# THE ZERO SPLICE ENGINE INTAKE LINER: AN EFFICIENT WAY OF REDUCING AIRCRAFT NOISE WITHOUT ANY WEIGHT OR AERODYNAMIC PENALTY.

**Dr Hervé Batard**
**Airbus France**

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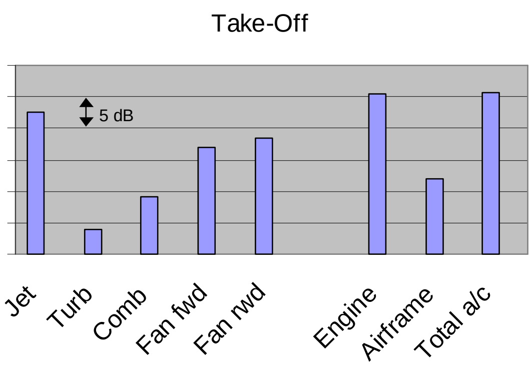
## Abstract

*The paper presents the benefit on aircraft noise of improving the engine intake liners homogeneity by removing the joints between acoustic panels. A special care is paid to the description of acoustic distortion phenomena and their impact on forward fan noise. An application to aircraft in-flight noise is presented.*

## 1 Industrial context

Community reaction to aircraft noise is now recognized as one of the most important constraints limiting future growth of air transport industry. At take-off condition, the acoustic signature of modern aircraft in flight perceived from the ground is dominated by the engine noise. Jet noise emerges and is immediately followed by fan noise. During approach, airframe becomes the dominant source with fan noise just behind. This paper deals with the reduction of forward fan noise.



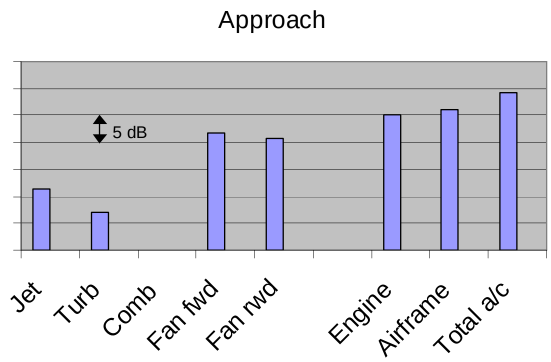




Fig. 1. Noise sources for a generic quad engine long-range aircraft at take-off and approach conditions. Airframe noise includes wings and landing gear noise. Engine noise includes Jet, Turbine, Combustion, fan forward and fan rearward components.

## 2 Position of the problem

Since the arrival of high bypass ratio engines, many studies have been devoted to the reduction of forward fan noise playing on both fan and intake designs. We propose to discuss here the improvement of acoustic liners installed in the intake.

Intake acoustic liners are manufactured in 2 or 3 curved segments that are assembled thanks to longitudinal splices. For many years the need to reduce both the number and the width of splices is well known. The expectation was to get an additional noise reduction proportional to the acoustic treated area recovery. However the difficulties in terms of feasibility compared to the small treated area recovery prevented the launch of ambitious work on that matter.

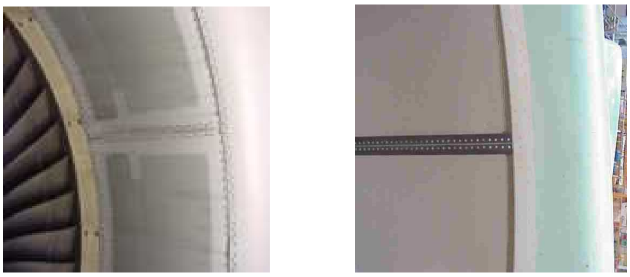


Fig. 2. 3 wide splices liner for A320 engine intake (left) and 2 narrow splices liner for A340-500/600 intake (right).

## 3 Splices effect modeling and understanding

In 1997, Airbus undertook thorough studies aiming at getting a better understanding and modeling of the fan noise propagation through the intake and its radiation towards ground. Numerous and various theoretical and experimental models have been used in this way with special emphasis given to induct noise distortion effects due to splices.

The results of these studies revealed the tremendous effect of splices on the forward fan noise This work provides a clear explanation of various promising results obtained in the past by most airframe or engine manufacturers showing that the benefit of splice reduction is largely beyond expectations based on treated area recovery considerations.

In a spliced intake liner configuration, the noise level rises as if splices generate an additional parasitic noise compared to the splice-less configuration.

