DELTALINK ELECTRONICS.

- All you have to know about MIMO ?
- By : Ahmad Mortazavi

28 AUGUST

MUM DUBAI(2012)

Introduction

- Based on the features and theory the 802.11a/g should be discontinue by now but 40% of installers still believe that 802.11a/g performance is better than 802.11n and they prefer to buy High Power 802.11a/g Radio modules.

Why !!!???

That's what we will Talk about ……

- As you find out reaching high Throughputs in 802.11n is not simple and needs knowledge

To achieve this Goal you need to have a good knowledge about Radio parameters and antenna parameters.

I am collect very useful information about this concepts in this presentation please pay special attention to it believe me it will change your professional vision and life

CHAPTER 1:

What is new in 802.11n

Radio Parameters

- Throughput:

Carrier efficiency x channel width x bit/symbols x FEC = Throughput

802.11a/g Data rates:

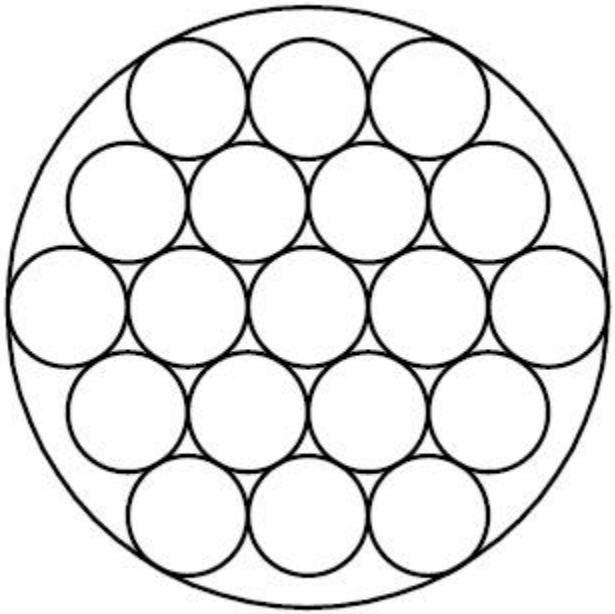
0.6	x	20 MHz	x	1(BPSK)	x	½	=	6 Mbps
0.6	x	20 MHz	x	1(BPSK)	x	¾	=	9 Mbps
0.6	x	20 MHz	x	6(64QAM)	x	¾	=	54 Mbps

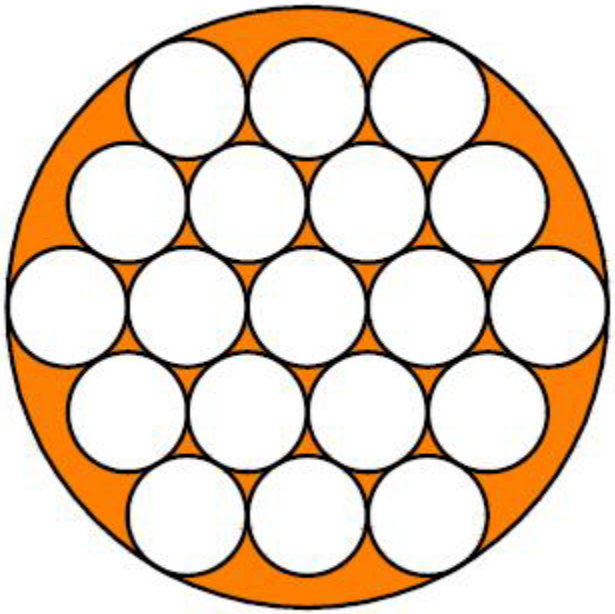
Turbo (allowed in few countries in limited frequency channels):

0.6	x	40 MHz	x	6(64QAM)	x	¾	=	108 Mbps

Carrier Efficiency

- what is the Carrier Efficiency ?





Carrier Efficiency

- Compare 802.11N vs 802.11a/g on Carrier Efficiency?

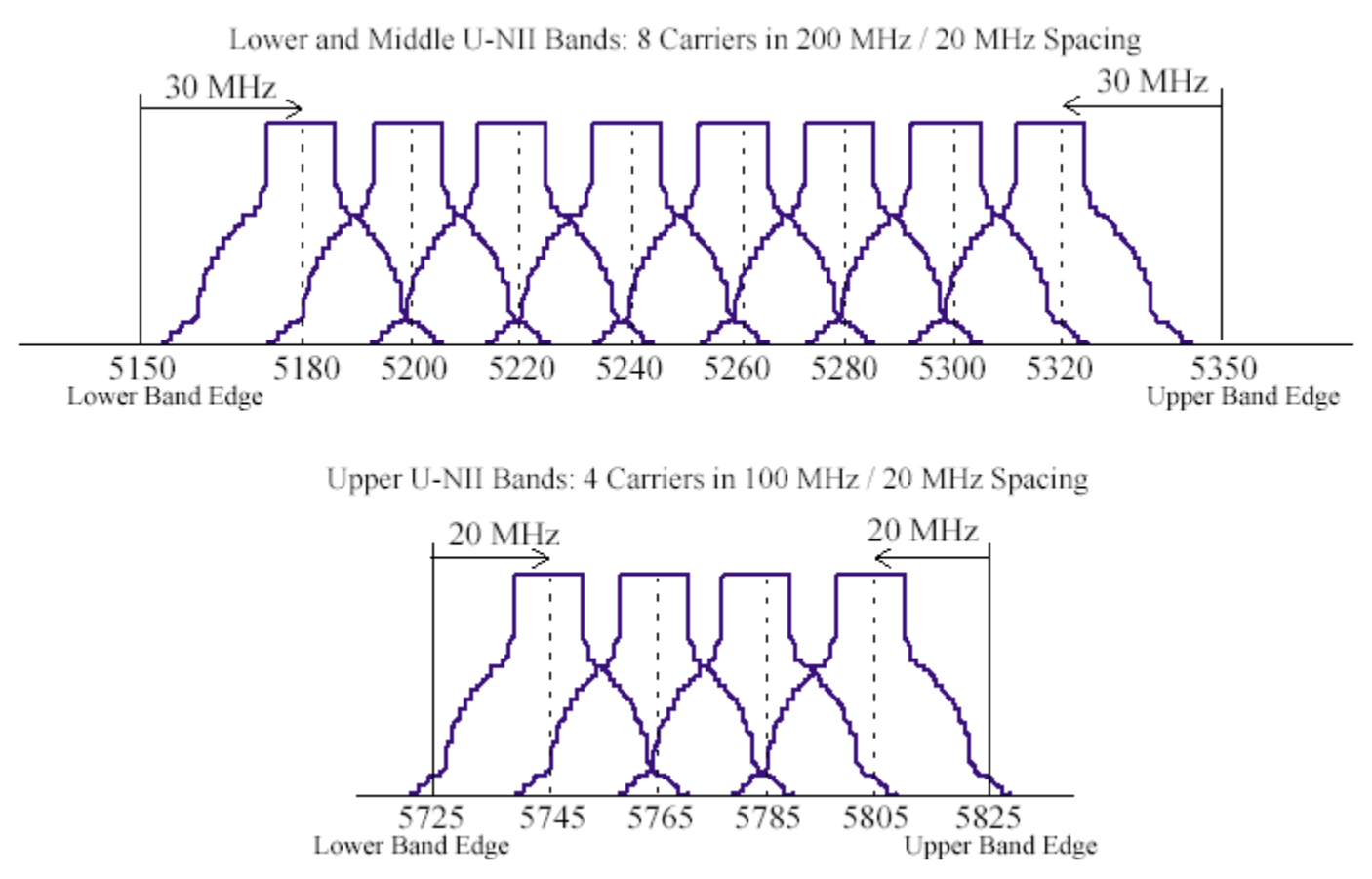
Carrier Efficiency on 802.11a/g is 0.6 but in 802.11N depends on Guard Interval(GI) is 0.65 and 0.72 in 20MHz channel and 0.65 and 0.75 in 40 MHz channel

Carrier efficiency x channel width x bit/symbols x FEC = Throughput

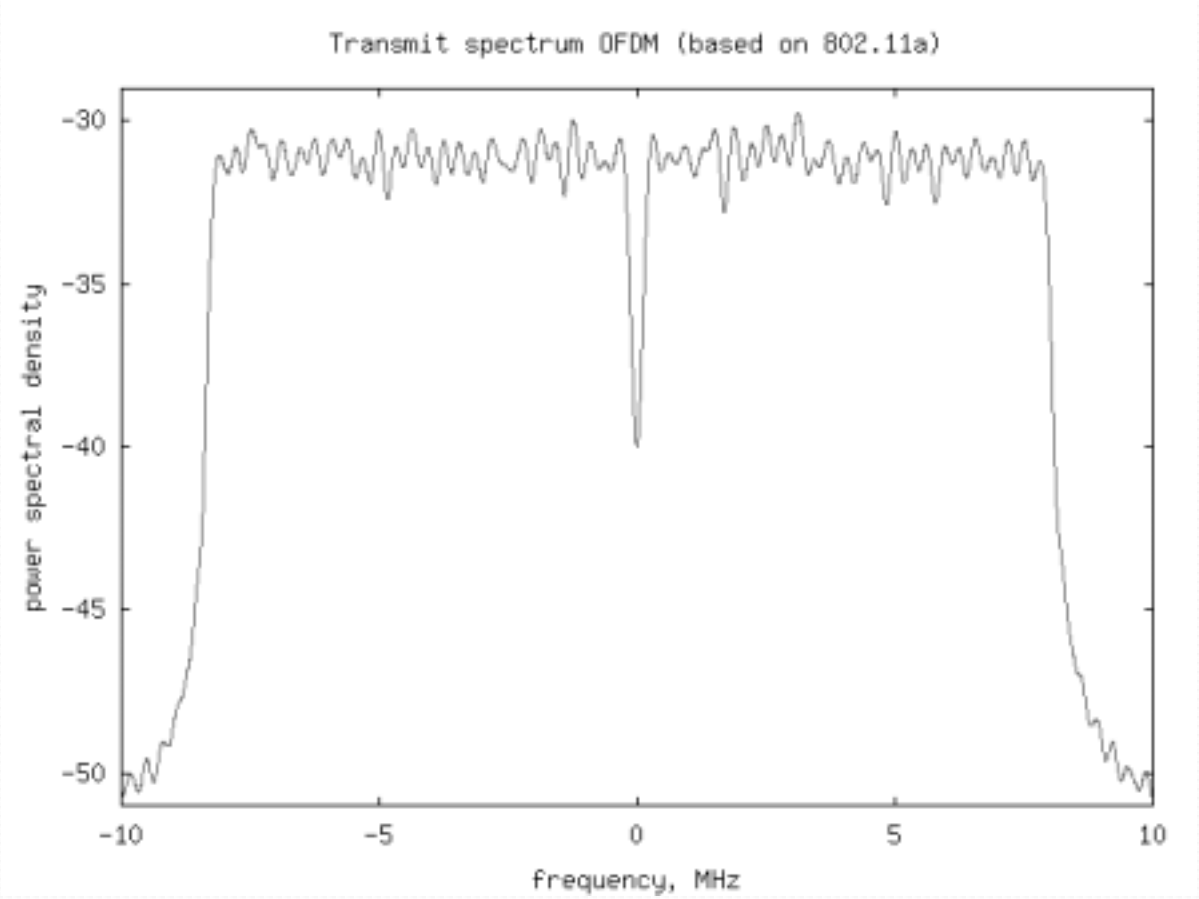
802.11a/g →	0.6	x	20 MHz	x	6(64QAM)	x	¾	= 54 Mbps
802.11n → (GI = Long)	**0.65**	x	20 MHz	x	6(64QAM)	x	¾	= **58.5 Mbps**
802.11n → (GI = Short)	**0.72**	x	20 MHz	x	6(64QAM)	x	¾	= **64.8 Mbps**

