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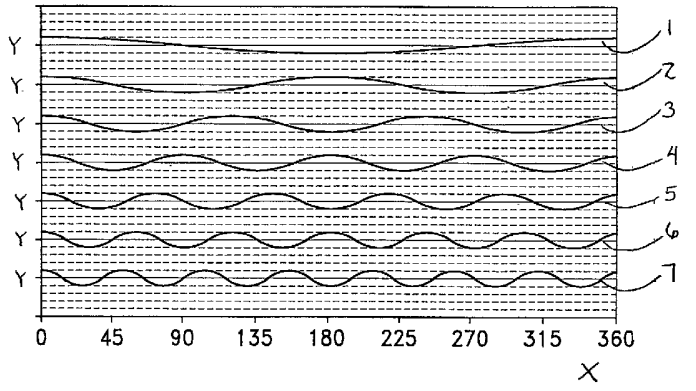
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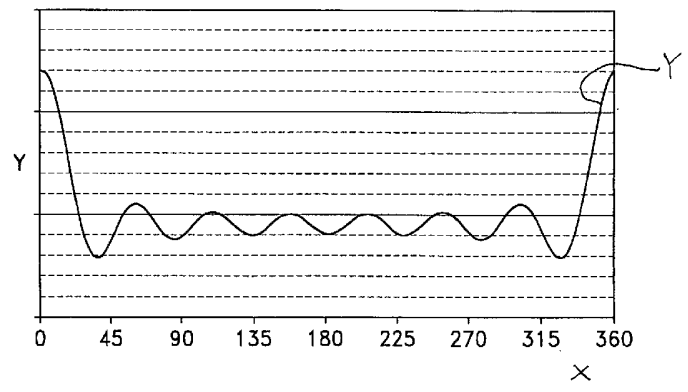
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[Continued on next page]

(54) Title: METHOD FOR DESIGNING TIRE NOISE PITCH SEQUENCE





(57) Abstract: A method of designing a pitch noise pitch sequence includes the steps of first defining the characteristics of the tire noise generated by tire tread lug stiffness variations and then defining a tire noise pitch sequence that yields the defined characteristics to provide preferred modulation characteristics and good level characteristics. A tire is provided having a pitch sequence designed from this method. The tire has five different pitches with pitch ratios of 1.00, 1.10, 1.25, 1.4, and 1.50.

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METHOD FOR DESIGNING TIRE NOISE PITCH SEQUENCE

BACKGROUND OF THE INVENTION

1. TECHNICAL FIELD

The present invention generally relates to methods of designing tread patterns for tire noise. More particularly, the invention relates to a method for designing tread pattern tire noise pitch sequences by pre-selecting variations in lug stiffness characteristics. The invention specifically relates to a method for designing tire noise pitch sequences to achieve preferred characteristics of variations in tread lug stiffness based on the distribution of the lugs in the tire noise pitch sequence.

2. BACKGROUND INFORMATION

One aspect of tire design involves minimizing undesirable tire noise. Tire noise is generated when the lugs of the tread pattern contact the road surface. An unvarying tread pattern, or mono pitch tread pattern, creates an undesirable tonal, or mono pitch sound. Tire designers vary the tread pattern to avoid mono pitch sounds. The tread patterns are typically varied by altering the size of the tread pitches around the circumference of the tire. Varying the sizes of the tread pitches tends to reduce mono pitch tire noise by broadening the frequency domain of the noise spectrum but undesirable noise in the time domain can still be created.

Tread patterns are currently analyzed by comparing the tire noise generated by different variations in the tread pitches. Known analysis techniques allow the tire designer to select a pitch pattern for the tread design that generates acceptable tire noise. One such technique uses the Fourier spectrum of the pitch sequence to identify objectionable pitch sequences. Another technique disclosed in US Patent 6,112,167 analyzes portions of the pitch sequence around the circumference of the tire. Although these techniques have been effective, tire designers have found that known techniques can result in tire noise pitch sequence designs that pass initial

screening while still having undesirable tire noise. Tire molds having such sequences must be rebuilt or modified to reduce the undesirable noise. One cause of undesirable noise is tire noise attributed to the variations in the lug stiffness around the circumference of the tire.

When the size of the tread pitches is varied, the size of the lugs of the tread pattern is varied. The lugs thus have different stiffnesses and produce different sound amplitudes when they contact the road surface. These differences create sound amplitude variation that can make an otherwise desirable pitch sequence undesirable. In the past, this undesirable tire noise was not analyzed and tires would be produced before the undesirable noise was recognized. If the customer objected to the noise, the tire manufacturer would have to scrap the expensive tire mold or would have to modify the mold. In response to this issue, the art thus desired a secondary screening method that allows the tire designer to compare a group of otherwise desirable pitch sequences. This screening technique is disclosed in pending patent application US 2003/0040886 A1 dated February 27, 2003, which describes a method for comparing tread designs based on tire noise generated by tire tread lug stiffness variation. The art thus desires a method to develop tread designs with pre-selected lug stiffness variation characteristics. Such a tread pattern design method would define tire noise pitch sequences for optimized lug stiffness variations and tire noise level characteristics. Figures 1A-C and 2A-C demonstrate the inherent difficulties in defining tire noise pitch sequences with optimized lug stiffness variations and tire noise level characteristics. Figures 1A-C provide for a 60-pitch noise sequence with good level characteristics, but poor lug stiffness (further referred to as modulation) characteristics. Good level characteristics consist of a smooth spectrum about the first tread passage harmonic range that is centered at 60 harmonics for 60 pitches (FIG. 1A). Notice that in the graph depicted in figure 1B, there is relatively high modulation levels at the first and second modulation order. These high levels would translate to a tire tread pattern with a strong once and twice per revolution noise variation. A tire pattern with good modulation characteristics would have low modulation levels. Figures 2A-C demonstrate a tire noise pitch sequence with

good modulation characteristics. An analysis of the harmonic content of this sequence provides for a narrow, tonal band of energy about the 60th, 120th, 180th harmonic and subsequent multiples of 60 harmonics with high, undesirable, level characteristics.

SUMMARY OF THE INVENTION

In view of the foregoing, the present invention provides a method of defining tire noise pitch sequences based on preferred characteristics of the tire noise generated by tire tread lug stiffness variations. The method of the invention may be used to provide a tire noise pitch sequence with preferred modulation characteristics and good level characteristics.

The invention provides a method including the steps of defining the amplitudes of the modulation orders; defining the phases for each order; summing the functions for each order; and defining the tire noise pitch sequence from the summation of the functions.

The invention also provides a tire having a pitch sequence designed from the method of the invention. In one embodiment, the invention provides a tire having a body having a tread that has a pitch sequence; and the pitch sequence having five different size pitches with pitch ratios of 1.00, 1.10, 1.25, 1.4, and 1.50.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1A is a graph showing the harmonic analysis result for a tire with a good harmonic spectrum; the X axis being the harmonic spectrum of event occurrences per tire revolution and the Y axis being the amplitude.

FIG. 1B is a graph showing the modulation analysis result for a tire with bad modulation orders; the X axis being the modulation order and the Y axis being the amplitude.

Fig. 1C is the pitch sequence analyzed in Figs. 1A and 1B with the pitch ratios listed at the end of the pitch sequence.

FIG. 2A is a graph showing the harmonic analysis result for a tire with a bad harmonic spectrum; the X axis being the harmonic spectrum of event occurrences per tire revolution and the Y axis being the amplitude.

FIG. 2B is a graph showing the modulation analysis result for a tire with good modulation orders; the X axis being the modulation order and the Y axis being the amplitude.

Fig. 2C is the pitch sequence analyzed in Figs. 2A and 2B with the pitch ratios listed at the end of the pitch sequence.

FIG. 3 is a graph showing a series of seven cosine functions with zero phase and equal amplitude; the X axis being degrees from a set point on a tire and the Y axes being amplitudes.

FIG. 4 is a graph showing the Y function for the seven signals of FIG. 3; the X axis being degrees from a set point on a tire and the Y axis being amplitude.

FIG. 5 is a graph showing the series of functions from Table 2, Set 1; the X axis being degrees from a set point on a tire and the Y axis being amplitude.

FIG. 6 is the Y function for the functions of Fig. 5; the X axis being degrees from a set point on a tire and the Y axis being amplitude.

FIG. 7 is a graph showing the series of functions from Table 2, Set 2; the X axis being degrees from a set point on a tire and the Y axis being amplitude.

FIG. 8 is the Y function for the functions of Fig. 7; the X axis being degrees from a set point on a tire and the Y axis being amplitude.

FIG. 9A is a graph showing the harmonic analysis result of the pitch sequence designed from the curve of FIG. 6; the X axis being the harmonic response and the Y axis being the amplitude.

FIG. 9B is a graph showing the modulation analysis result of the pitch sequence designed from the curve of FIG. 6; the X axis being the modulation orders and the Y axis being the amplitude.

