WISSENSCHAFTLICHE „PAPER“ & EMAIL

Evaluation of the Reliability of RSSI for Indoor Localization

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***Abstract*—In wireless sensor networks, nodes can be static or mobile, depending on the application requirements. Dealing with mobility can pose some formidable challenges in protocol design, particularly, at the link and network layers. These difficulties require mobility adaption algorithms to efficiently localize mobile nodes and predict the quality of link that can be established with these nodes. An off the shelf development platform that uses Radio Signal Strength Indication (RSSI) is mostly selected as the sensor localization method, especially in the indoor environment. Despite this, not much research work has been done to practically demonstrate the reliability of RSSI for indoor localization. Therefore, in this paper, we aim to calibrate and map RSSI to distance by doing a series of experiments. The result shows that the RSSI technology gives an unacceptable high error and thus is not reliable for the indoor sensor localization.**

***Keywords*-distance; localization; RSSI; wireless sensor networks;**

accurately they determine the location of mobile nodes. Most of the protocols employ RSSI for real-time localization, especially in the indoor environment. Nevertheless, not much research work has been done to practically demonstrate the reliability of RSSI for indoor localization. Therefore, in this paper, we aim to calibrate and map RSSI to distance by carrying out a series of experiments. Based on the observations, the conclusion that whether RSSI is reliable and thus feasible for indoor localization can be drawn.

The remaining part of this paper is organized as follows: in Section II, related work is summarized. In Section III, a brief introduction to RSSI technology is described. In Section IV, the experiment settings are presented. In Section V, the reliability of RSSI for indoor localization is investigated and the observations are discussed. Finally, in Section VI, concluding remarks are given.

