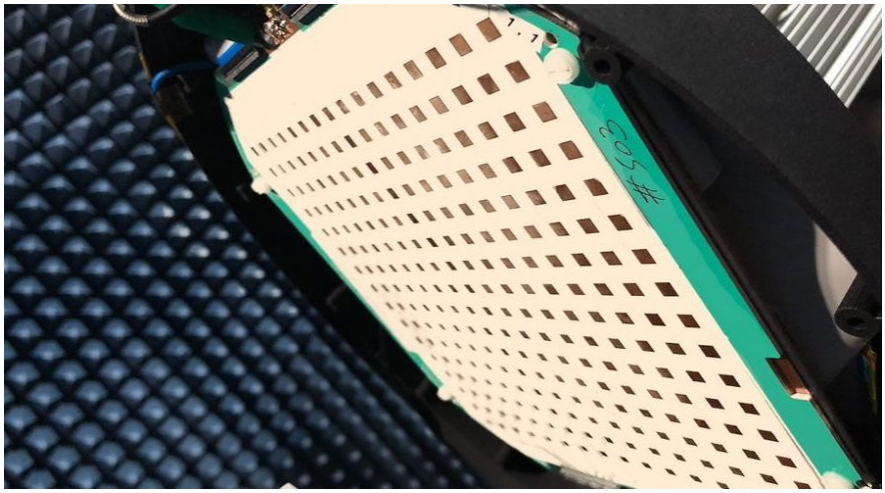
Flat Panel Antenna Technology and Applications

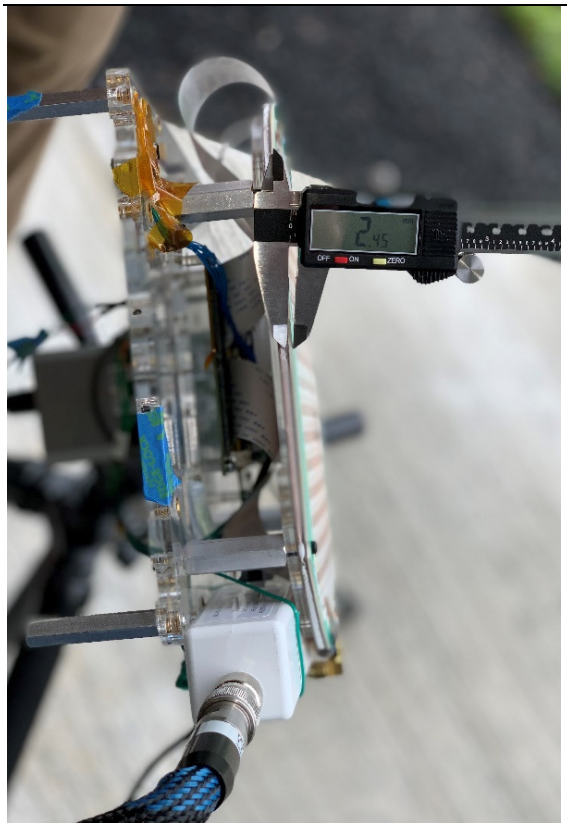


NexTenna™ , through years of fundamental research and development has created an ultra-thin, low cost, high rate production, steerable flat panel antenna technology. NexTenna™ has developed a fundamental software controlled Integrated RF Technology i.e. our Base-line Integrated planar phase shifter Technology, which is now creating a similar revolution to what the Integrated circuit technology that Intel has Invented done to the digital world around us. This new innovation would finally facilitate phased array antenna technology, (Holy Grale in wireless communication) to the mass market, and hence Bridge the digital divide

One of the fundamental uses of our base-line phase shifter Technology is building efficient, low cost, low power consumption phased array antenna ushering the path for global connectivity initiatives around the world such as Starlink By SpaceX, the OneWeb constellation and Kuiper Project By Amazon.

Those large satellite constellations need a low cost, steerable antenna technology at the terminal level to provide a viable alternative to terrestrial broadband connectivity on large scale.

One of the features of our antenna has been designed specifically to enable satellite communications for Coms on The Move (COTM), Coms on The Pause (COTP) and Fixed Applications which benefit from thin, low cost, low power self-steering antennas.



