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DATA ACQUISITION SYSTEMS IN THE "VALLE DE LOS CAIDOS" AND "CUEVA DE LOS VERDES" STATIONS

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ABSTRACT :
Both in the stations of the "Valle de los Caidos", near Madrid, and in the "Cueva de los Verdes", in Lanzarote, Canary Islands, two sets of data acquisition equipment have been set up that allow for the registration of all the information produced in both stations. Taking into account the special features of both locations, the two systems respond to different building principles, but their services are mainly similar. In this communication we give a description of both sets of equipment and present the results obtained.

1. DATA ACQUISITION SYSTEM IN THE "VALLE DE LOS CAIDOS"

The "Valle de los Caidos" (0401) is a geodynamic station, where permanent observation of earth tides (R. Vieira et al.,1986) has been carried out since 1973; it is located near Madrid, at approximately 50 Km., and is visited by staff from the institute once or twice a week. During these years of research, various instruments have been installed (R. Vieira et al, 1986) and new sensors will be installed in the near future (water-tube, extensometer, vertical pendulum,...).
Taking these characteristics into account, thought was given to developing a new data acquisition system, with the main interest being focused on: low power consumption, thus enabling it to operate during power cuts; it should be portable, given the nature of the entrance to the station; it should be versatile, capable of recording data from a large number of different sensors and of acting upon them; and it should be a system open to possible modifications as a result of experience in its use; for this reason, thought was given controlling the system by computer.

1.1. CONFIGURATION

The system was developed in collaboration with the electronics company GEONICA, S.A.; it comprises (figure 1): a central computer (Olivetti M24 with 20 MB hard disk); signal conditioners; a 12 bit A/D converter (DATA TRANSLATION) with differential inputs; variable gain amplifiers(2,4,8,16,32,64); 16 unipolar, or 8 differential input channels; auxiliary D/A outputs and 16 digital outputs for motors control. The measurement range is 5 volts, which varies in terms of the gain selected.

1.2. ACQUISITION PROGRAM

Figure 2 is a diagram of the data acquisition program utilized. The program enables us to collect data from all the sensors connected every dt time. Data is collected by realizing averages centred on the instant of the data, To, of the readings taken every two seconds. The interval of time between each average dt, as well as the period of time used to take the reading, $2\Delta T$, is determined from the computer, and may vary.

It was shown that this sampling method had no effect on the amplitude and that it causes no phase lag either, given that it is a centred average.

The computer stores the readings in its cyclical memory, which enables us to detect and record earthquakes. This is done by comparing the signal with the last average, and when this exceeds by n times the value of the product of a given constant k multiplied by the average, the earthquake recording equipment is activated, and files are formed with data every two seconds.

During the collection of data, the computer responds to the keyboard, in which the function keys have been programmed, and it has a set of screens with: data in real time in mV and in physical units, values of the last averages of all the sensors data on the stations, date and hour, whether an earthquake is being recorded at that moment, etc. Modifications may also be made to a whole range of parameters, such as the date, hour, etc..

In principle, considering international standards for the recording of meterological data, data acquisition was programmed for every ten minutes, and an average was taken of the readings made every two seconds for two minutes.

1.3. INSTALLATION

Once the system had been developed, to make it easier to control, it was first installed in the Madrid station (0402) located in the basements of the I.A.G. The instruments connected to the system were as follows: pressure, temperature and relative humidity sensors and the Lacoste romberg gravimeter, mod. G, N° 655, modified as a zero gravimeter (M.V. Ruymbeke, 1985).

The data was stored in two files, one for the meteorological parameters and another for the other sensors (in this case, only the gravimeter). The results of the analysis of the gravimetric tide data may be seen in Table 1, in which, though using a short serie of data, the errors and standard deviations are small. In the results of the atmospheric pressure data analysis (Table 2), the only relevant effect is semidiurnal; S2K2, with an amplitude of 0.5 mb. One problem that we have found has been the effect of the earthquakes on the tide signal, which is not filtered normally by the sampling method.

