Analysis of Intersymbol Interference in a 60 GHz-Band Compact-Range Wireless Access System Using Various Large Array Antennas

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***Abstract*— A compact-range wireless access system in the 60 GHz-band has been proposed for multi-Gb/s data transfer. Large array antennas adopting in the transmitter operate in their near-field regions, and provide us with a large communication zone and a pure propagation environment. However, intersymbol interference (ISI) may significantly degrade the system performance especially when the receiver is close the transmitter due to the large transmitting antenna size. In this paper, the corporate feed waveguide slot array with square aperture and the radial line slot array with circular aperture are investigated. The concept of ISI is essential to improve the overall system performance.**

Keywords—compact-range communication; near-field region; millimeter-wave; intersymbol interference; large array antenna; corporate feed; series feed

I. Introduction

A novel compact-range wireless access system in the 60 GHz-band is proposed to realize multi-Gb/s data transfer [1]. A GATE (Gigabit Access Transponder Equipment) has been developed as illustrated in Fig. 1. The 60 GHz-band GATE is to be equipped as the fixed terminal in public areas such as in corridors and escalators in stations et al. A large antenna adopted in the access point generates a quasi-plane wave in its near-field region. For example, the $(25\ \lambda)^2$ aperture antenna will provide a stable and large signal-reception zone, with an area proportional to the antenna aperture and a communication distance up to 10 m. The corporate feed waveguide slot arrays with square apertures [2] and the series feed radial line slot arrays (RLSAs) with circular apertures [3] are promising candidates for the transmitting antennas.

II. Analysis of Intersymbol Interference

The symbol rate of the prototype GATE is as high as 1.728 GS/s. That is the symbol duration is as shot as 0.579 ns. In that sense, the system would be susceptible even to a short delay time. The delay spread will degrade when the receiver moves along the central axis perpendicular to the transmitting antenna. Since the values of the delay and the abovementioned symbol duration could be comparable, the symbols send from different array elements will interfere with each other within the wireless channel. That is the reason why to introduce intersymbol interference (ISI) [4] in this study.

An equivalent BB communication system is proposed as shown in Fig. 2. The transfer function of a wireless channel is $H(\omega+\omega_c)$ and the frequency spectrum of the pulse waveform shaping filters in Tx and Rx are $G_t(\omega)$ and $G_r(\omega)^*$, respectively. Here, ω_c is the center angular frequency of RF carrier. $\{s_n\}$ is the transmitted symbol sequence. By sampling the received signal by $t = nT + t_d$, the received symbol can be expressed as follows.

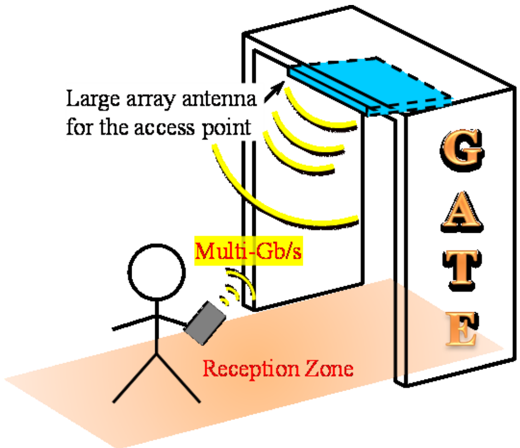

Fig. 1. 60 GHz-band GATE for compact-range wireless access system.

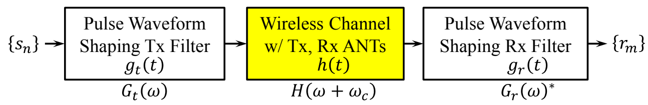

Fig. 2. Proposed equivalent baseband (BB) communication system.

$$y_k = \sum_n s_n K_{m-n} = \cdots + s_{m-1}K_1 + s_m K_0 + s_{m+1}K_{-1}\cdots \quad (1)$$

$$K_{m-n} = \frac{1}{2\pi}\int H(\omega+\omega_c)G_t(\omega)G_r(\omega)e^{j\omega(nT+t_d)}d\omega \quad (2)$$

Here, K_{m-n} is defined as the interference sequence. Finally, ISI is defined as the ratio between interference and signal.

$$\mathrm{ISI} = \frac{\left|\sum_n s_n K_{m-n}\right|^2 - \max_n\left|s_n K_{m-n}\right|^2}{\max_n\left|s_n K_{m-n}\right|^2} \quad (3)$$

III. Analysis Results

As shown in Fig. 3, the square slot array with corporate feed is analyzed first. The slots are approximated by infinitesimal dipoles, and there is no delay within the antenna feeding circuit as the ideal case. Three large arrays with 16×16, 32×32 and 64×64-elements are adopted in the transmitter. Their element spacing along both *x* and *y* directions are 4.2 mm in common. The symbol rate is 1.728 Gb/s, and the carrier frequency is 60.48 GHz in our GATE. For the waveform

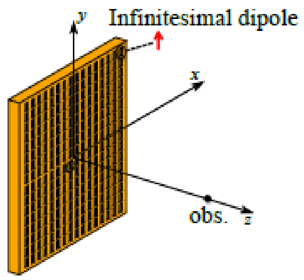

Fig. 3. Corporate feed waveguide slot array with square aperture.

