Antennas for Meteosat satellites

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Antennas for Meteosat Satellites

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Abstract –The paper describes antenna activities for Meteosat program developed under ESA's technical management. The program started in the 70's and the first satellite was launched in 1977 with VLF, UHF, L- and S-band antennas. The operational Meteosat satellites carried UHF, L- and S-band antennas. Antennas for the Second Generation Meteosat have been discussed in [1]. This paper contributes in complement with early antenna configurations as used for the pre-operational and operational Meteosat program. Together with [1] it provides a description of > 35 year of antenna activities for spinning spacecrafts for the Meteosat program.

I. Introduction

The Meteosat program has been very important for meteorological services in Europe. The first two 'pre-operational' Meteosat satellites have been launched in 1977 and 1981 respectively. Following a very successful data provision in the beginning over several years, the Meteosat Operational Program (MOP) was started in 1983 with an agreement to launch 3 operational satellites. A pre-operational satellite P2 was prepared with some modifications for launch with the first ARIANE 4 launcher in 1988. The last MOP satellite was launched in 1997 and is still functioning 13 years later. ESA carried out initially the operations of the Meteosat satellites for Eumetsat (data collection, pre-processing and redistribution of meteorological information), after which the European organisation **Eumetsat** took over in 1995:www.eumetsat.int.

Eumetsat's services continued and expanded and new spacecrafts were prepared: Meteosat Second Generation (MSG). With Eumetsat responsible for exploitation of the satellites, ESA handled the satellite procurement. Such collaboration continues for the Meteosat Third Generation (MTG) program. The latter program is in preparation phase today, it is only mentioned 'in this sentence'.

Meteosat satellites operate from geostationary orbit and are spinning satellites. They rotate at 100 revolutions per minute about an axis perpendicular to the plane of the Earth orbit around the Sun (~equatorial plane on 21 March and 21 September). The on-board radiometer observes the Earth in the visible and infrared regime in different wavelength channels. It 'sees' the Earth disk (~20˚) during about 1/30 of a revolution (azimuth) and build up an image by consecutive incremental 'North-South' scanning with a dedicated mirror tilting the beam after each revolution from Nord to South. It takes 30 minutes to cover the Earth with accordingly 3000 image lines in this way. The observed line data are reformatted during the remainder of the revolution in azimuth and sent to Earth via a dedicated radio-link. After processing, data with supplemented other meteorological information are redistributed via the satellite to the users (sent up and retransmitted via the electronically despun antenna -EDA). The EDA antenna has an electronically counter-rotating beam, synchronised with the spin rate. In this way the antenna beam (with a good directivity) can be kept pointed always towards the Earth while the satellite is spinning.

The principle of spinning has been applied for all satellite models in orbit. It clearly requires dedicated antennas for all frequency bands, with a need for sectorial coverage by means of toroidal pattern antennas or a despun antenna synchronised with the spin rate.

Dedicated radio links are provided by Meteosat for respectively the following services (Fig.2): data-transmission to the Earth, telemetry and telecommand and data redistribution. The Second Generation Meteosat has also a Search and Rescue transponder on-board.
The configuration differences between the pre-operational models and the MOP satellites are small. The antennas are slightly different with a difference in frequency band and thus antennas for the TT+C (telemetry and telecommand) link. The difference between a MOP and MSG model quite large and is outlined in Figure 1. The MSG mission scenario is shown in Figure 2. The reader can find details at www.eumetsat.int.
Thales Alenia Space-Roma (formerly Alenia) has been in charge of the realisation of these antenna subsystems, whereas ThalesAleniaSpace-Cannes (formerly Aerospatiale) has been in charge of the complete satellite.
Intriguing constraints related with the spinning configuration did lead to dedicated modelling and design efforts in order to – with volume constraints present – realise the antenna requirements for different radio links. In [1] one might find further information, especially concerning the antennas for Meteosat Second Generation.
In-orbit monitoring and observations have provided interesting aspects, with diagnostic information which compared with modelling and also provided information about precise antenna functioning.

