INDUCED BIAS IN ATTENUATION MEASUREMENTS TAKEN FROM COMMERCIAL MICROWAVE LINKS

TEL AVIV UNIVERSITY אוניברסיטת תל אביב

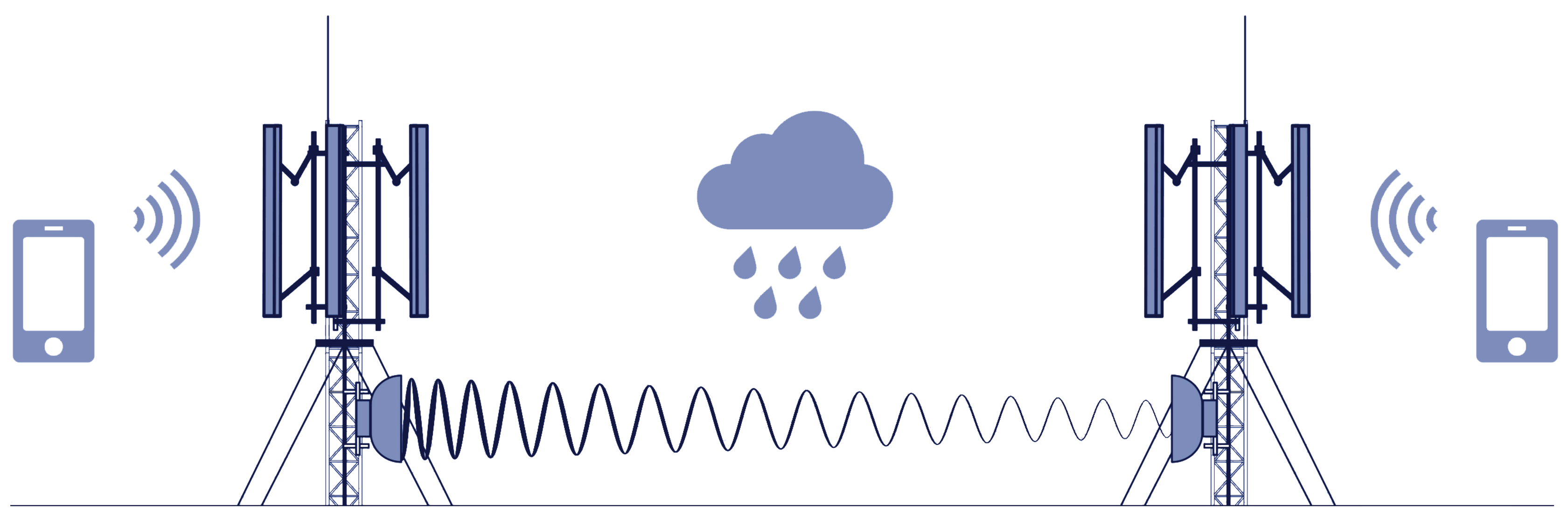
Jonatan Ostrometzky, Adam Eshel, Pinhas Alpert, and Hagit Messer

