A 61 GHZ DOPPLER RADAR USING INVERTED STRIP DIELECTRIC WAVEGUIDE

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ABSTRACT

The measurement of true speed over ground is of great importance for road as well as rail vehicles. Using simple mm-wave systems, there is a potentially wide range application in individual car traffic. In this context, a 61 GHz Doppler radar was investigated and tested. It is based on inverted strip dielectric waveguide for both oscillator/mixer and antenna. A simple Gunn element serves as transmitter as well as (self-oscillating) mixer. In this way, a simple, compact, and potentially low-cost system is realized.

1. INTRODUCTION

Due to the potential applications in individual car traffic, mm-wave systems have found an increasing interest for civil applications /1/, /2/, especially for collision avoidance and speed measurements. This type of application demands a reliable performance as well as extremely low production costs requiring compact integrated systems.
In this contribution, a 61 GHz Doppler radar system based on inverted strip dielectric waveguide is described. Compared to integrated transmission line media like microstrip and coplanar line, dielectric guides provide lower loss and are inherently well suited for antenna structures /3/-/6/. Together with a distributed Bragg reflector type Gunn oscillator /7/, /9/ serving as a very stable transmitter as well as self-oscillating mixer, an integrated, compact and potentially low cost system has been realized.

2. SYSTEM DESCRIPTION

The basic set-up of the investigated system is given in Fig. 1. The inverted strip dielectric guide consists of a dielectric strip of relatively low permittivity placed on a metallic ground plane covered with another dielectric layer with higher permittivity. In this case, PTFE material was used for the strip and fused quartz for the cover layer; the latter, however, finally could be replaced by some material which is cheaper and easier to handle.

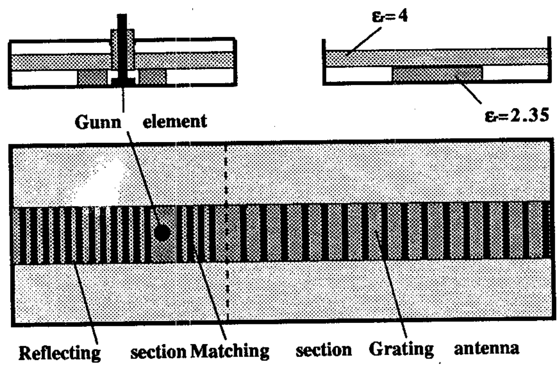

Fig. 1: Set-up of 60 GHz Doppler system

Passive circuit elements were realized using printed metallic gratings on the dielectric strip /4/, /5/. The properties of the homogeneous dielectric guide and of the grating structures were determined by approximate methods /6/-/8/.
For the Gunn element, a narrow grating structure was chosen for the matching and reflection sections, being well within the slow-wave region of the related periodic structure. The Gunn element was placed on the metallic ground plane as heat sink and contacted through a hole in the dielectric layers. To prevent spurious radiation, the oscillator section was covered with a metallic shielding. A capacitor and an inductor were used to separate the DC power supply and the IF output.

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The antenna section uses a grating arrangement of wider spacing, resulting in a fast wave operation of the structure. The strip spacing was chosen in accordance with the required E-plane beam position, while the H-plane beamwidth mainly is determined by the strip width. The E-plane beam width is given by the overall lengths of the antenna structure.

3. RESULTS

In a first step, oscillator and antenna were built up separately including a transition to metal waveguide.
Due to the low losses of the dielectric structure, a relatively stable oscillator results. In Fig. 2, the dependence of frequency and output power on bias voltage, and in Fig. 3 the dependence of frequency on temperature is plotted showing a very good stability by far sufficient for this application.
The output power is in the range of a few mW, according to the expected PTT regulations of an effective radiated power (ERP) of 1...2 W including the antenna gain.
The radiation characteristic of the antenna with a single beam is plotted in Fig. 4. Beamwidths of 5°and 18.5° in the E- and H-plane, respectively, were observed.

