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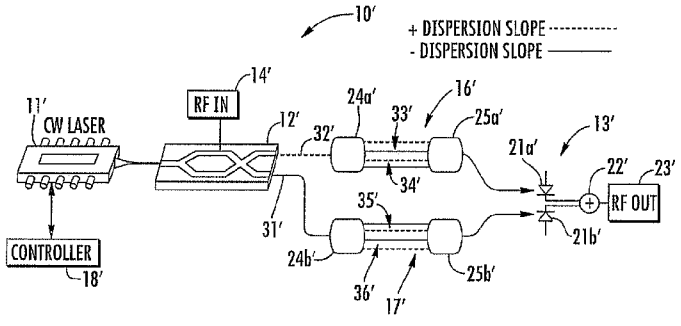

FIG. 6

(57) Abstract: A tunable Radio Frequency (RF) filter device includes a tunable optical source generating an optical carrier signal, and a modulator coupled to the tunable optical source and modulating the optical carrier signal with an RF input signal. The tunable RF filter device may include first and second optical waveguide paths coupled to the modulator and having first and second dispersion slopes of opposite sign from each other, one or more of the first and second optical waveguide paths comprising an optical splitter and combiner pair therein, and an optical-to-electrical converter coupled to the first and second optical waveguide paths and generating an RF output signal with a frequency notch therein based upon the tunable optical source.

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TUNABLE RF FILTER DEVICE USING OPTICAL WAVEGUIDE PATHS WITH DISPERSION SLOPES OF OPPOSITE SIGNS AND RELATED METHODS

The present invention relates to the field of radio frequency (RF) filtering, and, more particularly, to RF filtering with optical components and related methods.

As wireless communications has become prevalent in society, it is not uncommon for two wireless communications devices to interfere with the operation of each other when operating within transmission range of each other. Indeed, this type of interference has become more frequent with increasing wireless connectivity permeating society, such as the use of cellular phones and mobile email devices. For example, when IEEE 802.11b (WiFi) wireless devices, for example, laptop computers, became readily available to the home consumer, "cordless" home telephones were capable of rendering the WiFi devices inoperable due to interference.

Interference is typically categorized into two types: narrowband interference and wideband interference. Narrowband interference includes forms of interference that are concentrated around a relatively small frequency bandwidth. Several common approaches to compensating for narrowband interference may include, for example, forward error correction (FEC), baseband coding (FHSS/DSSS spread spectrum), diversity in frequency and/or time, and signal cancellation.

Differently, wideband interference includes forms of interference that are spread out across a relatively large frequency bandwidth. Several common approaches to compensating for wideband interference may include, for example, FEC, adaptive data rate (modulation and channel bandwidth), adaptive power control, diversity in frequency and/or time, and signal cancellation.

Another common type of interference is self interference. Common causes of self interference may include, for example, collocation or frequency reuse. In particular, collocation may be caused by two wireless communication systems being deployed too closely together while frequency reuse may be caused by two wireless communication systems using the same frequency band/channel. Several approaches to compensating for self interference, which are available during planning and development stages of wireless communication systems, include, for example,

installation (isolation between antennas), frequency planning, antenna pattern manipulation, synchronization of transmitters, and filtering (duplexing).

In particular, one filtering approach to narrow band interference may be to apply a notch filter to the received signal. The notch filter is a type of band-stop filter that includes a narrow stop band. In typical applications, when a communication system is subject to narrow-band interference, the stop band of the notch filter is tuned to the frequency of the narrow-band interference, thereby mitigating the effect of the narrow-band interference.

In some applications, it may be desirable to mitigate narrow-band interference from a relatively high-power interference source, for example, a jammer device. Typical RF notch filters may be applied in these applications, but they may suffer damage from the high-power interference source. One approach to this drawback may be a photonic implementation of an RF notch filter.

For example, U.S. Patent Application Publication No. 2010/0046952 to DeSalvo et al., also assigned to the present application's assignee, discloses an RF notch filter including photonic components. In particular, this RF notch filter comprises a modulator for modulating an optical carrier signal, and a pair of optical fibers receiving the modulated optical signal. Phase delay is introduced into one of the optical fibers by "lengthening" the optical fiber. The outputs of the optical fibers may be combined to notch filter an input signal via superposition. A potential drawback to this approach may be that this lengthening of one optical fiber may be cumbersome to implement on-the-fly. A potential drawback to typical optical notch filters may be sensitivity to polarization changes due to environmental conditions.

In particular, for the typical optical notch filter that uses a coherent optical source, the optical source may need to have a high degree of coherence. Moreover, the optical phase may need precise control mechanisms, which may add to the cost of the device. Also, coherent applications may be highly sensitive to the aforementioned polarization issue.

In view of the foregoing background, it is therefore an object of the present invention to provide a tunable RF filter device for effective notch filtering.

