Jan. 28, 1936. M. E. STRIEBY 2,029,041

LOADED TRANSMISSION LINE

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FIG. 1

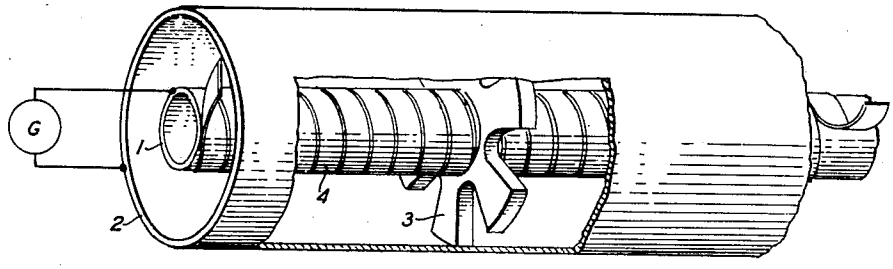


FIG. 2

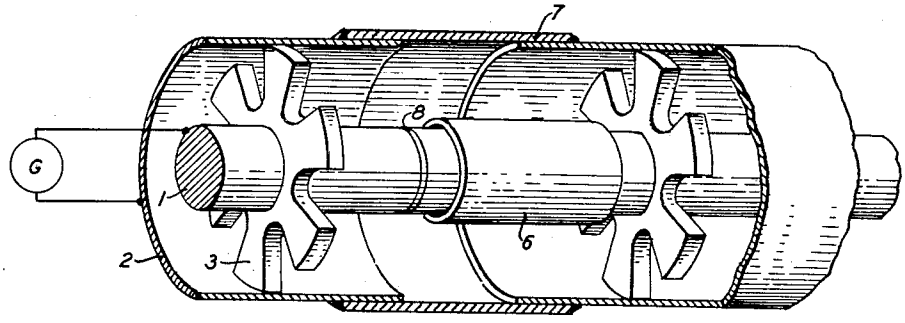
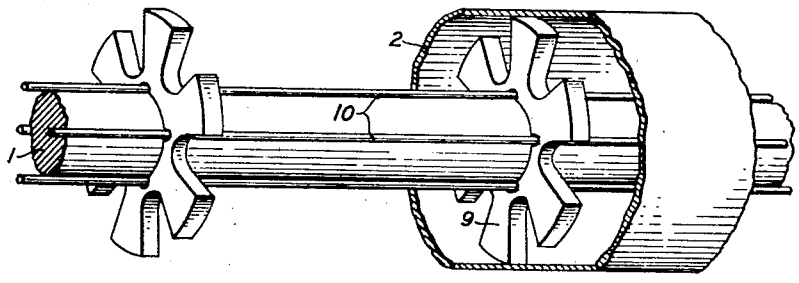


FIG. 3



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FIG. 4

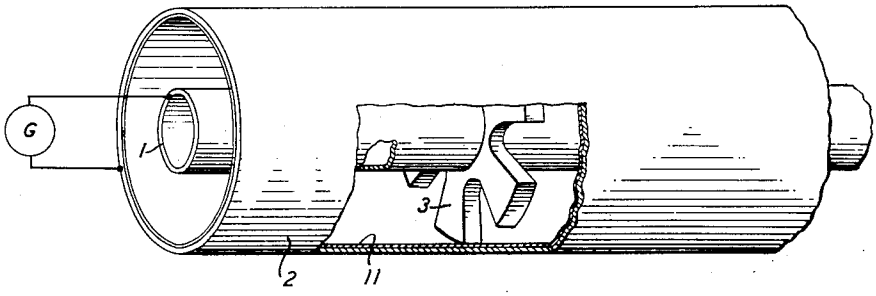


FIG. 5

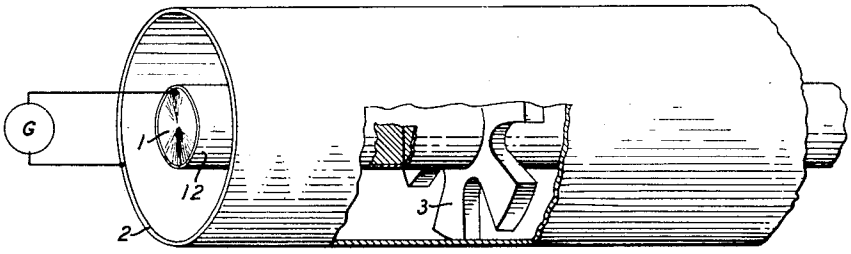
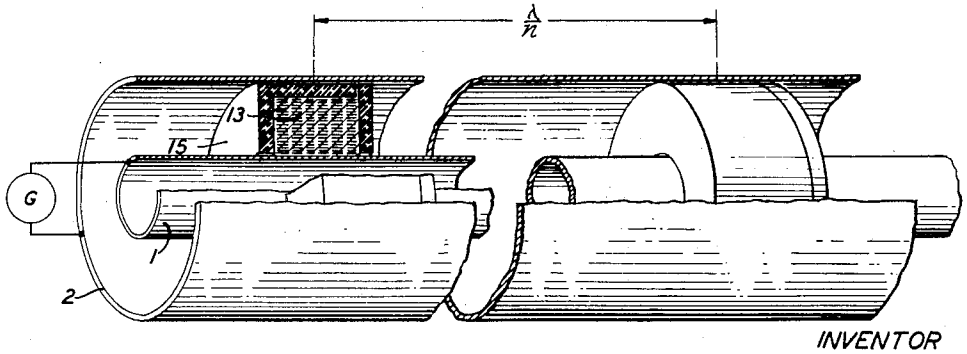