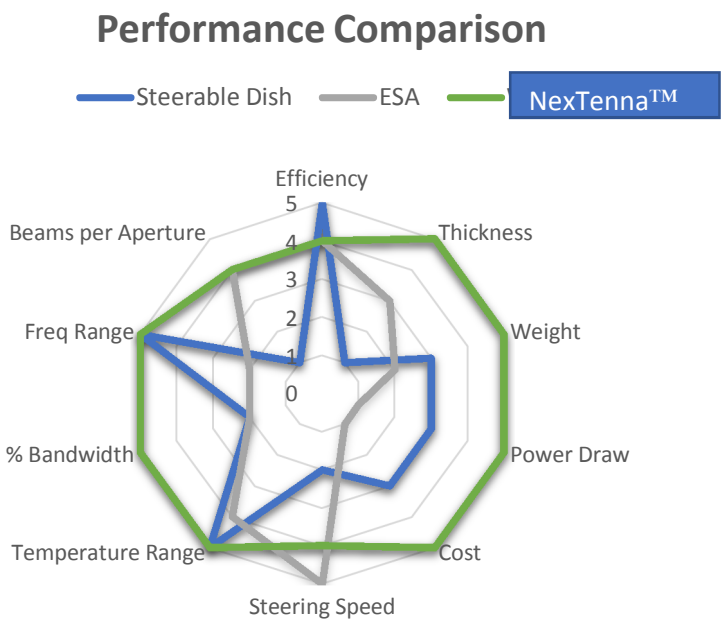
The NexTenna™ technology can be designed for virtually any frequency from 1 to 90 GHz and can be made to achieve virtually any gain or G/T [dB/k] performance by tiling the components together. From rooftop sized large scale arrays, to IoT sized receivers like the unit shown above, the product is extensible in design and scale.

For conformal applications, the antenna can be shaped to meet the curve of a helmet, vehicle, airplane or other surface eliminating both wind resistance and radar reflections. Future versions will be flexible and can be actively conformed to a surface.

This white paper will review NexTenna™ strengths and some of the applications for which it is well suited; the paper will also provide a closer look at the technology itself, along with an overview of how to work with NexTenna™ to bring these benefits to your application.

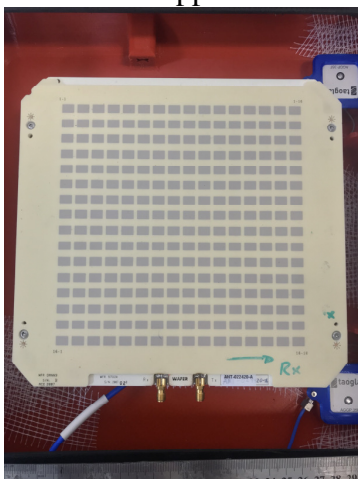
I. NexTenna™ Strengths and Capabilities

NexTenna™ true time delay flat panel antenna technology represents the lowest cost, widest bandwidth (continuous and operational) and the lowest Size, Weight, and Power (SWaP) of any available steerable antenna technology out there.
In addition our fundamental device technology our software controlled phase shifter technology can be applied to many different devices such as adaptive filters, power splitters and other specific devices needed across a broad range of markets and applications be it cellular, IOT or broadband from Space.



Thickness: For ultra-thin applications, the antenna can be less than 3mm. Adding a radome, and electronics boards such as the controller; modems can still keep the entire antenna less than 12.7mm. These boards may also be separated from the antenna so as to reduce the overall height and maintain the < 3mm thickness.

Common Rx/Tx in a single aperture *and* Full Duplex Operation: NexTenna™ antennas can be full duplex and support both transmit (TX) and receive (RX) within the same electronically steerable panel or can support TX and RX in two separate panels. The RX portion of the panel can be split in half for a short period of time to support make-before-break satellite-to-satellite handover for LEO or MEO constellations. Receive-only (RX-only) antennas can also be fabricated for broadcast data or satellite TV applications.

