THE KAROO ARRAY TELESCOPE (KAT)

&

FPA EFFORT IN SOUTH AFRICA

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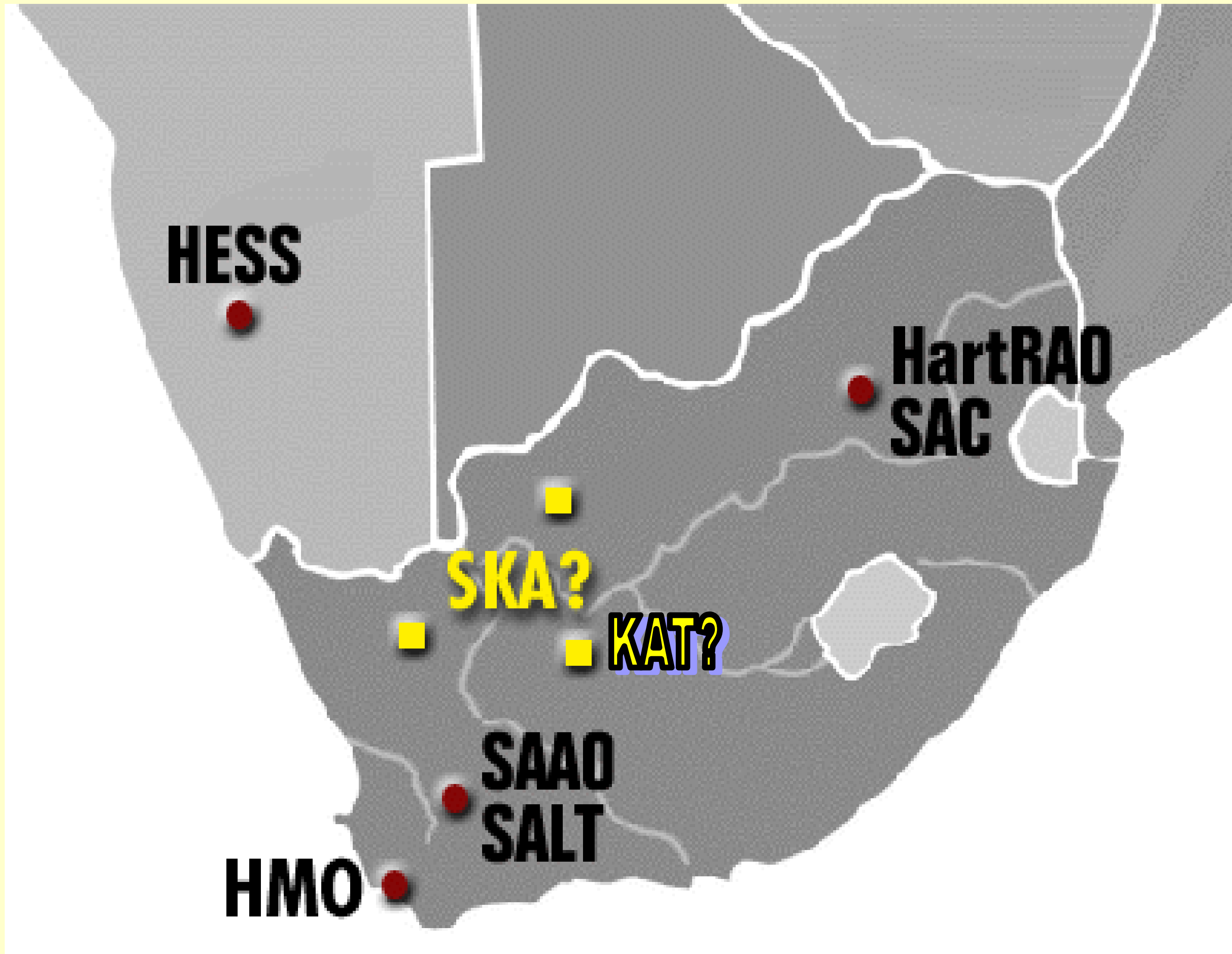
OUTLINE

- THE KAROO ARRAY TELESCOPE (KAT)
- ANALYSIS TOOLS AND APPROACH
- CONJUGATE FEED MATCHING AND EFFICIENCY
- FOCAL FIELDS FOR VARIOUS REFLECTORS
- 4 X 3 VIVALDI ARRAY
- REQUIREMENTS FOR ANTENNA STRUCTURE
- HIGH LEVEL FUTURE PLANS FOR KAT

SOUTHERN AFRICAN OBSERVATORIES



KAROO?


NOORDWESTER

NOORDWESTER
Oewernuus
MESSENGER

R3,00

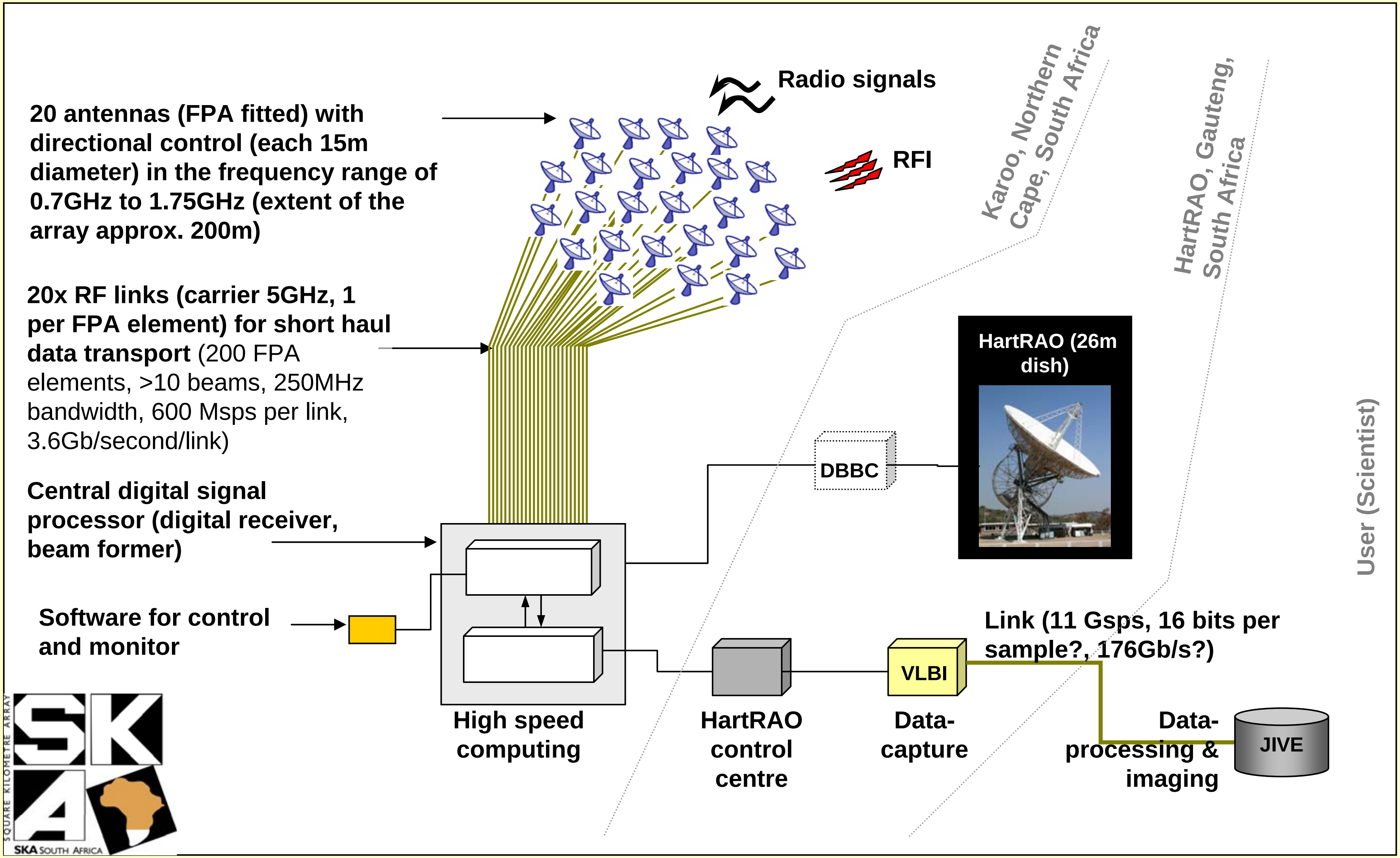
Burgemeester moes skuiling soek

Dis gevaarlik in hierdie laan

WHAT WILL KAT BE?

- A technology demonstrator
  - Developing technologies expected to be on the critical path of SKA
- A working science instrument
  - KAT will become part of the SA science infrastructure

KAROO ARRAY TELESCOPE



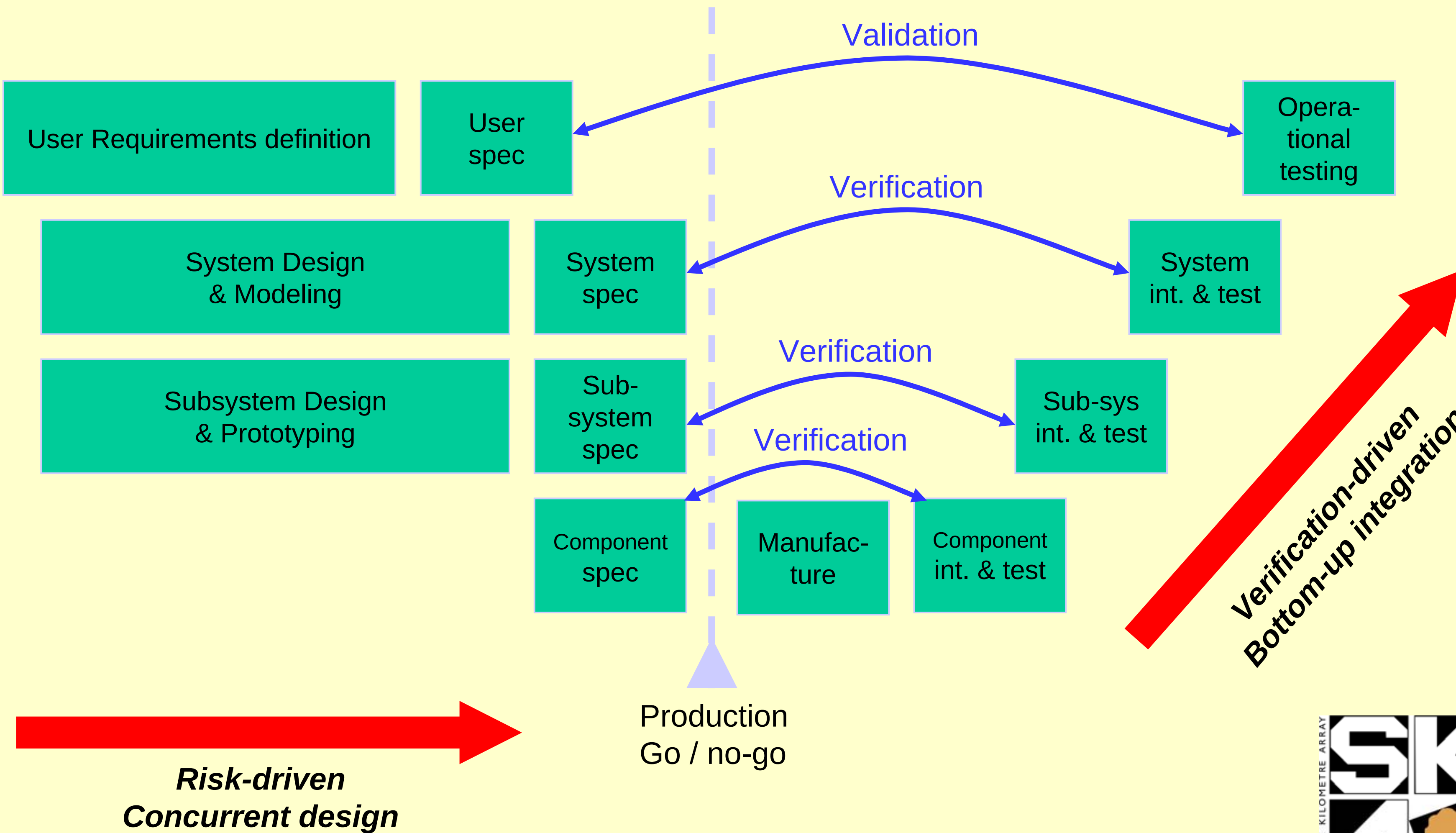
KAROO ARRAY TELESCOPE

- **Array of 20 x 15 m reflecting concentrators each fed with a focal plane array (10 x 10 element).**
- **Operating frequency range: 0.7 GHz – 1.75 GHz.**
- **Dual polarization.**
- **Instantaneous bandwidth: 250 MHz each polarization.**
- **Antenna array baselines: 20 m – 2000 m.**
- **Array resolution: 1’ @ 1420 MHz.**
- **>10 independent beams within 10-deg antenna FoV.**
- **Tsys < 50 K (< 0.5 dB LNA noise figure) .**
- **Fully digital with FPGA+HPC back-end.**
- **Multiple Correlators (imaging).**
- **Located in the Karoo, Northern Cape, South Africa.**
- **Four-year development and construction horizon *(very tight).***

