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(54) **LIQUID METAL MICROFIBER SYSTEM AND METHOD OF CONTROLLING A LIQUID METAL MICROFIBER SYSTEM**

(57) The invention relates to a liquid metal microfiber system with a balanced transmission line that comprises at least one liquid metal microfiber twin line section. The liquid metal microfiber twin line section comprises a plastic core material defining two separately formed por-

tions that each comprise a liquid metal such that two separate liquid metal conductors are confined by the plastic core material. Further, a method of controlling a flexible liquid metal microfiber system is described.

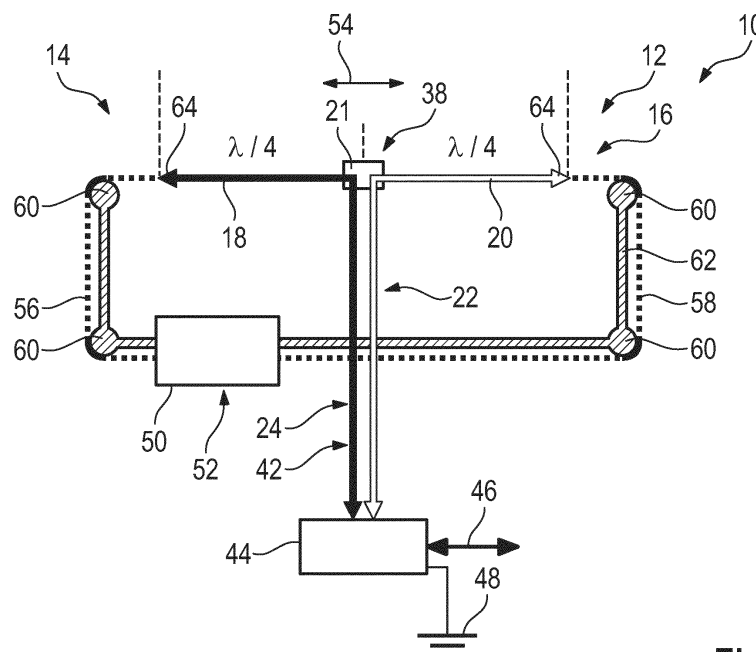


Fig. 1

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Description

[0001] The invention relates to a liquid metal microfiber system. Further, the invention relates to a method of controlling a liquid metal microfiber system.

[0002] In the state of the art, dipole antennas are known that typically have antenna elements with a fixed length, resulting in a fixed resonance frequency of the respective dipole antennas. For obtaining the desired resonance frequency, the length of the respective antenna elements have to be set accordingly, namely by trimming the length to equal a quarter wavelength associated with the desired resonance frequency.

[0003] The antenna elements are typically made of a solid metal rod such that no further adjustment is possible anymore once the length of the respective antenna elements has been set. Accordingly, an adaption of the resonance frequency is not possible anymore.

[0004] However, the dipole antenna can also be operated outside of its resonance frequency, but the efficiency is lowered since the dipole antenna does not work in its optimized operational range.

[0005] In addition, it is also complicated to connect such a dipole antenna to a receiver or to a transmitter.

[0006] Accordingly, there is a need for a possibility to provide a high-efficient antenna in a cost-efficient manner.

[0007] The invention provides a liquid metal microfiber system that comprises a balanced transmission line. The balanced transmission line has at least one liquid metal microfiber twin line section that comprises a plastic core material defining two separately formed portions that each comprise a liquid metal such that two separate liquid metal conductors are confined by the plastic core material.

[0008] The invention also provides a method of controlling a flexible liquid metal microfiber system with a balanced transmission line that comprises at least one liquid metal microfiber twin line section. The liquid metal microfiber twin line section comprises a plastic core material defining two separately formed portions that each comprise a liquid metal such that two separate liquid metal conductors are confined by the plastic core material. The flexible liquid metal microfiber system comprises at least one flexible liquid metal microfiber section that is connected with the liquid metal microfiber twin line section. The length of the liquid metal microfiber twin line section and/or the length of the at least one flexible liquid metal microfiber section are/is adapted, thereby introducing a phase shift and/or tuning a resonance frequency.

[0009] Accordingly, the two separate liquid metal conductors confined by the plastic core material relate to twin liquid metal conductors that function as the balanced transmission line. Both separate liquid metal conductors may be electrically isolated from each other. In fact, the liquid metal microfiber twin line section consists of the plastic core material that defines the two separately formed portions having the liquid metal in order to estab-

lish the separately formed liquid metal conductors that are confined by the plastic core material.

[0010] An aspect provides that the liquid metal microfiber twin line section is a flexible liquid metal microfiber twin line section, wherein the plastic core material is a flexible plastic core material. Hence, the length of the liquid metal microfiber twin line section can be adapted due to the flexibility provided, namely the plastic core material that is flexible together with the liquid metal establishing the conductors. Hence, the length of the entire balanced transmission line, particularly the liquid metal microfiber twin line section, can be adapted in order to change its characteristics.

[0011] Moreover, a flexible liquid metal microfiber twin line may be provided that comprises the liquid metal microfiber twin line section. Since the liquid metal microfiber twin line section is established by the flexible liquid metal microfiber twin line, the length of the flexible liquid metal microfiber twin line may be adapted. In case the flexible liquid metal microfiber twin line is stretched in the liquid metal microfiber twin line section, both electrical conductors are stretched simultaneously. Accordingly, a reconfigurable length of the flexible liquid metal microfiber (FLMM) twin line (section) is ensured.

