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PULSAR COMMUNICATION SYSTEMS

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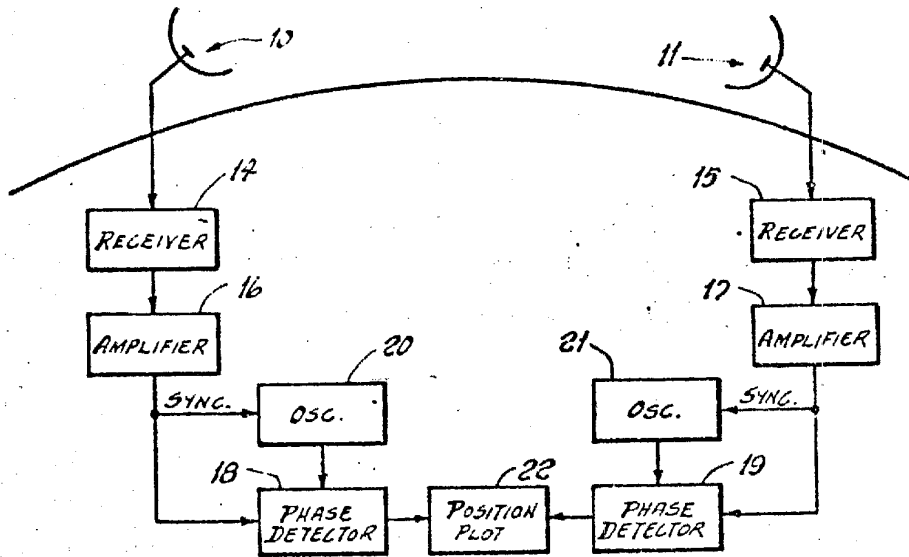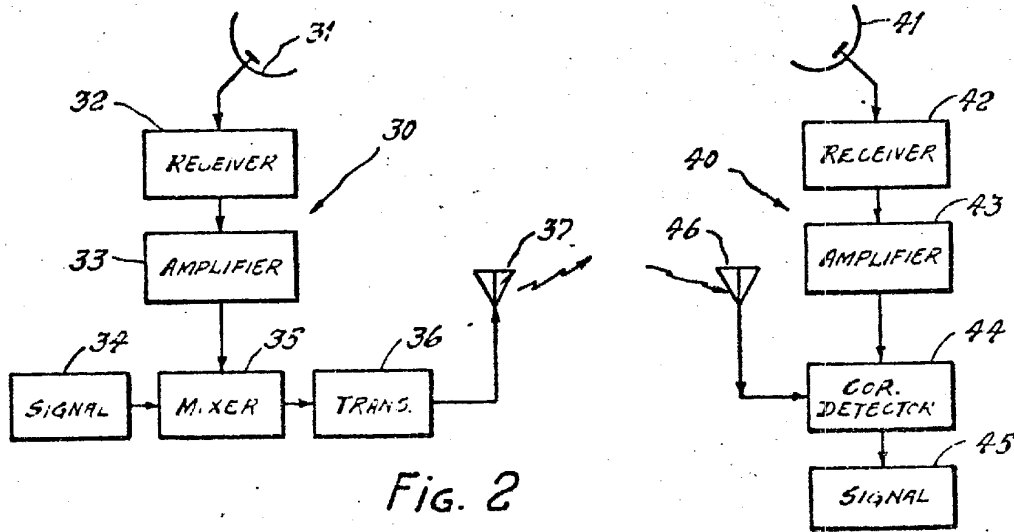

Fig. 1

Fig. 2

INVENTORS.
ARNOLD A. SHOSTAK
RONALD R. TROUTMAN

United States Patent Office

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ABSTRACT OF THE DISCLOSURE

There are disclosed arrangements which utilize the
signal energy from pulsars to accomplish, for example, the
synchronous operation of widely spaced electronic com-
ponents or the secure transmission of signal information.

