

[54] MICROWAVE SAMPLING DEVICE

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[51] Int. Cl. H03k 17/00

[58] Field of Search 328/151; 333/7, 7 D; 324/95; 332/52; 307/240

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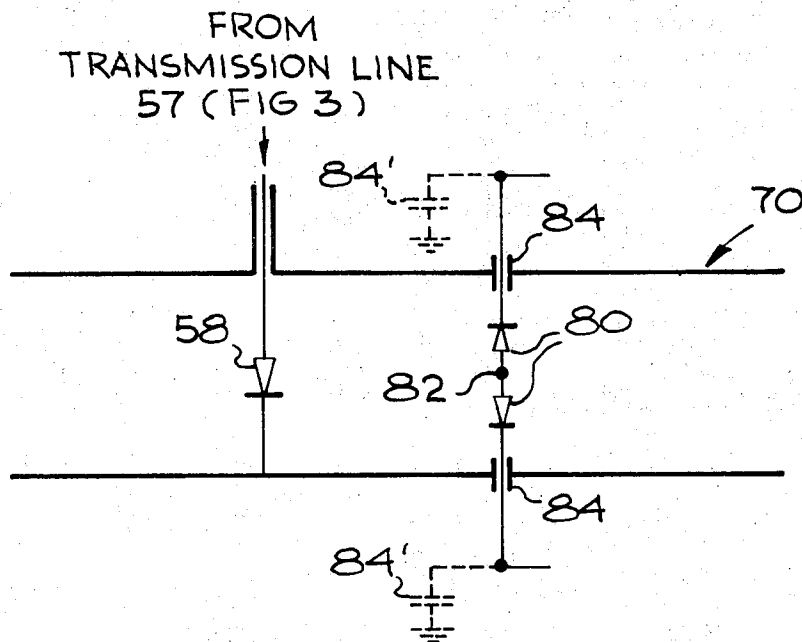
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[57] ABSTRACT

A broadband microwave sampling device employing a balanced arrangement of matched semiconductor sampling diodes mounted in a waveguide adjacent a step recovery diode across which sampling pulses are generated for coupling to the sampling diodes by propagation through the waveguide. The microwave signal to be sampled is coupled to the sampling diodes by a transmission line which passes through the waveguide. The waveguide is chosen to have a cut off frequency greater than that of the microwave frequency so that there is no propagation thereof within the waveguide.

