Phased Array Antenna Terminals for Satellite Communications- Fixed and Mobile Applications

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Abstract: **The presented material describes the developments in SkyGate, connected with phased array antenna terminals, dedicated to the fixed and mobile applications. The terminals are designed to work in Ku band with DBS and/or FSS satellites over the continental territory of USA and Europe. Flat multi-layer technology, initial elements grouping and proprietary designed MMIC phase controlling devices with high stage of integration are used in order to reduce size, power consumption, complexity and cost, as well as to achieve low profile suitable for integration in the vehicle's roof. Recently developed antenna prototypes are tested in Europe and USA to work successfully on different mobile platforms such as cars, vans, buses, trains etc., receiving TV programs and Internet.**

General

Interest to the ground based low cost antenna terminals that are capable to receive signals from several satellites has risen significantly since today's high power Ku band broadcast satellites makes it possible to use relatively small aperture subscriber's terminals. The investigations held in SkyGate during the last several years are focused to the application of phased array antenna technology and principles of operation to low cost fixed and mobile antenna terminals for satellite communication. SkyGate's approach to apply phased array antenna technology for the development of consumer products includes three main points:

- Flat antenna design – which transforms the antenna to a multi-layer PWB, making it low profile and producible using mass-market technologies
- Smart antenna design - initial antenna element grouping related to the required field of view and performance in order to reduce the required number of phase controlling devices (phase shifters)
- Implementation of proprietary phase controlling devices [7] with high stage of integration

Using the described above approach SkyGate has developed two families of products in which different beam controlling techniques are implemented.

TCC antenna family

TCC antennas (Television Communications Center) are limited electronically scanning antennas dedicated to the DBS reception in USA [1]. The antennas have field of view large enough to cover all three DBS satellites (101W, 109W and 119W) from any point over the continental territory of USA. The engineering model of the antenna EM2 was successfully demonstrated in the spring/summer of 2001 to receive TV programs and to switch between satellites and polarizations in different areas of USA – Washington DC, Los Angeles, Seattle and Tampa Florida. Picture of the antenna is shown on Fig.1 and the most important parameters are summarized in Table1. Initial grouping of the antenna elements and the use of proprietary phase controlling devices (chips) [2] with high stage of integration, makes it possible to reduce significantly the number of active components inside the antenna and respectively to reduce price, power consumption and complexity.

Table 1

Fig. 1

Parameter	Value
Antenna diameter, mm	800
Number of antenna elements (dual port)	1360
Scan area (field of view), deg	30 in azimuth 8 in elevation
Number of antenna beams	200 per polarization
Number of phase controlling devices (SkyGate's chips)	29
Number of LNAs	240
Frequency range, GHz	12.2 – 12.75
G/T (applicable beams), dB/K	>9.5
Automatic acquisition and pointing	Yes
Polarization (switchable)	RHCP, LHCP
Power consumption, W	50

Using the experience gained by the EM2 antenna model an improved version of the antenna was developed latter. Careful selection of the antenna layers materials as well as optimized vertical structure of the antenna package makes it possible to reduce significantly the size of antenna aperture, number of active components used, power consumption and price. The improved prototype called MMA (Multi-Satellite Multi-media Antenna) is shown on Fig.2. The size of antenna, power consumption and cost are reduced additionally, paid by a slight compromise in performance margin. [3].

Fig.2

Table 2

Parameter	Value
Frequency band, GHz	12.2 – 12.7
Polarization (switchable)	LHCP, RHCP
Applicable beams G/T, dB/K	>8.0
Cross polarization discrimination, dB	≥ 20
Power consumption, W	25
Number of PCD (SkyGate's chips)	12
Number of LNA's	96
Elevation scan range, deg	6
Azimuth scan range, deg	30
Type of steering	Electronic
Satellite search and recognition	Automatic
Size, mm	480 x 450 x 35

. The antenna automatically searches, finds and recognizes satellites using a build-in signal-processing unit. Main antenna parameters are summarized in Table 2.

Mobile antenna terminals

The main efforts of SkyGate team in the last two years are focused on the development of low-profile mobile antennas for broadband reception (Internet and Television programs). The problem is complicated since wide scanning angle is required, as well as a sensor navigation system capable to keep antenna beam pointed toward the satellite on move. Two types of mobile antenna prototypes were developed and successfully tested. The first one – MMM/T1 (Multi-Satellite Multi-Media Mobile) antenna terminal is fully mechanically controlled in azimuth and elevation using standard concept "antenna under dome". The main difference is that instead of standard reflector antenna, a flat active antenna panel is used, which gives the possibility to reduce the overall height of the antenna up to 200mm, making it acceptable for mounting even on relatively small vehicles. Application of flat panel instead of reflector antenna gives other opportunities to implement new attractive features. For example, implementation of proprietary techniques for tracking, as well as dynamic polarization control (polarization offset compensation) using proper phasing and amplitude control of the signals coming from the two outputs of the antenna elements. Several antenna prototypes were successfully tested to work in Europe and USA over different types of mobile platforms: cars, trucks, and trains. One of the MMM/T1 terminals is used successfully in three-months trial period in high-speed train on the route Gothenburg – Malmo – Copenhagen to provide high-speed Internet service on board. Picture of the antenna and its main parameters are shown on Fig. 3 and Table 3.