SQUARE KILOMETRE ARRAY

SKA SOUTH AFRICA

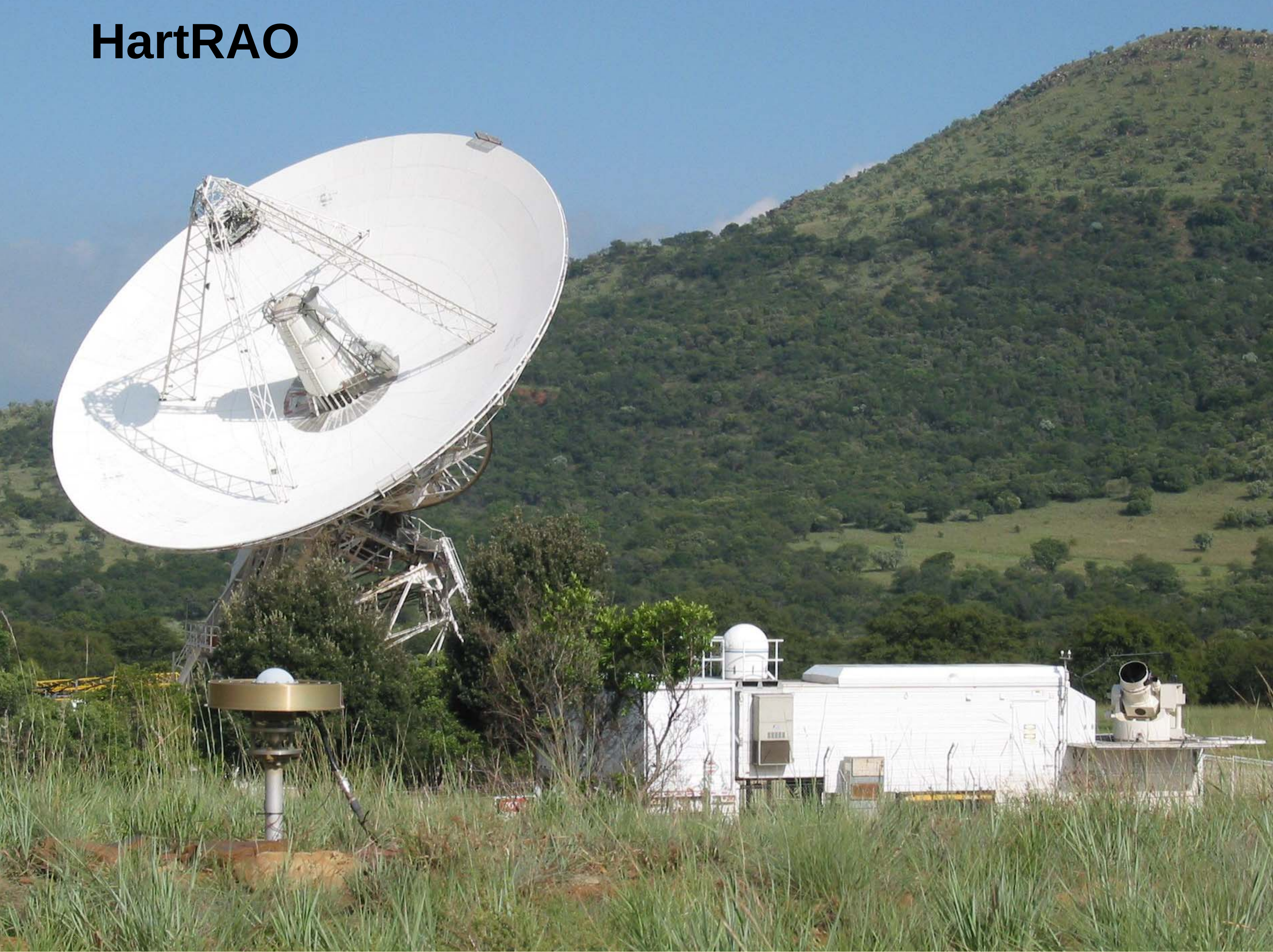
KAT SYSTEMS ENGINEERING APPROACH



KAT ROAD AHEAD

- Team of professional engineers appointed in key positions to implement sub-systems development plans (working with scientist(s)).
- Systems Engineering approach with tight project management - key milestones and go/no-go decision points.
- Simulation at all levels of all subsystems.
- Digital receiver developed for HartRAO 26-m 18cm signal path.
- Prototype 15-m dish constructed at HartRAO.
- Evolutionary digital focal plane array developed for HartRAO.
- Single baseline correlator at HartRAO.
- Growth of the Research and Technology Collaboration Centre (RTCC). Strong capacity building component to all work.
- Formalization of industrial and international partnerships.
- Roll-out of KAT at chosen site.

HartRAO



KAT FPA and DISH

ANALYSIS TOOLS AND APPROACH

FOCAL FIELDS

FEKO (FEldberechnung bei Körpern mit beliebiger Oberfläche) is a 3D full wave simulator, able to analyze small antennas with MoM and larger structures with either PO or UTD.   feko@emss.co.za / www.feko.info

**SolidWorks is a full 3D mechanical design program used extensively in the industry to do mechanical designs in all fields of engineering.
www.solidworks.com**

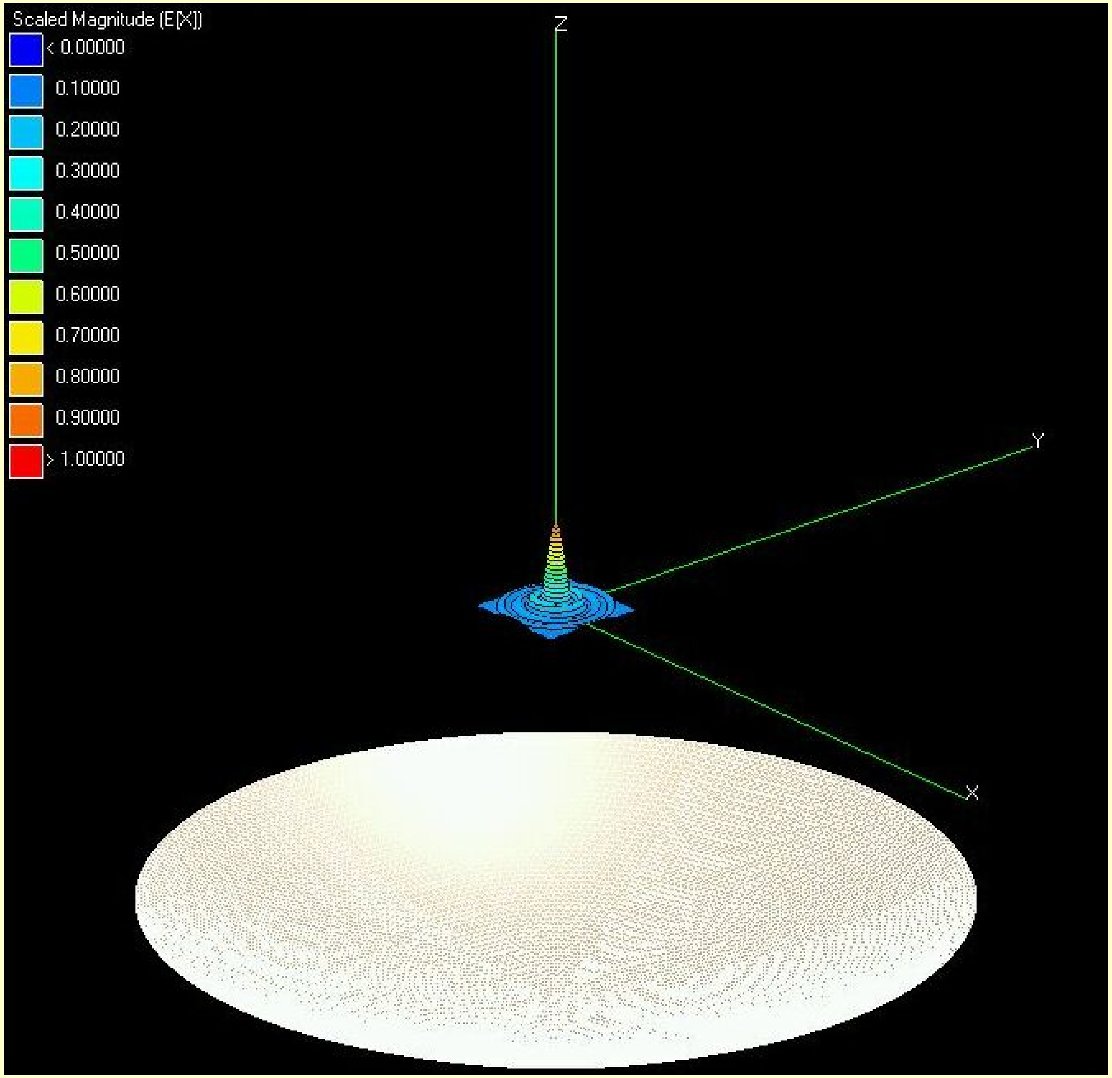
FEMAP is a program normally used to analyze mechanical structures. FEKO uses the meshing of FEMAP to input any structure from SolidWorks into the antenna analysis.   www.femap.com

VIVALDIS

IE3D is a full-wave, method-of-moments based electromagnetic simulator solving the current distribution on 3D and multilayer structures of general shape. www.zeland.com

APPROACH

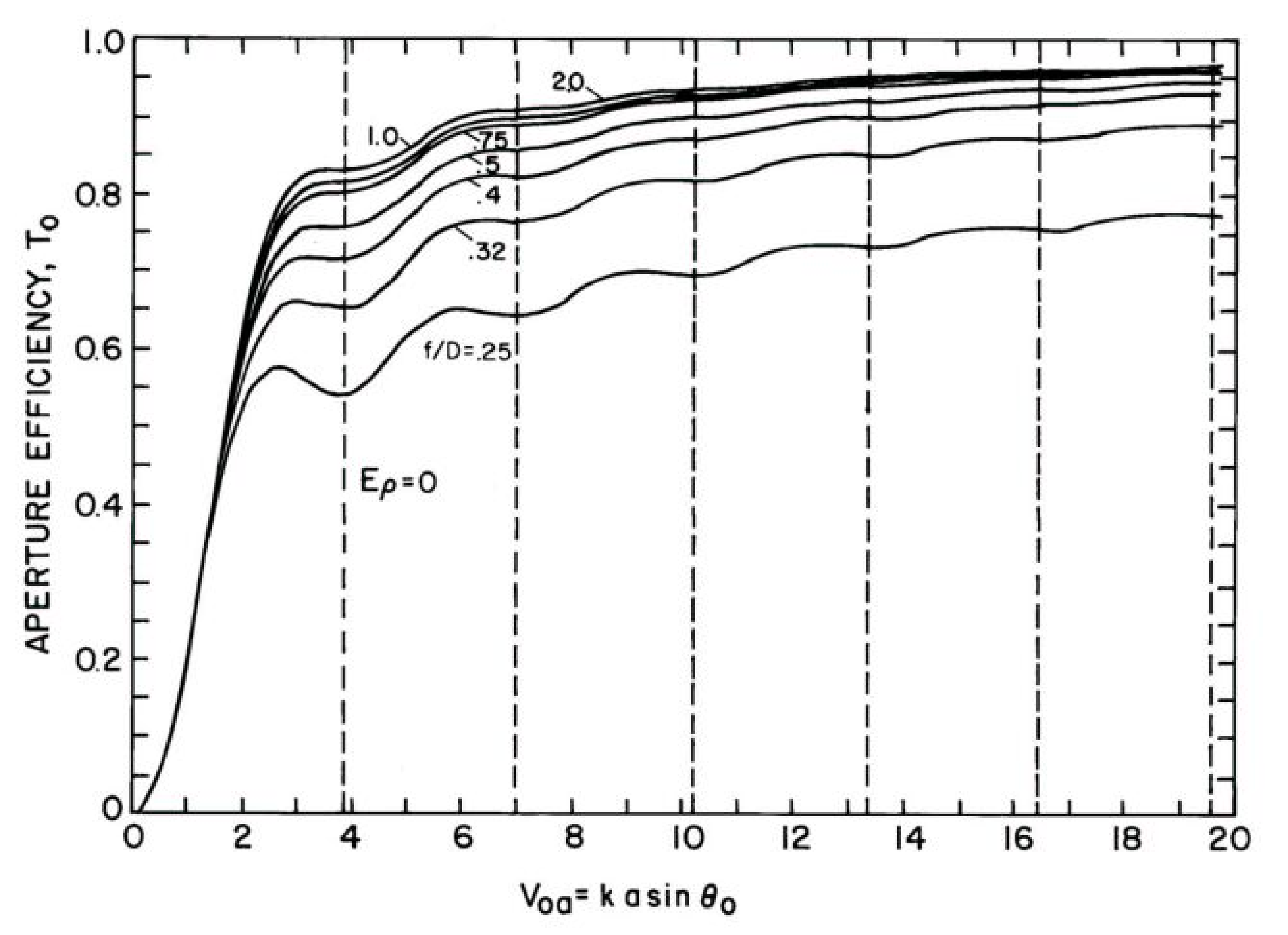
- **For dish use FEKO/FEMAP/SOLIDWORKS to analyze focal fields.**
- **Conjugate matching.**
- **In-house software for mutual coupling.**
- **Results presented are a summary of a project which has been running for only three months.**



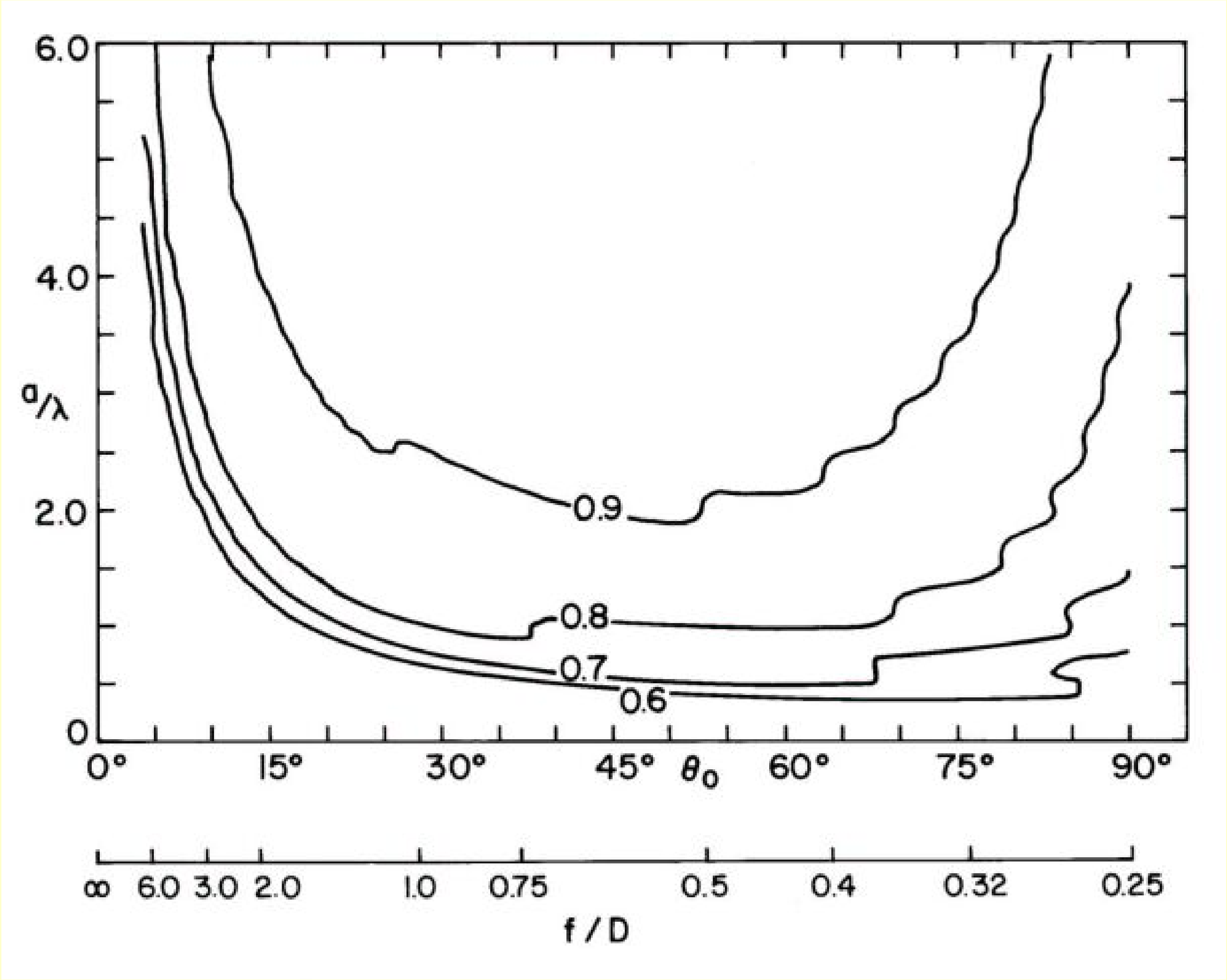
FEKO BASIC GEOMETRY FOR REFLECTOR,
WITH 3D PRESENTATION OF FOCAL REGION FIELD STRENGTH.

