



(11)

EP 3 200 282 A1

(12)

EUROPEAN PATENT APPLICATION

(43) Date of publication:
02.08.2017 Bulletin 2017/31

(51) Int Cl.:
H01Q 13/20 (2006.01)

(21) Application number: **16153437.5**

(22) Date of filing: **29.01.2016**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
MA MD

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

(74) Representative: **2SPL Patentanwälte PartG mbB**
Postfach 15 17 23
80050 München (DE)

(71) Applicant: **Alcatel-Lucent Shanghai Bell**
Shanghai 201206 (CN)

Remarks:

Amended claims in accordance with Rule 137(2) EPC.

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

(57) Embodiments provide a leaky coaxial cable, a computer program and a method for determining slot positions on a leaky coaxial cable. 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 (30a; 30b; 30c; 32a; 32b; 32c; 34a; 34b; 34c) along a longitudinal axis of the cable (10) to leak a radio frequency signal, wherein the slots (30a; 30b; 30c; 32a; 32b; 32c; 34a; 34b; 34c) are arranged in repetitive groups (30; 32; 34) of more than two slots.

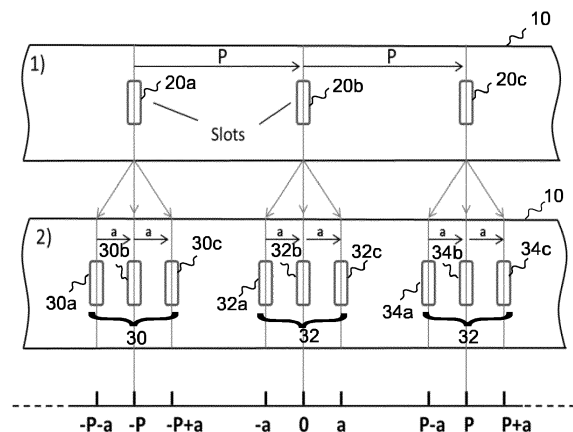


Fig. 1

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, and

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

Summary of illustrative Embodiments

[0007] Some simplifications may be made in the following summary, which is intended to highlight and introduce some aspects of the various exemplary embodiments, but such simplifications are not intended to limit the scope of the invention(s). Detailed descriptions of a preferred exemplary embodiment adequate to allow those of ordinary skill in the art to make and use the inventive concepts will follow in later sections.

[0008] Various embodiments provide a leaky coaxial cable, a computer program and a method for determining slot positions therefore. 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 longi-

tudinal 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 example embodiments will now be described more fully with reference to the accompanying drawings in which some example 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] Accordingly, while example embodiments are capable of various modifications and alternative forms, embodiments thereof are shown by way of example in the figures and will herein be described in detail. It should be understood, however, that there is no intent to limit example embodiments to the particular forms disclosed, but on the contrary, example embodiments are to cover all modifications, equivalents, and alternatives falling within the scope of the invention. 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] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of example embodiments. 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 example 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.

[0024] 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.

[0025] Embodiments may provide a broad bandwidth LCX.

[0026] 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.

[0027] 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).

[0028] 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.

[0029] 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 $ns=3$, $ns=4$.

[0030] 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:

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

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

For $\text{Ref} = 0$,

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

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

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

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

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

40

45

50

55

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

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
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														
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														
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
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
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 $P=800\text{mm}$, 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 $n_s=3$ and $a = P/6 = \sim 167 \text{ mm}$. 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 ($n_s > 2$) (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 n_s slots with a calculated distance (a) between them, the reflections appearing at each slot get superimposed (superposition), where the multiple phases of all n_s 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 $n_s = 3$ and $n_s = 4$ will be presented subsequently. An equation for any number n_s 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, 32c.1, 32c.2, 32c.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, 30c 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:

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

For $\text{Ref} = 0$,

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

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

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

[0038] For variable ns , for choosing any ns greater 2, the following equation can be considered:

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

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

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

[0039] 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.

[0040] 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 L_s , e.g. 30b, and two others of half-size $L_s/2$, e.g. 30a and 30c. A calculation of the distance between slots can be given according to the following approach:

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

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

[0041] 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.

[0042] 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 L_s in subgroup 30b, and $L_s/2$ 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 $L_s/4$, $3L_s/2$ ($30a.2+30b.1$), and $L_s/4$. 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 ($2L_s$, $3L_s/2$, L_s , $L_s/2$, $L_s/4$, 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.

[0043] As shown, the sizes of overlapping slots are added up in this embodiment resulting in a large center slot 30b.2 of size $2L_s$. 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.

[0044] 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 $ns=3$. 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 (ns), the number of steps, the right combination of different ns at multiple steps or the combination of different slot shapes may be chosen based on the requirements or application.

[0045] 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.

[0046] 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.

[0047] The description and drawings merely illustrate the principles of the invention. It will thus be appreciated that those skilled in the art will be able to devise various arrangements that, although not explicitly described or shown herein, embody the principles of the invention and are included within its spirit and scope. Furthermore, all examples recited herein are principally intended expressly to be only for pedagogical purposes to aid the reader in understanding the principles of the invention and the concepts contributed by the inventor(s) to furthering the art, and are to be construed as being without limitation to such specifically recited examples and conditions. Moreover, all statements herein reciting principles, aspects, and embodiments of the invention, as well as specific examples thereof, are intended to encompass equivalents thereof.

[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] Furthermore, the following claims are hereby incorporated into the Detailed Description, where each claim may stand on its own as a separate embodiment. While each claim may stand on its own as a separate embodiment, it is to be noted that - although a dependent claim may refer in the claims to a specific combination with one or more other claims - other embodiments may also include a combination of the dependent claim with the subject matter of each other dependent claim. Such combinations are proposed herein unless it is stated that a specific combination is not intended. Furthermore, it is intended to include also features of a claim to any other independent claim even if this claim is not directly made dependent to the independent claim.

