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WIDE BAND IMPEDANCE TRANSFORMER

Filed Oct. 27, 1964

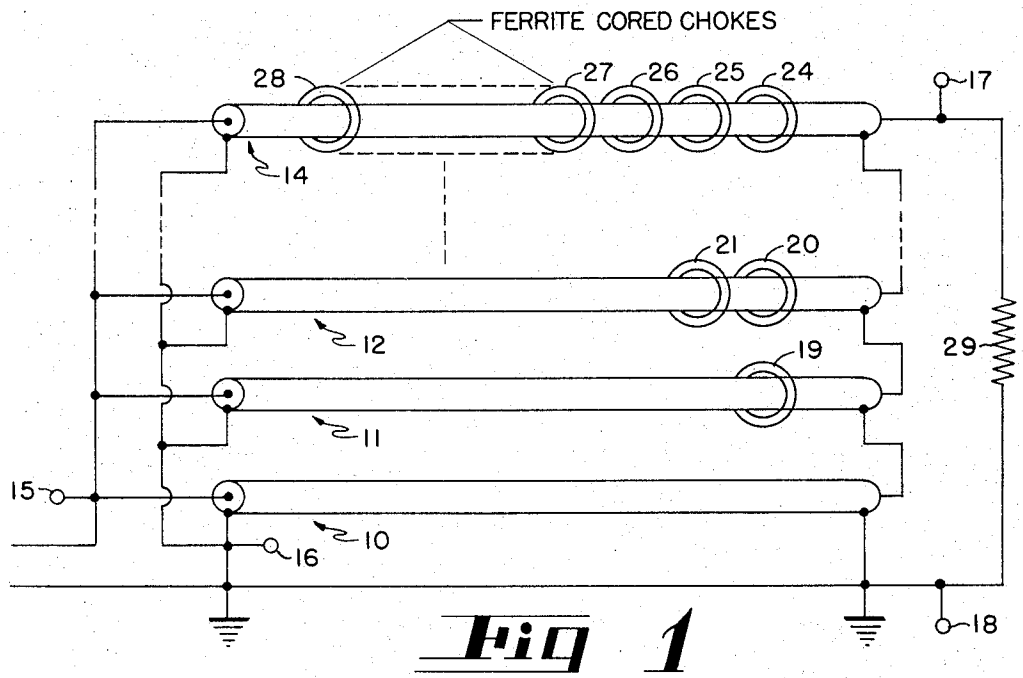


Fig 1

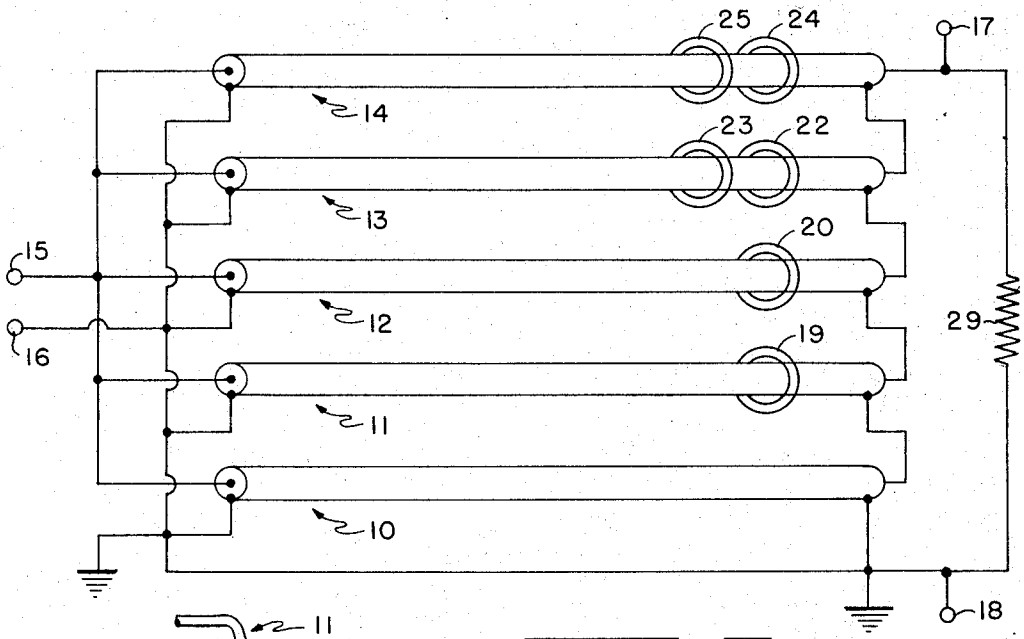


Fig 2

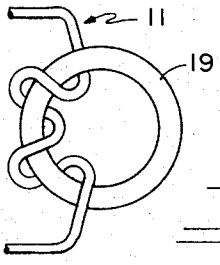


Fig 3

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WIDE BAND IMPEDANCE TRANSFORMER

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ABSTRACT OF THE DISCLOSURE

This is a wide band impedance transforming device comprising a plurality of coaxial transmission lines. The lines are connected in parallel at the input end, the outer conductors being there connected to ground and the inner conductors being there connected to an ungrounded input terminal.

The output ends are connected in series and at that end one of the outer conductors is connected to ground, the other outer conductors being at progressively higher potentials relative to ground. In order to prevent current flow back through the outer conductors, portions of the outer conductors adjacent the output end are wound about one or more cores of magnetic material to provide "choking action." The effective characteristic impedance of the system at the output end is equal to the sum of the characteristic impedances of the several coaxial lines. At the input end the reciprocals of the several characteristic impedances sum to equal the reciprocal of the effective characteristic impedance.

The present invention relates to impedance-matching and transmission devices.

A primary object of the invention is to provide a device of this character which efficiently transforms signals from one impedance level to another impedance level in a manner substantially independent of frequency.

Restated, a principal object of the invention is to provide an impedance transformation device which is operable over a wide range of frequencies.

Another object of the invention is to provide an impedance transfer device of resistive character.

Other objects of the invention are to provide an impedance-matching or transfer device which is flexible in design principle, involves no moving parts, is compact, and uses low-cost and readily available material.

