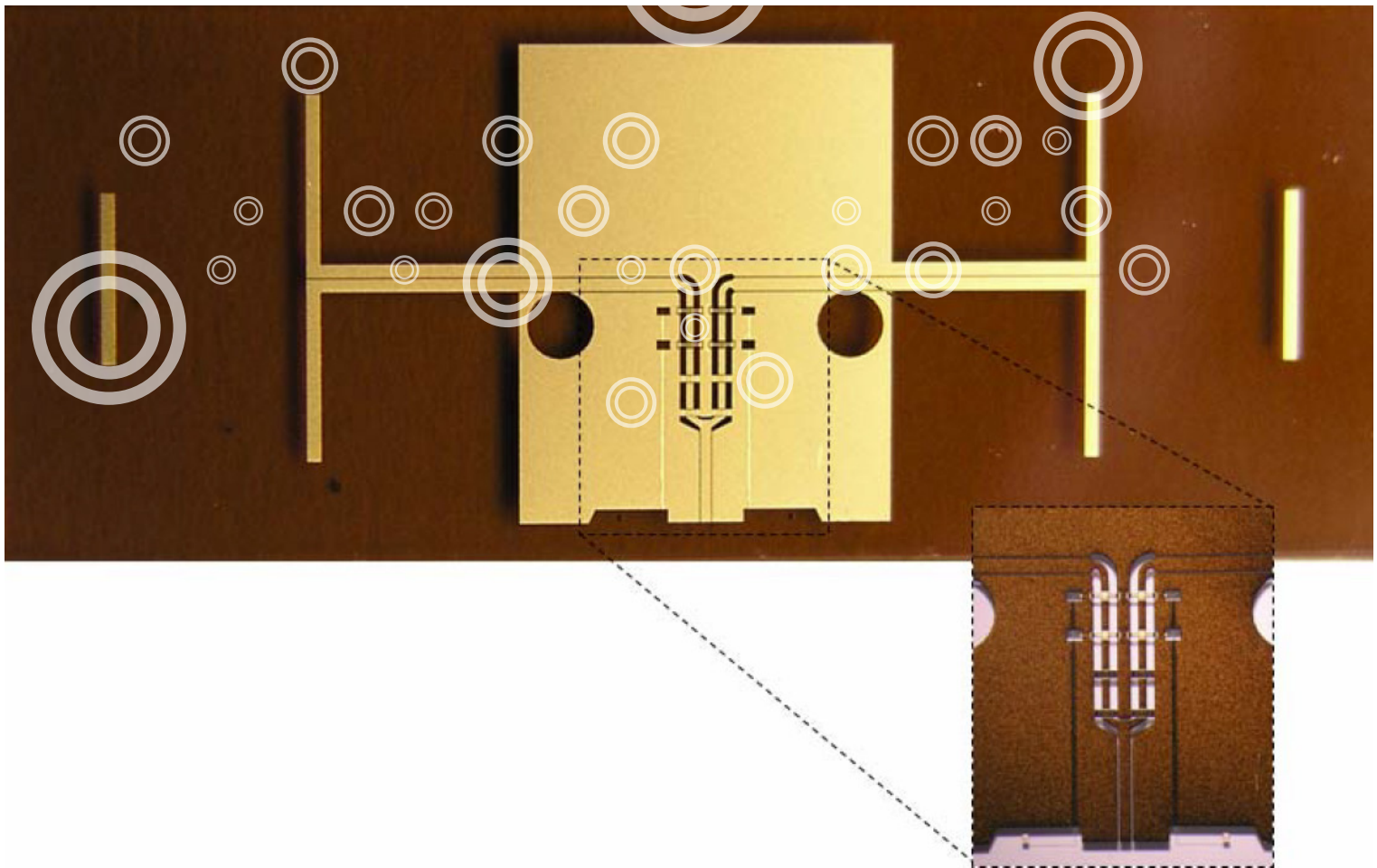
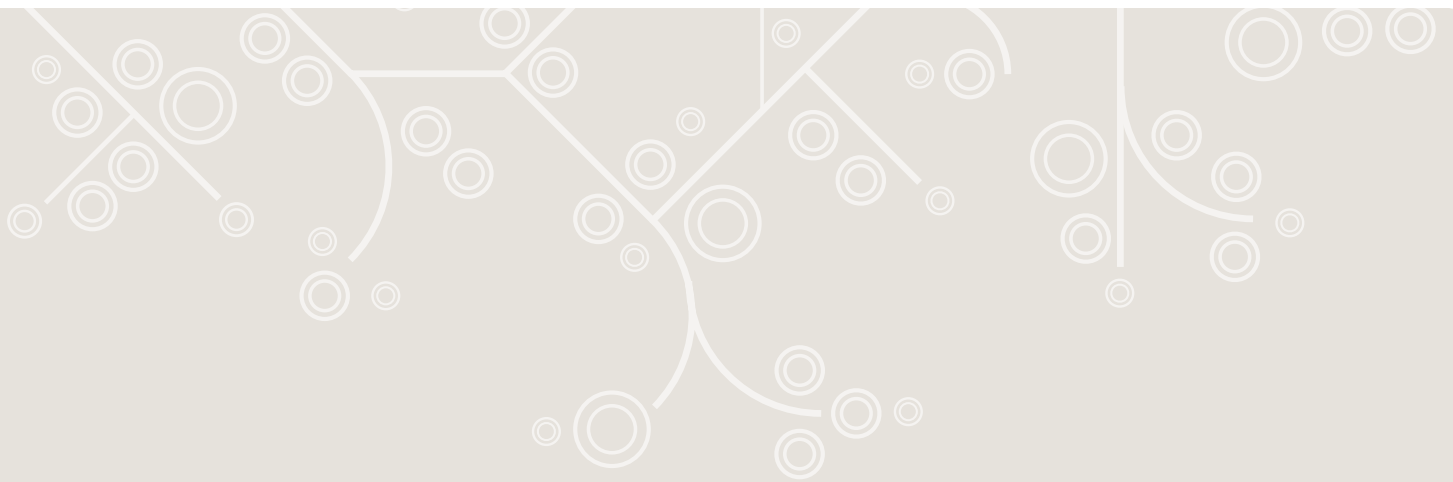


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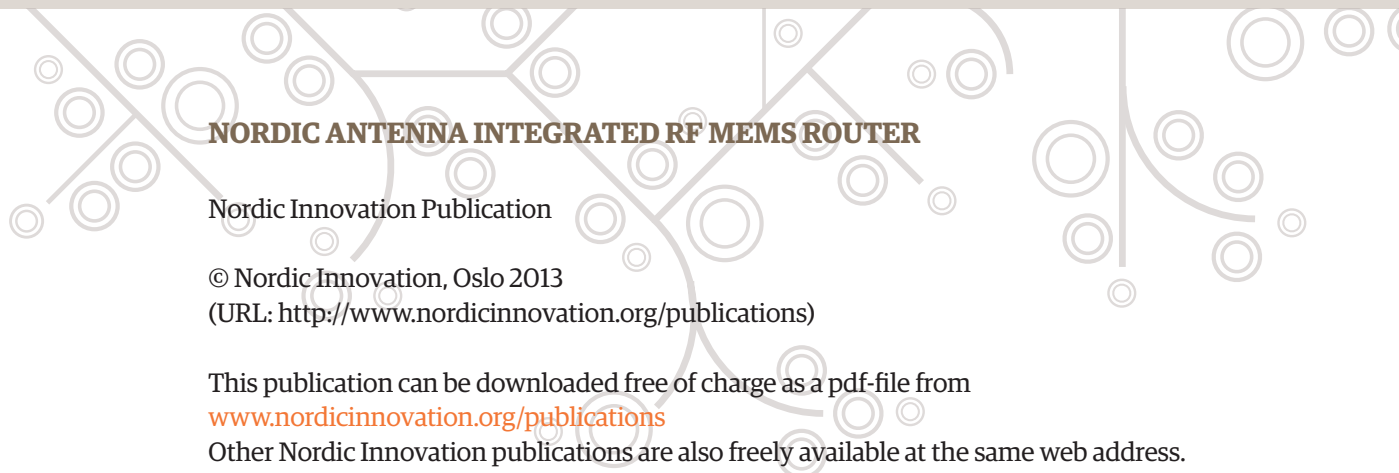
NORDIC ANTENNA INTEGRATED RF MEMS ROUTER



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Summary



In this report, we summarize all the experimental results obtained in the four work packages of the NAME project. A more thorough handling is given for the SPxT and router results from the last manufacturing run performed in FBK, Trento, Italy. Results from earlier work in SINTEF, Norway, FOI and Uppsala University, Sweden, and VTT, Finland, are also given. More information can be found in the previously published Deliverable 1-3 reports as well.