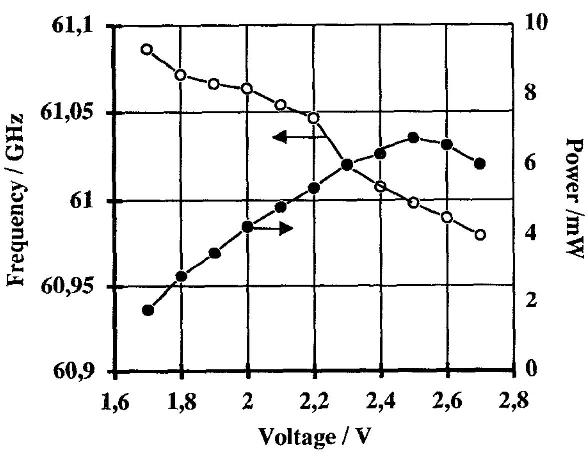

Fig. 2: Oscillator frequency and output power as a function of supply voltage

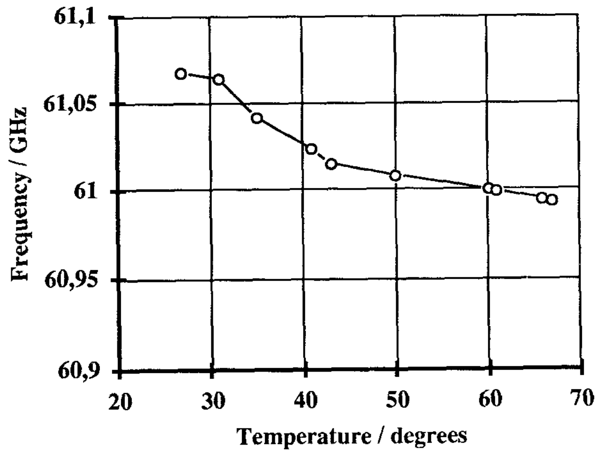

Fig. 3: Oscillator frequency as a function of temperature

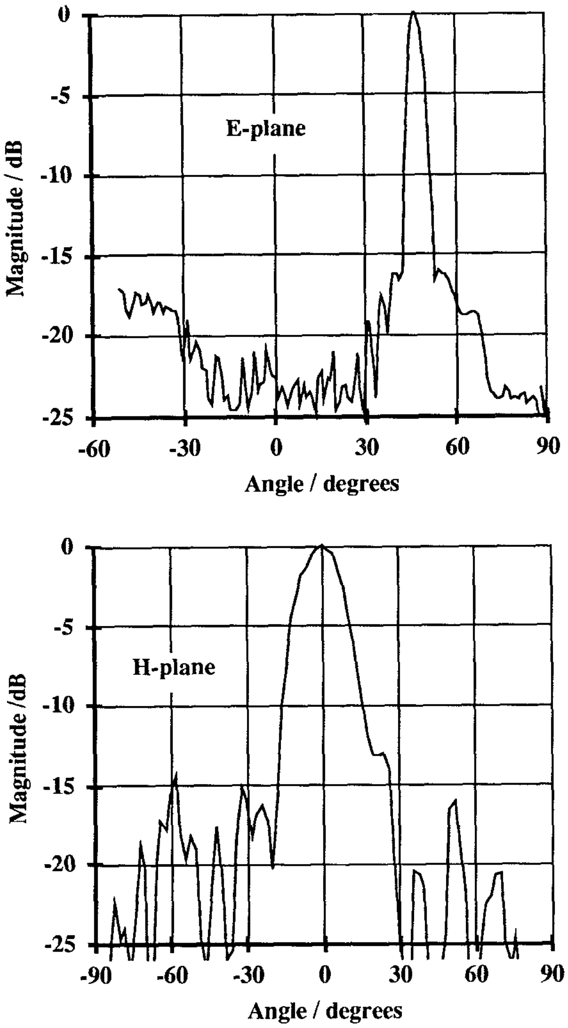

Fig. 4: E- and H-plane radiation pattern of the grating antenna

For some applications, double beam antennas with symmetry in respect to the broadside direction are discussed to compensate for errors due to vertical movements of the complete system. To this end a two beam antenna was built up as well; its E-plane radiation pattern is shown in Fig. 5.

