

The Medicina IRA-SKA Engineering Group

**The BEST-1 SKA demonstrator.
(Release A)**

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IRA N. 352/04



1 Abstract.

A substantial adaptation of the Northern Cross radiotelescope is planned to set up a demonstrator for gaining experience for the Square Kilometre Array (SKA) design. The Northern Cross is an array, composed of 5632 dipoles, and represents one of the largest collecting areas in the northern hemisphere (**30.000 m²**). Such a modification could produce a 3% SKA demonstrator at a relatively low cost (1.5 M€ to about 2.2 M€) and be ready to operate early 2006. It will also quickly deliver science in advanced pulsar or transient investigations. In this paper a first small prototype BEST-1 (**B**asic **E**lement for **S**KA **T**raining) is presented. It will allow testing of some basic concepts, algorithms and techniques for beamforming, adaptive beamforming and multibeamforming. As a second step, a larger BEST-2 test bed will be prepared. Finally, an overall Northern Cross Array modification will be performed to set up the full Italian SKA demonstrator (BEST-3). This could be considered a good starting point for the investigation of SKA concepts, algorithms and technology.

2 Introduction.

In the future Square Kilometre Array (SKA) design, many concepts and critical hardware problems will need to be overcome with different approaches, techniques and technologies. In this paper we will describe the BEST-1 (**B**asic **E**lement for **S**KA **T**raining), a small scale prototype demonstrator based on a single cylindrical antenna element of the North-South arm of the Northern Cross (about 176 m²). It will allow to gain experiences and prove crucial concepts, algorithms and techniques for:

- ❑ RF beamforming.
- ❑ Digital beamforming.
- ❑ Adaptive algorithms.
- ❑ Data acquisition / transmission (optical fibers)
- ❑ Calibration techniques.
- ❑ RFIs mitigation.

After tests of both the electronic (hardware) and algorithms (software) and the concepts proven, the same type of receivers will be installed on 8 cylinders to form a N/S station element equipped with multiple receivers. This will be referred to as the BEST-2, a larger demonstrator (about 1410 m²) that will allow us to proceed step by step toward the global Cross modification and to finally produce a large 1/33 scale (3%) SKA demonstrator. At that point, 256 receivers will be installed on all the cylinders composing the N/S arm, a 640x23.5 m array with 64 (7.5x23.5 m) cylindrical reflectors. This could quickly allow experiments on RFI rejection algorithms, multibeamforming and adaptive beamforming to be initiated. While developing and implementing BEST-1 and BEST-2, actions will be taken to widen the bandwidth of both the antenna and receivers (say 300 up to 1400 MHz). Simulations have demonstrated good characteristics of the cylinders from 140 to 700 MHz.

2.1 Architecture of the BEST-1.

We plan to start to develop low-cost, low-noise, high-dynamic range LNA, optical fibres links and digital down converter prototypes. Four receivers will be installed on a single N/S cylinder in order to initially set up the BEST-1. The basic block diagram is shown in Fig.2.1.1. A first step of analog adaptive beamforming is implemented at the RF level by means of a Vector Modulator (VM) that multiplies the RF signal by a complex weight $a_k e^{j\theta}$. The further step of adaptive beamforming is

placed at the back-end level. After the down conversion to the IF centre-band value (30 MHz) the signal is digitised with a 14 bit A/D converter (84 dB dynamic range) and then down converted around zero frequency via a DDC (complex form). The working principle of the DDC is illustrated in Fig.2.1.2: the digitised input band is mixed, via a complex multiplication, to 0 Hz. This complex mixer is actually a multiplier which is able to multiply the input band by the output signal of a Numerically Controlled Oscillator (NCO) operating at a frequency f_c equal to the desired tuning frequency. Many of the present commercial DDC devices have a sync feature that makes the phase synchronisation possible [1]. The DDC can be used to adjust the offset phase of the receiver, by starting each channel NCO phase accumulator with a proper value, then a phase delay can be easily introduced. In addition, by using the DDC amplitude scaling function, the amplitude weighting can be accomplished. In the same Fig.2.1.2 the low-pass filter (LPF) passes $1/M$ of the input band. After filtering, the rate can be “decimated” by a factor of M . In multi-channels applications, such as the N/S arm beamforming, each of the receivers must be phase synchronous. The current idea is to send the A/D sync and PPS via an optical link while the 378 MHz Local Oscillator is an analog signal via the already existing low losses coaxial cables (30 dB /Km @ 378 MHz)

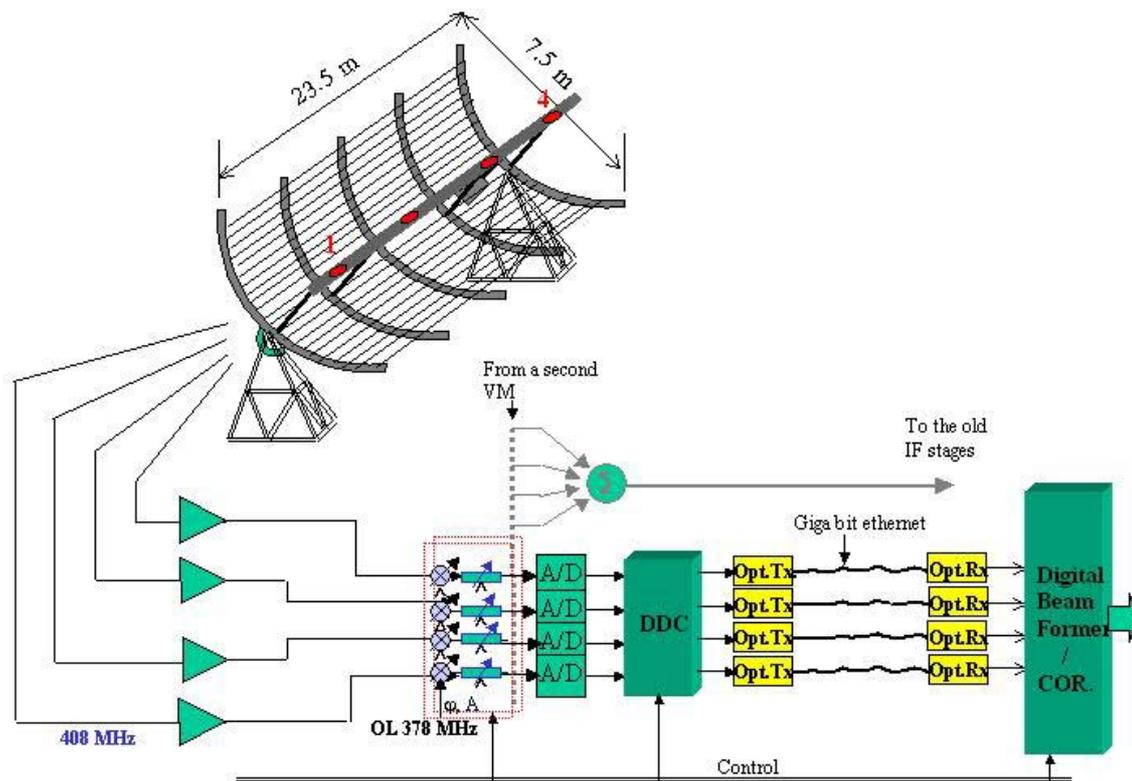


Fig. 2.1.1: Basic architecture of BEST-1

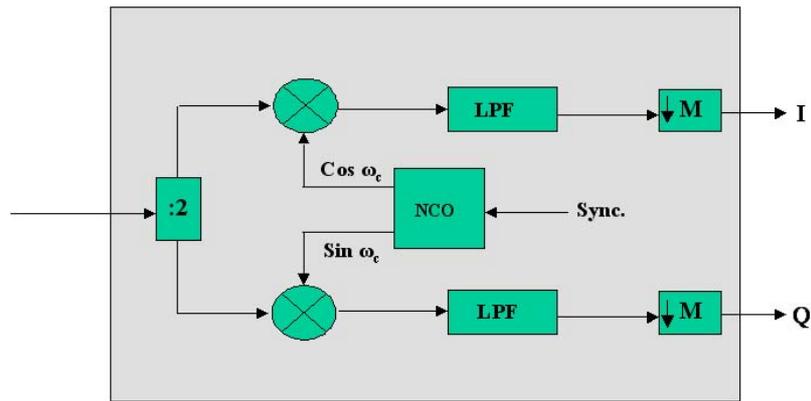


Fig. 2.1.2: Working principle of a Digital Down Converter

A last note: in Fig.2.1.1 we can see a second VM. This is used to calibrate each receiver in order to allow (after a summation) the use of the former telescope hardware.

2.2 The BEST –1

As already mentioned, the BEST-1 demonstrator is based on a single N/S arm reflector where four receivers are installed on the focal line (See Fig.2.1.1). The focal line has been uninstalled from the cylinder reflector and the dipole array was extracted from the plastic container, as visible in Fig. 2.2.2 and Fig. 2.2.3 respectively. The front-end (LNA) has already been designed and tested. In Fig.2.2.4, Fig. 2.2.5 and Fig.2.2.6, the block diagram, a photography and the measured S-parameters are reported. The LNAs will be connected to the baluns at the output of each block of *16 dipoles* on the focal line and then sent down to the small cabs, placed along the N/S arm, via a 70 m long low-loss coaxial cable. All cables have the same length in order to present the same delay. The IF stages are composed of commercial (Mini Circuits) COTS and do not represent a problem. In Fig. 2.2.7 two different block diagrams with and without VM (it will depend on the chosen architecture) are reported. The front-end plus the IF stage need more than 70 dB of gain.

