June 9, 1953 N. L. COHEN ET AL 2,641,702

CONTROL OF WAVE LENGTH IN WAVE GUIDE AND COAXIAL LINES

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Fig. 1.

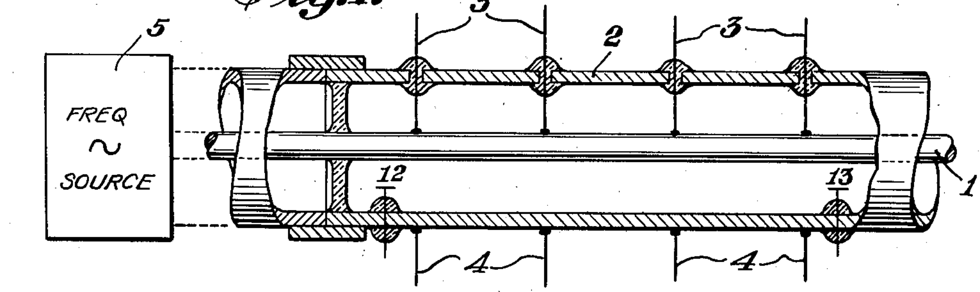


Fig. 2.

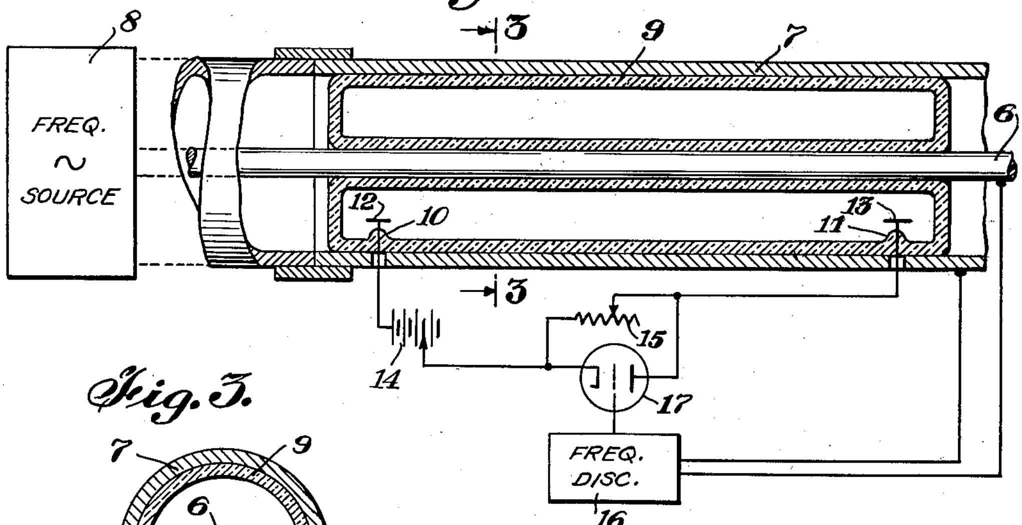


Fig. 3.

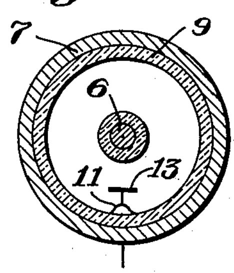
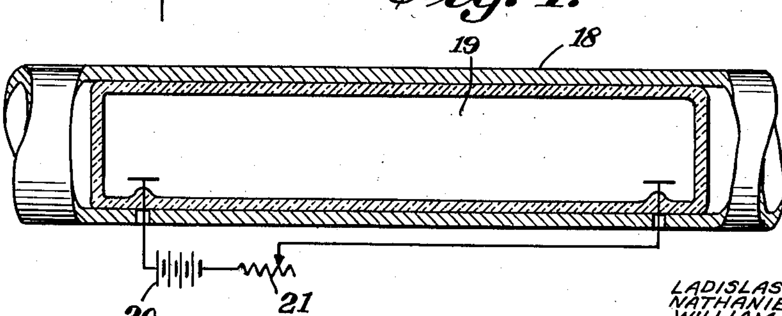


Fig. 4.



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CONTROL OF WAVE LENGTH IN WAVE GUIDE AND COAXIAL LINES

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This invention relates to wave transmission systems and more especially to the art of controlling the wave length of propagated waves in a transmission medium.

In wide band transmission media such as coaxial transmission lines or dielectric wave guides the wave length of electric energy is generally determined by the dimensions of the conductors and the insulating media. The speed of transmission is substantially constant so that at a given frequency the nodes and loops will be differently distributed along the line than at any other frequency. In many instances it is desired to have the wave distribution constant along a line with changes in frequency of energy in the line. A particular example of such systems is when it is desired to feed the antennas of an array, or other loads, with a given phase relationship, regardless of wave length, over a relatively wide band. With the usual transmission system, an elaborate tuning means to vary the inductance or capacitance of the line is required to achieve this purpose.

