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TECHNICAL REPORT

Fixed Radio Systems;
Energy efficiency metrics and test procedures
for Point-to-point fixed radio systems

Reference

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ETSI

650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - NAF 742 C
Association à but non lucratif enregistrée à la
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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Access, Terminals, Transmission and Multiplexing (ATTM).

Modal verbs terminology

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Introduction

The present document deals with the definition of the metrics, methodology and test conditions for the evaluation of the Energy Efficiency of Point-to-point fixed radio systems.

The tremendous growing of telecom applications is leading to a strong escalation in bandwidth needed to expand telecom solutions. Improved telecommunication networks are under deployment, and consequently the power needed to operate and cool the connected equipment is also likely to increase. As a consequence, the concept of "Energy Efficiency" is getting more and more important in the telecommunication world. Numerous definitions are in use according to the different technologies and network segments they are applied to.

Most of the standardization organizations have identified "Energy Efficiency" as a key area, looking at it from different perspectives as the standards can help providing a common base of understandings, concepts and targets.

The initial stimulus for the present document comes from the European Mandate M/462 [i.1] on the "efficient energy use in fixed and mobile information and communication networks", which among other things states that "it is vital to consider ways to maintain sustainable growth in the transmission capacity of telecommunication networks while limiting and optimizing the energy consumption". However, in line with the European Code of Conduct on Energy Consumption [i.2], it is as much important that the intention of reducing the energy consumption is pursued without hampering the technological developments and the services provided.

Although in the European Mandate M/462 [i.1] and most of the relevant technical documents, Fixed Radio access and transport infrastructures are still mostly disregarded or just mentioned without any specific treatment, the present document aims at giving a correct technical interpretation of the concept of Energy Efficiency when applied to Point-to-point fixed radio systems.

It is important to consider that unlike wired networks, the performance characteristics of a microwave radio system is prone to variations, either due to external factors (e.g. weather) or by the action of the network operator. In a given frequency band, there may be requirements for maximum radiated power levels, particular efficient modulation types, and even standards for the radiation patterns of directional antennas. These criteria are established to reduce or minimize interference among systems that share the same spectrum, and to ensure that the spectral efficiency is sufficiently high to justify the occupancy of the spectrum.

Moreover, propagation characteristics of the microwave signal can differ significantly according to the operating conditions, like frequency band and geographical location.

All the different operating conditions summarily mentioned here above have led to the development of many types of equipment that can address different applications and can work in a large variety of set-up.

It follows that any definition of the Energy Efficiency for Point-to-point fixed radio systems should not be considered without taking into account the specific characteristics of those systems collected in the present document. The present document is thus intended also to provide the necessary technical background in the event that in the future any of the Technical Committees in charge wanted to define any Energy Efficiency KPI's related to P-t-p wireless fixed radio systems.

1 Scope

The present document defines the Energy Efficiency specifically for Point-to-point fixed radio systems, taking into account the specific characteristics of that technology. The technical background and the methodology used to obtain the formula are described together with the test conditions within which carrying out the related measures.

Due to the peculiarity of fixed wireless systems, having various architectures, applications and set-ups, the target to define the Energy Efficiency with a single formula valid for all the categories of systems is very challenging and could be even technically misleading.

As consequence, the main part of the present document is intended to explain the methodology used to derive the EEER, defined as the Equipment Energy Efficiency Ratio. The provided technical description is the necessary complement of the given definition, as it helps to understand the complexity of the matter and how the formula should be used.

That is particularly important in the event that Technical Committees intend to further proceed with the present analysis and derive from the given definition any practical standardization activities.

2 References

2.1 Normative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the reference document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found at http://docbox.etsi.org/Reference.

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The following referenced documents are necessary for the application of the present document.

Not applicable.

2.2 Informative references

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NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] European Commission - M/462 EN: "Standardisation mandate addressed to CEN, CENELEC and ETSI in the field of ICT to enable efficient energy use in fixed and mobile information and communication networks".

[i.2] European Commission, Veer 4, Feb 2011: "Code of Conduct on Energy Consumption of Broadband Equipment".

[i.3] Recommendation ITU-R F.1703 (2005): "Availability objectives for real digital fixed wireless links used in 27 500 km hypothetical reference paths and connections".

[i.4] ETSI EN 302 217-1 (V1.3.1): "Fixed Radio Systems; Characteristics and requirements for point-to-point equipment and antennas; Part 1: Overview and system-independent common characteristics".

[i.5] ETSI EN 302 217-2-2 (V2.2.1): "Fixed Radio Systems; Characteristics and requirements for point-to-point equipment and antennas; Part 2-2: Digital systems operating in frequency bands where frequency co-ordination is applied; Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive".

