proximus

Syndicat d'Initiative et d'Intérêts Locaux
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L-1280 Luxembourg

Notre réf: L-0574 Cents
Votre réf: 242-2021

Bertrange, le 6 janvier 2021

Concerne : Site de Mobilophonie L-574 Cents

Madame, Monsieur,

Tout d'abord permettez-nous de vous souhaiter une bonne et heureuse année 2021.

Nous accusons bonne réception de votre courrier du 4 Janvier 2021 et nous avons le plaisir de vous répondre en toute transparence comme suit :

1. Nous regrettons d'apprendre que le certificat n'aurait pas été posé en temps opportun. Nous ne croyons pas que c'est le cas, mais nous allons nous renseigner auprès de nos équipes et sous-traitants.
2. Votre souci concernant la compatibilité entre nos équipements et les équipements radars et autres de l'ANA sont légitimes. Soyez rassurés que depuis très longtemps tout émetteur à proximité de l'aéroport et soumis à une étude détaillée. Preuve à l'appui, nous voulons vous faire parvenir en annexe une copie d'un rapport d'étude concernant justement le risque d'interférence. Ce rapport est en anglais et très technique, mais en résumé, prouve qu'il n'y a aucune incompatibilité à retenir.
3. En annexe, nous vous joignons un courrier de l'ANA pour ce site.
4. En ce qui concerne le rayonnement électromagnétique d'un site d'antennes de télécommunication mobile, tout opérateur de mobilophonie est obligé à demander une autorisation Commodo-Incommodo auprès de l'ITM et de l'Administration de l'Environnement. Sans cette autorisation un site ne peut pas être opéré avec plus de 50W de puissance émettrice. Cette autorisation a pour but de valider qu'à aucun endroit où peuvent séjourner des personnes, le champ électromagnétique dépasse 3V/m. Nous tenons à signaler que la norme européenne autorise 42V/m et que le Luxembourg a adopté une norme beaucoup plus stricte.
5. Il vous sera loisible de consulter cette autorisation qui reprends tous les détails demandés auprès de l'Administration de l'Environnement en temps opportun. Plus tard aussi sur le Geoportail.
6. Pour information : Le site n'est pas encore en service et la procédure d'autorisation Commodo-Incommodo est en cours.

Madame, Monsieur, nous espérons que ces informations vous seront utiles et nous vous prions; Madame, Monsieur, l'expression de nos salutations distinguées.

Gilles Mulheims
Head of Networks

Georges Majerus
Gestionnaire des Sites

LE GOUVERNEMENT
DU GRAND-DUCHÉ DE LUXEMBOURG
Ministère de la Mobilité
et des Travaux publics

Direction de l'aviation civile

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**TANGO S.A.**
**Monsieur CACHADA José**
**Site Acquisition Coordinateur**

**18, rue du Puits Romain - Z.A. Bourmicht**
**L-8070 BERTRANGE**

**Aussi par courriel :**
**Jose.cachada@proximus.lu**

Luxembourg, le 07 OCT. 2019

**V/Réf L0574 -Cents**
**Objet : Station de base de mobilophonie à Cents**

Monsieur Cachada,

J'ai l'honneur de me référer à votre demande du 19 septembre 2019 concernant le projet de construction d'une station de base de téléphonie mobile aux coordonnées N49°37'10,3"; E006°10'42,5" sur la parcelle cadastrale P&CH de la commune de Luxembourg, Section HaA de Hamm au lieu dit « Rue Cents ».

Vu l'altitude du terrain de 338.00m.n.m. et la hauteur projetée de 42.00m de l'antenne, celle-ci n'est pas de nature à porter préjudice à la circulation aérienne.

Je n'ai donc pas d'objection à formuler à l'encontre de la construction de cette station de base de téléphonie mobile. Un marquage et un balisage comme obstacle à la navigation aérienne ne sont pas requis.

Veuillez agréer, Monsieur Cachada, l'expression de mes considérations respectueuses.

Pierre JAEGER
Directeur de l'Aviation Civile

Copies : ANA - aro@airport.etat.lu
Lux Airport - operations@lux-airport.lu

NAVCOM Consult

**FINAL REPORT**

# <u>Expertise</u>

# Assessment of the Impact of Interference from GSM Base Stations on ATC-Radar and Navaids Systems at the Airport Luxembourg (ELLX)

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# 0 Table of Contents

## 0.1 Contents

**Page**

## 0.2 List of Tables

**Page**



## 0.3 List of Figures

**Page**

## 0.4 List of Acronyms and Abbreviations

P GSM: primary GSM 900 band (900 MHz).
E GSM: extended GSM 900 band (includes P GSM band).
R GSM: Railways GSM 900 band (includes P GSM band and E GSM band).

| | |
|---|---|
| 3GPP | 3rd Generation Partnership Project |
| BS | (GSM) base station |
| BSS | (GSM) base station (sub)system (radio part) |
| BTS | (GSM) base transceiver station (part of BSS) |
| CAA | Civil Aviation Authority |
| CAT | ILS Operational Category (CAT I, CAT II, CAT III) |
| CEPT | European Conference of Postal and Telecommunications Administrations |
| CH | Channnel |
| dB | Decibels |
| dBc | Decibels relative to carrier power |
| dBm | Decibels relative to 1mW |
| DCS | Digital Communication System (1800 MHz band) |
| DME | Distance Measurement Equipment (962 MHz – 1213 MHz) |
| DVOR | Doppler Very High Frequency Omnidirectional Range |
| E | Electric Fieldstrength (V/m) |
| ECC | Electronic Communications Committee |
| EMC | Electromagnetic Compatibility |
| ERC | former European Radio Committee in CEPT, now ECC |
| EIRP | Effective Isotropic Radiated Power |
| ERP | Effective Radiated Power |
| ETSI | European Telecommunications Standards Institute |
| ICAO | International Civil Aviation Organization |
| ITM | Inspection du Travail et des Mines, Luxembourg |
| ITU | International Telecommunication Union |
| GMSK | Gaussian Minimum Shift Keying: modulation type as defined by 3GPP TS 45.004 |
| GP | ILS Glide Slope (Subsystem of ILS for elevation guidance, 329 MHz – 335 MHz)) |
| GSM | Global System for Mobiles |
| ILS | Instrument Landing System (108 MHz – 112 MHz) |
| LOC/LLZ | ILS Localizer (Subsystem of ILS for azimuthal guidance) |
| MC | Multi Carrier |
| MCL | Minimum Coupling Loss |
| MCBTS | Multi Carrier Base Transceiver Station |
| MR | Medium Range |
| MS | mobile station, the handset in the GSM standard |
| MSL | Mean sea level |
| MSSR | Monopulse SSR |
| MTL | Minimum Triggering Level |
| NC | NAVCOM Consult |
| PSR | Primary Surveillance Radar |
| RF | Radio Frequency |
| RWY | Runway |
| RX | Receiver |
| S | Power density ($W/m^2$) |
| SARP | Standard and recommended practices (specs in ICAO Annex 10, "white pages") |
| SSR | Secondary Surveillance Radar |
| TRX | Transceiver |
| TX | Transmitter |
| VHF | Very High Frequency (30 MHz – 300 MHz) |
| $Z_0$ | Impedance of free space ($120\pi\ \Omega$) |

# 1 Introduction

## 1.1 General

On and around the area of airports such as Luxembourg airport a number of stationary and mobile radio systems exist which are based on the radiation or receiving of electromagnetic waves and may have mutual impact which has to be considered.

In the following some definitions are listed as they are used in ETSI/3GPP documents for the mobile radio environment:

The present document defines RF characteristics for the Mobile Station (MS) and Base Station System (BSS). The BSS will contain Base Transceiver Stations (BTS), which contains the equipment for transmitting and receiving radio signals (transceivers), antennas, and equipment for encrypting and decrypting communications. A BTS can be normal BTS, micro-BTS (reduced range requirements) or pico-BTS (extension of the micro-BTS concept to the indoor environments).

Multicarrier BTS are classes of BTS, characterized by the ability to, in addition to single carrier operation, process two or more carriers in common active RF components simultaneously, either in multicarrier transmitter only or, in both multicarrier transmitter and multicarrier receiver.

A MS is the complete equipment configuration which may take part in a communication, contains the equipment for transmitting and receiving radio signals (transceivers) and antennas.

The term GSM 900 or only GSM is used in this document for any GSM system, which operates in any 900 MHz band. Other GSM bands (GSM 450, GSM 480, GSM 850) are not part of this expertise. The term DCS 1800 or only DCS is used for any DCS system, which operates in any 1800 MHz band.

At the airport of Luxembourg (ICAO Code ELLX) the following relevant navigation and radar systems are installed (**Fig. 1**):

- ILS 06/24 (localizer 109.9/110.7 MHz, glide path 333.8/330.2 MHz; with field monitors)
- DME 06/24 (CH36X/CH44X: TX 1060 MHz RX 997 MHz / TX 1068 MHz RX 1005 MHz)
- DVOR/DME LUX (112.25 MHz / CH 59Y: TX 1083 MHz RX 1020 MHz; with field monitor)
- DVOR/DME DIK (114.40 MHz / CH 91X: TX 1115 MHz RX 1178 MHz; with field monitor; far away from the airport area)
- TAR1 (primary radar, see **Table 9**; secondary radar 1030 MHz/1090 MHz; not permanent operation for future)
- TAR2 (primary radar, see **Table 9**; secondary radar 1030 MHz/1090 MHz; much higher installation than TAR1)

The co-existence of GSM 900 and DCS 1800 stations with these systems requires regulations in principle if there exists a real operational threat for these systems. Therefore, a specification has been released by Luxembourg authorities (ITM-CL 179.4, /1/) about "Electromagnetic Compatibility" (EMC) which also includes the above systems and defines restriction areas of the installation in article 6 (*Protection des appareils sensibles*) with respect to GSM stations (**Fig. 1**). This article 6 contains the quoted misleading equipment names which are commented in the remarks of the following table:

| Para. | Equip-ment | Coordinates | Altitude /m | Protection distance /km | Remarks ("real" equipment) |
|---|---|---|---|---|---|
| 6.3.1 | Radar | 49°37'09"N, 006°12'16"E | 415.0 | 5 | the "old TAR1". |
| 6.3.2 | VOR | 49°37'04"N, 006°11'30"E | 360.0 | 2 | the ILS-GP06-antenna |
| 6.3.3 | VOR | 49°37'59"N, 006°14'01"E | 375.0 | 2 | the ILS-GP24-antenna |
| 6.3.4 | VOR | 49°38'25"N, 006°14'55"E | 369.8 | 1 | the DVOR/DME LUX-in approach area 24 in front of THR24 |
| 6.3.5 | VOR | 49°51'39"N, 006°07'51"E | 325.0 | 1 | the DVOR/DME DIK (Diekirch) some 26km off the airport |

**Table 1:** Protection areas (ITM-CL 179.4, /1/)

The following constraints apply (extract from ITM-CL 179.4, /1/):

- *la puissance isotrope rayonnée équivalente (p.i.r.e.) de chaque élément rayonnant est à limiter à 100 W (20dBW);*

- *les bandes de fréquence 908,0 à 912,0 MHz et 941,5 à 945 MHz sont interdites (uniquement obligatoire pour le radar visé sub 6.3.1)*

The power limit of 20dBW (EIRP) is equivalent to 50dBm (EIRP).

For a GSM directional sector antenna of 17dBi at the pattern maximum, a base station-radar-antenna input power of only 2W (3dBW) is allowed if the base stations are installed inside the defined protection radii (i.e. 5km for the PSR).

Typical GSM transmitters do have up to 60W per carrier. This explains that the GSM-operators cannot install GSM-base stations close to the airport boundaries if these areas are located inside the protection radii if they want to provide a "standard coverage and range".

## 1.2 Task and general technical background of this expertise

The above discussed "rules" have been defined in order to protect the operation of the related systems on the basis of the general "possibility" of an impact. It is most likely that no deeper and quantitative analysis has been processed.

This study shall carry out this "deeper and quantitative" analysis as well as qualitative theoretical considerations

- on the practical aspects of the GSM operation which consists not only of the regulated base stations but also of the totally unregulated mobile systems (e.g. mobile telephones, GSM-interfaces for computers and laptops)
- on the experience with potential impacts on these radar and navaids systems and potentially existing rules in other countries.

It should be addressed that mobile units (e.g. GSM telephones) can be used fully unregulated in the closest distance to the systems in question. GSM-operation by mobile units are possible in the system shelters in the very vicinity of the antennas and receivers.

As a result of the analysis, recommendations shall be given if

- the current rules can be withdrawn totally or
- the current rules can be relaxed to an extent that the GSM-operations have practical installation possibilities for base stations for closer distances to the systems.

General technical recommendations may be given for installations of base stations if it deems advantageous or for extreme and unexpected cases.

The regulated systems in question are characterized by the following relevant features

- S-band PSR radar: The ground based radar emits high power short pulse signals in the 2.8GHz frequency range which are back reflected from the aircraft to be detected. By that the received back reflected radar signals are extremely weak and generally prone to distortions, such as clutter effects and "strobing" effects by intentionally or unintentionally jammers. The minimum distance of GSM-base stations to the PSR radar is defined in any case by the airport boundaries. However, unregulated mobile GSM units can be very close to the PSR ground station, e.g. in the radar operating room directly below the PSR.
- L-band MSSR Secondary radar operating at 1030MHz and 1090MHz. This system is in fact a bi-directional cooperative communication system. The ground based interrogator collocated with the PSR-radar transmits interrogating streams of coded pulses with relatively high power (up to about 1kW TX pulse power, highly directive and shaped antenna pattern rotating antenna of 27dBi gain) and the transponder on board of the aircraft answers. The MSSR does not have continuously receiving monitors devices, but in case test transponders ("parrots") in some distance on the airport.
  The minimum distance of GSM-base stations to the MSSR radar is defined in any case by the airport boundaries. However, unregulated mobile GSM units can be very close to the MSSR ground station.
- ILS Localizer and Glidepath operating at about 110MHz and about 330MHz which is far below the GSM 900 frequency range. By that the GSM-antennas are highly mismatched to the VHF-frequency and cannot radiate practically potentially existing and distorting signal components. The ground based subsystems radiate signals which are processed by the receivers on board of the aircraft which have naturally very much higher signal levels compared to the potentially received distorting GSM 900-sub-spurious signals when close to the airport and low during the landing phase. Due to the installation scenario of the ground based systems on the airport itself, there is always a natural minimum distance to the potential base stations. However also, unregulated mobile GSM units can be very close to the ILS ground stations.
- DVOR navigation system which operates in the 110MHz frequency range which is far below the GSM frequency range. By that the GSM-antennas are highly mismatched to

the VHF-frequency. Therefore, potentially existing and distorting signal components cannot be transmitted and radiated practically. The DVOR-systems do have nearfield monitoring components which are very close to the transmitting components and operated at very much higher signal levels than potentially received distorting GSM-signals on the DVOR frequency. The DVOR signals are received and processed by receivers on board of the aircraft when high up en-route or greater heights and larger distances when processing a non-precision approach and landing. However also, unregulated mobile GSM units can be very close to the DVOR ground station.

- DME navigation "distance measuring equipment" operating between 960-1213MHz. This frequency range is slightly above the GSM 900 frequency range.
  The ground based system part (transponder) is interrogated by the equipment on board of the aircraft. The transponder on the ground answers and the receiver on board processes the time difference of the transmitted and received coded pulses when being high up in the air during en-route procedures or during landing or starting phases. It has to be noted the signal level of the DME pulses in the aircraft is most likely much higher than the ones of potentially emitted spectral components of the GSM 900.
  The DME ground based systems do not have a field monitor. However also, mobile GSM units can be very close to the DME ground station.

# 2 Technical Background and Results

## 2.1 GSM

### 2.1.1 Definitions and Specifications

#### 2.1.1.1 Base Station, Mobile Station

**Specifications, Data**

BTS and MS emissions are characterized based on levels derived from standards such as 3GPP/ETSI /2/,/3/,/4/,/5/. The GSM frequencies are divided in two parts for uplink (MS transmit, BS receive, RX) and downlink (BS transmit, MS receive, TX). In the following tables main relevant data are listed.

| Name | TX: | RX: |
|---|---|---|
| **P-GSM 900** | 935 MHz to 960 MHz | 890 MHz to 915 MHz |
| **E-GSM 900** | 925 MHz to 960 MHz | 880 MHz to 915 MHz |
| **R-GSM 900** | 921 MHz to 960 MHz | 876 MHz to 915 MHz |
| **DCS 1800** | 1 805 MHz to1 880 MHz | 1 710 MHz to 1 785 MHz |

**Table 2:** Frequency bands for Base Station Systems (GSM 900, DCS 1800)

For a normal BTS, the maximum output power measured at the input of the BSS TX/RX-combiner ("duplexer" or "diplexer" **Fig. 18, Fig. 19**) shall be, according to its class, as defined in the following tables.

| TRX power class | GSM 900 Maximum output power | DCS1800 Maximum output power |
|---|---|---|
| 1 | 320 – (<640) W; 55 – (<58) dBm | 20 - (< 40) W; 43 – (<46) dBm |
| 2 | 160 - (< 320) W; 52 – (<55) dBm | 10 - (< 20) W; 40 – (<43) dBm |
| 3 | 80 - (< 160) W; 49 – (<52) dBm | 5 - (< 10) W; 37 – (<40) dBm |
| 4 | 40 - (< 80) W; 46 – (<49) dBm | 2,5 - (< 5)W; 34 – (<37) dBm |
| 5 | 20 - (< 40) W; 43 – (<46) dBm | |
| 6 | 10 - (< 20) W; 40 – (<43) dBm | |
| 7 | 5 - (< 10) W; 37 – (<40) dBm | |
| 8 | 2,5 - (< 5)W; 34 – (<37) dBm | |

**Table 3:** Output power, BTS TRX Power Classes

| TRX power class | GSM 900 micro and pico-BTS Maximum output power | DCS1800 micro and pico-BTS Maximum output power |
|---|---|---|
| M1 | (>19)-24 dBm | (>27)-32 dBm |
| M2 | (>14)-19 dBm | (>22)-27 dBm |
| M3 | (>9)-14 dBm | (>17)-22 dBm |
| P1 | (>13)-20 dBm | (>16)-23 dBm |

**Table 4:** Output power, micro and pico-BTS Power Classes

| Multicarrier BTS class | Total power limit |
|---|---|
| Wide Area | No limit |
| Medium Range | ≤ 38 dBm |
| Local Area | ≤ 24 dBm |

**Table 5:** Output power, multicarrier BTS classes

"Normal" base-stations (single carrier or multi carrier derived from one RF-TX) have mostly a maximum TX output power of 60W. Losses between the TX itself and the (common) antenna have to be subtracted. A higher output power per carrier does not make sense due to the up-/downlink power budget where the output power of the mobile stations are limited, unless techniques such as e.g. RX-diversity would be used.