The invention described herein may be manufactured
and used by or for the Government of the United States
of America for governmental purposes without the pay-
ment of any royalties thereon or therefor.

The present invention relates generally to electronic
control arrangements and, more particularly, to appara-
tus for and methods of synchronizing electronic devices,
such as, receiving antennas, which are located at two or
more widely separated, geographical locations.

There are a wide variety of electronic control systems,
such as time display, pulse navigation, long base-line in-
terferometers, and radar countermeasure circuits, which
require synchronizing signals for their proper operation.
In the Loran navigation system, for example, the various
transmitters of the network must radiate their identifying
pulse trains at extremely precise times during their opera-
tional cycles. Any deviation in the time of transmission
introduces an appreciable error in the system. One way
of accomplishing this synchronization is by an ultra-stable
master oscillator which must be brought to each location.
This transportation, of course, is expensive and oftentimes
impractical. Also, since the local timing standard of the
system is subject to continuous drift, this comparison must
be made periodically. The same synchronization problem
is also present in the operation of large base-line micro-
wave interferometers where the receivers are located at
widely spaced geographical locations.

Pulsating radio sources, or so-called "pulsars," have
recently been observed both in the UHF and S-bands of
the spectrum. The signals from these pulsars have ex-
tremely regular repetition periods. For example, pulsar
C.P. 1919 has a period of 1.3373008 secs.; that of C. P.
0834, 1.2737620; and that of C.P. 1133, 1.87911019; all
plus or minus 3×10^{-7}

Since these pulsars are remote electromagnetic energy
sources, they may be simultaneously observed at widely
spaced receiving stations equipped with suitable antennas.
These antennas may be programmed to track a particular
pulsar or shift from one pulsar to another to insure the
continuous availability of a suitable signal from these ex-
traterrestrial sources.

It is accordingly a primary object of the present inven-
tion to provide a method for accomplishing synchronous
operation of electronic devices which makes use of the
radiation emanating from pulsars.

Another object of the present invention is to provide
a method of synchronizing electronic circuits which utilizes
electromagnetic signal information originating from one
or more extraterrestrial radio sources.

A still further object of the present invention is to pro-
vide an arrangement for maintaining phase coherence be-
tween elements of an antenna interferometer, thus per-

mitting detection and precision tracking of remote radiat-
ing sources such as satellites.

Other objects, advantages and novel features of the
invention will become apparent from the following de-
tailed description of the invention when considered in
conjunction with the accompanying drawings wherein:

FIG. 1 schematically illustrates one arrangement for
utilizing pulsar signals in an antenna interferometer hav-
ing a large base line; and

FIG. 2 illustrates a communication system where the
pulsar signal is utilized to achieve secure communication
between a pair of stations.

Referring now to FIG. 1 of the drawings, a pair of
steerable antennas 1 and 2 of a long base-line microwave
interferometer are oriented at one time during their opera-
tion to receive electromagnetic signals originating from a
predetermined remote pulsar. This pulsar may be C.P.
1919, for example, whose period is 1.3373008 secs.

The signals simultaneously detected by these antennas
are coupled to receivers 14 and 15 at the two sites, and
the outputs of these receivers are suitably amplified in
appropriate circuits 16 and 17. These amplifiers are ar-
ranged to control local free-running oscillators 20 and 21
whose instantaneous phase is precisely regulated thereby.
Any drift, for example, in the oscillator signals at each
site is recognized by an appropriate detecting system, and
the magnitude and direction of the resulting error signal
is used to return the oscillator back to its proper condition.
Circuits and techniques for achieving this control are well
known in the art.

It will be appreciated that the pulses appearing in the
outputs of amplifiers 16 and 17 at each site, without fur-
ther signal processing, may be used as synchronizing
signals for any appropriate purpose. In this respect, the
period of these pulses is, of course, invariably fixed by
the characteristics of the particular pulsar 12 then under
observation. If desired, these pulses may be fed to multi-
plying circuits to increase or decrease their repetition
rate. If such a conversion is desired or utilized, the new
repetition rate of these pulses will, of course, be as stable
as the pulsar from which they are originally derived. This
stability may be in the order of one part 10^7.

