Self-Steering Systems for Tractors and Other Cultivation Machinery

Lutz Kohler
Institute for Engineering in Horticulture, Fachhochschule Weihenstephan, Bavaria, Germany

INTRODUCTION

Most field-grown horticultural crops are planted in rows. Cultivation is necessary both between the rows and in the rows for weed control. On large nurseries cultivation is mechanised to a greater or lesser extent to keep labour costs as low as possible but in most cases cultivation relies on human input to steer the cultivation machinery. Existing mechanical aids to steering use feelers. The feeler often uses the crop plants themselves to provide a fixed reference point for the rows. Such feelers can only be used if the crop plants are robust as damage to stems may occur. However, feelers are used in fruit and vegetable production and also in hardy nursery stock production. Feeler-based systems are costly to purchase because they are produced in relatively low numbers. They also bear high maintenance costs. Steering guidance using satellite global positioning systems (GPS) (Fig. 1) is a more sophisticated option for the future. However, the level of accuracy is at present only to the nearest metre, and therefore not exact enough for horticultural cultivation.

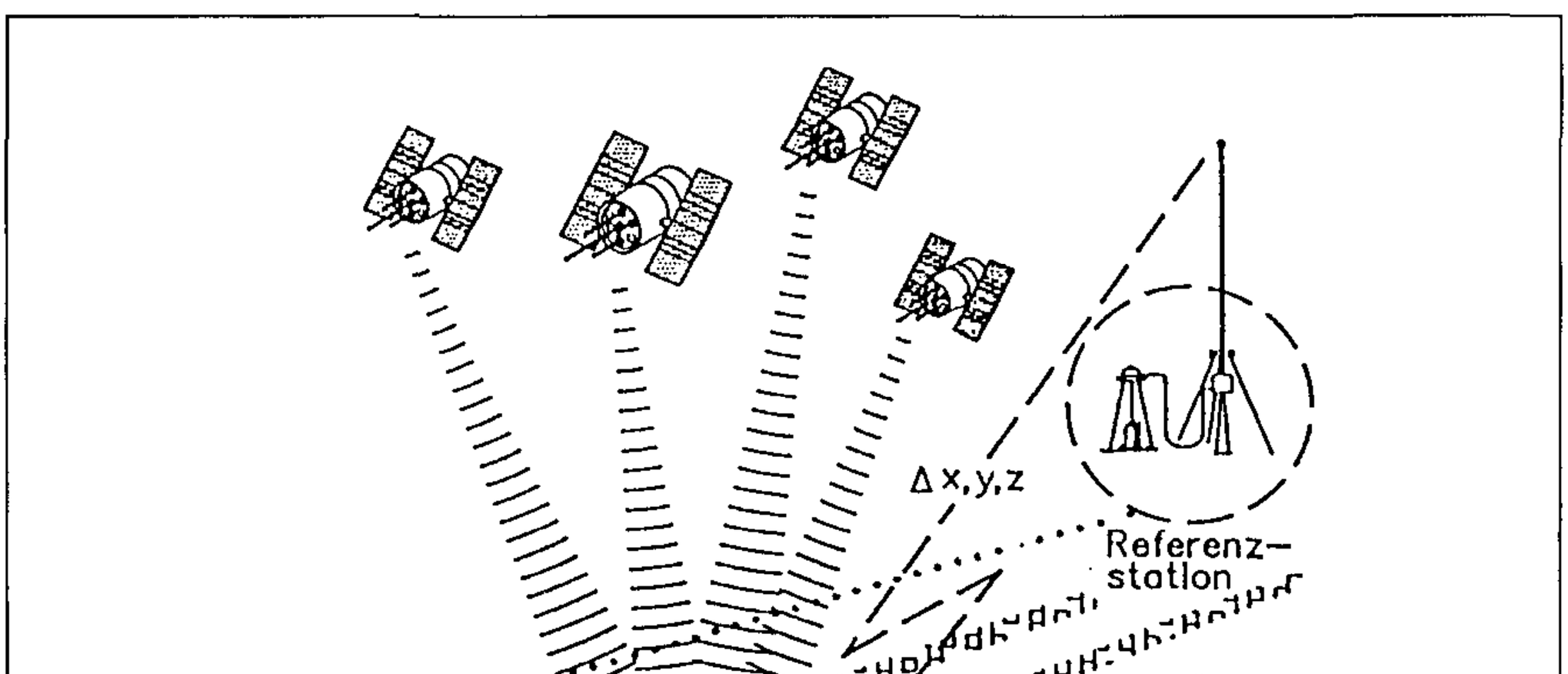

Figure 1. Steering with satellites.

