Title: **Radio link performance with EDGE repeaters**

Source: Ericsson

1 Introduction

This report presents some results on the effect of introducing a repeater in an EDGE radio link. The results are limited to the link; i.e. no system impacts are described.

Two types of repeaters are considered, the non-frequency shifting channel selective repeater and the channel selective repeater system using frequency shift.

It is shown that both repeaters have impact on the EDGE radio link performance. For the non-frequency shifting repeater the loss is not so large, but for the repeater system using frequency shift the loss is much larger with the assumptions made in this report. However, designing a frequency-shifting repeater system that causes little degradation may be expensive, so the loss could be accepted.

2 Existing specifications

The specifications for GMSK modulation cover some of the performance requirements for repeaters. In GSM 05.05 [1] annex E.5 the frequency and phase error is defined. This clause only covers a repeater system using frequency shift, and it states that this system shall not increase the phase error of the signal by more than 2 degrees. The frequency error shall not exceed 0.1 ppm.

Other information sources about repeaters are found in [2], [3], and [4].

3 Repeater systems

There are two basic types of repeaters, the non-frequency shifting stand-alone repeater and the repeater system using frequency shift. The non-frequency shifting repeater, which is shown in Figure 1, is a stand-alone unit used to increase coverage in certain locations such as buildings, tunnels etc. The non-frequency shifting repeater receives the carrier from the base station with a directional antenna, which is then amplified and transmitted from the repeater to the mobile station on the same frequency. The repeater also receives the carrier from the mobile, which is amplified and transmitted to the BTS on the same frequency.

Since the non-frequency shifting repeater use the same frequency on both antennas, the gain is limited in order to reduce coupling of donor antenna and coverage antenna. A repeater system using frequency shift, which is shown in Figure 2, relax the limitation on the gain by using a separate link frequency, fl. The master unit is placed in the vicinity of the BTS and the remote unit in the area, which is to be covered.

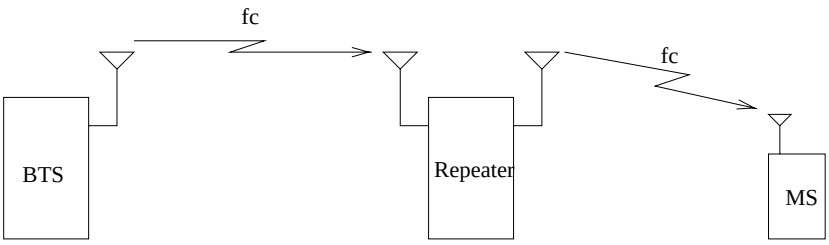

Figure 1: A repeater system with a non-frequency shifting repeater

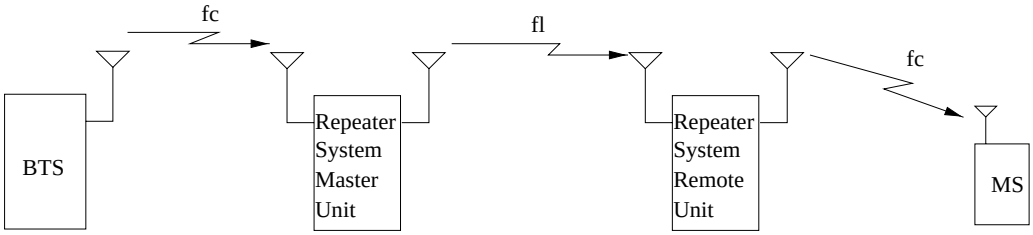

Figure 2: A repeater system using frequency shift

4 Error sources in repeaters

The frequency-shifting repeater has several error sources. Both the master and remote unit have two synthesizers and one PA each, and due to the frequency shift a frequency error is also introduced. Also both units may have a band selective filter.

The non-frequency shifting repeater usually have some kind of band selective filter, but since the same synthesizer can be used for both up- and down-converting there is no frequency error added, and the phase noise contribution is very small. The main error sources in the non-frequency shifting repeater are therefore a band selective filter, which introduces some time dispersion, and the power amplifier.

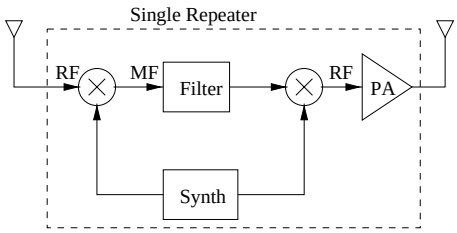

Figure 3: Simplified view on the functions inside a non-frequency shifting repeater.

