The Seismic Alert System of Mexico (SASMEX) and their Alert Signals Broadcast Results

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SUMMARY
The Mexican Seismic Alert System (SASMEX) is integrated by the Seismic Alert System of Mexico City (SAS), in continuous operation since 1991, and the Seismic Alert System of Oaxaca City (SASO) that started its services in 2003. The SAS generates automatic broadcast of Public and Preventive Alert Signals to the cities of Mexico, Toluca, Acapulco and Chilpancingo, and SASO by now only to Oaxaca City. Two types of SASMEX Seismic Alert Signals ranges were determinated in accordance with each local Civil Protection Authorities: Public Alert if they expect strong earthquake effects and Preventive Alert Signal, for moderated once. Since 1993, the SAS is pioneer in the automatic public alerts broadcast services, thanks to the support of the Asociación de Radiodifusores del Valle de México, A.C. (ARVM). Today the SAS and SASO have been generated respectively 14 and 20 Public Alert Warning Signals. To reach better efficiency in the SAS warning delivery, the Mexico City's government auspice the installation of VHF radio transmitters, similar to the communication technology like the National Weather Radio (NWR) and Specific Area Message Encoding (SAME) called NWR-SAME, following the code standards of the National Oceanographic and Atmospheric Administration (NOAA) and the Emergency Alert Systems (EAS) of United States; adding a new code (SARMEX) with the capabilities like fast response (two seconds or less) to emit the earthquake early warning signal in order to enhance the effectiveness in the Seismic Alert Signals required.

Keywords: Earthquake Early Warning System of Mexico

1. INTRODUCTION

After experiencing the serious seismic disaster generated by the "Caleta de Campos" M8.1 Michoacán earthquake in 1985, Mexico City Authorities have been promoting since 1989 the design and evolution of *Sistema de Alerta Sísmica* (*SAS*) (Figure 1.1), with the aim to mitigate possible future earthquake damage produced by such as the latent "Guerrero Gap" seismic danger (Espinosa-Aranda, et *al*., 1992).

The original *SAS* idea was developed by *Centro de Instrumentación y Registro Sísmico* (CIRES) Civil Association. This technological resource started its experimental operation in August 1991 and has been available and evaluated as a public service since 1993. To date it is applied and evaluated in more than 80 elementary schools, both private and public, located in urban regions prone to seismic risk and where early warning of seismic alert signals from *SAS* has been useful, as well as in the Mexico City subway rail transport (METRO). Recently has started the installation of more than 40,000 NWR-SAME-SARMEX receivers for elementary public schools of Mexico City.

SAS disseminates public seismic alert in the valleys of Mexico and Toluca, this one located about 50 km NW of Mexico City. In addition, it also alerts on a contract basis to more than 280 miscellaneous institutions comprising schools, public buildings and emergency organizations.

