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TECHNICAL REPORT

Universal Mobile Telecommunications System (UMTS); Universal Terrestrial Radio Access (UTRA) repeater planning guidelines and system analysis (3GPP TR 25.956 version 15.0.0 Release 15)

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Contents

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1 Scope

The purpose of the following document is to describe planning guidelines and system scenarios for UTRA repeaters. In addition it also contains simulations and analysis of the usage of repeaters in UMTS networks.

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
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[1] 3GPP TR 25.942

[2] R4-030365

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply, unless otherwise stated:

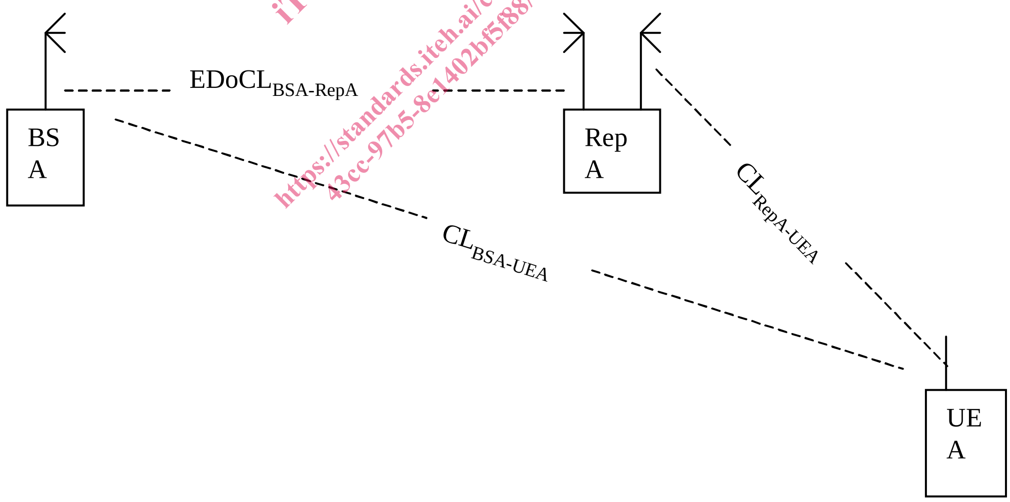

Figure 3.1

$ACRR_{RepA}$	Adjacent Channel Rejection Ratio for repeater A.
ACG_{RepA}	Adjacent Channel Gain for repeater A.
$CL_{BSA-UEA}$	Coupling Loss between Base Station A and the User Equipment A.
$CL_{RepA-UEA}$	Coupling Loss between Repeater A and User Equipment A.
d_{RepA}	Group delay of repeater A.
$EDoCL_{BSA-RepA}$	Effective Donor Coupling Loss between the donor Base Station A and the Repeater A.
G_{RepA}	Set gain of Repeater A.
$Gmax_{RepA}$	The maximum Gain possible to set of Repeater A.
M_{RepA}	Noise Margin for repeater A.
NF_{RepA}	Noise Figure of repeater A.

P_{repA}	Output power of repeater A.
$Pmax_{RepA}$	Maximum output power of repeater A.
$Pmax_{BSA}$	Maximum output power of base station A

