



SPECTRUM GLOSSARY

Centre for Policy Studies & Research, NICF



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The Centre for Policy Studies & Research, NICF, was established in the year 2024. It works in close coordination with bureaucracy, academia and industry to produce quality research papers.

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FOREWORD

Telecommunications is the backbone of modern society, facilitating instant communication and connectivity across the globe. Central to this intricate web of communication is the concept of spectrum—a finite, invisible resource that enables the transmission of data through electromagnetic waves. Understanding spectrum is essential not only for those working in the Department of Telecom, but also for policymakers, business leaders, and consumers who rely on seamless connectivity for everyday tasks.

This glossary on telecom spectrum is designed to demystify the terminology and concepts that underpin this critical aspect of telecommunications. It serves as a comprehensive reference, providing clear and concise definitions of terms related to spectrum management, allocation, and technology. Whether you are a seasoned professional or a newcomer to the field, this glossary will equip you with the knowledge to navigate the intricacies of spectrum.

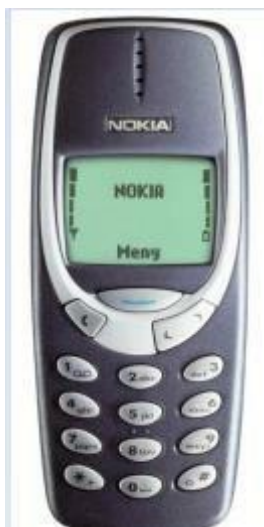
The advent of 5G technology has brought spectrum into sharper focus, highlighting the need for efficient management and innovative use of this resource. As we stand on the brink of a new era in telecommunications, where the Internet of Things (IoT), smart cities, and connected devices are set to transform our lives, the importance of understanding spectrum cannot be overstated. Spectrum is not just about bandwidth and frequencies; it is about the potential for innovation and the opportunities it creates for economic growth and societal advancement.

In an era where technology evolves at a rapid pace, staying informed about fundamental concepts like spectrum is crucial. This glossary aims to be a trusted companion, guiding you through the ever-changing landscape of telecommunications. As you delve into the definitions and explanations within these pages, I hope you gain a deeper understanding of spectrum and its pivotal role in shaping our connected world.

I would like to acknowledge the contribution of **Sh. Kunal Srivastava**, Dy. Dir., NICF, for his efforts in conception of this glossary, selection of terms and subsequent compilation. The able assistance by **Ms. Kritika**, Research Assistant, NICF, also deserves a mention. I also thank **Sh. P. S. Shekhawat**, Dir, WMTDC, for his valuable inputs. I also want to thank you, the reader, for your curiosity and willingness to explore the fascinating world of telecom spectrum.

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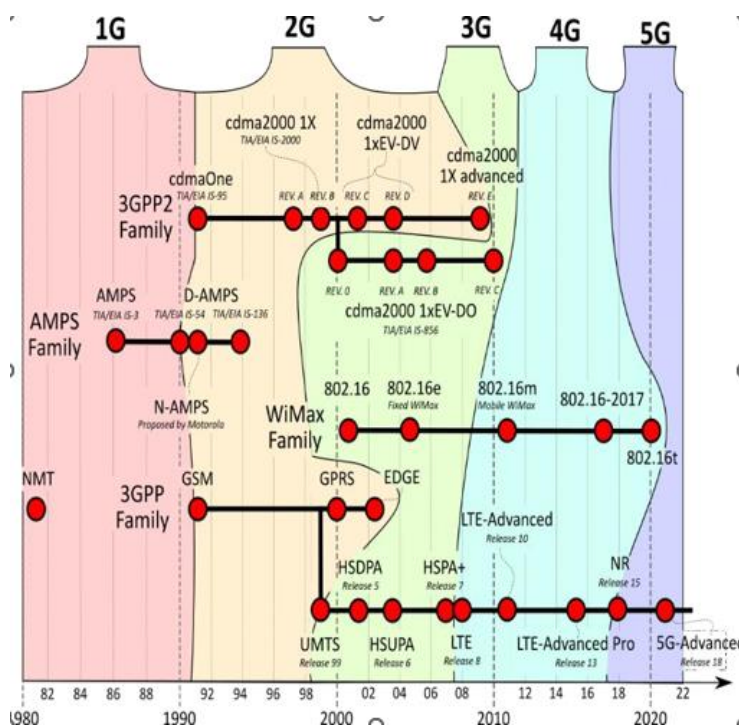
1. **1G:** 1st Generation, Analog communication system and the first wireless system. It operated on frequency of 800 MHz - 900 MHz and with bandwidth of 30 kHz. The voice quality was poor and phone sizes were big. It was introduced in 1980s. The Nordic Mobile Telephone (NMT) and Advanced Mobile Phone Systems (AMPS) were popular standards and FDMA technique was used. The 1G is also seen as successor of 0G where portable phones will connect to a centralized operator.



2. **2G:** 2nd Generation, digital communication system, supported voice and text messages and introduced in 1990s. It achieved transmission speeds up to 64 kbps and operated on 900 MHz and 1800 MHz bands. It was the pioneer in supporting international roaming. TDMA and CDMA techniques were used. The 2G services using TDMA were branded as GSM which became quite popular. Further developments were 2.5 G (GPRS) and 2.75 G (EDGE).

3. **3G:** Also called as IMT-2000 and has peak data rate of 2 MBPS, or at least 144 kbps. The two branded standards of 3G are UMTS (using WideBand CDMA) and CDMA2000. The 3G systems uses spread spectrum technology for achieving higher spectral efficiency. It was designed from the start to support high data rates. In India, 3G was offered in 1800 MHz and 2100 MHz band. The later versions of 3G were 3.5G (HSPA) and 3.75G (HSPA+).

4. **4G:** The 4th generation of mobile networks that was able to support much higher data rates by leveraging wider channel bandwidths and Orthogonal Frequency Division Multiplexing (OFDMA) for better spectral efficiency. Often 4G is branded into two standards terms: LTE and WiMax. The 4G is also called as IMT Advanced and supports peak data rate of 1 GBPS. The applications of 4G are IP telephony, high-definition TV, gaming services, etc. 4G is characterized by use of techniques like beamforming, multiple input multiple output (MIMO), etc. for much reduced latency, higher spectral efficiency and data rate. In India, 4G services are offered in many bands like 800 MHz, 900 MHz, 2300 MHz, etc. the 4G was further advanced as 4.5G (LTE Advanced) and 4.9G (LTE Advanced Pro) to support better performance.



5. **5G:** The 5th generation of mobile wireless networks, that can connect machines, objects, etc. Technically, it is called as IMT- 2020 and is designed to deliver multi gigabit data speed rates, ultra-low latency, massive network capacity and much higher reliability.

The data speeds can peak up to 10 GBPS. The typical use cases are eMBB, uRLLC and mMTC. Like 4G before it, 5G is also based upon OFDMA. However, 5G is categorized into Standalone 5G and non-standalone 5G. The latter uses the 4G LTE Core in its network but the former is a true 5G network with all intended benefits. In India, 5G is offered in various bands like 700 MHz, 800 MHz, 900 MHz, 2100MHz, etc. and even in 26 GHz.

6. **6G:** The 6th generation of mobile networks and planned as a successor to the 5G. It is under the standards called IMT 2030 but the frequency bands are yet to be decided. It is commonly believed that 100 GHz to 1THz may be a suitable band and use of Artificial Intelligence will be a key feature. It is expected that 6G will be deployed in 2030s.
7. **6 GHz band:** The spectrum in 5,925 MHz -7,125 MHz, often in news due to competing interest groups to either de-license it for ISM uses or reserve it for IMT. Many nations have de-licensed it fully for unlicensed use, like USA, but most European nations have partly de-licensed it and partly reserved for IMT.
8. **Absorption:** The irreversible conversion of the energy of an electromagnetic wave into another form of energy as a result of wave interaction with matter (IEEE). Above 20 GHz, in the millimeter wave band, other atmospheric gases begin to absorb the waves, limiting practical transmission distances to a kilometer or less. Above 300 GHz, in the terahertz band, virtually all the power is absorbed within a few meters, so the atmosphere is effectively opaque.
9. **Access Frequencies:** The range of frequencies used for communication between user equipment such as mobile phones and the base stations, as compared to backhaul frequencies used for communication between base stations.
10. **Access Point:** A wireless access point (WAP) is a networking device that allows a Wi-Fi compliant device to connect to a wired network. The WAP can either be physically connected to a router or be integrated into the router itself.

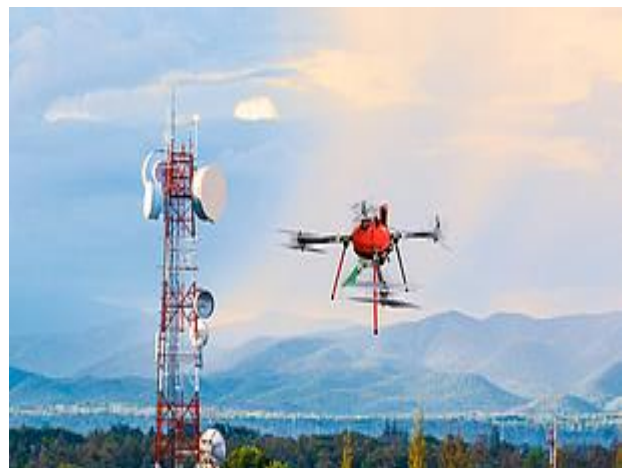




11. **Access Services:** A telecommunication service provided to subscribers by means of a telecommunication system for the conveyance of voice or non-voice messages through wired or wireless telegraphy on the network of the Access Service Provider. The subscriber shall have identity indicated by a number or any other address.
12. **Access Spectrum:** It means the Radio Frequency Spectrum allotted for use to carry voice or non-voice messages from subscriber terminal to the Base Station/designated point of aggregation.
13. **Active Satellite:** A satellite carrying a station intended to transmit or retransmit radiocommunication signals. Unlike the passive satellites, active satellites intensify the transmitted signals before re-transmitting, it returns to Earth. Passive satellites were the most primitive communication satellite, but today, the majority of them are active satellites.
14. **Activity Requirement:** The percentage of the Bidder's Eligibility Points (rounded up to the nearest whole number) that determines the level of activity that a Bidder must meet in that Clock Round in order to maintain its eligibility in the following Clock Round. This threshold is referred to as the Bidder's Activity Requirement in that Clock Round.
15. **Administration:** Any governmental department or service responsible for discharging the obligations undertaken in the Constitution of the International Telecommunication Union, in the Convention of the International Telecommunication Union and in the Administrative Regulations.
16. **Administrative Approach:** The command-and-control

model where the government has overall control and allots frequency is termed as administrative approach of spectrum assignment such as FCFS, beauty contest. Th approach is quite subjective and may easily fail to match demand and supply factors.

17. **Administrative Incentive Pricing:** A fee charged from the users of the spectrum to promote efficient usage of spectrum. The user may have an incentive to rather submit the unused spectrum than pay the fee. The figure is largely driven by the opportunity costs of the spectrum which is itself determined by the value of spectrum for a user with other service or the additional costs to be incurred for alternate means.
18. **Aggregate Demand:** The total number of Bids for the Blocks in the license service area at a value equal to the Clock Round price in the last completed Clock Round.
19. **Aggregation Risk:** It arises when a spectrum bidder needs to secure two spectrum bands to offer a particular service, but there is a risk they may only secure one which will fail to meet their need and therefore be worth less than they would otherwise have paid.
20. **Airborne Monitoring:**
It is a complementary method of spectrum monitoring which is independent of channel environment, allows wide coverage but also has higher cost. It usually is used on airplanes but recently drones are becoming popular vehicles due to less costs.



