Spectrum Unlimited

Dr. John Howard, Steve Jalil, Rana Barsbai

Electromagnetics Technology Industries, Inc.
50 Intervale Road, Boonton, NJ 070058

***Abstract*-- In the United States there are about 144,000 Telecom Towers. It is possible for a substantial number of them to be employed for both Fixed and Mobile Communications with very high data throughput speeds. The advantages of using wireless telecom towers are, high data speed, lower deployment cost, fast implementation and mobility.**

***Keywords*—fixed wireless, mobile communications, multibeam, beamforming**

I. Introduction

Today, data has become a major part of digital existence. The demand for faster, more reliable, and ubiquitous connectivity has reached unprecedented heights. The United States, home to around 144,000 to 145,000 telecom towers, stands at the forefront of this digital revolution. These towers have long been the backbone of communication networks, facilitating both fixed and mobile communications. However, today the FCC proposes the national fixed broadband standard requiring 100 Megabits per second for download speeds and 20 Megabits per second for upload speeds.

II. Wireless Technology Today

In order to increase wireless telecommunications data throughput speeds various methods exist. For example:

1. Larger bandwidth
2. Millimeter Waves (mmWaves)
3. Higher modulation indices
4. Multi-user Multiple-Input and Multiple-Output (MU-MIMO)

II.I Larger Bandwidth

It is well known, that as the channel bandwidth increases, the data throughput speeds in bits per second also increase. Unfortunately, increase in bandwidth also increases the noise effects. Please see equation 1 below. For constant power output, the effect of this noise increase is to reduce the ratio of the signal to noise (SNR). This in turn reduces the modulation index, thus reducing the data throughput speed. The increase of data throughput speed due to bandwidth extension is therefore substantially reduced.

$$N = KTB \qquad (1)$$

where:

N = Noise Power in Watts (W)
K = Boltzmann's constant = 1.381 × 10-23 W/Hz/K,
T = 290K at room temperature and
B= RF carrier bandwidth (Hz)

II.II mmWaves

Frequencies from 30-300 GHz are considered mmWaves. In telecommunications, in the context of 5G technology, mmWaves are employed to provide high data rates and low latency in wireless communication systems. However, mmWaves have limitations in terms of signal propagation, as they are more liable to atmospheric absorption plus scattering[1] and obstacles like buildings and foliage. Due to these limitations higher transmission powers are intended to be utilized, which in turn introduce more noise. Absorption plus scattering because of hydrometeors [2,3] in the transmission medium cause depolarisation of the transmitted radiation. This effect may represent a severe limitation on system performance particularly in the case where two orthogonal polarisations may be used as separate communication channels. Figure 1 presents the impact of absorption and scattering on RF signals in varying rain conditions versus distance. As it can be seen the loss is increased at millimeter waves.

