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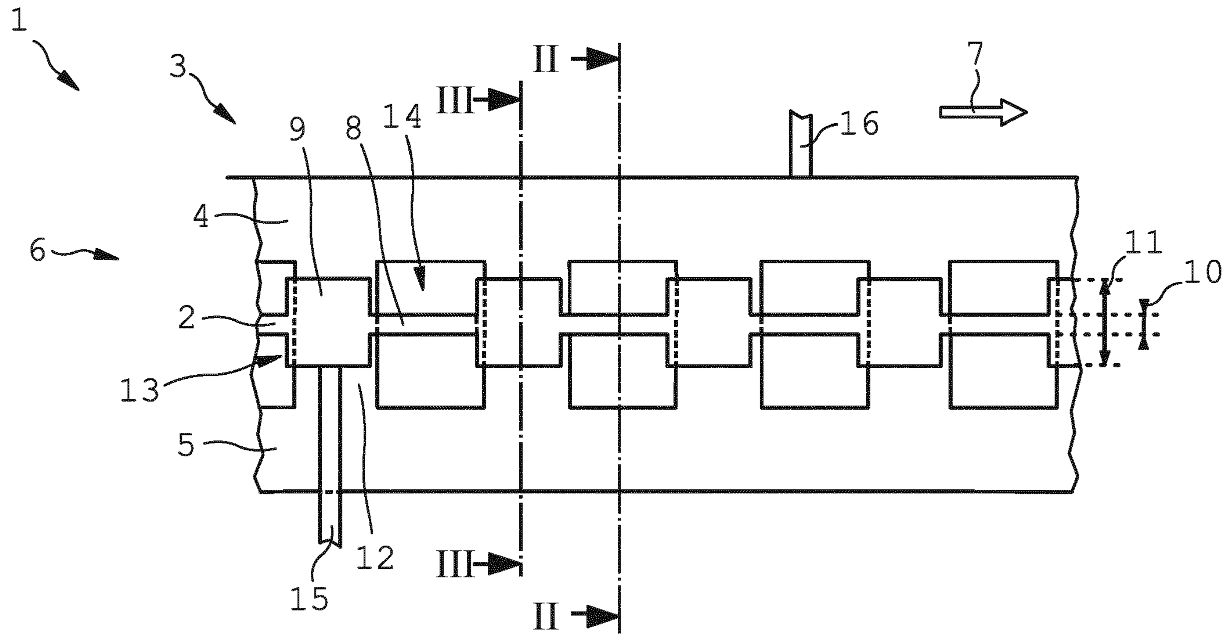
(54) **RADIO FREQUENCY PHASE SHIFT DEVICE**

(57) A Radio frequency phase shift device (1) comprising a transmission line (6) with a ground electrode arrangement (3) and a signal electrode (2). The ground electrode arrangement (3) comprises a first ground electrode (4) and a second ground electrode (5). Along a signal propagation direction (7) of the transmission line (6) the signal electrode (2) is arranged in between and spaced apart from the first ground electrode (4) and the second ground electrode (5). The ground electrode arrangement (3) comprises multiple connection elements (12) each electrically connecting the first ground electrode (4) and the second ground electrode (5). The connection elements (12) are spaced apart along the signal propagation direction (7), and are electrically insulated from the signal electrode (2).

FIG 1




EP 3 745 526 A1

## Description

Technical field

**[0001]** The invention relates to a radio frequency phase shift device comprising a transmission line with a ground electrode arrangement and a signal electrode, wherein the ground electrode arrangement comprises a first ground electrode and a second ground electrode, wherein along a signal propagation direction of the transmission line the signal electrode is arranged in between and spaced apart from the first ground electrode and the second ground electrode.

Background of the invention

**[0002]** It is well known to emit and receive an information signal that is propagated as an electromagnetic wave between an emitter and a receiver. For many applications the frequency of the electromagnetic wave can be within the radio frequency range that comprises a range of frequencies from at least 30 kHz to 300 GHz. Usually the emitter and the receiver comprise electromagnetic conducting transmission lines that allow for signal propagation of a radio frequency signal along the transmission line that has been received or that will be emitted. Such transmission lines can also be included in other signal transmitting devices that are not explicitly dedicated to signal emission or signal reception.

**[0003]** For some applications it is important to control the phase of the electromagnetic signal that is transmitted along the transmission line with respect to the phase of another signal propagation along the same or another transmission line, or with respect to an event like e.g. a trigger event that is related to the signal propagation along the transmission line. The length of the transmission line causes a phase shift that depends on the length of the transmission line and the electromagnetic characteristics of the transmission line and the surrounding material that affects the propagation of radio frequency electromagnetic waves along the transmission line. Thus, such a static phase shift can be preset by controlling the length and characteristics of the transmission line and the surroundings.

**[0004]** Transmission lines can be manufactured by depositing thin film electrodes on insulating substrates, where the alternating current is conducted along a length of a thin film signal electrode and where along the length and spaced apart from the signal electrode at least one ground electrode is arranged. An electrical field component of an electromagnetic field generated by the alternating electrical current conducted along the signal electrode can be at least partially shielded by the ground electrode.

**[0005]** In a microstrip line the transmission line is formed on a planar insulating substrate by arranging the signal electrode on a front surface and the ground electrode on a back surface of said planar insulating substrate with a width of the ground electrode being several times larger than a width of the signal electrode. The substrate material is typically a dielectric material exhibiting low dielectric loss and a negligible facility for tuning of the dielectric properties at a set frequency.

