# $TE_{21}$ TRACKING SOLUTIONS

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**ALPERTON Monopulse Tracking Systems** are an high performance and effective solution for antenna tracking applications, **including GEO, LEO**, etc.

Tracking systems can be provided for **linear and/or circular polarization** tracking, for different frequency bands, e.g. **X, Ku, Ka,** etc. Multi-band solutions can be also provided. It's also possible to provide custom design according specific user needs (e.g. custom frequency bands, etc.).

The architecture that is described in this document is based on $TE_{21}$ higher order coupling, providing reliable and efficient tracking solutions.

As an example of our monopulse $TE_{21}$ tracking architecture, below a description of one of our linear/circular polarization monopulse $TE_{21}$ tracking couplers is provided, showing the tracking coupling section and the tracking branching network.

In the following:

- 1A, 1B, 1C, 1D represents the coupling section, making use of coupling holes arrays, for $TE_{21}$ mode #1;
- 2A, 2B, 2C, 2D represents the coupling section, making use of coupling holes arrays, for $TE_{21}$ mode #2;
- $\varepsilon_1$ and $\varepsilon_2$ represents the error signals at the output of the tracking branching network, giving information about azimuth and elevation errors.

In case circular polarization type "V + jH" (let's name it type 1), the system generates azimuth and elevation tracking errors as shown below:

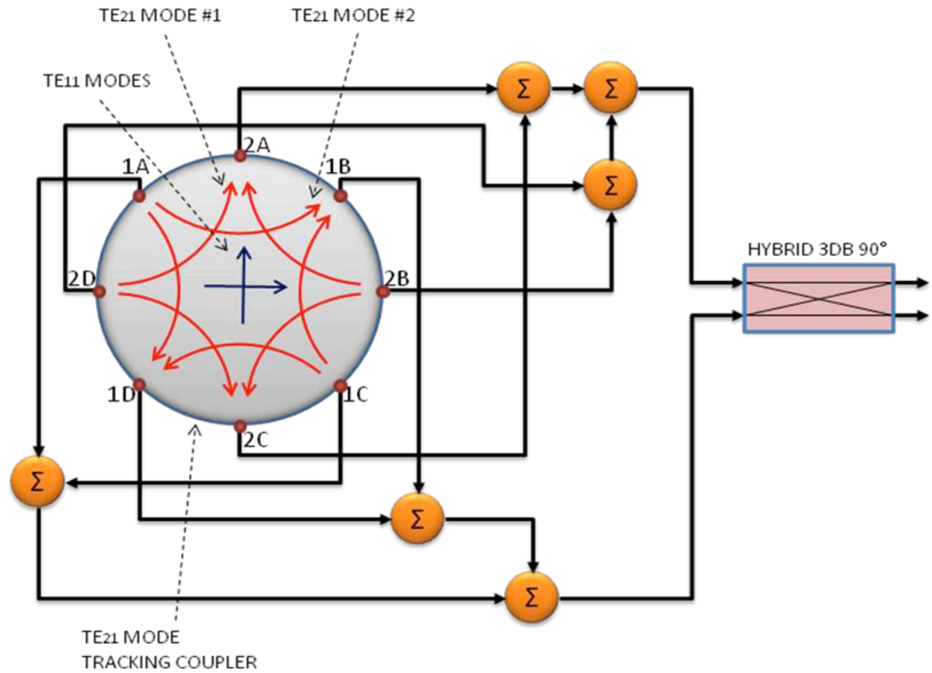


**Fig. 1 - Linear/circular polarization $TE_{21}$ tracking coupler architecture**

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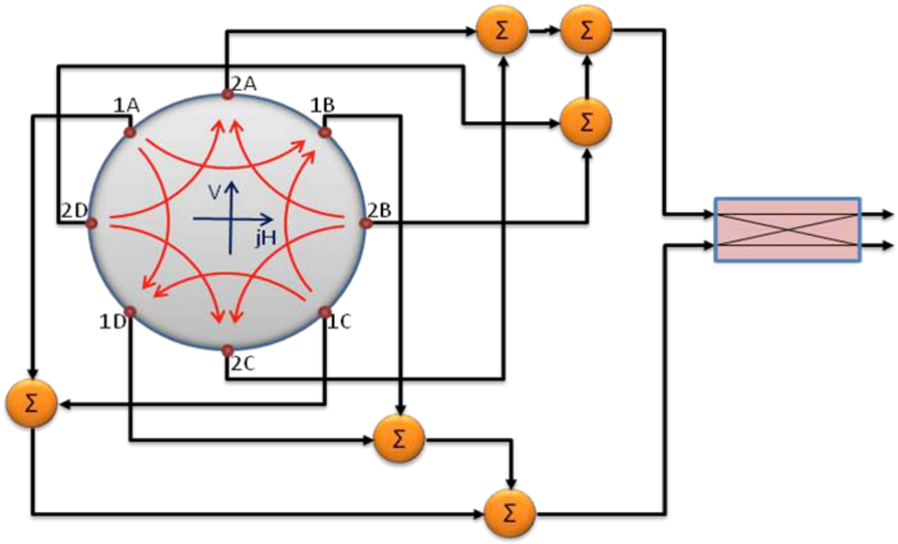


