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(54) LEAKY COAXIAL CABLE, COMPUTER PROGRAM AND METHOD FOR DETERMINING SLOT POSITIONS ON A LEAKY COAXIAL CABLE

ABSTRAHLENDES KOAXIALKABEL, COMPUTERPROGRAMM UND VERFAHREN ZUR
FESTLEGUNG VON SLOT-POSITIONEN AUF EINEM ABSTRAHLENDEM KOAXIALKABEL

CÂBLE COAXIAL À FUITE, PROGRAMME INFORMATIQUE ET PROCÉDÉ DE DÉTERMINATION
DE POSITIONS DE FENTES SUR UN CÂBLE COAXIAL À FUITE

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(73) Proprietor: **Nokia Shanghai Bell Co., Ltd.
Shanghai 201206 (CN)**

(72) Inventors:
• **Raya, Moustafa
39106 Magdeburg (DE)**
• **Mahlandt, Erhard
30179 Hannover (DE)**

(74) Representative: **Novagraaf Technologies
Bâtiment O2
2, rue Sarah Bernhardt
CS90017
92665 Asnières-sur-Seine Cedex (FR)**

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- **CHI-HYUNG AHN ET AL: "DESIGN OF A RADIATED-MODE MULTISLOT LEAKY COAXIAL CABLE", MICROWAVE OPT TECHNOL LETT, vol. 45, 1 January 2005 (2005-01-01), pages 338-342, XP055285418, DOI: 10.1002/mop**
- **JUN HONG WANG ET AL: "THEORY AND ANALYSIS OF LEAKY COAXIAL CABLES WITH PERIODIC SLOTS", IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION, IEEE SERVICE CENTER, PISCATAWAY, NJ, US, vol. 49, no. 12, 1 December 2001 (2001-12-01), pages 1723-1732, XP001086035, ISSN: 0018-926X, DOI: 10.1109/8.982452**
- **NORITAKA KURAUCHI ET AL: "Wideband Leaky Coaxial Cables", ELECTRONICS AND COMMUNICATIONS IN JAPAN., vol. 54-B, no. 11, 1 November 1971 (1971-11-01), pages 96-100, XP001383596,**

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DescriptionTechnical Field

[0001] Embodiments relate to a leaky coaxial cable, a computer program and a method for determining slot positions on a leaky coaxial cable, particularly, but not exclusively to using slot pattern in an outer conductor of a leaky coaxial cable that allow for vector cancellation of more than two reflections.

Background

[0002] This section introduces aspects that may be helpful in facilitating a better understanding of the invention(s). Accordingly, the statements of this section are to be read in this light and are not to be understood as admissions about what is in the prior art or what is not in the prior art.

[0003] Data demand for fast and reliable data transmissions is always increasing. In recent years, data-intensive content, such as streaming video, digital software distribution, online data storage or smartphone mobile data have greatly increased the amount of data transmitted in wired and wireless communication systems. Coverage of wireless services is a contributor to grade of service. Some environments are challenging for wireless service provision. For example, tunnels may generate difficulties for continuous wireless service provision.

[0004] Leaky Coaxial Cables (LCX) are considered as one of the best solutions to enable communication in indoor environments like tunnels, mines etc. With growing demands for data communications more frequency bands and/or broader bandwidths may be required; examples are 4th Generation (4G) communication systems today and 5th Generation (5G) communication systems in the future, etc. LCX may be considered as a distributed antenna. Slots on the outer conductor of coaxial cables may allow radiation of Radio Frequency (RF) signals in controlled portions into a surrounding area. Low loss dielectric material is usually used for isolation between inner- and outer conductors. For efficient covering, LCX are usually operated in radiating mode, where a group of slots are replaced periodically with a distance P greater than a half-wavelength of operated frequency. Due to the periodical position of single slot-antenna or slot-groups along the LCX, harmonic resonance frequencies (f_i) get reflected. The reflections occur because of the impedance change between slot- and non-slot positions. The reflected peaks at level higher than 20% or lower than ~7dB may lead to so called stop bands. Within these stopbands a communication may be distorted, the Transverse ElectroMagnetic (TEM) waves are attenuated and some areas along the cable may experience reduced or even no coverage. The reflected power can also influence repeaters or other components in a communication system.

[0005] Some conventional concepts use Fourier-Transformation to improve energy distribution of an LCX. For example, selected harmonic frequencies may be suppressed by replacing one slot into two identical slots with a certain spacing. The selected distance between the two slots leads to the generation of a reflected wave in antiphase (180° difference of phases) with the same magnitude, which results in cancelation of specific reflections. For each order of f_i , it is a corresponding distance between two slots to achieve a cancellation. Furthermore, periodical longitudinal slots which are $\frac{1}{2}$ as long as the period-length may be used for LCX. With such a defined design all even orders of f_i should be suppressed. However, a selected or a particular harmonic may be difficult to suppress considering broadband communications.

[0006] Further background information may be found in:

EP0375840B1,

"Die Berechnung von geschlitzten Koaxialkabeln für den UKW-Funk" by Ulrich Petri of 21.01.1977,

EP 1 739 789 A1, describing aperture patterns for radiation from a leaky coaxial cable,

US 5,705,967, relating to periodic slot patterns of a radiating cable,

Jun Hong Wang et al, "Design of leaky coaxial cables with periodic slots", RADIO SCIENCE, VOL. 37, NO. 5, 2002,

Chi-Hyung Ahn, et al, "Design of a radiated-mode multislot leaky coaxial cable", MICROWAVE AND OPTICAL TECHNOLOGY LETTERS, VOL. 45, NO. 4, 2005,

Jun Hong Wang, et al, "Theory and Analysis of Leaky Coaxial Cables With Periodic Slots, IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION, VOL. 49, NO. 12, 2001,

CN101895000A, describing a leaky coaxial cable with a plurality of slots arranged in repetitive groups and subgroups along a longitudinal axis of the cable, and

Noritaka Kurauchi et al, "Wideband Leaky Coaxial Cables", ELECTRONICS AND COMMUNICATIONS IN JAPAN, VOL. 54-B, NO. 11, 1971.

Summary of illustrative Embodiments

[0007] The invention relates to a leaky coaxial cable comprising a plurality of slots according to claim 1. A method and

a computer program for determining positions of the slots is provided in claims 8 and 9, respectively.

[0008] Embodiments make use of slot pattern that cause more than two harmonic reflections in a leaky coaxial cable such that cancellation or reduction of the reflected harmonics can be based on vector superposition (multiple or more than two signal components with different phases and/or amplitudes). Having more than two signal components for harmonic reflection reduction by adapting the slot pattern in a leaky coaxial cable allows for reduction of more harmonic reflection and improvement of broadband properties of the cable.

[0009] Embodiments provide a leaky coaxial cable with an inner conductor, an outer conductor and an isolation layer between the inner conductor and the outer conductor. The outer conductor comprises a plurality of slots along a longitudinal axis of the cable to leak a radio frequency signal. The slots are arranged in repetitive groups of more than two slots. The grouping of more than two slots may enable a suppression of further or specific harmonics.

[0010] In some embodiments the slots within one group have the same geometrical arrangement. The same geometrical arrangement within the repetitive groups may enable uniform harmonic reflection suppression along the cable. The radio frequency signal has a carrier wavelength and the repetitive groups may be spaced more than half of a carrier wavelength apart from each other (e.g. basically one carrier wavelength or at least more than half of a wavelength apart from each other). The spacing of the groups may be such that the carrier frequency can be leaked and some of the harmonic reflections may be cancelled or even reduced based on the spacing between the groups, e.g. because a main reflection may experience a 180° degree phase shift from group to group. The slots of one group may have an equidistant spacing along the longitudinal axis of the cable. The more than two reflected components may be generated by equidistantly spaced slots on the cable. The equidistance may lead to equal phase shifts of the reflected components within the slots of a group and hence form a basis for estimating the practical reflective behavior of the cable. In general, embodiments may use differently spaced slots within a group.

[0011] In further embodiments the slots of one group may be arranged in subgroups of more than two slots and the subgroups may have an equidistant spacing along the longitudinal axis of the cable within a group. In embodiments a group may be a geometrical arrangement of subgroups of slots. Within the subgroups suppression or reduction of different harmonic reflections may take place than in the between the subgroups, between the groups, respectively. According to the above, in some embodiments the slots within one subgroup may have an equidistant spacing. Furthermore, there may be more than two subgroups in a group. More than two subgroups per group may allow harmonic reflection reduction based on more than two signal components in line with the above description. Furthermore, as has already been outlined above, the radio frequency signal has a carrier wavelength and the slots within one group are geometrically arranged such that a cancellation or reduction of one or more harmonics of a carrier frequency is achieved based on more than two reflections, signal components, respectively.

[0012] In some embodiments the slots within one group are configured to generate reflections of one or more harmonics of the carrier frequency with different phase and/or amplitude relations. Embodiments may generate signal component superposition based on more than two components, potentially having different phase and possibly also different amplitudes. In further embodiments the leaky coaxial cable may comprise slots of different shapes. The different shapes may allow for further improvement of the broadband properties of the leaky cable. For example, the slots within one group may have different shapes, which may lead to different intensities or amplitudes of the corresponding reflections, signal components, respectively. In further embodiments the slots within a first group have a first shape, the slots within a second group have a second shape, and the first and second shapes are different. Having different slot shapes along the cable may allow for further influence on the overall and broadband characteristics of the cable. Additionally or alternatively, the slots within a first subgroup may have a first shape, the slots within a second subgroup may have a second shape, and the first and second shapes may be different. Moreover, the slots within one group and/or subgroup may have different extents towards a lateral axis of the leaky coaxial cable, e.g. for influencing reflection intensities (phases and/or amplitudes).

[0013] Embodiments further provide a method for determining slot positions of a leaky coaxial cable with an inner conductor, an outer conductor and an isolation layer between the inner conductor and the outer conductor. The method comprises determining a plurality of slot positions along a longitudinal axis of the cable to leak a radio frequency signal, and arranging the slots in repetitive groups of more than two slots.

[0014] Embodiments further provide a computer program having a program code for performing at least one of the above methods, when the computer program is executed on a computer, a processor, or a programmable hardware component. A further embodiment is a computer readable storage medium storing instructions which, when executed by a computer, processor, or programmable hardware component, cause the computer to implement one of the methods described herein.

[0015] Embodiments may provide a multiphase-slot-method which may avoid overlaps of slots due various ways of design. Embodiments may allow choosing a number of slots (ns) for each step or group (further subdivision of groups, subgroups, sub-subgroups etc.) of superposition. Using the groups may provide further suppressions of harmonics and may result to a broader bandwidth in the characteristics of the cable. Embodiments may enable a suppression of any resonance by going into different steps of slot replacement.