To make the handling of the data easier and more efficient, the collection programme was modified so that the files would be daily ones. Also, to facilitate consultation of the data, the hard disk was divided into four directories: tide, meteorological parameters, calibrations and earthquakes. One tide file uses 10657 bytes of memory, a meteorological parameter file uses 8497 bytes, and the calibrations and earthquakes files both use 48664 bytes. Therefore the storage capacity, supposing there are 15 MB free in the PC, would be:

without any earthquake or calibration file aproximately 26 months; with one earthquake or calibration file a day 7.5 months.
The possibility was introduced by pressing a key, of interrupting the programme and going to a menu which allows us to: go to the PC operative system, record the data on a floppy disk, visualize the file contents, and also to graphically represent any parameter. It is similarly easy to return to the acquisition program.
After the satisfactory test in Madrid, it was installed in the Valle de los Caidos station (0401). The pressure, temperature and humidity sensors were connected to it, together with the Askania GS15 gravimeter, modified to a zero instrument at our Institute (M. Orejana et al., 1983).
For diverse reasons unrelated to the data collection system, we have not been able to obtain a sufficiently ample set of gravimetric tide data to be able to make an analysis, from which to draw definitive conclusions. However, we may, by way of example, compare the output obtained with the preprocessing method of S. Nakai (1977, 1979) for two sets of data, one obtained with the Acquisition System and the other with an analogical recorder (Table 3). The greatest standard deviations are due in main to the occurrence of earthquakes or to the realization of drift corrections. In the absence of any of these problems, the quality of the digital register is enhanced. A wider set has been obtained from the atmospheric pressure data, which has enabled us to make an analysis (Table 4) where the clearest effect, again, is semidaily and meteorological (S2 wave). With the continuous register of the meteorological parameters, we have been able to contrast the great thermic stability of the station, where the daily variations in temperature are of around 1 or 2 tenths of a degree.
We have once more encountered the problem of the effect of the earthquakes on the tide signal, and a good example of this is to be seen in Figure 3 We must work on this in two aspects: on the filtering when collecting the data and on the elimination of the residual effect after the filtering. Another path that could be taken would be to use the system's digital outputs for the control of motors, for correcting drift and calibrating the sensors, thus eliminating all possible personal errors.

2. DATA ACQUISITION SYSTEM IN THE "CUEVA DE LOS VERDES" STATION

Due to the characteristics of the Cueva de Los Verdes station in Lanzarote (R. Vieira el al., 1988, 1989), we had to overcome several problems in the installation of a data acquisition system: it should not be difficult to transport, given the difficult access to the station, through the volcanic tunnel; it should work by itself and require minimum maintenance; furthermore, it should be able to transmit the data to a computer located outside the tunnel, and thus at a considerable distance from the station. For this reason, a system developed by GEONICA S.A. (internal document) was chosen and a series of modifications were necessary in order to adapt it to our needs.

2.1. CONFIGURATION AND CHARACTERISTICS

This acquisition module is a closed system, which consists of 16 analog input channels with a range of measurements between 2500mV, with an A/D conversion time of 800 fsec. The input impedance is > 10 MΩ in voltage and 10 Ω ± 0.02 % in current. It has 24 digital input/output signals; a processor and associated logic in CMOS technology, low power consumption; "watch-dog" supply failure

detection and data protection monitoring circuit; clock and calendar; memory of 256K RAM CMOS with Li-battery for retaining data; RS232C and FSK communication lines. External supply may be 220 VAC or 12VDC; it also has internal supply of 12VDC/7 Ah NiCd batteries (rechargable from mains).
The input signals are protected with "tranzorb" diodes and "RC" filters, and supply inputs are protected with fuses and varistors. The environmental operating conditions are: between -15 and +70 degrees centrigrade and between 0 and 100% relative humidity, without condensation.
All the components are contained in a lockable box which is protected from humidity by a special covering. To enable its handling and use, there is a display (4x40 alphanumeric characters) and a frontal keyboard which permits us to call up instantaneous values, which will be shown in the relevant units on the display; to call up the results obtained during the latest computation period; to change the computation period; to change the date and time, and data may be transferred to an 80-column serial printer connected to the system via RS232C.

