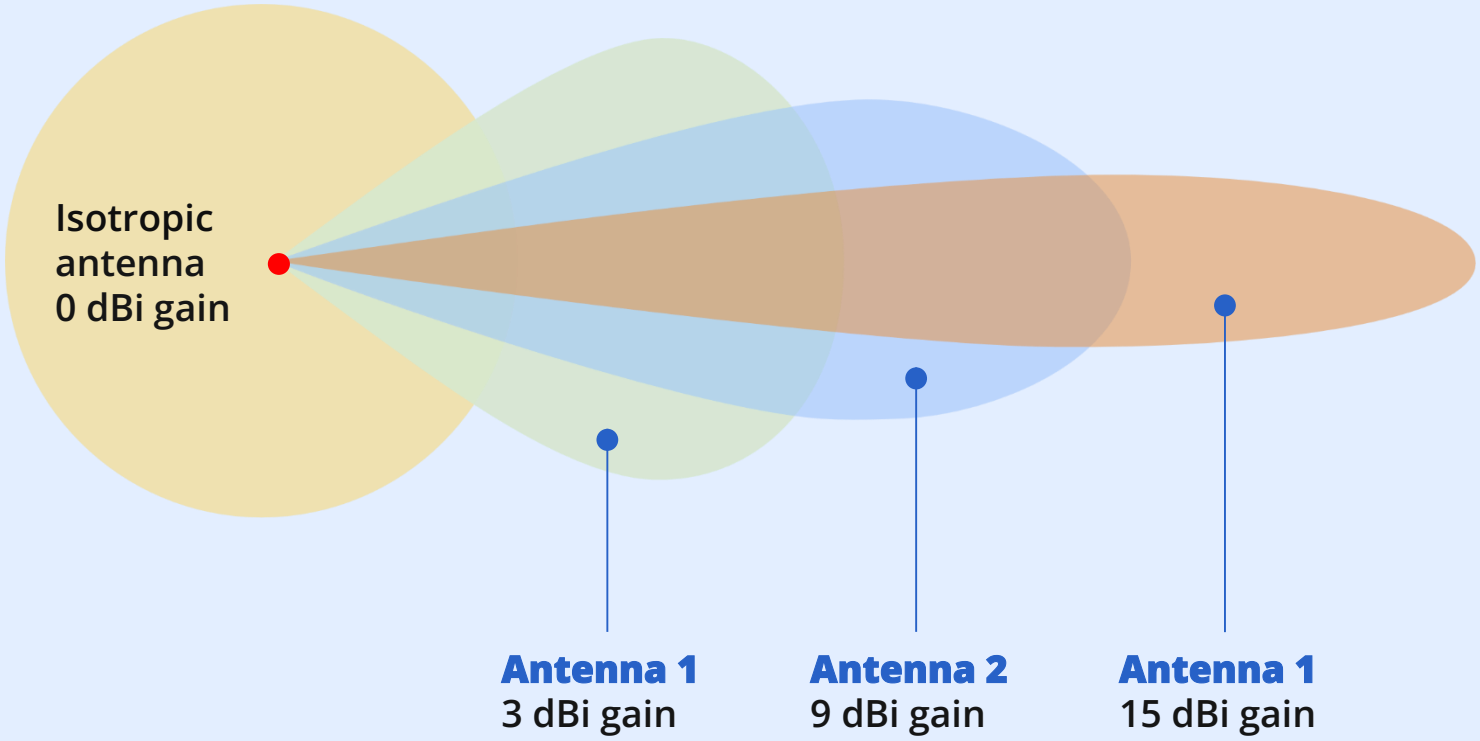
# Radio network planning

# What is antenna gain?

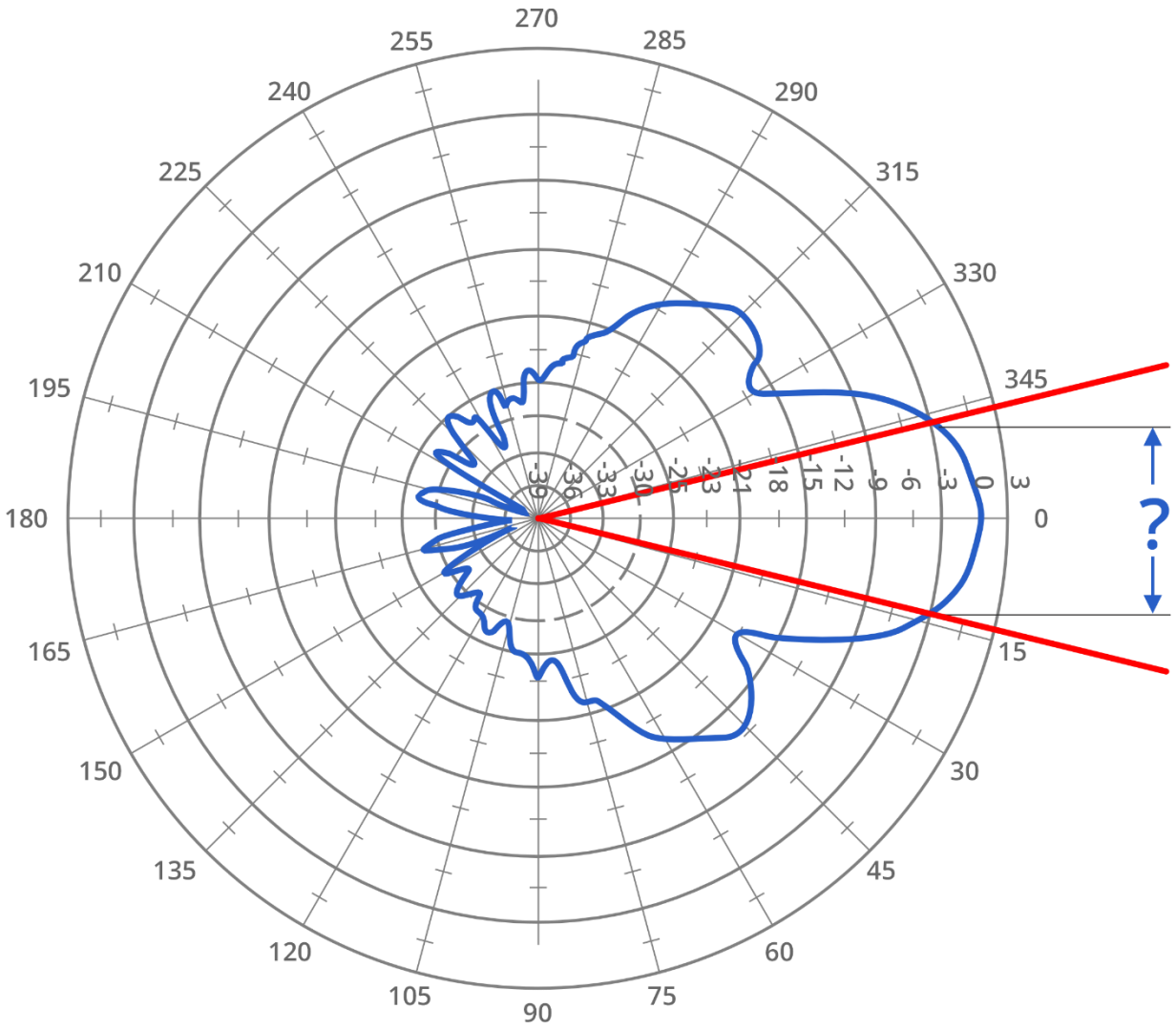
## Antenna does not gain!

The ratio of the radiation intensity in a given direction to the radiation intensity that would be produced if the power accepted by the antenna were isotropically radiated



# Marketing changes the antenna`s angle

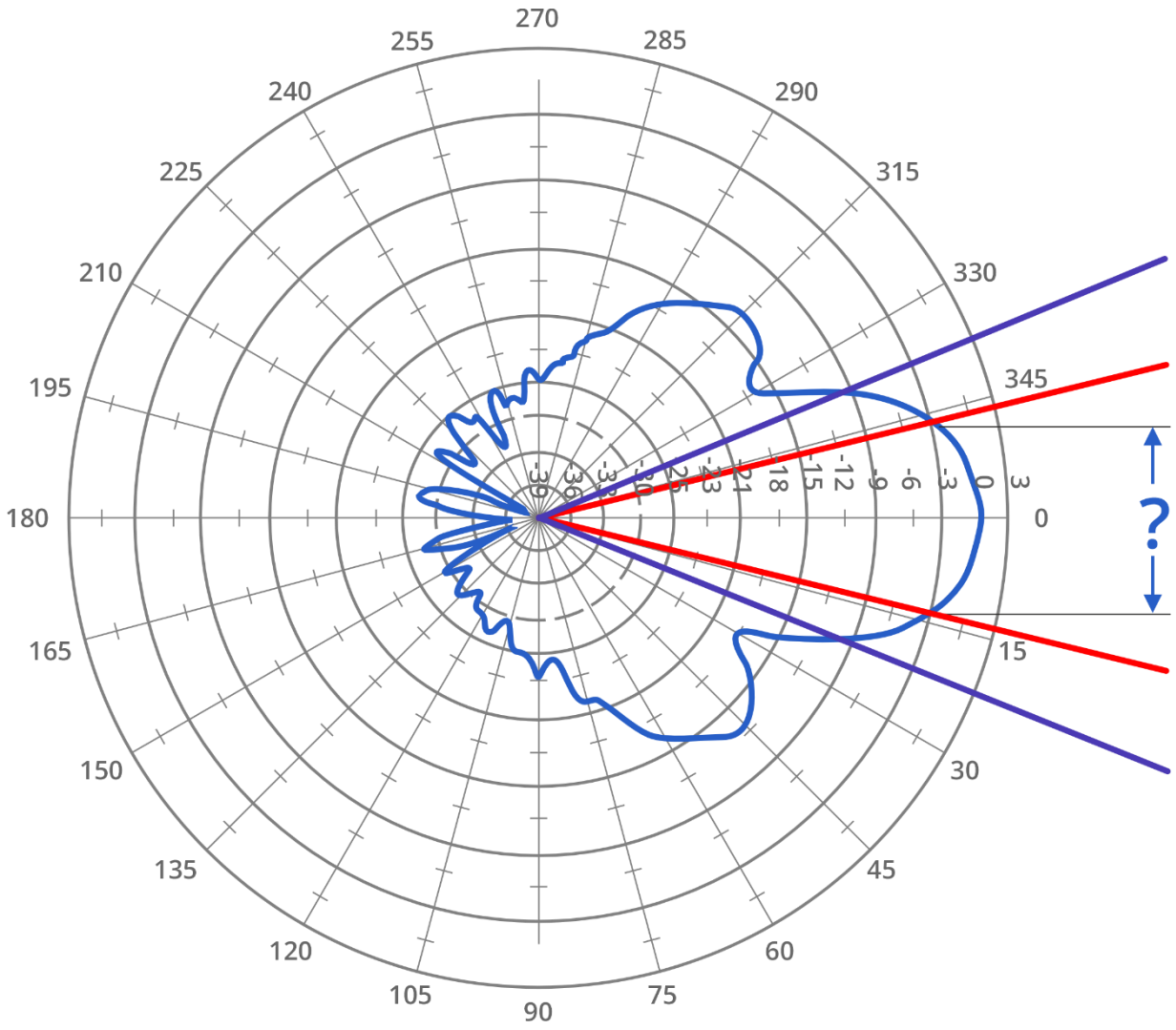
Antenna angle usually means angle between to the right and left of the direction in which it is set, working at a gain by 3 dB less than that specified in the technical data



# Marketing changes the antenna`s angle

Antenna angle ussially means angle beetween to the right and left of the direction in which it is set, working at a gain by 3 dB less than that specified in the technical data".