**[0006]** It is also known to provide for phase shifting devices that allow for a variable phase shift along the transmission line. For an easily workable modification of the transmission properties of the microstrip line a material with tunable dielectric properties can be arranged on top of the front surface of the substrate above the signal electrode, with the signal electrode being connected to a bias line. Furthermore, on a surface of the material with tunable dielectric properties opposite and spaced apart from the signal electrode a tuning electrode can be fabricated and connected to another bias line, so that by applying an electrical bias field to the material with the tunable dielectric properties the transmission properties of the transmission line can be modified. Such a device with electrodes arranged on several distinct layers can be complicated to fabricate.

**[0007]** In another transmission line configuration typically referred to as coplanar waveguide (CPW) the signal electrode is arranged in between and spaced apart from two ground electrodes, which are all deposited on the front surface of the insulating substrate.

**[0008]** Radio frequency phase shift devices comprising transmission lines in CPW-configuration with modifiable transmission properties are known in the art. The signal electrode and the ground electrodes are typically fabricated on the same surface of a dielectric substrate. A bridge electrode is arranged above and spaced apart from the transmission line with the bridge electrode overlapping the signal electrode and sometimes also partially overlapping the two ground electrodes. A static bias field can be applied in between the bridge electrode and the signal and ground electrodes by applying a direct current bias voltage via bias lines connected to the bridge electrode and to the signal and ground electrodes. The bias line connecting the ground electrodes and the signal electrode consists of a material with a low electrical conductivity shorting the ground electrode with respect to the applied direct current voltage, but which does not short the signal electrode and the ground electrodes with respect to the alternating current conducted along the transmission line. A volume between the bridge electrode and the transmission line is filled with a dielectric material whose dielectric properties can be tuned by application of the bias field, allowing for a modification of the transmission properties of the CPW-derived transmission line.

**[0009]** A phased array antenna usually comprises a multitude of individual antennas typically arranged next to each other on an antenna plane. For each antenna at least one radio frequency phase shift device can be connected between the respective antenna and a common electromagnetic wave transmitting and receiving source. By using a predetermined phase shift between the respective antennas and the common transmitting and receiving source a superposition of emitted or received signals can be maximized for a given direction, resulting in a preset spatial antenna characteristic of the phased array antenna. Hence, by adjusting the predetermined phase shift a direction of a signal beam emitted or received by the phased array antenna can be steered.

**[0010]** Radiative loss of the electromagnetic wave propagating along the connection of the electromagnetic wave transmitting and receiving source to each of the individual antennas can substantially degrade the performance of the phased array antenna. The phased array antenna typically comprises a large number of the individual antennas each connected via one of the radio frequency phase shift devices to the common electromagnetic wave transmitting and receiving source. Therefore, it is beneficial to reduce the radiative loss of the transmission lines of the radio frequency phase shift devices.

**[0011]** Accordingly, there is a need to provide for a phase shift device improving upon the aforementioned issues.

## Summary of the invention

**[0012]** The present invention relates to a radio frequency phase shift device comprising a transmission line with a ground electrode arrangement with a first ground electrode and a second ground electrode and a signal electrode wherein the ground electrode arrangement comprises multiple connection elements each electrically connecting the first ground electrode and the second ground electrode, wherein the connection elements are spaced apart along the signal propagation direction, and wherein the connection elements are electrically insulated from the signal electrode.

**[0013]** It has been found that the conversion away from CPW-type signal propagation into other parasitic types or modes of signal propagation along the transmission line structure can be reduced by electrically connecting the two ground electrodes at either side of the signal electrode which ultimately reduces radiative loss. In particular, the electromagnetic wave propagating along a curved line along the transmission line as in a bend, a circle or in a spiral can exhibit a significantly reduced coupling into other parasitic types of propagation. This allows for an arrangement of a curved transmission line that only requires a small quadratic or rectangular footprint or surface area on a substrate layer. By being able to implement bends or circles, the overall length can be easily maximized if the available space has e.g. a square footprint of limited size, as it is usually the case in array antennas.

**[0014]** To reduce the metallic loss of the transmission line the signal electrode and the ground electrodes are preferably fabricated from highly conductive metals such as copper or gold. Preferably a thickness of the signal electrode and a thickness of the first and of the second ground electrode are at least larger than a penetration depth of the skin effect for a minimal frequency the radio frequency phase shift device is anticipated to be used at. The connection elements are preferably fabricated from the same material as the ground electrodes. The connection elements are preferably formed featuring the same thickness as the ground electrodes. The connection elements can also exhibit a different thickness than the ground electrodes. It is also possible that different connection elements are formed with a different thickness.

**[0015]** According to another advantageous aspect of the invention the signal electrode is arranged at least partially above the connection elements, wherein a lower surface of the signal electrode is spaced apart from an upper surface of the respective connection element, wherein an overlapping area of the signal electrode and the respective connection element provides for a capacitor. The terms "above", "upper" and "lower" are only used to help clarifying the layout of the electrodes of the radio frequency phase shift device with respect to each other and do not infer that within a practical embodiment of the invention the signal electrode must be arranged at a higher elevation in space than the connection element.