After oscillators 20 and 21 have been synchronized by
the pulsar, the antennas can then move off this source and
track any other extraterrestrial radiating source such as
satellite 13 to determine its precise location. In this case,
antennas 10 and 11 serve as part of a microwave inter-
ferometer, and their output signals, after reception and
amplification, pass to suitable phase detectors which have
as their other input signals from the now stabilized local
oscillators 20 and 21. Each phase difference so deter-
mined may be sent or otherwise processed at 22 to obtain
a position plot.

Since each pulsar can be observed throughout a
hemisphere of the earth surface because of their remote-
ness, calibration signals may be generated according to
the system of FIG. 1 at any number of points within
this area. The antennas may be shipborne, airborne or
ground-base.

The arrangement of FIG. 1 can provide a time stand-
ard from the pulsar source which may be simultaneously
observed at widely different geographical locations. The
signal available at the various amplifiers may be fed
to pulse counters to obtain the clock pulses. Each pulse
counter, in effect, would multiply the pulse rate of the
pulsar by a known period to produce the desired clock
pulses.

The availability of the pulsar signal and its stability
make it particularly useful in security communications
systems. Each pulse may be used as a means for masking
or coding the message signal.

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In FIG. 2 a transmitting station 30 equipped with a tracking antenna 31 for observing a particular pulsar utilizes the signal so detected as one input to a mixer 35 which has as its other input a message signal 34. The output from mixer 35 modulates or otherwise controls transmitter 36 which radiates the encoded signal via a suitable antenna 37 towards a remote receiving station 40. This station, too, has a tracking antenna 41 which is simultaneously observing the same pulsar. The pulsar signal available at the output of the amplifier 43 at this station is fed to a correlation detector 44 which has as its other input the encoded signal picked up by receiving antenna 46.

If the pulsar signal received at station 30 is $f_1(t)$ and the message signal is $S(t)$, the signal received by antenna 46 will be $S(t)+f_1(t)$. This signal is correlated with $f_2(t)$, the pulsar signal detected by antenna 41 at station 40. The results of this operation is

$$(S+f_1)*f_2=S*f_2+f_1*f_2 \qquad 20$$

where the asterisk represents correlation. If the autocorrelation of the pulsar signal is substracted off or if the statistics of $S(t)$ are made such that the cross-correlation term is much larger than the autocorrelation term, only the first term $S*f_2$ is left. Since f_2 is available and known at the receiving site, any conventional signal processing can be used to extract the message signal $S(t)$ therefrom.

If the wave form characteristics of the pulsar change slightly, there is no degradation of the system since $f_1(t)$ and $f_2(t)$ are changed simultaneously and in a similar manner. It would be pointed out that the slight delay brought about by the finite transmission time between stations 30 and 40 may be readily compensated for by adding an appropriate signal delay means any-

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where between tracking antenna 41 and the correlation detector 44.

What is claimed is:

1. A communication system for achieving secure signal transmission between a pair of locations, comprising:
   means at said locations for simultaneously receiving signals from a particular pulsar;
   means at one of said locations for encoding an information signal with said pulsar signals and for transmitting the encoded signal;
   means at the other of said locations for receiving said encoded signal; and
   means for processing said encoded signal with said pulsar signals to reproduce said information signal.

2. In a method for achieving secure signal transmission between a first and second location, the steps of:
   coding an information signal available at said first location with particular pulsar signals from a preselected pulsar;
   transmitting said encoded signal to said second location;
   receiving said encoded signal at said second location; and
   decoding the received signal by utilizing the same particular pulsar signals from said preselected pulsar.

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RODNEY D. BENNETT, Primary Examiner
R. E. BERGER, Assistant Examiner

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