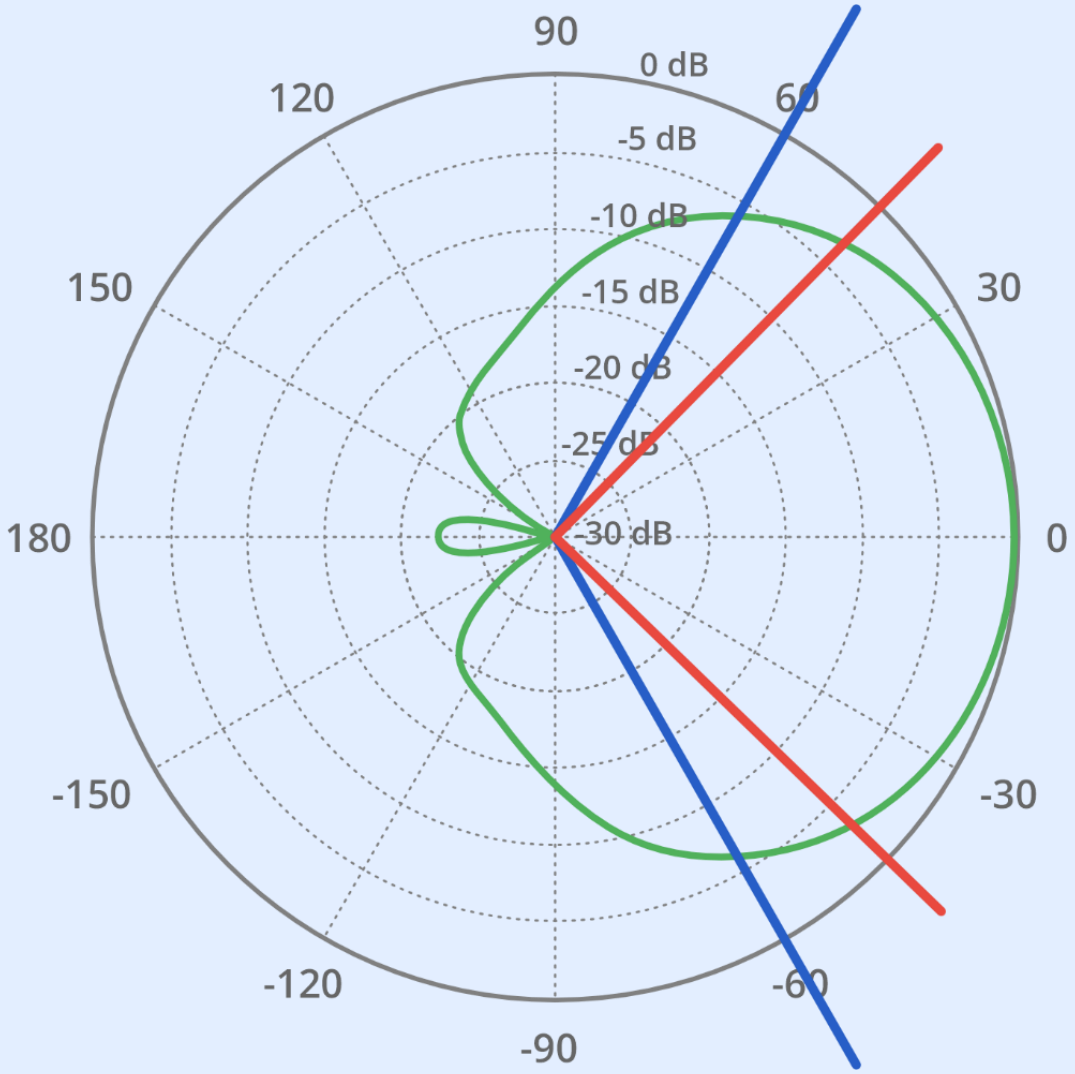
But what's happens, if we agree with gain less more then 3 dB? For example 6 or 9 dB?



# Marketing changes the antennas angle

## Horizontal Azimuth

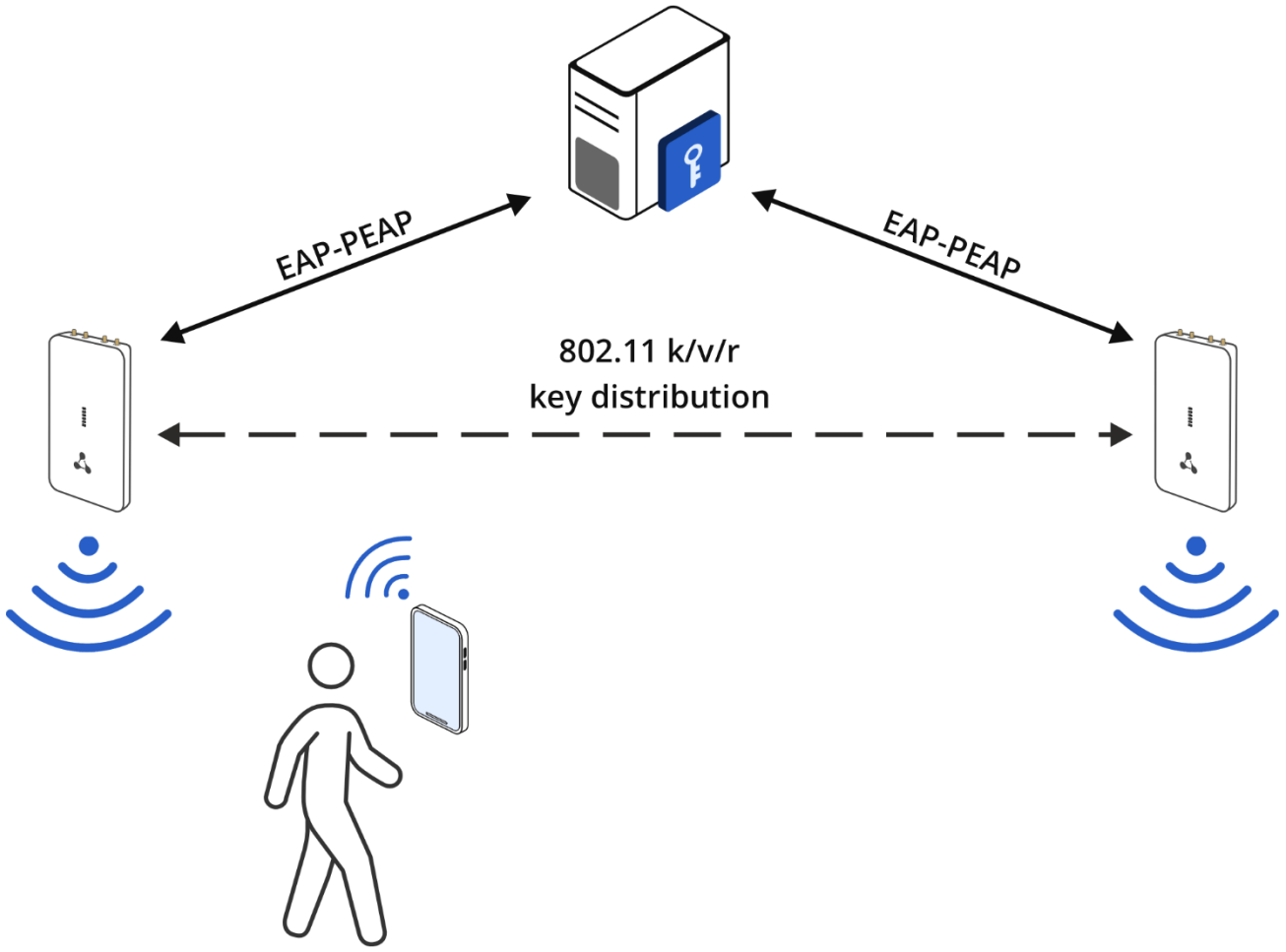
| | |
|---|---|
| HPOL Beamwidth | 123º (6 dB) |
| VPOL Beamwidth | 123º (6 dB) |