IEEE Signal Processing Society

MOTIVATION

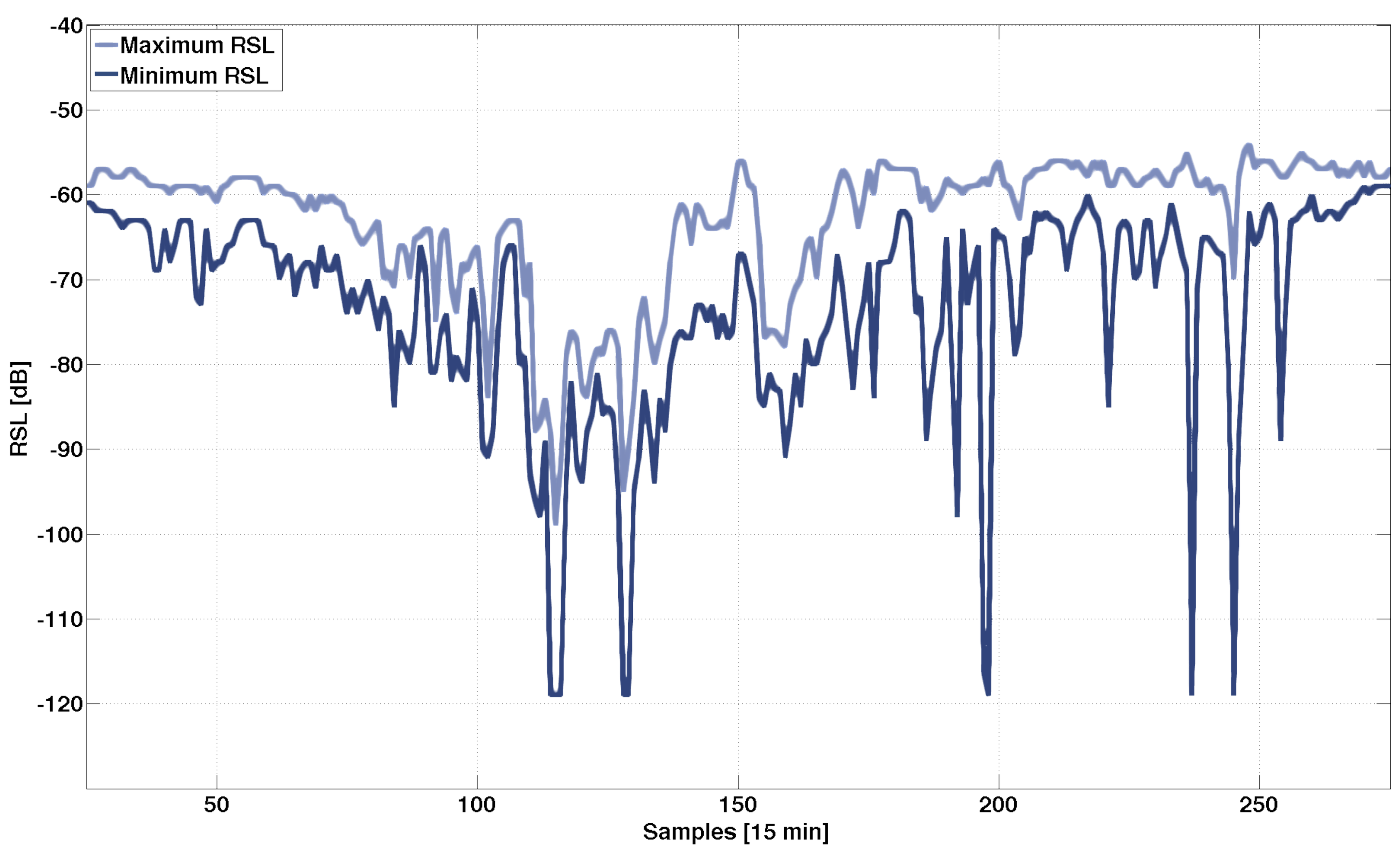
ACTUAL ATTENUATION MEASUREMENTS

Current cellular communication networks are based, at least partly, on Commercial Microwave Links (CMLs). In order to inspect and analyse the performance of these networks, current Network Management Systems (NMS) constantly monitor the CMLs Transmitted Signal Level (TSL) and Received Signal Level (RSL).



Commercial Microwave Link

The NMS log only the minimum and the maximum measured Received and Transmitted Signal Levels, for every 15-minute interval.



The Motivation: The logged extreme Signal Level measurements are quantized, which induces bias.

The Challenge: Inspect the combined effect of a uniform quantizer and the non-linear min\max transformation.

METHODOLOGY

THE QUANTIZER

The nearest-neighbour (or a "round") quantizer is defined by:

$$y = q(x) = L \cdot round\left(\frac{x}{L}\right)$$

where x is the input signal, y is the quantized output, and L is the quantization interval.

COMBINATION OF q(x) WITH THE MIN/MAX OPERATOR

$$q\left(min(x(t_1), x(t_2), \cdots, x(t_n))\right) = q(A) = Q0$$
$$q\left(max(x(t_1), x(t_2), \cdots, x(t_n))\right) = q(B) = Q1$$

