June 13, 1961 A. D. FROST 2,988,636

PARAMETRIC AMPLIFIER ANTENNA

Filed April 22, 1960

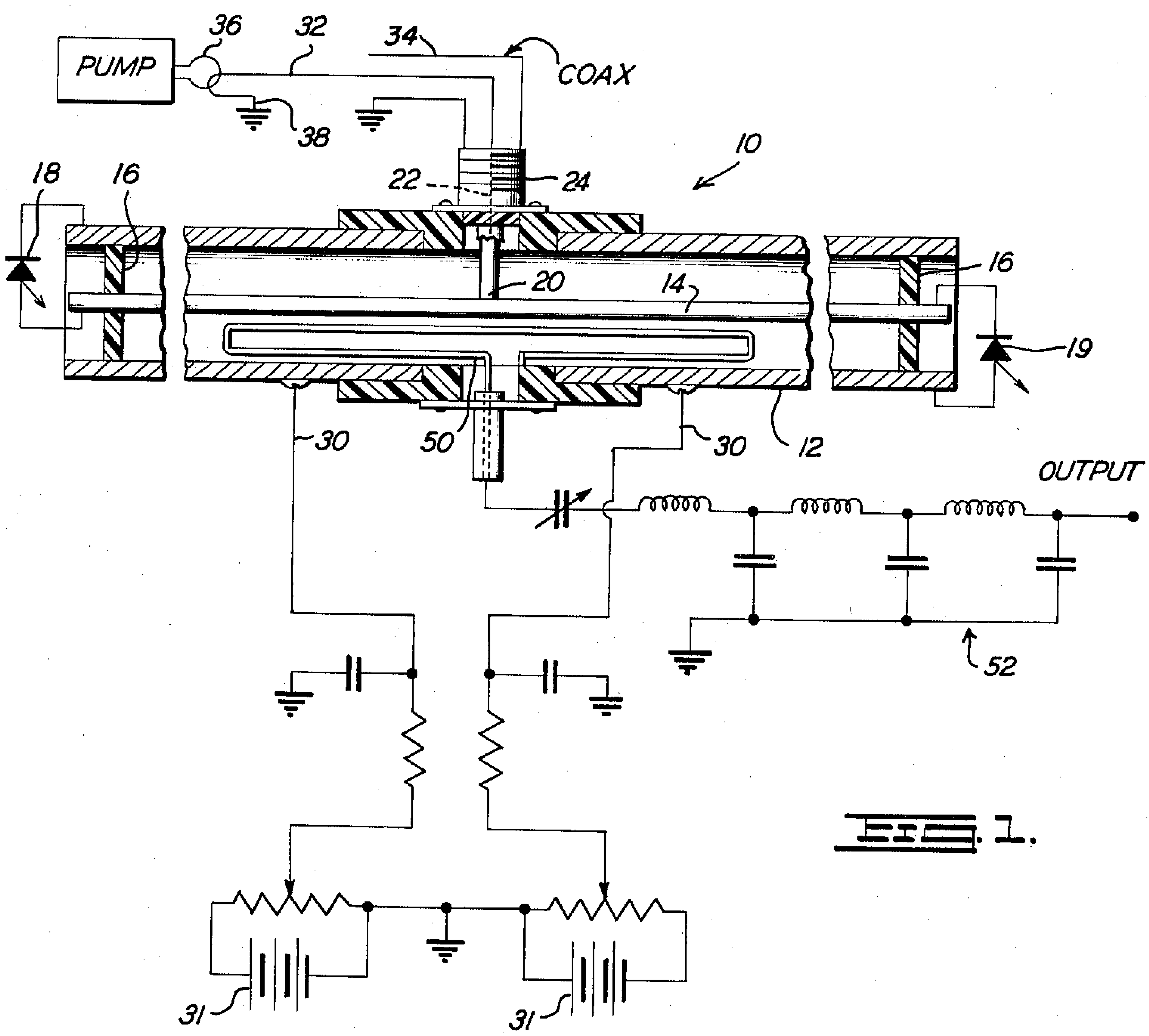


FIG. 1.