21. **Allocation:** It refers to decision on what services are to be offered or operated in a specific band. It is done by ITU and reviewed at WRCs where re-allocations can be done. Allocations are done with primary and secondary services. So, basically it is the entry in the Table of Frequency Allocations of a given frequency band for the purpose of its use by one or more terrestrial or space radiocommunication services or the radio astronomy service under specified conditions.
22. **Allocative efficiency:** It means maximizing social value through the allocation of scarce resources (such as spectrum) to those users who will best deploy them.
23. **Allotment:** It means the entry of a designated frequency channel in an agreed plan, adopted by a competent conference, for use by one or more administrations for a terrestrial or space radiocommunication service in one or more identified countries or geographical areas and under specified conditions. So, allotment is done after allocation.
24. **Amateur Service:** A radiocommunication service for the purpose of self-training, intercommunication and technical investigations carried out by amateurs, that is, by duly authorized persons interested in radio technique solely with a personal aim and without pecuniary interest. Hams are a typical example of this kind of service.
25. **Angle of Arrival (AOA):** A traditional and popular method of locating a transmitter by determining the direction of propagation of a radio-frequency wave incident on an antenna array under many circumstances.

26. **Asia Pacific Tele-community:**

Also called as APT, it is an intergovernmental organization established in 1979 with the aim of promoting ICT development in the Asia-Pacific region. APT has 38 members administrations (“Member”), 4 administrations who are under the category of “Associate Members”, and 135 private companies and academia (“Affiliate Members”) whose works are relevant to ICT field.



27. **Assignment:** The grant of a frequency band/ spot by the national regulator or the government to a particular corporate or user. It is different from allocation and can be done by beauty contests or auctions. So, basically it is the authorization given by an administration for a radio station to use a radio frequency or radio frequency channel under specified conditions.

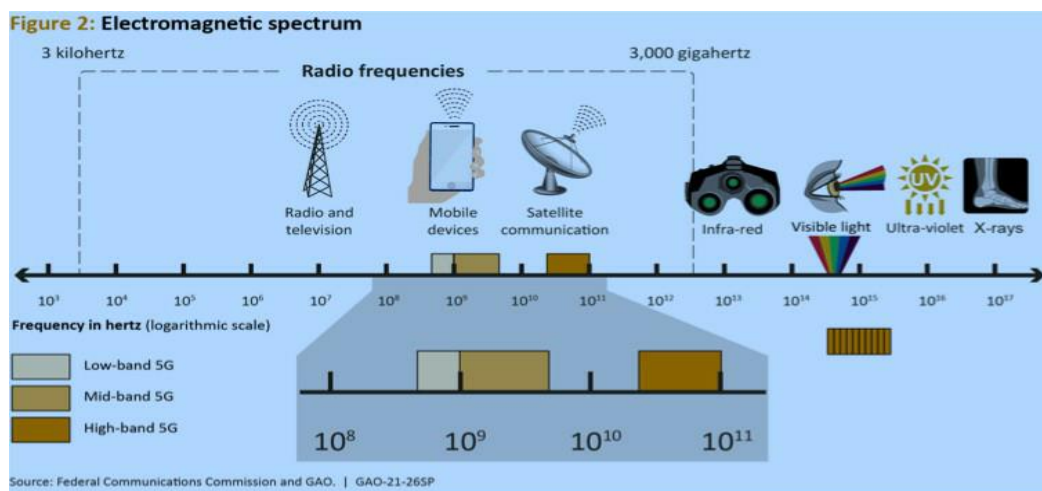
28. **Attenuation:** The decrease in amplitude of a field with the distance or with changes in the propagation path in excess of the decrease due to geometrical spreading. So, it limits the range of radio signals and is affected by the materials a signal must travel through (e.g., air, wood, concrete, rain).

29. **Auction:** A market driven mechanism to assign spectrum to a specific user with rights for certain time period. There are various formats like Japanese auctions, Dutch auctions, Combinatorial Clock auction, Simultaneous Multi Round Auction.

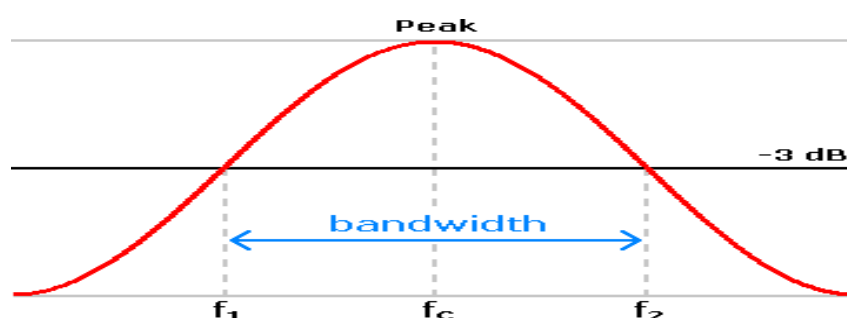
30. **Auction Theory:** A branch of market design applying game theory that practitioners draw on when designing real-world

auctions because it analyses bidders' incentives in response to different auction designs and can characterize the potential resulting outcomes in terms of economic efficiency, revenue, and bidder profits.

31. **Augmented Reality:** An interactive technology that combines the real world with computer-generated 3D content. AR can use multiple sensory modalities, including visual, auditory, haptic, somatosensory, and olfactory. It often uses a smartphone's camera to add digital elements to a live view, such as text, graphics, and audio.
32. **Band:** A discrete block of spectrum that can be allocated for certain use and can be assigned by national regulators to specific operator.



33. **Bandwidth:** Range of frequencies that have a particular use or characteristics, measures in Hertz.



34. **Base Earth Station:** An earth station in the fixed-satellite service or, in some cases, in the land mobile-satellite service, located at a specified fixed point or within a specified area on land to provide a feeder link for the land mobile-satellite service.

35. **Base Station:** It means a fixed radio transmitter/receiver station, which provides a link between the Mobile Station and Mobile Switching Centre.

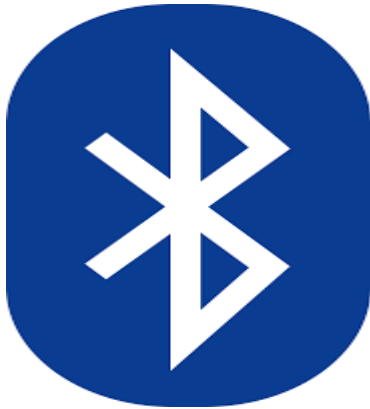


36. **Beauty contest:** Administrative method of assignment of frequency spectrum as opposed to competition-based auction. Here a regulator issues a spectrum license after listening to all proposals and then choosing the one which offers the greatest benefit.

37. **Benchmarking:** A technique to arrive at the fair price of the spectrum. It uses the results of similar auctions in other markets to estimate the expected value of a spectrum band.

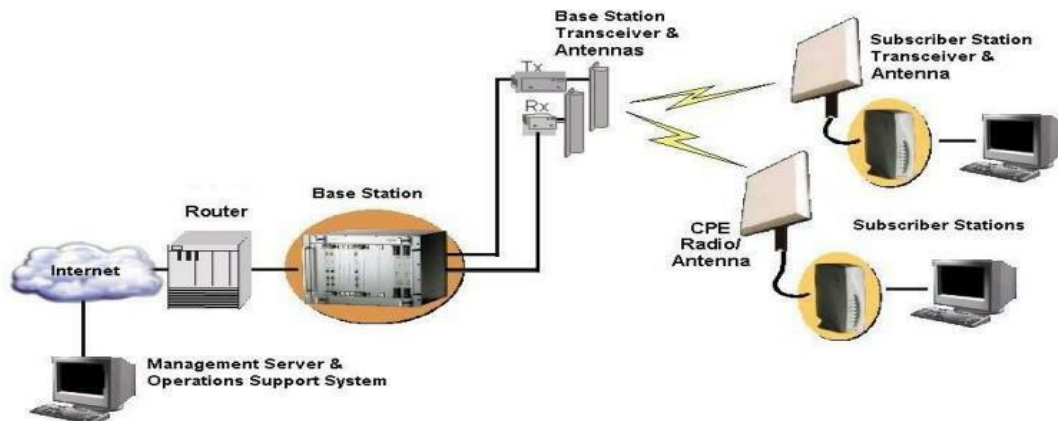
38. **Bid Shading:** A company lowering its bid amount below its intrinsic value in order to reduce the price paid if it wins. Bid shading is used for one of two purposes. In a common value auction with incomplete information, bid shading is used to compensate for the winner's curse. Bid shading is also used in first-price auctions, where the winning bidder pays the amount of his bid. If a participant bids an amount equal to their value for the good, they would gain nothing by winning the auction, since they are indifferent between the money and the good.

39. **Bluetooth:** It is an unlicensed consumer device that is used for very short-range wireless personal area networks (WPANs). Bluetooth uses 2.4 GHz spread spectrum frequency hopping



technology, and is included in devices such as mobile, radio, telephones, laptops, personal computers, printers, and personal digital assistants (PDAs). The name comes from a Scandinavian king who wished to unify many tribes, Bluetooth was seen as a unifying platform for various wireless technologies.

40. **Broadcasting service:** A radiocommunication service in which the transmissions are intended for direct reception by the general public. This service may include sound transmissions, television transmissions or other types of transmission.
41. **BTS:** Base Transceiver Station, it is a fixed radio transceiver in any mobile network. The BTS connects mobile devices to the network. It sends and receives radio signals to mobile devices and converts them to digital signals that it passes on the network to route to other terminals in the network or to the Internet. In 4G networks, it is called as evolved Node B.
42. **Bundled Spectrum:** Till 2012, the spectrum was given with service provider license, as there was no separate mechanism to assign it. However, later spectrum was de-linked from license.
43. **BWA:** Broadband Wireless Access, a technology that provides high-speed wireless Internet access or computer networking access over a wide area. It can have fixed and mobile broadband. The following schematic shows a typical BWA network architecture.

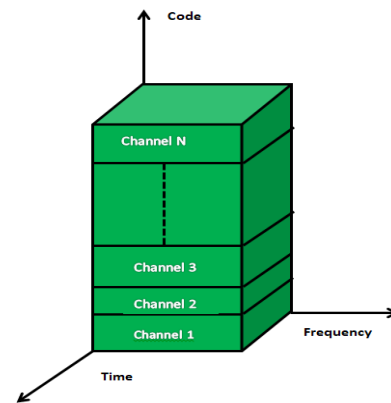


44. **C- Band:** A part of electromagnetic spectrum in 4.0 GHz to 8.0 GHz, used for satellite communications, radar and weather systems. Typically, antennas operating in C-Band have sizes of 1.8m to 2.4 m. There are use cases being done for 5G in C-Band as well, as it can support high speeds and low latency.
45. **Capacity Spectrum:** Higher-frequency spectrum bands that are especially suitable for providing additional network capacity, because radio signals generally have more data-carrying capability, the higher the frequency.
46. **Captive Non-Public Network:** CNPN, it means a terrestrial wireless telecommunication network established for captive use within a specified geographical area. Such networks cannot be used for providing commercial telecommunication services.
47. **Carrier Aggregation:** A technique used in wireless communication to boost data speeds. It uses multiple carriers simultaneously to create a wider channel. In other words, multiple frequency blocks are assigned to the same user. The effect is increased data throughput and reduced latency.
48. **Carrier Power:** The average power supplied to the antenna

transmission line by a transmitter during one radio frequency cycle taken under the condition of no modulation. This definition does not apply to pulse modulated emissions.