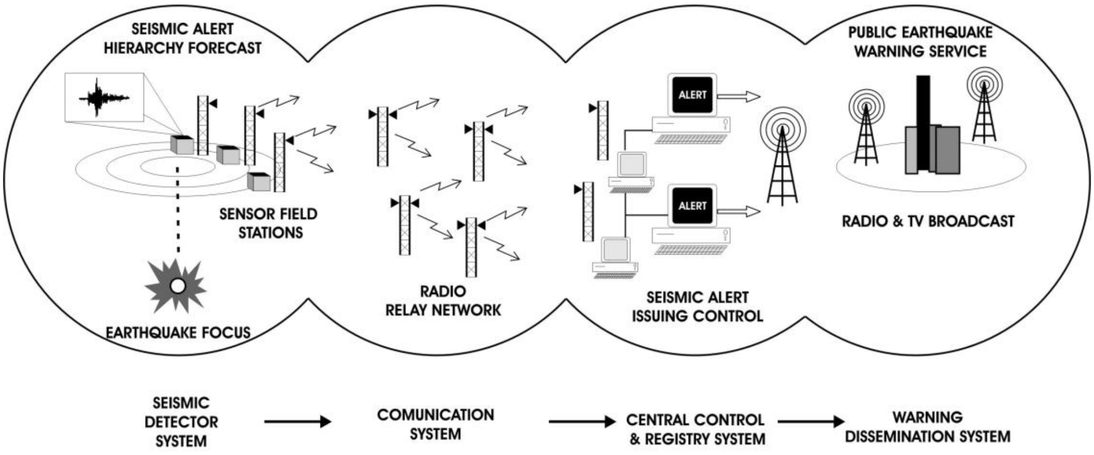

Figure 1.1 Seismic Alert System of Mexico diagram

The implementation of *SAS* in the Mexico Valley has made possible to anticipate the arrival of the effects of S-waves with an average of 60 seconds, time enough to allow execution of safety of automatic system procedures for the protection of equipment or systems susceptible to undergo damage, such as power plants, computer systems and telecommunication networks (Kanamori, 2003).

On May 14, 1993, after *SAS* identified an earthquake M6.0 and anticipated with 65 seconds the imminent arrival of its effect in Mexico City, the local authorities decided to disclose early warning notices publicly. The alert signal broadcast was possible thanks to the support from most of the commercial radio and television networks grouped in the *Asociación de Radiodifusores del Valle de Mexico* (ARVM), Civil Association, which agreed to contribute as a social service for their audience since August 1993.

SAS, has evolved aiming the best on availability and reliability of their four basic sub-systems: Seismic Detection, Communication, Warning Dissemination and Central Control and Recording, to guarantee the effective earthquake alert public service (Espinosa-Aranda, et *al*., 1995).

On September 14, 1995 at 8:04 AM in Mexico City, having elapsed almost ten years after the tragic earthquake of 1985 (Espinosa-Aranda, *et al*., 1995), *SAS* anticipated with 72 seconds the arrival of the effect of an M7.3 earthquake occurred near the town of Copala, Guerrero, This earthquake proved the adequacy of the processes of response and evacuation of schools, where the *SAS* early warnings were received, since the population performed these activities successfully (Goltz and Flores, 1997).

On June 15th 1999, a damaging M6.7 earthquake induced the Department of Civil Protection of Oaxaca to request CIRES the design, construction and installation of the *Sistema de Alerta Sísmica de Oaxaca* (*SASO*). A better time-efficiency criteria to define the seismic range of the *SASO* warnings, has outcome in a technological evolution from the original algorithm used by *SAS*, designed back in 1989 (Espinosa-Aranda *et al*., 1992), to fulfill the requirements demanded by this application.

Thanks to the Oaxaca Authorities initiative, the Mexico City Mayor, with the participation of the Mexican Secretariat of the Interior, it has been agreed a *SASO* and *SAS* function integration to constitute them as a single entity, the so-called *Sistema de Alerta Sísmica Mexicano* (*SASMEX*). And recently has been decided to increase as necessary the number of seismic sensors to provide an effective warning of impending regional seismic risk disseminating notices of seismic alert in vulnerable cities (Figure 1). With the service rendered by EA*SAS* systems in each sensible region, it will be possible to prevent in advance the seismic effects on the site as well as define the most suitable alert warning for each particular risk condition, and to review these factors systematically (Espinosa-Aranda, *et al*., 2009).

In 2007, to support the activities of Civil Protection of the coastal state of Guerrero, Mexico City Authorities authorized the installation of Alternate Emitters for the warning issued by the *SAS* (EA*SAS*) in the cities of Acapulco and Chilpancingo. The EA*SAS* of Guerrero provide public automatic alert services controlling the transmissions of the local commercial broadcasting stations covering the demand of private seismic alert services offered to 102 institutional users.

In order to improve the efficiency in the dissemination of the warning provided by *SAS* initially in schools, recently *La Autoridad del Centro Histórico* in Mexico City sponsored the installation of three dedicated VHF radio transmitters, thus benefiting by the use of commercially available low-cost receivers carrying the Public Alert™ logo, that meet technical standards of NOAA Weather Radio (NWR) Specific Area Message Encoding (SAME) protocols and the Emergency Alert System (EAS) event codes, such as those in use to warn against diverse natural hazards in the USA. The Mexico City application require the NOAA-SAME-EAS protocols, an enhancement in order to include a new code to operate earthquake early warning signals, without delay, omitting the normal two tones previous to signal advise (Espinosa-Aranda, *et al.*, 2009).

