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Modelling of Zenneck Wave Transmission System in Super High Frequency spectrum

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Abstract

Zenneck wave (ZW) have shown potential to address the Faraday shielding losses offered by metallic components to the wireless systems in the industrial environments. Understanding ZW properties becomes particularly important in the super high frequency (SHF) spectrum, for their applications to Industrial Internet of things (IIoT). In the past we had shown that ZW's transmit power to multiple receivers for a range of 1.5 times the wavelength in the high frequency (HF) spectrum. The range of ZW's in the SHF spectrum becomes an important aspect for their applications to 1-3GHz and 5GHz technologies. In this study we gain important insights into the ZW behaviour through finite element methods numerical simulation. The study would be helpful for researchers and practicing engineers in developing wireless solutions for IIoT.

Keywords: Electromagnetics; Surface waves; Zenneck Waves; Wireless Power Transfer; Power.

Introduction

The Zenneck wave (ZW) system for transmission of electrical power was demonstrated by us in [1],[2]. ZW's are interface electromagnetic (EM) waves and are a subset of surface EM waves, the majority of their energy is carried in the form of modes/packets of energy.

Our earlier work in ZW was focused in the HF spectrum and needs a thorough numerical investigation for their scalability in the SHF spectrum. We had demonstrated that in the HF spectrum it was possible to transmit power and data efficiently across several metal obstacles aboard the marine vessels and under laboratory conditions.

Since the wireless network of an IIoT systems suffer from signal losses due to Faraday shielding effect due to metals, therefore, the ZW systems presented by us attracted considerable interest [3].

However, the performance metrics of ZW's in the SHF spectrum remained unanswered. The SHF spectrum is where the bulk of the wireless systems

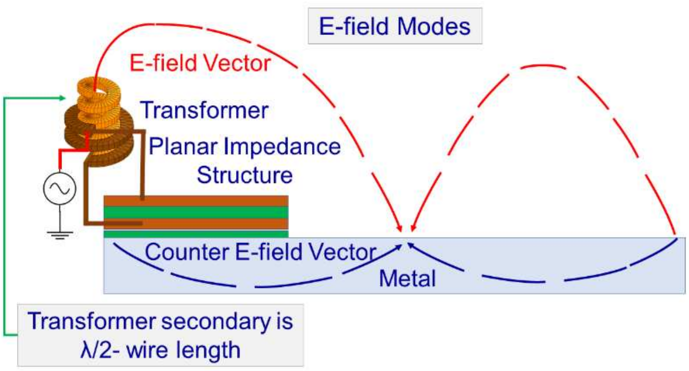

Figure.1. Concept Diagram: E-field modes generated by the resonator system on metal surface

such as proprietary long-term evolution (LTE) networks, WIFI, Bluetooth, Zigbee and USRP exist[4-7].

For example, it remains unknown if ZW can transmit signals beyond 10λ (λ is wavelength) in the SHF spectrum. Prediction of such important metrics shall be useful in defining specifications and standards for IIoT systems.

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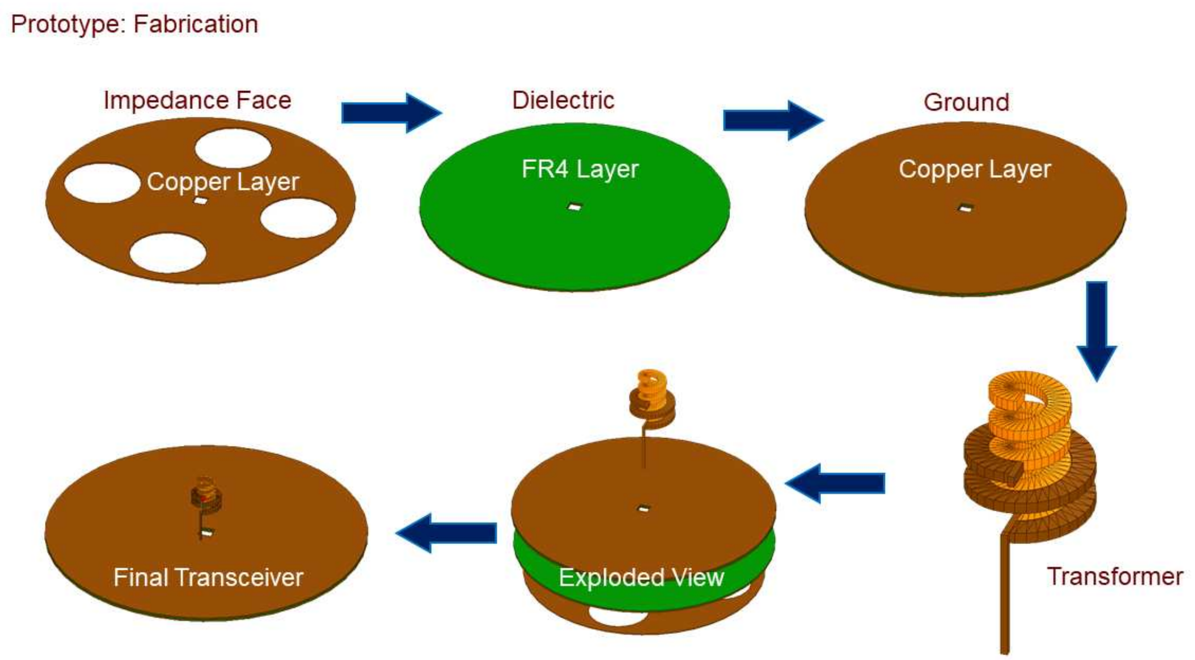