[i.6] Recommendation ITU-R P.530-15 (2013): "Propagation data and prediction methods required for the design of terrestrial line-of-sight systems".

[i.7] Recommendation ITU-R P.837-6 (2012): "Characteristics of precipitation for propagation modelling".

[i.8] Recommendation ITU-R P.838-3 (May 2005): "Specific attenuation model for rain for use in prediction methods".

[i.9] Recommendation ITU-T G.826 (2002): "End-to-end error performance parameters and objectives for international, constant bit-rate digital paths and connections".

[i.10] ITU-R WP5C, Contribution 345, Huawei Technologies Co. Ltd., Oct 2014: "Error performance and availability issues in ITU: Background and current status".

[i.11] Bell System Technical Journal, Barnett, W. T.: "Multipath propagation at 4, 6 and 11 GHz", Vol. 51, No. 2, 311-361, Feb 1972.

[i.12] Bell System Technical Journal, Vigants A.: "Space-diversity engineering", Vol. 54, No. 1, 103-142, Jan 1975.

[i.13] Recommendation ITU-R F.1668-1 (2007): "Error performance objectives for real digital fixed wireless links used in 27.500 km hypothetical reference paths and connections".

[i.14] IETF RFC 2544 (1999): "Benchmarking Methodology for Network Interconnect Devices".

[i.15] IEC 60038: "IEC standard voltages".

[i.16] ETSI EN 300 132-2: "Environmental Engineering (EE); Power supply interface at the input to telecommunications and datacom (ICT) equipment; Part 2: Operated by -48 V direct current (dc)".

3 Symbols and abbreviations

3.1 Symbols

For the purposes of the present document, the following symbols apply:

Kn	normalized system signature parameter
p_0	multipath occurrence factor
P_{in}	input power (power consumption)
PTx	output transmitted (radio) power

3.2 Abbreviations

For the purposes of the present document, the following abbreviations apply:

AC	Alternating Current
AM	Adaptive Modulation
C	Capacity
CS	Channel Spacing
DC	Direct Current
dN1	point refractivity gradient
EE	Energy Efficiency
EEER	Equipment Energy Efficiency Ratio
f_{BAND}	Frequency Band
FS	Fixed Service
HL	Hop Length

HL_M	Maximum Hop Length
IDU	InDoor Unit
L2	Layer 2
MW	MicroWave
ODU	Outdoor Unit
QAM	Quadrature Amplitude Modulation
RF	Radio Frequency
RIC	Radio Interface Capacity
RTh	Receiver Threshold
SES	Severely Errored Second
SG	System Gain

4 Definition of the EE metrics of Point-to-point fixed radio systems

4.1 General

In general, the energy efficiency of a system should reflect its ability in exploiting the external resources (energy) needed for its operation in order to reach a certain defined level of quality in terms of performance.

The list here below summarizes the different factors that heavily influence the performance of a wireless Fixed Service system:

- Type of application: FS systems can be used in different network segments like access, short haul or long haul. Systems located in different portions of the network are required to provide different features and to work for different link lengths, capacity and quality of service, with consequent impact on their settings and power consumption.
- Frequency bands: FS applications expand from "low" frequencies at around 2 GHz up to 95 GHz or more, though the typical use can be restricted from 6 GHz to 42 GHz. It is well known that in such a wide spectrum range the propagation characteristics are rather different and heavily influence the systems behaviours.
- Environment: those generic terms can refer to different geographical areas of application, including different climatic conditions, but also different morphology like flat ground areas instead of mountainous regions, rural environment up to dense urban.
- Architectures: different systems architectures are available on the market, like all indoor, split-mount indoor-outdoor or full outdoor.
- Features: some equipment types have integrated data processing, including switch devices, monitoring capabilities or ancillary equipment, that can drive the overall power consumption of the system.

All the listed elements can have a direct and relevant impact on the power level needed by the FS systems to handle the traffic and correctly transmit the microwave signal through the hop, and that can clearly influence the evaluation of the their efficiency from the energy point of view.

4.2 Parameters affecting the EE of Point-to-point fixed radio systems

According to the considerations reported in clause 4.1, the following parameters have been identified as possible candidates in the definition of the metrics:

- Frequency band (f_{BAND})
- Bandwidth (Channel Spacing, CS)

  CS represents the amount of spectrum (Bandwidth) used for the transmission of the MW signal.

- Capacity (C)

  The transmission of a certain amount of traffic over the radio link, here called Capacity, is the main purpose of the system and thus considered one of the main important performance indicator, also because the needed capacity is the driver for the operative set-up (CS, modulation format, etc.) The relationship between capacity and bandwidth represents actually another characteristic parameter of the FS systems, the Spectral Efficiency.

- Power consumption (P_{in})

  Input DC Power (P_{in}) has been identified as power consumption parameter, thus excluding any AC-DC converter.

