

## Antenna tuners voor mobiele telefoons

Bits&Chips Hardware Conference 2010

**EPCOS AG**

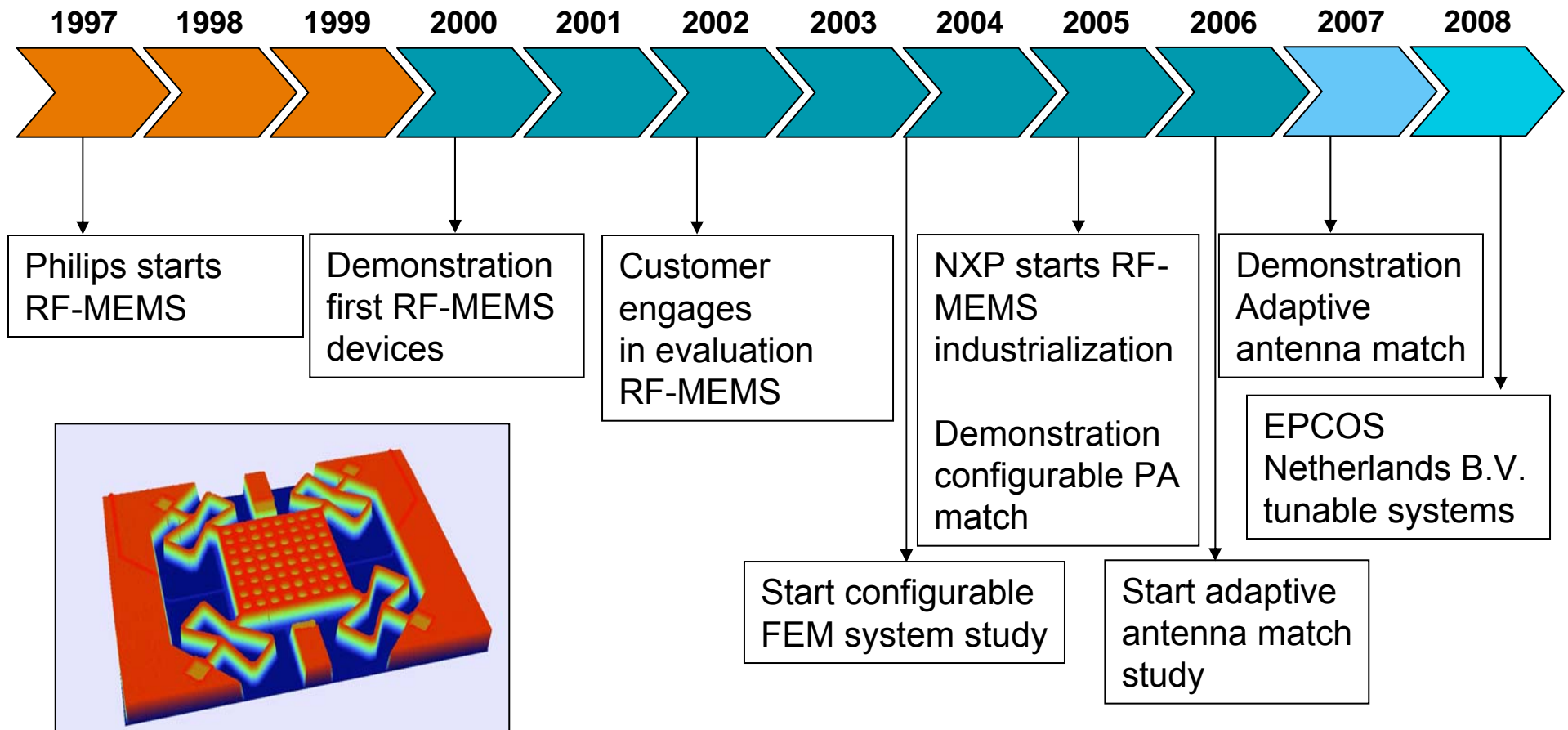
A Group Company of TDK-EPC Corporation

SAW • TunelC

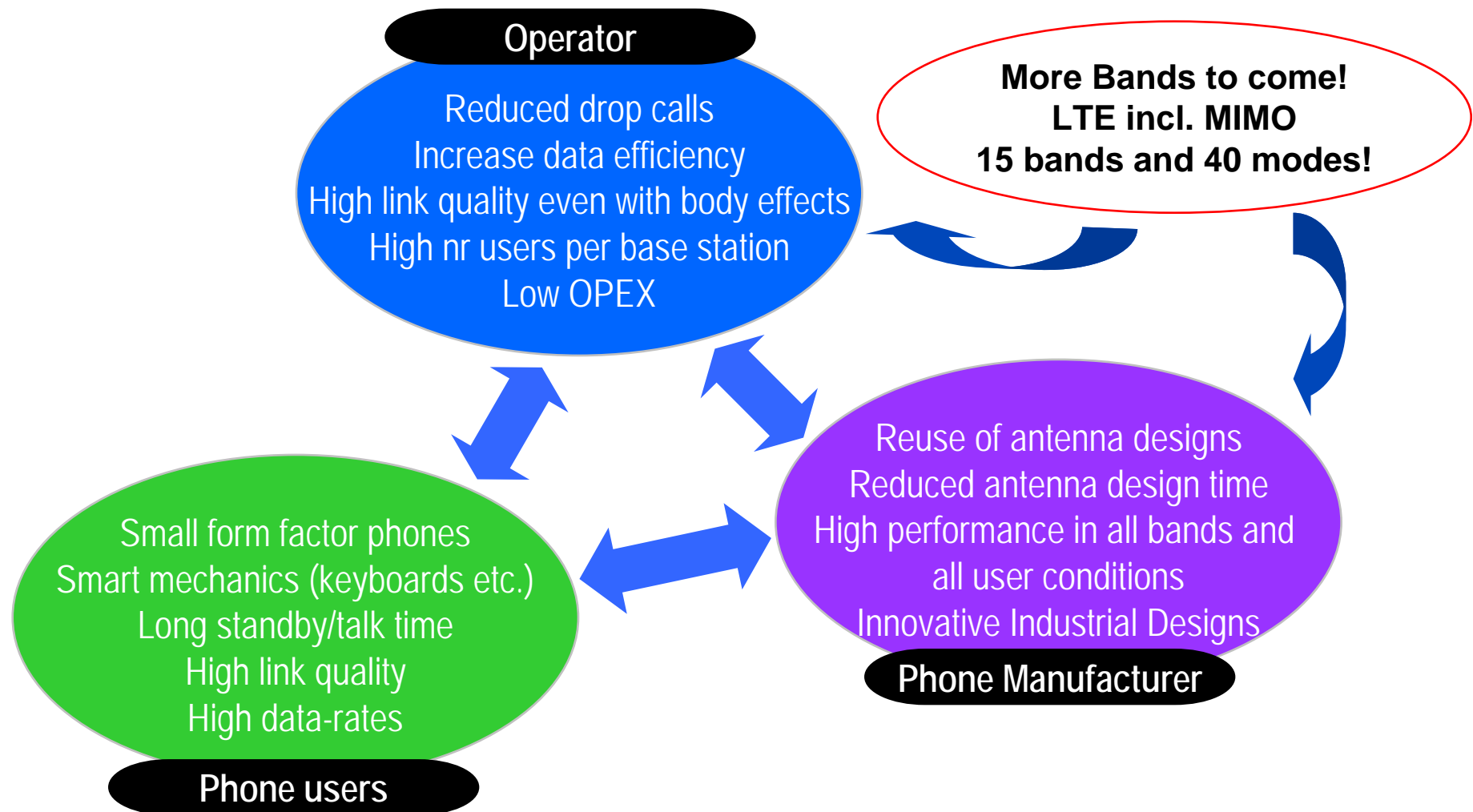
Nijmegen, the Netherlands

June 17, 2010

# History of EPCOS and tuneable systems



# Benefits of TDK-EPC Antenna Tuner Systems





## Future requirements: other

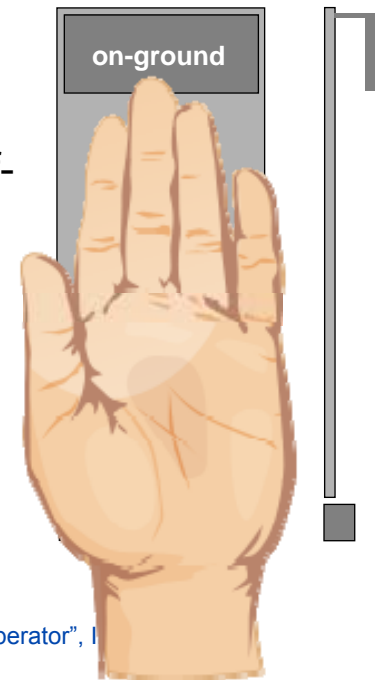
- In addition to an increased number of bands, several other important changes are on the horizon:
- **MIMO**: a big challenge due to the substantial increase in the number of antennas and the need to maintain good isolation and low correlation (particularly in the low frequency bands)
- **The HSPA Rel. 10**: the dual-band dual-carrier feature will require simultaneous transmission and reception in different frequency bands (low-band and high-band at the same time)

## Antenna efficiency

- Antenna efficiency may have reduced over the last approx. 10-15 years, for the following reasons:
  - **Integration:** mobile antennas are now often part of an assembly that includes a camera, speakers, etc.
  - **Size and style constraints:** antennas have been reduced in size, in particular to allow highly stylised and very thin phone designs
  - **Antenna technology:** there have been no significant advances (in terms of RF performance)
  - **Quad- and penta-band platforms:** these have lead to more “off-ground”, “monopole-like” antennas located at the bottom of the phone. These antennas suffer greater losses when held next to the user’s head.

For example, from [1], when held by real users, “off-ground” antennas are more lossy than “on-ground” antennas by:

- 3 - 3.5 dB in the 900 MHz region
- 8.5 - 9 dB in the 1900 MHz region



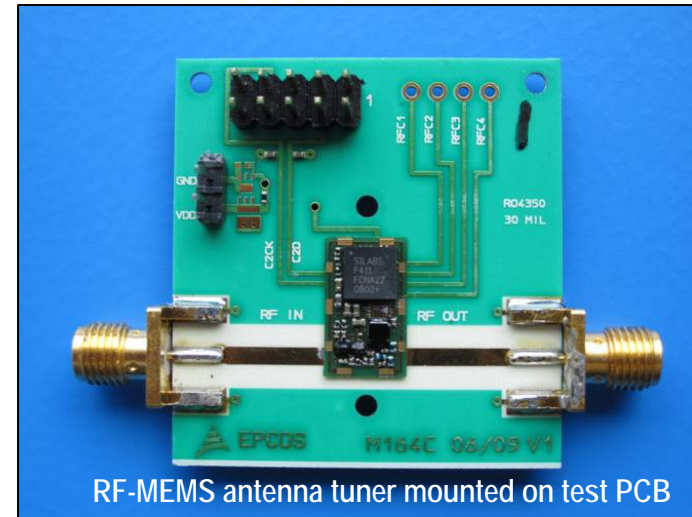
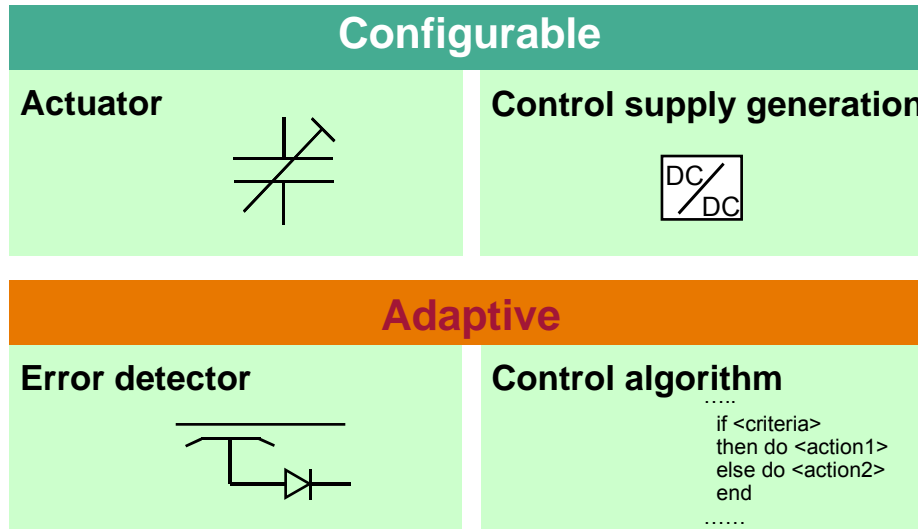
[1] Lindberg, P., Kaikkonen, A., Kochali, B., “Body Loss Measurements of Internal Terminal Antennas in Talk Position using Real Human Operator”, IET Workshop on Antenna Technology (iWAT), 4-6 March 2008, pp. 358 - 361.

