



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



**FURTHER SHARING STUDY BETWEEN THE FIXED SERVICE AND
EARTH EXPLORATION-SATELLITE SERVICE IN THE BAND 55.22 - 55.78 GHz**

Sesimbra, January 1997

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SHARING BETWEEN THE FIXED SERVICE AND EARTH EXPLORATION SATELLITE SERVICE IN THE BAND 55.22 - 55.78 GHz

1 INTRODUCTION

ERC Report 45 contains an examination of the feasibility of sharing between the fixed service (FS) and Earth exploration-satellite service (EESS) in the range 50.2 to 58.2 GHz. This report concludes that sharing between passive remote sensors and the fixed service is feasible between 55.78 and 58.2 GHz, but not feasible between 50.2 and 55.22 GHz; in the initial study there was no definitive conclusion on the feasibility of sharing in the range 55.22 - 55.78 GHz. The following report contains the results of further studies focusing in particular on the band 55.22 - 55.78 GHz

2 PASSIVE SENSORS

2.1 Introduction

The electromagnetic spectrum contains many frequency bands where, due to molecular resonances, absorption mechanisms by certain atmospheric gases are taking place. Frequencies at which such phenomena occur characterise the gas. The absorption coefficient depends on the nature of the gas, on its concentration, and on its temperature. A combination of passive measurements around these frequencies can be performed from spaceborne platforms, to retrieve temperature and/or concentration profiles of absorbing gas. Of particular significance to the EESS below 200 GHz are the oxygen resonance frequencies between 50 and 70 GHz, and at 118.75 GHz, and the water vapour resonance frequencies at 22.235 GHz and at 183.31 GHz.

A general view of the atmospheric attenuation due to oxygen and water vapour at frequencies up to 350 GHz is shown in Figure 1.

Detailed oxygen absorption spectrum in the vicinity of 60 GHz is shown in Figure 2. The two neighbouring absorbing peaks which limit the frequency slot under consideration in this document are also indicated.

2.2 Significance of passive measurements performed by the EESS near the resonance frequencies around 60 GHz

Spaceborne microwave passive sounders making passive measurements near the resonance frequencies around 60 GHz are deployed, particularly by the meteorological services. Their purpose is to provide on a worldwide basis "all weather" three dimensional measurements of the temperature profiles, key parameters which describe the status of the atmosphere.

Temperature profiles are among the few essential parameters describing the status of the atmosphere, which are fed directly into the operational Numerical Weather Prediction models (NWP) operated by the meteorological services.

Weather forecasting is a "Public Service" which leads to significant economic benefits for most human activities such as agriculture, transport, construction, energy production etc, and contributes also to protect human lives and properties. There is a strong demand for improvements of this service, particularly in accuracy and in reliability.

All weather atmospheric temperature profiles are also essential for scientific applications such as climate and environment monitoring ("Global change" for example). They are also the key auxiliary parameter, which is necessary to extract the concentration profiles of radiatively and chemically important atmospheric gases (such as ozone), from radiometric measurements in their specific absorption bands.

Compared to infra-red (IR) techniques, the **all-weather capability** (the ability for a spaceborne sensor to "look" through most clouds) is probably the most important feature that is offered by microwave techniques.

This is fundamental for operational weather forecast and atmospheric science applications, because more than 60% of the earth's surface, on average, is totally overcast by clouds, and only 5% of all 20x20 km pixels (corresponding to the typical

spatial resolution of the IR sounders) are completely cloud-free. This situation severely hampers operations of IR sounders, which have very little or no access to large, meteorologically active regions.

High resolution all-weather temperature profiles can only be obtained by passive measurements from low-earth polar orbiting satellites within the oxygen absorption spectrum around 60 GHz. High vertical resolution is rendered possible by the multi-line structure of the absorption spectrum.

Because of its specific absorption level, the 55.22 - 55.78 GHz sub-band is the only suitable one in the spectrum where tropopause information can be collected, as for example by the AMSU-A channel 8 (as shown in Figure 3). **This is a unique natural resource for which no alternative exists.**

2.3 Current and future satellite systems and instrumentation

2.3.1 Satellite systems

Meteorological services operate essentially two complementary types of satellite systems:

- Systems based on satellites in *low sun-synchronous polar orbits* are used to acquire high resolution environmental data on a global scale. The repeat rate of measurements is limited by the orbital mechanics. A maximum of two global coverages are obtained daily, with one single satellite.

Two low orbiting meteorological satellites in coordinated orbits (“morning” and “afternoon”) are currently operated by NOAA (NOAA-K/L/M/N/N’, USA). This network yields one complete coverage every 6 hours on average. NOAA-M, to be launched in 1999, will be the last “morning” satellite of the series.

Consequently, Europe (ESA and EUMETSAT) has accepted to take up the responsibility of a “morning” satellite system, “METOP”, which will be developed in Europe. The first satellite of this European series is planned to be launched in 2002;

- Systems involving satellites in *geostationary orbit* are used to gather low to medium resolution data at regional scale. The repeat rate of measurements is limited only by hardware technology, and is typically one regional coverage every 30 minutes or less.

Five to six geostationary meteorological satellites regularly spaced around the earth’s equator are deployed. The European component, METEOSAT, is positioned at 0° longitude.