The just mentioned LNA is suitable to be modified to work at different frequencies and wide band

2.3 Digital Receiver

The output of the IF is fed to a digital receiver which is able to digitise a bandwidth of 3.5 MHz at least with 14 bits in order to present a high dynamic range for RFI. The signal is then sent to a Digital Down Converter (DDC) devoted to down convert it to a complex video band. This is supplied to a series of Gigabit Ethernet converter blocks (IIM7010) that are time multiplexed in order to obtain a 1 Gigabit optical signal to be sent down to the processing room. At this level the optical information enters, through a commercial Gigabit Ethernet, a computer cluster. This seems to be a good way, in the sense that industry takes care of the modification and upgrade of such a standard. In the case we will use the Australian correlator (may be in the final Cross modification), a custom optical link needs to be designed. The complete block diagram of the receiver is summarised in Fig. 2.3.1 and 2.3.2. In Fig. 2.3.3. a complete block diagram of the whole receiver is reported.

2.4 Minimum detectable flux

An estimation of the minimum detectable flux with BEST-1 is given by:

$$\Delta S_{\min} \approx \frac{k T_{\text{sys}}}{A_{\text{eff}} \sqrt{B \tau}} \frac{1}{10^{-26}} \text{ Jy} \text{ and considering a } B=3.5 \text{ MHz, } T_{\text{sys}}=100 \text{ K, } \tau=420 \text{ sec at } \delta=0$$

and an $A_{\text{eff}}=108 \text{ m}^2$, the minimum detectable flux is (single polarisation):

$$\Delta S_{\min} \approx \frac{1.38 \cdot 10^{-23} \cdot 100}{108 \sqrt{3.5 \cdot 10^6 \cdot 420}} \frac{1}{10^{-26}} \approx 33 \text{ mJy}$$



Fig.2.2.1: A single N/S cylindric element used for BEST-1



Fig. 2.2.2 Uninstalling the focal line from a cylindrical reflector



Fig. 2.2.3: The linear array of dipoles extracted out of the plastic container

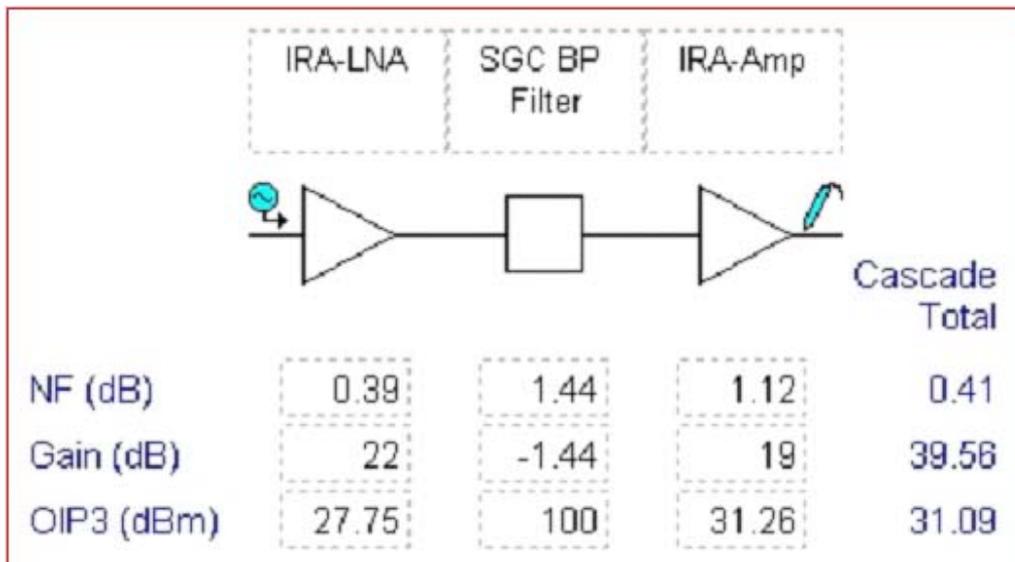


Fig.2.2.4: Block diagram of the final version of the front-end

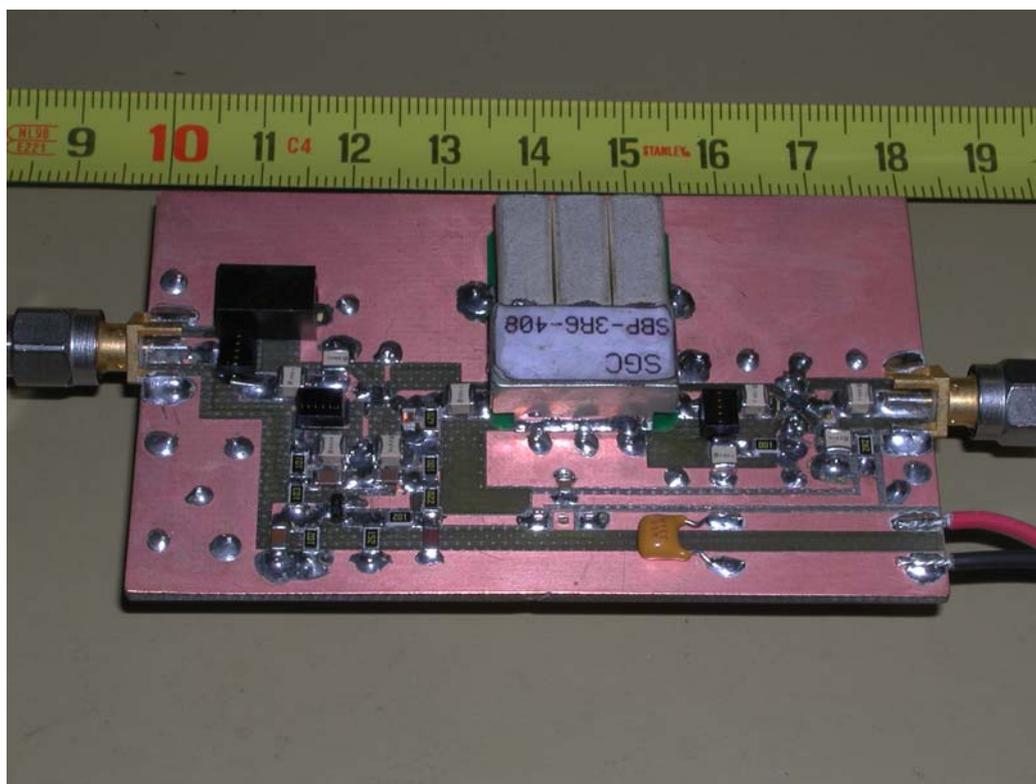


Fig.2.2.5: View of the double stage front-end prototype with interstage band pass filter

