RECONFIGURABLE ACTIVE RECEIVE ANTENNAS FOR FUTURE GEO COMMUNICATION SATELLITES

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1. Introduction

Looking at future GEO communication satellites from a European perspective, the upcoming new generation of L/S-band personal communication systems (PCS, S-UMTS), new Ka-band multimedia services, and EHF-band highly protected/wideband services for European military forces (MilSatcom) are the three emerging applications for the next decade which will need and drive the development of reconfigurable active antennas in order to ensure the desired quality of service as well as an improved flexibility over the satellite lifetime of 10-15 years. Whereas such antennas can be realized as direct radiating arrays, array-fed or single-feed reflector antennas, it can be expected that GEO satellites will mostly rely on reflector type antennas because of the required large apertures which would imply an enormous complexity and power demand in case of direct radiating configurations. For the transmit function, passive antennas with high-power tube amplifiers (TWTAs) are still very strong competitors to active antenna configurations, whereas future receive antennas will neccessarily require some kind of active stages to maintain a high sensitivity i.e. high G/T of the uplink, especially, if Ka- or EHF-band frequencies are addressed and advanced beamforming/beamsteering schemes are to be implemented.

Based on this background, the paper provides an overview of typical requirements imposed by the mentioned new applications together with an illustration of the need for active receive antennas and presents the status of related developments from a company perspective.

2. Typical Antenna Requirements of Future GEO Communication Satellites

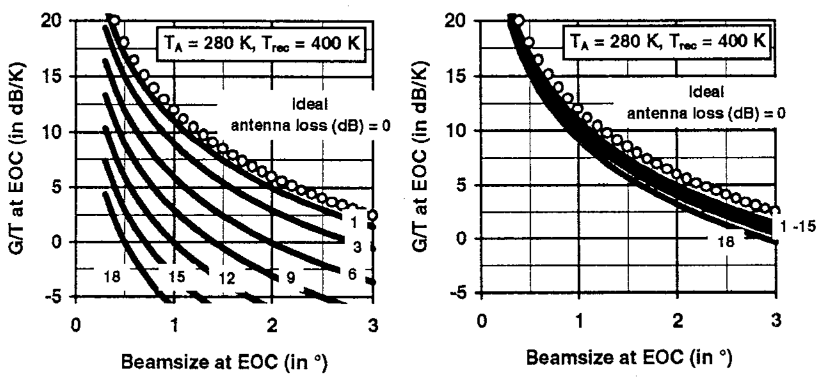
An overview of typical requirements for the antennas of future GEO communication satellites is provided in Table 1 which addresses frequency bands, polarization, typical coverage types, the size and number of beams and the provided uplink G/T at the edge of these beams (edge-of-coverage, EOC).

Application	Frequency (in GHz)	Polarisation	Typical Coverages	Beams per S/C	Beamsize (in °)	G/T at EOC (in dB/K)
S-UMTS PCS	<u>L/S-Band</u> 1.5/1.6 1.9/2.2	circular	Grid of Spots + Combinations	50 - 100	0.8 - 1.2	11 - 12 (1°)
MULTI MEDIA	<u>Ka-Band</u> 29.4 - 30.0 / 19.6 - 20.2	linear (circular)	Single Spots Grid of Spots Agile Spots	1 - 2 40 - 60 1 - 2	1.0 - 2.0 0.6 - 1.0 0.3 - 0.6	9 - 11 (1°) 9 - 11 (1°) 19 - 21 (0.3°)
MIL SATCOM	<u>EHF-Band</u> 43.5 - 45.5 / 20.2 - 21.2	circular	Steerable Contoured Spots	2 - 6	0.5 - 2.5 spot - region	14 - 16 (0.5°) 0 - 3 (2.5°)

Table. 1 Typical Antenna Requirements of Future GEO Communication Satellites

For future <u>PCS-systems</u>, typically 50 – 100 circularly polarized spots with beamsizes of 0.8 – 1.2° are desired which are used either as a cellular grid or as the basis for the formation of multiple coverages through active beamforming. In case of <u>multimedia services</u> three possible implementations arise which can be seen as evolutionary steps : If a Ka-band coverage is desired as an add-on to other services supported by the satellite, 1 – 2 spots with 1 – 2° size are a typical requirement whereby these spots are usually ellipses which may be pointed to the desired ground area via mechanical steering. More sophisticated, dedicated Ka-band satellites usually follow an approach similar to the cellular PCS-case or conventional C/Ku-band spacecrafts. Here, typically 40 – 60 either linearly or circularly polarized spots with beamsizes of 0.6 – 1.0° are desired which are used again either as a cellular grid or as the basis for the formation of multiple coverages. As a third option, very advanced approaches for TDM-based systems foresee the use of 1 – 2 agile spots with 0.3 – 0.6° beamsize which are synchronized to the TDM system clock. Finally, MilSatcom systems usually need 2 – 6 circularly polarized spots per spacecraft which can be steered to the desired ground location. Depending on the purpose of these spots, typical beamsizes can vary from 0.5° for smaller theaters to 2.5° for regional coverages whereby a flexible adaption of the spot contour is desired in order to counter ECM-measures.

