COUPLING BETWEEN A FEED AND A REFLECTOR CALCULATED USING GRASP8

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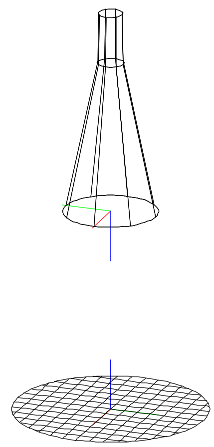
Abstract Silver's original procedure for calculating coupling between a feed and a parabolic reflector antenna in order to design a vertex plate for a centre-fed reflector is implemented in a more general form to determine coupling between feeds and arbitrarily shaped reflectors. The method is validated by comparison to a moment method approach for the case of a corrugated horn placed in front of a small flat reflector.

Keywords: Reflector antenna, vertex plate, PO, GRASP8,coupling, CHAMP

Introduction A vertex plate is a flat disc which may be placed at the vertex of a reflector antenna to reduce the interaction between the feed and the reflector, thus minimizing the VSWR of the feed system. Silver (1949) described a simple method for optimising such vertex plate by calculating the complex coupling coefficient between the feed and the reflector. This was done analytically for a rotationally symmetric antenna using a simple model for a scalar feed and assuming that the reflector shape was parabolic. The technique consists of first calculating the PO induced currents on the reflector and then evaluating the complex coupling between each current element and the feed (cf. Ch. 4.2 of Clarke & Brown (1980)) . By performing a summation over all current elements a complex number is obtained which represents the coupling from the reflector back into the feed. A reduction of this number will reduce the return loss of the feed in general.

Viskum et al (1996) showed an example on how Silver's method could be extended to other reflectors than circular symmetric by designing a vertex plate for a shaped reflector generating an elliptical beam. The need for relying on analytic methods was the only reason that Silver's original approach was limited to simple reflectors, and modern tools and computers have eliminated this hindrance. However, it is still based on the theory of Physical Optics and because vertex plates are typically small in extent it is interesting to verify the approach by comparing to results otherwise obtained, for example by using moment-method based software. In the following we will compare data obtained by incorporating Silver's technique in the general reflector antenna analysis software GRASP8 (Pontoppidan (1999)) to data generated from a very accurate mode-matching/moment-method program CHAMP (Frandsen (1990)) used for corrugated horn analysis. The CHAMP program analyses the aperture field of the corrugated horn by employing mode matching from the throat section to the aperture. The effect of the outer structure of the horn, including that of a plate located in front of the feed, can be accounted for in the evaluation of both the radiation pattern and the return loss at the input, by way of a moment method. CHAMP is a well-established standard for designing corrugated horns, and agreement with measurements in the order of 1 dB at cross-polar levels 45 dB below peak is not un-common.



Description of the problem A corrugated horn operating at 11 GHz is placed in front of a circular plate as shown in Figure 1. The horn aperture, located 200 mm in front of the plate, is 90 mm in diameter.

A series of calculations is now carried out for varying values of the plate diameter up to 200 mm. In CHAMP we calculate the complex value of the return loss also in the case where there is no plate at all, thereby establishing the VSWR of the feed itself. Because the feed is well-designed with a matching section its VSWR is better than 30 dB. In GRASP8 we calculate how much the feed receives of the field reflected by the plate and relate this number to the total field radiated by the feed. It is important to note that the latter procedure does not take the VSWR of the feed itself into account.

The complex coupling ratio as a function of the diameter of the plate will describe a spiral when plotted in the complex plane, and it is this spiral curve that Silver used to determine the appropriate diameter and location of the vertex plate.

Numerical results Figure 2 shows the coupling coefficient in the complex plane, and the spiral shape eluded to above is evident. Although the two methods agree very well on the overall shape of the curve there are a few distinctive differences: the curves are displaced relative to one another, and the moment-method data do not produce a pure spiral but has some apparent modulation.

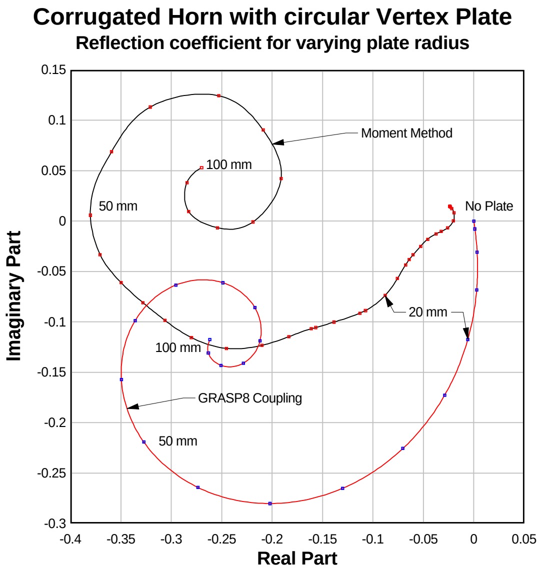


Figure 2. Plot of coupling coefficient in the complex plane. GRASP8 and Moment Method data

The differences are caused by the way the two methods work. As pointed out above the CHAMP program calculates the VSWR at the input of the horn and thus shows the composite effect of the horn and plate. Therefore the curve does not start in 0 as the GRASP8 curve does (corresponding to no plate at all) but at the point which defines the intrinsic horn return loss, around -32 dB. Furthermore, the horn return loss and the reflection from the plate will sometimes be in phase and sometimes out of phase; hence the modulation of the spiral.