Carrier & Subcarriers

- Lower, Middle and Upper U-NII Bands Carriers :



- Closer look in to a 20 MHz Carrier :



- **Extended Channel width in 802.11n**:

Since you are allowed to bind two 20MHz channels on 802.11n then you will have 2X speed compare to 802.11a/g

Carrier efficiency x **Channel width** x bit/symbols x FEC = Throughput

802.11a/g → 0.6 x 20 MHz x 6(64QAM) x ¾ = 54 Mbps

802.11n → **0.75** x **40 MHz** x 6(64QAM) x ¾ = **135 Mbps**
(GI = Short)

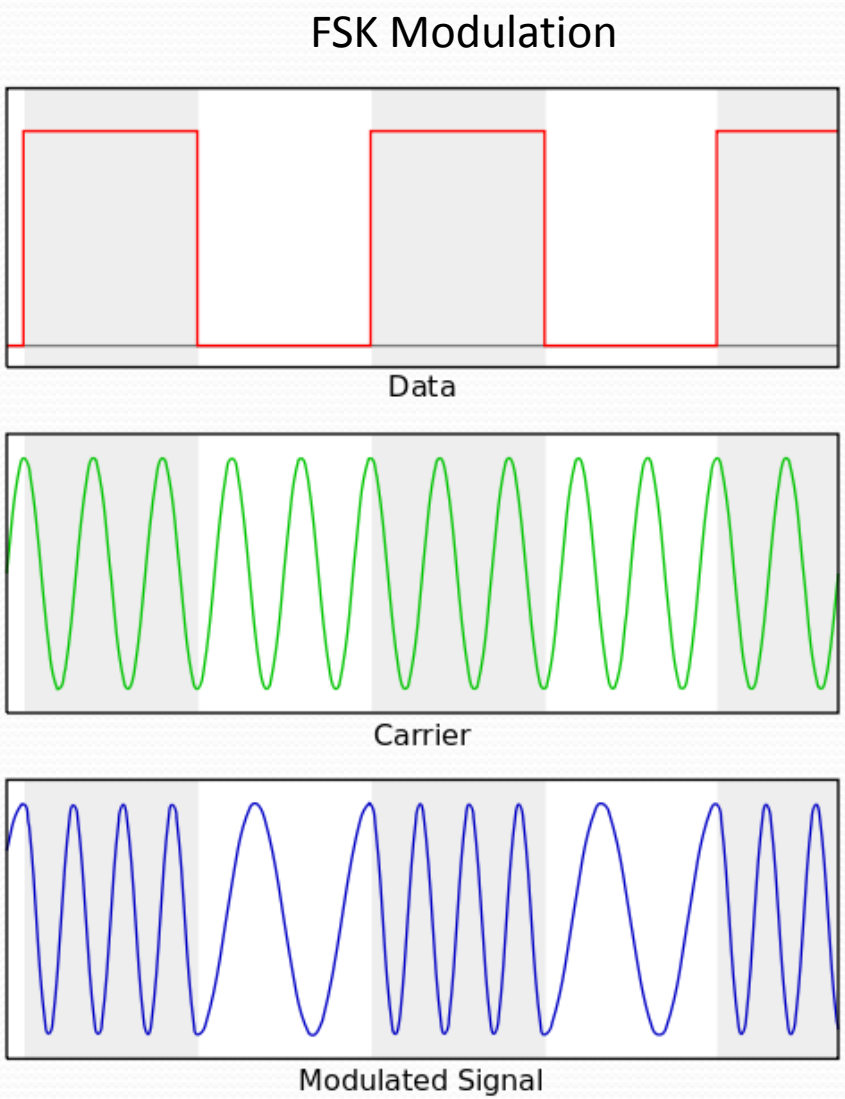
Modulation

- What is the Modulation ?

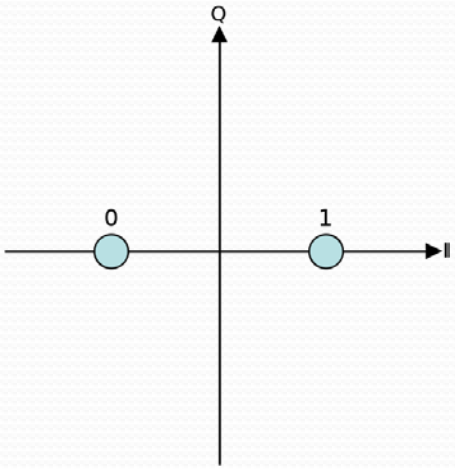
  Converting Digital to Analog

- Don’t get it, Do you?

  The FSK(Frequency Shift Keying) Is simple enough to help you to Understand the Modulation

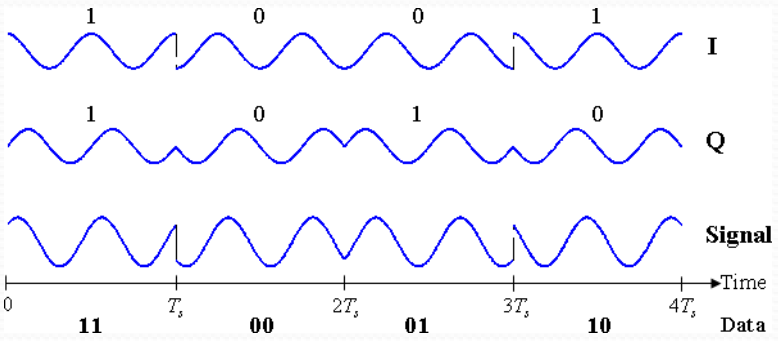


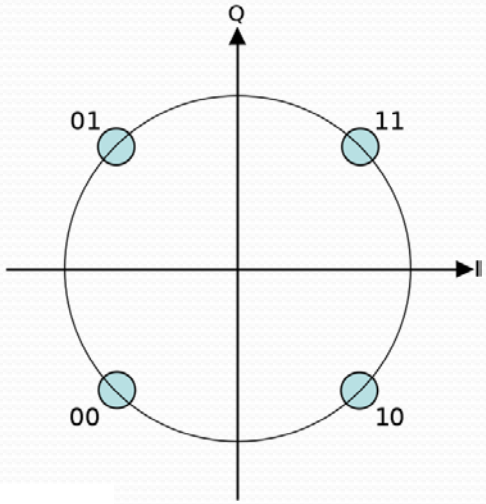
- Phase Shift keying PSK (BPSK, QPSK)



