COVERAGE PREDICTION OF HF WIRELESS NETWORK FOR DISASTER EARLY WARNING SYSTEM IN INDONESIA

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ABSTRACT

HF Radio communication (2 – 25 MHz) is relatively low cost beyond the line-of-sight application. And have an alternative to satellite and tropospheric scatter communication. Using the wireless sensor array network for monitoring and identifying of sea, land, mountain etc which deal with activity of earthquake disaster in relatively small area. The data collected and processed in one center node regional divisions, then using the HF wireless network build a national disaster early warning system. The important medium for HF radio communication is Ionosphere, which have spatially and temporally propagation characteristics, but when used appropriate time and location a long range communication can be done.

This paper focuses on coverage prediction of point to point HF radio communication, which used to communicate from six center node regional divisions to national main control system in Indonesia. Using statistical based tool communication analysis and prediction program VOACAP is yielded that the best communication can be done at disaster frequency 12.6MHz almost all day long. Padang, Pontianak, Palu, Ambon, Kupang and Tembagapura is set as center node regional divisions with main control system at Surabaya, they have coverage capability when used in the disaster early warning system in Indonesia.

Keyword: *coverage prediction, HF radio communication, wireless sensor array.*

1. PENDAHULUAN

HF communications links have remained popular with both civilian and military users, because of their relatively low cost for beyond-line-of-sight applications. Civilian. Applications include international shortwave broadcasting, ship-to-shore communications, radio telegraphy, and transoceanic air-traffic control. All military services rely on HF for some long-haul strategic and short-haul tactical links [1].

Although HF sky wave offers some unique properties, the general consensus is that its shortcomings limit its full utility as an effective means of long-range communications. The ionosphere constantly changes and the HF user has only a few opportunities, that is, frequency allocations, for adaptation. Furthermore, there is usually no direct method of measurement, reporting, or evaluation that could enable the user to effectively employ what little flexibility he has.

Geographically Indonesia reside on the meeting of three especial plate [of] earth, that is the Plate of Indies or Indo-Australia in the South which relatively move to North-East about 7 cm/year, the Eurasian plate in the North which relatively move 9cm/year and the Pacific plate in the East which relatively move to the West 11 cm/year. There for Indonesian archipelago is a potentially dangerous site with high activity of earthquake [2]. In order to minimize the risk which causes earthquake activity, like tsunami, landslide, land deformation etc, we propose an Indonesian disaster early warning system. This system consists of any wireless sensor array network for monitoring and identifying of sea, land, mountain etc which deal with activity of earthquake disaster. All data from sensors should be collected and processed in one machine in center node regional division area of national services. After that, the data should be sent to main control station periodically, where all of data from all regional division be collected and processed. Communication between center node regional divisions with main control station is conducted to use HF wireless network as seen on Figure 1.

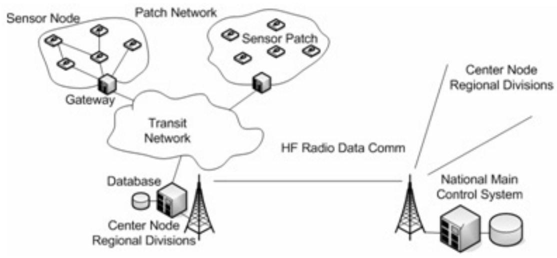

Figure 1 Disaster Early Warning System Using HF Wireless Network

Table 1 Geographic location and Intercity distance

City	latitude	longitude	Ambon	Kupang	Padang	Palu	Pontianak	Surabaya	Tembagapura
Ambon	3.72S	128.2E	0	880	3109	977	2136	1754	1008
Kupang	10.17S	123.58E	880	0	2765	1111	1938	1233	1628
Padang	0.95S	100.35E	3109	2765	0	2171	1004	1543	4117
Palu	0.88S	119.88E	977	1111	2171	0	1177	1061	1973
Pontianak	0.03S	109.3333	2136	1938	1004	1177	0	888	3142
Surabaya	7.25S	112.75E	1754	1233	1543	1061	888	0	2725
Tembagapura	4.62S	137.25E	1008	1628	4117	1973	3142	2725	0

We assumed that the Indonesia national service is divided in six regional divisions with each center node area. They are: Padang, Pontianak, Palu, Ambon, Kupang and Tembagapura as seen on Figure 2. Then all of center nodes connected to national main control station in Surabaya.

