

A WIDE BANDWIDTH DISCRIMINATOR FOR USE IN A RADIO RECEIVER

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Field of the Invention

The present invention is related to radio frequency (RF) receivers and particularly to the construction of a discriminator circuits for use in such a receiver.

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Background of the Invention

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RF communication systems employing angle modulation (e.g., frequency modulation (FM) or phase modulation (PM)) for transmission of data, have historically been extremely susceptible to the deleterious effects of co-channel interference.

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Co-channel interference is caused by the transmission of a signal from a nearby source on the communications channel of concern. As is known, conventional FM receivers suffer from the basic inability to distinguish a desired signal from an undesired signal transmitted by an interfering source, especially when the transmissions are on the same communications channel (i.e., frequency).

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In order to overcome this shortcoming and guarantee adequate levels of system performance, communication systems employing FM receivers often require that all such receivers must maintain a predetermined desired signal (i.e., carrier) to interference (C/I) ratio. Typical cellular communication systems, such as the Advanced Mobile

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Phone Service (AMPS) or Narrow band Advanced Mobile Phone Service (NAMPS) cellular systems deployed by Motorola Inc. requires a C/I ratio of at least 18 decibels (dB). While 18dB of separation between the
5 desired carrier and an interference source is adequate to protect the system from co-channel interference, it nonetheless fails to maximize spectral efficiency, especially when one of the known frequency reuse schemes is also employed by the system in question.

10 It would be extremely advantageous therefore to provide a radio receiver architecture which operates at a lower C/I separation than is taught by the prior art, in the effort to increase overall spectral efficiency without adversely impacting system performance. Of
15 note, additional information on the AMPS and NAMPS systems has in the past been available by contacting Motorola Inc. at 1303 East Algonquin Road, Schaumburg, Illinois 60196.

20 Summary of the Invention

Briefly described the present invention is a wide bandwidth frequency discriminator circuit for use within a radio receiver. The discriminator employs a
25 wide bandwidth limiting amplifier that amplifies the IF signal portion of a received RF signal to provide an amplified output signal. A delay circuit, coupled to the amplifier, provides a delayed representation of the amplified output signal to a multiplier circuit. The
30 multiplier in turn provides a product signal which is the product of the amplified output signal and the delayed representation of the amplified output signal. As will be appreciated, said product signal will be

proportional to the phase difference between the amplified output signal and the delayed representation of the amplified output signal.

5 Brief Description of the Drawings

FIG. 1 is a block diagram representation of an FM receiver circuit as is known in the art; and

10 FIG. 2 is a block diagram representation of a portion of the FM receiver of FIG. 1 showing the discriminator circuit of the present invention.

Description of a Preferred Embodiment

15 FIG. 1 is a block diagram representation of an FM receiver 100 as is known in the art. For purposes of this discussion, receiver 100 may be divided into a front end section and a back end section. The front end section comprises an antenna 101, RF filter 102, RF
20 amplifier 104, mixer 106, local oscillator 108 and an IF filter 110. The back end section comprises an IF amplifier 112, a discriminator 114 circuit and a output terminal 116.

During operation, RF signals as received by
25 antenna 101, applied to RF filter 102 and amplified by RF amplifier 104 may contain both a desired signal and an interfering signal. The interfering signal will typically exhibit a different amplitude than the desired signal, but the interfering signal and the
30 desired signal may exhibit nearly identical frequencies. The term carrier-to-interference (C/I) ratio is therefore used to characterize the received RF energy and represents the amplitude of the desired

signal divided by the amplitude of the interfering signal.

As is known in the art mixer 106 down-converts the received RF signal into an IF signal by mixing it with
5 a signal from local oscillator 108. This IF signal preserves the carrier to interference ratio of the received RF signal, as well as the frequencies of the desired and interfering signals. IF filter 110
10 provides predetection filtering of all signals falling within the nominal RF bandwidth of the desired ensemble of signals for which the receiver is intended.

Amplifier 112 represents a non linear device which eliminates all amplitude variations in the signal presented, but preserves all phase variations. The
15 amplified IF signal is then passed to discriminator 114 which operates to detect data within the output of the filtered IF signal.

