mmWave Applications in NextGen Wireless Broadband Evolution in 5G Era Impact of Sir JC Bose invention

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Abstract

Sir JC Bose, the Original Inventor, Pioneer, and Scientist was first in the past era to discover the mmWave based Radio communications and his famous invention has become now a reality in mass adoption in this world of 5G Wireless communications. 5G and mmWave Communications have now become the defacto choice for Mobile Gigabit Broadband Speeds based Internet Access. mm Wave technology, coupled with MIMO Antenna technology invention by Prof Arogya Swamy Paul Raj of Stanford University, USA, another living legend in this 2019 era paved the way for Mobile Internet Access in Megabits era from Minutes era of Wireless Phone communications on Smart Phones/Laptops and many other form factor-based end user devices. Prof Paulraj, an Indian is a globally acclaimed Scientist, Engineer, Technologist, and Academician who is also in the National Inventors Hall of Fame, USA. Now with 2 global societal life impacting inventions of mm Wave communications and massive MIMO from 2 great Indians, we are set to experience Gigabit speed of Internet access in 5G NR (New Radio) era starting from 2020.

1. Introduction.

mmWave technology historical invention by Sir JC Bose 100 years ago has been used with practical products only since a decade through what is known as E and V Spectrum bands. Telecom NW Operators have deployed them as Point to Point and Point to Multipoint Radio links as Back haul links as "Wireless Fiber" high speed links. Now mmWave has come to be seen as Wireless Access technology for cellular applications .This is a huge transformation for mmWave adoption at massive global scale and is ready to serve Billions of people for Mobile Gigabit speed experiences .Telecom operators have done trials since past 2 years and now ready to launch live mmWave radio based 5G NR networks in USA/Europe/APAC/China /Middle East and India.

2. Digital Transformation of Our World

Digital Transformation of our World is taking place around the Mobile going from 4G to 5G driving Gbps speed Internet connectivity. If we can recall the LAN speed what we experience in our day to day office has gone from 10Mbps to 100Mbps to 1Gbps and now 10Gbps.LAN based access to Internet is the reality on the copper wire .Same kind of LAN speed we are now set to experience from the Wireless LAN (WLAN) from 1G to 10G through 5th Gen WiFi in offices and the new 5G Wide Area Radio Access technologies like 4G.

To make this Digital transformation a true reality, we need to adopt the 100 years old mmWave invention from Sir JC Bose.

JC Bose invention of mmWave is all about facilitating GHz spectrum band hitherto not used for adoption in 26/28/29 GHz bands with wide RF channel widths of n* 20 MHz to n*100Mhz bands for Gigabit Broadband delivery. Thus, a massive Digital Transformation of our world from 3 to 4 Billion People having access to high speed Internet to approximately 50 Billion Devices getting connected on Internet on massive Machine Type Communications (mMTC).

3. IT/Telecom/Internet/Media, Silicon Technologies driving the scaling potential in the society

In that, the following 5 technologies are defining the 3C's i.e. Computer, Communication, and Civilization

5G / MEC / Cloud Tech Base
Blending technologies of Communications and Computing in new ways is unleashing next generation Communication and Computational networks like **M**obile **E**dge **C**omputing

Machine Intelligence (MI)
Moving from cognitive MI toward augmented human intelligence in Radio NW planning and Performance monitoring and Optimisation has reached a level where past algorithms used have reached a limit and MI and ML based Dynamic algorithms and tools have become an imperative need due to massive scale of Network elements, devices and users in any geographic coverage.

NB-IoT
Internet of Things (IoT) getting connected is a revolutionary adoption in every walk of life, be it environmental sensors, Traffic sensors, Video Surveillance, Defence sector, Manufacturing, Automobiles, Railways, Electricity distribution Airline industry and Agriculture.

AI
AI for Analysis, computation, and decision making has become a compelling need in Telecom networks

AR/VR (Augmented Reality /Virtual Reality)
Immersive user experience to the physical world is rapidly becoming a huge adoption level.

