SPECIAL ENQUIRY

Planning Application submitted by

Isle of Man International Broadcasting plc

to construct a Crossed Field Antenna

at Cranstal, near Bride, Isle of Man

PROOF OF EVIDENCE

Submitted by

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1. Introduction

1.1 My name is Brian G Stewart and I am currently a lecturer in the Department of Engineering at the Glasgow Caledonian University in Scotland. I graduated with a B.Sc. in Physics and Astronomy from Glasgow University and went on to study a Ph.D. in electronic and optical instrumentation for astronomical applications. My main teaching responsibilities relate to electronic communication systems. My main research area is concerned with antenna design and currently I lead an antenna research group in the Department which is involved in novel antenna design and associated applications.

1.2 I have been involved in antenna design and research since 1985 when I first started lecturing at the School of Electronic and Electrical Engineering at the Robert Gordon University in Aberdeen.

1.3 I have also been involved in the design and construction of Crossed Field Antennas (CFAs) since1985 and have published papers related to their design and performance.

1.4 I hold an amateur radio licence which allows me to conduct tests and experiments on new antenna developments - indeed most of the major developments in radio engineering have been made by licensed radio amateurs.

1.5 My proof of evidence is related to detailing information in respect to the general operation of antennas and the Crossed Field Antenna (CFA) and in particular to valid proof of CFA performance and suitability for medium wave and long wave broadcasting applications.

1.6 I am not employed by the developers of the CFA, nor by Isle of Man International Broadcasting Plc

2. RadioTransmission: Basic Generalities

2.1 When a voltage is applied across the ends of a conductor, the free charges within the conductor start to move, resulting in what is known as an electrical current. A steady current is known as a Direct Current or DC current (its frequency is zero) and is produced when a constant DC voltage is applied to a conductor. If the voltage is alternating or oscillating with a given frequency, i.e. varied positively and negatively, often many times each second, an alternating current is formed. The voltage and current are then generally referred to as an Alternating Current AC source voltage and an AC current.

2.2 When an AC voltage is applied to a suitable conductor called an antenna (often referred to as an aerial, because such devices are usually raised aloft), then an AC current is produced on the antenna. The consequence of this current flow is that it also produces a voltage distribution on the antenna. Together the AC current and AC voltage on the antenna conductor produce alternating electric and magnetic fields (called **E** and **H** fields respectively) which interact together to produce electromagnetic waves which radiate into space.

2.3 Suitable AC frequencies are generated by equipment known as transmitters which take raw electrical energy from a voltage supply, either as DC from batteries, or from the mains supply, or elsewhere, and converts this to a much higher frequency to form the driving AC voltage. This voltage stimulates an AC current on the antenna which produces the electromagnetic fields for radiation. The information such as a radio programme is mixed in some way with the AC source voltage in which case this information is also present on the AC current and therefore also in the **E** and **H** waves which are radiated outwards and away from the antenna.

2.4 The earliest demonstrations of the phenomena of launching radio waves into space were performed by Oliver Lodge of Liverpool University in 1894. Three years later, Guglielo Marconi took the idea to the British Army and Navy, convincing them it was a useful form of communication. The success of Marconi's initiative paved the way for the successful modern era of radio communications.

2.5 The frequency (f in Hertz (Hz)) and the wavelength (λ (lambda) in metres (m)) of a radio wave in space are interdependent and are related through the well known simple formula:

$$f \times \lambda = c$$

i.e. frequency multiplied by wavelength equals c the speed of the electromagnetic waves in space. The value of c is approximately 298,000,000 metres/sec. This figure is better known as the speed of light by most people - light of course being a higher frequency form of electromagnetic radiation. The above formula can be used to determine the approximate size of a conventional broadcast antenna.

2.6 The wavelengths used in the first radio transmissions by Marconi and others were in the Long Wave (LW) (30kHz - 300kHz) and Medium Wave (MW) (300kHz - 3000kHz) bands. As those bands have filled up, transmissions have been forced to use higher and higher frequencies, where there is more free transmission frequency space available. Recent broadcast and communications developments have used much higher frequencies - for example, short wave radio, FM radio, television, cellular phones, with still higher frequencies for radar and satellite communications. If we go higher still we come to infra-red, then the visible part of the electromagnetic spectrum, then to ultraviolet and x-rays. All these are forms of electromagnetic radiation.

