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[54] **FLAW DETECTION SYSTEM USING MICROWAVES**

[75] Inventors: **Don U. Bennion; Leonard R. West,** both of Salt Lake City, Utah

[73] Assignee: **Industrial Development Design,** Salt Lake City, Utah

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[51] **Int. Cl.** **G01r 27/04**

[58] **Field of Search** .. 324/58.5 A, 58 A, 95, 58.5 B; 246/169 D; 340/248; 73/104, 159; 144/312

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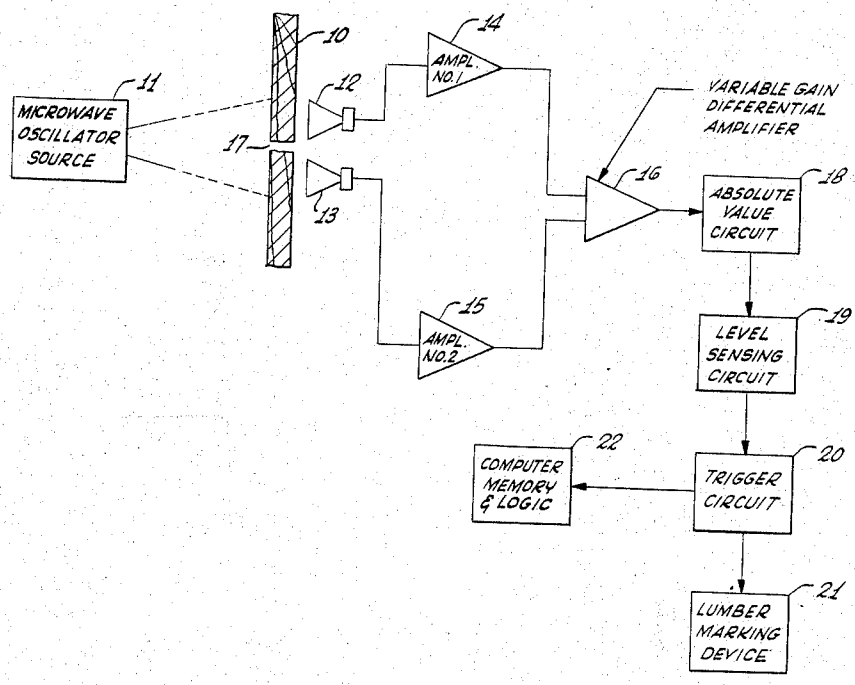
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Attorney, Agent, or Firm—Fulwider, Patton, Rieber, Lee & Utecht

[57] **ABSTRACT**

A method and apparatus for the detection of flaws in pieces of lumber or like material in which there may be wide variations in density within each piece, or among the pieces being examined. Lumber being processed is moved past two adjacent microwave detectors positioned to receive microwave radiation transmitted through the moving lumber from a conventional microwave source, and the outputs from the detectors are amplified and compared in a differential amplifier, the presence of flaws resulting in difference signals which are used to generate pulses for controlling a lumber processing device or for storage in a memory device and use in subsequent processing steps.