The Consumer Electronics Association Standards of United States (CEA), approved the Mexican Risks Advisory System (SARMEX) standard that uses all characteristics of the NWR-SAME protocols in March 2011, but enhances the response time when the Earthquake Early Warning codes are emitted, additionally, the Mexican earthquake early warning sound is included to distinguish it for the others messages codes.

2. SASMEX PERFORMANCE

The SASMEX for the Mexico City (called SAS) has been regarded as the first system in the world for earthquake early warning that disseminates its notices to the public (Lee, *et al*., 1998). The Prevention Time is close to 60 seconds. This is because the major seismic effects threatening the Valley of Mexico are originated at the coastal region of the Pacific Ocean at a distance of about 320 km and since their strongest components travel at a rate of 4 km per second, taking 80 seconds to arrive, whereas notices broadcasted by radio from the epicenter area can be transmitted instantaneously anticipating the seismic effects.

The SASMEX forecast begins calculating parameters measured in the Field Stations, FS, when a earthquake is detected, SASMEX in the Mexican Pacific Coast from Colima to Oaxaca, uses the acceleration data of the vertical, longitudinal and transversal components to calculate the Acceleration Quadratic Integration and the rate of this integration, both measured during the 2*(S-P) lapse, that is, the first P wave arrives until the S wave begins. In north and center of Oaxaca it uses the dominant period, measured in the vertical component during the first three seconds after de P wave begins; in case of the S-P is less than three seconds, then the FS uses two additional parameters: the Maximum Acceleration and the Acceleration Quadratic Integration, from the vertical component too (Espinosa-Aranda, *et al.*, 2011).

The parameters are sent automatically to determine the alert range, this forecast is used to define the seismic warning range of the impending occurrence of a dangerous earthquake detected by the first two FS (Espinosa-Aranda and Rodriguez, 2003). The first FS message defines the warning range, either strong or moderate, and with the second one, triggers the Type of Warning process respectively as “Public Alert” or “Preventive Alert”. However the range of Public and Preventive in Oaxaca, Chilpancingo and Acapulco is less than Mexico City, in order to be more sensible due to minor distance from these cities to the danger seismic area in contrast with Mexico City.

The Prevention Time is defined as the time elapsed between the beginning of the warning signal and the beginning of the S phase, related to the region where it is intended to mitigate the risk (Espinosa-Aranda et *al*., 2009).

SASMEX for Mexico City (SAS) since its experimental operational stage in 1991, *SAS* has detected more than 2300 seismic events with magnitudes from M3.0 to M7.4 and it has emitted 14 earthquakes warnings as “Public Alerts” and 59 as “Preventive Alerts (Table 2.1). The *SAS* performance showed in the Table 2.1 is accounted by the number of FS´s that registered each warned earthquake (# SENS. OP.), the Forecast (MAGNITUDE), the Type of Warning emitted (ALERT RANGE) and Prevention Time. The DISTANCE in Table 1 is measured from the epicenter to the first FS which detected the earthquake.

SASMEX for Oaxaca (called *SASO)* constitutes a technological development evolved from *SAS*; *SASO* has 36 FS and 11 radio relay stations to link its coastal, central, and northern included isthmus regions (Figure 2.1). Since its commissioning, *SASO* has issued 20 Public Alert and 13 Preventive Alert warnings from the detection and analysis of more than 230 sensed earthquakes (Table 2.2 similar to Table 2.1).