$$RSSI = -(10 \times n) log_{10}(d) - A$$

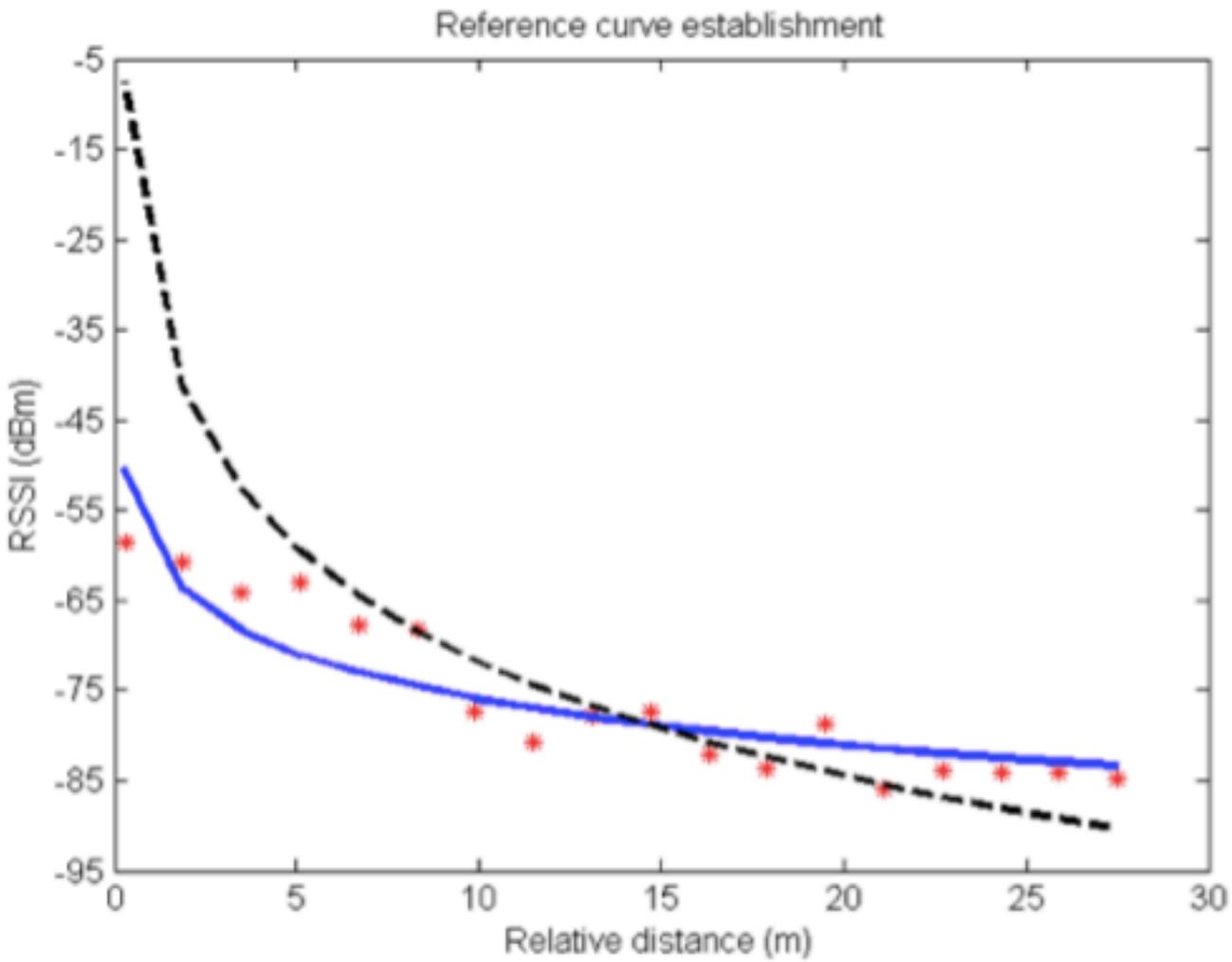

Figure 1. The establishment of the reference curve

$$d(i) = \frac{R}{t_{max} - t_{min}} t(i) \qquad i \in [1, n]$$

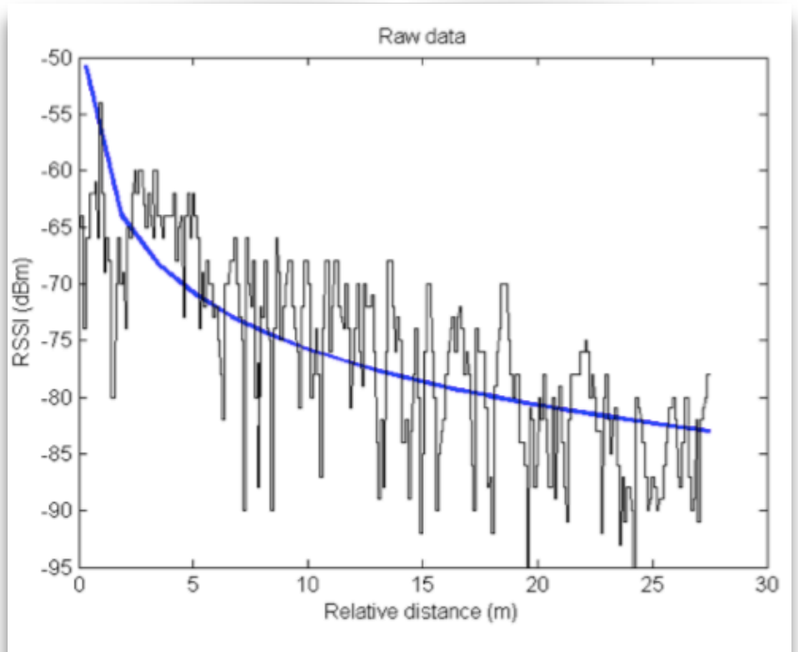

Figure 2. Utilization of the raw data for localization

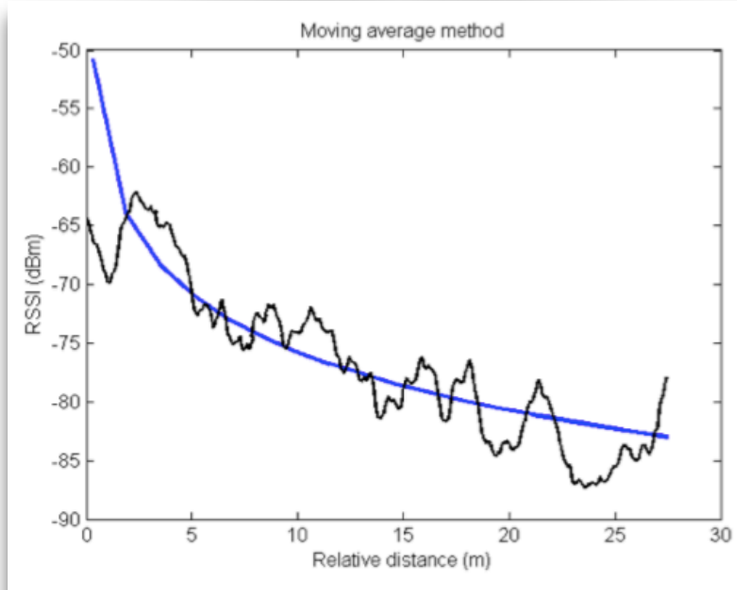

Figure 3. Utilization of the moving average method for localization

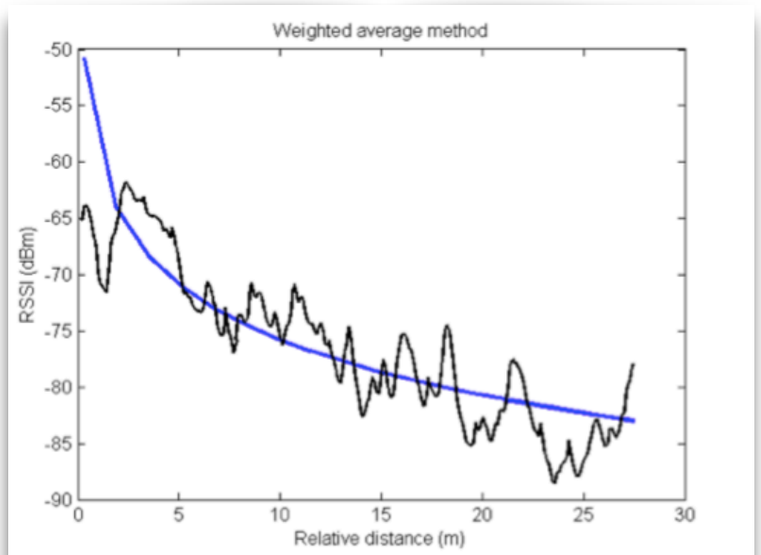

Figure 4. Utilization of the weighted average method for localization

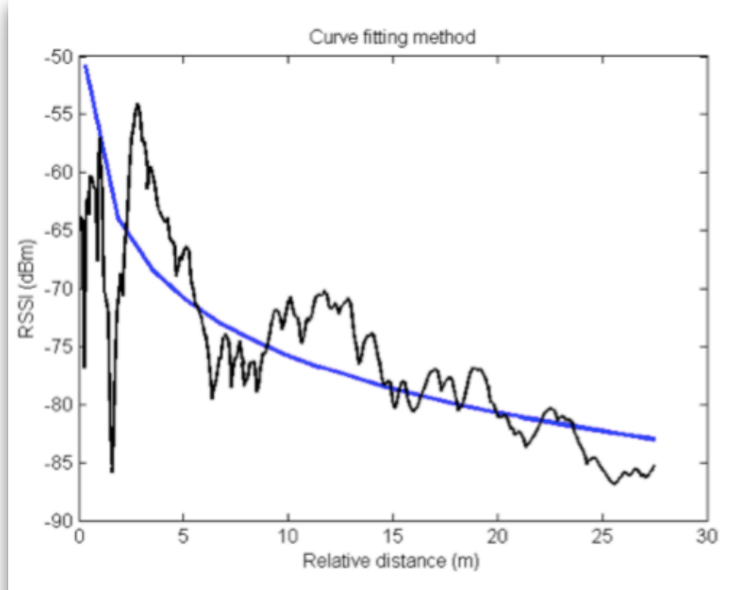

Figure 5. Utilization of the curve fitting method for localization

```
HCI sniffer - Bluetooth packet analyzer ver 5.43
device: hci0 snap_len: 1500 filter: 0xffffffff
> 04 3E 2B 02 01 03 01 78 05 B7 B5 73 1A 1F 1E FF 06 00 01 09
  20 00 A3 AD F4 5C D0 39 B7 0F 32 7C 1F AA 4F 21 ED 97 4D EB
  59 D9 E2 C7 6B B3
> 04 3E 2B 02 01 03 01 78 05 B7 B5 73 1A 1F 1E FF 06 00 01 09
  20 00 A3 AD F4 5C D0 39 B7 0F 32 7C 1F AA 4F 21 ED 97 4D EB
  59 D9 E2 C7 6B B9
> 04 3E 2B 02 01 03 01 78 05 B7 B5 73 1A 1F 1E FF 06 00 01 09
  20 00 A3 AD F4 5C D0 39 B7 0F 32 7C 1F AA 4F 21 ED 97 4D EB
  59 D9 E2 C7 6B BE
> 04 3E 2B 02 01 03 01 78 05 B7 B5 73 1A 1F 1E FF 06 00 01 09
  20 00 A3 AD F4 5C D0 39 B7 0F 32 7C 1F AA 4F 21 ED 97 4D EB
  59 D9 E2 C7 6B AA
> 04 3E 2B 02 01 03 01 78 05 B7 B5 73 1A 1F 1E FF 06 00 01 09
  20 00 A3 AD F4 5C D0 39 B7 0F 32 7C 1F AA 4F 21 ED 97 4D EB
  59 D9 E2 C7 6B BC
> 04 3E 2B 02 01 03 01 78 05 B7 B5 73 1A 1F 1E FF 06 00 01 09
  20 00 A3 AD F4 5C D0 39 B7 0F 32 7C 1F AA 4F 21 ED 97 4D EB
  59 D9 E2 C7 6B AA
> 04 3E 29 02 01 00 00 4F 6E C2 80 2F 7C 1D 02 01 06 09 03 03
  18 02 18 04 18 F5 FE 0F 09 47 69 67 61 73 65 74 20 6B 65 65
  70 65 72 AE
> 04 3E 19 02 01 04 00 4F 6E C2 80 2F 7C 0D 0C FF 80 01 02 15
  01 00 80 C2 6E 4F C5 AD
> 04 3E 2B 02 01 03 01 78 05 B7 B5 73 1A 1F 1E FF 06 00 01 09
  20 00 A3 AD F4 5C D0 39 B7 0F 32 7C 1F AA 4F 21 ED 97 4D EB
  59 D9 E2 C7 6B B2
> 04 3E 2B 02 01 03 01 78 05 B7 B5 73 1A 1F 1E FF 06 00 01 09
