FORM 1
REGULATION 9

COMMONWEALTH OF AUSTRALIA

PATENTS ACT 1952-1973

APPLICATION FOR A PATENT

631015

We STC PLC

of 1B Portland Place, LONDON WIN 3AA, ENGLAND

hereby apply for the grant of a Patent for an invention entitled:

DEPLOYING CABLES

which is described in the accompanying complete specification. This Application is a Convention Application and is based on the Application numbered: 8922643.5 for a Patent or similar protection made in Great Britain on 7 October 1989.

Our address for service is:

GRIFFITH HACK & CO
71 YORK STREET
SYDNEY NSW 2000

DATED this 4th day of October 1990

STC PLC
By their Patent Attorney

GRIFFITH HACK & CO

TO: THE COMMISSIONER OF PATENTS
COMMONWEALTH OF AUSTRALIA

S017634 04/10/90

6236A:rk

AUSTRALIA

PATENTS ACT 1952

B

APPLICATION
BY ASSIGNEE
OF INVENTOR

DECLARATION IN SUPPORT OF AN APPLICATION FOR A PATENT

NAME OF APPLICANT

In support of an application made by:

STC PLC of 1B Portland Place, London WIN 3AA

TITLE

for a patent for an invention entitled:

DEPLOYING CABLES

FULL NAME AND ADDRESS OF SIGNATORY

I, Mark charles Dennis

of STC Patents West Road Harlow Essex CM20 2SH

do solemnly and sincerely declare as follows:

1. I am authorised by the above mentioned applicant for the patent to make this declaration on its behalf.

FULL NAME AND ADDRESS OF INVENTOR(S)

2. The name and address of each actual inventor of the invention is as follows:

David Lancelot Walters of 18 Parsonage Lane Bishop's Stortford Herts

Martin Healy of 166 Jocelyns Harlow Essex

Ernest Charles Marlow of 20 Coney Gree Sawbridgeworth Herts

David Frederick Harrison of 1A Meadham ~~Churchgate~~ Street Old Harlow Essex

SEE NOTES OVER

3. The facts upon which the applicant is entitled to make this application are as follows:

The Applicant is the Assignee of the Actual Inventors

DELETE PARAGRAPHS 3 AND 4 FOR NON-CONVENTION APPLICATION

4. The basic application(s) as defined by Section 141 of the Act was (were) made as follows:

Country Great Britain on 7th October 1989

in the name(s) STC PLC

and in on

in the name(s)

PLACE AND DATE OF SIGNING

5. The basic application(s) referred to in the preceding paragraph was (were) the first application(s) made in a Convention country in respect of the invention the subject of this application.

Declared at Harlow Essex England

this 1st day of October 1989

Signed

Position Manager Patents-Fundamental Applications and Their Attorney

GRIFFITH HACK & CO

PATENT AND TRADE MARK ATTORNEYS

MELBOURNE · SYDNEY · PERTH

(12) PATENT ABRIDGMENT (11) Document No. AU-B-63793/90
(19) AUSTRALIAN PATENT OFFICE (10) Acceptance No. 631015

(54) Title
DEPLOYING CABLES

International Patent Classification(s)
(51)[5] G02B 006/00 G01B 011/16

(21) Application No. : 63793/90 (22) Application Date : 04.10.90

(30) Priority Data

(31) Number (32) Date (33) Country
8922643 07.10.89 GB UNITED KINGDOM

(43) Publication Date : 11.04.91

(44) Publication Date of Accepted Application : 12.11.92

(71) Applicant(s)
STC PLC

(72) Inventor(s)
DAVID LANCELOT WALTERS; MARTIN HEALY; ERNEST CHARLES MARLOW; DAVID FREDERICK HARRISON

(74) Attorney or Agent
GRIFFITH HACK & CO. , GPO Box 4164, SYDNEY NSW 2001

(56) Prior Art Documents
AU 616779 37435/89 G02B 6/00
AU 614556 25966/88 G02B 6/00
EP 253635

(57) Claim

1. A method of deploying an optical fibre cable by pulling the cable from a store of cable, comprising monitoring the strain in the cable by monitoring an optical signal in a fibre of the cable and controlling the deployment according to the strain monitored, and wherein the cable is pulled from the store by friction between the cable and a flowing fluid.

