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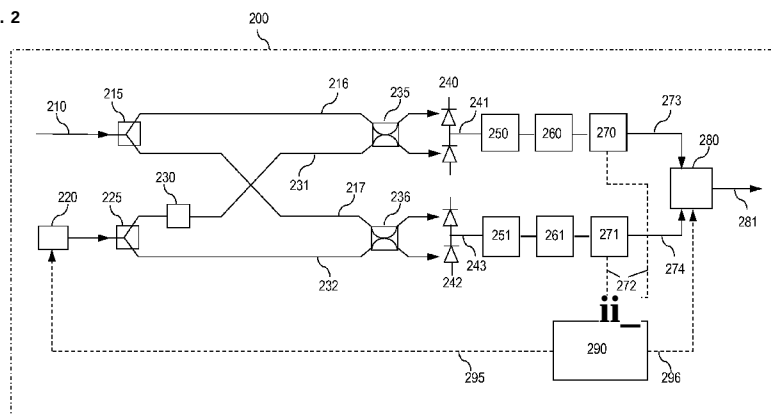
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(54) Title: METHOD AND DEVICE FOR DETERMINING THE POLARIZATION SPLIT IN A HETERODYNE COHERENT RECEIVER

Fig. 2



(57) Abstract: A coherent polarization diversity receiver is disclosed in which the phase angle difference between the first polarized input signal and the first polarized local oscillator signal is determined and also the phase angle difference between the second polarized input signal and the second polarized local oscillator signal is determined and based on this information a portion of the generated first and second electrical output signals is selected to produce the final output signal for further processing.

Description

Method and device for determining the polarization split in
a heterodyne coherent receiver

5

Field of the invention

The invention relates to optical transmission systems with
phase modulated signal transmission and heterodyne coherent
10 polarization diversity receivers.

Optical access networks become more and more popular to
satisfy the growing demand for higher bandwidth. Different
types of passive optical networks (PON) have been deployed
15 in the past, but next generation optical access networks
can provide higher bandwidth by using more powerful and
efficient modulation techniques and transmission
principles .

20 In phase-modulated transmission systems the data is coded
in the phase angle of the carrier light, generally called
phase shift keying (PSK) . An embodiment of PSK for instance
is quadrature phase shift keying (QPSK) , wherein the
symbols hold angles of 0° , 90° , 180° , and 270° . Therefore
25 the receiver needs to determine the phase angle of the
received light in order to extract the data. Instead of
setting the phase angle to code symbols, an alternative is
to change the phase between two consecutive symbols. This
method is called differential phase shift keying (DPSK) .
30 DPSK is significantly simpler to implement than ordinary
PSK since there is no need for the demodulator to have a
copy of the reference signal to determine the exact phase
of the received signal.

Next generation optical access systems not only shall
35 provide higher bandwidth but also higher reach. Higher
reach means to convey data over longer distances. Both

requirements are the motivation to use coherent communication techniques.

Coherent transmission systems have several advantages. The receiver sensitivity can be improved by up to 20 dB compared with that of systems implementing intensity modulation with direct detection. Second, the use of coherent detection also allows a more efficient use of fiber bandwidth by increasing the spectral efficiency of the systems.

A key component in coherent optical transmission systems is the receiver. A coherent receiver is able to distinguish and evaluate the optical phase and polarization of the received light. The basic principle of a coherent receiver is to combine the incoming signal light with light which is locally generated by a narrow line width laser, called local oscillator.

Mixing of the received optical signal with the local oscillator improves the receiver's performance.

As mentioned before, a coherent receiver must be able to distinguish and evaluate the optical phase and polarization of the received light. In an asynchronous receiver the receiver does not get any phase information from the sender and therefore has to retrieve the phase information by itself. Especially the phase information is necessary to decode the information coded in the phase shifts of a phase shift keying signal. Another important aspect is polarization. The polarization state of the received signal and the local oscillator plays an important role. Since the polarization state of the received optical signal is unknown, there might be a polarization mismatch with the local oscillator.

To cope with this problem, a two port balanced coherent receiver can be used. Fig. 1 illustrates a schematic coherent polarization diversity receiver.

The incoming input signal light is split by a polarization beam splitter into two orthogonal polarization planes. Further, the local oscillator (LO) light is divided into two light beams by a splitter and one branch is left
5 unchanged while the other branch shifts the polarization of the LO light by 90° . Now there are two orthogonal polarized components of the signal light available as well as two orthogonal polarized components of the LO light. According to Fig. 1 the components of the signal and the LO light are
10 combined by a 3 dB coupler. The resulting light paths leaving the couplers are fed into two pairs of photodiodes. The photodiodes create electric current which is typically transformed into a proportional voltage by a so called trans-impedance amplifier. The resulting signals are
15 digitized by analog-to-digital converters (ADC) and fed to appropriate electronics for further data processing. Each beam combiner in the two branches combines signal light with local oscillator light of the proper polarization. Dependent on the polarization state of the
20 signal light, which is time variable in a transmission system, the relative weight of the signal in the two branches will vary.

However it is guaranteed, that independent from the
25 polarization state of the input signal, the projection of the signal onto the local oscillator light cannot be zero for both branches at the same time. It could be zero for one and maximum for the other, or equally distributed between the two branches, or any distribution between those
30 two extreme cases.

