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FULL-DUPLEX MULTIFUNCTION TRANSCEIVER WITH JOINT CONSTANT ENVELOPE TRANSMISSION AND WIDEBAND RECEPTION

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Introduction

- FD capable system for simultaneous jamming, radar, data transmission and spectral monitoring.

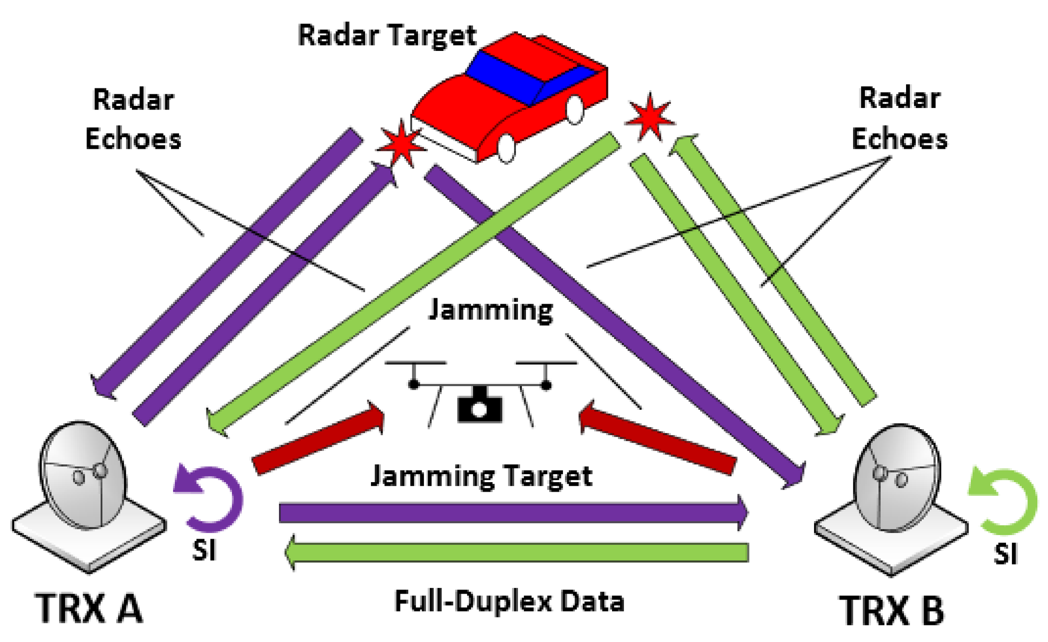
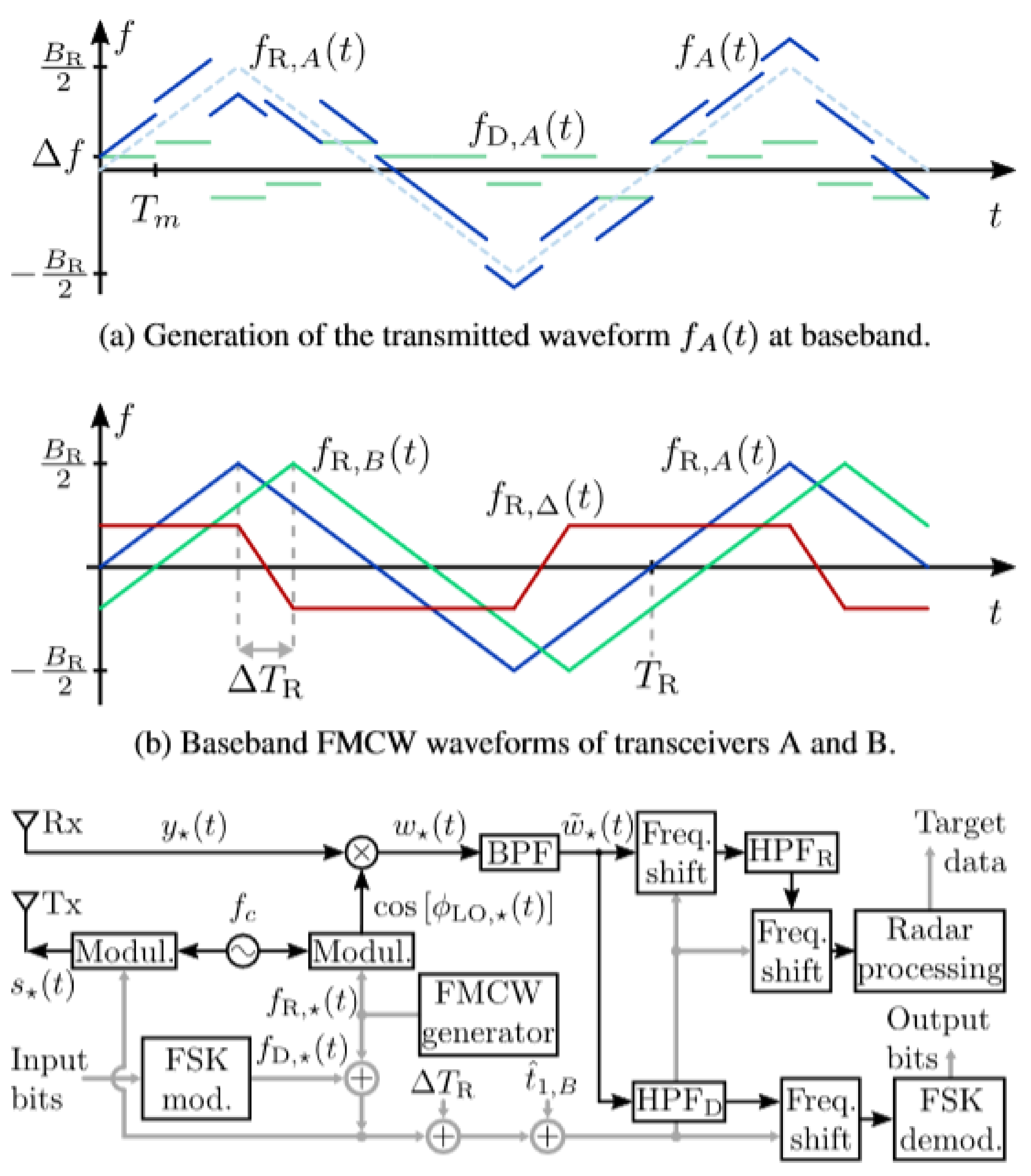


