

IMPROVING MEDIUM WAVE SIGNAL TRANSMISSION USING A FLEXIBLE IMPEDANCE MATCHING UNIT

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ABSTRACT: This paper is on improving medium wave signal transmission using a flexible impedance matching unit. The system is T arrangement of impedance network that provides impedance matching between the transmitter and antenna. The parallel feeder used in the medium frequency ground wave signal transmission gives rise to a mismatch between antenna and the generator (transmitter). This network is a lumped reactance that effectively matches the transmitter to the antenna. The vertical antenna used in this range of frequency require a radial wire earth to achieve good ground; with effective connection to the matching network a good path to ground was achieved and noise associated with the transmission line was highly reduced.

KEYWORDS: wave signal transmission, impedance matching.

1 INTRODUCTION

Medium wave has frequency range between 300 KHz to 3 MHz of electromagnetic wave spectrum.

They are used in Radio terrestrial broadcasting in Amplitude Modulation mode of propagation. Because of the wavelength involved the electrical lengths of the antenna system are in the range of 25 meters to 250 meters, using quarter wavelength dipole antenna system. These are vertical of antenna with the whole mast radiating and called mast radiator. They are vertically polarized. The vertical antenna will provide adequate efficiency and bandwidth [1]. The radiation efficiency of a medium wave length antenna system are influenced by radiation resistance and they are proportional to loop radiation resistance and the ground resistance. Radiation resistance is the fictional resistance that would dissipate the amount of power that is radiated away from the antenna and loop resistance is the resistance between the antenna element and the antenna feed point. The loop resistance is very low for lower antenna and peak for antenna just less than 180° high.

The ground resistance is affected greatly by ground conductivity, antenna height and ground system. This ground system is very important in the operation of medium wave antenna [2]. These include the radial ground, the impedance matching network and the grounding system. Besides atmospheric fading, great amount of signal loss occur in the antenna ground system. Apart from the noise that is generated within the feeder, antenna noise is greatly reduced if appropriate ground is provided. Vertical polarization of this antenna is excellent for ground wave and even sky wave propagation.

The ground losses are also greatly reduced if the mast has radial copper ground system and the ground current will be in the low resistance copper ground system rather than the mass of earth which has high impedance.

Open wire feeders are installed between the transmitter and the antenna match unit. This is usually housed closely to the antenna to couple RF from the transmitter to the antenna. This ensures the transformation of the antenna impedance to the impedance of the open wire. Even in the digital format, the best of digital radio (the DRM) will fail in its reach if poor ground and matching systems are used [3] The flow of election up and down the vertical antenna creates the RF field, the more electrons flow, the stronger the field. In order to set greatest number of electron to flow, there is the need to have low

resistance storage full of electron, that means that the lower the resistance, the more electrons that can be forced up and back down out of the vertical radiator.

2 BACKGROUND/MATHEMATICAL THEORY

BACKGROUND OF THE STUDY

If the efficiency of a radio transmitter is guaranteed, and the antenna gain known, the antenna efficiency is realized if maximum energy is transferred from the transmitter to the antenna (Constantine, 2012). For this to happen, the input impedance of the antenna must be the same with the transmitter output impedance.

A mismatch of impedance causes degradation in antenna performance and the effect on both the transmitter and the antenna depends on its severity. Some of the transmitted power could be reflected back and, or the estimated signal reach is not realized [4].

(I) ANTENNA SYSTEM

Almost always and particularly for a medium frequency (medium wave) transmitter, the antenna is separated from the transmitter by a transmission line called antenna feeder, for a medium wave transmitter, an open wire parallel feeder is always used. This antenna, which is by design a function of the wavelength is always large and a mast radiator for medium wave transmission. This antenna is a transducer that converts electrical signal into an electromagnetic wave propagating in free space. The polarization is in the direction of E. field (electric field), this is a function of the geometry of the radiating element, hence a vertical antenna is vertically polarized. In practice a vertical antenna would be either, one wavelength, half wavelength or quarter wavelength. A half wave dipole antenna is always preferred.

From the work done by [1], a perfect quarter wave dipole antenna has a quarter of this antenna standing vertically as a radiating element, without ground resistance and 36 ohm radiation resistance.

However radio transmitter has other wavelengths in practice other than quarter wavelength and the ground has some measure of resistance. For a half wave dipole, the quarter of this half wavelength is used on the ground to improve the ground resistance; this is otherwise called the image aerial [5]. For the medium wave antenna system, there are two distinct meanings of ground. (a) A connection to ground at the base of a vertical antenna to enable election flow in and out of the antenna (b) A large area under the vertical antenna that will hold the electro-magnetic wave field near the earth. Medium Wave propagation is therefore a ground wave propagated wave. An antenna can radiate an r.f field even on a poor ground but the field will be weak.

The vertical radiator and the radial wires form a giant capacitor supplying the flow of electron in the antenna. The efficiency of an antenna is equal to

$$\eta = \frac{\text{radiation resistance}}{\text{sum of all the resistances in the antenna ground}} \times 100 \quad (1)$$

Sum of all the resistances in the antenna ground.

(II) EARTHING OF AN ANTENNA FIELD

Before earthing is done, the present conductivity of the ground must be ascertained. An earth resistance meter is used to measure the resistance of the ground. It is usually taken at four different points in the field.

Soil test. Factors that give rise to the conductivity of the ground, include water content of the soil, and salt content of the soil. When these preliminary tests are obtained, the depth of earth pith, length of earth rod, and impurity material to be used can be determined so as to achieve the required earth conductivity [7].

The process of determining water content of the soil (W_c) is simple, a known quantity of the soil is oven dried and weighed in a scale (B), then the same quantity is weighed without drying (A), the difference is obtained, and the percentage absorption is obtained as

$$W_c = \frac{A - B}{B} \times 100 \quad (2)$$

Where A is the sample of weight of saturated sand, and B is the weight of oven dried sand.

To assess the organic impurity content of the soil, the Sand is mixed with sodium hydroxide (NaOH) and the resulting colour compared with a standard colour and if it is darker, then the sand has sufficient impurity to support good ground.

The conductivity of the ground determines the depth of the earth pith. The resistance can be improved using copper earth mat and sufficient organic impurity and ingress material. The terminals of the matching unit and antenna ground are now bonded to the station ground provided. The Earth resistance should be less than one ohm.

