International Telecommunication Union

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Use and examples of systems in the fixed-satellite service in the event of natural disasters and similar emergencies for warning and relief operations

S Series
Fixed satellite service

International Telecommunication Union

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REPORT ITU-R S.2151-1

Use and examples of systems in the fixed-satellite service in the event of natural disasters and similar emergencies for warning and relief operations

(2009-2012)

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1 Introduction

This Report describes how fixed-satellite service (FSS) systems can provide disaster relief radiocommunications.

When developing a new FSS system in preparation to respond to natural disasters, the technical characteristics of the satellite(s) to be accessed should be considered in the design of such FSS system. In § 2 of this Report, the summary of system design and examples of characteristics of systems using small aperture earth stations are provided. Additionally, since FSS systems are inherently suitable for data delivery, they are expected to be utilized for warning operations. In § 3 of this Report, the outline of an earthquake early warning system is provided as an example of warning operations using FSS system.

FSS systems operate in general on frequency bands as identified in Recommendation ITU-R S.1001.

2 The use of small aperture earth stations for relief operation in the event of natural disasters and similar emergencies

2.1 Introduction

In the event of natural disasters, epidemics and famines, etc., there is an urgent need for a reliable telecommunication link for use in relief operations. Satellite appears as the most appropriate means to quickly set up a telecommunication link with remote facilities. The main requirements of such a satellite system are discussed here. Assuming the system is to operate in the FSS, it is desirable that a small earth station, such as a fixed VSAT, a vehicle-mounted earth station or a transportable earth station, with access to an existing satellite system, should be available for transportation to, and installation at, the disaster area. It is also desirable that the system relies on widespread standards so that:

– equipment is readily available;

– interoperability is ensured;

– reliability is ensured.

This § 2 provides material that may be useful in planning the use of systems in the FSS in the event of natural disasters and similar emergencies for warning and relief operations.

2.2 Basic considerations

2.2.1 Required services

The basic telecommunication architecture for relief operations should be composed of a link connecting the disaster area with designated relief centres, and its basic telecommunication services should comprise at least telephony, any kind of data (IP, datagrams, facsimile, ...), video. For such transmission, digital transmission technologies are employed in most cases.

2.2.2 Channel and physical layer requirements

In digital transmissions, one means to measure the performance of the coded channel is the bit error probability (BEP). The recommended objective BEP in the FSS provided in Recommendation ITU-R S.1062 is 10^{-6} for 99.8% of time in the worst month. This BEP results both from the signal-to-noise and interference ratio (SNIR), which is the performance of the channel, and from the coding. Appropriate coding can compensate, to a certain extent, for poor channel quality but lowers the useful bit rate.

The particular conditions of transmission in the place of a disaster in case of both warning and relief operation (e.g. climate of site, nature of mission, …), which might degrade the channel quality, should be taken into account by reinforcing coding. The ideal would be to have adaptive coding, i.e. a system able to get back information from the channel and to respond by adapting the coding rate.

2.2.3 Network requirements

For relief operations, due to the essential requirement of having small antennas, it is preferable to operate the network in the 14/12 GHz band or even in the 30/20 GHz band. Although the bands such as 6/4 GHz require larger antennas, they are also suitable depending on conditions of transmission and coverage of satellite resources. In order to avoid interference, it should be taken into account that some bands are shared with terrestrial services.

The network should offer suitable quality of service. In case the network is shared with customers having non-urgent needs, the emergency operations should have absolute priority which means a "pre-emption" class of service. A fully private network, with reserved frequency bands and facilities, could be desirable.

When the number of operational earth stations is large, a network control based on demand assignment multiple access (DAMA) may be necessary.

2.2.4 Associated earth station

For (a) small earth station(s) on site, a vehicle-mounted earth station or a transportable earth station should be considered. The material provided in § 2.3 to § 2.6 may be useful for sizing of such earth stations.

For the smooth operation of earth stations in the event of a disaster, regular training for potential operators and preparatory maintenance of the equipment is essential. Particularly, special attention should be given to the inclusion of autonomous battery or power systems.

2.3 Required earth station e.i.r.p. levels and satellite resources

In § 2, required earth station e.i.r.p. levels and satellite resources are studied by link budget calculations based on the assumption that a small earth station (a fixed VSAT, a vehicle-mounted earth station or a transportable earth station) operating in the disaster area communicates with a hub earth station equipped with a larger antenna.

The choice of system parameters should be based on considerations listed in § 2.3 for the 6/4 GHz band, the 14/12 GHz and the 30/20 GHz band. The system parameters are listed in Table 1a) to 1f).

QPSK with rate 1/2 convolutional code, 3/4 convolutional code, 1/2 convolutional code + 188/204 Reed Solomon outer code and 1/2 turbo code are typical digital modulation and FEC methods commonly used for FSS satellite links. It is worth stressing that the combination of a convolutional code as the inner code with a Reed-Solomon code as the outer code is now rendered obsolete by turbo coding or low density parity check (LDPC) coding which performs better in general; the former coding scheme is surviving as a past legacy.

The antenna diameter of a small earth station (vehicle-mounted or transportable) is assumed to be 2.5 m or 5 m for the 6/4 GHz band and 1.2 m or 3 m for the 14/12 GHz band and 1.2 m or 2.4 m for the 30/20 GHz band in this example of the link budget calculation. For 14/12 GHz and 30/20 GHz stations, smaller diameter antennas may be used if appropriate measures, such as satellites with greater *G*/*T* or spread spectrum techniques are used to allow reduction of the off-axis emissions to acceptable levels.

In the 4 GHz band, a typical *G*/*T* of an earth station is 17.5 dB/K and 23.5 dB/K for the 2.5 m and 5 m antenna, respectively. In the 12 GHz band, a typical *G*/*T* of an earth station is 20.8 dB/K and 28.8 dB/K for the 1.2 m and 3 m antenna, respectively. In the 20 GHz band, a typical *G*/*T* of an earth station is 25.1 dB/K and 31.1 dB/K for the 1.2 m and 2.4 m antenna, respectively. The noise temperature of low noise amplifier is assumed to be 60 K, 100 K and 140 K for the 4 GHz band, the 12 GHz band and the 20 GHz band, respectively. Although small aperture antennas such as 45 cm, 75 cm, etc., can be used, Radio Regulations (RR) including the off-axis limitation should be considered when using those antennas. The use of small antennas may not allow meeting the off-axis emission criteria, therefore, the earth station transmit power should be reduced in order to avoid the interference to adjacent satellites and other services.

It should be noted that values of satellite e.i.r.p. and earth station e.i.r.p. are for a small earth station with antenna elevation 10° and 2 dB of the total margin.

In Table 1f), typical satellite parameters for global beams in the 6/4 GHz band, spot beams in the 14/12 GHz band and the 30/20 GHz band are provided. The "transponder gain #a" and "transponder gain #b" in Table 1f), are defined as shown in Fig. 1.

TABLE 1

Typical satellite, earth station, carrier parameter for calculation

a) Distance to GSO satellite

Elevation (degrees)	10
Distance (km)	40 600

b) Path loss (EL = 10°)

Frequency (GHz)	6/4		14/12		30/20	
	4.0	6.2	12.25	14.25	20.0	30.0
Wavelength (m)	0.08	0.05	0.02	0.02	0.02	0.01
Path loss (dB)	196.7	200.5	206.4	207.7	210.6	214.2

c) Transmission channel parameter

Modulation FEC	**QPSK 1/2 Conv.**[(1)]	**QPSK 3/4 Conv.**[(1)]	**QPSK 1/2 Conv.**[(1)]	**QPSK 1/2 turbo coding**	**8-PSK 2/3**
BER	10^{-6}	10^{-6}	10^{-6}	10^{-6}	10^{-6}
Required E_b/N_0 (dB)	6.1	7.6	4.4	3.1	9.0
FEC rate	0.5	0.75	0.5	0.5	0.67
Outer code rate	1.0	1.0	188/204	1.0	1.0
Number of bits in a symbol	2	2	2	2	3
Required C/N (dB)	6.1	9.4	4.0	3.1	12.0

(1) Constraint length k = 7.

d) Earth station antenna gain and G/T

Frequency band (GHz)	6/4				14/12				30/20			
Antenna diameter	2.5 m		5.0 m		1.2 m		3.0 m		1.2 m		2.4 m	
Frequency (GHz)	4.0	6.2	4.0	6.2	12.25	14.25	12.25	14.25	20.0	30.0	20.0	30.0
Efficiency	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Antenna gain (dBi) peak	38.2	42.0	44.2	48.0	41.5	42.8	49.5	50.8	45.8	49.3	51.8	55.3
G/T (dB/K)	17.5		23.5		20.8		28.8		25.1		31.1	

e) HUB earth station antenna gain and G/T

Frequency (GHz)	6/4		14/12		30/20	
	4.0	6.2	12.25	14.25	20.0	30.0
Antenna gain (dBi)	55.7	59.5	57.9	59.5	58.0	61.8
HUB earth station G/T (dB/K)	35.0		35.0		35.0	
HUB earth station antenna size (m)	18 m		7.6 m		4.7 m	

f) The satellite transponder gain

Satellite (GHz)	6/4	14/12	30/20
Frequency band (GHz)	6/4	14/12	30/20
Wavelength (m)	0.05	0.02	0.01
Beam type	GLOBAL	SPOT	Multi
Satellite receive *G*/*T* (dB/K)	−13.0	2.5	11.0
Transponder saturation e.i.r.p. for single carrier (dBW)	29.0	45.8	54.5
SFD (dB(W/m^2))	−78.0	−83.0	−98.4
IBO-OBO (dB)	1.8	0.9	5.0
Gs (dB)	37.3	44.5	51.0
Transponder gain #a (dB)	146.1	174.2	200.2
Transponder gain #b (dB)	−55.3	−33.5	−14.0

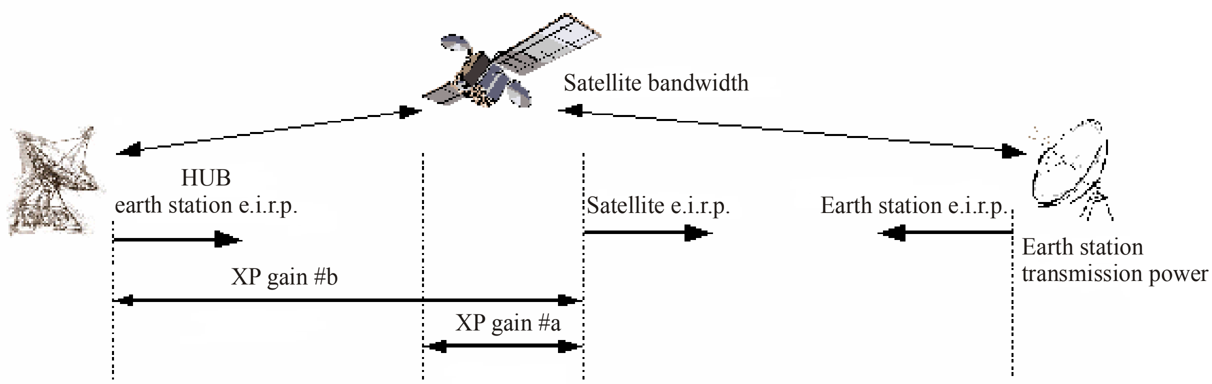
SFD: Saturation flux-density.

IBO: Input back-off.

OBO: Output back-off.

FIGURE 1

Definition of transponder gain (XP gain)



XP gain #a = *Gs* + e.i.r.p. (satellite saturation) SFD + Δ (IBO-OBO)
XP gain #b = satellite e.i.r.p. HUB eath station e.i.r.p.
Gs: Antenna gain of 1 m^2

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As a result of link budget calculation of the outbound (hub-to-VSAT) and inbound (VSAT-to-hub) direction, Tables 2a), 2b) and 2c) provide examples of required earth station e.i.r.p. levels and satellite resources including the required satellite e.i.r.p., the earth station e.i.r.p. and the bandwidth required for typical digital modulation and FEC methods in the 6/4 GHz band, the 14/12 GHz and the 30/20 GHz band.

