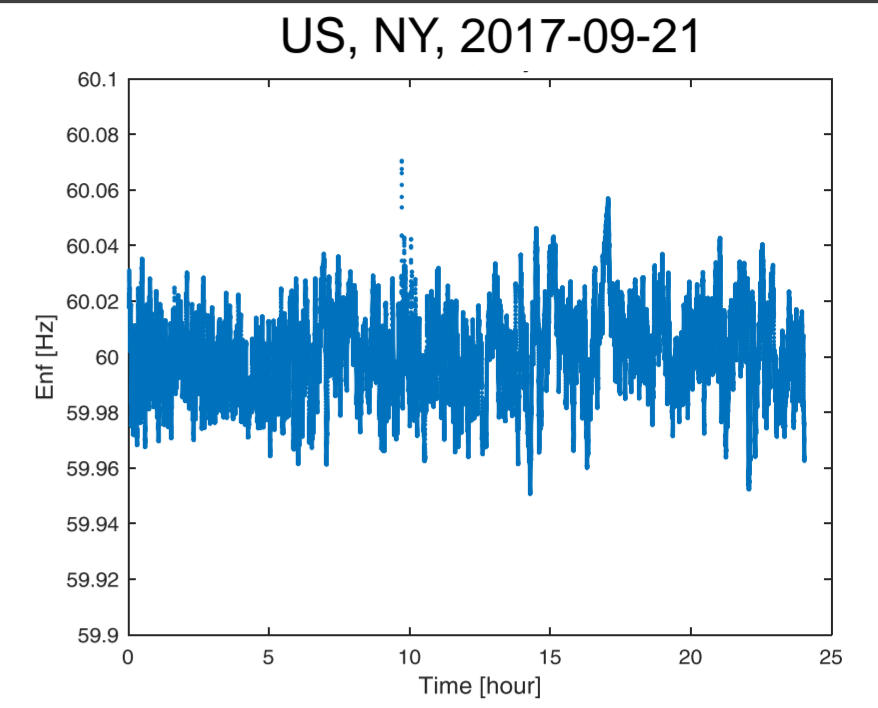
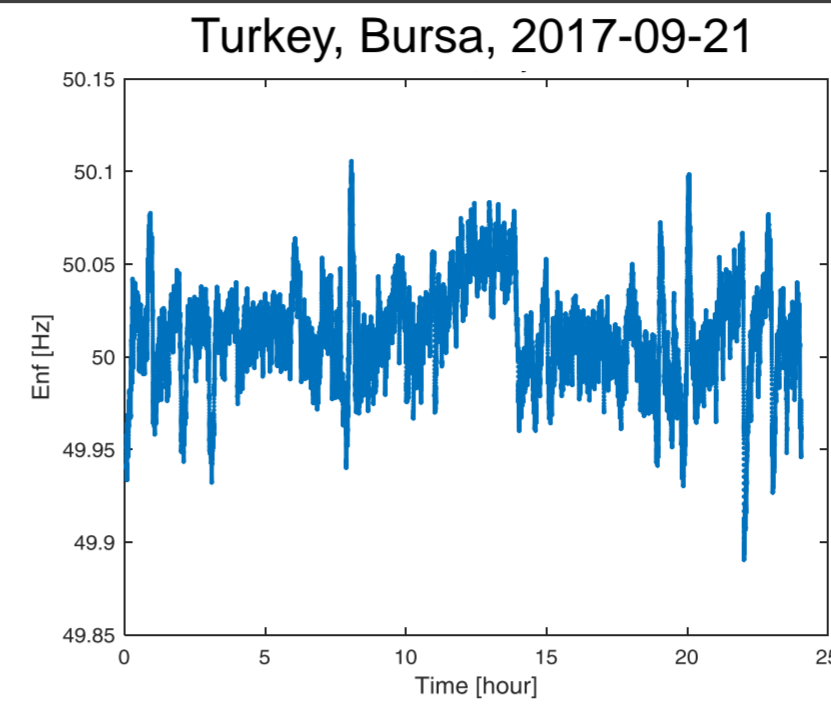
