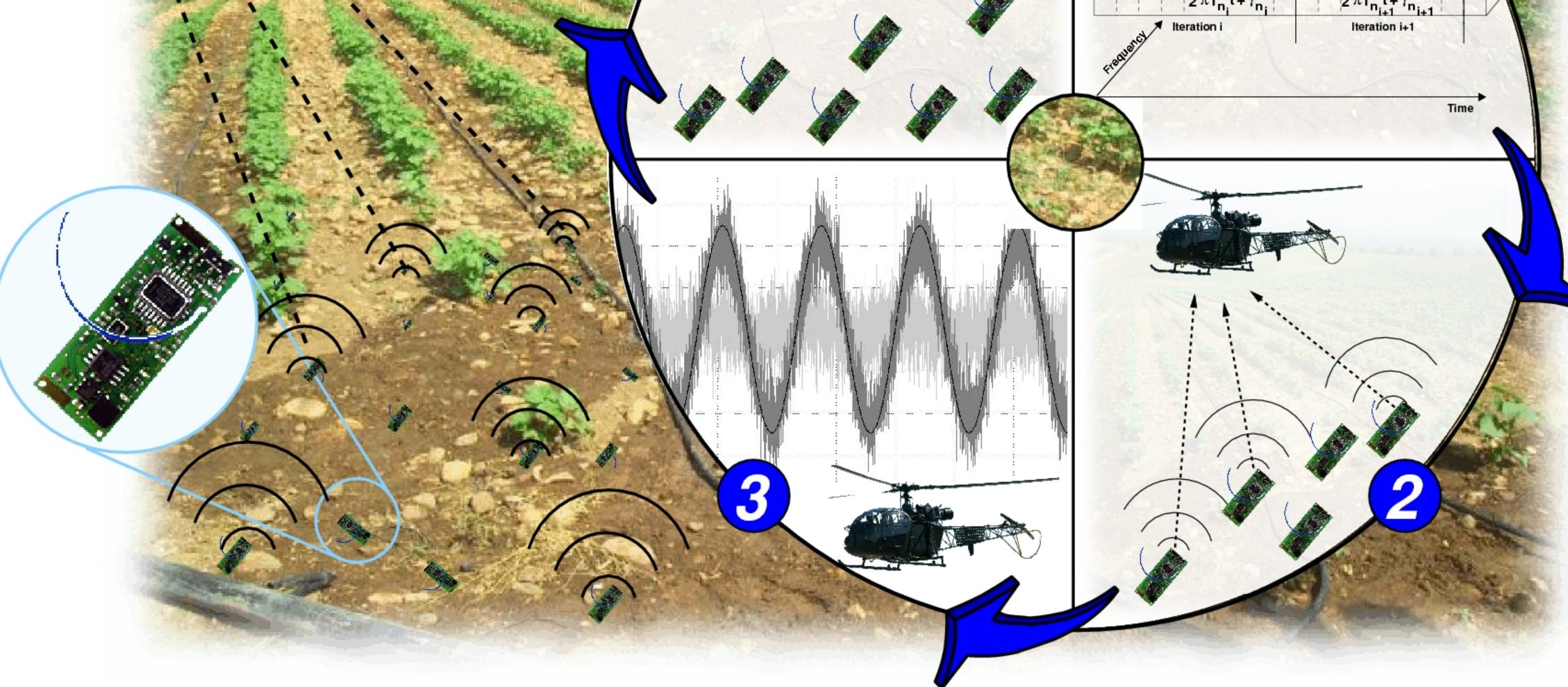
Distributed beamforming with software radios

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		Iterative process
	$2\pi f_1 t + \gamma_1$ $2\pi f_2 t + \gamma_2$	Phase 1: Random adaptation of carrier phase and frequency
	Mutation $2\pi f_{-} t + \gamma_{-}$ $2\pi f_{-} t + \gamma_{-}$	



Phase 2:

Transmit to destination as distributed beamformer

Phase 3:

Receiver estimates phase synchronisation of received superimposed signal

Phase 4:

Receiver broadcasts feedback to the network

Instrumentation



Experimental results

Experimental setting

4 transmit devices

Transmission: 2.4 GHz, 1.5dBi

Seedback: 900 MHz, 3 dBi

Solution Stance: 3m, 12, 24m, 45m



USRP Source Jnit Number: 0 Decimation: 20 Variable Sink **/ariable:** root mean squ requency (H Gain (dB): 2 Side: B **X Antenna:** RX2 GMSK Mod Samples/Symbol: 2 USRP Sink Packet Encoder Unit Number: 0 amples/Symbol: 3 Interpolation: 400 Bits/Symbol: 1 in Frequency (Hz): 902M Access Code: Gain (dB): 0 Pad for USRP: Y Multiply Const Side: A Payload Length: 8 C**onstant:** 16.384k Transmit: Auto T/R USRP Source GMSK Demo Jnit Number: 0 amples/Symbol: 2 Decimation: 200 Packet Decod Gain Mu: 0 🕨 in Message Sink Access Code: requency (Hz): 902 G**ain (dB):** 20 mega Relative I Side: A Freq Error: 5m X Antenna: RX USRP Sink Signal Source Unit Number: 0 ample Rate: 320k erpolation: 40 Multiply Const Vaveform: Sine Multiply Cons Frequency (Hz): 2.40 requency: 1k ain (dB): 0 Amplitude: 1)ffset: 0 ransmit: Auto T/I

GNU Radio

Implement: transmit- receive strategy

Carrier phase offset uniformly random

Real valued feedback modulated

% 600 iterations

3 meters distance:

Gain (single link): 3.99 dB Gain (unsynchronised): Iteration of best amplitude: 224.4