3. Conventional Broadcast Antennas – The Quarter Wave Vertical

3.1 Traditional broadcast antennas for LW and MW are vertical conductors which are usually a resonant proportion of the wavelength in size. The often quoted examples are a quarter wavelength ($\lambda/4$) vertical and a half wavelength ($\lambda/2$) vertical. As the term vertical suggests, these antennas are positioned in the vertical direction with respect to ground level as this provides the most effective and efficient way for **E** and **H** fields to produce radiated waves which spread out to fill space.

3.2 Much smaller lengths for vertical antennas result in poorer levels of radiation being produced. Indeed, this has often been used as an argument by opponents of the Crossed Field Antenna (CFA) who intimate that by reference to conventional antenna theory and experimental practice, the CFA must inherently be a very poor or inefficient radiator of waves as its height is very much smaller than a traditional $\lambda/4$ vertical.

3.3 The frequency allocated to the Isle of Man station is 279 kHz. Using the simple formula frequency multiplied by wavelength equals the speed of light, as a rough guide it is easy to evaluate that a quarter wave antenna for use at this frequency would be about 260m in height (about 865 feet tall), in other words a pretty enormous structure, although many in service today are much higher - e.g. 600m (about 2000 feet) is the accepted tallest economical height.

3.4 In addition to significant height, traditional LW vertical antennas require a substantial area of surrounding land where a number of conductors are normally buried. These conductors are referred to as "ground radials" and are required to help produce efficient radiation from the antenna. Generally a circular area of radius $\lambda/4$ would not be uncommon to lay ground radials. For a 279kHz vertical antenna, this would result in a circular radius of around 260m resulting in a land area of more than 229,000 square meters.

3.4 It is clear that in many situations the limitations to efficient LW and MW broadcasts relate to antenna height and also to suitable land area.

4. Fundamental Broadcast Antenna Performance Parameters

Efficiency/Field Strength

4.1 To quantify an antennas ability to produce radiated power, engineers often refer to the efficiency of an antenna. The efficiency of an antenna is the percentage of power radiated by an antenna as the electromagnetic wave, compared to the amount of power being fed into it.

4.2 Often broadcast engineers evaluate efficiency in terms of the distant **E** field strength (units of V/m i.e. volts per metre) of the radio waves referenced to a 100% efficient $\lambda/4$ vertical antenna with 1kW of power fed from the transmitter. Usually this **E** field strength is evaluated at a distance of 1km or 1mile at ground level.

4.3 The important ground level values for reference are as follows:

1 km	**E** = 311 mV/m
1 mile	**E** = 193 mV/m

4.4 In practice measured values are less due inefficiencies in the antenna system and also because the radiated signal attenuates as it propagates across the surface of the earth. This attenuation is a function of ground conductivity and usually tables can be consulted to help evaluate the attenuation for different frequencies of transmission. This is of importance in evaluating the effective coverage area of transmitted signals.

4.5 In reality it is often possible to achieve 90%-95% efficient vertical antennas (in situations of negligible attenuation) which would correspond to **E** field strengths of around 295 mV/m to 303 mV/m measured at ground level.

4.6 To evaluate the efficiency of an antenna with a transmitter power other than 1kW, the **E** field value is simply multiplied by the square root of the power in kW. For example, if a transmitter was operating on 50kW (i.e. 50,000W) the expected 100% efficient value at 1 km would be the square root of 50 multiplied by 311 mV resulting in 2.20 V/m.

Bandwidth

4.7 The bandwidth of an antenna is its ability to radiate efficiently a band of frequencies around its stated operational frequency. This is very important for radio stations as the information such as music or speech (comprising frequencies up to 5kHz for AM at LW and MW) is modulated or contained within a frequency band around the transmitting frequency.

4.8 As an example, the antenna for an AM station operating on a frequency of 279kHz requires the ability to transmit efficiently frequencies from approximately 279kHz - 5kHz to 279kHz + 5kHz i.e. from 274kHz to 284kHz, resulting in a bandwidth of 10kHz around the transmitting frequency.

4.9 If there is too little bandwidth, an AM transmission when received, will sound muffled as the higher frequencies, for example those around 3kHz - 5kHz, will not be transmitted so well as the lower frequencies.