Brief description of the figures

[0016] Some other features or aspects will be described using the following non-limiting embodiments of apparatuses or methods or computer programs or computer program products by way of example only, and with reference to the accompanying figures, in which:

Fig. 1 illustrates an embodiment of a leaky coaxial cable;

Fig. 2 shows a leaky coaxial cable with groups of two slots;

Fig. 3 shows simulation results of a LCX with periodical slots (at the top) and simulation results of an embodiment with three slots in a group at the bottom;

Fig. 4 illustrates a slot arrangement in an embodiment (on the left), resulting phase shifts in reflection components (in the middle), and the superposition of the components in a vector representation (on the right);

Fig. 5 illustrates an embodiment using groups of three subgroups with three slots;

Fig. 6 illustrates another embodiment using groups of three subgroups with five slots;

Fig. 7 illustrates an embodiment using slots of different sizes;

Fig. 8 illustrates a slot arrangement in an embodiment (on the left) with different slot sizes, resulting phase shifts in reflection components (in the middle), and the superposition of the components in a vector representation (on the right);

Fig. 9 shows simulation results obtained for the embodiments depicted in Figs. 7 and 8;

Fig. 10 illustrates an embodiment using groups of three subgroups with three slots with different sizes (per subgroups and slots);

Fig. 11 shows an embodiment with slots of different shapes;

Fig. 12 shows an embodiment with slots of different shapes in different groups; and

Fig. 13 shows a block diagram of a flow chart of an embodiment of a method for manufacturing a leaky coaxial cable.

Description of Embodiments

[0017] Various embodiments will now be described more fully with reference to the accompanying drawings in which some embodiments are illustrated. In the figures, the thicknesses of lines, layers or regions may be exaggerated for clarity. Optional components may be illustrated using broken, dashed or dotted lines.

[0018] Like numbers refer to like or similar elements throughout the description of the figures.

[0019] As used herein, the term, "or" refers to a non-exclusive or, unless otherwise indicated (e.g., "or else" or "or in the alternative"). Furthermore, as used herein, words used to describe a relationship between elements should be broadly construed to include a direct relationship or the presence of intervening elements unless otherwise indicated. For example, when an element is referred to as being "connected" or "coupled" to another element, the element may be directly connected or coupled to the other element or intervening elements may be present. In contrast, when an element is referred to as being "directly connected" or "directly coupled" to another element, there are no intervening elements present. Similarly, words such as "between", "adjacent", and the like should be interpreted in a like fashion.

[0020] As used herein, the singular forms "a," "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises," "comprising," "includes" or "including," when used herein, specify the presence of stated features, integers, steps, operations, elements or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components or groups thereof.

[0021] Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which embodiments belong. It will be further understood that terms, e.g., those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent

with their meaning in the context of the relevant art and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

[0022] The embodiments presented in the following provide a leaky coaxial cable and a method for determining slot positions to suppress the reflected waves in order to enable communication with more bandwidth.

[0023] For the following description the fundamental resonance frequency is:

$$f_0 = \frac{c_0}{2P \cdot \sqrt{\epsilon_r}} \quad \text{eq.1}$$

where P is the period-length between two slots or slot groups,

c_0 is the velocity of light in free space, and

ϵ_r is the dielectrical constant for the isolation material between inner- and outer-conductor.

And the harmonic resonance frequency

$$f_i = i \cdot f_0 \quad \text{eq.2}$$

where $i = \{1, 2, 3 \dots\}$ is the order of the harmonic.

[0024] Embodiments may provide a broad bandwidth LCX.

[0025] In the following slots are considered in an outer conductor of a coaxial cable. These slots correspond to areas in which the outer conductor or shielding of the cable is interrupted. Such slots may have different spacings, shapes, forms, extent, etc. They may correspond to a gap or hole in the outer conductor. Although the following embodiments show mostly rectangular slots other shapes or sizes may be used as will be detailed subsequently.

[0026] Fig. 1 illustrates an embodiment of a leaky coaxial cable 10. The leaky cable comprises periodical slots 20a, 20b, 20c as shown at the top, each of which is then subdivided in a group 30, 32, 34 of slots at the bottom. Fig. 1 shows at the bottom a leaky coaxial cable 10 with an inner conductor, an outer conductor and an isolation layer between the inner conductor and the outer conductor. For simplicity reasons these components are not explicitly shown in the Fig., the outer surface shown in the Fig. correspond to the outer conductor and is referred to as cable 10. The outer conductor of the cable 10 comprises a plurality of slots 30a, 30b, 30c, 32a, 32b, 32c, 34a, 34b, 34c along a longitudinal axis of the cable 10 to leak a radio frequency signal. The slots 30a, 30b, 30c, 32a, 32b, 32c, 34a, 34b, 34c are arranged in repetitive groups 30, 32, 34 of more than two slots, in this particular embodiment there are three slots (referred to with reference signs *abc) per group. This embodiment can also be considered as being the first order of a multiphase slot cable or method with $ns=3$ (number of slots= ns).

[0027] As a comparison, Fig. 2 shows a leaky coaxial cable with groups of two slots. Each of the slots with period P shown at the top (LCX with periodical slots) is subdivided in two slots (LCX first step mode suppression) with spacing of P/x shown in the middle, each of which is further subdivided in two slots (LCX second step mode suppression) with spacing P/y . As shown in Fig. 2 at the bottom the second step results into a slot overlap. By using multiple orders of this method to suppress further harmonics, the number of slots is doubled after each step within a defined largeness. Since the slots have a certain width (for example, 3 to 5mm wide) the overlap probability of the slots increases. The design possibilities of broadband LCX get limited (see Fig. 2). Using this method, the suppression of multiple harmonic orders may lead to slot pattern, which may offer in some cases unstable behavior for radiations in azimuthal and elevation direction. Embodiments may improve this behavior. Before a comparison will be conducted by means of simulation results in Fig. 3, the mathematical background of embodiments will be described.

[0028] As described above, by replacing a slot with a group of slots with number greater than two, selected harmonic frequencies can be suppressed. In this part the way how to determine the equation of the distance between the slots (a) will be presented. As an example, calculation will be shown for $ns=3$, $ns=4$.

[0029] For $ns=3$:

Starting from zero position (on the axis shown at the very bottom) of the drawing in Fig. 1, the appearing reflections on a LCX with N number of periods can be calculated as follows:

$$\begin{aligned} \text{Ref} = & \dots e^{-2j\beta(-P-a)} + e^{-2j\beta(-P)} + e^{-2j\beta(-P+a)} \\ & + e^{-2j\beta(-a)} + e^{-2j\beta(0)} + e^{-2j\beta(a)} \\ 5 & + e^{-2j\beta(P-a)} + e^{-2j\beta(P)} + e^{-2j\beta(P+a)} \dots \end{aligned}$$

$$\begin{aligned} 10 & = \sum_{n=1}^N [2 \cos(2\beta(n \cdot P + a)) + 2 \cos(2\beta(n \cdot P)) + 2 \cos(2\beta(n \cdot P - a)) + 2 \cos(2\beta(a)) + 1] \\ 15 & = [2 \cos(2\beta(a)) + 1] \cdot \sum_{n=1}^N [2 \cos(2\beta(n \cdot P)) + 1] \end{aligned}$$

[0030] For Ref = 0,

$$20 \quad [2 \cos(2\beta(a)) + 1] = 0,$$

$$25 \quad \rightarrow a_{ki} = \frac{P \cdot k}{3 \cdot i}$$

$$30 \quad \forall k((k \in N \wedge k \neq k_1) \rightarrow k_1 = \{0, 3, 6, 9 \dots\}),$$

where β is the wave propagation phase constant, and n, i are positive integer values. Due to two variables k and i , a matrix can be created for defined k and i , where

$$35 \quad f_{ki} = \frac{a_{ki}}{P}.$$

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Table 1: f_{ki} Matrix for k between 1 and 11, and i between 1 and 14:

5	f_{ki}	i=1	i=2	i=3	i=4	i=5	i=6	i=7	i=8	i=9	i=10	i=11	i=12	i=13	i=14
	k=1	0,3333	<u>0,1667</u>	<u>0,1111</u>	0,0833	0,0667	0,0556	0,0476	0,0417	0,0370	0,0333	0,0303	0,0278	0,0256	0,0238
10	k=2	0,6667	0,3333	0,2222	<u>0,1667</u>	0,1333	<u>0,1111</u>	0,0952	0,0833	0,0741	0,0667	0,0606	0,0556	0,0513	0,0476
	k=3														
15	k=4	1,3333	0,6667	0,4444	0,3333	0,2667	0,2222	0,1905	<u>0,1667</u>	0,1481	0,1333	0,1212	<u>0,1111</u>	0,1026	0,0952
	k=5	1,6667	0,8333	0,5556	0,4167	0,3333	0,2778	0,2381	0,2083	0,1852	<u>0,1667</u>	0,1515	0,1389	0,1282	0,1190
	k=6														
20	k=7	2,3333	1,1667	0,7778	0,5833	0,4667	0,3889	0,3333	0,2917	0,2593	0,2333	0,2121	0,1944	0,1795	<u>0,1667</u>
	k=8	2,6667	1,3333	0,8889	0,6667	0,5333	0,4444	0,3810	0,3333	0,2963	0,2667	0,2424	0,2222	0,2051	0,1905
25	k=9														
	k=10	3,3333	1,6667	1,1111	0,8333	0,6667	0,5556	0,4762	0,4167	0,3704	0,3333	0,3030	0,2778	0,2564	0,2381
30	k=11	0,9167	0,4583	0,3056	0,2292	0,1833	0,1528	0,1310	0,1146	0,1019	0,0917	0,0833	0,0764	0,0705	0,0655

[0031] The above matrix (Table 1) shows the relation between the distance of slots and the harmonic frequencies, which shall be suppressed or reduced accordingly. The repetition of same f_{ki} value for different i orders, means the suppression or reduction of all these orders. For example, by having $f_{ki} = 1/6 \approx 0,1667$ (underlined and highlighted in light grey), the second, fourth, eighth, tenth, fourteenth... resonance peaks will be suppressed. For a period of P=800mm, Matlab simulations are done and presented in Fig. 3.

[0032] Fig. 3 shows simulation results of a LCX (at the top) with periodical slots (based on Fig. 2) and simulation results of an embodiment with three slots (as shown in Fig. 1) in a group at the bottom. Simulation results are illustrated using diagrams showing frequency on the abscissa and reflected energy on the ordinate. Fig. 3 shows at the top the harmonic resonance frequencies for LCX without any suppression method, where the first resonance is at 167.6MHz. Fig. 3 shows simulation results of an embodiment at the bottom using the described method with ns=3 and $a = P/6 \approx 167$ mm. The following frequencies get suppressed: 355, 670, 1341, 1676, 2346 and 2682 MHz.

