Sept. 7, 1937. H. ROST 2,092,023

CONCENTRIC CONDUCTOR FOR COMMUNICATION SYSTEMS

Filed April 13, 1935

Fig. 1.

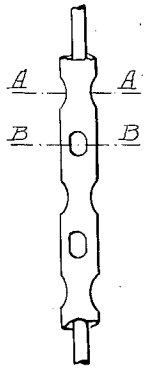


Fig. 2.



Fig. 3.



Fig. 4.

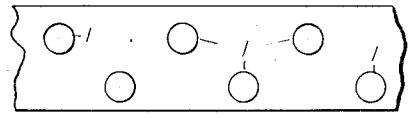


Fig. 5.



Fig. 6.

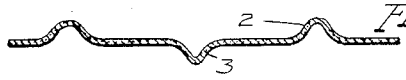


Fig. 8.

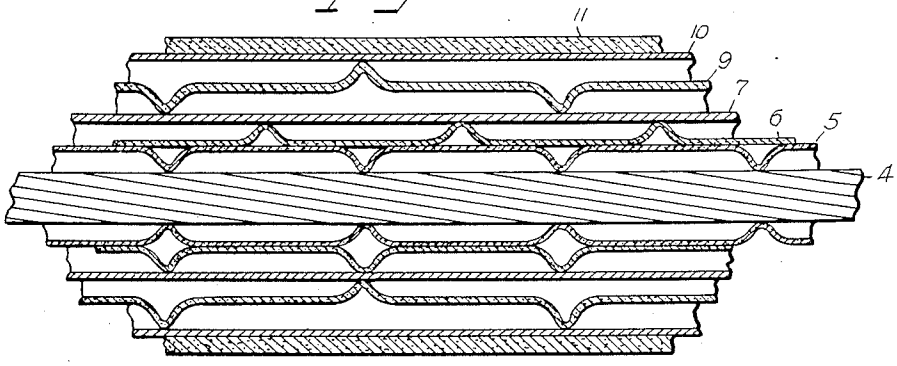


Fig. 9.

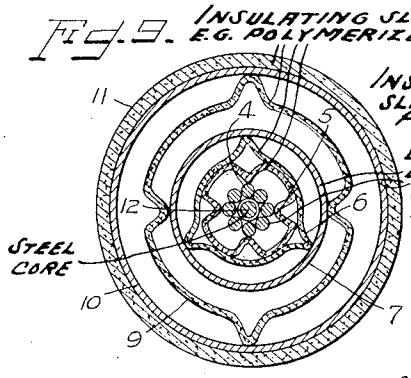


Fig. 10.

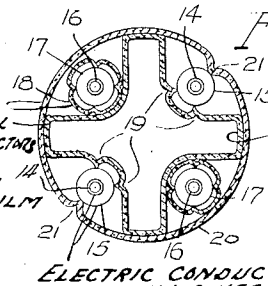


Fig. 11.

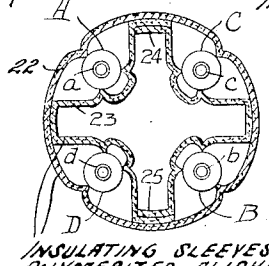
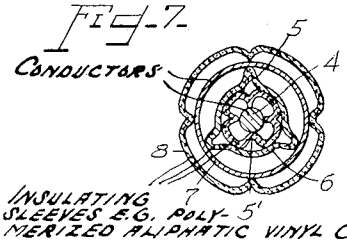


Fig. 7.



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Patented Sept. 7, 1937

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UNITED STATES PATENT OFFICE

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CONCENTRIC CONDUCTOR FOR COMMUNICATION SYSTEMS

Helge Rost, Stocksund, Sweden

Application April 13, 1935, Serial No. 16,157
In Sweden July 26, 1932

20 Claims. (Cl. 179—78)

The present invention relates to a conducting system for transmitting with small attenuation a band of frequencies, whose upper limit extends well above the frequencies now employed in carrier communication transmissions.

The present application is a continuation in part of my copending application, Serial No. 681,136, filed July 19, 1933.

