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Title: **E-MBMS Performance with Repeaters**
Document for: **Discussion**

1. Introduction

It is well-known that repeaters (optical as well as RF) can be used to improve the user coverage in cellular networks. For broadcast networks operating in single frequency (SFN) mode, downlink repeater deployment is a potential low-cost solution to improving coverage and increasing the maximum supportable spectral efficiency. The delay from "feeding" the eNB output to a repeater will result in the degradation of link performance if the cyclic prefix length is insufficient to accommodate the increased composite ('RF combined') channel delay spread. Since light propagates at a lower speed in an optical fibre (assumed here to be $2/3$ of the speed of light in vacuum), the potential for the "feeding" delay to be significant is non-negligible.

In this document, we briefly assess the impact of optical repeaters on achievable coverage of an E-MBMS network deployed in single frequency (SFN) mode. Specifically, we address the issue of cyclic prefix length requirement in the presence of repeaters in a system with reasonably large cell radii.

2. Network Simulation Results

A three ring hexagonal grid layout with the eNBs operating in SFN mode and the UE drop locations confined to cell sites within the second ring (to minimize edge effects) was simulated. The simulation assumptions were based to a large extent on [1] and are summarized in Table 2. The system simulation scenario of Case 3 was considered because of the large cell radius (1 km). Figure 1 shows cells sites and UE drop locations for a 1km cell radius.

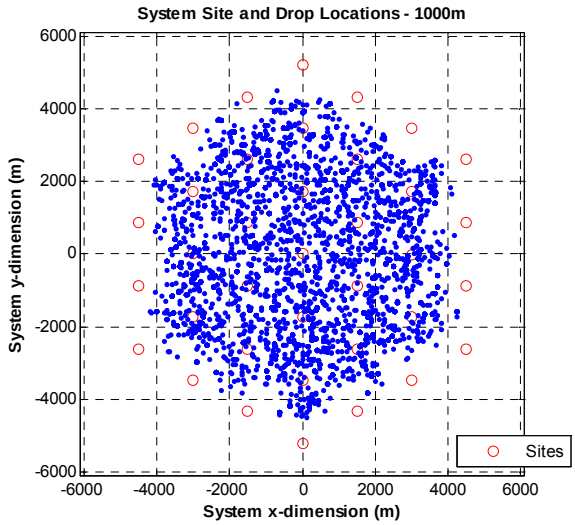

Figure 1 – Cell layout and UE drop locations

Log-normal shadowing was modelled for signals originating both from eNBs and repeaters. Optimisation of repeater placement was not considered in order to simplify the simulations. Instead, a finite set of obvious symmetrical placements were evaluated and the results for the placement that resulted in maximum spectral efficiency are reported here. This placement of repeaters is shown in Figure 5 in the Appendix. The height of the antennas at both eNBs and the repeaters was fixed at 15m[1]. Maximum transmit powers of 33 dBm (2W) and 30 dBm (1W) were considered, consistent with low-cost repeater deployment. Omni-directional (along the azimuth) antennas with a gain of 9 dB were considered for the repeaters. The refractive index of the fibre optic cable was assumed to be 1.5.