BPSK

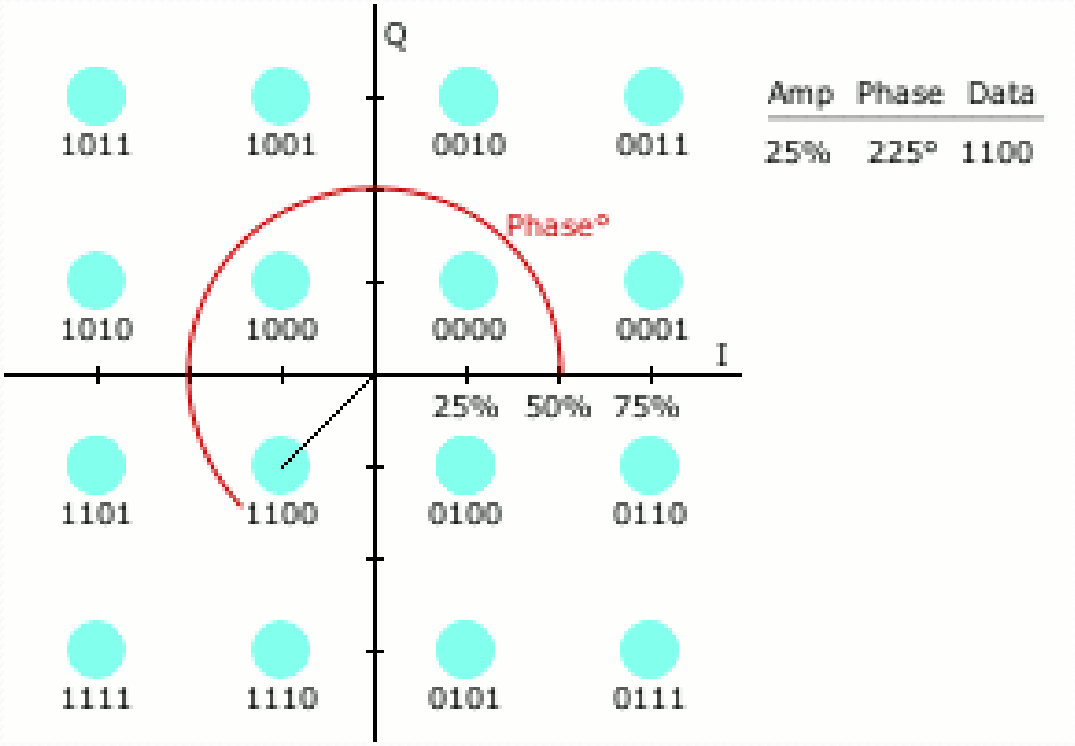
QPSK





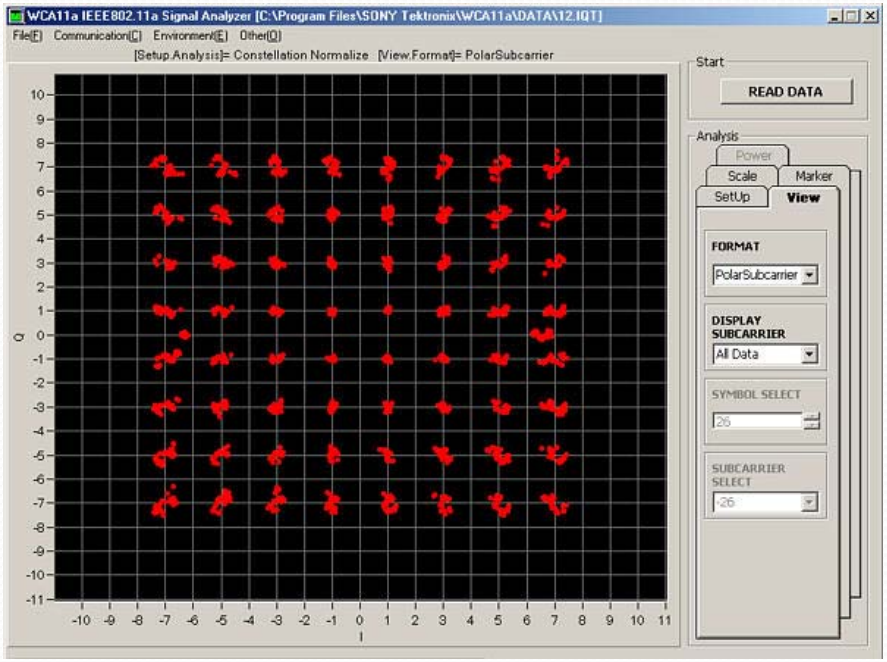
QPSK

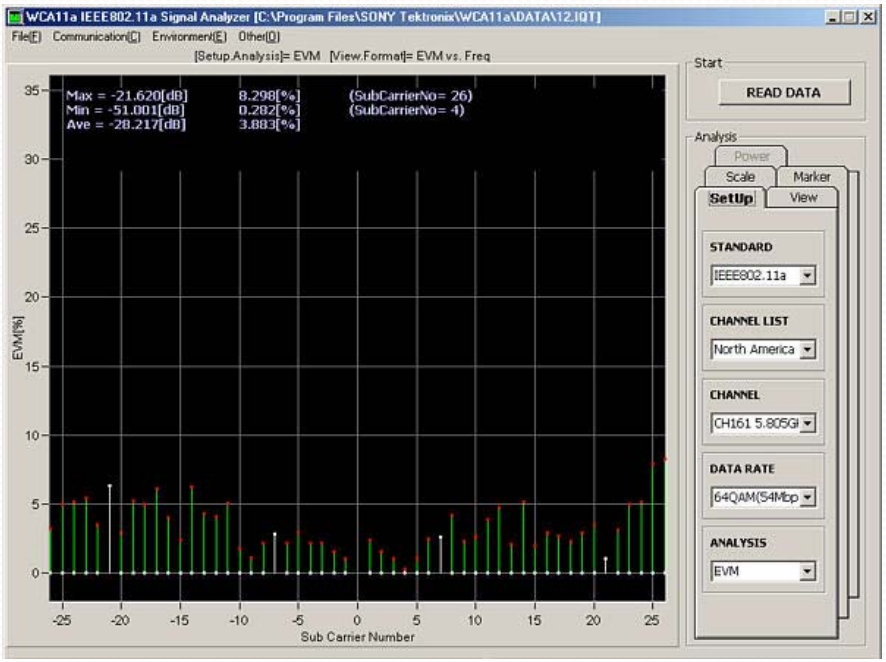
- QAM (Quadrature Amplitude Modulation) 16QAM



16-QAM

- QAM (Quadrature Amplitude Modulation) 64QAM





64-QAM

- Modulation Effects:

Carrier efficiency x channel width x **bit/symbols** x FEC = Throughput

0.6	x	20 MHz	x	1(BPSK)	x	¾	=	9 Mbps
0.6	x	20 MHz	x	2(QPSK)	x	¾	=	18 Mbps
0.6	x	20 MHz	x	4(16QAM)	x	¾	=	36 Mbps
0.6	x	20 MHz	x	6(64QAM)	x	¾	=	54 Mbps
0.6	x	20 MHz	x	8(256QAM)	x	¾	=	72 Mbps

The maximum modulation on 802.11n is 64-QAM just like 802.11a/g

FEC (Forward Error Correction)

- Understanding the object :

Triplet received	Interpreted as
000	0 (error free)
001	0
010	0
100	0
111	1 (error free)
110	1
101	1
011	1

FEC= 1/3

- Compare 802.11N vs 802.11a/g

Carrier efficiency x channel width x bit/symbols x **FEC** = Throughput

802.11a/g → 0.6 x 20 MHz x 6(64QAM) x ¾ = 54 Mbps

802.11n → 0.72 x 20 MHz x 6(64QAM) x **5/6** = **72 Mbps**
(GI = Short)