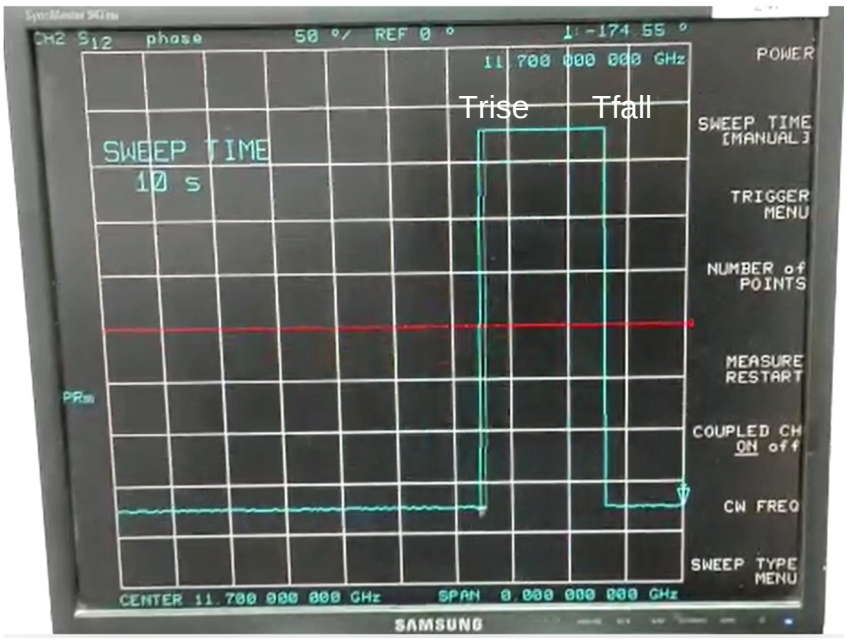


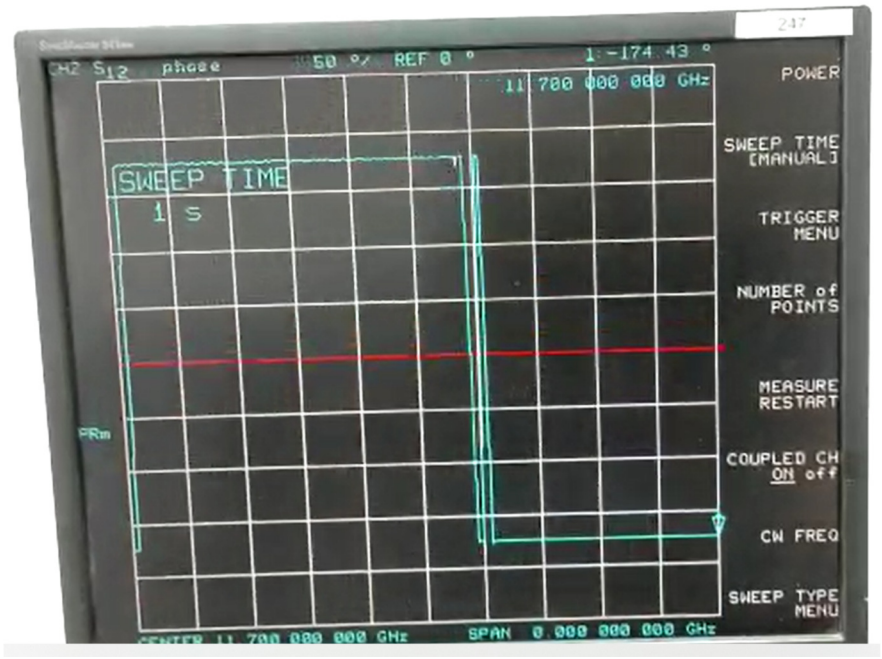
Weight: The antenna itself weighs about 10g/in^2 of surface area and can be reduced further to around 4g/ in^2 for specific weight sensitive applications. The control board weighs under 10g and there is no need for a heat sink for the antenna system. Larger, more efficient antennas will need less RF amplifier power, and as such, the use of NexTenna™ technology can significantly reduce the RF amplification needed and eliminate the need for heavy heat sinks. While the antenna itself is light – the reduced size and number of ancillary components makes the whole terminal lighter and more reliable.

Power Draw: The antenna itself, including the controller, draws very little power. The bulk of the power will be for the modem and power amplifier. The larger more efficient apertures enabled by NexTenna™ can, in most cases reduce the power amplifier size and the total system power draw.

Cost: NexTenna™ technology is designed for high volume applications. It is manufactured with standard manufacturing tooling and can reach consumer product cost levels at consumer product volumes. There is no lower cost steerable antenna technology.