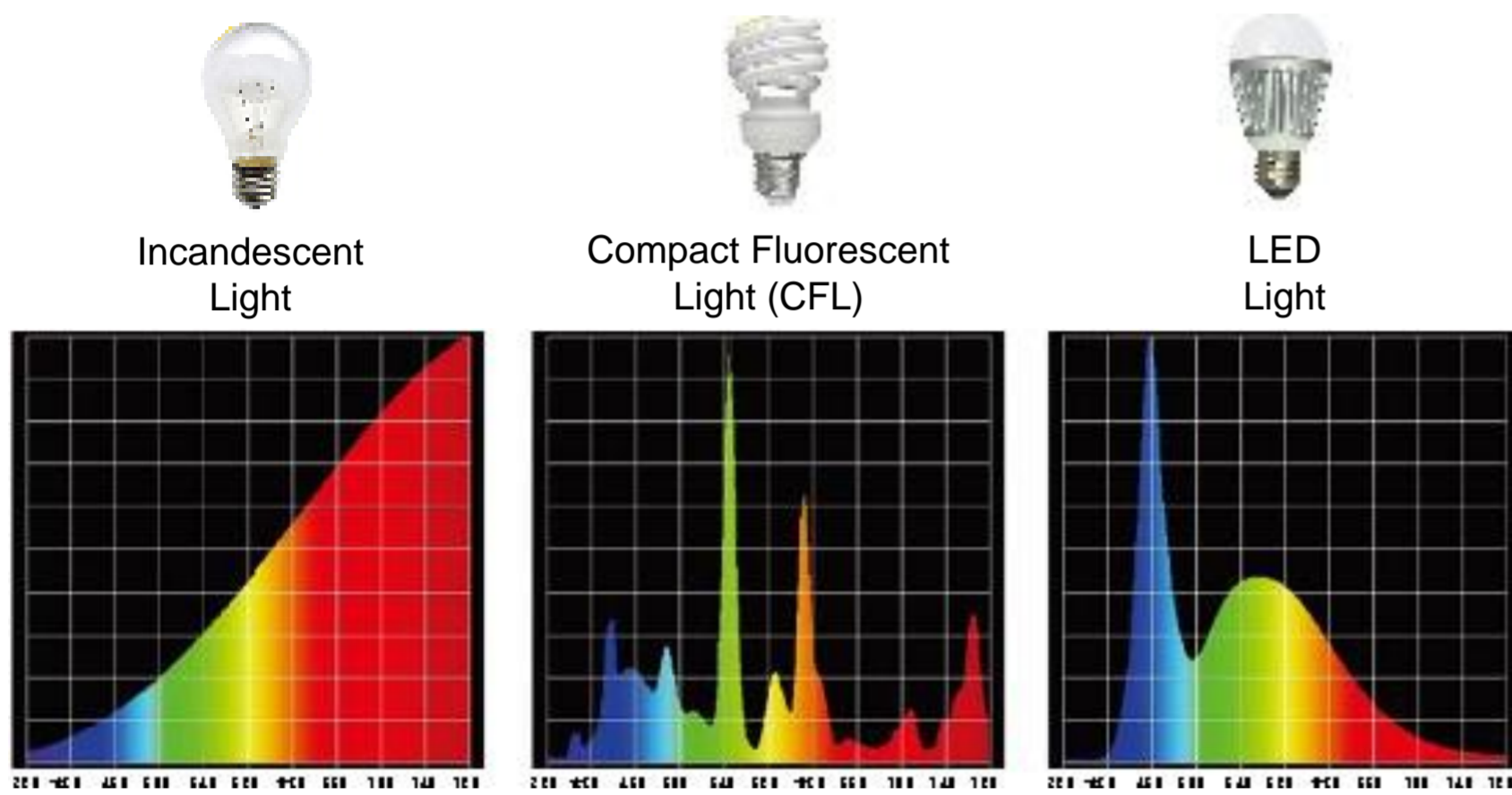


