Locating and distance measurement by high frequency radio waves

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Abstract – A new system for distance measurement has been developed which is suitable for location and rescue purposes, as well as for indoor-location applications. The system achieves a high range at low cost and is very robust. Prototype tests have already been run under realistic conditions in pilot projects in the field of the location of avalanche victims and searches for missing persons.

Keywords – distance measurement, indoor location, stepped frequency radar

I. Introduction

For many professional groups – such as the fire brigade, police and mountain-rescue teams - it is of utmost importance to be able to locate individual team members while in action. Other such situations of interest would be the search for people in natural disasters, such as earth quakes. In the search for persons, the factor ‘time’ usually is of highest criticality.

A technology has been developed in the high frequency area which is applicable in different fields. A special application is locating for rescue purposes. The technology transmits on a frequency of 2.4 GHz and includes prototypes of a locating device and various transmitter prototypes.

In the winter season 2010/2011 some pilot projects for the application “locating of avalanche victims” and “locating of missing people” started. First the concentration is on the equipment of professional rescuers and military groups which are in the alpine terrain most of the time. Other applications are in logistics, industry manufacturing or areas like eHealth and indoor location.

The directional analysis of the signals is based on determining the angles, by which the signal reaches the receiver.

The system has included a distance measurement equipment. For the distance calculation between the locating device and low cost transmitter a "standing wave" is built up on several discrete frequencies and the phases of the returning ("standing") waves are measured. With the measured phaseshifts depending on the change in the frequency the distance is calculated (in analogy to a stepped frequency radar [1]).

II. Components of the Locating System

The locating device can be held easily in the hand. It is approx. 1.2 kg in weight. The power supply is via rechargeable batteries, which are located in a folding handle. Intuitive use is possible with the help of simple colour displays.

Figure 1: Locating device and transmitter

There are various transmitter prototypes. They differ in their transmitting power and size (see Figure 2 and 3). The smallest transmitter has roughly the format of a matchbox and the flattest one is comparable with a credit card. Bigger ones are around the size of a cigarette packet. The transmitters do not have any control elements and are permanently switched on. They only transmit a signal if they are contacted by a locating device. The compact design of the transmitters means they can easily be taken with you or integrated in other products – for example a ski ticket or SCBA equipment. A special transmitter is deployed for indoor locating purposes. It has an air pressure sensor, an identbutton and needs three AA batteries. A motion sensor is installed in all transmitters, so that you can distinguish which transmitter is still moving (e.g. rescuer) and which is not (e.g. buried person).

Figure 2: Various transmitters

III. Basic Principle of Distance Measurement

In the following, individual phase measurements are provided on different discrete frequencies, one after the other. The individual phase measurements then constitute the basis for calculating the distance by means of mathematical methods.

Each individual measurement sets up a ‘standing wave’ between station S1 and the low-cost transponder T1, see figure 4.

The method filed for patent protection achieves the same result (see functional equivalent, figure 3) as if:

1. the unmodulated carrier of station S1 were transmitted to transponder T1,
2. there were an active (amplified) reflection in T1 and
3. the reflected signal were mixed with the emitted signal in station S1 and measured as a complex I/Q value.

The phase as measured (I/Q) is then constant (in a constant frequency and an unmoved system).

The phase as measured (I/Q), however, changes upon variation of the frequency (wave length) directly proportionately to the distance (ideal case without multipathing).

Example

Supposing, (at c=300,000km/s), the following 10 frequencies are used:
2401.0 Hz, 2402.0 MHz … 2410.0 MHz.

Wave lengths:
F0 = 0.124948 m, F1 = 0.124896 m …

Distance to be determined:
10m, the way and the way back together 20m.

For F0 (20m / 0.124948) = 160.067 waves (measured I/Q phase = 0.067 = 24°) is obtained

For F1 (20m / 0.124896) = 160.133 waves (measured I/Q phase = 0.133 = 48° is obtained
Etc.

Thus (in an ideal case), per 1 MHz change in frequency, a phase shift between the measurements of ca. 24° respectively can be observed. Twice the distance leads to a double phase shift.

So much concerning the ideal case without multipathing - with multipathing everything becomes much more complex.
However, methods such as Fourier analysis and high resolution methods are applicable, because (except small restrictions) this is a linear system.

Advantages as against Pulse Methods

- Narrow-band measurements are performed on the individual frequencies, such that a good interference resistance against other users of the frequency band (for ex. WLAN) and a high range can be achieved.
- Applicable also in ranges of for ex. 868MHz or 915 MHz, where only small frequency bands can be used.
- A complex accurate time measurement or synchronization between the different sites is not necessary.
- The transponders can provide a very simple and therefore cost-efficient structure.
- In an unmoved system and with a constant orientation (polarization) of the antennas, an accuracy in the millimetre range can be achieved.