[0051] 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 (30a; 30b; 30c; 32a; 32b; 32c; 34a; 34b; 34c) along a longitudinal axis of the cable (10) to leak a radio frequency signal, wherein the slots (30a; 30b; 30c; 32a; 32b; 32c; 34a; 34b; 34c) are arranged in repetitive groups (30; 32; 34) of more than two slots.
2. The leaky coaxial cable (10) of claim 1, wherein the slots (30a; 30b; 30c; 32a; 32b; 32c; 34a; 34b; 34c) within one group (30; 32; 34) have the same geometrical arrangement.
3. The leaky coaxial cable (10) of claim 1, wherein the radio frequency signal has a carrier wavelength and wherein the repetitive groups (30; 32; 34) are spaced more than half of a carrier wavelength apart from each other.
4. The leaky coaxial cable (10) of claim 1, wherein 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).
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) of one group (30; 32) are arranged in subgroups (30a; 30b; 30c; 32a; 32b; 32c) of more than two slots and wherein 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).
6. The leaky coaxial cable (10) of claim 5, 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 subgroup (30a; 30b; 30c; 32a; 32b; 32c) have an equidistant spacing and/or wherein there are more than two subgroups (30a; 30b; 30c; 32a; 32b; 32c) in a group (30; 32).
7. The leaky coaxial cable (10) of claim 1, wherein the radio frequency signal has a carrier wavelength and wherein the slots (30a; 30b; 30c; 32a; 32b; 32c; 34a; 34b; 34c) within one group (30, 32, 34) 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.
8. The leaky coaxial cable (10) of claim 7, wherein the slots (30a; 30b; 30c; 32a; 32b; 32c; 34a; 34b; 34c) within one group are configured to generate reflections of one or more harmonics of the carrier frequency with different phase and/or amplitude relations.
9. The leaky coaxial cable (10) of claim 1, comprising 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) of different shapes.
10. 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 (30a, 30b, 30c) have different shapes.
11. 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.
12. 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 (30) have different extents towards a lateral axis of the leaky coaxial cable (10).
13. The leaky coaxial cable (10) of claim 5, 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/or 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).
14. 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 along a longitudinal axis of the cable to leak a radio frequency signal, and

arranging (44) the slots in repetitive groups of more than two slots.

15. A computer program having a program code for performing the method of claim 14, when the computer program is executed on a computer, a processor, or a programmable hardware component.

5

Amended claims in accordance with Rule 137(2) EPC.

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 (30a; 30b; 30c; 32a; 32b; 32c; 34a; 34b; 34c) along a longitudinal axis of the cable (10) to leak a radio frequency signal, wherein the slots (30a; 30b; 30c; 32a; 32b; 32c; 34a; 34b; 34c) are arranged in repetitive groups (30; 32; 34) of more than two slots, 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) of one group (30; 32) are arranged in subgroups (30a; 30b; 30c; 32a; 32b; 32c) of more than two slots and wherein 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), 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 subgroup (30a; 30b; 30c; 32a; 32b; 32c) have an equidistant spacing, and wherein the radio frequency signal has a carrier wavelength and wherein the slots (30a; 30b; 30c; 32a; 32b; 32c; 34a; 34b; 34c) within one group (30, 32, 34) 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.
2. The leaky coaxial cable (10) of claim 1, wherein the slots (30a; 30b; 30c; 32a; 32b; 32c; 34a; 34b; 34c) within one group (30; 32; 34) have the same geometrical arrangement.
3. The leaky coaxial cable (10) of claim 1, wherein the radio frequency signal has a carrier wavelength and wherein the repetitive groups (30; 32; 34) are spaced more than half of a carrier wavelength apart from each other.
4. The leaky coaxial cable (10) of claim 1, wherein 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).
5. The leaky coaxial cable (10) of claim 1, wherein there are more than two subgroups (30a; 30b; 30c; 32a; 32b; 32c) in a group (30; 32).
6. The leaky coaxial cable (10) of claim 1, wherein the slots (30a; 30b; 30c; 32a; 32b; 32c; 34a; 34b; 34c) within one group are configured to generate reflections of one or more harmonics of the carrier frequency with different phase and amplitude relations.
7. The leaky coaxial cable (10) of claim 1, comprising 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) of different shapes.
8. 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.
9. 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.
10. 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 (30) have different extents towards a lateral axis of the leaky coaxial cable (10).
11. 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).

12. 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 along a longitudinal axis of the cable to leak a radio frequency signal, and
arranging (44) the slots in repetitive groups of more than two slots, 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) of one group (30;
32) are arranged in subgroups (30a; 30b; 30c; 32a; 32b; 32c) of more than two slots and wherein 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),
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 subgroup (30a; 30b; 30c; 32a; 32b; 32c) have an equidistant spacing, and
wherein the radio frequency signal has a carrier wavelength and wherein the slots (30a; 30b; 30c; 32a; 32b; 32c;
34a; 34b; 34c) within one group (30, 32, 34) 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.
13. A computer program having a program code for performing the method of claim 12, when the computer program is
executed on a computer, a processor, or a programmable hardware component.