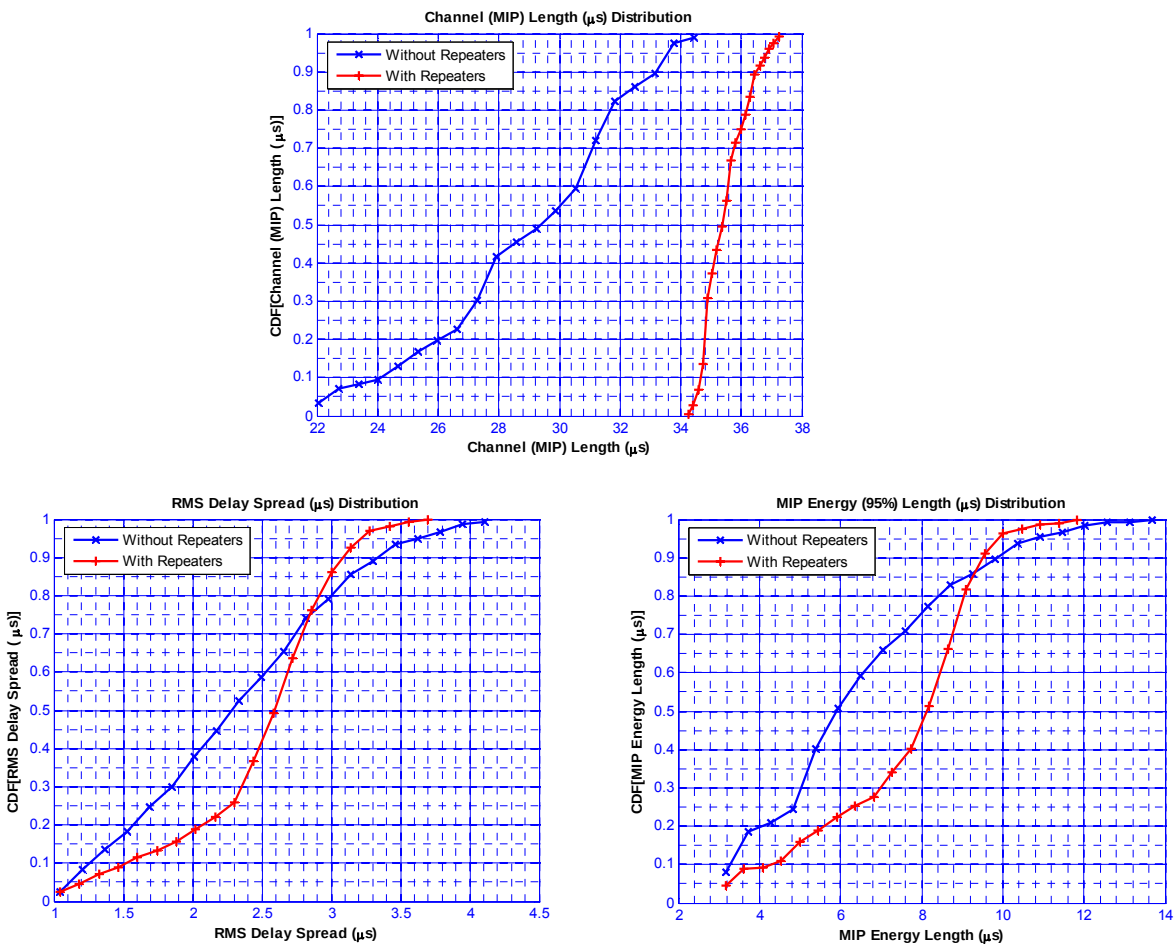

Figure 2 – Delay spread statistics

Figure 2 shows the statistics of the composite delay spread observed at the UE drop locations. The individual channels from each of the eNBs (and repeaters) to the UEs is modelled as Typical Urban (TU). The first plot shows the cumulative distribution function (CDF) of the total delay spread of composite multi-path intensity profile (MIP) observed at the UE drop locations. Although the inclusion of repeaters increases the median delay spread perceptibly, the effect on delay spread measures such as root mean

[1] *It is recognized that the height of repeater antennas is generally smaller than 15m. This assumption has minimal affect on the conclusions drawn in this document and hence considered reasonable*

square (RMS) delay spread and 95% energy delay spread – which have a direct bearing on the CP length requirement – is marginal.

