THE VERIFICATION OF 2-D WAVE PARAMETER FROM MARINE RADAR BY IN SITU MEASUREMENT

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ABSTRACT

The objective of this study is validation of 2-D wave parameter from marine radar by comparing in situ measurement.
Before the marine radar is calibrated by comparing in situ data. Firstly we proposed the method for monitoring 2-D wave parameter, especially wave length and wave direction, by using simulated image of marine radar. The accuracy of the proposed method in this study is concluded over 90%.
Secondary we observed the wave parameter around the coast area near Komatsu city besides Sea of Japan by marine radar from Jan.5 to Jan.6, 1995 when the highest significant wave in winter of 1995's was observed. From Image of marine radar we obtained the wave direction and wave length. These two parameter was calibrated by in situ data by Ministry of Construction Japan.
The Accuracy of wave direction fits to the in situ data. But the accuracy of wave frequency is lower than wave direction. The error depends on the reason that we use small amplitude wave theory on translating from spatial frequency monitored by marine radar to time series frequency. Translation from spatial frequency to special frequency is a big problem on wave theory. Making allowance for the reason mentioned above,we find that it is accurate enough for operational use.

1. INTRODUCTION

The Observation of two dimensional (2-D) wave parameter distribution is important for the estimation of the wave force to marine constructions, such as jetty. The in situ data routinely observed now are point data and the cost is expensive, so the number of observation point is a few. There is no routine method for monitoring 2-D wave parameter distribution.
Marine radar can offer the image of 2-D wave field by monitoring the sea clutter from the sea surface. F.Ziemer,and W.Rosenthal[1)] was developed the transfer function for marine radar for imaging ocean waves. After applying the transfer function to the image spectra, significant wave heights were estimated and compared with results from other sensors during LEWEX[2)]. Results of their study are very promising.
M.D.Henschel, Robert A. Paul, and B.M.Eid[3)] developed the prototype marine radar ocean wave imaging system, MACRADAR, for validation of the ERS-1 SAR wave mode operation by using F. Ziemer et al 's method. But their application was carried out only on the offshore region.
In this study we use the marine radar in near shore region for verification 2-D wave parameter by using in situ data.

2.DATA ANALYSIS METHOD

Fig.1 shows the flow diagram of analysis procedure. As the received power from the sea surface become more and more weakly as the radar is far from the radar site. The correction function are applied to correct the difference of these power due to the distance from the radar to the sea surface. And the received power from the radar is PPI image shown as Fig.2 on polar coordinate system, so the image is transformed to x-y coordinate system for FFT analysis.The Fourier transformation F(kx,ky) is defined by

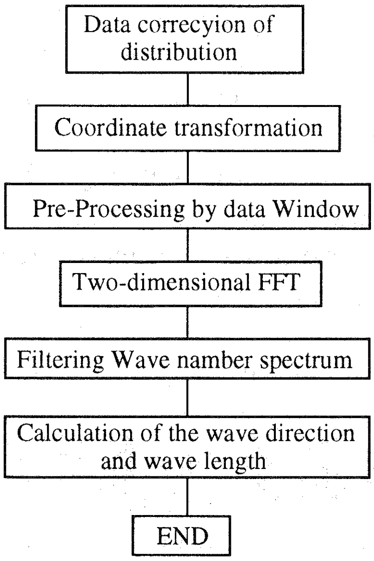

Fig.1 Flow diagram showing the analysis procedures.

$$F(kx,ky)= 1/(2\pi)^2 \cdot \iint_{\infty}^{\infty} \eta(x,y) \cdot \exp(-i(kxx+kyy))dxdy \qquad \text{.......... 1)}$$

$\eta(x,y)$ is the radar image defined on x-y coordinate system. And Wave number spectrum is defined by

$$S(kx,ky)= | F(kx,ky)^2 | \qquad \text{.......... 2)}$$

The relationship between wave number spectrum and 2-D wave parameter is shown in Fig.3. We use the discrete Fourier component, eq.2) is written as follows.

$$S(m,n) = | F(m,n)^2 | /(M\triangle x)(N\triangle y) \quad \text{.... 3)}$$

Where $-(M/2-1) \leqq m \leqq (M/2-1)$, and $-(N/2-1) \leqq n \leqq (N/2-1)$. Wave number k, wave length L, wave frequency T, and wave direction α is defined as Fig.3. In this study we use small amplitude wave theory in definition of T vs. wavenumber (m,n).

$$L = (gT^2/2\pi)\tanh(2\pi/L) \qquad \text{.......... 4)}$$

where g is the gravity acceleration, and h is the averaged depth of target area.