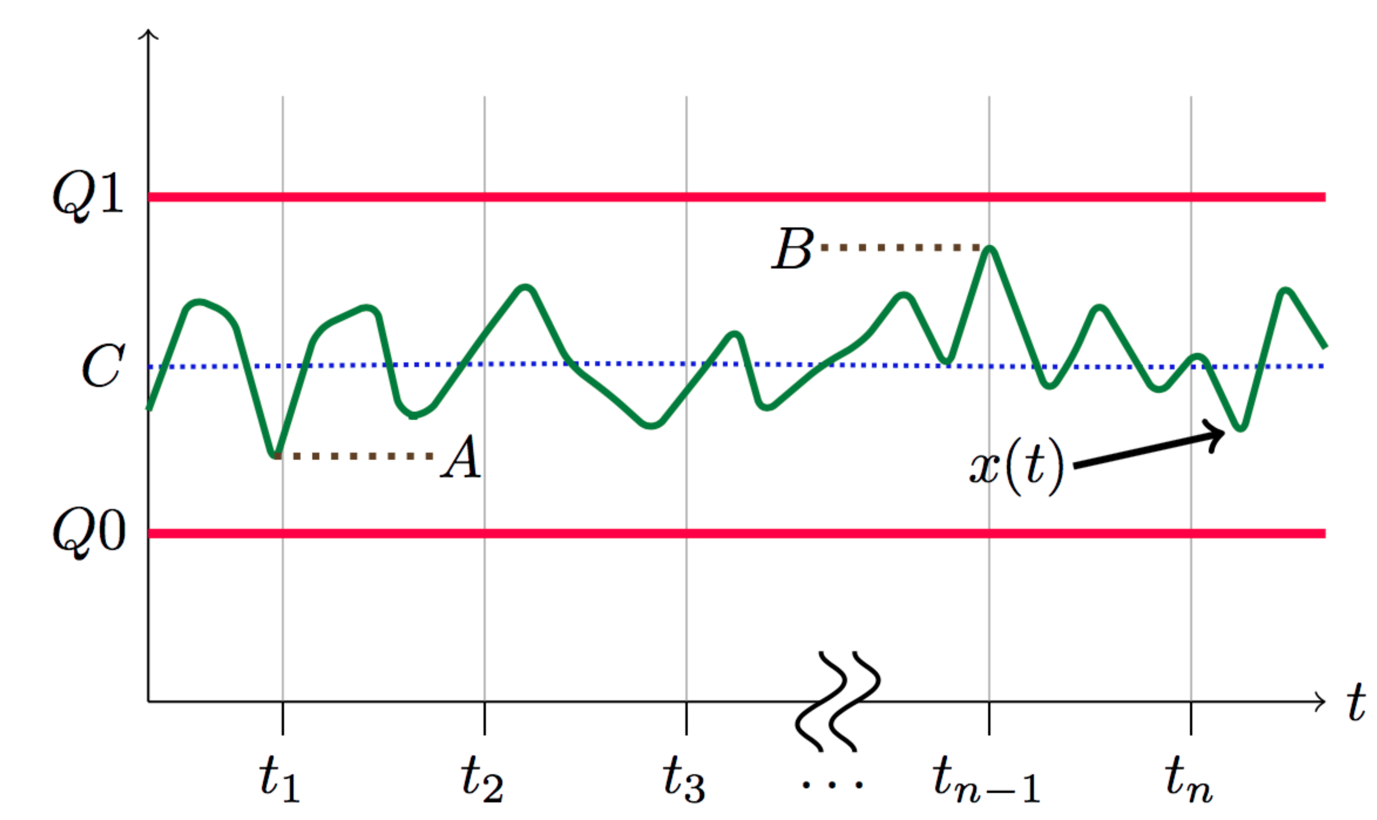


Fig. 1. Illustration of $x(t)$: The two consecutive quantization levels are plotted in RED (marked by $Q0$ and $Q1$), and $x(t)$ is plotted in GREEN for $C = Q0 + 0.5 \cdot L$, which is marked by a dotted BLUE line. A represents $min(x(t_1), x(t_2), \cdots, x(t_n))$, and B represents $max(x(t_1), x(t_2), \cdots, x(t_n))$.

THE BIAS ON THE AVERAGE

$$\boxed{\begin{aligned} &E\left[min\left(q(x(t_1)), \cdots, q(x(t_n))\right) - x(t_i)\right] = \\ &= E\left[min\left(q(x(t_1)), \cdots, q(x(t_n))\right) - x(t_i)\right] - Q0 - C = \\ &= g\left(\frac{1}{2} - \frac{g}{4l} + \frac{C}{2l}\right)^n - C \xrightarrow[n\to\infty]{} -C \end{aligned}}$$

$$\boxed{\begin{aligned} &E\left[max\left(q(x(t_1)), \cdots, q(x(t_n))\right) - x(t_i)\right] = \\ &= E\left[max\left(q(x(t_1)), \cdots, q(x(t_n))\right) - x(t_i)\right] - Q0 - C = \\ &= g - C - g\left(\frac{1}{2} + \frac{g}{4l} - \frac{C}{2l}\right)^n - C \xrightarrow[n\to\infty]{} g - C \end{aligned}}$$

$$min(q(x(t_i))) : \frac{1}{g}\int_0^g (-C)\, dC = -\frac{g}{2} \qquad n >> 1$$
$$max(q(x(t_i))) : \frac{1}{g}\int_0^g (g - C)\, dC = \frac{g}{2} \qquad n >> 1$$