8. Apparatus for measuring cable strain during deployment from a storage drum, the cable being drawn from the storage drum by friction between the cable and a flowing fluid, the apparatus comprising means for feeding an optical signal into the cable via a rotary optical joint, means for detecting a received signal from the cable via a reflective end termination at the end of the cable, means for determining the strain in the cable being deployed, and means for changing the deployment speed in response to the detected strain.

COMMONWEALTH OF AUSTRALIA 631015

PATENTS ACT 1952 Form 10

COMPLETE SPECIFICATION

FOR OFFICE USE

Short Title:

Int. Cl:

Application Number:
Lodged:

Complete Specification-Lodged:
Accepted:
Lapsed:
Published:

Priority:

Related Art:

TO BE COMPLETED BY APPLICANT

Name of Applicant:	STC PLC
Address of Applicant:	1B Portland Place, LONDON WIN 3AA, ENGLAND
Actual Inventor:	David Lancelot Walters; Martin Healy; Ernest Charles Marlow and David Frederick Harrison
Address for Service:	GRIFFITH HACK & CO 71 YORK STREET SYDNEY NSW 2000

Complete Specification for the invention entitled:

DEPLOYING CABLES

The following statement is a full description of this invention, including the best method of performing it known to us:-

18075-GX:CLC:RK

6236A:rk

D.L. Walters - E.C. Marlow - D.F. Harrison
- M. Healy 3-2-1-1

DEPLOYING CABLES.

This invention relates to deploying cables, particularly although not exclusively, to laying cables in ducts using a fluid to transport or help transport the cable through the duct.

Our granted British patent 2171218B discloses a method of deploying a communications cable in a pipeline by inserting one end of the cable into the pipeline and causing liquid flowing through the pipeline to pull the cable in the direction of liquid flow. Usually a drogue is attached to the front of the cable, and this acts not only as a drag-inducing device against the flow of liquid to pull the cable, but also to guide the front end of the cable along the duct.

In some instances it is necessary to use this technique to lay a pull-line and then attach the pull-line to the cable and pull the cable through the duct using the pull line together with the assistance given by liquid flowing through the duct and the buoyancy of the liquid. In this instance the pull line acts in place of the drogue, and is useful in situations where a high pulling force is required.

Where a cable is deployed by such a technique over long distances, then larger forces can be exerted on the cable, and careful control is necessary so that the speed of deployment of the cable being laid can be adjusted in accordance with the flow conditions and route i.e. whether it is a smooth unobstructed route or a more tortuous route with obstructions on the way. If careful control is not employed or if flow is interrupted, then damage can result to the cable being deployed. Deployment may include recovery of the cable. It is an object of the present invention to enable greater control over the cable deployment to be achieved.

According to the present invention there is provided a method of deploying an optical fibre cable by pulling the cable from a store of cable comprising monitoring the strain in the cable by monitoring an optical signal in a fibre of the cable and controlling the deployment according to the strain monitored, and wherein the cable is pulled from the store by friction between the cable and a flowing fluid.

According to another aspect of the invention there is provided an apparatus for measuring cable strain during deployment from a storage drum, the cable being drawn from the storage drum by friction between the cable and a flowing fluid, the apparatus comprising means for feeding an optical signal into the cable via a rotary optical joint, means for detecting a received signal from the cable via a reflective end termination at the end of the cable, means for determining the strain in the cable being deployed, and means for changing the deployment speed in response to the detected strain.

Conveniently, a light source such as a laser is modulated with an rf signal, and the phase change of the modulated signal is measured after traversing the measured fibre within the cable. Changes in this phase change can then be related directly to optical length changes, and absolute optical length can be measured from the gradient of the phase/frequency characteristic. This enables the "global" fibre strain to be determined.