Figure.2. Prototype Fabrication steps and FEM Model; Excitation is provided across the transformer terminals

TABLE I
DIMENSIONS

Parameter	Dimensions	Units
Planar structure Diameter	120	mm
Planar structure layer Height	0.5	mm
Primary coil diameter	7.2	mm
Secondary coil diameter	5	mm
Primary Turns	2	-NA-
Secondary Turns	5	-NA-
Pitch	3	mm
Mesh Circular slot diameter	30	mm
Coil Height × Width	1×1	mm

FEM Model

In this study we built an FEM model suitable for SHF zone on a commercially available full wave electromagnetic simulation software tool. We use the concept of planar waveguide with a half-wave open-ended secondary transformer across the waveguide to drive the voltage across the terminals. The concept diagram is shown in Figure 1. On the other hand, the Figure 2 shows the fabrication of the transceiver with its construction and its dimensions are listed in table I.

Experiments, Results and Discussions

ZW is a near-field systems the field profiles become important parameter in the evaluation of metrics. The reflectance parameters are also known as S11 parameters play a critical role in the evaluation of the said system at hand.

The Figure 3A shows the reflectance parameters(angle) as function of length of coil. At resonance the S11 angle reverses polarity from negative to positive. Thus, indicative of a non-capacitive and a dominant inductive nature of the system

The Figure 3B shows the reflectance parameters as a function of length of coil. In both the cases, the resonant frequency of the system can be adjusted by changing the secondary coil lengths.

The Figure 3C shows the simulation of the E-field modes or Zenneck Iso-phases. The Iso-phases are tilted backwards for the case of metal-air interfaces, as predicted by the simplified form of the equation earlier presented by us [1,2].

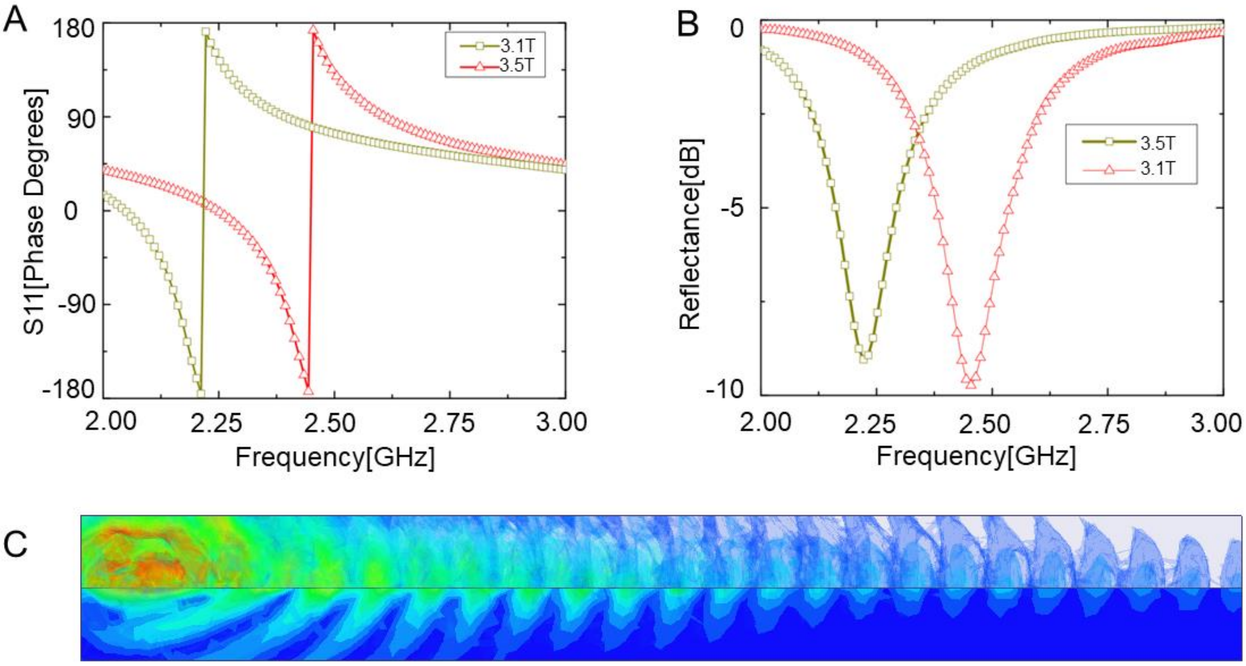

Figure.3. Simulations: A Reflectance in degrees. B. Reflectance in decibels C. E-field modes or Zenneck Iso-phase along a metal of 1540mm length.

