# Low-Dispersive Dielectric Reflectors for Future Wireless Terahertz Communication Systems

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***Abstract*— Dielectric mirrors have recently been proposed to be a key component for future wireless terahertz communication systems. Here, we examine the dispersion properties of a reflector that consists of nine layers with two different materials. The refractive index of the layers differs considerably. The mirror is highly reflecting and omnidirectional in a very extensive frequency band. We find that the group delay is in the order of picoseconds inside the frequency band of interest (330-370GHz), which is a reasonable value for such a component.**

***Index Terms*— Terahertz communication, Wireless LAN, Dielectric mirrors, Sub-millimeter wave communication.**

## I. Introduction

High-speed wireless local area networks have attracted noticeable interest during the last years. It is expected that a wireless data rate of several Gb/s will be required within the next 10 to 15 years [1-3] to meet the increasing bandwidth demand. In order to achieve the desired bandwidth, future short-range indoor communication systems are likely to work in the terahertz (THz) range. Although there is a frequency window of about 40 GHz around 350 GHz with low attenuation of less than 40 dB/km such systems will require highly directive antennas. The consequence is a directed transmission between a transmitter and a receiver. To avoid shadowing, e. g. by randomly moving people, such systems should make use of non line-of-sight paths that involve reflections off the walls. The reflectivity of standard wall covering materials at THz frequencies is very low [4]. A dielectric mirror can enhance the reflected power significantly. Propagation analysis shows that only some "hot spots" need to be covered with such mirrors [5] to considerably increase the system performance. However, intersymbol interference (ISI) has to be considered in order to build efficient components for high-speed communication systems.

Here, we examine the group delay of an omnidirectional dielectric terahertz mirror for various incidence angles and for s- as well as p-polarization. The first terahertz mirror was demonstrated by Turchinovich et al. [6] in 2002. In comparison to optical wavelengths, sub-mm waves are quite long. Hence, the quarter-wave thick layers of the dielectric structure have to be in the range of approximately 40 µm to 450 µm depending on the refractive index of the material and the central frequency of the stop band the mirror is designed for.

We investigate the dispersive properties of a reflector that was recently demonstrated [5]. The dielectric mirror is composed of a stack of alternating layers of high-resistivity silicon and polypropylene. Four layers of silicon with a refractive index of 3.418 and a thickness of 63µm are arranged between five layers of polypropylene with a refractive index of 1.53 and a thickness of 150µm.

We use a THz time-domain spectrometer in reflection geometry for the characterization of the structure [7]. We replace the THz mirror by a polished copper plate in order to measure an almost perfectly reflected and synchronized reference pulse. We obtain the frequency dependent reflectivity of the mirror and its dispersive properties by dividing the spectrum of the sample pulse by the spectrum of the reference pulse. The group delay is calculated from the obtained phase information.

## II. Simulated and Measured results

Measured phase and the associated group delay for s-polarization and incidence angles from 20° to 70° are shown in Fig. 1. Due to setup limitations [5] no experimental data for very small and very high angles could be obtained. The measured phase response of the reflection is shown as symbols in Fig. 1a. The phase decreases almost linear in the frequency range between 270 GHz and 390 GHz for angles of incidence below 40°. This response is expected as the phase within the stop band follows a linear evolution as a function of frequency [8]. The data in Fig. 1a have to be differentiated in order to calculate the group delay. The small experimental noise on the curves of Fig. 1a will convey extremely noisy curves after the differentiation. Hence, we first obtain smooth fits of the phase data (shown as solid lines in Fig. 1a) from which we then take the first derivative. The result is the group delay which is depicted in Fig. 1b.

To simulate the phase, we use the transfer matrix method of the reflected signal as a function of frequency [9]. Fig. 2a depicts the simulated unwrapped phase for various angles of incidence and s-polarization. A micro cavity inside the dielectric mirror is formed for higher incidence angles because the quarter-wave condition is no longer matched. Hence, an increasing convex shape of the curves is formed. At an incidence angle of 89° a substantial phase jump occurs at around 400 GHz where a distinctive narrow band of high transmission is located [5] which is caused by the micro cavity.