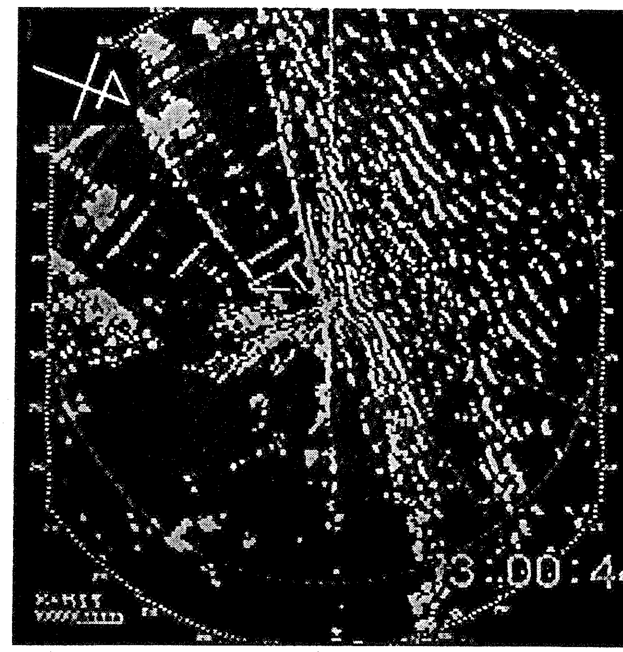

Fig.2 The radar image(PPI).

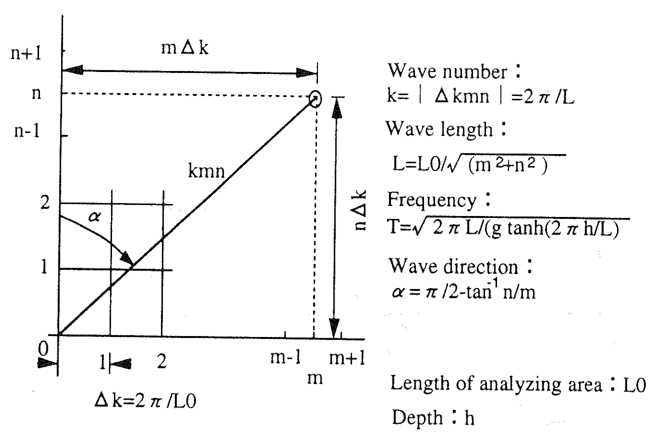

Fig.3 The relationships between wave number spectrum and wave parameter

3. 2-D WAVE PARAMETER FROM SIMULATED IMAGE OF MARINE RADAR

3.1 Simulation of Marine Radar Image

Image of marine radar is simulated by FFT. Firstly 2-D Gaussian distribution is made as Fig.4. where A is the peak value of Gaussian

distribution at (x0,y0), and Sx, Sy is the deviation to x direction and y direction respectively. And wave direction α is yield by using x0 and y0 as Fig.4.
Secondary power spectrum at (i,j) is calculated as follows.

$$\text{power}(i,j) = \sqrt{\ } A\exp\{-[(i-x0)2/sx2+(j-y0)2/sy2]/2\} \qquad \cdots\cdots 5)$$

Random phase θ is used to simulate the random wave. Real part : power R and imaginary : power I part are defined as eq.6) and 7) respectively.

$$\text{powerR}(i,j) = \text{power}(i,j)^* \cos\theta \qquad \cdots\cdots 6)$$
$$\text{power I}(i,j) = \text{power}(i,j)^* \sin\theta \qquad \cdots\cdots 7)$$

The simulate image of marine radar is yield through inverse FFT by using power R(i,j) and Power I(i,j). In this case the data from marine radar is only real part, eq.6) is used to simulate the image of marine radar.