[0012] Another aspect provides that the liquid metal microfiber system comprises at least one flexible liquid metal microfiber section that is connected with the liquid metal microfiber twin line section. The flexible liquid metal microfiber section acts an antenna element that is exposed to surrounding air. The liquid metal microfiber system comprises the flexible liquid metal microfiber section, the length of which can be adapted. Since the length of the flexible liquid metal microfiber section acting as the antenna element can be adapted, the resonance frequency of the antenna having the antenna element can be tuned. Actually, the length of the flexible liquid metal microfiber section corresponds to a quarter wavelength.

[0013] The flexible liquid metal microfiber section may be formed separately with respect to the (flexible) liquid metal microfiber twin line section, but electrically connected thereto.

[0014] Alternatively, the liquid metal microfiber twin line section is flexible. The flexible liquid metal microfiber twin line section and the flexible liquid metal microfiber section are established by a common microfiber, particularly the flexible liquid metal microfiber twin line.

[0015] Another aspect provides that the liquid metal microfiber system comprises an adjustment device that is configured to adapt the length of the flexible liquid metal microfiber. The adjustment device may relate to a mechanism that is capable of pulling and releasing the at least one flexible liquid metal microfiber section in order to adapt its length accordingly. Since the at least one flexible liquid metal microfiber section acts as the antenna element, the resonance frequency of the antenna having the antenna element can be tuned.

[0016] When releasing the at least one flexible liquid

metal microfiber section, no external force is applied anymore such that the at least one flexible liquid metal microfiber section is able to get back into its original state.

[0017] For instance, the liquid metal microfiber system comprises an actuating element that is interconnected between the adjustment device and the at least one flexible liquid metal microfiber section. The adjustment device is configured to pull or release the actuating element, thereby adapting the length of the at least one flexible liquid metal microfiber section. Particularly, the actuating element is a (nylon) string that is guided along the pulleys. In fact, the adjustment device does not directly interact with the at least one flexible liquid metal microfiber section, but with the actuating element that may release or pull the at least one flexible liquid metal microfiber section, which depends on the action initiated by the adjustment device.

[0018] Actually, the at least one flexible liquid metal microfiber section is stretched in case the adjustment device pulls the actuating element. When the adjustment device releases the actuating element, the at least one flexible liquid metal microfiber section tries to get back into its original state due to its inherent elastic characteristics.

[0019] In fact, the flexible liquid metal microfiber (section) is reversibly elastic. Hence, the at least one flexible liquid metal microfiber section gets back into its original state once no stretching force is applied, e.g. once a releasing takes place.

[0020] For instance, the at least one flexible liquid metal microfiber section is guided along two pulleys. Particularly, the pulleys are arranged such that the at least one flexible liquid metal microfiber section and the pulleys together establish a symmetrical arrangement. In fact, a folded dipole antenna is established. The respective resonance frequency may be tuned accordingly.

[0021] The pulleys may be located at a radiofrequency inert structure, for instance a cantilever.

[0022] According to a certain embodiment, the liquid metal microfiber system comprises a first flexible liquid metal microfiber section and a second flexible liquid metal microfiber section that are connected with the liquid metal microfiber twin line section. For instance, the liquid metal microfiber system comprises a junction at which the liquid metal microfiber twin line section as well as the first and second flexible liquid metal microfiber sections are connected with each other.

[0023] Alternatively, the flexible liquid metal microfibers may be connected with the electrical contacts of the liquid metal microfiber twin line section, namely the liquid metal conductors, in order to establish continuous electrical conductors.

[0024] Particularly, the liquid metal microfiber twin line is terminated at a split point from which the first flexible liquid metal microfiber and the second flexible liquid metal microfiber originate. Put differently, the liquid metal microfiber twin line section as well as the flexible liquid metal microfiber sections are established by a single

component, namely the liquid metal microfiber twin line that is a flexible one. The flexible microfiber plastic core material is split at the split point in order to ensure that the first flexible liquid metal microfiber section and the second flexible liquid metal microfiber section can be separated from each other at the split point such that they do not run in parallel with respect to each other, but in opposite directions. Hence, the flexible liquid metal microfiber sections may establish the poles of a dipole antenna. Up to the split point, the (flexible) liquid metal microfiber twin line ensures that the liquid metal conductors confined by the plastic core material run in parallel with each other such that the balanced transmission line is obtained.

[0025] The liquid metal microfiber system may comprise a balance-to-unbalance (balun) transformer. The balance-to-unbalance transformer may be connected to ground and to a signal line, for instance a coaxial cable, particularly an unbalanced coaxial cable. The balance-to-unbalance transformer allows impedance transformation and connection to either a receiver or a transmitter, particularly a transceiver, e.g. by using an unbalanced (coaxial) cable.

[0026] For instance, the balance-to-unbalance transformer is connected with the liquid metal microfiber twin line section, particularly directly. Thus, the balanced transmission can be ensured due to the balanced transmission line that comprises the flexible liquid metal microfiber twin line section.

[0027] Further, the liquid metal microfiber system comprises a dipole antenna and/or a balanced phase shifter. The dipole antenna is a tunable dipole antenna, as the resonance frequency can be adapted while adapting the length of the (flexible) liquid metal microfiber section. Alternatively or additionally, the balanced transmission line can be stretched, thereby providing the stretchable balanced phase shifter.

[0028] Another aspect provides that each of the liquid metal conductors has at least one electrical contact. The electrical contact is located at one end of the liquid metal conductor. Therefore, the liquid metal conductors can be contacted via the electrical contacts. In a certain embodiment, the liquid metal conductors each has two electrical contacts at opposite ends.

