The Double-sided 4-port Bow-tie Antenna: A New Compact Wideband MIMO Antenna

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The Double-sided 4-port Bow-tie Antenna: A New Compact Wideband MIMO Antenna

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***Abstract*—We present a new compact ultra-wideband 4-port antenna for use in MIMO systems, such as in reverberation chambers for OTA measurements. The new antenna is based on the self-grounded bow-tie antenna with a very compact size. The design was done through an optimization by employing the genetic algorithm in order to obtain low reflection coefficient and mutual coupling between ports. The designed antenna has an embedded radiation efficiency higher than -0.35 dB, reflection coefficient below -7 dB, mutual coupling between ports below -12.5 dB (in most frequencies below -20 dB), over a frequency range of 0.4–15 GHz.**

***Index Terms*—MIMO antenna, ultra-wideband, bow-tie antenna**

I. Introduction

The reverberation chamber (RC) is a measurement instrument used to characterize small antennas for wireless devices as the active devices themselves, such as cell phones. The reverberation chamber is capable to emulate an isotropic multipath environment. A typical reverberation chamber is a metal cavity with a size large enough to support many resonant modes at the frequency of test [1], [2].

In order to have a wideband measurements by a reverberation chamber, the calibration antennas and the chamber-fixed antennas must have a wideband performance. As an example, the RTS90 Bluetest reverberation chamber [3] can make accurate measurements down to 0.4 GHz, and it is an advantage to locate the three chamber antennas closely together in one unit with three uncoupled ports. The purpose of this work is therefore to develop an extremely wideband 4-port antenna working from 0.4 GHz to a frequency as high as possible (we reached 15 GHz) for use in reverberation chambers, and potential use in other MIMO (Multiple Input Multiple Output) communication systems. The reason that we would like to reach 15 GHz is that we can do measurements for wideband antennas, such as 2–14GHz Eleven antenna [4]–[6].

The design concept is an utilization of the self-grounded bow-tie antenna [7], [8], which has many applications in ultra-wideband (UWB) systems [9], [10]. Then, the dimensions of the antenna has been optimized by using genetic algorithm via simulations by CST MWS.

Another ultra-wideband MIMO antenna we have investigated is to the so-called eleven antenna [11], [12]. The Eleven antenna is an 8-port antenna and can be used for MIMO systems, but the geometry is much more complicated than the antenna presented in the paper. Therefore, this work is focused on developing a multi-port bow-tie antenna for MIMO systems [13].

The multi-port bow-tie antenna is protected by a pending patent [14].

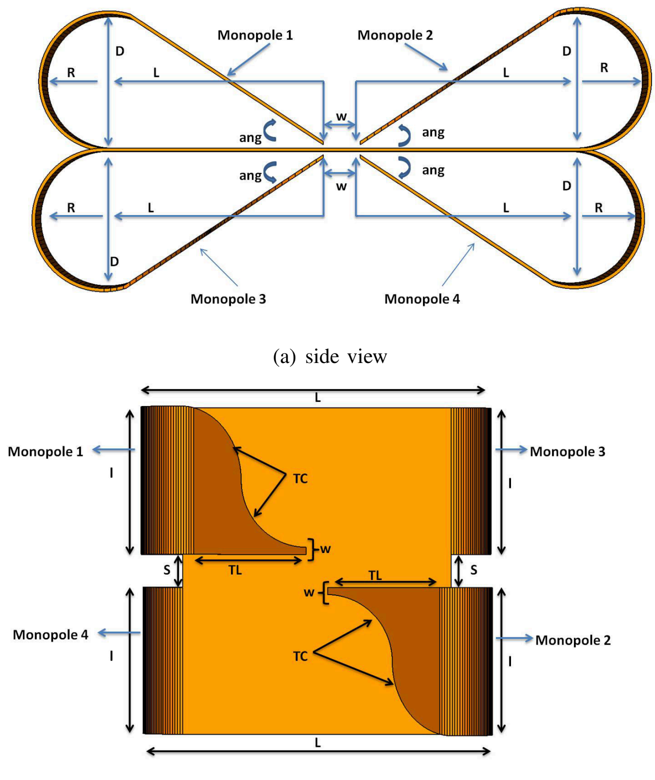
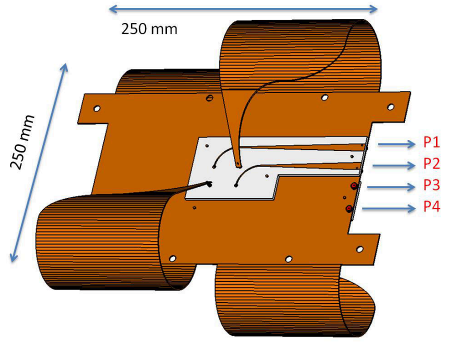


