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A DIELECTRIC ROD WAVEGUIDE ANTENNA DESIGNED BY TO REDUCE THE DUAL POLARIZATION BY USING WIDE BAND FREQUENCY

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ABSTRACT: The design of a dielectric rod waveguide (DRW) antenna for frequencies of 75–325 ghz is presented. The optimal Broadband antenna geometry is determined using numerical simulations. A single DRW antenna is matched with metal Waveguides of different sizes for different frequency bands. Measurement results agree very well with the simulation results up to 325 ghz; the gain of the antenna stays nearly constant (db) over the whole frequency range measured from 75 to 325 ghz (160% relative bandwidth). The upper limit is due to our limited manufacturing capability to produce sharp antenna tips. The return loss of the antenna is better than 15 db. The radiation patterns are nearly independent of frequency. The 3 db beamwidth is 50 –60 , and the 10 db beamwidth is about 95 . This indicates that the aperture size of this end-fire antenna decreases as a function of frequency, and this observation agrees well with the earlier observation that the phase center of a DRW antenna moves towards the antenna tip as a function of frequency. Also the cross polarization was studied. The cross-polarization level is better than 15 db at all frequencies.

I.INTRODUCTION:

Operating frequencies of wireless communication systems have increased in order to assign radio access to a less crowded part of the electromagnetic spectrum and also provide a wider bandwidth for data transmission. The relatively low atmospheric absorption rate at E/W-band, 140 GHz, 220 GHz, 340 GHz, and 410 GHz Figure as transmission windows has spurred many applications and innovations at millimeter-wave frequencies and beyond [1]. A wide range of applications have attracted much attention from industry and academia to the exploitation of E/W-band (71-97 GHz). The E/W-band spectral window offers possibility great potential of gigabyte data wireless transmission over several kilometers in normal weather conditions. Frequency bands of 71-76 GHz, 81-86 GHz (usually referred as E-band), and 94.1-97 GHz (part of W-band) are all allocated by the US Federal Communication Commission (FCC) as gigabyte wireless spectrum .Over those frequency windows, the atmospheric absorption drops to less than 1dB/Km and spells out the capability of long-range

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gigabyte point-to-point wireless services . Obviously, wide bandwidth and low atmospheric loss allow for the E/W-band implementation of high resolution and long-range radars [6], detectors, and sensors , which may be used in helicopter, aircraft/automobile collision avoidance radar, passive millimeter wave imaging, and radar sensors.

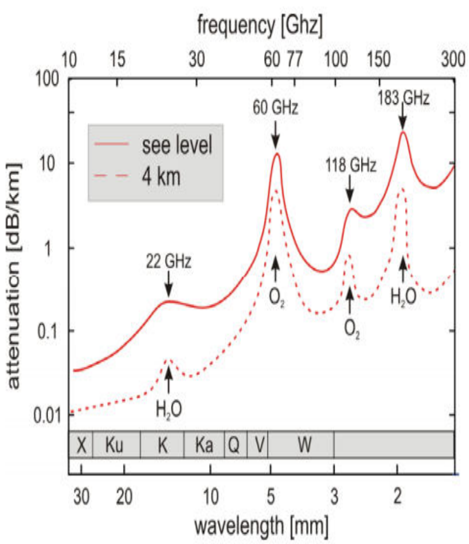

Fig: Average atmospheric attenuation versus frequency

Propagation of modes in circular DRW can be calculated analytically, however DRW with rectangular cross-section can be described only with approximate methods, such as Marcatili's or Goell's. The difference between the methods is that Goell's approach is more accurate while Marcatili's approach is easier to apply but more approximate. The desired mode in a rectangular DRW is a hybrid mode. is the dominant electric field component of the mode, and other components are , and while and are negligible. Calculations help to estimate the optimum cross section of a rectangular DRW which can operate in the single mode regime in the given frequency range. The optimum crosssections for high permittivity silicon or GaAs DRW are 1.0 mm 0.5 mm for 75–110 GHz range, 0.60 mm 0.30 mm for 110–150 GHz range, and 0.30 mm 0.15 mm for 220–325 GHz range The DRW antennas can be excited from a rectangular metal waveguides, however the important advantage of DRW is the possibility of integrating semiconductor devices into DRW, hence the DRW can be used to guide the radiation from other semiconductor sources, e.g., photo mixers . DRW can be also coupled with other printed antennas, e.g., a ring slot [14]. By the type of radiation DRW antennas can be divided into two groups: end-fire antennas and leaky-wave antennas. Leaky wave DRW antennas have periodic discontinuities, which cause energy to leak from the antenna. The angle of radiation from these antennas depends on frequency and they do not radiate to the bore sight direction. The end-fire DRW antenna, on the other hand, radiates to the bore sight direction and its radiation pattern is almost independent on frequency. Our current work considers DRW end-fire antennas using rectangular metal waveguides for excitation