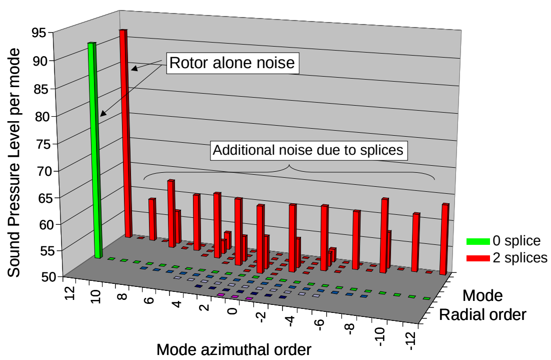



Fig. 3. Induct noise for a 2 splices (red) and a 0 splice (green) intake liner configurations.

As shown in Fig. 3., for the 0 splice intake, the noise is generated and propagated by a single "rotor alone" acoustic mode. With splices, this mode is scattered into other modes so that additional parasitic noise appears.

In fact, splices break the circumferential symmetry of the intake wave-guide. As a result, spinning modes that carry fan noise are scattered and other modes are generated. Each rotor alone mode excites a family of rotor-splice interaction modes the orders of which are given by the Tyler and Sofrin relationship that is well known for rotor-stator interactions.

$$m_{scattered} = m_{EO} +/- pN,$$

where $m_{EO}$ is the rotor alone mode at EO frequency, p is an integer and N is the number of splices. For instance, a five splices configuration would have lead to a scattering into m = 7, 2, -3, ... modes.

## 4 Splices effect tests

The effect of splices has been checked by test with careful attention to the analysis of transmitted modal content and radiated field.

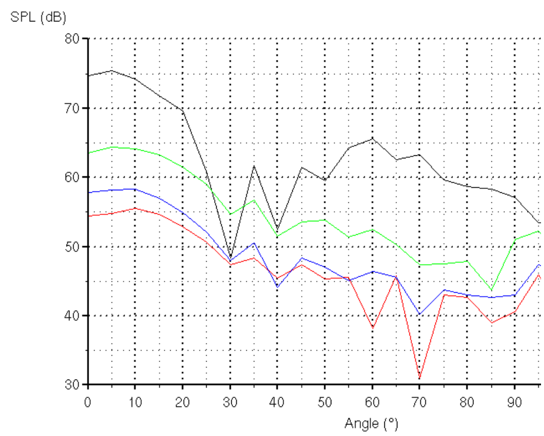



Fig. 4. No-flow tests of splice effects on radiated forward noise (kR=4). — Hardwall duct. — 1 circumferential splice liner. — A340-500/600 style 2 axial splices liner. — 0 splice liner.

As part of an extensive joint technology development programme between Airbus and Rolls-Royce, The 0 splice intake performance has also been measured on a Rolls-Royce 1/3 scale model fan rig. As shown in Fig. 5, the results revealed a significant reduction of noise at fly-over Cut-back engine working conditions.

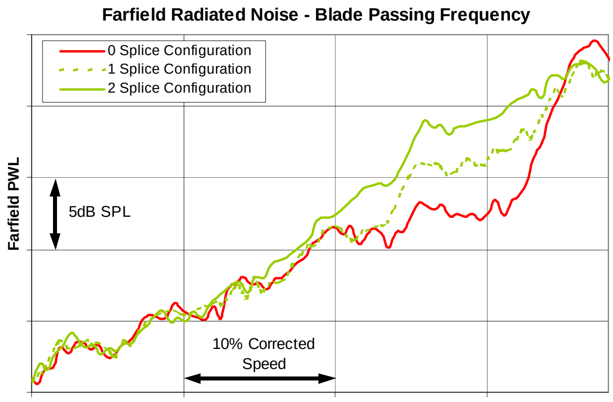



Fig. 5. 1/3 scale fan rig tests of splice effects on radiated forward noise. 1st Blade Passing Frequency fwd noise vs engine speed.

The results from this rig test programme will be the subject of a forthcoming joint Airbus/Rolls-Royce paper.

In conclusion, all tests done confirmed the high benefits due to splices reduction. As a result, the 0 splice intake will be used for the forthcoming 550 passengers A380 aircraft.

## 5 Impact on aircraft noise

Beyond the understanding of phenomena, this study allowed to compute the radiated noise fields in all relevant engine-working conditions, then extrapolate them in flight and finally predict the Aircraft noise savings in certification conditions.

