Review Article

Upper Mid-Band Spectrum for 6G: Vision, Opportunity and Challenges

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Driven by the pursuit of gigabit-per-second data speeds for future 6G mobile networks, in addition to the support of sensing and artificial intelligence applications, the industry is expanding beyond crowded sub-6 GHz bands with innovative new spectrum allocations. In this paper, we chart a compelling vision for 6G within the frequency range 3 (FR3) spectrum, i.e. 7.125-$24.25 GHz$, by delving into its key enablers and addressing the multifaceted challenges that lie ahead for these new frequency bands. Here we highlight the physical properties of this never-before-used spectrum by reviewing recent channel measurements for outdoor and indoor environments, including path loss, delay and angular spreads, and material penetration loss, all of which offer insights that underpin future 5G/6G wireless communication designs. Building on the fundamental knowledge of the channel properties, we explore FR3 spectrum agility strategies that balance coverage and capacity (e.g., data rate) tradeoffs, while also examining coexistence with incumbent systems, such as satellites, radio astronomy, and earth exploration. Moreover, we discuss the potential of massive multiple-input multiple-output, compact and digital architectures, and evaluate the potential of multiband sensing for FR3 integrated sensing and communications. Finally, we outline 6G standardization features that are likely to emerge from 3GPP radio frame innovations and open radio access network developments.

I. Introduction

By 2034, global mobile data traffic is expected to grow by 5x–9x, with artificial intelligence (AI) accounting for one-third of the traffic. There is an industry-wide consensus that 6G is expected to launch around 2030 with new spectrum in frequency range 3 (FR3) [1], which spans 7.125-24.25 GHz [2]. To meet the 6G timeline, it is crucial to allocate the necessary spectrum a few years in advance, in order to

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ensure incumbents are accommodated and that the technology is ready for mass adoption at the global launch of 6G. Companies are actively conducting proof-of-concept product trials to address bottlenecks and tackle myriad implementation challenges. At the same time, regulators must determine how the spectrum will be allocated, and operators need to develop viable business cases and deployment/integration strategies for nationwide 6G networks.

A. The FR3 Spectrum

As the global wireless industry advances towards 6G, the upper mid-band frequencies, being a part of the high super high frequency (SHF) bands, are critical resources due to their balance between coverage and bandwidth availability, compared to the lower frequency range 1 (FR1) (up to $7.125 GHz$ [3]) and the higher frequency range 2 (FR2) ranges, which includes $24.25 GHz$ to $71 GHz$ [4]. Often termed the “Golden Band”, or ”Goldilocks Spectrum”, for 6G, FR3 frequencies (7.125-24.25 GHz [2] as depicted in Fig. 1 [1]) are particularly suited for enhancing network capacity while maintaining reasonable propagation characteristics, offering moderate propagation losses, enabling extensive urban and suburban reach using existing towers.

The FR3 spectrum holds growing importance and interest for industry and regulatory bodies like the U.S. National Telecommunications and Information Administration (NTIA), the 3rd Generation Partnership Program(3GPP) [5] and the Federal Communications Commission (FCC), who are currently evaluating its potential alongside existing mobile radio bands in order to expand cellular services. Besides mobile operator use, the upper mid-band is being considered to coexist with incumbent services such as satellite communications, radio astronomy, and earth exploration, in addition to warfare activities, such as the next generation jammer mid-band (NGJ-MB) operating within $509 MHz$to $18 GHz$ [6].

