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Some ideas for short range radiopositioning free running animals

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1. Introduction

The solution of several problems in biology often require to measure position vs. time of free running animals inside an assigned region.

Numerous and different methods have been proposed and experimented for this purpose; taking into account only techniques based on radio systems the most commonly used are:

- techniques using a radio-transmitter attached to the animal and suitable receiving systems;
- radar techniques where moving animal is a passive reflecting target;
- more cumbersome satellite based systems when very wide regions are to be monitored.

Here reference will be made to the case where distances ranging from few kilometers to almost about few tens of kilometers are to be measured and the possibility of signal generation and processing on board of the animal itself is very limited.

2. Hyperbolic radio-positioning system

Let's assume that the animal carries only a transmitter T which radiates RF pulses T(t) in a free running mode (see fig. 1).

$$\frac{x^2}{a_{12}^2} - \frac{y^2}{b_{12}^2} = 1$$

$$\frac{x'^2}{a_{13}^2} - \frac{y'^2}{b_{13}^2} = 1 \qquad (3)$$

where

$$a_{12} = \frac{c|\tau_{12}|}{2}$$

$$a_{13} = \frac{c|\tau_{13}|}{2}$$

$$b_{12} = \sqrt{c_{12}^2 - a_{12}^2} \qquad (4)$$

$$b_{13} = \sqrt{c_{13}^2 - a_{13}^2}$$

with

$$c_{12} = \frac{d_{12}}{2}$$

$$c_{13} = \frac{d_{13}}{2} \qquad (5)$$

focal distance of the two hyperbolas and (x,y), (x',y') cartesian references with the origins at points 0 and 0' put at the mid point between R_1 and R_2/T_2, R_1 and R_3/T_3 respectively.

In fig. 4 an hyperbola family for a distance d between focuses = 3 km is reported.

2a) Preliminary calibration procedure

The use of eqs. (2) require a preliminary calibration procedure to obtain τ_0, d_{12} and d_{13}.

From eqs. (2), taking into account eq. (1), we have:

$$Tm_{12} = \frac{d_2 - d_1}{c} + \tau_0 + \frac{d_{12}}{c} \qquad (6)$$

An approximate estimation of the height h of T can be obtained by the following use of the successive approximation method.

On the basis of τ_{12} and τ_{13} the position of T is derived by using the previously explained method (2-D solution), then distance d_4 is calculated and finally, by measuring τ_{14}, the heigth h is obtained from the third equation of (8); it is

$$h - h_4 = \pm \sqrt{2 d_1 d_4} \sqrt{1 - \frac{c\,\tau_{14}}{d_1 - d_4}} \tag{9}$$

The ambiguity of eq. 9 can be, generally, eliminated by further available informations.

3. Elliptical radio-positioning system [1]

Let's refer to fig. 6, where T, R_1 and R_2 are ground located transmitter and receivers, while R/T is a transponder system carried by the animal.

All the involved transmitting and receiving systems have non directional characteristics and the same working frequency f_o.

More particularly, the transmitted signal is a radio frequency pulse of duration τ, carrier frequency f_o and repetition period T_o; a same shape signal is retransmitted by the trasponder R/T with a time delay τ_o with respect to the receiving time.

With reference to the other symbols of fig. 6, the signals received at R_1 and R_2 can be represented as shown in fig. 7, where r_1, r_1^* and r_2, r_2^* are the signals received directly from T and through the transponder R/T, respectively.

The time delay D_1 between r_1 and r_1^* is

$$D_1 = \tau_1 + \tau_2 + \tau_o - \overline{\tau}_1 = \tau_o + \frac{d_1 + d_2 - \overline{d}_1}{c} \tag{10}$$

and the time delay D_2 between r_2 and r_2^* is

$$D_2 = \tau_1 + \tau_3 + \tau_o - \overline{\tau}_2 = \tau_o + \frac{d_1 + d_3 - \overline{d}_2}{c} \tag{11}$$

$$D_2''' = \frac{\overline{d_1} + \overline{d_2}}{c} + \tau_0 - \frac{\overline{d_{12}}}{c} \qquad (18)$$

By using eqs (15), (16), (17),(18) the values of τ_0, d_1, d_2,d_{12} can be calculated.

