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DEVELOPMENTS IN M.F RADIATOR SYSTEMS

UMBRELLA ANTENNAS

Development in recent years in m.f antennas has been concerned to a large extent with economic considerations. In the area of low-power antennas the umbrella antenna, (Fig.1) consisting of a control mast with a number of wires, (typically 9), attached to the top and radiating outwards at 45° to the horizontal has been used when anti-fading properties are not required. The limitations consequent upon making the mast short compared to a wavelength are in efficiency and bandwidth. Acceptable values of 90% in efficiency and 10kHz bandwidth with a s.w.r less than 1·2 can be obtained with a mast height of 1/10 wavelength at frequencies as low as 500kHz. The umbrella is more economic than the 'Tee' antenna because, for the same performance, it uses one mast where the latter uses two.

A further simplification is obtained by folding the vertical element to raise the impedance to the value required by the feeder. The latter may then be connected directly to the antenna without the need for a matching circuit.

The mast is earthed at the base and a number of wires run parallel to it, connected at the top and insulated at the bottom. The feeder is then connected directly to the bottom of this cage of wires surrounding the mast.

The antenna must first be made self resonant, i.e the capacity of the umbrella top must tune with the inductance of the mast and cage of wires in parallel. The input impedance (base of mast insulated) will then be of the order of 15Ω and purely resistive. This will be raised to the impedance of the feeder (50–100Ω) by the folding process by adjusting the number of wires in the cage surrounding the mast.

A number of other benefits besides the elimination of the matching circuit derive from using a folded element. Since the mast is earthed at the base an insulator is no longer required and the mast is solidly earthed in the event of a lightning strike. The mast lighting isolating transformer normally needed to prevent the mast lighting circuit from short circuiting the radio-frequency circuit is not required.

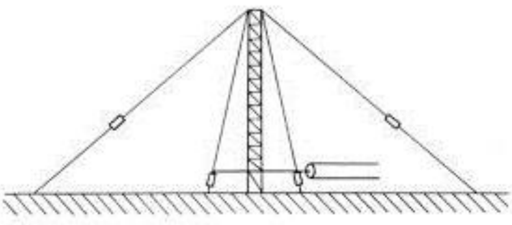

Fig.1 Folded umbrella antenna.

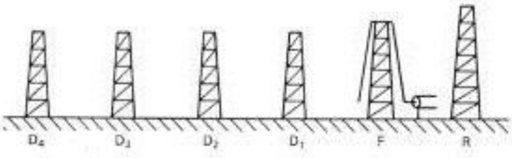

Fig.2 Yagi antenna, folded fed element.

YAGI ANTENNA

An economic solution to high-power directional antennas is afforded by the Yagi antenna, (Fig.2) using vertical monopoles instead of dipoles as in the familiar v.h.f Yagi. An optimum number of elements from various considerations is six. The fed element can be folded and made to match directly to a coaxial feeder. Practical types of fold consist of a cage of six wires surrounding the mast. This gives an input impedance of 100Ω.

Absence of structural insulators, matching circuit and mast lighting isolating transformers make this a competitive antenna where high power is involved. The Yagi antenna, being an end-fire array, produces a beam which is narrow both in the vertical and horizontal planes. For a given gain, therefore, it gives a wider coverage than a broadside array. The narrowing of the vertical beam gives an anti-fading performance which, while not as good as that of a halfwave antenna, is close to it.

The currents in the individual elements of such an array can be monitored by loops coupled to the base and the radiation pattern measured from the amplitude and phase distribution. The results of such a measurement are shown in figure 3 and the calculated diagram in figure 4.

ANTI-FADING ANTENNAS

For omnidirectional anti-fading antennas the half-wave vertical monopole is most generally used and the ring antenna somewhat neglected. This is probably due to the complexity of the feed system

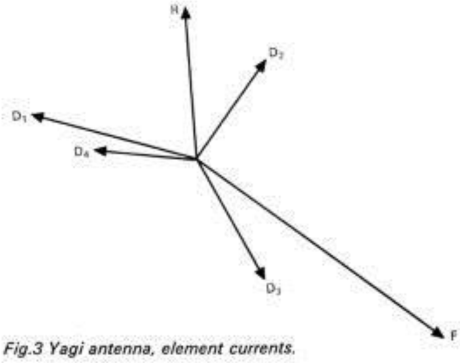

Fig.3 Yagi antenna, element currents.

Fig.4 6-element Yagi horizontal radiation pattern. Gain 8·5dB calculated from currents in elements.

where all elements have their individual feed. However, a form in which a centrally-fed mast is surrounded by a ring of five parasitic elements is very much simpler and has distinct attractions, particularly at lower frequencies, (Fig.5).

Because the central element has about five times the current in the individual ring elements its mutual impedance can induce high voltages in them compared to the voltage due to their self impedance. It therefore enables great control of the parasitic currents in the elements to be obtained. The antenna can, as a result, be made to work over a relatively wide range of frequencies for a given ring diameter. The vertical radiation pattern which controls the anti-fading properties can also be made to vary over a wide range, (Fig.6).

EFFECTS OF LIGHTNING AND STATIC

Major hazards with m.f radiators using stayed masts can be lightning and static electricity. Mast stays are normally broken into short lengths by sectionalizing insulators to eliminate radiation currents. Static electricity due to wind borne charges can build up on the sections of the stays and eventually cause flash-over on the insulators. This will be followed by a power arc due to a high-power r.f transmission which can damage the insulator. The static charge flow is relatively slow and can be prevented from accumulating by placing a relatively high resistance (of the order of 1MΩ) across the insulator.

Lightning causes a much more rapid increase in voltage: as a charged cloud approaches the mast it induces charges of opposite sign on the sections of the stays by slow leakage across the insulators. When the cloud is discharged by a lightning stroke, the field collapses in a time interval of the order of a microsecond. Charges on the stays thus immediately produce high voltage across the insulators. The insulator can be prevented from flashover by placing a non-linear resistor in parallel with it. As the voltage across the resistor rises, the value of the resistor falls; typically, doubling the voltage reduces the resistance to one tenth its value. Thus a resistor which would have a value high enough not to absorb significant power at the working m.f voltage of the insulator would have a low enough resistance to discharge the stay charges before the flashover voltage of the insulator was reached. This involves operating the relevant stay insulator at about $\frac{1}{4}$ of the flashover voltage.

The material used in the non-linear resistor is silicon carbide. It has very effective properties at d.c and 50Hz but its performance is more limited at radio frequencies. This is because it behaves as a lossy capacitor of rather high capacitance. Thus the r.f causes dielectric losses which are more than the loss due to its resistance.

However, by carefully choosing the grade of commercially available silicon carbide and the length to breadth ratio of the built-up resistor, suitable non-linear resistors can be obtained.

LIGHTNING DETECTORS

A second method of avoiding damage to stay insulators due to lightning is to instal a lightning detector which, when it registers a lightning dis-

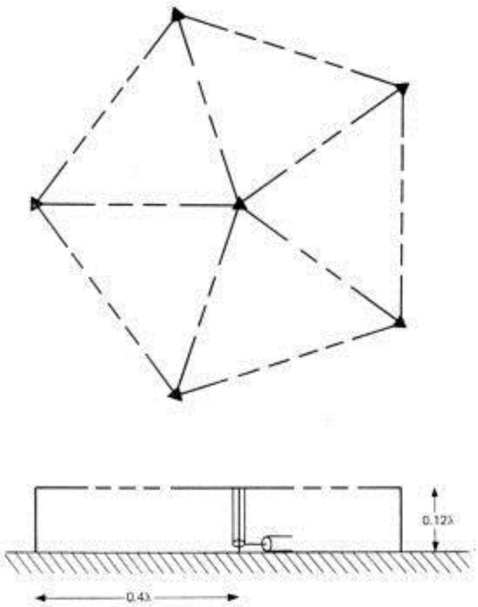

Fig.5 Anti-fading ring antenna.

