International Telecommunication Union

ITU-R

Radiocommunication Sector of ITU

Report ITU-R SM.2270

(06/2013)

The radio source visualizing technology for spectrum monitoring

SM Series

Spectrum management

International Telecommunication Union

Foreword

The role of the Radiocommunication Sector is to ensure the rational, equitable, efficient and economical use of the radio-frequency spectrum by all radiocommunication services, including satellite services, and carry out studies without limit of frequency range on the basis of which Recommendations are adopted.

The regulatory and policy functions of the Radiocommunication Sector are performed by World and Regional Radiocommunication Conferences and Radiocommunication Assemblies supported by Study Groups.

Policy on Intellectual Property Right (IPR)

ITU-R policy on IPR is described in the Common Patent Policy for ITU-T/ITU-R/ISO/IEC referenced in Annex 1 of Resolution ITU-R 1. Forms to be used for the submission of patent statements and licensing declarations by patent holders are available from http://www.itu.int/ITU-R/go/patents/en where the Guidelines for Implementation of the Common Patent Policy for ITU-T/ITU-R/ISO/IEC and the ITU-R patent information database can also be found.

Series of ITU-R Reports

(Also available online at http://www.itu.int/publ/R-REP/en)

Series	Title
BO	Satellite delivery
BR	Recording for production, archival and play-out; film for television
BS	Broadcasting service (sound)
BT	Broadcasting service (television)
F	Fixed service
M	Mobile, radiodetermination, amateur and related satellite services
P	Radiowave propagation
RA	Radio astronomy
RS	Remote sensing systems
S	Fixed-satellite service
SA	Space applications and meteorology
SF	Frequency sharing and coordination between fixed-satellite and fixed service systems
SM	**Spectrum management**

***Note**: This ITU-R Report was approved in English by the Study Group under the procedure detailed in Resolution ITU-R 1.*

Electronic Publication
Geneva, 2013

REPORT ITU-R SM.2270

The radio source visualizing technology for spectrum monitoring

(2013)

1 Introduction

1.1 Background

With the progress of wireless communication technology in recent years, more and more people are using wireless communication systems. In addition, radio waves are being used in an increasing variety of general electronic products. As a result, the number of interference cases is rising due to such increase in radio use and associated frequency shortage.

In particular, more cases of interference in the higher frequency ranges are being reported in recent years. Moreover, because communication devices are becoming more and more sophisticated in sensitivity, even an interference source with a small transmitter power could greatly affect the surrounding devices.

In the conventional estimation scheme of radio source position using the angle of arrival (AOA) method, the position on the two-dimensional map of the radio source can be detected, however the position of the height cannot be calculated.

Therefore, in the area of the estimated point of the emitted radio source, it was necessary to identify the position of the radio source using the portable direction finding system.

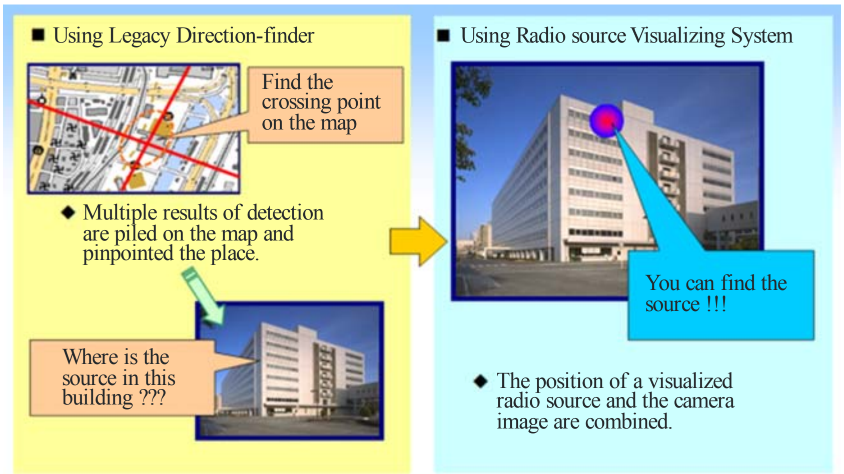
The radio source visualizing technology (RAVIT) can visually pinpoint the location of the emission source over a short distance and therefore it is very useful in the final phase of identifying the exact emission source after the estimated source area has been detected by the legacy direction finding system.

This Report introduces the example of application to actual spectrum monitoring activities while introducing the outline, the principle, and the basic performance of RAVIT, and it has proposed the application example towards future spectrum monitoring.

The feature of RAVIT is shown in Fig. 1.

