BROADBAND VHF ANTENNA

ABSTRACT

Investigations are reported of an electrically short, asymmetrically fed broadband antenna employing a base isolation choke. The base isolation choke minim excitation of the mounting platform and improves radiation patterns. The asymmetri feed optimizes the antenna current distribution over the 30 to 90 MHz frequency ran resulting in improved field strength on the horizon and extended impedance bandwidt The antenna characteristics have been determined by numerical methods and confirmed experimentally.

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ACTIVE LOOP ANTENNAS

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1.Introduction

Due to their small physical size active receiving antennas are very frequently applied especially in mobile communication systems /1,2/.Up to now reports on the design considerations, the available sensitivity, and the dynamic range of such antennas are mainly restricted to active electrical dipole antennas. In the present paper an active loop antenna is introduced, which by means of optimum coupling between the loop and the active circuit provides maximum sensitivity as well as high linearity in a broad frequency range.

2.Fieldstrength-sensitivity

With active electrical dipole antennas a broadband frequency independent fieldstrength-sensitivity is obtained by means of a high impedance capacitive element such as fieldeffect transistors (FET) at the amplifier input. The noise of this element can be described by a frequency independent equivalent noise voltage source in series. A dual active element with low input impedance and a frequency independent equivalent noise current in parallel for application in a magnetic antenna is not available. By means of a special coupling between the amplifier and the loop it is possible to obtain the required sensitivity in the HF-frequency range with a loop of only 0.8 m diameter. Fig 1 shows the basic circuit diagram of a broadband active loop antenna. The FET in grounded-gate circuit symbolizes an electronic circuit with low input impedance. Its noise contribution can be described by an equivalent noise voltage source in series. At the output of this amplifier stage a highly linear low noise transistor amplifier is cascaded. An appropriate transformer coupling between the amplifier and the loop in combination with a smallest possible load capacitance C are the

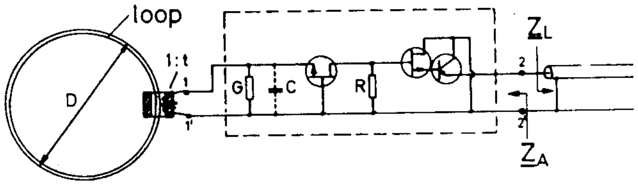

Fig1:Principle of a broadband active loop antenna

determining factors for broadband sensitivity optimization. The analysis of the noise has to consider the noise contribution of the conductance G, which is described by Nyquist's formula $\overline{i_{rG}^2} = 4kT_0BG$. The shot noise of the FET, described by an equivalent noise source in series to the input, reads as $\overline{u_{re}^2} = 4kT_0BR_e$, with R_e representing the equivalent noise resistance in this circuit. R_e is approximated by $R_e \approx (1+g_m/R_c)/g_m$. Herein g_m = forward transconductance, and R_c = channel resistance. Under the assumption of a negligibly small noise contribution of the gate leakage current the equivalent noise-fieldstrength of the active loop antenna reads as:

$$\frac{E_a}{\sqrt{B}} \approx \frac{1}{h_{effl}} \cdot \sqrt{4kT_o} \cdot \sqrt{R_e \cdot \frac{[1-(\frac{\omega}{\omega_o})^2]^2}{t^2} + \frac{1}{Q^2 \cdot t^2 \cdot G} \cdot (\frac{\omega}{\omega_o})^2} \qquad (1)$$