FIG. 9C is a graph showing the pitch sequence designed from the curve of FIG. 6; the X axis being the pitch number and the Y axis being the pitch size.

FIG. 9D is a graph showing the comparison between the target design curve and the actual curve obtained from the designed pitch sequence; the X axis being location in degrees and the Y axis being the amplitude.

FIG. 10A is a graph showing the harmonic analysis result of the pitch sequence designed from the curve of FIG. 8; the X axis being the harmonic response and the Y axis being the amplitude.

FIG. 10B is a graph showing the modulation analysis result of the pitch sequence designed from the curve of FIG. 8; the X axis being the modulation orders and the Y axis being the amplitude.

FIG. 10C is a graph showing the pitch sequence designed from the curve of FIG. 8; the X axis being the pitch number and the Y axis being the pitch size.

FIG. 10D is a graph showing the comparison between the target design curve and the actual curve obtained from the designed pitch sequence; the X axis being location in degrees and the Y axis being the amplitude.

FIG. 11 is a flow chart showing a method for creating and comparing tire noise pitch sequences.

Fig. 12 shows the relationship between Figs. 12A and 12B and showing exemplary pitch sequences for 53-67 pitch designs.

Figs. 12A and 12B are a chart of exemplary pitch sequences designed in accordance with the present invention (Fig. 12B is a continuation of Fig. 12A).

Fig. 13 shows the relationship between Figs. 13A and 13B and showing exemplary pitch sequences for 68-80 pitch designs.

Figs. 13A and 13B are a chart of exemplary pitch sequences designed in accordance with the present invention (Fig. 12B is a continuation of Fig. 12A).

Similar reference numbers refer to similar elements.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The first part of the method is to define the preferred modulation characteristics and to build a function based on the combined modulation characteristics. It is generally known in the art that a first or second order is undesirable. Lug stiffness variations of the first order can magnify any imbalance or out of round in the tire relating to uniformity performance. As the

order increases the effect on uniformity is diminished. Thus it is preferred to minimize the first two modulation orders. It is not prudent, though, to minimize all of the modulation orders, because the only way to have a noise treatment without modulation, is one in which all of the pitch sizes are the same. This type of sequence, commonly referred to as a mono pitch, produces a constant tone or mono pitch sound, which is also undesirable. Thus, it is desired to have some modulation in each of the orders 3 and above. It is desirable to have a smooth transition of the modulation orders. The number of modulation orders and the levels selected can vary. It has been found that it is not necessary to analyze modulation orders higher than seven because they generally approach zero and the analysis of these orders consumes too much processing time compared to the benefit received from the analysis.

In order to show an example of the invention, the data shown in Table 1 is analyzed in the following description. Table 1 lists the pre-selected levels for the selected modulation orders. Although the levels for the first and second orders preferably are selected to be zero in the exemplary embodiment, values other than zero may be used with the method of the present invention as long as these values are minimized with respect to the remaining orders. It is also desirable to set the value of the third order to be less than the values of the fourth and fifth orders. As noted above, all of the values cannot be set to zero because a monopitch would be the result. The levels should be set high enough to avoid a monopitch while low enough to avoid undesirable tones. The individual level can range from as little as 0 to as much as 20. The preferred embodiment sets a preferable range of between 1 to 5 for modulation orders above and including 3.The numbers in Table 1 meet these limitations and provide a smooth transition between different orders.

Table 1

Order	Level
1	0
2	0
3	1.5
4	2.2
5	2.25
6	2
7	1.5

After the levels for the modulation orders have been defined, a complex wave is created by a summation of cosine waves with pre-selected amplitude and phase characteristics. Equation 1 is the Fourier series expansion of the cosine functions.

$$Y = \sum_{k=1}^{n} A_k \cos\left(k \bullet \theta + \varphi_k\right)$$

... where Y is the resultant function, A_k are the amplitudes of each k^{th} order, theta is the angle from 1 to 360 degrees and phi_k is the phase angle of the k^{th} order.

Figure 3 graphically shows a series of 7 cosine functions with zero phase and equal amplitude. Figure 4 shows the function, Y, for the 7 signals of figure 3.

By building a series of Y functions for a set of pre-defined A_k as defined in table 1, noise sequences can be defined by randomly, or in an orderly manner, defining the phase angles, f_k, for each order. The phase angles may be defined in an orderly manner by looping through the potential phases at a fixed increment such as 1 degree. Table 2 shows two sets of phases. The first set has all of the modulation orders in phase and the second set has orders 4 through 7 with varying phase.

Table 2

Order	Level	Phase Angles in Degrees	
		Set 1 In Phase	Set 2 Phased
1	0	0*	0*
2	0	0*	0*
3	1.5	0**	0**
4	2.2	0	97
5	2.25	0	-73
6	2	0	-105
7	1.5	0	4

* Phase angle for 0 amplitude is irrelevant

** All non-zero order phases are relative to lowest non-zero order

Figures 5, 6, 7 and 8 represent the waves for each curve with specified phase as well as the resultant wave shape, which is a representation of the lug stiffness variation of some tire noise treatment. A computer may be used to generate a large number of modulation characteristics including different amplitudes and phase angles. A computer program may be used to create a wide variety of resultant waves shapes that are then used to design a wide variety of pitch sequences that are then compared to obtain desirable pitch sequences.

The second part of the method constructs a tire noise pitch sequence where the calculation of the lug stiffness variation curve matches, as closely as possible, the resultant wave shape. The shape of the lug stiffness variation curve D, as discussed in prior art (publication no. US 2003/0040886 A1 dated February 27, 2003), is defined as the accumulation of the deviation of the arc length from the arc length of the mean pitch size. D is a vector of the difference in the actual arc length from a fixed arbitrary reference point to the end of the i^{th} pitch size.

$$D = \{D_1, D_2, D_3, \ldots, D_i, \ldots D_{N-1}, D_N\}$$

N is the total number of tread pitches placed about the circumference of the tire. D_i can be calculated using the following relationship:

$$D_i = X_i - \overline{X}_i$$

$$X_i = \sum_{j=1}^{i} L_j$$

$$\overline{X}_i = i \times \frac{C}{N}$$

wherein:

X_i is the arc length from the fixed reference point to the end of the i^{th} tread pitch.

$\overline{X}_i$ is the arc length of i pitches times the mean pitch size.

L_j is the pitch length of the j^{th} tread pitch.

C is the tire circumference in degrees = 360 degrees.

N is the number of tire tread pitches.

Y is a function of circumferential angle, theta. Y_i can be defined as the target curve, Y, evaluated at the at i times the circumference, C, divided by the number of pitches, N.

$$Y_i = Y\Big|_{\theta = i \times \frac{C}{N}}$$

D_i, the design curve shape at i is an approximation of Y_i.

$$Y_i \cong D_i$$

$$Y_i \cong \sum_{j=1}^{i} L_j - i \times \frac{C}{N}$$

$$\sum_{j=1}^{i} L_j \cong Y_i + i \times \frac{C}{N}$$

Once the desired number or tread pitches, N, each pitch length can then found in sequential order. For reference in this example N=60, although N can range from as low as 20 to as high as 100 total pitches. The first size is found by solving the equation for i=1 with N =60 & C=360.

$$\sum_{j=1}^{1} L_j = Y_1 + 1 \times \frac{360}{60}$$

$$L_1 = Y_1 + 60$$

The second size is found in the same manner as the first while utilizing L_1.

$$\sum_{j=1}^{2} L_j = Y_2 + 2 \times \frac{360}{60}$$

$$L_1 + L_2 = Y_2 + 120$$

$$L_2 = Y_2 + 120 - L_1$$

$$L_2 = Y_2 + 120 - (Y_1 + 60)$$

$$L_2 = (Y_2 - Y_1) + 60$$

The general form of the solution of the L_i array is as follows.

$$L_{i=1} = Y_i + \frac{C}{N}$$

$$L_{i\geq 2} = Y_i - \sum_{j=1}^{i-1} Y_j + \frac{C}{N}$$

This process will define a unique set of pitch sizes, L_i, which will give the specified lug stiffness variation characteristics. L_i will yield N unique pitch lengths. N unique tire tread pitch lengths, while desired by the tire noise pitch sequence designer, is impractical when considering the design of a tire mold. The higher the number of unique pitch lengths, the higher the complexity and cost associated with the production of the tire mold. The art typically uses as few as 2 to as many as 10 unique pitch sizes in order to decrease the complexity of the mold making process. If desired, a larger number of pitch sizes may be used.