This and other objects, features, and advantages in accordance with the present invention are provided by a tunable RF filter device comprising a tunable optical source configured to generate an optical carrier signal, and a modulator coupled to the tunable optical source and configured to modulate the optical carrier signal with an RF input signal. The tunable RF filter device includes first and second optical waveguide paths coupled to the modulator and having first and second dispersion slopes of opposite sign. At least one of the first and second optical waveguide paths includes an optical splitter and combiner pair therein. The tunable RF filter device also includes an optical-to-electrical converter coupled to the first and second optical waveguide paths and configured to generate an RF output signal with a frequency notch therein based upon the tunable optical source. Advantageously, the tunable RF filter device notch filters the RF input signal with deep spectral nulls and a broad pass band.

In some embodiments, each of the first and second optical waveguide paths may comprise at least one optical splitter and combiner pair. The first optical waveguide path may comprise a first optical waveguide coupled to the modulator and having a first dispersion slope, and the second optical waveguide path may comprise a second optical waveguide coupled to the modulator and having a second dispersion slope having an opposite sign of the first dispersion slope. Additionally, the first optical waveguide path may comprise at least one pair of optical waveguides coupled between the optical splitter and the optical combiner, the at least one pair of optical waveguides having dispersion slopes of opposite sign.

In some embodiments, the at least one optical splitter and combiner pair may comprise a plurality thereof coupled in series. Also, the tunable RF filter device may further comprise a controller coupled to the tunable optical source and configured to tune a frequency of the optical carrier signal over a desired frequency range. The controller may be configured to tune the frequency of the optical carrier signal to generate the RF output signal with the at least one frequency notch therein by causing interference between outputs of the first and second optical waveguide paths.

Moreover, the first and second dispersion slopes may intersect at a desired frequency point in the desired frequency range. For example, the optical-to-electrical converter may comprise first and second optical detectors coupled respectively to the first and second optical waveguide paths, and a combiner coupled to the first and second optical detectors. More so, the tunable optical source may comprise a tunable continuous wave laser, for example. The tunable RF filter device may further comprise an antenna coupled to the modulator and configured to provide the RF input signal.

Another aspect is directed to a method of RF filtering. The method includes generating an optical carrier signal using a tunable optical source, modulating the optical carrier signal with an RF input signal using a modulator coupled to the tunable optical source and first and second optical waveguide paths coupled to the modulator and having first and second dispersion slopes of opposite sign from each other, at least one of the first and second optical waveguide paths comprising at least one optical splitter and combiner pair therein, and generating an RF output signal with at least one frequency notch therein based upon the tunable optical source using an optical-to-electrical converter coupled to the first and second optical waveguide paths.

FIG. 1 is a schematic diagram of a tunable RF filter device, according to the present invention.

FIG. 2 is a detailed schematic diagram of the tunable RF filter device from FIG. 1.

FIG. 3 is a diagram of the transfer characteristics of the tunable RF filter device of FIG. 2.

FIG. 4 is a diagram of the dispersion slopes of the waveguides of the tunable RF filter device of FIG. 2.

FIG. 5 is a schematic diagram of another embodiment of the tunable RF filter device, according to the present invention.

FIG. 6 is a detailed schematic diagram of the tunable RF filter device from FIG. 5.

FIG. 7 is a schematic diagram of another embodiment of the optical waveguide path from the tunable RF filter device from FIG. 5.

FIG. 8 is a diagram of the transfer characteristics of the tunable RF filter device of FIG. 6.

The present invention will now be described more fully hereinafter with reference to the accompanying drawings, in which preferred embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. Like numbers refer to like elements throughout, and prime notation is used to indicate similar elements in alternative embodiments.

Referring initially to FIG. 1, a tunable RF filter device **10** according to the present invention is now described. The tunable RF filter device **10** illustratively includes an antenna **15**, and processing circuitry **14** downstream therefrom for providing an input RF signal. For example, the processing circuitry **14** may comprise a receiver module.

The tunable RF filter device **10** includes a tunable optical source **11** configured to generate an optical carrier signal, and a modulator **12** coupled to the tunable optical source and configured to modulate the optical carrier signal with the RF input signal. For example, the tunable optical source **11** may comprise a tunable continuous wave laser, a diode laser, etc. The tunable RF filter device **10** includes first and second optical waveguides **16-17** coupled to the modulator **12** and having first and second dispersion slopes of opposite sign. Particularly, the modulator **12** generates a modulated optical signal and transmits the modulated optical signal into the first and second optical waveguides **16-17**, i.e., the modulator is a dual output variant. As will be appreciated by those skilled in the art, the dispersion slope is a characteristic that governs induced phase delay as an optical signal travels through a medium varied over frequency, for example, a signal with a wavelength of 1525 nm may experience phase delay of 200 ps/nm.

The first and second optical waveguides **16-17** may comprise optical fibers, but of course, other waveguides may be used. In advantageous embodiments, the first and second optical waveguides **16-17** comprise photonic crystal fibers, which may be tailored to yield a wide tuning range over short fiber lengths. More specifically, with regards to the dispersion slopes of the first and second optical waveguides **16-17**, the first slope may be negative and the second slope may be positive, or vice versa, or one of the first and second slopes may be zero while the other is either positive or negative and this permutation is also considered to be of opposite sign. In other words, as the modulated optical signal travels simultaneously through the first and second optical waveguides **16-17**, the paths impart opposite shifts in phase at a respective frequency.