4.10 Low frequency antennas often have restricted bandwidth making the fidelity of the transmitted sound worse than stations with wider bandwidth. Achieving adequate bandwidth becomes more difficult as a traditional antenna is made shorter. Thus a further reason for having such large antennas such as a $\lambda/4$ vertical.

4.11 To complicate matters further, the bandwidth and radiation efficiency of vertical antennas are also interdependent. As the antenna is reduced in size the bandwidth also reduces, but this is also accompanied by a reduction in radiation efficiency i.e. a reduction in the radiated power produced by the antenna.

4.12 For conventional smaller antennas to achieve reasonable radiation efficiencies, they must have very large current and voltage distributions on the structure, resulting in very fierce electric field strengths close to the antenna. For such small antennas, radiation efficiencies are very much less than 100%.

4.13 Broadcast engineers measure the bandwidth of an antenna in terms of Standing Wave Ratio (SWR), which is a measure of how efficiently the frequency range around the transmitting frequency can be fed into the antenna and therefore radiated.

4.14 A standard evaluation is to accept SWR values in the range 1 to 1.6 for broadcasting. For Long Wave (LW) and Medium Wave (MW) Amplitude Modulation (AM) the bandwidth for SWR at 1.6 must be a minimum of about 10kHz.

4.15 As the Crossed Field Antenna is much smaller in height than a conventional vertical antenna, opponents have stated that it must have many limitations for broadcasting. Namely, a very small bandwidth, accompanied by poor radiation efficiency. As we shall see later, in practice this is not the case.

5. The Crossed Field Antenna (CFA)

5.1 The CFA is a revolutionary radio antenna. The start of CFA work goes back to around 1985, when Maurice Hately of The Robert Gordon University in Aberdeen proposed an alternative design for antennas which differed from conventional antenna conductor techniques. This process was call Poynting Vector Synthesis. Hately and his then student, an Egyptian called Fathi Kabbary, constructed several prototypes which gave promising results.

5.2 I joined with them in this project and over a period of two years several small scale CFAs of less than 5% in wavelength (i.e. less than $\lambda/20$) were constructed and appeared to performed satisfactorily.

5.3 After returning to Egypt to work in the Engineering Section of ERTU (the Egyptian Radio and TV Union - the Egyptian state broadcaster) Fathi Kabbary and a larger team of engineers commissioned and built several successful commercial MW CFAs which are still in active broadcast service.

5.4 To help appreciate the ideas behind the development of CFAs, it is beneficial to detail the proposed concepts behind their design.

5.5 Hately, Kabbary and myself reasoned Poynting Vector Synthesis in an article in Electronics and Wireless World ("Maxwell's equations and the Crossed Field Antenna" - Vol. 95, pp 216-218, 1988). In this article we argued that if the power to be transmitted was divided into two equal parts, half used to create a radio frequency **E** field and half used to create an **H** field, situated so as to cut the **E** field at right angles, and timed to be synchronised with **E**, it should be possible to synthesise the radio wave from a small antenna structure rather than a traditional antenna of large height.

5.6 This was called "Poynting Vector Synthesis" since it is was based upon the well established theory called the Poynting Theorem by which physicists and engineers understand the radio wave when travelling well away from its source. In 1884 Poynting showed that all known electrical power transfer processes involve geometrically crossed in-phase **E** and **H** field vectors.

5.7 The premise behind the CFA is to synthesise **E** and **H** fields in time-phase and engineer the ratio E/H to equal space impedance which is 377 Ohms. These are the field conditions which exist for radiated waves far from an antenna, but the CFA now synthesises these conditions, not in the distant field, but much closer to the antenna system.

5.8 Basically a CFA comprises two separate electrodes, one electrode creates the **E** field while the other creates the **H** field. In contrast, a conventional antenna uses the current flow on the antenna structure to simultaneously establish both the **E** and **H** fields.

5.9 In the CFA the fields are time-synchronised and matched to 377 Ohms with a suitable electrical phasing circuit in order to produce the distant wave conditions for radiated power close to the antenna. Once a suitable electrical circuit is designed the CFA produces efficient radiated power.

