Point-One

Pole of innovative technology on nanoelectronics and embedded systems

MEMSLand

Cost Effective MEMS to Develop a Sustainable High Tech Business

BC BAW Filters

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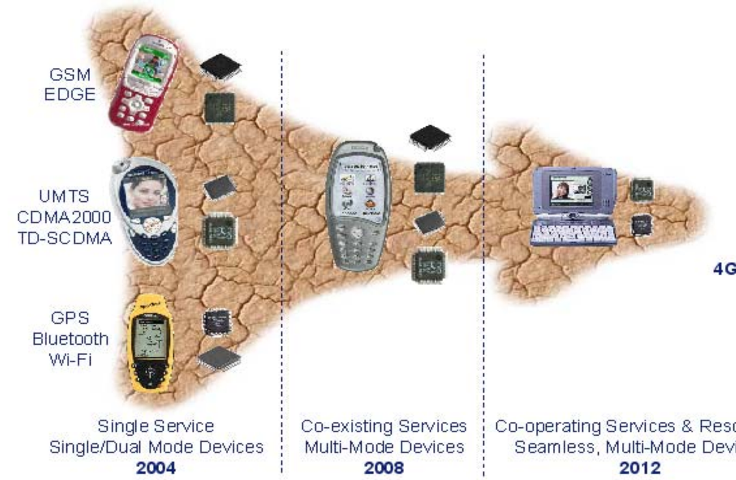
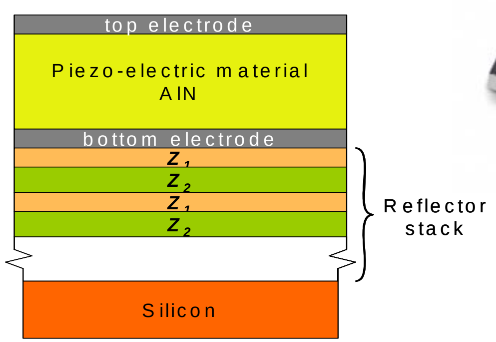
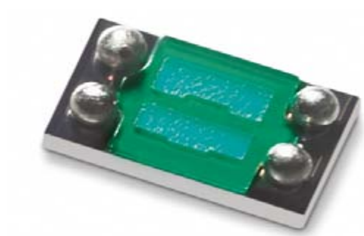
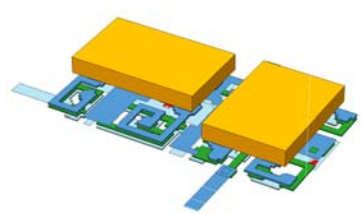
BAW Filters: Introduction

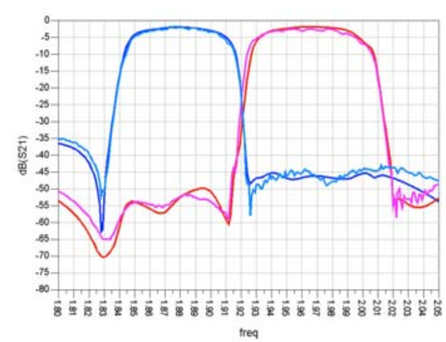
- future multimode applications require improvements in RF filter size and performance
- BAW uses piezoelectric thin film MEMS resonators to design small, high quality RF filters

