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Ultra-Fast Reflectometry Upgrade within the framework of the WPSA

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CEA \ IRFM Cadarache

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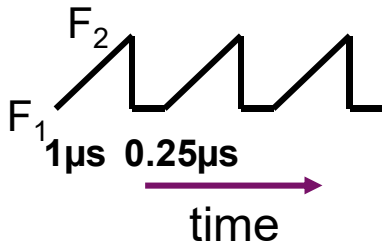
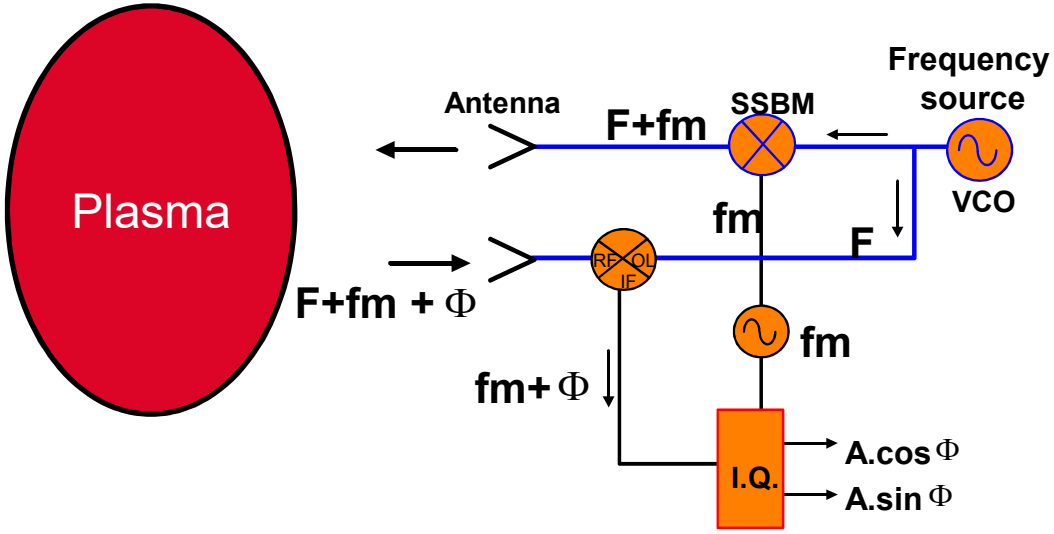
Ultra-fast sweeping reflectometer

Clairet *et al.* RSI 2017

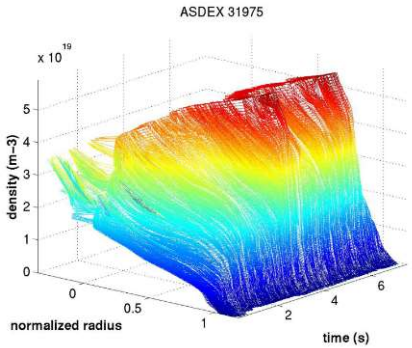
FM-CW reflectometry caracteristics

- High sensistive detection : **S/N > 30 dB**
- Ultra-fast sweeping : **1 µs (dead time 0.25 µs)**