It is a further object of the invention to provide a linear impedance transformer of extensive frequency range, high power handling capability, and low cost.

Another object of the invention is to provide a device of this character which is free of external electromagnetic fields and unaffected by fields generated nearby.

For a better understanding of the invention, together with other and further objects, advantages, and capabilities thereof, reference is made to the following description of the accompanying drawings, in which:

FIG. 1 is a circuit schematic employed in describing the principles on which a transfer device in accordance with the invention is constructed;

FIG. 2 is a schematic diagram of a preferred embodiment of the invention; and

FIG. 3 is a fragmentary perspective view showing how a line is wound around a toroid.

The present invention fully exploits the fact that a transmission line terminated in its characteristic impedance presents to its input terminals a constant impedance which is independent of frequency. The invention further exploits the fact that a network of several such transmission lines may be connected in one fashion, let us say in parallel, to present a low impedance "looking into" the input terminals of the network, while the lines may be connected in series, for example, to present a high impedance across the output terminals of the network.

Reference is made to FIG. 1 for an illustration of the general case in which these principles are utilized. The impedance transmission device is made up of coaxial lines **10**, **11**, **12**, **13** (not shown in FIG. 1), and so forth, the *n*th line being referred to in FIG. 1 by the reference numeral **14**. The central conductor of each coaxial line is conductively connected to an input terminal **15**. The outer conductors of the lines are connected to an input terminal **16**, which is grounded. The outputs of the several lines are connected in series between output terminals **17** and **18**, the latter being grounded. Toroids **19**, **20**, **21**, **24**, **25**, **26**, **27**, and **28** are provided, as needed, for a purpose described below.

