Minimum constrained adaptive monopulse estimation in radio interference

Hirofumi Fukushima, Ryuhei Takahashi, and Nobuhiro Suzuki
Information Technology R&D Center, Mitsubishi Electric Corporation, Kamakura, Japan

◆Monopulse estimation

● **Monopulse** technique is extensively used in practical applications, such as radar, communications, and sonar systems, because of its ease of implementation and low computational complexity. However, its performance deteriorates under radio interference as it cannot separate the desired signal from interference.

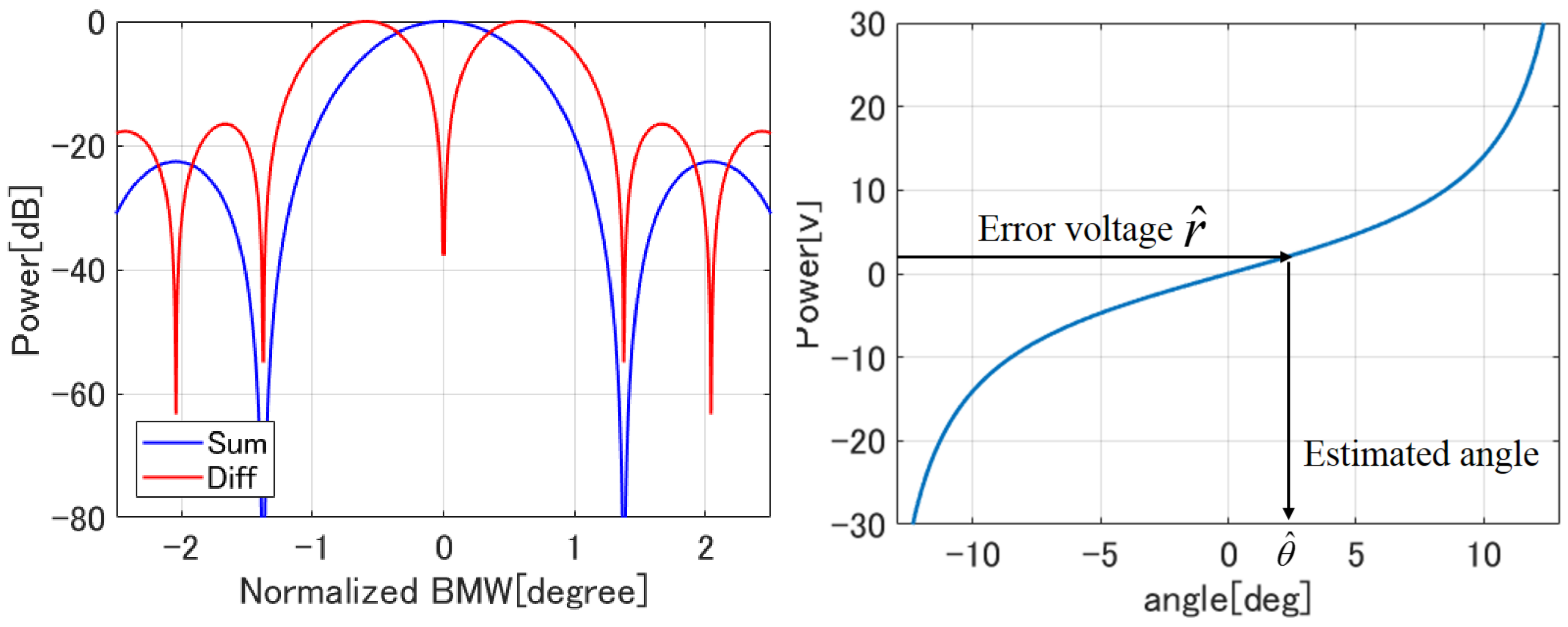

Fig. 1. Sum and difference beam pattern and monopulse ratio curve without radio interference