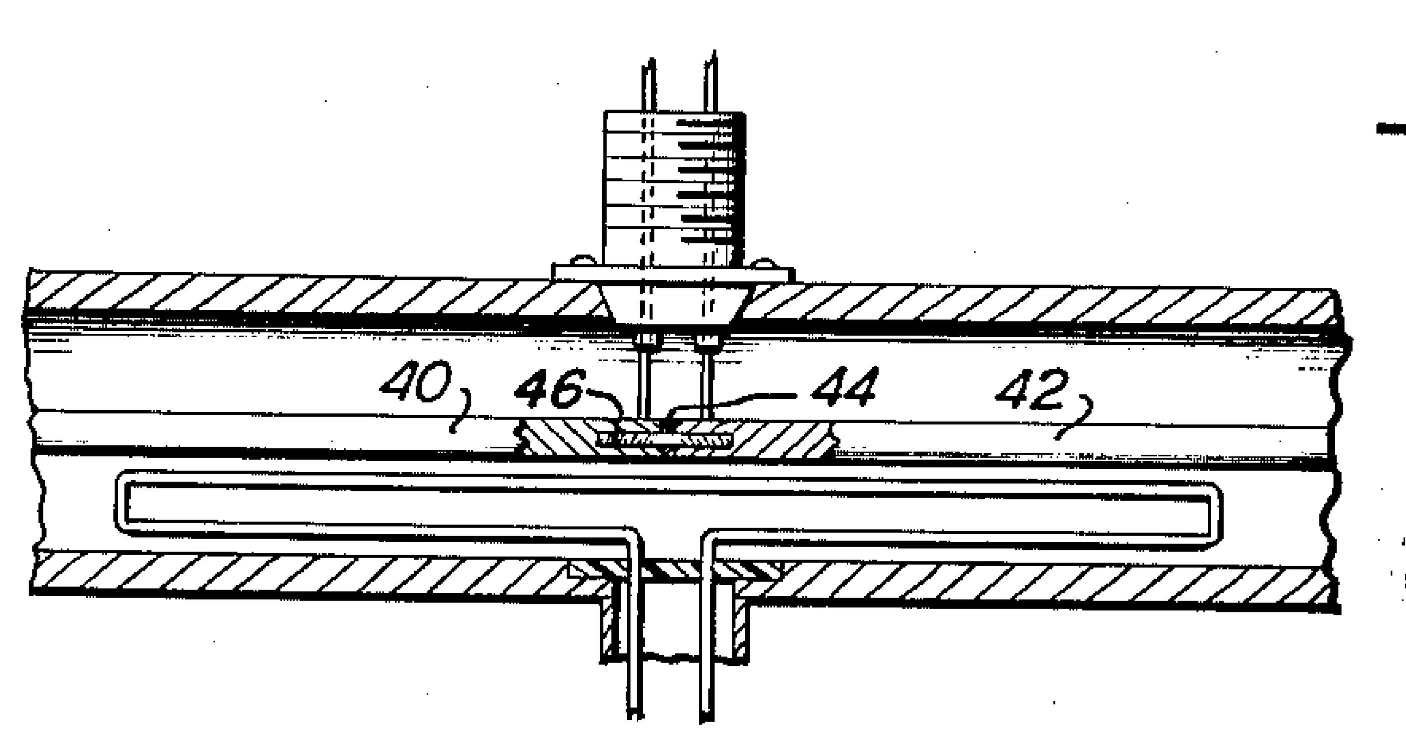


FIG. 2.

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2,988,636
Patented June 13, 1961



2,988,636

# PARAMETRIC AMPLIFIER ANTENNA

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Filed Apr. 22, 1960, Ser. No. 24,161
8 Claims. (Cl. 250—20)

The present invention relates to parametric amplification of electromagnetic signals in signal acquisition structures or antennas and resonating devices, and has particular reference to an improved device for parametric amplification of electromagnetic signals within a half-wave antenna dipole.

The invention relates to improvements in and relating to non-linear circuits and more particularly to electronic resonators having reactive non-linear circuit elements and the application thereof to electromagnetic wave acquisition devices.

The present invention utilizes the phenomenon that oscillation is built up in an electric resonator by varying a parameter of the electronic resonator. Since such a phenomenon may be called "parametric excitation of oscillation," the electric resonator used in the present invention can be called a "parametrically excited resonator." This invention, therefore, relates to a parametric amplifier adapted for amplification of radio and microwave frequency signals, and in which a parametric reactance element may be periodically varied in value, in accordance with the applied voltage.

By applying a pump frequency voltage $f_p$ to the input terminals of the line for the purpose of varying the reactance of the parametric elements, a signal frequency voltage $f_s$ which is applied to the input terminals is amplified. The pump frequency must equal the sum of the signal frequency plus an idler frequency.