Several systems have been devised, which utilize the well known coaxial structures embodying concentric conductors having insulating means so formed, that the dielectric between adjacent surfaces of the conductors will be principally gaseous.

Heretofore such insulation has consisted of washers or of discs of hard rubber, steatite, pyrex glass, etc., placed at fairly wide intervals, between the rigid conductors generally in the form of tubes of copper or lead with the central conductor either of solid copper or in the form of a tube. A semi-flexible structure of small diameter has been made, having a solid central conductor with an outer conductor of overlapping copper strips, held in place with a binding of iron or brass tape spirally wound on the copper strips. In this case the insulation consists of a cotton string wound spirally around the inner conductor.

The object of the present invention is to produce a commercial flexible coaxial structure, which can be handled on reels after the fashion of ordinary cables, which will be mechanically and electrically satisfactory, and which may be manufactured economically in a continuous process of fabrication.

The structure is suited to coaxial circuits of both small and large size conductors, without any danger of metallic contact between respective conductors, and still leaving ample air space between the insulation and the conductors, which are contacted by the insulation in a few isolated spots only. The coaxial structures of this invention will according to my preferred construction, be immensely lighter in weight and easier to handle than those now known.

By arranging several coaxial structures in the corners of perfect squares and by insulating them according to this invention, several combinations of both balanced and unbalanced circuits offer wide possibilities for future transmissions.

According to this invention, it will not be necessary to use the highest band of frequencies with large size coaxial structures, but use can be made of the smaller sizes of coaxial structures, which when combined with highly balanced circuits, possible according to this invention, will render the same number of circuits as one large coaxial structure.

In this way several inconveniences of special large size coaxial structures would be eliminated, viz., standard type construction practice can be continued, repeater stations may be placed at longer distances from one another with the resulting lower initial and maintenance costs.

Furthermore, according to this invention, numerous limitations of existing balanced communication cables of today are eliminated, and a wider field is opened up for several carrier channels in both directions of the same cable, which so far has not been possible, without special shielding arrangements or the use of different cables for transmission in each direction.

The invention may be more fully understood from the following description, when read in connection with the accompanying drawing, in which Fig. 1 is a side elevation of a conductor surrounded by an insulating sleeve; Figs. 2 and 3 are cross-sections along lines A—A and B—B of Fig. 1; Fig. 4 is an elevation and Figs. 5 and 6 longitudinal cross-sections of an insulating tape; Figs. 7, 9, 10 and 11 are transverse sections; and Fig. 8 is a longitudinal cross-section of coaxial cables in accordance with the present invention. Figures 1, 2 and 3 show an insulating sleeve around a conductor provided with interior individual protuberances, said protuberances contacting the conductor at separated points in such a way, that the conductor is kept in the center of the sleeve. The point-like protuberances are arranged so that two protuberances A—A, Figure 1, are situated opposite to one another on each side of the conductor, while another pair of protuberances B—B are arranged at a suitable distance from A—A and are situated opposite to each other and at right angles to the protuberances A—A. Other protuberances A—A and B—B are alternatingly arranged along the conductor at suitable intervals.

Figures 4, 5 and 6 are views of tapes of insulating and flexible material provided with individual point-like protuberances 1, 2 and 3, on one side (2) as in Figure 5, or on both sides (2 and 3), as in Figure 6.

Figure 7 is a substantially transverse sectional view of a coaxial structure, consisting of a central conductor 4, an insulating sleeve 5, provided with interior protuberances 5' as in Figures 1, 2 and 3; 6 denotes an insulating tape, see Figures 4 and 5, wound about the outside of the insulating sleeve 5, the tape having exterior point-like protuberances; 7 designates a concentric metallic conductor, preferably formed of one or several annealed tapes of aluminium, disposed parallel to the core and of such width, that the edges meet, or if necessary overlap, and the seams are welded according to any electric resistance welding principle, according to which the metal continuously melts or is fused between the electrodes, thus forming a perfect seam, while the core and the concentric conductor are passed through the welding machine.