2.2. ACQUISITION AND COMMUNICATION

The programme, as well as the acquisition method, are analog to the acquisition system of the Valle de los Caidos. The main difference is that this system is not equipped to register earthquakes. Furthermore, when the average data is calculated and stored in memory, the maximum and minimum values of the signal during the sampling time, is also stored.
The reading of the data stored in memory, which as we have seen, may be printed out at the site of the system, is normally done directly via a PC, with two communication options (Figure 4):

- by means of on site connection via RS232C
- by means of an internal modem which transmits the data through a two-wire conductor (600 Ω, electrically isolated) through Frequency Shift Modulation (FSK), duplex, with the data being received at the UCO-V21 Communications Unit, which adapts the FSK signal to an RS232C serial interface, thus allowing communication with a computer located at a maximum distance of 5 km.

As was noted before, the communication expected to be used normally in our case is of the second type, where the system communicates with a computer located in the Casa de los Volcanes, over one kilometer away. In both communications it is possible to request instantaneous data, stored data, daily average data, consult the data base (on screen or via the printer); modifications may also be made to the constants or the operating mode, for example, the state of the clock may be corrected or the average period may be modified. all the information is viewed on a series of screens. The data storage capacity, taking one piece of data from all the sensors every 10 minutes, is of 30 days.

2.3. INSTALLATION

This system has been installed recently, and has been connected to the following sensors: Lacoste Romberg gravimeter, model G, N°434, modified as a zero gravimeter by M. Van Ruymbeke; pressure, temperature and humidity sensors, high precision sensors for measuring rock temperature (M.V. Ruymbeke et al., 1989); and a two component vertical pendulum. We hope to obtain results in the near future. To only use the computer when communication is established with the acquisition system, will enable us to develop a series of preprocessing and processing programmes for all the signals collected that are run automatically after each reading of data stored in the system, which provides us quick preliminary results.

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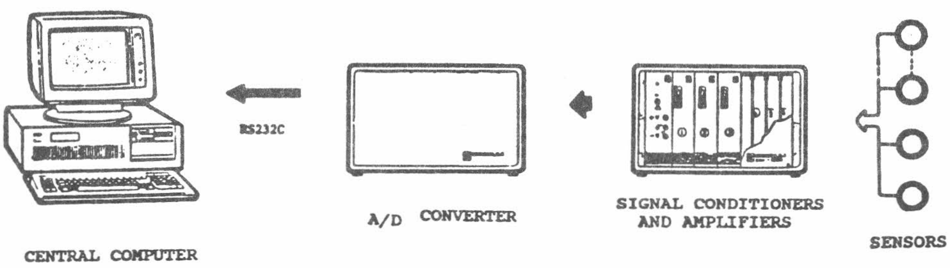