Steering Speed: NexTenna™ has had so far full range steering speed of less than 200ms which is fast enough for COTM applications such as Aircraft, Land Mobility, and LEO operations. The next phase of the technology has been completed in the past year and moved us to less than 1msec response time with sub 0.1msec solution that we have completed and provided a breakthrough solution for fast steering antennas, without hurting our efficiency at all, this breakthrough Technology innovation is the Key differentiator from our Current Competitors such as Kymeta, Alcan and Others which had very slow response time in the range of 10's of msec and 100 of msec, with Huge losses down to 10dB for Kymeta and Alcan.





New Frequency Developments:

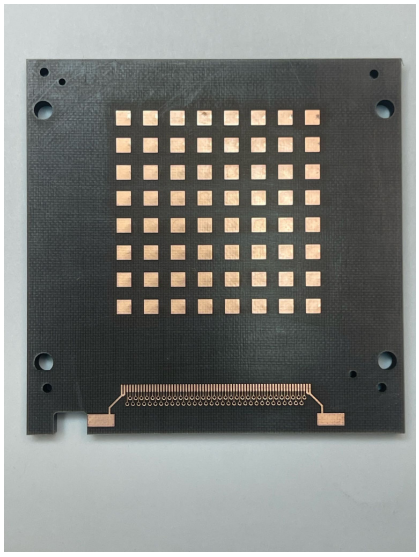
In the past year NexTenna™ has developed its technology and fundamental manufacturing process in various frequency Bands such as Ka [26-31GHz], K Band [17-22GHz], Q Band [35-38GHz] and have developed a base-line 5G Antenna for a Local large customer In Israel.

New Markets and Customers

This year NexTenna™ Has entered the Space Segment by providing our unique low power steerable antenna Technology to a specific Weather Radar satellite constellation designed by Tomorrow.IO we have also partnered with IAI and AirBus US to deliver a full solution BUS plus payload for the space segment. This entrance into space will alter the way Space Segment systems will be designed going forward, NexTenna™ Has proved that having steerable antenna systems in Space is feasible with very low power consumption below 50W power consumption for a 1m^2 antenna.

This year we also have penetrated the 5G world with our next Generation small form factor 5G antennas and controller aimed to provide connectivity to drones and other moving platforms on a Mesh network. It's a 5G covering 26-31GHz with 64 elements and Gain above 19dBi fully steerable in 2D.

5G Antenna 64 elements fully steerable covers 26-31GHz



5G Client Antenna
38mmX38mm

The NexTenna™ antenna operates through -60C.

Temperature Range: The NexTenna™ technology has been tested and validated to operate down to -60°C. It has also been tested in off mode for 4 weeks at this temperature with no performance degradation. NexTenna™ has tested as high as 85°C in both static and active performance with no degradation.

Wide Frequency: Wafer Technologies' unique capabilities lend it to be wider range than any other available technology. This makes space saving single aperture Tx/Rx flat panels a possibility. Antennas have been designed with a single aperture from 10.7-14.5GHz (30% bandwidth). Wider can also be achieved, The current limit may be considered 38% bandwidth which is the array limitation. The planar phase shifter itself can support 50% or more bandwidth.

Freq. Range: 1 to 90 gigahertz (GHz)

Beams per Aperture: NexTenna™ antennas typically have two independently steerable beams per aperture, and both beams operate across the full aperture at full performance. Many terminals place a separate Tx and Rx capability within the same structure, but each has only

a portion of the total surface area. NexTenna™ enables Rx/Tx from the same aperture, even from different satellites.
We have also developed a multi-beam capability in the past year that allows via both front end and base-band generates multi-beam base-stations for specific applications.

Radiation Efficiency: NexTenna™ antennas maintain a high efficiency, similar to, if not better than, other flat panel technologies. However, it is less expensive and consumes less power, so dollar for dollar; NexTenna™ can have a higher gain by using a larger panel.

II. NexTenna™ Technology

NexTenna™ key technology is its "Planar Phase Shifter™". To understand why this technology is so important, we need to compare it to the current antenna systems.

