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Individual tracking of laying hens with an RFID-System

In a laboratory test of a low-frequency RFID system the probability of registration was assessed and this system was used to study ranging behavior of laying hens. To test the equipment, tags with various orientations on a platform were moved with varying speeds across a different number of antennas. The probability of registration declined when the speed of tags was greater than 1.5 m/s. In the field test on 12 farms antennas were placed on both sides of every pophole and tags were attached to a sample of laying hens. The probability of registration of a hen was 94 %. It is suggested to decrease the ID of the tag from 64 bit to 32 bit in order to read tags up to a speed of 3.2 m/s, reliably. In order to find a possible influence of the magnetic fields that were generated by reading the tags on ranging behavior, the use of two popholes was evaluated while the system at the popholes was alternatively switched off. The use of the two popholes was not affected by that so with the proposed modification of the tag this system seems suitable to study ranging behavior in laying hens.

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Laying hen, ranging behavior, welfare, RFID, transponder

Abstract
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Most Swiss laying hens have access to a covered (veranda) and an open outdoor range (pasture). In order to study the use of both outdoor ranges an RFID system with stationary antennas was employed. In this paper we describe this system and report its reliability during testing and operation at laying hen farms.

The method of RFID has proven to be a useful tool to monitor the behavior of farm animals [1] including laying hens [2-4]. However, RFID in agriculture poses problems [5], e.g. the low range of tags without batteries. In our study individual ranging behavior in different sized flocks of laying hens was studied without altering any housing parameters including the number or size of popholes.

Birds including chickens are known to detect (electro)magnetic fields [6-11]. A possible influence of RFID on the ranging behavior of laying hens was investigated because RFID generates magnetic fields. Finally, we discuss and evaluate the usefulness of this RFID system for tracking ranging behavior of laying hens.

Test in the laboratory

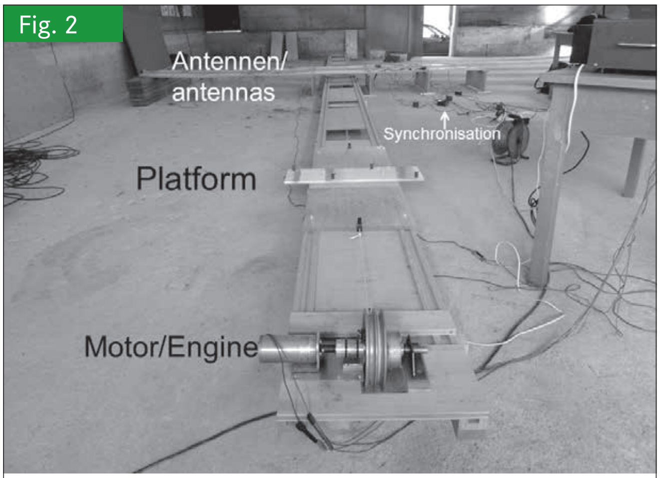
Material and Methods

The test was conducted with part of the system which was used on farms. The RFID System (Gantner Pigeon Systems GmbH, Schruns, Austria) consisted of RFID tags, RFID antenna pads and data loggers with time recording. The RFID antenna pads consisted of 12 single overlapping antenna coils to achieve a field without gaps and arranged in two lines to read every RFID tag at least twice (**Figure 1**). The RFID tags (ø 4.0/34.0 mm Hitag S 2,048 bits, 125 kHz) were programmed by the manufacturer of the RFID system. Every time a tag was scanned by the antenna the connected data logger stored the ID of the tag, the timestamp (with a precision of