17 Claims, 5 Drawing Figures



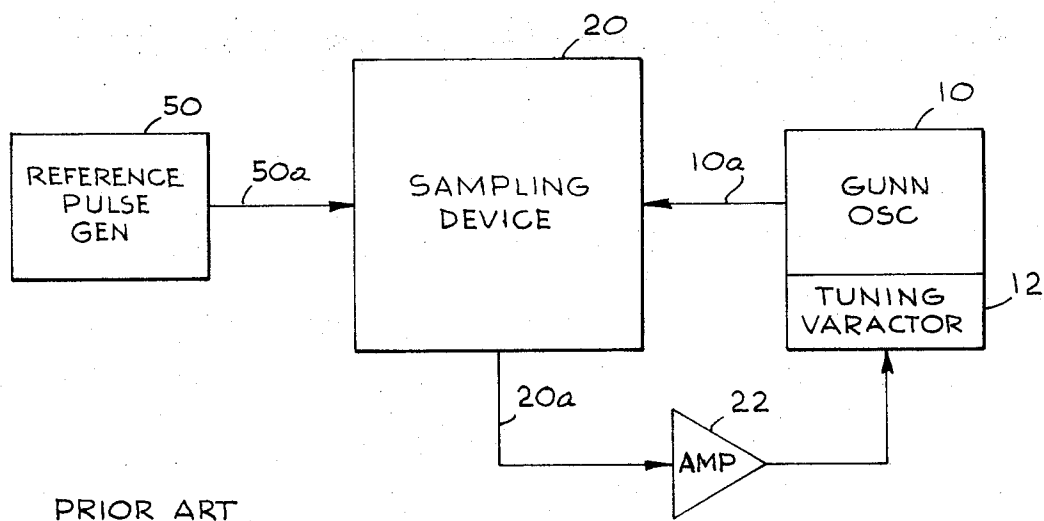


Fig. 1

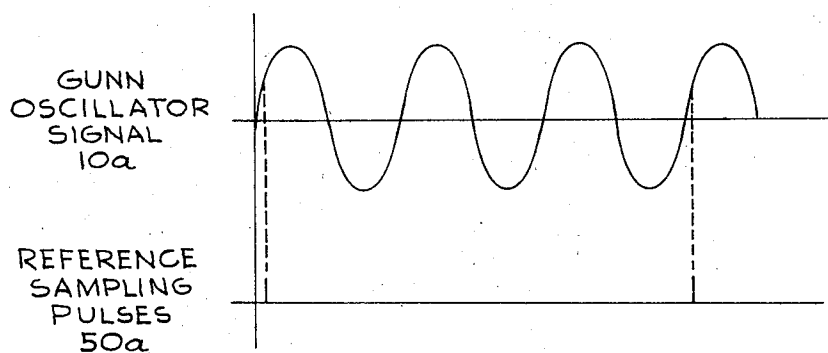


Fig. 2

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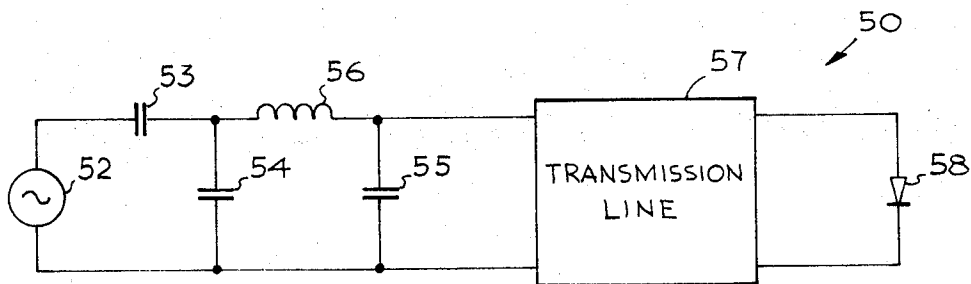