Fig. 1. A concept picture of the novel multifunction system.



(a) Generation of the transmitted waveform $f_A(t)$ at baseband.

(b) Baseband FMCW waveforms of transceivers A and B.

(c) Block diagram of a transceiver ('$\star$' refers either to A or B).

System model

- FMCW triangular sweep radar waveform combined with FSK modulated data (1)-(4).

$$f_{\mathrm{R},\star}(t) = \begin{cases} -\frac{B_\mathrm{R}}{2} + \frac{\rho\, t}{m}, & (m-1) < \frac{t-\delta_\star}{T_\mathrm{R}} \leq \frac{2m-1}{2} \\ +\frac{B_\mathrm{R}}{2} - \frac{\rho\, t}{m}, & \frac{2m-1}{2} < \frac{t-\delta_\star}{T_\mathrm{R}} \leq m, \end{cases} \quad (1)$$

$$f_{\mathrm{D},\star}(t) = \frac{\Delta f}{2}\alpha(t),\ \alpha(t) \in \{\pm1, \pm3, \ldots, \pm(2M-1)\} \quad (2)$$

$$\phi_\star(t) = 2\pi \left[f_\mathrm{c} t + \int_0^t (f_{\mathrm{D},\star}(\tau) + f_{\mathrm{R},\star}(\tau))\, \mathrm{d}\tau \right] \quad (3)$$

$$f_\star(t) = \frac{1}{2\pi}\phi'_\star(t) \quad (4)$$

- At reception, received signal is downconverted with the FMCW signal, with frequencies $f_\mathrm{R}(t)$.
  - ➢ Sweeping signals have fixed carrier frequencies equal to the time difference $t_{\bigstar,k}$ of the echo k from TRX ★.
  - ➢ Due to triangular FMCW waveform, the carrier frequency shifts rapidly between positive and negative carrier during ΔT_R.
  - ➢ Previously fixed signals are now sweeping the band according to the FMCW signal.
- All of the TRXs need to have the same FMCW bandwidth B_R and sweep rate ρ.
- The fixed delays $\delta_\bigstar$ are used to offset the sweeping signals to reduce overlap.
  - $\Delta T_\mathrm{R} = \delta_\mathrm{B} - \delta_\mathrm{A}$.

Fig. 2. (a) Example waveforms of the FMCW, FSK and the combined signal. (b) Example waveform of the FMCW signal from TRX B after downconversion at TRX A. (c) Transceiver structure and signal processing.

Multifunction receive processing

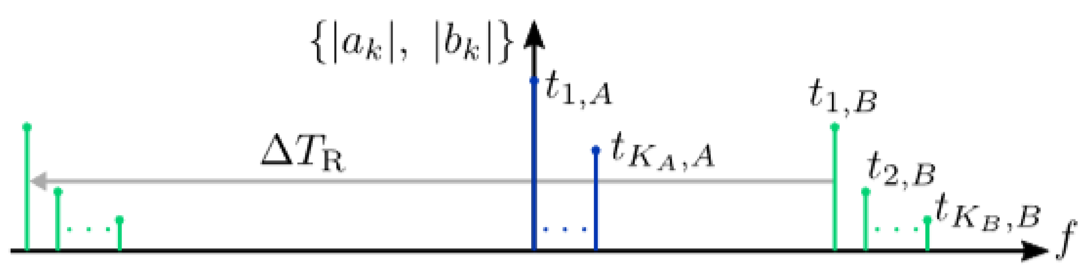


Fig. 3. One-sided spectrum of the downconverted signal, where the shift to the negative frequencies during ΔT_R is shown.