2.3.2 Instrumentation

Since 1978, the Meteorological Satellite Service has used sections of the oxygen absorption spectrum around 60 GHz for passive microwave sounding of the atmosphere. These measurements are provided by the *Microwave Sounding Unit (MSU)* instrument which is flown on the operational series of polar-orbiting weather satellites operated by NOAA. MSU is a 4 channel radiometer.

On the basis of experience gained with the MSU data, NOAA is going to upgrade the microwave sounding capability on its operational polar-orbiting satellites in the near future. This capability will be provided by two new instruments:

- The *Advanced Microwave Sounding Unit - A (AMSU-A)*, for determining atmospheric temperature profiles, has 15 channels of which 12 channels fall within the 50.2 - 58.2 GHz band;
- The *Advanced Microwave Sounding Unit - B (AMSU-B)*, supplied by the UK, for determining atmospheric water vapour profiles, has 5 channels of which 3 channels fall around 183.31 GHz.

The first flight of the AMSU-A and AMSU-B instruments, on the NOAA-K/L/M/N/N’ series, is currently scheduled for the end of 1996. The AMSU-A is also going to fly on the European satellite series METOP.

Further upgrading of the microwave sounding capability will be achieved:

- In the 2005 timeframe, “stratospheric” channels in the frequency range 60.3 - 61.3 GHz, will be added to the AMSU-A instrument. Such channels will increase the maximum height at which the atmospheric temperature is retrieved from approximately 45 km to approximately 70 km. This technique relies on a special interaction between the Earth’s magnetic field and particular O₂ absorption lines (“Zeeman splitting”).

- In the 2002 timeframe, on the METOP satellite, the water vapour sounding capability will be ensured by the *Microwave Humidity Sounder* (MHS), an improved version of the AMSU-B, which is being developed in Europe. The MHS may replace the AMSU-B on the NOAA-N and N' "afternoon" satellites.

A number of other microwave sounding instruments using similar frequency bands are also in operation, in particular on US military weather satellites, and on Russian weather satellites.

Due to technological constraints, no microwave sounder has been flown as yet on a geostationary meteorological satellite. This is however envisaged on future systems. Microwave sounders for geostationary platforms will have channels around 183.31 GHz for water vapour profiling, as for the instruments in low earth orbits. For temperature profiling, the 118.75 GHz region is preferred over the 60 GHz in order to minimise the size of the antenna.

2.3.3 Typical characteristics of microwave sounders

	Present :	Future :
Antenna diameter :	15 cm	45 cm
IFOV 3dB points :	3.3°	1.1°
FOV (cross-track) :	+/- 50°	+/- 50°
Antenna gain :	36 dBi	45 dBi
Side lobes :	- 10 dBi	-10 dBi
Beam efficiency :	> 95%	> 95 %
Radiometric resolution :	0.3 K	0.1 K
Swath width :	2300 km	2300 km
Pixel size (nadir) :	49 km	16 km
Number of pixels/line :	30	90
Orbit altitude (circular) :	850 km	850 km
Orbit inclination (sun-synchronism) :	98.8 °	98.8 °

2.4 Interference criteria for passive sensors, and vulnerability to interference

2.4.1 Current interference criteria definition

Recommendation ITU-R SA 1029 sets the permissible interference threshold as follows:

- In the 50 to 66 GHz frequency band: -161 dBW for a scanning sensor and -166 dBW for a pushbroom sensor, in a reference bandwidth of 100 MHz. These levels are equivalent to brightness temperature increases of 0.06 K and 0.02 K respectively;
- The recommendation mentioned above indicates also that "*These levels may be exceeded for less than 5% measurement cells where interference occurs randomly, and for less than 1% measurement cells where interference occurs systematically at the same locations*".

These criteria may be unsuitable for protection of passive sensors in these bands when considering the use of the data in Numerical Weather Prediction models.

2.4.2 Vulnerability to interference

Passive sensors integrate all natural (wanted) and man-made (unwanted) emissions. They cannot in general differentiate

between these two kinds of signals because the atmosphere is naturally a fast changing medium, spatially and temporally.

If undetected, corrupted data propagate dramatically in the numerical weather prediction models (NWP), rendering the whole forecast useless. Recently, the European Centre for Medium-range Weather Forecasting (ECMWF) demonstrated that as few as 0.1 % of contaminated satellite data could be sufficient to generate unacceptable errors in NWP forecasts, thus destroying confidence in these unique all weather passive measurements.

On the contrary, if corrupted data can be detected and then are systematically rejected over areas where the probability for interference is suspected to be high, important natural warnings are likely to remain ignored and the consequence may be also negative. The systematic deletion of data could postpone or render impossible the recognition of new developing weather systems, and vital indications of rapidly developing potentially dangerous storms may be missed. The possible presence of undetected errors for some points would make this situation worse and add the possibility that false predictions of severe weather could be produced.

For climatological studies and particularly “global change” monitoring, interference could be interpreted as artificial warming of the atmosphere.

Concerning passive microwaves calibration and atmospheric retrieved profiles (temperature and humidity), it is necessary to correlate microwave measurements and conventional radiosonde measurements, each 12 hours. This is often done near large cities where interference could lead to wrong calibration, retrievals, and statistics for NWP.

2.5 Interference classification

Interference can be broadly classified as follows.

a- Undetectable :

An interfering signal of up to the interference threshold contributes normally to the expected error budget of the instrument, but would not endanger the required quality of measurements. Interference at this level would make sharing possible without restriction.

b- Likely to cause misinterpretation :

An interfering signal causing an apparent warming of up to around 5 K cannot be detected at the data processing level, because it does not differentiate from the values which are normally expected.