5.10 There appears to be many advantages to such a non-resonant height antenna system, for example:

- smaller height structures may be employed
- CFAs can possess a wide bandwidth since they are not particularly restrained by height limitations associated with standard antennas
- no requirement for a large area to lay ground radials

5.11 The wave radiated from a CFA is an entirely conventional radio wave - if it were not then it would not be possible to receive it on a domestic radio.

5.12 There has been some suggestion that the CFA is very wasteful of power and is energy inefficient. The measurements I have taken and which are presented in the next section prove conclusively that this is not the case and that the CFA is in fact a highly efficient radiator of electromagnetic waves, and that it possesses a wide bandwidth suitable for broadcasting purposes.

5.13 Since the energy fed into the CFA is intended to be radiated as an electromagnetic wave, and with high efficiency of conversion, there is therefore unlikely to be any 'side effects', as has been claimed in letters of objection.

6. Recent CFA Measurements and Tests
Barnis CFA Egypt 603kHz

CFA site

6.1 From the 7th to 11th August 2000, I visited the CFA situated in Barnis in Egypt along with Derrick Connolly, the Director of Engineering and Information Technology of *Isle of Man International Broadcasting plc*. I understand that the Barnis CFA has been in service and fully operational since 1996 and transmits *The General Programme Service* to southern Egypt.

6.2 This CFA antenna has been built at ground level on the desert floor and transmits across the open desert. Its height is approximately 9.4m and transmits on 603 kHz. It is therefore approximately 1.92% of a wavelength in height, i.e. about $\lambda/52$ tall, and thus very much smaller than a $\lambda/4$ vertical antenna. The ground plane or copper sheets on which the CFA sits is approximately 25m by 25m in area.

6.3 About 170m from the CFA is a microwave tower of approximately 120m in height. The tower is grounded and is used only for microwave communication purposes. At 170m distance the tower should receive less than 1% - 2% of any incident radiated power from the CFA. Because it is grounded and because of the low incident power it receives, any re-radiation effects associated with the tower can be considered negligible.

Transmitter

6.4 The station uses a Harris DX-100 to broadcast at either 10kW or 50kW power levels, though the transmitter is capable of producing 100kW power. The transmitter has a stated output impedance of 50 Ohms. It is set for 140% modulation at these power levels. The transmitter is located in an air conditioned room approximately 160m from the electrical phasing unit which feeds the CFA. The phasing unit is about 12.5m from the actual CFA. The feed lines to the CFA are fed horizontally above the ground plane.

6.5 Since the intended size of the CFA for Cranstal is about 27m, which is about 3 times the size of the Barnis CFA, and the frequency of operation is 279kHz, about 0.46 times

603kHz, then its performance should indeed be a reasonable gauge to the intended performance of the Cranstal CFA.

6.6 The 10 kW or 50kW power levels for the CFA can be expected to behave in the same manner as a 500 kW CFA. In radio engineering terms, the main difference is the voltage which is found on the elements of the antenna, and thus the difference in the **E** field produced in the far field.

6.7 A translation from 10kW to 500kW is only a matter of multiplying the **E** field strength values by the square root of (500/10), i.e. by a factor of 7.07. Translation from 50kW to 500kW results in a factor of 3.16.

Measuring Equipment

6.8 In making my measurements I used the following professional measuring equipment and took a series of readings after properly calibrating the equipment:

- FIM-21 Potomac Field Strength Meter; Operating range 54kHz - 1.6MHz
- HP 8753C Network Analyser; Operating range 300kHz - 3.0 GHz
- Delta RF Ammeter TCA-80-EX; Operating range 500kHz - 2MHz
- Garmin GPS 12 for distance determinations; Quoted accuracy +-15m

(The GPS was calibrated using a measuring tape for distances less than 100m and was established to be very accurate even at that level.)

Table 2 Equipment used for measurements

Field Strength Measurements

6.9 The Potomac Field strength meter was calibrated against the nearest station's field strength. To the best of my current knowledge this station is approximately 170 miles across the Red Sea at Doba in Saudi Arabia operating on 594kHz at currently 2 MW during daytime hours. The expected and measured values were found to be consistent.

6.10 It is also of interest to note that the field strength meter used in my measurements was also calibrated against 3 other Potomac FIM devices used by independent Brazilian Engineers associated with ABERT, the Brazilian national broadcasting federation, who performed similar field strength measurements on other Egyptian CFAs in 1999. These engineers can confirm that all 4 Potomac were consistent in their readings across all ranges.