FIGURE 1

Feature of RAVIT



Report SM.2270-01

1.2 Principle of visualization

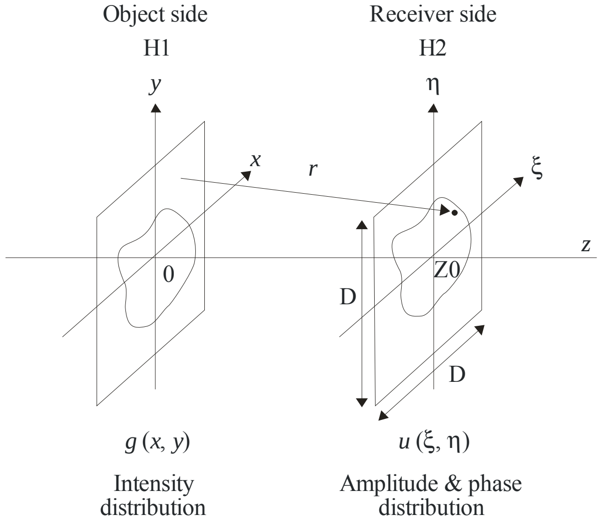
The principle and basic equation of a radio holography method which is used in RAVIT are shown in Fig. 2.

In Fig. 2, there is an intensity transmittance distribution: $g(x, y)$ on the Object Side H1. When the two-dimensional electric wave (wavelength: λ) is emitted in vertically, in the Receiver Side H2 which is separated distance Z0 from the H1, the diffraction pattern u (ξ, η) occurs in H2.

This is denoted by form (1) of Fresnel Kirchhoff's diffraction integration.

FIGURE 2

Principle of radio-holography method



Report SM.2270-02

$$u(\xi,\eta)=\frac{j}{\lambda}\iint g(x,y)\frac{\exp(-jkr)}{r}\,dxdy \tag{1}$$

The basic equation of Fresnel Kirchhoff's diffraction integration

$$r=\sqrt{{z_0}^2+(\xi-x)^2+(\eta-y)^2} \tag{2}$$

When the distance between Object Side H1 and the Receiver Side H2 is set to far-field conditions, and satisfies Fraunhofer conditions, formula (1) can be transformed as shown below.

In formula (3), the amplitude and the phase distribution $u(\xi, \eta)$ in the Receiver Side H2 is described by the two-dimensional inverse Fourier-transform type of the intensity distribution of a radio source side.

$$u(\xi,\eta)=\frac{j}{\lambda\cdot z_0}\exp(-jkz_0)\exp\left(-jk\frac{\xi^2+\eta^2}{2z_0}\right)\iint g(x,y)\exp\left\{j\frac{2\pi}{\lambda\cdot z_0}(\xi\cdot x+\eta\cdot y)\right\}dxdy$$

$$=const\cdot Fourier2^{-1}[g(x,y)] \tag{3}$$

where:

– *const* is a constant

– Fourier2[…] is the two-dimensional Fourier-transform.

The signal intensity distribution $g(x, y)$ of Object Side which is needed with RAVIT is described by Fourier-transforming of the formula shown in (4).

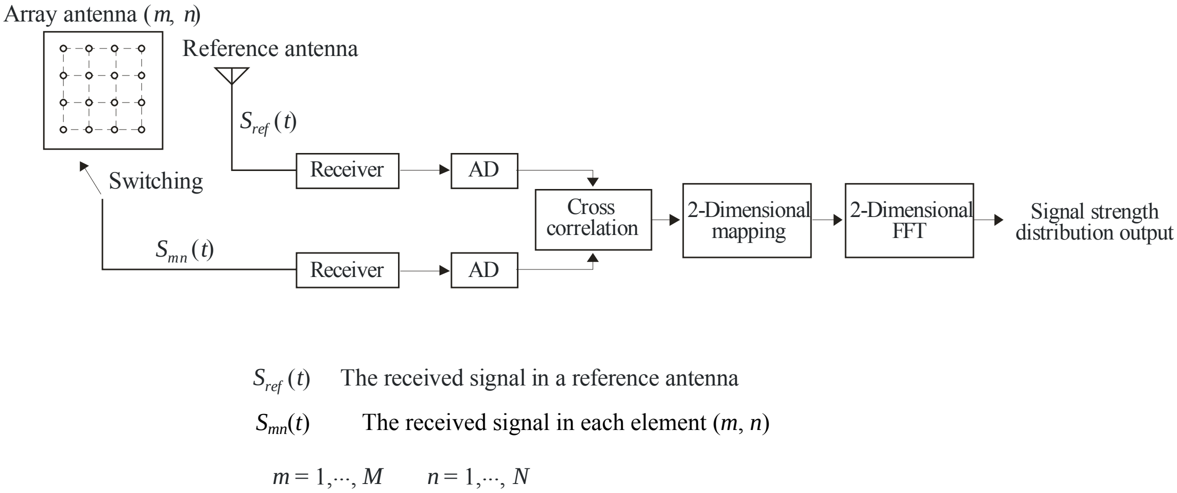
$$g(x,y)=const\cdot Fourier2[u(\xi,\eta)] \tag{4}$$

In the actual system, in order to get the amplitude and phase distribution of a receiving side, the cross-correlation of the received data from each array antenna elements and a reference antenna element is acquired.

The amplitude and the phase distribution $u(\xi, \eta)$ at a receiving side are computed by mapping in the shape of a two-dimensional plane. The image of signal intensity distribution of the emitted radio wave can be outputted by carrying out a two-dimensional FFT of this result. The numerical computation by digital signal processing is performing these processes using the algorithm shown in Fig. 3.

