A High Performance 220-GHz Broadband Experimental Radar

Helmut Essen[a], Stefan Stanko[a], Rainer Sommer[a], Alfred Wahlen[a], Ralf Brauns[a], Joern Wilcke[a], Winfried Johannes[a], Axel Tessmann[b] and Michael Schlechtweg[b]
[a]FGAN-Research Institute for High Frequency Physics and Radar Techniques (FHR), D-53343 Wachtberg, Germany
[b] Fraunhofer Institute for Applied Solid State Physics (IAF), D-79108 Freiburg, Germany

***Abstract*— Millimeterwave radars at Ka- and W-band are state of the art and are used as well for civilian as military applications. The higher atmospheric windows, 140 GHz and 220 GHz, are not widely used to date. With the advance of automotive and security applications requiring short and medium range radars, these frequency bands become an interesting alternative. At the same time technology to expand radar use to the upper millimeterwave bands becomes available. An experimental radar has been designed and built using the most advanced solid state technology available in this frequency region. The paper describes the radar set-up at 220 GHz and gives results achieved with this instrument.**

I. Introduction And Background

RADARS operating at millimeterwave frequencies have been designed for missile seeker applications, for reconnaissance purposes and for automotive sensor systems. Driving impetus for the development of those radars have mainly been the high real beam resolution with small antennas and the small size of the hardware. Whenever possible, Ka-band systems were preferred, as the available technology has been more advanced and atmospheric propagation offers lower losses especially under adverse weather conditions. With the advance of SiGe technology civilian W-band applications will considerably increase and result in the possibility of a crowded frequency band. Especially short range applications demanding broad band radars may take advantage of the higher millimeterwave bands at 140 GHz and 220 GHz. With the extension of existing technologies and the development of new techniques at higher millimeterwave bands, this region may gain more importance in future, as far as short and medium range applications are concerned. This could even be interesting for future automotive applications. The considerably higher gain of antennas will partly compensate the atmospheric losses inherent to this frequency band. These frequencies are also of high interest for security applications. Especially the possibility to look through textile materials and to detect weapons or explosives even in a standoff geometry give an enforced interest for sensors operating in this frequency region. Being situated at the borderline between microwave and laser technology very often the notation “terahertz-sensors” is used for respective systems.

The work discussed in the following was dedicated to the development of an FM-CW miniaturized radar operating in the 220 GHz transmission window and featuring a high bandwidth resulting in a range resolution better than 2 cm.

II. Results

Fraunhofer IAF has developed a range of novel G-band components for active and passive sensors and imaging systems using a well established metamorphic HEMT technology with 0.1 µm gate length. Key components are LNA modules, doublers and medium power amplifiers. Figure 1 shows photos of a 220-GHz LNA chip, of the complete LNA module and the performance diagrams of that device [1].

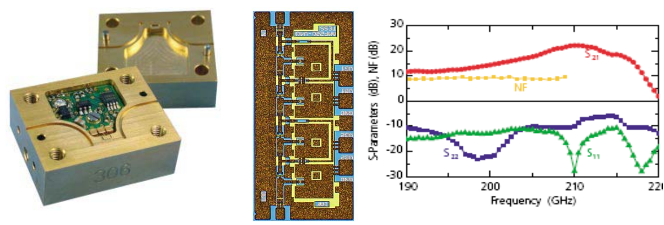

Figure 1: Photos of LNA Module and Chip together with performance Data

Figure 2 shows as a further example a chip photo and the performance diagram for a doubler from 110 GHz to 220 GHz.

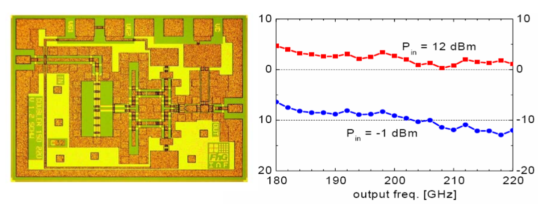

Figure 2: Photos and Performance Diagram for 110-GHz to 220-GHz Doubler

These components have been used as a basis for the development of a 220-GHz broad band experimental radar for signature measurements. A FM-CW concept was developed based upon upconverting and mixing resulting at an intermediate frequency at 110 GHz and a bandwidth of 4 GHz. This frequency is doubled to result in an output frequency of 220 GHz with a bandwidth of 8 GHz. The receive signal is amplified with a low noise amplifier and downconverted by subharmonic mixing with the W-band local oscillator sample. Figure 3 shows the block diagram.

978-1-4244-2120-6/08/$25.00 ©IEEE.

