Jan. 6, 1953 R. H. DICKE 2,624,836

RADIO NOISE TRANSMITTER

Filed Aug. 30, 1945

FIG.1

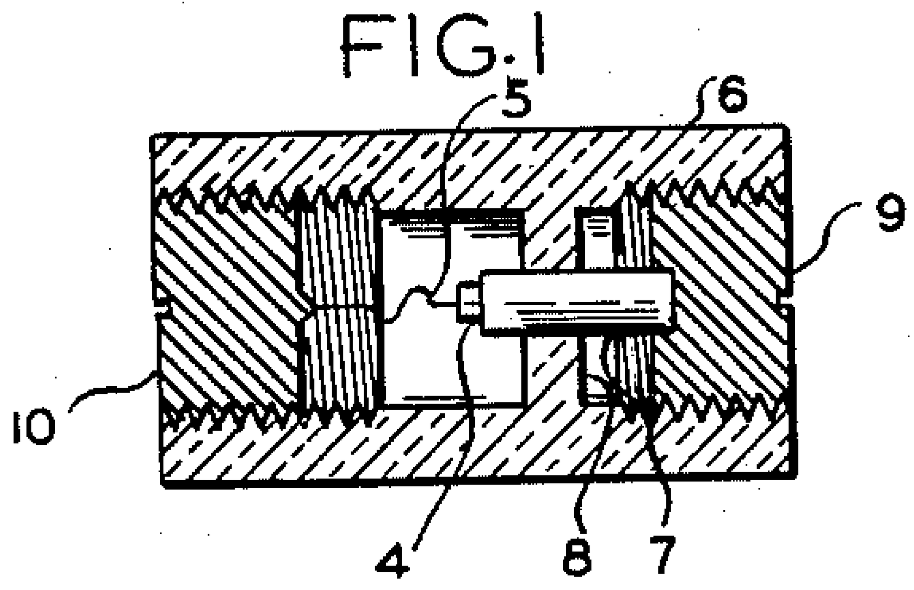


FIG.2

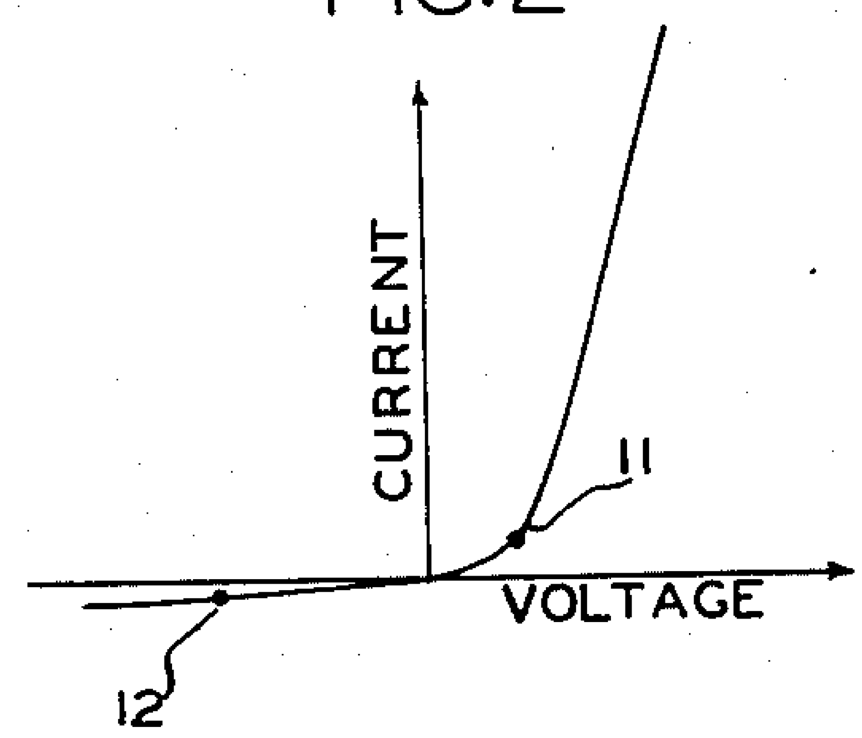