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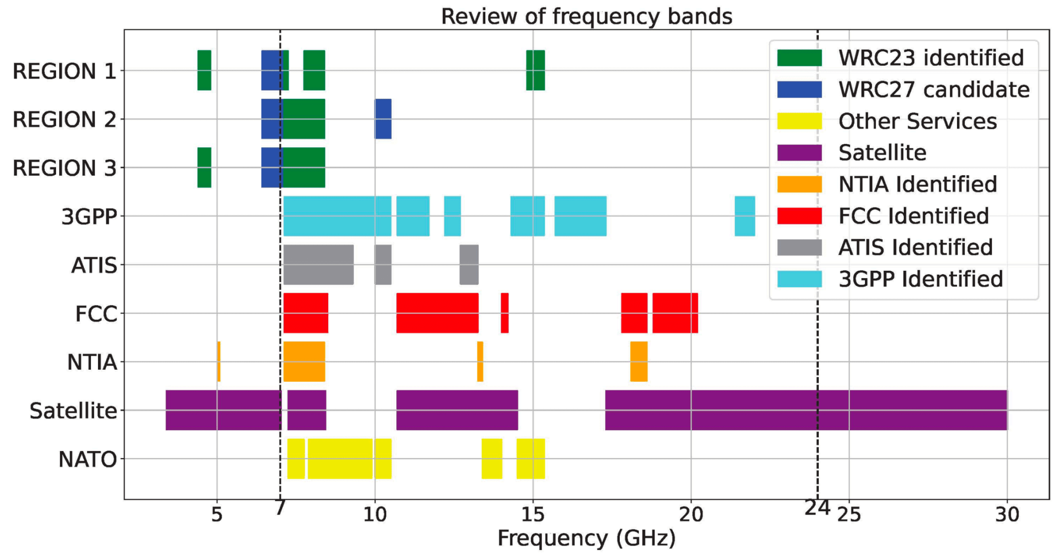

Figure 1. The spectrum showing the placement of FR3 Golden band, relative to its other counterparts according to different bodies and in various regions[1].

Notably, the NTIA highlighted specific FR3 bands, including $7.125GHz$-$8.4GHz$, and 14.8-$15.35GHz$, as part of the International Telecommunication Union (ITU) World Radio Conference 2023 (WRC-23) agenda, emphasizing the pending authorization in the USA and hence the need for precise channel modeling to ensure effective spectrum utilization and sharing.

II. FR3 Channel Characteristics

Env	Freq. (GHz)	Dist (m)	LOS		NLOS		LOS Omni RMS DS	NLOS Omni RMS DS	LOS Omni RMS ASA	NLOS Omni RMS ASA
			Omni PLE	Sigma	Omni PLE	Sigma				
InH[1]	6.75	11–97	1.34	3.51	2.72	9.21	37.7	48	40.9	58.2
	16.95	11–97	1.32	2.66	3.05	8.11	22.1	40.7	34.2	43.5
	28	4–46	1.2	1.8	2.7	9.7	10.8	17.1	Med: 39.1	Med: 31.8
UMi[7]	6.75	40–1000	1.79	2.57	2.56	6.53	62.8	75.6	16.79	25.62
	16.95	40–1000	1.85	4.05	2.59	8.78	46.5	65.8	18.23	19.08
	28	31–187	2.02	8.98	3.56	8.91	26.7	46.3	Med:14	Med:30
InF[8]	6.75	9–38	1.39	1.86	1.78	2.46	14	30.3	23.71	66.38
	16.95	9–38	1.75	3.1	2.11	3.29	12.7	29	14.32	50.4

Table 1. Omni PLEs from the CI PL model with 1 m reference distance, Omni DS, and Omni ASA at RX[1][7][8].

A. FR3 Channel Modeling

The channel model introduced in TR 38.901 as part of the 3GPP global standard body was designed to encompass the entire frequency range from 0.5 to 100 GHz [9]. Integrated channel models are indispensable for addressing diverse propagation scenarios, ranging from urban environments to free space, yet 3GPP developed the TR 38.901 channel models without many field measurements across much of the $100GHz$ wide swath of the spectrum and without any measurements from the FR3 bands. As a result, the model is an estimate, formulated from sparse measurements across particular bands within the 0.5 to $100GHz$ range. Channel modeling research for spectra above $6GHz$ was completed in Release 17 of TR 38.901 in April 2022, offering a comprehensive set of models for evaluating various physical layer technologies. However, the primary focus of 5G channel modeling has been on frequencies below

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$6GHz$ (FR1) and above $24GHz$ (FR3). To address this gap, frequency interpolation techniques were used by 3GPP to estimate channel parameters in the $7\text{-}24GHz$ band. *To establish a more accurate channel model for the FR3 band, it is crucial to validate the TR 38.901 model and carefully examine the details of FR3 channel parameterization.* For this, true empirical characterization of the many channel parameters is required. 3GPP channel parameters include pathloss exponents, penetration losses, shadowing effects, cross-polarization discrimination (also referred to as cross-polarization isolation), in addition to delay and angular spreads across different environments, such as indoor hotspot (InH), indoor factory (InF), and urban microcell (UMi), under various conditions, such as line of sight (LoS) and non-line of sight (NLoS) with minimal outages.