**[0016]** Within the overlapping area of the signal electrode and the respective connection element, the upper surface of the respective connection element faces the signal electrode and the lower surface of the signal electrode faces the connection element. The overlapping parts of the signal electrode and the connection element provide for a capacitor. The characteristics of the capacitor depend on the material that is arranged in between the overlapping parts of the signal electrode and the connection element.

**[0017]** Thus, the transmission line is loaded with a capacitance of the multiple capacitors formed along the transmission line. The capacitors are connected in shunt between the signal electrode and the ground electrode arrangement.

**[0018]** The signal electrode can be spaced apart from the straight-line connection between the first and second ground electrode. Thus, the ground electrode arrangement is manufacturable with the connection elements at least in sections formed along the straight-line connection between the two ground electrodes. Manufacture of the electrodes of the transmission line then only requires forming the ground electrode arrangement on a front surface of a first substrate and forming the signal electrode on a front surface of a second substrate. Forming of the electrodes can be performed by well-known semiconductor or display manufacturing methods. The transmission line only comprises and requires an arrangement of the two front surfaces of the two substrates with the signal electrode and the connection elements facing each other.

**[0019]** To avoid a short circuit of the connection elements and the signal electrode an insulating material is arranged in between the signal electrode and the connection elements. The insulating material can be made of dimensionally stable material that also defines and maintains the distance between the signal electrode and the connection elements during operation of the phase shifting device. Alternatively, a compressible insulating material like a fluid or even a vacuum can be used. For using such an insulating material, spacers are integrable between the two substrates, so that the signal electrode and the connection elements remain spaced apart after arranging the two substrates face to face.

**[0020]** According to an embodiment of the invention, the substrates feature at least one flat front surface. Preferably, the substrates are formed from an insulating material exhibiting low dielectric loss. The substrates can also be formed by a conductive or semi-conductive material comprising an insulating layer arranged at the front surface. Most preferably the substrate is optically transparent to allow for optically aligning the two substrates so that the signal electrode is arranged in between the two ground electrodes facing the connection elements. The front surface of the substrate can be an arbitrarily chosen surface of the substrate. In case the substrate exhibits two surfaces with a different surface roughness it is preferable that the surface featuring the lower surface roughness is chosen as the front surface.

**[0021]** According to another advantageous embodiment of the invention the connection element comprises a flat lower surface that is arranged on a same level as the flat lower surfaces of the first and second ground electrodes. Preferably the ground electrode arrangement is fabricated collectively on the front surface of the first substrate. In such a way the ground electrode arrangement can be manufactured with existing thin film deposition technologies in a technically simplified manner. The connecting elements can be simultaneously formed with the first and second electrode, e.g. on top of the front surface of the first substrate.

**[0022]** According to another advantageous embodiment of the invention a capacitor volume between the signal electrode and the respective connection element is filled at least in sections with a dielectric material that creates a large phase shift. Using the dielectric material inside the capacitor volume of the parallel plate capacitor the capacity of the parallel plate capacitors can be increased, if need arises. As the dielectric material a substantially linear dielectric material as MgO, $Al_2O_3$ or $SiO_2$ can be chosen. A relative permittivity of the linear dielectric materials does not change with application of an electrical field.

**[0023]** The dielectric material can be a continuous layer sandwiched between the first and the second substrate. The dielectric material can also be only in sections formed in the overlapping area between the signal electrode and the connection elements. It is also possible that the overlapping areas between the signal electrode and the respective connection element is only in sections filled with the dielectric material. Different overlapping areas between the signal electrode and the connection elements can be filled differently and can even be void if the dielectric material.

**[0024]** To allow for adjusting the phase shift of the electromagnetic wave propagating along the transmission line during operation of the phase shifting device, the dielectric material comprises a tunable dielectric material. The dielectric material can solely consist of the tunable dielectric material. The dielectric material can also be a mixture of the linear dielectric material and the tunable dielectric material. The tunable dielectric material can comprise a non-linear dielectric material. The non-linear dielectric material exhibits a change in the relative permittivity with application of an electrical field to the non-linear dielectric material. The non-linear dielectric material can be a ferroelectric material in its paraelectric phase at an operation temperature of the radio frequency phase shift device as for instance an appropriate composition of $Ba_{1-x}Sr_xTiO_3$.

**[0025]** For a simplified manufacturing of the radio frequency phase shift device by using existing liquid crystal display manufacturing methods according to another advantageous embodiment of the tunable dielectric material comprises a liquid crystal material. Preferably the liquid crystal material exhibits a strong change in the relative permittivity as measured from the upper surface of the connection element to the lower surface of the signal electrode forming the plate capacitor when applying the electric field. In this way the capacitance of the parallel plate capacitor filled with the liquid crystal material can be tuned by applying an electrical field between the signal electrode and the respective connection element. The electric field for tuning the dielectric material is preferably a DC or low frequency electric field which superimposes the electromagnetic field of the actual signal without interfering with it. Preferably the liquid crystal material exhibits very low dielectric loss with a dielectric loss factor below 0.01, with the loss factor defined as tangent of the ratio of the imaginary part of the relative permittivity and the real part of the relative permittivity. Suitable liquid crystal materials are known in the art. In radio frequency phase shift devices comprising liquid crystal materials the first and the second substrate are preferentially composed of a silicate glass material.