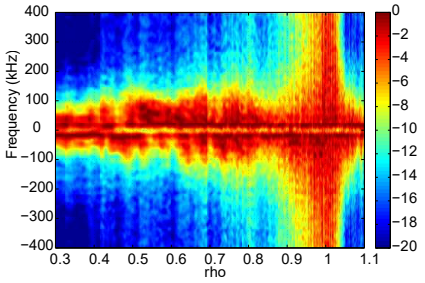




Density



Fluctuations



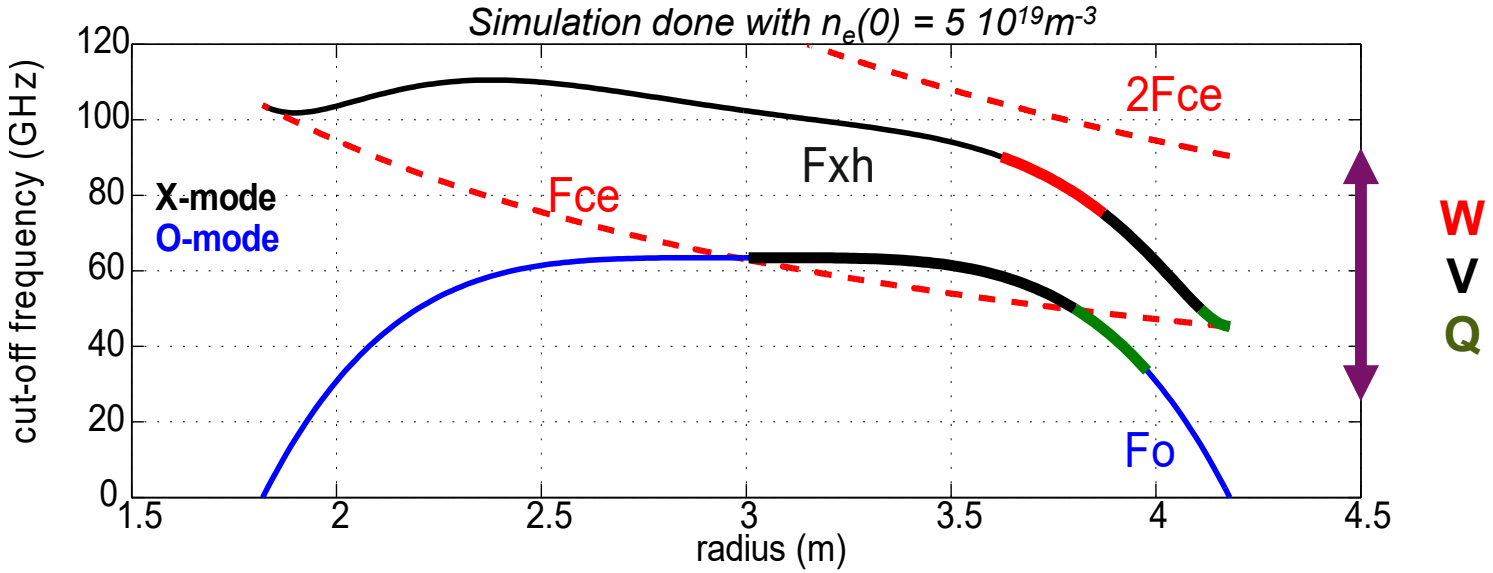
JT-60SA : FREQUENCY BANDWIDTHS NEEDED

JT-60SA
R = 3 m
a = 1.18 m
B = 2.3 T

Frequency bandwidths required

- Q-band (33-50 GHz)
- V-band (50-75 GHz)
- W-band (75-110 GHz)

Very similar to JET



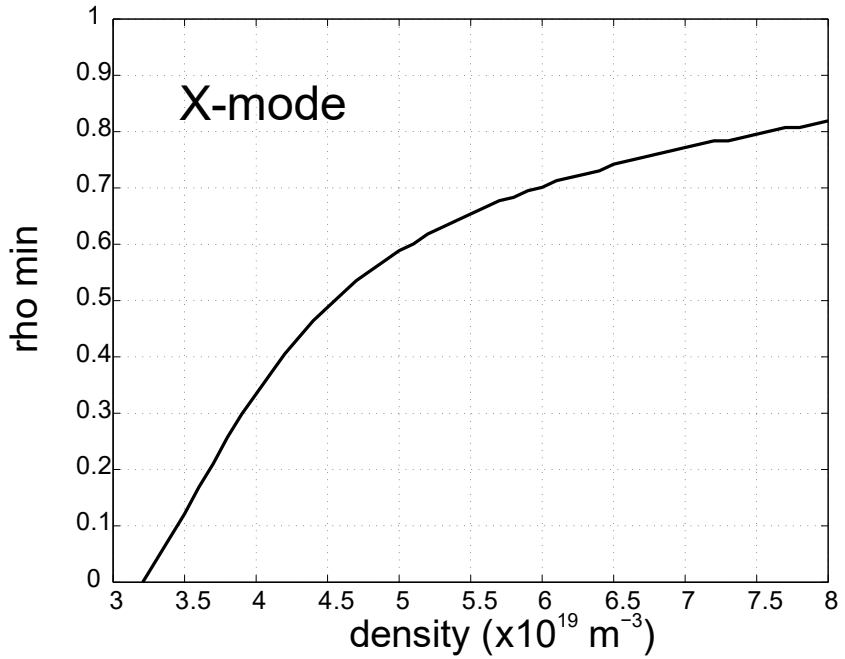
Recommanded systems

- **3 X-mode : Q, V and W-bands for edge measurement.**
- **1 O-mode : V or E band in O-mode for core measurement.**