The third part of the method involves converting from N unique pitch sizes to M prescribed pitch sizes. A numeric value is selected that defines the ratio between the largest pitch size to the smallest pitch size (the pitch ratio). This pitch ratio typically ranges from 1.2 to 1.8, but other ratios are not outside the embodiment of this method. For the purposes of continuing the example of N=60, M is chosen as 3 and the pitch ratio, P, is set at 1.5. The three sizes, designated as 1, 2, and 3 have the internal pitch ratios of 1.00, 1.25, and 1.50 respectively. The N unique pitch sizes are then fit to the M selected sizes. For example, if N ranges from 3.5 degrees to 6.5 degrees, size 1 may be set to include all N sizes from 3.5 degrees to 4.5 degrees; size 2 may be set to include all N sizes from 4.5 degrees to 5.5 degrees; and size 3 may be set to include all N sizes from 5.5 degrees to 6.5 degrees. If this example, size 1 may be 4 degrees, size 2 may be 5 degrees, and size 3 may be 6 degrees. The pitch ratio is 6/4 or 1.5.

Figures 9 and 10 show the two pitch sequences for N = 60, M=3, and P=1.5 for the two resultant wave curves from Figures 6 and 8 respectively that contain the amplitude and phase information from table 2.

As can be seen, the actual response function, bottom set of curves in figures 9 and 10, is set to match as closely as possible, the design response function. Additionally, as can be seen, the actual set of modulation order amplitudes has the basic features for good modulation performance. The reason the actual modulation amplitudes and the design modulation amplitudes vary is the selection of M = 3 design sizes rather than N unique design sizes.

Another pitch design that has been found to be particularly useful with the method of the present invention is a pitch design having five different pitch sizes defined by the pitch ratios of 1.00 (smallest pitch length), 1.10, 1.25, 1.4, and 1.5 (largest pitch length). This type of pitch design has been found to be useful for creating pitch sequences having between 53 and 80 pitches. Exemplary pitch sequences that have been designed using the method of the present invention and this pitch design include the following pitch sequences for 53 pitch, 68 pitch, and 80 pitch sequences.

53 pitch

32111233444333323344321113455421113444322233322234555

68 pitch

444433222112234555543111123455432222334333223345543221112333-
4443322333

80 pitch

332111233444332222334555443221111223344554433211112345554332-
11123334333223344554

These pitch sequences have been found to have prescribed modulation (as defined by the method described above) and controlled higher harmonics. Additional examples are shown in Figs. 12 and 13.

The fourth part of the model involves selecting a tire noise treatment. The tire noise treatment can be selected in any number of ways used by one skilled in the art. Preferably, for a tire noise treatment to be acceptable it should have good level characteristics. A comparison of the two tire noise treatments, A and B, from figures 9 and 10 respectively, provides that the modulation performance of designs A and B are similar, but design A has a narrow band with high amplitude and is therefore undesirable. Design B has both good level and amplitude characteristics and therefore would be a candidate to be used in a design. Design B thus provides a tire noise pitch sequence that has both good modulation and good level characteristics. In past design methods, the art recognized bad modulation as a byproduct of a design with good level characteristics. The method described above allows the designer to create tire noise pitch sequences having good performance for both modulation and level.

Fig. 11 shows a method for creating and comparing tire noise pitch sequences. Block 1 is the step of defining the amplitudes of the modulation orders. Block 2 is the step of prescribing the phases (either orderly or randomly). Block 3 is the step of prescribing the number of pitches, the number of unique pitch sizes, and the pitch size ratios. Block 4 is the step of defining the tire noise pitch sequence and analyzing its performance. Block 5 is the step of determining the tire noise pitch sequence is optimized. If the answer is no, the user goes back to Block 1. If the answer is yes, the user proceeds to Block 6 where the pitch sequence is stored for use on a tire. This method allows the user to create a catalog of acceptable pitch sequences that may be used on future tires.

In the foregoing description, certain terms have been used for brevity, clearness, and understanding. No unnecessary limitations are to be implied therefrom beyond the requirement of the prior art because such terms are used for descriptive purposes and are intended to be broadly construed.

Moreover, the description and illustration of the invention is an example and the invention is not limited to the exact details shown or described.

CLAIMS

1. A method for designing a tire noise pitch sequence for a pneumatic tire; the method comprising the steps of:

selecting a number of modulation orders;

defining the amplitudes of the modulation orders;

defining the phases for each modulation order;

creating a function for each modulation order that includes the defined amplitudes and phases;

summing the functions that define the modulation orders; and

defining the tire noise pitch sequence from the summation of the functions.

2. The method of claim 1, wherein the step of defining the tire noise pitch sequence includes the step of calculating a determined number of pitch sizes from the summation of the functions.

3. The method of claim 2, wherein the step of calculating the determined number of pitch sizes from the summation of the functions includes the step of using the accumulation of the deviation of the arc length from the arc length of the mean pitch size.

4. The method of claim 3, further comprising the step of interpolating a curve defined by the accumulation of the deviation of the arc length from the arc length of the mean pitch size.

5. The method of claim 4, further comprising the steps of:

selecting the total number of pitches, the number of different pitch sizes, and the pitch ratios; and

fitting the determined number of pitch sizes to the selected number of pitch sizes.

6. The method of claim 2, further comprising the steps of:

selecting the total number of pitches, the number of different pitch sizes, and the pitch ratios; and

fitting the determined number of pitch sizes to the selected number of pitch sizes.

7. The method of claim 6, further comprising the step of setting the selected number of pitch sizes to a number between 3 and 7.

8. The method of claim 6, wherein the step of fitting the determined number of pitch sizes to the selected number of pitch sizes includes the step of identifying the range of determined number of pitch sizes and evenly dividing the identified range by the selected number of pitch sizes.

9. The method of claim 6, further comprising the steps of selecting the number of different pitch sizes to be 5 and selecting the pitch ratios to be 1.00, 1.10, 1.25, 1.40, and 1.50.

10. The method of claim 6, further comprising the steps of selecting the number of different pitch sizes to be 3 and selecting the pitch ratios to be 1.00, 1.25, and 1.50.

11. The method of claim 1, wherein the step of selecting the number of modulation orders includes the step of selecting between 3 and 7 modulation orders.

12. The method of claim 11, wherein the step of defining the amplitudes of the modulation orders includes the step of defining the amplitudes of the first and second orders to be smaller than the amplitudes of the remaining orders.

13. The method of claim 12, wherein the step of defining the amplitudes of the modulation orders includes the step of defining the amplitudes of the first and second orders to be zero.

14. The method of claim 12, wherein the step of defining the amplitudes of the modulation orders includes the step of varying the amplitudes for the selected modulation orders.

15. A method for defining a tire noise pitch sequences; comprising the steps of:

(a) first defining the characteristics of the tire noise generated by tire tread lug stiffness variations; and

(b) then defining a tire noise pitch sequence that yields the defined characteristics to provide preferred modulation characteristics and good level characteristics.

16. The method of claim 15, wherein step (a) includes the steps of:

defining the amplitudes of at least five modulation orders;

defining the phases for each modulation order;

creating a function for each modulation order that includes the defined amplitudes and phases; and

summing the functions that define the modulation orders to create a complex wave Y.

17. The method of claim 16, further comprising the steps of:

defining a lug stiffness variation curve (Di) to be the accumulation of the deviation of the arc length from the arc length of the mean pitch size;

setting the lug stiffness variation curve equal to the Y curve; and

solving the equation to obtain a unique set of pitch sizes.

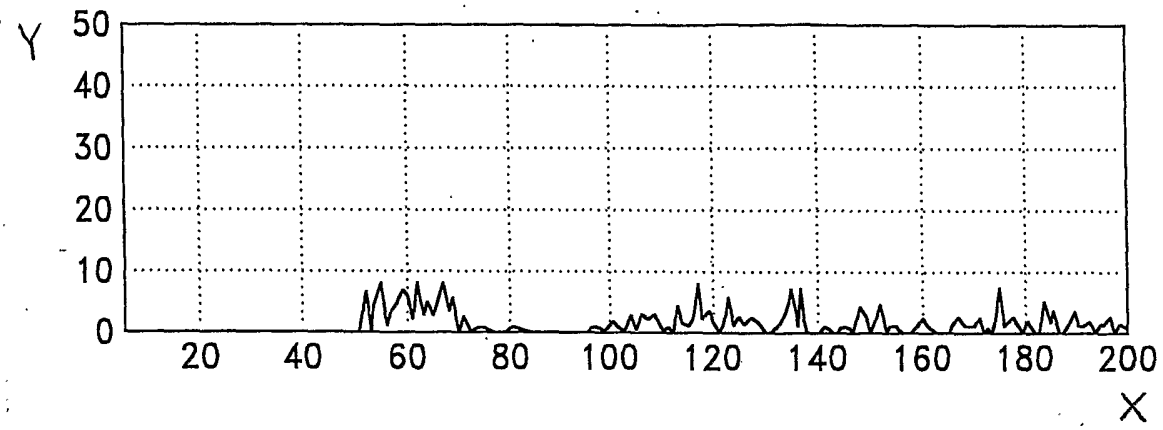
18. The method of claim 17, further comprising the steps of selecting the total number of pitches, the number of different pitch sizes, and the pitch ratios; and fitting the unique set of pitch sizes to the selected number of pitch sizes.