**[0026]** According to another advantageous aspect of the invention, the lower surface of the signal electrode and the respective upper surface of the connection elements are parallel, so that the overlapping area between the signal electrode and the respective connection element form a parallel plate capacitor with a capacitor distance between the lower surface of the signal electrode and the upper surface of the respective connection element being constant. In this way the applied electrical field perpendicular to the electrodes of the parallel plate capacitor can be constant so that the whole liquid crystal material in the capacitor volume can be tuned homogeneously.

**[0027]** In yet another aspect of the invention, the capacitor distance between the lower surface of the signal electrode and the upper surface of the respective connection element is below 50 micrometers, preferably below 15 micrometers, and particularly preferred below 5 micrometers.

**[0028]** In another advantageous embodiment, to provide for a bias voltage for tuning the parallel plate capacitors the signal electrode is connected to at least one first bias line and the ground electrode arrangement is connected to at least one second bias line, wherein the at least one first bias line and the at least one second bias line are connected to at least one bias voltage source, so that a bias electrical field can be applied to the plate capacitors.

**[0029]** To reduce a parasitic propagation along the bias lines of the electromagnetic wave propagating along the transmission line according to another advantageous aspect of the invention the first and the second bias line comprise a material with an electrical conductivity below the conductivity of a material forming the signal electrode and the ground electrode arrangement. Preferably the bias electrodes are formed from a material with a low electrical conductivity below $1*10^6$ S/m. The signal electrodes can be formed by metals with a low electrical conductivity as NiCr. The signal electrodes can also be formed by a transparent conductive oxide as Sn-doped $In_2O_3$, also known as ITO. The electrical conductivity of the ITO can be selected inter alia by choosing an appropriate Sn doping concentration of $In_2O_3$.

**[0030]** According to another advantageous embodiment of the invention, the signal electrode comprises alternating transport sections and capacitor sections, wherein the capacitor sections are arranged as to overlap with the connection elements and wherein the transport sections do not overlap with the adjacent connection elements. The width of the respective transport sections and the width of the respective capacitor sections can be constant. Furthermore, the width of the transport sections and of the capacitor sections can be equal. It is also possible that the widths of the capacitor sections and of the signal section are variable. It is preferential that the width of the respective transport sections is smaller than one quarter of the wavelength of the electromagnetic wave propagation through the transmission line.

**[0031]** According to another advantageous aspect of the invention the connection elements are spaced apart along the signal propagation direction with a constant distance between the connection elements. In this way the transmission line can provide for a constant phase shift per length of the transmission line. It is also possible that the spacing between the connection elements varies along the signal propagation direction of the transmission line.

**[0032]** According to another advantageous embodiment of the invention the overlapping areas of the signal electrode and the respective connection elements cover more than 10 %, preferable more than 30 %, and most preferable more than 50 % of the area that is located between the first ground electrode and the second ground electrode and wherein the connection elements are arranged that connect the first and second ground electrode. A percentage of overlapping areas of the signal electrode and the respective connection elements of 10 % results in only a small part of overlapping areas, thus in either small connection elements or in a small signal electrode wherein small refers to the surface coverage of the respective connection elements or signal electrode. A larger percentage of overlapping areas of e.g. more than 30 % or more than 50 % increases the surface space between overlapping areas that is available for arranging a tunable dielectric material in between the signal electrode and the connection elements, resulting in an increased capacitor volume that can be used for affecting and modifying the phase shift of the signal that is transmitted along the signal electrode.

## Brief description of the drawings

**[0033]** The present invention will be more fully understood, and further features will become apparent, when reference is made to the following detailed description and the accompanying drawings. The drawings are merely representative and are not intended to limit the scope of the claims. In fact, those of ordinary skill in the art may appreciate upon reading the following specification and viewing the present drawings that various modifications and variations can be made thereto without deviating from the innovative concepts of the invention. Like parts depicted in the drawings are referred to by the same reference numerals.

Figure 1 illustrates a schematic top view of a transmission line of a radio frequency phase shift device,

Figure 2 illustrates a sectional view of the transmission line as shown in figure 1 along the line II-II,

Figure 3 illustrates a sectional view of the transmission line as shown in figure 1 along the line III-III,

Figures 4 to 6 illustrate top views of the transmission line of three alternative embodiments of the radio frequency phase shift device.

## Detailed description of the invention

**[0034]** In figure 1 a radio frequency phase shift device 1 comprises a signal electrode 2 and a ground electrode arrangement 3. The ground electrode arrangement 3 comprises a first ground electrode 4 and a second ground electrode 5. In the top view of the radio frequency phase shift device 1 the signal electrode 2 is arranged in between the two ground electrodes 4, 5. The signal electrode 2 and the two ground electrodes 4, 5 form a transmission line 6 in which electromagnetic waves propagate along a signal propagation direction 7.

**[0035]** The signal electrode 2 comprises alternating transport sections 8 and capacitor sections 9. A width 10 of the transport sections 8 is smaller than a width 11 of the capacitor sections 9 of the signal electrode 2.

**[0036]** The ground electrode arrangement 3 comprises connection elements 12 electrically connecting the first ground electrode 4 with the second ground electrode 5. The signal electrode 2 is arranged above the connection elements 12, forming overlapping areas 13 between the connection elements 12 and the signal electrode 2. In this embodiment the overlapping areas 13 are formed between the capacitor sections 8 of the signal electrode 2 and the connection elements 12. Furthermore, the transmission line 6 comprises non-overlapping areas 14 in which the signal electrode 2 runs at a distance to both of the ground electrodes 4, 5 and does not overlap with either of the ground electrodes 4, 5 and also does not overlap with a connection element 12.

