

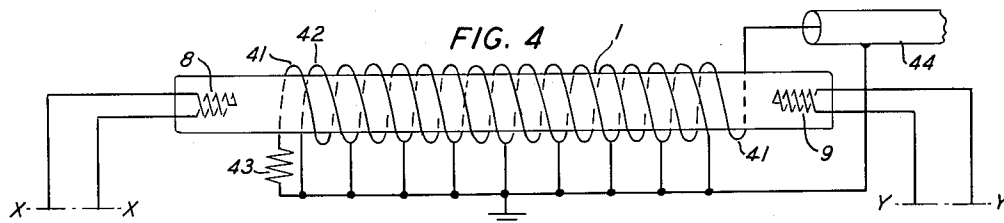
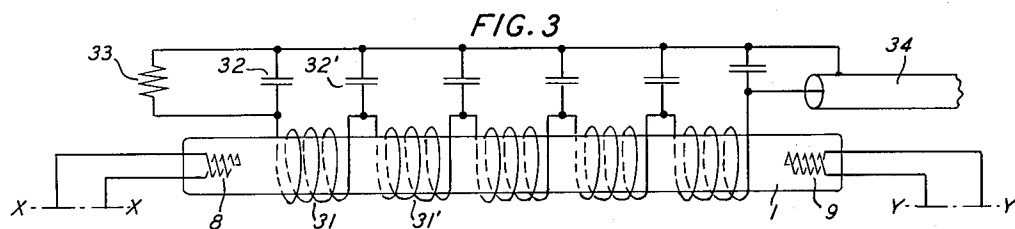
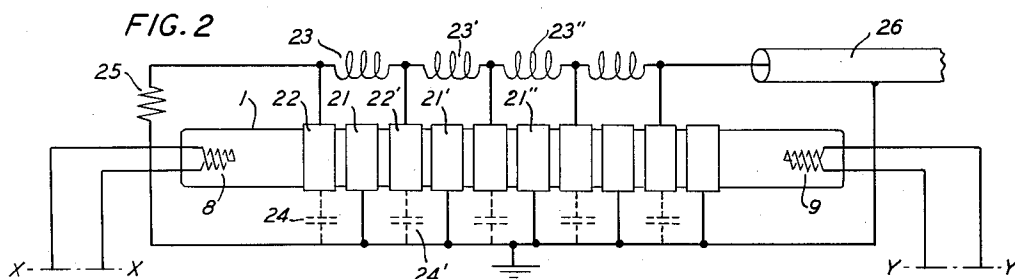
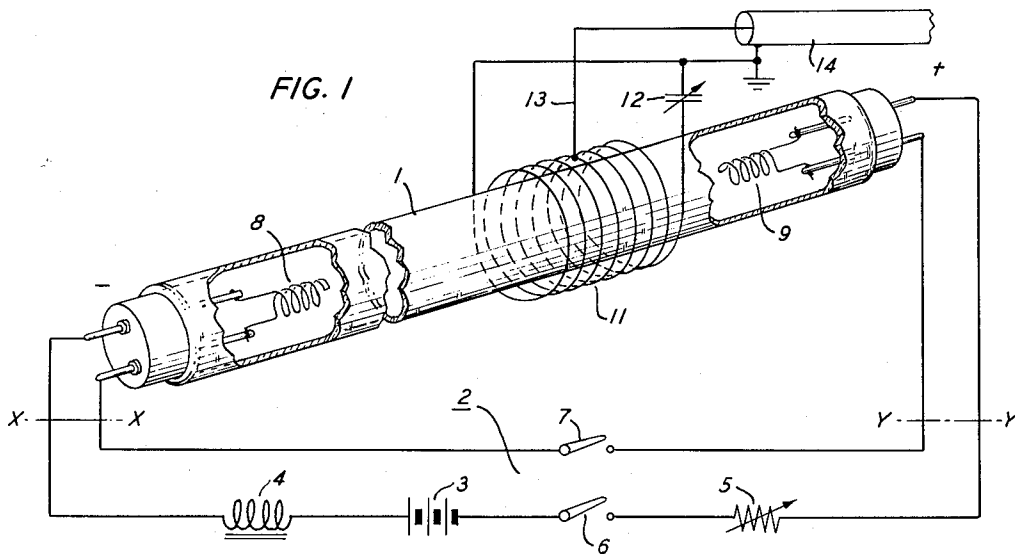
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VERY HIGH FREQUENCY GAS DISCHARGE NOISE SOURCE

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VERY HIGH FREQUENCY GAS DISCHARGE NOISE SOURCE

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This invention relates to transmission systems in the very high frequency range and more particularly to noise sources employing electric gas discharges of the positive column type for this higher intermediate frequency range.