(III) TRANSMITTER OUTPUT NETWORK/OUTPUT IMPEDANCE

Most transmitters are designed with coaxial feeder of 50 ohm output impedance but for the open wire with different transmission line impedance, an impedance matching is required to couple the transmitter output to the feeder.

The characteristic impedance of a parallel feeder is about 230 ohm. To overcome the mismatch between the feeder and transmitter output, a balancing unit transformer is used.

An approximate transformation ratio of 1:4 is required. BALUN is short form for balancing unit transformer.

This is a transformer which provides a broad means of matching the transmitter output to the parallel feeder. Fig 1 show the circuit configuration of BALUN transformer.

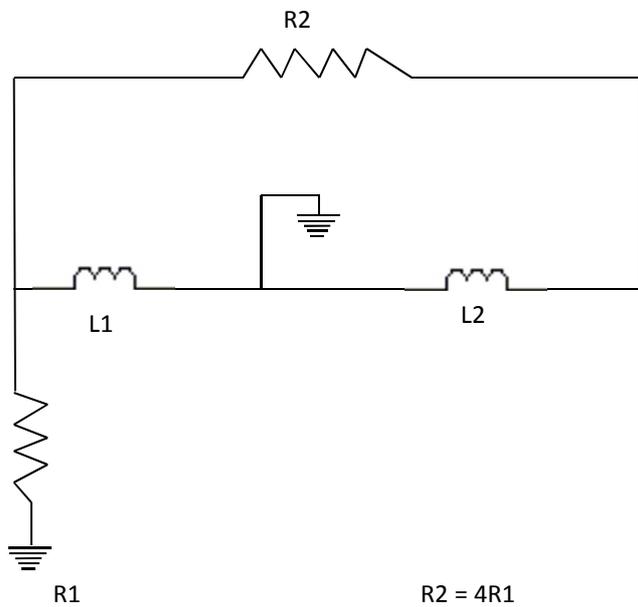


Fig. 1 Configuration of the BALUN Transformer

L_1 and L_2 is directly proportional to the number of turns and it is chosen to provide the balanced to unbalanced output. R_1 is the input, taken between the line and ground (balanced), while R_2 is the unbalanced output [6].

(IV) ANTENNA MATCHING UNIT

Transmission lines and wave guides are means of sending signal from signal generator to the load.

The signal is a radio frequency signal (RF), generated by a radio transmitter.

The transmission line comprises of basic electrical components of resistance, capacitance and inductance distributed along the line [8].

It's analysis is as with Resistance, Inductance and Capacitance (RLC) network. Medium Wave transmission frequency lies between 300 KHz to 3 MHz in the broadcast frequency spectrum and has an elaborate mast as a radiator.

The transmission line is an open wire parallel feeder. The characteristic impedance of a transmission line (Z_0) is a function of the per unit length parameters of resistance (R), inductance (L), conductance (G) and capacitance (C).

$$Z_0 = \sqrt{\frac{R + j\omega L}{G + j\omega C}} \tag{3}$$

Below in figure 2 is the circuit representation of a transmission line.

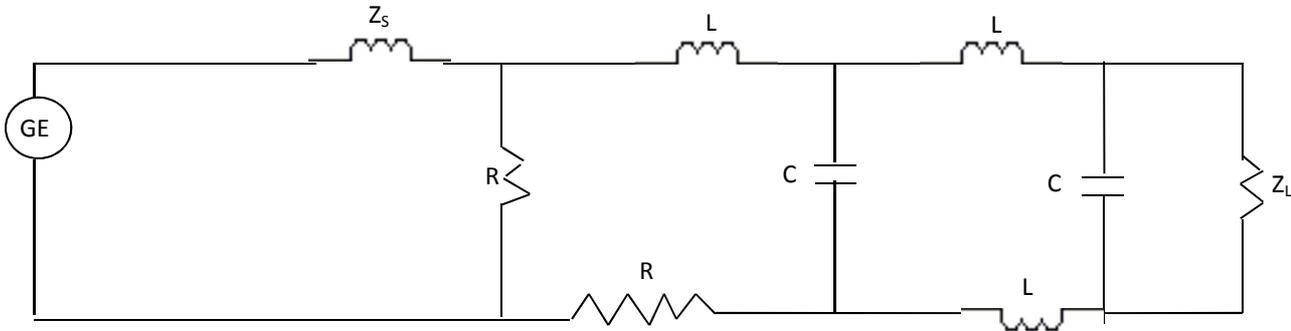


Fig.2: Equivalent circuit of a transmission line

Between the impedance of the transmission line and the load, (antenna) is an impedance matching network. Its Thevenin equivalent provides circuit analysis of maximum power transfer from the signal generator to the load.

When the load is a conjugate match to the generator $Z_L = Z^{th*}$

Where Z^{th*} indicates the conjugate Thevenin impedance.

If $Z^{th} = R^{th} + j X^{th}$ and $Z_L = R_L + j X_L$. This condition is equivalent to $R_L = R^{th}$ and $X_L = -X^{th}$. In this case half the generated power goes to the load, while half is dissipated on the generator Thevenin resistance.

The current through the load is given as

$$I_L = \frac{V^{th}}{Z^{th} + Z_L} = \frac{V^{th}}{(R^{th} + R_L) + j(X^{th} + X_L)} = \frac{V^{th}}{2R^{th}} \tag{4}$$

Thus the total reactance of the circuit is cancelled.

It follows that the power delivered by the Thevenin generator to the load and the power dissipated in the Thevenin resistance and the load will be

$$P_{tot} = \frac{|V|^{2}}{4R_{th}} \tag{5}$$

Assuming a lossless line (ie real values of Z_0 and B), the conjugate match condition can also be written in terms of the reflection coefficient (Γ) corresponding to Z_L and Z^{th} .

$$\Gamma_L = \Gamma_{th}^* = [\Gamma e^{2jBd}] \text{ --- conjugate} \tag{6}$$

Moving the phase exponentially to the left, the conjugate match condition can be written in terms of the same quantities at the input of the transmission line.

$$\Gamma_d = \Gamma_L e^{-2jBd} \leftrightarrow Z_d = Z_0^* \text{ (conjugate match).}$$

Indeed the transmission line can be cut at any distance from the load and its entire left segment including the generator replaced by a thevenin equivalent circuit. The conjugate matching is obtained by propagating to the left by distance L or to the right by a distance $d - L$ hence

$$\Gamma_L = \Gamma_L e^{-2jB(d-L)} \tag{7}$$

In practice, network match is used at one or both end of the transmission line to achieve the desired type of matching.