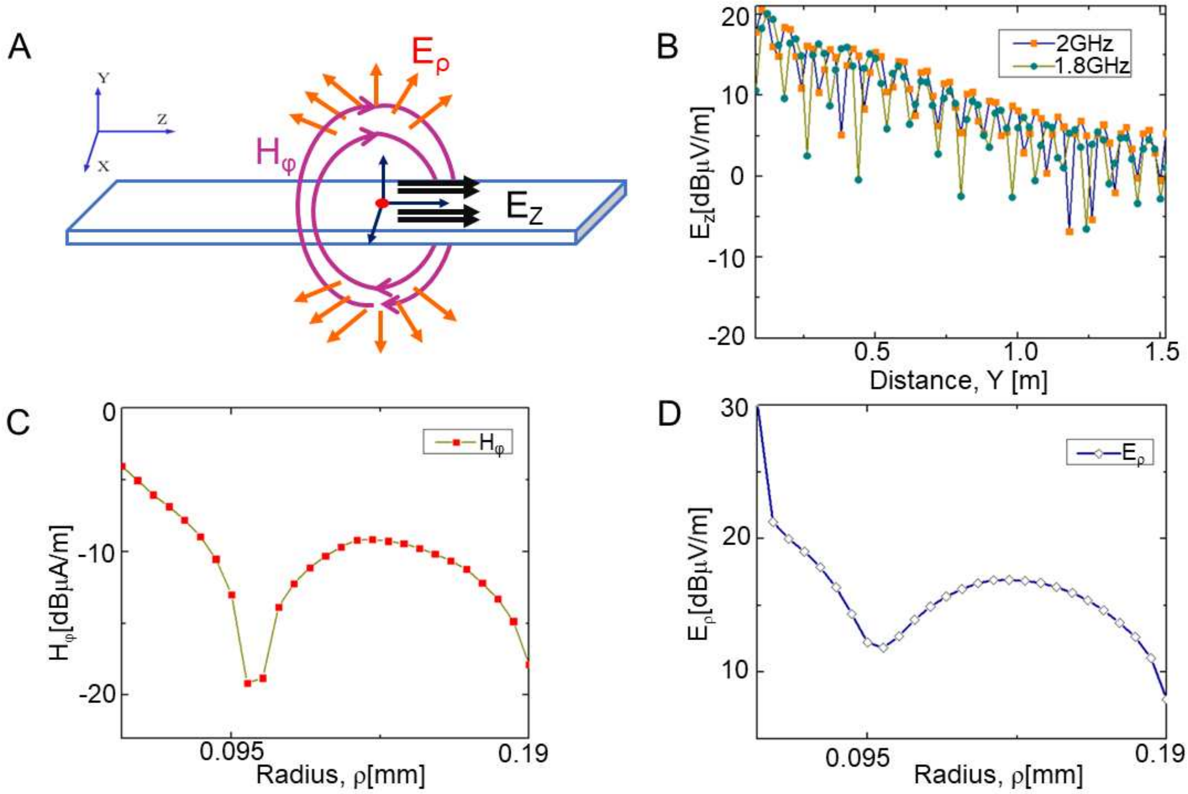

Figure.4. Field Profiles: A. TM Mode Fields around the metal due to excitation of Zenneck Waves; B. Electric field attenuation along the metal air interface independent of Frequency; C. Magnetic field radial decay away from metal; D. Electric field radial decay away from metal.

The Figure 4A shows the radial fields setup around the metal due to a transverse magnetic (TM) mode.

The Figure 4B shows the E-field attenuation along the metal-air interface for 2GHZ and 1.8GHz. As expected, the attenuation in the present case is of similar magnitude despite of the change in the frequencies. This was also the case in the articles [1,2,4].

The Figure 4C is the H-field radial decay away from the metal surface. The corresponding E-field decay is shown in Figure 4D. It is evident that the field decays quickly away from the interface of the metal and air. Hence the major part of the EM energy exists at the interface.

Conclusions

In this study we attempted to provide useful insights into the FEM modelling of the ZW systems for the SHF zone. The S11 Phase angle result shows that the ZW system is not capacitive in nature in the SHF zone.

The Simulation model shows the frequency dependence on the resonant length of the open ended secondary of the transformer.

Based on the field attenuation rates obtained from the FEM modelling, along the metal-air interface the field decay is extremely slow irrespective of the frequency. These results do indicate that the communications can be conducted for > 300λ distance [5,6]. This range is at least 1.5 times the current Bluetooth and WIFI capabilities in an industrial setting.

Power transmission using the system in its current form would witness high losses. The transmittance parameters observed in the present design are at a maximum of -23.76dB (not disclosed here). However, an appropriate excitation network must be designed to attain high transmittance parameters, also noted in the study [6].

The findings of the study can be beneficial in the design of wireless systems for their applications in the IIOT [7].

Author Contributions

Dipra Paul [DP], Sai Kiran Oruganti [SK] and Ajit Khosla [AK].

DP & SK were responsible for simulations; SK & AK were responsible for design idea and draft of the manuscript.

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Data

The authors have no data to declare.