Fig. 1

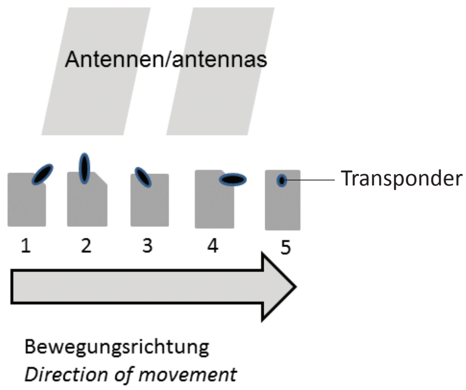
Antenna pad (‚antenna') with 12 single antennas in two rows, top of the antenna is removed (Photo: S. Gebhardt-Henrich)

Fig. 2



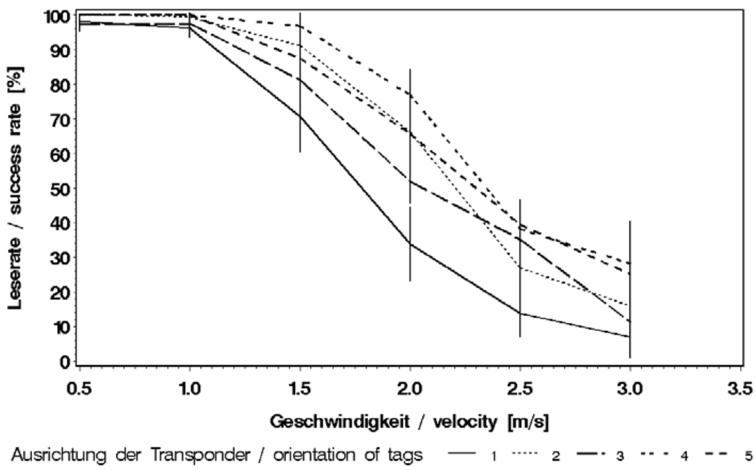
Set-up of the laboratory test: plastic platform with 4 tags was moved underneath two rows of antennas. The engine moved the platform with varying velocities. (Photo: S. Gebhardt-Henrich)

Fig. 3



Orientation of the tags on the platform regarding to the direction of movement

Fig. 4



Success rate of registration depending on orientation of the tags on the platform and the velocity during the test

0.1 s) and the number of the antenna. The ID was 64 bit long. This information was passed every 0.5 s to the central PC for data logging in a .csv file (software "Chicken tracker" by Gantner Pigeon Systems GmbH).

Four RFID-tags were attached onto a movable plastic platform which was moved by an electric engine through the magnetic field of a stationary antenna system (**Figure 2**). One to eight flat antennas were placed side-by-side above the runway of the platform. A second row of the same number of antennas was placed at a distance of 30 cm. They were laid upside down. All RFID antennas were synchronized. The distance between the tip of the tags and the antennas was 4.5 cm. Three parameters were varied:

- number of antennas: 1, 3, 5, or 6 per side
- velocity: 0.5, 1.0, 1.5, 2.0 2.5, 3.0 m/s
- five different orientations of the tags (**Figure 3**)

The orientation was the same for all four tested tags. For each combination of parameters the platform was moved in both directions under the antennas five times yielding ten passages.

The success rate was defined as the number of registered tags per passage and could have one of five values, namely reading 0, 1, 2, 3, or all 4 tags. In order to test the influence of the velocity of the tags and the number of antennas on the success rate the data were analyzed with a generalized linear model (Proc Genmod of SAS® 9.1.3) using the multinomial distribution.

Results

The success rate of registering the four tags declined with increasing velocity and was different for different orientations of the tags (**Figure 4**). There was a significant interaction in the generalized linear model between velocity and orientation of the tags (**Table 1**). The success rate (number of registered tags) declined fastest when tags were oriented vertically to the antennas. The success rate declined the least when tags were oriented horizontally to the antennas. The number of antennas did not influence the success rate, even when the number was increased to 16 antennas (number of antennas: df = 1, χ^2 = 0.19, NS).