● **Conventional monopulse weight**

$$W_\Sigma = a(\theta_0) \qquad W_\Delta = \dot{a}(\theta_0)$$

◆Adaptive monopulse estimation

● **To** address monopulse problem, an adaptive processing technique has been applied to the monopulse technique, called an adaptive monopulse. However, because of this nulling, the sum and difference patterns are distorted relative to the sum and difference beams with no radio interference

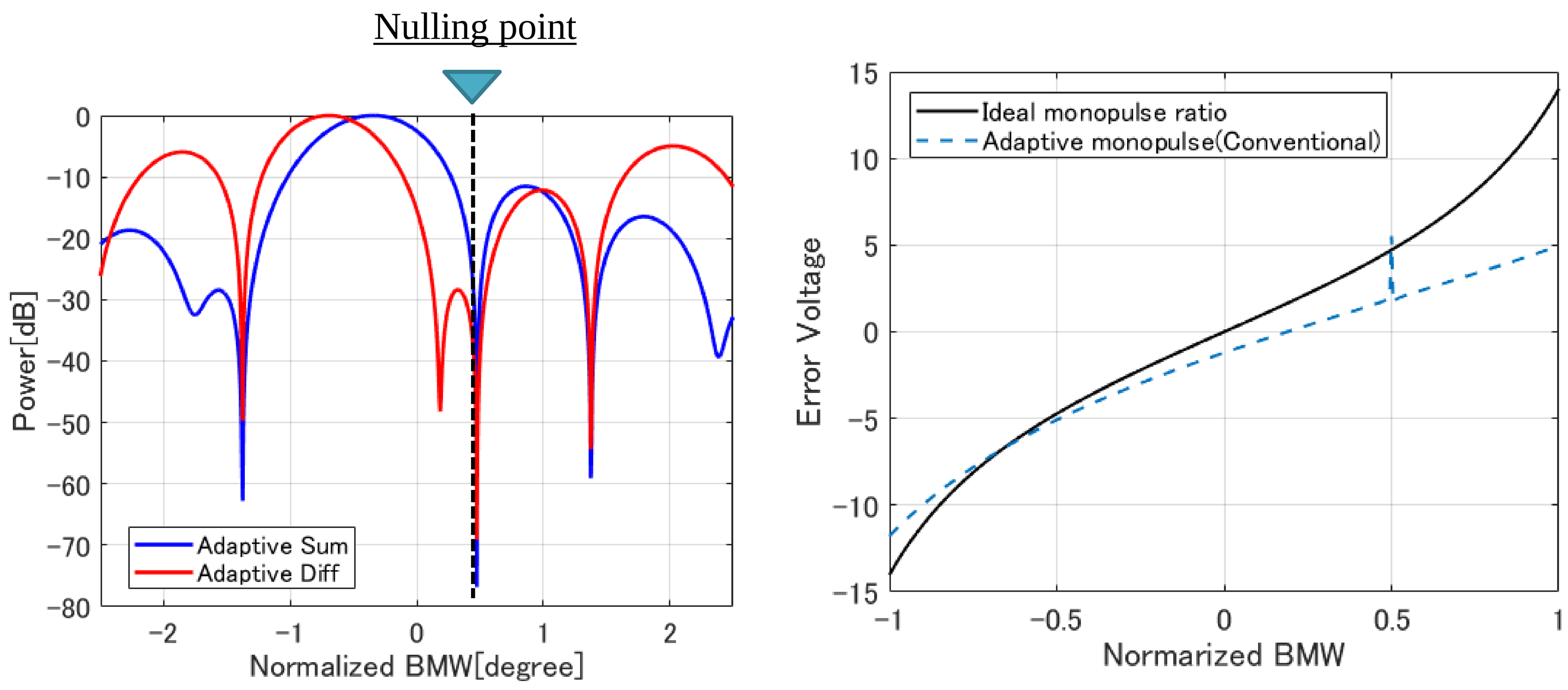

Fig. 2. Adaptive sum and difference beam pattern and monopulse ratio curve with radio interference

● **Conventional adaptive monopulse weight**

$$W_{\Sigma-adaptive} = \gamma_\Sigma R^{-1} W_\Sigma \qquad W_{\Delta-adaptive} = \gamma_\Delta R^{-1} W_\Delta$$

◆Proposed method

● **To** improve on the conventional method, we proposed a minimum constrained adaptive monopulse technique so that the monopulse ratio can be preserved without wasting degrees of freedom.