Measurements 1

6.11 The first measurements taken were between 7:30pm and 8:15pm on the evening of 8th August. The transmitter was set to 50kW power and the following set of field strength measurements were taken in a southerly direction across desert from the CFA:

Distance	Potomac height above ground	
	0 m	2 m
1 km	3.00 V/m	3.09 V/m
1.61 km (1 mile)	2.39 V/m	2.35 V/m
5 km	0.50 V/m	0.49 V/m

Table 1 Measurements 1
Initial field strengths measured near Barnis CFA operating at 50kW
8th August 2000

As can be seen there is little difference between measurements made at ground level and also at a height of 2m.

Measurements 2

6.12 In order to evaluate the CFA more effectively, 4 radial directions were measured from around 100m out to 1km at the 10kW power setting. These measurements were taken between 11:45am and 2:30pm on the 9th of August, with the field strength meter at a height of about 1m from the ground level. These radial field strength measurements were taken at 90^0 intervals around the CFA.

6.13 Radial directions 1, 3 and 4 were chosen to cover open desert terrain. Radial 2 was measured only from 200m up to 500m due to restricted access onto nearby military desert, and also because of nearby fencing around the CFA compound and building. This resulted in the field strength meter indicating that the maximum field strength was not coming from the direction of the CFA but was due to field coupling effects associated with the fencing. On radial 4, as the CFA was approached at distances less than 150m there was clearly some effect caused by a quantity of nearby metal lying on the desert floor.

6.14 Radial distances further than 1km were not measured due to both difficulty of vehicle mobility in soft desert sand and time constraints.

6.15 Tabulated results are:

Distance	Radial 1	Radial2	Radial 3	Radial 4
80 m	9.2 V/m	-	-	-
100 m	7.6 V/m	-	7.0 V/m	7.1 V/m
150 m	5.9 V/m	-	5.2 V/m	7.4 V/m
200 m	4.2 V/m	4.8 V/m	4.3 V/m	4.8 V/m
250m	3.2 V/m	3.8 V/m	3.6 V/m	3.8 V/m
400 m	2.9 V/m	2.9 V/m	2.5 V/m	2.8 V/m
500m	2.13 V/m	2.7 V/m	2.1 V/m	2.15 V/m
1 km	1.10 V/m	-	1.82 V/m	1.09 V/m

Table 2 Measurements 2
4 Radials covering 90^0 intervals at power of 10kW
9th August 2000

6.16 These radial measurements are plotted on graphs in Figure 1.

6.17 It is of interest to note that for the 50 kW measurements presented in Table 1, the 1km measurement was taken about 1^0 off Radial 3; the 1 mile measurement about 7^0 off Radial 3; and the 5 km measurement about 6^0 off Radial 2.

Discussion of field strength measurements

6.18 The results of these measurements demonstrate that the CFA performs with a high level of efficiency. To put the results into perspective they can be compared with the expected field strengths at 1 km from a 100% efficient quarter wave vertical operating at 10kW and at 50 kW.

6.19 These values are, for a 10kW antenna - 0.98 V/m and for a 50 kW antenna - 2.20 V/m. For each of the radial measurements presented in Tables 1 and 2, the CFA exceeded these values for the associated power level.

6.20 The effects of attenuation in the desert at 1 km or 1mile have not been considered. At 1 mile, dry desert attenuation may be considered to reduce the signal strength by a factor of between 0.72 and 0.85 which is characteristic of very poor soil conditions.

6.21 With or without attenuation taken into consideration it is clear that the Barnis CFA is producing impressive radiated ground wave efficiency, in excess of the 100% efficient conventional quarter wave antenna.

