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Corner Reflector Antenna Design for Interference Mitigation between FM Broadcasting and Aeronautical Ground to Air Communication Radios

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Abstract
Third order intermodulation products caused by two or more FM broadcasting radios transmitter on a site to inter modulate either within transmitters themselves or within a non-linear component on site and those intermodulation products due to non-linearity's of passive circuits of transmitters sharing same radiating element have been the source of interference in Tanzania to aeronautical ground to air communication (COM) systems which are safety services due to its nature of safeguarding human life and properties. These intermodulation products have been found in frequencies used by COM systems. This research work focused on using of corner reflector antenna to mitigate interference caused by FM broadcasting radio stations to COM facilities which are used for ground to air communication between control tower and pilots in Tanzania. Through simulations it is observed that the corner reflector antenna provide sufficient front to back ratio which facilitate in reducing electric signal strength and hence forth power level from FM broadcasting stations reaching the aeronautical facilities and hence mitigate the interference.
Keywords: COM, FM, third order, intermodulation

1. Introduction

Intermodulation products caused by two or more FM broadcasting radios transmitter on a site to inter modulate either within transmitters themselves or within a non-linear component on site to produce intermodulation products and intermodulation due to passive circuits at FM broadcasting radio which is caused by transmitters sharing same radiating element and intermodulation occurs due to non-linearity's of passive circuits have been identified as the source of interference in aeronautical ground to air communication (COM) systems in Tanzania(Jan Kaaya, 2014) and hence affect proper functioning of aeronautical systems which have been categorized as safety services. Third order intermodulation products signal from FM broadcasting radio stations observed in aeronautical Very High Frequency (VHF) was higher than minimum established threshold levels which were set by International Civil Aviation Authority (ICAO). Henceforth immediate measures which will mitigation interference to aeronautical systems have to be taken. There are number of proposed mitigation techniques and measures that may be used in order to minimize harmful interference from FM broadcasting transmitters to safety services. These include:

Frequency relocation; this is where a number of frequencies are available in FM broadcasting range hence one of the station which cause intermodulation products which fall within aeronautical band will be relocated to new frequency. Dis advantage of this technique is that it is spectrally inefficient(ITU, 2001).

Another technique for interference mitigation is through use of filter to attenuate large power signals from FM broadcasting signal which cause harmful interference to aeronautical systems. Notch filter and band pass filter can be applied to both transmitter and receivers(ITU, 2001).

Third technique is through modification of antenna radiation pattern which facilitated in directing the signal into intended area. (ITU, 2001).

At themi hill site, most of FM broadcasting stations was observed to use dipole antenna systems, this is due to its radiation patterns which provide good coverage in all direction and hence allow broadcasting signals propagated to be received. In this paper as interference mitigation measure, design and use of reflector antenna is recommended for those broadcasting stations which have been identified to produce third order intermodulation products which fall within aeronautical VHF range. Corner reflector antenna is made up of two plane reflector panels and the feed element which is always a dipole or an array of collinear dipoles placed parallel to the vertex a distance s away. To obtain a greater bandwidth the feed elements are thick cylindrical or bi conical dipoles instead of thin wires. These antennas have high gains up to 12 dBi (Aleksandar Nesic1, 2012; K. Vasudevan, 1982) and have good front to back ratio hence this will limit broadcasting radio stations signal strength which is in the direction of aeronautical communication facilities.

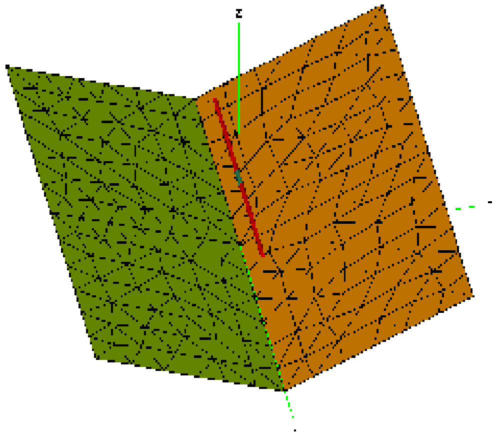


Figure 1: Corner Reflector Antenna.