  20 00 A3 AD F4 5C D0 39 B7 0F 32 7C 1F AA 4F 21 ED 97 4D EB
```

```
HCI sniffer - Bluetooth packet analyzer ver 5.43
device: hci0 snap_len: 1500 filter: 0xffffffff
> HCI Event: LE Meta Event (0x3e) plen 43
    LE Advertising Report
      ADV_NONCONN_IND - Non connectable undirected advertising (3)
      bdaddr 26:C6:B9:07:BB:3A (Random)
      Unknown type 0xff with 29 bytes data
      RSSI: -70
> HCI Event: LE Meta Event (0x3e) plen 43
    LE Advertising Report
      ADV_NONCONN_IND - Non connectable undirected advertising (3)
      bdaddr 26:C6:B9:07:BB:3A (Random)
      Unknown type 0xff with 29 bytes data
      RSSI: -94
> HCI Event: LE Meta Event (0x3e) plen 43
    LE Advertising Report
      ADV_NONCONN_IND - Non connectable undirected advertising (3)
      bdaddr 26:C6:B9:07:BB:3A (Random)
      Unknown type 0xff with 29 bytes data
      RSSI: -83
> HCI Event: LE Meta Event (0x3e) plen 37
    LE Advertising Report
      ADV_IND - Connectable undirected advertising (0)
      bdaddr F5:21:9F:4D:65:99 (Random)
      Flags: 0x05
      Complete service classes: 0x180d
      Unknown type 0x07 with 16 bytes data
      RSSI: -72
> HCI Event: LE Meta Event (0x3e) plen 43
    LE Advertising Report
      ADV_NONCONN_IND - Non connectable undirected advertising (3)
      bdaddr 26:C6:B9:07:BB:3A (Random)
      Unknown type 0xff with 29 bytes data
```

```
bdaddr 7C:2F:80:C2:6E:4F (Public)
RSSI: -52
bdaddr 02:FA:35:52:09:C0 (Random)
RSSI: -75
bdaddr 02:FA:35:52:09:C0 (Random)
RSSI: -88
bdaddr 02:FA:35:52:09:C0 (Random)
RSSI: -71
bdaddr 02:FA:35:52:09:C0 (Random)
RSSI: -86
bdaddr 02:FA:35:52:09:C0 (Random)
RSSI: -83
bdaddr 02:FA:35:52:09:C0 (Random)
RSSI: -71
bdaddr 02:FA:35:52:09:C0 (Random)
RSSI: -73
bdaddr 02:FA:35:52:09:C0 (Random)
RSSI: -71
bdaddr 7C:2F:80:C2:6E:4F (Public)
RSSI: -55
bdaddr F5:21:9F:4D:65:99 (Random)
RSSI: -76
bdaddr 02:FA:35:52:09:C0 (Random)
RSSI: -60
bdaddr 02:FA:35:52:09:C0 (Random)
RSSI: -83
bdaddr 02:FA:35:52:09:C0 (Random)
RSSI: -60
bdaddr 02:FA:35:52:09:C0 (Random)
RSSI: -82
```