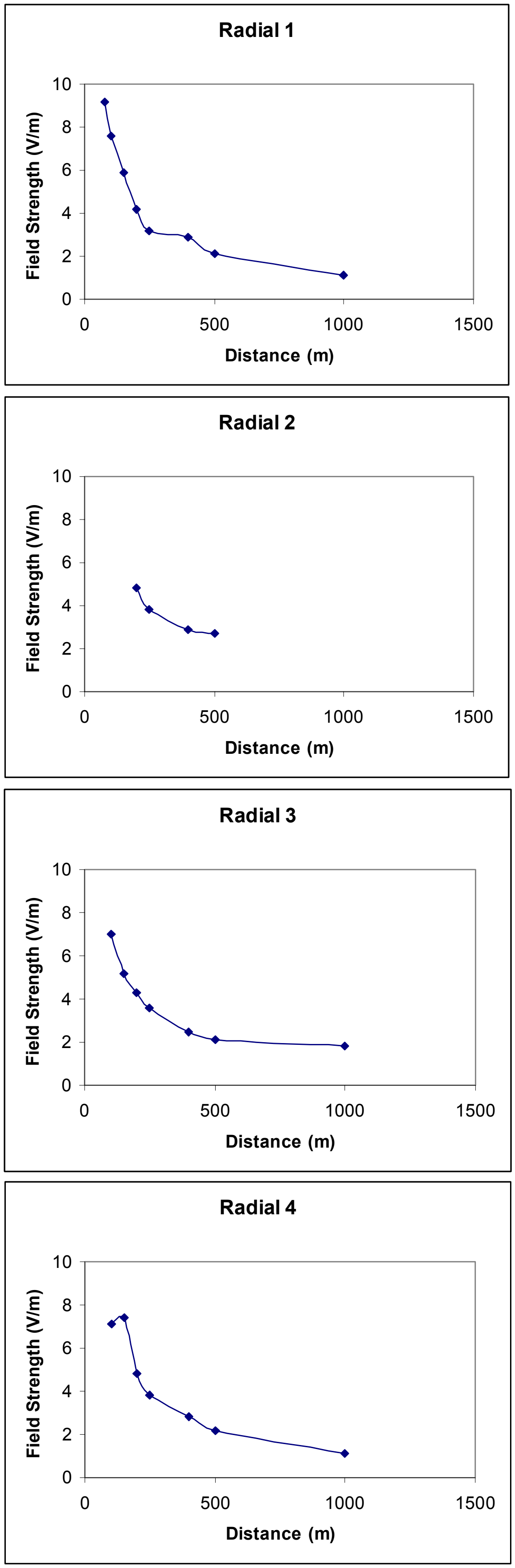

Figure 1 Field strength plots for the 4 radial measurements at 10kW

Bandwidth

6.22 I was given access to the transmitter feed line in order to measure the bandwidth of the CFA**.** After calibrating the Hewlett Packard network analyser using a 50 Ohm calibration load, evaluations of SWR were obtained directly from the analyser. The following results were obtained:

SWR	Frequency Range	Bandwidth
1.6	592 kHz – 623 kHz	31 kHz

Table 3 Bandwidth measurement on Barnis CFA

6.23 The measured SWR 1.6 bandwidth is 31kHz, indicating that an excellent quality audio signal is being transmitted using this CFA. This bandwidth is more than the minimum requirement of about 10 kHz.

6.24 For reference, at 603 kHz, the transmission frequency, the SWR was noted to be 1.25. The minimum value of SWR was 1.10 which occurred at a frequency of 608 kHz.

Confirmation of power fed to the CFA

6.25 The Harris DX-100 transmitter has an analogue power level meter which displays the transmitter output power. At the 10kW setting this read 10kW. At the 50kW setting it read approximately 52kW. In both cases the Harris transmitter also indicated on an analogue meter a very low SWR.

6.26 In order to substantiate the power delivered to the CFA in both cases, I was again given access to the transmitter feed where the RF current meter was then installed. The following current measurements were read off the meter for each power setting on the transmitter and the power evaluated from the square of the current multiplied by 50 Ohms.

Transmitter Power Setting	Current	Calculated Power to CFA
10 kW	14.5 A	10.51 kW
50 kW	31.5 A	49.61 kW

Table 4 Evaluated current and power levels delivered to CFA

6.27 The measured values of power appear to be entirely consistent with the stated power delivered to the CFA as indicated by the Harris DX-100 transmitter. Every confidence exists to believe that the CFA was being fed with the stated power outputs during field strength measurements.

General Conclusion on Barnis CFA

6.28 The Barnis CFA is working with exceptionally strong ground wave efficiency and more than adequate bandwidth for AM transmission. The measured values indicate that the CFA is easily outperforming standard quarter wave vertical antennas in terms of simultaneous high efficiency and large bandwidth requirements.