ACCESSIBILITY OF DENSITY THE MEASUREMENT

rho_{min} accessibility

(The limitation is due to the 2nd harmonic Fce)

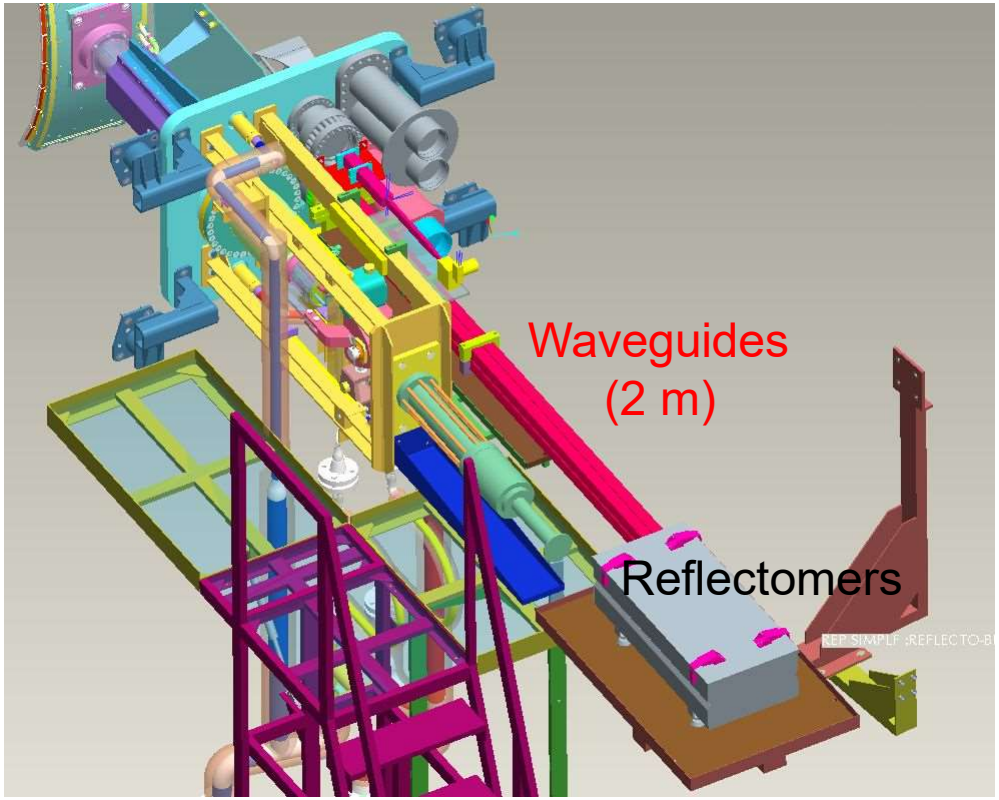


Core plasma will be less accessible as the density increases.

(O-mode can extend the accessibility in the core but do not generally access rho < 0.2 or 0.4)

WAVEGUIDES

1 – Short distance antenna/reflectometers (as WEST).