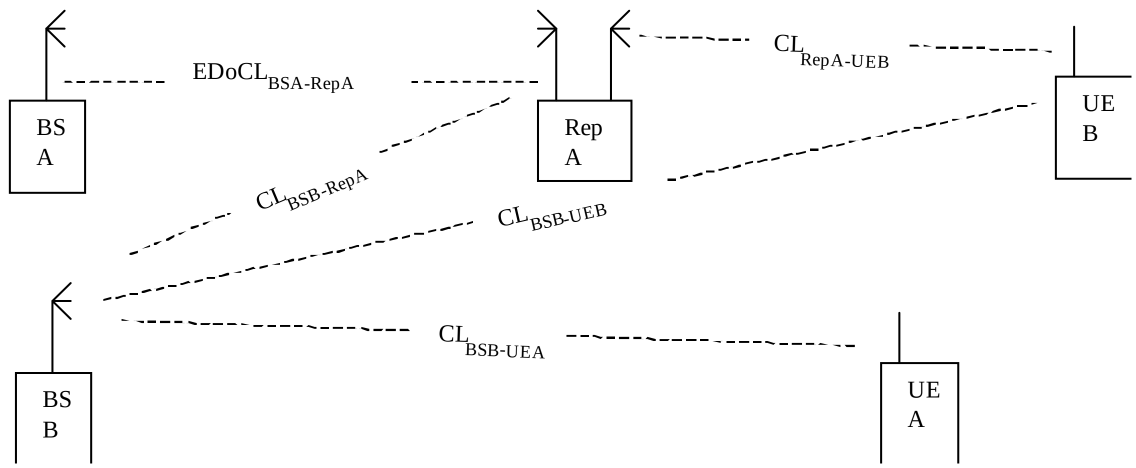

Figure 3.2

$CL_{BSB-UEA}$	Coupling Loss between Base station B and the User equipment A.
$CL_{RepA-UEB}$	Coupling Loss between Repeater A and User equipment B.
$CL_{BSB-RepA}$	Coupling Loss between Bas station B and Repeater A.
$CL_{BSB-UEB}$	Coupling Loss between base station B and User equipment B.
SsIR	Signal to self Interference Ratio. (Described below)

3.2 Symbols

(void)

3.3 Abbreviations

(void)

4 System Impacts of Repeaters

4.1 Error Vector Magnitude (EVM)

The introduction of a repeater has an impact in the EVM of the system. The basic effect is reflected in a system noise rise, which can be calculated from the EVM value the received signal exhibits. The formula is

$$\text{Noise rise} = 10 \log(1 + EVM^2)$$

In the scenario of a Repeater amplifying the signal the EVM of the signal is calculated according to the following formula for uncorrelated processes:

$$(EVM\_total)^2 = (EVM\_NodeB)^2 + (EVM\_Repeater)^2$$

Taking the specified value of 17,5 % for both the Node B (as well as for the UE) and the Repeater result in a total EVM of 24,7 %. Calculating the noise rise for the Repeater scenario gives a value of 0,26 dB in the area of the repeater's coverage. This compares to a noise rise in a scenario without Repeater of 0,13 dB. The difference between the two numbers is the worst-case closed loop power rise in an otherwise perfect system that would occur with a Repeater being used.

4.2 Peak Code Domain Error (PCDE)

In the specification of the Peak Code Domain Error value of the Repeater -35 dB is used. The number for the Node B is -33dB. If we assume the processes in the Repeater that lead to the PCDE being independent of the equivalent process in the Node B we can assume that they can be treated as noise. In this case the resulting value for PCDE is calculated from the linear addition of the two signals that will lead to -31 dB. This is a 2 dB degradation to the value of the Node B. For the repeated cell the degradation might be negligible. In case of a neighbour cell the might be affected to some extend. Presumably the soft handover gain will be reduced by the tenth of a dB.

4.3 Frequency error

The effect of the additional frequency error will be a reduction of the maximum speed. In the repeater core specification the minimum requirement on frequency stability is 0,01 ppm. Hence, with the 0,05 ppm minimum requirement for the base station frequency stability the resulting "worst case" for a signal that have been amplified by the repeater is 0,06 ppm.

4.4 Adjacent Channel Leakage Ratio (ACLR)

With regard to the mentioned ACLR we have to investigate the behaviour of the Repeater. For this reason we use the model shown in the following Figure 4.1:

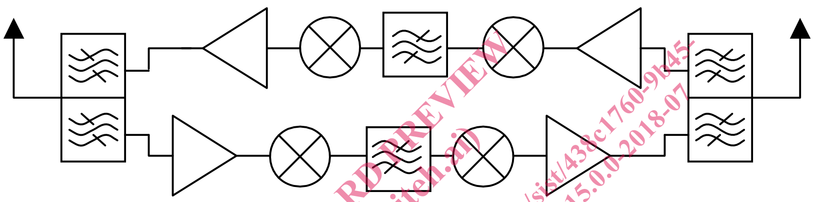

Figure 4.1: Simplified Repeater model.

The Repeater in its basic function is bi-directional amplifier of RF signals from Base Stations in the downlink path and from Universal Equipments (UE) as mobile stations in the uplink path. The operating bands in which the Repeater amplifies is determined by the IF filter in its bandwidth and by the duplexer filter in its frequency range for operational configuration. In our discussion we will use the parameters defined in Table 4.1.

Table 4.1: Parameters of the Repeater model.

