Far-Field Measurements and Characterization of the Cyclostationary Unintentional Stochastic Radiations from the Digital Electronic Device

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Outline

• Spatial localization of the pass between the source and the load on the PCB surface

• Characterization of the cyclostationary properties of the PCB pseudorandom emissions

• Characterization of the far-field pattern for the unintentional stochastic emissions of the PCB

• Parametric identification of the ultra wideband near-field probes in time and frequency domains
Measurement setup

➢ Time-domain measurement system

- Digital oscilloscope
- Amplifiers
- Scanning probe
- Scanning plane
- Reference probe
- Device under test (DUT)
Device under test

- Atlys Spartan-6 Training Board
Device under test

Test signal: pseudo random bit sequence (PRBS)
Measurement setup

- Langer EMV-Technik RF-R 50-1 magnetic field probes
- Frequency band from 30 MHz up to 3 GHz
Data analysis

- Pseudo random bit sequence (PRBS)

\[ s_T(t) = \sum_{n=0}^{N-1} a_n s_0(t - n\Delta) = s_T(t - lT), \forall l = 0, \pm 1, \pm 2, \ldots, \]

\[ \Delta = 3\text{ns}; \quad T = N\cdot\Delta; \quad N = 8192 \]
Data analysis

Autocorrelation function of the PRBS

\[ R_{ST}(\tau) = \frac{1}{N\Delta} \int_{0}^{N\Delta} s_T(t)s_T(t - \tau) \, dt \]
Data analysis

Averaged signal in the reference probe

\[ \mu_X[m][k] = \frac{L}{K} \sum_{j=0}^{(K/L)-1} X[m][k - jL] \]

- \( L = N \cdot \Delta \cdot F \)
- \( K = 30L \)
- \( F = 10 \text{ GSa/s} \) – sampling frequency
Data analysis

Autocorrelation function of the reference probe’s signal

\[ r_{X_m}[k] = \frac{1}{L} \sum_{l=0}^{L} \mu_{X_m}[l] \mu_{X_m}[l - k] \]
Data analysis

- Autocorrelation function of the reference probe’s signal
Cyclostationary analysis

➢ Periodic autocorrelation function

\[ \rho_X[i, v] = \frac{L}{K} \sum_{j=0}^{(K/L) - 1} x[i + \frac{v}{2} - jL] x[i - \frac{v}{2} - jL] \]

\( i/F \) – global time
\( v/F \) – relative time
Cyclostationary analysis

- Cyclic autocorrelation function

\[
R_x^L[v] = \frac{1}{L} \sum_{i=-(L-1)/2}^{(L-1)/2} \rho_x[i, v] e^{-j\frac{2\pi i v}{L}} \quad \text{for } l \cdot F/L \text{ – cyclic frequency}
\]
Cyclostationary analysis

Cyclic spectrum

\[ S_X^l[m] = \frac{1}{L} \sum_{v=-(L-1)/2}^{(L-1)/2} R_X^l[v] e^{-j\frac{2\pi vm}{N}} \]

\( m \cdot F / L \) – cyclic frequency
Data analysis

Cross-correlation function of the reference probe’s signal and PRBS

\[ \rho_{SX_m}[n] = E\{S[k]X_m[k-n]\} = \frac{L}{K} \sum_{j=0}^{(K/L)-1} \sum_{k=0}^{L-1} S[k]X_m[k-n-jL] \]
Experimental results

- Measurement grid

- 20 x 23 points
- 5 mm step
- $H_X$ and $H_Y$ polarization
- $M = 20 \cdot 23 = 460$
- $m = 1 \ldots M$
Experimental results

- Time evolution of the cross correlation function

- 8192 bit sequence
Experimental results

➤ Time evolution of the cross correlation function

✔ 1024 bit sequence
Experimental results

➤ Measurement along the strip line
Experimental results

✓ Measurement points along the strip line
Experimental results

Delay of the cross correlation function

\[ \rho_{X_{ref}X_m}[n] = E\{X_{ref}[k]X_m[k - n]\} \]
Experimental results

- Dependence on the distance between DUT and near-field probe
Experimental results

- **Vertical polarization**
- **Horizontal polarization**

- distance 1...15 mm
- step size 1 mm
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• **Characterization of the far-field pattern for the unintentional stochastic emissions of the PCB**

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Anechoic chamber

- Antenna R&S HL 562E
- 30 MHz … 6 GHz
- Amplifier 30 dB
Data analysis

- Measured signal
Data analysis

- Cross-correlation function of the antenna’s signal and PRBS
Anechoic chamber

- Vertical polarization
- Horizontal polarization

✓ distance 1 m
Experimental results

- Vertical polarization
- Horizontal polarization

✓ distance 1 m
Anechoic chamber

- Vertical polarization
- Horizontal polarization

✓ distance 3 m
Experimental results

- Vertical polarization
- Horizontal polarization

✓ distance 3 m
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Measurement setup

- Frequency-domain measurement system

![Diagram of measurement setup]

- Vector network analyzer
- Amplifier
- Near-field probe
- Matched load
- Strip line
Probe identification

- S-parameters of Langer RF-R 50-1 probe
Probe identification

Impulse response of the near-field probe

- RF-R 50-1
- 10 mm
Probe identification

- Step response of the near-field probe

- RF-R 50-1
- Ø 10 mm
Measurement setup

- Time-domain measurement system

- Synchronization

- Digital oscilloscope

- Amplifier

- Near-field probe

- Matched load

- Strip line

- Pulse generator
Probe identification

✓ Langer RF-R 50-1
✓ Ø 10 mm

✓ Langer RF-R 3-2
✓ Ø 3 mm
Probe identification

➢ Step responses of the near-field probes

✓ RF-R 50-1
✓ Ø 10 mm

✓ RF-R 3-2
✓ Ø 3 mm
Probe identification

- Frequency characteristic of the near-field probes
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