Tabelle 1

	A	B
1	**bdaddr 02:FA:35:52:09:C0 (Random)**	
2	RSSI: -73	
3	bdaddr 02:FA:35:52:09:C0 (Random)	
4	RSSI: -87	
5	bdaddr 02:FA:35:52:09:C0 (Random)	
6	RSSI: -86	
7	bdaddr 02:FA:35:52:09:C0 (Random)	
8	RSSI: -77	
9	bdaddr 02:FA:35:52:09:C0 (Random)	
10	RSSI: -74	
11	bdaddr F5:21:9F:4D:65:99 (Random)	
12	RSSI: -88	
13	bdaddr F5:21:9F:4D:65:99 (Random)	
14	RSSI: -87	
15	bdaddr 02:FA:35:52:09:C0 (Random)	
16	RSSI: -73	
17	bdaddr 02:FA:35:52:09:C0 (Random)	
18	RSSI: -74	
19	bdaddr 02:FA:35:52:09:C0 (Random)	
20	RSSI: -89	
21	bdaddr 02:FA:35:52:09:C0 (Random)	
22	RSSI: -84	
23	bdaddr 02:FA:35:52:09:C0 (Random)	
24	RSSI: -75	
25	bdaddr F5:21:9F:4D:65:99 (Random)	

adamAC233F24CCE9

1	bdaddr	65:E3:B7:D8:4C:05
2	RSSI:	-73
3	bdaddr	AC:23:3F:24:CC:E9
4	RSSI:	-59
5	bdaddr	AC:23:3F:24:CC:E9
6	RSSI:	-61
7	bdaddr	65:E3:B7:D8:4C:05
8	RSSI:	-53
9	bdaddr	65:E3:B7:D8:4C:05
10	RSSI:	-53
11	bdaddr	AC:23:3F:24:AF:81
12	RSSI:	-71
13	bdaddr	AC:23:3F:24:AF:81
14	RSSI:	-71
15	bdaddr	65:E3:B7:D8:4C:05
16	RSSI:	-53
17	bdaddr	65:E3:B7:D8:4C:05
18	RSSI:	-52
19	bdaddr	F5:21:9F:4D:65:99
20	RSSI:	-78
21	bdaddr	F5:21:9F:4D:65:99
22	RSSI:	-78
23	bdaddr	65:E3:B7:D8:4C:05
24	RSSI:	-71
25	bdaddr	65:E3:B7:D8:4C:05
26	RSSI:	-71

Go to file/function | Addins

adamAC233F24CCE9 | myfunction* | myfunction | myfunction | Untitled1*

Function: myfunction (.GlobalEnv)

```
1  function(){
2      adamAC233F24CCE9 <- read_excel("Desktop/adamAC233F24CCE9.xlsx")
3      m <- matrix(0,3803,2)
4      for (i in 1:3803){
5          if (adamAC233F24CCE9[i,3] == "AC:23:3F:24:CC:E9"){
6
7              m[i,2] = as.numeric(adamAC233F24CCE9[i+1,3])
8              m[i,1] = as.numeric(adamAC233F24CCE9[i+1,1])
9
10         }
11         i=i+1
12     }
13     return(m)
14 }
15
```

Console | Terminal

```
[478,]   0   0
[479,]   0   0
[480,]   0   0
[481,] 482 -64
[482,]   0   0
[483,] 484 -64
[484,]   0   0
[485,]   0   0
[486,]   0   0
[487,]   0   0
[488,]   0   0
[489,]   0   0
[490,]   0   0
[491,]   0   0
[492,]   0   0
[493,]   0   0
[494,]   0   0
[495,]   0   0
[496,]   0   0
[497,]   0   0
[498,]   0   0
[499,]   0   0
[500,]   0   0
 [ erreichte getOption("max.print") --  3303 Zeilen ausgelassen ]
> write.csv(myfunction(), "Desktop/mtest.csv")
> View(myfunction)
> View(myfunction)
>
```

Go to file/function | Addins

adamAC233F24CCE9 | myfunction* | myfunction | myfunction | Untitled1*

```
1  myfunction <- function(){
2  adamAC233F24CCE9 <- read_excel("Desktop/adamAC233F24CCE9.xlsx")
3  m <- matrix(0,3803,2)
4  n <- matrix(0,1000,2)
5      for (i in 1:3803){
6          if (adamAC233F24CCE9[i,3] == "AC:23:3F:24:CC:E9"){
7             m[i,2] = as.numeric(adamAC233F24CCE9[i+1,3])
8             m[i,1] = as.numeric(adamAC233F24CCE9[i+1,1])
9             print(adamAC233F24CCE9[i+1,1])
10            print(adamAC233F24CCE9[i+1,3]) }
11             i=i+1
12             }
13             for (j in 1:1000){
14             if (m[i,2] =! 0){
15             n[i,2]
```