[0029] Generally, an array may be provided that comprises a plurality of flexible liquid metal microfiber sections, a plurality of flexible liquid metal microfiber sections or flexible liquid metal microfibers. The array ensures beam forming. The respective array may comprise several units that can be arranged horizontally in a stack or collinear or side-by-side. Actually, vertical dipole antennas or vertical collinear antennas may be established in the array, depending on the desired polarization or radiation pattern needed.

[0030] As indicated above, the at least one flexible liquid metal microfiber section, particularly the first flexible liquid metal microfiber section and the second flexible liquid metal microfiber section, relates to an antenna

element. The adjustment device is capable of adapting the length of the at least one flexible liquid metal microfiber section, thereby tuning the resonance frequency of the (folded) dipole antenna having the at least one antenna element.

[0031] The at least one antenna element, namely the at least one flexible liquid metal microfiber section, is connected with the balanced transmission line that comprises the at least one liquid metal microfiber twin line section. Particularly, the balanced transmission line is established by the (flexible) liquid metal microfiber twin line. The (flexible) liquid metal microfiber twin line can be adapted in its length (additionally) such that a delay can be introduced such that the (flexible) liquid metal microfiber twin line acts as the phase shifter, namely the stretchable balanced phase shifter.

[0032] The at least one flexible liquid metal microfiber section, particularly the first flexible liquid metal microfiber section and the second flexible liquid metal microfiber section, originate(s) from the flexible liquid metal microfiber twin line section. Put differently, the flexible liquid metal microfiber twin line comprises the flexible liquid metal microfiber twin line section as well as the first and second flexible liquid metal microfiber sections. The flexible liquid metal microfiber twin line is split at the split point at which the flexible liquid metal microfiber twin line section ends and the first and second flexible liquid metal microfiber sections start. Accordingly, the balanced transmission line may be split at the antenna junction to the necessary antenna elements, namely $\lambda/4$ lengths for the desired operating frequency. The free ends of the first and second flexible liquid metal microfiber sections are attached to RF inert actuating elements, e.g. nylon strings, guided by the pulleys to a programmable adjustment device designed to release or pull both ends equally to any desired resonant frequency within the microfiber stretchable range. The other end of the balanced transmission line is connected to the (balance-to-unbalance) balun transformer that allows impedance transformation and connection to either a receiver or transmitter while using a normal coaxial cable, namely an unbalanced one.

[0033] In an alternative embodiment, the liquid metal microfiber twin line section is provided by the liquid metal microfiber twin line that is connected to the at least one separately formed flexible liquid metal microfiber (section). This embodiment relates to a folded dipole antenna. The flexible liquid metal microfiber (section) is connected to the liquid metal microfiber twin line section via the electrical contacts, namely at an antenna junction box. Moreover, the single flexible liquid metal microfiber (section) is wrapped around two adjustment pulleys that are released or pulled in order to adapt the length of the single flexible liquid metal microfiber (section), thereby tuning the resonance frequency.

[0034] In a further embodiment, the liquid metal microfiber twin line section is provided by the liquid metal microfiber twin line that is connected to two separately formed flexible liquid metal microfibers that establish the

antenna elements of the dipole antenna. In this specific case, the liquid metal microfiber twin line functions as a transmission line phase shifter.

[0035] The (flexible) liquid metal microfiber twin line consist of a flexible liquid metal microfiber (FLMM) that has the flexible plastic core material defining both separately formed portions that each comprise the liquid metal such that two separate liquid metal conductors are confined by the flexible plastic core material.

[0036] A single adjustment device is sufficient to adapt the length of the antenna elements of the (folded) dipole antenna due to the actuating elements guided to the flexible liquid metal microfiber(s) or rather flexible liquid metal microfiber section(s), acting as the antenna element(s) of the (folded) dipole antenna.

[0037] Alternatively or additionally, the length of the flexible liquid metal microfiber twin line (section) is adapted to introduce a phase shift.

[0038] Generally, a flexible liquid metal microfiber has at least one electrical contact, e.g. a metal contact. In addition, the flexible liquid metal microfiber comprises a flexible plastic core material for the liquid metal such that the liquid metal is confined by the flexible plastic core material. The electrical contact is in connection with the liquid metal confined, thereby ensuring a continuous line, namely a continuous conductor. The flexible plastic core material is elastic, thereby ensuring that the flexible liquid metal microfiber can be adapted with regard to its length in a reversible manner.

[0039] Once no force is applied to the flexible liquid metal microfiber, the flexible liquid metal microfiber gets back into its original state due to its elastically reversible properties. The flexible liquid metal microfiber, particularly the flexible liquid metal microfiber section, may be stretched and/or released in order to adapt its length.

[0040] Actually, a solid metal rod typically used is replaced by the flexible liquid metal microfiber (section) that can be stretched. Therefore, the at least one flexible liquid metal microfiber (section), for instance the first flexible liquid metal microfiber (section) acting as the first antenna element and the second flexible liquid metal microfiber (section) acting as the second antenna element, can be adapted with regard to their length such that a resonance frequency can be tuned, namely within the stretchable limits of the at least one flexible liquid metal microfiber (section). The (adapted) length defines the resonance frequency, as the length corresponds to a quarter wavelength.

[0041] Further aspects and advantages of the claimed subject matter will become more readily appreciated as the same become better understood by reference to the following description, when taken in conjunction with the accompanying drawings. In the drawings,

- Figure 1 schematically shows a liquid metal microfiber system according to a first embodiment of the invention,

- Figure 2 schematically shows a balanced transmission line with a liquid metal microfiber twin line section, which is used in the liquid metal microfiber system shown in Figure 1,
- Figure 3 schematically shows a liquid metal microfiber system according to a second embodiment of the invention, and
- Figure 4 schematically shows a liquid metal microfiber system according to a third embodiment of the invention.