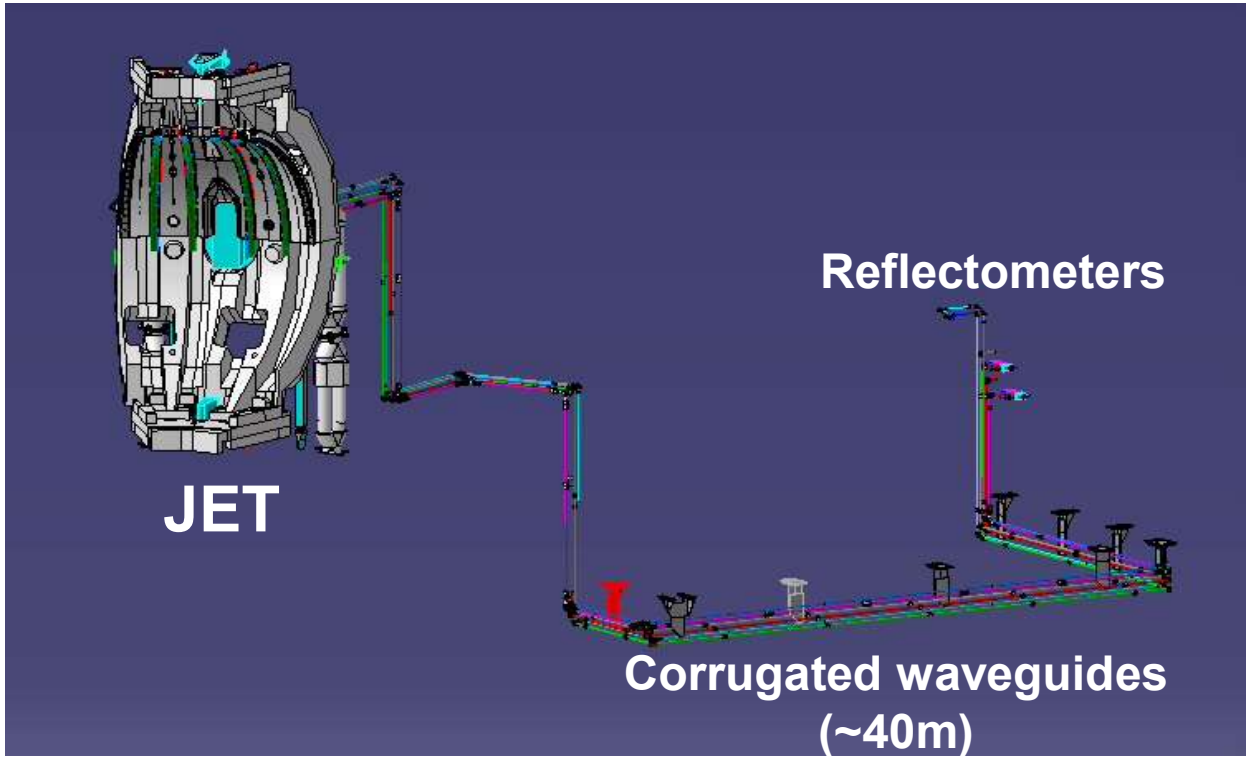
Efficient, low loss, easy to handle and low cost effective.

WAVEGUIDES

2 - Long distance antenna - reflectometer (as JET).

➔ Low loss (10^{-3} dB/m) circular corrugated waveguides needed.

(Cupido et al. Fusion Eng. Des. 2005)



Still efficient and ease access to diagnostic during plasma operation.

ANTENNA SIZE

- **Idealy the directivity (or gain) of the antennas should be > 25 dB.**

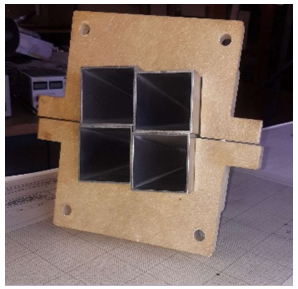
According the frequency range the

Bandwidth (GHz)	25 dB (cm^2)	30 dB (cm^2)
33-50	6x4.5 / Φ6	10x8 / Φ10
50-75	4x3 / Φ4	7x5 / Φ7
60-90	3x2.5 / Φ3	6x4 / Φ6

Rectangular / Circular horn

ANTENNAS ARRANGEMENT

1 – Expanded antenna system (as WEST)



V and W bandwidths with their emitting and receiving antennas (square 4 cm).

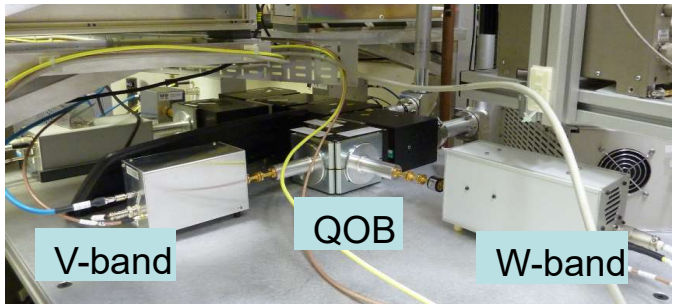
➔ JT-60SA

Antenna system could occupy an aperture between 30 to 50 cm diameter on the port hole.

