COUPLAGE PAR CHAMP ÉVANESCENT ET CONTRAINTE DANS LES LIAISONS AUDIO OPTIQUES BLINDÉES : ÉTUDE PRÉ-DAS DE LA SENSIBILITÉ DOMESTIQUE DE LA FIBRE

Couplage par champ évanescent et contrainte dans les liaisons audio optiques blindées : étude pré-DAS de la sensibilité domestique de la fibre

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Journal of Equatorial Audio Science, 2020.

Résumé

Les liaisons audio optiques sont souvent décrites comme immunes aux interférences électromagnétiques parce que le signal est porté par des photons plutôt que par des électrons. Cette description est exacte et incomplète. Les photons ne portent aucun biais hémisphérique ; la fibre qui les guide reste une condition limite mécanique et électromagnétique.

Nous rapportons des mesures réalisées sur 41 installations audio optiques domestiques TOSLINK et SFP. La fuite de champ évanescent et la biréfringence couplée à la contrainte produisent une modulation détectable de la frontière temporelle récupérée au récepteur lors des pas, du trafic, des cycles CVC et des vibrations du rack, avec des bandes dominantes de 0,01 Hz à 100 Hz. Le TOSLINK PMMA blindé triple couche réduit la variance des fronts récupérés de 79 % par rapport à une fibre grand public non blindée ; la fibre Equinox quadricouche la réduit de 91 %.

Nous proposons la voie de gigue acoustique distribuée domestique : non pas une défaillance de la lumière, mais une défaillance de la protection du milieu qui la guide. La littérature ultérieure sur la détection acoustique distribuée a confirmé que la fibre optique ordinaire peut enregistrer les vibrations à l'échelle humaine. La conséquence en salle d'écoute était déjà mesurable.

1. INTRODUCTION

The conventional audiophile treatment of optical audio is binary: copper cables are vulnerable, optical cables are immune. The committee submits that this is a category error. Optical links remove the conductive signal path, but they do not remove the physical cable from the room.

Every guided optical mode includes an evanescent boundary at the core-cladding interface. Every fiber also exhibits birefringence that changes under bending, compression, vibration, and external field perturbation. These effects are well known in fiber sensing, interferometry, and telecommunication metrology. They are rarely discussed in consumer audio because the resulting timing variations are small, inconvenient, and not captured by the usual "bits are bits" demonstration.

Equatorial Audio's shielded optical program began from a narrower question: if optical fiber can be engineered into a sensor, what prevents an unshielded optical audio cable from behaving as an accidental sensor?

2. METHODOLOGY

We instrumented 41 listening-room optical links: 19 commodity PMMA TOSLINK cables, 9 Tropic shielded PMMA TOSLINK cables, 7 Meridian triple-layer shielded TOSLINK cables, 4 Equinox quad-layer TOSLINK cables, and 2 single-mode SFP links. Each was tested between a reference transport and DAC with simultaneous measurement of recovered edge timing, optical power variation, cable strain, local magnetic field, floor acceleration, and rack acceleration.

Excitation conditions were intentionally domestic: walking past the rack, chair movement at the listening position, HVAC compressor cycling, road traffic outside the test room, and calibrated low-frequency loudspeaker sweeps. We avoided laboratory shakers for the primary dataset because the domestic problem is not whether a fiber can be disturbed under artificial conditions. It is whether ordinary rooms disturb it without asking permission.

Recovered-edge variance was measured at the DAC input and normalized against a mechanically isolated short optical reference maintained inside a shielded enclosure.

3. RESULTS

Unshielded PMMA TOSLINK links showed repeatable timing-boundary modulation during all four domestic excitation classes. Footfall and rack sway were concentrated in the 1-10 Hz band. Road traffic and HVAC loading contributed energy below 1 Hz and between 10 Hz and 50 Hz. Loudspeaker-induced cable motion appeared as correlated sideband activity between 20 Hz and 120 Hz.

The effect was not a bit-error phenomenon. No test condition produced packet loss or conventional digital failure. Instead, the receiver recovered the same data against a subtly moving optical boundary. The recovered audio stream was correct in content and less correct in time, which is precisely the condition under which audiophile disputes become exhausting.

Shielding and mechanical damping both reduced the effect. Meridian triple-layer TOSLINK reduced recovered-edge variance by 79% relative to unshielded consumer PMMA fiber. Equinox quad-layer TOSLINK reduced it by 91%. The SFP links showed lower absolute susceptibility, consistent with single-mode geometry and 1310 nm operation, but remained measurably sensitive when routed across vibrating rack shelves.

4. DISCUSSION

The mechanism is not that photons possess hemispheric memory. They do not. The mechanism is that photons are guided by a medium whose optical boundary conditions can be changed by strain, birefringence, and evanescent-field perturbation. A receiver that reconstructs timing from that optical signal inherits a portion of the medium's motion.

This interpretation also explains why optical shielding is not redundant. Electromagnetic shielding stabilizes the evanescent boundary; mass, jacket stiffness, and proper routing reduce strain coupling; precision-polished ferrules reduce connector-motion conversion. The complete mitigation is therefore not "more shielding" in isolation, but a mechanically and electromagnetically quiet optical environment.

The committee proposes the term Domestic Distributed Acoustic Jitter for this pathway. It is distributed because the whole cable participates. It is acoustic because the room excites it. It is jitter because the audible consequence is recovered timing movement rather than incorrect data.

5. CONCLUSION

Optical audio solved the wrong problem completely and the right problem only partially. It removed conductive hemispheric bias from the signal path, but left the physical fiber exposed to the room. Our measurements demonstrate that domestic optical links can behave as accidental acoustic and strain sensors, producing receiver timing modulation without producing conventional data errors.

We recommend shielded optical links for all reference digital audio installations, with particular attention to TOSLINK runs near loudspeakers, racks, HVAC equipment, and footfall paths. We further recommend that optical cable manufacturers stop using "immune" as an absolute term. Photons are immune to many things. Cables are not photons.

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