[0033] Since the values of f_{12} approach other neighboring f_{ki} (see the above table), neighboring reflection peaks get partially suppressed as shown in the bottom diagram of Fig. 3. At frequencies 503, 1508 and 2514 MHz more partial suppression appears due to the suppression of two neighboring resonances. As shown in Fig. 1, in this embodiment the slots a, b, c within one group 30, 32, 34 have the same geometrical arrangement. In other embodiments different geometrical arrangements may be used. Moreover, in the embodiment shown in Fig. 1 at the bottom the radio frequency signal has a carrier wavelength and the repetitive groups 30, 32, 34 are spaced more than half of a carrier wavelength apart from each other. In the embodiment shown in Fig. 1 the slots 30a, 30b, 30c, 32a, 32b, 32c, 34a, 34b, 34c of one group 30, 32, 34 have an equidistant spacing along the longitudinal axis of the cable 10.

[0034] By replacing each slot of a periodical distribution along a LCX 10 into an equidistant number of slots greater than two ($ns > 2$) (cf. Figs. 1, 5 and 6), selected harmonic frequencies can be suppressed as shown in Fig. 3. A finding of embodiments is based on theory of multiple-phase-superposition. By replacing each slot into ns slots with a calculated distance (a) between them, the reflections appearing at each slot get superimposed (superposition), where the multiple phases of all ns slots add up and result in cancelation or reduction of selected harmonic orders (Figs. 4 and 8). An equation for calculating the factor (a) of ns =3 and ns =4 will be presented subsequently. An equation for any number ns will also be interpreted finally.

[0035] Mode suppression may be based on vector and phase arrangements in embodiments. The suppression for a

resonance or reflection frequency based on phase and vector arrangement can be explained using corresponding Fig. 4. Fig. 4 illustrates a slot arrangement in an embodiment (on the left), resulting phase shifts in reflection components (in the middle), and the superposition of the components in a vector representation (on the right). In this embodiment for the second resonance frequency $i = 2$, P is equivalent to 360° phase (one wavelength), $a = P/6$ corresponds to 60° . Reflections appearing at a distance from the first slot correspond to a bidirectional path of 120° , arrow 2 (Fig. 4 in the middle showing reflections of the second resonance represented as vectors in a unit circle). For slot 3 the phase for the bidirectional path is 240° . At position 0 arrow 1 has the phase 0° . The addition of all three arrows shown on the right of Fig. 3 results to 0 and the according sum of reflections cancels out. The vector diagram on the right of Fig. 3 describes the way how the addition of multiphase components of the three slots can suppress specific resonances. Accordingly, in embodiments the radio frequency signal has a carrier wavelength and the slots within one group are geometrically arranged such that a cancellation or reduction of one or more harmonics of a carrier frequency is achieved based on more than two reflections. The slots within one group are configured to generate reflections of one or more harmonics of the carrier frequency with different phase and/or amplitude relations.

[0036] In embodiments the use of a multi-order $ns=3$ is an example and any higher number ns may be used. A use of this method in further steps for suppression more reflections is also possible. By taking for example on the first step a_{12} , same frequencies will be suppressed as shown in Fig. 3 at the bottom (underlined and highlighted in light grey in the above table). In a second step of replacing based on distance a_{13} , all orders of the resonances, which are shown in italic letters with darker grey background in the above table, will be suppressed. Fig. 5 illustrates an embodiment using groups 30, 32 of three subgroups 30a, 30b, 30c, 32a, 32b, 32c with three slots 30a.1, 30a.2, 30a.3, 30b.1, 30b.2, 30b.3, 32a.1, 32a.2, 32a.3, 32b.1, 32b.2, 32b.3 in each of the three subgroups 30a, 30b, 30c, 32a, 32b, 32c. In such an embodiment the slots of one group 30, 32 are arranged in subgroups 30a, 30b, 30c, 32a, 32b, 32c of more than two slots, e.g. $ns=3$ slots, and the subgroups 30a, 30b, 30c, 32a, 32b, 32c have an equidistant spacing along the longitudinal axis of the cable 10 within a group 30, 32. Moreover, in the embodiment shown in Fig. 5 the slots within one subgroup, for example slots 30a.1, 30a.2, 30a.3 in subgroup 30a, have an equidistant spacing. Additionally or alternatively, there are more than two subgroups in a group, e.g. in Fig. 5 there are three subgroups in a group, e.g. subgroups 30a, 30b, 30c in group 30. Fig. 5 further shows an explanation for the way of superposition of the slots. As can be seen the spacing between the groups 30, 32 is P , the spacing between the subgroups 30a, 30b, 30 and 32a, 32b and 32c is a_{12} . The spacing of the slots within one subgroup is a_{13} , e.g. between slots 32a.1, 32a.2, and 32a.3.

[0037] In further embodiments, e.g. $ns=4$, the same approach may be applied. a_{ki} for $ns=4$ can be derived as follows:

$$\text{Ref} = [2 \cos(3\beta a) + 2 \cos(\beta a)] \cdot \sum_{n=1}^N [2 \cos(2\beta(n \cdot P)) + 1]$$

[0038] For $\text{Ref} = 0$,

$$[\cos(3\beta(a)) + \cos(\beta a)] = 0,$$

$$\rightarrow a_{ki} = \frac{P \cdot k}{4 \cdot i}$$

$$\forall k((k \in N \wedge k \neq k_1), \rightarrow k_1 = \{0, 4, 8, 12 \dots\})$$

[0039] For variable ns , for choosing any ns greater 2, the following equation can be considered:

$$(with \ ns \in N \wedge ns > 2)$$

$$\rightarrow a_{ki} = \frac{P \cdot k}{ns \cdot i}$$

$$\forall k((k \in N \wedge k \neq k_1), \rightarrow k_1 = \{0, ns, 2 \cdot ns, 3 \cdot ns \dots\}).$$

[0040] A combination of different ns in different steps is also possible. Such an embodiment is illustrated in Fig. 6. Fig. 6 illustrates another embodiment using groups of three subgroups with five slots, i.e. a combination of the above two steps of slot superposition for ns=3 and ns=5. For ease of illustration only for group 30 reference signs are provided in detail for some slots, for group 32 and other slots similar considerations apply. As shown in Fig. 6 the spacing between the groups 30, 32 corresponds to P. In group 30 there are three subgroups 30a, 30b, and 30c, based on ns=3 in the first step. The spacing between the subgroups is accordingly referenced with a_{3ki} . In each of the three subgroups 30a, 30b, and 30c there are five slots based on ns=5 in the second step, e.g. subgroup 30a comprises slots 30a.1, 30a.2, 30a.3, 30a.4, 30a.5 with an according spacing of a_{5ki} . An example of combination a_{3ki} and a_{5ki} is presented on Fig. 6. Other embodiments may use further combinations, i.e. a third, fourth, fifth, etc. step and other combination for ns. In embodiments the particular application of the LCX may be considered to choose ns and a. For the design of LCX, the parameters depend on the requirement and application to choose the right number of slots ns and the corresponding distance a_{ki} between.

[0041] In a further embodiment slots of different shapes are used. Fig. 7 illustrates an embodiment using slots of different sizes. Fig. 7 shows an LCX with periodical slots at the top and a slot replacement according to an embodiment with different slot sizes at the bottom. The groups 30, 32, 34 comprise three slots 30a, 30b, 30c, etc. Mode suppression by having slots of different sizes or shapes is also possible. In the embodiment presented in Fig. 7 one slot gets replaced into three, one with the same size Ls, e.g. 30b, and two others of half-size Ls/2, e.g. 30a and 30c. A calculation of the distance between slots can be given according to the following approach:

$$\rightarrow a_{ki} = \frac{P \cdot (1 + 2k)}{2 \cdot i}$$

$$\forall k((k \in \mathbb{N}))$$

[0042] An example of ($a=P/4$) to explain the mode suppression based on phase and vector arrangement is illustrated by Fig. 8. Fig. 8 illustrates a slot arrangement with $a=P/4$ in the embodiment (on the left) with different slot sizes, resulting phase shifts in reflection components based on the second resonance $i=2$ represented as vectors in a unit circle (in the middle), and the superposition (sum of the reflections) of the components in a vector representation (on the right). Fig. 9 shows simulation results obtained for the embodiments depicted in Figs. 7 and 8. The simulation results shown in Fig. 9, which are depicted in a similar representation as used in Fig. 3, and confirm the suppression of the second, sixth, tenth, fourteenth etc. resonance frequency.

[0043] Using slots of different-sizes at multiple steps is also possible in some embodiments. Fig. 10 illustrates an embodiment using groups of three subgroups with three slots with different sizes (per subgroups and slots). Fig. 10 shows two steps (top to middle, middle to bottom) of slot replacement in order to suppress further resonances, which results in three different sizes of slots. In line with the above referencing, a group 30 is subdivided in three subgroups 30a, 30b, and 30c using different slot sizes in line with the embodiment described with the help of Figs. 7 and 8. After this first step the resulting slots would have sizes Ls in subgroup 30b, and Ls/2 in subgroups 30a and 30b. Fig. 10 illustrates at the bottom that these subgroup sizes are considered in a second subdivision step yielding the actual slots, e.g. 30a.1, 30a.2, and 30a.3 with sizes Ls/4, 3Ls/2 (30a.2+30b.1), and Ls/4. The embodiment shown in Fig. 10 is also an example of slots within one group having different shapes. The slots within one group 30 have different extents (2Ls, 3Ls/2, Ls, Ls/2, Ls/4, etc.) towards a lateral axis of the leaky coaxial cable. As can also be seen from Fig. 10 the slots within a first subgroup 30a have a first shape, wherein the slots within a second subgroup 30b have a second shape, and wherein the first and second shapes are different. The slots within one subgroup, e.g. 30a have different extents towards a lateral axis of the leaky coaxial cable 10, in the particular embodiment a different height in Fig. 10.

[0044] As shown, the sizes of overlapping slots are added up in this embodiment resulting in a large center slot 30b.2 of size 2Ls. The neighboring slots scale accordingly as shown in Fig. 10. Embodiments of suppression methods with replacement of one slot into a number of slots of different sizes and different shapes for the same target are shown in Figs. 10, 11 and 12. Fig. 11 shows an embodiment with slots 30a, 30b, and 30c in a group 30 of different shapes. In the embodiment shown in Fig. 11 a multiphase slot method is utilized with ns=3 for the other shape structure. The utilization of the multiphase-slot-method in embodiments for slot shapes other than shown until now is hence also possible. Fig. 11 shows an example of replacement with ns=3 for a different slot shape, which is suitable, for example, for vertically polarized LCX. This method can therefore be used for any slot shapes. A combination of different slot shapes into the same LCX is also possible.

[0045] Fig. 12 shows an embodiment for a combination of three different slot shapes. This can be used for example for design of multi-polarized LCX. Fig. 12 shows an embodiment with slots of different shapes in different groups. Fig.

12 shows an embodiment using a multiphase slot method for a combination of different slot shapes for $n_s=3$. As can be seen from Fig. 12 the slots 30a, 30b, 30c within a first group 30 have a first shape, and slots 32a, 32b, and 32c within a second group 32 have a second shape. The first and second shapes are different. As further indicated by Fig. 12 further shapes may be used. Embodiments allow a designer of LCX to choose the parameters according to the respective application, e.g. the desired leakage, frequency band, bandwidth, etc. For example, the matched number of slots (n_s), the number of steps, the right combination of different n_s at multiple steps or the combination of different slot shapes may be chosen based on the requirements or application.

