Automatic Impedance Matching for 13.56 MHz NFC Antennas

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Outline

NFC Research Lab

- Part of the R&D department of the Upper Austria University of Applied Sciences
- Funded by the BMVIT (Federal Ministry for Transport, Innovation and Technology) and FFG (Austrian Research Promotion Agency)
- We are focusing on
  - NFC hardware development
  - interoperability and performance testing for NFC systems
  - implementation of NFC applications
  - secure aspects for NFC systems and applications
- 1st Austrian NFC Trial
- Annual NFC Congress in Hagenberg

Outline

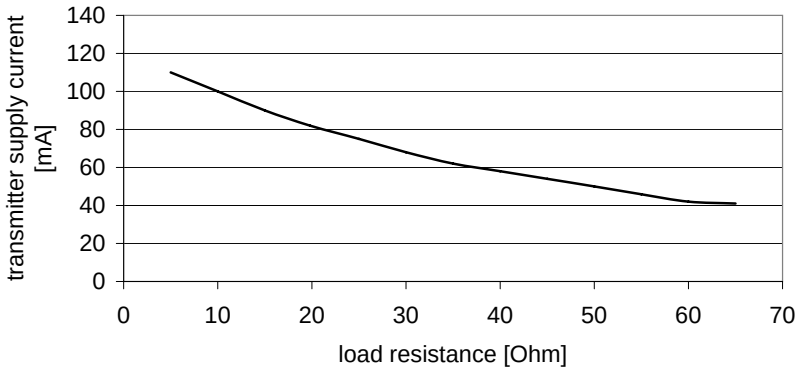
NFC Equipment and its Antennas

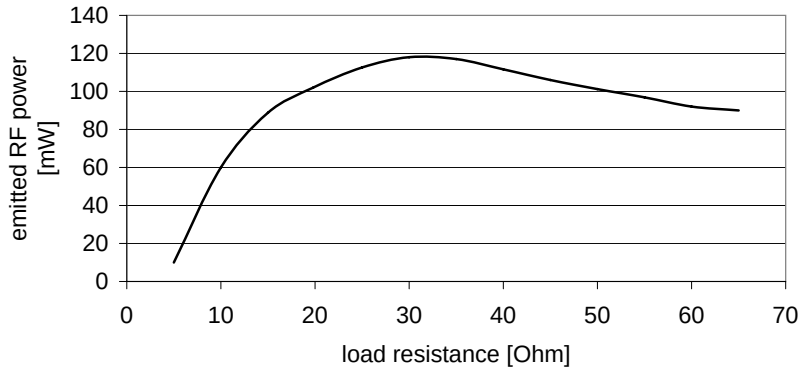
- NFC transmission module IC has external antenna
- Mobile devices have though space-saving requirements
- Non-standard antennas necessary to fit casings
  - antennas have varying characteristics (shape, impedance)
  - each antenna has a certain impedance measured at its clamps

Outline

What is Impedance Matching?

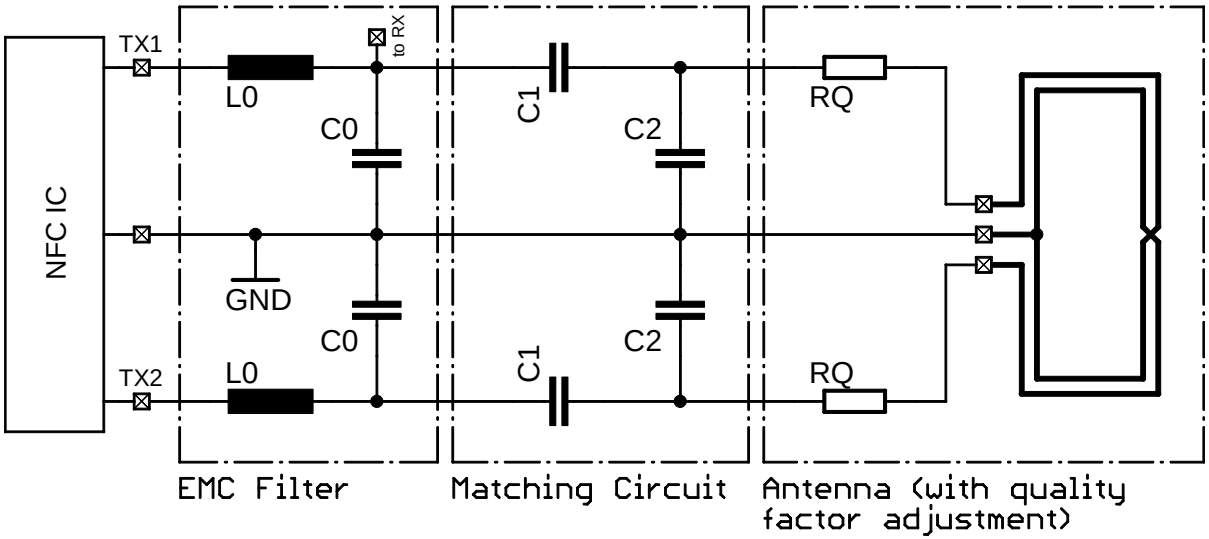
- Antenna's impedance is the NFC IC's load resistance
- 2 parameters depend on the NFC IC's load resistance
  - the transmitter supply current and
  - the emitted RF power
- Both parameters decrease with increasing load resistance





