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MICROWAVE NOISE GENERATOR

Filed May 15, 1962

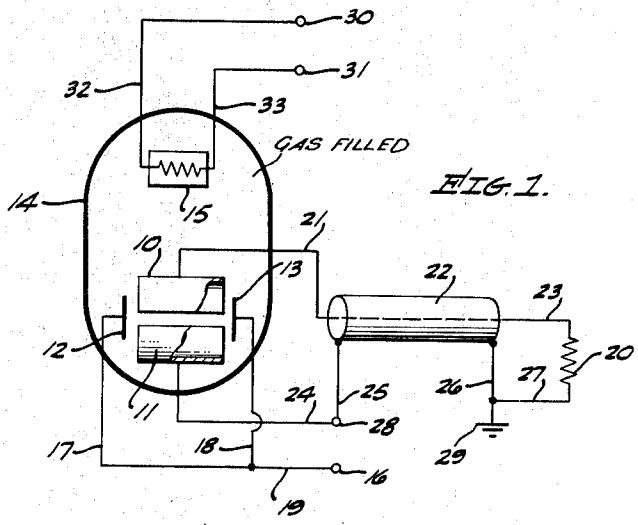


FIG. 1.

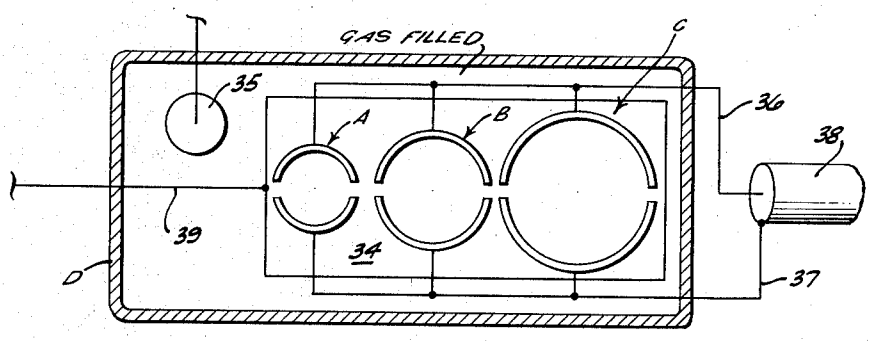


FIG. 2.

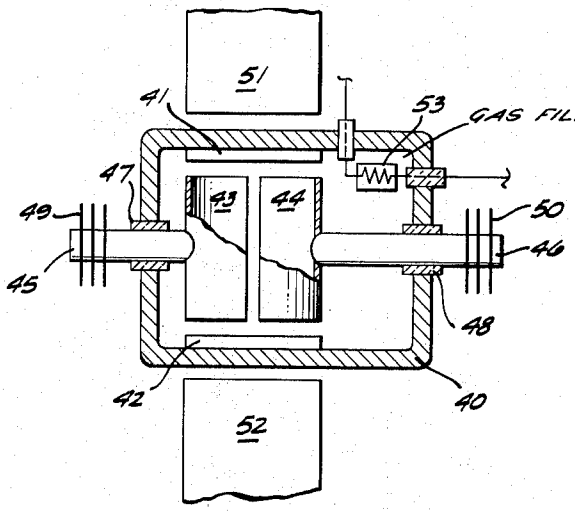


FIG. 3.

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MICROWAVE NOISE GENERATOR

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The present invention relates to the generation of radio frequency noise, particularly the generation of relatively high power noise in the ultra high frequency and microwave frequency range, and especially for application in electronic countermeasure systems.

One current method of generating noise in the frequency range from 40 to 500 megacycles involves the use of electron beam switching tubes which produce maximum noise power densities of approximately 0.2 milliwatt per megacycle. For many electronic countermeasure applications this noise power density is inadequate.

Accordingly, an important object of this invention is to provide a noise generator which will produce noise in the ultra high frequency and microwave frequency with a noise power density of several orders of magnitude greater than that of prior art devices.