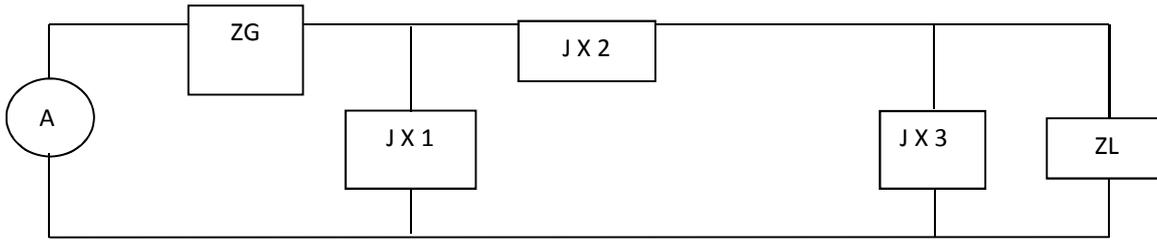


Fig. 3: A typical matching diagram

In the first case both the generator and the load are matched to achieve $Z_G = Z_L = Z_o$.

There are however cases where $Z_G = Z_o$ but $Z_L \neq Z_o$ the first case is the reflection less matching, while the second is the conjugate matching.

In the second case the load is connected to the line without matching circuit and the generator is conjugate matched to the input impedance of the line.

The line remains conjugate matched everywhere along its length, therefore the matching network can be inserted at any convenient point, and not necessarily at the input.

Because the value of Z_o depends, on Z_L and the frequency, the conjugate match will work as designed only at a single frequency. On the other hand if the load and generator are purely resistive and are matched individually to the line, the matching will remain reflectionless over a larger frequency bandwidth.

Conjugate matching is usually accomplished using L – section reactive network: We are concerned in this work with the L – section impedance parameter reactive matching networks.

MATHEMATICS OF TECHNIQUE USED

At lower frequency lumped parameters circuit elements may be used to construct a matching network? Figure 4 below shows an L - section network. It consists of only reactive elements (inductors or capacitors) to conjugate match any load Z_L to any generator Z_G . The use of reactive elements minimizes power loss in matching network. An arbitrary load impedance may be matched by normal L - section or if not possible by a reversed L - section.

Sometime both normal L- section and reversed L- section are possible.

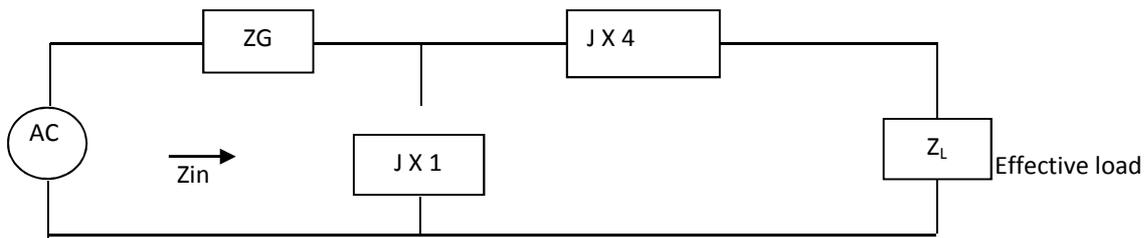


Fig .4: L- section network

The input to the design procedure are complex load and generator impedances; $Z_L = R_L + jX_L$ and $Z_G = R_G + jX_G$: The outputs are reactants X_1 and X_2 . For either type, the matching network transforms the load impedance Z_L into complex conjugate of the generator, [9]. Hence

$$Z_{in} = Z_G^* \text{ (conjugate match)} \tag{8}$$

Where Z_{in} is the input impedances looking into the L section.

$$Z_{in} = \frac{Z_1(Z_2 + Z_L)}{Z_1 + Z_2 + Z_L} \quad (\text{normal}) \quad (9)$$

$$Z_{in} = \frac{Z_2 + Z_1 Z_L}{Z_1 + Z_L} \quad (\text{reversed}) \quad (10)$$

With $Z_1 = jx_1$ and $Z_2 = jx_2$. Inserting equation 9 into 8 and equating real and imaginary parts of the two parts, we obtain a system of equations for X_1, X_2 with solution for the two types.

$$X_1 = \frac{X_G \pm R_G Q}{R_G / R_L} \quad - \quad - \quad (11)$$

$$X_2 = -X_L \pm R_L Q \quad (\text{Normal}) \quad - \quad - \quad (12)$$

$$Q = \sqrt{\frac{R_G - 1 + X_G^2}{R_L R_G}} \quad - \quad - \quad - \quad (13)$$

$$X_1 = \frac{X_L \pm R_L Q}{R_L / R_G - 1} \quad (\text{Reversed}) \quad - \quad - \quad - \quad (14)$$

$$X_2 = X_G \pm R_G Q \quad - \quad - \quad - \quad (15)$$

$$Q = \sqrt{\frac{R_L - 1 + X_L^2}{R_G R_L}} \quad (16)$$

If the load and generator impedances are both reactive, so that $X_L = 0$ and $X_G = 0$, the above solutions take the simple forms:

$$X_1 = \frac{\pm R_G}{Q} \quad - \quad - \quad (17)$$

$$X_2 = \pm R_L Q \quad - \quad - \quad - \quad (18)$$

$$Q = \frac{\sqrt{R_G}}{R_L} - 1 \quad (\text{normal}) \quad - \quad - \quad - \quad (19)$$

$$X_1 = \frac{\pm R_L}{Q} \quad - \quad - \quad - \quad (20)$$

$$X_2 = \pm R_L \quad - \quad - \quad - \quad (21)$$

$$Q = \frac{\sqrt{R_L}}{R_G} - 1 \quad - \quad - \quad - \quad (22)$$

We note that the reversed is obtained from the normal by exchanging Z_L with Z_G .

Both solution assumes that $R_G \neq R_L$. If $R_G = R_L$, then for either side $X_1 = X_2 = \infty$, $X_2 = (X_L + X_G)$ thus X_1 is open circuited and X_2 is such that $X_2 + X_L = -X_G$.

