This invention relates to electrical connectors and has particular reference to connectors for coaxial transmission lines. More specifically it relates to angle connectors so designed as to be suited for use at higher frequencies than practicable with connectors of the types hereetofore known.

The need for improvements in all connectors suited to such frequencies has long been felt, but it is particularly pressing in connection with angle connectors. This may well be due in large part to the fact that the technical considerations governing the performance of transmission lines meeting at an angle to each other are not fully understood even by persons most closely associated with this field of endeavor and most learned in the art, but in any event it is a fact that there has heretofore been an unsatisfied demand for a connector which is capable of the requisite electrical and electronic performance. This involves certain requirements, but particularly requires that the connector be of such design and construction that it maintains a low VSWR (voltage standing wave ratio) characteristic over a wide band of frequencies. This is due to the known fact that any abrupt deviation from the desired characteristic impedance along successive incremental portions of the propagation path of the signal gives rise to undesired reflections of signal energy and produces standing waves in the line unless compensated. Such uncompensated reflections decrease the efficiency of the line in all radio frequencies, and are particularly troublesome in the higher frequency ranges.

There are angle connectors commercially available which have been employed rather widely and are well suited to certain uses, but when used in the extreme upper frequency ranges, any of the types heretofore developed have shown themselves to be subject to certain shortcomings which have seriously interfered with their acceptability in the more technical phases of the electronic arts. The reasons for these shortcomings may not be fully understood, but it is believed that they stem primarily from the fact that in structures of the types heretofore proposed, the configuration of the line is so abruptly changed at the point of junction between the angularly disposed lines as to produce high electrical field distortions, increase the shunt capacitance, and thus produce a high standing wave ratio.

It is, therefore, an important aim to provide an improved angle connector for a high frequency coaxial transmission line wherein these shortcomings of prior art devices are overcome and a higher standard of performance than heretofore possible is attained. More specifically, it is an object of the present invention to produce an angle connector wherein the VSWR of the line remains substantially constant even in the extreme frequency ranges, not only at the point at which the direction of propagation of the signal is changed, but throughout the connector. This is accomplished according to the present invention by a structure wherein compensation for field distortion through decrease in shunt capacitance and subsequent reduction in

VSWR is obtained by increasing the internal volume at the intersection of the coaxial lines through termination of at least one of the bores in a flat bottomed surface.

Notwithstanding the need for extremely efficient performance, it is important from a manufacturing standpoint that connectors of this type have several parts so designed, constructed and related that they are capable of manufacture by economical methods, are readily assembled, and are at the same time so constructed that the various and sundry varieties of connectors required may be assembled from a relatively small number of component parts.

All of the requirements enumerated above are essentially conflicting, and not easily reconciled to simultaneous accomplishment. This is amply evidenced by the fact that no mechanically simple device capable of satisfactory electronic performance has heretofore been proposed.

As a matter of fact, the mechanical aspects alone present a serious production problem in connectors of this type, for the reason that the various types of angle connectors (including X connectors, simple angled connectors and T-connectors) required in the art give rise to a need for a surprisingly large number of different variations of structure, particularly in the various permutations of male and female terminal fittings thereon. This brings about a situation wherein all of the various forms of connectors that may be required can be manufactured by conventional methods only by stocking an unusually large variety of component parts.

Even the seemingly simple T-connector requires many variations in structure to provide the variety of fittings called for. For example, it may require all male terminals or all female; or it may require male terminals at the opposite ends with a female center terminal, or female terminals at the opposite ends with a male center terminal. It may further require one end and the center terminal male, and vice versa. Thus, with the numerous possible permutations of fittings required, a single basic type of T-connector has in actuality some six different body types.

There are three additional possibilities for the right angle connector, and an even larger number for an X connector, for example.

It is therefore seen that, from a manufacturing standpoint, it is an extremely important aim to be able to produce any one of these various types of angle connectors which may be required, yet to do so without undue complications and without an unnecessarily large variety of component parts.

