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Citation: AIP Conf. Proc. **1406**, 17 (2011); doi: 10.1063/1.3664919
View online: http://dx.doi.org/10.1063/1.3664919
View Table of Contents: http://proceedings.aip.org/dbt/dbt.jsp?KEY=APCPCS&Volume=1406&Issue=1
Published by the American Institute of Physics.

Parasitic signals in the receiving band of the Sub-Harmonic Arc Detection system on JET ICRF Antennas

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Abstract. When testing the SHAD system on JET ICRF antennas, parasitic signals in the detection band (5-20MHz) were detected. We have identified emission from grid breakdown events in the Neutral Beam injectors, and Ion Cyclotron Emission from the plasma. Spurious signals in the band 4-10 MHz are also often observed at the onset of ELM events. Such parasitic signals could complicate the design and operation of SHAD in ICRF systems for fusion devices.

Keywords: Tokamak, JET, ICRF, Antenna, Arc protection.
PACS: 52.55.Fa, 52.50.Qt, 52.40.Fd, 52.80.Mg, 52.80.Vp

INTRODUCTION

Arc detection on ICRF systems are a critical point for future ITER designs. A Sub-Harmonic Arc Detection (SHAD) system was tested in the transmission lines feeding the JET ICRF ITER like Antenna (ILA) [1], and also in the A2 antenna system with External Conjugate-T (ECT) configuration [2]. The capability of the system to detect arcs was already reported in [3], but the arc detection system operation was complicated by false detections triggered by parasitic signals in the SHAD detection band. During the commissioning of SHAD, extensive measurements of the RF signal at the input of the system were carried-out using fast (125 MSample/s) oscilloscopes. Figure 1 shows a block diagram of the RF measurement and arc detection systems, when SHAD was tested in the ILA or in the A2-ECT system. 80 dB couplers installed in the transmission lines feeding the antennas were used. The RF signal was filtered and amplified (~ 20 dB gain typically) in the 5-20 MHz band and then sampled by the oscilloscopes. The acquisition window was ~125 ms, and Fourier analysis of the RF signals was carried out. It is important to notice that the antenna system acts as a

* See the Appendix of F. Romanelli et al., Proceedings of the 23rd IAEA Fusion Energy Conference 2010, Daejeon, Korea.

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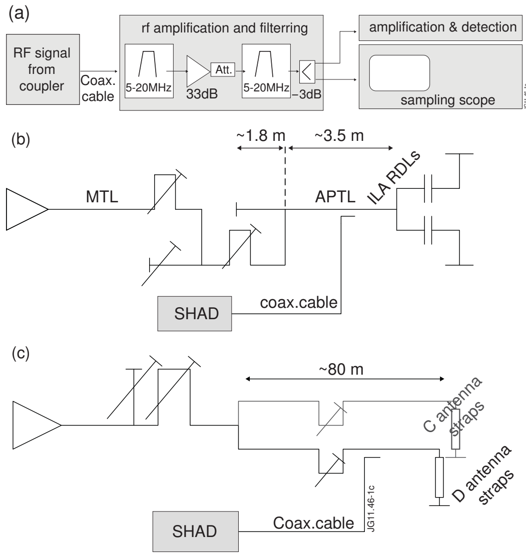

Figure 1. (a) Block diagram of the SHAD measurement system and configuration in the ILA (b) or in the A2-ECT antenna systems (c).

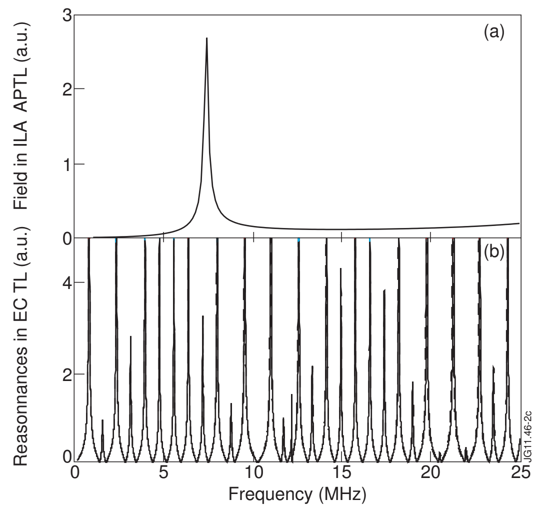

Figure 2. Typical calculated frequency response of the electrical field for strap excitation, (a) in ILA APTL section, and b) in ECT Transmission lines.

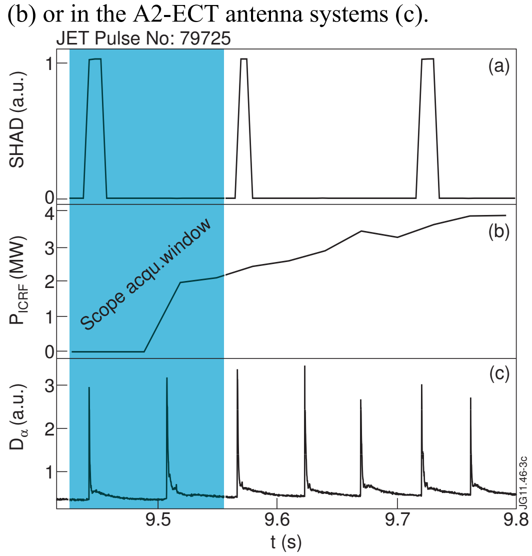

Figure 3. Pulse 79725, illustration of arc false detection triggered by ELMs . (a) SHAD logical signals, (b) ICRF power, (c) D_α signal. SHAD is in ECT system.