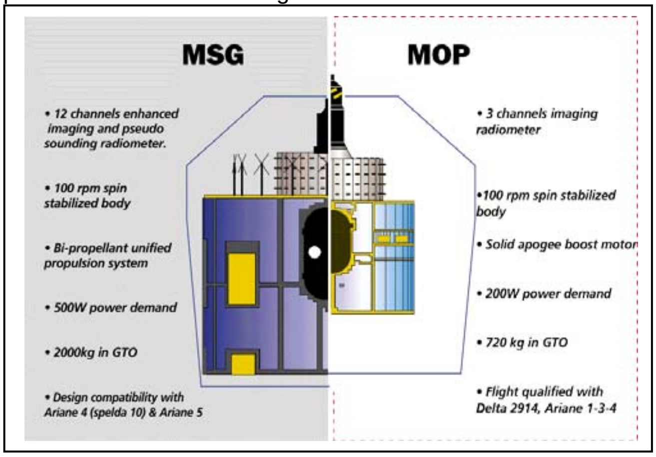

Figure 1. Relative Comparison MSG and MOP Satellite Configuration.

II. Pre-Operational /Operational Meteosat

The two pre-operational Meteosat satellites made use of a radio-link for telemetry/telecommand in VHF band (137 and 148 MHz). The meteorological data were sent to the Earth in L-band, using the EDA antenna. It had a toroidal L-band antenna as back-up. The latter data were processed and retransmitted towards the satellite in S-band. Both toroidal antennas are shown in fig.4 and are slotted waveguide antennas. Distribution of data to the users occurred via the Electronically Despun Antenna (EDA). Additional meteorological data were collected from buoys in UHF band.

For the VHF link four ¼ wavelength monopoles were optimized on the satellite body, in order to provide the desirable antenna pattern from the satellite configuration by connecting the latter monopoles in phase-quadrature (turnstile). In [3] there are details. Turnstile antenna aspects are also found in [2, 4].

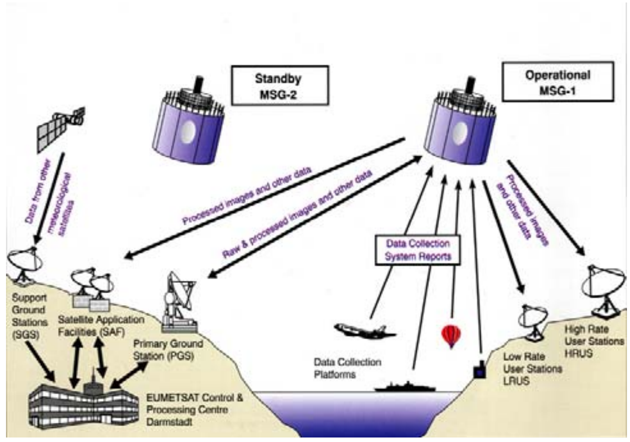

Figure 2. Meteosat MSG Mission scenario showing different radio links.

The turnstile configuration was applied on several other early satellites of ESA. Detailed dedicated antenna optimizations have been carried out for Meteosat in the mid 70's exploiting Method of Moment for the configuration of the spacecraft. It led to a slight inclination of the monopoles. It is worthwhile to consult related information in [3]. It is interesting to mention, that a spare antenna monopole was adapted later on for a student-satellite [6].

A change was made from VHF to S-band for the TT+C link frequency for the P-2 model and for the operational program of Meteosat. Changing to S-band implied that the antenna tower had to be precisely adapted, with consequences for the antennas below the S-band antenna: the UHF antenna pattern was clearly affected. A quadrifilar helix is used for the S-band antenna on top of a cone, with all dimensions optimized (MoM), such that an antenna pattern is provided for coverage from an angle theta = 0º (satellite axis) up to theta = 140º in circular polarization. The satellite body blocks part of the radiation pattern (towards the 'south' direction). During the early orbit shortly after launch, there are situations, that the link can not be maintained. However, once when on station in the geostationary orbit, the link in S-band is provided, with theta in the direction of 90º ($\pm 22.5^{\circ}$). The quadri-filar helix was designed for this task by Ericsson (later Saab-Ericsson, now Ruag) and positioned on top of the antenna tower (Fig.3).