DEVELOPING AUTOMATIC STEERING SYSTEMS

Other special measuring systems and radar equipment are being investigated. These systems use one or more fixed points in the field for navigation. These can operate effectively with a maximum distance of 1500 m between the fixed reference point and the cultivator. The accuracy is higher than with GPS but the working speed is very slow. Fully automatic guidance must be able to undertake the following processes:

1) The identification of the plants or detection of rows or other guide lines.
2) Output of a steering signal.
3) Reception and conversion of the signal by the electronic steering.

Signalling Systems. Mechanical vibrations and electromagnetic waves are identical in the rate of transmission and reflection. The direction of these waves and their reflection is the basis for steering system signalling mechanisms. Mechanical vibrations and electromagnetic waves will be referred to simply as "waves". Wave transmission between transmitter and receiver is demonstrated in Fig. 2.

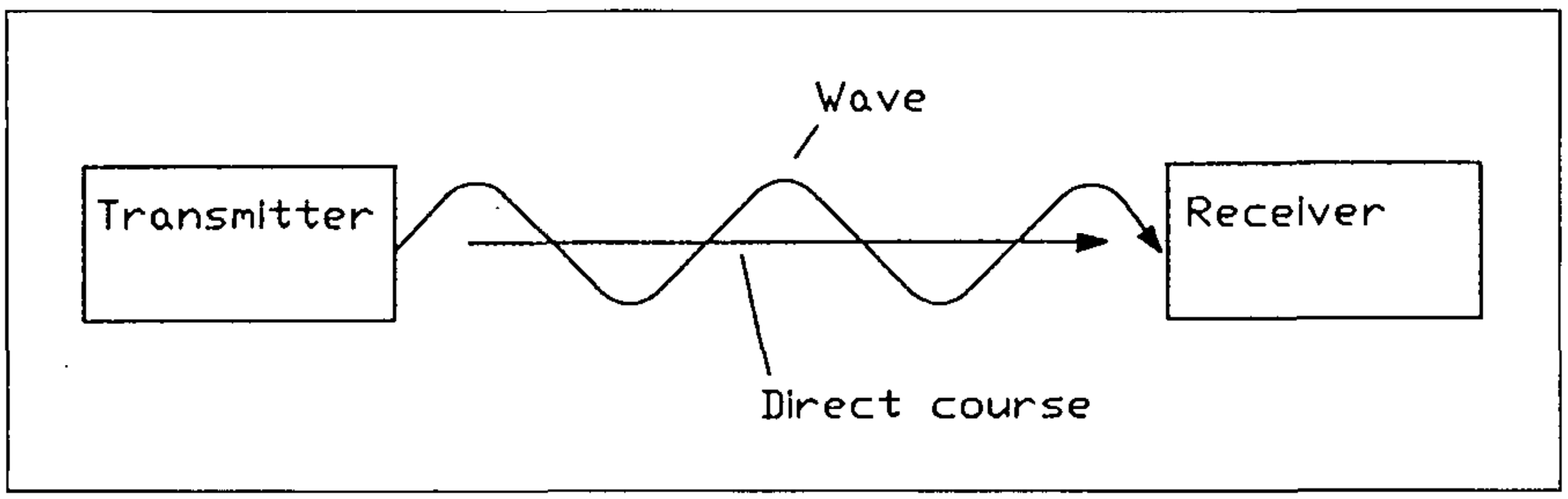

Figure 2. Wave transmission between transmitter and receiver.

In most cases, transmitter and receiver are placed in the tractor. The signal is sent to a fixed point from where it is reflected back to the receiver. The difference in position between the transmitter/receiver, a "black box", measures the difference in position of the sent and received signal, thus giving a measurement of the tractor's position (Fig. 3). The receiver can detect objects in the receiver area and calculate the exact distance from the sensor to the object.

The following systems can be used for steering machines in nursery.

- Ultrasound (mechanical vibrations)
- Infrared light (electromagnetic waves).
- Laser light (electromagnetic waves).