19. A tire comprising:

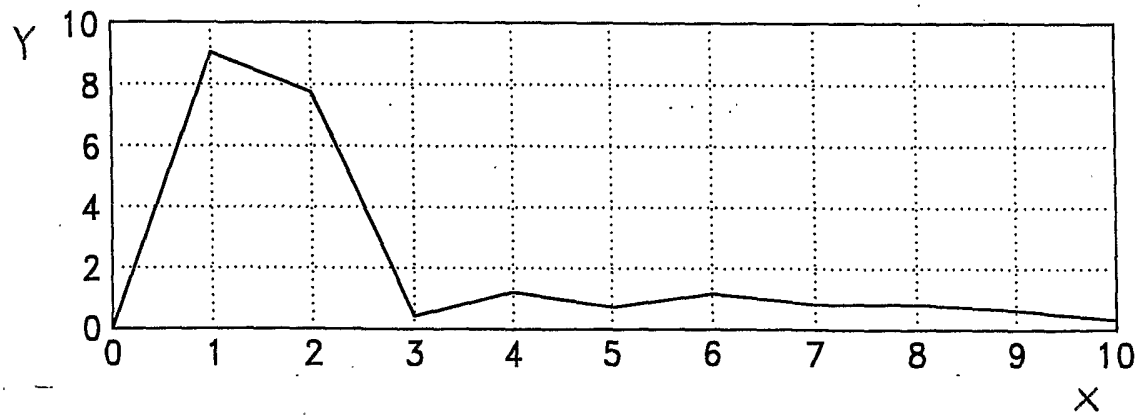
a body having a tread that has a pitch sequence; and

the pitch sequence having five different size pitches with pitch ratios of 1.00, 1.10, 1.25, 1.4, and 1.50.

20. The tire of claim 19, wherein the pitch sequence includes 53 to 80 pitches.



FIG–1A



FIG–1B

60GB2 – 12131233131333223333223121211131112211231322221323321121232 → 8 : 10 : 12

FIG–1C

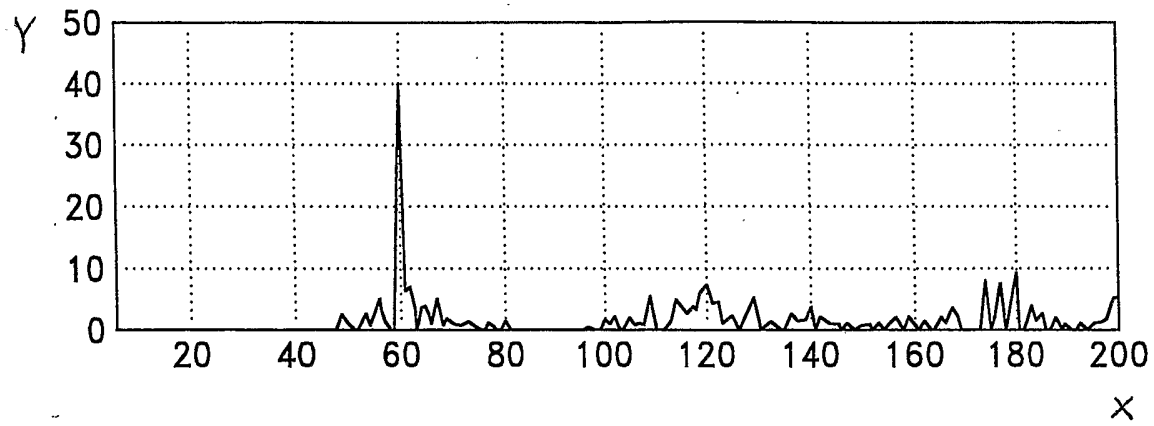


FIG-2A

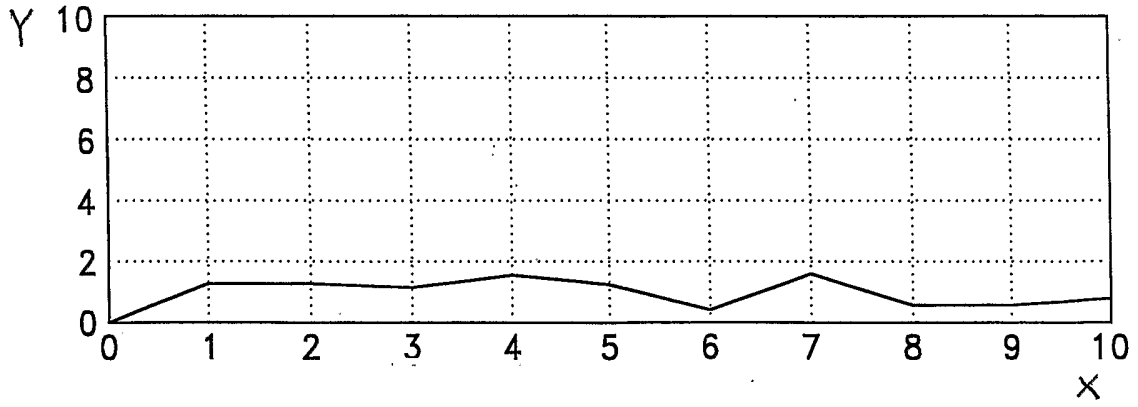
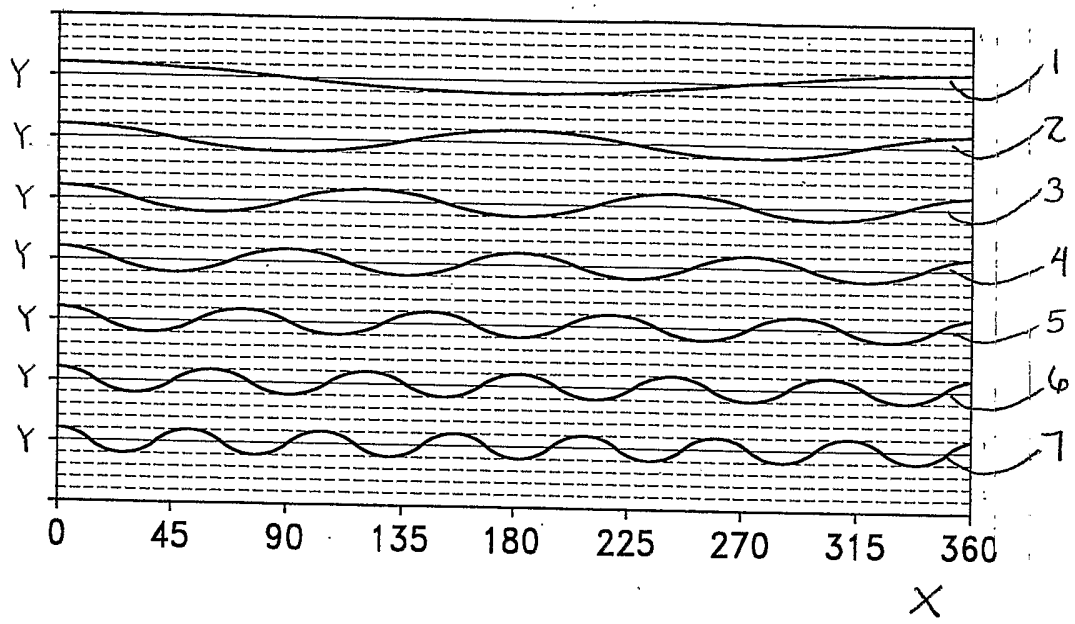