ECMWF simulation demonstrates that the 5-days forecast over Europe can be completely changed by small perturbations (typically a few cells per thousand) compared to the analysis over North America 5 days earlier.

If the location of such interference sources is perfectly known worldwide, the contaminated measurements can be systematically rejected without significant consequences provided that rejected measurements are evenly distributed worldwide, because large patches of missing data could have severe impact on the model forecast (longwave effects). Furthermore, the total data loss should be limited to around 1%.

If the location of interfering sources is unknown, contaminated data would cause an incorrect adjustment to the numerical weather prediction model and hence would significantly degrade analysis and forecast.

Interference within this range of magnitude would be acceptable if the location of interfering sources is perfectly known and evenly distributed worldwide (for instance no more than one cell in a grid of 10 x 10 cells). However it appears that monitoring and control of the situation worldwide cannot be implemented.

c- Easily detectable :

Interference above around 5 K would be easily detectable and could be automatically removed. For the reasons described above, rejected data must be evenly distributed worldwide, and the total amount of missing data should not exceed around 1%.

Interference in this range would be acceptable if the amount of rejected data is no more than one cell in any grid of 10 x 10 cells.

2.6 Sharing conditions

Due to the natural variability of atmosphere in time and space, and due to the behaviour of the NWP models which are designed to describe the highly unstable dynamic mechanisms which characterise the atmosphere, temperature measurements which are obtained by microwave passive sensing in this part of the spectrum are totally vulnerable to interference, and require that new sharing rules be defined and implemented.

A certain amount of interference exceeding threshold can be tolerated only if measurement cells contaminated by interference are identified in advance, or can be detected in real time, and can be removed from the data set. It is not considered to be practical for the fixed services to give notification of the location of interference “hot-spots”, particularly when considering that interference could occur by indirect propagation effects. Thus only interference described as “type-c” above could be removed from the data set.

It is obviously possible to define a set of technical/operational characteristics applicable to the FS network (such as antenna mask and maximum pointing elevation, maximum transmitter power which must be adjusted to the specific frequency and altitude, maximum geographical density...) which make sharing feasible without interference to the passive sensors. However it is not acceptable to the passive sensor community to let the FS networks develop and grow without verifying that all constraints are effectively respected worldwide.

Therefore the key problem is how to define and to implement a practical procedure to exercise this verification and to prevent any uncontrolled development which may be harmful for the operations of the passive sensors.

This is a fundamental condition, because it was demonstrated that even a small amount of undetected contaminated measurement cells may destroy forecasts.

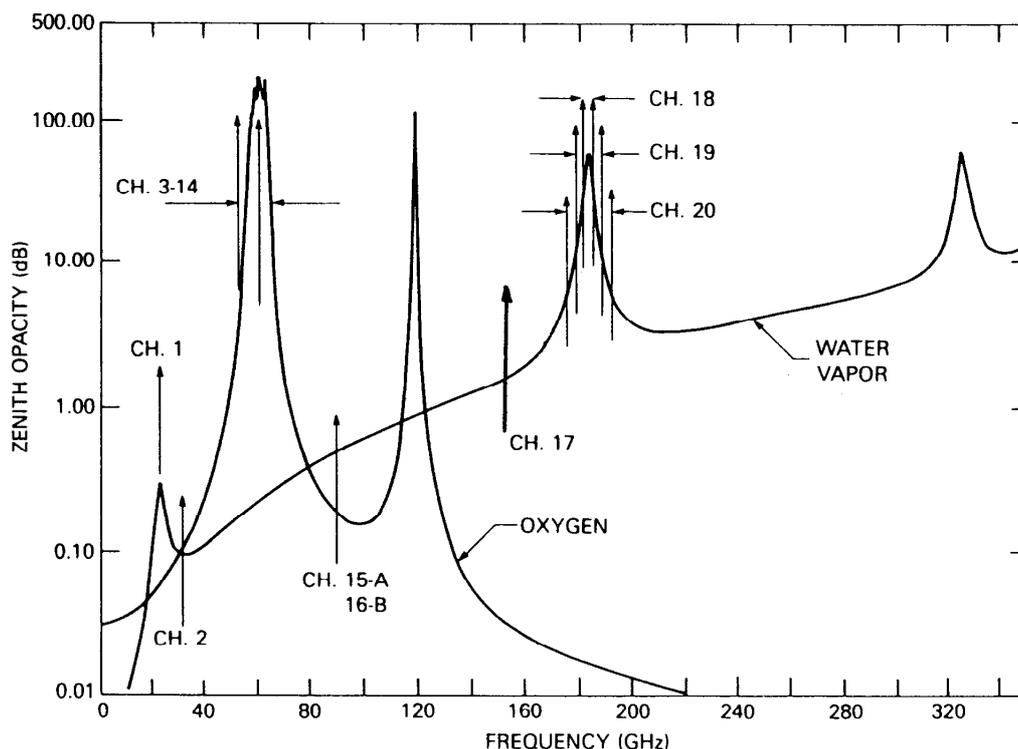


Figure 1 Atmospheric attenuation at microwave frequencies due to oxygen and water

Figure 2 shows how oxygen absorption on the zenith path varies with frequency. The difference in the absorption minima above 55.22 GHz and above 55.78 GHz is about 20 dB.