Fig. 2 - Circular polarization type 1

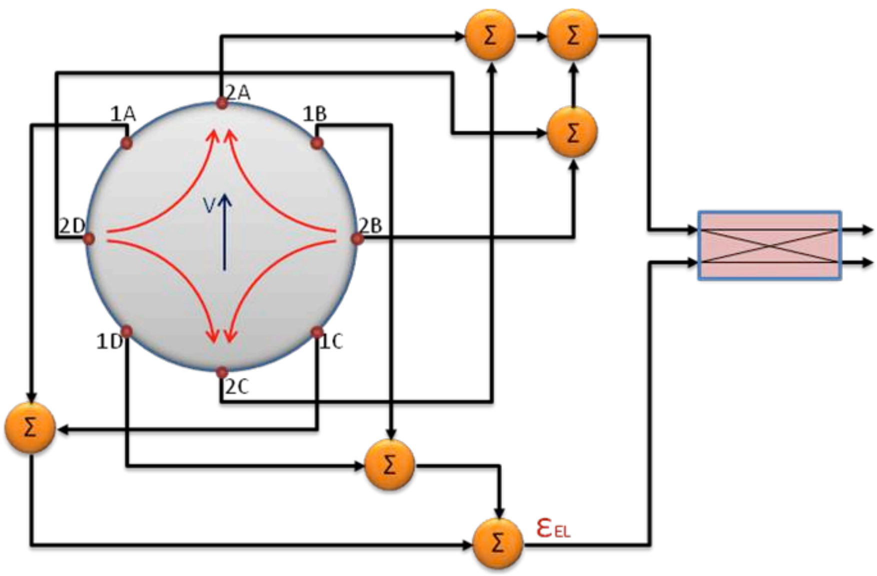


Fig. 3 - Circular polarization type 1 - V component - $TE_{21}$ mode #1 excitation

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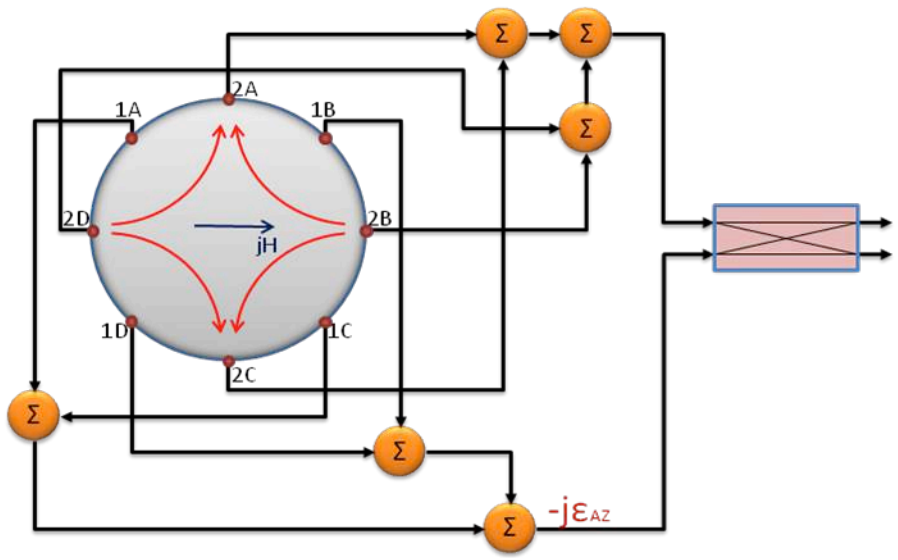


