European Radiocommunications Committee (ERC)
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COMPATIBILITY BETWEEN TFTS (1670-1675 MHZ/1800-1805 MHz) AND SERVICES IN THE SAME AND ADJACENT BANDS

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1. INTRODUCTION

This report is a summary of the compatibility studies that have been done within the CEPT-Spectrum Engineering Working Group concerning Terrestrial Flight Telephone System (TFTS) and services in the same and adjacent bands.

2. RADIO ASTRONOMY (1660 - 1670 MHz)

See ERC Report 11. It should be noted that ETSI decided to increase the maximum EIRP for TFTS from 44 dBm to 49 dBm.

3. METEOROLOGICAL SATELLITE, SPACE - TO - EARTH (1670 - 1710 MHz)

3.1 Low-earth-orbit

The upper portion of the band, from approximately 1695 to 1710 MHz is used for Low-Earth-Orbit Meteorological satellites. It is necessary to have tighter limits for the spurious emissions than those in the draft ETS. The value should be - 60 dBW / MHz.

3.2 Geostationary

The geostationary satellites use the lower portion of the band, e.g. 1670 MHz to approximately 1695 MHz.

3.2.1 METEOSAT

Primary and secondary data user stations (PDUS and SDUS)

There are approximately 2000 user stations in Europe receiving the frequencies 1691 MHz and 1694,5 MHz (Meteorological centres, airports, military installations, universities, etc.).

The frequency 1695,7 MHz is or will be received by approximately 200 to 300 stations which are already in operation or planned to be installed in the future. The conclusion is the same as for the LEO-METSAT, i.e. the spurious level should be reduced to - 60 dBW / MHz.

Data acquisition telecommand and tracking station (DATTS)

The DATTS are receiving on frequencies close to 1675 MHz, see below:

1676.180 MHz	Housekeeping, telemetry
1675.281 MHz	Data collecting platform
1686.833	Raw Image
1675.929	Telemetry (F)
1676.228	""
1676.328	""
1676.028	""
1676.128	""

These frequencies are presently received only in:

- Michelstadt (Germany)
- Lannion (France)

Additional receiving equipment for these frequencies is planned in:

- Italy (Fujino)
- Ireland (one location)
- Germany (Usingen?)

The coordination distance is 7 km for frequencies below 1673 MHz. Since it has not been possible to achieve enough information about the filter characteristics, the coordination distance for frequencies above 1673 MHz is 250 km (land) but this distance can be reduced CONSIDERABLY by better information about the specific earth station (including the filter characteristics, antenna pattern, C/N, etc.), by taking into account the terrain, and using the same measures as for Radio Astronomy (see ERC-report 11).

The table below indicates how much the coordination distance can be reduced by taking into account the terrain.

Coordination distance, (km) due to ducting, 0.1 % of time.

land			sea
A_h	$\Delta H = 50$	$\Delta H = 100$	
0	250	200	650
10	200	150	
20	140	110	
30	85	65	

The interference distance due to troposscatter is shorter than the distance above.

3.2.2 Goes

The frequencies 1687,1 MHz and 1694,5 MHz are received in UK and in Ireland the Meteorological Service has the capacity to receive on 1691 MHz. Since the assigned frequency bands are 8.2 MHz, 400 kHz resp. 30 kHz, it is only spurious emission that can cause interference to these frequencies. In Spain the frequency 1687,1 MHz has been received but is at present interrupted, however another GOES satellite will this year operate the service, probably at the same frequency.

Since it is only spurious that has to be taken into account, the same conclusion as for the METSAT (PDUS and SDUS) stations are valid.

4. FIXED SERVICE

In the frequency bands concerned, there exist different kinds of fixed services, both analogue and digital, wide- and narrow band. Some administrations use fixed services according to CCIR Rec. 283 or CCIR Rec. 382 and some administrations use fixed services according to other channel arrangements.

4.1 Analogue, 1 + 1 channels (1672 - 1676 MHz)

In UK, the frequency band 1672 - 1676 MHz is used for analogue fixed links with a channel spacing of 0,05 MHz. It is recognised that under some circumstances there could be considerable co-channel interference and some adjacent channel interference into fixed links from TFTS and vice versa. Annex 1 identifies some elementary measures that may be taken, whereby any harmful mutual interference can be eliminated.
120 kHz from the carrier, it is necessary to reduce the out-of-band emission to - 68 dBc.