[0042] The detailed description set forth below in connection with the appended drawings, where like numerals reference like elements, is intended as a description of various embodiments of the disclosed subject matter and is not intended to represent the only embodiments. Each embodiment described in this disclosure is provided merely as an example or illustration and should not be construed as preferred or advantageous over other embodiments. The illustrative examples provided herein are not intended to be exhaustive or to limit the claimed subject matter to the precise forms disclosed.

[0043] For the purposes of the present disclosure, the phrase "at least one of A, B, and C", for example, means (A), (B), (C), (A and B), (A and C), (B and C), or (A, B, and C), including all further possible permutations when more than three elements are listed. In other words, the term "at least one of A and B" generally means "A and/or B", namely "A" alone, "B" alone or "A and B".

[0044] In Figure 1, a liquid metal microfiber system 10 is shown that comprises an antenna 12 that relates to a dipole antenna.

[0045] The antenna 12 comprises two antenna elements 14, 16 that are established by a first flexible liquid metal microfiber section 18 as well as a second flexible liquid metal microfiber section 20, which are running in opposite directions from an antenna junction 21.

[0046] In the shown embodiment, the first flexible liquid metal microfiber section 18 as well as the second liquid metal microfiber section 20 originate from a liquid metal microfiber twin line 22 that also comprises a liquid metal microfiber twin line section 24.

[0047] As shown in Figure 2, the liquid metal microfiber twin line section 24 comprises a plastic core material 26 that defines two separately formed portions 28, 30 that each comprise a liquid metal 32. Accordingly, two separate liquid metal conductors 34, 36 are provided by the liquid metal 32 confined in the separately formed portions 28, 30 within the plastic core material 26.

[0048] In the shown embodiment, the liquid metal conductors 34, 36 each comprise electrical contacts A to D that are located at the respective ends of the liquid metal conductors 34, 36. However, the electrical contacts B, D are optional ones as will be described later in more detail.

[0049] As discussed above, the first flexible liquid metal microfiber section 18 as well as the second liquid metal

microfiber section 20 both originate from the same component, namely the liquid metal microfiber twin line 22.

[0050] Therefore, the liquid metal microfiber twin line 22 is split at a split point 38 that is located at the antenna junction 21 as shown in Figure 1.

[0051] At the split point 38, the flexible microfiber plastic core material 26 is split or rather cut, particularly in its center or rather along a middle line, such that the first and second flexible liquid metal microfiber sections 18, 20 can be separated from each other in order to run into opposite directions in order to establish the antenna elements 14, 16.

[0052] The respective split line is illustrated in Figure 2 schematically by means of the dashed line 40 running from an end to the split point 38. Accordingly, the respective ends associated with the electrical contacts B, D can be moved into opposite directions as indicated by the arrows in order to ensure the antenna structure shown in Figure 1, namely the antenna elements 14, 16 facing in opposite directions.

[0053] Consequently, the electrical contacts B, D can be omitted since they relate to the free ends of the antenna elements 14, 16 of the dipole antenna 12, which do not have to be connected electrically.

[0054] In addition to the flexible liquid metal microfiber sections 18, 20 provided by the liquid metal microfiber twin line 22, the liquid metal microfiber twin line 22 also provides the liquid metal microfiber twin line section 24 that establishes a balanced transmission line 42, as the liquid metal conductors 34, 36 run in parallel along the liquid metal microfiber twin line section 24.

[0055] The balanced transmission line 42 ends in a balance-to-unbalance (balun) transformer 44 that is connected with an unbalanced coaxial cable 46 as well as ground 48.

[0056] Accordingly, the antenna 12 obtained can be connected to a transmitter, a receiver or a transceiver by means of the unbalanced coaxial cable 46.

[0057] In addition, the antenna 12 relates to a tunable antenna as its resonance frequency can be adapted due to the flexible liquid metal microfiber sections 18, 20.

[0058] In fact, the liquid metal microfiber system 10 comprises an adjustment device 50 that has a mechanism 52 used to pull or release the flexible liquid metal microfiber sections 18, 20, thereby adapting their lengths as indicated by arrow 54.

[0059] For this purpose, the respective adjustment device 50 interacts with actuating elements 56, 58, e.g. (nylon) strings, that are each guided along two pulleys 60 arranged at a radiofrequency inert structure 62. The radiofrequency inert structure 62 has a rectangular C-shape with pulleys 60 at the corners and free ends, which are used for guiding the actuating elements 56, 58 accordingly.

[0060] The actuating elements 56, 58 are connected with opposing ends 64 of the flexible liquid metal microfiber sections 18, 20, particularly their free ends.

[0061] Hence, the adjustment device 50 may pull the

actuating elements 56, 58, thereby stretching the flexible liquid metal microfiber sections 18, 20 in order to adapt the length of the antenna elements 14, 16, which in turn adapts the resonance frequency of the dipole antenna 12.

[0062] Moreover, the adjustment device 50 may release the actuating elements 56, 58, thereby reducing the length of the flexible liquid metal microfiber sections 18, 20, thereby reducing the length of the antenna elements 14, 16, which in turn adapts the resonance frequency of the dipole antenna 12.

[0063] Alternatively to the shown embodiment, the liquid metal microfiber twin line 22 may end at the antenna junction 21, wherein two separately formed flexible liquid metal microfibers 18, 20 are connected with the electrical contacts of the liquid metal microfiber twin line 22 at the antenna junction 21, e.g. the electrical contacts B, D. The separately formed flexible liquid metal microfibers 18, 20 are released or pulled by the adjustment device 50 as described above.