4. Drivers & Prerequisites for 5G NR in India

Drivers
Aim for End user Enhanced Mobile Broad Band (eMBB) Target Speeds from average of evolution from 4 Mbps to 10Mbps **…**100Mbps **….**to 1Gbps and potential 100 M Subs to 500 M subs to 1B subscribers by 2025

Aspire for massive Machine Type Communications (IoT)
300M devices to 3 B devices**…**to 5B devices In India to be connected during 2019 to 2025 period

Evolve large scale Sensor centric Connected Smart Cities
50 **…**to 100**….** to **…..**1500 Smart cities

Prerequisites for 5G NR NW Infrastructure Launch
Ubiquitous availability of OFC Tx NW with Tbps Bandwidth.
Scalable Cloud Architectures in place for Core NW with strong Cyber Security framework
Always available &reliable Energy Infrastructure and Attractive Right of Way (RoW) policies

5. Diverse User demands for services

Users
Anywhere 1Gbps service
Ultra-high definition mobile video experiences

Battery Consumption
Battery consumption capability where it survives 5-6 hours a day. Making GPU's, CPU's and audio processor in the devices need to go to sleep mode whenever it is not in use so that the battery power stays longer for phone use.

Latency
<1ms NW latency

NW Element level Capacity at the Point of Presence (PoP)
<10 Gb/s peak data rates and **100 Mb/s** whenever needed

Ultra-low cost for massive machine type communications

6. mmWave 5G Network level - 5 Attributes

Cell Site Perspective
Today 300 Mbps is the capacity on the 4G /cell and in the order of migration it has go from 300Mbps to 50Gbps per cell at the expectations of anytime, anywhere, anyone (human beings or IoT devices to anything connectivity needs for 5G at higher scale.

Performance Perspective
Ultra-High Capacity(x1000) more than current level at **1,000,000** user devices per km² with Massive Connectivity (IoT) (Peak Data Rate > 50Gbps/cell) 4A Connectivity (Anytime, Anywhere, Anyone, Anything)

Management Perspective
Energy-efficient infrastructure
TCO Reduction
Flexible Configuration /Mgmt.
Load /Resource Balancing)

Architecture Perspective
Flat Structure/High Scalability
S/W- based Flexibility & Agility (Ease of innovation)
Analytics- based NI/BI
Network as-a-Service (NaaS)-Operation Perspective
High Reliability & Security
Automatic Optimization & Recovery
E2E QoE Control

7. mmWave based 5G NR – KPI s

Area	Requirements
Cell Spectral Efficiency	DL:10 bit/Hz/Cell(@10/30 Km/h)
	UL: 5 bit/Hz/cell(@10/30 Km/h)
Peak Data Rate	DL: 50 Gbps
	UL : 25 Gbps
Cell Edge Data Rate	DL : 1 Gbps(@ 10/30 Km/h)
	UL : 0.5 Gbps (@ 10/30 Km/h)
Latency	Control Plane: 50 ms
	User Data Plane : 1ms
Handover Interruption Time	10 ms

Above Peak data rates or the KPIs will not be possible if we don't have mmWave Spectrum band and the wide RF channels

8. India -Telecom NW Infra - mm Wave Scaling

Today we have around 1.8 Million Route KM route of fiber connecting all the cell towers whether Intra city or Inter City

To make 5G as a reality in India this order of the magnitude has to increase 3X times of the existing fiber i.e. from 1.8 M to 3M to cover all the cell towers and Point of presence

We need this huge magnitude increase because we are now going into mmWave which has the lesser range and hence we need that many more cell sites as the points of presence

Need to move from 500K cell sites to 1.5Million cell sites when we move to 5G

Today we have 0.5M cell towers but we need at least 0.5M cell towers additional or the poles, since we cannot have many towers, we may plan to use the existing street poles or the electrical poles to put a 5G mmWave Radio to bring the 5G technology for ubiquitous coverage reality. In summary we will approximately need the following additional NW infrastructure for 5G NR.

