NRD-GUIDE TECHNOLOGY
FOR MILLIMETER-WAVE WIRELESS APPLICATIONS

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Abstract

Starting with a brief review of millimeter wave research and development, basic concept, theory and applications of NRD-guide technology are described. A particular emphasis is placed on short distance propagation of millimeter waves such as indoor HD-TV wireless transmission and Giga-bit video downloader. It is also emphasized that NRD-guide can offer advantages of easy fabrication, low cost and high performance over other millimeter wave circuit technologies.

I. Introduction

The paper is concerned with topics related to NRD-guide. NRD-guide is a special type of dielectric waveguide which can suppress unwanted radiation generated at curved sections and discontinuities of the waveguide, as the name "Non-radiative Dielectric Waveguide" implies. This paper starts with a brief review of millimeter wave research and development, introduces the basic concept and properties of NRD-guide, and covers practical aspects of NRD-guides applications such as video wireless transmission and download.

II. Millimeter Wave History

After the worldwide research activity on the development of millimeter-wave circular waveguide communications systems was quitted by the appearance of practical optical fibers in 1970, most of millimeter wave researchers and engineers changed their research field from millimeter waves to optical communications. The others still remained in the field of millimeter-waves and switched their way from the long distance waveguide communications to the short distance wireless communications.

MMIC technology was expected to play an important role in the new generation of millimeter wave research and development, but it was by no means successful particularly beyond 40GHz. One of the reasons for MMIC difficulty in the millimeter wave region could be attributed to large transmission losses of the various printed lines. In order to overcome such a difficulty, many types of dielectric waveguides such as image guide and insular guide were proposed. These dielectric waveguides are excellent in transmission loss characteristics, but the advantage is limited only to the straight portion of dielectric waveguide and deteriorated at curved sections and discontinuities due to large amount of radiation loss. In order to suppress such unwanted radiation, NRD-guide has been proposed in 1981 [1].

III. Basic Properties of NRD-guide

The idea of NRD-guide comes from the prediction that unwanted radiation at discontinuities of a dielectric waveguide could be suppressed if the waveguide is located in the space where electromagnetic waves cannot exist at all. Such a space can be realized within a below cutoff parallel plate waveguide as shown in Fig.1. The cutoff nature of the parallel plate waveguide is very effective for radiation suppression in the dielectric waveguide as expected, and more than that it never spoils the inherent low loss property of the dielectric waveguide at all. As a result, very sharp bends can be built in NRD-guide to create compact millimeter wave circuits. It should be mentioned that a recent advance in NRD-guide technology is an invention of design technique for NRD-guide bends with arbitrary radius of curvature [2].

IV. NRD-guide Transceiver

The most attractive application of NRD-guide technology would be the fabrication of millimeter-wave transceivers which operates in the unlicensed 60GHz band. In order to design an NRD-guide transceiver of good productivity, a novel type of circuit structure is adopted.

In the new design, the 3-dB coupler plays a key role as shown in Fig.2. It is predicted by theory that complete power transfer of millimeter waves takes place between the adjacent arms of the 3-dB coupler. Therefore, a couple of Schottkey diodes can operate as a modulator in the transmitting mode, while they operate as a balanced mixer in the receiving mode. A fabricated transceiver is shown in Fig.3. Though the circuit configuration is surprisingly simple, it can be a transmitter, a receiver, and even a time sharing transceiver, if necessary.

A special emphasis is also placed on antenna design. Antennas to be used for HD-TV wireless transmission have to have low side lobe characteristics to reduce multi-path effects. Dielectric lens antennas of 58mm in diameter were designed for the present application [3]. Radiation patterns in both the E-plane and H-plane are shown in Fig.4. It can be seen that side lobe level of the antenna are less than 23dB and half power widths are about 6 degrees in both the E-plane and H-plane, respectively. The measured antenna gain is 30dBi, implying that the aperture efficiency of the antenna is 75.4%.

Since the fabricated NRD-guide transceiver is small in size and flat in shape as shown in Fig.3, it can be installed at the base of the lens antenna as shown in Fig.5. Such a compact arrangement is very convenient for practical millimeter-wave applications.

V. Applications of NRD-guide Transceivers

I. HD-TV Wireless Transmission

Though there are many millimeter wave applications proposed so far, the most attractive one would be uncompressed HD-TV wireless transmission, which requires high data rate of 1.5Gbps for operation. Such a high data rate is by no means difficult for the NRD-guide to achieve with the simple ASK modulation. In practice, the transmitter and receiver have to be provided with A/D and D/A converters which change YPbPr signal to HD-SDI signal of 1.485Gbps and vice versa. The experiment was successful and uncompressed HD-TV was transmitted without any remarkable bit-error occurrence throughout experiment.

II. Giga-Bit Video Downloader

Another attractive application of millimeter waves would be the Giga-Bit Video Downloader. The system has been newly proposed to make millimeter-waves really popular. The system consists of a movie file server equipped with the millimeter-wave transmitter and mobile HDD terminals equipped with an inexpensive NRD-guide detector which can operate as a receiver over a distance of several meters without any need of RF and IF amplifiers. A promising application of the downloader includes quick download of movie files in the server to the mobile HDD terminals within a few seconds. The downloader may be able to be a movie file vending machine replacing the conventional rental DVD/CD shops.

VI. Practical Merits of NRD-guide

NRD-guide circuit technology can offer powerful solutions to various millimeter-wave applications such as uncompressed HD-TV wireless transmission, Giga-bit video download system, last one mile access problem and so on. Practical advantages of NRD-guide exist in the fact that NRD-guide does not require any expensive manufacturing machines and any skilled labor at all.