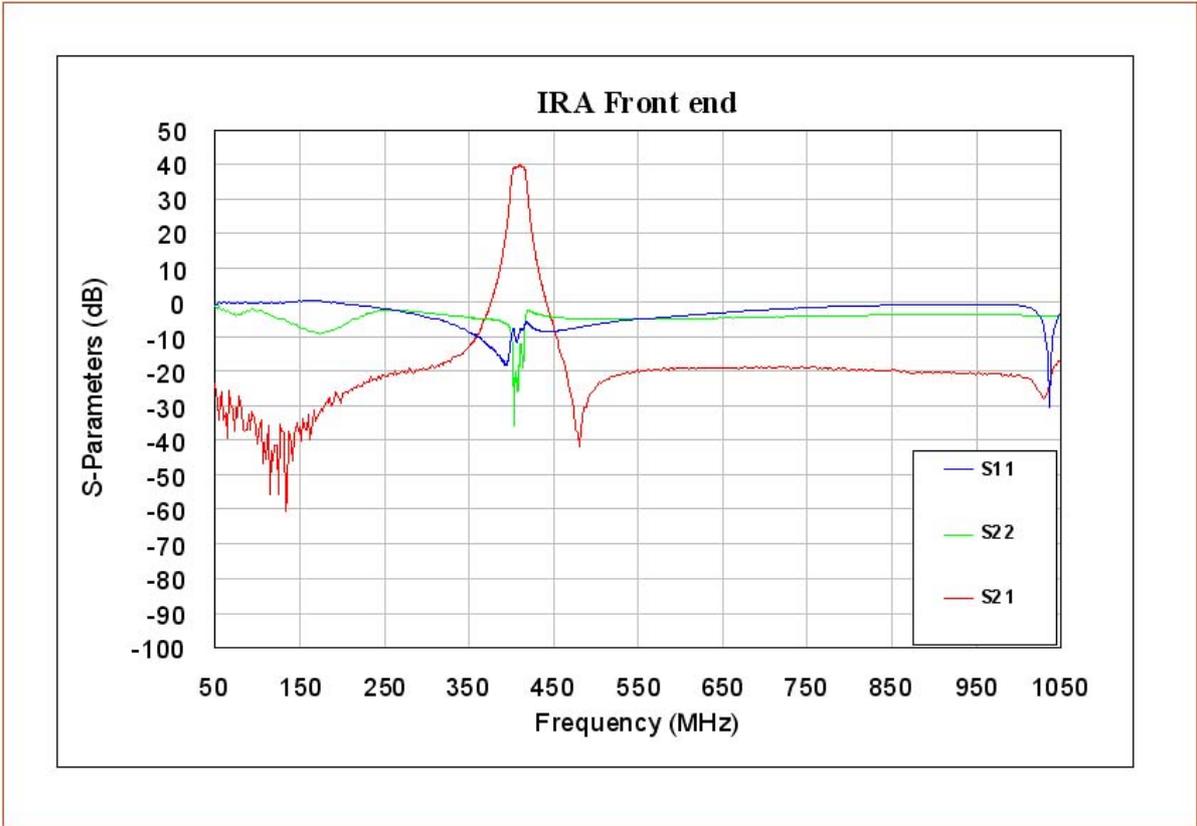


Fig.2.2.6: S-Parameters measurement

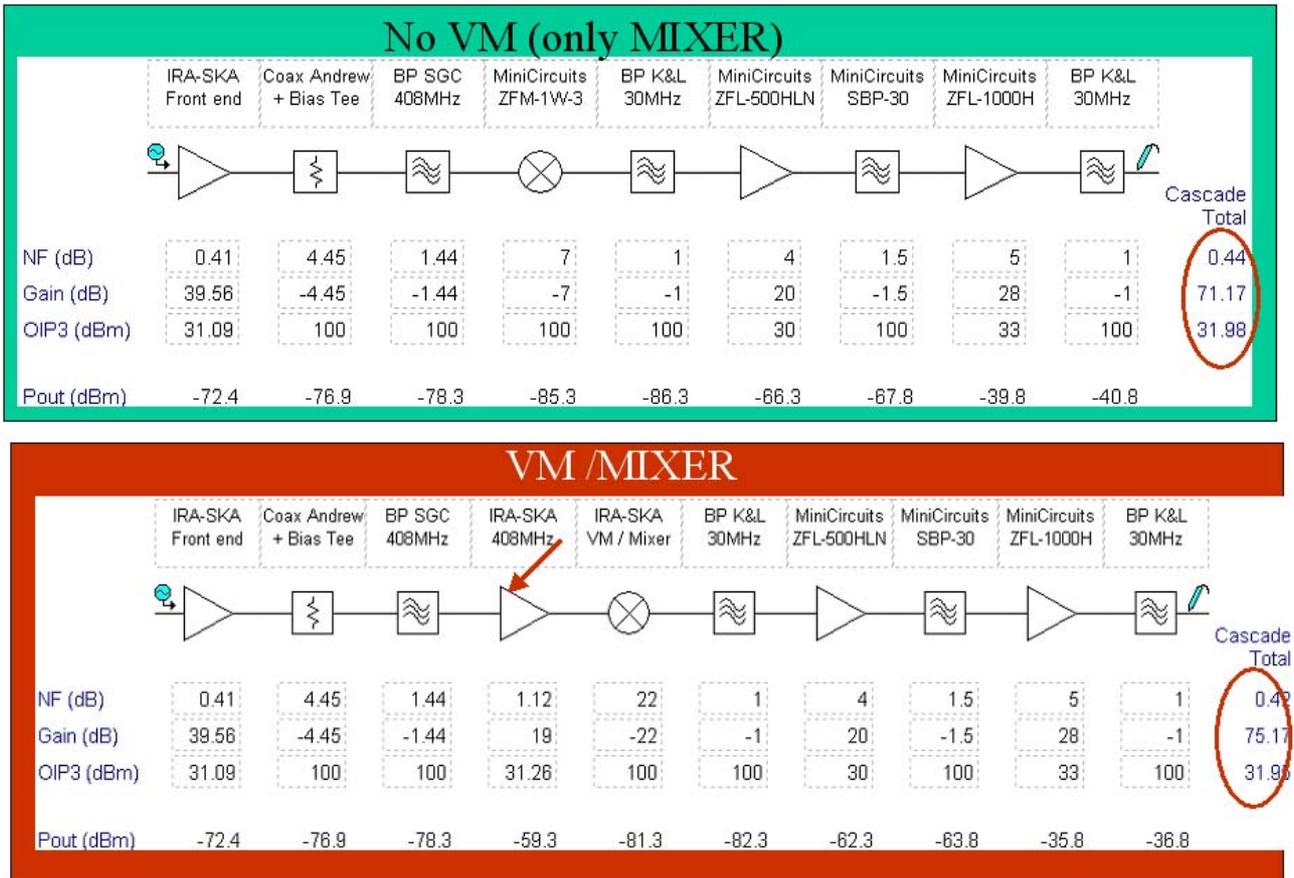


Fig.2.2.7: Block diagram of the IF in case the VM is respectively not used or used.

IRA-BCE DIGITAL RECEIVER block diagram

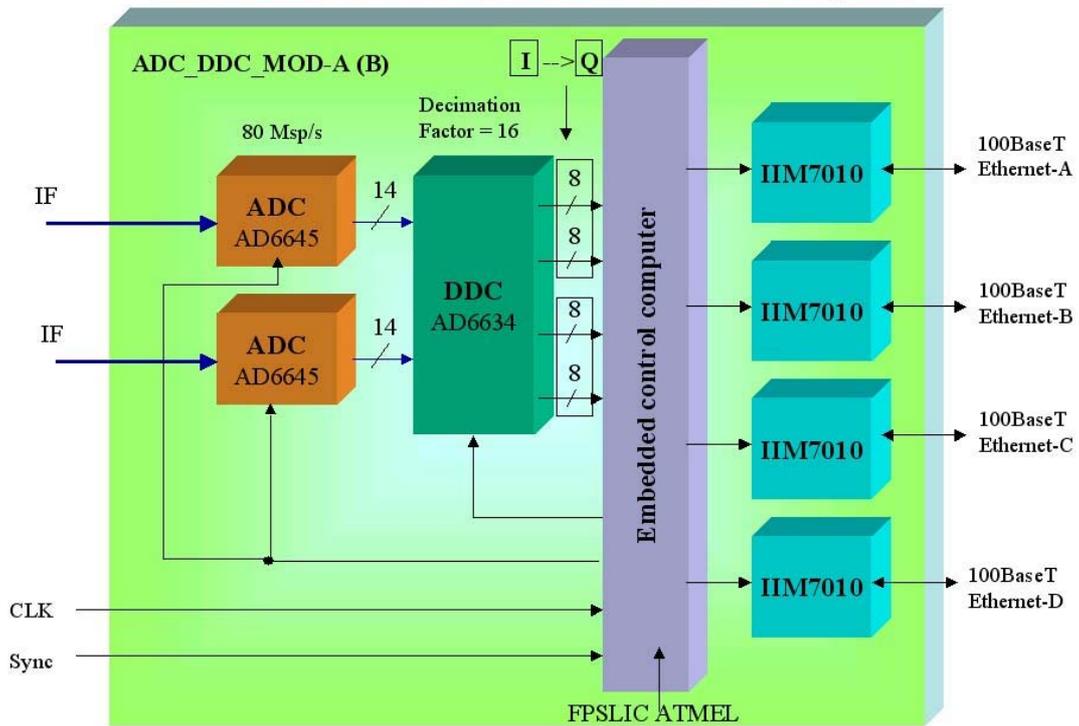


Fig.2.3.1: Detailed block diagram of the double channel digital receiver

2 ADC/DDC Boards & Switch + elet/opt converter

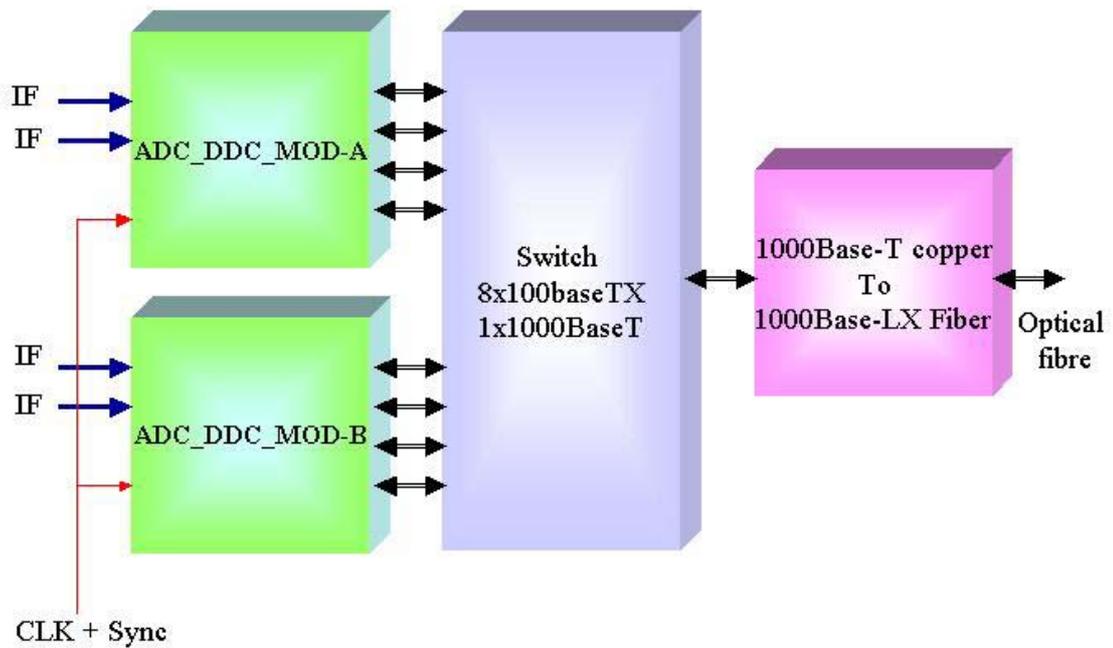


Fig.2.3.2: Detailed block diagram of the complete digital receiver board (4 channels)