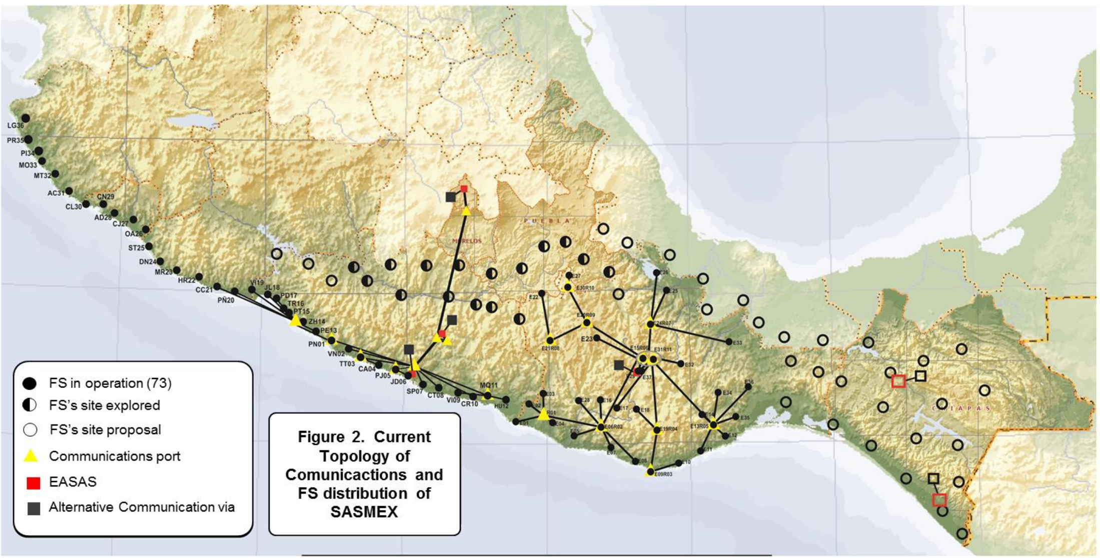

Figure 2.1. Current Topology of communications and FS of SASMEX

From April 2012, *SASMEX* identifies the strong earthquakes along the coast of the State of Guerrero, Michoacán, Jalisco and Colima with a linear layout of 36 of SAS and 11 of SASO FS spaced approximately every 25 km to be able to perform an efficient survey because many seismic foci of this region occur at similar depths (Figure 2.1).

Table 2.1. SAS Performance of earthquake early warnings since 1991 to 2012

		NACIONAL SEISMIC SERVICE (SSN), UNAM				SAS FORECAST RESULT		
#	Region	Local Date-Time	Latitude	Longitude	Depth (Km)	Sens. Op.	Alert Range	Prevention Time (s)
72	Oaxaca	02/04/2012 12:36	16.27	-98.47	10	6	Preventive	80
71	Oaxaca	20/03/2012 12:03	16.42	-98.36	15	7	Preventive	80
70	Guerrero	10/12/2011 19:48	17.84	-99.98	58	10	Preventive	16
69	Costa de Guerrero	18/06/2011 17:55	16.92	-99.60	26	5	Preventive	
68	Costa de Guerrero	05/05/2011 08:24	16.61	-98.91	11	6	Public	65
67	Costa de Guerrero	25/05/2010 18:36	17.11	-101.2	15	8	Preventive	63
66	Costa de Guerrero	27/04/2009 16:46	16.90	-99.58	7	4	Preventive	57
65	Guerrero	27/03/2009 02:48	17.35	-100.82	30	7	Preventive	58
64	Guerrero	11/11/2008 05:02	16.62	-100.8	15	4	Preventive	
63	Guerrero	06/11/2007 00:35	17.08	-100.14	9	9	Public	68
62	Guerrero	28/04/2007 08:56	16.94	-99.82	9	6	Preventive	
61	Guerrero	13/04/2007 03:43	17.27	-100.27	51	8	Preventive	56
60	Guerrero	13/04/2007 00:42	17.09	-100.44	41	6	Public	58
59	Guerrero	31/03/2007 00:18	17.00	-99.79	34	5	Preventive	
58	Guerrero	18/09/2005 06:25	17.05	-100.02	8	3	Preventive	