## Summary

- Antenna mismatch due to user interaction is an unsolved problem that must be addressed by adaptive circuitry.
- Antenna efficiency can be improved, but normally at the expense of bandwidth. The antenna could be tuned/reconfigured in order to recover this bandwidth.
- More bands are required in the future, increasing the need for tuned/reconfigured solutions
- Multi-band MIMO will be required. To maintain good isolation and low correlation over a wide frequency range, some additional tuned circuitry may be required.
- **“Passive” antennas are at/beyond the limits of their capability.**

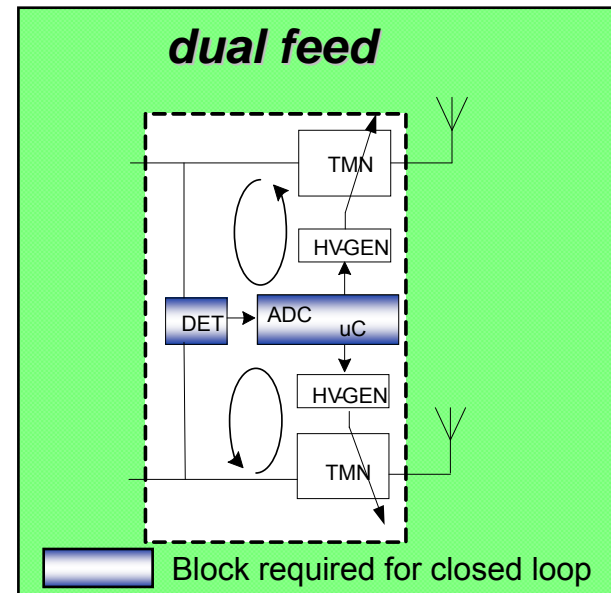
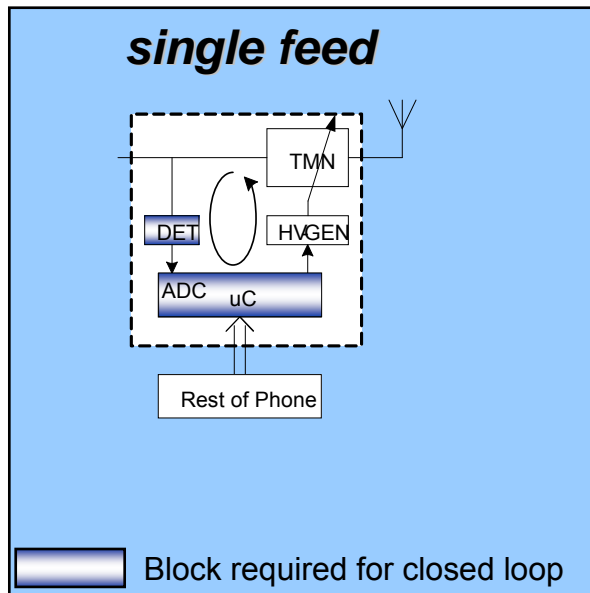
# Antenna Tuners

# Key elements of Antenna Tuner Products



- **1. RF-MEMS or semiconductor switches**  
RF-MEMS designed by EPCOS NL
- **2. Control supply and High Voltage generation**  
Designed by EPCOS NL
- **3. RF Detection**  
Designed by EPCOS NL
- **4. Microcontroller**  
Specified by EPCOS NL
- **5. Control Algorithm & Software**  
Developed by EPCOS NL
- **6. Multi Chip Module**  
Designed by EPCOS NL