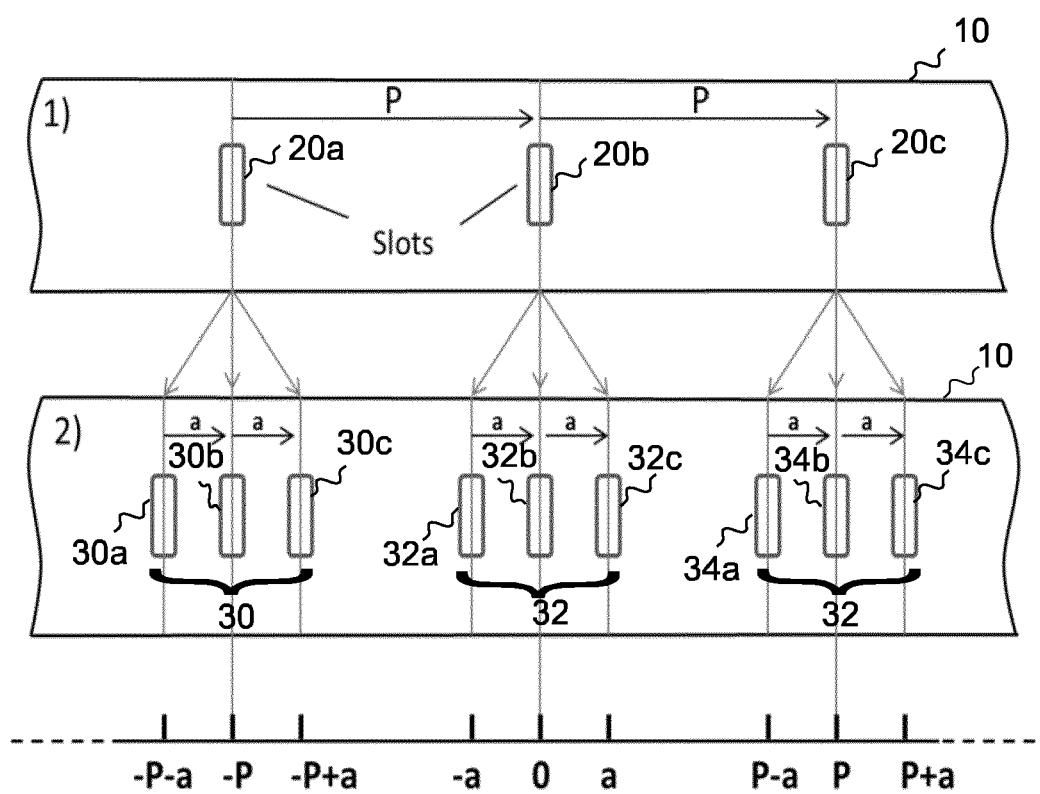


Fig. 1

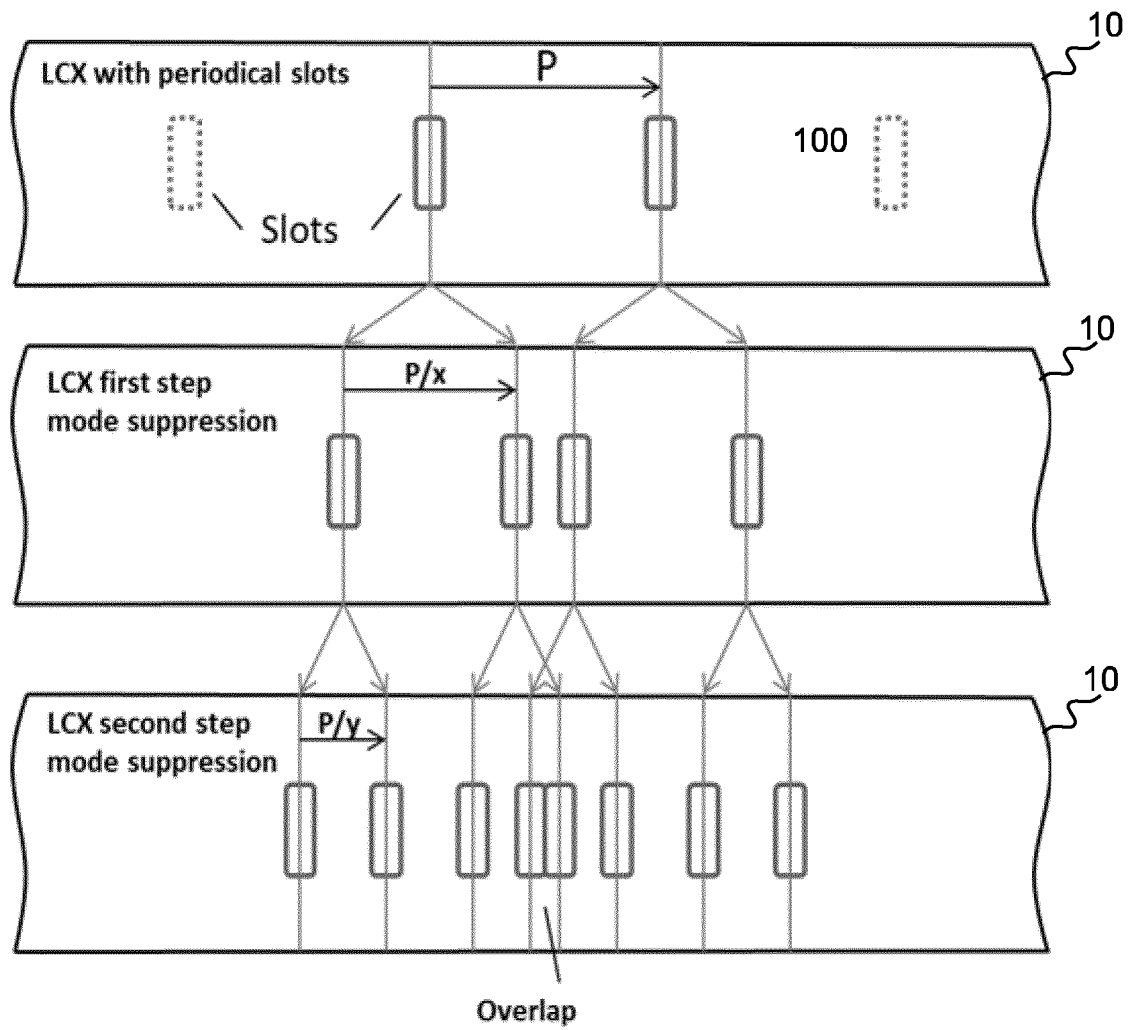