RF power control functions ("dynamic power control", power steps) may be implemented in GSM Base Station Systems.

A BTS may be configured with a multiple antenna port connection for some or all of its TRXs or with an antenna array related to one cell (not one array per TRX), i.e. one GSM cell is covered by only one array of e.g. three or four antennas with input of several TRXs. A BTS may be used in normal operation in conjunction with an antenna system which contains filters (e.g. **Fig. 12**) or active elements to meet the requirements.

Because of the frequency ranges of the systems to be investigated and listed in chapter 1.1, relevant in this study are GSM spurious emissions outside the GSM transmit/receive band. The following table lists the standard measurement conditions.

| Frequency Band | Frequency offset | Resolution Bandwidth |
|---|---|---|
| 100 kHz - 50 MHz | | 10 kHz |
| 50 MHz - 500 MHz | | 100 kHz |
| 500 MHz - 12,75 GHz and outside the relevant transmit band | (offset from the edge of the relevant transmit band) | |
| | ≥ 2 MHz | 30 kHz |
| | ≥ 5 MHz | 100 kHz |
| | ≥ 10 MHz | 300 kHz |
| | ≥ 20 MHz | 1 MHz |
| | ≥ 30 MHz | 3 MHz |

**Table 6:** Spurious Emissions Measurements outside the transmit band

The maximum power limits of BTSs itself outside the transmit band (spurious emissions) are based on earlier general CEPT recommendations (/7/) adopted by ETSI/3GPP and shall not exceed (e.g. /3/):

- -36dBm for frequencies up to 1GHz;
- -30dBm for frequencies above 1GHz.

The DCS 1800 may be sensitive to distortions by second harmonics of the GSM 900, if GSM 900 and DCS 1800 systems co-exist. For this reason the ETSI 3GPP standards require specific cross band performance to ensure GSM transmitters put minimum energy into the DCS1800 band and vice versa. Therefore, e.g. high performance filtering equipment such as depicted in **Fig. 12** is implemented which also influences the behavior of out-of-band transmissions, e.g. in the radar band and in the navaids band below the GSM 900-bands . In any case a duplexer filter is located between the common antenna and TX- and RX-subsystems separated by 45MHz.

In general, the RF signal level is expressed in terms of field strength E in dBµV/m. This is related to the power level P in dBm by the following formula using a frequency dependent conversion factor (assuming a 0dBi gain antenna, $E=\sqrt{(Z_o*S)}$; see 3GPP TS 05.05 /4/):

- GSM 900: E (dBµV/m) = P (dBm) + 136.5 (calculated for a frequency of 925MHz).
- DCS 1800: E (dBµV/m) = P (dBm) + 142.3 (calculated for a frequency of 1795MHz).

<u>**Evaluated Spectral Measurements**</u>

The evaluation of the measurements has the goal to see the real level of the spurious emissions and in particular to evaluate the level of the 3rd harmonic of the GSM 900 operation which has been the background of the restrictions imposed on GSM in Luxembourg. For that the 3rd harmonic must be visible in the spectral measurements and must not be covered by "noise" which may be originated also by the modulation and the "normal GSM traffic". The noise must be low enough. This can be achieved by measuring with a sufficiently small bandwidth and a slow sweep time until the harmonics are visible, such as in **Fig. 13** for a GSM **MS** module.

Measurements were available of the GSM-transmitters and -receivers provided by the operators in Luxembourg (EPT, TANGO, ORANGE). Some selected data and measurement results are shown for measurements of a GSM-transmitter at the relevant antenna connector in

- **Fig. 20** Summarizing table for spurious in the total frequency range (RX; 0.1MHz – 12750MHz BW as denoted)
- **Fig. 21** Single carrier; 60W=48dBm, TX; Spurious 1000MHz-12750MHz; BW=3MHz
- **Fig. 22** Single carrier; TX; Spurious 50MHz – 500MHz; BW 100kHz
- **Fig. 23** Six carriers; TX, Spurious 1000MHz – 12750MHz, BW 3MHz.

These measurements have been carried out along the "standard ETSI specifications". The relevant GSM spurious spectra have been measured covering the interesting radar and navaids bands by a spectrum analyzer with a specified bandwidth of 3MHz or 100kHz .

For the navaids (ILS, DVOR) the spectral content even for an MS is very low (<-70dBm; Eurofins GSM Test Report G0M20807-1884-T-51), so that no impacts have to be expected at all.

Further specially non-standard measurements for a "typical modern BTS", conducted and requested by NAVCOM Consult have been achieved by generous courtesy of Alcatel-Lucent using much smaller bandwidths for the spectrum analyzer measurements :

- **Fig. 14** Spurious spectrum of a BTS TX (antenna connector; TX 60W=+48dBm; 1.5-7GHz; BW=3MHz); In the PSR radar frequency range: **<-52dBm, -100dBc** .
- **Fig. 16** Spurious spectrum of a BTS TX (antenna connector; TX 60W=+48dBm; 10MHz – 925MHz; **BW=3kHz**); In the ILS LOC, DVOR and ILS GP frequency ranges : **<-85dBm, <-130dBc**
- **Fig. 17** Spurious spectrum of a BTS TX (antenna connector; TX 60W=+48dBm; 1.4GHz – 4GHz; **BW=1kHz**, 2600s); In the PSR frequency range : **<-95dBm, <-140dBc**

These non-standard measurements with narrow bandwidths were only made to identify the level of the harmonics, and not to find absolute spectrum levels of the GSM signal. The measurements with the standard bandwidth do not give the important information for the level of the 3rd harmonic of the GSM-frequency in the PSR frequency range because the level of the harmonics is simply much too low.

It can be clearly seen that the radiated power levels at the transmitter output connector are very safely far below any threat-level for the addressed systems: ILS LOC, ILS GP and DVOR.

It can be seen that the general spurious suppression is better than 130dBc for the lower band below the GSM-band and better than 140dBc for the 3rd harmonic in the upper PSR band

These transmitted, potentially impacting power levels are so low that no effects have to be expected for the navaids systems and for the PSR in realistic minimum distances to the systems (e.g. outside the fence of the airport).

It can be assumed that the equivalent power levels for other BTS of other manufacturers may be worse, but it is not likely that they are decisively worse with respect to the discussed impact topic.

#### 2.1.1.2 Mobile Stations (MS)

Although the main subject of this study (as is done solely in the regulation rules) is directed to base stations, the mobile stations (e.g. mobile telephones, laptops equipped with GSM-plugins; smart phones) may have also considerable effects because its relative location to the considered systems is not regulated at all. The conditions are listed in the following tables.

| Power class | GSM 900 Nominal maximum output power | DCS1800 Nominal maximum output power |
|---|---|---|
| 1 | ------------- | 1 W (30 dBm) |
| 2 | 8 W (39 dBm) | 0.25 W (24 dBm) |
| 3 | 5 W (37 dBm) | 4 W (36 dBm) |
| 4 | 2 W (33 dBm) | |
| 5 | 0.8 W (29 dBm) | |

**Table 7:** MS nominal maximum output power, Power Classes, GMSK modulation

| Power class | GSM 900<br>Nominal maximum output power | DCS1800<br>Nominal Maximum output power |
|---|---|---|
| E1 | 2 W (33 dBm) | 1 W (30 dBm) |
| E2 | 0.5 W (27 dBm) | 0.4 W (26 dBm) |
| E3 | 0.2 W (23 dBm) | 0.2 W (22 dBm) |

**Table 8:** MS nominal maximum output power, Power Classes, 8-PSK modulation

The maximum power of mobile stations (GSM/DCS MS) outside the transmit band (spurious emissions) shall not exceed:

- for frequencies 30 MHz to 1GHz

  -36dBm (0.25µW), Tx operating

  -57dBm (2nW), IDLE mode

- for frequencies 1GHz to 4 GHz.

  -30dBm (1µW), Tx operating; (-36dBm, DCS 1710 MHz – 1785 MHz)

  -47dBm (20nW), IDLE mode

"Idle mode" are any emissions radiated by the cabinet and structure of the mobile station, including all interconnecting cables. Power control will typically be used, so that mobiles not always transmit at their maximum rated power.

Under practical aspects, the electrical spectral performance of mobile stations is (naturally) much worse than the ones of the base stations. Typically the suppression of spurious is at least 20dB worse than for the base stations. This is generally understandable due to the small size of the mobile stations, while the base stations use high-tech relatively bulky multi stage cavity filters to achieve the specified suppression.

It is by that immediately understandable that the mobile stations are by far tentatively more impacting the aviation related systems on the airports and in general. E.g., **Fig. 13** shows the spectral measurements of an MS under standard conditions (BW 3MHz) between 1GHz and 4GHz. The harmonics are clearly visible and above the "noise floor". However despite these facts and the fact that mobile stations can be used without license, they are not regulated and not covered at all by the imposed restriction rules.

### 2.1.2 Radiation, Antenna Patterns

There are different types of GSM BSS antennas with different radiation patterns:

- azimuthal omnidirectional (e.g. **Fig. 3**)
- azimuthal sector (e.g. **Fig. 4**)
- elevation shaped (with optional down tilt, e.g. **Fig. 4**)

Azimuthal sector antennas can be grouped to arrays with switching possibilities. Two examples are depicted in **Fig. 6** and **Fig. 7**. Due to the horizontal pattern shape the antennas may be directed to reduce radiation into a stationary interference direction such as a PSR-radar, see marking in the **Fig. 6** and **Fig. 7**.

With a down tilted elevation pattern less power is radiated in the direction of e.g. a higher positioned radar.

Generally, a power budget may be calculated as depicted in **Fig. 2**. A minimum coupling loss (MCL) in the link budget is necessary to get e.g. radar performance degradation by exceeding the appropriate receiver sensitivity. This graphic contains quite a number of relevant and minor loss factors which each increase the total transmission loss between the GSM and the PSR system. Not all of these factors are specified in the following loss budget. If all would be taken into account, the safety margin would be even increased.

## 2.2 ATC-Radar

### 2.2.1 PSR

The frequency band of the PSR of the ATC-Radar is 2700MHz to 2900MHz (S-band). Therefore, the PSR may be distorted via the third harmonics of the 900MHz GSM band. The interference is quantified by the sensitivity of the PSR-receiver, which can be assumed to be -120dBm at a bandwidth of 1MHz (-120dBm/MHz, 1µs pulse).

The exact frequencies of the Luxembourg PSR are listed in **Table 9**. These frequencies correspond to the ITM-CL 179.4 /1/ restrictions ($3^{rd}$ harmonics).

| PSR | Frequency | $3^{rd}$ sub harm. |
|---|---|---|
| TAR1 | 2730 MHz | 910 MHz |
| TAR1 | 2750 MHz | 917 MHz |
| TAR2 | 2830 MHz | 943 MHz |
| TAR2 | 2850 MHz | 950 MHz |

**Table 9:** Luxembourg TAR1, TAR 2 PSR frequencies; band variation ±4.3MHz (pulse compression bandwidth; linear FM)

The frequencies listed in **Table 9** are now fully assigned to TAR2 PSR enabling a fourfold frequency hopping since the TAR1 PSR was switched off already several years ago. The TAR2 PSR is a solid state transmitter using the pulse compression techniques of a linear FM-pulse-compression bandwidth of ±4.3MHz around the nominal carrier frequency.
The following table gives the limitation data for the installed SELEX PSR TAR2 radar (courtesy of SELEX).

| | |
|---|---|
| **MDS** (Minimum Detectable Signal) | **-120 dBm** |
| **RX Loss** (from the antenna to the RX input) | **~ 2 dB** |
| Minimum Signal/Nois ratio in input to the receiver (**$V_0$** in diversity) | **5.8 dB** |
| **Tilt** ALE3x5 | **+ 0.5 deg** |

**Table 10:** SELEX TAR2 33S parameters + ALE3x5 antenna

The TAR2 PSR system at the airport of Luxembourg consists of a modern planar SELEX ALE3x5 antenna.
An example of a PSR antenna pattern is depicted in **Fig. 9**. Their main characteristic is the "co-sec"-shape in elevation. The antenna patterns are at the horizon about 6dB lower than at their maximum.

A distortion mechanism is "blocking". Blocking is defined as the signal level that would cause the loss of radar performance due to a mechanism such as target compression, intermodulation and other effects, potentially causing false target identification and confusion with valid targets.

An effect called "strobing" may also occur where a spot of higher intensity appears on the radar screen or an artificial line from the center points to the azimuth of the interferer. As reported by SELEX /9/ such kind of effect has never been reported by field engineers regarding GSM for known radar installations.

A method to see the harmonics effects could be trying to measure it after the LNA of the radar stopping the antenna in that direction. Then attenuation should be inserted in the azimuth sector where GSM interference is located but it would desensitize all ranges in that sector. If the radar type has a programmable STC it could be constantly added all over that range. This means the loose of detection for aircraft crossing that radials or flying on that radial.

The highest levels of interference are captured when the main beam of the radar antenna points at the interferer. This also suggests that the level of interference is lower by the sidelobe suppression (>30dB) if the main beam does not point to the interferer (i.e. here the GSM station). It is assumed that these low levels captured by the antenna pattern side-lobes will have not relevant effects when they point to a GSM interferer during the rotation of the radar.

The tradeoff-analysis of the effects of the emissions from both the base stations and mobile stations may require to take into account several (incomplete) aspects and the adjustment of certain parameters, including

- EIRP
- Antenna height of the radar and base stations
- rotation of the radar and the radar antenna pattern
- Antenna tilt
- Power control
- Propagation model
- Spectrum emission mask
- Filtering
- Radar receiver sensitivity and bandwidth .

As forwarded by the "Institut Luxembourgeois de Regulation" and requested by the operators, the maximum EIRP assumed for the GSM stations at Luxembourg are 2000W to 5000 W (63dBm to 67dBm). This figure can only be achieved by multicarrier operation on one base-station mast and applying the high gain sector antennas (typically up to 17 to 18dBi).

The EIRP includes antenna gain and losses. If a maximum gain of 17dBi is assumed (e.g. **Fig. 4**), the GSM BTS power is assumed to be in the range of class 5 or 4 (**Table 3**, ca. 60W, 48dBm, EIRP: 48dBm+17dB=65dBm; 63dBm-17dB=46dBm; 67dBm-17dB=50dBm).

The ETSI specifications for spurious emissions (chapter 2.1.1) are defined in absolute terms and by that are independent from the EIRP. So, for the same TX "architecture" the spurious may vary appropriately the radiated TX power.

As can be seen in **Fig. 14**, typical really measured BTS spurious emissions in the radar band are less than -50dBm when measured with 3MHz bandwidth and 60W (48dBm) output power measured after the duplex filter. The harmonics are covered obviously by the almost constant "noise floor".

The spurious are typically safely below -60dBm when measured with a smaller bandwidth of 110kHz according information gathered. The 3$^{rd}$ harmonics are typically about -100 dBc (below carrier) and lower and therefore not visible in these measurements with a bandwidth of 3MHz (**Table 6**), because the modulation and GSM-traffic is included in the measured noise like floor (i.e. far below the noise which is created by the modulation and the GSM-traffic) – see in details the chapter 2.1.1

To visualize the harmonics a narrower bandwidth must be used.

Theoretically, with a total summed EIRP of +67 dBm and an assumed emission of -100 dBc a power level of -33dBm would result for the 3$^{rd}$ harmonic in the pattern maximum. However, one has to take into account that the multicarrier multi-TX do not radiate on the same channels. By that the 3$^{rd}$-harmonics should not add up.

As can be seen in **Fig. 13** mobile stations are exhausting the spurious emission limits, as can be seen by the clearly visible harmonics, e.g about -35dBm for the second harmonic at about 1.8GHz (limit -30dBm). The type of mobiles station is also important. Mobile phones may have better spurious rejection than small USB GSM-adaptors.

The spurious characteristics of GSM base stations are much better (i.e. lower level by >20dB) as for the typical mobile hand held units (e.g. phones).