This work consists of the research and development of Indonesian disaster early warning system wireless network using HF radio data communication from one center area to others in Indonesian country service. This is done in order to back up existing satellite communication network fails to work during disaster time. HF radio communication is possible to done by using ground wave propagation especially at sea. Ground wave propagation is much less efficient over land than it is over sea because of the much lower conductivity of the ground and other factors. In [3] IPS introduced that it is possible to communicate over distances of about 900 kilometers at 2 MHz by using a 100 Watts transmitter. At 8 MHz, under the same conditions and using the same transmitter power, the maximum range is reduced to about 270 kilometers. We used frequency bellow 14 MHz and transmitting power at about 500 Watts for the system in order to exploiting the ground wave propagation. Base on ITU Article S5 Radio Regulation [4] we chose some frequency between 4 MHz to 14 MHz which allocated for distress communication. They are: 4.2 MHz; 6.3 MHz; 8.4 MHz and 12.6 MHz. Frequency bellow 4 MHz are not use with consideration of the pattern of their antenna are too wide.

The research objective is limited in prediction of HF wireless network coverage for disaster early warning system in Indonesia, which proposed above. What are the places for center node regional division answering the demand coverage requirement, and which frequency is possible to use. We used ionospheric radio prediction program to plan maximum coverage transmission of each center node regional divisions and their data communication to main control system using HF radio.

2. COVERAGE PREDICTION USING VOACAP

In order to plan coverage area of an HF wireless communication network system, the attenuation, multi-path fading etc. observed during the propagation should be predicted. For that purpose, prediction programs are widely used which can be grouped as statistical, empirical add numerical. Modern HF radio performance prediction programs calculate a signal power distribution as well as a noise power distribution as a function of geographic location, frequency, hour, month and sunspot number. The most widely used statistical methods are implemented in ITUs REC 533**,** Ionospheric Communication Analysis and Prediction Program; IONCAP, Voice of America's VOACAP and Ionospheric Communication Enhanced Profile Analysis and Circuit Prediction Program; ICEPAC [5] REC 533 stands for the coverage area prediction software developed by ITU (Recommendation No.533). Bradley et al [6] introduced that more accurate formulations for some of the component terms involved would be possible, given additional resources to carry out the necessary studies. And a simpler prediction approach could and should be devised that would give estimates no less accurate than those currently produced.

About the ICEPAC, Lane [7] introduced that ICEPAC is created for prediction of EM propagation in the low, mid and high-latitude and Polar Regions. The models used in ICEPAC are basically similar to those in IONCAP, but some modifications have been made to include some empirical and measurement corrections. ICEPAC uses Chapman layers for the E, F1 and F2 layers instead of the parabolic layers and also new coefficients recently approved by URSI are implemented. The Ionospheric Conductivity and Electron Density (ICED) profile model used by ICEPAC, is a statistical model of the large scale features of the northern hemisphere, namely, the sub auroral through, the equator-ward portion of the auroral zone, the pole-ward region of the auroral zone and the polar cap zone. Hereinafter Lane [7] also introduced that ICEPAC still seems to be in the development stage with some significant errors.

Gökhun et al [5] also introduced that VOACAP could simply be stated as the IONCAP working on the Windows and Unix/Linux environment. It is an internationally used computer-based program, which predicts the performance of HF propagation system by calculating HF propagation parameters at any location on the earth. VOACAP developer team [8] introduced that VOACAP computed detailed point to point and area coverage maps for many parameters such as: SNR; Reliability; Required power gain; Signal power; MUF; Takeoff/Arrival Angle, and more. Two methods of coverage maps in VOACAP: one transmitter to many receivers [VOAAREA], or many transmitters to one receiver [VOAAREA Inverse] for bi-directional circuit studies. Many researchers have been proving that VOACAP prediction is more accurate than others [5][6], on that account we predicted HF radio communication coverage in the system using the VOACAP.