TABLE 2a

Examples of the required earth station e.i.r.p. levels and satellite resources in 6/4 GHz band

IR(1)	Modulation/FEC	QPSK 1/2 Conv.(2)		QPSK 3/4 Conv.(2)		QPSK 1/2 Conv.(2)+RS		QPSK 1/2 TC	
	Antenna diameter	**2.5 m**	**5.0 m**	**2.5 m**	**5.0 m**	**2.5 m**	**5.0 m**	**2.5 m**	**5.0 m**
64 kbit/s	Allocated satellite bandwidth (kHz)	90	90	60	60	90	90	60	60
	Satellite e.i.r.p. (dBW)	6.8	0.9	8.3	2.4	6.8	0.9	8.3	2.4
	Earth station e.i.r.p. (dBW)	46.2	46.2	47.7	47.7	46.2	46.2	47.7	47.7
	Earth station transmit power (W)	3.1	0.8	4.4	1.1	3.1	0.8	4.4	1.1
1 Mbit/s	Allocated satellite bandwidth (kHz)	1 434	1 434	956	956	1 434	1 434	956	956
	Satellite e.i.r.p. (dBW)	18.8	12.9	20.3	14.4	18.8	12.9	20.3	14.4
	Earth station e.i.r.p. (dBW)	58.2	58.2	59.7	59.7	58.2	58.2	59.7	59.7
	Earth station transmit power (W)	50.3	12.6	71.1	17.8	50.3	12.6	71.1	17.8
6 Mbit/s	Allocated satellite bandwidth (kHz)	8 602	8 602	5 734	5 734	8 602	8 602	5 734	5 734
	Satellite e.i.r.p. (dBW)	26.6	20.7	28.1	22.2	26.6	20.7	28.1	22.2
	Earth station e.i.r.p. (dBW)	66.0	66.0	67.5	67.5	66.0	66.0	67.5	67.5
	Earth station transmit power (W)	302.1	75.5	426.7	106.7	302.1	75.5	426.7	106.7

(1) IR: Information rate.

(2) Constraint length $K = 7$.

TABLE 2b

Examples of the required earth station e.i.r.p. levels and satellite resources in 14/12 GHz band

IR(1)	Modulation/FEC	QPSK 1/2 Conv.(2)		QPSK 3/4 Conv.(2)		QPSK 1/2 Conv.(2)+RS		QPSK 1/2 TC	
	Antenna diameter	**1.2 m**	**3.0 m**	**1.2 m**	**3.0 m**	**1.2 m**	**3.0 m**	**1.2 m**	**3.0 m**
64 kbit/s	Allocated satellite bandwidth (kHz)	90	90	60	60	97	97	90	90
	Satellite e.i.r.p. (dBW)	14.7	7.4	16.2	8.9	13.0	5.7	11.7	4.4
	Earth station e.i.r.p. (dBW)	35.6	35.6	37.1	37.1	33.9	33.9	32.6	32.6
	Earth station transmit power (W)	0.3	0.1	0.5	0.1	0.2	0.04	0.2	0.03
1 Mbit/s	Allocated satellite bandwidth (kHz)	1 434	1 434	956	956	1 556	1 556	1 434	1 434
	Satellite e.i.r.p. (dBW)	26.7	19.4	28.2	20.9	25.0	17.7	23.7	16.4
	Earth station e.i.r.p. (dBW)	47.7	47.7	49.2	49.2	46.0	46.0	44.7	44.7
	Earth station transmit power (W)	5.3	0.9	7.5	1.2	3.6	0.6	2.7	0.4
6 Mbit/s	Allocated satellite bandwidth (kHz)	8 602	8 602	5 734	5 734	9 334	9 334	8 602	8 602
	Satellite e.i.r.p. (dBW)	34.5	27.2	36.0	28.7	32.8	25.5	31.5	24.2
	Earth station e.i.r.p. (dBW)	55.4	55.4	56.9	56.9	53.7	53.7	52.4	52.4
	Earth station transmit power (W)	32.0	5.1	45.1	7.2	21.6	3.5	16.0	2.6

(1) IR: Information rate.

(2) Constraint length $K = 7$.

TABLE 2c

Examples of the required earth station e.i.r.p. levels and satellite resources in 30/20 GHz band

IR[(1)]	Modulation/FEC	QPSK 1/2 Conv.[(2)]		QPSK 3/4 Conv.[(2)]		QPSK 1/2 Conv.[(2)]+RS		QPSK 1/2 TC	
	Antenna diameter	**1.2 m**	**2.4 m**	**1.2 m**	**2.4 m**	**1.2 m**	**2.4 m**	**1.2 m**	**2.4 m**
64 kbit/s	Allocated satellite bandwidth (kHz)	90	90	60	60	97	97	90	90
	Satellite e.i.r.p. (dBW)	25.8	25.5	27.3	27.0	24.1	23.8	22.8	22.5
	Earth station e.i.r.p. (dBW)	30.7	30.7	32.2	32.2	29.0	29.0	27.7	27.7
	Earth station transmit power (W)	0.024	0.006	0.035	0.009	0.017	0.004	0.012	0.003
1 Mbit/s	Allocated satellite bandwidth (kHz)	1 434	1 434	956	956	1 556	1 556	1 434	1 434
	Satellite e.i.r.p. (dBW)	37.9	37.6	39.4	39.1	36.2	35.9	34.9	34.6
	Earth station e.i.r.p. (dBW)	42.8	42.8	44.3	44.3	41.1	41.1	39.8	39.8
	Earth station transmit power (W)	0.4	0.1	0.6	0.1	0.3	0.1	0.2	0.05
6 Mbit/s	Allocated satellite bandwidth (kHz)	8 602	8 602	5 734	5 734	9 334	9 334	8 602	8 602
	Satellite e.i.r.p. (dBW)	45.6	45.4	47.1	46.9	43.9	43.7	42.6	42.4
	Earth station e.i.r.p. (dBW)	50.6	50.6	52.1	52.1	48.9	48.9	47.6	47.6
	Earth station transmit power (W)	2.3	0.6	3.3	0.8	1.6	0.4	1.2	0.3

(1) IR: Information rate.

(2) Constraint length $K = 7$.

As the required bandwidth shows for one direction, twice the listed value is needed for both directions. The required satellite e.i.r.p. shows the one for the downlink of outbound direction which is usually under a power limited situation at satellites. The required earth station e.i.r.p. and transmit power shows the one for the uplink of inbound direction which is usually under a power limited situation at earth stations.

Rain attenuation is not included in the above calculations. Depending on local conditions, provision for rain margin may be needed. The interference or intermodulation is not taken into account. Therefore, additional margin is needed. (See Recommendation ITU-R P.618 for the rain attenuation for local climate and Recommendation ITU-R S.1432 for the various interference criteria.)

2.3.1 Example of link budget calculation

For illustrative purpose, details of the link budget calculation of Table 2a (in case of 6 Mbit/s of 6/4 GHz band with QPSK 1/2 Conv., 2.5 m antenna) are shown in Table 3a.

A mark of [(2)] in Table 3a are the values listed in Table 2a as results of calculation.

TABLE 3a

The link budget calculation of Table 2a
(6 Mbit/s of 6/4 GHz band with QPSK 1/2 Conv., 2.5 m antenna)

Item		Unit	Value	
A. Transmission channel parameter				
Modulation			QPSK 1/2 Conv.(1)	
BER			10^{-6}	
Required E_b/N_0 (dB)		dB	6.1	
Required *C*/*N* (dB)		dB	6.1	
B. Satellite main parameter				
SFD (beam edge)		dB(W/m^2)	−78.0	
G/*T* (beam edge)		dB/K	−13.0	
Transponder saturation e.i.r.p. for single carrier (beam edge) (dBW)		dBW	29.0	
IBO		dB	−5.4	
OBO		dB	−4.5	
Δ(IBO-OBO)		dB	0.9	
Gain of 1 square metre		dB	37.3	
TP gain (#a)		dB	145.2	
C. Transmission carrier parameter				
Information rate		kbit/s	6 144.0	
FEC rate			0.5	
RS (Reed Solomon) rate			1.0	
Transmission rate		kbit/s	12 288.0	
Noise bandwidth		kHz	6 144.0	
Allocated bandwidth(2)		kHz	8 601.6(2)	
D. Earth station main parameter				
G/*T*	dB/K		17.5 (2.5 m earth station)	35.0 (HUB earth station)
E. Link budget calculation				
			Outbound (HUB ≥ 2.5 m earth station)	**Inbound (2.5 m earth station ≥ HUB)**
1. Uplink C/N (HUB E/S -> satellite)				
HUB/earth station e.i.r.p.	dBW		81.9	66.0(2)
Free space loss (6 GHz)	dB		200.5	200.5
Satellite *G*/*T* (beam edge)	dB/K		−13.0	−13.0
C/*N* (a)	dB		29.1	13.21
2. IM (intermodulation) of earth station				
C/*N* (b)	dB		99.0	99.0
3. IM (intermodulation) of satellite				
C/*N* (c)	dB		99.0	99.0

TABLE 3a (*end*)

Item	Unit	Value	
4. Downlink C/N (satellite -> E/S)			
Satellite e.i.r.p. (beam edge)	dBW	26.6(2)	10.7
Pattern advantage etc.	dB	0.0	0.0
Free space loss (4 GHz)	dB	196.7	196.7
Earth station G/T	dB/K	17.5	35.0
C/N (d)	dB	8.1	9.7
5. Co-channel interference			
C/N (e)	dB	99.0	99.0
Total C/N (C/N (a) ~ C/N (e))	dB	8.1	8.1
Margin	dB	2.0	2.0
Total C/N	dB	6.1	6.1
Transponder gain (#b)	dB	−55.3	
Feed loss	dB		0.8
Antenna gain of earth station (2.5 m)	dBi		42.0
Required earth station transmit power	W		302.1(2)

(1) Constraint length $K = 7$

2.4 Configuration of the transportable earth station

The earth station may be divided into the following major subsystems:

– antenna;
– power amplifier;
– low noise receiver;
– ground radiocommunication equipment;
– control and monitoring equipment;
– terminal equipment, including facsimile and telephones;
– support facilities.

This section should be referred to as a guideline of actual characteristics of the system and small earth stations such as transmission capability, weight/size and performance of the subsystem.

2.4.1 Weight and size

All the equipment, including shelters, should be capable of being packaged into units of weight which can be handled by a few persons. Furthermore, the total volume and weight should not be in excess of that which could be accommodated in the luggage compartment of a passenger jet aircraft. This is readily attainable with present-day technology. The allowable size and weight specifications of the various aircraft should be consulted during the design of satellite terminals for disaster relief telecommunications.

2.4.2 Antenna

One of the major requirements for the antenna is ease of erection and transportation. For this purpose, the antenna reflector could consist of several panels made of light material such as fibre reinforced plastic or aluminium alloy. The use of an antenna of a diameter from 2.5 m to 5 m is foreseen for use in the 6/4 GHz band. However, for other frequency bands, antenna construction requirements are eased because smaller antenna sizes can be used.

The main antenna reflector may be illuminated by a front-fed horn or a feed which includes a sub-reflector. The latter type may have a slight advantage in G/T performance, since the curvature of both the sub-reflector and main reflector can be optimized, but ease of erection and alignment may take precedence over G/T considerations.

A manual or automatic pointing system may be provided commensurate with weight and power consumption, by monitoring a carrier signal from the satellite, having a steerable range of approximately ±5°.

2.4.3 Power amplifier

Air-cooled klystron and TWT (helix-type) amplifiers are both suitable for this application, but from the point of view of efficiency and ease of maintenance, the former is preferred.

Although the instantaneous transmission bandwidth is small, the output amplifier may need to have the capability of being tuneable over a wider bandwidth, e.g. 500 MHz, since the available satellite channel may be anywhere within this bandwidth.

For power requirements less than 100 W, a solid state power amplifier (FET) would also be suitable.

In the 30 GHz band, solid-state, TWT and klystron amplifiers are suitable for this application.

2.4.4 Low-noise receiver

Because the low-noise receiver must be small, light and be capable of easy handling with little maintenance, an uncooled low noise amplifier is the most desirable.

A temperature of 50 K has been realized and even lower temperatures are expected in the future in the 4 GHz band. A FET amplifier is more suitable from the point of view of size, weight and power consumption than a parametric amplifier. A noise temperature of 50 K in the 4 GHz band and 150 K in the 12 GHz band has been realized by FET amplifiers. In the 20 GHz band, an FET amplifier with a noise temperature of 300 K or less at room temperature has been realized.

2.5 Examples of transportable earth station realizations and system implementation

2.5.1 Small transportable earth stations

In the 14/12 GHz and 30/20 GHz bands, most of the transportable stations have antennas with around 1.2 m diameters.

2.5.1.1 Examples of air transportable and vehicle equipped small earth stations in the 14/12 GHz band

Various types of small earth station equipment have been developed for the use of new satellite radiocommunication systems in the 14/12 GHz band. For implementing small earth stations, efforts have been made to decrease the size and to improve transportability so as to ease their use for general applications. This allows the occasional or temporary use of these earth stations for relief operation elsewhere in the country or even worldwide. Such temporary earth stations are installed either in a vehicle or use portable containers with a small antenna. It is thus possible to use them in an emergency.