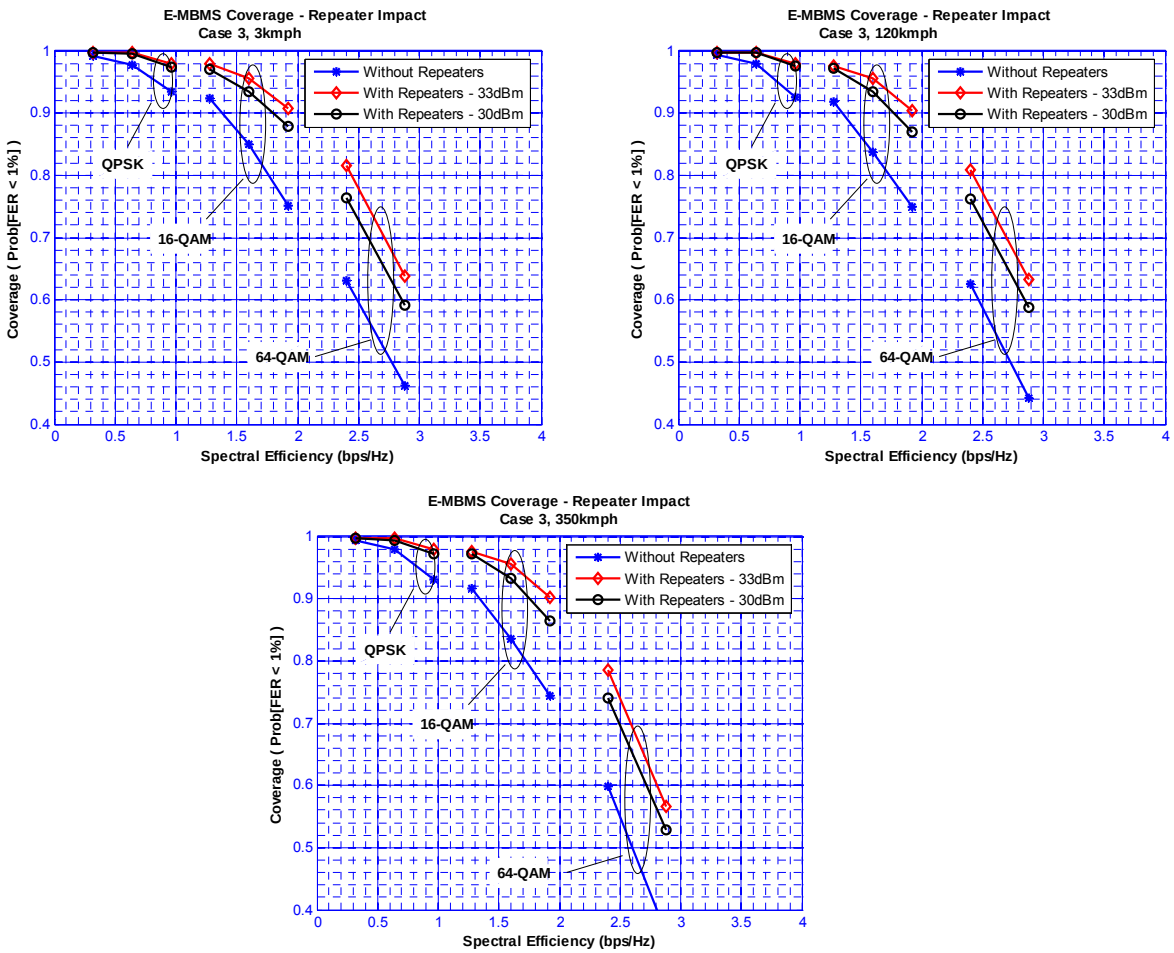

Figure 3 – Repeater Impact on E-MBMS Performance

The impact of repeaters on spectral efficiency[2] was evaluated using the methodology described in [2]. Figure 3 shows achievable spectral efficiency gains with low-cost repeater deployments using current reference L1 parameters (RLP) [2] at UE speeds of 3, 120 and 350 kmph. It can be observed that spectral efficiencies in excess of 1bps/Hz are possible even with 1W transmitters at the repeaters. Figure 4 shows similar curves for the modified L1 parameter sets [2] for 3 kmph UE speed and 2W transmitters at the repeaters. The simulation results for different L1 parameter sets are summarized in Table 1. It can be observed that, for all the L1 parameter sets, the relative improvement in spectral efficiencies is similar. The advantage of using modified L1 parameters sets (which have a larger CP length) is marginal. It can also be concluded that the gains achieved due to the repeater deployment are mostly because of the increased power injection into the system and outweighs any impact of a larger CP length.

