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(54) Title: PHASE NOISE MEASUREMENT SYSTEM
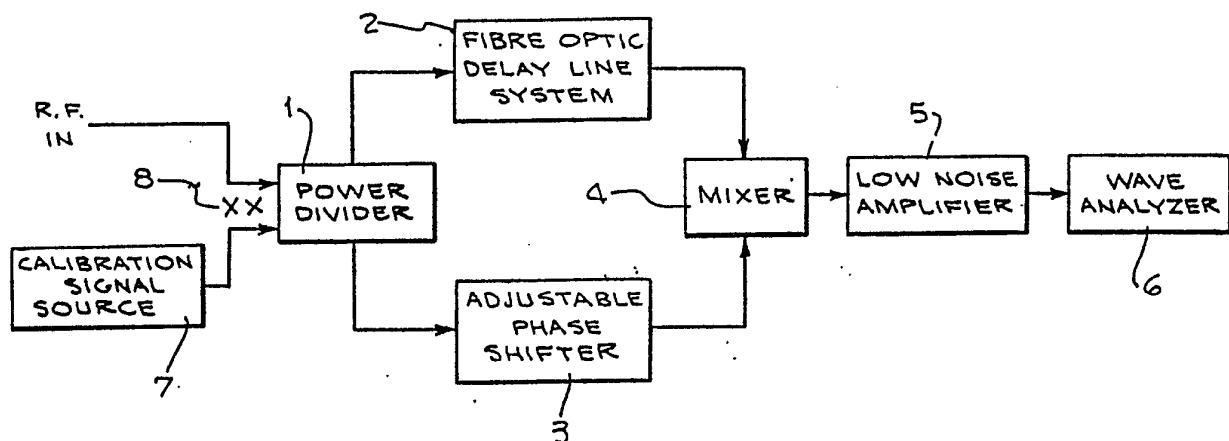
(57) Abstract

A noise test set for analysing the presence of phase noise in a radar test signal. A delay line discriminator using a fiber optic cable and laser light modulated by the test signal are used. Both direct and indirect modulation techniques are disclosed, together with techniques for generating and injecting a calibration signal.

1

Phase noise measurement system.

1. Field of the Invention

This invention relates to devices which measure
noise present in R.F. signals and, more specifically, to
radar noise test sets which measure random phase noise
present in radar signals. The radar noise test set
incorporates a frequency discriminator which uses a
fiber optic cable to produce the needed delay.

2. Background of the Invention

Oscillators which produce R.F. energy typically
generate sideband noises, including thermal noise, shot
noise, and flicker noise. This noise is typically
random and is referred to as phase noise.

The presence of phase noise in R.F. signal sources
is a concern in several applications, including applica-
tions related to frequency conversion, digital com-
munication, and analog communication.

Phase noise is also of great concern in radar
equipment, especially doplar radar equipment which
determines the velocity of a target by measuring the
small shifts in frequency in the return echoes. When
decorrelation techniques are used to measure this
frequency shift, the presence of phase noise can
partially or even totally mask the target signal.

In order to minimize the amount of phase noise
generated by a particular system, it is highly ad-
vantageous to be able to measure that phase noise. As a
result, there has been a continuing need for equipment
which can accurately measure such phase noise.

The most straight forward technique is to connect
the test signal to a spectrum analyzer, a device which
directly measures the power spectral density of the
oscillator. However, this method is limited by the
5   dynamic range and resolution of the spectrum analyzer,
as well as the phase noise which the spectrum analyzer
itself produces. Moreover, it is difficult with this
method to accurately measure phase noise which is close
in frequency to the carrier signal.

10   There are also time-domain techniques which down
convert the signal under test to an intermediate
frequency. A high-resolution frequency counter is then
used to take repeated measurements of the intermediate
frequency signal. The frequency differences between the
15   measurements are then used to compute the amount of the
phase noise.

Time-domain methods, however, are not well suited
for measuring phase noise having a frequency
substantially different from the carrier frequency. It
20   is also difficult to utilize such techniques for
measuring phase noise that is flat or decreasing slowly
in frequency.

Another technique is to demodulate the carrier on
which the phase noise is present. However, this
25   technique requires complex phase locking circuitry.
Moreover, it does not work well with signal sources
which are not constant in frequency.

A still further technique is to use a frequency
discriminator. With this technique, a delay line, phase
30   shifter and detector are used to decorrelate the phase
noise present in the R.F. signal source. This converts
the phase noise into a base band signal which can be
conveniently measured on a spectrum analyzer.

One principal problem using frequency
35   discriminators are limitations imposed by the delay
element.