- After downconversion, radar information is in the center frequency of the echoes, data is in the frequency shifts caused by the FSK.
  - ➢ **Sweep compensation and highpass filters can be used to remove interference.**
- For data reception, SI and echoes removed with a HPF with a cutoff frequency of

$$f_{\mathrm{HPF_D}} = \frac{\Delta f}{2}(2M-1) + \rho\, t_{K,A} \quad (5)$$

- Sweeping of both TRX compensated with multiplication operations:

$$\begin{aligned} f_{B,A}(t) &= f_B(t - t_{1,B}) - f_{\mathrm{LO},A}(t) \\ &= f_{\mathrm{D},B}(t - t_{1,B}) + f_{\mathrm{R},B}(t - t_{1,B}) - f_{\mathrm{R},A}(t) \end{aligned} \quad (6)$$

$$\begin{aligned} \tilde{f}_B(t) &= f_{B,\mathrm{A}}(t) + (f_{\mathrm{R,A}}(t) - f_{\mathrm{R,B}}(t - \hat{t}_{1,B})) \\ &= f_{\mathrm{D},B}(t - t_{1,B}) \end{aligned} \quad (7)$$

- The FSK data from TRX B can be demodulated through normal means (7).
- Similar compensation and filtering can be done to remove the TRX B signal before radar calculations.

Simulation results

- Two FSK-FMCW tranceivers, A and B.
- Following parameters were used in the simulations:
  - FSK-FMCW parameters
    - M = 1 and 3 (BPS), $\Delta f = 200$ kHz, symbol duration 0.1 ms.
    - $B_\mathrm{R} = 80$ MHz, $\rho = 33\ \mu s$ (4.8 MHz/μs).
    - $\Delta T_\mathrm{R} = 4.2\ \mu s$ (20 MHz) difference between TRX A and B.
  - Single radar target
    - Doppler velocity = 100 m/s.
    - RCS = 200 m^2
    - Distances 20, 60 and 100 m.

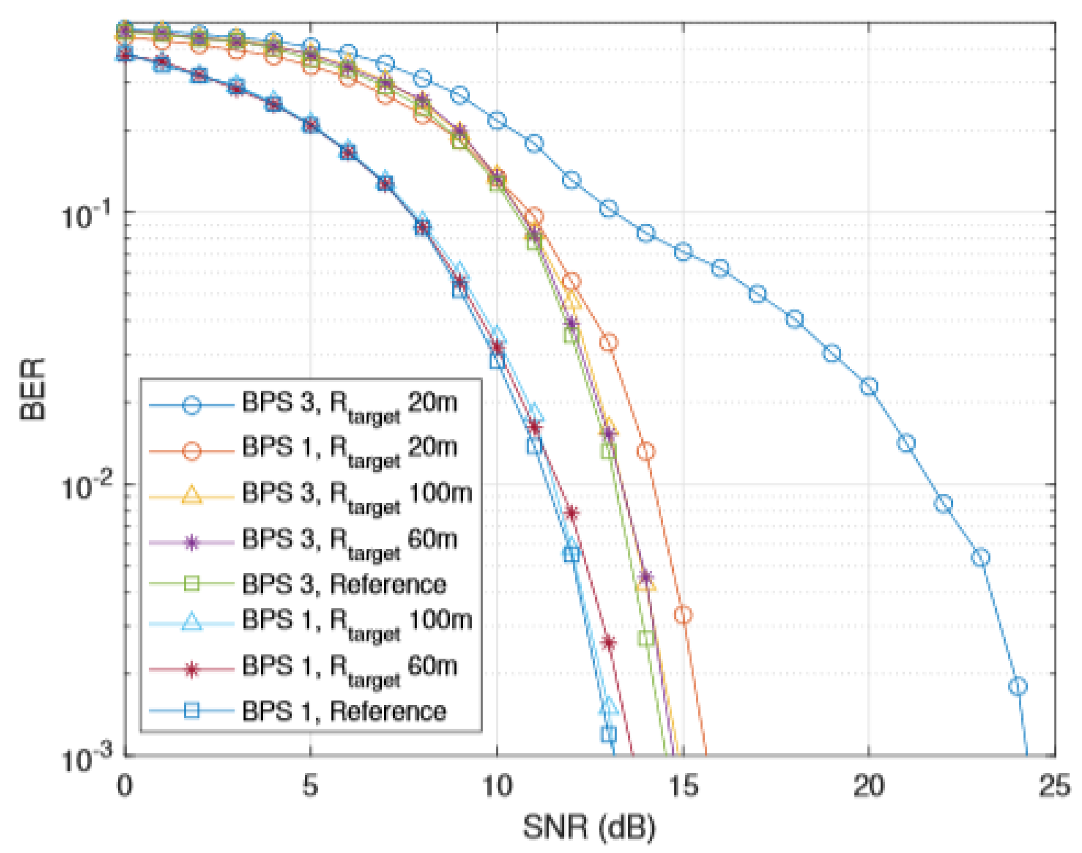


Fig. 4. Simulated FSK demodulation performance. The reference case is half-duplex operation without FMCW sweeping.

- The FSK demodulation works as well as the reference case when the radar target is at least 60 m away.
- Radar performance was found to be as good as the reference case when TRX B signal's SNR was under several tens of decibels.

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