# USING THE RE235734 RADAR FROM JOHN DEERE TO MEASURE ACTUAL DISTANCE COVERED BY A TRACTOR ON SELECTED NURSERY GROUNDS[1]

Krzysztof Słowiński
*Department of Forest Work Mechanisation, Agricultural University of Cracow*

**Abstract.** The work presents the evaluation of a measuring system consisting of a radar giving information on actual distance covered by a tractor and a computer interface archiving measurement data. The measuring system was installed on the Ursus MF235 tractor. The research was carried out for selected ground types, on which tractor wheels move in a forest nursery: asphalt, green fallow, and technological tracks next to sowing ridge. Obtained results allowed determining suitability of this radar for measuring distance covered by tractor or its speed in open forest nurseries. Obtained data shows that the number of pulses generated by the radar per distance unit depends on the angle of radar position relative to the ground. The highest accuracy was reached while the radar was set at the angle of 40˚-45˚.

**Key words:** radar, tractor, forest nursery

## Introduction

The term "radar", used in the USA since 1940, is short for Radio Detection and Ranging [Buderi 2006].

Radars are devices, which allow simplifying many works carried out by machinery in agriculture, transport, aviation, automotive industry, and other sectors. They have started the era of precise agriculture, they allow determining the distance, speed and position, and are used to measure the skid of tractor wheels [Budyn et al. 2003; Reed and Turner 1993; Szafarz and Błaszkiewicz 2007]. Owing to their precision and fast operation they made it possible to carry out works faster, more accurately and cheaper.

The purpose of the research was to verify operating accuracy of a selected radar from John Deere, no. RE235734, taking into account angles of inclination towards the ground, movement speed of nursery machines, and types of ground where certain machines were moving, and determining best position from among the examined ones for a selected model.

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## Research methodology and scope

The research was carried out in an open forest nursery located in Niepołomice forest division, in Kłaj forest administration region, largest nursery in the vicinity with operating area of 5.86 ha.

A stable stand was built for proper radar mounting onto a tractor. The stand was equipped with a protractor measuring radar position relative to the ground. The stand was fixed to tractor gearbox casting, to threaded holes used for cab mounting, between tractor front and rear wheel (Fig. 1.). This location allowed carrying out visual radar check from driver's seat during the tests. The radar was supplied from an external 12V battery, and its output was connected to the APEK 154 interface input. Recorder setting options used during tests were as follows: sampling time - 100 ms, number of measurements in one block - 3000. 25-metre long measurement sections were set out using ranging poles, the distances were measured with steel measuring tape, poles were spaced every 5 metres. Each measurement section consisted of five analysed parts (Fig. 2.).

The course of tests: setting the proper radar inclination angle - this operation was carried out using moving stand head, on which the radar was installed; then the tractor was driven with engine set at a selected gear with a constant motor speed along set out measurement section (25 metres). An interface recording data transmitted by radar was on

Fig. 1. Radar mounted onto a tractor, visible protractor measuring radar position relative to the ground

Fig. 2. Poles setting out specific measurement sections, visible green fallow and fragment of asphalt road

during each test, and the researchers were measuring the duration of tractor run from the first to the last pole setting out a measurement zone, which allowed computing actual speed of the tractor. Five values of radar inclination angle towards the ground were selected - α: 25°, 40°, 45°, 55° and 75° (Fig. 3) - inclination angle of 45° and deviation from that value: 5°, 10°, 20° and 30°.

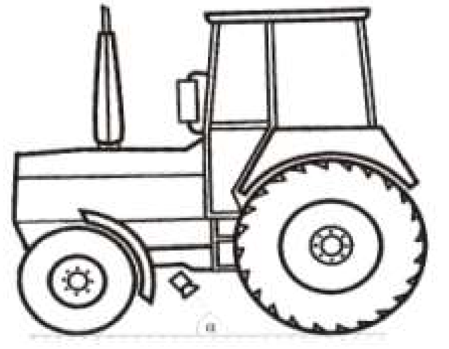

Fig. 3. Illustration of angle measurement for radar position relative to the ground

Five tractor runs were completed in each variant. Four speed values were selected for a given radar inclination. After the analysis of data obtained from tests on asphalt ground and green fallow, the researchers reduced for technological track the number of measurement variants and omitted extreme radar setting angles (25° and 75°) due to high standard deviation of the results. The measurements were carried out for two higher speed values.