When a waveguide is used as the delay element, for
example, it is very difficult to obtain long delays such

as 10 microseconds. Although long delays can be achieved with long lengths of coaxial cable, very high losses result, making measurement of low noise levels very difficult. In addition, coaxial cables are usually

5   quite bulky, making it difficult to change cables when a different length delay is desired.

Another technique mixes the test signal to a lower frequency and then transports that lower mixed frequency signal through a digital, quartz, or surface acoustic

10   wave (SAW) delay line. Such techniques, however, require complex synchronization circuitry, often introduce undesirable distortion, and are bulky.

A still further technique has been to use a cavity resonator as the delay element. This device, however,

15   requires a very high Q to detect low level noise. Unfortunately, high Q resonators are very expensive and are very sensitive to vibration. They also require mechanical adjustment in order to match the desired frequency range.

20   In short, there has been a continuing need for a noise test set which can accurately measure low level phase noise, especially phase noise that is near in frequency to the carrier frequency.

25   SUMMARY OF THE INVENTION

One object of the present invention is to obviate these and other problems in the prior art.

Another object of the present invention is to provide a noise test set which is simple and inexpen-

30   sive, but which can accurately measure low level phase noise, including noise which is close in frequency to the signal carrier frequency.

A still further object of the present invention is to provide a radar noise test set which has a very wide

35   band frequency response.

A still further object of the present invention is to provide a radar noise test set which is highly efficient and results in losses which are not primarily

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a function of the length of the delay device.

A still further object of the present invention is to provide a radar noise test set capable of delaying the tested signal at least 10 microseconds without

5   causing appreciable loss.

These and other objects of the present invention are achieved through the use of a fiber optic cable as the delay line in a delay line discriminator. More specifically, a laser light is created and modulated

10   with the R.F. test signal. It is then propogated through the fiber optic cable which delays it in time. The delayed modulated laser light is then demodulated, thereby extracting the delayed radar signal for further processing.

15   , An improved technique for injecting a calibration signal is also disclosed.

These as well as other objects, features, and advantages of the present invention will become apparent from consideration of the following detailed description

20   and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of the preferred embodiment of the present invention.

25   FIG. 2 is a pictorial diagram of the fiber optic delay line system shown in FIG. 1 using laser light and an indirect modulation technique.

FIG. 3 is a schematic diagram showing circuitry which directly modulates the laser light.

30   FIG. 4 is a schematic diagram showing circuitry used to operate the optical detector shown in FIG. 2 to demodulate the laser light.

FIG. 5 is a schematic diagram of an alternate technique for developing and injecting the calibration

35   signal source shown in FIG. 1.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 is block diagram of the preferred embodiment to the present invention.

As can be seen in FIG. 1, the signal to be tested, such as the continuous wave output from a radar exciter, is injected into a power divider 1 which splits the signal into two components.

One component of the signal split from the power divider 1 is delivered to a fiber optic delay line system 2 which causes the delivered signal to be delayed for a predetermined amount of time.

The other component from the power divider 1 is delivered to an adjustable phase shifter 3, typically a ferrite device, which shifts the phase of the signal that is delivered to it by an adjustable amount.

The delayed signal from the fiber optic delay line system 2 and the phase shifted signal from the adjustable phase shifter 3 are then both delivered to a mixer 4. The output of the mixer 4 is amplified by a low noise amplifier 5 and then displayed on a wave analyzer 6.

In operation, the adjustable phase shifter 3 is adjusted for each new test signal so that the R.F. signal which is delivered to the mixer 4 is 90 degrees out of phase with the R.F. signal that is delivered to the mixer 4 from the fiber optic delay line system 2. When so adjusted, the mixer 4 acts as a phase detector and outputs a steady state D.C. current when no noise is present on the R.F. input signal.

When noise is present on the R.F. input signal, this noise will arrive at the mixer 4 from the adjustable phase shifter 3 before it arrives from the fiber optic delay line system 2. The result will be a change in the relative phase difference of the signals presented to the mixer 4, which will be reflected at the output of the mixer 4 as a variation in the amplitude of its D.C.

In other words, the system thus far described will

decorrelate phase noise present on the input R.F. signal and will produce that decorrelated phase noise as an amplitude variation on the D.C. output of the mixer 4. For a greater understanding of how this works, reference

5   is made to the published article Phase Noise and its Effects on Microwave Systems, published in Microwave Systems News and Communications Technology, July 1986 (Vol. 16, No. 7).