10:43 Text File

Console | Terminal

```
[478,]   0   0
[479,]   0   0
[480,]   0   0
[481,] 482 -64
[482,]   0   0
[483,] 484 -64
[484,]   0   0
[485,]   0   0
[486,]   0   0
[487,]   0   0
[488,]   0   0
[489,]   0   0
[490,]   0   0
[491,]   0   0
[492,]   0   0
[493,]   0   0
[494,]   0   0
[495,]   0   0
[496,]   0   0
[497,]   0   0
[498,]   0   0
[499,]   0   0
[500,]   0   0
 [ erreichte getOption("max.print") --  3303 Zeilen ausgelassen ]
> write.csv(myfunction(), "Desktop/mtest.csv")
> View(myfunction)
> View(myfunction)
>
```

Go to file/function | Addins

adamAC233F24CCE9 | myfunction* | myfunction | myfunction | Untitled1*

```
1  myfunction <- function(){
2  adamAC233F24CCE9 <- read_excel("/Users/hospimac19/Desktop/adam0.5m81.xlsx")
3  m <- matrix(0,438,2)
4      for (i in 1:438){
5          if (adamAC233F24CCE9[i,3] == "AC:23:3F:24:AF:81"){
6             m[i,2] = as.numeric(adamAC233F24CCE9[i+1,3])
7             m[i,1] = (-1)*as.numeric(adamAC233F24CCE9[i+1,3])
8              }
9             i=i+1
10             }
11             for (i in 1:438){
12             if(m[i,1]== 0) j++
13             i=i+1
14             }
15             n <- matrix(0,j,2)
16             d=1
17             for (i in 1:438){
18             if(m[i,1]=! 0){
19             n[i,1]=m[d,1]
20             d++
21             }
22             i++
23             }
24             return(m)
25 }
```

10:15 Text File

Console | Terminal

```
[423,]   0   0
[424,]  62 -62
[425,]   0   0
[426,]  62 -62
[427,]   0   0
[428,]   0   0
[429,]   0   0
[430,]   0   0
[431,]   0   0
[432,]   0   0
[433,]   0   0
[434,]   0   0
[435,]   0   0
[436,]   0   0
[437,]   0   0
[438,]   0   0
> write.csv(myfunction(), "Desktop/positiv0.5:81mtest.csv")
>
```

adamAC233F24CCE9

mtest

	V1	V2
1	0	0
2	0	0
3	4	-59
4	0	0
5	6	-61
6	0	0
7	0	0
8	0	0
9	0	0
10	0	0
11	0	0
12	0	0
13	0	0
14	0	0
15	0	0
16	0	0
17	0	0
18	0	0
19	0	0
20	0	0
21	0	0
22	0	0
23	0	0
24	0	0
25	0	0
26	0	0

mtest

	V1	V2	
1	0	0	
2	0	0	
3	4	-59	
4	0	0	
5	6	-61	
6	0	0	
7	0	0	
8	0	0	
9	0	0	
10	0	0	
11	0	0	
12	0	0	
13	0	0	
14	0	0	
15	0	0	
16	0	0	
17	0	0	
18	0	0	
19	0	0	
20	0	0	
21	0	0	
22	0	0	
23	0	0	
24	0	0	
25	0	0	
26	0	0	
27	0	0	
28	0	0	
29	0	0	
30	0	0	
31	0	0	
32	0	0	
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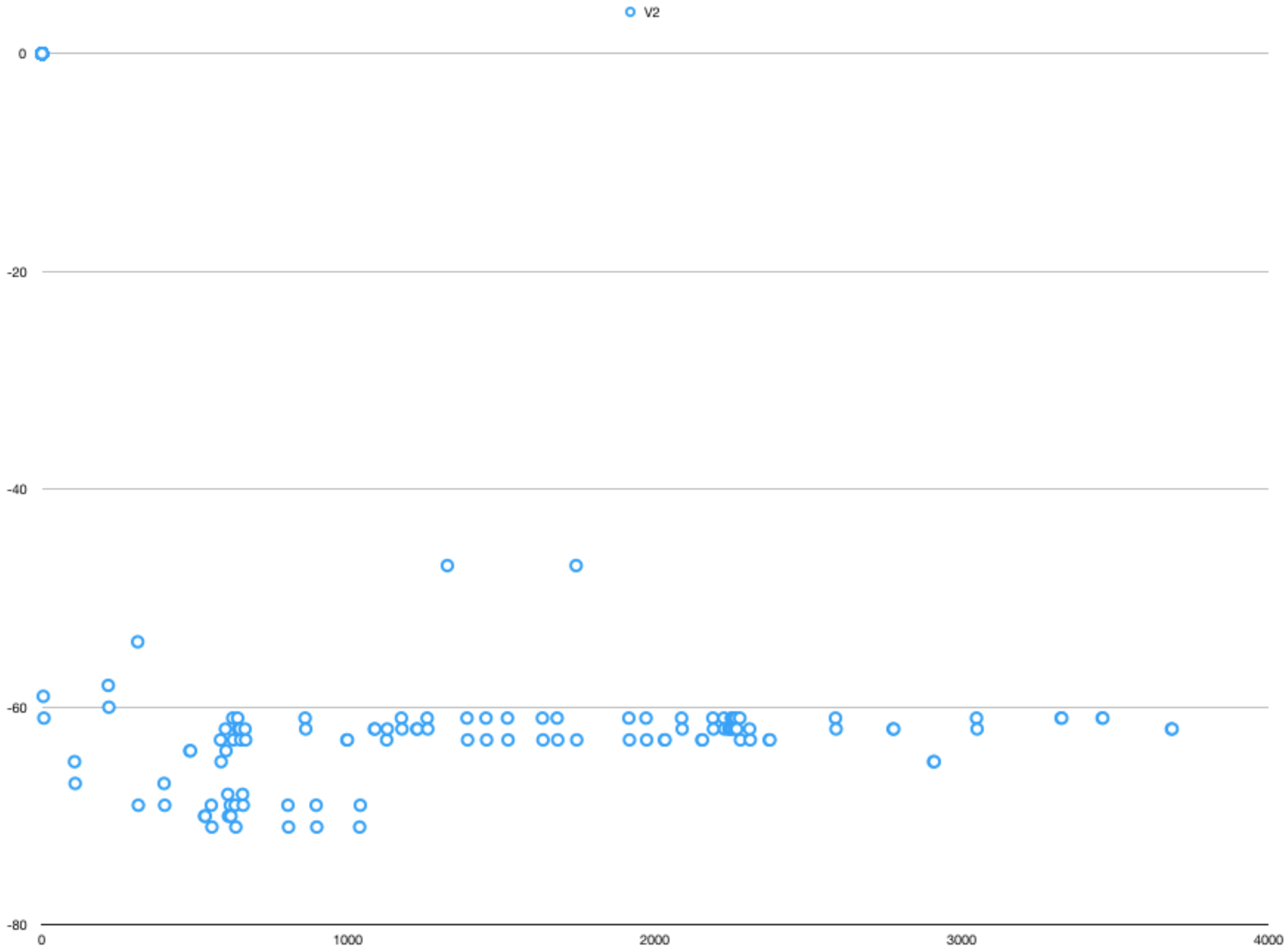
36	0	0	
37	0	0	
38	0	0	
39	0	0	



