

# Minimum Scattering Probe for High Accuracy Planar NF Measurements

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**Abstract**— Dual polarized wideband probes are convenient for accurate and time efficient Planar Near Field (PNF) antenna testing [1]–[2]. Traditional probe designs are often bandwidth limited and electrically large leading to high scattering [3]–[4] in PNF measurements with short probe-AUT distances. In this paper, a full octave bandwidth probe design with minimum scattering characteristics is presented, discussing design considerations, trade-offs and experimental results of the manufactured hardware.

**Keywords**— *Planar near field, probe, measurement, scattering*

## I. INTRODUCTION

Dual polarized probes with wide bandwidth operational capabilities are convenient for accurate and time efficient Planar Near Field (PNF) antenna testing [5]–[8]. Nevertheless, traditional probe designs are often limited in terms of bandwidth and their electrically large size leads to high scattering in PNF measurements with short probe-AUT distances. An innovative full octave band probe design is presented in this paper with minimum scattering characteristics. The scattering minimization is mainly obtained by an electrically small and axially symmetric aperture of  $0.4\lambda$  diameter at the lowest frequency. The aperture provides a near constant directivity in the full bandwidth and very low cross polar. The probe is fed by a balanced ortho-mode junction (OMJ) with external feeding circuitry to obtain high polarization purity.

## II. PERFORMANCE SPECIFICATIONS

In addition to wide band performance and dual polarisation capabilities, which are attractive features for time efficient testing, PNF antenna measurements put additional requirements on the characteristics of the measurement probe [9]–[11]. These are summarised in Table I. Most of these specifications depend on the geometry of the test set-up, but qualitative features beneficial for most measurement accuracy can be identified.

TABLE I. PERFORMANCE SPECIFICATIONS

| Item                       | Specification   | Comments                                                                        |
|----------------------------|-----------------|---------------------------------------------------------------------------------|
| Polarisation               | Dual            | H/V preferable                                                                  |
| Bandwidth                  | /               | trade-off with performance                                                      |
| Return loss                | > 10dB          | /                                                                               |
| Isolation                  | > 45dB          | /                                                                               |
| Directivity                | < 10dBi         | in case of short probe-AUT distance, wide angle coverage, stable over frequency |
| Cross-polar discrimination | > 45dB          | on-axis, often additional value specified at probe field-of-view                |
| Pattern shape              | /               | no side-lobes, no nulls in the forward hemisphere, equalised E/H cuts           |
| Scattering                 | to be minimised | critical for measurement accuracy                                               |

## III. DESIGNED PROBE

A general representation of a dual polarised probe and its building blocks is reported in Figure 1.

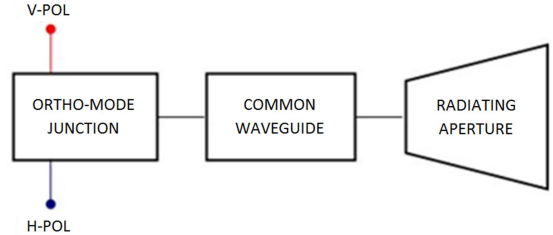


Figure 1. Probe components

In more detail, the probe presented in this paper is based on a wide-band inverted quad-ridge ortho-mode junction (OMJ) with balanced feeding enforced by external feeding circuits [12]–[13]. The schematic of the OMJ is outlined in Figure 2.

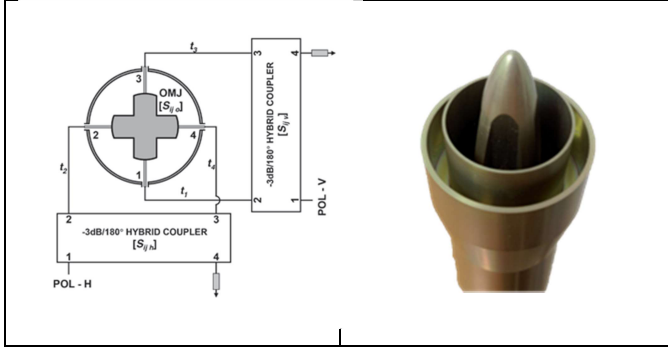


Figure 2. Ortho-mode junction based balanced inverted quad-ridge design (left) and detail of the probe radiating aperture (right).

The inverted quad-ridge waveguide cross-section has been specifically conceived in order to achieve an electrically small cross-section while maintaining reasonable impedance values. The achieved inner diameter is on the order of  $0.4\lambda$  at the lowest operational frequency, representing a down-sizing of approximately 50% compared to traditional hollow circular waveguides. The OMJ feeds directly into an axially symmetric tapered aperture of compact size. To avoid its cut-off, the inner conductor of the of the inverted quad-ridge waveguide is smoothly profiled and protrudes from the aperture plane to avoid abrupt impedance discontinuities. The overall cross-section of the aperture is then minimized and ensures low back-scattering properties. To further control the radiation pattern symmetry, increase boresight directivity at lowest frequencies and minimize the front-to-back ratio, a recessed axial corrugation has been added externally.