**[0037]** The signal electrode 2 comprises one or more first bias lines 15 and the ground arrangement 3 comprises one or more second bias lines 16 so that a bias voltage can be applied between the signal electrode 2 and the respective connection element 12 in the overlapping areas 13 via a bias voltage source that is not shown in figure 1. The signal electrode 2 and the ground electrode arrangement 3 can be composed of Au while the bias lines 15, 16 can be composed of ITO. In such a way a large difference in electrical conductivity between Au and ITO with the electrical conductivity of ITO being substantially lower can reduce parasitic loss of an electromagnetic wave propagating along the signal electrode 2 and ground electrode arrangement 3 composed of Au into the bias lines 15, 16 composed of ITO.

**[0038]** Figures 2 and 3 illustrate two sectional views of the radio frequency phase shift device 1 as shown in figure 1. Figure 2 is a sectional view of a non-overlapping area 14 of the transmission line 6 whereas figure 3 is a sectional view of an overlapping area 13 of the transmission line 6.

**[0039]** The ground electrode arrangement 3 is arranged on a front surface 17 of a first substrate 18 made of a glass or ceramic material. The front surface 17 of the first substrate 18 faces a front surface 19 of a second substrate 20 also made of preferably the same glass or ceramic material. The signal electrode 2 is arranged on the front surface 19 of the second glass substrate 20. A liquid crystal material 21 which provides for a tunable dielectric material is sandwiched between the two substrates 18, 20. The two substrates 18, 20 are arranged in parallel and spaced apart by spacers not shown in figures 2 and figure 3.

**[0040]** A flat lower surface 22 of the first ground electrode 4, a flat lower surface 23 of the second ground electrode 5, and a flat lower surface 24 of the connection element 12 are arranged on the front surface 17 of the first substrate 18, so that the front surface 17 forms a common ground level 25 of the ground electrode arrangement 3. The signal electrode 2 is arranged on the front surface 19 of the second substrate 20. In the overlapping area 13 between the capacitor section 9 of the signal electrode 2 and the connection element 12 a parallel plate capacitor 26 is formed. The parallel plate capacitor 26 comprises a capacitor volume 27 filled with the liquid crystal material 21 between an upper surface 28 of the connection element 12 and a lower surface 29 of the capacitor section 9. The upper surface 28 of the connection element 12 and the lower surface 29 of the capacitor section 9 are spaced part by a capacitor distance 30.

**[0041]** The operating principle of the radio frequency phase shift device 1 will be outlined with reference to the detailed embodiment shown in figures 1 to 3. An electromagnetic wave, i.e. an information signal passes along the transmission line 6 along overlapping areas 13 and non-overlapping areas 14 of the signal electrode 2 and the respective connection elements 12. The electromagnetic wave passes along each respective non-overlapping area 14 with a fixed delay time as the delay time is dependent on the relative permittivity of the glass or ceramic material of the first and second substrate 18, 20 and of the liquid crystal material 21, the permittivity of which is substantially constant along the non-overlapping area 14. In the overlapping sections 13 inside the capacitor volume 27 the relative permittivity of the liquid crystal material 21 is modifiable with application of a bias field via the first bias line 15 and the second bias line 16. In this way the delay of the electromagnetic wave passing along the respective overlapping areas 13 is changeable. Thus, an adjustable phase shift is providable by the radio frequency phase shift device 1.

**[0042]** Figure 4 illustrates a top view of another embodiment of the radio frequency phase shift device 1. In this embodiment a first length 33 of the non-overlapping areas 14 as measured along the signal propagation direction 7 is shorter than a second length 34 of the non-overlapping areas 14 of the transmission line 6. The non-overlapping areas 14 alternate between the first length 33 and the second length 34. It is also possible for the non-overlapping areas 14 to create a sequence of varying lengths.

**[0043]** In figure 5 a top view of an alternative embodiment of the radio frequency phase shift device 1 is shown. Here the width 11 of the different capacitor sections 9 of the transmission line 6 varies from one to another. Furthermore, the width 10 of different transport sections 8 varies from one to another.

**[0044]** Figure 6 illustrates a top view of another alternative embodiment of the radio frequency phase shift device 1. Here the width 11 of the capacitor sections 9 is tapered down to the width 10 of the transport sections 8 in a region of the capacitor section 9 adjacent to the transport section 8.

## Claims

1. Radio frequency phase shift device (1) comprising a transmission line (6) with a ground electrode arrangement (3) and a signal electrode (2), wherein the ground electrode arrangement (3) comprises a

first ground electrode (4) and a second ground electrode (5), wherein along a signal propagation direction (7) of the transmission line (6) the signal electrode (2) is arranged in between and spaced apart from the first ground electrode (4) and the second ground electrode (5), **characterized in that** the ground electrode arrangement (3) comprises multiple connection elements (12) each electrically connecting the first ground electrode (4) and the second ground electrode (5), wherein the connection elements (12) are spaced apart along the signal propagation direction (7), and wherein the connection elements (12) are electrically insulated from the signal electrode (2).

**2.** Radio frequency phase shift device (1) according to claim 1, **characterized in that** the signal electrode (2) is arranged at least partially above the connection elements (12), wherein a lower surface (29) of the signal electrode (2) is spaced apart from an upper surface (28) of the respective connection element (12), wherein an overlapping area (13) of the signal electrode (2) and the respective connection element (12) provides for a capacitor.