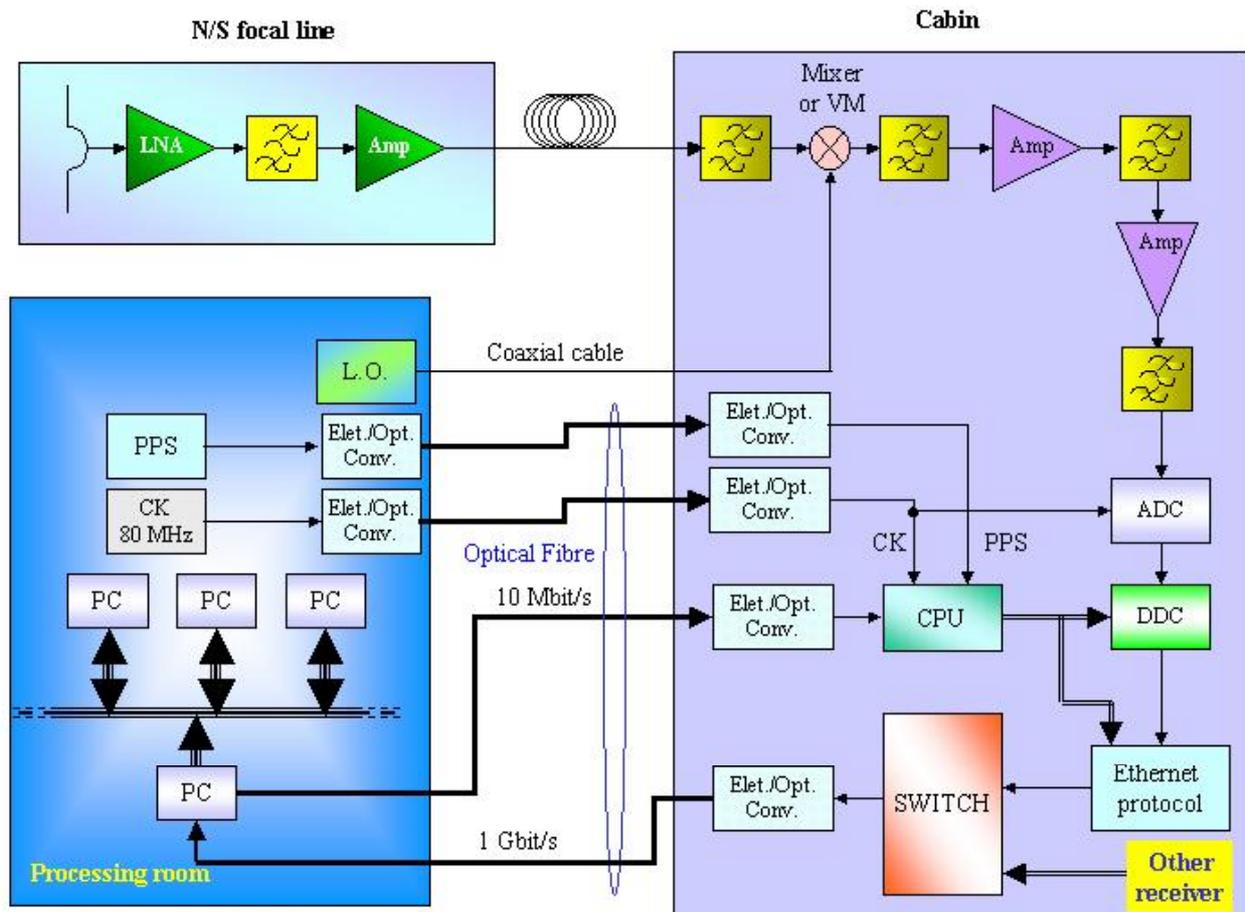


Fig.2.3.3 Final block diagram of the receiver

2.5 Imaging

There are two possible procedures to produce images :

1. Cross correlation followed by gridding and FFT of the uv data to the sky plane [5].
2. Direct imaging (pixeling the FOV with multibeams).

The standard procedure in radioastronomy (arrays) is to average the cross correlation function from all the single interferometers that can be formed. In our case (filled array with 352 receivers) a direct pixeling of the FOV with N beams could be more computationally attractive. In the traditional way, N beams mean N independent hardware branches but this inflates the costs of the same factor N but today it is possible to computationally obtain the direct imaging by means of:

- FFT method
- Digital direct multiple beamforming (Hardware or Software approaches)

In both these two cases the velocity and flexibility of FPGAs could be exploited. In fact, besides the well known FFT method, a digital /software approach could produce multiple beams, as reported in Fig. 2.5.1 where the blocks labelled $1...i...N$ are powered by fast FPGA like the Xilinx Virtex® family.

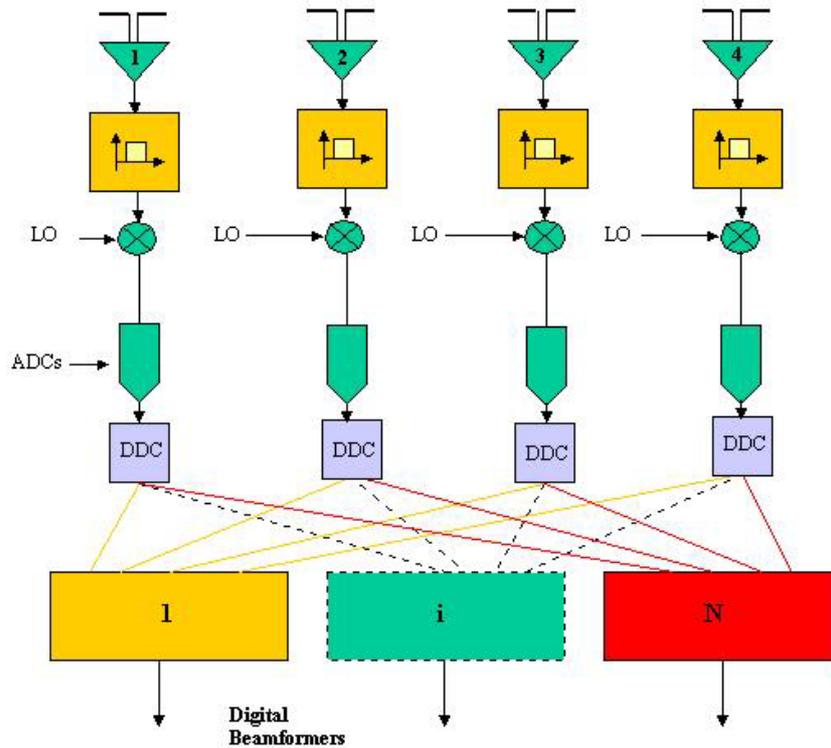


Fig. 2.5.1 Hardware / software multiple beams

2.6 Data handling

The BEST-1 is based on a single N/S (E/W aligned) 23.5 x 7.5 m cylinder so only the phases need to be compensated to form a beam. BEST-1 is intended to be a test bench to investigate the above mentioned methods (correlation and direct imaging) to acquire experience for next generation of demonstrator.

a) Computation power requested by a FX correlator [6]

For BEST-1 we have:

$N_{rx}=4$	(Number of receivers)
$B_w= 3.5$ MHz	(Bandwidth)
$N_s=128$	(Spectral channels)

The bandwidth B_w in Hz is the same complex data digitizer speed in sample/sec.

Then:

$FFT=5 N_{rx} B_w \log_2 N_s$	(Operations / sec.)
$Cross\ Correlation \approx 8 N_{rx}^2 B_w$	(Operations / sec.)

The factor “5” in the FFT comes from the number of multiplies and adds in a FFT butterfly stage. In fact there are 10 operations per butterfly (time decimation), but a butterfly operates on 2 data points at a time.

We obtain:

$$N_{\text{tot}} = (8 \times 16 \times 3.5\text{E}6) + (5 \times 4 \times 3.5\text{E}6 \log_2 128) \approx \mathbf{938\text{E}6} \text{ (Operations/sec)}$$

Since with 4 rx we obtain (synthesis imaging) 16 beams, the total computation amount per each beam is:

$$\mathbf{938\text{E}6} / \mathbf{16} \approx \mathbf{59\text{E}6} \text{ (Operations/sec)/beam}$$

b) Computation power requested by a direct beamforming

We estimate here the computation power requested to perform a direct beamforming.