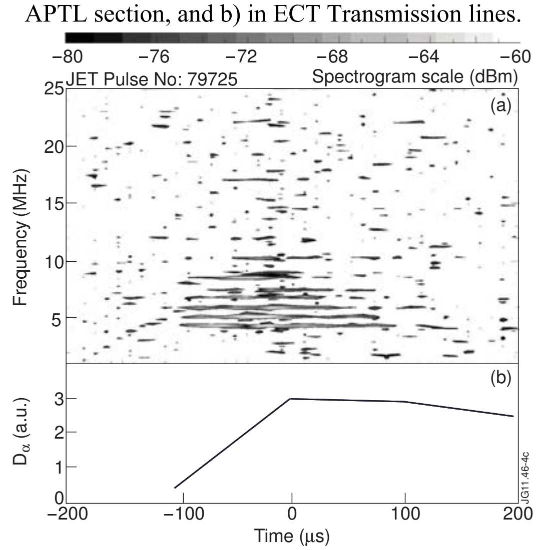

Figure 4. (a) Spectrogram of the SHAD input signal during first ELM event of Fig. 3, time=0 corresponds to t=9.442 s in JET time base. (b) D_α signal.

frequency filter, the selected frequencies depending on the exact configuration of the transmission lines. When using SHAD in the ILA APTL section, RF signals developing on the straps (arcs or pick-up from plasma) are typically filtered by the ILA transmission line system in a narrow band ($\Delta f_{-10dB} \sim 0.5$MHz) centered at $f_0\sim7$MHz (Figure 2-a). For ECT, the system responds with frequency peaks spaced at $\Delta freq\sim1$MHz (Figure 2-b). This is coherent with the measured spectra in Figure 4 and Figure 6.

SIGNALS ANALYSIS

JET ICRF systems are extensively used on H-mode plasmas with type I ELMs. In these conditions many SHAD events occurred at the onset of ELMs. An example is given in Figure 3 and Figure 4 for pulse 79725 (SHAD in the A2-ECT antenna) where a sub-harmonic signal is detected before the ICRF power is turned-on. Typically, these signals in the 4-10 MHz band picked-up by the SHAD system are detected during ~100 μs at the onset of ELMs. We could not establish a clear dependency of the signal frequency with plasma parameters (for example B_T). A candidate to explain this observation would be emission from weakly-damped modes in the plasma, similar to Compressional Alfvén Eigenmodes [4], excited either by tritons and/or protons with non-relaxed distribution functions born in DD fusion reactions, or by high-frequency MHD perturbation associated with ELMs. Emission from ELM triggered arcs in the vacuum vessel as reported in AUG [5] could also generate these parasitic detections.

Figure 5 describes a case where continuous emission from the plasma caused many SHAD false detections. Pulse 79363 is from a series of pulses where 2^{nd} harmonic heating of ^3He in H plasmas was studied, the plasma parameters were: B_T=2.62 T, I_P=1.4 MA, f_{ICRF}=51 MHz, P_{ICRF}=5.4 MW, P_{NBI}(D)= 1.3 MW. A continuous signal of

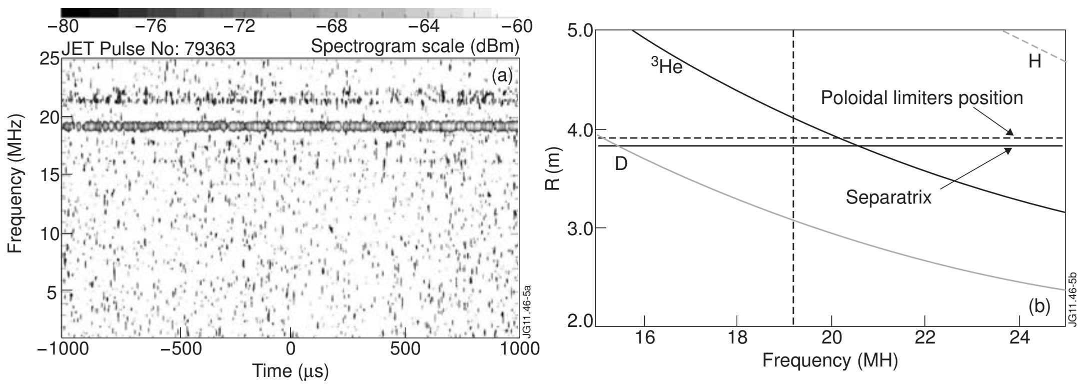

Figure 5. Pulse 79363, (a) spectrogram of ICE signal; time=0 corresponds to t=6.892s in JET time base; SHAD is in the ECT system. (b) D, ^3He and H ions $^1\Omega_c$ resonance position vs frequency.