**3.** Radio frequency phase shift device (1) according to one or more of the preceding claims, **characterized in that** each connection element (12) comprises a flat lower surface (24) that is arranged on a same level (25) as the flat lower surfaces (22, 23) of the first and second ground electrodes (4, 5).

**4.** Radio frequency phase shift device (1) according to one or more of the preceding claims, wherein a capacitor volume (27) between the signal electrode (2) and the respective connection element (12) is filled at least in sections with a dielectric material.

**5.** Radio frequency phase shift device (1) according to claim 4, **characterized in that** the dielectric material comprises a tunable dielectric material.

**6.** Radio frequency phase shift device (1) according to claim 5, **characterized in that** the tunable dielectric material comprises a liquid crystal material (21).

**7.** Radio frequency phase shift device (1) according to claim 2, **characterized in that** the lower surface (29) of the signal electrode (2) and the respective upper surface (28) of the connection elements (12) are parallel, so that the overlapping area (13) between the signal electrode (2) and the respective connection element (12) form a parallel plate capacitor (26) and that a capacitor distance (30) between the lower surface (29) of the signal electrode (2) and the upper surface (28) of the respective connection elements (12) is constant.

**8.** Radio frequency phase shift device (1) according to one or more of the claims, **characterized in that** the capacitor distance (30) between the lower surface (29) of the signal electrode (2) and the upper surface (28) of the respective connection element (12) is below 50 micrometers, preferably below 15 micrometers, and particularly preferred below 5 micrometers.

**9.** Radio frequency phase shift device (1) according to one or more of the claims 5 to 10, **characterized in that** the signal electrode (2) is connected to at least one first bias line (15) and the ground electrode arrangement (3) is connected to at least one second bias line (16), wherein the at least one first bias line (15) and the at least one second bias line (16) are connected to at least one bias voltage source, so that a bias electrical field can be applied to the plate capacitors.

**10.** Radio frequency phase shift device (1) according to claim 11, wherein the first and the second bias line (15, 16) comprise a material with an electrical conductivity below the conductivity of a material forming the signal electrode (2) and the ground electrode arrangement (3).

**11.** Radio frequency phase shift device (1) according to one or more of the preceding claims, **characterized in that** the signal electrode (2) comprises alternating transport sections (8) and capacitor sections (9), wherein the capacitor sections (9) are arranged as to overlap with the connection elements (12), and wherein the transport sections (8) do not overlap with the adjacent connection elements (12).

**12.** Radio frequency phase shift device (1) according to one or more of the preceding claims, **characterized in that** the connection elements (12) are spaced apart along the signal propagation direction (7) with a constant distance between the connection elements.

**13.** Radio frequency phase shift device (1) according to one or more of the claims 2 to 14, **characterized in that** the overlapping areas (13) of the signal electrode (2) and the respective connection element (12) cover more than 10 %, especially preferable more than 30 %, and most preferable more than 50 % of the area between the first ground electrode (4) and the second ground electrode (5) where the connection elements (12) are arranged that connect the first and second ground electrode (4, 5).

