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ADVANCED TOPICS IN OPTOELECTRONICS, MICROELECTRONICS AND NANOTECHNOLOGIES

Close-range indoor transmitter localization using a system of low-cost SDR receivers

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ABSTRACT

This paper presents a close-range indoor transmitter localization system using a low-cost RTL-SDR setup. The purpose is the detection of illegal radio communications during class exams in a class where radio transmitters might be used. Current experiments are made on FM transmitter localization in 433MHz ISM band but the components were chosen to allow monitoring various frequencies.
Keywords: target localization, software-defined radio, close-range, indoor

1. INTRODUCTION: THEORY OF OPERATION AND DISCUSSION ABOUT RF

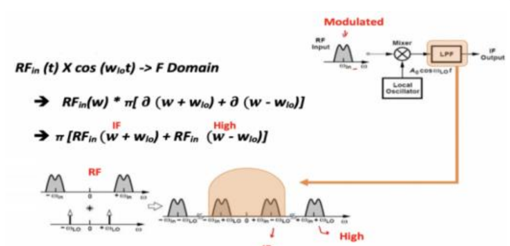
Fig.1 Theory of operation for a mixer. Bringing the spectrum towards 0 Hz, sampled by ADCs

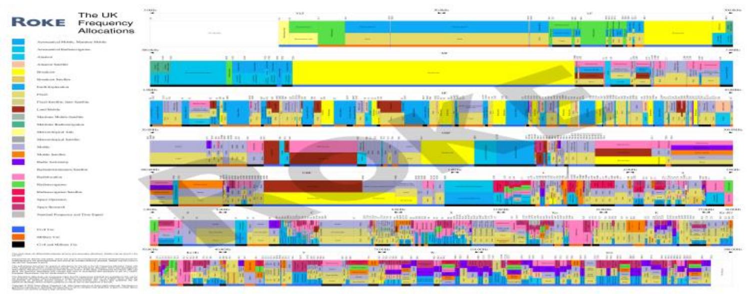
Fig 2. National treasure: RF spectrum allocation

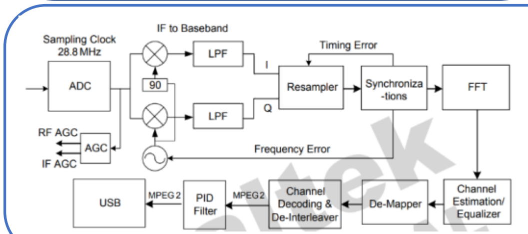

Fig. 3 The original low-cost RTL-SDR MPEG2 tuner IC: the Realtek RT2832U. A special raw mode allows I and Q direct sampling via integrated ADCs, bypassing the hardware processing chain (FFT, channel estimation, decode, de-interleaver), replaced by software processing chain running on the PC

Table 1. Low-cost RTL-SDR devices available on the market

Device Name	Tuneable frequency range or band	BW (MHz)	Cost (USD)
YARD Stick One	281 MHz – 481 MHz 749 MHz – 962 MHz	0.25	106.95
RTL-SDR	24 MHz -1766 MHz	2	29.95
HackRF One	1 MHz – 6 GHz	20	300
Ubertooth One	2.4 GHz	1	137.95
Kiwi SDR	10 KHz – 30 MHz	32	320
Nooelec NESDR Nano	24 MHz – 1766 MHz	2	23.95
Nooelec NESDR XTR Tiny(E4000)	65 MHz – 2300 MHz (with 1100 MHz – 1250 MHz gap)	2	33.95

2. STATE OF THE ART

Illegal transmitter localization is usually done using methods:

(a) Range-based: multiple receivers measure the distance to TX (via the Received Signal Strength or Time of Arrival)

(b) Angle-based: (via triangularization or angle of arrival)

(c) Fingerprint matching-based

3. CALIBRATION AND SIMULATIONS

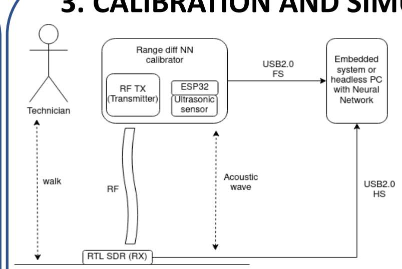

Fig. 4a
distance calibration.

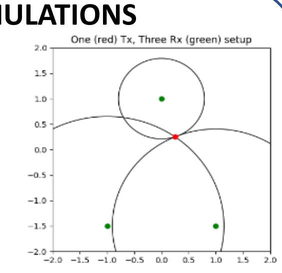

Fig. 4b
MLP-based sim experiments

4. MEASUREMENT SETUP AND RESULTS

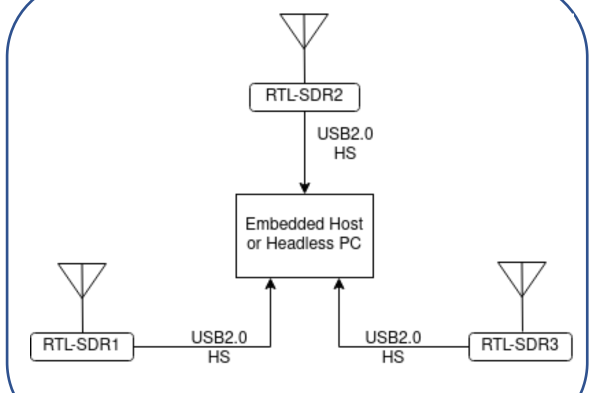

Fig.5 Measurement setup

$$(x-x_0)^2 + (y-y_0)^2 = r_0 \quad (1)$$
$$(x-x_1)^2 + (y-y_1)^2 = r_1 \quad (2)$$
$$(x-x_2)^2 + (y-y_2)^2 = r_2 \quad (3)$$

Fig.6 Three circle equations to be solved in range-based method of position solving

Table 2. Measurement results

Total covered area (m^2)	28.2	3.1	0.8	0.13
Avg positioning error (m)	0.11	0.2	0.1	0.06

5. CONCLUSIONS

- E4000 tuner IC setup could not sweep 2.4 … 5 GHz but HackRF devices could
- Precise indoor localization is hard as low-cost SDRs are not similar even if they are from the same batch.
- Plastic enclosures should be avoided, metal provides RF shielding
- A lot of RF pollution in cities => decreases the precision of measurements
- Sweeping speed of RF range depends on bandwidth of the receiver => as improvement one could only sweep common frequencies
- No low-cost solution to detect 5G mmWave transmitters

6. REFERENCES

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