**Fig. 4 - Circular polarization type 1 - H component - $TE_{21}$ mode #1 excitation**

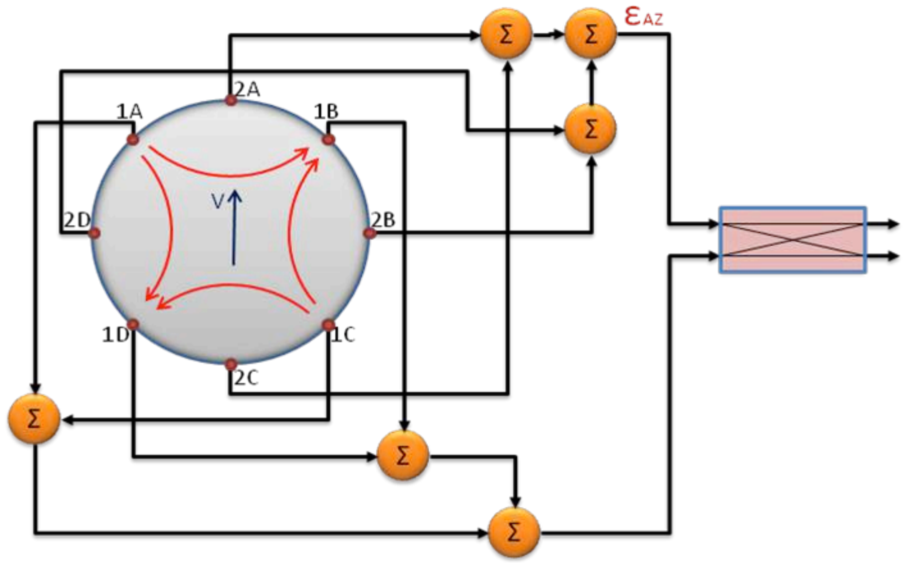


**Fig. 5 - Circular polarization type 1 - V component - $TE_{21}$ mode #2 excitation**

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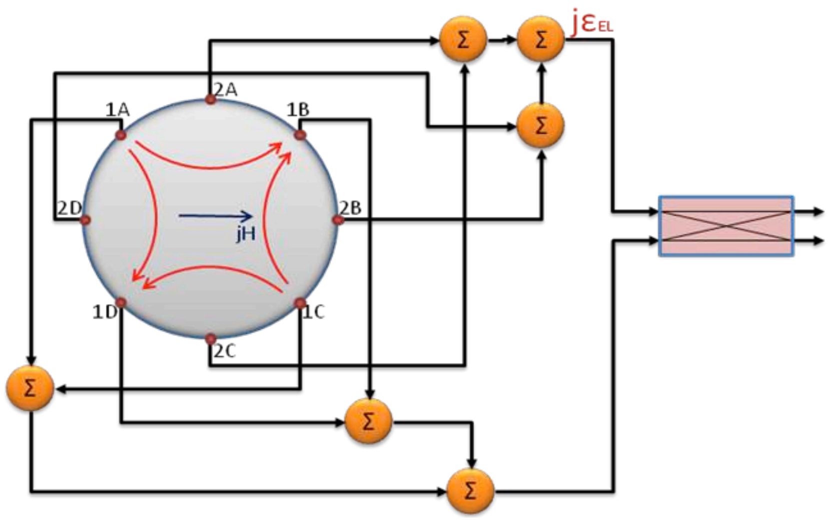



**Fig. 6 - Circular polarization type 1 - H component - $TE_{21}$ mode #2 excitation**

Therefore, the output of the tracking system is given by:

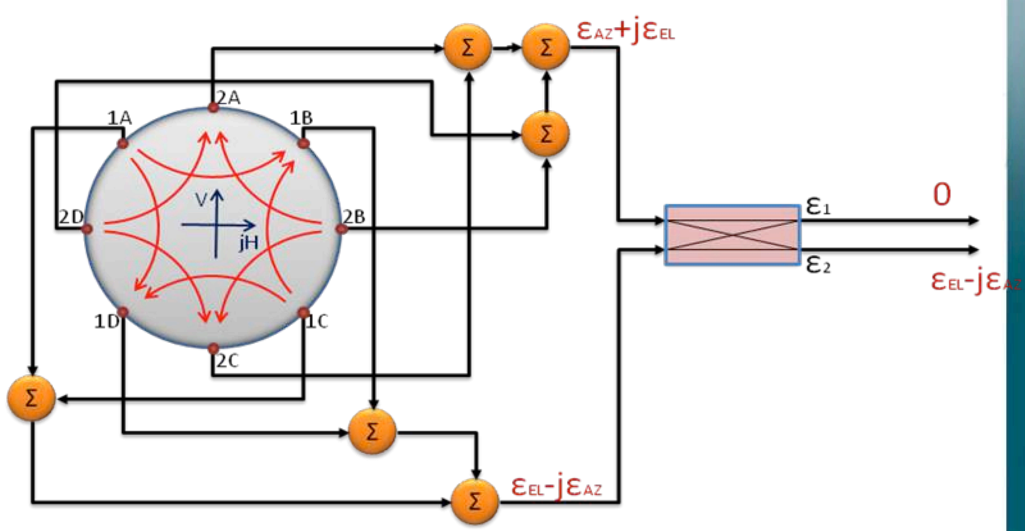



**Fig. 7 - Circular polarization type 1 - Error output of the tracking network**

As it can be noted, the system provides quadrature azimuth and elevation error signals at $\varepsilon_2$ output.