CONJUGATE FEED MATCHING AND EFFICIENCY

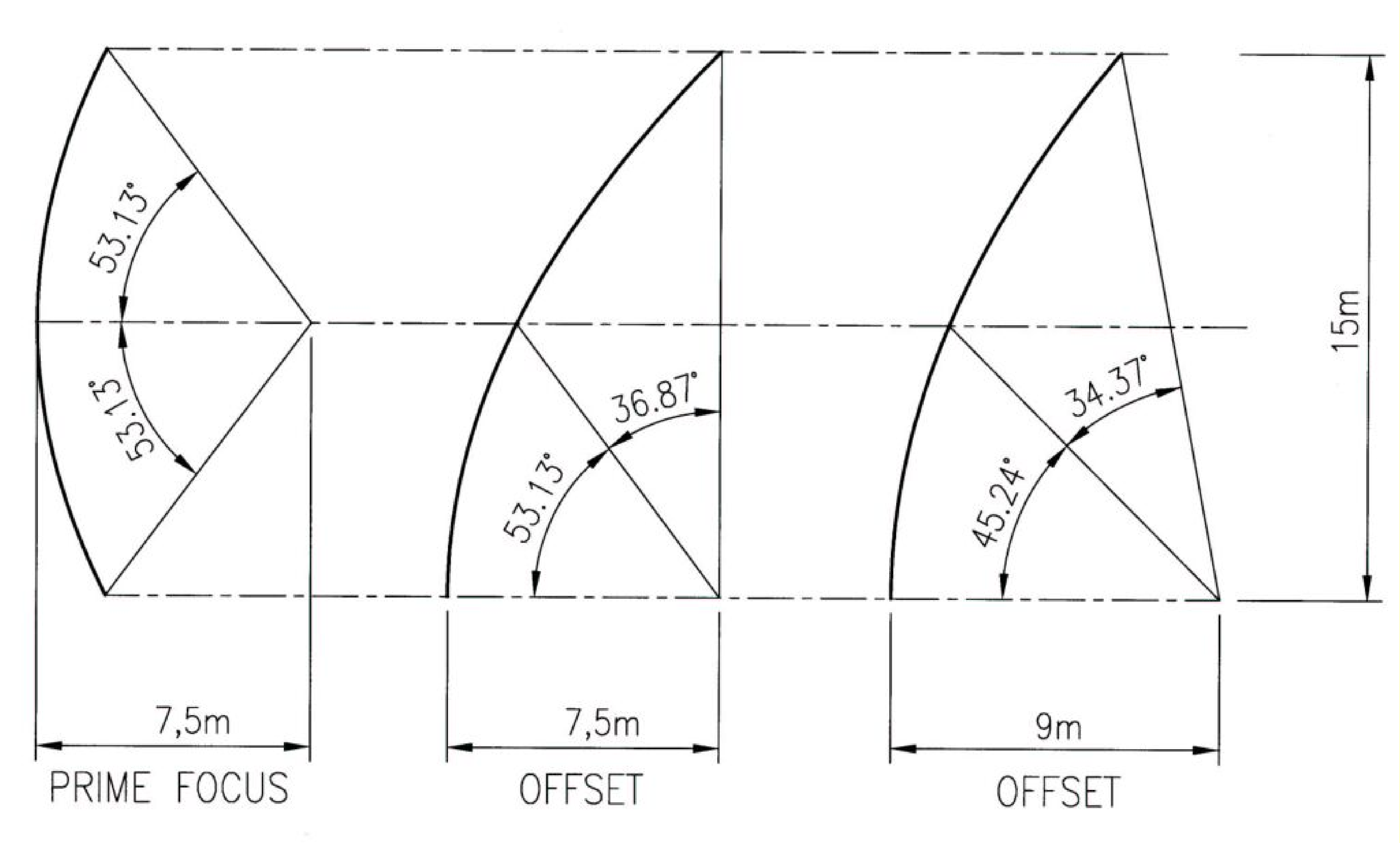
- Compute focal fields (E, H), hence Poynting vector.
- Use Robieux's theorem for conjugate match of incident focal fields with the transmit fields of the feed for maximum power transfer.
- Integrating the focal fields over an ideal feed of radius a gives the power extracted from the focal fields. By dividing by the total power incident on the reflector get the efficiency.
- By plotting the computed efficiencies with a normalised radius, the efficiencies for all f/D can be displayed on one graph.
- From this deduce radius of feed for achieving optimum efficiency.
- There is a minimum radius for various efficiencies in the 0.4 to 0.6 f/D range.
- Since have choice of f/D, examined f/D = 0.5