The findings of FR3 channel measurements conducted by NYU WIRELESS in[1][7][8] reveal that for wideband channels at 16.95 GHz in the FR3 band, the omnidirectional pathloss exponent (PLE) values, synthesized from directional channel measurements, in LoS scenarios were slightly lower than those in millimeter wave (mmWave), indicating less signal attenuation and more of a waveguide effect over distance, e.g., the omnidirectional LoS PLEs in InH, UMi, and InF for 6.75 GHz, 16.75 GHz, and 28 GHz are given in Table 1, e.g., 1.34 at 6.75 GHz, 1.32 at 16.75 GHz, and 1.2 at 28 GHz [1]. In UMi, the omnidirectional LoS PLEs are 1.79 at 7 GHz [1], 1.85 at 16.75 GHz [1], and 2.02 at 28 GHz [1], which indicates slightly less loss over distance than a free space channel (e.g., when PLE $= 2$) and with less loss at lower frequencies. Although antenna patterns and gains vary widely, and higher frequencies enable the use of directional antennas that can offset channel loss in mmWave bands, 3GPP and researchers often use an omnidirectional channel model to standardize link analysis and ensure consistency in evaluations while enabling the use of any type of directional pattern to be applied to the models[10],[11]. NLoS PLEs were found to be higher than those in the LoS scenario, as is found in all 3GPP bands as per Table I, e.g., the NLoS PLE for UMi of 2.56 at 6.75 GHz [1], 2.59 at 16.75 GHz [1], and for InF, the NLoS PLE is 1.78 at 6.75 GHz [8], and 2.11 at 16.75 GHz [8], the loss over distance is much lower (e.g., 14.5 dB per decade less) than those observed at mmWave frequencies, e.g., the NLoS PLE of 3.56 at 28 GHz, highlighting how FR3 offers improved coverage for a comparable equivalent isotropic radiated power (EIRP) and radio frequency (RF) bandwidth relative to higher frequencies. Referring to Table I, the PLE for LoS in UMi is 1.79 for 6 GHz and 2.02 for 28 GHz, implying greater coverage with a 2.2 dB stronger signal per decade of distance, resulting in 4.4 dB over 100m and 6.6 dB stronger signal over 1km, which clearly demonstrates how a lower PLE translates into significant coverage improvement, which may be traded

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for higher capacity for users within a cell, a factor that will be of paramount importance to carriers when deploying 6G technologies.

The time delay spread of a propagation channel has an impact on signaling formats, in addition to accuracy for integrated sensing and communications (ISAC) applications such as position location and multi-user synchronization methods. Measurements in[1],[7],[8] show that the root mean square (RMS) delay spread (DS) decreases with carrier frequency, with FR3 exhibiting smaller DS values than sub-6 GHz, but larger than at FR2 mmWave frequencies, e.g. $14ns$ and $12.7ns$ LoS omnidirectional RMS DS at $6.75GHz$ and $16.95GHz$, respectively, for InF. The range of RMS DS was found to be $12.7 - 37.7ns$ across InF, UMi, and InH. DS values observed in the field indicate that multipath components are closer in time at FR3, suggesting limited temporal dispersion, which could favor high-speed, low-latency communications and more accurate position location and timing methods in dense environments. Furthermore, the measurements in[1] found that higher FR3 frequencies, i.e. $16.75GHz$, exhibited a narrower RMS angular spread compared to the higher FR1 frequency at $6.75GHz$, hence indicating fewer, more focused multipath components, which is beneficial for spatial multiplexing as it reduces interference between signal paths and allows more precise beamforming. Regarding material penetration, losses were consistently higher at $16.95GHz$ in FR3 than at lower frequencies, with losses dependent on material type and polarization configuration, confirming the inherent limitations of FR3 in penetrating certain materials, such as low-emissivity (IRR) glass and concrete[1], yet able to allow more penetration than at FR3 mmWave[1].