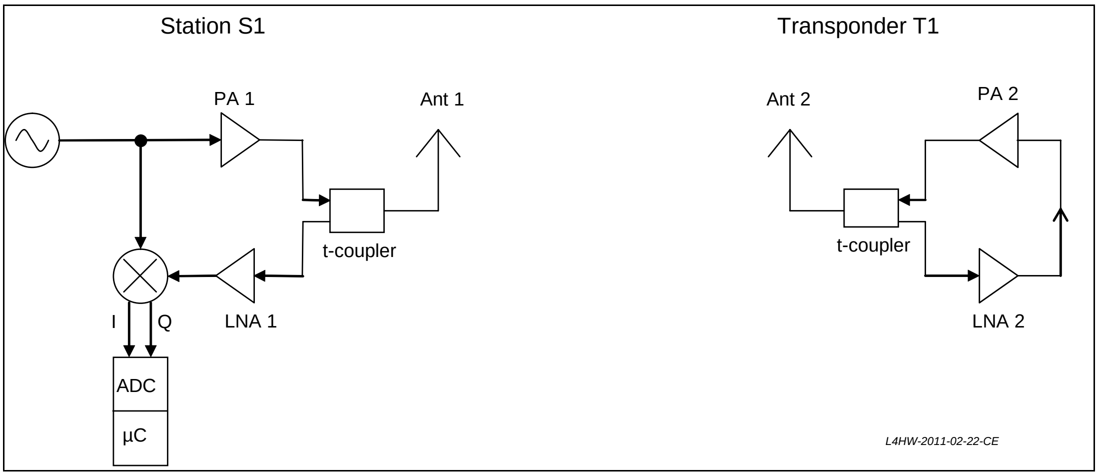
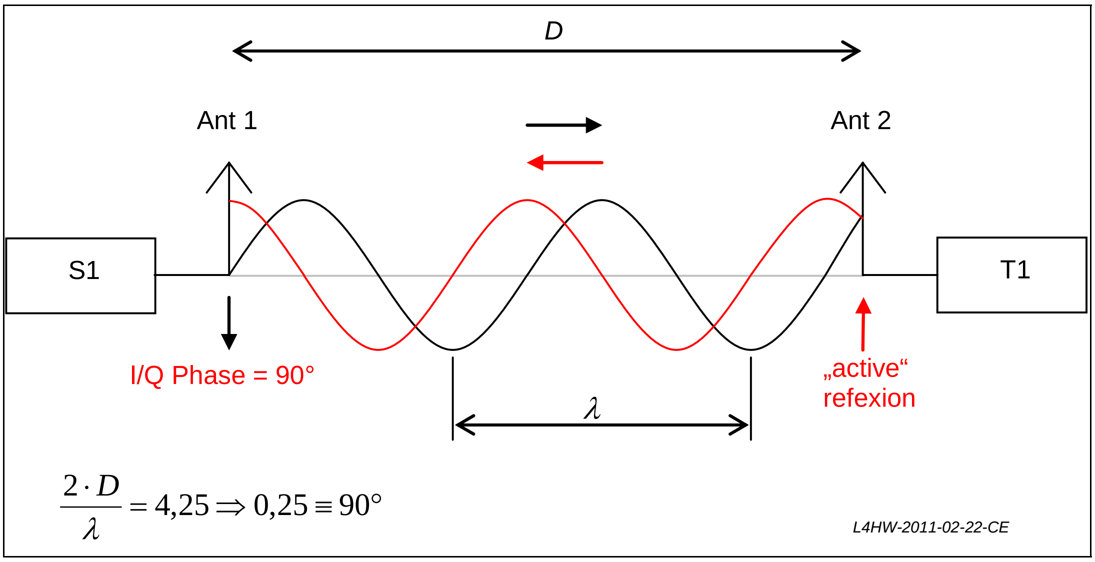


Figure 3: Functional equivalent consisting of station S1 and transponder T1



$$\frac{2 \cdot D}{\lambda} = 4{,}25 \Rightarrow 0{,}25 \equiv 90^\circ$$

Figure 4: “Standing wave” between station S1 and transponder T1

Concept Indoor Positioning System

A system can be designed which operates similarly to the GPS principle.

Several stations (satellites) emit narrow-band signal sequences which can be used by many low-cost receivers at the same time in order to calculate their own position.

The receivers are very small, low-cost and energy saving.

The receiver can, similarly to GPS receivers, simply be integrated into existing mobile devices (for ex. cell phones).

Performance Distance Measurement in today's prototype "Smilla2b".

Frequency band 2.4 GHz, 0.5 watt transmitting power.

Reach with existing LOS ca. 2-5km.

Accuracy ca. 1-5m, passing through walls, < 1m with existing LOS.

IV. Conclusion and Outlook

To begin with, the location system which has been developed and the possible fields of application were presented. A system for direction analysis as well as for distance measurement was integrated in the location device. The distance-measurement method, including the installation of a standing wave, and the measurement of phase shifts was presented. The low-cost location system can be used without further infrastructural measures and achieves high ranges and altogether is considered as being very robust.

A next step could be the integration of the system into existing infrastructure-based systems.

Reference

[1] K. Iizuka, A.P. Freundorder, K.H. Wu, H. Mori, H. Ogura, and V.-K. Nguyen, „Step-frequency radar", Journal of Applied Physics, vol. 56, no.9, pp. 2572-2583, 1984