Compensating Distortion of Antenna Frequency Characteristics Using Pre-filtering

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Abstract Since a very wide frequency band is utilized in the Ultra Wide Band (UWB) communication system, wideband characteristics are also required for the antennas. However, it is difficult to construct an antenna that has uniform characteristics throughout the UWB frequencies. Distortion in the antenna frequency characteristics causes distortion in the output waveform of the antenna. This paper proposes a new method that compensates for the distortion due to the antenna characteristics before transmission. Numerical results show that the proposed method, which employs a transversal filter, is effective in compensating for the distortion.

1. INTRODUCTION

In recent years, there have been remarkable advances in wireless access technologies (e.g., cellular phones, wireless LANs), and it is anticipated that wireless technologies with high capacity and high quality will be achieved. Since the usable frequencies for wireless communications are limited, the Ultra Wide Band (UWB) system, which shares frequencies with conventional systems, has attracted much attention [1]. An antenna that has wideband characteristics is required for the system because a very wide frequency band is utilized in the UWB. However, it is difficult to obtain an antenna that has uniform characteristics throughout the UWB. Thus, the communication quality tends to degrade because of the distortion in the antenna frequency characteristics. This paper proposes a new method (pre-filtering) that compensates for the distortion due to the antenna characteristics based on the UWB communication scheme called the impulse Radio scheme, which transmits very short impulse waves [2]. Numerical results show that the proposed method is effective in compensating for the distortion. In addition, the influences of the Signal to Noise power Ratio (SNR) and the number of taps of the filter on the effect of the pre-filter are evaluated.

2. PRE-FILTERING TO COMPENSATE FOR DISTORTION

Figure 1 shows the concept behind the new method that compensates for the distortion of a transmitted signal waveform due to the frequency characteristics of the antenna. If the antenna frequency characteristics, $A(f)$, are distorted, then the amplitude spectrum of the transmitted signal is also distorted according to the shape of the antenna frequency characteristics. Thus, filter frequency characteristics, $F(f)$, are set to the inverse of the antenna frequency characteristics, $A(f)$. The amplitude spectrum of the signal transmitted from the antenna, $Z_{flt}(f)$, can be compensated. Accurate filtering is required to compensate completely for the distortion; however, a filter with finite accuracy and a finite

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impulse response should actually be used. Therefore, the compensation effect of an achievable filter is evaluated by computer simulation in the following section.

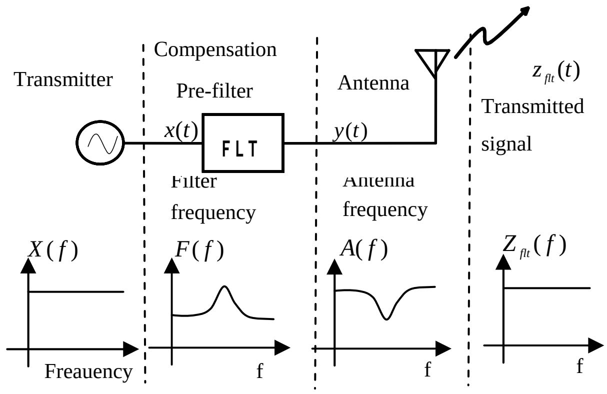


Fig. 1 Concept of proposed method (Pre-filtering)

3. SIMULATION MODEL

3.1. Antenna Frequency Characteristics

The antenna frequency characteristics in the simulation shown in Fig. 2 are determined using Eq. (1). Parameters G_0 and G_1 shown in Fig. 2 are the gain at the center frequency and the distortion coefficient of the frequency characteristics, respectively. The phase of the antenna characteristics is inverted where the amplitude of the antenna frequency characteristics is a negative value.

$$A(f) = A(x) = G_1 * x^n + G_0$$
$$x = \frac{2(f - f_0)}{f_H - f_L} \qquad \ldots\ldots(1)$$
$$n = 1, 2, 3$$

