Application of Ferromagnetic/Ferroelectric Material to Design Reconfigurable Components for Smart Millimeter-Wave Systems

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***Abstract*—Millimeter wave (mmWave) is known as the key toward higher transmission capacity and speed in under development 5G networks. However, smart mmWave communications seems more promising by enabling smart RF resource (frequency band, polarization, power and etc.) allocation resulting in improved quality of service and efficiency. On the other hand, ferromagnetic materials shows a great potential in realizing tunable component needed to build an smart system. This brief reports the author works on exploiting the nonreciprocal and variable properties of ferromagnetic materials in order to design tunable component required in a smart antenna array for 30 GHz mmWave communication.**

***Index Terms*—Ferrite, mmWave, Smart Antenna, Tunable Component.**

I. Introduction

THE air interface of the 5G networks is evolving toward micro, pico and femto cells with a very dense topology resulting is high co-channel interference. As a results, smart antenna arrays and smart antenna beamforming are gaining a lot of attentions by providing opportunities for higher system capacity, improved quality of service (QoS), improved power efficiency. Millimeter-Wave (mm-Wave) is known as one of the key enabling technologies of 5G to provide very high transmission capacity.

Tunable components are the key toward smart antenna systems. Ferrite as the most common ferromagnetic materials are widely used in realizing tunable and nonreciprocal devices. Poldar tensor defines the dependence of ferrite characteristics versus an applied magnetic bias. However, the actual solutions for tunable components are not adapted to mm-Wave in terms of loss, efficiency, integrability and switching speed. The most common way in realizing a tunable component based on ferrite is to use a magnetic bias field to set the ferromagnetic resonance frequency close to the desired communication frequency. This requirement leads to an extreme magnetic bias in higher frequencies making it impractical for 30 GHz mm-Wave applications.

This brief shows the authors approach in employing ferrites to build integrable tunable components for an smart mmWave antenna system. Despite conventional method in using an strong magnetic bias to change the permeability of the material, authors achieve tunablity by using mechanical movements or controlling the Poldar tensor by adjusting the direction of the magnetic bias applied to the ferrite material. These have enabled tunble component that does not rely on a very strong magnetic bias resulting in more integrable designs.

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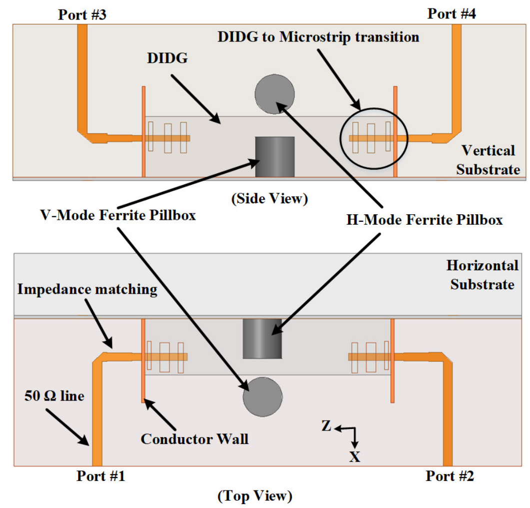

Fig. 1. Schematic of the controllable orthogonal mode transducer (OMT) proposed in [1].

II. Ferrite Based Tunable Components for Smart mm-Wave Communication

Figure 1 shows the schematic of the controllable orthogonal mode transducer (OMT) for smart polarization diversity application at 29 GHz mmWave communication proposed in [1]. The design employs a pair of horizontally (axis of cylindrical is parallel to the horizontal ground) and vertically (axis of cylindrical is normal to the horizontal ground) placed ferrite pillboxes to filter (if wanted) the horizontal or vertical polarizations traveling within the dual image dielectric line.

TABLE I
Different state of the controllable orthogonal mode transducer (OMT) proposed in [1] (1 means a the magnetic bias fields is normal to the grand plane holding the pillbox while -1 means the opposite direction).

State	V-bias	H-bias	Resulted Communication
(1)	1	-1	H-Polarized
(2)	-1	1	V-Polarized
(3)	-1	-1	Dual-Polarized
(4)	1	1	No Communication

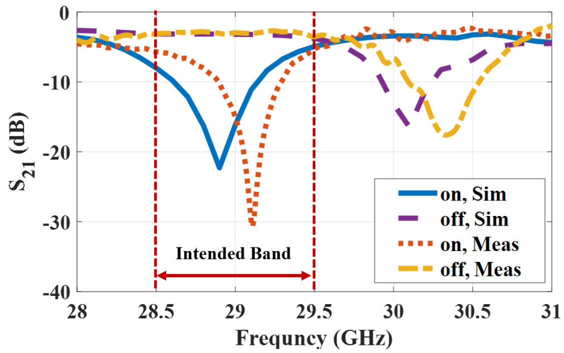

Fig. 2. Transmission loss of the proposed controllable OMT reported [1] showing vertical polarization filtering states.