57	Costa de Guerrero	09/01/2003 20:08	16.97	-100.3	30	7	Preventive	58
56	Guerrero	27/09/2002 02:04	17.16	-100.59	37	4	Preventive	58
55	Costa de Guerrero	25/09/2002 13:14	16.86	-100.12	5	4	Preventive	57
C	Costa de Guerrero	18/04/2002 12:02	16.42	-101.1	15	0	Fail	
54	Costa de Guerrero	16/02/2002 22:10	16.94	-99.93	37	6	Preventive	
53	Costa de Guerrero	07/10/2001 22:39	16.94	-100.14	4	8	Public	65
52	Guerrero	06/03/2001 15:57	17.14	-100.1	32	9	Preventive	63
51	Costa de Guerrero	05/03/2001 04:17	17.13	-100.06	32	8	Preventive	66
50	Costa de Guerrero	14/04/2000 20:45	16.88	-100.35	9	5	Preventive	66
49	Guerrero	17/03/2000 18:50	17.08	-99.31	31	7	Preventive	68
48	Frontera Puebla-	15/06/1999 15:42	18.18	-97.51	69	9	Preventive	15
47	Guerrero	30/05/1999 04:58	17.26	-100.79	53	5	Preventive	68
46	Guerrero	24/04/1999 22:08	17.28	-100.8	27	4	Preventive	68
45	Costa de Guerrero	07/09/1998 01:53	16.77	-99.67	12	3	Preventive	
44	Costa de Guerrero	09/08/1998 11:18	16.87	-100.25	3	3	Preventive	
43	Costa de Guerrero	17/07/1998 06:18	16.98	-100.16	27	7	Public	74
42	Costa de Guerrero	05/07/1998 14:55	16.83	-100.12	5	6	Public	66
41	Costa de Guerrero	09/05/1998 12:03	17.34	-101.41	18	4	Preventive	60
40	Guerrero	11/03/1998 08:13	17.01	-100.11	40	4	Preventive	
39	Costa de Guerrero	21/12/1997 23:22	17.14	-101.24	5	5	Public	69
38	Costa de Guerrero	26/08/1997 19:13	16.76	-99.00	28	6	Preventive	45
37	Guerrero	19/07/1997 02:34	17.22	-100.56	51	6	Preventive	56
36	Costa de Oaxaca-	14/07/1997 20:26	16.39	-98.74	11	3	Preventive	
35	Costa de Guerrero	11/07/1997 17:23	16.76	-99.7	10	3	Preventive	
34	Low Balsas River	22/05/1997 02:50	18.41	-101.81	59	4	Preventive	
33	Guerrero	08/05/1997 10:58	17.32	-100.44	12	5	Preventive	55
32	Guerrero	23/03/1997 14:23	17.39	-100.88	31	4	Preventive	
31	Guerrero	21/03/1997 21:49	17.04	-99.76	30	7	Preventive	55
30	Costa de Michoacán	11/01/1997 14:28	17.91	-103.04	16	7	Preventive	42
29	Guerrero	27/10/1996 03:15	17.11	-100.9	27	3	Preventive	
28	Guerrero	19/07/1996 04:00	17.35	-100.29	20	6	Preventive	
27	Costa de Guerrero	15/07/1996 16:23	17.45	-101.16	20	6	Preventive	65
26	Costa de Guerrero	13/03/1996 15:04	16.52	-99.08	18	6	Public	74
25	Costa de Guerrero	16/09/1995 10:09	16.4	-98.69	10	2	Preventive	
24	Costa de Guerrero	15/09/1995 21:20	16.3	-98.62	10	4	Public	
23	Costa de Oaxaca-	14/09/1995 08:09				5	Preventive	
22	Oaxaca-Guerrero	14/09/1995 08:04	16.31	-98.88	22	9	Public	72
21	Costa de Oaxaca	31/05/1995 06:49	15.97	-98.77	14	2	Preventive	
20	Costa de Guerrero	14/04/1995 00:01	16.44	-99.09	15	6	Preventive	
19	Low Balsas River	10/12/1994 10:17	18.02	-101.56	78	6	Preventive	34
18	Costa de Guerrero	29/10/1994 10:44	16.97	-99.89	24	9	Preventive	58
17	High Balsas River	22/05/1994 19:41	18.03	-100.57	23	8	Preventive	30
B		16/11/1993 19:11				1	Public	
A	Costa de Guerrero	24/10/1993 01:52				9	(Fail)	
16	Costa de Guerrero	10/09/1993 04:50	16.57	-98.94	20	4	Preventive	70
15	Guerrero	29/07/1993 14:17	17.38	-100.65	43	4	Preventive	
14	Costa de Oaxaca-	15/05/1993 02:26	16.54	-98.65	20	4	Public	
13	Costa de Oaxaca-	14/05/1993 21:12	16.47	98.72	15	6	Public	73
12	Costa de Oaxaca-	14/05/1993 21:09	16.43	-98.74	20	6	Public	65
11	Costa de Guerrero	31/03/1993 04:18	17.18	-101.02	8	4	Preventive	
10	Costa de Guerrero	09/11/1992 20:13	16.89	-100.1	6	3	Public	
9	Costa de Guerrero	04/11/1992 22:33	16.83	-99.66	8	2	Preventive	
8	Costa de Guerrero	30/10/1992 02:16	17.14	-100.79	21	3	Preventive	
7	Costa de Guerrero	16/10/1992 11:28	16.51	-99.17	17.4	5	Preventive	
6	Guerrero	02/08/1992 06:54	17.13	-100.3	25	6	Preventive	
5	Costa de Oaxaca-	07/06/1992 11:41	16.22	-98.87	5.2	3	Preventive	
4	Costa de Oaxaca-	07/06/1992 03:01	16.17	-98.9	2	3	Preventive	
3	Costa de Guerrero	15/05/1992 02:35	16.83	-99.98	23	3	Preventive	
2	Costa de Guerrero	26/04/1992 14:53	16.78	-100.09	15	4	Preventive	
1	Costa de Oaxaca-	16/10/1991 12:36	16.83	-100.24	5	1	Preventive	