For purposes of discussion, let it be assumed that the particular application involves working out of a low impedance device and into a high impedance device, let us say 10 ohms and 250 ohms, respectively. The required number of lines n equals the square root of Z_2/Z_1, in this case 5. The required characteristic impedance of each line $Z_0=\sqrt{Z_1 \cdot Z_2}=\sqrt{2500}=50$. In other words, five fifty-ohm lines connected as shown in FIG. 1 provide an input impedance of 10 ohms and an output impedance of 250 ohms. The 250-ohm terminating load is numbered **29** in FIG. 1 and is, of course, connected across the output terminals **17** and **18**. The load **29** places a 50-ohm load across each line. Since the input terminals of all the lines are connected in parallel, the input impedance at terminals **15** and **16** "looks like" 10 ohms. The output impedance looking into terminals **17**, **18** is 250 ohms. Since the lines are non-resonant, the transforming action is independent of frequency.

Now, reference has been made to the toroids such as **19**, **20**, and **21**, and their purpose will now be described. Broadly speaking, they function as chokes. All of the outer conductors are at the ground potential of input terminal **16** on the low impedance side. However, at the high impedance side only the outer conductor of line **10** is at ground potential, while the other outer conductors (i.e., those of lines **11**, **12**, . . . **14**) are progressively higher than ground potential. These potential differences can cause current flow on the outside of the coaxial lines, setting up power reflections, disturbing the line termination, and introducing stray coupling to nearby circuitry. In fulfillment of one of the objects of the invention, this surface current and its resultant magnetic fields are eliminated.

Each line (such as **11**) having an outer conductor in which there is a potential difference between one end and the other sufficient to produce such current flow is wound (in the manner of a simple conductor) about one or more toroids such as **19** (FIG. 3). For example, the line **12** is wound about toroid **21** for one or more turns and then is wound on toroid **20** for one or more turns. The toroids are of ferrite and therefore have high permeability. They are located near the high potential side of each line. When a line is wound about a toroid, there is formed a high impedance choke which looks like an open circuit to the

flow (toward ground) of signal current on the outside of the outer conductors, and accordingly it impedes or prevents such flow. However, this use of the toroids does not affect the flow of signal currents within the coaxial lines or cables.

The more cables used for higher transformation ratios, the more will be the isolation or choking required to prevent external current flow on the outer conductors of the coaxial cables.

As indicated, the toroids are located as close as possible to the high impedance or series-connected end of the transformer. The amount of choking action should be such that the summation of currents flowing back on the outside conductor of all the cables will be very small compared to the current delivered to the load.

Use of high permeability toroids requires fewer turns of the cable on the toroid for a given choke action. That keeps the cable length down, reduces the signal loss and the size of the transformer, and lowers the shunt capacity across the choke, improving high frequency operation.

The electromagnetic fields set up by the choking action are self-contained, since the coaxial cables are wrapped around the toroids, each of which forms a complete low reluctance path. And, since the choking action eliminates current flow on the external conductors of the cables, no ambient or external electromagnetic field is generated. Likewise, the transformed signal within the transformer is unaffected by any fields generated by other nearby current flow.

Each coaxial cable of the transformer can be physically treated completely independent of the other cables. Thus each cable can be located or routed at the discretion of the designer or as dictated by the available space. The impedance transformer may assume odd and compact assembly form.

The ferrite material of the toroids is not in the desired signal path. It is used as a choke means to eliminate unwanted signal paths. That feature eliminates the associated losses and non-linearities usually experienced with ferrite materials at large power levels. This allows the use of smaller volumes and weights of ferrite with respect to the higher power levels of signal power transfer.

Now making reference to the particular embodiment illustrated in FIG. 2, it consists of coaxial lines **10–14** and toroids **19**, **20**, and **22–25**. It feeds into a 250-ohm load **29** and out of a 10-ohm input network or device (not shown). The inputs of the lines are connected in parallel and the outputs of the lines are connected in series, this being a specific application of the general case. The number of cables is 5, and the characteristic impedance of each is 50 ohms. Therefore, at the low impedance side the impedance seen looking into the input terminals is 50/5 ohms, or 10 ohms. On the high impedance side the terminating load is equal to 5 times 50 ohms, or 250 ohms, the signal paths of transmission being restricted to the inside of the coaxial cables. All of the power delivered to the device, independent of frequency, will be absorbed by the load (neglecting the loss in the cables). The impedance transformation ratio is equal to

$$\frac{nZ_0}{\frac{Z_0}{n}}=n^2, \text{ or } \frac{5\cdot 50}{\frac{50}{5}}=\frac{250}{10}=25$$

Persons skilled in the art will now recognize that various combinations of lines may be employed to obtain various transformation ratios. Many variations and ramifications are permissible within the scope of this concept.