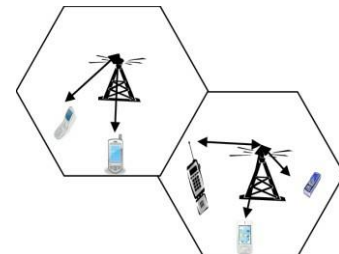
49. **CDMA:** Code Division

Multiple Access is a technique of allowing multiple users to send their information over a channel, as compared to TDMA and FDMA. The users are allowed to send information in different encoded formats generated by spread spectrum technique. It is analogous to a situation where multiple people are speaking at the same time and in the same pitch but in different languages. It encompasses IS-95 and CDMA 2000 standards representing 2G and 3G services.



50. **Cell:** A typical hexagonal

geographical area served by a station for wireless telegraphy which is dedicated to transmitting or receiving Messages which have been or are to be conveyed by



telecommunication systems designed or adapted to, and capable of being used while in motion situated for the time being in that area.

51. **Channel:** The amount of spectrum used for the transmission of a radio signal. For example, a 2G (GSM) channel is 200 kHz wide, a 3G (WCDMA) channel is 5 MHz wide and a 4G (LTE) channel can be up to 20MHz wide.

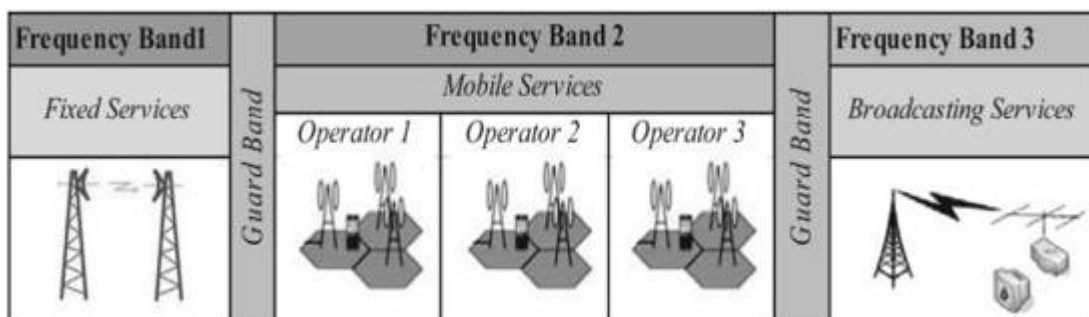
52. **Class of emissions:** The set of characteristics of an emission, designated by standard symbols, e.g., type of modulation of the main carrier, modulating signal, type of

information to be transmitted, and also, if appropriate, any additional signal characteristics. For example, F3E for frequency modulated broadcast emission.

53. **Clock Auction:** An auction format where the auctioneer specifies the prices for each lot category, and bidders place bids for the quantities they want at those prices. There is no time limit as such for the auction process.
54. **Closed User Group:** A supplementary service provided by mobile operators to mobile subscribers who can make and receive calls or messages from any member associated with the group. It is allowed for certain categories of business association.
55. **CMTS:** Cellular Mobile Telephone Service, it is a telecommunication service provided through a radio network distributed over geographical areas called Cells, each served by at least one Base Station. The radio frequencies used to connect the mobile stations to telecom systems are designed to be assigned automatically and hand-off is also allowed. In India, CMTS was introduced in 1994.
56. **Coase Theorem:** A legal and economic theorem developed by Ronald Coase regarding property rights. IT basically says that bargaining between individuals and groups related to property rights will lead to an optimal outcome and efficient outcome. For this to occur, there must be competitive markets with zero transaction costs. He extended this concept to spectrum treating it as property and argued for its auction to the highest bidder with freedom of usage.
57. **Cognitive Radio:** A radio that can be programmed to have dynamic configuration capabilities to use the best channels in its vicinity. The objective is to avoid interference and congestion.

Such a radio automatically detects available channels and then sets its parameters for better spectrum management. The term was coined in 1999 by Joseph Mitola to describe a reconfigurable radio.

58. **CoDec:** A Coder-DECoder converts analog signals, (voice or video), into digital form (1 or 0) for transmission over a digital medium and, upon reception at a second codec, reconverts the signals to the original analog form. Two codecs are needed - one at each end of the channel.
59. **Command & Control:** The traditional method of spectrum allocation where the spectrum is divided into bands and allocated to specific services like radio, mobile satellite, etc. The advantage is interference free environment but the downside is inefficient usage of a limited resource. The allocations can be by administrative approach, auction or de-licensed.



60. **Combinatorial Auction:** A type of auction in which participants can place bids on combinations of discrete heterogeneous items, or “packages”, rather than individual items or continuous quantities. It is used when bidders have non-additive valuations on bundles of items. If there are multiple rounds and at the end of each round, bidders can bid for different combinations of licenses, it is called Combinatorial Clock Auction.

61. **Community Reception:** The reception of emissions from a space station in the broadcasting-satellite service by receiving equipment, which in some cases may be complex and have antennae larger than those used for individual reception, and intended for use either by a group of the general public at one location; or through a distribution system covering a limited area.
62. **Compensation Principle:** It is a decision rule used to select between pairs of alternative feasible social states. It states that if the prospective gainers could compensate prospective losers and leave no one worse off, the alternate state is to be selected. The idea of compensation principle is used to evaluate the success of spectrum auction.
63. **Complements:** Items for which the whole is worth more than the sum of the parts, yielding synergy value so that acquiring the first item increases the willingness to pay for the second. The blocks of spectrum put on auction evince interests from participating bidders based upon the complementary value.
64. **Concealed monitoring:** A spectrum monitoring method that uses hidden antenna like antenna installed on roof of vehicle or backseat window.
65. **Conform Assignment:** The assignment of a frequency band in the Master Register of ITU can be either conform or non-conform assignment. The conform assignment means that the frequency assignment is with a favorable finding under ITU's Radio Regulations and will have a right to international recognition. So, the other administrations shall take this into account when making their own assignments, in order to avoid harmful interference.
66. **Contiguous spectrum:** Adjoining spectrum frequencies,

which can usually be deployed more efficiently because of the way wireless technology is optimized.

67. **Coordination Area:** When determining the need for coordination, the area surrounding an earth station sharing the same frequency band with terrestrial stations, or surrounding a transmitting earth station sharing the same bidirectionally allocated frequency band with receiving earth stations, beyond which the level of permissible interference will not be exceeded and coordination is therefore not required.
68. **Cost-Benefit Analysis:** It is a systematic approach to estimating the strengths and weaknesses of alternatives and hence, to determine options which provide the best approach to achieving benefits while preserving savings. Thus, it gives a framework to compare the options available and is used to evaluate the behavior of competing players.
69. **Coverage Spectrum:** The lower-frequency spectrum bands that are especially suitable for providing wide area network coverage, because radio signals generally travel further, the lower the frequency.
70. **Crowdsourcing monitoring:** A spectrum monitoring method that uses public vehicle or people to obtain comprehensive and massive field strength data and then do massive data processing. For example, a person carrying antenna in his bag, or an antenna on vehicle top.
71. **Densification:** Augmenting the capacity of a mobile network by increasing the number of base stations or cells in a given geographic area.
72. **Diffraction:** The deviation of the direction of energy flow

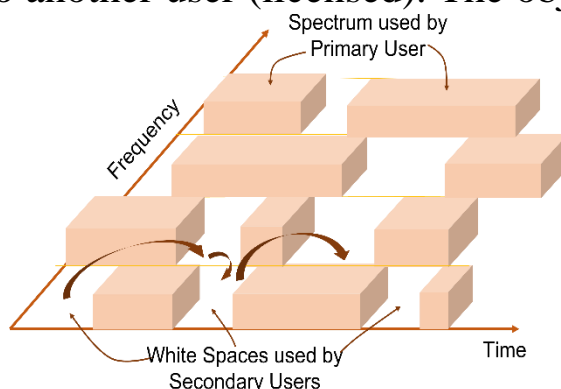
of a wave when it passes an obstacle, a restricted aperture, or other inhomogeneities in a medium. It is different from reflection or refraction.

73. **DTH:** Direct to Home, a method of receiving satellite television by means of signals transmitted from direct broadcast satellites. This was approved in India in 2000 and India is the largest DTH market in the world. DTH network has broadcasting center, satellites, encoders, multiplexers, modulators, etc.

74. **Dutch Auction:** Also called descending price auction, it is a type of auction in which an auctioneer starts with a very high price, incrementally lowering the price until some participant accepts the price or reserve price is reached.


75. **Duplex operations:** A kind of transmission method in which transmission is possible simultaneously in both directions of a telecommunication channel. So, it leads to better use of resources and simultaneous communications.

76. **Dynamic Spectrum Access:** It allows a new user (unlicensed) to access spectrum which has been already allocated to another user (licensed). The objective is real-time cooperative



optimization of spectrum resources. The software defined radio or the cognitive radio makes this possible. One use case is Underlay spectrum access where both licensed and unlicensed users can simultaneously transmit

provided the service quality of the licensed user does not degrade. Another is the overlay spectrum access where the unused license spectrum is being used by the unlicensed users.

77. **EDGE:** Also called as 2.75G or Enhanced Data Rates for GSM Evolution, it is the fastest 2G service with speeds up to 384 kbps. It represents a 3x better performance over GSM by better data encoding and can be used for any packet-switching application. 
78. **Electromagnetic Compatibility (EMC):** The condition that prevails when telecommunications equipment is performing its individually designed function in a common electromagnetic environment without causing or suffering unacceptable degradation due to unintentional electromagnetic interference (EMI) to or from other equipment in the same environment.
79. **Eligibility Points:** The number of points associated with a Block per LSA based on the Reserve Price of spectrum in that particular LSA. This is done to ensure application of activity rules. The initial Eligibility Points for each bidder would be determined by the amount of EMD which they have submitted to the Government. At no stage in the auction shall they be allowed to bid for more LSAs than the initial eligibility points corresponding to the EMD will permit. The initial Eligibility Points of bidders and the identities of bidders participating in the auction will be made public.
80. **eMBB:** It means Enhanced Mobile Broadband, one of the three services for 5G identified by 3GPP. It to provide higher data rates, better bandwidth, higher throughput, increased reliability and lower latency as well as improved multimedia functionality for the end user. It will help new high-definition video streaming, immersive augmented reality and virtual reality on the go.
81. **English Auction:** Also called as Open Outcry Ascending

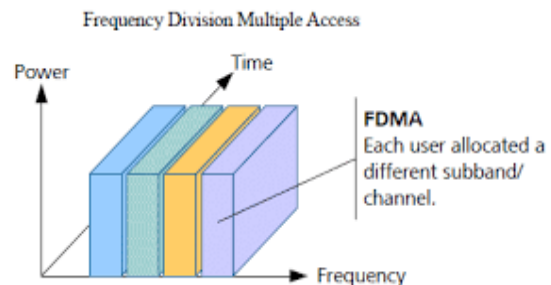
Price bid, here the price is successively raised until only one bidder remains, and that bidder purchases the auctioned item at a price equal to the final bid. The initial price is the reservation price.