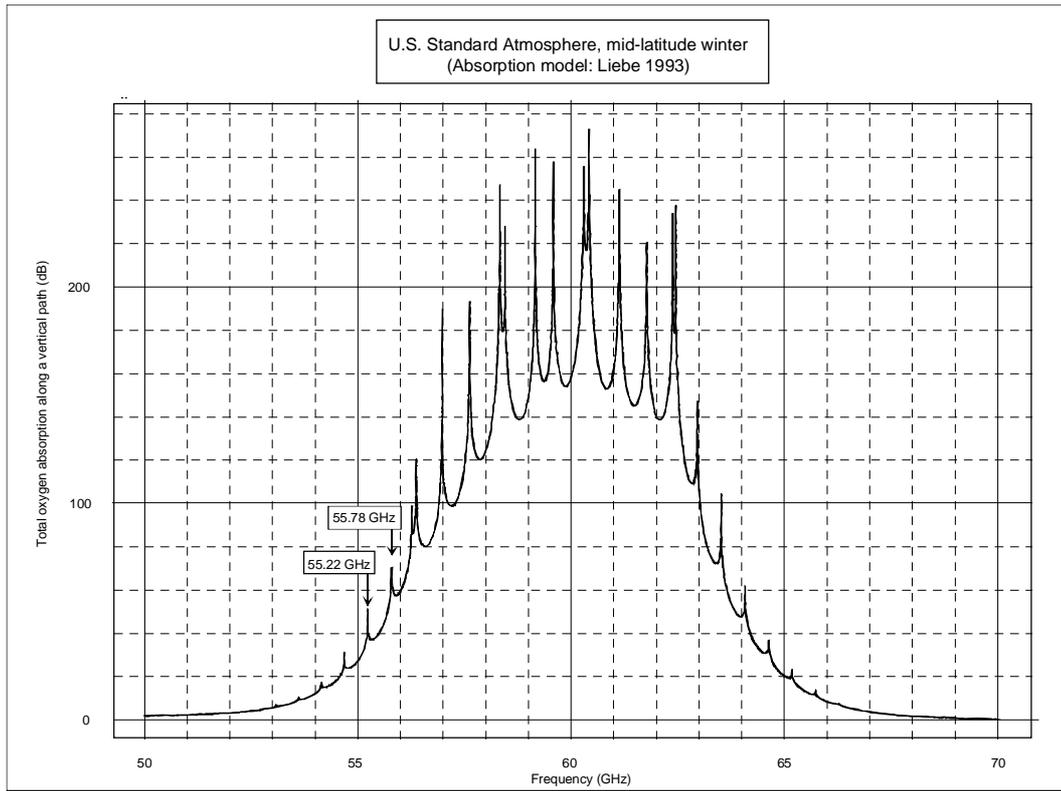


Figure 2 O₂ absorption spectrum along a vertical path around 60 GHz (multiple absorption lines)

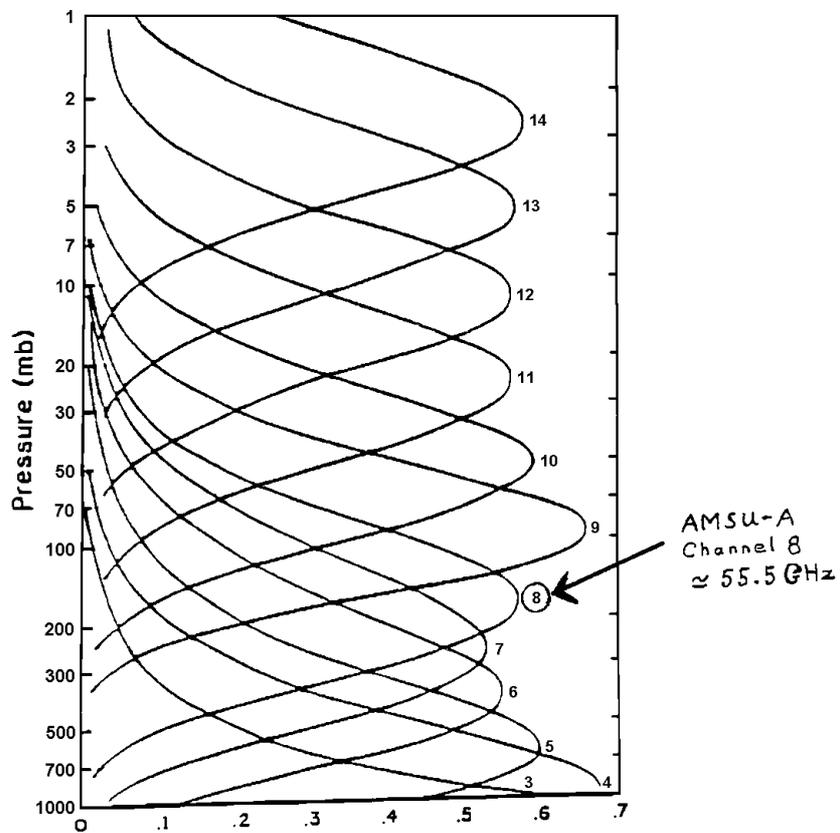


Figure 3 Typical weighting functions of a microwave temperature sounder

3 REQUIREMENTS FOR FIXED SERVICES

3.1 Introduction

Within CEPT, the ERC Report 25 shows, in the European Table of Frequency Allocations and Utilisations, for the band 55.2 - 57.2 GHz a major utilisation for low and medium capacity fixed links. These are intended for support structure for large scale mobile networks. The band 57.2 - 58.2 GHz has an allocation for fixed links, which do not require coordinated frequency planning.