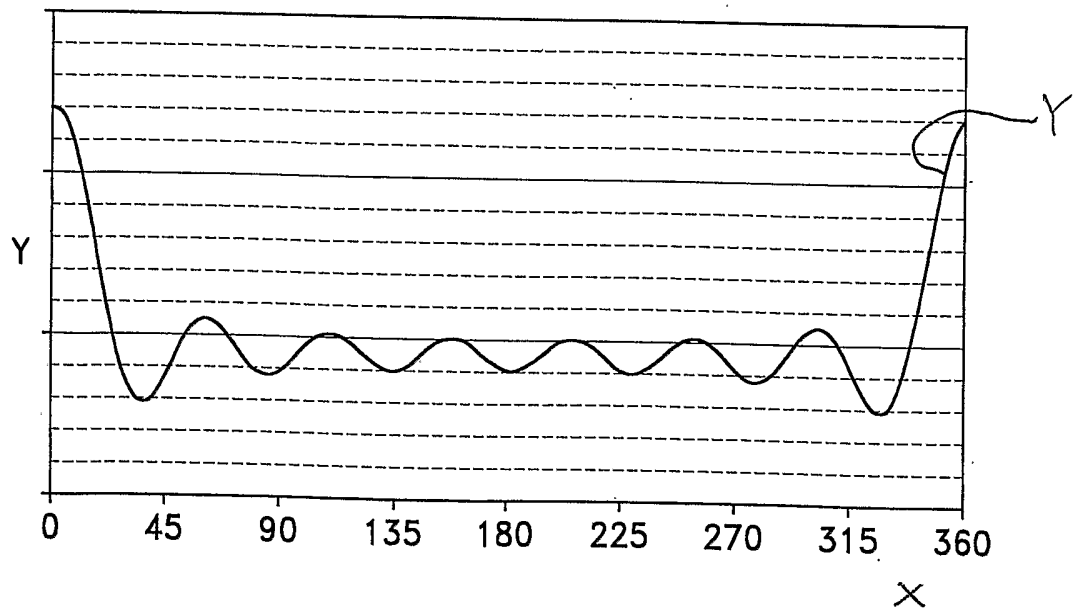
FIG-2B

60BG3 – 13213223111312233322113331121321322212313131311233222221132 3 → 8 : 10 : 12

FIG-2C


Y
Y
Y
Y
Y
Y
Y
1
2
3
4
5
6
7
0
45
90
135
180
225
270
315
360
X

FIG–3


Y
Y
0
45
90
135
180
225
270
315
360
X

FIG–4

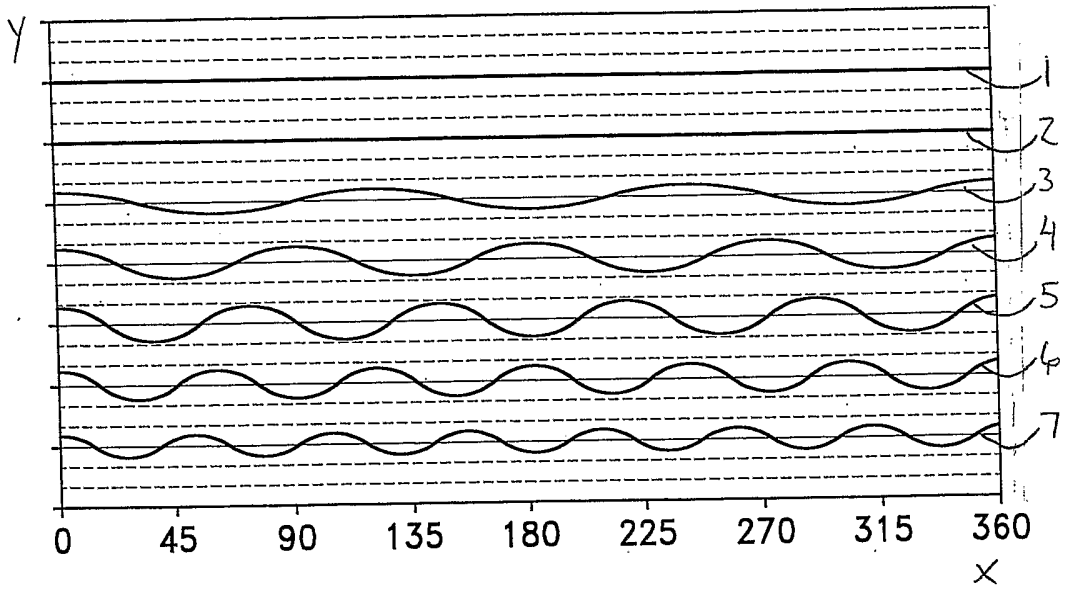

Y
1
2
3
4
5
6
7
0
45
90
135
180
225
270
315
360
X

FIG-5

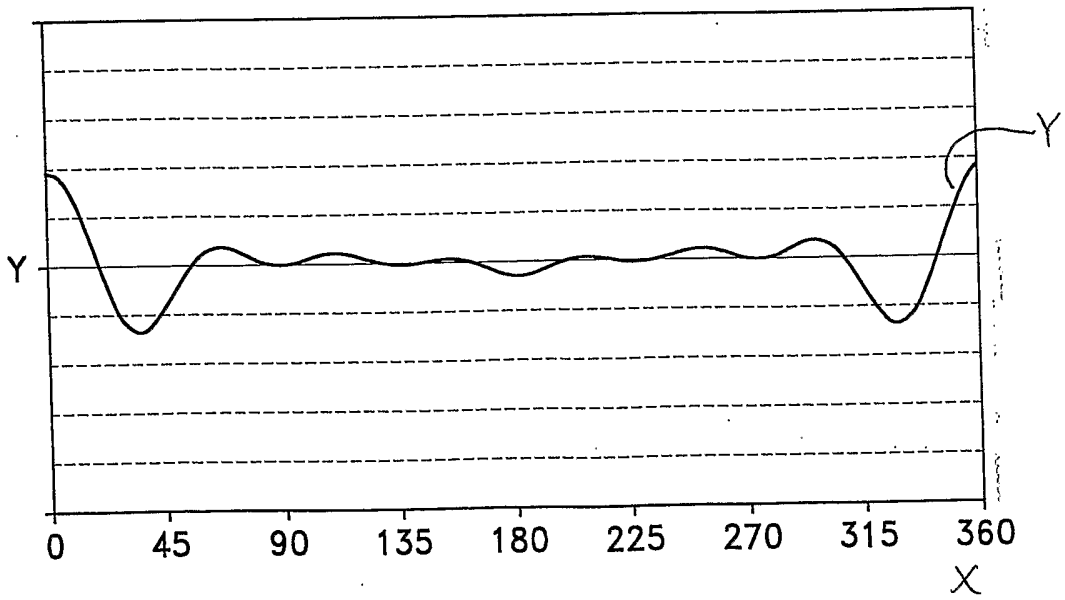

Y
Y
0
45
90
135
180
225
270
315
360
X

FIG-6

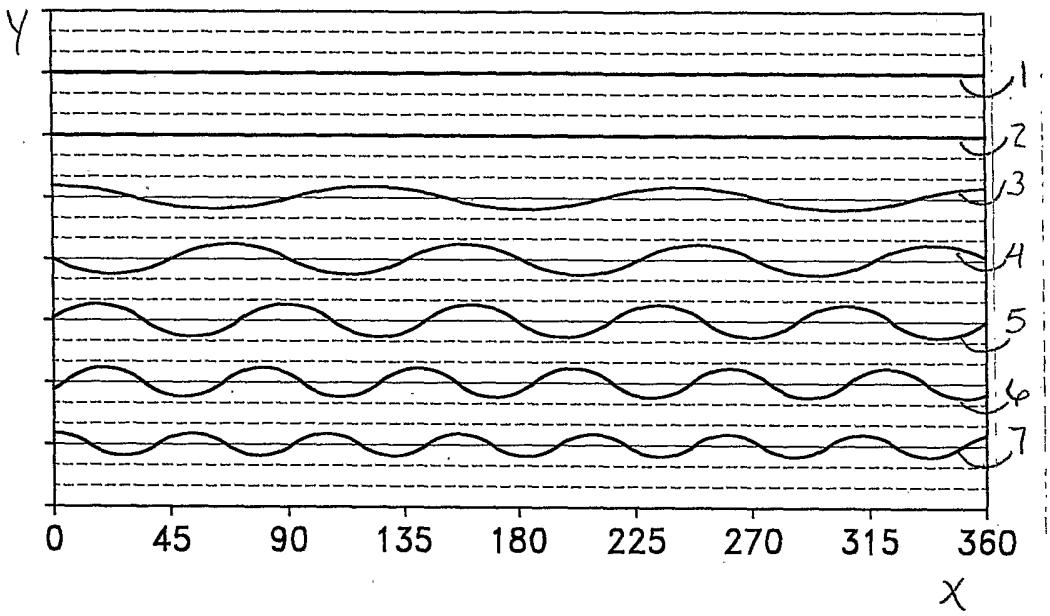

Y
1
2
3
4
5
6
7
0
45
90
135
180
225
270
315
360
X

FIG-7

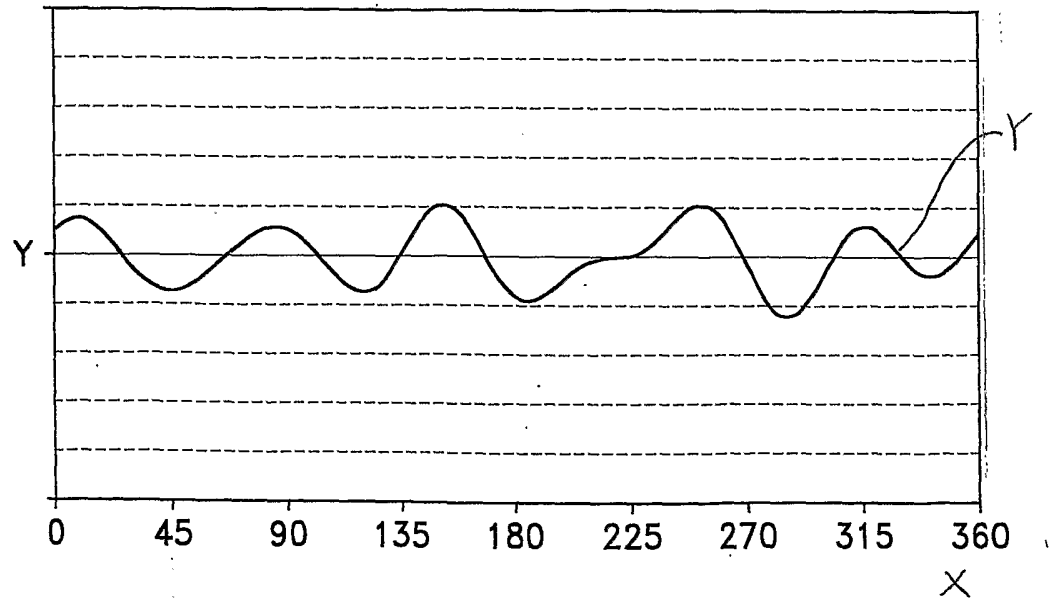

Y
Y
0
45
90
135
180
225
270
315
360
X

FIG-8

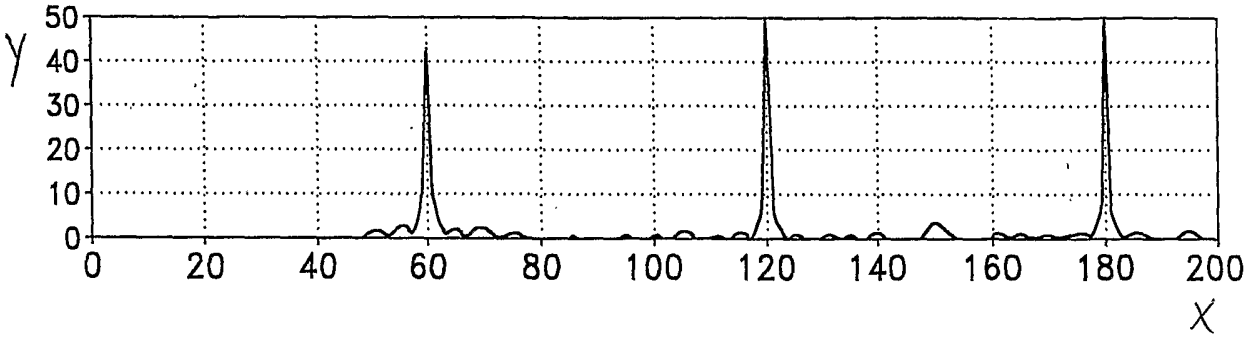


FIG-9A

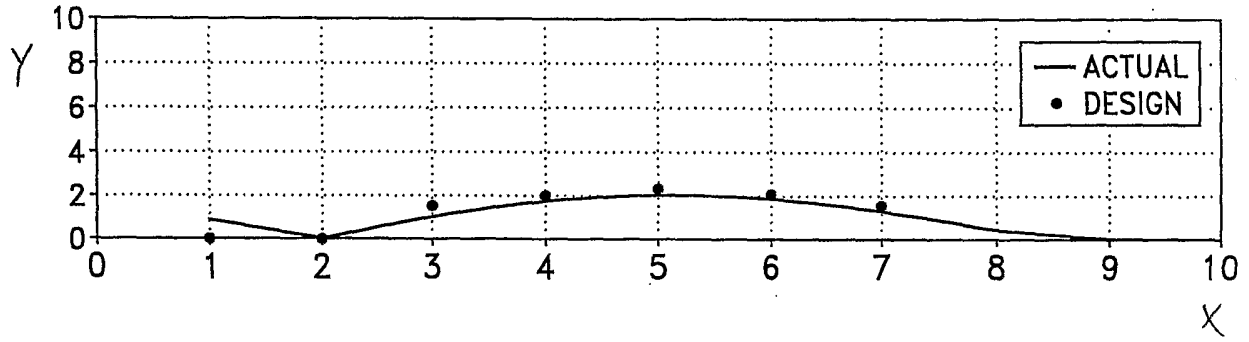


FIG-9B

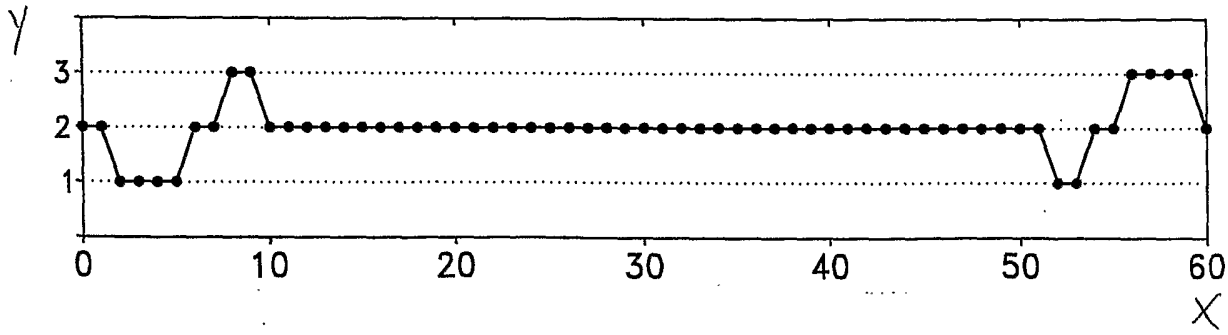


FIG-9C

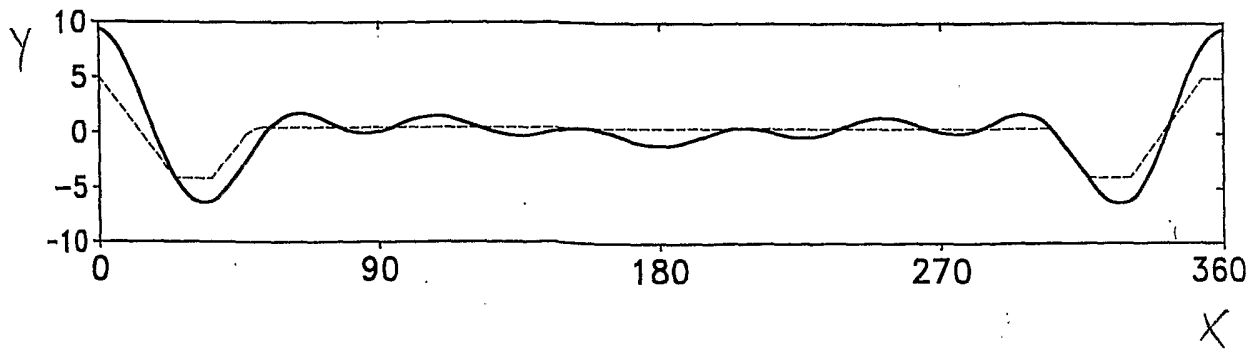


FIG-9D