Where g is the quantization gap (i.e., L, or multiplications of L if the additive noise is larger than L), and l is the additive noise bounds.

EXPERIMENTAL RESULTS

EXPERIMENTAL SETUP

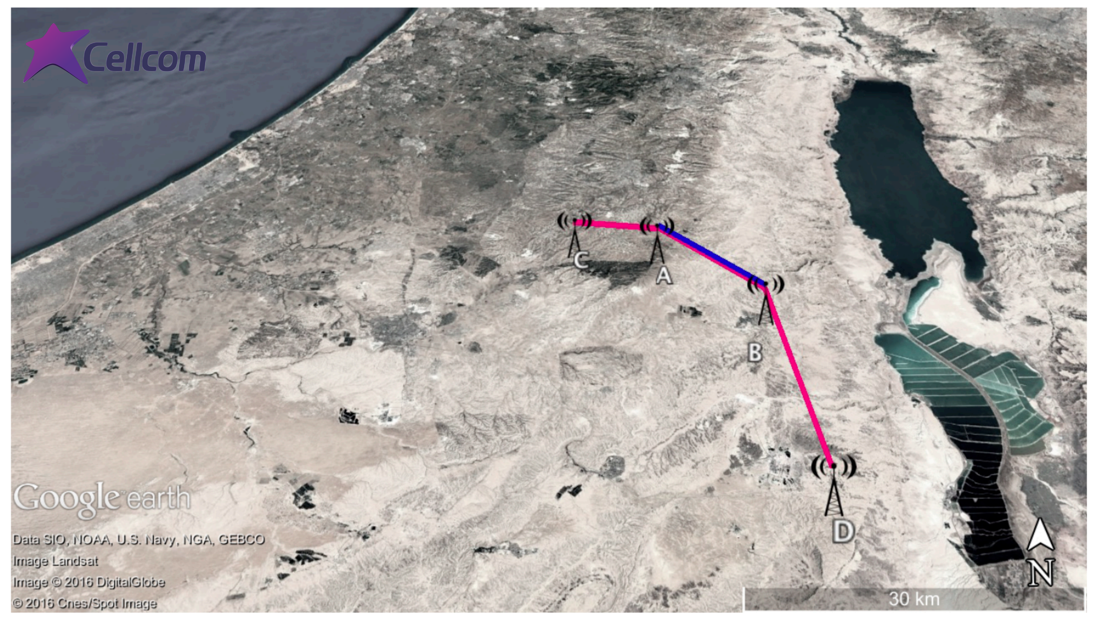


Fig. 2. Map of the experiment location (captured from *Google Earth*), showing the four different CMLs (Colored in RED and BLUE). The sites which hold the CMLs antennas are marked by A,B,C,D, where B is the city of *Arad* near the Dead-Sea.

TABLE I
DETAILED PROPERTIES OF THE FOUR AVAILABLE CMLS: THE SPECIFIC LOCATION (PATH), PATH-LENGTH (LENGTH), FREQUENCY (FREQ.) AND POLARIZATION (POL.) ARE SUMMARIZED.

CML No. #	Path	Length (km)	Freq. (GHz)	Pol.
1	$A \leftrightarrow C$	10.3	18.6	hor
2	$A \leftrightarrow B$	16.0	18.6	hor
3	$A \leftrightarrow B$	16.0	18.73	ver
4	$B \leftrightarrow D$	26.4	18.6	ver

$$\begin{aligned} A_{min} &= TSL_{min} - RSL_{max} = \\ &= (Tx - \frac{g_T}{2}) - (Rx + \frac{g_R}{2}) = \\ &= (Tx - Rx) - (\frac{g_T}{2} + \frac{g_R}{2}) \end{aligned}$$

