Multi-element MMIC focal array for radio telescope

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Focal receiver arrays seem to be an unavoidable solution for the existing and the next generation reflector radio telescopes where high sensitive (or high speed) mapping is the main goal (Parijskij et al., 1993). The significant progress in MMIC array technologies in MM band (Weinreb, 1998) gives us a chance to realize an important RATAN-600 advantage: the wide aberrationless focal zone (Khaikin et al., 1999). A multi-element feed array placed at the focal plane may significantly increase sensitivity and the field of view of any radio telescope.

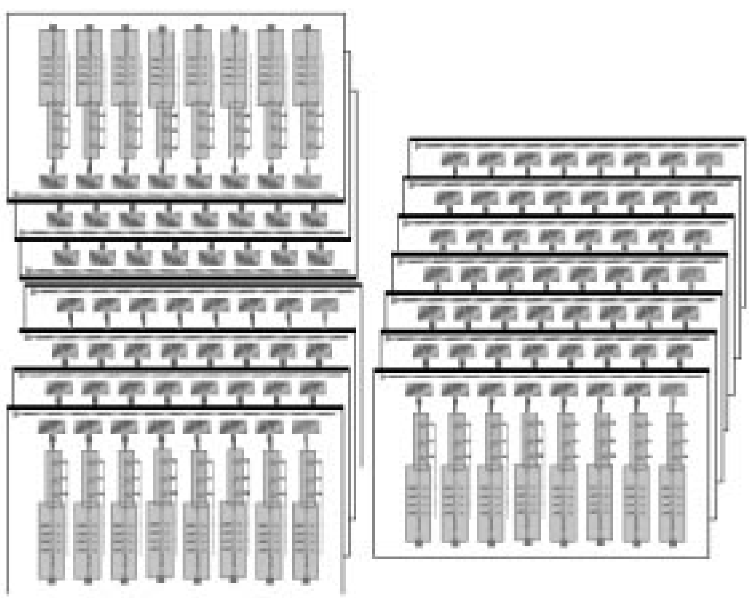

Figure 1: “Terraced” 7×8 element MMIC array architecture

For the array substrate we use Rogers Corp. ceramic filled composite materials with 0.0013 loss tangent and 3.02 dielectric constant. Microstrip radiators of each level are fed by microstrip lines in the plane of radiating sheet. In the first MMIC array prototype at 26 – 30 GHz radiators receive the signal of Y polarisation, X/Y linear or circular polarisation will be available with the next prototypes as well. Mutual radiator coupling is provided at −30 dB level, VSWR<1.35 in the range 26.5 – 30.5 GHz. Rather wide bandwidth for the microstrip radiator is reached by an air cavity under the dielectric substrate (Khaikin et al., 1999).