An Overview on ENF (Electric Network Frequency)

- ENF instantaneously fluctuates around its nominal value
- Luminous intensity of a mains-powered light source varies depending on ENF fluctuations
- Variations in the luminance over time can be captured from video recordings
- ENF can be estimated through content analysis of these recordings



Impact of Illumination Source On ENF



Spectra of various Light Sources

- Different type of light sources have different spectral responses.
- Different type of light sources affect the quality of the estimated ENF signal differently.

Evaluation Metrics

- Normalized cross correlation (NCC) is used as primary metric.
- Each estimated video ENF signal is first searched on both true reference ENF database and false reference ENF database.
- **H0**: Lag point of the maximum correlation coefficient between the estimated video ENF and the reference ENF (ground-truth) does not match with the video recording time.
- **H1**: Lag point of the maximum correlation coefficient between the estimated video ENF and the reference ENF (ground-truth) matches with the video recording time.
- ROC (Receiver Operating Characteristic) curves and AUC (Area Under the Curve) are computed.

Different light types used in the recording scene

Source No	Type	Luminous Flux	Color Temperature
S1	Halogen	834 (lm)	2800 (K)
S2	CFL	870 (lm)	6500 (K)
S3	CFL	840 (lm)	2700 (K)
S4	LED	810 (lm)	6500 (K)
S5	LED	810 (lm)	2700 (K)

Time-of-recording detection: AUC values for different light sources

L. Clip (in min.)	S1	S2	S3	S4	S5
1	0.79	NA	0.32	0.45	0.65
2	0.74	0.48	0.79	0.94	0.91
5	1.00	0.85	0.87	1.00	0.99
10	1.00	1.00	1.00	1.00	1.00

The rates of correct time-of-recording estimations (%) for different light sources

L. Clip (in min.)	S1	S2	S3	S4	S5
1	2.25	0.00	0.50	26.37	20.00
2	100	51.75	47.25	100	97.75
5	100	100	100	100	100
10	100	100	100	100	100

- Different light sources contribute to the quality of the estimated ENF signal differently.
- ENF is best estimated for videos recorded under LED illumination
- The quality of the ENF signal significantly drops under CFL illumination.

The Effect of Compression on ENF

Time-of-recording detection: AUC values for different compression rates for LED

Bit Rate (Kbps)	Av. Size (MB)	2 min.	5 min.	10 min.
Original	938	0.94	1.00	1.00
5000	415	0.94	1.00	1.00
1000	94	0.93	1.00	1.00
500	53	0.91	1.00	1.00
100	20	0.84	0.62	0.77
Facebook	13	0.57	0.72	0.68

The rates of correct time-of-recording estimations (%) for different compression rates for LED

Bit Rate (Kbps)	Av. Size (MB)	2 min.	5 min.	10 min.
Original	938	100	100	100
5000	415	100	100	100
1000	94	100	100	100
500	53	100	100	100
100	20	19.75	87.50	100
Facebook	13	12.25	56.88	100

Time-of-recording detection: AUC values for different compression rates for CFL

Bit Rate (Kbps)	Av. Size (MB)	2 min.	5 min.	10 min.
Original	973	0.48	0.85	1.00
5000	430	0.55	0.89	1.00
1000	98	0.66	0.89	1.00
500	55	0.11	0.66	1.00
100	20	failed	failed	0.98
Facebook	14	failed	failed	failed

The rates of correct time-of-recording estimations (%) for different compression rates for CFL

Bit Rate (Kbps)	Av. Size (MB)	2 min.	5 min.	10 min.
Original	938	100	100	100
5000	415	100	100	100
1000	94	100	100	100
500	53	100	100	100
100	20	19.75	87.50	100
Facebook	13	12.25	56.88	100

- The performance for the compressed video vary depending on the type of light source.
- The performance is quite robust for 500 Kbps compression rates
- The best verification results are observed under the white LED illumination.
- CFL yields the worst results.
- For two minutes Facebook videos, ENF based video time-of-recording verification fails for both CFL (0%) and LED cases (12%).

The Effect of Ground-truth ENF of Different Lengths

Time-of-recording detection: AUC values for different lengths of ground-truth ENF data for LED

L. Database	2 min.	5 min.	10 min.
One-day	0.94	1.00	1.00
One-week	0.91	1.00	1.00
One-month	0.82	1.00	1.00

The rate of correct time-of-recording estimations (%) for different lengths of ground-truth ENF data for LED

L. Database	2 min.	5 min.	10 min.
One-day	100	100	100
One-week	100	100	100
One-month	100	100	100

Time-of-recording detection: AUC values for different lengths of ground-truth ENF data for CFL

L. Database	2 min.	5 min.	10 min.
One-day	0.48	0.85	1.00
One-week	0.45	0.80	1.00
One-month	0.38	0.75	1.00

The rate of correct time-of-recording estimations (%) for different lengths of ground-truth ENF data for CFL

L. Database	2 min.	5 min.	10 min.
One-day	51.75	100	100
One-week	27.50	100	100
One-month	11.00	98.13	100

- ENF show similar variations in time.
- The performance is unstable especially for short videos.
- When searched in longer database, the performance varies depending on:
 - the video length
 - light source

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