In the microwave frequency range, in the vicinity of 4000 megacycles, it has previously been proposed to couple noise sources of the positive column type to transmission systems by wave guides. In this respect, the applications of W. W. Mumford, Serial No. 98,553, filed June 11, 1949 now Patent No. 2,706,782, granted April 19, 1955, and Serial No. 169,125, filed June 20, 1950 now Patent No. 2,706,784, granted April 19, 1955, both of which are assigned to the assignee of this invention, are considered pertinent. At frequencies below 50 megacycles, the currently used temperature limited noise diode appears to be quite satisfactory. In the higher intermediate frequency range, however, noise diodes tend to become unstable, and wave guide coupling means for a gaseous electric discharge tend to be too large and cumbersome.

It is, therefore, an object of this invention to improve noise sources for the higher intermediate frequency range.

A collateral object is to increase the frequency band width of the output noise in the higher intermediate frequency range.

In a noise generator in accordance with this invention, the positive column of a gas discharge device is coupled efficiently and substantially directly to a multiple conductor output circuit. In one embodiment of the invention, to be described in detail hereinafter, a single coil around the gas discharge tube picks up random energy and is tuned to the desired frequency and matched to the output circuit by an appropriate tuned circuit and autotransformer arrangement. In accordance with other alternatives, the positive column gas discharge tube may be coupled to the output circuit through transmission line, or filter type circuits either repeatedly through lumped reactive circuit elements, or continuously, as a result of the proximity of the discharge to a transmission line type circuit.

The nature of the present invention and various objects, features, and advantages in addition to those pointed out above will appear more fully from the following description of the embodiments of the invention that are illustrated in the accompanying drawings.

In the drawings:

Fig. 1 illustrates a simple, basic embodiment of the invention;

Figs. 2 and 3 represent embodiments of the invention employing artificial transmission lines; and

Fig. 4 depicts an arrangement where the two wires of a transmission line are wrapped around the noise source.

Before entering on a more detailed discussion of the drawings, a few general statements will be made concerning noise generators and the nature of the gaseous discharge involved in noise sources of the instant type.

In accordance with the objects of the invention, it has been determined that the random motions of the elec-

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trons and ions in the positive column of a gas discharge will induce random fluctuation currents into a coil encircling this positive column. While it might have been anticipated that the net mass random motion of the ions in the positive column might cancel out in so far as the motion in any direction susceptible of energy transfer into the coil was concerned, substantial coupling into the coil is, nevertheless, observed for the high frequency noise generated in the discharge.

Such random fluctuation currents can be used to excite the input of a radio receiver or other sensitive amplifier and the signal so generated and amplified is termed "noise" by radio engineers. The discharge tube and its immediately associated circuits is termed a "noise generator." As is well known in the art, noise generators are particularly useful in testing the ultimate sensitivity of amplifiers for the detection of weak signals in the presence of noise generated by the amplifier itself.

Ordinarily, such noise generators are provided with an output connection consisting of a pair of terminals, a transmission line or a wave guide connection. The noise signal which appears at the terminals or line should desirably have the following characteristics:

(a) The frequency spectrum of the noise should be uniform over as wide a frequency band as possible. That is, that portion of the total noise power available within some artificially small band of frequencies should be independent of where that band is chosen within some very large band covered by the generator. For example, if a noise generator had a uniform spectrum from 50 megacycles per second to 100 megacycles per second, the noise power in the band 50 to 51 megacycles per second would be the same as that in the band 75 to 76 or 99 to 100 megacycles per second. The feature desired is that the region of uniformity covers a frequency band as broad as possible;

(b) The high frequency impedance as seen at the terminals should be substantially resistive in character and be constant with frequency over as wide a frequency range as possible, corresponding to the frequency range of constant noise output;

(c) The noise power available from the generator should be sufficiently great that it will be readily detectable by a well designed amplifier or radio receiver;

(d) The noise power output should be constant with time and be accurately known in terms of watts per cycle of band width within its particular useful frequency band.