# Enterprise Wi-Fi

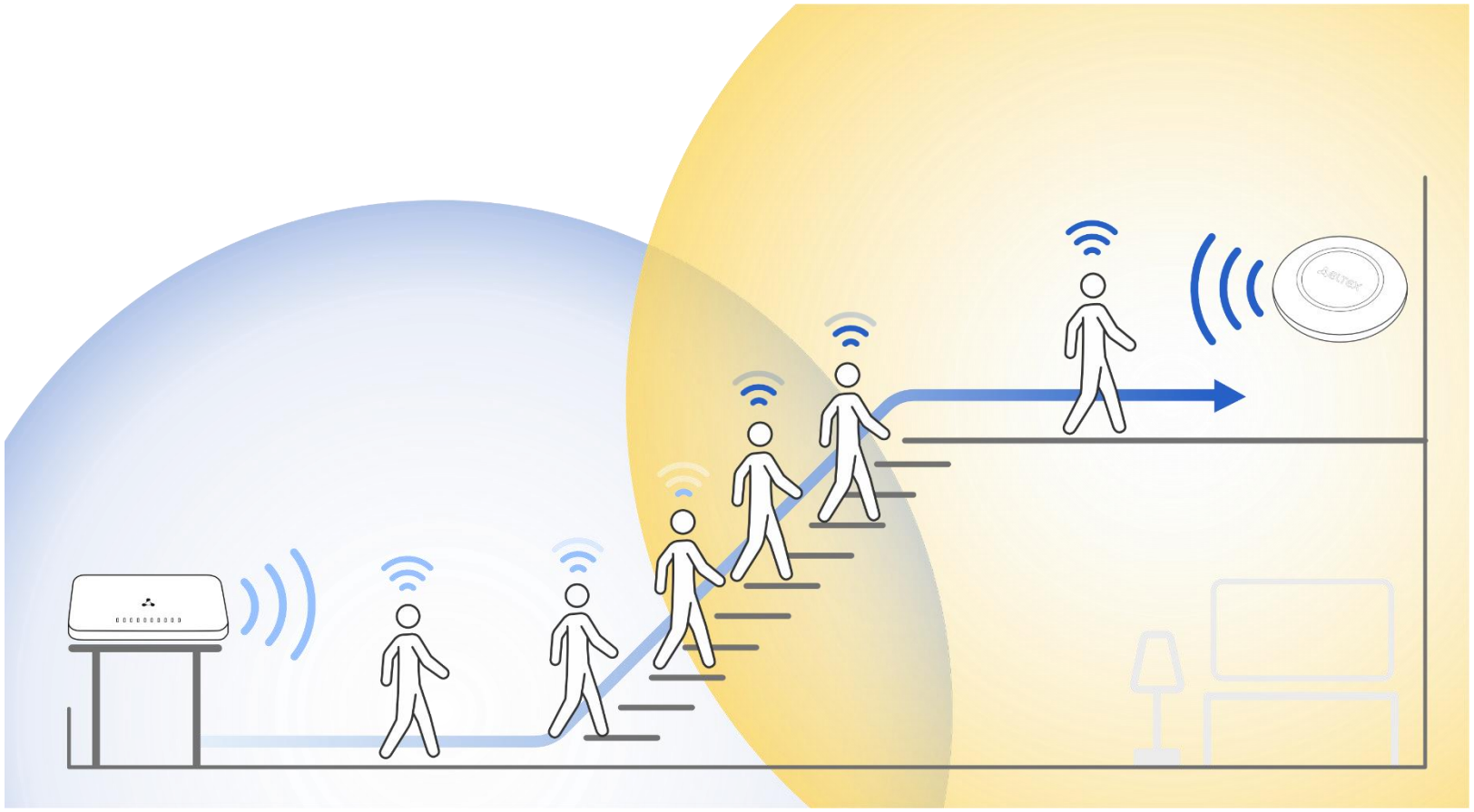
In enterprise network SSID, which uses a radius-server (remote authentication dial-in user service) to authenticate a client, switching from one access point to another can take a lot of time, which is needed for exchanging auth information between access point and radius-server. It can take nearly 1 second!

802.11k/v/r standard is responsible for seamless roaming



# Seamless Wi-Fi roaming

802.11 k / v / r



# Basics of Radio Planning

TamoGraph Site Survey
https://www.tamos.com/products/wifi-site-survey

Ekahau connect
https://www.ekahau.com/products/ekahau-connect

# Modulation and Coding Scheme Table

| HT MSC | VHT MCS | Modulation | Coding | 20MHz | | | | 40MHz | | | | 80MHz | | | | 160MHz | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Data rate | | Min. SNR | RSSI | Data rate | | Min. SNR | RSSI | Data rate | | Min. SNR | RSSI | Data rate | | Min. SNR | RSSI |
| | | | | 800ns | 400ns | | | 800ns | 400ns | | | 800ns | 400ns | | | 800ns | 400ns | | |
| **1 Spatial stream** | | | | | | | | | | | | | | | | | | | |
| 0 | 0 | BPSK | 1/2 | 6,5 | 7,2 | 2 | -82 | 13,5 | 15 | 5 | -79 | 29,3 | 32,5 | 8 | -76 | 58,5 | 65 | 11 | -73 |
| 1 | 1 | QPSK | 1/2 | 13 | 14,4 | 5 | -79 | 27 | 30 | 8 | -76 | 58,5 | 65 | 11 | -73 | 117 | 130 | 14 | -70 |
| 2 | 2 | QPSK | 3/4 | 19,5 | 21,7 | 9 | -77 | 40,5 | 45 | 12 | -74 | 87,8 | 97,5 | 15 | -71 | 75,5 | 195 | 18 | -68 |
| 3 | 3 | 16-QAM | 1/2 | 26 | 28,9 | 11 | -74 | 54 | 60 | 14 | -71 | 117 | 130 | 17 | -68 | 234 | 260 | 20 | -65 |
| 4 | 4 | 16-QAM | 3/4 | 39 | 43,3 | 15 | -70 | 81 | 90 | 18 | -67 | 175,5 | 195 | 21 | -64 | 351 | 390 | 24 | -61 |
| 5 | 5 | 64-QAM | 2/3 | 52 | 57,8 | 18 | -66 | 108 | 120 | 21 | -63 | 234 | 260 | 24 | -60 | 468 | 520 | 27 | -57 |
| 6 | 6 | 64-QAM | 3/4 | 58,5 | 65 | 20 | -65 | 121,5 | 135 | 23 | -62 | 263,3 | 292,5 | 26 | -59 | 526,5 | 585 | 29 | -56 |
| 7 | 7 | 64-QAM | 5/6 | 65 | 72,2 | 25 | -64 | 135 | 150 | 28 | -61 | 292,5 | 325 | 31 | -58 | 585 | 650 | 34 | -55 |
| | 8 | 256-QAM | 3/4 | 78 | 86,7 | 29 | -59 | 162 | 180 | 32 | -56 | 351 | 390 | 35 | -53 | 702 | 780 | 38 | -50 |
| | 9 | 256-QAM | 5/6 | | | 31 | -57 | 180 | 200 | 34 | -54 | 390 | 433,3 | 37 | -51 | 780 | 866,7 | 40 | -48 |
| **2 Spatial stream** | | | | | | | | | | | | | | | | | | | |
| 8 | 0 | BPSK | 1/2 | 13 | 14,4 | 2 | -82 | 27 | 30 | 5 | -79 | 58,6 | 65 | 8 | -76 | 117 | 130 | 11 | -73 |
| 9 | 1 | QPSK | 1/2 | 26 | 28,8 | 5 | -79 | 54 | 60 | 8 | -76 | 117 | 130 | 11 | -73 | 234 | 260 | 14 | -70 |
| 10 | 2 | QPSK | 3/4 | 39 | 43,4 | 9 | -77 | 81 | 90 | 12 | -74 | 175,6 | 195 | 15 | -71 | 151 | 390 | 18 | -68 |
| 11 | 3 | 16-QAM | 1/2 | 52 | 57,8 | 11 | -74 | 108 | 120 | 14 | -71 | 234 | 260 | 17 | -68 | 468 | 520 | 20 | -65 |
| 12 | 4 | 16-QAM | 3/4 | 78 | 86,6 | 15 | -70 | 162 | 180 | 18 | -67 | 351 | 390 | 21 | -64 | 702 | 780 | 24 | -61 |
| 13 | 5 | 64-QAM | 2/3 | 104 | 115,6 | 18 | -66 | 216 | 240 | 21 | -63 | 468 | 520 | 24 | -60 | 936 | 1040 | 27 | -57 |
| 14 | 6 | 64-QAM | 3/4 | 117 | 130 | 20 | -65 | 243 | 270 | 23 | -62 | 526,6 | 585 | 26 | -59 | 1053 | 1170 | 29 | -56 |
| 15 | 7 | 64-QAM | 5/6 | 130 | 144,4 | 25 | -64 | 270 | 300 | 28 | -61 | 585 | 650 | 31 | -58 | 1170 | 1300 | 34 | -55 |
| | 8 | 256-QAM | 3/4 | 156 | 173,4 | 29 | -59 | 324 | 360 | 32 | -56 | 702 | 780 | 35 | -53 | 1404 | 1560 | 38 | -50 |
| | 9 | 256-QAM | 5/6 | | | 31 | -57 | 360 | 400 | 34 | -54 | 780 | 866,6 | 37 | -51 | 1560 | 1733,4 | 40 | -48 |
| **3 Spatial stream** | | | | | | | | | | | | | | | | | | | |
| 16 | 0 | BPSK | 1/2 | 19,5 | 21,6 | 2 | -82 | 40,5 | 45 | 5 | -79 | 87,9 | 97,5 | 8 | -76 | 175,5 | 195 | 11 | -73 |
| 17 | 1 | QPSK | 1/2 | 39 | 43,2 | 5 | -79 | 81 | 90 | 8 | -76 | 175,5 | 195 | 11 | -73 | 351 | 390 | 14 | -70 |
| 18 | 2 | QPSK | 3/4 | 58,5 | 65,1 | 9 | -77 | 121,5 | 135 | 12 | -74 | 263,4 | 292,5 | 15 | -71 | 226,5 | 585 | 18 | -68 |
| 19 | 3 | 16-QAM | 1/2 | 78 | 86,7 | 11 | -74 | 162 | 180 | 14 | -71 | 351 | 390 | 17 | -68 | 702 | 780 | 20 | -65 |
| 20 | 4 | 16-QAM | 3/4 | 117 | 129,9 | 15 | -70 | 243 | 270 | 18 | -67 | 526,5 | 585 | 21 | -64 | 1053 | 1170 | 24 | -61 |
| 21 | 5 | 64-QAM | 2/3 | 156 | 173,4 | 18 | -66 | 324 | 360 | 21 | -63 | 702 | 780 | 24 | -60 | 1404 | 1560 | 27 | -57 |
| 22 | 6 | 64-QAM | 3/4 | 175,5 | 195 | 20 | -65 | 364,5 | 405 | 23 | -62 | | | 26 | -59 | 1579,5 | 1755 | 29 | -56 |
| 23 | 7 | 64-QAM | 5/6 | 195 | 216,6 | 25 | -64 | 405 | 450 | 28 | -61 | 877,5 | 975 | 31 | -58 | 1755 | 1950 | 34 | -55 |
| | 8 | 256-QAM | 3/4 | 234 | 260,1 | 29 | -59 | 486 | 540 | 32 | -56 | 1053 | 1170 | 35 | -53 | 2106 | 2340 | 38 | -50 |
| | 9 | 256-QAM | 5/6 | | | 31 | -57 | 540 | 600 | 34 | -54 | 1170 | 1299,9 | 37 | -51 | | | 40 | -48 |

