

Multi-Band Wireless Sensing Fusion and Communication through Hybrid Multiplexing

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Abstract— In order to improve operational flexibility while merging distinct radar and communication features for creating a joint multifunction system, this work proposes a unique hybrid multiplexing approach and architecture for next-generation wireless systems. This approach allows for flexible resource use by dynamically allocating radar or communication functions among three scattered frequency bands (B_1 , B_2 , B_3) over discrete time periods (T_1 , T_2 , T_3). The instantaneous aggregated radar bandwidths can then be stitched together to enhance the radar resolution. The suggested scheme and proposed architecture are believed to be a viable strategy for next-generation wireless systems as simulation results show how well it supports multi-modal functionality while optimizing spectral efficiency and operational dependability and adaptability.

I. INTRODUCTION

Integrated radar sensing and wireless communication (ISAC or RadCom) including near-field schemes has drawn significant interest because of its potential for use in next-generation mobile networks, autonomous cars, and intelligent transportation systems [1-4]. For these systems to offer multifunctionality while guaranteeing low interference and optimum spectral efficiency, effective allocation of operational resource is necessary.

In addition to code-division technique, frequency-division and time-division multiplexing are two traditional multiplexing techniques that frequently lack the adaptability needed to dynamically adjust themselves to changing operating requirements [5]. To overcome this constraint, this work proposes a hybrid multiplexing scheme that enables a dynamic assignment of communication and radar functions across several frequency bands and time slots.

To enhance the radar resolution during simultaneous radar chirps, and independently of specific bandwidths and center frequencies, the proposed structure leverages the multiband chirp stitching methodology of [6] to linearly aggregate each transmitted radar bandwidth, thus magnifying the resolution.

This method offers more flexibility and efficient use of resources and is especially useful in situations where the need for either radar sensing or data communication changes across time and frequency. In the following sections, the multiplexing technique is described, and the simulation results confirm the relevance of such multiplexing scheme.

II. MULTIPLEXING SCHEME AND ARCHITECTURE

The suggested plan is to separate time into distinct slots over three different frequency bands. As described in Fig. 1, each

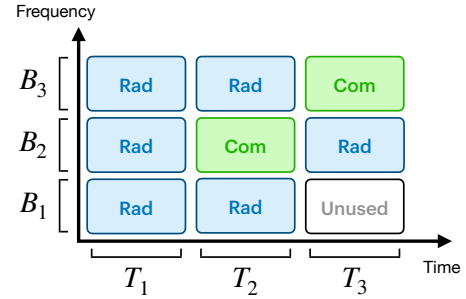


Figure 1. Hybrid multiplexing scheme for flexible multi-band wireless sensing and communication.

time-frequency block may be allocated to communication, radar, or left unutilized. In this example, a control unit is responsible for generating either FMCW (Frequency Modulated Continuous Wave) chirps or 32-QAM (Quadrature Amplitude Modulation) over B_1 , B_2 and B_3 during T_1 , T_2 and T_3 . Commonly used frequency band in ADAS (Advance Driver Assistance Systems) are selected for this work: B_1 : 24-24.5 GHz, B_2 : 76-77 GHz and B_3 : 79-81 GHz. Based on the methodology described in [6], the radar range resolution can be adaptative and will depend on the activated radar bands. With three bands, seven combinations are possible: B_1 , B_2 , B_3 , B_1+B_2 , B_1+B_3 , B_2+B_3 , and $B_1+B_2+B_3$. Hence, the adaptative fused resolution $\delta_{r,fused}$ can be expressed as:

$$\delta_{r,fused} = \frac{c}{2 \sum_{i=1}^N B_i} \quad (1)$$

where c is the speed of light and N is the number of active radar bands where $N \in \{1,2,3\}$. If $N = 0$, no sensing is performed. TABLE I summarizes the achievable resolution for each combination.

TABLE I. THEORETICAL RANGE RESOLUTION OF COMBINATIONS.

Combination	Bandwidth (GHz)	Resolution (cm)
B_1	0.5	30
B_2	1	15
B_3	2	7.5
B_1+B_2	1.5	10
B_1+B_3	2.5	6
B_2+B_3	3	5
$B_1+B_2+B_3$	3.5	4.3