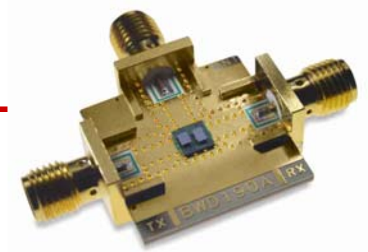












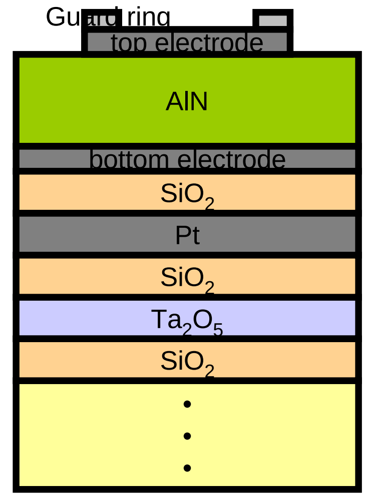
NXP BAW technology performance

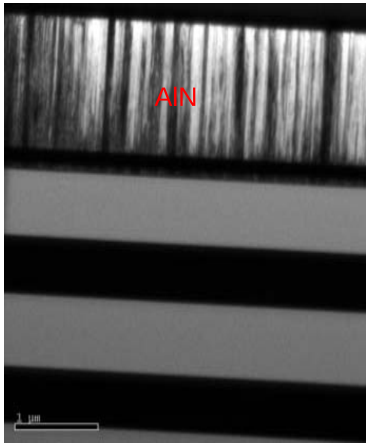
- Very low insertion loss - typical 2dB for Tx-part US-PCS band 2 duplexer
  - worst case 2.5dB for UMTS applications
- Superior linearity performance
  - IM2: -104dBm, IM3: –108dBm High coupling coefficient of 6.7%
  - experimental flow enables even >7.0%
- Low EVM, low out-of-band rejection, high return loss
- Small package size : 3.0x2.5mm for duplexer, 2.0x1.6mm for Tx-filter

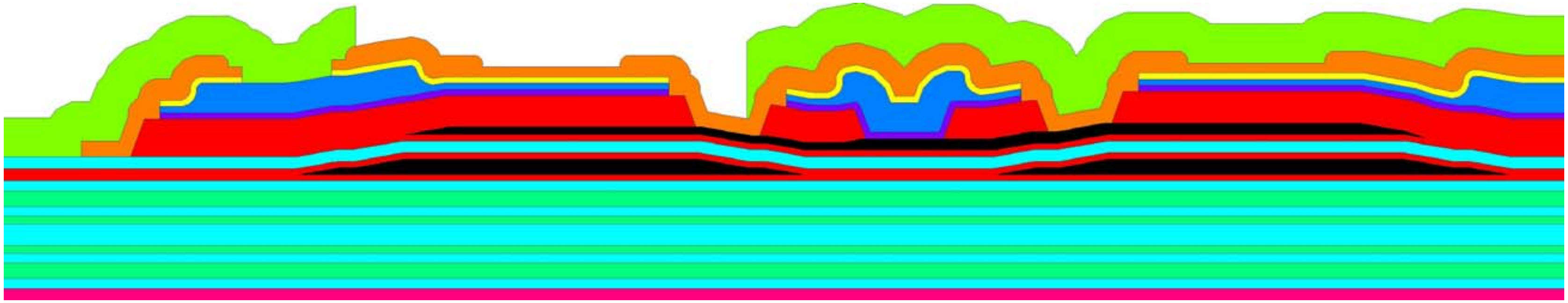
- Longer battery lifetime, larger range, higher data rate, less dropped calls
  - relevant for all 3/4G applications and frequency bands
- Basic requirement for 3G CDMA 1X applications
  - can not be met by SAW technology
- Enabling band 14 extended-UPCS filters and duplexers
- Lower cost, less external optimization components, shorter time-to-market
- Less real-estate on phone PCB

BAW FE Process Flow

- Front-end Process flow developed
  - 13 mask steps.
  - AlN as piezoelectric material
  - Ta2O5/SiO2 reflector stack
  - Pt as mass loading and bottom electrode
  - SiN, AlCu as additional material
  - Ion beam trimming for tuning resonators
  - E-sort yield (wafer level) consistent around 70%
  - Epoxy rim material for cap-support