The particular noise generators disclosed herein are designed to fulfill the above-noted desiderata in so far as possible. In particular, the particular circuits employed are designed to fulfill (a) and (b) above, in giving a uniform frequency spectrum from a few tens of megacycles to a few thousand megacycles. The use of the positive column gas discharge tube itself is useful in meeting the objectives of (c) and (d).

Many of the characteristics and phenomena of electrical gas discharges have been known for some time, although it has not always been possible to give a complete explanation of the observable phenomena. It is known, for example, that when a tube containing a pair of plane parallel electrodes between which is contained a fixed quantity of gas at a low pressure, for example, a few millimeters of mercury, is connected by means of the electrodes to a source of potential, the gas in the tube will begin to glow, the color of the luminous region being a function of the gas or gases contained in the tube. If the gas in the tube is ionized by means of a suitably large potential applied or by means of heat applied at the electrodes, the gas will break down and readily conduct current. This characteristic is known as a discharge and is visually characterized by brightly lighted, but differently

colored, luminous regions in the gas. These regions are known as follows.

Very close to the cathode, there is a narrow, dark region known as the "Aston dark space." Adjacent to this is a brightly colored region known as the "cathode glow." The "Crookes dark space" extends outward for some distance from the cathode glow. Adjacent to the Crookes dark space is a luminous region known as the "negative glow," which starts quite abruptly and gradually faces into the region known as the "Faraday dark space." The Faraday dark space merges into the luminous "positive column." This terminates in the "anode glow," which is separated from the anode by a narrow "anode dark space."

The largest portion of the glow is the positive column, in which region there appears to be substantially an equal number of positive ions and electrons, so that the net charge in this region is zero. For any particular gas at a given pressure, a certain minimum voltage is required to sustain gaseous discharge of this type having a positive column. In addition, the current must be regulated so as to be greater than the non-luminous, pre-breakdown range and less than the high current arc discharge region. This is normally accomplished by the use of a resistor in series with the current source.

For more detailed discussion of the various factors involved in these gas discharge phenomena, reference is made to chapter III, article 9, of *Applied Electronics*, by the E. E. Staff of the Massachusetts Institute of Technology, The Technology Press, New York, John Wiley, 1943, and to chapter XI of *Fundamental Processes in Electrical Discharges in Gases*, by L. B. Lieb, New York, John Wiley, 1939.

It has also been found that the noise power is substantially independent of the current flowing through the discharge tube. As noted in the above-mentioned Patent No. 2,706,784 of W. W. Mumford, discharge tubes can now be made having substantially uniform noise power output at varying temperatures. In addition, preliminary investigation indicates that the noise frequency spectrum available from the discharge is substantially uniform over a wide frequency band ranging from 50 to 10,000 megacycles, though various circuit arrangements are necessary for different ranges in this band.

The same is not necessarily true of energy radiated by the other regions of the discharge. In certain of these regions located on either side of the positive column, noise energy is variously affected by current, temperature, pressure of the gas; and the impedance is adversely affected by the nearby presence of the electrodes. It would therefore appear that the level and quality of noise energy radiated by the positive column depends upon some invariant physical property of the atoms and ions within the positive column of the discharge. It is thus a purpose of the present invention to isolate and utilize high frequency noise energy developed by such a positive column of a gas discharge.