As an example, in fig. 8 two families of ellipses are reported for the case $TR_1 = TR_2 = 30$ km, $\tau_0 = 1\mu s$.

It is to note that this method require to measure time intervals $D_1(D_2)$ between signals received at the same location $R_1(R_2)$ so that a radio link between receiving stations R_1 and R_2 is not strictly necessary.

Time intervals D_1 and D_2 can be measured, suitably stored and successively processed for obtaining position of animal vs. time.

References

1. M. Bramanti "A system for the positioning of moving objects", Electronic Engineering, 63, n. 2, 1990, pp. 27-29.

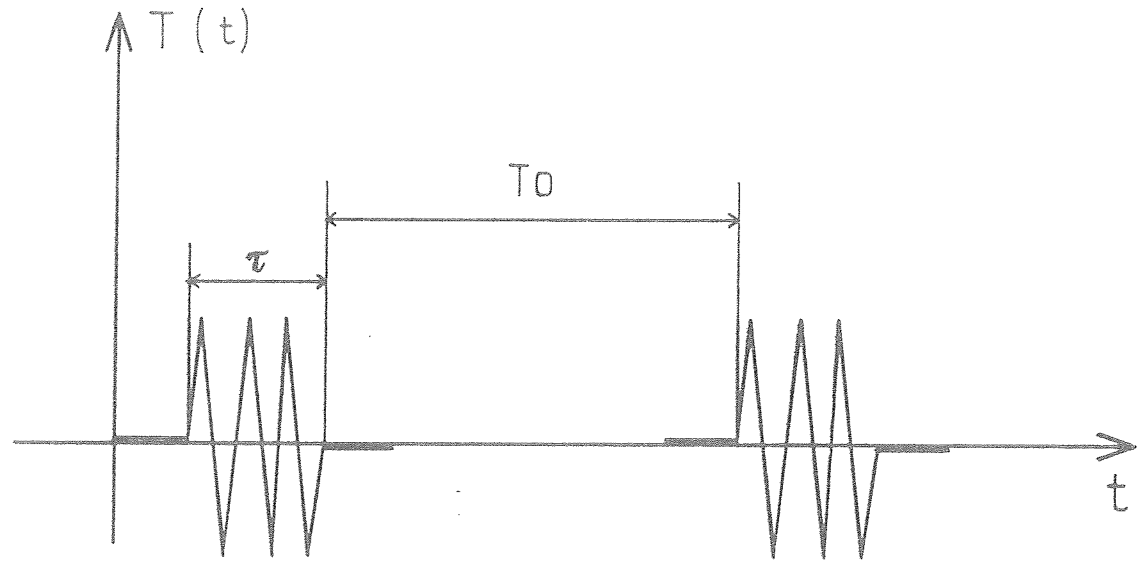
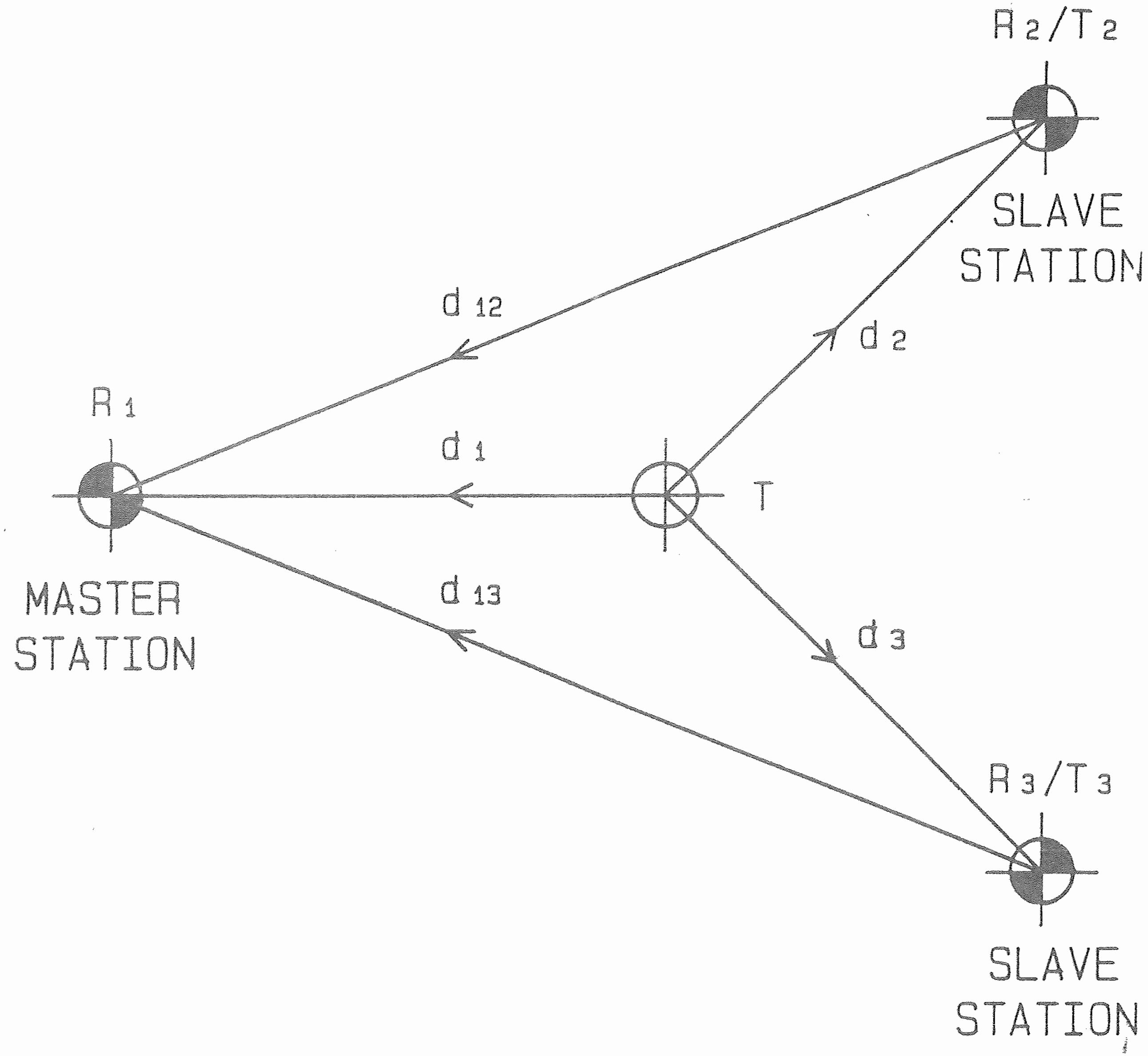