28 Claims, 2 Drawing Figures



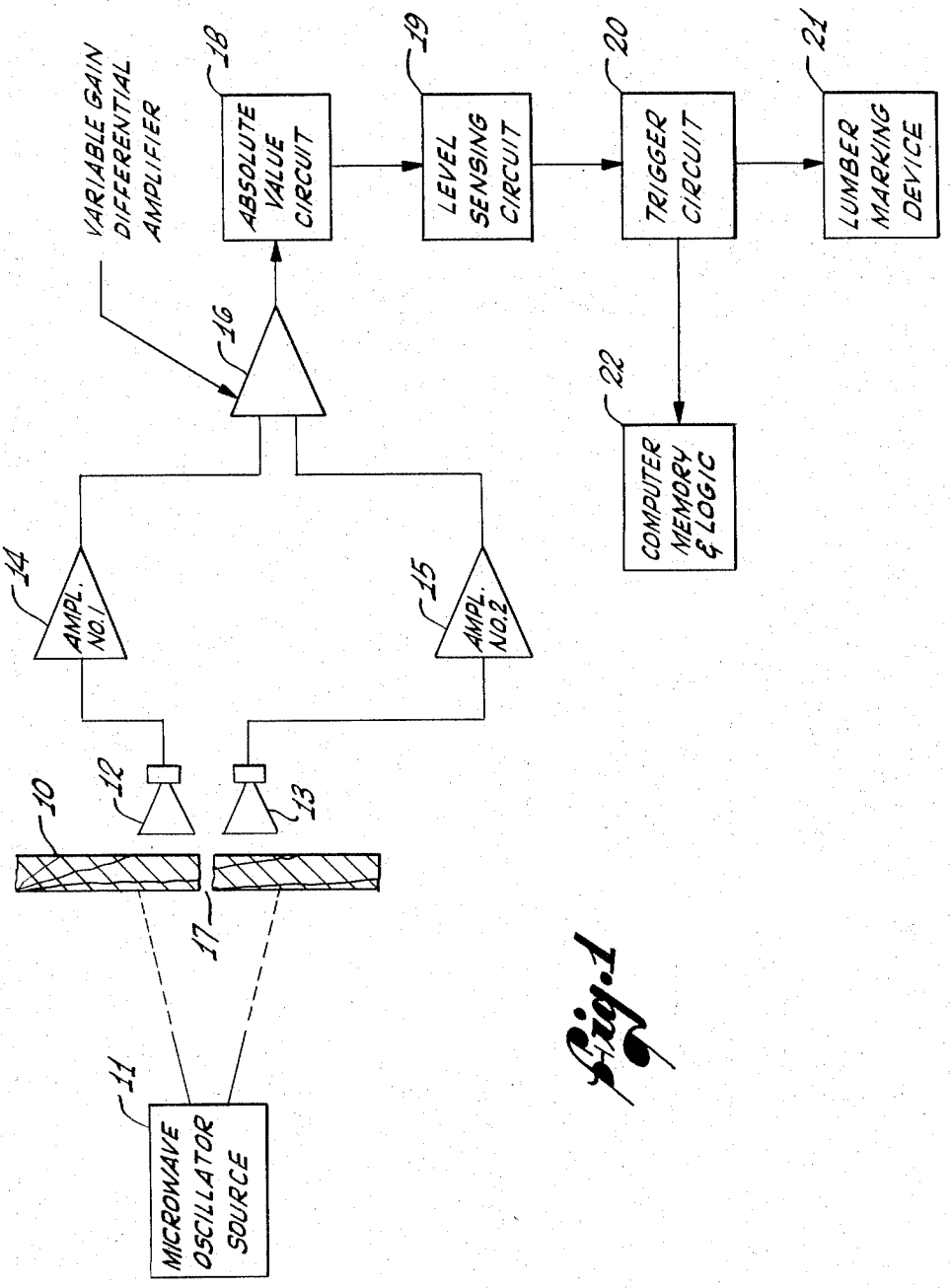
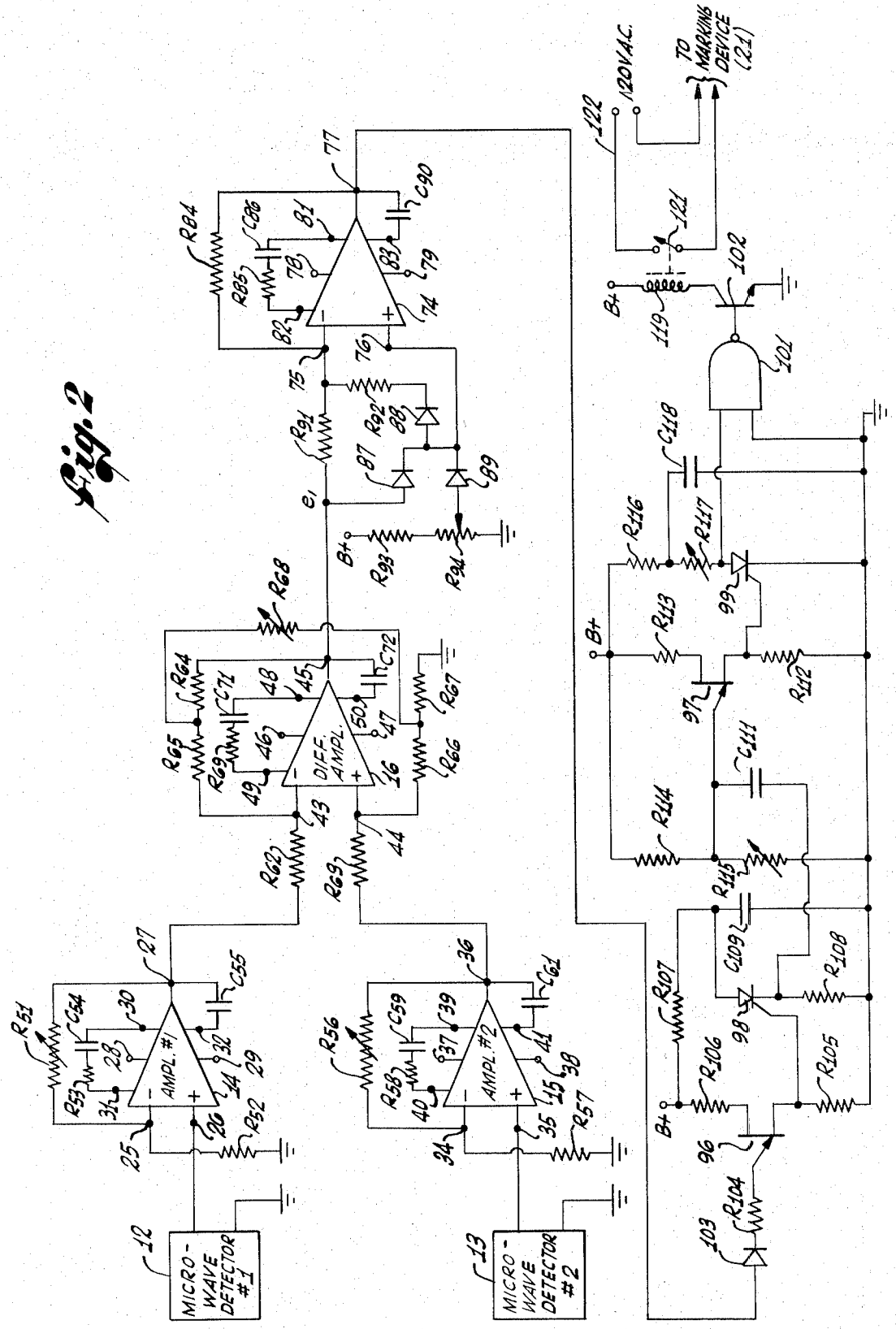

