Effect of Smooth Bends on Microwave Electromagnetic Surface Wave Propagation

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Introduction

Vehicles are becoming more and more computerized, each of these components needs to be connected via copper wiring. In an aircraft this cabling can total 42 miles in length [1].

The disadvantages of this are threefold:

- Copper is increasingly expensive.
- Copper is heavy in the required amounts.
- Copper is becoming increasingly scarce.

These effects compound together to form an environmental issue, the increased weight of the aircraft increases fuel consumption. The copper mining industry also produced 75 Mt of CO_2 in 2016 [2].

Instead of transmitting the signals via copper wiring, SurFlow aims to instead transmit these signals via surface wave bound to the chassis of the vehicles itself, removing the need for copper wiring.

Theory

The chassis of vehicles in aerospace are typically constructed with a metal outer layer, with a composite layer mounted inside. These composites are generally fibre reinforced. The reinforcing fibres can be, for example, glass or carbon however they can support the same types of modes as an isotropic dielectric slab.

This system has been widely studied and is able to support a family of modes like the modes present in a parallel plate waveguide. Due to the upper boundary being now a 'soft' dielectric-air boundary the fields are evanescent perpendicular to the surface, this is shown in figure (1). It is using these modes that the signals may be transmitted.

The signals are bound within the dielectric and thus will keep to the dielectric around geometrical features such as bends, however they will not do so without a degree of signal loss in the form of air waves.