In the case where the polarization of the signal light happens to be perfectly aligned to the polarization of the local oscillator light in one branch, this branch will
35 receive all the useable signal, while the orthogonal polarization component associated with the other branch is zero, so that only local oscillator light is present in

this branch. This results in a high quality signal in the well aligned branch while the other branch produces a receiver signal having significant noise.

5 However the polarization state of the incoming signal is random and not predictable. The source for unpredictable polarization state is caused by the so called polarization-mode dispersion. Perfect operation of a coherent receiver requires exact matching of the polarization state of the
10 local oscillator to that of the received input signal. This is given when the polarization state of the optical fields of the LO and the input signal are equal. If however the polarization states of the LO and the input signal are orthogonal to each other, the resulting signal disappears
15 completely.

To cope with the problem of unknown polarization state of the incoming signal, both branches of the balanced receivers with orthogonal polarization have to be evaluated. The analysis which one of the balanced receivers
20 has a useful signal and which one outputs more or less noise, is an important task.

A known method for analyzing the signal and to decide which path contains the better signal is to process both signal paths in the receiver and to perform error estimation e.g.
25 determining the error rate via FEC. The disadvantage of this procedure however is that appropriate electronics have to be provided for both signal paths. This results in higher footprint of electronics, higher power consumption and increased costs.

30 Another known method consists in adding a polarization controller at the signal input port of the receiver, which is then dynamically adjusted to align the polarization of the input light to the local oscillator light. This method
35 requires another optical element (the polarization controller) which is costly and attenuates the input signal, leading to a decreased receiver sensitivity. It

also requires sophisticated and fast control electronics in order to follow the polarization variations of the signal.

Another known method consists of adding a 90 degree optical hybrid to the receiver, and doubling the number of photodiodes. In such a receiver, the signal light is mixed once with the LO light of each polarization directly, and once with the LO light of the each polarization phase shifted by 90 degrees, essentially creating two polarization diverse balanced receivers, with the LO light of one polarization diverse balanced receiver phase shifted by 90 degrees with respect to the LO light in the other polarization diverse balanced receiver. This allows for the full recovery of the optical field, and with data processing the distribution of the signal among the two orthogonal polarizations can be determined. The disadvantage of the method is the doubling of the number of photodiodes and TIAs that are necessary, the splitting of the LO power between the two pairs of polarization diverse balanced receivers, and the sophisticated data processing. The recovery algorithm also requires the insertion of a training pattern in the data, which increases the overhead and decreases the usable data bandwidth.

The invention proposes to use the differences between the estimated phase deviations for the four possible symbols (0° , 90° , 180° , 270°) to decide which of the two orthogonal polarization directions is better aligned to the signal.

Signal light :

$$A_s \sin(\omega_s t + \varphi_s) \quad (1)$$

A_s = signal amplitude (electric field amplitude)

φ_s =signal phase (symbol, 0 , 90° , 180° , 270°)

ω_s =**signal** frequency (optical)

35

Local oscillator light:

$$A_{LO} \sin(\omega_{LO} t + \phi_{LO}) \quad (2)$$

A_{LO} =local oscillator amplitude (electric field amplitude)

ϕ_{LO} =LO phase

ω_{LO} =LO frequency (optical)

- 5 Coherent reception multiplies the electrical fields of the signal and local oscillator:

signal*LO

->

$$\frac{A_s A_{LO}}{2} [\sin((\omega_s + \omega_{LO})t + \phi_s + \phi_{LO}) + \sin((\omega_s - \omega_{LO})t + \phi_s - \phi_{LO})] \quad (3)$$

- 10 The component at the sum frequency cannot be detected by the receiver due to its low-pass characteristics.

$$\text{Received signal: } \frac{A_s A_{LO}}{2} [\sin((\omega_s - \omega_{LO})t + \phi_s - \phi_{LO})] \quad (4)$$

The difference between the signal frequency and the LO frequency is the intermediate frequency ω_{IF} plus the

- 15 frequency error $\Delta\omega$:

$$\omega_i - \omega_{LO} = \omega_{IF} + \Delta\omega \quad (5)$$

After analog to digital conversion, the received signal (4) is multiplied in the digital signal processing unit (DSP) with $\sin(\omega_{IF}t)$ and $\cos(\omega_{IF}t)$ to detect the I and Q channels.

- 20 I channel:

$$\begin{aligned} s_I &= \frac{A_s A_{LO}}{2} [\sin((\omega_{IF} + \Delta\omega)t + \phi_s - \phi_{LO})] * \sin(\omega_{IF}t) \\ &= \frac{A_s A_{LO}}{4} [\cos(\Delta\omega t + \phi_s - \phi_{LO}) - \cos((2\omega_{IF} + \Delta\omega)t + \phi_s + \phi_{LO})] \end{aligned} \quad (6)$$

$$\begin{aligned} s_Q &= \frac{A_s A_{LO}}{2} [\sin((\omega_{IF} + \Delta\omega)t + \phi_s - \phi_{LO})] * \cos(\omega_{IF}t) \\ &= \frac{A_s A_{LO}}{4} [\sin(\Delta\omega t + \phi_s - \phi_{LO}) + \sin((2\omega_{IF} + \Delta\omega)t + \phi_s + \phi_{LO})] \end{aligned} \quad (7)$$

- 25 Again, a low pass filter removes the terms which contain the high ($2\omega_{IF}$) frequencies.