Fig. 2

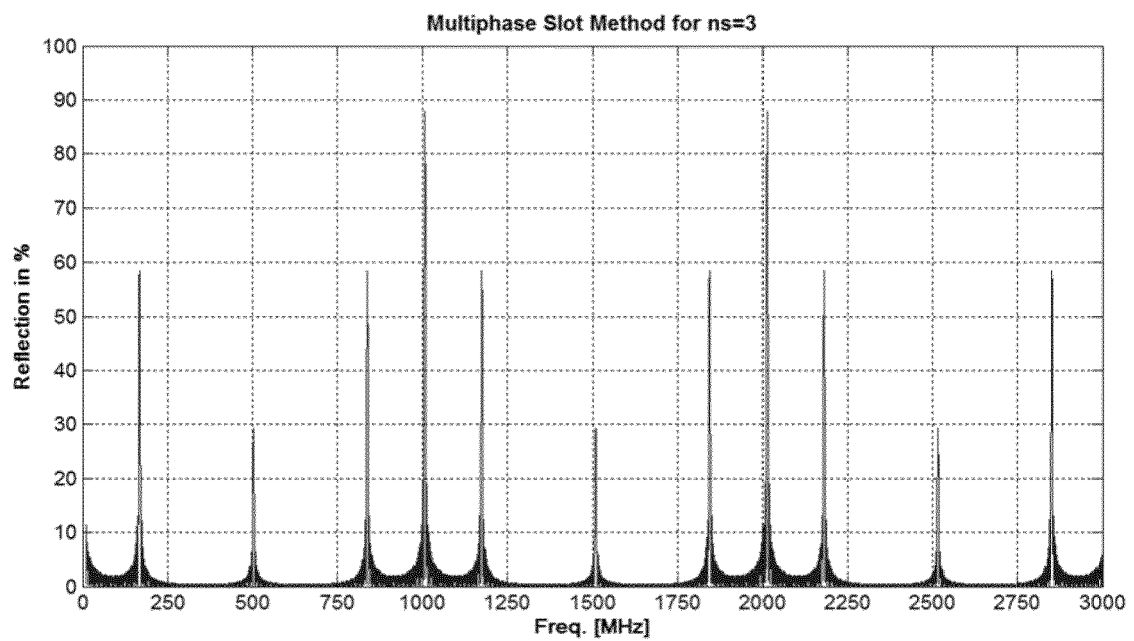
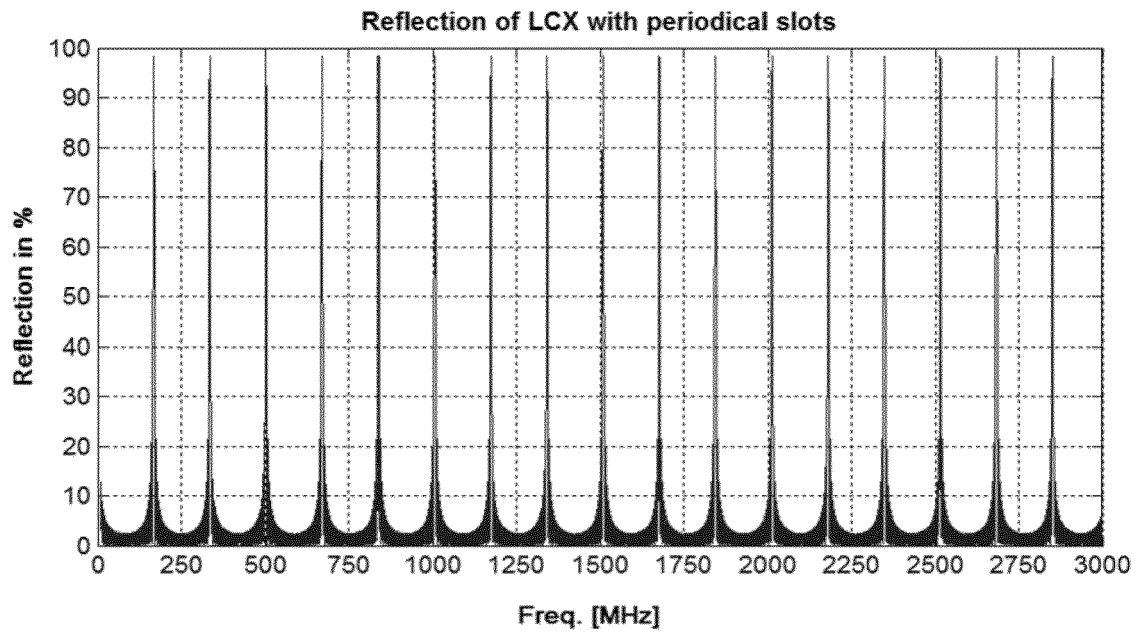