Fig. 3

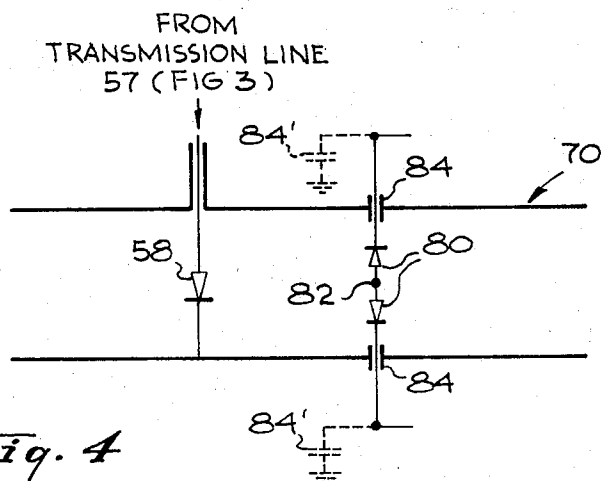


Fig. 4

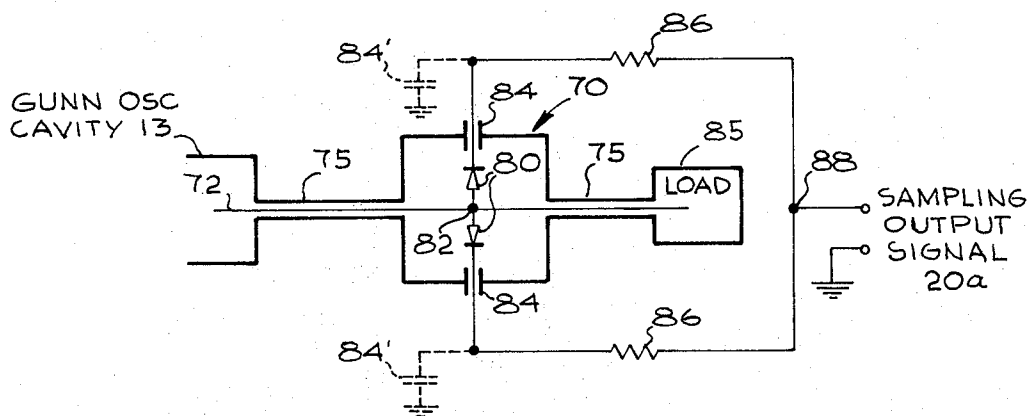


Fig. 5

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MICROWAVE SAMPLING DEVICE

BACKGROUND OF THE INVENTION

The present invention relates generally to means and methods for sampling high frequency electronic signals, and more particularly to improved means and methods for providing broadband sampling at microwave frequencies.

A typical application which requires broadband sampling of a microwave signal arises, for example, where it is desired to provide for automatically controlling the tuning of a Gunn oscillator which may typically operate at a frequency of 10 GHz. Although semiconductor diodes having appropriate frequency response for sampling at microwave frequencies have been available for some time, such as epitaxially grown Schottky-barrier junctions in low parasitic packages, it has nevertheless remained a most difficult problem to design a sampling device using such diodes which is capable of providing satisfactory microwave sampling, particularly at X-band and higher frequencies. The primary reason for this difficulty is that the frequency response of a sampling device employing semiconductor diodes is determined not only by the frequency characteristics of the sampling diodes and the sampling pulse, but also by the frequency characteristics of the coupling structure employed to connect them to one another. It has been the provision of such coupling structure which has presented the greatest difficulty in the design of a broadband sampling device. Further considerations in this regard and an example of a typical prior art approach will be found in the article "Sampling for Oscilloscopes and Other RF Systems: Dc Through X-band," W. M. Grove, IEEE Transactions on Microwave Theory and Techniques, Vol. MTT-14, No. 12, December, 1966, pages 629-635.

SUMMARY OF THE PRESENT INVENTION

It is accordingly a broad object of the present invention to provide improved means and methods for providing sampling of high frequency microwave signals.

A more specific object of the invention is to provide improved means and methods for providing unusually broadband sampling of microwave signals in the range of C-band through K-band.

Another object of the invention is to provide a sampling device in accordance with the foregoing objects which is relatively simple, reliable, and economical.

A further object of the invention is to provide a sampling device in accordance with the foregoing objects which employs semiconductor diodes.

A still further object of the present invention is to provide improved means and methods for obtaining broadband coupling at microwave frequencies.

An additional object of the invention is to provide improved means and method for automatically controlling the tuning of a bulk-effect oscillator and other electronic oscillators.

The above objects are accomplished in an exemplary embodiment of the present invention by the provision of a novel broadband sampling device which achieves broadband microwave sampling by taking advantage of the properties of a waveguide to provide the required coupling between the sampling pulse, sampling diodes and the microwave signal to be sampled. More specifically, in the exemplary embodiment of the invention, a microwave sampling device is provided in which a

waveguide is employed to provide broadband coupling of reference sampling pulses generated by a step recovery diode generation circuit to a balanced configuration of sampling diodes mounted in the waveguide along with the step recovery diode. The microwave signal to be sampled is coupled to the sampling diodes by a transmission line which passes through the waveguide and is terminated in its characteristic impedance. The waveguide is chosen to have a cut off frequency greater than that of the microwave signal to be sampled so that there is no propagation thereof within the waveguide. Also, the cut off frequency of the waveguide is further chosen in conjunction with the reference sampling pulses applied to the step recovery diodes to provide for the propagation of energy from the step recovery diode to the sampling diodes via the waveguide so as to result in the application of appropriately shaped driving pulses to the sampling diodes.

The specific nature of the invention as well as other objects, uses, advantages and features thereof will become apparent from the following description of an exemplary embodiment in conjunction with the accompanying drawings in which:

FIG. 1 is an electrical block diagram illustrating a conventional circuit arrangement including a sampling device for automatically controlling the tuning of a Gunn oscillator.

FIG. 2 is a graphical representation illustrating the operation of the circuit arrangement of FIG. 1.