In order that the invention can be clearly understood reference will now be made to the accompanying drawings in which:-

Fig. 1 is a block schematic diagram of an optical cable laying system according to an embodiment of the present invention and;

Fig. 2 shows a detail of the arrangement of Fig. 1.

Referring to Fig. 1 of the drawings, it is proposed to lay a cable 1 in a duct 2 through which a liquid such as water is flowing in the direction of arrow A from right to left as viewed in the Figure. The technique employed in deploying the cable is similar to that disclosed in our patent 217128B mentioned above.

As the cable is deployed from a drum 3 via a side entrance tube 2A and suitable seal 2B to prevent water leakage out of tube 2A, the length of cable entering the duct is measured by a mechanical length counter 4.

At the remote end of the cable 1 there is a silvered and terminated end arrangement 5 so that a signal passed down a fibre of the cable 1 will be reflected back along the cable.

A drogue or pull line is normally attached to the front of the cable, and this assists the liquid in installing the cable.

This optical transmission is made possible by an optical rotary joint 6 attached to the cable drum 3.

One form of joint is shown in Fig 2. The joint 6 (Fig 2) comprises a stator 20 which has a flange 21 secured by screws 22 to one cheek 3A of the drum 3. The inner end 1A of the cable 1 on the drum 3 is optically connected to the stator 20 and a rotor 23 of the joint is optically connected to the connecting cable 13.

Fig. 1 also shows a block diagram of the measurement arrangement. A low power 1300 nm laser with a single mode fibre tail 7 is modulated with a radio frequency signal wave from a frequency synthesiser 8, and a vector volt meter 9 measures the phase difference between the signal applied to the laser 7 and the signal received at the output of a PINFET detector 10 which detects the returned optical signal along the cable 1 by means of the silvered and terminated end arrangement 5. A single mode optical Y coupler 11 couples the output signal from the laser 7 to the fibre of the cable 1 via connecting cable 13 and the rotary joint 6, and also couples the output signal from the cable 1 which has been returned by the silvered and terminated arrangement 5, to the receiver 10.

Changes in the phase change can be related directly to optical length changes caused by stress in the laying procedure, or absolute optical length can be measured from the gradient of the phase/frequency characteristic. This enables the global fibre strain to be determined. As shown in the drawing, the equipment is controlled by a small computer 12 with appropriate software to process the results and display the relevant information digitally or graphically as required.

The silvered and terminated end arrangement is protected from the liquid in which the cable is immersed by a termination arrangement 5A. The optical Y-coupler 11 is coupled via an optical cable 13 to the optical rotary joint 6, and there is a plug and socket arrangement 15 so that the test equipment can be plugged into and unplugged from the cable drum.

The mechanical length counter 4 provides a pulse per unit length which is fed to a pulse counter 14 which feeds the controlling computer 12.

Measurement Method.

For an rf signal with modulation frequency f, the phase change ϕ across a length of fibre with effective refractive index N, is:

$$\phi = 360 \ell Nf/C \qquad (C = 3 \times 10^8 \text{ ms}^{-1})$$

The length can therefore be found from the gradient of the phase/frequency characteristic, assuming the refractive index. Since the refractive index itself varies with temperature and strain, it is useful to define the concept of optical length i.e. N - an assumed refractive index (1.453). In order to obtain this optical length with 10 ppm resolution a phase change of at least 5×10^4 degrees must be observed. As with any phase-measuring instrument, the vector velometer measures a phase difference between -180° and $+180^\circ$, any multiples of 360° being ignored. To allow for this, the modulation frequency is varied by a small amount at first, and then by increasingly larger amounts, obtaining at each stage a more accurate figure for the optical length, while ensuring that at no time is the frequency change sufficiently large to "miss" a 360° phase shift. Once the operator has aligned the system optically, the measurement sequence is completely automatic. Total measurement time is about two minutes, and at the end of the measurement sequence the controller pronts the optical length, together with the estimate of its standard error calculated from a least squares fit.