FIG. 6



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UNITED STATES PATENT OFFICE

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LOADED TRANSMISSION LINE

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Application December 31, 1931, Serial No. 584,045

3 Claims. (Cl. 178—45)

This invention relates to electrical conducting systems and more particularly to conducting systems adapted to transmit high frequency signals.

For the transmission of electrical waves having frequencies of the order of a million cycles per second, a system comprising a pair of coaxial conductors connected one as a return for the other, is inherently well adapted. The transmission cut-off of such a system, which is determined by its inductance and capacitance, occurs at a frequency that is higher than any it is ordinarily desired to transmit. Furthermore, because of the effect of the outer conductor in shielding the system against disturbance from extraneous sources, signals may be attenuated to very low levels without being masked by noise. The diameter of the conductor, however, must in some cases be as much as several inches in order to maintain the attenuation of the high frequency waves at a reasonably low value. To reduce the attenuation or to increase the range of frequencies that may be transmitted where the maximum attenuation permitted is fixed, for example, by the gain of the repeaters, as in the carrier transmission system disclosed in L. Espenschied et al. Patent 1,835,031, Dec. 8, 1931, it has heretofore been thought necessary to increase the diameter of the conductors. In a long transmission system a slight increase in diameter may entail a considerable expense.

An object of the present invention is to increase the efficiency of transmission and to decrease the cost of a coaxial conductor system.

In another aspect, an object of the invention is to increase the maximum frequency that may be practically transmitted over a coaxial conductor system.

More particularly, the object of the present invention is to provide a multiplex carrier wave conducting system adapted to transmit with high efficiency and at low energy levels a band of signals extending in frequency to at least several hundred thousand cycles per second.

The present invention lies in a coaxial conductor system that is inductively loaded. Specifically, applicant proposes to load a coaxial conductor system by placing magnetic material in the magnetic field of the system, either continuously along the conductor system, whereby continuous or Krarup inductive loading is obtained, or at regular intervals along the system whereby lumped or Pupin loading is obtained. The claims of this application are directed to the use of the latter type of loading. The remaining subject-matter disclosed but not specifically claimed herein is claimed in a divisional application, Serial No. 52,911, filed December 4, 1935.

An attempt to load a transmission system of this type to reduce attenuation might at first thought appear to be impractical, if not impossible. Increasing the inductance of the system tends to reduce the cut-off frequency as is shown by the equation for the cut-off frequency f_c:

$$f_c = \frac{1}{\pi\sqrt{LC}},$$

whereas it is the high cut-off frequency of a coaxial conductor system that is one of the chief characteristics in favor of its use for high frequency transmission. In many cases, however, the maximum signaling frequency transmitted is far below the inherent cut-off frequency of the system; loading may therefore effectively be employed to reduce the signal attenuation despite the decrease in cut-off frequency attending it. Even though the signaling band approaches relatively close to the cut-off frequency, light loading in accordance with the present invention may be employed to advantage.

Again, in a system where a thousand or more telephone channels are superposed on a single transmission line, as contemplated in the present case, intermodulation and cross-talk arising from the slightly non-linear characteristics of the repeaters and other translating devices in the line, create highly serious problems. An intolerable amount of cross-talk, noise and distortion, it might be anticipated, would follow the insertion of magnetic material in the high frequency field between the conductors. Finally, when it is considered that the energy loss occurring in the magnetic material due to hysteresis and eddy currents varied at the first and second powers respectively of frequency, it might appear questionable whether the signal attenuation thus introduced would not be many times greater than the gain attending the increase in inductance.

Applicant has found, however, that the difficulties aforementioned are not insuperable and that by proper design, to be set forth hereinafter, a substantial net gain in transmission efficiency can be realized by inductively loading the coaxial transmission system. Several embodiments of applicant's invention are disclosed in the accompanying drawings:

Fig. 1 shows a coaxial conductor system continuously loaded with a tape of magnetic material served on the central conductor;

Fig. 2 shows a system lump-loaded with short sleeves of magnetic material placed at intervals on the central conductor;

Fig. 3 shows how wires of magnetic material may be arranged to provide continuous loading;

Figs. 4 and 5 show systems loaded with iron plated on the conductors; and

Fig. 6 shows a preferred form of lump-loading unit.