Rapid development of the millimeter wave market can be expected if powerful applications such as in-room video wireless transmission and download system are put to practice. The NRD-guide technology can be expected to play an important role in the near future.

VII. Conclusions

Tight shortage of the frequency resource will accelerate shifting the spectrum toward the millimeter wave region. In particular, the 60GHz band is expected to occupy a dominant position in broadband applications because of less interference due to the large atmospheric absorption and the license-free advantage. NRD-guide can be a powerful tool for the construction of the in-room broadband wireless systems which include uncompressed HD-TV transmission and Giga-bit video downloader due to its easy fabrication, low cost and high performance advantages.

REFERENCES

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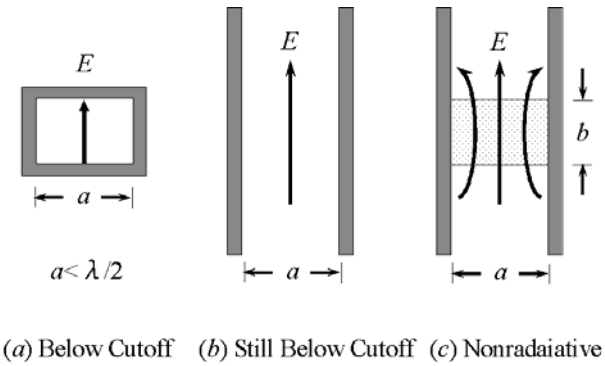


Fig.1 Principle of NRD-guide

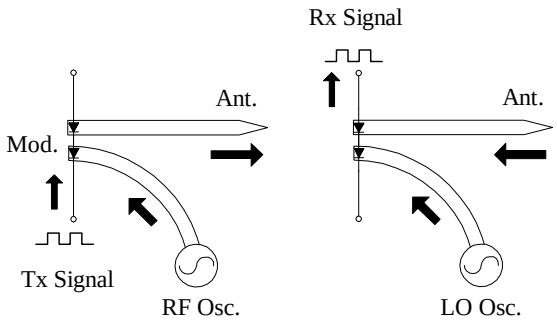


Fig.2 Circuit Configuration of NRD-guide for both transmitting(left) and receiving(right)operation

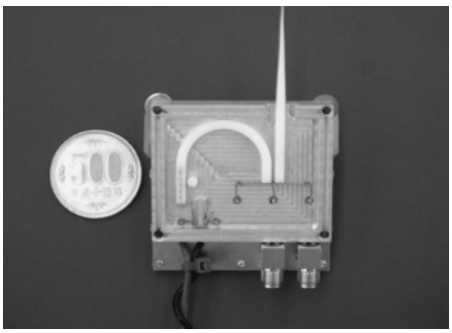
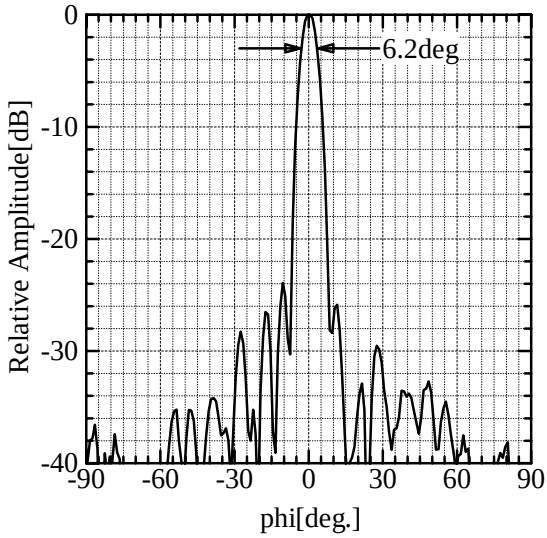


Fig.3 Fabricated NRD-guide transceiver



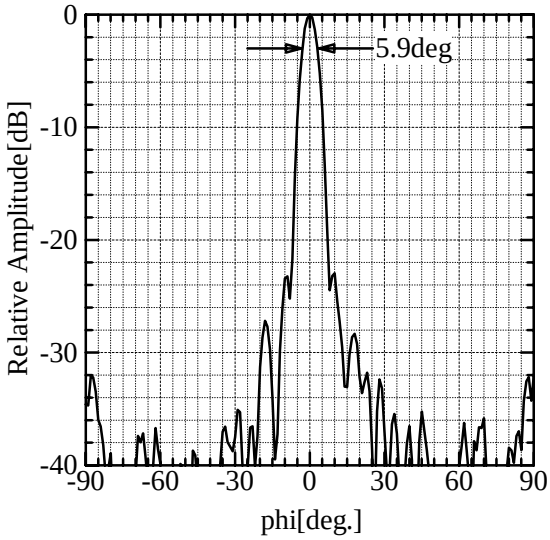


Fig.4 Radiation Patterns of Lens Antenna in E-plane(upper) and H-plane(lower)

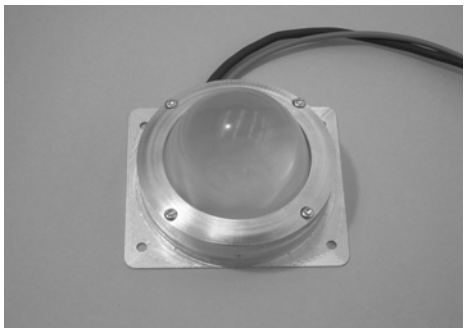


Fig.5 Lens Antenna with NRD-guide Transceiver at the Base