The “DLP-PNF-650” probe layout @ C/X-band equipped with its mounting fixture and with the absorber provisions removed is shown in Figure 3.

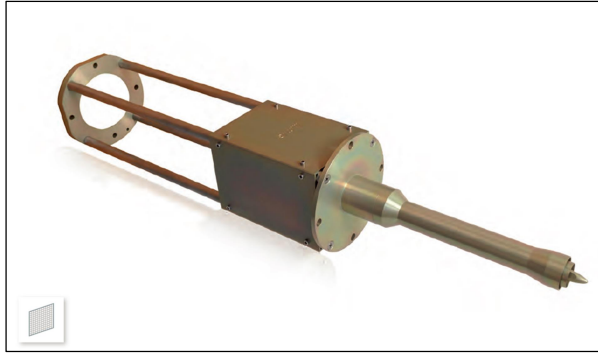


Figure 3. Dual Linear Polarized Minimum Scattering Probe for Planar Near-Field

The measured S-parameters at input connectors are presented in Figure 4. Performance figures have been recorded over an extended band (nearly an octave and a half) to demonstrate the stability of the design.

Radiation patterns have been calculated [14] by means of high-fidelity models including materials and manufacturing constraints.

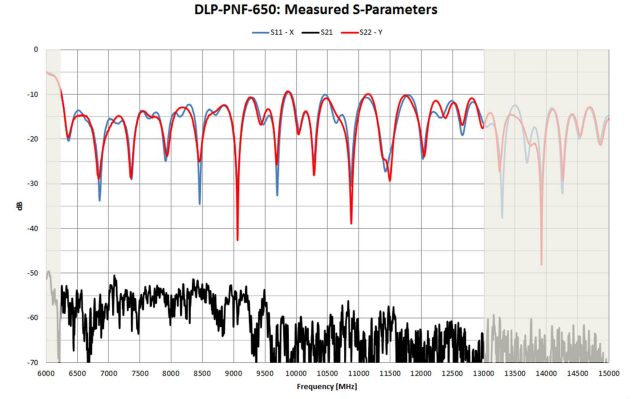


Figure 4. Measured S-parameters referenced to 50 Ohms.

Also, the absorber screen covering the probe stand-off has been included in the modeling, considering 5” pyramidal foam absorbers [15] with a circular cross-section of 12” in diameter. Directivity pattern cuts at start and stop frequencies are shown in Figure 5. Across the full operational band, boresight directivity remains stable at 8dBi, with some slow varying oscillations of half of a dB. Symmetry between E and H plane is also noticeable, with a cross-polar pattern in the inter-cardinal planes typical of corrugated circular apertures, in shape and magnitude. An additional attractive feature is the volumetric pattern dynamic range, considered as the difference between the boresight and minimum directivity values within the  $\pm 90^\circ$  conical angle. This value is always greater than 23dB over the full octave bandwidth.

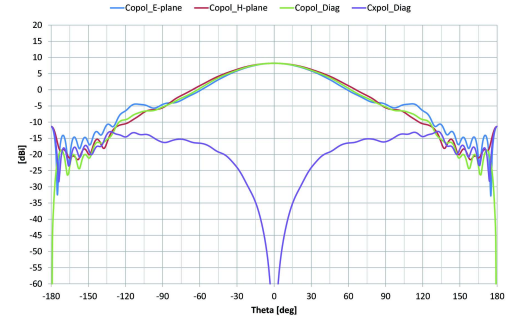


Figure 5. Directivity pattern cuts @ 6.2GHz (start frequency) including absorbing provisions.

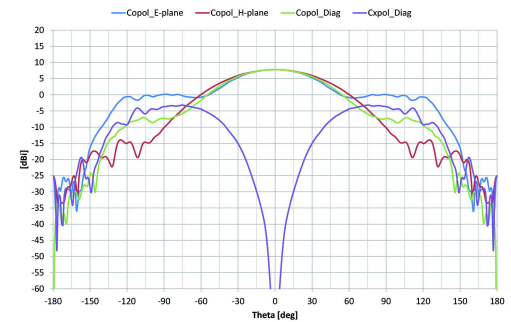


Figure 6. Directivity pattern cuts @ 13.0GHz (stop frequency) including absorbing provisions.

#### IV. CONCLUSION

A full octave bandwidth probe designed with minimum scattering characteristics has been presented in this paper, discussing design considerations, trade-offs and experimental results. The probe technology has demonstrated excellent characteristics for testing scenarios in which the probe-AUT distance is short and interaction is consequently a limiting factor in the overall measurement accuracy. Although the probe has been manufactured and demonstrated at C/X-band, the technology is well suited to cover the full frequency spectrum, from L up to Ka-band, due to its compactness, flexibility and ease of scalability.

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