Table 2.2 SASO performance of earthquake early warnings since 2003 to 2012

		NACIONAL SEISMIC SERVICE (SSN), UNAM				SASO FORECAST RESULT		
#	**Region**	**Local Date-Time**	**Latitude**	**Longitude**	**Depth**	**Sens.**	**Alert**	**Prevention**
33	Oaxaca	13/04/2012 08:07	16.22	-98.15	16	12	Public	38
32	Oaxaca	13/04/2012 05:10	16.11	-98.34	14	12	Public	40
31	Oaxaca	02/04/2012 12:36	16.27	-98.47	10	15	Public	40
30	Oaxaca	23/03/2012 19:58	16.26	-98.29	10	5	Preventive	
29	Oaxaca	22/03/2012 17:47	16.48	-98.29	24	13	Public	40
28	Oaxaca	22/03/2012 16:14	16.22	-98.47	9	8	Preventive	
27	Oaxaca	21/03/2012 05:36	16.51	-98.5	20	5	Preventive	
26	Oaxaca	20/03/2012 14:14	16.34	-98.28	15	12	Preventive	
25	Oaxaca	20/03/2012 12:36	16.21	-98.58	14	9	Public	
24	Oaxaca	20/03/2012 12:23	---	---	---	10	Public	
23	Oaxaca	20/03/2012 12:02	16.42	-98.36	15	22	Public	40
22	Oaxaca	04/03/2012 03:58	16.68	-94.4	108	3	Preventive	
21	Oaxaca	11/02/2012 23:56	17.36	-96.51	96	6	Preventive	
20	Oaxaca	15/01/2012 16:49	16.35	-97.83	5	10	Preventive	
19	Oaxaca	30/12/2011 09:47	16.91	-95.37	90	4	Preventive	
18	Oaxaca	16/12/2011 07:02	16.22	-98.3	5	8	Public	
17	Oaxaca	09/07/2011 07:43	15.87	-96.42	22	18	Public	
16	Guerrero	05/05/2011 08:25	16.61	-98.91	11	15	Public	
15	Oaxaca	14/04/2011 11:34	16.7	-95.09	102	5	Public	
14	Veracruz	07/04/2011 08:12	17.2	-94.34	167	23	Public	
13	Oaxaca	05/04/2011 15:18	16.32	-96.15	15	4	Public	
12	Oaxaca	04/02/2011 11:32	17.25	-96.56	76	3	Public	
11	Oaxaca	30/06/2010 02:22	16.22	-98.03	8	22	Public	
10	Oaxaca	16/04/2010 05:01	16.14	-98.41	10	4	Public	
9	Oaxaca	08/02/2010 18:48	15.9	-96.86	37	14	Public	
8	Chiapas	05/07/2007 20:09	16.35	-93.99	113	5	Preventive	40
7	Oaxaca	15/03/2007 07:13	16.08	-97.26	15	6	Preventive	
6	Oaxaca	24/01/2007 22:23	16.21	-97.14	6	2	Preventive	
5	Oaxaca	19/08/2006 00:41	15.91	-97.3	52	8	Public	
4	Oaxaca	15/12/2004 02:05	16.05	-95.43	10	4	Preventive	
B	Oaxaca	18/08/2004 04:03	16.3	-95.12	63	9	(Comx	
A	Veracruz-Oaxaca	07/08/2004 06:49	17.06	-95.44	112	10	(Fail)	
3	Costa de Oaxaca-	14/06/2004 17:54	16.31	-98.06	10	6	Public	30
2	Costa de Oaxaca	13/01/2004 15:28	16	-97.16	14	10	Public	
1	Oaxaca	13/01/2004 13:50	16.01	-97.16	14	6	Preventive	