[0046] Fig. 13 shows a block diagram of a flow chart of an embodiment of a method for determining slot positions of a leaky coaxial cable with an inner conductor, an outer conductor and an isolation layer between the inner conductor and the outer conductor. The method comprises determining 42 a plurality of slot positions along a longitudinal axis of the cable to leak a radio frequency signal, and arranging 44 the slots or slot positions in repetitive groups 30, 32, 34 of more than two slots 30a.1, 30a.2, 30a.3, 30b.1, 30b.2, 30b.3, 30b.1, 30b.2, 30b.3, 32a.1, 32a.2, 32a.3, 32b.1, 32b.2, 32b.3, 32b.1, 32b.2, 32b.3.

Another embodiment is a computer program having a program code for performing at least one of the above methods, when the computer program is executed on a computer, a processor, or a programmable hardware component. A further embodiment is a computer readable storage medium storing instructions which, when executed by a computer, processor, or programmable hardware component, cause the computer to implement one of the methods described herein.

[0047] A person of skill in the art would readily recognize that steps of various above-described methods can be performed by programmed computers, for example, positions of slots may be determined or calculated. Herein, some embodiments are also intended to cover program storage devices, e.g., digital data storage media, which are machine or computer readable and encode machine-executable or computer-executable programs of instructions where said instructions perform some or all of the steps of methods described herein. The program storage devices may be, e.g., digital memories, magnetic storage media such as magnetic disks and magnetic tapes, hard drives, or optically readable digital data storage media. The embodiments are also intended to cover computers programmed to perform said steps of methods described herein or (field) programmable logic arrays ((F)PLAs) or (field) programmable gate arrays ((F)PGAs), programmed to perform said steps of the above-described methods.

[0048] When provided by a processor, the functions may be provided by a single dedicated processor, by a single shared processor, or by a plurality of individual processors, some of which may be shared. Moreover, explicit use of the term "processor" or "controller" should not be construed to refer exclusively to hardware capable of executing software, and may implicitly include, without limitation, digital signal processor (DSP) hardware, network processor, application specific integrated circuit (ASIC), field programmable gate array (FPGA), read only memory (ROM) for storing software, random access memory (RAM), and non-volatile storage. Other hardware, conventional or custom, may also be included. Their function may be carried out through the operation of program logic, through dedicated logic, through the interaction of program control and dedicated logic, or even manually, the particular technique being selectable by the implementer as more specifically understood from the context.

[0049] It should be appreciated by those skilled in the art that any block diagrams herein represent conceptual views of illustrative circuitry embodying the principles of the invention. Similarly, it will be appreciated that any flow charts, flow diagrams, state transition diagrams, pseudo code, and the like represent various processes which may be substantially represented in computer readable medium and so executed by a computer or processor, whether or not such computer or processor is explicitly shown.

[0050] It is further to be noted that methods disclosed in the specification or in the claims may be implemented by a device having means for performing each of the respective steps of these methods.

Claims

1. A leaky coaxial cable (10) with an inner conductor, an outer conductor and an isolation layer between the inner conductor and the outer conductor, wherein the outer conductor comprises a plurality of slots arranged periodically along a longitudinal axis of the cable (10) to leak a radio frequency signal, wherein the plurality of slots are arranged in repetitive groups (30; 32; 34), wherein the slots in each group (30; 32; 34) are arranged (2)) in a plurality of subgroups (30a; 30b; 30c; 32a; 32b; 32c) of more than two slots, and the more than two slots within each subgroup (30a; 30b; 30c; 32a; 32b; 32c) have an equidistant spacing, wherein the radio frequency signal has a carrier frequency, and the more than two slots within each subgroup are configured to generate reflections at one or more harmonics of the carrier frequency, and are geometrically arranged such that a cancellation or reduction of the one or more harmonics is achieved based on more than two reflections, **characterized in that**, in each group, there are more than two subgroups (30a; 30b; 30c; 32a; 32b; 32c), and said subgroups (30a; 30b; 30c; 32a; 32b; 32c) have an equidistant spacing along the longitudinal axis of the cable (10) within said group.

2. The leaky coaxial cable (10) of claim 1, wherein the radio frequency signal has a carrier wavelength, and wherein the repetitive groups (100; 30; 32; 34) are spaced more than half of the carrier wavelength apart from each other.
3. The leaky coaxial cable (10) of claim 1, wherein the reflections of the radio frequency signal at the one or more harmonics of the carrier frequency include different phase and amplitude relations.
4. The leaky coaxial cable (10) of claim 1, wherein the slots (30a. 1; 30a.2; 30a.3; 30b.1; 30b.2; 30b.3; 30b.1; 30b.2; 30b.3; 32a.1; 32a.2; 32a.3; 32b.1; 32b.2; 32b.3; 32b.1; 32b.2; 32b.3) have different shapes.
5. The leaky coaxial cable (10) of claim 1, wherein the slots (30a.1; 30a.2; 30a.3; 30b.1; 30b.2; 30b.3; 30b.1; 30b.2; 30b.3; 32a.1; 32a.2; 32a.3; 32b.1; 32b.2; 32b.3; 32b.1; 32b.2; 32b.3) within one group have different shapes.
6. The leaky coaxial cable (10) of claim 1, wherein the slots (30a; 30b; 30c) within a first group (30) have a first shape, wherein the slots (32a; 32b; 32c) within a second group (32) have a second shape, and wherein the first and second shapes are different.
7. The leaky coaxial cable (10) of claim 1, wherein the slots (30a.1; 30a.2; 30a.3) within a first subgroup (30a) have a first shape, wherein the slots (30b.1; 30b.2; 30b.3) within a second subgroup (30b) have a second shape, and wherein the first and second shapes are different, and wherein the slots (30a.1; 30a.2; 30a.3) within one subgroup (30a) have different extents towards a lateral axis of the leaky coaxial cable (10).
8. A method for determining slot positions of a leaky coaxial cable with an inner conductor, an outer conductor and an isolation layer between the inner conductor and the outer conductor, the method comprising
 - determining (42) a plurality of slot positions arranged periodically along a longitudinal axis of the cable (10) to leak a radio frequency signal,
 - arranging (44) the slots in repetitive groups of more than two slots, wherein the slots in each group (100; 30; 32; 34) are arranged in a plurality of subgroups (30a; 30b; 30c; 32a; 32b; 32c) of more than two slots, and the more than two slots within each subgroup (30a; 30b; 30c; 32a; 32b; 32c) have an equidistant spacing, and wherein the radio frequency signal has a carrier frequency, and the more than two slots within each subgroup are configured to generate reflections at one or more harmonics of the carrier frequency, and are geometrically arranged such that a cancellation or reduction of the one or more harmonics is achieved based on more than two reflections,
 - characterized in that,**
 - in each group, there are more than two subgroups (30a; 30b; 30c; 32a; 32b; 32c), and said subgroups (30a; 30b; 30c; 32a; 32b; 32c) have an equidistant spacing along the longitudinal axis of the cable (10) within said group.
9. A computer program having a program code for performing the method of claim 8, when the computer program is executed on a computer, a processor, or a programmable hardware component.

Patentansprüche

1. Leckes Koaxialkabel (10) mit einem Innenleiter, einem Außenleiter und einer Isolierschicht zwischen dem Innenleiter und dem Außenleiter, wobei der Außenleiter eine Vielzahl von Schlitten umfasst, die entlang einer Längsachse des Kabels (10) periodisch angeordnet sind, um ein Funkfrequenzsignal zu streuen, wobei die Vielzahl von Schlitten in sich wiederholenden Gruppen (30; 32; 34) angeordnet sind, wobei die Schlitten in jeder Gruppe (30; 32; 34) in einer Vielzahl von Untergruppen (30a; 30b; 30c; 32a; 32b; 32c) von mehr als zwei Schlitten angeordnet sind (2), und die mehr als zwei Schlitten in jeder Untergruppe (30a; 30b; 30c; 32a; 32b; 32c) eine gleichabständige Beabstandung aufweisen, wobei das Funkfrequenzsignal eine Trägerfrequenz aufweist, und die mehr als zwei Schlitten in jeder Untergruppe dazu ausgelegt sind, bei einer oder mehreren Oberschwingungen der Trägerfrequenz Reflexionen zu erzeugen, und geometrisch derart angeordnet sind, dass eine Unterdrückung oder Reduzierung der einen oder der mehreren Oberschwingungen auf Basis von mehr als zwei Reflexionen erreicht wird, **dadurch gekennzeichnet, dass** es in jeder Gruppe mehr als zwei Untergruppen (30a; 30b; 30c; 32a; 32b; 32c) gibt, und die Untergruppen (30a; 30b; 30c; 32a; 32b; 32c) entlang der Längsachse des Kabels (10) in der Gruppe eine gleichabständige Beabstandung

aufweisen.