[0064] However, the liquid metal microfiber twin line 22 or rather the liquid metal microfiber twin line section 24 ensures that the balanced transmission line 42 is provided that is connected with the balance-to-unbalance transformer 44.

[0065] In Figure 3, another embodiment is shown that distinguishes from the first embodiment shown in Figure 1 in that the antenna is a folded dipole antenna.

[0066] In fact, the liquid metal microfiber system 10 comprises only a single flexible liquid metal microfiber 66 that is separately formed with respect to the balanced transmission line 42, but connected thereto.

[0067] As discussed with respect to the first embodiment, the balanced transmission line 42 comprises the liquid metal microfiber twin line section 24.

[0068] The single flexible liquid metal microfiber 66 is connected at the antenna junction 21 with the balanced transmission line 42, namely the liquid metal microfiber twin line section 24, e.g. the electrical contacts B, D shown in Figure 2.

[0069] The single flexible liquid metal microfiber 66 is guided about two adjustment pulleys 68 that are connected to the actuating elements 56, 58.

[0070] Accordingly, the adjustment device 50 pulls or releases the actuating elements 56, 58 which in turn displace the adjustment pulleys 68 accordingly. This causes an adaption of the length of the single flexible liquid metal microfiber 66 in order to adapt its length. Thus, the resonance frequency of the antenna 12 is tuned accordingly.

[0071] As usual, the folded dipole antenna 12 has a cylindrical closed shape, as the single flexible liquid metal microfiber 66 and the adjustment pulleys 68 together establish a symmetrical arrangement. As shown in Figure 3, the length of the dipole is half of the wavelength. The length of the portion of the single flexible liquid metal microfiber 66 between the antenna junction 21 and a respective adjustment pulley 68 equals quarter of the

wavelength as shown in Figure 3.

[0072] In Figure 4, a further embodiment is shown, wherein the balanced transmission line 42 itself is stretchable. In fact, the balanced transmission line 42 relates to a balanced phase shifter that is stretchable.

[0073] Accordingly, an additional adjustment device 68 is provided that is capable of adapting the length of the balanced transmission line 42 in order to introduce a phase shift into the signal processed by the balanced transmission line 42. As discussed above, the balanced transmission line 42 comprises the liquid metal microfiber twin line 22. Particularly, the balanced transmission line 42 consists of the liquid metal microfiber twin line 22 having the liquid metal microfiber twin line section 24.

[0074] In addition, the liquid metal microfiber system 10 comprises the first and second flexible liquid metal microfibers 18, 20 that are separately formed with respect to the balanced transmission line 42.

[0075] The flexible liquid metal microfibers 18, 20 are connected to electrical contacts of the liquid metal microfiber twin line 22, namely the electrical contacts B, D shown in Figure 2.

[0076] The respective embodiments shown relate to an antenna unit that can be multiplied in order to establish an array having two or more of these antenna units. The array may be used for beam forming purposes.

[0077] In fact, the respective units can be arranged horizontally in a stack or collinear or as side-by-side vertical dipoles or vertical collinear depending on the desired polarization or radiation pattern needed.

[0078] In general, the liquid metal microfiber system 10 comprises the (flexible) liquid metal microfiber twin line section 24 to function as the balanced transmission line 42.

[0079] The balanced transmission line 42, namely the (flexible) liquid metal microfiber twin line section 24 or rather the (flexible) liquid metal microfiber twin line 22, is used to provide the reconfigurable dipole and folded dipole antenna 12. The (folded) dipole antenna 12 can be either vertically or horizontally mounted depending on the desired response. Actually, there is no need for a ground plane such that the antenna 12 can be provided in a lightweight manner.

[0080] In addition, the (flexible) liquid metal microfiber twin line section 24 or rather the (flexible) liquid metal microfiber twin line 22 is used as phase shifter for beam forming.

[0081] Generally, the flexible liquid metal microfiber system 10 can be controlled such the length of the liquid metal microfiber twin line section 24 and/or the length of the flexible liquid metal microfiber section(s) 16, 18 are/is adapted, thereby introducing a phase shift and/or tuning a resonance frequency of the antenna 12.

[0082] Certain embodiments disclosed herein, particularly the respective module(s), utilize circuitry (e.g., one or more circuits) in order to implement standards, protocols, methodologies or technologies disclosed herein, operably couple two or more components, generate in-

formation, process information, analyze information, generate signals, encode/decode signals, convert signals, transmit and/or receive signals, control other devices, etc. Circuitry of any type can be used.

[0083] In an embodiment, circuitry includes, among other things, one or more computing devices such as a processor (e.g., a microprocessor), a central processing unit (CPU), a digital signal processor (DSP), an application-specific integrated circuit (ASIC), a field-programmable gate array (FPGA), a system on a chip (SoC), or the like, or any combinations thereof, and can include discrete digital or analog circuit elements or electronics, or combinations thereof. In an embodiment, circuitry includes hardware circuit implementations (e.g., implementations in analog circuitry, implementations in digital circuitry, and the like, and combinations thereof).

[0084] In an embodiment, circuitry includes combinations of circuits and computer program products having software or firmware instructions stored on one or more computer readable memories that work together to cause a device to perform one or more protocols, methodologies or technologies described herein. In an embodiment, circuitry includes circuits, such as, for example, microprocessors or portions of microprocessor, that require software, firmware, and the like for operation. In an embodiment, circuitry includes one or more processors or portions thereof and accompanying software, firmware, hardware, and the like.