E-MAIL

Hi Adam,

Bluetooth is one of the best technologies available for indoor location positioning due to its high speed data transmission, low power budget, and minimal infrastructure demands. In our latest article, we're taking a closer look at why you may want to consider Bluetooth for your indoor location positioning system . . .

Best Regards,

Dominic Marcellino
<dominic.marcellino@link-labs.com>

ZUSAMMENFASSUNG => TODO´S

1) Technische Probleme/ störungen lösen

2) Besprechung mit dem Dozent (Einfluss der Ergebnisse des Experiments auf das Projekt)

3) Termin mit einem Wissenschaftlicher Mitarbeiter der Labor für Elektromagnetische Verträglichkeit (Disskution &Vergleich der Ergebnisse von der Experiment innerhalb und außerhalb des Labors)

4) Wissenschaftliche Paper suchen

5) Autoren Kontaktieren

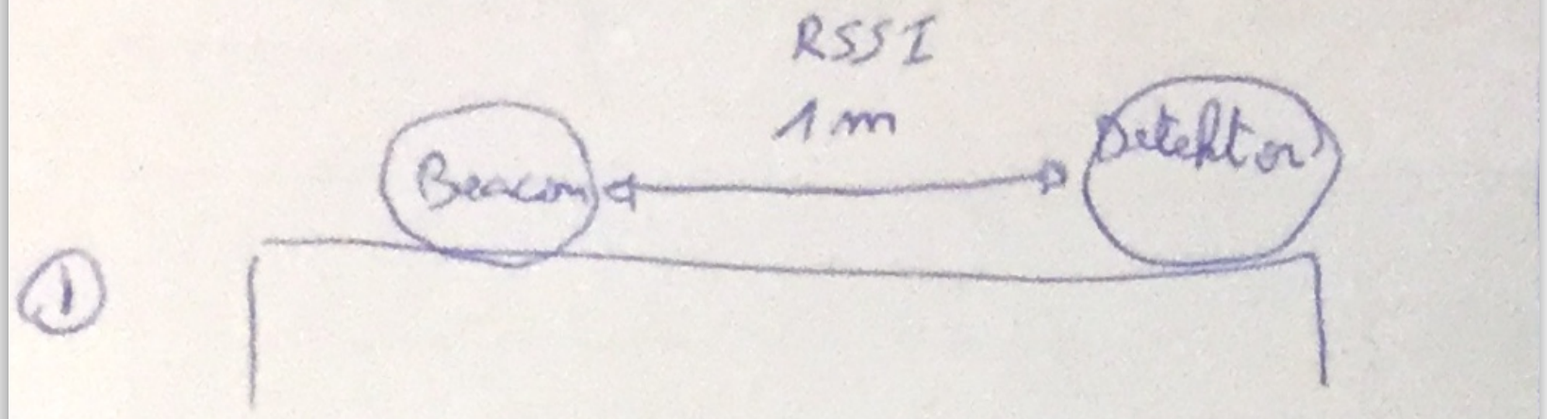
6) Daten Erhebung (Beacon) => AC233F24CCE9 & AC233F24AF81 in der Firma, in der Uni und zu Hause => 0.5m => 1m => 1.5m => 2m .

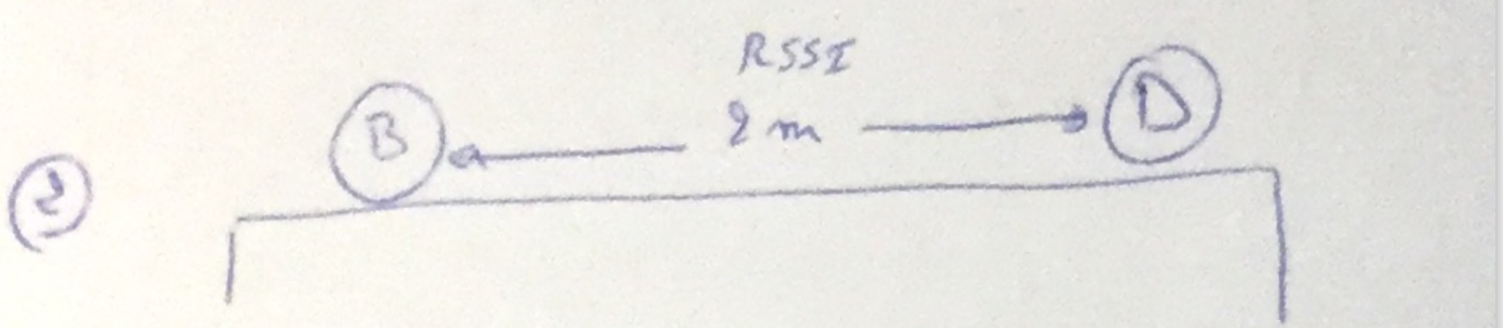
7) Daten bearbeiten von Terminal => .TXT => .CSV => XLSX => Programmieren in R-Studio => Funktion () => .CSV => Numbers => Visualisieren ! (Mittelwert, Max, Min)