The vehicle equipped earth station in which all the necessary equipment is installed in the vehicle, e.g. a four-wheel drive van, permits operation within 10 min of arrival including all necessary actions such as antenna direction adjustments.

A portable earth station is disassembled prior to transportation and reassembled at the site within approximately 15 to 30 min. The size and weight of the equipment generally allow it to be carried by hand by one or two persons, and the containers are within the limit of the International Air Transport Association (IATA) checked luggage regulations. Total weight of this type of earth station including power generator and antenna assembly is reported to be as low as 150 kg, but 200 kg is more usual. It is also possible to carry the equipment by helicopters.

Examples of small transportable earth stations for use with Japanese communication satellites in the 14/12 GHz band are shown in Table 4.

TABLE 4

Example of small transportable earth stations for the 14/12 GHz band

Example No.	1	2	3	4(1)	5	6
Type of transportation	Vehicle equipped					
Antenna diameter (m)	2.6 × 2.4	1.8	1.2	1.8	0.9	1.5 × 1.35
e.i.r.p. (dBW)	72	70	62.5	65.1-71.2 (95-400 W)(2)	54-64 (20-200 W)(2)	72 (400 W)(2)
RF bandwidth (MHz)	24-27	20-30	30	1.4-60 Mbit/s	64 kbit/s- 60 Mbit/s	1.4-60 Mbit/s
Total weight	6.4 tons	6.0 tons	2.5 tons	250 kg(3)	70 kg(4)	210 kg
Package: – Total dimensions (m) – Total number – Max. weight (kg)	 – – –	 – – –	 – – –	 2.62 × 1.95 × 0.88 – < 345 kg	 1.2 × 1.1 × 0.4 m 1 –	 2.37 × 1.53 × 0.45 1 –
Capacity of engine generator or power consumption	7.5 kVA	10 kVA	5 kVA	~ 4 100 W	~ 4 100 W	~ 4 100 W
Required number of persons	1-2	1-2	1-2	1	1	1

TABLE 4 (*end*)

Example No.	7	8	9	10	11	12	13	14	15
Type of transportation	Air transportable								
Antenna diameter (m)	1.8	1.4	1.2	0.75	0.9	0.9 × 0.66	1	0.9	0.9 × 0.66
e.i.r.p. (dBW)	70	64.9	62.5	42.5	44.0	51.7	55	66	51.7
RF bandwidth (MHz)	20-30	30	30	Up to 0.5	Up to 0.5	2	6	64 k ~ 60 Mbit/s	64 k ~ 4 Mbit/s
Total weight (kg)	275	250	200	131	141	100	110	130	39
Package: – Total dimensions (m) – Total number – Max. weight (kg)	 < 2 10 45	 < 2 13 34	 < 2 8 20	 1 5 37	 1.2 5 37	 – – –	 – – –	 1 × 0.6 × 1.2 3(5) < 43 kg	 70 × 47 × 31 (cm) 1 39 kg
Capacity of engine generator or power consumption	3 kVA	0.9-1.3 kVA	1.0 kVA	< 370 W	< 370 W	< 2 kVA	< 2 kVA	~ 4 100 W	750 W
Required number of persons	2-3	2-3	1-2	1-2	1-2	2	3	1	1

(1) Flyaway.

(2) The amplifier size is selectable for the purpose.

(3) Total weight does not include the weight of the car.

(4) Without amplifier.

(5) There are three packages; the sizes are 72 × 60 × 26 (cm), 51 × 29 × 40 (cm) and 100 × 60 × 40 (cm) respectively.

2.5.1.2 Examples of small transportable earth stations for operation at 30/20 GHz

Several types of 30/20 GHz small transportable earth stations, which can be transported by a truck or a helicopter, have been manufactured and operated satisfactorily in Japan.

Examples of small transportable earth stations for operation at 30/20 GHz are shown in Table 5.

TABLE 5

Examples of small transportable earth stations for the 30/20 GHz band

Operating frequency (GHz)	**Total weight (tons)**	**Power require-ment (kVA)**	**Antenna**		**Maxi-mum e.i.r.p. (dBW)**	***G/T* (dB/K)**	**Type of modulation**	**Total setting-up time (h)**	**Normal location of earth station**
			Diameter (m)	**Type**					
30/20	5.8	12	2.7	Cassegrain	76	27	FM (colour TV 1 channel)[1] or FDM-FM (132 telephone channels)	1	On a truck
	2	9	3	Cassegrain[2]	79.8	27.9	FM (colour TV 1 channel)[1] and ADPCM-BPSK-SCPC (3 telephone channels)	1	On the ground
	1	1[3]	2	Cassegrain	56.3	20.4	ADM-QPSK-SCPC (1 telephone channel)	1.5	On the ground
	3.5[4]	< 8.5	1.4	Offset Cassegrain	68	20	Digital-TV (3 voice channels are multiplexed)[1] or 1 voice channel	> 1	On a van/SUV
	0.7	3	1	Cassegrain	59.9	15.2	FM-SCPC (1 telephone channel) or DM-QPSK-SCPC (1 telephone channel)	1	On a truck

(1) One-way.

(2) The reflector is divided into three sections.

(3) Excluding power for air conditioning.

(4) Include vehicle.

2.5.2 Example of an emergency network and associated earth stations

2.5.2.1 Example of an emergency network in Italy using the 14/12 GHz band

An emergency satellite network has been designed and implemented in Italy for operation in the 14/12.5 GHz frequency band via a EUTELSAT transponder. This dedicated network, which is based on the use of wholly digital techniques, provides emergency voice and data circuits and a time shared compressed video channel for relief operations and environmental data collection. The network architecture is based on a dual sub-networking star configuration, for the two services and makes use of a TDM-BPSK and an FDMA-TDMA-BPSK dynamic transmission scheme, respectively for the outbound and inbound channels. The ground segment is composed of: a master common hub station for the two star networks, which is a fixed-earth station having a 9 m antenna and a 80 W transmitter; a small number of transportable earth stations, having antennas of 2.2 m and 110 W transmitters; a number of fixed data transmission platforms with 1.8 m dishes and 2 W solid state power amplifier transmitters.

These platforms have a receive capability (*G*/*T* of 19 dB/K), in order to be remotely controlled by the master station, and their average transmit throughput is 1.2 kbit/s. The transportable earth stations are mounted on a lorry, but if necessary, can also be loaded in a cargo helicopter for fast transportation. They have a *G*/*T* of 22.5 dB/K and are equipped with two sets of equipment each containing one 16 kbit/s (vocoder) voice channel and one facsimile channel at 2.5 kbit/s. These earth stations which are also able to transmit a compressed video channel at 2.048 Mbit/s in SCPC-BPSK, are remotely controlled by the master station. The major features of this *ad hoc* emergency network are summarized in Table 6.

TABLE 6

Example of an emergency satellite radiocommunication network operating at 14/12 GHz

Station designation	Antenna diameter (m)	*G*/*T* (dB/K)	Trans-mitter power (W)	Primary power requirement (kVA)	Transmission scheme		Service capability
Master	9.0	34.0	80	15.0	Tx	512 kbit/s-TDM/BPSK (+ FEC 1/2)	12 × 16 kbit/s (vocoder) voice channels
					Rx	"*n*" × 64 kbit/s-FDMA/TDMA/BPSK (+ FEC 1/2) and 2.048 Mbit/s-SCPC/QPSK (+ FEC 1/2)	12 × 2.4 kbit/s facsimile channels 1 × 2.048 Mbit/s video channel
Peripherals (transportable)	2.2	22.5	110	2.0	Tx	64 kbit/s-TDMA/BPSK (+ FEC 1/2) and 2.048 Mbit/s-SCPC/QPSK (+ FEC 1/2)	2 × 16 kbit/s (vocoder) voice channels 2 × 2.4 kbit/s facsimile channels
					Rx	512 kbit/s-TDM/BPSK (+ FEC 1/2)	1 × 2.048 Mbit/s video channel
Unattended platforms	1.8	19.0	2	0.15	Tx	64 kbit/s-TDMA/BPSK (+ FEC 1/2)	1 × 1.2 kbit/s data transmission channel
					Rx	512 kbit/s-TDM/BPSK (+ FEC 1/2)	

2.5.2.2 Example of an emergency network in Japan using the 14/12 GHz band

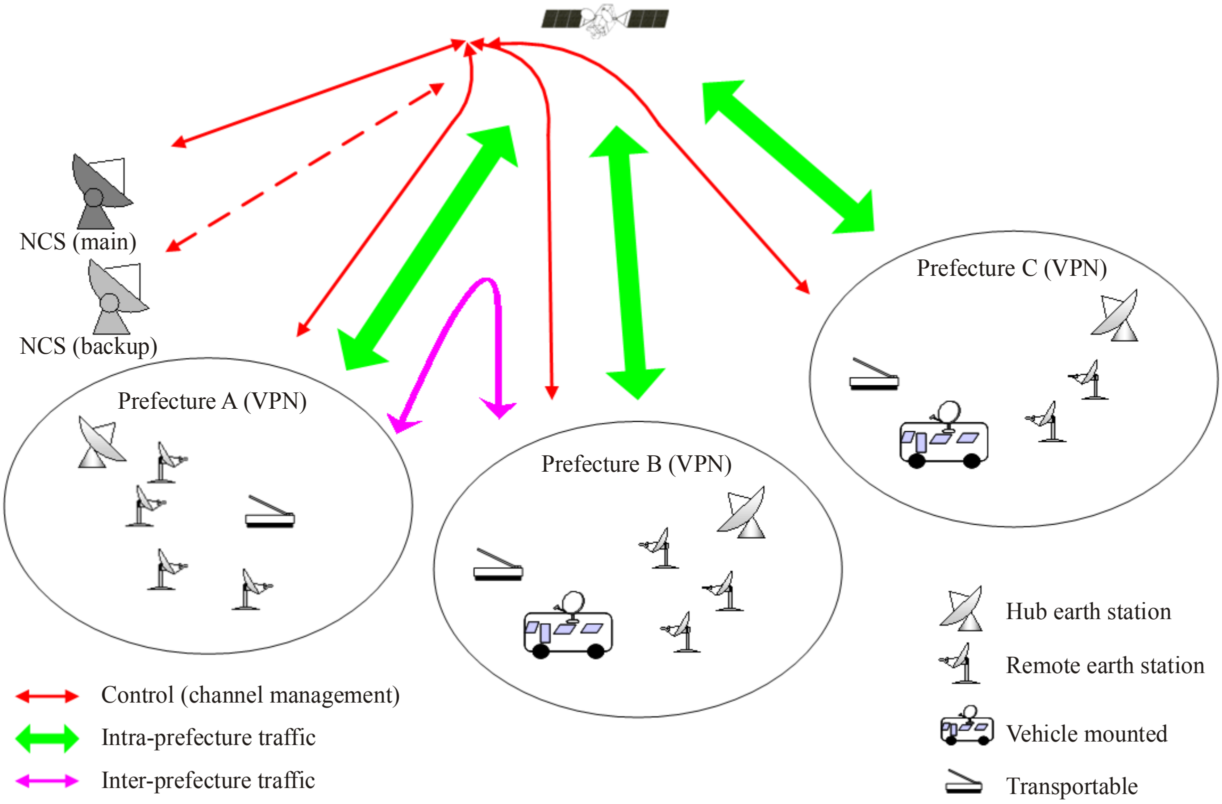
In Japan, there is a satellite network operating in the 14/12.5 GHz frequency band mainly for the purpose of emergency radiocommunications that accommodates more than 4 700 earth stations including VSATs located at municipal offices and fire departments, transportable earth stations and vehicle-mounted earth stations. The network provides voice, facsimile, announcement (simplex), video transmission and high-speed IP data transmission.

As shown in Fig. 2, the network is based on DAMA, so that satellite channels can be efficiently shared by as many as 5 000 earth stations. An earth station asks the network coordination station (NCS) for the assignment of traffic channels such as voice, facsimile and IP transmission prior to its radiocommunication with other earth stations. Note that there are two NCSs, main and backup, in the network.

The network is designed to have a multi-star topology where each prefecture (note that Japan consists of 47 prefectures) configures an independent sub-network so that the principal office of the prefecture can be the hub of emergency radiocommunications in the case of an event. By virtue of the closed-group network, the satellite resources can be controlled by the NCS depending on urgency of events. For instance, the NCS can provide priorities for radiocommunications originated from a particular prefecture where an emergency event occurs over routine radiocommunications in other prefectures. The network also provides inter-prefecture radiocommunications if any.