As is known in the art, prior art discriminators are designed to operate at a frequency bandwidth that
20 is nearly identical to the bandwidth of the IF signals upon which they operate. In the presence of interference, however, frequencies outside of the nominal IF bandwidth are typically present at the output of IF amplifier 112. When a narrow band
25 discriminator is employed the high frequency components of these signals are amplitude limited, thereby leaving only the in band (i.e., IF frequency) frequency components. It will be appreciated by those skilled in the art, that these in band frequency components of
30 interference cause the greatest distortion of the desired signal. For further information on this subject the interested reader is referred to Proceedings of the IRE, "Theory of Stronger-Signal

Capture in FM Reception" by Elie J. Baghdady, April 1958, pgs. 728-738.

5 In order to properly detect and discriminate all interference components, the discriminator circuit of the present invention employs a bandwidth that is greater than the bandwidth of those signals present at the output of the IF amplifier 112.

10 FIG. 2 is a block diagram representation of a portion of the FM receiver 100 of FIG. 1 showing the discriminator circuit 200 of the present invention. The discriminator circuit 200 comprises a wide band limiting amplifier 202, a multiplier 206 and a delay circuit 204.

15 During operation, an IF signal from IF filter 110 is applied to the input of the wide band limiting amplifier 202. Such wide band limiting amplifiers are known in the art and require no additional discussion. As previously mentioned, the received IF signal preserves the carrier to interference ratio of the received RF signal, as well as the frequencies of the desired and interfering signals. The amplified output signal of the wide band limiting amplifier 202 has a bandwidth that is at least 3 times the bandwidth of the IF signal itself. This amplified output signal is
20 applied to both the delay circuit 204 and multiplier 206.
25

The delay circuit 204 is employed to provide a delayed version of the amplified output signal to multiplier 206. In accordance with the present
30 invention delay circuit 204 may comprise any of the known delay devices such as, but not limited to active filters, passive filters, micro strip transmission lines and coaxial cables. Of importance the bandwidth

of the delay circuit 204 must be greater than or equal to the bandwidth of those signal present at the output of limiting amplifier 202.

Multiplier 206 provides a product signal which is
5 the product of the amplified output signal and the
delayed representation of the amplified output signal
of limiting amplifier 202. The amplitude of the
product signal is proportional to the phase difference
between the amplified and the delayed representation of
10 the amplified output signal. The wide band
discriminator of the present invention when used in
conjunction with wide band limiting amplifier 202
operates to form a detection system capable of
discriminating between a desired and undesired signal
15 even when said signals are nearly identical in
amplitude because of the enhanced frequency response
provided by discriminator circuit 200.

Of note, the bandwidth of multiplier 206 is at
least 3 times greater than the bandwidth of those
20 signals at the output of limiting amplifier 202. While
the present invention suggests the use of a multiplier,
additional multiplying circuitry including but is not
limited to: mixers, analog multipliers and digital
phase detectors, may be substituted without departing
25 from the spirit of the present invention.

30 What is claimed is:



Claims

1. A wide bandwidth frequency discriminator circuit
5 comprising:

an input for receiving an intermediate frequency
(IF) signal;

10 a wide bandwidth limiting amplifier, coupled to
the input and having a first bandwidth, for providing
an amplified output signal;

a delay circuit having a second bandwidth equal to
15 or greater than the first bandwidth, coupled to the
amplifier, for providing a delayed representation of
the amplified output signal; and

a multiplier, coupled to the amplifier and the
20 delay circuit and further having a third bandwidth, for
providing a product signal representation of the
amplified output signal and the delayed representation
of the amplified output signal.

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2. The circuit of claim 1 wherein the third bandwidth is greater than the first and the second bandwidth.
- 5 3. The circuit of claim 1 wherein the delay circuit is selected from the group consisting of:
- active filters
 - passive filters
 - micro strip transmission lines; and
 - 10 coaxial cable.
4. The circuit of claim 1 wherein the multiplier is selected from the group consisting of:
- mixers;
 - 15 analog multipliers; and
 - digital phase detectors.
5. The circuit of claim 1 wherein the product signal is proportional to a phase difference between the
- 20 amplified output signal and the delayed representation of the amplified output signal.
6. The circuit of claim 5 wherein the product signal has a wide bandwidth frequency response.