Many of the existing Fixed Service allocations are shared with at least one Space Service. In the lower frequency bands, pressure on Fixed Service spectrum from other services is increasing. The DSI Phase II includes a recommendation to limit the use of Fixed Services below 1 GHz. Consequently the Fixed Service is under increasing pressure to make use of higher frequency bands where possible.

3.2 Terrestrial Propagation in the Millimetric Wavebands

In addition to free space path loss, radio signals are attenuated by atmospheric gases and hydrometeors. Figure 4 shows how the specific attenuation at sea level on a terrestrial path varies due to these factors. The rain curve is based on an average rainfall level of 25 mm/hour.

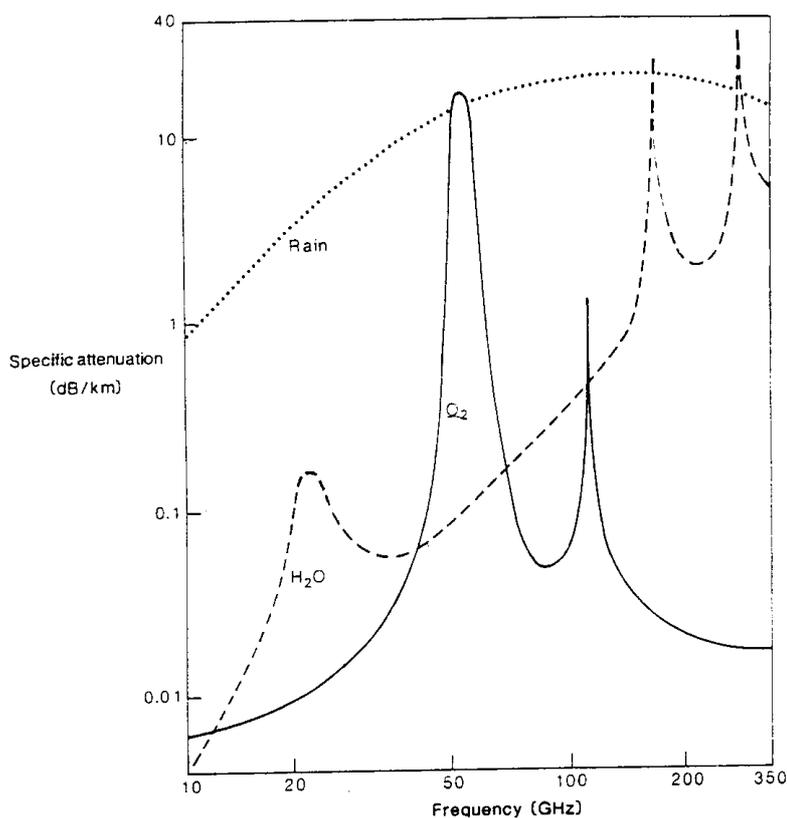


Figure 4 Attenuation by atmospheric gases and rain
(source: "The Use of the Radio Frequency Spectrum above 30 GHz", UK DTI, September 1988)

In the regions near the absorption peaks the high attenuation makes these bands suitable only for short distance links. However the attenuation also limits the distance over which radio systems will interfere with each other. One effect of this is that the re-use distance is relatively small in the absorption bands, by comparison with other millimetric bands. Figure 5 shows how the link length and re-use distance vary with frequency in this region.

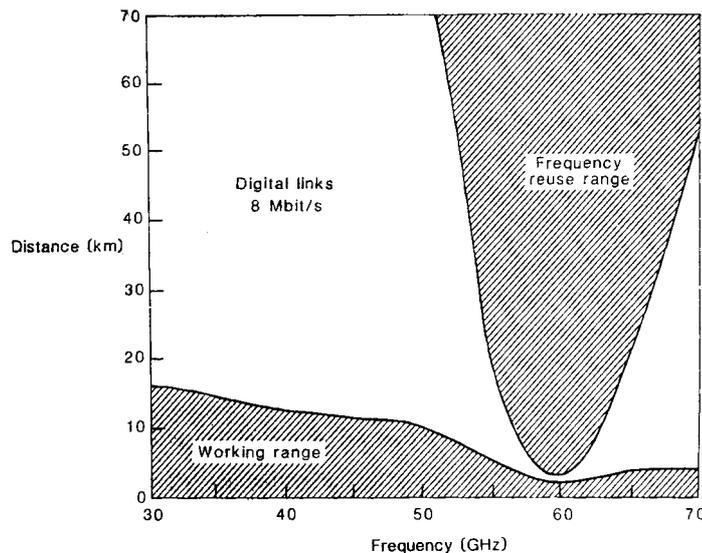


Figure 5 Potential working and frequency re-use range of millimetric fixed links
(source: “The Use of the Radio Frequency Spectrum above 30 GHz”, UK DTI, September 1988)

3.3 Current and Future Use of the Oxygen Absorption Band by the Fixed Service

The properties of the oxygen absorption region make these bands ideal for short distance fixed links. In particular the high absorption at 57.2 - 58.2 GHz minimises the risk of interference from nearby links, making it possible to use this as an uncoordinated band. The ETSI standard prETS 300 408 was developed for this purpose and covers both analogue and digital equipment. One administration had 446 fixed links in this band at 26 April 1996, many being used for security video applications. This use is expected to continue in the future.