2 M RKM urban Intracity Fiber NW
3 M RKM Intercity Fiber for 6000 Cities
Addl 1.5 Million BTS with 4G/5G capacity
Addl 0.5 Million Poles &Towers

9. Next generation 5G mobile experience varieties are indicated below

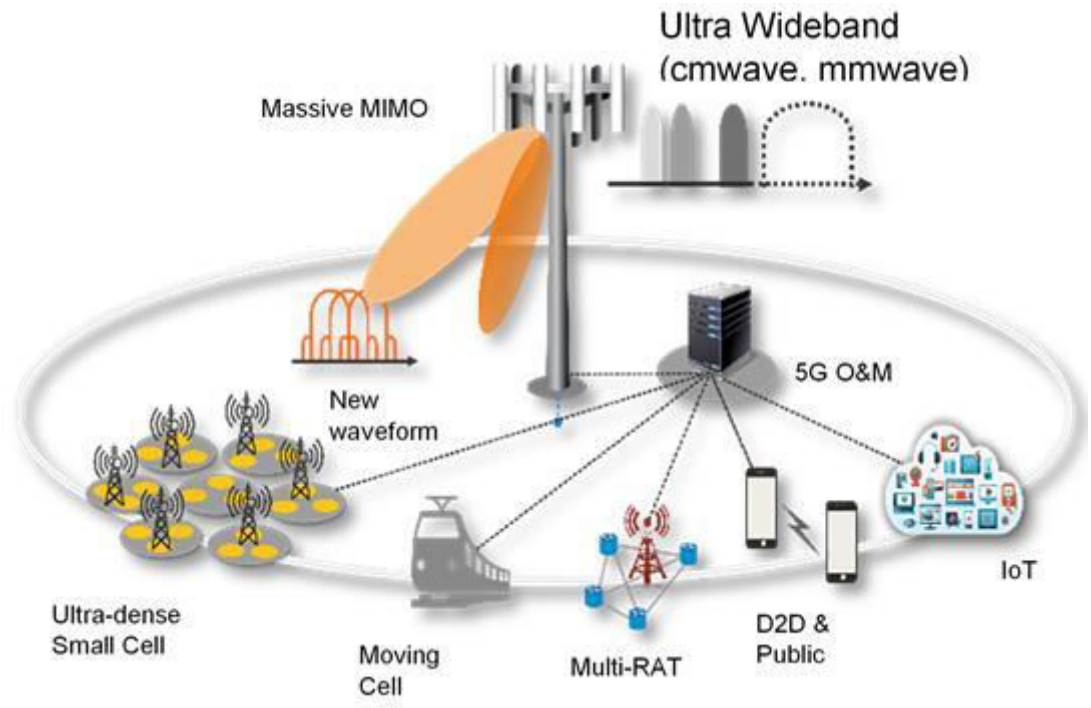
10. mmWave based 5G Applications.

Below listed Applications are driving 5G mmWave adoption need.

High speed mobility
Augmented Reality
Virtual Reality
Real-time remote-control cars
Sensors
Telepresence
Hologram Gaming

Till a few years ago the Content were getting generated by the Media and the Broadcasting houses. But in today's real life the content is getting generated by users and so the uplinking is also significantly higher compared to downlink data consumption because people want to update any events in the real time. All this content has to be backhauled and hence again this will be the big application for mmWave backhaul.

11. 5G mmWave NR Deployment Considerations



Higher Spectral Efficiency needs

Ultra-Wideband: While moving to mmWave, the RF channel bandwidth will move from 5MHz to 100MHz and upto n*100MHz and n*1 GHz facilitating high throughputs.

New Waveform will be adopted (NOMA, FBMC).

Massive MIMO, Full Duplex: From a Cell site to Handset, a MIMO of 8x8/64x64/256x256 Antenna array. facilitates Beamforming and Beam-tracking to guarantee required speeds with Radio resources. MIMO of higher degree will need higher spectrum which is provided through mmWave. 5G spectrum allocation with sub 6GHz (3.5-6GHz) will provide required coverage whereas in mmWave bands 28/39GHz will achieve capacity requirements.

Cell Densification

Ultra- dense Small Cell: mmWave Spectrum transmissions will not penetrate enough through concrete walls, and this requires small cell deployments for Ultra-Dense areas.