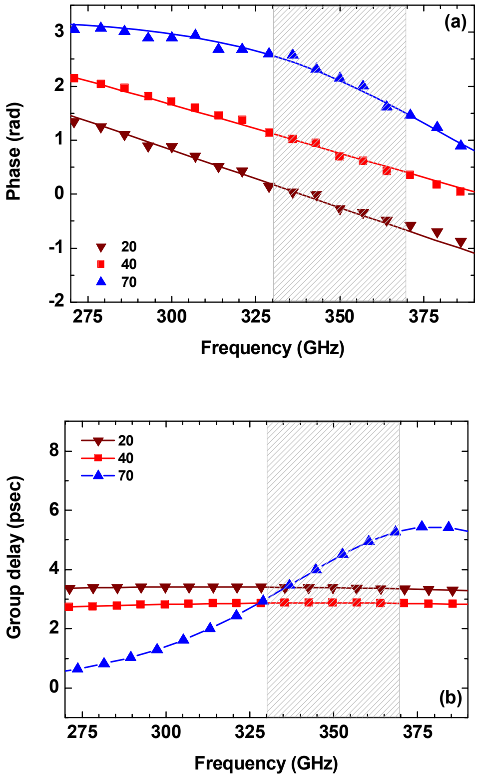


Fig. 1. Measured reflected phase (a) and the associated group delay (b) for s-polarization and for different incidence angles.

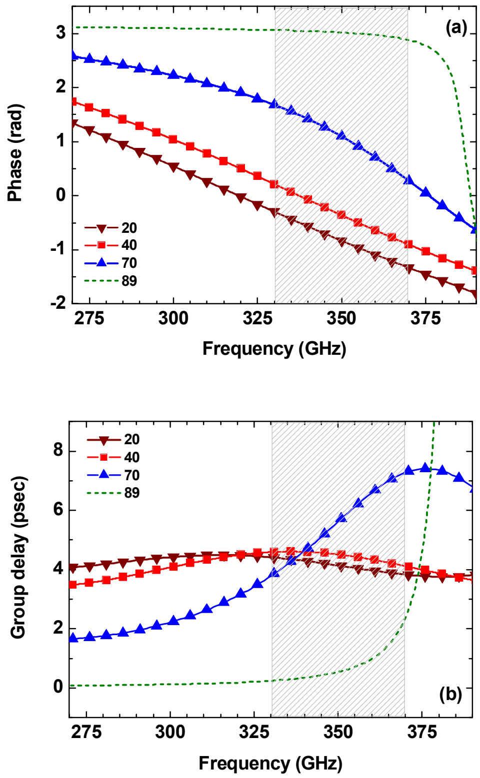


Fig. 2. Simulated reflected phase (a) and the associated group delay (b) for s-polarization and for different incidence angles.

Fig. 2b depicts the associated group delay. The group delay is in the order of picoseconds, which is a suitable value for such a component. The maximum group delay variation is 4 ps inside the frequency band of interest (330-370 GHz), which is designated by the shaded area, at an angle of incidence of 70° and s-polarization. The qualitative agreement is reasonable between the simulation and the measured results.

For p-polarization, not only do the stop bands of the mirror broaden, but they also shift towards higher frequencies [5]. Therefore, substantial phase jumps occur at frequencies of very high transmission. However, these features are not detectable inside the band of interest (330GHz – 370GHz). The experimental results are in good agreement with the simulation (not shown here due to the limited space). The maximum group delay variation is 1.6 ps.

## III. Conclusion

We have studied the dispersive properties of an omnidirectional THz mirror. Experimental data agree well with transfer matrix calculations. The group delay is in the order of a few picoseconds. This is an acceptable value for such a component. The maximum variation in the group delay is 4 ps at an angle of incidence of 70° and s-polarization inside the frequency band of interest (330-370 GHz). Hence, we can conclude that dielectric mirrors are well suited as reflectors in future short-range terahertz communication systems.


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