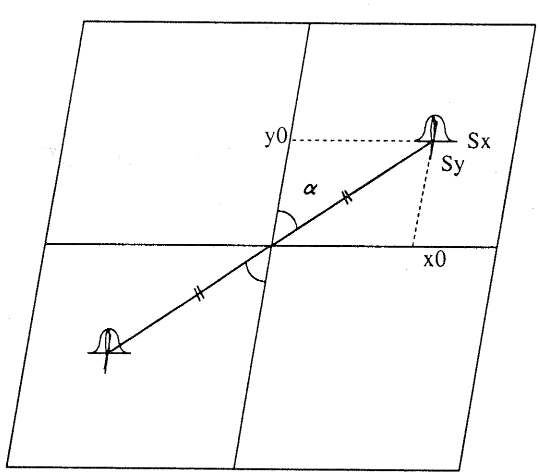

Fig.4 The definition sketch of the wave number spectrum of the simulated wave

3.2 Verification of the Radar data Analysis method

Fig.5 shows the simulated image of marine radar. This image is simulated as the wave direction is 45 deg. And Fig.6 shows the wave number spectrum distribution of the wave field defined as Fig.5. Fig.6 shows there are two peaks in the wavenumber space, 45 deg and 225 deg. In this case sea covers 0 - 180 deg, the wave direction is defined as 45 deg. This shows that if the wave with incident angle 45 deg is monitored by marine radar the wave direction is estimated 45.6-49.2 deg.
When wave direction is 0, 30, 45, 60, and 90 deg and wave length is 1/8, 1/4 and 3/8 of perimeter size of target area. It is concluded that the accuracy of the proposed method in this study is over 90% [4].
And Fig.7 shows the result of translating wave direction-frequency space for coastal engineering use through eq.4).

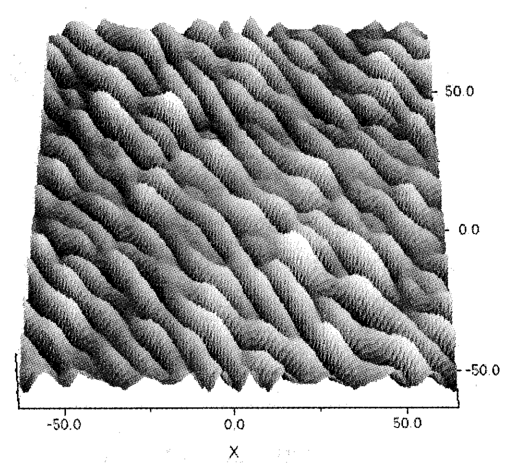

Fig.5 The simulated image of marine radar (wave direction: 45 deg)

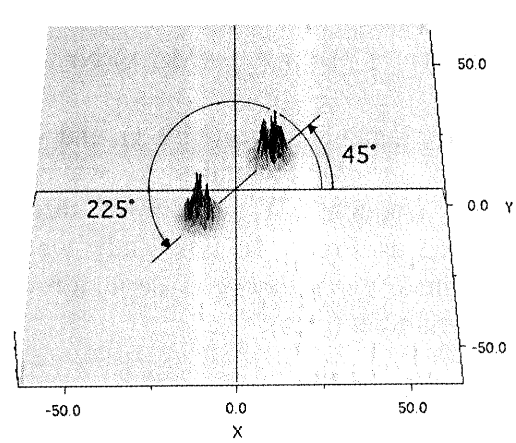

Fig.6 The wave number spectrum distribution of the simulated wave of Fig.5 in the Kx-Ky space.

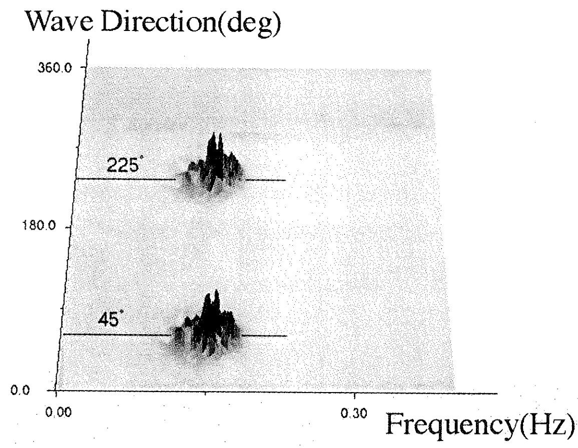

Fig.7 The wave number spectrum distribution of he simulated wave of Fig.5 in the wave direction-frequency space

4. MARINE RADAR OBSERVATION RESULT AND DISCUSSION

The marine radar site was shown in Fig.8 and Fig.9. We observed the target area on Jan.5-6, 1995, when the most highest wave was observed by the wave observational system of in situ data by Ministry of Construction Japan at the same area as Fig.8. The PPI image was converted by A/D convertor and saved into the computer for analysis.