These desirable results are attained by the novel types of connectors here disclosed, in which the conflicting mechanical and electronic requirements are reconciled so well that connectors according to the present disclosure have electronic characteristics surpassing the best of the previously known types, yet are so designed mechanically that the units are simpler and more convenient to manufacture than those hereinafter described. This may be best explained in connection with the drawings of the present specifications, wherein several preferred commercial embodiments of angle connectors made according to the present teachings are illustrated.

In the drawings:

Figure 1 is a central sectional view through a right angle coaxial connector constructed in accordance with the teachings of this disclosure;

Figure 2 is a detail sectional view taken on the plane of the line 2--2 of Figure 1;

Figure 3 is a detail sectional view taken on the plane of the line 3--3 of Figure 1;

Figure 4 is an exploded sectional view showing the principal component parts of the "shell" or housing of the right angle connector illustrated, showing the manner in which the connector is preferably assembled;
Figure 5 is an exploded perspective view of the principal internal component parts of the connector; that is, the central terminals, the conductors integral therewith and the insulating tubes which form the dielectric of the device;

Figure 6 is a central sectional view through an angle connector of a T type, constructed in accordance with the present teachings;

Figure 7 is a central sectional view taken on the plane of the line 7--7 of Figure 6;

Figures 8, 9, 10 and 11 are perspective views of the four principal component parts of the connector shell utilized in the several types of angle connectors illustrated; and

Figures 12 to 19, inclusive, are reduced scale elevational views of the various styles and types of angle connectors which may be assembled from the same principal component parts employed in the connectors heretofore illustrated.

It is contemplated that the teachings of the present invention may be utilized in any one of the various types of angle connectors employed in connection with coaxial transmission lines, but the right angle connector illustrated in Figures 1 to 3, inclusive, is probably the simplest form of the invention, and will accordingly be described first. The component parts of this connector are illustrated in Figure 4, where it will be seen that the connector comprises a body portion 10 which is of cubical exterior shape (see Figure 8), a female connector subassembly 11 (Figure 9), a male connector subassembly 13 (Figure 10), and a pair of closure plugs 133 (Figure 11). The body portion 10 has a plurality of counterbored apertures which, in the present example of the inventive teaching, comprise apertures 14, 15, 16 and 17 spaced on the opposite faces of the body and arranged at right angles to each other. These apertures are at the opposite ends of a pair of cylindrical holes 18 and 19 which extend into the body and intersect each other at the center of the body portion. That is, the bore 18 extending from the aperture 14 to the aperture 16 intersects the bore 19 extending between the apertures 15 and 17. The point of axial intersection of the bores 18 and 19 is at the geometric center of the body 10 as indicated at 21. It is to be particularly noted, however, that even when the apertures 16 and 17 are closed by the plugs 13, the bore from each of the apertures 14 and 15 extends beyond the point of axial intersection and continues as a cylindrical portion, with the inside faces 22 of the plugs 13 providing each bore with right angles to its opposite side walls 23 (Figure 2). The bottom of the bore 18 is in line with the lower wall of the bore 19, and the flat bottom at the right end of the bore 19 is in line with the right side of the bore 18.

The bores 18 and 19 and the counterbores of their respective apertures 14, 15, 16 and 17 are of identical size and shape, so that the counterbored mouths of either of these apertures may receive and mate with the pilot portion 24 and bore 26 of a terminal sleeve 27 of the female connector subassembly 11, or the pilot portion 28 and bore 29 of one of the male fittings subassembly sleeves 12 (Figure 4). The terminal sleeve 27 of the female subassembly 11 has an external coupling ring 31 rotatably locked thereon by a flange 32 and locating ring 33. The coupling ring 31 has internal bayonet slots 34 arranged to engage the external pins 35 of the male subassembly 12. The bore 25 of the male terminal sleeve 12 has a tapered counterbored portion 56 to receive the end portion 37 of the sleeve 27 of another connector of the same design (see Figure 1). Similarly, the female subassembly 11 is adapted to receive the mating male assembly of another connector. In either case, when a pair of the interengaging male and female subassemblies are united, the separate walls of the bore assemblies, concentric and of uniform diameter throughout. This is an important feature in maintaining the desired constant impedance characteristic throughout the point of union between two connectors, as will appear.