In the FIG. 2 embodiment, ample choking was obtained by the use of toroids **19**, **20**, and **22–25**. About fifteen turns of cable were wound on each toroid (see FIG. 3) to provide the desired filter or choking action. Note is made of the fact that the mode of winding is shown in FIG. 3. For purposes of simplicity in illustration, it is not shown in FIGS. 1 and 2. An impedance transfer device in accordance with FIG. 2 and constructed in this

manner was utilized to produce a power drive at the output load in excess of 80 watts, and measurements were as follows, R_s being the series input resistance and X_s being the series input reactance:

Frequency in megacycles	R_s, ohms	X_s, ohms
2	9.7	+0
5	9.6	+0
10	9.6	+0.7
15	9.5	+1.26
20	10.0	+1.0
25	9.8	+1.36
30	9.7	+1.33
35	10.5	+0.4
40	9.8	+1.7
50	10.0	+2.3
60	10.1	+2.5
70	10.4	+2.7
80	10.0	+3.0

The new device may be adapted and used between any and all types of stages where impedance transformation may be needed. This device is very useful as an antenna coupler in wide frequency band equipment.

The rugged nature of this device makes it desirable as a coupler and/or impedance transformer for use in equipment which is subjected to severe shock and vibration such as is required in military applications. Here, too, the absence of moving parts contributes to increased reliability. Also, the mechanical flexibility enhances miniaturized compact packaging.

This invention provides improvements of utility in field and space vehicular electronic equipment.

Objectives achieved by the present invention will now be understood to include:

An extremely wide frequency band of signal transmission;

High order power handling—e.g., in coupling a power amplifier to an antenna system;

Reduced power loss in the coupler;

Linear signal transfer;

Inexpensive rugged construction;

Small size with mechanical flexibility;

Elimination of moving parts in operation;

Elimination of external electromagnetic fields;

Imperviousness to electromagnetic fields in which it may be immersed; and

The unique use of ferrites as an isolator on a flexible coaxial conductor.

While there has been shown and described what is at present considered to be the preferred embodiment of the invention, it will be understood by those skilled in the art that various changes and modifications may be made therein without departing from the scope of the invention as defined by the appended claims. For example, in the embodiment shown, the inputs of the lines are connected in parallel and the outputs are connected in series, but it is within the scope of the invention to connect the outputs in parallel and the inputs in series. It is also within the scope of the invention to connect the inputs in any one of a variety of series-parallel arrangements. Likewise, it is within the scope of the invention to connect the outputs in any one of a large variety of series-parallel arrangements, and it is not necessary that the input arrangement be the same as the output arrangement.

Additionally, in the embodiment herein shown, a ferrite toroid is utilized to provide a closed low reluctance magnetic path and to prevent current flow along the outside of the outer conductors of the coaxial lines shown. It is within the purview of the invention to utilize any means for suppressing the flow of currents on the outside of the coaxial lines without introducing external magnetic fields.

Having disclosed my invention, I claim:

1. A wide band impedance transmission device comprising:

a plurality of coaxial transmission lines providing a group of input ends and a group of output ends,

said lines having inner and outer conductors,

means for series relating said lines at one end so that their characteristic impedances sum, looking into that end,

the outer conductors at said end being at progressively higher potentials relative to a point of reference potential,

means for parallel relating said lines at the other end, so that the reciprocals of their characteristic impedances sum, looking into said other end, and

cores of magnetic material about which portions of said coaxial lines, including outer conductors having substantial potential differences with respect to said point, are wound, to provide choking action,

said portions being adjacent said one end,

the number of cores and turns being determined by said differences.

2. A device according to claim 1 in which the cores are of toroidal form.

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