



European Radiocommunications Committee (ERC)
within the European Conference of Postal and Telecommunications Administrations (CEPT)



**TECHNICAL AND OPERATIONAL CHARACTERISTICS OF
WEATHER RADIOSONDES IN EUROPE**

Rome, October 1996

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1. INTRODUCTION

This paper is intended as a comprehensive response to the recommendations in DSI Phase II that affect the radiofrequency spectrum available for weather radiosondes in Europe. The relevant recommendations are listed in detail in Annex A.

2. USE OF RADIOSONDES

Radiosondes are lifted by weather balloons to heights from 20 to 35 km. The radiosonde will be often carried more than 100 km from the launch site before falling to earth and on some occasions more than 300 km from the launch site when upper winds are strongest. Therefore, most radiosondes are treated as disposable and are used only once. In order to keep operational costs to a minimum, the radiosonde design is kept as simple as possible within the constraints of achieving the necessary standards of measurement accuracy. Data processing and storage on the radiosonde are kept to a minimum with measurements transmitted in real time to the ground station receiver. Thus, successful operation of all modern radiosonde systems relies on essentially uninterrupted communication between the radiosonde and its ground receiver.

2.1. Daily Meteorological Operations

Radiosondes are mainly used for upper air measurements from the surface up to altitudes of between 20 and 35 km of the meteorological variables: pressure, temperature, relative humidity, wind speed and direction. More than 150000 radiosondes per year are launched for this purpose in Europe and western Russia. The radiosonde measurements are vital to national weather forecasting capability (and hence severe weather warning services for the public involving protection of life and property).

The measurements are mostly performed routinely at 00 and 12 UTC, but in some countries in Europe where significant changes in weather are common the separation between measurements is reduced to 6 hours. For specific research into severe weather, time separations as low as 3 hours may be used over large areas of Europe for several days. The launch times actually fall within a window of about 3 hours, with the window starting about 45 minutes before the nominal time. The launch may be up to 2 hours late if the initial radiosonde fails in flight. The radiosonde will usually transmit for about 3 hours in total during preparation, flight and falling to earth after balloon burst.

The majority of the critical information for weather forecasters is contained in the detail of the variation of temperature, relative humidity and wind speed and direction in the vertical. The radiosonde systems are the only meteorological observing system able to regularly provide the vertical resolution that meteorologists need for all four variables. Accurate measurement of the height where a discontinuity in a variable occurs is vital. Such features often occur shortly after launch, for example the height of fog top, cloud base or the top of the atmospheric boundary layer. Uninterrupted communication between the radiosonde and the ground station is essential if the necessary measurement accuracy is to be sustained.

Radiosonde observations are considered essential to maintain stability in the World Meteorological Organisation (WMO) Global Observing System. Successful derivation of vertical temperature structure from satellite sounding measurements requires a computation initialised either directly from radiosonde statistics or from the numerical weather forecast itself. In the latter situation, the radiosonde measurements ensure that the vertical structure in these forecasts remains accurate and stable with time. Thus, radiosonde observations are expected to remain absolutely necessary for meteorological operations for the foreseeable future.

2.2. Monitoring Climate Change

Large world-wide changes have occurred in atmospheric temperature and ozone in the last 20 years. Many of the largest changes have occurred at heights between 12 and 30 km above the surface of the earth. The changes are large enough to cause concern about safety of future public health. The routine daily radiosonde observations to heights above 30 km identify the vertical distribution of the temperature changes that occur and hence the causes of the changes can be evaluated. In addition, ozonesonde measurements to similar heights determine the vertical distribution of the ozone depletion that now appears to be occurring in northern Europe in winter and spring. In many cases, radiosondes and ozonesondes flown in winter in northern Europe will encounter very strong upper winds. Good communications between radiosonde and ground receiver are essential under these circumstances when slant ranges may exceed 200 km and balloon elevations may be well below 10° at upper levels towards the end of a flight.

Successful sampling of climate change requires the use of radiosondes with established systematic error characteristics. The requirement for continuity in the time series of upper air measurements world-wide means that new radiosonde designs are only introduced into operation after several years of intensive testing, both in the laboratory and in the free atmosphere.

2.3. Defence use

Radiosondes are used in significant numbers for military operations in most countries in Europe. The radiosonde use by the military does not usually duplicate the civilian weather forecasting operations. Upper air measurements are essential to the accuracy of modern artillery and rocket operations, as well as safety and noise control at military ranges. The military use is not decreasing with time, since with modern automation it is now much easier to successfully operate mobile battlefield systems and shipboard systems without highly skilled operators and a large amount of supporting equipment. The number of radiosondes used by the military on average is probably up to one third of those used for civilian operations. Civilian radiosonde operations have to accommodate the military use and this expands the radiofrequency spectrum required for radiosonde operations. This is particularly critical when military launch sites are within 150 km of the civilian launch sites.