Using the ratio of the Q and I channels we can extract the phase :

$$\arctan\left(\frac{s_Q}{s_I}\right) = A\omega t + \varphi_s - \varphi_{L0} \quad (8)$$

Subtracting the previous angle from the current one yields
 $A\omega t_D + A\varphi_s$ (9)

- 5 where t_D is the bit period. The first term of (9) is proportional to the frequency offset of the local oscillator laser and will be used as control input for the laser control algorithm, which aims to minimize this offset by changing the LO laser frequency ω_{L0} until $\Delta\omega t_D$ is zero.
- 10 The second term is the data symbol for differential phase coded communication. In the case of DQPSK, $A\varphi_s$ is a multiple of 90° .

- If the polarizations of LO and signal are badly aligned
 15 (for one receiver), there will be very little signal and the inbuilt automatic gain control (AGC) of the receiver amplifier will not be saturated. In this case, the carrier (= unmodulated laser light) will not be suppressed in comparison to the signal.
- 20 This will add a term to the detected signal which does not include the symbol phase:

$$s_I = \frac{A_s A_{L0}}{4} [\cos(A\omega t + \varphi_s - \varphi_{L0}) + a_{cw} \cos(A\omega t - \varphi_{L0})] \quad (10)$$

$$25 \quad s_Q = \frac{A_s A_{L0}}{4} [\sin(\Delta\omega t + \varphi_s - \varphi_{L0}) + a_{cw} \sin(A\omega t - \varphi_{L0})] \quad (11)$$

- Here a_{cw} is the fractional contribution of the carrier peak to the received signal. This contribution will shift the frequency estimator line for $\varphi_s = 90^\circ$ and 270° by an equal amount, but in opposite directions. For 0° there is no
 30 shift, because both terms are identical, and for 180° there is also no shift because of the periodicity of the arctan function.

Therefore, by comparing the measured frequency shifts for the different symbols it is possible to distinguish between a shift which is caused by a frequency error and a shift which is caused by a polarization mismatch.

5 The difference D between the estimator output for 90° and 270° is proportional to the misalignment of the polarizations. This is used to determine which of the two polarizations should be used (the one with the smaller D). In case D is 0 for both polarizations, either one is picked
10 at random (if newly starting the system), or, if D was previously not 0 for one of the receivers so that the other was picked, the system continues in this polarization, or an equally weighted sum of the two can be used, since they both have sufficient alignment of their polarizations.

15

It is an object of the invention to provide a beneficial solution for utilizing a simple and efficient way to evaluate the polarization state in each path of the
20 receiver and to select the appropriate signal part for further processing.

This is achieved according to the features of the independent claims. Further embodiments result out of
25 dependening claims.

In order to overcome the disadvantages, a method and an arrangement for a coherent polarization diversity receiver is presented.

30 In an embodiment of the invention, the coherent polarization diversity receiver comprises a local oscillator laser, the light of which is split into two parts of mutually orthogonal polarizations, which are mixed optically with the signal light, the signal light also
35 having been split into corresponding polarizations, so that light of the local oscillator and signal having equal polarization directions is combined in the two paths of the

receiver optics. Each polarization is then detected separately by a pair of photodiodes, generating an electrical output signal proportional to the optical signal for each polarization.

- 5 The phase angle difference between the first polarized input signal and the first polarized LO portion is determined, and also the phase angle difference between the second polarized input signal and the second polarized LO portion is determined. This information is then used to
10 select a portion of the first electrical output signal and a portion of the second electrical output signal.

- The advantage of this method is, that the phase information, which is necessary for the correct operating of the
15 receiver, can be used directly to decide and to determine, which portion of the digitized signal light of each branch of the receiver is used for the final output signal.

- To achieve the mixing, 2x2 waveguide couplers might be
20 used. In another embodiment, free-space beam splitters might be used. In yet another embodiment, the optical splitting and mixing might be achieved using fiber-based 2x2 couplers.

- 25 In one embodiment, each pair of photodiodes is configured so that the electrical signal proportional to the power in the local oscillator laser and in the signal light cancels and the electrical output is only proportional to the product of the local oscillator light and the signal light.
30 In another embodiment, one arm of the 2x2 splitters is terminated, and a single photodiode is used on the other arm, generating a signal proportional to the sum of the local oscillator laser power, the optical signal power, and the product of the local oscillator light and the signal
35 light. AC coupling of the electrical output is then used to remove the components of the electrical signal which are proportional to the power of the local oscillator light and

the signal light, leaving only the electrical signal proportional to the product of the local oscillator light and the signal light for further analysis.

5 In an embodiment, a signal analysis block determines the phase angle difference between the first polarized input signal and the first polarized local oscillator signal and the phase angle difference between the second polarized input signal and the second polarized local oscillator
10 signal. A decision algorithm then selects a first portion of the first electrical output signal and a second portion of the second electrical output signal for further processing .

15 In an embodiment, these first and second portions are determined by a control and decision unit.

In another embodiment of the invention, these first and second portions are combined by a signal selection and
20 weighting unit. This weighting unit may assign weights to the signal with values between 0 and 1 .

In a simplified version of the invention, the decision unit does not combine the first and second signal, but instead
25 selects one for further processing and discards the other, leading to a further simplification of the data processing unit, because in this case, it is not necessary to determine the proper time shift between the first signal and the second signal. This might be achieved with a simple
30 switch.

Embodiments are possible in which the first input signal and the second input signal are orthogonal to each other, and the first LO signal and the second LO signal are
35 orthogonal to each other.