More Spectrum Bands and need for the following will arise like cm/mm Wave Transmission

Unlicensed Spectrum, D2D as Relay, Moving Cells will also be used.

Operational Efficiency based tools for NW Performance Monitoring (NPM)will be needed.

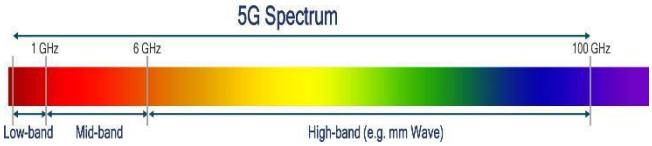
Advanced SON-Self Optimised Networks

Analytics based Control of Networks

IOT and Public Safety Networks

12. Key spectrum initiatives across the world for 5G:

Across low-band, mid-band, and high-band including mmWave FCC of USA considered the following



Low-band

- Successfully auctioned a portion of the 600 MHz band
- Spectrum availability timing aligns with 5G

Mid-band

- Opening up 150 MHz in 3.5 GHz band.
- CBRS Alliance launched to drive 5G like eco system
- 3.7-4.2 GHz and 5.9-7.1 GHz

High-band

- Opened with 11 GHz Bands leading in to mmWave bands
- 70% of newly opened spectrum is shared or unlicensed.
- Considering adding 24.25-24.45, 24.75-25.25 GHz, and 42-42.5 GHz

13. High-band: Spectrum for 5G mmWave with Ultra-Wide RF Channel widths can be seen below

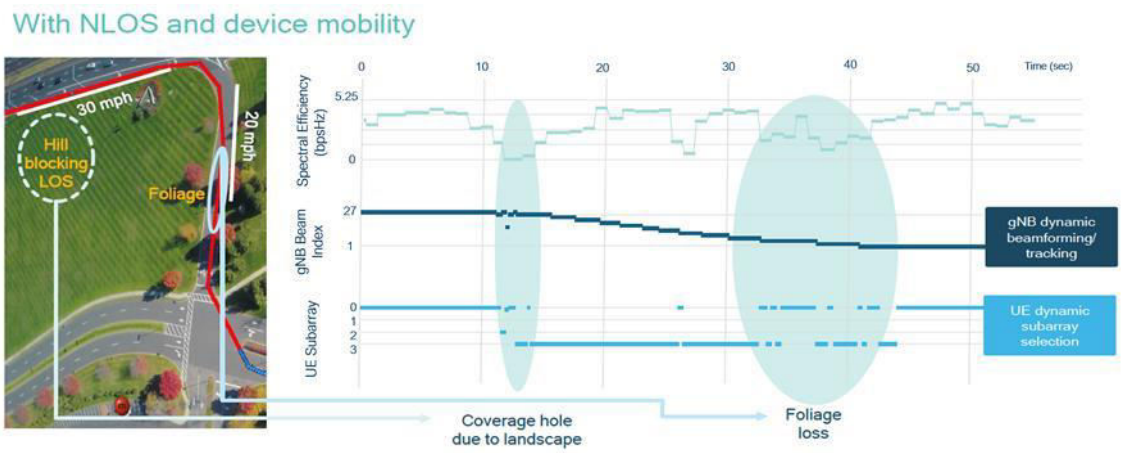
- 27.5to 28.35Ghz-850MHz@2x425 MHz of RF Channels)
- 37.6 to 38.6 GHz: 1 GHz @5x200 MHz)
- 38.6 to 40 GHz: 1.4 GHz @7x200 MHz)
- 37 – 37.6 GHz: 600 MHz @3x200 MHz)
- 64 - 71 GHz: 7 GHz @1Ghz