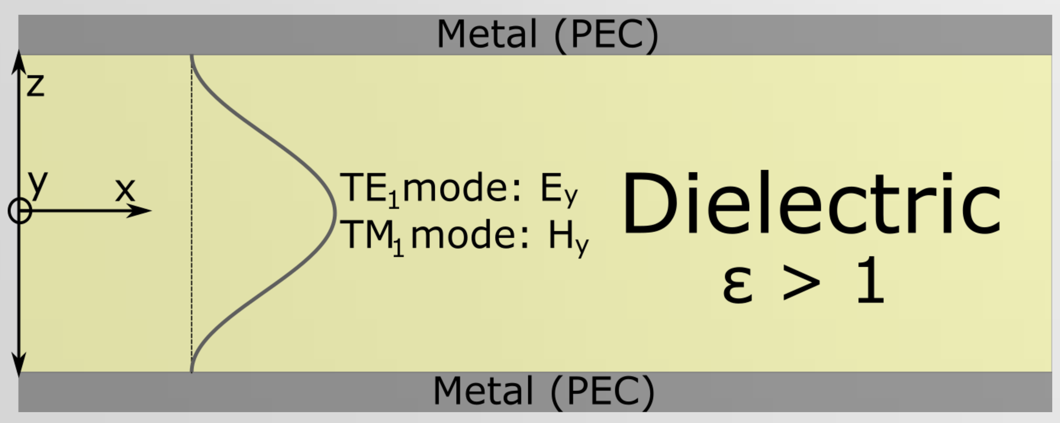

Figure 1a. Dielectric filled parallel plate waveguide

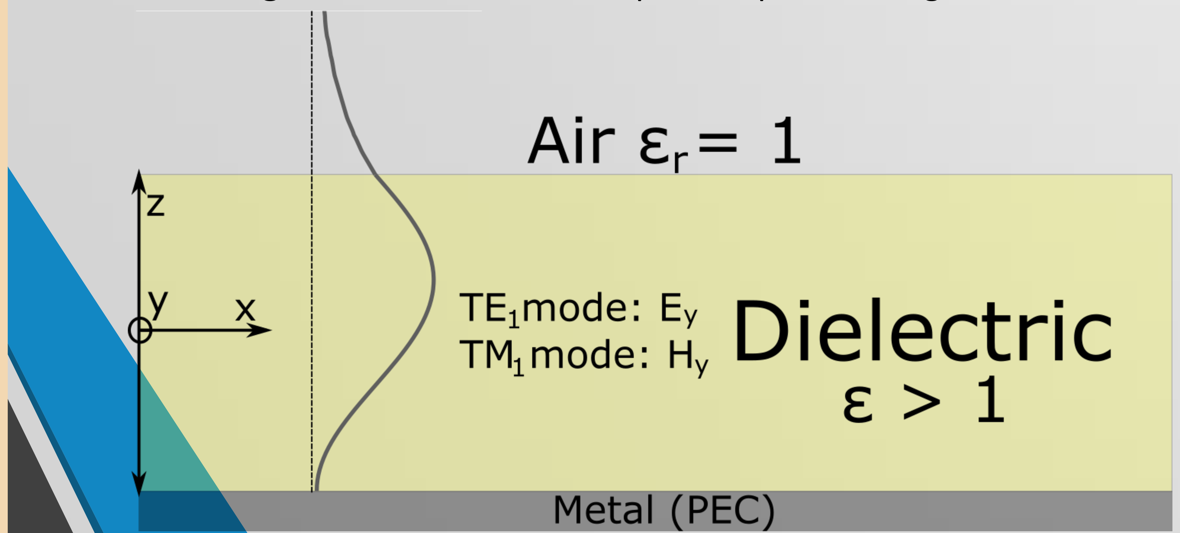

Figure 1b. Grounded dielectric slab

Copper wires are expensive, heavy and environmentally damaging and, soon, scarce.

Method

These modes have been simulated using the FEM solver Comsol, with the set-up shown in figure (2).

The power transmission around the bend will not be 100% as the distance the mode must travel around the inside of the bend is shorter than the distance the mode must travel around the outside of the bend, this results in a phase mismatch which results in loss.

This can be seen in figure (3) where the field amplitudes after the bend are significantly weaker than before the bend.

The transmission around the bend is increased by increasing the relative permittivity of the dielectric to 20 around the bend compared to 5 in the straight sections, this is seen in figure (4) where the relative field amplitudes before and after the bend are now similar. This corresponds to an increase in power transmission from 20% to 80%.

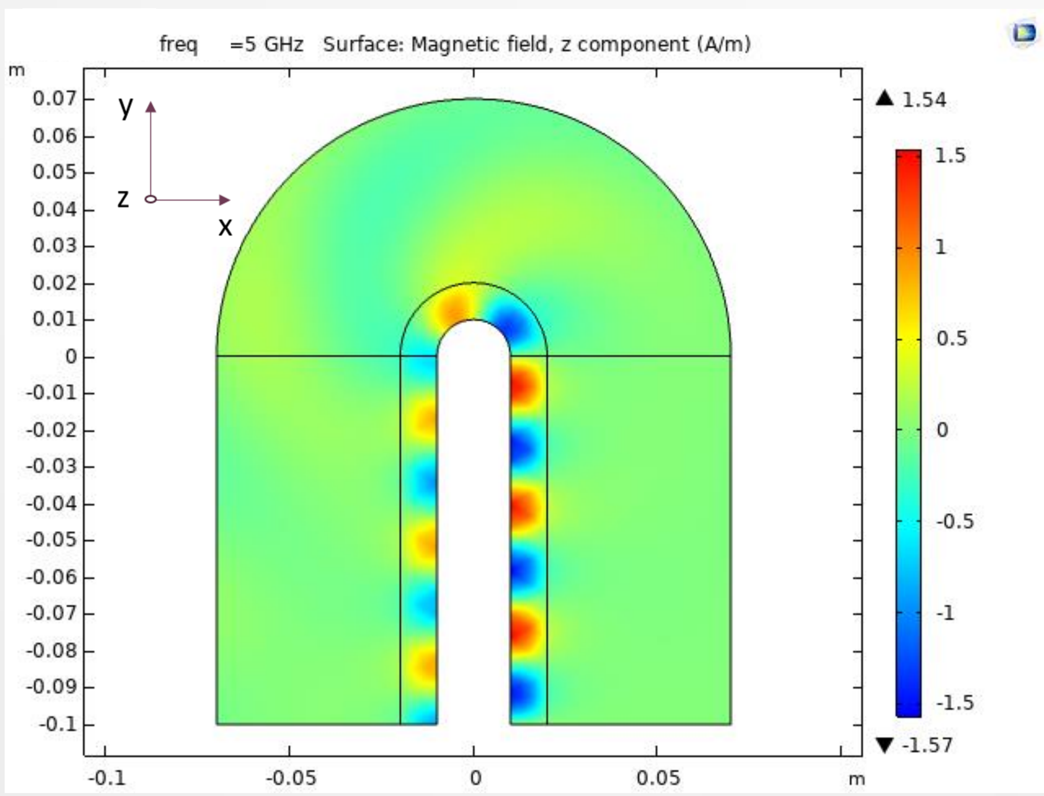

Figure 3. Loss due to bend in the dielectric. Field amplitude is lower on the LHS compared to the RHS