It is not important that the weld be water-

tight, and as the conductor is not exposed to heavy mechanical tension strains, instead of welding by an electric resistance welding process, spot welding may also be used, or the edges of each tape may be held together simply by using a metal spraying device with aluminium as the sprayed metal and by this means a rapid and cheap welding of the longitudinal seam of the conductor can be made. If the aluminium tape is heavy enough, no welding is needed at all, as the edges can be laid side by side. In order to make the tubular conductor stiff enough, instead of pure aluminium tape, an alloy of for instance, silicon and aluminium can be used.

In order to decrease the attenuation due to the skin effect, the concentric conductor can be composed of several thin shells of metal, of which the first one can be arranged from a longitudinal tape as described above, and the remainder from tapes put on with longitudinal seams with or without welding, or wound spirally outside the first shell. Each shell or layer should be isolated from the others, either by a thin insulating film or if aluminium is used preferably by means of an insulating oxide film.

Figures 8 and 9 are substantially longitudinal and transverse sectional views, respectively, of a coaxial structure containing 3 concentric conductors, conveniently insulated from each other according to the principles of this invention. The central conductor can be solid, stranded or hollow, depending in each case upon how the coaxial structure shall be used. In the drawing a stranded conductor **4** is shown, said conductor being composed of several strands of wire, preferably of aluminium with steel-reinforced central strand **12**. Eventually the individual wires of the conductor are provided with an insulating film. By using a steel-reinforced central strand conductor a greater stability is given to the whole coaxial structure, in which the reinforced aluminium steel strand will take up the longitudinal stresses of the coaxial structure, especially when the structure is being pulled into and out of an underground duct, or when said coaxial structure is placed as an aerial cable on existing pole structures. The coaxial structure with or without outside insulation can be attached to existing messenger wires and pole line hardware, but the coaxial structure can in certain cases be suspended without special messenger wires, using the central conductor as messenger, which in such a case will take up the longitudinal stress. In these cases the whole manufacturing length of the coaxial structure is placed on the poles and attached to same by suitable fastening means, and at each end of such manufacturing lengths the steel reinforced central conductor is spliced to the corresponding central conductor of the next manufacturing length, and the other concentric conductors shall be spliced and insulated in a regular manner; suitable sleeves of somewhat larger diameter of both insulating and conducting materials must of course be used for such splices. Similar splices can be used for coaxial structures placed either on poles or underground.

Continuing the description of Figures 8 and 9, (**5**) is an insulating sleeve as per Figures 1, 2 and 3, holding the central conductor in the center of said sleeve. **6** denotes an insulating sleeve directly outside sleeve **5** with outside point-like protuberances as per Figure 5, in order to give to the concentric conductor **7** convenient insulating air space. The insulating sleeves **5** and **6** could of course be substituted by a single sleeve with protuberances on both sides as in Figure 6, whereby said sleeve can be made up by overlapping longitudinal or spirally wound tape with protuberances on both sides of the tape. **9** designates an insulating sleeve with individual point-like protuberances on its inside and outside surfaces. **10** denotes a third concentric conductor of annealed aluminium tape as above described, and **11** designates an outside mechanically and electrically insulating flexible and resilient sleeve of the same linear coefficient of expansion, as the inside insulating sleeves, said outside sleeve of sufficient mechanical strength to withstand crushing action from exterior sources, and have sufficient tensile strength together with the steel-reinforced central conductor to withstand normal longitudinal stresses, **12** being the steel strand of the central conductor.