It is an object of this invention to stabilize the wave length of waves propagated along a wave transmission line even though the frequency of the impressed waves is varied.

Another object is to provide an arrangement for producing a stabilized directional radiation pattern from an antenna array fed from a wave transmission line, even though the frequency of the waves impressed on said line is varied.

Another object is to provide a method of controlling the wave length of waves propagated along a transmission line of the coaxial or wave-guide type, by constituting a gaseous discharge plasma as part of the line, and controlling the electron density of the plasma to control thereby the dielectric constant of the said line.

A feature of the invention relates to a wave transmission line having incorporated therein a gaseous discharge of controllable current density for stabilizing the wave length of variable frequency waves impressed on said line.

Another feature relates to a wave transmission line of the coaxial type or wave guide type, having located within the guide space a tubular elongated gaseous discharge tube whose plasma electronic density is adjustable to control the overall dielectric constant of the wave propagation region within the guide.

The above-mentioned and other features and objects of this invention and the manner of attaining them will become more apparent and the invention itself will be best understood, by reference to the following description of an embodiment of the invention taken in conjunction with the accompanying drawings, wherein:

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Fig. 1 is a schematic representation of a typical radiation system to which the invention is applicable.

Fig. 2 is a longitudinal central cross-section of a coaxial transmission line embodying the invention.

Fig. 3 is a sectional view of Fig. 2, taken along the line 3—3 thereof.

Fig. 4 is a longitudinal central cross-section of a wave guide embodying the invention.

In certain kinds of wave transmission systems such, for example, as radiating antenna systems and the like, it is highly desirable to produce a field or radiation pattern which has substantially constant directional properties, even though the impressed waves are varied in frequency. Thus, there is shown in Fig. 1, a typical antenna array comprising a coaxial feed line with its central conductor 1 and its outer concentric conductor or pipe 2. Connected at suitable spaced points along the length of conductor 1, are the several radiator elements 3. Likewise, connected to the conductor 2 at the same spaced intervals are the complementary radiator elements 4. The showing of Fig. 1 is intended to be generically schematic, in that the radiator elements are arranged to extract wave energy from the coaxial transmission line at appropriate numerous points along its length. It will be understood, of course, that the radiator elements may be coupled to a wave guide instead of a coaxial line, for the same purpose. The theory of such an arrangement is that each set of radiator elements extracts small packets of energy content from definitely phased points along the line. Thus, for example, the spacing interval between the successive radiator elements may be one-quarter wave length at the operating frequency of the antenna array. The particular array shown in Fig. 1 is of the "end fire" type, and the directional radiation properties of the system are largely dependent upon the relative phase relations of the said small portions of the extracted energy. Hence, any change, either in the spacing of the several radiator elements, or of the frequency of the source 5 from which the waves are impressed on the line, will result in a shift in the direction of radiation.

In certain cases, it is desirable to be able to operate such a system over a wide range of impressed frequencies, for example from 1,000 megacycles to 2,000 megacycles. Therefore, in order to avoid any substantial shift in the radiation direction for the different impressed frequencies, it is necessary to maintain the wave length of the waves propagated along the line at a stabilized selected value. The present invention provides a method and arrangement of apparatus for securing this desirable objective.

It has been determined heretofore, that at high frequencies, the dielectric constant of a conductive gaseous discharge plasma depends on the electronic charge density contained in the plasma, the plasma as is well-known, constituting the largest portion of the discharge column between the anode and cathode of a gaseous conduction tube. The relation between this dielectric constant and the electronic charge density is given by the following formula:

$$\epsilon_g=\epsilon_0\left(1-\frac{4\pi Ne^2}{m\cdot\omega^2}\right) \quad (1)$$

where

ϵ_g is the effective dielectric constant at frequency $\omega/2\pi$;

E_0 is the dielectric constant of free space;

Ne is the electronic charge density;

and

$$\frac{e}{m}$$

is the ratio of charge to mass of the electron. In the case where the electronic collisional frequency ν in the discharge plasma is of the order of or larger than the signal frequency $\omega/2\pi$, this expression becomes:

$$\epsilon_g=\epsilon_0\left(1-\frac{4\pi Ne^2}{m(\omega^2+\nu^2)}\right) \quad (2)$$

However, for purposes of this discussion, we will omit this case.

It is also known that the wave length of a wave in dielectric medium is related to its free space wave length by:

$$\lambda_d=\frac{\lambda_c}{\sqrt{\epsilon_d}} \quad (3)$$

where

λ_c is the free space wave length;

λ_d is the wave length in the dielectric medium;

E_d is the relative dielectric constant of the medium.