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7. A wide bandwidth frequency discriminator circuit comprising:

5 an input for receiving an intermediate frequency (IF) signal;

10 a wide bandwidth limiting amplifier, coupled to the input and having a first bandwidth, for providing an amplified output signal;

15 a delay circuit having a second bandwidth equal to or greater than the first bandwidth, coupled to the amplifier, for providing a delayed representation of the amplified output signal; and

20 a multiplier having a third bandwidth greater than the second bandwidth, coupled to the amplifier and the delay circuit, for providing a product signal representation of the amplified output signal and the delayed representation of the amplified output signal.

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8. The circuit of claim 7 wherein the third bandwidth is at least three times greater than the first bandwidth.

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9. A radio frequency (RF) receiver comprising:

5 means for receiving an RF signal comprising data
and converting it to an intermediate frequency (IF)
signal;

10 an IF filter, coupled to the receiving means, for
filtering the IF signal to remove those components
above and below a desired frequency range; and

an FM discriminator circuit, coupled to the
intermediate frequency filter and comprising:

15 a wide bandwidth limiting amplifier having a first
bandwidth, coupled to the IF filter, for providing an
amplified output signal of the filtered IF signal;

20 a delay circuit having a second bandwidth equal to
or greater than the first bandwidth, coupled to the
wide bandwidth limiting amplifier, for providing a
delayed representation of the amplified output signal;
and

25 a multiplier having a third bandwidth at least
three times greater than the first bandwidth, coupled
to the wide bandwidth limiting amplifier and the delay
circuit, for providing a product signal having a wide
bandwidth frequency response.

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10. The radio receiver of claim 9 wherein the product
signal amplitude is proportional to a phase difference
between the amplified output signal and the delayed
5 representation of the amplified output signal.