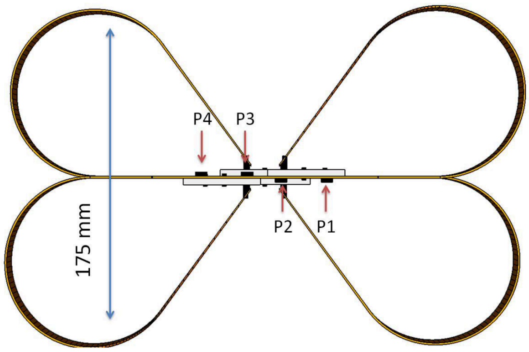
Fig. 1. Antenna Genes: 7 dimensional parameters

II. Antenna Modeling and Optimization.

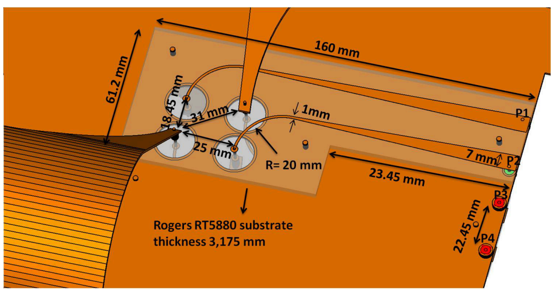
The antenna shown in Fig. 1 has been modeled in CST MWS. The idea is to use the self-grounded bow-tie antenna concept to generate a multiport antenna made of self-grounded monopoles, i.e several half bow-tie elements. Each monopole has the same geometry consisting of a tapered exponential



(a) perspective view



(b) side view



(c) The designed Wideband impedance Transformer

Fig. 2. The final geometry of the optimized wideband MIMO antenna

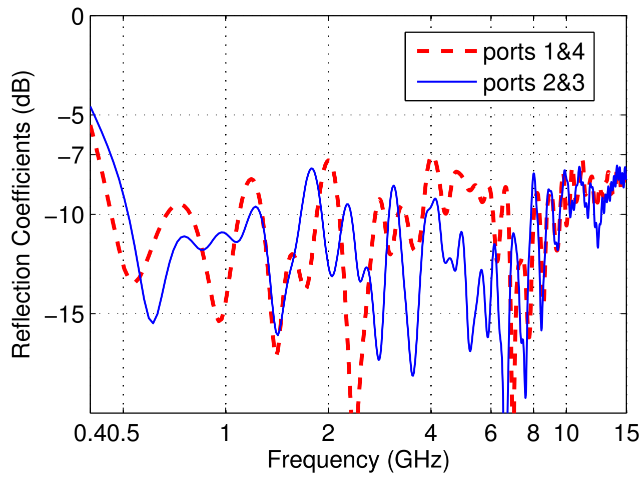


Fig. 3. Simulated reflection coefficients at all ports of the designed antenna.