3. SASMEX WARNING BROADCAST

After the damages suffered in Mexico City during the 1985 earthquake, the law for Civil Protection and its bylaw were established. Among other requirements, it states that individuals and corporations must design action plans and emergency drills to mitigate vulnerability conditions and reduce the severity of disasters. Each action plan must be registered and certified in presence of municipal or local authorities that also supervise and enforce the regular practice of emergency response procedures (Suárez et *al*., 2009). The safety and security procedures, as well as the activity of each group in a certain facility, are established accordingly to the display of every building. Distribution of spaces and the identification of the risk and safety zones are considered. (Official Gazette of the Federation, 2006; Mexico City Official Gazette 1996).

SASMEX for Mexico City (SAS) has been able to recognize a great number of seismic events, encode their range, and spread warnings as Public or Preventive Alerts. This service operates through three alternative technologies: remotely controlled audio switches installed in radio and TV stations operated by *SAS* that broadcast Public Alert warnings for strong earthquakes; radio receivers that radiate warnings when *SASMEX* emits Preventive and Public Alert signals of strong and moderate earthquakes; and beginning in December of 2008, receivers that include NWR-SAME technology capable of disseminating the Preventive and Public *SAS*'s alerts, as well as other natural disasters' warnings. These warning messages represent a useful service to reduce the vulnerability against a variety of risk conditions. During 2009, in accordance to the Civil Protection of Mexico City Officials (*Secretaría de Protección Civil del GDF*), access to the use of the radio receiver makes mandatory to have an Internal Civil Protection Plan and practice emergency response procedures frequently.

Mexico City since 1992, have pioneered in the use of the *SAS* (Espinosa-Aranda, et al., 1998) beginning with twenty six Elementary Schools of the Ministry of Education of Mexico City (*Secretaría de Educación Pública de la Ciudad de México*). Each facility has an internal plan for civil protection that is systematically practiced and executed whenever *SAS* sends a warning signal to the radio receiver. From 1993 to the date, as stated before, more than 80 elementary, middle, and higher education institutions have been furnished with this equipment.

The Public Electric Transportation System and the METRO have used the *SAS* warnings by means of radio receivers in their control center since 1992, but they do not share the signals with the passengers. In case of a seismic warning, the manager of the control center gives proper instructions for the train operators to stop in the nearest station, or delay their start and keep the doors open for passengers' safety. This is an internal security and emergency procedure that has given great use to the 60 seconds that *SAS* can offer.