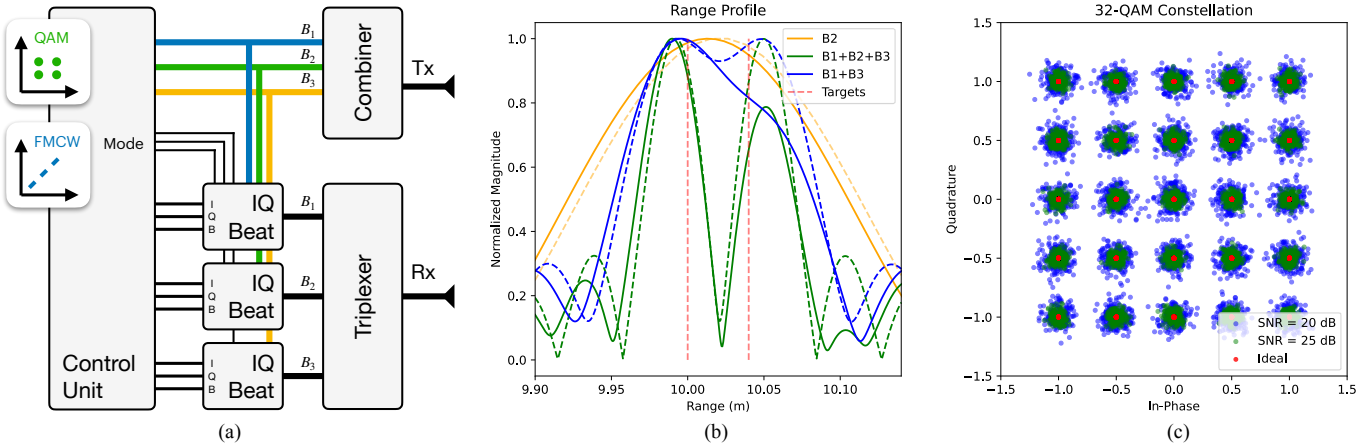


Figure 2. (a) Architecture of reconfigurable triple-band radar and communication transceiver (b) FFT fusion range profile of simulated targets with B_2 , B_1+B_3 and $B_1+B_2+B_3$ combinations (dashed line: theory, plain lines: simulation) (c) 32-QAM constellation diagram at 100 Mbit/s for signal-to-noise ratios of 20 and 25 dB.

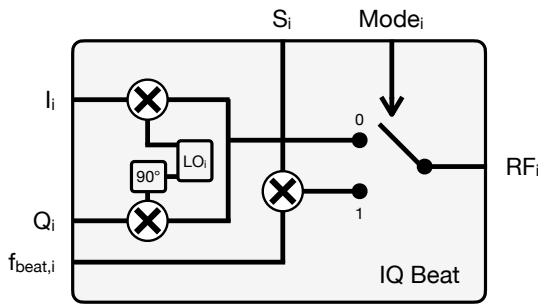


Figure 3. IQ-Beat demodulator with RF switch for beat frequency FMCW retrieval and IQ demodulation.

A typical application scenario of such system is two cars performing radar measurements individually and occasionally communicating with each other. To communicate effectively in a RadCom scenario, a synchronizing protocol is typically used, which is not demonstrated in this work [7].

Fig. 2(a) presents the RF front-end architecture leveraging the hybrid multiplexing scheme. In the transmission chain (Tx), three signals over the three bands are generated by the control unit and combined for transmission with a multi-band antenna. In the reception chain (Rx), the signals are received, and each band is separated using a triplexer. Based on the selected mode (Rad or Com), one of the two downconversion path is preferred and the corresponding beat frequency (Rad) or I and Q (In-phase and Quadrature) signals are then processed with the IQ-beat demodulator presented in Fig. 3.

III. SIMULATION RESULTS

The proposed architecture and hybrid multiplexing scheme are simulated in the Keysight ADS (Advanced Design System) software. Fig. 2(b) presents the multi-band radar simulation results with B_2 , B_1+B_3 and $B_1+B_2+B_3$ involving two targets, the first at 10 m and the second at 10.04 m. The simulated range resolution yield 17.9 cm, 7.2 cm and 5.1 cm for the single-band, dual-band and triple-band configuration, respectively. Compared to their theoretical counterparts, the simulated range resolutions yield a resolution difference of 17 %, 19 % and 20 % for the single-band, dual-band and triple-band configuration,

respectively. A 4 cm target's spacing is chosen so that it is undetectable by any of the individual band, while only a fusion of the bands can retrieve the target's locations. Fig. 2(c) shows the constellation diagram of the simulated transmission and reception chain for a 32-QAM with several signal-to-noise ratios, with respect to their ideal position. In the simulations, the switching effect of the RF switch was neglected.

IV. CONCLUSION

A hybrid multiplexing approach and architecture for combining communication and multi-band radar fusion for next-generation wireless systems is jointly presented in this work. The proposed method is an attractive contender for future applications as it exhibits notable benefits in terms of adaptability and resource usage. The scheme's capacity to improve spectral efficiency and operational flexibility is confirmed by simulation findings, opening the door for its applications in practical settings.

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