Referring briefly to FIG. 4 and diagram **55**, illustrative examples of the first and second dispersion slopes **56-57** of opposite sign are shown. Since the first and second dispersion slopes are negative and positive, respectively, the slopes intersect at the point corresponding to an optical wavelength that produces no frequency notches in the RF spectrum. These exemplary dispersion slopes are calculated using an assumed optical fiber dispersion of 4x10-6 ps/nm/km at a wavelength of 1552 nm and a dispersion slope of ± 0.08 ps/nm2/km with 1 km of fiber length.

Referring now once again to Fig. 1, the tunable RF filter device **10** includes an optical-to-electrical converter **13** coupled to the first and second optical waveguides **16-17** and is configured to generate an RF output signal with one or more frequency notches therein. The frequency notches in the modulated optical signal are generated by way of destructive interference (superposition) of the modulated optical signals output from the first and second optical waveguides **16-17**. Advantageously, the frequency notches are selectively adjusted by varying the frequency of the optical carrier signal via the tunable optical source **11**. Also, in some embodiments, the depth of the frequency notches are selectively adjusted by varying the optical power balance between arms of the modulator **12**, as would be appreciated by those skilled in the art.

Referring now to FIG. 2, the tunable RF filter device **10** is described in detail and includes a controller **18** coupled to the tunable optical source **11**, illustrated as a continuous wave laser, and configured to cooperate therewith to tune the frequency of the optical carrier signal as needed for an application. Moreover, the optical-to-electrical converter **13** illustratively includes first and second optical detectors **21a-21b**, which in some embodiments may be balanced, coupled respectively to the first and second optical waveguides **16-17**, a combiner **22** (e.g., optical fiber coupler) coupled to the first and second optical detectors, and an RF output module **23** performing any needed finishing processing, such as decoder processing.

Helpfully, in balanced detector **21a-21b** embodiments, the link performance may be improved with a 6 dB gain increase and with common-mode noise cancellation. This occurs by subtracting the output of two photodetectors **21a-21b**: if the signals at each detector are exactly out of phase, they add when the detector outputs are subtracted. Common-mode noise is always in phase at both detectors **21a-21b**, so the subtraction removes it. So a dual-output modulation device is required, and it must impart a 180° phase shift on one of the two outputs. The 6 dB of gain comes from the fact that in a modulator with a single output, half of the optical power is lost in the output coupling process, but in a dual-output modulator this optical power is retained. And 3 dB of optical power corresponds to 6 dB of RF power.

Also, the tunable RF filter device **10** may not be subject to the polarization sensitivity of typical optical devices since the balanced detectors **21a-21b** convert the optical signals to electrical signals before interference occurs. In the illustrated embodiment, the modulator **12** comprises a dual-output Mach-Zehnder modulator. Of course, other suitable optical modulator types may be used.

Referring now additionally to FIG. 3, a diagram **50** illustrates the transfer characteristics of the tunable RF filter device **10** as the frequency of the optical carrier signal is varied by the tunable optical source **11**. The diagram **50** includes a curve **53** representing the zero dispersion point **58** (FIG. 4), i.e., when the interference from

combining the modulated optical signals from the first and second optical waveguides **16-17** cancel each other out (flat transfer characteristic). Advantageously, the tunable optical source **11** can be tuned to provide the flat transfer characteristic, thereby providing an optical link with no filtering. The diagram **50** illustratively includes a curve **52** representing a 3nm shift of the optical carrier signal from the zero dispersion point **58**, and a curve **51** representing a 5nm shift of the optical carrier signal from the zero dispersion point **58**. Advantageously, the shifts in the optical carrier signal may provide versatility as the frequency notches can be adjusted depending on the application. As will be appreciated by those skilled in the art, this may be helpful in interference mitigation applications, for example, co-site interference mitigation. Also, as the skilled person will appreciate, the tunable RF filter device **10** may be used for moving object identification in radar applications and other typical digital signal processing applications.

Advantageously, the tunable RF filter device **10** may push the frequency limitations from solely RF components technology to the active photonic device realm. That is, the ability to create frequency notches over a wide bandwidth or at very high frequencies—a constant challenge for RF components—is not limited by the physical process of contrasting dispersion slopes, but would only be restricted by the frequency limitations of the modulator **12** and balanced detector **21a-21b**. The periodic spacing and depth of the frequency notches is the same at 1 GHz as it is at 100 GHz. More so, the tunable RF filter device **10** is able to attenuate potential inference sources by more than 40 dB with little to no impact on a signal or signals of interest (SOI).

Another aspect is directed to a method of RF filtering. The method comprises generating an optical carrier signal using a tunable optical source **11**, modulating the optical carrier signal with an RF input signal using a modulator **12** coupled to the tunable optical source and first and second optical waveguides **16-17** coupled to the modulator and having first and second dispersion slopes of opposite sign, and generating an RF output signal with at least one frequency notch therein

based upon the tunable optical source using an optical-to-electrical converter **13** coupled to the first and second optical waveguides.