Fig.1



R 2/T 2
SLAVE STATION
d 12
d 2
R 1
d 1
T
MASTER STATION
d 13
d 3
R 3/T 3
SLAVE STATION

Fig: 2

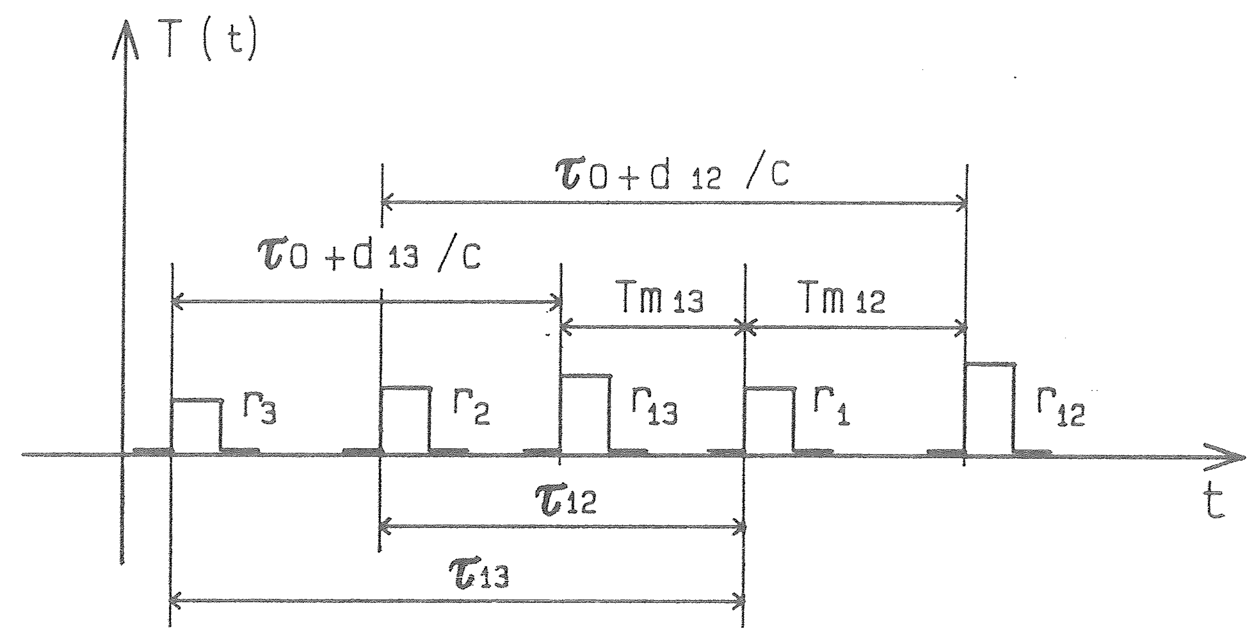