Table 1

Results of the test with up to 12 antennas (number of antennas, velocity and orientation of the tags were varied)

Quelle/*Source*	df	X^2	Signifikanz/*Significance*
Anzahl Antennen (2–12)/*Number of antennas*	1	0,89	n.s.
Orientierung der Transponder (1–5)/*Orientation of the tags*	4	38,19	p < 0,0001
Geschwindigkeit der Transponder (0,5 bis 3,5 m/s)/*Velocity of the tags*	1	365,99	p < 0,0001
Anzahl × Geschwindigkeit/*Number × velocity*	1	2,23	p = 0,1356
Orientierung × Geschwindigkeit/*Orientation × velocity*	4	27,60	p < 0,0001

df = Freiheitsgrade/*degrees of freedom*
n.s. = Nicht signifikant/*not significant*

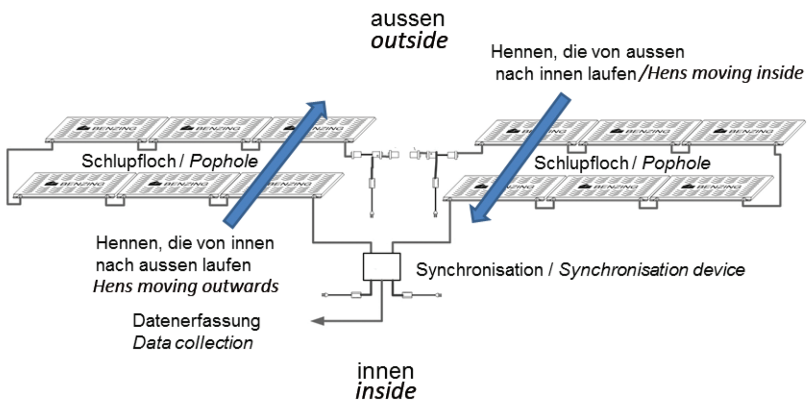
Use of the RFID system on commercial farms

Twelve flocks of laying hens with 2000 to 18000 birds were investigated. The popholes were always positioned at the long side of the barn to the covered outdoor range (veranda) and to the pasture. Antennas were placed at both sides of each pophole at least three weeks before data were collected (**Figures 5** and **6**).

The widths of the popholes ranged from 1.2 to 4.6 m. If necessary, up to 12 antennas, six on each side of the pophole, were put side-by-side to cover the entire width of the pophole. To avoid interference the antennas of different synchronization units were separated by at least 1 m distance. Up to eight data loggers were connected to a multiplexer (Com Server Moxa 8-port Nport 5650-8) and each multiplexer was connected to a laptop by an ethernet cable. Depending on the size of the barn up to 120 antennas and 15 data loggers were used.

The sample size (number of birds with tags) was 5 % per flock, i.e. at night when hens were asleep RFID tags were attached to 100 to 900 birds. The glass tag was placed into a plastic wing tag

Fig. 5

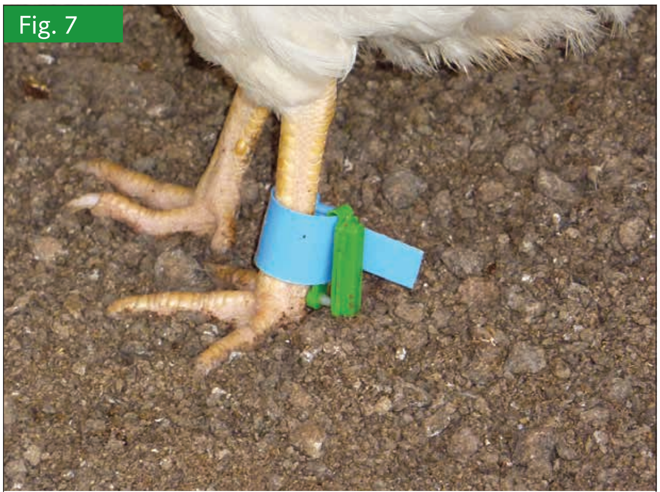


Set-up of the RFID system at two popholes during the on-farm application

Fig. 6

RFID antennas on both sides of a pophole during the field test (Photo: S. Gebhardt-Henrich)