The processing run performed in FBK was not completely successful. The devices suffered from anisotropic mechanical stresses and electric breakdowns. Pull-in voltages were generally high: about 40 V for the devices fabricated on quartz and much higher on Silicon.

The Si devices suffered from electric breakdowns before the RF MEMS switches could be pulled down. A few functioning quartz devices were obtained. The wafers contained devices designed for higher frequencies than the NAME application, and from these functioning 35 GHz SPDT switches were found. The 35 GHz SPDT switch had a transmission loss of 1 dB and an isolation of 18 dB. The input and output matches were -15 dB or better. Compared to simulations the performance was slightly poorer than expected. No functioning 20 GHz SPDT's were obtained.

No functioning router switch networks were obtained in the FBK processing run. Hence, no test results characterising the routers themselves are available. Also the intended main deliverables, the antenna integrated routers with three quasi-Yagi antenna elements, were not functioning due the anisotropic mechanical stresses. Fortunately, integrated routers with two antenna elements were found, and the correct operation of switching the antenna beam in the two opposite directions was demonstrated. The antenna performance was conformant to specifications with 28% impedance bandwidth ($S_{11} = -10$ dB), 4.6 dBi gain, and .better than 14 dB front-to-back ratio at 20 GHz.

Although the NAME project suffered from manufacturing difficulties, the obtained results indicate that the design specifications are reachable, and that the NAME concept of higher level integrated routers for wireless communications or sensor networks is successful.

Contents



Summary	5
1. Introduction	8
1.1 Requirements for an RF MEMS based router.	8
2. Router Design and Characterisation	9
2.1 Router Architecture, Design and Test (WP100)	9
2.1.1 Characterisation of RF MEMS SPxT switches manufactured in VTT process.	10
2.1.2 Characterisation of RF MEMS switch networks manufactured in FBK process.	14
2.2 Switch Design and Fabrication (WP200)	17
2.2.1 Capacitive RF MEMS switches manufactured in SINTEF process	17
2.3 Antenna Design, Fabrication and Test (WP300)	19
2.3.1 Yagi integrated antennas	19
2.4 Integration and System Demonstration (WP400)	22
2.4.1 Characterisation of antenna integrated RF MEMS routers.	22
3. Conclusions	26
References	28

1. Introduction

1.1 Requirements for an RF MEMS based router

A microwave router based on RF MEMS switching is a novel and application driven component for wireless communications (e.g. in microwave links or sensor networks). Integrating MEMS switches and transmission lines on a single router chip will enable a higher level of integration to be achieved. This and simple IC fabrication techniques make MEMS technology a cost-effective solution.

Table 1 shows a target specification for the main performance parameters of the RF MEMS based router switch network that is to be designed and fabricated within the NAME project [1]. A possible targeting application for such a MEMS router can, for example, be microwave (communication) links that typically operate within the 5-40GHz frequency range. In this report, we choose to focus on a router centre frequency around 20GHz, although both a somewhat higher as well as a lower frequency of operation in principle should be possible. In this case, the main challenges have to do with possibilities of achieving adequate isolation and low losses over a wide bandwidth.

The requirements for the most critical key parameters of a switching network (router) have been identified by the research and industry partners participating in NAME. The requirements are expressed in terms of minimum acceptable and goal values, respectively. In addition to those requirements, the router should have a high linearity (a third order intercept point of 30-40dBm) and can consist of up to five ports (input/outputs). Capacitive MEMS switches with a relatively high down-state capacitance and a small up-state capacitance are needed to be able to achieve adequate isolation and low losses for the router, respectively. It is assumed that a capacitance ratio of 20 (C_{max}/C_{min}) should be possible to achieve. The MEMS switches should also be able to switch relatively fast ($<10-100\mu s$) and require an actuation voltage in the order of 12-30V. The input and output impedance level is assumed to be 50Ω although in principle it should also be possible to design for other impedance levels.

Table 1. Target specification for the RF MEMS router switch network developed within the NAME project

Requirement	Insertion loss [dB]	Return loss [dB]	Isolation [dB]	Bandwidth [%]
Minimum (acceptable)	1	-15	30	15
Goal	0.7	-20	40	20

2. Router Design and Characterisation

In this report, we summarise the experimental results of the antennas, RF MEMS switches, and RF MEMS router circuits produced in the NAME project. Especially, the test results of the final router devices fabricated in the Trento FBK run are given here.

The design work of the different router chips was done in collaboration between FOI and VTT. High capacitance ratio RF MEMS switch design work was done by SINTEF and VUC. The antenna design work was performed by the Uppsala University. The work in the different work packages that contribute to the making of the final antenna integrated MEMS router are summarized in sections 2.1-2.4.

2.1 Router Architecture, Design and Test (WP100)

The switching router developed within the NAME project has been sent to be fabricated using a MEMS process at Trento FBK in Italy. Different kind of switch networks (e.g. SPDT, SP3T and SP4T) has been designed based on using high-resistivity silicon or quartz as the substrate material. The substrate thickness used is approximately 500 μm . VTT in Finland also uses quartz (fused silica) as substrate material in their MEMS processes. Compared with silicon, quartz offers a lower substrate loss but the lower ϵ_r of quartz will result in larger circuit dimensions. Table 2 shows the process parameters we have used in the circuit simulations of the different switching networks.

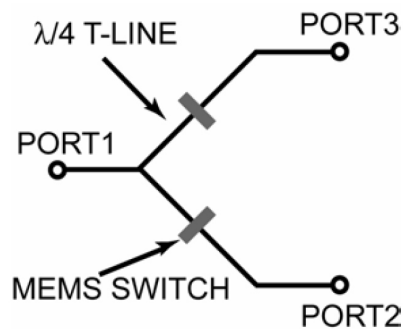
Table 2. Process parameters used in the circuit simulations of different switching networks.

Substrate	Substrate height H (μm)	Rel. permittivity ϵ_r	Conductivity (S/m)	Metal thickness T (μm)	Loss factor $\tan\delta$
Silicon	500	11.8	$4 \cdot 10^7$ [Au]	3.0	≈ 0.001
Quartz	520	3.8	$3.8 \cdot 10^7$ [Al]	1.5	≈ 0

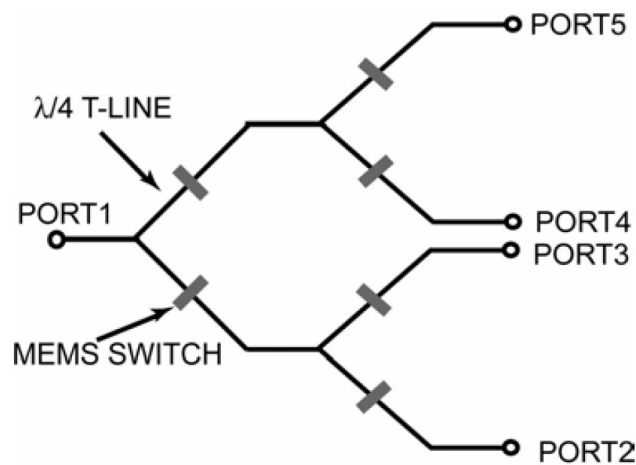
Trento FBK and VTT as well as Sintef RF MEMS processes contain capacitive switches. These switches are most suitable to be used in shunt configuration. Due to this, Single-Pole-Double-Throw (SPDT) switching networks need to be realized with shunt switches connected to quarter wavelength ($\lambda/4$) transmission lines as shown in Fig. 1a. One

possible way to realize a Single-Pole-4-Throw (SP4T) switch is to combine three SPDTs (see Fig. 1b).