7. Cranstal CFA 279kHz Calculations

Field strength determination

7.1 Based on the measurements set out in Tables 1 and 2 above I have made a series of calculations on the resulting field strengths expected for the proposed 27m tall 500kW Cranstal CFA on 279kHz. These are shown in Table 5 for poor conductivity and perfect conductivity conditions. Plots are given in Figure 2.

7.2 In evaluating this data I have included firstly a scaling factor of 0.33 to compensate for the height multiplication of approximately 3 for the Cranstal CFA, and secondly a scaling factor of 2.16 to compensate for the effect of reducing the frequency from 603kHz to 279kHz. This results in an effective scaling factor of 0.71.

7.3 The expected lowest case field strength scenario would result from very poor conductivity comparable with the surrounding desert of Barnis which probably has a typical conductivity of 0.002S/m or less. For this situation the Cranstal CFA results are simply the Barnis results multiplied by a scaling for the power and also a scaling of 0.71 as outlined in the above paragraph.

7.4 Evaluation of perfect conductivity field strength determinations are indicative of maximum expected field strength values. However, for distances less than 1 mile it is difficult to evaluate actual attenuation values. I have assumed that the Cranstal CFA should function like the Barnis CFA at 1 mile, but compensate for the worst case attenuation of 0.72. I have therefore compensated (i.e. increased) all values from 100m out to 1 mile of the CFA by multiplying up by a factor of 1/1.7 which equals 1.4 . This of course will provide overestimates closer to the CFA as there is in fact very little attenuation expected in the first few hundred meters.

7.5 As the Potomac field strength device is a magnetic device which measures **H** field and converts this to an equivalent **E** field determination, some opponents may argue that the field strength measurements at distances less than about one sixth of a wavelength (i.e. 180m at 279kHz) do not include non-radiated field strength components. In my opinion these effects should not be dramatic when a CFA is operating efficiently, but as a precaution only, some people may wish to multiply the values presented in the table which are less than 200m by a suitable factor. For example, previous reports (confidential to IMIB plc by BAE Systems (Marconi)) suggest that much closer to a

CFA the **E** field should be prudently assessed as being about 3 times larger than those determined by a magnetic loop device.

Distance	Poor Conductivity	Perfect Conductivity
80m	> 75 V/m	> 106 V/m
100m	58 V/m	81 V/m
150m	45 V/m	63 V/m
200m	32 V/m	45 V/m
250m	24 V/m	34 V/m
400m	22 V/m	31 V/m
500m	16 V/m	23 V/m
1km	8.5 V/m	12 V/m
5km	5.6 V/m	7.8 V/m

Table 5 Expected Field Strengths for Cranstal CFA of height 27m, operating at 500kW on 279 kHz based on evaluation of Barnis CFA

7.6 As the perfect conductivity column is an overestimate of maximum possible values based on the Barnis CFA, these should never be achieved in practice and values somewhere between the two levels tabulated should be expected.

7.7 Determinations indicate that the field strengths should be much lower and safer than critics of the CFA have been suggesting.

Bandwidth determination

7.8 Based on the SWR 1.6 bandwidth measurement of 31 kHz on the Barnis CFA, the required bandwidth for the IOM 279kHz CFA should be easily attainable for a 27m height antenna. Indeed following a simple linear scaling formula, the bandwidth should surprisingly be expected to increase to approximately 1.4 times 31 kHz which equals 43.4 kHz which is well in excess of 10kHz.