In case circular polarization type "V - jH" (let's name it type 2), the system generates tracking errors as shown below:

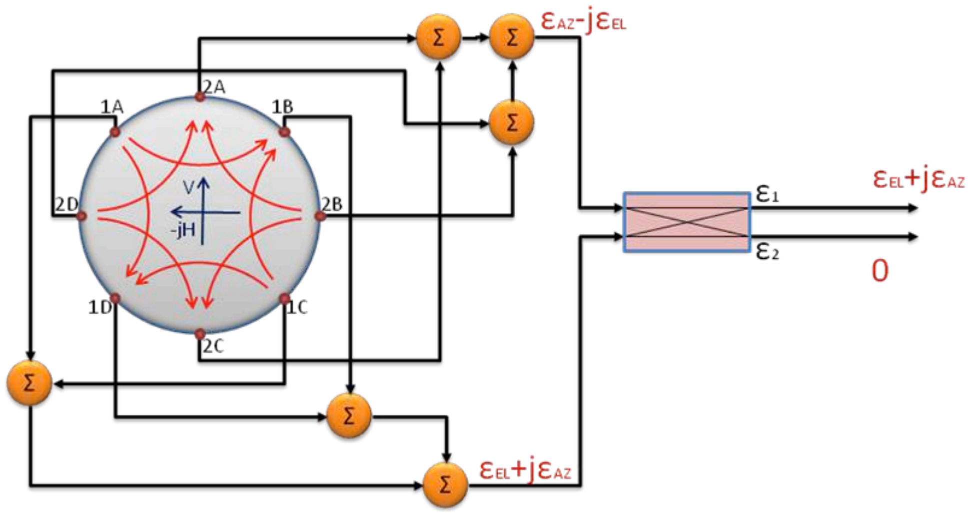



**Fig. 8- Circular polarization type 2 - Error output of the tracking network**

As it can be noted, the system provides quadrature azimuth and elevation error signals at $\varepsilon_1$ output. In case linear polarization type "V" and type "H", the system generates tracking errors as shown below:

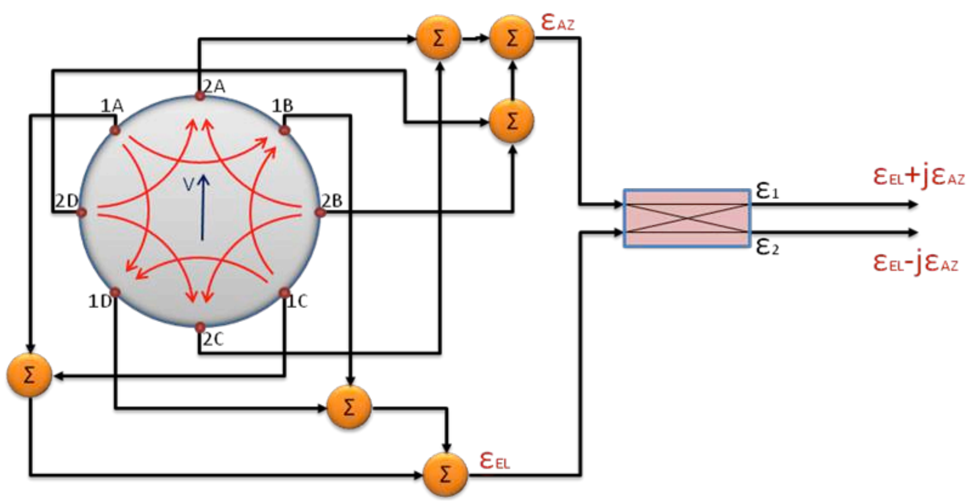



**Fig. 9- Linear polarization type "V" - Error output of the tracking network**

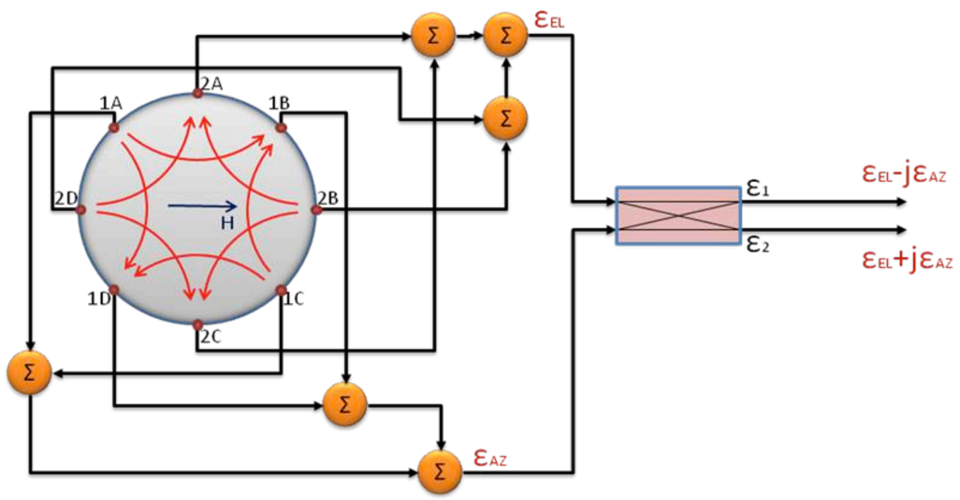



**Fig. 10- Linear polarization type "H" - Error output of the tracking network**

As it can be noted, the system provides quadrature azimuth and elevation error signals at both $\varepsilon_1$ and $\varepsilon_2$ outputs (both can be equally used for linear tracking).