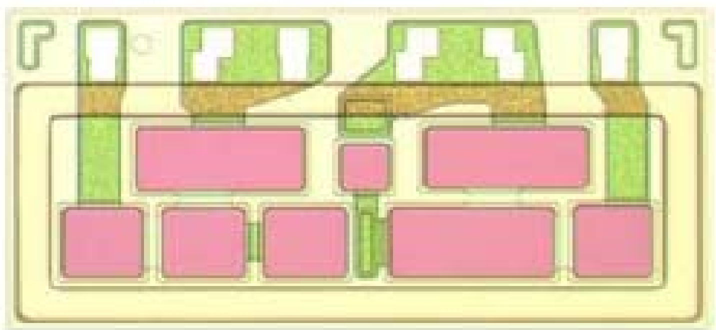


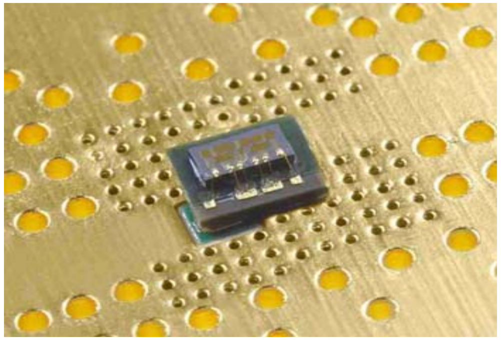


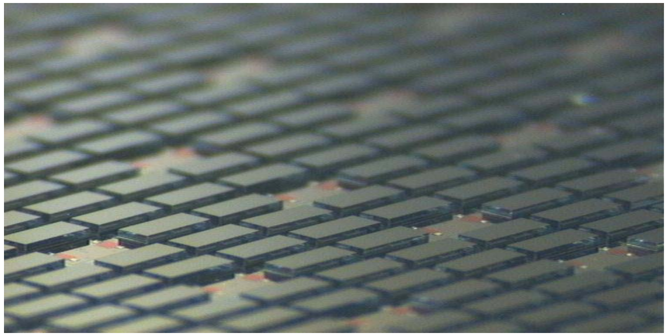


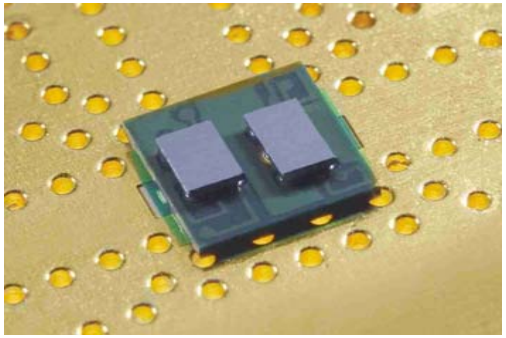
BAW Wafer-Level-Package process flow

- Back-end
  - Si Cap placement: cap-wafer (uncertainty in f-shift << 200kHz)
  - Datacon for cap placement

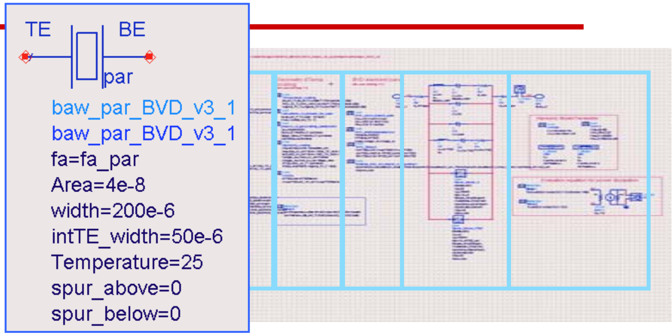






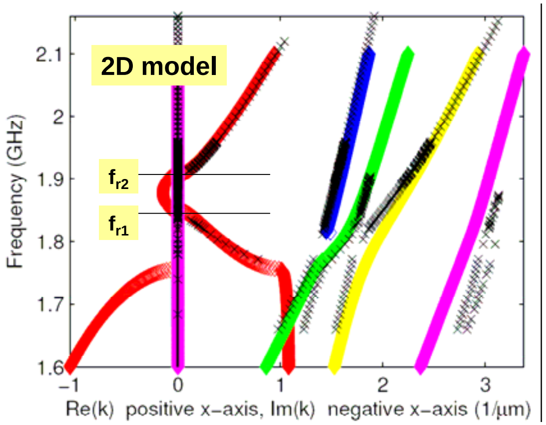


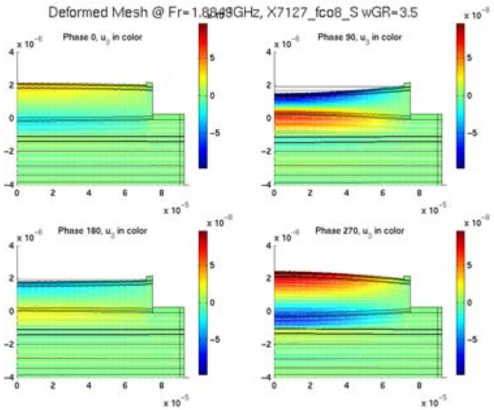
BAW Device Technology



Key to the BAW design kit are accurate and scalable device models based on physical material parameters

