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Dual Optics vs Prime Focus Offset Antennas

Dated 2006-08-17

General

Nowadays, small size satellite earth station antennas for DSNG or VSAT applications are of two types

- Prime Focus Offset Antennas
- Dual Optics Offset or Gregorian Antennas (or dual reflector)

The prime focus offset (prime focus for short below) is the traditional antenna optics widely used for VSATs at C band and at Ku band. However, the large antenna manufacturers like Channel Master and Prodelin are now converting some of there prime focus antenna models to dual optics for better performance at Ku band.

The objective of this paper is to discuss the advantages and disadvantages of the two antenna optics concepts in a reasonably unbiased manner.

Gain

The most evident difference between dual optics and prime focus antennas is the second reflector – the so called subreflector. With the subreflector, the antenna designer has more freedom of design. Combined “shaping” of the two reflectors allows the designer to perform a deliberate deviation from the true parabolic shape in order to control phase and amplitude of the aperture field (main reflector).

Dual optics can thus have higher aperture efficiency due to this shaping. Analysis of the dual optics geometry used for the SWE-DISH antennas show that close to 80% efficiency is achieved.

Practical SWE-DISH antennas have somewhat lower efficiency due to feed losses and some loss due to reflector surface inaccuracy.

Prime focus offset antennas have an efficiency in the 60% range – in some cases up to 65% is claimed. Going from 60% to 80% efficiency means a 1.2 dB gain increase.

Gain-wise, the dual optics antenna has a gain corresponding to a prime focus offset antenna with 32% larger area/aperture or a 15% larger diameter (based on 60/80% efficiencies)

Cross Polar Discrimination (XPD)

The freedom of design of dual reflector systems helps in cross-polar reduction in two ways. First, dual optics geometries represent an equivalent focal length longer than the actual.

Second, only dual optics satisfies the Mizuguchi condition, which is a geometrical condition granting minimized level of cross polarization. In simple words - dual optics have a XPD canceling effect.

In order to achieve good XPD, prime focus offset antennas must have a large f/D ratio (shape factor). The disadvantage is that a high f/D means a long focal distance (long feed arm), causing mechanical problems.

In order to meet Eutelsat requirements for XPD, some manufacturers convert their prime focus designs to dual reflector by adding a subreflector and a new feed horn. The XPD performance is improved but the aperture efficiency is not – there is no reflector shaping.

Spill-over/Antenna Noise Temperature

Prime focus offset antennas may have quite high reflector edge illumination in order to optimize gain. This could lead to high edge spillover and consequently diffraction sidelobes. The resulting sidelobes are looking at the ground and will therefore pick up thermal noise from the “warm” ground.

On a dual optics antenna, the spillover can be controlled in a much better way (feed – subreflector-main reflector chain). The sidelobes are looking at the cold sky and therefore noise pick up is less than for a prime focus antenna.

Sidelobe Performance

Once more, the dual optics makes available extra parameters for optimizing antenna sidelobe performance.

As a proof of dual optics design possibilities, we like to mention that the design objective for the 150-series antennas was “as small aperture as possible, compliant with the FCC rules for 2º satellite spacing”. The antenna passed and an FCC license has been granted.

In fact, all the SWE-DISH 150-series antennas have all at least 3 dB lower sidelobes that the mandatory mask 29-25Log Theta dBi, starting at Theta =1.0º. Often only a few sidelobes overshoot the 23-25Log Theta dBi mask - that’s 6 dB lower sidelobes than required…

For prime focus offset antennas there is a trade off between sidelobe performance and gain.

Good sidelobe performance is decisive for limiting the off-axis EIRP density and hence the risk for adjacent satellite interference at high output power.

Elliptical Aperture Antennas

Due to the presence of the subreflector, shaping gives the possibility to generate an elliptical beam from a circular one, illuminating the sub reflector. This ensures optimal illumination of the main reflector, regardless of polarization, in case elliptical aperture antennas are employed (SWE-DISH IPT Suitcase or 150-series).

If a single offset solution is combined with an elliptical aperture, then the feed horn has to radiate an elliptical beam, causing two main disadvantages. First, the horn gets more complex and more expensive. Second, the polarization cannot be changed from vertical to horizontal by simply rotating the feed.

Frequency Response

For dual optics, gain saturated corrugated feed horns can be used. These horns have an inherently large bandwidth, allowing tighter control of the radiation pattern over the full frequency range.

The SWE-DISH 150-series antennas cover the 10.70 – 14.5 GHz band seamlessly, because of the wide frequency response in combination with a broad band OMT. In transmit mode, the 150-series antennas cover 12.75 to14.5 GHz, using two different transmit reject filters (TRF)

Prime focus feed horns generally produce a broad illumination pattern but the characteristics of these horns tend to vary more with frequency – with subsequently less control of the antenna radiation pattern as a result.

Packaging

The SWE-DISH dual optics antennas (IPT Suitcase and 150-series) have a very short and compact feed arm. This compact feed arm makes it possible to fold the feed arm and subsequently stow the antenna in a small volume.

Deployment and stowing can therefore be done in a few minutes. Therefore, compact packaging has become a SWE-DISH trademark.

Prime focus antennas, with their long feed arm, must be handled in a different way. For Fly-Away antennas, the feed arm, with or without the feed system, is often transported in a separate crate.

For vehicle mount antennas, the compactness of the 150-series Drive-Away “Pod” antenna system is unchallenged.

Are there disadvantages?

Yes, the compactness of the dual optics feed system makes it virtually impossible to add a four port feed system – there is simply not enough room for the rotating waveguide components.

However, a sophisticated three-port feed (cross- and co-pol reception simultaneously) is now an option for the IPT Suitcase and the Fly-Away 150-series antennas. The co-pol diplexer is an “add-on” device (mounted on the feed arm) with minimum losses, thus assuring only a small degradation of G/T.

It should be noted that change of circular polarization sense is not a problem for SWE-DISH dual optics antennas.

A prime focus offset antenna has no feed space limitations. Quite bulky waveguide assemblies can be places behind the feed horn without causing blockage – if the feed arm construction can take the load.

Karlstad 2006-08-17

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