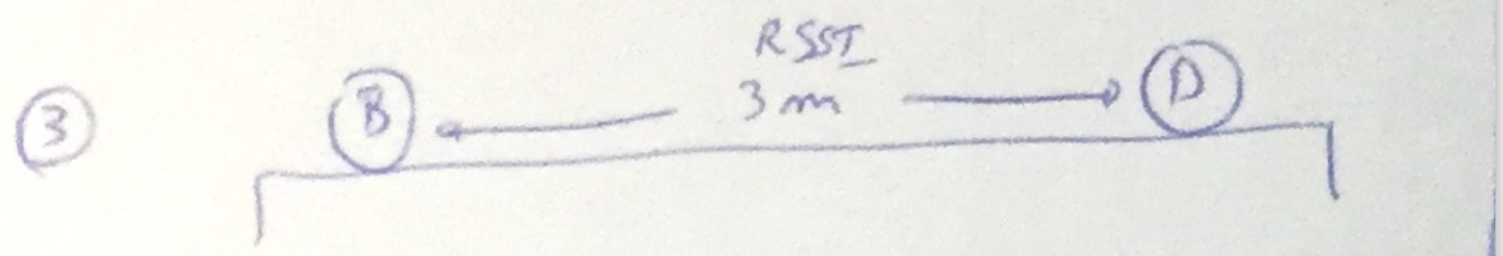
8) Ergebnisse der Datenerhebung in Tabelle darstellen !
9)Entscheidung treffen
10) mit Hilfe der berechneten Mittelwert in alle Entfernungen von jede Beacon Nährungsfunktion ermitteln => F(x)