Parameter	Description	Unit	Assumed value	Comment
G	Repeater gain	dB	90 dB	UL and Dl gain should be the same for a balanced link.
Pout_DL_max	maximum Repeater average output power measured with WCDMA signal according to model 1 of TS25.141.	dBm	30 dBm	DL value
Pout_UL_max	maximum Repeater average output power measured with WCDMA signal according to model 1 of TS25.141.	dBm	12 dBm	UL value
NF	Repeater Noise Figure	dB	5 dB	valid for UL and DL
N_therm (30 kHz)	Thermal Noise Power density in a Bandwidth of 30 kHz	dBm / 30 kHz	-129 dBm / 30kHz	-174 dBm/Hz (at 25 °C) + 45 dB
S (30 kHz)	WCDMA Signal Power Density	dBm / 30 kHz	Pout - 21 dB	the factor of 21 dB is the relation of channel bandwidth to 30 kHz

The Repeater output noise density can be calculated according to the formula:

$$N\_Rep\ (30kHz) = N\_therm\ (30kHz) + NF + G = -34\ dBm/30\ kHz\ .$$

Considering the output of the Repeater in the Downlink path we will find an average power 30 dBm in the WCDMA channel. This is resulting in a signal density of

S_Downlink = +9 dBm/30 kHz.

This leads to a signal-to-noise ratio of the Downlink of:

S / N_Downlink = 43 dB.

The Adjacent Channel Leakage Ratio (ACLR) as defined for BS is stating -45 dB for the first adjacent channel and -50 dB for the second adjacent channel. This situation is illustrated in Figure 4.2.

In the Repeater case the resulting output frequency spectrum is shown below.

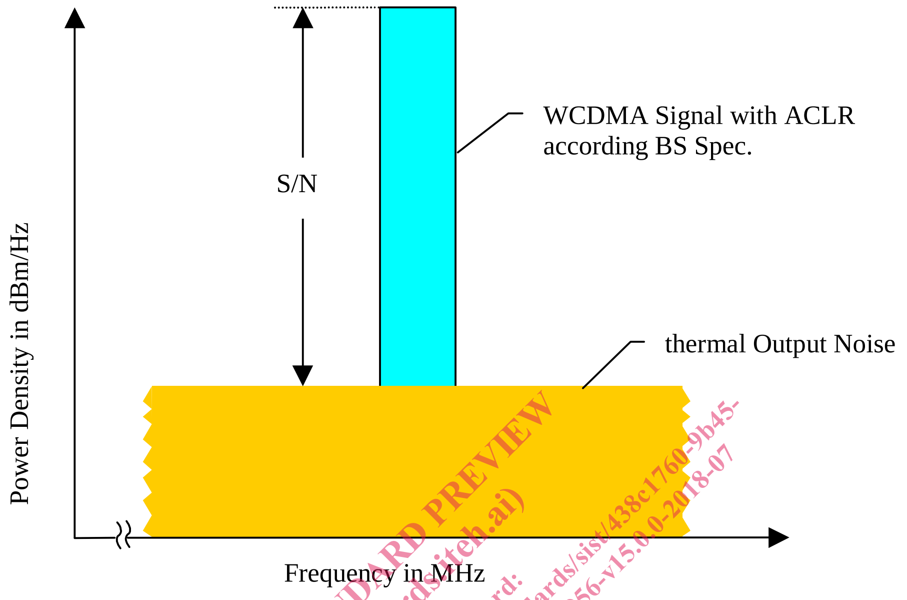

Fig. 4.2: Repeater output frequency spectrum.

It is obvious that the ACLR cannot be measured in the Repeater case due to the fact that the this signal is below the amplifier thermal noise of the Repeater amplifier chain.

This even get worse when the Uplink is considered. As in this path the maximum average value of the output power is reduced to 12 dBm resulting in a signal power density of S = -9dBm / 30 kHz, the signal-to-noise ratio will be even smaller:

S / N_Uplink = -9 dBm / 30 kHz - (-43 dBm / 30 kHz) = 34 dB.

This collision is the reason why the ACLR requirement as it is written for the BS equipment cannot be met with a Repeater. The ACLR measurement will be limited by the thermal noise of the Repeater amplifier chain.

Spectral components (noise, ACP, intermodulation products, spurious signals, ...) falling outside the operating band are fully addressed in the TS 25.106 subclause 9.

4.5 Time Delay

Using common narrow band filter technologies (SAW) the IF-filtering process introduces a time delay of about 5-6 µs to the signal. This puts a requirement on the length of the receiver's search window. It is, however, believed that the channel models now specified in TS 25.104 are sufficient for guaranteeing the receiver's performance in an area covered by both a repeater and a base station.

Figure 4.3 illustrates a case where the UE receives multipath signals, both from the repeater and from the BS. Here, the repeater will introduce artificial multipaths. This could possibly reduce the effects from fading, but also increase the number of paths that are needed to capture a certain percentage of the energy is increased and it is therefore important to have a sufficient amount of RAKE fingers in the receiver.