In accordance with the present invention, the transmission feed line has incorporated in the wave propagating spaced thereof a gaseous discharge plasma of controllable electronic charge density. For example, in the case of a coaxial line as in Fig. 1, the interior of the line can be filled with a pure rare gas such as Argon, Krypton, Helium, etc., at a pressure of a few millimeters of mercury. If, by means of suitably energized electrodes located within the gas column, 12, and 13, Fig. 1, a conductive discharge is set up therein, and a signal of frequency "f" is impressed on the line, then the propagated wave length in the line will be given by the following formula:

$$\lambda_d=\frac{C}{f\sqrt{\epsilon_d}}=\frac{C}{f\,\epsilon_0\left(1-\frac{4\pi Ne^2}{m(2\pi f)^2}\right)^{1/2}} \quad (4)$$

$$\lambda_d=\frac{C}{f\epsilon_0\left(1-\frac{Ne^2}{\pi m f^2}\right)^{1/2}} \quad (5)$$

If we set λ_d as a constant and with $\epsilon_0=1$, we have

$$N=\pi\frac{m}{e^2}\left[f^2-\left(\frac{C}{\lambda_d}\right)^2\right] \quad (6)$$

That is, N, the electron density, is a function of frequency for a constant wave length $\lambda=\lambda_d$. Now, it is known that N is a function of the current density, and hence the current in the discharge, for a given set of conditions of gas pressure, nature of the gas and gas purity and geometry.

Referring to Figs. 2 and 3, there is shown a suitable arrangement whereby the wavelength of a signal in a coaxial line can be held constant over a wide range of transmitted frequencies. The line comprises the usual central conductor 6 and its coaxial guide or pipe conductor 7, arranged to be connected to a suitable high frequency source 8. Surrounding the conductor 6 and located within the wave propagational space of the coaxial line, is an elongated tubular glass container 9, having side seals 10 and 11. Suitably mounted in the side seals 10 and 11, are respective electrodes 12, 13, which are connected in series with a suitable source of potential 14, and an adjustable resistor 15. The container 9 after being suitably evacuated and processed as is well-known in the gaseous conduction tube art, is provided with a filling of a pure rare gas such as Argon, Krypton, Helium, or the like at a pressure of a few millimeter of mercury. When the electrodes 12 and 13 are thus energized, there is set up a gaseous conduction column extending throughout the length of the tube 9, the greater part of this column being constituted of the plasma. By means of the source 14 and the adjustable resistor 15, the current density in the plasma can be adjusted to fit the requirements of the above-noted formula #6. As a typical example, if the impressed frequencies from source 8 are variable between 1,000 megacycles and 2,000 megacycles, and it is desired to maintain the wave length in the line at 30 centimeters, which is a free space wave length of 1,000 megacycle signals, then from Formula #6 it can be seen that for $f=1{,}000$ megacycles, $N=0$. For a frequency of 2,000 megacycles, $N=3.68\times10^{10}$ electrons per cubic centimeter within the plasma. Then for different frequencies between 1,000 megacycles and 2,000 megacycles, the relation of the impressed frequency and stabilized wave length and the number of electrons per cubic centimeter in the plasma is given in the following table:

f	λ_0	N electrons/cc.	λ_d
	Cms.		Cms.
1,000 mcs	30	0	30
1,250 mcs	24	6.85×10^9	30
1,500 mcs	20	1.53×10^{10}	30
1,750 mcs	17.1	2.5×10^{10}	30
2,000 mcs	15	3.68×10^{10}	30

Thus, it will be seen that by adjusting the current density in the plasma, the wave length can be stabilized at any particular value in accordance with Formula #6.

In the event that the stabilization is to be effected automatically, a sample of the energy propagated through the line can be applied to any well-known frequency discriminator 16 whose output can control a variable resistor tube 17 connected across resistor 15. By this arrangement therefore, the propagated wave length in the coaxial line will be automatically stabilized at the predetermined value.

It will be clear that the invention is not limited to a transmission line of the coaxial type. Thus, there is shown in Fig. 4 a transmission line of the wave guide type wherein the wave guide 18 has on the interior thereof an elongated gaseous conduction tube 19 which may be similar to tube 9 of Fig. 2. Here again, the current density in the plasma within the tube 19 can be adjusted by potential source 20 and variable resistor 21 in accordance with the above-noted Formula #6 to stabilize the wave length of the propagated waves within the wave guide. It will also be understood that the transmission line with which the controlled plasma cooperates may be of any other well-known type.

While we have described above the principles of our invention in connection with specific apparatus, it is to be clearly understood that this description is made only by way of example and not as a limitation to the scope of our invention.

What is claimed is:

1. A high frequency wave transmission line, comprising a hollow member defining a wave-propagating line upon which high frequency waves are impressed, an enclosed gas-tight device extending along a predetermined length of the interior of said member, said device containing a filling of an ionizable gaseous medium, electrodes at opposite ends of said device, means to adjust the potential between said electrodes

to control the density through said medium to stabilize the physical wave length of the waves propagated along said line within said medium, and a plurality of radiator elements coupled to said wave propagating line through the ionizing device at spaced points along said device, said means to adjust being controlled to present the high frequency energy at the same relative phase to said radiators over a range of frequency of said high frequency source.

2. Apparatus according to claim 1, in which said line is of the coaxial type.

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