VARIABLE GAIN DIFFERENTIAL AMPLIFIER
18
ABSOLUTE VALUE CIRCUIT
19
LEVEL SENSING CIRCUIT
20
TRIGGER CIRCUIT
21
LUMBER MARKING DEVICE
16
22
COMPUTER MEMORY & LOGIC
14
AMPL. NO.1
15
AMPL. NO.2
12
13
10
17
11
MICROWAVE OSCILLATOR SOURCE

Fig. 1

Fig. 2


MICRO-WAVE DETECTOR #1
MICRO-WAVE DETECTOR #2
AMPL. #1
AMPL. #2
DIFF. AMPL.
120 V A.C.
TO MARKING DEVICE (21)
B+

FLAW DETECTION SYSTEM USING MICROWAVES

BACKGROUND OF THE INVENTION

This invention relates generally to systems for the detection of flaws in lumber and, more particularly, to lumber flaw detection systems using microwave radiation. Such systems are used to supply information for automatically marking or cutting the lumber into desired lengths free of flaws.

In the prior art, short-wave electromagnetic radiation, widely known as microwave radiation, has been used to detect flaws or non-homogeneous zones in electrically non-conducting material, particularly glass. The microwave radiation is either transmitted through or reflected from the material being examined, and a microwave receiver is used to detect variations in the transmitted or reflected radiation caused by flaws in the material as it is moved past the receiver.

Common defects in lumber, such as knots, pitch, and wind shake, are non-homogeneous zones which can be readily detected using a microwave technique. However, because lumber is not, in general, as homogeneous as many synthetic materials, such as glass, prior art microwave techniques are not directly transferable to lumber flaw detection systems. Because of the widely varying moisture content of lumber, the density of the lumber may vary widely within a single piece as well as from piece to piece. These density variations show up as variations in the received microwave radiation, making the detection of flaws in the lumber very difficult, if not impossible, using prior art methods. One possible solution to this problem is to filter out the density variations, which will generally be more gradual than the variations due to flaws, by employing, for example, some form of capacitance coupling in circuitry associated with the receiver. This is not a completely satisfactory solution, however, since the speed of the lumber with respect to the receiver then becomes a critical factor in the use of the technique.

Ideally, a flaw detection system for lumber should be insensitive to normal variations in density of the lumber from piece to piece and within single pieces, while still remaining sufficiently sensitive to changes in density due to flaws in the lumber. Furthermore, this insensitivity to normal density variations should not be achieved at the expense of a lower processing speed. The present invention meets all of these needs.

SUMMARY OF THE INVENTION

The present invention resides in an improved method and apparatus for the detection and location of flaws in lumber and like material, using microwave radiation. Basically, the apparatus of the invention includes a source of microwave radiation, at least two microwave detectors, a differential amplifier for detecting a difference in output between the detectors, and a means for coupling the differential amplifier to a control or storage device used for subsequent processing of the lumber.

Normal variations in the density of the lumber, because of their gradual nature, will generally have equal effects on adjacent detectors and will produce very little difference signal. Small flaws such as knots, on the other hand, will affect the output of only one detector at a time, and will result in a momentary difference signal which can be used to operate a lumber marking or cutting device, or stored for subsequent use in processing the lumber.

The method of the present invention basically includes the steps of transmitting microwave radiation through the lumber, measuring received radiation at at least two adjacent positions, sensing differences in the measured radiation at the adjacent positions, and generating therefrom control signals for use in processing the lumber.

More specifically, in a presently preferred embodiment of the invention, two microwave detectors are employed, the output of each being amplified and fed to a variable gain differential amplifier, the output of which is proportional to the difference between the outputs of the two detectors. Since the detectors are positioned close together, gradual variations in lumber density produce no difference signal, or a negligibly small difference signal, but small flaws in the lumber produce substantial difference signals at the output of the differential amplifier. An absolute value circuit is included, following the differential amplifier, in order that both positive and negative difference signals will be detected. Then, a level sensing circuit serves a filtering function by rejecting difference signals below a certain level, and passing others on to a trigger circuit which, in cooperation with the level sensing circuit, produces pulse signals to be stored or used to operate lumber processing equipment.