## Research results

Tables 1 through 3 show obtained results for ground types depending on tractor speed and radar setting angle towards the ground.

Table 1. Results showing the number of pulses generated by radar on asphalt ground, depending on its setting angle towards the ground and tractor speed

| Asphalt ground | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| α angle | speed | Measurement blocks | | | | | average | stand. deviation | variation coef. |
| | | 1 | 2 | 3 | 4 | 5 | | | |
| deg | $m \cdot s^{-1}$ | $pulses \cdot m^{-1}$ | | | | | | | % |
| 25 | 0.25 | 69.0 | 38.5 | 51.3 | 72.6 | 34.0 | 53.1 | 17.42 | 32.8 |
| 25 | 0.33 | 149.4 | 126.0 | 156.6 | 131.0 | 148.5 | 142.3 | 13.10 | 9.2 |
| 25 | 0.97 | 140.4 | 150.7 | 143.5 | 140.7 | 145.9 | 144.2 | 4.25 | 2.9 |
| 25 | 1.28 | 151.4 | 149.2 | 152.4 | 147.1 | 148.3 | 149.7 | 2.19 | 1.5 |
| 40 | 0.26 | 116.1 | 93.3 | 121.1 | 98.0 | 101.2 | 105.9 | 12.02 | 11.4 |
| 40 | 0.32 | 126.6 | 111.6 | 130.2 | 119.4 | 100.6 | 117.7 | 11.92 | 10.1 |
| 40 | 1.04 | 102.0 | 106.4 | 116.9 | 113.0 | 107.6 | 109.2 | 5.83 | 5.3 |
| 40 | 1.20 | 115.5 | 112.3 | 115.6 | 114.8 | 118.1 | 115.3 | 2.07 | 1.8 |
| 45 | 0.25 | 59.7 | 74.0 | 70.1 | 57.2 | 67.4 | 65.7 | 7.06 | 10.7 |
| 45 | 0.32 | 128.5 | 102.9 | 118.0 | 133.8 | 136.7 | 124.0 | 13.77 | 11.1 |
| 45 | 0.98 | 114.5 | 113.7 | 115.9 | 114.4 | 115.2 | 114.7 | 0.84 | 0.7 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 45 | 1.17 | 114.7 | 114.4 | 117.3 | 116.8 | 113.5 | 115.3 | 1.63 | 1.4 |
| 55 | 0.26 | 0.0 | 16.3 | 6.0 | 0.0 | 20.5 | 8.6 | 9.43 | 110.1 |
| 55 | 0.32 | 73.8 | 61.0 | 91.5 | 54.0 | 78.5 | 71.8 | 14.75 | 20.6 |
| 55 | 1.01 | 87.9 | 91.5 | 91.4 | 93.5 | 92.5 | 91.4 | 2.11 | 2.3 |
| 55 | 1.20 | 94.3 | 89.5 | 93.0 | 90.4 | 91.2 | 91.7 | 1.95 | 2.1 |
| 75 | 0.25 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.18 | 223.6 |
| 75 | 0.33 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.00 | - |
| 75 | 0.99 | 53.5 | 56.2 | 55.0 | 54.0 | 55.2 | 54.8 | 1.06 | 1.9 |
| 75 | 1.31 | 48.6 | 50.3 | 50.6 | 53.1 | 51.2 | 50.8 | 1.63 | 3.2 |