II.LITURARE SURVEY

1: Millimeter-wave power sensor based on silicon rod waveguide

Author: A. A. Generalov, D. V. Lioubtchenko, J. A. Mallat, V. Ovchinnikov, and A. V. Räisänen

This thesis is focused on the development of dielectric rod waveguide (DRW) components at sub-THz frequencies. DRWs proved themselves as low loss transmission lines at sub millimeter wave and THz frequencies; they can be well matched with rectangular metal waveguides, and also used as antennas. In addition, the DRW allows integration of various components using standard micro fabrication techniques, e.g. the bolometric power sensor can be integrated in the center of the DRW and measure the power travelling in the DRW, and a phase shifter based on a high impedance surface (HIS) can be manufactured on the surface of the DRW and can change the phase of the propagating wave inside the DRW. In the first part of this thesis the narrow band and wide band DRW antennas were designed, manufactured and tested. The DRW antennas are lightweight, compact and easy to manufacture. The narrow band DRW antenna proved to operate in the range of 220 – 325 GHz. The wideband DRW antenna showed a constant performance over the band of 75 – 1100 GHz according to numerical simulations and over the band of 75 – 325 GHz experimentally. The radiation patterns of the antenna were measured in co- and cross-polarization. The co polarization radiation patterns are nearly independent of frequency. The 3 dB beam width is 50º - 60º, and the 10 dB beam width is about 95º. The return loss of the antenna is better than 15 dB. In the second part of this thesis the bolometric power sensor integrated into DRW was designed, manufactured and tested at frequencies 75 – 1010 GHz. The power sensor consists of a metallic antenna -like structure in the center of the DRW in E-plane suspended on a membrane over an air gap to improve the thermal insulation. The power sensor showed good matching with the rectangular metal waveguides and constant responsively over the wide band of frequencies, as well as a linear responsively up to 500 mW applied power. In the third part of this thesis the micro electro mechanical system (MEMS) tunable HIS was developed for integration on to the surface of a DRW using suspended carbon nanotube (SWCNT) film as a movable element of the HIS. The implementation of a SWCNT network as a material for movable suspended film allows to significantly simplify the fabrication process of the HIS due to a simple technique of the SWCNT film deposition by dry transfer, and additionally it allows to reduce the actuation voltage of the HIS due to the low Young's modulus of the SWCNT network. The unique deposition technique of the SWCNT film allows to design a HIS phase shifter directly on the surface of the DRW. The suspended SWCNT film structure showed the tunability of the capacitance of 100% at 0 – 10 V applied bias voltage. Such properties allow to create a SWCNT MEMS HIS with a phase shift of 260° at 0 – 7 V bias voltage

2: "Dielectric rectangular waveguide and directional coupler for integrated optics,"

Author: E. A. J. Marcatili

We study the transmission properties of a guide consisting of a dielectric rod with rectangular cross section, surrounded by several dielectrics of smaller refractive indices. This guide is suitable for integrated optical circuitry because of its size, single-mode operation, mechanical stability, simplicity, and precise construction. After making some simplifying assumptions, we solve Maxwell's equations in closed form and find, that, because of total internal reflection, the guide supports two types of hybrid modes which are essentially of the tem kind polarized at right angles. Their attenuations are comparable to that of a plane wave traveling in the material of which the rod is made. If the refractive indexes are chosen properly, the guide can support only the fundamental modes of each family with any aspect ratio of the guide cross section. By adding thin lossy layers, the guide presents higher loss to one of those modes. As an alternative, the guide can be made to support only one of the modes if part of the surrounding dielectrics is made a low impedance medium. Finally, we determine the coupling between parallel guiding rods of slightly different sizes and dielectrics; at wavelengths around one micron, 3-dB directional couplers, a few hundred microns long, can be achieved with separations of the guides about the same as their widths (a few microns).