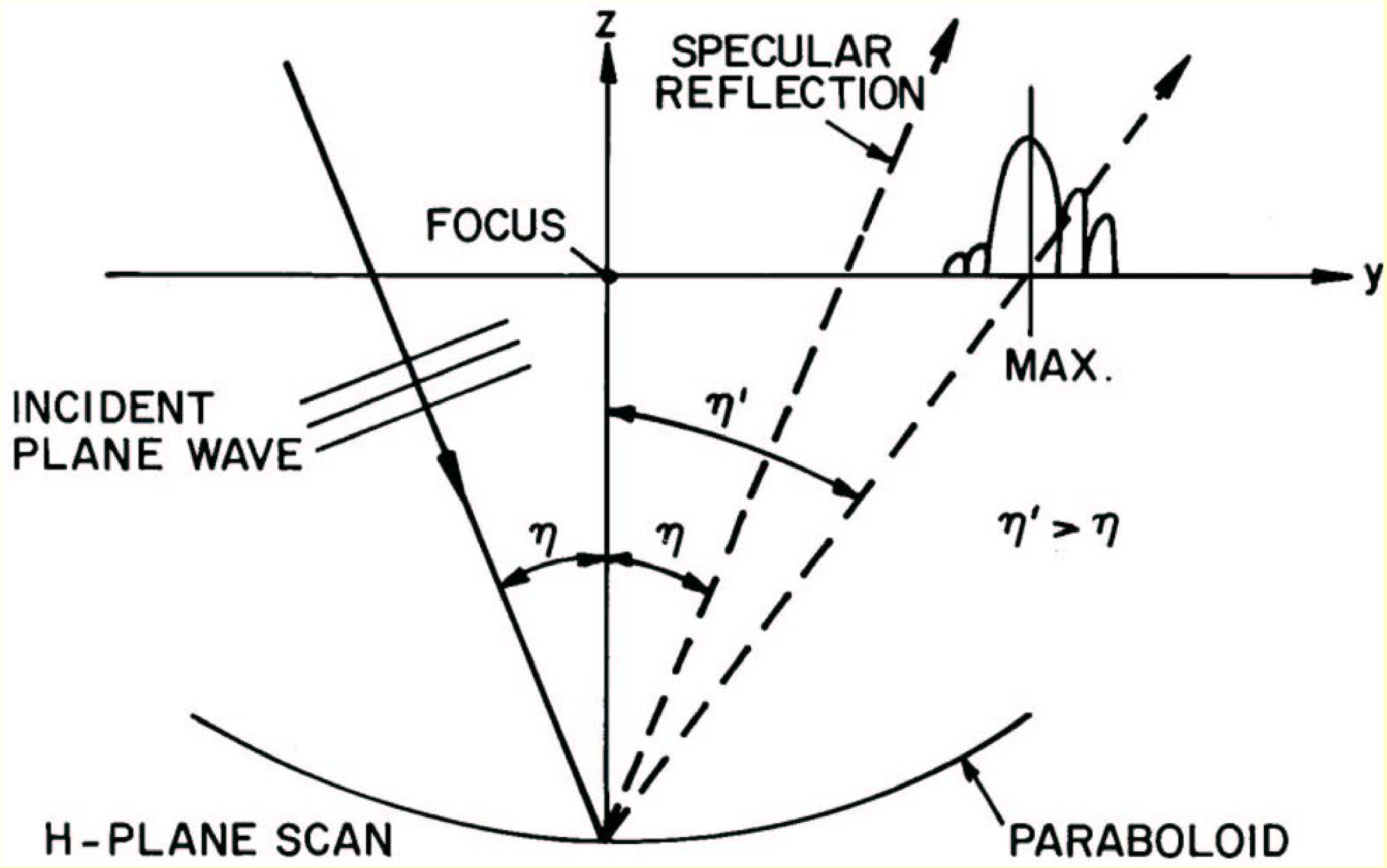
MAXIMUM EFFICIENCY OF IDEAL CONJUGATE MATCHED FEED



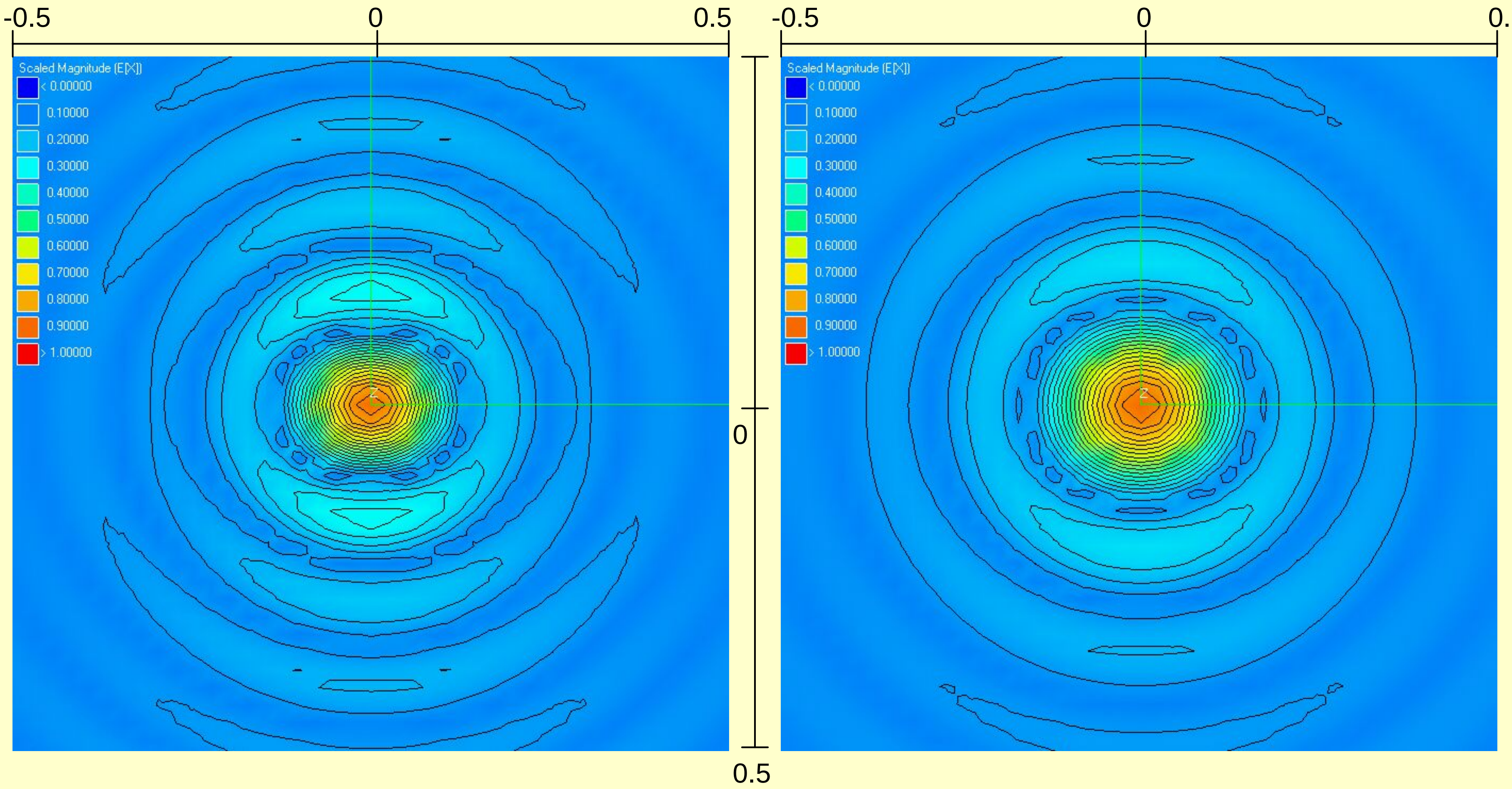
EQUAL EFFICIENCY CONTOURS FOR IDEAL FEED RADIUS a/λ VS f/D OR HALF ANGLE



GEOMETRY FOR 15 m DIAMETER REFLECTORS



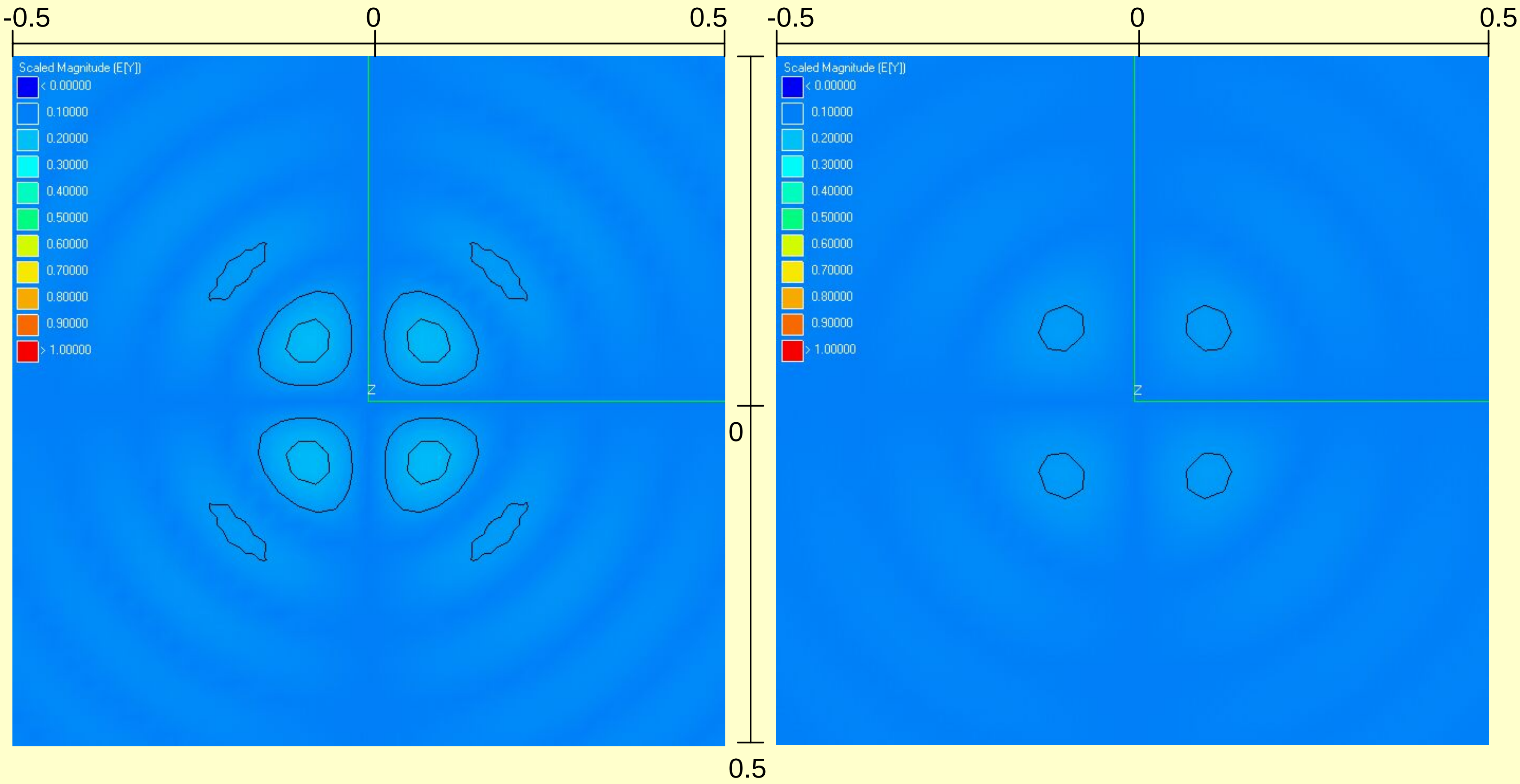
SCANNING GEOMETRY FOR REFLECTOR



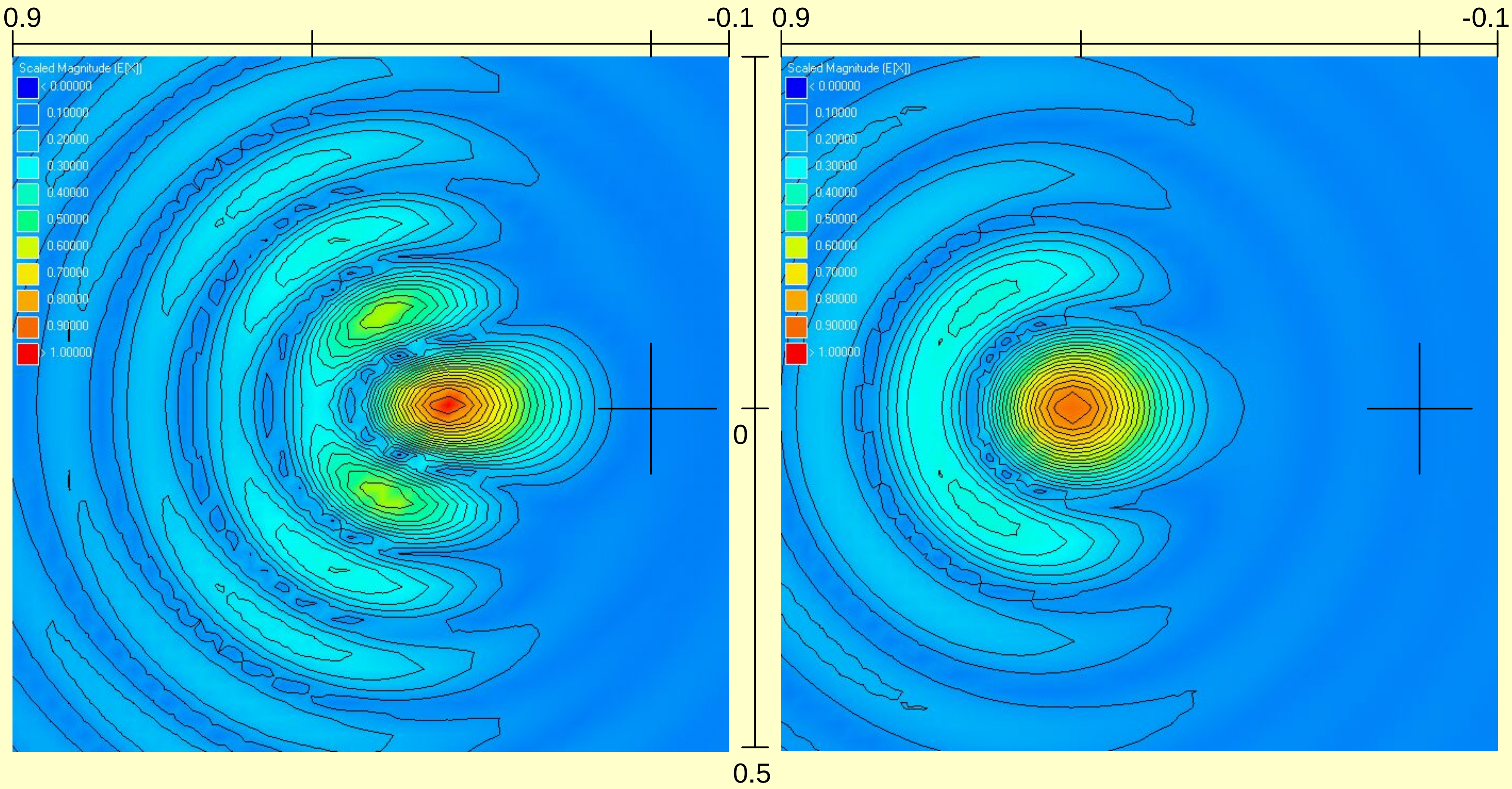
COMPARISON IN FOCAL POINT NEAR FIELD STRENGTH ON A 15m DISH;
F/D = 0.33 (LEFT) AND F/D = 0.5 (RIGHT)

GRINTEK ANTENNAS

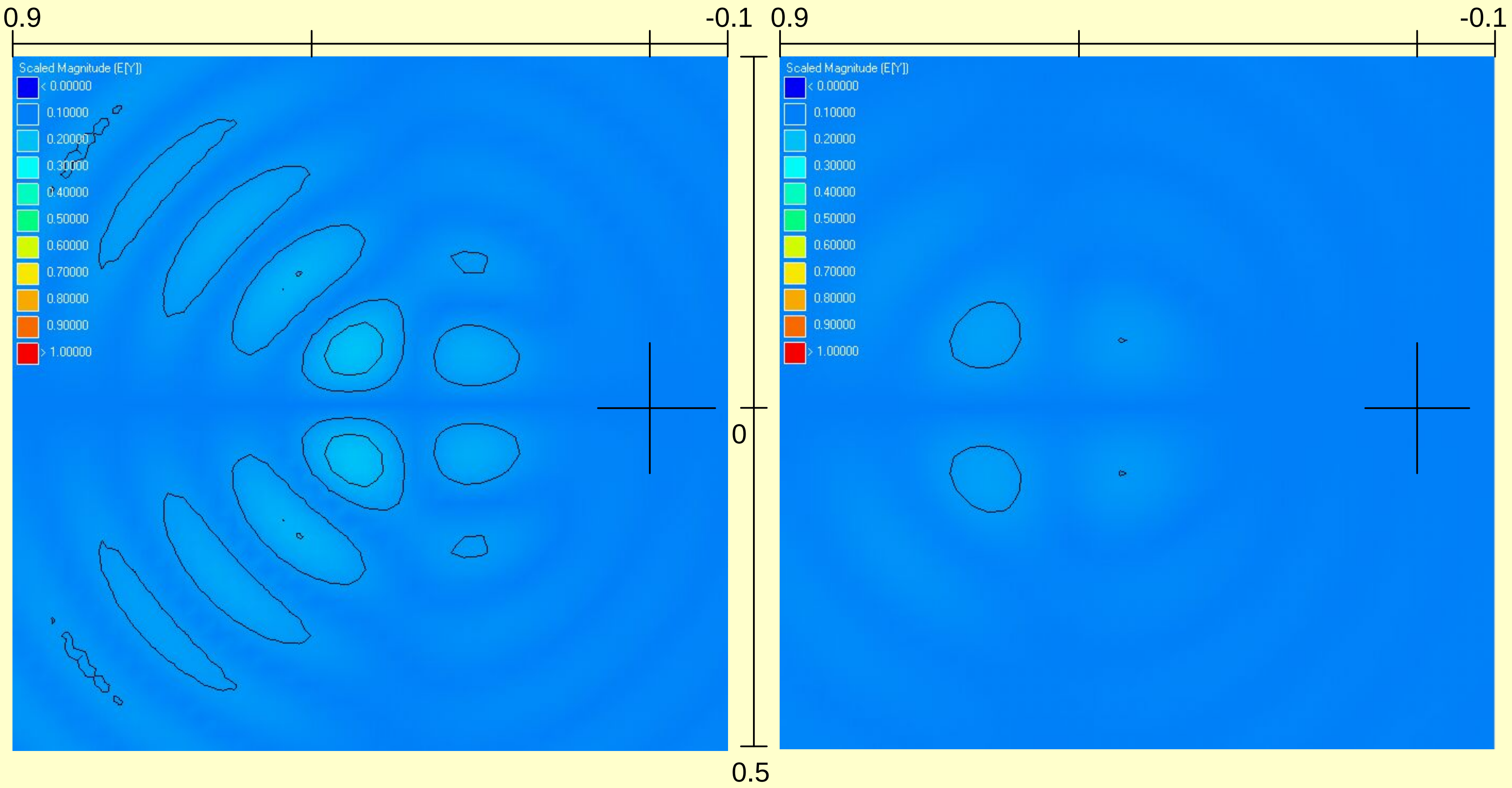
SQUARE KILOMETRE ARRAY SKA SOUTH AFRICA



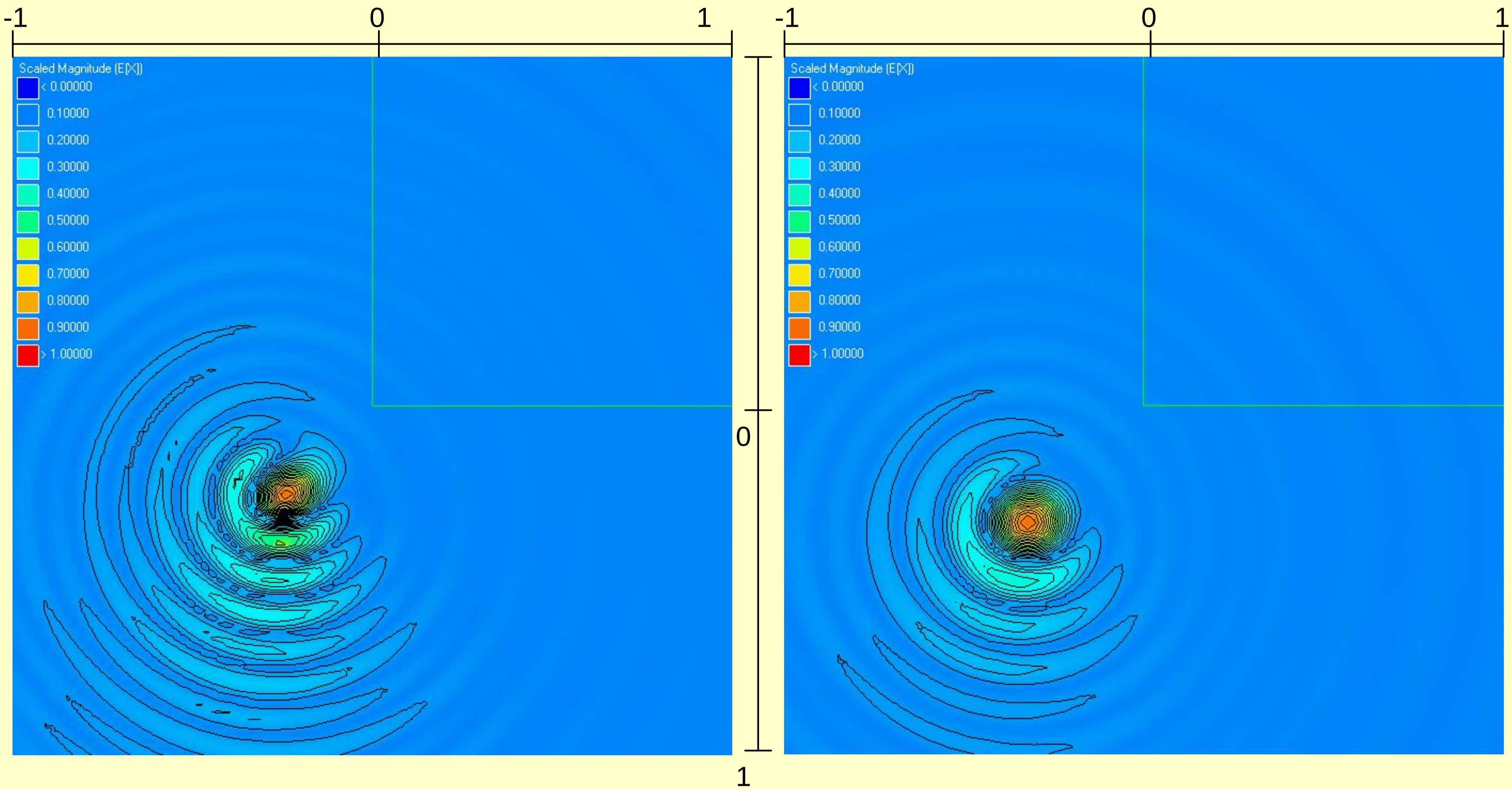
COMPARISON IN X-pol FOCAL POINT NEAR FIELD ON A 15m DISH; F/D = 0.33 (LEFT) AND F/D = 0.5 (RIGHT)