82. **Entry fee:** The prescribed non-refundable amount of fee to be paid before signing of license agreement to provide authorized Services in a Service Area. For example, Entry Fee is Rs. 15 crores for UL, Rs. 2.5 crores for NLD license.
83. **Excess Demand:** The total number of blocks for which bids have been received in a license service area in a particular band at a Clock Round price equal to the Clock Round price set in the last completed Clock Round minus the number of blocks available in that license service area in that particular band. It does not count any bids made at a price strictly lower than the Clock Round price of the last completed round. Based upon the negative or non-negative value of excess demand, the clock round prices for the next clock round are set.
84. **Exclusive License:** A licensee having the sole right to make radio transmissions in the specified frequencies and locations (usually subject to technical conditions that manage the risks of interference with neighboring users).
85. **Extension Budget:** To guard against technical problems and provide bidders with some additional flexibility in making bidding decisions, Bidders are provided with limited opportunities to extend a Clock Round and defer submission of a bid. Each Bidder is allocated an Extension Budget of 6 hours. The reductions from the Extension Budget are to be carried out for the extended duration consumed; with parts rounded up.
86. **Fading:** The temporal variation of received signal power

caused by changes in the transmission medium or path(s).

87. **FCFS:** First Come First Served, a policy followed by Government of India in allocation of 2G spectrum in 2008. Later it was quashed by the Supreme Court in favor of public auction. Though the process is followed for administrative assignment of spectrum for non-commercial uses and at fixed spectrum charges. In such cases, first a letter of intent is issued, followed by frequency assignment and wireless operating license.

88. **FDMA:** Frequency Division Multiple Access, is a shared channel access technique where the users get different frequency bands to transmit their information. So, the available bandwidth is divided into slots for each user. It is analogous to a situation where multiple people are speaking at the same time and in the same language but in different pitch.



89. **FDD:** Frequency Division Duplex, means two separate frequency bands or channels for uplink and downlink, as opposed to TDD which uses the same link but at different times. FDD is used in microwave links, 2G, 3G and 4G.

90. **Feeder Link:** A radio link from an earth station at a given location to a space station, or vice versa, conveying information for a space radiocommunication service other than for the fixed-satellite service. The given location may be at a specified fixed point, or at any fixed point within specified areas.

91. **Fixed HF Monitoring Receiver:**

A monitoring receiver device that allows high performance spectrum monitoring in the HF band 3 kHz to 30 MHz.

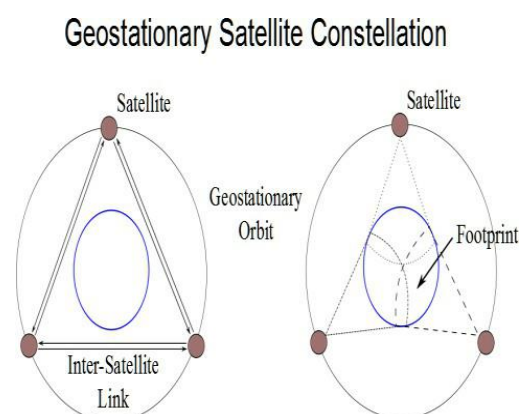


92. **Fixed Satellite Services (FSS):** A radiocommunication service between earth stations at given positions, when one or more satellites are used; the given position may be a specified fixed point or any fixed point within specified areas; in some cases, this service includes satellite-to-satellite links, which may also be operated in the inter-satellite service; the fixed-satellite service may also include feeder links for other space radiocommunication services.

93. **Footnotes:** They are an integral part of the Table of Frequency Allocations in the Radio Regulations and, as such, form part of an international treaty text. There are country footnotes as well which are specific to a nation. These footnotes qualify a particular use of frequency bands. The Indian National Frequency Allocation Plan has international footnotes and Indian footnotes (prefixed with IND).

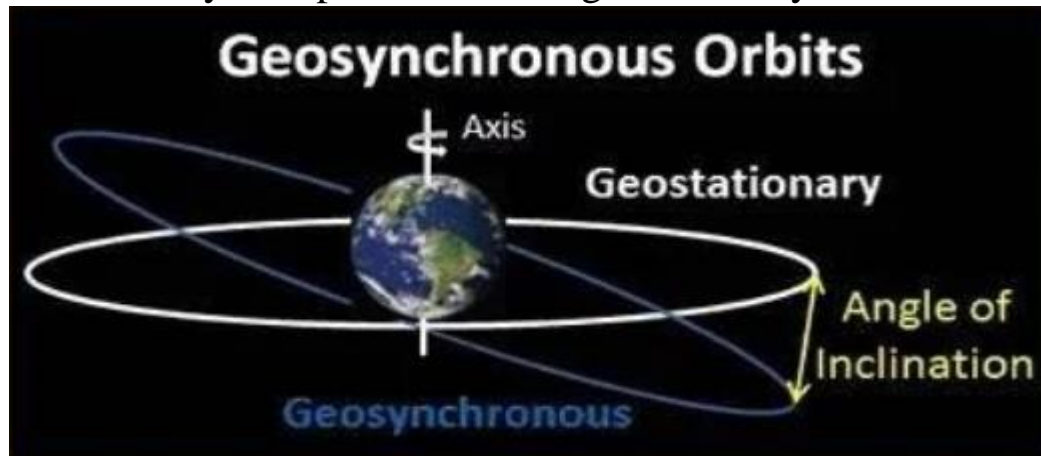
94. **Frequency Difference of Arrival:** An effective method of locating a transmitter in motion or locating a transmitter by a mobile monitoring station, especially an airborne one. Sometimes rapidly selecting signals from different antennas of a monitoring receiving antenna array has similar effectiveness with relative motion between transmitter and monitoring station. This relative motion results in different Doppler shifts, which can be used to calculate transmitter location with knowledge of vector velocities.

95. **Frequency Hopping:** This is a modulation technique that is employed in the spread spectrum signal transmission. It involves the continuous switching of frequencies in the process of radio transmission. This reduces the chances of interception or jamming of signals.
96. **Frequency Tolerance:** The maximum permissible departure by the center frequency of the frequency band occupied by an emission from the assigned frequency or, by the characteristic frequency of an emission from the reference frequency. The frequency tolerance is expressed in parts in 10^6 or in hertz.
97. **Game theory:** A mathematical field in economics used in auction theory, to illuminate strategic behavior and to study conflict and cooperation. The interdependence of each player makes each player consider the moves made or to be made by the others.
98. **Gain Ratio of Arrival (GROA):** It is an energy-based passive method that can be used to estimate the positions of the source from multiple sensors. This method does not require accurate time synchronization between sensors. A particular value of GROA estimate defines a circle between the two receivers on which the radio transmitter may exist.
99. **Geostationary satellite:**
A geosynchronous satellite whose circular and direct orbit lies in the plane of the Earth's equator and which thus remains fixed relative to the Earth; by extension, a satellite which remains approximately



fixed relative to the Earth.

100. **Geosynchronous Satellite:** An earth satellite whose period of revolution is equal to the period of rotation of the Earth about its axis. So, such a satellite returns to the same position in the sky after each day. Its special case is a geostationary satellite.



101. **Gilder's Law:** An observation made by George Gilder in the 1990s that the total bandwidth of communication systems will triple every year, leading to an exponential increase in network capacity.
102. **GMPCS:** Global Mobile Personal Communications by Satellite, means any satellite system whether it is fixed or mobile, broadband or narrowband, geostationary or non-geostationary, that provides telecommunication services directly to end users from a single or a constellation of satellites.
103. **GPRS:** It is basically packet switching data service overlaid on GSM infrastructure. Also called as 2.5G and used on 2G networks, it allows data speed of 56-114 kbps. It uses GMSK modulation (same as GSM) but is packet switched unlike circuit switched GSM. It bills as per the volume of the data transferred.

104. **GSM:** Global System for Mobile Communications is a standard developed for 2G networks and protocols. It is trademark owned by GSM Association. It mostly works in 900 MHz and 1800 MHz bands with TDMA and FDMA. It was developed by the European Telecommunications Standards Institute and was first implemented in Finland in 1991. It was designed as digital, circuit switched network for full duplex operations. It gradually developed into GPRS and EDGE.



105. **HetNet:** Heterogenous networks, is a modern mobile network comprising of combination of different cell types and different access technologies. It can use a combination of UMTS and GSM with modern radio access of LTE and then also compliment with Wi-Fi. So, basically, it is the integration of various network types, including radio access networks, macro sites, in-building wireless systems, and Wi-Fi, to establish a unified and efficient network infrastructure. The objective is to enhance network coverage while also lowering power consumption and improving spectral efficiency.



106. **High Altitude Platform Station (HAPS):** A radio station located on an object at an altitude of 20 to 50 km and at a specified, nominal, fixed point relative to the Earth. It is also called as Atmospheric Satellite, can potentially provide both fixed broadband and transmission links. It is a candidate for IMT Base station. It can be a great asset for

disaster mitigation as it can be quickly deployed and needs minimum ground infrastructure.

107. **Hotspot:** A hotspot is a physical location where people can access the Internet, typically using Wi-Fi, via a wireless local area network (WLAN) with a router connected to an Internet service provider. A hotspot can be in a private location or a public one.



108. **HSPA:** High Speed Packet Access, it is an enhancement to WCDMA (3G) and also called as 3.5G. It allows faster data connections and encompasses downloads (HSDPA, 14 MBPS) or uploads (HSUPA, 5.76 MBPS). Later it was upgraded to HSPA+ or evolved HSPA.

109. **IMEI:** International Mobile Equipment Identity is a unique identification code for each mobile device, 15 digits code with values from 0 to 9. India has banned import of mobile handsets without IMEI codes.

110. **IMT:** International Mobile Telecommunications, a generic term used by the ITU community to designate broadband mobile systems. It encompasses IMT-2000, IMT- Advanced and IMT-2020 collectively, representing 3G, 4G and 5G services.

111. **Incentive Auction:** A two-sided auction where holders of items, e.g. spectrum rights, sell them in a 'reverse auction' and buyers purchase them in a 'forward auction', coordinated by the regulator acting as a clearinghouse.

112. **Incrementalism:** An approach to decision-making using successive limited comparisons or small changes from the pre-existing position (in contrast to considering all possible options

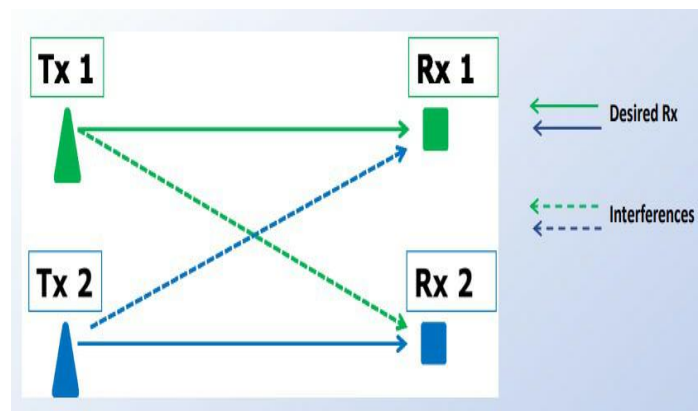
with a blank slate).