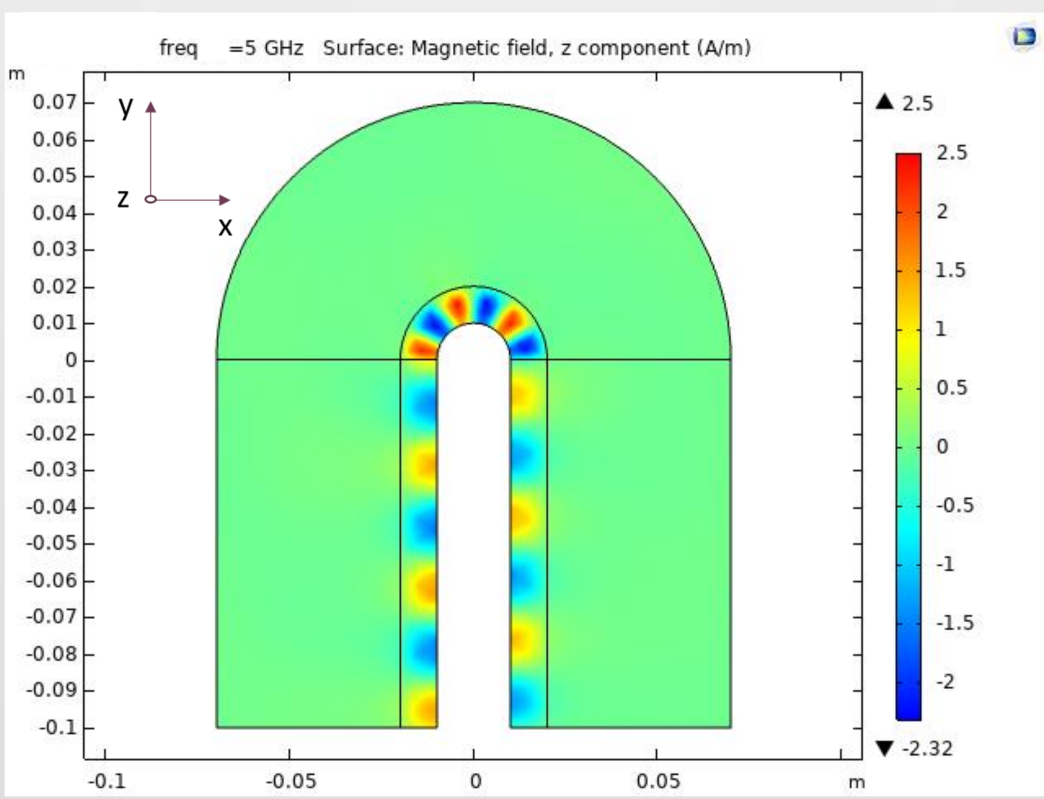

Figure 4. With the increased permittivity around the bend, losses are reduced as the relative amplitude remains constant.

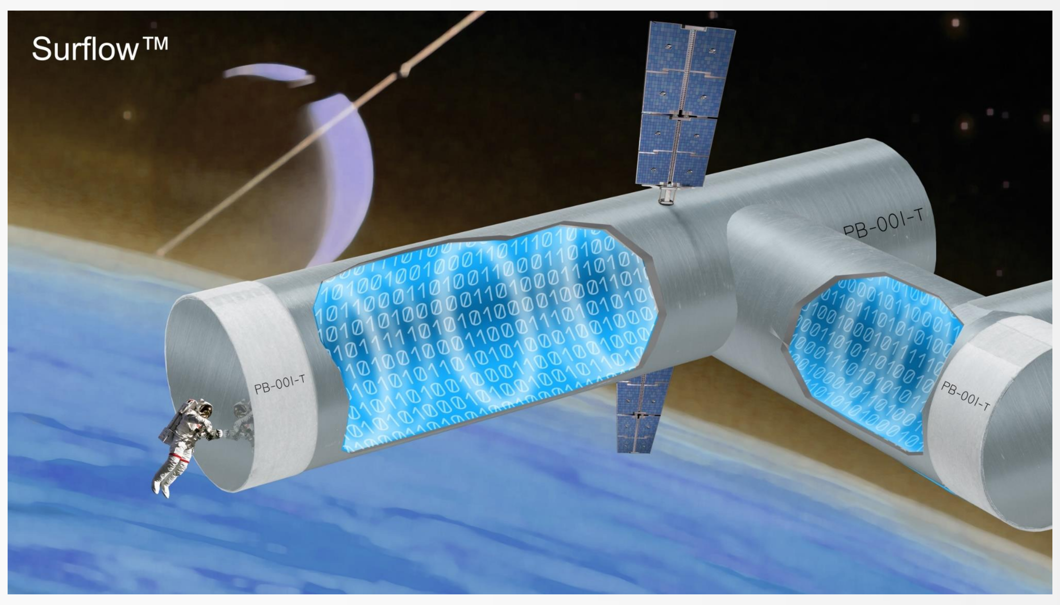

Figure 5. Removing cabling from space shuttles could reduce fuel costs. [3]