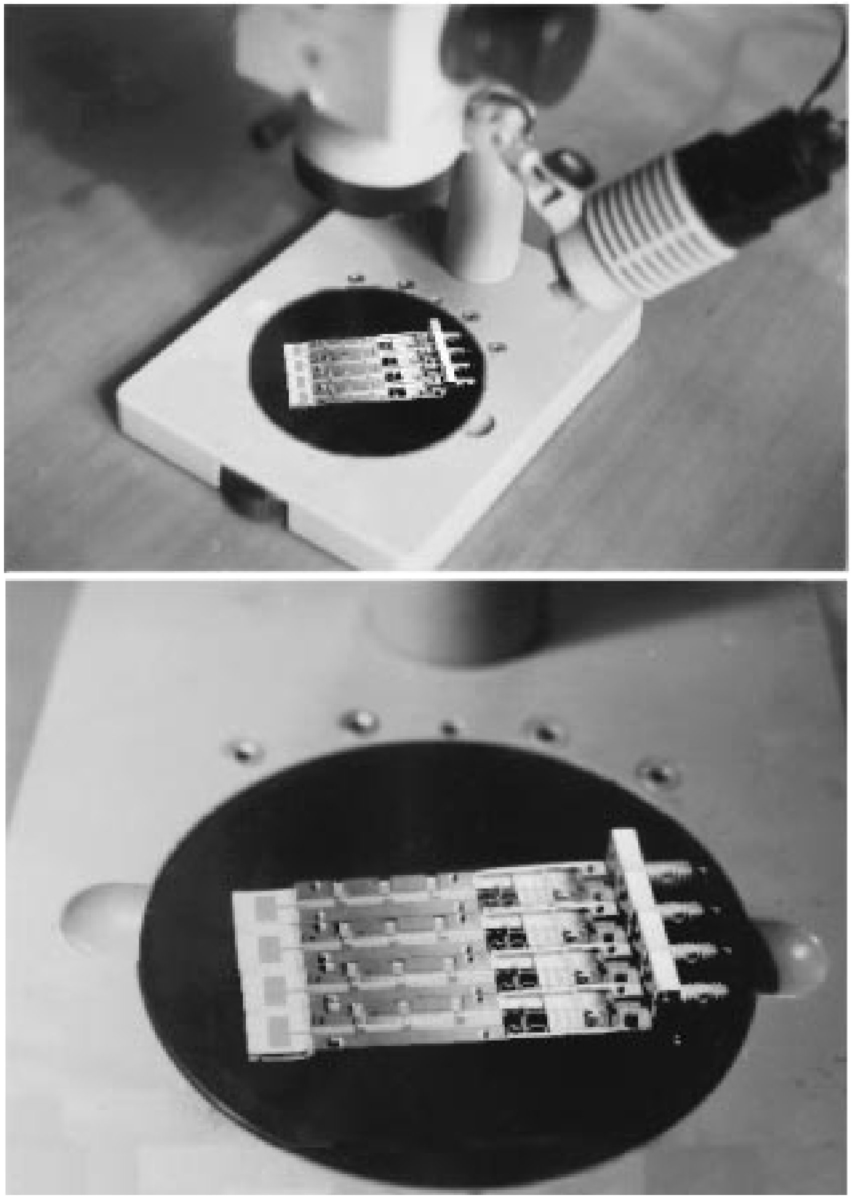

Figure 2: 4 element MMIC sub-array prototype at 26-30 GHz

In the first 8-element front-end prototype we used MMIC amplifiers of Litton SSD (NF=2.5 dB) which give us direct RF amplification (60 dB) in receiving channels in the "total power" mode. With UMS MMIC amplifiers (NF=1.8 dB) we expect System temperature about 200 K for the array directed to Zenith. Input-output and mutual channel coupling is provided at a low enough level with the help of a cut-off waveguide covering each channel up to the detector (Fig.1). The microstrip bandpass filters put before detectors limit channel bandwidth to 4 GHz in agreement with the input radiator bandwidth. A communal input channel calibration is produced through a special loaded 50 Ohm microstrip line connected with a loaded LMA-422 used as a noise oscillator in the same frequency range. Mutual coupling of the microstrip line with radiators is about −40 dB. Super low noise HP Schottky square low detectors complete VHF parts of array. Low noise high precision AD FET monolithic operational amplifiers are applied in the wideband multi-channel back-end. Four-element sub-array prototype is shown in Fig.2.