Compare Result

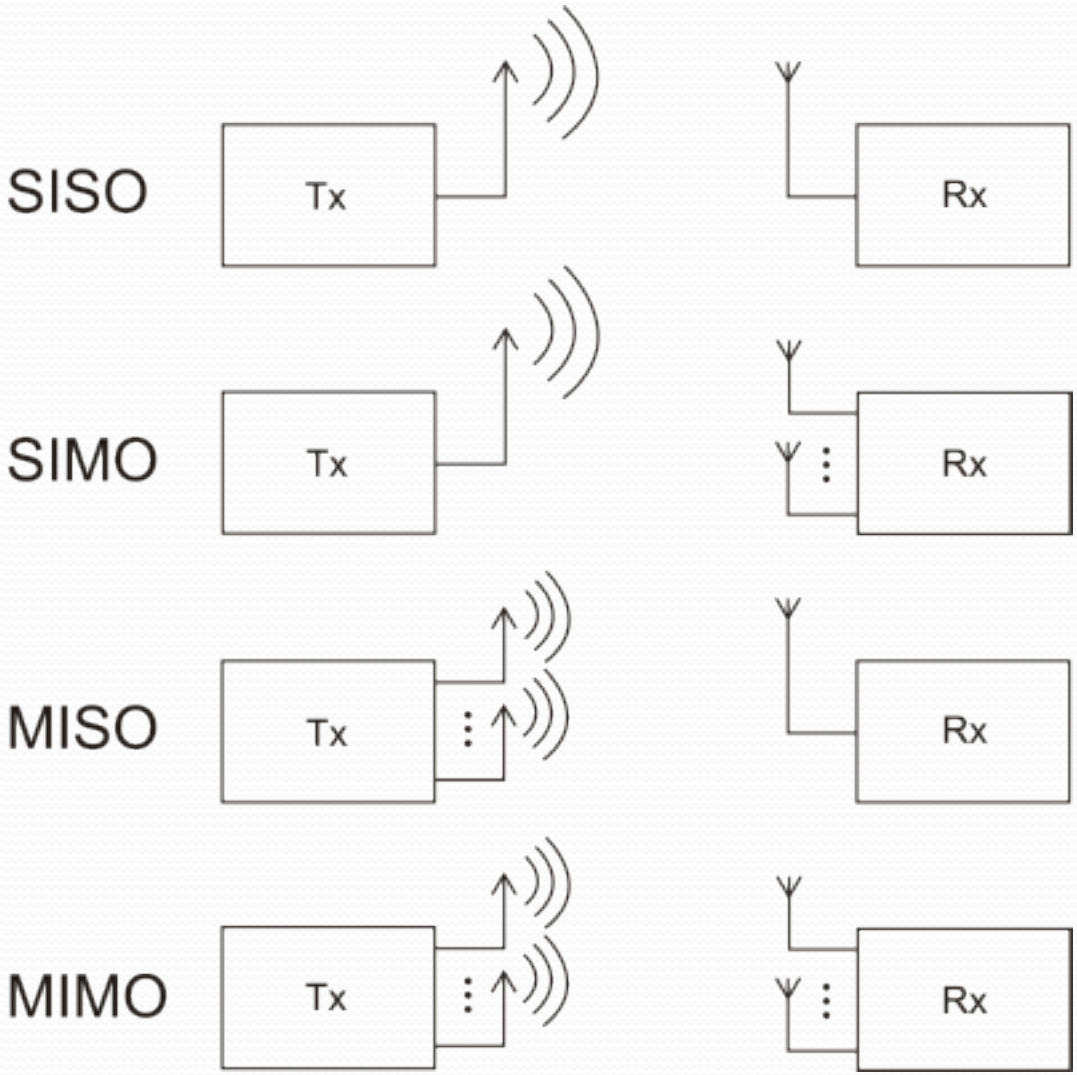
- Compare 802.11N vs 802.11a/g

802.11a/g → 0.6 x 20 MHz x 6(64QAM) x ¾ = 54 Mbps

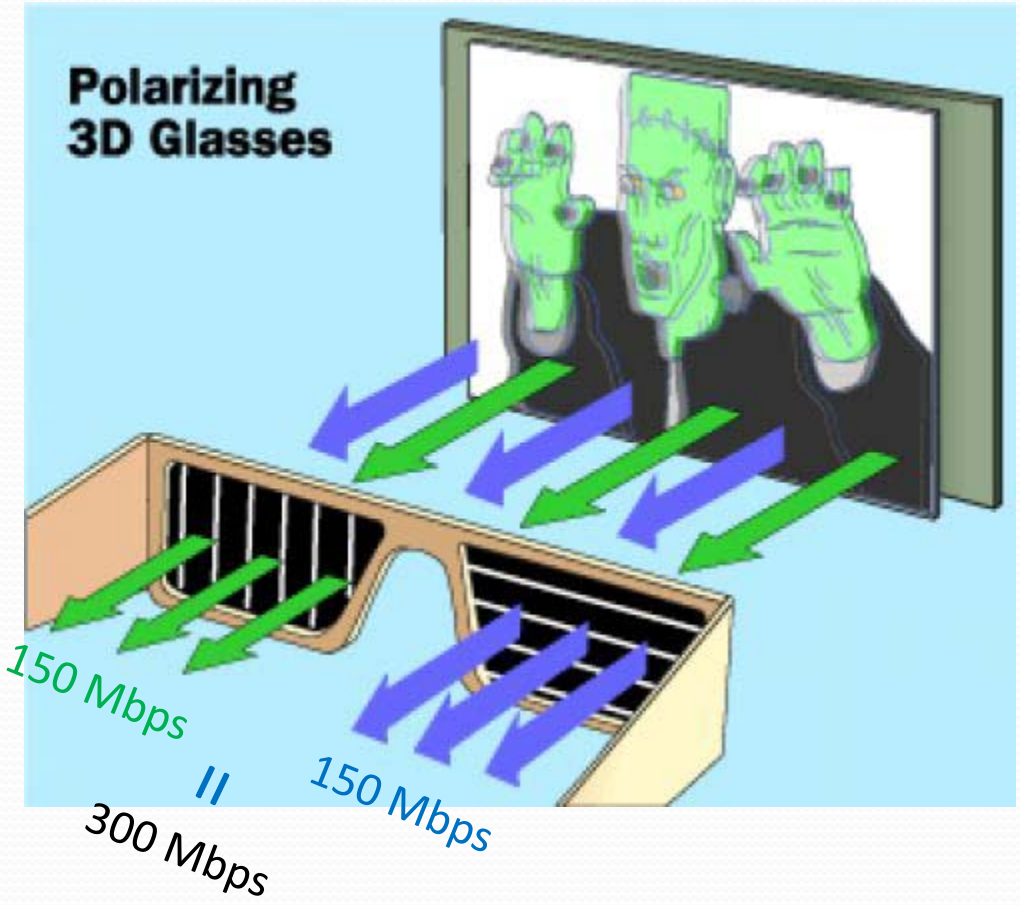
802.11n → **0.75** x **40 MHz** x 6(64QAM) x **5/6** = **150 Mbps**
(GI = Short)

- Now The question is what else we can do to improve the performance ???

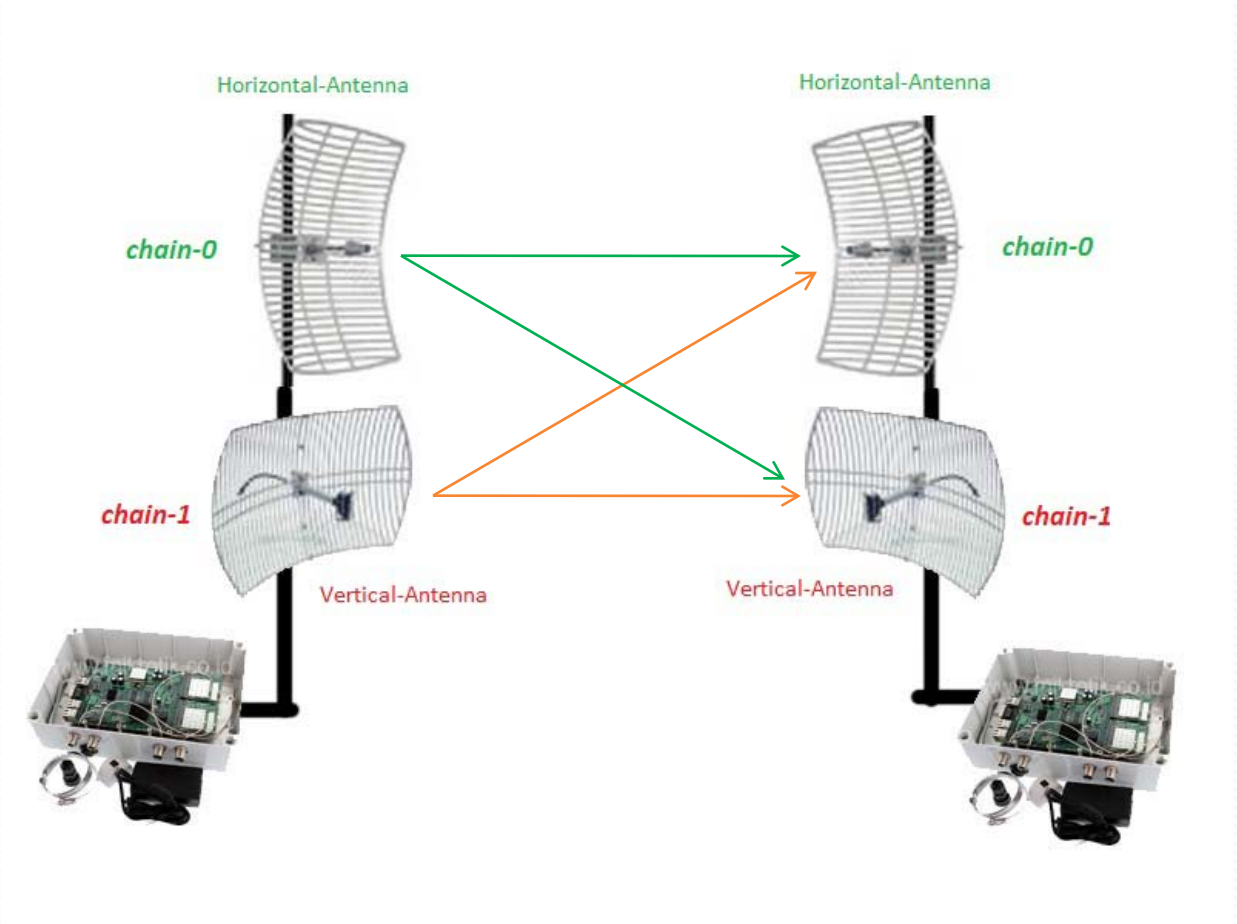
MIMO(Multiple In Multiple Out)



- You are familiar with MIMO because of the 3D TV and Cinemas



- Another feature added to 802.11N is MIMO technology. By using two antennas in different polarity or by using one dual polarity antenna in one side our MIMO radio can double the aggregate speed and we can reach 300 Mbps in Theory



- 802.11N Data rates :

802.11n → (SISO) 1x1

802.11n → (MIMO) 2x2

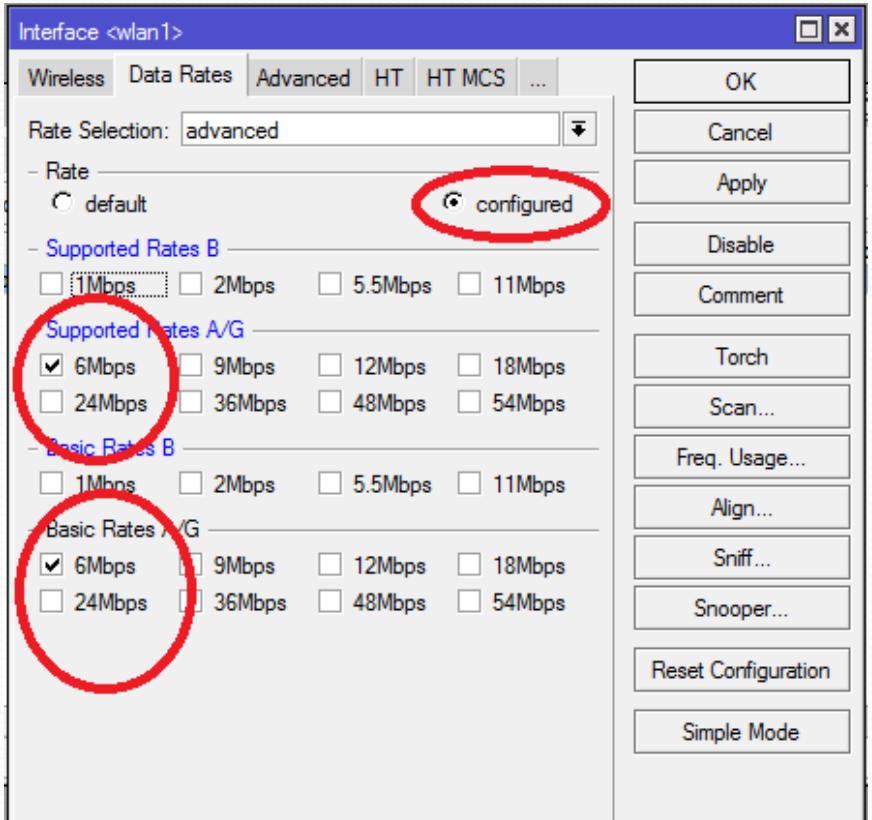
MCS Index	Spatial Streams	Modulation Type	Coding Rate	Data Rate Mbit/s			
				20 MHz channel		40 MHz channel	
				800ns GI	400ns GI	800ns GI	400ns GI
0	1	BPSK	1/2	6.50	7.20	13.50	15.00
1	1	QPSK	1/2	13.00	14.40	27.00	30.00
2	1	QPSK	3/4	19.50	21.70	40.50	45.00
3	1	16-QAM	1/2	26.00	28.90	54.00	60.00
4	1	16-QAM	3/4	39.00	43.30	81.00	90.00
5	1	64-QAM	2/3	52.00	57.80	108.00	120.00
6	1	64-QAM	3/4	58.50	65.00	121.50	135.00
7	1	64-QAM	5/6	65.00	72.20	135.00	150.00
8	2	BPSK	1/2	13.00	14.40	27.00	30.00
9	2	QPSK	1/2	26.00	28.90	54.00	60.00
10	2	QPSK	3/4	39.00	43.30	81.00	90.00
11	2	16-QAM	1/2	52.00	57.80	108.00	120.00
12	2	16-QAM	3/4	78.00	86.70	162.00	180.00
13	2	64-QAM	2/3	104.00	115.60	216.00	240.00
14	2	64-QAM	3/4	117.00	130.00	243.00	270.00
15	2	64-QAM	5/6	130.00	144.40	270.00	300.00

CHAPTER 2:

Tips for Special Wireless Configurations on your Mikrotik wireless Router

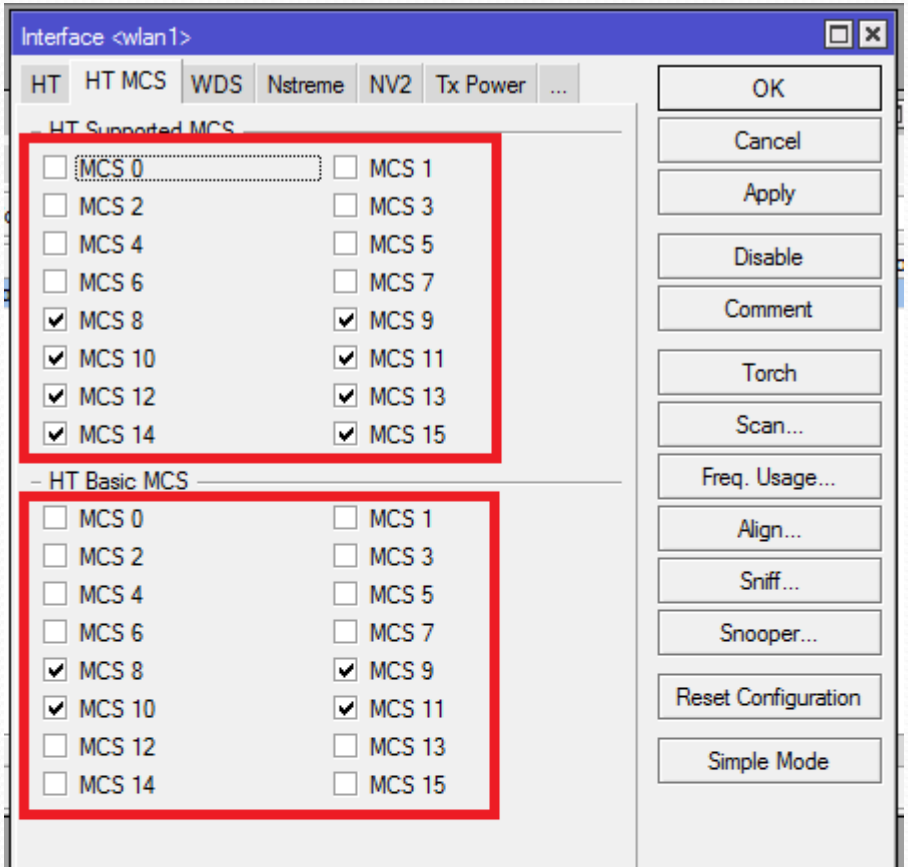
Wireless Interface Important settings

- After Basic Configurations and after established your link you should force your router to use dual Stream MCS to double our throughput if you are using dual polarity Antenna first change the data rate mode to manual.



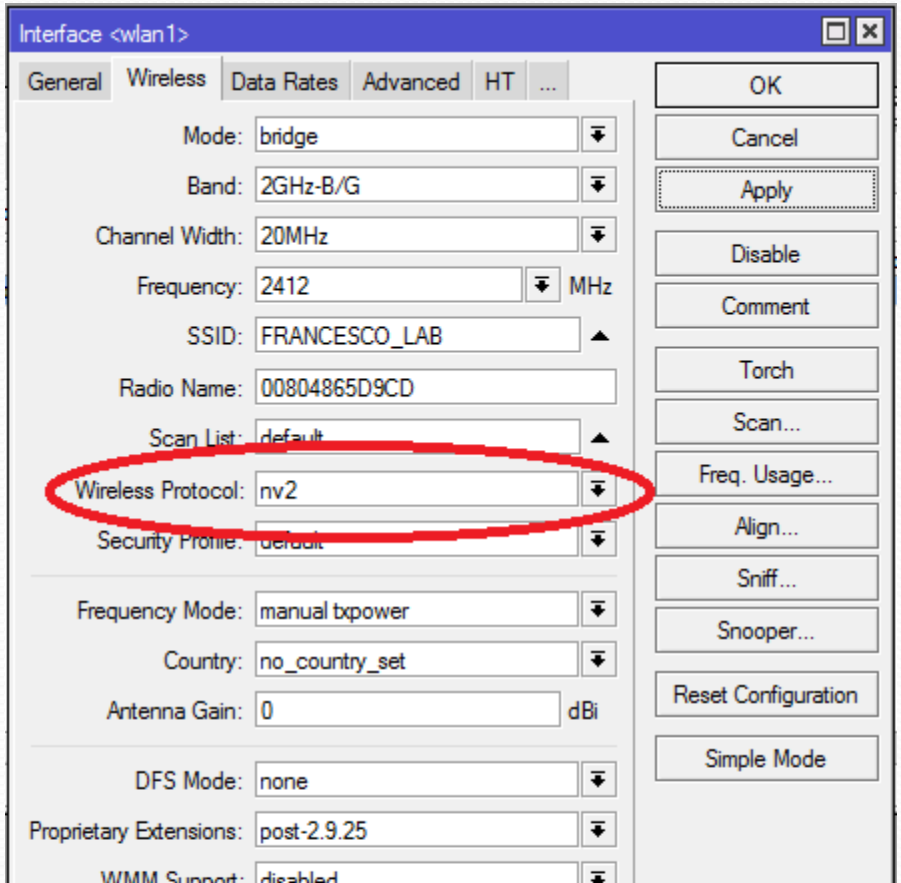
Wireless Interface Important settings

- Then uncheck the MCS 0 – 7 both in the basic and Supported rates and check the MCS 8 to 15 only in basic and Supported rates.



Wireless Interface Important settings

- Do not forget to use NV2 as your wireless protocol and set your wireless mode to Station Bridge

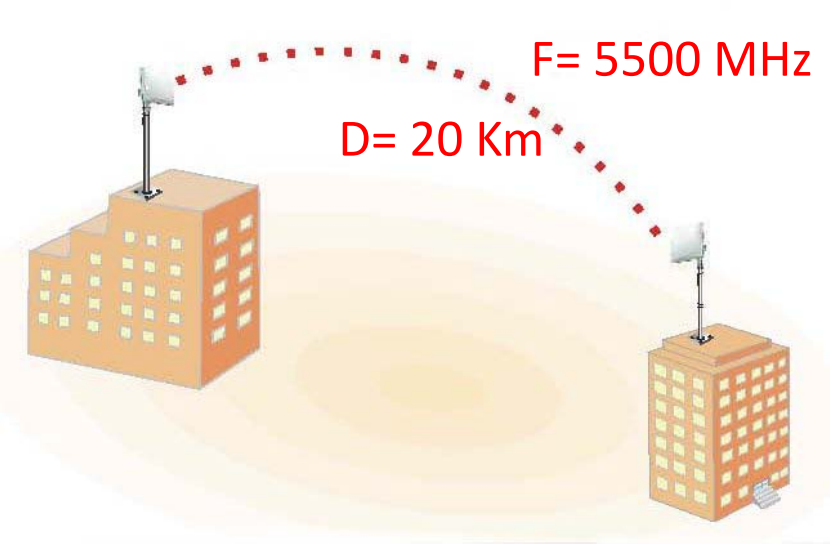


CHAPTER 3:

Antenna parameters

1- Calculating The Antenna Gain

- First you have to Calculate the path loss :

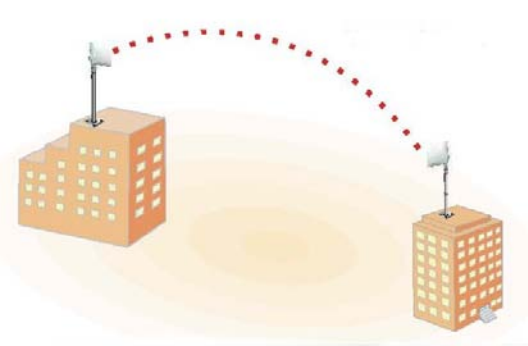


Path Loss(LOS) = 20 log (distance in mile) + 20 log (frequency in MHz) + 36.6

Path Loss(20 Km) = 20log(20km/1.61 = Mile) + 20 log (5500) + 36.6

Path Loss(20 Km) = 21.9 + 74.8 + 36.6 ➔ 133.3 dB

- Second based on your desire RX level Calculate the Antenna Gain that you have to use:



Path loss =133.3 dB

RX Signal = TX power – Cable loss + TX Antenna gain – Path loss + RX Antenna gain – Cable Loss

Check Your MiniPCI wireless adapter RX level @ MCS7 or MCS 15

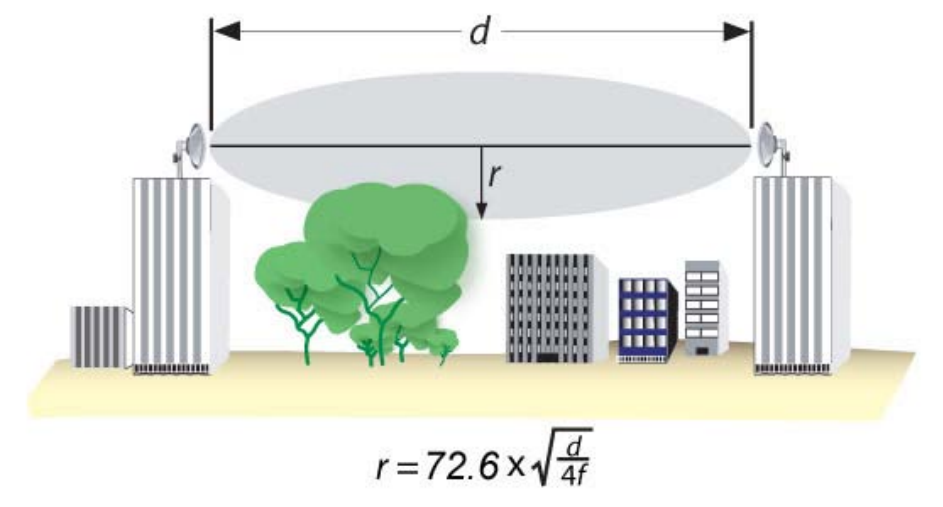
Check Your MiniPCI wireless adapter maximum TX power @ MCS7 or MCS 15

-65 = +19 – (Jumper + Pigtail loss) 2 + Antenna gain – 133.3 + Antenna gain – 2

-2(Antenna gain) = 65 +19 – 2 – 133.3 – 2

Antenna gain = 53.3 / 2 ➔ 26.6 dBi (Minimum Antenna that you need to reach -65 RX)