In the coaxial conductor system shown in Fig. 1, a tubular central conductor 1 and a tubular return conductor 2 are connected to the terminals of a high frequency signaling source G, which may be a multiplex carrier wave telephone circuit as described, for example, in the patent to Espenschied et al., supra. The loading material in this case is applied to the central conductor 1 as a serving of tape of magnetic material 4. In an alternative embodiment, iron wire may be wrapped about the central conductor. Preferably the magnetic material has high permeability and low hysteresis and eddy current losses; permalloy in dust form or any other suitable material may be used. A wide airgap between turns tends to reduce the loss. The degree of loading obtained depends on the amount of material used, its disposition, its permeability and several other factors. The design of any particular system, however, may proceed in accordance with principles that are now well known in the art and that require no discussion here. Insulating washers 3 serve to maintain the two conductors in their coaxial relation.

In Fig. 2 is illustrated a method of lump-loading a coaxial conductor transmission line. At regular intervals along the line, a short sleeve 6 of magnetic material is provided about the central conductor. The inductance of the line is thereby increased at that point and the effect of a loading coil is obtained. The distance between these magnetic loading units determines the cut-off frequency of the system and hence is varied in accordance with the maximum frequency it is desired to transmit. Eight or more units per wave-length at the highest signaling frequency may be required; the optimum design in any particular case, however, may be determined in accordance with principles that are well known to those skilled in the art of loading transmission systems. Preferably the sleeves of magnetic material are so designed that they may be inserted at every cable joint. In the particular embodiment illustrated, the two sections of outer conductors are joined by means of a soldered sleeve 7 while the central conductors are butt welded together at 8.

In the preferred form of lump-loading unit shown in Fig. 6, a number of thin strips of magnetic material are wound around the central conductor, each roll 13 of magnetic material being separated from adjacent rolls by a film of oxide, air or other suitable insulating material. The insulating container 15 which completes the unit may or may not serve also to separate the conductors.

Fig. 3 represents another method of continuously loading a coaxial conductor system. In this case the magnetic material is in the form of fine wires 10 arranged longitudinally between the two conductors. The wires may be held in position on the central conductor 1 by the separators 9, which are notched on their inner periphery for this purpose. The lateral separation of the wires, which effectively introduces airgaps in the magnetic circuit, makes it possible to use other materials than those having optimum magnetic characteristics.

In Fig. 4 is shown a coaxial conductor system in which the central conductor comprises a tubular copper member 1. Alternatively, of course, a solid structure may be used. The magnetic loading material is shown as a continuous thin sheath 11 on the inner surface of the outer conductor 2. It may be conveniently formed as an electrolytic deposit, especially where only a thin film of magnetic material is required. In another embodiment of the invention, shown in Fig. 5, the magnetic material is formed, as by electrolytic deposition, as a film 12 on the surface of the solid central conductor 1. In both cases the material is traversed by the magnetic field between the conductors, the inductance of the system is increased, and signal attenuation is thereby reduced.

Other embodiments of the present invention, perhaps differing widely from those that have been described herein for purposes of illustration, will occur to those skilled in the art. Applicant's invention, therefore, is to be limited only by the scope of the appended claims.

What is claimed is:

1. In a signaling system, a transmission line comprising a central conductor and a return conductor concentric therewith, said line being divided by joints into a plurality of sections, members of magnetic material encircling said central conductor at said joints for lump loading said line, adjacent ends of said sections of outer conductor being spaced apart by a distance comparable with the diameters of said conductors so that said members may readily be inserted, and means at said joints for electrically connecting said sections.

2. In a multiplex carrier wave communication system, a transmission line comprising a hollow conductor and a return conductor enclosed thereby, said conductors being separated by a dielectric that is substantially gaseous, means to apply to said line carrier telephone signaling bands having a maximum frequency of at least several hundred thousand cycles per second, and magnetic members disposed between said conductors at intervals along said line for reducing the attenuation of signals, said members being of such short lengths that they are adapted to be inserted readily at joints of said line during installation.

3. In a high frequency communication system, a transmission line consisting of a pair of coaxial conductors connected one as a return for the other, said conductors being separated by a dielectric that is chiefly gaseous, means for applying to said line carrier wave signals in a multiplicity of closely-spaced channels, said signals ranging in frequency to a maximum of at least a hundred thousand cycles per second, and means for reducing the attenuation of signals lying in the upper portion of the frequency range transmitted comprising magnetic material disposed along said line in the magnetic field created by said signals and at intervals of a fraction of the shortest transmitted signal wave length, said material being in the form of a ring or short sleeve surrounding the inner of said conductors and so disposed as to retain the circular symmetry of said line and maintain inter-channel modulation below a predetermined limiting value.

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