The low noise amplifier 5, of course, simply

10   amplifies the extracted phase noise signal and presents it to the wave analyzer 6 for analysis. Typically, the wave analyzer 6 would be a spectrum analyzer which would graphically display the frequency distribution of the phase noise and the relative amplitude of each portion

15   in the distribution.

To provide a qualitative analysis, the amplitude of the phase noise relative to the amplitude of the R.F input signal can be determined by using a calibration signal source 7.

20   More specifically, the calibration signal source 7 is an oscillator which generates a very low level noise side band having a precisely-known magnitude relative to the magnitude of the R.F. input signal, typically about 60 db down.

25   As is known in the art, the calibration signal source 7 typically generates the calibration signal by sampling the input test signal, shifting the sampled signal 90° in phase, and mixing the shifted sampled signal with a low frequency signal, having a frequency

30   in the range of the anticipated frequency by which the phase noise is offset from the test carrier. The mixed signal is then attenuated a known amount with respect to the amplitude of the input signal and is then injected into the power divider 1 through a coupler 8.

35   This calibration signal is then interpreted as phase noise by the system and thus would also appear on the wave analyzer. Since its magnitude with respect to the test signal is precisely known, the magnitude of the

real phase noise which is also displayed on the wave
analyzer can then easily be calculated. It would simply
be the known magnitude of the calibration source signal
7 multiplied by the ratio of the displayed height of the
5 phase noise (for a particular displayed frequency band)
to the displayed height of the calibration signal.

FIG. 2 is a pictorial diagram of the fiber optic
delay line system 2 shown in FIG. 1 using laser light
and an indirect modulation technique.

10 More specifically, the fiber optic delay line
system 2 includes a light emitting diode 23 which, as is
well known in the art, is a semiconductor device which
emits a light when current is passed through it.
Although any type of light emitting diode could be used,

15 a laser diode, i.e. a diode which emits laser light, is
preferred.

In order to insure that the emitted laser light is
of constant amplitude, the current passed through the
laser diode 23 should also be constant.

20 The laser light emitted by the laser diode 23 is
then coupled to a light modulator 25 through a short
length of a fiber optical cable 27.

It is important that the coupling from the laser
diode 23 to the fiber optic cable 27 be highly effi-

25 cient, so as to minimize signal losses at the coupling
juncture. It is also important that reflection of this
coupling be kept to a minimum, so as to minimize non-
linearities in the system.

Techniques for minimizing losses and reflection at

30 the coupling juncture are well know in the art and
should be followed. Alternately, the laser diode 23 can
be purchased having already affixed thereto a "pigtail",
i.e., a short length of fiber optic material coupled to
the laser diode by the manufacturer in a fashion which

35 minimizes loss and reflection.

Although other types could be used within the scope
of the present invention, the light modulator 25 in the
preferred embodiment is the Mock-Zehnder interferometric

modulator described by Gee et al. in their article _17-GHz band with Electro-Optic Modulator_, published December 1, 1983 in Applied Physic Letters, Vol 43, pp. 998-1000.

5   Essentially, the light modulator 25 is a device which directs the light through a titanium wave guide 27 which is embedded into a lithium niobate electro-optic crystal 29. The R.F. input which modulates the light comes from the power divider 1 shown in FIG. 1. It is 10   delivered through a transmission line 31 which, in turn, is connected to one end of a pair of conducting coplanar strip lines 33 and 35. The other end of the coplanar strip lines 33 and 35 are matchingly terminated by a resistance 37.

15   In operation, the imposition of the R.F. input across the coplanar strip lines 33 and 35 creates an electric field which modulates the intensity of the intervening light in accordance with the intensity of the electric field. For more information concerning the 20   structure and operation of the light modulator 25, the referenced article by Gee et al. should be reviewed.

The light output 38 of the light modulator 25 is then coupled to one end of the fiber optic cable 7. The other end of the fiber optic cable 7 is coupled to an 25   optical detector 39 which, as is well known in the art, is a semiconductor device which produces a voltage which is directly proportional to the intensity of the light, thereby demodulating the delayed R.F. signal. The delayed R.F. is then delivered to the mixer 4 shown in 30   FIG. 2. Other demodulation techniques could also be used within the scope of the present invention.

As with the laser diode 23, it is also important to efficiently couple the output of the fiber optic cable 7 to the optical detector 39 so as to minimize losses and 35   reflection, all in accordance with techniques well known in the art. Optical detectors can also be purchased with a pigtail of fiber optic material already attached to the optical detector in a fashion which is efficient

and results in minimum reflection. If an optical
detector is selected which already has a pigtail
attached by the manufacturer, this can be conveniently
connected to the fiber optic cable 7 by a fiber optic

5   connector or any of the other well known techniques for
efficiently joining separate fiber optic cables.