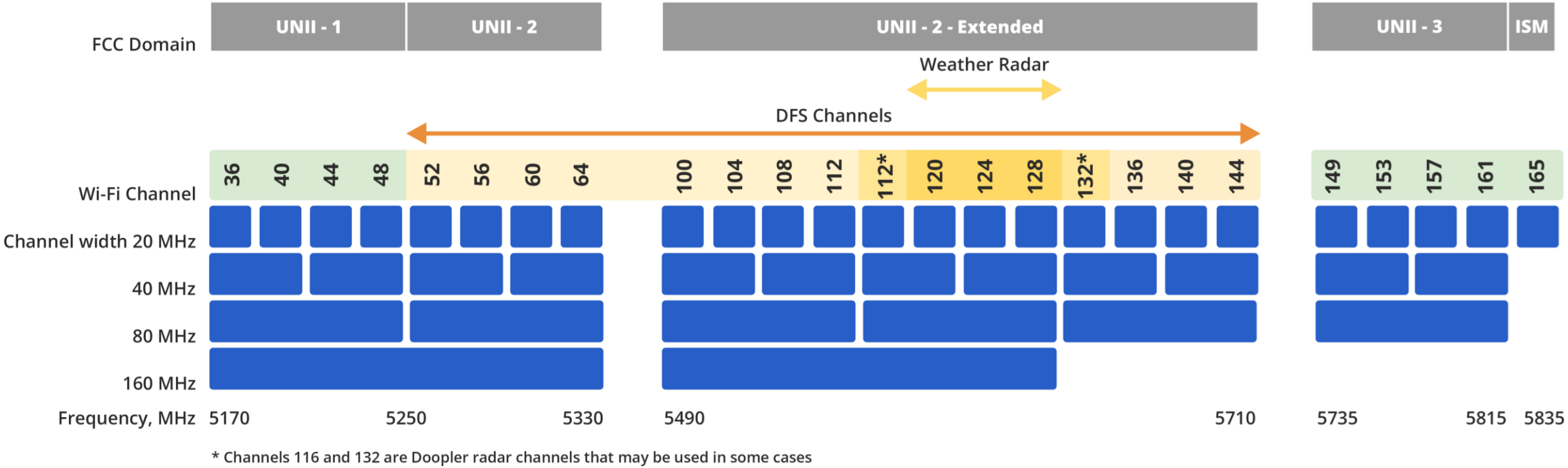
# Basic recommendations

Access point should be placed on the level below the lowest hanging systems

There are must not any metal constructions or concrete objects around a meter close to access point

At any point of room we have to have line of sight at least to once access point

# 802.11ac channel allocation (5 GHz band)




* Channels 116 and 132 are Doopler radar channels that may be used in some cases

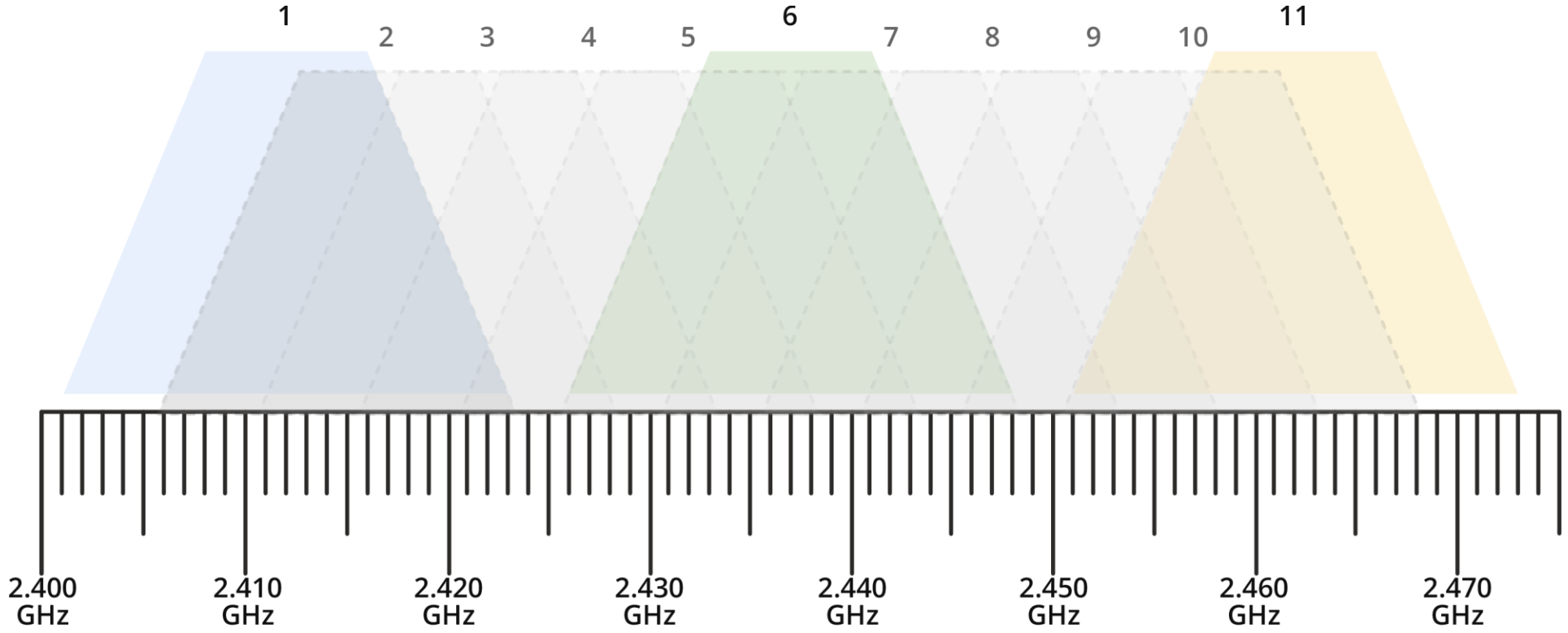
# 5 GHz (802.11a/h/n/ac/ax) channel restriction

| Ch., 20Mhz | Freq., MHz | UNNI band | Russia |
|---|---|---|---|
| 32 | 5160 | UNII-1 | Indoors/TPC |
| 36 | 5180 | | |
| 40 | 5200 | | |
| 44 | 5220 | | |
| 48 | 5240 | | |
| 52 | 5260 | UNII-2A | |
| 56 | 5280 | | |
| 60 | 5300 | | |
| 64 | 5320 | | |
| 68 | 5340 | | |
| 72 | 5360 | UNII-2B | Unused |
| 76 | 5380 | | |
| 80 | 5400 | | |
| 84 | 5420 | | |
| 88 | 5440 | | |
| 92 | 5460 | | |
| 96 | 5480 | UNII-2C | No |
| 100 | 5500 | | |
| 104 | 5520 | | |
| 108 | 5540 | | |
| 112 | 5560 | | |
| 116 | 5580 | | |
| 120 | 5600 | | |
| 124 | 5620 | | |
| 128 | 5640 | | |
| 132 | 5660 | | Indoors/TPC |
| 136 | 5680 | | |
| 140 | 5700 | | |
| 144 | 5720 | UNII-2C/3 | |
| | 5730-5735 | | |
| 149 | 5745 | UNII-3 | |
| 153 | 5765 | | |
| 157 | 5785 | | |
| 161 | 5805 | | |
| 165 | 5825 | | |
| 169 | 5845 | UNII-3/4 | |
| 173 | 5865 | UNII-4 | No |
| 177 | 5885 | | |

| | |
|---|---|
| Yes | May be used without restrictions |
| No | Forbidden to use |
| Indors | MUST be used indoor only |
| DFS | MUST be used with DFS regardless indoor or outdoor |
| SDR | MUST comply with SRD requirements regardless indoor or outdoor |
| Indoors/DFS | MUST be used with DFS and indoor only |
| Indoors/TPC | MUST be used with TPC and indoor only |
| DFS/TPC | MUST be used with DFS and TPC |
| DFS/TPC + SRD | MUST be used with DFS, TPC and comply with SRD requirements |
| Indoors/DFS/TPC | MUST be used with DFS, TPC and indoor only |

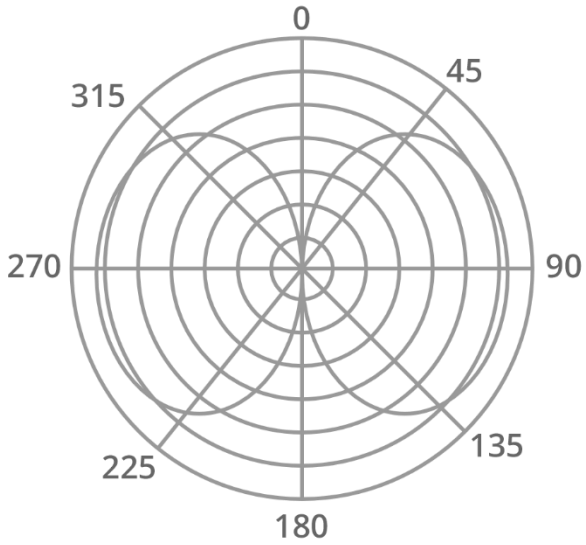
- DFS: dynamic frequency selection (It was standardized in 2003 as part of IEEE 802.11h)
- SRD: short-range device (typically limited to 25–100 mW, described by ECC Recommendation 70-03)
- TPC: transmit power control (this feature include in IEEE 802.11h)