113. **Infrastructure providers:** A company registered to provide either end-to-end bandwidth to telecom service providers (called as IP-II) or provide active elements of the telecom networks like dark fiber, right of way, towers, etc. (called as IP-I).

114. **Intrinsic Value:** Sometimes also referred to as use value, an operator's value from using the spectrum, which is the difference in its expected profit with and without that spectrum, e.g. from commercial or technical value (without weakening the downstream competitive process, and so excluding any strategic investment value).

115. **ISM:** Industrial, Scientific and Medical which means operation of equipment or appliances designed to generate and use locally radio frequency energy for industrial, scientific, medical, domestic or similar purposes, excluding applications in the field of telecommunications.

116. **Interference:** The Radio Regulations define it "as the effect of unwanted energy due to one or a combination of emissions, radiations or inductions upon reception in a radiocommunication



system, manifested by any performance degradation, misinterpretation, or loss of information which could be extracted in the absence of such unwanted energy." The sources of interference can be background noise, receiver parameters,

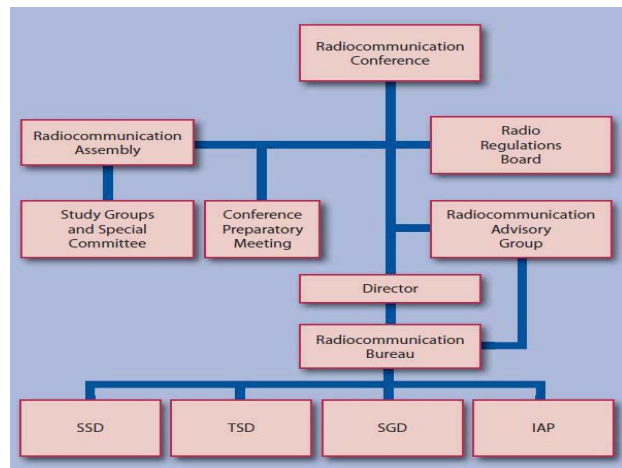
intermodulation, etc. all of which are further categorized into generic categories for modelling.



117. **ITU:** International Telecom Union, a specialized agency of United Nations for the Information and Communication technologies. It was founded in 1865 and has 193 member states and thousands of companies, universities, regional organizations etc. The key work areas are allocation of global radio spectrum doe wireless services, coordination of world satellites and develop technical standards and facilitate international connectivity.

118. **ITU-D:** One of the three organs of ITU, it works to close the digital divide and drive digital transformation to leverage the power of ICTs for economic prosperity, job creation, digital skills development, gender equality, diversity, a sustainable and circular economy, and for saving lives. Its work prioritizes those most in need- from people living in the world’s Least Developed Countries to marginalized communities everywhere.

119. **ITU-R:** One of the three organs of ITU, it deals with global management of radio frequency spectrum and satellite orbits, with the purpose to ensure the rational, equitable, efficient and economical use of the radio-frequency spectrum.



The primary instruments of its governance are Radio Regulations and Regional Agreements which are updated by World and Regional Radiocommunications Conferences.

120. **ITU-T:** One of the three organs of ITU, which works to

develop international standards known as ITU-T Recommendations which act as defining elements in the global infrastructure of information and communication technologies (ICTs). These standards aim to create a level playing field which provides access to new markets. They are an essential aid to developing countries in building their infrastructure and encouraging economic development, and through economies of scale, they can reduce costs for all: manufacturers, operators and consumers. These standards are driven in a contribution led, consensus-based manner.

121. **ISP**: Internet Service Provider, a license through which the licensee can buy bandwidth from the telecom companies and provide internet subscribers with internet access. Category A ISPs have all India coverage, Category B has broadly a state coverage or strictly a service area coverage; and lastly category C covers a secondary switching area.
122. **Japanese Auction**: It is also called Ascending Clock Auction where the auctioneer begins at a low price and only the other auctioneers willing to pay it proceed to the next round when the price is raised again and the process is repeated until only one remains.
123. **Licensed Shared Access**: An approach of in spectrum management whereby a license owner can allow access to its spectrum in some areas or at some times when the spectrum is not being used. Usually, it is against some compensation. Thus, this approach ensures that spectrum is efficiently used and demand is matched with supply.
124. **Licensed Spectrum**: The spectrum block needing a license from the government or the regulator for operation by a specific service provider. Most of the spectrum is licensed as per

geographical area and usage characteristics. Like 900 MHz band for 2G. It may be contrasted with the unlicensed band where no explicit authorization is needed, like Wi-Fi.

125. **Lot:** In spectrum auctions, lots are blocks of spectrum in specified bands and defined geographic areas. The term generically means the items offered in an auction.
126. **LTE:** Long Term Evolution, or the 4G wireless standard that provides increased network capacity and speed, along with reduced latency and backwards compatibility with GSM (2G) and UMTS (3G). Technically speaking, LTE can be called 3.95G as it is slightly slower than 4G.
127. **LTE Advanced:** It is an upgrade over the LTE standards and was submitted as a candidate for 4G to ITU-T in 2009. It was further standardized by 3GPP to ensure global roaming, smooth handover between networks, and interoperability with existing wireless standards.
128. **Market Discovered Pricing:** One of the spectrum valuation techniques used by TRAI, where the prices discovered in the last auction can be taken as one of the values of spectrum in the respective band for the forthcoming auction, duly indexed since these are more than one year old.
129. **Maritime Mobile Services:** A mobile service between coast stations and ship stations, or between ship stations, or between associated on-board communication stations; survival craft stations and emergency position-indicating radio beacon stations may also participate in this service.
130. **MIFR:** Master International Frequency Register, also called the Master Register, it contains frequency assignments together

with their particulars as notified to the ITU in accordance with Article 11 of the Radio Regulations (RR). Thus, basically it is the ITU database. The recording of a frequency assignment in the Master Register is preceded by various examinations so as to determine the conformity of the concerned frequency assignment with those conditions that could determine its status. Also, the recording in the Master Register does not mean an end of activities of the notifying administration in respect to the concerned frequency assignment. The assignments can be conformed and non-conform assignments.

131. **MIMO**: Multiple Input Multiple Output is a method of using multipath propagation to augment the capacity of a radio link. Here many antennas are used for reception and transmission. It is used in Wi-Fi 4, WiFi5, HSPA and LTE. It helps achieve higher data rates, increased coverage, and improved reliability.

132. **Massive MIMO**: It is a multi-user MIMO technology that can provide proper service in high-mobility environments. The key idea is to provide many antennas in the base stations and these serve many users at a time. The word massive doesn't mean big size, just the larger number of antennas. The standard MIMO has 2-4 antennas only while the massive MIMO can have hundreds. It operates in TDD mode and is scalable with number of the base station antennas.

133. **Microwave Bands**:

Microwaves travel by line-of-sight and do not diffract around hills, follow the earth's surface as ground waves, or reflect from the ionosphere. So, their

| | |
|---------|---------------|
| L Band | 1 to 2 GHz |
| S Band | 2 to 4 GHz |
| C Band | 4 to 8 GHz |
| X Band | 8 to 12 GHz |
| Ku Band | 12 to 18 GHz |
| K Band | 18 to 27 GHz |
| Ka Band | 27 to 40 GHz |
| V Band | 40 to 75 GHz |
| W Band | 75 to 110 GHz |

travel limit is visually defined up to 60 km. Some common examples are radar, relay networks, collision avoidance, microwave oven, etc.

134. **Mid-Band:** The range of spectrum in 1GHz to 6 GHz is called midband. It is considered perfect for 5G due to balance of speed, capacity, coverage, and penetration. The other two bands are called low band (can travel long distance but low speed) and high bands (travels short but high speeds).
135. **Minimum Rollout Obligations:** It means site rollout and provisioning of network services as per the pre-stipulated terms and conditions. These can be specified in licenses or in Notice Inviting Applications. The test procedures and roll out phases are determined by department.
136. **Mixed Reality:** It is a term used to describe the merging of a real-world environment and a computer-generated one. Physical and virtual objects may co-exist in mixed reality environments and interact in real time.
137. **Mm Wave:** Millimeter wave or EHF (Extremely High Frequencies) having high frequencies above 30 GHz till 300 GHz. They offer low coverage and high bandwidth resulting in many new use cases. Due to smaller wavelengths, the antenna used for mm Wave is also smaller.
138. **mMTC:** Massive Machine Type Communication, is one of the three core service areas of 5G. It has been created specifically to enable a huge volume of small data packets to be collected from large numbers of devices, simultaneously. This is used to connect large numbers of devices and is expected to transform the IoT industry. mMTC supports connection densities of up to one million devices per square kilometer. This is over ten times higher

than 4G LTE network capability. Smart cities are an example of such mMTC applications.

139. **Modelling:** An approach to estimate the value of spectrum by using the current cash value of the expected stream of revenues that the spectrum will bring in the future (less costs). The weakness is the heavy reliance on the accuracy of cost and revenue projections. It is one of the three methods of valuing spectrum – the others are ‘benchmarking’ and ‘opportunity cost’.
140. **Muddling through:** A model of decision-making including incrementalism, where means and ends are not distinct, and acceptable outcomes are sought through consensus-building and bargaining, taking a pragmatic approach.
141. **Modulation:** A controlled variation with time of any property of a wave for the purpose of transferring information. It can be amplitude, frequency or phase modulation, each having unique advantages in signal transmission.
142. **Multi Satellite Link:** A radio link between a transmitting earth station and a receiving earth station through two or more satellites, without any intermediate earth station. A multi-satellite link comprises one up-link, one or more satellite-to-satellite links and one down-link.
143. **MVNO:** Mobile Virtual Network Operator, a retail provider of mobile services that does not have its own network and relies on obtaining wholesale mobile services from network operators.
144. **Near Field Communication:** It is a radio technology that operates at a short-range using the 13.56 MHz frequency. Communication between two NFC-compatible devices is activated when they are put within the proximity of about 4 cm.

NFC can be applied to mobile handsets, enabling them to interact with posters, magazines, and various products.

145. **Necessary bandwidth:** For a given class of emission, the width of the frequency band which is just sufficient to ensure the transmission of information at the rate and with the quality required under specified conditions.
146. **NFAP:** National Frequency Allocation Plan, it contains details of the frequency bands that are allocated for various technologies such as IMT (2G/3G/4G/5G), IoT, satellite communication, etc. NFAP is formulated after carrying out detailed stakeholder consultations and examining global best practices. It flows from the international Radio Regulations. The latest is NFAP 2022 based upon RR 2020 highlighting 41 services.
147. **NIA:** Notice Inviting Application, the first step of spectrum auctions in India. It has details on spectrum put on auction, eligibility criteria, license terms, payment terms, rollout obligations, etc.
148. **Network Slicing:** A technique that allows multiple logical networks over the same shared physical networks, thus, allowing multiple SLAs and dedicated use cases. Each network slice can be configured as per the needs and allow real-time flexibility.
149. **NOCC:** Network Operations Control Centre, it was set up in India to perform certain regulatory and enforcement functions in domain of satellite communications. It was created to control the transmissions from ground segment (satellite earth stations) along with the master control facility under the Department of Space to manage the operation of satellites in orbit. The objective is to provide interference free environment to various satellite

users in the country while providing mandatory clearances within three working days to applicant agencies. To enhance the ease of doing business, in 2002, DoT removed the NOCC charges for use of space segments for all services.