The following **Table 11** lists a worst case (conservative) power budget assumption for BTS applied to the Luxembourg scenario including antenna elevation pattern shape loss (**Fig. 9**).

| | | | |
|---|---|---|---|
| frequency [MHz] | 2800 | radar height [m] | 55 |
| | | GSM height [m] | 10 |
| PSR RX sensitivity [dBm] | -120 | | |

| | | | | |
|---|---|---|---|---|
| distance GSM-PSR [m] | 500 | 1000 | 2000 | 4000 |
| elevation difference [°] | 5,14 | 2,58 | 1,29 | 0,64 |

| | | | | |
|---|---|---|---|---|
| freespace att. [dB] | -95,4 | -101,4 | -107,4 | -113,4 |
| GSM antenna gain [dBi] | 17 | 17 | 17 | 17 |
| GSM pattern (tilt) [dB] | -10 | -8 | -6 | -3 |
| GSM TX system [dB] *) | -3 | -3 | -3 | -3 |
| PSR RX system [dB] *) | -6 | -6 | -6 | -6 |
| PSR antenna gain [dBi] | 33 | 33 | 33 | 33 |
| PSR pattern cosec [dB] | -20 | -20 | -15 | -9 |

| | | | | |
|---|---|---|---|---|
| loss sum [dB] | 84,4 | 88,4 | 87,4 | 84,4 |

| | | | | |
|---|---|---|---|---|
| GSM TX spurious [dBm] spec **) | -30 | -30 | -30 | -30 |
| power level [dBm] | -114,4 | -118,4 | -117,4 | -114,4 |
| **difference [dB]** | **5,6** | **1,6** | **2,6** | **5,6** |

| | | | | |
|---|---|---|---|---|
| GSM TX spurious [dBm] meas ***) | -50 | -50 | -50 | -50 |
| power level [dBm] | -134,4 | -138,4 | -137,4 | -134,4 |
| **difference [dB]** | **-14,4** | **-18,4** | **-17,4** | **-14,4** |

*) system: includes all kind of RF losses e.g cables
**) much better (=lower) in reality
***) typically measured spurious levels are much better for the spurious and, in particular for the 3rd harmonics

**Table 11:** Power budget for GSM spurious and PSR sensitivity

It can be seen that for modern BTS on the market, the measured spurious emissions are finally below the sensitivity of the PSR receiver with a lot of margin having in mind that not all loss factors are taken into account and the real spurious and harmonics are clearly lower than taken into account.
On the other hand mobile stations which use the tolerance spectrum (-30dBm) are much more critical. Also the mobile GSM units (e.g. phones, USB GSM adaptors for laptops) can be operated in very close distances to the systems in question compensating by far the lower output power.

If only the 3rd harmonic is considered as suggested in the current restriction rules, the difference [dB] is even clearly higher: For a typical maximum output power of 60W (=+47.8dBm) the power level of the 3rd harmonic is <-52.2dBm and probably in reality even much lower.

It has to be kept in mind that in BTS appropriate design and/or filters may already be built in to avoid the interference problems of the second harmonic with the DCS band.

For the DCS 1800 MHz band and the frequency separation, no adjacent channel operation exists and the harmonics do not fall into the PSR band.

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Bank account: Landesbank BW, Account No.: 4000006 BLZ 60050101 SWIFT-Code: SOLADEST Ident-Nr. DE188340830

### 2.2.2 SSR/MSSR

SSR/MSSR uses the 1030MHz (ground interrogator) and 1090 MHz (airborne transceiver) frequencies (L-band), which are 70 MHz and 130 MHz above the highest GSM frequency (960 MHz). Therefore, only frequency adjacent spurious emissions outside the GSM transmit band may have effects.

The minimum interrogator (ground station) receiver level is -80dBm.

The MTL of the airborne transponder which initiates the reaction of the airborne transponder is according to ICAO Annex 10 Vol. IV „nominal" -71dBm and minimum -77dBm for Mode A/C. For MODE S Annex 10 Vol. IV specifies in §3.1.2.10 a MTL („minimum input power level for 90 percent reply to interrogation ratio") of -74 dBm ±3dB ("no more than 10 per cent at signal input levels below –81dBm").

Examples of a SSR antenna pattern are depicted in **Fig. 8**.

The MSSR system at the Airport in Luxembourg (TAR 2) consists of a SIR-S MSSR LVA SELEX ALE 9.

It can be easily seen from **Table 11** and by the much reduced RX-sensitivity that the MSSR cannot be harmed by the harmonics and the spurious of the GSM 900 at all.

For the DCS 1800 MHz band and the frequency separation, no adjacent channel operation exists and the harmonics and sub-harmonics do not fall into the PSR band. Additionally, the pulse coded SSR data transfer is less sensitive.

## 2.3 Navaids

### 2.3.1 ILS (Localizer, Glide Path)

The ILS (Localizer RF ~100 MHz, GP RF ~330 MHz) may only be distorted by subharmonics or sub-spurious of the GSM/DCS.
The figures **Fig. 15**, **Fig. 16** und **Fig. 22** depict MS spectral measurements of the low frequency range; standard bandwidth and reduced bandwidth.

As it is seen the noise level is in the range of -70 dBm and therefore more than 30 dB less than the ETSI limit (-36dBm, chapter 2.1.1.2).

From experience as well, no distortion is known even if personal are talking with mobile units close to the ILS-shelter and close to the monitor systems. A minimum distance between the GSM base stations and the ILS-receivers in the aircraft is always given during ILS-operation.

### 2.3.2 VOR/DVOR and ILS

VOR/DVOR (RF ~110 MHz) may only be distorted by sub-harmonics or sub-spurious of the GSM/DCS.

The measured power level of the sub-harmonics and the sub-spurious is <-70dBm and far below any threat level having in mind that the typical output power of the ILS- and VOR-TX are 15W to 100W.

From experience as well, no distortion is known even if personal is talking with mobile units close to the VOR-shelter (or even inside the ILS/VOR-shelters by MS) and close to the monitor systems. A minimum distance between the GSM base stations and the VOR-receivers in the aircraft is always given during VOR-operation.

The ILS at Luxembourg airport consists of a Localizer (operating in almost the same frequency range as the VOR/DVOR system) and of a Glide-Path operating at about 330MHz). The same technical arguments apply for the ILS-subsystems as for the VOR/DVOR. Also, from experience, no distortion by the GSM base stations is known under realistic conditions. In particular this applies for mobile units operating in the direct vicinity of the ILS-subsystems.

### 2.3.3 DME

A CEPT report /8/ deals among others with the compatibility of the GSM MC (multi carrier) and DME adjacent channel operation.

The DME-system operates with an airborne based transceiver and a ground based transponder operating on the same frequency channel, but time synchronized (shifted). The airborne part is not threatened at all due to the directive and relatively high power pulse coded radiation and due to the natural separation between the aircraft transceivers and the BSS.

The DME frequency range is 962MHz to 1213MHz. Currently only frequencies above 977MHz are used. The lower frequencies up to 1025MHz are reserved for airborne transceivers. Therefore, only these may be affected if at all.

This frequency scheme results in a frequency separation of 17MHz for BTSs. Mobiles are separated by at least 62MHz.

Relevant is the maximum interference power received at the DME antenna port in a 1 MHz bandwidth. DME interference threshold at DME antenna port is –129 dB (W/MHz) according to ECC Report 096. The safety margin should be 6dB (Recommendation ITU-R M.1477).

The spectral measurements show that in the DME frequency range a spurious level is <-42dBm even for a bandwidth of 3MHz (**Fig. 23**). For smaller bandwidth the spurious is much lower.

While a minimum distance between the base stations and DME-ground antennas can be assumed the (much worse) MS can be very close to the DME-system. No distortions are known for the mobile units.

In conclusion, the threat for the DME in Luxembourg is qualified to be negligible and practically not existent. Formally the DME is also not mentioned explicitly in the restriction rules as well.

# 3 Other qualitative aspects

## 3.1 Regulations in other countries

Some investigations were made for other countries (B, NL, USA) about the handling of GSM BSS/MS and the coexistence with the discussed systems (navaids, radar).
No restrictions or rules were found that limit the location of GSM BSS and MS in the vicinity of radar and navaids stations. There are no published distorting effects by "strobing" etc. caused by GSM-base-stations nor by GSM-mobile units.

In some detail:

**Belgium:**
No effects by GSM base stations are known. Base stations have to be applied for approval and are be checked by Belgocontrol. The information was gathered that obstacle clearance aspects are checked, but no spectral aspects. If an incident would occur which could be suspected to spectral aspects, the policy may change.

**Netherlands**
No effects by GSM base stations are known although many GSM-stations are in a close vicinity to the TAR Schiphol (**Fig. 24**). Base stations have to be applied for approval and are be checked by LVNL. The information was gathered that obstacle clearance aspects are checked, but no spectral aspects (so far). It may be suspected that this policy might change if an incident would occur which could be suspected to spectral aspects.

**USA**
No effects on ATC-radar are known to long-term radar experts such as "strobing" which could be related to spectral aspects of mobile systems. No rules are known which would restrict the placement of mobile masts due to spectral aspects.

## 3.2 Qualitative technical statement of the TAR2-manufacturer

The TAR1 as well as TAR2 is manufactured and installed by the company SELEX Italy.
An inquiry has been sent to SELEX about potential information on distortions by GSM or mobile telephones in general on radar such as installed in Luxembourg. In particular it was asked about known "strobing effects" at the worldwide installations.
The answer was clearly "no". Also in case some emergency mitigation measures would be possible by internal means such as selective desensitizing. However this would reduce the range in that angular region and would be unwanted and, in case, would be only a temporary measure.

# 4 Conclusions and Recommendations

The GSM-service providers apply for more degrees of freedom for positioning their base stations closer to the airport and within the refined restricted areas around certain systems installed on and around the Airport Luxemburg. They also apply for increasing their transmitter output power which is restricted now by specified regulatory restrictions.

The systems that have to be protected are

- The ATC TAR radar on the airport; in particular the primary radar PSR.
  This is the system of most concern to be potentially distorted by the 3rd harmonic .
- The ILS GP-subsystems(GP06 and GP24)
- The DVOR/DME on the airport at the eastern rim and the DVOR/DME DIK.

The impact of GSM stations (base and mobile) on the radar and navaids systems on the airport Luxembourg have been investigated qualitatively and quantitatively.

Relevant for distortions of the considered systems are in case the harmonics and the spurious of the GSM 900 band. In particular, the 3rd harmonic may fall into the primary S-band radar band by coincidence of the channel assignment causing mainly "strobing" effects.

Due to the co-existence of DCS (second GSM harmonic) inherently integrated measures have to be installed (design, filters) to avoid cross-GSM-interference. These measures also have reducing effects for the 3rd harmonic and the spurious. In any case a highly effective TX/RX-duplexer is present between the GSM90-TX/RX and the antenna suppressing also effectively the spurious and the harmonic radiation via the antenna.

A link budget has been established which shows that no sufficient input power can be transferred to the PSR-S-band-receiver(s) assuming conservative parameters and realistic distances (outside the airport area).

The spurious and harmonic radiations have been evaluated by available measurements of the GSM-providers and by additional narrow-band spectral measurements got by courtesy of Alcatel-Lucent. It has been found that the concerned 3rd harmonics of GSM 900-BSS are in fact very low (<-130dBc) and cannot constitute any threat by far for the PSR. This figure applies as well for the spurious in the PSR-band.

The radiated sub-spurious and sub-harmonics of the GSM 900 have been evaluated by the available measurements. Their radiated level is so weak (<-70dBm) that a threat for the ILS and DVOR is concluded to be impossible under realistic assumptions.

It has been concluded that the mobile units MS (e.g. GSM telephone, laptop GSM operation) constitute relative to the BSS a much larger threat. However, distortions have never been experienced. By that the practically non-existent threat by BSS is confirmed by that fact in addition.

The procedures of the GSM-approval have been inquired in several states with regard to navaids and radar systems. It has been found that no approval aspects such as listed in the Luxembourg-document ITM-CL 179.4 /1/ exists (so far) related to the electrical spectrum of the GSM.

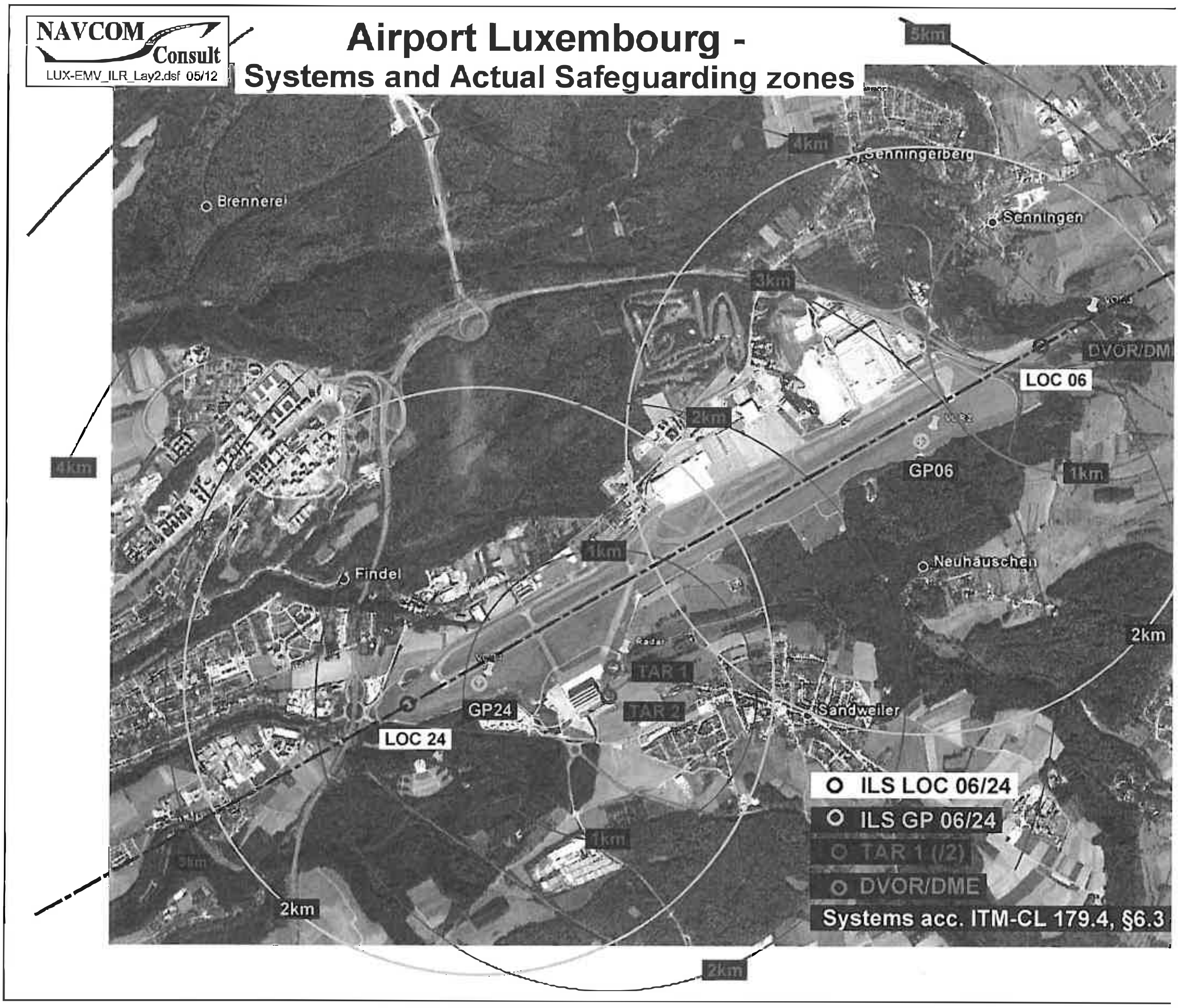
Also the manufacturer of the TAR1 and TAR2 did not experience among their worldwide ATC-radar installations any effect by GSM or mobile radio.

**In conclusion, it is summarized that no restrictions are recommended for BSS base stations under spectral distortion aspects related to navaids and radar systems, not for single carrier nor for realistic multi carrier GSM 900-operation.**

It is finally recommended due to a minimization of the threat aspects to install omni multi sector BSS inside the restriction areas in a way that the radiation minimum between the sectors is directed towards the TAR2 .