The operations required for phasing each receiver are reported in Fig. 2.6.1. Practically, considering 4 receivers, to directly form one single beam we need [6]:

- 4 Multiplications per sample each receiver
- 2 Sum per sample each receiver
- $2(N_{\text{rx}} - 1)$ Sum per sample each beam

$$\text{Beamforming} = [2(N_{\text{rx}} - 1) + N_{\text{rx}}(4+2)]B_w = [2N_{\text{rx}} - 2 + 4N_{\text{rx}} + 2N_{\text{rx}}] B_w \text{ (operation /sec) per beam, then}$$

$\text{Beamforming} = (8N_{\text{rx}} - 2) B_w, \quad \text{(Operation /sec) / beam}$

Considering that all operations are executed at 3.5 MS/s (complex base band signal), we obtain:

$$(8 \times 4 - 2) \times 3.5\text{E}6 = 105 \text{ (Million Operations /sec.) / beam}$$

in addition we have to consider 14E6 for power and average computations (2 multiplications and 2 additions per sample each beam). The total computation power requested is then **119E6 (Operations /second) / beam**

$$W_k = a_k e^{j\phi_k} = a_k \cos \phi_k + j a_k \sin \phi_k \quad \leftarrow \text{Weight (Phase and Amplitude)}$$

$$S_k(t) = I_k(t) + jQ_k(t) \quad \leftarrow \text{Complex Signal}$$

$$S_k(t)W_k = a_k [I_k(t) \cos \phi_k - Q_k(t) \sin \phi_k] + j a_k [I_k(t) \sin \phi_k + Q_k(t) \cos \phi_k] \quad \leftarrow \text{Weighted Signal}$$

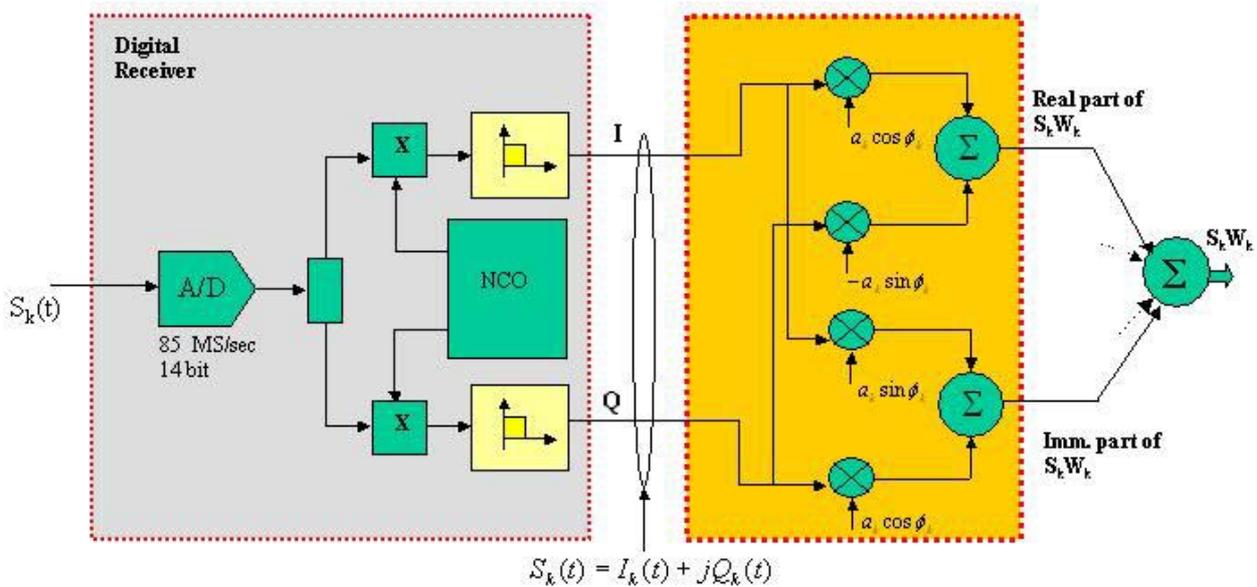


Fig. 2.4.1: Beamforming Operations to be implemented on each receiver

3.0 Either Correlator or Cluster of Personal Computers?

On the BEST-1 demonstrator (4 receivers – 6 baselines) we plan to test both a correlator based on a small cluster of PCs and the Australian correlator designed for the Molonglo radiotelescope [7], [8]. In the first case, once the signal is transformed in a “Giga Ethernet” format, it is sent to the central processing building, at the other side of the link, data are introduced to the PC cluster via a commercial Giga Ethernet interface. The choice of the optical link seems to be one of the most crucial points where bandwidth and speed requirements generally don’t fit the low costs demand. Once the digital signals are in the receiver room, they have to be distributed to all the PCs composing the cluster. In order to evaluate the performances of the network hardware available on the present market, some tests were carried out. The aim was to establish how much of the declared bandwidth can be really exploited.

To run the experiments we used two PCs with the following configurations:

- MARK5P (MK5) – 64 bit double PCI bus motherboard with 1 Gbit Ethernet board;
- Commercial PC (Titan) – PIV 2GHz with Titan533 standard PCI motherboard and 1 Gbit Ethernet board.

A first test concerned the UDP protocol and was performed using the UDP_BW_MON software, while a second experiment regarded the TCP protocol and was carried out with TCP_BW_MON1.

Both programs transfer data packets - using respectively the UPD and TCP protocols - through the net, spaced by decreasing time intervals.

The tests consisted in measuring how the bit-rate varies with this time delay.

Figure 1 shows UPD results:

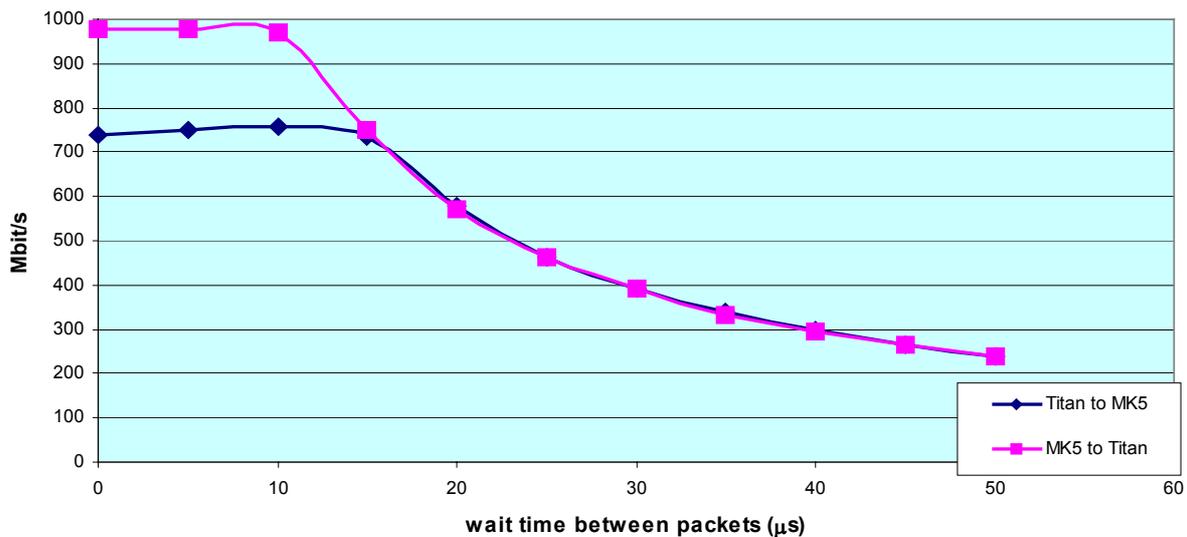
- Transferring data from MK5 to Titan, a saturation plateau of 975 Mbit/s is reached for time delays lower than about 11 μ s. This value is almost coincident with the nominal one.
- Transferring data from Titan to MK5, the network saturation level is reached at 737 Mbit/s.

This difference can probably be explained considering the limited bandwidth offered by the standard PCI bus of the Titan533 motherboard.

TCP results are, instead, restricted to a one-way transmission from Titan to MK5 (see next figure); the maximum obtained bit-rate is only around 828 Mbit/s, and this is due to the fact that TCP is a heavier protocol. It is interesting to notice that, despite what could be thought a priori, the CPU usage relative to the first test is higher than the one obtained during the second experiment. Evidently, the greater network traffic achieved in the former case has a weight on the CPU which is higher than the saving obtained employing UDP instead of TCP.

Given the low cost of these devices, our proposal is to employ them for the development of a multi-purpose software station to be used also within the SKA project.

