obtained. Antenna 10' and RF amplifier 11' are the same as in FIG. 8, but element 14' includes band-pass filter 18' connected between 11' and amplifier 19'. Local oscillator 20' is connected to one input of mixer 21'. The other input of 21' is on lead 19'a from amplifier 19'. Band-pass filter 18' passes only the carrier of the AM signal. If the output of RF amplifier 11' is sufficient, amplifier 19' may be omitted. In either event, the mixer of the RF carrier from line 19' and the local oscillator frequency in mixer 21 provides an output having sum and difference frequencies in like manner to FIG. 8. These frequencies are filtered by band-pass filters 22 and 23. Elements 12', 13', 14', 15', 16', and 17' of FIG. 9 correspond exactly to their respective elements in FIG. 8, and the output on lead 17'a of FIG. 9 is the same (for the same RF signal) as that on line 17a of FIG. 8. The same signal-to-noise improvement as discussed with FIG. 8 is obtained.

While the invention has been discussed with audio communication in mind, it obviously would be useable with any desired AM information.

I claim:

1. A method of intensifying signals carried by an amplitude modulated carrier, including the steps of:

simultaneously mixing said carrier with a first local frequency higher than said carrier by a predetermined intermediate frequency and a second local frequency lower than said carrier by said intermediate frequency, to produce first and second intermediate frequency spectrums;

band-pass filtering said first and second spectrums to obtain two intermediate frequency signals; and adding said two intermediate frequency signals.

2. The method as set forth in claim 1 wherein said local frequencies are generated by:

band-pass filtering said carrier;

mixing the resulting wave with the output of a local oscillator; and

band-pass filtering the resulting mixture to obtain said first and second local frequencies.

3. The method as set forth in claim 1 wherein said local frequencies are generated by:

synchronizing a first local oscillator with said carrier;

mixing the resulting wave with the output of a second local oscillator; and

band-pass filtering the resulting mixture to obtain said first and second local frequencies.

4. The method as recited in claim 1 wherein said two intermediate frequency signals have fundamental frequencies of identical frequency and phase.

5. An apparatus for intensifying signals carried by an amplitude-modulated RF carrier including: RF-receiving means; first and second mixers each having first and second inputs and an output;

frequency providing means having at least two outputs for providing respectively a first local frequency higher than said carrier by a predetermined intermediate frequency

and a second local frequency lower than said carrier by said intermediate frequency on said outputs;

said RF-receiving means connected to said first input of each of said mixers, and one each of said outputs of said frequency providing means respectively connected to one each of said second inputs of said mixers;

first and second IF filters each having an input and an output; and adder means having two inputs and an output;

wherein said output of said first mixer is connected to the said input of said first IF filter, and said output of said second mixer is connected to said input of said second IF filter, and said outputs of said filters are connected to respective inputs of said adder and said frequency providing means includes:

a carrier band-pass filter connected to said receiving means; a mixer having two inputs and an output, with one of said inputs connected to said band-pass filter;

an oscillator having an output connected to the other input of said mixer;

first and second band-pass filters, each having an input connected to the output of said mixer, and each having an output.

6. The apparatus as defined in claim 5, wherein said outputs of said first and second IF filters have fundamental frequencies identical in frequency and phase.

7. An apparatus for intensifying signals carried by an amplitude modulated RF carrier including:

RF-receiving means;

first and second mixers each having at least first and second inputs and an output;

frequency providing means having at least two outputs for providing a first local frequency higher than said carrier by a predetermined intermediate frequency and a second local frequency lower than said carrier by said intermediate frequency on said outputs;

said RF-receiving means connected to said first input of each of said mixers and one each of said outputs of said frequency-providing means respectively connected to one each of said second inputs of said mixers;

first and second IF filters each having an input and an output; and
adder means having two inputs and an output;
wherein said output of said first mixer is connected to the input of said first IF filters, and said output of said second mixer is connected to said input of said second IF filter, and said outputs of said filters are connected to respective inputs of said adder and said frequency-providing means includes:
a carrier synchronized oscillator connected to said receiving

means;
a mixer having two inputs and an output with one of said inputs connected to said carrier-synchronized oscillator;
a local oscillator having an input connected to the other input of said mixer;
first and second band-pass filters each having an input connected to the output of said mixer, and each having an output.

* * * * *

15

20

25

30

35

40

45

50

55

60

65

70

75