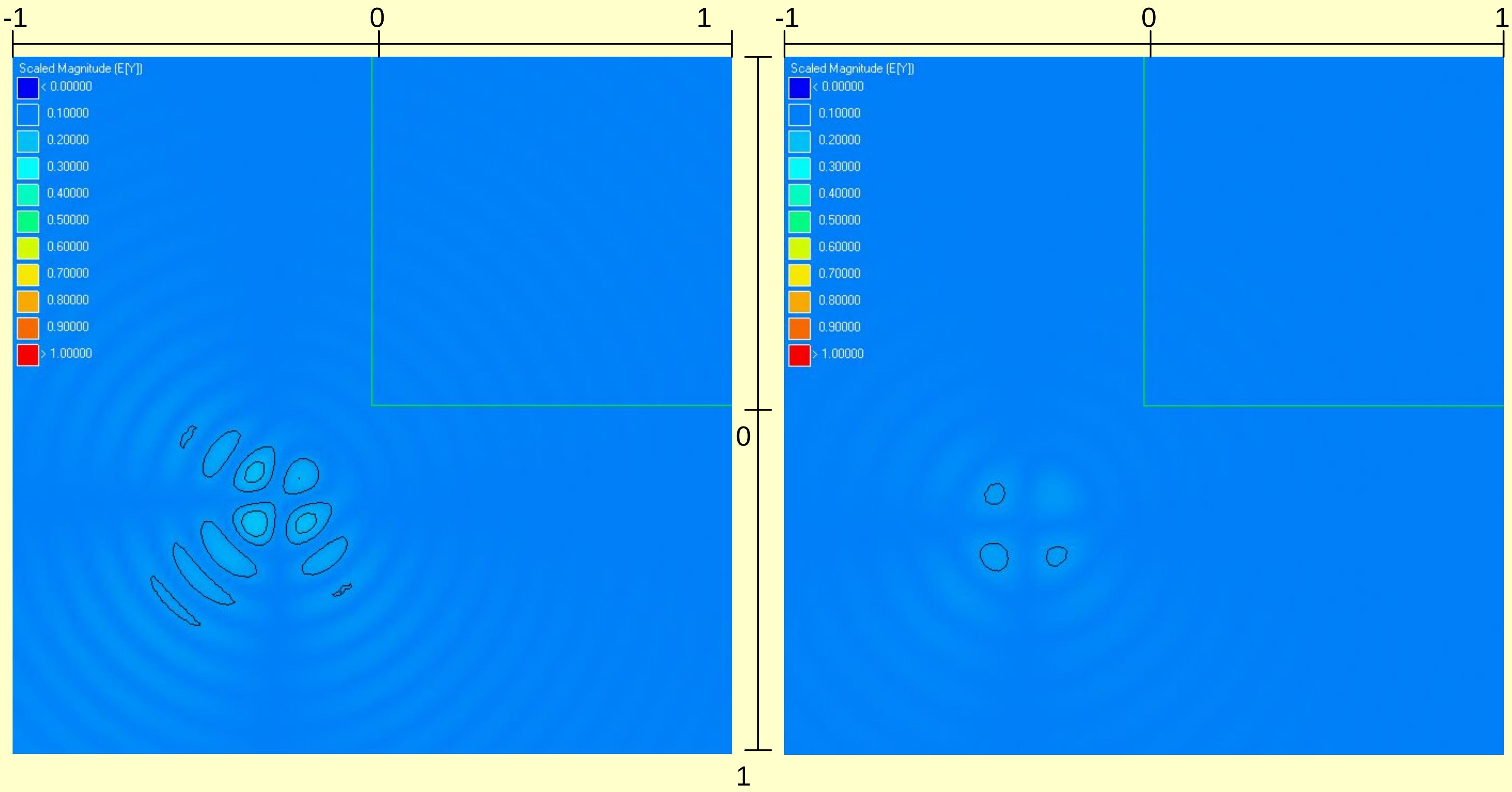
COMPARISON IN FOCAL POINT NEAR FIELD; 4° OFF-AXIS SCANNING ON A 15m DISH; F/D = 0.33 (LEFT) AND F/D = 0.5 (RIGHT)



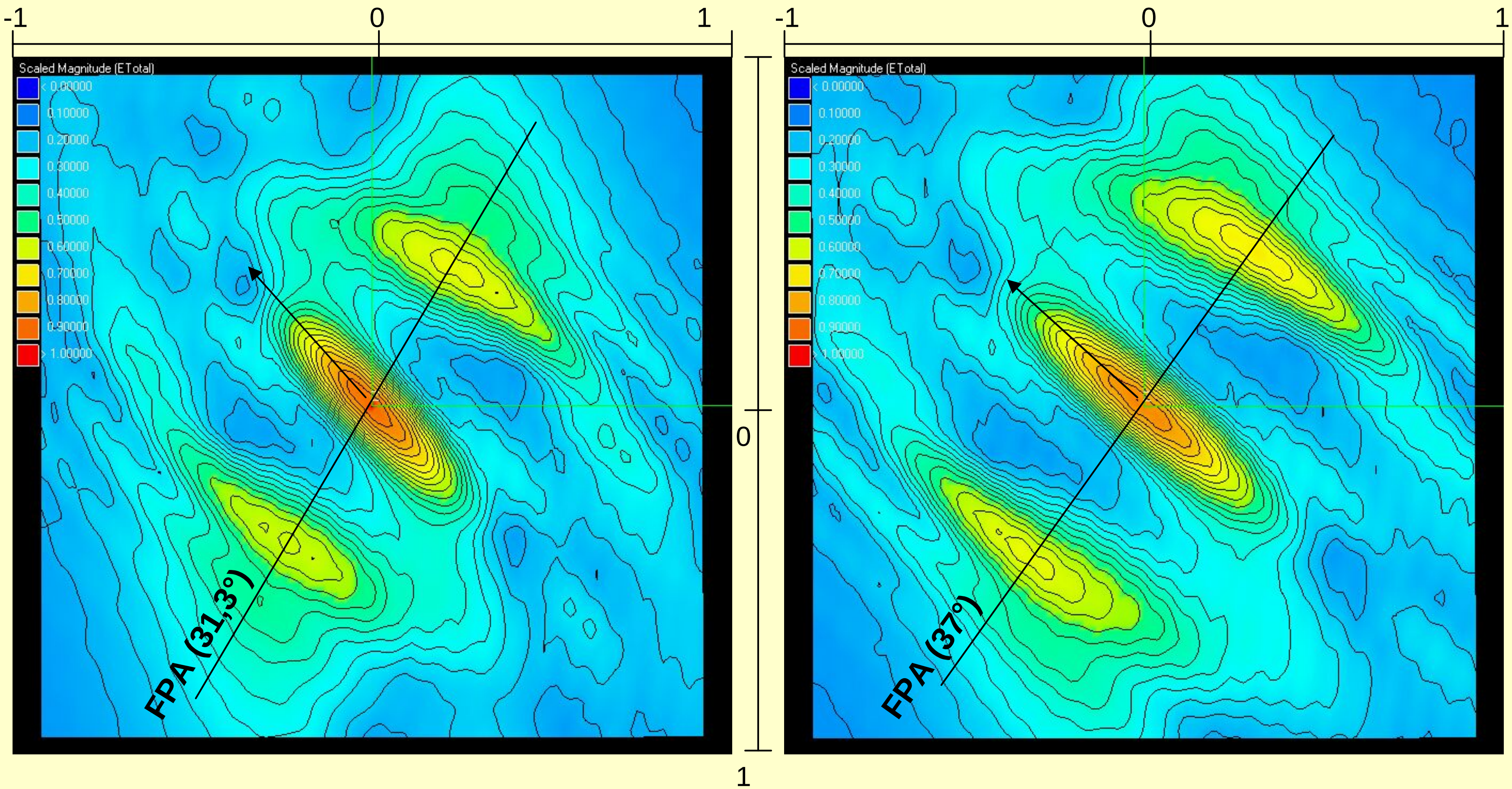
COMPARISON IN X-pol FOCAL POINT NEAR FIELD; 4° OFF-AXIS SCANNING ON A 15m DISH; F/D = 0.33 (LEFT) AND F/D = 0.5 (RIGHT)



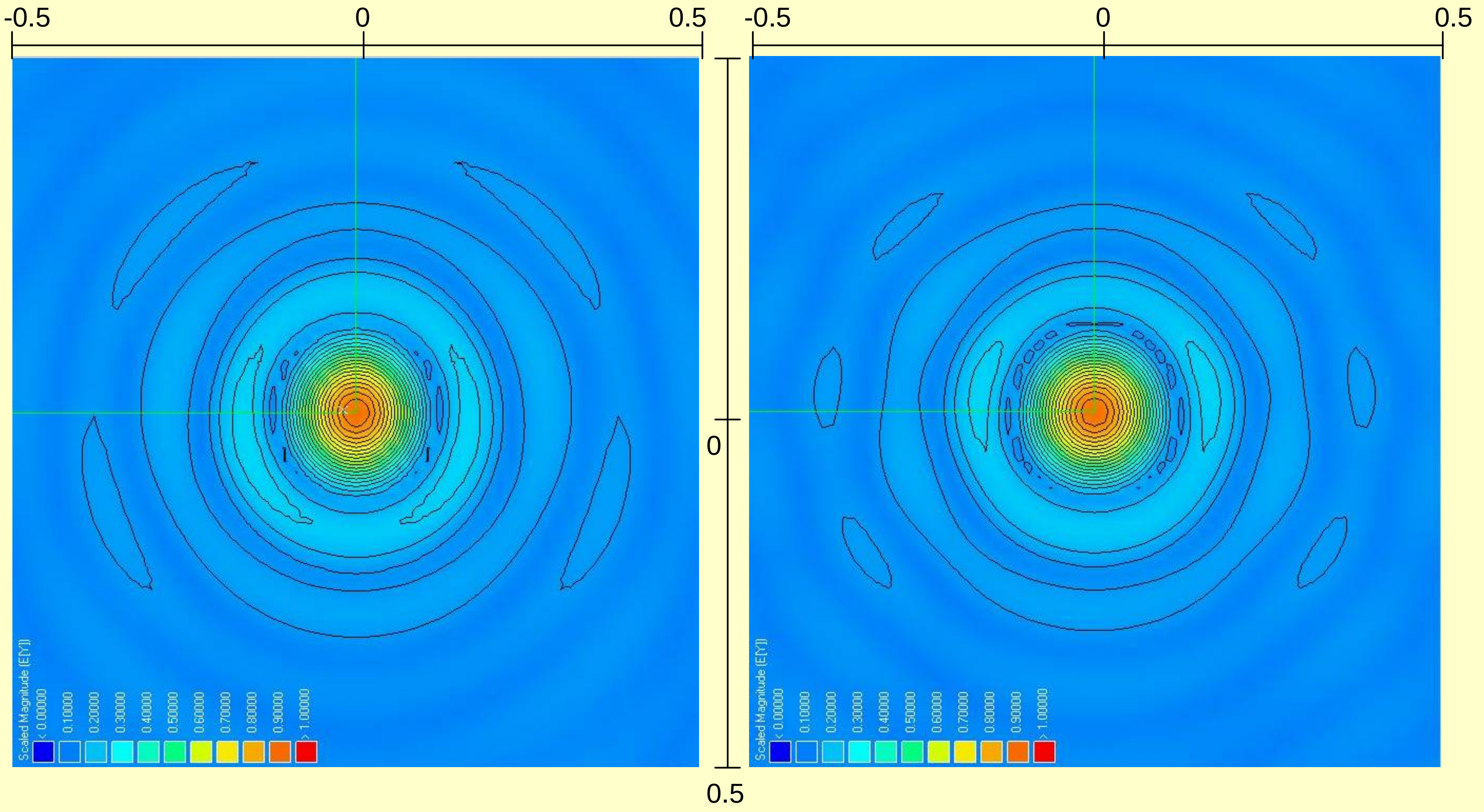
COMPARISON IN FOCAL POINT NEAR FIELD; 3° AT 45° TO PRINCIPAL PLANE ON A 15m DISH; F/D = 0.33 (LEFT) AND F/D = 0.5 (RIGHT)



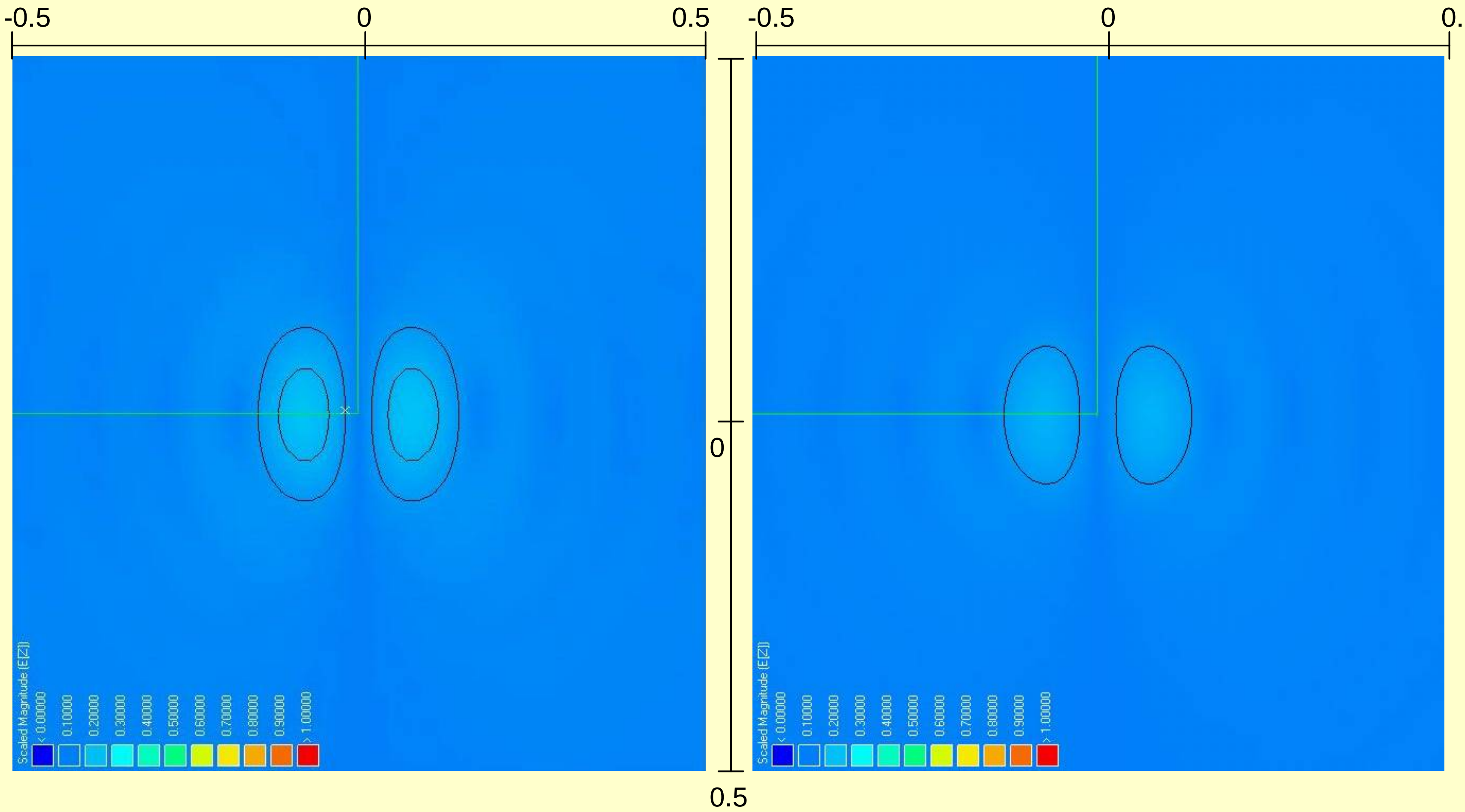
COMPARISON IN X-pol FOCAL POINT NEAR FIELD; 3° OFF-AXIS SCANNING ON A 15m DISH; F/D = 0.33 (LEFT) AND F/D = 0.5 (RIGHT)