2. Leckes Koaxialkabel (10) nach Anspruch 1, wobei das Funkfrequenzsignal eine Trägerwellenlänge aufweist, und wobei die sich wiederholenden Gruppen (100; 30; 32; 34) um mehr als die Hälfte der Trägerwellenlänge voneinander beabstandet sind.
3. Leckes Koaxialkabel (10) nach Anspruch 1, wobei die Reflexionen des Funkfrequenzsignals an der einen oder den mehreren Oberschwingungen der Trägerfrequenz unterschiedliche Phasen- und Amplitudenbeziehungen aufweisen.
4. Leckes Koaxialkabel (10) nach Anspruch 1, wobei die Schlitze (30a.1; 30a.2; 30a.3; 30b.1; 30b.2; 30b.3; 30b.1; 30b.2; 30b.3; 32a.1; 32a.2; 32a.3; 32b.1; 32b.2; 32b.3; 32b.1; 32b.2; 32b.3) unterschiedliche Formen aufweisen.
5. Leckes Koaxialkabel (10) nach Anspruch 1, wobei die Schlitze (30a.1; 30a.2; 30a.3; 30b.1; 30b.2; 30b.3; 30b.1; 30b.2; 30b.3; 1; 32a.2; 32a.3; 32b.1; 32b.2; 32b.3; 32b.1; 32b.2; 32b.3) in einer Gruppe unterschiedliche Formen aufweisen.
6. Leckes Koaxialkabel (10) nach Anspruch 1, wobei die Schlitze (30a; 30b; 30c) in einer ersten Gruppe (30) eine erste Form aufweisen, wobei die Schlitze (32a; 32b; 32c) in einer zweiten Gruppe (32) eine zweite Form aufweisen, und wobei die erste und die zweite Form unterschiedlich sind.
7. Leckes Koaxialkabel (10) nach Anspruch 1, wobei die Schlitze (30a.1; 30a.2; 30a.3) in einer ersten Untergruppe (30a) eine erste Form aufweisen, wobei die Schlitze (30b.1; 30b.2; 30b.3) in einer zweiten Untergruppe (30b) eine zweite Form aufweisen, und wobei die erste und die zweite Form unterschiedlich sind, und wobei die Schlitze (30a.1; 30a.2; 30a.3) in einer Untergruppe (30a) unterschiedliche Erstreckungen zu einer Seitenachse des lecken Koaxialkabels (10) aufweisen.
8. Verfahren zum Bestimmen von Schlitzpositionen eines lecken Koaxialkabels mit einem Innenleiter, einem Außenleiter und einer Isolierschicht zwischen dem Innenleiter und dem Außenleiter, wobei das Verfahren Folgendes umfasst
Bestimmen (42) einer Vielzahl von Schlitzpositionen, die periodisch entlang einer Längsachse des Kabels (10) angeordnet sind, um ein Funkfrequenzsignal zu streuen,
Anordnen (44) der Schlitze in sich wiederholenden Gruppen von mehr als zwei Schlitzten, wobei die Schlitze in jeder Gruppe (100; 30; 32; 34) in einer Vielzahl von Untergruppen (30a; 30b; 30c; 32a; 32b; 32c) von mehr als zwei Schlitzten angeordnet sind, und
die mehr als zwei Schlitze in jeder Untergruppe (30a; 30b; 30c; 32a; 32b; 32c) eine gleichabständige Beabstandung aufweisen, und
wobei das Funkfrequenzsignal eine Trägerfrequenz aufweist und die mehr als zwei Schlitze in jeder Untergruppe dazu ausgelegt sind, bei einer oder mehreren Oberschwingungen der Trägerfrequenz Reflexionen zu erzeugen, und geometrisch derart angeordnet sind, dass eine Unterdrückung oder Reduzierung der einen oder der mehreren Oberschwingungen auf Basis von mehr als zwei Reflexionen erreicht wird,
dadurch gekennzeichnet, dass
es in jeder Gruppe mehr als zwei Untergruppen (30a; 30b; 30c; 32a; 32b; 32c) gibt, und die Untergruppen (30a; 30b; 30c; 32a; 32b; 32c) entlang der Längsachse des Kabels (10) in der Gruppe eine gleichabständige Beabstandung aufweisen.
9. Computerprogramm, das einen Programmcode zum Durchführen des Verfahrens nach Anspruch 8, wenn das Computerprogramm auf einem Computer, einem Prozessor oder einer programmierbaren Hardwarekomponente ausgeführt wird, aufweist.

Revendications

1. Câble (10) coaxial à fuite ayant un conducteur intérieur, un conducteur extérieur et une couche d'isolation entre le conducteur intérieur et le conducteur extérieur, dans lequel le conducteur extérieur comprend une pluralité de fentes agencées périodiquement le long d'un axe longitudinal du câble (10) pour laisser passer un signal de radiofréquence, dans lequel la pluralité de fentes sont agencées en groupes (30 ; 32 ; 34) répétitifs, dans lequel les fentes de chaque groupe (30 ; 32 ; 34) sont agencées (2) en une pluralité de sous-groupes (30a ;

30b ; 30c ; 32a ; 32b ; 32c) de plus de deux fentes, et les plus de deux fentes à l'intérieur de chaque sous-groupe (30a ; 30b ; 30c ; 32a ; 32b ; 32c) ont un espacement équidistant,

dans lequel le signal de radiofréquence a une fréquence porteuse, et les plus de deux fentes au sein de chaque sous-groupe sont configurées pour générer des réflexions au niveau d'une ou plusieurs harmoniques de la fréquence porteuse et sont agencées géométriquement de sorte qu'une annulation ou une réduction des une ou plusieurs harmoniques est effectuée sur la base de plus de deux réflexions,

caractérisé en ce que,

dans chaque groupe, il y a plus de deux sous-groupes (30a ; 30b ; 30c ; 32a ; 32b ; 32c), et lesdits sous-groupes (30a ; 30b ; 30c ; 32a ; 32b ; 32c) ont un espacement équidistant le long de l'axe longitudinal du câble (10) à l'intérieur dudit groupe.

2. Câble (10) coaxial à fuite de la revendication 1, dans lequel le signal de radiofréquence a une longueur d'onde de porteuse et dans lequel les groupes (100 ; 30 ; 32 ; 34) répétitifs sont espacés les uns des autres de plus de la moitié de la longueur d'onde de porteuse.

3. Câble (10) coaxial à fuite de la revendication 1, dans lequel les réflexions du signal de radiofréquence au niveau des une ou plusieurs harmoniques de la fréquence porteuse comportent différentes relations de phase et d'amplitude.

4. Câble (10) coaxial à fuite de la revendication 1, dans lequel les fentes (30a.1 ; 30a.2 ; 30a.3 ; 30b.1 ; 30b.2 ; 30b.3 ; 30b.1 ; 30b.2 ; 30b.3 ; 32a.1 ; 32a.2 ; 32a.3 ; 32b.1 ; 32b.2 ; 32b.3 ; 32b.1 ; 32b.2 ; 32b.3) ont différentes formes.

5. Câble (10) coaxial à fuite de la revendication 1, dans lequel les fentes (30a.1 ; 30a.2 ; 30a.3 ; 30b.1 ; 30b.2 ; 30b.3 ; 30b.1 ; 30b.2 ; 30b.3 ; 1 ; 32a.2 ; 32a.3 ; 32b.1 ; 32b.2 ; 32b.3 ; 32b.1 ; 32b.2 ; 32b.3) au sein d'un groupe ont différentes formes.

6. Câble (10) coaxial à fuite de la revendication 1, dans lequel les fentes (30a ; 30b ; 30c) au sein d'un premier groupe (30) ont une première forme, dans lequel les fentes (32a ; 32b ; 32c) au sein d'un deuxième groupe (32) ont une deuxième forme, et dans lequel les première et deuxième formes sont différentes.

7. Câble (10) coaxial à fuite de la revendication 1, dans lequel les fentes (30a.1 ; 30a.2 ; 30a.3) au sein d'un premier sous-groupe (30a) ont une première forme, dans lequel les fentes (30b.1 ; 30b.2 ; 30b.3) au sein d'un deuxième sous-groupe (30b) ont une deuxième forme, et dans lequel les première et deuxième formes sont différentes, et dans lequel les fentes (30a.1 ; 30a.2 ; 30a.3) au sein d'un sous-groupe (30a) présentent différentes extensions vers un axe latéral du câble (10) coaxial à fuite.

8. Procédé de détermination de positions de fentes d'un câble coaxial à fuite ayant un conducteur intérieur, un conducteur extérieur et une couche d'isolation entre le conducteur intérieur et le conducteur extérieur, le procédé comprenant

la détermination (42) d'une pluralité de positions de fentes agencées périodiquement le long d'un axe longitudinal du câble (10) pour laisser passer un signal de radiofréquence,

l'agencement (44) des fentes en groupes répétitifs de plus de deux fentes, dans lequel les fentes de chaque groupe (100 ; 30 ; 32 ; 34) sont agencées en une pluralité de sous-groupes (30a ; 30b ; 30c ; 32a ; 32b ; 32c) de plus de deux fentes, et

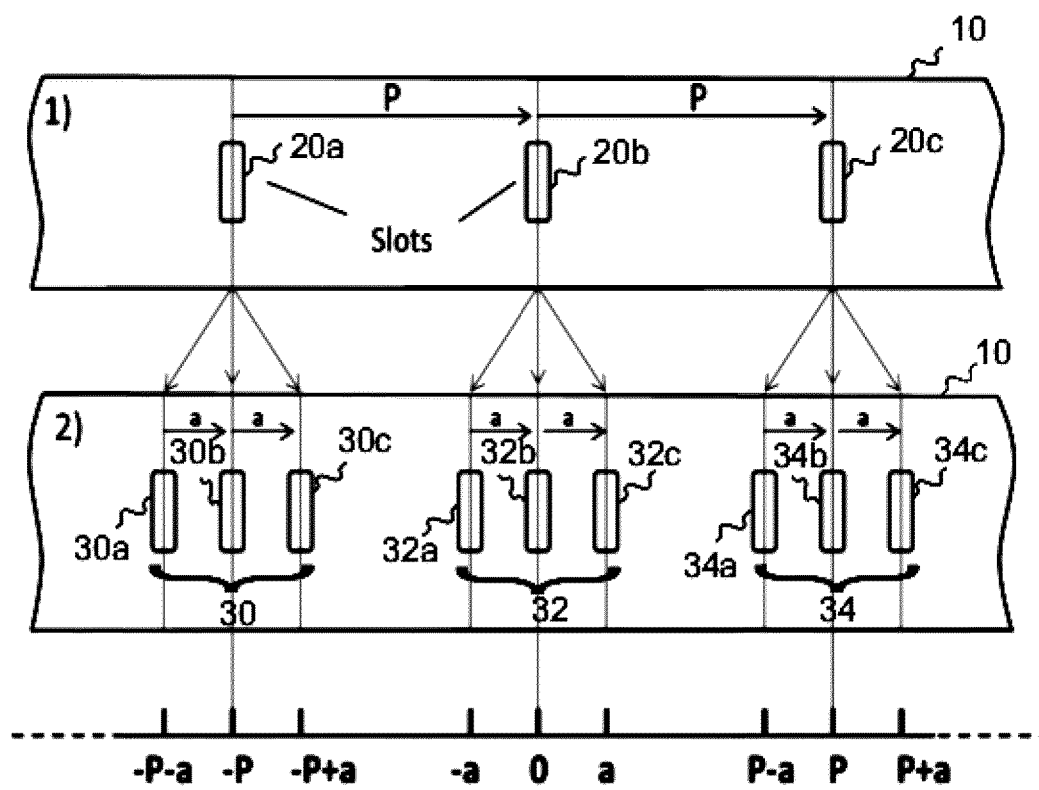
les plus de deux fentes au sein de chaque sous-groupe (30a ; 30b ; 30c ; 32a ; 32b ; 32c) ont un espacement équidistant, et