FIG. 3 is an electrical circuit diagram illustrating a typical embodiment of the reference pulse generator in FIG. 1.

FIGS. 4 and 5 are schematic and electrical diagrams illustrating the construction and arrangement of a preferred embodiment of a sampling device in accordance with the invention.

Like designations refer to like elements throughout the figures of the drawings.

Referring initially to FIG. 1, illustrated therein is a typical prior art circuit arrangement which may be employed for automatically controlling the tuning of a Gunn oscillator 10, an associated electronically adjustable tuning varactor 12 being provided in the oscillator cavity for this purpose. As illustrated in FIG. 1, a signal 10a representative of the Gunn oscillator output signal is applied to a sampling device 20 for a comparison with reference sampling pulses 50a provided by a reference pulse generator 50, a typical relationship between the Gunn oscillator signal 10a and the reference sampling pulses 50a being illustrated in FIG. 2.

It will be understood from FIG. 2 that operation of the sampling device 20 is typically such that, if the pulse repetition rate of the reference sampling pulses 50a is coherent with the frequency of the Gunn oscillator signal 10a, the sampling pulses 50a will occur at substantially the same point on the Gunn signal waveform for each cycle sampled, resulting in an average or direct current value being obtained at the output 20a of the sampling device 20. On the other hand, if the pulse repetition rate of the reference sampling pulses 50a is not coherent with the Gunn oscillator frequency, then the periodic sampled value will be random so that the resulting average value provided at the sampling device output 20a will then essentially be zero. The sampling device output 20a is applied via a suitable amplifier 22 to the tuning varactor 12 which responds thereto in a conventional manner to maintain the de-

sired phase and frequency relationships between the Gunn oscillator signal 10a and the reference sampling pulses 50a.

Referring next to FIG. 3, illustrated therein is a typical embodiment which may be employed for the reference pulse generator 50 in FIG. 1 for generating the reference sampling pulses 50a. An oscillator 52, which typically includes a crystal oscillator for high stability, provides a large amplitude sine wave at the frequency desired for the output reference sampling pulses. The output of the oscillator 52 is applied to a transmission line 57 via a shaping network comprised of capacitors 53, 54 and 55 and inductance 56. The transmission line 57 is terminated by a step recovery diode 58 across which the resulting reference sampling pulses appear.

The design of the reference pulse generator circuit of FIG. 3 is such that the step recovery diode 58 conducts during the forward half cycle of the sine wave provided by the oscillator 52 and for a fixed time during the negative half cycle. When the stored charge in the diode 58 is depleted, the diode 58 snaps off, producing a fast negative wavefront which travels in both directions on the transmission line 57. The wavefront component traveling down the transmission line 57 towards the oscillator 52 inverts upon encountering the capacitor 55 and travels back down the transmission line 57 towards the diode 58, thus forming the trailing edge of the resulting output pulse appearing across the step recovery diode 58. The width of the resulting output pulse is determined by appropriate choice of the total delay time provided by the transmission line 57. The values of the capacitors 53 and 54 and the inductance 56 are chosen to achieve maximum pulse amplitude.

Reference is now directed to FIGS. 4 and 5 which illustrate the manner in which the coupling characteristics of a waveguide 70 may advantageously be employed in accordance with the present invention to provide an unusually broadband and unexpectedly simple and inexpensive sampling device for use, for example, as the sampling device 20 in the system illustrated in FIG. 1.

As illustrated in FIG. 4, which is a side view of the waveguide 70, a pair of matched semiconductor diodes 80 which are to serve as sampling diodes are mounted in the waveguide 70 in a balanced configuration parallel to and spaced from the step recovery diode 58 which is also mounted within the waveguide 70 for injection of the sampling pulses therein. These diodes 58 and 80 are preferably epitaxially grown Schottky-barrier diodes provided in low parasitic packages and their mountings in the waveguide 70 may be conventional with appropriate care being taken to minimize any stray inductance in the diode-to-waveguide connections. Also, sampling capacitors 84 required for sampling are advantageously incorporated into the waveguide mountings of the sampling diodes 80 in a conventional manner so as to provide an appropriate sampling capacitance with respect to ground, as indicated by the dashed line capacitors 84'. As illustrated in FIG. 5, the sampling diodes 80 and sampling capacitors 84' are coupled via respective summing resistors 86 to an output junction 88 at which the resulting sampling output signal 20a is provided.