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FIG. 1

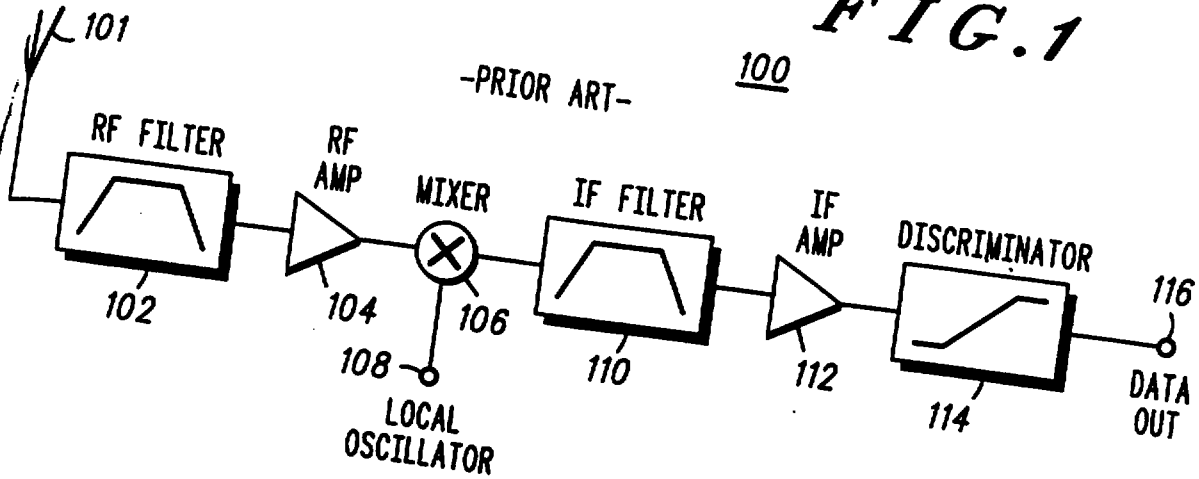
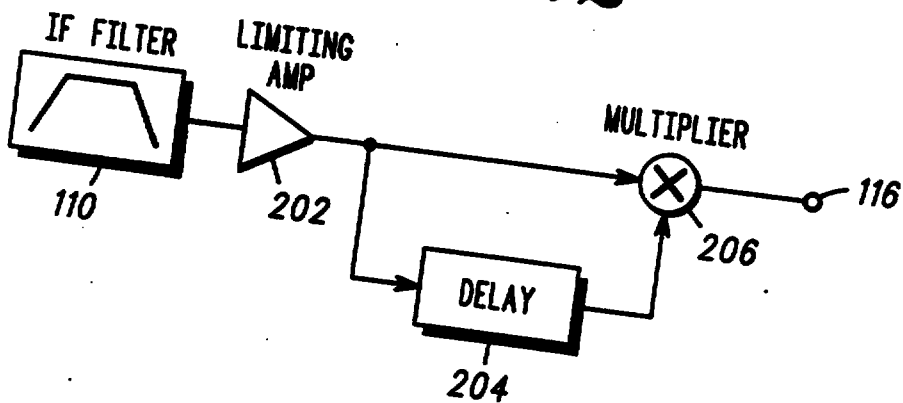
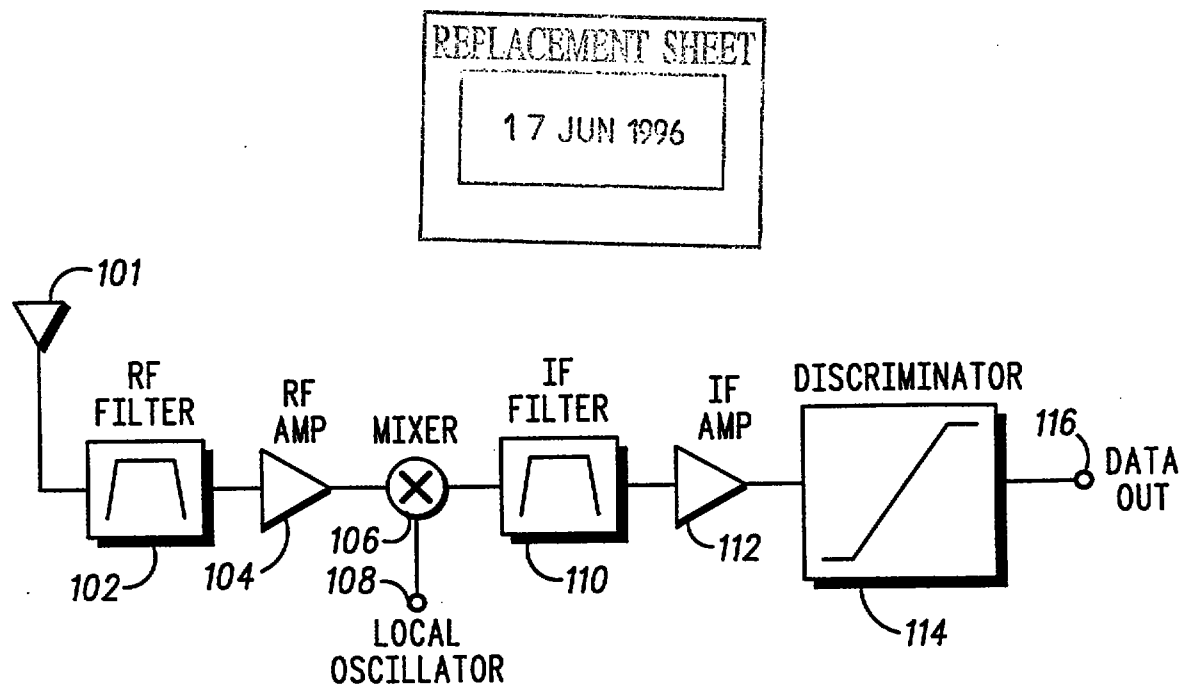