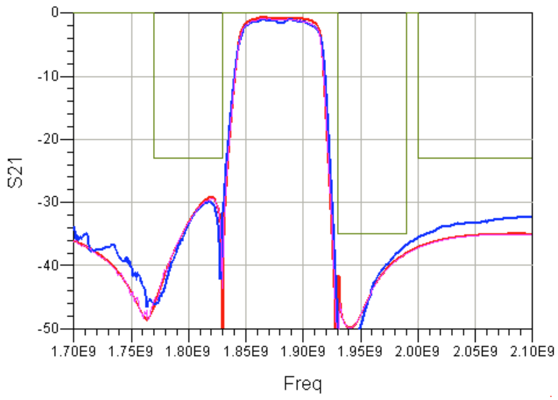
- Acoustic simulation methods to optimize the BAW device performance
  - Physical 2D-model for calculating acoustic dispersion of the BAW reflector stack
  - Finite Element Method (FEM) simulation of BAW resonator using commercial tools
- Validated compact models of the BAW resonator
  - scalable including spurious resonances and non-linear effects



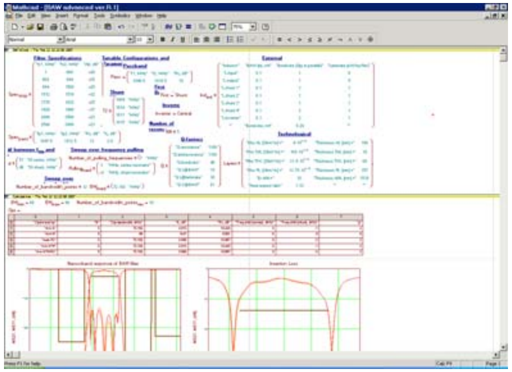


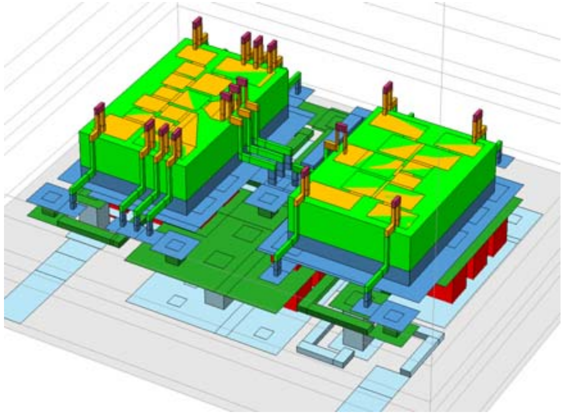
BAW Design Flow

Key to the BAW filter performance is an efficient integrated design flow for fast accurate filter layout and design



- Automated design flow for accurate BAW filter design
  - BAW filter synthesis tool for rapid design prototyping
  - electromagnetic simulations of BAW die assembled on laminate predicts accurately measured filter performance
  - BAW device library in Agilent ADS using scalable compact device models





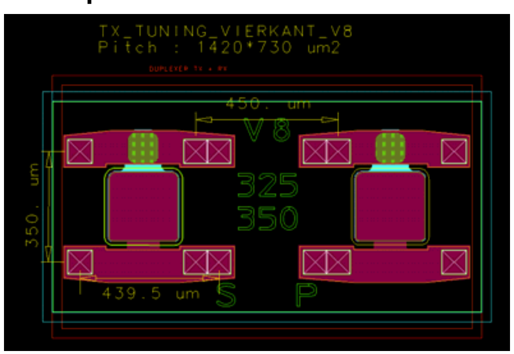
BAW RF Test

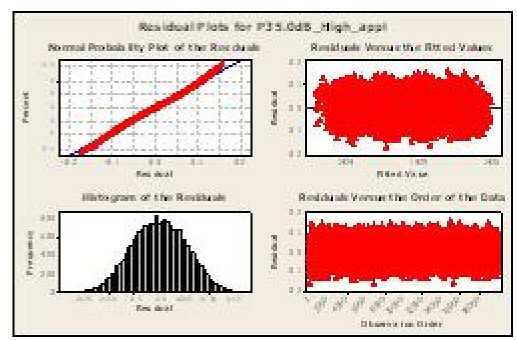
Key to the BAW filter production is the accurate and reliable RF testing of BAW resonators and filter parameters

BAW resonator RF test

- on-wafer structures for accurate measurement of BAW resonator RF parameters
- only 4ppm measurement spread in production on resonator frequency

- BAW filter RF test
  - accurate on-wafer measurement of BAW dies using RF probes
  - infrasturucture for 2-port and 3-port RF test of filter and duplexer dies and products





NXP BAW Technology Reliability

Test	Conditions	Batches	168hr	500hr	1000hr	1500hr
HTOL	Device specific	3	0/120	0/80	0/40	0/40
THB	85°C/85%RH, no bias	2	0/80	0/40	0/40	