$$\begin{aligned} A_{max} &= TSL_{max} - RSL_{min} = \\ &= (Tx + \frac{g_T}{2}) - (Rx - \frac{g_R}{2}) = \\ &= (Tx - Rx) + (\frac{g_T}{2} + \frac{g_R}{2}) \end{aligned}$$

$$A_{diff} \equiv A_{max} - A_{min} = g_T + g_R$$

DETECTED INDUCED BIAS

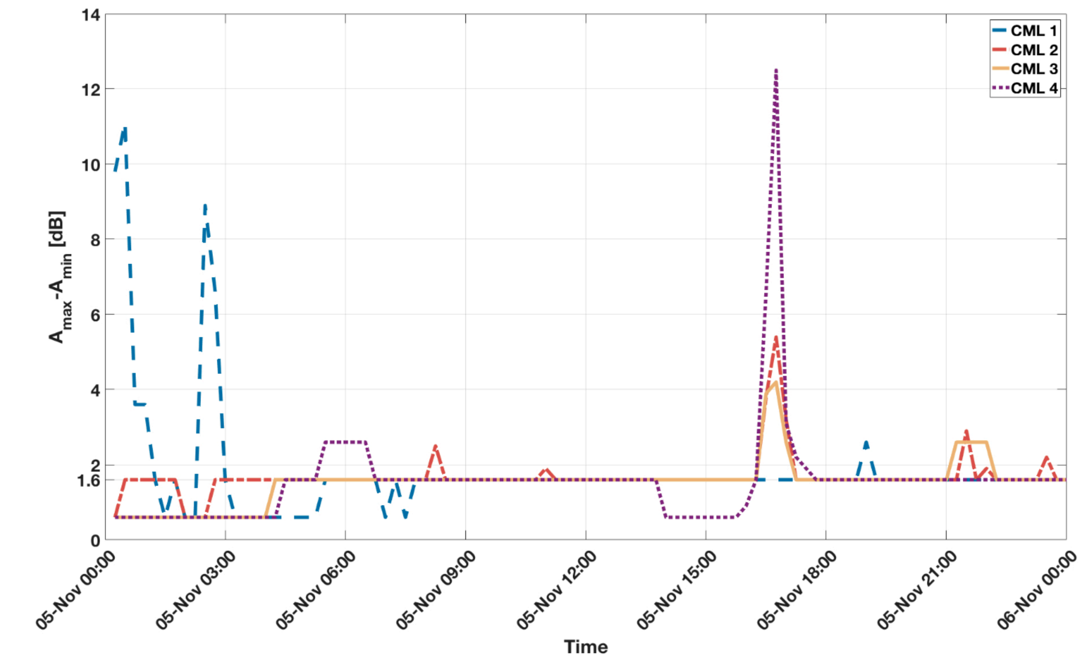


Fig. 3. Calculation of $A_{diff} \equiv A_{max} - A_{min}$ based on the measurements taken from CMLs 1,2,3 and 4, during November 5^{th} 2015.

TABLE II
AVERAGE (MEAN) AND MEDIAN VALUES OF $A_{diff} \equiv A_{max} - A_{min}$ AS MEASURED BY CMLS 1,2,3 AND 4, FROM 05-NOV-2015, 00:00 UNTIL 06-NOV-2015, 00:00.

CML No. #	mean(A_{diff}) (dB)	median(A_{diff}) (dB)
1	1.8187	1.6000
2	1.6729	1.6000
3	1.5365	1.6000
4	1.5750	1.6000

$$g_T = L_T = 1 \quad (dB)$$
$$g_R = 2 \cdot L_R = 0.6 \quad (dB)$$

$$RSL_{min} : -0.3 \quad (dB)$$
$$RSL_{max} : +0.3 \quad (dB)$$
$$TSL_{min} : -0.5 \quad (dB)$$
$$TSL_{max} : +0.5 \quad (dB)$$

CONCLUSION

This paper deals with CMLs measurements which are produced by current NMS. We show that the measurements which are being produced by these systems include an inherited bias. This bias can cause an error in the link budget monitoring procedures, as well as in the estimation of rain, which may not be neglected. We present a theory which explains the origin of this bias, and suggest a methodology which can be used to calculate this induced bias using only the available measurements themselves.

We demonstrate our approach using four CMLs, and show that a bias is indeed induced into the measurements produced by these CMLs, and that our suggested methodology is capable of determining its value