14. Global snapshot of 5G spectrum allocations Around the world, these bands have been allocated or targeted.

15. European Commission driving a Gigabit Society

Pioneer spectrum bands for 5G adoption in Europe are

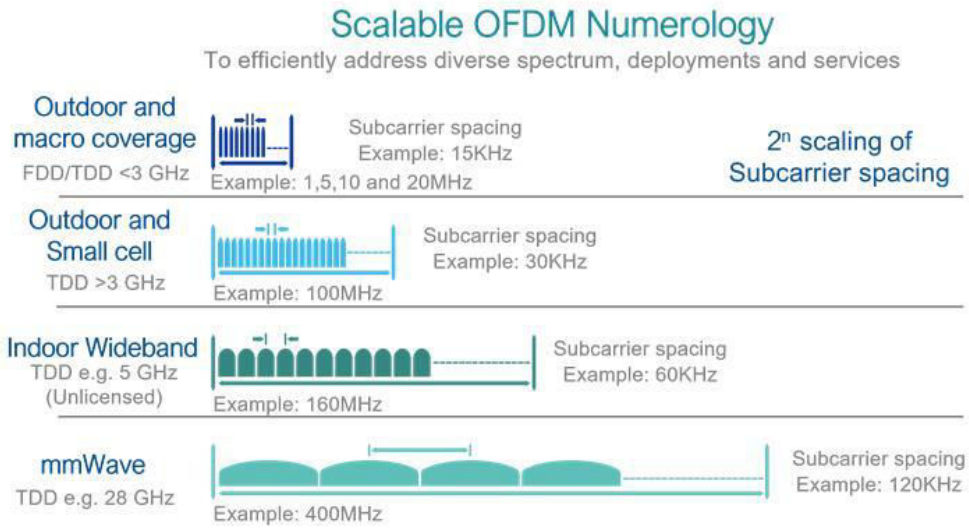
- CEPT - 26 GHz mm Wave band
- 5G commercial services to use both 3.4–3.8 GHz and 26 GHz mmWave in Europe by 2020
- Bands as per WRC-19 (e.g., 31.8 – 33.4 GHz, 40.5 – 43.5 GHz in addition to 24.25 – 27.5 GHz)



16. mmWave –NLOS-Device Mobility

Cellular Access network is always on a Non-Line of Sight (NLOS) where devices can transmit/receive data despite of foliage, constructions appearing between the transmissions. As 5G device is in mobility at 20-30 mph speed in mmWave mode of use due to landscape and foliage, spectral efficiency varies and throughput goes down, with inspite of dynamic Beamforming/Beam-tracking on UE.

17. 5G – mmWave – Numerology



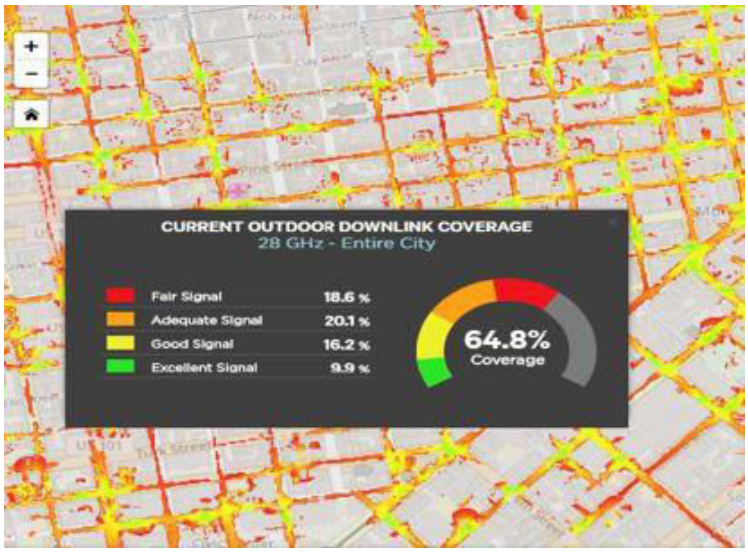
- RF Channel Width in OFDM Technology changes from 5MHz to 20MHz in 4G era
- RF Channel Width in OFDM Technology in 5G era varies from n*20 to n*100 to n*400MHz upto n*1 GHz
- Sub carrier spacing increases from 15KHz to 120KHz and Mbps era to Gbps Internet access era on mobiles.