It can be readily seen that the invention provides a new and useful tool for the detection and location of flaws in lumber. The invention overcomes the disadvantages of prior art microwave flaw detection systems as applied to lumber and like materials, in that small flaws can be conveniently distinguished from normal fluctuations in density without imposing any limitation on lumber processing speed. Other aspects and advantages of the invention will become apparent from the following detailed description taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of a flaw detection system embodying the invention; and

FIG. 2 is a more detailed electrical schematic diagram of the system shown in FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENT

As shown in the drawings for purposes of illustration, the invention is embodied in an improved system using microwave radiation for the detection of flaws, such as knots, pitch, and wind shake, in lumber. It will be understood that, while the invention is particularly well suited for the detection of flaws in lumber, it could also be used for the detection of flaws in other like materials, lacking perfect homogeneity.

In accordance with the present invention, as illustrated in FIG. 1, a piece of lumber **10** being examined for flaws is passed between a microwave oscillator source **11** and two microwave detectors **12** and **13**, the outputs of which are amplified by two corresponding amplifiers **14** and **15**, and connected to a differential amplifier **16**, which produces an output proportional to the difference between the outputs of the two microwave detectors. Since the detectors **12** and **13** are disposed close together in the line of motion of the lumber

10, gradual density variations along the length of the lumber will generally affect both detectors equally, and will result in a negligibly small difference signal, if any, at the output of the differential amplifier **16**. A small flaw, on the other hand, such as the one shown at **17**, will affect the output of only one of the detectors **12** and **13** at a time and will produce a relatively large difference signal at the output of the differential amplifier **16**. Thus, the system is capable of detecting flaws in material having normal inherent density fluctuations.

More specifically, the microwave oscillator **11** is a conventional microwave source, of either the klystron or the solid state diode variety, generating microwave radiation having a wavelength typically in excess of one centimeter. Flaws detected by the system are typically larger than one-eighth inch (approximately 3 mm) in diameter. The microwave detectors **12** and **13** are positioned adjacent to each other in the path of the radiation transmitted through the lumber **10**, and include microwave horns and diode detectors of conventional design.

The amplifiers **14** and **15**, to which the outputs of the detectors **12** and **13** are connected, are single-ended operational amplifiers. Since these devices have a characteristically high input impedance and low output impedance, they serve the dual function of amplification and impedance transformation. The differential amplifier **16** is also an operational amplifier, connected to have a variable gain so that the sensitivity of the detection system may be varied.

The output from the differential amplifier **16** is connected to an absolute value circuit **18** providing a positive output signal equal in magnitude to that of its input signal but without regard to the sign of the input signal. The output from the absolute value circuit **18** is, in turn, connected to a level sensing circuit **19**, which serves a filtering function in that it rejects difference signals below a certain selectable threshold value. Difference signals of sufficient magnitude to activate the level sensing circuit **19** are conveyed to a trigger circuit **20**, which, in cooperation with the level sensing circuit, produces signals in pulse form to operate a lumber marking device **21**, or other lumber processing device, or to be stored in computer memory and logic elements **22** for subsequent use in processing the lumber **10**.

Referring now to FIG. **2**, there is shown by way of example and not by way of limitation, a detailed schematic diagram of a presently preferred embodiment of the invention. The amplifiers **14** and **15** and the differential amplifier **16** each include an operational, or d.c. amplifier having characteristically high gain, high input impedance, and low output impedance. Such operational amplifiers are typically available in integrated circuit form. In a presently preferred embodiment of the invention, each of the three amplifiers **14**, **15** and **16** utilizes one-half of a dual operational amplifier integrated circuit chip, device type MC1437L, manufactured by Motorola Semiconductor Products, Inc., Phoenix, Ariz.

The first operational amplifier **14** has an inverting input terminal **25**, a non-inverting input terminal **26**, an output terminal **27**, a B+ power supply terminal **28**, a B− power supply terminal **29**, two input lag terminals **30** and **31**, and an output lag terminal **32**. The second operational amplifier **15** has an inverting input terminal **34**, an non-inverting input terminal **35**, an output terminal **36**, a B+ power supply terminal **37**, a B− power supply terminal **38**, two input lag terminals **39** and **40**, and an output lag terminal **41**. Similarly, the differential amplifier **16** has an inverting input terminal **43**, a non-inverting input terminal **44**, an output terminal **45**, a B+ power supply terminal **46**, a B− power supply terminal **47**, two input lag terminals **48** and **49**, and an output lag terminal **50**.

Both the amplifiers **14** and **15** are connected in a non-inverting configuration, i.e., the output has the same sign as the input. The output of the first microwave detector **12** is applied between the non-inverting input terminal **26** of amplifier **14** and ground, a variable feedback resistor **R51** connects the output terminal **27** to the inverting input terminal **25**, and another resistor **R52** is connected between the inverting input terminal **25** and ground. In this configuration, the closed loop gain, i.e., the ratio of the voltage at the output terminal **27** to the voltage at the non-inverting input terminal **26** is positive and is determined primarily by the values of the resistors **R51** and **R52**. Power is supplied to the amplifier **14** through the power supply terminals **28** and **29**, and frequency compensation of the amplifier is provided by a resistor **R53** and a capacitor **C54** connected in series between the input lag terminals **30** and **31** and a further capacitor **C55** connected between the output terminal **27** and the output lag terminal **32**.