Various features of this invention will become apparent from the following description which is given primarily for purposes of illustration and not limitation.

Stated in general terms, the objects of this invention are attained by providing a radio frequency noise generator comprising a plurality of hollow anode elements, such as are produced by splitting a hollow cylindrical, or tubular, anode along its axis. The generally cylindrical anode elements are mounted between two generally flat, spaced parallel cathode elements. The cathode elements are mounted in transverse relationship to the axes of the anode elements and are spaced from each end of the anode elements. The resulting anode-cathode assembly is enclosed in a suitable vacuum-tight envelope and submerged in a magnetic field so that the lines of force of the field are coaxial with the longitudinal axes of the split anode elements. A gas pressure is maintained inside the envelope at a low value, of the order of 10^{-3} to 10^{-4} millimeter of mercury, by suitable means. A gas discharge is produced by connecting a high voltage source to the anode elements and the cathodes. Suitable circuitry, including an ohmic load, is connected across the anodes so that radio frequency noise is produced by the interaction of the anode elements with the electrons of the gas discharge. The resulting noise is suitable for direct output from the generator, or for transfer to a suitable radio frequency noise transmitter.

A more detailed description of the invention is given below with reference to the accompanying drawings, wherein:

FIG. 1 is a diagram schematically showing a single element radio frequency noise generator;

FIG. 2 is an elevational view in section schematically showing several anode noise generator elements of various sizes connected in parallel; and

FIG. 3 is an elevational view in section schematically showing a high power noise generator with magnets, cooling fins and a regulated gas supply.

The basic configuration of this invention is schematically illustrated in the diagram of FIG. 1. Two hemi-cylindrical, or tubular anodes **10** and **11**, prepared by axially splitting a hollow cylinder or tube, are mounted between two flat cathodes **12** and **13**. The cathodes **12** and **13** are parallel to each other and are normal to the cylindrical, or longitudinal axes of the anodes **10** and **11**. The resulting assembly of anodes **10** and **11** and cathodes **12** and **13** is enclosed in gas-tight envelope **14**. Envelope **14** is filled

with an appropriate gas (e.g., hydrogen) at pressure of about 10^{-3} to 10^{-4} millimeter of mercury. It is maintained at this pressure by a gas pressure regulator **15**, which also is enclosed in envelope **14**, as shown.

Gas pressure regulator **15** includes an absorbent, such as absorbent titanium or zirconium, which absorbs large amounts of hydrogen, or other gases. When the absorbent metal is heated, as indicated at **15**, the absorbed gas is released to maintain the low pressure desired inside envelope **14**. The gas release rate is very closely controlled by controlling the temperature of the absorbent metal. The temperature of the absorbent metal in turn is controlled by means of an auxiliary heater, which in turn is controlled by a feed-back amplifier (not shown) in the low voltage regulator connected at **30**, **31**. The feedback amplifier in turn is controlled by the pressure-dependent gas discharge current. In this manner the gas pressure inside envelope **14** is stabilized automatically. Gas pressure regulator **15** also serves as an ion supply source because the released gas is ionized by the electrical discharge formed inside envelope **14**. Alternately, a liquid metal of appropriate vapor pressure characteristics can be used instead of a non-condensable gas like hydrogen for the atmosphere in envelope **14**. In this case, the gas pressure in envelope **14** is controlled by the envelope temperature and equals the vapor pressure of the liquid metal corresponding to the envelope temperature. Examples of such liquid metals are mercury and cesium. To obtain vapor pressures between 10^{-3} and 10^{-4} millimeter of mercury, envelope temperatures of the order of about 10° C. and about 90° C., are required for mercury and cesium, respectively.