Ultrasound. Ultrasound waves are spread and be can reflected. These waves work with a frequency of 20 kilo Hz to 1 giga Hz. The waves are reflected from the surfaces of objects, including plants, in different ways according to the type of surface. The reflected waves are evaluated by the receiver. The steering system identifies objects in the adjustable receiver area and calculates the distance between the sensor and the objects (Fig. 4).

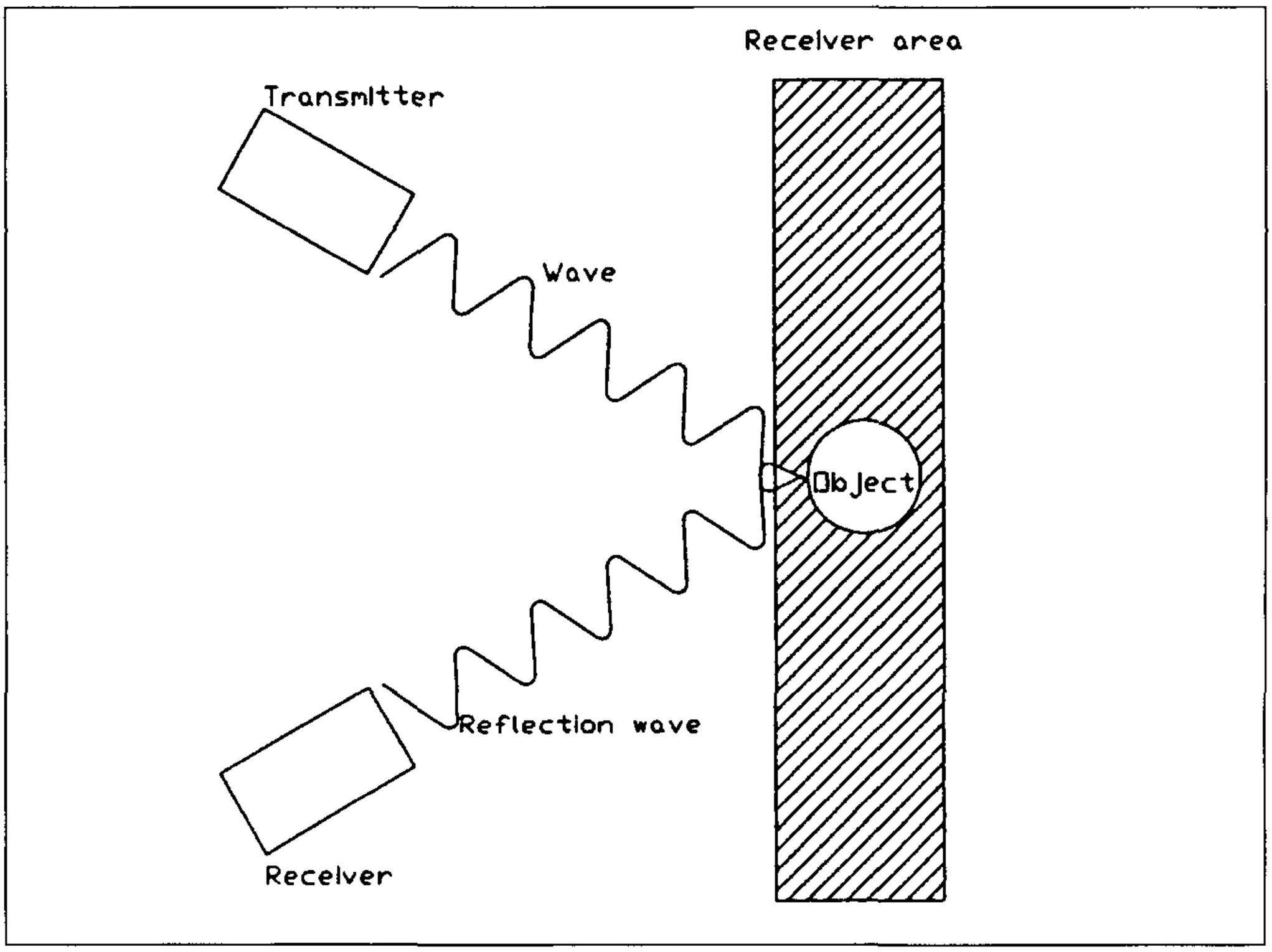

Figure 3. The reflection of the waves on an object.