Fig. 1. Schematics of switch networks realized with capacitive shunt switches:
a) SPDT



b) SP4T. 7 [22]



2.1.1 Characterisation of RF MEMS SPxT switches manufactured in VTT process

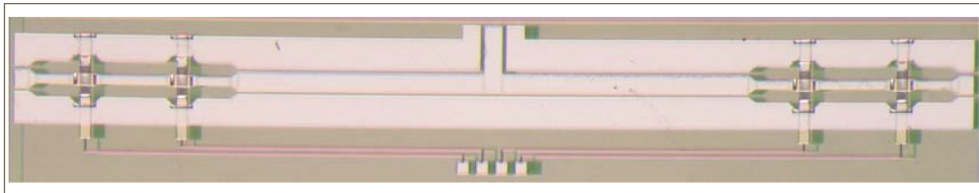
Due to participation in the EC NoE AMICOM by some of the NAME participants, NAME got an opportunity to submit some early and preliminary router chip designs to a processing run performed at VTT. The processing was cost-free to NAME and the design work was done in late 2006 at VTT and at FOI, respectively. The Milestone 1 analysis (Selection of requirements and architectures for the router [1]) was used as the basis for the designs (see also [2,3]). The MEMS test circuits (router chips) fabricated at VTT were characterized during September-October 2007 and the experimental results obtained are summarized below.

SPDT

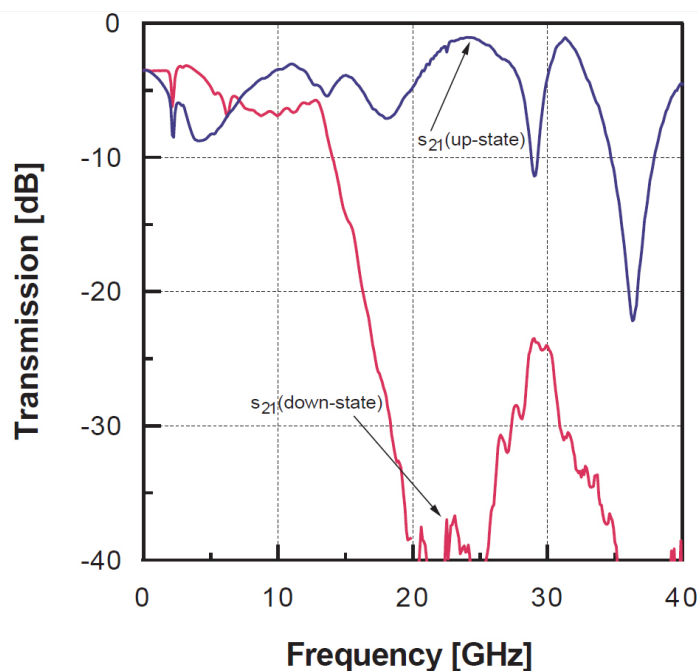
In summary, several circuits were designed and submitted to the VTT fabrication run. The designs are based on MEMS switches and CPW transmission lines on fused silica substrates. Fig. 2 a shows the chip photo of an SPDT design with $\lambda/4$ transmission line sections between the switches and the T-junction. Isolation between the ports has been improved with doubleswitch structures. The circuit dimensions of this particular design are 6.6 mmx1.3 mm. Figure 2 b shows measured transmission and isolation in the ON- and OFF-state, respectively (close to -1 dB and -39 dB at 24 GHz, respectively). The results are relatively close to the expected values (-0.44 dB and -36 dB simulated at 20 GHz) and also to our target specification (0.7-1 dB of insertion loss and 30-40 dB of isolation). The bandwidth is at best 12%, which is somewhat below requirement. The requirement is, however, reachable. The somewhat higher measured losses than expected could be explained by higher metallic losses and the fact that only the T-junction was simulated using an EM-simulation tool. The pull-in voltage was 10 V, which was an excellent value.

Fig. 2. A 24 GHz SPDT RF MEMS switch made on quartz (fabricated at VTT):

a) chip-photo



b) measured transmission and isolation in the on- and off-state, respectively (circuit area is 6.6x1.3 mm²).

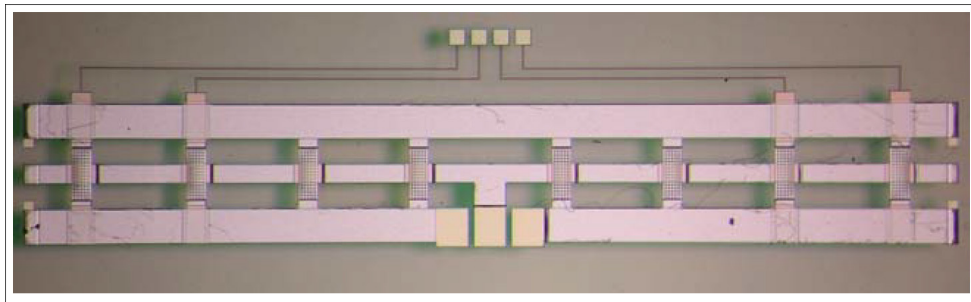


Since higher order switch networks may consist of several SPDT structures, the dimensions of each SPDT should be minimized in order to reduce the over-all circuit size and cost. Several SPxT switch networks (with $x=2, 3, 4$) were designed at VTT and also included on the VTT processing run. A summary of these designs has been given in Deliverable 2 report [4]. In these designs, slow wave/loaded line structures are used to minimize the size of the $\lambda/4$ sections. These structures are realized by high impedance transmission lines that are capacitively loaded. Since this will increase their electrical length the physical size can be reduced.

Photographs of such SPDT networks are shown in Figs. 3 a and 4 a. The outputs of the design in Fig. 3 a are in 180 degree angle compared to each other, whereas they are parallel in the design in Fig. 4 a. Insertion loss should be less than 1 dB and isolation better than 30 dB at the center frequency, if we assume a capacitance ratio of 20 for the MEMS switches.

The measured results are shown in Figs. 3 b and 4 b. For the SPDT design in Fig. 3 a, the insertion loss was 1.0 dB and isolation -19.3 dB; as for the SPDT design in Fig 4 a, they were 1.1 dB and -20.6 dB respectively at the center frequency of 20 GHz. Bandwidth is around 10% in this case. The pull-in voltage in the case of the first device was 15 V, whereas with the second approximately 20 V. In addition, two somewhat modified SPDT networks were designed, and they were also used in an SP3T and SP4T designs (see [4]).

Fig. 3. An SPDT design with capacitive loading
a) photograph



The circuit dimensions of the SPDT design in Fig. 3 a equal to 4.1mm x 0.6mm (2.5 mm²).

b) measured S-parameters.