The UHF antenna operates in 401.5 MHz and consists of a group of in-phase fed inclined printed dipoles around a perimeter of a supporting polyester tube. Fig. 3 shows the UHF antenna on a pre-operational model and on an operational model. The UHF antenna compares to a Lindenblatt-antenna [2] configuration with four dipoles at a specific radius and inclined with respect to the plane of the perimeter by an angle, such, that a toroidal pattern is produced in circular polarization. The spacecraft body has influence on the pattern shape and accurate modeling on the basis of Method of Moment has been mandatory. Detailed numerical analyses have been carried out by Ticra [5], showing the effect of the presence of another antenna (slotted waveguide antenna – see below) as well as the satellite body. Within the field of view (Earth disk as seen over ±9.2º wrt the orbit plane) there is a minimum directivity always higher than 1 dB, with about 2.2 dB ellipticity. Dimensions were selected as compromise between amplitude ripple in the plane (larger radius) and coupling between the dipoles (smaller radius). Fig.3 shows the UHF antenna very clear on the right hand side (without thermal protective paint).

The change in TT&C to S-band caused a need to re-optimise the UHF antenna to a lower position, with a lower gain as result, due to the presence of the satellite body.

The L-band data downlink antenna is an electronically despun antenna (EDA) and is used in all models (also in the later MSG model). It consists of a cylindrical array of 32 columns with each column consisting of an array of four dipole elements. The beauty of the antenna design is that there is instantaneous a sub-group of 4 to 5 columns active on the Earth-facing side. This allows to switch the antenna transmit functionality to that set of columns out of the 32 columns towards the Earth during the spinning. Gradual take over is provided by 7 intermediate switching states (non-equidistant in time, optimized for a cylindrical configuration) over the angular interval determined by the column spacing of 360/32 degrees. The antenna array is positioned on top of the spacecraft body and the presence of the latter has been taken into account in the antenna design. On the other hand the fairing configuration aspects provided such a volume constraint, which had to be complied with, causing the EDA beam to be tilted slightly in the North direction during the spinning. The influence of the satellite body had to be modeled to derive the pattern performances. Geometrical Theory of Diffraction (GTD) analyses assisted to handle such aspects and antenna testing was carried out on the basis of near-field probing after integration and after environmental testing [7].

The reliability of the switching electronically despun antenna EDA has been estimated and was considered sometimes critical for this aspect. It is however interesting to know, that the EDA functioned well. The number of switching changes in the on-board pin-diode switch-network has been well behaving and reliable. The last MOP satellite has been operating for more than 13 years. That means more than 10^{10} switching states for the EDA antenna. From the launch 1977 of the first model up to today, there has been nearly uninterrupted service with the downlink using the Electronically Despun Antenna.

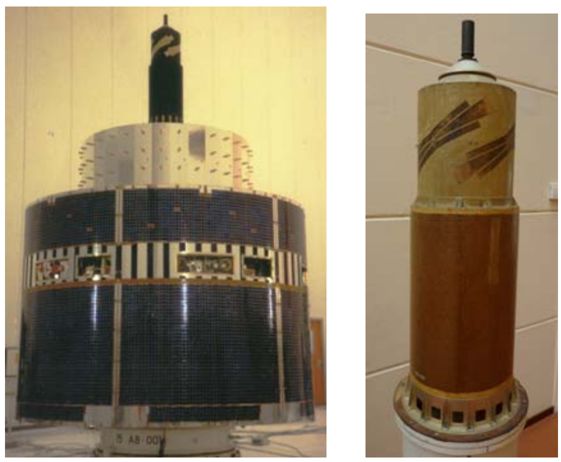

Figure 3. MOP Satellite with L-band EDA and antenna tower (left). The antenna tower (on the right) has a UHF Lindenblat antenna and S-band quadrifilar helix. The lower compartment houses two slotted waveguide antennas.

There are two slotted waveguide antennas mounted side-by-side in the lower part of the antenna tower shown in Fig.3. They have slots on each side of the broad-wall and provide a toroidal pattern. One antenna operates in L-band (~1685 MHz) and the other operates in S-band, Tx and Rx respectively. Decoupling is important.

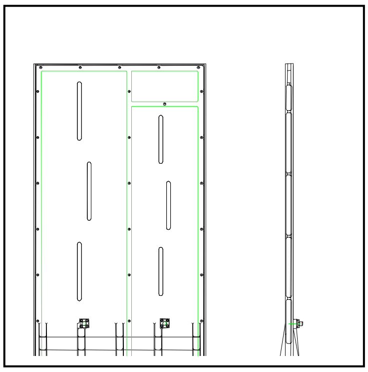

Figure 4. L-band and S-band slotted waveguide antennas with toroidal patterns for up and down-link, side by side. The antennas are positioned side-by-side on top of the L-band EDA below the UHF within the cylindrical radome (see Figure 3).