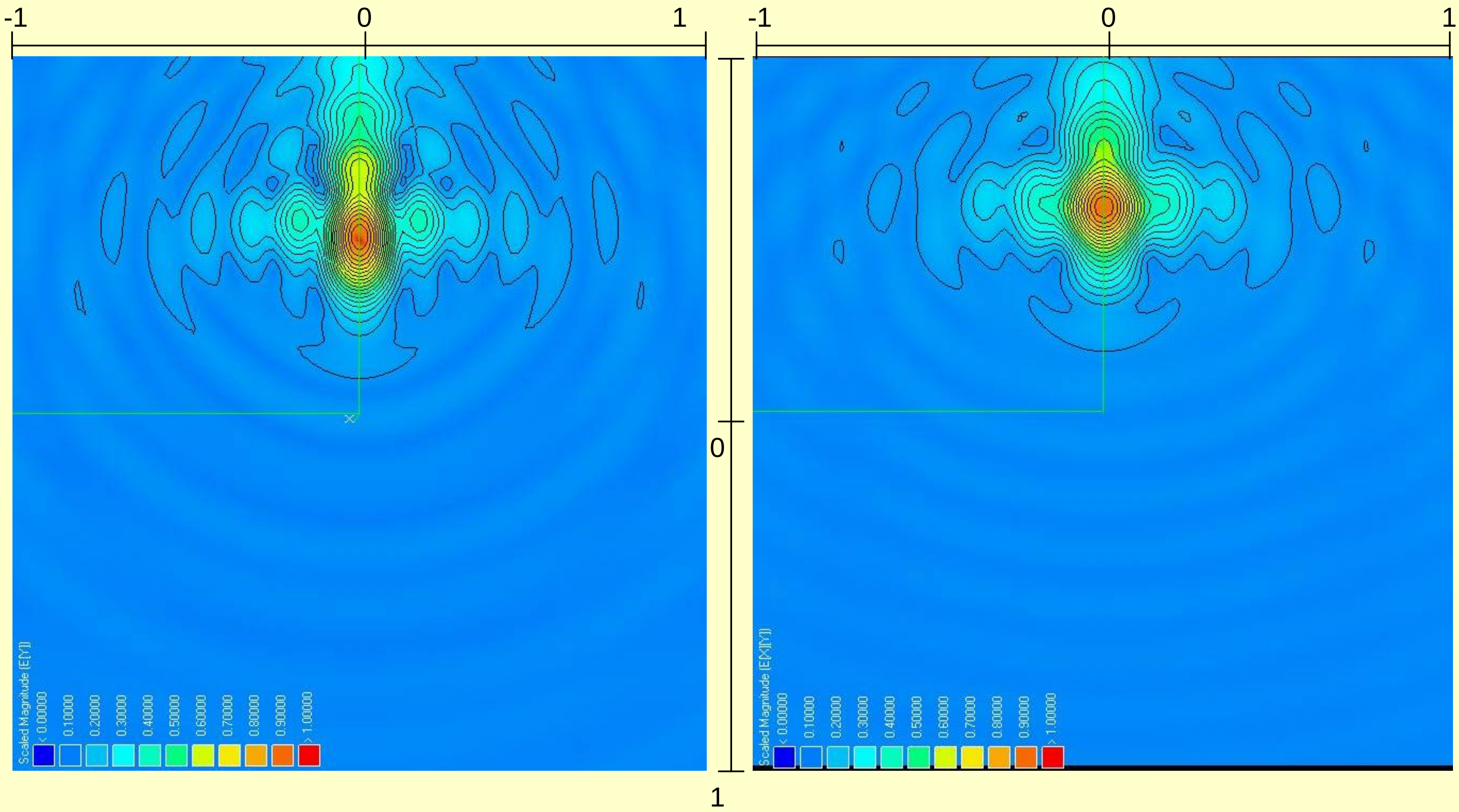
TOTAL E-FIELD STRENGTH AT -3, 0° AND 3° INCOMING WAVE FOR AN OFFSET REFLECTOR WITH FOCAL DISTANCE 7.5m (LEFT) AND 9m (RIGHT).



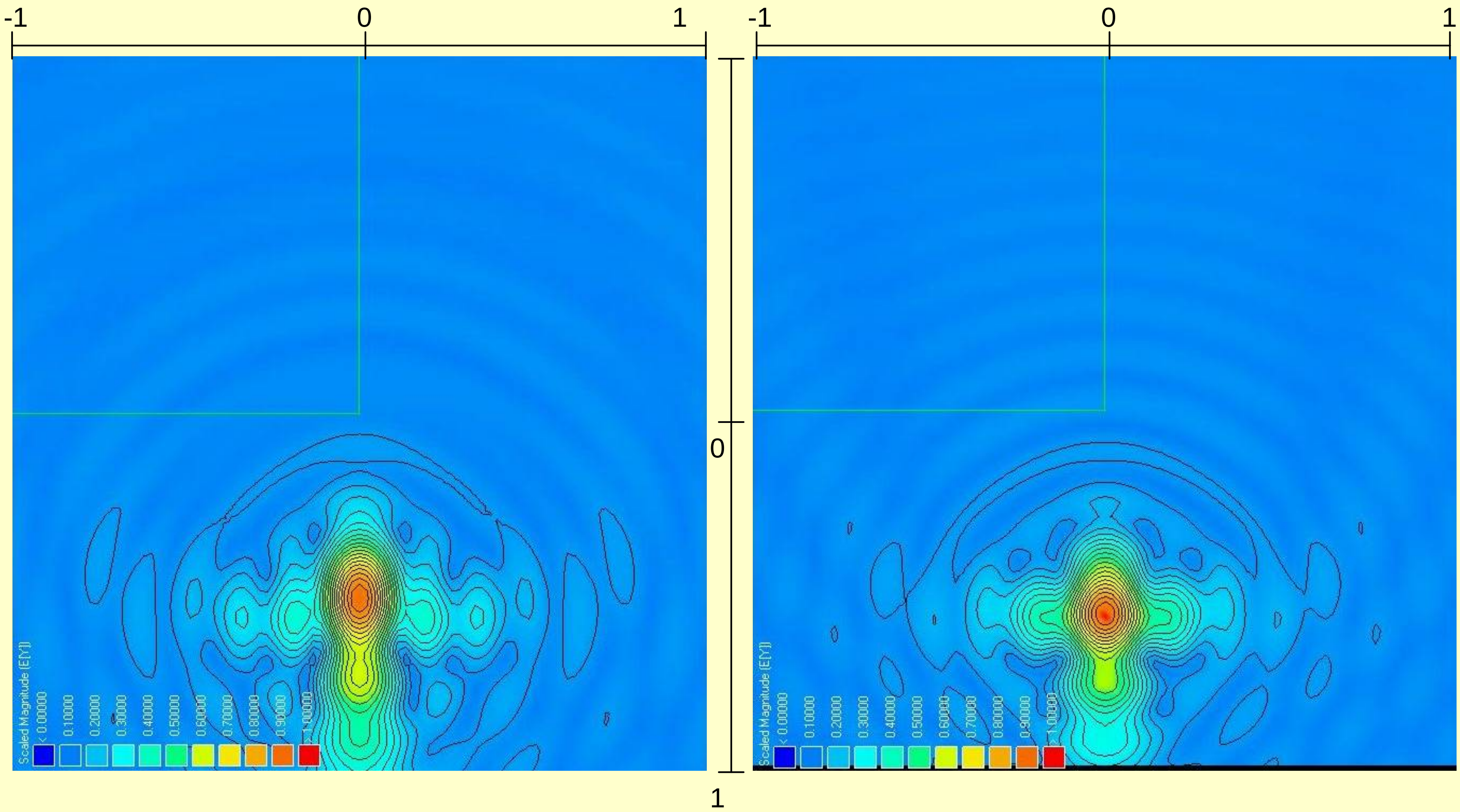
Co-pol E-FIELD STRENGTH AT BORESIGHT INCOMING WAVE FOR AN OFFSET REFLECTOR WITH FOCAL DISTANCE 7.5m (LEFT) AND 9m (RIGHT).



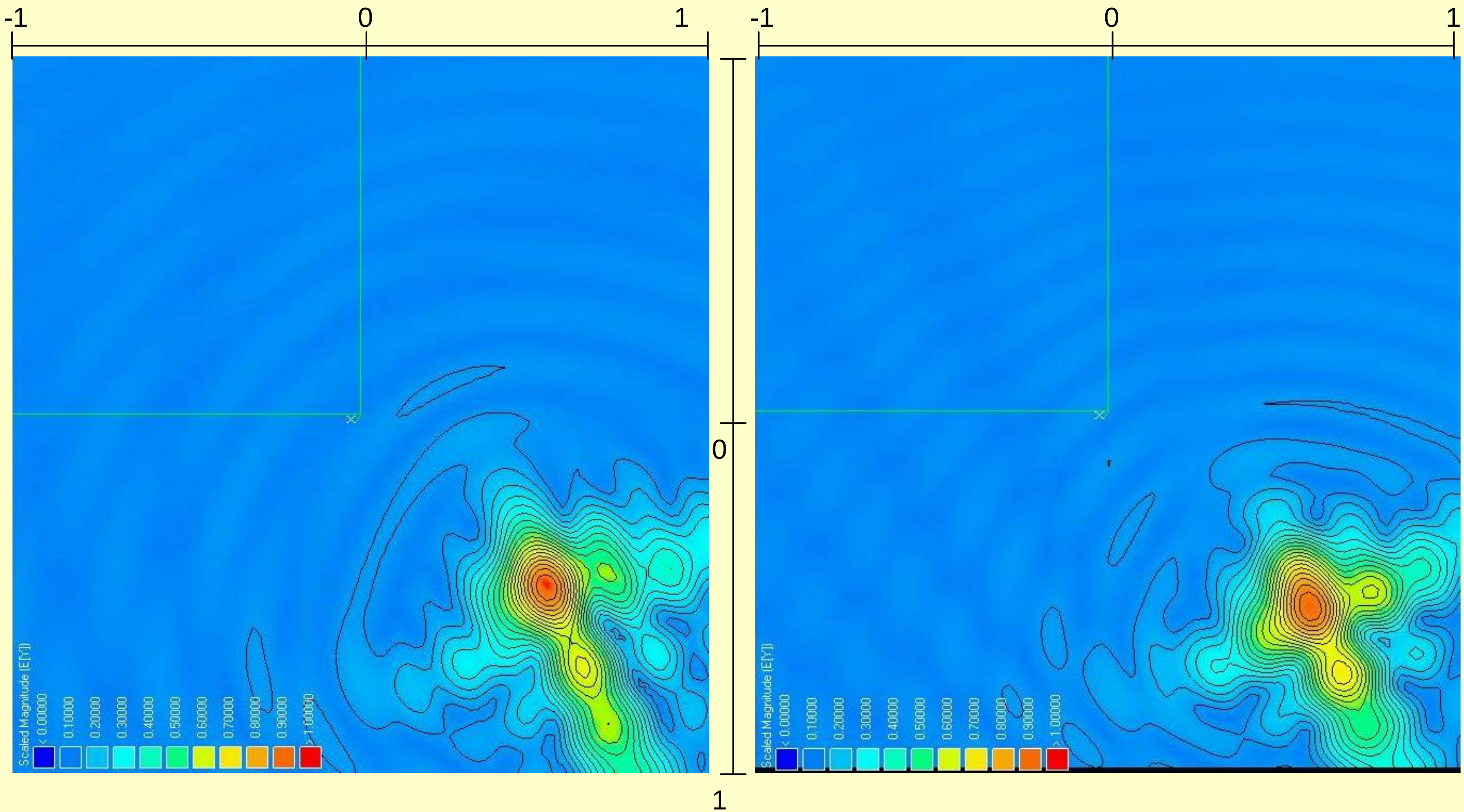
X-pol E-FIELD STRENGTH AT BORESIGHT INCOMING WAVE FOR AN OFFSET REFLECTOR WITH FOCAL DISTANCE 7.5m (LEFT) AND 9m (RIGHT).



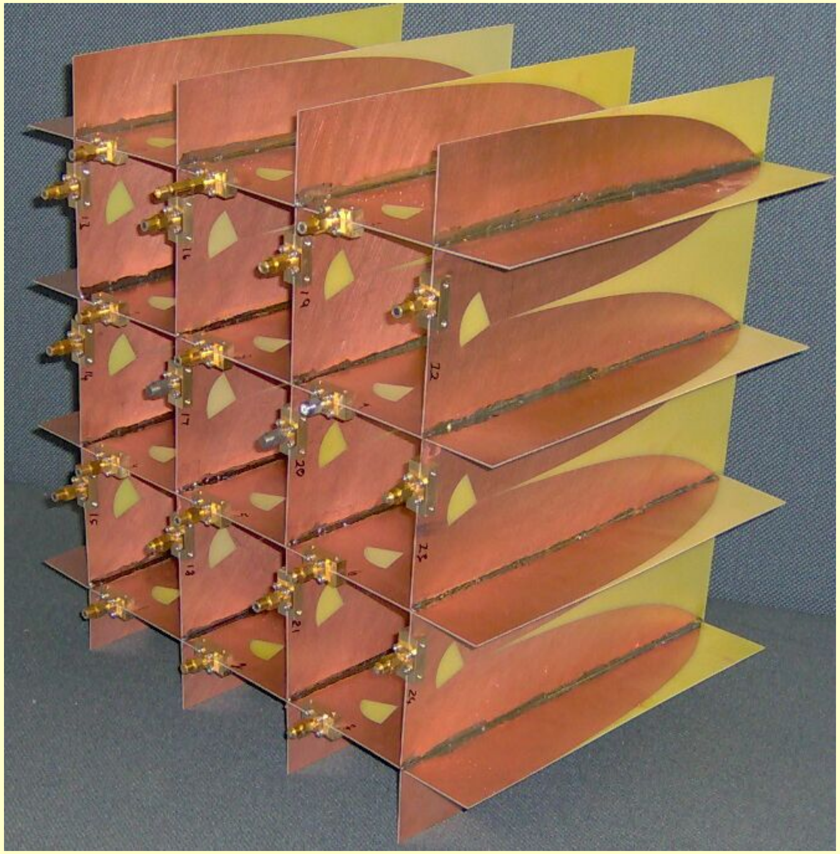
Co-pol E-FIELD STRENGTH AT -3° ON-AXIS INCOMING WAVE FOR AN OFFSET REFLECTOR WITH FOCAL DISTANCE 7.5m (LEFT) AND 9m (RIGHT).

