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ON THE INTEGRATED ANTENNA SYSTEMS

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1. Introduction

A recent trend of the development in the field of antennas may be the sophistication of antennas; especially for linear antennas, integration technique seems to be one of the most significant ones, which would bring a new concept into the field of antennas.

A brief discussion of treatment of the IAS (Integrated Antenna System) by using a model, which consists of Space Domain and Immittance Domain, has been shown previously.[1] It is the purpose of this paper to present a discussion on the concept and the significance of the IAS in view of the practical applications.

2. Concept

The IAS is described as "Antenna Systems, in which a circuitry or some components are incorporated with an antenna structure in an unified form, being inseparable in terms of function of both antenna and circuitry".

Essentials of IAS lie in variation or modification of current by means of integration of some components into antenna structure. Components to be integrated may be either passive or active. A typical example of passive integration is found in what is called "loading" so as to make antenna match effective and its efficiency high. On the other hand, integration of active components have been applied to various ways and many types of antennas with much wider sense compared with passive integration have been developed. The active integration should imply sophistication of antennas, which includes enhancement of antenna functions and provides flexible and controlable performance to the antennas. The most important feature of integration with active components is to realize antenna functions, which can not be realized by the conventional passive antennas.

3. Physical significance

As is well known, an antenna is considered bo be two-port transducer, which trnasforms energy in space, the electromagnetic field, into that which can be treated in circuitry, such as voltage or current at the terminals of a device, which is connected to the antenna. This is schematically shown in Fig.1. Here an antenna is expressed by a two-port box, where one port is fictitious and faces to the space, while the other port is connected to the terminals of the device; receiver or transmitter.

We know that the electromagnetic field is given in connection with the current density as follows:

$$-1/j\omega\mu \nabla \times \nabla \times \mathbf{E} - j\omega\epsilon\mathbf{E} = \mathbf{J} \quad (1)$$

This relation is determined by Maxwell's equations. The inverse caluulations can also be made; typical equation is

$$\mathbf{E} = \iiint G(\mathbf{r}', \mathbf{r})\, \mathbf{J}(\mathbf{r}')\, d\tau , \quad (2)$$

where G is Green's function. If we take an operator L, Eqs(1) and (2) are expressed as

$$\begin{aligned} L(\mathbf{E} \text{ or } \mathbf{H}) &= \mathbf{J} , \\ L^{-1}(\mathbf{J}) &= \mathbf{E} \text{ or } \mathbf{H}. \end{aligned} \quad (3)$$

This implies that in the Space Domain

a mathematical operation is performed and the field and the current are interrelated each other. This domain is essentially linear, passive, reciprocal and time invariable in nature.

If we give boundary conditions at each of the terminals of the antenna elements, relationships existing among the voltages and currents will be determined. In this case, terminals on the antenna refer to points on the antenna where fictitious terminals can be set to show potentials arising because of integration or other discontinuities on the antenna elements. It is given by matrix form as

$$[I] = [Y][V]$$
or
$$[V] = [Z][I] . \qquad (5)$$

Now the significance of the IAS may be explained by using this model. When a circuitry or electronic components are integrated into antenna structure, the terminal condition in the Immittance Domain will be changed. If an active component is used, the Immittance Domain will become active. If antenna itself is made of active element, Immittance Domain itself becomes active. It should be noted that "active" does not only mean amplification, but includes many variations to be utilized for realizing various antennas. The nature of this domain depends upon that of element integrated, so that it may be active, non-linear, non-reciprocal, or time variable.

4. Applications

Variety of application may be considered. Among those, small sizing an antenna seems to have been the most frequently applied technique and discussed subject. There are still many problems to be solved in making an antenna small with regard to gain, bandwidth, radiation patterns and noise. When it is made by active components, the gain should be considered with respect to S/N as a system.

A ferrite antenna is made active by exciting with pumping signal so as to obtain much amplification within the antenna itself. In this case, the ferrite core acts as antenna and the time-variable inductance element at the same time.

A reactance transistor is applied to make matching over wide frequency bandwidth with gain (not with loss).

Radiation patterns can be controlled by means of variable control of transistor circuitry integrated in antenna.

In any case, taking parameters in the Immittance Domain into consideration, antenna design may become very feasible.

Potential of application would be to develop antennas, in which sginal processing or information handling is performed.

Reference

1. K. Fujimoto, "A Treatment of the Integrated Antenna Systems", 1970G-AP International Symposium Digest, p.120.

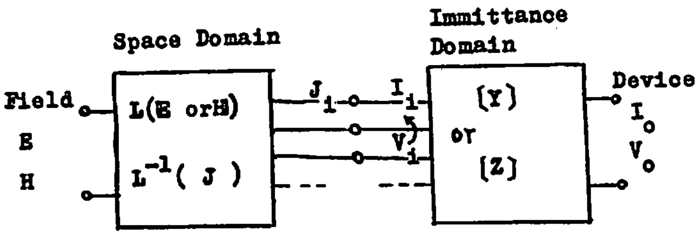

Fig.1 Antenna System