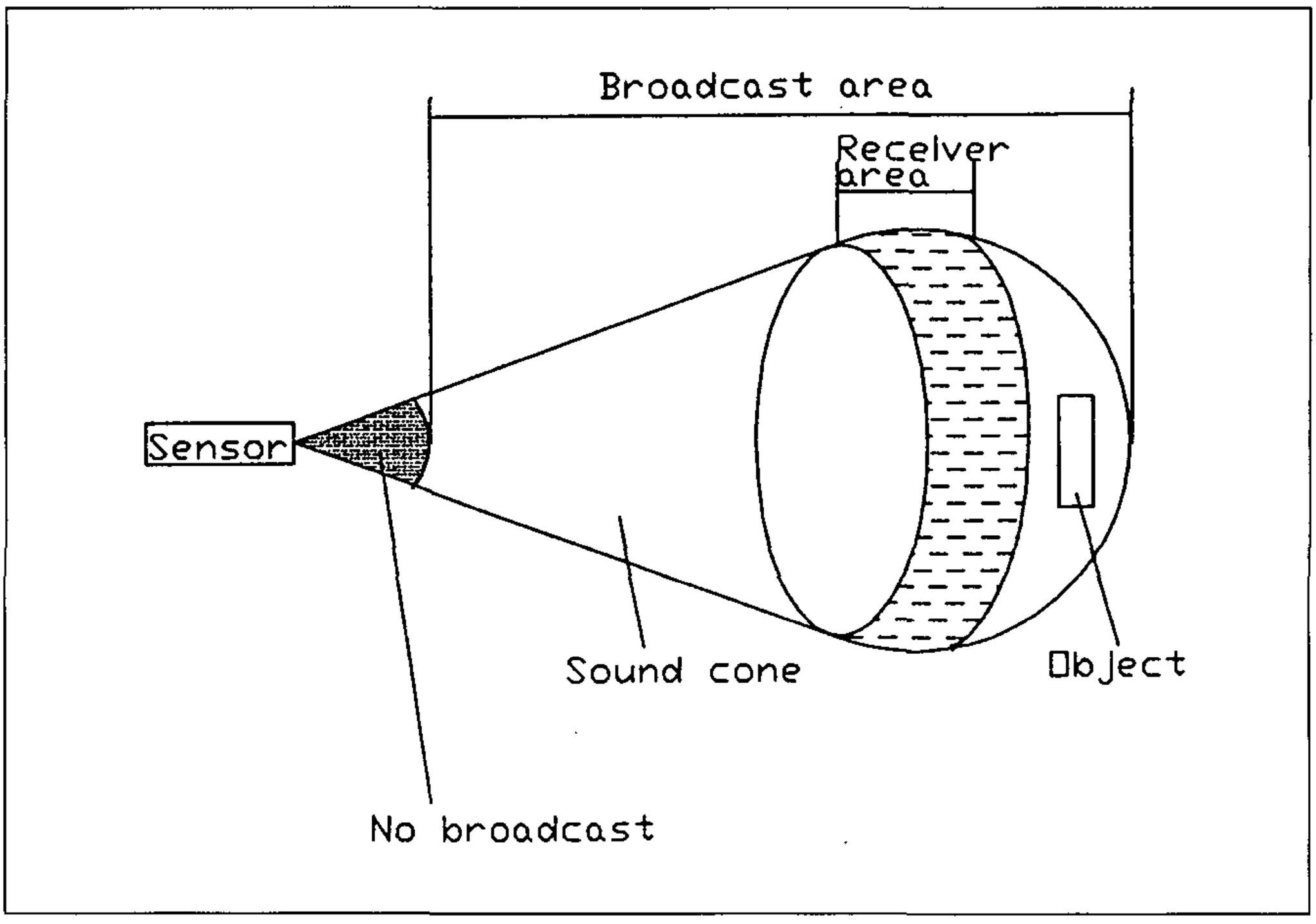

Figure 4. Receiver area of an ultrasound sensor (transmitter and receiver).

The receiver coverage can be adjusted from 5 cm to 3 m and the angle of spread ranges from 6 to 90 degrees. A maximum of three objects can be recognised per second. The sensor can be adjusted to recognise objects three times in order to avoid mistakes. Ultrasound sensors have the advantages that both foreground and background cut off are possible and that the receiver area can be adjusted accurately. But dust, fog, smoke, and hot air can cause errors, which is why there have been problems with thermal weed control using ultrasound sensors. An ultrasound sensor costs between 50 and 100 Euros ($56 and $133 U.S.A).