First the results were analyzed considering the fan forward noise separately. Noise reductions were computed in terms of Effective Perceived Noise Levels (certification unit). The study showed that more than 3 EPNdB can be eliminated thanks to the 0 splice technology. This is a significant reduction especially if one keeps in mind that the reference was the low noise A340-500/600 style 2 thin splices intake.

Then, these predictions were applied to a generic long-range aircrafts. Up to –0.9 EPNdB reduction was predicted for a quad engine aircraft at fly-over cut-back condition.

## 6 Introduction to RAMSES intakes

On the ground of these promising results achieved on intake liner, Airbus undertook to extend the 0 splice concept to the entire intake. The first idea was to enhance also the benefit of the fan case liner, which is located between fan and the intake liner. The second idea was to take benefit of the following snowball effect: the efficiency of any liner in a nacelle duct is improved by reducing acoustic mode scattering upstream of propagation.

Then was born the RAMSES concept (Reduced Acoustic Mode Scattering Engine duct System).

The first aim of RAMSES project was to assess the effect of splices in the fan case liner on the efficiency of the 0 splice intake liner and then the attenuation efficiency of the complete intake.

The investigation was done through computations

### 6.1 Computational study

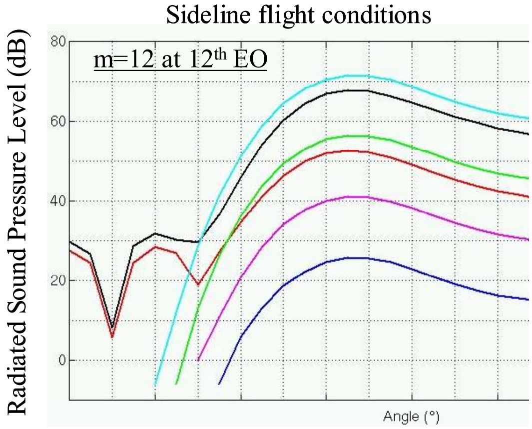
In the framework of A380 development, a BEM computation campaign was launched with the aim at evaluating several fan case lining technologies: the zero splice perforated one, a reference 3 splices perforated one and a hardwall one (no liner). Computations were done with both hardwall and 0 splice treated intakes.

The results are illustrated in Fig. 6. Two main conclusions were pointed out of this study

First, they confirmed the high benefit of eliminating splices everywhere in nacelle ducts.

Secondly, a close look at Fig. 6 allows identifying a very interesting behavior. With a hard wall intake, the acoustic lining of the fan case with 3 splices enables to reduce noise with respect to a hard wall configuration. But it can be the contrary for a lined intake: the efficiency loss due to splices is greater than the benefit due to the increase of treated area. It is a very meaningful demonstration that adding acoustic treatment somewhere in a nacelle duct can be detrimental if noise scattering is not controlled.

Sideline flight conditions




Directivity angle (degree vs engine axis)

Fig. 6. Acoustic radiation of 12th azimutal mode at 12th EO frequency at Sideline conditions.
— Intake HW – Fan-case (FC). HW.
— Intake HW - FC treated 3 spl.
— Intake HW - FC treated 0 spl.
— Intake treated 0 spl. - FC treated 3 spl.
— Intake treated 0 spl. - FC HW.
— Intake treated 0 spl. - FC treated 0 spl.

On the ground of these snowball effects of splices on the whole acoustic efficiency of intakes, Airbus designers are now working on the ultimate RAMSES intake configurations going from the fan up to the lip highlight without any acoustic distortions.

The zero splice intake and the RAMSES concept are Airbus patented technologies.

## 6 Conclusion

In this paper are summarized the results of Airbus recent studies on the reduction of forward fan noise thanks to improved acoustic liners.

The tremendous effect of splices between acoustic panels is first simulated and explained. These splices scatter the incoming noise so that the rotor modes, which are theoretically well attenuated by the liner, are converted into less attenuated modes. Fan forward noise is therefore less attenuated and aircraft noise is increased. Simulations and tests results are provided to illustrate the phenomena.

On these grounds, the RAMSES technology featuring an extension of the 0 splice concept to the entire intake is proposed. The idea is to consider that any reduction of scattering improves the efficiency of the next liner. Meaningful examples are provided on the effect of the fan case liner on the whole acoustic efficiency of the intake.

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