Fig.10 shows the result of comparison between wave direction by marine radar and the in sits data. From this result the wave direction is same as in situ data except the case pre-processed by Hanning window only. Another two case filtered by moving average have good correlation to the observed data.

And Fig.11 shows the result of comparison between wave frequency and in situ data. This shows the frequency observed by marine radar is larger than the data from in situ data.

The error depends on the reason that we use small amplitude wave theory on translating from spatial frequency monitored by marine radar to time series frequency. Translation from spatial frequency to time series frequency is a big problem on wave theory. Making allowance for the reason mentioned above, we find that it is accurate enough for operational use.

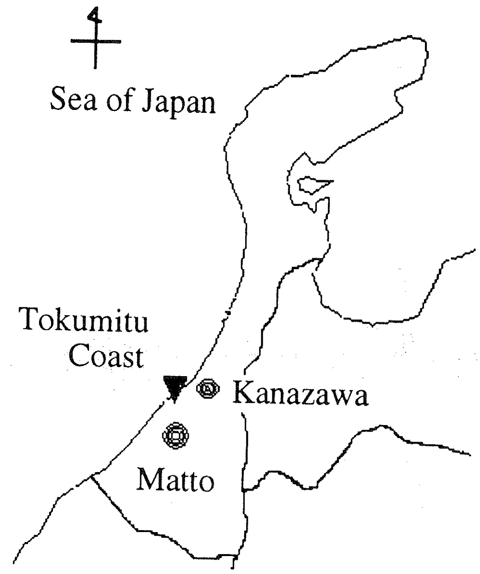

Fig.8 The marine radar site

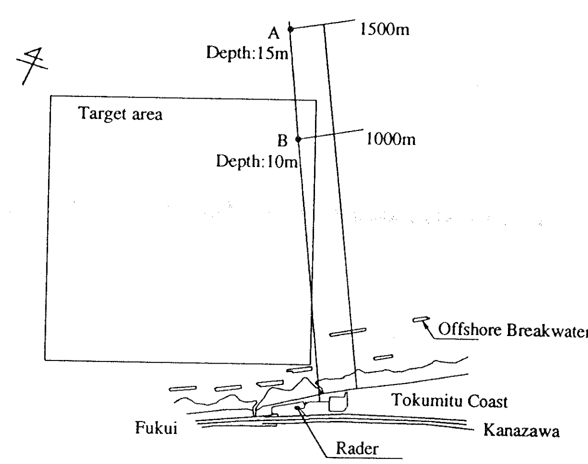

Fig.9 The observational area

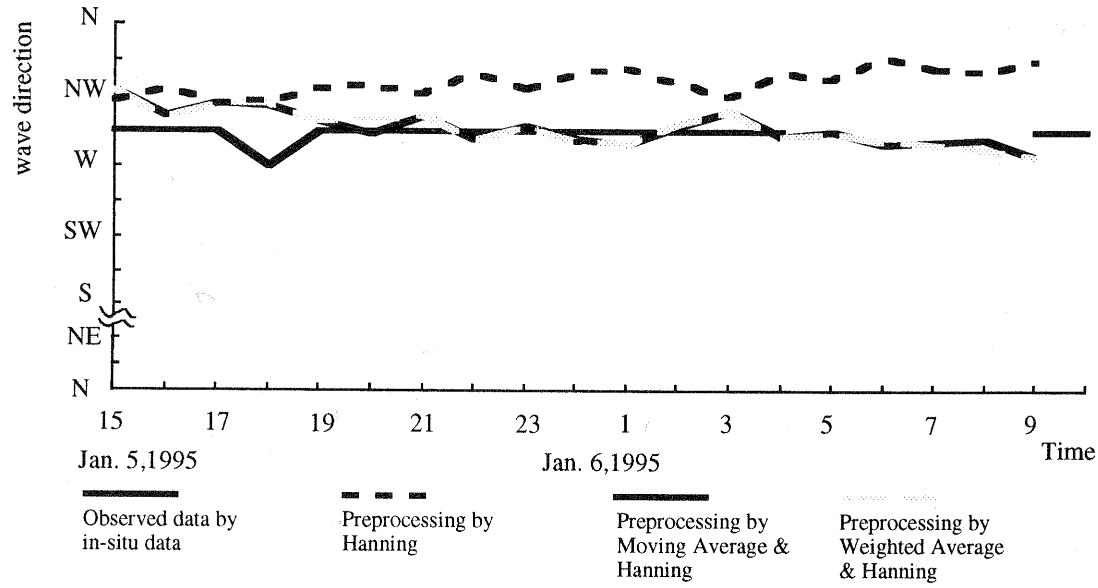

Fig. 10 The result of comparison between wave direction by marin radar and the in situ data