In Mexico, the transmission of radio and TV seismic alert signals began in 1993, through most of the partners of the Association of Broadcasters of the Mexico Valley (*Asociación de Radiodifusores del Valle de México A.C.*) and TV channels 11, 22, 13, and channel 34 in Toluca Valley. To be able of properly disseminate the signals, the broadcasters accepted the use of a remotely controlled switch operated by *SAS*, which substitutes the regular signal for the official alert signal during 60 seconds in case of a strong earthquake warning. The effectiveness of this resource is optimal in top rating periods because a greater part of the population is warned and can start predefined preventive actions. To date, twenty eight AM, FM and TV channels spread the warnings in Mexico City and Toluca Valley as well as nine radio and two TV stations in Oaxaca City. Also, Emergency Response and Civil Protection Institutions use the radio receiver to prepare emergency vehicles and start the evacuation of their parking lots. There are 13 institutions that use this equipment, including the Red Cross and Firefighters.

Nowadays, *SASMEX for Mexico City (SAS)* serves more than 240 public and private buildings in Mexico City; they receive seismic alert signals through the radio receiver. To guarantee the dissemination of the warning sound, some buildings have displayed loudspeakers arrays where their correct performance should be verified.

In addition to start preventive measures, *SASMEX* signals are used to trigger structural health recording procedures to identify possible damage in buildings.

Since March 27, 2009 at 02:48:32 (local time), when *SAS* emitted a "Preventive Alert" signal, anticipating the effects of the M5.3 earthquake from the coast of Guerrero.Then for the first time *SAS* used the NOAA-SAME technology validating the effective use of this resource. At that time eight monitoring NOAA receivers successfully reacted and provided 58 seconds of Prevention Time. Nowadays with a technical enhancement to expedite reaction, by reducing receiver's response time, the NWR-SAME with SARMEX protocol helps to mitigate the seismic vulnerability in Mexico.

On April 27, 2009 at 11:46:45 (local time), *SAS* emitted a signal of "Preventive Alert", anticipating the effects of the M5.7 earthquake from the coast of Guerrero. *SAS* confirmed the adequacy to use the NOAA-SAME technology in the city for this purpose.

SASMEX in Oaxaca has a similar range of users to the one of Mexico City, with the exception of automatic powerful loudspeakers installed in public spaces, which can be heard in the public squares of Oaxaca City.

As in Mexico City, Oaxaca and Toluca, in Chilpancingo and Acapulco both Guerrero State cities, received *SAS* warnings in more than 100 users, among radio, TV stations, schools, emergency response institutions and others in 2007, see Table 3.

On 20th March 2012,for the earthquake M7.4 of Oaxaca, SASMEX broadcasted Public Alert Warning to Oaxaca, and Acapulco cities, Chilpancingo and Mexico City, were activated with Preventive Alert Warning range, due to communication issues.

On April 13th 2011 SASMEX activated two earthquake early warnings at 05:10:03 08:07:23 (Local Time) for the seismic event M5.2 and 5.1 respectively;, with that seismic events, SASMEX for Mexico City worked for first time as an interconnected system.

4. DISCUSSION

Since damaging earthquakes are not so frequent, the development of this technological resource has deemed necessary to optimize the reliability and availability indexes of their basic elements in order to guarantee the effective dissemination of alert warnings in the occurrence of damaging events including forecasting criteria of seismic risk. The *SASMEX* system has its own designs and self-evaluation procedures as well as a continuing technological improvement program aimed to have an assurance of its services.

In the design, development and operation of *SAS* and *SASO*, it was acquired the compromise to improve continuously their subsystems that conform them as well as the processes of detection, computation, communication, forecast and effective broadcast of the warnings in case of earthquake. Nevertheless, other high-priority tasks must be reinforced by the authorities, like the diffusion and knowledge of the seismic danger around the city, the continuous program of prevention when the signal of seismic alert is emitted, the feasibility to acquire NOAA/SAME low-cost radios that could disseminate other natural hazards, enhance of coverage of the seismic zone, etc.

Public-oriented discussions together with the proper detection of the earthquake, the reliability of message transmission and the risk evaluation constitute necessary elements in the systems of early warning systems. However, if dissemination and training campaigns launched among the population exposed to natural hazards continue to be insufficiently funded, any early warning system will be exposed to failure to comply with its main objective for which it was designed (United Nations, 2006). The technological development of early warning systems applicable to earthquakes is continuously improving and it is convenient to analyze the full spectrum of earthquake early warning as a whole (Malone, 2008).

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