2.4. Other Civilian Users

Additional radiosonde systems are operated independently of the main civilian meteorological organisation by national research institutes. Specific investigations will include environmental pollution, hydrology, radioactivity in the free atmosphere, significant weather phenomena (e.g. winter storms, thunderstorms, etc.) and oceanography. In some areas of Europe there will be negligible additional use. However, in other areas it has been found that additional users are operating for up to 20 per cent of the time when the main civilian operations are in progress.

3. RADIOFREQUENCY USED FOR RADIOSONDE OPERATIONS

3.1. Choice of Met-aids band

In Europe and Western Russia there are about 214 radiosonde launch sites that report information daily to all the other meteorological services worldwide through the WMO Communications network. Of these stations, 111 use the Met-aids band centred at 403 MHz, 11 use the Met-aids band centred at about 1685 MHz and 92 stations in Russia or associated states use equipment operating at 1780 MHz.

At this time 403 MHz radiosondes are primarily used by CEPT Members. The radiofrequency characteristics of the 403 MHz radiosonde systems are summarised in Annex B. The low power output of radiosondes is dictated by the capability of the batteries that can safely be flown without endangering public safety. 403 MHz has been chosen for radiosonde operations for the two following reasons:

- (i) In many countries in north-west Europe average upper winds are often very strong for prolonged periods during the year. The better signal reception at 403 MHz than at 1680 MHz for very long ranges and low elevations allows satisfactory radiosonde operations to the longest ranges encountered. 403 MHz radiosondes with navaid windfinding (either Loran-C or GPS) or used with independent tracking from a primary radar are essential for accurate winds when average upper winds are very strong. This is because radiotheodolite systems that rely on passive tracking of radiosonde direction by the receiving aerial have great difficulty in measuring elevation with sufficient accuracy at low elevations to provide reliable winds.
- (ii) Fully automated ground systems have reduced radiosonde operational costs across Europe in the last decade. The most common fully automated system operates at 403 MHz and relies on Omega navaid signals for windfinding. The Omega system will be closed within a couple of years. At stations where very strong upper winds are rare, a choice will have to be made between a radiotheodolite at 1685 MHz or the more accurate GPS windfinding at 403 MHz. A radiotheodolite has high initial capital cost and requires more staff for operations and maintenance. The GPS radiosondes will be more expensive than those for radiotheodolite operations.

In most of Europe, upper winds are strong for part of the year. Thus, most countries using Omega windfinding will have to change to GPS windfinding at 403 MHz.

Thus, it is impossible for most countries in Europe to move to using 1685 MHz for weather radiosonde operations and Recommendation 39 of DSI Phase II must be rejected as impractical.

3.2. Radiofrequency occupancy required for radiosonde operations

In some parts of Europe, the radiosonde stations operated by the national meteorological service are spaced about 500 km or further apart and there is negligible additional radiosonde use by the military or other researchers. In this situation, even with radiosonde transmitters at 403 MHz that may drift by about 500 kHz during flight, successful radiosonde operations only requires two or three frequencies each separated by about 1 MHz at most. In several countries, this situation has been exploited by the national radiocommunication authorities by restricting radiosonde operations to only part of the Met-aids band and utilising the remaining spectrum for defence and commercial applications. The current allocation situation needs to be carefully reviewed before planning future radiofrequency allocations in the Met-aids bands.

However, in many densely populated areas of Europe the spacing of the stations operated by the national meteorological services is close to 300 km, the optimum recommended by the World Meteorological Organisation. This is necessitated by the large variability in weather experienced by north-west Europe (variable both in time space) for most of the year. There are also many military stations at distances less than 150 km from the civilian stations as well as many additional users. In this situation, radiosonde observations from one site will interfere with the other sites unless strict radiofrequency management is adopted. Interference will be particularly bad in winter when the radiosondes may travel in excess of 300 km before falling to the ground. In this situation, the main national radiosonde operators are already using radiosondes with relatively stable transmitters, (stable to better than ± 5 kHz in Germany, stable to better than ± 100 kHz during flight in the UK).

Table 1 summarises the spectrum occupancy required by the radiosonde users at present in countries where very stable transmitters are in use. This suggests that there is little scope for a reduction in the size of the Met-aids allocation at 403 MHz. If sharing is to be increased in future, then it should be with systems that are able to operate with the radiosondes without co-channel interference. There is little room for band segmentation and adjacent channel sharing.