- **Tip1 : Obstacles or Ground in the First Fresnel Zone can Kill your signal before saying bad words to me please check your link for line of sight**



- **Tip2 : The Antenna Gain is not a Fix Parameter and it depends on the frequency and it could be weaker or stronger in your desire frequency**

- **Tip3 : The output power of your Wireless Adapter Could be variable in different frequencies and data rates if this is your job and you want to be a professional buy a Power meter**

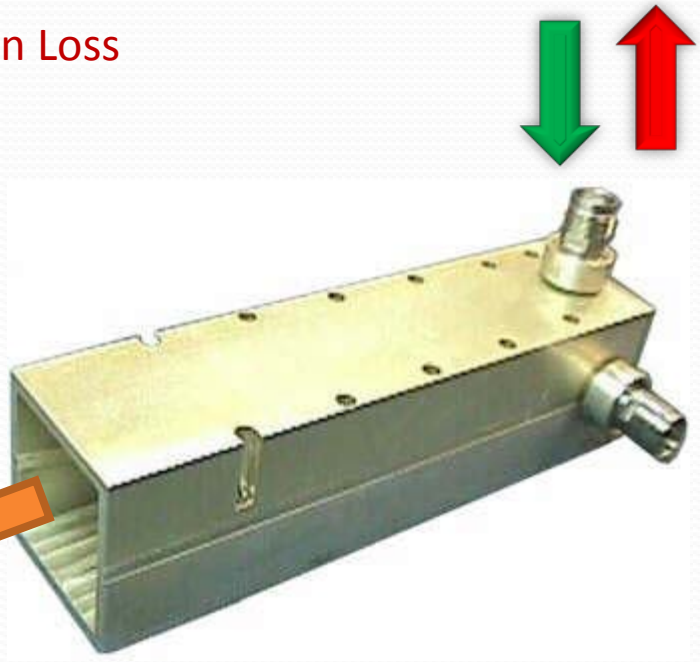
2- VSWR and Return loss

- If you measure the returned signal (because of the Impedance Mismatching) from your antenna then you can calculate your antenna return loss

Transmitted Signal – Returned Signal = Antenna Return Loss

16 dBm – 6 dBm = Antenna Return Loss

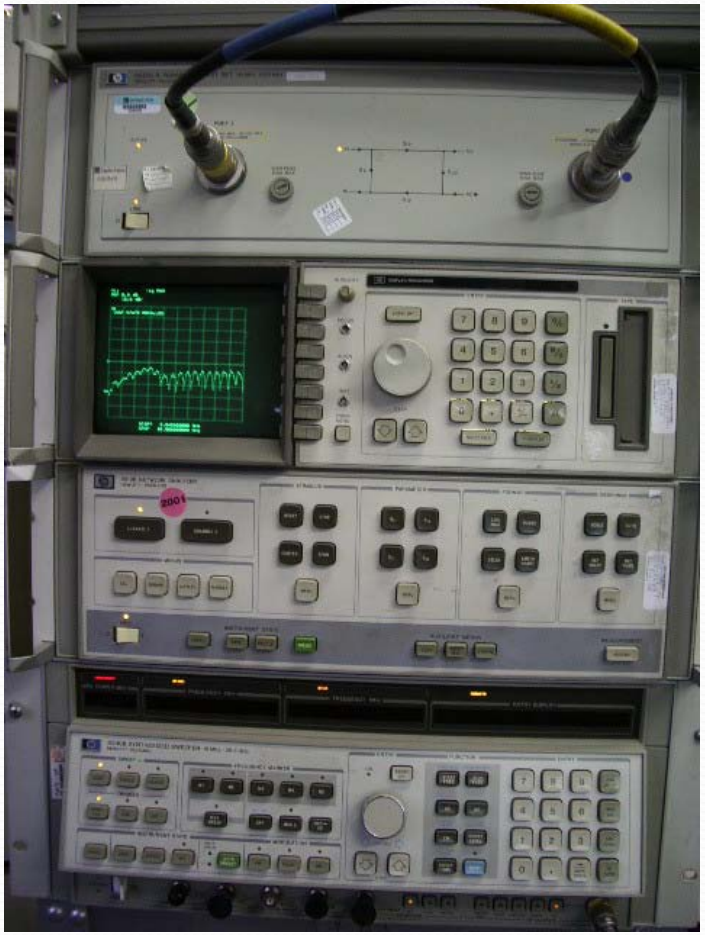
16 dBm 6dBm



16 dBm + 12dBi = 28 dB

EIRP

- Most of Wireless Radios can handle the Return loss up to -9.5 or better(The Best Measurable Return loss is -100 and you can measure it by a RF Network Analyzer)



- **You can Convert the VSWR to Return Loss by using this Formula:**

Return Loss = 20 log((VSWR+1) / (VSWR-1))

VSWR 2:1 → RL: -9.54

VSWR 1.01:1 → RL: -46

- **Tip4 : Just like the Gain the VSWR or Return Loss is not a Fix Parameter and it depends on the frequency so become sure the antenna that you want to use is has a VSWR better than 2:1 on the frequency that you want to use it.**

- **Tip5 : If you Established a link and after 1 week the RX signal is fall down for 10 or 20 dB it means your system VSWR is more than 2:1**

3- Port to Port Isolation:

- The signal generated by one chain can travels to the other chain and it could effect on performance and even cause damage.

Output signal from chain0
16 dBm

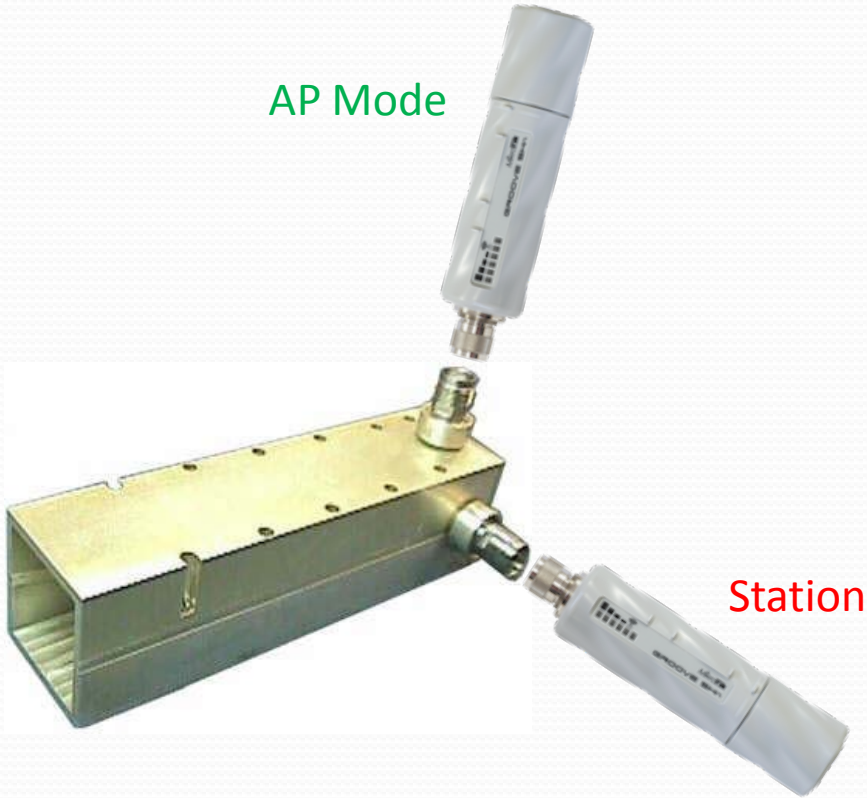
16 dBm + 12dBi = 28 dB
EIRP

Go back to chain1

16 dBm – (Antenna Port to Port Isolation)

- Most of Wireless manufacture offer to use the antennas with a port to port Isolation better than -25

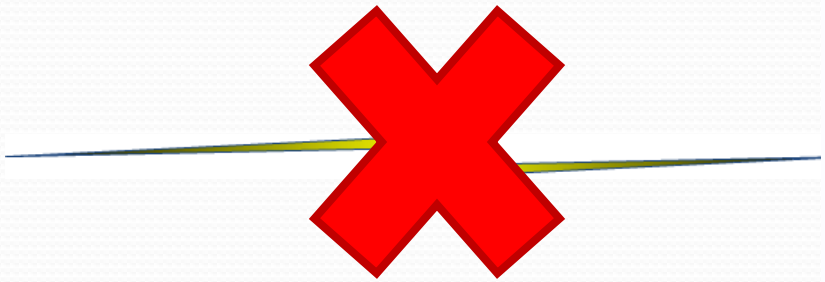
- you can measure your antenna port to port Isolation by link two radio over the ports of your antenna, minimizing the output power and check the receiving signal(it is not very accurate but at least you can understand the meaning of P-to-P Isolation)



4- Cross Polarization

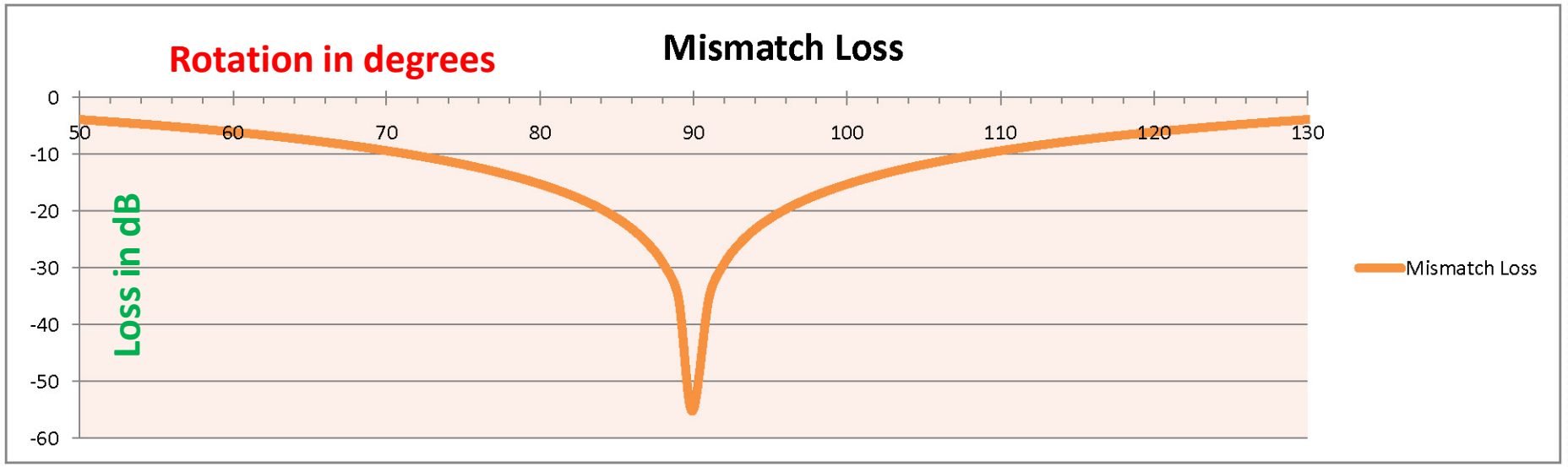
- **This is the Most Important parameter in your MIMO radio link and it direcly effect your throughput better Cross Polarization means better throughput.**