3: Dielectric rod leaky-wave antennas for millimeter-wave applications

Author: S. Kobayashi, R. Lampe, R. Mittra, and S. Ray

This paper introduces an analytical solution for a dielectric rod leaky wave antenna loaded by a met surface. The advantage of adding met surface on the dielectric rod is that it introduces an additional degree of freedom in the design of this antenna by controlling the outer boundary condition. Modified Generalized Sheet Transition Condition on a cylindrical geometry is used to model the met surface on the dielectric rod. The analysis is based on developing the characteristic equation of the proposed structure. This characteristic equation is used to obtain the complex propagation constant of this structure and the corresponding field distribution inside and outside the rod including the resulting radiated fields. Parameters of the met surface are extracted from the reflection and transmission properties of its elements in infinite periodic structure. An example of a dielectric rod loaded by a met surface is presented analytically based on the introduced analysis and also simulated numerically for comparison. The effect of different polarizabilities of the loading meta surface on the leaky wave properties of the dielectric rod is discussed

4: Micromachined step-tapered high frequency waveguide inserts and antennas

Author: A. Marconnet,M.He, S. Sengele, S.Ho,H. Jiang,N. Ferrier, D. van der Weide, and J. Booske

Waveguide-fed plastic horn antennas have been demonstrated for W-band applications using a versatile and cost-effective micro hot embossing process. The three-dimensional (3D) polymer structure with internally coated conductor is composed of a pyramidal horn, an E-plane waveguide bend,

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two resonant cavities for impedance matching and a connecting rectangular waveguide. Measurement results show broadband characteristics in W-band with a return loss of better than –10 dB; the bandwidth is 25.2 GHz between 76.5 and 101.7 GHz (26.5%), and the 3 dB beam widths of the E- and H-plane gain patterns at 95 GHz are 26◦ and 23◦, respectively. The antenna gain is 17.04 dB at 95 GHz and the cross-polarization discriminations for E- and H-plane are 19.5 dB and 22.2 dB, respectively

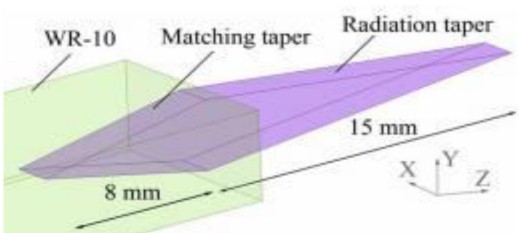

Fig. Geometry of the DRW antenna fed with WR-10 waveguide.

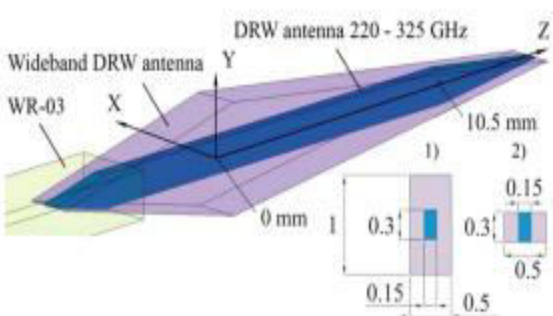

Fig. Comparison of the dimensions of the DRW antenna under study with previously studied DRW antenna with the cross section of 0.30 mm 0.15 mm. 1)—cross section at mm, 2)—cross section at mm. Dimensions are in mm.

III.ANTENNA MEASUREMENTS

S-parameters of the antenna were measured with Agilent E8361C PNA using WR-10, WR-06, WR-05, and WR-03 waveguide extensions. In case of the WR-10 waveguide the antenna was inserted to the waveguide at full length of the matching taper, i.e., 8 mm (see Figure), and in case of the WR-06, WR-05, and WR-03 waveguides the antenna was inserted up to the maximum possible length, 6.0, 5.5, and 3.5 mm, respectively. The measurement results together with the simulated results are shown in Fig. 8. One can see that the measurement data correspond well with simulated results at 75–110 GHz (WR-10), 110–170 GHz (WR-06), and 140–220 GHz (WR-05) bands. However, at 220–325 GHz (WR-03) band the measured reflection is higher than the simulated one. It can be explained by the fact that the tip of the antenna is not perfect. One can see in Figure that the tip of the antenna is broken and the cracks on the surface have dimensions of the order of 100 m. At lower frequencies when the cracks are much smaller than the wavelength, the unideality does not affect the results. At 300 GHz the wavelength is 1 mm in free space and inside the DRW is of the order of 300 m, so the cracks of the antenna are of the order of one quarter wavelength. As it can be seen in Fig. 8, it results in higher return loss than that expected from the simulation results. At frequencies higher than 300 GHz the cracks affect results even more and it is not possible to use the antenna. Therefore, due to current manufacturing equipment in our laboratory the operational frequency of