150. **Non-Conform Assignment:** The assignment of a frequency band in the Master Register of ITU can be either conform or non-conform assignment. The latter is frequency assignment when it is not in accordance with the Table of Frequency Allocations or the other provisions of these regulations. Such an assignment shall be recorded for information purposes.
151. **NPN:** Non-Public Network is a network deployed for private uses or dedicated set of users and can have many configurations. 3GPP defines two major configurations: Standalone NPN and Public Network Integrated NPN. India recognizes NPN as an essential part of 5G usage.
152. **NPV:** Net Present Value, is the concept used in bid amount payments. Theoretically, it is the difference between the present value of cash inflows and the present value of cash outflows over a period of time. NPV is used in capital budgeting and investment planning to analyze the profitability of a projected investment or project. An interest rate of 8.65% is used for protecting the NPVs in spectrum bid payment.
153. **Occupied bandwidth:** The width of a frequency band such that, below the lower and above the upper frequency limits, the mean powers emitted are each equal to a 0.5% of the total mean power of a given emission.
154. **OFDM:** Orthogonal Frequency Division Multiplexing (OFDM) is a method for transmitting a bulk quantity of digital

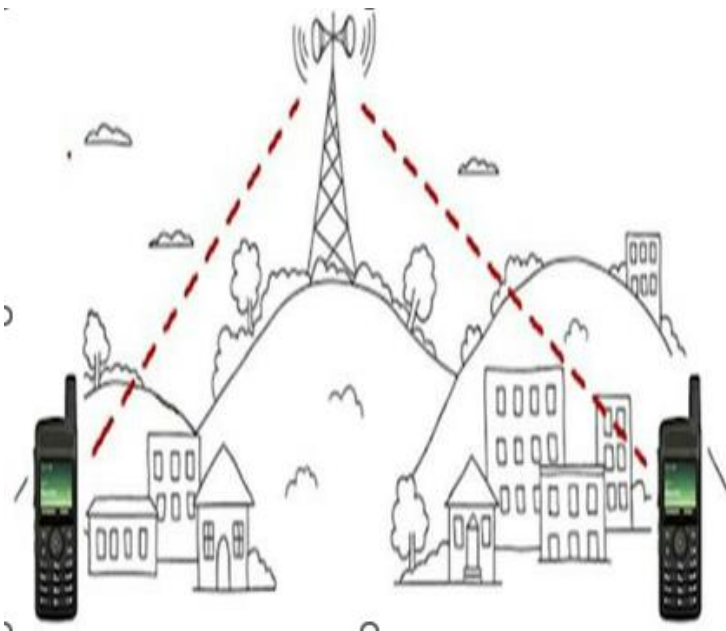
data over spectrum. The advantage of this technique is that it reduces the amount of crosstalk within signal transmission. This is done by dividing the radio signal into several sub-signals and transmitting them to the receiver at the same time using different frequencies. OFDMA provides for a multiple access on the same channel. It distributes subcarriers between all users so that everyone can transmit and receive simultaneously.

155. **Opportunity Cost:** A method of valuing spectrum that assumes that the cost of purchasing a specific band should be less than the alternative method of delivering the same capabilities. For example, a new license will give an operator a certain amount of additional network capacity which could also be achieved by deploying a certain number of additional base stations - the value of which can be easily calculated. It is one of the three methods of valuing spectrum – the others are ‘benchmarking’ and ‘modelling’.
156. **OSP:** Other Service Providers, it means an Indian company registered with the department to provide applications like tele-education, e-Commerce, call center, etc. by using telecom facilities provided by various telecom licensees.
157. **Out of Band Domain (of an emission):** The frequency range, immediately outside the necessary bandwidth but excluding the spurious domain, in which out-of-band emissions generally predominate. Out-of-band emissions, defined based on their source, occur in the out-of-band domain and, to a lesser extent, in the spurious domain. Spurious emissions likewise may occur in the out-of-band domain as well as in the spurious domain.
158. **Paired Spectrum:** A configuration where a block of spectrum in lower band and an associated block in upper band are

paired together. It is generally used in FDD.

159. **Pareto Efficiency:** It is a situation accomplished if there are no longer any ways left to make one person better-off, unless we are willing to make some other person worse-off. A good auction should strive to become Pareto efficient.
160. **Parking:** A strategy of bidding for lots in a category, not to win them but to maintain eligibility.
161. **Passive Sensor:** A measuring instrument in the earth exploration-satellite service or in the space research service by means of which information is obtained by reception of radio waves of natural origin.
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166. **PMRTS:** Public Mobile Radio Trunking Service (PMRTS) is a two-way mobile radio service in which users communicate amongst themselves in a designated group, talk through a pair of

radio frequencies which get assigned out of a common pool of frequencies in a designated frequency band. It has a unique capability of communication instantly within the closed user group (CUG) specially in the sectors of manufacturing, oil & gas, mining, construction, courier, emergency medical services, etc. A captive version is called CMRTS.



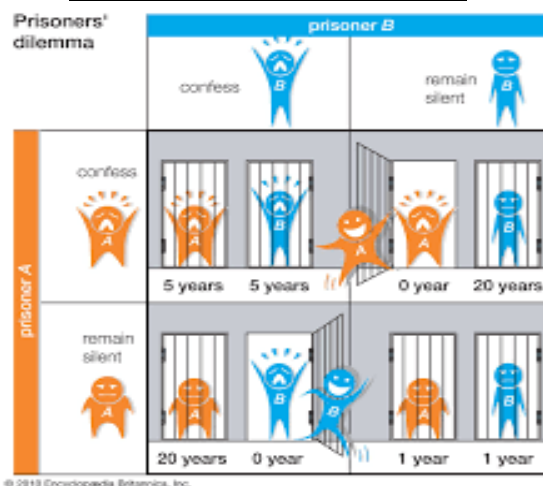
167. **Port operations Service:** A maritime mobile service in or near a port, between coast stations and ship stations, or between ship stations, in which messages are restricted to those relating to the operational handling, the movement and the safety of ships and, in emergency, to the safety of persons.
168. **Power of Arrival:** economical method of locating a transmitter because POA does not require additional monitoring receiver hardware. The power of a radio signal can be estimated according to propagation models with the knowledge of transmitter power and propagation path, especially used for standardized wireless communication systems.
169. **Price Driving:** A strategy where an operator bids above its own intrinsic value, not to win the spectrum but to increase the prices paid by its rivals.

170. **Primary Services:** The first priority of services for which spectrum is allocated. These services are written in capitals in the regulation document like Radio Regulations, NFAP. The primary services have the full right to use the allocated spectrum.

| MHz 3300-3600 NATIONAL ALLOCATION | |
|---|---------|
| INDIA | REMARKS |
| 3300-3400 RADIOLOCATION FIXED MOBILE Amateur 5.149 | IND 65 |

Red arrows point from 'IND 65' to 'National Footnotes' and from 'RADIOLOCATION' to 'Primary Services'.

171. **Prisoner's Dilemma:** It is a thought experiment of game that involves two rational agents, each of whom can cooperate for mutual benefit or betray their partner for individual reward. The quantum of rewards and penalties are such as to invoke thoughtful responses. It is used to analyze the behavior of competing



players in a spectrum auction. The whole experiment is summed as examining the behavior of two separated prisoners who have to either cooperate or defect, with incentive being higher to defect. The experiment aims to show how two rational agents will not cooperate despite it being in their best interests to do so.

172. **Producer Function Model:** One of the spectrum valuation techniques used by TRAI. It is based on the assumption that the two inputs spectrum and Base Transceiver Station (BTS) that can be substituted for each other over a range of output. It provides a reasonable approximation to equivalent cost savings on BTS conserved by deploying an additional unit of spectrum. The



Coob-Douglas production function is used for estimating the relationship between the inputs and outputs. It provides a reasonable approximation of the value per MHz of spectrum to a TSP. It was used for 1800 MHz band by TRAI.

173. **Producer Surplus Model:** One of the spectrum valuation techniques used by TRAI. It assumes that there is an inverse relationship between the quantum of spectrum allocated and the expenditure on radio access network required to serve a level of demand, and hence, the allocation of the additional spectrum to an existing service provider will create a producer surplus. So, the value of the spectrum block is arrived at by determining the opportunity of cost savings to an average service provider in network expenditure and spectrum usage charges during the period upon getting this additional spectrum.
174. **Protection Ratio:** The minimum value of the wanted-to-unwanted signal ratio, usually expressed in decibels, at the receiver input, determined under specified conditions such that a specified reception quality of the wanted signal is achieved at the receiver output.
175. **Public Safety Spectrum Trust Corporation:** It is a non-profit organization which represents the radio spectrum needs of police, fire and ambulance agencies in the United States. It was selected by the US spectrum regulator as the license for 10 MHz of 700 MHz public safety nationwide broadband spectrum.
176. **Public Value:** What is valued by the public or adds value to the public sphere, highlighting longer term outcomes and processes of value creation in the policy, authorizing, and operating environments.
177. **Radio determination:** The determination of the position,

velocity and/or other characteristics of an object, or the obtaining of information relating to these parameters, by means of the propagation properties of radio waves. It can be used for radionavigation or radiolocation.



178. **Radio network Analyzer:** A device used for IMT coverage testing of all networks at once. It allows for multi-band and multi-technology scanners for simultaneous measurements in an open- source environment. It can be used indoors and as well as drive tests.

179. **Radio Regulations:** A basic document of ITU that governs the law of nations on radiocommunication services and frequencies. It is supplement to ITU Constitution and regulate the allocated electromagnetic spectrum of 9 kHz to 300 GHz. Its purpose is to ensure interference-free operations of radiocommunication systems and to provide ITU Member States with equitable access to the radio spectrum. They contain general rules for the assignment and use of frequencies and include a Table of Frequency Allocations for the various radio services simultaneous measurements in an open- source environment. It can be used indoors and as well as drive tests.

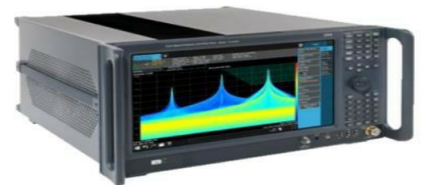
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181. **Radio Receivers:** A device used for RF signal detection and analysis. It can detect low-powered weak hidden within the envelop of strong signals.

182. **Radio Waves:** Any electromagnetic wave of any frequency below 3000 GHz, is called so or hertzian wave, as it can propagate in space without any artificial guide.

183. **Real Time Spectrum Analyzer:** It is device used for satellite monitoring up to frequency range of 26.5 GHz. It is capable of showing all the active signals in real time in a span, as compared to the swept-tuned spectrum analyzer where results are shown sequentially not real-time.



184. **Regional Licensing Office:** Some licensing functions of WPC Wing was decentralized in the year 2007 and delegated to 5 Regional Licensing Offices (RLOs) situated at New Delhi, Mumbai, Kolkata, Chennai & Guwahati. These work under the control of WPC HQ, New Delhi and deal with the issue and renewal of non-network licenses.

