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(54) **Manufacturing method for a connection between a coaxial cable and a coaxial connector and a coaxial cable with a terminating coaxial connector thereof**

(57) The invention relates to a method for manufacturing an electrical connection between a coaxial cable (COAX1) and a coaxial connector (CON1), the method comprising the step of connecting at least one conductor (COAX_IC1, COAX_OC1) of the coaxial cable (COAX1)

to a conductor (CON_IC1, CON_OC1) of the coaxial connector (CON 1) by a welding process, wherein the coaxial connector (CON1) is connected to an end face of the coaxial cable (COAX1) and the welding process is applied with a concentrated application of energy.

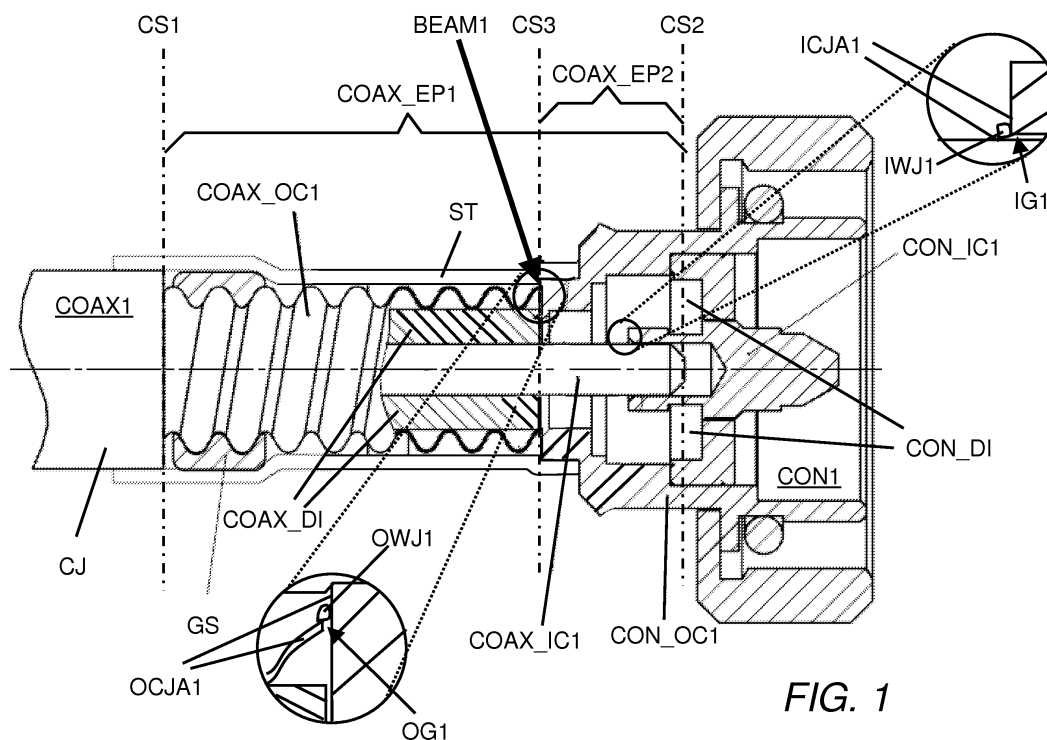


FIG. 1

Description**FIELD OF THE INVENTION**

[0001] The invention relates to a method for manufacturing an electrical connection between a coaxial cable and a coaxial connector according to the preamble of claim 1, to a coaxial connector according to the preamble of claim 9, and to a coaxial cable terminated by a coaxial connector according to the preamble of claim 12.

BACKGROUND OF THE INVENTION

[0002] Radio communication systems operate in dedicated frequency ranges or frequency bands for high power transmit and low power receive signals. In antenna systems both signals are transmitted over the same components in both directions.

[0003] An electromagnetic effect, which has to be taken into account, is passive inter-modulation. If two signals s_1 and s_2 using two different frequencies f_1 (s_1) and f_2 (s_2) pass an electrical component, further signals with additional frequencies can be generated by a non-linear electromagnetic effect. For example, third order inter-modulation signals s_3 and s_4 can be generated, whose frequencies f_3 (s_3) and f_4 (s_4) are given by the following equations:

$$f_3 = f_1 - \Delta f \quad \text{and} \quad f_4 = f_2 + \Delta f \quad (f_1 < f_2, \Delta f = f_2 - f_1)$$

[0004] If frequency difference Δf of the two signals s_1 and s_2 is in the order of the dedicated frequency band, the possibility is very large, that the frequencies f_3 and f_4 of the signals s_3 and s_4 are outside the dedicated frequency band.

[0005] It is in particular critical, if the frequency of the inter-modulation signal falls into the receive band of the radio communication system. In that case, a receiver of the radio communication system can be disturbed to such an extent, that calls or data connections are dropped.

[0006] Therefore, strong electrical requirements exist according to the components (transmitter, transceiver, antenna, components connecting transmitter/transceiver and antenna) used in a base station, which generate and transmit the electromagnetic radiation. Requested values according to a power ratio of a disturbing signal to a carrier signal for the components of the base station are in the range of -155 dBc (dBc = dB Carrier) and lower.

[0007] If a coaxial cable terminated by one coaxial connector or two coaxial connectors is used for transmitting an RF signal (RF = radio frequency), a conductor junction area between conductors of the coaxial connector and the coaxial cable are critical according to the passive inter-modulation effect. A main reason for appearance of passive inter-modulation at the conductor junction area of outer conductors of the coaxial connector and the coaxial cable is a non-perfect electrical contact. Especially, the electrical contact must provide a 360 degree contact. The 360 degree contact means, that in case of a circular end face of a cylindrical outer conductor, a closed electrical contact must be provided along the whole circular end face of the outer conductors.

[0008] Electrical contacts between the conductors of the coaxial cable and the coaxial connector are provided either by a soldering process or by a clamping process.

[0009] The soldering process requires to monitor and control a lot of process and material parameters such as temperature, temperature profile, thermal capacity, time, material combinations, dimension tolerances etc. to achieve an appropriate capillarity at the conductor junction areas of the inner conductors as well as of the outer conductors. Due to the large number of process and material parameters the soldering process is difficult to control, provides a limited reproducibility, and has a limited reliability.

[0010] In some cases, the conductor junction area of the outer conductors is not easily accessible and cannot be inspected by a visual check due to coaxial connector parts covering the conductor junction area. Therewith, the occurrence of any air pockets cannot be prevented.

[0011] Furthermore, if the conductor junction area has an extension perpendicular to the earth surface, the impact of gravity on solder material involves, that the solder material preferably accumulates at the lower part of the conductor junction area and not homogeneously across the conductor junction area.

[0012] In addition, if one of the conductors comprises a material such as aluminium, the conductor surface needs an additional treatment during the soldering process. In case of aluminium, the surface being exposed to the Earth's atmosphere always reacts with the oxygen of the Earth's atmosphere and provides a thin layer of aluminium oxide, which prevents wetting the surface with the solder material. A corrosive flux has to be applied to the surface during the soldering process in order to remove the thin layer of aluminium oxide. After the soldering process the remaining corrosive flux must be removed in order to avoid a long-term corrosion of the conductor material degrading the electrical performance and the mechanical stability of the conductor junction area. Depending on the coaxial connector design, it is difficult to

remove the remaining corrosive flux and therewith it can't be avoided, that a small amount of the corrosive flux remains on the conductor surface.

[0013] The use of a less corrosive flux is not possible, because the less corrosive flux requires an activation temperature of more than 400 °C, which melts a dielectric (e.g. polyethylene foam) between the inner and outer conductors of the coaxial cable.

[0014] By exposing the jumper cable to rain or a salty atmosphere, it cannot be prevented that some moisture can penetrate to the solder material. By humidity effects, the solder material is getting brittle. Therewith, the mechanical stability but also the electrical properties of a solder joint degrade.

[0015] Mechanical effects such as vibrations and stress (e.g. wind load) during operation of the jumper cable can cause a brittle failure and a complete separating of the conductors of the coaxial cable and the coaxial connector. In that case, the moisture can penetrate into the coaxial cable and can absorb an RF signal transmitting along the coaxial cable. The absorption generates heat and results in an attenuation of the RF signal.

[0016] Connecting the conductors of the coaxial cable and the coaxial connector by a clamping process doesn't fulfils the required electrical performance in terms of the passive inter-modulation especially when taking into account, that the jumper cable is exposed to the vibrations and the mechanical stress during installation and the operation. In addition, a proper sealing of the inner parts of the conductor junction area against the moisture is not possible by clamping.

[0017] In GB 1 361 609 a coaxial connector is permanently secured perpendicular to a longitudinal axis of an electric power distribution cable comprising a number of insulated electric power conductors and a neutral conductor. The electrical connection between the conductors of the coaxial connector and the electric power distribution cable is produced by welding techniques such as friction welding or tungsten-inert-gas welding.

[0018] The way of connecting the coaxial connector to the coaxial cable affects the electrical and mechanical characteristics of the connection.

[0019] Therefore, it is the object of the invention to improve the electrical and mechanical characteristics of the connection between the coaxial cable and the coaxial connector.

SUMMARY OF THE INVENTION

[0020] This object is achieved by a method for manufacturing an electrical connection between a coaxial cable and a coaxial connector, the method comprising the step of connecting at least one conductor of the coaxial cable to a conductor of the coaxial connector by a welding process, wherein the coaxial connector is connected to an end face of the coaxial cable and the welding process is applied with a concentrated application of energy.

[0021] The object is further achieved by an independent claim 9 for a coaxial connector and by an independent claim 12 for a coaxial cable terminated by a coaxial connector.

[0022] The method according to the present invention offers a benefit of manufacturing a cable junction at the end face of the coaxial cable with an improved mechanical stability because a welded joint being exposed to outdoor environmental conditions is not getting brittle. Mechanical and humidity effects cannot change the mechanical properties of the welded joint. Therewith, also the electrical performance of the welded joint remains the same (e.g. no occurrence of passive inter-modulation).

[0023] The welding process provides a further benefit of generating stepwise a 360 degree contact at a conductor junction area of the coaxial cable and the coaxial connector. The 360 degree contact avoids any occurrence of passive inter-modulation.

[0024] A gravity effect as arising during the soldering process cannot occur by the stepwise generation of the welded joint during the welding process.

[0025] A utilization of the concentrated application of energy provides a further benefit, because the application of energy can be confined to the conductor junction area. In that case, it is avoided that other components of the coaxial cable and the coaxial connector such as a dielectric heat up by the welding process and melt or get deformed.

[0026] The material thickness of one of the conductors of the coaxial connector is adapted to a material thickness of the conductor of the coaxial cable.

[0027] This provides the advantage of heating up the conductor material of the coaxial cable and the coaxial connector near the conductor junction area homogeneously. This avoids too much thermal energy at the conductor of the coaxial cable and any deformation or melting of components of the coaxial cable. The consumption of less conductor material during the manufacturing process is a further advantage.

[0028] In a preferred embodiment of the invention, the application of energy during the welding process is below a threshold. The threshold is given in such a way, that on the one hand, the application of energy at the conductor junction area is sufficient for welding the material of the conductors of the coaxial cable and the coaxial connector, and on the other hand, the conductor material does not suffer a thermal shape distortion. A limited application of energy provides a further advantage of not hitting any critical material temperatures for deforming or melting material of any other components of the coaxial cable and the coaxial connector.

[0029] In a further preferred embodiment of the invention, the welding process uses a laser beam or an electron beam. By using laser or electron beam welding, parameters of the beam such as beam power, operating distance, spot size etc. can be precisely controlled which provides a high reliability.

[0030] Furthermore, the welding of the conductor junction area can be done with a large speed of travel. Thereby, the manufacturing time can be reduced. Both, the laser and the electron beam welding can be done without use of a filler material.

[0031] In another preferred embodiment of the invention, the laser or electron beam is operated in a pulsed mode. Therewith, the application of energy can be reduced and optimised and the thermal shape distortion of the conductors can be minimised.

[0032] In an even further preferred embodiment of the invention, the outer conductor of the coaxial cable is helically or annularly corrugated and the method further comprises a step of squeezing at least one winding of the helically or annularly corrugated outer conductor at an end face of the helically or annularly corrugated outer conductor. The squeezing provides the benefit of a more suitable fitting of the end face of the helically or annularly corrugated outer conductor to the end face of the outer conductor of the coaxial connector and thereby avoiding any cavities between the conductors of the coaxial cable and the coaxial connector.

[0033] By squeezing the at least one winding to an opened ring or a rotationally symmetric form, a further benefit is related to the welding process. If either the tool holder is rotated around the axis of the coaxial cable or a welding head of a welding apparatus is rotated around the tool holder, a parallel translation of either the tool holder fixing the coaxial cable and the coaxial connector or the welding head of the welding apparatus is not required. Performing only a rotation increases the precision of the welding process around the conductor junction area.

[0034] In yet another preferred embodiment of the invention, at least one of the conductors of the coaxial cable or the coaxial connector comprises a bi-metal or a plastic material covered with a metal.

[0035] The usage of metal-metal combinations or plastic-metal combinations for the conductors in the welding process increases the flexibility in the selection of adequate conductor materials to achieve the required electrical and mechanical properties for the coaxial cable terminated by the coaxial connector.