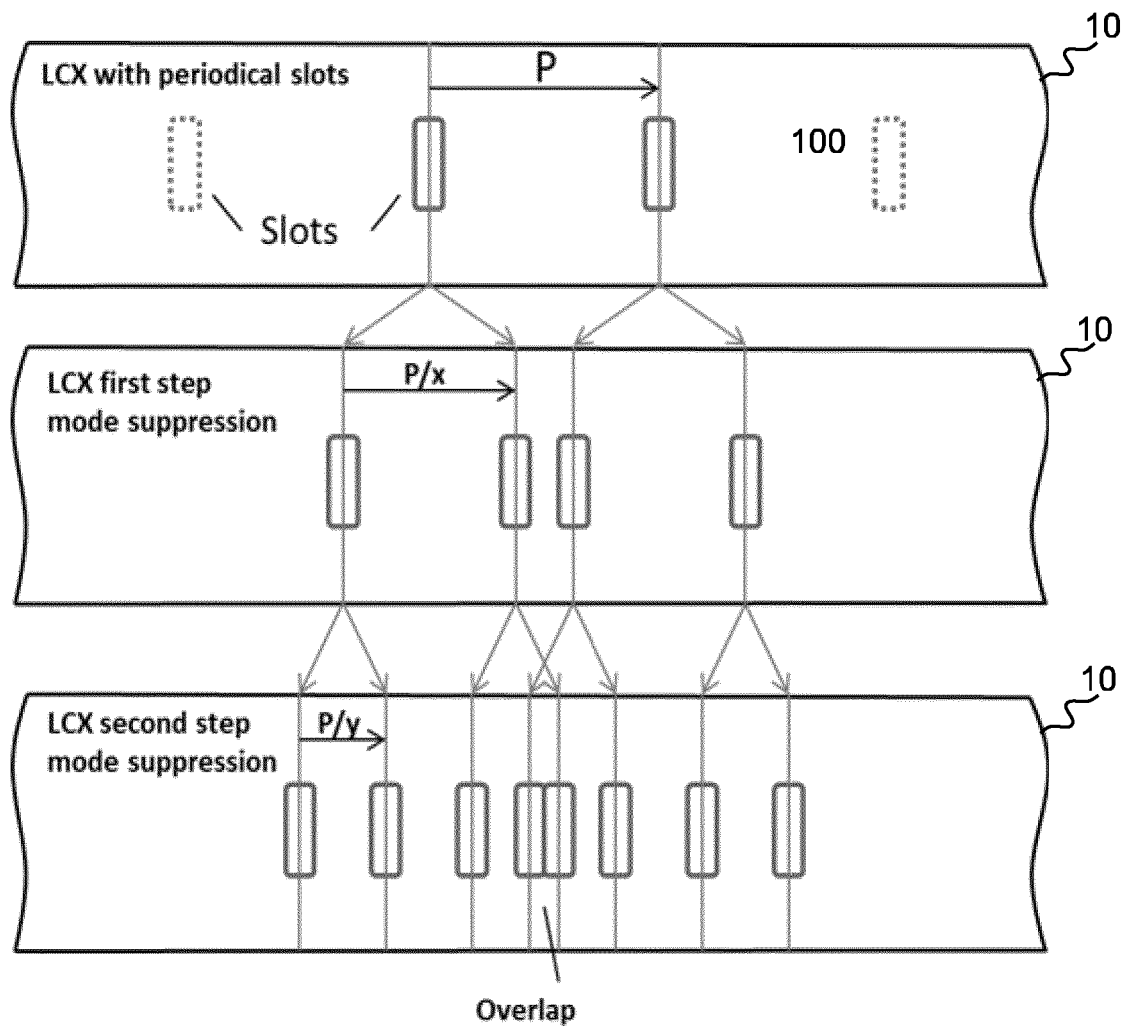
dans lequel le signal de radiofréquence a une fréquence porteuse, et les plus de deux fentes au sein de chaque sous-groupe sont configurées pour générer des réflexions au niveau d'une ou plusieurs harmoniques de la fréquence porteuse, et sont agencées géométriquement de sorte qu'une annulation ou une réduction des une ou plusieurs harmoniques est effectuée sur la base de plus de deux réflexions,

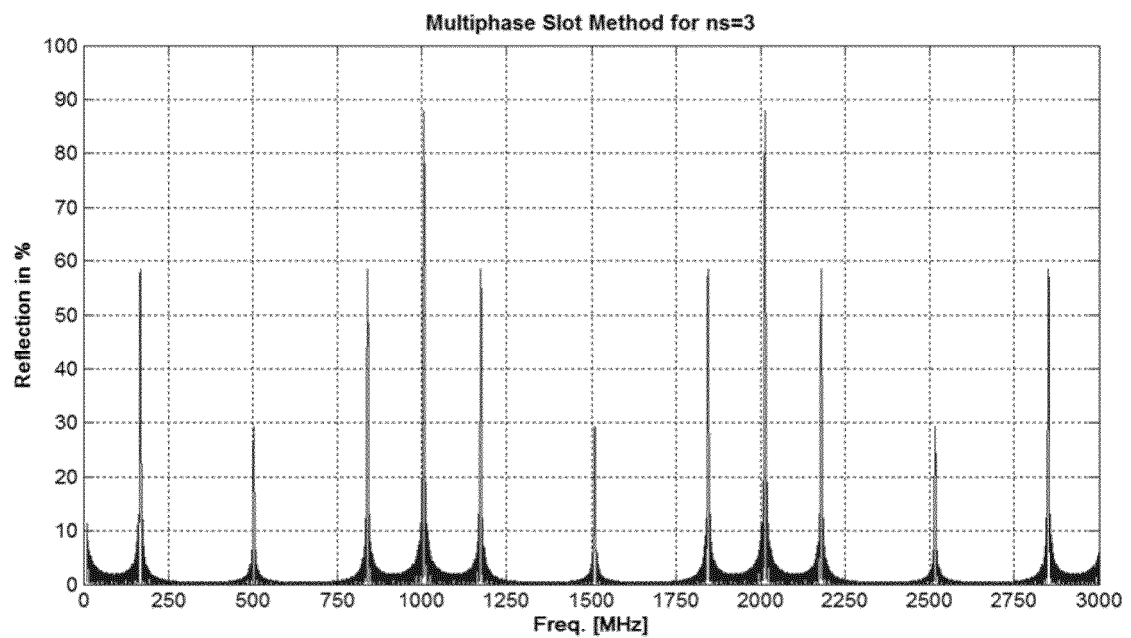
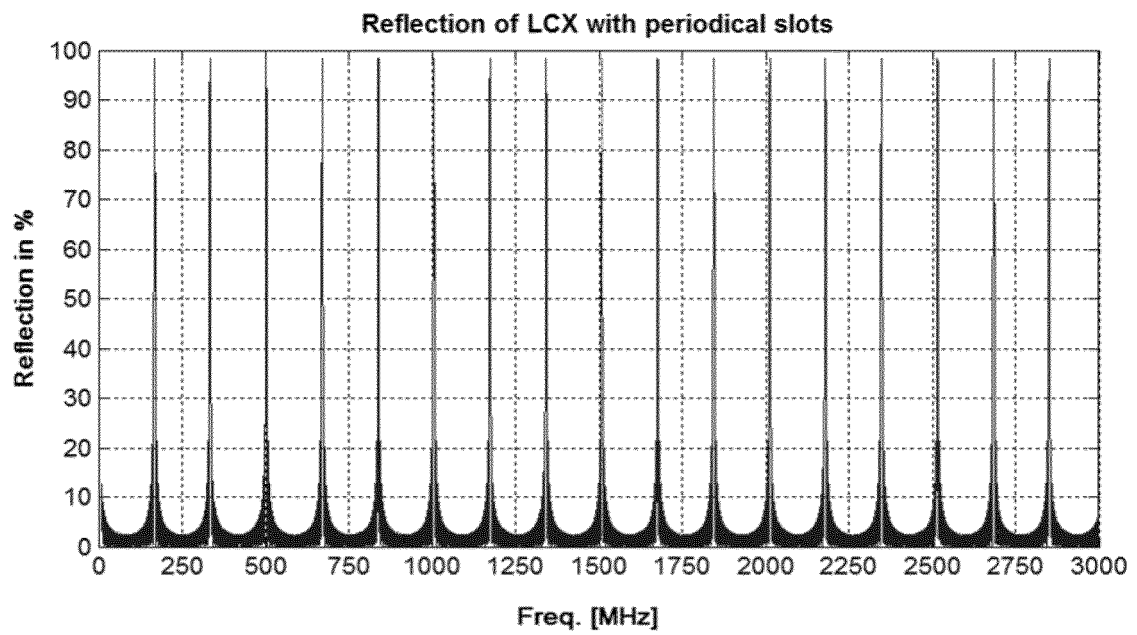
caractérisé en ce que,

dans chaque groupe, il y a plus de deux sous-groupes (30a ; 30b ; 30c ; 32a ; 32b ; 32c), et lesdits sous-groupes (30a ; 30b ; 30c ; 32a ; 32b ; 32c) ont un espacement équidistant le long de l'axe longitudinal du câble (10) à l'intérieur dudit groupe.

9. Programme informatique, dont un code de programme est destiné à réaliser le procédé de la revendication 8 lorsque le programme informatique est exécuté sur un ordinateur, un processeur, ou un composant matériel programmable.