Test	Conditions		168hr	500hr	1000hr	1500hr	2000hr
HTSL	+150°C	3	0/160	0/80	0/80	0/80	0/80
HTSL	+175°C	2	0/120	0/40	0/40	0/40	0/40

Test	Conditions		96hr	192hr	288hr	384hr	480hr
PPOT	121°C/100%RH	1	0/40	0/40	0/40	0/40	0/40
UHAST	130°C/85%RH	3	0/152	0/120	0/80	0/80	0/80
HAST	130°C/85%RH, 5V	3	0/120	0/80	0/80	0/40	0/40

Test	Conditions		100cycles	500cycles	1000cycles	1500cycles
TMCL	-55°C/125°C	3	0/160	0/120	0/80	0/40
TMCL	-65°C/150°C	2	0/80	0/80	0/80	0/40

Test	Conditions		Result
PRECON	MSL3	1	0/40

Partner Roles in MEMSLAND

- NXP: design, modeling, process integration, testing, industrialization
- NXP Belgium: 2nd generation process development
- AppTech: 1st generation package concept
- TNO: 2nd generation package development
- Univ. Twente: non-linear compact modeling

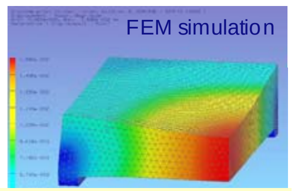
TNO: 2nd generation Package Development

Process flow

Options:

- pre-perforated polymer film
- opening of bond pad area after application of film