However, traditionally the repeater is deployed to cover a smaller area compared to the BS and the number of resolvable multipaths could therefore be believed to lower compare to that of macrocellular deployment.

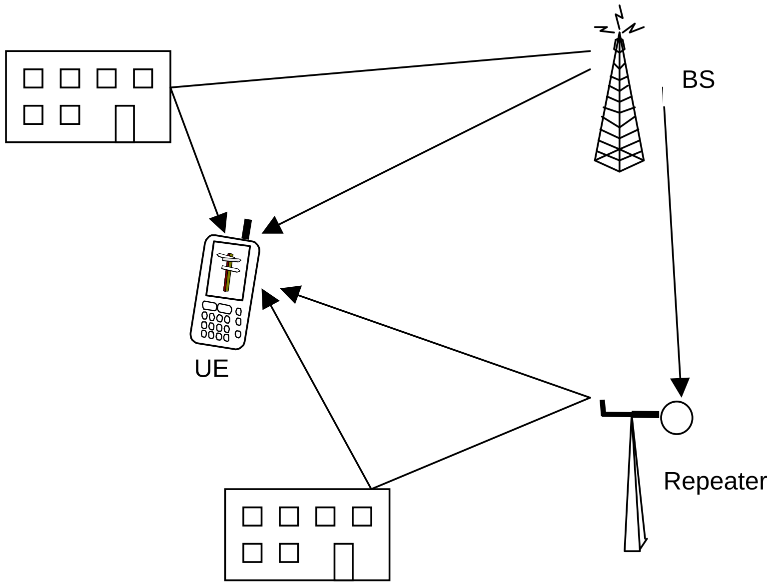

Fig. 4.3: Illustration of the excess multipaths that are introduced by the repeater in a scenario where the UE is receiving the signal, from both the BS and the repeater.

4.6 Location Services (LCS)

The co-existence between repeaters and location services (LCS) is studied in this clause. Three methods for location services are currently specified in TS 25.305: OTDOA, Cell coverage based positioning and Network assisted GPS.

4.6.1 OTDOA

The OTDOA method is based on measurements of the UTRA pilot signal (CPICH) made by the UE and the Location Measurement Unit (LMU). The position of the UE is estimated by using the observed time difference of arrival (OTDOA) from three, or more, base stations.

Figure 4.4 is an illustration of a network using repeaters. In this case the signal path from BS4 to the UE can be either the direct path, with a time delay of τ4, or the path through the repeater, with a time delay of τRB+τd+τR, where τd is introduced by the repeater. This extra time delay introduces an ambiguity when performing the location estimation.

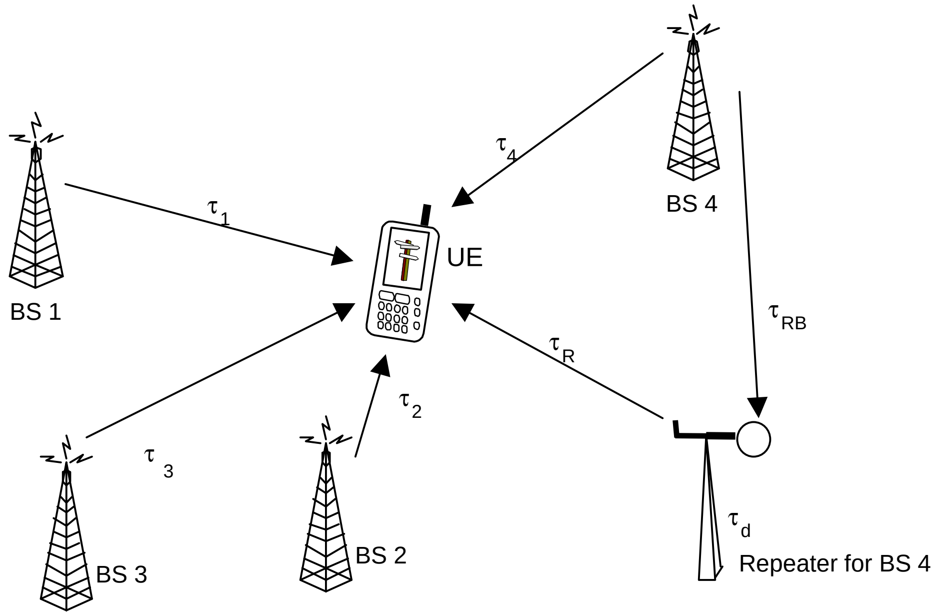

Fig. 4.4: Illustration of the effect of a repeater installation in a network using OTDOA based LCS.