Fig. 7



Hen with tag (Photo: S. Gebhardt-Henrich)

Table 2

Influence of the factors farm, day, and size of the flock on registration rates

Schlupflöcher zwischen Stall und Außenklimabereich/*Popholes between house and veranda*			
Quelle/*Source*	**df**	**X²**	**Signifikanz/Significance**
Herdengröße/*Flock size*	2	16,4	p < 0,0003
Betrieb (Herdengröße)/*Farm (flock size)*	7	87	p < 0,0001
Tag (Betrieb, Herdengröße)/*Day (farm, flock size)*	10	195,8	p < 0,0001
Schlupflöcher zwischen Außenklimabereich und Auslauf/*Popholes between veranda and free range*			
Quelle/*Source*	**df**	**X²**	**Signifikanz/Significance**
Herdengröße/*Flock size*	2	45,3	p < 0,0003
Betrieb (Herdengröße)/*Farm (flock size)*	9	60,1	p < 0,0001
Tag (Betrieb, Herdengröße)/*Day (farm, flock size)*	12	195,8	p < 0,0001

and attached with an adjustable RFID leg band (both products from the company Roxan, Scotland) to one leg of the hen (**Figure 7**). At depopulation of the hens most tags were recovered. Tags that were not recovered were excluded from the analyses.

Results

The success rate for validation of the method was modeled as a binomial variable of 1 if 100 % of the hens that left the barn or the veranda were registered as they returned or 0 if fewer than 100% were registered. This binomial variable was analyzed using a generalized linear model (GENMOD Procedure, SAS). This model took into account that hens of the same flock were not independent.

Only results regarding the technical function of recording the movements of hens through the popholes are reported here. Results on the ranging behavior were already published [11]. In general, hens were more likely registered when they exited the barn or the veranda than when they reentered (exiting the barn = 94.3 %, entering the barn = 83.5 %, Wilcoxon test P < 0.0008, N = 10, exiting the veranda to the pasture = 94.8 %, entering the veranda from the pasture = 83 %, Wilcoxon test P < 0.0005, N = 12). Farms, flock sizes, and different days differed in success rate (**Table 2**).

Influence of the RFID system on ranging behavior

For the test of the influence of the RFID system on ranging behavior a flock of 2,000 white laying hens was used. Two popholes connecting the veranda and the pasture were recorded on video under different conditions with the system switched on or off (**Table 3**). Before this test the antennas had been present for about 5 weeks and the laying hens had experienced the RFID system for about three weeks. Video recordings lasted approx. between 10:30 a.m. and 12:00 a.m. local time, starting when the hens were allowed into the outdoor ranges. The weather during recordings was the same. From the video recordings the number of hens passing the popholes was counted every 5 min noting which pophole and the direction of movement. The movement from the veranda to the pasture was called 'exit', the movement from the pasture to the veranda was called 'entry'. Prior to analyses data were checked for normality. To compare exits and entries through the popholes the general linear model was used (PROC GLM, SAS® Institute). There was clearly no effect whether the RFID system was switched on or off but pophole # 2 had more exits and entries than pophole # 1 (pophole: $F_{1,19}$= 37.86, P < 0.0001, RFID: $F_{1,19}$= 0.7, n.s.).

Discussion

The requirements for the method of individual registration of ranging behavior included a mobile system which could be easily installed at farms for a few weeks, then disassembled and moved to another farm. Farms varied greatly in the number and width of popholes. On some farms popholes were elevated and were reached from ramps, platforms or perches. Changing parameters like the width of popholes could have altered ranging behavior and was avoided.

The described RFID System fulfilled the requirements to various degrees and fell short in several aspects. Joining antennas to cover wide popholes was no problem. As the laboratory test of the system showed the performance was the same even when 16 antennas were connected. The main problem of the system was the velocity of the moving tags. As the laboratory test showed the success rate started to decrease sharply for tags moving faster than 1.5 m/s. For a further use with laying hens we would decrease the length of the ID of the tag to 32 bit. In that case the maximum speed would increase to 3.2 m/s.