When considering the design and comparison of air interface standards, such as the 3GPP TR 38.901 statistical channel model, the channel measurements[7][8] conducted at new FR3 frequencies suggest that no major changes are needed in terms of numerology compared to existing 5G new radio (NR) protocols; however, the *beam management* may need modifications due to the different temporal and spatial statistics and the different number of antenna elements at both gNodeB (gNB) and user equipment (UE). In particular, directional links rely on precise angular alignment of transmitter and receiver beams, a process facilitated through beam management operations. For next-generation cellular networks, mechanisms are being discussed in 3GPP technical documents that address beam management, such as R1-2409673 in November $18 - 22$ as part of the 3GPP technical specification group (TSG) radio access network (RAN) working group (WG1), in addition to other 3GPP contributions such as R1-2409710, R1-2409741, and more. Directional combining in beam management dramatically enhances link gains and coverage distances, as first shown in[12], thereby maintaining acceptable communication quality when beam combining is available – something that both FR2 and FR3 will support. However, as shown in[7], as the carrier frequency increases, the angular spread tends to decrease. In addition, the empirical RMS angular spread of arrival (ASA) at both $6.75GHz$ and $16.95GHz$ was noticeably lower than the 3GPP model predictions[7]. Factors such as mobility, device rotation, and wide angular spread channels can impact beam alignment. In dynamic scenarios, beam measurements can quickly become outdated, leading to inaccurate beam selection and performance degradation, which further impacts the signal-to-interference-plus-noise ratio (SINR) and spectral efficiency (SE). *The newly reported angular spreads in[7] implies that modifications are required for beam management in the new goldilocks FR3 mid-band spectrum. For sensing applications in ISAC, this also means that precise and accurate beam alignment is needed for target detection, localization, and tracking.* In addition to channel modeling, the call for new metrics and figures-of-merit, such as the *Waste Factor*, offers potential for energy efficiency optimization in 6G wireless systems.

B. FR3 frequency-dependent features and losses

As discussed in the previous section, empirical field data[8] in InF (dense-scatterer environment) indicate frequency-dependent trends for DS and angular spread (AS). This is not surprising, as frequency-dependent propagation features were measured and revealed in[13] for both outdoors and indoors, empirically discovered in what eventually became the FR3 bands of 28 and $73GHz$. For modeling the channel path loss over distance, extensive empirical measurements show that the close-in free space model with a frequency-weighted path loss exponent (CIF) is more suited for indoors[13], and extends the CI model, which has a physics-based close-in free space reference distance as a leverage point for the slope of the exponential path loss, while incorporating the frequency dependence feature of path loss observed indoors. The multipath temporal and spatial statistics at the lower part of the FR3, e.g., $7GHz$, vary considerably compared to the higher part of FR3, e.g., 16-$24GHz$, which confirms less multipath dispersion in both time and space at higher mmWave frequencies[1]. Perhaps most importantly, rain attenuation and foliage losses vary significantly across the FR3. Following ITU-R recommendation (P.838 -3), the specific attenuation at $7GHz$ for heavy rain (corresponding to a rain rate of $8mm/hr$) is $0.04dB/km$, whereas at $24GHz$, the specific attenuation is $1.16dB/km$, i.e., a gap of $1.16dB$ difference over $1km$. Following Weissberger's model, the foliage loss difference at $24GHz$ relative to that at $7GHz$ is $14.52dB$ at $100m$. In particular, the foliage loss is $34.66dB$ at $7GHz$ over $100m$, whereas it is

$49.18dB$ at $24GHz$ over $100m$. However, the link can be improved to extend the transmitter's coverage area via coherent multi-beam combining[12].