The reception of low level radio frequency signals used in tracking sources of radio frequency energy that emit or reflect weak signals has been improved by the conjunctive use of parametric amplifiers. In the present invention the device is an antenna-amplifier in which the resonant elements are made part of and included within a half-wave dipole antenna. It has been found that a parametric amplifier antenna in which are several resonant circuits required in the parametric technique for (1) the acquisition and storage of the input signal, (2) the storage of an idler frequency component, and (3) the storage and distribution of an output signal, together with suitable connecting structure for the application of a pumping signal and appropriate fixed bias potentials as are required, may be contained within the structure of a half wave antenna dipole in which the structure is made part of the circuit of the parametric amplifier.

The parametric amplifier antennas used in the invention may include printed circuitry techniques. Such devices have been found to provide stable gains up to 20 decibels. The upper frequency limit of parametric amplifier antennas within the scope of the present invention extends from 800 to 1000 mc. These limits depend on the limitations of presently available solid state elements and not on any restriction in the principles involved.

Accordingly, the present invention is directed to a device that receives an electromagnetic input signal and for deriving an output signal from a resonant element, the resonant element being in circuit with a parametric amplifier to enhance the energy content of the input signal and applying a bias and an excitation frequency to the input signal and a resonant frequency of the resonant element, and deriving therefrom an output signal that has an enhanced characteristic of the original electromagnetic input signal.



Perhaps the outstanding advantage of the new antenna is that it provides amplification of the original signals as received before any transmission losses are incurred, as well as using the physical and electrical characteristics of the antenna as part of an electrical circuit for the amplification means.

A complete understanding of the invention may be had from the following description of a particular embodiment of the invention. In the description, reference is made to the accompanying drawings of which:

FIG. 1 is a partially cross-sectional and partially schematic circuit diagram of a preferred embodiment of the present invention; and

FIG. 2 shows another embodiment of the invention using a split center conductor for the coaxial antenna together with the D.C. bias circuits used with the split center conductor dipole and using a balanced output loop.

Referring now to the figures, the antenna dipole generally designated by reference numeral **10** consists of a hollow conducting outer cylinder **12** and inner coaxially disposed conductor **14**. The inner conductor **14** is supported in spaced relation within the outer cylinder **12** by a pair of disc-shaped dielectric elements **16, 16.** The external cylinder **12** exhibits a resonance condition and is indicated by a maximum amplitude of axial current when placed in an electromagnetic field of frequency $f_s$ and oriented so that some component of the electric field is parallel to the major axis of the dipole antenna **10**. The inner conductor **14** of the antenna is supported at its midpoint **20** by an extension of the center conductor **22** of a suitable coaxial line or connector **24.**

It has been found that the outer cylinder and the inner conductor of the antenna must of necessity include the characteristic that there is a continuity for the flow of axial high frequency currents along the inner and outer surfaces of the dipole cylinder **12** and along the outer surface of the inner conductor **14**, and that, depending on the character of the active circuit element employed, there are isolated independent D.C. bias paths that are provided for each parametric element.

There are parametric elements or junction diodes **18** and **19** connected between each of the exterior ends of the dipole between the center or inner conductor and the cylindrical or outer conductor. These diodes are reversely connected as is shown in FIG. 1, and provide, as is well known, a voltage variable reactance or capacitance.

Separate D.C. paths for the oppositely polarized diodes are provided by circumferential splitting (not shown) of the cylinder and the insertion therein of a thin insulating low loss layer between the cylinder and the couplings. Bias connections **30, 30** to batteries **31, 31** are provided at the inner ends of the insulated sections. Connections to the other terminal of each parametric element is made through conductor **32**, the center conductor. The center conductor is at D.C. ground potential. The D.C. ground potential is provided by a high impedance RF stub in the coaxial pumping line **34** or through a loop coupling **36** of the pumping signal source in which one side **38** of the output loop is grounded.

Dividing of the inner conductor into two sections **40, 42** with a thin capacitive junction **44** at the center of the length of the inner conductor is shown in FIG. 2. A threaded fastener **46** having each of its ends oppositely threaded may be employed to suitably secure the two sections **40** and **42.** Bias connections are then made to each of the center conductors through a suitable dividing network placed in the twin conductor coaxial line connected to the pumping source. A common return to ground potential is provided in this case by the solid outer cylinder.

Other techniques for providing a proper miniaturized component operating environment such as internal batteries and self-biasing may be provided.