The modulation technique pictorially illustrated in
FIG. 2 is known as indirect modulation because the light
intensity is not modulated until after it is created.

10   FIG. 3 is a schematic diagram of an alternate
embodiment of the light source and modulator 5 shown in
FIG. 1. This embodiment uses a direct modulation
technique. The light intensity is modulated at the very
moment of its creation.

15   FIG. 3 consists of the laser diode 23 having one
end connected to ground and the other connected to a
capacitor 41 and an inductor 43. The other end of the
capacitor 41 is connected to the input R.F. signal, and
the other end of the inductor 43 is connected to a con-

20   stant source of D.C. current I_B.

This configuration is known as a bias-tee network.

The purpose of the constant D.C. current I_B is to
bias the laser diode 23 such that it always operates in
its linear region during modulation. Although the exact

25   amount of this current will vary depending upon the
specific choice for the laser diode 23, typical bias
currents will be in the order of 70 - 100 milliamps.

The purpose of the capacitor 41 is to allow passage
of the R.F. signal into the laser diode 23 and at the

30   same time to prevent the R.F. source from offsetting the
D.C. bias current. Although the exact value of this
capacitance will vary depending upon the relative
magnitude and frequency of the signals involved, capaci-
tances in the order of 100 picofarads would be typical.

35   The inductor 43 performs a function basically
opposite of the function performed by the capacitor 25.
More specifically, the inductor 43 allows passage of the
bias current into the laser diode 23, while at the same

time prevents the current source from draining the R.F. coming from the capacitor 41. Although the value of the inductor 43 will similarly vary depending upon the relative magnitude and frequency of the signals in-

5   volved, its value will typically be around one microhenry.

The light output of the laser diode 23 is then coupled to the fiber optic cable 7, using the same techniques and with the same considerations as was

10 discussed above with respect to FIG. 2.

The amount of delay, of course, will be directly proportional to the length of the fiber optic cable 7. And in practice, different lengths can easily be switched in and out as needed.

15 When long delays are desired, as is often the case, the length of the fiber optic cable 7 will be such that it may be wound in a coil in order to cause the test set to be small in size. Although almost any type of coiling is acceptable, in the preferred embodiment

20 applicant chooses to keep the radius of all windings at no less than one inch. Otherwise, the level of undesirable loss may increase.

The material of fiber optic cable 7 should be selected so as to minimize loss, distortion and disper-

25 sion. Generally, this will mean that the diameter of the cable should match the wavelength of the laser light and that "single mode" fiber optic material should be used.

It is also preferred that the laser light emitted

30 by the laser diode 23 be very short in length, typical around .85 micrometers. Although longer wave lengths can be used, these longer wave lengths contribute to losses in the fiber optic material and increases in undesirable dispersion.

35 FIG. 4 is a schematic diagram of a preferred embodiment of the circuitry used to operate the optical detector 39 shown in FIG. 2. As shown in FIG. 4, the other end of the fiber optic cable 7 is coupled to the

optical detector 39, one end of which is grounded. The
other end of the optical detector 39 is connected to a
capacitor 45 and an inductor 47. The other end of the
capacitor 45 is connected to an R.F. pre-amplifier 49,

5   and the other end of the inductor 47 is connected to a
constant source of negative D.C. voltage -V_B.

     Just as with the laser diode 23, it is also
necessary to bias the optical detector 39 to ensure that
it always operates in its liner region. However, unlike

10   the laser diode 23, the purpose of the bias is to reduce
junction capacitance which might otherwise deteriorate
its high frequency performance. This is done by
delivering a constant negative voltage -V_B into the
optical detector 39 through the aforementioned cir-

15   cuitry, which is also known as a bias-tee network.
Although the exact amount of the negative voltage will
depend upon the particular optical detector which is
chosen and the relative magnitude and frequency of the
signals involved, typically it will be around minus 10-

20   20 volts.

     The inductor 47 and the capacitor 45 perform a
function similar to the inductor 43 and the capacitor 41
shown in FIG. 3. More specifically, the inductor 47
allows passage of the reverse biasing voltage into the

25   optical detector 39 without allowing the R.F. component
of the demodulated laser light to be loaded by the
voltage source. Similarly, the capacitor 45 allows
passage of the demodulated R.F. into the pre-amplifier
45 without allowing the pre-amplifier 45 to affect the

30   reverse bias voltage. Although the exact values of the
inductor 47 and the capacitor 45 will, again, depend
upon the precise frequency and magnitude of the signal
involved, they will typically be around 1 microhenry and
100 picofarads, respectfully.