# 802.11 b/g/n channel allocation (2.4 GHz band)

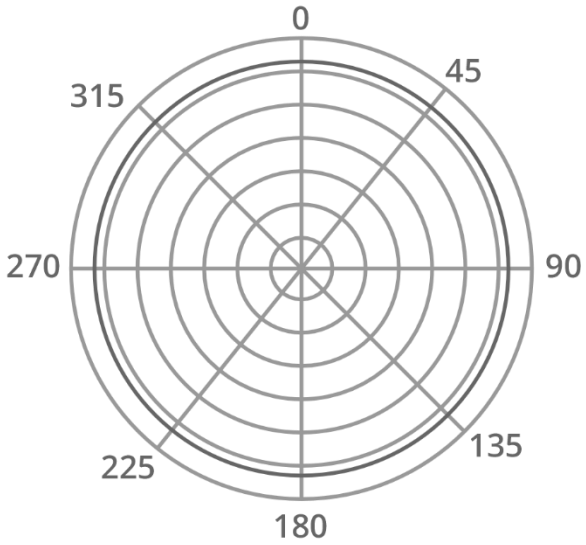


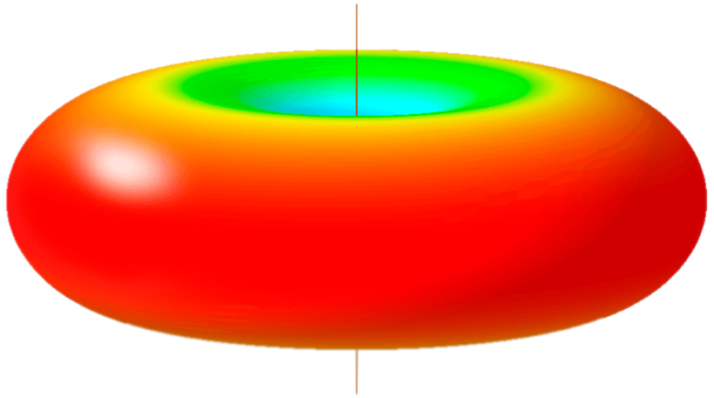
# Beam Pattern Indoor Access Point

ELEVATION PATTERN

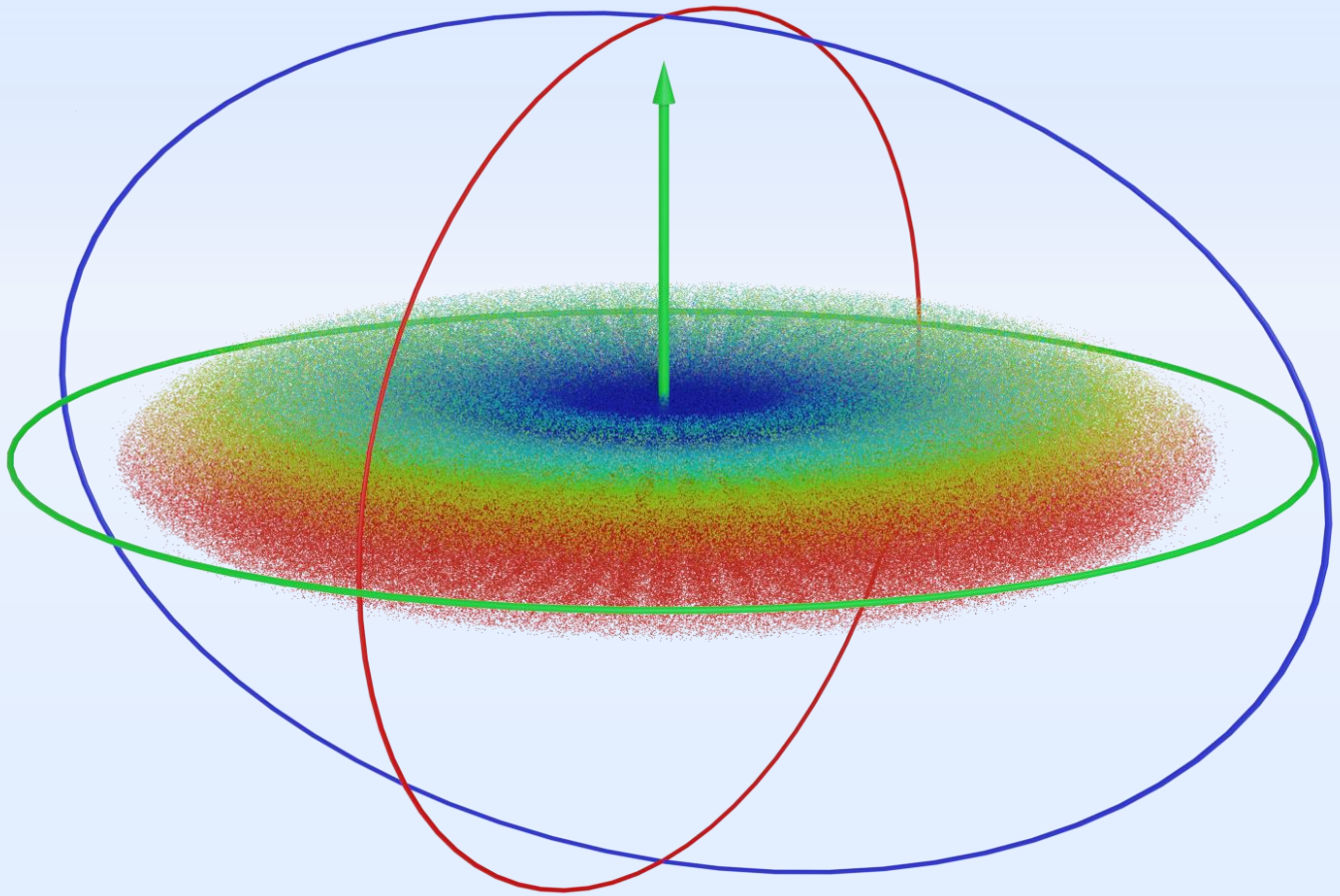



AZIMUTH PATTERN



# 8dB Omni radiation pattern example

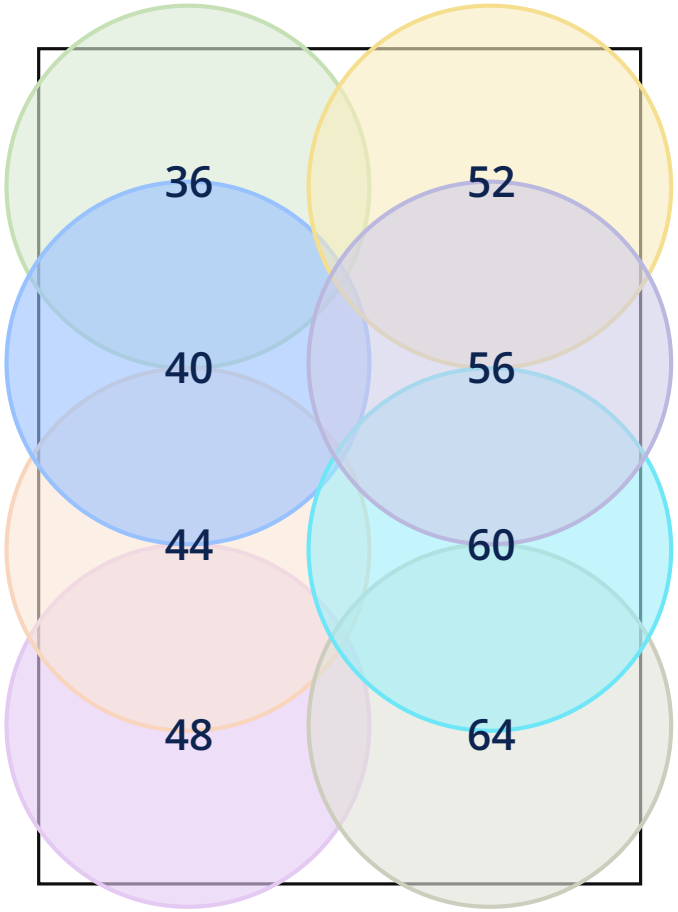


# 5 GHz channel allocation indoor example

In 5GHz band we can use 8 separated channels and easily distribute its to cover the room. As toy can see, cover zone of any AP overlapped this others. In 5GHz we have no problems with it.

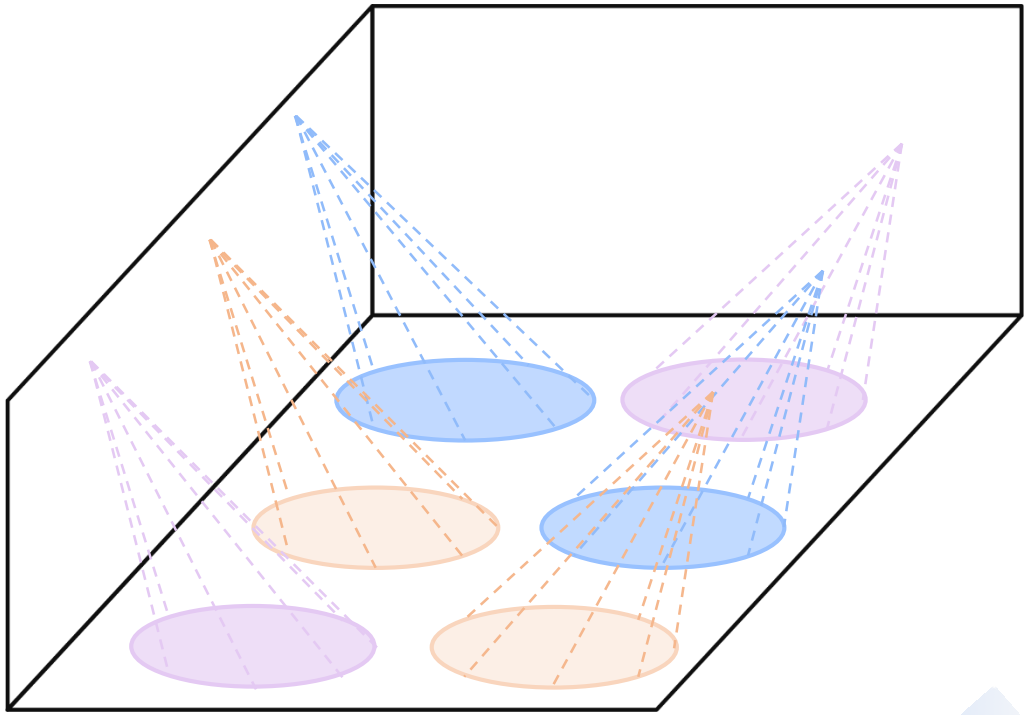
Hoy most important thing in 5GHz Wi-Fi channel allocation is the ability to spread identical channels to long distance between its.