◆ Two constrained condition

① Solution of the monopulse ratio does not change

$$r_{proposed}(\theta_0) = r(\theta_0) = 0$$

$$\Leftrightarrow$$

$$\mathrm{Re}\left(\frac{W_\Delta^H a(\theta_0)}{W_\Sigma^H a(\theta_0)}\right) = \mathrm{Re}\left(\frac{\dot{a}^H(\theta_0) a(\theta_0)}{a^H(\theta_0) a(\theta_0)}\right) = 0$$

First condition

$$W_\Delta^H a(\theta_0) = 0$$

② Solution of the monopulse ratio slope also does not change

$$\dot{r}_{proposed}(\theta_0) = \dot{r}(\theta_0)$$

$$\dot{r}_{proposed}(\theta_0) = \mathrm{Re}\left[\frac{W_\Delta^H \dot{a}(\theta_0)\{W_\Sigma^H a(\theta_0)\} - W_\Delta^H a(\theta_0)\{W_\Sigma^H \dot{a}(\theta_0)\}}{|W_\Sigma^H a(\theta_0)|^2}\right] = \mathrm{Re}\left[\frac{W_\Delta^H \dot{a}(\theta_0)}{W_\Sigma^H a(\theta_0)}\right]$$

$$\dot{r}(\theta_0) = \mathrm{Re}\left[\frac{\dot{a}^H(\theta_0)\dot{a}(\theta_0)\{a^H(\theta_0)a(\theta_0)\} - \dot{a}^H(\theta_0)a(\theta_0)\{a^H(\theta_0)\dot{a}(\theta_0)\}}{|a^H(\theta_0)a(\theta_0)|^2}\right] = \mathrm{Re}\left[\left|\frac{\dot{a}(\theta_0)}{a(\theta_0)}\right|^2\right]$$

Second condition

$$\frac{W_\Delta^H \dot{a}(\theta_0)}{|W_\Sigma^H a(\theta_0)|} = \left|\frac{\dot{a}(\theta_0)}{a(\theta_0)}\right|^2$$

● **Condition of the delta weight**

$$\left[a(\theta_0), \frac{\dot{a}(\theta_0)}{|W_\Sigma^H a(\theta_0)|}\right]^H W_\Delta = \begin{bmatrix} 0 \\ \left|\frac{\dot{a}(\theta_0)}{a(\theta_0)}\right|^2 \end{bmatrix}$$

$$\equiv C_{pro}^H W_\Delta = H_{pro}$$

◆ Proposed constrained adaptive delta weight

$$\min_{W_\Delta}\left(P_{out} = \frac{1}{2} W_\Delta^H R_{xx} W_\Delta\right) \quad \text{subject to } C_{pro}^H W_\Delta = H_{pro}$$

$$W_{\Delta-proposed} = R_{xx}^{-1} C_{pro}\left(C_{pro}^H R_{xx}^{-1} C_{pro}\right)^{-1} H_{pro}^*$$

◆ Simulation results

● Proposed method can preserve the monopulse ratio and can maintain exact nulling position comparable to or more accurately than the other methods while only constraining two points.

