TSG-RAN WG1 #85 R1-165346
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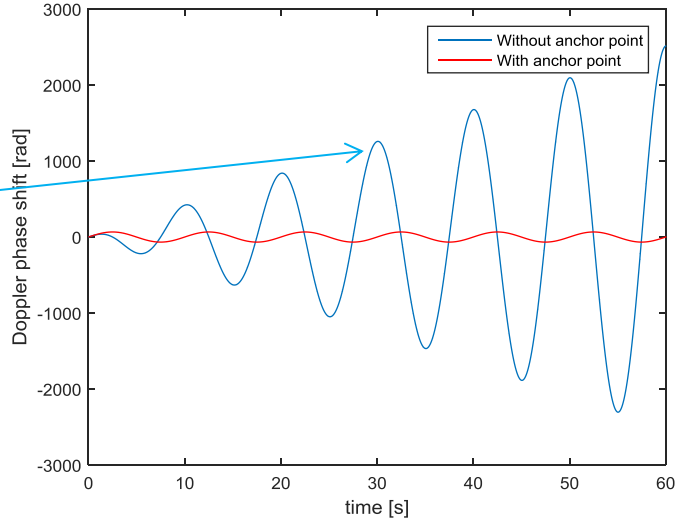
Agenda Item: 7.2.2
Document for: Discussion, Decision

WF on modifying channel coefficient equation for time-varying Doppler frequencies

Background

- Introduction of spatial consistency modeling will result in time-varying angles of departure and arrival leading to time-varying Doppler frequencies
- Non-linear UE motion will also lead to time-varying Doppler frequencies
- In R1-163246 it was observed that the equation in 36.873 for generating channel coefficients is ill-suited to handle time-varying Doppler frequencies
  - Doppler shifts become unbounded as simulation time increases

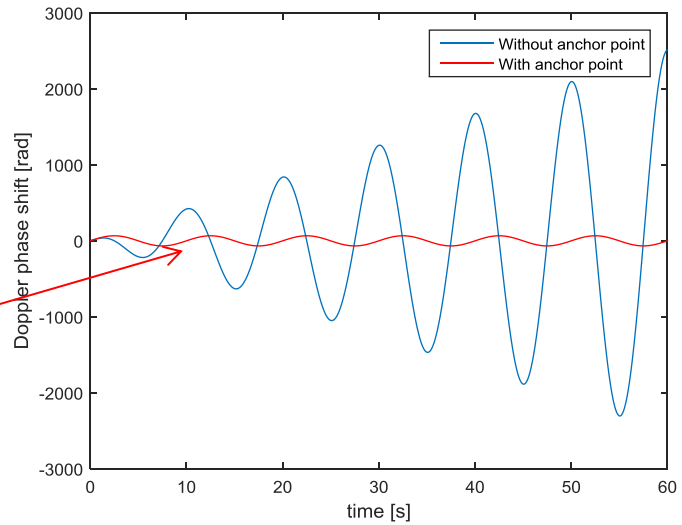
$$H_{u,s,n}(t) = \sqrt{P_n/M} \sum_{m=1}^{M} \begin{bmatrix} F_{rx,u,\theta}(\theta_{n,m,ZOA}, \phi_{n,m,AOA}) \\ F_{rx,u,\phi}(\theta_{n,m,ZOA}, \phi_{n,m,AOA}) \end{bmatrix}^T \begin{bmatrix} \exp(j\Phi_{n,m}^{\theta\theta}) & \sqrt{\kappa_{n,m}^{-1}} \exp(j\Phi_{n,m}^{\theta\phi}) \\ \sqrt{\kappa_{n,m}^{-1}} \exp(j\Phi_{n,m}^{\phi\theta}) & \exp(j\Phi_{n,m}^{\phi\phi}) \end{bmatrix} \begin{bmatrix} F_{tx,s,\theta}(\theta_{n,m,ZOD}, \phi_{n,m,AOD}) \\ F_{tx,s,\phi}(\theta_{n,m,ZOD}, \phi_{n,m,AOD}) \end{bmatrix} \exp\left(j2\pi\lambda_0^{-1}\left(\hat{r}_{rx,n,m}^T \cdot \bar{d}_{rx,u}\right)\right) \exp\left(j2\pi\lambda_0^{-1}\left(\hat{r}_{tx,n,m}^T \cdot \bar{d}_{tx,s}\right)\right) \exp(j2\pi v_{n,m} t) \quad (7.21)$$