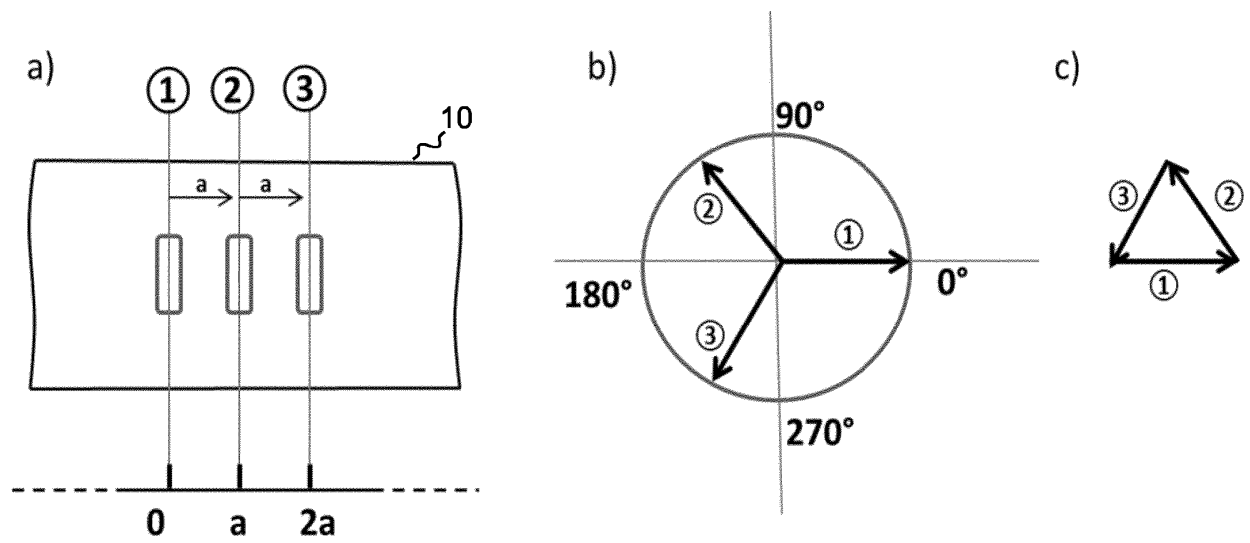


Fig. 4

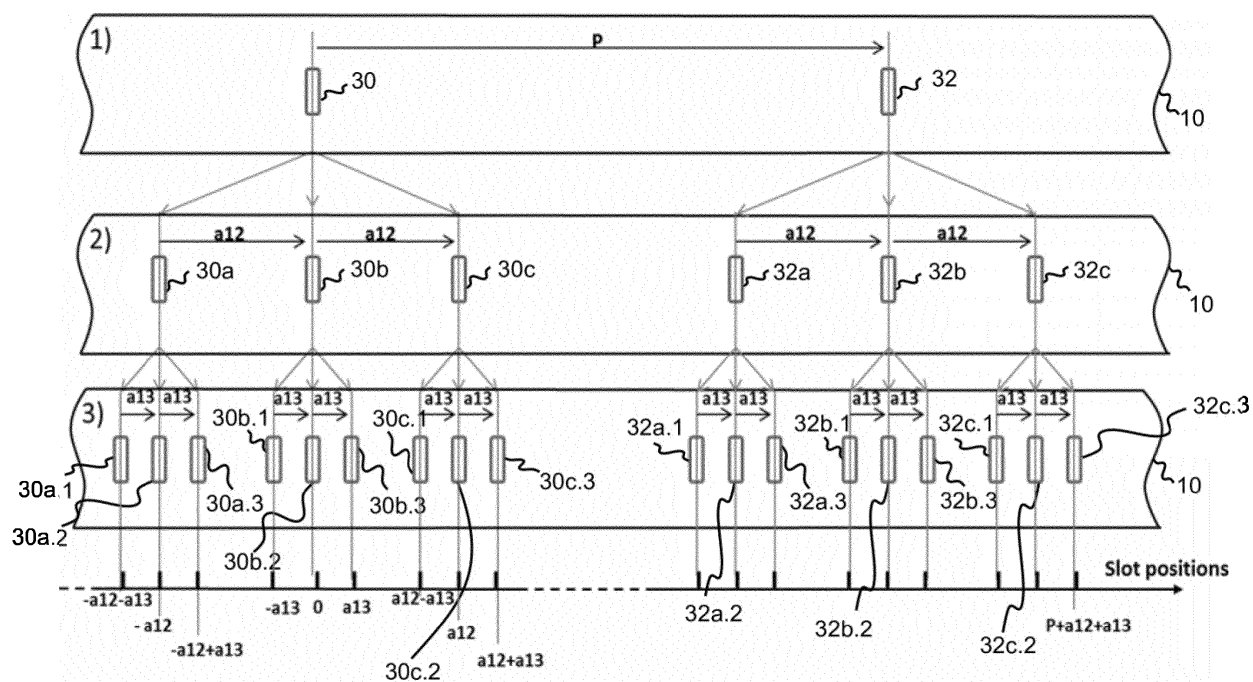


Fig. 5

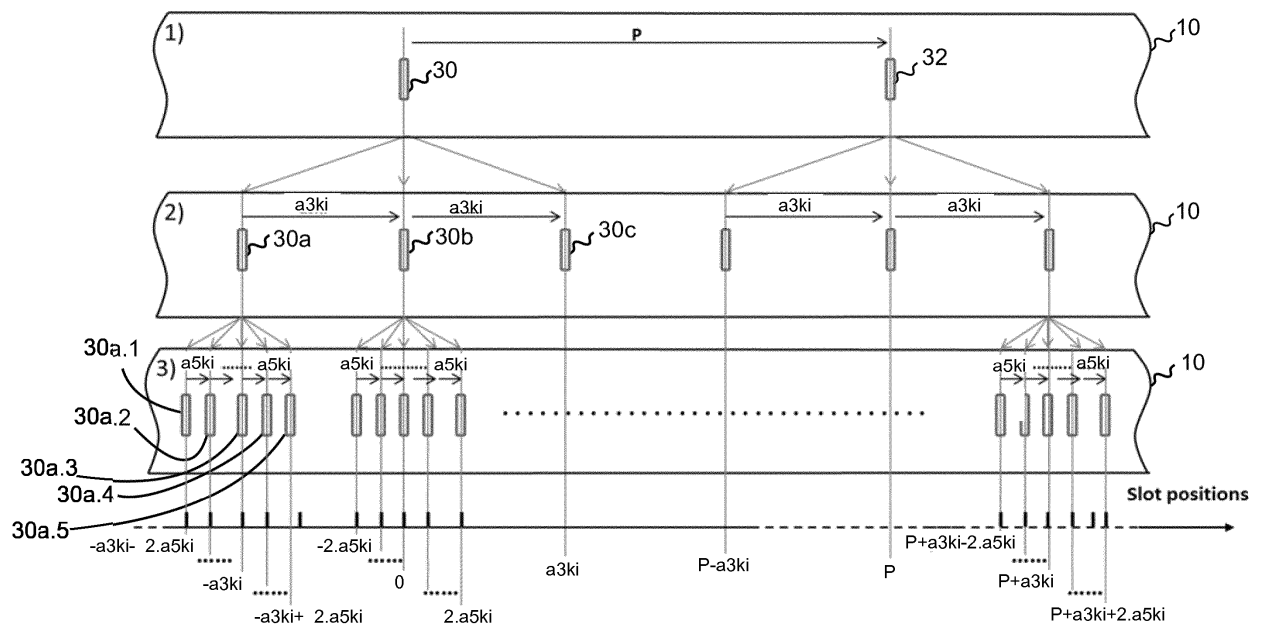


Fig. 6

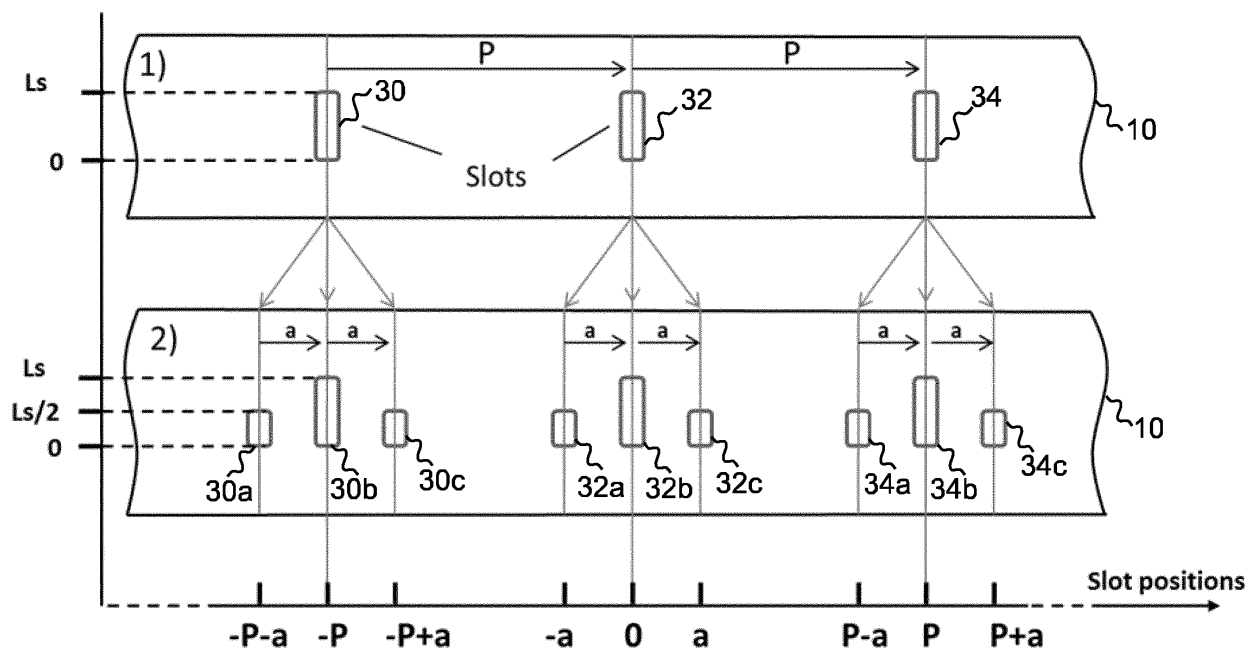


Fig. 7

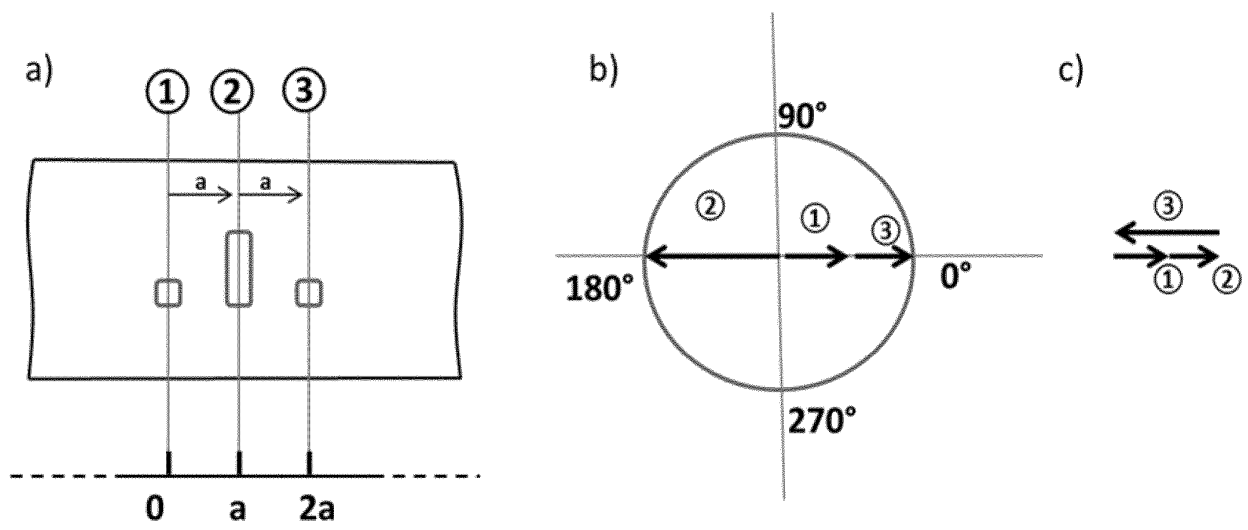


Fig. 8

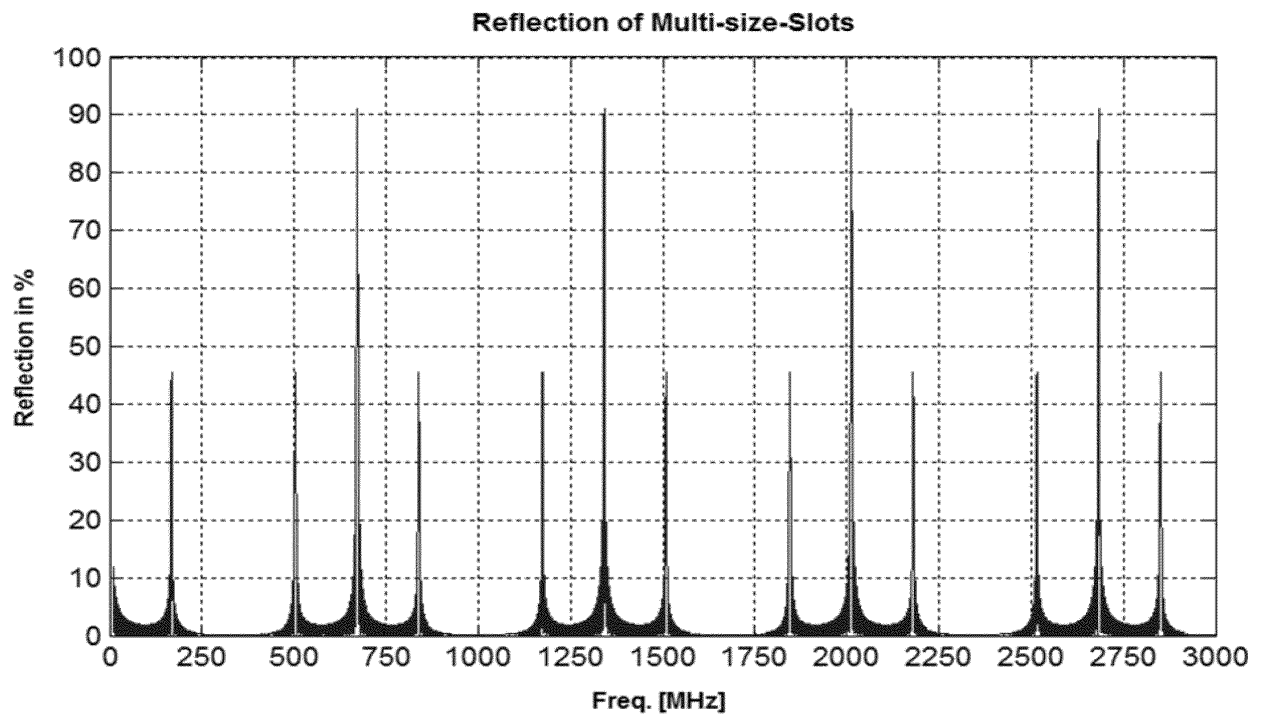