Further on, an additional low pass filter may be installed later on the BSS-side between the GSM-TX/RX and the antenna, in the very unlikely case that one of the systems to be protected would experience any negative effects due to a GSM base station

# 5 Figures


NAVCOM Consult
LUX-EMV_ILR_Lay2.dsf 05/12
Airport Luxembourg -
Systems and Actual Safeguarding zones
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Neuhäuschen
Sandweiler
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DVOR/DME
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O TAR 1 (/2)
O DVOR/DME
Systems acc. ITM-CL 179.4, §6.3

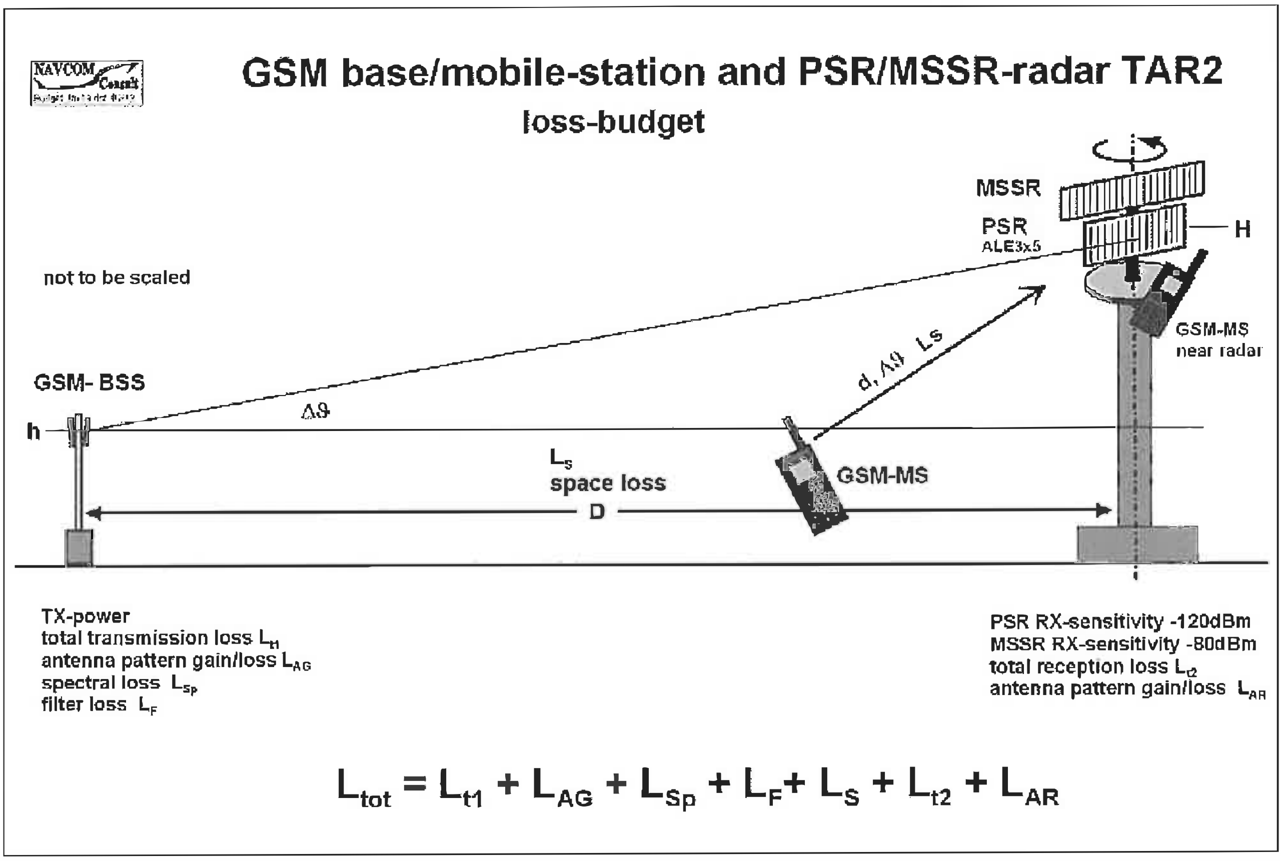
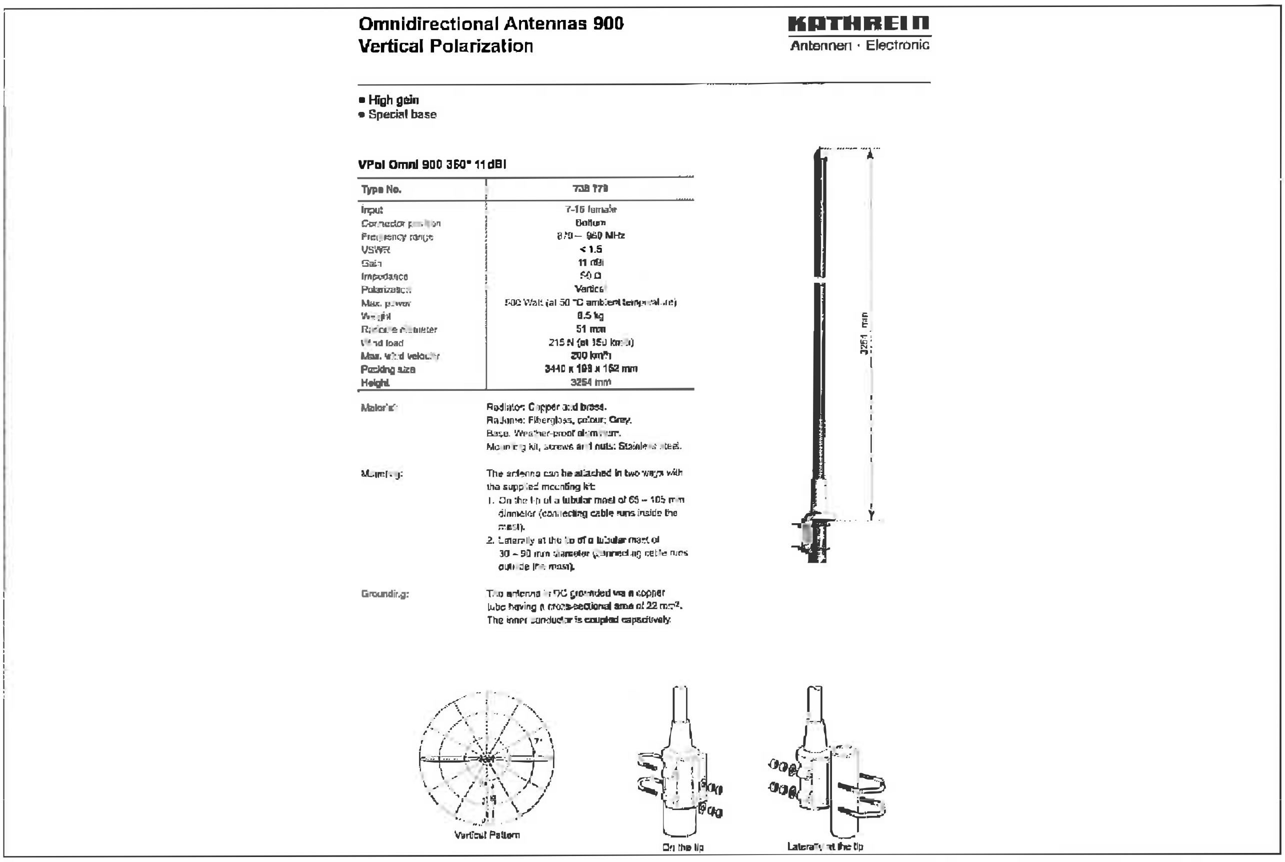



**Fig. 2:** PSR and GSM 900 Power budget, losses; base station and mobile station; qualitative diagram



**Omnidirectional Antennas 900**
**Vertical Polarization**

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- High gain
- Special base

**VPol Omni 900 360° 11 dBi**

| Type No. | 739 179 |
|---|---|
| Input | 7-16 female |
| Connector position | Bottom |
| Frequency range | 870 – 960 MHz |
| VSWR | < 1.5 |
| Gain | 11 dBi |
| Impedance | 50 Ω |
| Polarization | Vertical |
| Max. power | 500 Watt (at 50 °C ambient temperature) |
| Weight | 8.5 kg |
| Radome diameter | 51 mm |
| Wind load | 215 N (at 150 km/h) |
| Max. wind velocity | 200 km/h |
| Packing size | 3440 x 199 x 162 mm |
| Height | 3254 mm |

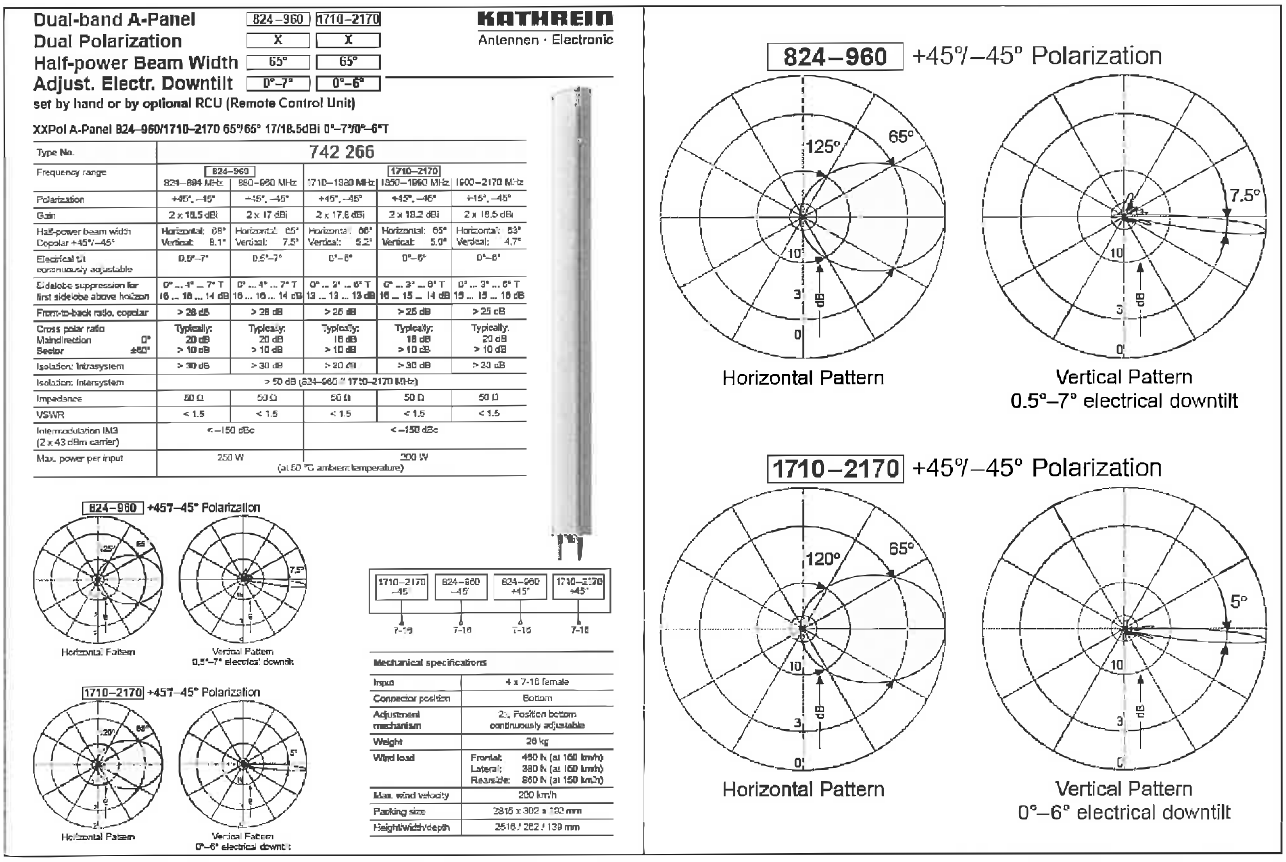
Material: Radiator: Copper and brass. Radome: Fiberglass, colour: Grey. Base: Weather-proof aluminium. Mounting kit, screws and nuts: Stainless steel.

Mounting: The antenna can be attached in two ways with the supplied mounting kit:
1. On the tip of a tubular mast of 65 – 105 mm diameter (connecting cable runs inside the mast).
2. Laterally at the tip of a tubular mast of 30 – 90 mm diameter (connecting cable runs outside the mast).

Grounding: The antenna is DC grounded via a copper tube having a cross-sectional area of 22 mm². The inner conductor is coupled capacitively.



**Fig. 3:** Example of omnidirectional GSM antenna



| Dual-band A-Panel | 824–960 | 1710–2170 |
|---|---|---|
| Dual Polarization | X | X |
| Half-power Beam Width | 65° | 65° |
| Adjust. Electr. Downtilt | 0°–7° | 0°–6° |

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set by hand or by optional RCU (Remote Control Unit)

**XXPol A-Panel 824–960/1710–2170 65°/65° 17/18.5dBi 0°–7°/0°–6°T**

| Type No. | 742 266 | | | | |
|---|---|---|---|---|---|
| Frequency range | 824–960: 824–894 MHz | 824–960: 880–960 MHz | 1710–2170: 1710–1880 MHz | 1710–2170: 1850–1990 MHz | 1710–2170: 1900–2170 MHz |
| Polarization | +45°, –45° | +45°, –45° | +45°, –45° | +45°, –45° | +45°, –45° |
| Gain | 2 x 16.5 dBi | 2 x 17 dBi | 2 x 17.8 dBi | 2 x 18.2 dBi | 2 x 18.5 dBi |
| Half-power beam width Copolar +45°/–45° | Horizontal: 68° Vertical: 8.1° | Horizontal: 65° Vertical: 7.5° | Horizontal: 68° Vertical: 5.2° | Horizontal: 65° Vertical: 5.0° | Horizontal: 63° Vertical: 4.7° |
| Electrical tilt continuously adjustable | 0.5°–7° | 0.5°–7° | 0°–6° | 0°–6° | 0°–6° |
| Sidelobe suppression for first sidelobe above horizon | 0° ... 4° ... 7° T 16 ... 16 ... 14 dB | 0° ... 4° ... 7° T 16 ... 16 ... 14 dB | 0° ... 3° ... 6° T 13 ... 13 ... 13 dB | 0° ... 3° ... 6° T 16 ... 15 ... 14 dB | 0° ... 3° ... 6° T 15 ... 15 ... 16 dB |
| Front-to-back ratio, copolar | > 28 dB | > 28 dB | > 26 dB | > 26 dB | > 25 dB |
| Cross polar ratio Maindirection 0° Sector ±60° | Typically: 20 dB > 10 dB | Typically: 20 dB > 10 dB | Typically: 18 dB > 10 dB | Typically: 18 dB > 10 dB | Typically: 20 dB > 10 dB |
| Isolation: Intrasystem | > 30 dB | > 30 dB | > 30 dB | > 30 dB | > 30 dB |
| Isolation: Intersystem | > 50 dB (824–960 // 1710–2170 MHz) | | | | |
| Impedance | 50 Ω | 50 Ω | 50 Ω | 50 Ω | 50 Ω |
| VSWR | < 1.5 | < 1.5 | < 1.5 | < 1.5 | < 1.5 |
| Intermodulation IM3 (2 x 43 dBm carrier) | < –150 dBc | | < –150 dBc | | |
| Max. power per input | 250 W (at 50 °C ambient temperature) | | 200 W (at 50 °C ambient temperature) | | |

| Mechanical specifications | |
|---|---|
| Input | 4 x 7-16 female |
| Connector position | Bottom |
| Adjustment mechanism | 2x, Position bottom continuously adjustable |
| Weight | 26 kg |
| Wind load | Frontal: 490 N (at 160 km/h) Lateral: 380 N (at 160 km/h) Rearside: 860 N (at 150 km/h) |
| Max. wind velocity | 200 km/h |
| Packing size | 2816 x 302 x 192 mm |
| Height/width/depth | 2516 / 262 / 139 mm |