Fig.3

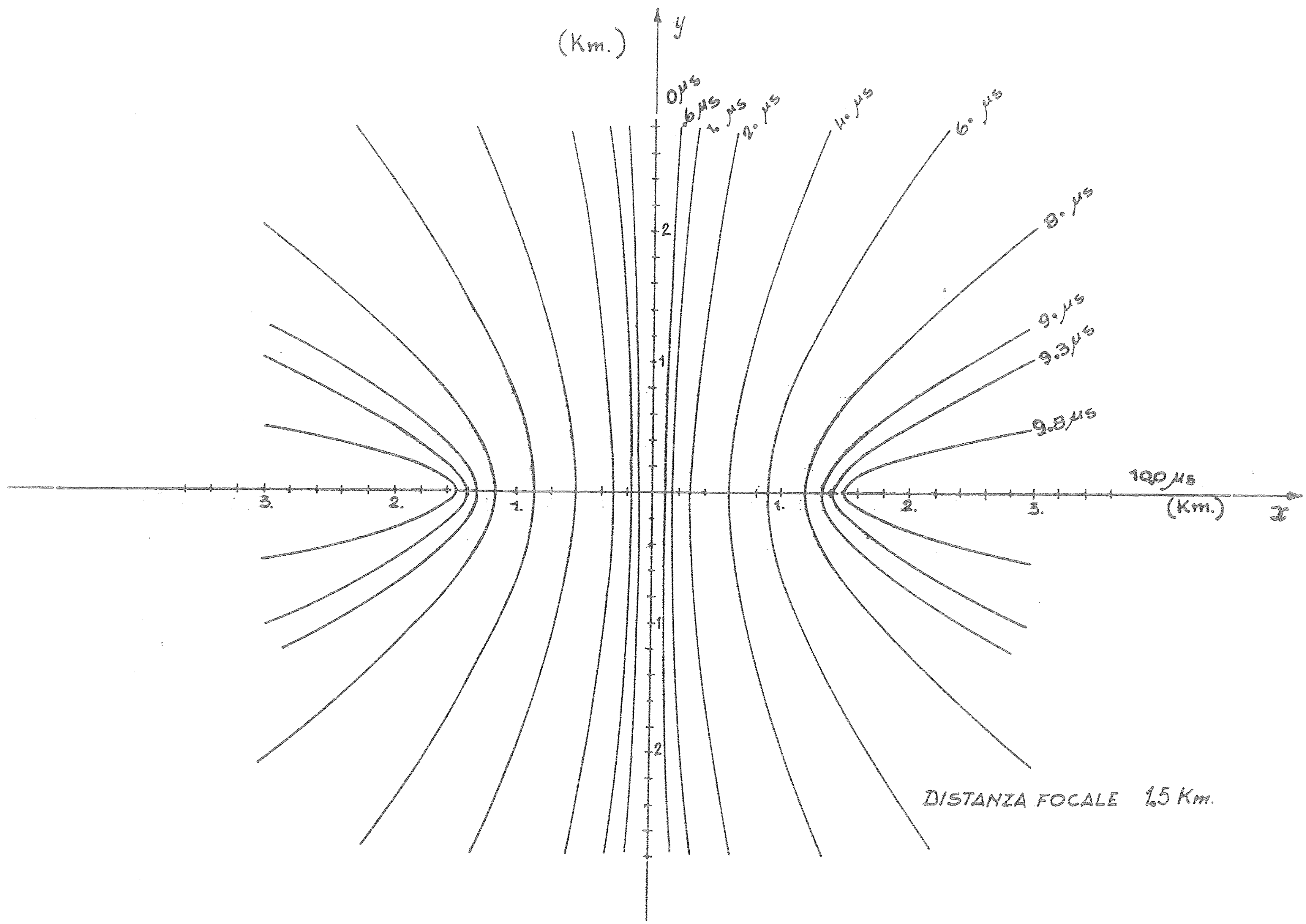

(Km.)
y
0µs
.6µs
2. µs
6. µs
8. µs
9. µs
9.3µs
9.8µs
(Km.)
x
DISTANZA FOCALE 1,5 Km.