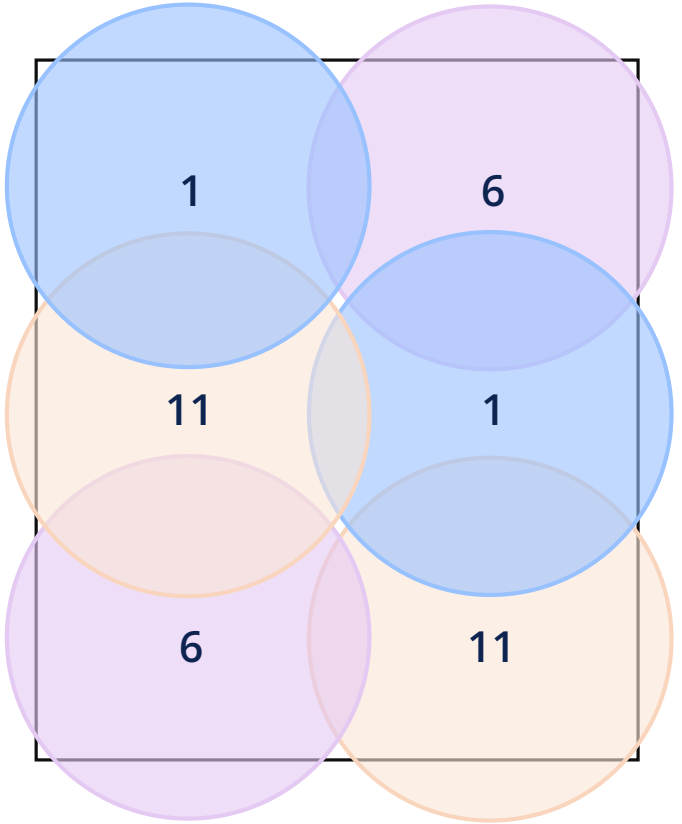
The diagram shows some an “ideal” room, but usually there are some constructions and engineering structures. Should not forget about it.



# 2.4 GHz channel allocation: how we see the perfect picture

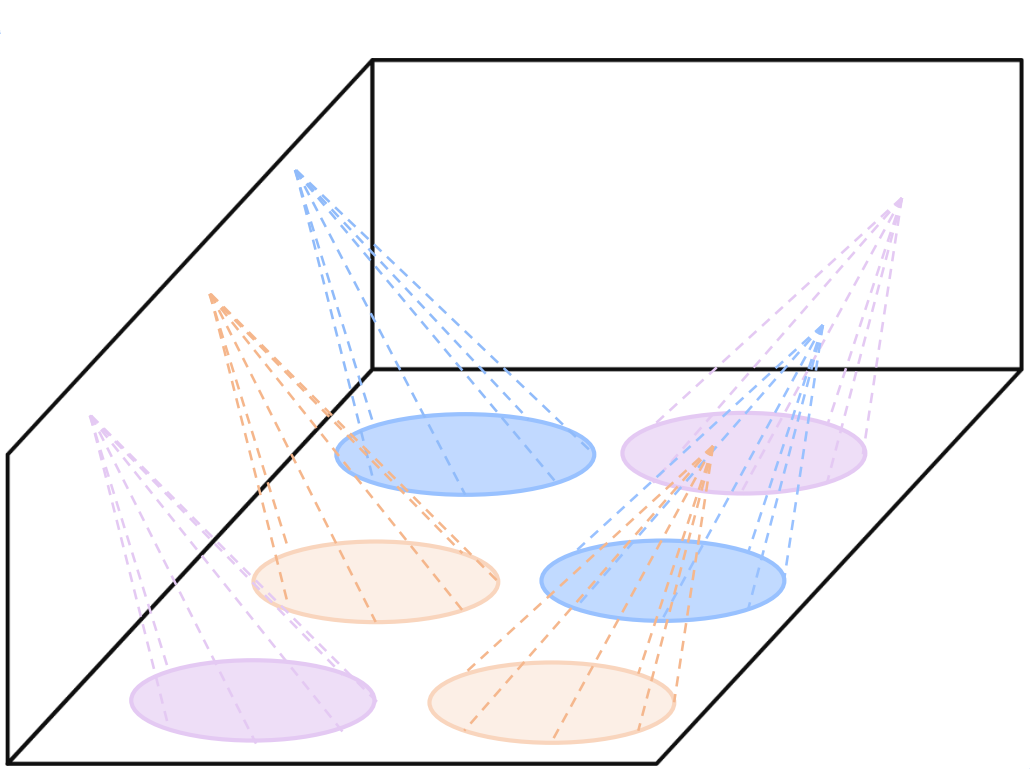
Wrong!

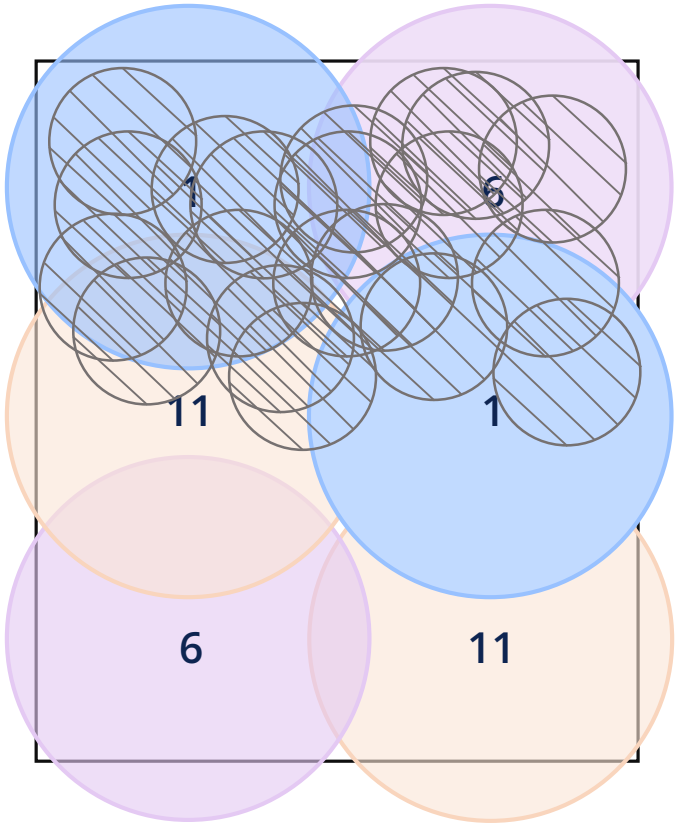




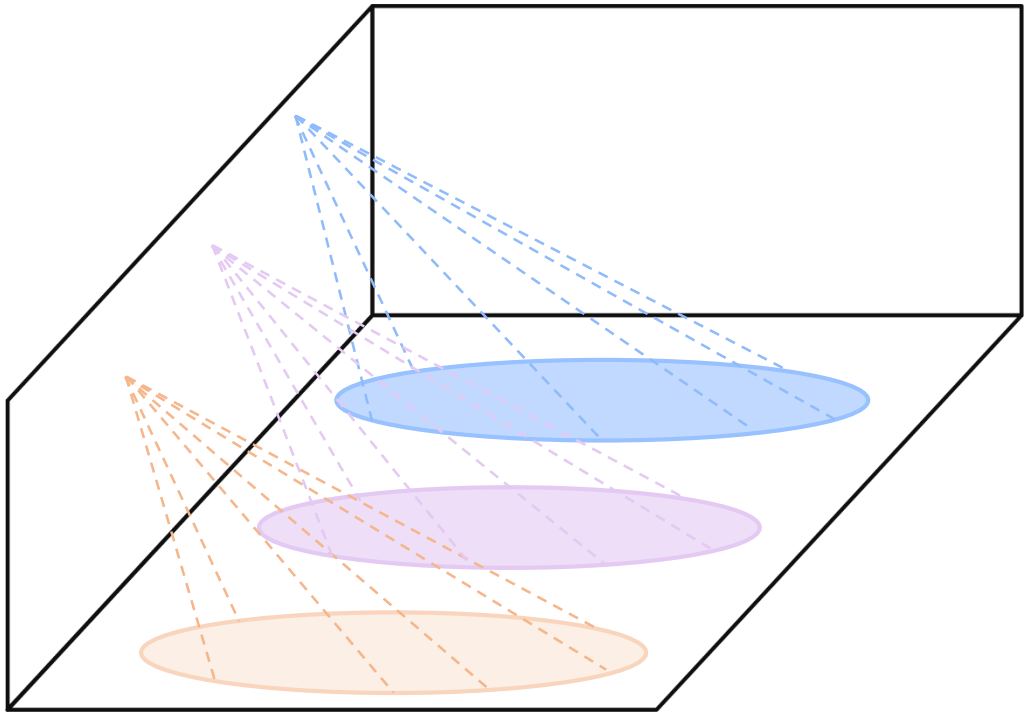
# 2.4 GHz channel allocation: real life

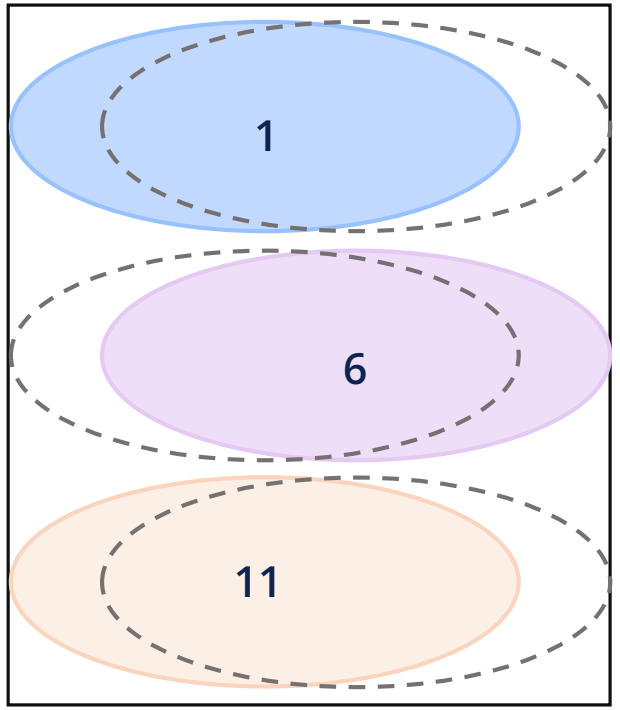
## Wrong!