FIGURE 3

Signal-processing algorithm

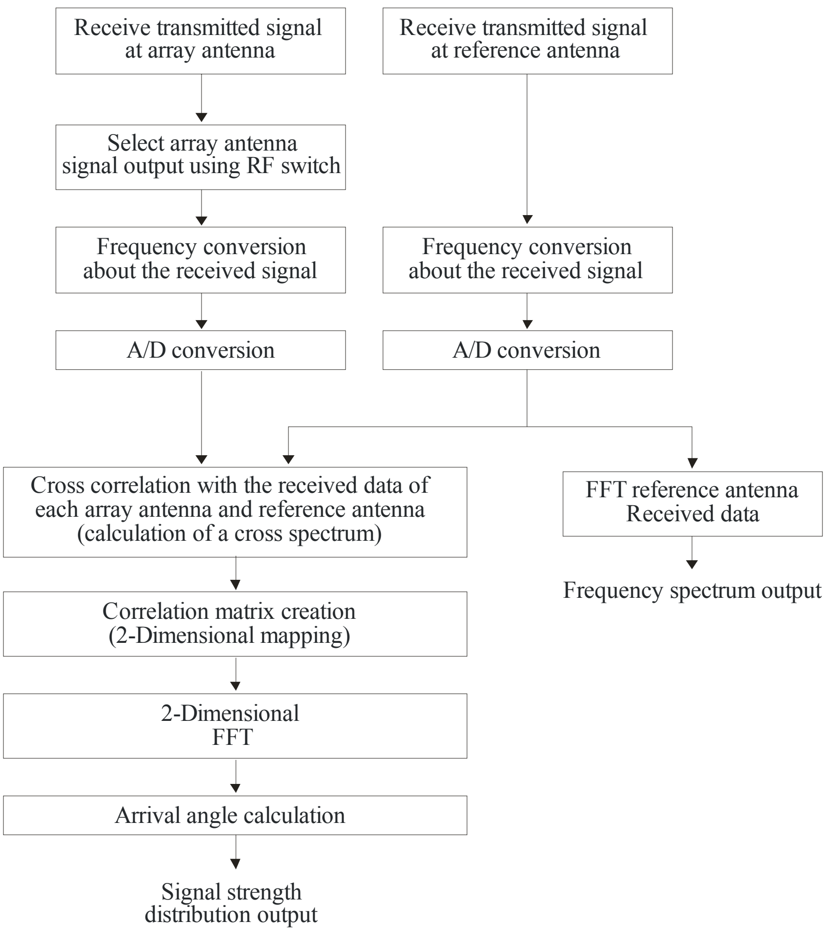


Report SM.2270-03

The flow of signal processing is shown in Fig. 4.

FIGURE 4

Signal processing flow



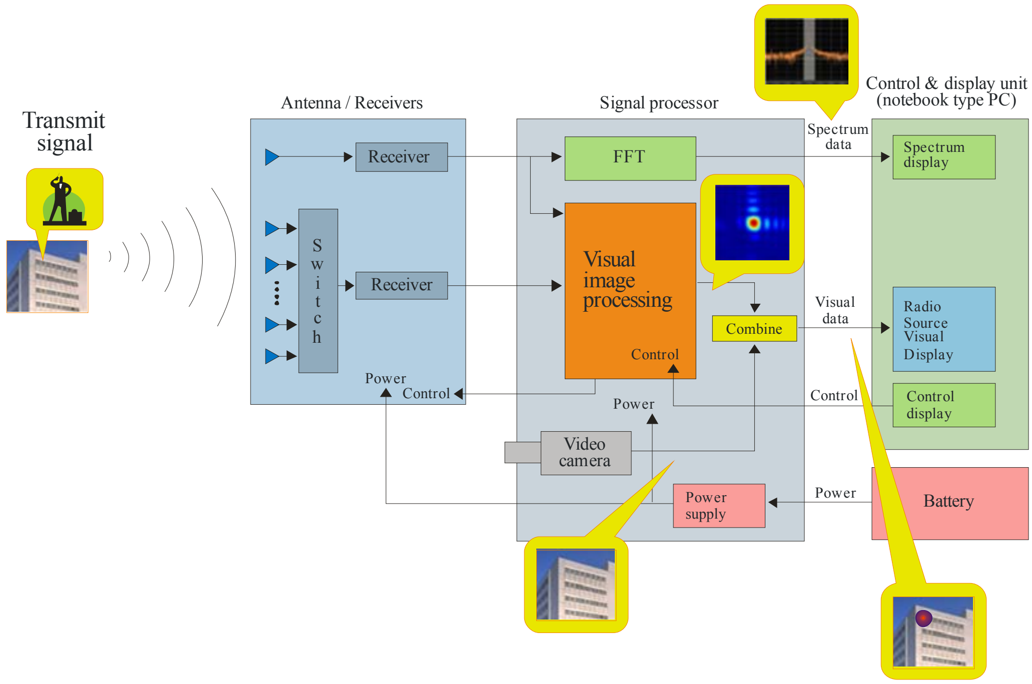
Report SM.2270-04

1.3 The functional diagram in systematization

The example of the functional diagram for applying RAVIT toward the actual system is shown in Fig. 5.