Cathodes **12** and **13** are connected to one pole **16** of a high voltage source by means of leads **17** and **18**, respectively, and line **19**. Anode **11** is connected to the other pole **28** of the high voltage source and leads **26** and **27** are connected to ground as indicated at **29**. Anode **10** is connected to one end of ohmic load **20** through lead **21**, one line of coaxial cable **22** and lead **23**, and anode **11** is connected to the other end of the ohmic load through leads **24**, **25**, the other line of the coaxial cable **22** and leads **26** and **27**. It will be understood that instead of coaxial cable **22**, a pair of balanced, parallel lines can be used. Gas pressure regulator **15** is connected to the poles **30** and **31** of a low voltage regulator (not shown) by leads **32** and **33**, respectively.

In operation, the discharge cell consisting of anodes **10** and **11**, and cathodes **12** and **13**, is immersed in a magnetic field with the line of force of the field oriented parallel with the axes of the anodes **10** and **11**. A magnetic field in excess of about 1 kilogauss is used and a high voltage of several kilovolts is applied between 16 and 28. The discharge then ignites. Electrons are then emitted from the cathodes **12** and **13** as a result of bombardment thereof by ions produced in the gas discharge. The axial magnetic field prevents these electrons from reaching the anodes **10** and **11** directly. They remain trapped in the discharge region and ionize the neutral gas very effectively. At pressures below 10^{-3} millimeter of mercury the discharge is characterized by a pronounced plasma sheath at the anodes **10** and **11**. The potential drop across this sheath is abrupt and extends from the potential of the anodes **10** and **11** to near that of cathodes **12** and **13**. As a consequence of this, electrons in the sheath are subjected to crossed electric and magnetic fields and therefore rotate close to the anode in a direction perpendicular to the crossed fields, and thus produce a substantial rotating electron current close to the inside surfaces of anodes **10** and **11**. The split structure of anodes **10** and **11** causes an interaction of the rotating current with the external circuit consisting of anodes **10** and **11**, ohmic

load **20** and connecting lines **21–27**. In one specific operation, with a magnetic field of 2900 gauss, a high voltage of 8 kilovolts and with a 50 ohm load, 10 watts of noise power was generated and the radiation frequency spectrum was observed to be continuously distributed over three partially overlapping bands in the frequency range between 50 and 500 megacycles.

These bands are interpreted as the first, third and fifth harmonics of the angular frequencies of the rotating electrons. No trace of coherence between different portions of the rotation spectrum could be discovered. The noise obtained from the device of this invention represents an improvement of several orders of magnitude over prior art noise generators and is suitable for use in connection with electronic countermeasures systems. The noise generator of this invention can be employed for direct radiation of noise, or as a driver for a transmitter of noise at higher frequencies. The inherent simplicity of the device, its small size, and its relatively broad bandwidths, make it uniquely suitable as a noise generator.

A further interesting characteristic of the device of FIG. 1 is that it can be tuned electronically. The frequencies of the noise bands are directly proportional to the azimuthal velocity of the electrons in the plasma sheath of the anodes **10** and **11**. This velocity is of the order of E/B where E is the average electric field in the plasma sheath, and B is the axial magnetic field. Furthermore, E increases with discharge voltage applied at electrodes **16**, **28** from the high voltage source. Hence, either an increase of discharge voltage or a decrease of magnetic field results in a shift of the noise spectrum toward higher frequencies. The noise spectrum can thus conveniently be tuned during operation, which is an advantage of this invention.

To achieve higher powers and greater frequency ranges of noise and to provide a more constant output power-density over the frequency range than is attainable with the single element configuration shown in FIG. 1, a plurality of elements can be connected in parallel as shown in FIG. 2. Several split anode cells A, B and C, of different sizes are combined in a single envelope D, between spaced parallel cathodes **34** (only one shown). A gas pressure regulator is shown at **35**. The anode elements of slit anode cells A, B and C are shown connected in parallel by leads **36** and **37**, which in turn are connected to coaxial cable **38**. Coaxial cable **38** is connected to an ohmic load (not shown) and cathodes **34** are connected to a high voltage source (not shown) by leads **39** (only one shown) in a manner similar to that described for the single element noise generator shown in FIG. 1.