To measure the strain i.e. it is not necessary to know the exact refractive index, but merely how it varies with temperature and strain.

It can be shown that:

$$\Delta \ell = \frac{\Delta L - \ell \Delta T\ (6\alpha + \beta)}{6}$$

where $\Delta \ell$ = change in physical length, ΔL = change in optical length, L = optical length, ℓ = datum physical length, T = temperature change, α = physical length temperature coefficient, β = refractive index temperature coefficient, $6 = 1 + \frac{\ell \partial N}{N \partial \ell}$

The refractive index strain coefficient $\ell / N.\ \partial N / \partial \ell$ can be measured for a particular fibre by measuring fibre extension under load v phase change. This parameter is linear up to at least 2% strain, and has been found in practice to vary very little from fibre to fibre.

If it is required to measure length change while monitoring at a constant frequency as is normally the case during cable installation, the same equipment can be used with different software. In this case the length change $\Delta \ell$ which produces a phase change $\Delta \phi$ at constant frequency is

$$\Delta = \ell \quad \frac{\Delta \phi c}{720f\ N6}$$

Thus there has been described a method of continuously measuring the strain in an optical cable during installation by fluid friction into a duct using a computer-controlled frequency-domain optical strain measuring apparatus and coupling via a single-mode rotary optical joint. By monitoring the strain the rate of deployment can be optimised, and the apparatus indicates immediately if the cable or installation system develops a fault. A likely practical situation is for the flow to die or change without warning. This will be detected by the strain equipment and corrective action, eg halting installation, can be taken. Without this facility both cable and duct may be damaged.

This equipment can measure lengths up to 30 kilometres of single mode fibre cable.

The connection between the cable 13, the fibres of the cable 1 and the optical rotary joint 6 can be made via elastomeric or fusion splices.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A method of deploying an optical fibre cable by pulling the cable from a store of cable, comprising monitoring the strain in the cable by monitoring an optical signal in a fibre of the cable and controlling the deployment according to the strain monitored, and wherein the cable is pulled from the store by friction between the cable and a flowing fluid.

2. A method as claimed in claim 1 wherein a drogue is attached to the front of the cable.

3. A method as claimed in any preceding claim, comprising providing a reflecting end termination at the front end of the cable being deployed, and sending an optical signal along the fibre of the cable via an optical rotary joint coupled to a supply drum of the store, and monitoring the returned signal.

4. A method as claimed in claim 3 wherein the optical signals are radio frequency signals modulated on a light carrier, and wherein the phase difference between transmitted and received optical signals is used to determine the strain in the cable.

5. A method as claimed in claim 3 or claim 4, wherein the transmitted and received signals are radio frequency signals which are fed into a vector voltmeter to determine the phase difference.

6. A method as claimed in any preceding claim comprising measuring the length of cable being deployed by means of a pulse counter to determine the overall strain in the cable.

7. A method of deploying a cable substantially as hereinbefore described with reference to and as illustrated in the accompanying drawing.

8. Apparatus for measuring cable strain during deployment from a storage drum, the cable being drawn from the storage drum by friction between the cable and a flowing fluid, the apparatus comprising means for feeding an optical signal into the cable via a rotary optical joint, means for detecting a received signal from the cable via a reflective end termination at the end of the cable, means for determining the strain in the cable being deployed, and means for changing the deployment speed in response to the detected strain.

9. Apparatus as claimed in claim 8, comprising a rotary optical joint for coupling to the cable drum from which the cable is to be deployed and an optical Y coupler for coupling to a fibre of the cable via the rotary joint, whereby both transmitted and received signals can travel along the same fibre, and a vector voltmeter for determining the phase difference between the transmitted and received signals to thus determine strain in the cable.