4.2 1807.5 MHz to 1815.5 MHz, requirements for the spurious emissions

The fixed links used in the UK, are analogue frequency division multiplex, with channel capacities of 1 + 1, 8, 12, 24, 36 channels.

Annex 2 gives the methodology used for determining interference from TFTS aircraft station (AS) to a fixed link.

The table below summarises the result of the analyses for a busy airport where aircraft arrive every 3 minutes.

TFTS Spurious Emission Level	Off-axis coordination distance	Max % interference time for AS traversing fixed beam	Max. aircraft height likely to cause interfe-rence (in main beam)
As ETSI specification	0.7 - 8.9 km	3.1%	2100 m
With 15 dB improvement	0.1 - 1.5 km	0.55%	400 m

The results of this study show that with a 15 dB improvement (at a frequency offset of 2.5 MHz) in the TFTS AS spurious emission level, a significant increase of protection is afforded to the adjacent band fixed links. The coordination distance is not unrealistic and when combined with information on the location and direction of peak antenna gain of the fixed links, incompatibility problems will be minimised.

4.3 CCIR recommendation 283, 2 x 8 Mbit/s

The TFTS aircraft station can cause interference to fixed service on a height of 500 meter, i.e. when the aircraft is approximately 8 km from the airport. If there is a TFTS ground station close to the airport the transmitter power may be reduced and the interference distance will then be reduced. In the worst case, i.e. the mainlobe is pointing in the direction of the airport, the coordination distance is approximately 25 km.

5. MOBILE SERVICE

5.1 DCS 1800

In the band 1710 - 1785 MHz, DCS 1800 base stations (BS) may receive interference from TFTS aircraft stations (AS) since it is likely that both systems could be operated physically close to each other. The most common scenario would be where a DCS 1800 BS is sited near or at an airport i.e. close to TFTS AS. In the analysis it was assumed that the minimum separation distance between the TFTS AS and DCS 1800 BS would be 100 m. The existing radio parameter specifications were used. It is necessary to reduce the spurious emissions for the TFTS AS to - 62 dBW / 30 kHz. However, part of the additional attenuation will be achieved by the diplexor.

In the band 1805 - 1880 MHz, DCS 1800 may operate mobile receivers which are handportable and could operate very close to a TFTS AS at airport terminals. It was assumed in the analysis that the minimum separation between a DCS 1800 mobile receiver and a TFTS AS transmitter could be as little as 30 m, particularly when DCS 1800 mobiles are used at departures gates. The carrier can then cause interference if the frequency separation is less than 1.6 MHz. However, the main problem is the spurious emissions since they can cause interference at much greater frequency separations. It is necessary to reduce the spurious emissions to - 40 dBm / 30 kHz.

It can be noted that the problem may be reduced if:

i) an aircraft approaches an airport where a TFTS GS is situated, the TFTS AS will dynamically reduce transmit power in order not saturate the TFTS GS receiver;

ii) a TFTS AS communicates to a TFTS airport station (low power TFTS GS for coverage around the airport;

iii) Coordination, to ensure that near airports a DCS 1800 system should not use the frequencies adjacent to TFTS AS frequency band;

iv) Planning the DCS 1800 base stations so that the wanted signal, at the departure gates, is kept on a level which gives the required protection ratio.

In the scenarios (i) and (ii), the TFTS AS is unlikely to be transmitting at full power. The spurious emissions can be expected to be reduced when the output power is reduced. This reduction may however not be linear.

5.2 Other mobile systems

There is a potential for interference to the TFTS ground stations from a Swedish aeronautical mobile system operating in the adjacent band. Theoretical calculations give interference distances from the aeronautical mobile aircraft to TFTS GS, ranging from 15 km for the TFTS frequency 1800 MHz to 50 km for 1805 MHz. Field measurements will be carried out, as soon as the first TFTS test station is taken into operation, to verify these values.

6. CONCLUSIONS

It can be concluded that there are potential incompatibility problems between TFTS transmitter and adjacent services. The incompatibility stems from the transmitter mask for the TFTS ground station (GS) as well as for the TFTS aircraft station (AS) defined in the draft ETS, permitting high levels of spurious emissions.