User	Width of radiofrequency spectrum required between 400.15 and 406 MHz
National civilian meteorological service, station spacing 300 km [*8 stations]	2 MHz
Defence use at range stations or mobile systems interspersed between civilian stations [**at least 8 stations + mobile systems]	2 MHz
Other additional users [at least 10 systems, exploiting time share of channels]	1 MHz
Data Collection platforms, uplink to meteorological satellites [at least 100 sites, time share of channels]	0.5 MHz

Table 1 Radiofrequency spectrum for Met-aids and meteorological satellite operations in north-west Europe with radiosondes using high stability transmitters at 403 MHz

- * Each main station requires at least two independent frequency allocations to cope with crash launches and repeat flights
- ** Some military stations require 3 or 4 frequencies to allow radiosondes to be launched at 30 minute intervals

4. POSSIBILITIES OF SHARING WITH OTHER PRIMARY USERS

In those countries where the radiosonde stations are separated by large distances there is clearly scope for national agreements so that radiosonde operations share with other services within the band from 400.15 to 406 MHz.

DSI Phase II proposes sharing with a general low power device band (Recommendations 28,29 and 35) and also possibly with the Mobile Satellite Service (Recommendation 38). WMO will also propose at WRC-97 that the Meteorological Satellite services, earth to space links, should be raised to primary status from 401 to 403 MHz.

4.1. Meteorological satellite services (earth to space links from data collection platforms)

The possibilities of co-channel sharing between Data Collection Platform (DCP) uplinks to meteorological satellites and radiosonde operations are to be studied by WMO. Most DCPs in Europe currently operate at frequencies between 401.6 and 402.2 MHz with transmitted power in the range 5 to 50 watts depending on the antenna available. There is no evidence to suggest that radiosonde operations interfere with DCP reception. DCPs transmitting close to radiosonde ground systems do cause interference to radiosonde reception. However, this problem is usually managed by ensuring that DCP transmissions are short and take place at time during flight when a short radiosonde data loss is less critical. The Meteorological Satellite operators require that a theoretical study of interference from radiosondes be completed before agreeing to co-channel sharing with radiosondes.

Co-channel sharing between DCP and radiosonde operations may be possible in some countries.

4.2. Low Power Devices

For a low power device to be capable of co-channel sharing with radiosonde systems, the low power device should have a minimum distance to avoid interfering of less than about 100m. Alternatively, it must be possible to regulate the deployment of the low power device so that it never approaches within the isolation distance required to protect the radiosonde operations. A compatibility study between short range devices and Meteorological Aids at 403 MHz has been presented by France to SE24[ref. SE24(96)12, SE19(96)41].

This study has confirmed earlier assertions in previous SE19 documents that the horizontal separations required to protect radiosonde operations from SRDs of power 500 to 1 mW are clearly too large to allow co-channel sharing between a general low power device band and radiosonde operations. If there is to be any co-channel sharing with radiosonde operations, it must be with extremely low power devices (possibly employing spread spectrum techniques) and not the general low power device band suggested by DSI Phase II, Recommendations 28,29 and 35.

4.3. Mobile Satellite Service

At present the Mobile Satellite Services have an allocation for space to earth downlinks from 400.15 to 401 MHz in Region 2. At the meeting of ITU-R Study Groups 7B and 7C in Toulouse in March 1996, papers were presented proposing that not only should this primary allocation be made on a world-wide basis but that the allocation should be extended to cover most of the 400.15 to 406 MHz band. The MSS proposals do not seem to take any account of all the other users who currently share with Met-aids in this band.

The proposed power output characteristics of the majority of the MSS system downlinks in this band are such that co-channel sharing with radiosonde operations will be impossible.

(It is easier for radiosondes to share with earth to satellite uplinks, such as the DCPs, than with downlink broadcasts from satellites that will inevitably fill the main beam of the ground system antenna for much of the time.) The inevitability of interference is accepted by the MSS operators who are proposing band segmentation to accommodate their systems. As indicated in earlier sections, band segmentation is not a viable option for many CEPT Members. CEPT need to decide whether little LEO systems offer any advantage. Otherwise the radiofrequency allocations to MSS systems within this Met-aids band need to be strongly opposed.

Sharing studies between MSS and Met-aids in preparation for WRC-97 will continue during the year. Note: MSS systems are also requesting sole use of at least 10 MHz of the 1685 MHz Met-Aids band.