10. Apparatus for deploying a cable substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

11. A cable deployed by a method or apparatus according to any preceding claim.

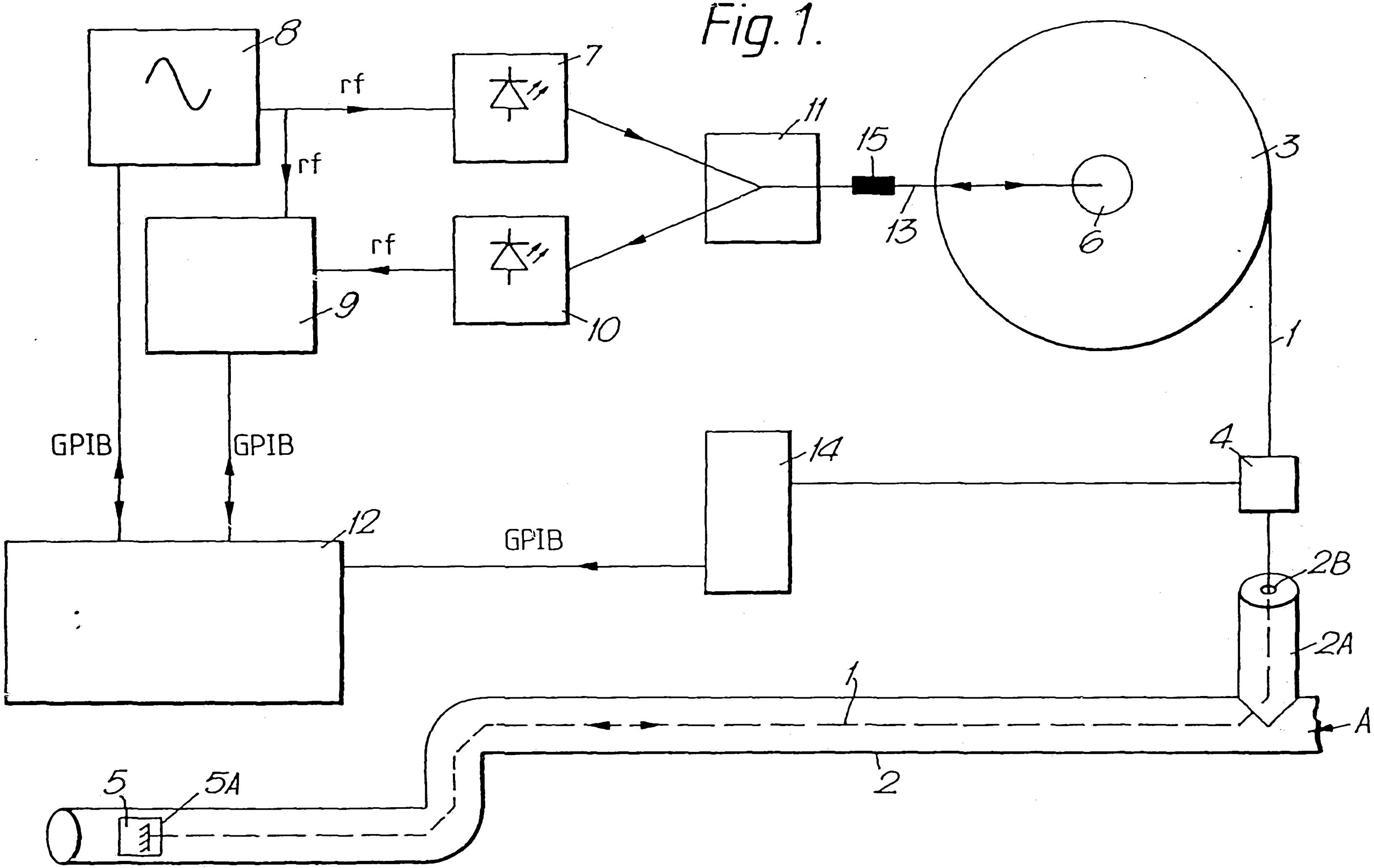
12. A cable as claimed in claim 11, having been deployed in a duct full of flowing liquid.

Dated this 11th day of September 1992

STC PLC
By their Patent Attorney
GRIFFITH HACK & CO.

4 10 90 63793

Fig. 1.



63793/90

63793/90

Fig. 2.