Below, the 3D layout of one coupling branch of a linear/circular $TE_{21}$ tracking coupler is shown.

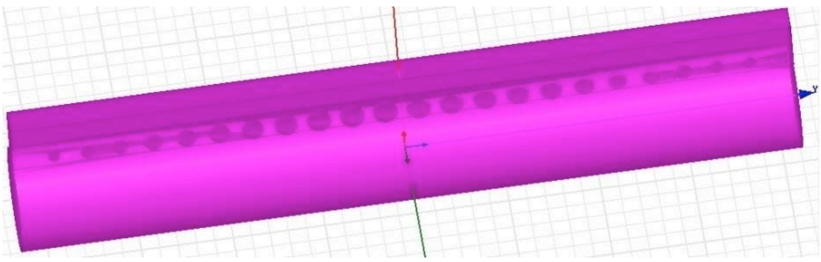


**Fig. 11 - 3D layout of one coupling branch of a linear/circular $TE_{21}$ tracking coupler**

The $TE_{11}$ mode propagates through the main circular waveguide, while $TE_{21}$ mode gets coupled, through a properly designed holes array, into the rectangular waveguide branch, thus feeding the branching network to which it is connected.

Below, front and side views of the 3D layouts of an entire linear/circular pol. $TE_{21}$ tracking coupler are shown. All eight $TE_{21}$ waveguide coupling branches, with coaxial outputs, along with coupling holes array and are visible.

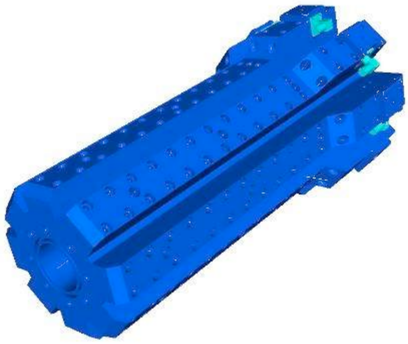


**Fig. 12 - 3D layout of an entire linear/circular pol. $TE_{21}$ tracking coupler**

**(side view)**

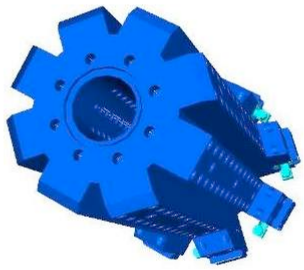
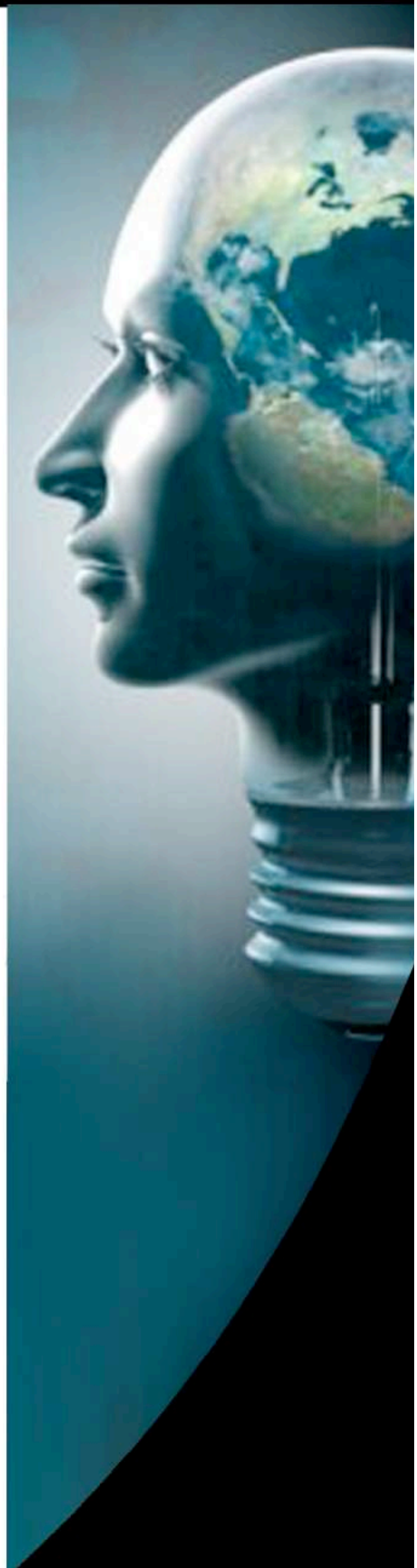


**Fig. 13 - 3D layout of an entire linear/circular pol. TE21 tracking coupler**

**(front view)**

Just as an example of one of our tracking coupler applications, a Ku-band linear/circular polarization $TE_{21}$ tracking coupler along with the entire branching network is shown below. The combining network of the eight coaxial coupler outputs, the hybrid 3dB 90°, the coaxial switch for the selection of one of two tracking outputs (according the polarization of the signal to be tracked) and the tracking LNA are visible.