The need for active receive antennas to comply to these requirements becomes evident, if typical G/T-figures are considered and passive and active configurations are compared which is shown in Fig. 1 for beamsizes and antenna losses (radiator system and beamforming network, BFN) of 0.3 - 3.0° and 0 - 18 dB, respectively. Whereas the passive antenna case is shown on the left, the right diagrams presents the simplest form of an active antenna composed of a passive radiator system with 1.0 dB loss followed by low noise amplifiers (LNA) with 20 dB gain and 400 K noise temperature and additional passive beamforming stages leading to the total losses (excl. LNA gain) indicated in the figure. The corresponding G/T-formulas for both antenna configurations can be taken or derived from [1 - 3].



For both diagrams, an antenna temperature of T_A = 280 K (antenna beam pointed on dry land surfaces) and a receiver with an input noise temperature of T_{rec} = 400 K have been assumed and the ideal case of a noise and loss-free antenna has been added for reasons of comparison.

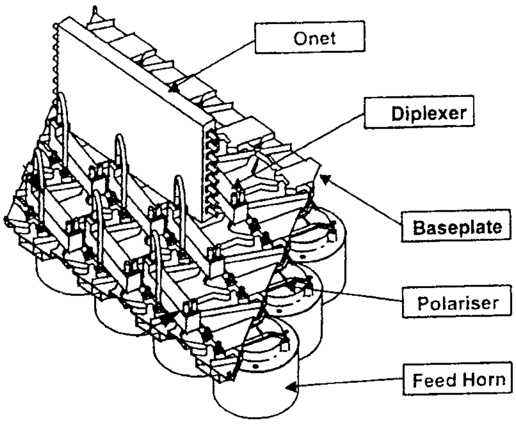
Fig. 1 Typical G/T-Figures for Passive and Active Antennas

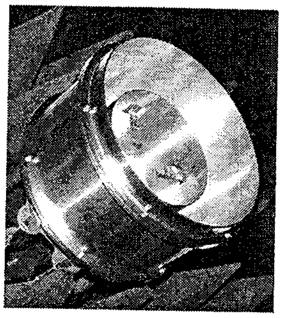
For the passive antenna case, it is evident that total loss figures of only 1 - 3 dB which are easily achieved by passive BFNs at all frequency bands or even input waveguide stages (polarizer, diplexer) at Ka/EHF frequencies seriously deteriorate the overall G/T to a level, that makes it impossible to meet the requirements presented in Table 1. This problem is solved in the active antenna case where the introduction of LNAs permits to meet the described system requirements for overall antenna losses of up to 15 dB. Equivalent results for more complex active BFNs are covered in [1 - 3].

3. Related Antenna Developments from a Company Perspective

Knowing the challenges of future satellite communication systems, Dornier Satellitensysteme GmbH (DSS) is actively working with national, European and transatlantic organisations such as DLR (German Space Agency), the German Ministry of Defense, ESA/ESTEC and INTELSAT in order to develop and qualify the required key technologies for the implementation of active, reconfigurable antennas. An overview of these activities covering all previously discussed application fields is given below.

In the area of L/S-band personal communication systems (PCS), the technology focus is placed on active feed arrays for combined transmit/receive operation with minimum mass, cable-less assembly technology, high power-handling capability, PIM-free realisation and directly integrated LNAs being the premium driving factors. Basically, such arrays consist of feed/polarizer units which have to operate over both receive and transmit band, diplexers for the separation of theses bands, LNAs integrated into the receive path and an ONET which is the output network of a butler-matrix power amplifier (Fig. 2a). Using lightweight magnesium technology DSS is developing such a circularly polarized array with both horn/polarizer units having Rx/Tx gain and axial ratio figures of 10.8/10.5 dBi and 0.6/0.5 dB and the associated diplexers (Fig. 2b) as well as 8 x 8 ONETs with interdigital filters under several contracts from ESA/ESTEC. The required LNAs using discrete HEMT input stages and MMIC gain blocks and delivering gains of up to 56.5 dB and noise figures down to 0.6 dB are available from previous development projects (Fig. 2c).