# Antenna Tuner Projects



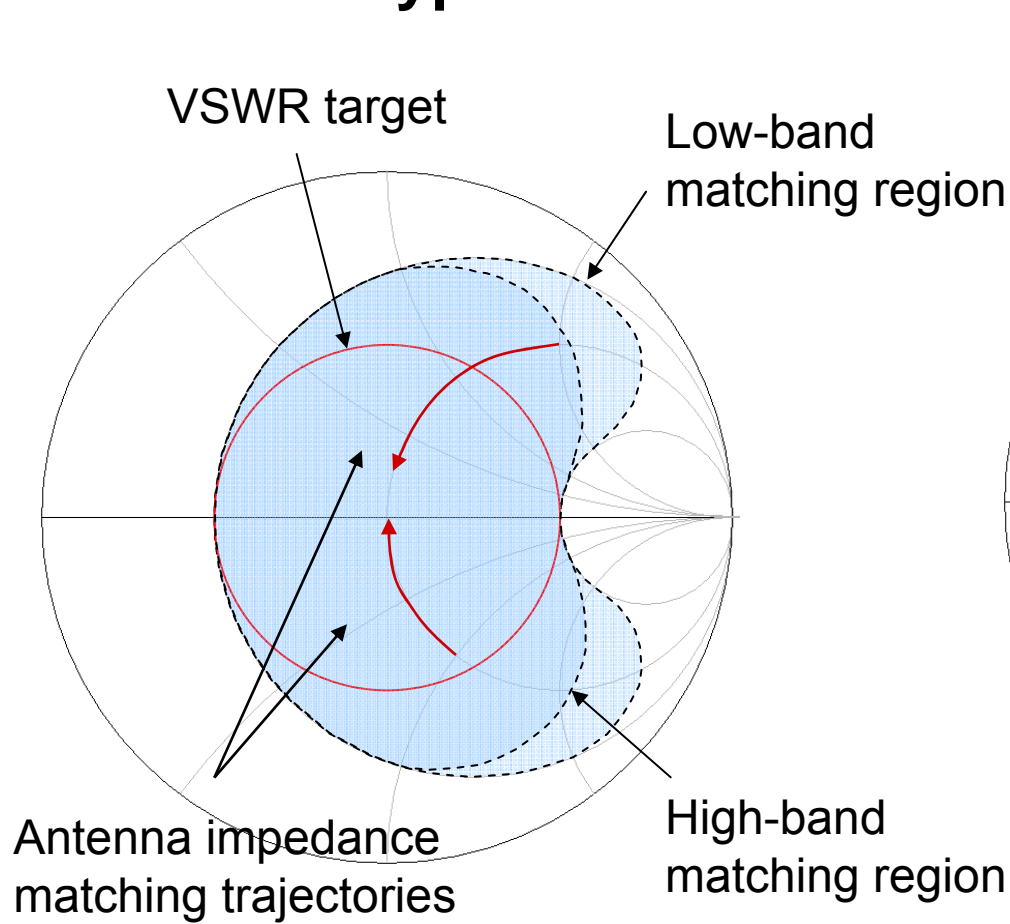
**Open loop:** front-end sets frequency band tuner; fixed settings, pre-programmed

-> Improved performance for default user case (no hand, no head)

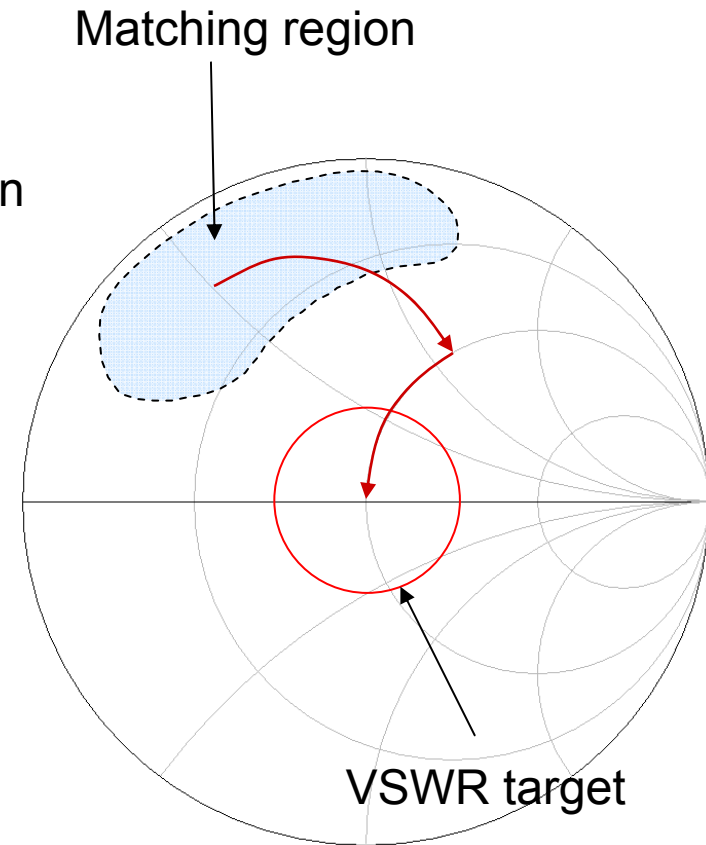
**Closed loop:** tuner searches most optimal matching situation; dynamic, continuous adaptation