12 meters distance:

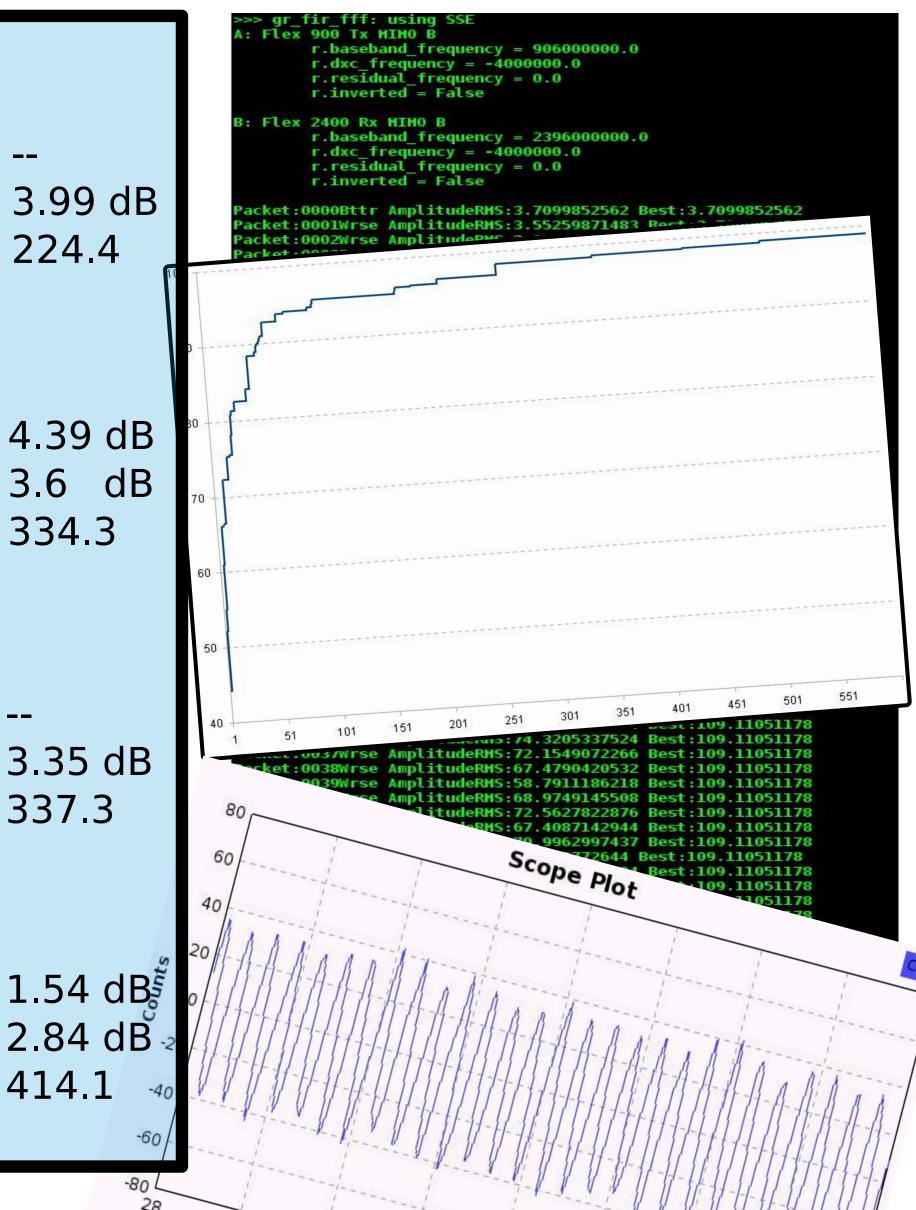
Gain (single link): Gain (unsynchronised): 334.3 Iteration of best amplitude:

24 meters distance:

Gain (single link): 3.35 dB Gain (unsynchronised): Iteration of best amplitude: 337.3

45 meters distance:

Gain to single link: Gain to unsynchronised: Itertion of best amplitude



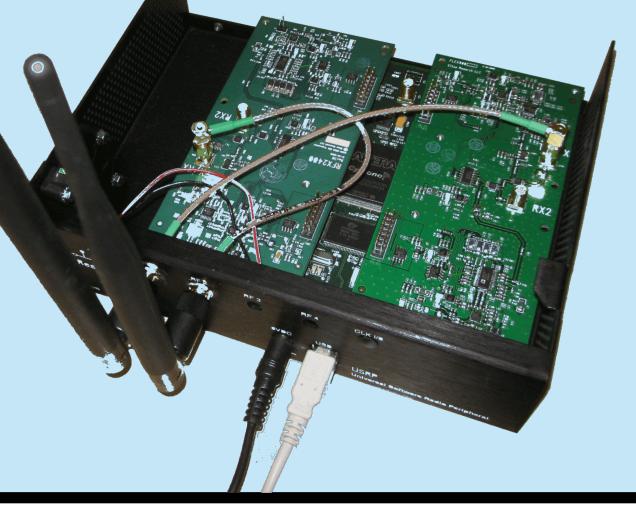
USRP software radio

Sclock synchronised

🔦 Separate boards for transmit / receive

RFX2400 and RFX900 motherboards

WSRP2



Future work

- Improve synchronisation performance
 Reduce randomness in the synchronisation process
 Utilisation of the FPGA
- Synchronisation via GPS
- Sonsider movement of nodes
- Utilise TX/RX port of USRP daughterboards
- BER for data transmission

Node	Which USRP
 Transmitter 	● 0
⊖ Receiver	O 1
	O 2
teration:	O 3
teration: Amplitude RMS: Start	O 3 Multiplier USRP: 16.3 Volume: 1