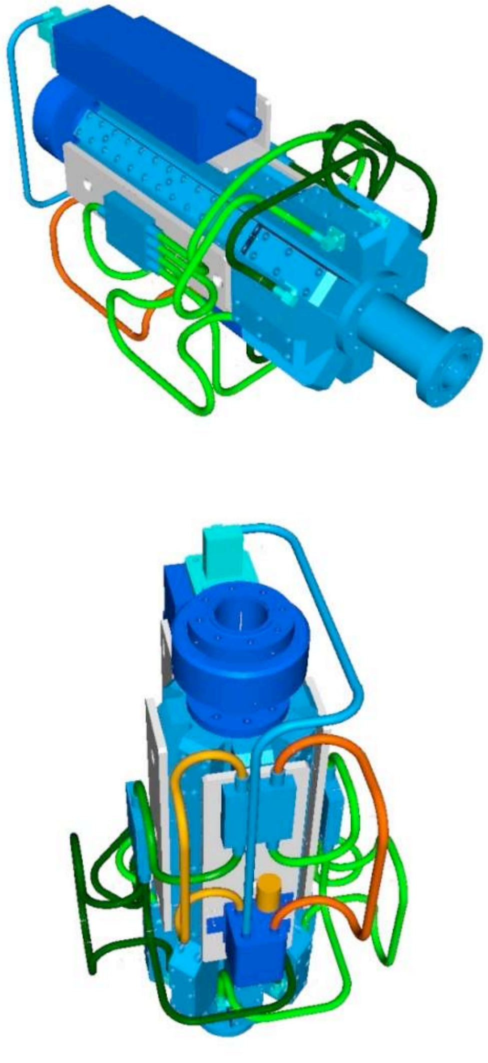
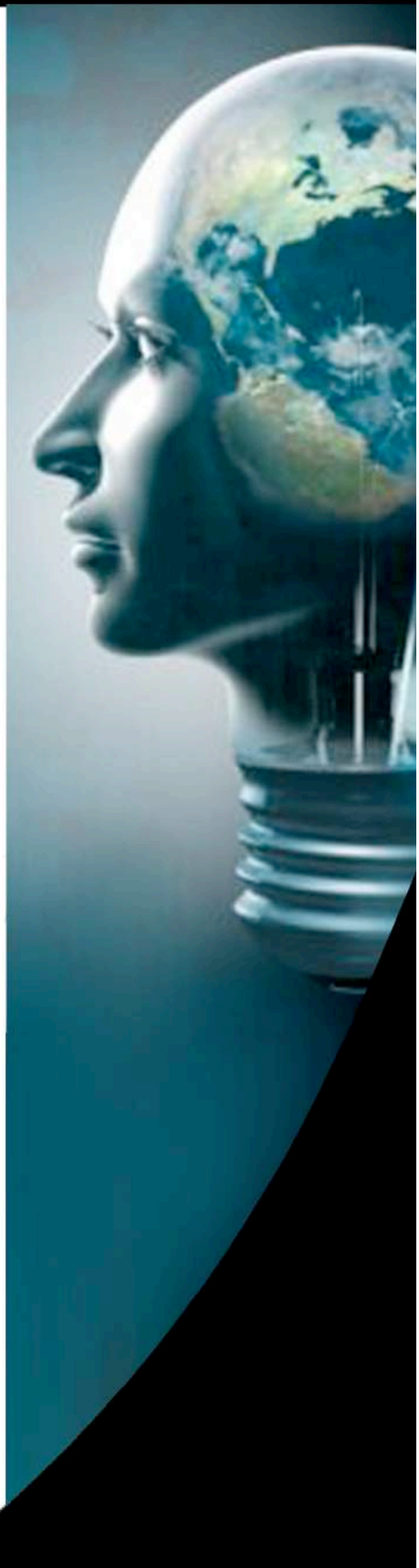


**Fig. 14 - 3D layout of a Ku-band linear/circular polarization $TE_{21}$ tracking system**



A manufactured Ku-band linear/circular pol. $TE_{21}$ tracking coupler is shown below. This coupler architecture has been used, for example, in a 9.3mt Ku-band antenna for GEO satellites tracking (data acquisition and LEOP applications), among others.

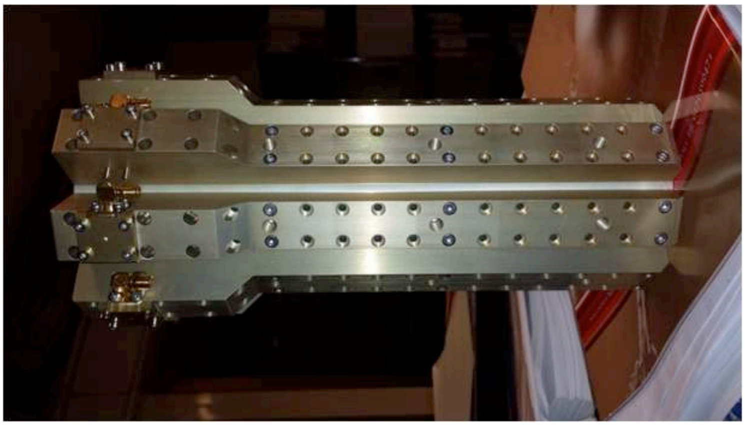


**Fig. 15 - Manufactured Ku-band linear/circular pol. $TE_{21}$ tracking coupler**

A measured tracking pattern of the Ku-band linear/circular pol. $TE_{21}$ tracking coupler is shown below. The tracking null and its depth are well visible.