EXPERIMENT 1

Experiment I







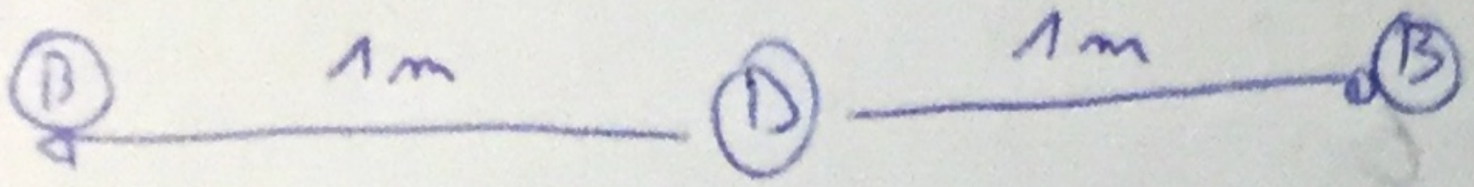
4 bis 10 m ⇒ RSSI

Korelationsfunktion

10

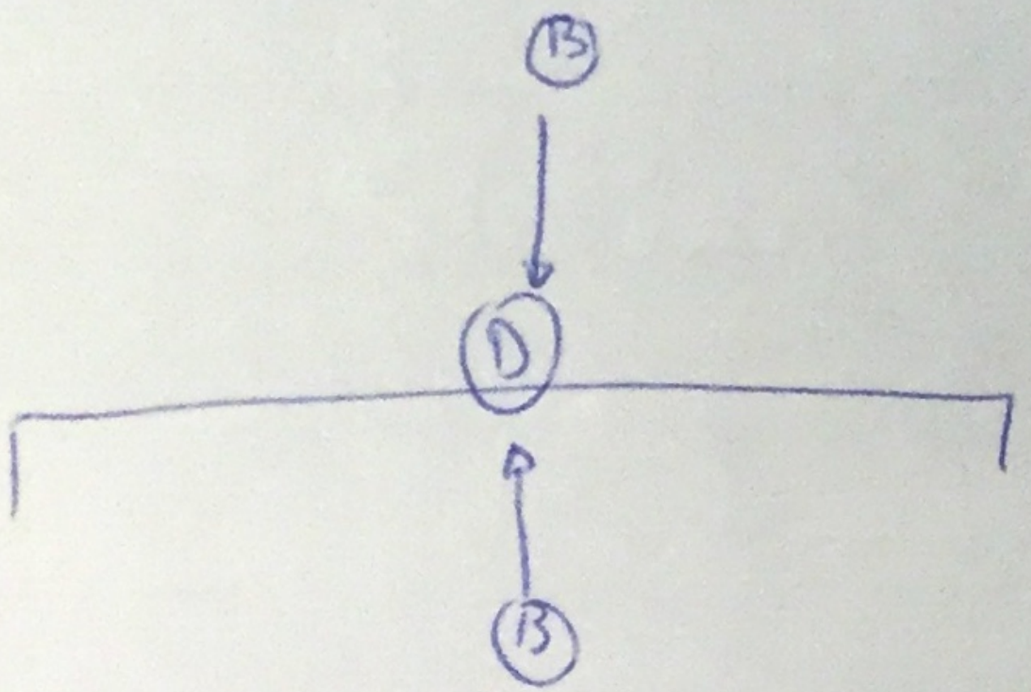
EXPERIMENT 2

(II) a - b gleichen RSST



Horizontal / Vertical

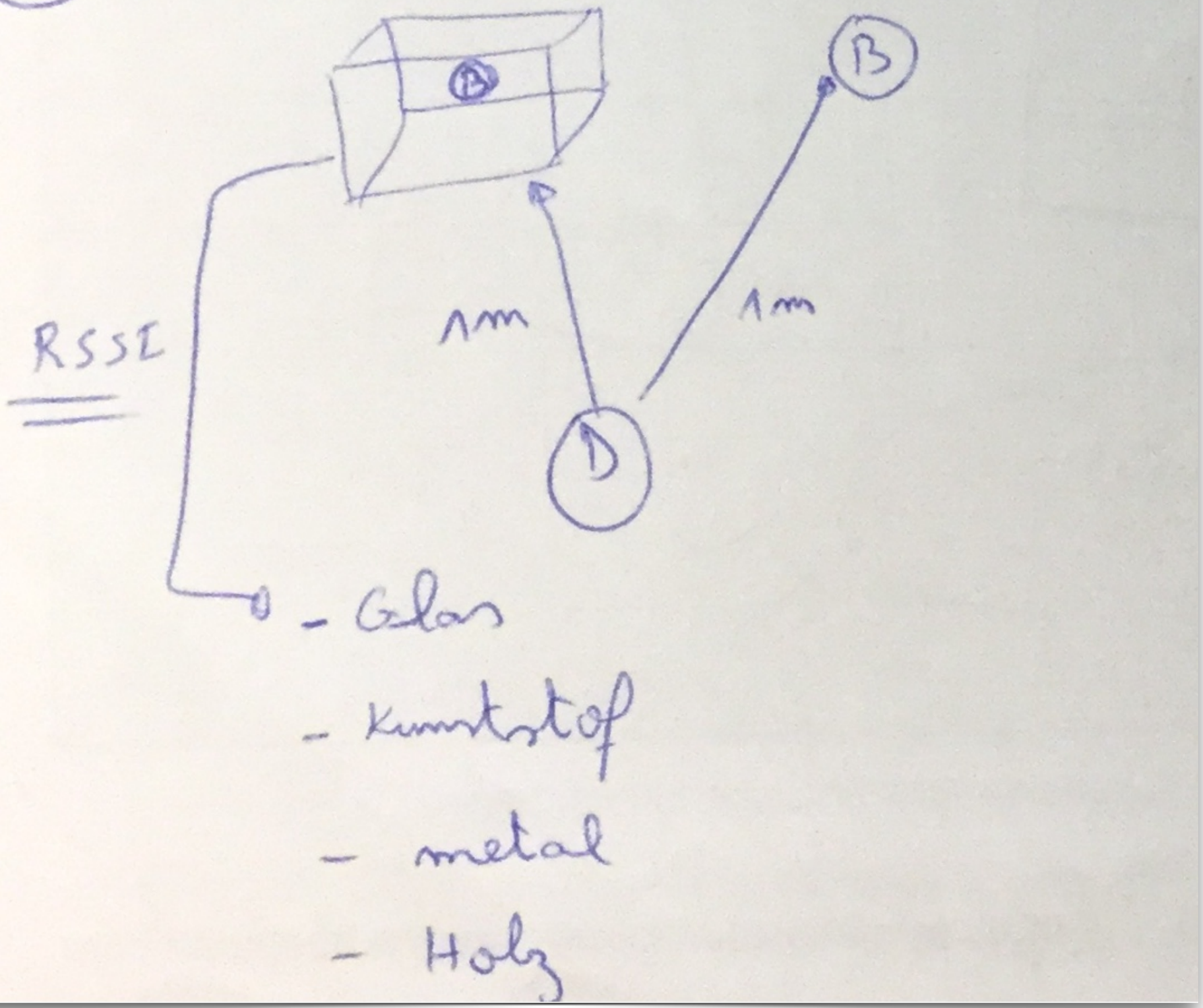
(II) - C



EXPERIMENT 3

III

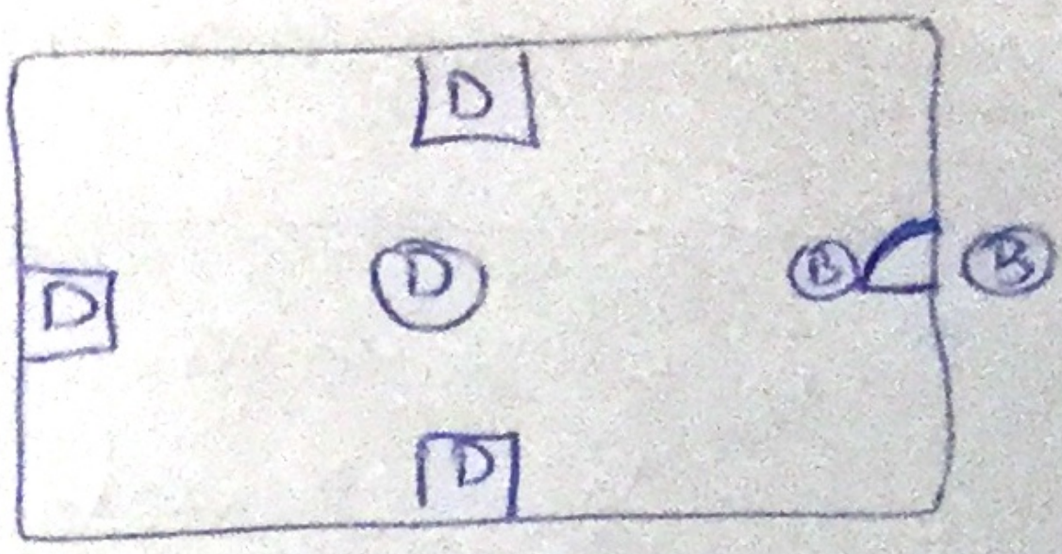
Schrank



EXPERIMENT 4

4

Tür



Tür auf / Tür zu

5

Wand