35   An alternate technique for development and
injection of the calibration signal source 7 shown in
FIG. 1 is shown in FIG. 5.

     As shown in FIG. 5, the signal from a calibration

signal source 55 is injected directly into the low noise amplifier 5.

In order to generate the calibration signal which is used in the embodiment shown in FIG. 5, the R.F. test

5   signal is sampled by a coupler 51 and delivered into a detector 53 which produces a D.C. signal having a magnitude which is proportional to the magnitude of the R.F. test signal. In turn, the D.C. developed from the detector 9 is delivered to the calibration signal source

10   55. The calibration signal source 55 in this embodiment simply generates a low frequency signal having a magnitude attenuated a known amount from the magnitude of the input D.C. signal, typically in the area of 60 db. As with the calibration signal source 7 shown in

15   FIG. 1, the frequency of the low frequency signal is selected to be within the range of the anticipated frequency by which the phase noise is offset from the test carrier.

Use of the technique described above and shown in

20   FIG. 5 involves much simpler and less expensive hardware. However, because it does not account for test signal level changes caused by the frequency discriminator, a slightly more complex computation is required to determine the amplitude of the displayed

25   phase noise.

More specifically, it is not simply the amount the calibration signal is attenuated from the test signal multiplied by the ratio of the displayed calibration signal height to the phase noise signal height. Rather,

30   this computation must be performed and must then be further multiplied by the attenuation (or amplification) caused by the frequency discriminator. This later factor can easily be ascertained by comparing the height of the calibration signal displayed by the system shown

35   in FIG. 5 to the height of the calibration signal displayed by the system shown in FIG. 1, the magnitude of the test input signal, of course, being the same during each measurement. Once this later factor is

determined, it can be applied to all subsequent measurements.

Although the test set described above has been described as being useful to measure phase noise in radar signals, it may also advantageously be used to measure a variety of noises in other types of R.F. signals. Moreover, although only certain embodiments of the present invention have been described, it is to be understood that the present invention is applicable to a broad variety of other embodiments, processes and parameters and that the present invention is defined and limited solely by the following claims.

5.   The noise test set of Claim 2 wherein said
fiber optic cable has a diameter which is matched to the
frequency of the laser light.

6.   The noise test set of Claim 1 wherein said
modulation means modulates the intensity of the light at
the moment it is generated.

7.   The noise test set of Claim 1 wherein said
demodulation means includes an optical detector.

8.   The noise test set of Claim 7 wherein said
demodulation means further includes a bias-tee network
connected to said optical detector.

9.   The noise test set of Claim 8 wherein said
bias-tee network includes a capacitor and an inductor,
each connected at one end to said optical detector, the
other end of said capacitor being connected to deliver
5   the demodulated R.F. output, and the other end of said
inductor being connected to a source of constant D.C.
voltage.

10.   The noise test set of Claim 1 wherein said
light means generates a light of substantially constant
intensity and wherein said modulation means modulates
the light after the light is produced.

11.   The noise test set of Claim 10 wherein said
modulation means includes a device which directs the
laser light through a pair of electrodes and wherein a
potential is applied to said electrodes having a
5   magnitude substantially proportional to the test signal.

12.   The noise test set of Claim 11 wherein said
modulation means includes an interferometric modulator.

13.   The noise test set of Claim 12 wherein said
interferometric modulator includes a wave guide embedded
in an optical crystal.

14.   The noise test set of Claim 13 wherein said
wave guide is made of titanium and wherein said optical
crystal is made of lithium niobate.

15.   The noise test set of Claim 1 wherein said
fiber optic cable is coiled and wherein no portion of
said coil makes an arc having a radius less than one
inch.

16.   The noise test set of Claim 1 wherein said
fiber optic cable is a single mode type.

17.   The noise test set of Claim 1 wherein said
detector means includes a mixer connected to said delay
means.

18.   The noise test set of Claim 17 wherein said
detector means further includes a phase shifter
connected to the test signal and also to said mixer for
delivering a signal to said mixer which is substantially
90 degrees out of phase with the delayed test signal
delivered to said mixer from said delay means.

19.   The noise test set of Claim 1 further includ-
ing a calibration signal source.

20.   The noise test set of Claim 19 wherein said
calibration signal source is added to the test signal
before the test signal enters said modulation means.