FIGURE 2

Configuration of the emergency network



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The summary of channel parameters is listed in Table 7. There are six types of channels consisting of SCPC (voice/data/fax), announcement, IP data transmission, digital video, satellite data broadcast and common signalling channel (CSC). SCPC channels (32 kbit/s ADPCM) and IP data transmission channels (32 kbit/s-8 Mbit/s variable rate) are assigned to earth stations on a demand basis by the NCS. The bandwidth of an IP data transmission channel is requested from an earth station based on its instantaneous throughput of IP data traffic and assigned by the NCS. Thus, the NCS manages the satellite resource efficiently by accommodating traffic channels with variable bandwidth by a novel channel management algorithm. An earth station designated to high-speed TCP/IP transmission is equipped with a 2-segment splitting TCP gateway to enhance the TCP throughput (see Recommendation ITU-R S.1711).

In order to help telecommunications from/to an area damaged by disasters, the development of smaller user earth stations with high performance is under way. Typical parameters of such earth stations are listed in Table 8. There are two types of vehicle-mounted earth stations. Type-A earth station is designed to transmit full motion picture based on MPEG-2 (i.e. 6 Mbit/s) and provide a voice circuit simultaneously available during video transmission. The earth station is to be mounted on a relatively large vehicle such as "Wagon" type. On the other hand, a type-B earth station is designed to transmit a low rate limited-motion picture by MPEG-4/IP (i.e. 1 Mbit/s) with a voice circuit switchable with video transmission. The earth station is to be mounted on a smaller vehicle such as "Land-cruiser" type. Similar to type-B vehicle-mounted earth stations, the transportable earth station is designed to transmit a low rate limited-motion picture by MPEG-4/IP with a voice circuit switchable with video transmission. Its video transmission rate is only 256 kbit/s.

TABLE 7

Summary of channel parameters of the satellite network

Parameters	SCPC (voice, fax, data)	Announcement	IP data transmission	Digital video transmission	Satellite data broadcast	CSC
Direction	2-way	2-way	2-way	1-way	1-way	2-way
Multiple access(1)	DA-FDMA	PA-TDMA/ FDMA	DA-FDMA	DA-FDMA	DA-FDMA	RA-TDMA/ FDMA
Modulation	QPSK(2)	QPSK(3)	QPSK	QPSK	QPSK	QPSK(3)
Information rate	32 kbit/s	32 kbit/s	32k-8 Mbit/s(4)	7.3 Mbit/s	6.1 Mbit/s	32 kbit/s
FEC	1/2 FEC	1/2 FEC	1/2 FEC (5)	3/4 FEC+RS	3/4 FEC+RS	1/2 FEC
Ciphering	N/A	N/A	(IPSec)(6)	(MULTI2)(6)	MISTY	N/A
Encoding	32k ADPCM	32k ADPCM	N/A	MPEG2	N/A	N/A

(1) The following are acronyms of multiple access schemes:

DA-FDMA: Demand assignment – frequency division multiple access

PA-TDMA: Permanent assignment – time division multiple access

RA-TDMA: Random access – time division multiple access.

(2) The burst channel is employed because of voice activation.

(3) The burst channel is employed in the uplink direction.

(4) Asymmetric type variable rate with IP.

(5) 3/4 FEC + RS is employed for channels over 3 Mbit/s.

(6) Optional.

TABLE 8

Parameters of the vehicle-mounted and transportable earth station

Parameters	Vehicle-mounted earth station		Transportable earth station
	Type-A	Type-B	
Description	– Full-motion pictures based on MPEG-2 – Simultaneous voice circuit	– IP-based low-rate motion picture based on MPEG-4 – Voice circuit switchable with the video circuit	– IP-based low-rate motion picture based on MPEG-4 – Voice circuit switchable with the video circuit
Antenna diameter	1.5 m (offset parabola)	75 cm (offset parabola)	1 m (Flat array)
Output power	70 W (SSPA)	15 W (SSPA)	15 W (SSPA)
Number of channels and transmission rate	Video: 1 channel (6 Mbit/s, MPEG2) Voice/IP: 1 channel	Video: 1 channel (1 Mbit/s, IP) Voice/IP: 1 channel	Video: 1 channel (256 kbit/s, IP) Voice/IP: 1 channel
Type of vehicle	Wagon type	Land-cruiser type	N/A

2.5.2.3 Example of an emergency network in South-East Asia using the 14/12 GHz band

An agency in South-East Asia has set up an end-to-end broadband VSAT system to improve the broadband telecommunication between its offices and enhance the e-risk management policy.

The satellite network interconnects the headquarters (redounded) with: 13 national offices, 25 county offices, 72 villages and 12 emergency vehicles. Based on IP, it offers all the common services of an intranet such as access to web and FTP servers, electronic messaging and content distribution in multicast, e.g. streaming. In addition, it offers broadband applications relevant for crisis management (e-risks services suite): videoconferencing, collaborative working and voice-over-IP.

In normal situations, the system carries up to 8 Mbit/s:

– 2 Mbit/s shared by all voice radiocommunications;

– 3 Mbit/s for central data exchanges;

– 3 Mbit/s for data shared by other data exchanges.

In crisis situations, the system carries up to 21 Mbit/s:

– 12 Mbit/s for two video streams;

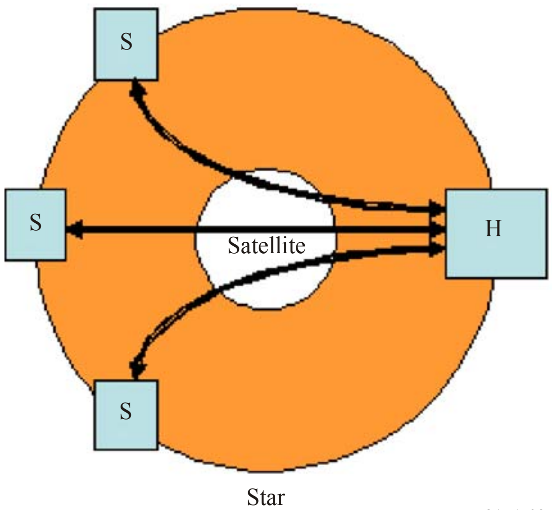
– 9 Mbit/s for up to 16 videoconference terminals.

It is based on a DVB-RCS star satellite network. DVB-RCS stands for digital video broadcasting-return channel via satellite. This technology corresponds to the ETSI standard (EN 301 790) and enables access to multimedia services by satellite by the means of a small dish. It is cited in the Recommendation ITU-R S.1709 – Technical characteristics of air interfaces for global broadband satellite systems.

The topology chosen is the star topology (as opposed to the mesh one) with a hub installed at the headquarters and satellite terminals installed at the remote sites listed above (see Fig. 3).

FIGURE 3

Star topology



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This topology is the best suited to services such as videoconferencing since they are by nature point-to-multipoint with a multipoint control unit located at the hub. This one also enables access to the Internet by means of a broadband access server. It shall be located abroad from the place of the disaster, and therefore there is less constraint on the facilities; for example, the antenna can be as large as necessary.

The network operates in 14/12 GHz band (the 14 GHz band for the uplinks; the 12 GHz band for the downlinks). 14/12 GHz band antennas are smaller and lighter, which eases the use and the transportation of material. The terminals are state-of-the-art with a diameter ranging from 0.6 m to 1.2 m; the diameter is chosen so as to optimize the trade-off between the signal-to-noise ratio and the ease of transportation. The RF subsystem of remote terminals is specified in the norm as the outdoor unit.

The forward link is compliant with the DVB-S standard implying QPSK modulation and a combination of a Reed-Solomon (188, 204) code as the outer code and a convolutional 1/2 code as the inner code. The protocol stack for the forward link is IP/MPE/MPEG2-TS/DVB-S[1].

The return link relies on QPSK modulation and a 2/3 turbo code. The protocol stack for the return link is IP/AAL5/ATM/DVB-RCS.

The satellite access technology on the return link is fixed multifrequency time division multiple access (fixed MF-TDMA). Fixed MF-TDMA allows a group of satellite terminals to communicate with the hub using a set of carrier frequencies of equal bandwidth while the time is divided into slots of equal duration. The network control centre at the hub will allocate to each active satellite terminal series of bursts, each defined by a frequency, a bandwidth, a start time and a duration.

The satellite network supports quality of service thanks to standard features at the MAC level: the so-called capacity categories; but the architectures enables the definition of a QoS policy at higher levels such as DiffServ or InterServ based policies (DiffServ is generally preferred).

Satellites terminals can be controlled from the hub, they can be configured, faults can be detected and software can be downloaded.

2.6 Example of the use of satellite telecommunications to support response to Great East Japan Earthquake

2.6.1 Overview

At 14:46 Friday, March 11, 2011, a magnitude 9.0 earthquake hit Japan. Its hypocenter was approximately 130 km east of Sendai, the capital of Miyagi prefecture. The tremor triggered a massive tsunami and seriously damaged the Tohoku districts. The tsunami brought destruction along the Pacific coastline of the Tohoku districts and resulted in the loss of thousands of lives and devastated entire towns. The tsunami reached inland a maximum of 12 km from the coastline and inundated a total area of approximately 807 km^2 in Japan. It was the most powerful known earthquake to have hit Japan, and one of the five most powerful earthquakes in the world.

The communication infrastructure was severely damaged in the coastal region and the communication capability was almost completely lost for the few weeks immediately following the tsunami.

For example, up to 14,000 base stations of the three major mobile telephone carriers stopped operation, 1.5 million telephone lines suffered damage, and the sudden jump of communication traffic immediately after the disaster led to communication problems in wide areas.

After such damage, it was vital for the government and/or press to grasp the situation and communicate between the affected area and center and for the afflicted people to access information regarding help and/or information from local authorities. Dependable two-way telecommunications are essential to ensure the above use and support using the FSS network was essential for relief, restoration and reconstruction from the earthquake. An additional bandwidth (about 500 MHz in

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1 MPE stands for MultiProtocol Encapsulation.

total) was allocated to priority use and more than 180 VSATs were newly installed in the affected area for Internet access, entrance link of the cell-phone systems, and other various purposes.

Meanwhile, a broadband communication satellite originally created for technology demonstration purposes was also used on request by government rescue and relief organizations. The satellite has an onboard switch for Internet Protocol (IP) communications and its earth stations have Gigabit Ethernet interface, which were used for the connections of commercial instruments with IP interface in the rescue and relief operation support.

2.6.2 Materials and methods

In this section, the roles and usage trends of satellite communications in the following phases are summarized:

1) relief phase;

2) restoration phase;

3) reconstruction phase.

In addition, at the time of the earthquake, Earthquake Early Warning system (see section 3 of this Report) was activated 9 seconds prior to the initial tremor and the railroad train system emergency brake procedure was activated 70 seconds prior to the most destructive quake. None of the trains with the Earthquake Early Warning system (including 27 Shinkansens) running at the time of the earthquake were derailed.

2.6.2.1 Relief phase

In the relief phase, emergency links for connecting people to each other and conveying damage status information are most important. A satellite communications operator allocated the additional bandwidth (amounting to about 500 MHz from its entire fleet) to priority use, such as rescue, government, and so on and this bandwidth was utilized by governmental organizations, local authorities and/or information media to transmit information (mainly voice and video) between the affected area (including naval vessels) and emergency command posts. This operator also distributed satellite phones (MSS terminals) to customers through joint efforts of a group company of this operator and a global remote communications solutions provider. The ITU also deployed 78 Thuraya satellite phones, 13 Iridium satellite phones, 32 Inmarsat broadband global area network terminals and 30 Inmarsat global satellite phone services terminals through the Japanese Administration.