**Fig. 4:** Example of sectored GSM antenna; horizontal and vertical antenna patterns

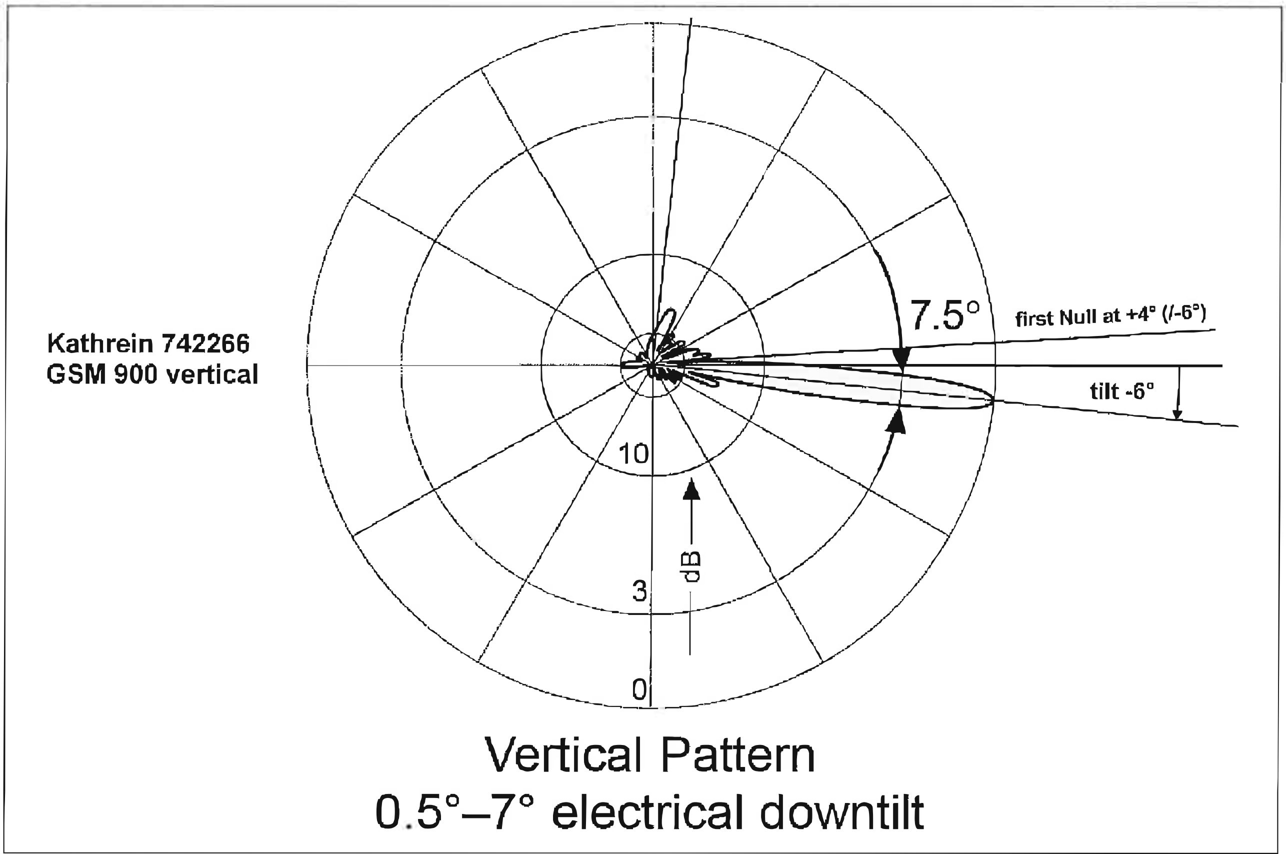



**Fig. 5:** Example of GSM-antenna Kathrein K742266 vertical pattern in detail (tilt -6°); see also **Fig. 4**

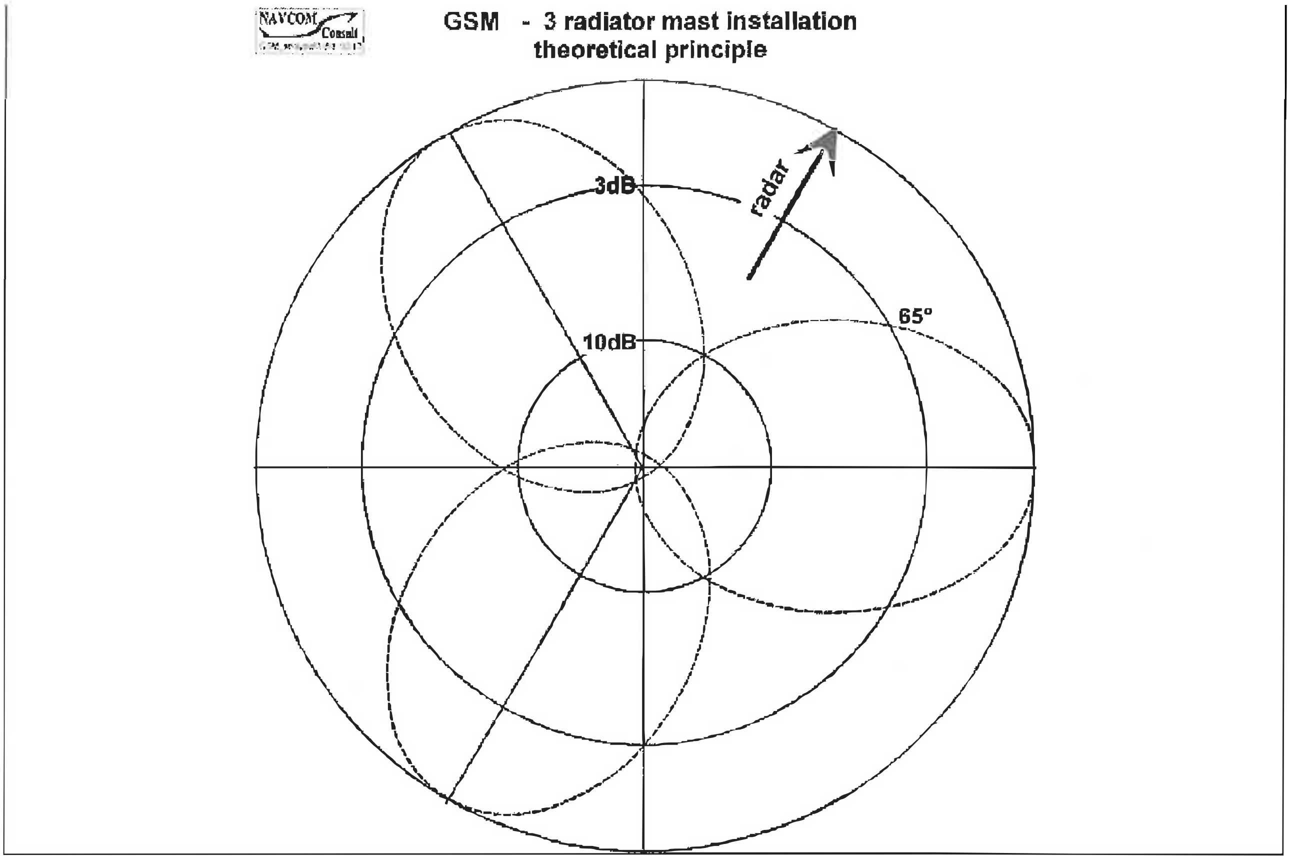



**Fig. 6:** Example of GSM 3 radiator mast installation, minimized interference direction (radar) , see also **Fig. 4**

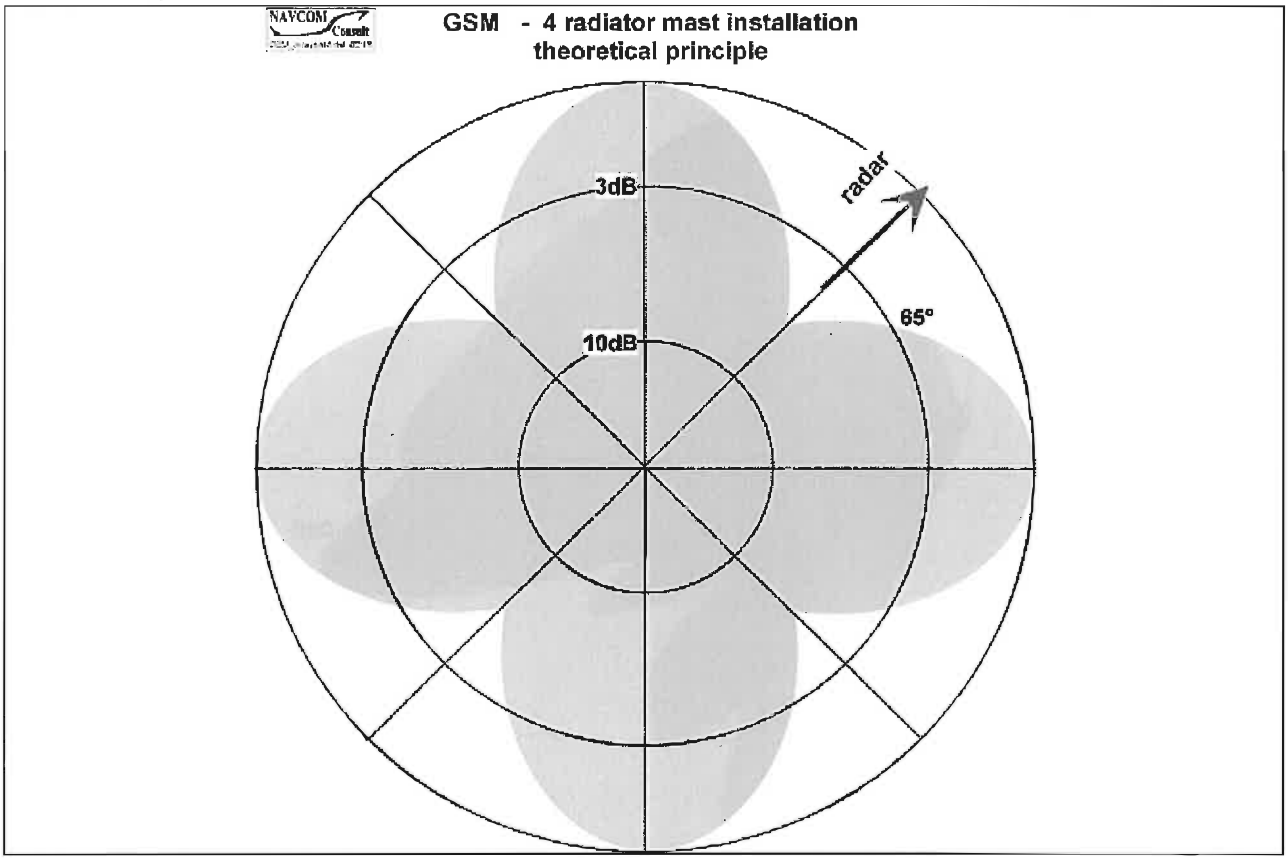



**Fig. 7:** Example of GSM 4 radiator mast installation, minimized interference direction (radar) , see also **Fig. 4**

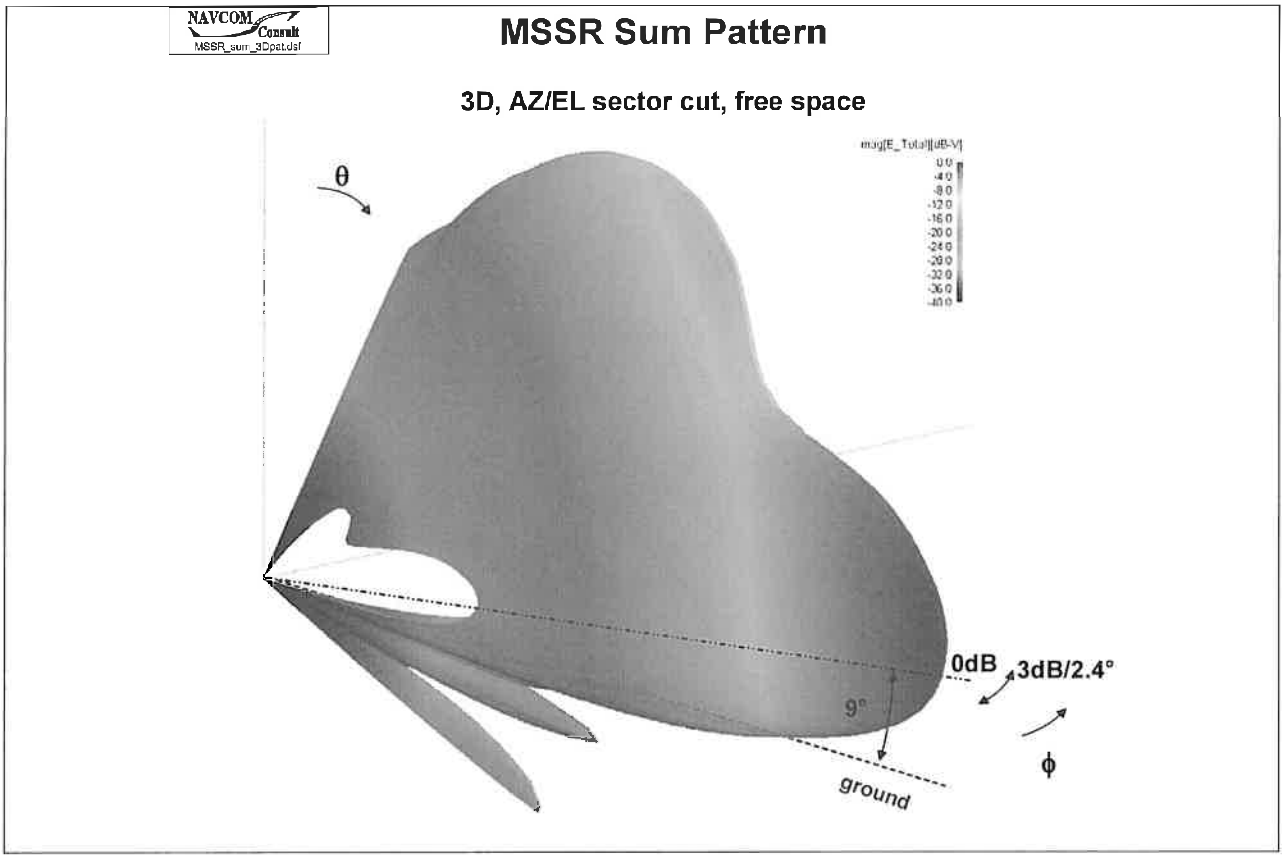



**Fig. 8:** Example of SSR antenna pattern

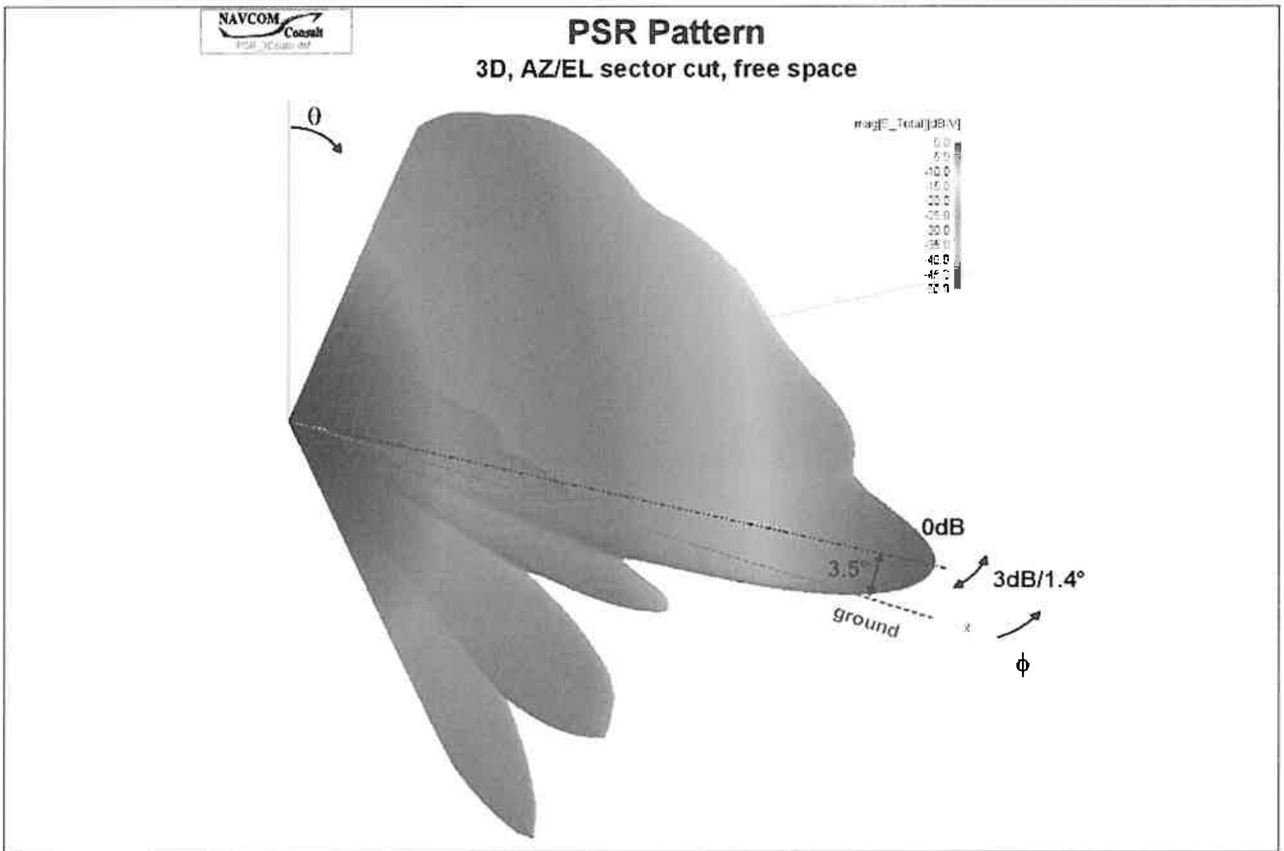