FIGURE 5

Functional diagram of RAVIT system



Report SM.2270-05

In this diagram, the transmitted signal from the emitted radio source is received with a reference signal antenna and some array antenna elements. The received signal from each of the antenna elements is converted to IF (intermediate frequency) signal in antenna/receiver module, and digitized by A/D converters.

The receiver frequency range is UHF to C-Band, and covered by three antenna/receiver modules.

In the processor module, digitized signals are outputted as a frequency spectrum signal and a signal intensity distribution image by the signal-processing flow shown in Fig. 4. By combining this signal strength distribution image with the video camera image, a visualization image is generated and it is displayed on a monitor with a spectrum signal.

2 The basic performance evaluation in the radio anechoic chamber

2.1 Examination contents

In order to evaluate the basic performance of the system using RAVIT, the position accuracy performance to received signal level and the space separation performance about evaluation of two transmitted signals arrival are evaluated in the radio anechoic chamber.

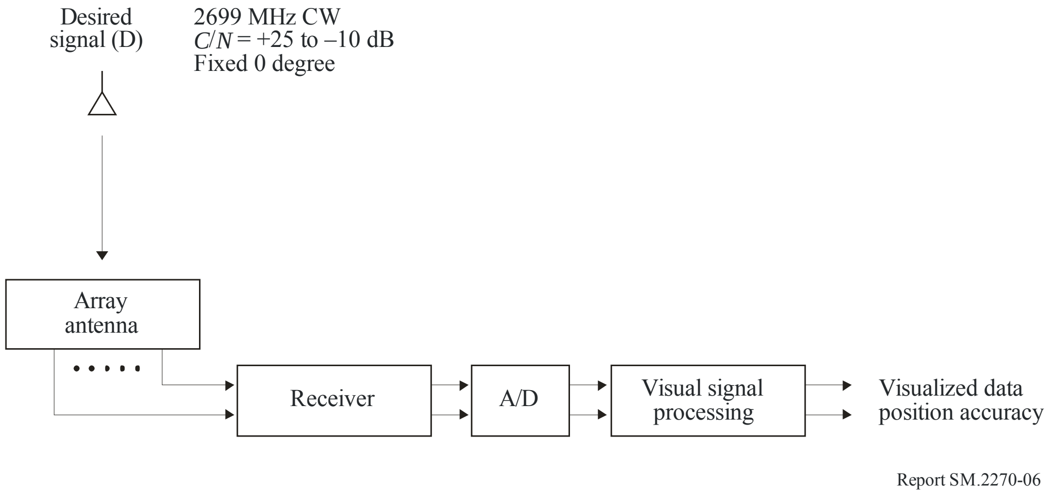
Evaluation of a positioning accuracy to receiving input level is as follows:

A visualization display situation and positioning accuracy are measured where the *C*/*N* ratio of the receiving signal is varied from +25 dB to –10 dB.

The schematic diagram of the evaluation test circuit is shown in Fig. 6.

FIGURE 6

Schematic diagram of the evaluation test circuit
(Positioning accuracy to receiving input level)



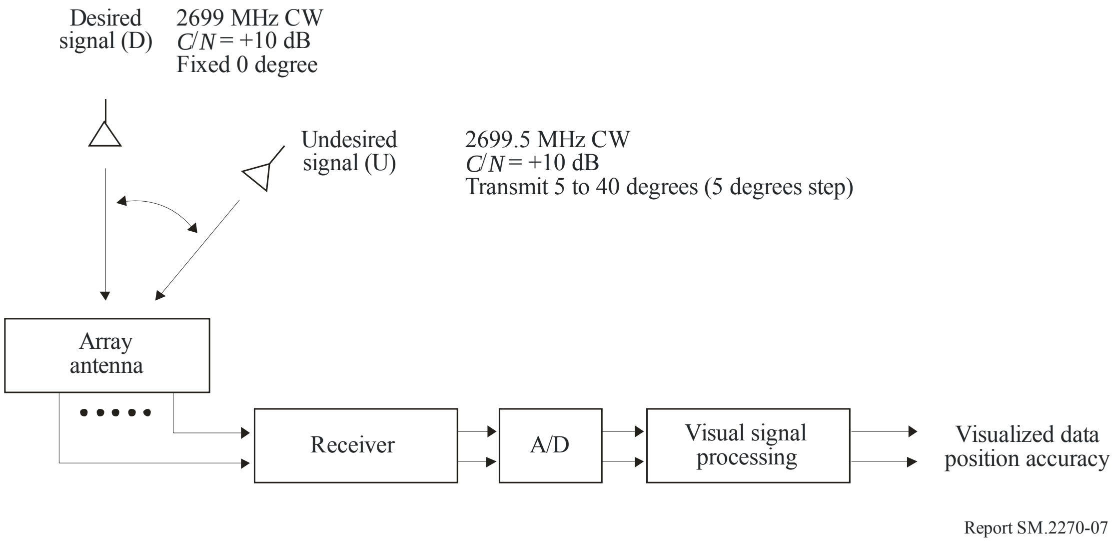
Evaluation of the spatial resolution at the multiple radio signals arrival is as follows:

Two transmitted signals input into test equipment as a test signal, and the arrival direction of one of the two signals is changed from 5 degrees to 40 degrees, and measured visualized data of the display outputs at each of the given arriving angles.

