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エスパアンテナの原理を用いたラジアルキャビティ給電アンテナの解析

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あらまし　エスパアンテナはアダプティブアンテナとして利用する以外に空間フェージングエミュレータ利用可能なことが知られている。ところが、エスパアンテナは給電素子と励振素子の電磁結合のためその大きさには厳しい制約があり狭い角度広がりしか実現できない。 本報告ではエスパアンテナの原理を用いたキャビティ給電アンテナを提案する。提案する構造ではキャビティを給電線として使用するのでエスパアンテナのサイズに関する制約が克服できる。フェージングエミュレータとしてみた場合、中央の給電端子をアンテナに接続しないので直接波に対応する成分を抑える事ができる。本報告では主にアンテナの基本構造を述べる。

キーワード　エスパアンテナ、空間フェージングエミュレータ、角度広がり、レイリーフェージング、キャビティ

Analysis of a Radial-Cavity-Excited ESPAR Antenna

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Abstract　In this paper we propose a fading simulator which can generate Rayleigh fading in the spatial domain. The conventional fading simulator using ESPAR antenna works well as a fading simulator. However, the ESPAR antenna has very small angular spread because of proximity coupling between parasitic antennas and an excited antenna. We introduce an ESPAR-like cavity-fed antenna as a spatial fading emulator which can simulate more realistic base station environment. The proposed structure uses a radial cavity as a feeding circuit, and the fundamental size limitation of an ESPAR antenna can be overcome in the proposed structure. In the proposed structure, the feed probe is not directly connected to the antenna element, so that the strong radiation from the feed element is suppressed. We present the basic structure and features of the proposed antenna.

Key words　Espar antenna, Spatial fading emulator, Angular spread, Rayleigh fading, Cavity

1. Introduction

Field testing of mobile radio transmission techniques is often time consuming and inconclusive. Laboratory testing with signals that fairy duplicate the statistical properties of the signals encountered in the fields is an attractive alternative when all the relevant properties can be simulated [1]. Therefore, we need a standard mobile communication environment, which provide suitable condition of circumstance for mobile radio transmission experiment. Of course, there are several approaches to generate fading signals. First is a stored channel approach in which actual fading fluctuation is stored on the memory [2]. Second is so called “Jakes type” fading simulator in which a steady signal is split into several paths, each of which suffers from different Doppler shift, and they are combined again to generate the fading [1]. Third is the Gaussian amplitude modulation of the in-phase and quadrature components of a steady carrier which can be used to provide uniform phase modulation and Rayleigh envelop fading [3]. The fading simulators can only work in the delay and Doppler domains, and the effect of antenna can not be considered. To overcome this problem, a fading emulator called a field simulator has been proposed. For the mobile terminals, a field simulator composed of a phased ar-

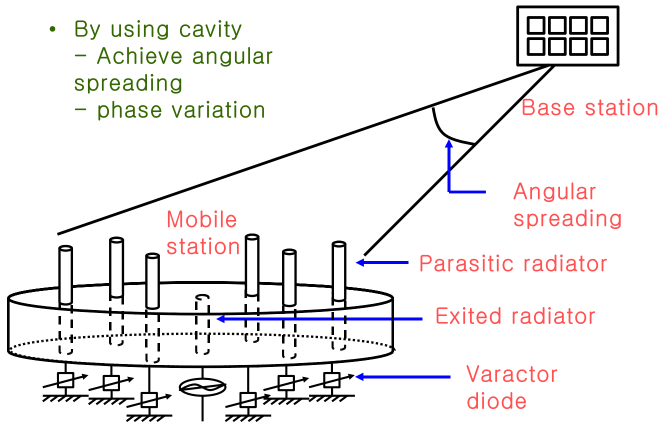

Fig. 1 Structure and Concept to show how to form Rayleigh fading channel

ray antenna and the shielded box has been proposed [4]. For the base stations, another field simulator using the moving metal bars have been proposed to realize the finite angular spread [5]. Yet another field emulator using ESPAR antenna has recently been proposed by the authors [6] [7]. ESPAR field simulator is with a simple structure, but only a small angular spread (AS) can be generated. In this paper we propose an ESPAR-like cavity-fed antenna array to achieve a wider AS which can be inspected in more realistic base station environment in mobile communication systems. We show some basic characteristics by using a commercial Method of Moment (MoM) software - FEKO [8] and by experiments using a prototype.