**Fig. 9:** Example of PSR antenna pattern

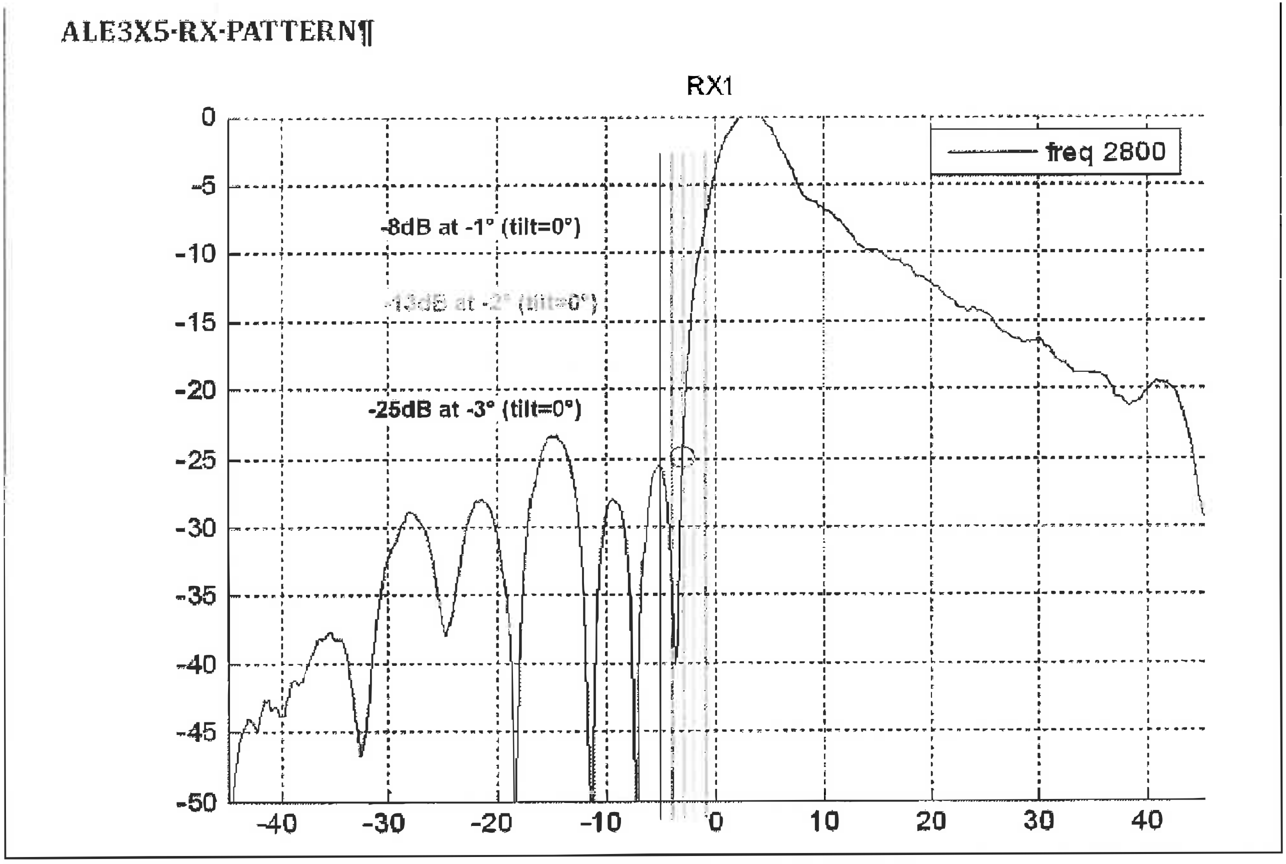



**Fig. 10:** Example of PSR antenna pattern; TAR2 SELEX ALE3x5 RX1

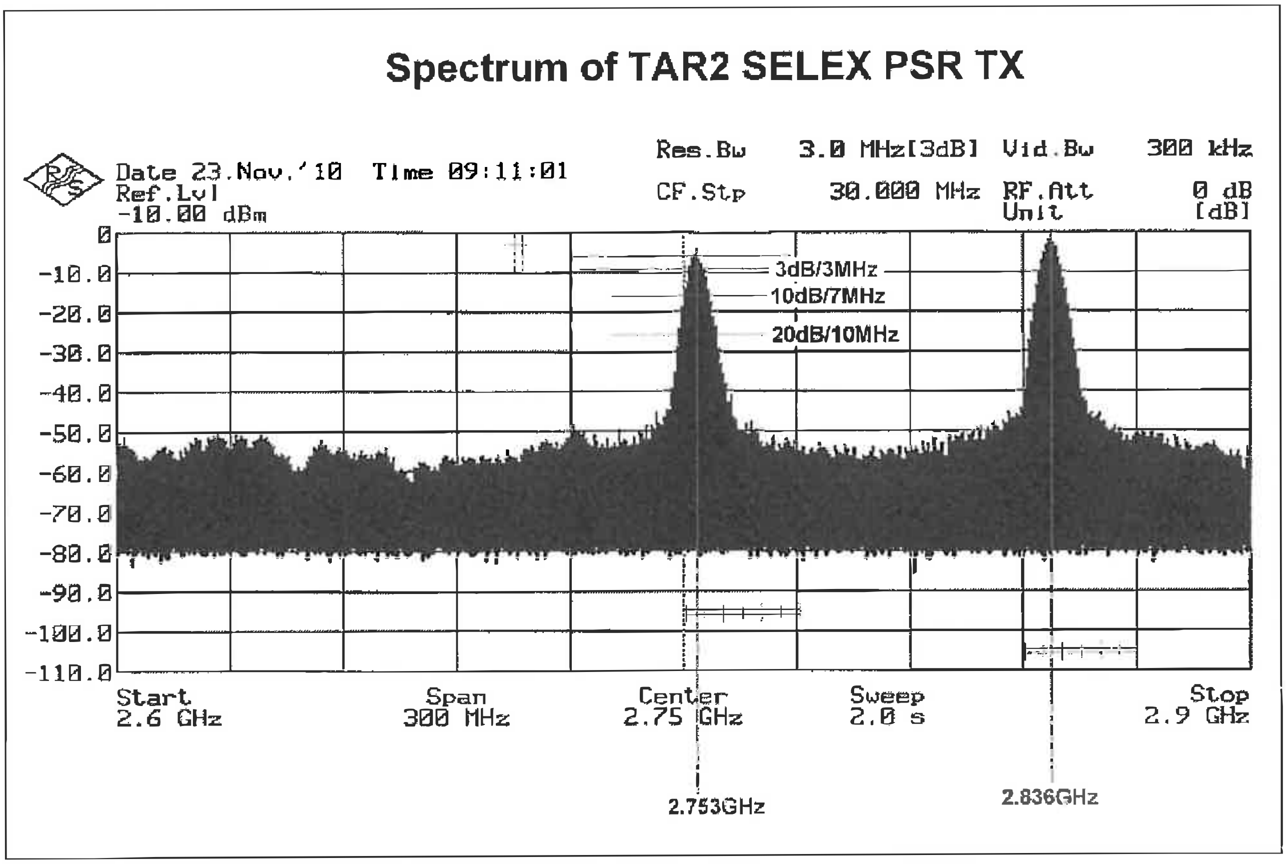



**Fig. 11:** Measured TX-spectrum of TAR2 SELEX PSR

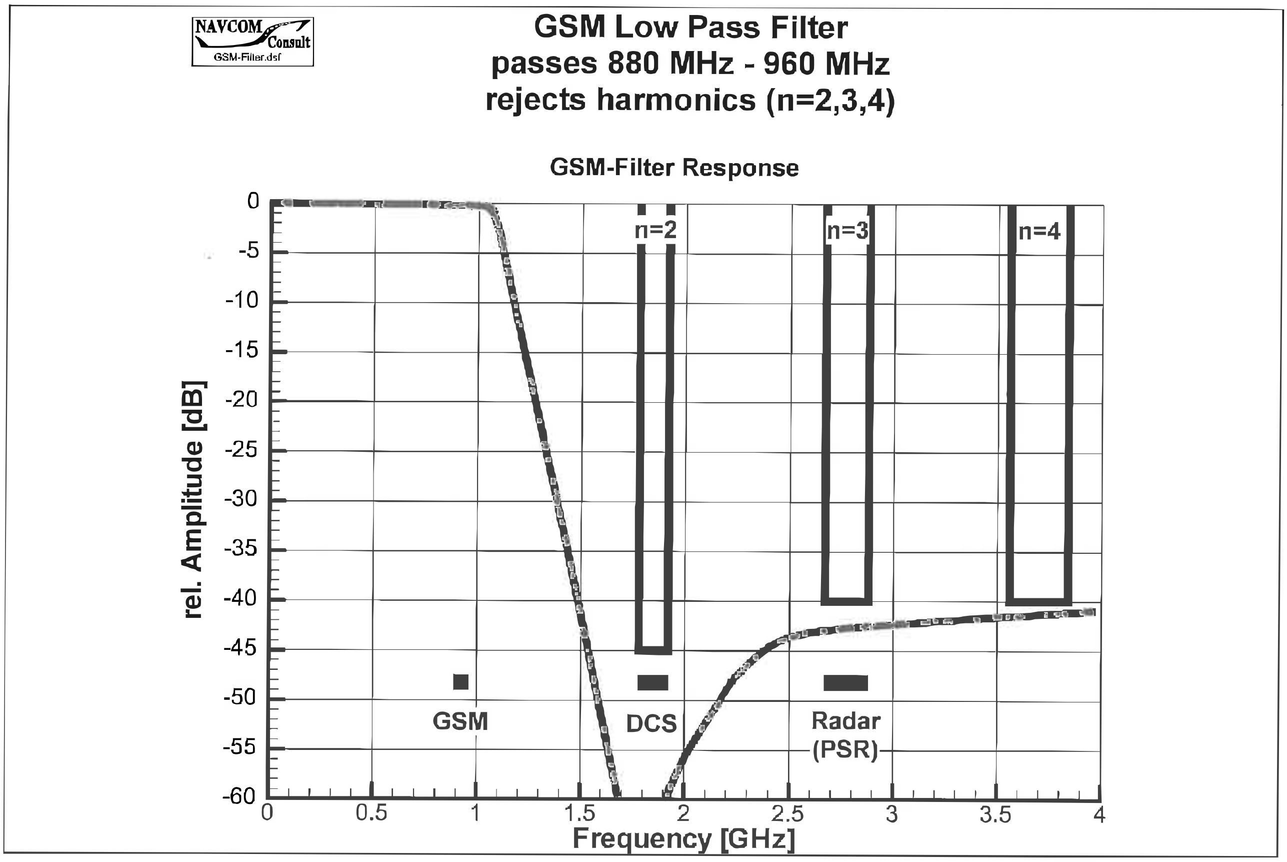



**Fig. 12:** Example of GSM low pass filter design, rejection of harmonics n=2,3,4

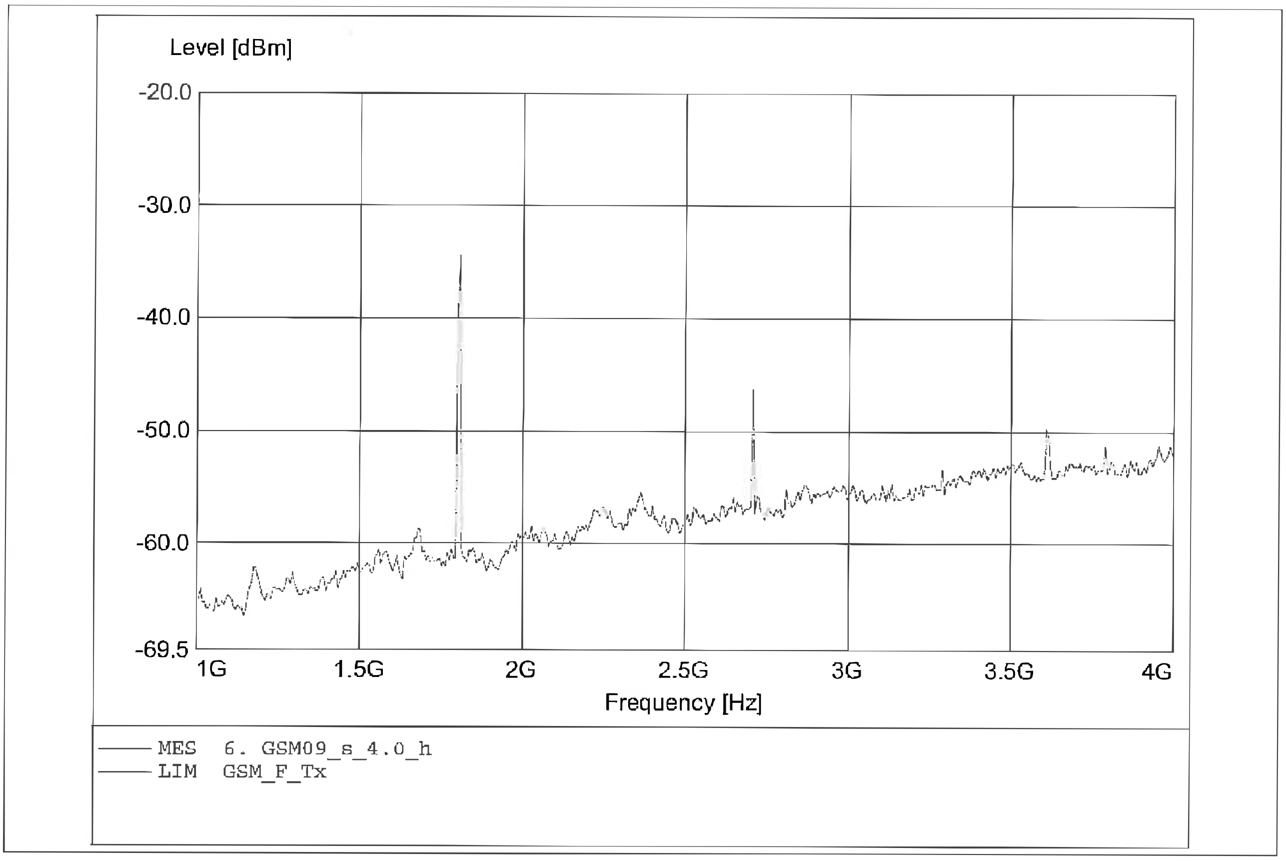



**Fig. 13:** Example of spurious emission measurement of a GSM MS module (1 GHz – 4GHz, BW 3MHz), visibility of harmonics n=2,3,4 (see **Fig. 12**)

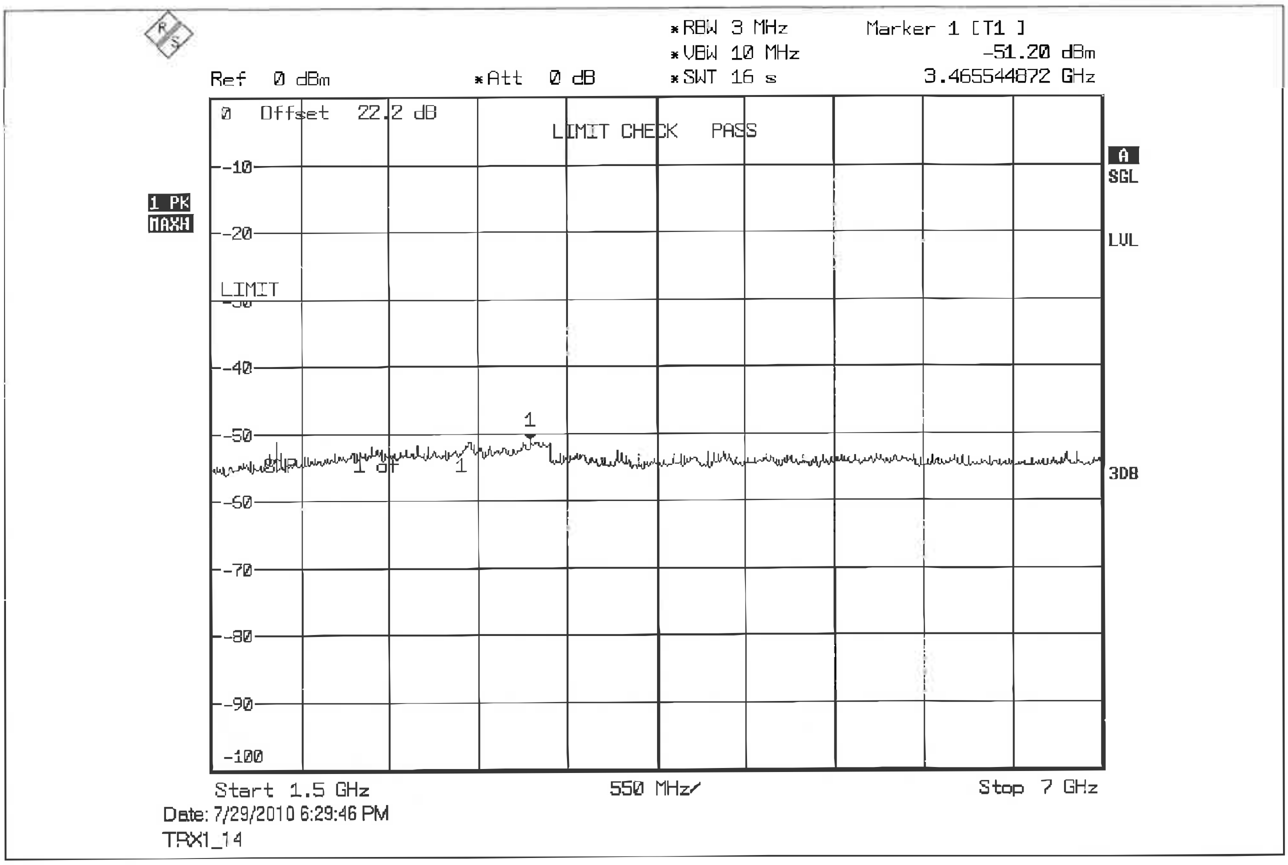



**Fig. 14:** Example of spurious emission measurement after duplex filter of a GSM BTS (1.5 GHz - 7 GHz); (by courtesy of Alcatel-Lucent)