Figure 1

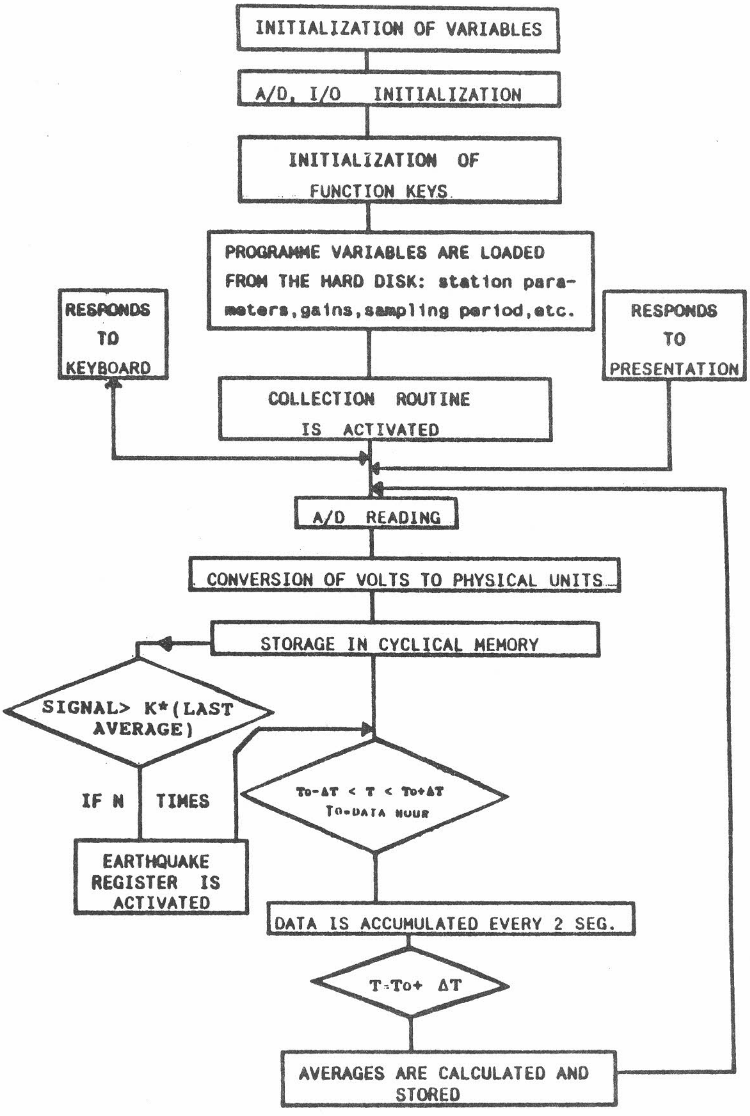

DIAGRAM OF DATA ACQUISITION PROGRAM

Figure 2

TRANS IBERIAN PENINSULA PROFILE STATION MADRID

STATION 0402 MADRID VERTICAL COMPONENT SPAIN
40 27 N 03 43 W H 630 M P 5 M D 310 KM

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SOTANOS DE LA FACULTAD DE CIENCIAS
FORMACION TERCIARIA (MIOCENO)
ALTERNANCIA DE ARENISCAS ARCILLOSAS Y SABULOSAS, INTERCALANDO LECHOS
CALCAREOS EN LA CAPA SUPERIOR Y CANTOS EN LA INFERIOR
GRAVIMETRO L.R. MOD G 665 (M-0) (M. VAN RUYMBEKE)
CALIBRATION VALLE DE LOS CAIDOS. FUNDAMENTAL STATION
INSTALATION: R.VIEIRA
MANTENANCE : R.VIEIRA, J.FERNANDEZ

LEAST SQUARE ANALYSIS / VENEDIKOV FILTERS ON 48 HOURS / PROGRAMMING B. DUCARME
POTENTIAL CARTWRIGHT-TAYLER-EDDEN / COMPLET DEVELOPMENT
COMPUTING CENTER OF UNIVERSIDAD COMPLUTENSE DE MADRID
COMPUTER IBM 360 PROCESSED ON 88/ 5/30

INERTIAL CORRECTION PROPORTIONAL TO THE SQUARE OF ANGULAR SPEEDS
NORMALISATION FACTOR 0.99237
PHASE LAG O1 0.20 M2 0.41 O1/M2 0.49
INSTRUMENTAL LAG 5.41 MIN.
CORRECTION FOR ATTENUATION O1 1.00001 M2 1.00003 /MODEL 1/

87 1 8/87 110 87 114/87 120 87 123/87 131 87 2 6/87 2 6 87 210/87 212
87 215/87 221 87 224/87 3 4 87 3 7/87 3 7 87 310/87 314 87 319/87 319
87 324/87 328

TIME INTERVAL 80.5 DAYS 1488 READINGS 11 BLOCKS

WAVE GROUP ARGUMENT	N	WAVE	ESTIMATED AMPL.	R.M.S.	AMPL. FACTOR	R.M.S.	PHASE DIFF.	R.M.S.	RESIDUALS AMPL.	PHASE
115.-11X.	11	SIGMQ1	0.35	0.11	1.5408	0.6116	5.31	22.27	0.09	20.8
124.-129.	21	SIGMA1	1.15	0.11	1.2264	0.1176	-15.53	5.51	0.31	-86.2
133.-139.	30	Q1	6.76	0.14	1.1514	0.0233	-1.24	1.15	0.15	-108.5
143.-149.	26	O1	35.25	0.13	1.1490	0.0041	-0.76	0.21	0.57	-124.2
152.-158.	22	M1	2.60	0.15	1.0771	0.0627	3.39	3.33	0.25	142.7
161.-168.	33	PISIK1	48.16	0.14	1.1162	0.0031	-0.37	0.16	0.98	-161.2
172.-177.	22	J1	2.92	0.14	1.2103	0.0575	1.83	2.71	0.15	38.6
181.-186.	18	OO1	1.58	0.09	1.1960	0.0660	-1.67	3.16	0.07	-45.0
191.-195.	14	NU1	0.15	0.09	0.6111	0.3672	-4.22	34.08	0.14	-175.3
215.-22X.	19	EPS2	0.38	0.06	1.1755	0.1769	-3.31	9.03	0.02	-78.8
233.-23X.	20	2N2	1.45	0.05	1.0909	0.0339	1.63	1.77	0.10	156.1
243.-248.	24	N2	9.36	0.06	1.1244	0.0067	4.93	0.34	0.87	112.4
252.-258.	26	M2	49.83	0.05	1.1457	0.0012	4.44	0.06	3.94	101.4
262.-265.	14	L2	1.39	0.02	1.1273	0.0201	3.20	1.03	0.09	118.8
267.-277.	21	S2K2	24.01	0.04	1.1866	0.0020	3.39	0.10	1.50	70.8
282.-285.	15	ETA2	0.40	0.04	1.2905	0.1305	0.58	5.81	0.04	5.8
292.-295.	11	2K2	0.12	0.02	1.5127	0.2598	10.96	9.80	0.04	41.5
335.-375.	16	M3	0.67	0.02	1.0250	0.0358	1.20	1.96	0.02	35.1