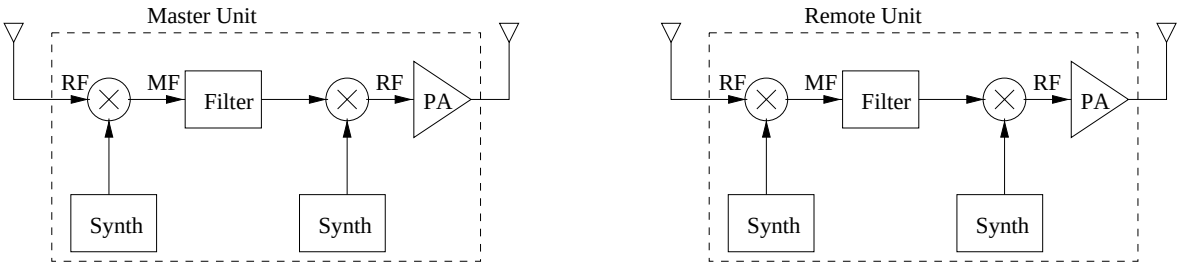

Figure 4: Simplified view on the functions inside a frequency-shifting repeater.

The band selective filter used in this report has been measured on a band selective non-frequency shifting repeater. The frequency-shifting repeater uses two equal filters, one in each unit. The EVM for the repeaters are shown in Table 1.

The power amplifier used in the simulations is a basic PA intended for base stations and its characteristics are shown in Figure 5.

Table 1: EVM for the different repeaters.

Repeater type	EVM measured in simulator [%]		Description
	Total	Max burst	
Freq shift, compete system	12,6	14,5	Repeater filter with PA (5dB back off)+ Synth + FreqErr
Freq shift, single unit	6,4	10,5	Repeater filter with PA (5dB back off)+ Synth + FreqErr
Non-frequency shifting	6,5	8,4	Repeater filter and PA with back off 4,5 dB

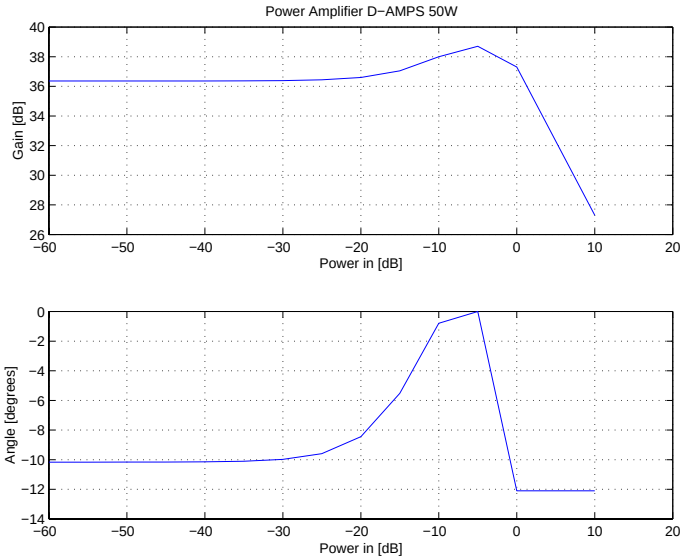

Figure 5: Gain and phase characteristics for the D-AMPS PA used in the repeaters.

5 Simulations of a non-frequency shifting repeater

5.1 Introduction

The effect of introducing a non-frequency shifting repeater is evaluated in the simulator. The repeater is modeled as in Figure 3 with the synthesizer assumed ideal, i.e. only the filter and the PA imperfections are added. The simulation setup is shown in Figure 6, where the EDGE transmitter and receiver can contain realistic impairments if desirable. There is no channel model between the transmitter and repeater since it is assumed that there is a direct line of sight, and since both parts are stationary, the channel can also assumed to be static.