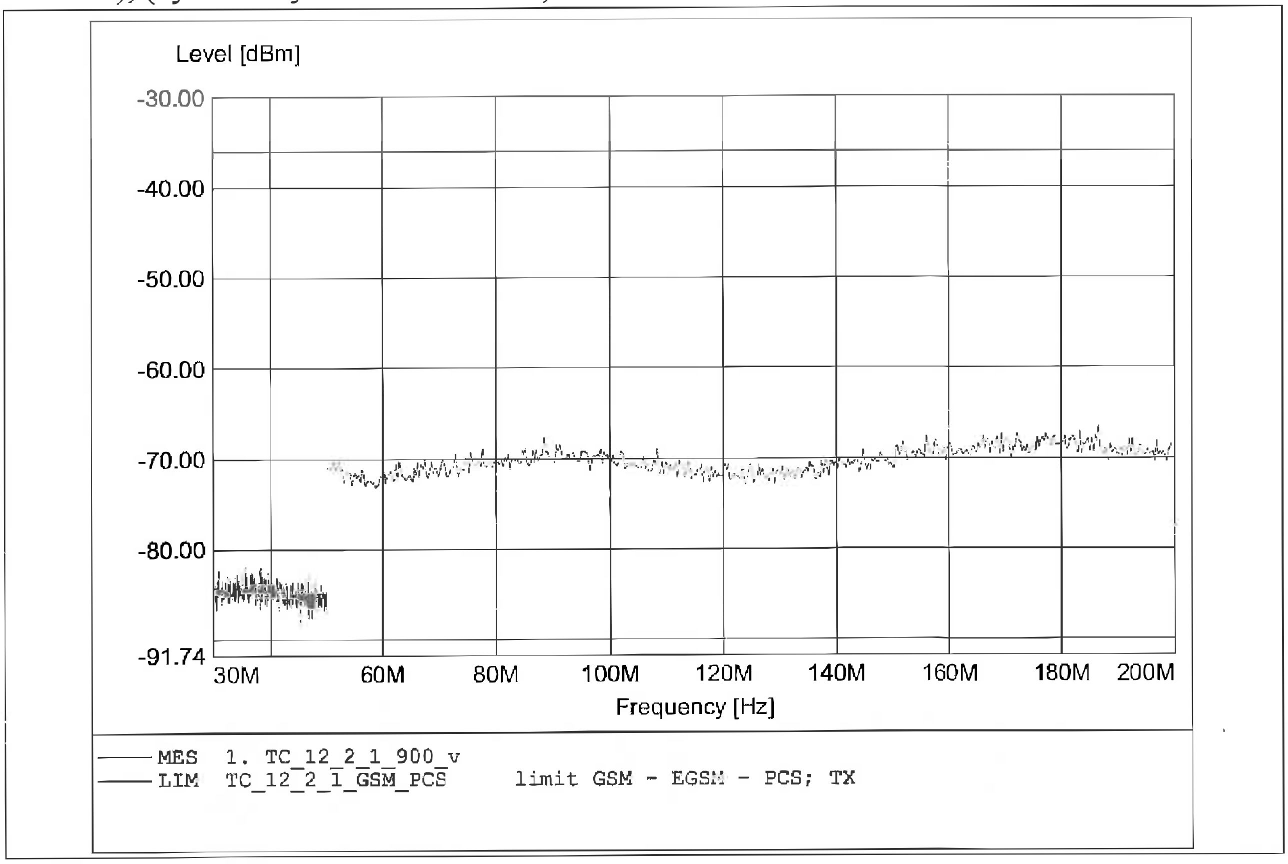



**Fig. 15:** Example of spurious emission measurement of a GSM MS module (30 MHz – 200 MHz, BW 3 MHz)

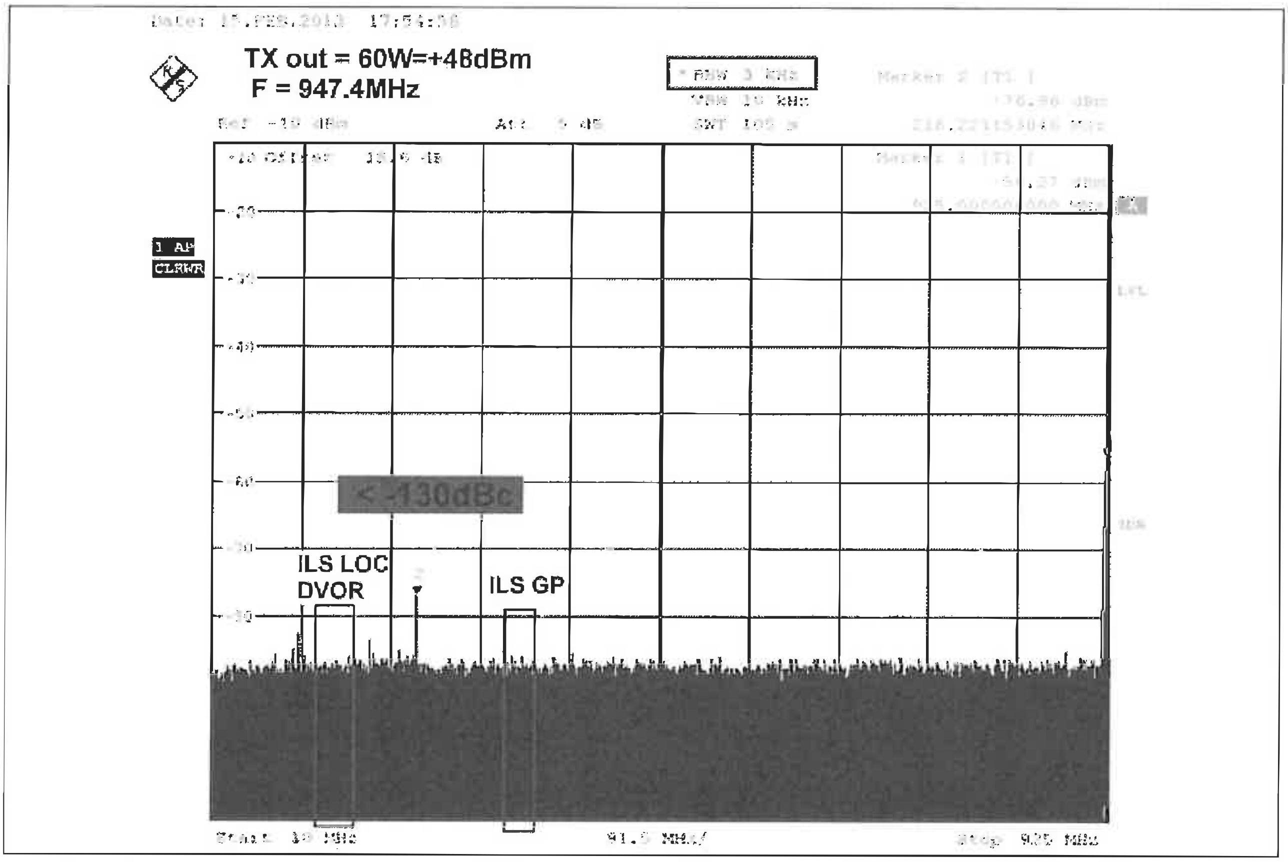



**Fig. 16:** Example of spurious emission measurement of a GSM BTS (60W=+48dBm; one carrier; 947.4MHz; 10MHz-925MHz; BW=3kHz, 105s); (by courtesy of Alcatel-Lucent)

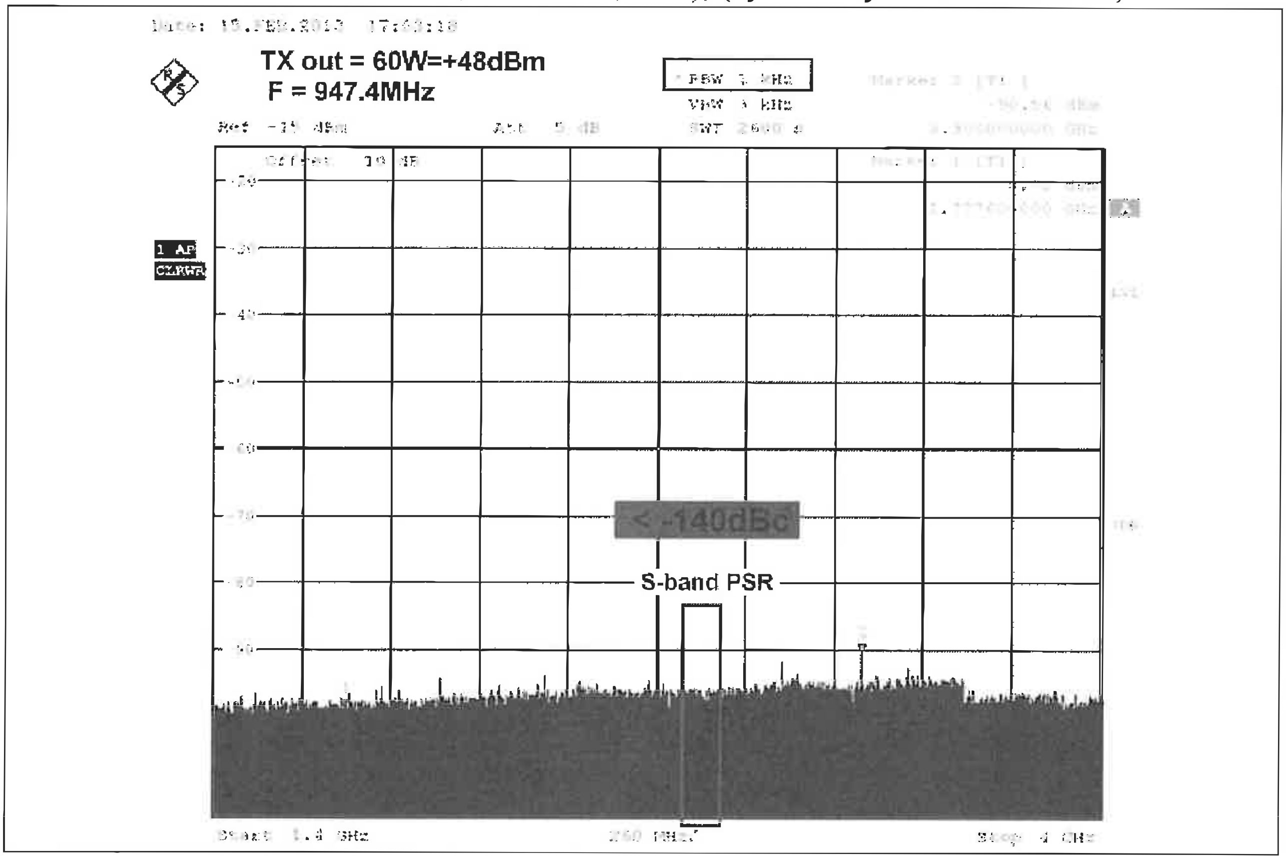



**Fig. 17:** Example of spurious emission measurement of a GSM BTS (60W=+48dBm; one carrier; 947.4MHz; 1.4GHz-4GHz; BW=1kHz, 2600s); (by courtesy of Alcatel-Lucent)

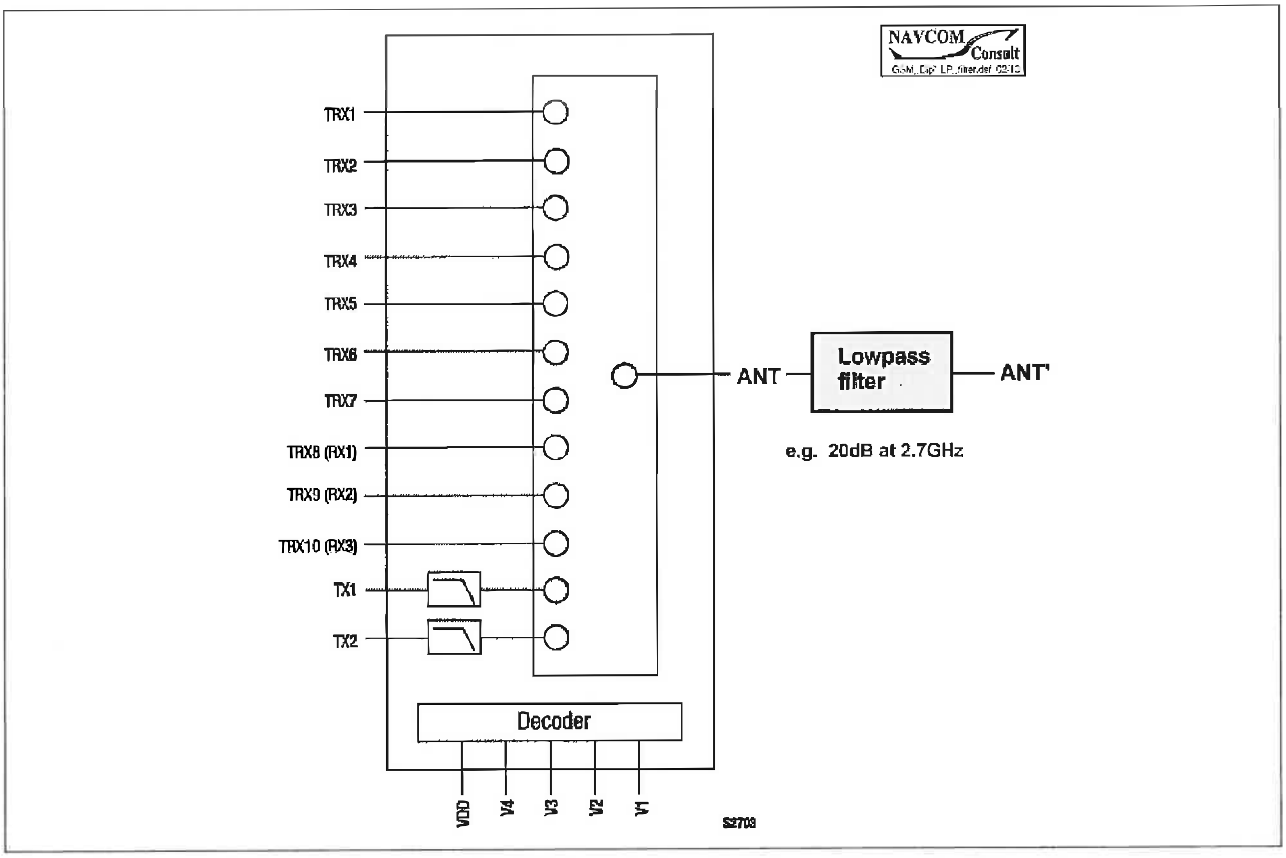



**Fig. 18:** Example block diagram of a GSM switch (taken from Skyworks©): with integrated GSM spurious/harmonic filter; additional external lowpass filter if required

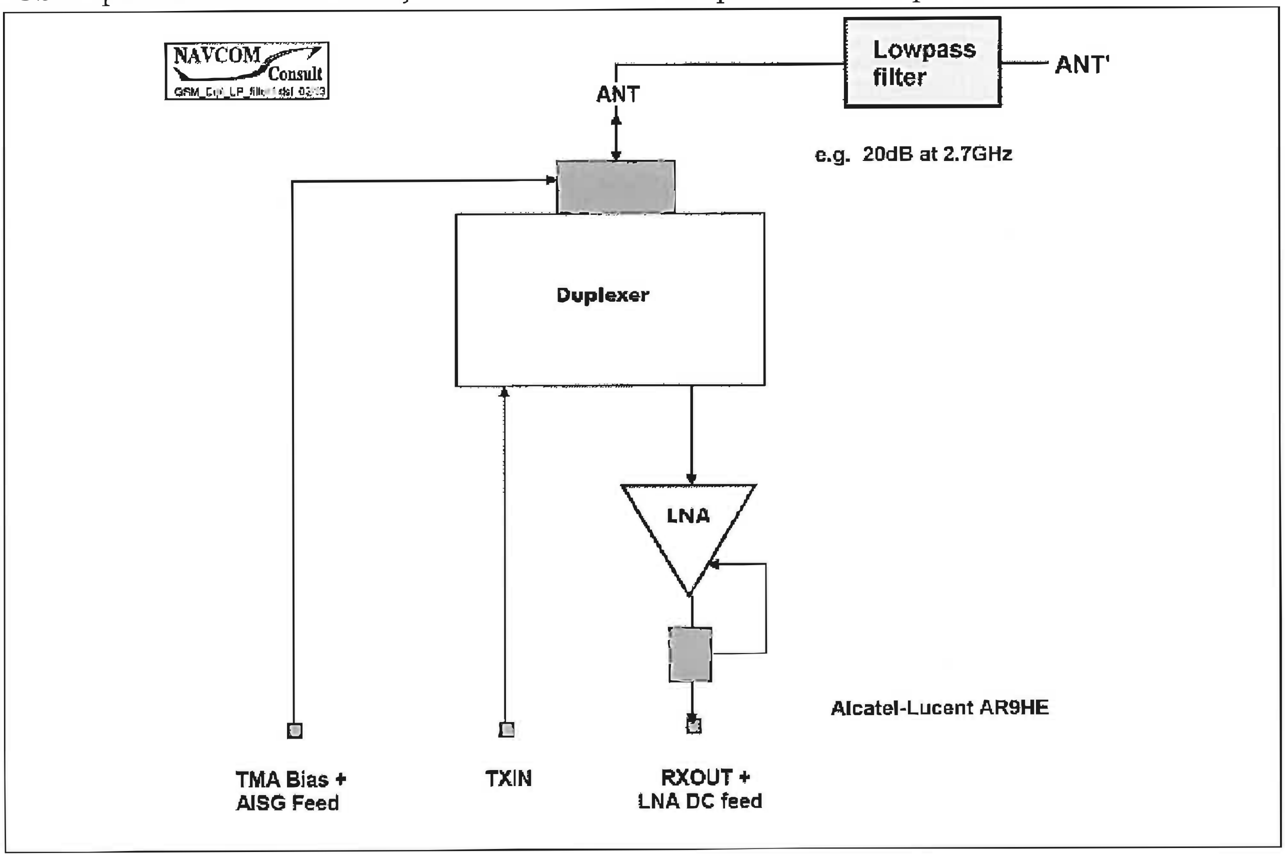



**Fig. 19:** Example block diagram of a GSM duplexer (taken from Alcatel-Lucent©): additional external lowpass filter if required

Product Service

## RF-TEST REPORT

| | | | |
|---|---|---|---|
| Report Number | : 68 850 0 014 01 | Date of Issue: | Feb 10, 2010 |
| Model / Serial No. | : **BTS3900/ BTS3900 GSM /BT3900L/RFC** | | |
| Product Type | : **Indoor Macro BTS/ Indoor Macro BTS /High Capacity Indoor Macro BTS/RF unit Cabinet** | | |