Table 2. Results showing the number of pulses generated by radar on green fallow, depending on its setting angle towards the ground and tractor speed

| Asphalt ground | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| α angle | speed | Measurement blocks | | | | | average | stand. devia- tion | variation coef. |
| | | 1 | 2 | 3 | 4 | 5 | | | |
| deg | $m \cdot s^{-1}$ | $pulses \cdot m^{-1}$ | | | | | | | % |
| 25 | 0.24 | 158.2 | 152.8 | 153.8 | 159.4 | 148.8 | 154.6 | 4.29 | 2.8 |
| 25 | 0.32 | 159.0 | 157.1 | 153.6 | 155.0 | 158.1 | 156.6 | 2.23 | 1.4 |
| 25 | 0.91 | 157.9 | 158.5 | 158.8 | 158.7 | 158.1 | 158.4 | 0.39 | 0.2 |
| 25 | 1.26 | 157.7 | 159.0 | 155.6 | 159.2 | 156.5 | 157.6 | 1.56 | 1.0 |
| 40 | 0.24 | 140.7 | 140.3 | 136.8 | 144.7 | 142.8 | 141.1 | 2.96 | 2.1 |
| 40 | 0.33 | 136.6 | 131.2 | 139.7 | 134.8 | 135.8 | 135.6 | 3.08 | 2.3 |
| 40 | 0.92 | 130.7 | 133.4 | 131.3 | 133.0 | 128.2 | 131.3 | 2.08 | 1.6 |
| 40 | 1.25 | 133.7 | 130.8 | 130.8 | 132.0 | 130.4 | 131.5 | 1.35 | 1.0 |
| 45 | 0.24 | 127.9 | 129.2 | 126.3 | 128.6 | 125.9 | 127.6 | 1.43 | 1.1 |
| 45 | 0.32 | 127.7 | 115.8 | 110.0 | 122.6 | 128.6 | 120.9 | 7.96 | 6.6 |
| 45 | 0.91 | 126.1 | 126.1 | 124.7 | 124.6 | 124.7 | 125.2 | 0.79 | 0.6 |
| 45 | 1.21 | 130.8 | 126.7 | 126.6 | 126.7 | 128.0 | 127.8 | 1.80 | 1.4 |
| 55 | 0.24 | 109.0 | 82.3 | 76.7 | 117.6 | 100.8 | 97.3 | 17.40 | 17.9 |
| 55 | 0.33 | 107.1 | 81.9 | 87.8 | 109.4 | 91.7 | 95.6 | 12.11 | 12.7 |
| 55 | 0.89 | 100.8 | 100.0 | 99.9 | 100.2 | 100.6 | 100.3 | 0.39 | 0.4 |
| 55 | 1.22 | 99.2 | 97.9 | 98.0 | 99.7 | 97.5 | 98.5 | 0.94 | 1.0 |
| 75 | 0.24 | 10.0 | 0.0 | 6.0 | 0.6 | 0.0 | 3.3 | 4.51 | 135.7 |
| 75 | 0.33 | 51.3 | 6.3 | 70.6 | 20.5 | 0.0 | 29.7 | 30.22 | 101.6 |
| 75 | 0.91 | 55.2 | 60.1 | 60.2 | 62.7 | 58.7 | 59.4 | 2.75 | 4.6 |
| 75 | 1.29 | 47.6 | 49.9 | 46.9 | 49.7 | 51.2 | 49.1 | 1.77 | 3.6 |