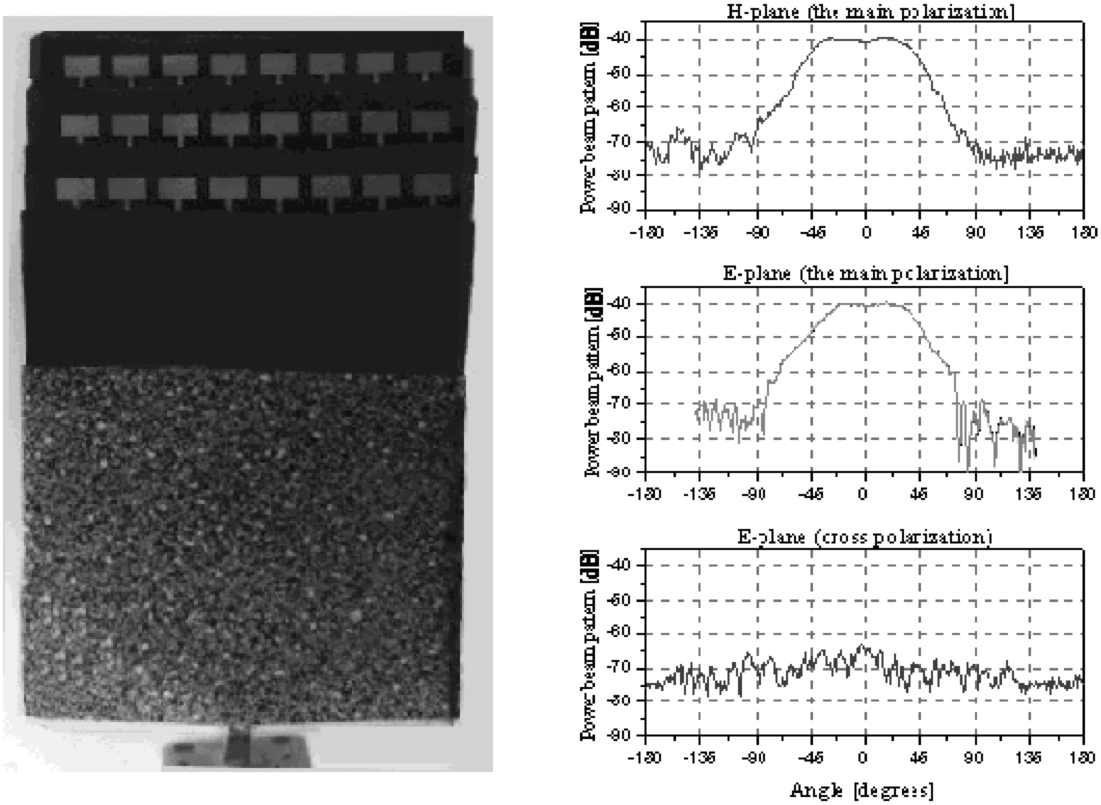

Figure 3: 3 × 8 element array prototype at 26-30 GHz(a), beam pattern measurements in HUT anechoic chamber (b)

Beam patterns of a microstrip radiator in a 3×8-element array prototype at 26 – 30 GHz (Fig.3a) measured in HUT anechoic chamber are close to expected (Fig.3b).

The measured System temperature of the 8-element MMIC array prototype is 300 K. We expect 10 – 15 mK sensitivity per second in a channel in the "total power" receiving mode. To reduce 1/F noise and DG/G contribution into sensitivity we are testing now a modified radiometric "total power" scheme with a monochromatic "compensating" signal that can give us a factor 2 – 3 in sensitivity. Gann oscillator at 28 GHz with relative amplitude instability of 4×10^{-6} per second has been manufactured and tested for this aim.

Calculations show that up to 70 7×8 element feed sub-arrays may be installed along the focal plane of the largest RATAN-600 secondary mirror so that a total number of RATAN-600 beams can exceed 3000 (Khaikin et al., 1999).

The prototype of Multi-Channel Data Acquisition System (MCDAS) for multi-element MMIC Array with the use of ADSP-2181 was developed, manufactured and tested in St.Petersburg State Technical University. A block diagram of MCDAS is shown in Fig.4.

The described array technology can be used at RATAN-600 or other radio telescopes for different radio astronomy applications. It can give us new possibilities to study CMBA at sub-degree scales with high integrated sensitivity in a wide field of view (Parijskij et al.,

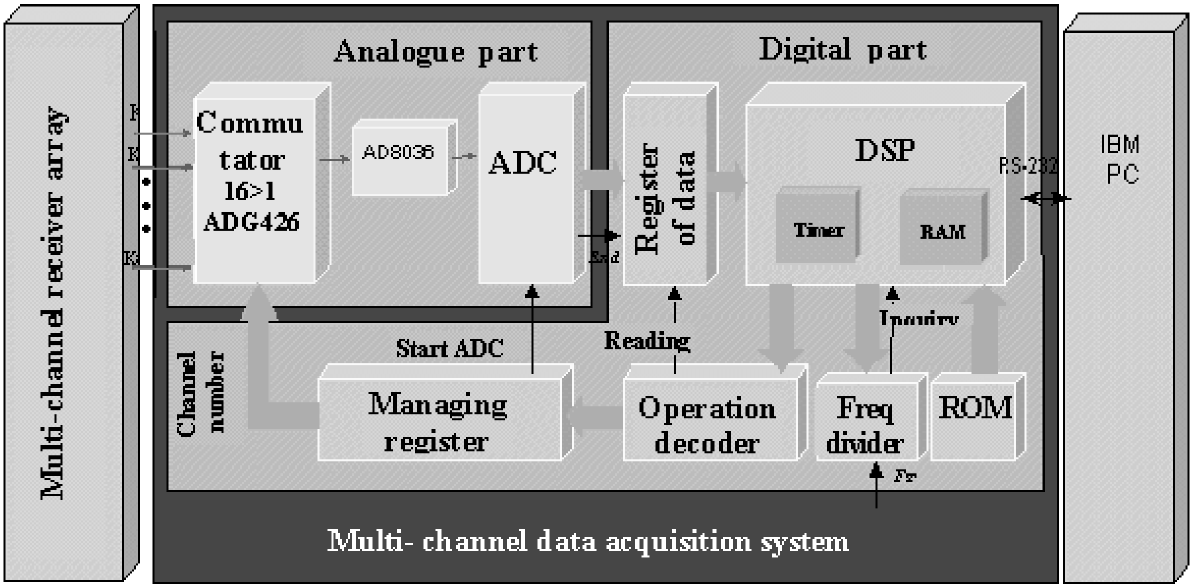

Figure 4: Block-diagram of Multi-channel Data Acquisition System

1997). The search of Synaev-Zeldovich effect at RATAN-600 (Parijskij et al., 1997) is among other possible applications. Mapping of the Sun and studying of the fast-variable solar events will be available. We plan to use it for the moment holography of radio telescope surface as well.

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