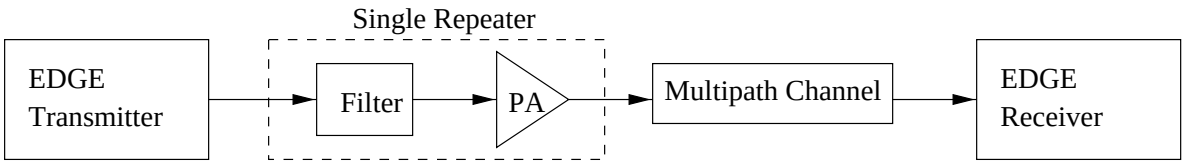

Figure 6: The simulation chain for non-frequency shifting repeater

5.2 Simulation results

In Figure 7 the block error rate (BLER) is shown for MCS-6, which has a code rate of 0.5, when the non-frequency shifting repeater is used. For comparison a RMS 4.1° phase noise curve is shown, which has the same EVM (6.7%) in average as the repeater with a PA. The loss for the repeater with a PA is about 0.9 dB at 10% BLER.

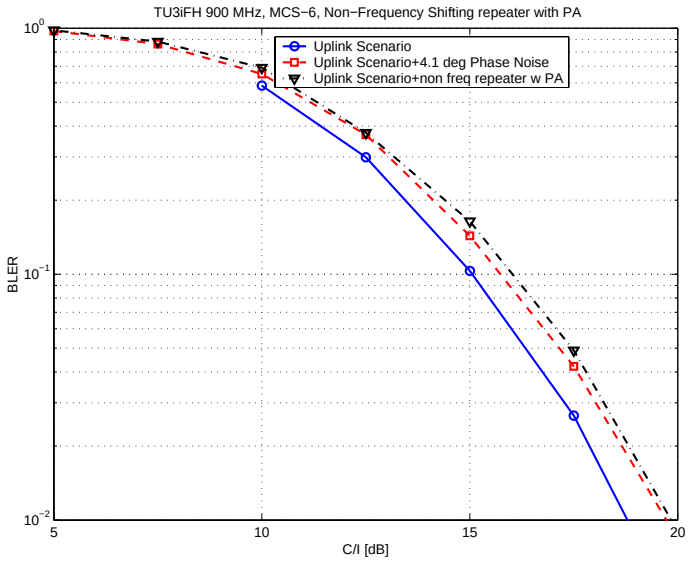

Figure 7: BLER for MCS-6 when the non-frequency shifting repeater is used together with a PA. The PA has 5-dB back off.

6 Simulations of a frequency-shifting repeater

6.1 Introduction

The simulation setup for the frequency-shifting repeater is shown in Figure 8. Both the channel from the BTS to the master unit and the channel between the master and remote unit are assumed ideal in these simulations. The filters assumed are the same as the filter used in the non frequency-shifting repeater. The PA is also the same, a D-AMPS PA, but with a back off of 5.0 dB. The synthesizers have a phase noise of 1.5° RMS, and the frequency error introduced is 100 Hz.

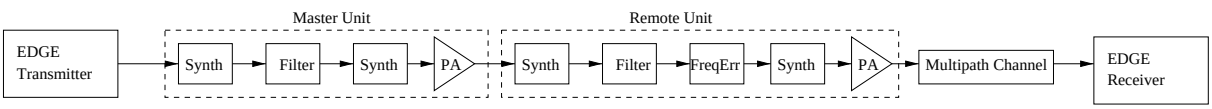

Figure 8: The simulation chain for the frequency-shifting repeater

6.2 Simulation Results

In Figure 9 the block error rate for MCS-6 is shown with and without the frequency-shifting repeater. Impairments in the transmitter and receiver are present in all cases according to the 'Uplink Scenario'. The loss is in the range of 2.5 dB for MCS-5 and 5dB for MCS-7.

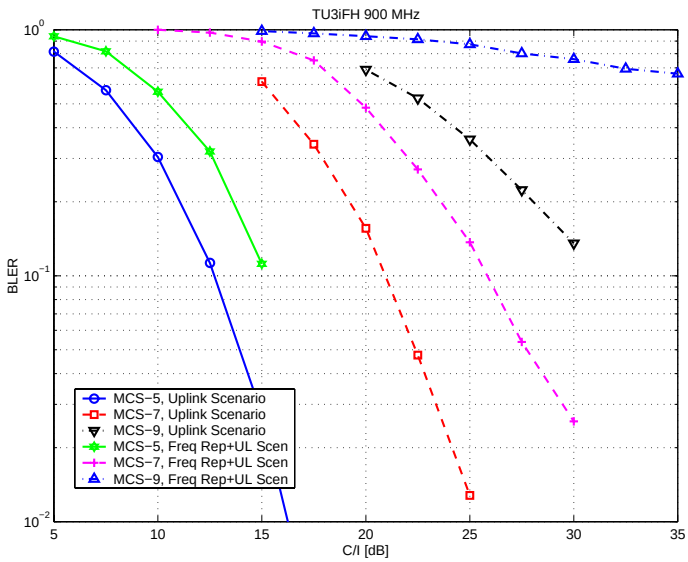

Figure 9: BLER for MCS-5, 7 and 9 with and without the frequency-shifting repeater. The transmitter and receiver contains impairments according to a typical uplink scenario.