Figure 10 is a substantially transverse sectional view of four groups of coaxial structures (**14**—**15**) and (**16**—**17**) arranged in a perfect square (so-called quad-formation) and held at equilateral distances from each other by means of a hollow insulating core **13** with or without point-like protuberances **19**, to keep the coaxial structures principally in air. Instead of providing the insulating core with protuberances, it may be constructed with smooth surface in which case each coaxial structure may be provided with an outside insulation (**18**), in the same manner as (**8**) in Figure 7, the whole coaxial structure in such a case having a form as shown in Figure 7. The conductors **14** and **15**, **16** and **17** are of course separated by insulating sleeves as previously shown, although not marked in the figure. The hollow insulating core may be made in one operation by a thermo-plastic extruded insulating material, the hollow core being twisted spirally with suitable devices in order to give to the coaxial conducting structures a transposed position in relation to outside inductive disturbances. If deemed necessary the whole quad-structure may be provided with a common insulating sheath (**20**), eventually with interior protuberances (**21**) and an outside metallic sheath or armor against outside inductive disturbances (the latter not being shown in the drawing). Figure 11 is a substantially longitudinal sectional view of four groups of coaxial structures with conductors (A—*a*), (B—*b*), (C—*c*) and (D—*d*) arranged in a perfect square and held at equilateral distances from each other by means of a hollow insulating core. This core is made preferably of one, two or more pieces, as **20** in Figure 10, or **22** and **23** in Figure 11, which afterwards are pasted or held together as shown at **24** and **25**. Should the insulating core be provided with point-like protuberances as shown, it will be easier to make these protuberances before the integral pieces are assembled.

Insulating materials

The materials preferably to be used according to this invention for the insulating sleeves shall consist of a synthetic, organic homogeneous and isotropic, chemical reaction product, without heterogeneous inclusions, as according to the experience of the inventor only such homogeneous chemical reaction products of definite and saturated organic linkages, that contain no foreign or heterogeneous inclusions, such as water, acids, salts, air, fillers, etc., show the lowest dielectric constants and lowest dielectric losses, due to the fact that conductivity through the dielectric does not exist, contrary to what

takes place in other dielectrics used heretofore, such as rubber-compounds, resins with heterogeneous plastifiers and fillers, etc.

By using pure homogenous insulating products as above specified, the capacity between the respective conductors is reduced to a minimum at zero frequency which minimum is further reduced with increased frequency, wherefore the material here specified is specially suitable for the insulation of coaxial conductors with the high frequencies to be passed through them. This is specially the case, as most of these materials are absolutely non-hyroscopic.

The organic chemical reaction products to be used according to this invention are generally obtained from cellulose-derivates or by polymerization or condensation processes of hydrocarbons or derivates thereof, or by combination of both of said processes. The chemical constituents should preferably be chosen with a view of obtaining stable and final reaction products of saturated linkages. The flexibility and needed softness of the final synthetic resins for the purpose of this invention are obtained by choosing plastic compounds of similar chemical relation to the principal constituent of the product, it being known, that these plastic compounds chemically react with the principal constituent, when both or all constituents in a polymerization or condensating process contain a common chemical group or have the same linkage.

The following examples of suitable compounds will illustrate the variety of combinations that can be made:

Examples of polymerization products

Polymerized aliphatic vinyl compounds, like polymerized vinyl acetate, polymerized styrol, polymerized vinyl halides, polymerized vinyl alcohol.

Suitable plastifiers to react chemically with said vinyl-derivates: tricresyl phosphate, diphenylol-propane, triphenyl-phosphate, diphenylol cyclohexane, butyl acetate, etc.

Examples of condensation products

Aldehyde-derivates like diphenylol-propan-formaldehyde, cresol-formaldehyde, diphenyl-cyclohexane-formaldehyde, etc.

Plasticizers for aldehyde derivates: tricresyl-phosphate, triphenyl-phosphates, butyl-acetate, etc.

Examples of polymerization and condensation products

Dibenzyl-idene-acetone of the formula

$$C_6H_5.CH=CH.CO.CH=CH.C_6H_5;$$

Examples of cellulose-derivatives

Cellulose esters like cellulose-acetate, cellulose butyrate, cellulose-benzoate;

Cellulose ethers like methyl-cellulose, ethyl-cellulose, benzyl-cellulose, etc.

Plastifiers for cellulose derivates: triacetine, tricresyl-phosphate, triphenyl-phosphate, etc.

The proportions of plastifiers to the principal constituent must be chosen in each individual case, depending upon the desired hardness, flexibility, softening temperature, etc.

Outside sheath

The outside electrically and mechanically insulating sheath around the outside concentric conductor in a concentric structure, or around a quad group of concentric conductors as per Figures 10 and 11, shall preferably be made of the same synthetic organic reaction products as the individual insulating sleeves between the respective conductors, as in that way the linear coefficient of expansion will be alike for the inside and the outside insulation, no serious or dangerous mechanical stresses taking place, due to temperature variations. By choosing aluminium for the respective conductors, the difference between the linear coefficients of expansion of the conductors and the insulating material will be less, than if copper or other conducting material were used.