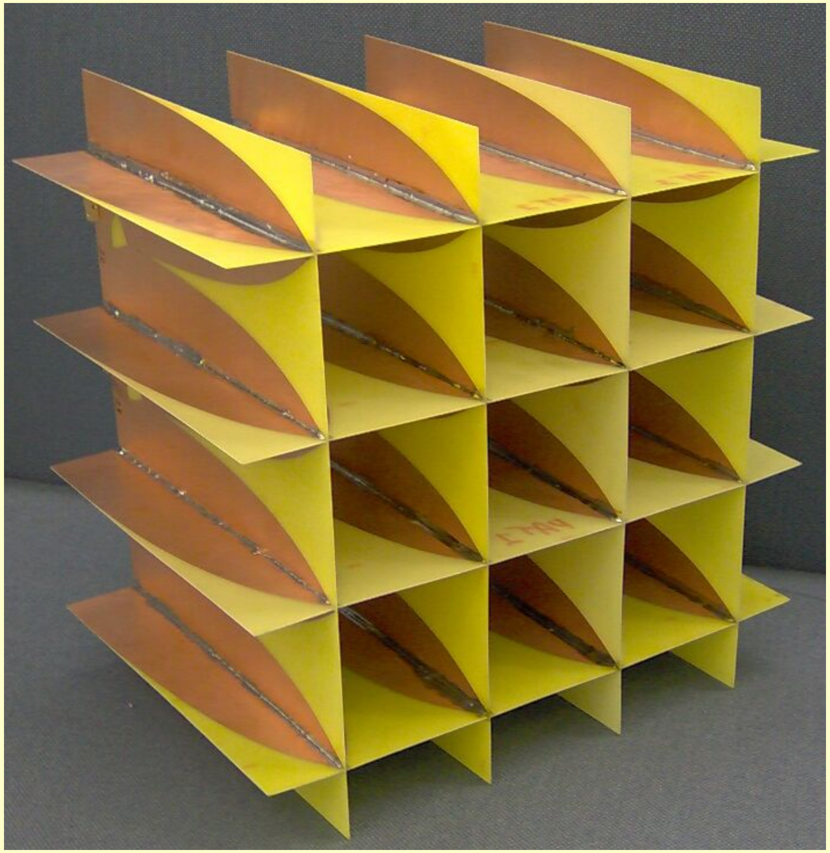


Co-pol E-FIELD STRENGTH AT +3° ON-AXIS INCOMING WAVE FOR AN OFFSET REFLECTOR WITH FOCAL DISTANCE 7.5m (LEFT) AND 9m (RIGHT).

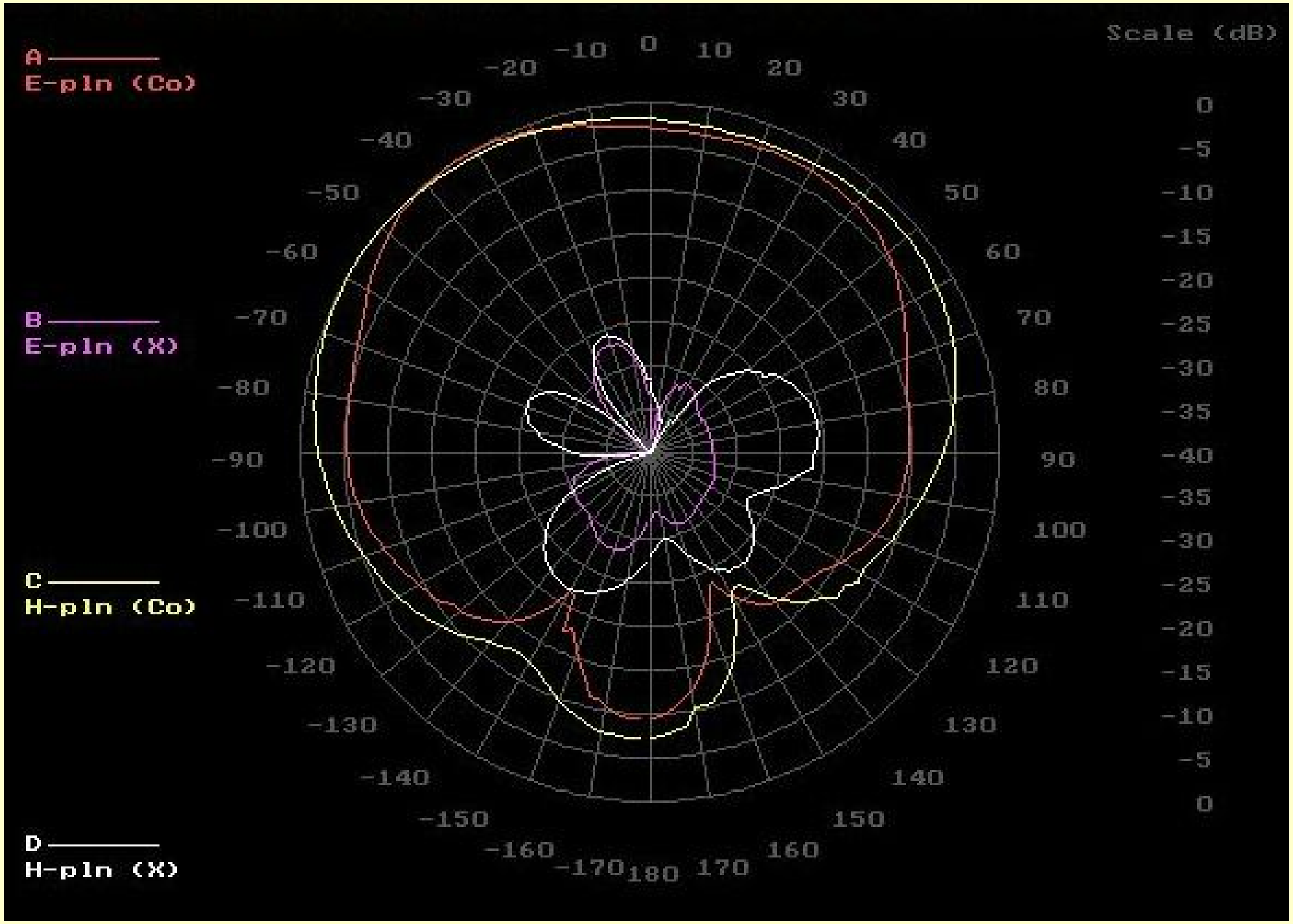


Co-pol E-FIELD STRENGTH AT +3° OFF-AXIS INCOMING WAVE FOR AN OFFSET REFLECTOR WITH FOCAL DISTANCE 7.5m (LEFT) AND 9m (RIGHT).