In an embodiment, the control signals necessary to decide on the proper weighting between the first portion of the signal and the second portion of the signal is derived from the control signal used for frequency control of the local oscillator laser.

In another embodiment, separate control circuitry may be used for the laser frequency control and the weighting and decision unit.

In another embodiment, the phase offset measured for symbols 0° and 180° is used to control the LO frequency, and the difference between the phase offset measured for symbols 90° and 270° is used to control a selection switch which switches from one polarization to the other.

It is further noted that the method steps described above may be processed by an apparatus, which comprises a local oscillator having a polarization, wherein the local oscillator generates a first and a second polarized local oscillator signal, the apparatus having a polarization unit to split the polarization of the input signal into a first polarized input signal and a second polarized input signal, the apparatus having a first coupler/splitter unit configured to mix the first polarized input signal with the first polarized local oscillator signal and to feed the signal light into a pair of photo diodes to generate a first electrical output signal, the apparatus further having a second coupler/splitter unit configured to mix the second polarized input signal with the second polarized local oscillator signal and to feed the signal light into a further pair of photo diodes to generate a second electrical output signal, the apparatus further comprises a phase angle detection unit configured to detect the phase angle difference between the first polarized input signal and the first polarized local oscillator signal and another

phase angle detection unit configured to detect the phase angle difference between the second polarized input signal and the second polarized local oscillator signal, the apparatus comprising a selection and weighting unit
5 configured to select a first portion of the first electrical signal and a second portion of the second electrical signal to combine an output signal for further processing .

10 Embodiments of the invention are shown and illustrated in the following figures:

Fig. 1 shows a known coherent polarization diversity receiver

15

Fig. 2 and 3 show examples of the inventive coherent polarization diversity receiver with a control and decision circuit and a selection and weighting unit

20 Detailed description

Figure 1 shortly illustrates a state of the art receiver. The input signal 110 is split by a polarization splitter 115 in signals 116 and 117. A local oscillator (LO) light 120 is also split by splitter 125 into a LO light 132 and an LO light 131 the polarization of which is made
25 orthogonal to LO light 132 by polarization rotator 130, so that now the polarizations of signal 116 and LO light 131 are aligned and also the polarizations of signal 117 and LO light 132 are aligned. In a first branch the signal light 116 and LO light 131 is mixed by a coupler/splitter and fed into a pair of photo diodes. The same processing is done in
30 the second branch with signal light 117 and LO light 132. The resulting analog electrical signals leaving the balanced photo detectors 140 and 141 in the first and the
35 second branch of the receiver are further processed by

appropriate units 150,160 and combined by digital combiner 170 to a final output signal 180.

Figure 2 shows a first embodiment of the invention. An
5 input signal 210 of the receiver 200 is split by a
polarization splitter 215 into two orthogonal components
216 and 217. A local oscillator 220 generates laser light
having a polarization (LO light). This LO light is split
evenly by a splitter 225 into a first part 232 which is
10 left unchanged while a second part is polarization shifted
by 90 degrees via a polarization shifter 230 to LO light
231, so that now the polarizations of signal 216 and LO
light 231 are aligned and also the polarizations of signal
217 and LO light 232 are aligned. Signal light 216 and one
15 part of the LO light is mixed with a combiner/splitter 235
and fed to a first pair of photodiodes 240.
Also the orthogonal polarized signal light 217 and the
other part of the LO light 232 is mixed with a combiner/
splitter 236 and fed to a second pair of photodiodes 241.
20 Both pairs of photodiodes are arranged as balanced
receivers and output an electric signal current. This
signal current generated by the photodiodes is typically
transformed to a proportional signal voltage by so called
trans impedance amplifiers (TIA) 250, 251. Then the output
25 of the TIAs is fed to analog digital converters (ADC) 260,
261 and further fed into the phase detectors 270, 271. The
phase detectors each output a digital electrical signal and
feed it into a selection and weighting unit 280. The
weighting unit composes an output signal 281 by combining
30 arbitrary portions of the digitized signals 273 and 274.
The phase detectors 270 and 271 each analyze the phase
angles of the signals in both branches and transfer this
information into a control and decision unit 290. The
control and decision unit controls on the one hand via
35 control signal 295 the frequency of the local oscillator
laser and on the other hand the selection and weighting
unit 280 via control signal 296.

For perfect setting of the local oscillator laser, the detected symbols will be perfect multiples of 90° . If the local oscillator is detuned, the detected angles will be larger or smaller proportional to the frequency offset.

5 Therefore, this offset can be used as input to the frequency control unit.

If the weight of the signal light is very small in one branch of the balanced receiver, most of the electrical signal will be due to un-modulated light. This results in
10 an offset in the detected phases which is not due to the frequency offset of the local oscillator light. It can be distinguished because the offset due to frequency detuning is the same for all detected angles, whereas the offset due to unmodulated light is 0 for phase angles 0° and 180° , and
15 of opposite sign for 90° and 270° .

The advantage of this method is, that the phase information, which is necessary for the correct operating of the receiver, can be used directly to decide and to determine, which portion of the digitized signal light of each branch
20 of the receiver is used for the final output signal 281. If the phase angle deviation from multiples of 90° varies strongly for 90° and 270° in one branch of the receiver, then a big portion of the signal in the other branch of the receiver is used to create the final output signal and in
25 consequence, if the phase angle deviation from multiples of 90° is near zero for all 4 symbols simultaneously in a branch of the receiver, a big portion of the resulting signal in this branch is taken to form the final output signal .