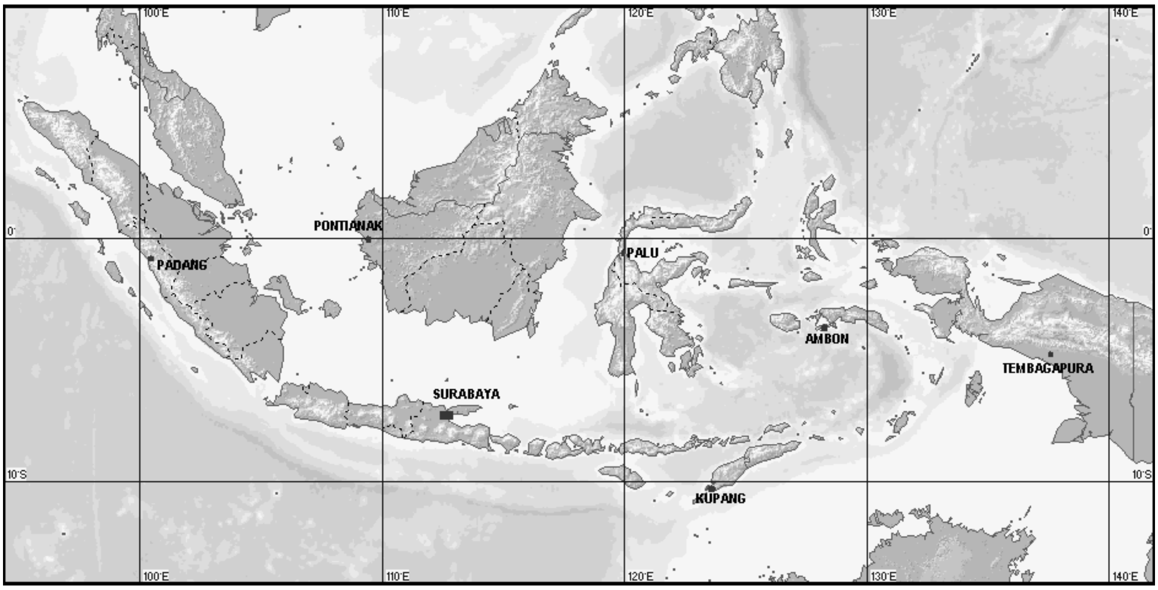

Figure 2 Indonesian Archipelago with alternatively HF center node area:
Padang, Pontianak, Palu, Ambon, Kupang and Tembagapura with national main control station in Surabaya.

3. NUMERICAL RESULT

We have chosen frequencies to use, namely: 4.2 MHz; 6.3 MHz; 8.4 MHz and 12.6 MHz. Propagation method is set to short/long method smoothing for all seasons: January, April, July and October 2008. Transmit and Receive Antenna for all nodes in system specified as Isotropic with +10dBi gain to simulate real-world gains without bias due to antenna type or height. System parameter is set to default: noise level is minus 145dBw/Hz, minimum take-off angle 0.1 degree, required circuit reliability 90%, and required S/N ratio (REQ.SNR) 73 dB. We calculated communication system point to point from each center node Tembagapura, Ambon, Kupang, Palu, Pontianak, and Padang to main control Surabaya. Performance of HF radio systems is dependent on the ratio of the wanted signal power at the receiver to the unwanted noise power. The unwanted noise is usually the composite of atmospheric, man-made and galactic radio noise. In some cases, the systems engineer may wish to include the presence of an interfering signal along with the noise power when making performance assessments.

To achieve the target of this research we use the result parameters of the program prediction:

a. Median signal power expected at the receiver input terminals, S dBw.
b. The SNR distribution which tells us what grade of service is to be expected over the days in the month on a given frequency at a given hour. The SNR indicates the dB-Hz value that can be maintained on 50% of the days (i.e. on 15 days) in the month.
c. MUFday is the fraction of the days in a month at that hour that the operating frequency is below the MUF for the most reliable mode.
d. The REL is related to the SNR and REQ.SNR, and is defined as a circuit reliability factor. It tells us the percentage of days in the month when the SNR value will equal to or exceed the REQ.SNR.