The second amplifier **15** is connected in a similar fashion, i.e., the output from the second microwave detector **13** is applied between the non-inverting input terminal **35** and ground, a variable feedback resistor **R56** is connected between the output terminal **36** and the inverting input terminal **34**, and another resistor **R57**, is connected between the inverting input terminal **34** and ground. Again, power supplied to the amplifier **15** through the power supply terminals **37** and **38**, and frequency compensation is provided by a resistor **R58** and a capacitor **C59** connected in series between the input lag terminals **39** and **40**, and a further capacitor **C61** connected between the output terminal **36** and the output lag terminal **41**.

Output from the amplifier **14** is connected from the output terminal **27** through a resistor **R62** to the inverting input terminal **43** of the differential amplifier **16**, and output from the amplifier **15** is connected from the output terminal **36** through a resistor **R63** to the non-inverting input terminal **44** of the differential amplifier.

A feedback resistance comprising two resistors **R64** and **R65** in series is connected between the output terminal **45** and the inverting input terminal **43**. Another resistance consisting also of two resistors **R66** and **R67** in series is connected between the non-inverting input terminal **44** and ground, and a variable resistor **R68** is connected between the junction point of resistors **R64** and **R65**, and the junction point of resistors **R66** and **R67**. In this configuration, the differential amplifier **16** produces an output signal between its output terminal **45** and ground which is proportional to the difference between the output signals of amplifiers **14** and **15**, and the variable resistor **R68** operates to vary the gain of the differential amplifier. As in the other amplifiers, power is supplied to the differential amplifier **16** through the power supply terminals **46** and **47**, and frequency compensation is effected by means of a resistor **R69** and a capacitor **C71** connected in series between the input lag terminals **48** and **49**, and a further capacitor **C72** connected between the output terminal **45** and the output lag terminal **50**.

The absolute value circuit **18** utilizes an additional operational amplifier **74**, which, like the others, has an inverting input terminal **75**, a non-inverting input terminal **76**, an output terminal **77**, power supply terminals **78** and **79**, input lag terminals **81** and **82**, and an output lag terminal **83**. A feedback resistor **R84** is connected between the output terminal **77** and the inverting input terminal **75**, and frequency compensation is provided by a resistor **R85** and a capacitor **C86** connected in series between the input lag terminals **81** and **82**, and a further capacitor **C90** connected between the output terminal **77** and the output lag terminal **83**.

The output of the differential amplifier **16** is connected to the absolute value circuit through a network including three diodes **87**, **88** and **89**, two resistors **R91** and **R92**, and a voltage divider consisting of an additional resistor **R93** connected to the B+ voltage, and a low-resistance potentiometer **R94** connecting the resistor **R93** to ground.

The output terminal **45** of the differential amplifier **16** is connected through the resistor **R91** to the inverting terminal **75**, and is also connected to the anode of the first diode **87**, the cathode of which is connected to the anode of the second diode **88**. The cathode of the second diode **88** is, in turn, connected through the resistor **R92** to the inverting terminal **75**. Finally, the sliding contact of the potentiometer **R94** is connected to the anode of the third diode **89**, the cathode of which is connected both to the non-inverting input terminal **76** and to the junction point between the first and second diodes **87** and **88**.

In a presently preferred embodiment of the invention, the feedback resistor **R84** is 10kΩ, and the resistors R91 and R92 are 10kΩ and 5kΩ, respectively. With these values of resistance, the absolute value circuit **18** acts as an inverter with a gain of unity when negative signals are presented to it, and as a unity-gain amplifier for positive signals. For negative input signals, the only effective path is through the resistor **R91** to the inverting input terminal **75**, since other possible paths are blocked by the first diode **87**. The non-inverting, or positive terminal **76** is held as close to ground potential as possible by adjustment of the potentiometer **94**, and, for negative input signals, the circuit is effectively connected in a conventional inverting configuration for operational amplifier, the closed loop gain being primarily determined by the ratio of the resistances **R84** and **R91**, i.e., −1.

For positive inputs, there are three possible paths: through the resistor **R91** to the inverting input terminal **75**, through the first diode **87** to the non-inverting input terminal **76**, and through the first and second diodes **87** and **88** and the resistor **R92** to the inverting input terminal **75**. Using familiar principles of superposition, the closed loop gain can be computed for each path separately, and the values added to obtain the effective gain for positive input signals. For the first path, through the resistor **R91** to the inverting terminal **75**, the gain is −1, as was shown for negative input signals. The second path, through the first diode **87** to the non-inverting input terminal **76**, is effectively a conventional non-inverting configuration for operational amplifiers, with the input connected to the non-inverting input terminal, and the inverting input terminal **75** having a resistance to ground comprising the resistors **R91** and **R92** in parallel, i.e., a value of 10/3kΩ.