2. Antenna concepts and theory

Antenna is a transducer which converts electrical energy from transmitter to electromagnetic radio frequency energy waves and converting back electromagnetic energy to electrical energy at the receiver. With passing of electric current through an antenna magnetic field (H) and electrical field (E) are generated and these fields are perpendicular to each other(Huang, 2008). FM broadcasting radio stations use dipole antenna type. This antenna consists of a conducting element whose length is half the transmitting wavelength. In order to increase the antenna gain and achieving desired characteristics array of dipole antennas are used. This system usually consist of more than one dipole antenna elements placed in stack of strategically spaced radiating elements fed with currents having the varying amplitude and phase. Desired characteristics are achieved by varying the feed (amplitude and phase) and relative position of each radiating element. The total radiated field is determined by vector addition of the fields radiated by the individual elements. The total dimensions of the antenna are enlarged without increasing the size of the individual element(Fung, 2011). The total radiated field can be obtained by summing up the radiated field from each element antenna, i.e.

$$E(\mathrm{r},\theta,\phi) = \sum_{n=1}^{N} E_n J_n \qquad (1)$$

The major advantages of using dipole array are its flexibility to form a desired radiation pattern and high directivity and gain while its drawbacks include the complexity of the feeding network required and bandwidth limitation

Figure 2: Array of broadcasting antennas.

As interference mitigation measure during design of corner reflector antenna a number properties were taken in consideration in order to achieve desired goal of received power level from FM broadcasting signal to be less than -102 dBm. These antenna properties include;

2.1 Antenna Gain

Gain of antenna entails the ratio of antenna radiated power at a given point to the power at that point when isotropic antenna was used. Isotropic antenna is a reference ideal antenna which radiates power equally in all direction. For transmitting antenna gain describes how an antenna converts input power into radio waves in a given direction while in receivers side antenna gain describes how the antenna converts radio waves received from a specified direction into electrical power. Increasing gain of antenna facilitates in increase Effective Isotropic Radiated Power (EIRP) hence increase received power at the target point. Due to Corner reflector antenna has high gain compared to a single dipole antenna.
Corner reflector antenna gain can be represented by equation:

$$G(\theta_0,\phi_0)=\frac{8\pi RS(\theta_0,\phi_0)}{I_0^2R_r}-\left[\frac{2}{15R_r}\left[\frac{R^2\left|\bar{E}_0\right|}{I_0^2}f^2(\mathrm{s},\theta_0,\phi_0)\right]\right] \quad (2)$$