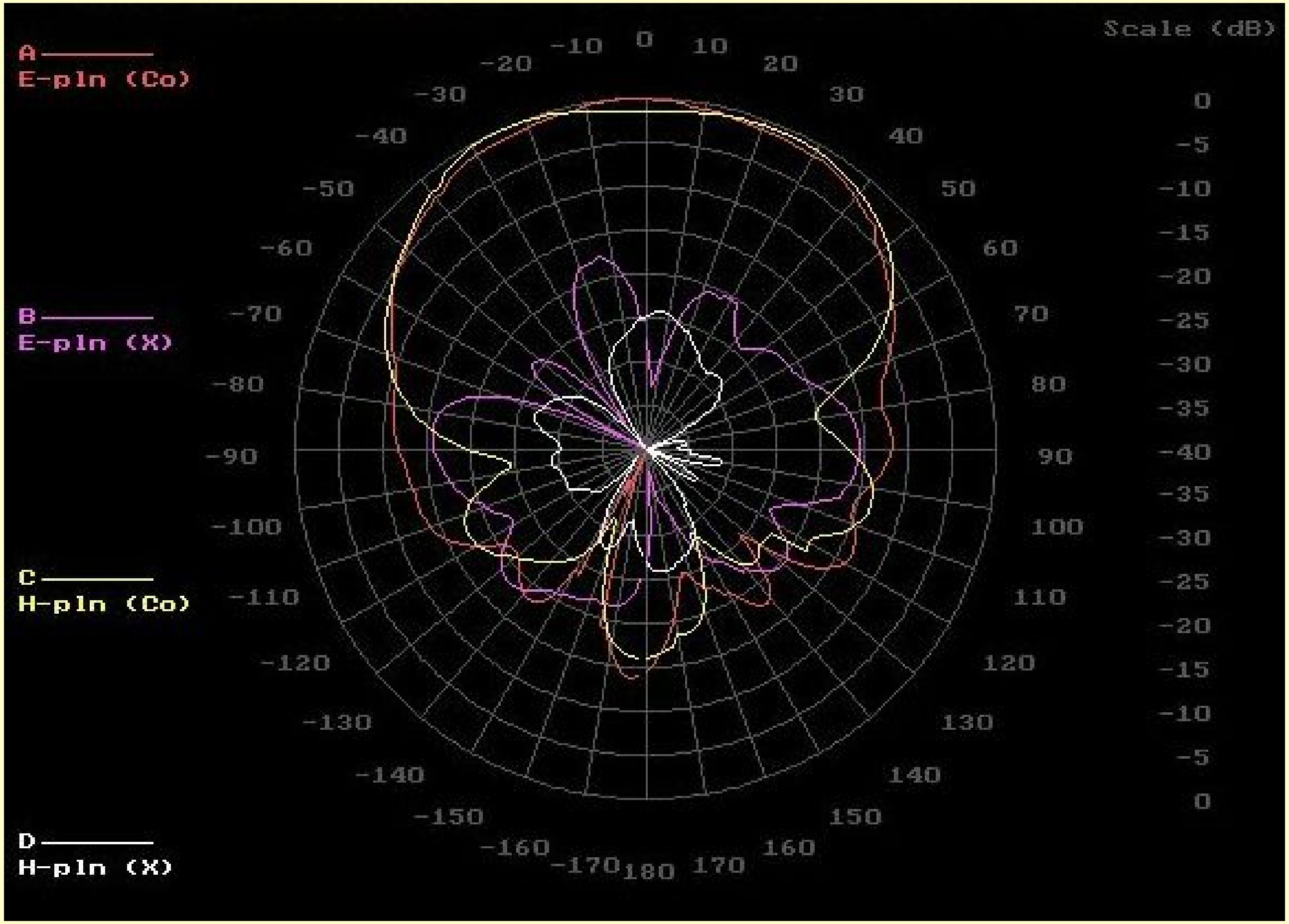




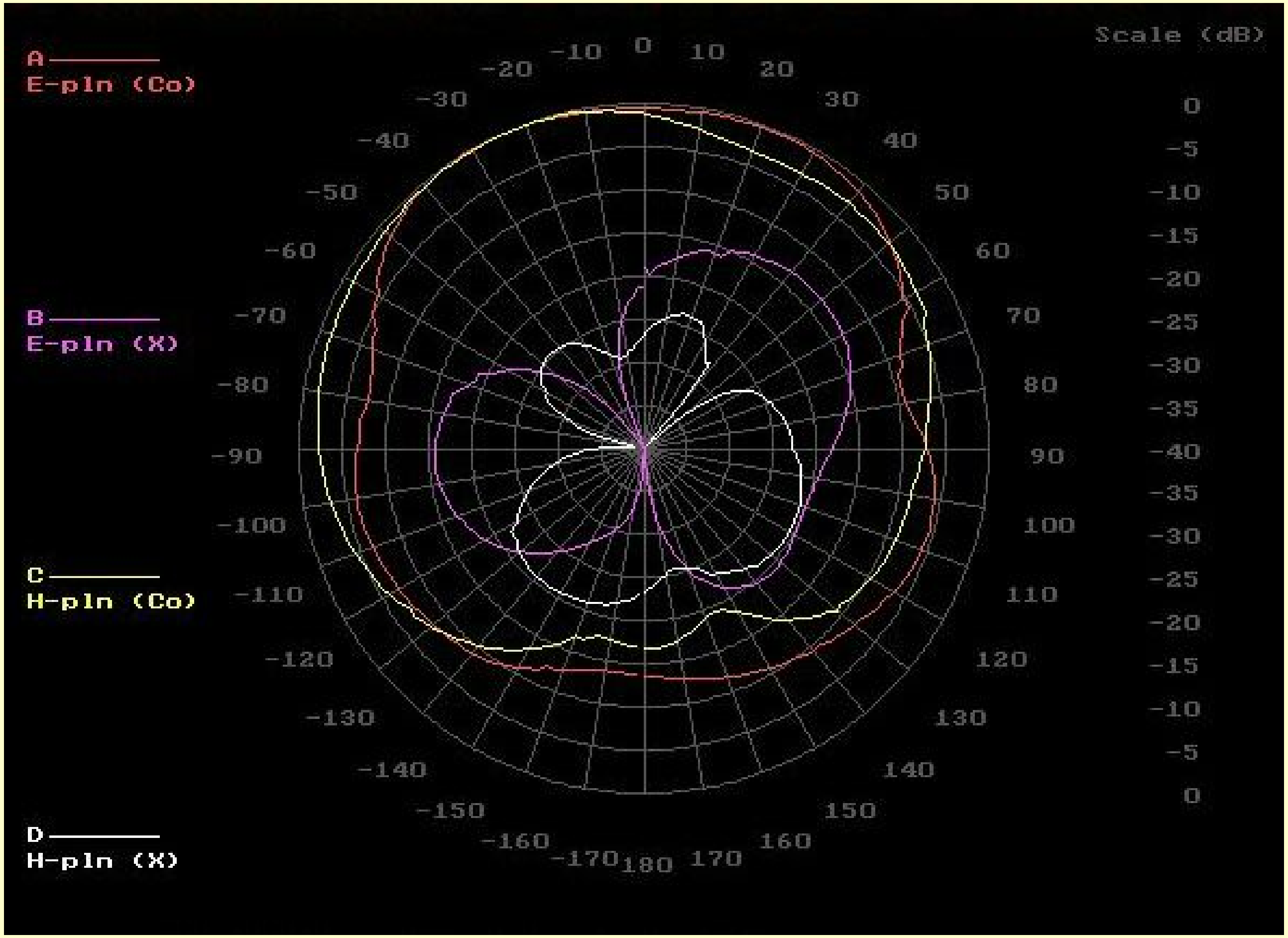
FIRST ITERATION 4x3 VIVALDI ARRAY INVESTIGATED AT GRINTEK ANTENNAS



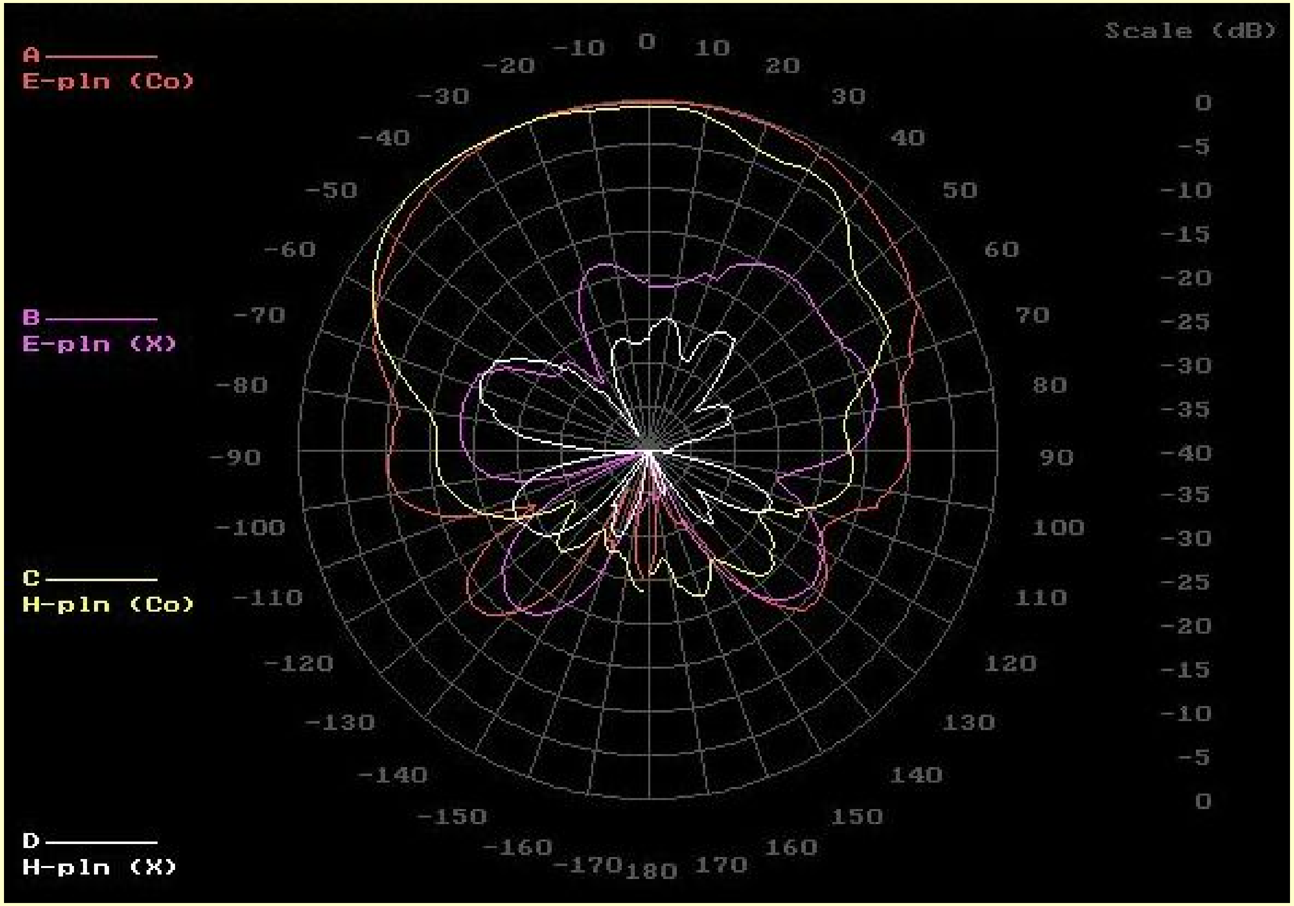
700MHz RADIATION PATTERN OF VIVALDI ANTENNA IN CENTER OF 4x3 ARRAY
ELEMENT 5



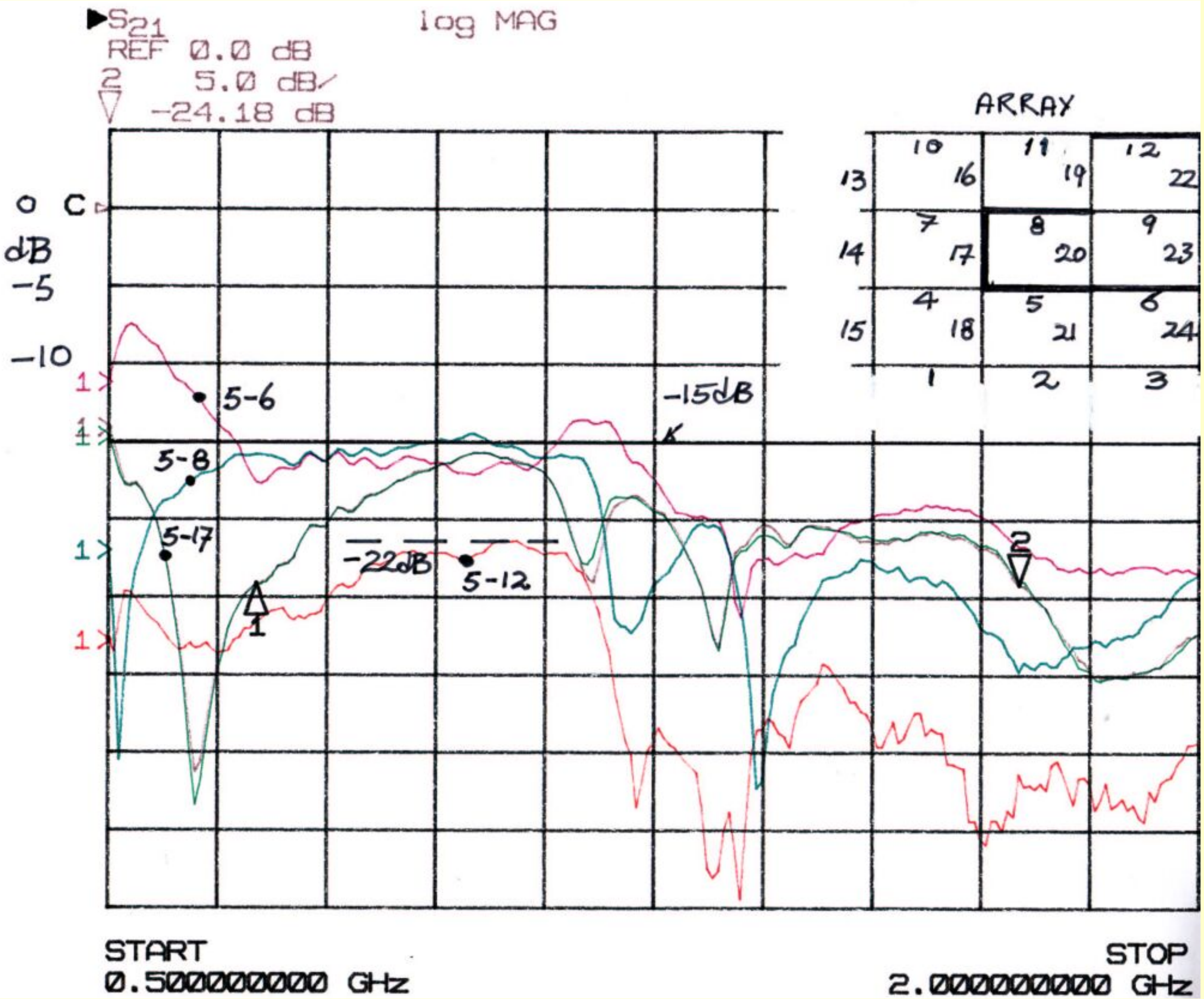
1750MHz RADIATION PATTERN OF VIVALDI ANTENNA IN CENTER OF 4x3 ARRAY
ELEMENT 5



700MHz RADIATION PATTERN OF VIVALDI ANTENNA ON EDGE OF 4x3 ARRAY
ELEMENT 11



1750MHz RADIATION PATTERN OF VIVALDI ANTENNA ON EDGE OF 4x3 ARRAY
ELEMENT 11

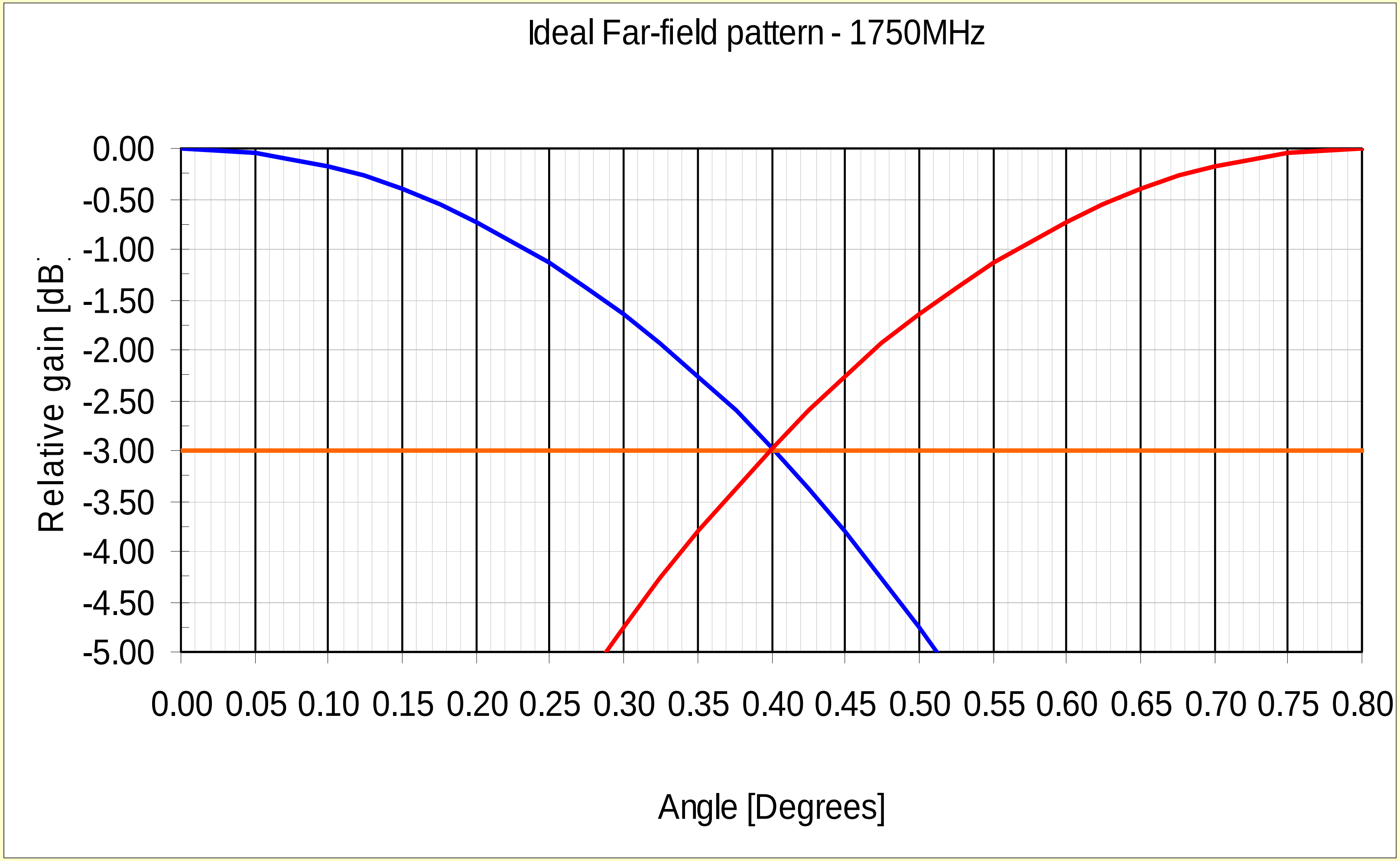


COUPLING BETWEEN ELEMENTS IN 4 X 3 VIVALDI ARRAY

REQUIREMENTS FOR ANTENNA STRUCTURE FOR KAT

Operation	Gravity [El-range]	Temp	Rain	Ice & Snow	Wind incl gusts
	[° El]	[° C]	[mm/h]	[kg/m²]	[km/h]
Normal	-5 to 90	-5 to 40	None	None	0 – 20
Drive to stow	N/A	N/A	10	25	36
Survival in any position	N/A	-20 to 50	25	25	100
Survival in stow position	N/A	-20 to 50	50	25	200

- **Must be equipped with lightning protection.**
- **Surface accuracy: 2 to 3 mm rms (random surface error factor = 0.979 to 0.953).**
- **Pointing accuracy 0.01. (set by dB variation at 3 dB crossover between adjacent beams).**



CROSS-OVER REGION BETWEEN TWO ADJACENT MAIN BEAM PATTERNS

DRIVE DATA

	Elevation	Azimuth
	Zenith	**From true North**
Range of Motion	-5 to 90	+-230
Slew speed	2 deg/s	2 deg/s
Slew acceleration	2 deg/s²	2 deg/s²
Duty cycle (slewing / tracking	20 min	

HIGH LEVEL FUTURE PLANS FOR KAT

- **R&D, Trade-offs and iterations until end of 2006 (technology freeze)**
- **Continue investigation of electrical performance of prime focus, offset, folded optics, etc antennas.**
- **Investigate alternate elements to Vivaldis for FPAs.**
- **Manufacture 10 x 10 x 2 FPA and evaluate (include mutual coupling).**
- **Dish mechanical design and investigation of low cost manufacture including pedestal and control.**
- **Digital receiver prototype.**
- **Digital beamformer prototype.**
- **Correlator prototype.**

GRINTEK ANTENNAS

SQUARE KILOMETRE ARRAY SKA SOUTH AFRICA