As also illustrated in FIG. 5, which is an end view of the waveguide 70, a small portion of the microwave output signal from the Gunn oscillator signal is extracted for application to the sampling diodes 80 using

a probe 72 extending into the Gunn oscillator cavity 13. The probe 72 is coupled to a transmission line 75, such as a coaxial line, for example, which passes through the waveguide 70 and is terminated by a load 80 having an impedance equal to the characteristic impedance of the transmission line 75. Appropriate care is taken to keep the line impedance of the transmission line 75 constant to minimize reflections. As also shown in FIG. 5, the transmission line 75 passes through the waveguide 70 perpendicularly to the sampling diodes 80 and intersects the junction 82 therebetween, thereby providing balanced coupling of the microwave signal to the sampling diodes 80.

The waveguide 70 is chosen to have a cut off frequency greater than that of the microwave signal output of the Gunn oscillator so that there is no propagation of the sampling pulses through the transmission line 75. The cut off frequency of the waveguide 70 is also chosen so that each reference sampling pulse appearing across the step recovery diode 58 will cause energy to be propagated via the waveguide to the sampling diodes 80 so as to cause each sampling diode 80 to be driven from cut off into forward conduction for an appropriate predetermined sampling time. As will be understood from FIG. 2, this predetermined sampling time is chosen so as to be relatively short as compared to the Gunn oscillator period, but sufficiently long to permit the charging capacitors 84 to be charged to a value representative of the amplitude of the sampled portion of the Gunn oscillator waveform appearing at junction 82. The magnitudes of the sampling capacitors 84 and the charging resistors 86 are appropriately chosen so that the average or direct current value of the resulting output signal 20a obtained at the output junction 88 indicates the coherency relationship between the Gunn oscillator frequency and the pulse repetition frequency of the reference sampling pulses. As will be understood from the previous consideration of FIGS. 1 and 2, if coherency exists, a corresponding average or direct current output voltage signal will be obtained at the output junction 88, but if they are not coherent, then the periodic voltage at junction 88 will be random and an essentially zero output voltage signal will then be obtained.

A particular embodiment of a sampling device in accordance with the invention was constructed and successfully tested for Gunn oscillator microwave signals ranging from 4 to 20 GHz using reference sampling pulses of approximately 100 MHz repetition rate with the pulse generator circuit 50 in FIG. 3 being designed to provide a reference pulse width of less than 50 psec. The particular waveguide employed for the waveguide 70 in FIGS. 4 and 5 was a 1½ inch section of WR-28 waveguide having a cut off frequency of about 22 GHz. The sampling capacitors 84 each had a value of approximately 25 pico farads. The step recovery diode 58 and the sampling diodes 80 were centrally mounted in this waveguide section with a spacing of about 0.25 inch. The spacing between the diodes was not found to be critical.

Although the present invention has been disclosed with reference to a particular exemplary embodiment thereof, it is to be understood that various modifications in the construction, arrangement and use of the invention are possible without departing from the true spirit of the invention contribution. For example, an alternative way to couple the Gunn oscillator signal to

the sampling diodes 80 would be to mount the sampling device 20 directly on the Gunn oscillator cavity with a probe extending into the cavity from the junction 82 within the waveguide 70. Such a modification is merely one example of various alternative possibilities which may be employed. The invention is accordingly to be considered as encompassing all possible variations and modifications coming within the scope of the invention as defined by the appended claims.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. In a microwave sampling device for sampling a microwave signal, the combination of:

a waveguide having a cut off frequency greater than that of the microwave signal to be sampled, first and second diodes mounted in said waveguide in a balanced configuration,

means for providing balanced coupling of a microwave signal to be sampled to said first and second diodes,

a third diode mounted in said waveguide spaced from said first and second diodes and across which sampling pulses are generated for coupling to said first and second diodes by propagation through said waveguide.