[0085] The present application may reference quantities and numbers. Unless specifically stated, such quantities and numbers are not to be considered restrictive, but exemplary of the possible quantities or numbers associated with the present application. Also in this regard, the present application may use the term "plurality" to reference a quantity or number. In this regard, the term "plurality" is meant to be any number that is more than one, for example, two, three, four, five, etc. The terms "about", "approximately", "near" etc., mean plus or minus 5% of the stated value.

Claims

1. A liquid metal microfiber system, wherein the liquid metal microfiber system comprises a balanced transmission line that comprises at least one liquid metal microfiber twin line section, wherein the liquid metal microfiber twin line section comprises a plastic core material defining two separately formed portions that each comprise a liquid metal such that two separate liquid metal conductors are confined by the plastic core material.
2. The liquid metal microfiber system according to claim 1, wherein the liquid metal microfiber twin line section is a flexible liquid metal microfiber twin line section, and wherein the plastic core material is a flexible plastic core material.

3. The liquid metal microfiber system according to claim 1 or 2, wherein a flexible liquid metal microfiber twin line is provided that comprises the liquid metal microfiber twin line section.
4. The liquid metal microfiber system according to any one of the preceding claims, wherein the liquid metal microfiber system comprises at least one flexible liquid metal microfiber section that is connected with the liquid metal microfiber twin line section.
5. The liquid metal microfiber system according to claim 4, wherein the liquid metal microfiber system comprises an adjustment device that is configured to adapt the length of the at least one flexible liquid metal microfiber section.
6. The liquid metal microfiber system according to claim 5, wherein the adjustment device is configured to adapt the length of the at least one flexible liquid metal microfiber, thereby tuning a resonance frequency.
7. The liquid metal microfiber system according to claim 5 or 6, wherein the liquid metal microfiber system comprises an actuating element that is interconnected between the adjustment device and the at least one flexible liquid metal microfiber section, and wherein the adjustment device is configured to pull or release the actuating element, thereby adapting the length of the at least one flexible liquid metal microfiber section, in particular wherein the actuating element is a string guided along the pulleys.
8. The liquid metal microfiber system according to any one of claims 4 to 7, wherein the at least one flexible liquid metal microfiber section is guided along two pulleys, in particular wherein the pulleys are arranged such that the flexible liquid metal microfiber section and the pulleys together establish a symmetrical arrangement.
9. The liquid metal microfiber system according to any one of the preceding claims, wherein the liquid metal microfiber system comprises a first flexible liquid metal microfiber section and a second flexible liquid metal microfiber section that are connected with the liquid metal microfiber twin line section.
10. The liquid metal microfiber system according to claim 9 when referred back to claim 3, wherein the liquid metal microfiber twin line is terminated at a split point from which the first flexible liquid metal microfiber section and the second flexible liquid metal microfiber section originate.
11. The liquid metal microfiber system according to any one of the preceding claims, wherein the liquid metal

microfiber system comprises a balance-to-unbalance transformer.

12. The liquid metal microfiber system according to claim 11, wherein the balance-to-unbalance transformer is connected with the liquid metal microfiber twin line section, particularly directly. 5
13. The liquid metal microfiber system according to any one of the preceding claims, wherein the liquid metal microfiber system comprises a dipole antenna and/or a balanced phase shifter. 10
14. The liquid metal microfiber system according to any of the preceding claims, wherein each of the liquid metal conductors has at least one electrical contact. 15
15. A method of controlling a flexible liquid metal microfiber system with a balanced transmission line that comprises at least one liquid metal microfiber twin line section, wherein the liquid metal microfiber twin line section comprises a plastic core material defining two separately formed portions that each comprise a liquid metal such that two separate liquid metal conductors are confined by the plastic core material, and wherein the flexible liquid metal microfiber system comprises at least one flexible liquid metal microfiber section that is connected with the liquid metal microfiber twin line section, and wherein the length of the liquid metal microfiber twin line section and/or the length of the at least one flexible liquid metal microfiber section are/is adapted, thereby introducing a phase shift and/or tuning a resonance frequency. 20 25 30 35