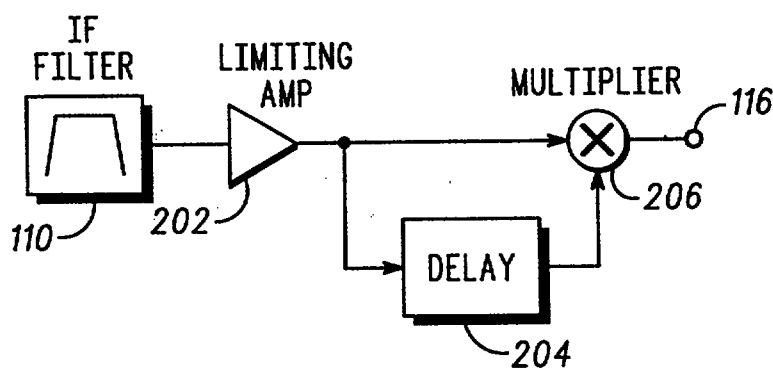
FIG. 2



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**FIG. 1**100

—PRIOR ART—

**FIG. 2**

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Phone Service (AMPS) or Narrow band Advanced Mobile Phone Service (NAMPS) cellular systems deployed by Motorola Inc. requires a C/I ratio of at least 18 decibels (dB). While 18dB of separation between the desired carrier and an interference source is adequate to protect the system from co-channel interference, it nonetheless fails to maximize spectral efficiency, especially when one of the known frequency reuse schemes is also employed by the system in question.

It would be extremely advantageous therefore to provide a radio receiver architecture which operates at a lower C/I separation than is taught by the prior art, in the effort to increase overall spectral efficiency without adversely impacting system performance. Of note, additional information on the AMPS and NAMPS systems has in the past been available by contacting Motorola Inc. at 1303 East Algonquin Road, Schaumburg, Illinois 60196.

Summary of the Invention

According to one aspect of the present invention there is provided a wide bandwidth frequency discriminator circuit including:

- an input for receiving an intermediate frequency (IF) signal;
- a wide bandwidth limiting amplifier, coupled to the input and having a first bandwidth at least three times the bandwidth of the IF signal, for providing an amplified output signal;
- a delay circuit having a second bandwidth equal to or greater than the first bandwidth, coupled to the amplifier, for providing a delayed representation of the amplified output signal; and
- multiplying circuitry, coupled to the amplifier and the delay circuit and further having a third bandwidth greater than the first bandwidth, for providing a product signal representation of the amplified output signal and the delayed representation of the amplified output signal.

According to a further aspect of the present invention there is provided a wide bandwidth frequency discriminator circuit including:

an input for receiving an intermediate frequency (IF) signal;

a wide bandwidth limiting amplifier, coupled to the input and

5 having a first bandwidth at least three times the bandwidth of the IF signal, for providing an amplified output signal;

a delay circuit having a second bandwidth equal to or greater than the first bandwidth, coupled to the amplifier, for providing a delayed representation of the amplified output signal; and

10 multiplying circuitry having a third bandwidth greater than the second bandwidth, coupled to the amplifier and the delay circuit, for providing a product signal representation of the amplified output signal and the delayed representation of the amplified output signal.

According to a still further aspect of the present invention there is provided a radio frequency (RF) receiver including:

15 means for receiving an RF signal including data and converting it to an intermediate frequency (IF) signal;

an IF filter, coupled to the receiving means, for filtering the IF signal to remove those components above and below a desired frequency range;

20 and

an FM discriminator circuit, coupled to the intermediate frequency filter and including:

a wide bandwidth limiting amplifier having a first bandwidth, coupled to the IF filter, for providing an amplified output signal of the
25 filtered IF signal;

a delay circuit having a second bandwidth equal to or greater than the first bandwidth, coupled to the wide bandwidth limiting amplifier, for providing a delayed representation, of the amplified output signal; and

a multiplier having a third bandwidth at least three times greater than the first bandwidth, coupled to the wide bandwidth limiting amplifier and the delay circuit, for providing a product signal having a wide bandwidth frequency response.

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Brief Description of the Drawings

FIG. 1 is a block diagram representation of an FM receiver circuit as is known in the art; and

10 FIG. 2 is a block diagram representation of a portion of the FM receiver of FIG. 1 showing the discriminator circuit of the present invention.

Description of a Preferred Embodiment

15 FIG. 1 is a block diagram representation of an FM receiver 100 as is known in the art. For purposes of this discussion, receiver 100 may be divided into a front end section and a back end section. The front end section comprises an antenna 101, RF filter 102, RF amplifier 104 mixer 106, local oscillator 108 and an IF filter 110. The back section comprises
20 an IF amplifier 112, a discriminator 114 circuit and a output terminal 116.