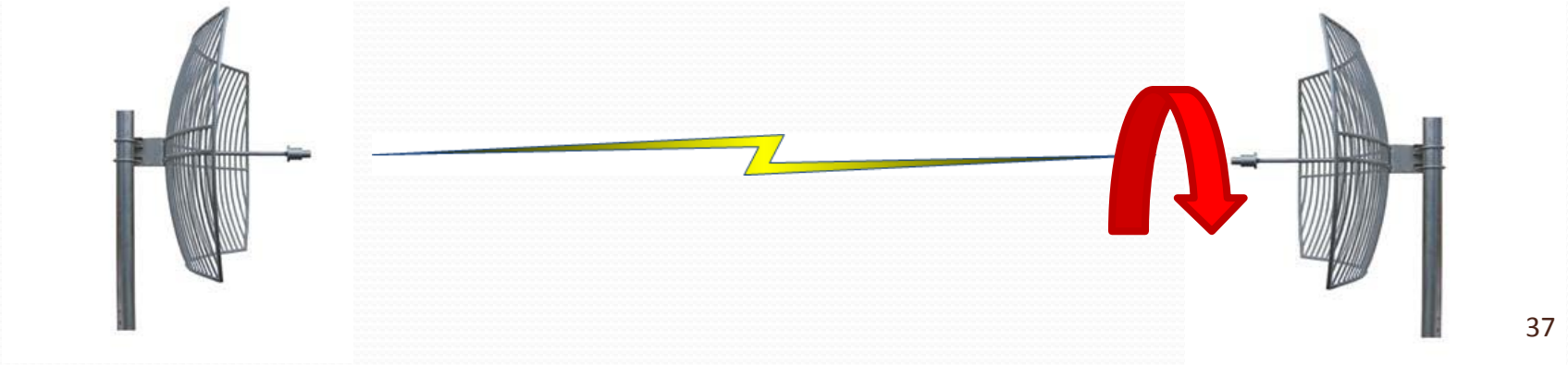
- When you are Using two antennas with Liner polarization linked together if you rotate one side 90 digress you have to lose your link theoretically :



- While we are rotating the far end site antenna we will have the below graph if we monitor loss / rotation degree :

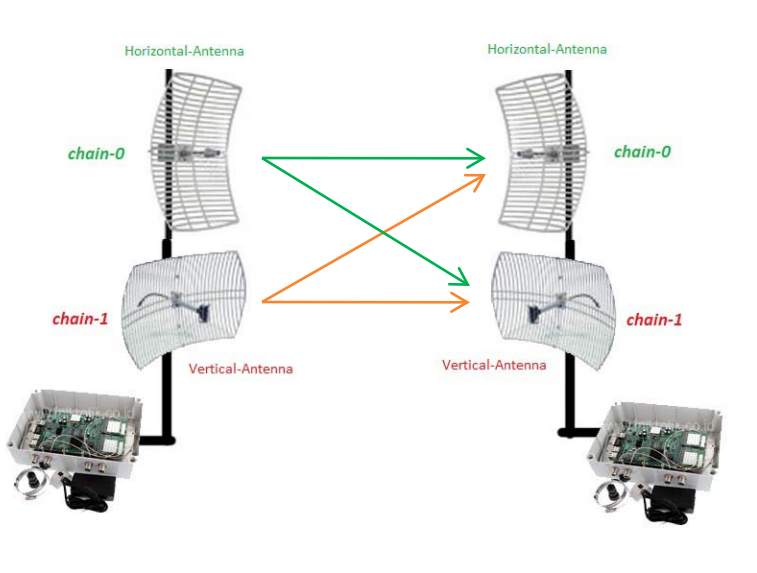
Polarization Mismatch Loss (dB) = 20 log (cos θ)





- Cross polarization is used by MIMO MCS-8 to MCS-15 to double the throughput and the radio can use the carrier twice by using this mismatch loss of the other chain.

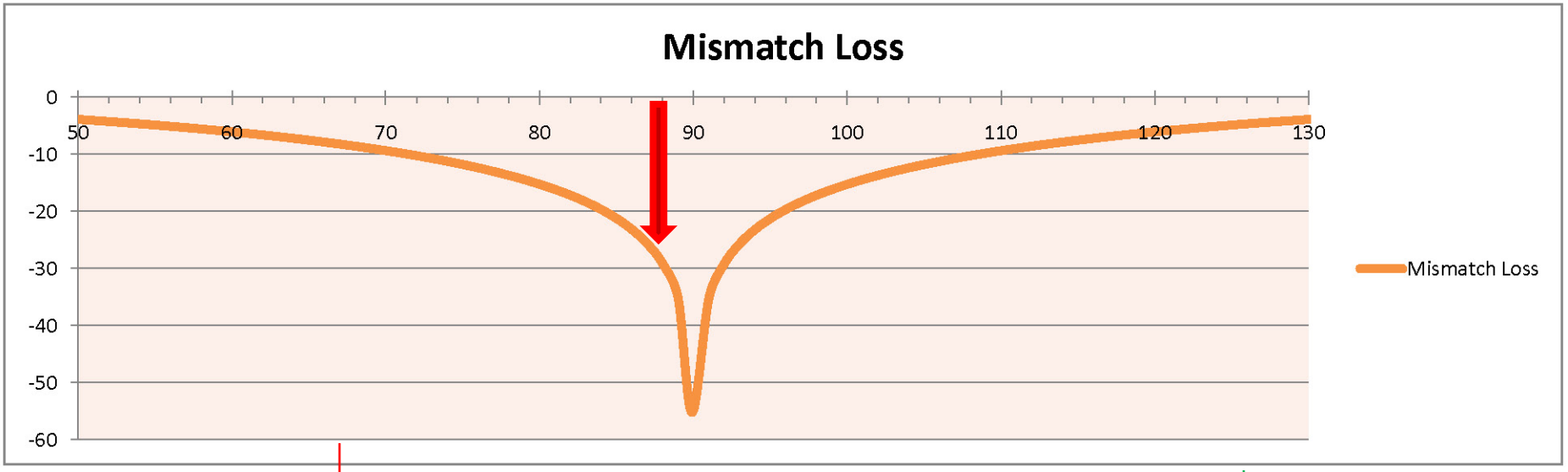
- The opposite chains signal is like noise and interfered each other. Better cross polarization gives you more throughputs.

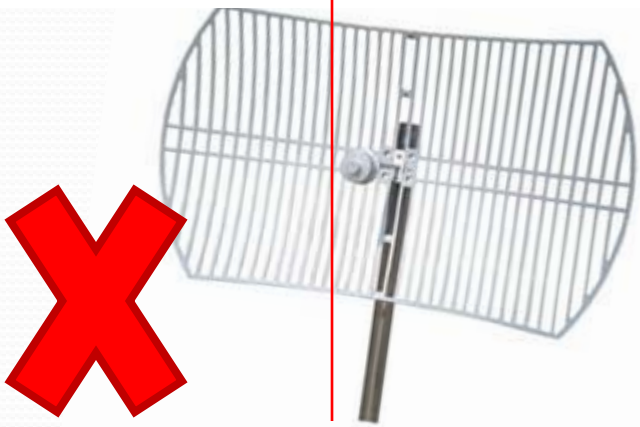


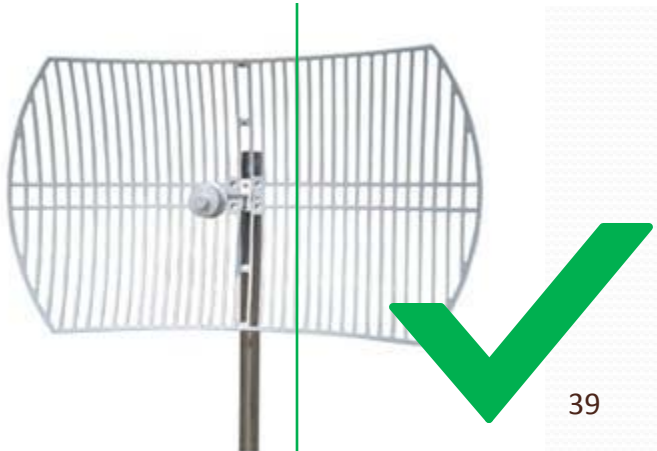
RX chain1(TX chain1) = -45dBm

RX chain1(TX chain0) = -45dBm – 25dBi(RX Antenna Cross Pol.) = -70 dBm

- **Tip6: In a dual polarity outdoor link always Level your antenna only 1 degree mismatch in each side can drop your Cross pol. for more than 20dB**