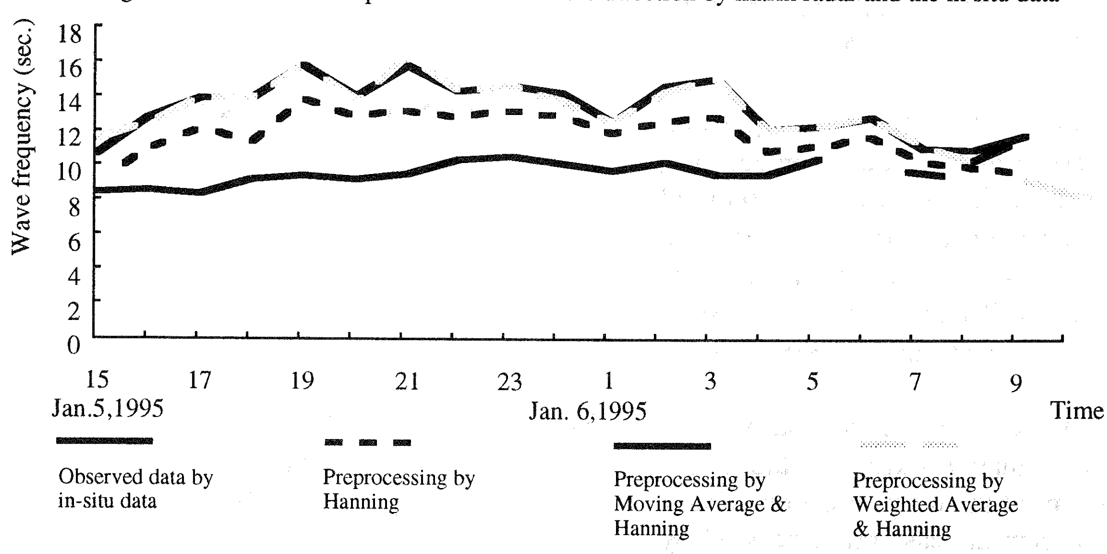

Fig. 11 The result of comparison between wave frequency by marine radar and in situ data

5. CONCLUSIONS

The marine radar is effective for observing wave direction and the accuracy is good for operational use. Another wave parameter such as wave frequency and wave height must be checked by further study.

References

1) F.Ziemer, and W.Rosenthal : On the Transfer Function of Shipbone Radar for Imaging Ocean Waves, Proc.IGARSS'87, Ann Arbor, Michigan, pp.1559-1564, 1987.
2) F.Ziemer: Directional Spectra from Shipbord Navigation Radar during LEWEL, DIRECTIONAL OCEAN WAVE SPECTRA, pp.80-84,1989.
3) M.D.Henschel, R.A.Paul, and B. M. Eid : Use of Satellite Synthetic Aperture Radar for Operational Measurement of Ocean Wave Spectra, Proc. ERIM Second Themantic Conference: Remote Sensing for Marine and Coastal Environments, New Orleans, LA, Vol.1, PP.I-269 - I-273,1994.
4) Shintaro Goto, and Kiyonori Iisawa: Study on the Monitoring of 2-D Wave Parameter Using Simulated Image of Marine Radar, Journal of Photogrammetry and Remote Sensing,