The use of narrow bandwidth resonant slots implies a low coupling between respective S and L-band Rx- and Tx channels. It is an interesting feature of the configuration with the antennas side-by-side, that a remarkably good (toroidal) antenna pattern is provided in the azimuth plane, also in the direction, where there is “the neighbour” antenna. The far-field phase behaves cosine-like, as expected due to the offset from the spin-axis. The related phase modulation doesn’t cause any problem for the data link. The L-band toroidal pattern antenna acts as the back-up transmit antenna for a highly unlikely situation of a failure of the L-band EDA Antenna.

III. Meteosat Second Generation

The Meteosat Second Generation satellite included several modifications compared to the satellites of the operational program. Fig.1 shows configuration aspects. Volume requirements for the complete satellite have been dictated by dual-launch satellite requirements. Therefore the height limitation for the antenna assembly has been very critical. Detailed antenna descriptions for MSG are found [1] and not repeated here.

The MSG antenna configuration is shown in Fig.5.

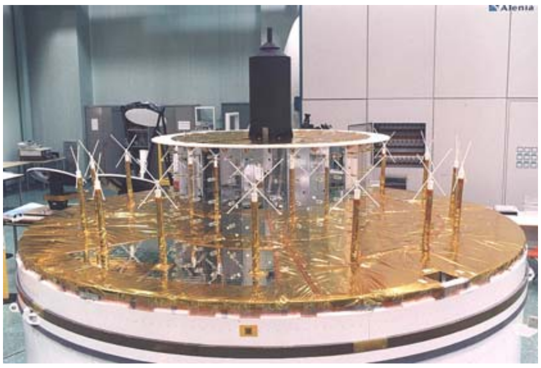

Figure 5. MSG Flightmodel Antenna Subsystem in the clean room (Courtesy ThalesAleniaSpace Roma - Italy).

Some aspects are mentioned though: the volume constraint led to a selection of a different UHF antenna, compared to MOP, capable of providing higher gain in comparison with the previous toroidal approach. Such higher gain was needed for the Search and Rescue reception as well. A 16 element crossed dipole cylindrical configuration was selected, positioned around and in front of the L-band EDA. MoM optimizations and spacecraft configuration aspects did lead to the slightly inclined and rotated positioning of the dipoles in order to provide the maximum gain and the best axial ratio. (The rotation of the elements assisted to improve the axial ratio). An additional Rx channel was added to the UHF antenna in order to be able to receive Search and Rescue signals transmitted in the 406.5 MHz band. An additional downlink channel was added into the L-band EDA at a frequency of 1544.5 MHz. With the EDA antenna originally not designed for such frequency, it implied a modification as well. But [1] should be red in order to find details concerning the antenna aspects for the Meteosat Second Generation satellites.

IV. Conclusion

In this paper historical aspects have been addressed related to the antenna configurations for the spinning satellites for Meteosat satellites. The program started with design activities in the 70’s, with a first launch in 1977. Since then there have been nearly uninterrupted services up to today. The paper covers mainly antenna aspects, as addressed early in the program. Reference [1] is the complementary description for the antenna aspects for Meteosat Second Generation.

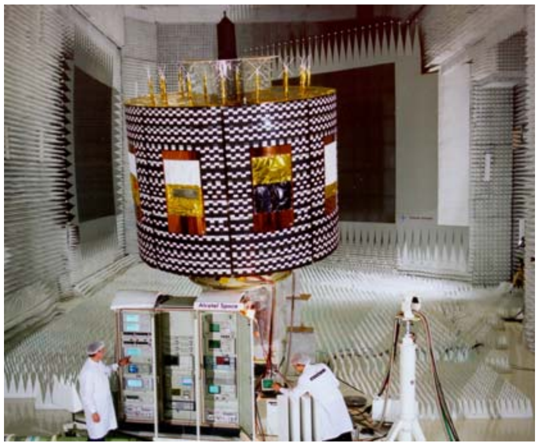

Figure 6. MSG Flightmodel Antenna Subsystem in the RF testrange (courtesy ThalesAleniaSpace Cannes -France).

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