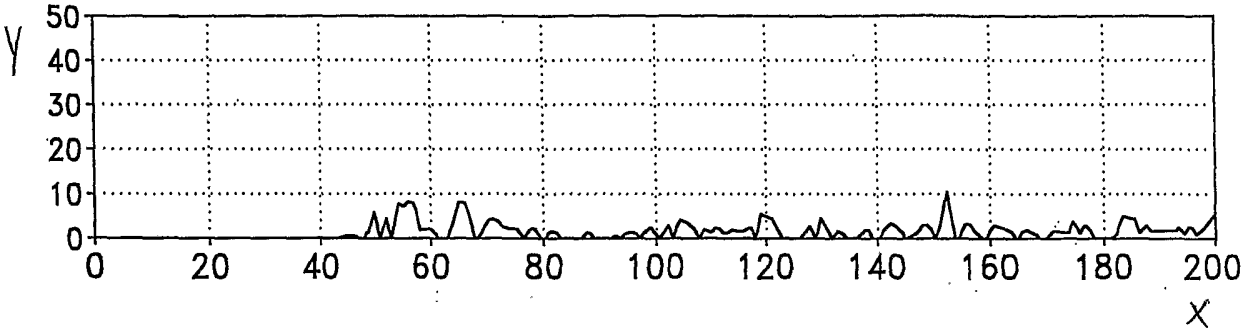


FIG-10A

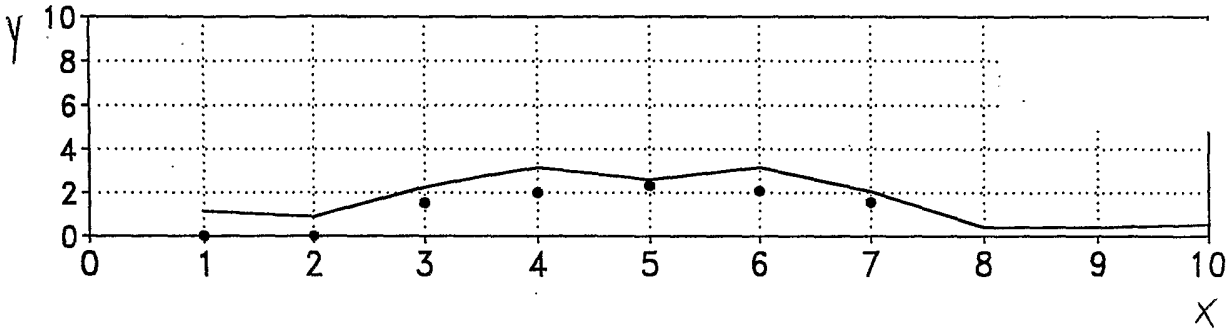


FIG-10B

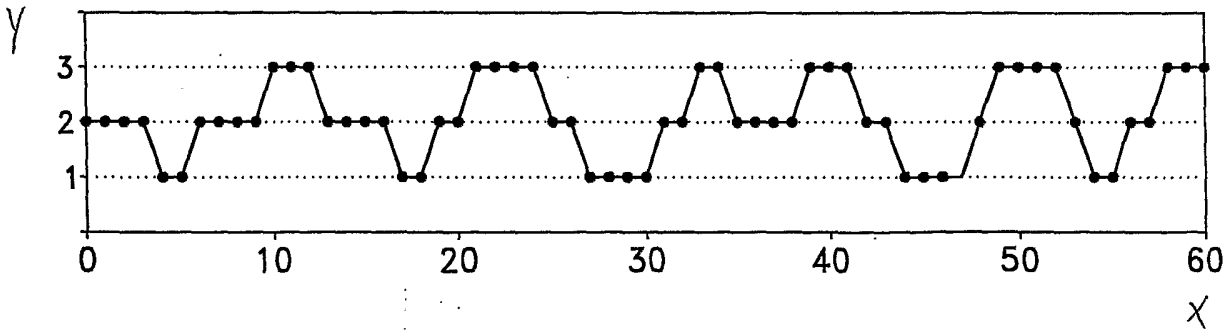


FIG-10C

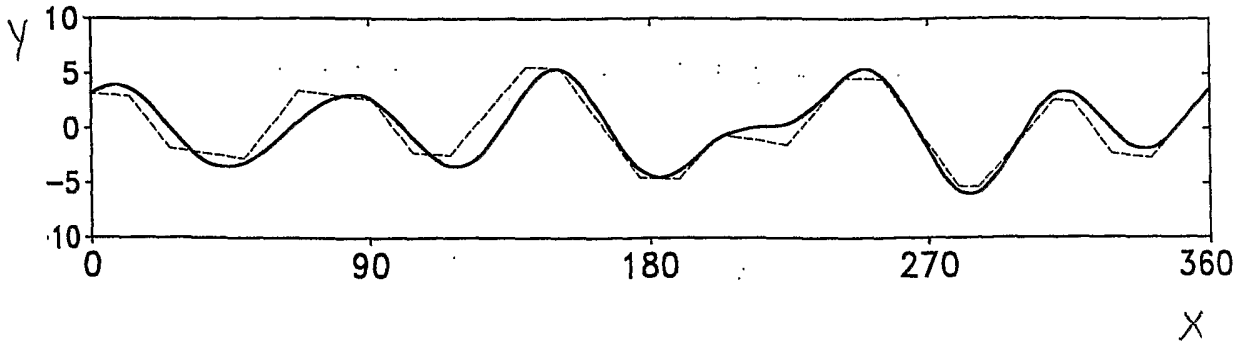


FIG-10D

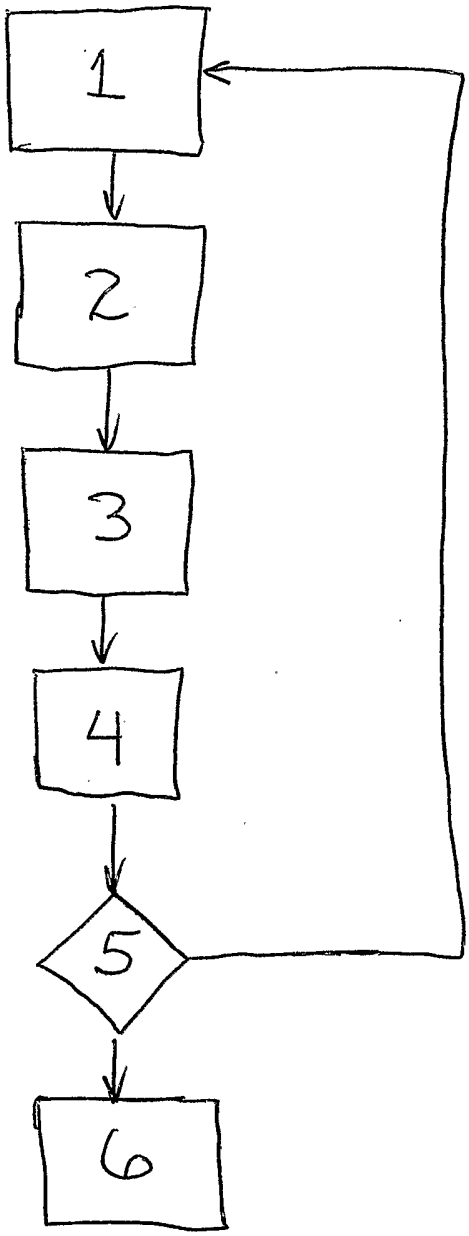


FIG 11

FIG 12

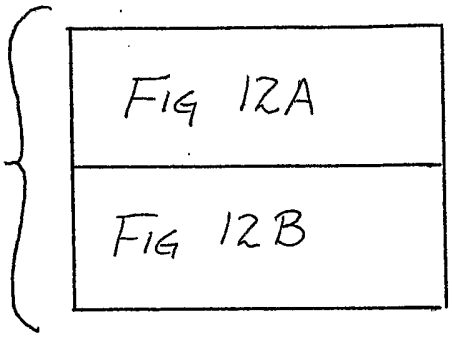


FIG 13

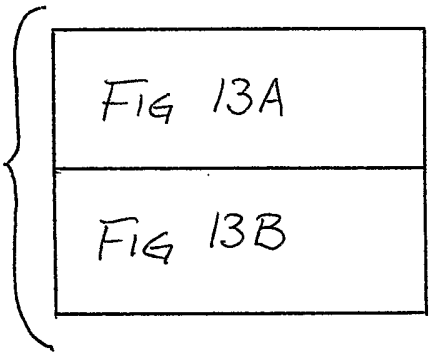


FIG 12A

	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67
1	3	2	3	4	4	3	2	3	4	4	4	4	2	4	3
2	2	2	2	3	3	2	1	1	3	3	3	3	1	3	3
3	1	3	2	2	2	2	1	1	2	3	3	3	1	3	3
4	1	4	1	2	1	3	1	1	2	2	2	2	2	2	2
5	1	4	2	1	1	3	2	2	1	2	2	2	3	2	2
6	2	3	2	1	1	4	3	3	1	1	1	1	3	1	2
7	3	2	3	2	2	4	4	4	2	1	1	1	4	2	1
8	3	1	3	3	3	3	4	4	2	2	2	2	4	2	2
9	4	1	3	3	4	2	3	4	3	2	2	2	3	2	2
10	4	2	4	4	5	2	3	3	4	3	3	3	3	3	3
11	4	3	4	5	5	1	2	2	5	4	3	4	2	4	4
12	3	4	4	5	5	2	2	2	5	5	4	5	2	4	4
13	3	5	4	5	5	3	2	2	5	5	5	5	3	5	5
14	3	4	3	4	4	4	3	3	5	5	5	5	3	5	5