Infrared Light. The transmission principles are the same as for ultrasound, and infrared sensors can be used for object identification. The degree of reflection by objects depends on the surface colour. The maximum range for object identification is 8 m (Fig. 5).

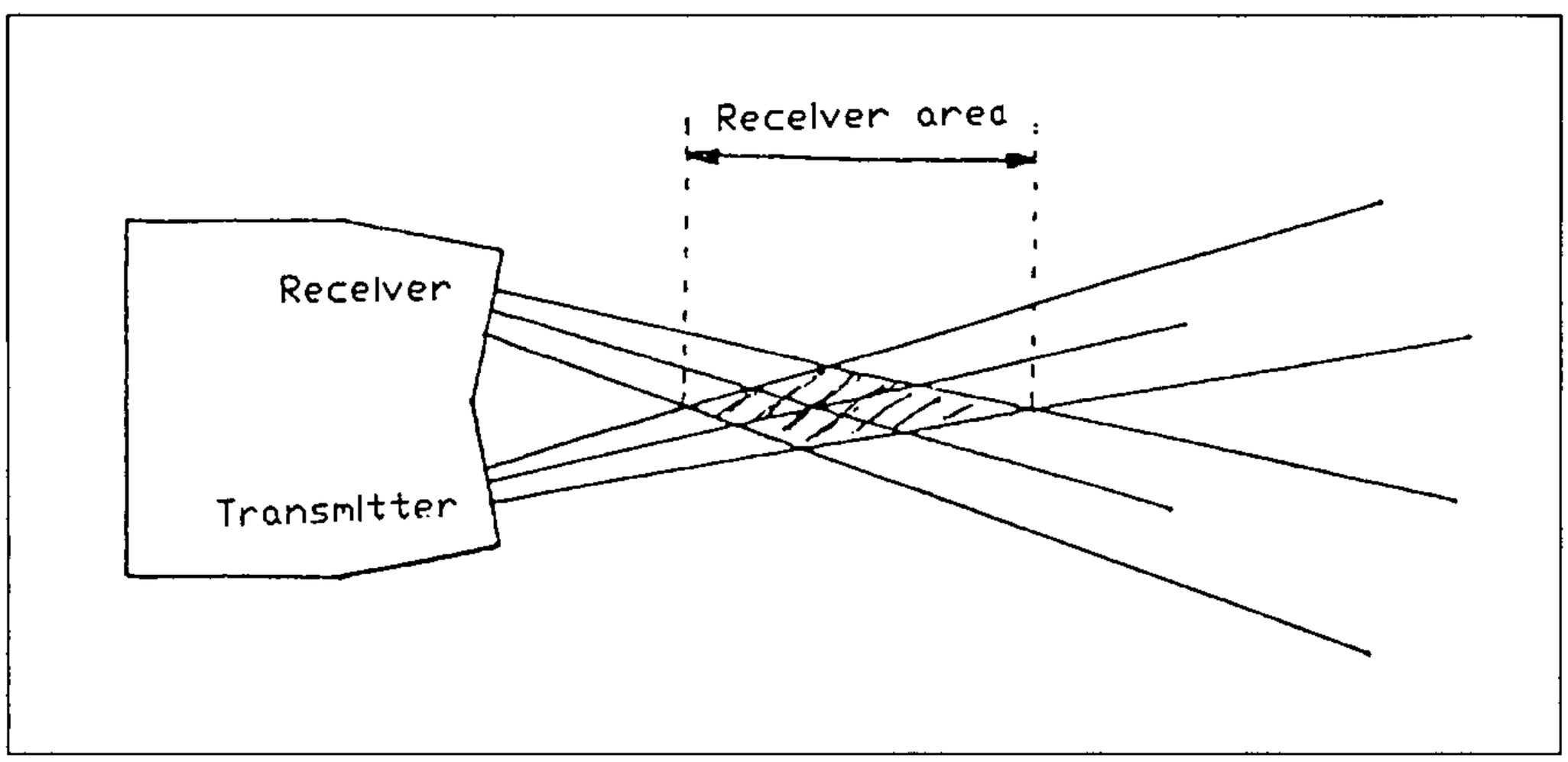

Figure 5. Principle of the background cut off.