STANDARD DEVIATION D 3.55 SD 1.11 TD 0.53 MICROGAL
STUDENT FACTOR T(S=95(,M> 53)=1.96

O1/K1 1.0294 1-O1/1-K1 1.2822 M2/O1 0.9972
CENTRAL EPOCH TJJ= 2446843.0

Table 1

MAREA ATMOSFERICA

ESTACION	MADRID (0402).
SITUACION	40 27 N - 03 43 W
ORGANISMO RESPONSABLE	INSTITUTO DE ASTRONOMIA Y GEODESIA (C.S.I.C. - U.C.M.)
SENSOR DE PRESION	NUMERO 002
MODULO DE ADQUISICION DE DATOS	
INSTALACION	F.LAMBAS, R.VIEIRA, C.TORO, J.FERNANDEZ
CALIBRACION	GEONICA S.A.
MANTENIMIENTO	J.FERNANDEZ, R.VIEIRA
ANALISIS	MINIMOS CUADRADOS. FILTROS DE VENEDIKOV SOBRE INTERVALOS DE 48 HORAS. POTENCIAL CARTWRIGHT-TAYLER-EDDEN. DESARROLLO COMPLETO CENTRO DE PROCESO DE DATOS DE LA UNIVERSIDAD COMPLUTENSE DE MADRID. COMPUTADOR I.B.M. 4381 PROCESADO EL 89/ 7/19
INTERVALO DE OBSERVACION	87 1 8/87 118 87 124/87 130 87 2 6/87 328
	80.5 DIAS 1728 LECTURAS 3 BLOQ

GRUPO			AMPLITUD		FASE	
ARGUMENTO	N	ONDA	H	E.Q.M.	DIF.	E.Q.M.
115.-11X.	11	SIGMQ1	0.353	0.1441	-10.59	23.46
124.-129.	21	SIGMA1	0.139	0.1188	85.91	48.57
133.-139.	30	Q1	0.130	0.1402	-54.35	62.04
143.-149.	26	O1	0.149	0.1365	82.49	52.27
152.-158.	22	M1	0.206	0.2009	-77.73	55.69
161.-168.	33	P1S1K1	0.194	0.1486	-36.55	44.02
172.-177.	22	J1	0.096	0.1287	10.37	76.95
181.-186.	18	OO1	0.162	0.0905	10.95	31.84
191.-195.	14	NU1	0.102	0.0910	40.67	51.13
215.-22X.	19	EPS2	0.022	0.0438	-12.50	113.58
233.-23X.	20	2N2	0.087	0.0340	-59.85	22.40
243.-248.	24	N2	0.045	0.0420	-81.45	52.30
252.-258.	26	M2	0.055	0.0367	58.18	38.31
262.-265.	14	L2	0.026	0.0212	-72.73	46.11
267.-277.	21	S2K2	0.529	0.0287	-72.43	3.10
282.-285.	15	ETA2	0.007	0.0275	-67.22	239.57
292.-295.	11	2K2	0.015	0.0149	-78.92	55.67
335.-375.	16	M3	0.061	0.0302	54.77	28.50