If the input voltage is designated e_1 and the voltage drop across the first and second diodes **87** and **88** are designated v_1 and v_2, respectively, then the voltage applied to the non-inverting input terminal **76** through the second path is $(e_1 - v_1)$ and the closed loop gain for this voltage is: $1 + (R84 \div 10/3) = +4$.

For the third path, through the first and second diodes **87** and **88** and the resistor **R92**, the effective input voltage is $(e_1 - v_1 - v_2)$ and the closed loop gain is −R84/R92, or −2. Thus, the overall closed loop gain sums to +1, if $v_1 = v_2$; and the absolute value circuit **18** outputs to the level sensing circuit **19** a positive signal equal in magnitude to that of the input signal.

The level sensing circuit **19** (FIG. 1) and the trigger circuit **20** (FIG. 1) include, as shown in FIG. **2**, two unijunction transistors **96** and **97**, two silicon controlled rectifiers (SCR's) **98** and **99**, a NAND gate **101**, and an npn transistor **102**. The output signal from the absolute value circuit **18** is applied from the output terminal **77** through diode **103** and a resistor **R104** to the emitter terminal of the first unijunction transistor **96**, the base-one terminal of the unijunction transistor **96** is connected to ground through a resistor **R105**, and power is supplied to the base-two terminal of the unijunction transistor **96** through a resistor **R106**. In a presently preferred embodiment of the invention, the first unijunction transistor **96** will be turned on when the output from the absolute value circuit **18** is in the region of 50 to 80 per cent of the power supply (B+) voltage.

Whenever the first unijunction transistor **96** is turned on by a sufficiently high output voltage from the differential amplifier **16**, the first SCR **98** is also turned on, since the base-one terminal of the first unijunction transistor **96** is connected to the gate terminal of the first SCR **98**, the anode terminal of which is supplied with power (B+) through a resistor **R107**, and the cathode terminal of which is connected to ground through a resistor **R108**. A capacitor **C109** is connected between the anode terminal of the SCR **98** and ground, so that, when the SCR **98** is non-conducting, the capacitor **C109** is charged from the power supply. When the SCR **98** is triggered, the capacitor **C109** is discharged through the SCR **98** and through the resistor **R108** to ground.

The pulse generated by the discharge of the capacitor **C109** is fed through a coupling capacitor **C111** to the emitter terminal of the second unijunction transistor **97**, which has its base-one terminal connected to ground through a resistor **R112** and its base-two terminal connected to the power supply (B+) through a resistor **R113**. In a voltage divider circuit consisting of a resistor **R114** and a variable resistor **R115** connected in series between the power supply (B+) and ground, the junction between the resistors **R114** and **R115** is connected to the emitter terminal of the second unijunction transistor **97**, and the variable resistor **R115** is adjusted so that a pulse from the capacitor **C109** in the circuit of the first SCR **98** will, together with the voltage from the voltage divider circuit, apply a high enough voltage to the emitter of the second unijunction transistor **97** to momentarily turn that device on.

The second SCR **99** has its anode terminal connected to the power supply (B+) through two resistors **R116** and **R117** in series, the resistor **R117** being variable and connected to the anode. A capacitor **C118** is connected between the junction of the two resistors **R116**

and R117 and ground, the cathode of the SCR 99 is connected to ground, and the base-one terminal of the second unijunction transistor 97 is connected to the gate terminal of the second SCR 99. Thus, when the second unijunction transistor 97 is turned on, a pulse is applied to the gate terminal of the second SCR 99, which is turned on by the pulse. The capacitor C118, which is charged when the SCR 99 is non-conducting, is discharged through the resistor R117 and the SCR 99 when the latter is triggered, thus momentarily lowering the potential at the anode of the SCR 99.

The combination of the two unijunction transistors 96 and 97 and the two SCR 98 and 99 is designed to provide one short pulse to the NAND gate 101, which has one input connected to the anode terminal of the second SCR 99 and the other input terminal grounded. The logic of the NAND gate is such that ground voltage is a logical "1" and a positive voltage is a logical "0." Thus, the inputs change momentarily from "0" and "1" to "1" and "1," respectively, when the anode potential of the SCR 99 falls, and the output of the NAND gate 101 momentarily changes from "1" to "0," i.e., a positive pulse is output. The output terminal of the NAND gate 101 is connected to the base terminal of the npn transistor 102, the emitter terminal of which is grounded and the collector terminal of which is connected to the power supply (B+) through a relay 119. When the NAND gate 101 is pulsed, the transistor 102 is momentarily forward biased, and the resulting collector current operates the relay 119. As shown by way of example in FIG. 2, the relay 119 may operate a switch 121 in an a.c. circuit 122 connected to supply power to the lumber marking device 21, or the operation of the unijunction transistors 96 and 97 can be used to enter information into computer memory and logic circuits 22 (FIG. 1).