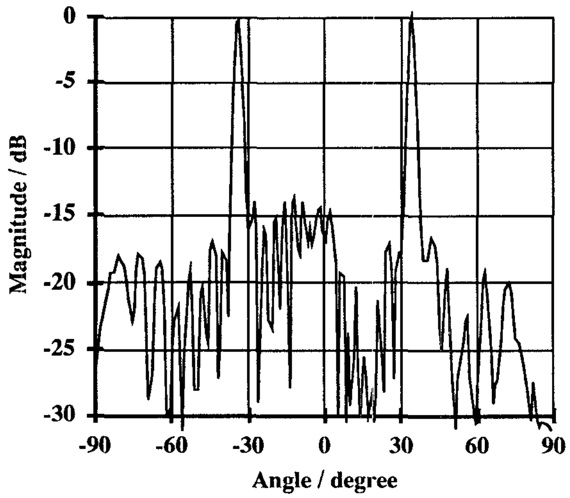

Fig. 5: E-plane radiation diagram of dual beam grating antenna

Finally, an integrated system was built up and mounted to a standard car for a first test. The evaluation of the results was done with a simple frequency counter. Fig. 6 shows these results, where the vertical bars indicate the range of the measured frequencies, and the solid line gives the calculated Doppler frequencies from the speedometer display of the car. A more exact evaluation of the system performance was done using a special test vehicle with a calibrated Peiseler wheel for speed measurement and a digital recording system for the Doppler system (clock frequency ca. 25 kHz). The recorded data were checked using a 500 points FFT and integrating over 10 FFTs; this corresponds to an integration time of 0.4 s and a resolution of 50 Hz, or ca. 0,6 km/h. A typical spectrum of this kind for 70 km/h is shown in Fig. 7. Some spurious lines appear, these are probably due to vibrations of the (Diesel) car. In Fig. 8, a number of spectra for 25, 40, 50, 70 and 95 km/h, together with the Doppler frequency values calculated from the speed given by the Peiseler wheel are given. The results are quite satisfying, although the sidelobe level of the antenna should be reduced further to increase the dynamic range.

Similar tests were run using the two beam antenna. However, as only a single mixing element for, in this case, two sidebands was used, strong fluctuations of the output signal occured due to arbitrary phase relations of the two sidebands.

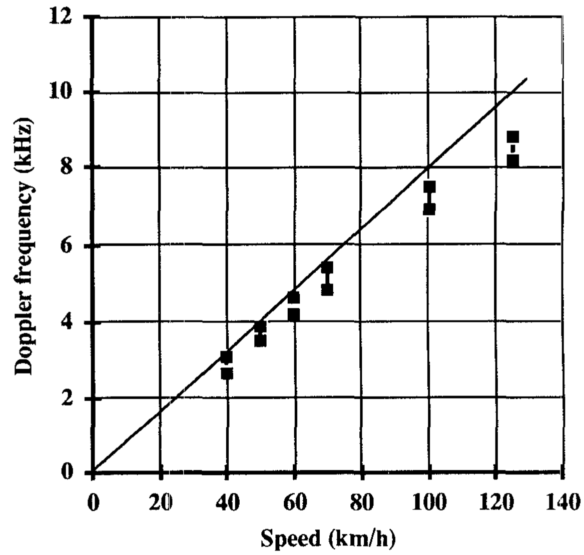

Fig. 6: Results of first system test (Solid line: Doppler frequencies calculated from speedometer display, bars: Doppler frequencies measured with a frequency counter)

CONCLUSION

A potentially low-cost realization of a 60 GHz Doppler radar system for speed measurement over ground was presented.
A number of tests confirmed its good performance. A reduction of the antenna sidelobe level could further improve the system.
Furthermore, additional test on different types of road surfaces, and under different weather conditions should be done, too.

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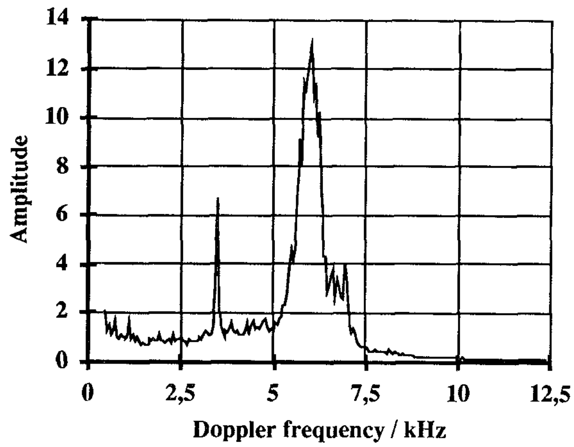

Fig. 7: Typical Doppler spectrum (70 km/h)

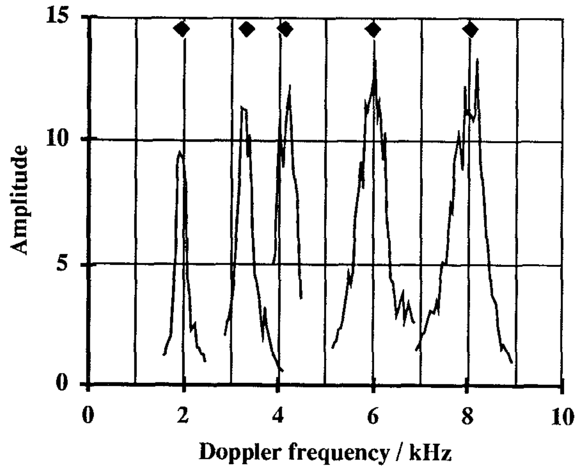

Fig. 8: Doppler spectra for 25, 40, 50, 70, and 95 km/h. Points at the top indicate Doppler frequencies calculated from the exact speed.

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