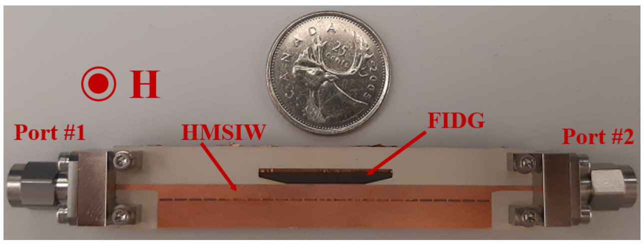

Fig. 3. Fabricated tunable isolator based on RO6002 and LF-1300-150 reported in [2].

Therefore, by controlling the magnetic DC bias of the ferrite pillboxes as shown in Tab.I, undesired polarization can be filtered out. Fig. 2 shows the vertical polarization insertion loss of the fabricated prototype showing the polarization can be filtered out by controlling the magnetic bias direction of the related ferrite pillbox. The prototype used a permanent magnet having surface field of 3158 gauss as the magnetic bias of the two ferrite pillbox. This relatively small magnetic field make the design desirable for integrated applications.

A tunable isolator is reported in [2] that provides the tunability by changing the distance between the ferrite slab and half-mode substrate integrated waveguide (HMSIW). Fig. 3 shows the fabricated tunable isolator that includes a ferrite based image dielectric guide placed close to magnetic wall of the HMSIW. Fig 4 shows the measured isolation of the proposed isolator for different positions of the ferrite slab. Similar to the reported controllable OMT, the tunable isolator is using a lightweight permanent magnet having a strength of 1mT.

III. Conclusion and Future Works

This brief has summarized the authors latest published designs achieving ferrite based tunable component for smart mm-Wave communication. Despite conventional method of using a relatively high magnetic bias on the ferrite, the reported designs exploits magnetic bias direction variation (in [1]) and mechanical movement of the ferrite slab (in [2]). These works highlight the possibility of achieving integrable tunable components that do not require an extreme magnetic bias for high frequencies such as 30 GHz.

The reported designs have unveiled the potential of the authors approach in employing ferrite materials in mm-Wave

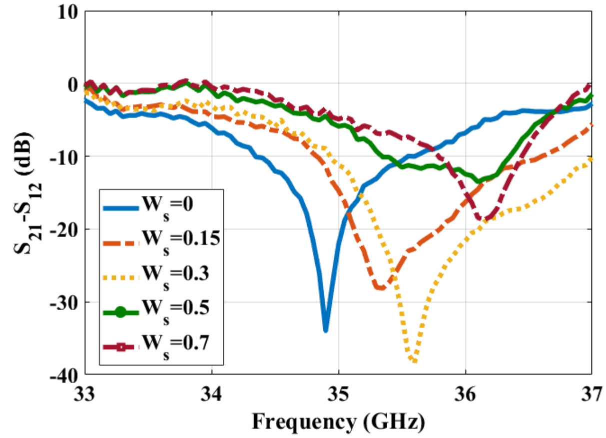

Fig. 4. Measured differential isolation provided by the tunable isolator reported in [2] versus different distance between the ferrite slab and HMSIW excluding the effective width of the HMSIW. W_s unit is mm.

range to achieve tunable component for future smart communication. Integrating the reported controllable OMT with a dual polarized antenna to have a fully tunable front-end and a fully integrated filter are the under development works of the authors.

Career Plan and Statement

It was indeed a true honor to receive the MTT-S Graduate Fellowship Award. Being selected as one of the recipient significantly boosted my motivation and confidence to continue my research activity. It's been a great experience and has opened interesting opportunities for me. I would like to acknowledge the committee members effort and the impact they are making on students experience and career development.

Currently, I am finalizing my last works to finish my Ph.D. I've started an internship to familiarize myself with industry. I am planning to enter an industrial career after graduation and use my academic skills and knowledge in developing tunable front-ends for future smart communication. Depending on the early experience in industry, I will make a decision on staying in industry or reentering the academia via a post-doc position.

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References

[1] M. Noferesti and T. Djerafi, "Controllable Orthogonal Mode Rejection for Smart Polarization Diversity at Millimeter-Wave Frequency," in IEEE Transactions on Circuits and Systems II: Express Briefs, vol. 68, no. 1, pp. 171-175, Jan. 2021, doi: 10.1109/TCSII.2020.3011513.

[2] M. Noferesti and T. Djerafi, "A Tunable Ferrite Isolator for 30 GHz Millimeter-Wave Applications," in IEEE Transactions on Magnetics, vol. 57, no. 7, pp. 1-7, July 2021, Art no. 4001707, doi: 10.1109/TMAG.2021.3071684.