Some improvement of 15 dB is required at the TFTS AS for 2.5 MHz frequency offset in order to minimise the coordination distance with fixed links. Reduction in spurious emissions will also aid the coordination between TFTS GS and fixed links. A reduction of the spurious emissions for the TFTS GS to -30 dBm / MHz is necessary to prevent interference to MET-SAT. A reduction to -40 dBm / 30kHz for the TFTS AS is necessary to prevent interference from TFTS AS to DCS 1800 mobile stations operating at airports.

ANNEX 1

Measures to eliminate interference between TFTS GS and fixed service

1. Partition of fixed link and TFTS bands

It would seem that there is a scope for the TFTS and Fixed Link operators to agree to a mutually beneficial partitioning of the band 1670 - 1675 MHz.

An EXAMPLE is given here:

a	1670 - 1671.88	TFTS	Fill from bottom up
b	1671.88 - 1672	Coordination Band*	
c	1672 - 1672.45	Fixed Links	Currently in use
d	1672.45 - 1673.88	Fixed Links	Fill from bottom up
e	1673.88 - 1674	Coordination Band*	
f	1674 - 1675	TFTS	Fill according to usage of sub-bands (d) & (h)
g	1675 - 1675.12	Coordination Band*	
h	1675.12 - 1676	Fixed Links	Fill from top down

*) Band where careful coordination between services is required

Analysis in the UK assumes that the existing fixed links would be protected by not using co-channel TFTS assignments (including 120 kHz coordination band). It has been shown that coordination is required close to a TFTS GS if adjacent channels are to be used by fixed links. The exact separation distance required depends on the terrain profile and ground clutter between the services as well as the exact gain of the fixed antenna towards the TFTS GS. Careful coordination of some specific links may be required.

Further analysis has shown that it may be possible to coordinate some fixed links co-channel to TFTS if the services are sufficiently separated.

2. POSSIBLE 3 DB REDUCTION OF TFTS AMPLIFIER PRODUCTS

The draft ETSI standard specifies that TFTS out-of-band (OOB) products should be at a level less than -65 dBc at more than 120 kHz from the centre of a TFTS carrier.

Manufacturer of the TFTS airborne equipment, has stated that measurements on bench development equipment shows that the out-of-band is expected to be 10 dB better than the -65 dBc specified (except for isolated spikes where the out-of-band level degrades back to - 65 dBc).

Unlike the airborne equipment, the TFTS GS equipment is not constrained in weight, size and heat dissipation and discussions with one manufacturer suggested that an extra 3 dB may be possible (i.e. improving the OOB spec to - 68 dBc).

The example in chapter 2.2 provides a minimum of 120 kHz guard band, i.e. a minimum of -65 dBc for the rf spectrum mask. It can be safely assumed that separations much greater than 120 kHz will be initially obtained as the bands fill in the most judicious manner.

3. ANTENNA GAIN

The fixed link antennas are directional and have gain as follows:

main beam	17 dBi
20°	12 dBi (5 dB rejection of sidelobe)
50°	4 dBi (12 dB rejection of sidelobe)
100°	-5 dBi (23 dB rejection of sidelobe)

By careful selection of TFTS and Fixed links sittings, it should be possible for the fixed link operators to obtain 23 dB rejection of interference from TFTS.

The TFTS uses omni-azimuthal antennas so no gain discrimination is possible by the TFTS antennas.

4. POLARISATION

The TFTS GS uses only vertical polarisation. The fixed links uses both vertical and horizontal polarisation and has cross-polarisation discrimination as follows:

main beam	20 dB rejection of X-polar
20°	14 dB rejection of X-polar
40°	9 dB rejection of X-polar
60°	5 dB rejection of X-polar
>100°	0 dB rejection of X-polar

If it is possible to arrange the fixed link networks so that stations near a TFTS GS (and particularly those links that 'look' towards a TFTS GS) use horizontal polarisation, then considerable rejection of unwanted signals may be obtained.

5. PATH LOSS

Ideally, fixed links and TFTS stations should be widely separated in order to increase the path loss between them.

It will not be possible to achieve large separation distance between the different stations in some areas, since the station sites are already fixed.