[0036] In a further preferred embodiment of the invention, aluminium is used as a metal for at least one of the conductors of the coaxial cable or the coaxial connector. Thereby, the total weight of the coaxial cable and/or the coaxial connector can be reduced, which makes transport and installation easier. Furthermore, the utilization of aluminium in comparison to metals such as copper, silver or gold reduces the manufacturing costs.

[0037] Further advantageous features of the invention are defined by dependent claims for the method, for the coaxial connector, and for the coax cable comprising the coaxial connector.

BRIEF DESCRIPTION OF THE DRAWINGS

[0038] The embodiments of the invention will become apparent in the following detailed description and will be illustrated by accompanying drawings given by way of non-limiting illustrations.

Figure 1 shows a cross-sectional view of a coaxial cable end piece and a coaxial connector connected to the coaxial cable end piece in accordance to a first example of a first embodiment of the invention.

Figure 2 shows a flow diagram of a method in accordance to the first embodiment of the invention.

Figure 3 shows a flow diagram of a method in accordance to a second embodiment of the invention.

Figure 4 shows a cross-sectional view of inner conductors of a coaxial cable end piece and a coaxial connector connected to the coaxial cable end piece in accordance to a first application of a third embodiment of the invention.

Figure 5 shows a cross-sectional view of outer conductors of a coaxial cable end piece and a coaxial connector connected to the coaxial cable end piece in accordance to a second application of the third embodiment of the invention.

Figure 6 shows a cross-sectional view of outer conductors of a coaxial cable end piece and a coaxial connector connected to the coaxial cable end piece in accordance to a third application of the third embodiment of the invention.

Figure 7 shows a flow diagram of a method in accordance to a fourth embodiment of the invention.

Figure 8 shows a cross-sectional view of outer conductors of a coaxial cable end piece and a coaxial connector connected to the coaxial cable end piece in accordance to an application of the fourth embodiment of the invention.

Figure 9 shows a flow diagram of a method in accordance to a fifth embodiment of the invention.

Figure 10 shows a cross-sectional view of outer conductors of a coaxial cable end piece in accordance to an application of the fifth embodiment of the invention.

Figure 11 shows a cross-sectional view of the outer conductors of the coaxial cable end piece and a coaxial connector connected to the coaxial cable end piece in accordance to the application of the fifth embodiment of the invention.

Figure 12 shows a flow diagram of a method in accordance to a sixth embodiment of the invention.

Figure 13 shows a cross-sectional view of outer conductors of a coaxial cable end piece and a coaxial connector

connected to the coaxial cable end piece in accordance to a first application of the sixth embodiment of the invention. Figure 14 shows a cross-sectional view of outer conductors of a coaxial cable end piece and a coaxial connector connected to the coaxial cable end piece in accordance to a second application of the sixth embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

[0039] Figure 1 shows a cross-sectional view of a coaxial cable COAX1 and a coaxial connector CON1 according to a first application of a first embodiment of the invention.

[0040] The coaxial cable COAX1 is terminated by the coaxial connector CON1 at one of its two end faces. In an alternative both end faces of the coaxial cable COAX1 are terminated by coaxial connectors of a type of the coaxial connector CON1.

[0041] The coaxial cable COAX1 may be in a first alternative an RF cable for radio frequency applications in telecommunication such as a jumper cable, which is used between a rack of a base station and an antenna of the base station. In a further alternative, the coaxial cable COAX1 may be a cable used for transmitting television or video signals. In an even further alternative, the coaxial cable COAX1 may be used for transmission of data signals in computer networks.

[0042] According to the first alternative, a connection between the rack and the antenna usually consists of a feeder cable and two jumper cables. The feeder cable with a diameter of 7/8 inch or more according to an outer conductor is typically used for bridging most of a distance between the rack and the antenna. Due to its weight and inflexibility and strong mechanical forces on its coaxial connectors, the feeder cable is not directly connected to components of the rack and to the antenna. For a remaining cable connection (typically up to 2 m) each of the two jumper cables is connected to one of the end faces of the feeder cable. The diameter according to an outer conductor of the jumper cable is smaller than the diameter of the outer conductor of the feeder cable and is typically 1/2 or 3/8 inch. Therewith, the two jumper cables provide smaller mechanical forces on its coaxial connectors and on connected devices such as a transceiver, transmitter or receiver unit or the antenna.

[0043] The coaxial cable COAX1 comprises an inner conductor COAX_IC1, a dielectric COAX_DI surrounding the inner conductor COAX_IC1, an outer conductor COAX_OC1 surrounding the dielectric COAX_DI, and a cable jacket CJ covering the outer conductor COAX_OC1.

[0044] The cable jacket CJ may be comprise an isolating, corrosion-resistant, and waterproof material such as PE (PE = polyethylene), PVC (PVC = polyvinyl chloride) or vulcanised rubber.

[0045] In an alternative, the coaxial cable COAX1 may be comprise no cable jacket CJ, if the coaxial cable COAX1 is used in an environment, where the outer conductor COAX_OC1 of the coaxial cable COAX1 has no contact to other conductive materials or humidity during operation.

[0046] The dielectric COAX_DI of the coaxial cable COAX1 may comprise a polyethylene foam. In further alternatives, a material of the dielectric may be PTFE (PTFE = polytetrafluorethylene), ceramic (such as steatite or aluminium oxide), mica or air.

[0047] The outer conductor COAX_OC1 of the coaxial cable COAX1 may be helically corrugated. In an alternative, the outer conductor of the coaxial cable may be annularly corrugated with rings of equal spacing. In a further alternative, the outer conductor COAX_OC1 of the coaxial cable COAX1 may comprise a cylindrical tube with a flat surface. In an even further alternative, the outer conductor may comprise thin wires, which are twisted or not twisted.

[0048] The inner conductor COAX_IC1 of the coaxial cable COAX1 may comprise a solid cylinder. In an alternative, the inner conductor of the coaxial cable may comprise a hollow cylinder. In a further alternative, the inner conductor of the coaxial cable may comprise thin wires, which are twisted or not twisted.

[0049] The coaxial connector CON1 comprises an outer conductor CON_OC1, an inner conductor CON_IC1 and a dielectric CON_DI in-between the outer conductor CON_OC1 and the inner conductor CON_IC1.

[0050] The dielectric CON_DI of the coaxial connector CON1 may comprise PTFE (PTFE = polytetrafluorethylene). In an alternative, the dielectric CON_DI of the coaxial connector CON1 may comprise a ceramic.

[0051] The inner conductor CON_IC1 of the coaxial connector CON1 may comprise a solid pin, allocating the coaxial connector CON1 to a group of male connectors. In an alternative, the inner conductor of the coaxial connector may comprise a hollow cylinder, allocating the coaxial connector to a group of female connectors. In a further alternative, the coaxial connector may be a neutral connector such as an APC7 coaxial connector. A material of the outer conductors COAX_OC1, CON_OC1 of the coaxial cable COAX1 and the coaxial connector CON1 may be aluminium.

[0052] Using aluminium provides the advantages of reducing total weight of the coaxial cable COAX1 and the coaxial connector CON1 and of making transport and installation of the coaxial cable COAX1 terminated by the coaxial connector CON1 easier. Furthermore, the utilization of aluminium reduces the manufacturing costs.

[0053] In further alternatives, metals such as copper, gold, or silver may be used for the material of the outer conductors COAX_OC1, CON_OC1 of the coaxial cable COAX1 and the coaxial connector CON1.

[0054] A material of inner conductors COAX_IC1, CON_IC1 of the coaxial cable COAX1 and the coaxial connector

CON1 may be copper. In further alternatives, metals such as aluminium, gold, or silver may be used for the material of the inner conductors COAX_IC1, CON_IC1 of the coaxial cable COAX1 and the coaxial connector CON1.

[0055] The inner and outer conductors COAX_OC1, CON_OC1, COAX_IC1, CON_IC1 of the coaxial cable COAX1 and the coaxial connector CON1 may comprise a single metal. In an alternative, at least one of the conductors of the coaxial cable COAX1 and the coaxial connector CON1 may comprise a bi-metal with two metals joined together. In a further alternative, at least one of the conductors of the coaxial cable COAX1 and the coaxial connector CON1 may comprise a plastic material covered with a metal.

[0056] The usage of metal-metal combinations or plastic-metal combinations for the conductors of the coaxial cable COAX1 and the coaxial connector CON1 increases the flexibility in the selection of adequate conductor materials to achieve the required electrical and mechanical properties for the coaxial cable COAX1 terminated by the coaxial connector CON1.

[0057] The cable jacket CJ is removed along an end piece COAX_EP1 of the coaxial cable COAX1 between a first cross section CS1 and a second cross section CS2. The second cross section CS2 crosses an end face of the inner conductor COAX_IC1 of the coaxial cable COAX1.

[0058] A shrink tube ST may cover the outer conductor COAX_OC1 of the coaxial cable COAX1, an intersection of the outer conductor COAX_OC1 to the cable jacket CJ, and an intersection of the outer conductor COAX_OC1 to the outer conductor CON_OC1 of the coaxial connector CON1. A gasket sealing GS surrounding the outer conductor COAX_OC1 of the coaxial cable COAX1 may be located near an end face of the cable jacket CJ.

[0059] The gasket sealing GS and the shrink tube ST seal a hollow space between the cable jacket CJ and the outer conductor COAX_OC1 of the coaxial cable COAX1 and an outer conductor junction area OCJA1 of the outer conductors COAX_OC1, CON_OC1 of the coaxial cable COAX1 and the coaxial connector CON1 to avoid ingress of any humidity.

[0060] In an alternative, the gasket sealing GS may be not used, if the sealing by the shrink tube ST already meets all sealing requirements.

[0061] In a further alternative, the gasket sealing GS and the shrink tube ST may be not used, if humidity on the surface of the outer conductor COAX_OC1 does not degrade electrical properties of the coaxial cable COAX1 terminated by the coaxial connector CON1.

[0062] The outer conductor COAX_OC1 and the dielectric COAX_DI of the coaxial cable COAX1 may be removed along an end piece COAX_EP2 of the inner conductor COAX_IC1 of the coaxial cable COAX1 between the second cross section CS2 and a third cross section CS3. The third cross section CS3 is located at an end face of the outer conductor CON_OC1 of the coaxial connector CON1.

[0063] In an alternative, the outer conductor COAX_OC1 and the dielectric COAX_DI of the coaxial cable COAX1 may be not removed at the end piece of the inner conductor COAX_IC1 of the coaxial cable COAX1, if an electrical and mechanical connection of the inner conductors of the coaxial cable and the coaxial connector can be generated via an access provided by a specific geometrical construction of the coaxial connector.

[0064] The outer conductor junction area OCJA1 of the outer conductors COAX_OC1, CON_OC1 of the coaxial cable COAX1 and the coaxial connector CON1 comprises surfaces of the outer conductors COAX_OC1, CON_OC1 of the coaxial cable COAX1 and the coaxial connector CON1 near an outer gap OG1 between the outer conductors COAX_OC1, CON_OC1 of the coaxial cable COAX1 and the coaxial connector CON1. The outer conductors COAX_OC1, CON_OC1 of the coaxial cable COAX1 and the coaxial connector CON1 are contacted at the third cross section CS3 and at the outer gap OG1 by an outer welded joint OWJ1. The outer welded joint OWJ1 surrounds and seals the outer gap OG1 between the outer conductors COAX_OC1, CON_OC1 of the coaxial cable COAX1 and the coaxial connector CON1.

[0065] According to the application of the first embodiment of the invention shown in Figure 1, the inner conductors COAX_IC1, CON_IC1 of the coaxial cable COAX1 and the coaxial connector CON1 may be contacted by a solder joint.

[0066] In an alternative, the outer conductors COAX_OC1, CON_OC1 of the coaxial cable COAX1 and the coaxial connector CON1 may be contacted at the third cross section CS3 and at the outer gap OG1 by an outer solder joint and the inner conductors COAX_IC1, CON_IC1 of the coaxial cable COAX1 and the coaxial connector CON1 may be contacted between the second cross section CS2 and the third cross section CS3 at an inner gap IG1 between the inner conductors COAX_IC1, CON_IC1 of the coaxial cable COAX1 and the coaxial connector CON1 by an inner welded joint IWJ1.

[0067] In a further alternative, the outer conductors COAX_OC1, CON_OC1 of the coaxial cable COAX1 and the coaxial connector CON1 may comprise the outer welded joint OWJ1 and the inner conductors COAX_IC1, CON_IC1 of the coaxial cable COAX1 and the coaxial connector CON1 may comprise the inner welded joint IWJ1.

[0068] An inner conductor junction area ICJA1 of the inner conductors COAX_IC1, CON_IC1 of the coaxial cable COAX1 and the coaxial connector CON1 comprises surfaces of the inner conductors COAX_IC1, CON_IC1 of the coaxial cable COAX1 and the coaxial connector CON1 near the inner gap IG1.

[0069] A connection between the coaxial cable COAX1 and the coaxial connector CON1 comprising the outer welded joint OWJ1 and/or the inner welded joint IWJ1 offers a benefit of providing an improved mechanical stability, because

by an exposition of the inner or outer welded joint IWJ1, OWJ1 to outdoor environmental conditions, the inner or outer welded joint IWJ1,

[0070] OWJ1 is not getting brittle. Mechanical and humidity effects cannot change the mechanical properties of the inner or outer welded joint IWJ1, OWJ1. Therewith, also the electrical performance of the inner or outer welded joint IWJ1, OWJ1 remains the same during operation (e.g. no occurrence of passive inter-modulation).