with $h_{eff} = 2\pi A/\lambda$ representing the effective height of the passive loop with area A. As a result of the inevitable capacitor C and the transformed loop inductance an undesired resonance is formed at frequency ω_0 with a quality factor $Q = \omega_0 C/G$. Curves of the equivalent noise fieldstrength of the active loop antenna for a channel bandwith of B = 1 Hz are plotted versus frequency in Fig 2. Optimum sensitivity is obtained with a transformation ratio of 1:12 assuming a minimum possible capacitance of 2 pF, which is only realistic if a gallium-arsenide FET is applied to the circuit. The external noise-fieldstrength in the frequency range regarded has been found to be -42 dBμV/m by CCIR and is represented by the dash-dotted line in Fig 2. The curves show that Q = 10 is an appropriate value to satisfy the sensitivity requirement for this small loop antenna in the entire frequency range from 1 MHz to 30 MHz. Different circuit dimensions result in a less appropriate sensitivity performance, as to be seen from the thin curves. Fig 1 shows very clearly the undesired influence of a large load capacitance C on the sensitivity although this high impedance capacity is shunted by the low input impedance of the FET in gate-grounded circuit. This capacitance, which is composed of the inevitable capacitances of the transistor, the transformer, and the line in between has to be as small as possible. This problem can only be solved by means of an active antenna with no disturbing line between the passive antenna and the antenna amplifier.

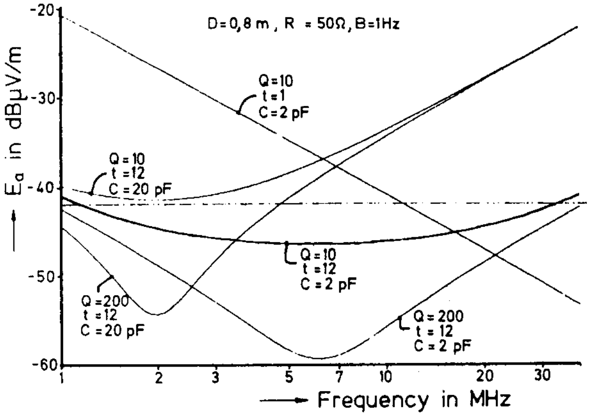

Fig 2: Equ. noise-fieldstrength of a .8 m diameter active loop antenna with various circuit dimensions

3. Effective height of the active loop antenna

After the analogy of passive receiving antennas the electromotoric force at the output (2 and 2' in Fig 1) in relation to the electric fieldstrength E can be defined as the effective height of the active loop antenna h_{effa}. With the impedances as defined in Fig 1 h_{effa} reads as: $h_{effa} = V_{22} \cdot (Z_L+Z_A)/(Z_L \cdot E)$. With active antennas the impedance ratio $(Z_L+Z_A)/Z_A$ can be realized to be frequency independent without any problems. This reduces the problem of a broadband frequency independent output voltage V_{22}/E in the circuit in Fig 1 to the problem of a frequency independent transistor current I/E. Under the assumption of a $G \ll g_m$, which in practice is always true, this current can be described as follows.

$$I \approx E \cdot A \cdot \frac{1}{L_i \cdot t \cdot C_o} \cdot \frac{1}{\sqrt{1 + [Q \cdot \frac{G}{g_m}(\frac{\omega}{\omega_o} - \frac{\omega_o}{\omega})]^2}} \qquad (2)$$

L_i: inductance of the loop. c_o: light velocity
If $Q' = Q \cdot G/g_m$ is regarded the effective quality factor of the circuit it can be realized that in contrary to the sensitivity performance the resonant character is of only negligible influence on the signal behaviour of the active loop antenna. With the optimum dimensioned antenna in Fig 2 (t=12, C=2 pF) the variation of h_{effa} is far less than 1 dB in the regarded frequency range. Hence the circuit in Fig 1 satisfies the required sensitivity and the required flatness of the amplitude response versus frequency as well.

4. Linearity

In addition to the broadband behaviour of the active loop antenna the gate-grounded FET provides the antenna with considerable large-signal qualities. With two undesired signals of 40 V/m each a suppression of the second order intermodulation products of 70 dB has been measured in a realized antenna. This provides the antenna with a second order dynamic of 113 dB as defined in /3/. This excellent value is obtained as a result of the high impedance signal source at the secondary winding of the transformer, by means of which the FET is linearised in its source. Fig 3 presents the basic circuit of a realized antenna amplifier. A highly linear symmetrical amplifier with high impedance input is applied as a second amplifier stage. Due to the limited linearity characteristics of this amplifier the total second order dynamic has been found to be 100 dB.