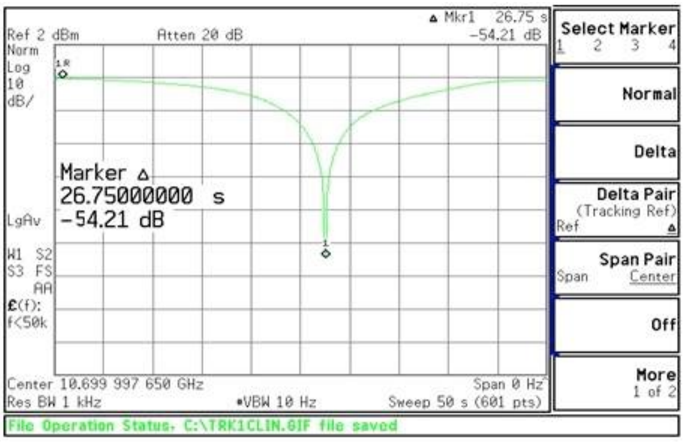



**Fig. 16 - Measured tracking pattern of the Ku-band linear/circular $TE_{21}$ tracking coupler**

**The 3D layout of a complete feed assembly, which the above described Ku-band linear/circular pol. tracking system was part of, is shown below.**

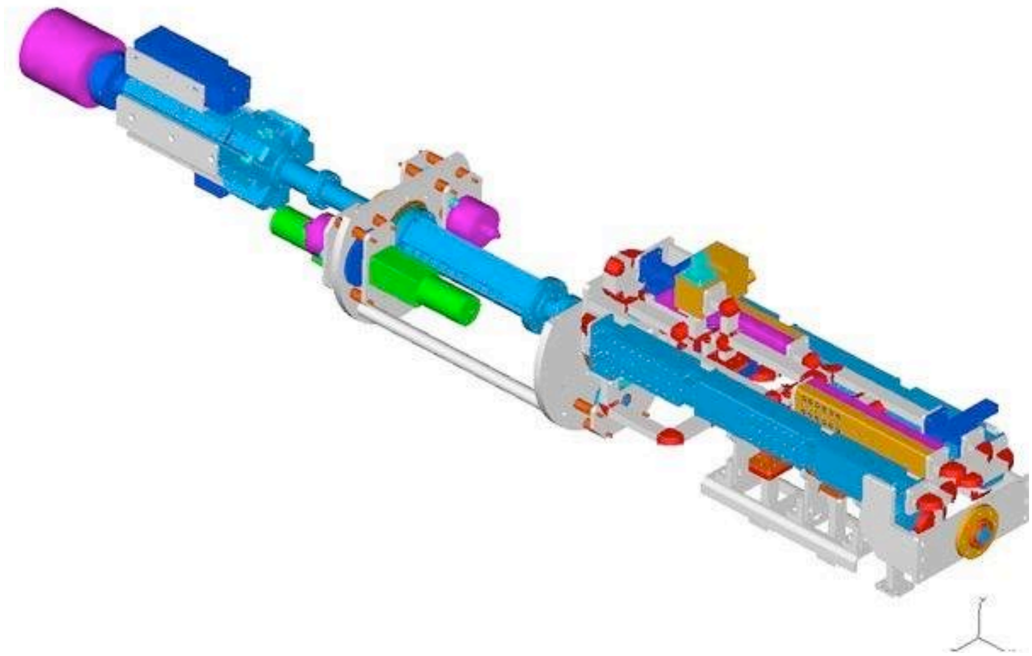


**Fig. 17 - 3D layout of a complete feed assembly which includes the above described Ku-band linear/circular pol. tracking system**

Following pictures shows an example of another $TE_{21}$ tracking coupler architecture of ours, i.e. a X-band circular polarization $TE_{21}$ tracking coupler. This coupler architecture has been used, for example, in a 10mt X-band antenna for LEO satellites tracking (remote sensing, data acquisition and LEOP applications), among others. The system provides quadrature azimuth and elevation error signals at its tracking output port. The same output port can be used to track LHCP and RHCP signals.