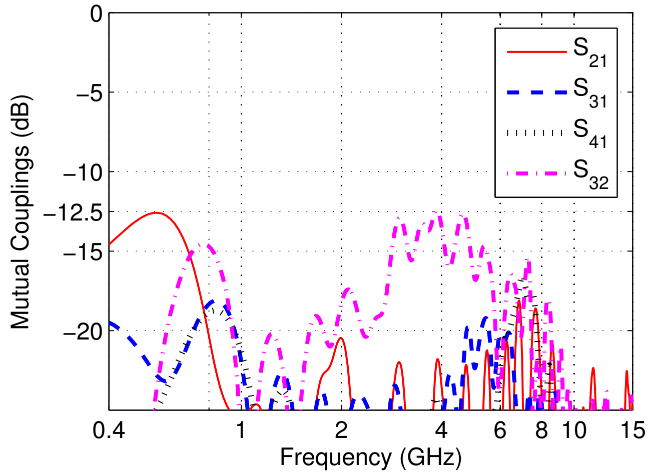


Fig. 4. Simulated mutual couplings between ports of the antenna

form in order to provide wideband performance. By an optimal arrangement, four monopoles are combined in such a way that the four ports together has a wide radiation coverage over the entire unit sphere, and low correlation between the ports in rich isotropic multipath (RIMP) environment. Both features are needed in order to ensure good performance both in RIMP and in random Line-of-Sight (LOS) [15]. The monopole has its inherent characteristic impedance of 135 Ohms. Therefore, a wideband impedance transformer from 135 Ohms to 50 Ohms is designed by using a microstrip line transition on a printed circuit board (PCB), and connected to the port of each monopole, as shown in Fig.2.

The genetic algorithm (GA) optimization scheme has been employed in the design. The configuration of the proposed antenna provided a good enough isolation between ports (i.e., a mutual coupling). Therefore, the optimization is mainly to minimize the reflection coefficients of all ports over the whole band. The algorithm also monitors the mutual couplings to ensure that the good performance is preserved along the optimization precess.

The geometrical configuration of the single monopole is described by seven genes, shown in Fig.1. One combination of these genes forms a chromosome string presenting one antenna. A group of chromosomes form the initial population. In this work, a population of 300 individuals is created randomly in the initial generation. A dominating sorting and natural selection transfer the best 15 individuals to a mating pool where they cross over each other to produce the next generation. The optimization precess is terminated after fourth generations when convergence status is observed. The algorithm is written in MATLAB.

III. Simulated and Computed Results.

Fig. 3 shows the simulated reflection coefficients at all four ports, which are all below -7 dB over 0.5–15 GHz and

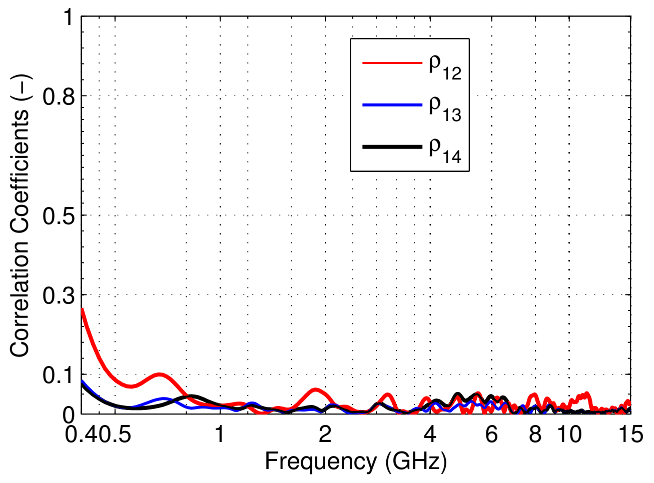


Fig. 5. Envelop correlation coefficients, computed from the S-Parameters.

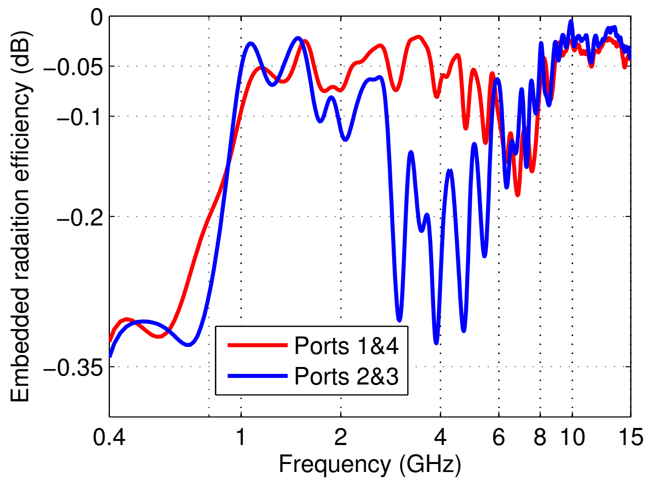


Fig. 6. Computed embedded radiation efficiency (mismatch factor not included).

almost below -5 dB down to 0.4 GHz. A slight difference in the performance between the ports is due to the different physical arrangements of the transformers. Monopoles 1 and 4 (monopoles 2 and 3) are images of each other; see Fig. 2(c). Therefore, they have the same performance.