In another kind of infrared sensor the direction of waves is parallel between transmitter and receiver (Fig. 6).

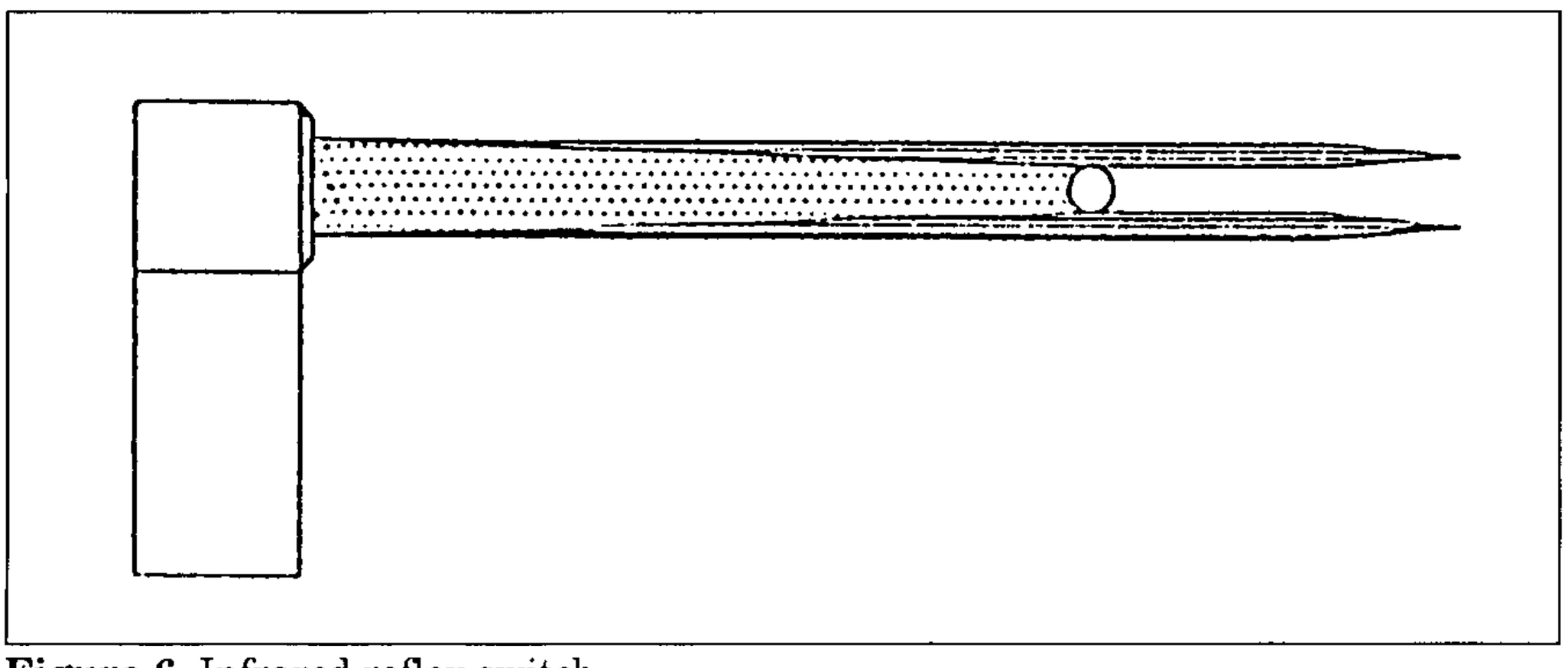

Figure 6. Infrared reflex switch.

The receiver area is adjustable within fixed limits with some infrared systems but foreground cut off is not. Infrared systems can be very good at higher speeds (over 1 km h^{-1}) and for small objects (not less than 2 mm thick). Dust, fog, and smoke do not have any effects on the identification process. The cost of infrared sensors is between 50 to 100 Euros ($56 and $113 U.S.A).

Laser Light. Laser light has been used both to carry signals for systems based on reflection (as in ultrasound and infrared light) and to operate steering over a long distance with separated transmitter and receiver. Reflected laser light systems will detect objects of less than 2 mm and the plant rows are used for the steering signal. The price is about 500 Euros ($560 U.S.A).