Thanks to the few point-like protuberances of the elastic insulating sleeves, contacting the conductors, said conductors will slide over said protuberances, thus facilitating bending and internal movements due to temperature changes, which is an important point in these semi-flexible structures.

Thanks to the outside insulating sheath, these cable structures will be immune against electrolysis or vagabond currents in the ground.

Distribution of frequencies

Unless the shell of an outer conductor of a coaxial structure for high frequency transmission is sufficiently thick, adequate shielding is not obtained for the lower part of the frequency spectrum.

Messrs. L. Espenschied and M. E. Strieby in their paper on "Systems for wide band transmission over coaxial lines" published in "The Bell System Technical Journal" October 1934, therefore propose to suppress the lowest 5 or 10% of the frequency range, not using it for signal transmission. As it besides appears to be impractical to design repeaters, that will satisfactorily transmit a broad band of both high and low frequencies, the suppression of the lowest 5 or 10% of the frequency range is resorted to in the proposed transmission system over coaxial structures, according to Messrs. Espenschied and Strieby.

According to this invention said lower part of the frequency spectrum can be utilized to great advantage, without any of the drawbacks encountered by Messrs. Espenschied and Strieby, by simply arranging four groups of concentrically arranged conductors in a square with means of holding said groups at equilateral distance from each other, see Figures 10 and 11, and grouping the respective conductors according to balanced systems in forms of quads, whereby ordinary repeaters now used in cables with balanced conductors can be used. The shielding problem for the lower frequencies, transmitted through coaxial conductors will entirely disappear and additional valuable advantages will be obtained, which present day balanced cable conductors are lacking, as I will presently show.

By arranging four coaxial structures as shown in Figures 10 and 11, a lower part of the high frequency spectrum can be used repeatedly with the same result as if a broad band of say 1,000,000 cycles should be transmitted through one structure. Instead of for example, transmitting one million cycles' band through one large coaxial structure with 10-mile spacing of the repeaters, the same number of channels can be transmitted, according to this invention, over four smaller coaxial structures, each one with a band of up to 250,000 cycles. In this case repeaters are needed at every 20 miles only, which means a consider-

able saving of repeaters and maintenance costs.

For a coaxial circuit with about 0.3" inner diameter of the outer conductor, a 20-mile repeater spacing will enable a frequency band up to 250,000 cycles to be transmitted over each coaxial circuit. In order to avoid interference on the lower part of the spectrum, it is proposed according to this invention to use 4 coaxial circuits arranged in quad form, each coaxial circuit to transmit a frequency band from about 50,000 to 250,000 cycles.

The lower end of the frequency spectrum up to about 50,000 cycles can be transmitted over 4 balanced circuits, each one transmitting a band of about 50,000 cycles, from which we see, that with a structure as proposed according to this invention more than 200 telephone circuits (corresponding to a frequency band of 1,000,000 cycles over one coaxial line) can be obtained with 20-mile repeater spacing or more.

If instead of 2 concentric conductors, 3 such conductors are used in each coaxial structure, with of course a larger diameter of the complete quad cable, still further circuits and combinations could be obtained.

The following balanced circuits for the transmission of the lower part of the frequency spectrum can eventually be obtained, (see Figure 11):

A—B, using the upper side band of carrier,
C—D, using the upper side band of carrier,
a—*b*, using the lower side band of carrier,
c—*d*, using the lower side band of carrier.

Phantom A—B—C—D for talking frequency and eventually using the upper side band of carrier.

Phantom *a*—*b*—*c*—*d* for carrier telegraph and eventually using the lower side band. In order to obtain the best results, the carrier wave should be suppressed in above cases.

Thanks to the high symmetry and stable insulating conditions of the transmitting system according to this invention, the transmission of the same frequencies over the balanced circuits is entirely feasible.