These differences apart the two curves are very alike. To further compare we have plotted the amplitude and the phase of the coupling in Figures 3 and 4 respectively. In addition to the predicted coupling values, the amplitude plot also contains two lines which define a band around the GRASP8 data. These curves are obtained by adding the intrinsic return loss of the feed as calculated by CHAMP to the GRASP8 data, in phase and 180° out of phase. It is seen that the moment method curve is inside this band except for a very minor region around a plate radius of 75 mm, thus verifying the GRASP8 approach.

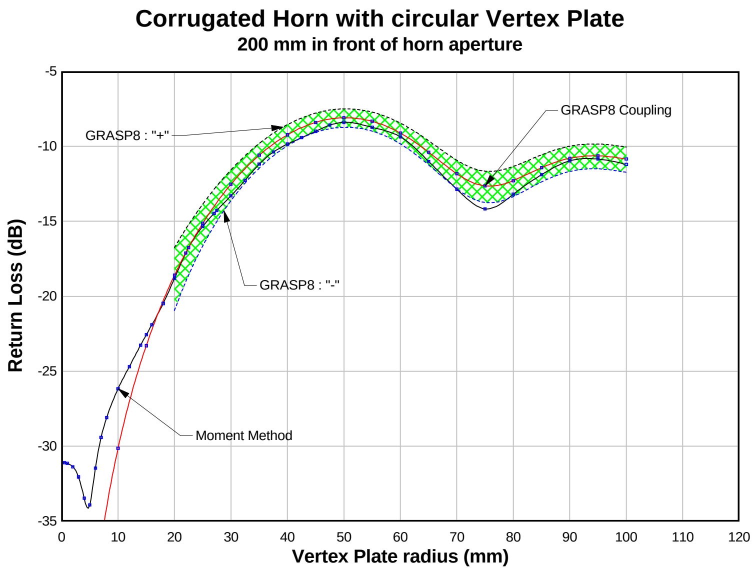


Figure 3. Calculated coupling in dB. The band around the moment method data are obtained by adding and subtracting the absolute value of the horn return loss to the GRASP8 data

The phase curves also share the same characteristics but with an almost constant offset between them. The phase difference is calculated and shown in the top of the plot. The fact that there is a phase difference is not surprising since CHAMP calculates the effect at the input section of the horn, while the reference plane used in GRASP8 is at the horn aperture. It is emphasized that there is no implications for the application of GRASP8 to vertex-plate design because the technique relies only on the relative position of the spiral to derive the optimum size and position of the plate.

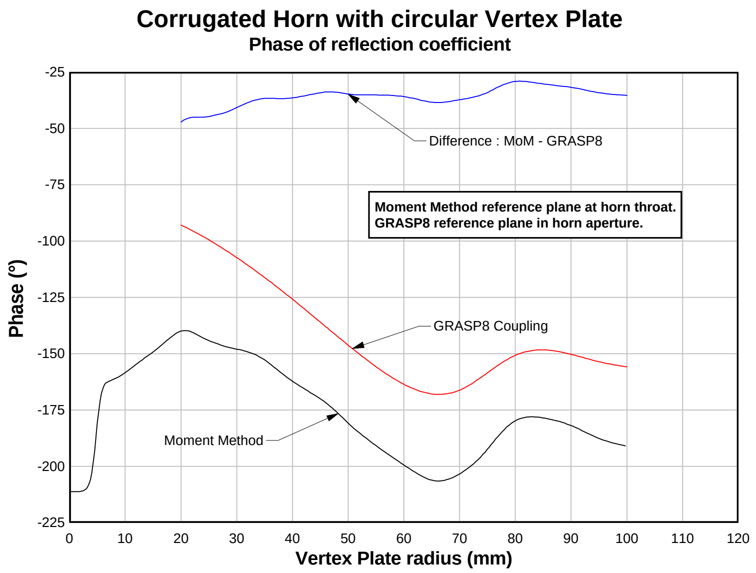


Figure 4. Phase of coupling. The almost constant difference between the moment method data and the GRASP8 data is also shown at the top.

The rather good agreement is even more convincing in view of the plate size in terms of wavelengths. Even for a plate diameter of 40 mm which at 11 GHz corresponds to 1.5λ the PO-based GRASP8 predictions and the MoM data compare most favourably.

Conclusion The method for calculating coupling between a reflector and a feed as implemented on a general form in GRASP8 is verified by comparison to moment method data. The feature is useful for designing vertex plates following the method originally proposed by Silver. Since it is implemented in a general program as GRASP8 is can also be used for numerous other purposes, for example to estimate the coupling from one feed in a reflector antenna system on a spacecraft to a feed in a completely different system through scattering in a series of reflectors (Nielsen (1999)). It is also useful for array synthesis using the principle of conjugate field matching where the coupling from e.g. a plane wave to each element in an array may be used to determine those excitation coefficients that will produce a plane wave in the opposite direction when used in transmit mode.

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