Q quantities play the role of series impedance Q - factor. Indeed, the X_2 equation in all cases imply that Q is equal to the ratio of total series reactance and the corresponding series resistance, that is $(X_1 + X_L) / R_L$ or $(X_2 + X_G) / R_G$.

The condition for real valued solution for X_1, X_2 are that Q factors in equation (19) and (20) be real valued or the quantities under the square root be non negative.

(B) Π SECTION NETWORK

Figure 5 Shows the Π Section network and it offers an extra freedom in the control of the Q factor and bandwidth of the match. In particular the bandwidth can be made as narrow as possible.

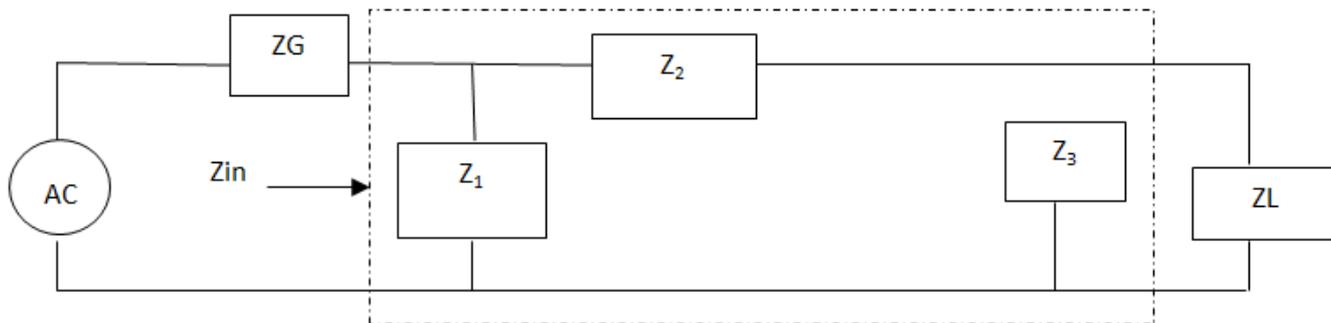


Fig.5: π Section matching unit

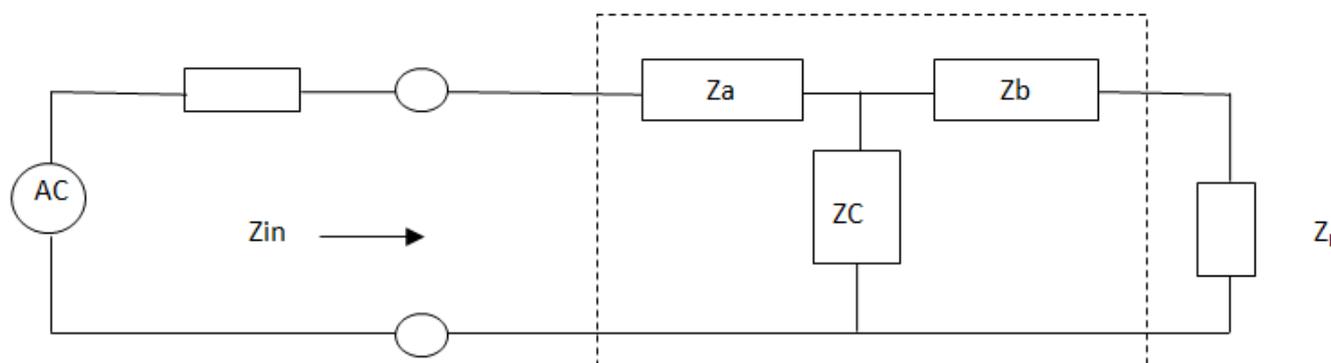


Fig.6: T-Section matching unit

(c) T. NETWORK

The π, T (also called D,Y network) can be transformed into each other. In practice the T network is more efficient and easier to construct. In the analysis network, the system is divided into two L-network as shown in figure 7

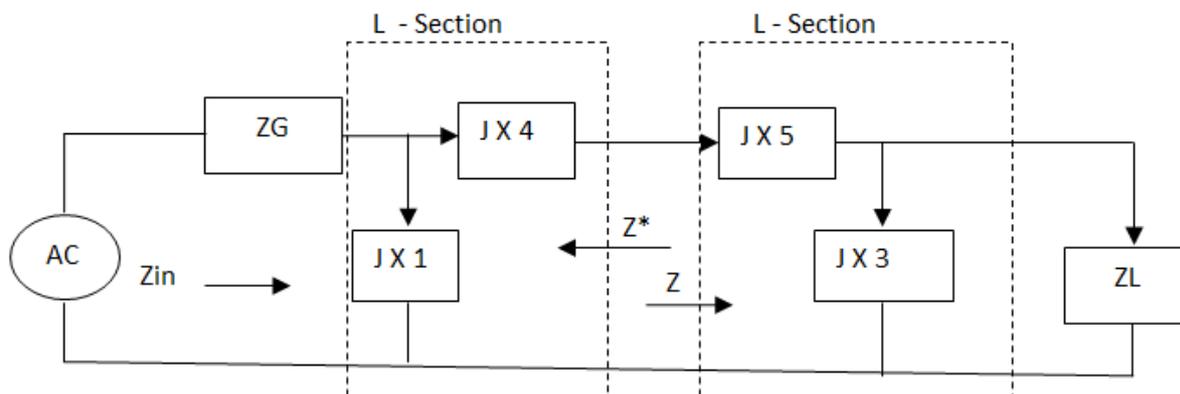


Fig.7: Equivalent L section arranged back to back

From the previous analysis, Z left, Z right and Z_{in} , can be gotten as show earlier.

Where $jx_2 = jx_4 + jx_5$

3 METHODOLOGY

TRANSMITTER OUTPUT IMPEDANCE

Most Transmitter outputs are designed to have the impedances of a coaxial feeder of 50ohms. But for a Medium Wave signal that requires a vertical antenna, a parallel feeder is required. The transmission line consist a BALUN transformer and the parallel feeder.

Usually the parallel feeder is a line (core) and ground. For most feeders used in Medium Wave high power transmission, the open wire parallel feeder is a six wire unbalanced line and the dielectric is air. Two of the wire form the core and represents the inner conductor. The remaining four wires form the shield with effective ground coupling.

The characteristic impedance of the feeder are calculated from the equation;

$$Z_0 = \left(69 \log_{10} \frac{2h^2}{p^2} + k \log_{10} \frac{4h^2}{cd} \right) \quad (23)$$

$$K = - \frac{2 \log_{10} \frac{4h^2}{cd}}{2h^2 + \log_{10} \frac{2h^2}{a^2}}$$

= 40mm, C = 326. 5mm, d = 382.9mm and h = 3600mm and $\rho_1 = 2.5\text{mm}$, $\rho_2 = 2.5\text{mm}$.

hence K = 0.772 and Zo = 234 ohms.

In figure 8, points 1,2 & 6 shows the arrangement of feeder line, letter a,b,c,d,h and p are indicated as

h = height above ground

c = distance of one of the shield of the nearest core feeder

d = distance of the same shield to the farther core feeder

a = radius of the circle joining the four feeders (shields)

b = distance of the core feeder to the centre.

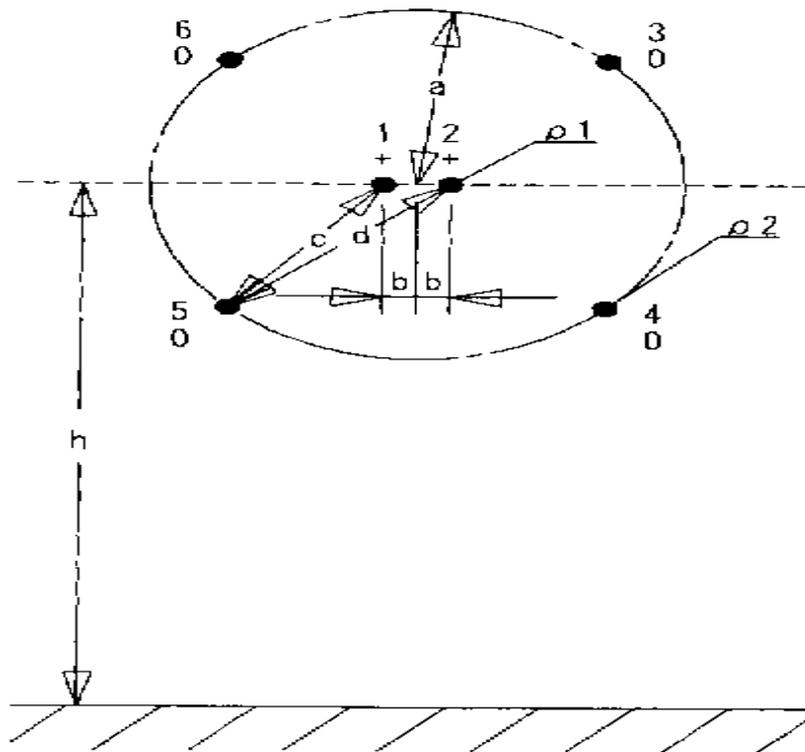


Fig. 8: An open wire parallel feeder.

THE ANTENNA MATCHING UNIT

Pi – Matching Unit

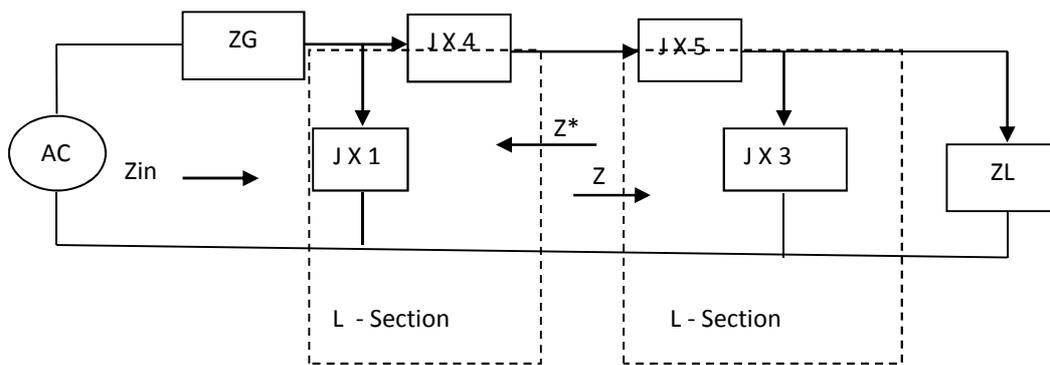


Fig. 9: Equivalent L section arranged back to back

The L Section matching can be used to match any arbitrary load to an arbitrary source, but its bandwidth and Q. factor are fixed by the value of the load and the source impedance as seen in section 2 of this work.

The diagram of Figure 3 is that of Pi – section or Pi – network. This gives more flexibility to the determination of the Q factor and the bandwidth of the system. This degree of freedom allows the designer to make the bandwidth as narrow as desired.

In practice the realization of a Pi network is difficult. The T. network showed in fig 6 design yields more practical values for the circuit element.

The Pi – section can be transformed to a T. section by the equation below.

Z_1, Z_2, Z_3 are Pi – section values while Z_a, Z_b and Z_c are T. section values in Fig 5 and 6.

$$Z_a = \frac{Z_2 Z_3}{u}, Z_b = \frac{Z_3 Z_1}{u}, Z_c = \frac{Z_1 Z_2}{u} \quad (24)$$

where $u = Z_1 + Z_2 + Z_3$

Also transformation equation from T. section to Pi section is given as

$$Z_1 = \frac{V}{Z_a}, Z_2 = \frac{V}{Z_b}, Z_3 = \frac{V}{Z_c} \quad (25)$$

Where $V = Z_a Z_b + Z_b Z_c + Z_c Z_a$.

Z_1, Z_2, Z_3 are purely reactive hence

$Z_1 = jX_1, Z_2 = jX_2, Z_3 = jX_3$ and so are $Z_a, Z_b,$ and Z_c

Mat lab function Pi2T and t2pl transform Pi to T and Vice Versa.

Pi 2t takes in arrays of three values

$Z_{123} = [Z_1, Z_2, Z_3]$ and outputs

$Z_{abc} = [Z_a, Z_b, Z_c]$.

and t2Pi does the reverse.

$Z_{abc} = \text{Pi2t}(Z_{123}); \% \text{ Pi To T section}$

$Z_{123} = \text{t2Pi}(Z_{abc}), \% \text{ T to Pi}$

Here, π Sec. (Pi Section) is discussed and transformed to T.

An additional degree of freedom is introduced into the design by an intermediate reference impedance, for instance $Z = R + jX$, such that looking into the right L – section of Fig 9, the input impedance is Z and looking into the left L - section it is Z^* , Note that $Z_1 = jX_1, Z_4 = jX_4, Z_3 = jX_3$

$$Z_{\text{left}} = Z_4 + \frac{Z_1 Z_G}{Z_1 + Z_G} = Z^* \quad (26)$$

$$Z_{\text{right}} = Z_3 + \frac{Z_1 Z_L}{Z_1 + Z_L} \quad (27)$$

As shown above, the right L – section and the load can be replaced by the effective load impedance $Z_{\text{right}} = Z$. Because Z_1 and Z_4 are purely reactive, their conjugate $Z^* = Z_1$ and $Z_4^* = Z_4$. It then follows that equation for Z_{right} ,

$$Z_{\text{in}} = \frac{Z_1 (Z_4 + Z)}{Z_1 + Z_4 + Z} = Z_G^* \quad (28)$$

This is the desired conjugate matching condition that must be satisfied by the network and can be interpreted as the result of matching the source Z_G to the load with a normal L section.

An equivalent point of view is to interpret equation as the result of matching the source Z to the load Z_G using a reversed L. section.

Similarly, the second equation is the result of matching the source Z_G to the load Z_L by the input looking into the right section

The reactance of the two sections can be obtained by the two successive call to L match using matlab function

$X_{14} = [X_1, X_4] = \text{Lmatch}(Z_G, Z, 'n')$

$X_{35} = [X_3, X_5] = \text{Lmatch}(Z, Z_G, 'v')$

For the above equation to have a solution the condition $R < R_G$ and $R < R_L$. ($Z \equiv R$)

This means that R must be chosen to satisfy this condition.

For Design purposes, Q factors of the left section and right section can be

taken to be as $Q_G = \sqrt{\frac{R_G}{R} - 1}$, and $Q_L = \sqrt{\frac{R_L}{R} - 1}$
 $Q = \sqrt{\frac{R_{max}}{R} - 1}$, where $R_{MAX} = \text{Max}(R_G, R_L)$.

R max is the greater of the two resistances R_G (generator impedance) and R_L (load impedance).

The Q factor controls the bandwidth, given a value of Q, the corresponding

R is obtained by $R = \frac{R_{Max}}{Q^2 + 1}$ (29)

Q_G and Q_L can be written in terms of Q as

$$Q_G = \sqrt{\frac{R_G(Q^2 + 1) - 1}{R_{max}}}$$

$$Q_L = \sqrt{\frac{R_L(Q^2 + 1) - 1}{R_{max}}}$$

The equation $Z_{in} = \frac{Z_1(Z_2 + Z)}{Z_1 + Z_2 + Z} = Z_G$ (31)

The equation 31 is implemented by the Mat lab function Pmatch which also constructs the value

$$X_2 = X_4 + X_3$$

Because there are two solutions for X_4 and two solution for X_3 , we can combine them in four different ways leading to four different solutions for the reactive network.

The input to the Pmatch function are impedances Z_G , Z_L and a reference impedance Z which must satisfy the condition $R < R_G$ or $R < R_L$

$Q = \sqrt{\frac{R_{max}}{R_{min}} - 1}$. The output is 4 x 3 matrix

Whose row are the different solutions for X_1, Z_2, X_3 . Hence the Mat Lab code

X123 = Pmatch (Z_G, Z_L, R): % Pi-matching

The model equation for this design is $Z_{in} = \frac{Z_1(Z_2 + Z)}{Z_1 + Z_2 + Z}$ (32)

Where $Z = Z_3 + \frac{Z_1 Z_G}{Z_1 + Z_G}$ (33)

Q is the quality factor of the matching network. The Q factor determines the bandwidth of the matching network. The Pi or T section gives the designer the opportunity of making the bandwidth as narrow as required. The Medium Wave frequency is between 300KHZ to 3 MHz Designing for 500KHZ medium wave frequency and the antenna impedance of 50ohms while the transmitter parallel feeder (transmission Line) impedance is 230ohms and $Q = 15$.

$$R = \frac{R_{max}}{Q^2 + 1} = \frac{230}{15^2 + 1} = 0.855$$

Using Mat lab code P match (Pi-matching),

X1 23 = [X₁, X₂, X₃] = Pmatch (50, 230, 0.885) % Pi match

	Z ₁	Z ₂	Z ₃
=	[6.7116	-19.8671	13.3333]
=	[-6.7116	19.8671	-13.3333]
=	[6.7116	6.6816	-13.3333]
=	[-6.7116	-6.6816	13.3333]

The above was used to obtain the various reactances for the Pi section unit.

Simulation: Z, Zin and reflection coefficient were simulated and the result is shown in table 1

$$Z = Z_3 + \frac{Z_1 Z_G}{Z_1 + Z_G}$$

$$Z_{in} = \frac{Z_1(Z_2 + Z_3)}{Z_1 + Z_2 + Z_3}$$

$$\text{Reflection Coefficient} = \frac{Z_1 - Z_G}{Z_1 + Z_G} \quad Z_1 = Z_{load}$$

Table 1 : The result of the simulations Z, Zin and reflection coefficient

Zin	Z	Reflection coefficient
4.447	6.578	0.9621
486.7	-6.973	0.3582
1473	6.465	0.7299
-1520	-6.854	1.331

TERMINATION OF ANTENNA MATCHING UNIT OUTPUT

Below (Fig. 10) are the arrangement of both the antenna base and the termination of the radial wires and the antenna tuning unit an extract from Denki Kogyo Co. Ltd Japan. The whole mast base is covered with copper plate and the radial wire terminated on it. A copper plate is provided to ensure firm connection of the output to ground.