Referring now to FIG. 5, another embodiment of the tunable RF filter device **10'** is now described. In this embodiment of the tunable RF filter device **10'**, those elements already discussed above with respect to FIGS. 1-2 are given prime notation and most require no further discussion herein. This embodiment differs from the previous embodiment in that the tunable RF filter device **10'** includes first and second optical waveguide **16'-17'** paths coupled to the modulator **12'** and having first and second dispersion slopes of opposite sign, the first optical waveguide path illustratively including an optical splitter and combiner pair therein. Although illustrated as a typical waveguide, it should be appreciated that the second optical waveguide path **17'** may also comprise an optical splitter and combiner pair therein, i.e., each of the first and second optical waveguide paths **16'-17'** may comprise an optical splitter and combiner pair.

Referring now additionally to FIG. 6, the tunable RF filter device **10'** illustratively includes one optical splitter and combiner pair in each of the first and second optical waveguide paths **16'-17'**. Each of the splitters **24a'-24b'** includes a 1x4 splitter, and each of the combiners **25a'-25b'** includes a 4x1 combiner, but of course, other configurations may be used, for example, 1x2, 1Xn. As shown, the first and second optical waveguides **31'-32'** couple the modulator **12'** to the optical splitters **24a'-24b'**, the waveguide pair having dispersion slopes of opposite sign.

Moreover, the first optical splitter and combiner pair **24a', 25a'** is coupled therebetween with a pair of waveguides **33'-34'**, each pair also comprising waveguides of opposite dispersion slopes. The second optical splitter and combiner pair **24b', 25b'** is coupled therebetween with a pair of waveguides **35'-36'**, each pair also comprising waveguides of opposite dispersion slopes.

Referring briefly and additionally to FIG. 7, another embodiment of the first optical waveguide path **16'** is now described. In this embodiment, the first optical waveguide path **16'** includes an optical splitter **24a'**coupled in series to a plurality of parallel optical splitters **26a'and 27a'**, and a corresponding optical

combiner **25a'**coupled in series to a plurality of parallel optical combiners **28a'and 29a'** downstream from the optical splitters. In other embodiments (not shown), the second optical waveguide path **17'** may similarly comprise a plurality of optical splitters and a plurality of optical combiners.

Advantageously, the combination of the optical splitters and the combiners deepens the null of the notch filtering. Moreover, the pass band of the tunable RF filter device **10'** is broadened, which overcomes the cosine squared limitation of the signal bandwidth. As in the above embodiments, the frequency of the notch filtering may be readily manipulated by changing the frequency of the optical carrier signal.

Referring now to FIG. 8, a diagram **60** illustrates the transfer characteristics of the tunable RF filter device **10'.** The diagram **60** illustratively includes a curve **61** illustrating the transfer characteristics up to 25 GHz, and demonstrates two desirable deep nulls at approximately 6 GHz and 19 GHz with a wider pass band than the typical cosine squared response, based on a simulation of a system similar to that depicted in FIG. 6.

Another aspect is directed to a method of RF filtering. The method includes using a tunable optical source **11'** to generate an optical carrier signal, and using a modulator **12'** coupled to the tunable optical source to modulate the optical carrier signal with an RF input signal. The method may also include using first and second optical waveguide paths **16'-17'** coupled to the modulator **12'** and having first and second dispersion slopes of opposite sign, at least one of the first and second optical waveguide paths comprising at least one optical splitter and combiner pair therein, and using an optical-to-electrical converter **13'** coupled to the first and second optical waveguide paths to generate an RF output signal with at least one frequency notch therein based upon the tunable optical source.

CLAIMS

1. A tunable Radio Frequency (RF) filter device comprising:

a tunable optical source configured to generate an optical carrier signal;

a modulator coupled to said tunable optical source and configured to modulate the optical carrier signal with an RF input signal;

first and second optical waveguide paths coupled to said modulator and having first and second dispersion slopes of opposite sign from each other;

at least one of said first and second optical waveguide paths comprising at least one optical splitter and combiner pair therein; and

an optical-to-electrical converter coupled to said first and second optical waveguide paths and configured to generate an RF output signal with at least one frequency notch therein based upon said tunable optical source.

2. The tunable RF filter device of Claim 1 wherein each of said first and second optical waveguide paths comprises at least one optical splitter and combiner pair.

3. The tunable RF filter device of Claim 1 wherein said first optical waveguide path comprises a first optical waveguide coupled to said modulator and having a first dispersion slope; and wherein said second optical waveguide path comprises a second optical waveguide coupled to said modulator and having a second dispersion slope having an opposite sign of the first dispersion slope.

4. The tunable RF filter device of Claim 1 said first optical waveguide path comprises at least one pair of optical waveguides coupled between the optical splitter and the optical combiner of said at least one optical splitter and combiner pair, the at least one pair of optical waveguides having dispersion slopes of opposite sign.

5. The tunable RF filter device of Claim 1 wherein said at least one optical splitter and combiner pair comprises a plurality thereof coupled in series.

6. The tunable RF filter device of Claim 1 further comprising a controller coupled to said tunable optical source and configured to tune a frequency of the optical carrier signal over a desired frequency range.