Table 2

ANALOGIC RECORDING OF DATA					DIGITAL RECORDING OF DATA				
212 4014771389 7 60	1.00356	0.00*	4084.94	1.04	212 4014771389 7 60	1.00618	-0.01	1608.38	0.94
212 4014771589 7 80	0.99100	0.25*	4031.01	0.79	212 4014771589 7 80	0.99210	0.05	1661.99	0.74
					212 4014771789 7100	0.99444	0.12	1722.03	0.99
212 4014772089 7122	0.98866	1.43*	3884.82	0.68	212 4014772089 7122	0.99455	1.06	1791.73	0.59
212 4014772289 7142	0.99573	0.99*	3804.46	1.11	212 4014772289 7142	0.99929	0.95	1872.00	0.85
212 4014772489 7162	0.99770	1.13*	3739.48	1.11	212 4014772489 7162	1.00038	1.23	1938.28	0.99
212 4014772689 7182	1.00154	0.58*	3664.69	1.11	212 4014772689 7182	1.00593	0.50	2013.28	0.62

Table 3

MAREA ATMOSFERICA

ESTACION	VALLE DE LOS CAIDOS (0401).
SITUACION	40 38 N - 04 09 W
ORGANISMO RESPONSABLE	INSTITUTO DE ASTRONOMIA Y GEODESIA (C.S.I.C. - U.C.M.)
SENSOR DE PRESION	NUMERO 002
MODULO DE ADQUISICION DE DATOS	
INSTALACION	J.FERNANDEZ, R.VIEIRA
CALIBRACION	GEONICA S.A.
MANTENIMIENTO	J.FERNANDEZ, R.VIEIRA, J.VELASCO, J.L.VALBUENA
ANALISIS	MINIMOS CUADRADOS. FILTROS DE VENEDIKOV SOBRE INTERVALOS DE 48 HORAS. POTENCIAL CARTWRIGHT-TAYLER-EDDEN. DESARROLLO COMPLETO CENTRO DE PROCESO DE DATOS DE LA UNIVERSIDAD COMPLUTENSE DE MADRID. COMPUTADOR I.B.M. 4381 PROCESADO EL 89/ 7/19

INTERVALO DE OBSERVACION 871015/8711 2 8711 9/871113 871126/8712 8
88 113/88 119 88 2 5/88 227
INTERVALO DE OBSERVACION 88 3 4/88 314 88 4 9/88 419 88 423/88 5 3
88 512/88 528 88 6 2/88 720
INTERVALO DE OBSERVACION 88 723/88 816 881119/89 124 89 128/89 213
89 3 5/89 510 89 514/89 6 5
601.0 DIAS 9120 LECTURAS 15 BLOQ

GRUPO			AMPLITUD		FASE	
ARGUMENTO	N	ONDA	H	E.Q.M.	DIF.	E.Q.M.
115.-11X.	11	SIGMQ1	0.031	0.0289	-21.16	53.13
124.-126.	10	2Q1	0.039	0.0294	-24.00	43.47
127.-129.	11	SIGMA1	0.018	0.0292	-40.69	95.49
133.-136.	20	Q1	0.047	0.0284	-89.64	34.43
137.-139.	10	RO1	0.022	0.0287	-7.30	75.55
143.-145.	16	O1	0.048	0.0277	87.96	32.88
146.-149.	10	TAU1	0.031	0.0401	-78.67	73.11
152.-155.	15	NO1	0.026	0.0221	28.41	49.32
156.-158.	7	KI1	0.040	0.0271	-13.54	38.73
161.-163.	10	P1	0.049	0.0322	77.86	37.84
164.-168.	23	S1K1	0.053	0.0288	-49.91	31.16
172.-174.	8	TETA1	0.018	0.0273	-69.92	86.88
175.-177.	14	J1	0.074	0.0279	83.03	21.49
181.-183.	7	SO1	0.027	0.0268	64.69	57.33
184.-186.	11	OO1	0.037	0.0177	70.65	27.60
191.-195.	14	NU1	0.021	0.0187	-17.55	49.73
215.-22X.	19	EPS2	0.008	0.0116	-20.00	83.74
233.-23X.	20	2N2	0.026	0.0098	-48.80	21.29
243.-248.	24	N2	0.007	0.0116	6.32	99.94
252.-258.	26	M2	0.016	0.0111	-17.50	38.77
262.-264.	5	LAMB2	0.006	0.0113	60.57	103.21
265.-265.	9	L2	0.022	0.0107	-70.84	28.15
267.-273.	9	S2	0.543	0.0107	-58.24	1.12
274.-277.	12	K2	0.023	0.0082	-43.18	20.61
282.-285.	15	ETA2	0.006	0.0076	34.66	74.61
292.-295.	11	2K2	0.005	0.0044	-8.42	50.63
335.-375.	16	M3	0.022	0.0100	-74.17	25.93