[0071] If the coaxial cable COAX1 terminated by the coaxial connector CON1 provides both, the inner or outer welded joint IWJ1, OWJ1, the mechanical and electrical properties of the whole connection between the coaxial cable COAX1 and the coaxial connector CON1 can be optimised.

[0072] Referring to Figure 2 a flow diagram of a method M1 for manufacturing an electrical and mechanical connection between the coaxial cable COAX1 and the coaxial connector CON1 in accordance to the first embodiment of the invention is shown.

[0073] In the following, a description of the method M1 is given for the outer conductors COAX_OC1, CON_OC1 of the coaxial cable COAX1 and the coaxial connector CON1. A person skilled in the art is able to transform the description for the method M1 according to the outer conductors COAX_OC1, CON_OC1 to the inner conductors COAX_IC1, CON_IC1 of the coaxial cable COAX1 and the coaxial connector CON1.

[0074] In a first step M1/1, the outer conductor junction area OCJA1 is aligned. This means, that the longitudinal axes of the coaxial cable COAX1 and the coaxial connector CON1 superimpose and a size of the outer gap OG1 between the outer conductors COAX_OC1, CON_OC1 of the coaxial cable COAX1 and the coaxial connector CON1 is below a first threshold. The first threshold is a few tenth of millimetre. In a preferred alternative, end faces of the outer conductors COAX_OC1, CON_OC1 of the coaxial cable COAX1 and the coaxial connector CON1 are in contact.

[0075] The outer conductor junction area OCJA1 may be aligned automatically using first translation units and first distance sensors for a reliable high precision alignment. In an alternative, the outer conductor junction area may be automatically aligned based on a fitting of the outer conductors of the coaxial cable and the coaxial connector into gaps of a tool holder. In a further alternative, the outer conductor junction area may be aligned manually by an operator.

[0076] In a further step M1/2, a welding head of a welding apparatus may be automatically aligned according to the outer conductor junction area OCJA1 using second translation units and second distance sensors for a reliable high precision alignment. In an alternative, the welding head may be aligned automatically by predefined three-dimensional positions according to a fixed tool holder. In a further alternative, the welding head may be aligned manually by an operator.

[0077] The welding apparatus may be a laser beam welding apparatus. The laser beam welding apparatus provides the advantage of a laser beam being focussed on the outer conductor junction area OCJA1 around the outer gap OG1 and thereby the laser beam does not get in contact with other parts of the coaxial cable COAX1 and the coaxial connector CON1.

[0078] In an alternative, the welding apparatus may be an electron beam welding apparatus. The advantage of an electron beam is no tendency to diverge, when the electron beam arrives at the outer conductor junction area OCJA1.

[0079] An alignment of the laser beam in the step M1/2 is performed in such a way, that a welding process can be applied with a concentrated application of energy. This means, that a diameter of a spot size of the laser beam at the outer conductor junction area OCJA1 is below a second threshold. The second threshold is a few tenth of millimetre. The concentrated application of energy provides the advantage of heating-up of the surface of the outer conductor junction area OCJA1 at a limited range around the outer gap OG1.

[0080] By using the laser or electron beam welding apparatus, parameters of the laser or electron beam such as beam power, operating distance, spot size etc. can be precisely controlled, which provides a high reliability.

[0081] In a next step M1/3, the outer welded joint OWJ1 is generated at the outer conductor junction area OCJA1 by the welding process.

[0082] The welding process may use a continuous mode of the laser beam welding apparatus. The continuous mode provides the advantage of generating deep weld seams.

[0083] In an alternative, the welding process may use a pulsed mode of the laser beam welding apparatus reducing an application of energy on the outer conductor junction area OCJA1.

[0084] A beam BEAM1 of the laser beam welding apparatus may be focussed on the outer conductor junction area OCJA1 from a direction perpendicular to the longitudinal axes of the coaxial cable COAX1 and the coaxial connector CON1. In an alternative the beam BEAM1 may be focussed on the outer conductor junction area OCJA1 from a direction not perpendicular to the longitudinal axes of the coaxial cable COAX1 and the coaxial connector CON1 depending on the geometrical form of the conductor junction area. The outer welded joint OWJ1 is produced stepwise during the welding process until an endless weld seam surrounds and seals the outer gap OG1 of the outer conductor junction area OCJA1.

[0085] Contacting the outer conductors COAX_OC1, CON_OC1 of the coaxial cable COAX1 and the coaxial connector CON1 with the outer welded joint OWJ1, gravity effects during the welding process have no impact on the electrical and mechanical properties of the outer welded joint OWJ1.

[0086] By the stepwise production of the outer welded joint OWJ1, a requirement of generating a 360 degree contact

for avoiding passive inter-modulation effects can be easily fulfilled.

[0087] The mechanical stability of the outer welded joint OWJ1 provides a further advantage of sealing the dielectrics COAX_DI, CON_DI and the inner conductors COAX_IC1, CON_IC1 of the coaxial cable COAX1 and the coaxial connector CON1 against any humidity during its time of operation. The stepwise production of the outer welded joints OWJ1 may be done by fixing the outer conductors COAX_OC1, CON_OC1 of the coaxial cable COAX1 and the coaxial connector CON1 with the tool holder and moving the welding head of the laser beam welding apparatus around the outer conductor junction area OCJA1.

[0088] In an alternative, the welding head may be fixed and the outer conductors COAX_OC1, CON_OC1 of the coaxial cable COAX1 and the coaxial connector CON1 may be rotated using the tool holder around the longitudinal axes of the coaxial cable COAX1 and the coaxial connector CON1.

[0089] Generating the outer welded joint OWJ1 by the beam BEAM1 of the laser beam welding apparatus provides the advantage of welding the outer conductor junction area OCJA1 with a large speed of travel. Thereby, the manufacturing time can be reduced. The manufacturing time can be further reduced, if a further beam is focussed on the outer conductor junction area OCJA1 from an opposite direction.

[0090] In addition, if aluminium is used for the outer conductor in combination with the welding process, a corrosive flux must not be applied to a surface of the outer conductor to remove a thin layer of aluminium oxide, because an efficiency of the welding process is not impacted by the thin layer of aluminium oxide.

[0091] The laser or the electron beam welding process provides the further advantage of welding without use of a filler material.

[0092] The sequence and the number of the steps for performing the method M1 is not critical, and as can be understood by those skilled in the art, that the sequence and the number of the steps may vary without departing from the scope of the invention.

[0093] In a first alternative, the steps M1/1, M1/2, and M1/3 are done in a first cycle for the outer conductors of the coaxial cable COAX1 and the coaxial connector CON1. In a second cycle, the steps M1/1, M1/2, and M1/3 are done for the inner conductors of the coaxial cable COAX1 and the coaxial connector CON1.

[0094] In a second alternative, the steps M1/1, M1/2, and M1/3 are done simultaneously for the inner and outer conductors of the coaxial cable and the coaxial connector.

[0095] In a third alternative, the steps M1/1, M1/2, and M1/3 are done only for the inner or the outer conductors of the coaxial cable and the coaxial connector.

[0096] Referring to Figure 3 a flow diagram of a method M2 in accordance to the second embodiment of the invention is shown. In addition to the steps M1/1, M1/2, and M1/3 performed in the first embodiment of the invention, step M2/1 may be performed between the step M1/2 and the step M1/3. The sequence and the number of the steps for performing the method M2 is not critical, and as can be understood by those skilled in the art, that the sequence and the number of the steps may vary without departing from the scope of the invention.

[0097] In the following, a description of the method M2 is given for the outer conductors COAX_OC1, CON_OC1 of the coaxial cable COAX1 and the coaxial connector CON1. A person skilled in the art is able to transform the description for the method M2 according to the outer conductors COAX_OC1, CON_OC1 to the inner conductors COAX_IC1, CON_IC1 of the coaxial cable COAX1 and the coaxial connector CON1.

[0098] In the further step M2/1, the welding process is applied with the application of energy staying below a third threshold. The third threshold is selected according to different parameters of the outer conductor junction area OCJA1 such as density of the material of the outer conductors, material thickness of the outer conductors, absorptivity of the material of the outer conductors, size of the outer gap OG1 between the outer conductors etc. The threshold is selected in such a way, that the application of energy at the outer conductor junction area OCJA1 is sufficient for welding the material of the outer conductors COAX_OC1, CON_OC1 of the coaxial cable COAX1 and the coaxial connector CON1 near the outer conductor junction area OCJA1 but insufficient for generating a thermal shape distortion of the material of the outer conductors COAX_OC1, CON_OC1 distant from the outer conductor junction area OCJA1.

[0099] A limitation of the application of energy provides a further advantage of not hitting any critical temperatures for deforming or melting material of any other components of the coaxial cable COAX1 and the coaxial connector

[0100] CON1 such as the dielectrics COAX_DI, CON_DL by heat dissipation.

[0101] Figure 4 shows a cross-sectional view of inner conductors COAX_IC2, CON_IC2 of an end piece of a coaxial cable COAX2 and of a coaxial connector CON2 connected to the coaxial cable COAX2 in accordance to a first application of a third embodiment of the invention.

[0102] A first end face CON_IC_EF1 of the inner conductor CON_IC2 of the coaxial connector CON2 facing towards the coaxial cable COAX2 may be in contact with an end face of the inner conductor COAX_IC2 of the coaxial cable COAX2 at a fourth cross section CS4. In an alternative, a small gap may exist between the end faces of the inner conductors CON_IC2, COAX_IC2.

[0103] A second end face CON_IC_EF2 of the inner conductor CON_IC2 of the coaxial connector CON2 opposing to the first end face CON_IC_EF1 comprises an opening OP at a fifth cross section CS5. The opening OP may be a

bore hole. In an alternative, the opening OP may be a hole being produced by milling. In a further alternative, the opening OP may be produced by casting the inner conductor CON_IC2 of the coaxial connector CON2.

[0104] The opening OP provides the advantage of requiring fewer conductor material for the inner conductor CON_IC2 of the coaxial connector CON2. A beam BEAM2 of the laser beam welding apparatus oriented in a direction parallel to the longitudinal axes of the inner conductors COAX_IC2, CON_IC2 is focussed during the welding process via the opening OP onto a bottom BOT of the opening OP.

[0105] In an alternative, the beam BEAM2 may be extracted from the electron beam welding apparatus.

[0106] A distance DIS between the bottom BOT of the opening OP at a sixth cross section CS6 and the first end face CON_IC_EF1 of the inner conductor CON_IC2 of the coaxial connector CON2 is preferably adapted to a material thickness of the inner conductor COAX_IC2 of the coaxial cable COAX2.

[0107] This provides a first advantage by heating up the material of the inner conductors COAX_IC2, CON_IC2 of the coaxial cable COAX2 and the coaxial connector CON2 at an inner conductor junction area ICJA2 homogeneously for generating an inner welding joint IWJ2 by the welding process. Therewith any deformation of either the inner conductor COAX_IC2 of the coaxial cable COAX2 or the inner conductor CON_IC2 of the coaxial connector CON2 is avoided.

[0108] A second advantage of the opening OP is related to the possibility, that both the outer and the inner conductors of the coaxial cable and the connector can be welded by the beams BEAM1 (see Figure 1), BEAM2 (see Figure 4) at the same time.

[0109] Figure 5 shows a cross-sectional view of outer conductors COAX_OC3, CON_OC3 of an end piece of a coaxial cable COAX3 and of a coaxial connector CON3 connected to the coaxial cable COAX3 in accordance to a second application of the third embodiment of the invention.

[0110] The outer conductor CON_OC3 of the coaxial connector CON3 may be tapered and reduced to a cylindrical tube CYL_TUB1 at an end face CON_OC_EF3 of the outer conductor CON_OC3 of the coaxial connector CON3. A thickness of the cylindrical tube CYL_TUB1 is adapted to a material thickness of the outer conductor COAX_OC3 of the coaxial cable COAX3.

[0111] The outer conductor COAX_OC3 of the coaxial cable COAX3 may be a cylindrical tube with a flat surface, which surrounds a dielectric and an inner conductor of the coaxial cable COAX3.

[0112] The end face CON_OC_EF3 of the cylindrical tube CYL_TUB1 of the outer conductor CON_OC3 of the coaxial connector CON3 facing towards the coaxial cable COAX3 may be in contact with an end face of the outer conductor COAX_OC3 of the coaxial cable COAX3 at a seventh cross section CS7. In an alternative, a small gap may exist between the end faces of the outer conductors COAX_OC3, CON_OC3.

[0113] An outer conductor junction area OCJA3 being located at a seventh cross section CS7 comprises an outer welded joint OWJ3 surrounding an outer gap OG3 between the outer conductors COAX_OC3, CON_OC3 of the coaxial cable COAX3 and the coaxial connector CON3.

[0114] The tapered outer conductor CON_OC3 of the coaxial connector CON3 provides the same advantage as mentioned according to Figure 4 of heating up the material of the outer conductors COAX_OC3, CON_OC3 of the coaxial cable COAX3 and the coaxial connector CON3 near the outer conductor junction area OCJA3 during the welding process homogeneously and avoiding any deformation or melting of components of the coaxial cable COAX3 and the coaxial connector CON3 distant from the outer conductor junction area OCJA3.