As laser light has a virtually parallel beam, rather than a spreading beam of the other systems, it can be used to guide cultivators over long distances with separated transmitter and receiver. For example, planting machines can use laser guidance for high quality, straight-row planting. This system works over a distance of 500 m between transmitter and receiver. In such a system the laser is set up to transmit 5 or 7 beams arranged close together horizontally. When the tractor mounted receiver detects the middle beam the position is correct. If a beam to the left or right is detected a corresponding adjustment is made to the steering. As laser light travels in a straight line there must be a clear unobstructed view between transmitter and receiver. Compensation can be made for small height differences across the field (Fig. 7).

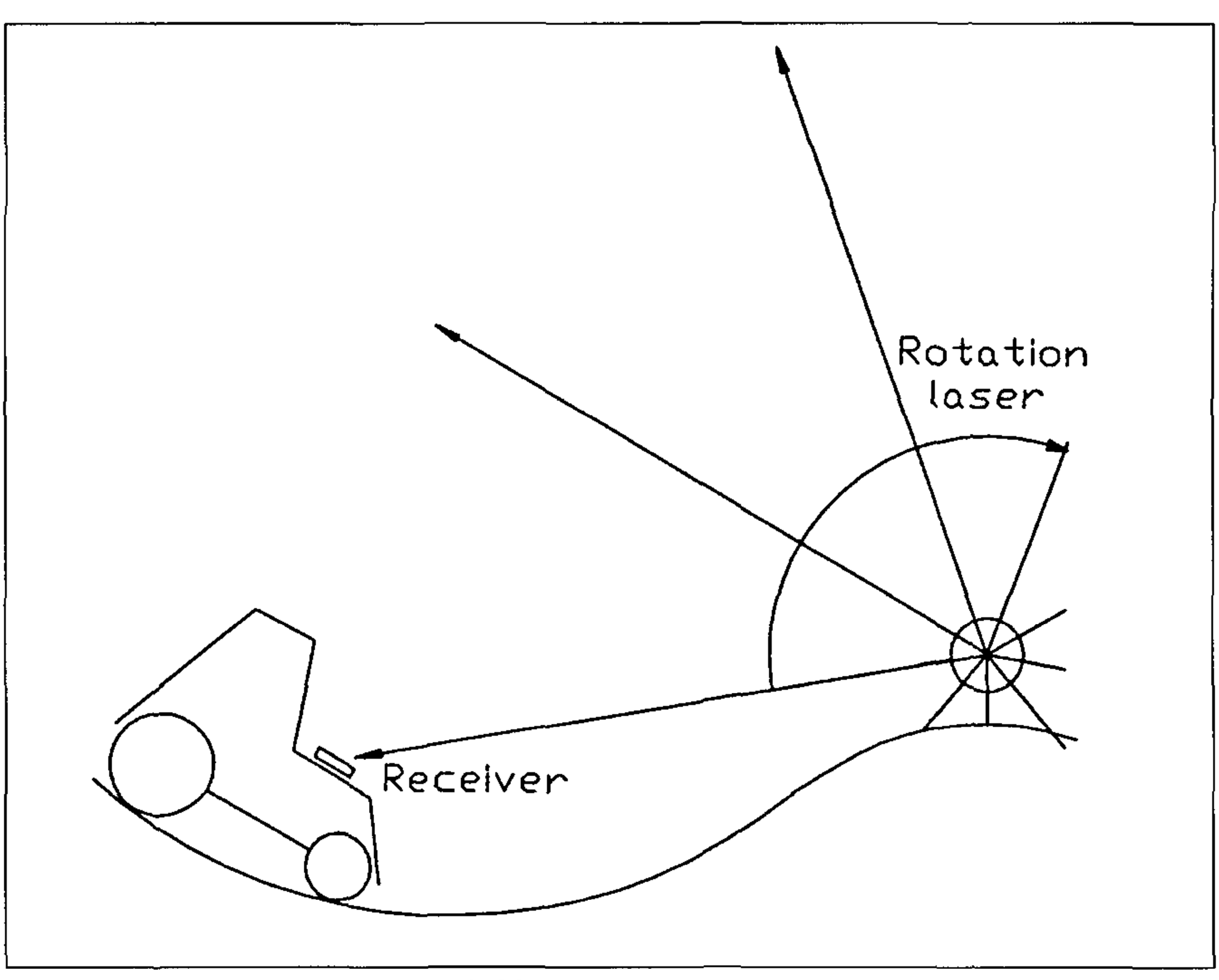

Figure 7. Laser steering in the field.