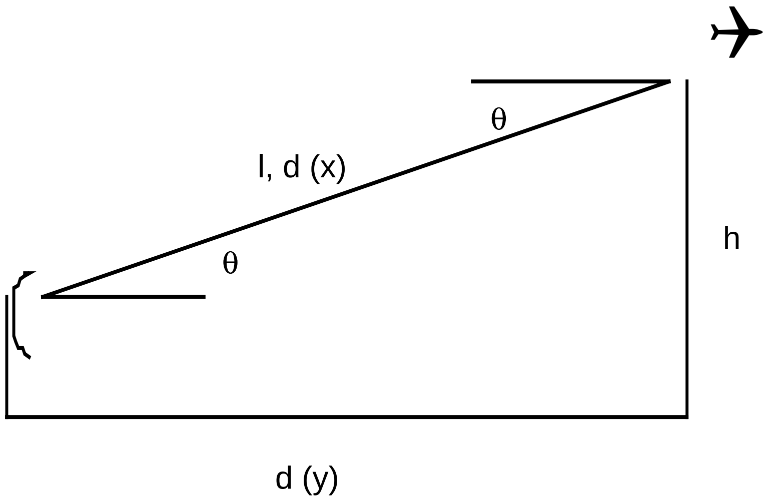
Fixed link antennas could possibly be shielded in the direction of a TFTS GS by the erection of a metal 'blinker'. No such shielding can be fixed to the TFTS GS because TFTS GSs are required to be omni-azimuthal.

6. POSSIBLE RELAXTION OF FIXED LINK C/I MARGIN

A figure of 40 dB has been given as the minimum required C/I margin for fixed link system. This figure is under review. So far, there has been no indication that these fixed link parameters may be either improved or relaxed.

ANNEX 2

Methodology for determining interference from TFTS (aircraft) to fixed service



1. THE NECESSARY ATTENUATION

To prevent interference from the aircraft, the necessary attenuation is given by :

$$A = E - Sr(f) - Si(f) + \text{linterp}(G_r, \theta) - I + 10\log(n) \qquad (1)$$

Where:

E = EIRP of the TFTS
Sr(f) = Rf - filter attenuation (receiver)
Si(f) = IF - filter attenuation (receiver)
linterp (G_r, θ = Receiving antenna gain, depending on the off-axis angle (degrees)
I = Max tolerable interference level at the fixed Rx, including feeder losses
n = number of transmitters
θ = Off-axis angle (degrees)

The reference radiation patterns for the antennas can be found in CCIR Rec. 699. However, it should be noted that the interference distance can be reduced by taking into account the specific antenna diagram for the radio-relay.

2. CALCULATION OF THE COORDINATION DISTANCE AROUND THE RADIO-RELAY

The coordination distance, i.e. using maximum antenna gain for TFTS, is given by:

$$d(x) = 10^{(A - 32.5 - 20\log(f)) / 20} \qquad (2)$$

Where:
f: MHz
d (x): km

3. CALCULATION OF THE ALTITUDE (h) AND THE DISTANCE d (y)

The coordination distance has been calculated by using the maximum antenna gain for TFTS. By taking into account the antenna gain for TFTS, the interference distance can in some cases be reduced.

$$1 = 10^{(A + \text{linterp}(D, \theta) + \text{linterp}(G_r, \theta) - 32.5 - 20 \log(f) / 20} \qquad (3)$$

$$h = l \times 1000 \times \sin(\theta), \qquad (4)$$

$$d(y) = l \times \cos(\theta), \qquad (5)$$

Where:

l = The interference distance, when the aircraft is flying in the direction of the main beam
linterp (D, θ) = The antenna gain for TFTS, depending on the off-axis angle
h = Altitude (m)
d (y) = Distance on the ground between the radio-relay and the aircraft (km)

4. CALCULATION OF PERIOD OF AIRCRAFT IN THE MAIN BEAM OF THE FIXED LINK

If the calculations indicate that interference will occur it is then necessary to calculate the percentage of time the interference will be caused to the fixed station, by taking into account the time each aircraft is causing interference, the density of aircrafts and the probability that the interference will occur while the fading margin is fallen to 0 dB.

The time the aircraft is passing perpendicularly to the mainlobe is calculated by formula 6.

$$t = (1 \sin(\theta(d))\ 1 \times 2\ d(x) \times 1000) / v \qquad (6)$$

Where:

θ(d) is the angle for a given d (x) (degree)
v is the velocity for the aircraft (m/s)
t is in seconds

It should be noted that the radio-relay can receive higher interference levels from the radio-relay itself, due to reflections from the body of the aircraft.