All mutual couplings between ports are below -12.5 dB over the whole band; see Fig. 4. This performance is crucial for the antenna to have low correlation between the ports in order to have a good diversity measurement in RIMP for use in MIMO system. Fig. 5 shows the corresponding correlation coefficients, which is below 0.1 over the frequency band 0.5–15 GHz.

The embedded radiation efficiency is the contribution of the efficiency due to the antenna ohmic losses and the decoupling efficiency due to fractions of the input power being coupled to the neighboring ports excluding the miss match loss (i.e reflection coefficients). Fig. 6 shows that the embedded radiation efficiency is higher than -0.35 dB over the whole frequency band, a very good performance for this MIMO antenna. Fig. 7 shows that the total embedded radiation efficiency which is the aforementioned efficiencies including the miss-match loss is better than -1 dB in the frequency band 0.5–15 GHz. It can be noticed that the miss-match loss efficiency has the dominant impact on the total embedded radiation efficiency.

The radiation patterns of one monopole, excited only at port 1 and terminated at other ports, is shown in Fig. 8. It can be observed that when we use all four ports, the MIMO antenna can provide a wide coverage over a wide band.

IV. Measured Results

A prototype has been manufactured as shown in Fig. 9. The measurement of the antenna S-parameters has been conducted in the frequency range 0.4–9 GHz. The measured reflection coefficients is below -6.5 dB and better than -7 dB in the most of the measured frequency band (0.4–9 GHz); see Fig. 10. The isolation between ports is excellent as the measured

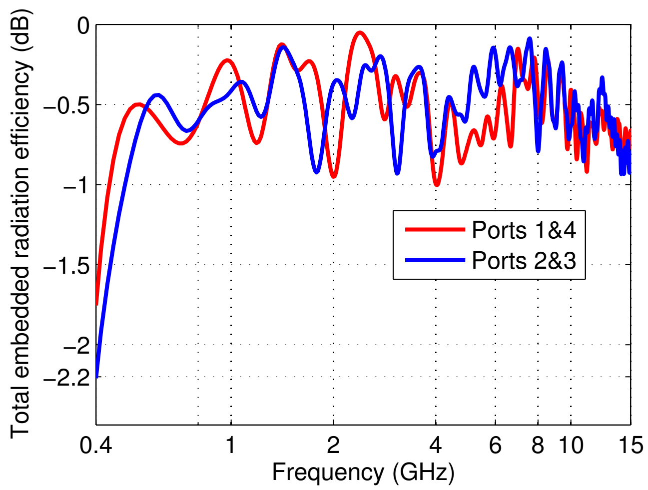
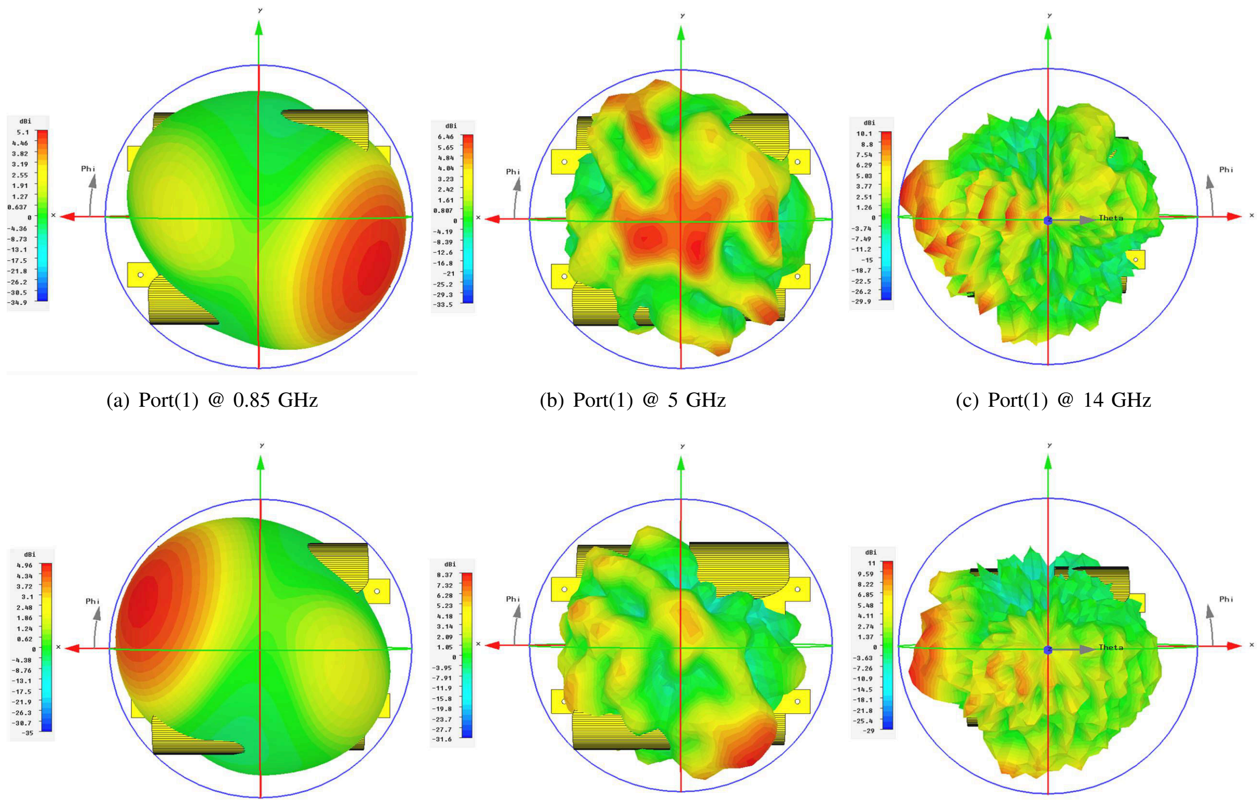