-> Greatly improved performance in all user cases

# AdAM: Tuner types



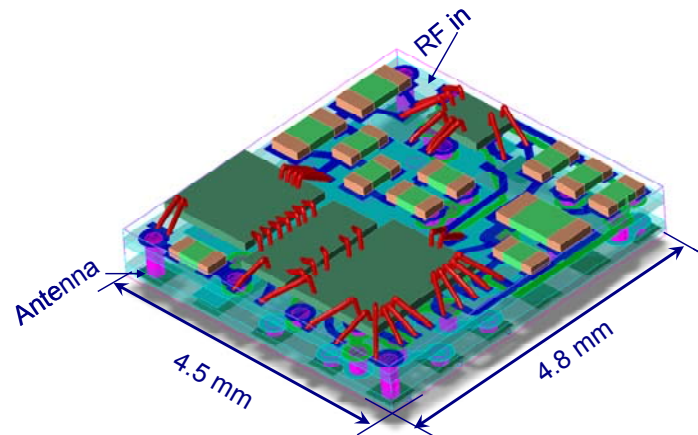
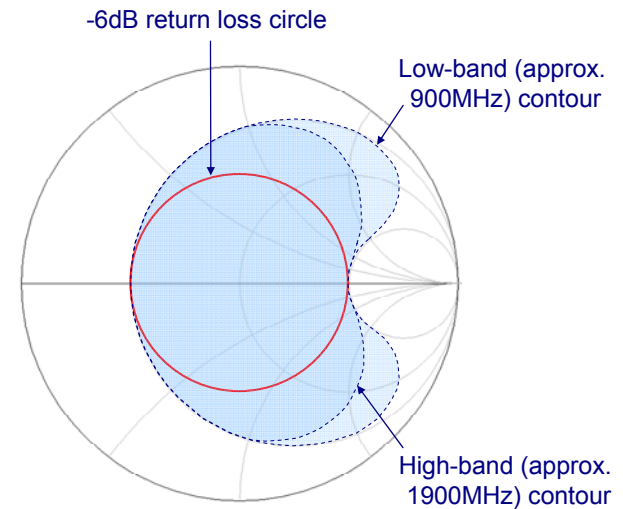
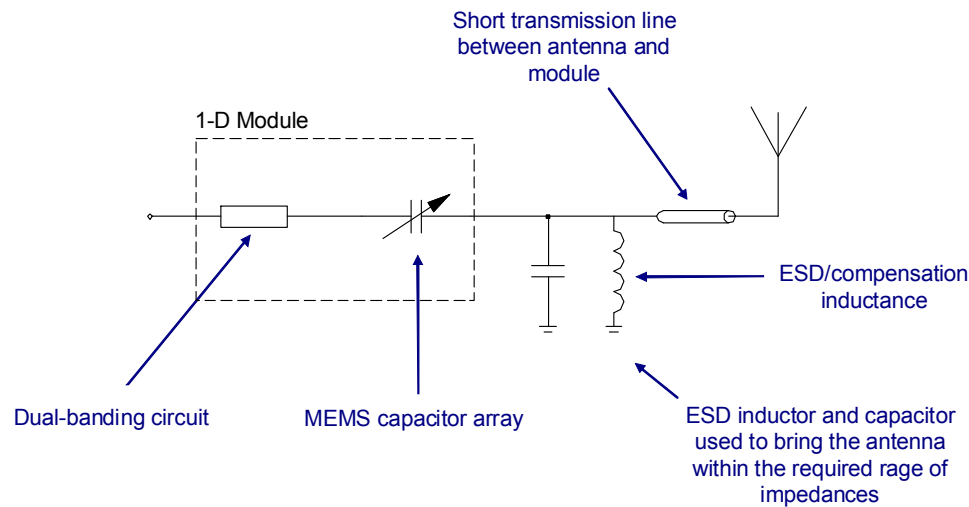
1 dimension (1-D)



2 dimensions (1-D)

# Single Feed Antenna Tuner: T100

Basic topology:



Latest version, currently in assembly

- Impedances within the -6dB return loss circle are generally improved (reactance cancelled)
- Impedances outside the -6dB return loss circle are brought within it

# Interface domains

The T100 adaptive antenna matching module has three interface domains towards the rest of the mobile phone system:

- RF
- Supply
- Control

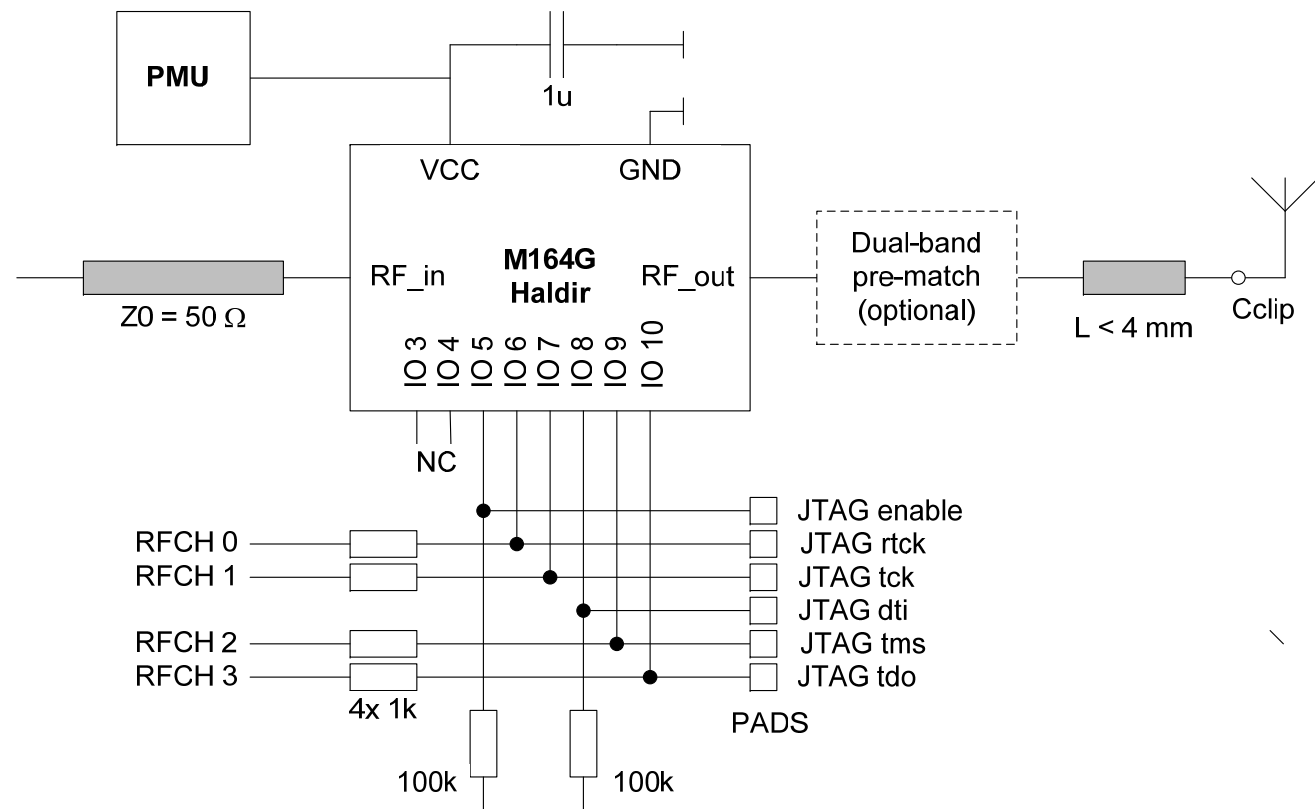
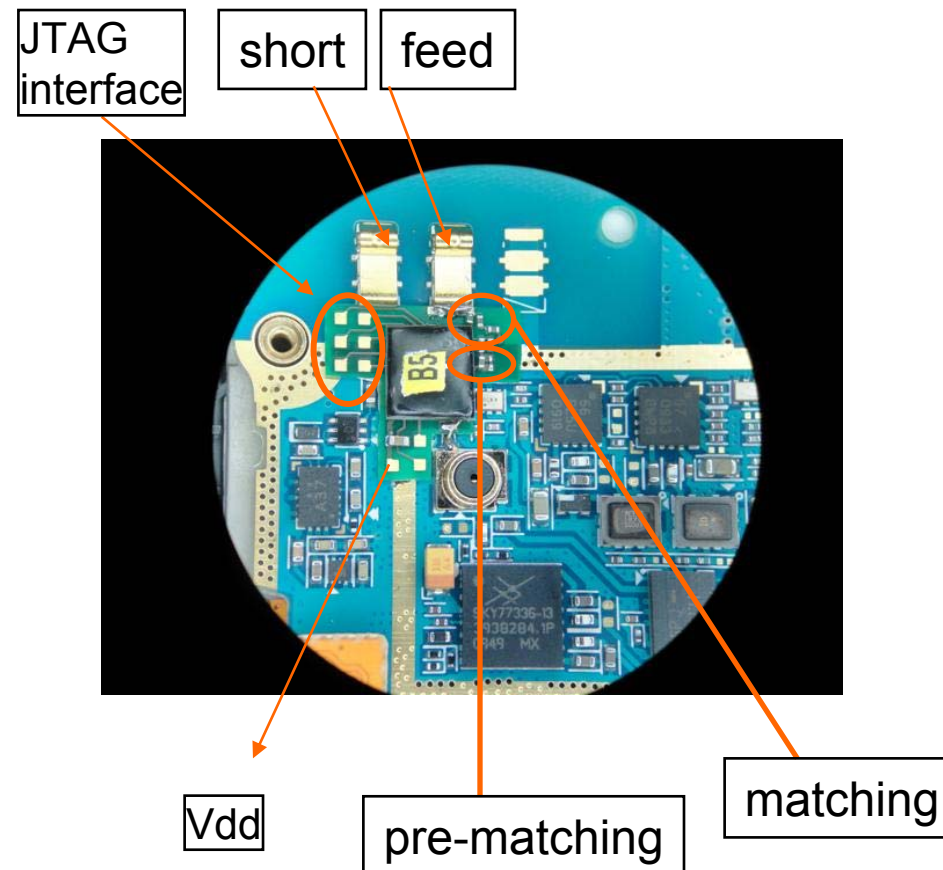