In theory, laser-guided systems can be used at distances of over 500 m but in practice systems cannot make fine enough adjustments at more than this distance. The cost for steering systems of this kind is approximately 5000 Euros ($5600 U.S.A).

Steering Systems. The technology needed to receive the steering signal is not very complex. An electrical connection gives a command to a pneumatic or a hydraulic steering mechanism like those used in car power-steering systems.

PRACTICAL APPLICATIONS

Thermal in-row Weed Control. At the Institute for Engineering in Horticulture, of the Fachhochschule Weihenstephan, we have run trials with a thermal weed control machine for in-row weed killing. The device has two burners which send a flame and hot air between the plants in the rows. Two sensors have been installed. The first detects the cultivated plant and switches off the burner. The second is placed 3 to 7 cm back from first and recognizes the weeds and switches on the burners. The signals from the sensors close and open a magnetic valve from the gas supply.

Soil Cultivation for in-row Weed Control. The Clemens company developed a soil cultivator which used an ultrasound sensor to guide the shear and steer the machine. When the ultrasound sensor detected a crop plant, a signal was transmitted to the hydraulics. The signal had to steer the hydraulics and move the share out of the rows. Combining two functions on one sensor caused problems with the equipment so, in cooperation with the Clemens Company, the Institute for Engineering in Horticulture, of the Fachhochschule Weihenstephan, has added an infrared sensor to a new steering system and this has improved the effectiveness of the machine. The machine is effective with plant distances in the rows greater than 40 cm and with a workspeed slower than 4 km h^{-1}.

Laser Guided Steering for Planting Accurate Rows. There are many situations in horticultural production where exact straight rows are necessary (e.g., 6-row planter and 12-row spraying systems for strawberry production) and for accurate cultivation work exact rows are a great advantage. Planters with laser light steering, such as those currently being produced by the Wagner Company, can be used.

There are two kinds of laser-guided steering system. In one, the receiver emits an acoustic or a light signal. The tractor driver uses this signal to keep on a straight line. In the other, the signals from the receiver are used to control an electrical or hydraulic steering mechanism and the driver has only a supervisory function.

TECHNICAL ASPECTS OF STEERING CONTROL

Very costly systems have been developed to transform the signals received from sensor but new technical developments are helping to greatly reduce costs. For example, on-board computers have been developed for use on agricultural machinery. It is possible for the computer to accept signals from, for example, sensors so that the steering can be guided by the computer. It is also now possible to develop programmable industrial steering originally developed for factory handling systems.

SUMMARY

Plant rows can been used as guide lines for steering machines on the nursery. Sensors which emit ultrasound or light detect the position of the plants. In many cases infrared and ultrasound sensors work very well in soil cultivators. For planters, laser beams are used for accurate rows.

REFERENCES

Auernhammer, H. 1989. Elektronik in Traktoren und Maschinen. Munchen, Verlagsunion Agrar.

Bohm, E. 1988. Messen, Steuern, Regeln in der Landtechnik, 1. Auflage. Würzburg, Vogel Buchverlag.

Kohler, L. and **J. Rannerthauser.** 1993. Ultraschall lasst Baume kalt. Deutsche Baumschule, S. pp. 33-35.

Kohler, L. and **J. Rannerthauser.** 1997. Steuerung von Maschinen in Reihenkulturen. Deutscher Gartenbau 38, S. pp. 2029-2031.

Lauer, G. 1995. Steuerung von Maschinen und Geraten im Gemusebau. Diplomarbeit Fachhochschule Weihenstephan.

Rieder, S. 1993. Untersuchungen zur thermischen Unkrautbekampfung. Diplomarbeit Fachhochschule Weihenstephan.

Romer, H.-R. 1998. Portalversuchsrahmen. www. tec. agrar. tu-muenchen. de/roemer/ gartenbau/pvr/ htmb.

Schon, H. 1993. Elektronic und Computer in der Landwirtschaft. Stuttgart, Ulmer-Verlag.

Weik, M. 1998. Praxiserprobung eines Gerates zur Zwischenstockpflege in Kombination mit einer Steuereinheit auf Basis der beruhrungslosen Pflanzenerkennung. Diplomarbeit Fachhochschule Weihenstephan.