Fig. 7. Computed total embedded radiation efficiency of all ports.

mutual coupling below -14 dB and better than -15 dB in most of the measured frequency band (0.4–9 GHz); see Fig. 11. The degradation in the performance from the simulation is due to the difficulties accompanied the manufacturing process; see Fig. 12. Nevertheless, the new 4-port bow-tie antenna has better reflection coefficient performance compared to the existing 3-port cube antenna, especially in the frequency band 0.5-1 GHz; see Fig. 13. The full measurements on the designated frequency band (0.5-15 GHz) will be presented in a journal paper, with other quantities.

V. Conclusions

A new compact MIMO antenna has been developed. This antenna has many good features: compact size, high radiation efficiency, low correlations between ports in RIMP environment, and full 3-D radiation coverage over 0.4–15 GHz. The antenna has been installed as the chamber-fixed measurement



(a) Port(1) @ 0.85 GHz (b) Port(1) @ 5 GHz (c) Port(1) @ 14 GHz

(d) Port(2) @ 0.85 GHz (e) Port(2) @ 5 GHz (f) Port(2) @ 14 GHz

Fig. 8. 3-D Radiation Pattern of Port 1 and Port 2

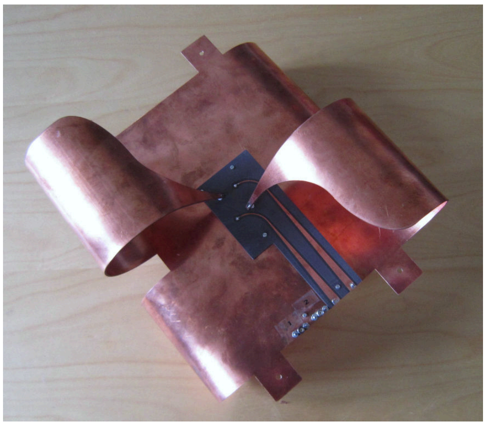


Fig. 9. The manufactured prototype of the proposed wideband MIMO antenna.