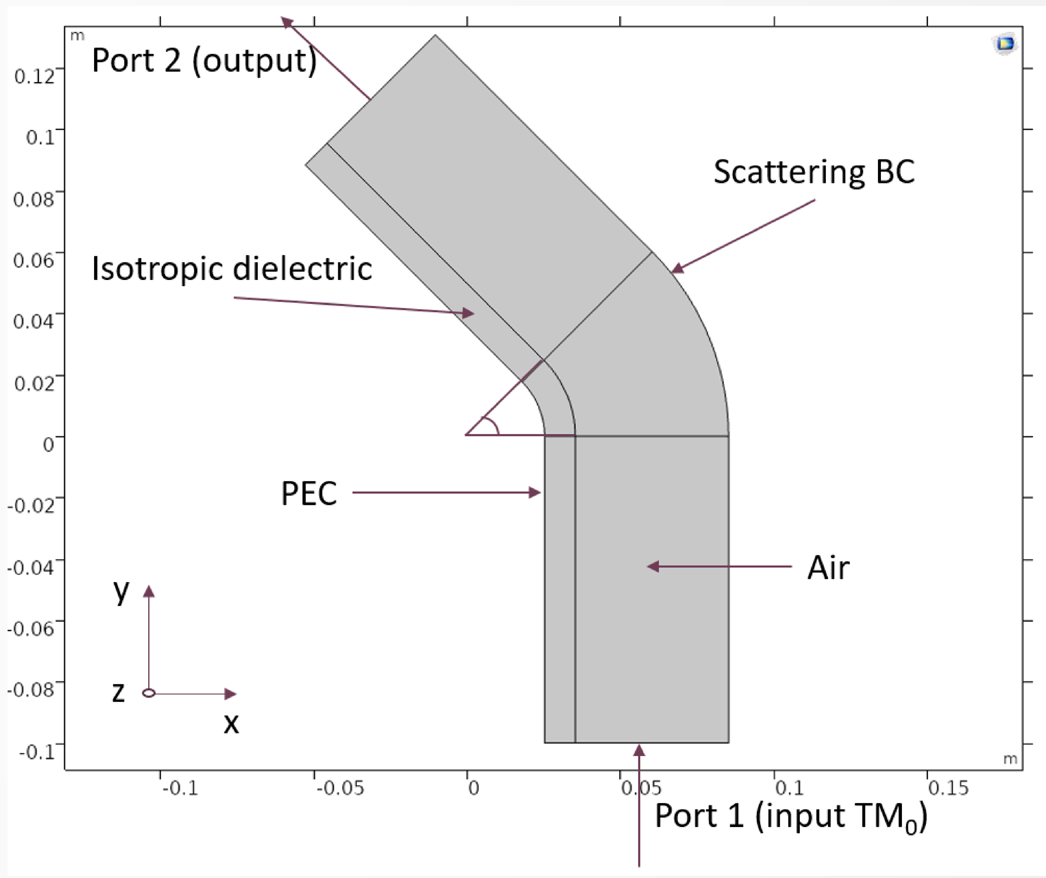

Figure 2. Simulation set-up in Comsol

Discussion

We have shown that by increasing the permittivity in the curved region, the losses due to the bend may be reduced by a large factor. This means the bend is effectively cloaked to the surface wave – it acts as though the bend is not there.

This is important for two reasons:

- Losses lead to air waves which may be intercepted.
- Losses mean the signal may not be received at all by the requisite component.

Future Work

This work has detailed the possibility of cloaking one type of geometry. In the real case there are many other types of geometry to consider. For example, bumps, terminations and inside bends.

Geometry is not the only factor which will affect signal propagation around a real aircraft fuselage. There will also be scatterers in the form of metal rivets within the dielectric due to structural constraints.

The dielectric itself will also be anisotropic due to the woven nature of the composite.

All these parameters must be investigated, and their effects minimized in order to ensure secure, efficient signal transmission.

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