Fig. 4

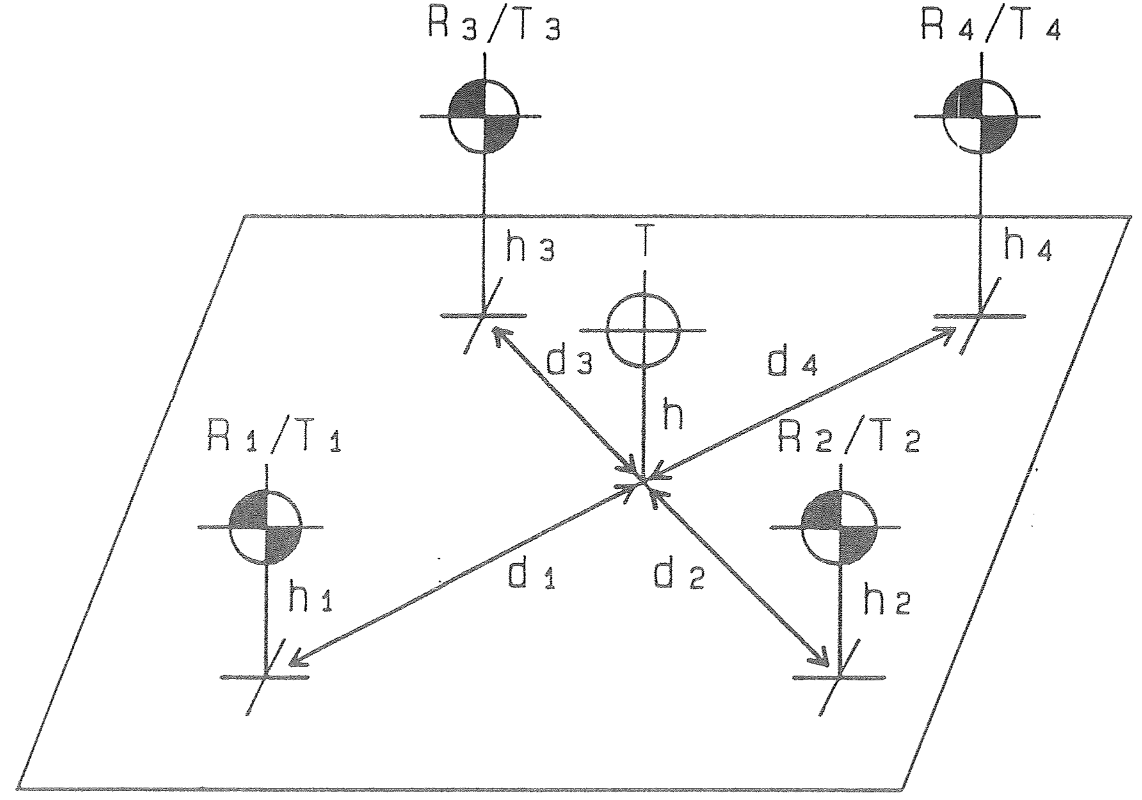


Fig. 5