- Good trade-off between both parameters around 40 to 50 ohms

NFC Antenna Topology



- NFC antenna topology with EMC filter, matching circuit, quality factor damping resistors and antenna coil
- C_1 and C_2 are adjusted until the whole topology circuit matches 50 ohms at its clamps (TX1, TX2)

Disadvantages of Manual Impedance Matching

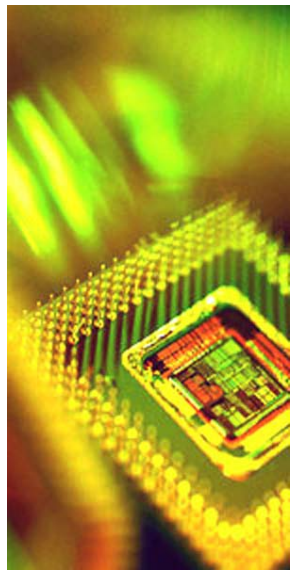
- Expensive equipment (network analyzer, impedance analyzer)
- Time-consuming procedure
- Good sense of choosing the right capacitor values necessary

Outline

Requirements

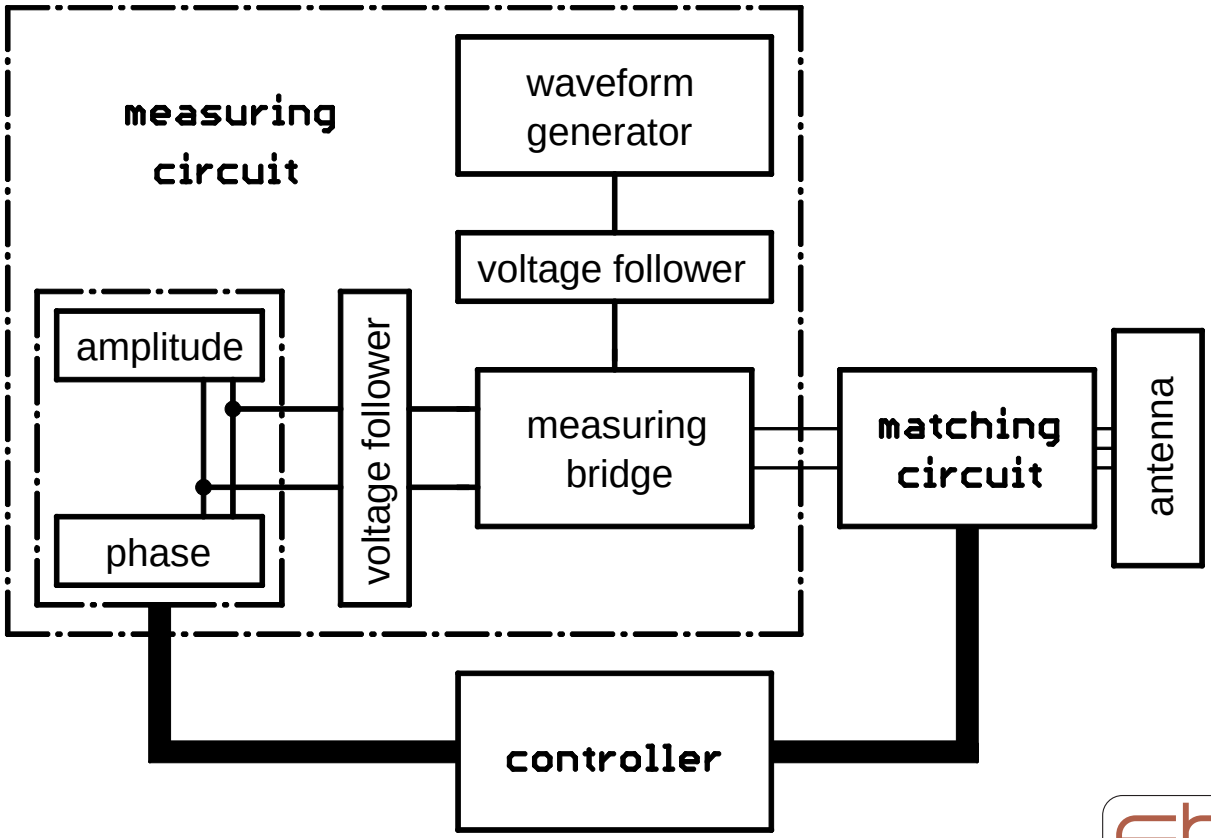
- Most NFC devices are mobile handsets
- Automatic tuning system must be small in shape and size
- Single chip solution preferred