185. **Reference frequency:** A frequency having a fixed and specified position with respect to the assigned frequency. The displacement of this frequency with respect to the assigned frequency has the same absolute value and sign that the displacement of the characteristic frequency has with respect to the center of the frequency band occupied by the emission.

186. **Regression technique:** One of the methods used by TRAI for spectrum valuation. Using this approach, the prices realized through previous auctions in the License Service Areas (LSAs) can be correlated with other relevant variables such as GSDP, population density, subscribers etc. that affect the demand for wireless services for estimating the values of spectrum in the LSAs where spectrum was auctioned. The exercise can be done using multiple variable regressions.
187. **Regulatory sandbox:** A live testing environment where new products, services, processes and business models which may be deployed, on a limited set of users, for a specified period of time, with certain relaxations from the existing laws. Spectrum Regulatory sandbox is different from experimental licenses/Trail Licenses that are issued by WPC/WMO.
188. **Revenue Surplus Model:** Another technique used by TRAI for valuation of spectrum. The valuation of spectrum is based on the perspective of an access service provider willing to invest in spectrum to realize the net revenue potential/revenue surplus per MHz from the wireless segment over the period for which the spectrum is granted to it. In other words, it is premised on the assumption that the net present value (NPV) of the projected revenue surplus over the tenure of assignment could potentially represent the maximum amount which the spectrum holder would be willing to pay for additional spectrum in that very spectrum block. This technique was used in 1800 MHz band by TRAI.
189. **RFID:** Radio Frequency Identification is used as a reference to a system that uses radio waves to wirelessly transmit the identity of an object or person in the form of a unique serial number. RFID applications



include ID tags, EZPasses, SpeedPasses, and many others. It operates without needing a contact or a line of sight for communication and can be traced through the human body, clothing, and non-metallic object.

190. **Reserve Price:** The lowest price seller is willing to accept to supply spectrum. The minimum bid required to win a license at an auction. The reserve price can materially affect the final outcome of the auction. It should be set high enough to discourage all speculative bidding but not too high otherwise it will dissuade bidders or prevent the eventual winner from being able to invest appropriately in the resulting network which could result in poor quality services. In India, TRAI calculates the reserve price per MHz of spectrum using different econometric techniques. Usually, 70% of average valuation is fixed as reserve price or in some cases, the Auction determined price of the last auction, duly indexed.
191. **SACFA:** Standing Advisory Committee on Radio Frequency Allocations is a high-level committee headed by the Secretary (DoT) and makes recommendations on major frequency allocation issues, formulation of NFAP and issues referred by wireless users. The SACFA clearance is issued after NOC from members of SACFA who have to undergo detailed technical analyses.
192. **Satphone:** A kind of mobile phone that connects to the other phones by radio link through satellites orbiting the earth, unlike the usual route of terrestrial cell towers. They support voice calling, text messaging and low bandwidth internet as well. They can use Geostationary orbits or low earth orbits. Inmarsat is a popular example.
193. **Sealed bid Auction:** Also known as closed-bid auctions or

first-price sealed-bid auctions or Vickrey auction, are a type of auction where bidders submit their bids privately and simultaneously. In sealed bid auctions, bidders are unaware of each other's bids, and the bids are only revealed to the auctioneer after the bidding period ends. Thus, it is a private bidding with simultaneous and one-time submission.

| | | | |
|--------------------|--|--------|----------------------------|
| Secondary Services | 3400 - 3500 FIXED FIXED-SATELLITE (space-to-Earth) MOBILE except aeronautical mobile Amateur Radiolocation 5.433 5.282 | IND 66 | International Footnotes |
| | 3500 - 3600 FIXED FIXED-SATELLITE (space-to-Earth) MOBILE except aeronautical mobile 5.433A Radiolocation 5.433 | IND 66 | |

194. **Secondary services:** The services other than the primary services, these are printed in small letters in regulation documents. They

can bear interference from the primary services. They are subject to certain conditions like they cannot cause interference with primary services, cannot claim protection from interference caused by primary services, etc.

195. **Set-aside:** Reservation in the auction of pre-specified spectrum for which only eligible bidders are allowed to compete, such as new entrants.

196. **Simplex operation:** Operating method in which transmission is made possible alternately in each direction of a telecommunication channel.

197. **Signaling:** A strategy where bids are used to indicate information to rival bidders, including invitations to coordinate or threats to punish.

198. **SMRA:** Simultaneous Multiple Round Auction, an auction method where groups of related spectrum licenses are auctioned

simultaneously with the bidding raised until only one bidder remains for each license. Simultaneous means that all offerings open simultaneously, remain open together and close together. Multiple rounds mean auction event is open over multiple clock rounds. Ascending means that the clock round price never decreases but increases or remains same based upon the demand. The SMRA is characterized by two stages: clock round stage and frequency identification stage.

199. **SMS4DC**: Spectrum Management System for Developing Countries, is a software developed by ITU for assisting developing nations to achieve spectrum planning, monitoring, optimization and training.

200. **Space operation Service**: A radiocommunication service concerned exclusively with the operation of spacecraft, in particular space tracking, space telemetry and space telecommand

201. **Spectrum Analyzer**: A handheld device used for monitoring 1MHz to 20 GHz frequency range. It is used for Coverage test, interference analysis occupancy/ vacancy check and spectrum monitoring.



202. **Spectrum Audit**: An assessment of spectrum usage, utilization, survey and evaluation of the inventory. It aims at promoting spectrum efficiency and re-farming. The idea of spectrum audit flows from the Art 44 of ITU's Constitution. The audit ensures efficiency across technical, economic and social domains. In 2021, government had ordered for spectrum audit for all government departments. C&AG also carried out spectrum performance audit of administrative assigned ones.

203. **Spectrum Cap:** The limit imposed by government on spectrum holdings or spectrum allowed to win in an auction. For example, 40% of 26 GHz band in an LSA. The overall cap is 35% and is 50% for sub-1-GHz bands.
204. **Spectral Efficiency:** A measure of how much data can be squeezed into a certain amount of spectrum. Newer generations of mobile technology such as 4G are far more spectrum efficient than earlier 2G systems. Strictly speaking it measures the number of bits of information that can be delivered per hertz of spectral bandwidth.
205. **Spectrum Harmonization:** It simply means rearrangement of frequency ranges but the intention is to achieve uniform allocation of radio frequency bands across a region. It achieves the use of the same spectrum for the same types of service across international borders. So, it reduces radio interference along borders and helps in international roaming and interoperability. It can be done post auction, post liberalization, post re-farming or post change in carrier plan. The harmonization process ends up allowing much higher capacity utilization.
206. **Spectrum liberalization:** The process of allowing the owners of licenses to change their spectrum usage rights with full flexibility on choices of technology and services. However, certain conditions prescribed by the regulator are to be met. In India, the scope of spectrum liberalization is limited to auctioned spectrum.
207. **Spectrum Monetization:** It refers to the process through which telecommunication regulatory bodies or governments generate revenue by allocating, licensing, or auctioning electromagnetic spectrum rights to service providers or other entities. Such monetization can be done by auctions,

administrative pricing, beauty contests, sharing and leasing and secondary market transactions.

208. **Spectrum Re-farming:** It means repurposing of a frequency range for a different use, other than that for which it is used by an existing assignee. So, a frequency band allocate for 2G services may now be used for 3G or 5G services as technology evolves or more efficiency is sought or international rules have changed. ITU defines it as a combination of administrative, financial and technical measures aimed at removing users or equipment of the existing frequency assignment either completely or partially from a particular frequency band. The frequency band may then be allocated to the same or different service(s). These measures may be implemented in short, medium or long timescales.

209. **Spectrum Sharing:** A technique to optimize the use of limited spectrum by allowing multiple categories of users to safely share the same frequency bands. This can be done by administrative, technical or financial methods. Sharing can be done in space or time or geography. Three approaches are in vogue:

- (a) **CBRs:** The Citizens' Broadband Radio Service approach in USA, uses 3 tiers with graded protection measures.
- (b) **License Shared Access:** Originated in Europe for 2.3 GHz band, has two tiers and the idea is that the license holder can sub-license spectrum to other users in a controlled manner.
- (c) **Concurrent Shared Access:** It is also called as club licensing; it allows only class of users unlike the other two approaches as above. The sharing is done in a coordinated way between the between mobile operators.

The new Telecom Act, 2023, permits for spectrum sharing under rules. In 2024, TRAI published recommendations for inter-band spectrum sharing between operators. As on date,

India allows intra-band spectrum sharing.

210. **Spectrum Supportability:** The determination as to whether the electromagnetic spectrum necessary to support the operation of a spectrum-dependent equipment or system during its expected life cycle is, or will be, available (i.e., from system development through developmental and operational testing, to actual operation in the electromagnetic environment). The assessment of an equipment or system as having “spectrum supportability” is based upon, at a minimum, receipt of equipment spectrum certification, reasonable assurance of the availability of sufficient frequencies for operation, and consideration of EMC.
211. **Spectrum Trading:** A market-based method of spectrum assignments and its uses by sellers and buyers. Here the seller transfers the right of spectrum usage, in full or part, to buyer while retaining the ownership. The trading unit can be time, geography or bandwidth. The end result is efficient usage of spectrum and better service to the customer. Trading can be seen as a subset of sharing but there are nuances in terms of usage rights. New Zealand and Australia were first to implement spectrum trading. India has allowed spectrum trading in certain cases. It can be said that auctions bring the allocative efficiency but spectrum trading brings dynamic efficiency.



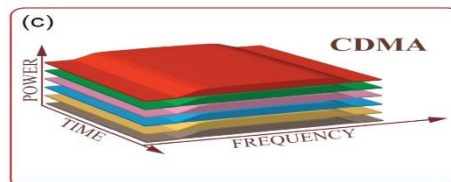
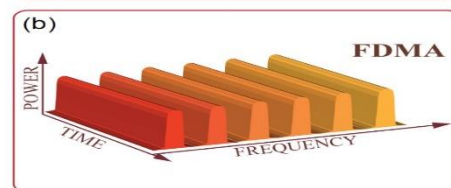
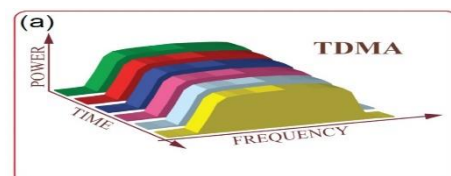
212. **Spectrum Usage Charges:** As per the Unified License agreement, if the licensee obtains spectrum, the licensee shall pay spectrum related charges including the payment for allotment and

use of spectrum. The spectrum related charges are in addition to the License Fee. The process of SUC assessment starts with submission of audited financial statement based upon which provisional SUC assessment is done. Thereafter DoT HQ carries out the Licensee Fee assessment which results in the final SUC assessment.