30 It is an advantage, that always the majority of the output signal can be taken from the receiver branch, which has lower noise figures.

It is also an advantage, that not any additional electronics or circuits in the signal path are necessary to
35 decide, which portion of the signals 273 and 274 have to be taken to create an optimal output signal 281. Only the selection and weighting unit 280 is necessary to create the

final output signal 281. The selection and weighting unit 280 is controlled by the control and decision unit 290. The control unit is arranged to receive the phase information from the phase detectors 270, 271 and controls the
5 selection and weighting unit 280 via control signal 296.

Figure 3 shows an interesting and cost saving alternative of the invention having an extremely simplified selection and weighing unit 380. Figure 3 shows an inventive
10 receiver, the structure of which is identical to Figure 2 but differs only in the selection and weighing unit.
Unit 380 consists of a simple switch to select exclusively either the electrical signal of one or the other branch of the receiver, depending on the fact, which one of the
15 signals 373 or 374 has the better phase angle difference.

REFERENCE SIGNS:

	100	coherent polarization diversity receiver
	110	received input signal
	115	polarization beam splitter
5	116	polarized input signal
	117	Orthogonal polarized input signal
	120	local oscillator
	125	3 dB splitter
	130	90° polarization shifter
10	131	90° shifted local oscillator light
	132	local oscillator light
	135,136	coupler/beam splitter
	140,141	photo diodes
	150,160	electronic circuit
15	170	signal combiner
	180	electrical bit stream

200 selective coherent polarization diversity receiver
210 received input signal
215 polarization beam splitter
216 polarized input signal
5 217 orthogonal polarized input signal
220 local oscillator
225 3 dB splitter
230 90° polarization shifter
231 90° shifted local oscillator light
10 232 local oscillator light
235,236 coupler/beam splitter
240.242 pair of photo diodes
241.243 electrical output signal
250,251 trans impedance amplifier
15 260,261 analog/digital converter
270,271 phase detector
272 phase information signal
273 electrical output signal of first branch
274 electrical output signal of second branch
20 280 signal selection and weighting unit
281 final receiver output
290 control and decision unit
295 control signal for local oscillator
296 control signal for selector unit
25

300 selective coherent polarization diversity receiver
310 received input signal
315 polarization beam splitter
316 polarized input signal
5 317 orthogonal polarized input signal
320 local oscillator
325 3 dB splitter
330 90° polarization shifter
331 90° shifted local oscillator light
10 332 local oscillator light
335,336 coupler/beam splitter
340.342 pair of photo diodes
341.343 electrical output signal
350,351 trans impedance amplifier
15 360,361 analog/digital converter
370,371 phase detector
372 phase information signal
373 electrical output signal of first branch
374 electrical output signal of second branch
20 380 signal selector switch
381 final receiver output
390 control and decision unit
395 control signal for local oscillator
396 control signal for selector unit
25

Claims:

1. A method for a coherent polarization diversity receiver, the coherent polarization diversity receiver (200) comprising a local oscillator (220) having a polarization and configured to generate a first and a second polarized local oscillator signal (231, 232), the method comprising:
 - splitting the polarization of the input signal (210) to generate a first polarized input signal (216) and a second polarized input signal (217),
 - mixing the first polarized input signal (216) with the first polarized local oscillator signal (231) via a coupler/splitter unit (235), generating a first electrical output signal (241) via a pair of photo diodes (240),
 - mixing the second polarized input signal (217) with the second polarized local oscillator signal (232) via a coupler/splitter unit (236), generating a second electrical output signal (243) via a further pair of photo diodes (242),
 - detecting the phase angle difference for the first polarized input signal and the first polarized local oscillator signal (270),
 - detecting the phase angle difference for the second polarized input signal and the second polarized local oscillator signal (271),
 - selecting a first portion of the first electrical output signal (273) and a second portion of the second electrical output signal (274) for further processing .
2. A method for a coherent polarization diversity receiver according to claim 1,
 - wherein the first portion of the first output signal (273) and the second portion of the second output

signal (274) is determined by a control and decision unit (290) .

3. A method for a coherent polarization diversity receiver according to claim 1 and 2,
5 - wherein the first portion of the first output signal (273) and the second portion of the second output signal (274) is combined by a signal selection and weighting unit (280) .
10
4. A method for a coherent polarization diversity receiver according to claim 3,
 - wherein the ratio of the first portion of the first output signal (273) and the ratio of the second
15 portion of the second output signal (274) can vary between 0 and 1.
5. A method for a coherent polarization diversity receiver according to claim 3,
20 - wherein the signal selection and weighting unit (280) either selects only the first portion of the first output signal (273) or the second portion of the second output signal (274) to create an output signal (281) .
25
6. A method for a coherent polarization diversity receiver according to claim 5,
 - wherein the signal selection and weighting unit (280) is a simple switch (380) .
30
7. A method for a coherent polarization diversity receiver according to claim 1 - 6,
 - wherein the polarization of the second input signal (217) is orthogonal to the polarization of the first
35 input signal (216) .