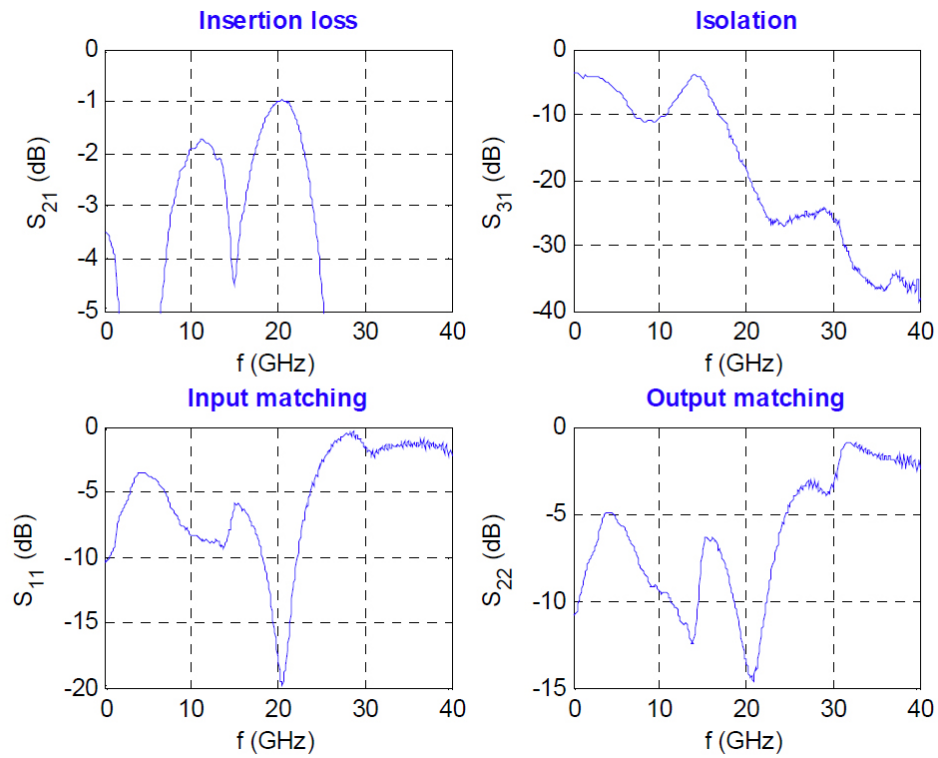
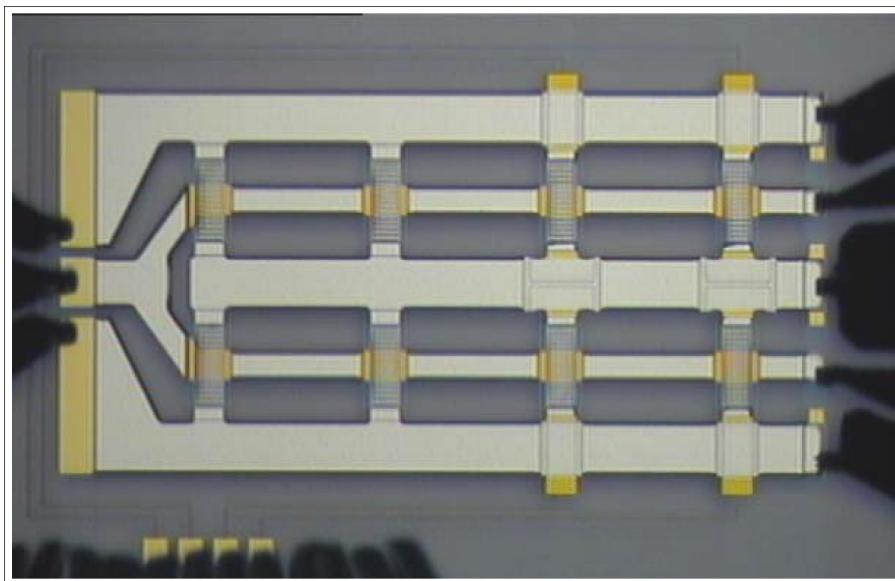
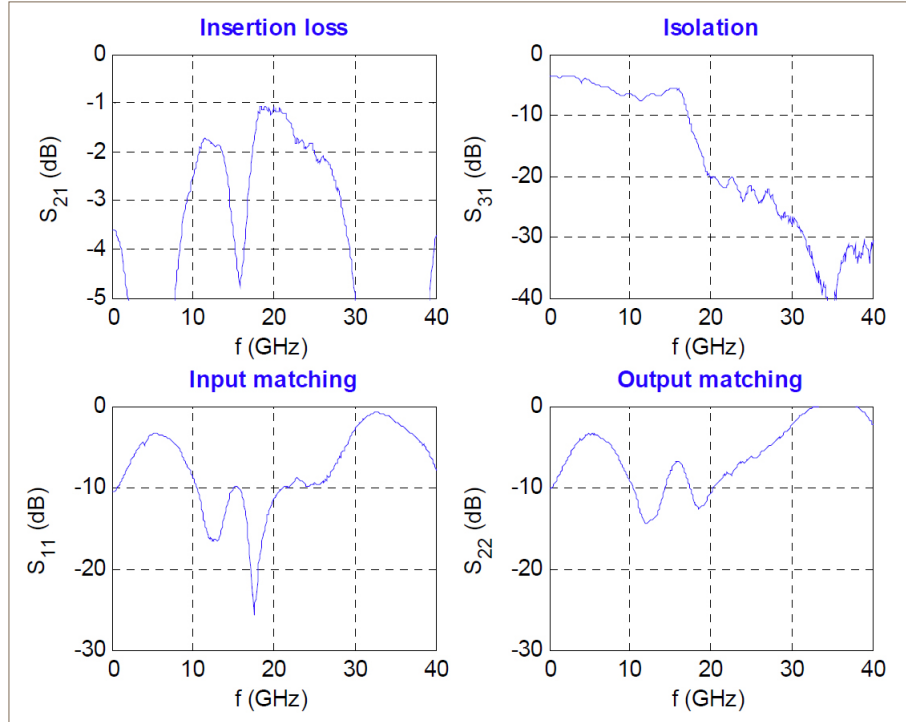


Fig. 4. An SPDT design with capacitive loading (parallel outputs)

a) chip photo



b) measured Sparameters.



2.1.2 Characterisation of RF MEMS switch networks manufactured in FBK process

Several RF switch networks for a variety of frequencies (some of them outside the scope of NAME) were designed and submitted to the FBK fabrication run starting in the early autumn of 2007. Included on this run were also some SPDT and SP3T switch designs combined with integrated antennas in order to realise a fully integrated on-chip RF MEMS switched based 10 (22) antenna router (see section 2.4.1 for experimental evaluation of a 20 GHz antenna integrated RF MEMS router chip).

Different RF MEMS switch designs were made at both VTT and FOI using high resistivity silicon and fused silica as substrate material. Characterization of the fabricated test circuits were done both at VTT, FOI and UU and experimental results of functional RF MEMS switches were obtained only for two different types of designs; a) a 20 GHz MEMS SPDT router (i.e. with integrated antennas on-chip, see section 2.4.1) and b) a 35 GHz MEMS SPDT switch network (see results below). These two RF MEMS switch based designs were both fabricated on quartz (fused silica substrate). The majority of the designs did not work properly due to mechanical stresses in the switch structures and electric breakdowns in the protective capacitors.

The stresses were orientation dependent. Many of the designs had switch structures oriented in both lateral directions on the wafer. As a result, only the switches of a one

orientation worked, while the ones in the other did not rendering the designs useless. The electric breakdown problem has been suggested to be due to defects in the capacitor dielectric layer. The top metal layer of the capacitor had perforation, which in the time of etching may have caused the defects. The pull-in voltages were generally high: a little below 40 V with quartz wafer designs and with the devices on Si so high, that the devices broke down without fail, before the switches could be pulled down.