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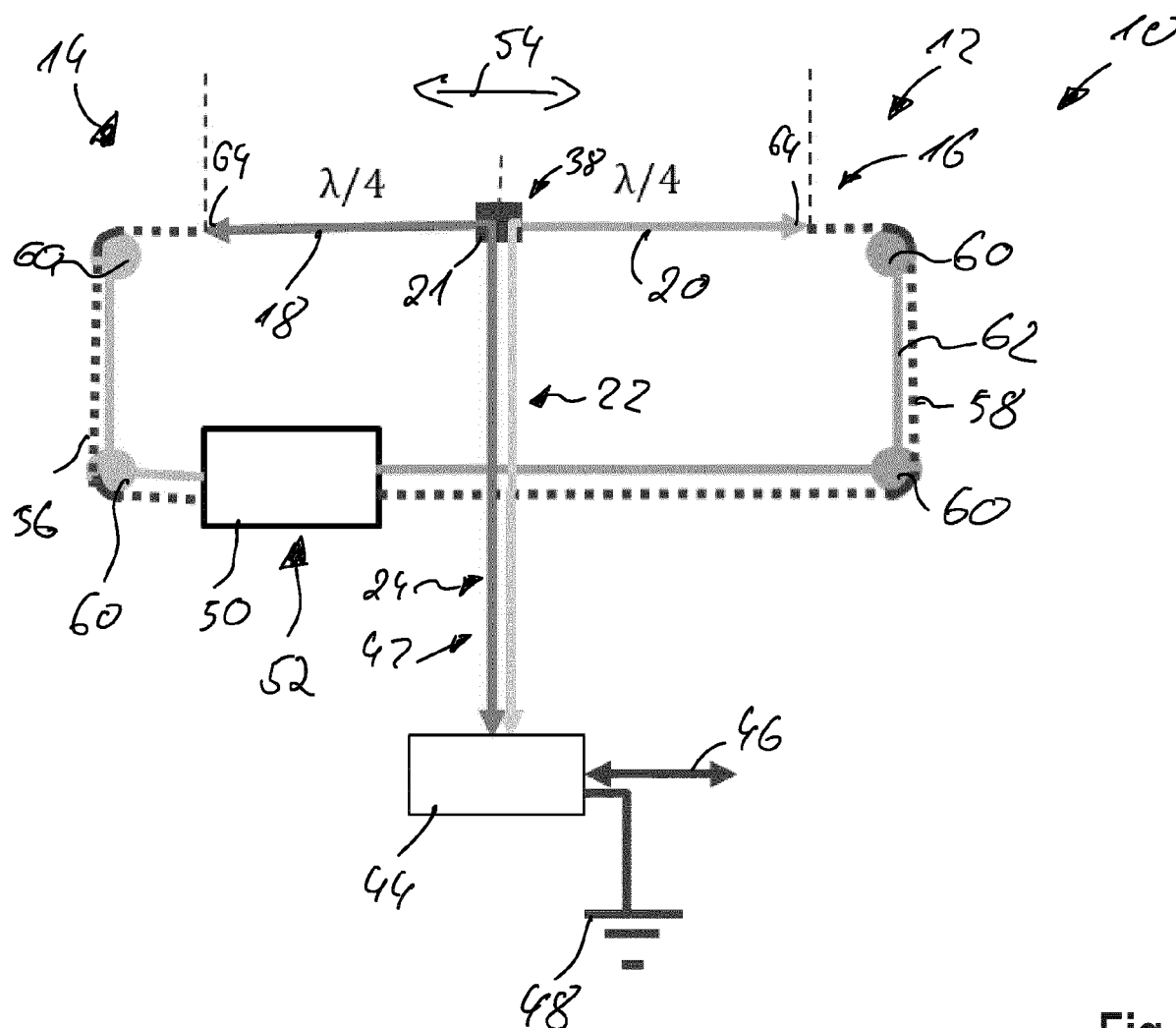