[0115] Figures 6 shows a cross-sectional view of outer conductors COAX_OC4, CON_OC4 of an end piece of a coaxial cable COAX4 and of a coaxial connector CON4 connected to the coaxial cable COAX4 in accordance to a third application of the third embodiment of the invention.

[0116] The outer conductor COAX_OC4 of the coaxial cable COAX4 is annularly corrugated with a wavelike surface.

[0117] An end face CON_OC_EF4 of the outer conductor CON_OC4 of the coaxial connector CON4 facing towards the coaxial cable COAX4 may be tapered to a trapezoidal tube TRAP_TUB and may be in contact with an end face of the outer conductor COAX_OC4 of the coaxial cable COAX4 at a wave trough of the surface of the outer conductor COAX_OC4 at the seventh cross section CS7.

[0118] In an alternative, small gaps may exist between the end faces of the outer conductors CON_OC4, COAX_OC4.

[0119] Thickness of the trapezoidal tube TRAP_TUB at the seventh cross section CS7 is adapted to a material thickness of the outer conductor COAX_OC4 of the coaxial cable COAX4.

[0120] This provides the advantage of heating up of the outer conductors COAX_OC4, CON_OC4 of the coaxial cable COAX4 and the coaxial connector CON4 during the welding process homogeneously.

[0121] Referring to Figure 7 a flow diagram of a method M3 in accordance to a fourth embodiment of the invention is shown. In addition to the steps M1/1, M1/2, and M1/3 performed in the first embodiment of the invention, step M3/1 may be performed before the step M1/1.

[0122] The sequence and the number of the steps for performing the method M3 is not critical, and as can be understood by those skilled in the art, that the sequence and the number of the steps may vary without departing from the scope of the invention.

[0123] In the further step M3/1, an annularly corrugated outer conductor of a coaxial cable may be cut at a largest

diameter of a winding of the annularly corrugated outer conductor.

[0124] Cutting the winding at the largest diameter provides the advantage of a larger angular range, which can be used for an angle of incidence of the beam of the laser or electron beam welding apparatus.

[0125] Figures 8 shows a cross-sectional view of outer conductors COAX_OC5, CON_OC5 of an end piece of a coaxial cable COAX5 and of a coaxial connector CON5 connected to the coaxial cable COAX5 in accordance to an application of the fourth embodiment of the invention.

[0126] The outer conductor COAX_OC5 of the coaxial cable COAX5 is annularly corrugated with a wavelike surface.

[0127] An end face CON_OC_EF5 of the outer conductor CON_OC5 of the coaxial connector CON5 facing towards the coaxial cable COAX5 may be tapered to a conical tube CON_TUB and may be in contact with an end face of the outer conductor COAX_OC5 of the coaxial cable COAX5 at a wave crest (largest diameter of a winding) of the surface of the outer conductor COAX_OC5 at the seventh cross section CS7.

[0128] In an alternative, small gaps may exist between the end faces of the outer conductors CON_OC5, COAX_OC5.

[0129] Thickness of the conical tube CON_TUB at the seventh cross section CS7 is adapted to a material thickness of the outer conductor COAX_OC5 of the coaxial cable COAX5.

[0130] This provides the advantage of heating up of the outer conductors COAX_OC5, CON_OC5 of the coaxial cable COAX5 and the coaxial connectors CON5 during the welding process homogeneously. Furthermore, a large angular range can be used for an angle of incidence of the beam of the laser or electron beam welding apparatus because the outer conductor COAX_OC5 of the coaxial cable COAX5 is cut at a wave crest.

[0131] Referring to Figure 9 a flow diagram of a method M4 in accordance to a fifth embodiment of the invention is shown. In addition to the steps M1/1, M1/2, and M1/3 performed in the first embodiment of the invention, step M4/1 may be performed before the step M1/1.

[0132] The sequence and the number of the steps for performing the method M4 is not critical, and as can be understood by those skilled in the art, that the sequence and the number of the steps may vary without departing from the scope of the invention.

[0133] In the further step M4/1, a first winding of a helically corrugated outer conductor of a coaxial cable may be squeezed at an end face of the outer conductor of the coaxial cable.

[0134] In an alternative, the first and at least a second winding of the helically corrugated outer conductor of a coaxial cable may be squeezed at an end face of the outer conductor of the coaxial cable.

[0135] In further alternatives, a first winding or at least two windings of an annularly corrugated outer conductor of a coaxial cable may be squeezed at an end face of the outer conductor of the coaxial cable to provide more material of the annularly corrugated outer conductor at the outer conductor junction area.

[0136] The squeezing of the first winding of the helically corrugated outer conductor of the coaxial cable generates a rotationally symmetric form according to the longitudinal axis of the coaxial cable. This provides the benefit, if either the tool holder is rotated around the longitudinal axis of the coaxial cable or the welding head is rotated around the tool holder, a distance between the conductor junction area and the welding head of the welding apparatus is kept constant during the welding process and a parallel translation of either the tool holder fixing the coaxial cable and the coaxial connector or the welding head of the welding apparatus is not required. Performing only a rotation increases the precision of the welding process around the conductor junction area.

[0137] In an alternative, the squeezing of the first winding of the helically corrugated outer conductor of the coaxial cable generates a form, which fits to the surface of the outer conductor of the coaxial connector. This provides the further advantage of avoiding any cavities between the outer conductors of the coaxial cable and the coaxial connector resulting in an extension of an overlap area between the outer conductors of the coaxial cable and the coaxial connector for getting an electrical contact with an optimised electric resistance.

[0138] Figure 10 shows a cross-sectional view of an outer conductor COAX_OC6 of an end piece of a coaxial cable COAX6 in accordance to an application of the fourth embodiment of the invention.

[0139] The cable jacket CJ of the coaxial cable COAX6 may be removed at a first, a second, a third, and a fourth winding COAX6_WI1, COAX6_WI2, COAX6_WI3, COAX6_WI4 at the end piece of the coaxial cable COAX6. A fifth and a sixth winding COAX6_WI5, COAX6_WI6 of the outer conductor COAX_OC6 are covered by the cable jacket CJ.

[0140] The first, the second, the third, and the fourth winding COAX6_WI1, COAX6_WI2, COAX6_WI3, COAX6_WI4 may be squeezed by the squeezing step M4/1 of the method M4 in a squeezing direction SQ_DIR along the longitudinal axis of the coaxial cable COAX6 directed to a centre of the coaxial cable COAX6.

[0141] Figure 11 shows a cross-sectional view of the outer conductors COAX_OC6, CON_OC6 of an end piece of a coaxial cable COAX6 and of a coaxial connector CON6 connected to the coaxial cable COAX6 in accordance to the application of the fourth embodiment of the invention. Positions and shapes of the first, the second, the third, and the fourth winding COAX6_WI1, COAX6_WI2, COAX6_WI3, COAX6_WI4 at the end face of the outer conductor COAX_OC6 of the coaxial cable COAX6 are different to a periodic position and periodic shape of the first, the second, the third, and the fourth winding COAX6_WI1, COAX6_WI2, COAX6_WI3, COAX6_WI4 shown in Figure 10.

[0142] The first, the second, the third, and the fourth winding COAX6_WI1, COAX6_WI2, COAX6_WI3, COAX6_WI4

have been squeezed exemplarily in such a way, that on the one hand, nearly no space between the first, the second, the third, and the fourth winding COAX6_WI1, COAX6_WI2, COAX6_WI3, COAX6_WI4 and the dielectric COAX_DI of the coaxial cable COAX6 exists. On the other hand, nearly no space between the first, the second, the third, and the fourth winding COAX6_WI1, COAX6_WI2, COAX6_WI3, COAX6_WI4 exists as well.

[0143] Using such a squeezing structure of the first, the second, the third, and the fourth winding COAX6_WI1, COAX6_WI2, COAX6_WI3, COAX6_WI4 of the outer conductor COAX_OC6 of the coaxial cable COAX6, an almost perfect rotational symmetry exists at the outer conductor junction area. If the outer conductors COAX_OC6, CON_OC6 are in direct contact, at most a gap in a range of a thickness of the outer conductor COAX_OC6 of the coaxial cable COAX6 exists.

[0144] Preferably, the squeezing structure is generated by a separate manufacturing step to provide a high reliability. But it is also possible, that the squeezing structure can be generated by fitting the coaxial connector to the end piece of the coaxial cable.

[0145] The squeezing structure of the outer conductor of the coaxial cable provides the advantages of an increased precision of the welding process and of an increased angular range of the angle of incidence PHI of the beam BEAM1.

[0146] Referring to Figure 12 a flow diagram of a method M5 in accordance to a sixth embodiment of the invention is shown. In addition to the steps M4/1, M1/1, M1/2, and M1/3 performed in the fourth embodiment of the invention, step M5/1 is performed between the step M4/1 and the step M1/1.

[0147] In the further step M5/1, an end face of an outer conductor of a coaxial connector is fit into an end face of an outer conductor of a coaxial cable. This provides the advantage of an automatic alignment of the outer conductor junction area and an automatic execution of the step M1/1.

[0148] In the step M1/3, an outer welded joint is made through a material of the outer conductor of the coaxial cable preferably close to an end face of the outer conductor of the coaxial connector.

[0149] This provides the advantage of minimising passive inter-modulation effects.

[0150] Figures 13 and 14 show cross-sectional views of outer conductors COAX_OC7, CON_OC7 of an end piece of a coaxial cable COAX7 and of a coaxial connector CON7 connected to the coaxial cable COAX7 (Figure 13) and of outer conductors COAX_OC8, CON_OC8 of an end piece of a coaxial cable COAX8 and of a coaxial connector CON8 connected to the coaxial cable COAX8 (Figure 14) in accordance to a first and a second application of the sixth embodiment of the invention.

[0151] According to the first application (Figure 13) of the sixth embodiment of the invention, a first and a second winding COAX7_WI1, COAX7_WI2 at the end face of the outer conductor COAX_OC7 of the coaxial cable COAX7, which may be helically corrugated, have been squeezed to a rotationally symmetric cylindrical tube CYL_TUB2. In an alternative, the outer conductor of the coaxial cable may be annularly corrugated.

[0152] A third and a fourth winding COAX7_WI3, COAX7_WI4 of the outer conductor COAX_OC7 may be not changed by squeezing.

[0153] A rotationally symmetric cylindrical tube CYL_TUB3 of an end piece of the outer conductor CON_OC7 of the coaxial connector CON7 has an outer diameter compatible to an inner diameter of the rotationally symmetric cylindrical tube CYL_TUB2 of the outer conductor COAX_OC7 of the coaxial cable COAX7.

[0154] The rotationally symmetric cylindrical tube CYL_TUB3 of the end piece of the outer conductor CON_OC7 of the coaxial connector CON7 is fitted into the rotationally symmetric cylindrical tube CYL_TUB2 of the outer conductor COAX_OC7 of the coaxial cable COAX7.

[0155] According to the second application (Figure 14) of the sixth embodiment of the invention, a first winding COAX8_WI1 at the end face of the outer conductor COAX_OC8 of the coaxial cable COAX8, which may be helically corrugated, has been squeezed to a rotationally symmetric hollow conical frustum CON_TUB2 with a larger opening at the end face of the outer conductor COAX_OC8 of the coaxial cable COAX8. In an alternative, the outer conductor of the coaxial cable may be annularly corrugated.

[0156] A second, a third and a fourth winding COAX8_WI2, COAX8_WI3, COAX8_WI4 of the outer conductor COAX_OC8 may be not changed by squeezing.

[0157] A size of a rotationally symmetric hollow conical frustum CON_TUB3 with a smaller opening at an end face of the outer conductor CON_OC8 of the coaxial connector CON8 is adapted to a size of the rotationally symmetric hollow conical frustum CON_TUB2 of the outer conductor COAX_OC8 of the coaxial cable COAX8.

[0158] The rotationally symmetric hollow conical frustum CON_TUB3 of the outer conductor CON_OC8 of the coaxial connector CON8 is fitted into the rotationally symmetric hollow conical frustum CON_TUB2 of the outer conductor COAX_OC8 of the coaxial cable COAX8.

[0159] According to the first and the second application of the sixth embodiment of the invention, circular welded joints may be generated by the beam BEAM1 of the laser or the electron beam welding apparatus and may be surround an overlap area of the outer conductors COAX7_OC, CON7_OC and COAX8_OC, CON8_OC preferably near the end faces of the outer conductors CON7_OC, CON8_OC of the coaxial connector CON7 and the coaxial connector CON8 respectively.

[0160] This provides the advantage of minimising passive inter-modulation effects. The rotational symmetry of the overlap area of the outer conductors of the coaxial cable and the coaxial connector provides the advantage of avoiding the parallel translation of either the tool holder fixing the coaxial cable and the coaxial connector or the welding head of the welding machine and of increasing the precision of the welding process.