We tabulated the forth parameters on each evaluated seasons month's per each frequencies which have chosen, partly the tables is seen on Table 2. Based on VOACAP result table and coverage maps, we can observe that:

The most weak median signal power expected occurred in January 2008 03.00UTC at frequency 4.2 MHz between Surabaya and Tembagapura -396dBw and the best is -63dBw occurred at January 2008 22.00 UTC at 4.2 MHz between Surabaya and Pontianak. But from the average value of signal, frequency 12.6 MHz with -80dBw until -120dBw variation from all nodes to Surabaya is preferred to choose. See Figure 3 and 4. To clarify result of VOACAP table, that -103.1dBw of S is equal with 33.98dBuV, 50.000uV at 50 ohm input.

From SNR distribution we can see that variation between 25dB until 83dB which occurred in January 2008 at 12.6 MHz is better than all. The best of average MUFday variation occurred on October 2008 at 12.6 MHz. And the average circuit reliability on January 2008 at 12.6 MHz is better then another frequencies for all seasons. For the far site edge especially Tembagapura, about 2,100 kilometers distance to Surabaya, have more good average MUFday at 12.6, 8.4 and 6.3 MHz. This condition indicates that mode 1F2 is more effective another sites at these frequencies. The weak signal and lowest S/N ratio is occurred at near noon, and the best is occurred near midnight local time. There for the circuit reliability is decreased near zero at noon local time. From Figure 5: coverage area receiver maps at 12.6 MHz, we have the information that coverage area of each node as part of the disaster early warning system is possible to use. Minimum Signal to Noise median decile (dB) no less then 20 dB that is enough for data communication between each node to main control system. The best frequency which discussed here is included in the disaster band and possible to communication use with at least 300 bps data modem.

4. CONCLUSIONS

In order to implement point to point communication system, the attenuation, multi-path fading etc. observed during the propagation should be predicted. The HF wireless communication network between center nodes and main control system in disaster early warning system in Indonesia, to backup existing communication system is feasible to use. With modern digital communication system speed can be increase to reduce time delay during communication. The best and the second best frequencies to use are 12.6 MHz and 8.4 MHz, respectively except for certain far edge sites. The selected sites for center node regional divisions provide sufficiently good coverage, except for the far edge regions especially Tembagapura for which the best frequency might change with time

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Table 2. Characteristic Prediction of SNR, S, MUFday Probability and Circuit Reliability from or to Surabaya at 12.6 MHz January 2008.