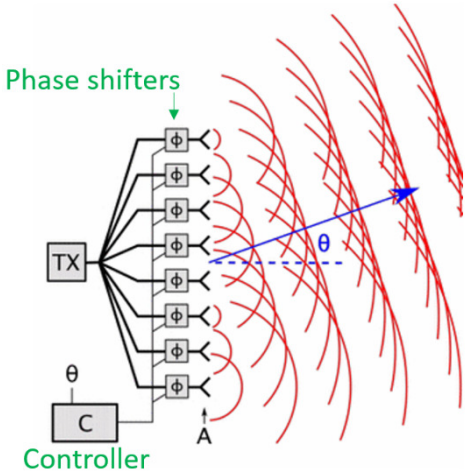
a. Mechanically Steerable Antennas

Mechanically steerable antennas, which most commonly are gimballed parabolic dishes opened new markets for satcom connectivity. These antennas use motors to physically move the parabolic dish into the correct direction. While this is effective, the moving parts impact reliability, take up large swept volumes and make the antenna heavy. The benefit of these antennas is the RF simplicity, they are widely available, and they maintain full performance at every angle.

b. Electronically Steerable Antennas

Electronically steerable antennas (ESAs) have also been in use for over 50 years, but they have been expensive and consume a lot of power. ESAs operate by combing an array of many small antennas and varying the 'delay time' for the RF signals at each small antenna. This delay changes the phase relation of the signal from each antenna using a 'phase shifter'. Phased array technologies have been the subject of huge investment in order to make lower cost flat antennas with no moving parts, until now, they remain very expensive primarily because of the large number of board layers required, the high cost of the low loss board material and the low yield and high cost of the GaAs and/or SiGe fabrication processes.

As can be seen from this diagram of a simple phased array antenna, the TX transmitter sends its RF energy through each of 8 antennas, and each antenna releases a red radio wave. The waves propagate no differently than dropping a stone in a pond. As each wave exits its antenna, the waves combine to create a steerable "wave front".

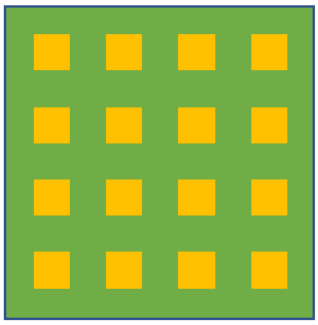


The phase shifters are the key to steering. The Controller commands each phase shifter to delay the signal to its antenna by n degrees. This causes the beam to steer away from "boresight" (perpendicular to the line of the antenna array).

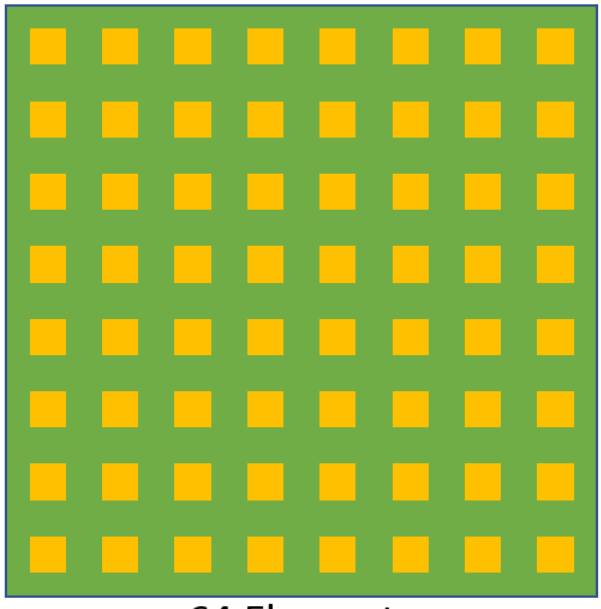
The physics of phased arrays are well known, the challenge has been that until now, phase shifters have been made from semiconductor circuits and are expensive, consume a lot of power, and generate a lot of heat. Thus, most phased array antennas have large heavy heatsinks. While phase shifters are semiconductor based, they are analog, rather than digital circuits, and the normal digital circuit cost reductions do not apply.

The challenges of semiconductor-based phased arrays are further exacerbated because their costs go up by 4x with every doubling of antenna gain. This is because every antenna element needs a phase shifter and you need 4x the phase shifters to double the performance of an antenna. Phased array antennas, except for Wafer Technologies, do not scale well.