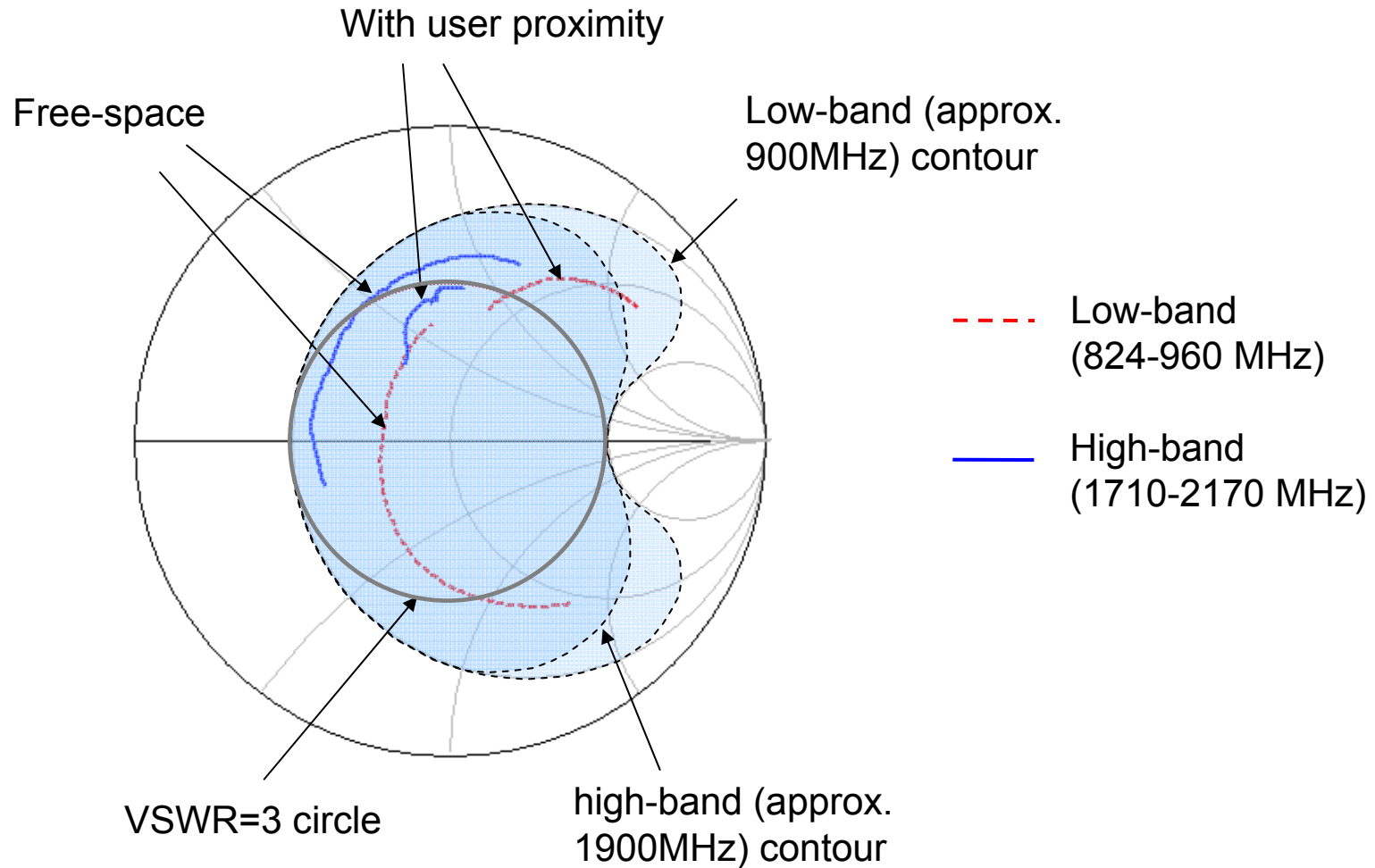
Figure 2. Application diagram

## Module build in

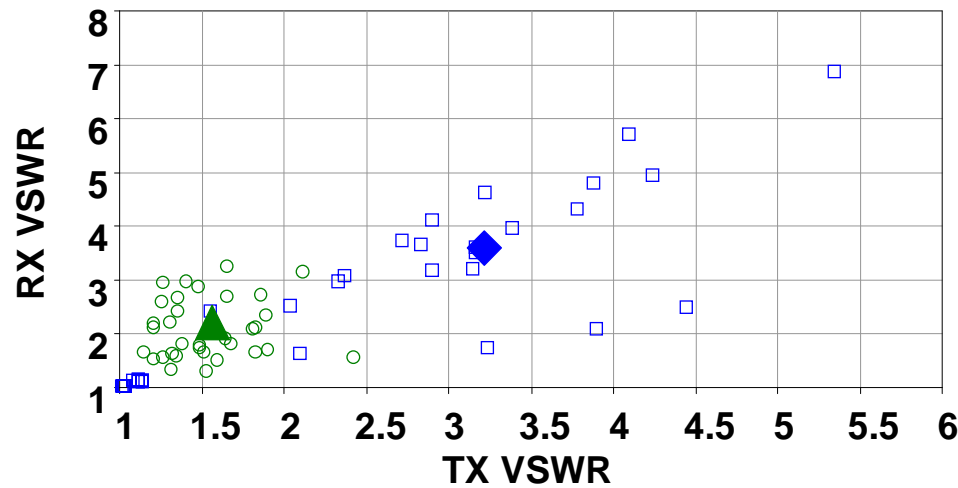
- A small module is made and is placed inside a commercial available phone:



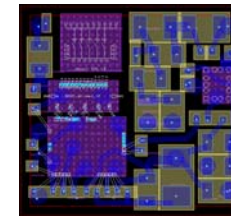
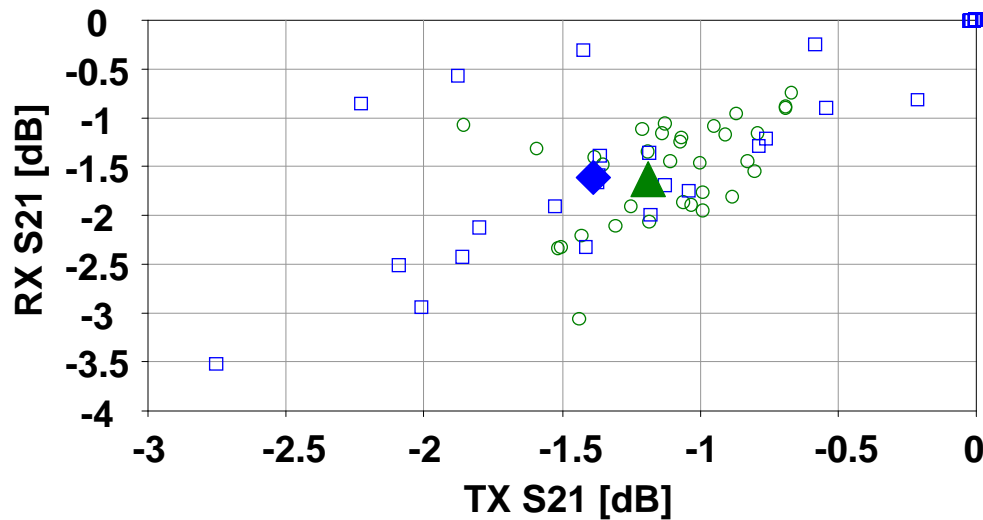
# AdAM 1-D: antenna response