2 – Compact antenna system (as JET)

Several frequency bandwidths (Q, V, W, D) are launched into two wg and received by one wg which requires combining quasi-optical boxes (QOB) with filters. However, for transmission issue at frequencies < 50GHz, the waveguide diameter should be ~6 cm.
(Wang *et al.* RSI 2017)

2 Emitting and 1 receiving antennas



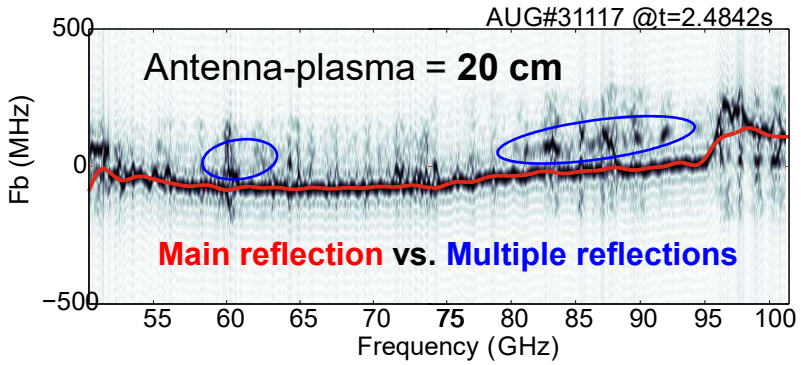
➔ JT-60SA

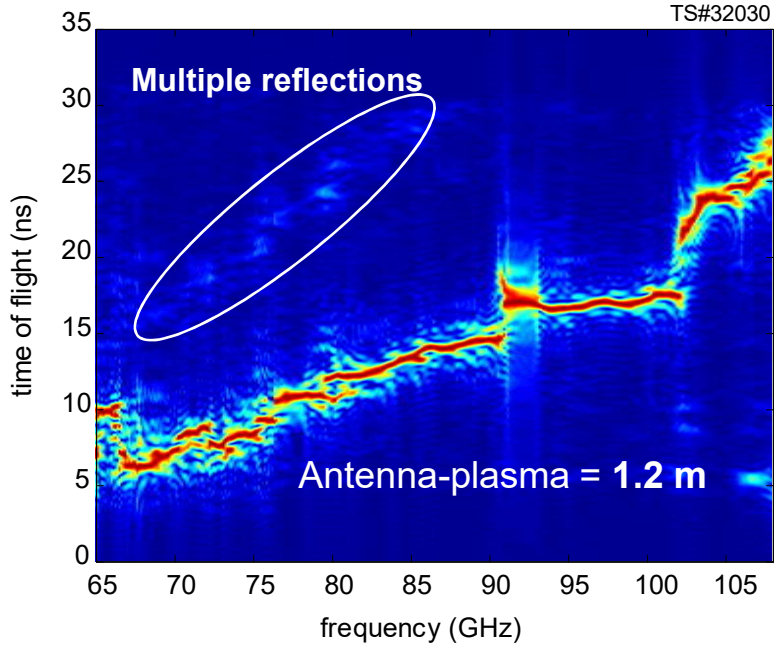
Antenna system could occupy an aperture of less than 20 cm diameter on the port hole.

ANTENNAS LOCATION

- Measurements should be performed at the equatorial plane from the low field side.
- In vessel or outside vessel antenna can be equaly managed.

- Deleterious multi-reflections, mainly X2 between plasma and inner wall, are difficult to discriminate from main reflection if a distance antenna-plasma is to short.





