Beam-steerable Flat Panel Antennas for Ka-Band SATCOM Terminal
—Evolving Toward Versatile Solutions

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In today’s Ka-band satellite communications-on-the-move (COTM) industry, one of the most significant evolutions for ground terminal design is to employ compact, low-profile, and reconfigurable flat-panel antennas (FPAs) as a replacement for their conventional counterpart, the dish antenna, dominated by its bulky parabolic reflector.
The FPA evolution is naturally driven by new market demand and user expectations for high-speed satellite communications from ubiquitous on-the-move platforms.
Over the past four years, the design of Ka-band SATCOM FPAs has become one of the most attractive and best supported R&D topics in the industry and the research community alike.
Ultimately, there is no “best” answer for antenna choice. To use a racing analogy, it is “horses for courses”!

- Parabolic antennas offer the advantages of constant high gain, and certified compliant antenna patterns over broad bandwidths.
- Flat panel antennas compromise two or all three of these advantages in favour of low profile.
Although the concept of generating a focused-beam through a planar-shaped antenna is not new, it is still extremely challenging to design a feasible FPA solution that meets the RF constraints, matches the market needs, and is commercially profitable.
Future solutions for flat panel antennas roughly follow four parallel routes as grouped below, in terms of their design philosophy and working principle.

1) FPA with fixed radiation pattern, rotated mechanically in azimuth and elevation.

2) FPA using a phased antenna array

3) FPA using a digitized impedance surface

4) FPA made using sliding mechanical structures for two-dimensional steering

What is next? - The combination use of the philosophy as above
1) FPA with fixed radiation pattern, rotated mechanically in azimuth and elevation.

Mainly be used to reduce the terminal’s body weight on large-footprint platforms, but this solution will not lead to ubiquitous low-profile or conformal terminals because of their requirement for azimuth and elevation movement and the need to maintain good radiation patterns.
2) FPA using a phased antenna array

Analog beamforming can generate a high-quality steerable beam useful for satellite communications, but in low volumes such systems can be very expensive, while digital beamforming has very low $G/T$. 

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3) FPA using a digitized impedance surface

The FPA is made from a software-defined holographic impedance surface consisting of a large matrix of metamaterial units digitally controlled. It is a cheaper solution compared with phased array antennas.

- limited bandwidth due to the inherent narrowband properties of metamaterials.
- Faced with challenging compromises between antenna radiation performance, resolution, accuracy of steering, and sidelobe levels.
4) FPA made using sliding mechanical structures for one-dimensional steering

The FPA suffers degradation in its radiation efficiency as it is steered, with fluctuating antenna gain in different beam directions, and limited working bandwidth.
At EM Solutions, a long-term research collaboration has been established with the University of Queensland (UQ) to develop a versatile and low cost FPA solution for the COTM market.
EM Solutions’ Flat Panel Antenna Technology

From the proof-of-concept to the working prototype

- The invented technology is NOT based on conventional leaky-wave methodology; it can not be regarded as a passive phased array either.
- The perturbed structure is a continuous-modulated artificial surface, which introduces the displacement current (instead of electric current) to support the radiation.
Beam steering via two dimensional mechanical gliding

Linear- to Circular- polarization conversion
Near-field radiation measurement
Steerable beam with displacement of movement layer

- 30 dB XPD (linear)
- 25 dB XPD (RHCP/LHCP)
RADIATION PATTERN GENERATED FROM $\Sigma$-PORT AND $\Delta$-PORT

Main beam for Communication

Secondary beams for Monopulse tracking
Advantages of the technology

- Compared with other key players in the industry, the developed technology has unique advantages and broadened applications:

**Advantages:**

- **Continuous** beam steering with low noise level;
- Support **Tracking** of incoming signal;
- Capable to work in much **higher frequency** range;
- **Low-cost** of manufacturing and maintenance
- Compatible with **Various** satellite operators
- **SLL suppression** over wide range of beam angles
- Good purity of radiation **polarization**

The invented antenna is able to operate effectively over a broad range of frequencies, it could be used to communicate with different satellite operators with a re-index process.