7. The tunable RF filter device of Claim 6 wherein said controller is configured to tune the frequency of the optical carrier signal to generate the RF output signal with the at least one frequency notch therein by causing interference between outputs of said first and second optical waveguide paths.

8. A method of Radio Frequency (RF) filtering comprising:

generating an optical carrier signal using a tunable optical source;

modulating the optical carrier signal with an RF input signal using a modulator coupled to the tunable optical source and first and second optical waveguide paths coupled to the modulator and having first and second dispersion slopes of opposite sign from each other, at least one of the first and second optical waveguide paths comprising at least one optical splitter and combiner pair therein; and

generating an RF output signal with at least one frequency notch therein based upon the tunable optical source using an optical-to-electrical converter coupled to the first and second optical waveguide paths.

9. The method of Claim 8 further comprising using the first optical waveguide path comprising a first optical waveguide coupled to the modulator and having a first dispersion slope, and the second optical waveguide path comprising a second optical waveguide coupled to the modulator and having a second dispersion slope having an opposite sign of the first dispersion slope.

10. The method of Claim 8 further comprising using the first optical waveguide path comprising at least one pair of optical waveguides coupled between the optical splitter and the optical combiner of the at least one optical splitter and combiner pair, the at least one pair of optical waveguides having dispersion slopes of opposite sign.

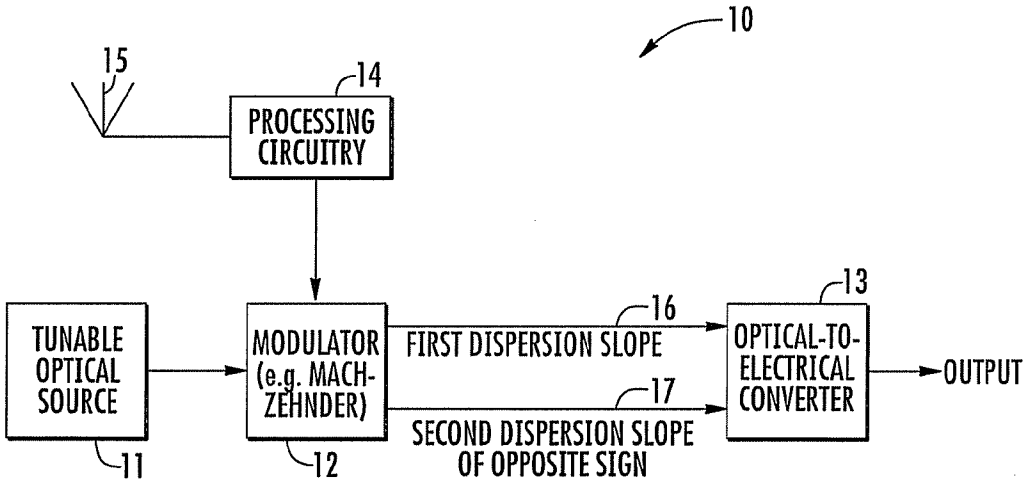

10
15
14
PROCESSING CIRCUITRY
TUNABLE OPTICAL SOURCE
11
MODULATOR (e.g. MACH-ZEHNDER)
12
16
FIRST DISPERSION SLOPE
17
SECOND DISPERSION SLOPE OF OPPOSITE SIGN
13
OPTICAL-TO-ELECTRICAL CONVERTER
OUTPUT