Attention is called to the peculiar feature of this invention, according to which two extra balanced transmission circuits are obtained from two coaxial two-conductor circuits, one balanced circuit inside the other balanced circuit and shielded by same.

Another important feature of the invention consists of the fact that although said balanced circuits are parallel and its conductors run side by side, transmission interference between both circuits is avoided, although the same frequencies are transmitted over both conductors, simply by using the upper side band for one circuit and the lower side band for the other circuit.

Apart from above mentioned four single balanced circuits, two extra balanced phantom circuits can be obtained, one within the other and shielded by same, which circuits will allow at least one low frequency talking circuit, one alternating power circuit for the feeding of the repeaters, one frequency range up to 50,000 cycles using the upper side band, and another similar frequency range using the lower side band.

According to need, different structures of both the unbalanced coaxial and the balanced symmetrical circuits can be chosen for transmission in one or the other direction, sufficient shielding effect between the different circuits existing to avoid interference due to high gain of the repeaters.

It will be obvious. that the general principles herein disclosed may be embodied in many other combinations different from those here mentioned without departing from the spirit of the invention as defined in the following claims.

What is claimed is:

1. In a conducting system for the communication of intelligence, a plurality of conductors arranged concentrically, a flexible continuous insulating sleeve interposed between each pair of adjacent conductors, said sleeve completely surrounding the inner conductor and being provided with individual protuberances on its inside to support the said sleeve in spaced relation with respect to the said inner conductor, said sleeve being provided with a second set of protuberances on the outside surfaces to support the outer conductor in spaced relation thereto, said individual protuberances contacting the respective conductors at separated points and establishing a relatively large air space between each conductor and the sleeve.

2. In a conducting system for the communication of intelligence, a plurality of conductors arranged concentrically as claimed in claim 1, the center conductor being in the form of a stranded conductor, composed of several solid wires of conducting material and of sufficient strength to withstand longitudinal mechanical stresses.

3. In a conducting system for the communication of intelligence, a plurality of conductors arranged concentrically as per claim 1, the center conductor being in the form of a stranded conductor, composed of several solid wires of aluminum, each wire having an insulating film.

4. In a conducting system for the communication of intelligence, a plurality of conductors arranged concentrically as per claim 1, the center conductor being in the form of a stranded conductor, composed of several solid wires of conducting material, the center strand consisting of steel and the outer wires of aluminium.

5. In a conducting system for the communication of intelligence, a plurality of conductors arranged concentrically as claimed in claim 1, at least one of said conductors consisting of a plurality of superimposed cylindrical shells of metal, an insulating film being disposed between each pair of adjacent shells.

6. In a conducting system for the communication of intelligence, a plurality of conductors arranged concentrically as claimed in claim 1, at least one of said conductors being in the form of a plurality of cylindrical shells of annealed aluminium, each shell provided with an insulating film.

7. In a conducting system for the communication of intelligence, a plurality of conductors arranged concentrically, as claimed in claim 1, the outermost conductor being provided with an external electrical insulating and mechanically protecting sheath, consisting of a tough, flexible, synthetic, organic, chemical reaction product of similar linear coefficient of expansion as the insulating sleeves, separating the respective conductors.

8. In a conducting system for the communication of intelligence, a plurality of conductors arranged concentrically as claimed in claim 1, four groups of such concentrically arranged conductors arranged in a square and held at equilateral distances from each other by means of a hollow insulating core of suitable cross section, formed of a synthetic organic homogeneous and isotropic chemical reaction product, and provided with longitudinal recesses for the reception of the cor-

responding groups, the so-formed quad group being provided with a common external insulation.

9. In a conducting system for communication of intelligence, several conductors arranged concentrically as claimed in claim 1, four groups of such concentrically arranged conductors arranged in a square and held at equilateral distances from each other by means of a hollow insulating core of suitable cross-section, formed of a synthetic organic homogeneous and isotropic chemical reaction product, and provided with longitudinal recesses for the reception of the corresponding groups, the quad being provided with a common external insulation of the same insulating material as the hollow core, the longitudinal recesses of the hollow core and the external insulation being provided with individual protuberances and recesses at the points of contact with the individual groups.