An output signal is derived from the interior of the cylindrical antenna dipole by a coupling loop **50** which is oriented so as to enclose the magnetic field components of the dominant TEM wave and of such length as to minimize coupling to the idler mode. A frequency selective filter designed to prevent loss of the idler frequency may be inserted in the output path.

As has been shown above the outer surface of the dipole cylinder is provided with a resonant character as low level energy is received thereby. The inner region of the dipole cylinder exhibits a multiplicity of resonances in which the magnitude of the electromagnetic field will have, as a function of frequency, local maximum values. The boundary conditions which determine the location of these resonances include: the length of the inner conductor which may be slightly less than, equal to or greater than the length of the outer cylinder; the extent and distribution of the fringing fields extending beyond and between the ends of the inner conductor and the rim of the outer conductor; the static component of lumped impedance of the parametric elements connected between the ends of the center conductor and the corresponding end of the cylinder; the relative dielectric constant of the volumes containing the fringing fields; the dielectric constant of the annular region between the inner conductor and the inner surface of the outer cylinder, if this region is filled with a uniform material or gas, or the composite dielectric effect of all materials in this region together with their interfaces; and, the scattering produced by any conducting discontinuities or surfaces present within this annular region the input signal to be amplified is provided by the periodic charge concentrations at the ends of the dipole cylinder. Since the interior region of the dipole cylinder can support a large number of resonant conditions, there are numerous possibilities for the application of this structure to parametric amplification techniques. An output signal at the same frequency as the input signal can be obtained by providing a region within the dipole that is resonant at $f_s$. The interior resonance can best be obtained by using the lowest TEM mode of the inner coaxial region. The length of a dipole at resonance is less than $\lambda/2$ (where $\lambda$ is the free-space wavelength of a signal of frequency $f_s$). As a consequence, the idealized interior coaxial region is resonant at a frequency greater than $f_s$. In practice the actual resonant value of the region will be lowered by cumulative shunting effects that may appear. The relative dipole length required for resonance together with the influence of these shunting components on the inner region resonance may be determined and is useful information to determine the amount of capacitance required to match the interior cavity resonance with the external dipole cylinder.

It is possible to adjust the inner cavity resonance by the amount of D.C. bias applied to the parametric diodes **18** and **19**. Since optimum bias should be determined on the basis of most effective gain and minimum noise, this form of electrical tuning, except for minor adjustments is usually done at the expense of amplifier performance. The capacitance required for resonance in the region from 100 to 150 mc. is larger than could be properly derived from the presently available parametric elements. Since the required shunting capacitance for resonance can be simulated by an effective increase in line length, this was accomplished by the insertion of a sheet of a low loss dielectric, such as polystyrene, within the annular region between the inner conductor and the outer cylinder. The thickness was calculated on the basis of the approximate increase in line capacitance per unit length required to produce the desired fractional reduction in propagation velocity, and hence increase in effective length.

Dielectric spacers for additional support of the center conductor may be provided throughout the length of the conductor in addition to the primary support provided by the dielectric spaces **16, 16** at each end thereof.

The parametric amplifier antenna may be used with other antenna elements to form, for example in combination a Yagi form array.

The pumping frequency used in the antenna amplifiers was four times the signal frequency ($4 f_s$) with a resulting idler component at $3 f_s$ and also six times the signal frequency ($6 f_s$) with an idler at $5 f_s$.

It appears that dielectric loading will provide a satisfactory method for adjusting half wave dipoles below 150 mc. For quarter-wave dipoles, this is not necessary, since the additional length required for the inner region is obtained by an extension of the antenna below the ground plane which defines the length of the outer wave portion.

The internal amplifier technique for coaxial dipole antennas may be extended above 300 mc. And may further require a modification of the interior region of the dipole antenna, including such possibilities as the generation of the pumping signal within the antenna using the interior of the center conductor as a further resonant cavity in connection with a negative resistance device.

It should be understood, however, that the specific apparatus herein illustrated and described is intended to be representative only, as many changes may be made therein without departing from the clear teachings of the invention. Accordingly, reference should be made to the following claims in determining the full scope of the invention.

What is claimed is:

1. A device for acquisition and storage of an electromagnetic input signal and for deriving an output signal therefrom comprising a half-wave dipole antenna within a resonant element, parametric amplifier means connected between the ends of the resonant element and the dipole antenna, means coupled to said parametric amplifier means for applying an excitation signal $f_p$ thereto to enhance the energy content of the input signal, the frequency of said excitation signal being related to the sum of the input signal frequency and the resonant frequency of the resonant element, and an output loop coupling an output signal from the resonant element.