15	3	3	3	2	2	5	3	3	4	5	5	5	4	5	5
16	2	2	2	1	1	4	4	4	3	3	4	4	5	4	4
17	3	2	2	1	1	4	4	4	2	2	3	2	5	3	3
18	3	3	3	1	1	3	4	4	1	1	1	1	4	2	2
19	4	3	3	2	2	2	4	4	1	1	1	1	3	1	1
20	4	4	4	4	4	2	3	3	1	1	1	1	1	1	1
21	3	4	4	5	5	3	3	3	3	2	1	2	1	1	1
22	2	3	3	5	5	3	3	3	4	3	3	3	1	2	2
23	1	2	2	4	5	4	2	3	5	4	4	4	1	3	3
24	1	1	1	3	3	4	2	2	5	5	5	5	3	4	4
25	1	1	1	2	2	3	1	2	4	4	5	5	4	5	5
26	3	1	1	2	1	3	1	1	3	4	4	4	5	5	5
27	4	2	3	2	2	2	2	1	2	3	3	3	5	4	4
28	5	4	4	3	2	1	2	2	2	2	2	2	5	3	3
29	5	5	5	3	3	1	3	3	2	2	2	2	4	2	2
30	4	5	5	4	4	2	4	3	2	2	2	2	3	2	2
31	2	5	4	3	4	3	5	4	3	3	2	2	2	2	2
32	1	4	3	3	3	4	4	4	4	3	3	3	1	2	2
33	1	3	1	2	3	4	4	4	4	4	3	3	1	3	3
34	1	3	1	2	2	5	3	4	3	3	4	4	1	3	3
35	3	2	1	3	3	5	3	3	3	3	3	3	2	4	4
36	4	1	2	4	3	4	2	3	2	2	3	3	3	4	3
37	4	1	3	5	4	4	2	2	2	2	2	3	3	3	3
38	4	2	4	5	5	3	3	2	3	2	2	2	4	3	3
39	3	2	5	4	5	2	3	3	4	3	2	2	5	2	2
40	2	3	4	3	4	1	3	3	5	4	3	3	5	2	2

