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M. E. STRIEBY

2,118,952

LOADED TRANSMISSION LINE  
Original Filed Dec. 31, 1931

FIG. 1

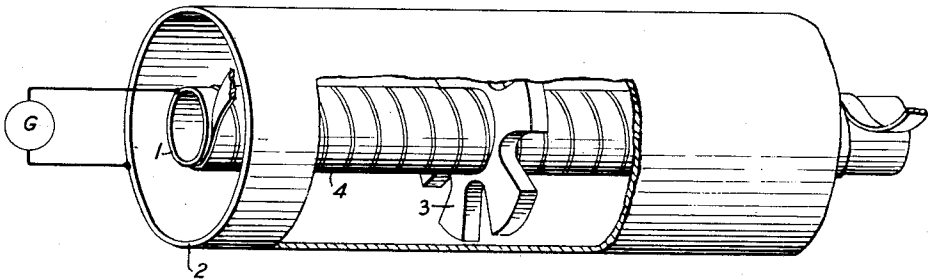


FIG. 2

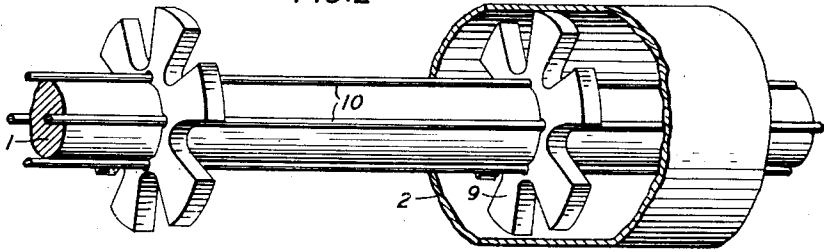


FIG. 3

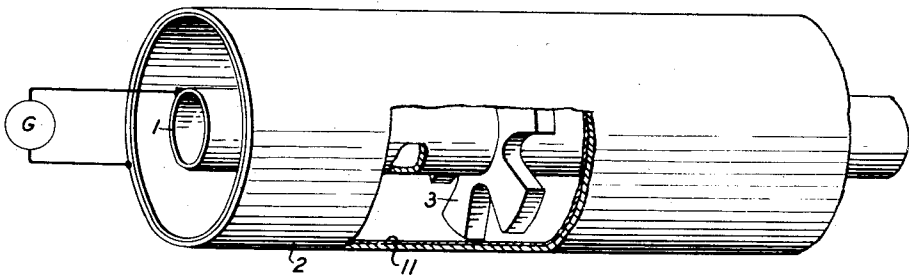
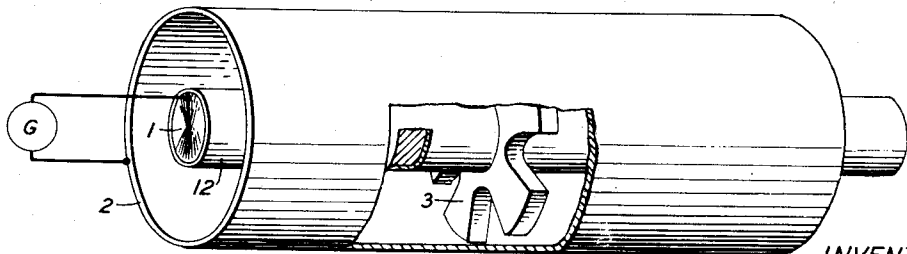


FIG. 4



INVENTOR  
M.E. STRIEBY  
BY

H.A. Burgess  
ATTORNEY

## UNITED STATES PATENT OFFICE

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## LOADED TRANSMISSION LINE

Maurice E. Strieby, Maplewood, N. J., assignor to  
Bell Telephone Laboratories, Incorporated, New  
York, N. Y., a corporation of New York

Original application December 31, 1931, Serial  
No. 584,045, now Patent No. 2,029,041, dated  
January 28, 1936. Divided and this applica-  
tion December 4, 1935, Serial No. 52,911

6 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, December 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 by means of magnetic material disposed in the magnetic field of the system. Specifically, applicant proposes to load a coaxial conductor system by disposing magnetic material continuously along the conductor system in the space between conductors, whereby continuous or Krarup inductive loading is obtained. A coaxial conductor system in which magnetic material is disposed between the conductors at regular intervals along the system to provide lumped or Pupin loading, is the

subject-matter of applicant's copending application for patent, Serial No. 584,045, filed December 31, 1931, (U. S. Patent 2,029,041, Jan. 28, 1936), of which this application is a division.

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 varies as 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 drawing:

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

Fig. 2 shows how wires of magnetic material may be arranged to provide continuous loading; and

Figs. 3 and 4 show systems loaded with iron plated on the conductors.

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 Espenscheid 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; perm-alloy in dust form or any other suitable material may be used. A wide air-gap 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, but as to these 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.

Fig. 2 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 air-gaps in the magnetic circuit, makes it possible to use other materials than those having optimum magnetic characteristics.

In Fig. 3 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. 4, 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 high frequency carrier telephone sig-

nalizing system, a transmission circuit consisting of a hollow outer conductor and a central conductor connected one as a return for the other, said conductors being separated by a dielectric that is essentially gaseous, means for applying to said circuit for transmission thereover a multiplicity of closely-spaced bands of carrier wave signals occupying a frequency range extending to at least several hundred thousand cycles per second, and magnetic material disposed in the field between said conductors in such manner as to increase the effective series inductance of said circuit and reduce the attenuation of waves of maximum frequency.

2. A combination in accordance with claim 1 in which said magnetic material is disposed as a thin plating on one of the adjacent surfaces of said conductors.

3. In a multiplex carrier wave communication system, a transmission line comprising a central conductor and a hollow return conductor coaxial therewith, said conductors being separated by a dielectric that is chiefly gaseous, means to apply to said line a wide band of signaling waves having a maximum frequency of the order of a megacycle per second or higher, and means to reduce the attenuation of said waves of maximum frequency comprising a thin plating of magnetic material on one of the adjacent surfaces of said conductors.

4. In a multiplex carrier wave communication system, a transmission line comprising a central conductor and a hollow return conductor coaxial therewith, said conductors being separated by a dielectric that is chiefly gaseous, means to apply to said line a wide band of signaling waves having a maximum frequency of the order of a megacycle per second, and means to reduce the attenuation of said waves of maximum frequency comprising magnetic loading material applied to said central conductor as a serving of tape.

5. A shielded transmission line comprising a plurality of conductors, one of said conductors comprising a substantially continuous metallic sheath surrounding the other or others of said conductors, means for applying high frequency signals to said conductors, and means to reduce the attenuation of said signals comprising an elongated member of magnetic loading materials disposed substantially continuously and longitudinally along said line in the magnetic field associated with said conductors.

6. A transmission line comprising a pair of coaxial conductors separated by a substantially gaseous dielectric and connected one as a return for the other, the outer of said conductors providing a substantially continuous metallic sheath, means for transmitting over said line signal waves having a frequency of at least a megacycle per second, and loading means for reducing the attenuation of said signal waves comprising a plurality of filamentary members of magnetic material disposed longitudinally in the space between said conductors.

MAURICE E. STRIEBY.