Claims

1. A method for manufacturing an electrical connection between a coaxial cable (COAX1, ..., COAX8) and a coaxial connector (CON1, ..., CON8), said method comprising the step (M1/3) of connecting at least one conductor (COAX_IC1, COAX_IC2, COAX_OC1, ..., COAX_OC8) of said coaxial cable (COAX1, ..., COAX8) to a conductor (CON_IC1, CON_IC2, CON_OC1, ..., CON_OC8) of said coaxial connector (CON1, ..., CON8) by a welding process, **characterized in that** said coaxial connector (CON1, ..., CON8) is connected to an end face of said coaxial cable (COAX1, ..., COAX8) and said welding process is applied with a concentrated application of energy.
2. The method according to claim 1, said welding process is applied with an application of energy below a threshold.
3. The method according to claim 1, said welding process uses a beam (BEAM1, BEAM2) of a laser beam welding apparatus or an electron beam welding apparatus.
4. The method according to claim 3, said beam (BEAM1, BEAM2) is a pulsed beam.
5. The method according to claim 1, said conductor of said coaxial cable (COAX5) is an annularly corrugated outer conductor (COAX_OC5) and said method further comprises the step (M3/1) of cutting said annularly corrugated outer conductor (COAX_OC5) at a largest diameter of a winding of said annularly corrugated outer conductor (COAX_OC5).
6. The method according to claim 1, said conductor of said coaxial cable (COAX6, ..., COAX8) is a helically or an annularly corrugated outer conductor (COAX_OC6, ..., COAX_OC8) and said method further comprises the step (M4/1) of squeezing at least one winding (COAX6_WI1, ..., COAX6_WI4, COAX7_WI1, COAX7_WI2, COAX8_WI1) at an end face of said helically or said annularly corrugated outer conductor (COAX_OC6, ..., COAX_OC8).
7. The method according to claim 6, said at least one winding (COAX7_WI1, COAX7_WI2, COAX8_WI1) is squeezed to a first rotationally symmetric form (CYL_TUB2, CON_TUB2), an outer conductor (CON_OC7, CON_OC8) of said coaxial connector (CON7, CON8) comprises a second rotationally symmetric form (CYL_TUB3, CON_TUB3) compatible to said first rotationally symmetric form (CYL_TUB2, CON_TUB2) and said method further comprises the step (M5/1) of fitting an end face of said outer conductor (CON_OC7, CON_OC8) of said coaxial connector (CON7, CON8) into an end face of said helically or said annularly corrugated outer conductor (COAX_OC7, COAX_OC8) of said coaxial cable (COAX7, COAX8).
8. The method according to claim 7, said first and second rotationally symmetric forms (CYL_TUB2, CON_TUB2, CYL_TUB3, CON_TUB3) are cylindrical or conical.
9. A coaxial connector (CON1, ..., CON8), said coaxial connector (CON1, ..., CON8) comprises an inner conductor (CON_IC1, CON_IC2) and an outer conductor (CON_OC1, ..., CON_OC8), said coaxial connector (CON1, ..., CON8) is adapted to be connected to a coaxial cable (COAX1, ..., COAX8) using at least one welded joint (OWJ1, IWJ1, IWJ2, OWJ3), **characterized in that** said coaxial connector (CON1, ..., CON8) is adapted to be connected to an end face of said coaxial cable (COAX1, ..., COAX8) and a material thickness of at least one of said conductors (CON_IC1, CON_IC2, CON_OC1, ..., CON_OC8) of said coaxial connector (CON1, ..., CON8) is adapted to a material thickness of a conductor (COAX_IC1, COAX_IC2, COAX_OC1, ..., COAX_OC8) of said coaxial cable (COAX1, ..., COAX8).
10. The coaxial connector (CON2) according to claim 9, an end face (CON_IC_EF2) of said inner conductor (CON_IC2) of said coaxial connector (CON2) comprises an opening (OP) and a distance (DIS) between a bottom (BOT) of said opening (OP) and an opposing end face (CON_IC_EF1) of said inner conductor (CON_IC2) of said coaxial connector (CON2) is adapted to said material thickness of said conductor (COAX_IC2) of said coaxial cable (COAX2).
11. The coaxial connector (CON3, ..., CON5) according to claim 9, said outer conductor (CON_OC3, ..., CON_OC5) of

said coaxial connector (CON3, ..., CON5) comprises a rotationally symmetric tapered form (CYL_TUB1, TRAP_TUB, CON_TUB) at an end face (CON_OC_EF3, ..., CON_OC_EF5) of said outer conductor (CON_OC3, ..., CON_OC5) of said coaxial connector (CON3, ..., CON5), and a thickness of said rotationally symmetric tapered form (CYL_TUB1, TRAP_TUB, CON_TUB) is adapted to said material thickness of said conductor (COAX_OC3, ..., COAX_OC5) of said coaxial cable (COAX3, ..., COAX5).

12. A coaxial cable (COAX1, ..., COAX8) terminated by a coaxial connector (CON1, ..., CON8), at least one conductor (CON_IC1, CON_IC2, CON_OC1, ..., CON_OC8) of said coaxial connector (CON1, ..., CON8) is connected to a conductor (COAX_IC1, COAX_IC2, COAX_OC1, ..., COAX_OC8) of said coaxial cable (COAX1, ..., COAX8) using a welded joint (OWJ 1, IWJ1, IWJ2, OWJ3), **characterized in that** said coaxial connector (CON1, ..., CON8) is connected to an end face of said coaxial cable (COAX1, ..., COAX8) and said welded joint (OWJ 1, IWJ1, IWJ2, OWJ3) is manufactured with a concentrated application of energy.
13. The coaxial cable (COAX1, ..., COAX8) terminated by the coaxial connector (CON1, ..., CON8) according to claim 12, said at least conductor (CON_IC1, CON_IC2, CON_OC1, ..., CON_OC8) of said coaxial connector (CON1, ..., CON8) or at least one conductor (COAX_IC1, COAX_IC2, COAX_OC1, ..., COAX_OC8) of said coaxial cable (COAX1, ..., COAX8) comprises a bi-metal.
14. The coaxial cable (COAX1, ..., COAX8) terminated by the coaxial connector (CON1, ..., CON8) according to claim 12, said at least conductor (CON_IC1, CON_IC2, CON_OC1, ..., CON_OC8) of said coaxial connector (CON1, ..., CON8) or at least one conductor (COAX_IC1, COAX_IC2, COAX_OC1, ..., COAX_OC8) of said coaxial cable (COAX1, ..., COAX8) comprises a plastic material covered with a metal.
15. The coaxial cable (COAX1, ..., COAX8) terminated by the coaxial connector (CON1, ..., CON8) according to claim 12, at least one metal of said at least conductor (CON_IC1, CON_IC2, CON_OC1, ..., CON_OC8) of said coaxial connector (CON1, ..., CON8) or of at least one conductor (COAX_IC1, COAX_IC2, COAX_OC1, ..., COAX_OC8) of said coaxial cable (COAX1, ..., COAX8) is aluminium.

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

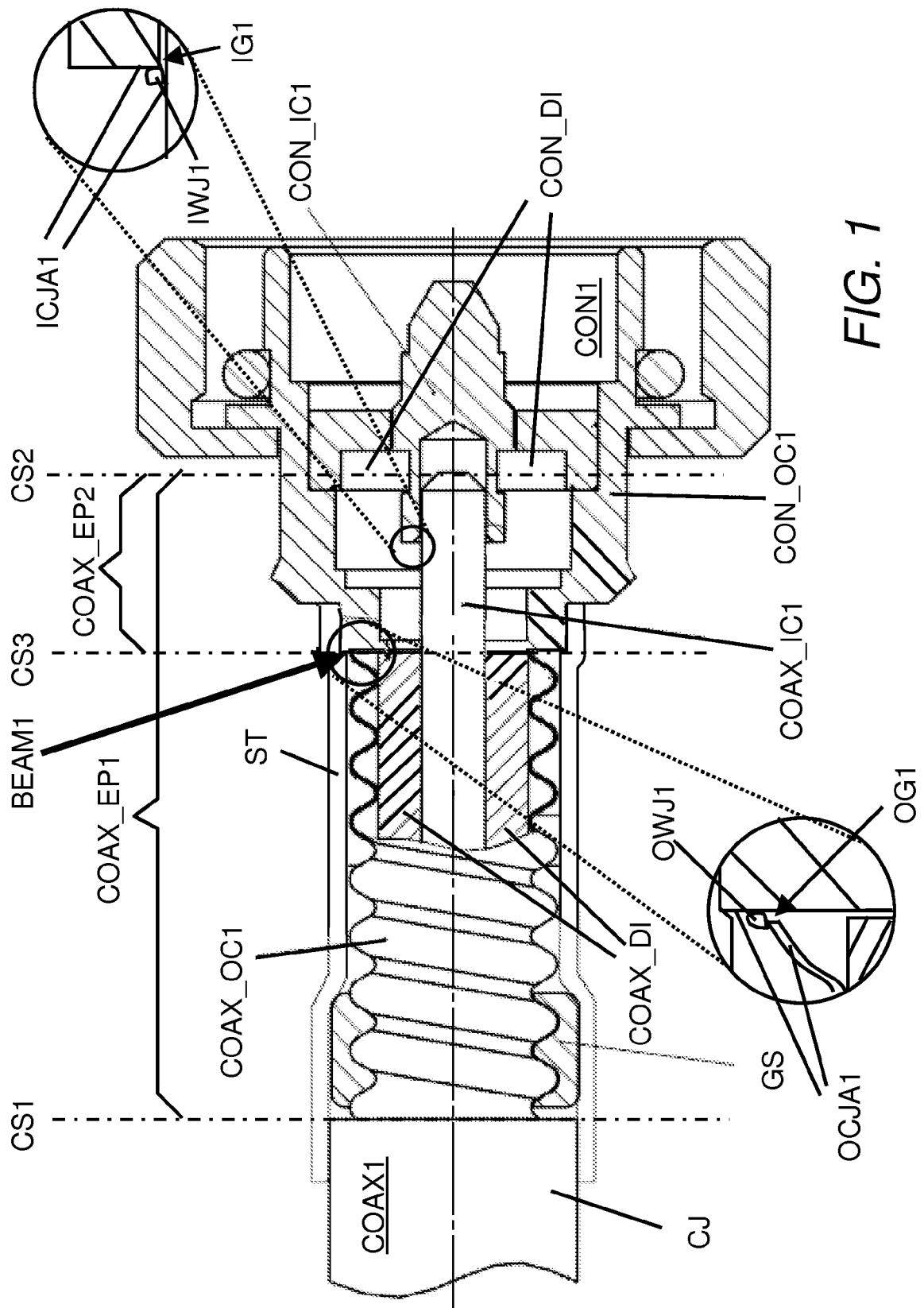
1. A method for manufacturing an electrical connection between a coaxial cable (COAX1, ..., COAX6) and a connector (CON1, ..., CON6), said method comprising the step (M1/3) of connecting at least one conductor (COAX_IC1, COAX_IC2, COAX_OC1, ..., COAX_OC6) of said coaxial cable (COAX1, ..., COAX6) to a conductor (CON_IC1, CON_IC2, CON_OC1, ..., CON_OC6) of said connector (CON1, ..., CON6) by applying a welding process with a concentrated application of energy, **characterized in that** said connector (CON1, ..., CON6) is a coaxial connector and a welded joint (OWJ1, OWJ3, IWJ2) is generated at an end face of said at least one conductor (COAX_IC1, COAX_IC2, COAX_OC1, ..., COAX_OC6) of said coaxial cable (COAX1, ..., COAX6) by said welding process.
2. The method according to claim 1, said welding process is applied with an application of energy below a threshold.
3. The method according to claim 1, said welding process uses a beam (BEAM1, BEAM2) of a laser beam welding apparatus or an electron beam welding apparatus.
4. The method according to claim 3, said beam (BEAM1, BEAM2) is a pulsed beam.
5. The method according to claim 1, said conductor of said coaxial cable (COAX5) is an annularly corrugated outer conductor (COAX_OC5) and said method further comprises the step (M3/1) of cutting said annularly corrugated outer conductor (COAX_OC5) at a largest diameter of a winding of said annularly corrugated outer conductor (COAX_OC5).
6. The method according to claim 1, said conductor of said coaxial cable (COAX6) is a helically or an annularly corrugated outer conductor (COAX_OC6) and said method further comprises the step (M4/1) of squeezing at least one winding (COAX6_WI1, ..., COAX6_WI4) at an end face of said helically or said annularly corrugated outer conductor (COAX_OC6).
7. The method according to claim 3 or claim 4, wherein said beam (BEAM1) is focussed on a conductor junction area (OCJA1, OCJA3) around a gap between said at least one conductor (COAX_OC1, ..., COAX_OC6) of said

coaxial cable (COAX1, ..., COAX6) and said conductor (CON_OC1, ..., CON_OC6) of said coaxial connector (CON1, ...,CON6).

5 **8.** The method according to claim 3 or claim 4, wherein an end face (CON_IC_EF2) of an inner conductor (CON_IC2) of said coaxial connector (CON2) comprises an opening (OP) with a bottom (BOT) and wherein said beam (BEAM2) is focussed onto said bottom (BOT) of said opening (OP).

10 **9.** A coaxial cable (COAX1, ..., COAX6) with a terminating connector (CON1, ..., CON6), at least one conductor (CON_IC1, CON_IC2, CON_OC1, ..., CON_OC6) of said connector (CON1, ..., CON6) is connected to a conductor (COAX_IC1, COAX_IC2, COAX_OC1, ..., COAX_OC6) of said coaxial cable (COAX1, ..., COAX6) using a welded joint (OWJ1, IWJ2, OWJ3) manufactured with a concentrated application of energy,

15 **characterized in that** said connector (CON1, ..., CON6) is a coaxial connector and said welded joint (OWJ1, IWJ2, OWJ3) is generated at an end face of said at least one conductor (CON_IC1, CON_IC2, CON_OC1, ..., CON_OC6) of said coaxial cable (COAX1, ..., COAX6).