Fig. 9

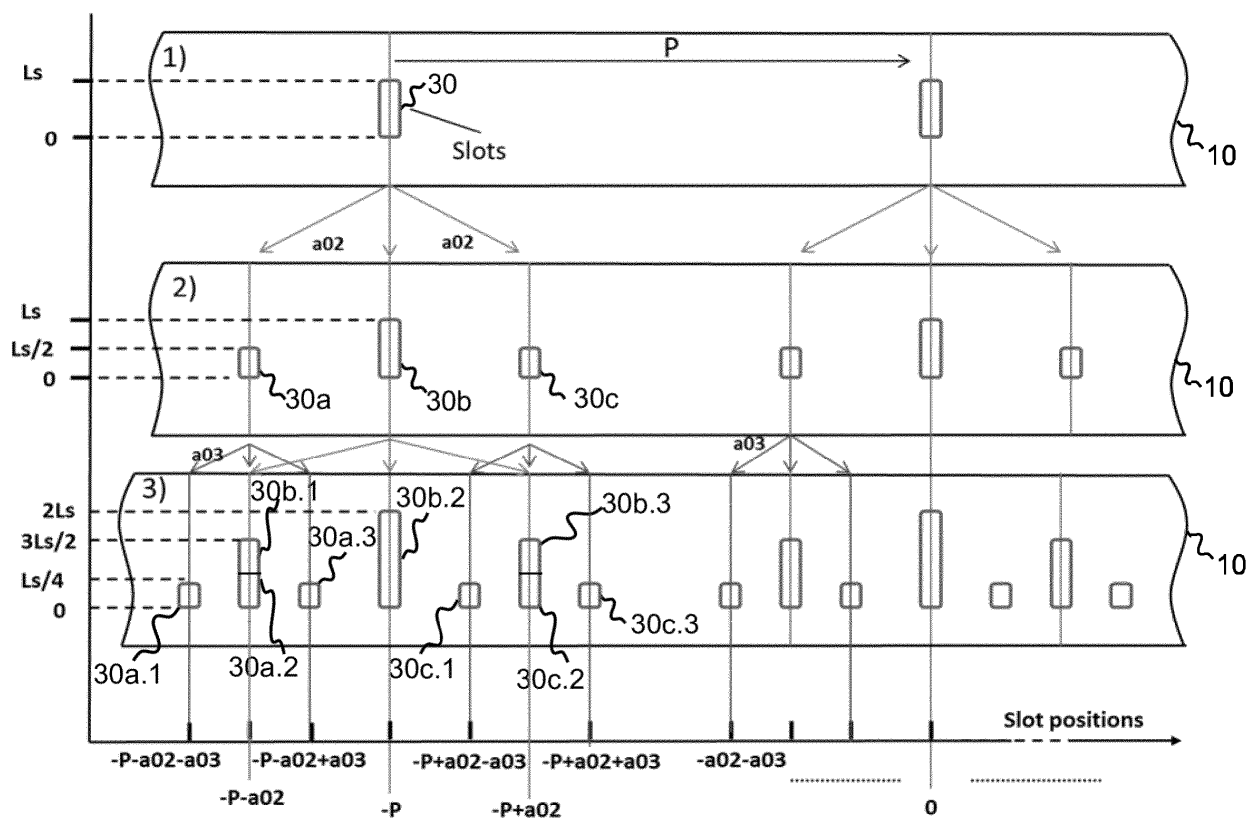


Fig. 10

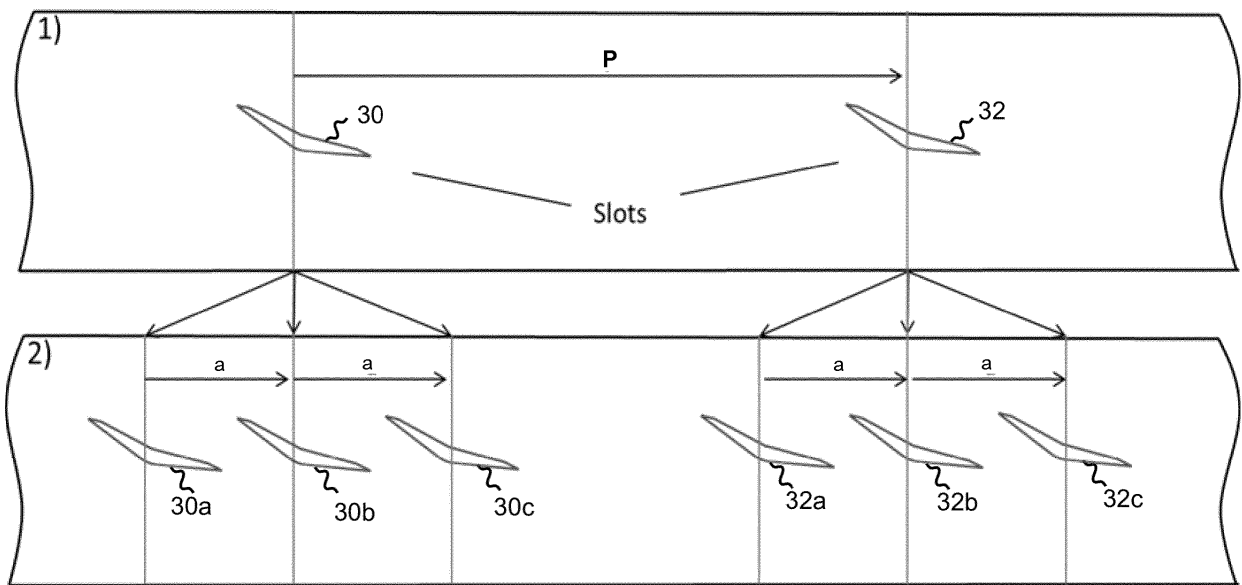


Fig. 11

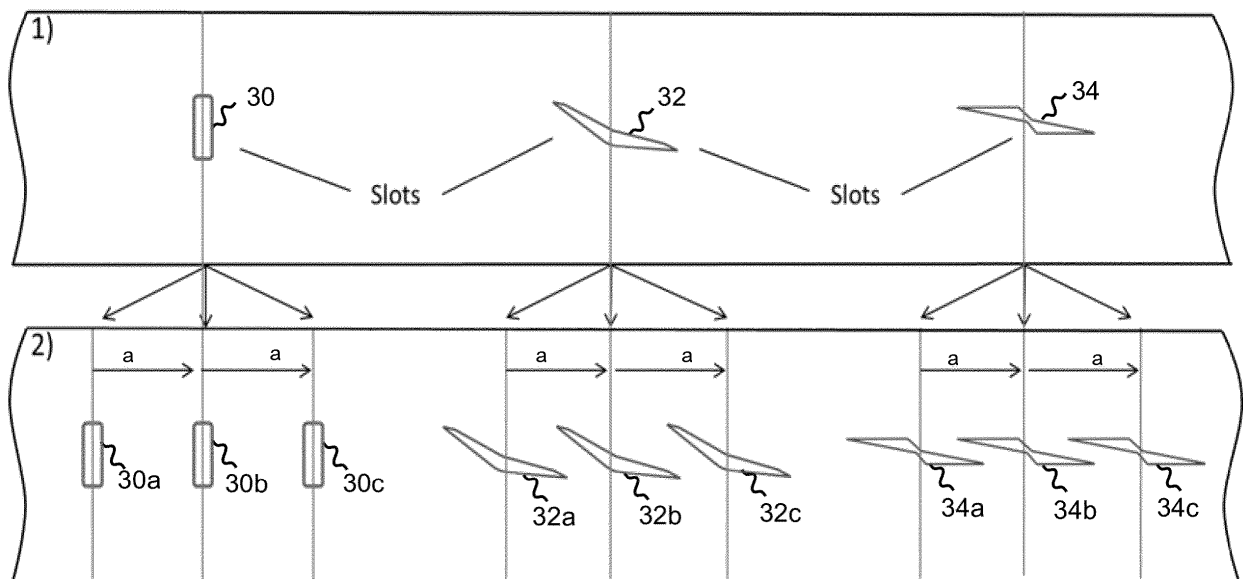


Fig. 12

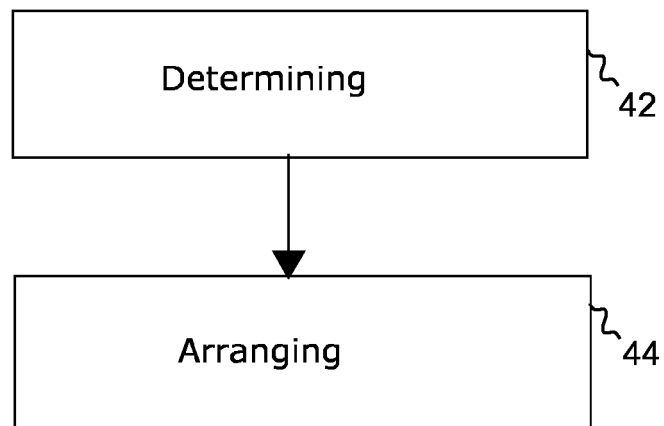


Fig. 13

REFERENCES CITED IN THE DESCRIPTION

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