21.   The noise test set of Claim 19 wherein a
coupler effectuates said addition.

22.   The noise test set of Claim 19 further

including a low noise video amplifier connected to the
output of said detector means and wherein said calibra-
tion signal source is injected directly into said low
5   noise video amplifier.

     23. The noise test set of Claim 22 wherein the
amplitude of said calibration signal source is substan-
tially attenuated from the amplitude of the test signal.

     24. The noise test set of Claim 23 further
including second detector means coupled to the test
signal and connected to said calibration signal source
for generating a D.C. signal having an amplitude
5   proportional to the amplitude of the test signal, said
.D.C. signal controlling the amplitude of said calibra-
tion signal source.

     25. The noise test set of Claim 1 further includ-
ing:

          a.   a power divider connected to the test
               signal for dividing the test signal into
5   two segments, one of said segments being
               delivered to said modulation means, the
               other of said segments being delivered to
               said detector means;
          b.   a low noise amplifier connected to the
10   output of said detector means; and
          c.   a wave analyzer connected to the output
               of said low noise amplifier.

     26. The noise test set of Claim 25 wherein said
wave analyzer is a spectrum wave analyzer.

     27. A noise test set for analyzing noise present
in a test signal comprising:
          a.   a   frequency   discriminator   for
               decorrelating the noise present in the
5   test signal, said frequency discriminator

having an output;

b. detector means connected to the test signal for generating a D.C. signal having an amplitude proportional to the amplitude of the test signal; and

c. calibration signal means connected to the D.C. signal generated by said detector means and to the output of said frequency discriminator for generating a calibration signal having an amplitude proportional to the amplitude of the D.C. signal but substantially attenuated therefrom by a predetermined amount.

28. A noise test set for analyzing noise present in a test signal comprising:

a. a laser diode for generating laser light;

b. modulation means connected to the test signal for modulating the laser light generated by said laser diode with the test signal;

c. a fiber optic cable having two ends, one of which is connected to the modulated laser light, said fiber optic cable having a diameter which is matched to the frequency of the laser light, being of a single mode type, and being coiled but having no portion of said coil making an arc with a radius less than one inch;

d. a detector connected to the other end of said fiber optic cable for extracting the delayed test signal from the modulated laser light;

e. a phase shifter connected to the test signal for producing a signal which is substantially 90 degrees out of phase with the delayed test signal coming from said detector; and