8. A method for a coherent polarization diversity receiver according to claim 1 to 6,
- wherein local oscillator signal (231) is polarization shifted by 90 degrees compared to the local oscillator signal (232).
9. A coherent polarization diversity receiver apparatus (200), the apparatus comprising a
- a local oscillator (220) having a polarization and configured to generate a first and a second polarized local oscillator signal (231, 232),
- a polarization unit for splitting the polarization of the input signal (210) into a first polarized input signal (216) and a second polarized input signal (217),
- a coupler/splitter unit (235) configured to mix the first polarized input signal (216) with the first polarized local oscillator signal (231) for feeding the signal light into a pair of photo diodes (240) to generate a first electrical output signal (241),
- a coupler/splitter unit (236) configured to mix the second polarized input signal (217) with the second polarized local oscillator signal (232) for feeding the signal light into a pair of photo diodes (242) to generate a second electrical output signal (243),
- a phase angle detection unit (270) configured to detect the phase angle difference between the first polarized input signal (216) and the first polarized local oscillator signal (231),
- a further phase angle detection unit (271) configured to detect the phase angle difference between the second polarized input signal (216) and the second polarized local oscillator signal (232),
- a selection and weighting unit (280) configured to select a first portion of the first electrical signal (273) and a second portion of the second

electrical signal (274) to combine an output signal (281) for further processing.

10. A coherent polarization diversity receiver apparatus
5 according to claim 9,
- wherein the ratio of the first portion of the first output signal (273) and the ratio of the second portion of the second output signal (274) is determined by a control and decision unit (280) .
- 10
11. A coherent polarization diversity receiver apparatus according to claim 9 or 10,
- wherein the control and decision unit (280) determines the ratio of the input signals (273) and
15 (274) based on the control signals received from the phase angle detection units (270), (271).