FIG.3

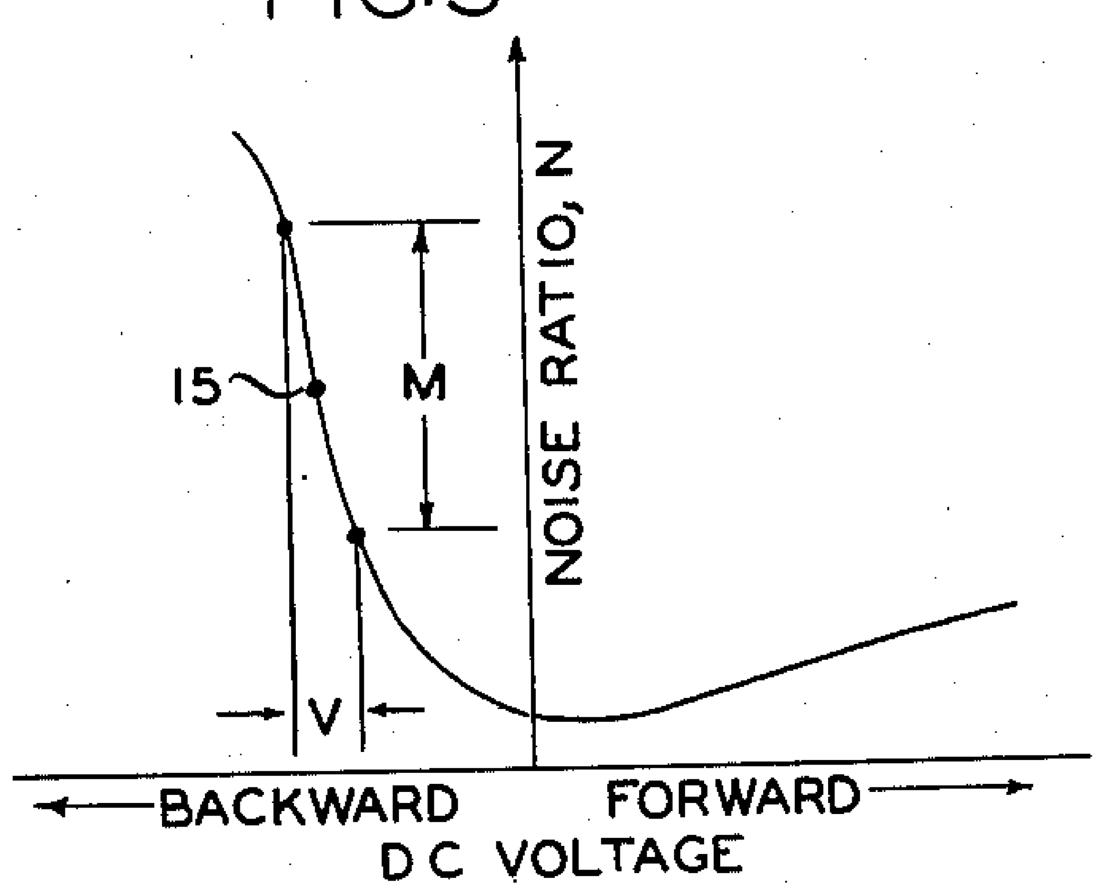
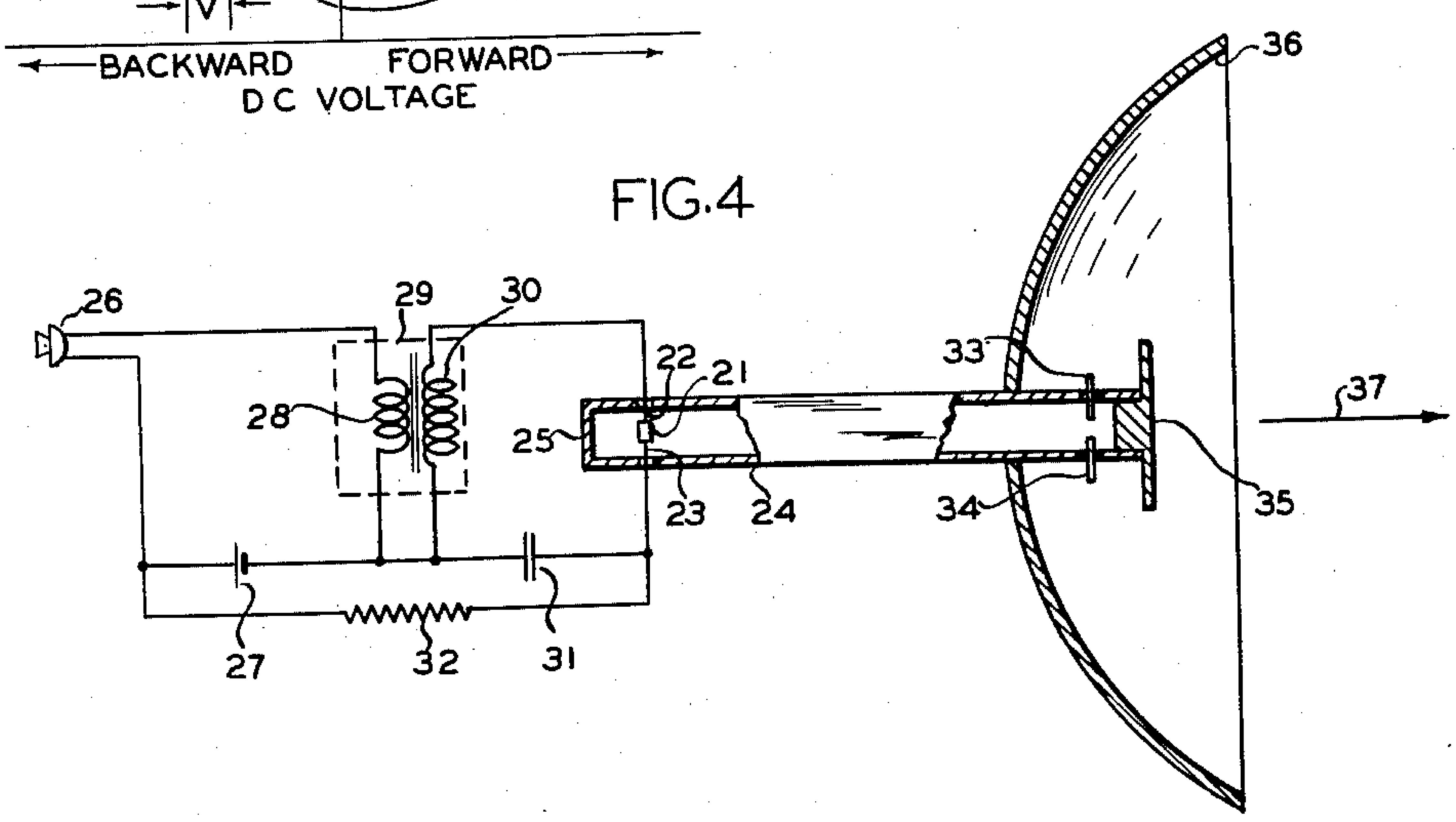