# 2.4 GHz channel allocation: how to make its better

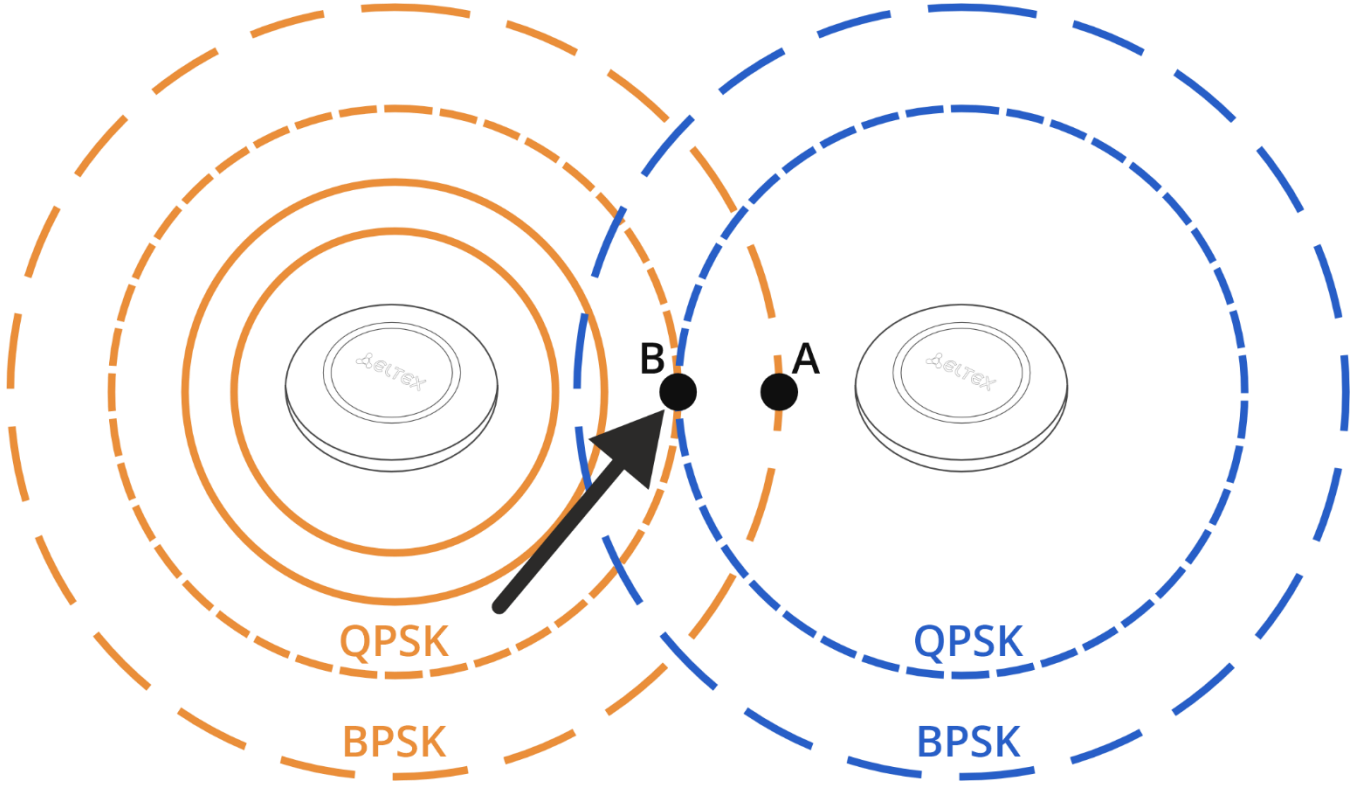





Disable 2.4 GHz on half of the access points

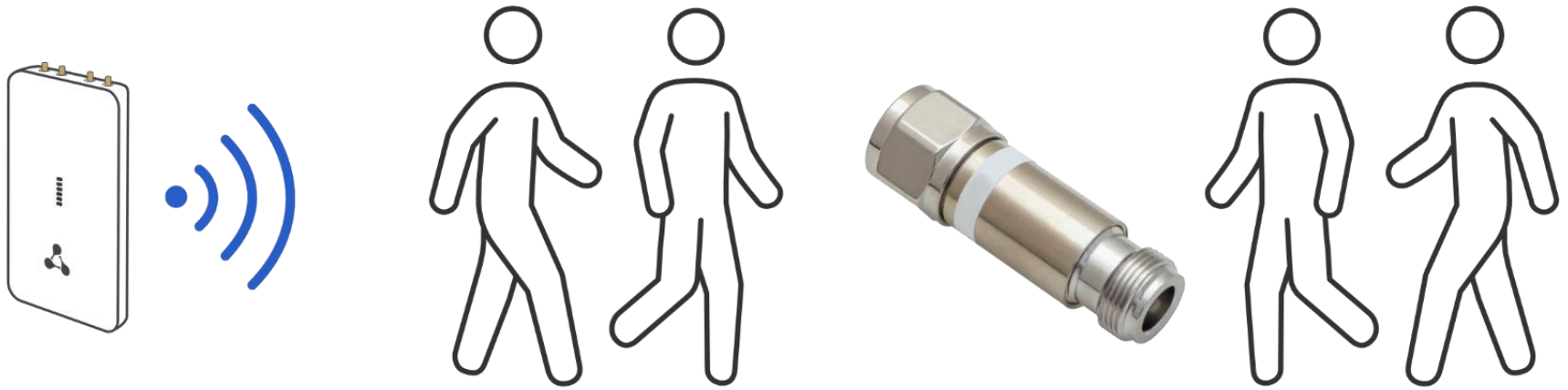
# Disabling slow modulations, like BPSK and QPSK

We have to place APs with taking in account that lower modulation would be turned off! The decision to disable lower modulation must not appear after we have placed APs!



# Attenuator Man

Man himself is a kind of source of attenuation



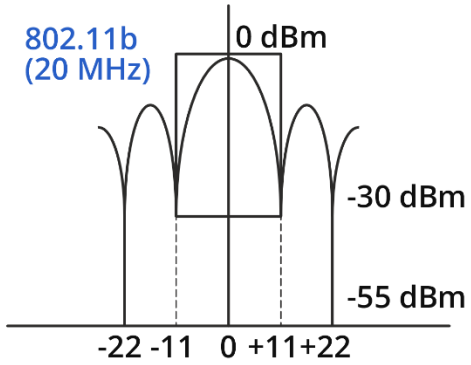
# Optimization for highload

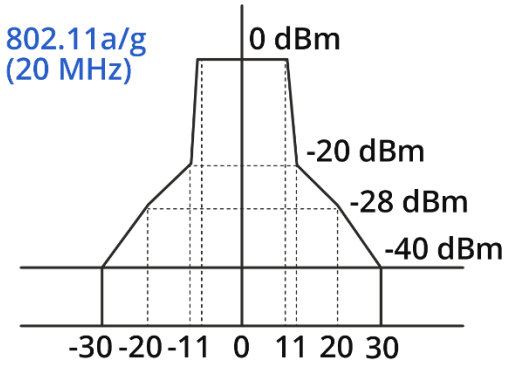
- Using access points with directional antennas
- Shutdown lower modulations (BPSK, QPSK)
- Shutdown part of Wi-Fi SSIDs at 2.4 GHz
- Clients are source of interference