The schematic diagram of the evaluation test circuit is shown in Fig. 7.

FIGURE 7

Schematic diagram of the evaluation test circuit
(Spatial resolution at two signals arrival)



2.2 Test result in anechoic chamber

Figure 8 shows the measurement results of the positioning accuracy to receiving signal level of the RAVIT system. Under the condition of low level signal input, positioning accuracy is degraded owing to the effect of receiver's thermal noise.

The specification of system positioning accuracy is 6 degrees rms. The receiving *C*/*N* level which satisfied the specification is –4 dB.

Figure 9 shows the display result at each input level of receiver. In Fig. 9, the red points are the results of measured position, and the yellow points are the position of the transmitter antenna.

FIGURE 8

Positioning accuracy vs received signal level

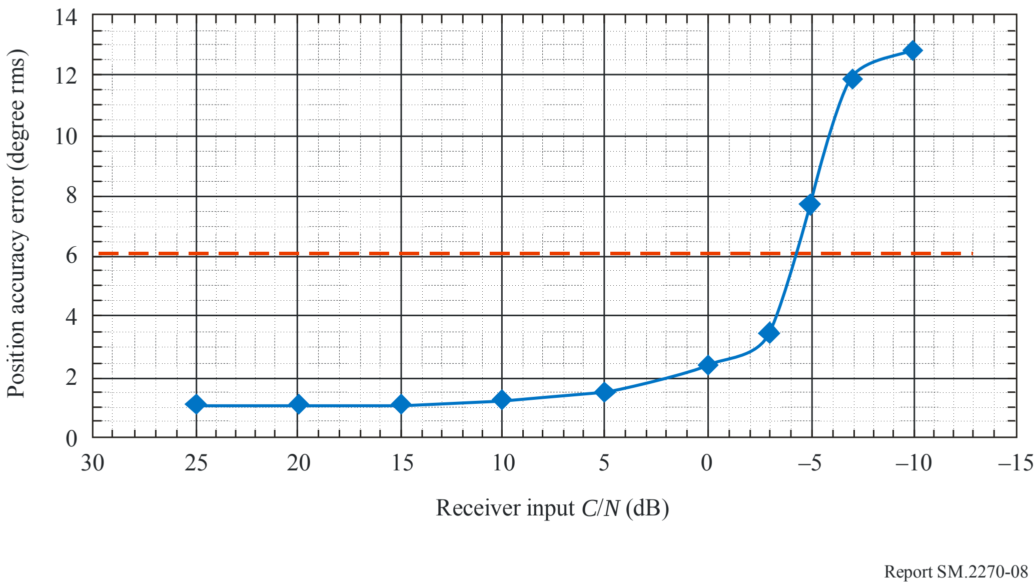
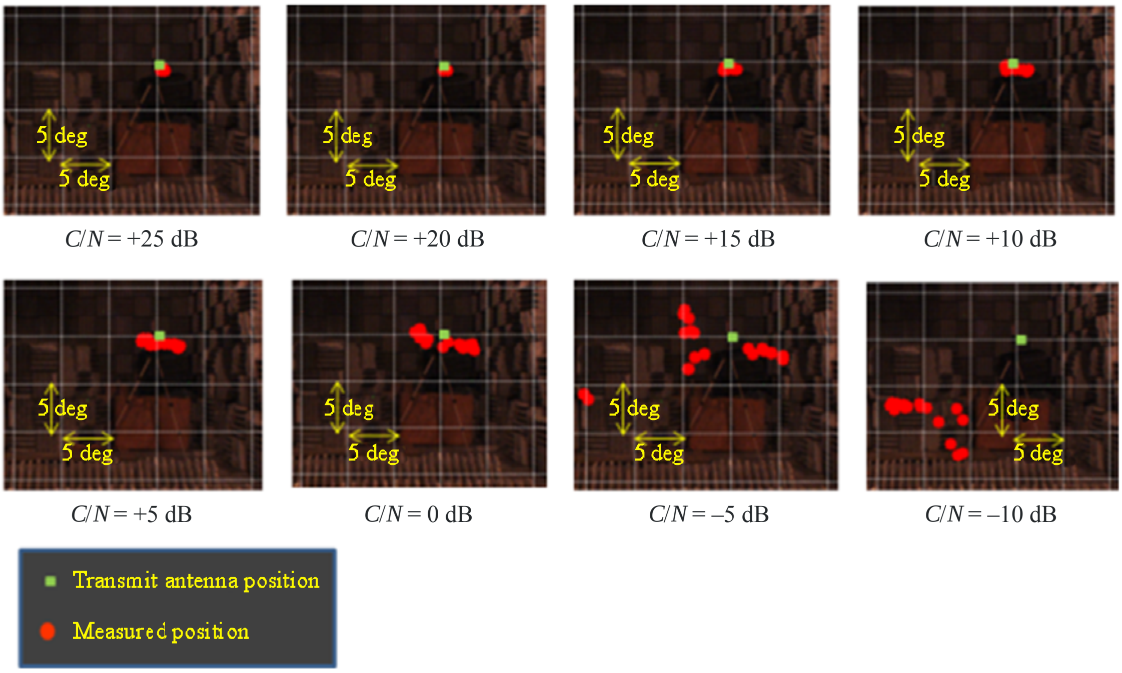