$\Rightarrow$ ideal solution has only integrable parts



System Design

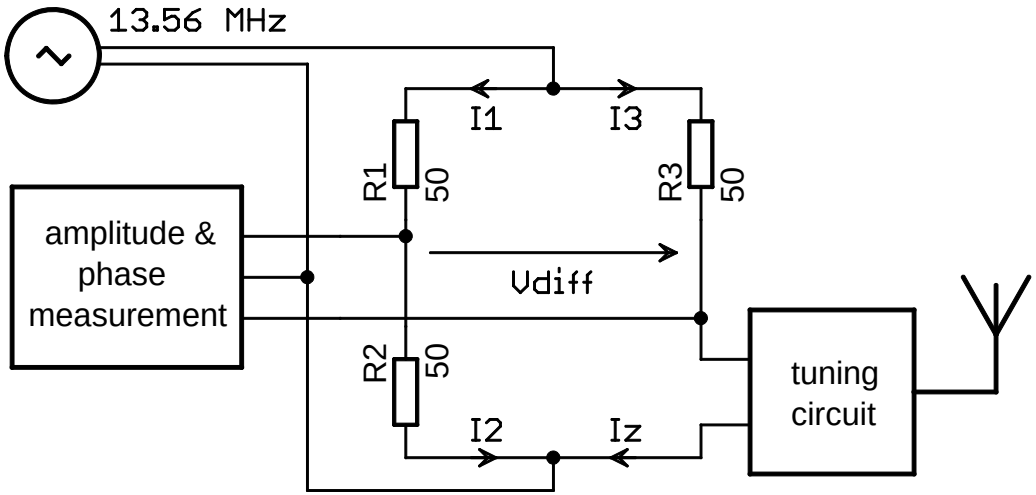
- Automatic tuning system design split into its three components: measuring circuit, matching circuit and controller component.



Outline

Measuring Bridge

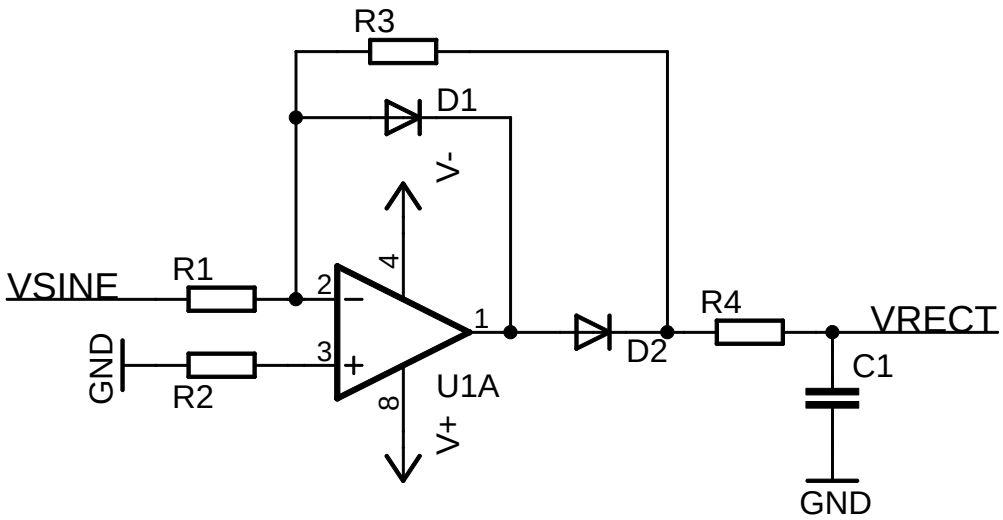
- Wheatstone bridge with 13.56 MHz sinusoidal supply
- Bridge is balanced ($V_{diff} = I_2 \cdot R_2 - I_Z \cdot Z = 0$ V)



$\Rightarrow$ Tuning circuit is matched to 50 ohms (at the operating frequency)