FIG. 1

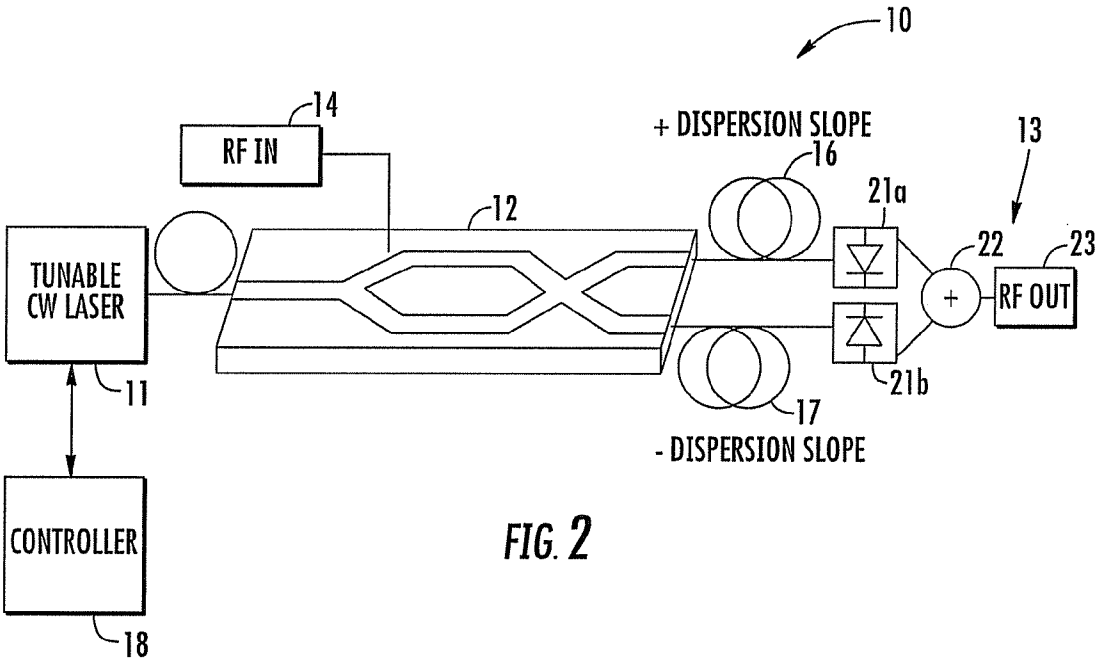

10
14
RF IN
12
TUNABLE CW LASER
11
CONTROLLER
18
+ DISPERSION SLOPE
16
17
- DISPERSION SLOPE
21a
21b
13
22
+
23
RF OUT

FIG. 2

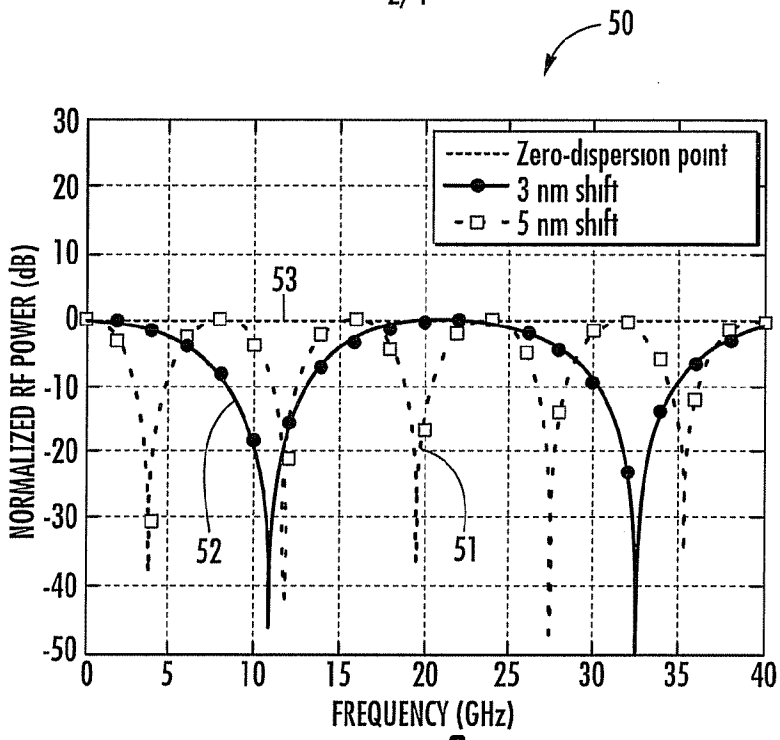
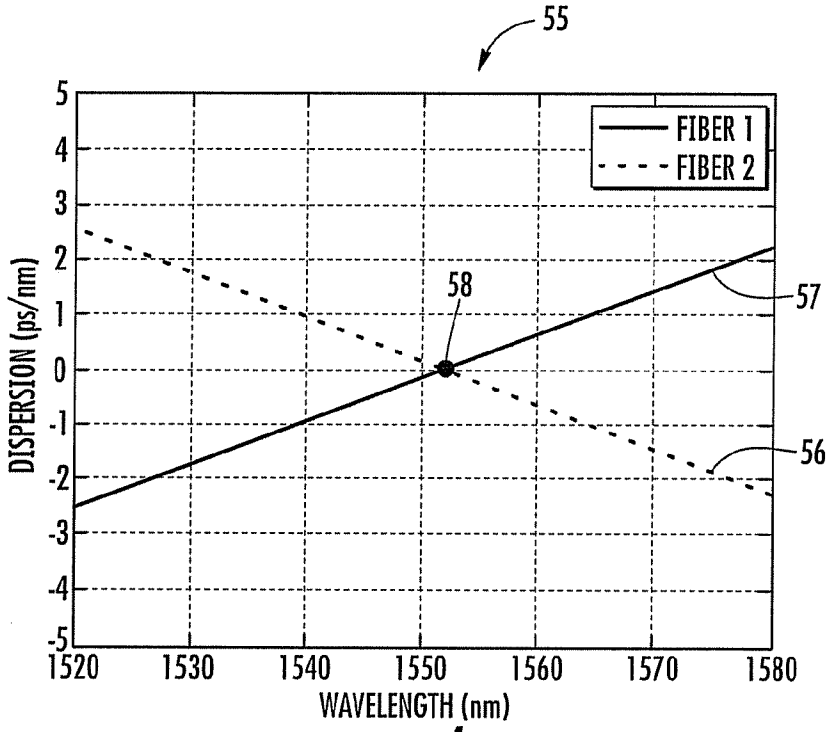

50
Zero-dispersion point
3 nm shift
5 nm shift
53
52
51
NORMALIZED RF POWER (dB)
FREQUENCY (GHz)
30
20
10
0
-10
-20
-30
-40
-50
0
5
10
15
20
25
30
35
40