FIGURE 9

Result of positioning accuracy by the RAVIT system



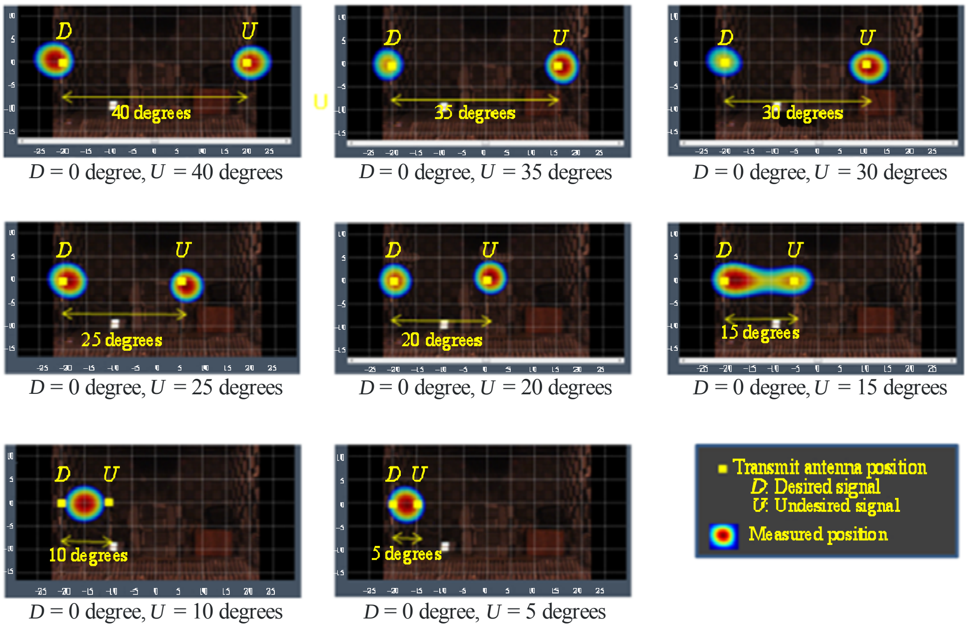
Report SM.2270-09

The results of measured space separation performance with two transmitted signal arrivals are shown in Fig. 10. In Fig. 10, the red points are the results of RAVIT processing results, and the yellow points are positions of two transmitter antennas.

When the difference angle of two incidence signals are set between 40 degrees and 15 degrees, the RAVIT system can separate two transmitted signals. However, when the difference angle of two signals are set between 10 degrees and 5 degrees, the two transmitted signals cannot be separated, so the visualized image of the emitted radio source is displayed at the centre position of the two transmitted antennas as one radio source.

FIGURE 10

Result of measurement of spatial separation at the multiple (two) signals arrival



Report SM.2270-10

3 Evaluation in field space

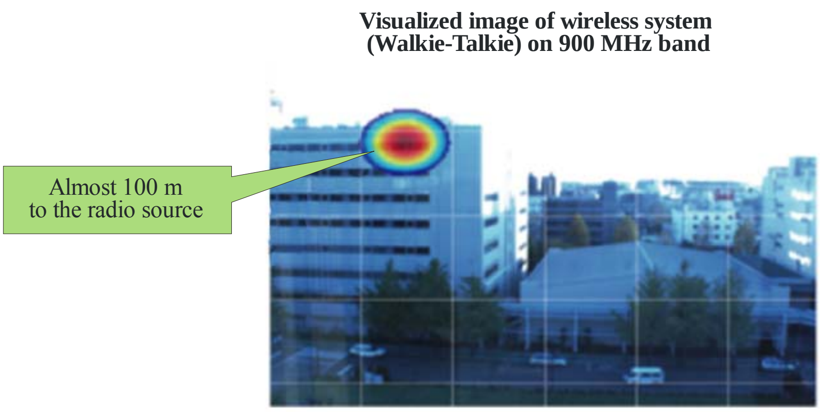
3.1 Detection of a wireless system (Walkie-Talkie)

Figure 11 shows a case example of how the location of a personal wireless system (Walkie-Talkie) was detected from a distance of nearly 100 m. This personal wireless system was emitting radio waves at 900 MHz.

This figure shows how RAVIT is capable of identifying not only the building but even the floor on which the emission source was located.