Fig. 3

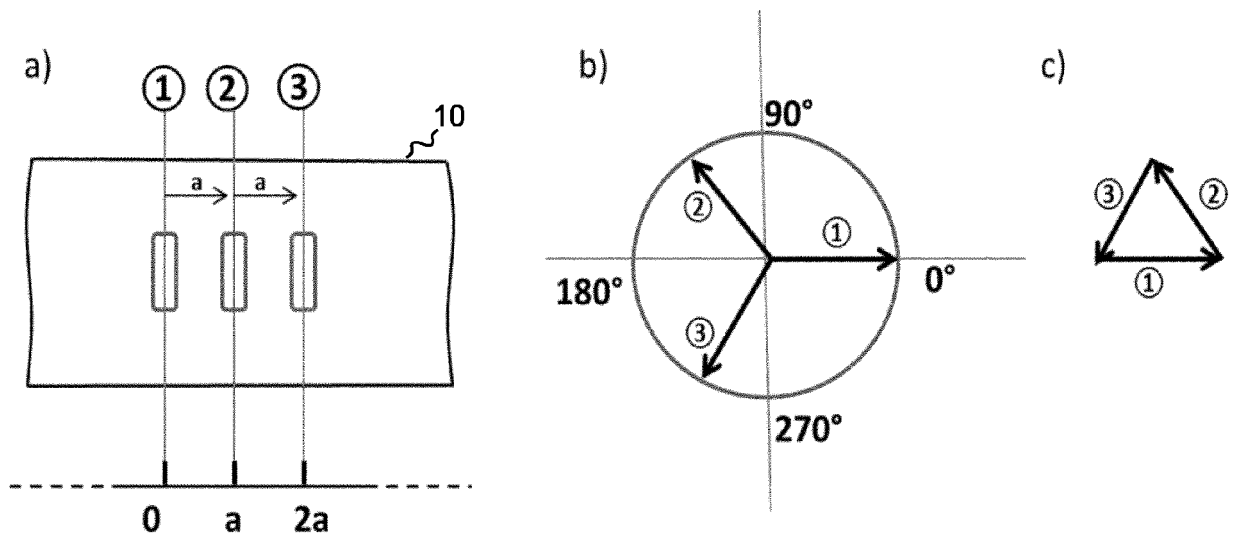


Fig. 4

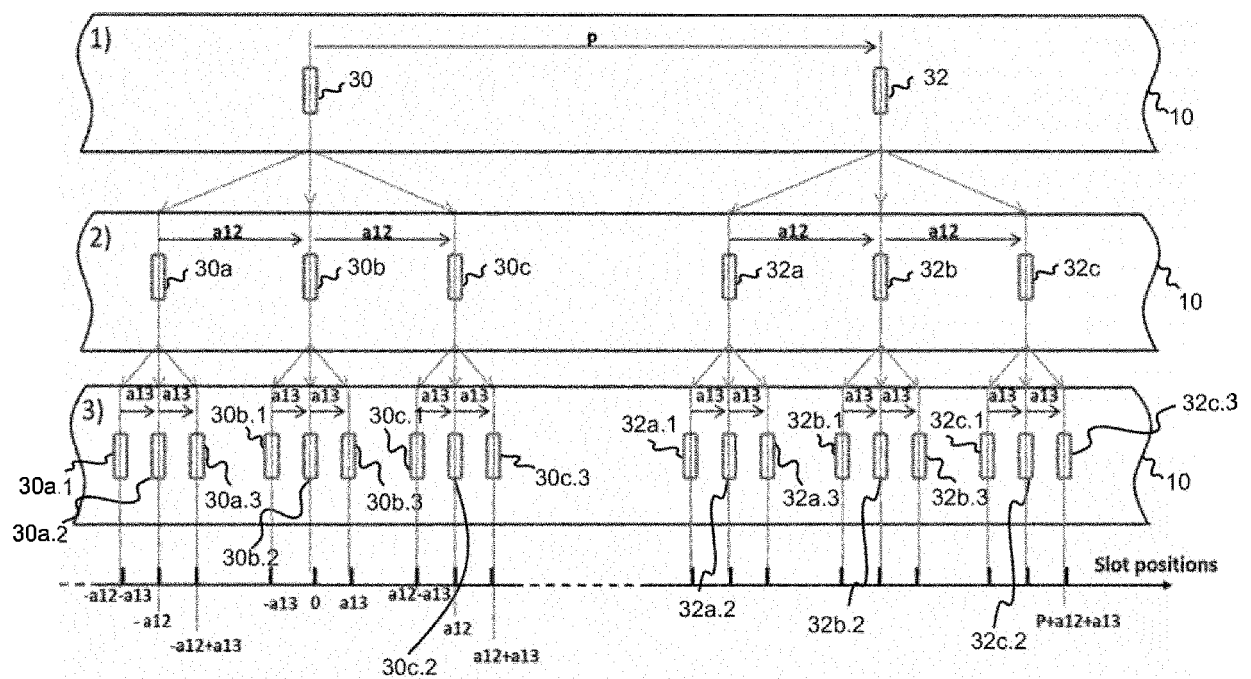


Fig. 5

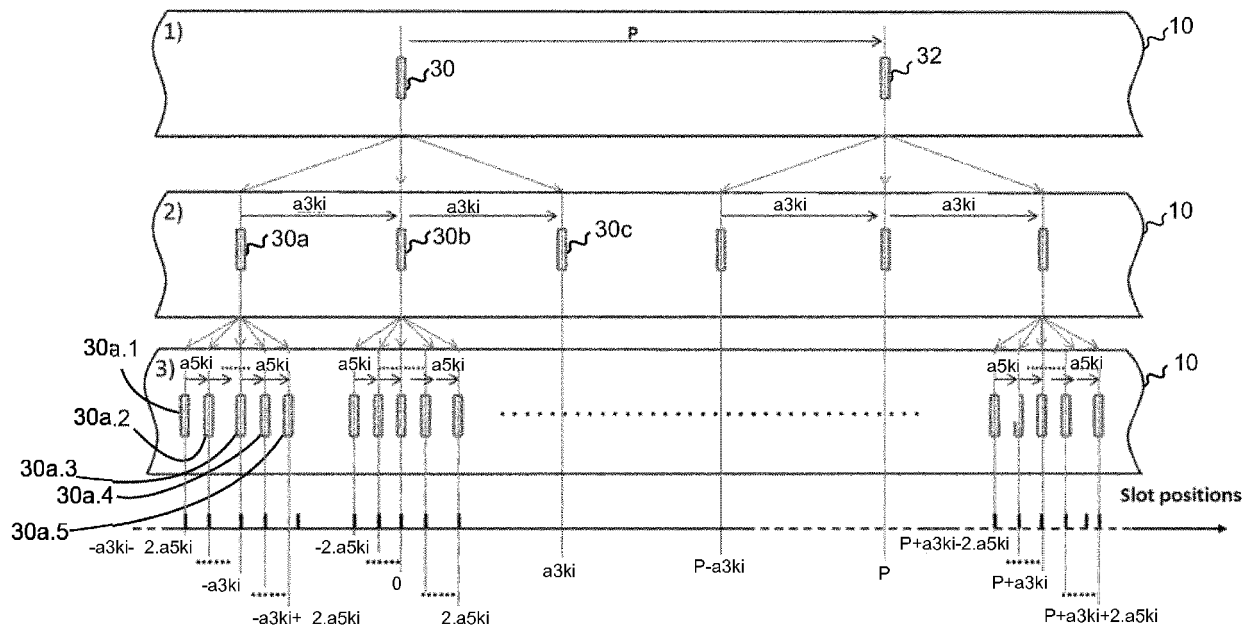


Fig. 6

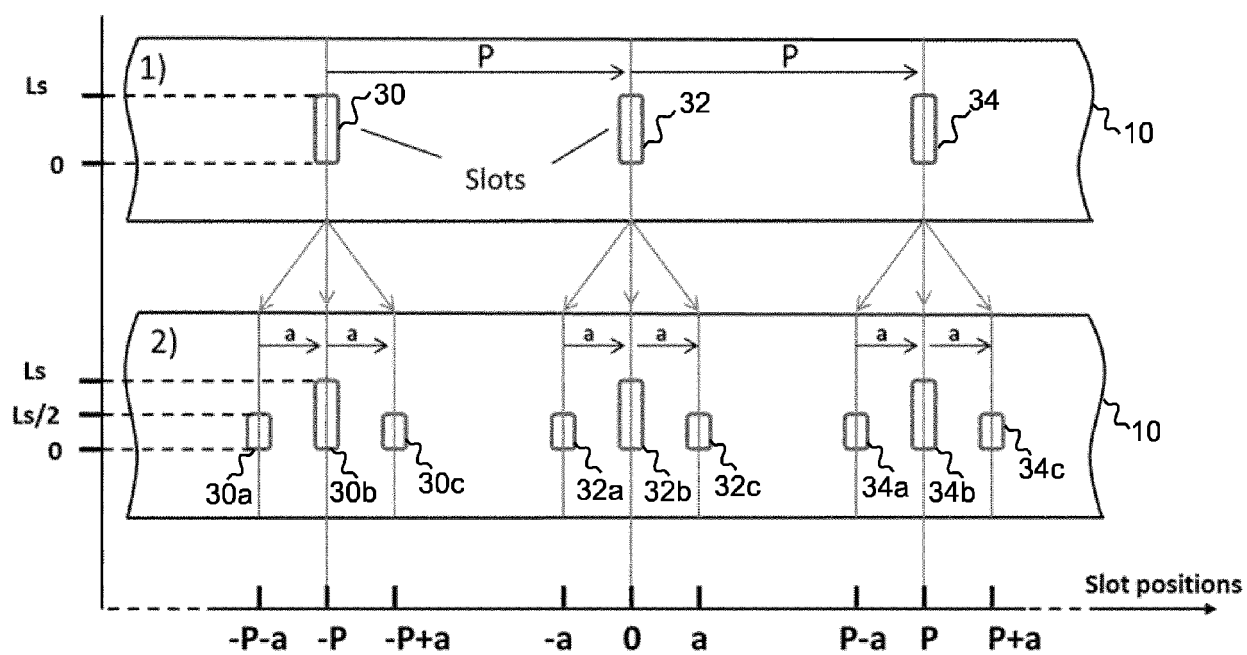


Fig. 7

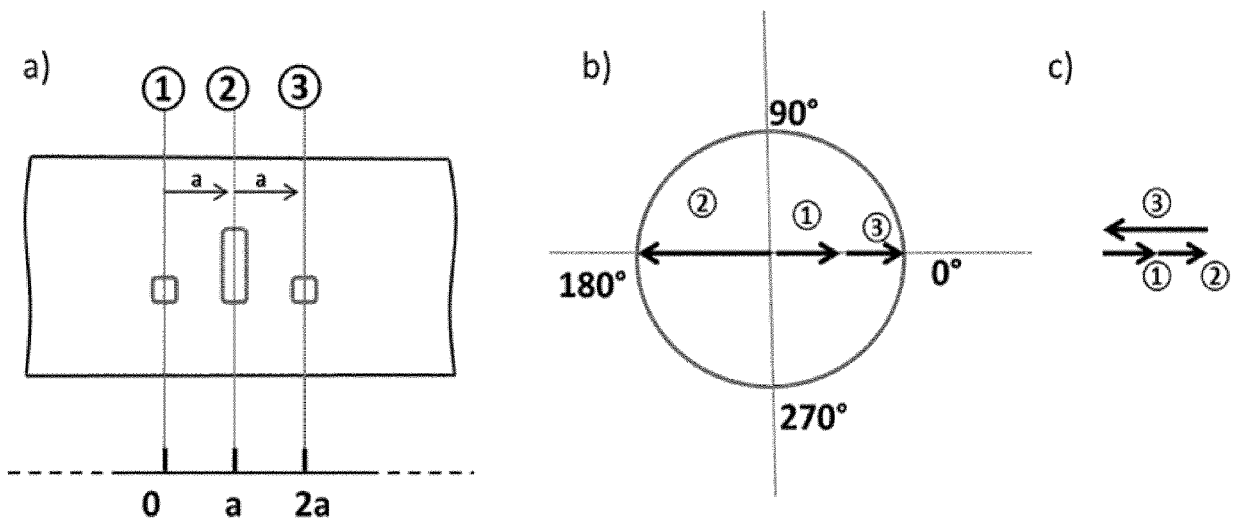


Fig. 8

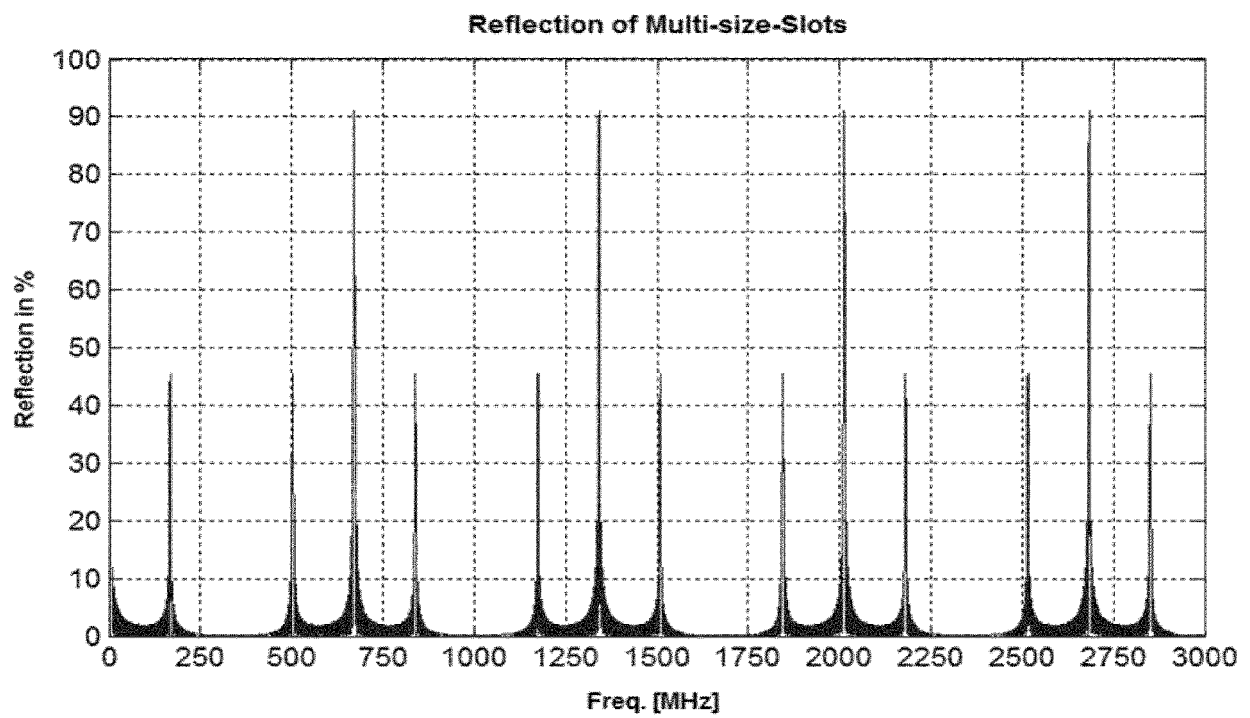


Fig. 9

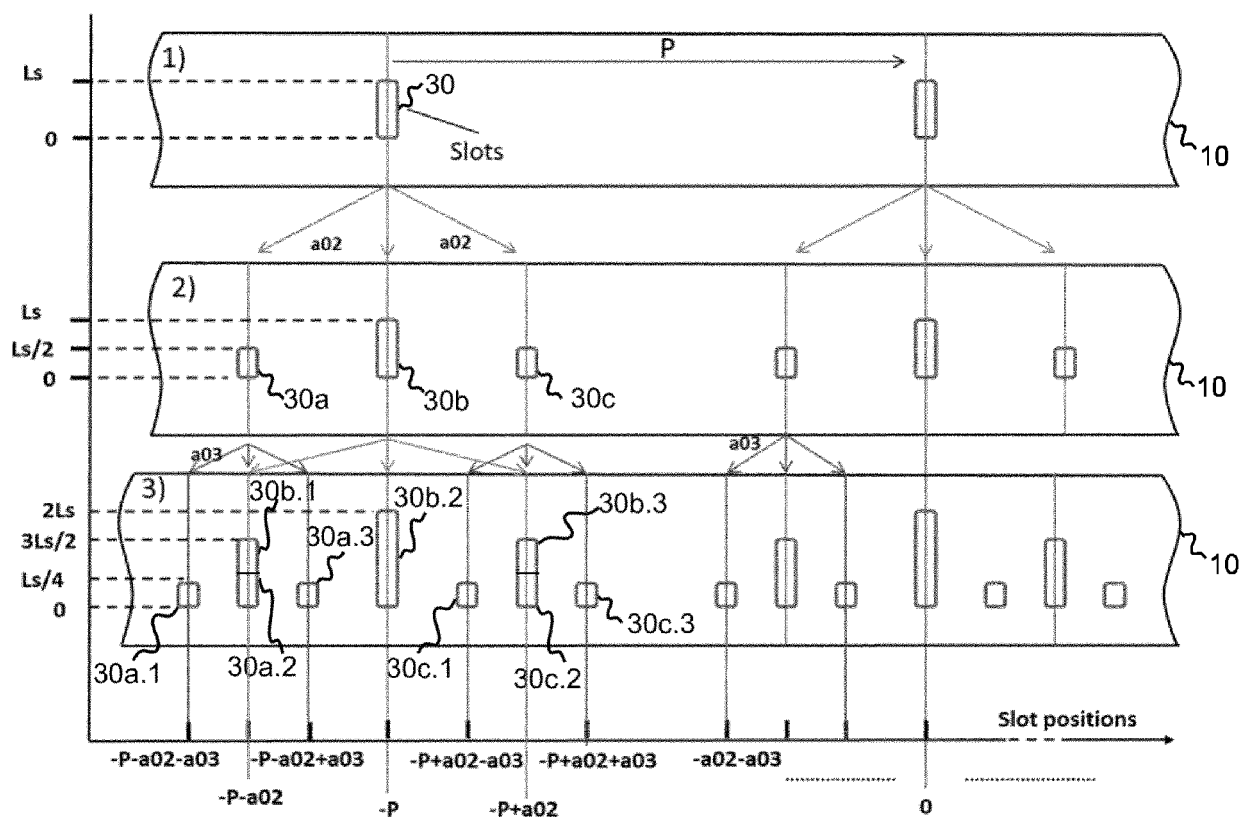


Fig. 10

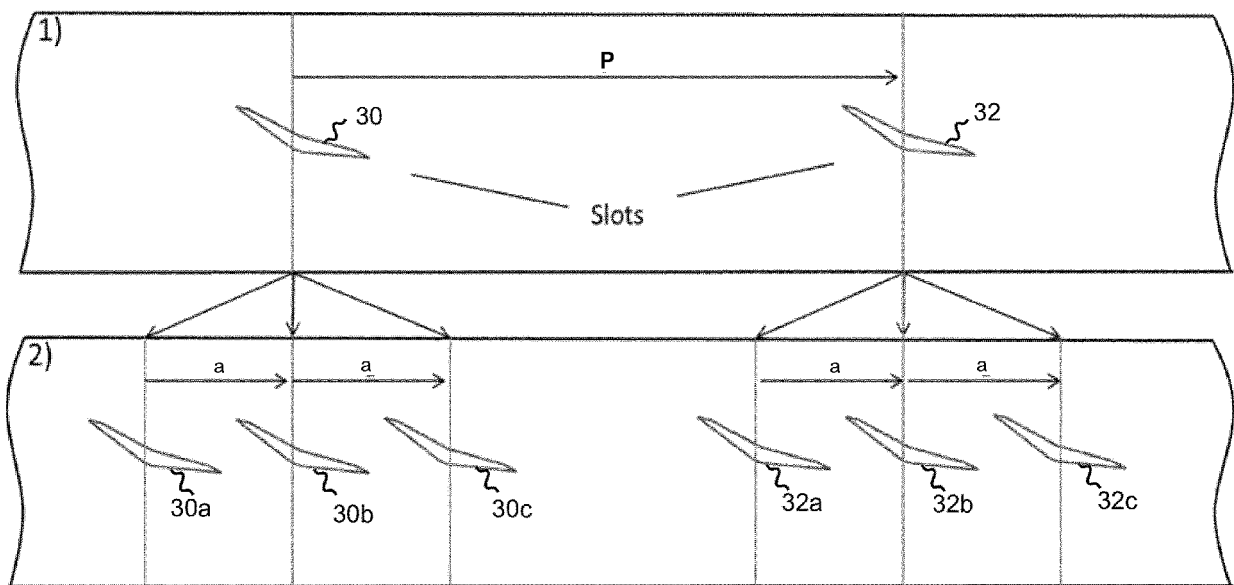


Fig. 11

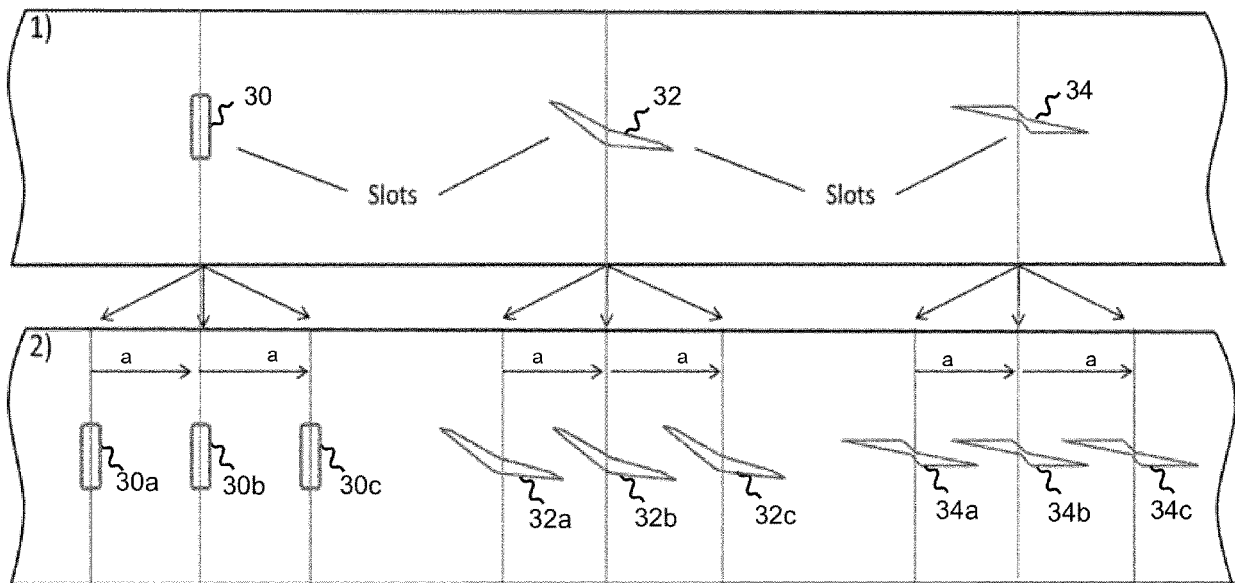


Fig. 12

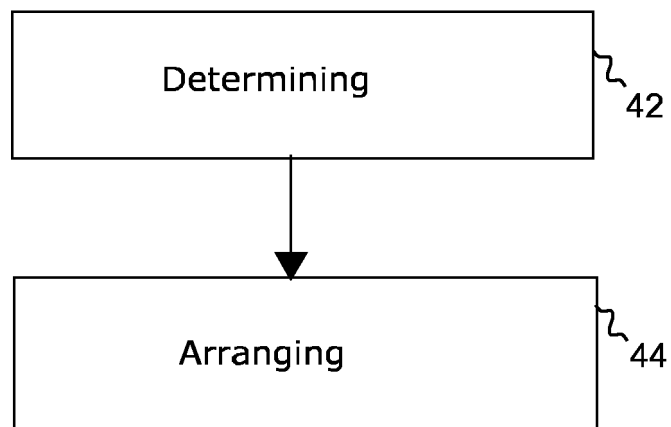


Fig. 13



EUROPEAN SEARCH REPORT

Application Number
EP 16 15 3437

5

10

15

20

25

30

35

40

45

50