Normally, the RC time constant of the trigger circuit 20 is adjusted, using the variable resistor R117, to keep the transistor 102 switched on for long enough for a flaw to pass the second of the two detectors 12 and 13. Thus, for a given maximum flaw size and lumber speed, only one pulse would be generated during the transition of one flaw past the detector system. For very large flaws, a second pulse will be generated as the last portion of the flaw passes the second detector. This will usually be a desirable result, since a small flaw can be removed with a single cut of a double-blade saw, while a large flaw will require two cuts.

In a presently preferred embodiment of the invention, the following values of resistance and capacitance may be used. It will be understood by those of ordinary skill in the electronics art that the invention is not limited to circuitry using the specific values set forth herein.

R51	10kΩ (max.)	R105	100Ω
R52	1kΩ	R106	470Ω
R53	1.5kΩ	R107	1MΩ
R56	10kΩ (max.)	R108	1kΩ
R57	1kΩ	R112	100Ω
R58	1.5kΩ	R113	470Ω
R61	10kΩ	R114	30kΩ
R63	10kΩ	R115	50kΩ (max.)
R64	10kΩ	R116	1MΩ
R65	10kΩ	R117	5kΩ (max.)
R66	10kΩ	C54	100pfd
R67	10kΩ	C55	100pfd
R68	10kΩ (max.)	C59	100pfd
R69	1.5kΩ	C61	100pfd
R84	10kΩ	C71	100pfd
R85	1.5kΩ	C72	100pfd
R91	10kΩ	C86	100pfd
R92	5kΩ	C90	100pfd
R93	10kΩ	C109	0.1μfd
R94	500Ω	C111	1μfd
R104	1kΩ	C118	5μfd

In the presently preferred embodiment, conventional components are employed throughout. As mentioned above, the operational amplifiers used in the embodiment are half-sections of dual operational amplifier modules designated MC1437L. The SCR's employed are designated 2N5060, the unijunction transistors 2N4891, the diodes 1N34A, the NAND gate MC673P, and the npn transistor 2N4921. Again it will be understood that the invention is not limited to the use of these specific components.

From the foregoing, it can be seen that the invention as described in detail for purposes of illustration, provides a new and useful tool for the detection and location of flaws in lumber and like material. Small flaws in moving pieces of lumber can be reliably detected and located, and can be conveniently distinguished from normal fluctuations in lumber density without imposing any limitation on processing speed. It will also be seen that, while a particular form of the invention has been illustrated and described, various modifications can be made without departing from the spirit and scope of the invention. Accordingly, the invention is not to be limited, except as by the appended claims.

We claim:

1. For use with a system for detecting flaws in non-conducting material having at least one widely varying physical characteristic affecting the attenuation of microwave radiation transmitted through the material, the combination comprising:

at least two microwave detectors positioned to receive microwave radiation transmitted through and consequently attenuated by the material;

signal difference sensing means responsive to differences in output signals from said microwave detectors and non-responsive to variations in attenuation characteristics of the material affecting said microwave detectors substantially equally; and

electrical means for coupling said signal difference sensing means to means for controlling processing of the material, whereby a flaw in the material produces a momentary difference in output signals from said microwave detectors as the flaw passes said detectors, and the difference signal is used to control processing of the material in such a fashion as to avoid the flaw.

2. A combination as set forth in claim 1, wherein there are two microwave detectors.

3. A combination as set forth in claim 1, wherein said electrical means include level sensing means for rejecting signal differences below a selectable threshold level.

4. A combination as set forth in claim 3, wherein said electrical means include trigger circuit means for generating control pulse signals in response to signal differences above said threshold level.

5. A combination as set forth in claim 4, wherein said electrical means include absolute value generation means equally responsive to positive and negative signal differences.

6. A combination as set forth in claim 4, wherein there are two microwave detectors and the material is lumber.

7. Apparatus for detection of flaws in moving lumber of widely varying density, said apparatus comprising:

a source of microwave radiation positioned to irradiate the moving lumber;

at least two microwave detectors adjacently positioned to receive the radiation after transmission through the lumber and consequent attenuation and distortion by the presence of flaws;

differential amplifier means for detecting and amplifying differences in output signals from said microwave detectors, said differences being generated as a result of flaws passing across one of said detectors and said differential amplifier means being non-responsive to variations in the output signals due to variations in lumber density affecting said microwave detectors substantially equally; and

electrical means for coupling said differential amplifier means to means for controlling processing of the lumber in such a fashion as to avoid the flaws.

8. Apparatus as set forth in claim **7**, wherein there are two microwave detectors.

9. Apparatus as set forth in claim **8**, wherein:

said source of microwave radiation generates electromagnetic radiation having a wavelength greater than 1 centimeter; and

the flaws to be detected exceed 3 millimeters in diameter.

10. Apparatus as set forth in claim **7**, wherein said differential amplifier means include level sensing means for rejecting signal differences below a selectable threshold level.

11. Apparatus as set forth in claim **10**, wherein said electrical means include trigger circuit means for generating control pulse signals in response to signal differences above said threshold level.

12. Apparatus as set forth in claim **11**, wherein there are two microwave detectors.

13. Apparatus as set forth in claim **12**, wherein said electrical means include absolute value generation means equally responsive to positive and negative signal differences.