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      f.   a mixer connected to the output of said phase shifter and to the output of said detector for extracting the noise present in the test signal.
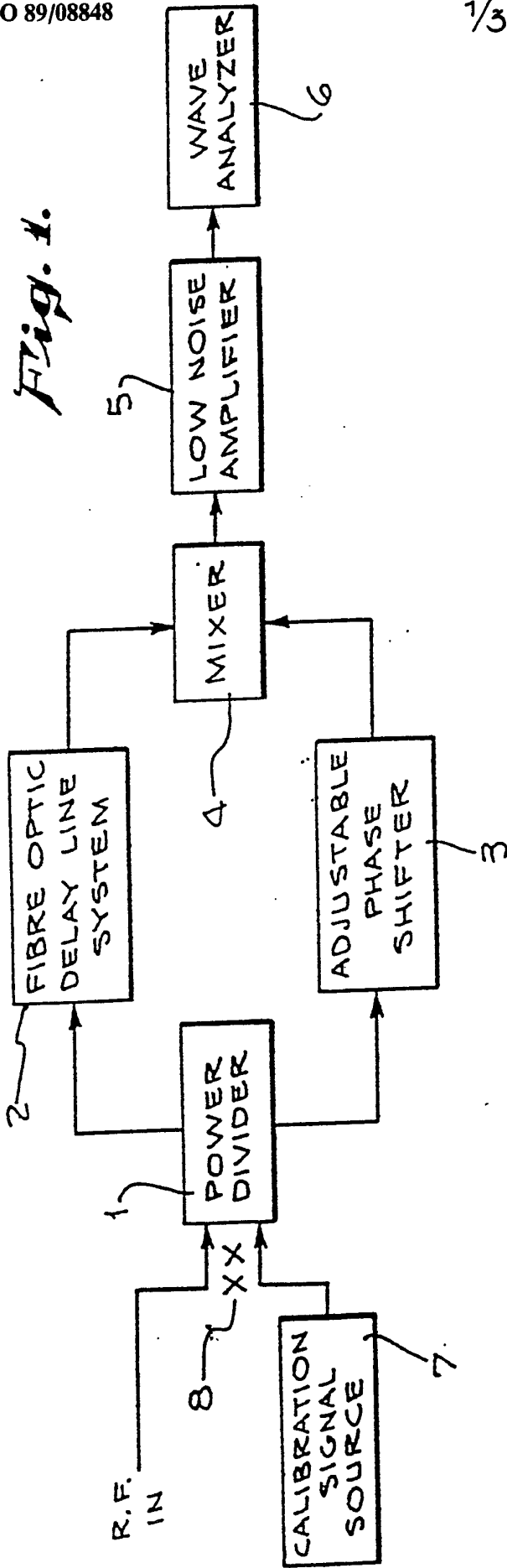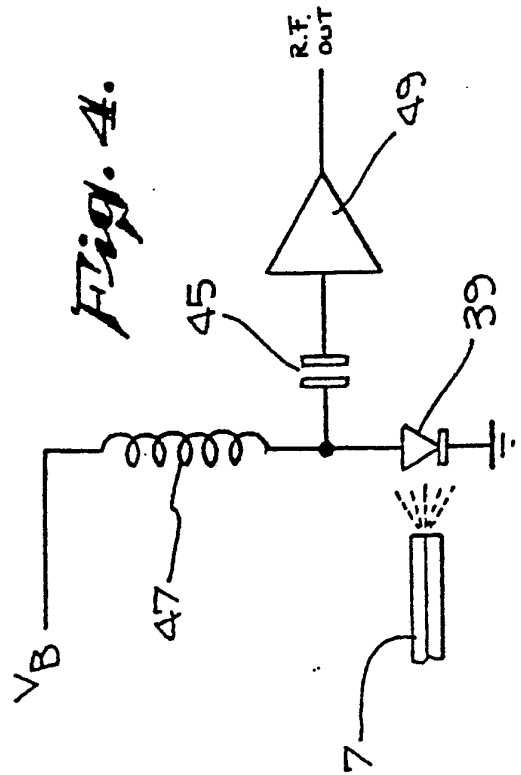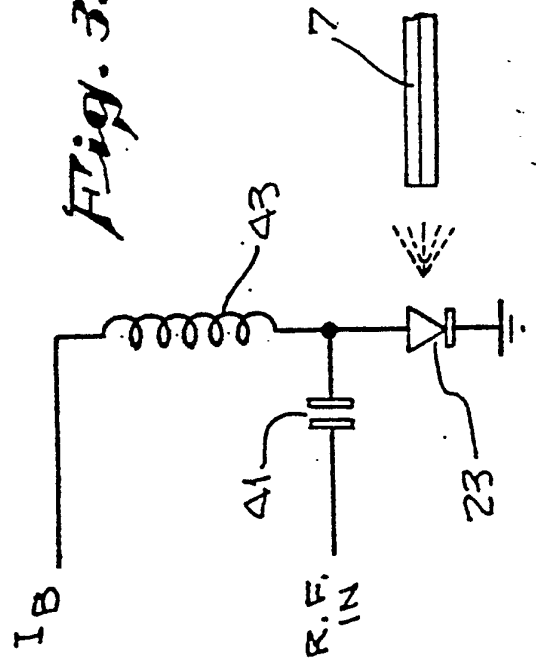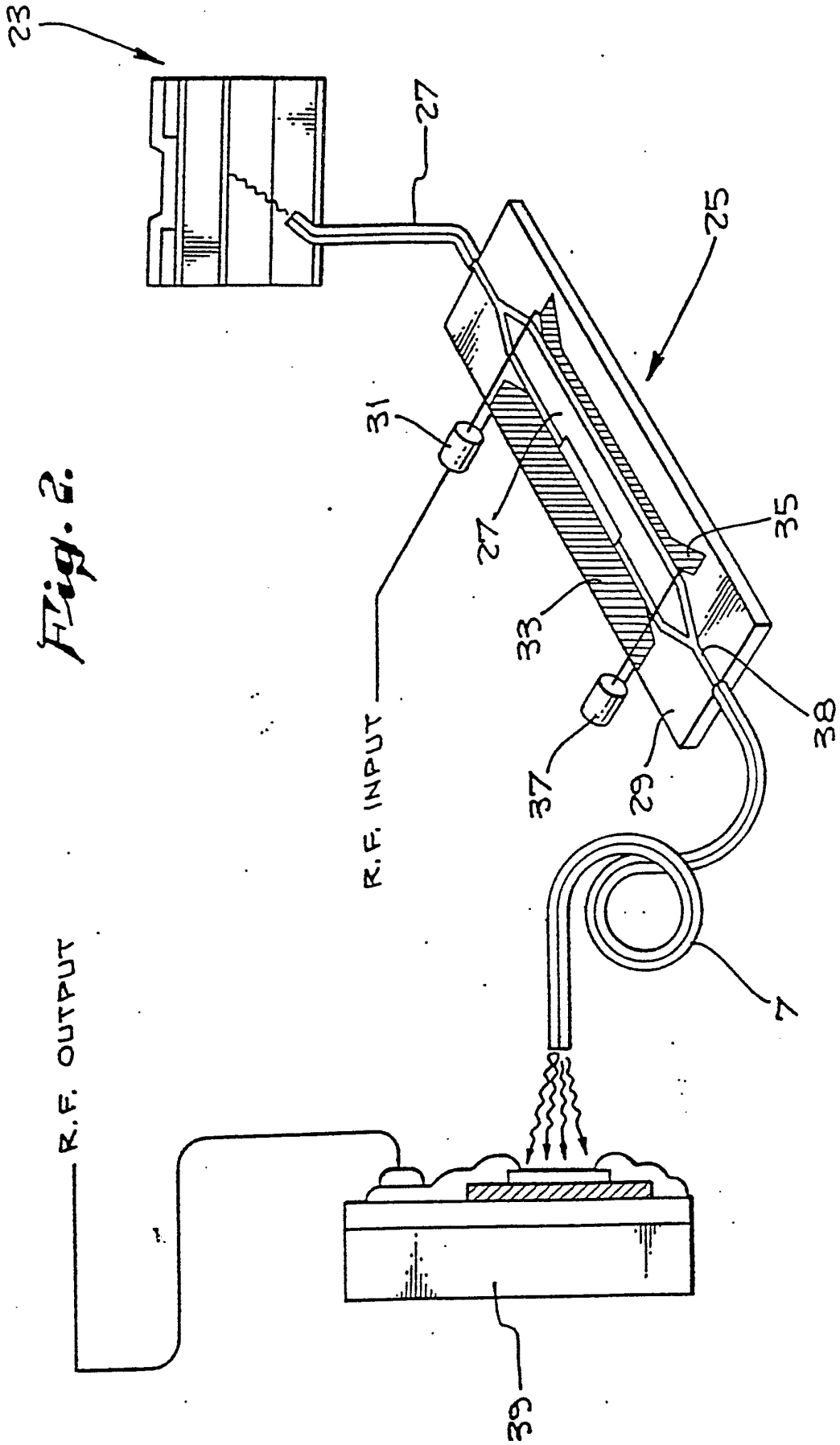
Fig. 1.