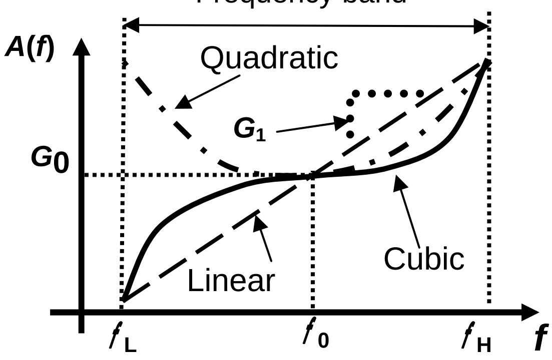


Fig.2 Antenna frequency characteristics

3.2. Pre-filter Composition

We assumed that the pre-filter comprises a transversal filter [3]. The inverse Fourier transform of the objective frequency characteristics is used for the coefficient of the filter in order to form the inverse of the antenna frequency characteristics using the transversal filter.

4. EVALUATION OF PRE-FILTER COMPENSATION EFFECT

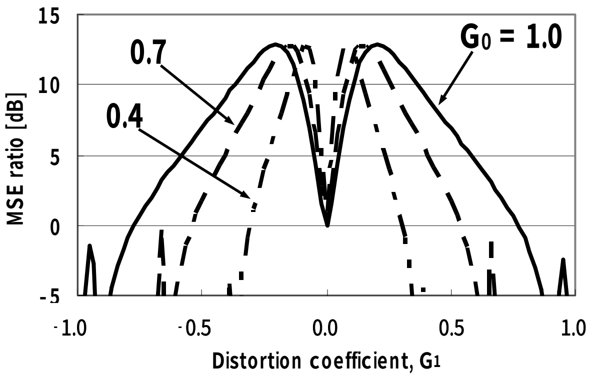
4.1. Pre-filter Compensation Effect

The effect of the pre-filter is evaluated using the Mean Square Error (MSE) ratio, which is the difference between the expected signal and the transmitted signal from the antenna. Figure 3 shows the relationship between the distortion coefficient of antenna frequency characteristic G_1 and the MSE ratio when the number of taps of the filter is 64 and the SNR is 50 [dB]. The MSE ratio represented on the vertical axis is calculated using Eq. (2).

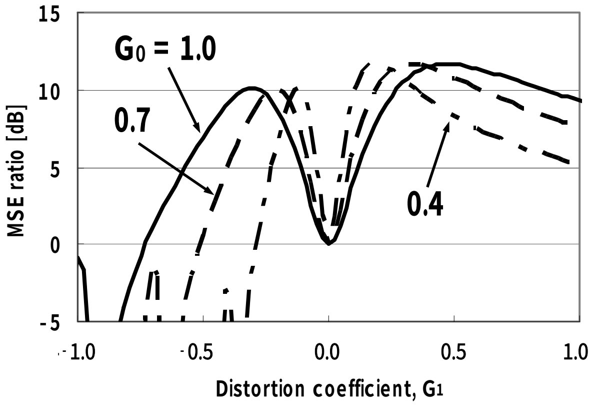
$$MSE\_Ratio = 10 \times \log_{10}\left(\frac{\text{MSE without the pre-filter}}{\text{MSE with the pre-filter}}\right) \quad \cdots\cdots\cdots \ (2)$$

A positive value of the ratio means that the pre-filter compensation effect is obtained. In Fig. 3, the value of the MSE ratio becomes positive when $|G_1|$ is small, then the pre-filter compensation effect can be obtained. However, the pre-filter becomes ineffective due to a negative MSE ratio. This is because when $|G_1|$ becomes larger, the distortion of the antenna frequency characteristics is increased.

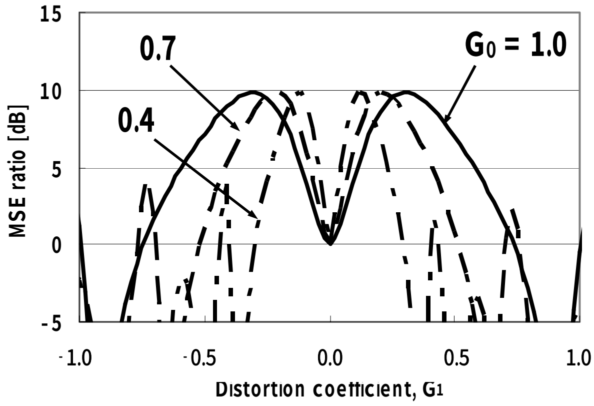
The figure also shows that the compensation effect is increased as the gain G_0 becomes large.