SPDT

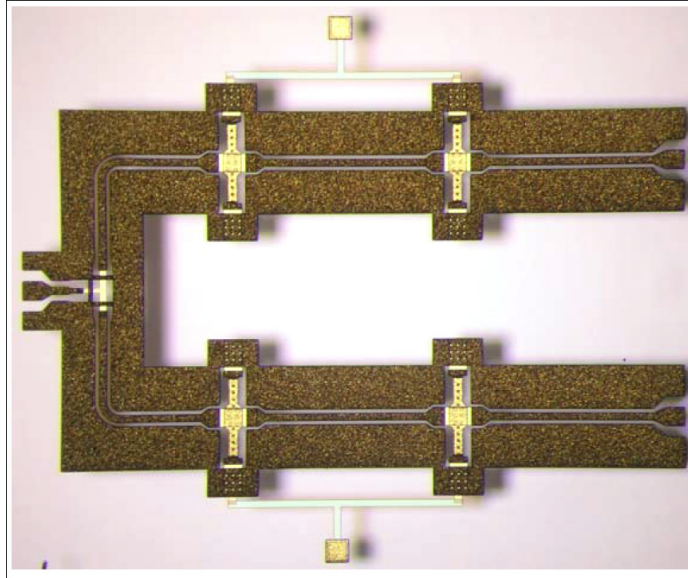
The 35 GHz MEMS SPDT switch design is based on two capacitive MEMS switches (in each branch) and CPW transmission lines on fused silica substrates. A motivation for implementing also some switch designs at 35 GHz was is in this case to be able to evaluate the potential of the studied MEMS switch technology also at frequencies above 30 GHz and for some future applications as well. For example, the use of a suitable low-loss switch technology at 35 GHz is currently being investigated in a national funded project in Sweden (with participation of FOI and Saab) that targets a low-power multi-functional radar system for aerospace applications.

Fig. 5 a shows a chip photo of a fabricated 35 GHz RF MEMS SPDT switch network with $\lambda/4$ transmission line sections between the switches and the T-junction. Isolation between the ports has been improved with double-switch structures. The circuit dimensions of this particular design are 3.5 mmx2.9 mm.

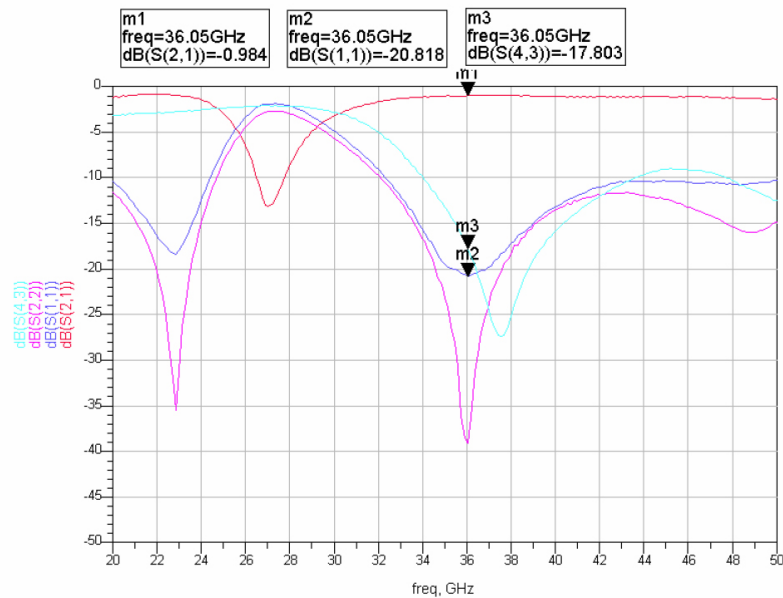
Fig. 5 b shows measured transmission and isolation in the ON- and OFF-state, respectively (close to -1 dB and -18 dB at 36 GHz, respectively). The somewhat higher measured transmission loss of 1 dB (a few tenths of a dB higher than anticipated) as well as a centre frequency shift in the order of a few percent from 35 to 36 GHz could probably be explained by the fact that a relatively simple lumped equivalent circuit model was used in this case in the simulations. The results also indicate that the achieved capacitance ratio (C_{up}/C_{down}) is somewhat lower than expected (around 5 according to the measured data compared with 20 assumed in the simulations). The input and output impedance matching is equal to -15 dB or better over a 5 GHz frequency range (i.e. close to 14% bandwidth) which, at least, may be adequate for certain narrow-band applications as, for example, the 35 GHz multi-functional radar system mentioned above.

Fig. 5. A 35 GHz SPDT RF MEMS switch made on quartz (fabricated at FBK)

a) chip photo



b) measured transmission (in the on- and off-state, respectively) and return losses (circuit area is 3.5x2.9 mm²).



SP3T

No working devices were found on the wafers due to orientation dependent mechanical stresses.

SP4T

No working devices were found on the wafers due to orientation dependent mechanical stresses.

2.2 Switch Design and Fabrication (WP200)

2.2.1 Capacitive RF MEMS switches manufactured in SINTEF process

The SINTEF RF MEMS switch manufacturing process and process characterisation have been described in the Deliverable 2 report [4] (see also Table 3). The router design was planned to be based on a high capacitance ratio (~20) shunt switch fabricated using gold on high resistivity silicon, with photoresist as a sacrificial layer. Due to delays in processing the switch fabrication was not finished until August 2007, and the testing was finished in early October, unfortunately too late to include NAME routers in the current process. A second fabrication and characterisation round was completed in December 2007, resulting in several improvements:

- High yield
- Controlled thickness and adhesion of the tungsten electrode layer
- Considerably less over-etching during the tungsten patterning
- A pull-in voltage of 30V, which is close to the design target
- Successfully actuated more than one million cycles.

Table 3. Processing steps of the SINTEF capacitive switch.

Layer	Material	Thickness	Deposition Method	Patterning mask name	Etching Method
Substrate	Silicon, 4000-8000 Ohm cm resistivity	280 μm	Float zone growth	- None -	- None -
Insulator	Silicon dioxide	500 nm	Wet thermal oxidation	- None -	- None -
Electrode (& CPW)	Tungsten (W) with titanium adhesion	500 nm	Sputtering	ELECTRODE	Reactive Ion Etching (RIE)
Dielectric layer on electrode	Silicon nitride	200 nm	PECVD	DIELECTRIC	Reactive Ion etching (RIE)
Sacrificial layer (below bridge)	HiPR 6517 positive photoresist	2500 nm	Spin Coating	SACRIFICIAL	UV photolithography
Bridge and CPW	Gold (Au) with NiCr adhesion	1200 nm	Sputtering	BRIDGE	Potassium Iodide wet etching

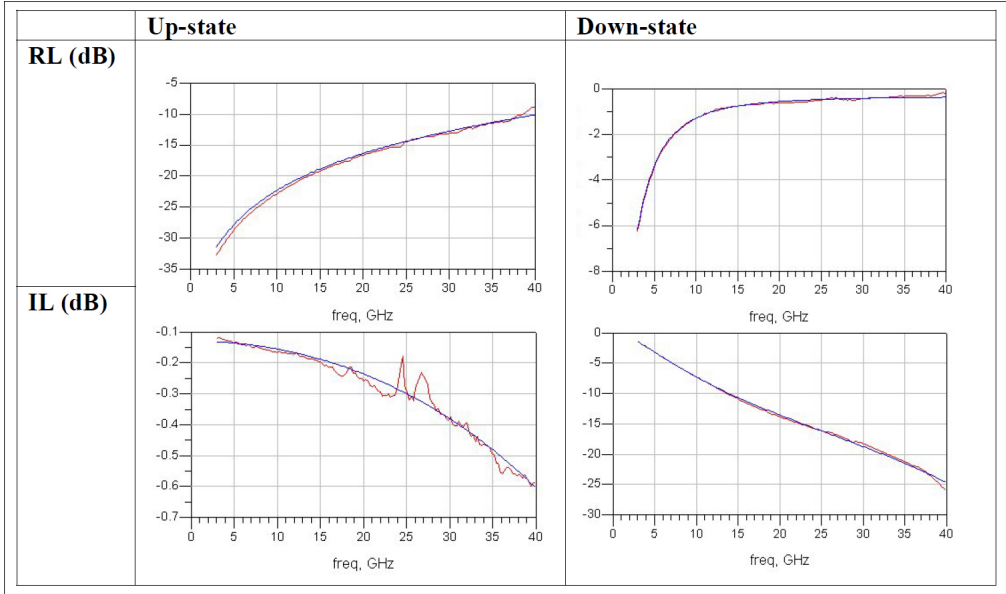
Several switch design variants were fabricated. These had small differences in the dimensional parameters. In the main design, the gold bridge suspended over the coplanar waveguide was 360 μm long and 80 μm wide anchored from both ends to the ground planes of the waveguide. The air gap between the bridge and the signal line was 2.5 μm . Fig. 6 shows SEM images of the SINTEF RF MEMS switch.