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[2] *Throughout this paper, spectral efficiency numbers are quoted at 95% user coverage. A UE is considered to be in outage when its frame error rate (FER) is greater than 1%*

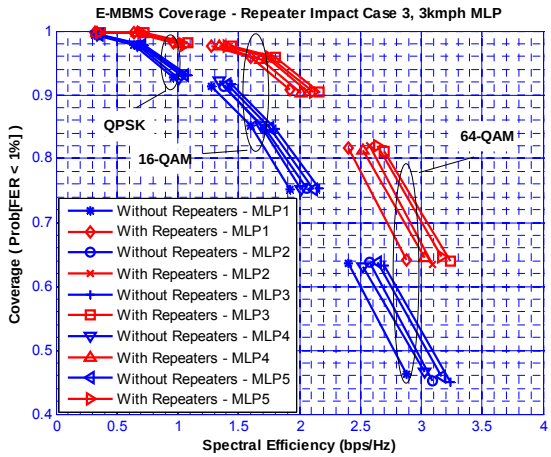

Figure 4 – Performance with Modified L1 Parameters

L1 Parameter Set	Speed (kmph)	Without Repeaters	With Repeaters (33 dBm)	With Repeaters (30dBm)
RLP	3	0.85	1.65	1.46
RLP	120	0.84	1.64	1.46
RLP	350	0.83	1.64	1.44
MLP1	3	0.84	1.64	–
MLP2	3	0.88	1.76	–
MLP3	3	0.92	1.84	–
MLP4	3	0.88	1.7	–
MLP5	3	0.9	1.8	–

Table 1 – Spectral Efficiencies (in bps/Hz) with different L1 parameters sets

3. Conclusions

In this contribution, we presented system simulation results that quantify the achievable spectral efficiency gains of a low-cost optical repeater deployment for both reference and modified L1 parameter sets. For typical cell radii that are being targeted by the LTE study item [1] in RAN1, it was observed that the deployment of repeaters did not significantly alter the "effective" channel delay spread. Therefore, the need for a larger CP length is reduced. The marginal difference in gains between RLP and MLP confirms this observation.

4. Appendix - Simulation Assumptions

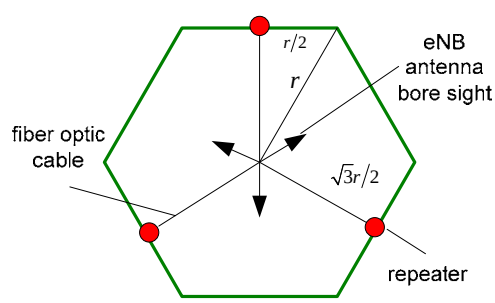

Figure 5 – Repeater placement in a cell site

Parameter	Units	Value
Carrier Frequency	MHz	2000
Inter Site Distance	m	1732 (Case 3 - Refer [1])
Bandwidth	MHz	5 (as against 10 assumed in reference [1])
Penetration Loss (PL)	dB	20
Speed	km/h	3 (Case 3 - Refer [1]). 120 and 350 also were considered
Cell Layout		Hexagonal grid, 37 cell sites, 3 sectors per site
Path Loss	dB	UMTS 30.03 (with deltaH = 15 m) = 128.2 + 37.6log10(d(km))
Lognormal Std Dev.	dB	8
Inter-Site Shadow Corr. Coeff.		0.5
Intra-Site Shadow Corr. Coeff.		1
Channel Model		Typical Urban (TU)
BS transmit power	dBm	43
BS # Antennas		1
BS Ant. Pattern		Refer [1]
BS Ant. Gain	dBi	14
BS Ant. 3dB Beamwidth	degs	70
BS Ant. Front-Back Ratio	dB	20
MS Noise Figure	dBi	9
MS # Antennas		2
MS Ant. Gain	dBi	0
MS Ant. Corr. Coeff.		0
Repeater transmit power	dBm	33
Optical Fibre Refractive Index		1.5
Repeater placement		See Figure 5
Repeater Ant. Gain	dB	9
Repeater Ant. Pattern		Omni
Impairments Modelling		1. Doppler induced inter-carrier interference
		2. Delay spread in excess of CP length
		3. Maximum link SNR was set to 20dB
		(See reference [2] for details)

Table 2 – Simulation Assumptions

5. References

[1] 3GPP TR 25.814, v.7.0.0, “Physical Layer Aspects for Evolved UTRA”, 3GPP TSG RAN, June 2006

[2] R1-061998, “Observations on Alternative L1 Parameters for E-MBMS”, Motorola, 3GPP TSG RAN WG1 #46, Tallinn, Estonia, August 28 – September 1, 2006.