The plugs 13 (Figures 4 and 11) each include a center pilot portion 41 of size and shape to fit any one of the bores 18 or 19, and a flange 42 is dimensioned to close any one of the counterbores of the apertures 14, 15, 16 and 17. Thus, it will be apparent that by employing various combinations of the female subassemblies 11, the male subassemblies 12, the body portions 10 and the plugs 13, it is possible to provide any one of a large variety of different angle connector types. For example, by utilizing one of each of these parts, the right angle connector illustrated in Figures 1 to 3 may be constructed, while by utilizing a body 10 with two female subassemblies or a body with two male subassemblies, the modified right angle connectors illustrated in Figures 18 and 19 may be assembled. Similarly, by utilizing three of the terminal sleeve subassemblies and eliminating one of the plugs 13, any one of the different angle connectors of the several T types illustrated in Figures 12 to 17, inclusive, may be assembled, yet all of these may be assembled from a relatively small number of identical external component parts.

To assemble a connector, a body portion 16 is first fitted with male subassembly sleeves 12 and female subassembly sleeves 27 as desired. Plugs 13 are placed in any unused apertures. These several components of the shell of the connector are then clamped together in fixtures provided for the purpose, and soldered or brazed.

This is conveniently done by placing a thin ring of silver solder between the body portion and each of the terminal sleeves or plugs thereof, holding the parts together under pressure and heating the entire unit by induction heating apparatus to melt the solder and fuse the terminal sleeves and plug in firm electrical union with the bores and counterbore apertures in the body shell.

The dielectric body of the connector consists of a pair of insulating tubes which support a metallic center conductor (Figure 5). In the angle connector of Figure 1, the sleeves 43 and 44 have internal bores 45 and 46 to fit the conductors 47 and 48, respectively. The tubes 43 and 44 are mitered at their inner ends 49 so that when assembled, may lie in the relation illustrated in Figures 1 to 3. The dielectric tubes 43 and 44 may be of any suitable insulating material, but in the preferred form of the invention, the plastic known under the trade name of "Teflon" is employed, since it has the desired electrical characteristics and is capable of withstanding high temperatures, not only during the assembly of the fitting, but when in use in applications designed for such temperatures.

The tube 44 has a reduced end portion 51 at its outer end and the tube 43 has a count bore 52 of corresponding size and shape so that when male and female connectors are coupled together, they will interfit as shown in Figure 1 to afford a substantially uninterrupted dielectric body of uniform thickness throughout. This avoids variations in impedance that might otherwise give rise to reflections and standing waves.

The central conductor 47 has a tapered connecting pin 53 at its outer end and a reduced inner end portion 54 bent at right angles and brazed or soldered into the end bore 55 of the conductor 48. A solder port 56 is provided to facilitate soldering. The outer end of the conductor 48 is end drilled and split at 57, to afford a spring receptacle for the contact pin 53 of a mating connector.

From the foregoing it will be apparent that to assemble a simple angle connector such as illustrated in Figures 1 to 3, inclusive, it is only necessary to insert the internal metallic parts 47 and 48 (which have been previously soldered together), into a connector shell prepared as orthofoley described, and to slide the sleeves 43 and 44 into position. These sleeves may be pressed into the bores of the shell if desired, or held by small
indentations of the shell or other means. It is to be noted, however, that in the assembled structure the dielectric inserts are fitted closely into the bores of the body portion, but that since the bore 18 extends to the flat bottom surface 22 of one of the plugs 13, the walls 23 extend beyond the walls of the bore 19 with which it intersects. This provides open voids or air spaces 50 adjacent the intersection of the bores (Figure 2). Similarly, it is seen that when the right hand end of the bore 19 is closed by the plug 13 (Figure 3), the plug forms a flat bottom 22 for the bore, and provides for similar voids or air spaces 50c.