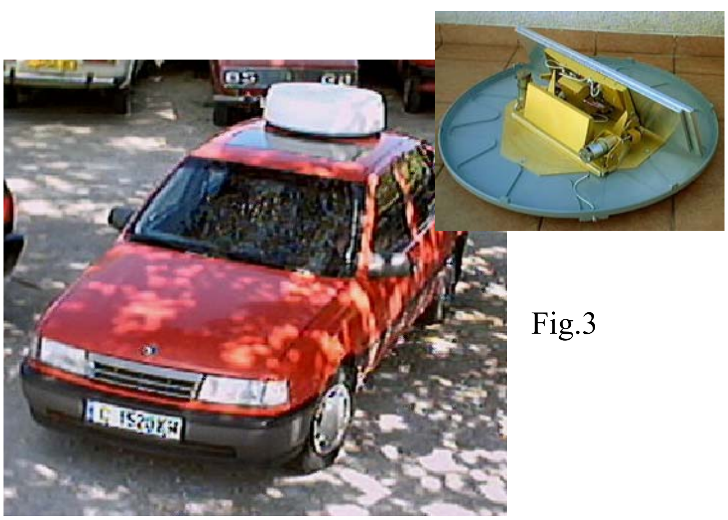

Fig.3

Table 3

Parameter	Value
Frequency band, GHz	10.7 – 12.7
Polarization (switchable)	LHCP and RHCP or linear
Power consumption, W	18
Elevation range, deg	15 – 75
Elevation Speed, º/s	>60
Azimuth range, deg	0 – 360 (unlimited)
Azimuth Speed, º/s	>60
Type of tracking	Mechanical
Satellite search and recognition	Automatic
Net Weight (including Indoor unit and Display unit), kg	16
Size of the ODU, mm Diameter, Height	 778 200

The second type of mobile terminal MMM/T2 [6] uses flat semi-electronically steerable antenna, achieving the height of only 60 mm. The antenna panel is steered mechanically in azimuth and electronically in elevation. A specially designed for broadband scanning dual port cavity back patch [4] is used as radiating element. The feeding structure, active components – LNAs and phased shifters are situated on two RF layers, connected by proprietary designed, low-cost microwave transitions, suitable to be mounted by use of pick-and-place machine. MMIC phase shifters control the antenna elements, grouped in rows. An advanced, patent pending tracking systems [5], using low cost gyros and information from the built-in RSSI detectors, gives the possibility to track reliably the selected satellite in extreme mobile conditions. The picture of the terminal mounted on a car is shown on Fig.4, and the main parameters are summarized in Table 4.

Fig.4

Parameter	Value
Frequency band, GHz	12.2 – 12.7
Polarization (switchable)	LHCP, RHCP
Power consumption, W	110
Elevation range, Deg	35 – 90
Elevation Speed, °/s	>60
Azimuth range, Deg	0 – 360 (unlimited)
Azimuth Speed, °/s	>60
Type of the tracking (Azimuth plane)	Mechanical
Type of the tracking (Elevation plane)	Electronic
Satellite search and recognition	Automatic
Net weight, kg	25
Size, mm	865 x 810 x 60

The described above mobile terminals MMM/T1 and MMM/T2 are now in the process of preparation for production in small series.

A lot of efforts were dedicated to the development of a fully electronically steered phase array antenna. The multi-chip module approach for building the antenna panel was investigated. Pictures of one type of modules developed in SkyGate are shown of Fig.5. The module consists of 8 antenna radiating elements (cavity back patches), feeding structure implemented as multi-layer PWB, 8 discrete LNAs and phase controlling chip (equivalent of 8 3-bit phase shifters).

Fig.5

Fig.6

Antenna terminals for satellite communications in C and L bands were developed also. Some of them are shown on fig.6. The terminals could boost the traffic and in that way to increase the speed of communications with mobile platforms. They work in transmit/receive mode and could track the satellite fully electronically or mechanically, using low-cost navigation system.

Conclusions:

The technologies developed in SkyGate give the possibility to reduce significantly the complexity of “classical” phased array antennas and to achieve commercially applicable solutions for Ku band (TVRO) antenna terminals for fixed and mobile applications. Prototypes of such antennas were successfully demonstrated to provide TV and Internet service on move in Europe and USA. The important features of the presented above antenna terminals are lower profile, significantly reduced cost and power consumption (compared with the “classical” phased array solutions). The use of proprietary designed chips with high stage of integration as well as the multi-chip module approach could contribute significantly for further reduction of size, weight and cost.

References:

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