10. In a conducting system for communication of intelligence, several conductors arranged concentrically as claimed in claim 1, four groups of such concentrically arranged conductors arranged in a square and held at equilateral distances from each other by means of a hollow insulating core of suitable cross section, each concentric unbalanced circuit to be used for a range of frequencies extending upwards from the limit, above which the shielding effect of the outer coaxial conductors of the system makes the coaxial circuits immune to external interference, and balanced circuits, each one composed of a concentric conductor of a coaxial structure and the corresponding conductor, occupying the same position in a diagonally situated coaxial structure to be used for ranges of frequencies below said limit.

11. In a conducting system for communication of intelligence, several conductors arranged concentrically as claimed in claim 1, four groups of such concentrically arranged conductors arranged in a square, and held at equilateral distances from each other by means of a hollow insulating core of suitable cross section, two balanced transmission circuits being formed from two diagonally situated coaxial structures, one of said balanced circuits being located inside the other and shielded by same, both of said balanced circuits to be used for ranges of frequencies, extending from zero to a frequency, above which the shielding effect of the outer coaxial conductors of the system makes the coaxial circuits immune to external interferences.

12. In a conducting system for communication of intelligence, several conductors arranged concentrically as claimed in claim 1, two pairs of groups of said concentrically arranged conductors, arranged in a square and held at equilateral distances diagonally from each other by means of a hollow insulating core of suitable cross-section, said two pairs of groups forming four balanced transmission circuits, two of the said circuits being located inside the other two and shielded by the same, said circuits being connected to form two balanced four-conductor phantom transmission circuits, one inside the other and shielded by the same.

13. In a conducting system for communication of intelligence, several conductors, arranged concentrically as claimed in claim 1, four groups of such concentrically arranged conductors arranged in a square, and held at equilateral distances from each other, by means of a hollow insulating core of suitable cross section, two balanced circuits, each one composed of an interior concentric conductor of a coaxial structure and the corresponding interior conductor, occupying the same position in a diagonally situated coaxial structure, both balanced circuits being side-circuits of and forming a phantom circuit, both side-circuits being shielded from each other through exterior concentric conductors of the corresponding coaxial structures.

14. The system claimed in claim 1, in which said insulating sleeve between adjacent conductors consists of two parts, one of said parts being provided with the said inside protuberances and the second part of said sleeve being provided with the said outside protuberances.

15. The system claimed in claim 1, in which said insulating sleeve between adjacent conductors consists of two parts, one of said parts being provided with the said inside protuberances and the second part of said sleeve being provided with the said outside protuberances, the said outside and inside protuberances being off-set with respect to one another.

16. The system claimed in claim 1, in which said insulating sleeve between adjacent conductors consists of two parts, one of said parts being provided with the said inside protuberances and the second part of said sleeve being provided with the said outside protuberances, the said outside and inside protuberances coinciding with one another, an air space being formed between each pair of coinciding protuberances.

17. In a conducting system for the communication of intelligence, a plurality of conductors arranged concentrically as claimed in claim 1, the center conductor being in the form of a stranded conductor, composed of several solid wires of aluminium, each wire having an insulating film consisting of a layer of oxide formed thereupon.

18. In a conducting system for the communication of intelligence, a plurality of conductors arranged concentrically as per claim 1, at least one of said conductors being in the form of a plurality of cylindrical shells of annealed aluminium, each shell provided with an insulating film consisting of a layer of oxide formed thereupon.

19. In a conducting system for the communication of intelligence, a plurality of conductors arranged concentrically, as per claim 1, the outermost conductor being provided with an external electrical insulating and mechanically protecting sheath, consisting of a tough, flexible, synthetic, organic, chemical reaction product of similar linear coefficient of expansion as the insulating sleeves, separating the respective conductors, said external insulating and protecting sheath being provided with indentations contacting the adjacent conductor and serving to support the same in spaced relation with respect thereto.

20. In a conducting system for the communication of intelligence, a plurality of conductors arranged concentrically as claimed in claim 1, the center conductor being in the form of a stranded conductor, composed of several solid wires, each wire having an insulating film.

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