Fig. 1

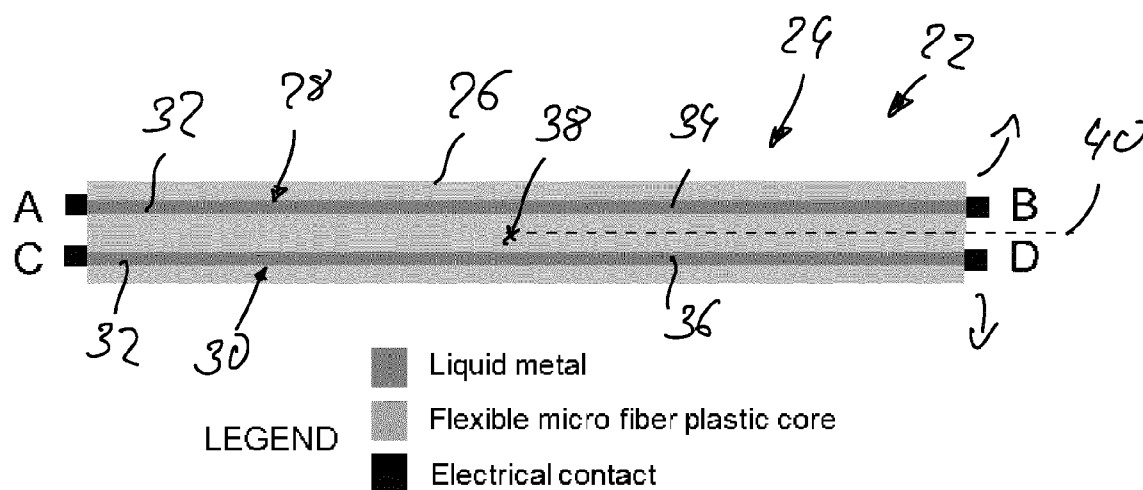


Fig. 2

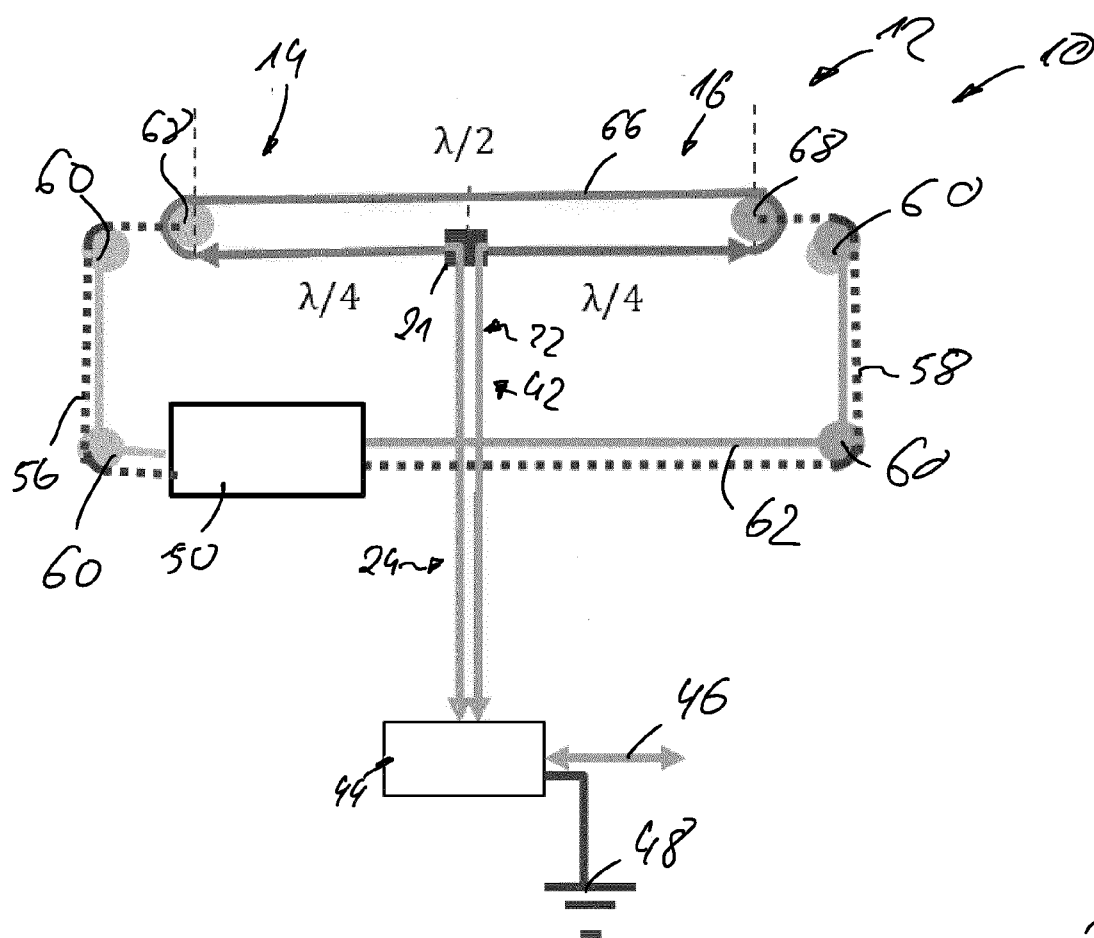


Fig. 3

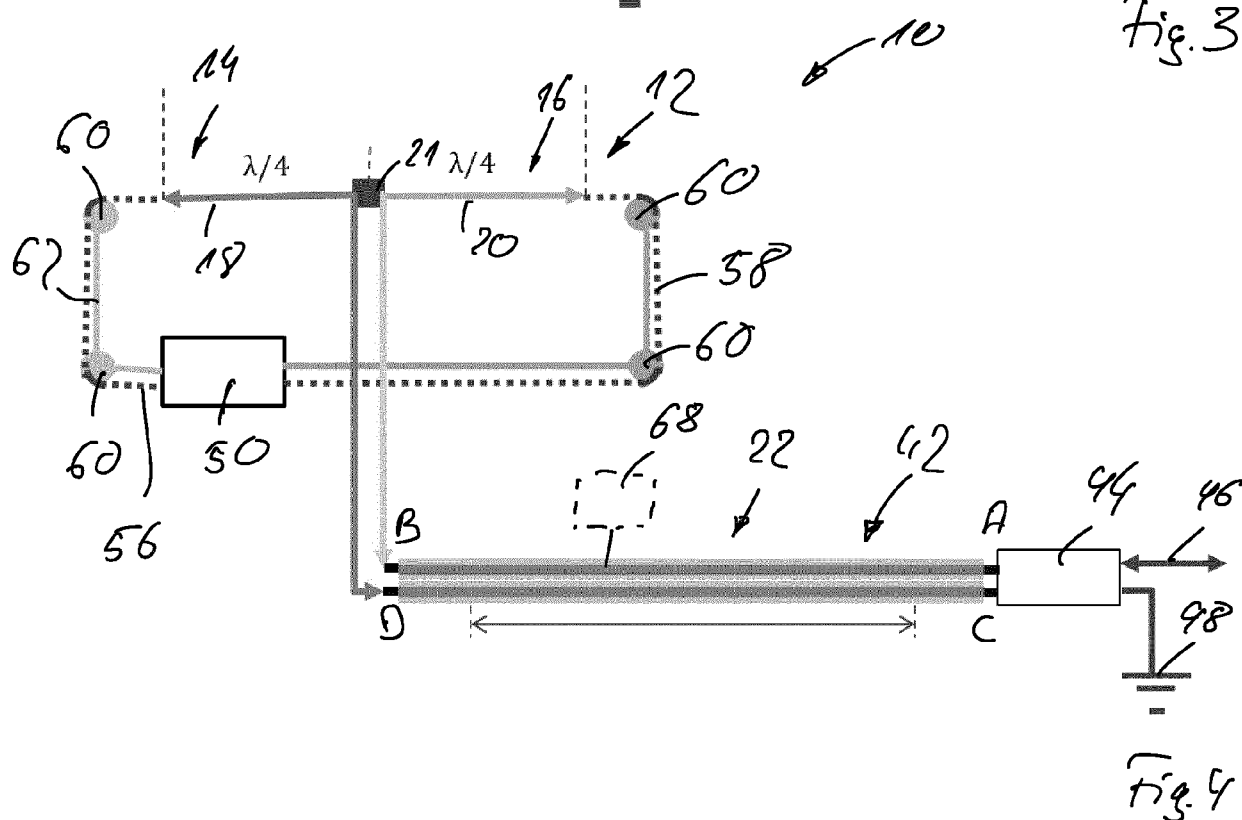


Fig. 4



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A	figure 1 *	7, 8, 10	H01Q7/00
	* paragraph [0013] - paragraph [0015];		H01Q9/14
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Place of search		Date of completion of the search	Examiner
The Hague		4 December 2023	Pastor Jiménez, J
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The present search report has been drawn up for all claims			TECHNICAL FIELDS SEARCHED (IPC)
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