4.4. Future trends in Met-aids spectrum occupancy

It is probable that the weather radiosonde operations of the majority of CEPT Members could be accommodated in a continuous band with a spread nearer to 5 MHz than the current 6 MHz. This would require effective regulation of the radiofrequency use of military and additional users, and would also rely on co-channel sharing with the meteorological satellite ground to earth links. Co-channel sharing should be evaluated with extremely low power devices, possibly those used for implantable medical devices, or future auditory assistance devices. Sharing with MSS systems should only be contemplated if use of that particular part of the spectrum for Met-aids is no longer required.

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ANNEX A

DSI PHASE II RECOMMENDATIONS AFFECTING THE AVAILABILITY OF RADIOFREQUENCY SPECTRUM FOR USE BY WEATHER RADIOSONDES

METEOROLOGICAL AIDS SERVICE

39. Weather sonde systems operating in the 400.15-406 MHz band should be moved gradually to the 1.7 GHz band.

LOW POWER DEVICES

28. The band 48.5-49.5 MHz should be used as the main on-site paging band in accordance with the existing CEPT Recommendation T/R 02-01 and from within the band 403-404.5 MHz, 5 call-out and 5 talkback frequencies should be chosen by Working Group FM to be introduced on a co-ordinated and harmonised basis.

LOW POWER DEVICES

29. The DSI Management Team recommend that :
- a) the different terms used in CEPT Recommendations and ETSI Standards for low power applications be harmonised
 - b) protected channels for the control of model aircraft within the band 34.995-35.225 MHz be agreed
 - c) a general low power application band at 138.00-142.00 MHz be agreed
 - d) an allocation be agreed for a general low power band at 403-404.5 MHz intended for new applications and to avoid placing new equipment at 433 MHz unless absolutely essential, the 433 MHz band to be subject to a general review at an appropriate time

DEFENCE

35. Further sharing possibilities be actively explored, especially the accommodation of low power devices in defence bands, in particular the band 403-404.5 MHz should be available for low power devices.

MOBILE SATELLITE SERVICE

38. The management Team recommend that CEPT Administrations urgently address the market potential and their national requirements for 'little LEO' systems. The policy and priorities concerning 'little LEO' and existing services should be developed in particular for the band 148-150.05 MHz but also a position for the bands 137-138 MHz and 400.15-401 MHz is required. If 'little LEO' systems are found to have sufficient priority it is further recommended that a timetable be established for transferring existing services from this band(s) or identifying alternative bands which might be more appropriate for use in CEPT countries, recognising the complications that would arise in utilising different frequency bands in Europe to those used in other regions of the world.

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ANNEX B

RADIOFREQUENCY CHARACTERISTICS OF RADIOSONDE SYSTEMS AT 403 MHz

Tuning range	400.15 - 406 MHz
Maximum drift in flight	± 500 kHz, but can be ± 100 kHz or ± 5 kHz at extra cost
Emission type	F9D
Nominal output power	200 mW
Modulation	FM
Modulating PTU signal	7-10 kHz
Deviation	45 ± 15 kHz
Deviation caused by the VLF/Loran-C relay link	100 kHz/300 kHz
Occupied bandwidth with Omega VLF	280 kHz
Occupied bandwidth with Loran-C	480 kHz
Occupied bandwidth with GPS	TBD
Equivalent data rate	TBD
Out-of-band emission	TBD

Table B.1 Characteristics of 403 MHz radiosonde transmitters widely used in Europe

Type	Omnidirectional, used for low level observations	Directional corner reflector, six corners, used at main stations
Frequency range	397-409 MHz	400-406 MHz
Horizontal gain	omnidirectional	8 dB
Vertical gain	omnidirectional	-3 dB
Amplifier NF	< 3.5 dB	< 2.5 dB
Amplifier gain	13 dB	20 dB

Table B.2 Typical characteristics of ground system antenna used in Europe

Performance Factor	
Link function	Analogue and digital data transfer from radiosonde to ground receiver using FSK
Modulation type	FM
Receiver bandwidth (kHz)	300
Carrier Frequency (MHz)	400.15 - 406
Transmitter output Power level (dBW)	-6
Transmitter antenna gain (dBi)	0
Free space path loss (at 200 km) (dB)	131
Excess path loss (fading ,etc.) (dB)	5
Receiver antenna gain (dBi)	10
Antenna pointing error (dB)	3
Received power level (dBW)	-135
Minimum carrier to interference ratio (dB)	-145
Maximum permissible interference level (on 300 kHz BW) (dBW)	-145
Equivalent power density	-160.2 dBW/m ² /4kHz

Table B.3 Operating Characteristics of a typical radiosonde system using 403 MHz