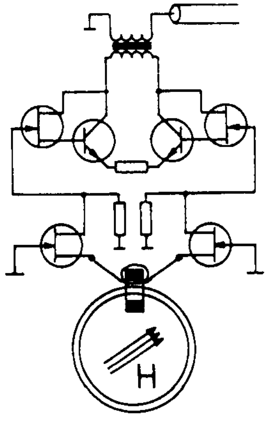

Fig 3: Realized antenna

5. Preferential application of active loop antennas.

The ratio of the electric fieldstrength of a nearby located vertically polarized transmitting antenna, and the equivalent noise fieldstrength of the receiving system can be regarded as a related distortion level. With this definition the obtainable gain in dynamic range, which is available if a receiving loop antenna is applied instead of a receiving rod antenna, can be found by the negative difference of these related distortion levels. This difference is plotted in Fig 4 versus the distance from a 7 m high transmitting rod antenna.

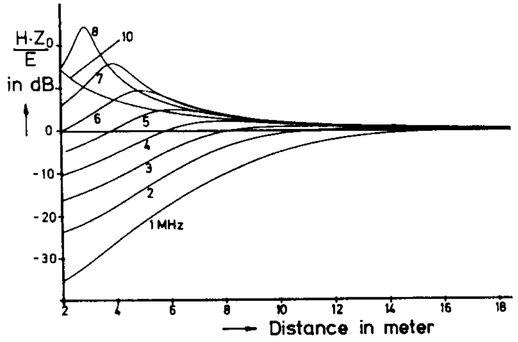

Fig 4 Dynamic considerations

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A NEW CLASS OF WIRE ANTENNAS

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The idea of reducing the antenna size, especially for resonant antennas, has been considered by many investigators. In general, any attempt to reduce the size of a monopole while preserving the same resonant frequency ends up in deficiencies such as bandwidth deterioration, pattern distortion and reduction in efficiency. Previous works on the subject include either changing the geometrical structure of the wire such as in "T" antennas and inverted "L" wires or the use of various types of loading and differently coated materials. In this work the objective is to present a new class of wire antennas called meander antennas as possible elements for size reduction. The new antenna is simple in geometry and unlike most other size reduction schemes, losses are not appreciable. This structure can be used to reduce the size of the existing wire antennas such as Yagi-Uda antennas and log-periodic dipole arrays.

Meander antennas are constructed of a wire with a zig-zag path (Fig. 1). Their properties depend on "N" the number of sections per wavelength and "W" the width of each rectangular section. Figure 2 shows some special cases of meander monopoles. We define a quantity $\beta<1$ as the reduction factor for a meander antenna. If a resonant monopole of length "L" and a meander monopole of length "ℓ" have the same resonant frequency, $\beta = \ell/L$ is designated as the reduction factor. This factor depends primarily on N and W. In practice W is kept small in comparison to the length of the antenna. Preliminary experiments show that β is in the neighborhood of 0.6 rather than one third, the ideal value for a threefold meander antenna.

To understand the characteristics of meander antennas, some impedance measurements were performed. A circular ground plane with a radius of R = 60 cm is used with the antenna erected from the center of the ground plane. The height of the meander antennas measured from the surface of the ground plane corresponds to $\ell = 4.5$ cm with separation W less than 0.3 cm. A monopole with a length of L = 13 cm was used as a reference. The diameter of the wire used in the experiments is 0.8 mm. Experiments show that as N increases, the resonant frequency f, increases which means a higher value of β or less size reduction. The experimental data and the calculated β are given in Table 1. The bandwidth was determined using a VSWR = 2 circle on the normalized impedance curve with respect to the resonance value. R is the experimental