

AUTOMATICALLY SELF-CALIBRATING OSCILLATORS
IN HETERODYNED RADIO RECEIVERS

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Field of Invention

This invention relates to automatic calibration of oscillators. More particularly, this invention relates to temperature and frequency calibration of oscillators in
10 High Frequency Single Side Band (HF SSB) heterodyned radio receivers to achieve frequency accuracy and stability.

Background of the Invention

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Frequency accuracy and stability are major problems in radio communications, particularly in HF SSB. The oscillating frequency of oscillator components (and especially the oscillating crystal) for radios are particularly sensitive to temperature variation and are,
20 therefore, commonly isolated from ambient temperature conditions by being maintained at a constant temperature within oven enclosures.

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The oscillator's frequency and frequency vs. temperature behaviour is mainly determined by the crystal. A typical frequency deviation vs temperature
characteristic for a crystal is illustrated in Figure 1. Thus, substantial frequency stability can be achieved by regulating the temperature of the crystal about the point of minimum frequency deviation for given changes in
30 temperature (i.e., zero slope).

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This optimum temperature for maximum frequency stability varies considerably from crystal to crystal. The oven temperature is ordinarily individually set within a certain tolerance by the use of precision
instrumentation at the factory for each oscillator before being assembled into the radio and then individually frequency adjusted once assembled. Frequency calibration will also require adjustment throughout its lifetime in

the field and as it ages (or whenever the oscillator unit is replaced); *this feature is the subject of divisional application publication number 2244877A.*

What is needed, then, is a method -- integral to the radio itself -- for individually regulating the temperature of the oscillator according to its prevailing temperature vs. frequency characteristics and subsequently adjusting the frequency for maximum accuracy. In modern HF SSB radios, it is now possible to do automatic calibration within the radio itself in the field, without the use of precision test instrumentation but simply using elements of the radio itself, because the frequency error is multiplied in the radio receiver such that it can easily be measured at the audio output with conventional microprocessors using known methods of frequency sampling.

It is, therefore, one object of the invention to provide a method for automatically and integrally calibrating the temperature and frequency of the oscillator according to the basic prevailing characteristics of the oscillator to achieve appreciable frequency stability, using only an external frequency reference signal.

Summary of the Invention

In accordance with a first aspect of the present invention, there is provided a method of automatically and integrally calibrating the temperature of an oscillator to achieve frequency stability in a radio including a frequency synthesizer where the temperature of an oscillator can be set, characterized by: integrally determining the present optimal operating temperature for the oscillator and integrally resetting the temperature of the oscillator to that optimal temperature, whereby frequency vs. temperature stability is achieved.

Frequency calibration may follow.

In accordance with a second aspect of the invention, there is provided a method of automatically and integrally calibrating an oscillator to achieve frequency

stability in a radio including a frequency synthesizer where the oven temperature of a crystal oscillator can be set, characterized by: integrally determining the present optimal operating temperature for the oscillator by:

- 5 deriving the specific frequency vs temperature characteristic of said oscillator and calculating the optimal operating temperature where relative temperature differentials result in relatively minimal frequency deviations by adjusting the operating temperature of the
- 10 oscillator across its operating temperature range, noting the resultant frequency deviations, calculating the coefficients of a representative polynomial equation and calculating the relative minima of said polynomial equation (whereby said relative minima represents the
- 15 optimal operating temperature of said oscillator), by noting three frequency vs temperature pairs to resolve the coefficients and to calculate the relative minima of a parabolic quadratic equation representative of a crystal oscillator; integrally resetting the temperature of the
- 20 oscillator to that optimal temperature by utilizing a microprocessor-driven digital-to-analogue converter to adjust the operating temperature of the oscillator by altering the voltage supplied to the temperature control of an oscillator by utilizing a microprocessor-driven
- 25 digital-to-analogue converter to generate a voltage proportional to the optimal operating temperature and to supply said current to the temperature control of an oscillator; and calibrating the operating frequency of said oscillator following said temperature calibration by
- 30 noting the resultant frequency deviation following said temperature calibration and adjusting the frequency of said oscillator to eliminate said frequency deviation by, utilizing a microprocessor-driven digital-to-analogue converter to adjust the frequency of the oscillator by
- 35 altering the voltage supplied to varicap diodes in the frequency generator of the oscillator; wherein a microprocessor is utilized to note said resultant frequency deviations using digital frequency sampling

techniques and whereby frequency vs. temperature stability is achieved and whereby frequency accuracy is achieved.

In accordance with a third aspect of the invention, a radio is provided comprising: a frequency synthesizer and an oscillator, the temperature of which can be set; means for integrally determining the present optimal operating temperature for the oscillator and means for integrally resetting the temperature of the oscillator to that optimal temperature, whereby frequency vs. temperature stability is achievable.