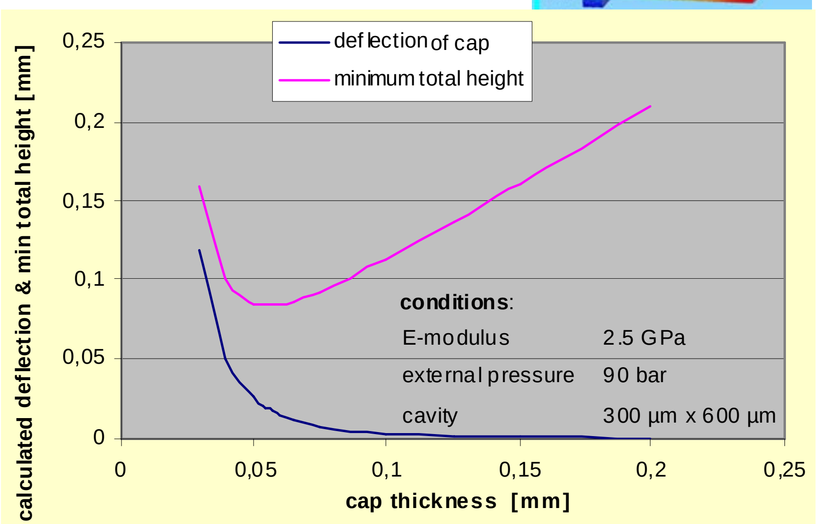
Pictures

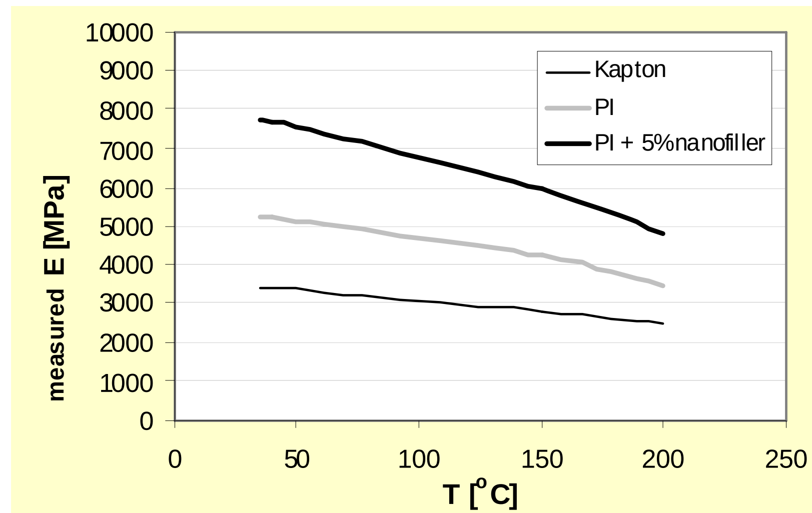


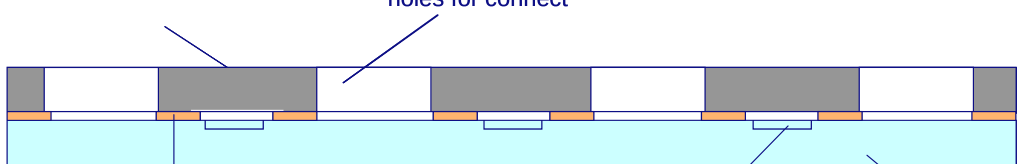
Developed technologies

Feasibility study on polymer film i.s.o. silicon cap

- numerical simulations of deformation on over-moulding conditions
- experimental overmoulding simulation apparatus built
- nanofillers used to increase HT strength of polymers (photo senstitive polyimides, hybrid anorganic – organic films)
- waferscale polymer capping process flow concepts developed



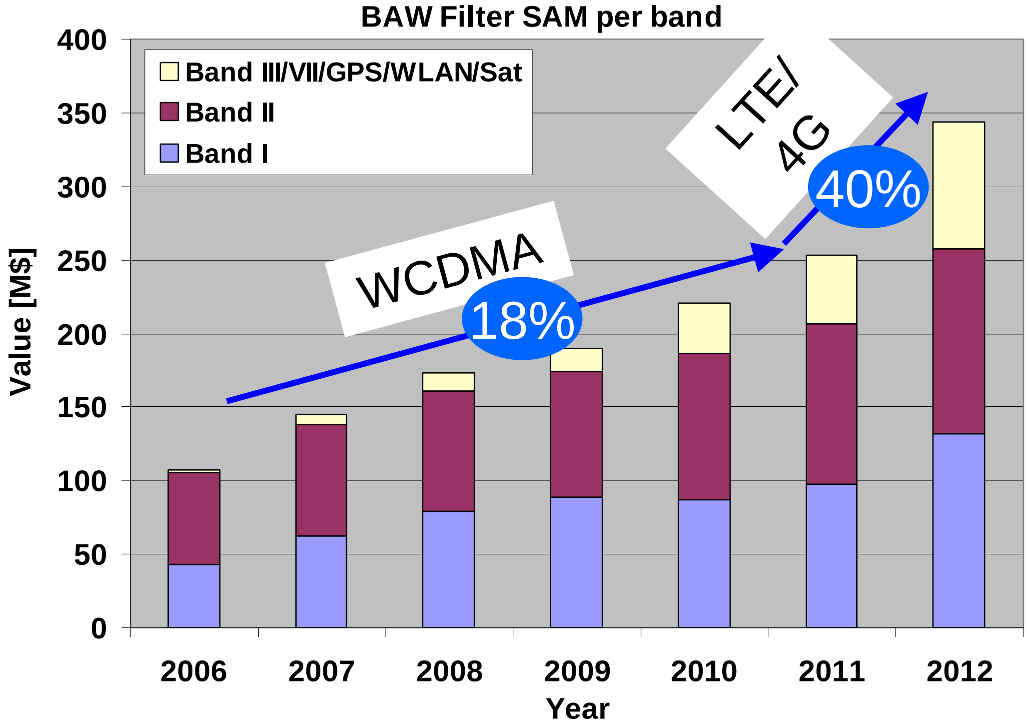




Univ. Twente: Non-linear Compact Model

- PhD student Sumy Jose started end 2007
- Activities in H1 2008:
  - Research carried out at NXP Research Eindhoven
  - Literature survey & comparison 1D models
  - Introduction to BAW team, the simulation tools and measurement equipment
  - First publications written on BAW device modelling

BAW Market: small but high growth



- Market growing 18% p/y until ’11 driven 3G (W)CDMA (‘wave1’) ….
  - accelerating to 40% p/y in ’12 due to takeoff LTE/4G (‘wave2’)
- LTE/4G bandwidth requires filters at higher frequencies (>2.5GHz)
  - SAW unable to perform at these frequencies – BAW only solution
- Share of integration in modules growing to 50% driven by RF complexity & BOM/size pressure

- Treats to the BAW market
  - SAW’s performance/price improving taking more share from BAW
  - Market moving from single-ended to balanced duplexers – fits better with SAW than BAW
  - 4G take-up slower than expected
    - shifting need for higher frequencies (and BAW) back to beyond 2012