2. Structure and Concept

Figure 1 shows a radial cavity-fed ESPAR-like antenna array. In this example, the array is composed of six inductance-loaded element arranged concentrically for the structural symmetry and one feed pin at the center of radial cavity. In appearance, inductance-loaded elements seem to be parasitic elements. But, in this structure, contrary to the ESPAR antenna, these elements are not the parasitic elements in the sense that they are fed via the cavity. Namely, radial cavity may be regarded as a feed circuit and the elements above cavity are fed by the cavity with pins connected to reactance elements. Each of the fed elements has different phase due to the varied excitation coefficient by controlling the load impedance as well as the generation of higher order modes in the cavity. This quasi-random phase generates the Rayleigh fading. This structure is advantageous in the sense that the excitation strength is almost independent of the size of the cavity, since elements are fed by the radial cavity and not by the proximity coupling. Therefore, this has a wider AS than

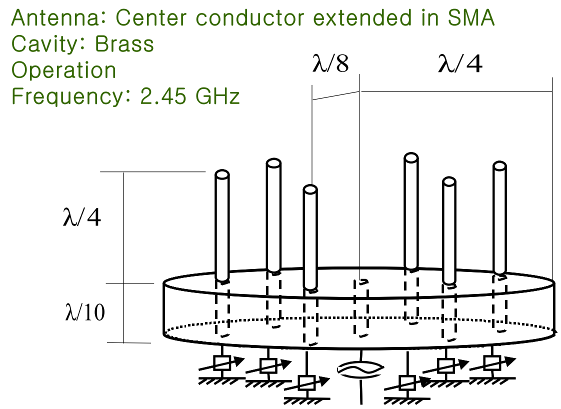

Fig. 2 Specification of fabrication

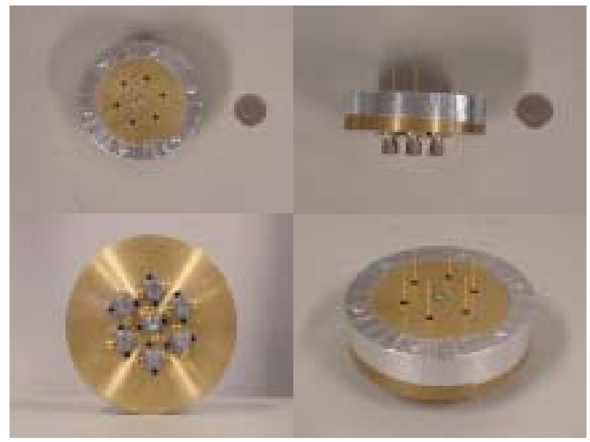

Fig. 3 Prototype model

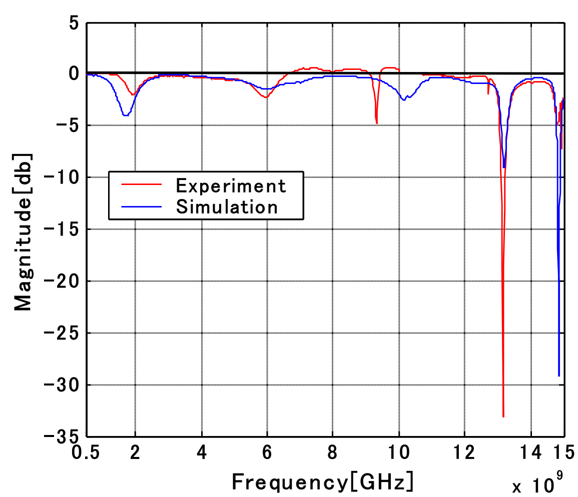

Fig. 4 S_{11}- simulation vs. experiment

that ESPAR antenna can achieve. As a spatial fading simulator, Rayleigh fading statistics is expected as in the same manner as an ESPAR antenna, whereas the angular spread would be easily controlled by selecting the appropriate size of the cavity and array.

3. Characteristics of the Prototype

A prototype is fabricated to confirm the simulation model which operates at 2.45 GHz. Figure 2 shows the physical dimension of the prototype and Figs. 3 show the photos 50 ohm dummy load connected instead of varactors. We present the characteristics of this prototype, although we know that the dimension of this antenna is not well designed. The 50 ohm dummy is loaded at every element for S_{11} to compare simulation model to experiment and all simulations - FEKO - are performed at 2.45 GHz. Figure 4 shows a comparison of S_{11} between simulator and experiments when 50 ohm dummy is loaded at every element. Most of the energy is rejected at the feed of the cavity except in the range between 13 GHz and 14.8 GHz. In theory, this cavity is resonant at around 6 GHz, but, little energy has gone into cavity at 6 GHz as figure shows. This may be due to some perturbation from the radiation elements, but the detailed mechanism shall be studied further.