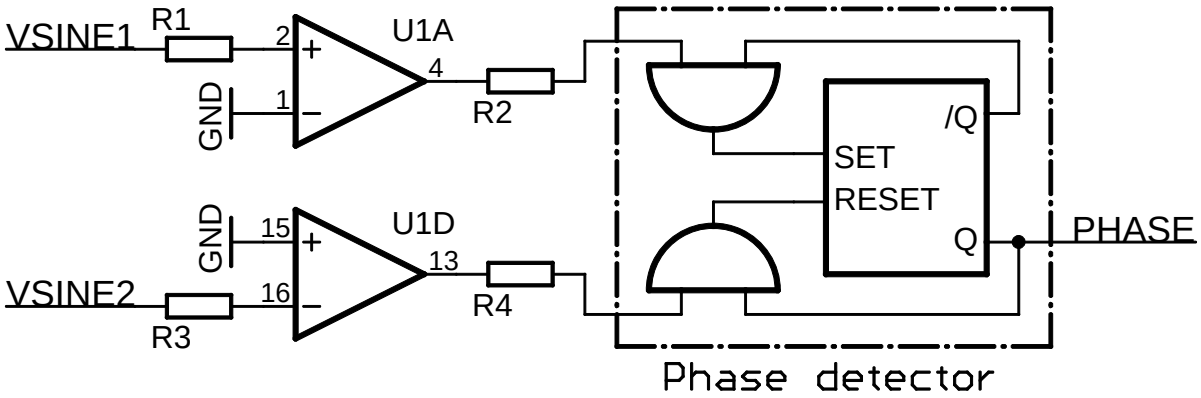
Balancing the Amplitude of V_{diff}

- Measuring rectifiers are used to rectify
  $V_{SINE1} = I_2 \cdot R_2$ and
  $V_{SINE2} = I_Z \cdot Z$
- Resulting signals are low pass filtered
- V_{diff} is calculated in software after analog-digital conversion



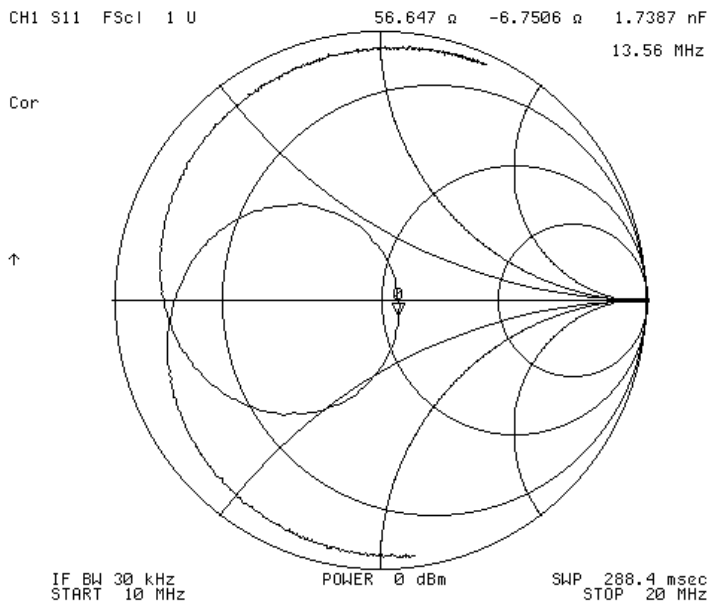
Balancing the Phase of V_{diff}

- V_{SINE1} and V_{SINE2} shaped into rectangular signals
- Phase detector: phase-offset is converted into a pulse-width modulated signal
- PWM signal is low pass filtered and fed into an analog-digital converter



Verification of the Measuring Circuit

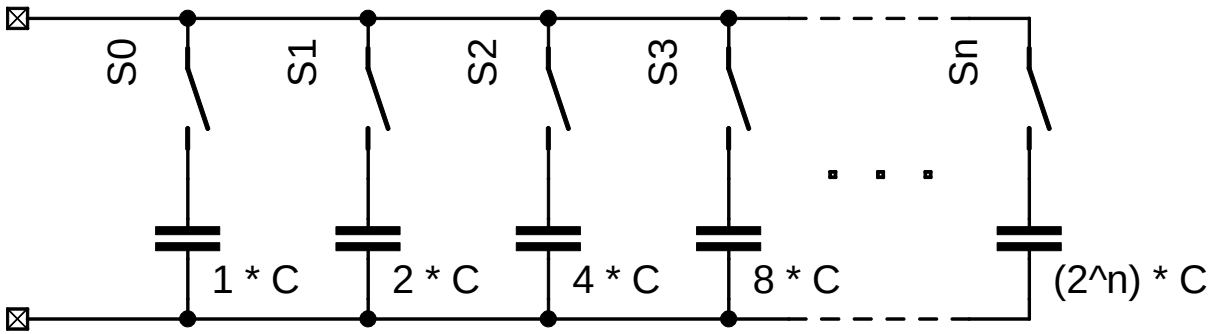
- Verified with a manually tunable antenna circuit
- The antenna is connected to the measuring circuit and tuned
- Tuning is verified with a network analyzer
- Result is approximately the same with several tested antennas:



Outline

Matching Circuit

- C_1 and C_2 in the antenna topology are replaced with capacitance arrays
- Capacitance array: network of parallel switched capacitors
- Capacitors switched with low-capacitance DMOS switches



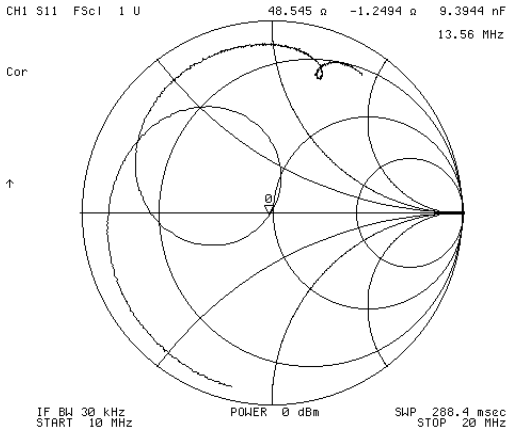
Outline

Controller

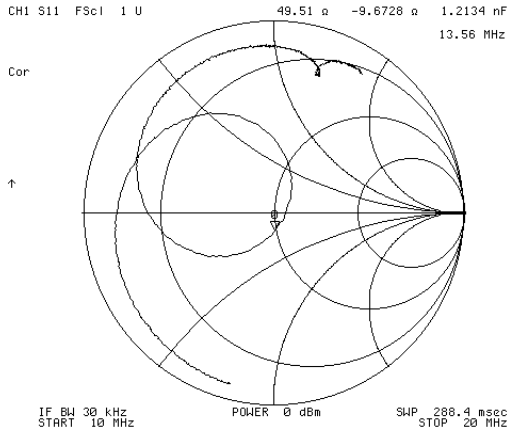
- Analyses the measurands by reading the values from analog-digital converter
- Controls the capacitance arrays
- Tuning algorithm to minimizes amplitude and phase of V_{diff} by optimal adjustment of C_1 and C_2

Outline

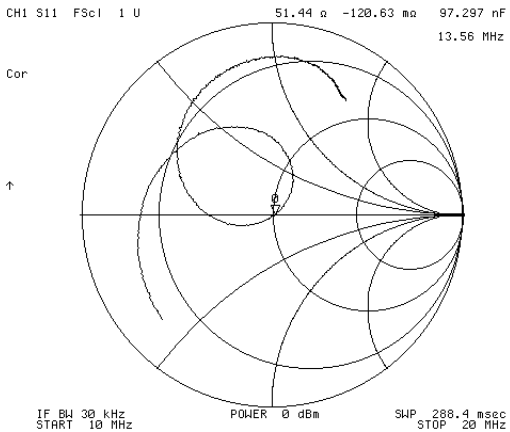
Automatic Tuning Results



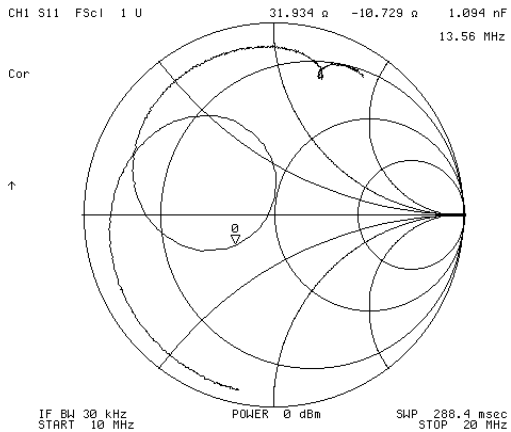
Antenna 1



Antenna 2



Antenna 3



Antenna 4

Summary and Outlook

- Automatic impedance matching significantly simplifies the integration of NFC ICs into applications.
- This automatic tuning system successfully finds the optimum values for the antenna circuit's tuning capacitors.
- Only integrable components are used.

- Outlook
  - Parasitic effects of the DMOS switches need to be investigated.
  - The tuning algorithm may be optimized.
  - The whole system should be integrated into a single IC.