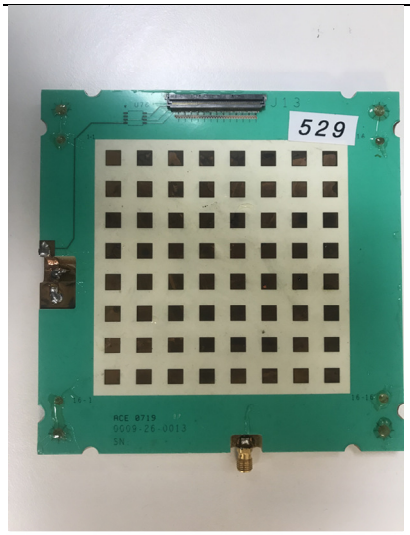
For example – the below images are standard 16 and 64 element phased array antennas (each element is a copper square antenna called a patch). Behind each element is a phase shifter (two phase shifters per element are required for full duplex TX and RX). The antenna on the right has twice the performance of the antenna on the left (4x the surface area), but also has 4x the cost because it needs 4x the phase shifters. Phase shifters can cost nearly $50 in small quantities. With the latest technologies and consumer volumes they will reach $1 or less at large scale, however, typical high throughput satellite antenna would require 8096 elements to have two steerable beams.



16 Elements



64 Elements



KU IOT

KU BroadBand

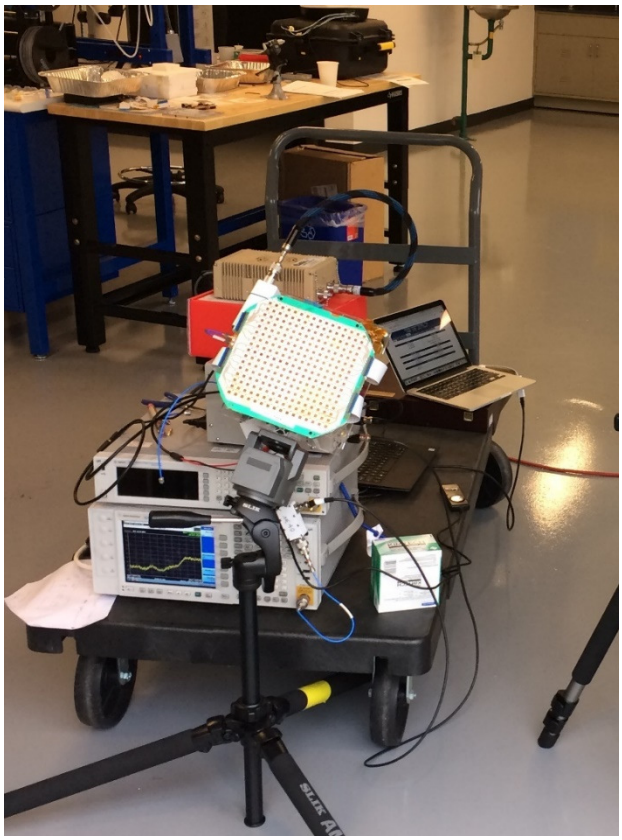
III. Applications

Below we review some key applications and use cases for Wafer Technologies' thin, low power steerable antenna technology.

Consumer Level LEO Broadband: requires a low cost, low power, self-steering antenna. User Terminals have been the single most important barrier to adoption for consumer broadband as they are the most expensive part of the entire LEO broadband system. High Gain User Terminal cost points below $300 have, until Wafer Technologies, never been achievable, while maintaining incomparable performance in terms of bandwidth, G/T and steerability.

Low Power is required for many Consumer applications in emerging markets because the homes and small businesses have intermittent power. Wafer Technologies' terminal is so low power it can operate for days on a small battery system, allowing the end-users to operate their laptops, cell phones and tablets even while the electrical grid is down.

NexTenna™ technology is ideal for high velocity self-install residential and small business applications.



NexTennaAntenna Connected to a GEO satellite

GEO Satellites typically use a fixed antenna, but unfulfilled requirements, such as on-demand satellite diversity, automated fail-over and self-install become key differentiators.

Fixed antennas require professional installation for residential and business use. A self-steering antenna can be self-installed and will automatically find, *and maintain*, the link to the satellite.

In the event a satellite itself becomes congested or fails, a NexTenna™ enabled antenna can immediately switch to a different satellite. Eliminating the truck role for repointing antennas will save more costs than the equipment itself.

The NexTenna™ single aperture multi-beam capability can talk with more than one satellite at the same time to provide unique route diversity capabilities for the end-user.