(a) n = 1,(Linear distortion)



(b) n = 2,(Quadratic distortion)



(c) n = 3,(Cubic distortion)

Fig. 3 Pre-filter compensation effect

4.2. Influence of SNR on Compensation Effect

The influence of the SNR on the pre-filter compensation effect is evaluated in this section. Figure 4 shows the relationship between the gain at center frequency G_0 and the maximum distortion coefficient $|G_1|_{max}$ that can be compensated by the pre-filter. The parameter is the SNR of the input signal. In Fig. 4, the effect of the pre-filter is increased as the SNR becomes large. When the SNR is greater than 40 dB, the effect of the pre-filter is almost the same as the case without noise.

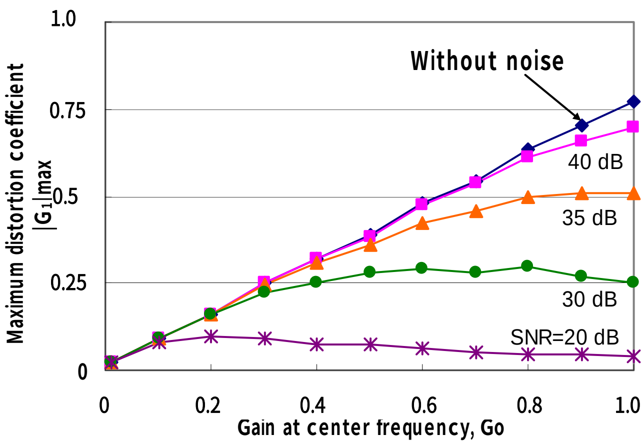


Fig. 4 Relationship between Go and $|G1|_{max}$

4.3. Influence of Number of Taps on Compensation Effect

Figure 5 shows the relationship between the distortion coefficient of the antenna frequency characteristics G_1 and the MSE ratio. Here, the antenna frequency characteristics are linear distortion and the SNR is 50 [dB]. The parameter is the number of taps of the filter. In Fig. 5, the MSE ratio is decreased when the number of taps of the filter is decreased. It clears that the compensation effect tends to degrade, and finally, the compensation effect cannot be obtained when the number of taps is 16.

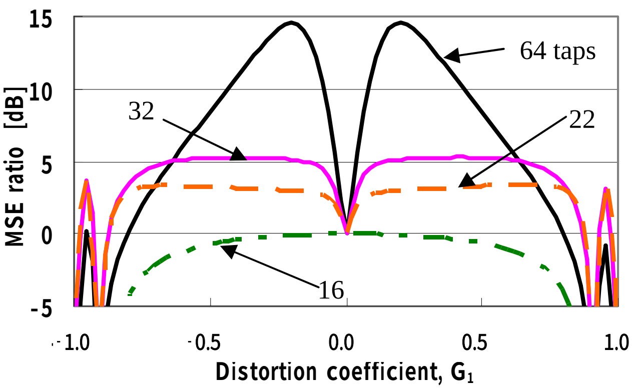


Fig. 5 Relationship between G_1 and MSE Ratio

5. CONCLUSIONS

A new method (pre-filtering) was proposed that compensates for the distortion due to the antenna frequency characteristics, and the pre-filter compensation effect was evaluated.

The simulation results showed that the distortion compensation effect on the transmitted signal waveform by the pre-filter could be obtained for all cases of linear distortion, quadratic distortion, and cubic distortion for the antenna frequency characteristics. We found that the compensation effect was increased as the gain increased.

Furthermore, it was shown that the effect of the pre-filter was almost the same as the case without noise when the antenna frequency characteristics were linear distortion and the SNR was 40 dB.

Finally, it was indicated that the compensation effect tended to become worse when the number of taps of the filter was decreased, and the compensation effect could not be obtained when the number of taps was 16.

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