Referring more particularly to Fig. 1, the discharge tube 1 is filled with a gaseous material of any of the types known to support an electrical gas discharge. This includes substantially all gases or combinations thereof, and suitable proportions required to sustain a positive column electric gas discharge therein are well known to all familiar with gas discharge devices. Among the several gases in common use in many commercial discharge devices are neon, helium, argon, sodium vapor, and mercury vapor. This is, however, by no means an exclusive list. Thus, this discharge tube 1 may be of a standard commercial fluorescent lighting type. In particular, a General Electric type T-5, 6-watt daylight fluorescent lamp is satisfactory. The external circuit 2 connected to the filamentary electrodes is quite conventional, being similar to the one commonly used in commercial fluorescent light circuits. It consists of a source of direct-current potential 3 connected in series with an iron core inductance 4, a variable re-

sistance 5, switches 6 and 7, and the electrodes 8 and 9. In order to apply the direct current, the switch 6 is closed. Starting switch 7 is then closed, completing the series circuit through filaments 8 and 9 and the voltage source 3. After the filaments have become sufficiently hot to produce partial ionization of the surrounding gas, switch 7 is opened, and the inductive kick due to the iron core inductance 4 causes the electric discharge to extend through the length of the envelope 1 from electrode 8 to electrode 9. Resistance 5 is provided to regulate and control the discharge current after it is started. Suitably placed filtering chokes and condensers may be employed when it is desired to isolate the noise source. It may also be considered desirable to use a milliammeter in series with the variable resistance and power source to measure the current passing through the tube.

For maximum noise power output, it is desired that the discharge be properly coupled to the output circuit. In order to obtain an efficient coupling it is necessary that the impedance of the noise generator as seen at its output terminals be the same as the characteristic impedance of the line to which it is attached. Furthermore, it is desirable that this impedance be purely resistive and that such resistance arise because of coupling to the gas discharge, rather than from other resistive circuit elements.

In order to obtain an impedance match between the positive column noise source 1 and the coaxial cable 14 at a particular frequency band, the circuit shown at 11, 12, 13 and including the variable resistance 7 is employed. The actual coupling to the positive column is by means of the coil 11 which consists of a relatively few turns of wire wound around the gaseous discharge tube. The coil 11 is tuned to resonance by the shunt capacitance 12 and is tapped at 13 to get the proper impedance to match the coaxial line 14. The conductance could be varied by changing the current in the discharge by varying the resistance 7 and the susceptance by tuning the shunt condenser 12.

In one instance, an experimental set-up using this circuit proved adequate for a moderate frequency band, about 10 megacycles to the three decibel down points in the range between 40 and 100 megacycles.

An improved embodiment of this lumped circuit element type noise source, having broader frequency response and other improved characteristics, forms the subject-matter of B. C. Bellows application, Serial No. 288,869, filed on May 20, 1952, concurrently with the instant application.

The transmission line type devices illustrated in Figs. 2 to 4, inclusive, are designed for still broader frequency response bands and for use at somewhat higher frequencies. This goal is obtained by coupling extended transmission line type circuits either in a repeated manner (Figs. 2 and 3) or continuously (Fig. 4) to the noise source.

Inasmuch as the control circuits for the gas discharge devices of Figs. 2 to 4, inclusive, are conventional and are the same as those of Fig. 1, they are not redrawn in each figure but merely indicated by the letters xx adjacent the four lamp terminals. Discharge tubes of a length suitable to accommodate the plurality of coupling elements of these species are, of course, used in the devices of Figs. 2 to 4, inclusive, and more than one tube could readily be used, where this appears desirable.

Figs. 2 and 3 represent artificial transmission lines of the low pass filter type, with Fig. 2 showing capacitive coupling metal foils 21, 22 and inductive elements 23, and Fig. 3 showing inductive coupling means 31 and capacitive elements 32. In conjunction with Fig. 2, additional capacitance 24 may be added when the circuit constants, to be developed below, make this desirable.

The terminating resistors 25 and 33 normally match the characteristic impedance of the coaxial lines 26 and 34; special terminating sections may, however, be employed. In each case, the artificial transmission line

may advantageously be constructed with the same characteristic impedance as the coaxial output line, and the cut-off frequency of the line considered as a filter should be well above the highest frequency for which the device is intended.