18. Mobilising 5G mmWave in Real world environments

Car based 5G Devices, Small cell BTSs, Embedded Medical Devices, Robots, and Smart Phones deployed in mmWave trials for testing outdoor coverage as well as Indoor coverage applications are given below indicating seamless handover at speeds of 30 mph.

mmWave mode of RF propagation in 5G is fully dependent on adaptive Beamforming/Beam-tracking with upto 128 antenna elements on gNodeB and UE supporting 4 sub arrays.

19. 5G NR mmWave Network Coverage Simulation



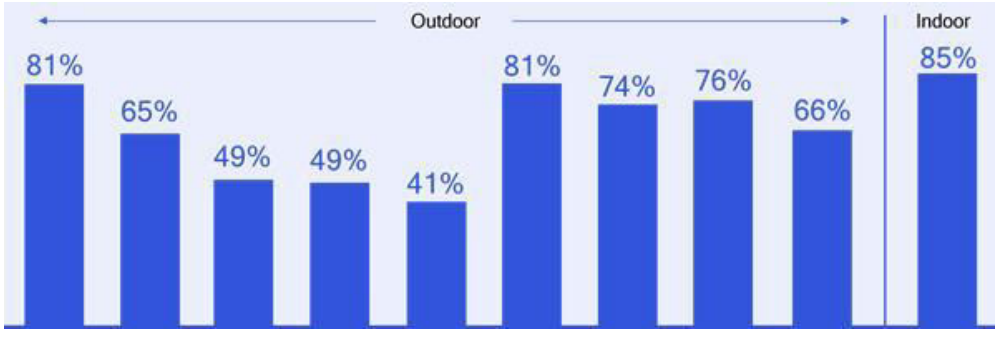
- Outdoor coverage simulated using existing LTE sites.
- Outdoor coverage complements indoor deployments.
- Below Table captures simulation results of DL coverage in mmWave coverage mode indicated.

Frequency	mm Wave 28GHz
Site Locations	Entire City
Total Area	9.77km2
Macro sites	77
Small cells	275
Site Density	36/km2
Excellent to Fair Signal	65 % Coverage

- Cell Site density per Sq.km is far higher in mmWave bands.

20. Significant 5G NR mmWave coverage via co-siting Simulations

Extensive over-the-air testing and channel measurements shown below for % of coverage with different cell density deployments in different cities is shown below.



28 GHz downlink coverage % Co-siting with LTE

Site density (per km2)	Total	48	36	32	31	28	41	31	39	37	134
	Macro	0	8	15	14	7	33	31	39	37	
	Small	48	28	17	17	21	8	0	0	0	

21. Mm Wave – Pico Radio Deployments
3 distinct form factors of BTS sites shown for mmwave based 28 -39GHz for 5G NR

Pole Top Mounted Cylinder: 12" tall x 14" OD cylindrical shape 5G BTS on pole tops Provide 360-degree coverage

Pole Wrap-Around Mounting: 12" H x 8" W x 4" D
Provide 120-degree coverage per 5G radio unit

Flat Panel *:*8" H x 8" W x 4" D Traditional Flat panel design. Provide 120-degree coverage per radio unit

mmWAVE Band
28-39GHZ FWA form factor Small cell BTSs

22. Conclusion
Inventions made by Sir JC Bose 100 years ago is becoming a reality now. This will transform next generation Wireless Access technologies for global citizen around the world. Upcoming interoperability testing at sub-6 GHz & mmWave will ensure future 5G deployments to be great success. OEMs like Nokia, Ericsson, Huawei, Samsung and ZTE etc. and Telcos like AT&T, China Mobile, Sprint, SK Telecom, Vodafone conducting trails in their Networks & laboratories promises 5G to be great success ***for pioneering invention based mmWave centric Gigabit era***

References

a) *Qualcomm 5G Technical literature.*
b) *Telco trial data simulations*
c) *QuadGen 5G Network element database*

About the authors

Former President and CEO of Lucent, India, Mr. Rao have had a distinguished career in telecommunications. In addition to holding executive positions with BT India, Intel India, Tellabs India, CDOT India and Reliance Communications India, Mr. Rao is the President of AUSPI India, Chairman of the WiMAX Forum India and former Chairman of ASSOCHAM - a premier national Chamber of Commerce India.

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