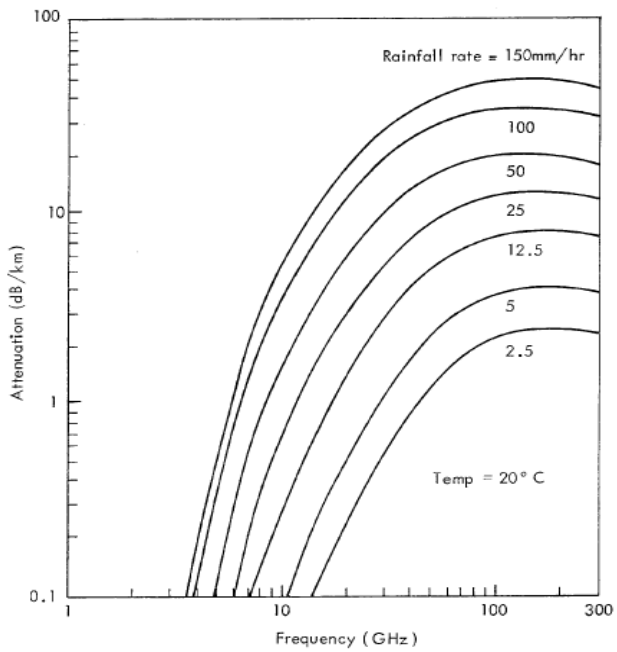

Figure 1: Logarithmic Plot of Atmospheric Attenuation of RF Signal Propagation

II.III High Modulation Indices

Higher modulation indices, such as 64 QAM, 256 QAM or a 1024 QAM provide high data throughput speeds but they require high signal to noise ratios (SNR)[4]. Please refer to figure 2 for an example of SNR requirements verses coding rate and modulation scheme. In noisy channel environments due to absorbing, scattering, and reflections and if high interfering sidelobes are present inability to increase data throughput speeds by repeating spectrum in various directions becomes a serious problem. In addition, due to spreading loss with distance, the receiver signal is reduced whereas interfering noise increases, thus reducing SNR, which results in the lowering of modulation index and consequently reducing the data throughput speeds.

Required Base Band SNR

SNR Requirements Versus Coding Rate and Modulation Scheme

Modulation	Code Rate	SNR [dB]
QPSK	1/8	-5.1
	1/5	-2.9
	1/4	-1.7
	1/3	-1.0
	1/2	2.0
	2/3	4.3
	3/4	5.5
	4/5	6.2
16 QAM	1/2	7.9
	2/3	11.3
	3/4	12.2
	4/5	12.8
64 QAM	2/3	15.3
	3/4	17.5
	4/5	18.6

Figure 2: SNR Requirements Versus Coding Rate and Modulation Scheme

II.IV MU-MIMO

Multi-User Multiple input and multiple output (MIMO), similar to troposcatter diversity permits separate streams of data to be propagated in parallel. Such a multiple stream propagating system increases the data throughput speeds depending on channel conditions.

For multiple streams, only a portion of an antenna phased array is used[5] per stream (beam), thus reducing the EIRP of the communication's link.

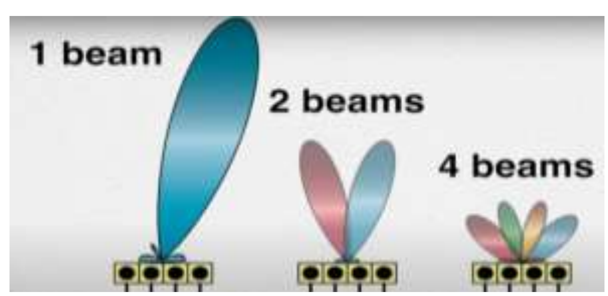

Figure 3: Gain reduction in Massive MIMO System

This reduction of antenna gain seen in figure 3 reduces in turn the SNR, the effect of which is to reduce the modulation index and diminish the data throughput speeds. The law of diminishing returns applies here.

III. The Solution

What is presented herein is a solution that avoids the problems in sections II.I – II.IV. In section II.I, it has been shown that although increase in bandwidth increases the throughput speeds, noise also increases with bandwidth, which due to the reduction of the modulation index negates the increase in throughput speeds. Instead of increasing the bandwidth in a sector, the bandwidth is kept the same but it is repeated multiples times within the sector. This not only behaves similarly to an increase in bandwidth for data throughput speeds, but in addition reduces the noise received by each of the sub-sectors (beams).

As an example, figure 4 shows a 20 MHz channel in a 120-degree sector having an average of 28 Mbps in an urban environment. By employing a simple 4-beam scheme in the same 120-degree sector, each beam having the same 20 MHz bandwidth repeated, speeds were increased by a factor of ten. [6] The live results of both deployments are presented in figure 4. Table 1 shows the increase of the modulation index due to the ETI 4-Beam Telecom System. Please refer to figure 5 for rendering of the 4-beam radiation pattern in azimuth and figure 6 for the schematic of the simple 4-beam MIMO Beamforming Network deployed.