FIG.4



INVENTOR.
ROBERT H. DICKE
BY
William D. Hall
ATTORNEY

Patented Jan. 6, 1953 2,624,836

UNITED STATES PATENT OFFICE

2,624,836

RADIO NOISE TRANSMITTER

Robert H. Dicke, Cambridge, Mass., assignor, by mesne assignments, to the United States of America as represented by the Secretary of War

Application August 30, 1945, Serial No. 613,610

4 Claims. (Cl. 250—17)

1

This invention relates to high frequency generators and particularly to an electrical apparatus for generating and modulating radio frequency energy in the microwave region.

An object of the present invention is to provide a simple and highly efficient microwave generator.

Another object is to provide a modulated microwave transmitter which requires extremely low power for its operation.

Other objects and advantages will become apparent from the following description when read in connection with the drawing, in which:

Fig. 1 is a longitudinal cross-section of an ultra-high-frequency rectifying crystal;

Fig. 2 is a typical current-voltage characteristic curve of a silicon-tungsten crystal;

Fig. 3 is a typical noise characteristic curve of a silicon-tungsten crystal; and

Fig. 4 is an embodiment of a transmitter apparatus in accordance with the present invention.

The illustrated embodiment of the invention includes a crystal rectifier which here functions in novel manner as a radio frequency generator. The term "crystal" or "crystal rectifier" as used in the art refers to a combination of two dissimilar crystals in contact, or a crystal in contact with a metal point. For example, a crystal unit may include a tungsten "whisker" in contact with a smooth silicon surface. Such crystal units have unilateral or asymmetrical conductivity and are ordinarily utilized for radio frequency detection purposes.

A cartridge-type silicon-tungsten crystal suitable for use at ultra-high-frequencies is illustrated in Fig. 1, in which the silicon crystal **4** and tungsten whisker **5** are shown contained within an internally threaded shell **6**. Shell **6** may be made of ceramic or other insulation material, and all other parts of the crystal cartridge here shown are of metal to provide electrical continuity to the silicon crystal and tungsten whisker. A portion of silicon crystal **4** is embedded in one end of a post **7**, slidably mounted in an aperture of internal wall **8** as shown. The other end of the post is journaled against an externally threaded plug **9** which engages with shell **6**. The tungsten whisker is secured to the inner face of a similar plug **10** which is threaded into the opposite end of insulating shell **6**. Plugs **9** and **10** thus serve for adjustment of the crystal unit.

The operation of the crystal unit as a detector is generally with a relatively small biasing or polarizing voltage applied to the crystal in a "forward" direction, placing it at an operating point as indicated at **11** in Fig. 2. In the illustrated embodiment of the present invention, however, a biasing potential is applied to the crystal in an opposite or "backward" direction, as indicated by

2

an operating point **12**, to secure best action as a radio frequency generator.

It has been found that "noise" voltage is developed at the terminals of a crystal unit. The noise voltage is characterized by a wide distribution in frequency including the very high radio frequencies, and the corresponding noise power is more or less uniformly distributed over the entire frequency band. The magnitude of the noise voltage is dependent upon the conditions of operation of the crystal. In particular, when no polarizing or radio frequency potentials are applied to the crystal, the noise voltage developed is relatively small and due solely to thermal agitation effects. When a polarizing potential is applied in a forward direction, the noise voltage is little greater and again is due principally to thermal agitation. The noise voltage produced is relatively large in magnitude, however, when a polarizing potential is applied to the crystal in a backward direction, and may be due principally to Schottky and other effects.

Noise may be produced by many other electronic components, for example in resistors as a result of thermal agitation, and such resistor noise forms a convenient basis of comparison. The noise power available from a resistor is proportional to the absolute temperature (Kelvin), and to the band width of the frequencies involved. The output noise ratio N of a crystal is then defined as the ratio of the output noise power of the crystal to that of an equivalent resistor at a standard temperature here taken as 300° K., absolute. N may also be termed the "noise temperature," for it is equal to the ratio of the absolute temperature (Kelvin) at which an equivalent resistance would generate just as much noise as the crystal, to the standard temperature given above. The noise ratio or temperature may, under suitable conditions, reach large values for the type of crystal shown in Fig. 1. The manner in which the output noise ratio or noise temperature of a crystal varies as a function of the crystal polarizing voltage is illustrated in Fig. 3. As there shown, a relatively small voltage applied to the crystal in a backward direction greatly increases the noise output of the crystal over that available when the biasing potential is in a forward direction.

In accordance with the present invention, a band of frequencies in the ultra-high-frequency region is selected from the crystal noise, and the corresponding energy is concentrated into a narrow beam by a wave guide and reflector structure. The apparatus is shown schematically in Fig. 4, in which reference numeral **21** designates a crystal connected to and mounted upon probe elements **22**, **23** within one end of a relatively short length of hollow wave guide **24**. The crystal and probe elements act as exciting means for the wave guide, and a proper impedance match is secured by conventional means including end plate 25. Other means than that illustrated may, of course, be utilized for coupling the crystal to the wave guide for excitation purposes. Probe elements 22, 23 communicate with a polarizing and modulating circuit as shown. A microphone 26, connected in series with a potential source 27 and the primary 28 of a microphone transformer 29, is adapted to produce alternating voltages at voice frequencies across secondary winding 30 in response to voice energy impinging on the microphone. A capacitance 31 of relatively low impedance completes the alternating current circuit between secondary winding 30 and crystal 21. Secondary winding 30 is also included in a direct current polarizing circuit for the crystal, being connected in series with the potential source 27, crystal 21, and a resistance 32 adapted to limit the crystal voltage to the value necessary for proper operation.