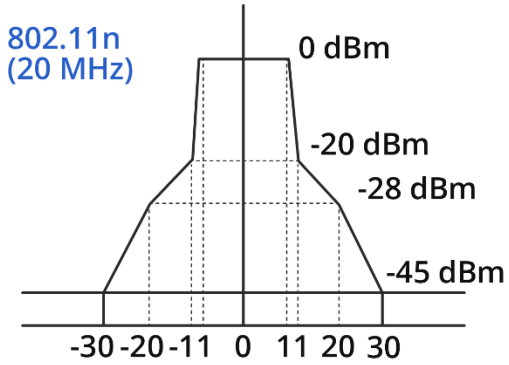
# Close layout of access points

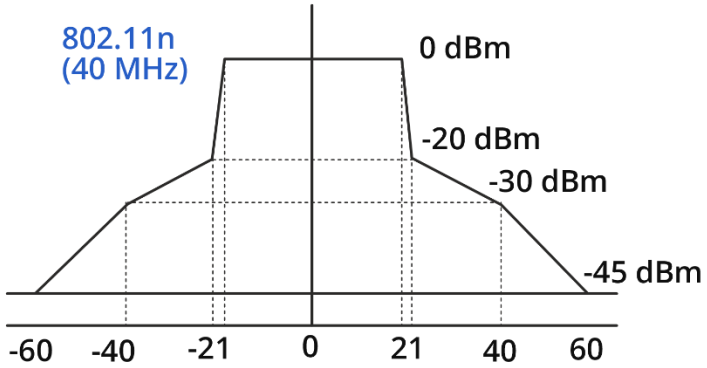
Close layout
of access points

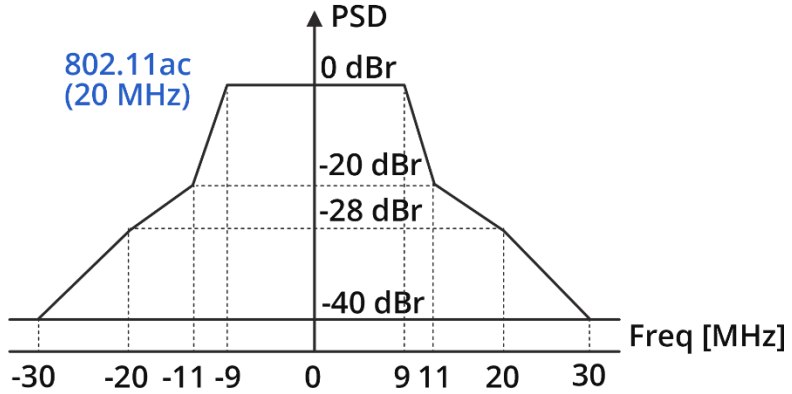
# Spectral mask



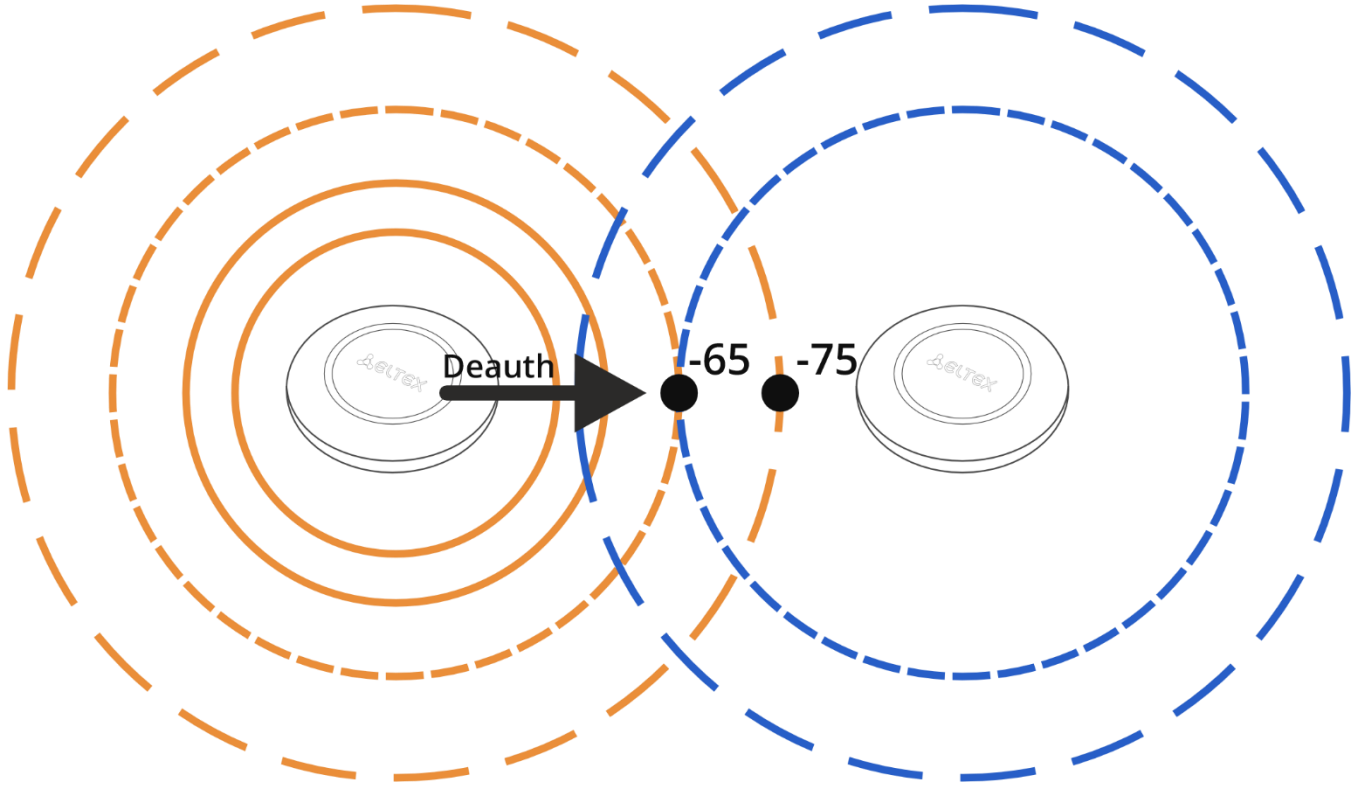



# Using high minimal signal level



# Received Signal Strength Indicator (RSSI)

| Signal strength, dBm | Quality | Description | Enough for |
|---|---|---|---|
| -30 | Amazing | Max achievable signal strength. The client can only be a few feet from the AP to achieve this. Not typical or desirable in the real world. | Everything |
| -67 | Very good | Minimum signal strength for applications that require very reliable, timely delivery of data packets. | VoIP, streaming video |
| -70 | Okay | Minimum signal strength for reliable packet delivery. | Email, web |
| -80 | Not good | Minimum signal strength for basic connectivity. Packet delivery may be unreliable. | N/A |
| -90 | Unusable | Approaching or drowning in the noise floor. Any functionality is highly unlikely. | N/A |

# Large number of SSID at AP

| Variables: | | | Assumptions: |
|---|---|---|---|
| Beacon data rate (Mbps) | 802.11g 5Mbps | | 802.11b long preambule used for 1Mbps; short preambule used for 2, 5.5, 11Mbps |
| Beacon frame size (bytes) | 300 | | 801.11g short slot time is assumed, with no 802.11b clients within range |
| Beacon interval (ms) | 102,4 | | WMM is enables and beacons are transmitted using "Best effor AC" |

| Amount of overhead | | 0-10% Low | | 10-20% Medium | | 20-50% High | | >50% Very high | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Number of SSIDs | | | | | | | | | |
| Number of APs on channel | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 1 | 0,45% | 0,90% | 1,35% | 1,80% | 2,25% | 2,70% | 3,15% | 3,60% | 4,05% | 4,50% |
| 2 | 0,90% | 1,80% | 2,70% | 3,60% | 4,50% | 5,40% | 6,30% | 7,20% | 8,10% | 9,00% |
| 3 | 1,35% | 2,70% | 4,05% | 5,40% | 6,75% | 8,10% | 9,45% | 10,80% | 12,16% | 13,51% |
| 4 | 1,80% | 3,60% | 5,40% | 7,20% | 9,00% | 10,80% | 12,60% | 14,40% | 16,21% | 18,01% |
| 5 | 2,25% | 4,50% | 6,75% | 9,00% | 11,25% | 13,50% | 15,75% | 18,00% | 20,27% | 22,52% |
| 6 | 2,70% | 5,40% | 8,10% | 10,80% | 13,50% | 16,20% | 18,90% | 21,60% | 24,32% | 27,02% |
| 7 | 3,15% | 6,30% | 9,45% | 12,60% | 15,75% | 18,90% | 22,05% | 25,20% | 28,38% | 31,52% |
| 8 | 3,60% | 7,20% | 10,80% | 14,40% | 18,00% | 21,60% | 25,20% | 28,80% | 32,43% | 36,03% |
| 9 | 4,05% | 8,10% | 12,15% | 16,20% | 20,25% | 24,30% | 28,35% | 32,40% | 36,49% | 40,53% |
| 10 | 4,50% | 9,00% | 13,50% | 18,00% | 22,50% | 27,00% | 31,50% | 36,00% | 40,54% | 45,04% |
| 11 | 4,95% | 9,90% | 14,85% | 19,80% | 24,75% | 29,70% | 34,65% | 39,60% | 44,60% | 49,54% |
| 12 | 5,40% | 10,80% | 16,20% | 21,60% | 27,00% | 32,40% | 37,80% | 43,20% | 48,65% | 54,04% |
| 13 | 5,85% | 11,70% | 17,55% | 23,40% | 29,25% | 35,10% | 40,95% | 46,80% | 52,71% | 58,55% |
| 14 | 6,30% | 12,60% | 18,90% | 25,20% | 31,50% | 37,80% | 44,10% | 50,40% | 56,76% | 63,05% |
| 15 | 6,75% | 13,50% | 20,25% | 27,00% | 33,75% | 40,50% | 47,25% | 54,00% | 60,82% | 67,56% |
| 16 | 7,20% | 14,40% | 21,60% | 28,80% | 36,00% | 43,20% | 50,40% | 57,60% | 64,87% | 72,06% |
| 17 | 7,65% | 15,30% | 22,95% | 30,60% | 38,25% | 45,90% | 53,55% | 61,20% | 68,93% | 76,56% |
| 18 | 8,10% | 16,20% | 24,30% | 32,40% | 40,50% | 48,60% | 56,70% | 64,80% | 72,98% | 81,07% |
| 19 | 8,55% | 17,10% | 25,65% | 34,20% | 42,75% | 51,30% | 59,85% | 68,40% | 77,04% | 85,57% |
| 20 | 9,00% | 18,00% | 27,00% | 36,00% | 45,00% | 54,00% | 63,00% | 72,00% | 81,09% | 90,08% |
| 21 | 9,45% | 18,90% | 28,35% | 37,80% | 47,25% | 56,70% | 66,15% | 75,60% | 85,15% | 94,58% |
| 22 | 9,90% | 19,80% | 29,70% | 39,60% | 49,50% | 59,40% | 69,30% | 79,20% | 89,20% | 99,08% |
| 23 | 10,35% | 20,70% | 31,05% | 41,40% | 51,75% | 62,10% | 72,45% | 82,80% | 93,26% | 100,00% |
| 24 | 10,80% | 21,60% | 32,40% | 43,20% | 54,00% | 64,80% | 75,60% | 86,40% | 97,31% | 100,00% |
| 25 | 11,25% | 22,50% | 33,75% | 45,00% | 56,25% | 67,50% | 78,75% | 90,00% | 100,00% | 100,00% |
| 26 | 11,70% | 23,40% | 35,10% | 46,80% | 58,50% | 70,20% | 81,90% | 93,60% | 100,00% | 100,00% |

# Get member list

| Name | Organization | Phone | Email | Description |
| --- | --- | --- | --- | --- |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

# At the beginning of the project

Get schemes for all rooms

Specify which rooms must be covered by Wi-Fi

For every room must specify maximum of clients

All rooms must have unique identifier

All rooms should have sizes

All rooms must have scale

# Goals for radio surveyor

## Survey and information collection

Take photos and make videos of rooms CONNECTED TO ROOM`S IDENTIFIER to make clear that room it is about

Get information about walls width, materials and be aware of metal grids or any other constructions

Make clear the presence and position of mobile operator femtocells - it can bring jams to Wi-Fi

Decide the parts of the room where it’s possible APs placement. Agree APs locations with rooms owners, designers and etc.

Define height of ceilings and its construction

# Goals for radio surveyor

## Design of the project

- Write on schemes places of every AP
- Appoint unique identifier of every AP
- For sector APs appoint directions for antennas

For every AP - write point of AP placement in room photo, linking its unique identifier

Appoint AP position:
- horizontal or vertical
- on ceiling, on wall, or on some other place

Appoint installation newances: construction of attachment fittings, containing separate antennas or not

After installation of AP, technician must write AP MAC-address linked to it unique identifier

# Goals for radio surveyor

Get all information about networks and services

Whether GRE tunneling is used or not?

Who issues the DHCP addresses? Is it separate DHCP-server or its do by switches and routers? Whether or not DHCP-relay is used?

Specifying the existence of using VLANs.
Specifying the existence of using IP subnets.
Is there a management VLAN for the APs?

Whether the wired access VLANs are isolated from the SSIDs VLANs (especially multicast) ?

Allocate sufficient resources for the management system

Provide for redundancy of critical parts:

- Routers, switches
- DHCP-servers
- Servers for Management System

# Thank you for your attention!

**We are always ready to discuss, develop and finalize solutions for your specification**


29V, Okruzhnaya St., Novosibirsk, Russia, 630020
09:00 — 18:00 (GMT+7)
Monday — Friday

+7 (383) 274-10-01, 274-48-48
eltex@eltex-co.ru; eltex-co.com