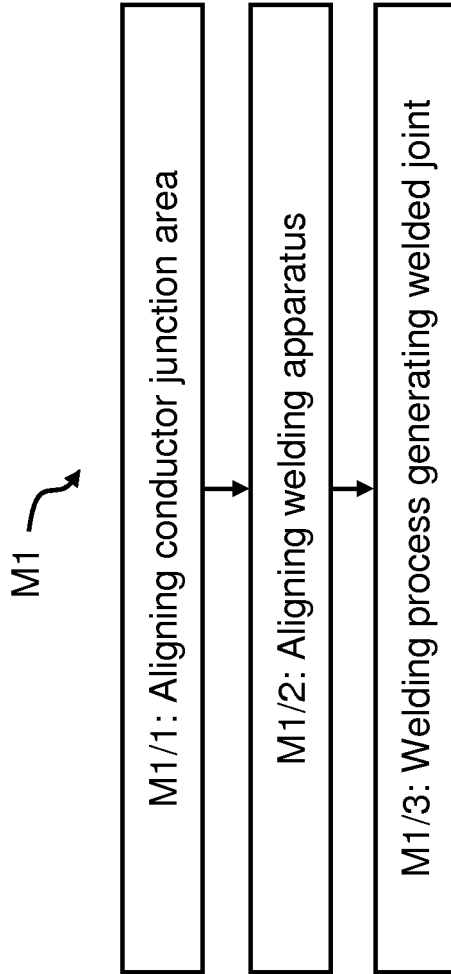


FIG. 2

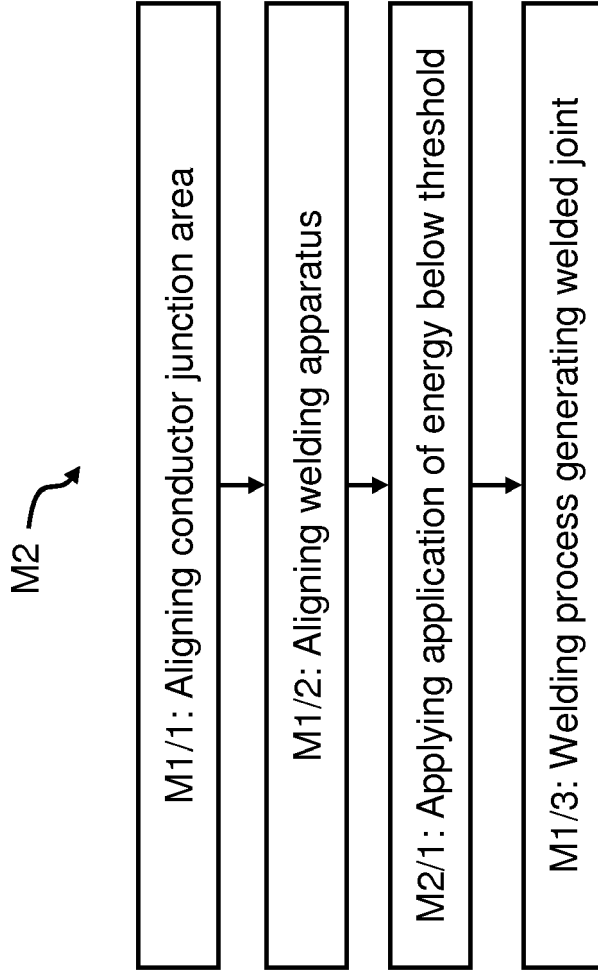


FIG. 3

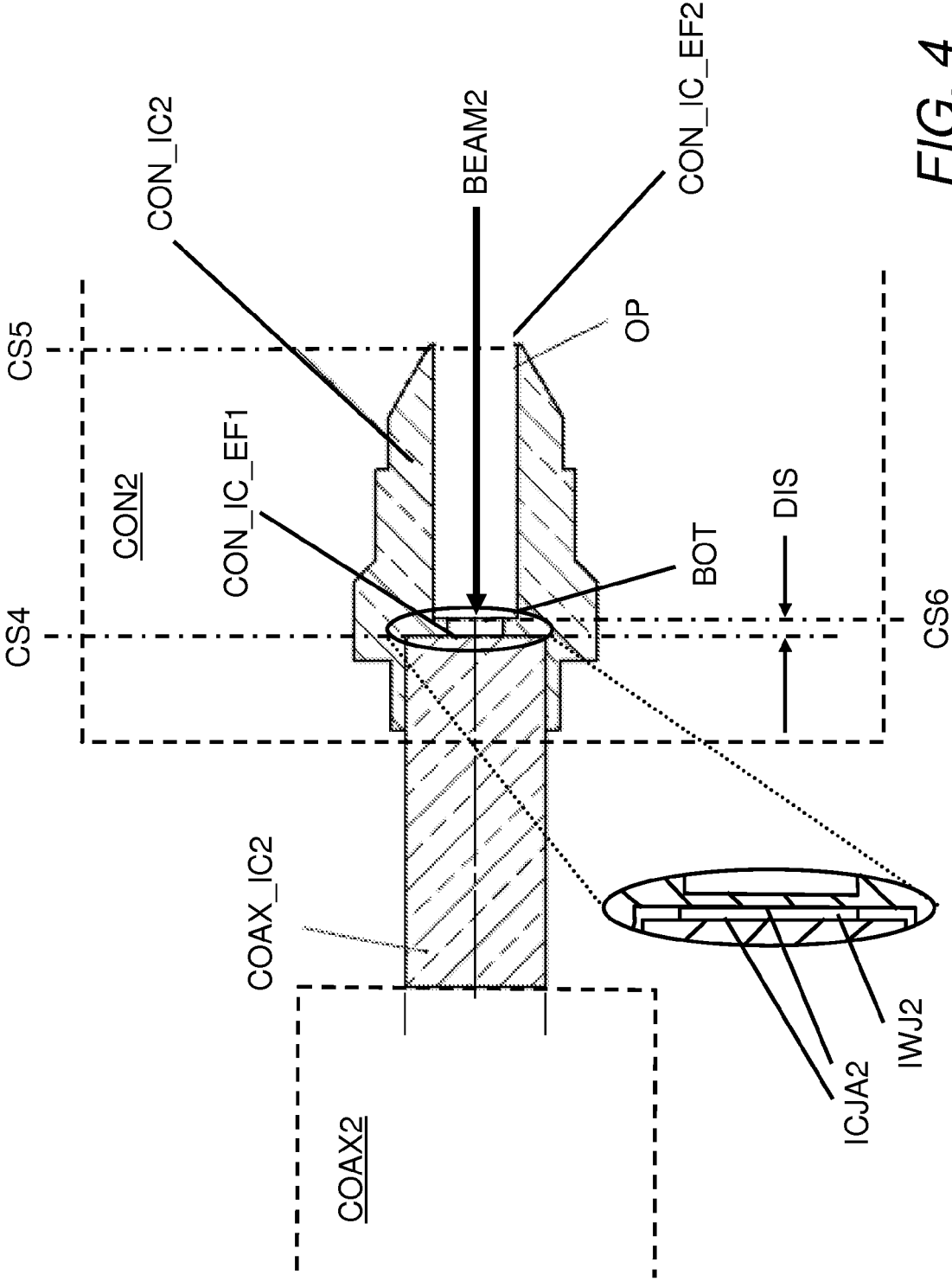


FIG. 4

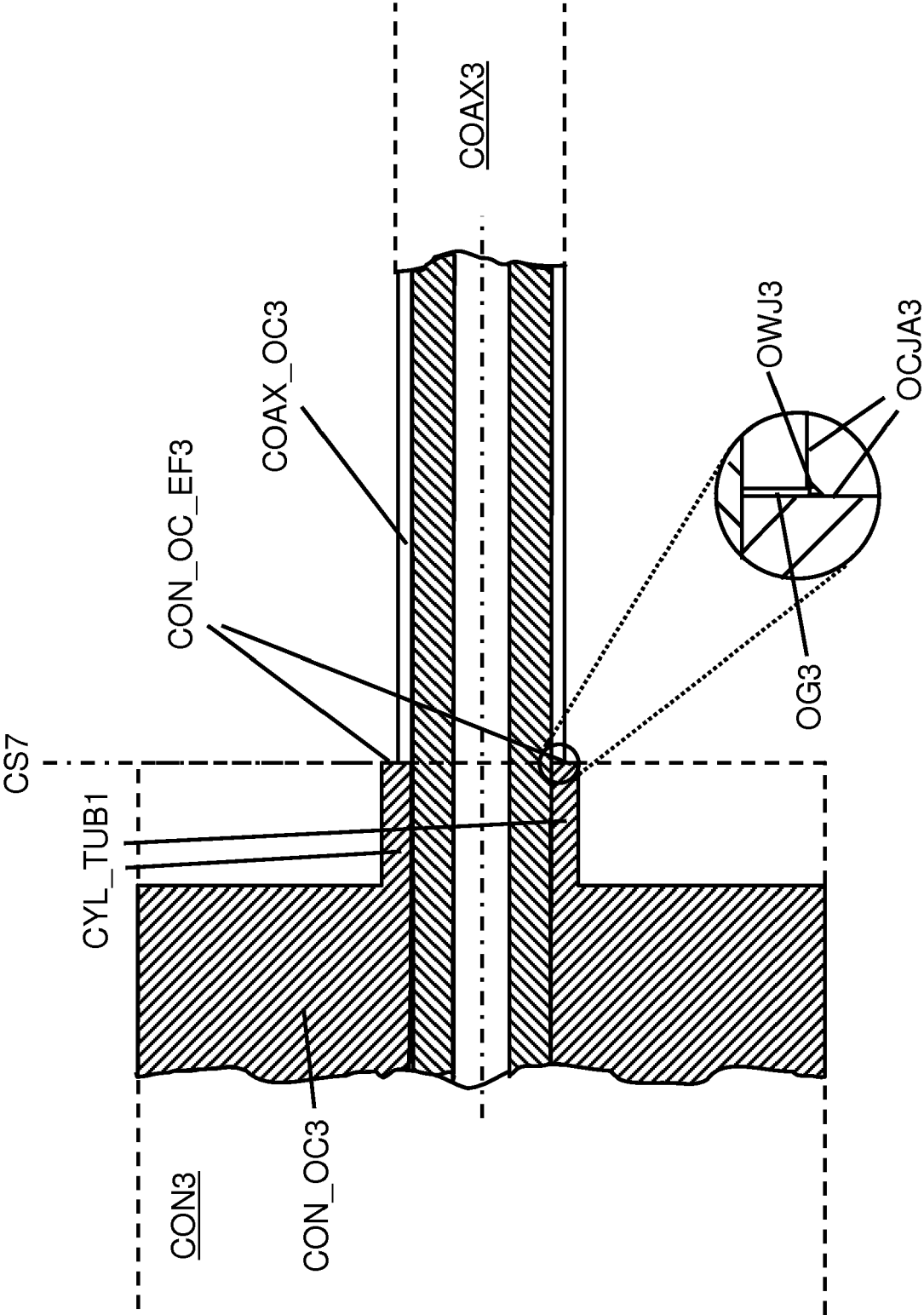