FIG 1

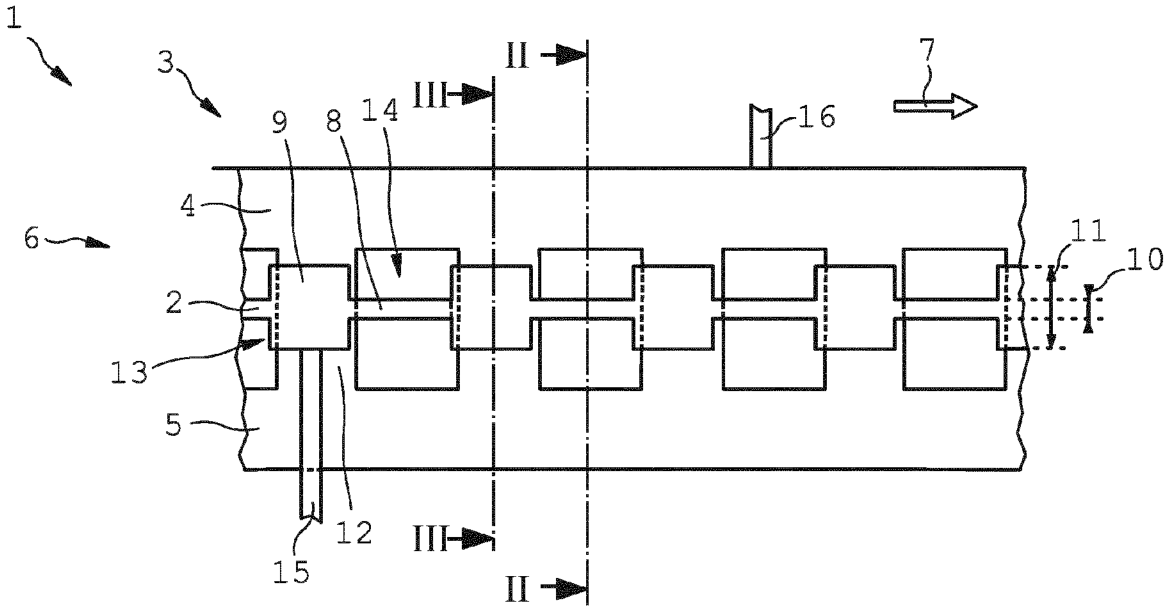



FIG 2

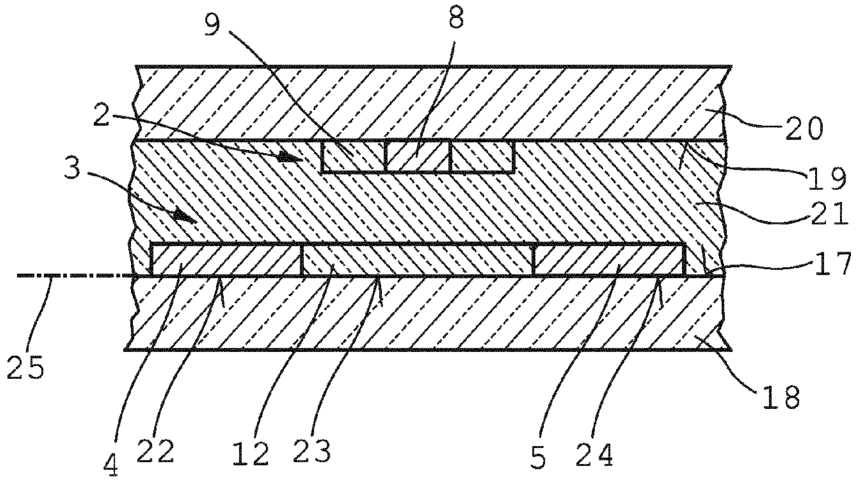



FIG 3

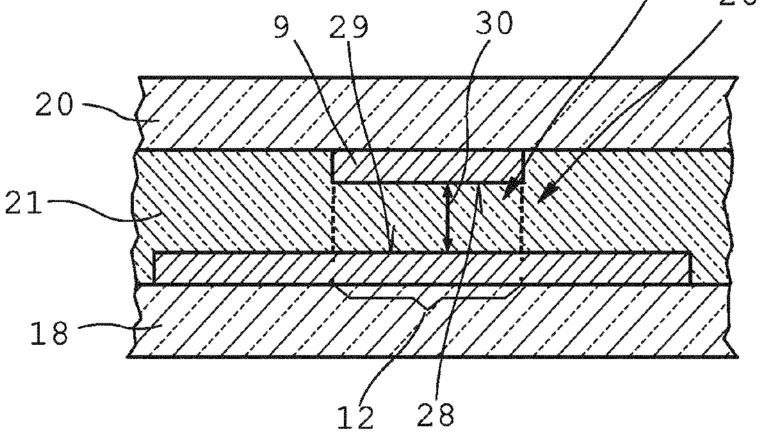


FIG 4

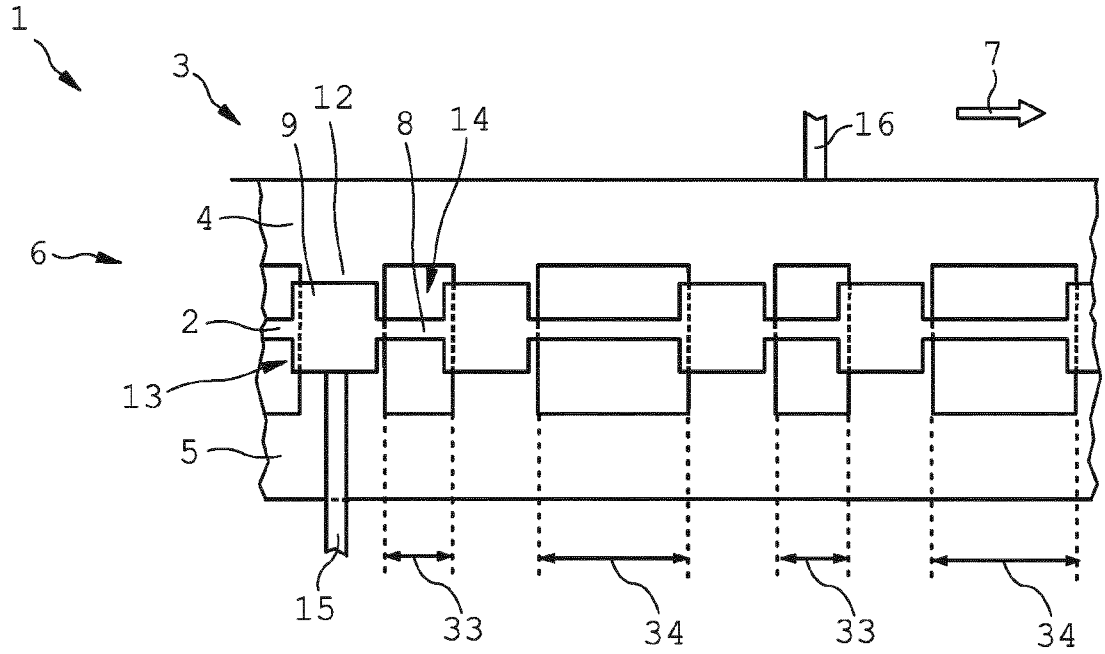

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FIG 5

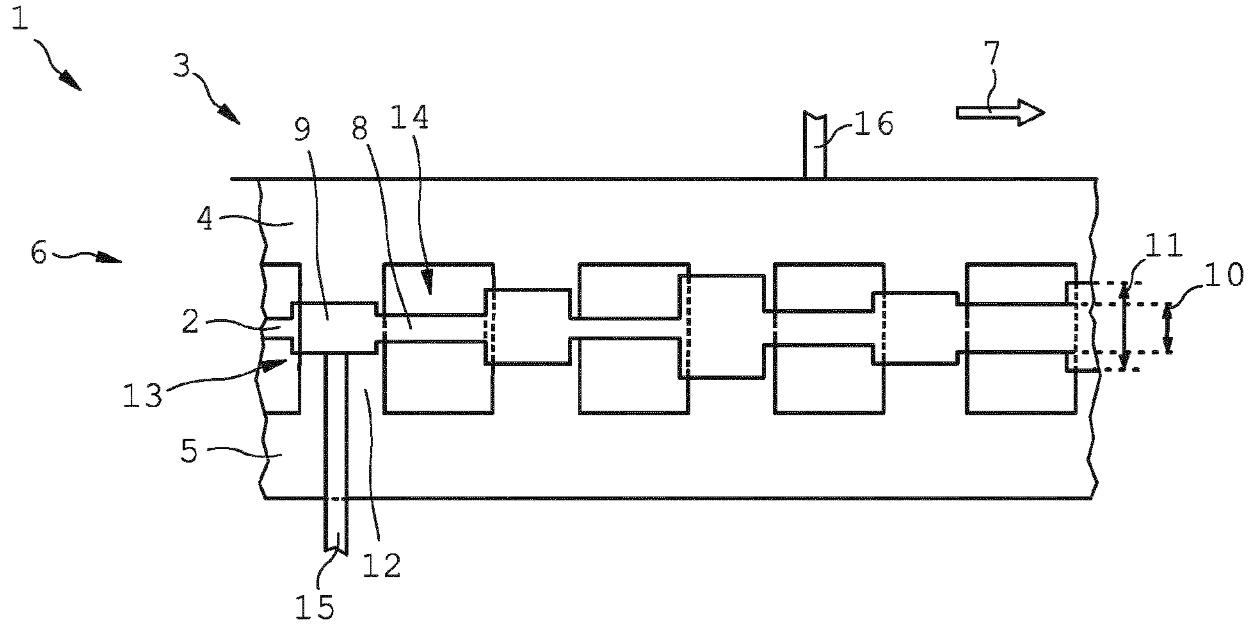