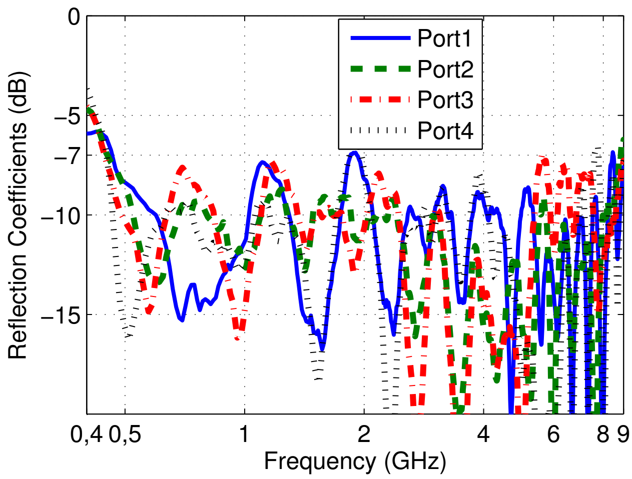


Fig. 10. The measured Reflection Coefficients of all ports in the frequency band of 0.4–9 GHz

antenna in the Bluetest reverberation chambers, and we believe that it can find applications also in wireless communication systems with MIMO capability.

ACKNOWLEDGEMENT

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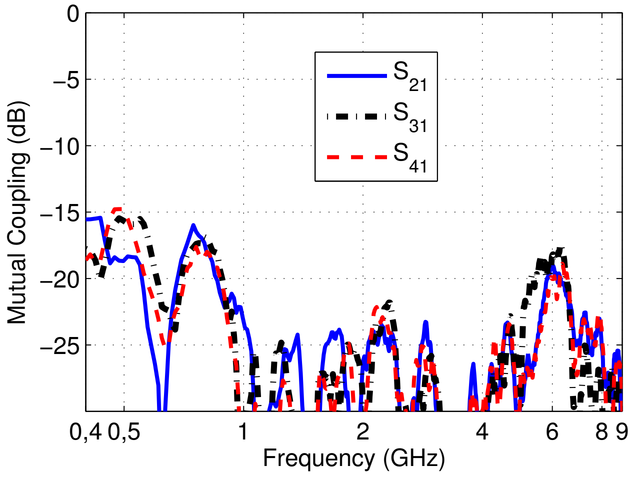

Fig. 11. The measured mutual couplings in the frequency band of 0.4–9 GHz

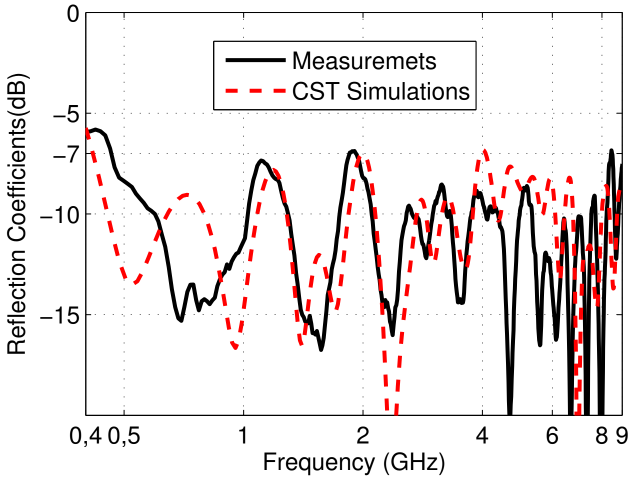

Fig. 12. Simulated and measured reflection coefficient

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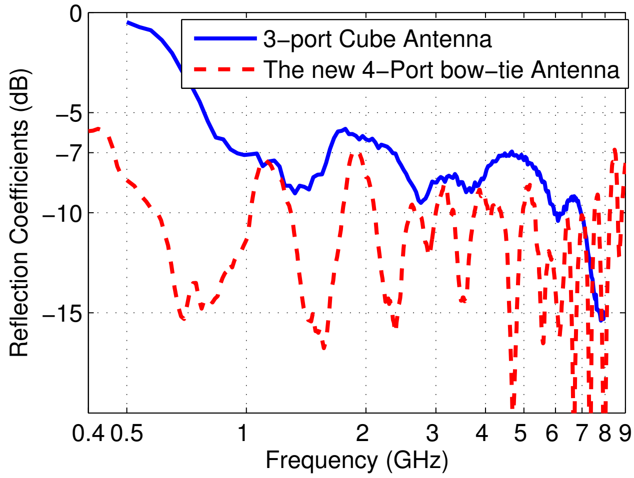

Fig. 13. Comparison of reflection coefficient between the presented antenna and the existing 3-port cube antenna. Measurements on Port1

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