14. Apparatus as set forth in claim **13**, wherein:

said source of microwave radiation generates electromagnetic radiation having a wavelength greater than 1 centimeter; and

the flaws to be detected exceed 3 millimeters in diameter.

15. Apparatus for detection of flaws in moving lumber of widely varying density, said apparatus comprising:

a source of microwave radiation positioned to irradiate the moving lumber;

first and second microwave detectors positioned adjacently in the line of motion of the lumber to receive the radiation after transmission through the lumber and consequent attenuation and distortion by the presence of flaws;

first and second single-ended operational amplifiers for receiving and amplifying corresponding output signals from said first and second microwave detectors;

a differential operational amplifier for detecting and amplifying signal differences between the output signals from said first and second microwave detectors, said signal differences resulting from flaws passing across one of said detectors and said differential operational amplifier being non-responsive to variations in the output signals from said first and second single-ended operational amplifiers due to variations in lumber density affecting said first and second microwave detectors equally;

absolute value generation means for inverting negative signal differences but not positive signal differences;

signal level sensing means for rejecting those of said signal differences below a selectable threshold level and thereby rejecting variations in the output signals from said first and second single-ended operational amplifiers due to variations in lumber density affecting said first and second microwave detectors substantially equally; and

trigger circuit means for generating control pulse signals in response to those of said signal differences above said threshold level.

16. Apparatus as set forth in claim **15**, wherein:

said source of microwave radiation generates electromagnetic radiation having a wavelength greater than 1 centimeter; and

the flaws to be detected exceed 3 millimeters in diameter.

17. Apparatus as set forth in claim **15**, wherein:

said level sensing means includes at least one unijunction transistor; and

said trigger circuit means includes at least one silicon controlled rectifier.

18. A method for detecting flaws in moving lumber of widely varying density, comprising the steps of:

transmitting microwave radiation through the lumber;

measuring received radiation at at least two adjacent positions substantially equally affected by attenuation variations caused by the widely varying lumber density;

sensing significant differences in the radiation measured at said adjacent positions, said differences resulting only from the presence of flaws in the lumber moving through said adjacent positions; and

generating in response to said significant differences control signals for use in processing the lumber.

19. A method as set forth in claim **18**, wherein said step of sensing significant differences includes amplifying said differences.

20. A method as set forth in claim **19**, wherein said step of sensing significant differences includes sensing the absolute magnitude of said differences and rejecting those of said differences below a selectable threshold level.

21. A method as set forth in claim **20**, wherein said step of generating control signals includes triggering generation of control pulse signals in response to those of said differences above the threshold level.

22. A method for detecting flaws in lumber of widely varying density, comprising the steps of:

transmitting radiation from a microwave oscillator source;

moving the lumber through the microwave radiation;

receiving the microwave radiation at two adjacent microwave detectors after transmission through the lumber, the two detectors being substantially equally affected by variations in attenuation of the radiation due to the widely varying lumber density;

detecting significant difference signals between outputs from the two detectors, said significant differ-

ence signals resulting only from the presence of flaws in the lumber moving across one of the detectors; and

generating in response to said significant difference signals control signals for use in processing the lumber.

23. A method as set forth in claim **22,** wherein:

said step of transmitting utilizes a wavelength greater than 1 centimeter; and

the flaws to be detected exceed 3 millimeters in diameter.

24. A method as set forth in claim **22,** wherein said step of detecting significant difference signals includes inverting all negative ones of the signal differences, thereby generating absolute values of the signal differences.

25. A method as set forth in claim **24,** wherein said step of detecting significant difference signals includes sensing the absolute values of the signal differences and rejecting those below a selectable threshold level.

26. A method as set forth in claim **25,** wherein said step of generating control signals includes triggering generation of control pulse signals in response to those of said significant difference signals above the threshold level.

27. A method for detecting flaws in lumber with widely varying density, comprising the steps of:

transmitting microwave radiation from a microwave oscillator source;

receiving the microwave radiation at two adjacent microwave detectors after transmission through the lumber;

moving the lumber between the microwave oscillator source and the two microwave detectors in a direction substantially at right angles to the direction of radiation;

amplifying output signals from the two microwave detectors in two corresponding single-ended operational amplifiers;

detecting and amplifying in an operational amplifier difference signals representative of the difference between the two output signals, said difference signals resulting from the momentary presence of flaws in the lumber moving across one of the detectors;

disregarding gradual fluctuations in lumber density, said fluctuations resulting in practically equal effects on the microwave radiation received at the microwave detectors;

inverting all negative ones of said difference signals, thereby generating absolute magnitudes of said difference signals;

sensing the absolute magnitudes of said difference signals and rejecting those of said difference signals below a selectable threshold level; and

generating control pulse signals for use in processing the lumber, in response to those of said difference signals above the threshold level.

28. A method as set forth in claim **25,** wherein:

said step of transmitting utilizes a wavelength greater than 1 centimeter; and

the flaws to be detected exceed 3 millimeters in diameter.

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