On one farm the speed of brown hens was estimated (unpublished data). The median of the calculated speed of the tagged hens when passing the pop-holes was 1.5 m/s, but some hens reached more than 4.5 m/s. With the modification of reading 32 bit most laying hens would be registered. In many cases hens were chased back into the veranda from the pasture and from the veranda into the house at night by the farmer. The greater speed could have had two effects: Decreasing the likelihood of registration per se and the wider gaits of fast moving hens might

Table 3

Set-up of the test on the influence of the RFID system on ranging behavior of laying hens

	Stichprobe *Sample*	Schlufploch 1/*Pophole 1*			Schlufploch 2/*Pophole 2*		
	n	Antenne *Antenna*	Austritte *Exits*	Eingänge *Entries*	Antenne *Antenna*	Austritte *Exits*	Eingänge *Entries*
Tag/*Day* 1	14	an/*on*	255	226	an/*on*	341	390
Tag/*Day* 2	18	an/*on*	264	262	an/*on*	390	441
Tag/*Day* 3	14	an/*on*	228	188	an/*on*	321	350
Tag/*Day* 4	12	aus/*off*	204	141	aus/*off*	–[2)]	–[2)]
Tag/*Day* 5	17	aus/*off*	331	347	aus/*off*	386	468
Tag/*Day* 6	16	aus/*off*	235	162	aus/*off*	296	324
Tag/*Day* 7	15	an/*on*	262	197	aus/*off*	432	448
Tag/*Day* 8	16	an/*on*	298	226	aus/*off*	382	421
Tag/*Day* 9	16	aus/*off*	259	186	an/*on*	362	389
Tag/*Day* 10	18	aus/*off*	359	286	an/*on*	473	560
Tag/*Day* 11	13	aus/*off*[1)]	224	133	aus/*off*[1)]	378	250
Tag/*Day* 12	13	aus/*off*[1)]	267	215	aus/*off*[1)]	339	394
Total	182		3 186	2 569		4 100	4 435
Durchschnitt [/5 min] *Mean [/5 min]*			17,51	14,12		24,12	26,09
Verhältnis Austritte/Eintritte *Ratio exits/Entries*			55 %	45 %		48 %	52 %
Bewegungen pro Schlupfloch *Movements per pophole*			42 %			58 %	
Eintritte/Entries				35 %			65 %
Austritte/Exits			39 %			61 %	

1) Keine Antennen, keine Kabel/*no antennas, no cables.*
2) Keine Daten/*data missing.*

have moved the tags outside the recording range of the antenna. These phenomena were probably the cause of the difference in success rate when hens were moving out of the house towards the outdoor ranges and the reverse direction. Speed and the likelihood of stepping on the antenna were also probably reasons for the differences in success rate between farms and individuals. Installations of the antennas at the popholes differed. Regarding the probability of registering hens moving between the house and the veranda the five farms with the highest success rates had ramps because the house was higher or lower than the veranda. Ramps probably slowed down hens.

A similar RFID system was used in other studies on ranging behavior of laying hens [12, 13] and the identical system was used by Hörning et al. [14]. In these studies the reliability of the method was not assessed or the assessment was not published. However, knowing the reliability of the RFID system might improve the validity of the analyses and the interpretation of the data. Therefore, a test of the system is recommended for applications in the field.

Conclusions

When fast moving hens should be registered this system's reliability is limited. When using this low-frequency-RFID system it should be assured that the speed of the hens will not exceed 1.5 m/s. Alternatively, systems with higher frequencies and a higher speed of registration might be applied. The equipment and the magnetic fields did not seem to influence the hens' behavior of using the popholes. Registration of hens performing slow behaviors like occupying a nest should be no problem with this system, so that nest use could be automatically assessed [15].

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