The noise from the several sources A, B and C superimpose linearly. It has been found that the noise power spectrum obtained by coupling several different split anode cell units, or elements, in parallel is approximately equal to the sum of the spectra of the individual elements. Furthermore, by appropriate adjustment of circuit dimensions and/or operating voltage and/or magnetic field it has been found that the noise bands of an individual element can be shifted anywhere in the range of 40 megacycles to about 400 megacycles. Hence, by parallel coupling of a number of appropriately designed elements, it is possible to synthesize any desired noise spectrum between 40 megacycles and about 400 megacycles, with continuous production of noise power densities exceeding 0.1 watt per megacycle.

Measurements have indicated that the noise power output increases as the potential of split anodes **10** and **11** is raised. The maximum noise power output is limited only by heat dissipation in the element itself. The construction of a metal-ceramic discharge tube envelope **40**, shown in FIG. 3, made of copper, for example, in combination with cathodes **41** and **42** mounted inside envelope **40**, as shown, and anode elements **43** and **44**, mounted on metal lead rods **45** and **46**, respectively, permit a high rate of heat dissipation. Leads **45** and **46** are insulated from metal envelope **40** by ceramic insulators **47** and **48**, respectively, and are cooled by metal cooling fins **49** and **50**, respectively. Cooling fins **49** and **50** radiate heat from leads **45** and **46**, respectively, which serve as heat sinks for heat generated by the cathode discharge and its interaction with the split anodes. Cathodes **41** and **42** and anodes **43** and **44** are in solid contact with large external surfaces which are adapted to be air cooled. The poles **51** and **52** of a magnet are shown in axial alignment with the axes of anodes **43** and **44**. A gas regulator is shown at **53**.

Although the split anode configurations described above, and illustrated in FIGS. 1 to 3, contain two segments, it will be understood that more than two segments per anode can be used. Higher frequency noise is produced by using more than two segments per anode element or cell. A four-segment anode element produces noise of about twice the frequency obtained from a two-segment element.

Obviously many other modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention can be practiced otherwise than as specifically described.

What is claimed is:

1. A radio frequency noise generator comprising:

(a) a hollow cylindrical anode means split along its axis into two generally cylindrical anode elements;

(b) cathode means spaced axially from each end of the anode means;

(c) a vacuum-tight envelope means enclosing the anode means and the cathode means;

(d) means for maintaining a gaseous atmosphere at a controlled low pressure inside the envelope means;

(e) magnetic field generation means cooperatively associated with the anode means for maintaining a magnetic field with its lines of force in alignment with the axes of the anode means;

(f) a high voltage source connected between the cathode means and the anode means for producing a cathode discharge; and

(g) circuit means including an olmic load connected to the cylindrical anode elements for interaction with the cathode discharge and generation of radio frequency noise.

2. A noise generator according to claim **1**, wherein: the hollow cylindrical anode means is split along its axis into a number of generally cylindrical anode elements, in excess of two such elements.

3. A noise generator according to claim **1** wherein several hollow cylindrical anode means, each split along their axes into two generally cylindrical anode elements, are mounted in an envelope and connected in parallel relationship with each other.

References Cited by the Examiner

UNITED STATES PATENTS

2,187,149	1/1940	Fritz	315—39.67 X
2,658,149	11/1953	Gallagher	331—78
2,819,449	1/1958	Herold	332—5

ROY LAKE, *Primary Examiner.*

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,231,830 January 25, 1966

Wolfgang Knauer

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 1, line 22, after "frequency", second occurrence, insert -- spectrum --; line 61, after "generator" insert -- provided --; column 2, line 49, for "line" read -- lines --; line 53, strike out "then", second occurrence.

Signed and sealed this 6th day of December 1966.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents