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Characteristics of High-Gain Wideband Ring Loop Antenna and its Application

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1. Introduction

Digital terrestrial broadcasting services are in the Japanese UHF band of 470 to 770 MHz. The bandwidth of the UHF-TV channel is 6 MHz. In this paper we investigate the ring loop antenna for the UHF digital terrestrial broadcasting. The characteristics of the linear ring loop and circular ring loop antenna are calculated by NEC-WIN Pro. We evaluate the characteristics of these antennas in the Japanese UHF-TV broadcasting band (470MHz-770MHz).

A broadband antenna consisting of the ring loop antenna is presented for the digital terrestrial broadcasting. A ring loop antenna is excited by a simple and low-cost feeder system. The broadband input impedance and the high gain are obtained in the calculation and the measurement.

The input impedance became $50\,\Omega$ and wideband characteristics were obtained in the simple power supply construction. Then the high-gain and wideband characteristics were obtained with the simple power supply construction. This antenna has sufficient characteristics as the transmitting antenna for digital terrestrial broadcasting stations and repeater stations in the Japanese UHF band.

The characteristics of the ring loop antenna were calculated using the moment method proposed by Harrington[1][2], who conducted experiments on this antenna.

This antenna examined the ring loop antenna with which circumference length fed in parallel in about full-wavelength of loop antenna element as an antenna for digital terrestrial broadcasting. That is, numerical analysis was performed about conditions for both the directivity of the ring loop antenna of many stages and the impedance characteristic to show the broadband characteristic. It is the ring loop antenna of the structure, which carried out parallel electric feed of all the elements in this antenna, added one reflector element, and was arranged to the vertical form. All number element of the antenna was consisted of sum total of 5-elements of director element of 3-elements, radiator element, and compound reflector element. This antenna it was the simple structure in order to solve the problem, and the diameter was small, and the miniaturization was possible, and again, it developed ring loop antenna (RLA) for the digital terrestrial broadcasting of which

good voltage standing wave ratio (VSWR) characteristics over all bands in the use frequency band was obtained. That is to say, the circumference length parallels supplied loop antenna element of the about one wavelength on the 5-element loop antenna. Both directionalities, impedance characteristic show wide-band characteristics on the loop antenna. The next high-gain ring loop antenna element for the digital terrestrial broadcasting with wide-band characteristics is described. As a feed circuit of the log-periodic structure, the condition as radiation pattern and impedance characteristic of ring loop antenna of the 12-elements together showed wide-band characteristics was analyzed numerically in respect of all component count.

It is possible that it is high-gain by arranging loop antenna element of the 12-elements, and again, that it gets the good antenna of impedance characteristic with the feeder circuit of the log-period structure.

The Log-Periodic antenna did the feeder circuit system in the log-period structure, and the constant of the antenna structure was made to be τ =0.9 and σ =0.16. And, it was made to change at W_0=50Ω-200Ω characteristic impedance of the feeder, and it was made to be optimum value W_0=70Ω. The antenna element number is wide-band ring loop antenna of the N=12 structure which lined up vertically.

The ring loop antenna to which the circumference length parallel supplied loop antenna element of the about one wavelength in the previous paper was described. This antenna described the antenna which constituted the circularly polarized wave characteristics in order to use for the experiment which verifies the digital broadcasting system using the airship which does the fixed point stay in ground station, and it described the condition necessary for generating the circularly polarized wave.

This antenna was used as an antenna of the digital terrestrial broadcasting experiment with the airship in NICT, and it got the result of the good reception experiment .

Finally, characteristics of the 16-element ring antenna are shown. This antenna was used as an antenna for the transmission, and it was used as repeater antenna, and wide band, high gain, low-cost and simple structure, miniaturization were made to be a goal.

2. Moment Method

2.1 Thin wire
This antenna discusses with the moment method proposed by Harrington and deals with the Garlerkin's method where antenna current is developed using triangle function and the same weight function as the current development function is used.   The Garlerkin's method can save calculation time because the coefficient matrix is symmetrical, and the triangle function is widely used because it presents a better performance in calculation time and accuracy, etc. for an antenna element without sudden change in antenna current.

Scattering electric field E^s by antenna current and charge is given by

$$E^s = -j\omega A - \nabla \phi \tag{1}$$

Vector potential A and scalar potential ϕ are given by

$$A = \frac{\mu}{4\pi} \iint_S J \frac{e^{-jkr_0}}{r_0} dS \tag{2a}$$

$$\phi = \frac{1}{4\pi\varepsilon} \iint_S \sigma \frac{e^{-jkr_0}}{r_0} dS \tag{2b}$$

The following relation exists between charge density σ and current J

$$\sigma = \frac{-1}{j\omega} \nabla \cdot J \tag{2c}$$

Now, assuming that the surface of each conductor is perfect conductor and letting E^i be incoming electric field, the following equation must hold true:

$$n \times E^S = -n \times E^i \tag{3}$$

The following simultaneous equation holds true from the boundary condition of the antenna surface of this antenna system:

$$\sum_{i=1}^{N} I_i \left\langle W_j, E^i_{\tan} \right\rangle, \quad (i=1,\dots,N, \quad j=1,\dots,M) \tag{4}$$

where L is the operator for integration and differentiation. Current is given, from (4), by

$$[I_i] = \left[\left\langle W_j, LF_i \right\rangle \right]^{-1} \left[\left\langle W_j, E^i_{\tan} \right\rangle \right] \tag{5}$$

and the matrix representation of (5) gives (6).

$$[I] = [Z]^{-1}[V] \tag{6}$$

Now, let the current at point t on each element be represented by

$$I(t) = \hat{t} \sum_{i=1}^{N} I_i T_i(t) \tag{7}$$

where $\hat{t}$ is the unit vector in the direction of antenna axis, and coefficient I_i is the complex coefficient determined by boundary condition. Letting $T_i(t)$ be the triangle development function, $T_i(t)$ is given by (8),

$$T_i(t) = \begin{cases} 1 - \dfrac{|t - t_i|}{\Delta l_i} & t_{i-1} \langle t \langle t_{i+1} \\ 0 & \end{cases} \tag{8}$$

where for $\Delta l_i = t_i - t_{i-1}$ and for $\Delta l_i = t_{i+1} - t_i$.
Impedance matrix Z in (6) is given by (9),

$$Z_{ji} = \int_{axis} dl \int_C dl' \left[j\omega\mu W_{jm} F_{in} + \frac{1}{j\omega\varepsilon} \frac{dW_{jm}}{dl} \cdot \frac{dF_{in}}{dl'} \right] \frac{e^{-jkr_0}}{4\pi r_0} \tag{9}$$

where C represents an antenna surface l' parallel to the antenna axis l. F_{in} and W_{jm} are divided into four in the triangle development function shown in Fig.1, the triangle is configured so that the value is one at the center, and the divided antenna elements are obtained approximately by the four pulse functions. The expansion equation of (5) is used for Green function.

2.2 Thick wire

As shown in Fig.2, a monopole antenna excited by a coaxial cable line consists of a perfectly conducting body of revolution being coaxial with the z-axis. Conventionally, the integral equation is derived on the presumption that the tangential component of the scattered field cancels the corresponding impressed field component on the conductor surface.

Alternately, according to the boundary condition proposed by Dr. P. C. Waterman [3], an integral equation can be derived by utilizing the field behavior within the conductor. Also, the conventional integral equation has a singular point when the source and the observation point are the same. On the other hand, the integral equation, after Waterman, is well behaved, and so it is more convenient for numerical calculation. When applying the extended boundary condition to an antenna having an axial symmetry as shown in Fig.2, the axial component of the electric field is required to vanish along the axis of the conductor. More explicitly, on the axis inside the conductor, the axial component of the total field is the sum of the scattered field (the field from current on the conductor) and the impressed field (the field from excitation). The corresponding integral equation is written as

$$\frac{j\eta}{4\pi k} \int_{-h}^{h} I_z(z') \left(k^2 + \frac{\partial^2}{\partial z^2} \right) G(z, z') dz = E_z^{inc} \tag{10}$$

$$I_z(\pm h) = 0$$

with $G(z, z') = \dfrac{e^{-jk\sqrt{(z-z')^2 + a^2}}}{\sqrt{(z-z')^2 + a^2}}$ and $k = \dfrac{2\pi}{\lambda}, \quad \eta = 120\pi, \quad I_z = 2\pi a J_z$

This integral equation reduces to the well-known equation (11) when the current is assumed to be zero on the antenna end faces:

$$\frac{j\eta}{4\pi k}\left\{k^2\int_S J_z(z')G(z,z')ds' + \frac{\partial}{\partial z}\int_S \nabla' \cdot JG(z,z')ds'\right\}$$
$$= E_S^{inc} \tag{11}$$

Taking the current at the end faces into account, (11) becomes

$$\frac{j\eta}{4\pi k}\left\{k^2\int_{-h}^{h} I_z(z')G(z,z')dz' + \frac{\partial}{\partial z}\int_{-h}^{h}\frac{\partial I_z(z')}{\partial z'}G(z,z')dz'\right.$$
$$+ \frac{\partial}{\partial z}\int_{S'}\frac{1}{\rho'}\frac{\partial J_\rho(\rho')}{\partial \rho'}G(z,z')ds' = E_S^{inc}, \quad ds' = \rho'd\phi'd\rho' \tag{12}$$

where, on the end surface S', a in $G(z,z')$ becomes ρ.

Dr. C. D. Taylor and Dr. D. R. Wilton[4] analyzed the current distribution on the flat end by a quasi-static type approximation method; the resulting theoretical and experimental values were in good agreement. This analysis makes the same assumption that, as show in Fig.3, the current flowing axially to the center of the end surface without modification.

In applying the moment method, sinusoidal functions were used as expansion and weight functions. Accordingly, the Galerkin's method was used to generate the integral equation.

Notice that the expansion and weight functions have been changed only on the dipole end faces. This is done so that the impedance matrix becomes symmetrical for the end current and for the current flowing on the antenna surface (excluding the antenna end face).

Expanding the unknown current in terms of sine functions, we have

$$I_z(z') = \sum_{n=1}^{N} I_n F_n \tag{13}$$

If the expansion functions are overlapped,

$$F_n = \begin{cases} \dfrac{\sin k(\Delta - |z' - z_n|)}{\sin k\Delta} & z' \in (z_{n-1}, z_{n+1}) \\ 0 & z' \notin (z_{n-1}, z_{n+1}) \end{cases} \tag{14}$$
$$\Delta = |z_{n+1} - z_n|$$

where z' indicates an axial coordinate taken along the conductor surface. Equations (13) and (14) are substituted into (12) to obtain

$$\frac{j\eta}{4\pi k \sin k\Delta} \sum_{n=1}^{N} I_n \left[\int_{Z_{n-1}}^{Z_{n+1}} G(z,z')\left(k^2 + \frac{d}{dz'^2} \right) F_n dz' + \right.$$

$$k\{G(z,z_{n+1}) + G(z,z_{n-1}) - 2\cos k\Delta G(z,z_n)\}\Big]$$

$$+ \frac{j\eta}{4\pi k} \frac{\partial}{\partial z} \int_{S'} \frac{1}{\rho'} \frac{\partial J_\rho(\rho')}{\partial \rho'} G(z,z')ds' = E_z^{inc} \tag{15}$$

The first term in the integral is zero because F_n consists of sine functions. Assuming that

$$E_z^{end} = \frac{j\eta}{4\pi k} \frac{\partial}{\partial z} \int_{S'} \frac{1}{\rho'} \frac{\partial J_\rho(\rho')}{\partial \rho'} G(z,z')ds' \tag{16}$$

then (15) becomes

$$\frac{j\eta}{4\pi \sin k\Delta} \sum_{n=1}^{N} I_n \left\{ G(z,z_{n+1}) + G(z,z_{n-1}) - 2\cos k\Delta G(z,z_n) \right\} + E_z^{end} = E_z^{inc} \tag{17}$$

Applying a weight function of the same form as (13) and taking the inner product of both sides of (17) and the weight function, the equation becomes

$$\frac{j\eta}{4\pi \sin k\Delta} \sum_{n=1}^{N} I_n \left\langle G(z,z_{n+1}) + G(z,z_{n-1}) - 2\cos k\Delta G(z,z_n), W_m \right\rangle$$

$$+ \left\langle E_z^{end}, W_m \right\rangle = \left\langle E_z^{inc}, W_m \right\rangle \qquad (m = 1, 2, \cdots N) \tag{18}$$

where

$$W_m = \begin{cases} \dfrac{\sin k(\Delta - |z - z_m|)}{\sin k\Delta} & z \in (z_{m-1}, z_{m+1}) \\ 0 & z \notin (z_{m-1}, z_{m+1}) \end{cases} \tag{19}$$

$$\Delta = |z_{m+1} - z_m|$$

Here z indicates a coordinate taken on the axis. The above results can be expressed in matrix form as

$$[Z][I] = [V] \tag{20}$$

The impressed field E_z^{inc} of the $[V]$ matrix is considered to be excited by a frill of magnetic current[5] across the aperture of the coaxial cable line feeding a monopole as shown in Fig.2. In other words, assuming the field on the aperture of a coaxial cable line at $z = 0$ to be identical to that of a transverse electromagnetic (TEM) mode on the coaxial transmission line, the equivalent frill of magnetic current can be determined. And, by considering the image of an excitation voltage as V_0, and the inner diameter and outer diameter of the coaxial cable line by a and b, respectively, it follows that

$$E_z^{inc} = \frac{V_0}{2l_n(b/a)} \left\{ \frac{e^{-jk\sqrt{z^2+a^2}}}{\sqrt{z^2+a^2}} - \frac{e^{-jk\sqrt{z^2+b^2}}}{\sqrt{z^2+b^2}} \right\} \tag{21}$$

2.3 Charge density and current on end faces

Now, we proceed with the study of the current over the antenna end surface. We presume that the current is zero at the center to the edge (in the case of a thin cylindrical antenna, the end current is assumed to be zero as shown by the dotted line the figure). If we express the total charge on the end surface by Q and its radius by a, then the charge density, σ, and the current density, J_ρ, are given by

$$\sigma = \frac{Q}{\pi a^2}, \quad J_\rho = \frac{-j\omega Q}{2\pi a^2}\rho \tag{22}$$

Also, by the current continuity condition on the edge, we have

$$Q = \pm \frac{I_z(z')}{j\omega} \tag{23}$$

Furthermore, the axial component of the field strength on the z-axis, produced by sources on the end surfaces, is given by

$$E_z = \pm \frac{j\eta I_z(z')}{2\pi k a^2}(z-z')\left\{ \frac{e^{-jk\sqrt{(z-z')^2+a^2}}}{\sqrt{(z-z')^2+a^2}} - \frac{e^{-jk|z-z'|}}{|z-z'|} \right\} \tag{24}$$

We impose the boundary condition that the total axial field is zero in the range of $-h\langle z \langle h$, not including $z = \pm h$. Now, if we select the end face weight functions to be the same as the expansion functions, it follows that the same weight function will also be applied to the end faces $z = \pm h$, as shown in Fig.3.

Referring to the difference between the analysis of Taylor and Wilton and that presented here, the former uses the point-matching method and is applied only to the body of revolution. On the other hand, the latter employs the Galerkin's method and is applied to antennas which are asymmetrical and which also contain discontinuities in the conductors. By using the moment method and taking the end surfaces into consideration, a relatively thick antenna can be treated.

For example, the calculated input admittance for $a = 0.0423\lambda$ and $b/a = 1.187$, is given in Fig.4, as a function of h . For comparison, the values measured by Holly[6] are also shown. In the calculation, the number of subsections, N , was chosen as 50 to 60 per wavelength. The theoretical values agree well with the measured values. Therefore, it is concluded that the analytic technique is adequate for thick cylindrical antennas.

3. Frequency Characteristics of Impedance and Radiation Pattern

Figure 5 showed the fundamental composition of the 5-RLA (Photo.1) for the wide-band digital terrestrial broadcasting. Theoretical calculation was carried out on these loop antenna by reception band (470-770MHz) for digital terrestrial broadcasting. The following are shown in Fig.5 horizontal of parallel feed loop antenna and frequency characteristics of the directionality in both vertical sides. The interval of the loop is the about 0.2λ for the center frequency. Especially, the loop interval could not see large difference on both directionalities and impedance in the 0.2-0.3 λ . The following were obtained: Horizontal directionality shown at Fig.7 (a) and vertical directionality shown in same Fig.7 (b).

In horizontal directionality shown at Fig.7 (a), the directionality over 8dB was obtained over 470-770MHz all UHF bands. And, it becomes almost similar characteristics in vertical directionality shown at Fig. 7(b) with the horizontal directionality.

And, 5-element composition linear polarization RLA VSWR characteristics of 470-770MHz in VSWR characteristics shown in Fig.6, about -7.5dB(VSWR=2.5) or less were obtained. Measured value and it Figure (b) of horizontal directionality of linear polarization RLA of the 5-element composition, which used the parallel feed system showed the measured value of the vertical directionality on Fig.7 (a). At Fig.7 (a), (b) and Figure have 3(a) and (b), the following are shown: Characteristics at 470MHz low frequency, characteristics at 620MHz center frequency, and directionality at 770MHz high frequency.

In horizontal directionality shown at Fig.7(a) and Fig.9 (a), the directionality over 8dBi was obtained over 470-770MHz all UHF bands. And, it becomes almost similar characteristics in vertical directionality shown at Fig.7 (b) and Fig.9 (b) with the horizontal directionality. In linear polarization RLA of the 5-element composition using the parallel feed system, good characteristics were obtained both horizontal directionalities and vertical directionalities. And, Fig.8 measured value parallel feed system 5-element composition linear polarization RLA VSWR characteristics and, characteristic impedance is 75Ω . Though the case in which it was made to constitute 5-elements the antenna, was shown, it is possible to make more and more to be the multiple-device composition. It is possible to improve the gain further by making to be the multiple-device composition. For example, it is possible to obtain the actual gain of about 10dBi, when it was made to be actual gain and 16-element composition of about 12dBi.

Next, the log-period type ring loop antenna was calculated on the basis of the theory. The dimension univocally depends on the value of τ, σ of the antenna constant on the interval of the loop. Frequency characteristics of the directionality in the horizontal plane of 12-element log-period type ring loop antenna and feed point are shown in Fig 10(a),(b). The impedance band is decided by the characteristic impedance of the antenna in this case of parallel line. The characteristic impedance of the antenna of This antenna shows frequency characteristics of VSWR voltage standing wave ratio using coaxial feed impedance Z_0=50 Ω as W_0=70 Ω in Fig.11. The voltage standing wave ratio characteristics shows the characteristics which are good over all bands, and it becomes under 2.0 over all bands in the UHF band almost. And, there is almost over 10dB for gains, and the before and behind ratio is also -20dB or less in Fig.12. An easy way to comply with the conference paper formatting requirements is to use this document as a template and simply type your text into it.

4. Ring Loop Antennas and its Application

4.1 Circularly polarized wave ring loop antenna

In the UHF band transmitting and receiving antenna, it is required the result to of be wide-band characteristics of linear polarization and circularly polarized wave. Until now, Yagi-Uda antenna of the linear polarization characteristics is mainly utilized in the transmitting and receiving antenna of the UHF band. However, the band property is narrow band on this Yagi-Uda antenna[7][8]. Therefore, in recent years, band property is improved using the looped antenna element, and circularly polarized wave Yagi-Uda array antenna, which enabled the circularly polarized wave, are considered.

However, the bandwidth is insufficient in superscription circularly polarized wave Yagi-Uda array antenna, because it has the very wide band in the UHF band. Then, establishing the one point reactance loading in radiating element, since circularly polarized antenna is constituted generates the circularly polarized wave. This antenna shown in Fig.13 showed the fundamental configuration example of 5-element circularly polarized wave ring loop antenna[9].

The reactance loading element was established 90° feeding point (the lower end division) feed line almost fixed position this circularly polarized wave ring loop antenna parallel feed system ring loop antenna radiating element. It becomes the right-hand circularly polarization in this case and the case in which the reactance loading element was established in right side of radiating element by viewing from the rear, as it is shown in Photo.2, and it becomes the left hand circularly polarized wave, when the reactance loading element was established at the left side of radiating element. Still, the case in which it is physically and electronically done is considered the reactance loading. The directionality of circularly polarized wave characteristics of circularly polarized wave ring loop antenna in the 5-element composition is shown in Fig.14. The good circularly polarized wave axial ratio characteristics were obtained. Figure 15 are the directionality (theory) in the basic configuration, and the value that it is the front face direction and that the axial ratio is good is shown. As a result, it was used as an antenna of the digital terrestrial broadcasting experiment with the airship in NICT(Photo.3), and the result of the good reception experiment was obtained.

The fundamental configuration example of 5-elements right-hand circularly polarization ring loop antenna :

Frequency band: 476-482MHz
VSWR: All bands of 1.2 less than
The gain: 8dB more than
Right-hand circularly polarization characteristic: 3dB less than
Characteristic impedance: 50 Ω

The VSWR characteristics: The reactance loading element is established 90° feeding point (the lower end part) feed line almost fixed position right-hand circularly polarization ring loop antenna parallel feed system ring loop antenna radiating element, and it is VSWR=1.2 less than at 476-482MHz (Fig.16).

The hand circularly polarization characteristics: The circularly polarized wave axial ratio characteristic of which the directionality (measured value) of circularly polarized wave characteristics of right-hand circularly polarization ring loop antenna in the 5-element composition was good was obtained.

The axial ratio is good in the front face direction of the directionality (theory) in basic configuration.

4.2 Circularly polarized wave ring loop antenna and its application

The following were carried out : Transmitting and receiving antenna for ground digital broadcasting and design for practical application of transmission receiving antenna of repeater station, trial manufacture. There is sufficiently a practicability on the wide-banding of this antenna and can be carried out. And, circularly polarized wave ring loop antenna can be realized without changing the composition of linear polarisation ring loop antenna by establishing the reactance loading element in the radiating element. Circularly polarized wave ring loop antenna also succeeded on the experiment which verified digital broadcasting experimental system with airship [10] for fixed point stay in air by NICT in November, 2004 Hokkaido Daiki experiment station in photo.3, and it was able to be used for the application to the urgent broadcasting in the disaster prevention, and the good reception experiment had been obtained, and it was realized for the expectation of the party.

4.3 Multi-ring loop antenna

Photo.4 supplies the loop in the symmetrical parallel feed element, and in addition, this is parallelly connected, and the guided wave element is arranged at the front, and loop antenna of the structure which arranged the reflection element rear are called the symmetrical parallel feed.

The type of the frequency band was divided into A,B,C, and the C- type made low-pass range, B- type medium range, A- type to be the high pass range in respect of each channel. Figure 17 shows horizontal of B- type by the symmetrical parallel feed of the 16-element ring loop antenna and pattern in the vertical plane. Almost similar characteristics in the vertical plane pattern with the horizontal plane pattern were obtained, as it was shown in the same figure. Figure 18 showed VSWR characteristics in the B- type. By going 530MHz-690MHz in VSWR characteristics shown in Fig.18, VSWR=2.0 or less than was obtained. The gain over 14dBi was obtained Fig. 19 over all UHF bands. Table 1 shows the specification for the 16-element ring loop antenna .

4.4 Ring loop antenna for pattern synthesis

The result of the pattern synthesis on the composition which placed the #1 and #2 antenna in the 90° direction, as it is shown in Photo.5, is described. The composition layout drawing is shown in Fig.20. It is necessary to contribute to the uniform electric field in the district limited to the range in which service area is very narrow in the service area direction. The directionality in supplying the #2 antenna with the current of $1\angle0(\deg.)$ and $1\angle90(\deg.)$ and $1\angle180(\deg.)$ in making the #1 antenna with reference value of $1\angle0(\deg.)$ in order to obtain the sectorial directionality in the horizontal plane in the reason, is shown in Fig. 21. The improvement in the poor televiewer in broadcasting area is possible by constituting like this. Table 2 shows the specification of ring loop antenna for pattern synthesis

5. Conclusions

It was possible to make the wide-band antenna using the loop antenna, which arranged circumference length about one wavelength loop antenna vertically. It was possible that the miniaturization became possible in the element composition of the simple shape, and again, that it realizes wide-band and high-gain linear polarization RLA. And, though in this RLA, UHF band receiving antenna for the general of the 470-770MHz band was explained as an example, there is sufficiently a practicability and so on this as transmission receiving antenna of the repeater station for the digital terrestrial broadcasting and can be carried out. By the element composition of the simple shape, the antenna element was united with feeder circuit, and light weight and miniaturization became possible, and it was possible to realize wide-band and high-gain linear polarization RLA which moreover, it covers the all UHF bands.

Theoretical calculation and measured value were performed about two kinds of above-mentioned ring loop antennas in the zone (470-770MHz) for digital terrestrial broadcasting.

As a result, the VSWR characteristic is about 2.5 or less over all the zones of a UHF band, and a gain is about 8.0-10 dBi or more. It was possible to make the wide-band antenna using ring loop antenna, which arranged the circumference length about one wavelength ring loop antenna in the log-period structure. It was possible to make to be circularly polarized wave ring loop antenna This antenna without changing the composition of linear polarization ring loop antenna by establishing the reactance loading element in radiating element. And, UHF band receiving antenna for the general of the 470-770MHz band was explained as an example, and it can be carried out and so on as a transmitting and receiving antenna of repeater station for the digital terrestrial broadcasting for example.

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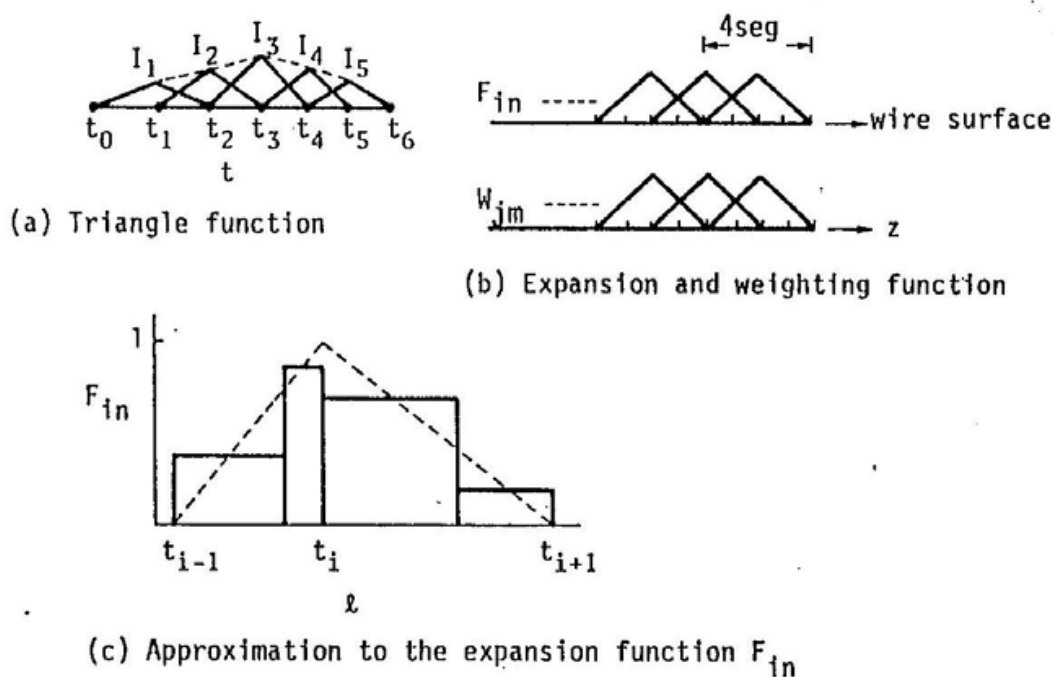
Fig. 1. Approximation to the expansion and weighting function
(a) Triangle function
(b) Expansion and weighting function
(c) Approximation to the expansion function F_{in}
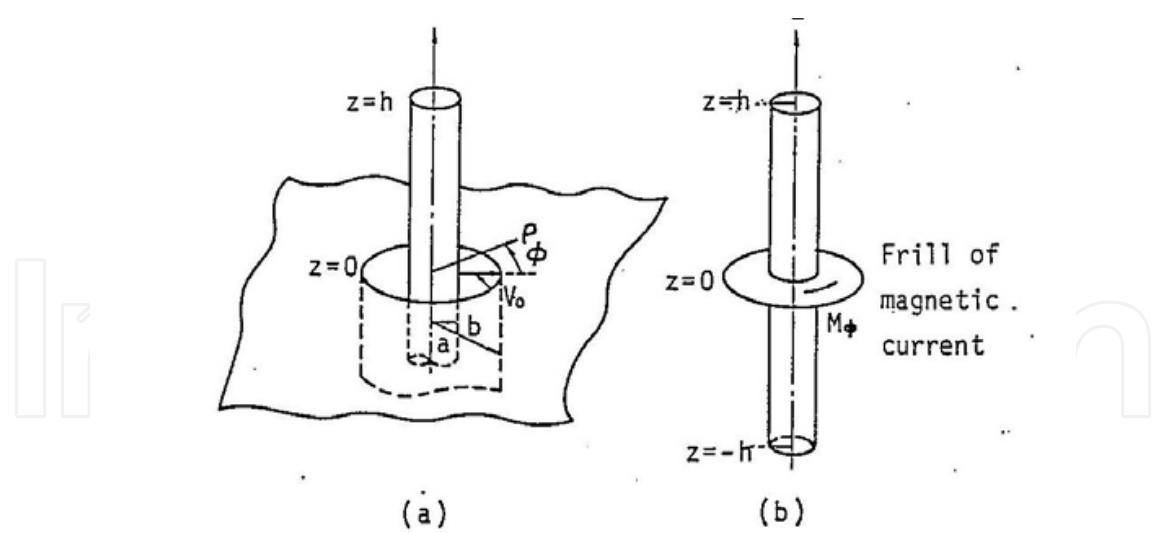
Fig. 2. Coaxial cable line feeding a monopole through a ground plane and mathematical model of the antenna
(a)   Coaxial cable line feeding a monopole through a ground plane
(b)   Mathematical model of the antenna
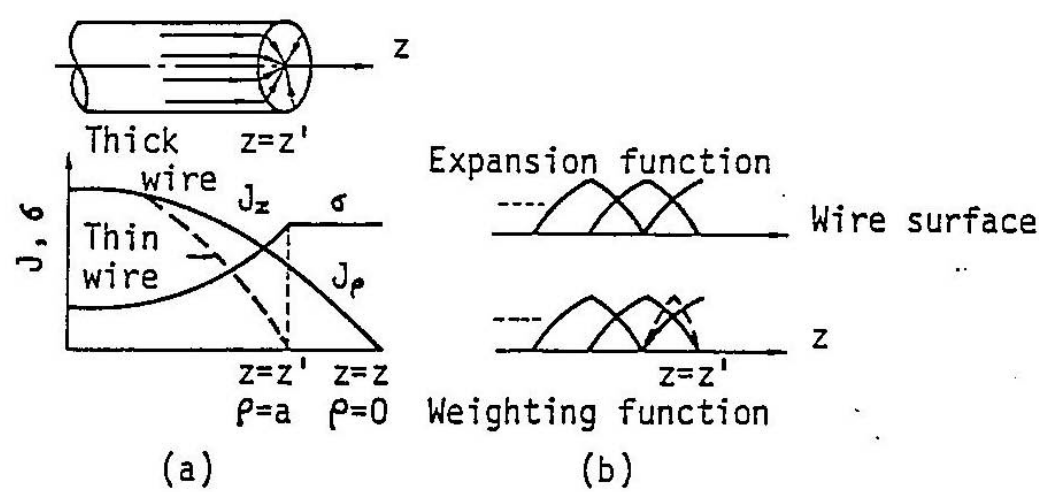
Fig. 3. Current and charge for flat end faces, expansion and weighting function
(a)   Current and charge for flat end faces
(b)   Expansion and weighting function
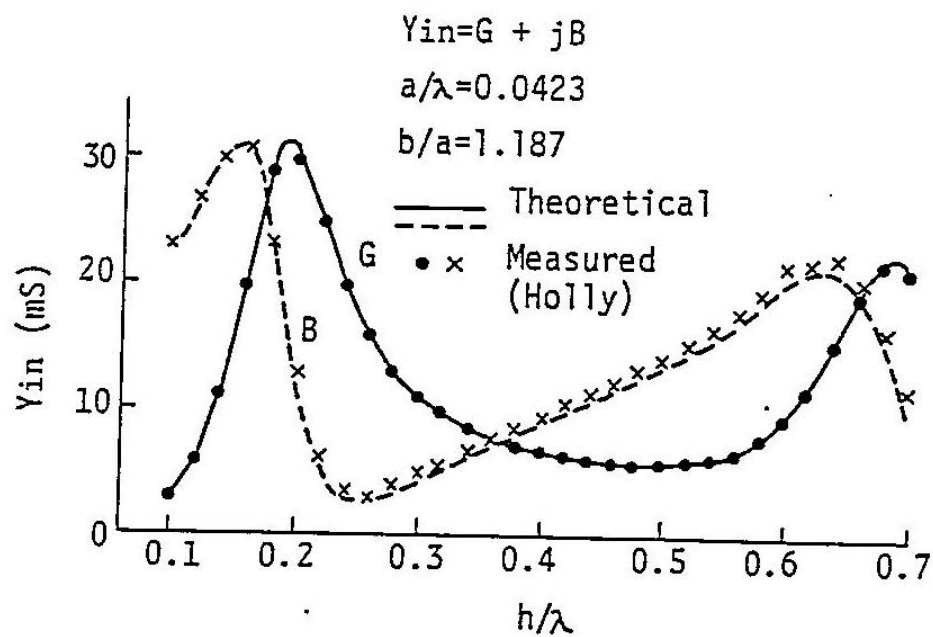
Fig. 4. Input admittance of thick-cylindrical antenna
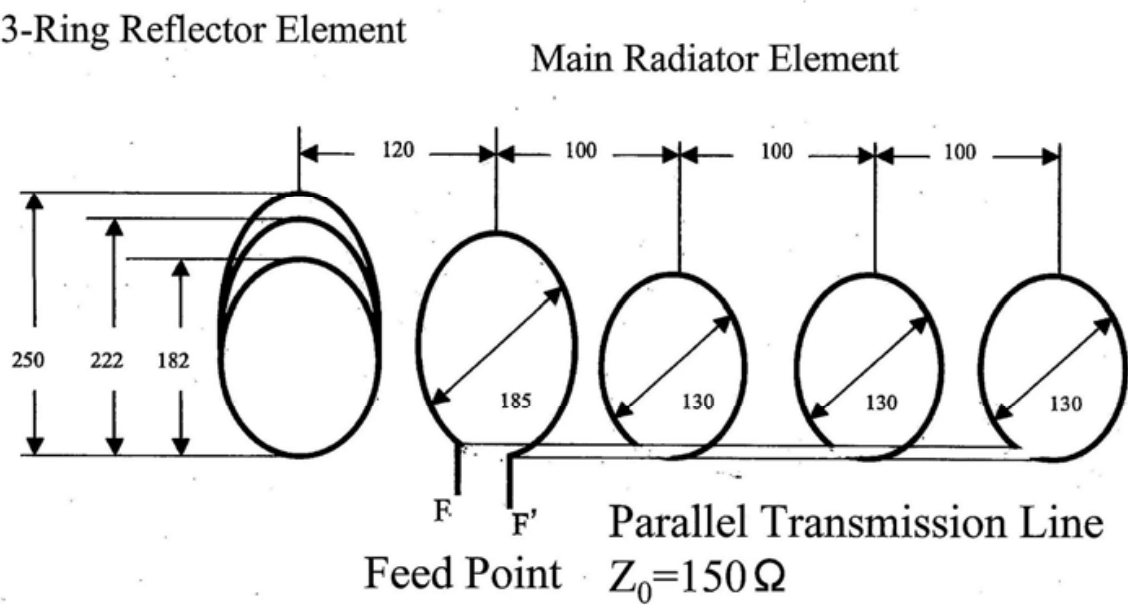
Fig. 5. Structure of RLA

Photo 1. Trial manufacture of RLA
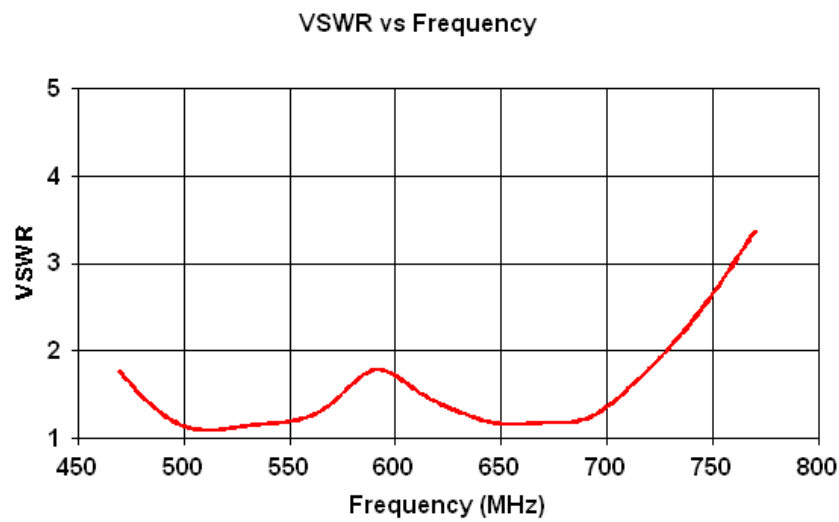
Fig. 6. VSWR characteristics of RLA (Theoretical Value)
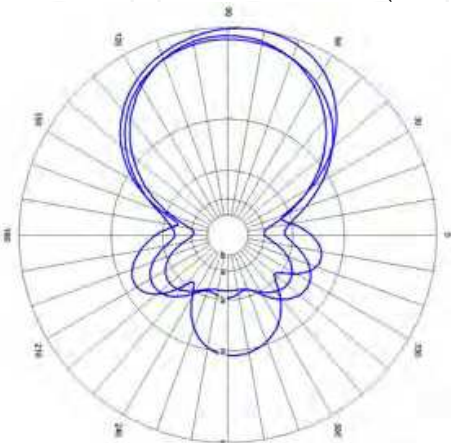
Fig. 7. (a) Horizontal Radiation Pattern   Fig.7 (b) Vertical Radiation Pattern
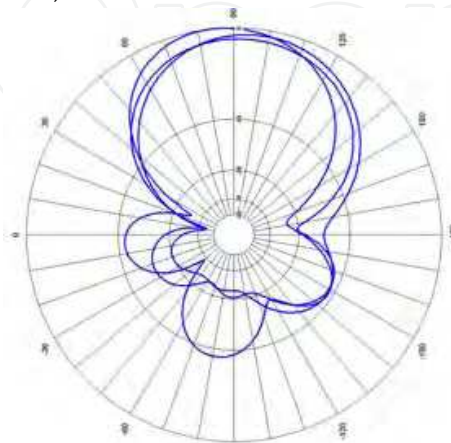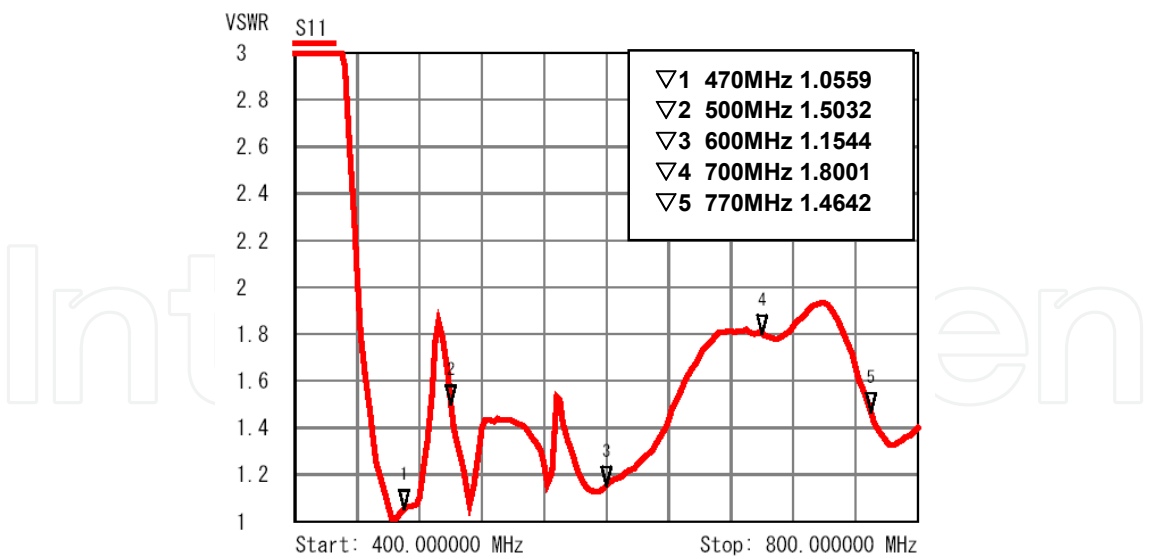
Fig. 8. VSWR characteristics of RLA (Measured Value)
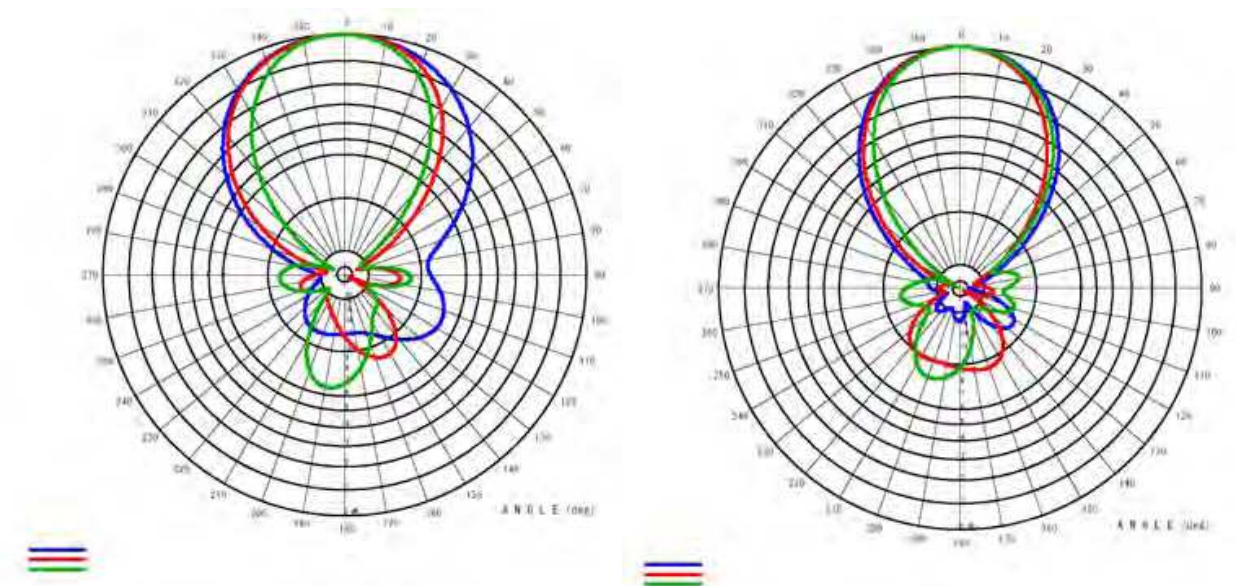
Blue line 470MHz   Red line 620MHz   Green line 770MHz
Fig. 9. (a) Horizontal Radiation Pattern   Fig.9 (b) Vertical Radiation Pattern (Measured Value)
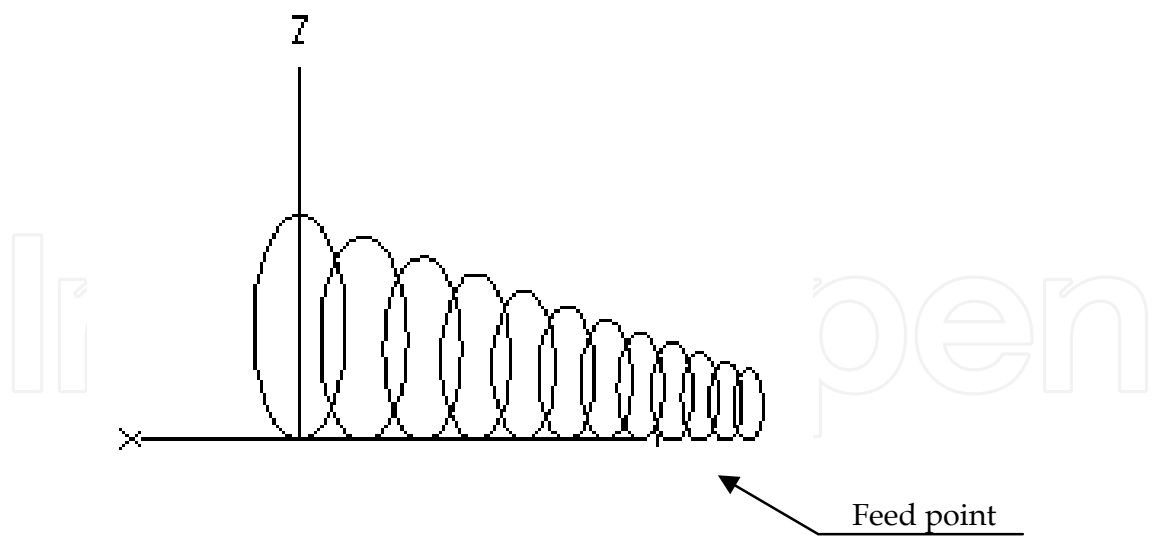
Fig. 10. (a) Structure of LPRLA
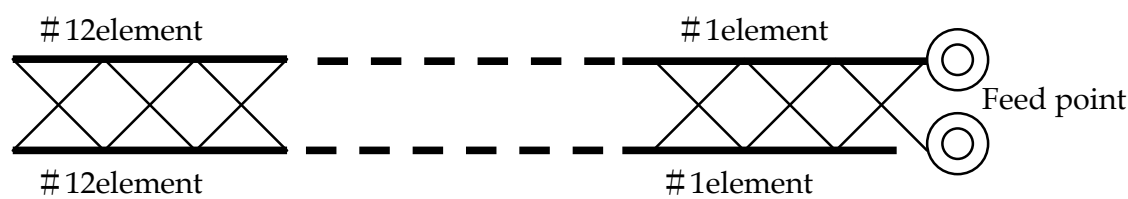
Fig. 10. (b) Feed point system
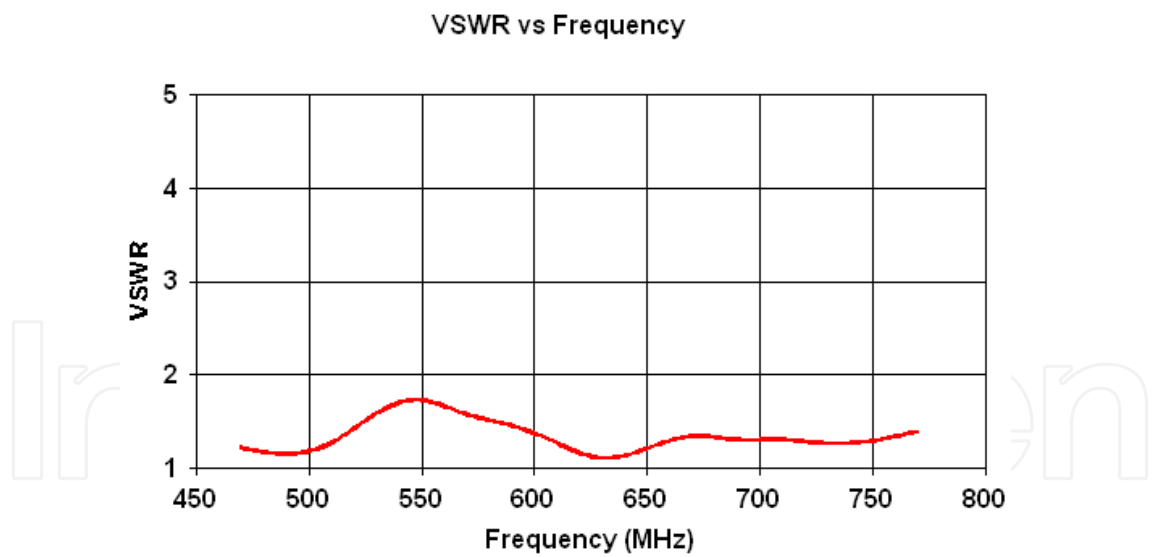
Fig. 11. VSWR characteristics of LPRLA (Theoretical Value)
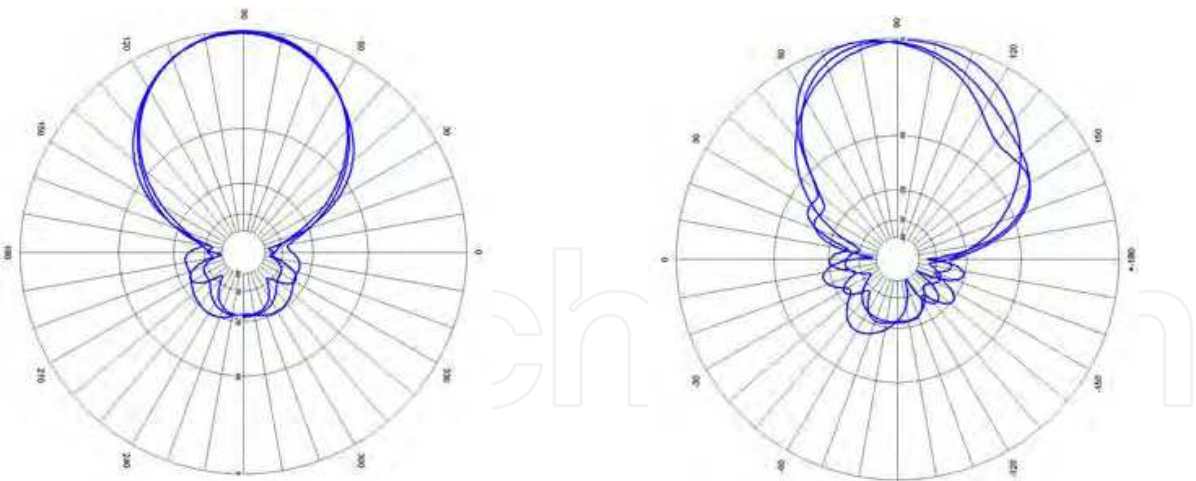
Fig. 12. (a) Horizontal Radiation Pattern
Fig. 12. (b) Vertical Radiation Pattern
(Theoretical Value)
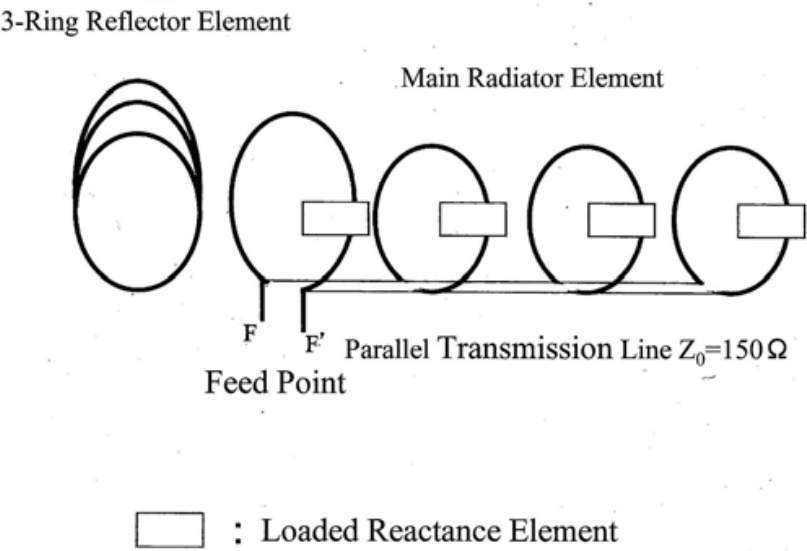
Fig. 13. Structure of Right-hand Circularly Polarized Ring Loop Antenna

Photo 2.Right-hand Circularly Polarized Ring Loop Antenna

Fig. 14. Radiation Pattern of Right-hand Circularly Polarized Ring Loop Antenna (Measured value: 476MHz, 479MHz, 482MHz)
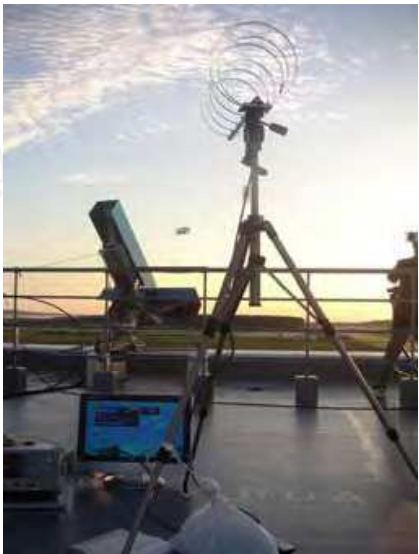
Photo 3. An antenna of the digital Right- hand Terrestrial broadcasting experiment Ring Loop with the airship in NICT
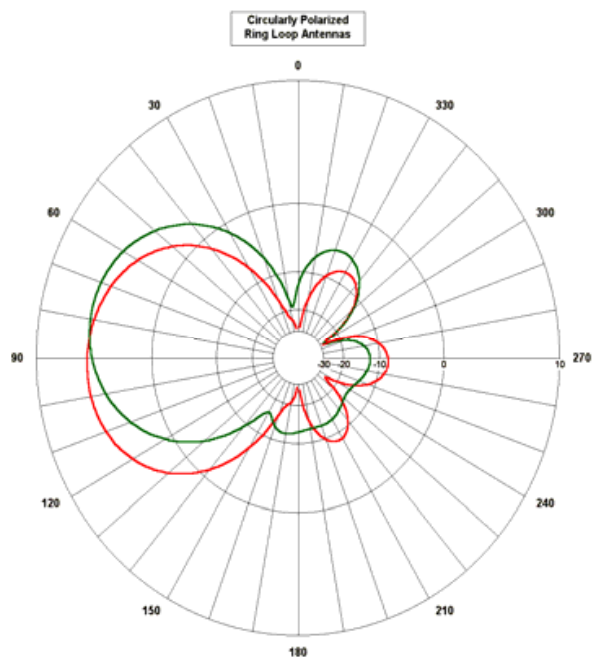
Fig. 15. Radiation Pattern of Circularly Polarized Antenna
(Theoretical value)
(red：horizontal, green：vertical) (Center frequency：479MHz)
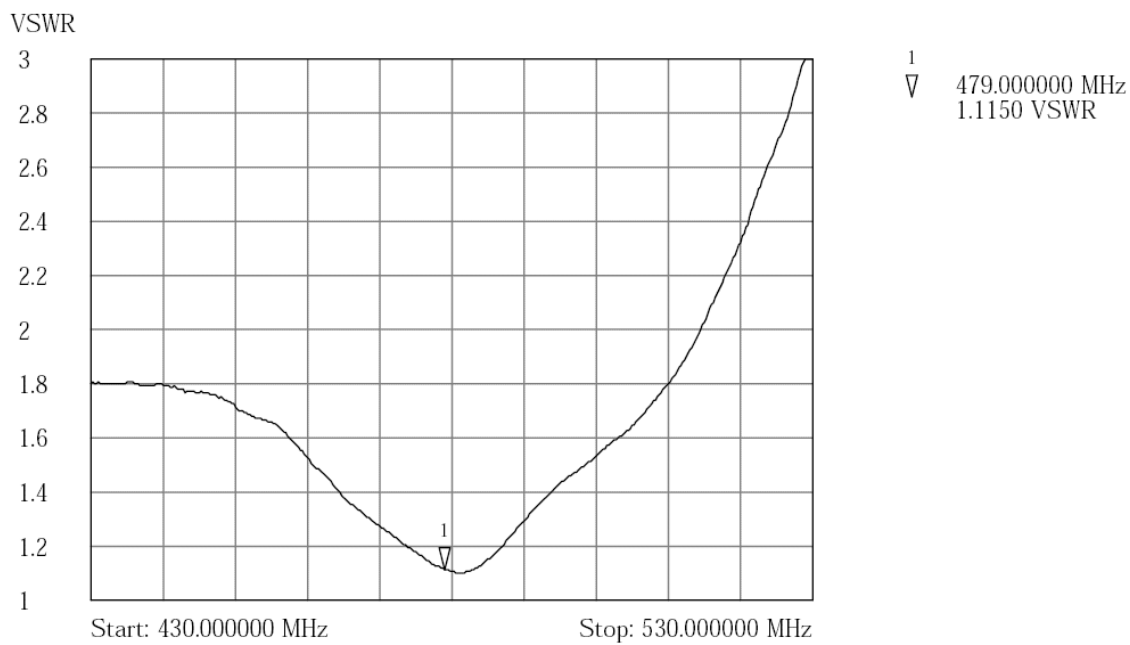
Fig. 16. Characteristics of VSWR
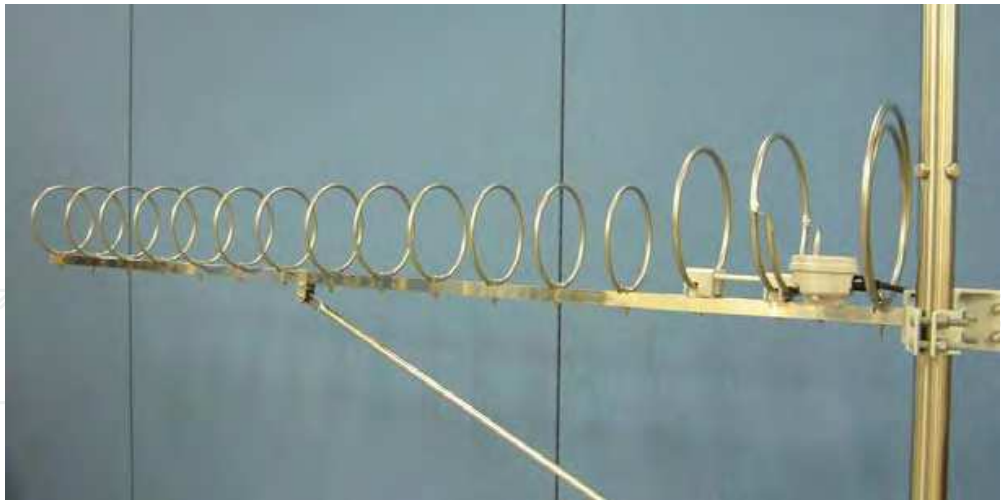
Photo 4. 16-element ring loop antenna

Frequency band	470MHz~770MHz(13ch~62ch)		
	C-Type (13ch~33ch)	B-Type (23ch~49ch)	A-Type (35ch~62ch)
Impedance	50Ω(normalized)		
VSWR	Less than 2.0		
Polarization	Horizontal		
Gain	12dBd		
Connector	N-P type		
Weight	About 3kg		

Table 1. specification for the 16-element ring loop antenna
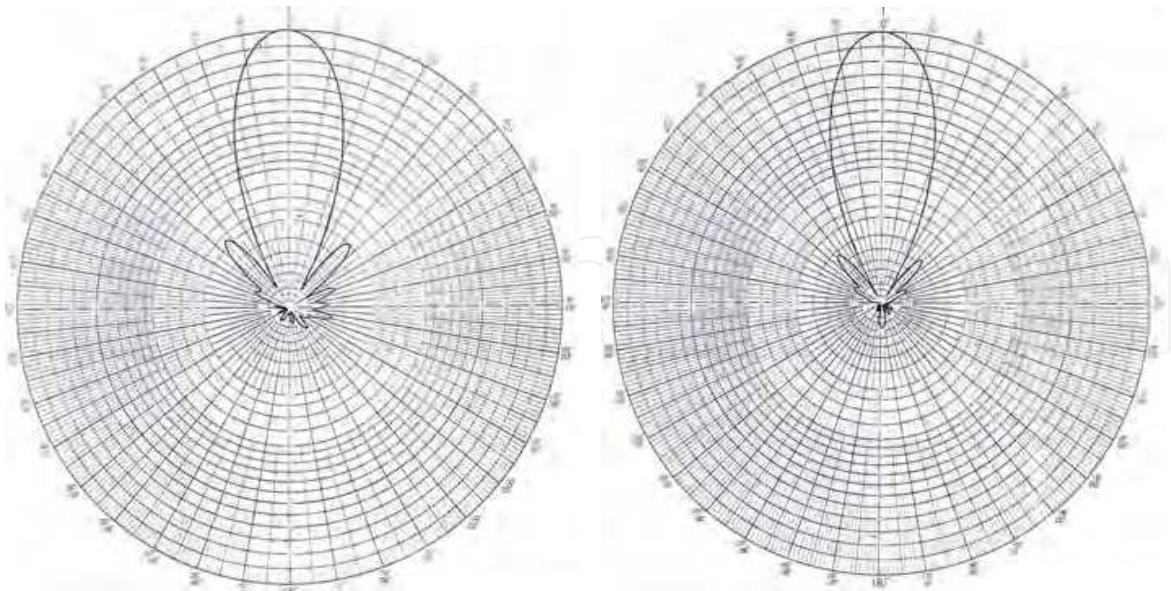
(b) H-plane radiation patterns of B-Type antenna (641 MHz)

(a) E-plane radiation patterns of B-Type antenna (641 MHz)

Fig. 17. Radiation patterns of B-type antenna
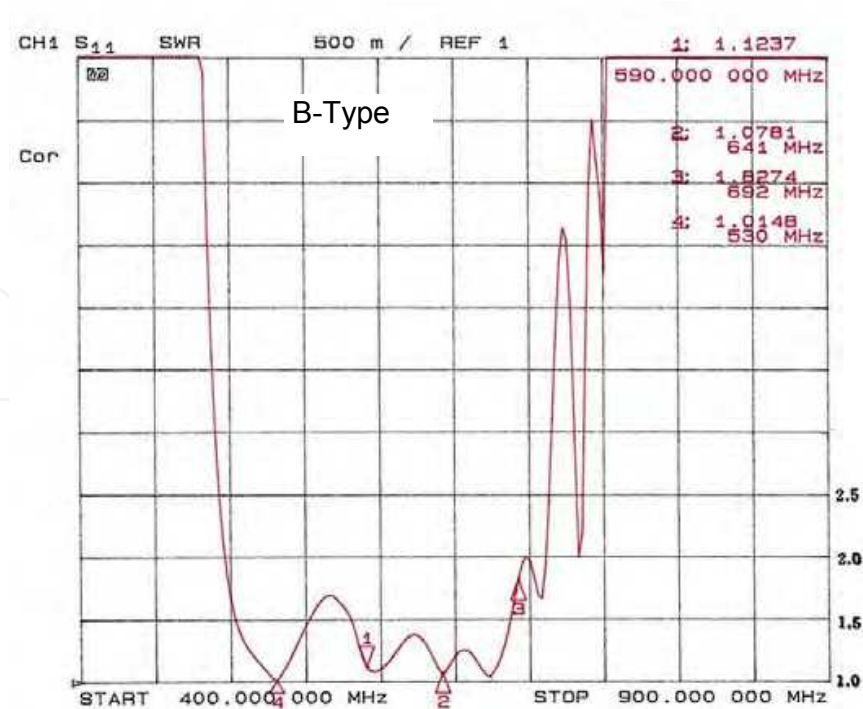
Fig. 18. Characteristics of VSWR
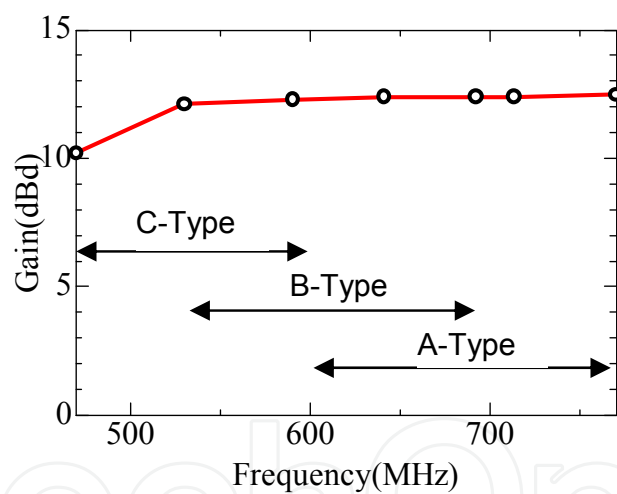
Fig. 19. Characteristics of Gain

Photo 5. pattern synthesis of ring loop antenna
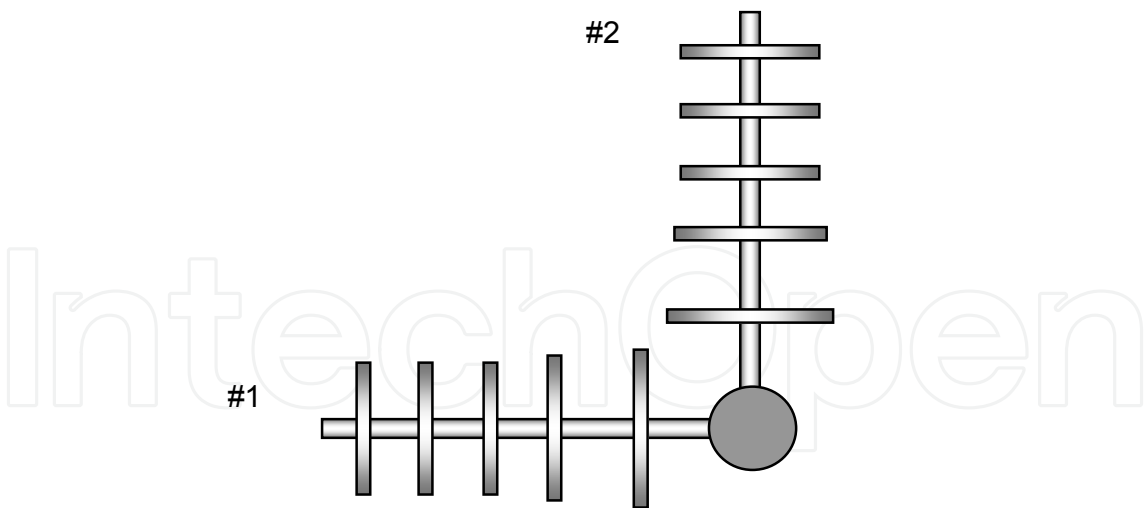
Fig. 20. Antenna arrangement
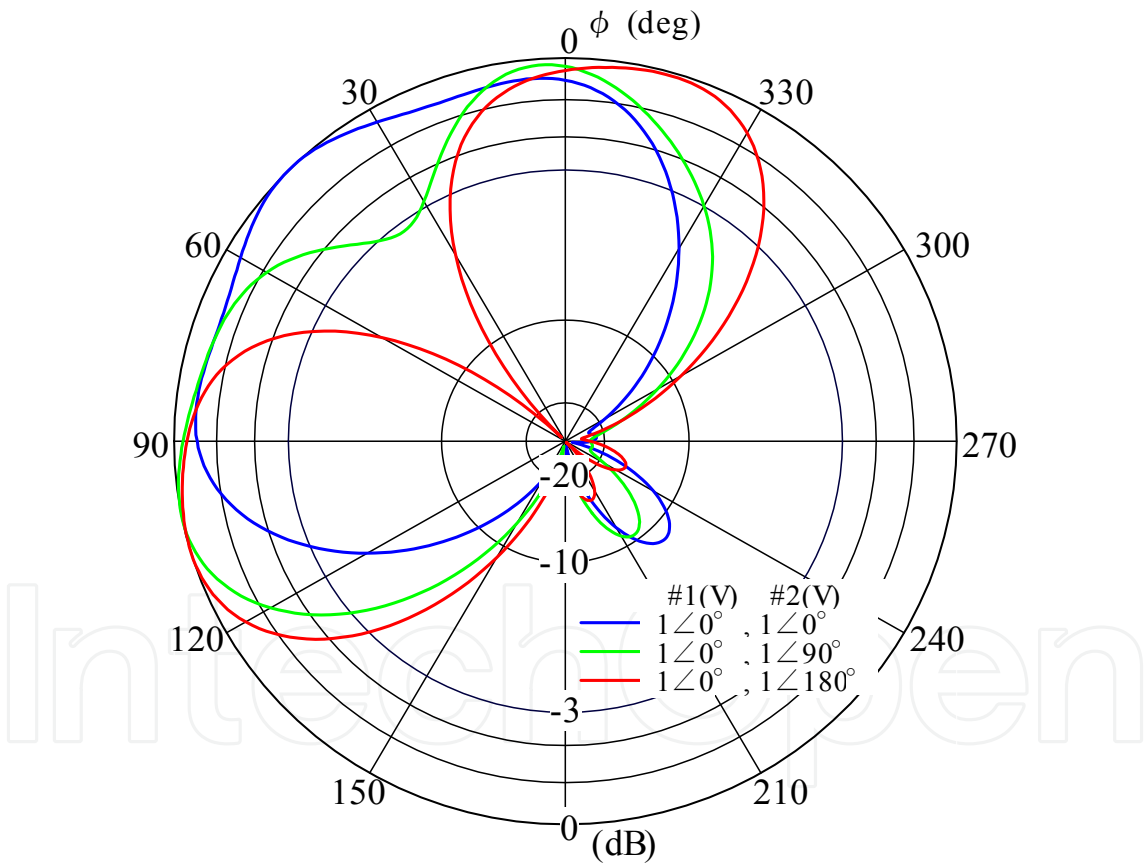
Fig. 21. Ring loop antenna for pattern synthesis of horizontal patterns

Frequency band	470MHz~770MHz(13ch~62ch)
Impedance	75Ω(normalized)
VSWR	Less than 2.0
Polarization	Horizontal
Gain	6dBi
Connector	F-P type
Weight	About 600g(with a 1.2m feeder)

Table 2. specification for Ring loop antenna for pattern synthesis
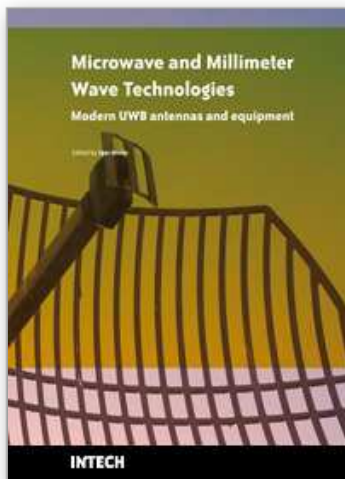
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