FIG. 5

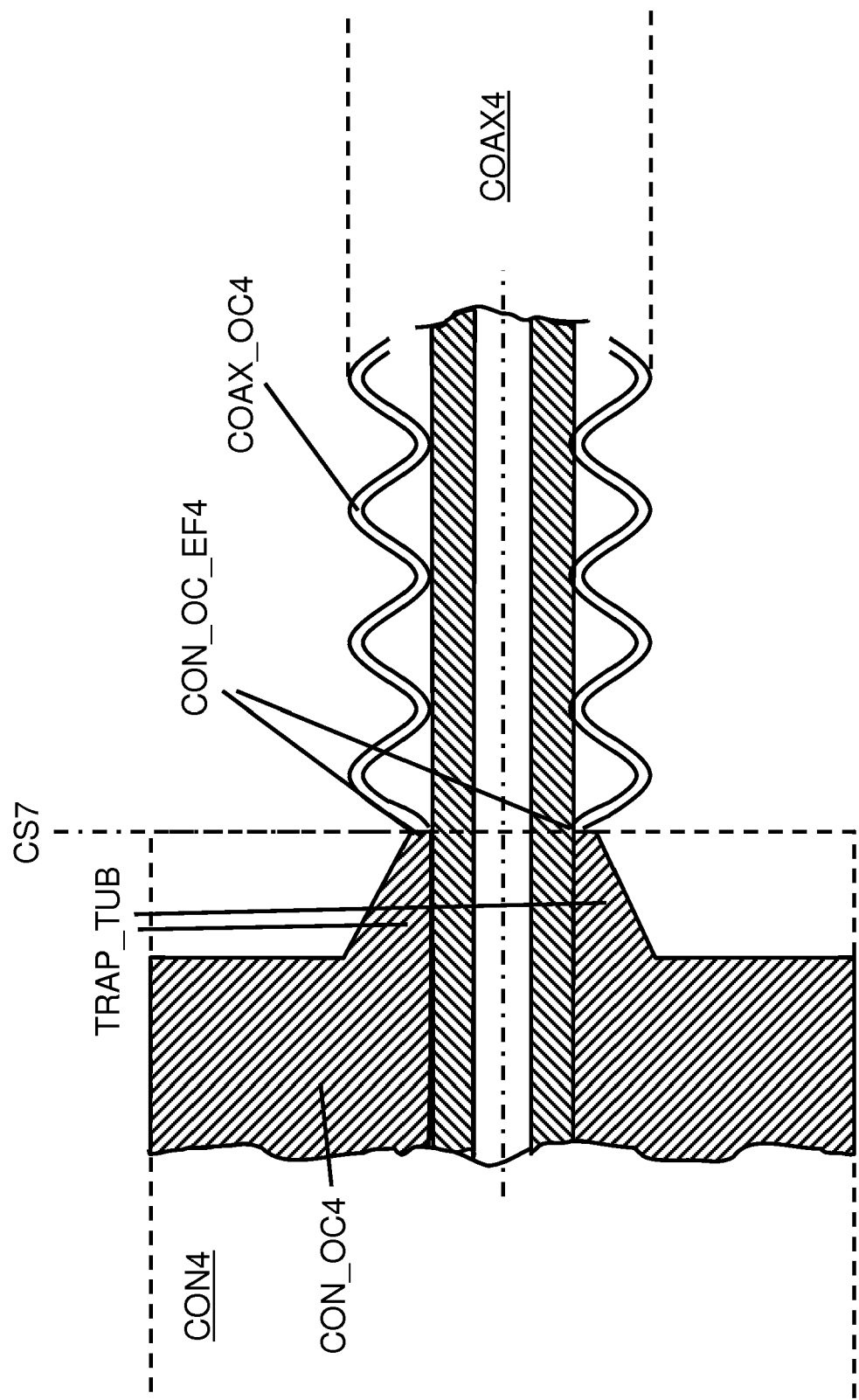


FIG. 6

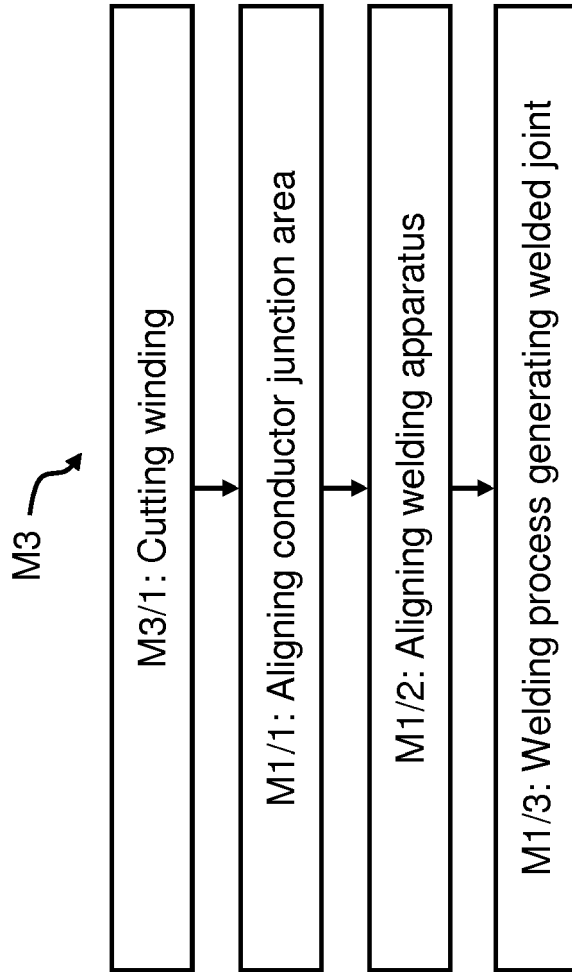


FIG. 7

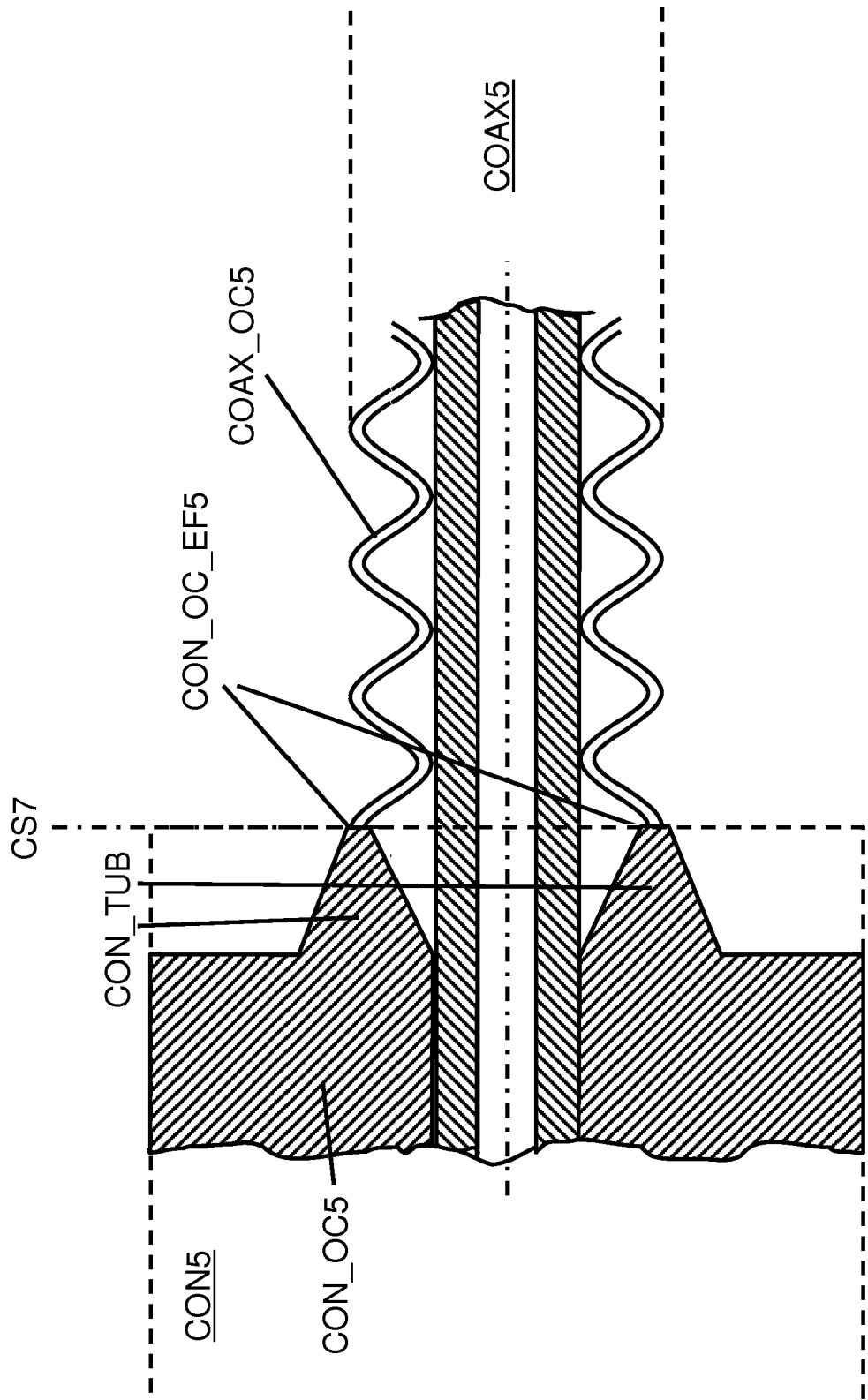
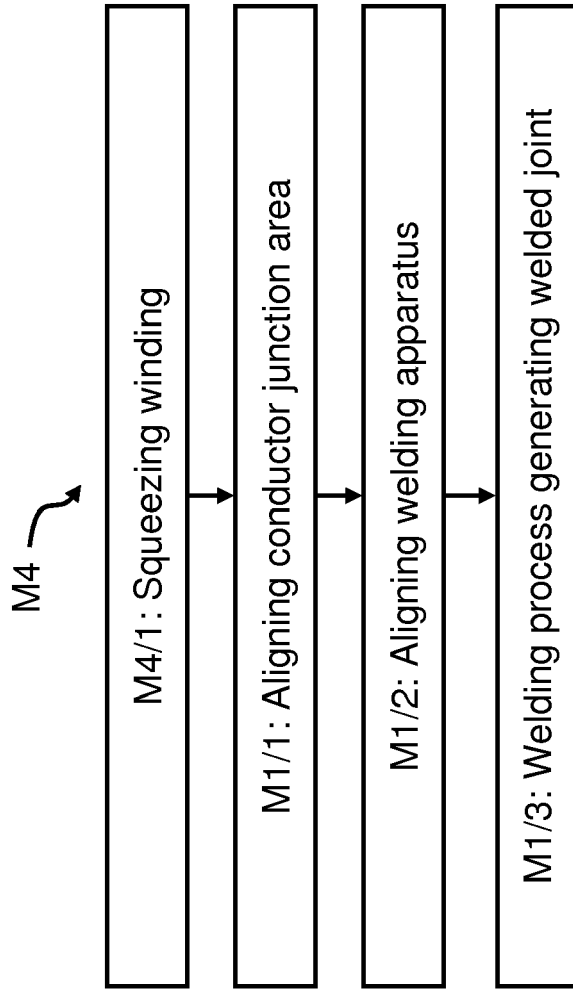