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the antenna is limited to 325 GHz (WR-03 waveguide band), however using a modern and more advanced dicing saw it will be possible to fabricate an antenna with smoother surface and increase the highest operational frequency.Dielectric resonator design and analysis utility

Rectangular resonator design Resonant frequency (GHz) = 300.0000

Mode = TE(x)d11

Minimum fractional impedance bandwidth = 0.0500

VSWR for the bandwidth calculations = 2.0000

Dielectric constant of the resonator = 2.0000

Minimum 'width/height' (w/h) ratio = 0.3000

Maximum 'width/height' (w/h) ratio = 0.5000

Number of ratios to study = 10.0000

Minimum 'depth/height' (d/h) ratio = 0.4000

Maximum 'depth/height' (d/h) ratio = 0.5000

Number of ratios to study = 10.0000

IV.RADIATION PATTERNS

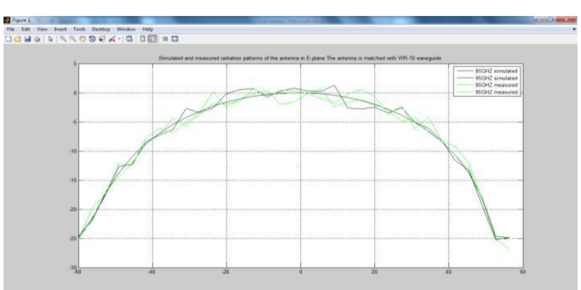

FIG:Simulated and measured radiation patterns of the antenna in E-plane The antenna is matched with WR-06 waveguide

FIG:Simulated and measured radiation patterns of the antenna in H-plane The antenna is matched with WR-10 waveguide

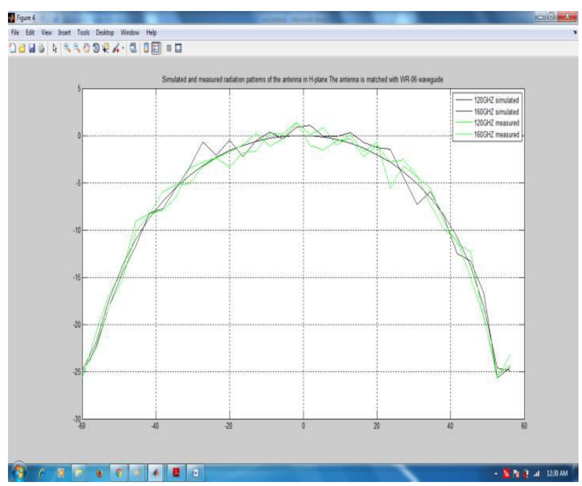

FIG:Simulated and measured radiation patterns of the antenna in H-plane The antenna is matched with WR-06 waveguide

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V.ADVANTAGES APPLICATIONS

ADVANTAGES

- Optimization problem can be reduce
- High frequncy data can be transmitted
- Power consumption is low

APPLICATIONS

1. Radar system
2. Broad cast channel
3. Television communication
4. Imo communication

CONCLUSION

The dielectric rod antenna that has been described can be well matched to metal waveguides at frequencies from 75 to 325 GHz. The measurement data agree very well with predictions. A small discrepancy between measured and simulated results is explained by the quality of the tip of the antenna. The quality of the tips also limits the performance of the antenna at frequencies above 325 GHz. The antenna can be improved by using a more advanced and accurate dicing saw. The radiation patterns of the antenna are consistent at all used frequencies; the 3 dB beam width of the antenna is about 60$_{\circ}$ and the 10 dB beam width is about 95$_{\circ}$ leading to an antenna gain of about 10 dB at all frequencies measured. This indicates that the aperture size of this end-fire antenna decreases as a function of frequency, and this observation agrees well with the earlier observation that the phase center of a DRW antenna moves towards the antenna tip as a function of frequency. The maximum cross polarization levels are of the order of 15 dB at different frequencies

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