During operation, RF signals as received by antenna 101, applied to RF filter 102 and amplified by RF amplifier 104 may contain both a desired signal and an interfering signal. The interfering signal will typically exhibit a different amplitude than the desired signal, but the interfering
25 signal and the desiredm signal may exhibit nearly identical frequencies. The term carrier-to-interference (C/I) ratio is therefore used to characterize the received RF energy and represents the amplitude of the desired



Claims

1. A wide bandwidth frequency discriminator circuit including:
 - 5 an input for receiving an intermediate frequency (IF) signal;

a wide bandwidth limiting amplifier, coupled to the input and having a first bandwidth at least three times the bandwidth of the IF signal, for providing an amplified output signal;
 - 10 a delay circuit having a second bandwidth equal to or greater than the first bandwidth, coupled to the amplifier, for providing a delayed representation of the amplified output signal; 1 and
 - 15 multiplying circuitry, coupled to the amplifier and the delay circuit and further having a third bandwidth greater than the first bandwidth, for providing a product signal representation of the amplified output signal and the delayed representation of the
 - 20 amplified output signal.



2. The circuit of claim 1 wherein the third bandwidth is greater than the second bandwidth.
3. The circuit of claim 1 wherein the delay circuit is selected from the
5 group consisting of:
 - active filters;
 - passive filters;
 - micro strip transmission lines; and
 - coaxial cable.
- 10 4. The circuit of claim 1 wherein the multiplier is selected from the group consisting of:
 - mixers;
 - analog multipliers; and
 - 15 digital phase detectors.
5. The circuit of claim 1 wherein the product signal is proportional to a phase difference between the amplified output signal and the delayed representation of the amplified output signal.
- 20 6. The circuit of claim 5 wherein the product signal has a wide bandwidth frequency response.



7. The circuit of claim 6 wherein the third bandwidth is at least three times greater than the first bandwidth.



8. A radio frequency (RF) receiver including:

means for receiving an RF signal including data and converting it to an intermediate frequency (IF) signal;

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an IF filter, coupled to the receiving means, for filtering the IF signal to remove those components above and below a desired frequency range; and

10 an FM discriminator circuit, coupled to the intermediate frequency filter and including:

a wide bandwidth limiting amplifier having a first bandwidth, coupled to the IF filter, for providing an amplified output signal of the filtered
15 IF signal;

a delay circuit having a second bandwidth equal to or greater than the first bandwidth, coupled to the wide bandwidth limiting amplifier, for providing a delayed representation of the amplified output signal; and

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a multiplier having a third bandwidth at least three times greater than the first bandwidth, coupled to the wide bandwidth limiting amplifier and the delay circuit, for providing a product signal having a wide bandwidth frequency response.

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9. The radio receiver of claim 8 wherein the product signal amplitude is proportional to a phase difference between the amplified output signal and the delayed representation of the amplified output signal.



10. A wide bandwidth frequency discriminator circuit substantially as herein described with reference to Fig. 2 of the accompanying drawings.
11. A radio frequency receiver substantially as herein described with reference to Fig. 2 of the accompanying drawings.
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A WIDE BANDWIDTH DISCRIMINATOR
FOR USE IN A RADIO RECEIVER

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Abstract of the Invention

A wide bandwidth frequency discriminator circuit (200) employs a wide bandwidth limiting amplifier (202) to amplify the IF signal portion a received RF signal. A delay circuit (204), such as a micro strip transmission line, provides a delayed representation of the amplified signal to a multiplier circuit (206). The multiplier (206) in turn provides a product signal which is the product of the amplified output signal and the delayed representation of the amplified output signal. As will be appreciated, said product signal will be proportional to the phase difference between the amplified output signal and the delayed representation of the amplified output signal. This discriminator (200) operates to form a detection system capable of discriminating between desired and undesired components of the received RF signal even when said desired and undesired components are nearly identical in amplitude. This is due in part to the enhanced frequency response provided by the discriminator (200).