The polarizing potential applied to the crystal in the embodiment here described is of suitable value to secure operation on the substantially straight line portion of the backward characteristic. This condition of operation is illustrated in Fig. 3, in which an operating point 15 is located at about the center of the straight line portion of the noise characteristic curve. A voice modulation voltage swing designated V will then cause the output noise level to vary through a range M, and the time curve of noise level will bear a substantially linear relation to the time curve of the modulating voltage. The noise level corresponding to operating point 15 may thus be linearly modulated in accordance with a signal voltage impressed upon the biasing voltage, as by the circuit means shown in Fig. 4.

Referring again to the wave guide and radiating structure of Fig. 4, a pair of antenna rods 33, 34 protrude through the walls of the radiating end of wave guide 24, and this end of the wave guide is closed by a reflector plate and plug structure 35. The distances between the inner wall of the plug and the antenna rods, and between the reflector plate and the antenna rods, are suitably chosen to provide proper impedance matching over the operating frequency band. If desired, filter means adapted to pass a frequency band of selected width may be included in the wave guide transmission line between the crystal 21 and antenna rods 33, 34. Noise voltages present at the terminals of crystal 21, and and at its connecting probe elements 22 and 23, excite microwaves which are guided toward antenna rods 33, 34. A parabolic reflector 36, mounted upon the wave guide as shown, coacts with the antenna rods and reflector plate to focus or concentrate the wave energy into a narrow beam, so that highly efficient transmission in the direction indicated by arrow 37 may be secured.

A microwave receiver for detection of the signals may be of the conventional superheterodyne type, except for the band width of the intermediate frequency amplifier. It is desirable that the said band width be large, for the signal to noise ratio as seen at the receiver output is proportional to the square root of the band width. The band width of the microwaves beamed toward the receiver by the present invention is determined by the characteristics of the wave guide and associated structure of the transmitter apparatus, and is sufficiently broad to insure sufficient wave energy for satisfactory signal communication.

The entire apparatus may be physically compact when designed for operation at the extremely high radio frequencies. Other forms of noise generators may be utilized, but a crystal as here described is the preferred embodiment because of its compactness, light weight, and large noise capabilities. The actual range of transmission of the illustrated embodiment of the invention is in large part dependent upon the noise temperature of the crystal over the operating frequency band, and upon the diameter or aperture of the parabolic reflector. The various electronic components may be variable, as is common in electronic apparatus for adjustment purposes to secure optimum performance.

It will be understood that the specific embodiment of the invention shown and described is but illustrative, and that various modifications may be made therein without departing from the scope and spirit of the invention.

What is claimed is:

1. In a system for radio frequency electromagnetic wave transmission, apparatus for generating radio frequency noise signals comprising a crystal and a potential source biasing said crystal in the less conductive direction so that said crystal generates noise signals, said crystal having a noise signal energy output characteristic which is substantially linear within a certain range of said biasing potential, and means for amplitude modulating said noise signals to cause said noise signal output level to vary within said range.

2. In a microwave transmission system, a wave guide, a crystal and a potential source biasing said crystal in the less conductive direction so that said crystal functions as a source of radio frequency noise signals, said crystal mounted within said wave guide, and an antenna coupled to said wave guide for transmitting said radio frequency noise signals.

3. In a very high frequency electromagnetic wave transmitter, a crystal and a potential source biasing said crystal in the less conductive direction so that said crystal generates very high frequency noise signals, means for modulating said noise signals and a high frequency transmission device for transmitting a band of said modulated noise signals.

4. A noise source comprising a crystal rectifier and a potential source biasing said crystal rectifier in the less conductive direction so that said crystal generates radio frequency noise signals, a coupling device, an antenna connected to said crystal by said coupling device for radiating said noise signals.

ROBERT H. DICKE.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,165,569	Ring	July 11, 1939
2,207,620	Hilferty	July 9, 1940
2,253,975	Guanella	Aug. 26, 1941
2,370,053	Lindenblad	Feb. 20, 1945
2,408,420	Ginzton	Oct. 1, 1946

FOREIGN PATENTS

Number	Country	Date
271,915	Great Britain	June 8, 1927