Brief Description of the Drawings

An exemplary system in accordance with the present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is a graph that illustrates a typical frequency deviation vs temperature characteristic for a crystal.

Figure 2 is a block diagram of a synthesized radio incorporating the present invention.

Figure 3 is a block diagram of the Processing Unit of Figure 2 and constructed according to the present invention.

Detailed Description of the Invention

Figure 2 is a block diagram of a synthesized radio incorporating the present invention. The synthesized radio includes a frequency oscillator 10 providing a reference frequency, a synthesizer 12 providing a first and second injection frequency for first and second Intermediate Frequency mixers 14 and 16 and whose programmable frequency dividers are loadable from a processor 18, and a demodulator, 20 whose ordinary audio output is advantageously used in accordance with the

preferred embodiment of the present invention to provide frequency deviation and calibration information to the processor.

5 The oscillator 10 of this synthesized radio can be accurately calibrated because the frequency error of the internal reference frequency is transformed to the base-band and multiplied by the ratio of the received frequency to the reference frequency. Thus, with an internal reference frequency of 11.4 MHz and with the
10 reciever tuned to a 10 MHz and an external frequency of 10.001 MHz, a tone of approximately 1 KHz will be produced at the audio output -- a 0.1 ppm oscillator error is reflected in the audio output as an approximate 1000 ppm deviation. This multiplication of the frequency error is
15 then easily measured in the audio output by modest microprocessors clocked by low cost crystals. This feature is the subject of divisional application No.9018896.

20 Figure 3 is a block diagram of the processor 18 of Figure 2 and constructed according to the present invention. The processor includes a microprocessor 22 coupled to the audio output of the reciever and is used in accordance with the preferred embodiment of the present invention to provide frequency deviation and calibration
25 information to the processor and further includes digital-to-analogue converters 24 and 26 to supply temperature and frequency calibration information to the oscillator.

To calibrate the oscillator, the reciever is tuned to a calibration frequency (recieved from a
30 calibrated transmitter, from an external precision test instrument or from a transmitted frequency standard -- time and frequency reference signals are commonly available in the HF band for navigation and time distribution purposes). Next, the voltage generated using
35 the Temperature Digital-to-Analogue converter 24 is varied to drive the oven temperature of the oscillator 10 across its design range from its minimum temperature to its maximum temperature.

Once a sufficient number of frequency/temperature points have been noted (for example, a minimum of three is required for the parabolic curve approximation of Figure 1), the oven temperature at which the least frequency deviation exists can be determined. Again, for the basic parabolic characteristic of Figure 1, this optimum temperature (where the slope is zero) is determined from coefficients of the parabola $f=At^2+Bt+C$ where:

$$T_{\text{calibration}} = B/2A \quad \text{and where}$$

$$A = [(f_1 - f_0)(t_2 - t_0) - (f_2 - f_0)(t_1 - t_0)] / (t_1 - t_0)(t_2 - t_0)(t_1 - t_2)$$

and

$$B = [f_2 - f_0 - A(t_2^2 - t_0^2)] / (t_2 - t_0)$$

from the temperature/frequency pairs (t_0, f_0) , (t_1, f_1) and (t_2, f_2) .

Finally, the voltage corresponding to the optimum temperature $T_{\text{calibration}}$ is generated through the Temperature D/A 24 and the Frequency Tuning D/A 26 is adjusted (varying the voltage on varicap diodes in the oscillator) until the frequency deviation measured at the audio output disappears. The calibration is complete when the values of both the Temperature and the Frequency Tuning D/As are stored in non-volatile memory.

Thus, what has been provided is a system for automatically and integrally calibrating the temperature of an oscillator to achieve frequency accuracy and stability in a synthesized radio where the temperature of an oscillator can be set. The temperature calibration is performed by integrally determining the present optimal operating temperature for the oscillator and integrally resetting the temperature of the oscillator to that optimal temperature. Thus, frequency vs. temperature stability is achieved; frequency calibration may follow.

The method of calibration of the invention is suitable for use with any oscillator where frequency accuracy and stability is a concern, including those that are not oven temperature controlled. It is particularly advantageous for field frequency adjustments to compensate for crystal aging.

While the preferred embodiment of the invention has been described and shown, it will be understood by those skilled in the art that other variations and modifications of this invention may be implemented.



CLAIMS:

5 1. A method of automatically and integrally calibrating the temperature of an oscillator to achieve frequency stability in a radio including a frequency synthesizer where the temperature of an oscillator can be set, characterized by:

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integrally determining the present optimal operating temperature for the oscillator and

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integrally resetting the temperature of the oscillator to that optimal temperature,

whereby frequency vs. temperature stability is achieved.