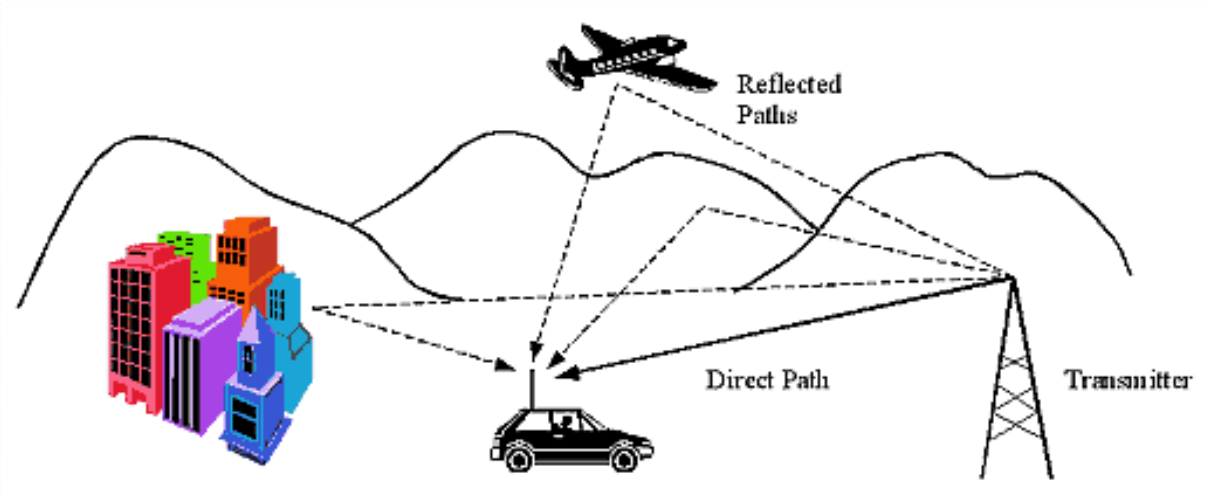






- **Tip7: In the real world situation every antenna shows different reactions for different frequencies in cross polarization. For better performance if you have any option to chose the frequency, select the channel that your antenna cross polarization are better on it.**

- **Tip8: In long range links the multipath signals will have small(1-5 Degrees) mismatch caused by reflections. Adjusting the level of your antenna some times will improve your performance but it only suggested to advanced installers and wireless experts.**



CHAPTER 4:

Tips for choosing a right Pigtail and Jumper for your Link

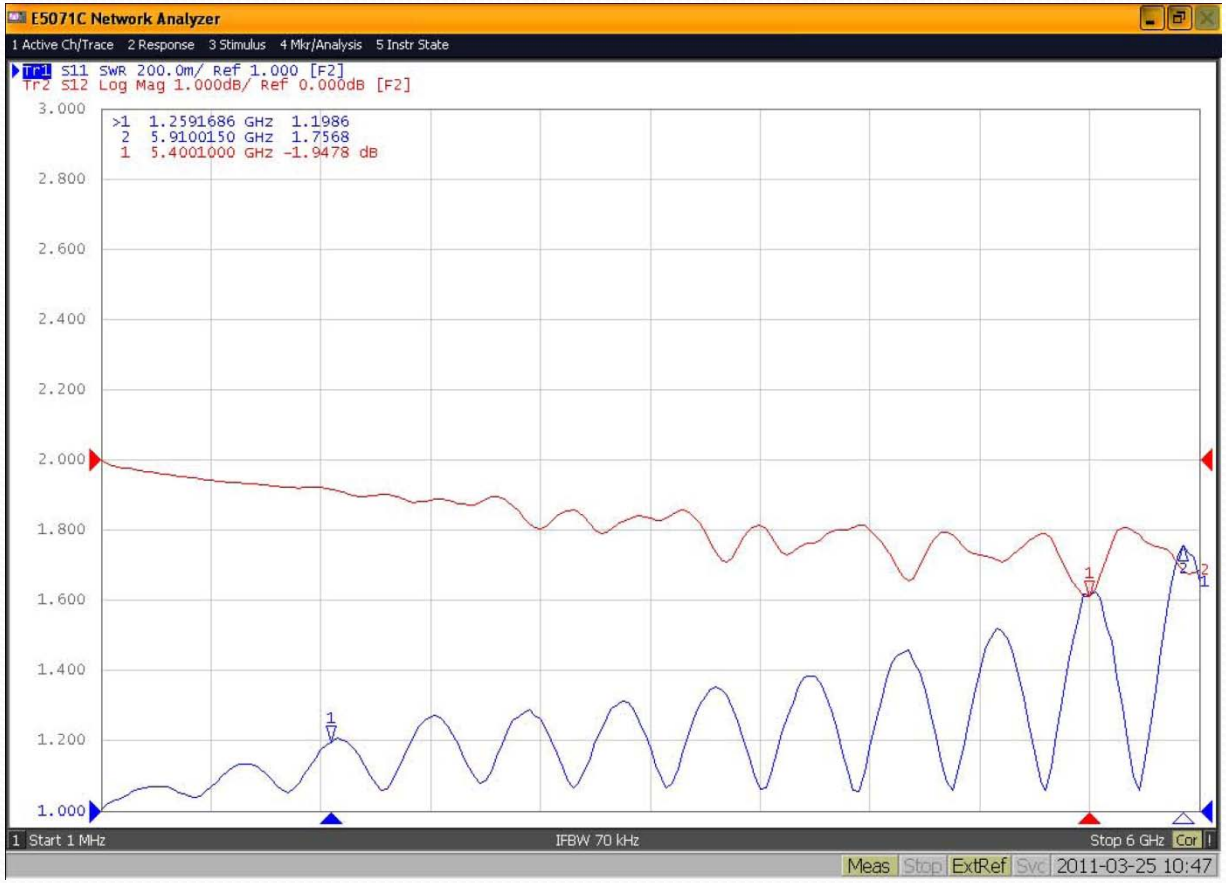
Pigtails an Jumpers

- We are using the pigtails and jumpers to connect our radio to the antenna and we only care about the loss

- Please remember the Jumpers and Pigtails is a important part of your radio system and just like the antennas they have there own Return Loss(or VSWR).

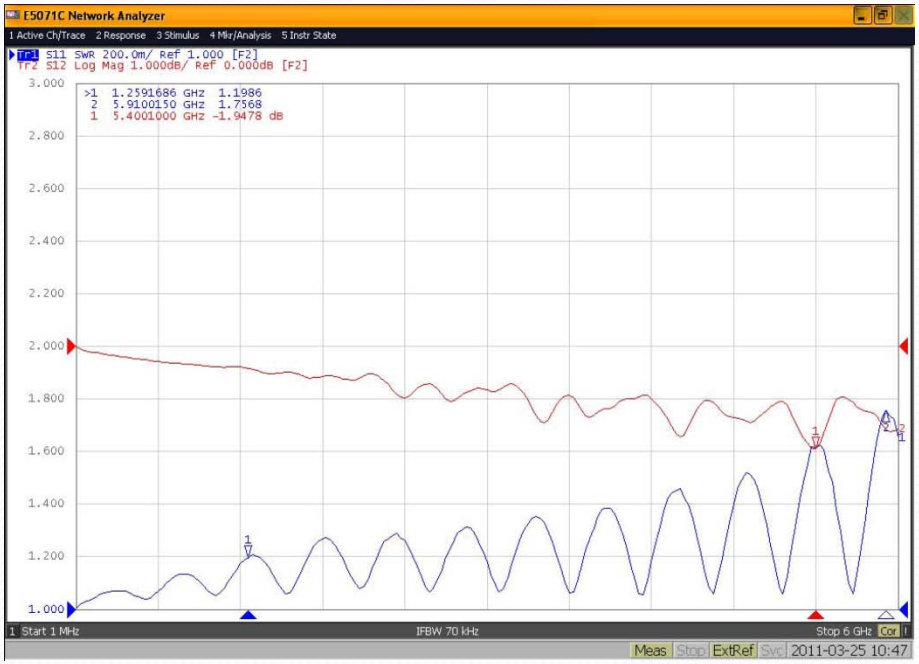
- Cable loss and VSWR are depends to the frequency and most of the RF cables cannot gives you a good VSWR in High frequencies(5 GHz specially)

Cable:1.13
Loss(red)
VSWR(blue)



- Here is a compare between 1.13 cable and RG-178

Cable:1.13



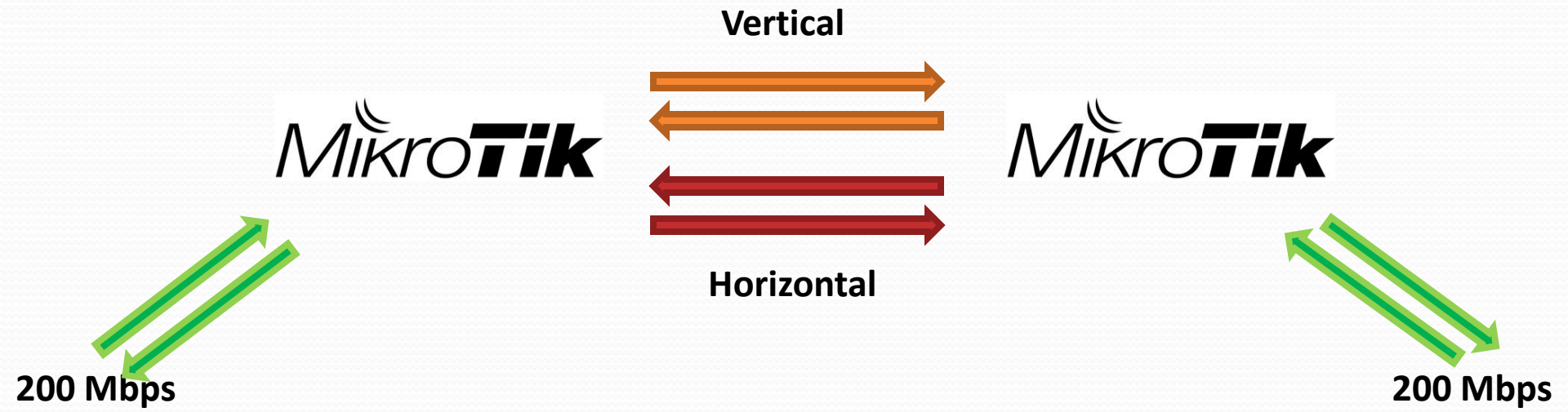
Cable:RG-178

- **Tip9: it is highly recommended to test the jumpers and pigtail cables that you will commonly use for VSWR even once.**

- **Tip10: Using Thick jumpers dose not improve your link performance or even make it worse because of the flexibility issues you have to use longer cable and have more loss.**

- **Tip11: It is necessary to seal and water proof your outdoor connector, the water or dust can increase the System VSWR and you will lose you link after maximum One year**

Now It’s a good time to go and use this Tips to improve your performance and enjoy the real meaning of MIMO.



For more information please contact me at:
ahmad@deltalink.com.tr
www.deltalink.com.tr