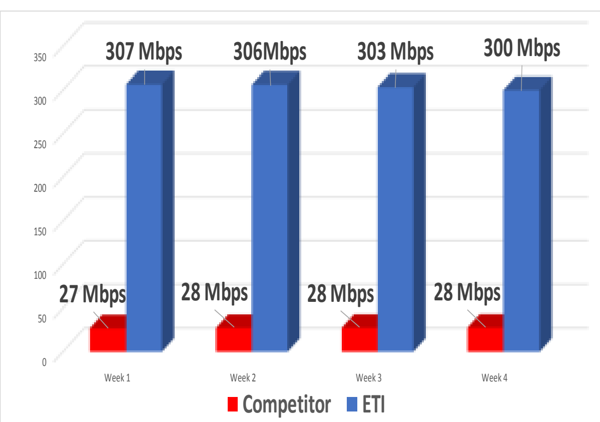

Figure 4: 4-Beam System Speeds (Blue) vs Original System (Red)

Table 1: Improvement of Modulation due to the 4-Beam System

Modulation	*Original System Percentage of Time (%)*	*4-Beam System Percentage of Time (%)*
BPSK	**60**	**0**
QPSK	**40**	**10**
16 QAM	**0**	**90**
64 QAM	**0**	**0**

Figure 5: Rendering of Simple 4-Beam Azimuth Pattern

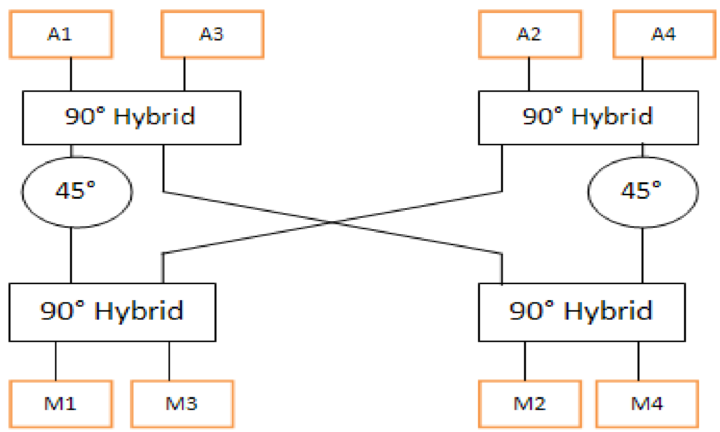

Figure 6: Simple 4-Beam MIMO Beamforming Network

The problem of the use of mmWaves in II.II, is simply eliminated by employing frequencies below 10 GHz. Figure 1 shows unequivocally the extinction of mmWave signals passing through rain. Additionally, use of US patent 10,141,640 B2 is pivotal in MIMO dual polarisation scenarios. [7]

Increase of data throughput speeds is shown in section II.III by employing high modulation indices. High modulation indices though require increasingly high SNR values. In order to achieve this, higher gain antennas and narrower multiple beams are required. By employing passive or active beamforming networks in azimuth and elevation this can be easily achieved.

Finally, in section II.IV MU-MIMO is presented as a method to increase data throughput speeds by employing a number of bit streams by using different beams each one of which utilizes a section of an antenna array. Employing a section in lieu of using the complete antenna array reduces the gain of each beam further reducing the SNR of the system. This in turn reduces the modulation index thus diminishing the data throughput speeds. By employing the same beamforming networks mentioned previously and additionally adding beamshaping networks the gain of the antenna can be maintained, thus maintaining the SNR unaffected.

Figure 7 portrays a 23-beam system in a 90-degree azimuth sector, which has reduction sidelobe levels better than -25dB. Figure 7 also shows the diminishing gain at the edges of the 90-degree coverage due to a beam being at an angle away from broadside. This reduction of gain away from broadside can be corrected by proprietary and patented techniques.