2.6.2.2 Restoration phase

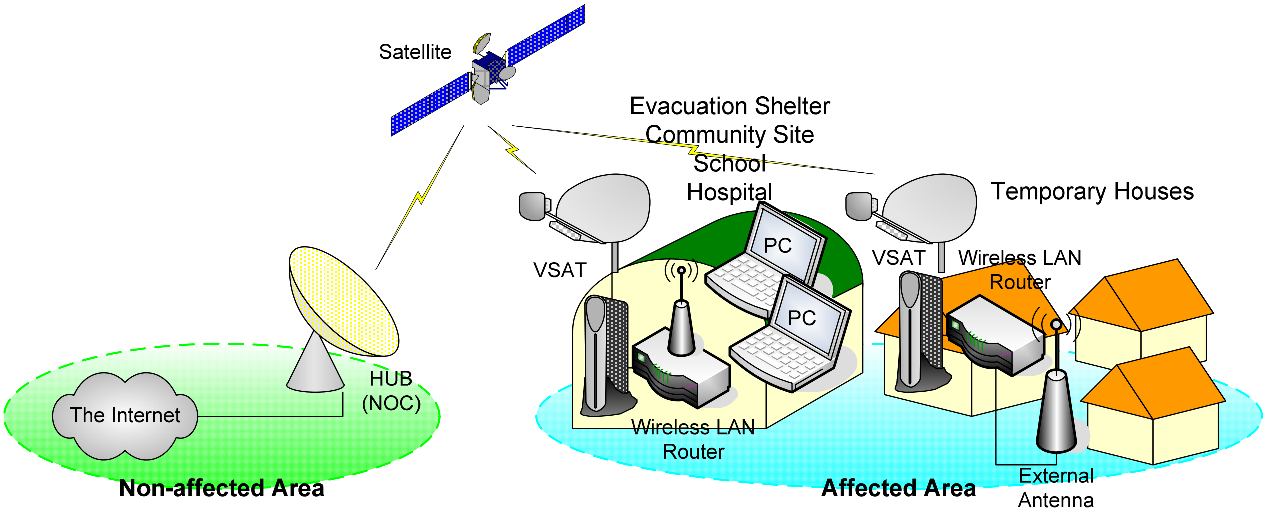
The restoration phase covered efforts to establish evacuation shelters for people, to restore the administrative functions of local communities, and to rebuild the basic infrastructure of daily life. Satellite communications during this phase were used mainly as a backup and/or substitute for interrupted landlines for the lifeline infrastructure, such as telephone, cell phone, power, gas, railway companies, etc. (further information regarding satellite backhauls of mobile base stations can be found in section 2.8 of this Report). To deal with the drastic increase in demand, this operator expanded its VSAT service to double in its Network Operations Center (NOC).

2.6.2.3 Reconstruction phase

In the reconstruction phase, the communication infrastructure necessary for the rebuilding of the disaster affected area must be provided. This operator formed dedicated teams within its organization and worked together with the Tohoku Bureau of Telecommunications of the Ministry of Internal Affairs and Communications (local agency of the Administration) and a PC manufacturer, under financial support provided by the Administration. These teams installed VSAT equipment and set up wireless LANs and PCs at more than 180 sites before the end of fiscal 2011 (see Fig. 4).

FIGURE 4

Use of VSAT in community facilities and/or temporary houses



2.6.3 Discussion and lessons

The FSS, especially VSATs have proved to be a useful means of communication in the reconstruction effort from the earthquake. The main reasons for this are as follows:

1) Logistical advantage:

VSATs can generally be delivered quickly (subject to availability), thanks to the mass production. VSATs would be easily transported because of their size and weight.

2) Installation advantage:

The set-up period is generally short because VSATs do not require groundwork but require only a mast. Since the assembling of VSATs is relatively easy (compared to non-VSAT earth stations), specialized knowledge, skills or a lot of manpower are not required in their installation. (Transportable VSAT equipped with auto-pointing antennas would be useful for temporary use.)

3) Regulatory advantage:

Some administrations have introduced simple licensing procedures, so called type approval and/or blanket licenses. (Some sort of quick measures would be efficient in case of major disasters.)

The applications in exceptionally high demand after the earthquake were Internet access and the access links of the cell-phone systems.

VSAT systems to be used in the event of natural disasters need to accommodate a sudden increase in the communications traffic, and scalability is quite important. Additionally, one alternative and practical solution would be to outfit a small/transportable HUB system right after natural disasters and to connect it to existing radio-frequency facilities in a timely manner.

2.7 Example of support activity by broadband communication satellite for rescue and relief

2.7.1 Overview

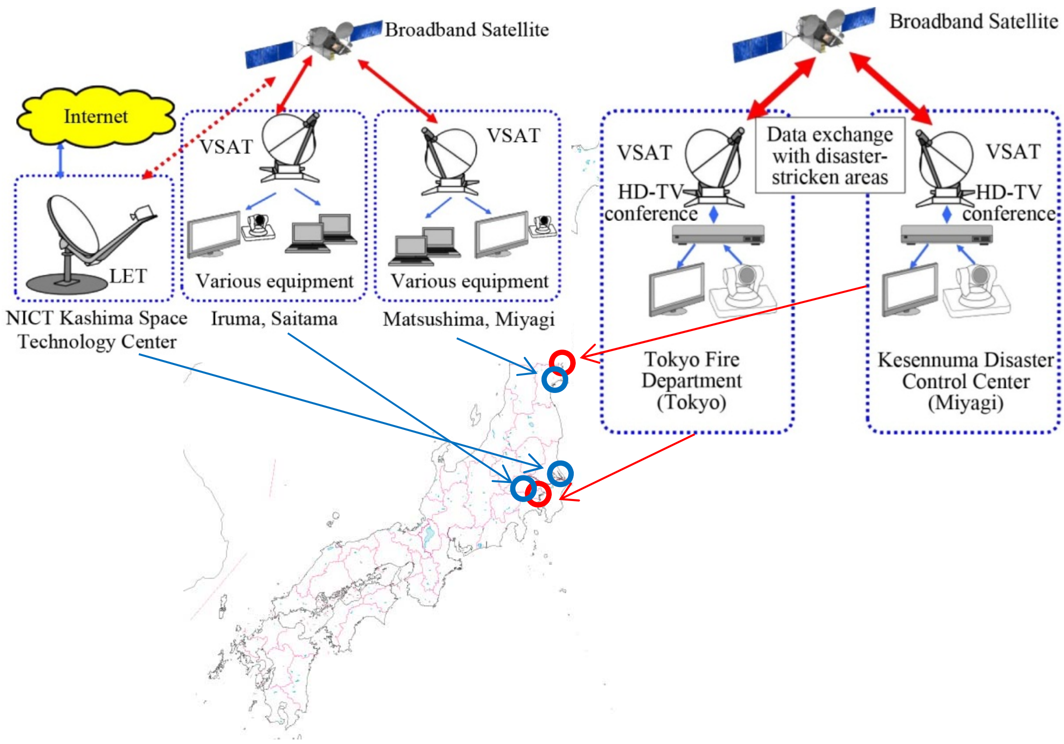
On the initial rescue phase, a Japanese experimental broadband communication satellite was used to support rescue and relief operation. This operation was based on requests by the government rescue and relief teams after the earthquake. The research staff of the experimental satellite project carried the earth station to the disaster area and established the communication link and applications between their headquarters in the Tokyo area and the disaster area.

After the earthquake, on 14 March 2011, the research staff departed from Tokyo with the rescue party of Tokyo Fire Department and arrived at Kesennuma City at midnight that day. Early next morning, the party moved into the local fire station of the city and installed the earth station and IP-based application instruments between the Command Response Team at the disaster area and the headquarters of Tokyo Fire Department. It took about half a day to complete the setup of the instruments and the communication link-up.

Following the support activity for the Emergency Fire Response Team, the party moved into Matsushima city which served as a dispatch center for relief operation. Figure 5 summarizes the series of operations during the support activity. In this operation, the communication link with the broadband satellite was operated to support the communication between Matsushima city and Tokyo. In the disaster area, the terrestrial broadband link was disrupted although a temporary mobile base station with a limited backhaul capacity was provided near Matsushima city.

FIGURE 5

Series of operations using satellite links during the support activity



2.7.2 Satellite communication system

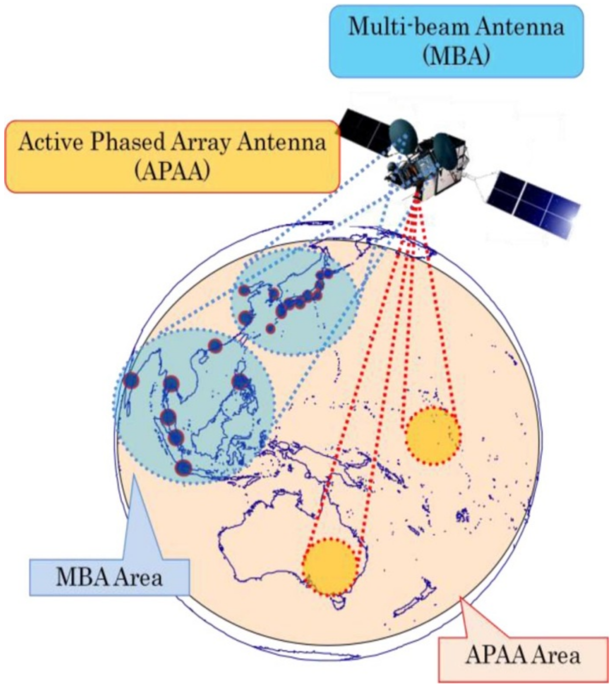
The broadband communication satellite system used in this event is a state of the art experimental communication satellite to demonstrate technology for broadband satellite communications with Internet Protocol (IP) in the 20/30 GHz band. One of the major characteristics of this satellite is its onboard switch which demodulates the signal from the antenna, switches the data based on the area covered by the antenna beam, modulates the signal, and sends the signal to the antenna. The uplink data rate can be selected from 1.5 Mbit/s, 6 Mbit/s, 24 Mbit/s, 51 Mbit/s, or 155 Mbit/s, with the downlink data rate of 155 Mbit/s.

As shown in Fig. 6, the satellite has two antenna systems. One is a fixed beam, with multiple sub-beams, antenna and a multi-port amplifier; another is a steerable beam antenna with an active phased array system. In this disaster support, the fixed beam for Japan Island was used. The steerable beam antenna has a service coverage over the Asian and Pacific countries.

The satellite supports several types of earth stations. In this operation, a portable type earth station with 1.0 m aperture dish and a 40 W solid state power amplifier was used. The 51 Mbit/s uplink and 155 Mbit/s downlink were used with the portable earth station and onboard switch.

FIGURE 6

Service areas of the broadband communication satellite



2.7.3 Communication equipment used for the operation

The earth stations for the broadband satellite are equipped with Gigabit Ethernet as the external interface. This allows devices with an Internet connection to easily communicate with remote locations via the satellite link. Therefore, conventional terminals such as IP telephones, high definition video conferencing setups, high-resolution web cameras, file transfer servers, etc. can be used in the affected area.

High-resolution images and map data can be transferred, directly into a display at the remote site, making it easier to provide information. The combination of Full HD quality TV conference equipment and a HD web camera system was very useful for very quick information exchange and sharing with the remote site. High-speed file transfer played a major role in enabling information sharing between the disaster area and Tokyo. By using a Linux-based terminal, over 30 Mbit/s throughput TCP/IP data transfer was used with 51 Mbit/s after some trials and errors.

An IP telephone system provides an easily deployed temporary communication tool over the remote site. The Session Initiation Protocol (SIP) server was installed on a LAN connected by the satellite link. A conventional IP telephone system was operated for voice communications. By using wireless access point on the network, the IP phone service was used via personal "Smart Phone" with Wi-Fi interface after set-up for the SIP server access. Based on the experience and lesson described above, the list of application instruments useful for the rescue and relief activity support with broadband satellite communications are summarized in Table 9.

TABLE 9

Useful communication equipment

Equipment type	Merit of utility	Speed
Personal computer	Information exchange and setup of equipment	1-30 Mbit/s
Printer and scanner	Support swift information sharing	~1 Mbit/s
HD web camera or streaming camera	Vivid transfer and information sharing of disaster area and rescue situation	2-10 Mbit/s
HD TV conference set		2-10 Mbit/s
Wi-Fi access point	Expansion of utility area and access by Wi-Fi terminal including personal terminal.	–
SIP server for IP phone system	Temporary personal communication tool within disaster area, as well as between disaster area and headquarters over satellite link.	~1 Mbit/s
IP phone terminal		
Wireless IP phone or Smart Phone with Wi-Fi		

2.7.4 Conclusion

Broadband satellite links between remote sites were useful for the rescue and relief operation support for this huge disaster. A broadband communication satellite with Ethernet interface was convenient because the broadband link with Ethernet interface could offer a variety of communication services and easy connection with commercial equipment with IP interface.

2.8 Example of mobile base stations with satellite backhaul

2.8.1 Overview

In the event of natural disasters, mobile base stations can be damaged or destroyed over large areas. Even if the base stations are not damaged, terrestrial lines can be damaged, which leads to service outages of mobile base stations. Mobile communications are commonly and widely used all over the world and play an important role in our daily life. In a disaster relief phase, it is a matter of urgency to recover mobile base stations in order to obtain any information about the well-being of missing persons, recover and reconstruct damaged or destroyed roads, public facilities, buildings, etc. In these cases, mobile base stations with satellite backhauls appear as the most appropriate and the only means to quickly set up and provide mobile services, particularly immediately after the disaster.