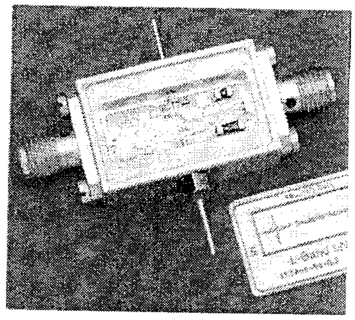
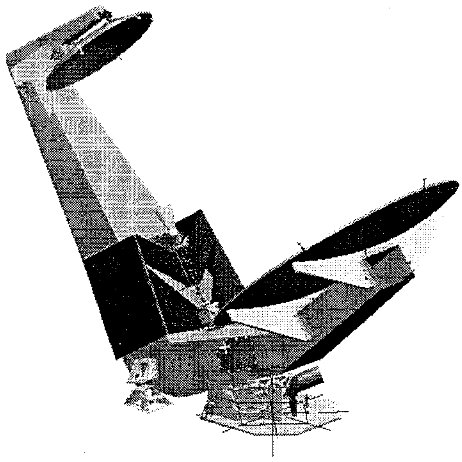
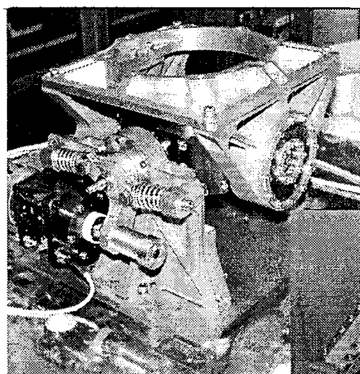


Fig. 2a Array Configuration **Fig. 2b Horn/Polarizer Unit** **Fig. 2c Low-Noise Ampl.**

For the implementation of <u>multimedia services</u> using Ka-Band, the DSS activities cover both mechanically steerable antennas for the implementation of add-on Ka-band spots on multiband spacecrafts as well as more sophisticated multi-feed antennas for dedicated Ka-Band satellites. For the former case, a mechanically steerable single-feed Gregory antenna (Fig. 3a) offering beamsizes of 1° and above is developed with cofunding from DLR and technical support from ESA/ESTEC. Key elements of this antenna are a new 2-axis gimbal-type pointing mechanism with a pointing range and accuracy of +-10° and 0.015 °(Fig. 3b) and a high power transmit/receive feed system which comprises a corrugated feed-horn, polarizer and diplexer (Fig. 3c). In order to achieve active receive operation, separatly developed LNAs with 28 dB gain and 2.5 dB noise figure are connected to the diplexer output.





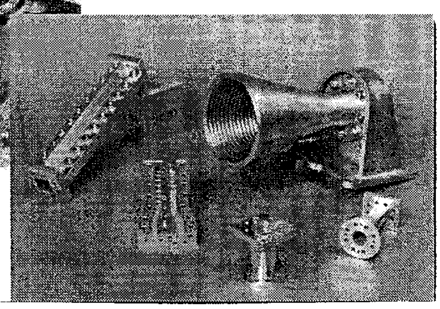
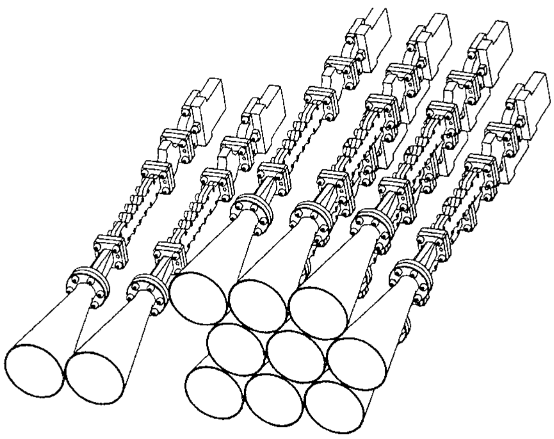


Fig. 3a Antenna Configuration **Fig. 3b Pointing Mechanism** **Fig. 3c Feed System**

For the latter case, the key developments are carried out under a number of contracts from both ESA/ESTEC and INTELSAT which cover antenna, feed system and component level. On antenna level, a multifeed shaped reflector antenna is under development for INTELSAT which comprises a complete feed system (Fig. 4a) as well as specific shaped reflector technology. On feed system level, the development of a fully redundant temperature controlled receive chain with integrated LNA (Fig. 4b) is is carried under ESA/ESTEC contract. Finally, component level developments are performed again for ESA/ESTEC comprising generic, discrete and MMIC modules for Ka-band receive antenna frontends and beamforming networks such as LNAs, variable gain amplifiers and variable phase shifters. An example for these kind of building blocks is given in Fig. 4c.