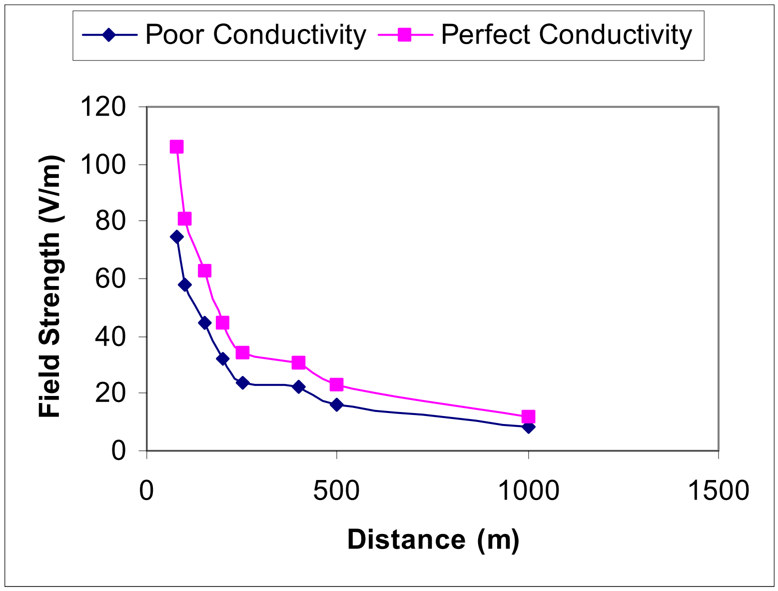

Figure 2 Expected Poor Conductivity and Perfect Conductivity Field Strengths for the 500kW 279kHz CFA, based on the Barnis CFA measurements.

8. Corroboration of Results by Other Independent Sources

Previous BAE Systems (Marconi) report(s)

8.1 In October 1999 after some criticism of its proposals, and false stories being circulated by objectors, IMIB Plc commissioned BAE Systems (Marconi Research Centre) of Chelmsford to carry out a thorough investigation on the Crossed Field Antenna and ascertain what type of signal was formed by a CFA.

8.2 In January 2000 two scientists from BSE Systems visited several operational CFAs and produced a confidential/commercial in confidence report, that the CFA forms an entirely conventional radio wave which can be measured and quantified. They also state that the CFAs operate with high efficiency.

8.3 The field strength measurements can be further compared from results taken by the engineers from BAE Systems who from their assessment of two MW CFAs, one in Tanta and one in Alexandria, deduced the following results for a 500kW CFA:

Distance	Field Strength
25m	848 V/m
50m	434 V/m
75m	283 V/m
100m	212 V/m
200m	106 V/m
400m	16 V/m
800m	8 V/m
1.2km	6 V/m

Table 6 Calculated field strengths for a 500 kW CFA made by BAE Systems, January 2000

8.4 The results for distances below 180m have been multiplied by a factor of about 3 as a case of near field prudence.

8.5 Away from the CFA these values are comparable in nature to my own evaluations. Indeed for distances over 400m my own independent assessments of field strength are actually greater than those presented in Table 6.

Independent Brazilian Broadcast Engineers

8.6 The measurements of a CFA by independent professional Brazilian broadcast engineers associated with ABERT has also been openly published on the Internet at AntenneX (www.antennex.com). Their results refer to the Tanta CFA operating on 1161kHz with 25 kW power and having a height of about 8.2m i.e. 3% of a wavelength or $\lambda/32$.

8.7 Using 3 Potomac field strength meters which were all in agreement, the equivalent 1kW attenuated field strength at 1km was measured to be 359.4 mV/m.

8.8 The results taken by myself at 10kW for the Barnis CFA indicate an attenuated 1kW field strength at 1km of around 348 mV/m radial directions 1 and 4, with 585 mV/m in radial direction 3. Two 1km radiated field strength measurements at Barnis are therefore less than the reported radiated field strength measured by these Brazilian engineers on a different CFA, substantiating further the validity of my measurements.

9. Response to Criticisms of the CFA

9.1 Objectors have indicated in their list of documents to be referred to, a letter by Alan Boswell of then Marconi (dated 1991) criticising the CFA.

9.2 The following two points are very relevant:

- The CFA does not rely on conventional antenna theory and challenges a lot of previously thought to be standard theories. It is not unusual for new inventions and developments to undergo rigorous challenging by peers, and review. This is a common occurrence.

- The letter quoted was written by Mr Boswell almost a decade ago, in the very early days of CFA developments. At that time very little was known about true CFA performance and none had been brought into commercial service. In addition his letter was also written when few people had ever constructed or had a CFA functioning properly and efficiently.

9.3 This year Mr Boswell has inspected some operational broadcast CFAs and has agreed that they DO work, " and show a high degree of efficiency".

10. Final Conclusions

10.1 From the measurements taken on the Barnis CFA, it can be concluded that it is operating as a very efficient groundwave antenna system with wide bandwidth characteristics which make it wholly suitable for MW AM broadcasting on 603kHz.

10.2 There is no reason to doubt that based on these measurements, a LW CFA at 279 kHz, should provide both high groundwave efficiency and adequate bandwidth requirements for AM broadcasting.