III. Spectrum Agility & Coverage-Rate Tradeoffs

A. Spectrum Agility for Coverage-Rate Tradeoffs

The lower FR3 frequencies provide better coverage, as detailed in Section II; hence, a fundamental question arises: *What mechanism can optimally balance rate-coverage tradeoffs*? A particularly interesting ray tracing simulation was conducted in[14] to study the coverage and rate statistical behaviour across the FR3 spectrum. In terms of rate, with no blockages, and as expected, it was shown that $24GHz$ usage dominates in terms of rate for outdoors. Interestingly, when a 3GPP blockage model B was used, it was shown that there was a fallback need towards $12GHz$ and $6GHz$ for maximum rate. But even more, making use of the comprehensive and detailed penetration models and findings from NYU WIRELESS[1], it is observed that while materials like glass and wood exhibit relatively permeable characteristics at FR3 frequencies, others, e.g., low-emissivity glass, are not permeable. A particularly intriguing observation is that concrete, which is relatively permeable at sub-6 GHz frequencies, becomes completely impermeable at FR3. Additionally, as reported in[14], the indoor user rate distribution indicates that users operating at $24GHz$ will need to fallback to lower frequencies, which means that if we really want to leverage the large FR3 spectrum, frequency hopping mechanisms between FR3 bands should be designed to account for the various blockages and penetration losses. The diversity and hopping mechanism naturally push forward the need for a *spectrum agility* in the FR3. Besides, the agility also inherently secures certain transmissions from malicious users and eavesdroppers. A natural question then to ask would be *what hopping mechanism should be adopted between the FR3 bands in order to be spectrally efficient and agile*?

B. Incumbents: Coexistence & Opportunity

The primary challenge of utilizing FR3 for 6G lies in regulatory issues. The spectrum is densely populated with both civilian and government incumbents for various applications beyond fixed and mobile wireless access, like meteorology, radio astronomy, and maritime radio navigation. In contrast to 5G, one would need to pay special care towards such incumbents. Even if regulators reach consensus on spectrum availability and licensing frameworks, the most technically demanding aspect will be determining how to share this spectrum without interfering with existing users. Note that satellite users

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are already spectrum-sharing amongst themselves. Vice-versa, we can also consider a fundamental question that is: *are commercial services and malicious users able to harm satellites?* A possible approach would be through interference nulling to guarantee the protection of satellite uplink (UL) communications without sacrificing much of the terrestrial downlink (DL), which translates into a greater chance of co-existence. Sharing spectrum efficiently while avoiding interference, especially in cases where users operate close to one another, is a technical challenge that requires effective coordination mechanisms. Relocating incumbent users can be expensive, often eclipsing the auction value of the spectrum itself. Inspired by spectrum refarming mechanisms, dynamic spectrum sharing (DSS) can ensure backward compatibility with older generations in a dynamic way. More specifically, DSS allows service providers to bypass a static cut between different generations in frequency, allowing for wiser spectral utilization. Similarly, DSS can allow a dynamic smart way of sharing spectrum between 6G users and incumbents within the band, but this would be very challenging.

IV. Massive MIMO, Compact Arrays & Power Considerations

Doubling the frequency implies a loss by a factor of 4 in Watts. However, this loss can be regained by filling the same effective area, covering the space, which also means more compact (but not bigger) arrays, which is referred to as antenna gain. Given half a wavelength spacing, then multiplying the carrier frequency by N necessitates N^2 more antennas to cover the aperture area. For FR3, transitioning from $3.5\,\mathrm{GHz}$ to $7\,\mathrm{GHz}$ faces a $6\,\mathrm{dB}$ free space path-loss, but also a $6\,\mathrm{dB}$ antenna gain assuming the same aperture size, enabling similar coverage to lower frequencies with higher efficiency. Meanwhile, the *coherence distance* shrinks with higher frequencies, which implies that the minimum distance over which signals are uncorrelated in phase and amplitude also decreases, giving rise to the need to pack up more antennas in a given aperture. The challenge remains in the NLoS case, especially for a neutral host, where there are much more severe penetration losses at higher frequencies compared to lower counterparts, as mentioned in Sections II and III, in addition to diffraction losses which scale as $10\log f$.