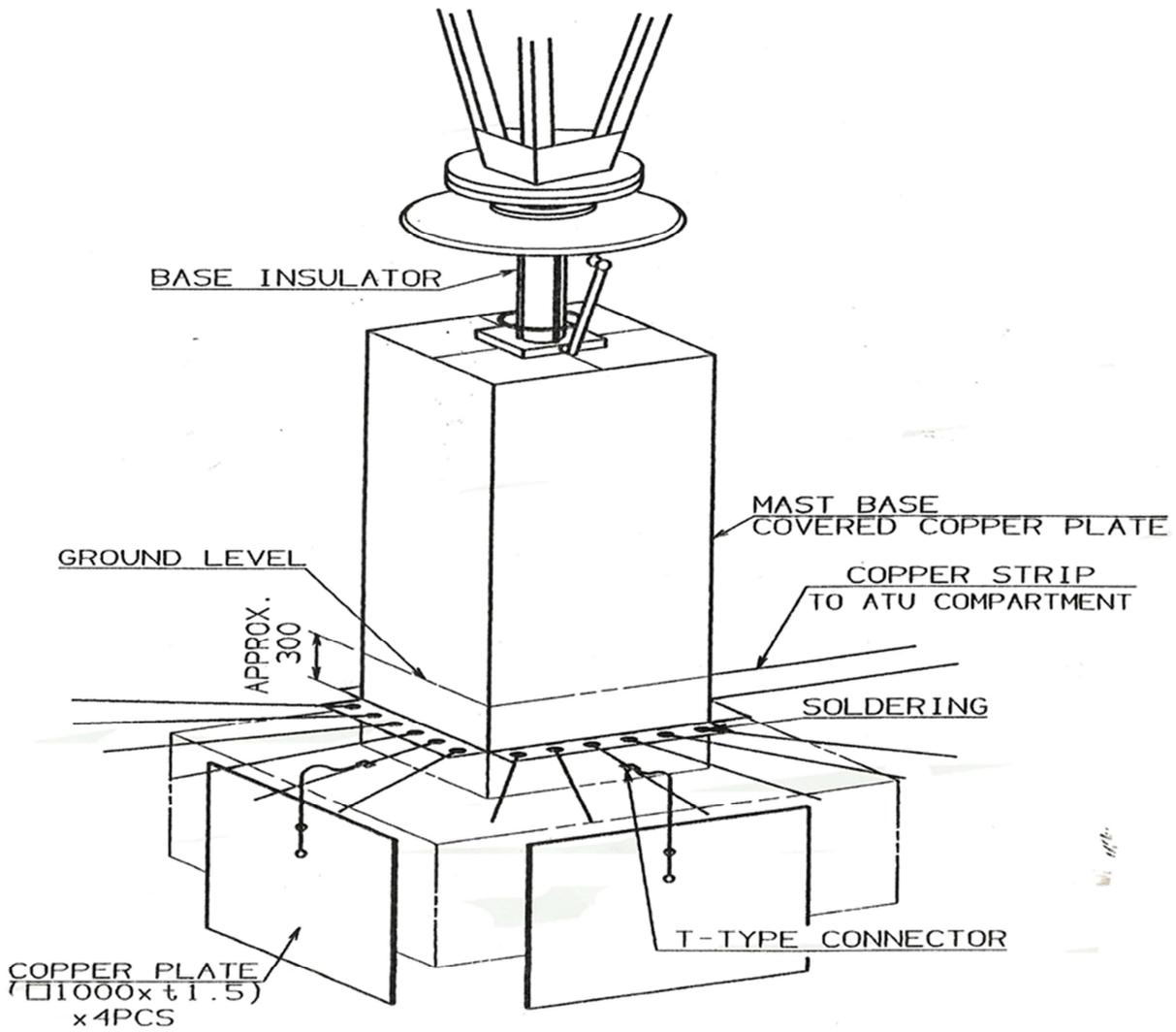


Fig. 10 Grounding at the mast base

DETERMINATION OF SIGNAL FIELD STRENGTH

Field strength is measured using a field strength meter, a half wave dipole antenna and feeder. The field strength meter is essentially a ratio receiver equipped with attenuator and generator of comparison signal serving as reference in the measurement, for the measurement to be taken the output in receiver and the attenuator adjusted for calibration.

Then the field strength is found by measuring the rf voltage V induced on the attenuator placed within the unknown field. The voltage obtained $v = kE$ (dB(uvm⁻¹)). The voltage and field strength are expressed as follows.

Voltage = RF attenuation reading + If attenuator reading + meter reading (conversion factor not included)

Field strength = RF attenuation reading + If attenuator reading + meter reading.

The field is kept from being disturbed to the extent possible by separating the antenna far from an obstacle as much as possible.

The transmitter antenna is 90meter has an adequate terrain clearance. According Roding and Collen (1990), $E_o = \sqrt{30Pt Gt}$

Where Pt = average transmitter power

Gt = Directivity gain power.

E_0 = Field strength

Field strength were measured along different routes from the transmitter site as shown below

Note! Path difference = $\frac{2h \sin \theta}{d}$

phase difference = $\frac{2\pi \sin \theta}{\lambda d}$

$\frac{E_0}{d}$ is the field strength at a unit distance

The decreasing field strength arises from 1/d factor for the signal radiated into free space.

Distance from transmitter (km)	1	10	20	30	40	50	60	70
Field strength (dB (u v/m))	101.78	61.79	49.75	42.70	37.70	33.03	30.66	27.98

4 DATA COLLECTION AND ANALYSIS

THE REFLECTION COEFFICIENT

This is the ratio reflected voltage to the forward voltage and measures the level of impedance mismatch. When the value is 1, the line is a short circuited line and the whole power is reflected back and when it is 0, the line is perfectly matched.

Table 2: Design Values of Impedance

Z_1	Z_2	Z_3
6.7116	-19.8671	13.3333
-6.7116	19.8671	-13.3333
6.7116	6.6816	-13.3333
-6.7116	-6.6816	13.3333

Table 3: Simulated Values of Z_{in} , Z and the reflection coefficient

Z_{in}	Z	Reflection coefficient [
4.447	6.578	0.9621
486.7	-6.973	0.3582
1473	6.465	0.7299
-1520	-6.854	1.331

Fig.11 Graph of input reflection coefficient against Z_{in} . Z_{in} is the input impedance looking into the generator and serves a feed to the matching unit. The result shows the choice of reflection coefficient at 0.358 which is the lowest. This corresponds to the reactances $Z_1 = -6.7116$, $Z_2 = 19.8671$, $Z_3 = -13.3333$.