7 Impairments in transmitter, repeater and receiver

To evaluate the performance that can be achieved in a 'real' EDGE link impairments are added in the transmitter and receiver. Figure 10 shows four throughput curves, ideal, "Uplink Scenario" without repeater ,"Uplink Scenario" with non frequency-shifting repeater and finally "Uplink Scenario" with frequency-shifting repeater. The link adaptation is assumed to be ideal, i.e. the best modulation and coding scheme (MCS) is used at every C/I. All simulations only includes MCS-5 to 9, thereby the bad performance below 7 dB. The uplink scenario uses impairments that are typical for an MS transmitter and BTS receiver.

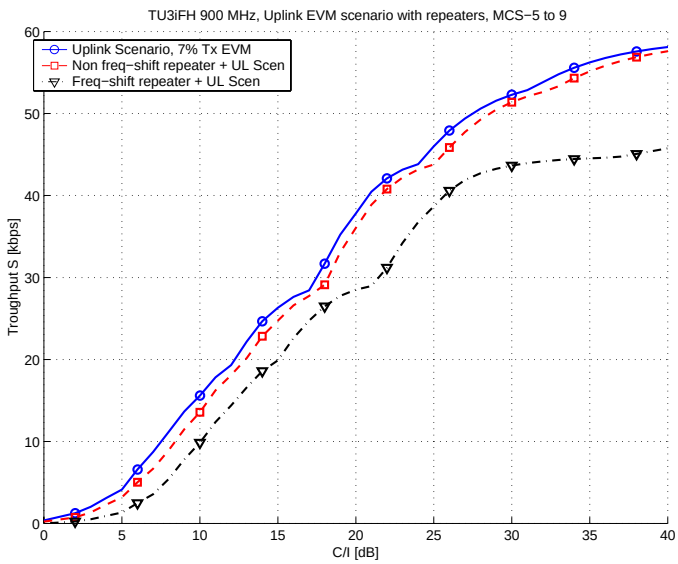

Figure 10: Throughput in kbps per timeslot.

8 Conclusions

This report has shown the effect of introducing a repeater in an EDGE radio link. For a non frequency-shifting repeater the performance loss is 1-1.5 dB below 40 kbps under the given assumptions. The peak user data rate is reduced from 58 kbps to 57 kbps. For a frequency shifting repeater the loss is in the range 2.5–4.5 dB below 40 kbps and the peak data rate is reduced from 58 to 46 kbps.

The report also shows that the effect of the channel selective filter in the repeater is at least not less than a noise source with the same amount of EVM. The EVM could therefore be considered as a requirement on repeaters.

9 References

[1] GSM 05.05: “European digital telecommunications system (Phase 2+); Radio transmission and reception”, Ver 6.3.0, Release 1997.
[2] GSM 03.30: “European digital telecommunications system (Phase 2+); Radio network planning aspects”, Ver 6.0.1, Release 1997.
[3] GSM 05.50: “European digital telecommunications system (Phase 2+); Background for RF requirements”, Ver 7.0.0, Release 1998.
[4] GSM 11.26: “European digital telecommunications system (Phase 2+); Base Station System (BSS) equipment specification; Part 4: Repeaters”, Ver 5.2.0, Release 1997.
[5] ETSI. Tdoc SMG2 080/99. “Performance for EVM scenarios in EDGE”
[6] ETSI. Tdoc SMG2 143/99. “EVM performance with frequency offset and carrier leakage”
[7] ETSI. Tdoc SMG2 236/99. “Receiver Implementation margin for EDGE”
[8] ETSI. Tdoc SMG2 021/99. “Noise Model of transmitter – receiver chain for EDGE”
[9] ETSI. Tdoc SMG2 266/99. “Radio link performance with EDGE repeaters”