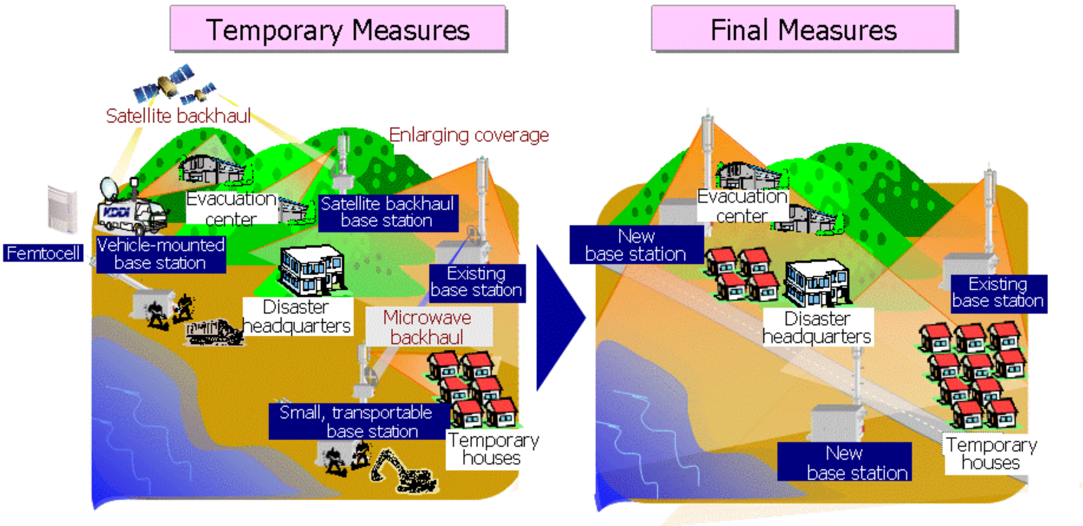
Temporary measures in the disaster relief phase and final measures are shown as follows and in Fig. 7.

1) Temporary measures:
- deploying vehicle-mounted base stations with satellite backhaul;
- restoring existing base stations with satellite backhaul;
- enlarging coverage of existing base stations;
- installation of femtocell with satellite backhaul;
- installation of small, transportable base stations with microwave backhaul.

2) Final measures:
- recovery of the coverage areas with new base stations;
- recovery of existing base stations with terrestrial lines.

FIGURE 7

Measures to recover mobile services



2.8.2 Configuration and guidelines for satellite backhaul

The applications in exceptionally high demand after the earthquake are the voice communication and the data communication (email, the emergency information board and Internet access) of mobile phone systems. It should be noted that the required QoS, particularly the transmission rate, is different from one another and the VSAT system to be used in the event of disasters should be capable of achieving the required transmission rate for connecting the base transceiver station (BTS) regardless of the access scheme, and meeting the QoS requirements for the voice and data communications.

Table 10 summarizes the guidelines to recover mobile base stations with the satellite backhaul and Table 11 lists example parameters of VSAT used in a disaster relief operation.

A typical base station adopts both the E1/T1 interface and the Ethernet interface. Although the E1/T1 interface requires a constant transmission rate of 768 kbit/s or 1.5 Mbit/s, the number of simultaneous channels can be maximized. In using the Ethernet interface, while additional transmission rates are required due to the overhead of IP headers, the backhaul link can be established at less transmission rate than the case of E1/T1.

Also important is the transmission rate allocation particularly in the use of the mobile BTS. In a typical satellite system employing the TDMA scheme, the maximum (Max) and the minimum (Min) transmission rate should be pre-determined for each VSAT depending on the type of BTS.

For example, in using the VSAT types-A and B in Table 11 the required satellite transmission rate is approximately 900 kbit/s for connecting BTS of 768 kbit/s with the Ethernet interface. This difference in the transmission rate includes an overhead of IP headers and additional margins for transmission rate degradation. In order to ensure a constant transmission rate of 900 kbit/s, the transmission rate should be set as Max=Min=900 kbit/s. On the other hand, the femtocell can be operated with a dynamic transmission rate assignment in the satellite link. Therefore, an example transmission rate setting is Max=500 and Min=50 kbit/s.

In disaster relief operations, mobile operators can provide a "public telephone service" by using dedicated mobile handsets which connect to a dedicated base station.

The features of each system will be described in the following sections.

TABLE 10

Guidelines for recovery with satellite backhaul (Note 1)

		Vehicle-mounted base station	**Macro base station with satellite backhaul**	**Femtocell with satellite backhaul**
Main usage		In emergency phase	In recovery phase	In recovery phase
Number of maximum channels		65 ch	65 ch	6-14 ch
Required transmission rate for BTS		768 kbit/s	768 kbit/s	50-500 kbit/s (Note 2)
Transmission rate allocation		Dedicated allocation per BTS	Dedicated allocation per BTS	Shared among multiple Femtocells
Interface		E1/T1 or Ethernet	E1/T1 or Ethernet	Ethernet
Operation		Attended	Unattended	Attended or Unattended
Power supply		Not required (Vehicle-mounted)	Required	Required
Cell range		500-1 000 m	3-5 km	50-100 m
Service	Voice	OK	OK	OK
	Data	OK	OK	OK
	Emergency call	OK	OK	OK

NOTE 1 – Parameters in Table 10 depend on the model of base stations.

NOTE 2 – The required transmission rate for the femtocell depends on the number of simultaneous channels.

TABLE 11

Example parameters of VSAT used as satellite backhaul

	Type-A	Type-B	Type-C
Antenna diameter	1.2 m	84 cm, 1.2 m	1.2 m
Interface	Ethernet	Ethernet	T1
Output power	8W	1W	2W
Access scheme of VSAT	TDMA	TDMA	SCPC
Satellite transmission rate	900 kbit/s (Note 3)	900 kbit/s (Note 3)	1.5 Mbit/s
Transmission rate setting (Max/Min) for mobile BTS	Max: 900 kbit/s, Min: 900 kbit/s	Max: 900 kbit/s, Min: 900 kbit/s	N/A
Transmission rate setting (Max/Min) for femtocell	Max: 500 kbit/s, Min: 50 kbit/s	Max: 500 kbit/s, Min: 50 kbit/s	N/A

NOTE 3 – The satellite transmission rate required to connect BTS of 768 kbit/s in using the Ethernet interface.

2.8.3 Deploying a vehicle-mounted base station

Immediately after the earthquake, a vehicle-mounted base station appears as the most useful communication means, because it can be quickly dispatched from around the country and set up a telecommunication link in disaster areas.

The vehicle-mounted base station is equipped with base station equipment, a self-standing mobile antenna, a satellite modem, a satellite dish and an in-vehicle generator. Although it provides almost the same channel capacity as the macro base station, its cell range is smaller than that of the macro base station. Therefore, the vehicle-mounted base station tends to be dispatched at public facilities such as the city office, schools, etc. After the ordinary macro base station recovers its services, the vehicle-mounted base station ceases its operations and may move to other under-serviced areas.

In a catastrophic disaster, the operations by a vehicle-mounted base station can last for long periods. Special attention should be given to keeping personnel for maintaining the base station, foods and water for those personnel and to fuelling and exercising the generator regularly (see Fig. 8).

FIGURE 8

Vehicle-mounted base station and power supply

2.8.4 Restoring macro base stations with satellite backhaul

In parallel with dispatching a vehicle-mounted base station, it is important to restore coverage to the same level as before the disaster as soon as possible. There are two phases to the restoration of the base station operation:

1) restoration of existing base stations with the satellite backhaul;

2) reconstruction of a new facility.

In phase-1 the service will be restored after the power line is recovered or a generator is installed. Phase-2 includes removal of debris, repair of base station facilities and access lines to cellular base stations before operating the base station. Figure 9 shows the steps toward service recovery.

It should be noted that also introduced are the large-coverage base station scheme and terrestrial microwave radio to connect to the base stations in emergency or recovery situations.

Figure 10 shows the network configuration in using a macro base station with satellite backhaul. In a normal operation, the base station is connected to the mobile network centre by a terrestrial dedicated line. In the disaster relief phase, some portions of the terrestrial line in this scheme are replaced by the satellite backhaul. Current base stations employ interface of Ethernet or E1/T1 and the satellite systems also employ these interfaces. In some combination of the mobile system and the satellite system, an interface converter may be required at both the base station and the centre facility.

The delay in a satellite link could affect the link establishment between a base station and a base station controller. In some types of mobile systems it is necessary to adjust parameters, including timers, so as to establish the mobile backhaul link through the satellite system. Also to be adjusted is the depth of a jitter buffer. Jitter deviation in a satellite link can affect the link quality between a base station and a centre facility, and/or voice quality of mobile handsets. A buffer size of 40-60 ms in the interface converter can absorb the jitter deviation in the satellite link.

Since both voice and data traffic is transmitted in the E1/T1 bit stream, the QoS function to prioritize certain traffic is not required in this configuration.

FIGURE 9

Restoring base station with satellite backhaul

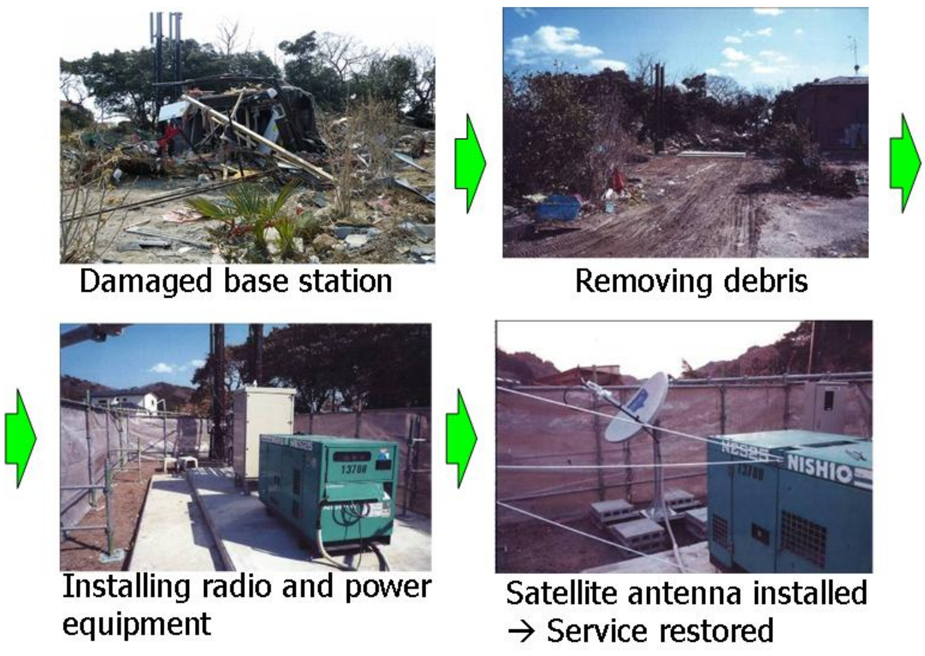
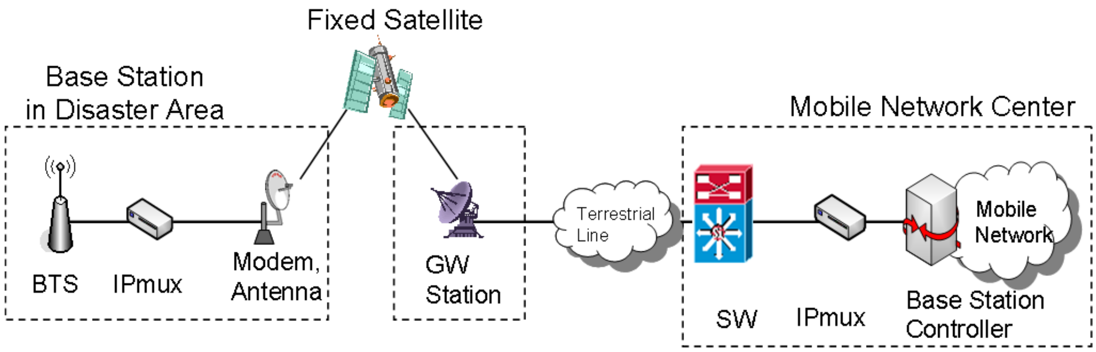


FIGURE 10

Network configuration in using a macro base station with satellite backhaul



2.8.5 Femtocell with satellite backhaul

The femtocell, which was originally developed for providing mobile services in underserved areas such as cell edges, underground areas, etc., also appears as a powerful means to provide mobile services as a supplement to a vehicle-mounted base station and/or a macro base station in an early stage of the disaster.

The biggest advantage is its size and weight. The example size is as small as 23(H) x 15(W) x 6(D) centimetres, the weight is one kilogram or less, and the power consumption is 20W or less. In the event that roads are damaged or blocked by debris, the femtocell can be transported by hand or a small vehicle.