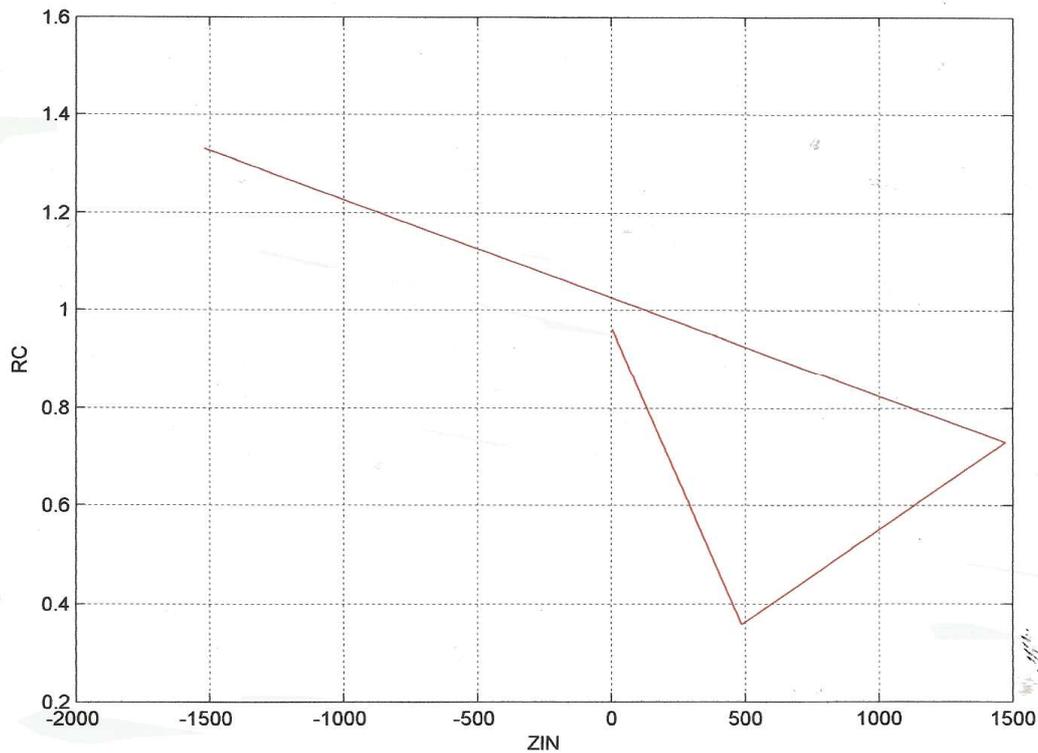


Fig. 11: Graph of input Reflection Coefficient versus Zin

The positive sign indicates inductive reactance, while negative sign indicates capacitive reactance.

BANDWIDTH MANAGEMENT

Bandwidth is determined by the value of R. the value is used in Mat Lab simulation to generate the reactance. The value of R as obtained in equation 29 is given by $\frac{R_{Max}}{Q_2 + 1}$

Where R_{Max} is the bigger of the two impedances of Z_G (Generator) and Z_L (Load).

In the graph of Fig 12 and the design for medium wave frequency of 500KHZ indicates the narrow bandwidth achievable using Pi- matching network at a low reflection coefficient of 0.3582.

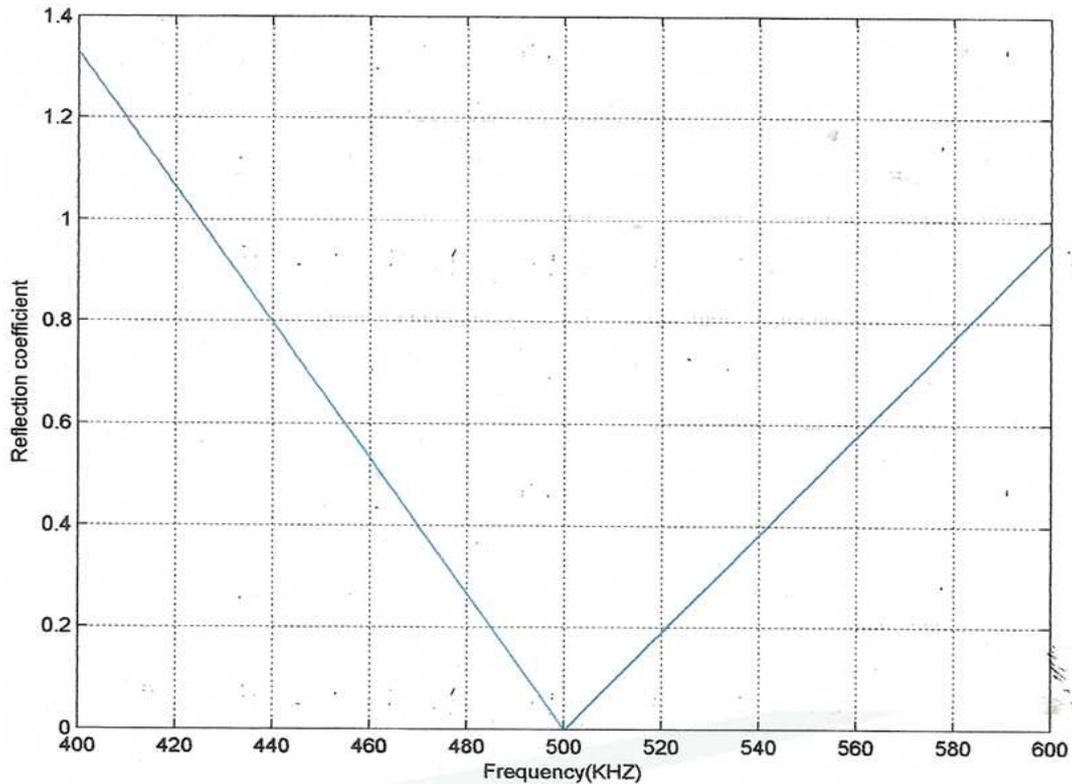


Fig.12: Graph of input reflection coefficient at the frequency of transmission

DATA ANALYSIS

From fig.11 in the input impedance looking into the generator and serves a feed to the matching unit. The result shows the choice of reflection coefficient at 0.358 which is the lowest. This corresponds to the reactances $Z_1 = -6.7116$, $Z_2 = 19.8671$, $Z_3 = -13.3333$. The positive sign indicates inductive reactance, while negative sign indicates capacitive reactance.

Also Fig 12 shows the Bandwidth at the Q factor of 15. The Pi-section network gives the operator control over bandwidth. The bandwidth depends on the value of Q (Q is the quality factor of the impedance network) chosen and the impedance of the transmission line Z_G now Z_{in} simulated.

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