To avoid this ambiguity different mechanisms can be implemented:

1. For small cells one can exclude one of the signals if it has to long path delay (i.e. passed through a repeater). Hence, for cells smaller than 1500 m (corresponding to 5 μs) it is detectable, whether or not, a repeater has transmitted the signal.

2. If the UE detects more than three sites, as the case is in Figure 4.4, the measurement of the time delay from BS 3 can be excluded, based on a too large relative difference to the time delays from BS 1-3. The probability of detecting three sites is much lower compared to that of detecting four or five sites. This result holds true for both the urban and the suburban environment, when the UE uses 16 ideal periods.

4.6.2 Cell coverage based positioning method

The only impact is that the cells become larger using repeaters and that this method thereby has less accuracy compared to a smaller cell. Other than that the repeater does not affect this LCS method.

4.6.3 Network assisted GPS methods

The UTRA network can assist the UE GPS receiver in several ways. E.g. by providing a frequency reference, since UTRAN has a better frequency stability compared to GPS (0,05 ppm frequency error compared to 20 ppm). UTRAN can also provide the UE with a timing reference to reduce the UE GPS search time and improve the accuracy.

If a repeater is deployed in the network this will lead to about 5 μs extra delay. This extra delay is not of the extent that it will affect the performance of GPS assisted method. It is however important that the frequency stability of UTRAN is maintained in the repeater.

4.7 Automatic Gain Control (AGC)

Repeaters use a function called Automatic Gain Control (AGC) to adjust the gain so that self-oscillation is avoided. The gain of the repeater shall be adjusted so that there is a margin to the port isolation between the up- and down-link directions as described in the sub-clause Gain Settings.

As a consequence the AGC is not intended to the constantly adjust the gain during the normal mode of operation. It shall be seen as a fall back to prevent self-oscillation if, for some reason, the isolation between the ports is reduced compared to the isolation measured during the deployment or an increase in input power to a level larger than the input level creating the maximum output power.

The AGC is also slow in comparison to the fast power control (the range of several microseconds) in order not to interfere with the system performance. The AGC should further adjust the gain in both the up and downlink in order to make the repeater a transparent system element.

4.8 Adjacent Channel Rejection Ratio (ACRR)

The secondary impact on the adjacent channel operator as described in section 5.2.2 gives rise to a requirement of an explicit requirement on ACRR in the requirement specification. After simulations described in section 6.5 the requirements are introduced in the repeater specifications.

5 Planning with Repeaters

5.1 Sole System

5.1.1 Antenna Isolation

Antenna isolation is an essential issue for the performance of a repeater.

As a repeater only amplifies a received signal, it can act as an oscillator under certain circumstances. The feedback path in this amplifier system are the two antennas: coverage antenna and donor antenna.

In order to prevent oscillation of the system, the feedback must be lower than the amplifier gain. This loss in the feedback path is called the *Antenna Isolation*. It must be 15 dB higher than the repeater gain to guarantee an adequate protection against self-oscillation of the repeater.

Several factors have influence on the antenna isolation:

1. Antenna pattern (Horizontal and vertical)

The optimum is a combination of donor and coverage antennas that are mounted the way that there is a null in the antenna pattern in the direction pointing towards the other antenna. A null means minimum antenna gain in the specified direction.

As both antennas are usually mounted in opposite directions, it is useful to chose both donor and coverage antenna types that have a high front-to-back ratio.

2. Vertical separation

Typical antennas that are used for repeater sites have a narrower aperture in the vertical antenna pattern, the vertical distance of the antenna influences the isolation of the antenna system. In a typical configuration, when both antennas are mounted on a pole, there is a null in the antenna pattern pointing vertically up and down from the antenna's feeding point. If there is a horizontal separation between the antennas, additional lobes in the vertical antenna pattern have to be taken into account.

3. Environment of both antennas

The environment of the antennas is a very important factor. The reflection and attenuation properties of all materials near the antenna can influence the antenna isolation drastically.

- The waves transmitted by antennas are reflected by surfaces, depending on the materials. If there is a reflection from a building towards the pole with the mounted antennas, this can decrease the antenna isolation by more than 10 dB.
- The material of the tower itself has also an effect on the isolation: If both antennas are mounted on a tower made of concrete, this improves the antenna isolation, as signals are attenuated and reflected by the material of the tower. A steel grid tower however might not increase antenna isolation particularly, as the distances between the single elements might be bigger than half a wavelength, which means that radiated power can pass the tower almost unattenuated. In this case, antenna isolation is more dependent on the antenna patterns.