4. Characteristics of Radial Cavity fed Antenna with a wide cavity

The aim of using cavity is to achieve a wider AS than ESPAR antenna. Figure 5 shows the physical dimension of simulation model which is designed to resonate at around 2.45 GHz. The capacitance of the varactor has been varied in the range of 0.5 pF – 9 pF , which corresponds to -130 ohm - -7.2 ohm in reactance domain at 2.45 GHz. Figure 6 shows the current distribution of the antenna element when all the elements are connected to 4.2 pF varactors. When reactance values of varactors are varied, we can observe the phase variation at each of the parasitic antenna elements. Figures 7 and 8 are examples of the current distributions of all the antenna elements when 0.5 pF, 9 pF, 4.7 pF, 1 pF, 2.8 pF and 7.3 pF are respectively loaded. We expect that this variation of the phase at each of the antenna elements shall generate the spatial Rayleigh fading, although further simulation is necessary to confirm.

5. Conclusion

An ESPAR-like antenna fed by a cavity as spatial fading emulator has been proposed and its features based on simulation by an MoM simulator and on measurements of a prototype. The proposed antenna is expected to perform Rayleigh fading channel with wide AS which can simulate the base station environments. Further investigations about the fading statistics as well as the shape optimization are necessary.

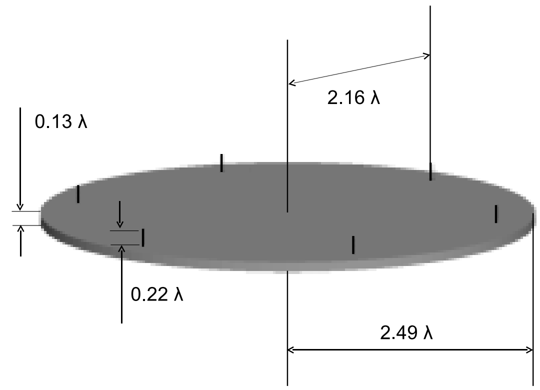

Fig. 5 Specification of a model with wide cavity

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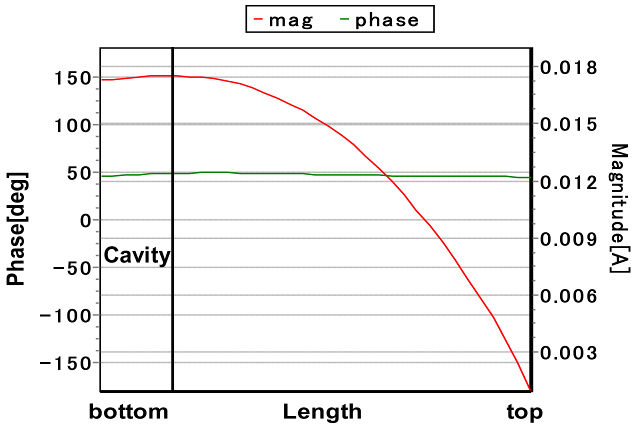

Fig. 6 Current - varactor loaded(4.2 pF)

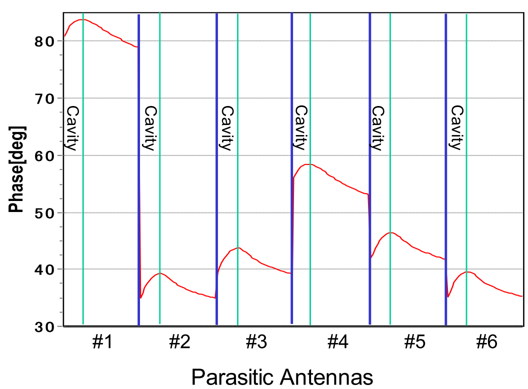

Fig. 7 Phase at each parasitic antenna - random reactance

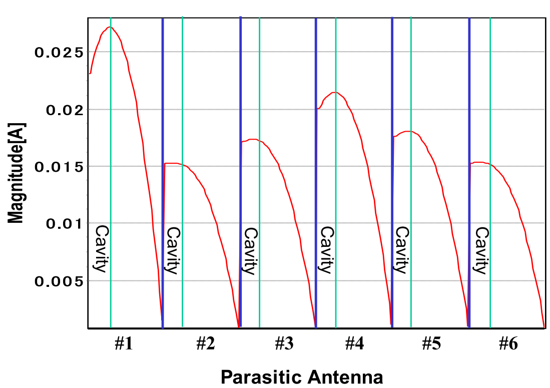

Fig. 8 Magnitude at each parasitic antenna - random reactance