	Surabaya S (dBW) 12.6MHz						Surabaya SNR (dB Hz) 12.6MHz						Surabaya MUFday Prob. 12.6MHz						Surabaya Cir Reliability 12.6MHz						
Time UTC	Tembagapura	Ambon	Kupang	Palu	Pontianak	Padang	Tembagapura	Ambon	Kupang	Palu	Pontianak	Padang	Tembagapura	Ambon	Kupang	Palu	Pontianak	Padang	Tembagapura	Ambon	Kupang	Palu	Pontianak	Padang	Local Time (WITA)
1	-103	-88	-81	-80	-84	-83	59	74	81	81	78	78	0.89	0.99	0.88	0.73	0.46	0.97	0.02	0.56	0.84	0.85	0.61	0.76	9
2	-109	-92	-84	-82	-85	-84	53	70	78	80	77	78	0.93	0.99	0.92	0.73	0.49	0.97	0	0.31	0.75	0.8	0.61	0.73	10
3	-116	-96	-89	-86	-86	-90	46	65	73	76	76	72	0.98	1	0.97	0.81	0.52	0.98	0	0.07	0.49	0.64	0.65	0.42	11
4	-119	-100	-93	-90	-87	-96	43	62	69	72	75	66	1	1	1	0.93	0.73	0.99	0	0.02	0.23	0.44	0.58	0.1	12
5	-116	-100	-93	-90	-88	-99	46	62	69	71	73	63	1	1	1	0.98	0.9	1	0	0.03	0.25	0.39	0.52	0.04	13
6	-108	-95	-89	-88	-86	-97	54	66	72	74	75	64	0.99	1	1	0.99	0.95	1	0	0.12	0.45	0.53	0.6	0.06	14
7	-97	-89	-85	-84	-83	-92	64	72	76	77	78	69	1	1	0.99	0.96	0.9	1	0.06	0.42	0.67	0.72	0.73	0.22	15
8	-91	-84	-81	-81	-80	-87	70	76	79	79	80	74	1	1	0.99	0.94	0.88	0.99	0.27	0.68	0.8	0.81	0.83	0.54	16
9	-87	-82	-79	-79	-79	-84	73	77	80	80	81	76	1	1	0.98	0.92	0.85	0.99	0.47	0.73	0.85	0.85	0.86	0.66	17
10	-85	-81	-78	-79	-78	-82	73	77	80	80	80	76	1	0.99	1	0.91	0.82	0.99	0.52	0.74	0.85	0.84	0.85	0.69	18
11	-84	-81	-78	-78	-78	-81	74	78	80	80	80	77	1	0.98	1	0.85	0.75	0.97	0.56	0.75	0.84	0.84	0.83	0.74	19
12	-84	-81	-79	-78	-78	-81	75	78	80	81	81	78	1	0.98	0.9	0.84	0.73	0.97	0.6	0.78	0.86	0.86	0.84	0.78	20
13	-84	-81	-79	-78	-78	-81	76	79	81	81	81	79	1	0.98	0.9	0.83	0.72	0.97	0.62	0.8	0.87	0.86	0.85	0.81	21
14	-84	-81	-79	-78	-78	-81	77	79	81	82	82	79	1	0.99	0.92	0.81	0.7	0.97	0.64	0.8	0.88	0.87	0.85	0.82	22
15	-84	-81	-79	-78	-79	-81	77	79	82	82	82	80	1	0.99	0.91	0.8	0.66	0.97	0.64	0.78	0.88	0.86	0.82	0.82	23
16	-84	-82	-79	-79	-80	-81	77	79	82	82	81	80	1	0.98	0.87	0.68	0.51	0.96	0.64	0.75	0.88	0.82	0.76	0.81	24
17	-85	-82	-79	-84	-85	-81	76	79	82	77	76	80	1	0.94	0.75	0.47	0.32	0.91	0.63	0.76	0.86	0.64	0.6	0.81	1
18	-86	-83	-81	-87	-89	-81	75	78	81	74	72	80	0.91	0.74	0.52	0.29	0.16	0.82	0.56	0.71	0.76	0.53	0.47	0.8	2
19	-88	-84	-85	-87	-87	-83	74	78	76	75	74	79	0.86	0.65	0.4	0.28	0.19	0.6	0.52	0.67	0.61	0.55	0.53	0.71	3
20	-88	-84	-87	-90	-91	-83	73	77	74	71	71	79	0.79	0.51	0.28	0.16	0.11	0.5	0.5	0.64	0.53	0.43	0.42	0.7	4
21	-89	-89	-89	-94	-96	-88	72	72	72	67	66	73	0.76	0.44	0.22	0.09	0.05	0.38	0.45	0.48	0.48	0.32	0.29	0.5	5
22	-90	-83	-107	-90	-96	-89	72	78	55	71	66	72	0.99	0.68	0.03	0.14	0.05	0.33	0.4	0.71	0.14	0.42	0.29	0.46	6
23	-91	-85	-80	-97	-136	-89	71	77	81	65	25	72	1	0.97	0.55	0.08	0	0.41	0.37	0.67	0.79	0.26	0.01	0.47	7
24	-95	-86	-81	-81	-92	-83	67	76	81	81	70	79	1	0.99	0.83	0.62	0.11	0.89	0.17	0.65	0.85	0.82	0.38	0.78	8