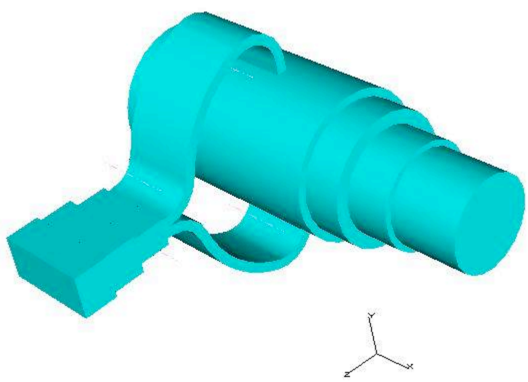


**Fig. 18 - 3D layout of a X-band circular polarization $TE_{21}$ tracking coupler**

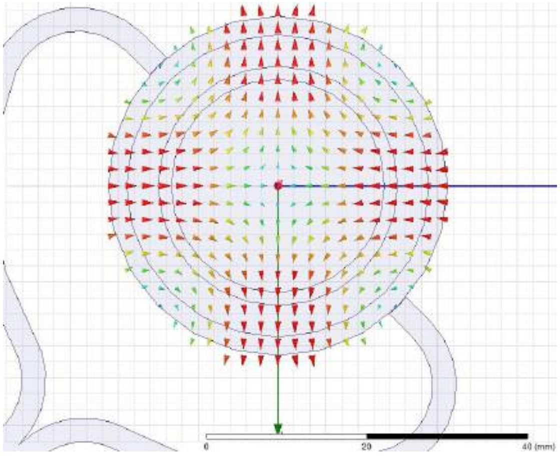


**Fig. 19 - $TE_{21}$ mode excited inside the X-band circular polarization $TE_{21}$ tracking coupler**

A measured tracking pattern of the X-band circular pol. $TE_{21}$ tracking coupler is shown below. The tracking null and its depth are well visible.

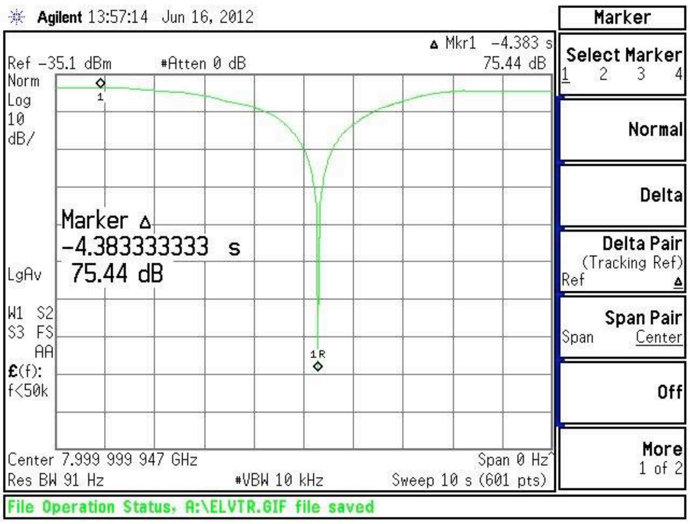



**Fig. 20 - Measured tracking pattern of the X-band circular pol. $TE_{21}$ tracking coupler**

The 3D layout of a complete feed assembly, which the above described X-band circular pol. tracking system was part of, is shown below.

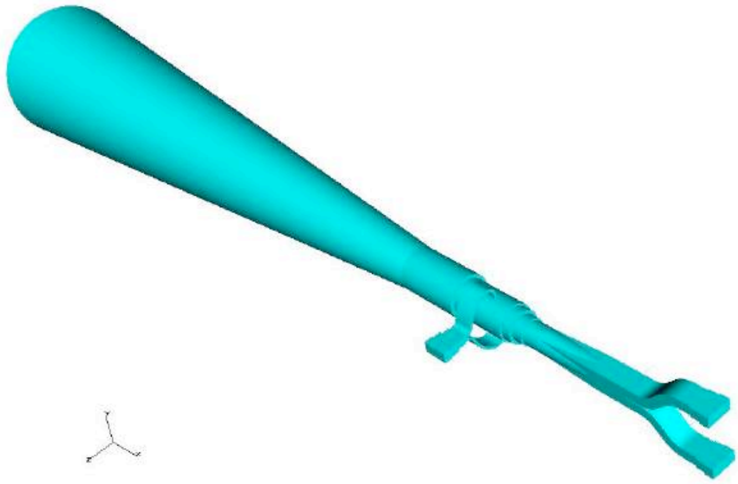


**Fig. 21 - 3D layout of a complete feed assembly which includes the above described X-band circular pol. tracking system**

The quadrature error signal, along with the “sum” signal ($TE_{11}$ mode), provided by the system can be used, after proper frequency downconversion, e.g. using a 2-channel tracking downconverter, to feed the “sum” and “delta” channels of a monopulse tracking receiver, which performs discrimination between azimuth ($\varepsilon_{AZ}$) and elevation ($\varepsilon_{EL}$) error signals.

Several tracking architectures can be provided, for different frequency bands, as well as multi-band solutions, e.g. X/Ka, etc.