2. The invention in accordance with claim 1, wherein said waveguide is chosen so that the generation of a sampling pulse across said third diode will cause energy to be propagated via the waveguide to said first and second diodes for providing sampling of said microwave signal.

3. The invention in accordance with claim 2, wherein capacitors are incorporated in the waveguide mountings provided for said first and second diodes for detecting the microwave signal sampled thereby.

4. The invention in accordance with claim 2, wherein said means for providing balanced coupling of said microwave signal to said first and second diodes includes a transmission line passing through said waveguide and coupled between said first and second diodes.

5. A microwave sampling device for sampling a microwave signal, said device comprising:

a waveguide having a longitudinal axis and a cut off frequency greater than the microwave signal to be sampled,

a pair of sampling diodes mounted in said waveguide in a balanced configuration with respect to the waveguide longitudinal axis,

transmission means for providing balanced coupling of a microwave signal to be sampled to said sampling diodes,

means external to said waveguide for generating sampling pulses of predetermined width and repetition rate appropriate for sampling of said microwave signal,

means for injecting said sampling pulses into said waveguide at a location longitudinally spaced from said sampling diodes for coupling to said sampling diodes via longitudinal propagation in said waveguide so as to cause sampling of said microwave signal by said sampling diodes in response to said sampling pulses, and

output means coupled to said sampling diodes for providing an output signal in response to the sampling of said microwave signal provided by said sampling diodes.

6. The invention in accordance with claim 5, wherein said transmission means for providing balanced coupling of a microwave signal to said sampling diodes includes a transmission line passing through said waveguide.

7. The invention in accordance with claim 6, wherein said transmission line is coupled to a point between said diodes.

8. The invention in accordance with claim 7, wherein said transmission line receives said microwave signal at one end and is terminated by its characteristic impedance at its other end.

9. The invention in accordance with claim 5, wherein said means for injecting sampling pulses into said waveguide is chosen in conjunction with the frequency characteristics of said waveguide so that each sampling pulse injected into the waveguide causes energy to be longitudinally propagated in the waveguide to said sampling diodes for driving thereof between conductive and non-conductive states for a predetermined period of time appropriate for providing sampling of said microwave signal.

10. The invention in accordance with claim 9, wherein said means for injecting sampling pulses into said waveguide includes an injecting diode mounted in said waveguide adjacent said sampling diodes.

11. The invention in accordance with claim 10, wherein said means for injecting comprises a step recovery diode generation circuit in which said injecting diode serves as a step recovery diode across which the sampling pulses are generated.

12. The invention in accordance with claim 5, wherein said output means is constructed and arranged so that said output signal is representative of the coherence between the pulse repetition rate of said sampling pulses and the frequency of the microwave signal being sampled.

13. The invention in accordance with claim 5, wherein said output means includes sampling capacitors respectively coupled to said sampling diodes for detecting the microwave signal sampled thereby.

14. The invention in accordance with claim 13, wherein said sampling capacitors are respectively incorporated in the waveguide mountings provided for said sampling diodes.

15. A method for providing broadband sampling of a microwave signal comprising the steps of:

mounting sampling diodes within a waveguide in a balanced configuration, said waveguide having a longitudinal axis and a cut off frequency greater than the microwave signal to be sampled,

coupling the microwave signal to be sampled to said sampling diodes in a balanced manner,

generating sampling pulses externally to said waveguide having a pulse width and repetition rate appropriate for sampling of said microwave signal, injecting said sampling pulses into said waveguide at a location longitudinally spaced from said sampling diodes and so that each sampling pulse will cause energy to be longitudinally propagated in the waveguide to drive said sampling diodes in a manner appropriate for providing sampling of said microwave signal, and

generating an output signal in response to the sampling of said microwave signal provided by said sampling diodes.

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16. The invention in accordance with claim 15, wherein said sampling diodes are driven between conductive and non-conductive states in response to each sampling pulse for a predetermined period which is relatively short as compared to the period of said microwave signal.

wherein the step of generating an output signal is such that the generated output signal is representative of the coherency between the pulse repetition rate of the sampling pulses and the frequency of said microwave signal.

17. The invention in accordance with claim 16,

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