Table 3. Results showing the number of pulses generated by radar on technological track, depending on its setting angle towards the ground and tractor speed

| Ground: technological track | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| α angle | speed | Measurement blocks | | | | | average | stand. devia-tion | variation coef. |
| | | 1 | 2 | 3 | 4 | 5 | | | |
| deg | $m \cdot s^{-1}$ | $pulses \cdot m^{-1}$ | | | | | | | % |
| 40 | 1.12 | 110.0 | 114.6 | 125.2 | 118.4 | 118.0 | 117.2 | 5.58 | 4.8 |
| 40 | 1.17 | 156.2 | 151.6 | 157.5 | 146.3 | 160.3 | 154.4 | 5.50 | 3.6 |
| 45 | 1.00 | 117.6 | 124.6 | 118.3 | 117.8 | 120.1 | 119.7 | 2.92 | 2.4 |
| 45 | 1.31 | 125.2 | 122.9 | 117.1 | 113.4 | 120.8 | 119.9 | 4.69 | 3.9 |
| 55 | 1.14 | 70.4 | 75.2 | 74.8 | 82.9 | 83.6 | 77.4 | 5.69 | 7.3 |
| 55 | 1.09 | 123.0 | 120.3 | 103.8 | 118.5 | 137.6 | 120.6 | 12.06 | 10.0 |

## Summary

The tested radar, RE235734, was working correctly. The number of transmitted pulses was directly proportional to the distance covered by tractor. Analysis of the obtained results allows to state that the radar measurement is more precise at higher tractor speeds (lower standard deviations of the obtained results), considerably less pulses per one metre of covered distance occurs for lowest speed (ca. 0.25 $m \cdot s^{-1}$) on asphalt (tab. 1) for all setting angles and on green fallow for setting angle α = 75° (tab. 2). There is a visible dependence between angle α of radar setting/position towards the ground and the number of pulses F generated by radar per covered distance unit - Fig. 4.

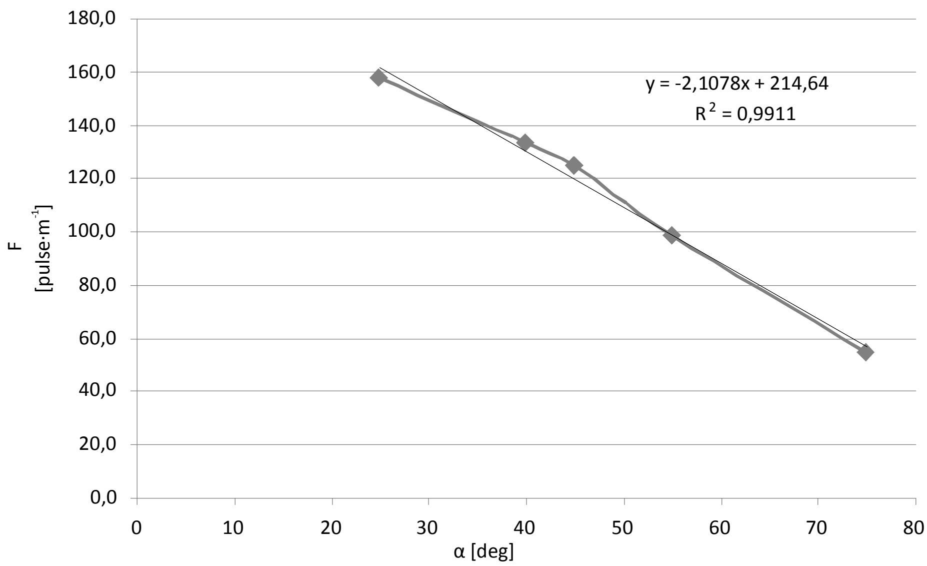

Fig. 4. Diagram showing a dependence between the angle of radar setting towards the ground - α and the number of pulses F generated by radar per covered distance unit

While analysing the diagram (Fig. 4), we see a bend near 40° - 45° - smaller change in the number of transmitted pulses, which would suggest using these radar positions relative to the ground. For these radar setting angles, also standard deviations of the obtained measurement results for the examined ground types are lowest. For technological track and this radar position, variability coefficient is lowest and ranges from 2.4% to 4.8% (tab. 3).

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**Correspondence address:**
Krzysztof Słowiński
rlslowin@cyf-kr.edu.pl
Katedra Mechanizacji Prac Leśnych
Wydział Leśny
al. 29 Listopada 46
31-425 Kraków, Poland