Fig. 6. SEM images of the fabricated main switch, in up and down state.



The pull-in voltage was 30V, not far from the calculated value of 37V. The down-state capacitance is lower than expected, and one likely cause for this is roughness on the bottom surface of the bridge. However, this has not been measured and verified.

Fig. 7. Measured (red curves) and fitted (blue curves) reflection and insertion loss



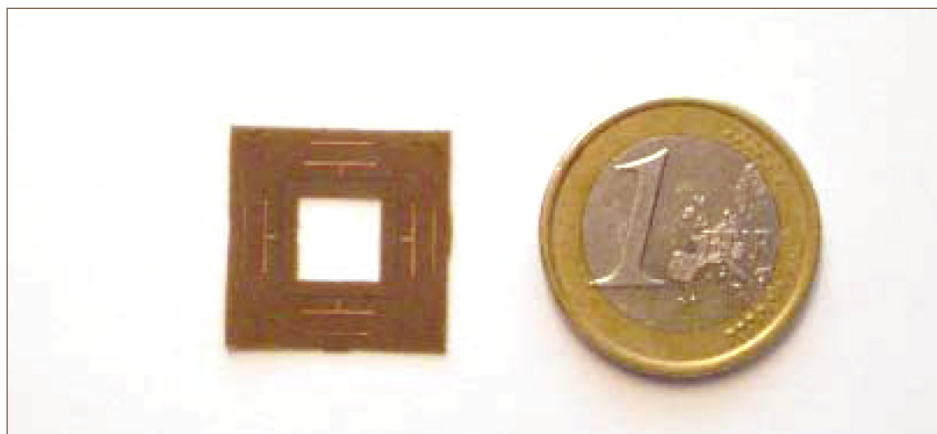
In addition to switch structural characterisation by SEM and optical profilometry, the RF performance of the switch was determined in the 3-40 GHz range. Fig. 7 shows the measured S-parameters of the switch. The ripple seen for the insertion loss in the up-state position may be a calibration issue in combination with nearness to other switch structures that may act as a resonator. The up-state and down state capacitance values were calculated using a simple L-C circuit model to fit to the experimental curves. The fitted switch capacitance of the main switch was 48 fF in the up-state and 1.2 pF in the down state, giving a capacitance ratio of approximately 25. The switch consists of a single capacitive shunt and is not optimized for a specific frequency. Between 10-32GHz, the measured insertion loss is between -0.17 and -0.4dB, the return loss is between -23 and -12dB, and the isolation is between 7.5 and 20dB. The achieved capacitance ratio of the switch is 25.

2.3 Antenna Design, Fabrication and Test (WP300)

2.3.1 Yagi integrated antennas

In WP300, three 20 GHz antenna designs were manufactured for flip-chip bonding with RF MEMS switching routers. The test results showed that all the antennas were well matched to the desired input impedance at the operation frequency. The presented dipole and uniplanar Yagi antenna featured about 10 % 10 dB return loss bandwidth at 20 GHz. The maximum gain of 3.8, 4.8 and 6.8 dBi was achieved, respectively. Moreover, good front-to-back ratio and appropriate beam coverage of all the antennas were observed. These antennas are good candidates for electrically steerable antenna arrays. By carefully selecting one type of the antennas integrated with an appropriate RF MEMS switching router, e.g. SPDT, SP3T, or SP4T, omni-directional beam coverage can be possibly realized. Further information can be found in the Deliverable 3 report [5].

Fig. 8. Photograph of the four element Yagi antenna array.



During the WP300 antenna tests, no functional RF MEMS routers were available, and unfortunately the Trento FBK run did not yield any functioning ones either. However, the antenna operation was further tested with a power splitter embedded into a uniplanar Yagi antenna to emulate the operation of a SPDT switch (Fig. 9). Both the reflection coefficient (Fig. 10) and the radiation patterns (Fig. 11) of the antenna were measured with the antenna attached to a probe holder utilizing a GSG coplanar probe.

Fig. 9. Photograph of a uniplanar Yagi antenna combined with a power splitter.

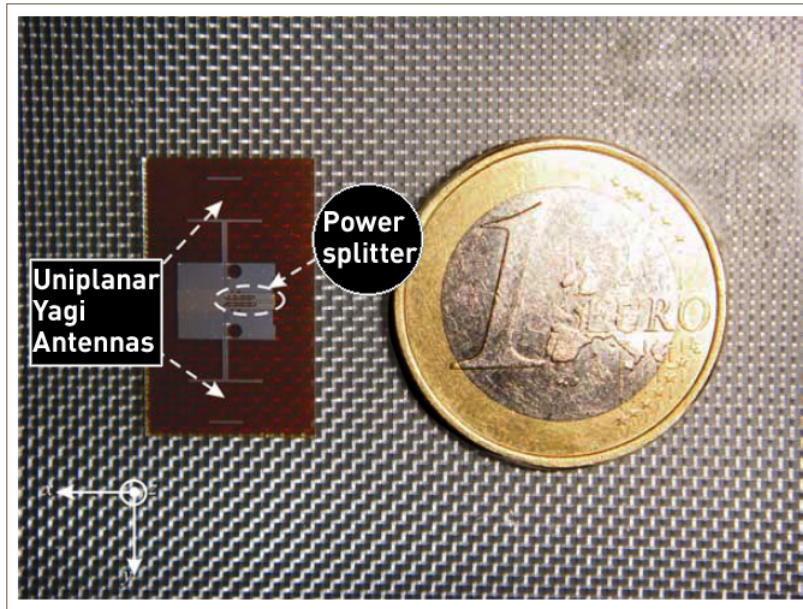


Fig. 10. Measured reflection coefficient of the uniplanar Yagi antenna array.