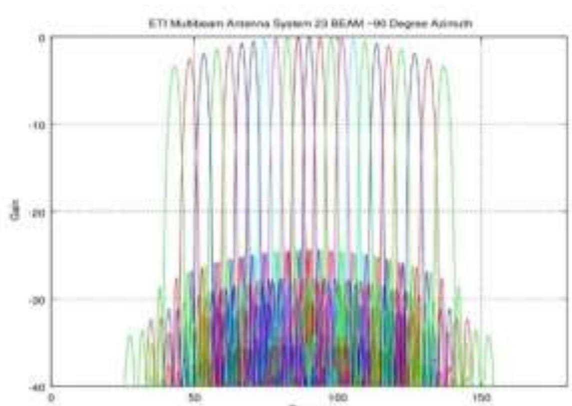

Figure 7: 23-Beam Antenna System with 90-Degree Azimuth Coverage and better than -25dB sidelobe levels

Figures 8 and 9 show the results of two such proprietary and patented techniques. Figure 8 shows a sidelobe reduction better than -38 dB with constant beamwidth. Figure 9 shows a second such technique reducing sidelobe levels better than -50 dB. Figure 8 and 9 show the possibility of employing extremely high indices of modulation.

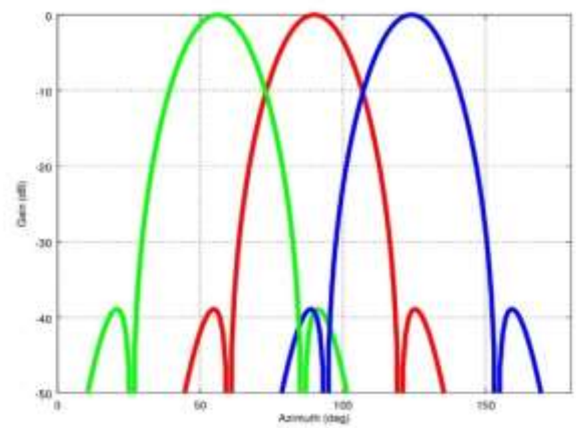

Figure 8: Proprietary and Patended Sidelobe Reduction Technique for better than -38dB

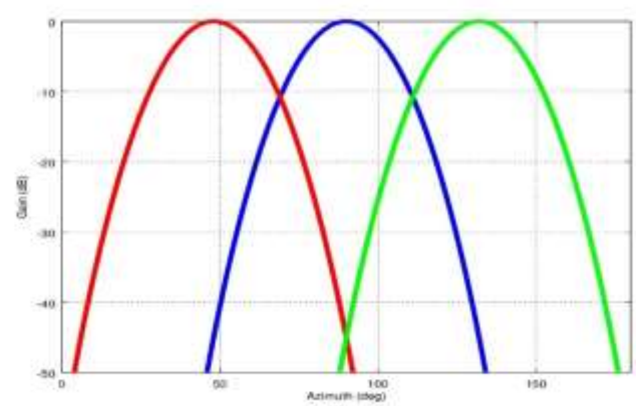

Figure 9: Proprietary and Patended Sidelobe Reduction Technique for better than -50dB Sidelobe Levels

IV. Terabit Wireless Solution

Enhancing the performance of wireless networks involves elevating the amount of bandwidth and number of channels provided by base-station antennas. This entails employing multiple radiating lobes in both azimuth and elevation to effectively cover a designated geographic area. By use of proprietary and patented sidelobe reduction techniques, modulation indices of 256 QAM and 1024 QAM can be achieved, whilst repeating the full bandwidth in each beam. Figure 10 is a rendering of the radiation pattern of an antenna system, which employs beamforming in the azimuth and elevation.

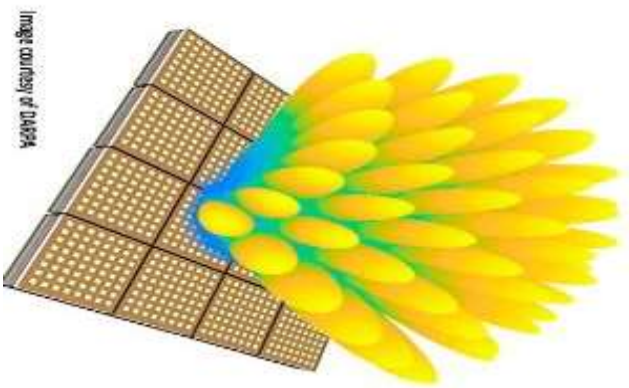

Figure 10: Phased Array with Multiple Beams in Azimuth and Elevation

Traditional tower deployments have three 120-degree sectors. The proposed solution has the configuration described in the below example.