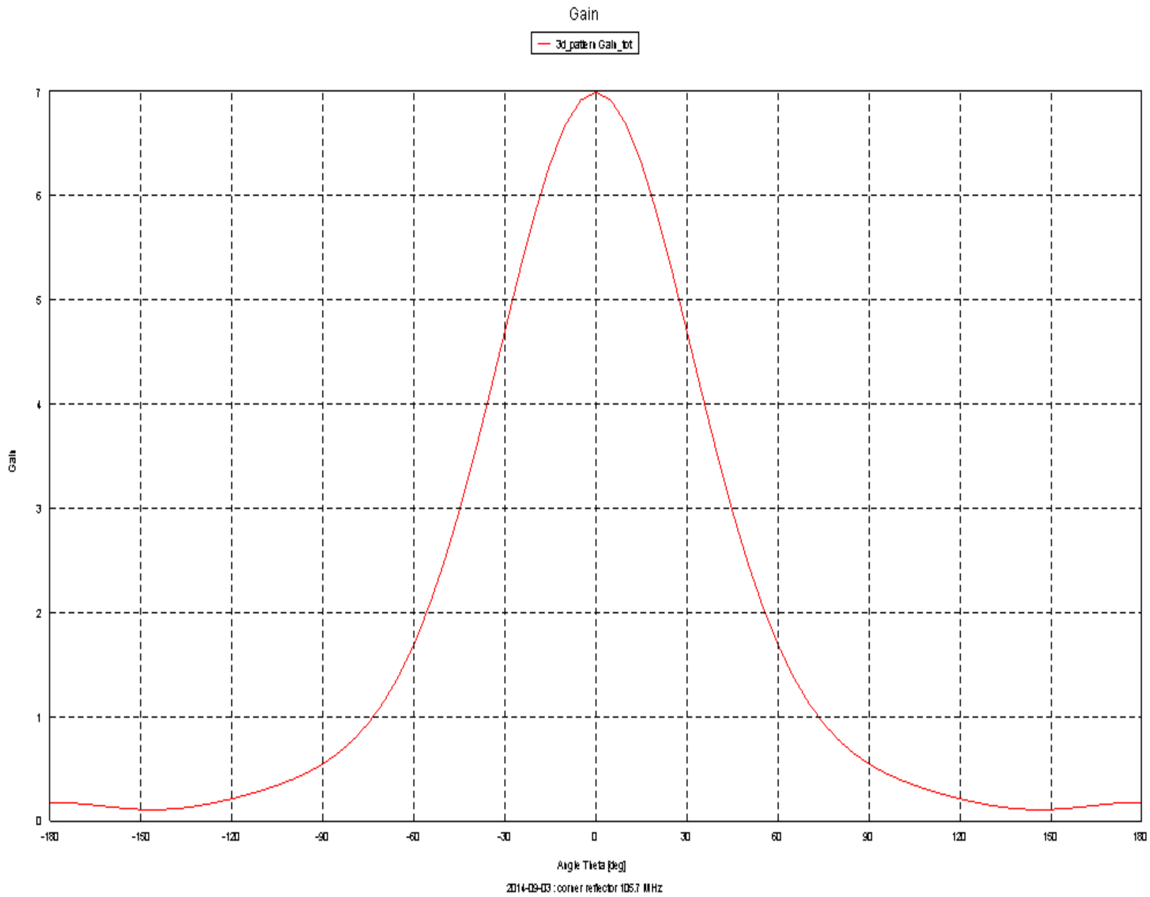


Figure 3: Gain of Corner Reflector Antenna

2.2 Radiation pattern

Antenna radiation pattern refers to variation of the power radiated by an antenna with regard to distance from the antenna. Radiation pattern depend upon shape of antenna. Dipole antenna in free space have radiation pattern which is strongest at right angles to the wire and resembles figure eight when the antenna is positioned horizontally over the ground. Corner reflector antenna radiation pattern depends much on the design parameter(Epis, 1954). Its far field electric field strength can be represented mathematical by the following equation.

$$\bar{E} = 2j\bar{E}_0 \sum_{m=0}^{m/2-1} (-1)^n \sin\left\{[ks\sin\theta][\cos\frac{2\Pi n}{m} - \phi]\right\} \tag{3}$$

Where m=2, 6, 10, 14

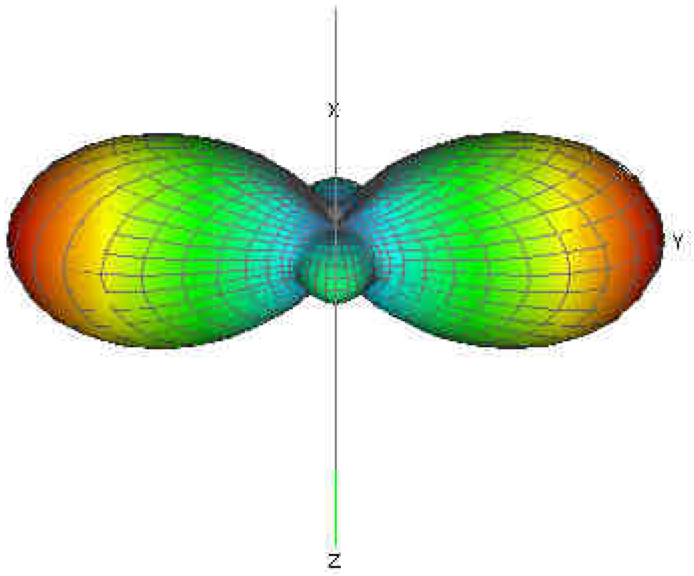


Figure 4: Antenna Radiation Pattern

2.3 Polarization

Polarization of an antenna describes the orientation of the electric field of the radiated wave with reference to ground. Types of antenna polarization include vertical, horizontal circular and mixed polarization. Most of FM broadcasting stations antennas observed was vertically polarized and circular polarized. As electromagnetic interference mitigation technique polarization of antenna has to be changed such that large portion of unwanted interfering signal will be lost or distorted. (Huang, 2008)