FIGURE 11

Example of visualized image: portable Walkie-Talkie



Report SM.2270-11

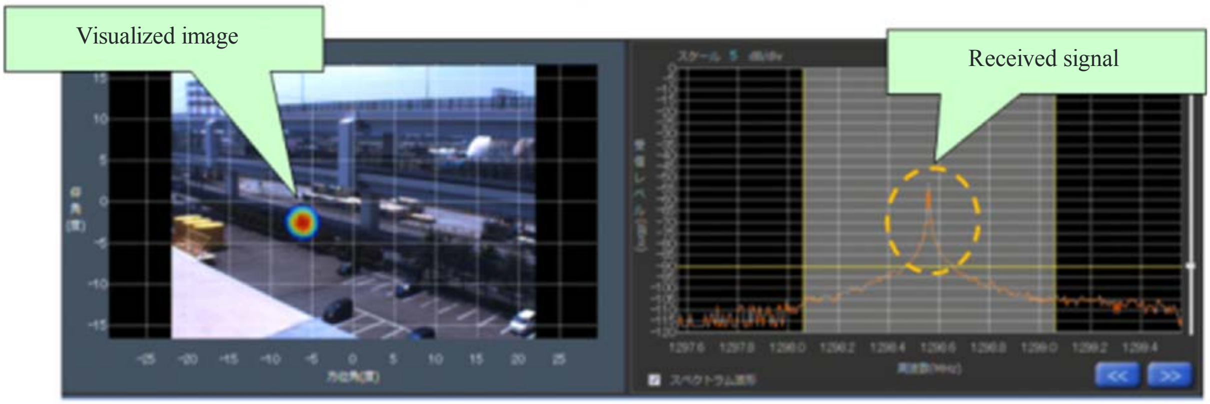
3.2 Detection of a wireless system (amateur radio)

Figure 12 shows a case example of how emissions from a car-mounted amateur radio was visualized. In this case, the target was relatively close to the monitoring point, so the radio wave emitted from the amateur radio could be clearly distinguished.

FIGURE 12

Example of visualized image: car-mounted Walkie-Talkie

Visualized image of wireless system (amateur radio) on 1200 MHz band



Report SM.2270-12

3.3 Detection of an illegal repeater station of a cellular phone system

Figure 13 shows a case example of how an illegal repeater station in the downtown area was detected. This repeater (circled in yellow) is illegally installed, and may cause interference to nearby cellular phone base stations.

FIGURE 13

Detection of an illegal repeater located in downtown

Searching for a illegal repeater of a cellular phone system

Report SM.2270-13

4 Application in the future

4.1 Detection of the pulse signal (radar wave)

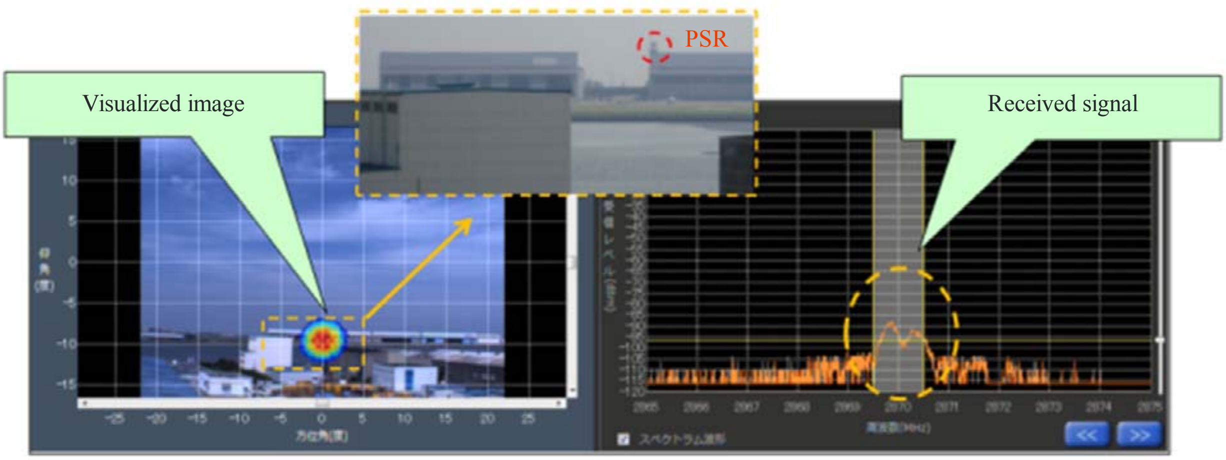
RAVIT can also detect the pulse radio waves. Therefore, using RAVIT is expected to be useful in detecting interferences with communication systems in the high frequency ranges above 3 GHz.

Figure 14 shows an example of a visualized image of waves transmitted from the primary surveillance radar (PSR) system of Haneda Airport in Tokyo. In this case, the RAVIT-mounted equipment is set on a roof of a building 2 km away from the airport to monitor the pulse waves of the PSR.