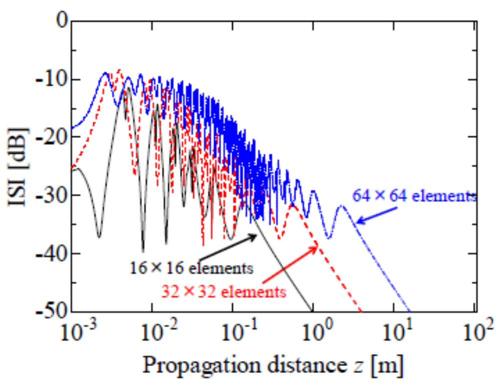

Fig. 4. Calculated ISI as a funtion of propagation distance z.

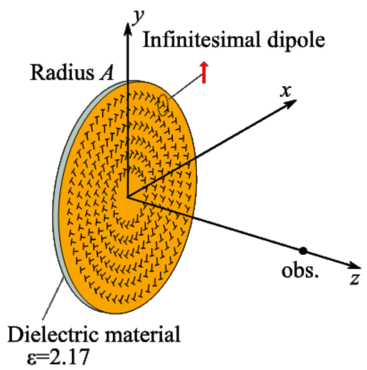

Fig. 5. Series feed radial line slot array with circular aperture.

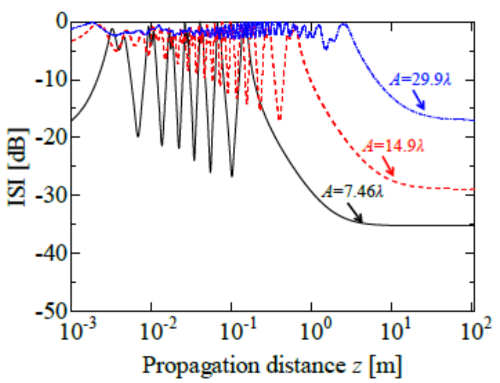

Fig. 6. Calculated ISI as a funtion of propagation distance z.

shaping filters, a roll-off factor of $\alpha = 0.25$ is applied in this study. The input power to the transmitting antenna is fixed at 10 mW, and an open-ended waveguide probe with 6 dBi antenna gain is used as the receiving antenna. The received RF signals in frequency domain are calculated first as the transfer function $H(\omega + \omega_c)$ of the wireless channel with interest. The ISI is analyzed for each array, and the results are summarized in Fig. 4. It can be easily observed that, there are ripples in the near-field region of transmitting antenna, and ISI will decrease monotonically in its far-field region. For the largest array, enlarging the distance between the two antennas at more 10 cm may sufficiently suppress ISI lower than -15 dB.

Secondly, the RLSA as illustrated in Fig. 5 can also be the promising candidate for transmitting antenna, due to its simple feeding structure and easiness in fabrication. Its typical weakness is the delay inside due to the series feed. Here, the dielectric constant inside RLSA is assumed at 2.17. Three RLSAs with radius of 7.46, 14.9 and 29.9 λ, whose aperture sizes are equal to the 16×16, 32×32 and 64×64-elements square arrays, are investigated. For simplicity, the approximation by infinitesimal dipoles is assumed again. As summarized in Fig. 6, ISIs for three antennas are calculated, after the calculation of their transfer functions. Compared with Fig. 4, ISI is high and the ripple is deep in the near-field region. The large RLSA with a radius smaller than 30 λ will function in its far-field region in our present GATE system as usual for ISI <-15dB.

IV. Conclusion

The intersymbol interferences of the 60 GHz-band compact range wireless access system adopting various large array antennas are analyzed. An equivalent baseband communication system is proposed to evaluate the wireless channel including transmitting and receiving antennas. Two types of array antennas are investigated: one is the corporate feed waveguide slot array with square aperture; the other one is the series feed radial line slot array with circular aperture. The effects due to the mismatch inside the feeding circuit and the multiple reflections between two antennas are under investigation. It will provide us with the new guidelines to design the array antennas operating in a millimeter-wave band high-speed near-field communication system.

Acknowledgment

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