2.4 Impedance Matching and Voltage Standing Wave Ratio

Antenna input impedance is the ratio of the Voltage (V) to current (I) flowing at pairs of the terminal for efficient transfer of RF energy impedance of the transmitter, transmission line which connect transmitter to the antenna and that of the antenna must have same value hence being matched. Typical input impedance used in communication systems are 50 ohms, 75 ohms and 120 ohms. When two systems which have different input impedance are connected to each other impedance matching circuits for balancing unbalanced impedance are then required to match the two systems(Onnigian, 1995). When there is impedance mismatch in communication system Voltage Standing Wave Ratio (VSWR) appear in a link. VSWR describe numerically how well the antenna impedance is matched to the radio or transmission line which is connected to. VSWR is a function of the reflection coefficient, which describes the power reflected back from the antenna to the transmitter. An ideal transmission line would have an SWR of 1:1, which implies all power generated by transmitter is dissipated by the antenna(Fung, 2011).

During antenna design resonance will be obtained at the centered frequency, this is when the characteristic impedance of the antenna is strictly resistive: the minimum reactive part should be observed at the considered frequency. While proper impedance matching ensures all RF energy delivered the feed point is converted in an electromagnetic field. When there is impedance mismatch, a Standing Wave phenomena appears, and some energy returns to back to the transmitter instead of being radiated. Voltage Standing Wave Ratio (VSWR) determines the amount of energy which is not converted by the antenna into Radio Frequency energy(P. Singhal, 2012).

Center frequency depends on the size of the wire. For fine tuning, take a wire just a little bit longer than the theoretical value, perform field measurement, and shorten until the correct value is obtained. Depend on the width of the wire. The bandwidth will depend on the number of channels required, the data rate, the kind of modulation used. If a large bandwidth is required, use a rather thick wire(Fung, 2011).

$$VSWR = \frac{1+\Gamma}{1-\Gamma} \qquad (5)$$

Where Γ stands for reflection coefficient given by formula

$$\Gamma = \frac{Z - Z_0}{Z + Z_0} \qquad (6)$$

In which: Z= load impedance
Z0= characteristic impedance of the line

3. Methodologies

The corner reflector antenna was designed and simulated by using FEKO simulating software having following parameters:

The feed-to-vertex distance (s) was taken to be two-thirds of the wavelength (2/3 λ) [1]. The length of the sides of was taken to be twice the distance from the vertex to the feed L= 2S. The height (H) of the reflector was set to be about 1.2 times greater than the total length of the feed element, this facilitate in reducing back lobes(Shashank Kulkarni, 2005). Centre frequency for this antenna was set to 93.0 MHz

Table 1: Corner Reflector Antenna Parameters

S/N	PARAMETER	VALUE
1	Frequency	93.0 MHz
2	Lambda	C0/Frequency
3	Feed to Vertex Distance (S)	2/3*Lambda
4	Angle (θ)	135º
5	Length (Lr)	1.5/2*Lambda
6	Width (Wr)	1.2/2*Lambda
7	Dd	0.0012m