Fig. 4.

Fig. 3.
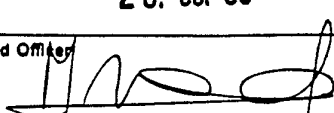
Fig. 2.

R.F. INPUT

R.F. OUTPUT

R.F.

X X   51

53 | DETECTER |

| CALIBRATION SIGNAL SOURCE | 55

TO POWER DIVIDER

| LOW NOISE AMPLIFIER | | WAVE ANALYZER |

5

6

FROM MIXER

Fig. 5.

INTERNATIONAL SEARCH REPORT

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) *

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC^4: G 01 R 29/26

II. FIELDS SEARCHED

Minimum Documentation Searched [7]	
Classification System	Classification Symbols
IPC^4	G 01 R

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category *	Citation of Document, [11] with Indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
Y	Microwave Journal, vol. 26, no. 12, December 1983 (Dedham, MA, US), C. Schiebold: "Theory and design of the delay line discriminator for phase noise measurements", pages 103,104,106,108, 110,112, see the whole article	1,2,5-7, 15-18,25, 26,28
A	--	22,27
Y	EP, A, 0252620 (COSSOR ELECTRONICS LTD) 13 January 1988, see page 2, lines 36-45; figure 1	1,2,5-7, 15-18,25, 26,28
A	--	3
A	IEEE Transactions on Microwave Theory and Techniques, vol. 36, no. 1, January 1988, IEEE (New York, N.Y., US), A. Cappy: "Noise modeling and measurement techniques", pages 1-10, see figure 8	3,4,8,9
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	./.	

* Special categories of cited documents: [10]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

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IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
1st August 1989	2 8. 08. 89

International Searching Authority	Signature of Authorized Officer
EUROPEAN PATENT OFFICE	M. VAN MOL

Form PCT/ISA/210 (second sheet) (January 1985)

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
The members are as contained in the European Patent Office EDP file on 21/08/89
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP-A- 0252620	13-01-88	GB-A- 2192272 US-A- 4777433	06-01-88 11-10-88
GB-A- 924794		None	

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