Figure 1: UDP send data_rate Mbit/s

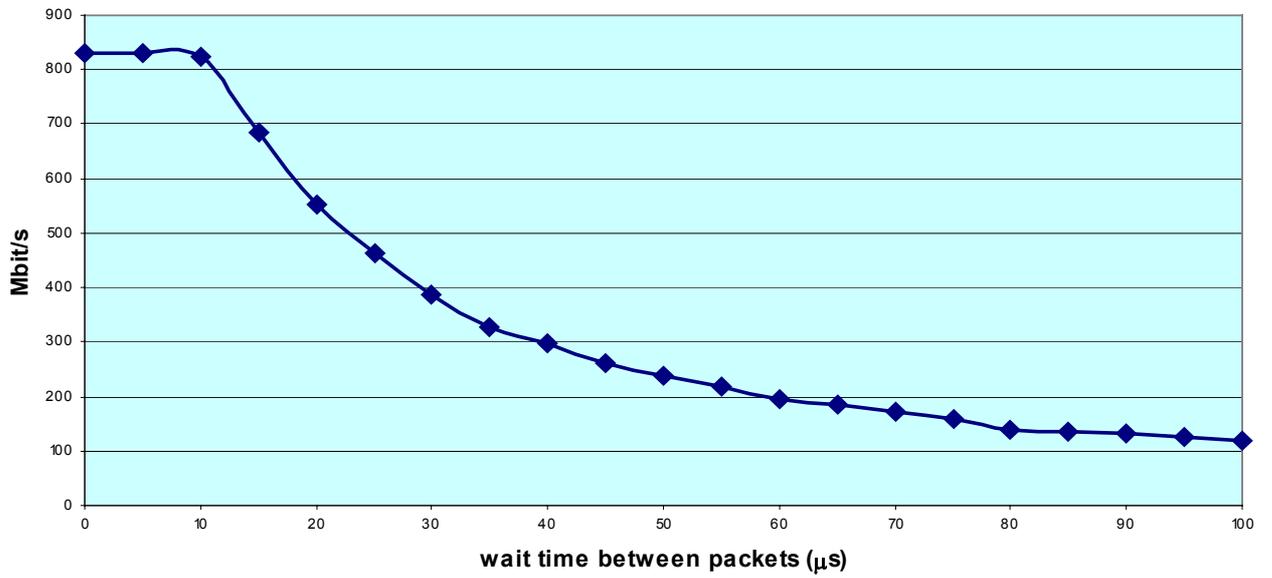


CPU usage (MK5 to Titan533)

60% on MK5

45% on Titan 533

Figure 2: TCP send data_rate Mbit/s



CPU usage

57% on MK5

16

4.0 Time schedule

The BEST-1 demonstrator time schedule is reported in the Table 1. The time starts from the August 1st, date at which we consider placed all the orders for the required materials and replication of LNAs, IF stages and digital receivers.

BEST-1	Aug.03	Sept. 03	Oct. 03	Nov. 03	Dec. 03	Jan. 04	Feb. 04	Mar. 04	Apr. 04
LNA & Dig. Rec. Replicat.	████████████████████								
Optical Fibre Instal.			██████						
Assembl.			████████████████						
Tests: -Beamf. -Adapt. Beamf					████████████████████				

Table 1

As already mentioned, we consider as a second step the assembling of the BEST-2 demonstrator (4 or 8 receivers grouped by two installed on 8 N/S cylinders). The time schedule for this phase is reported in Table 2. At the end of the BEST-2 test phase, we will start the replication of the receivers requested for the global Cross transformation in a very large (3% of SKA) demonstrator. We remember that, as stated in the American ATA definition, a demonstrator needs to be at least 0.5% or 1 % of the SKA effective area.

Once the BEST-1 and BEST-2 tests are completed, the final phase (total modification of the Cross) will be faced. In that phase it will be only matter to have funds to replicate the hardware and hire sufficient man power. Global modification of the Northern Cross array could end early 2006.

BEST-2	Apr. 04	May 04	Jun. 04	July 04	Aug. 04	Sept. 04	Oct. 04	Nov. 04	Dec. 04
LNA & Dig. Rec. Replicat.	████████████████████								
Optical Fibre Instal.						... *			
Assembl.						████████████████			
Tests: -Beamf. -Adapt. Beamf							████████████████		

Table 2

* Optical fibres have been already installed on the BEST-1 demonstrator. Here only fibers wiring and connectorization are considered.

5- Costs estimation

We give an estimation of the BEST-1 set up cost:

HARDWARE

- 1) Front end, Coaxial cable, IF and OL
- 2) Digital Receiver
- 3) Sync. Distribution
- 4) Temperature control system
- 5) Racks
- 6) Optical Fibre links
- 7) Back end

RF, COAXIAL CABLE, IF:

Front end (408MHz):

First stage (SMD components)	€ 12
Ceramic interstage filter SGC	€ 9
Second stage (SMD components)	€ 6
Power supply (SMD components)	€ 2,6
Front – End (hardware) subtotal	€ 29,6
Shielded box TEK0	€ 3,15
RADIALL R161410000 (2X) connectors	€ 12
Connectors for installation on the focal line	€ 30
Water proof housing box ROSE	€ 50
Production / assembling	€ 40
Front – end (housing/production/assembling) subtotal	€ 135,15
Subtotal Front-End	€ 164,75

1- Total cost for 4 Front ends: 4x164,75+20% (V.A.T.) ≈ € 791

Coaxial cables:

Andrew ½” LDF4-50A L=65mt + conn. N	€ 229
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2- Total cost for Coaxial cables 4x229+20% (V.A.T.) ≈ € 1100

I.F stage composed by COTS (30MHz):

Ceramic filter SGC (4X)	€ 36
Bias Tee MiniCircuits PBTC-1G (4X)	€ 136
Mixer MiniCircuits ZFM-1W-3 (4X)	€ 330
MiniCircuits ZKL-1R5 (4X) amplifier	€ 768
I.F filter K&L 6LB30-30/X5-OP/OP (8X)	€ 2400
OL MiniCircuits SLP-450 (4X) filter	€ 184
OL MiniCircuits SHP-300 filter	€ 51
Internal connectors	€ 200
OL MiniCircuits ZFL-1000H amplifier	€ 280
Splitter X4 MiniCircuits ZSC-4-1	€ 90
External connectors, power Supply	<u>€ 500</u>
	€ 4975

3- Total cost for the I. F stages 4975+20% (V.A.T.) = € 5970

DIGITAL RECEIVER:

Core digital receiver:

2 x ADC: AD6645 (€ 63.53 each)	€ 127
DDC: AD6634 (€ 32.30 each)	€ 32
Controller (FP Slic Atmel): AT94K40AL-25BQC	€ 50
5 x G. B. formatter: IIM7010 (€ 33 each)	€ 165
Connectors, assembling, various...	<u>≈ € 1000</u>

≈ € 1375

Digital receiver data interface and transmission, power supply, other:

Data link Switch (D-LINK, DES-1009G)	€ 200
Data link E/O converter	€ 1000
Control Signal (2 x E/O converters € 500)	€ 1000
Ethernet Switch	€ 500
Power Supply	€ 400
Cables	€ 100
Housing	<u>€ 100</u>
	≈ € 3300

4- Total cost for Digital receivers ≈ 2x1375+3300+20% (V.A.T) ≈ € 7260

SYNC. DISTRIBUTION:

TX:	Squarer LT1715	€ 5
	PLL ICS570	€ 1,4
	2 x TTL/PECL MC100EL111 (€ 4 each)	€ 8
	Transceiver E/O HFBR-5805	€ 50
	Fiber optic transmitter HFBR-1312	€ 20
	Fiber optic receiver HFBBR-2316	€ 20
	Power Supply /stab. 3V LT1584CT	€ 3
	Connect., switches, P.C. Board, assembling, other components	€ 2000
	Rack 4U	€ 200
		≈ € 2310

RX:	Transceiver O/E HFBR-5805	€ 50
	Fiber optic transmitter HFBR-1312	€ 20
	Fiber optic receiver HFBBR-2316	€ 20
	Connect., switch, P.C. Board, assembling, ..	€ 1000
		€ 1090

5-Total cost of the Sync. distribution links: 3400+20% (V.A.T.) = € 4080

6- Temperature control system: € 2000

7-Rack: € 1200

OPTICAL FIBRE LINKS:

multimode 6 cores cable (ST connectors):	€ 1504
monomode 20 cores cable (SC connectors):	€ 3020

8- Total cost for optical links = 4524+20% (V.A.T.) ≈ € 5430

BACK-END

Data link 1000LX Ethernet transceiver	€ 1000
PC (3X)	€ 3000
Network interface and links (3X)	€ 3000
	<u>€ 7000</u>