A. Massive MIMO (mMIMO) can favor bandwidth widening

It is worth noting that new approaches have emerged for the design of *ultra-wide band (UWB)* antenna arrays whereby *mutual coupling (MC)* is intentionally introduced between different elements to expand the bandwidth. As far as massive MIMO (mMIMO) is concerned, it was shown that compact mMIMO can open extra degrees of freedom in the frequency domain[15]. Specifically, MC between array elements can be leveraged in tightly coupled collinear antenna arrays to expand the bandwidth. While interesting to attain higher rates, *how can sensing be performed under intentionally induced MC in compact mMIMO designs, especially given its frequency dependence across the UWB?*

B. Indoor reflection modeling for extended targets

The reflections arising from a single target share a common relation simply because they arise from the same target, i.e., *extended target (ET)*. ETs can reveal information besides location, e.g., size, shape, and orientation, which can enable use cases like gesture recognition. In fact, ET modeling is particularly relevant indoors owing to its property of rich multipath reflections. Therefore, *more modeling efforts should be conducted to characterize ET on lower and higher counterparts of FR3*. Even more, as alluded to in Section IV-A, and besides UWB, mMIMO can allow resolving ET paths in the spatial domain.

C. mMIMO architectures: Fully-digital vs. hybrid

As the number of antennas grows large to support various FR3 ISAC applications, which will heavily depend on SE and multi-band operations, a fully-digital scheme may seem complex due to high power consumption issues. For ISAC, one can consider a fully digital array employing low-resolution digital-to-analog and analog-to-digital converters to trade off quantization noise with power consumption. Therefore, we can ask *what is an optimal fully digital design that can balance sensing tasks with reasonable power consumption*? In contrast, hybrid beamforming seems like a good tradeoff to alleviate the power consumption problem by trading off some beamforming and beam selection gains, which, in turn, has negative reverberation effects on the received SINR and SE for communications, in addition to detection and localization accuracy for sensing. Therefore, *what is the optimal analog beamforming number of sub-panels to strike such trade-offs in hybrid design for sensing and communication (S&C)?*

D. Coherence time across FR3

Higher frequencies naturally reduce the *coherence time*, which in turn increases the complexity of channel estimation and makes spatial multiplexing more challenging. An inherent property of FR3 is that the coherence time can significantly vary across FR3, especially in mobile and highly dynamic environments. The coherence block shrinks at higher frequencies; hence, the channel outdates faster. In turn, this can limit the duration available for multiplexing data, which can also limit the number of terminals that can be multiplexed simultaneously due to constraints on orthogonal pilot sequences fitting within the coherence time. Within the coherence time, we also know that the achievable rate grows as $\min(N_T, N_R)\log_2(1+\mathrm{SNR})$ per unit of frequency. Hence, mMIMO can allow for more data multiplexing in an environment where less coherence time is available, especially at the higher end of FR3 bands. However, special attention is needed for channel state information acquisition. A question here could be: *Should higher FR3 frequencies be dedicated to less mobile environments, while lower FR3 bands to highly dynamic environments*?

V. Multiband sensing for FR-3 ISAC

ISAC use cases planned for FR3 mean that channel models must support S&C functions. Multi-band sensing for future systems can be realized through non-contiguous aggregation, whereby different frequency blocks are spread across different bands or parts of the FR3 spectrum.

Next, we provide an insightful analysis of some aspects of multiband sensing. As frequency increases, there is typically more spectrum available, and more antennas can be packed per unit of space. Thus, we assume that the bandwidth and antenna gain are proportional to the center frequency. It can be verified that when the frequency is doubled, the signal-to-noise ratio (SNR) and the Cramér-Rao bound (CRB) drop by a factor of 2. An example is provided in Fig. 2. The drop in SNR at higher frequencies shifts the waterfall region, and the lower frequencies have more margin to accurately start estimating the delay as predicted by the CRB. Conversely, since the CRB of the higher frequency system is smaller, it means that after the waterfall region, the higher frequency achieves a more accurate estimate.