The 55.2 - 57.2 GHz band is not used at present pending the outcome of the sharing study in section 4. The characteristics of this band would make it useful for the provision of short distance coordinated links between base stations of mobile networks and for access to network nodes in city centres. Longer links would be provided in lower frequency bands.

Due to the pressure on lower frequency bands, administrations aim to ensure that point-to-point links are assigned in the highest frequency band compatible with achieving the user’s path length and availability requirements - a “link length policy”. This helps to reduce pressure, although at the present the highest band available for short distance coordinated links is 38 GHz. As a result, in the UK, this band is beginning to experience congestion in some vital regions. A band in the oxygen absorption region would be a suitable place for the very short links, which currently have to be accommodated here.

3.4 ETSI Standards Under Development

There are two ETSI equipment standards for Fixed Service systems in the oxygen absorption region:

- prETS 300 407 - Coordinated fixed point-to-point links in the 55.2 - 57.2 GHz band
- prETS 300 408 - Uncoordinated fixed point-to-point links in the 57.2 - 58.2 GHz band

A substantial effort has already been expended in development of these equipment standards. Equipment already in use in the 57.2 - 58.2 GHz band has been designed to adhere to the draft standard.

3.5 Fixed Service System Parameters

The following table (based on prETS 300 407) gives parameters for the Fixed Service systems which would be deployed in the 55.2 - 57.2 GHz band:

Modulation	2-FSK	2-FSK	4-PSK	4-PSK	FM	FM
Capacity	2 Mbit/s	8 Mbit/s	34 Mbit/s	140 Mbit/s	1 Video	1 Video
Channel spacing (MHz)	14	14	28	140	28	56
Antenna gain at boresight (dBi)	41	41	41	41	41	41
Maximum Antenna gain at 90° off boresight (dBi)	-10	-10	-10	-10	-10	-10
Feeder/multiplexer loss minimum (dB)	3	3	3	3	3	3
Antenna type	dish	dish	dish	dish	dish	dish
Maximum transmitter output power (dBW)	-10	-10	-10	-10	-10	-10

3.6 FS transmitter output power

As explained in section 3.3, longer distance links will be accommodated in the lower frequency bands. Because the links in this band will only be used for distances up to about 2 km, the EIRP will be very low. Manufacturers producing equipment for the 57.2 - 58.2 GHz frequency band have indicated that the maximum transmitter output power is -17 dBW. Maximum output power at 38 GHz is in the range -18 to -12 dBW. The studies have conservatively estimated an upper limit of -10 dBW for the 55 GHz band. A recent study, circulated as SE19(96)50, indicates that the increased attenuation in the upper half of the band puts the path length limit at about 2 km when the -10 dBW upper limit is used. With the reduced attenuation in the lower half of the band, the power requirement to cover this distance is about -26 dBW.

3.7 Possible Means of Sharing

Article 27 of the Radio Regulations covers terrestrial radiocommunication services sharing frequency bands with space radiocommunication services above 1 GHz. The shared bands all have power restrictions on the Fixed Service to prevent interference to Space Services. In the 55.22 - 55.78 GHz band a revision of the existing power restriction could be entered to provide the required level of protection to the Earth Exploration-Satellite Service.

4. IMPLICATIONS FOR SHARING IN THE BAND 55.22 - 55.78 GHz

4.1 Direct Interference Propagation Path

The maximum vertically radiated power within a pixel is given by:

$$VRP_{max} = I_{th} + FSL + \gamma - G_s$$

Where: I_{th} is the interference threshold = -166 dBW/100MHz

FSL is the free space path loss from ground to satellite = 185.9 dB

γ is the minimum gaseous absorption = 37 dB (from sea level)

$$= 32.2 \text{ dB (from 1000 m altitude)}$$

G_s is the remote sensor antenna gain = 45 dBi

This yields the following maximum vertically radiated powers per pixel:

Altitude of FS terminals	Minimum O ₂ absorption	VRP _{max} in 100 MHz	VRP _{max} in 15 MHz
0 m	37 dB	11.9 dBW	3.7 dBW
1000 m	32.2 dB	7.1 dBW	-1.1 dBW

A study has been conducted by the UK in order to determine the theoretical maximum number of fixed link terminals within a 16 km diameter passive sensor pixel. The study took assignment software used by the UK administration and attempted to place 14 MHz links within the test area, each time checking interference to and from each other link. All links were co-channel, while the directions and positions were chosen at random, but bound by the -10 dBW maximum power level. The software would continue to attempt to place new links in the area until 20 successive assignment failures occurred.

A significant finding of the study was that the link length was limited to ≈ 2 km by the -10 dBW maximum transmitter power and the increased attenuation in the upper half of the band. The corresponding transmitter power requirement (measured at the antenna input) to cover this distance in the lower half of the band was never greater than -26.2 dBW. Maximum eirps for such a transmitter are:

	Transmitter power	Antenna gain	EIRP
Horizontal plane	-26.2 dBW	41 dBi	14.8 dBW
Zenith	-26.2 dBW	-10 dBi	-36.2 dBW

On running the software several times, with the power levels and failure constraints described above, figures of 100-120 co-channel links were achieved. The theoretical maximum number of links within a pixel can conservatively be estimated at 150.