9- Total cost for back end = 7000+20% (V.A.T.) = € 8400

$$1+2+3+4+5+6+7+8+9= 36.200 \text{ €}$$

MAN POWER

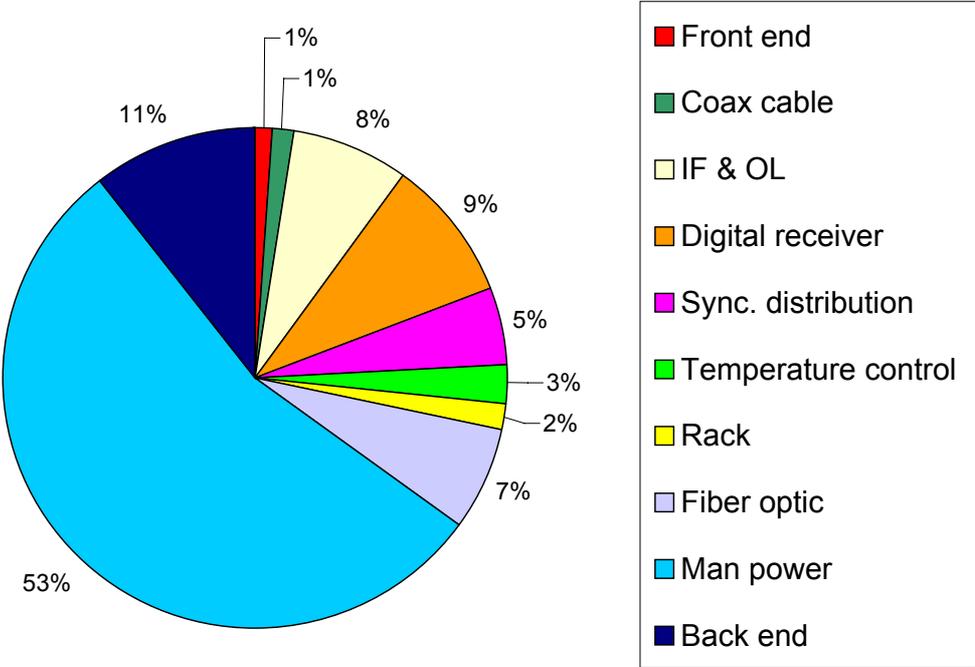
The Man Power required is estimated, with good accuracy, at about **43 K€**.

OVERHEAD

The Overhead (10%) is computed only on the not yet placed orders (Sync, Temperature, Rack, Fibre, Back-end and Man power). It's estimated at about **2,7K€**.

TOTAL COST OF BEST-1 ≈ € 36.2 K€ + 43 K€ + 2.7 ≈ 82 K€

BEST-1 COST DISTRIBUTION



NOTES:

- Since the optical fibers are used also for the BEST-2, this cost will not be reported in the future BEST-2 estimation costs.
- Crane for N/S lines dismounting / mounting and developing costs are included in the man power item and they will not appear in both BEST-2 and BEST-3 costs estimation.
- Costs estimation have been evaluated for the 4 receivers per cylinder configuration.

6.0 Preliminary adaptive beamforming simulation for BEST-1

A very preliminary version of a simulation program for conventional and adaptive algorithms for:

- null beam steering,
- Minimum Mean Square Error (MMSE)
- Minimum Variance Distorsionless Response (MVDR)

have been written in Matlab. Some different cases have been taken in considerations, particularly:

- Case with 64 receivers per cylinder, 64 theoretic sensors or 64 ($d=\lambda/2$).
- 4 receivers per cylinder, 4 theoretic sensors or 16 dipoles connected in parallel.
- 8 receivers per cylinder, 8 theoretic sensors or 8 dipoles connected in parallel.

Theoretical case

In this first step we consider the case with 64, 8 and 4 theoretic sensors (not dipole)

First we considered (Fig.6.0.1) a theoretical case in which one receiver per dipole is used (64 receivers each cylinder) having positioned twelve RFIs at $\theta_1 = -18^\circ$, $\theta_2 = -15^\circ$, $\theta_3 = -11^\circ$, $\theta_4 = -10^\circ$, $\theta_5 = -7^\circ$, $\theta_6 = -4^\circ$, $\theta_7 = 3^\circ$, $\theta_8 = 4^\circ$, $\theta_9 = 7^\circ$, $\theta_{10} = 10^\circ$, $\theta_{11} = 12^\circ$, $\theta_{12} = 15^\circ$

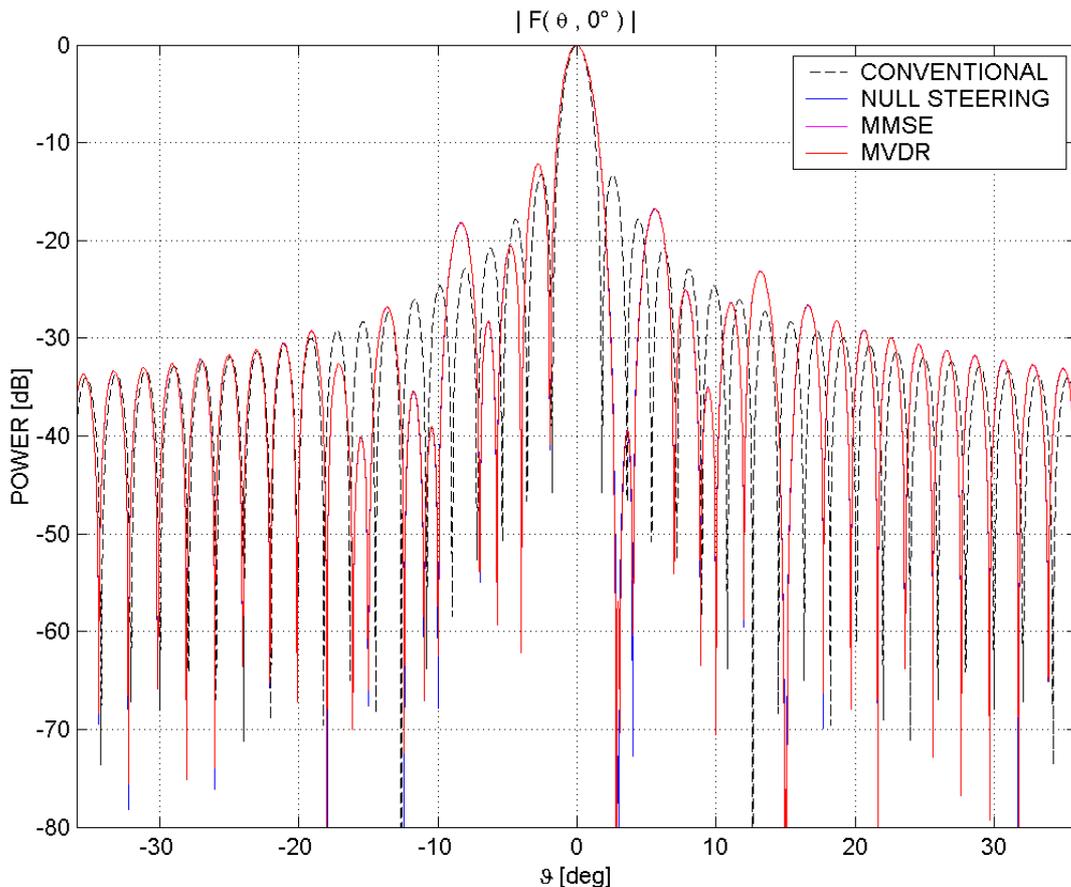


Fig. 6.0.1 Theoretical case of 64 dipoles / 64receivers.

We note that with the interferers placed in the selected locations, all the considered adaptive algorithms seem to work properly. Anyway the use of 64 receivers is not a practical approach

because it is too expensive. The BEST-1 prototype is planned to use 4 or, maximally, 8 receivers. In the case of 4 receivers the number of interferers that can be rejected seems to be extremely low (1 or 2) because with N receivers 1 degree of freedom is requested to maintain the main beam in the target direction and one for each null pointed toward each interference. Then in theory, we could say that a beamformer with N antennas can steer $N-2$ nulls. In practice, as the amount of interference increases, it becomes more and more difficult to steer nulls in the direction of such interference. It seems that, as a rule of thumb, removing more than $N/2$ interferers could be difficult unless we are operating with large aperture or well separated signals.

In Fig. 6.0.2 two interferers are supposed to be placed at $\theta_1 = 33^\circ$, $\theta_2 = -27^\circ$. Adding more interference the algorithms doesn't work properly. Also in this case the different algorithms appear to work properly. More interference can be rejected if BEST-1 is equipped by 8 receivers. In this case a simulation with 4 interferers at $\theta_1 = 33^\circ$, $\theta_2 = -27^\circ$, $\theta_3 = -40^\circ$, $\theta_4 = 22^\circ$, as been carried out as visible in Fig. 6.0.3.