Fig. 1

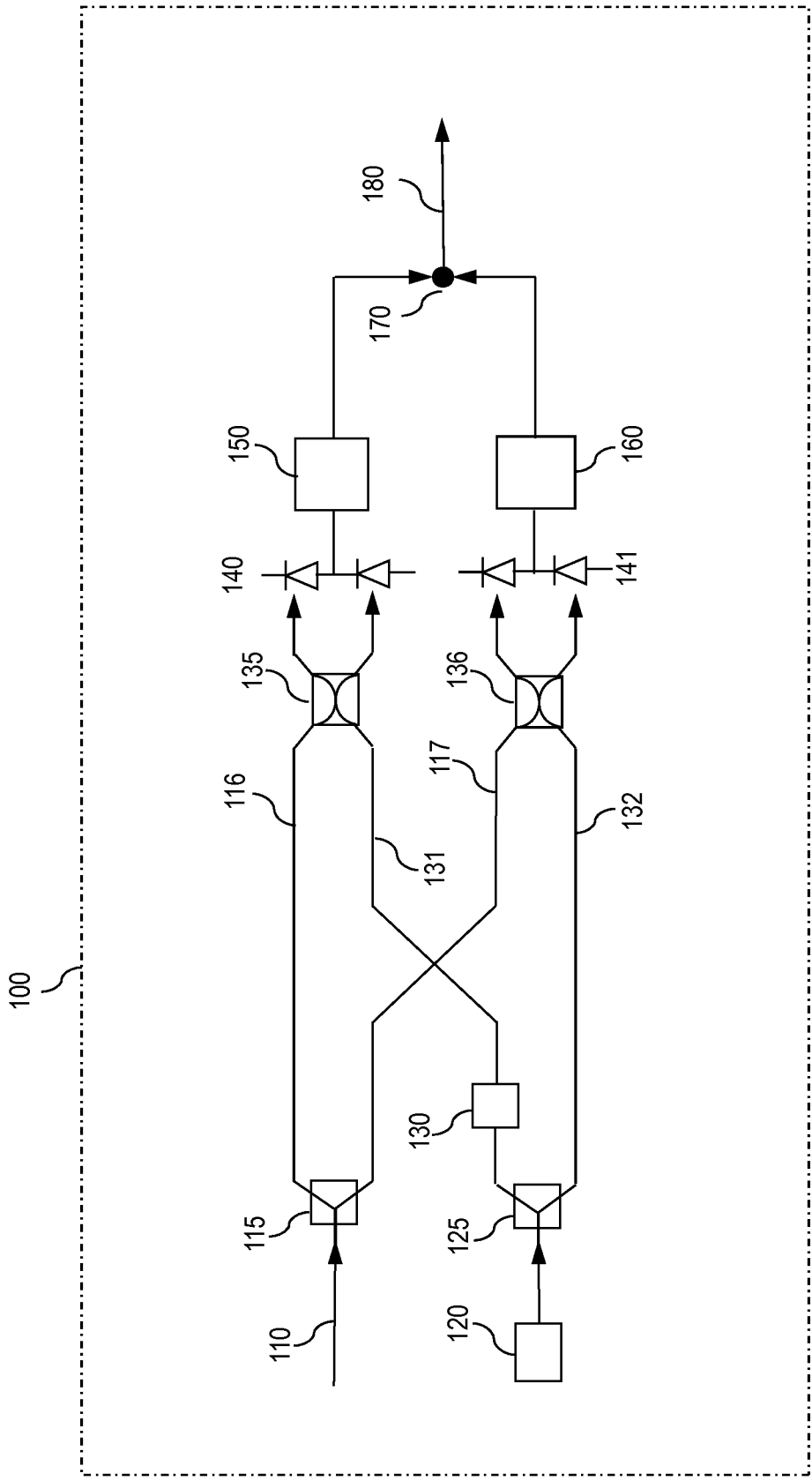


Fig. 2

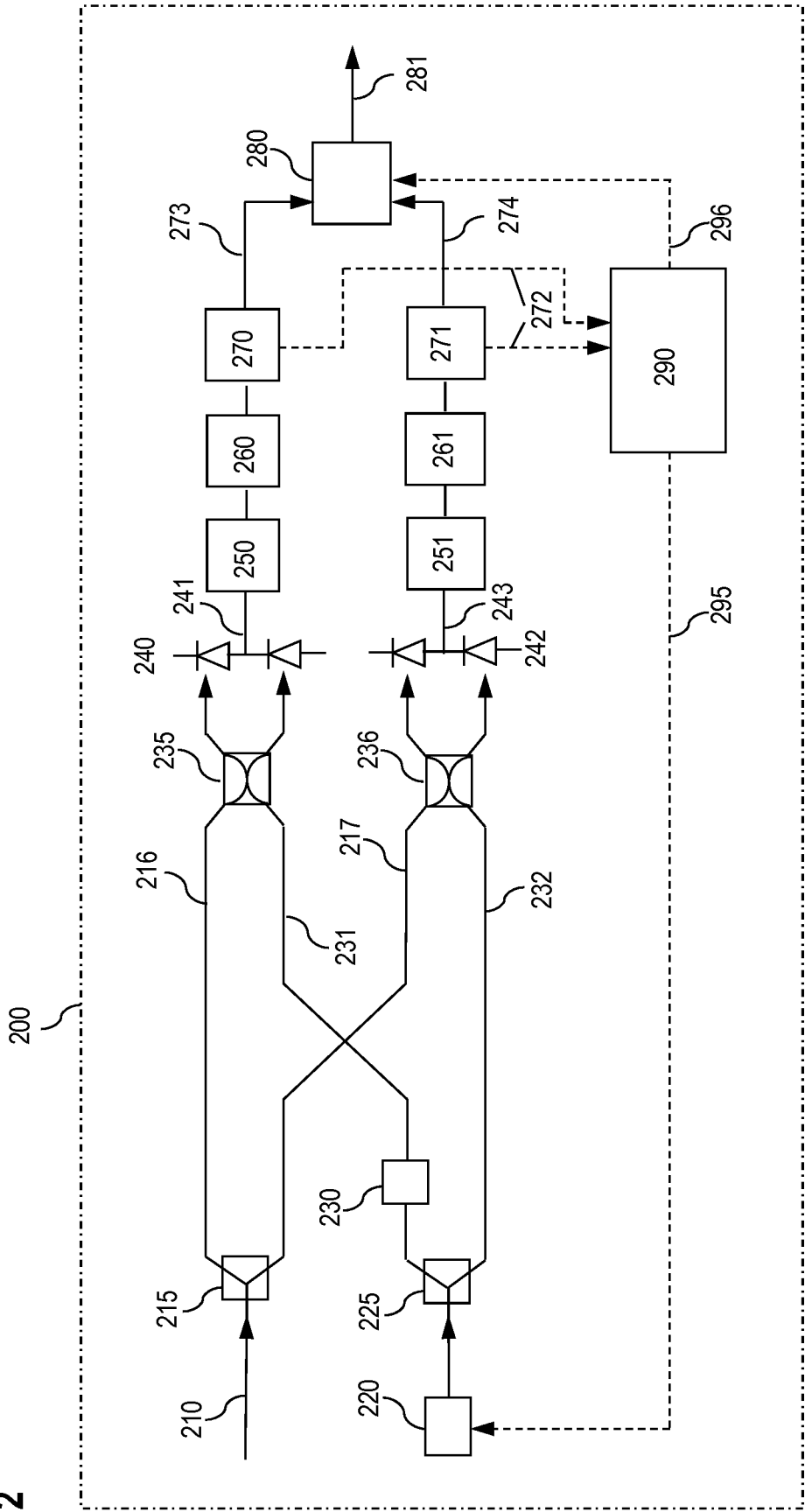
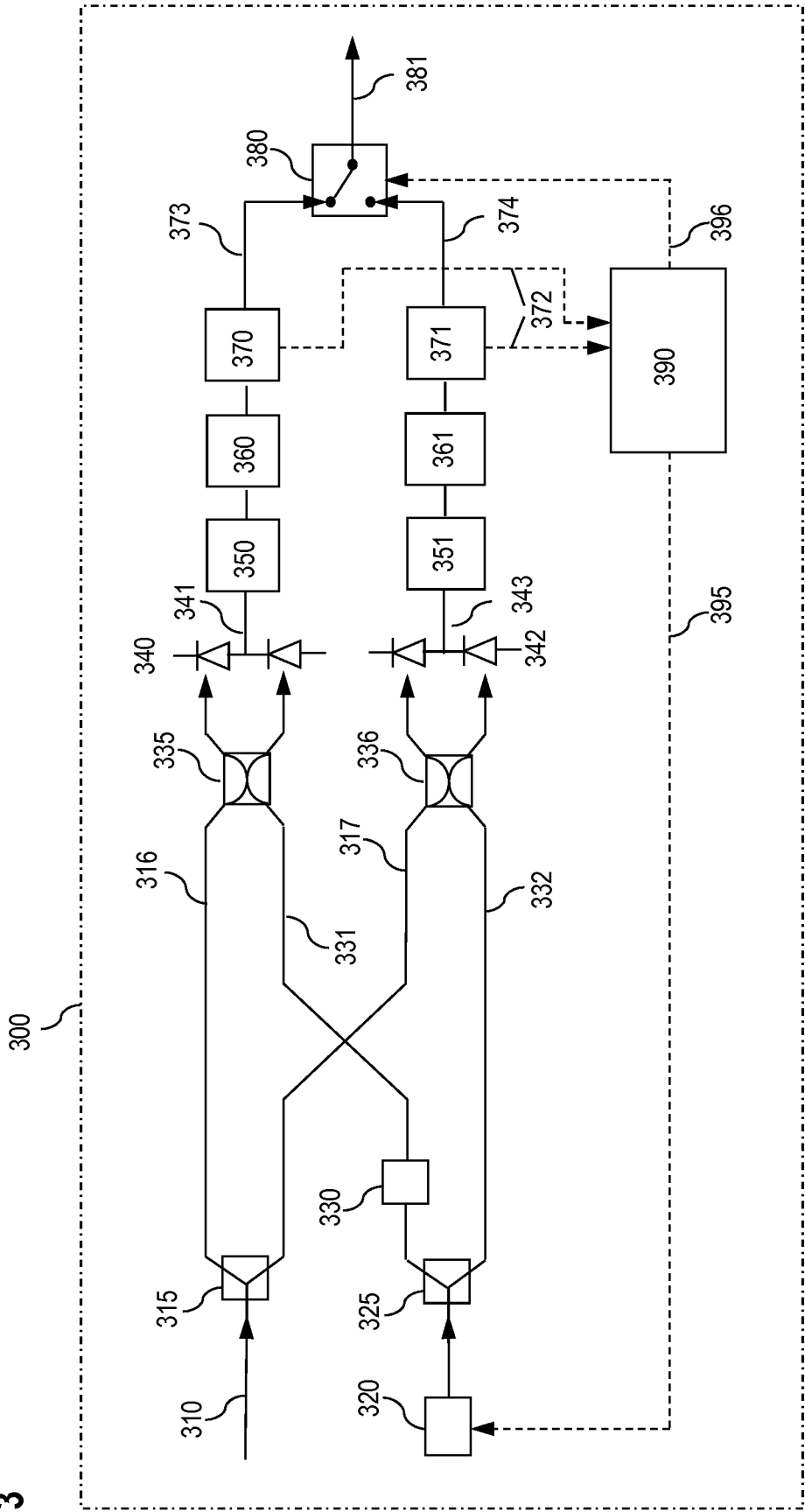