To determine the signal level at the satellite, the following worst case scenarios were considered:

- 150 FS terminals in pixel area
- Power at input to each antenna is -26.2 dBW in 14 MHz
- Push-broom sensor interference threshold (ITU-R Recommendation SA 1029)
- 0% of measurement cells exceed stated interference threshold (see Note below)
- 100% availability of passive sensor data (see Note below)
- FS terminals considered at sea level and 1000 m altitude

Note: ITU-R Recommendation SA 1028 gives performance criteria for satellite passive remote sensing and recommends that in shared frequency bands, availability of passive sensor data shall exceed 99% of all locations in the case where the loss occurs systematically at the same locations.

The permissible interference level for a push-broom sensor in the frequency range 50 - 66 GHz is -166 dBW/100 MHz, with a proposal that 0% measurement cells could exceed the protection level.

ITU-R Recommendation SA 1029 gives interference criteria for satellite passive remote sensing and recommends that stated interference levels can be exceeded in 1% of measurement cells, in the case where the interference occurs systematically at the same locations. In shared frequency bands, the interference thresholds and percentages of loss for specific systems must be greater than or equal to the values recommended

For a period of about 2 years, concern has been expressed by remote sensor data users over the adequacy of the criteria defined in the ITU-R Recommendations. A recent input to ITU-R Working Party 7C stated that these criteria may be unsuitable for protection of passive sensors in this band, however no output on this matter has yet been received from Working Party 7C. No alternative criteria have yet been proposed within Working Party 7C.

Both this section and the following section on indirect interference effects have worked to more stringent criteria so that 0% of measurement cells would exceed the protection levels. This percentage has not been agreed by ITU-R Study Group 7 and is still subject to much debate. The contribution from the meteorological community describes the technical justification for this requirement.

Using an antenna gain of -10 dB in the zenith direction, 150 terminals at -26.2 dBW give a combined EIRP towards zenith of -14.4 dBW in 14 MHz. Scaling to the push-broom sensor bandwidth gives an EIRP towards zenith of -14.1 dBW in 15 MHz. Comparing this to the stated thresholds gives the following margins:

Altitude of FS terminals	Minimum O ₂ absorption	EIRP towards zenith	VRP _{max}	Margin
0 m	37 dB	-14.1 dBW/15 MHz	3.7 dBW/15 MHz	17.8 dB
1000 m	32.2 dB	-14.1 dBW/15 MHz	-1.1 dBW/15 MHz	13.0 dB

Power limits can thus be determined for a single fixed service terminal, based on the conservative estimate of 150 terminals per pixel area and considering the limits on EIRP towards zenith in the above worst case scenarios. The levels are derived by dividing the permitted power level by 150 and scaling to the fixed link bandwidth:

	All links at 0 m altitude	All links at 1000 m altitude
Maximum	-18.1 dBW/15 MHz	-22.9 dBW/15 MHz
EIRP	-8.4 dBW/140 MHz	-13.2 dBW/140 MHz
towards	-18.4 dBW/14 MHz	-23.2 dBW/14 MHz
zenith	-29.9 dBW/MHz	-34.7 dBW/MHz

Applying these limits to the fixed service in the band 55.22 - 55.78 GHz would ensure that the sensor interference criterion of -166 dBW in 100 MHz would not be exceeded from direct propagation and would allow the fixed service to use transmitter powers up to the -26.2 dBW necessary.

4.2 Indirect Interference Propagation Path

Document SE19(96)9 gave some examples of indirect interference geometries involving reflection from rooftops. In a worse case example (as shown in Figure 6), interference may be caused by a reflection from a rooftop at 45° elevation, with a reflection coefficient (σ) of -10 dB. The gas absorption on the path d1 is 4.5 dB/km but has been ignored. Free space loss on the path d1 can also be ignored, giving the interference at the satellite:

$$I = \text{EIRP} + \sigma - 20\log(4.\pi.d2 / \lambda) - \gamma_2 + G_s$$

where EIRP is the boresight eirp of the fixed link, γ_2 is the gas absorption on the path d2, and G_s is the maximum antenna gain of the satellite receiver. Considering the pushbroom sensor, the satellite antenna gain is 45 dBi and its altitude, d2, is 850 km.

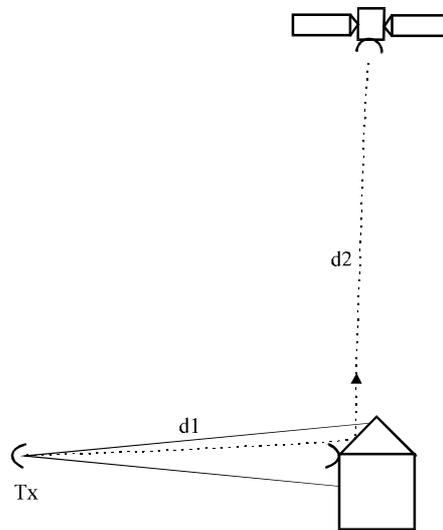


Figure 6 Worst case rooftop reflection

To determine the signal level at the satellite from this propagation mechanism, the following worst case scenarios were considered:

- Push-broom sensor interference threshold (ITU-R Recommendation SA 1029)
- 0% of measurement cells exceed stated interference threshold (see Note in previous section)
- 100% availability of passive sensor data (see Note in previous section)
- FS terminals considered at sea level and 1000 m altitude
- No atmospheric attenuation on fixed link (d1) path (4.5 dB/km at sea level)