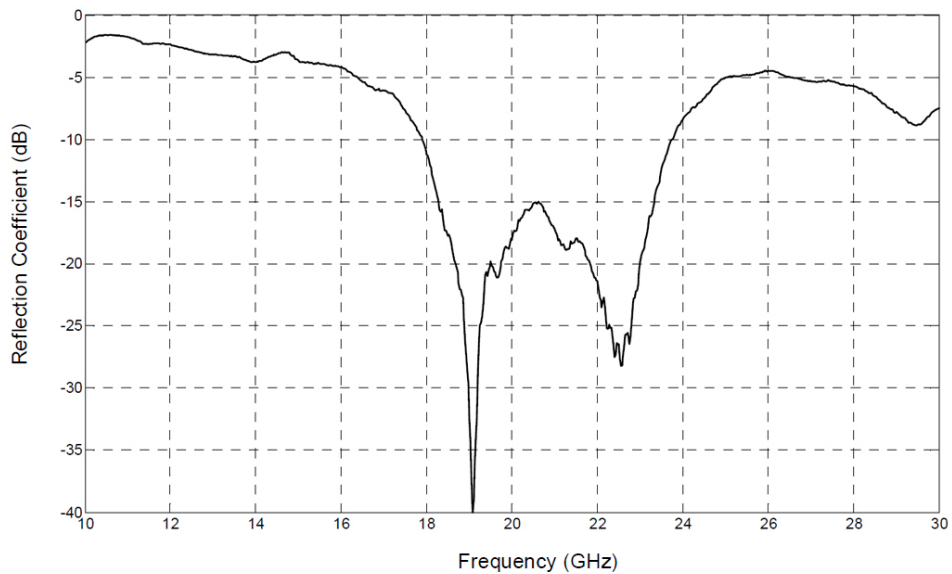
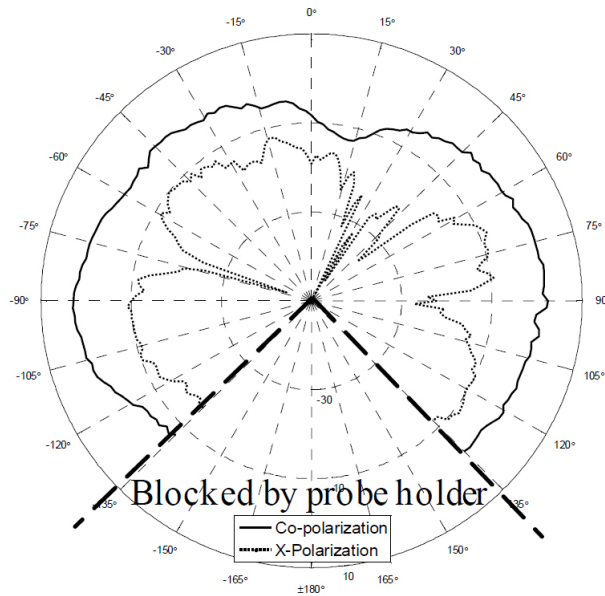
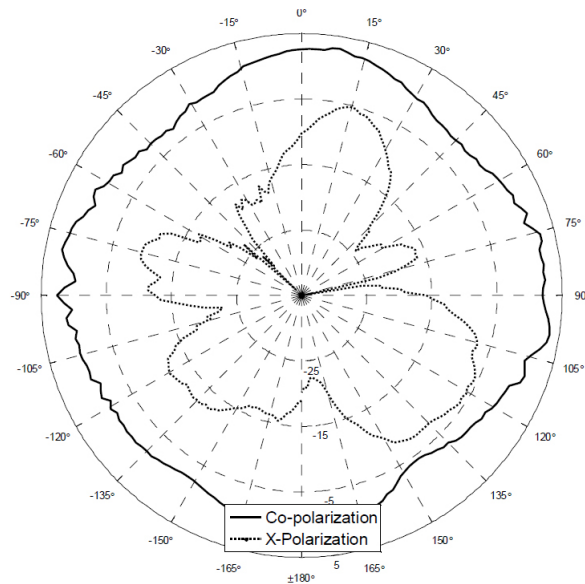


Fig. 11.**a) Measured xy-plane radiation patterns of the antenna array at 20 GHz.****b) Measured yz-plane radiation patterns of the antenna array at 20 GHz.**

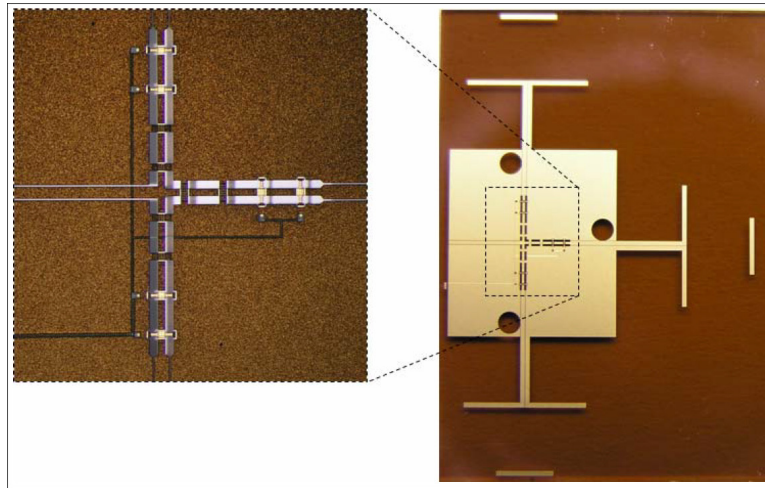
The results show that the presented antenna array achieved approximately 29% 10 dB returnloss bandwidth and 2 dBi maximum antenna gain at 20 GHz. Compared to earlier numerical estimates, the measured impedance bandwidth was wider and the gain is 3 dB lower due to the effect of the power splitter. But, good front-to-back ratio and appropriate beam coverage of the antenna array were observed.

2.4 Integration and System Demonstration (WP400)

2.4.1 Characterisation of antenna integrated RF MEMS routers

Fig. 12 shows a photograph of an antenna (three quasi-Yagi antennaelements) integrated RF MEMS based router on quartz substrate, which was planned to be the main deliverable demonstrator in the NAME project. These particular MEMS router designs were included on the Trento ICT process run and together with other fabricated break out circuits (SPxT networks). Unfortunately due to the orientation dependent mechanical stresses (as explained in Section 2.1.2), no functional devices of this type were obtained from the FBK wafers. However on the router devices with two quasi-Yagi antennas, the switch structures were all oriented in the same direction, and thus working devices of this type were obtained.

Fig. 12. A photograph and details showing the antenna integrated RF MEMS router.



The router consists of an SP3T switch network that is connected to three quasi-Yagi antennas designed in Uppsala. The device contains MEMS switch structures in both lateral directions, and due to anisotropic stresses the switches in one of the directions do not work. The circuit area equals approximately $13 \times 18 \text{ mm}^2$.

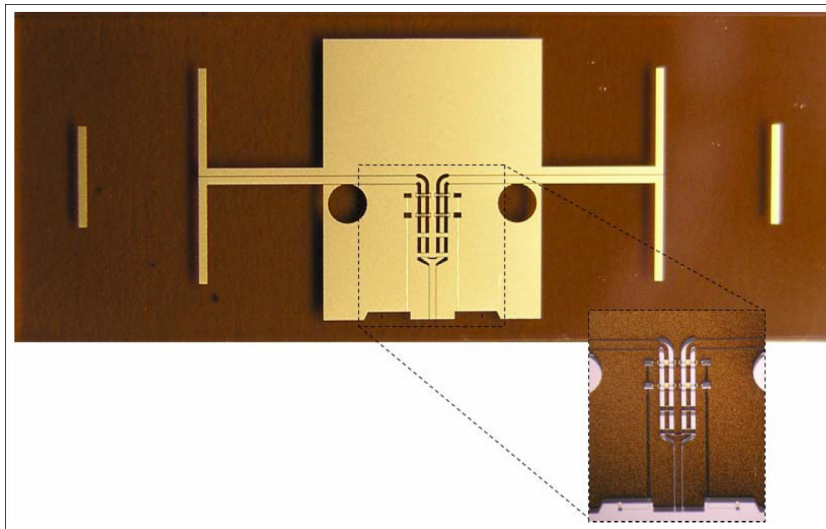
A photograph of the two antenna element type of the router on quartz substrate is shown in Fig. 13. The chip size is approximately $21 \text{ mm} \times 8 \text{ mm}$. With two elements, the antenna beam can be electrically switched between two opposite directions using the two switches (S1 and S2) in the routing network.

Fig. 13. Photographs of the array antenna integrated with RF MEMS based SPDT router on quartz substrate.

a) Scale in relation to one euro coin. The size of the router device is 21 mm x 8 mm.



b) Details of the switch network.



Port impedance and radiation patterns were characterized by applying pull-in voltages with various combinations to the two switches. Fig. 14 shows the measured reflection coefficients of the array antenna. The 10 dB return loss bandwidth is found to be around 28.2% at 20 GHz when the pull-in voltage either on S1 or S2.