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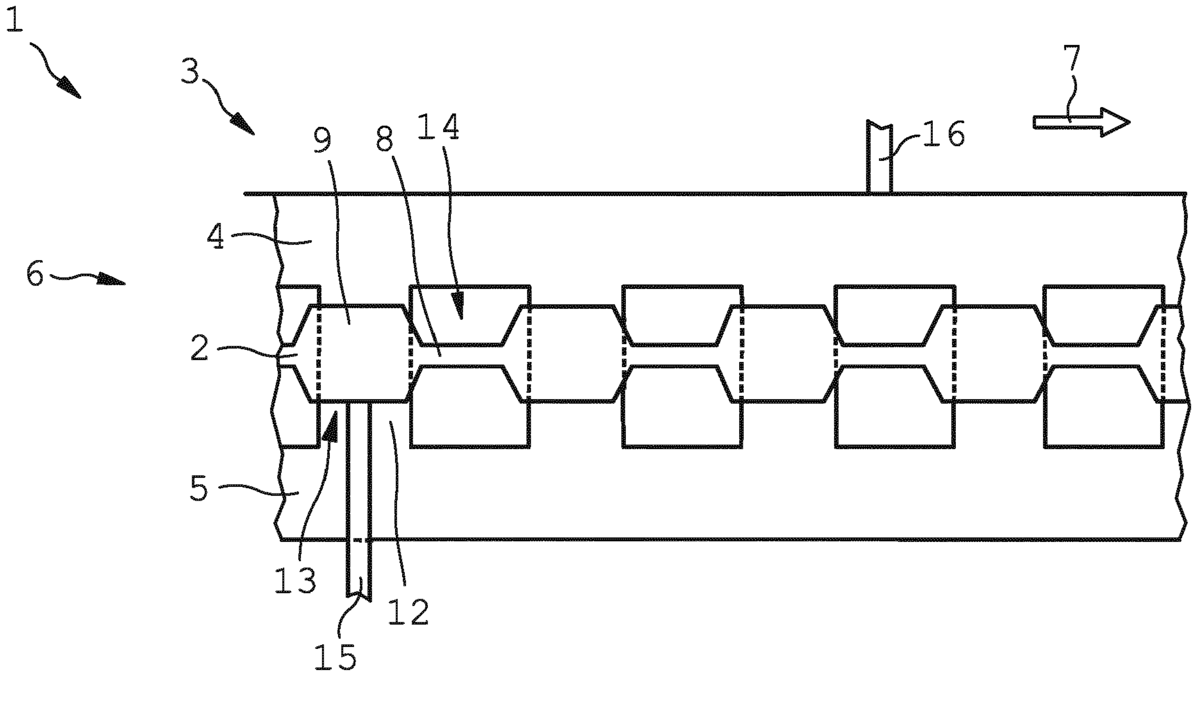
FIG 6



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# EUROPEAN SEARCH REPORT

Application Number
EP 19 17 7140

## DOCUMENTS CONSIDERED TO BE RELEVANT

| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (IPC) |
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