FIG. 3


55
FIBER 1
FIBER 2
58
57
56
DISPERSION (ps/nm)
WAVELENGTH (nm)
5
4
3
2
1
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-1
-2
-3
-4
-5
1520
1530
1540
1550
1560
1570
1580

FIG. 4

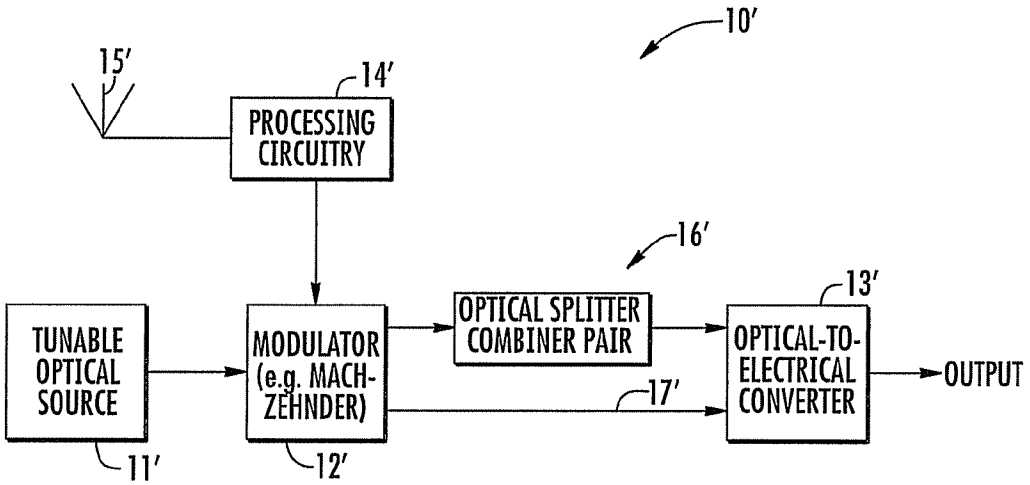
10'
15'
14'
PROCESSING CIRCUITRY
16'
13'
TUNABLE OPTICAL SOURCE
MODULATOR (e.g. MACH-ZEHNDER)
OPTICAL SPLITTER COMBINER PAIR
OPTICAL-TO-ELECTRICAL CONVERTER
OUTPUT
17'
11'
12'

FIG. 5

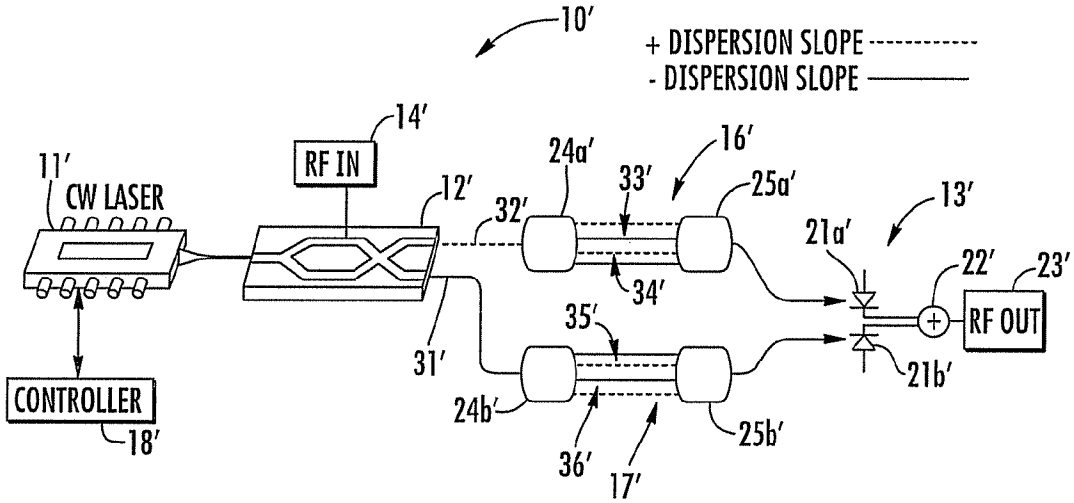
10'
+ DISPERSION SLOPE
- DISPERSION SLOPE
14'
RF IN
11'
CW LASER
12'
32'
24a'
33'
16'
25a'
13'
21a'
22'
23'
RF OUT
34'
35'
31'
21b'
CONTROLLER
18'
24b'
25b'
36'
17'