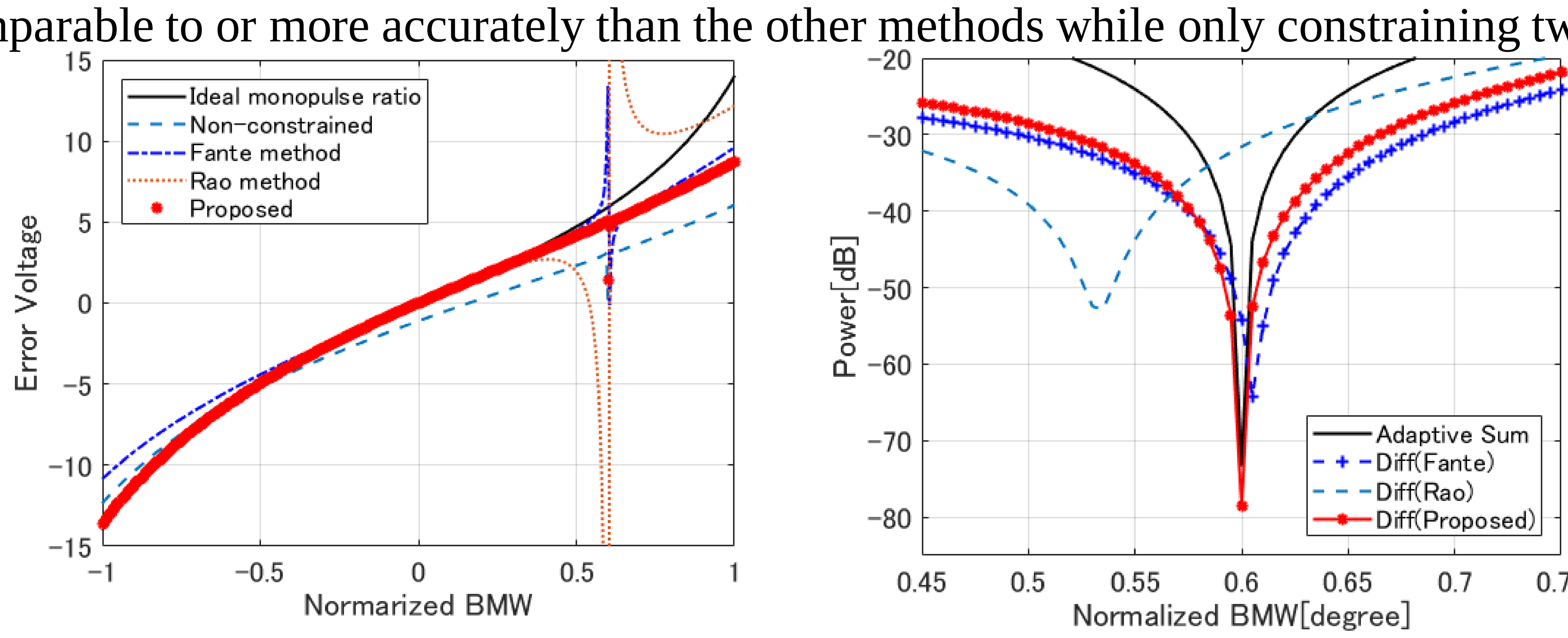

Fig. 3. Monopulse ratio and sum and difference beam pattern with interference angle: 0.6×BMW(Beamwidth).

Table. 1. Parameters for simulation

Item	Value
Array Configuration	16 element Uniform rectangular array with half wavelength interval
Snapshot Number	256
SNR	10 dB
INR	25 dB
Target DOA	0 deg
Interference DOA	0.45BMW*, 0.6BMW *BMW:Beam width

● Table 2 shows the powers at the interference angles after applying each adaptive weight, and it is clear that the proposed method is superior to the other methods.

Table. 2. Parameters for simulation

Interference angle	Interference angle 0.6 BMW	Interference angle 0.45BMW
Proposed method	-68.8 dB	-64.8 dB
Fante	-53.0 dB	-51.7 dB
Rao	-32.2 dB	-34.3 dB

◆ Conclusion

● We proposed a minimum constrained adaptive monopulse technique. An evaluation of the proposed method showed that the proposed method can preserve the monopulse ratio without wasting degrees of freedom and that it can suppress radio interference better than the other two methods.