The same types of component parts of the shell employed to make the simple two-branch, right angle connector shown in Figures 1 to 3 may also be employed to produce three-branch connectors as shown in Figures 6 and 7, and various combinations of these components may be employed to manufacture any one of the several forms of two- or three-branch angle connectors illustrated in Figures 12 to 19, inclusive. In constructing the connector of Figures 6 and 7, for example, the body section 10 is provided with two male subassemblies 12 on the ends and one female subassembly 11 in the center. Modified dielectric sleeves or tubes 58 and 59 are provided, and the central metallic conductor 61 is threaded at 62 to receive a reduced threaded portion of a conductor 63 having an integral male contact pin 64 therein. The conductor 61 is supported in the tubular dielectric insert 58 which has a ninety-degree notch intermediate its ends, and the conductor 63 is similarly supported by the tubular dielectric insert 59, which has its innermost end modified to fit within the notch as shown.

From the foregoing it should be clear that the present teachings provide an important advance in the connector art in two respects. In the first place, they make possible the convenient, economical and expeditious manufacture of the outer shells of any one of a large variety of slightly different types of angle connectors from one or more units of only four separate component parts. This is of considerable advantage from a manufacturing standpoint in that it permits flexibility of assembly and reduces inventory requirements, while at the same time providing for all contingencies as to demands for the various types of connectors involved.

In addition to this, the present teachings provide an angle connector which is of novel internal construction such that it achieves electronic efficiency not possible with types heretofore developed. This is due to the unique interior configuration of the body portion 10 wherein the bores 18 and 19 may both be bottomed with a surface 22 at right angles to the axis of the bore and in the same plane as one of the wall surfaces of the bores which it intersects. The continuation of either or both bores beyond the point of axial intersection and the termination of the bores in a flat bottomed surface increases the internal volume of the connector at the intersection of the coaxial lines, decreases the electrical field intensity and standing wave ratio, and reduces the electrical field distortions. The overall result is that a connector of lower VSWR is provided and that performance characteristics are improved, particularly in the higher frequencies.

It is also to be noted that connectors as disclosed herein maintain a constant characteristic at the point of union with other connectors, as well as at the point of intersection with an angularly disposed line. In the present connectors the several parts are so proportioned and dimensioned that the mating parts of the connector coact to produce a coaxial line having uniform bore diameter and uniform internal conductor diameter at all points, with the dielectric body extending entirely through. The internal and external surfaces of the conductors are thus smooth and uniform throughout, and there is no variation of the dielectric constant due to air gaps, etc. It follows that the connector presents a constant characteristic impedance to the signal, not only at the angle between the connector fittings, but also throughout the union between connectors.

Having thus described my invention, what I claim as new and desire to secure by United States Letters Patent is:

1. A junction between a coaxial cable terminal and a coaxial transmission line connector, the combination of a pair of mating terminal sleeves with connector fittings externally thereof, one of said sleeves having a counterbore at its outer end constructed and arranged to receive the outer end of the other sleeve; said sleeves having cylindrical bores of the same internal diameter extending therethrough, with said bores being of uniform diameter throughout their effective length; a dielectric within said bores comprising a pair of straight hollow cylindrical insulating tubes having the same internal and external diameters, with a complementary interfitting counterbore and reduced portion at their outer ends, together with a central conductor of uniform external diameter extending through said tubes and having mating interfitting connections at the outer ends thereof.

2. In a junction between a coaxial cable terminal and a coaxial transmission line connector, the combination of a pair of mating terminal sleeves having interfitting connections at their outer ends and connector fittings externally thereof, said sleeves each having a cylindrical bore extending therethrough, with said bores being of the same diameter at their outer ends and of uniform diameter throughout their effective length; a dielectric within said bores, and central conductors of the same exterior diameter extending through each of said sleeves and having mating interfitting connections at the outer ends thereof.

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