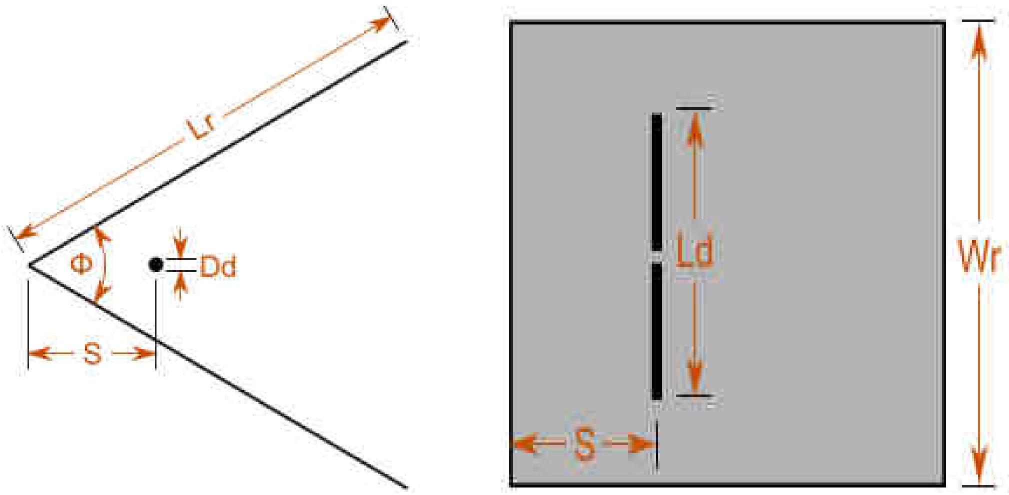
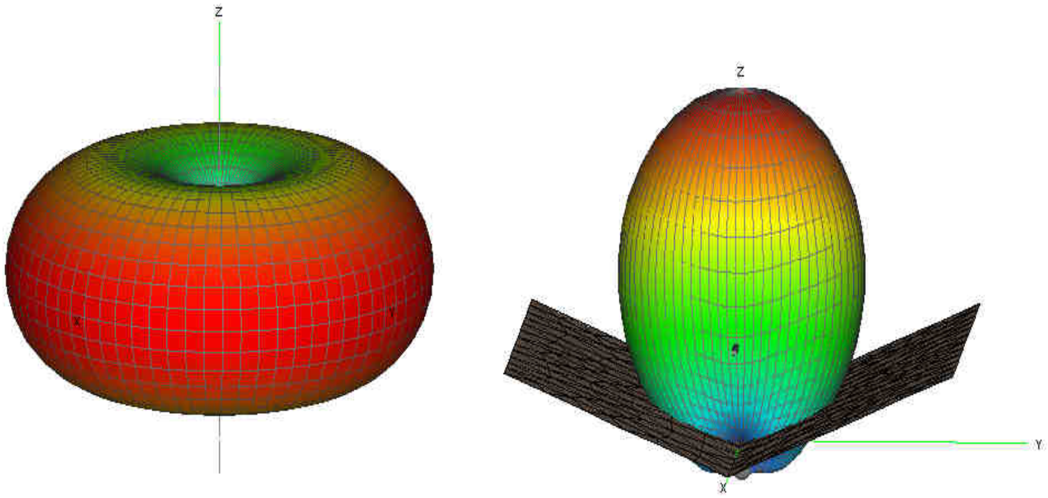


Figure 5: Corner Reflector Antenna specifications diagram

4. Result findings

After simulating the designed antenna by using FEKO the following are the results.

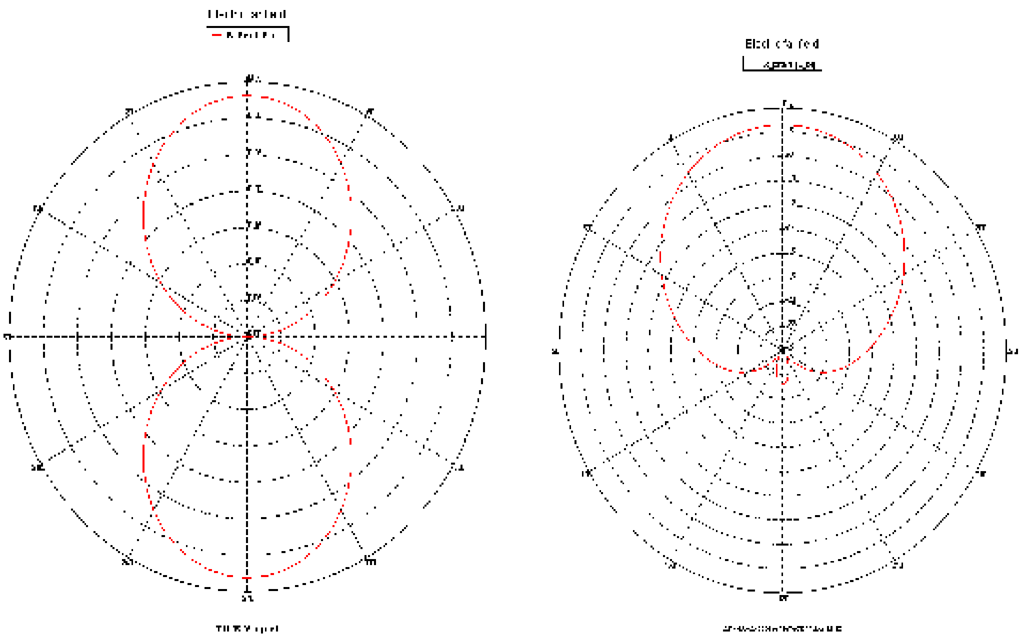
4.1 Radiation Pattern



(a) (b)