213. **Special Service:** A radiocommunication service, not otherwise defined as radio service in Radio Regulations, and is carried on exclusively for specific needs of general utility, and not open to public correspondence.
214. **Spread Spectrum:** A modulation technique for multiple access, or for increasing immunity to noise and interference. Spread spectrum systems makes use of a sequential noise-like signal structure like pseudo noise to spread the normally narrowband information over a relatively wide band of frequencies. The receiver correlates these signals to retrieve the original information signal.
215. **SSID:** A service set identifier is the unique name of a wireless network.
216. **Standing High Bids:** The provisional winning bids at each round in the auction used in the English auction and SMRA formats. They become winning bids in the auction if they are not displaced by higher bids (or withdrawn).
217. **Strategic Bids:** Deviations from straightforward bids by a bidder, usually intended to improve its own auction outcome or worsen its rivals' outcomes.
218. **Strategic demand reduction:** An operator bidding for less spectrum than indicated by its intrinsic value in order to reduce the price paid in the auction.

219. **Substitution Risk:** A bidder wishing to switch its demand between substitute spectrum in the auction, but being unable to do so (e.g. because its bids are standing high bids).
220. **Sub GHz:** The technologies operating at frequencies less than 1 GHz are termed as sub-GHz. It has longer range and lesser power consumption with reduced deployment and operating costs, allows low data transmission rate.
221. **Synergy value:** Additional value that arises from complements, such as an operator gaining cross-band synergies from having spectrum in two bands for coverage and capacity.
222. **TDD:** Time Division Duplexing is a multiplexing technology, allowing single frequency band is used for both transmit and receiving, as opposed to FDD. It is used in WiFi and 4G/LTE.

223. **TDMA:** Time Division Multiple Access, it is a channel access method for shared access which allows multiple users to share the same frequency channel by dividing the signal into different time slots. So, the users are allowed to transmit one after another. It is analogous to a situation when multiple people are speaking in the same language and at the same pitch but in turns. TDMA is widely used



in 2G systems. So as an analogy, we can sum up that TDMA systems is like multiple people taking turns to speak, FDMA is like multiple people speaking at different pitches while CDMA is

like multiple people speaking in different languages.

224. **Technical Efficiency Technique:** One of the methods used by TRAI for estimating spectrum value, here the valuation of spectrum can be based on the relative technical efficiency / spectral efficiency of a particular spectrum band with another spectrum band. For example, TRAI once chose the factor of technical efficiency of 0.83 for the spectrum in the 2100 MHz band with respect to the spectrum in the 1800 MHz band.
225. **Technical Value:** An operator's value of spectrum which is derived from avoiding network costs, such as using the spectrum to augment network capacity and avoid costs of densification.
226. **Technological neutrality:** Spectrum can be used for any IMT technology (GSM/WCDMA/LTE, etc). Thus, the choice is with the service provider who has spectrum holdings.
227. **Threshold Problem:** The difficulty for smaller bidders to collectively outbid a larger bidder due to their incentives for freeriding.
228. **Time Difference of Arrival (TDOA):** A method of locating a transmitter by estimating the difference in the arrival times of the signal from the source at multiple receivers. TDOA systems offer flexibility in antenna selection and placement as TDOA accuracy is minimally affected by nearby reflectors.
229. **Tragedy of Commons:** It is a situation in which individuals with access to a public resource—also called a common—act in their own interest and, in doing so, ultimately deplete the resource. This economic theory was conceptualized in 1833 by British writer William Forster Lloyd. In 1968, the term “tragedy of the commons” was used for the first time by Garret Hardin.



This theory explains individuals' tendency to make decisions based on their personal needs, regardless of the negative impact it may have on others.

230. **TRAI**: The Telecom Regulatory Authority of India, a statutory regulator set up in 1997, headed by a chairman and 2 full-time, 2 part-time members. Its jurisdiction is across Quality of Service, Tariff and



Interconnection. Its statute was amended to allow for another body TDSAT to take over its adjudicatory and dispute resolution functions. TRAI's major objective is to ensure fair and level playing field in telecom sector.

231. **Trend Line Analysis**: One of the spectrum valuation techniques used by TRAI, where based on the past available auction determined prices (ADPs), a trend line expressing ADP as a linear function of time, may be established for each LSA predicting expected ADP in the future auctions using extrapolation.

232. **UL (VNO)**: Unified License (Virtual Network Operators) is a license taken by entities who provide telecom services without owning the underlying network infrastructure. VNOs lease network capacity from licensed telecom operators and offer services under their own brand. VNOs are treated as extension of NSOs (Network Service Operators) or telecom service providers.

233. **UMTS**: Universal Mobile Telecommunications System is a 3rd generation cellular system based upon the GSM standard and maintained by 3GPP. It is a part of the IMT-2000 standards and uses Wide-CDMA technology to offer better spectral efficiency and bandwidth.

234. **Unliberalized spectrum:** The spectrum allotted administratively, there is no right of the users in terms of the choice of technology or services.
235. **Unlicensed Spectrum:** A frequency spot/band which can be used without a license from the government, however, there are some regulatory impositions on the usage like low power, interference, etc. They are mostly used for short distance communication. These are primarily driven by industry demands, international practices and public interests. For example, 2.4 GHz and 5.8 GHz bands used in Wi-Fi. The innovation and demands drive the unlicensed spectrum and there are little entry barriers here.
236. **Unpaired Spectrum:** Suitable for using Time-Division Duplexing (TDD) technology, where carriers for the uplink from the mobile handset to the base station and downlink from the base station to the handset are separated by time in the same frequency.
237. **uRLLC:** Ultra-reliable and Low-Latency Communications, a use case of 5G by 3GPP, it aims to ensure end-to-end latency less than 1 ms and reliability of more than 99.99%. Thus, a high-reliability and low-latency communication is ensured for mission-critical applications such as factory automation, autonomous driving, and virtual/augmented reality with superb quality of service. It works on the basis of network slicing.
238. **White Space:** White space is used to define licensed frequency bands that are not used at a particular time and geographic location and therefore could be used for other services – normally wireless broadband. Traditionally, the focus has been on TV white space, which consists of unused spectrum in the television broadcasting bands (for example, 470–790MHz in Europe and 470– 698MHz in the US). The approach relies on the

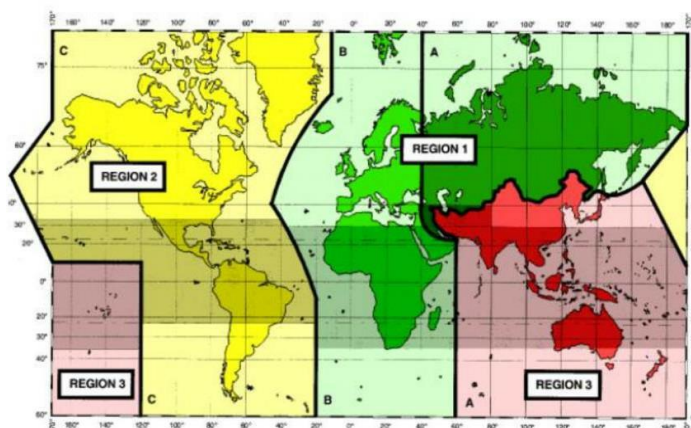
availability of sufficient spectrum in a given area to offer a reliable alternative service that will not cause interference to the license holder.

239. **Wi-Fi:** An unlicensed short-range wireless networking technology that uses radio waves to provide high-speed Internet and network connections. The technology has traditionally been used in homes, enterprises and shops but is increasingly being used by mobile operators as part of heterogeneous networks.
240. **Wi-Max:** An OFDM-based wireless communications standard that is similar to LTE but far less widely deployed. Although it was designed to be IMT2000 compliant – making it a 3G technology – it is commonly described as 4G.
241. **Winners’ Curse:** It is a tendency for the winning bid in an auction to exceed the intrinsic value or true worth of an item. The gap in auctioned versus intrinsic value can typically be attributed to incomplete information, emotions, or a variety of other subjective factors that may influence bidders.
242. **Wireless Monitoring Organization:** WMOs are a field unit of the Wireless Planning and coordination (WPC) Wing, carries out spectrum monitoring through a network of 1(one) International Satellite Monitoring Earth Station (ISMES), 5 International Monitoring Stations (IMSs), and 22 Wireless Monitoring Stations (WMSs), strategically located all over India. WMO is also equipped with 5 Radio Noise Survey Units, which undertake detailed and complicated measurements to aid in the spectrum management activity.
243. **WLL (Wireless Local Loop):** It is an access system that connects users to local telephone service provider’s switch via wireless links not conventional copper cables. It is also called as

Fixed Wireless Access (FWA) or Fixed radio. CDMA in India widely used WLL.

244. **WPC:** Wireless Planning and Coordination wing of Dept. of Telecom, India, is the national radio regulatory nodal agency of the Government of India and is responsible for planning, engineering, regulating, managing and monitoring the limited natural resources of Radio Frequency (RF) spectrum and satellite orbits, including geo-stationary (GSO) and non-GSO orbit. It caters to all the wireless users of the country, including licensing as per the statutory frameworks. It is also the nodal organization representing Government of India in the international forums.

ITU-R Radio Regulation - Regions



245. **World Regions:**

The ITU divides the globe into 3 regions for the purpose of spectrum governance.

Region 1 has Europe and

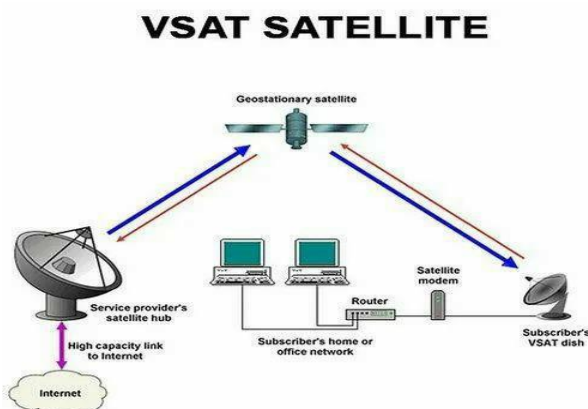
Africa; Region 2 has Americas and Region 3 has Asia. India lies in Region-3 as per ITU

246. **WRC:** World Radio Conference organized by ITU, held every 3-4 years to review and revise Radio Regulations. It can address any radiocommunication matter of worldwide character and has administration over Radio Regulations Board and Radiocommunications Bureau. The output documents are called as the Final Acts, having a record of the decisions taken and with revised provisions of Radio Regulations.

247. **V-Band:** The band in 40 GHz to 75 GHz as per IEEE. It is used for radar research and scientific purposes. In USA, 57-71 GHz has been allocated for unlicensed wireless systems requiring short distance and high capacity.

248. **Virtual Reality:** It is the use of computer modelling and simulation that enables a person to interact with an artificial three-dimensional (3-D) visual or another sensory environment. VR applications immerse the user in a computer-generated environment that simulates reality through the use of interactive devices, which send and receive information and are worn.

249. **VSAT:** Very Small Aperture Terminal, is a two-way ground station that transmits and receives data from satellites. A VSAT is less than three meters tall and is capable of both narrow and broadband data to satellites in orbit in real-time. The data can then be redirected to other remote terminals or hubs around the planet. VSAT can be used in place of a large physical network as it bounces the signal from satellites instead of being transported through physical means like an ethernet connection.



250. **Zigbee:** It is an open global standard of wireless technology which is used for low-cost, low-power machine to machine (M2M) networks. This standard uses unlicensed bands in the ranges of 2.4 GHz, 900 MHz and 868 MHz. It has standards for energy management, home and commercial automation, health care, retail, telecom, and consumer electronics.