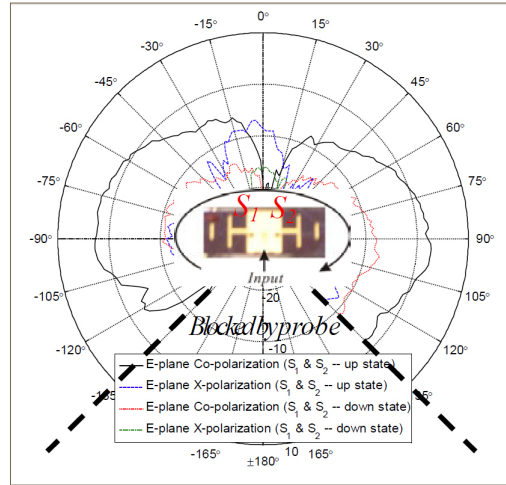
Fig. 14. Measured reflection coefficient of the array antenna integrated with SPDT router.

Measured radiation patterns are demonstrated in Figs. 15 and 16. Good isolation in the antenna radiation can be seen. By applying the pull-in voltages on both switches, the radiation decreases more than 10 dB compared to no pull-in voltages, see Figs. 14 a and 15 a. Figs. 14 b and 15 b show that the antenna beam can be switched between two opposite directions with a gain of 4.6 dBi, a half power beam width (HPBW) of 82°, and a front-to-back ratio of 14 dB. Moreover, as expected, the cross-polarization is much lower than the co-polarization in all the experimental results. Although some ripple can be found in the measured radiation patterns, they come from the reflection from the RF probe, DC bias needles, and probe holders.

To sum up, all the specifications on the antenna performance were fulfilled.

Fig. 15. Measured E-plane radiation patterns:

a). S1 & S2 -- up-state and S1 & S2 -- down-state.



b). S1 -- down-state & S2 -- up-state and S1 -- up-state & S2 -- down-state.

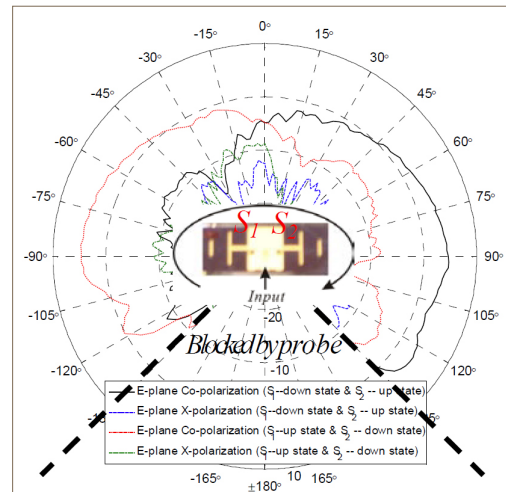
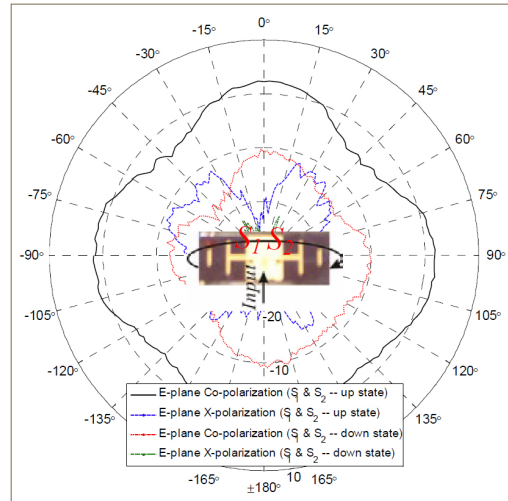
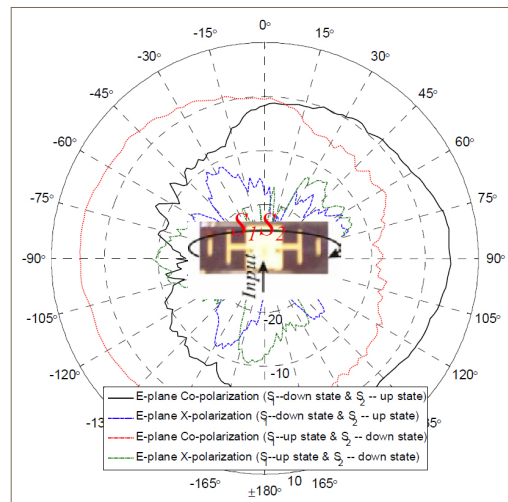


Fig. 16. Measured H-plane radiation patterns:
a). S1 & S2 -- up-state and S1 & S2 -- down-state.



b). S1 -- down-state & S2 -- up-state and S1 -- up-state & S2 -- down-state.



3. Conclusions

The original project plan indicated that the NAME router devices would be processed using SINTEF high capacitance ratio RF MEMS switch process finalised in this project. Unfortunately, the process was not ready in time to. For this reason, a third party fabrication run from Trento FBK was sub-contracted. In addition early in the project, the VTT process was made available to NAME via EU AMICOM network. However, no routers were manufactured in this run, but it yielded SPxT switches. The FBK run was also found to be problematic with most of the produced devices non-functioning. Yet, a few working devices were obtained, and the router operation was successfully demonstrated. Table 3 summarises the test results. SINTEF completed their process adjustments during the project. The process produces now a very high capacitance ratio (=25), RF MEMS switches with a high yield.

Table 3. RF MEMS device conformance to target specifications. C=conformant, NC=non-conformant, NA=not applicable.

Requirement	Min. accept.	Goal	Measured (@ 20 GHz)	Conformance
SPDT				
Insertion loss [dB]	1	0.7	1	C ¹
Return loss [dB]	-15	-20	-19	C
Isolation [dB]	30	40	39	C ¹
Switching time [μ s]	<100	<10	not tested	NA
Pull-down voltage [V]	<30	12	10-20 V	C
Power handling [W]	1	2	not tested	NA
IIP3 [dBm]	30	40	not tested	NA
Router				
Bandwidth [%]	15	20	could not be tested	NC ²
Insertion loss [dB]	1	0.7	could not be tested	NC ²
Return loss [dB]	-15	-20	could not be tested	NC ²
Isolation [dB]	30	40	could not be tested	NC ²
Switching time [μ s]	<100	<10	not tested	NA
Pull-down voltage [V]	<30	12	40	NC
Power handling [W]	1	2	not tested	NA
IIP3 [dBm]	30	40	not tested	NA
Number of ports	4	5	4 by design	C

(table cont.)

Requirement	Min. accept.	Goal	Measured (@ 20 GHz)	Conformance
Antenna				
Bandwidth, -10 dB return loss [%]	17	18	28.2	C
Gain [dBi]	4	5	4.6	C
Front to back ratio [dB]	11	12	14	C
HPBW [deg]	85	90	82	C
Number of elements	3	4	3 by design	C

1= The device in Fig. 2. Centre frequency has shifted to 24 GHz. devices manufactured in the VTT run.

2= See section 2.1.2. No functioning devices were obtained from the FBK run.

The SPDT results were obtained for devices from the VTT processing run, and the results are conformant to the specifications, although in some cases the centre frequency had shifted a few GHz. The devices were designed by FOI and VTT. The FBK run yielded no functioning 20 GHz SPDT, but working 35 GHz SPDT's (not in the scope of NAME) designed by FOI were obtained. Compared to simulations, the measured performance of these was slightly poorer with transmission loss about 1 dB, isolation 18 dB, and input and output match -15 dB.

The router and antenna results were obtained for the devices from the FBK run, and besides the antennas were mostly non-conformant. However, the non-conformancy is due to nonfunctionality of the devices, which therefore could not be tested. The results shown in Section 2.4 were obtained for the antenna integrated routers. None of the routers without antennas were functioning. For this reason the router switch networks could not be separately tested. But, the tests performed for the antenna integrated routers clearly demonstrated that the router concept works as designed. The switch networks were designed by FOI and VTT, and the antennas by Uppsala University.

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NORDIC ANTENNA INTEGRATED RF MEMS ROUTER

This report summarizes all the experimental results obtained in the four work packages of the Nordic Antenna Integrated RF MEMS Router (NAME) project.

The obtained results indicate that the design specifications are reachable, and that the NAME concept of higher level integrated routers for wireless communications or sensor networks is successful.

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