2. A device for acquisition and storage of an electromagnetic input signal and for deriving an output signal comprising a half wave dipole antenna within a resonant element, parametric amplifier means connected between the ends of the resonant element and the dipole antenna, means coupled to said parametric amplifier means for applying an excitation signal thereto to enhance the energy content of the input signal, and an output loop coupling an output signal from the resonant element.

3. A signal acquisition structure comprising a hollow conductor cylinder resonant at the frequency of an electromagnetic input signal, a transversely divided center conductor axially disposed to the cylinder, said conductor including at least two individual conductor elements, bias means connected to each of said conductor elements, parametric diode elements connected between each end of said center conductor and an adjacent portion of the hollow conducting cylinder, the amount of bias provided by the bias means controlling the amount of reactance of the parametric diode, and the reactance of the parametric diode being further responsive to the resonance of the hollow conducting cylinder and the center conductor, pumping frequency means also coupled to each of said conductor elements to control the resonance thereof and affect the rate at which the reactance for the parametric diode is varied, means for providing a non-linear mixing

component, and an output signal loop to couple from the hollow conducting cylinder an amplified input signal.

4. A signal acquisition structure comprising a hollow conductor cylinder resonant at the frequency of an electromagnetic input signal, a center conductor axially disposed within said cylinder, bias means connected to said center conductor, a parametric diode element connected between each end of said center conductor and an adjacent portion of said hollow conducting cylinder, the amount of bias provided by said bias means controlling the amount of conduction of the parametric diode, and the conduction of said parametric diode being further responsive to the resonance of said hollow conducting cylinder and said center conductor, pumping frequency means also coupled to said center conductor to control the resonance thereof and affect the rate at which the reactance for said parametric diode is varied, means for providing a non-linear mixing component, and an output signal loop to couple from said hollow conducting cylinder an amplified input signal.

5. A device for acquisition and storage of an electromagnetic input signal and for deriving an output signal comprising a half-wave dipole antenna within a resonant element, parametric amplifier means connected between the ends of the resonant element and the dipole antenna, means coupled to said parametric amplifier means for applying an excitation signal thereto to enhance the energy content of the input signal, the frequency of said excitation signal being related to the sum of the input signal frequency and the resonant frequency of the resonant element bias means coupled to the resonant element to adjust the frequency of said excitation signal, and an output loop coupling an output signal from the resonant element.

6. A signal acquisition amplifier comprising a hollow conducting cylinder resonant at an input frequency $f_s$ causing a periodic charge concentration at the ends of said cylinder, a center conductor coaxially disposed within said cylinder, the outer surface of said center conductor and the inner surface of said hollow cylinder forming electrical boundaries of a coaxial cylindrical zone of annular cross-section, said zone exhibiting a fundamental TEM type resonance at said signal frequency $f_s$, and means providing a non-linear mixing component at a frequency $f_i$ which is equal to one of the higher order TEM modes of said inner coaxial region, said means comprising a pair of reversed biased junction diodes providing a voltage variable reactance coupled between said cylinder and said center conductor, an alternating potential excitation coupled to said junction diodes to vary the net reactance about a mean value, said alternating potential being provided by a pumping source at a frequency $f_p$, a fixed bias source coupled to each of said diodes to establish the mean value about which the net reactance varies, and an output coupling for said coaxial zone for deriving therefrom an amplified signal at the same frequency as the input frequency $f_s$.

7. The signal acquisition amplifier of claim 6 wherein the center conductor is divided transversely into two sections having a thin capacitive junction at the longitudinal split, and separate bias connections and pumping frequency connections being provided for each of said sections.

8. A signal acquisition structure comprising a hollow conductor cylinder resonant at the frequency of an electromagnetic input signal, a center conductor axially disposed within said cylinder, bias means connected to said center conductor, a parametric diode element connected between at least one end of said center conductor and an adjacent portion of said hollow conducting cylinder, the amount of bias provided by said bias means controlling the amount of conduction of the parametric diode, and the conduction of said parametric diode being further responsive to the resonance of said hollow conducting cylinder and said center conductor, pumping frequency means also coupled to said center conductor to control the resonance thereof and affect the rate at which the reactance for said parametric diode is varied, means for providing a non-linear mixing component, and an output signal loop to couple from said hollow conducting cylinder an amplified input signal.


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