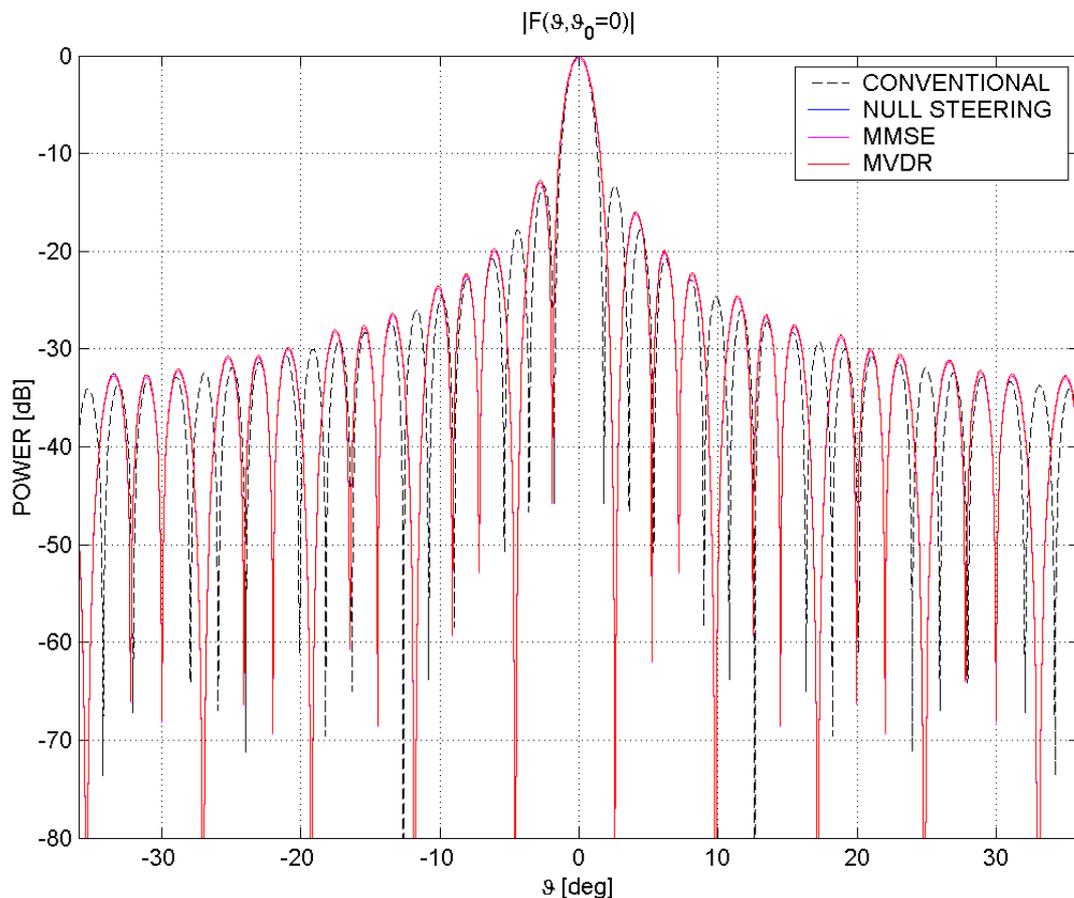


Fig. 6.0.2: 4 Rx per cylinder and 2 interferers: one at 33° and the other at -27° deg.

A zoomed view of a secondary lobes (using the 3 adaptive methods) around a zero placed at $\theta = 9$ deg (4 receivers configuration), is reported in Fig. 6.0.4. These very preliminary algorithms simulations seem to give positive results anyway this is just a starting point for future investigation.

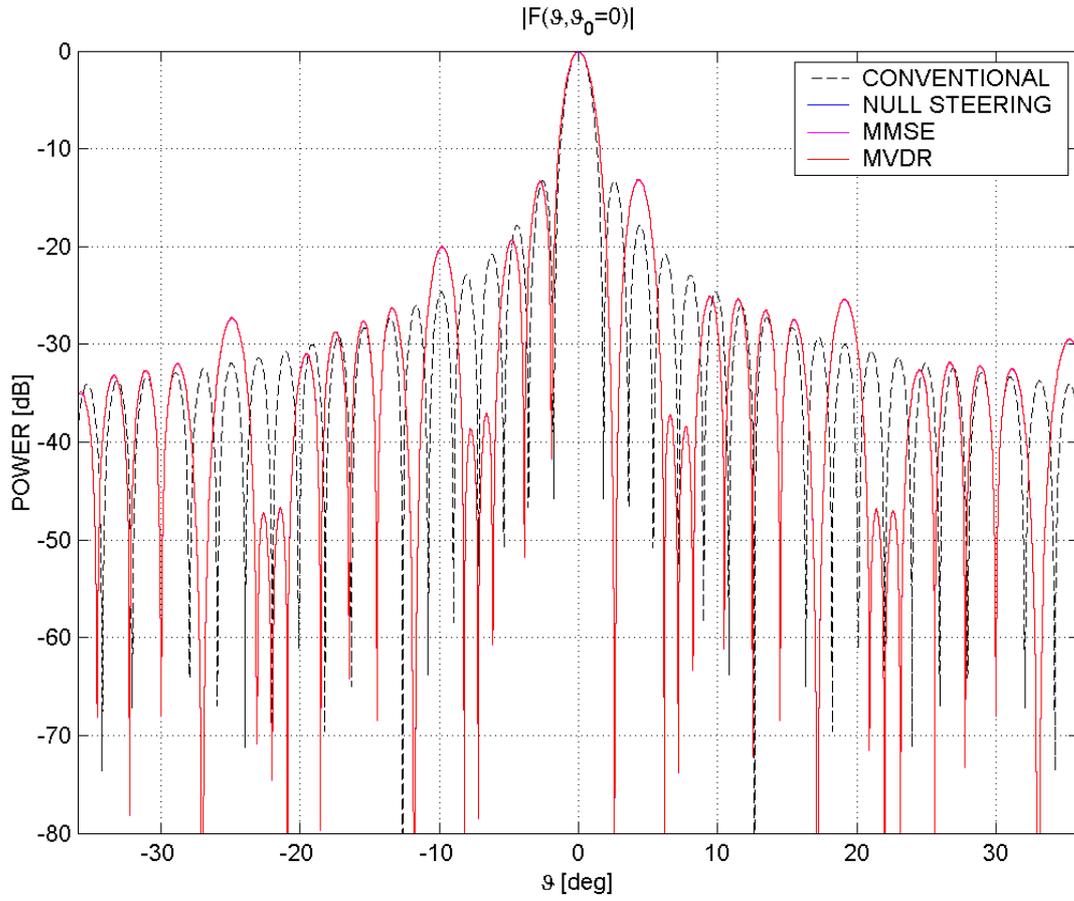


Fig. 6.0.3: 8 receivers per cylinder and RFIs at $\theta_1 = 33^\circ$, $\theta_2 = -27^\circ$, $\theta_3 = -40^\circ$, $\theta_4 = 22^\circ$,

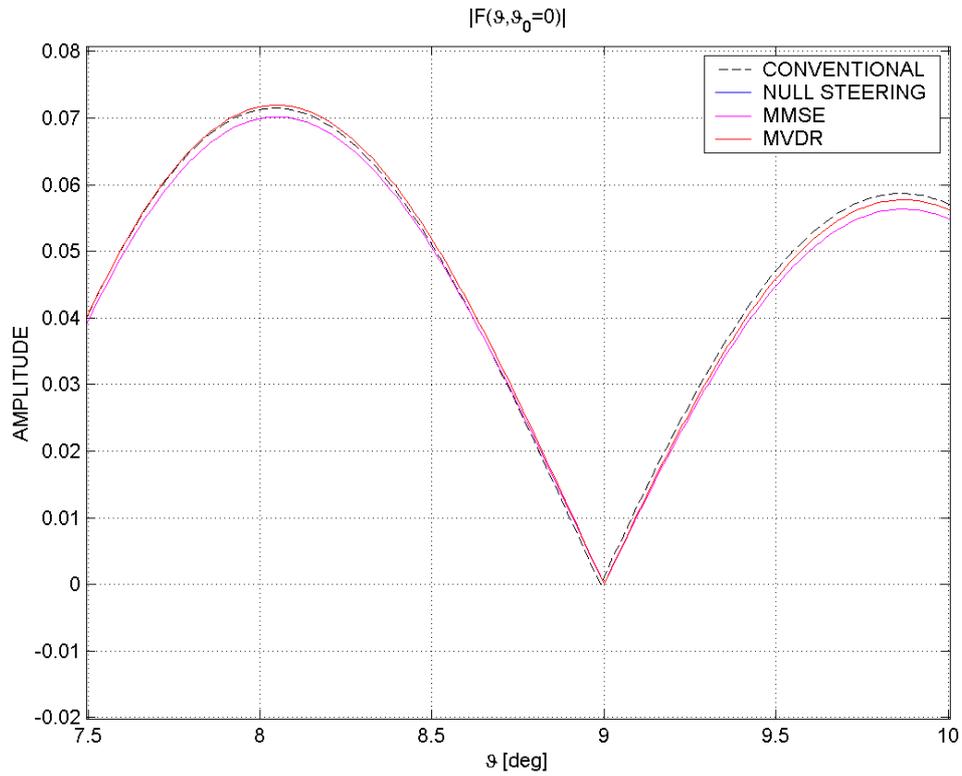


Fig. 6.0.4 zoom of the secondary lobes behavior with the 3 methods, around a zero placed at 9°

7.0 Conclusions

The design and construction of a reduced scale SKA demonstrator (BEST-1) based on a modification of the Cross radiotelescope, has been proposed here. The BEST-1 (176 m² collecting area) is just a first step of the Italian possible different size SKA demonstrators construction. As a second step the BEST-2 demonstrator (about 1410 m²) could be constructed within the year 2004. The final global Northern Cross transformation in a 3% SKA demonstrator (BEST-3) could be completed early 2006. This is just a starting point. Different and more suitable solutions can be chosen during the BEST-1 design and construction, in order to be exploited in the BEST-2 and/or in BEST-3.

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Acknowledgement

We thank Prof. G. Grueff for his revision of this paper.