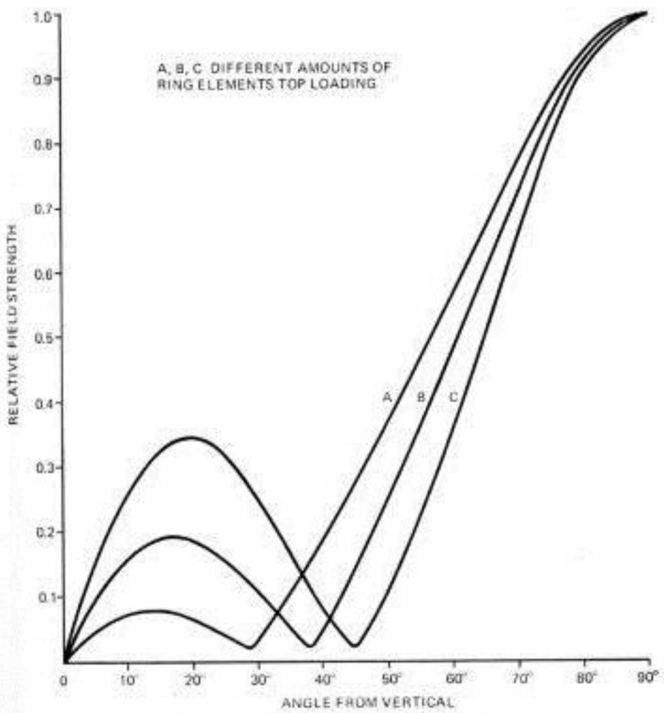

Fig.6 Ring antenna, vertical radiation pattern.

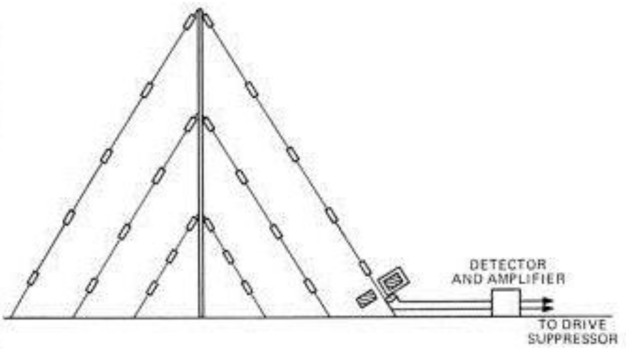

Fig.7 M.F antenna, lightning protection unit.

charge, momentarily causes the transmitter drive to be interrupted. In this way any flashover on a stay insulator is not followed by a power arc, the flashover extinguishes immediately and no damage is caused.

The detector is conveniently placed on one of the mast stays. The current induced in the stay by the lightning induces in turn a voltage in the secondary of a ferrite-cored transformer of which the stay forms the single turn primary. This is detected by a tunnel diode and amplified to operate a relay to suppress the transmitter drive. It is sufficient to suppress the drive for about one second for the flashover to extinguish.

The device can be made sensitive to about 5A which is much less than the current required to cause an arc, (Fig.7).

HIGH-POWER M.F FEEDERS

With the advent of high-power m.f transmitters in the 1–2MW range, transmission lines of equal

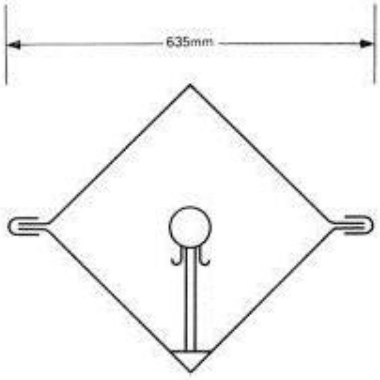

Fig.8 Coaxial feeder for 2MW carrier m.f. transmission.

capacity are required. These can be of the open-wire type but it is desirable that they be fully screened in order to eliminate ground losses and also to avoid environmental effects such as flying insects, etc, which can cause flashovers, as well as wind and ice which can cause excessive loadings. A fabricated feeder capable of handling these powers is shown in figure 8. It consists of a square section aluminium outer 350mm side with a tubular inner conductor of 79mm dia.

The square section splits along the diagonal so that the halves nest into each other for packing purposes. They are quickly assembled by U-section longitudinal strips which slip over the edges of the halves when they join. These in turn are held in position by a stainless steel strap which is fixed around the feeder. A neoprene U-section strip under the connecting U-section seals the feeder.

The characteristic impedance is 100Ω, this value having the following advantages

(i) It gives a convenient size inner conductor, rigid enough to span the 16ft support-point interval, yet not too big for suitable bellows expansion joints

(ii) It is in the region of maximum efficiency when a copper inner and aluminium outer are used

(iii) It is a convenient impedance when folded antennas are used as these tend to be high in impedance since the folding process is an upward-transforming one.

CONCLUSION

Recent progress towards smaller m.f antenna costs has been attained by reducing mast heights and simplifying impedance matching circuits.