The satellite antenna should also be transportable in order to maximize the advantage of the femtocell. Such a small (85 cm or less in diameter) and light-weight transportable satellite antenna can be used in spot beams in the FSS.

The femtocell covers only small areas due to its limited output power. As described above, the femtocell will supplement coverage areas and capacities of a vehicle-mounted base station and/or a macro base station in evacuation centres, public facilities, etc. Services provided by the femtocell are the same as the macro base station, i.e. all the voice and data communications can be provided.

With the low power consumption, energy or the fuel can be saved in a disaster situation. In the Great Japan East Earthquake, femtocells were operated only in daytime in evacuation centres such as schools, public facilities where a small generator was equipped.

Figure 11 depicts a network configuration in using a femtocell with the satellite backhaul which is similar to that of the macro base station. Since the femtocell employs the Ethernet interface, IP-based satellite systems have high affinity with the femtocell. The femtocell enables an effective use of the satellite bandwidth because the bandwidth can be shared among multiple femtocells, and in an idle state the femtocell does not waste the bandwidth, i.e. only transmits/receives small-size "keep-alive" packets (see also Fig. 12).

The femtocell employs unique ToS (Type of Service) values for voice and data communication in IP headers. The VSAT should be capable of prioritizing the voice packets to maintain voice quality equivalent to its QoS function.

FIGURE 11

Network configuration in using a femtocell with satellite backhaul

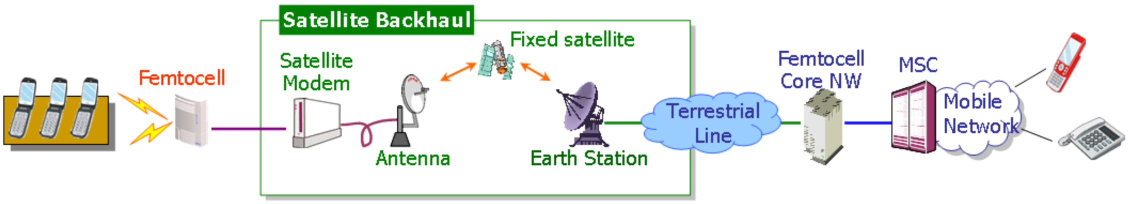
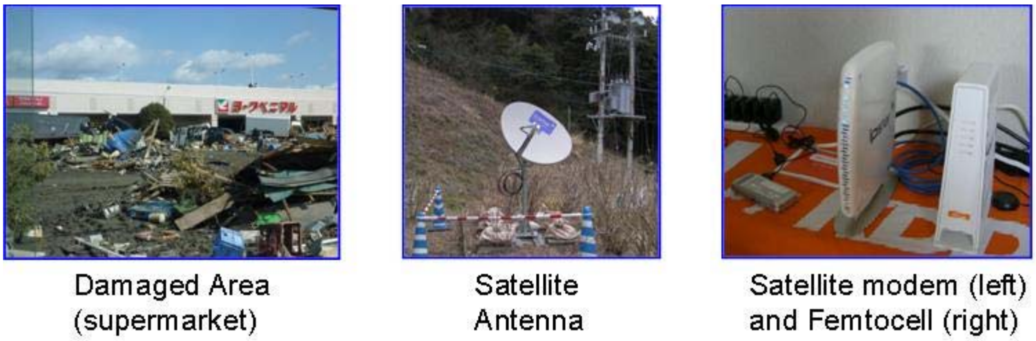


FIGURE 12

Installation of femtocell with satellite backhaul



3 An example describing use of FSS system for warning operations in the event of natural disasters and similar emergencies

3.1 Earthquake Early Warning System

In Japan, people have suffered from huge earthquakes since early times (see Fig. 13) and the demands on the protection of life and property and mitigation of damage to the functioning of society have been increased.

To respond to this demands, an observation network has been deployed all over Japan to seize P-wave by seismographs closely deployed to the epicentre and transmit the P-wave information to the meteorological centers responsible for processing such information (see Fig. 14).

The Japan Meteorological Agency (JMA) analyses this data and obtains the focus and magnitude of the earthquake and, based on these analyses, it estimates the expected arrival time and seismic intensity of the principal motion at each location. The advance announcement of these estimations is called the “Earthquake Early Warning” (EEW).

JMA currently uses this process to predict possibility of tsunami events and to provide early warning to the communities that may be impacted by such events.

FIGURE 13

Major earthquakes occurred around Japan (1996-2008 May)

(Obtained from the JMA website)

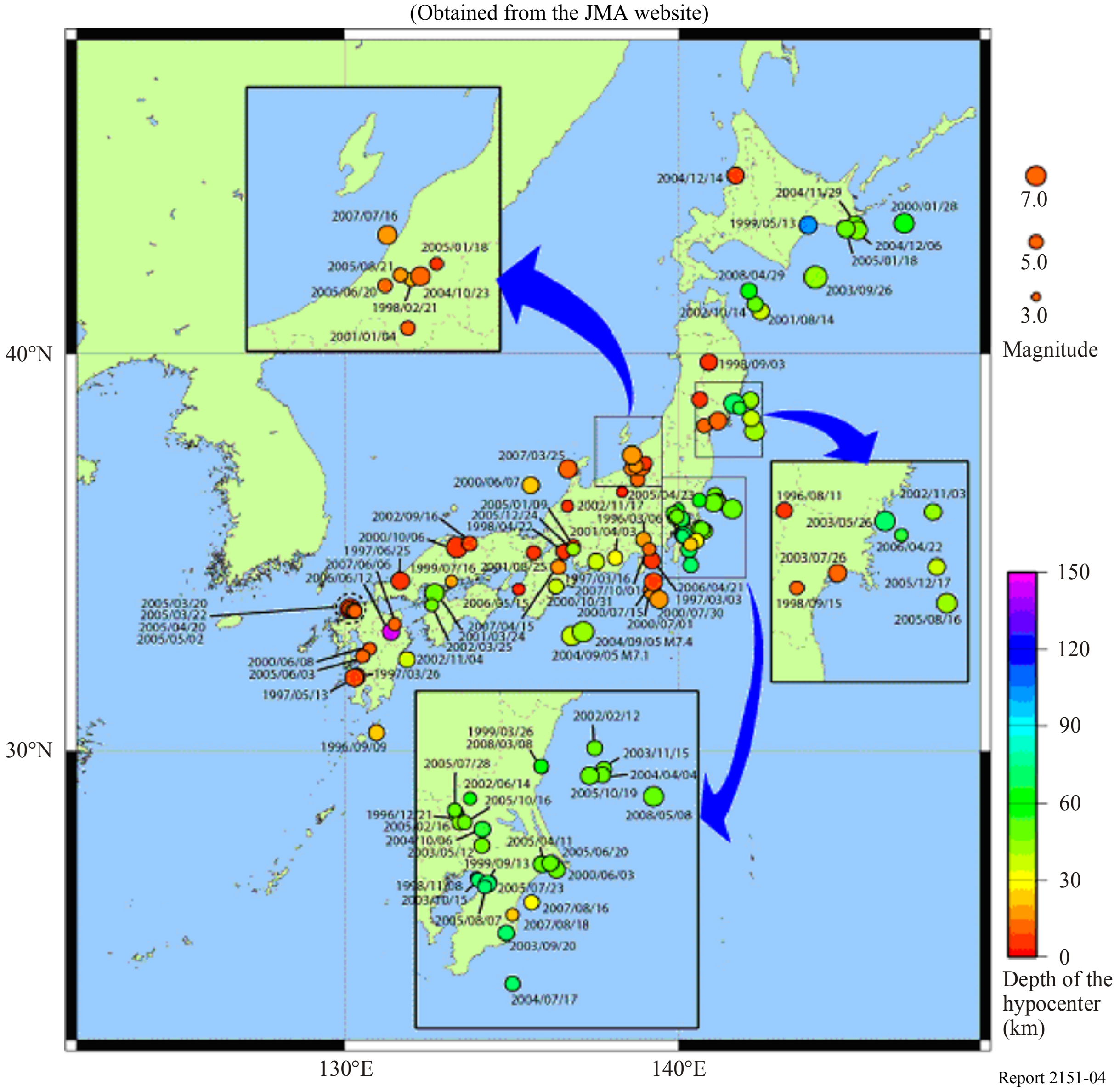


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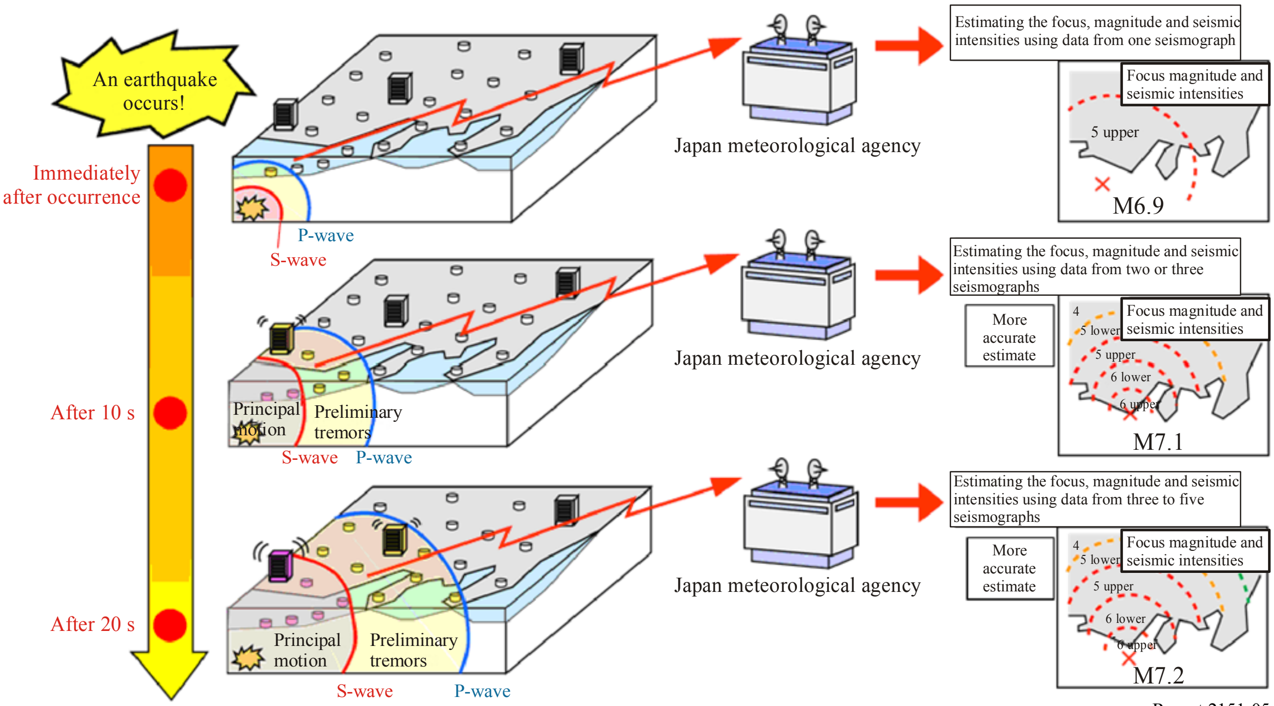
FIGURE 14

Mechanism of the EEW

(Obtained from the JMA website)



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3.2 Satellite delivery

In Japan, the EEW mentioned above is disseminated by various means, including FSS systems. In this section, advantages and system architecture of the EEW satellite delivery service are explained.

3.2.1 Advantage of the satellite network

Since a satellite network is inherently robust against natural disasters, information transmitted through satellite networks can be received securely and reliably even though the receiving site is close to the hypocentre. Unlike terrestrial-based networks, a satellite network is not likely to be congested or impaired in the event of natural disasters and similar emergencies.

Additionally, it is also an advantage of the satellite network that new receiver stations can be implemented with minimal difficulty anywhere within the coverage area of the satellite concerned.

3.2.2 Example of the system for satellite delivery

The outline of the EEW satellite delivery system is shown in Fig. 15, where the EEW sent by JMA is delivered via a satellite system to receiving terminals. The EEW information is also delivered through other telecommunications service systems.

The block diagram of the system is shown in Fig. 16. The EEW provided by JMA is delivered in a safe (from interception) and reliable (high-link performance) manner.

The IP multicast technology employed in this system allows customers and/or system integrators to customize user subsystems to meet their requirement. Additionally, the attached software enables receiving terminals to display necessary information concisely. Figures 17 and 18 show the system diagram of the receiving subsystem and screen display of the attached software, respectively.