FIGURE 14

Example of visualized image (Primary Surveillance Radar)

Visualized image of radar system (PSR) on 2.7 GHz band



Report SM.2270-14

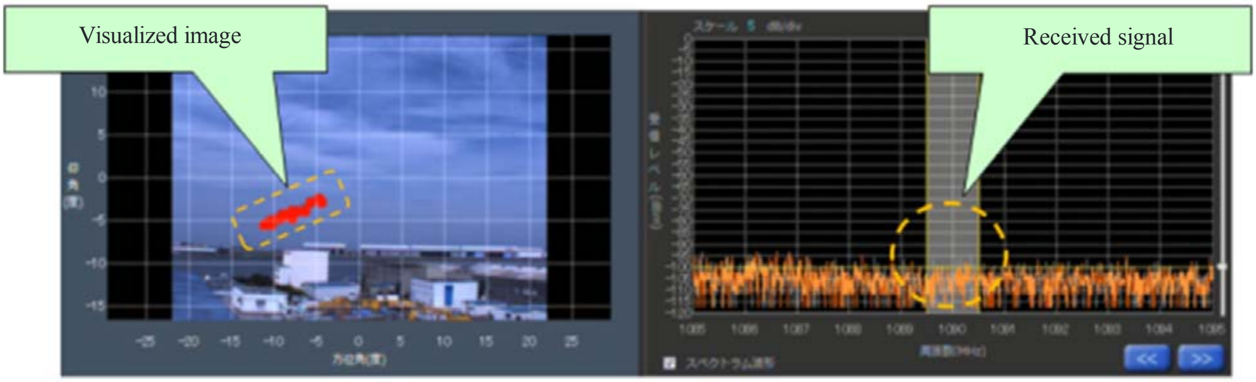
Figure 15 shows an example of a visualized image of transponder waves from an airplane.

In this case, an airplane taking off is emitting waves from its transponder to the secondary surveillance radar (SSR) system.

FIGURE 15

Example of visualized image (transponder waves sent to SSR system from an airplane)

Visualized image of radar system (SSR) on 1090 MHz



Report SM.2270-15

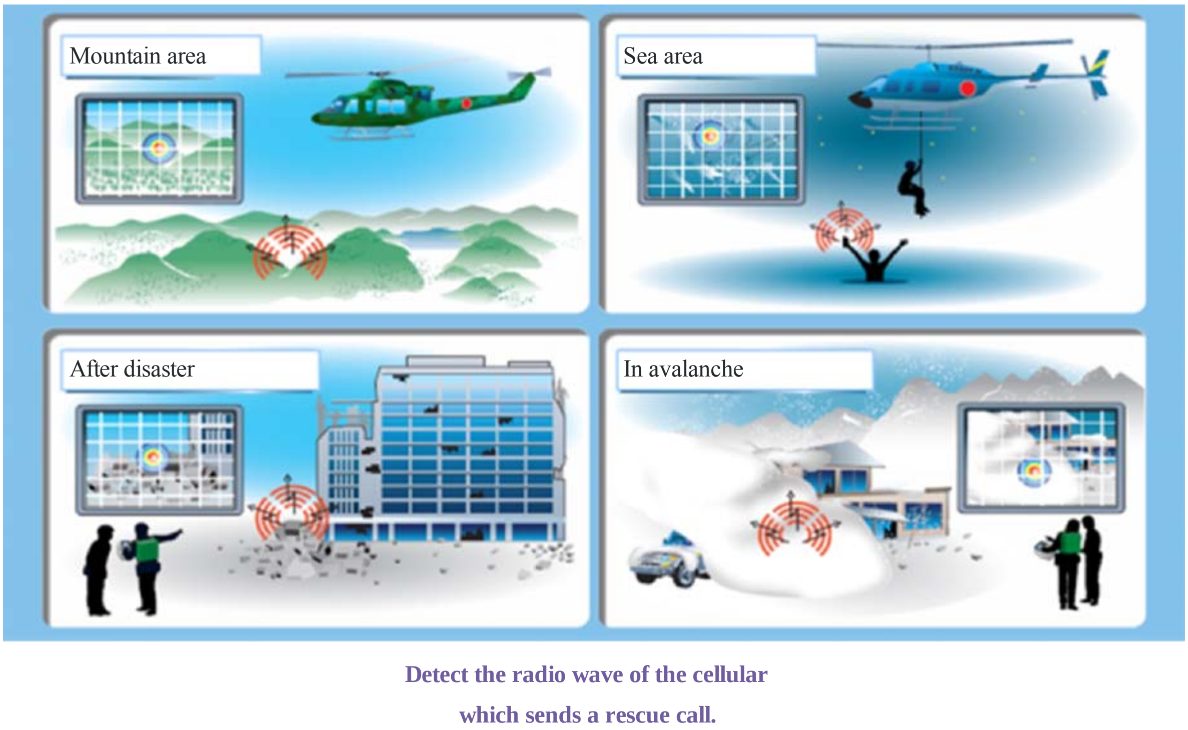
4.2 Application to future search and rescue missions

RAVIT is able to visualize radio signals from small transmitters such as cellular phones, so it is expected to be useful for applications in future search and rescue missions.

Figure 16 shows images of application to future search and rescue missions.

FIGURE 16

Images of application to future search and rescue missions



Report SM.2270-16

5 Conclusion

In recent years, the number of interference cases is rising due to such increase in radio source use and associated frequency shortage.

RAVIT has the ability to visualize and measure the exact location of the emission source, so it is effective in identifying the interference sources quickly.

Also, it can be applied in scenes such as search and rescue missions in the future.

____