FIG. 8

*FIG. 9*

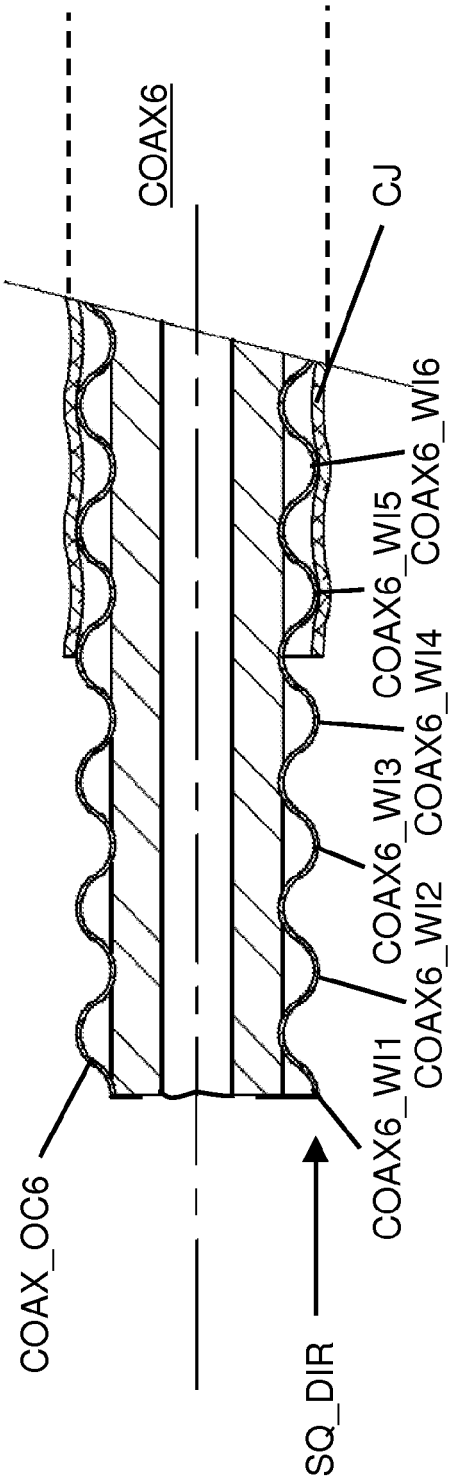


FIG. 10

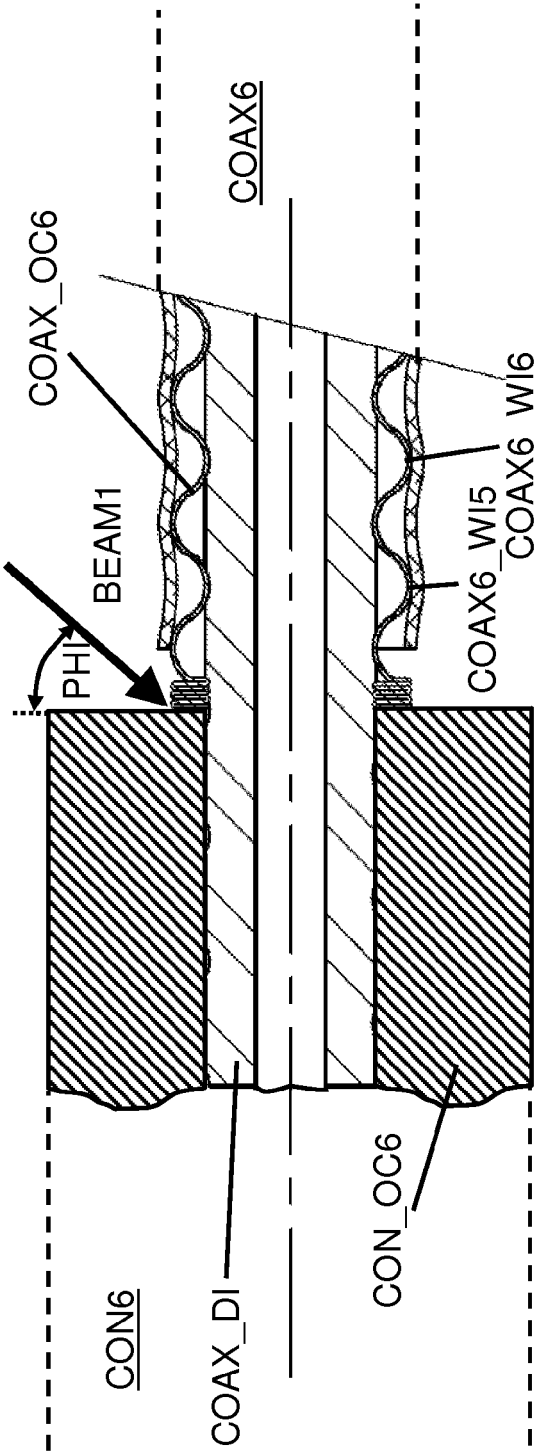
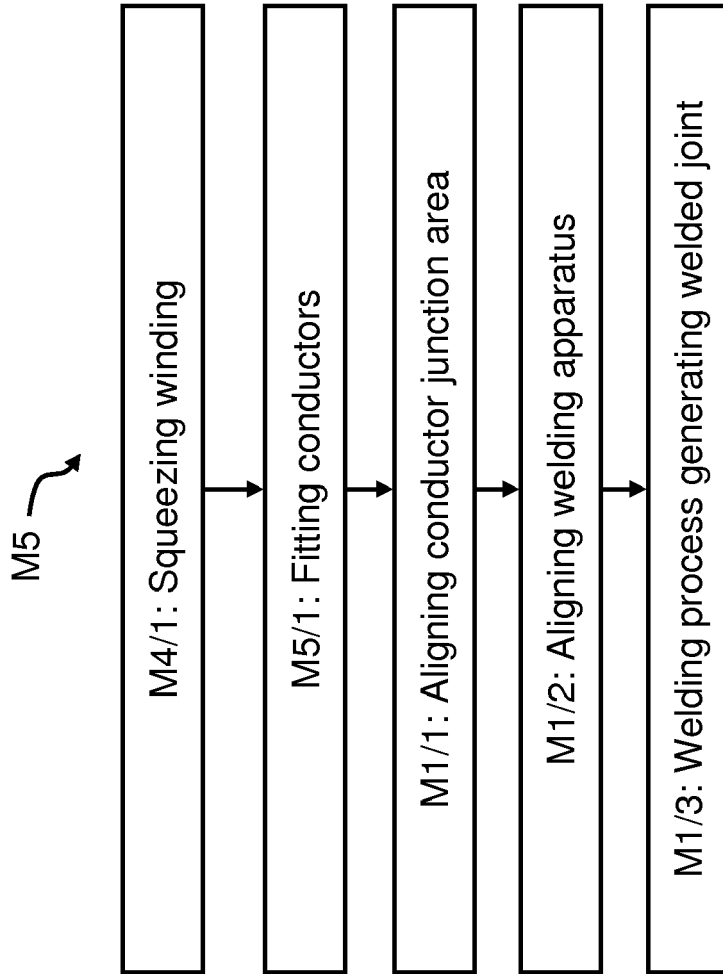


FIG. 11

*FIG. 12*

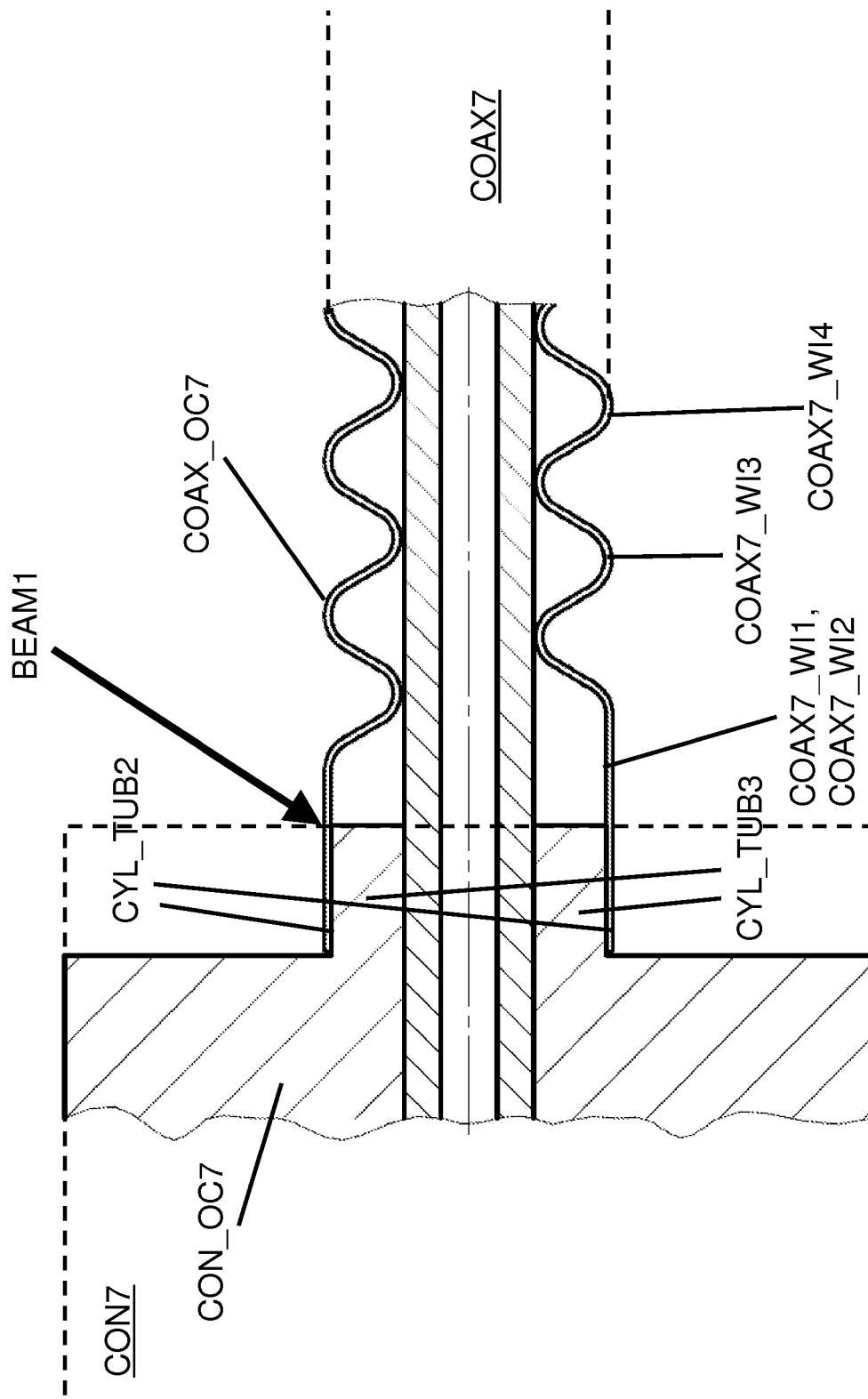


FIG. 13

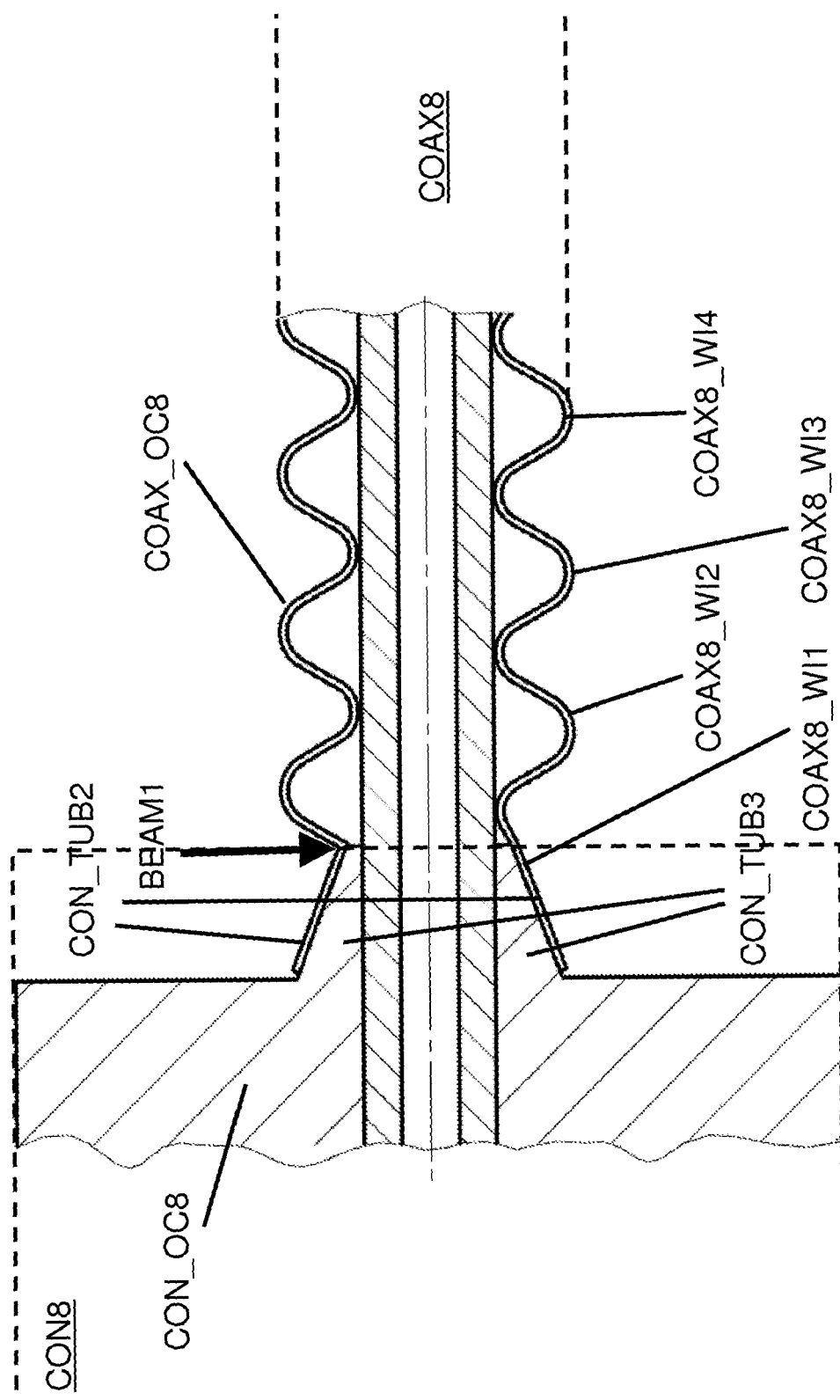


FIG. 14



EUROPEAN SEARCH REPORT

Application Number
EP 09 30 5139

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	US 5 171 166 A (SATO KENSAKU [JP] ET AL) 15 December 1992 (1992-12-15) * figure 2 *	1,2,9,12	INV. H01R4/02
X	----- CN 201 084 845 Y (CHANGZHOU ANFEINUO FUYANG COMM [CN]) 9 July 2008 (2008-07-09) * figure 2 *	1,9	
Y		10,11	
Y	----- DE 42 06 092 C1 (SPINNER GMBH ELEKTROTECHNISCHE FABRIK, 8000 MUENCHEN, DE) 1 July 1993 (1993-07-01) * figure 1 *	10	
D,Y	----- GB 1 361 609 A (BRITISH INSULATED CALLENDERS) 30 July 1974 (1974-07-30) * figure 4 *	11	

			TECHNICAL FIELDS SEARCHED (IPC)
			H01R
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 27 August 2009	Examiner Langbroek, Arjen
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			

 2
EPO FORM 1503 03/82 (P04C01)



Application Number

EP 09 30 5139

CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing claims for which payment was due.

☐ Only part of the claims have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due and for those claims for which claims fees have been paid, namely claim(s):

☐ No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due.

LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

see sheet B

☐ All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.

☐ As all searchable claims could be searched without effort justifying an additional fee, the Search Division did not invite payment of any additional fee.

☒ Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid, namely claims:

1-4, 9-12

☐ None of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims:

☐ The present supplementary European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims (Rule 164 (1) EPC).



**LACK OF UNITY OF INVENTION
SHEET B**

Application Number
EP 09 30 5139

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

1. claims: 1-4,12

Method and combination with specification of the welding process.

2. claims: 5-8

Method with specification of how to handle the outer conductor of the cable.

3. claims: 9-11

Connector in which the geometry of the connector is specified

4. claims: 13-15

Combination with material specification

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

EP 09 30 5139

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.

27-08-2009

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 5171166	A	15-12-1992	JP 4052374 U	01-05-1992
			JP 7027572 Y2	21-06-1995

CN 201084845	Y	09-07-2008	WO 2009052691 A1	30-04-2009

DE 4206092	C1	01-07-1993	CH 684719 A5	30-11-1994
			CH 684910 A5	31-01-1995
			FR 2688096 A1	03-09-1993
			GB 2264592 A	01-09-1993
			HK 1001704 A1	03-07-1998
			HK 1001706 A1	03-07-1998
			IT 1263628 B	27-08-1996

GB 1361609	A	30-07-1974	NONE	

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- GB 1361609 A [0017]