FIGURE 15

Outline of the EEW satellite delivery system

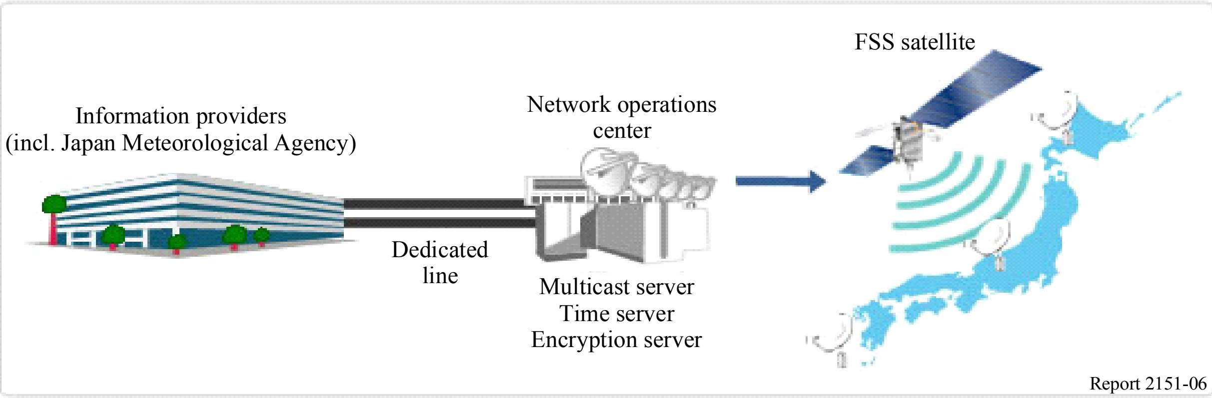


FIGURE 16

Block diagram of the EEW satellite delivery system

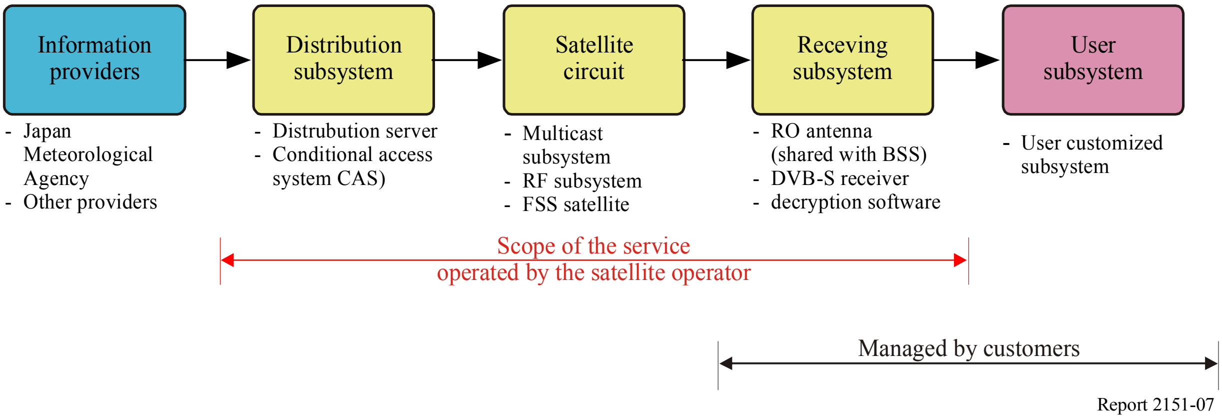


FIGURE 17

Receiving subsystem

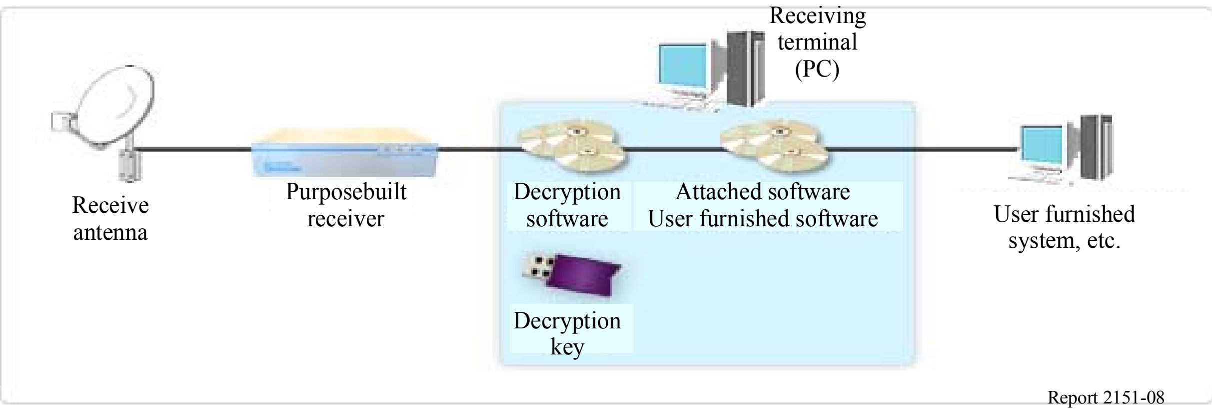
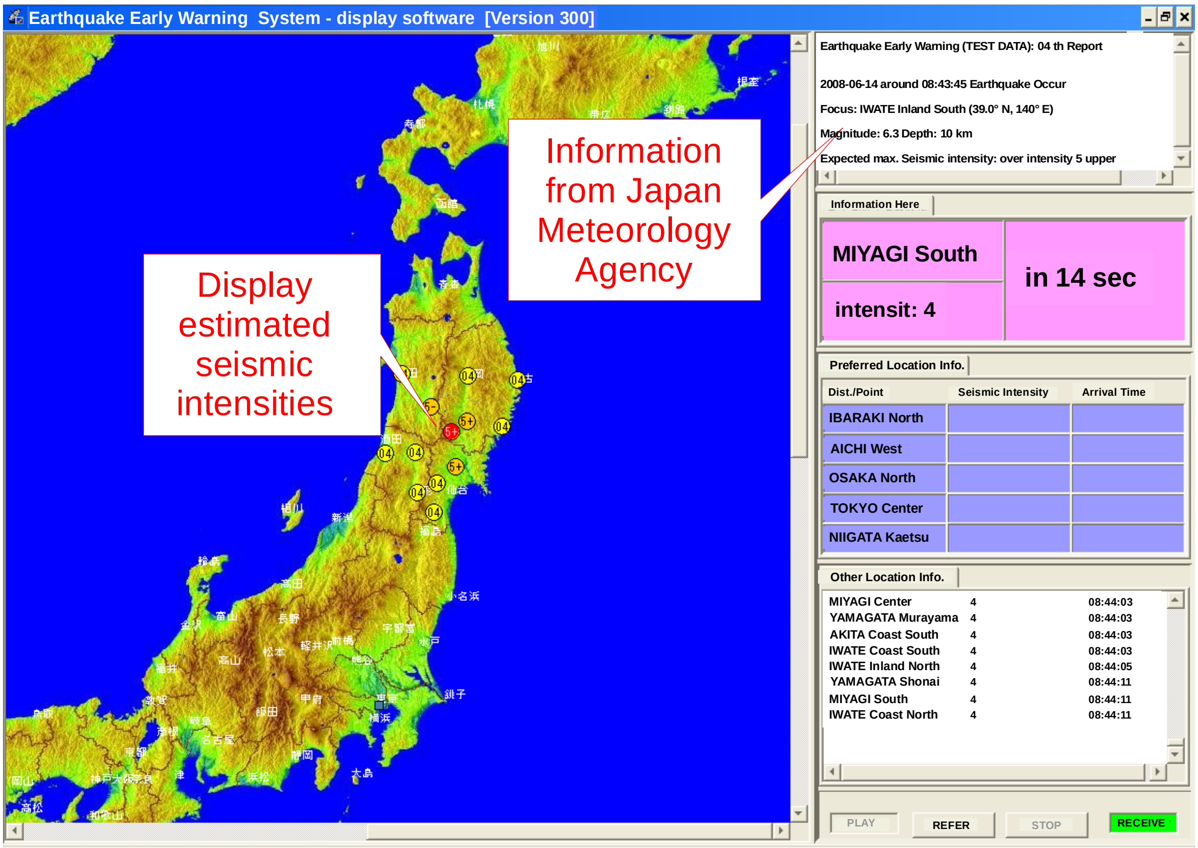


FIGURE 18

Example of screen display of the attached software



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3.3 Case examples of the EEW satellite delivery service

In the EEW satellite delivery receiving system, a number of functions such as contact output, audio playback, sending e-mail and so on can be customized to facilitate in-building announcements, radio warning devices, factory control equipment and video camcorder. These functions accommodate various entities such as railway companies, CATV operators, plants, schools, building management enterprises, elevator manufacturer and hospitals (see Fig. 19).

3.4 Further development of the satellite delivery system

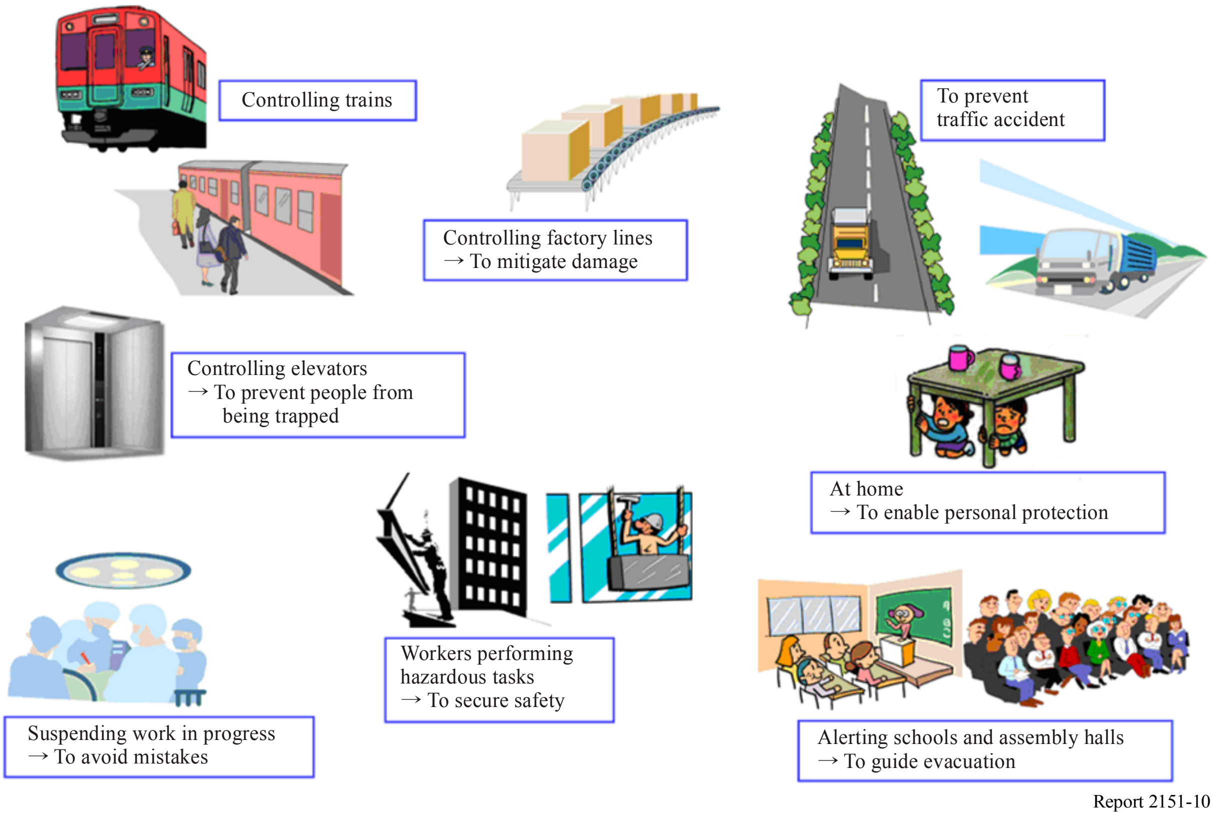
In Japan, prompt announcement and forecast of lightning strike and precipitation are also delivered through FSS networks.

An entity deployed a lightning observation network all over Japan to observe and record the location of lightening strikes, their time and lightning current magnitude and so on. This entity provides prompt announcement and forecast of lightning strike and precipitation.

FIGURE 19

Examples of utilization of the EEW

(Obtained from the JMA website)



4 Conclusions

This Report will be updated regularly.

Other examples of emergency networks associated with FSS are available in the draft new Report on Guidelines for Implementation of Satellite Telecommunications for Disaster Management in Developing Countries (see ITU-D Document 2/245).