Figure 11: Three Antenna System Deployment

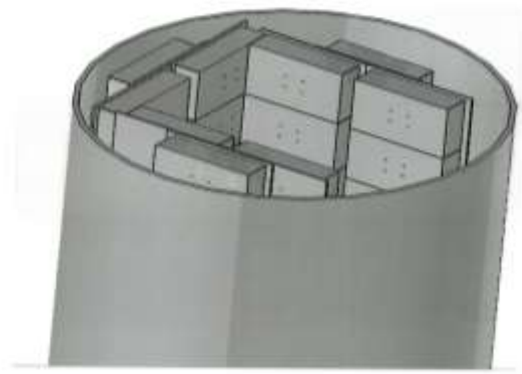

Figure 12: Radios housed inside monopole tower

Example

Three antennas, each antenna having for instance 32 radios. Please refer to figure 11 and 12 in the previous page for depictions of the deployment including radios housed inside a monopole tower as an illustration. As an example, 4-beams in azimuth and 8-beams in elevation are assumed. The maximum speeds available for various modulations and bandwidths are presented in the tables below.

Assuming a county with an area of 348 miles squared similar to Lehigh County in Pennsylvania, USA and only using 120 of the county telecom towers, an aggregate speed of 18.4 Terabits per second can be achieved. If this aggregate speed is to be distributed to 143,000 households then each household will receive 128.4 Megabits per second. This is without a contention ratio and still fulfilling the requirements of the USA government for broadband.

Table 2: Maximum Speeds for 1024 QAM Modulation

Channel Size	*Total Maximum Speed (Gbps)*
80	153
40	76
20	38

Table 3: Maximum Speeds for 256 QAM Modulation

Channel Size	Total Maximum Speed (Gbps)
80	122
40	61
20	30

V. Discussion

Comparison of various methods used throughout the industry to increase data throughput speeds have been presented. Each one of these methods has advantages and disadvantages. An improvement avoiding disadvantages of the various solutions in section II has also been presented. Results show that data throughput speeds even in simple cases can increase substantially.

VI. Conclusion

Simple methods have been presented allowing increased data throughput speeds without any significant disadvantages. In the words of Leonardo da Vinci, “Simplicity is the ultimate sophistication”.

References

1) H.C. Van de Hulst, "Light-scattering by small particles,” New York: Wiley, pp 28-36, 1957.
2) J. Howard and N.A. Mathews, "Crosspolarisation of Microwaves due to Rain on a Satellite to Earth Path," IEEE Trans. Antennas and Propagat., vol. AP 27, no. 6, pp 890-891, November 1979.
3) G. Brussaard, "A Meteorological Model for Rain-Induced Crosspolarisation,” IEEE Trans. Antennas and Propagat., vol. AP 24, no. 1, pp 5-11, January 1979.
4) Werther, Dr. Oliver, and Roland Minihold. Rohde & Schwarz Application Note, 2013, “LTE: System Specifications and Their Impact on RF & Base Band Circuits.”
5) Björnson, E., 2018. Basics of Antennas and Beamforming-Massive MIMO Networks. [online] Youtube.com. Available at: <https://www.youtube.com/watch?v=xGkyZw98Tug> [Accessed 27 September 2022].
6) Howard, J. “World’s First Wireless Fiber.” The North Jersey IEEE MTT/AP Societies 37th Annual Symposium and Mini-Show October 4, 2023, East Hanover, New Jersey, United States of America.
7) Howard, John. Isolation of Polarizations in Multi-Polarized Scanning Phased Array Antennas. Patent US 10 , 141 , 640 B2, 27 Nov. 2018.