Background

- A solution was proposed in R1-163246 where the channel coefficient equation is updated
  - The factor $exp\left(j2\pi\upsilon_{n,m}(t)\cdot t\right)$ in equation (7.21) is changed into $exp\left(j2\pi\upsilon_{n,m}(t)\cdot(t-t_i)\right)exp\left(j2\pi\upsilon_{n,m}(t_i)\cdot t_i\right)$ where the phase shift at time t_i is established as an anchor point and an incremental phase shift is applied.
  - The anchor point should be updated sufficiently often so that $\left|\upsilon_{n,m}(t_{i+1})-\upsilon_{n,m}(t_i)\right| \ll 1$
  - If the Doppler frequency is time-independent the original equation is obtained

$$exp\left(j2\pi\upsilon_{n,m}(t)\cdot(t-t_i)\right)exp\left(j2\pi\upsilon_{n,m}(t_i)\cdot t_i\right)$$



Proposal

- Proposal 1: Replace the factor $exp\left(j2\pi\upsilon_{n,m} \cdot t\right)$ with $exp\left(j2\pi\upsilon_{n,m}(t) \cdot (t - t_i)\right) exp\left(j2\pi\upsilon_{n,m}(t_i) \cdot t_i\right)$ in the channel coefficient equation
  - The phase shift at time t_i is established as an anchor point and an incremental phase shift is applied
  - The anchor point should be updated sufficiently often so that $\left|\upsilon_{n,m}(t_{i+1}) - \upsilon_{n,m}(t_i)\right| \ll 1$
- Proposal 2: Proposal 1 needs only to be considered in case the Doppler frequencies are time-varying. This could be due to:
  - Non-linear UE movement
  - Time-varying angles of arrival due to spatial consistency modeling

Appendix

- **Derivation:**
- The original formula (7.21) has a Doppler factor $exp\left(j2\pi v_{n,m} \cdot t\right)$ that only supports linear time dependence. We would like to generalize this.
- Step 1:
  To accommodate non-linear UE movement and/or time-varying angles of arrival due to spatial consistency modeling, we generalize the Doppler factor to non-linear time-variations $exp\left(j2\pi\varphi_{n,m}(t)\right)$. Where $\varphi_{n,m}(t)$ is to be determined, and depends on the UE-position over time, and the spatial variations of propagations angles. Typically it is straight forward to determine/approximate the derivative of $\varphi_{n,m}(t)$ with respect to time, herein denoted $v_{n,m}(t)$. In order to determine $\varphi_{n,m}(t)$ we then need to integrate over time.
- Step 2:
  Introduce a piecewise linear approximation of the phase function $\varphi_{n,m}(t)$:
  $$\varphi_{n,m}(t) \approx \hat{\varphi}_{n,m}\ (t_i) + v_{n,m}(t_i)(t - t_i)$$
- Step 3:
  Assuming continuity between line segments
  $$\hat{\varphi}_{n,m}(t_i) = \hat{\varphi}_{n,m}(t_{i-1}) + v_{n,m}(t_{i-1})(t_i - t_{i-1})$$

- **Algorithm:**
- Split the time in discrete sets of time, e.g. one time step per TTI. Maintain a state with the current phase $\hat{\varphi}_{n,m}\ (t_i)$ for the most recent anchor point in time t_i. Update the phase as time progress beyond an anchor point:
  $$\hat{\varphi}_{n,m}(t_{i+1}) = \hat{\varphi}_{n,m}(t_i) + v_{n,m}(t_i)(t_{i+1} - t_i)$$
- In between anchor points t_{i+1} and t_i use the linear approximation of the Doppler factor:
  $$\varphi_{n,m}(t) \approx \hat{\varphi}_{n,m}\ (t_i) + v_{n,m}(t_i)(t - t_i)$$
- At time zero we may start with a random initial phase, the absolute phase is not the main concern. Phase continuity in time is what is important here.