**2.3.2.2 Transmit power:**

Table 5 Transmit power of EUT

| | | |
|---|---|---|
| Transmit power (per antenna port) | One Carrier | 46dBm(GMSK) and 44.2dBm(8PSK) |
| | Two Carriers | 2* 46dBm(GMSK) and 2*44.2dBm(8PSK) |
| | Three Carriers | 3* 44.3dBm(GMSK) and 3*42.5dBm(8PSK) |
| | Four Carriers | 4* 43dBm(GMSK) and 4*41.2dBm(8PSK) |
| | Five Carriers | 5* 40.8dBm(GMSK) and 5*39dBm(8PSK) |
| | Six Carriers | 6* 40dBm(GMSK) and 6*38.2dBm(8PSK) |

Product Service

**4.2.7 Spurious Emissions from the Receiver Antenna Connector Clause 7.9**

Table 44 Test conditions

| Condition Type | Description |
|---|---|
| Test Configuration | a) Normal Conditions (Tnom & Vnom).<br>b) single carrier.<br>c) RF Channels (TX): M.<br>d) SFH disabled.<br>e) Measurement carried out at output of BSS (Antenna Connector) |

**4.2.7.1 Spurious Emission-900M**

| FREQUENCY (MHz) | SPURIOUS EMISSION LEVEL (dBm) Channel M | Conclusion |
|---|---|---|
| | outside band spurious | |
| 0.1 – 50.0 | -83.2 | PASS |
| 50.0 – 500.0 | -81.6 | PASS |
| 500.0 – 895.0 | -77.5 | PASS |
| 895.0 – 905.0 | -79.3 | PASS |
| 905.0 – 915.0 | -81.2 | PASS |
| 915.0 – 920.0 | -91.5 | PASS |
| 920.0 – 923.0 | -82.4 | PASS |
| 962.0 – 965.0 | -83.4 | PASS |
| 965.0 – 970.0 | -80.7 | PASS |
| 970.0 – 980.0 | -78.3 | PASS |
| 980.0 –990.0 | -84.3 | PASS |
| 990 – 1000 | -80.9 | PASS |
| 10000-12750 | -80.8 | PASS |
| | Inside Band Spurious | |
| 925-936.6 | -87.1 | PASS |
| 936.6-940.8 | -91.9 | PASS |
| 944.4-948.6 | -93.6 | PASS |
| 948.6 – 960 | -88.3 | PASS |

**Fig. 20:** Test Report Excerpts supplied by TANGO/ORANGE; Results RX, RBW 3MHz (The printed frequency of 10000Mhz is treated as a typo and must read 1000MHz.)

Product Service

## 6.2 GMSK Outside transmit bands (One Carrier)

Product Service

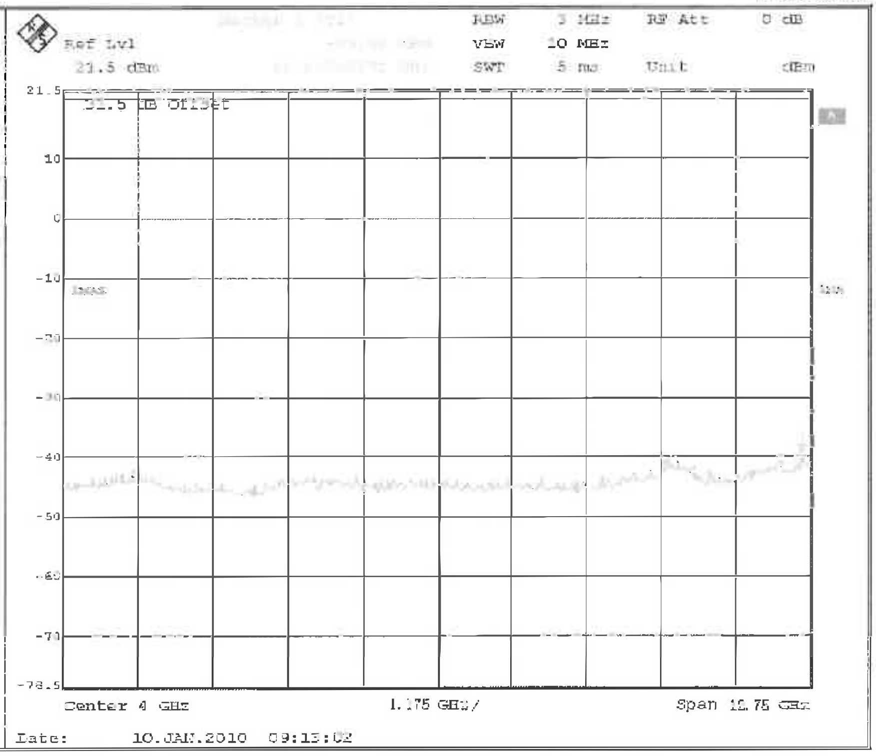
| | | |
|---|---|---|
| | 1000 - 12750 |  |





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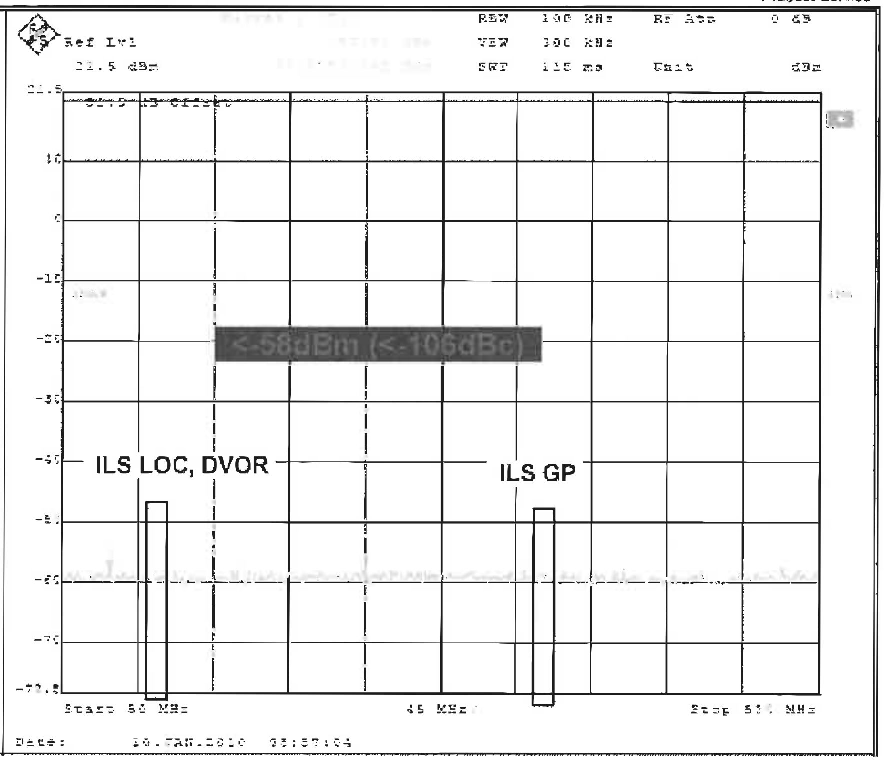
**Fig. 21:** Test Report Excerpts supplied by TANGO/ORANGE; Results TX Single/One carrier; Spurious Emissions ("Outside Transmit Band") 1000MHz – 12750MHz; RBW 3MHz

Product Service

**6.2 GMSK Outside transmit bands (One Carrier)**

Product Service

50.0 – 500.0




Appendix Part 3 of Report Number: 68.850.0.013.02 Page 483 of 584

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**Fig. 22:** Test Report Excerpts supplied by TANGO/ORANGE; Results Single carriers Spurious Emissions (“Outside Transmit Band”) 50MHz – 500MHz; RBW 100kHz

Product Service

### 6.3 GMSK Outside transmit bands (Six Carriers)

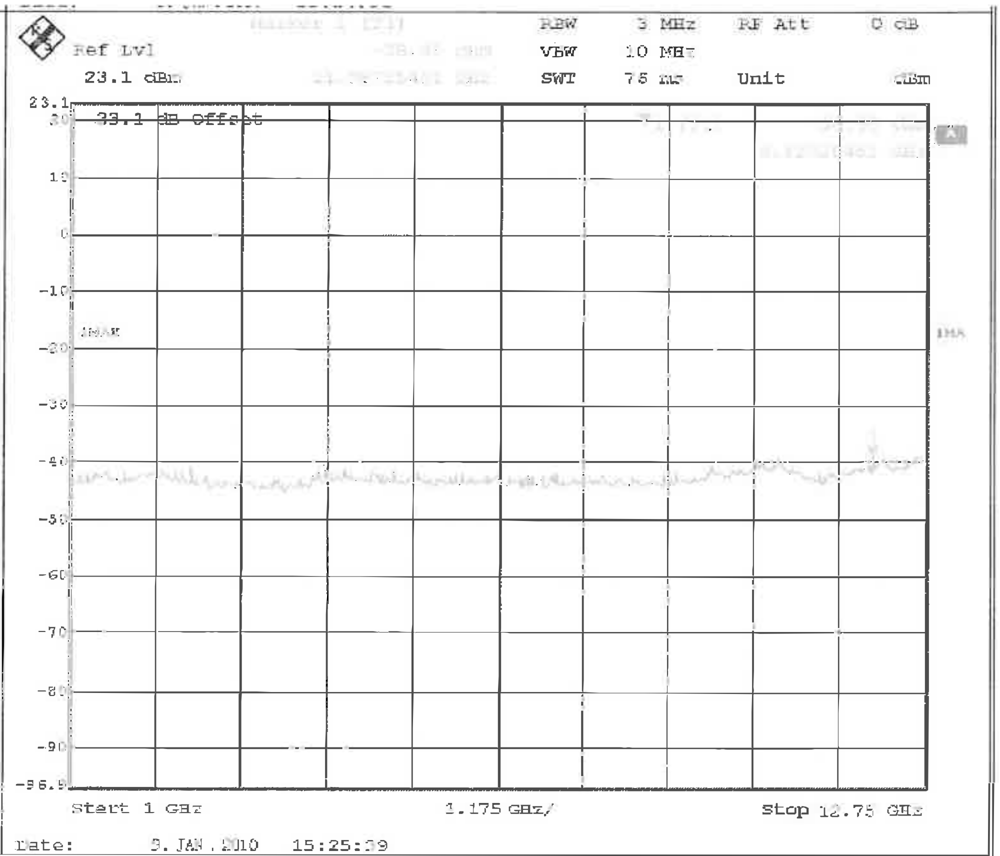
| | | |
|---|---|---|
| | 1000 - 12750 |  |





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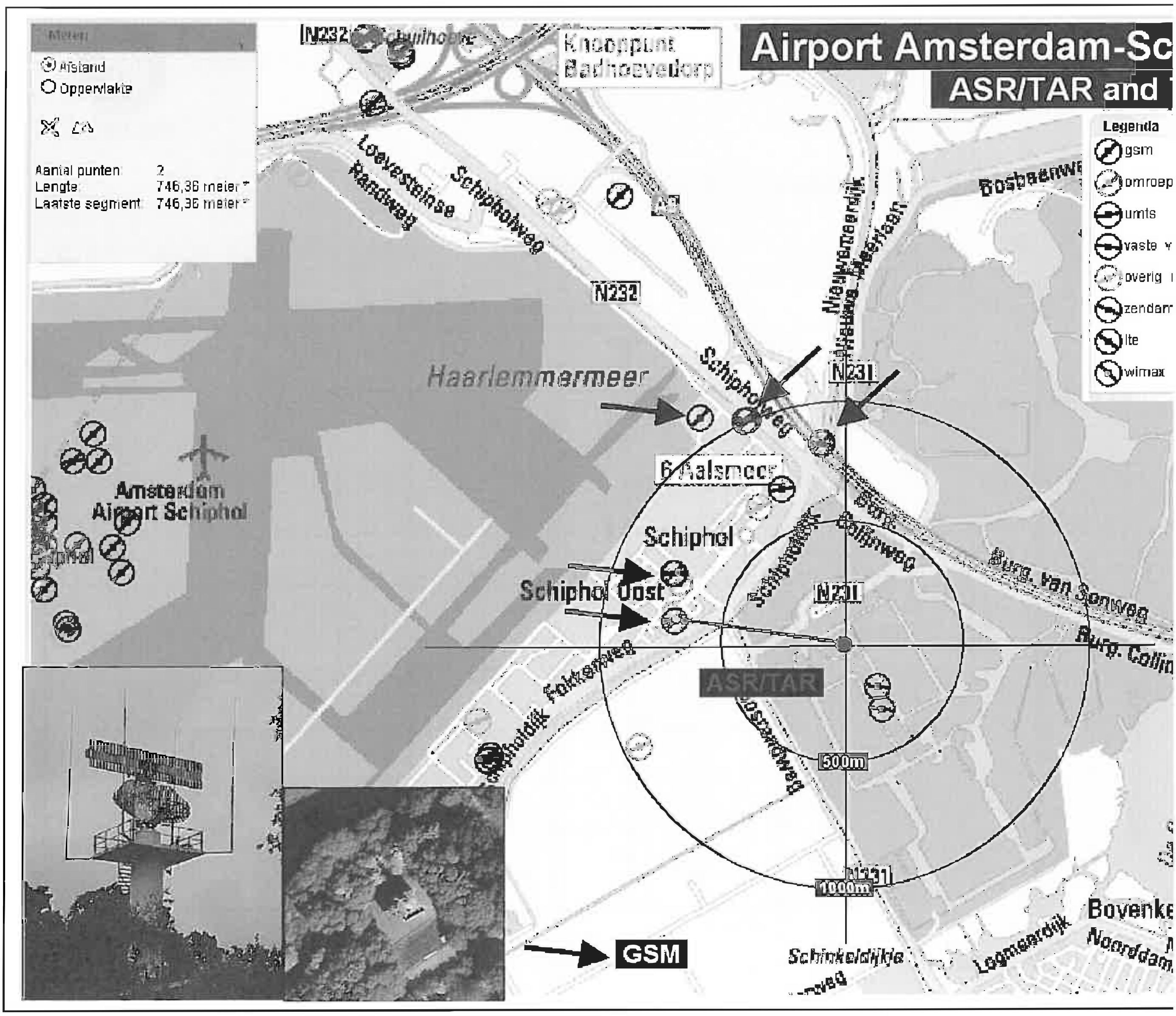
**Fig. 23:** Test Report Excerpts supplied by TANGO/ORANGE; Results Six carriers; Spurious Emissions ("Outside Transmit Band") 1000MHz – 12750MHz; RBW 3MHz


Airport Amsterdam-Sc
ASR/TAR and
Meten
Afstand
Oppervlakte
Aantal punten: 2
Lengte: 746,36 meter
Laatste segment: 746,36 meter
Legenda
gsm
omroep
umts
vaste
overig
zendam
lte
wimax
Knooppunt Badhoevedorp
N232
Loevesteinse Randweg
Schipholweg
Haarlemmermeer
Amsterdam Airport Schiphol
Nieuwemeerdijk
N231
6 Aalsmeer
Schiphol
Schiphol Oost
Burg. Colijnweg
Burg. van Sonweg
ASR/TAR
Fokkerweg
500m
1000m
GSM
Schinkeldijkje
Bovenke
Noorddam
Bosbaanweg

# 6 Literature, Publications


/1/ **INSPECTION DU TRAVAIL ET DES MINES, GRAND DUCHE DE LUXEMBOURG**
ITM-CL 179.4, Conditions d'exploitation pour les émetteurs d'ondes électromagnétiques à haute fréquence, 2006; http://www.itm.public.lu

/2/ **3rd Generation Partnership Project** Technical Specification Group GSM/EDGE; Radio Access Network; Radio transmission and reception; 3GPP TS 45.005; ETSI TR 145 050

/3/ **3rd Generation Partnership Project;** Digital cellular telecommunications system (Phase 2+); Mobile Station (MS) conformance specification; Part 1: Conformance specification; 3GPP TS 51.010; ETSI TS 151 010-1

/4/ **3rd Generation Partnership Project** Base Station System (BSS) equipment specification; Radio aspects; 3GPP TS 51.021; ETSI TS 151 021

/5/ **ETSI** Technical Specification GSM 11.1
MOBILE STATION CONFORMITY SPECIFICATION

/6/ **ETSI** Digital cellular telecommunications system (Phase 2+); Radio transmission and reception; ETSI EN 300 910

/7/ **CEPT/ERC/RECOMMENDATION 74-01E** UNWANTED EMISSIONS IN THE SPURIOUS DOMAIN

/8/ **CEPT/ECC REPORT 146** COMPATIBILITY BETWEEN GSM MCBTS AND OTHER SERVICES (TRR, RSBN/PRMG, HC-SDMA, GSM-R, DME, MIDS, DECT) OPERATING IN THE 900 AND 1800 MHz FREQUENCY BANDS, 2010

/9/ **Communications with SELEX; Emails dated February 11 2013**

/10/ **IEEE Std 211-1997** IEEE Standard Definitions of Terms for Radio Wave Propagation, The Institute of Electrical and Electronics Engineers, Inc.; New York

/11/ **ICAO** INTERNATIONAL STANDARDS AND RECOMMENDED PRACTICES
AERONAUTICAL TELECOMUNICATIONS
ANNEX 10, VOLUME I (RADIO NAVIGATION AIDS