Fig. 3



INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2012/075439

A. CLASSIFICATION OF SUBJECT MATTER

INV. H04B10/64

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)

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 , INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 2 086 130 A1 (ALCATEL LUCENT [FR]) 5 August 2009 (2009-08-05)	1-10
A	paragraphs [0023] - [0025] paragraphs [0044] - [0061] figures 3, 4	11
X	US 2011/103529 A1 (KIM INW00NG [US] ET AL) 5 May 2011 (2011-05-05)	1-10
A	abstract paragraphs [0023] - [0025] paragraphs [0027] - [0028] pages 1B, 2	11
	----- -/- .	



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

29 January 2013

Date of mailing of the international search report

05/02/2013

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INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2012/075439

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 467 358 A2 (FUJITSU LTD [JP]) 22 January 1992 (1992-01-22) page 2, line 28 - page 3, line 12 page 8, line 53 - page 9, line 19 page 10, line 43 - page 11, line 18 figures 11, 17-19 -----	1-11
A	EP 0 390 069 A2 (NEC CORP [JP]) 3 October 1990 (1990-10-03) abstract figures 1-3 -----	1-11
A	EP 0 352 809 A2 (NEC CORP [JP]) 31 January 1990 (1990-01-31) the whole document -----	1-11
A	EP 0 329 186 A2 (FUJITSU LTD [JP]) 23 August 1989 (1989-08-23) abstract column 1, line 6 - column 3, line 2 figures 2, 4-7 -----	1-11

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2012/075439

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 2086130	AI	05-08-2009	CN 101499873 A 05-08-2009
			EP 2086130 AI 05-08-2009
			US 2009190926 AI 30-07-2009

US 2011103529	AI	05-05-2011	JP 2011103650 A 26-05-2011
			US 2011103529 AI 05-05-2011

EP 0467358	A2	22-01-1992	CA 2047284 AI 19-01-1992
			DE 69124301 DI 06-03-1997
			DE 69124301 T2 05-06-1997
			EP 0467358 A2 22-01-1992
			JP 2820511 B2 05-11-1998
			JP 4078251 A 12-03-1992
			US 5253097 A 12-10-1993

EP 0390069	A2	03-10-1990	DE 69024989 DI 07-03-1996
			DE 69024989 T2 30-05-1996
			EP 0390069 A2 03-10-1990
			JP 2254830 A 15-10-1990
			JP 7067093 B 19-07-1995
			US 5138476 A 11-08-1992

EP 0352809	A2	31-01- 1990	DE 68927969 DI 22-05-1997
			DE 68927969 T2 11-09-1997
			EP 0352809 A2 31-01-1990
			US 5023946 A 11-06-1991

EP 0329186	A2	23-08- 1989	DE 68927524 DI 23-01-1997
			DE 68927524 T2 30-04-1997
			EP 0329186 A2 23-08-1989
			JP 1211736 A 24-08-1989
			JP 6003512 B 12-01-1994
			US 4965858 A 23-10-1990