Fig 6: (a) Dipole Antenna radiation pattern (b) Corner Reflector antenna radiation pattern

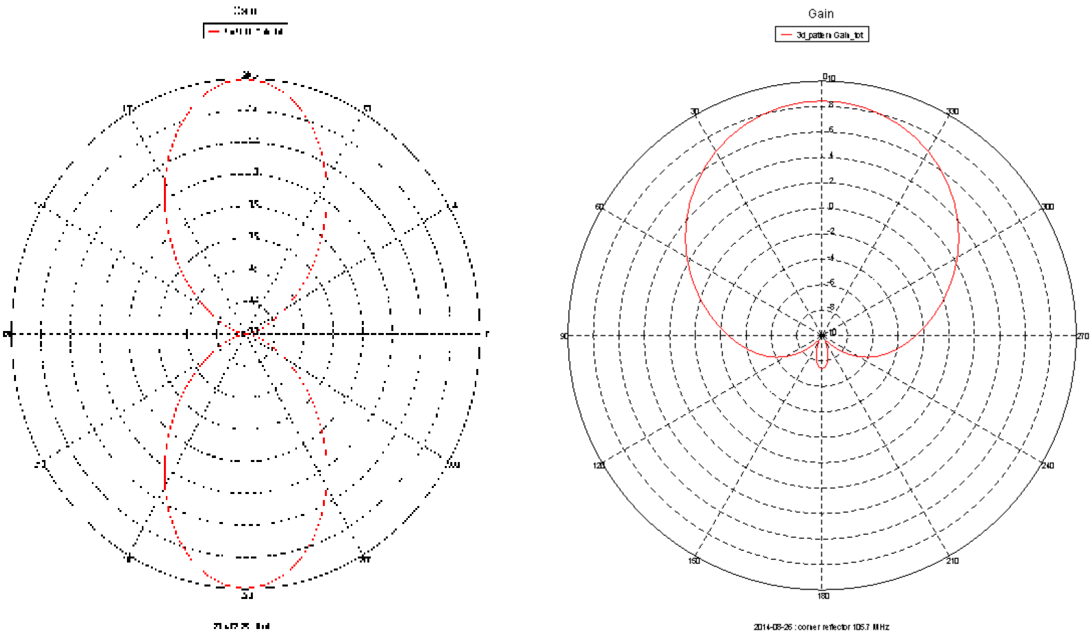
From figure 6, Antenna radiation pattern of a corner reflector antenna is more directional with good front to back ratio compared to dipole antenna which are used by FM Broadcasting stations. This facilitates in reducing the amount of power from FM broadcasting radio station reaching aeronautical systems facilities.



(a) (b)

Figure 7: (a) Electric far field polar plots dipole antenna (b) Corner reflector antenna.

From figure 7, it can be realized that the electric field radiation pattern of corner reflector antenna has changed its shape form eight figure of dipole antenna to be more directional. This facilitates in having coverage only in the intended direction



(a) (b)

Figure 8: (a) Polar plots for dipole antenna Gain (b) polar plot corner reflector antenna Gain.

From the figure 8 above, corner reflector antenna has much higher gain compared to dipole antenna. This gives a chance for FM broadcasting station with the same broadcasting transmission power to increase coverage in intended service area due to increase in Effective Isotropic Radiated Power (EIRP)

5. Conclusion and recommendation

The research work has focused on using of corner reflector antenna to mitigate interference caused by FM broadcasting radio stations to COM facilities which are used for ground to air communication between control tower and pilots in Tanzania. It is observed that the corner reflector antenna will provide sufficient front to back ratio which will facilitate in reducing electric signal strength and hence forth power level from FM broadcasting stations reaching the aeronautical facilities and hence mitigate the interference. The corner reflector antenna will give maximum of electric field which is less that the threshold level of -102dBm when maximum power of 2KW is used for FM broadcasting station.

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