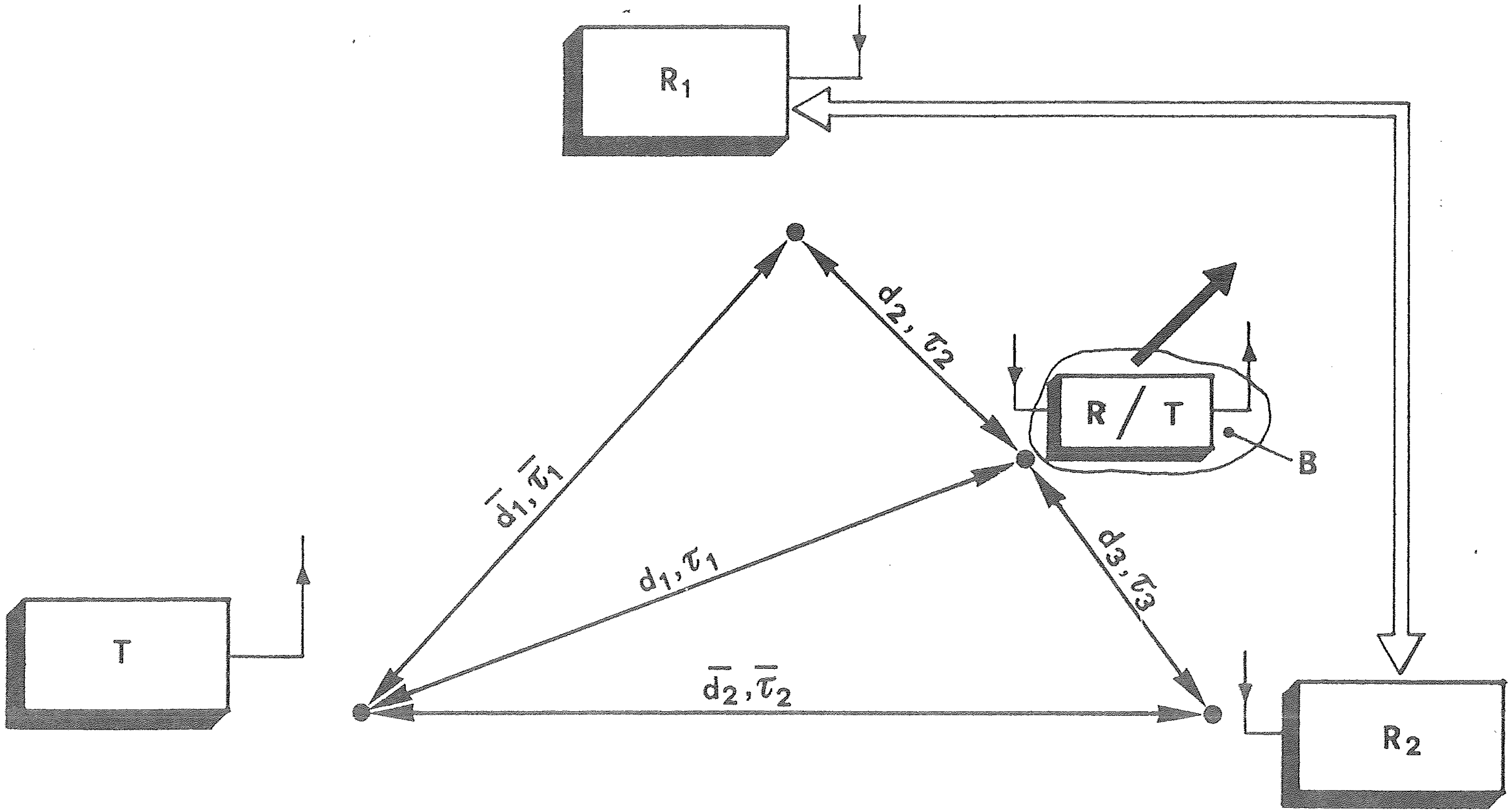


Fig. 6

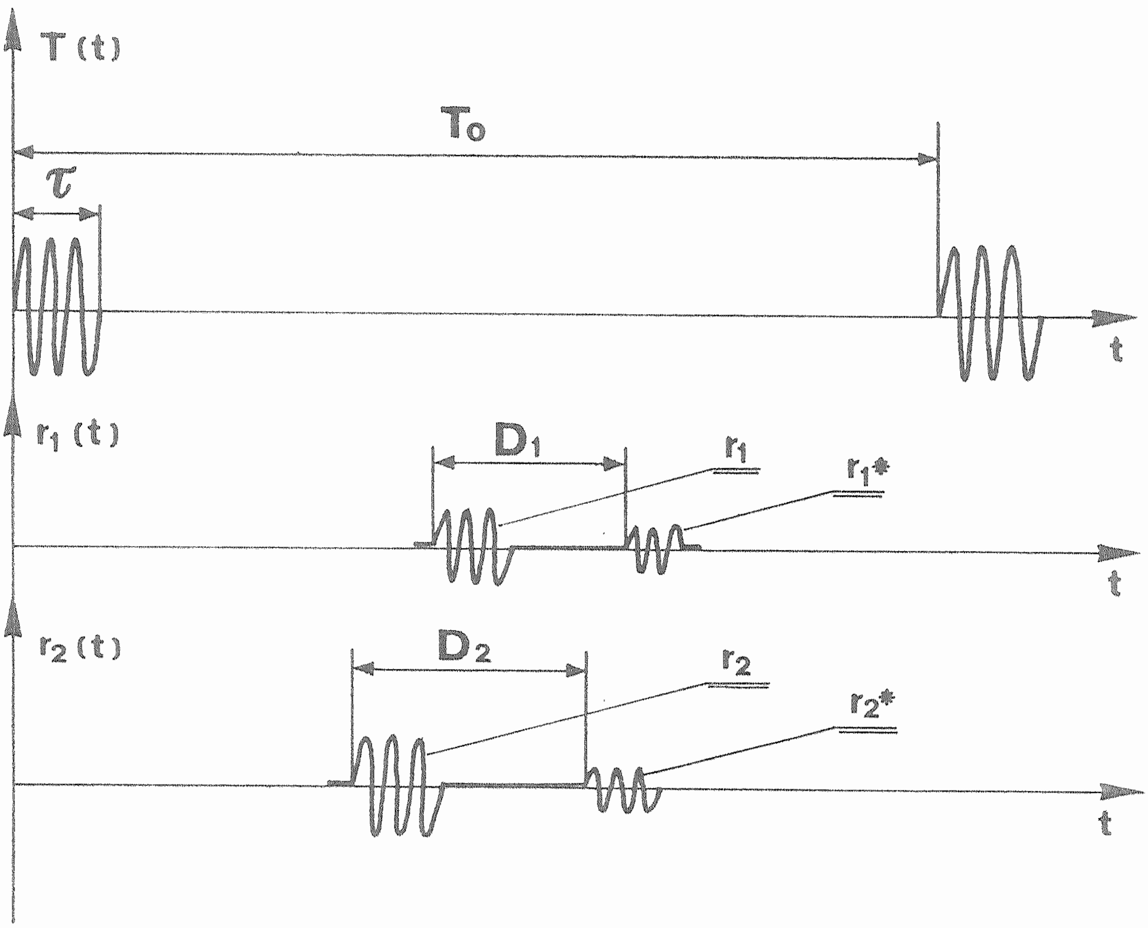