# AdAM 1-D: VSWR and $S_{21}$ after adaptation

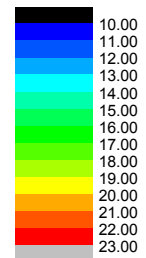
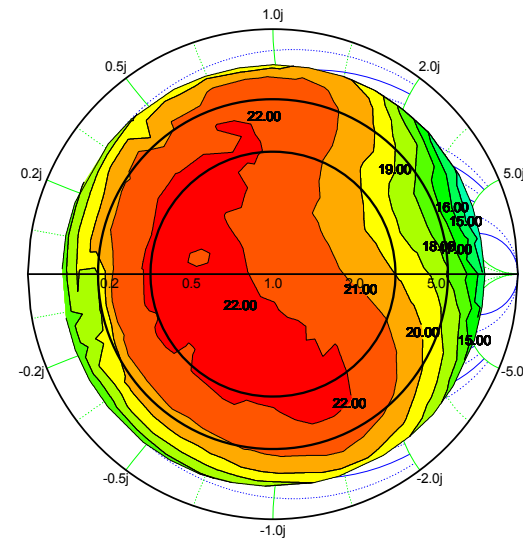
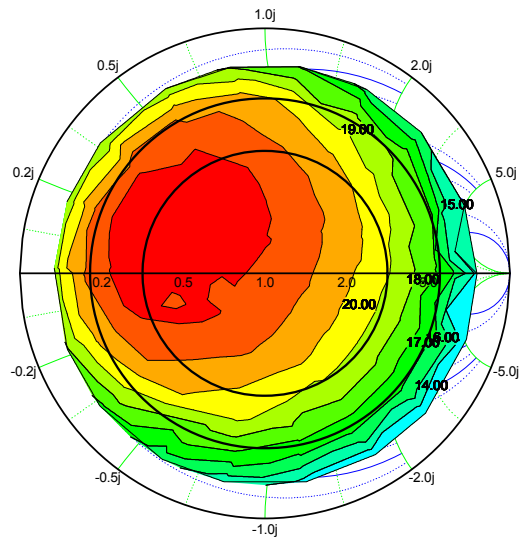


- per freq with AdAM
- ▲ average with AdAM
- per freq without AdAM
- ◆ average without AdAM



- 4.8 \* 4.5 mm
- Integrated controller

## Phone Load-pull on BandVIII (882MHz)



- Phone loadpull Antenna + fixed match removed
- Due to the antenna tuner the max achievable output power is reached at a larger range of mismatch conditions.
  - Mismatch conditions might be caused by body-effects (hand-covering the antenna)
  - or
  - Antenna not covering all frequency bands equally optimal

Phone + T100 loadpull

## Definitions

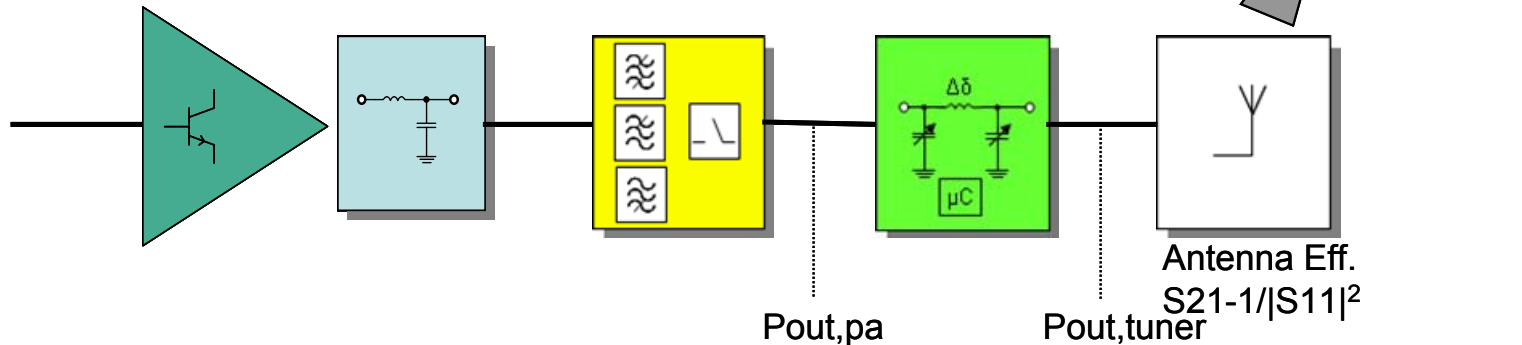
- **In order to quantify performance improvements the following terms are defined:**

$$\text{MobilePhoneEfficiency}(\eta) = \frac{\text{Average\_RF\_Power\_out}}{\text{average\_DC\_Power\_in}} = \frac{P_{\text{out, average}}(\text{mW})}{P_{\text{in, average}}(\text{mW})} * 100\%$$

$$\text{MPE\_improvement} = \frac{\text{MPE\_with\_tuner} - \text{MPE\_without\_tuner}}{\text{MPE\_without\_tuner}}$$

- **Remark: Current consumption is measured during active connection with CMU, however without any other peripheral active. Also LCD is blank during current consumption measurement.**

## Definitions cont'd



- $P_{out,pa}$  → Without Antenna Tuner:  
Output power after Duplexer, filter and switches, **including estimated loss of fixed matching network!**
- $P_{out,tuner}$  → With Antenna Tuner  
Output power after Antenna tuner
- Antenna Eff → Antenna efficiency in dB including fixed matching network.
- $P_{out,ant}$  → Actual transmitted RF power by the antenna

$$P_{out,ant} = P_{out,pa} - \text{Antenna Eff}$$

## Overall Conclusions

- User Interactions used:
  - The used user interactions are very mild interactions, real case user interactions cause much greater effect on the antenna. In these cases the improvements caused by the Antenna Tuner are much greater.
- The T100 can improve a typical commercial phone very well, in both low and high band, overall Mobile Phone Efficiency increases with on average 50%.
- A bad designed phone can be improved very well, improvements of MPE of >800% are seen (in low band), while on average the MPE improves with >200%.

## Final Conclusion

- Antenna tuners can greatly help out to improve MPE, however:
  - The antenna tuner requires series resonant antenna's
  - For optimum performance the antenna, antenna tuner and PA should be designed together, optimally matching each impedances.
- A very good designed phone can not be improved that much, however with the launch of more frequency spectrum antenna tuners will be required to meet the overall operator demands.
- Newly launched mini phones are expected to suffer more on user interactions and will have overall a less good antenna. Expectations are that antenna tuners will show significant performance improvements.

**TDK-EPC**

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