 ISSN: 1907-5022

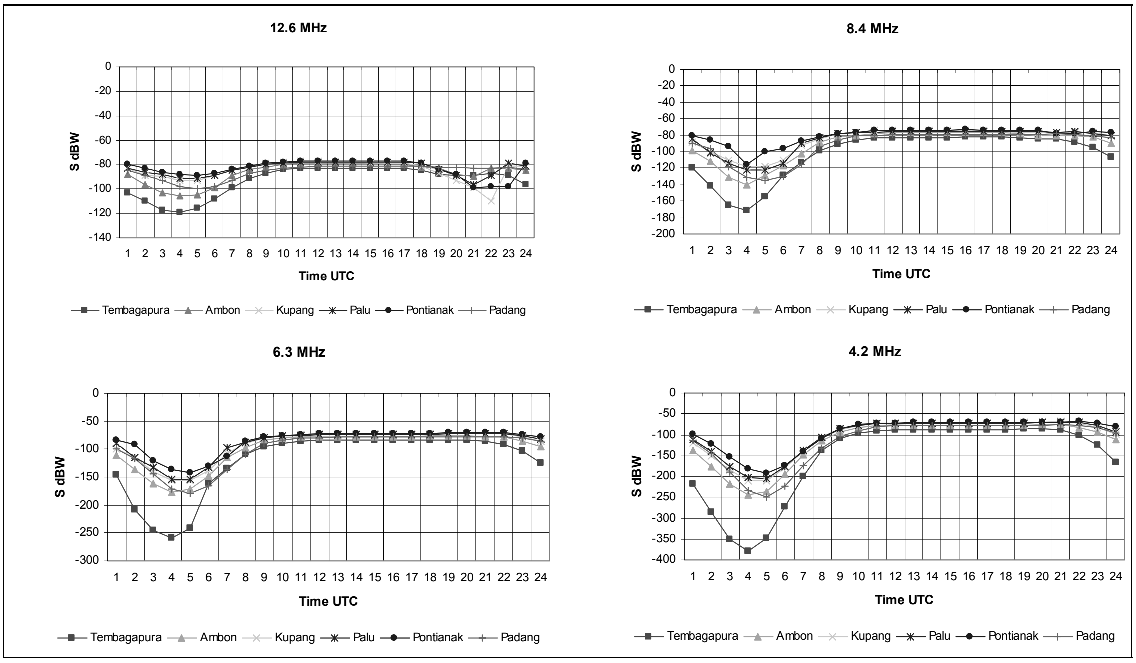

Figure 3. Daily Signal Characteristic Prediction from and to Surabaya on April 2008.

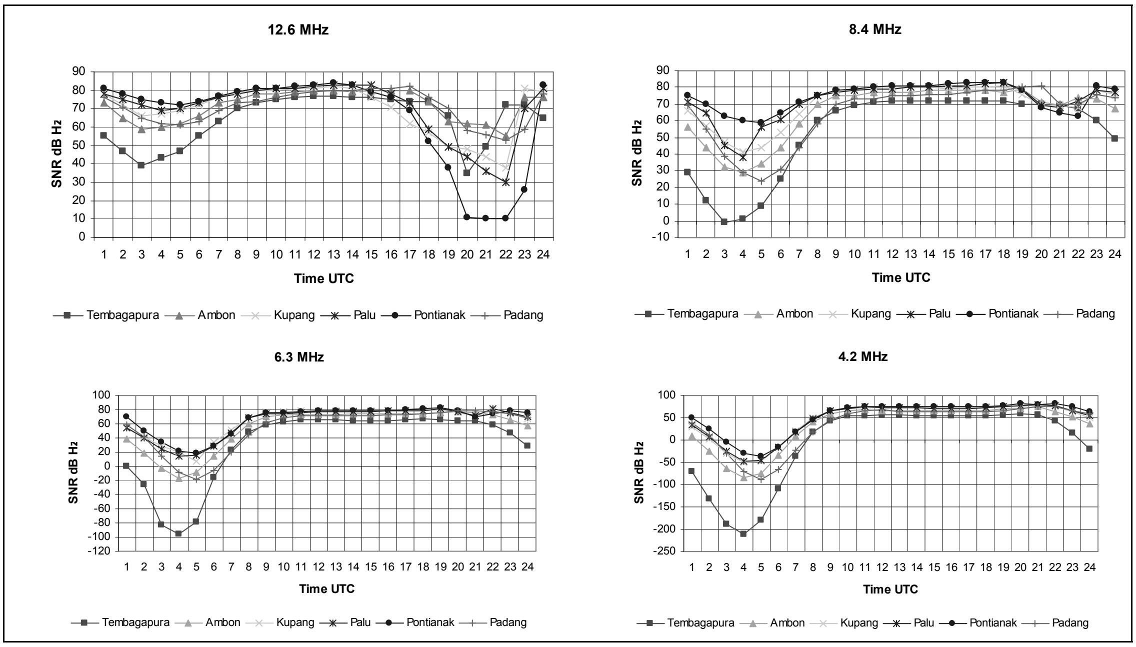

Figure 4. Daily Signal to Noise Ratio Characteristic Prediction from and to Surabaya on July 2008