FIG. 6

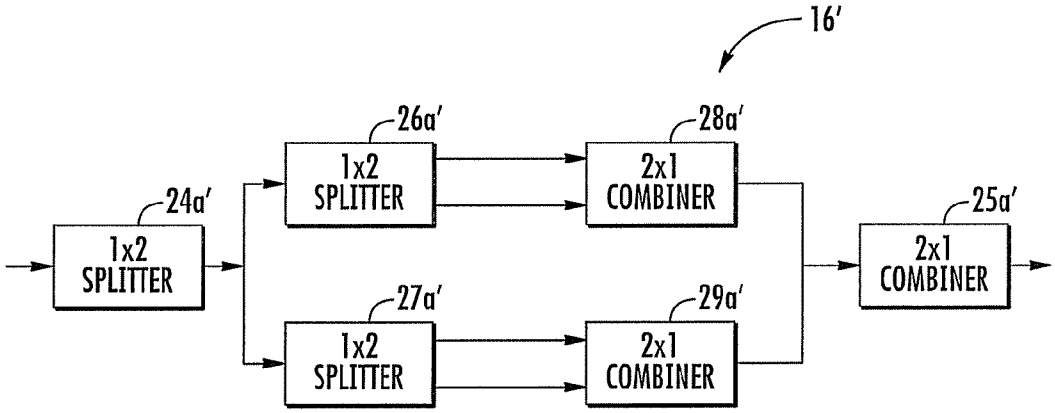
16'
26a'
28a'
1x2
SPLITTER
2x1
COMBINER
24a'
25a'
1x2
SPLITTER
2x1
COMBINER
27a'
29a'
1x2
SPLITTER
2x1
COMBINER

FIG. 7

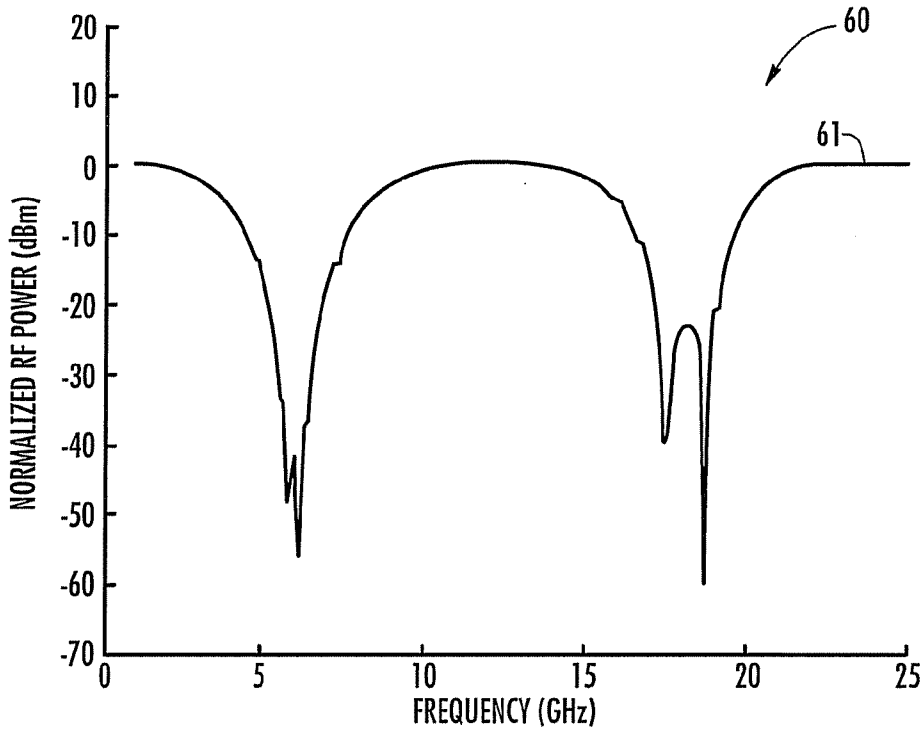
60
61
20
10
0
-10
-20
-30
-40
-50
-60
-70
NORMALIZED RF POWER (dBm)
0
5
10
15
20
25
FREQUENCY (GHz)

FIG. 8

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2012/047976

A. CLASSIFICATION OF SUBJECT MATTER
INV. H03H2/00 H04B10/12
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H03H H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2009/214223 A1 (CHEN YOUNG-KAI [US] ET AL) 27 August 2009 (2009-08-27) paragraph [0036]; figures 1A, 3	1-10
A	MAHMOUD S RASRAS ET AL: "Demonstration of a Fourth-Order Pole-Zero Optical Filter Integrated Using CMOS Processes", JOURNAL OF LIGHTWAVE TECHNOLOGY, IEEE SERVICE CENTER, NEW YORK, NY, US, vol. 25, no. 1, 1 January 2007 (2007-01-01), pages 87-92, XP011175489, ISSN: 0733-8724, DOI: 10.1109/JLT.2006.888932 figure 5	1-10

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

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

"E" earlier application or patent 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 when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
19 October 2012	26/10/2012

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Naumann, Olaf

1

Form PCT/ISA/210 (second sheet) (April 2005)

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	YU YAN ET AL: "Tunable Photonic Microwave Bandpass Filter With Negative Coefficients Implemented Using an Optical Phase Modulator and Chirped Fiber Bragg Gratings", JOURNAL OF LIGHTWAVE TECHNOLOGY, IEEE SERVICE CENTER, NEW YORK, NY, US, vol. 25, no. 11, 1 November 2007 (2007-11-01), pages 3283-3288, XP011194820, ISSN: 0733-8724, DOI: 10.1109/JLT.2007.906821 section II; figures 1, 2 -----	1-4,6-10

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2012/047976

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2009214223 A1	27-08-2009	NONE	