- Maximum Hop length (HL_M)

  The capability to reach longer distances is related both to the system technical quality and to the operative set-up (f_{BAND}, modulation format, etc.). As a consequence, the definition of maximum hop length is meaningful only when the operative conditions are clearly stated.

- Output power (PTx, dB_m)

- Receiver Thresholds (RTh, dB_m)

- System Gain (SG)

  Another noteworthy parameter for p-t-p fixed wireless links is the System Gain (SG), defined as the difference in dB between the transmitter RF output power and the practical thresholds of the receiver.

$$SG_{dB} = PTx - RTh \qquad 4.2a)$$

SG and maximum hop length are strictly related, as in principle a higher SG implies a better capability of the system to reach longer distances maintaining the needed signal level.

However, the relationship between SG and maximum hop length can be rather complicated to be defined, and is subject to variation according to the propagation conditions, mainly frequency.

It can be shown that while for frequencies above about 15 GHz the SG and HL_M are almost linearly related, for lower frequencies HL_M depends also on other significant parameters like the signature, making the SG to HL_M relation more complex.

Another difference related with the frequency range is the reference application of systems: while lower frequencies are generally used for long distance transport links (typically between 30 km and 100 km) which can anyway include mobile backhaul application, higher frequencies are more typically employed for short range links (from a few hundred meters up to a few tens of kilometres) and very often as mobile infrastructure like backhaul. The different application justifies also the fact that while for the lower frequencies the link performance in terms of quality is used as main requirement for the link design, for the higher frequencies one of the most important requirement is the link availability, as explained in the next clauses.

The different behaviour in frequency explains the reason why in the following clauses a separate analysis has been carried out for frequencies up to about 13 GHz and for 15 GHz and above.

4.3 Equipment Energy Efficiency Ratio

4.3.1 Definition of EEER

A straightforward way to define the concept of Energy Efficiency for systems within the scope of the present document, is the Equipment Energy Efficiency Ratio (EEER), defined as the simple ratio among the relevant quantities listed in clause 4.2:

$$EEER = \frac{HL_M \times C}{Log_{10}(P_{in}) \times CS} \qquad 4.3a)$$

where:

- C is the link Capacity, expressed in Mbit/s.
- HL_M is the maximum hop length that can be covered under a set of conditions, expressed in km.
- CS is the channel spacing, in MHz.
- P_{in} is the power consumption in Watt, even if in the formula its weight is in logarithmic units.

Looking at the dimensional analysis $[EEER] = \frac{[km]\times\left[\frac{bit}{s}\right]}{[W]\times[Hz]} = \frac{[km]\times[bit]}{[W]}$

However, it is important to note that the link capacity (C) is very variable according to the width of the channel used for the signal transmission. As consequence any numerical outcome of the formula 4.3a) has to be correlated with a specific value of CS. In other words, the EEER definition can be normalized with respect to the specific reference CS and that term can be removed from the formula, which thus becomes:

$$EEER = \frac{HL_M \times C}{Log_{10}(P_{in})} \qquad 4.3.b)$$

and its dimensional analysis $[EEER] = [km]\times\left[\frac{bit}{s}\right]$

In the formula 4.3b) the two elements C and P_{in} are easily found for the systems under analysis, while the term HL_M has to be calculated or derived from SG. This last step can be easily performed for frequencies above about 15 GHz, where the dependency between SG and HL_M is almost linear, while can be rather complicated for lower frequencies, where other factors like signature enter into the calculation.

4.3.2 EEER applicability

There are many factors that influence the operating settings of a microwave system, and the parameters included in the EEER definition given in formula 4.3b) are strongly impacted by those operating settings or design objectives.

As consequence, the given formulation of Energy Efficiency is consistent only if associated with the specific operating conditions listed here below:

- Frequency band f_{BAND}: the propagation conditions are different in the different frequency bands. The relevance of that parameter is of immediate comprehension considering that the term HL_M is very sensitive to the frequency band it is referred to. It means the EEER given in formula 4.3b) for the fixed wireless system is not an absolute value, but is defined per each frequency band of interest.
- Channel spacing CS: it is the assumption for the definition given in formula 4.3b).
- Spectral Efficiency Class: the same way of the above point, it is possible to show that the same equipment operating with the same CS, but with different Modulation formats (alias different Spectral Efficiency Classes) would obtain different values for its EEER. That requires the EEER to be defined per each Spectrum Efficiency Class.
- Features list: the presence of different features embedded into the system, like switching or routing parts or data compression techniques, can have a not negligible impact on the P_{in} and/or on C.
- Architecture: different system architectures like full-indoor, split-mount or full-outdoor, can address different purposes/scopes, with a consequent impact on performances and power consumption.