55

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	EP 1 739 789 A1 (INST SCIENT DE SERVICE PUBLIC [BE]) 3 January 2007 (2007-01-03) * paragraph [0006] * * paragraphs [0018] - [0025] * * paragraphs [0042] - [0043] * * paragraph [0055] * * paragraph [0059] * * paragraph [0072] * * paragraphs [0082] - [0083] * * paragraphs [0085] - [0087] * * figures 3, 4, 5 *	1-13	INV. H01Q13/20
X	US 5 705 967 A (PIRARD WILLY [BE]) 6 January 1998 (1998-01-06) * column 3, line 40 - column 4, line 33 * * column 5, line 3 - column 8, line 21 * * figures 1-4 *	1,2,4,7, 8,14,15	
X	JUN HONG WANG ET AL: "Design of leaky coaxial cables with periodic slots", RADIO SCIENCE., vol. 37, no. 5, 1 October 2002 (2002-10-01), pages 2-1, XP055285412, US ISSN: 0048-6604, DOI: 10.1029/2000RS002534 * page 2-1, paragraph 3 - page 2-6, paragraph 7 * * figures 2, 3a, 3b *	1-4,7,8, 14,15	TECHNICAL FIELDS SEARCHED (IPC) H01Q
X	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 * page 338, column 2 - page 340, column 1; figures 1, 2 *	1,2,4,7, 8,14,15	
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 11 July 2016	Examiner Culhaoglu, Ali
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

EPO FORM 1503 03.02 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 16 15 3437

5

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

11-07-2016

10

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 1739789 A1	03-01-2007	EP 1739789 A1	03-01-2007
		US 2007001788 A1	04-01-2007

US 5705967 A	06-01-1998	BE 1010528 A5	06-10-1998
		DE 29606368 U1	08-08-1996
		FR 2732820 A1	11-10-1996
		US 5705967 A	06-01-1998

15

20

25

30

35

40

45

50

55

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- EP 0375840 B1 [0006]

Non-patent literature cited in the description

- **ULRICH PETRI.** *Die Berechnung von geschlitzten Koaxialkabeln für den UKW-Funk*, 21 January 1977 [0006]