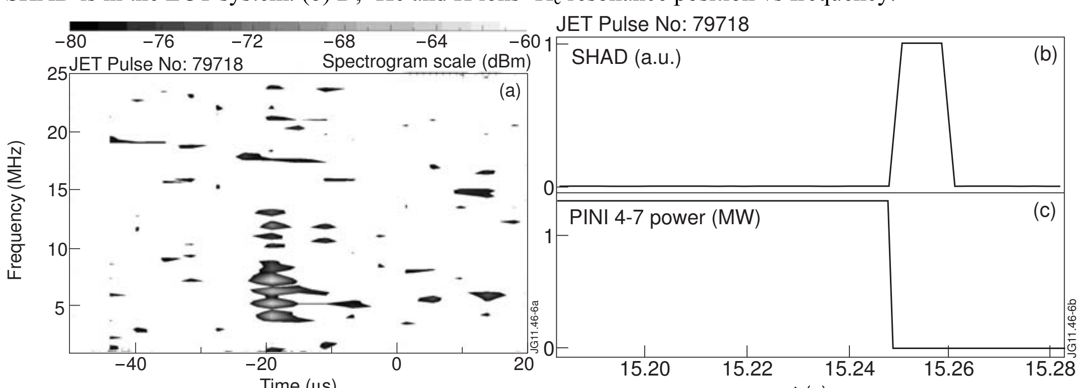

Figure 6. Pulse 79718, (a) spectrogram of the SHAD input during breakdown in PINI 4-7; time=0 corresponds to t=15.249 s in JET time base. (b) SHAD logical signal and (c) PINI 4-7 neutral beam power. SHAD is in the ECT system.

frequency ~19.25 MHz was detected by the system. This signal is attributed to the excitation of magnetosonic waves by Ion Cyclotron Emission (ICE) [6]. In particular in this case, the signal frequency is compatible with ICE from fast ^{3}He with a non relaxed distribution function at the plasma periphery. In this series of pulses fast ^{3}He ions could indeed be observed [7]. We have also observed emission attributed to fast protons (Hydrogen minority ICE) in other pulses, when using the more conventional (H)D ICRF heating scheme, as was reported in [8].

Finally, the last class of events that caused frequent false SHAD detection is the occurrence of breakdown in the accelerator of the Positive Ion Neutral Injectors (PINI) of the JET NBI system. An example is shown in Figure 6, where in this case a breakdown in PINI 4-7 generates a signal in the 5-15 MHz band at the input of the SHAD system. The duration of the signal (~10 μs or less) corresponds roughly to the time for the Neutral Beam High Voltage (HV) protection system to detect breakdown and shut-down the HV supply; therefore we can conclude that the signal detected in our system corresponds probably to electro-magnetic emission from the breakdown in the PINI itself (not emission from the HV protection system). We have observed such events when breakdowns occurred in various PINIs of Octant 8 or Octant 4 neutral beam systems (using different types of HV power supplies and with HV protection systems located in different buildings).

CONCLUSIONS

If SHAD has proven its capability to detect arcs in the JET ILA and A2-ECT antenna systems, many false detection events also occurred, which made the system unreliable and difficult to operate. In this document we have described parasitic signals (with power levels at SHAD input of the same order as arc signals) which caused most of these erroneous detections. If one wants to consider SHAD in an ICRF system for fusion devices, potential emission in the tens of MHz range from the plasma must be considered. A system using real time Fourier analysis and spectrum computation is feasible but emission from the plasma via ICE or other mechanisms in this range of frequency are not easily predictable. Electromagnetic Compatibility/Immunity issues against other high power electrical systems operating in the tokamak environment is another important issue.

ACKNOWLEDGMENTS

This work, part-funded by the European Communities under the contracts of Association between EURATOM and CCFE, was carried out within the framework of the European Fusion Development Agreement. The views and opinions expressed herein do not necessarily reflect those of the European Commission. This work was also funded by the RCUK Energy Programme under grant EP/I501045.

REFERENCES

[**1**] F. Durodie, *et al.*, Fus. Eng. and Des. **74** (2005) 223-228. [**2**] I. Monakhov, *et al.*, AIP Conf Proc. **1187**, p 205 (2009). [**3**] P. Jacquet, *et al.*, AIP Conf Proc. **1187**, p 241 (2009). [**4**] M.P. Gryaznevich, S.E. Sharapov, *et al.*, Nucl. Fus. **48** (2008) 084003. [**5**] V. Rohde, *et al.*, Jour. of Nucl. Mat., in press (2010). [**6**] T. Hellsten, *et al.*, Nucl. Fus. **46** (2006) S442–S454. [**7**] V. Kiptily, *et al.*, submitted to Plasma Physics and Controlled Fusion. [**8**] G. A. Cottrell, PRL **84**, No. 11, 2397- 2400 (2000).