The maximum permissible power output from the antenna can be calculated from:

$$\text{EIRP}_{\text{max}} = I_{th} - \sigma + 20\log\left[\frac{4\pi d_2}{\lambda}\right] + \gamma_2 - G_s$$

where

I_{th} is the interference threshold = -166 dBW/100 MHz

γ_2 is the minimum gas absorption = 37 dB (sea level)

$$= 32.2 \text{ dB (1000 m altitude)}$$

G_s is the remote sensor antenna gain = 45 dBi

With scaling to various bandwidths, this produces the following EIRP limits:

	All links at 0 m altitude	All links at 1000 m altitude
Maximum EIRP	13.7 dBW/15 MHz	8.9 dBW/15 MHz
	23.4 dBW/140 MHz	18.6 dBW/140 MHz
	13.4 dBW/14 MHz	8.6 dBW/14 MHz
	1.9 dBW/MHz	-2.9 dBW/MHz

Bearing in mind the low probability of such alignments, one could be confident that by applying these eirp limits to each transmitter of the fixed service, the passive sensor would not suffer unacceptable interference from indirect propagation mechanisms. Results from the UK study indicate that these power levels would allow the maximum link length to reach about 2 km (assuming all links are at 0 m altitude) or 1.5 km (assuming all links are at 1000 m altitude). To enable a single set of limits to be applied throughout Europe, it is proposed that the high altitude limits be adopted.

4.3 Effect of Antenna Elevation

Using the methodology of the SE20 Final Report, one can determine the elevation angle at which the interference by path (b) exceeds the interference by path (a) as shown in Figure 7.

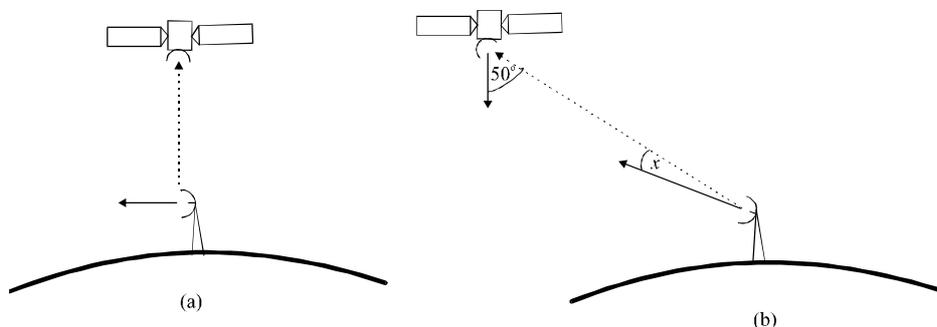


Figure 7 Zenith/nadir path (a) and boresight-to-boresight path (b)

A link will be considered at 1000m altitude, transmitting with a frequency of 55.22 GHz with a high performance antenna as described by the mask in prETS 300 407. The figures for free space loss and oxygen absorption are:

Zenith/nadir path (a):	Free space loss (FSL _a)	:	185.9 dB
	Minimum gaseous absorption (γ_a)	:	32.2 dB
30° elevation path (b):	Free space loss (FSL _b)	:	190.7 dB
	Minimum gaseous absorption (γ_b)	:	63.9 dB

If the fixed link transmitter power is P_T , the fixed link antenna gain at an angle ϕ is $G(\phi)$, and the satellite sensor antenna gain is G_s , then the interference caused by each alignment is:

$$I_a = P_T + G(90) - FSL_a - \gamma_a + G_s$$

and
$$I_b = P_T + G(x) - FSL_b - \gamma_b + G_s$$

Equating I_a to I_b leads to:

$$G(x) = G(90) - FSL_a + FSL_b - \gamma_a + \gamma_b$$

For the high performance antenna mask, $G(90) = -10$ dBi. Thus

$$G(x) = 26.5 \text{ dBi.}$$

Referring to the same antenna mask shows that the antenna gain of 26.5 dBi could only be obtained for angles less than 5° from boresight. Thus if the angle between the antenna boresight and the alignment to the boresight of the satellite antenna exceeds 5° , one can be sure that the interference on path (a) exceeds the interference on path (b).

For a remote sensor at an altitude of 850 km which scans to 50° from the nadir, the incident angle at the earth's surface is 30° . Thus a limit on the antenna elevation angle of 25° will ensure that interference cannot exceed the level assumed in the direct interference analysis in Section 4.1.

5. CONCLUSIONS

The band 55.2 - 55.78 GHz is shared on a primary basis between the Fixed Service and the Earth Exploration-Satellite (Passive) Service.

The sharing studies have been carried out based on the following assumptions for the EESS:

- pushbroom-type remote sensor;
- interference criterion of -166 dBW/100MHz;
- measurement cells exceeded;

and based on the following assumptions for the Fixed service:

- all links at 1000m altitude;
- maximum link length of about 1.5 km;
- maximum transmitter power of -26.2 dBW;
- minimum transmitter bandwidth of 14 MHz;
- maximum number of co-channel links in a sensor cell of 150¹.

The sharing study has considered the following cases:

- direct/zenith interference path;
- indirect interference path;
- fixed link antenna at elevation angle above 0° ;

and as a result, has concluded that the following limits should be applied to fixed links in the band 55.2 - 55.78 GHz:

- maximum EIRP: -2.9 dBW/MHz;
- maximum EIRP towards zenith: -34.7 dBW/MHz;
- maximum elevation angle: 25° .

Subject to the above assumptions and application of the recommended limits to the fixed service, sharing appears to be technically feasible.

¹ This conservative assumption is based on self limitation due to intra-service interference.