ISSN: 1907-5022

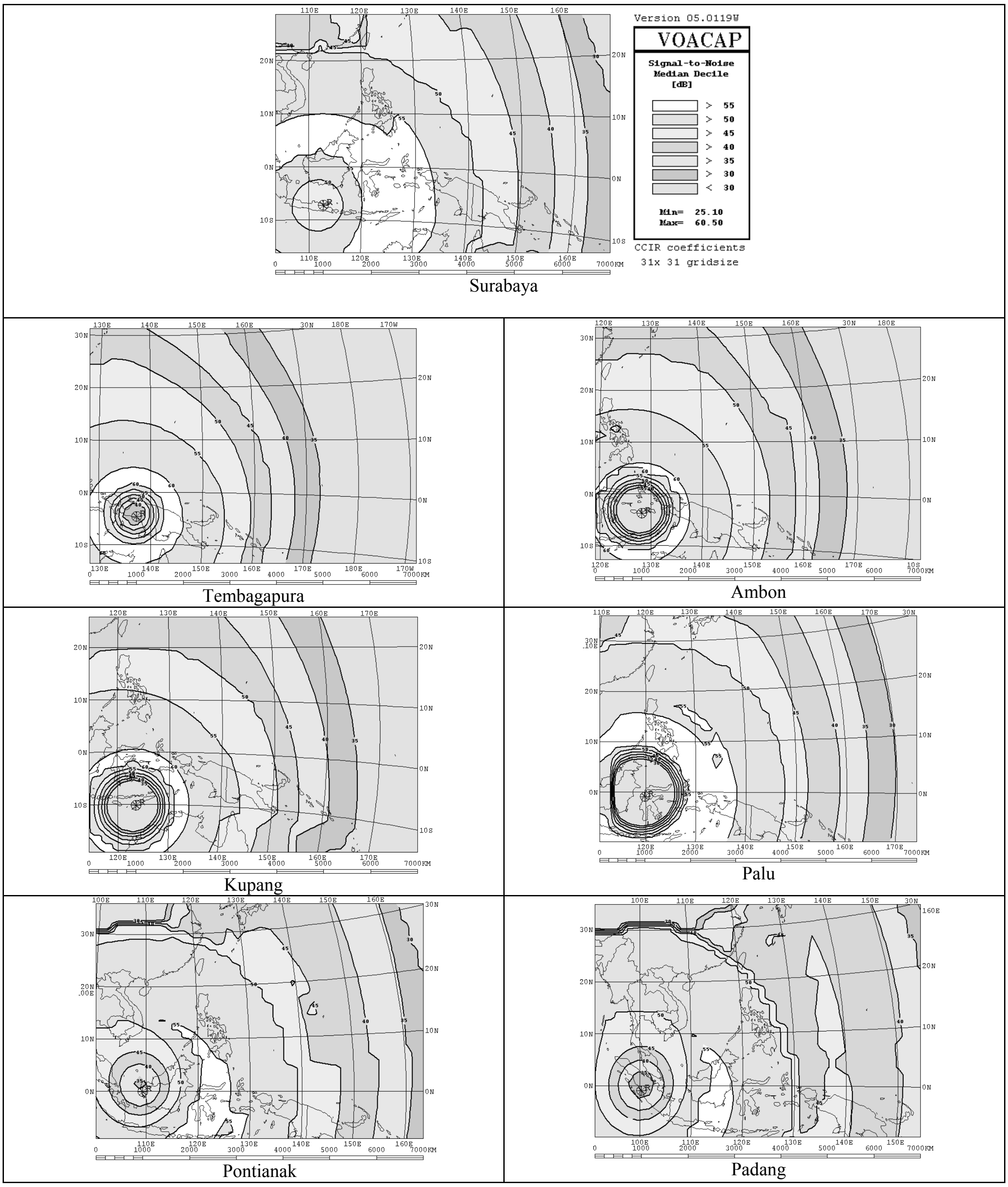

Figure 5. Coverage area receiver all node maps on October 2008 at 22.00UTC