A minimal distance between the antennas and the plasma of at least 0.50 m is required.
(1 m is recommanded…)

Cost *(rough estimate)*

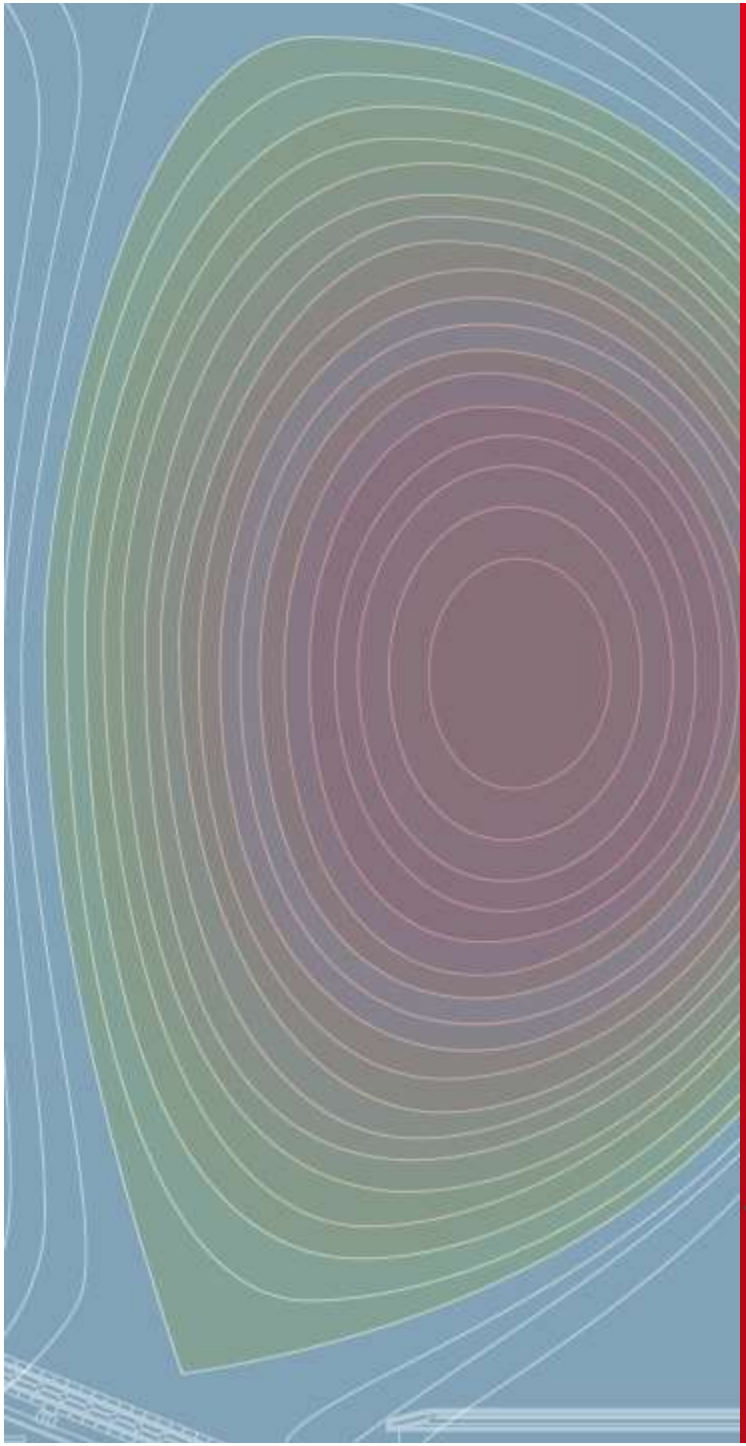
- **Reflectometers (Microwave – Electronic – Acquisition) : ~ 300 k€**
- **QOB : ~ 50 k€**
- **Waveguides : ?**

Project execution

- **Implementation (wg route, antennas...) : requires direct contact from QST.**
- **Time development for reflectometers (electronic & µ-wave) : ~ 1 year.**
- **Human ressources : limited at CEA (1.5 people).**

Summary

- **3 frequency bandwidths are required to perform density measurements in JT-60SA** *: Q, V and W*
- **Frequency sweeping reflectometry would not access the plasma core at moderate and high densities.**
- **Expanded antenna arrangement provides simplicity and is cost effective but may appear to be cumbersome.**
- **Compact antenna system substantially less cumbersome but requires QOB system to manage all the bandwidths into same waveguide.**
- **For multi-reflections issue, antenna-plasma distance is preferably > 0.5m.**
- **Reflectometry offer versatile possibilities as microwave and electronic devices can be located close or away from the machine.**



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