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2. A method according to claim 1, further characterized by calibrating the operating frequency of said oscillator following said temperature calibration, whereby frequency accuracy is achieved.

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3. A method according to claim 1, wherein a microprocessor-driven digital-to-analogue converter is utilized to adjust the frequency of the oscillator by altering the voltage supplied to varicap diodes in the frequency generator of the oscillator.

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4. A method according to claim 1, wherein said integral determination is further characterized by:

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deriving the specific frequency vs temperature characteristic of said oscillator and calculating the optimal operating temperature where relative temperature differentials result in relatively minimal frequency deviations.



5. A method according to claim 4, wherein said derivation is further characterized by:

5 adjusting the operating temperature of the oscillator across its operating temperature range,

noting the resultant frequency deviations and

10 calculating the coefficients of a representative polynomial equation and

15 calculating the relative minima of said polynomial equation,

whereby said relative minima represents the optimal operating temperature of said oscillator.

20 6. A method according to claim 5, wherein three frequency vs temperature pairs are noted to resolve the coefficients and to calculate the relative minima of a parabolic quadratic equation representative of a crystal oscillator.

25 7. A method according to any one of the preceding claims, wherein a microprocessor-driven digital-to-analogue converter is utilized to adjust the operating temperature of the oscillator by altering the voltage
30 supplied to the temperature control of an oscillator.

8. A method according to any one of the preceding claims, wherein a microprocessor-driven digital-to-analogue converter is utilised to generate a current
35 proportional to the optimal operating temperature and to supply said voltage to the temperature control of an oscillator.

9. A method of automatically and integrally
calibrating an oscillator to achieve frequency stability
in a radio including a frequency synthesizer where the
oven temperature of a crystal oscillator can be set,
5 characterized by:

integrally determining the present optimal
operating temperature for the oscillator by:

10 deriving the specific frequency vs
temperature characteristic of said
oscillator and calculating the optimal
operating temperature where relative
temperature differentials result in
15 relatively minimal frequency deviations by:

adjusting the operating temperature of
the oscillator across its operating
temperature range,

20 noting resultant frequency deviations

calculating the coefficients of a
representative polynomial equation and

25 calculating the relative minima of said
polynomial equation (whereby said
relative minima represents the optimal
operating temperature of said
30 oscillator), by:

noting three frequency vs
temperature pairs to resolve the
coefficients and to calculate the
relative minima of a parabolic
quadratic equation representative
35 of a crystal oscillator,



integrally resetting the temperature of the oscillator to that optimal temperature by:

5 utilizing a microprocessor-driven digital-to-analogue converter to adjust the operating temperature of the oscillator by altering the voltage supplied to the temperature control of an oscillator by:

10 utilizing a microprocessor-driven digital-to-analogue converter to generate a voltage proportional to the optimal operating temperature and to
15 supply said current to the temperature control of an oscillator.

and calibrating the operating frequency of said oscillator following said temperature calibration
20 by:

noting the resultant frequency deviation following said temperature calibration and adjusting the frequency of said oscillator
25 to eliminate said frequency deviation by:

utilizing a microprocessor-driven digital-to-analogue converter to adjust
30 the frequency of the oscillator by altering the voltage supplied to varicap diodes in the frequency generator of the oscillator,

wherein a microprocessor is utilized to note said resultant frequency deviations using digital frequency
35 sampling techniques and

whereby frequency vs. temperature stability is achieved and whereby frequency accuracy is achieved.



10. A radio comprising: a frequency synthesizer and an oscillator, the temperature of which can be set;

means for integrally determining the present
5 optimal operating temperature for the oscillator and

means for integrally resetting the temperature of the oscillator to that optimal temperature,

10 whereby frequency vs. temperature stability is achievable.

11. A radio according to claim 10, further comprising means for calibrating the operating frequency of said
15 oscillator following said temperature calibration, whereby frequency accuracy is achievable.

12. A radio according to claim 11, wherein the oscillator comprises a frequency generator having at least
20 one varicap diode to adjust the frequency of the oscillator.

13. A radio according to claim 10, further comprising means for deriving the specific frequency vs temperature
25 characteristic of said oscillator and calculating the optimal operating temperature where relative temperature differentials result in relatively minimal frequency deviations.

30 14. A radio according to claim 13, further comprising:

means for adjusting the operating temperature of the oscillator across its operating temperature
35 range,

means for noting the resultant frequency deviations,



means for calculating the coefficients of a representative polynomial equation and

5 means for calculating the relative minima of said polynomial equation,

whereby said relative minima represent the optimal operating temperature of said oscillator.

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15. A radio according to claim 10, wherein a microprocessor-driven digital-to-analogue converter is provided for adjusting the operating temperature of the oscillator by altering the voltage supplied to the

15 temperature control of an oscillator.