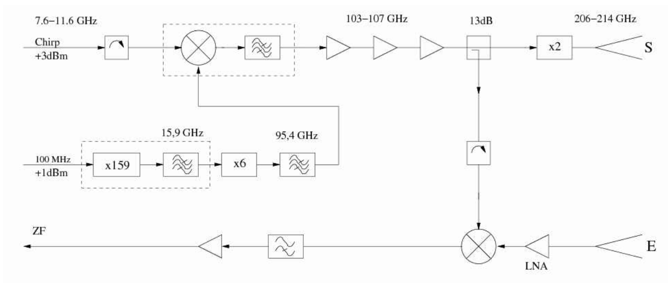

Figure 3: Block Diagram of the 220 GHz Front-End

The performance data of the 220-GHz radar are summarized in table 1.

Transmitter	220 GHz
Output Power	20 mW
Waveform	Linear Chirp FM / CW
Chirp Length	120 ms
Bandwidth	8000 MHz
Range Resolution	1.8 cm
Polarization	H-H, H-V
Dynamic Range	60 dB

Table 1: Block Performance Data of the 220-GHz Radar

The data acquisition and control electronics is based upon an industrial PC with an A/D-card National Instruments NI 6534. A custom designed PCI-bus card merges the radar data and all other necessary auxiliary data like acceleration values, angular position etc. The data handling and steering of the radar mode is supervised by a software, programmed under LINUX. The main problem with a FM-CW radar is to maintain a good decoupling between transmit- and receive channel and a sufficient linearity. From the bandwidth of 8 GHz a theoretical resolution of 1.7 cm for a point target is derived. However without any further correction this theoretical resolution can not be achieved. A special algorithm had to be developed to take this into account [2]. The key element for the processing is the linearization of the chirp which is derived from a calibration measurement against a corner reflector. Applying this correction, the resolution is improved to the theoretical value and the processing side lobe level reduces to 60 dB.

Test measurements in a tower-turntable configuration have been conducted and an ISAR imaging processing algorithm has been developed. Although the ISAR algorithm is typically very easy at millimeterwave frequencies [3] and typical range resolutions of about or below 20 cm, high bandwidth processing, as done here, requires adequate polar reformatting and focusing procedures. A respective algorithm had to be developed [2].

Figure 4 shows a photo and an accumulated scattering center distribution for a civilian vehicle. Figure 5 shows an equivalent photo and ISAR-image of a tractor and Figure 6 an accumulated ISAR image of a bicycle, all imaged over a range of 200 m with a resolution of 1.7 cm^2.

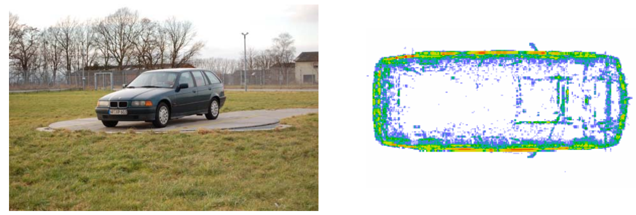

Figure 4: Photo and accumulated ISAR Image of a car at 220 GHz

Figure 5: Photo and accumulated ISAR Image of a tractor at 220 GHz

.

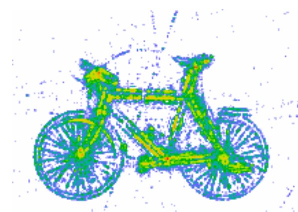

Figure 4: Accumulated ISAR Image of bicycle at 220 GHz

All images show the details of the respective targets much clearer than usual for e.g. at 94 GHz. This can mainly be attributed to the considerably higher roughness of scattering objects in relation to the illuminating wavelength. Especially remarkable is the reproduction of even the spokes of the bicycle wheels.

It can be concluded that the 220-GHz-band offers good system performance for imaging sensors. Due to propagation properties of the atmosphere, however, only distances of not more than 500 m can be surveyed.

REFERENCES

[1] A. Tessmann, " 220-GHz Low-Noise-Amplifier Modules for Radiometric Imaging Applications", Proc. 1st European Microwave integrated Circuits Conference, pp. 137 – 140, Sep. 2006.

[2] H. Essen, A. Wahlen, R. Sommer, G. Konrad, M. Schlechtweg, A. Tessmann, „A very high bandwidth Millimeter Wave Radar", Electronic Letters, Oct. 2005, Vol. 41, No 23, pp 124 - 1248

[3] H. Schimpf, H. Essen, S. Boehmsdorff, T. Brehm, MEMPHIS – a Fully Polarimetric Experimental Radar, Proc. IEEE IGARSS 2002, Vol. III pp.1714-16, Toronto 2002

978-1-4244-2120-6/08/$25.00 ©IEEE.