FIG 12B

	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67
41	2	5	3	1	2	1	2	3	5	5	4	4	5	3	3
42	2	5	2	1	1	1	2	3	5	5	5	5	4	3	3
43	3	5	2	1	1	1	2	2	4	4	5	5	4	4	4
44	3	4	2	2	2	3	2	2	2	3	4	4	3	5	5
45	3	2	3	3	3	4	3	3	1	2	3	3	2	5	5
46	2	1	3	4	4	5	4	3	1	1	2	2	2	4	4
47	2	1	3	4	4	5	4	4	1	1	1	1	1	3	3
48	2	2	2	4	4	5	4	4	2	2	1	1	1	2	2
49	3	3	2	3	3	4	3	4	3	2	1	1	1	1	2
50	4	4	3	2	3	2	2	3	4	3	2	2	2	1	1
51	5	5	3	2	2	1	1	2	5	4	3	3	3	2	1
52	5	5	4	3	2	1	1	1	4	4	4	4	4	2	2
53	5	3	4	3	3	2	1	1	3	4	4	4	4	3	3
54		3	5	4	4	3	2	1	3	3	4	4	4	4	3
55			4	5	5	4	4	2	2	3	3	3	3	4	4
56				4	5	4	5	3	2	2	3	3	3	4	4
57					4	4	5	5	3	2	2	2	2	3	3
58						4	5	5	4	3	2	2	2	3	3
59							4	5	4	3	3	3	3	2	3
60								4	5	4	3	3	3	2	2
61									5	4	4	4	4	3	3
62										4	4	4	5	3	3
63											4	4	4	4	3
64												4	4	4	4
65													3	5	4
66														4	4
67															4
68															
69															
70															
71															
72															
73															
74															
75															
76															
77															
78															
79															
80															

FIG 13A

	68	69	70	71	72	73	74	75	76	77	78	79	80
1	4	2	4	4	4	2	2	2	2	2	2	1	3
2	3	1	4	3	3	1	2	2	1	1	1	1	2
3	3	1	3	3	3	1	2	1	1	1	1	1	1
4	2	2	3	3	3	1	3	2	1	1	1	1	1
5	2	3	2	2	2	2	3	2	2	2	1	2	1
6	2	3	2	2	2	3	4	3	3	2	2	3	2
7	1	4	2	2	2	3	4	4	3	3	3	4	3
8	1	4	1	1	1	4	4	5	4	4	3	4	3
9	2	3	2	2	2	4	3	5	4	4	4	4	4
10	2	3	2	2	2	3	2	5	3	3	5	4	4
11	3	2	3	3	2	3	2	4	3	3	5	3	4
12	4	2	3	3	3	2	1	3	3	3	5	2	3
13	5	3	4	4	4	2	1	2	2	2	5	1	3
14	5	3	5	5	5	3	2	1	2	2	4	1	2
15	5	4	5	5	5	3	3	1	3	2	3	1	2
16	5	5	5	5	5	4	4	1	3	3	3	1	2
17	4	5	5	5	5	5	4	1	4	3	3	2	2
18	3	5	4	4	4	5	5	2	5	4	2	3	3
19	1	4	3	3	3	5	5	3	5	4	2	4	3
20	1	2	2	2	2	4	4	4	4	4	2	5	4
21	1	1	1	1	1	3	3	5	4	4	2	5	5
22	1	1	1	1	1	2	3	5	3	3	3	5	5
23	2	1	1	1	1	1	2	5	2	3	3	4	5
24	3	1	2	2	2	1	2	5	1	2	3	3	4
25	4	3	3	3	3	1	2	4	1	2	4	3	4
26	5	4	4	4	4	2	3	4	1	1	4	2	3
27	5	5	5	5	4	3	3	3	2	2	5	2	2
28	4	5	5	5	5	4	4	2	3	2	5	2	2
29	3	5	4	4	4	5	4	2	4	3	5	2	1
30	2	5	4	3	4	5	4	1	5	3	4	3	1
31	2	3	3	3	3	5	3	1	5	4	3	3	1
32	2	3	2	2	2	4	3	1	5	3	3	3	1
33	2	2	2	2	2	3	2	1	5	3	2	3	2
34	3	1	2	2	2	2	1	2	4	3	1	2	2
35	3	1	2	3	2	1	1	3	3	2	1	1	3
36	4	1	3	3	3	1	1	3	2	2	2	1	3
37	3	2	3	3	3	1	2	4	1	2	2	1	4
38	3	3	4	4	4	1	2	5	1	2	3	1	4
39	3	3	3	3	3	2	3	5	1	3	4	2	5
40	2	4	3	3	3	3	4	5	1	3	5	3	5

13/13

FIG 13B

	68	69	70	71	72	73	74	75	76	77	78	79	80
41	2	4	3	3	3	3	5	4	2	4	5	4	4
42	3	5	2	2	2	4	5	4	3	4	5	5	4
43	3	5	2	2	2	4	5	3	3	4	4	5	3
44	4	5	3	3	2	5	5	2	4	4	3	5	3
45	5	4	3	3	3	5	4	2	4	3	2	5	2
46	5	4	4	4	3	5	4	2	5	3	2	4	1
47	4	3	5	5	4	4	3	3	5	2	2	3	1
48	3	2	5	5	5	4	3	3	5	2	2	3	1
49	2	1	4	4	5	3	2	4	5	1	3	2	1
50	1	1	4	4	4	3	1	4	4	1	3	1	2
51	1	1	3	3	3	2	1	4	3	2	4	1	3
52	1	2	2	2	2	1	1	4	3	2	5	1	4
53	2	3	1	1	2	1	1	3	2	3	5	1	5
54	3	3	1	1	1	1	2	2	1	3	5	2	5
55	3	4	1	1	1	2	3	2	1	4	4	2	5
56	4	4	2	2	2	3	4	1	1	4	3	3	4
57	4	4	3	3	2	3	5	1	2	4	2	3	3
58	4	3	4	4	3	4	5	2	2	4	2	3	3
59	3	3	4	4	4	4	5	3	3	3	1	4	2
60	3	2	4	4	4	4	5	4	4	3	1	4	1
61	2	2	4	4	4	3	4	4	4	3	2	4	1
62	2	2	3	3	4	3	3	5	4	2	2	4	1
63	3	3	3	3	3	2	2	5	4	2	3	3	2
64	3	4	2	2	3	2	1	4	3	1	3	3	3
65	3	5	2	2	2	2	1	3	3	1	4	2	3
66	4	5	3	3	2	3	1	3	2	1	4	2	3
67	4	5	3	3	3	3	2	2	2	1	4	1	4
68	4	4	4	3	3	4	3	2	2	2	3	1	3
69		3	4	4	3	5	4	3	3	3	3	1	3
70			4	4	4	5	5	3	3	3	3	1	3
71				4	4	4	5	4	4	4	3	2	2
72					4	4	4	4	5	5	4	3	2
73						3	4	4	5	5	4	4	3
74							3	4	5	5	5	5	3
75								3	4	5	5	5	4
76									3	4	5	5	4
77										3	4	4	5
78											3	3	5
79												2	4
80													3

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 03/34768

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 B60C11/00 //B60C113:00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 B60C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 327 792 A (LANDERS SAMUEL P) 4 May 1982 (1982-05-04) column 3, line 28 -column 5, line 53; figures	15
X	US 5 769 990 A (HOFFMEISTER KURT MATTHEW) 23 June 1998 (1998-06-23) column 5, line 56 - line 62 column 9, line 48 - line 52 figure 4	15
X	WO 97 09184 A (GOODYEAR TIRE & RUBBER) 13 March 1997 (1997-03-13) page 2, line 18 - line 21	19,20

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 March 2004	18/03/2004

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Peschel, W

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 03/34768

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 528 577 A (GEN TIRE INC) 24 February 1993 (1993-02-24) page 4, line 48 - line 50 page 5, line 12 claim 8	19,20
X	EP 0 846 576 A (SUMITOMO RUBBER IND) 10 June 1998 (1998-06-10) page 2, line 51 - line 53; figure 4	19,20

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. Claims: 1-14

   Method for designing a tire noise pitch sequence based upon superposition of functions representing particular modulation order properties

2. Claims: 15-18

   Method for designing a tire noise pitch sequence based upon selected noise charcteristics caused by tread lug stiffness variations

3. Claims: 19-20

   Tire having a tread with any tire noise pitch sequence having a pitch sizes ratio of 1.0, 1.10, 1.25, 1.40 and 1.50

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 03/34768

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. ☒ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

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PCT/US 03/34768

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