Expressing these relations mathematically, the cut-off frequency

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

and the approximate characteristic impedance

$$Z_0 = \sqrt{\frac{L}{C}}$$

where L is the inductance of each coil and C is the capacitance of each section. Thus, where the characteristic impedance of the coaxial line and the cut-off frequency are known, suitable values for the individual capacitive and inductive elements of the networks may be readily computed. For further mathematical analysis, E. A. Guillemin's *Communications Networks*, John Wiley, 1935, would be helpful. In each case, the values of the individual capacitances and inductances should be measured while the tube is conducting.

For a still broader and generally higher frequency band, the continuously coupled smooth transmission line of Fig. 4 is valuable. The two wires or metallic strips 41 and 42 are wound around the discharge tube in a double helix with wire 42 shorted to ground at many points. The other wire 41 is connected through the termination 43 at one end and leads to the coaxial output 44 at the other end. The spacing of the conductors 41 and 42 should be chosen so that the inductance and capacitance per unit length satisfy the equation given above for the characteristic impedance Z_0 .

It is to be understood that the above-described arrangements are merely illustrative of the application of the principles of the invention. Numerous other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention. By way of example, but not of exclusion of other variations, the noise source may be coupled through any of the inductive or capacitive elements of the periodic sections of filters or other simulated transmission lines of types other than those shown herein. Similarly, coupling through both inductive and capacitive elements as well as merely one or the other is within the scope of the invention.

What is claimed is:

1. A very high frequency noise generator comprising a gaseous discharge device, circuit means to establish an electrical gas discharge having a positive column portion within said device, and an artificial transmission line repeatedly coupled to said positive column portion to receive high frequency electrical energy from said positive column portion of said discharge.

2. A very high frequency noise generator comprising a gaseous discharge device, circuit means to establish an electrical gas discharge having a positive column portion within said device, and two spaced conductors helically encircling said positive column portion to receive high frequency electrical energy from said positive column portion of said discharge.

3. A very high frequency noise generator comprising a gaseous discharge device, an output circuit, an artificial transmission line network including a plurality of lumped reactive elements coupling said device with said output circuit and having a plurality of said reactive elements in electrical coupling proximity to said gaseous discharge device.

4. A very high frequency noise generator comprising a gaseous discharge device, an output circuit, an artificial transmission line network including a plurality of

repetitive sections of lumped reactive elements coupling said device with said output circuit and having a plurality of said reactive elements in electrical coupling proximity to said gaseous discharge device.

5. A very high frequency noise generator comprising a gaseous discharge device, an output circuit, an artificial transmission line network including a plurality of lumped reactive elements coupling said device with said output circuit and having a plurality of said reactive elements in electrical coupling proximity to said gaseous discharge device, and said artificial transmission line having a characteristic impedance of the same order of magnitude as that of said output circuit.

6. A very high frequency noise generator comprising a gaseous discharge device, an output circuit, an artificial transmission line network including a plurality of repetitive sections of lumped reactive elements coupling said device with said output circuit and having a plurality of said reactive elements in electrical coupling proximity to said gaseous discharge device, said artificial transmission line having a characteristic impedance of the same order of magnitude as that of said output circuit and having a special termination impedance at a point in said network remote from the output circuit.

7. In a noise source, an elongated gas tube, electrode means for establishing a steady positive column discharge of substantially constant extent for a predetermined distance along the length of said gas tube, and an extended artificial transmission line closely coupled to said positive column within said predetermined distance along the length of said transmission line.

8. A noise generator as defined in claim 7 wherein said artificial transmission line comprises two spaced conductors helically encircling said positive column to receive high frequency electrical energy from said positive column portion of said discharge.

9. In a noise source, an elongated gas tube, electrode means for establishing a steady positive column discharge of substantially constant extent for a predetermined distance along the length of said gas tube, and a coil having a plurality of turns encircling said positive column within said predetermined distance.

10. In a noise source, an elongated gas tube, electrode means for establishing a steady positive column discharge of substantially constant extent for a predetermined distance along the length of said gas tube, an output circuit, an artificial transmission line network including a plurality of lumped reactive elements coupling said positive column to said output circuit, said transmission line network including a plurality of said reactive elements in electrical coupling proximity with said positive column within said predetermined distance.

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