Commercial Aviation requires self-steering, low profile antennas. NexTenna™ technology allows a nearly flush mount, plus the unique ability to track and connect with *3 different satellites at the same time* using a standard ARINC 792 mount with a zero drag height of only 4". This multi-satellite operation ensures seamless handover for consumers, satellite combining for maximum throughput, and continuous connectivity throughout the entire flight even during turning and banking at higher latitudes.

Business Aviation from light aircraft to heavy jets all requires global connectivity. Light aircraft operate shorter more regional missions, but they operate from every country in the world. Wafer Technologies' thin and light antennas can easily fit on these aircraft with minimal power draw and nearly zero drag implications.

IoT is primarily about power and self-steering. NexTenna™ can operate IoT links from antennas as small as 2" square. Slightly larger 4" apertures can provide 1Mbps links to GEO or NGSO satellites and be used as a hub to connect to IoT tags within 5km using common IoT protocols such as SigFox or LoRa. These

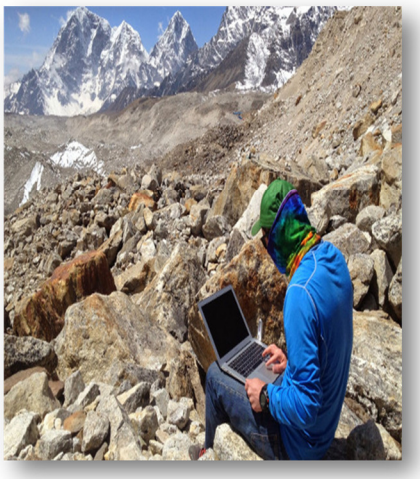
terminals can also be integrated with sensors and/or operate from solar power with their small electrical requirements.

NexTenna™ IoT antennas can be self-installed, an important feature for IoT applications. As NexTenna™ can find and track LEO spacecraft, as long as it can see the sky, it will work. For GEO spacecraft the antenna must be able to 'see' the GEO spacecraft which can often be at a low elevation angle and typically requires training to find and locate the GEO satellite. The entire IoT terminal is a simple hockey puck shaped object.

Many applications require continuous low profile, low heat-signature, and light weight connectivity from every vehicle, human, aircraft and location across many frequencies. NexTenna™ antenna systems can address most every communication related application.

On vehicles, NexTenna™ enables zero profile connectivity, or self-install stick-on connectivity as shown above.

For aircraft, NexTenna™ multi-beam, multi-frequency antennas can be zero profile for radar sensitive aircraft and can be used both for air-to-ground and air-to-satellite communications links.



For handheld and remote and extreme location communications, NexTenna™ antennas enable ultralight, ultraportable ‘throw on the ground’ instant high bandwidth connectivity. The high gain manpack antenna automatically aligns locks and tracks the satellites. The manpack antenna can be mounted to vehicles or hand carried and set on the ground. The low power draw enables hours of use on a single charge.

IV. Next Steps

Every partner has a different use case, and each use case focuses on one or more of NexTenna™ strengths. They may just need cost reduction, or there may be a need for a capability for which there is no other option due to size, power or other performance criteria.

NexTenna™ works with partners to design and produce custom antennas and full terminals. Starting with a quick discussion we can usually pinpoint the key features and we will know whether NexTenna™ can meet your need, now or perhaps the solution is on our roadmap.

We hope after reading this paper you has a better appreciation for the unique characteristics of NexTenna™ antenna capabilities.

Please feel free to reach us by email: rafi@nextenna.com we would be happy to evaluate your needs and determine how NexTenna™ can help get you connected.

Look at our Website for a live demo of the system:

www.nextenna.com

About The Author:

Dedi David Haziza – CEO and Founder

Entrepreneur with deep technological background ranging from Microwave circuitry and Antennas through various communication systems both for terrestrial networks and space. Led the technology innovation center for Google Air, developing space, air and ground platforms for Global connectivity. Over 20 years' experience spanning from Israeli defense and space industry through commercial Industry in the US [Companies like CalAmp, DirecTV, Google, WaveBender and few others], Function as the System Architect of NexTenna™ Technological innovation.
DirecTV Slim Line Ka/Ku, Dish1000 and other systems for Calamp Generated over $220M dollar revenue and increased the company Value.
Holds a BSc. In Electrical Engineering Suma Cum Laude from the Technicon Haifa and MSc. In Physical Electronics from Tel-Aviv University as well as an MBA, holds over 30 patents.