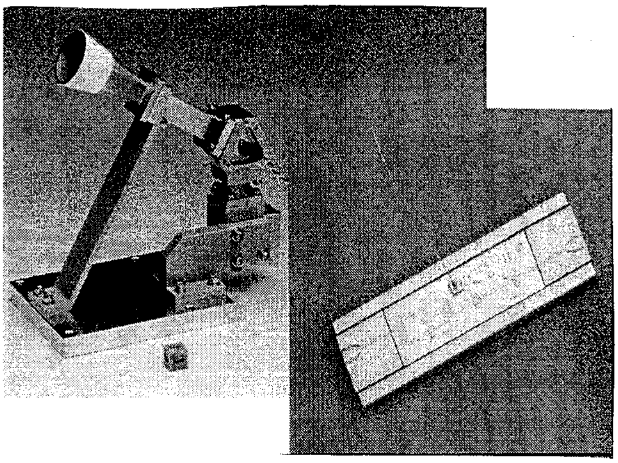
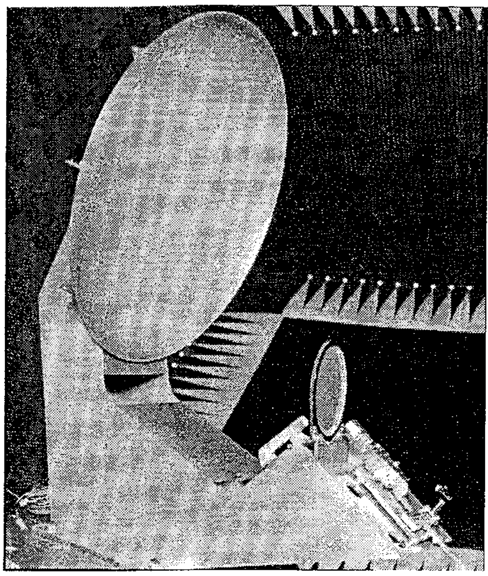


Fig. 4a Feed System Configuration **Fig. 4b Receive Chain** **Fig. 4c Active Module**

For the realisation of highly protected and wideband services for military forces utilising the EHF-band, DSS performs antenna level devlopments under contract of national authorities which comprise a mechanically steerable spotbeam antenna for transmit/receive operation and a fully active, electronically steerable receive antenna.



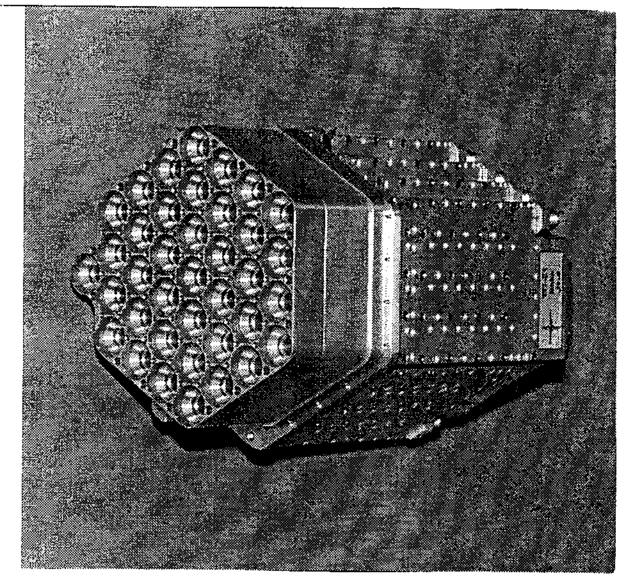


Fig. 5a Transmit/Receive Antenna **Fig. 5b Feed System of Receive Antenna**

The mechanically steerable spotbeam antenna (Fig. 5a) uses an electronically controlled multifeed receive system with an active beamforming network on MIC basis in order to generate contoured theater beams with variable sizes of about 0.5 - 1.5° for the receive function. For the transmit function, zoomable beams of about the same size are generated via a second multifeed system using a reconfigurable passive beamforming network. The electronically steerable receive antenna generates contoured beams with sizes of 2.5° and above for regional, zonal or global coverage by means of a multifeed receive system with an active beamforming network on MMIC basis (Fig 5b).

4. References

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