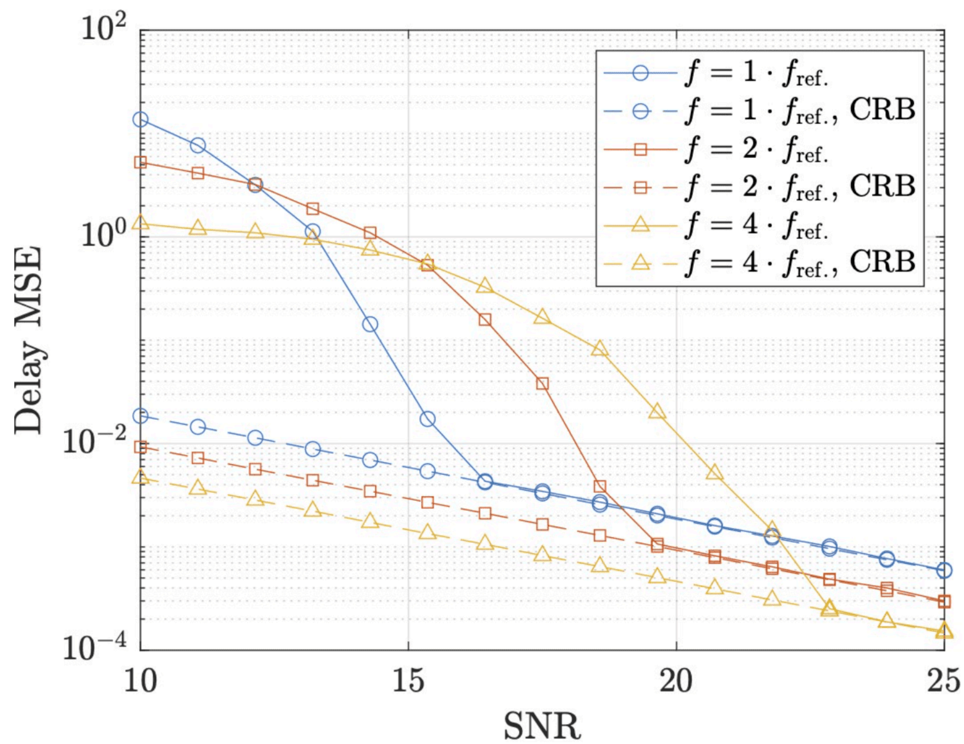

Figure 2. Multi-frequency ISAC trade-offs between low and high frequencies.

Our analysis reveals two insights for leveraging multi-band sensing. The first is to obtain estimates individually and combine them via a maximum ratio combining type approach. Specifically, one can assign more weights to estimates obtained at higher frequencies. The second is relevant for bistatic sensing, where we can rely on higher FR3 frequencies to obtain synchronization via the LoS path due to the need for accurate timing, but then we can tolerate falling back to lower frequencies, which we know can cover more targets. Based on this scheme, a good time difference of arrival location-based method can be developed leveraging the entire multi-band information on FR3.

VI. Key FR3 features in 6G Standards

This section explores key modifications envisioned for next-generation 6G cellular standardization to unlock the full potential of spectrally agile FR3 radios. Specifically, we examine both 3GPP innovations—focusing on radio frame enhancements tailored for spectral agility—and new O-RAN-based features, particularly in O-RAN open radio unit (O-RU) designs, that facilitate intelligent spectrum utilization.

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a) 3GPP

The challenges posed by FR3, e.g., wider bandwidths, non-contiguous carriers, increased propagation losses, and dynamic spectrum environments, necessitate innovations in frame design to ensure low-latency, high-reliability, and efficient multi-band operations. Below, we outline key advancements required to enhance spectral agility, synchronization, and resource management in next-generation wireless systems:

- *Multi-band aggregation*, i.e., combining separate, non-contiguous spectrum blocks to optimize the balance between performance and complexity, enhancing both S&C capabilities.
- *Dynamic slot configuration for multi-band coordination*, which implements AI-driven adaptive slot structures that dynamically adjust frame configurations across multiple bands. The dynamic strategy ensures optimized latency, throughput, and reliability by tailoring subframe allocations to each band's propagation characteristics.
- *Multi-band pilot design*, which aims at designing hybrid pilot structures that combine common and band-specific pilots while employing sparse allocation, frequency sharing, and adaptive density. Multi-band pilot design can be realized via AI-driven optimization and compressed sensing techniques to minimize redundancy and intelligently manage pilots for greater efficiency in multi-band environments.
- *Agile timing advance*, which aims at developing new timing advance strategies to ensure seamless switching and synchronization across carriers in different frequency bands, which is critical for achieving low-latency and high-reliability performance in 6G.
- *Multi-carrier synchronization and scalable numerology*, meaning that it is vital to introduce enhanced scalable numerology to support multi-carrier synchronization across diverse FR3 bandwidths, which further allows adaptive subcarrier spacing and multi-band coordination without excessive signaling overhead.

b) Open radio access network (O-RAN)

From an RAN perspective, the open radio access network (O-RAN) RAN intelligent controller (RIC) plays a crucial role in enabling spectral agility and intelligence by leveraging real-time (RT) and non-RT network optimizations. Through the use of xApps (near-RT RIC applications) and rApps (Non-RT RIC applications), the RIC can dynamically manage spectrum resources, adapt to changing conditions, and optimize performance in FR3. Hereafter, we examine how spectral agility and spectral intelligence can be achieved through the RIC.

Spectral Agility: The ability of a network to dynamically reconfigure spectrum usage based on real-time conditions, interference levels, traffic demands, and regulatory constraints can be achieved through the following mechanisms:

- *Dynamic carrier aggregation & multi-band adaptation:* The Near-RT RIC can monitor real-time spectrum conditions and trigger carrier aggregation adjustments across multiple FR3 bands, which enables on-the-fly switching between licensed, shared, and unlicensed spectrum resources, optimizing throughput and reducing congestion.
- *Intelligent spectrum sensing and sharing:* By integrating AI/ML models within rApps, the Non-RT RIC can analyze historical spectrum usage patterns and proactively allocate spectrum to different cells or operators, thus enabling dynamic spectrum access and coexistence with satellite, radar, or other wireless services operating in FR3.

Spectral Intelligence: Efficiency, reliability, and adaptability of spectrum can be achieved through intelligent decision-making and automation.

- *Beamforming, channel estimation, and interference management:* xApps in the Near-RT RIC continuously monitor spectrum conditions and adjust beamforming strategies for multi-user MIMO in FR3. Advanced channel estimation and interference prediction can help minimize co-channel and adjacent-band interference, ensuring optimal signal quality.
- *Multi-band O-RU control for distributed MIMO:* The Near-RT RIC can coordinate multi-band O-RUs across FR3 to enable distributed MIMO architectures. Leveraging O-RAN's open fronthaul interface, it ensures tight synchronization across spatially separated RUs, maximizing spectral efficiency.
- *Power efficiency:* Other key innovations that can be implemented by leveraging the RIC are adaptive sampling and dynamic range control. By adjusting these parameters based on real-time spectral conditions, FR3 O-RUs reduce unnecessary power consumption and enhance operational efficiency.

VII. Conclusions

This paper outlined a vision for 6G in the FR3 spectrum, exploring its upper mid-band potential, key challenges, and necessary standardization changes. We highlighted FR3's advantages in capacity, coverage, and SE, while emphasizing the impact of its channel characteristics on beam management.

Based on our FR3 measurements, we underscored the need for frequency hopping to mitigate blockages, maximize SE, and ensure incumbent coexistence, reinforcing the importance of spectrum agility. We examined the potential of mMIMO for FR3 and discussed design challenges, particularly in the uplink. For sensing, we analyzed performance bounds for FR3 ISAC multiband sensing. Additionally, we detailed key 6G standardization features, including 3GPP radio frame modifications and O-RAN-based innovations, using RIC-driven xApps and rApps for intelligent spectrum management. However, open questions remain regarding FR3 propagation characteristics, PHY design, and regulatory considerations.

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