Fig. 7

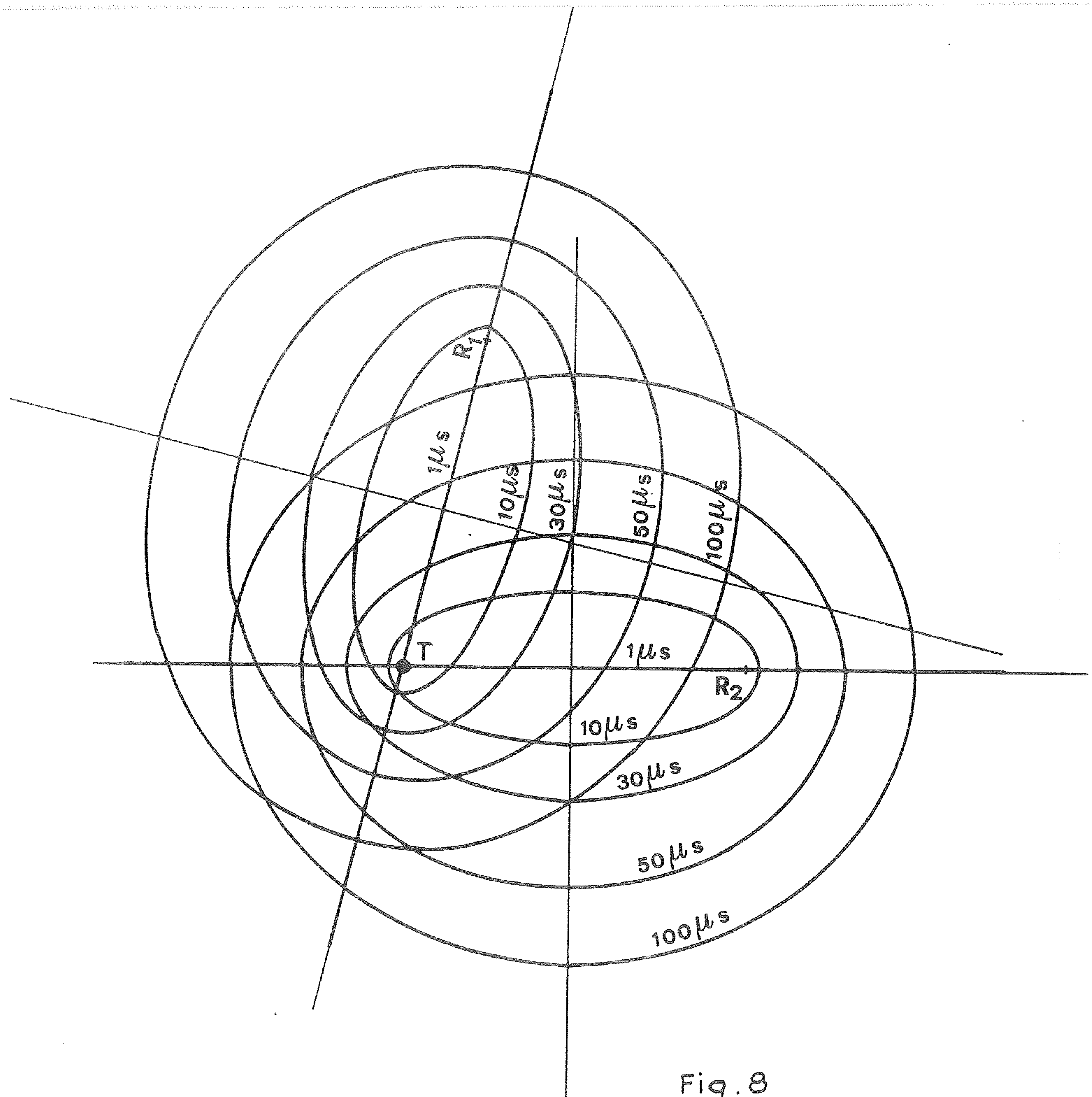


Fig. 8