Table 4

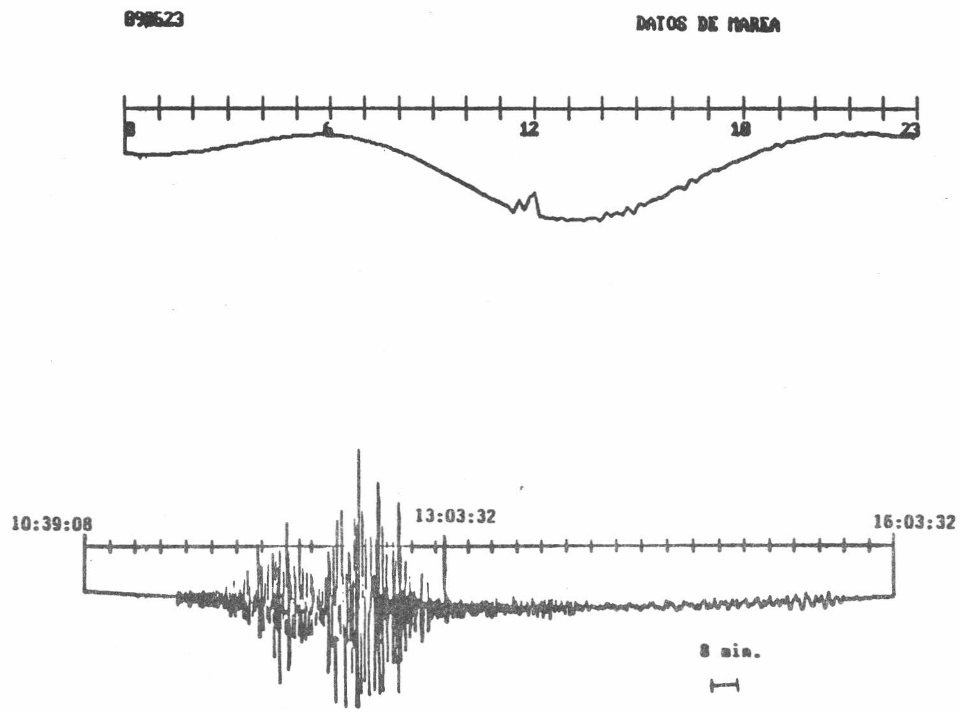

Figure 3

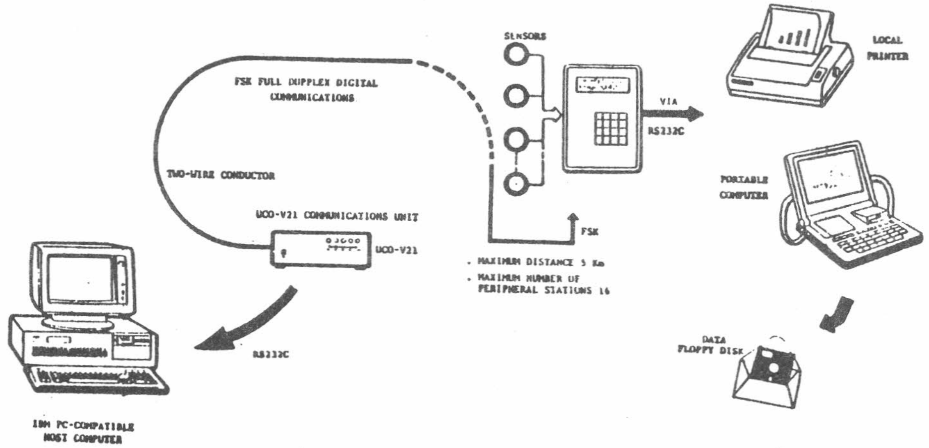

Figure 4